WHAT IS A MINERAL?

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During the nineteenth century minerals were considered to be natural inorganic substances of *definite chemical composition*. This was the view of practically all mineralogists[1] of all countries. During the last fifty years this view has been modified slightly so that now a mineral is said to have a composition which is expressed in a definite formula[2], but varieties are recognized which involve variations from that formula. In the opinion of the writer this view is a decided improvement over the older one, but is still not satisfactory. An attempt will be made in the following paragraphs to explain the reasons for this opinion.

A mineral should not be defined in terms of any simple formula because the formulas assigned to most minerals give the composition only *approximately* and two samples of the same mineral only very rarely have exactly the same composition. Even a single crystal of one mineral may vary considerably in composition (and properties) in crystals showing zonal growths. Indeed, two zones in a single crystal of one mineral such as plagioclase may differ in composition so much that one zone corresponds approximately with one formula while another zone in the same crystal corresponds approximately with a different formula.

It is well known that many minerals cannot be defined even approximately in terms of composition alone. Thus, at least three different minerals (adularia, sanidine, and microcline) have approximately the composition, $KAlSi_3O_8$, and at least six (α- and β-quartz, α- and β-tridymite, and α- and β-cristobalite) have more or less exactly the composition SiO_2.

According to common usage at the present time, many minerals, such as labradorite, chrysolite, hypersthene, clinochlore, actinolite, and aegyrinaugite are merely arbitrarily defined portions of some series or system of continuous variation in composition.

The name of a mineral should be the name of a natural unit and not the name of something which has arbitrary and artificial boundaries. It is quite true that these arbitrary and artificial boundaries are useful, and names defined by such limits are desirable at least in some cases; but such names should be recognized as the names of varieties and not as the names of mineral species.

[1] The only exception known to the writer is G. Tschermak who held that plagioclase illustrated continuous variation in composition from $NaAlSi_3O_8$ to $CaAl_2Si_2O_8$.

[2] See, for example, *Dana's System of Mineralogy*, 7th Ed. Vol. 1 (1944).

The writer would define a mineral species as a crystalline phase[3] found in inorganic nature.

In certain rare cases the phase is not crystalline, as illustrated by (amorphous) opal and (liquid) mercury and water. Rogers[4] has suggested that amorphous types should be called "mineraloids"; if this idea is adopted it still leaves the liquid types as minerals which are not crystalline. But such examples are so rare that they may reasonably be regarded as exceptions which do not make it necessary to change the definition.

It is well known that a crystalline phase may vary in composition; in some cases the amount of variation which is possible is only slight, but in other cases, continuous variation is possible in any amount from 0 to 100 per cent leading from one chemical formula to another different formula; more than one kind of variation is often possible, sometimes to the same unlimited extent. Such continuous variation does not change one phase into another phase. In the same way all these variations should be included as one mineral, no matter whether that means that the composition of the mineral can be expressed (at least approximately by one formula or that two or even many formulas are necessary to express it.

It is clear that, as thus defined, the term mineral includes all "organic" compounds, such as carbonates, oxalates, etc., which are found in inorganic nature (whether or not they are also found in living organisms).

This definition of a mineral is not yet widely accepted, although it seems to be gradually growing in favor. It may be worth while to review briefly some of the effects of its acceptance on mineralogical nomenclature. It is interesting to find that some minerals (as thus defined) have names accepted by all, while others have no names. The oldest example of such a name is plagioclase which was used in this sense (and not as the name of a group of minerals) by Tschermak more than fifty years ago. Another familiar example is olivine, though to many mineralogists that is still considered to be the name of a group of minerals rather than the name of one mineral species.

On the other hand orthoclase, as at present used, is one name for at least two minerals, namely, adularia, and sanidine.

The following list gives examples of minerals and some of their varieties according to this definition:

[3] As suggested by M. N. Godlevsky, *Min. Abst.*, **7**, 208 (1939). For a definition of phase see, for example, A. Findlay's *Phase Rule*, 8th Ed. (1938), or F. H. Getman and F. Daniels' *Outlines of Physical Chemistry*, 7th Ed. p. 308 *et. seq.* (1941).

[4] A. F. Rogers, *Am. Mineral.*, **21**, 194 (1936).

Species	*Subspecies*	*End-members (and some intermediate formulas)*
Electrum[5]	Gold	Au
	Silver	Ag
Cerargyrite	Chlorargyrite	AgCl
	Bromargyrite	AgBr
Gray Copper[6]	Tetrahedrite	$Cu_{10}Zn_2Sb_4S_{13}$
	Tennantite	$Cu_{10}Zn_2As_4S_{13}$
Ilmenite	Geikielite	$MgTiO_3$
	Crichtonite	$FeTiO_3$
	Pyrophanite	$MnTiO_3$
Spinel	Talcspinel	$MgAl_2O_4$
	Hercynite	$FeAl_2O_4$
	Chromite	$FeCr_2O_4$
	Picrochromite	$MgCr_2O_4$
	Gahnite	$ZnAl_2O_4$
Magnetite	Magnetite proper	$FeFe_2O_4$
	Magnesioferrite	$MgFe_2O_4$
	Jacobsite	$MnFe_2O_4$
	Franklinite	$ZnFe_2O_4$
Columbite	Columbite proper	$FeCb_2O_6$
	Mangancolumbite	$MnCb_2O_6$
	Tantalite	$FeTa_2O_6$
	Mangantantalite	$MnTa_2O_6$
Brownspar[7]	Magnesite	$MgCO_3$
	Siderite	$FeCO_3$
	Rhodochrosite	$MnCO_3$
	Smithsonite	$ZnCO_3$
	Spherocobaltite	$CoCO_3$
Dolomite	Magnesiodolomite	$CaMg(CO_3)_2$
	Ankerite	$Ca(Mg, Fe)(CO_3)$
	Ferrodolomite	$CaFe(CO_3)_2$
	Mangandolomite	$CaMn(CO_3)_2$
Wolframite	Ferberite	$FeWO_4$
	Hübnerite	$MnWO_4$

[5] Name suggested by Horace Winchell; designated "noble metal" in A. N. Winchell, *Elements of Mineralogy*, 225 (1942).

[6] A. N. Winchell, *Elements of Mineralogy* (1942).

[7] A. N. Winchell, *Elements of Mineralogy* (1942). Brownspar is simply a translation of the German name "braunspath."

Species	*Subspecies*	*End-members (and some intermediate formulas)*
Chalcanthite	Copper chalcanthite	$CuSO_4 \cdot 5H_2O$
	Siderotil	$FeSO_4 \cdot 5H_2O$
	Cobalt chalcanthite	$CoSO_4 \cdot 5H_2O$
Melanterite	Iron Melanterite	$FeSO_4 \cdot 7H_2O$
	Boothite	$CuSO_4 \cdot 7H_2O$
Amblygonite	Hebronite	$LiAlFPO_4$
	Montebrazite	$LiAlOHPO_4$
Apatite	Chlorapatite	$Ca_5ClP_3O_{12}$
	Hydroxylapatite	$Ca_5OHP_3O_{12}$
	Fluorapatite	$Ca_5FP_3O_{12}$
	Svabite	$Ca_5OHAs_3O_{12}$
	Ellestadite	$Ca_{10}(OH)_2S_3Si_3O_{24}$
Plagioclase	Albite	$Ab_{100}An_0$ to $Ab_{90}An_{10}$
	Oligoclase	$Ab_{90}An_{10}$ to $Ab_{70}An_{30}$
	Andesine	$Ab_{70}An_{30}$ to $Ab_{50}An_{50}$
	Labradorite	$Ab_{50}An_{50}$ to $Ab_{30}An_{70}$
	Bytownite	$Ab_{30}An_{70}$ to $Ab_{10}An_{90}$
	Anorthite	$Ab_{10}An_{90}$ to Ab_0An_{100}
Muscovite	Muscovite proper	$KAl_2(OH)_2Si_3AlO_{10}$
	Ferrimuscovite	$KAlFe(OH)_2Si_3AlO_{10}$
	Picrophengite	$K_2MgAl_3(OH)_4Si_7AlO_{20}$
	Ferrophengite	$K_2FeAl_3(OH)_4Si_7AlO_{20}$
Lepidolite	Polylithionite	$K_2Li_4Al_2(OH,F)_4Si_8O_{20}$
	Paucilithionite	$K_2Li_3Al_3(OH,F)_4Si_6Al_2O_{20}$
	Protolithionite	$K_2LiFe_4Al(OH,F)_4Si_6Al_2O_{20}$
Biotite	Phlogopite	$K_2Mg_6(OH)_4Si_6Al_2O_{20}$
	Eastonite	$K_2Mg_5Al(OH)_4Si_5Al_3O_{20}$
	Siderophyllite	$K_2Fe_5Al(OH)_4Si_5Al_3O_{20}$
	Annite	$K_2Fe_6(OH)_4Si_6Al_2O_{20}$
Chlorite[8]	Antigorite[9]	$Mg_6(OH)_8Si_4O_{10}$
	Amesite[10]	$Mg_4Al_2(OH)_8Si_2Al_2O_{10}$
	Daphnite	$Fe_4Al_2(OH)_8Si_2Al_2O_{10}$

[8] Many intermediate varieties have been named, such as clinochlore, prochlorite, penninite, thuringite, etc.

[9] "Ferroantigorite," $Fe_6(OH)_8Si_4O_{10}$, is a purely hypothetical end-member, being unknown in nature, even as an approximation.

[10] Amesite is a doubtful end-member of chlorite, having a structure resembling that of kaolinite according to J. W. Gruner: *Am. Mineral.*, **29**, 422 (1944).

Species	*Subspecies*	*End-members (and some intermediate formulas)*
Montmorillonite[11]	Leverrierite	$Al_4(OH)_4Si_8O_{20}\cdot 8H_2O$
	Beidellite	$Al_4(OH)_4Si_6Al_2O_{18}(OH)_2\cdot 8H_2O$
	Name?	$Mg_3Al(OH)Si_7AlO_{19}(OH)\cdot 11H_2O$
	Name?	$Mg_3Al(OH)Si_6Al_2O_{18}(OH)_2\cdot 11H_2O$
	Chloropal[12]	$Fe_4(OH)_4Si_8O_{20}\cdot 8H_2O$
	Canbyite(?)	$Fe_4(OH)_4Si_6Fe_2O_{18}(OH)_2\cdot 8H_2O$
	Name?	$Mg_3Fe(OH)Si_7FeO_{19}(OH)\cdot 11H_2O$
	Name?	$Mg_3Fe(OH)Si_6Fe_2O_{18}(OH)_2\cdot 11H_2O$
Enstenite	Enstatite	$MgSiO_3$
	Hypersthene	$(Mg,Fe)SiO_3$
	Ferrosilite	$FeSiO_3$
Clinoenstenite	Clinoenstatite	$MgSiO_3$
	Clinohypersthene	$(Mg,Fe)SiO_3$
	Pigeonite	$(Mg,Fe,Ca)SiO_3$
	Clinoferrosilite	$FeSiO_3$
Polyaugite[13]	Diopside	$CaMgSi_2O_6$
	Augite	$Ca(Mg,Fe)Si_2O_6$ with $(Mg,Fe)_2Si_2O_6$ and Al_4O_6
	Hedenbergite	$CaFeSi_2O_6$
	Johannsenite	$CaMnSi_2O_6$
	Acmite	$NaFeSi_2O_6$
	Jadeite	$NaAlSi_2O_6$
Hornblende[14]	Tremolite	$Ca_2Mg_5(OH)_2Si_8O_{22}$
	Actinolite	$Ca_2(Mg,Fe)_5(OH)_2Si_8O_{22}$
	Ferrotremolite	$Ca_2Fe_5(OH)_2Si_8O_{22}$
	Tschermakite	$Ca_2Mg_3Al_2(OH)_2Si_6Al_2O_{22}$
	Ferrotschermakite	$Ca_2Fe_3Al_2(OH)_2Si_6Al_2O_{22}$
	Edenite	$NaCa_2Mg_5(OH)_2Si_7AlO_{22}$
	Ferroedenite	$NaCa_2Fe_5(OH)_2Si_7AlO_{22}$
	Hastingsite	$NaCa_2Mg_4Al(OH)_2Si_6Al_2O_{22}$
	Ferrohastingsite	$NaCa_2Fe_4Al(OH)_2Si_6Al_2O_{22}$
	Ferritremolite	$Ca_2Fe_3Fe_2O_2Si_8O_{22}$
	Ferritschermakite	$Ca_2Fe(Al,Fe)_4O_2Si_8O_{22}$

[11] A. N. Winchell: *Am. Mineral.*, **30**, 510 (1945).

[12] The last four formulas of montmorillonite are those of the probable end-members of nontronite.

[13] Some name seems to be needed for this mineral; clinopyroxene is not suitable since it would include clinoenstenite and spodumene. Augite is much the commonest subspecies, and the mineral includes not only augite, but also leucaugite, ferroaugite, magaugite, titanaugite, and aegirinaugite, so polyaugite seems an appropriate name (all the other subspecies being closely related to augite).

[14] Hornblende is so complicated that recognition of three groups of subspecies seems desirable—namely "common hornblende" = tremolite to ferrohastingsite, oxyhornblende = ferritremolite to ferrihastingsite and soda-hornblende = glaucophane to eckermannite.

Species	*Subspecies*	*End-members (and some intermediate formulas)*
	Ferriedenite	$NaCa_2Fe_3Fe_2O_2Si_7AlO_{22}$
	Ferrihastingsite	$NaCa_2Fe_2(Al,Fe)_3O_2Si_6Al_2O_{22}$
	Glaucophane	$Na_2Mg_3Al_2(OH)_2Si_8O_{22}$ $Na_2CaMg_3Al_2O_2Si_8O_{22}$ $Na_3Mg_3Al_2OOHSi_8O_{22}$
	Gastaldite	$Na_2MgAl_4O_2Si_8O_{22}$
	Riebeckite	$Na_2Fe_3''Fe_2'''(OH)_2Si_8O_{22}$
	Arfvedsonite	$Na_3Fe_4''Fe'''(OH)_2Si_8O_{22}$
	Eckermannite	$Na_3Mg_4(Al,Fe''')(OH,F)Si_8O_{22}$
Tourmaline	Dravite	$H_4NaMg_3B_3Al_6Si_6O_{31}$
	Schorlite	$H_4NaFe_3B_3Al_6Si_6O_{31}$
	Elbaite	$H_4Na(Li,Al)_3B_3Al_6Si_6O_{31}$
Melilite	Akermanite	$Ca_2MgSi_2O_7$
	Gehlenite	$Ca_2AlSiAlO_7$
	Hardystonite	$Ca_2ZnSi_2O_7$
Pyralspite	Pyrope	$Mg_3Al_2Si_3O_{12}$
	Almandite	$Fe_3Al_2Si_3O_{12}$
	Spessartite	$Mn_3Al_2Si_3O_{12}$
Ugrandite	Uvarovite	$Ca_3Cr_2Si_3O_{12}$
	Grossularite	$Ca_3Al_2Si_3O_{12}$
	Andradite	$Ca_3Fe_2Si_3O_{12}$
Olivine	Forsterite	Mg_2SiO_4
	Chrysolite	$Fo_{90}Fa_{10}$ to $Fo_{70}Fa_{30}$
	Fayalite	Fe_2SiO_4
	Tephroite	Mn_2SiO_4
Scapolite	Marialite	$Na_4ClSi_9Al_3O_{24}$
	Meionite	$Ca_4CO_3Si_6Al_6O_{24}$
Epidote	Clinozoisite	$Ca_2Al_3(OH)Si_3O_{12}$
	Pistacite	$Ca_2(Al,Fe)_3(OH)Si_3O_{12}$
	Piedmontite	$Ca_2(Al,Mn,Fe)_3(OH)Si_3O_{12}$