

Discussion Paper on Mineral Groups

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INTRODUCTION

There are two aspects to the compilation of mineral groups. One is the criteria to be used in defining a group. In a recent meeting of the CCM in Melbourne, it was generally agreed that the main criteria defining a group are that it should comprise at least two species, and that the species comprising the group should be isostructural, as indicated by similarity of space group and unit-cell parameters.

An important additional consideration is the need to develop an arrangement of the groups in a way that makes it relatively easy to find the group to which a particular mineral species should be consigned. There are many ways in which mineral groups can be classified, and I have looked at four different possibilities with the aim of initiating discussion on this topic. To illustrate the four different classification systems, I have applied them to the sulfide and sulfosalt minerals. The four systems, demonstrated below, are as follows: I) Alphabetical; II) Hey's chemical classification; III) A combination of Hey's chemical classification and Smith's structural formulae; and IV) Strunz's chemical-structural classification. Comments and suggestions are welcomed.

I) SULFIDE AND SULFOSALT GROUPS

ALPHABETICAL LISTING

- Argyrodite Group: Orthorhombic, $Pna2_1$ (33). Argyrodite structure type
- Arsenopyrite Group: Monoclinic, $P2_1/c$ (14). Related to marcasite structure.
- Berthierite Group: Orthorhombic, $Pnam$ (62). Berthierite structure type.
- Bournonite Group: Orthorhombic, $Pn2_1m$ (31). Bournonite structure type
- Bowieite Group: Orthorhombic, $Pbcn$ (60). Bowieite structure type.
- Braggite Group: Tetragonal, $P4_2/m$ (84). Braggite structure type.
- Brezinaite Group: Monoclinic, $I2/m$ (12). Nickeline structure type
- Bukovite Group: Tetragonal, $I4/mmm$ (139). Structure not known
- Chalcopyrite group: Tetragonal, $I\bar{4}2d$ (122) or $P\bar{4}2c$ (112). Chalcopyrite structure type (diamond-like structure)
- Chalcostibite Group: Orthorhombic, $Pnma$ (62). Chalcostibite structure type.
- Cobaltite Group: Orthorhombic, $Pca2_1$ (29). Related to pyrite structure.
- Cylindrite Group: Incommensurable lattices. Combination of galena and herzenbergite-type structures
- Djerfisherite Group: Cubic, $Pm\bar{3}m$ (221). Djerfisherite structure type.
- Enargite Group: Orthorhombic, $Pnm2_1$ (31) or related. Enargite structure type (similar to wurtzite)
- Freieslebenite Group: Monoclinic, $P2_1/a$ (14). A strongly distorted galena-type structure
- Galena Group: Cubic, $Fm\bar{3}m$ (225). Halite structure type.
- Geocronite Group: Monoclinic, $P2_1/m$ (11). Geocronite structure type
- Germanite Group: Cubic, $P\bar{4}3n$ (218). Germanite structure type (similar to sphalerite, but with additional cations in interstitial tetrahedral sites).
- Gersdorffite Group: Cubic, $Pa\bar{3}$ (205); related to pyrite structure
- Hatchite Group: Triclinic, $P\bar{1}$ (2). Hatchite structure type.
- Hauchecornite Group: Tetragonal, $I4/mmm$ (139). Hauchecornite structure type
- Heazlewoodite Group: Trigonal, $R32$ (155). Heazlewoodite structure type
- Hemusite Group: Space group and structure not known.
- Herzenbergite Group: Orthorhombic, $Pbnm$ (62). Herzenbergite structure type.
- Jamesonite Group: Monoclinic, $P2_1/a$ (14). Jamesonite structure type.
- Joseite Group: Trigonal, $R\bar{3}m$ (166). Related to tetradymite structure.
- Kesterite Group: Tetragonal, $I\bar{4}$ (82). Kesterite structure type (similar to sphalerite)
- Kobellite Group: Orthorhombic, $Pnmm$ (58). Kobellite structure type.
- Linnaeite Group: Cubic, $Fd\bar{3}m$ (227). Spinel structure type.
- Marcasite Group: Orthorhombic, $Pnmm$ (58). Marcasite structure type
- Matildite Group: Trigonal, $P\bar{3}m1$ (164). Matildite structure type; related to that of galena
- Mawsonite Group: Tetragonal, $P\bar{4}m2$ (115). Mawsonite structure type (similar to sphalerite, but with additional cations in interstitial tetrahedral sites).

Melonite Group: Trigonal, $P\bar{3}m1$ (164); brucite structure type.

Millerite Group: Trigonal, $R3m$ (160). Millerite structure type.

Molybdenite Group: Hexagonal, $P6_3/mmc$ (194); molybdenite structure type

Nickeline Group: Hexagonal, $P6_3/mmc$ (194). Nickeline structure

Orpiment Group: Monoclinic, $P2_1/n$ (14). Orpiment structure type.

Palladseite Group: Cubic, $Pm\bar{3}m$ (221). Palladseite structure type.

Pararammelsbergite Group: Orthorhombic, $Pbca$ (61). Structure similar to marcasite.

Pearceite Group: Monoclinic, $C2/m$ (12). Structure not known.

Pentlandite Group: Cubic, $Fm\bar{3}m$ (225). Pentlandite structure type

Petzite Group: Cubic, $I4_132$ (214). Petzite structure type (garnet-like structure)

Polarite Group: Orthorhombic, $Ccm2_1$ (36); structure not known

Polybasite Group: Monoclinic, $C2/m$ (12). Structure not known.

Pyrargyrite Group: Trigonal, $R3c$ (161). Pyrargyrite structure type

Pyrite Group: Cubic, $Pa\bar{3}$ (205); pyrite structure type

Pyrrhotite Group: A variety of unit cells based on the nickeline structure

Rhodostannite Group: Tetragonal, $I4_1/a$ (88). Spinel-like structure.

Safflorite Group: Orthorhombic, $Pnmm$ (58). Structure similar to marcasite.

Shandite Group: Trigonal, $R\bar{3}m$ (166). Shandite structure type

Skutterudite Group: Cubic, $Im\bar{3}$ (204). Skutterudite structure type.

Sphalerite Group: Cubic, $F\bar{4}3m$ (216). Sphalerite structure type (diamond-like structure)

Stannite Group: Tetragonal, $I\bar{4}2m$ (121). Stannite structure type (similar to sphalerite)

Stibnite Group: Orthorhombic, $Pbnm$ (62). Stibnite structure type.

Sulvanite Group: Cubic, $P\bar{4}3m$ (215). Sulvanite structure type

Tennantite Group: Cubic, $I\bar{4}3m$ (217). Tennantite structure type.

Tetradymite Group: Trigonal, $R\bar{3}m$ (166). Tetradymite structure type

Tsumoite Group: Trigonal, $P\bar{3}m1$ (164). Related to tetradymite group

Ullmannite Group: Cubic, $P2_13$ (198). Related to pyrite structure

Valleriite Group: Intercalated sulfide and hydroxide layers. Valleriite structure type.

Westerveldite Group: Orthorhombic, $Pmcn$ (62). Probably deformed nickeline structure.

Wurtzite Group: Hexagonal, $P6_3mc$ (186). Wurtzite structure type.

REFERENCE

Mandarino, J.A. (1999) *Fleischer's Glossary of Mineral Species 1999*. The Mineralogical Record, Tucson.

II. SULFIDE AND SULFOSALT GROUPS

ARRANGED ACCORDING TO HEY'S CHEMICAL CLASSIFICATION

3. Sulfides, Selenides, Tellurides, Arsenides, Bismuthides (except the arsenides, antimonides and bismuthides of Cu, Ag and Au, which are included in Section 1.

3.0 Sulfides etc. of the alkalis

3.1 Sulfides etc. of Cu

Chalcopyrite group: Tetragonal, $I\bar{4}2d$ (122) or $P\bar{4}2c$ (112). Chalcopyrite structure type (diamond-like structure)

3.2 Sulfides etc. of Ag

3.3 Sulfides etc. of Au

Petzzite Group: Cubic, $I4_132$ (214). Petzzite structure type (garnet-like structure)

3.4 Sulfides etc. of Group II metals other than Hg (Mg, Ca, Zn, Cd)

Sphalerite Group: Cubic, $F\bar{4}3m$ (216). Sphalerite structure type (diamond-like structure)

Wurtzite Group: Hexagonal, $P6_3mc$ (186). Wurtzite structure type.

3.5 Sulfides etc. of Hg and Tl

Bukovite Group: Tetragonal, $I4/mmm$ (139). Structure not known

3.6 Sulfides etc. of Sn and Pb

Galena Group: Cubic, $Fm\bar{3}m$ (225). Halite structure type.

Herzenbergite Group: Orthorhombic, $Pbnm$ (62). Herzenbergite structure type.

3.7 Sulfides etc. of V, As, Sb and Bi

Joseite Group: Trigonal, $R\bar{3}m$ (166). Related to tetradymite structure.

Orpiment Group: Monoclinic, $P2_1/n$ (14). Orpiment structure type.

Stibnite Group: Orthorhombic, $Pbnm$ (62). Stibnite structure type.

Tetradymite Group: Trigonal, $R\bar{3}m$ (166). Tetradymite structure type

Tsumoite Group: Trigonal, $P\bar{3}m1$ (164). Related to tetradymite group

3.8 Sulfides etc. of Cr, Mo, W and Mn

Brezinaite Group: Monoclinic, $I2/m$ (12). Nickeline structure type

Molybdenite Group: Hexagonal, $P6_3/mmc$ (194); molybdenite structure type

3.9 Sulfides etc. of Fe

Arsenopyrite Group: Monoclinic, $P2_1/c$ (14). Related to marcasite structure.

Marcasite Group: Orthorhombic, $Pnmm$ (58). Marcasite structure type

Pyrite Group: Cubic, $Pa\bar{3}$ (205); pyrite structure type

Pyrrhotite Group: A variety of unit cells based on the nickeline structure.

3.10 Sulfides etc. of Co

Cobaltite Group: Orthorhombic, $Pca2_1$ (29). Related to pyrite structure.

Linnaeite Group: Cubic, $Fd\bar{3}m$ (227). Spinel structure type.

Safflorite Group: Orthorhombic, $Pn\bar{m}$ (58). Structure similar to marcasite.

Skutterudite Group: Cubic, $Im\bar{3}$ (204). Skutterudite structure type.

3.11 Sulfides etc. of Ni

Gersdorffite Group: Cubic, $Pa\bar{3}$ (205); related to pyrite structure

Heazlewoodite Group: Trigonal, $R\bar{3}2$ (155). Heazlewoodite structure type

Melonite Group: Trigonal, $P\bar{3}m1$ (164); brucite structure type.

Millerite Group: Trigonal, $R\bar{3}m$ (160). Millerite structure type.

Nickeline Group: Hexagonal, $P6_3mmc$ (194). Nickeline structure

Pararammelsbergite Group: Orthorhombic, $Pbca$ (61). Structure similar to marcasite.

Pentlandite Group: Cubic, $Fm\bar{3}m$ (225). Pentlandite structure type

Shandite Group: Trigonal, $R\bar{3}m$ (166). Shandite structure type

Ullmannite Group: Cubic, $P2_13$ (198). Related to pyrite structure

Westerveldite Group: Orthorhombic, $Pmcn$ (62). Probably deformed nickeline structure.

3.12 Sulfides etc. of the platinum metals

Bowieite Group: Orthorhombic, $Pbcn$ (60). Bowieite structure type.

Braggite Group: Tetragonal, $P4_2/m$ (84). Braggite structure type.

Palladseite Group: Cubic, $Pm\bar{3}m$ (221). Palladseite structure type.

Polarite Group: Orthorhombic, $Ccm2_1$ (36); structure not known

4. Oxysulfides

Valleriite Group: Intercalated sulfide and hydroxide layers. Valleriite structure type.

5. Sulfosalts - sulfarsenites, sulfantimonites and sulfobismuthites (those containing Sn, Ge or V are in Section 6)

5.0 Sulfarsenites etc. of the alkali metals

5.1 Sulfarsenites etc. of Cu

Tennantite Group: Cubic, $I\bar{4}3m$ (217). Tennantite structure type.

Chalcostibite Group: Orthorhombic, $Pnma$ (62). Chalcostibite structure type.

5.2 Sulfarsenites etc. of Ag

Matildite Group: Trigonal, $P\bar{3}m1$ (164). Matildite structure type; related to that of galena

Pyrargyrite Group: Trigonal, $R\bar{3}c$ (161). Pyrargyrite structure type.

Pearceite Group: Monoclinic, $C2/m$ (12). Structure not known.

Polybasite Group: Monoclinic, $C2/m$ (12). Structure not known.

5.3 Sulfarsenites etc. of Au

5.4 Sulfarsenites etc. of Zn and Hg

5.5. Sulfarsenites etc. of Tl

5.6 Sulfarsenites etc. of Pb alone

Geocronite Group: Monoclinic, $P2_1/m$ (11). Geocronite structure type

5.7 Sulfarsenites etc. of Pb and other metals

Bournonite Group: Orthorhombic, $Pn2_1m$ (31). Bournonite structure type

Freieslebenite Group: Monoclinic, $P2_1/a$ (14). A strongly distorted galena-type structure

Kobellite Group: Orthorhombic, $Pnmm$ (58). Kobellite structure type.

Hatchite Group: Triclinic, $P\bar{1}$ (2). Hatchite structure type.

5.8 Sulfarsenites etc. of Mn, Fe, Co and Ni

Hauchecornite Group: Tetragonal, $I4/mmm$ (139). Hauchecornite structure type

Jamesonite Group: Monoclinic, $P2_1/a$ (14). Jamesonite structure type.

Berthierite Group: Orthorhombic, $Pnam$ (62). Berthierite structure type.

6. Sulfosalts - sulphostannates, sulfogermanates, sulfarsenates, sulfantimonates, sulfovanadates and sulfohalides

6.1 Sulfostannates and other sulfides containing Sn

Cylindrite Group: Incommensurable lattices. Combination of galena and herzenbergite-type structures

Hemusite Group: Space group and structure not known.

Kesterite Group: Tetragonal, $I\bar{4}$ (82). Kesterite structure type (similar to sphalerite)

Mawsonite Group: Tetragonal, $P\bar{4}m2$ (115). Mawsonite structure type (similar to sphalerite)

Rhodostannite Group: Tetragonal, $I4_1/a$ (88). Spinel-like structure.

Stannite Group: Tetragonal, $I\bar{4}2m$ (121). Stannite structure type (similar to sphalerite)

6.2 Sulfogermanates

Argyrodite Group: Orthorhombic, $Pna2_1$ (33). Argyrodite structure type

Germanite Group: Cubic, $P\bar{4}3n$ (218). Germanite structure type (similar to sphalerite, but with additional cations in interstitial tetrahedral sites).

6.3 Sulfarsenates and sulfantimonates

Enargite Group: Orthorhombic, $Pnm2_1$ (31) or related. Enargite structure type (similar to wurtzite)

6.4 Sulfovanadates

Sulvanite Group: Cubic, $P\bar{4}3m$ (215). Sulvanite structure type

6.5 Sulfohalides

Djerfisherite Group: Cubic, $Pm\bar{3}m$ (221). Djerfisherite structure type.

REFERENCE

Clark, A.M. (1993) *Hey's Mineral Index*, 3rd ed. Chapman & Hall, London

III. SULFIDE AND SULFOSALT GROUPS

ARRANGED ACCORDING TO SMITH'S STRUCTURAL FORMULAE WITHIN THE BROAD FRAMEWORK OF HEY'S CHEMICAL INDEX

(The structure-based chemical formulae employ a set of alphabetic characters to specify the structural sites in the mineral. They are defined as follows: **A**: "All" cations, *ie* to represent all the cations not in the structural unit, or for a site that is so variable that no simple combination of other symbols can be used. **D**: Large cations, with coordination ≥ 9 . **E**: Cations with coordination of 8 or 7. **G**: Cations with coordination 6, commonly octahedral. **J**: Cations with coordination 5. **T**: Cations in tetrahedral coordination. **R**: Cations in 3 planar coordination. **Q**: Cations in 4 planar or 2 linear coordination. **L**: Cations with lone-electron pair configuration. **X**: Monatomic anions. **Z**: Polyatomic anions. **M**: Molecules. The chemical formulae are arranged in alphabetical order within each of the broad Hey categories).

3. Sulfides, Selenides, Tellurides, Arsenides, Bismuthides (except the arsenides, antimonides and bismuthides of Cu, Ag and Au)

D₃DX₂ Compounds

Petzite Group: Cubic, I4₁32 (214). Petzite structure type (garnet-like structure)

D₂TT₃X₄ Compounds

Bukovite Group: Tetragonal, I4/mmm (139). Structure not known

E₂G₃X₂ Compounds

Shandite Group: Trigonal, R³ m (166). Shandite structure type

GGX Compounds

Matildite Group: Trigonal, P³ m1 (164). Matildite structure type; related to that of galena

GTLX₃ Compounds

Bournonite Group: Orthorhombic, Pn2₁m (31). Bournonite structure type

Freieslebenite Group: Monoclinic, P2₁/a (14). A strongly distorted galena-type structure

GT₈X₈ Compounds

Pentlandite Group: Cubic, Fm³ m (225). Pentlandite structure type

GX Compounds

Galena Group: Cubic, Fm³ m (225). Halite structure type.

Nickeline Group: Hexagonal, P6₃mmc (194). Nickeline structure

Pyrrhotite Group: A variety of unit cells based on the nickeline structure

Tsumoite Group: Trigonal, P³ m1 (164). Related to tetradymite group

Westerveldite Group: Orthorhombic, Pmcn (62). Probably deformed nickeline structure.

GX₂ Compounds

Marcasite Group: Orthorhombic, Pnnm (58). Marcasite structure type

Melonite Group: Trigonal, P³ m1 (164); brucite structure type.

Molybdenite Group: Hexagonal, $P6_3/mmc$ (194); molybdenite structure type

Polarite Group: Orthorhombic, $Ccm2_1$ (36); structure not known

Pyrite Group: Cubic, $Pa\bar{3}$ (205); pyrite structure type

Safflorite Group: Orthorhombic, $Pnmm$ (58). Structure similar to marcasite.

Pararammelsbergite Group: Orthorhombic, $Pbca$ (61). Structure similar to marcasite.

G_2X_3 Compounds

Bowieite Group: Orthorhombic, $Pbcn$ (60). Bowieite structure type.

Tetradymite Group: Trigonal, $R\bar{3}m$ (166). Tetradymite structure type

G_3X_4 Compounds

Brezinaite Group: Monoclinic, $I2/m$ (12). Nickeline structure type

G_4X_3 Compounds

Joseite Group: Trigonal, $R\bar{3}m$ (166). Related to tetradymite structure.

$G_{17}X_{15}$ Compounds

Palladseite Group: Cubic, $Pm\bar{3}m$ (221). Palladseite structure type.

GX_3 Compounds

Skutterudite Group: Cubic, $Im\bar{3}$ (204). Skutterudite structure type.

GXX Compounds

Arsenopyrite Group: Monoclinic, $P2_1/c$ (14). Related to marcasite structure.

Gersdorffite Group: Cubic, $Pa\bar{3}$ (205); related to pyrite structure

Ullmannite Group: Cubic, $P2_13$ (198). Related to pyrite structure

Cobaltite Group: Orthorhombic, $Pca2_1$ (29). Related to pyrite structure.

JX Compounds

Millerite Group: Trigonal, $R3m$ (160). Millerite structure type.

J_2X_3 Compounds

Stibnite Group: Orthorhombic, $Pbnm$ (62). Stibnite structure type.

LX Compounds

Herzenbergite Group: Orthorhombic, $Pbnm$ (62). Herzenbergite structure type.

L_2X_3 Compounds

Orpiment Group: Monoclinic, $P2_1/n$ (14). Orpiment structure type.

$Q_9E_2X_8$ Compounds

Hauchecornite Group: Tetragonal, $I4/mmm$ (139). Hauchecornite structure type

QX Compounds

Braggite Group: Tetragonal, $P4_2/m$ (84). Braggite structure type.

TG_2X_4 Compounds

Linnaeite Group: Cubic, $Fd\bar{3}m$ (227). Spinel structure type.

TTX_2 Compounds

Chalcopyrite Group: Tetragonal, $I\bar{4}2d$ (122) or $P\bar{4}2c$ (112). Chalcopyrite structure type (diamond-like structure)

TX Compounds

Sphalerite Group: Cubic, $F\bar{4}3m$ (216). Sphalerite structure type (diamond-like structure)

Wurtzite Group: Hexagonal, $P6_3mc$ (186). Wurtzite structure type.

T_3X_2 Compounds

Heazlewoodite Group: Trigonal, $R32$ (155). Heazlewoodite structure type

4. Oxysulfides

$TX \cdot nGX_2$ Compounds

Valleriite Group: Intercalated sulfide and hydroxide layers. Valleriite structure type.

5. Sulfosalts - sulfarsenites, sulfantimonites and sulfobismuthites

$EQTL_2X_5$ Compounds

Hatchite Group: Triclinic, $P\bar{1}$ (2). Hatchite structure type

$E_{14}X_5(LX_3)_6$ Compounds

Geocronite Group: Monoclinic, $P2_1/m$ (11). Distorted galena-type structure.

$GE_4L_6X_{14}$ Compounds

Jamesonite Group: Monoclinic, $P2_1/a$ (14). Jamesonite structure type.

GL_2X_4 Compounds

Berthierite Group: Orthorhombic, $Pnam$ (62). Berthierite structure type

$G_{12}(LX_3)_4X$ Compounds

Tennantite Group: Cubic, $I\bar{4}3m$ (217). Tennantite structure type.

$Q_{16}L_2X_{11}$ Compounds

Pearceite Group: Monoclinic, $C2/m$ (12). Structure not known.

Polybasite Group: Monoclinic, $C2/m$ (12). Structure not known.

$QTLX_3$ Compounds

Lapieite Group: Orthorhombic, $P2_12_12_1$ (19). Lapieite structure type.

R_3LX_3 Compounds

Pyrargyrite Group: Trigonal, $R3c$ (161). Pyrargyrite structure type.

$T_2E_{12}L_{14}X_{35}$ Compounds

Kobellite Group: Orthorhombic, $Pnmm$ (58). Kobellite structure type.

TLX_2 Compounds

Chalcostibite Group: Orthorhombic, $Pnma$ (62). Chalcostibite structure type.

$T_6T_3(LX_3)_4$ Compounds

Nowackiite Group: Trigonal, $R3$ (146). A defect ZnS-type structure.

$T_{12}X(LX_3)_4$ Compounds

Tennantite Group: Cubic, $I\bar{4}3m$ (217). Tennantite type structure.

6. Sulfosalts - sulphostannates, sulfogermanates, sulfarsenates, sulfantimonates, sulfovanadates and sulfohalides

$D_6GT_{24}X_{27}$ Compounds

Djerfisherite Group: Cubic, $Pm\bar{3}m$ (221). Djerfisherite structure type.

D_8TX_6 Compounds

Argyrodite Group: Orthorhombic, $Pna2_1$ (33). Argyrodite structure type

$G_{11}X_{14}$ Compounds

Cylindrite Group: Incommensurable lattices. Combination of galena and herzenbergite-type structures

GG_6TX_8 (?) Compounds

Hemusite Group: Space group and structure not known.

TGG_3X_8 Compounds

Rhodostannite Group: Tetragonal, $I4_1/a$ (88). Spinel-like structure.

T_2TTX_4 Compounds

Kesterite Group: Tetragonal, $I\bar{4}$ (82). Kesterite structure type (similar to sphalerite)

Stannite Group: Tetragonal, $I\bar{4}2m$ (121). Stannite structure type (similar to sphalerite)

Enargite Group: Orthorhombic, $Pnm2_1$ (31) or related. Enargite structure type (similar to wurtzite)

T_3TX_4 Compounds

Sulvanite Group: Cubic, $P\bar{4}3m$ (215). Sulvanite structure type

$T_{12}T_6X_{16}$ Compounds

Mawsonite Group: Tetragonal, $P\bar{4}m2$ (115). Mawsonite structure type (similar to sphalerite, but with additional cations in interstitial tetrahedral sites).

$T_{13}T_4X_{16}$ Compounds

Germanite Group: Cubic, $P\bar{4}3n$ (218). Germanite structure type (similar to sphalerite, but with additional cations in interstitial tetrahedral sites).

REFERENCES

Clark, A.M. (1993) *Hey's Mineral Index*, 3rd ed. Chapman & Hall, London.

Smith, D.K., Roberts, A.C., Bayliss, P. and Liebau, F. (1998) A systematic approach to general and structure-type formulas for minerals and other inorganic phases. *American Mineralogist* **83**, 126-132.

IV. SULFIDE AND SULFOSALT GROUPS

ARRANGED ACCORDING TO STRUNZ'S CHEMICAL-STRUCTURAL CLASSIFICATION

CLASS 2. SULFIDES AND SULFOSALTS (sulfides, selenides, tellurides, arsenides, antimonides, bismuthides, sulfarsenites, sulfantimonites, subismuthites, etc.)

2.A: Metal-metalloid Alloys

2.AA. Alloys of metalloids with Cu, Ag, Au

2.AB. Ni-metalloid alloys

2.AC. Alloys of metalloids with PGE

Polarite Group: Orthorhombic, $Ccm2_1$ (36); structure not known

2.B: Metal Sulfides, M:S > 1:1

2.BA. With Cu, Ag, Au

Argyrodite Group: Orthorhombic, $Pna2_1$ (33). Argyrodite structure type

Petzite Group: Cubic, $I4_132$ (214). Petzite structure type (garnet-like structure)

2.BB. With Ni

Heazlewoodite Group: Trigonal, $R32$ (155). Heazlewoodite structure type

Hauchecornite Group: Tetragonal, $I4/mmm$ (139). Hauchecornite structure type

Pentlandite Group: Cubic, $Fm\bar{3}m$ (225). Pentlandite structure type

2.BC. With Rh, Pd, Pt, etc.

Palladseite Group: Cubic, $Pm\bar{3}m$ (221). Palladseite structure type.

2.BD. With Hg, Tl

Bukovite Group: Tetragonal, $I4/mmm$ (139). Structure not known

2.BE. With Pb (Bi)

Shandite Group: Trigonal, $R\bar{3}m$ (166). Shandite structure type

2.C: Metal Sulfides, M:S = 1:1 (and similar)

2.CA. With Cu

2.CB. With Zn, Fe, Cu, Ag, etc.

Sphalerite Group: Cubic, $F\bar{4}3m$ (216). Sphalerite structure type (diamond-like structure)

Chalcopyrite group: Tetragonal, $I\bar{4}2d$ (122) or $P\bar{4}2c$ (112). Chalcopyrite structure type (diamond-like structure)

Stannite Group: Tetragonal, $I\bar{4}2m$ (121). Stannite structure type (similar to sphalerite)

Kesterite Group: Tetragonal, $I\bar{4}$ (82). Kesterite structure type (similar to sphalerite)

Germanite Group: Cubic, $P\bar{4}3n$ (218). Germanite structure type (similar to sphalerite, but with additional cations in interstitial tetrahedral sites).

Mawsonite Group: Tetragonal, $P\bar{4}m2$ (115). Mawsonite structure type (similar to sphalerite, but with additional cations in interstitial tetrahedral sites).

Wurtzite Group: Hexagonal, $P6_3mc$ (186). Wurtzite structure type.

Enargite Group: Orthorhombic, $Pnm2_1$ (31) or related. Enargite structure type (similar to wurtzite)

Sulvanite Group: Cubic, $P\bar{4}3m$ (215). Sulvanite structure type

Hemusite Group: Space group and structure not known

2.CC. With Ni, Fe, Co, etc.

Nickeline Group: Hexagonal, $P6_3mmc$ (194). Nickeline structure

Pyrrhotite Group: A variety of unit cells based on the nickeline structure

Westerveldite Group: Orthorhombic, $Pmcn$ (62). Probably deformed nickeline structure.

Millerite Group: Trigonal, $R3m$ (160). Millerite structure type.

Braggite Group: Tetragonal, $P4_2/m$ (84). Braggite structure type.

2.CC. With Sn, Pb, Hg, etc.

Herzenbergite Group: Orthorhombic, $Pbnm$ (62). Herzenbergite structure type.

Galena Group: Cubic, $Fm\bar{3}m$ (225). Halite structure type.

Matildite Group: Trigonal, $P\bar{3}m1$ (164). Matildite structure type; related to that of galena

2.D: Metal Sulfides, M:S = 3:4 and 2:3

2.DA. M:S = 3:4

Linnaeite Group: Cubic, $Fd\bar{3}m$ (227). Spinel structure type.

Rhodostannite Group: Tetragonal, $I4_1/a$ (88). Spinel-like structure.

Brezinaite Group: Monoclinic, $I2/m$ (12). Nickeline structure type

2.DB. M:S = 2:3

Stibnite Group: Orthorhombic, $Pbnm$ (62). Stibnite structure type.

Bowieite Group: Orthorhombic, $Pbcn$ (60). Bowieite structure type.

2.DC. Variable M:S

Tetradymite Group: Trigonal, $R\bar{3}m$ (166). Tetradymite structure type

Joseite Group: Trigonal, $R\bar{3}m$ (166). Related to tetradymite structure.

Tsumoite Group: Trigonal, $P\bar{3}m1$ (164). Related to tetradymite structure.

2.E: Metal Sulfides, M:S ≤ 1:2

2.EA. M:S = 1:2 - With Ni, Sn, Mo, W

Melonite Group: Trigonal, $P\bar{3}m1$ (164); brucite structure type.

Molybdenite Group: Hexagonal, $P6_3/mmc$ (194); molybdenite structure type

2.EB. M:S = 1:2 - With Fe, Co, Ni, PGE, etc.

Pyrite Group: Cubic, $Pa\bar{3}$ (205); pyrite structure type

Gersdorffite Group: Cubic, $Pa\bar{3}$ (205); related to pyrite structure

Cobaltite Group: Orthorhombic, $Pca2_1$ (29). Related to pyrite structure.

Ullmannite Group: Cubic, $P2_13$ (198). Related to pyrite structure

Marcasite Group: Orthorhombic, $Pnmm$ (58). Marcasite structure type

Arsenopyrite Group: Monoclinic, $P2_1/c$ (14). Related to marcasite structure.

Pararammelsbergite Group: Orthorhombic, $Pbca$ (61). Structure similar to marcasite.

Safflorite Group: Orthorhombic, $Pnmm$ (58). Structure similar to marcasite.

2.EC. M:S < 1:2

Skutterudite Group: Cubic, $Im\bar{3}$ (204). Skutterudite structure type.

2.F: Sulfides of Arsenic, Alkalies; Sulfides with Halide, Oxide, Hydroxide, H₂O

2.FA. With As (Sb), S

Orpiment Group: Monoclinic, $P2_1/n$ (14). Orpiment structure type.

2.FB. With Alkalies (without Cl, etc.)

2.FC. With Cl, Br, I

Djerfisherite Group: Cubic, $Pm\bar{3}m$ (221). Djerfisherite structure type.

2.FD. With O, OH, H₂O

Valleriite Group: Intercalated sulfide and hydroxide layers. Valleriite structure type.

2.G: Sulfarsenites, Sulfantimonites, Sulfbismuthites with AsS₃, SbS₃, BiS₃ Pyramids

2.GA. Neso-sulfarsenites, etc., without additional S

Pyrargyrite Group: Trigonal, $R\bar{3}c$ (161). Pyrargyrite structure type

2.GB. Neso-sulfarsenites, etc., with additional S

Tennantite Group: Cubic, $I\bar{4}3m$ (217). Tennantite structure type.

Pearceite Group: Monoclinic, $C2/m$ (12). Structure not known.

Polybasite Group: Monoclinic, $C2/m$ (12). Structure not known.

Geocronite Group: Monoclinic, $P2_1/m$ (11). Geocronite structure type

2.GC. Poly-sulfarsenites, etc.

Hatchite Group: Triclinic, $P\bar{1}$ (2). Hatchite structure type.

2.H: Sulfarsenites, Sulfantimonites, Sulfbismuthites with SnS Archetype Structures

2.HA. With Cu, Ag, Fe (without Pb)

Chalcostibite Group: Orthorhombic, $Pnma$ (62). Chalcostibite structure type.

Berthierite Group: Orthorhombic, $Pnam$ (62). Berthierite structure type.

2.HB. With Cu, Ag, Fe, Sn and Pb

Kobellite Group: Orthorhombic, $Pnmm$ (58). Kobellite structure type.

Jamesonite Group: Monoclinic, $P2_1/a$ (14). Jamesonite structure type.

Cylindrite Group: Incommensurable lattices. Combination of galena and herzenbergite-type structures.

2.HC. With only Pb

2.HD. With Tl

2.HE. With Alkalies, H₂O

2.HF. With SnS and PbS archetype structural units

2.J: PbS Archetype Structures (As,Sb,Bi)S₆ octahedra)

2.JA. Chains combined into sheets

2.JB. Galena derivatives, with Pb

Freieslebenite Group: Monoclinic, P2₁/a (14). A strongly distorted galena-type structure

Bournonite Group: Orthorhombic, Pn2₁m (31). Bournonite structure type

2K: Sulfarsenates

REFERENCE

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