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DEPARTMENT OF THE INTERIOR
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CHARLES D. WALCOTT, DIRECTOR

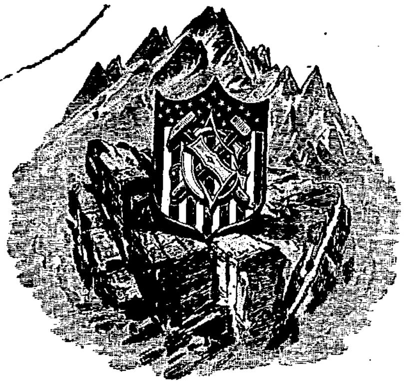
CHEMICAL COMPOSITION OF IGNEOUS ROCKS

EXPRESSED BY MEANS OF DIAGRAMS

WITH REFERENCE TO ROCK CLASSIFICATION ON A QUANTITATIVE CHEMICO-MINERALOGICAL BASIS

BY

JOSEPH PAXSON IDDINGS



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CONTENTS.

ILLUSTRATIONS.

LETTER OF TRANSMITTAL.

Department of the Interior,
United States Geological Survey,
Washington, D. C., May 26, 1903.

Sir: I have the honor to transmit herewith a manuscript by Joseph Paxson Iddings entitled "Chemical composition of igneous rocks expressed by means of diagrams, with reference to rock classification on a quantitative chemico-mineralogical basis," and to recommend that it be published as a Professional Paper.

The significance of a large number of chemical analyses of igneous rocks, with their many variable elements, each having a great range, is somewhat difficult of comprehension to all geologists and petrographers who have not devoted much time to their study. Mr. Iddings presents a method of expressing the most significant factors in each analysis by a simple diagram, and by grouping these individual diagrams on a certain principle he has succeeded in representing the great variation in composition and the chemical relationships of almost the entire range of igneous rocks in a way that is comprehensible at a glance. The facts thus brought out are discussed by him in their bearing on petrographic system. As a successful attempt at the elucidation of a complex problem the paper is of importance to all students of igneous rocks.

Very respectfully,

Whitman Cross,
Geologist in Charge, Section of Petrology.

Hon. Charles D. Walcott,
Director United States Geological Survey.

CHEMICAL COMPOSITION OF IGNEOUS ROCKS EXPRESSED BY MEANS OF DIAGRAMS, WITH REFERENCE TO ROCK CLASSIFICATION ON A QUANTITATIVE CHEMICO-MINERALOGICAL BASIS.

By Joseph Paxson Iddings.

INTRODUCTION.

The value of graphical methods for expressing relative quantities has been well established in all kinds of statistical exposition and discussion. Their use in conveying definite conceptions of relative quantities of chemical and mineral components of rocks is becoming more and more frequent, and the value of the results in some cases can not be overestimated. This is especially true when a series or group of rocks is being considered. The intricate variations in the amounts of numerous mineral components, or of chemical components, baffle most attempts to comprehend their interrelationships by simple contemplation or by study of the numbers in which they may be expressed. Many facts and relations are overlooked which are readily observed when diagrams are used to represent numerical figures. Moreover, visual memory is sufficiently developed in most persons to enable them to carry in mind simple geometrical forms, where it does not permit them to recollect manifold assemblages of oft-repeated numbers. Mental impressions of simple diagrams are, therefore, more definite and lasting and enable the student to store up a much greater amount of quantitative data than he could otherwise acquire.

Evidence of the appreciation of this fact by petrographers is found in the increasing use of diagrams in petrographical literature, and a brief sketch of the growth and elaboration of graphical methods for presenting quantitative petrographical data will serve as an appropriate introduction to the subject in hand. From this notice will be excluded those diagrams which serve to connect the names of rocks in series after the manner of expressing genealogical relationships, in which diagrams the space relationships are not strictly quantitative. Such diagrams have been used by George H. Williams, H. O. Lang, and other petrographers.

HISTORICAL REVIEW.

Among the earliest diagrams employed to represent relative quantities of rock constituents are those used by Reyer in 1877.[a] They are more or less generalized expressions, in one instance of the varying proportions of the chief oxide components in rocks and meteorites; in another of the varying amounts of the commoner rock-making minerals capable of being developed in rock magmas with different silica content. The diagrams used are rectangles subdivided by curved lines corresponding to the variations mentioned. Other diagrams express the variations of different kinds of rocks with respect to silica; the relation between specific gravity, silica percentage, and texture of mineralogically similar rocks; and the relative abundance of rocks of different compositions and textures.

Subsequently in his work, Theoretische Geologie,[b] he reproduces two of these diagrams and introduces others showing the proportions of chemical components in two series of minerals (feldspars and pyroxenes) and others showing the proportions of the chief minerals in three kinds of rocks. One diagram consists of adjacent, long, narrow rectangles, each divided into rectangular parts proportionate to the percentages of the oxide constituents in certain kinds of rocks, from granite to gabbro, and in five types of meteorites.

Judd,[c] in his book on Volcanoes, in 1881, makes use of a diagram to represent the varying amounts of chemical elements in rocks and meteorites. It is similar in form to one used by Reyer, already described.

In 1890 the author[d] constructed diagrams to exhibit the variation in chemical composition of rocks forming geologically related groups or series. In these diagrams the quantitative data represent specific analyses of different rocks in each series. The oxide constituents of each rock are referred to rectangular coordinates, the silica being plotted as abscissas, and the other oxides—alumina, ferric and ferrous iron, magnesia, lime, soda, and potash—being plotted as ordinates. Straight lines connecting successive loci of any one oxide, as those of alumina, indicate the variations in the amount of each constituent in the rock series. This is the chief feature brought out by these diagrams, the range and character of the variations being shown.

Similar diagrams have been used by Dakyns and Teall[e] to illustrate the chemical variations in the plutonic rocks of Garabal Hills and Meall Braec,

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[a] Reyer, E., Beitrag zur Fysik der Eruptionen. Vienna, 1877.

[b] Reyer, E., Theoretische Geologie. Stuttgart, 1888.

[c] Judd, J. W., Volcanoes. New York, 1881, p. 322, fig. 88.

[d] Iddings, J. P., The mineral composition and geological occurrence of certain igneous rocks in the Yellowstone National Park: Bull. Philos. Soc. Washington, vol. 11, January, 1890, pp. 207 and 211; also in Twelfth Ann. Rept. U. S. Geol. Survey, 1892, pp. 629 and 649; Mon. U. S. Geol. Survey, vol. 32, pt. 2, pp. 119 and 136; Origin of igneous rocks, Bull. Philos. Soc. Washington, vol. 12, June, 1892, and in Jour. Geol., vol. 1, 1893, p. 173.

[e] Dakyns, J. R., and Teall, J. J. H., Quart. Jour. Geol. Soc. London, vol. 48, 1892, p. 116.

Scotland; by Washington to express the chemical variation in the volcanic rocks of Ægina and Methana, Grecian Archipelago,[a] and in the rocks of Magnet Cove, Arkansas;[b] and by Cross[c] to show the chemical composition of the rocks of the Rosita Volcano, Colorado.

Harker[d] has employed the same form of diagram, but has used atomic ratios of the chemical elements instead of the oxides, to show the variations in the rocks of Carrock Fell, England. Subsequently he modified it slightly by using percentages of the oxide components instead of their molecular proportions to discuss the possibility of distinguishing igneous rock series from mixed igneous rocks.[e]

Loewinson-Lessing[f] has also made use of this method of exhibiting the variability of chemical composition in eruptive rocks, illustrating the great divergence in the composition of rocks classed under one name in the qualitative system and also the differences in composition of average magmas.

In 1900 Pirsson[g] pointed out the possibility of relating the variations in the chemical composition of rocks of one geological body to their position in that body by introducing their space relations into this form of diagram. He accomplished it by letting the abscissas represent distances in the rock body between the various rocks analyzed. By this modification of the diagram just described, he showed that the variations in chemical composition in such cases follow very regular laws, and with one or two elements determined in a variety of the rock the remainder may be found by means of the diagram.

Similar diagrams have since been used by Washington in discussing the differentiation in the rocks of Magnet Cove.[h]

Pirsson has also used a somewhat similar diagram to represent the variations in mineral composition of rocks of Yogo Peak, Little Belt Mountains, Montana.[i]

In 1896 Becke[j] represented the chemical composition of igneous rocks by diagrams of two kinds, constructed in a manner different from that of those just described. The first is a modification of a three-coordinate diagram for three variables, whose sum is a constant, based upon an equilateral triangle. The three factors chosen are Ca, Na, K. The zero point of the coordinate axis is the center of the triangle. From this point three axes run to the corners of the triangle, one for each of the elements, Ca, Na, K. The spot within the

[a] Washington, H. S., Jour. Geol., vol. 3, 1895, p. 160.
[b] Washington, H. S., Bull. Geol. Soc. America, vol. 11, 1900, p. 404.
[c] Cross, W., Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, p. 324.
[d] Harker, A., Quart. Jour. Geol. Soc. London, vol. 51, 1895, p. 146.
[e] Harker, A., Jour. Geol., vol. 8, 1900, pp. 389-399.
[f] Loewinson-Lessing, F., Compte rendu Congrès Géol. International, Seventh session, St. Petersbourg, 1899, Pls. I, II, and III.
[g] Pirsson, L. V., Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, p. 569 et seq.
[h] Washington, H. S., Bull. Geol. Soc. America, vol. 11, 1900, p. 651.
[i] Op. cit., p. 568.
[j] Becke, F., Min. Pet. Mitth., vol. 16, 1897, p. 315-320.

triangle determined by the values of Ca, Na, K, in a given rock analysis is the locus of the analysis (*Analysenort*). The various positions of these spots indicate the relative amounts of the elements named in the rocks compared. The other chemical elements in the rocks are represented on a second diagram supposed to stand at right angles to the plane of the first. It is drawn with rectangular coordinates, the abcissas being proportional to the ratio $\frac{Ca}{Ca + Na + K}$, and the ordinates representing the values of Si, Al, Fe, Mg. Each of these elements is located by a spot in the diagram.

In January, 1897, Michel Lévy[a] devised diagrams to exhibit certain chemico-mineralogical characters of igneous rocks, a single diagram representing an individual rock. The component oxides are first distributed into two groups, those that may combine with Al_2O_3 to form feldspars and those that may not. All the Al_2O_3 is set aside for feldspars, and to it is allotted K_2O, Na_2O, and sufficient CaO to satisfy it. An excess of CaO is placed with iron and magnesia. Silica may be introduced into the diagram or omitted, and in a subsequent publication[b] in the same year is expressed only in numbers stating the percentage. Rectangular coordinates are used and the values of the components are laid off on two axes intersecting at the zero point. Below this point is plotted the percentage of potash, and also that of iron oxide. To the right of the zero point is plotted the percentage of soda which may combine with alumina. In this direction, also, may be plotted the percentage of silica. Above the zero point is plotted the lime which may combine with alumina, and also the percentage of magnesia. If there is more lime than will satisfy the alumina remaining after potash and soda have been satisfied, this lime is plotted to the left of the zero point. Triangles are constructed by connecting the end of the potash line with that of the soda line, and the soda with feldspathic lime. Magnesia is connected with nonfeldspathic lime, and this with iron. Two triangles to the right of the y axis give an indication of the feldspathic constituents of the rock. The other two triangles to the left of the y axis represent the nonaluminous constituents. Modifications of the diagrams enter when there is an excess of alumina over alkalies and lime, and again when alumina is less than the alkalies.

Michel Lévy in the publication last cited also employs diagrams showing curves of variation for the percentages of the chemical components when subdivided in the manner just described.

These triangular diagrams have been used by Lacroix in describing the basic rocks accompanying the lherzolites and ophites of the Pyrenees,[c] and also in his

[a] Lévy, A. Michel, Bull. Serv. Carte géol. France, vol. 9, No. 57, 1897, p. 38 and Pls. VII, VIII.
[b] Lévy, A. Michel, Bull. Soc. géol. France, 3d series, vol. 25, 1897, Pls. X to XV.
[c] Lacroix, A., Compte rendu Congrès Géol. International, Eighth session, Paris, 1901, Part II, pp. 834, 835.

work on the alkaline rocks of the petrographical province of Ampasindava, Madagascar.[a]

In May, 1897, Brögger[b] presented a modification of the individual diagrams devised by Michel Lévy. This was done in illustrating the chemical composition of the group of rocks associated with the laurdalite of the Christiania region. Brögger's diagrams are composed of four coordinates in a plane intersecting in a common zero point. One is horizontal, another vertical, and the other two inclined, one 60° to the right, the other 60° to the left of the vertical axis. On these axes are plotted the molecular proportions of the chief oxide components of a rock. On the upper vertical axis are plotted the molecules of CaO, on the lower vertical axis the Al_2O_3. On the horizontal axis right and left is plotted the SiO_2, half and half. On the upper right inclined axis is plotted MgO; on the upper left one, the $FeO + Fe_2O_3$, indicated separately. On the lower right inclined axis is plotted K_2O, and on the lower left one Na_2O. The extremities of adjacent axes are connected by lines. These diagrams show at a glance the relative proportions of the molecules of the oxide constituents of each rock. The amount of CaO capable of being combined with Al_2O_3, not combined with K_2O and Na_2O, can be readily found by measuring the lengths of the several axes. The introduction of the silica and alumina adds to the instructiveness of this form of diagram.

Diagrams of this type have been employed by Hobbs[c] to express the average composition of groups of rocks classed together under various divisions of the qualitative system in general use at the present time. In these diagrams the inclined axes stand at 45° to the vertical axis.

Hackman[d] has made use of both the Becke and the Brögger diagrams to express chemical relations among the rocks associated with ijolite in Kuusamo, Finland.

Rosenbusch[e] uses narrow rectangular diagrams to express the relative proportions of the chemical elements (*Metallatome*) in two series of 26 rocks; one, a foyaite-theralite series, the other a granitodiorite and gabbro-peridotite series.

In February, 1898, the author[f] in an essay on rock classification, and later in another essay, made use of diagrams exhibiting the variations of rock analyses with reference to percentage of silica and alkali-silica ratio. These are constructed by using the silica percentages as abscissas, the zero point being to the

[a] Lacroix, A., Nouv. Arch. Museum Hist. Nat., 4th series, I, Paris, 1902, p. 180 et seq.
[b] Brögger, W. C., Die Eruptivgesteine des Kristianiagebietes. III. Videnskabsselskabets Schrifter. I. Math.-Naturv. Kl. 1897. No. 6. Christiania, 1898.
[c] Hobbs, W. H., Jour. Geol., vol. 8, 1900, pp. 1–31.
[d] Hackman, V., Bull. Com. Geol. Finlande, vol. 11, Helsingfors, 1900.
[e] Rosenbusch, H., Elemente der Gesteinslehre. Stuttgart, 1898.
[f] Iddings, J. P., Jour. Geol., vol. 6, 1898, pp. 92–111, 219–237.

right of the diagram, and 100 to the left. The ordinates represent the ratios obtained by dividing the sum of the molecular proportions of the alkalies, K_2O and Na_2O, by that of silica. The locus of each analysis is indicated by a round spot or by figures of other shapes.

In the same year, 1898, Michel Lévy[a] presented a new mode of coordination of diagrams to represent rock magmas, based in a measure on those just published by the author, to some features of which Michel Lévy took exception. These diagrams by Michel Lévy give the loci of rock analyses referred to two coordinates in the plane of drawing, and also to a third axis projected on the same plane. The abscissas (x) represent the silica percentages in the "white components" (elements blancs) of the rocks compared. The ordinates (y) represent the sum of the percentages of K_2O, Na_2O, and the CaO which may enter feldspar combined with Al_2O_3. The third coordinates (z) represent the percentages of MgO, FeO, Fe_2O_3, CaO, and SiO_2 in the ferromagnesian components of the rocks. The loci of the analyses are fixed by the rectangular coordinates x and y. Their relation to the axis z is indicated by their position with reference to diagonal lines representing the projected traces of certain planes with an inclined plane through z.

The usefulness of this diagram, which appears when the compositions of restricted groups of rocks are illustrated, is seriously impaired by repeated overlapping when many kinds of rocks are taken into account. The method undertakes to distribute the analyses with respect to the relative abundance of the white (leucocratic) components—quartz and feldspathic minerals—and the dark (melanocratic) ferromagnesian components in the first instance, and also with respect to the silica content of the leucocratic components.

It is clear that rocks containing various amounts of nephelite, leucite, and anorthite molecules with closely similar percentages of silica will be mingled together in the same part of the diagram, and that rocks with preponderant ferromagnesian minerals, since they are plotted wholly on a basis of characters belonging to the subordinate feldspathic minerals, will be indiscriminately mingled in one portion of the diagram.

In 1899 Loewinson-Lessing,[b] in his studies of eruptive rocks, an abstract of which was presented, without diagrams, to the International Geological Congress at St. Petersburg in 1897, makes use of two forms of diagrams, one after the method of the author, already alluded to, and another based on the method of relative rectangular areas used by Reyer. The diagram represents the various molecular proportions of the chemical components of a rock, or may represent the average of a group of rocks. It is a rectangular area divided by horizontal

[a] Lévy, A. Michel, Bull. Soc. géol. France, 3d series, vol. 26, 1898, Pls. III to VI.

[b] Loc. cit.

lines into spaces whose vertical dimensions correspond to the proportions of SiO, R_2O_3, RO, and R_2O in each case. These rectangles are subdivided by vertical lines into spaces whose horizontal dimensions correspond to the proportions of Al_2O_3 and Fe_2O_3 in R_2O_3, of FeO, CaO, and MgO in RO, and of K_2O and Na_2O in R_2O.

In 1900 Mügge[a] devised a form of diagram to express the proportions of the chemical components of rocks, based upon some features of Michel Lévy's and Brögger's diagrams. Several modifications of the diagram were suggested by Mügge. It will be sufficient to describe the form used by him to illustrate the composition of a number of selected rocks. The relative quantities of the oxide components, expressed molecularly, are plotted on four coordinate axes in one plane intersecting in a zero point and making equal angles with one another. One is vertical, one horizontal, and two inclined at 45°. The silica is represented by an octagonal area, constructed by plotting one-eighth of the total silica plus and minus on each axis. The other components are plotted outside this area on particular axes by adding their values to the silica already plotted. K_2O is plotted on the upper left inclined axis, Na_2O on the upper right one, MgO on the lower left inclined axis, CaO on the lower right one. FeO is plotted on the lower vertical axis, followed by Fe_2O_3 in the same direction. Al_2O_3 is divided into three parts, when sufficient, the first, equal molecularly to K_2O, is plotted to the left on the horizontal axis. A second, equal to the Na_2O is plotted upward on the vertical axis, and the remainder of the Al_2O_3 is plotted to the right on the horizontal axis. When there is less Al_2O_3 than K_2O+Na_2O, enough Fe_2O_3 is added to Al_2O_3 upward on the vertical axis to equal Na_2O. In this manner the relative amounts of potash-alumina molecules, soda-alumina molecules, and lime-alumina molecules are indicated.

In 1900 and 1901 Osann[b] made use of several types of diagrams to illustrate chemical characteristics of igneous rocks in his essay on a chemical classification of igneous rocks.

One is a triangular diagram somewhat similar to that used by Becke, exhibiting the distribution of analyses with respect to three coordinate axes making equal angles with one another. The three chemical factors of rocks employed in their comparison are chemico-mineralogical to some extent. One factor (A) consists of the sum of the percentages of K_2O and Na_2O which may be combined with Al_2O_3 in equal molecular amount. A second factor (C) represents the percentage of CaO which may be combined with Al_2O_3 in equal molecular amount. The third factor (F) represents the sum of the percentages of the remaining CaO,

[a] Mügge, O., Neues Jahrb. Min., Geol. und Pal., 1900, vol. 1, pp. 100-112, Pls. V-VII.
[b] Osann, A., Min. Pet. Mitth., vol. 19, 1900, Pls. IV-VIII, XXV; vol. 20, 1901, Pls. VIII-XIV.

MgO, FeO. The sum of these is assumed to be a constant, and their relative proportions are determined on a basis of 20 units. With these three variables the position of a rock analysis within the equilateral triangle is located.

A second form of diagram expresses the variation in silica and alkalinity in certain rocks by means of lines connecting loci of analyses referred to two rectangular coordinates, the abscissas corresponding to the alkalinity, and the ordinates to the silica percentage. Another diagram of the same type exhibits the variability of different kinds of rock with respect to the relative proportions of soda and potash.

A third form of diagram is composed of narrow rectangles, whose lengths correspond to the range of variation in silica ratios for different kinds of rocks. The rectangles are placed by the side of one another, with their longer diameters adjusted to one ordinate representing values of silica ratios.

In 1902 Reid[a] used an equilateral triangle whose sides are divided into 100 parts, as a basis on which to plot the oxide components of igneous rocks.

PURPOSE OF THE DIAGRAMS.

A study of the various diagrams that have been employed by petrographers shows that their value depends upon the readiness with which their significance may be grasped and the use that is made of them. The first condition varies directly as the simplicity of the method of construction, both as to geometrical form and as to the factors on which they are based. The simpler the form of the diagram and the more characteristic its shape, the more definite the visual impression and the stronger the hold on the mind. It is also self-evident that the simpler the factors entering into it the better. The quantitative values of single rock components are simpler conceptions than intricate ratios and functions involving several different rock components. Moreover, a diagram is comparatively worthless unless it can be made to convey some definite impression not otherwise obtainable, or obtainable only with difficulty. Its employment should have some specific object. It is hoped that the diagrams presented in this paper will justify themselves and will produce certain definite impressions on the minds of petrographers who may study them.

The author's first purpose in constructing the accompanying diagrams is to express in the simplest graphical manner the chief chemical composition of all kinds of igneous rocks in a form that will permit the student to compare them at a glance and obtain a comprehensive view of the whole range of differences.

The diagrams are intended to exhibit the manifold character of the variations of the chemical components of rocks, and their extent. They are to show the

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[a] Reid, J. A., Bull. Dept. Geol. Univ. California, vol. 3, 1902, p. 18.

gradual character of the variations; the transitions from rocks of one composition to those of another; and the distribution of the rocks throughout the range of their variations.

They are to demonstrate the absence of clusters of analyses in definite parts of the whole system and the absence of "natural" subdivisions of rocks on a basis of chemical composition.

They are to show the possibility of continuous series of rocks with diverse compositions, and to illustrate the chemical identity of rocks belonging to different genetic families.

Finally the diagrams exhibit the character of the quantitative classification of igneous rocks proposed by Cross, Iddings, Pirsson, and Washington, the range of composition of the five classes, as well as of the orders, rangs, and subrangs.

CONSTRUCTION OF THE DIAGRAMS.

As will be seen by looking at the plates, the diagrams are combinations of two kinds already in use. They consist of assemblages of individual rock diagrams, which are modifications of those devised by Michel Lévy and Brögger, the individual diagrams being arranged in a multiple diagram previously used by the author. The first are used to exhibit the chief chemical components of each rock taken into consideration; the second, to arrange these in an orderly manner for comparison with one another.

The small, individual diagrams are modified forms of those by Brögger. They are planned to exhibit the relative amounts of the chief oxide components of igneous rocks, namely: SiO_2, Al_2O_3, Fe_2O_3+FeO, MgO, CaO, Na_2O, K_2O, and also TiO_2. Other components are usually so slight that they are negligible in diagrams of such small scale. Owing to the fact that the small diagrams are arranged in the large diagram according to the silica, it is not necessary for the purposes of this paper to introduce SiO_2 into the construction of the individual diagram. The relative amount of SiO_2 is expressed by the position of the small diagram in the large one. This simplifies the small diagram.

The chemical components of rocks may be compared with one another as oxides of metals or as metals. As oxides, the form in which they are expressed in chemical analyses of rocks, they may be compared by means of percentage weights or of molecular proportions. As metals they would be compared by molecular or atomic proportions.

The use of oxides instead of metal elements is the more convenient method of comparison. It bears a more obvious and direct relation to the rock analysis and requires less effort to apply. It is as valuable in the discussion of chemico-mineralogical relationships as the use of metal elements. It has, therefore, been adopted in constructing these diagrams.

14474—No. 18—03——2

The value of basing the comparisons upon molecular proportions instead of percentage weights rests upon the fact that the chemical equivalency of the components is molecular or atomic, and that in this form they may be readily converted into mineral molecules for purposes of discussion and rock classification.

For purposes of comparison in diagrams of this type it is not necessary to reduce the original analysis to a sum of exactly 100. So far as the small individual diagrams are concerned the amount of change produced in the lengths of the lines would not be appreciable. Further, all elementary lines in one diagram would be affected in like proportion and the shape of the figure would remain unchanged, even could the alteration in the length of the lines be made visible. It would affect to a variable degree the position of the small diagrams within the large one in the direction of the silica abscissa, which will be discussed later.

The small, individual diagrams are constructed to exhibit the molecular proportions of the component oxides: Al_2O_3, Fe_2O_3+FeO, MgO, CaO, Na_2O, K_2O, and TiO_2. These are derived directly from the rock analysis by dividing the percentage weight of each oxide by its molecular weight. There is no further reduction. They are used in the proportions in which they are found in the rock, the assumption being that equal weights of different rocks are being compared.

Following Brögger's method, the several values of these oxides are plotted on coordinate axes in one place, intersecting at a common zero point. But the arrangement is different. For convenience in drawing on square-ruled paper the axes chosen are vertical, horizontal, and two at 45° to these. The simple, approximate relation between the sides and hypothenuse of a 45° triangle, namely, that when the hypothenuse is 10 units the sides are 7 units each (more exactly 7.071) allows the values to be readily plotted by assuming the diagonal of each square of the ruled paper to be 5 and the side 3½. With larger diagrams and more exact requirements more accurate methods of plotting may be employed.

Since the small diagrams are to be compared by means of the multiple one, the position of the Brögger diagrams is inverted to conform more closely to the manner of constructing the large diagram. In the multiple diagram the more alkalic, and consequently more alkali-feldspathic, members of the series of rocks compared occur in the upper part; the less alkalic, and more ferromagnesian, in the lower part. So the alumina and alkalies are placed in the upper part of the individual diagrams, the iron and magnesia in the lower. The mode of construction is as follows: Al_2O_3 is plotted upward on the vertical axis; K_2O upward to the left on one inclined axis; Na_2O upward to the right on the other inclined axis; CaO is plotted downward on the vertical axis; MgO downward to the right; $FeO+2Fe_2O_3$ downward to the left; and TiO_2, when present in appreciable amount, is plotted to the left on the horizontal axis. The end of the Al_2O_3 ordinate is connected by lines with the ends of the K_2O and Na_2O ordinates, producing two triangles having a common side—the Al_2O_3 ordinate—and one angle the same in each—45°. Consequently the areas of the two triangles are proportional to the lengths of the K_2O and Na_2O ordinates. The relative impressions produced by these two triangles, colored green and yellow in the diagrams, are quantitatively the same as the relations between the molecular proportions of K_2O and Na_2O in the rock.

The end of the CaO ordinate is connected with the ends of the MgO and $FeO+2Fe_2O_3$ ordinate, making two triangles, colored blue and red in the diagrams, whose areas bear the same proportion to one another as the ratio between the molecules of MgO and the iron converted to FeO.

When TiO_2 is represented, the end of its ordinate is connected with that of the FeO ordinate.

The FeO and Fe_2O_3 are combined chiefly for simplicity, and the Fe_2O_3 is reduced to FeO because there is then a more uniform basis of comparison and a means of avoiding the analytical defects or errors in the determination of the two oxides of iron. The combination prevents a proper conception of the possibilities of mineral molecular combination so far as the iron is concerned, but this is beyond the adaptability of the diagrams in a strict sense.

It is evident that diagrams constructed on the molecular proportions of the oxide components of rocks may be easily converted into others, based on the proportions of the metal elements, by doubling the lengths of the three upper ordinates, Al_2O_3, K_2O, Na_2O. The upper half of each diagram would be double its former size, while the angular shape of the whole would remain the same.

The multiple diagram, by which the small individual ones are arranged for comparison and study, is constructed in the manner already described in the article on rock classification previously cited. It is intended to exhibit the distribution or variation of igneous rock analyses with respect to the silica and alkalies. The reasons for choosing these two factors are: First, the important rôle played by silica, the most abundant chemical component, and that which is dominant in the development of quartz, orthoclase, albite, leucite, or nephelite, orthorhombic pyroxene or olivine; second, the equally important rôle played by the alkalies in conditioning the character of the feldspathic mineral components of rocks, which are the preponderant ones in the great majority of cases; third, the fact that the other chemical components—lime, magnesia, and iron oxide—sustain to a considerable extent a reciprocal relation to those just mentioned. The greater the silica the less the content in lime, magnesia, and iron oxide. The same is true in general for the alkalies and these oxides.

One of the chief purposes of the diagram is to distribute the rocks in an orderly manner, so that unlike rocks shall be separated from one another as widely as possible and gradations between the extremes shall be made evident.

The silica is made the abscissa because it is the greater component and has the widest range. It is plotted in percentages instead of molecular proportions because the process is simpler, and as it is not brought into immediate quantitative relations to the linear elements of the individual diagrams there is no occasion for its quantitative linear comparison with them. Moreover, the large diagram could not be constructed on the same scale of units as the individual diagrams. It is therefore simpler and more convenient to use the percentage of silica given in the analyses.

The vertical ordinates represent the ratio between the sum of the molecular proportions of the alkalies ($K_2O + Na_2O$) and of the silica $-\frac{(K_2O + Na_2O)}{SiO_2}$. This ratio was selected because of the relation between the development of the alkali-feldspathic minerals in highly feldspathic rocks and the ratio between the alkalies and silica in their magmas; the more siliceous ones yielding more orthoclase or albite, the less siliceous ones more leucite or nephelite. It is not a definite relationship in rocks generally, and, as Michel Lévy has pointed out, the character of the diagram would not have been altered materially had the vertical ordinates been made to correspond directly to the sum of the alkalies. In this case the curved lines which represent the loci of pure quartz-albite-nephelite rocks and quartz-orthoclase-leucite rocks would be straight lines instead of hyperbolas, as in the diagrams here used. There would be a slightly different vertical spacing of the analyses on individual diagrams. They would be spread more on the left side of the ordinate of 60 per cent SiO_2, and condensed more on the right of it. The multiple diagrams would be more simply constructed. Otherwise the results would be alike.

With diagrams constructed by using ratios between two or more rock components it matters not whether the analyses discussed by it are reduced to anhydrous compounds, or whether their summation is exactly 100. The ratio between the alkalies and silica is not affected by readjusting the analysis. The ordinate of an analysis so located is not changed by readjusting the percentages in the analysis, but the abscissa would be affected by changing the silica percentage. The position of an analysis would be shifted horizontally to the left or right according as the percentage of silica is raised or lowered.

The zero point of each individual diagram is located in the multiple diagram by reference to the silica percentage and the alkali-silica ratio of the analysis it represents. In some instances several individual diagrams belong so close together that they would overlap, so as to prevent their shapes from being easily seen. One or more of them is moved to the nearest available space in the multiple diagram. From this it happens that the distribution of the analyses in the large diagram is not strictly correct in the more crowded portions of it. A more exact representation of the distribution is given in another form of multiple diagrams on a smaller scale, in which round spots take the place of the individual diagrams.

ROCK ANALYSES USED IN CONSTRUCTING DIAGRAMS.

Having described the methods by which the diagrams are constructed, a more important matter to be considered is the data to be used—the rock analyses to be compared by them.

Analyses have been selected from all sources available, but not all analyses. It is important that they be correctly made and from good material. These conditions, however, can not always be recognized or known without careful study of the publications in which the analyses appear, and not always then. The collection is not above criticism in this respect. However, care was exercised to omit obviously defective analyses, as well as those from plainly declared altered rocks, except in cases where the altered form may be assumed to correspond approximately to the fresh rock, with the addition of water of hydration. For the strongly ferromagnesian rocks such analyses have been taken sometimes in default of better.

The analyses represent as many varieties of igneous rocks as could be found, with as wide a range as possible. Many analyses closely similar to those introduced into the large diagrams have been omitted because there was not space for them. Consequently the diagrams do not show the proper proportions between the commoner and rarer varieties of rocks. This can be shown by plotting the loci of all acceptable analyses by means of spots in a multiple diagram of fairly large scale. This has been done in constructing the diagram on Pl. VIII, which is composed of 2,000 analyses.

It was thought unnecessary to reprint the analyses themselves, for the reason that nearly all of them will be found in the collection of rock analyses made by Dr. Henry S. Washington and published by the United States Geological Survey,[a] and a large part of them also in Bulletin of the United States Geological Survey No. 168. Many of them will be found in Rosenbusch's Elemente der Gesteinslehre. So that these collections should be used in connection with the diagrams. For this reason reference is given in many cases to these publications, and to others where numerous analyses are assembled, instead of to the original sources, as the more convenient method of finding them.

A list of the analyses used in the diagrams is given. Their positions on the diagrams may be found by means of the silica percentage and alkali-silica

[a] Chemical analyses of igneous rocks from 1884 to 1900: Prof. Paper U. S. Geol. Survey No. 14.

ratio, which are stated in each case, besides the position given them when placed differently.

They are classified according to the quantitative classification, and the author wishes to express his thanks to Dr. Washington for the labor he has bestowed on the comparison of the list with his collection and for the correction of errors that appeared in the list. He is indebted to him also for valuable additions to it.

The list is far from complete, and petrographers may add to it and to the diagrams data which should have been included. But it seems as though enough has been introduced to accomplish the purpose for which the diagrams were prepared.

In order to shorten the references in the lists, a number of abbreviations are used which are given alphabetically.

ABBREVIATIONS EMPLOYED IN BIBLIOGRAPHIC REFERENCES.

A. G..................American Geologist. Minneapolis.
A. J. S................American Journal of Science. New Haven.
A. W. B...............Sitzungsberichte der König. Preuss. Akad. der Wissensch. Berlin.
A. W. W...............Sitzungsberichte der K. Akad. Wissensch. Wien.
B. C. G. F.............Bulletin de la Commission géologique de Finlande. Helsingfors.
B. G. S. A.............Bulletin of the Geological Society of America. Rochester.
B. M. A...............Bergens Museums Aarbog.
Bull. 168...............Bulletin of the U. S. Geological Survey, No. 168. Washington, 1900.
C. G. I.................Congrès géologique International, Compte Rendu, VIII session. Paris.
E. K...................Die Eruptivgesteine des Kristianiagebietes, W. C. Brögger. Christiania. I, 1894; II, 1895; III, 1898.
G. C...................Untersuchung einiger Gesteinssuiten gesammelt in Celebes, von P. and F. Sarasin. C. Schmidt, Wiesbaden, 1901.
G. F. S. F.............Geol. Fören. i Stockholm Förhandl.
I. R. A................The igneous rocks of Arkansas: vol. 2 of Ann. Rept. Geol. Surv. Arkansas.
J. G...................The Journal of Geology. Chicago.
O. N...................Recherches géologiques et pétrographiques sur l'Oural du Nord, Duparc et Pearce. Part I. Geneva, 1902.
M. M..................Materiaux pour la Minéralogie de Madagascar, A. Lacroix. Nouvelles Archives du Muséum. 4th series, Vol. I. Paris, 1902.
N. J...................Neues Jahrbuch für Mineralogie, Geologie, etc.
Q. J. G. S.............Quarterly Journal of the Geological Society of London.
Rosenbusch, El.........Rosenbusch. Elemente der Gesteinslehre. Stuttgart, 1898.
R. T...................Roth's tables of rock analyses. Beiträge zur Petrographie der Plutonischen Gesteine. Berlin.
S. M. Q................School of Mines Quarterly. New York.
T. M. P. M............Tschermak's Min. u. Petr. Mitth. Vienna.
W. T...................Washington's tables of chemical analyses of igneous rocks from 1884 to 1900. Professional Paper U. S. Geological Survey, No. 14, Washington, 1903.
Z. D. g. G.............Zeitschrift d. Deutschen geol. Gesellschaft. Berlin.
Z. K...................Zeitschrift für Krystallographie.
Z. P. G................Zeitschrift für Praktische Geologie. Berlin.
Fortieth Par...........U. S. Geol. Expl. Fortieth Parallel. Washington.

CLASSIFIED LIST OF ANALYSES USED IN CONSTRUCTING DIAGRAMS.

CLASS I. PERSALANE.

ORDER 3. COLUMBARE.

RANG 1. ALASKASE.

SUBRANG 1. ——.

(I. 3, 1, 1.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
79.25	0.057	Porphyry	Harz Mountains	R. T., 1861, 7.

SUBRANG 2. MAGDEBURGOSE.

(I. 3, 1, 2.)

79.75	0.062	Quartz-porphyry	Blowing Rock, Watauga County, N. C.	Bull. 168, 52.—W. T.
78.86	.079	Felsite-porphyry	Fichtelgebirge, Bavaria	R. T., 1879, XX.
76.10	.085	Granite	Crystal Falls district, Mich	Bull. 168, 66.—W. T.
75.39	.080	Rhyolite	Silver Cliff, Colo	Bull. 168, 149.—W. T.
74.40	.079	Granite	Pikes Peak district, Colo	Bull. 168, 142.—W. T.

SUBRANG 3. ALASKOSE.

(I. 3, 1, 3.)

80.24	0.070	Granite	Wexford, Ireland	R. T., 1861-2.
79.57	.070	Rhyolite	Montgomery County, N. C	Bull. 168, 53.—W. T.
77.68	.077	Granitite	Eldorado County, Cal	Bull. 168, 199.—W. T.
77.68	.075 (77.6)	Quartz-porphyry	Tryberg Fall, Black Forest	N. J., 1883, II, 29.—W. T.
77.59	.059	Rhyolite	Hauraki Goldfield, New Zealand	Q. J. G. S., 1899, LV, 467.—W. T.
77.33	.079 (.078)	Alaskite	Tordrillo Mountains, Alaska	Bull. 168, 228.—W. T.
77.20	.080	Quartz-porphyry	Kroftkollen, Norway	Z. K., XVI, 77.—W. T.
77.05	.080	Aplite	Butte, Mont	Bull. 168, 118.—W. T.
77.03	.081 (76.8-.082)	Granitite	Pikes Peak district, Colo	Bull. 168, 142.—W. T.
77.02	.077 (77.1)	Granite	Platte Canyon, Colo	Bull. 168, 164.—W. T.
76.87	.078	Aplite	Butte, Mont	Bull. 168, 118.—W. T.
76.73	.077 (76.6)	Aplitic granophyre	Hennum, Norway	Z. K., XVI, 77.—W. T.
76.10	.063	Muscovite-granite	Omeo, Victoria	Trans. R. S. Vict.—W. T.
75.84	.081	Tordrillite	Tordrillo Mountains, Alaska	Bull. 168, 229.—W. T.
75.52	.080 (75.7)	Obsidian	Obsidian Cliff, Yellowstone Park	Bull. 168, 104.—W. T.
74.70	.083	do	do	Do.
74.24	.069	Rhyolite	Plumas County, Cal	Bull. 168, 178.—W. T.
73.11	.082 (73.0)	Pitchstone	Rosita, Colo	Bull. 168, 150.—W. T.

SUBRANG 4. ——.

(I. 3, 1, 4.)

83.08	0.054	Spherulitic rock	Wales	Teall, British Petrography, 339.
82.80	.049	Perlite	Monte Menone	R. T., 1869, XC.
76.00	.067	Granite	Plumas County, Cal	Bull. 168, 187.—W. T.
75.19	.076 (75.1)	Rhyolite	Madison Plateau, Yellowstone Park	Bull. 168, 105.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

SUBRANG 5. WESTPHALOSE.

(I. 3, 1, 5.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
83.57	0.053	Quartz-keratophyre	Westphalia	N. J., 1893, VIII, 616.—W. T.
80.42	.059	....do	....do	N. J., 1893, VIII, 632.—W. T.
77.32	.081 (.083)	Granite	Roddö, Sweden	W. T.

RANG 2. ALSBACHASE.

SUBRANG 2. MIHALOSE.

(I. 3, 2, 2.)

73.15	0.055	Rhyolite	Nagy-Mihaly, Hungary	W. T.
73.07	.074	....do	Washoe, Nev	Bull. 168, 174.—W. T.
72.68	.054	....do	Nagy-Mihaly, Hungary	W. T.
70.59	.057	....do	....do	Do.

SUBRANG 3. TEHAMOSE.

(I. 3, 2, 3.)

79.95	0.049	Felsite-porphyry	Bohemia	R. T., 1884, XVIII.
77.34	.069	Aplite	Kirnechthal, Vosges	Rosenbusch, El., 207.
76.12	.059	Granitite	Riesengebirge, Silesia	N. J., 1898, XII, 233.—W. T.
75.89	.069 (75.8)	Rhyolite	Mount Sheridan, Yellowstone Park	Bull. 168, 105.—W. T.
75.34	.076	....do	Elephants Back, Yellowstone Park	Do.
75.21	.072	Granitite	Riesengebirge, Silesia	N. J., 1898, XII, 233.—W. T.
74.65	.074	Rhyolite	Tehama County, Cal	Bull. 168, 178.—W. T.
74.41	.067	Granite	Riesengebirge, Silesia	N. J., 1898, XII, 233.—W. T.
74.34	.072	Rhyolite	Butte district, Mont	Bull. 168, 119.—W. T.
73.62	.079 (73.7)	....do	Tehama County, Cal	Bull. 168, 178.—W. T.
72.37	.058	Granitite	Riesengebirge, Silesia	N. J., 1898, XII, 232.—W. T.
72.15	.067	....do	....do	Do.
72.04	.058	....do	....do	Do.
72.01	.073	Quartz-porphyry	Eureka, Nev	U. S. G. S., Mon. XX, 228.
71.45	.054	Granitite	Sykesville, Md	Bull. 168, 47.—W. T.

SUBRANG 4. ALSBACHOSE.

(I. 3, 2, 4.)

78.75	0.052	Granite	Storgord, Finland	R. T., 1869, XL.
77.35	.052	....do	Riesengebirge, Silesia	N. J., 1898, XII, 233.—W. T.
74.65	.064	Granitite	....do	Do.
74.13	.077	Alsbachite	Melibocus, Odenwald	Rosenbusch, El., 207.—W. T.
73.08	.080 (72.9)	Rhyolite	Waihi, Hauraki, New Zealand	Q. J. G. S., 1899, LV, 467.—W. T.
72.89	.056	Granitite	Riesengebirge, Silesia	N. J., 1898, XII, 232.—W. T.

SUBRANG 5. YUKONOSE.

(I. 3, 2, 5.)

74.79	0.067	Tonalite-aplite	Yukon River, Alaska	Bull. 168, 229.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

RANG 3. RIESENASE.

SUBRANG 2. ——.

(I. 3, 3, 2.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
72.11	0.041	"Schliere" in granite	Riesengebirge, Silesia	N. J., 1898, XII, 235.—W. T.
71.14	.055	Toscanite	Rocca Strada, Italy	J. G., V, 363.—W. T.
66.86	.052	Granite-porphyry	Nieder Modau, Hesse	W. T.

SUBRANG 3. RIESENOSE.

(I. 3, 3, 3.)

76.82	0.037	Granitite	Riesengebirge, Silesia	N. J., 1898, XII, 233.—W. T.
75.27	.036	Granite	....do	Do.
75.21	.048	Granitite	....do	Do.
73.00	.049	Toscanite	Rocca Strada, Italy	J. G., V, 363.—W. T.
72.92	.040	Granitite	Riesengebirge, Silesia	N. J., 1898, XII, 232.—W. T.
72.71	.038	....do	....do	Do.
69.04	.047	....do	....do	N. J., 1898, XII, 234.—W. T.

SUBRANG 4. ——.

(I. 3, 3, 4.)

76.13	0.055 (76.2)	Granite	Riesengebirge, Silesia	N. J., 1898, XII, 233.—W. T.
72.81	.041	Granitite	....do	N. J., 1898, XII, 232.—W. T.

SUBRANG 5. VULCANOSE.

(I. 3, 3, 5.)

72.24	0.062	Quartz-diorite-porphyry.	Calaveras County, Cal	Bull. 168, 203.—W. T.
66.99	.051	Vulcanite	Vulcano, Lipari	B. G. S. A., V, 601.—W. T.

RANG 4. ——.

SUBRANG 2. ——

(I. 3, 4, 2.)

68.87	0.028	"Schliere" in granite	Riesengebirge, Silesia	N. J., 1898, XII, 235.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

ORDER 4. BRITANNARE.

RANG 1. LIPARASE.

SUBRANG 1. LEBACHOSE.

(I. 4, 1, 1.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
69.06	0.117 (69.3)	Quartz-orthoclasite	Thüringerwald, Prussia	W. T.
68.13	.107	Quartz-porphyry	Hummelberg, Prussia	Do.

SUBRANG 2. OMEOSE.

(I. 4, 1, 2.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
75.20	0.096	Rhyolite	Silver Cliff, Colo	Bull. 168, 149.—W. T.
75.07	.084	do	Pine Nut Canyon, Nev	Fortieth Par., I, 652.
74.62	.095	do	Humboldt Sink Group, Nev	Do.
74.24	.089	Rapakiwi	Livland, Finland	R. T., 1873, X.
71.09	.112	Aplite	Satteljoch; Predazzo, Tyrol	K. A. W. W., CXI, I, 266.
70.91	.121	Graphic granite	Omeo, Victoria	Trans. R. S. Vict.—W. T.
68.99	.115	Pitchstone	Ponza, Italy	R. T., 1879, LII.
68.87	.084	Granite	Omeo, Victoria	Trans. R. S. Vict.—W. T.

SUBRANG 3. LIPAROSE.

(I. 4, 1, 3.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
77.61	0.088	Granite	Cape Ann, Mass	J. G. VI, 793.—W. T.
76.49	.092	Paisanite	Magnolia, Mass	J. G. VII, 113.—W. T.
76.33	.092	Graphic granite	Hochland	R. T., 1869, XLII.
76.30	.088	Alaskite	Alaska	Bull. 168, 228.—W. T.
76.20	.091	Obsidian	Obsidian Hill, N. Mex	Bull. 168, 172.—W. T.
76.05	.092	Aplitic granophyre	Konerudwege, Norway	Z. K., XVI, 77.—W. T.
75.71	.094 (75.6)	Rhyolite	Great Paint Pots, Yellowstone Park	Bull. 168, 105.—W. T.
75.44	.094	Comendite	Iskagan Bay, Siberia	A. J. S., XII, 1902, 180.—W. T.
75.44	.089	Rhyolite	Fish Creek Mountains, Nev	Fortieth Par., I, 652.
75.30	.082	do	Rimini, Mont	Bull. 168, 119.—W. T.
75.17	.085	Granitite	Pikes Peak district, Colo	Bull. 168, 142.—W. T.
74.90	.094	Rhyolite	Castle Mountain district, Mont	Bull. 168, 129.—W. T.
74.87	.084	Granite	Brookville, Md	Bull. 168, 46.—W. T.
74.76	.098	Comendite	Comende, San Pietro, Sardinia	Rosenbusch, El., 257.—W. T.
74.45	.090	Rhyolite	Chalk Mountain, Colo	Bull. 168, 156.—W. T.
74.05	.096	Obsidian	Mono Craters, Cal	Bull. 168, 219.—W. T.
73.93	.100	Granite	Quincy, Mass	J. G., VI, 793.—W. T.
73.69	.100	Granite-porphyry	Mount Ascutney, Vt	Bull. 168, 25.—W. T.
73.51	.094 (73.4)	Granitite	Pikes Peak district, Colo	Bull. 168, 142.—W. T.
73.35	.106	Paisanite	Mosques Canyon, Tex	T. M. P. M., XV, 439.—W. T.
73.09	.085	Granite-porphyry	Albany, N. H	A. J. S., XX, 1881, 25.
73.03	.104	Syenite-porphyry	Mount Ascutney, Vt	Bull. 168, 24.—W. T.
72.88	.093	Aplite-granite	Castle Mountain district, Mont	Bull. 168, 129.—W. T.
72.48	.099	Granite	do	Do.
72.35	.093	do	Ironton, Mo	Bull. 168, 60.—W. T.
72.26	.101	do	Albany, N. H	A. J. S., XXI, 1881, 25.
72.06	.107	do	Stony Creek, Conn	B. G. S. A., X, 375.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

SUBRANG 3. LIPAROSE—Continued.

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
71.90	.102	Granitite	Mount Ascutney, Vt	Bull. 168, 24.—W. T.
71.88	.095	Porphyry	Ironton, Mo	Bull. 168, 60.—W. T.
71.67	.101	Quartz-porphyry	Castle Mountain district, Mont	Bull. 168, 129.—W. T.
71.56	.086	Pitchstone	Silver Cliff, Colo	Bull. 168, 150.—W. T.
71.49	.109	Quartz-porphyry	Gislerud, Norway	Z. K., XVI, 46.—W. T.
71.07	.087	Granite-porphyry	Albany, N. H	A. J. S., XXI, 1881, 25.
70.92	.096 (70.7)	Rhyolite	Upper Geyser Basin, Yellowstone Park.	Bull. 168, 104.—W. T.
70.23	.113	Keratophyre	Marblehead Neck, Mass	Bull. 168, 34.—W. T.
70.09	.092	Orthoclase-porphyry	Cornon, Tyrol	R. T., 1879, XXVIII.
70.01	.113	Obsidian	Palmerola, Italy	R. T., 1879, LII.
69.91	.119	Ægirite-granite	Miask, Ural Mountains	A. J. S., XIII, 1902, 180.—W. T.
69.89	.098	Rhyolite	Nathrop, Colo	Bull. 168, 164.—W. T.
68.95	.144	Grorudite	W. Aker, Norway	E. K., I, 199.—W. T.
68.71	.114	Quartz-pantellerite	Vieja Mountains, San Carlos, Tex	Bull. 168, 61.—W. T.
68.65	.110 (68.5)	Granite-syenite-porphyry.	Little Rocky Mountains, Mont	Bull. 168, 134.—W. T.
68.34	.129	Quartz-syenite	Bearpaw Mountains, Mont	Bull. 68, 135.—W. T.
66.40	.097 (66.7)	Quartz-syenite-porphyry.	Fjelebua, Norway	Z. K., XVI, 46.—W. T.

SUBRANG 4. KALLERUDOSE.

(I. 4, 1, 4.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
75.92	0.093 (75.8-.094)	Granitite	Pikes Peak district, Colo	Bull. 168, 142.—W. T.
73.61	.089	Rhyolite	Oyacachi, South America	R. T., 1879, LIV.
73.50	.095 (73.8)	Quartz-bearing bostonite.	Ampangarinana, Madagascar	M. M., 55.
72.56	.099 (72.8)	Rhyolitic pitchstone	Castle Mountain district, Mont	Bull. 168, 129.—W. T.
72.46	.095	Rhyolite	Guomani, Ecuador, South America	R. T., 1879, LIV.
71.65	.119	Soda granite	Hougnatten, Norway	E. K., I, 198.—W. T.

SUBRANG 5. NOYANGOSE.

(I. 4, 1, 5.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
77.66	0.087 (77.9-.086)	Quartz-keratophyre	Omeo, Victoria	Rosenbusch, El., 260.—W. T.
75.78	.091	Granite	Rice Point, Duluth, Minn	21st Ann. Rept., Surv. Minn., 41.—W. T.
75.46	.097	Soda-rhyolite	Berkeley, Cal	Rosenbusch, El., 260.—W. T.

RANG 2. TOSCANASE.

SUBRANG 2. DELLENOSE.

(I. 4, 2, 2.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
69.19	0.102	Granite	Tryberg Fall, Schwarzwald	N. J., 1883, II.
68.36	.078	Dellenite	Dellen, Helsingland, Sweden	E. K., II, 59.—W. T.
66.24	.093	Toscanite	Monte Cucco, Italy	J. G., V, 362.—W. T.
65.19	.093	.....do	Tolfa, Italy	Do.

Classified list of analyses used in constructing diagrams—Continued.

SUBRANG 3. TOSCANOSE.

(I. 4, 2, 3.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
76.48	0.087	Aplite	Dargo, Victoria	Trans. R. S. Vict.—W. T.
76.03	.081	....do	Sierra County, Cal	Bull. 168, 192.—W. T.
76.00	.087	Granodiorite-aplite	Downieville area, Cal	J. G., VII, 160.—W. T.
75.97	.079 (76.1-.078)	Aplite	Sierra County, Cal	Bull. 168, 192.—W. T.
75.74	.086	Granite	Lier, Norway	Z. K., XVI, 77.—W. T.
75.08	.084 (75.0)	Obsidian	Laguna de Maricunga, Chile	Z. D. J., G. LI, 4.
75.01	.086 (75.1-.088)	Alaskite	Alaska	Bull. 168, 228.—W. T.
74.95	.088	Rhyolite	Montezuma Mountains, Nev	Fortieth Par., I, 652.
74.60	.081	....do	Shasta County, Cal	Bull. 168, 178.—W. T.
74.49	.088 (74.6)	....do	Thomas Range, Utah	Bull. 168, 168.—W. T.
74.37	.085	Granitite	Crazy Mountains, Mont	Bull. 168, 120.—W. T.
73.84	.083	Rhyolite-perlite	Midway Basin, Yellowstone Park	Bull. 168, 108.—W. T.
73.70	.092	Granite	Peterhead, Scotland	R. T., 1884, XIV.
73.64	.083	Rhyolite	Lassen trail, Tehama County, Cal	Bull. 168, 178.—W. T.
73.51	.097	Obsidian	Modoc County, Cal	Bull. 168, 217.—W. T.
73.38	.080	Granite	Lake Raslangen, Sweden	W. T.
73.12	.087	Quartz-porphyry	Little Belt Mountains, Mont	Bull. 168, 125.—W. T.
72.57	.090	Granite	Guilford, Md	Bull. 168, 46.—W. T.
72.40	.086	Rhyolite	Mount Stover, Cal	Bull. 168, 178.—W. T.
71.85	.087 (72.0)	....do	Tower Creek, Yellowstone Park	Bull. 168, 104.—W. T.
71.79	.082 (71.7)	Granitite	Woodstock, Md	Bull. 168, 46.—W. T.
71.78	.085	Granite	Cottonwood Canyon, Utah	Fortieth Par., I, 110.
71.53	.070	Granitite	Riesengebirge, Silesia	N. J., 1898, XII, 232.—W. T.
71.12	.098	Rhyolite	Ponza, Italy	R. T., 1879, LII.
71.08	.084 (71.0)	Granodiorite	El Capitan, Yosemite, Cal	Bull. 168, 207.—W. T.
70.87	.092	Rhyolite	Pennsylvania Hill, Silver Cliff, Colo	Bull. 168, 149.—W. T.
70.75	.080	Granite	Amador County, Cal	Bull. 168, 200.—W. T.
70.56	.105 (70.7)	Rhyolite	Ponza, Italy	
70.54	.107	Ægirite-granite	Löken, Norway	Z. K., XVI, 57.—W. T.
70.45	.084	Granite	Dorseys Run, Md	Bull. 168, 47.—W. T.
70.29	.101	Rhyolite	Harlequin Canyon, Nev	Fortieth Par., I, 652.
69.96	.089	Dacite	Washoe, Nev	Bull. 168, 174.—W. T.
69.95	.098 (70.1)	Quartz-porphyry	Butte district, Mont	Bull. 168, 119.—W. T.
69.94	.092	Granite	Ironton, Mo	Bull. 168, 60.—W. T.
69.68	.087	Granite-porphyry	Little Belt Mountains, Mont	Bull. 168, 125.—W. T.
69.52	.108	Trachyte	Pikes Peak district, Colo	Bull. 168, 145.—W. T.
69.45	.097	Rhyolo-trachyte	Sunset Peak, Mont	Bull. 168, 106.—W. T.
68.88	.100	Quartz-syenite-porphyry.	Squam Light, Mass	J. G., VII, 109.—W. T.
68.68	.077	Granite	Eureka, Nev	U. S. G. S., Mon. XX, 228.
68.60	.107 (68.7)	Granite-porphyry	Little Belt Mountains, Mont	Bull. 168, 125.—W. T.
68.58	.100	Granite	West Humboldt Mountains, Nev	Fortieth Par., I, 110.
68.55	.095	....do	Shap, England	Q. J. G. S., 47, 276
68.42	.083 (68.2)	Quartz-monzonite	Hailey, Idaho	Bull. 168, 137.—W. T.
68.40	.112 (68.2)	Granite	Millstone Point, Conn	B. G. S. A., X, 375.—W. T.
68.36	.105	Nordmarkite	Gloucester, Mass	J. G., VI, 800.—W. T.
67.45	.084	Granodiorite	Eldorado Canyon, Cal	Bull. 168, 199.—W. T.
67.44	.104	Granite-syenite-porphyry.	Little Belt Mountains, Mont	Bull. 168, 127.—W. T.
67.12	.082	Granite	Boulder, Mont	Bull. 168, 118.—W. T.
67.04	.107	Quartz-syenite-porphyry.	Little Belt Mountains, Mont	Bull. 168, 127.—W. T.
66.60	.111	Akerite	Gloucester, Mass	J. G., VI, 798.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

SUBRANG 3. TOSCANOSE—Continued.

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
66.12	.123 (66.3)	Trachyte	Wicher Mountain, Colo	Bull. 168, 145.—W. T.
65.58	.094	....do	Monte Amiata, Italy	Rosenbusch, El., 269.—W. T.
65.32	.096	....do	....do	Do.
65.05	.092	Toscanite	....do	J. G., V, 362.—W. T.
64.76	.094	Trachyte	....do	Rosenbusch, El., 269.—W. T.
64.64	.114 (64.5)	Syenite	Little Belt Mountains, Mont	Bull. 168, 125.—W. T.
64.62	.118	Diorite	Mount Ascutney, Vt	Bull. 168, 25.—W. T.
64.57	.095	Toscanite	Bracciano, Italy	J. G., V, 362.—W. T.
64.49	.103	Porphyrite	Crazy Mountains, Mont	Bull. 168, 120.—W. T.
62.33	.110	Latite	Clover Meadow, Tuolumne County, Cal.	Bull. 168, 205.—W. T.

SUBRANG 4. LASSENOSE.

(I. 4, 2, 4.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
75.50	0.083	Rhyolite	Obsidian Cliff, Yellowstone Park	Bull. 168, 104.—W. T.
73.27	.077	Granite	Florence, Mass	Bull. 168, 30.—W. T.
73.00	.075	....do	Rocklin, Cal	Bull. 168, 198.—W. T.
72.59	.083	Obsidian	Willow Park, Yellowstone Park	Bull. 168, 104.—W. T.
71.74	.075	Granitite	Riesengebirge, Silesia	N. J., 1898, XII, 232.—W. T.
71.19	.073	Quartz-porphyrite	Calaveras County, Cal	Bull. 168, 203.—W. T.
70.36	.082	Granodiorite	Enterprise, Butte County, Cal	Bull. 168, 190.—W. T.
69.93	.109	Granite-porphyry	Crazy Mountains, Mont	Bull. 168, 120.—W. T.
69.66	.084	Dacite	Lassen Peak, Cal	Fortieth Par., I, 652.
69.56	.076	....do	Colombia, South America	J. G., I, 171.—W. T.
69.51	.083	....do	Lassen Peak, Cal	Bull. 168, 179.—W. T.
69.00	.126	Quartz-lindoite	W. Aker, Norway	E. K., I, 198.—W. T.
68.72	.084 (68.8)	Dacite	Lassen Peak, Cal	Bull. 168, 180.—W. T.
68.65	.084	Quartz-monzonite	Sierra County, Cal	Bull. 168, 192.—W. T.
68.32	.086	Dacite	Lassen Peak, Cal	Bull. 168, 179.—W. T.
68.10	.088	....do	Shasta County, Cal	Bull. 168, 180.—W. T.
67.89	.088	Andesite	Buntingville, Cal	Bull. 168, 181.—W. T.
67.55	.087 (67.2)	Pitchstone	Butte district, Mont	Bull. 168, 119.—W. T.
67.49	.085 (67.6)	Dacite	Sepulchre Mountain, Yellowstone Park.	Bull. 168, 91.—W. T.
67.49	.112	Mica-dacite	Silver Cliff, Colo	Bull. 168, 149.—W. T.
67.42	.116	Augite-soda-granite	Kekequabic Lake, Minn	A. G., XI, 385.—W. T.
67.01	.120	Alaskite-porphyry	Alaska	Bull. 168, 228.—W. T.
66.46	.104	Dacite	Rosita, Colo	Bull. 168, 149.—W. T.
66.30	.098	Dacite-porphyry	Shasta County, Cal	Bull. 168, 177.—W. T.
66.28	.094 (66.5)	Porphyrite	Crazy Mountains, Mont	Bull. 168, 120.—W. T.
65.87	.099	Feldspar-porphyry	Castle Mountain district, Mont	Bull. 168, 130.—W. T.
65.78	.121	Mica-andesite	San Mateo Mountain, N. Mex	Bull. 168, 170.—W. T.
65.64	.108	Andesite-porphyry	Gray Peak, Yellowstone Park	Bull. 168, 107.—W. T.
64.98	.109	Oligoclasite	Preston, Norway	B. M. A., 1898, VII, 47.—W. T.
62.58	.109	Syenite-porphyry	Yogo Peak, Mont	Bull. 168, 127.—W. T.

SUBRANG 5. MARIPOSOSE.

(I. 4, 2, 5.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
74.21	0.100	Soda-granite	Mariposa County, Cal	Bull. 168, 207.—W. T.
67.88	.084 (67.8)	Granite	Cavaura River, British Guiana	W. T.

Classified list of analyses used in constructing diagrams—Continued.

RANG 3. COLORADASE.

SUBRANG 3. AMIATOSE.

(I. 4, 3, 3.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
68.97	0.075	Granite	Lower Elsass, Vosges	Rosenbusch, El., 78.
65.53	.085	Trachyte	Monte Amiate, Italy	Rosenbusch, El., 269.—W. T.
65.36	.085	Quartz-porphyrite	Mount Carbon, Colo	Bull. 168, 160.—W. T.
65.13	.082	Andesite-perlite	Eureka, Nev	U. S. G. S., Mon. XX, 264.—W. T.
63.17	.088	Dacite	Pergamon, Asia Minor	A. J. S., III, 1897, 45.—W. T.
61.93	.085	Andesite	Kara Tash, Asia Minor	A. J. S., III, 1897, 45.—W. T.

SUBRANG 4. YELLOWSTONOSE.

(I. 4, 3, 4.)

68.41	0.084	Dacite	Colombia, South America	J. G., I, 171.—W. T.
68.10	.065	Diorite	Ono, Cal	Bull. 168, 177.—W. T.
68.12	.078	Andesite	Shasta County, Cal	Bull. 168, 183.—W. T.
67.30	.075	Dacite	Colombia, South America	J. G., I, 171.—W. T.
66.94	.070	Andesite	Sierra County, Cal	Bull. 168, 193.—W. T.
66.65	.082	Quartz-diorite-porphyry.	....do	Bull. 168, 192.—W. T.
66.65	.074	Granodiorite	Nevada City, Cal	Bull. 168, 194.—W. T.
65.71	.065	Banatite	Banat, Hungary	Rosenbusch, El., 140.
65.66	.072	Dacite	Sepulchre Mountain, Yellowstone Park.	Bull. 168, 91.—W. T.
65.63	.080	Andesite	Fan Creek, Yellowstone Park	Bull. 168, 107.—W. T.
65.60	.086 (65.7)	Quartz-mica-diorite	Electric Peak, Yellowstone Park	Bull. 168, 88.—W. T.
64.85	.084	....do	....do	Do.
64.61	.088	Andesite	Crescent Hill, Yellowstone Park	Bull. 168, 108.—W. T.
64.52	.080	....do	Mount Shasta, Cal	Bull. 168, 176.—W. T.
64.48	.076 (64.7)	....do	....do	Do.
64.27	.081	....do	Sepulchre Mountain, Yellowstone Park.	Bull. 168, 91.—W. T.
64.24	.078 (64.1)	Dacite-porphyry	Shasta County, Cal	Bull. 168, 177.—W. T.
63.81	.079	Dacite	Mill Creek, Shasta County, Cal	Bull. 168, 180.—W. T.
63.42	.098	Quartz-diorite-porphyry.	Crandall Basin, Wyo	Bull. 168, 94.—W. T.
63.30	.087	Andesite	Mount Rose, Washoe, Nev	Fortieth Par. I, 604.
62.91	.094	Granitite	Dorseys Run, Md	Bull. 168, 47.—W. T.
62.85	.085	(?) Porphyrite-diorite	Mount Marcellina, Colo	Bull. 168, 160.—W. T.
61.42	.078	Porphyrite	Storm Ridge, Colo	Do.

SUBRANG 5. AMADOROSE.

(I. 4, 3, 5.)

69.66	0.074	Quartz-diorite-aplite	Amador County, Cal	Bull. 168, 201.—W. T.
69.34	.066	Granite	Saganaga Lake, Minn	21st Ann. Rept. Geol. Surv. Minn., 43.—W. T.

RANG 4. ——.

SUBRANG 3. ——.

(I. 4, 4, 3.)

65.81	0.047	Granite	Hochwald, Vosges	Rosenbusch, Steiger Schiefer (Strassburg, 1877), 167.

Classified list of analyses used in constructing diagrams—Continued.

ORDER 5. CANADARE.

RANG 1. NORDMARKASE.

SUBRANG 3. PHLEGROSE.

(I. 5, 1, 3.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
66.13	0.130	Quartz-syenite	Fjelebua, Norway	Z. K., XVI, 46.—W. T.
66.03	.132 (65.9)	Trachyte	Game Ridge, Custer County, Colo	Bull. 168, 147.—W. T.
65.43	.131	Syenite	Mount Ascutney, Vt	Bull. 168, 24.—W. T.
64.88	.128	Syenite-porphyry	do	Bull. 168, 25.—W. T.
64.04	.160	Nordmarkite	Tonsenas, Norway	Z. K., XVI, 54.—W. T.
63.71	.159	Pulaskite	Salem Neck, Mass	J. G., VI, 806.—W. T.
62.30	.142	Bostonite	Gran, Norway	E. K., III, 204.—W. T.
61.92	.151	Pulaskite	Lokobé, Madagascar	M. M., 204.
61.88	.176	Trachyte	Marecocco, Italy	A. J. S., VIII, 1899, 289.—W. T.
61.62	.170 (61.2)	do	Monte Rotaro, Italy	Do.
61.45	.143 (61.3)	do	Maros, Celebes	G. C., 16.
61.05	.166	Sölvsbergite	Coney Island, Mass	J. G., VII, 118.—W. T.
60.33	.193	Trachyte	Monte Nuovo, Italy	A. J. S., VIII, 1899, 287.—W. T.
60.13	.165	Nephelite-syenite	Fourche Mountain, Ark	J. G., IX, 610.—W. T.
60.02	.147	Syenite-keratophyre	Harz Mountains	R. T., 1884, XXII.
59.79	.186	Trachyte	Monte Nuovo, Italy	A. J. S., VIII, 1899, 287.—W. T.
59.70	.164	Nephelite-syenite	Fourche Mountain, Ark	I. R. A., 88.—W. T.
58.75	.176	Umptekite	Cabo Frio, Brazil	T. M. P. M., XX, 248.—W. T.
57.18	.171	Trachyte	Highwood Mountains, Mont	Bull. 168, 131.—W. T.

SUBRANG 4. NORDMARKOSE.

(I. 5, 1, 4.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
66.50	0.162	Lestiwarite	Kvella, Norway	E. K., III, 216.—W. T.
66.22	.149 (66.4)	Quartz-syenite-porphyry.	Bearpaw Mountains, Mont	Bull. 168, 135.—W. T.
66.06	.151	Liparite	Hohenburg, near Bonn, Prussia	R. T., 1884, XLVIII.
65.51	.143	Phonolitic andesite	San Mateo Mountains, N. Mex	Bull. 168, 170.—W. T.
65.43	.140 (65.1)	Nordmarkite	Shefford Mountain, Quebec	J. G., XI, 271.
64.92	.146	Quartz-sölvsbergite	Gran, Norway	E. K., I, 78.—W. T.
64.54	.157	Pulaskite	Lovasbucht, Norway	E. K., III, 198.—W. T.
64.33	.151	Acmite-trachyte	Crazy Mountains, Mont	Bull. 168, 123.—W. T.
63.76	.161 (63.4)	Syenite	Ahvenvaara, Finland	B. C. G. F., 11, 34.—W. T.
63.20	.164	Nordmarkite	Tonsenas, Norway	Z. K., XVI, 54.—W. T.
63.09	.164 (63.6)	Pulaskite	Salem Neck, Mass	J. G., VI, 806.—W. T.
62.17	.156	Acmite-trachyte	Crazy Mountains, Mont	Bull. 168, 123.—W. T.
61.67	.169	Keratophyre	Harz Mountains	R. T., 1884, XXII.
61.54	.180	Phonolite	Zittau, Saxony	R. T., 1861, 23.
61.08	.185	do	Black Hills, S. Dak	A. J. S., XLVII, 1894, 344.—W. T.
60.39	.184	Litchfieldite	Litchfield, Me	Bull. 168, 21.—W. T.
60.11	.161 (59.9)	Bostonite	Hedrum, Norway	E. K., III, 204.—W. T.
60.05	.157 (60.3)	Tinguaite	Gales Point, Mass	J. G., VII, 481.—W. T.
59.62	.173	Nephelite-syenite	Saline County, Ark	I. R. A., 135.—W. T.
59.31	.174	Foyaite	Great Haste Island, Mass	J. G., VII, 481.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

SUBRANG 5. TUOLUMNOSE.

(I, 5, 1, 5.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
67.53	0.165	Albitite	Tuolumne County, Cal	Bull. 168, 204.—W. T.
66.09	.162	....do	Koswinsky, Ural Mountains	O. N., 169.

RANG 2. PULASKASE.

SUBRANG 2. VULSINOSE.

(I. 5, 2, 2.)

58.48	0.165	Leucite-trachyte (?)	Rocca Monfina, Italy	J. G., V, 370 —W. T.
58.21	.142	Vulsinite	Bolsena Monfina, Italy	J. G., V, 358.—W. T.
57.32	.156	....do	Vetrella, Italy	Do.
55.17	.150	Leucite-trachyte	San Rocco, Italy	J. G., V, 370.—W. T.

SUBRANG 3. PULASKOSE.

(I. 5, 2, 3.)

65.54	0.135	Quartz-syenite	Highwood Mountains, Mont	W. T.
62.64	.119	Andesite (?)	Pikes Peak district, Colo	Bull. 168, 145.—W. T.
61.87	.145	Trachyte	Ischia, Italy	R. T., 1873, XXXVIII.
61.55	.141	....do	....do	R. T., 1873, XXXVI.
60.89	.131	Quartz-banakite	Ishawooa Canyon, Wyo	Bull. 168, 102.—W. T.
60.20	.165	Pulaskite	Fourche Mountain, Ark	J. G., IX, 609.—W. T.
60.03	.154	....do	....do	I. R. A., 88.—W. T.
59.51	.158	Leucite-trachyte	Viterbo, Italy	J. G., V, 370.—W. T.
59.23	.149	Nephelite-syenite	Fourche Mountain, Ark	I. R. A., 88.—W. T.
57.15	.149	Trachy-dolerite	Maros, Celebes	G. C., 14.
56.45	.175	Sodalite-syenite	Square Butte, Mont	Bull. 168, 134.—W. T.
55.52	.146	Bostonite	Gentungen, Celebes	G. C., 20.

SUBRANG 4. LAURVIKOSE.

(I. 5, 2, 4.)

65.41	0.139	Trachyte	Game Ridge, Custer County, Colo	Bull. 168, 147.—W. T.
64.80	.125	Domite	Puy de Dome, France	R. T., 1869, CXVIII.
64.63	.132	Quartz-syenite	Fourche Mountain, Ark	I. R. A., 96.—W. T.
63.49	.133	Andesite	Custer County, Colo	Bull. 168, 148.—W. T.
61.47	.120	....do	Pantellaria, Italy	Z. K., VIII, 155.
61.43	.133	....do	....do	Z. K., VIII, 164.
61.05	.147	Trachyte	Ischia, Italy	R. T., 1873, XXXVIII.
60.98	.142 (59.9)	Augite-porphyrite	Henry Mountains, Utah	Bull. 168, 167.—W. T.
60.72	.142	Rhombenporphyry	Nötterö, Norway	Z. K., XVI, 35.—W. T.
60.45	.168	Nordmarkite	Aneröd, Norway	Z. K., XVI, 54.—W. T.
60.24	.170	Augite-andesite	Pantellaria	Z. K., VIII, 155.
59.96	.165	Pulaskite	Shefford Mountain, Quebec	J. G., XI, 271.
59.38	.125	Tönsbergite	Tönsberg, Norway	E. K., III, 375.—W. T.
58.94	.109	Andesite	Silver Cliff, Colo	Bull. 168, 148.—W. T.
58.88	.141	Laurvikite	Laurvik, Norway	Z. K., XVI, 30.—W. T.
58.82	.155	Rhombenporphyry	Tönsberg, Norway	Z. K., XVI, 35.—W. T.
57.59	.139	....do	Nötterö, Norway	Do.
57.44	.157	Pulaskite	Mount Johnson, Quebec	J. G., XI, 271.

Classified list of analyses used in constructing diagrams—Continued.

SUBRANG 4. LAURVIKROSE—Continued.

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
57.33	.153 (57.1)	Rhombenporphyry	Nötterö, Norway	Z. K., XVI, 35.—W. T.
57.12	.138	Laurvikite	Fredriksvärn, Norway	Z. K., XVI, 30.—W. T.
56.85	.144	....do	Nötterö, Norway	Do.
56.25	.155 (55.9)	Micromonzonite	Ambodimadiro, Madagascar	M. M., 204.
56.19	.156	Tephritic trachyte	Columbretes Islands, Spain	T. M. P. M., XVI, 314.—W. T.
54.00	.162	Rhombenporphyry	Brumunthal, Norway	Z. K., XVI, 28.—W. T.

SUBRANG 5. ——.

(I. 5, 2, 5.)

62.90	0.135	Diorite	Jablanica, Herzegovina	W. T.
60.13	.164	Keratophyre	New Haven, Conn	A. J. S., III, 1897, 291.—W. T.

RANG 3. ——.

SUBRANG 2. ——.

(I. 5, 3, 2.)

59.33	0.135 (59.5)	Augite-syenite	Mazaruni district, British Guiana	W. T.

SUBRANG 3. ——.

(I. 5, 3, 3.)

59.26	0.139	Andesite	Table Mountain, Colo	Bull. 168, 141.—W. T.

SUBRANG 4. ——.

(I. 5, 3, 4.)

58.28	0.112	Diabase-porphyrite	Crazy Mountains, Mont	Bull. 168, 121.—W. T.

RANG 4. LABRADORASE.

SUBRANG 3. LABRADOROSE.

(I. 5, 4, 3.)

55.01	0.086	Anorthosite	Turtschinka, Wolynien, Russia	W. T.
54.62	.093	....do	New York State	N. J., 1893, VIII, 494.
54.45	.122	....do	Rawdon, Canada	Do.
53.53	.090 (53.6)	....do	Pökölä, Finland	W. T.
53.43	.099	....do	Labrador, Canada	N. J., 1893, VIII, 494.—W. T.
53.42	.096	....do	Ogne, Norway	B. M. A., 1896, V, 96.—W. T.
52.61	.092	....do	Ekersund, Norway	B. M. A., 1896, V, 79.—W. T.
49.78	.091	....do	Carlton Peak, Minn	Am. Geol., XXVI, 281.—W. T.
47.25	.056	....do	Beaver Bay, Lake Superior	U. S. G. S., Mon. V, 438.

RANG 5. CANADASE.

(I. 5, 5.)

47.32	0.048 (47.4)	Anorthosite	South Sherbrooke, Ontario	Am. Geol., XXIV, 280.—W. T.
46.24	.044	....do	Seine River, Canada	J. G., IV, 909.—W. T.
45.78	.036	....do	Monhegan Isle, Me	Am. Geol., XXVI, 340.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

ORDER 6. RUSSARE.

RANG 1. MIASKASE.

SUBRANG 3. BEEMEROSE.

(I. 6, 1, 3.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
60.42	0.184	Nephelite-syenite	Moita, Foya, Portugal	T. M. P. M., XVI, 225.—W. T.
59.20	.189 (59.1)	Microditroite	Nosy Komba, Madagascar	M. M., 169.
58.89	.180	Leucite-tinguaite-vitrophyre.	Picota, Portugal	T. M. P. M., XVI, 252.—W. T.
58.72	.199 (58.8-.200)	Ditroite	Nosy Komba, Madagascar	M. M., 204.
58.00	.199	Phonolite	Maros, Celebes	G. C., 18.
55.87	.201 (55.3)	Leucite-phonolite	Lake Bracciano, Italy	J. G., V., 370.—W. T.
55.38	.207	Foyaite	East Cape, Siberia	A. J. S., XIII, 1902, 176.—W. T.
53.56	.229 (53.1)	Nephelite-syenite	Beemerville, N. J	Bull. 168, 39.—W. T.
53.09	.226	Foyaite	Magnet Cove, Ark	J. G., IX, 611.—W. T.

SUBRANG 4. MIASKOSE.

(I. 6, 1, 4.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
60.02	0.202	Phonolite	Cripple Creek, Colo	Bull. 168, 143.—W. T.
59.38	.189	Trachytic phonolite	do	Bull. 168, 144.—W. T.
59.00	.196	Phonolite	do	Bull. 168, 143.—W. T.
58.98	.219	do	do	Do.
58.78	.213	do	do	Do.
58.77	.211 (59.1)	Foyaite	Salem Neck, Mass	J. G., VII, 481.—W. T.
58.74	.205	Nephelite-syenite	Salina County, Ark	I. R. A., 139.—W. T.
58.70	.190	Acmite-trachyte	Crazy Mountains, Mont	Bull. 168, 123.—W. T.
58.64	.195 (.196)	Phonolite	Cripple Creek, Colo	Bull. 168, 143.—W. T.
58.62	.191 (58.5-.18€)	do	Nosy Komba, Madagascar	M. M., 169.
58.61	.194 (58.3)	Foyaite	Heum, Lougenthal, Norway	E. K., III, 377.—W. T.
58.61	.213 (58.5)	do	Nosy Komba, Madagascar	M. M., 169.
58.51	.216 (58.2)	Phonolite	Velay, France	R. T., 1879, LVIII.
58.25	.197 (57.7)	Microfoyaite	Nosy Komba, Madagascar	M. M., 169.
58.20	.190	Ditroite	do	Do.
58.10	.191 (57.9)	do	do	M. M., 204.
57.86	.214 (57.8)	Phonolite	Black Hills, S. Dak	Bull. 168, 84.—W. T.
56.75	.228	Tinguaite	Pickards Point, Mass	J. G., VII, 481.—W. T.
56.67	.226 (56.3)	Nephelite-syenite	Picota, Portugal	T. M. P. M., XVI, 228.—W. T.
56.43	.195 (56.3)	Phonolite	Hegau, Germany	R. T., 1884, LIV.
56.40	.201	Nephelite-syenite	Poutelitschorr, Kola, Finland	Rosenbusch, El., 126.—W. T.
56.30	.235	Ditroite	Ditro, Siebenbürgen, Hungary	Rosenbusch, El., 126.
56.26	.199 (56.8)	Miascite	Mount Sobatchia, Siberia	W. T.
55.95	.256	Phonolite	Borczen, Bilin	R. T., 1869, XCVI.
55.93	.203 (55.6)	Trachytic phonolite	Columbretes Islands	T. M. P. M., XVI, 314.—W. T.
55.92	.198 (55.8)	Phonolite	Hegau, Germany	R. T., 1884, LII.
55.21	.226	do	do	R. T., 1879, LVIII.
55.01	.211	do	do	R. T., 1884, LII.
54.92	.243	Nephelite-aplite	Cabo Frio Island, Brazil	T. M. P. M., XX, 288.—W. T.
54.22	.224	Phonolite	Southboro, Mass	Bull. 168, 33.—W. T.
54.20	.237	Nephelite-syenite	Picota, Portugal	T. M. P. M., XVI, 218.—W. T.
53.95	.246	Phonolite	Sardinia	R. T., 1879, LVIII.
53.65	.231	do	Msid Gharian, Tripoli	R. T., 1884, LIV.
52.73	.202	Heronite	Heron Bay, Canada	J. G., VII, 435.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

SUBRANG 5. MARIUPOLOSE.

(I. 6, 1, 5.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
60.29	0.197 (60.5)	Mariupolite	Nikolajew, Russia	T. M. P. M., XXI, 244.—W. T.

RANG 2. VIEZZENASE.

SUBRANG 3. ——.

(I. 6, 2, 3.)

53.76	0.207 (53.6)	Nephelite-tinguaite	Magnet Cove, Ark	I. R. A., 266.—W. T.

SUBRANG 4. VIEZZENOSE.

(I. 6, 2, 4.)

56.04	0.201	Nephlite-rhomben-porphyry.	Vasvik tunnel, Norway	Z. K., XVI, 38.—W. T.
55.40	.184	Andesite	Palma, Sicily	R. T., 1879, LXVI.
54.68	.176	Nephelite-syenite	Brookville, N. J	Bull. 168, 39.—W. T.
54.61	.197	do	Caldas de Monchique, Portugal	N. J., B. B., III, 271.—W. T.
54.46	.186	Tinguaite	Umptek, Kola, Finland	Rosenbusch, El., 215.—W. T.

ORDER 7. TASMANARE.

RANG 1. LAUGENASE.

SUBRANG 4. LAUGENOSE.

(I. 7, 1, 4.)

55.50	0.248	Foyaite	Brathagen, Norway	E. K., III, 176.—W. T.

CLASS II. DOSALANE.

ORDER 3. HISPANARE.

RANG 1. VARINGASE.

SUBRANG 3. VARINGOSE.

(II. 3, 1, 3.)

74.35	0.092	Grorudite	Varingskollen, Norway	Z. K., XVI, 66.—W. T.
70.30	.128	Pantellerite	Pantellaria	Z. K., VIII, 173.—W. T.

SUBRANG 4. ——.

(II. 3, 1, 4.)

72.12	0.070	Felsite	Cudgegong River, New South Wales, Australia.	W. T.

Classified list of analyses used in constructing diagrams—Continued.

RANG 4. ———.

SUBRANG 3. ———.

(II. 3, 4, 3.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
66.88	0.020	Quartz-diorite	Little Falls, Minn	R. T., 1879, XXXVI.

ORDER 4. AUSTRARE.

RANG 1. PANTELLERASE.

SUBRANG 3. GRORUDOSE.

(II. 4, 1, 3.)

70.15	0.109	Grorudite	Grussletten, Norway	E. K., I, 199.—W. T.
69.61	.129	Pantellerite	Pantellaria	Z. K., VIII, 173.—W. T.
69.02	.121	do	do	Z. K., VIII, 182.—W. T.
68.33	.137	do	do	Z. K., VIII, 170.—W. T.
66.50	.123	Grorudite	Grussletten, Norway	E. K., I, 199.—W. T.
61.83	.102 (62.2)	Porphyrite	Süpplingen, Magdeburg, Prussia	W. T.

SUBRANG 4. PANTELLEROSE.

(II. 4, 1, 4.)

71.35	0.116	Grorudite	Kallerud, Norway	E. K., I, 199.—W. T.
67.89	.116	Pantellerite	Pantellaria	Z. K., VIII, 186.—W. T.
67.48	.131	do	do	Do.
67.18	.122	do	do	Do.

RANG 2. DACASE.

SUBRANG 3. ADAMELLOSE.

(II. 4, 2, 3.)

66.57	0.103	Granite-porphyry	Kirche Wang, Silesia	Rosenbusch, El., 195.
63.97	.105	Quartz-mica-diorite	Crandall Basin, Wyo	Bull. 168, 94.—W. T.
62.51	.090	Syenite	Reichenstein, Silesia	N. J., 1890, I, 206.—W. T.
61.93	.104	Granitite	Laveline, Vosges	Rosenbusch, El., 78.
59.24	.095 (59.5)	Trachyte-andesite	Highwood Mountains, Mont	Bull. 168, 131.—W. T.

SUBRANG 4. DACOSE.

(II. 4, 2, 4.)

65.50	0.107	Andesite	Sepulchre Mountain, Yellowstone Park.	Bull. 168, 91.—W. T.
64.47	.098	Granitite	Crazy Mountains, Mont	Bull. 168, 120.—W. T.
63.50	.101	Dacite	Chiles, Colombia, South America	J. G., I, 171.—W. T.
61.56	.102	Andesite	Tower Creek, Yellowstone Park	Bull. 168, 108.—W. T.
56.59	.083	Quartz-diorite	Sauk Center, Minn	R. T., 1879, XXXIV.

Classified list of analyses used in constructing diagrams—Continued.

RANG 3. TONALASE.

SUBRANG 3. HARZOSE.

(II. 4, 3, 3.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
64.34	0.081	Granite	Butte, Mont	Bull. 168, 117.—W. T.
63.85	.080	Granodiorite	Grass Valley, Cal	Bull. 168, 194.—W. T.
63.06	.069 (63.2)	"Schliere" in granite.	Riesengebirge, Silesia	N. J., 1898, XII, 236.—W. T.
61.73	.088	Syenite	Hodritch, Hungary	R. T., 1869, LX.
61.64	.078	Quartz-monzonite	Red Rock Creek, Butte, Mont	Bull. 168, 118.—W. T.
60.68	.090 (60.7)	Andesite	Mount Pagos, Asia Minor	A. J. S. III, 1897, 43.—W. T.
60.17	.090	Latite	Tintic district, Utah	Bull. 168, 166.—W. T.
59.76	.094	Monzonite	....do	Do.
57.80	.063	Quartz-pyroxene-diorite.	Sonora, Tuolumne County, Cal	Bull. 168, 204.—W. T.
57.69	.064 (58.1)	Mica-diorite	Gippsland, Victoria	E. K., II, 37.—W. T.
57.26	.076	Quartz-mica-diorite	Sierra County, Cal	Bull. 168, 192.—W. T.

SUBRANG 4. TONALOSE.

(II. 4, 3, 4.)

66.91	0.055	Tonalite	Adamello Stock, Tyrol	Rosenbusch, El., 140.—W. T.
65.83	.080	Granite	Granite Creek Station, Nev	Fortieth Par., I, 110.
65.39	.081	Dacite	Cumbal, Colombia, South America	J. G., I, 171.—W. T.
65.11	.083	Quartz-mica-diorite	Electric Peak, Yellowstone Park	Bull. 168, 88.—W. T.
64.81	.073	Porphyrite	Leadville district, Colo	Bull. 168, 155.—W. T.
64.12	.077 (.076)	Quartz-norite	Tyrol	Rosenbusch, El., 140.
64.07	.083	Quartz-mica-diorite	Electric Peak, Yellowstone Park	Bull. 168, 87.—W. T.
63.56	.084	Hornblende-dacite	Colombia, South America	J. G., I, 171.—W. T.
63.47	.075	Andesite	Suppans Mountain, Tehama County, Cal.	Bull. 168, 182.—W. T.
63.28	.077	....do	Mount Hood, Oreg	Fortieth Par., I, 604.
63.16	.089	Trachyte	Henry Mountains, Utah	Bull. 168, 167.—W. T.
63.03	.070	Andesite	Mount Shasta, Cal	Bull. 168, 176.—W. T.
62.71	.084	Diorite	Gunnison County, Colo	Bull. 168, 159.—W. T.
62.65	.095	Hornblende-porphyrite.	Herman Peak, Colo	Bull. 168, 164.—W. T.
62.62	.070	Quartz-mica-diorite	Mariposa County, Cal	Bull. 168, 209.—W. T.
62.44	.071	Andesite	Shasta County, Cal	Bull. 168, 181.—W. T.
62.09	.070	Hornblende-porphyrite.	Nevada City, Cal	Bull. 168, 194.—W. T.
61.58	.074 (61.8)	Andesite	Mount Shasta, Cal	Bull. 168, 176.—W. T.
61.40	.048	Syenite	Riesengebirge, Silesia	N. J., 1898, XII, 234.—W. T.
61.22	.089 (61.4)	Mica-diorite	Electric Peak, Yellowstone Park	Bull. 168, 87.—W. T.
61.17	.077	Andesite	Shasta County, Cal	Bull. 168, 183.—W. T.
61.16	.093	Andesite-porphyry	Crandall Basin, Wyo	Bull. 168, 94.—W. T.
61.09	.070	Andesite	Colombia, South America	J. G., I, 171.—W. T.
61.04	.090	....do	....do	Do.
60.93	.073	....do	Tuscan Buttes, Cal	Bull. 168, 181.—W. T.
60.30	.088 (60.4)	....do	Sepulchre Mountain, Yellowstone Park.	Bull. 168, 90.—W. T.
60.20	.068	....do	Pilot Peak, Plumas County, Cal	Bull. 168, 188.—W. T.
60.05	.079	....do	Colombia, South America	J. G., I, 171.—W. T.
60.04	.078 (60.3)	....do	Shasta County, Cal	Bull. 168, 181.—W. T.
60.02	.074 (59.8)	....do	Sierra County, Cal	Bull. 168, 193.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

SUBRANG 4, TONALOSE—Continued.

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
59.97	.076	Diorite	Vildarthal, Tyrol	Rosenbusch, El., 140.
59.84	.080	Andesite	Near Lassen Peak, Cal	Bull. 168, 183.—W. T.
59.77	.088	Average of 680 igneous rocks.	America	Bull. 148, 12.—W. T.
59.48	.082	Andesite	Red Bluff, Mont	Bull. 168, 114.—W. T.
59.34	.075	do	Sierra County, Cal	Bull. 168, 193.—W. T.
59.19	.094	Diorite	San Miguel Mountains, Colo	Bull. 168, 164.—W. T.
58.67	.065	Dolerite	Eskdale, Scotland	
58.63	.079 (58.9)	Diorite	Unalaska Island	Bull. 168, 226.—W. T.
58.46	.083 (58.7)	Average of 397 igneous rocks.	Great Britain	Geol. Mag., 1899, 220.—W. T.
58.08	.075 (58.2)	Andesite	Near Lassen Peak, Tehama County, Cal.	Bull. 168, 182.—W. T.
56.61	.082	do	Sepulchre Mountain, Yellowstone Park.	Bull. 168, 90.—W. T.
56.28	.065	Diorite	Electric Peak, Yellowstone Park	Bull. 168, 87.—W. T.
55.83	.069 (55.9)	Andesite	Sepulchre Mountain, Yellowstone Park.	Bull. 168, 90.—W. T.

SUBRANG 5. PLACEROSE.

(II. 4, 3, 5.)

64.67	0.064	Granite	Placer County, Cal	Bull. 168, 198.—W. T.
60.40	.068	Andesite	St. Augustine Volcano, Cook Inlet	Bull. 168, 226.—W. T.

RANG 4. BANDASE.

SUBRANG 1. SAGAMOSE.

(II. 4, 4, 1.)

55.48	0.023	Tonalite	Hokizawa, Sagami, Japan	W. T.

SUBRANG 3. BANDOSE.

(II. 4, 4, 3.)

61.58	0.057	Diorite	Kadiak Island, Alaska	Bull. 168, 227.—W. T.
59.66	.052	Andesite	Bandai San, Japan	W. T.
56.74	.047	Diabase-porphyry	Mount Morrison, Colo	Bull. 168, 141.—W. T.
56.51	.068 (56.7-.066)	Quartz-basalt	Near Lassen Peak, Cal	Bull. 168, 185.—W. T.
56.41	.052	Diorite	Georgetown, D. C.	Bull. 168, 44.—W. T.
56.31	.044	"Schliere" in granite	Riesengebirge, Silesia	N. J., 1898, XII, 235.—W. T.
55.97	.052	Diorite	Triadelphia, Md	Bull. 168, 44.—W. T.

RANG 5. ——.

SUBRANG 3. ——.

(II. 4, 5, 3.)

51.62	0.015	Diorite	Kagelholmsön, Sweden	R. T., 1879, XXXII.

Classified list of analyses used in constructing diagrams—Continued.

ORDER 5. GERMANARE.

RANG 1. UMPTEKASE.

SUBRANG 2. HIGHWOODOSE.

(II. 5, 1, 2.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
61.28	0.126	Syenite	Tuolumne County, Cal	Bull. 168, 204.—W. T.
58.04	.166	Trachyte	Highwood Mountains, Mont	Bull. 168, 131.—W. T.

SUBRANG 3. ILMENOSE.

(II. 5, 1, 3.)

62.99	0.139	Umptekite	Beverly, Mass	T. M. P. M., XX, 248.—W. T.
57.91	.181	Sodalite-trachyte	Monte Santo, Naples, Italy	A. J. S., VIII, 1899, 290.—W. T.
55.26	.171	Leucite-trachyte	Viterbo, Italy	J. G., V, 370.—W. T.

SUBRANG 4. UMPTEKOSE.

(II. 5, 1, 4.)

64.28	0.156	Sölvsbergite	Andrews Point, Mass	J. G., VII, 481.—W. T.
63.71	.152	Umptekite	Kola, Finland	Rosenbusch, El., 112.—W. T.
62.70	.162	Sölvsbergite	Laugendal, Norway	E. K., I, 199.—W. T.
60.50	.159	Hedrumite	Ostö, Norway	E. K., III, 377.—W. T.
59.66	.180	Nephelite-syenite	Crazy Mountains, Mont	Bull. 168, 123.—W. T.
59.01	.171	.....do	Red Hill, N. H	Bull. 168, 23.—W. T.
58.90	.181	Nephelite-sölvsbergite.	Aklungen, Norway	E. K., I, 199.—W. T.
58.81	.163	Soda-syenite	Laupstadeid, Norway	B. M. A., 1898, VII, 48.—W. T.
58.46	.162	Nordmarkite	Cabo Frio, Brazil	T. M. P. M., XX, 244.—W. T.
57.52	.172	Hedrumite	Brathagan, Norway	E. K., III, 190.—W. T.
57.00	.170	Heumite	.....do	E. K., III, 116.—W. T.

RANG 2. MONZONASE.

SUBRANG 2. CIMINOSE.

(II. 5, 2, 2.)

56.39	0.110 (56.6)	Mica-trachyte	Monte Catini, Italy	A. J. S., IX, 1900, 47.—W. T.
55.85	.157	Leucite-phonolite	Bolsena, Italy	J. G., V, 370.—W. T.
55.46	.107	Ciminite	Monte Cimino, Italy	A. J. S., IX, 1900, 44.—W. T.
55.21	.151	Leucite-trachyte	Viterbo, Italy	J. G., V, 370.—W. T.
51.05	.125	Durbachite	Schwarzwald, Baden	W. T.

SUBRANG 3. MONZONOSE.

(II. 5, 2, 3.)

61.65	0.113	Syenite	Yogo Peak, Little Belt Mountains, Mont.	Bull. 168, 125.—W. T.
60.56	.127	Granite	Elliott County, Ky	Bull. 168, 56.—W. T.
59.78	.140	Syenite	Custer County, Colo	Bull. 168, 151.—W. T.
58.18	.134	Kersantite	Tito, Chile	Z. D. G. G., LI, 4.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

SUBRANG 3. MONZONOSE—Continued.

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
58.00	0.142	Pulaskite	Laugenthal, Norway	E. K., III, 375.—W. T.
57.97	.116	Diorite	Mount Ascutney, Vermont	Bull. 168, 25.—W. T.
57.73	.147	Trachyte	Ischia, Italy	R. T., 1873, XXXVIII.
57.48	.118	Andesite	Pikes Peak district, Colo	Bull. 168, 145.—W. T.
57.29	.134	Quartz-banakite	Head of Ishawooa River, Wyo	Bull. 168, 102.—W. T.
56.75	.149	Ciminite	Arso, Ischia, Italy	A. J. S., VIII, 1899, 290.—W. T.
55.35	.100	Mica-basalt	Santa Maria Basin, Arizona	Bull. 168, 173.—W. T.
55.23	.143	Trachyte	Highwood Mountains, Mont	Bull. 168, 131.—W. T.
54.86	.114	Shoshonite	Indian Peak, Wyo	Bull. 168, 100.—W. T.
54.42	.109 (54.0)	Monzonite	Yogo Peak, Mont	Bull. 168, 128.—W. T.
54.20	.106	.....do	Monzoni, Tyrol	E. K., II, 24.—W. T.
52.81	.124 (52.6)	.....do	Bearpaw Mountains, Mont	Bull. 168, 135.—W. T.
52.80	.150	Shonkinite-monzonite	Máros, Celebes	G. C., 25.
52.63	.133	Banakite	Hoodoo Mountain, Wyo	Bull. 168, 101.—W. T.
52.33	.147	.....do	Head of Ishawooa River, Wyo	Do.
52.14	.116	Syenite	Heidelberg, Baden	R. T., 1879, XXIV.
51.82	.134	Banakite	Head of Lamar River, Yellowstone Park.	Bull. 168, 101.—W. T.
51.46	.131	.....do	Ishawooa Canyon, Wyo	Do.

SUBRANG 4. AKEROSE.

(II. 5, 2, 4.)

61.87	0.119	Syenite	Castle Mountain district, Mont	Bull. 168, 130.—W. T.
61.63	.125	Nephelite-syenite	Mulatto, Tyrol	K. A. W. W., CXI, 1, 260.
61.26	.104	Andesite	Colombia, South America	J. G., I, 171.—W. T.
61.08	.114	Porphyrite	Crazy Mountains, Mont	Bull. 168, 120.—W. T.
60.44	.110	Diorite-porphyry	La Plata Mountains, Colo	Bull. 168, 162.—W. T.
59.56	.125	Akerite	Vettakollen, Norway	Z. K., XVI, 50.—W. T.
58.28	.155	Syenite	Crazy Mountains, Mont	Bull. 168, 121.—W. T.
57.01	.124	Andesite	Silver Cliff, Colo	Bull. 168, 148.—W. T.
56.79	.118	Akerite	Vettakollen, Norway	Z. K., XVI, 50.—W. T.
56.75	.108	Porphyrite	Crazy Mountains, Mont	Bull. 168, 121.—W. T.
56.02	.119	Andesite	Taal, Luzon, P. I	N. J., B. B., I, 1881, 482.
55.95	.135	Ditroite	Nosy Komba, Madagascar	M. M., 204.
55.53	.115	Diorite	La Plata Mountains, Colo	Bull. 168, 162.—W. T.
54.69	.136 (54.6)	Porphyrite	Crazy Mountains, Mont	Bull. 168, 121.—W. T.
53.80	.144	Diorite	Silver Cliff, Colo	Bull. 168, 147.—W. T.
53.60	.124	Basalt	Reinhardswald, Prussia	W. T.
53.15	.129	Essexite	Shefford Mountain, Quebec	J. G., XI, 265.
53.12	.171	Tephritic-trachyte	Columbretes Islands	T. M. P. M., XVI, 314.—W. T.
51.42	.130 (51.3)	Basalt	S. Rhone	R. T., 1879, LXXII.
51.22	.162	Minette	Brathagen, Norway	E. K., III, 376.—W. T

RANG 3. ANDASE.

SUBRANG 2. ——.

(II. 5, 3, 2.)

57.31	0.094	Ciminite	Monte Cimino, Italy	A. J. S., IX, 1900, 44.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

SUBRANG 3. SHOSHONOSE.

(II. 5, 3, 3.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
59.41	0.102	Andesite	Cabo da Gata, Spain	Z. D., g. G., XLIII, 719.—W. T.
58.51	.095 (58.8)	Mica-diorite	Crystals Falls, Mich	Bull. 168, 67.—W. T.
57.97	.083 (57.8)	Diorite	Crazy Mountains, Mont	Bull. 168, 122.—W. T.
56.90	.097	Syenite	Denver Basin, Colo	Bull. 168, 140.—W. T.
56.78	.093	Latite	Clover Meadow, Cal	Bull. 168. 205.—W. T.
56.19	.092	.....do	Table Mountain, Tuolumne County, Cal.	Bull. 168, 205.—W. T.
56.05	.107	Shoshonite	Two Ocean Pass, Yellowstone Park	Bull. 168, 100.—W. T.
55.69	.100 (55.6)	Vulsinite	Rocca Monfina, Italy	J. G., V, 358.—W. T.
54.56	.076 (.075)	Andesite	Radicofani, Italy	A. J. S., IX, 1900, 52.—W. T.
54.14	.077	.....do	.....do	Do.
53.49	.104	Shoshonite	Beaverdam Creek, Yellowstone Park	Bull. 168, 100.—W. T.
52.93	.132	Banakite	.....do	Bull. 168, 102.—W. T.
52.59	.099 (52.7)	Basalt	Table Mountain, Colo	Bull. 168, 140.—W. T.
52.49	.102	Shoshonite	Pyramid Peak, Yellowstone Park	Bull. 168, 100.—W. T.
52.33	.103	Augite-porphyy	Cottonwood Creek, Mont	Bull. 168, 112.—W. T.
52.11	.097 (51.8)	Basalt	Crandall Basin, Wyo	Bull. 168, 92.—W. T.
51.00	.115	Monzonite	Highwood Mountains, Mont	Bull. 168, 133.—W. T.
50.98	.120 (50.7)	Mondhaldeite	Mondhalde, Kaiserstuhl, Baden	W. T.
50.08	.137	.....do	.....do	Do.
50.06	.110	Shoshonite	Lamar River, Yellowstone Park	Bull. 168, 100.—W. T.
49.69	.107	Basalt	Denver Basin, Colo	Bull. 168, 140.—W. T.
48.25	.118	Dolerite	.....do	Do.
47.50	.117	Labrador-porphyrite	Gran, Norway	Q. J. G. S., L, 33.—W. T.
45.53	.140	Leucite-monchiquite	Bohemian Mittelgebirge	Rosenbusch, El., 235.—W. T.

SUBRANG 4. ANDOSE.

(II. 5, 3, 4.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
58.45	0.080	Diorite	Pen Maen Mawr, N. Wales	Q. J. G. S., XXXIII, 424.
58.42	.099	Andesite	Taal, Luzon, P. I	N. J., B. B., I, 1881, 481.
58.05	.083	Diorite	Electric Peak, Yellowstone Park	Bull. 168, 87.—W. T.
57.64	.104 (57.8)	Augite-porphyrite	Crandall Basin, Wyo	Bull. 168, 93.—W. T.
57.59	.070 (57.8)	Quartz-basalt	Silver Lake, Lassen, Cal	Bull. 168, 185.—W. T.
57.38	.071 (57.1)	Pyroxene porphyry	Electric Peak, Yellowstone Park	Bull. 168, 87.—W. T.
57.32	.098 (57.5)	Monzonite	Crandall Basin, Wyo	Bull. 168, 93.—W. T.
57.26	.102	Diorite	.....do	Do.
57.25	.067	Quartz-basalt	Cinder Cone, Lassen, Cal	Bull. 168, 184.—W. T.
57.17	.079	Andesite	Sepulchre Mountain, Yellowstone Park.	Bull. 168, 90.—W. T.
57.11	.084 (57.5)	.....do	Mill Creek, Lassen, Cal	Bull. 168, 182.—W. T.
56.91	.085	.....do	Colombia, South America	J. G., I, 171.—W. T.
56.70	.074 (56.6)	Quartz-basalt	Cinder Cone, Lassen, Cal	J. G., I, 184.—W. T.
56.49	.112 (57.1)	Diorite	Little Falls, Minn	R. T., 1879, XXXIV.
56.21	.104	Gabbro-diorite	Crandall Basin, Wyo	Bull. 168, 93.—W. T.
56.19	.076	Andesite	Buffalo Peaks, Colo	Bull. 168, 153.—W. T.
56.09	.080	Diorite	Campo Major, Portugal	E. K., II, 37.—W. T.
56.07	.091 (55.9)	Andesite	Bogoslof Island	Bull. 168, 227.—W. T.
55.93	.103 (55.8)	Gabbro-diorite	Crandall Basin, Wyo	Bull. 168, 93.—W. T.
55.92	.095	Andesite	Sepulchre Mountain, Yellowstone Park.	Bull. 168, 90.—W. T.
55.80	.076	Diorite (norite)	Klausen, Tyrol	E. K., II, 37.—W. T.
55.34	.093	Norite	Montrose Point, N. Y	W. T.

Classified list of analyses used in constructing diagrams—Continued.

SUBRANG 4. ANDOSE—Continued.

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
55.20	0.075 (55.4)	Andesite	Butte County, Cal	Bull. 168, 182.—W. T.
55.13	.107	Diorite	Neihart, Mont	Bull. 168, 127.—W. T.
54.62	.075	Andesite	Luzon, P. I.	N. J., B. B., I, 1881, 471.
54.56	.108	Diorite-porphyrite	Crazy Mountains, Mont	Bull. 168, 121.—W. T.
54.52	.092	Diabase	Diabase Hills, Nev	Fortieth Par., II, 812.
53.94	.086	Dolerite	....do	Do.
53.89	.099	Basic andesitic glass	Indian Ridge, Wyo	Bull. 168, 92.—W. T.
53.71	.098	Mica-gabbro	Crandall Basin, Wyo	Do.
53.48	.089	Quartz-diorite	Crazy Mountains, Mont	Bull. 168, 121.—W. T.
53.10	.134 (53.2)	Covite	Nosey Komba, Madagascar	M. M., 204.
52.97	.107	Basalt	Pikes Peak district, Colo	Bull. 168, 145.—W. T.
52.91	.119	Diabase-syenite-porphyry.	Holmestrand, Norway	Z. K., XVI, 28.—W. T.
52.63	.082 (52.7)	Basalt	Shasta County, Cal	Bull. 168, 186.—W. T.
52.38	.093	....do	Rio Grande, N. Mex	Bull. 168, 169.—W. T.
52.37	.084	....do	Absaroka Range, Yellowstone Park	Bull. 168, 109.—W. T.
52.37	.082 (51.8)	....do	Rio Grande, N. Mex	Bull. 168, 169.—W. T.
52.27	.095	....do	....do	Do.
52.12	.095	Diorite	Mount Ascutney, Vt	Bull. 168, 25.—W. T.
52.09	.085	Basalt	Crandall Basin, Wyo	Bull. 168, 92.—W. T.
51.57	.090	....do	Rio Grande, N. Mex	Bull. 168, 169.—W. T.
51.54	.110	Andesite	Bogoslof Island, Alaska	Bull. 168, 227.—W. T.
50.99	.101	Camptonite	Ishawooa Canyon, Wyo	Bull. 168, 110.—W. T.
50.97	.112 (50.6)	Kersantite	Guanta, Chile	Z. D. g. G., LI, 4.
50.73	.099	Diorite	Crazy Mountains, Mont	Bull. 168, 122.—W. T.
50.56	.079	Basalt	Plumas County, Cal	Bull. 163, 189.—W. T.
49.40	.087	Facies of monzonite	Predazzo, Tyrol	E. K., II, 102.—W. T.
49.24	.092 (49.7)	Dolerite	Ferdinandea	T. M. P. M., 1883, 393.
49.04	.110	Basalt	Buffalo Peak, Colo	Fortieth Par., I, 676.
48.90	.090	Diorite	Schwarzenberg, Vosges	Rosenbusch, El., 140.
48.85	.131	Essexite	Mount Johnson, Quebec	J. G., XI, 265.
48.76	.105	Basalt	Pikes Peak district, Colo	Bull. 168, 145.—W. T.
48.18	.093	Olivine-diabase	Biella, Piedmont	R. T., 1884, XLII.
48.06	.084	Kersantite	Laugendal, Norway	E. K., III, 376.—W. T.
44.85	.110	Nephelite-tephrite	Mittelgebirge, Bohemia	Rosenbusch, El., 346.—W. T.

SUBRANG 5. BEERBACHOSE.

(II. 5, 3, 5.)

55.08	0.081	Andesite-basalt	Shasta County, Cal	Bull. 168, 176.—W. T.
52.58	.073	Andesite	S. W. Tiflis	Z. D. g. G., XXIX, 823.
47.21	.109	Beerbachite	Odenwald, Hesse	Rosenbusch, El., 219.—W. T.

RANG 4. HESSASE.

SUBRANG 3. HESSOSE.

(II. 5, 4, 3.)

57.47	0.072	Basalt	Cascade Range, Oreg	Bull. 168, 223.—W. T.
56.94	.074	Anorthosite	Elizabethtown, N. Y	Bull. 168, 37.—W. T.
55.53	.062	Andesite	Plumas County, Cal	Bull. 168, 181.—W. T.
55.14	.075	Secretion in dacite	Lassen Peak, Cal	Bull. 168, 179.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

RANG 4. HESSASE—Continued.

SUBRANG 3. HESSOSE—Continued.

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
53.91	0.066	Dolerite	Plumas County, Cal	Bull. 168, 189.—W. T.
53.35	.063	Secretion in dacite	Lassen Peak, Cal	Bull. 168, 180.—W. T.
53.18	.082	Anorthosite.	Whiteface Mountain, Adirondacks, N. Y.	Bull. 168, 36.—W. T.
53.00	.070	Diorite	Schwarzenburg, Vosges	Rosenbusch, El., 140.
52.95	.073 (52.7)	Basalt	Shasta County, Cal	Bull. 168, 186.—W. T.
52.16	.074	Monzonite	Predazzo, Tyrol	E. K., II, 25.—W. T.
52.05	.075 (51.7)	Diorite	Ouray County, Colo	Bull. 168, 161.—W. T.
51.27	.064	....do	Little Falls, Minn	R. T., 1879, XXXIV.
49.93	.074	Dolerite	Paterno, Etna, Sicily	R. T., 1884, LXXX.
49.88	.057	Olivine-gabbro	Pigeon Point, Minn	Bull. 168, 76.—W. T.
49.80	.049	Gabbro	Crystal Falls, Mich	Bull. 168, 67.—W. T.
49.15	.095	....do	Duluth, Minn	Rosenbusch, El., 151.
48.29	.039	Gabbro-diorite	Minnesota Falls, Minn	Bull. 168, 83.—W. T.
47.94	.060 (47.5)	Basalt	Shasta County, Cal	Bull. 168, 176.—W. T.
47.88	.065	Gabbro	Elizabethtown, N. Y	Bull. 168, 37.—W. T.
46.71	.036	Olivine-gabbro	Langenlois, Austria	R. T., 1879, XXXVIII.
46.45	.047	....do	Minnesota	Bull. 168, 82.—W. T.
45.20	.071	Diorite	Tuc d'Ess, Pyrenees	C. G. I., VIII, 1901, 832.—W. T.
44.72	.047	Corsite	Poudière, Auvergne	R. T., 1879, XXXVI.
43.42	.044	Gabbro-diorite	Ilchester, Md	Bull. 168, 44.—W. T.
43.19	.094	Basalt	Westphalia	R. T., 1879, LXXIV.

RANG 5. CORSASE.

(II. 5, 5.)

44.04	0.027	Diorite	Stone Run, Md	Bull. 168, 45.—W. T.
43.41	.020	Olivine-gabbro	Tuolumne County, Cal	Bull. 168, 206.—W. T.

ORDER 6. NORGARE.

RANG 1. LAURDALASE.

SUBRANG 2. FERGUSOSE.

(II. 6, 1, 2.)

51.75	0.147	Pseudoleucite-syenite	Highwood Mountains, Mont	Bull. 168, 133.—W. T.

SUBRANG 3. JUDITHOSE.

(II. 6, 1, 3.)

57.63	0.198	Tinguaite	Judith Mountains, Mont	A. J. S., II, 1896, 192.—W. T.
57.46	.196 (57.3)	....do	Bearpaw Mountains, Mont	Bull. 168, 136.—W. T.
53.09	.226 (53.2)	Foyaite	Magnet Cove, Ark	J. G., IX, 611.—W. T.
52.91	.224	Leucite-tinguaite	....do	I. R. A., 287.—W. T.
51.94	.157	Trachyte	Highwood Mountains, Mont	Bull. 168, 131.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

SUBRANG 4. LAURDALOSE.

(II. 6, 1, 4.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
59.88	0.188	Hedrumite	Hedrum, Norway	E. K., III, 377.—W. T.
56.58	.242	Tinguaite	do	E. K., I, 199.—W. T.
56.35	.211	Laurdalite	Farris, Norway	E. K., III, 375.—W. T.
55.90	.209	Tinguaite	Foya, Portugal	T. M. P. M., XVI, 262.—W. T.
55.65	.225	do	Hedrum, Norway	E. K., I, 199.—W. T.
55.18	.182	Syenite	do	E. K., III, 375.—W. T.
54.55	.192	Laurdalite	Lougendal, Norway	Do.
54.04	.233	Leucite-tinguaite	Magnet Cove, Ark	I. R. A., 287.—W. T.
53.81	.192	Syenite-pegmatite	Stoksund, Norway	Z. K., XVI, 116.—W. T.
53.73	.214	Nephelite-syenite	Transvaal	Rosenbusch, El., 126.—W. T.
51.95	.155 (51.6)	Soda-minette	Langesundsfjord, Norway	E. K., II, 376.—W. T.
50.96	.229	Leucite-nephelite-syenite.	Magnet Cove, Ark	I. R. A., 276.—W. T.
47.61	.190	Tinguaite	Two Buttes, Colo	Bull. 168, 165.—W. T.
45.16	.195	Olivine-laurdalite	Farris, Norway	E. K., III, 375.—W. T.

RANG 2. ESSEXASE.

SUBRANG 3. BOROLANOSE.

(II. 6, 2, 3.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
52.05	0.132	Monzonite	Highwood Mountains, Mont	Bull. 168, 133.—W. T.
51.35	.165	Nephelite-felsite	Magnet Cove, Ark	I. R. A., 263.—W. T.
50.24	.153 (49.9–.154)	Leucite-tephrite	Bolsena, Italy	J. G., IV, 561.—W. T.
50.15	.142 (49.8)	Shonkinite	Maros, Celebes	G. C., 24.
49.70	.167	Covite	Magnet Cove, Ark	J. G., IX, 612.—W. T.
47.8	.204	Borolanite	Lake Borolan, Scotland	Rosenbusch, El., 126.—W. T.

SUBRANG 4. ESSEXOSE.

(II. 6, 2, 4.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
55.07	0.162	Rhombenporphyry	Stoksund, Norway	Z. K., XVI, 116.—W. T.
54.34	.173	Nephelite-syenite	Cripple Creek, Colo	Bull. 168, 144.—W. T.
51.90	.210	Laurdalite	Lunde, Norway	E. K., III, 375.—W. T.
51.10	.173	Covite	Nosy Komba, Madagascar	M. M., 204.
50.50	.143	Nephelite-monzonite	Rongstock, Bohemia	T. M. P. M., XIV, 98, 99.—W. T.
50.26	.210	Nephelite-syenite-porphyry.	Viezzena, Tyrol	K. A. W. W., CXI, I, 275.
49.90	.155 (49.3)	Leucite-kulaite	Kula, Asia Minor	J. G., VIII, 613.—W. T.
48.69	.151 (49.0–.150)	Olivine-essexite	Mount Johnson, Quebec	J. G., XI, 265.
48.46	.243	Heumite	Lougendal, Norway	E. K., III, 376.—W. T.
48.35	.161	Kulaite	Kula, Asia Minor	J. G., VIII, 613.—W. T.
47.94	.150 (48.3)	Essexite	Salem Neck, Mass	Rosenbusch, El., 172.—W. T.
47.67	.150 (48.0)	Theralite	Alabaugh Creek, Mont	Bull. 168, 124.—W. T.
46.48	.162	Monchiquite	Rio de Janeiro, Brazil	Rosenbusch, El., 235.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

RANG 3. SALEMASE.

SUBRANG 4. SALEMOSE.

(II. 6, 3, 4.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
50.47	0.132	Augite-diorite	Silver Cliff, Colo	Bull. 168, 147.—W. T.
49.95	.132	Microessexite	Nosy Kamba, Madagascar	M. M., 204.
48.50	.138	Essexite	Jangoa, Madagascar	Do.
46.40	.151	Augite-diorite	Ullernas, Norway	Z. K., XVI, 49.—W. T.
45.32	.110	Hornblende-gabbro	Salem Neck, Mass	J. G., VII, 63.—W. T.
43.66	.142	Essexite	Cabo Frio Island, Brazil	Rosenbusch, El., 172.—W. T.

SUBRANG 5. ——.

(II. 6, 3, 5.)

47.30	0.137	Basalt	Pedregal, Mexico	W. T.

RANG 4. ——.

SUBRANG 3. ——.

(II. 6, 4, 3.)

45.76	0.086	Gabbro	Rosswein, Saxony	N. J., 1893, II, 503.—W. T.
45.11	.090	Diorite	Lindenfeld, Hesse	W. T.

ORDER 7. ITALARE.

RANG 1. LUJAVRASE.

SUBRANG 3. JANEIROSE.

(II. 7, 1, 3.)

51.93	0.278	Leucite-tinguaite	Bearpaw Mountains, Mont	Bull. 168, 136.—W. T.

SUBRANG 4. LUJAVROSE.

(II. 7, 1, 4.)

54.14	0.238	Lujavrite	Tschasnatschorr, Finland	Rosenbusch, El., 126.—W. T.
52.25	.255	Chibinite	Umptek, Finland	Fennia, XI, 2, 132.—W. T.
51.94	.208 (51.6)	Camptonitic tinguaite	Picota, Portugal	T. M. P. M., XVI. 272.—W. T.
50.63	.271	Nephelite-porphyry	Laugendal, Norway	E. K., III, 157.—W. T.
48.86	.234	Allochetite	Allochet, Monzoni, Tyrol	A. W. W., 1902, Anz. XXI.

RANG 2. VULTURASE.

SUBRANG 2. ——.

(II. 7, 2, 2.)

50.32	0.157	Basanite	Vesuvius	R. T., 1861, 25.
49.73	.158 (49.6)	Leucite-tephrite	Bracciano, Italy	J. G., V, 370.—W. T.
47.89	.161 (47.8)	Leucitite	do	Do.

Classified list of analyses used in constructing diagrams—Continued.

SUBRANG 3. ——.

(II. 7, 2, 3.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
48.03	0.167	Basanite	Granatello, Vesuvius	R. T., 1861, 25.

SUBRANG 4. VULTUROSE.

(II. 7, 2, 4.)

42.46	0.229	Haüynophyre	Melfi, Italy	Rosenbusch, El., 357.

RANG 3. ——.

SUBRANG 3. ——.

(II. 7, 3, 3.)

47.40	0.130	Leucite-tephrite	Rocca Monfina, Italy	J. G., V, 370.—W. T.

ORDER 8. CAMPANARE.

RANG 1. ——.

SUBRANG 3. ——.

(II. 8, 1, 3.)

50.00	0.267	Tinguaite	Beemerville, N. J	Bull. Mus. Comp. Zool., XXXVIII, 1902, 276.—W. T.
46.48	268	Leucitite	Etinde Volcano, Kamerund, Africa	W. T.

SUBRANG 5. ——.

(II. 8, 1, 5.)

47.43	0.333	Soda-sussexite	Penikkavaara, Finland	B. C. G. F., XI, 22.—W. T.

RANG 2. VESUVASE.

SUBRANG 2. VESUVOSE.

(II. 8, 2, 2.)

47.71	0.157	Leucite-basanite	Lava of 1631, Vesuvius	W. T.
47.65	.157	do	Lava of 1872, Vesuvius	W. T.
47.53	.149	Leucitophyre	Vesuvius	R. T., 1884, LVI.
46.36	.160 (46.2)	do	do	R. T., 1884, LVIII.

ORDER 9. LAPPARE.

RANG 1. URTASE.

SUBRANG 3. ARKANSOSE.

(II. 9, 1, 3.)

44.40	0.252	Arkite	Magnet Cove, Ark	J. G., IX, 616.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

SUBRANG 4. URTOSE.

(II. 9, 1, 4.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
45.46	0.397	Urtite	Lujavr Urt, Kola, Finland	G. F. S. F., XVIII, 462.—W. T.
45.43	.391	.....do	.....do	Do.
45.28	.418	.....do	.....do	Rosenbusch, El., 126.—W. T.
43.02	.378	Ijolite, rich in nephelite.	Kuusamo, Finland	B. C. G. F., XI, 17.—W. T.

CLASS III. SALFEMANE.

ORDER 3. ATLANTARE.

RANG 1. ROCKALLASE.

SUBRANG 2. ——.

(III. 3, 1, 2.)

68.75	0.144	Pantellerite	Pantellaria	Z. K., VIII, 179.—W. T.

SUBRANG 5. ROCKALLOSE.

(III. 3, 1, 5.)

73.60	0.091	Rockallite	Rockall Island, Atlantic Ocean	Geol. Mag., VI, 163.—W. T.

ORDER 4. VAALARE.

RANG 3. VAALASE.

SUBRANG 4. VAALOSE.

(III. 4, 3, 4.)

53.39	0.068	Quartz-gabbro	Harz	R. T., 1884, XXXIV.
53.35	.067 (52.8)	Basalt	Teanaway River, Kittitas County, Wash.	Bull. 168, 225.—W. T.
52.67	.047 (52.9)	Olivine-diabase	Cape Colony, Africa	N. J., 1887, V, 249.—W. T.
52.22	.048 (51.9–.051)	Olivine-disbase-porphyrite.	.....do	Do.

RANG 4. ——.

SUBRANG 3. ——.

(III. 4, 4, 3.)

56.18	0.036	Diorite	Washington, D. C	Bull. 168, 44.—W. T.
45.75	.027	Melaphyre	Holmestrand, Norway	Z. K., XVI, 27.—W. T.

RANG 5. ——.

(III. 4, 5.)

47.00	0.008	Olivine-gabbro-diabase.	Sölvsberget, Norway	Z. K., XVI, 27.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

ORDER 5. GALLARE.

RANG 1. ORENDASE.

SUBRANG 1. ORENDOSE.

(III. 5, 1, 1.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
54.17	0.160	Orendite	Leucite Hills, Wyo	Bull. 168, 86.—W. T.
54.08	.163	.....do	.....do	Do.
53.70	.160 (53.6)	Wyomingite	.....do	Bull. 168, 85.—W. T.

SUBRANG 2. ——.

(III. 5, 1, 2.)

50.23	0.150	Wyomingite	Leucite Hills, Wyo	Bull. 168, 85.—W. T.

RANG 2. KILAUASE.

SUBRANG 2. PROWERSOSE.

(III. 5, 2, 2.)

50.41	0.113	Syenitic lamprophyre	Two Buttes, Colo	Bull. 168, 165.—W. T.

SUBRANG 3. LAMAROSE.

(III. 5, 2, 3.)

48.98	0.107	Shonkinite	Yogo Peak, Mont	Bull. 168, 128.—W. T.
48.95	.097	Absarokite	Hoodoo Mountain, Wyo	Bull. 168, 99.—W. T.
47.56	.099	Mica-picrophyre	North of Prag, Bohemia	R. T., 1879, XLVI.
47.32	.090 (47.5)	Leucite-absarokite	Sunlight Valley, Wyo	Bull. 168, 97.—W. T.

SUBRANG 4. KILAUOSE.

(III. 5, 2, 4.)

46.52	0.085 (45.2)	Basalt	Volcano Butte, Castle Mountains	Bull. 168, 130.—W. T.
43.35	.099	Augitite	Mittelgebirge, Bohemia	Rosenbusch, El., 363.

RANG 3. CAMPTONASE.

SUBRANG 2. ABSAROKOSE.

(III. 5, 3, 2.)

49.71	0.090	Absarokite	Cache Creek, Yellowstone Park	Bull. 168, 99.—W. T.
19.03	.082	Leucite-basanite	Bolsena, Italy	J. G., V, 370.—W. T.
48.36	.080	Absarokite	Clark Fork, Wyo	Bull. 168, 99.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

SUBRANG 3. KENTALLENOSE.

(III. 5, 3, 3.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
52.09	0.074	Kentallenite	Glen Shira, Argyllshire, Scotland	Q. J. G. S., LVI, 537.—W. T.
51.76	.083	Absarokite	Absaroka Range, Yellowstone Park	Bull. 168, 99.—W. T.
51.65	.107	Lamprophyre	Cottonwood Canyon, Mont	Bull. 168, 112.—W. T.
50.82	.075	do	Antelope and South Boulder creeks, Mont.	Bull. 168, 113.—W. T.
50.35	.101	Olivine-monzonite	Smälingen, Sweden	E. K., II, 46.—W. T.

SUBRANG 4. CAMPTONOSE.

(III. 5, 3, 4.)

54.56	0.067	Quartz-basalt	Cinder Cone, Cal	Bull. 168, 185.—W. T.
53.56	.077	Mica-porphyry	Crandall Basin, Wyo	Bull. 168, 92.—W. T.
52.35	.067	Diorite	Little Falls, Minn	N. J., 1877, 129.
51.81	.077	Gabbro-porphyry	Crandall Basin, Wyo	Bull. 168, 92.—W. T.
51.23	.076	Diabase	Halleberg, Sweden	Rosenbusch, El., 323.
49.35	.074	Dolerite	Pantellaria	T. M. P. M., 1883, 393.
48.60	.095 (48.4)	Nephelite-basalt	Elkhead Mountains, Colo	Fortieth Par., I., 676.
48.22	.084	Camptonite	Mount Ascutney, Vt	Bull. 168, 26.—W. T.
47.91	.086	Basalt	Washoe, Nev	
47.90	.094	Essexite	Tofteholmen, Norway	E. K., II, 375.—W. T.
47.28	.083	Leucite-absarokite	Ishawooa Canyon, Wyo	Bull. 168, 99.—W. T.
47.16	.077	Gabbro	Elizabethtown, N. Y	Bull. 168, 37.—W. T.
46.74	.089	do	do	Do.
45.30	.107	Basalt	Mount Trumbull, Ariz	Bull. 168, 174.—W. T.
40.60	.078	Camptonite	Maena, Gran, Norway	E. K., III, 376.—W. T.

SUBRANG 5. ORNOSE.

(III. 5, 3, 5.)

54.14	0.074	Tachylite	Hanover	R. T., 1879, LXXIV.
46.11	.081 (.077)	Ornöite	Ornö, Sweden	G. F. S. F., XV, 108.—W. T.

RANG 4. AUVERGNASE.

SUBRANG 2. ——.

(III. 5, 4, 2.)

50.03	0.062 (49.4)	Lamprophyre	South Boulder Creek, Mont	Bull. 168, 113.—W. T.
46.86	.065	Diabase-pitchstone	Meriden, Conn	Bull. 168, 35.—W. T.

SUBRANG 3. AUVERGNOSE.

(III. 5, 4, 3.)

53.13	0.053	Diabase	Jersey City, N. J	A. J. S., IX, 1875, 187.
52.42	.046	do	Wintergreen Lake, Conn	A. J. S., IX, 1875, 189.
52.68	.057	Dolerite	Mount Holyoke, Mass	A. J. S., IX, 1875, 186.
51.78	.044	Diabase	New Haven, Conn	Do.
51.46	.057	Gabbro	Sturgeon Falls, Mich	Bull. 168, 70.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

SUBRANG 3. AUVERGNOSE—Continued.

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
51.36	0.040	Basalt	Orange, N. J	Bull. 168, 39.—W. T.
50.89	.053	.....do	Lassen Peak, Cal	Bull. 168, 186.—W. T.
49.87	.062	.....do	Pantellaria	T. M. P. M., 1883, 393.
49.63	.055 (49.5)	Diabase	Mount Ascutney, Vt	Bull. 168, 26.—W. T.
49.18	.035	Basalt	Disko, Greenland	T. M. P. M., 1874, 120.
48.23	.034	Norite	Crystal Falls, Mich	Bull. 168, 67.—W. T.
48.04	.045	Basalt	Ovifak, Greenland	T. M. P. M., 1874, 121.
47.93	.047 (47.7)	.....do	Paynes Creek, Cal	Bull. 168, 186.—W. T.
47.90	.043 (47.4-.040)	Diabase	Penokee-Gogebic Range, Mich	Bull. 168, 73.—W. T.
47.54	.070 (47.8-.079)	Basalt	Grant, N. Mex	Bull. 168, 170.—W. T.
47.45	.082	Gabbro	Saleix, Pyrenees	C. G. I., VIII, 1901, 832.—W. T.
47.29	.029	Pyroxene-ariegite	Lherz, Pyrenees	C. G. I., VIII, 1901, 833.—W. T.
45.66	.049	Olivine-gabbro	Birch Lake, Minn	Bull. 168, 81.—W. T.
44.90	.033	Pyroxene-ariegite	Tuc d'Ess, Pyrenees	C. G. I., VIII, 1901, 833.—W. T.
44.97	.072	Gabbro	Elizabethtown, N. Y	Bull. 168, 37.—W. T.
44.77	.057	Basalt	Kosk Creek, Cal	Bull. 168, 186.—W. T.
43.50	.062	Hornblende-monchiquite.	Magnet Cove, Ark	Rosenbusch, El., 235.—W. T.
42.77	.063	Olivine-diabase	Campton, N. H	A. J. S. XVII, 1879, 150.
42.68	.015	Ariegite	Escourgeat, Pyrenees	C. G. I., VIII, 1901, 833.—W. T.
42.03	.053 (.055)	Fourchite	Fourche Mountain, Ark	I. R. A., 108.—W. T.

RANG 5. KEDABEKASE.

(III. 5, 5.)

48.02	0.010	Norite	McKinseys Mill, Md	Bull. 168, 45.—W. T.
47.09	.014	Ariegite	Lherz, Pyrenees	C. G. I., VIII, 1901, 833.—W. T.
44.76	.020	Hypersthene-gabbro	Wetheredville, Md	Bull. 168, 44.—W. T.
44.64	.017 (45.1)	Kedabekite	Kedabek, Russia	W. T.
44.38	.019 (43.8)	Ariegite	Lherz, Pyrenees	C. G. I., VII, 1901, 833.—W. T.
44.11	.012	Kedabekite	Kedabek, Russia	W. T.
42.32	.025	Ariegite	Lherz, Pyrenees	C. G. I., VIII, 1901, 833.—W. T.
38.95	.029	.....do	.....do	Do.

ORDER 6. PORTUGARE.

RANG 1. WYOMINGASE.

SUBRANG 3. ——.

(III. 6, 1, 3.)

50.00	0.110	Shonkinite	Bearpaw Mountains, Mont	Bull. 168, 136.—W. T.

SUBRANG 4. ——.

(III. 6, 1, 4.)

48.39	0.121 (48.5)	Analcite-basalt	Little Belt Mountains, Mont	Bull. 168, 128.—W. T.
45.72	.166	Monchiquite	Fohberges, Baden	W. T.
42.30	.157	Nephelinite	Katzenbuckel, Odenwald	Rosenbusch, El., 357.
40.03	.140 (40.2)	Camptonite	Oxford, N. J	Rosenbusch, El., 235.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

RANG 2. MONCHIQUASE.

SUBRANG 3. SHONKINOSE.

(III. 6, 2, 3.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
49.59	0.139	Leucite-syenite	Highwood Mountains, Mont	Bull. 168, 132.—W. T.
48.05	.142 (48.5)	Shonkinite	Maros, Celebes	G. C., 23.
47.98	.136	Leucite-basalt	Highwood Mountains, Mont	Bull. 168, 132—W. T.
46.73	.088 (45.9)	Shonkinite	Square Butte, Mont	B. G. S. A., VI, 414.—W. T
45.19	.101 (44.8)	Nephelite-basalt	Breitfirst, Hesse	Rosenbusch, El., 357.
43.85	.150	Leucite-monchiquite.	Mittelgebirge, Bohemia	Rosenbusch, El., 235.—W. T.

SUBRANG 4. MONCHIQUOSE.

(III. 6, 2, 4.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
48.43	0.114	Hornblende-vogesite.	Hohwald, Elsass	Rosenbusch, El., 231.
47.82	.121	Monchiquite	Highwood Mountains, Mont	Bull. 168, 132.—W. T.
45.59	.110 (45.8)	Analcite-basalt	Pikes Peak district, Colo	Bull. 168, 146.—W. T.
45.56	.154	Nephelite-tephrite	Herrnberg, Tetschen, Bohemia	W. T.
44.54	.124	Limburgite	Heldburger Feste, S. Thüringen	Rosenbusch, El., 363.
43.84	.119	Leucite-basanite	Blankenhornberg, Kaiserstuhl, Baden	W. T.

RANG 3. LIMBURGASE.

SUBRANG 3. OUROSE.

(III. 6, 3, 3.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
46.65	0.114	Labradorite-porphyry	Wildkaar, Tyrol	R. T., 1879, XLIV.
43.74	.108	Monchiquite	Rio do Ouro, Brazil	Rosenbusch, El., 235.—W. T.
42.46	.068	.....do	Willow Creek, Mont	Bull. 168, 130.—W. T.

SUBRANG 4. LIMBURGOSE.

(III. 6, 3, 4.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
46.60	0.112 (46.3)	Nephelite-gabbro	Nosy Komba, Madagascar	M. M., 204.
46.35	.086	Nephelite-basanite	Römhild, S. Thüringen	Rosenbusch, El., 346.
44.82	.073 (44.5-.074)	Paleolimburgite	Atacama, Chile	Z. D. g. G., LI, 4.
43.65	.071 (43.8)	Olivine-gabbro-diabase.	Brandberget, Gran, Norway	Q. J. G. S., L, 19.—W. T.
43.50	.107	Augitite	Limberg, Baden	W. T.
41.01	.082	Hornblende-basalt	Sparbrod, Rhone	N. J., 1882, II, 155.
40.70	.084 (40.5)	Limburgite	Oberersteinberg, Lausitzer Mountains, Prussia.	Rosenbusch, El. 363.
40.10	.109 (40.4)	Ijolite	Ampasibitika, Madagascar	M. M., 204.
37.90	.095	Hornblendite	Brandberget, Gran, Norway	Q. J. G. S., L, 19.—W. T.

SUBRANG 5. ——.

(III. 6, 3, 5.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
41.94	0.121	Camptonite	Campton Falls, N. H	A. J. S., XVII, 1879, 150.

Classified list of analyses used in constructing diagrams—Continued.

RANG 4. ——.

SUBRANG 1. ——.

(III. 6, 4, 1.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
39.84	0.046 (40.4)	Hornblende-gabbro	Piedmont, Italy	Rosenbusch, El., 151.

SUBRANG 3. ——.

(III. 6, 4, 3.)

45.40	0.063	Dioritic gabbro	Nosy Komba, Madagascar	M. M., 204.

ORDER 7. KAMERUNARE.

RANG 1. MALIGNASE.

SUBRANG 3. ——.

(III. 7, 1, 3.)

47.85	0.144	Nephelite-malignite	Poohbah Lake, Ontario	Rosenbusch, El., 176.—W. T.

SUBRANG 4. MALIGNOSE.

(II, 7, 1, 4.)

51.88	0.180	Garnet-pyroxene-malignite.	Poohbah Lake, Ontario	Rosenbusch, El., 176.—W. T.
51.38	.193	Amphibole-malignite	do	Do.
44.65	.186	Theralite	Crazy Mountains, Mont	Bull. 168, 124.—W. T.
42.02	.161 (41.8)	Ijolite-porphyry	Alnö, Sweden	N. J., 1897, II, 99.—W. T.

RANG 2. KAMERUNASE.

SUBRANG 3. ——.

(III. 7, 2, 3.)

46.04	0.127	Leucite-basalt	Highwood Mountains, Mont	Bull. 168, 132.—W. T.

SUBRANG 4. KAMERUNOSE.

(III, 7, 2, 4.)

47.10	0.178	Heumite	Laugendal, Norway	E. K., III, 376.—W. T.
46.53	.123	Theralite	Umptek, Finland	Rosenbusch, El., 176.—W. T.
45.77	.163	Farrisite	Farris, Norway	E. K., III, 376.—W. T.
44.31	.147	Theralite	Gordons Butte, Mont	Bull. 168, 124.—W. T.
42.77	.143 (43.0)	Monchiquite	Kiechlinsbergen, Baden	W. T.
42.65	.133 (43.3)	Basalt	Cape Verde, Africa	R. T., 1884, LXXIV.
40.10	.167 (40.3)	Leucite-nephelinite	Etinde Volcano, Kamerun, Africa	W. T.
39.97	.183 (40.2)	do	do	Do.
39.30	.165 (40.8)	Haüynophyre	do	Do.

Classified list of analyses used in constructing diagrams—Continued.

RANG 3. ETINDASE.

SUBRANG 4. ETINDOSE.

(III, 7, 3, 4.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
40.52	0.097	Nephelite-basalt	Hesse-Darmstadt	Rosenbusch, El., 357.
39.33	.109	....do	Mittelgebirge, Bohemia	Do.
38.46	.143 (38.9)	Camptonite	Mulatto, Predazzo, Tyrol	K. A. W. W., CXI, I, 234.

ORDER 8. BOHEMARE.

RANG 1. CHOTASE.

SUBRANG 2. CHOTOSE.

(III. 8, 1, 2.)

46.51	0.167	Leucitite	Bearpaw Mountains, Mont	Bull. 168, 136.—W. T.

RANG 2. ALBANASE.

SUBRANG 2. ALBANOSE.

(III. 8, 2, 2.)

47.47	0.137	Leucite-tephrite	Vesuvius, lava of 1760	R. T., 1884, LVI.
45.99	.168 (46.1)	Leucitite	Capo di Bove, Italy	A. J. S., IX, 1900, 53.—W. T.

SUBRANG 3. ———.

(III. 8, 2, 3.)

41.24	0.141	Nephelinite	Laacher See, Rhine province	Rosenbusch, El., 357.

SUBRANG 4. COVOSE.

(III. 8, 2, 4.)

43.18	0.186	Theralite	Crazy Mountains, Mont	Rosenbusch, El., 176.
42.06	.132	Limburgite	Habichtswald, Hesse	Rosenbusch, El., 363.
41.74	.204	Ijolite	Magnet Cove, Ark	J. G., IX, 618.—W. T.
40.15	.204 (40.3)	Nephelinite	Etinde Volcano, Kamerun, Africa	W. T.
38.39	.150	....do	....do	Do.

ORDER 9. FINNARE.

RANG 1. IJOLASE.

SUBRANG 2. MADUPOSE.

(III. 9, 1, 2.)

42.65	0.139	Madupite	Leucite Hills, Wyo	Bull. 168, 85.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

SUBRANG 4. IIVAAROSE.

(III. 9, 1, 4.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
45.64	0.342	Nephelite-porphyry ..	Umptek, Finland	Fennia, XI, 2, 196.—W. T.
43.70	.257	Ijolite	Kuusamo, Finland	B. C. G. F., XI, 16.—W. T.
42.18	.268	Nephelite-basalt......	Bauersberg, Bavaria	R. T., 1879, LXII.

SUBRANG 5. IJOLOSE.

(III. 9, 1, 5.)

42.07	0.281	Ijolite	Kuusamo, Finland	B. C. G. F., XI, 16.—W. T.

CLASS IV. DOFEMANE.

ORDER 1. HUNGARARE.

SECTION 1. MINNESOTIARE.

RANG 1. MINNESOTASE.

SECTION 1. MINNESOTIASE.

SUBRANG 2. COOKOSE.

(IV. 1, 1, 1, 1, 2.)

51.83	0.005	Pyroxenite	Meadow Creek, Mont	Bull. 168, 114.—W. T.
50.64	.020	Wehrlite	New Braintree, Mass	Bull. 168, 33.—W. T.
46.96	.030	Hypersthene-gabbro .	Gunflint Lake, Minn	Bull. 168, 81.—W. T.

SECTION 2. ——.

RANG 1. ——.

SECTION 2. ——.

SUBRANG 1. BELCHEROSE.

(IV. 1, 2, 1, 2, 1.)

48.63	0.008	Peridotite	Belchertown, Mass	Bull. 168, 30.—W. T.

SUBRANG 2. ——.

(IV. 1, 2, 1, 2, 2.)

48.91	0.013	Olivine-gabbro	Orange Grove, Md	Bull. 168, 44.—W. T.
46.56	.050	Gabbro	Pharkowsky-Ouwal, Ural Mountains.	O. N., 145.
46.56	.043 (46.9)	.....do	Near Koswinsky, Ural Mountains....	Do.
46.06	.098	Missourite	Shonkin Creek, Mont	Bull. 168, 133.—W. T.
44.94	.000	Wehrlite	Koswinsky, Ural Mountains..........	O. N., 173.
44.39	.032	Gabbro	Pharkowsky-Ouwal, Ural Mountains.	O. N., 145.

Classified list of analyses used in constructing diagrams—Continued.

SECTION 3. HUNGARIARE.

Rang 1. Wehrlase.

SECTION 1. WEHRLIASE.

Subrang 2. Wehrlose.

(IV. 1, 3, 1, 1, 2.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
48.95	0.040	Wehrlite	Red Bluff, Mont	Bull. 168, 114.—W. T.
46.13	.001	Hornblende-picrite	Meadow Creek, Mont	Do.
45.68	.000	Lherzolite	Baldisser, Piedmont, Italy	Rosenbusch, El., 165.

SECTION 2. ——.

Subrang 2. Rossweinose.

(IV. 1, 3, 1, 2, 2.)

47.75	0.027	Peridotite	Cathay Hill, Mariposa County, Cal	Bull. 168, 209.—W. T.
46.00	.035 (46.1)	Hornblendite	Col d'Eret, Pyrenees	C. G. I., VIII, 1901, 833.—W. T.
44.99	.028	Wehrlite	Crystal Falls, Mich	Bull. 168, 67.—W. T.

SECTION 4. ——.

Rang 1. Cortlandtase.

SECTION 1. CORTLANDTIASE.

Subrang 1. Cortlandtose.

(IV. 1, 4, 1, 1, 1.)

44.61	0.000	Lherzolite	Lherz, Pyrenees	C. G. I., VIII, 1901, 833.—W. T.
36.80	.049	Peridotite	Syracuse, N Y	Bull. 168, 38.—W. T.

Subrang 2. Custerose.

(IV. 1, 4, 1, 1, 2.)

46.03	0.041	Peridotite	Silver Cliff, Colo	Bull. 168, 147.—W. T.

SECTION 5. PYRENIARE.

Rang 1. Lherzase.

SECTION 1. LHERZIASE.

Subrang 1. Lherzose.

(IV. 1, 5, 1, 1, 1.)

41.50	0.036	Hornblende-lherzolite	Caussou, Pyrenees	C. G. I., 1901, VIII, 833.—W. T.

Subrang 2. Argeinose.

(IV. 1, 5, 1, 1, 2.)

39.25	0.038	Hornblende-peridotite.	Argein, Pyrenees	C. G. I., 1901, VIII, 833.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

SECTION 3. VENANZIASE.

SUBRANG 2. VENANZOSE.

(IV. 1, 5, 1, 3, 2.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
41.43	0.152	Venanzite	San Venanzo, Umbria, Italy	A. W. B., 1899, VII, 113.—W. T.

ORDER 2. SCOTARE.

SECTION 1. ——.

RANG 1. ——.

SECTION 1. ——.

SUBRANG 2. ——.

(IV. 2, 1, 1, 1, 2.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
53.05	0.018	Augite-norite	Madras, India	W. T.

SECTION 3. BRANDBERGIASE.

SUBRANG 2. BRANDBERGOSE.

(IV. 2, 1, 1, 3, 2.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
45.05	0.030 (45.9)	Pyroxenite	Brandberg, Norway	Q. J. G. S., L, 31.—W. T.

SUBRANG 3. ——.

(IV. 2, 1, 1, 3, 3.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
45.04	0.209	Nephelite-basalt	Katzenbuckel, Odenwald, Baden	Rosenbusch, El., 357.

SECTION 2. PAOLIARE.

RANG 1. PAOLASE.

SECTION 2. ——.

SUBRANG 2. ——.

(IV. 2, 2, 1, 2, 2.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
47.41	0.031	Augite-peridotite	Peekskill, N. Y.	A. J. S., XXXI, 1886, 40.—W. T.
42.68	.077	Hornblende-basalt	Hauk, S. Rhone	Rosenbusch, El., 309.
40.42	.038	Olivine-gabbro	Crazy Mountains, Mont	Bull. 168, 122.—W. T.
40.15	.000	Koswite	Koswinsky, Ural Mountains	O. N., 119.
39.59	.057	Nephelite-basalt	Ottendorf, Silesia	R. T., 1884, LXIV.

SECTION 3. PAOLIASE.

SUBRANG 2. PAOLOSE.

(IV. 2, 2, 1, 3, 2.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
41.44	0.000 (41.6)	Koswite	Koswinsky, Ural Mountains	O. N., 119.
38.39	.031 (37.5)	Jacupirangite	Magnet Cove, Ark	J. G., IX, 620.—W. T.
38.38	.022	do	Sao Paulo, Brazil	Do.
36.51	.075	Eleolite-mica-syenite	Magnet Cove, Ark	Do.

Classified list of analyses used in constructing diagrams—Continued.

SECTION 3. TEXIARE.

Rang 1. Texase.

SECTION 1. MARQUETTIASE.

Subrang 2. Marquettose.

(IV. 2, 3, 1, 1, 2.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
39.37	0.017	Peridotite	Opin Lake, Mich	Bull. 168, 64.—W. T.

SECTION 2. UVALDIASE.

Subrang 2. Uvaldose.

(IV. 2, 3, 1, 2, 2.)

40.32	0.080	Nephelite-basalt	Uvalde County, Tex	Bull. 168, 62.—W. T.
39.92	.063 (41.0)	do	do	Bull. 168, 63.—W. T.
39.16	.081	do	Oberleinleiter, Baden	Rosenbusch, El., 357.
36.53	.108	Nephelite-melilite-basalt.	Wartenberg, Baden	Rosenbusch, El., 360.

SECTION 4. ——.

Rang 1. Casselase.

SECTION 2. CASSELIASE.

Subrang 1. ——.

(IV. 2, 4, 1, 2, 1.)

38.34	0.106	Limburgite	Rio de Janeiro, Brazil	T. M. P. M., XX, 304.
37.98	.121 (37.4)	Melilite-nephelite-basalt.	Hohenberg, Westphalia	Rosenbusch, El., 357.

Subrang 2. Casselose.

(IV. 2, 4, 1, 2, 2.)

39.20	0.056 (38.6)	Dike-rock	Kola Peninsula, Finland	Fennia, 15, 2, 1899, 27.—W. T.
37.96	.066	Nephelite-melilite-basalt.	Uvalde County, Tex	Bull. 168, 63.—W. T.

SECTION 5. ——.

Rang 1. ——.

SECTION 1. KALTENIASE.

Subrang 3. Kaltenose.

(IV. 2, 5, 1, 1, 3.)

34.98	0.101	Mica-peridotite	Kaltenthal, Harzburg, Harz Mts	Rosenbusch, El., 165.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

ORDER 3. SVERIGARE.

SECTION 1. BERGENIARE.

RANG 1. BERGENASE.

SECTION 1. BERGENIASE.

SUBRANG 3. BERGENOSE.

(IV. 3, 1, 1, 1, 3.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
31.59	0.032	Ilmenite-norite	Storgangen, Norway	B. M. A., 1896, V, 165.—W. T.

SECTION 2. ——.

RANG 1. ——.

SECTION 2. ——.

SUBRANG 2. ——.

(IV. 3, 2, 1, 2, 2.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
38.20	0.122	Nephelite-melilite-basalt.	Burgstall, Baden	Rosenbusch, El., 360.—W. T.
38.18	.036	(?) Pyroxenite	Predazzo, Tyrol	E. K., II, 76.—W. T.

SECTION 3. AVEZACIASE.

SUBRANG 3. AVEZACOSE.

(IV. 3, 2, 1, 3, 3.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
31.80	0.026	Avezacite	Avezac-Prat, Pyrenees	C. G. I., VIII, 1901, 832.—W. T.

ORDER 4. ADIRONDACKARE.

Suborder 2. Adirondackore.

RANG 1. ADIRONDACKASE.

SECTION 1. ADIRONDACKIASE.

SUBRANG 3. ——.

(IV. 4, 2, 1, 1, 3.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
24.74	0.000	Iron ore	Ulfö, Sweden	S. M. Q., XXI, 60.
22.87	.000	Iron ore	Cumberland Hill, R. I	S. M. Q., XXI, 60.
14.95	.000	.....do	Laanghult, Sweden	Do.

SUBRANG 4. ——.

(IV. 4, 2, 1, 1, 4.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
21.42	0.033	Iron ore	Elizabethtown, N. Y	S. M. Q., XX, 343.
11.73	.055	.....do	.....do	Do.
10.37	.057	.....do	Frontenac County, Ontario	S. M. Q., XX, 331.

Classified list of analyses used in constructing diagrams—Continued.

Suborder 3. Champlainore.

Rang 1. Champlainase.

SECTION 1. CHAMPLAINIASE.

Subrang 4. ——.

(IV. 4, 3, 1, 1, 4.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
17.90	0.000	Iron ore	Split Rock mine, N. Y	S. M. Q., XX, 343.
13.35	.000	....do	Tunnel Hill, N. Y	Do.

Order 5. ——.

Suborder 2. ——.

Rang 1. ——.

SECTION 1. ——.

Subrang 4. ——.

(IV. 5, 2, 1, 1, 4.)

10.77	0.039	Iron ore	Pine Lake, Ontario	S. M. Q., XX, 331.

Subrang 5. ——.

(IV. 5, 2, 1, 1, 5.)

10.26	0.000	Iron ore	Iron Mountain, N. Y	S. M. Q., XX, 343.

SECTION 2. ——.

Subrang 4. ——.

(IV. 5, 2, 1, 2, 4.)

9.79	0.000 (9.5)	Iron ore	Milford Pit, N. Y	S. M. Q., XX, 344.

CLASS V. PERFEMANE.

Order 1. Maorare.

SECTION 1. CAROLINIARE.

Rang 1. Websterase.

SECTION 1. MARICIASE.

Subrang 1. Maricose.

(V. 1, 1, 1, 1, 1.)

55.52	0.000	Lherzolite	Locano, Piedmont	Rosenbusch, El., 165.
55.23	.000	Pyroxenite	Marico district, Transvaal	A. J. S., VII, 1899, 318.—W. T.

Classified list of analyses used in constructing diagrams—Continued.

SECTION 2. WEBSTERIASE.

SUBRANG 1. WEBSTEROSE.

(V. 1, 1, 1, 2, 1.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
55.14	0.005	Websterite	Webster, N. C	Bull. 168, 53.—W. T.
53.98	.000	do	Hebbville, Md	Bull. 168, 43.—W. T.
52.55	.004	do	do	Bull. 168, 43.—W. T.

SUBRANG 2. CECILOSE.

(V. 1, 1, 1, 2, 2.)

53.21	0.003	Websterite	Cecil County, Md	Bull. 168, 43.—W. T.
53.25	.003 (53.6)	Pyroxenite	Mount Diablo, Cal	Bull. 168, 213.—W. T.

SECTION 2. MARYLANDIARE.

RANG 1. BALTIMORASE.

SECTION 2. BALTIMORIASE.

SUBRANG 2. BALTIMOROSE.

(V. 1, 2, 1, 2, 2.)

50.80	0.000 (50.6)	Pyroxenite	Johnny Cake road, Md	Bull. 168, 42.—W. T.
49.35	.000	Koswite	Koswinsky, Ural Mountains	O. N., 119.

SECTION 3. ——.

RANG 1. ——.

SECTION 2. ——.

SUBRANG 2. KOSWOSE.

(V. 1, 3, 1, 2, 2.)

43.20	0.00	Koswite	Koswinsky, Ural Mountains	O. N., 119.

SECTION 4. ——.

RANG 1. ——.

SECTION 1. ——.

SUBRANG 1. ——.

(V. 1, 4, 1, 1, 1.)

41.43	0.00	Saxonite	Riddles, Oreg	Bull. 168, 221.—W. T.

SUBRANG 2. ——.

(V. 1, 4, 1, 1, 2.)

42.39	0.000	Peridotite	Goose Bay, Straits of Magellan	W. T.

Classified list of analyses used in constructing diagrams—Continued.

SECTION 5. MAORIARE.

Rang 1. Dunase.

SECTION 1. DUNIASE.

Subrang 1. Dunose.

(V. 1, 5, 1, 1, 1.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
42.80	0.000	Dunite	Dun Mountains, New Zealand	Rosenbusch, El., 165.
40.11	.000	Dunite	Corundum Hills, N. C.	Bull. 168, 54.—W. T.
39.99	.00 (39.7)	Harzburgite	Olivine Hills Range, New Zealand	Rosenbusch, El., 165.

Order 2. ——.

SECTION 2. ——.

Rang 1. ——.

SECTION 2. ——.

Subrang 2. ——.

(V. 2, 2, 1, 2, 2.)

43.87	0.000	Lherzolite	Johnny Cake road, Md.	Bull. 168, 42.

SECTION 5. ——.

Rang 1. ——.

SECTION 1. ——.

Subrang 2. Permose.

(V. 2, 5, 1, 1, 2.)

31.84	0.000	Dunite sidéronitique.	Koswinsky, Ural Mountains	O. N., 128.

Order 3. ——.

SECTION 4. ——.

Rang 1. ——.

SECTION 1. ——.

Subrang 2. ——.

(V. 3, 4, 1, 1, 2.)

21.25	0.000	Iron ore	Taberg, Sweden	S. M. Q., XXI, 60.

Classified list of analyses used in constructing diagrams—Continued.

ORDER 4. ——.

Suborder 2. ——.

RANG 1. ——.

SECTION 1. ——.

SUBRANG 2. ——.

(V. 4, 2, 1, 1, 2.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
20.85	0.000	Iron ore	Cumberland Hill, R. I	S. M. Q., XX, 351.

SUBRANG 4. ——.

(V. 4, 2, 1, 1, 4.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
16.17	0.000	Iron ore	Iglamala, Sweden	S. M. Q., XXI, 60.
7.82	.088	do	Horton, Renfrew County, Canada	S. M. Q., XX, 331.

ORDER 5. ——.

Suborder 2. ——.

RANG 1. ——.

SECTION 1. ——.

SUBRANG 2. ——.

(V. 5, 2, 1, 1, 2.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
4.08	0.092	Magnetite-spinelite	Routivara, Sweden	Z. P. G.

SUBRANG 3. ——.

(V. 5, 2, 1, 1, 3.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
7.52	0.080	Iron ore	Leeds County, Ontario	S. M. Q., XX, 331.
6.88	.000	do	Alnö, Sweden	S. M. Q., XXI, 60.

SUBRANG 5. ——.

(V. 5, 2, 1, 1, 5.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
3.67	0.000	Iron ore	Mill Pond pit, N. Y	S. M. Q., XX, 344.
2.02	.000	do	Mayhew Iron Range, Minn	S. M. Q., XX, 337.
1.47	.000	do	Eagle Lake mine, Frontenac County, Ontario.	S. M. Q., XX, 331.
.87	.000	do	Sanford, N. Y	S. M. Q., XX, 344.

SUBORDER 3. ——.

RANG 1. ——.

SECTION 1. ——.

SUBRANG 4. ——.

(V. 5, 3, 1, 1, 4.)

Silica content.	Alkali-silica ratio.	Author's name.	Locality.	Reference.
0.76	0.000	Iron ore	Iron Mountain Wyo	S. M. Q., XX, 354.

DISCUSSION OF THE DIAGRAMS.

GENERAL DIAGRAMS.

On Pl. I are exhibited the comparative values of the chief chemical components of over 950 rocks. The relative molecular proportions of six oxides—Al_2O_3, K_2O, Na_2O, CaO, MgO, and FeO ($=FeO+2Fe_2O_3$)—are expressed by the shapes of the individual diagrams, the silica percentages are expressed by the relative lateral positions of these diagrams, and the comparative richness in alkalies is shown by the shapes of the individual diagrams and is also expressed by their relative vertical positions.

In the upper left-hand corner of the plate a smaller multiple diagram shows the distribution of the analyses in a more concise manner, the several colors of the spots indicating the classes into which they may be subdivided, according to the quantitative system, to be noticed more fully on page 68.

VARIATIONS IN COMPOSITION.

From the large diagram it is seen how manifold and intricate are the variations in chemical composition of igneous rocks. The larger the yellow triangles, the richer the soda and alumina; the larger the green ones, the more the potash and alumina; the taller the upper half of the individual diagram, the more the alumina; the narrower and taller the yellow and green triangles, the greater the excess of alumina over alkalies; the larger the blue triangles, the more the magnesia and lime; the larger the red triangles, the more the iron oxide and lime; the longer these lower triangles in the direction of the middle vertical line, the more the lime. Long, narrow, inclined, blue triangles indicate an excess of magnesia over lime; long, narrow, inclined, red triangles, an excess of iron oxide over lime.

The variation in the sizes of the individual diagrams, from the small ones at the left to the large ones at the right, corresponds to the great difference in silica content of the different rocks, as well as to differences in the components just named. Rocks with 75 per cent of silica have only 25 per cent of other constituents, while rocks with 40 per cent of silica have 60 per cent of other components. Moreover, the relative number of molecules for given percentages of mass increases with the decrease in molecular weight of the component oxides. It is to be observed that rocks high in silica are relatively high in alumina and the alkalies. The molecular weights of these are: Al_2O_3, 102; K_2O, 94; Na_2O, 62. Rocks low in silica may be high in alumina and alkalies, or high in lime, iron oxide, and magnesia. The molecular weights of the latter are: FeO, 72; CaO, 56; MgO, 40. The lightness of magnesia accounts for its greater proportions in the diagrams than in the analyses.

There are chemical variations which are somewhat regular, and others which seem irregular. First, it appears that the most siliceous rocks are rich in alumina and alkalies, and that lime increases at first more than iron and magnesia. But to this latter statement there are many exceptions.

In rocks with intermediate silica, 50 to 60 per cent, there is a gradation from those rich in alumina and alkalies and low in lime, iron, and magnesia to those rich in the latter and poor in the former. But there are rocks in this series high in alumina and lime and poor in alkalies and iron and magnesia.

The rocks low in silica, containing 35 to 50 per cent, have a wide range in variation, and attain the highest amount of magnesia. Those extremely low in silica, containing less than 30 per cent, are very rich in iron, with little or no alumina and alkalies, and little lime or magnesia.

The diagrams of rocks with less than 28 per cent of silica are found on Pl. VII. They are not repeated on Pl. I, because of the inconvenience of a plate of such length.

If the variations are studied in greater detail it is seen that in rocks having nearly the same silica and alkali ratios there is variation in the alumina, scarcely two rocks having the same amount. But there is more variation in the potash and soda. These values seem to be constantly shifting from place to place, with nothing suggesting a constant ratio between them. The great preponderance of soda is expressed by the predominance of yellow triangles over green ones. Dominantly potassic rocks are rare. They are more abundant among the more siliceous ones. Soda reaches its maximum in less siliceous rocks. Similar variability shows itself in the proportions of lime, iron oxide, and magnesia, whether these are subordinate or preponderant constituents.

TRANSITIONS AND EXTREMES.

It is possible to select certain shaped diagrams as types and discover many that are approximately the same. But closer inspection shows gradual variations from any two of these types to intermediate forms. And the general impression obtained from the whole assemblage is a regular variation from highly aluminous alkalic, yellow, and green figures to highly ferromagnesian calcic, red, and blue ones, combined with a very irregular variation in detail among adjacent figures.

The extremes of chemical variation reached in igneous rocks are exhibited in some of the diagrams. However, all known extremes are not expressed, because chemical analyses are wanting in several instances. Thus the extreme of pure silica attained by some intrusive dikes or veins of quartz is not represented. Chemical analyses have not yet been made of such rocks, or of the highly quartzose pegmatites with more than 85 per cent of silica. When they have been made the individual diagrams will extend to the extreme left-hand point of the multiple diagram.

Individual diagrams, composed of only a green triangle, exhibit the composition of a rock almost wholly orthoclase and quartz. One that is simply a yellow triangle is an almost pure albite rock. An almost pure nephelite rock from Ontario has been described by Adams, but analyses of it have not yet been made.

Diagrams consisting of only a narrow line represent an almost pure magnesium silicate, olivine, while those consisting of long triangles sloping to the left (Pl. VII) represent iron and titanium oxide—titaniferous magnetite.

The extremes of variability expressed in mineral terms are known to be as follows: Igneous rocks wholly quartz, almost wholly feldspar, orthoclase, albite, labradorite, and other varieties of feldspar, and those wholly nephelite; rocks almost wholly enstatite, hypersthene, olivine, magnetite. From what is known of the variable mineral composition of igneous rocks it is clear that with more analyses to introduce into the diagrams the variations in the shapes of the figures would be increased. Enough are shown to demonstrate the gradual character of the variations in chemical composition, and the transitions from rocks of one composition to those of another.

RELATIVE ABUNDANCE OF DIFFERENT KINDS OF ROCKS.

The distribution of the individual diagrams in the multiple one, and of the spots in the small composite diagram of Pl. I, shows that those varieties of rocks having extreme compositions, occurring in the margin of the multiple diagram, are less abundant than those having more nearly an average composition. This is still more evident when all those analyses are taken into account which were omitted because of lack of space for them. They will be found to belong to the central portion of the multiple diagram.

This is shown on Pl. VIII in a composite diagram exhibiting the variation in silica and alkali-silica ratio of 2,000 igneous rocks, which has been prepared by combining data found in this paper with those contained in the collection of analyses published by Washington,[a] to whom the author is indebted for an opportunity to study the collection in proof sheets. There are more than twice as many rocks involved in this diagram as in that on Pl. I, but the results are similar, and if the spots were replaced by individual diagrams the effect would be to doubly confirm all the conclusions drawn from a study of Pl. I. The construction of such a multiple diagram, however, is not feasible at this time.

The average rock, as calculated by Clarke[b] from 680 analyses of American rocks, is shown by diagram at 59.77–0.088, and that calculated by Harker[c]

[a] Op. cit. [b] Bull. U. S. Geol. Survey, No. 148, p. 12. [c] Geol. Mag., 1899, p. 220.

from 397 British rocks is shown by diagram at 58.7–0.083. These diagrams resemble those of rocks having like silica and alkali-silica ratios, and occur in the densest part of the assemblage. Other averages made from greater numbers of analyses yield almost identical results. A later average, made by Clarke[a] from 830 complete analyses of American rocks combined with 180 additional determinations of silica, 90 of lime, and 130 of alkalies, produce an average magma with 59.71 per cent of silica, and other constituents very nearly the same as those expressed in the diagram. Washington[b] obtained a closely similar average magma from 1,811 analyses of igneous rocks from all parts of the world, having 58.24 per cent of silica. The loci of the averages of American and of British rocks are marked by crosses on the diagram on Pl. VIII.

These prove that the average of a large number of known rocks is like the commonest rocks; conversely, that the commonest rocks are like the average of all known rocks; from which it is possible to derive all kinds of igneous rocks by processes of separation, splitting up (*spaltung*), differentiation. It does not follow from this that they have been produced from one common average magma, or even that they have been produced in this manner in actual fact; but such an origin is shown to be quantitatively possible and reasonable.

ABSENCE OF CLUSTERING.

A study of the diagrams of Pl. I and Pl. VIII fails to detect any clustering or grouping of analyses in definite parts of the multiple diagram, such as might serve as the basis for a chemical classification of rocks. This is the same as stating that there do not appear any "natural" recognizable subdivisions of rocks on a basis of their chemical composition. Variations in seven prominent chemical factors exist throughout the system of igneous rocks, the mathematical expression of which would be extremely intricate. The study of the chemical composition of igneous rocks by graphical methods does not reveal any simple method of grouping or classifying them on a basis of their chemical constituents alone.

SIMILARITY OF ROCKS FROM DIFFERENT PETROGRAPHICAL PROVINCES.

Further study of the diagrams and of the list of analyses shows the chemical similarity of many rocks that belong to different petrographical provinces. One illustration of this is taken from the best-known province, that of Christiania, made classic by the publications of Brögger. The diverse rocks of this region that are genetically related may be found in various places in the list and in the multiple diagrams. A comparison of the individual diagrams with those of

[a] Clarke, F. W., Bull. U. S. Geol. Survey No. 168, 1900, p. 14.

[b] Washington, H. S., Chemical analyses of igneous rocks from 1884 to 1900: Prof. Paper U. S. Geol. Survey No. 14, 1903, p. 107.

similar shape from other petrographical provinces will demonstrate the truth of Brögger's statement that "the same group of differentiated rocks can be produced by separation from mother magmas of quite different chemical composition."[a] A list of the chief cases of similarity is given briefly, as follows:

Table showing similarity between Norway rocks and those of other regions.

Place in classified list.	Norway rock.	Similar rocks of other regions.
I. 3, 1, 3	77.20–0.080	77.05–0.080, Butte, Mont.
		77.03– .080, Pikes Peak district, Colo.
	76.73– .077	77.33– .079, Alaska, and others.
I. 4, 1, 3	76.05– .092	76.20– .091, New Mexico.
		75.71– .094, Yellowstone Park, and others.
	71.49– .109	71.67– .101, Castle Mountain district, Mont.
		72.06– .107, Stony Creek, Conn.
		70.23– .113, Essex County, Mass.
I. 4, 2, 3	75.74– .086	76.00– .087, California.
		75.01– .086, Alaska.
		74.95– .088, Nevada.
	70.54– .107	71.88– .095, Iron Mountain, Mo.
		70.92– .096, Yellowstone Park.
		68.36– .105, Essex County, Mass.
I. 5, 1, 3	66.13– .130	66.03– .132, Custer County, Colo.
	64.04– .160	65.43– .140, Mount Ascutney, Vt.
I. 5, 1, 4	64.92– .146	65.51– .143, New Mexico.
	64.54– .157	63.71– .159, Essex County, Mass.
		63.09– .164, Essex County, Mass.
		62.17– .156, Crazy Mountains, Mont.
		61.05– .147, Ischia, Italy.
I. 5, 2, 4	59.38– .125	63.49– .138, Custer County, Colo.
		61.43– .133, Pantellaria.
		58.94– .109, Silver Cliff, Colo.
		58.28– .112, Crazy Mountains, Mont.
		57.48– .118, Pikes Peak district, Colo.
I. 6, 1, 4	58.61– .194	59.20– .189, Madagascar.
		58.70– .190, Crazy Mountains, Mont.
		58.64– .195, Cripple Creek, Colo.
		58.62– .191, Madagascar.
		58.20– .190, Madagascar.
II. 5, 2, 3	58.00– .142	59.78– .140, Custer County, Colo.
II. 5, 2, 4	59.56– .125	58.42– .099, Luzon, Philippine Islands.
	56.79– .118	57.97– .116, Mount Ascutney, Vt.
		57.01– .124, Silver Cliff, Colo.

[a] Brögger, W. C., Quart. Jour. Geol. Soc. London, vol. 50, 1894, p. 36.

Table showing similarity between Norway rocks and those of other regions—Continued.

Place in classified list.	Norway rock.	Similar rocks of other regions.
II. 5, 3, 4	52.91–0.119	52.97–0.107, Pikes Peak district, Colo.
		53.10– .134, Madagascar.
	48.06– .084	49.24– .092, Ferdinandea.
		48.90– .090, Vosges.
		50.56– .079, Plumas County, Cal.
III. 5, 3, 4	47.90– .094	48.22– .084, Mount Ascutney, Vt.
		47.16– .077, New York.
III. 6, 3, 4	43.65– .071	42.03– .053, Arkansas.
IV. 2, 1, 1, 3, 2	45.05– .030	46.56– .043, Ural Mountains.
		46.56– .050, Ural Mountains.

From this list it appears that among the various rocks, ranging from persalic to dofemic, that occur in the Christiania region there are those whose chemical composition is very similar to particular rocks found in the Ural Mountains, Vosges Mountains, Ischia, Pantellaria, Ferdinandea, Madagascar, Luzon, Vermont, New York, Massachusetts, Connecticut, Missouri, Arkansas, Colorado, New Mexico, Nevada, Yellowstone National Park, Montana, California, and Alaska. These regions belong to diverse petrographical provinces, some of them very similar to that of Christiania, but others distinctly different.

There are provinces in Finland, in Canada, and in parts of the United States closely resembling the Christiania province in the characters of their nephelite-bearing rocks, but the regions are not identical in petrography. It is possible to find all degrees of similarity between petrographical provinces in various parts of the world, and the most intricate web of similar differentiation products may be woven by their comparison.

From the chemical character of igneous magmas, their content of like elements, the chemical character of the rock-making minerals, the fixed composition of some of them, and the serial variation in the composition of others, the theory of differentiation leads us to expect diversity in the rocks of all petrographical provinces of such a kind that identical or closely similar varieties of rocks will occur in otherwise unlike provinces.

CLASSIFICATION OF IGNEOUS ROCKS.

From the foregoing considerations it is evident that if we attempted to classify igneous rocks on a basis of their groupings in petrographical provinces—that is, if we should unite in the first instance rocks that are said to be genetically related—we should separate in the system rocks of world-wide occurrence that are alike.

It must not be forgotten that igneous rocks are not like biological organisms, and that we are constantly misleading ourselves by the use of biological terms, such as generation, consanguinity, and family, into imagining that the relationships of various rocks should be treated like the relationships of organisms.

When we have had more experience in the synthesis and the differentiation of molten rock magmas in chemico-physical laboratories; have handled them like other solutions of salts, which have been studied at lower temperatures; have solidified them under diverse physical conditions, we shall no doubt free ourselves from the fascination of biology and look upon rocks as the chemist looks upon a solidified mass of mixed salts. Is it not possible, in the period of preparation of such properly equipped laboratories, to anticipate their psychological effects and to think of the study of igneous rocks, their magmas and relationships, as purely physico-chemical problems, involving the measurement and comparison of mass and force, and their definite quantitative expression?

It being evident from the diagrams that there are gradual transitions in the chemical composition of igneous rocks from one extreme to another, that there are no recognizable groupings of rocks or noticeable subdivisions of the chemical series, and that chemically similar rocks occur in genetically different families, it follows that the subdivision of all igneous rocks into groups for purposes of classification must be along arbitrarily chosen lines. And the intricate character of the chemical variations, apparent in the diagrams, prevents a simple quantitative statement of any possible limits which may be selected for subdivisions of the series, however arbitrarily chosen. A careful study of the diagrams will convince one of the truth of this statement. It is a problem involving at least seven variable factors, and in its exact statement still more. It is the problem of expressing quantitatively the chemical composition of solutions of mixed salts often containing identical elements. The most artificial method of statement would be to consider the elements regardless of the possible salts in solution. A less artificial method would seem to be one which takes into account the salts which may enter the solution or may separate from it. In rock magmas the salts in solution may properly be considered to have the composition of those minerals which separate and crystallize when the magmas solidify. But it is understood that salts in solution may become split up into molecules of simpler composition, may be partially dissociated into ions, and may be combined in more than one manner in the act of separating from solution under diverse conditions.

When it is remembered that igneous rocks are solidified and for the most part crystallized mixed solutions, the expression of their chemical composition in terms of the separated salts or minerals developed in them is eminently reasonable. These principles underlie the quantitative classification of igneous rocks proposed by Cross, Pirsson, Washington, and the author.

In expressing the chemical composition of the rocks in terms of the minerals developed it is advisable to reduce the complex possibilities by selecting the simpler and commoner minerals as standards of comparison. The details of the method must be learned from the published essay,[a] to which the reader is referred if he is not already familiar with it.

CLASSIFIED DIAGRAMS.

The resulting chemical subdivision and grouping of igneous rocks by the method of quantitative classification recently proposed can be well shown graphically by the diagrams already described. The clearest exposition, however, requires a greater number of multiple diagrams than has been prepared, in order to separate all the divisions established by the classification. But the expense of publication has prevented the carrying out of such a plan, and so fewer multiple diagrams have been used, with a consequent loss of simplicity and a greater complexity than exists in the actual system of classification itself. The advantages to be derived from the exposition made, however, are sufficient to warrant its publication. It presents the salient features and results of the classification in a manner which can not be conveyed by words.

Multiple diagrams have been prepared to exhibit the grouping and variations in rocks belonging to the five classes of the quantitative system. Those of the first, second, and third classes are represented on three separate diagrams, while those of Classes IV and V are placed on one diagram because of their smaller number. The diagrams are presented in two forms—in one form spots represent the distribution of loci of analyses and their range of variation with respect to silica and alkalies; the other form is an individual diagram showing the variations with respect to the principal chemical components. (Pls. III, IV, V, VI, and VII.)

The distribution of the analyses belonging to the five classes, with respect to silica and alkalies, is shown by the spotted diagrams on Pls. III, IV, and V and by the differently colored spots in the composite diagram on Pl. I, in which the yellow spots belong to Class I, the red spots to Class II, the blue ones to Class III, and the black ones to Classes IV and V.

Since Class I is persalic, that is, is extremely rich in salic minerals—quartz and aluminous feldspathic minerals—most of these rocks occur in the diagram near the curved lines showing the positions of rocks composed wholly of quartz with albite or orthoclase, and albite with nephelite, or orthoclase with leucite. But rocks of this class include all those rich in alumina, which may form anorthite, a nonalkalic mineral. Consequently they also occur in the diagram remote from the curved lines, approaching the locus of anorthite at 43.160.–0.0.

[a] Quantitative classification of igneous rocks. Chicago, 1903. Also Jour. Geol., vol. 10, 1902.

Class II is dosalic, that is, dominantly salic. There are less feldspathic minerals and more ferromagnesian ones, and since the latter are mostly low in alkalies, rocks of this class occur in the diagram farther from the limiting alkali-feldspathic curves than those of Class I.

As Class III is still richer in ferric minerals and lower in alkalies, rocks of this class occur still more removed from the curves just mentioned. The same is true to a greater degree for rocks of Classes IV and V.

It is seen that the positions of these classes of rocks overlap one another more or less in the composite diagram on Pl. I, hence the confusion of individual diagrams in the large multiple diagram of Pl. I.

DIAGRAMS OF CLASS I.

Let us consider separately the diagrams of the different classes of rocks, beginning with Class I. The persalanes, represented by 412 individual diagrams, being characterized by preponderant salic minerals, are subdivided into nine orders, according to the proportions of quartz and feldspars and of feldspars and feldspathoids (lenads). The order highest in quartz, perquaric, is highest in silica, and that highest in lenads, perlenic, is lowest in silica. Consequently the nine orders follow one another from left to right in the multiple diagram (Pls. II and III). The limits of the orders may be shown graphically for extreme cases, and may be interpolated for intermediate ones. Owing to the difference in the molecular weight of sodium and potassium, the limits for orders based on quartz and soda-feldspar (albite) and on quartz and potash-feldspar (orthoclase) do not coincide. Further, the greater chemical difference between the soda-lenad, nephelite, an orthosilicate, and the potash-lenad, leucite, a metasilicate, causes a still wider divergence between the boundaries of the orders based on albite and nephelite on the one hand and on orthoclase and leucite on the other. That is to say, the limits between the nine orders of persalic rocks vary according as the alkalies in the rocks are soda or potash. This is shown by the diagram on Pl. II. The black lines nearly at right angles to the upper curve mark the limits of the nine orders for ideal rocks composed wholly of quartz, albite, anorthite, or of soda-nephelite, albite, anorthite. The red lines transverse to the upper red curve mark the limits of the nine orders for rocks composed wholly of quartz, orthoclase, anorthite, or of leucite, orthoclase, anorthite.

The division lines for soda orders start from points on the quartz-albite-nephelite curve situated where q : ab :: 7 : 1; q : ab :: 5 : 3; q : ab :: 3 : 5; q : ab :: 1 : 7; ab : ne :: 7 : 1; ab : ne :: 5 : 3; ab : ne :: 3 : 5; ab : ne :: 1 : 7, and run to points on the quartz-anorthite line and the anorthite-nephelite line were q : an :: 7 : 1; q : an :: 5 : 3; q : an :: 3 : 5; q : an :: 1 : 7; an : ne :: 7 : 1; an : ne :: 5 : 3; an : ne :: 3 : 5; an : ne :: 1 : 7. The same may be said of the division lines for potash orders, substituting the names of orthoclase and leucite for those of albite and nephelite, respectively.

The diagram on Pl. II shows that the first four orders in each case nearly coincide, the boundary lines for potash rocks lying a little to the right of those for soda rocks. That is, the limit for each quaric order of potash rocks reaches a little lower silica than that for the corresponding orders of soda rocks.

The diagram also shows that the last four orders in each case differ more and more widely as they become more lenic. The range for the potash rocks is much more restricted than for the soda rocks, and the limits of orders for the potash rocks are higher in silica than for the corresponding soda rocks. This is because the potash lenad, leucite, is a metasilicate with 55.0 per cent SiO_2, while the soda lenad, nephelite, is an orthosilicate with 42.3 per cent SiO_2.

Since most rocks contain both soda and potash, the limits for the orders will occur between the extremes illustrated on Pl. II, varying with the ratio between soda and potash in each case. This explains the confused arrangement of the lenic orders in the upper right-hand portion of the diagram of persalic rocks on Pl. III.

In this diagram the number of the order of each rock is given by the first figure under its individual diagram. The number of the rang is given by the second figure. A study of these numbers will show that in the left-hand portion of the large diagram there is general concordance among the individual diagrams with respect to orders and rangs, except near the borders between orders, and between rangs. But in the right-hand upper portion of the large diagram there is great confusion of orders. It will be noted that where diagrams of different orders occur close together that with the higher number is the more potassic, other things being equal. The confusion would disappear if diagrams were constructed to exhibit the various subrangs. The correspondence between the distribution of the persalic rocks according to orders in the multiple diagram on Pl. III and the theoretical limits of the orders as shown on Pl. II is apparent. The orders form belts transverse to the curves which are the limits to ideally pure alkalic persalic rocks, namely, those consisting wholly of quartz, alkali-feldspars, or lenads.

As the wholly alkalic rocks occur along the limiting curves just mentioned and those free from alkali occur on the bottom line of the diagram, it follows that the various rangs of persalic rocks occur at intervals between these limiting lines; the peralkalic nearest the upper curves, the percalcic nearest the bottom line.

The boundary lines between the 5 rangs of persalic rocks are shown in the diagram on Pl. II. The black lines nearly parallel to the upper curve mark the limits for those based on soda alone; the red lines for those based on potash alone. Since most rocks contain both alkalies the limit for rangs will shift according to the ratio between soda and potash in the rocks. The rangs form belts roughly parallel to the limiting curves and bottom line of the multiple diagram. The limiting lines are drawn from the point of pure quartz, where they all become zero, to points on lines marking the middle of the perfelic order, 5—that is, the lines for mixtures of albite and anorthite in the case of pure soda rocks, and that for mixtures of orthoclase and anorthite for pure potash rocks. The points on these lines occur in the first case where Na_2O:CaO::7:1; Na_2O:CaO::5:3; Na_2O:CaO::3:5; Na_2O:CaO::1:7. They occur in the second case where K_2O:CaO::7:1, etc. From these points the limiting lines pass to corresponding points on lines representing mixtures of nephelite and anorthite and of leucite and anorthite.

From Pl. II it is seen that the range of rangs is nearly concordant in the quaric orders of persalic rocks and more and more divergent in the more lenic orders according as the rocks compared are more sodic or more potassic. This explains the apparent confusions of rangs in the right-hand portion of Pl. III.

There is a close correspondence between the distribution of the persalic rocks according to rangs in the large diagram (Pl. III) and the theoretical limits of rangs shown in Pl. II. This is shown by the second figure under each individual diagram.

The diagram on Pl. II exhibits the limitations of orders and rangs of the persalic rocks containing lenads. These are seen at the right end of the diagram. The limiting lines representing combinations of nephelite and anorthite and of leucite and anorthite cut diagonally across the belts of orders and rangs. Thus in soda rocks whose limits are shown by black lines order 9 has only rang 1; order 8 contains rangs 1 and 2; order 7 embraces rangs 1, 2, and 3; order 6 has four rangs—1, 2, 3, and 4, while all five rangs occur in order 5. In potash rocks, represented by red lines, the conditions are not quite so simple, as is seen in the diagram. Each of the lenic orders has a little larger range in calcic content and includes a small amount of a more calcic rang than occurs in the purely soda rocks.

There are variations in composition in rocks not yet taken into consideration which further modify the distribution and arrangement of the individual diagrams. Most rocks contain femic components, and these are generally low in alkalies or free from them. With increasing amount of nonalkalic femic components the limits of rangs in the multiple diagram shift downward, for rangs are established on the ratio between salic alkalies and salic lime—that is, between the K_2O and Na_2O and the CaO in the standard feldspars and lenads. Consequently the more femic minerals present, the less salic, and the smaller the alkalies necessary to maintain a given ratio with diminished salic lime. Hence the boundary line between rang 1 and rang 2 occurs farther below the limiting quartz-feldspar lenad curves the greater the amount of nonalkalic femic components in rocks. This is evident on comparing rangs in Pls. III and IV.

In the majority of rocks in which there is more alumina than alkalies there is usually more lime than is sufficient to satisfy the excess of alumina, so that the ratio between salic alkalies and salic lime, which determines the rang, is dependent on the amount of alumina in the rock. From this it happens that rocks having like silica percentages and alkali-silica ratios, located near one another in the multiple diagram, may differ in rang because of differences in alumina. Other things being equal, those with higher alumina will have lower ratios between salic alkalies and salic lime; and conversely, those with lower alumina will have higher alkali-calcic ratios. And these differences may affect the rang of the rocks compared. Examples of this kind are more evident in diagrams of rocks of Class II, and are found at 56.3–0.065 and 56.7–0.066, also 56.6–0.074 and 56.9–0.074, on Pl. IV.

Where the femic components of persalic rocks are alkalic the rocks are always in peralkalic rang 1, so that the limit of rang 1 is extended downward in the multiple diagram. The individual diagrams for rocks of this kind are characterized by comparatively short Al_2O_3 lines, less than the sum of K_2O and Na_2O.

The effect of increasing amounts of femic components in persalic rocks upon the limits of orders is not so easily appreciated, the relations being less simple. If we compare two rocks with like silica and alkali percentages, which would occur near one another in the diagram (Pl. III), the more nonalkalic femic components the less salic; that is, the less alumina and the less anorthite. If the rocks are quaric the ratio between quartz and feldspar is increased by decreasing the anorthite feldspar. But the substitution of FeO, MgO, or CaO for Al_2O_3 would require more SiO_2 to form metasilicates than that required to form anorthite, consequently the free SiO_2, quartz, would be reduced, but to a smaller amount than the feldspar is reduced, consequently the ratio between the quartz and feldspar would be higher in the rock with more nonalkalic femic components. The limits between the quaric orders would shift to the right.

If the rocks are lenic, containing nephelite, sodalite, or leucite, a reduction of anorthite feldspar would increase the ratio between lenads and feldspars. A substitution of FeO, MgO, or CaO for Al_2O_3 in amount equal to the CaO of presupposed anorthite would necessitate their conversion to metasilicates according to the method of the quantitative classification under discussion. This would require more silica than is required by anorthite, so that the amount of alkali feldspars would be reduced and the lenad-feldspar ratio further increased. In case the lime were replaced by magnesia and iron oxide and converted into orthosilicates there would be slight change in the silica available for the salic components, because of the general preponderance of magnesia in such rocks, and its lighter molecular weight and consequent greater number of molecules. Hence, in most cases an increase of femic components would increase the lenad-feldspar ratio, and the limits between lenic orders of persalic rocks would shift toward the left.

In the less frequent cases in which alkali femic components occur, the limits between all orders shift to right or left according to the relative proportions of the alkali-femic components and according as they are acmite or are free from ferric iron.

The occurrence of magnetite, ilmenite and other mitic components also modifies the position of the ordinal limits, but in peralkalic rocks these constituents generally occur in such small amounts that their effects may be disregarded in the interpretation of the diagram under consideration.

With respect to subrangs it may be said that in the great majority of cases they can be recognized by a comparison of the yellow and green triangles representing the relative amounts of soda and potash in the rock. For in most instances all of the alkali is salic. In other cases where part of it is femic, the ratio between the salic alkalies can be made out by a scrutiny of the triangles and a comparison of the amounts of alkalies and alumina expressed by the lengths of the potash, soda, and alumina lines. The ratio in this case would be

$$\frac{K_2O}{Al_2O_3-K_2O}.$$

In general, where alumina is in excess of the sum of the alkalies, a comparison of the triangles named, or of the lengths of the potash and soda lines, will determine the subrang to which the rock belongs. Those in which $\frac{K_2O}{Na_2O}>\frac{7}{1}$ are in perpotassic subrang 1; those with $\frac{K_2O}{Na_2O}<\frac{7}{1}>\frac{5}{3}$ are dopotassic subrang 2; when $\frac{K_2O}{Na_2O}<\frac{5}{3}>\frac{3}{5}$ the subrang is 3, sodipotassic; when $\frac{K_2O}{Na_2O}<\frac{3}{5}>\frac{1}{7}$ it is dosodic, subrang 4; and with $\frac{K_2O}{Na_2O}<\frac{1}{7}$ the subrang is 5, persodic.

These divisions apply only to the first three rangs. In the fourth rang, which is docalcic, there are only three subrangs, namely: 1, $\frac{K_2O}{Na_2O}>\frac{5}{3}$, prepotassic; 2, $\frac{K_2O}{Na_2O}<\frac{5}{3}>\frac{3}{5}$, sodipotassic; 3, $\frac{K_2O}{Na_2O}<\frac{3}{5}$, presodic. The fifth rang being precalcic, subrangs are not recognized.

A study of the diagrams on Pl. III shows that soda preponderates over potash in most persalic rocks; that sodipotassic rocks, subrang 3, are the most numerous; that dopotassic rocks are rare, and perpotassic ones extremely so. The numbers of rocks in the 5 rangs are 3, 31, 201, 156, 21.

Variations in the femic components, FeO, MgO, and femic CaO, are noticeable in the individual diagrams and represent differences among the subordinate mineral constituents of the rocks. Their quantity is so small that they may be neglected in the magmatic classification of these persalic rocks.

The diagrams plotted together demonstrate the gradual transition between orders of rocks of Class I, as well as between rangs and subrangs. And since any individual diagram may represent a large body of igneous rock or a small facies of one, and since any of the diagrams may represent rock bodies of considerable importance, it follows that all parts of the series may be of equal importance geologically or petrologically, and consequently rocks that happen to belong on the border line of any set of subdivisions into which the whole rock series must be divided, for purposes of classification of any kind, may be as important as those situated at the center of such an arbitrary division, and in some regions it will happen that such rocks are the most important.

When the student has become convinced of the continuity of the chemical series of igneous rocks he will not be surprised to discover that a rock of great importance belongs on the boundary of a classificatory division, or probably falls on both sides of a division line. It will not affect the importance of the rock or militate against the value of the system of classification. It will simply be a "natural" fact. And the system of classification will appear to him as "natural" as any other system which attempts to classify igneous rocks.

DIAGRAMS OF CLASS II.

The multiple diagram of 335 dosalic rocks of Class II (Pl. IV) may be readily interpreted by comparison with that of Class I (Pl. III). The spotted diagram to the left shows the distribution of the analyses with respect to silica and alkalies. The rocks are for the most part lower in alkalies than those of Class I, because the femic components are generally nonalkalic. The few cases with rather high alkalies contain acmite molecules, which fact is indicated in the individual diagrams by pronounced iron oxide and soda and by low alumina. Several of these occur in the left-hand part of the multiple diagram at 74.35–0.092, 69.02–0.121, etc.

The dominant constituents in dosalic rocks being the same as those in the persalic rocks, nine orders have been established, in the same manner as in Class I. Rangs and subrangs also correspond to those in Class I. So there is the same general arrangement of individual diagrams in Pl. IV, according to orders and rangs, as in the multiple diagram of Class I, with the modifications produced by increasing amounts of femic components, for the most part nonalkalic. The belts of orders are transverse to the limiting quartz-alkali-feldspar lenad curves. The limits of rangs are lower than in the diagram of Class I. There is the same confusion of orders and rangs along the division lines consequent upon variations in alumina and femic components, and a like diversity of alkalies, shown by the yellow and green triangles, with a strong preponderance of soda over potash. The greatest number of rocks are dosodic. The numbers in each rang are: 0, 17, 126, 183, 9.

With an increase in the femic components the variations in iron oxide, magnesia, and lime become more noticeable and important, and it is necessary to recognize distinctions among the subordinate femic components, that is, to note grads and subgrads. The nature of the grads can not be determined directly from the diagrams because it depends on the amount of available silica, which may be combined with femic bases to form silicates, pyroxene, olivine, or akermanite, and also on the amount of ferric oxide and titanium oxide. The ferric oxide is blended with ferrous oxide in the diagrams and is not indicated graphically. Titanium oxide is so small in most dosalic rocks that it is not introduced into the diagrams in this Class II.

It is to be noted, however, that the silica is sufficiently high to form silicates of almost all the femic bases, and ferric oxide is in most cases low, so that the great majority of dosalic rocks belong to the prepolic grad 1, that in which the femic silicates—pyroxene and olivine—preponderate over the femic nonsilicates—magnetite, hematite, ilmenite, rutile, and the silico-titanate, titanite.

As to the subgrad to which these rocks belong, by far the largest number contain nonalkalic femic components, and therefore fall in the premirlic subrang 1. A small number contain alkalic femic components in nearly the same proportions as nonalkalic ones, and fall in the alkalimirlic subrang 2. Some, characterized by highly alkalic femic constituents, such as acmite, belong to subrang 3.

The multiple diagram for Class II (Pl. IV) exhibits similar transitions between orders and between rangs as those shown by the diagram for Class I, and permits the same conclusions to be drawn from it. The chemical series will appear more and more complete as more varieties of rocks are analyzed.

DIAGRAMS OF CLASS III.

The chemical relations of the salfemic rocks, Class III, are expressed graphically on Pl. VI. Two of them are so high in silica that they have been plotted on Pl. IV with rocks of Class II. One is rockallose, with 73.60 SiO_2, 0.091 $\frac{\text{alk.}}{SiO_2}$. It is intermediate between Classes III and II. The other is a pantellerite, with 68.75 SiO_2, 0.144 $\frac{\text{alk.}}{SiO_2}$. It is also intermediate between Classes III and II.

The distribution of the rocks with respect to silica and alkalies is shown in the upper diagram of Pl. V. The location of the analyses in the multiple diagram is still farther from the limiting curves than in Class II; and the silica ranges lower. The alkali-silica ratios reach high values in some cases. TiO_2 is present in notable amount in a number of instances.

It will be observed that the lower half of the individual diagrams is the larger in nearly every case, but the long, narrow, upper triangles indicate that there is more alumina than alkalies, and that part of the lime is salic, so that the salic components are more nearly equal to the femic than appears at first glance.

There are but two rocks in quarfelic order 3, those mentioned above, and plotted on Pl. IV. Very few occur in order 4. The greatest number are perfelic, order 5, and the lenic orders are well represented.

Most of the perfelic rocks are alkalicalcic, rang 3, or docalcic, rang 4. The few that are peralkalic or domalkalic are low in alumina, as, for example, 54.2–0.160 and 45.2–0.085. It is noticeable also in the lenic salfemanes, orders 6, 7, 8, and 9, that the domalkalic character of the salic minerals in a number of rocks is due to low alumina rather than to high alkalies, as 50.00–0.110, 46.00–0.121, and 42.7–0.139.

There are great variations in the shapes of the diagrams of rocks nearly alike in silica and alkali-silica ratio. A few rocks are rich in potash, notably those from Leucite Hills, Wyoming, 54.08–0.163, and others. A greater number are rich in soda, occurring in the upper part of the multiple diagram. But the majority are sodipotassic and dosodic.

Since in these rocks the femic minerals are equal or nearly equal to the salic, and in some cases are more abundant, they are as characteristic of the rocks as the salic minerals. The salfemanes differ considerably with respect to these constituents, which is plainly shown by differences in the shapes of the lower part of the individual diagrams. Some are long in the direction of lime; others long in magnesia. Few have more iron oxide than magnesia. From this it follows that the grad, subgrad, and section of subgrad are as important in the classification of these rocks as are order, rang, and subrang.

The grad of these rocks can not be determined from the diagrams because it depends upon the proportions of ferromagnesian silicates and nonsilicates determined by the available silica and the ferric iron not allotted to acmite. It is to be remarked that the great majority of salfemic rocks included in the diagrams are dopolic, grad 2—that is, normative pyroxene and olivine dominate over magnetite, hematite, and ilmenite. In most of these rocks there is a notable amount of normative nonsilicates. The majority of these rocks are perpyric or dopyric, sections 1 and 2—that is to say, normative pyroxene preponderates over olivine.

The character of the subgrad is indicated by the diagrams, since this depends upon the proportion of alkalies that enter the femic minerals. With few exceptions the alumina is greater than the sum of the alkalies, so that the femic minerals are nonalkalic and the rocks belong to the permirlic subgrad 1. The exceptions to this are the two rocks rich in acmite—rockallose and the rock near varingose.

The diagrams also show that most of these salfemanes are domiric, section 2, ferrous oxide and magnesia dominating over femic lime. This, however, is not perfectly evident in the diagrams because of the lack of information concerning ferric iron and the necessity of deducting salic lime from the total lime.

Finally, when it is remembered that nearly half the molecules of iron oxide belong to ferric oxide, the diagrams show that in most cases the rocks are domagnesic, subsection 2, with magnesia dominant over ferrous iron. In a few instances they are permagnesic, which is indicated by long, narrow, blue triangles.

DIAGRAMS OF CLASSES IV AND V.

The diagrams of dofemic and perfemic rocks, Classes IV and V, are plotted together on Pl. VII. This has been done because of the comparatively small number of analyses of these rocks at hand and the desire to economize space. The distribution of these rocks with respect to silica and the alkalies is shown in the lower diagram on Pl. V. As should be expected, these rocks are far from the quartz-alkali-feldspathic curve, are low in alkalies, and extend to the lowest limit of silica. The diagram of one rock comparatively high in alkalies falls outside the area of Pl. VII, and is not represented. The rock is a nephelite-basalt from Katzenbuckel, Odenwald (45.04–0.209). Individual diagrams belonging to rocks of Classes IV and V are designated by Roman numerals, IV and V, before Arabic ones denoting orders and sections of orders.

The arrangement of the individual diagrams in the multiple one is in accord with the general system adopted with special reference to the great majority of rocks, the more salic ones. The rocks of Classes IV and V are less than one-tenth of all that are represented in the diagrams. Their arrangement is related to one component of prime importance, silica. But alkalies are extremely subordinate and would not properly be chosen as a basis for their coordination were these rocks considered by themselves. However, their relations to the more salic rocks are exhibited by retaining the same system of arrangement.

The chief difference between the rocks of Classes IV and V lies in the amount of alumina, with which in general there is sufficient lime or alkalies to form salic feldspars or lenads. In one case only is the composition of the magma such as to require the assumption of salic corundum, the rock being magnetite-spinelite from Routivare, Sweden (4.08–0.092). Most all of the rocks containing alkalies belong to Class IV, but this class also embraces rocks without alkalies, the diagrams occurring on the zero line for alkali-silica ratios. Nearly all the rocks of Class V are so low in alkalies as to occur on the zero line. The higher ratios obtaining in several iron ores with 4 to 8 per cent of silica may easily be due to errors in chemical analysis, though, of course, they may be correct values.

Since dofemic and perfemic rocks are divided into orders according to the relative proportions of femic silicates and nonsilicates, and into sections of orders according to the proportions of femic metasilicates and orthosilicates, it follows that the five orders and sections range according to the silica content of the rock from perpolic order 1, perpyric section 1, with highest silica, 55.5, to permitic order 5, with lowest silica, 0.7. In like manner the various sections under each order range from higher to lower silica. These distinctions do not appear in the shapes of the diagrams, but in their lateral position in the multiple diagram.

With respect to rangs it happens that without exception all the rocks represented in this collection of analyses belong to permirlic rang 1, the alkalies which occur in the rocks being salic, which is shown in the diagrams by the alumina line exceeding the sum of those of the alkalies.

Sections of rangs and subrangs are based on the proportions of femic lime, magnesia, and ferrous oxide, but the proportions of ferrous and ferric oxide are not indicated in the diagrams. It is to be noted, however, that iron is generally subordinate to magnesia in most perfemic rocks with more than 28 per cent of silica, so far as they are represented in the collection of analyses; and when it is remembered that a part of this iron is ferric, it will be seen that the proportion of ferrous iron is smaller than appears in the diagrams.

While the lime is considerable in a large number of cases, it is very small in many of the rocks, and when salic lime is deducted it is found that the femic lime is subordinate to the magnesia and ferrous iron in nearly every instance. A majority of the dofemic rocks, Class IV, are domiric, section 2 of rang 1. A smaller number are permiric, section 1 of rang 1. In nearly every case these rocks are domagnesic, subrang 2. The iron ores of Class IV are perferrous, subrang 5.

The perfemanes, Class V, with the exception of the iron ores, are permiric and domiric in about equal numbers. Lime is subordinate to magnesia and iron. They belong to sections 1 and 2 of rang 1. In nearly every case these rocks are permagnesic, subrang 1. This is shown by the elongation of the magnesia line. The iron ores of course are perferrous, subrang 5. The abrupt change from the titaniferous iron ores, below 27 per cent silica, to the magnesium-rich rocks above this percentage of silica is very noticeable. It indicates that the intermediate transitional rocks which have been described by petrographers have not been analyzed.

The diagrams of the different classes of igneous rocks established by the quantitative system illustrate the chemical characters of the rocks grouped together by this system, and show the degrees of similarity and the ranges of variation within the different divisions of the classification so far as they exist in the rocks represented by the 977 analyses in the collection.

A greater number of multiple diagrams representing separate divisions of the system will give more definite graphic expression to these minor groups of rocks. Their preparation and publication at this time have not been feasible. It is possible, also, to devise individual diagrams which shall express more or less definitely the norm of each rock, but these would of necessity be so intricate that a larger scale of drawing would be required, entailing serious difficulties of publication.

It is believed that the simpler individual diagrams and more composite multiple ones here presented will serve a better purpose at this time in demonstrating graphically some of the chemical facts and relationships that have been used by Cross, Pirsson, Washington, and the author as the foundation on which they have constructed the quantitative system of rock classification.

CORRELATION OF IGNEOUS ROCKS CLASSIFIED BY THE QUANTITATIVE AND QUALITATIVE SYSTEMS.

The classified list of rocks already given shows the character of the correlation that may be made of the two systems of classification. The variety of names that appear within any one of the more common divisions of the quantitative systems is due in part to differences in chemical composition, which are recognized by subdivisions of the system of a lower order, as grad and subgrad. It is in part due to diversity of texture and mineral development, which is expressed in this system by terms qualifying the magma names. But it is also due to a great extent to essential differences in the bases of classification in the two systems and to the flexibility of qualitative definitions.

A brief tabulated statement of the salient features of the correlation is given, with some general remarks concerning the more common relationships. Greater detail must be gotten from the classified list and from the collection of rock analyses published by Washington.

14474—No. 18—03— -6

CLASS I. PERSALANE.

1. Victorare.	2. Belgare.	3. Columbare.	4. Britannare.	5. Canadare.	6. Russare.	7. Tasmanare.	8. Ontarare.	9. ——.
Quartz-veins.	Quartz-pegmatite.	Granite.		Syenite, anorthosite.	Nephelite-syenite.			Nephelite-pegmatite.
	R. 1. Dargase.	**R. 1. Alaskase.**	**R. 1. Liparase.**	**R. 1. Nordmarkase.**	**R. 1. Miaskase.**	**R. 1. Laugenase.**	**R. 1. ——.**	**R. 1. ——.**
	Quartz-pegmatite.	Aplite. Granite. Alaskite. Tordrillite. Quartz-porphyry. Quartz-kerato-phyre. Rhyolite. Obsidian.	Aplite. Granite. Quartz-syenite. Syenite-porphyry. Grorudite. Quartz-pantellerite. Rhyolite. Paisanite. Comendite. Quartz-kerato-phyre. Obsidian.	Syenite. Quartz-syenite. Neph.-syenite. Nordmarkite. Pulaskite. Umptekite. Albitite. Sölvsbergite. Keratophyre. Bostonite. Trachyte. Phonolite.	Neph.-aplite. Neph.-syenite. Foyaite. Ditroite. Miascite. Mariupolite. Tinguaite. Heronite. Phonolite. Leucite-phonolite.	Foyaite.	Neph.-syenite.	Neph.-pegmatite.
		R. 2. Alsbachase.	**R. 2. Toscanase.**	**R. 2. Pulaskase.**	**R. 2. Viezzenase.**			
		Aplite. Granite. Alsbachite. Rhyolite.	Aplite. Granite. Quartz-monzonite. Granodiorite. Diorite. Syenite. Quartz-syenite-porphyry. Rhyolite. Toscanite. Latite. Dellenite. Dacite. Trachyte. Andesite.	Quartz-syenite. Neph.-syenite. Pulaskite. Nordmarkite. Laurvikite. Sodalite-syenite. Diorite. Bostonite. Rhomben porphyry. Vulsinite. Keratophyre. Trachyte. Leucite-trachyte. Andesite.	Neph.-syenite. Neph.-rhomben porphyry. Neph.-tinguaite. Tinguaite.			

CLASS I. PERSALANE—Continued.

1. Victorare.	2. Belgare.	3. Columbare.	4. Britannare.	5. Canadare.	6. Russare.	7. Tasmanare.	8. Ontarare.	9. ——.
Quartz-veins.	Quartz-pegmatite.	Granite.		Syenite, anorthosite.	Nephelite-syenite.			Nephelite-pegmatite.
		R. 3. Riesenase. Granite. Quartz-diorite-porphyry. Toscanite. Vulcanite.	**R. 3. Coloradase.** Granite. Granodiorite. Quartz-diorite. Banatite. Diorite. Dacite. Andesite. Trachyte.	**R. 3. ——.** Syenite. Diabase-porphyrite. Andesite. **R. 4. Labradorase.** Anorthosite. **R. 5. Canadase.** Anorthosite.				

CLASS II. DOSALANE.

1. ——.	2. ——.	3. Hispanare.	4. Austrare.	5. Germanare.	6. Norgare.	7. Italare.	8. Campanare.	9. Lappare.
		Granite and quartz-diorite.		Syenite, diorite, gabbro.	Nephelite, syenite, and essexite.		Leucite-basanite.	Urtite.
		R. 1. Varingase. Grorudite. Pantellerite. Felsite.	**R. 1. Pantellerase.** Grorudite. Pantellerite.	**R. 1. Umptekase.** Syenite. Nordmarkite. Umptekite. Hedrumite. Neph.-syenite. Heumite. Trachyte. Sodalite-trachyte. Leucite-trachyte.	**R. 1. Laurdalase.** Neph.-syenite. Leucite-neph.-syenite. Pseudoleucite-syenite. Laurdalite. Syenite. Hedrumite. Tinguaite. Leucite-tinguaite.	**R. 1. Lujavrase.** Lujavrite. Chibinite. Allochetite. Neph.-porphyry. Tinguaite. Leucite-tinguaite.	**R. 1. ——.** Soda sussexite. Tinguaite. Leucitite.	**R. 1. Urtase.** Urtite. Ijolite. Arkite.
			R. 2. Dacase. Granite. Quartz-diorite. Syenite. Dacite. Andesite. Trachyte-andesite.	**R. 2. Monzonase.** Syenite. Pulaskite. Monzonite. Durbachite. Neph.-syenite. Ditroite. Essexite. Granite. Diorite. Kersantite. Minette. Ciminite. Akerite. Shoshonite. Banakite. Trachyte. Leucite-trachyte. Leucite-phonolite. Andesite. Basalt.	**R. 2. Essexase.** Neph.-syenite. Neph.-monzonite. Laurdalite. Essexite. Monzonite. Shonkinite. Covite. Borolanite. Heumite. Monchiquite. Theralite. Kulaite. Leucite-kulaite. Tephrite. Neph.-felsite.	**R. 2. Vulturase.** Leucite-tephrite. Basanite. Leucitite. Haüynophyre.	**R. 2. Vesuvase.** Leucite-basanite.	

CLASS II. DOSALANE—Continued.

1. ——.	2. ——.	3. Hispanare.	4. Austrare.	5. Germanare.	6. Norgare.	7. Italare.	8. Campanare.	9. Lappare.
		Granite and quartz-diorite.		Syenite, diorite, gabbro.	Nephelite, syenite, and essexite.		Leucite-basanite.	Urtite.
			R. 3. Tonalase.	**R. 3. Andase.**	**R. 3. Salemase.**	**R. 3. ——.**		
			Granite.	Syenite.	Diorite.	Leucite-tephrite.		
			Quartz-monzonite.	Monzonite.	Gabbro.			
			Granodiorite.	Diorite.	Essexite.			
			Quartz-diorite.	Gabbro.	Basalt.			
			Tonalite.	Norite.				
			Quartz-norite.	Essexite.				
			Syenite.	Beerbachite.				
			Diorite.	Mondhaldeite.				
			Dacite.	Kersantite.				
			Latite.	Andesite.				
			Andesite.	Latite.				
			Trachyte.	Vulsinite.				
			Dolerite.	Ciminite.				
				Shoshonite				
				Banakite.				
				Quartz-basalt.				
				Basalt.				
				Dolerite.				
				Olivine-diabase.				
				Leucite-monchiquite.				
				Neph.-tephrite.				
		R. 4. ——.	**R. 4. Bandase.**	**R. 4. Hessase.**	**R. 4. ——.**			
		Quartz-diorite.	Tonalite.	Diorite.	Diorite.			
			Diorite.	Monzonite.	Gabbro.			
			Andesite.	Anorthosite.				
			Quartz-basalt.	Gabbro.				
				Corsite.				
				Andesite.				
				Basalt.				
			R. 5. ——.	**R. 5. Corsase.**				
			Diorite.	Diorite.				
				Olivine-gabbro.				

CLASS III. SALFEMANE.

1. ——.	2. ——.	3. Atlantare.	4. Vaalare.	5. Gallare.	6. Portugare.	7. Kamerunare.	8. Bohemare.	9. Finnare.
			Diorite and gabbro.		Lamprophyres and leucite-nephelite lavas.			
		R. 1. Rockallase. Rockallite. Pantellerite.		**R. 1. Orendase.** Orendite. Wyomingite.	**R. 1. Wyomingase.** Shonkinite. Camptonite. Nephelinite. Analcite-basalt.	**R. 1. Malignase.** Malignite. Theralite. Ijolite-porphyry.	**R. 1. Chotase.** Leucitite.	**R. 1. Ijolase.** Madupite. Ijolite. Nephelite-porphyry. Neph.-basalt.
				R. 2. Kilauase. Shonkinite. Syenite-lamprophyre. Mica-picrophyre. Absarokite. Basalt. Augitite.	**R. 2. Monchiquase.** Shonkinite. Leucite-syenite. Monchiquite. Vogesite. Tephrite. Leucite-basanite. Leucite-basalt. Nephelite-basalt. Limburgite.	**R. 2. Kamerunase.** Heumite. Theralite. Monchiquite. Farrisite. Leucite-basalt. Leucite-nephelinite. Haüynophyre. Basalt.	**R. 2. Albanase.** Ijolite. Nephelinite. Leucitite. Theralite. Leucite-tephrite. Limburgite.	
			R. 3. Vaalase. Quartz-gabbro. Olivine-diabase. Basalt.	**R. 3. Camptonase.** Kentallenite. Olivine-monzonite. Diorite. Gabbro. Essexite. Camptonite. Absarokite. Leucite-basanite. Neph.-basalt. Quartz-basalt.	**R. 3. Limburgase.** Neph.-gabbro. Ijolite. Camptonite. Monchiquite. Hornblende-basalt. Neph.-basanite. Limburgite. Augitite. Hornblendite.	**R. 3. Etindase.** Camptonite. Neph.-basalt.		

CLASS III. SALFEMANE—Continued.

1. ——.	2. ——.	3. Atlantare.	4. Vaalare.	5. Gallare.	6. Portugare.	7. Kamerunare.	8. Bohemare.	9. Finnare.
			Diorite and gabbro.		Lamprophyres and leucite-nephelite lavas.			
			R. 4. ——. Diorite. Melaphyre.	**R. 4. Auvergnase.** Gabbro. Norite. Dolerite. Ariegite. Fourchite. Monchiquite. Basalt.	**R. 4. ——.** Gabbro.			
			R. 5. ——. Olivine-gabbro-diabase.	**R. 5. Kedabekase.** Gabbro. Norite. Kedabekite. Ariegite.				

CLASS IV. DOFEMANE.

1. Hungarare.	2. Scotare.	3. Sverigare.	4. Adirondackare.	5. ——.
Gabbro and peridotite.			Iron ores.	
S. 1. Minnesotiare. Gabbro. Wehrlite. Pyroxenite.	**S. 1. ——.** Augite-norite. Pyroxenite. Neph.-basalt.	**S. 1. Bergeniare.** Ilmenite-norite.		
S. 2. ——. Gabbro. Missourite. Wehrlite. Peridotite.	**S. 2. Paoliare.** Gabbro. Koswite. Jacupirangite. Augite-peridotite. Hornblende-basalt. Neph.-basalt.	**S. 2. ——.** (?) Pyroxenite. Avezacite. Neph. melilite-basalt.	**S. 2. Adirondackore.** Iron ore.	**S. 2. ——.** Iron ore.
S. 3. Hungariare. Wehrlite. Peridotite. Hornblende-picrite. Hornblendite. Lherzolite.	**S. 3. Texiare.** Peridotite. Neph.-basalt. Neph. melilite-basalt.		**S. 3. Champlainore.** Iron ore.	
S. 4. ——. Peridotite. Lherzolite.	**S. 4. ——.** Limburgite. Neph.-melilite-basalt.			
S. 5. Pyreniare. Hornblende-peridotite. Hornblende-lherzolite. Venanzite.	**S. 5. ——.** Mica-peridotite.			

CLASS V. PERFEMANE.

1. Maorare.	2. ——.	3. ——.	4. ——.	5. ——.
Peridotite and pyroxenite.		Iron ores.		
S. 1. Caroliniare. Websterite. Pyroxenite. Lherzolite.				
S. 2. Marylandiare. Pyroxenite. Koswite.	**S. 2. ——.** Lherzolite.		**S. 2. ——.** Iron ore.	**S. 2. ——.** Iron ore.
S. 3. ——. Koswite.				**S. 3. ——** Iron ore.
S. 4. ——. Saxonite.		**S. 4. ——.** Iron ore.		
S. 5. Maoriare. Dunite. Harzburgite.	**S. 5. ——.** Dunite sidéronitique.			

Approaching the subject from the standpoint of the qualitative, mineralogical system we are interested in the distribution of rocks in the quantitative system in the first instance according to their content of quartz, feldspar, feldspathoid, or ferromagnesian minerals. We may consider the distribution of, first, rocks containing a notable amount of quartz and their equivalent lava forms; second, rocks characterized by feldspar without notable amounts of quartz or feldspathoids; third, rocks containing notable amounts of feldspathoids; fourth, rocks composed chiefly of ferromagnesian minerals.

In general, it may be said that the quartzose igneous rocks fall almost without exception in Classes I, II, and III, and those in Class III are comparatively rare, so that most quartzose rocks belong to Classes I and II, and those with notable amount of quartz $\left(\frac{Q}{F} > \frac{1}{7}\right)$ are in orders 4 and 3, very few occurring in orders 2 and 1, and these only in Class I.

Nearly all rocks known as granite, granodiorite, quartz-monzonite, quartz-diorite, and the rare quartz-gabbros, together with their aphanitic and glassy equivalents, belong to order 4, Classes I and II, in most part, and to some extent to order 3 in Class I, very few being found in this order of Class II. The most quartzose rocks belong to Class I.

Of the minerals associated with quartz the most abundant and frequent are feldspars, usually preponderant, and these are distinguished in the qualitative system as alkalic, alkalicalcic, and calcic. Since it is generally true that as magmas are richer in magnesium and iron they also contain more calcium, it follows that rocks richer in ferromagnesian minerals usually carry more calcic feldspars than rocks poor in those minerals. Consequently the greater number of quartzose rocks with alkalic feldspars occur in Class I, and the greater number with calcic feldspars are in Class II; and those with the most calcic feldspar should occur in Class III. To this, of course, there are notable exceptions, especially where the femic mineral is not ferromagnesian but alkalic, as acmite, in rockallose.

Most granites are found in Class I, and most of these are in order 4, with dominant feldspars; fewer in order 3. Most of these persalanes are peralkalic and domalkalic, rangs 1 and 2. But in order 4 a considerable number are alkalicalcic, rang 3. The more alkalic rocks are commonly sodipotassic, while the alkalicalcic ones are mostly dosodic; that is, with increase of lime there is a diminution of potash.

These quartz-bearing persalanes include rocks that have been named aplite, granite, granitite, granodiorite, quartz-monzonite, quartz-diorite, the phanerocrystalline porphyries of these, and quartz-porphyry, rhyolite, dacite, and andesite, together with those of special varieties—alaskite, alsbachite, tordrillite, comendite, paisanite, toscanite, and others. Some rocks that fall within the limits of these divisions of the quantitative system bear names occurring mostly in other divisions, such as syenite, nordmarkite, diorite, andesite. These are in part intermediate rocks deserving double magma names; in part, those, like some andesites, whose mineral composition is not completely determinable, and in which the quartz content is obscure or uncrystallized.

A much smaller number of granites belong to Class II, dosalanes. The most alkalic members of this class, pantellerite and grorudite, are comparatively rich in ferric oxide.

Most of the quaric rocks of Class II are alkalicalcic and dosodic. The greater number of them bear the names quartz-diorite, diorite, and andesite.

The quaric rocks i· Class III are low in quartz, except in the rare varieties of pantellerite and rockallite. But in the other rocks, also rare, quartz occurs in small amount with alkalicalcic feldspars and calcic feldspars. One of these rocks is quartz-gabbro, another a diorite, and several others olivine-bearing rocks, whose chemical analyses are such that they fall in order 4 of this class.

Rocks characterized by feldspars without notable amounts of quartz or feldspathoids occur in perfelic order 5 of Classes I, II, and III.

Among the perfelic persalanes, Class I, the more alkalic rocks are commonest (syenites), alkalicalcic ones are rare, while docalcic ones are well known (anorthosites). As to the character of the alkalies, soda preponderates in most cases, dosodic rocks being more abundant than sodipotassic ones, which, however, are common.

The names borne by these rocks are: Syenite, nordmarkite, pulaskite, laurvikite, bostonite, trachyte vulsinite, andesite, keratophyre, and others. The most sodic rocks have been called albitite; the most calcic, anorthosite. Some of them have been called nephelite-syenite, phonolite, leucite-trachyte, and other names.

The perfelic dosalanes, Class II, are more common than the extremely feldspathic persalanes, and the alkalicalcic ones are more numerous than the domalkalic or docalcic forms, but these are also well represented. Most of these rocks are dosodic, although many are sodipotassic.

They appear under the names of syenite, umptekite, monzonite, diorite, gabbro, norite, trachyte, ciminite, akerite, shoshonite, andesite, basalt, and others. They also include some rocks called granite, nephelite-syenite, leucite-trachyte, and kersantite.

The perfelic salfemanes, Class III, are alkalicalcic and docalcic, and most of them are dosodic. They embrace gabbro, norite, ariegite, kedabekite, camptonite, dolerite, and basalt. The more potassic and sodipotassic rocks of this class and order have been called kentallenite, absarokite, and lamprophyre. A few peralkalic rocks belonging here occur at Leucite Hills, Wyoming—orendite, wyomingite.

The rocks characterized by notable amounts of feldspathoids or lenads—leucite, nephelite, sodalite—with the exception of a few that belong in Class IV, fall within the lenic orders 6, 7, 8, 9 of Classes I, II, and III.

Lenic persalanes, Class I, are most abundant in order 6, with dominant feldspar, but they are known in each of the more lenic orders. They are mostly peralkalic and dosodic, some being sodipotassic. They have been named nephelite-syenite, foyaite, ditroite, miascite, phonolite, and tinguaite. Very few contain leucite.

The same is true for the lenic dosalanes, Class II. Most of them occur in lendofelic order 6, but the other lenic orders are represented.

In order 6 they are mostly peralkalic and domalkalic, and the majority are dosodic. They include nephelite-syenite, laurdalite, essexite, tinguaite, theralite, and others, besides some rocks called syenite, monzonite, diorite, and gabbro.

Rocks of the remaining orders are peralkalic and dominantly sodic. A few rocks in order 7 are sodipotassic.

Order 7 contains rocks called lujavrite, tinguaite, tephrite, leucitite, hauynophyre, and others.

Rocks of orders 8 and 9 are rare. The first embrace leucite-basanite, leucitite, and tinguaite. The ninth order is represented by urtite, an ijolite rich in nephelite, and sodipotassic arkite.

Lenic salfemanes, Class III, are about as numerous as lenic rocks in Classes I and II. They are more uniformly distributed through orders 6, 7, and 8. Perlenic rocks, order 9, are rare.

In order 6 there are more alkalicalcic rocks than in the corresponding order of Class II. Most of the rocks are sodipotassic and dosodic. The rocks have been called shonkinite, leucite-syenite, leucite-monchiquite, monchiquite, limburgite, basanite, and others.

In order 7 the rocks are dominantly alkalic and dosodic. They embrace malignite, theralite, nephelite-basalt, nephelinite, and others.

Order 8 is similar to order 7. The rocks are rarer and a few are dopotassic. They are theralite, ijolite, nephelinite, leucitite, and others.

The rocks of order 9 are peralkalic, and include dopotassic madupite of Leucite Hills, Wyoming; and dosodic ijolite, nephelite-porphyry, and nephelite-basalt.

Rocks with preponderant femic constituents, the dofemanes, Class IV, and perfemanes, Class V, are distinguished from one another by the presence in the former of a notable but subordinate amount of salic, feldspathic minerals and by their absence from the perfemanes. The dofemanes, then, contain either notable subordinate amounts of feldspar, leucite, nephelite, sodalite, or of aluminous ferromagnesian, alferric minerals.

In Class IV the five orders, based on the proportions of normative pyroxene and olivine, compared with magnetite, ilmenite, and other nonsilicates, are all represented. Orders 1 and 2 are most common. In each of these the more pyroxenic sections are better represented than the more olivinic. The rocks invariably belong to the permirlic rang, 1; that is to say, the femic minerals contain little or no alkali. In most cases ferrous oxide and magnesia preponderate over lime, and in the majority of rocks magnesia dominates over ferrous oxide.

In perpolic order 1 the rocks are known in the qualitative system as gabbro, olivine-gabbro, norite, koswite, peridotite, pyroxenite, jacupirangite, nephelite-basalt, nephelite-melilite-basalt, and limburgite.

In polmitic order 3, with nearly equal silicate and nonsilicate minerals, the few rocks as yet described have been called ilmenite-norite, pyroxenite, avezacite, and nephelite-melilite-basalt.

Orders 4 and 5, with preponderant magnetite and ilmenite, embrace certain feldspathic iron ores from Sweden, Canada, and New York State.

Rocks of Class V are comparatively rare; they have little or no feldspathic minerals or aluminous ferromagnesian minerals. Most rocks belong to perpolic order 1, and range from wholly pyroxenic to wholly olivinic kinds. A very few rocks fall within each of the other orders.

In order 1 the rocks have been called pyroxenite, websterite, koswite, peridotite, saxonite, harzburgite, and dunite.

In order 2, with notable, subordinate, nonsilicate minerals, occur a lherzolite, and dunite rich in iron ore.

In the other orders, 3, 4, and 5, the rocks are titaniferous iron ores, with variable amounts of ferromagnesian silicates. In one instance the rock consists of magnetite and spinel

INDEX.

A.

B.

PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

[Professional Paper No. 18.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of the United States—folios and separate sheets thereof, (8) Geologic Atlas of the United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

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Correspondence should be addressed to—

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

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