A TABULATION OF THE ALUMINIUM SILICATE MINERALS.

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The usual form of triangular diagram employed in plotting mineral analyses has certain inconvenient features, such as the difficulty of purchasing printed triangular coördinate paper with suitable spacings, the necessity of recalculating the analytical data or of laying off lines representing partial amounts across the corners of the triangle, etc. A modification which the writer has found useful in the study of minerals with three essential components is here described.

On two axes of ordinary rectangular coördinate paper lay off percentages from zero to 100, and draw a diagonal line connecting the two 100 points. From the common zero point draw a perpendicular to the diagonal line, and on this medial axis lay off percentages starting with the zero of the others as 100, and ending with zero at the intersection with the diagonal line. Then, when two of the components of the mineral series to be plotted are laid off with reference to the rectangular axes, the third component becomes entered automatically on the medial one.

In the case of the aluminium silicate minerals, the diagram is most conveniently placed so that the medial axis lies horizontal, with the portion corresponding to more than 50 per cent on that axis left blank for the insertion of mineral names. This plan has been followed in figure 1, alumina, together with other sesquioxides and with any dioxides present, being plotted along the upper axis, silica plus titania along the lower one, and the remainder, comprising water and alkalies, taking up its place on the medial axis. Variation in silica-alumina ratio then leads to shifting the position of a given mineral up and down; while variation in water content moves it right and left along lines diverging at small angles from the medial axis.

In order to decide which ratios are probably fundamental, a harmonic series of numbers, such as have been used with marked success in crystallography and other fields of science by Professor Victor Goldschmidt, was applied; there being about seven important ratios concerned, the series N_3 was the one selected. By considering the ratio of silicon to aluminium atoms (instead of oxides) the well-known halloysite-kaolinite group could be brought into medial position. For completeness, the end-minerals have been included, in parentheses.

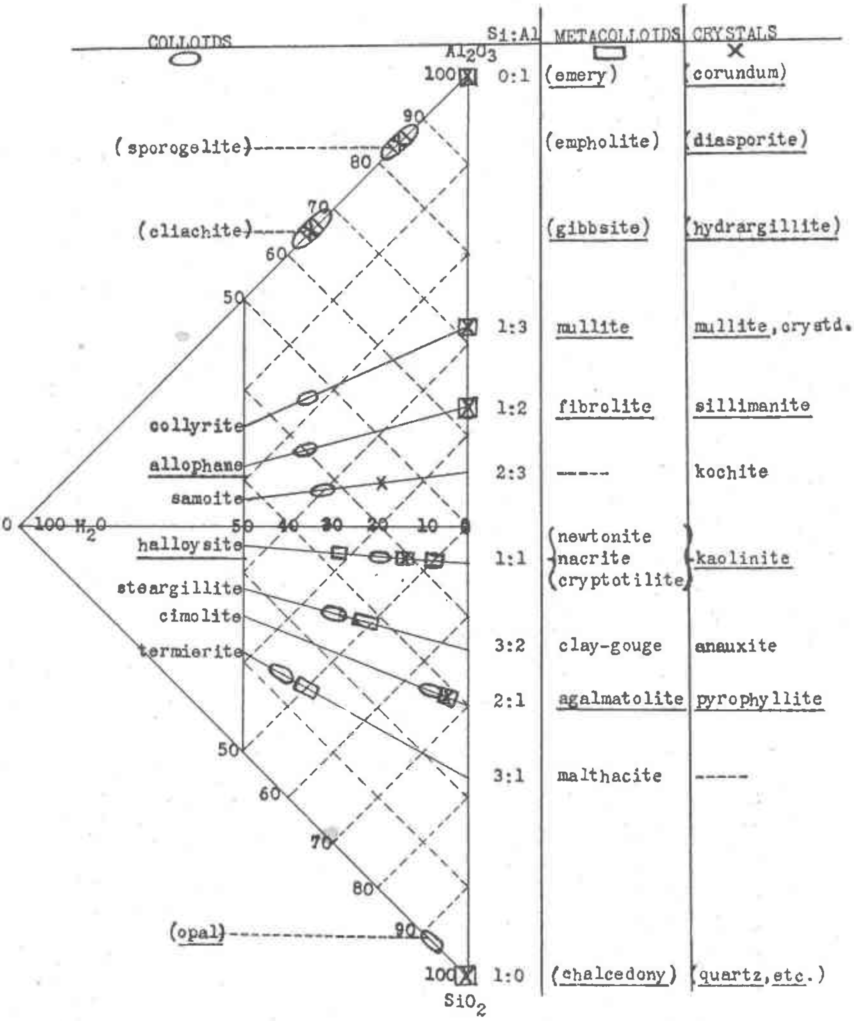

FIG. 1

Many of the recorded analyses of clay minerals fall fairly near the lines corresponding to the members of this harmonic series. Most of them not having been made on optically homogeneous materials, however, the status of some of the individual species can not be regarded as settled. Accordingly, while an effort has been made to include a colloidal, a meta-colloidal, and a crystallized representative of each ratio (indicated in the figure by an ellipse, a rectangle and a cross respectively) it is quite possible that further work will lead to re-interpretation of some of the names. This preliminary tabulation is, then, to be regarded as only an indication of what is to be looked for in future work.

The minerals to be recognized have been selected as critically as possible with the data available; those regarded as well established are underlined in the figure. Two of Dana's species, bauxite and schroetterite, are considered to be mixtures, and montmorillonite is omitted, since the recent studies of Ross and Shannon have shown that it contains a relatively large and definite amount of essential magnesia. On the other hand, several of Dana's varieties and relatives of species are tentatively raised to species rank. No new mineral names are here proposed, as there are already far too many extant in this series. Undoubtedly as the materials bearing these various names are re-examined by modern methods, representatives of practically all ratios and all particle sizes here recognized will be discovered among them; if after all known occurrences of aluminium silicate minerals have been studied, gaps remain, then will be the time to introduce new names.

Brief comments on the names here made use of seem called for; they are presented in tabular form, in the order of the ratios of silicon to aluminium atoms:

0:1 Two colloidal minerals have been recognized by Cornu and others at the alumina end of the series, sporogelite corresponding to diasporite and cliachite to hydrargillite; their separate existence needs confirmation by optical and X-ray examination, however. The anhydrous metacolloid is commonly known as emery, and the corresponding crystallized mineral as corundum. Diasporite has been found in metacolloidal form in Missouri, and the Swedish empholite may be similar; the crystallized form of this mineral is well known. The alleged dimorphous form "kayserite" needs confirmation. There has long been a dispute as to the nomenclature of the more hydrous minerals, simply settled here by recognizing as distinct species the metacolloidal gibbsite and the crystallized hydrargillite.

1:3 Collyrite may well be the colloidal representative of this ratio, the more complex formula often given being based on poor analyses of poorer material, and so unworthy of acceptance. This name has priority over schroetterite, which does not appear essentially different. One of the triumphs of modern methods of mineralogical research has been the recognition of the mineral mullite, an anhydrous member of this group. X-ray study shows it to have essentially the same crystal structure as sillimanite, which is possible, on the atomic-volume theory, if the simplest formula of mullite is tripled and that of sillimanite multiplied by eight, making them respectively $Al_{16}Al_2Si_6O_{39}$ and $Al_{16}Si_2Si_6O_{40}$; as the atoms of aluminium and silicon are similar in dimensions, and oxygen atoms are comparatively small, these two compounds should be capable of taking on closely similar space-arrangements.

1:2 Allophane or allophanite is well known to be the colloidal member. Again a minor dispute as to nomenclature may be settled by recognizing the metacolloid fibrolite and the crystallized sillimanite.

2:3 Dana does not accord to samoite species rank, but it deserves this as much as some other "species," and while awaiting optical study may be placed in the colloidal column opposite this ratio, which it approaches as closely as the dubious character of the material would lead one to expect. The apparently cubic crystallized kochite, while assigned a more complex formula, does not deviate far from the line of this ratio.

1:1 Halloysite is definitely known to be the collodial member of this group, modern analyses on optically examined isotropic material having been made. There appear to be several metacolloidal representatives, ranging from the high-water newtonite thru less hydrous nacrite to the low-water cryptotilite. The last name is given by Dana in the original German form kryptotil, but the Greek *kruptos* is commonly transliterated into English as the syllable *crypt*, and the mineralogical termination *ite* is systematically added to roots ending in *l*, hence the form of the name here adopted. Many china clays, soil colloids, etc., approximate to this aluminium-silicon ratio, and to the water content of cryptotilite. The so-called rectorite appears to be a one-dimensional colloid form of the same mineral, while leverrierite as originally described seems to be a similar material in which the metacolloidal flakes have aggregated themselves into vermicular crystals. The term kaolin has been applied to such varied members and relatives of this group that it is best considered a rock name; kaolinite is the crystallized representative.

3:2 Descriptions of steargillite suggest that it may be the colloidal member of this group, although it needs optical examination. Clay-gouge, as it is called by the miners, such as was described by Larsen and the writer under the heading "leverrierite from Colorado," is apparently more correctly assigned to this group, in which it occupies the place of the metacolloidal member, being actually a one-dimensional colloid. Anauxite has recently been shown to be well crystallized and to fall near this ratio, the single analysis being insufficient proof of greater complexity.

2:1 The colloidal member of this group is apparently cimolite, for although more complex formulas have been assigned to it, optical study has shown the frequent presence of admixed quartz in material like that analyzed. A low-water metacolloidal representative is the well-known agalmatolite, which grades into the crystallized pyrophyllite. Dana's formula for montmorillonite would bring it also into this group, but as already noted it is now known to be a magnesium-bearing mineral, and so is not properly included here.

3:1 Termierite has been described as the colloidal mineral of this ratio, but perhaps needs further study, as it shows some double refraction. The description of malthacite suggests that it may be a meta-colloidal representative, but it requires reinvestigation. No crystallized member has been recognized.

1:0 The minerals opal, chalcedony and quartz, with the other crystalline forms of silica, complete the series.

In conclusion, it may be hoped that this method of tabulation will aid other workers in recognizing what ratios are most probably represented by analyses of aluminium silicate minerals, and that the publication of this note will lead to further work on correlating the chemical and optical properties of members of this mineral series.

A NEW THEORY OF THE COMPOSITION OF THE ZEOLITES. PART III

(*Continued from page 117*)

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3. THE COMPOSITION OF CHABAZITE AND RELATED ZEOLITES

The composition of chabazite is usually given as $(Ca,Na_2)Al_2Si_4O_{12}.6H_2O$, which means that two atoms of sodium may replace one atom of calcium in the crystal space lattice. Since such a change, although apparently possible in artificial alterations of zeolites, and especially of the artificial zeolite known as permutite, is contrary to the condition in all anhydrous silicates, it seems worth while to test the matter somewhat carefully, particularly since it has been found that a different explanation can be applied to thomsonite.[1]

After a careful study of all available analyses, including the ninety-nine listed by Doelter[2] and a few others,[3] it seemed necessary to reduce the number in order to concentrate attention on the best or "superior" analyses. In chabazite and in many other zeolites the ratio of Al_2O_3 to $CaO+Na_2O$ is more constant than any other ratio which can be derived from the analyses, and varies very little from 1:1. By rejecting all the old analyses, and all those not made on selected crystal material and also five analyses in which this ratio was not satisfactory, the thirteen "best" analyses were selected.

The results of plotting these analyses on a square, on which the variables are the Al_2O_3-SiO_2 ratio and the CaO-Na_2O ratio, as described in the discussion of natrolite, are shown in Fig. 3. The distribution of these points seems to the writer to indicate the existence of an isomorphous series along the line ABC which is curved through those points which represent mix-crystals having the same number of Ca+Na atoms, and of Al+Si atoms for a

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[1] A. N. Winchell: *Am. Min.*, **X**, (1925).

[2] Hdb. Mineralchemie, **II**, 3, 1921, pp. 73-128.

[3] G. T. Prior: *Mineral. Mag.*, **XVII**, 1916, p. 274; and G. Stoklossa: *N. Jahrb. Min., Beil. Bd.* **XLII**, 1919, p. 39.