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A new review of the chlorites.

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THE chlorites form an extensive isostructural series with a high degree of isomorphous substitution, within which it has always been difficult to define or delimit species; until recently, owing to the lack of adequate X-ray studies, several structurally distinct species were included with the group, further complicating the problem. The group comprises aluminosilicates of magnesium and iron (ferrous and ferric); a few contain appreciable amounts of chromium, nickel, or manganese, and one (pennantite) contains manganese as a major constituent.

The first step towards the understanding of the relations of the chlorites was taken by G. Tschermak (1890, 1891), who divided them into two groups: the orthochlorites, with compositions between $(Mg,Fe'')_2Al_2SiO_5(OH)_4$ and $(Mg,Fe'')_3Si_2O_5(OH)_4$, and the leptochlorites, with compositions not explicable on this basis, and in general richer in trivalent ions (often including considerable Fe''') relative to silicon and divalent ions. The two orthochlorite end-members have the composition of amesite and serpentine respectively, but it is now known[1] that neither of these two minerals has the chlorite structure.

The other important clue to the relations of the chlorites is the observation of A. N. Winchell (1926, 1936), confirmed by G. L. Dschang (1931) and others, that most of the leptochlorites contain considerable amounts of ferric iron, and that if their analyses are recomputed with this iron in the ferrous state they fall in line with the orthochlorites, which for their

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[1] J. Orcel et al. (1950) claim that amesite is a true chlorite, but this requires confirmation. If it proves to be a valid chlorite, the following classification is not affected—a small field must be cut off for amesite.

part contain little or no ferric iron. It has been shown by Dschang and others that iron-rich orthochlorites can be oxidized by careful heating in air without change of crystal structure, and then approach in physical properties a leptochlorite of similar composition, rich in ferric iron. Winchell concludes that the chlorites are probably all strictly ferrous minerals as originally formed, but are liable to an oxidation of the type $Fe''OH \rightarrow Fe'''O$. It is possible that the few leptochlorite analyses in the literature that do not reduce to orthochlorites on recalculation of the iron to the ferrous state may all be either inaccurate analyses or analyses of mixtures or of minerals not having the chlorite structure, and that there are only two groups of chlorites, normal orthochlorites and oxidized chlorites.

A. N. Winchell (1936) proposed to classify the chlorites in terms of four end-members, antigorite $Mg_3Si_2O_5(OH)_4$ and ferroantigorite $Fe''_3Si_2O_5(OH)_4$, amesite $Mg_2Al_2SiO_5(OH)_4$, and daphnite $Fe''_2Al_2SiO_5(OH)_4$, calculating all iron as ferrous and assigning arbitrary boundaries to the several species. Unfortunately, he assigned most of his species names quite arbitrarily, without regard to the sense in which the name had been originally or normally applied, and fixed his boundaries at 20, 40, 60, and 80 molecules per cent., not of $(Mg,Fe'')_3Si_2O_5(OH)_4$ and $(Mg,Fe'')_2Al_2SiO_5(OH)_4$, but of $(Mg,Fe'')_6Si_4O_{10}(OH)_8$ and $(Mg,Fe'')_6Al_6Si_3O_{15}(OH)_{12}$; this nomenclature has never gained general acceptance.

J. Orcel (1926) collected and classified all available chlorite analyses and sought to define the several species on the basis of the original analyses and later analyses of material from the type localities. This is a sound method of approach, but a certain amount of adjustment of his arbitrary boundaries between species now seems desirable in the light of the crystal structure of the chlorites; when expressed in atoms of Si per half unit cell[1] Orcel's boundaries between groups of species fall at $2\frac{1}{2}$, $2\frac{4}{5}$, $3\frac{1}{7}$, and $3\frac{3}{11}$ atoms Si, and it is proposed to adjust the last two figures to 3·1 and 3·5; and similar rationalization of the Fe/(Mg+Fe) ratios is desirable. Moreover, neither here nor later (1950) did he distinguish the important group of oxidized chlorites.

The revised classification now proposed is shown graphically in fig. 1.

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[1] Most if not all of the chlorites appear to have 36(O,OH) per unit cell, but several authors have discussed the structure and chemistry of the group on a basis of 18(O,OH), or an anhydrous basis of 14 oxygen, and it is convenient to retain this unit, which exhibits the crystallo-chemical relation of the chlorites to the micas and allied layer structures very well.

A first division of the chlorites is made into the unoxidized normal series of orthochlorites and the oxidized chlorites, and it is suggested that an arbitrary figure of 4 % Fe_2O_3 be taken as the dividing line, any chlorite with more than 4 % Fe_2O_3 being regarded as oxidized. This line is in fairly close accord with past general practice. Within the unoxidized series, grochauite, leuchtenbergite, aphrosiderite, and bavalite appear hardly worthy of species rank, and it is suggested that they should be classed as varieties of sheridanite, clinochlore, ripidolite, and daphnite respectively. A plot of the published analyses calculated to an anhydrous basis of $O = 14$ shows an appreciable number of points with Si less than 2·5 and high in Fe'', a field for which there has hitherto been no generally accepted name; for this field the name pseudothuringite (Koch, 1884) seems appropriate, since the mineral originally described under this name falls in the field, which corresponds to part of the field proposed for the oxidized chlorite thuringite so that the prefix pseudo- is quite appropriate.

In the oxidized series, the three accepted species delessite, chamosite,[1] and thuringite are delimited with boundaries at Si 3·1 and 2·8, corresponding to two principal boundaries in the unoxidized series. It may be found convenient to retain the name klementite as a variety of thuringite with $Mg > (Fe''+Fe''')$; the original klementite analysis falls in this field. The boundaries now proposed for both oxidized chlorites and orthochlorites are shown in fig. 1.

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[1] Recent work by G. W. Brindley and R. F. Youell (1949, 1950, 1953) shows that the material hitherto called chamosite includes at least three and probably four distinct minerals: by far the commonest 'chamosite', including that from Frodingham, Lincolnshire (no. 72 below), is not a chlorite at all, consisting of an intergrowth in varying proportions of two structurally distinct phases, one monclinic and the other orthorhombic, both of which are based on kaolin-type layers; chamosite from the type locality and the magnesium-rich varieties from Wickwar, Gloucestershire, and Brinton's quarry, West Chester, Pennsylvania (nos. 73 and 71, below) appear to be true chlorites with d_{001} 14·2 Å. and a monoclinic unit cell, like most of the chlorites so far examined in detail; 'chamosite' from Schmiedefeld, Thuringia (no. 70, below), appears to have a closely allied orthorhombic structure based on the same type of triple layer as the other true chlorites.

These complex relations raise considerable difficulties in nomenclature, particularly as the commonest and best known 'chamosites' differ structurally from the original chamosite of Chamoson. In the present paper, the term chamosite is used for the true chlorites, excluding the unnamed kaolin-type minerals (though data for at least one of the latter have been included in deriving the regression equations cited below, this is not likely to cause any appreciable errors). But it is suggested that the best solution might well be to give new names to both the chlorite and kaolin-type structures, if not to all four structurally distinct phases, and to use the name chamosite as an inclusive term like limonite, or as an ore-name, like bauxite.

The manganese-bearing chlorites include the remarkable species pennantite, chemically a klementite with the magnesium almost wholly replaced by manganese, and two varieties with small percentages of MnO; grängesite, a manganiferous brunsvigite; and manganese-pennine.

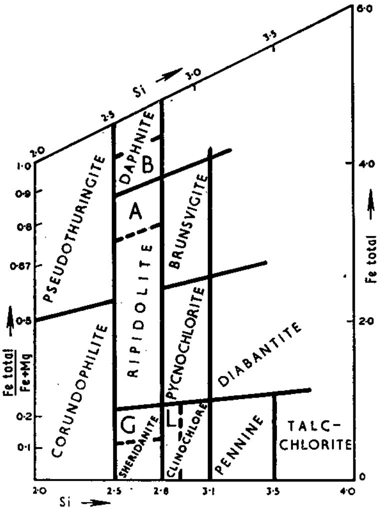

FIG. 1*a*

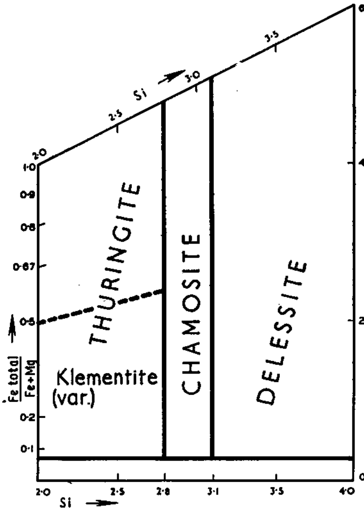

FIG. 1*b*

FIG. 1*a*. The orthochlorites, on basis of 14 oxygen (anhydrous), showing the proposed species and variety boundaries. L = Leuchtenbergite, var. of Clinochlore; G = Grochauite, var. of Sheridanite; A = Aphrosiderite, var. of Ripidolite; B = Bavalite, var. of Daphnite.

FIG. 1*b*. The oxidized chlorites ($Fe_2O_3 > 4\ \%$) on basis of 14 oxygen (anhydrous) calculating all iron as ferrous.

The chromiferous chlorites include three varieties: kämmererite, a variety of pennine; chrome-clinochlore, with less than 4 % Cr_2O_3; and kochubeïte, a variety of clinochlore with more than 4 % Cr_2O_3.

The following are doubtful species; if they are really chlorites and the analyses are trustworthy, they form a third division of true leptochlorites, in which the total cations are less than 10 per 14 oxygen (anhydrous basis): batavite, epichlorite, epiphanite,[1] moravite, parathuringite, phyllochlorite, steatargillite, and strigovite. Mackensite and viridite (of Kretschmer), according to their discoverer, grade continu-

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[1] X-ray photographs show that epiphanite is a chlorite; the one analysis would place it as a true leptochlorite, but the analysis may be inaccurate and it may prove to be a diabantite.

ously into thuringite; if they are really chlorites and the analyses are trustworthy, they are of a type otherwise unknown, viridite being an orthochlorite containing considerable ferric iron, near $Fe''_5Fe'''Si_2AlO_{10}(OH)_8$, and mackensite the corresponding oxidized chlorite, near $Fe'''_6Si_3AlO_{15}(OH)_3$.

A number of supposed species can safely be rejected on the basis of the original descriptions and analyses (if they are truly chlorites); berlauite, chloropite, euralite, and hallite (of Leeds) are delessite; metachlorite falls within the field now allotted to bavalite, which is the older name; subdelessite is a magnesian chamosite; rumpfite[1] included some sheridanites and some leuchtenbergites; pseudophite is in part clinochlore and in part pennine; loganite is a pseudomorph of pennine after amphibole; pyrosclerite a pseudomorph of pennine after pyroxene.

In 1926, A. N. Winchell attempted to show the variation of the optical properties of the chlorites with their chemical composition, and revised this plot in 1936 to include new data, but even so his plot was only based on 43 points; since then, much new data has accumulated, and 108 points are now available for the derivation of a relation between composition and refractive index, and 81 for birefringence; it therefore appeared opportune to revise the variation graphs. Temporarily rejecting 7 refractive index and 5 birefringence determinations on chromiferous chlorites, and assuming a linear correlation of the physical properties with the ferrous and ferric iron and the silica content,[2] regression equations were derived by the method of least squares, and the mean variance of the residuals was also calculated. The results gave, on the whole, gratifying agreement, especially in view of the very approximate nature of most of the birefringence data; the biggest departures from the regression equation were shown by a chamosite and two thuringites near the chamosite-thuringite boundary, and it is possible that these were not really chlorites. The equations are given below, while the departures from them are shown graphically in figs. 2 and 3; in fig. 2, the departures of the observed data from the calculated values are plotted against the number of silicon atoms per unit cell, and in fig. 3, against the total number of iron atoms per unit cell and against the number of ferric ions.

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[1] A. Hödl (1941, p. 59) gives a thorough review of rumpfite, and rejects it as a superfluous and often misapplied name.

[2] Three parameters suffice to define the composition of an orthochlorite or oxidized chlorite, and Si, total Fe (Fe^t), and Fe''', in atoms per 14 oxygen (anhydrous basis, all iron calculated as ferrous), have proved a convenient choice. If the correlation with these parameters is linear, it will be linear with any comparable choice of parameters.

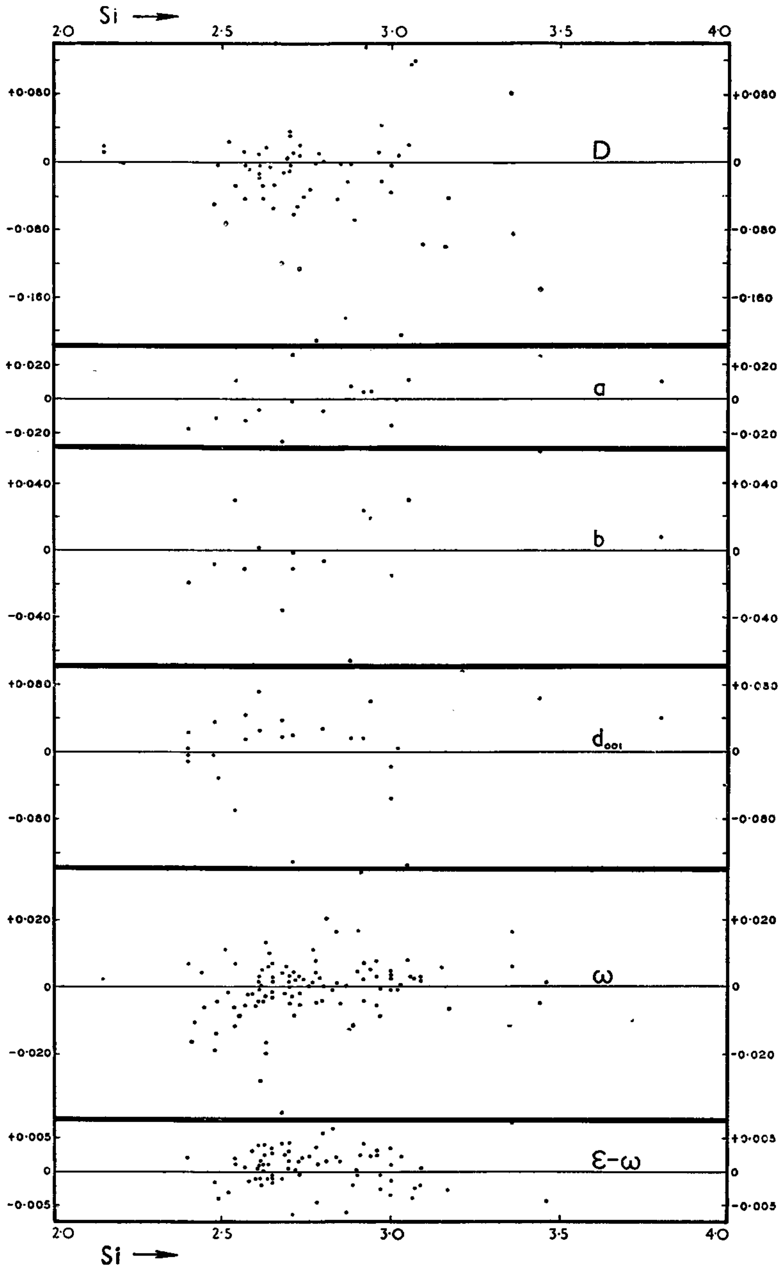

FIG. 2. Departures of observed physical data from the values calculated from the regression equations, in relation to the silica content.

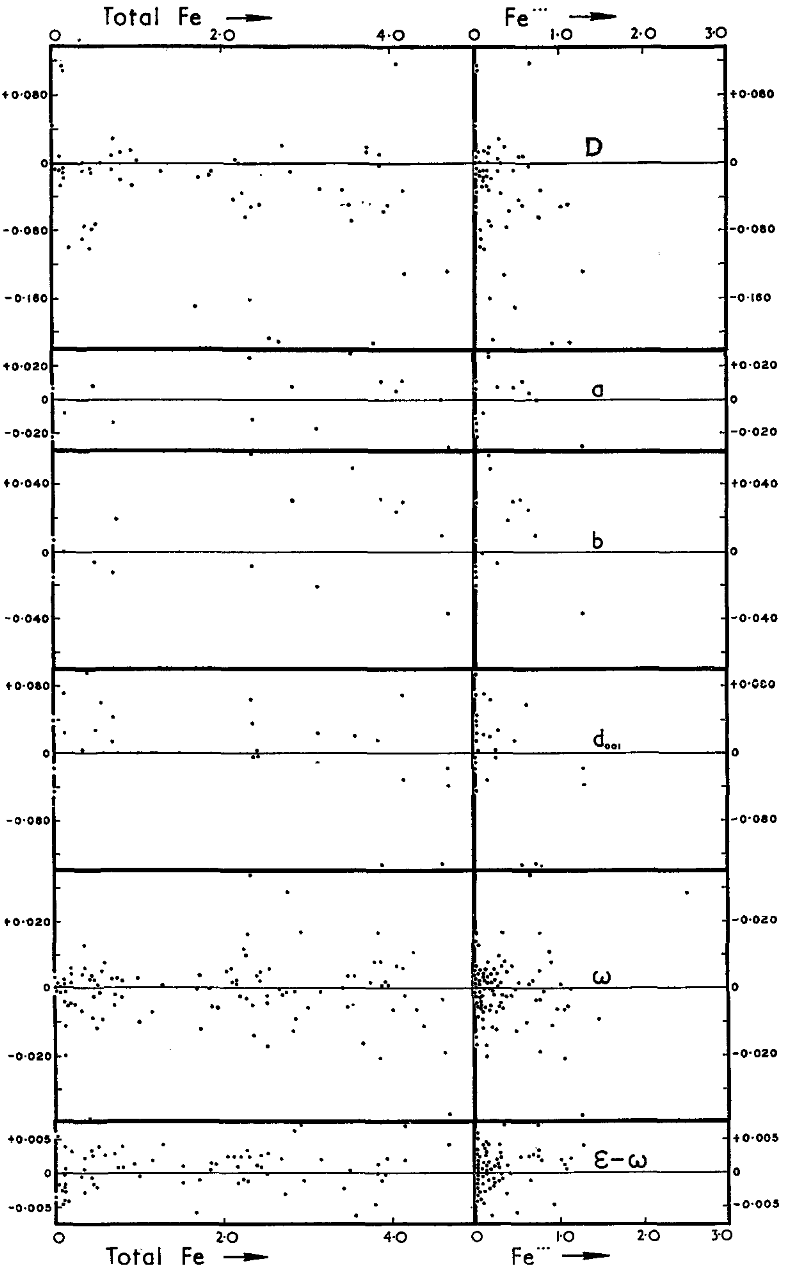

FIG. 3. Departures of observed physical data from the values calculated from the regression equations in relation to the total iron content (left), and to the ferric iron content (right).

It will readily be seen that there is nothing to suggest any notable departure from linear correlation, or any serious error in the regression coefficients calculated. The variations in birefringence and in refractive index with Si and total Fe are shown graphically in fig. 4. As compared with Winchell's diagram (1936, fig. 1), the most notable difference is in the birefringence, for which Winchell derives a non-linear correlation; there is no direct evidence for non-linear correlation, and it is usual to assume linear correlation until evidence to the contrary is obtained.

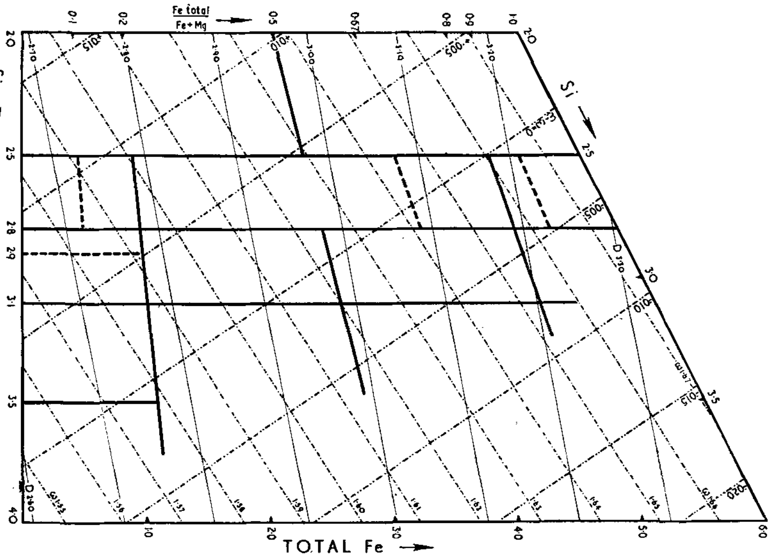

FIG. 4. Refractive index (ω), birefringence ($\epsilon-\omega$), and specific gravity (D) of orthochlorites in relation to composition. For oxidized chlorites, ω and D are higher and $\epsilon-\omega$ lower, in proportion to the percentage of Fe_2O_3. The boundaries of the orthochlorite species and varieties are shown.

Eight refractive index determinations and six birefringences are available on analysed chromiferous chlorites. The accuracy of the birefringence data is not sufficient to establish any definite effect of chromium on this property; Winchell believed he had evidence of a decrease in $\epsilon-\omega$ with increase of Cr, but the evidence for this is not adequate. There is, however, clear evidence of an increase in the refractive index with increase in Cr, at least comparable with the effect of Fe‴, and an approximate regression coefficient has been calculated.

From the available data on pennantite, Mn would appear to have much the same effect as Fe″ in the refractive index, increasing it, and an effect between those of Fe″ and Fe‴ on the birefringence, decreasing $\epsilon-\omega$. None of the other manganiferous chlorites for which optical data are available contains much manganese and for these small amounts its effect may be put equal to that of iron. The regression coefficients cited below are derived from the observations on pennantite.

W. von Engelhardt (1942), from X-ray data on three chlorites, believed he had evidence of a decrease in the cell side c and an increase in b with increase in iron content. F. A. Bannister and W. F. Whittard (1945) obtained clear evidence of an increase in c and in the related d_{001} with increase in Si. Regression equations have been calculated from all available X-ray data (twenty analyses with associated determinations of d_{001} and sixteen with determinations of a and b). From these it is quite clear that d_{001} increases with increase of Si, presumably owing to weaker inter-layer bonding, is independent of the Fe″ content, within the accuracy of measurement, but decreases slightly with increase of Fe‴, presumably owing to stronger inter-layer bonding; both a and b are independent of the Si content, but increase with increase of Fe″ or Fe‴; the effects of Fe″ and Fe‴ are equal within the accuracy of measurement, since when total Fe and Fe‴ are used as parameters, a and b appear to be independent of the latter. The expansions produced in a and b by increase in total Fe are proportional to the lengths of these axes within the accuracy of measurements. As with the optical data, the departures of the observed data from the regression equations for the cell-dimensions are plotted against Si, against total Fe, and against Fe‴ in figs. 2 and 3.

A comparison with the cell-dimensions of pennantite gives approximate values for the effect of Mn, which are included in the regression equations below; the effect proves to be an expansion in all three dimensions, and is presumably due to the greater diameter of Mn″ (Fe″ 0·72, Mg″ 0·75, Mn″ 0·91 Å.); again, the expansions produced in a and b are proportional to the lengths of these axes. There are no data at present available on the effect of Cr on the cell-dimensions of the chlorites.

From the atomic weights and the regression equations for the three cell-sides an equation for the theoretical density was calculated. This proved to give good agreement with the observed data, as may be seen from figs. 2 and 3, but it does not supply a further test of the regression equations for the cell-sides, since the differences in atomic weights supply the major element in each coefficient. As is to be expected, the observed densities tend to be rather lower than the theoretical.

The regression equations for the physical properties in terms of the composition[1] are given below, together with the mean standard deviation[2] of the observed data; the standard deviation is given both in direct measure and as a percentage of the mean value of the physical property except in the case of the birefringence.

	$\hat{\sigma}$.	$\hat{\sigma}$ %.
$d_{001} = 13{\cdot}925 + 0{\cdot}23\,(\mathrm{Si}-2) - 0{\cdot}05\,\mathrm{Fe}''' + 0{\cdot}05\,\mathrm{Mn}$	0·059	0·42
$a = 5.320 + 0{\cdot}016\,\mathrm{Fe}^t + 0{\cdot}027\,\mathrm{Mn}$		
$= 5{\cdot}320\,(1 + 0{\cdot}00304\,\mathrm{Fe}^t + 0{\cdot}0051\,\mathrm{Mn})$	0·015	0·28
$b = 9{\cdot}202 + 0{\cdot}028\,\mathrm{Fe}^t + 0{\cdot}047\,\mathrm{Mn}$		
$= 9{\cdot}202\,(1 + 0{\cdot}00304\,\mathrm{Fe}^t + 0{\cdot}0051\,\mathrm{Mn})$	0·028	0·30
$\mathrm{D} = 2{\cdot}694 - 0{\cdot}061\,(\mathrm{Si}-2) + 0{\cdot}136\,\mathrm{Fe}^t + 0{\cdot}010\,\mathrm{Fe}''' + 0{\cdot}110\,\mathrm{Mn}$	see footnote 3.	
$\omega = 1{\cdot}5954 - 0{\cdot}0263\,(\mathrm{Si}-2) + 0{\cdot}0208\,\mathrm{Fe}^t + 0{\cdot}0035\,\mathrm{Fe}''' + 0{\cdot}019\,\mathrm{Mn} + 0{\cdot}03\,\mathrm{Cr}$	0·0100	0·63
$\epsilon - \omega = 0{\cdot}0170 - 0{\cdot}0096\,(\mathrm{Si}-2) - 0{\cdot}00335\,\mathrm{Fe}^t - 0{\cdot}0048\,\mathrm{Fe}''' - 0{\cdot}006\,\mathrm{Mn}$	0·003	—

TABLE I. List of the analyses and physical determinations on which the regression equations are based. (The species names are given on the nomenclature now proposed, fig. 1; names in parentheses are the names under which the mineral was originally described.)

Pennine

1. Zillerthal, Tyrol, Austria. (Tschermak, 1891; Orcel, 1927, no. 204; Hutton, 1947.)
2. Nottingham, Chester County, Pennsylvania. (Shannon and Wherry, 1922; Orcel, 1927, no. 249; Winchell, 1936, no. 16.)
3. Valle de Secchia, Emilia, Italy. (Bertolani, 1949.)
4. Recess, County Galway, Ireland. (Hutchinson and Smith, 1912; Orcel, 1927, no. 188; Winchell, 1936, no. 17.)
5. Locality unknown. (Dschang, 1931; Winchell, 1936, no. 23.)

Diabantite

6. Farmington Hills, Hartford County, Connecticut. (Hawes, 1875; Orcel, 1927, no. 230; Bannister and Whittard, 1945.)
7. Murlough Bay, Ballycastle, County Antrim, Ireland. (Tomkeieff, 1943.)

Clinochlore

8. Bernstein, Burgenland, Austria. (Smith, 1924; Orcel, 1927, no. 179; Bannister and Whittard, 1945.)

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[1] In atoms per 14 oxygen, anhydrous basis, calculating all iron as ferrous; Fe^t is the total iron, Fe''' the ferric.

[2] The standard deviation, σ, of a series of experimental values is the square root of the mean of the squares of their departures from the true value; when the true value is not known, the estimated standard deviation, $\hat{\sigma}$, must be used, and is the square root of the mean of the squares of the departures of the experimental values from their mean, or, in the case of a regression equation, from the values given by the equation.

[3] This calculated regression equation is subject to a standard deviation of 0·016 = 0·60 % from the standard deviations of the equations for the cell-sides. The observed values are preponderantly low.

9. Philipsburg, Granite County, Montana. (Leuchtenbergite.) (Shannon, 1923; Orcel, 1927, no. 166; McMurchy, 1934; Winchell, 1936, no. 21; Gruner, 1944.)
10. Korea. (Leuchtenbergite.) (Satô, 1933; Winchell, 1936, no. 19.)
11. Korea. (Leuchtenbergite.) (Kinosaki, 1932; Winchell, 1936, no. 26.)
12. Mt. Ampanobe, Madagascar. (Lacroix, 1922; Orcel, 1927, no. 55; Winchell, 1936, no. 25.)
13. Red Mountain, Westland, New Zealand. (Hutton, 1936.)
14. Urals. (Leuchtenbergite.) (Dschang, 1931; Winchell, 1936, no. 20.)
15. Muruhatten, Jämtland, Sweden. (Du Rietz, 1935.)
16. Piedmont, Italy. (Rondolino, 1936.)
17. Dobrog Polya, Serbia, Jugoslavia. (Tajder, 1938.)
18. Besofotra, Madagascar. (Orcel, 1927, no. 170; Winchell, 1936, no. 24.)

Leuchtenbergite (var. of Clinochlore)

19. Westtown, Chester County, Pennsylvania. (Clinochlore.) (Dschang, 1931; Winchell, 1936, no. 23.)
20. Midongy, Madagascar. (Orcel, 1927, no. 47; Winchell, 1936, no. 29.)
21. Sierra de la Capelada, Galicia, Spain. (Garrido, 1949.)
22. Kings River, Fresno County, California. (Clinochlore.) (Durrell and Macdonald, 1939.)

Pycnochlorite

23. Old West mine, Penhalonga, Southern Rhodesia. (Prochlorite.) (Macgregor, 1941.)
24. Eilean Traighe, Tayvallich, Argyllshire, Scotland. (Prochlorite.) (Wiseman, 1934.)

Brunsvigite

25. Goose Creek, Loudoun County, Virginia. (Shannon, 1924.)
26. Mourne Mtns., County Down, Ireland. (Daphnite.) (Nockolds and Richey, 1939.)
27. Westfield, Hampden County, Massachusetts. (Diabantite.) (Orcel, 1927, no. 122; Winchell, 1936, no. 5.)

Sheridanite

28. Miles City, Custer County, Montana. (Shannon and Wherry, 1922; Orcel, 1927, no. 34; Winchell, 1936, no. 32; Gruner, 1944.)
29. Ambatofinandrahana, Madagascar. (Ripidolite.) (Orcel, 1927, no. 71; Winchell, 1936, no. 28.)
30. Kaintaleck, Styria, Austria. (Leuchtenbergite.) (Hödl, 1941.)
31. Oberdorf, St. Kathrein, Styria, Austria. (Leuchtenbergite.) (Hödl, 1941.)
32. Kaslinski, Urals. (Grochauite.) (Pavlovitch, 1931; Winchell, 1936, no. 30.)
33. Madison County, North Carolina. (Ripidolite.) (Orcel, 1927, no. 57; Winchell, 1936, no. 33.)
34. Brinton's quarry, West Chester, Chester County, Pennsylvania. (Corundophilite.) (Shannon and Wherry, 1922; Orcel, 1927, no. 32; Winchell, 1936, no. 37.)
35. Sheridan County, Wyoming. (Wolff, 1912; Orcel, 1927, no. 33; Winchell, 1936, no. 38.)

Grochauite (var. of Sheridanite)

36. Burra Burra, Ducktown, Polk County, Tennessee. (McMurchy, 1934; Gruner, 1944.)

37. Modena, Italy. (Ripidolite.) (Gallitelli, 1929; Winchell, 1936, no. 27.)
38. Achmatovsk, Urals. (Clinochlore.) (Dschang, 1931; Winchell, 1936, no. 35.)
39. Regné, Bihain, Luxembourg, Belgium. (Mélon, 1938.)
40. Haüselberg, Loeben, Styria, Austria. (Hödl, 1941.)
41. Rainbow Camp, Leysdorp, Transvaal. (Ripidolite.) (Orcel, 1927, no. 68; Winchell, 1936, no. 31.)
42. Antohidrano, Madagascar. (Orcel, 1927, no. 67; Winchell, 1936, no. 36.)
43. Madison County, North Carolina. (Ripidolite.) (Orcel, 1927, no. 58; Winchell, 1936, no. 31.)

Ripidolite

44. Coronet Peak, Wakatipu, Otago, New Zealand. (Hutton, 1938.)
45. Holleton, South-West Division, Western Australia. (Corundophilite.) (Simpson, 1936.)
46. Aorere, Nelson, New Zealand. (Hutton and Seelye, 1945.)
47. Isère, France. (Orcel, 1927, no. 95; Winchell, 1936, no. 6.)
48. Piz Urschaid, Silvretta, Tyrol, Austria. (Hödl, 1941.)
49. Springburn, Kawarau, Otago, New Zealand. (Hutton, 1938.)
50. Androta, Madagascar. (Orcel, 1927, no. 93; Winchell, 1936, no. 13.)
51. Masoala, Madagascar. (Orcel, 1927, no. 82; Winchell, 1936, no. 7.)
52. Laifour, Ardennes, France. (Orcel, 1927, no. 81; Winchell, 1936, no. 9.)
53. Field, British Columbia. (Aphrosiderite.) (Larsen and Steiger, 1917; Orcel, 1927, no. 98; Winchell, 1936, no. 12.)
54. Hawleyville, Fairfield County, Connecticut. (Agar and Emendorfer, 1937.)
55. Valais, Switzerland. (Dschang, 1931; Winchell, 1936, no. 8.)
56. Black Bear claim, Shoshone County, Idaho. (Shannon, 1926; Winchell, 1936, no. 10.)
57. Waterworks tunnel, Washington, District of Columbia. (Clarke and Schneider, 1891; Larsen, 1920; Shannon, 1920; Orcel, 1927, no. 78; Winchell, 1936, no. 14.)

Aphrosiderite (var. of Ripidolite)

58. Tolgus mine, Penzance, Cornwall. (Daphnite.) (Hallimond, 1939; Bannister and Whittard, 1945.)
59. Weilburg, Nassau, Germany. (Orcel, 1927, no. 123; Winchell, 1936, no. 4.)

Bavalite (var. of Daphnite)

60. Bas Vallon, Forêt de Lorges, Quintin, Côtes-de-Nord, France. (Orcel, 1927, no. 128; Winchell, 1936, no. 2; von Engelhardt, 1942.)

Daphnite

61. Penrhyn quarry, Llandegai, Carnarvonshire, Wales. (Thuringite.) (Pulfrey, 1933; Bannister and Whittard, 1945.)

Corundophilite

62. Chester, Hampden County, Massachusetts. (The mean of six analyses was used.) (Orcel, 1927, nos. 3, 4, 5, 6, 7, and 8; Gruner, 1944; Bannister and Whittard, 1945.)
63. Comberousse, Savoy, France. (Sheridanite.) (Orcel, 1927, no. 31; Winchell, 1936, no. 39.)

Pseudothuringite

64. Granitzer, Weiz, Styria, Austria. (Ripidolite.) (Hödl, 1941.)
65. Togo, Lembi County, Idaho. (Shannon, 1926.)

66. Sherman mine, Shoshone County, Idaho. (Shannon, 1926.)
67. Idval, north Urals. (Lyamina and Soboleva, 1937.)
68. Bolivia. (McMurchy, 1934; Gruner, 1944.)

Delessite

69. Challis, Custer County, Idaho. (A manganiferous variety.) (Shannon, 1926.)

Chamosite (nos. 70, 71, and 73 are true chlorites; some of the others may not be chlorites, see footnote on p. 279; no. 72 is not a chlorite).

70. Schmiedefeld, Thuringia, Germany. (Jung, 1931; von Engelhardt, 1942.)
71. Brinton's quarry, West Chester, Chester County, Pennsylvania. (Shannon and Wherry, 1922; McMurchy, 1933.)
72. Frodingham, Lincolnshire. (Hallimond, 1939; Bannister and Whittard, 1945.)
73. Wickwar, Gloucestershire. (Bannister and Whittard, 1945.)
74. Ernsthausen, Lahn, Germany. (Aphrosiderite.) (Holzner, 1938.)
75. Wołowiec, Tatra Mountains, Poland. (Kozik, 1930.)
76. Słowkowska valley, Tatra Mountains, Poland. (Kozik, 1930.)
77. Lembecq, Brabant, Belgium. (Mélon, 1938.)
78. Eppstein, Lahn, Germany. (Thuringite.) (Holzner, 1938.)

Klementite (var. of Thuringite)

79. Vals, Graubünden, Switzerland. (Ripidolite.) (Jakob and de Quervain, 1939.)
80. Vielsalm, Luxembourg, Belgium. (Mélon, 1938.)
81. Messina, Transvaal. (Thuringite.) (Orcel, 1927, no. 9; Winchell, 1936, no. 11.)
82. Val Cristallina, Val Medels, Graubünden, Switzerland. (Ripidolite.) (Jakob and de Quervain, 1939.)

Thuringite

83. Zirmsee, Rauris, Carinthia, Austria. (von Zepharovich, 1877; Orcel, 1927, no. 20; von Engelhardt, 1942.)
84. Schmiedefeld, Thuringia. (The mean of five analyses was used.) (Orcel, 1927, nos. 11, 12, 18, and 24; Jung and Kohler, 1930; von Engelhardt, 1942; Bannister and Whittard, 1945.)
85. Creede, Mineral County, Colorado. (Larsen and Steiger, 1917; Orcel, 1927, no. 28; Winchell, 1936, no. 1.)
86. Evisa, Corsica. (Orcel, 1927, no. 25; Winchell, 1936, no. 3.)
87. Weilburg, Lahn, Germany. (Aphrosiderite.) (Holzner, 1938.)
88. Kalgoorlie, Western Australia. (Simpson, 1937.)
89. Randalls, Western Australia. (Daphnite.) (Simpson, 1936.)
90. Schottgraben, Frohnleiten, Styria, Austria. (Ripidolite.) (Hödl, 1941.)
91. Nil-St.-Vincent, Brabant, Belgium. (Mélon, 1938.)
92. Fortuna mine, Lahn, Germany. (Holzner, 1938.)
93. *Allerheiligenbauen, St. Jakob, Breitenau, Styria, Austria.* (Hödl, 1941.)
94. Georg-Joseph mine, Lahn, Germany. (Aphrosiderite.) (Holzner, 1938.)
95. Klein-Litzner, Silvretta, Tyrol, Austria. (Hödl, 1941.)
96. Serpont Recogne, Luxembourg, Belgium. (Mélon, 1938.)
97. Rötzgraben, Trofaiach, Styria, Austria. (Hödl, 1941.)
98. Goldzeche, Rauris, Carinthia, Austria. (Hödl, 1941.)
99. Mt. Satirst, North-West Division, Western Australia. (Simpson, 1937.)
100. Zirmsee, Rauris, Carinthia, Austria. (A manganiferous variety.) (Hödl, 1941.)
101. Artificial, produced by heating no. 55 in air. (Dschang, 1931; Winchell, 1936, no. 8a.)

Manganese-pennine (var. of Pennine)

102. Långban, Sweden. (von Eckermann, 1927.)
103. Långban, Sweden. (von Eckermann, 1927.)

Pennantite

104. Benallt mine, Carnarvonshire, Wales. (Smith, Bannister, and Hey, 1946.)

Kämmererite (var. of Pennine)

105. Deer Park, Wyoming. (Shannon, 1920; Orcel, 1927, no. 285; Winchell, 1936, no. 2.)
106. Locana, Piedmont, Italy. (Sanero, 1933.)
107. Säkok Ruopsok, Jämtland, Sweden. (Du Rietz, 1935; Winchell, 1936, no. 7.)

Chrome-clinochlore (var. of Clinochlore)

108. Kaukapakapa, North Auckland, New Zealand. (Leuchtenbergite.) (Hutton and Seelye, 1947.)
109. Patevi, Togoland, West Africa. (Clinochlore.) (Orcel, 1927, no. 272; Winchell, 1936, no. 22.)
110. Newcastle, Eldorado County, California. (Kämmererite.) (Shannon, 1920; Orcel, 1927, no. 266.)
111. Mount Albert, Schickshock Mts., Quebec. (Osborne and Archambault, 1948.)

Kochubeite (var. of Clinochlore)

112. Patevi, Togoland, West Africa. (Orcel, 1927, no. 271; Winchell, 1936, no. 4.)
113. Kraubath, Styria, Austria. (Kopetzky, 1948.)

Leptochlorites (low cation totals, below 5·6 per 14 oxygen)

114. Kropfmühle, Passau, Bavaria. (Batavite.) (Weiss and Hofmann, 1951.)
115. Calton Hill, Derbyshire. (Delessite.) (Tomkeieff, 1926.)
116. Sungul, Urals. (Sokolov, 1931.)
117. Long Hill, Trumbull, Fairfield County, Connecticut. (Ripidolite.) (McMurchy, 1933; Orcel, 1927, no. 102; Gruner, 1944. For a discussion of the possible constitution of this abnormal chlorite, see Gruner, 1944.)

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