Nomenclature of the magnetoplumbite group

Dan Holtstam1 and Ulf Hålenius1

1Department of Geosciences, Swedish Museum of Natural History, Box 50007, SE-104 05 Stockholm, Sweden

Abstract

A nomenclature and classification scheme has been approved by IMA–CNMNC for the magnetoplumbite group, with the general formula $A[B_{12}]O_{19}$. The classification on the highest hierarchical level is decided by the dominant metal at the 12-coordinated $A$ sites, at present leading to the magnetoplumbite ($A$ = Pb), hawthorneite ($A$ = Ba) and hibonite ($A$ = Ca) subgroups. Two species remain ungrouped. Most cations, with valences from 2+ to 5+, show a strong order over the five crystallographic $B$ sites present in the crystal structure, which forms the basis for the definition of different mineral species. A new mineral name, chihuahuaite, is introduced and replaces hibonite-(Fe).

Keywords: magnetoplumbite group, plumboferrite, chihuahuaite, hexagonal ferrite, hexagonal aluminate, mineral nomenclature, mineral classification

(Received 13 February 2020; accepted 23 March 2020; Accepted Manuscript published online: 26 March 2020; Associate Editor: Anthony R Kampf)

Introduction

The mineral magnetoplumbite was described by Aminoff (1925) from the Långban iron-manganese mines, Värmland County, Sweden. The formula and the topology of the crystal structure was first correctly interpreted by Adelsköld (1938). The composition of this archetypal mineral is given as ideally $\text{Pb}[\text{Fe}_{12}]\text{O}_{19}$. It was first correctly interpreted by Adelsköld (1938). The composition of this archetypal mineral is given as ideally $\text{Pb}[\text{Fe}_{12}]\text{O}_{19}$. It is isostructural with $\text{Ba}[\text{Fe}_{12}]\text{O}_{19}$ (barioferrite), a common synthetic permanent magnetic material (e.g. Pullar, 2012). They both belong to a wider family of compounds, the so-called hexagonal ferrites (or hexaferrites). The group members (Table 1) are rare as minerals, but are found in a variety of geological environments, including metamafic skarns, high-grade metamorphic rocks (granulites), kimberlites, lherzolites, lamproites, volcanic and pyrometamorphic rocks and chondritic meteorites, altogether indicating significantly wide $P$–$T$–$fO_2$ stability conditions for the structure type. The minerals of the group, all possessing basic hexagonal crystal symmetry, are described by the general formula $AB_{12}O_{19}$, where $A$ is a large cation $(A^{2+}$ or $A^{3+})$ and $B$ usually represents more highly charged cations of intermediate size. In the present paper, we announce the newly approved (by the Commission on New Minerals, Nomenclature and Classification of the International Mineralogical Association, IMA–CNMNC) nomenclature for the magnetoplumbite group (decision 95–SM/20, Miyawaki et al., 2020). It should be noted that in this context, we use the commonly accepted formulae of mineral species; the exactness of some of them might be questioned, and a future revision based of reinvestigation of type specimens is desirable.

Crystal structure

Many detailed studies of the crystal structure exist (e.g. Obradors et al., 1985; Utsunomiya et al., 1988; Moore et al., 1989; Wagner 1998). It is based on an essentially closest-packed arrangement of oxygen (O) and A atoms, with B metals occupying voids. One fundamental building block, $S$, forms a CCP two-layer sequence, $\text{cc}$. A fraction of the interstitial sites is occupied by metal atoms in the same fashion as in the spinel structure, which gives an overall composition $\{B_2O_3\}^{2+}$ of the block. A different block, denoted $R$, is built up of a three-layer HCP sequence, $\text{hhhh}$. A quarter of the $O$ atoms of the intermediate h layer is replaced by a large cation $A$ (usually Ba$^{2+}$, Pb$^{2+}$, Ca$^{2+}$ or K$^+$ in minerals). Taking the interstitial $B$ atoms into consideration, $R$ is equal to $\{AB_2O_{11}\}^{2+}$ in composition. By stacking of the blocks along the hexagonal $c$ axis in the sequence $\text{RSR}^*\text{S}^*$, with a repeat of 22–23 Å, the magnetoplumbite unit cell with $Z = 2$ is obtained (Fig. 1). Starred blocks are rotated 180° in accordance with the space-group symmetry of the crystal structure, $P6_3/mmc$. The a unit-cell dimension is $\approx 5.6$ Å $(= 4 \times \text{radius of O}^2)$.

In the structure, the large $A$ cation is ideally 12-coordinated to O, forming a triangular orthobicupola, at $\left(\frac{5}{6}, \frac{5}{6}, \frac{5}{4}\right)$. The interstitial $B$ atoms occupy five unique sites with designations $M1$–$M5$. (Table 2). The five-fold coordinated $M2$ atom, ideally located at the centre of a trigonal bipyramid ($2b$), is in reality slightly displaced (split) into two statistically half-occupied, pseudotetrahedral $4e$ sites (Obradors et al., 1985). This kind of disorder is dynamic in most situations, i.e. a rapid diffusion of the metal atom takes place through the mirror plane of the bipyramid (Kimura et al., 1990; Kreisel et al., 1998; Du and Stebbins, 2004; Kržatela et al., 2018). The $M4$ coordination polyhedra are trigonally distorted octahedra that occur in pairs sharing a common face in a hematite-like arrangement, i.e. forming $B_2O_6$ dimers.
The total unit-cell contents for an $AB_{12}O_{19}$ compound can thus be expressed as $A_2^{[6]}(M1)_{[5]}(M2)_{[4]}(M3)_{[4]}(M4)_{[6]}(M5)_{[12]}/2_{2/3}O_{38}$.

The magnetic structure of magnetoplumbite can be described by the Néel model of ferrimagnetism. The spin orientation of Fe$^{3+}$ at each site (Table 2) is a result of superexchange interaction through the $O^{2−}$ ions. As the cation has a spin-only magnetic $\mu_B$, the total magnetisation per formula unit would be ($6−2−2+1+1)\times5\mu_B = 20\mu_B$ at absolute temperature, which is in good agreement with experimental results (Kojima, 1982). Magnetoplumbite possesses a large magneto-crystalline anisotropy, which is related to a strong preference of the magnetic moments of the ions to align along c.

**Nomenclature**

**Name of the group**

Prior to this work, the group had not been formally approved by CNMNC. However the term ‘magnetoplumbite group’ is prevalent in the literature. Strunz and Nickel (2001) denominated the oxide subclass 4.CC.45 as the magnetoplumbite group, which included diaoyudaoite, plumboferrite and lindqvistite. In recent editions of Fleischer’s Glossary of Mineral Species (Back, 2018) the ‘plumboferrite group’, covering the same group of minerals (Table 1), has been introduced. It was then in principle used as a synonym of the magnetoplumbite group.

Although plumboferrite has historical precedence over magnetoplumbite (discovered in 1881 and 1925, respectively), there are several good arguments to keep magnetoplumbite in the group name. In chemistry and materials science, the concept of magnetoplumbite (or simply ‘M’) type compounds for substances possessing a certain crystal structure is extremely well established (e.g. Collongues et al., 1990; Pullar, 2012). It would be misleading if the mineralogical nomenclature deviated from other areas of science. The true interpretation of the composition of plumboferrite, and its close relationship to magnetoplumbite is in fact a relatively late insight (Holtstam et al., 1995). Furthermore, plumboferrite is atypical in its formula and slightly different in atomic arrangement compared to other members, including positional disorder of Pb atoms and oxygen vacancies (related to $6s^2$ lone electron-pair effects of the Pb$^{2+}$ ion) in the region of $z = 1/4$ that give rise to weak superstructure reflections in X-ray diffraction data. This species is thus not ideal as an archetype for the group as a whole, although the deviations do not support it to be kept outside the group. The present choice agrees with the statement by Mills et al. (2009): “a group or a supergroup name can be selected contrary to the precedence rule because the name of this group (supergroup) is very firmly established in the literature.”

**Fig. 1.** Polyhedral representation of the ideal magnetoplumbite-type structure viewed approximately along [310]. The M3 octahedra (yellow) and the M3 tetrahedra (orange) are in the central section of the S block. The trigonal bipyramidal M2 positions in (green), face-sharing M4 octahedra (blue) and the large A atoms (grey spheres) belong to the central part of the R block. Layers of edge-sharing M5 octahedra (red) are sandwiched between the cores of blocks.

**Table 1.** The presently valid magnetoplumbite-group minerals.

| Name         | Formula                                      | Type locality                              | References                        |
|--------------|----------------------------------------------|--------------------------------------------|-----------------------------------|
| Plumboferrite| $\text{Pb}[\text{Fe}_{10.67}\text{Mn}_{2+}]$ | Jakobsterg mine, Värmland, Sweden          | Igelström (1881); Holtstam et al. (1995) |
| Magnetoplumbite| $\text{Pb}[\text{Fe}_{12}]$                 | Långban mines, Värmland, Sweden            | Aminoff (1925); Holtstam (1994)    |
| Hibonite     | $\text{Ca}[\text{Al}_{12}]$                 | Esiva alluvial deposit, Madagascar         | Curien et al. (1956); Bermanac et al. (1996) |
| Yimergite    | $\text{K}[\text{Ti}_{12}\text{Cr}_{2}\text{Fe}_{3+}]$ | Yimeng Shan, Shangdong, China              | Dong et al. (1983); Peng ad Lu (1985) |
| Hawthornite  | $\text{Ba}[\text{Ti}_{12}\text{Fe}_{3+}]$   | Bullfontein diamond mine, Northern Cape, South Africa | Grey et al. (1987); Haggerty et al. (1989) |
| Neblivote    | $\text{Pb}[\text{Mn}_{2+}]$                 | Neblivo, North Macedonia                   | Bermanac et al. (1996)             |
| Haggertyite  | $\text{Ba}[\text{Ti}_{12}\text{Fe}_{3+}]$   | Crater of Diamonds State Park, Arkansas, USA | Grey et al. (1998)                 |
| Batiferrite  | $\text{Ba}[\text{Ti}_{12}\text{Fe}_{3+}]$   | Udersdorf, Eifel area, Germany             | Lengauer et al. (2001)             |
| Barioferrite | $\text{Ba}[\text{Fe}_{12}]$                 | Mount Ye’elim, Hatrurim Complex, Israel     | Murashko et al. (2011)             |
| Hibonite-(Fe)* | $\text{Fe}^{3+}[\text{Al}_{12}]$             | Allende carbonaceous chondrite, Mexico      | Ma (2010)                         |
| Gorite       | $\text{Ca}[\text{AlFe}_{12}]$               | Hatrurim Complex, Israel                   | Galuskin et al. (2019)             |

*Here renamed chihuahuaite
Table 2. Properties of crystallographic sites for \( A \) and \( B \) metal atoms in magnetoplumbite-group minerals.

| Site | Wyckoff position | CN | Point symmetry | Block | Magnetic spin (\( Fe^{3+} \)) |
|------|-----------------|----|----------------|-------|-----------------------------|
| \( A \) | 2d | 12 | \( 6m2 \) | R | |
| \( M1 \) | 2a | 6 | 3m | S | ↑ |
| \( M2 \) | 2b (4e) | 5 (4 + 1) | \( 6m2 (3m) \) | R | ↑ |
| \( M3 \) | 4f | 4 | 3m | S | ↓ |
| \( M4 \) | 4f | 6 | 3m | R | ↓ |
| \( M5 \) | 12k | 6 | \( m \) | \( R - S \) | ↑ |

\( CN \) – coordination number

Table 3. Classification of the magnetoplumbite group.

| Magnetoplumbite subgroup, \( A = \) Pb | Magnetoplumbite | Plumboferite | Nežilovite |
|---|---|---|---|
| Hawthorneite subgroup, \( A = \) Ba | Hawthorneite | Haggertyite | Batiffereite |
| | | | Harioferrite |
| Hibonite subgroup, \( A = \) Ca | Hibonite | Gorerite |
| Members that do not belong to a subgroup | Yimengite, \( A = \) K | Chihuahuaite [previously hibonite-(\( Fe \)), \( A = \) \( Fe^{2+} \)] |

Consequences

Although the \( \beta \)-alumina-type minerals, presently diaoyudaoite (Shen et al., 1986) and kahlenbergite, \( K[Al_{12}]O_{17} \) (Krüger et al., 2019), were included in a previous grouping, they are not part of the present nomenclature because of the requirement of isosctructurality.

The mineral name hibonite-(\( Fe \)), for \( Fe[Al_{12}]O_{19} \) (Ma, 2010), does not fit well in this scheme as it does not belong to the same subgroup as the parent mineral, hibonite. In addition, suffixes tend to make nomenclature unnecessarily complex. Hibenite-(\( Fe \)) is thus assigned a new root name, ‘chihuahuaite’, after the state (estado) of Mexico where Allende, the holotype host meteorite fell in 1969 (King et al., 1969). Levison modifiers may, however, be used if rare earth element (REE) dominant species are to be approved (with new root names).

Lindqvistite, \( Pb[Fe_{16}Pb(Mn,Mg)]O_{27} \), is a related mineral (Holtstam and Norrestam, 1993). It has the block stacking sequence ‘RSSR’S’S’S’ and thus a different topology than magnetoplumbite. Lindqvistite is consequently not counted as a member of the magnetoplumbite group. Galuskin et al. (2018) have reported closely related Ba- and K-dominant ferrites from Jabel Harmun, West Bank, Palestinian Territories. Further discoveries could motivate the creation of a supergroup, covering different stacking themes among naturally occurring ferrites.

Subdivision

The nomenclature is devised to be simple and flexible at the same time. The group is divided into subgroups based on composition, specifically the dominant \( A \)-type cation (Table 3). The rationale for this scheme is that variations in \( A \) atom composition tend to be less complex compared to that of \( B \) atoms, and information on the precise stoichiometry, including any structural vacancies at cation or anion sites that might be present, is not necessary to determine the position at the highest hierarchical level in the group.

Definition of species

Individual species of the magnetoplumbite group are further defined from their composition and distribution of cations over the \( B \)-type positions (Table 4). Monovalent, divalent, tetravalent and pentavalent cations are incorporated in the magnetoplumbite structure by charge-coupled substitutions of \( \alpha^{2+} \) or \( \beta^{3+} \) ions (Table 5). It is evident that a large number of theoretically possible combinations of cation arrangements exist. However, studies on both minerals and synthetic materials show that most cations exhibit preferential ordering depending on their ionic size, charge and electronic configuration (Grey et al., 1987; Wagner and O’Keeffe, 1988; Xie and Cormack, 1990; Bermac et al., 1996; Holtstam, 1996; Nakashima et al., 2010). An important trend observed is that divalent \( B \)-type ions strongly prefer the tetrahedrally coordinated \( M3 \) sites (Batille et al., 1991), whereas highly charged species, like \( Ti^{4+}, Mn^{3+} \) and \( Sb^{5+} \), become enriched in the \( M4 \) octahedra (Doyle et al., 2014; Nemrava et al., 2017). For compositions with a high degree of replacement of trivalent ions, divalent species also become concentrated at octahedrally coordinated sites, preferentially \( M5 \) (Cabanças et al., 1994). Some trivalent \( d \) cations (\( Cr^{3+} \) and \( Mn^{3+} \)) are ordered at the distorted \( M5 \) octahedra (e.g. Kadakunta et al., 2015; Shlyk et al., 2015; Nemrava et al., 2017). This behaviour is explained largely by crystal-field effects. The \( Fe^{4+} \) cation, in cases when diluted in the compound and less abundant among \( B \) positions, e.g. in hibonite, is accumulated at \( M2 \) and \( M3 \) (Holtstam, 1996; Medina and Subramanian, 2017). \( Al^{3+} \) in turn, when competing with other trivalent species, tends

Table 4. Major components at the cation sites of magnetoplumbite-group minerals. Species-defining elements are given in bold.

| Mineral | \( A \) | \( M1 \) | \( M2 \) | \( M3 \) | \( M4 \) | \( M5 \) |
|---|---|---|---|---|---|---|
| Magnetoplumbite | \( Pb \) | \( Fe^{2+} \) | \( Fe^{2+} \) | \( Fe^{2+} \) | \( Fe^{2+}, Mn^{2+} \) | \( Fe^{2+}, Mn^{2+} \) |
| Plumboferite | \( Pb \) | \( Fe^{2+} \) | \( Pb^{2+} \) | \( Fe^{2+}, Mn^{2+} \) | \( Fe^{2+} \) | \( Fe^{2+}, Mn^{2+} \) |
| Nežilovite | \( Pb \) | \( Al \) | \( Fe^{2+} \) | \( Zn \) | \( Mn^{2+}, Ti^{4+} \) | \( Cr^{3+}, Fe^{3+} \) |
| Hawthorneite | \( Ba \) | \( Cr^{3+} \) | \( Fe^{2+} \) | \( Fe^{2+} \) | \( Ti^{4+} \) | \( Ti^{4+}, Fe^{2+} \) |
| Haggertyite | \( Ba \) | \( K \) | \( Ti^{4+}, Fe^{2+} \) | \( Fe^{2+} \) | \( Ti^{4+} \) | \( Ti^{4+}, Fe^{2+} \) |
| Batiffereite | \( Ba \) | \( Fe^{2+} \) | \( Fe^{2+} \) | \( Fe^{2+} \) | \( Ti^{4+}, Fe^{2+} \) | \( Fe^{2+} \) |
| Barioferrite | \( Ba \) | \( Fe^{2+} \) | \( Fe^{2+} \) | \( Fe^{2+} \) | \( Fe^{2+} \) | \( Fe^{2+} \) |
| Hibonite | \( Ca \) | \( Al \) | \( Al \) | \( Al \) | \( Al \) | \( Cr^{2+} \) |
| Gorerite | \( Ca \) | \( Al \) | \( Fe^{2+} \) | \( Mg^{2+} \) | \( Fe^{2+} \) | \( Cr^{2+} \) |
| Yimengite | \( K \) | \( Fe^{2+} \) | \( Fe^{2+} \) | \( Mg^{2+}, Fe^{2+} \) | \( Ti^{4+} \) | \( Cr^{2+} \) |
| Chihuahuaite | \( Fe^{2+}, Mg \) | \( Al \) | \( Al \) | \( Al \) | \( Al \) | \( Al \) |
to be concentrated at M1 (Bermanec et al., 1996), with the smallest octahedral volume.

**New or unaccredited mineral compositions**

In the literature, analytical data are available that suggest the existence of new, yet officially unrecognised members of the group. Titanium-rich analogues of yimengite and hawthorneite (~5 Ti atoms per formula unit) were analysed by Lu and Chou (1994). Lu et al. (2007) have described a “Ca analogue to yimengite” or rather a Ca analogue to hawthorneite, which would fit into the hibonite subgroup. Rezvukhin et al. (2019) recently found yimengite with high Al (>1 atom per formula unit) contents. Sandiford and Santosh (1991) described zoned ‘hibonite’ grains with REE-rich cores (REE > 0.6 atoms per formula unit). Holtstam (1994) reported a Ti-rich magnetoplumbite sample for which Ti > Fe at M4 could be inferred (a possible Pb analogue to batiferrite). A Mn3+-analogue to plumboferrite was detected by Chukanov et al. (2016). Furthermore, Chukanov et al. (2019) recently published analyses of a Ba-dominant analogue to nežilovite and of an Al analogue to yimengite.

From a vast amount of studies of synthetic compounds, it can be speculated that many new natural members exist with, for example: A = Sr2+, REE (Ce3+, La3+ etc.), Mg2+, Rb+, Cs+ or Ag+ along with enrichment in the B positions (non-exhaustive list) of: Si4+, Sc4+, Ti4+, V2+, V3+, V4+, Co2+, Ni2+, Cu2+, Ga3+, Ge4+, Zr4+, Nb5+, In3+, Sn4+, Te4+, Ta5+ or Bi3+ (e.g. Coutellier et al., 1984; Morgan and Miles, 1986; Li et al., 2016). The range of possible cation valences seem to be limited to 1–3 for A and 2–5 for B sites, which has implications when casting formulae of uncharacterised members of the group. Particular caution is needed for samples containing some of the divalent ionic species, as Fe2+, Mg2+ and Pb2+ have been shown to enter both kinds of sites. Substitutions at anion sites seem to be limited for this structure type.

**Acknowledgements**

Constructive comments on the original nomenclature proposal by members of the Commission on New Minerals, Nomenclature and Classification (CNMNC), and on the manuscript by two reviewers, are appreciated.

**References**

Adelsköld V. (1938) X-ray studies on magneto-plumbite, PbO-Fe₆O₁₀, and other substances resembling “beta-alumina”, Na₃O·11Al₂O₃. Arkiv för Kemi, Mineralogi och Geologi, Serie A-12, 29, 1–9.

Aminoff G. (1925) Über ein neues oxydisches mineral aus Längban. (Magnetooplumbit.) Geologiska Föreningens i Stockholm Förhandlingar, 47, 283–289.

Back M. (2018) Fleischer’s Glossary of Mineral Species 2018. Mineralogical Record Inc., Tucson, USA, 424 pp.

Batle X., Obradors X., Rodríguez-Carvajal J., Pernet M., Cabañas M.V. and Vallet M. (1991) Cation distribution and intrinsic magnetic properties of Co-Ti-doped M-type barium ferrite. Journal of Applied Physics, 70, 1614–1623.

Bermanec V., Holtstam D., Sturman D., Criddle A.J., Back M.E. and Scavnich S. (1996) Nežilovite, a new member of the magnetoplumbite group, and the crystal chemistry of magnetoplumbite and hibonite. The Canadian Mineralogist, 34, 1287–1297.

Cabañas M.V., González-Calbet J.M., Rodríguez-Carvajal J. and Vallet M. (1994) The solid solution BaFe₁₂₋₂₃Co₂₁Ti₁₉O₄₉ (0 ≤ x ≤ 6): cationic distribution by neutron diffraction. Journal of Solid State Chemistry, 111, 229–237.

Chukanov N.V., Akseenov S.M., Jančev S., Pekov I.V., Göttlicher J., Poleykovsky Y.S., Rusakov V.S., Nelyubina, Y.V. and Van K.V. (2016) A new mineral species ferricoronadite, Pb[Mn₉₋₆(F₆⁺, Mn³⁺)₃]O₉·₆, mineralogical characterisation, crystal chemistry and physical properties. Physics and Chemistry of Minerals, 43, 503–514.

Chukanov N.V., Vorobei S.S., Ermolaeva V.N., Varlamov D.A., Plechov P.Y., Jančev S. and Boykun A.V. (2019) New data on chemical composition and vibrational spectra of magnetoplumbite-group minerals. Geology of Ore Deposits, 61, 637–646.

Collognues R., Gourier D., Kahn-Harari A., Lejus A.M., Thery J. and Vivien, D. (1990) Magnetoplumbite-related oxides. Annual Review of Materials Science, 20, 51–82.

Coutellier J.M., Ferrand B., Daiv J., Grange, Y. and Joubert J.C. (1984) Research of substituted hexagonal crystals for the epitaxy of hexaferrite films. Materials Research Bulletin, 19, 1037–1046.

Curien H., Guillemot C., Oorcel J.T. and Sternberg M. (1956) La hibonite, nouvelle espèce minérale. Comptes Rendus Hebdomadaires des Séances de l’Académie des Sciences, 242, 2845–2847.

Dong Z., Zhou J., Lu Q. and Peng Z. (1983) Yimengite, K(Cr,Ti,Fe,Mg)₁₂O₁₉,a new mineral from China. Kexue Tongbao, 15, 932–936 [in Chinese].

Doyle P.M., Schofield P.F., Berry A.J., Walker A.M. and Knight K.S. (2014) Substitution of Ti⁴⁺ and Ti⁶⁺ in hibonite (Ca₁₂Al₉O₃₅). American Mineralogist, 99, 1369–1382.

Du L.S. and Stebbins J.F. (2004) Calcium and strontium hexaluminate: NMR evidence that “pentacoordinate” cation sites are four-coordinated. Journal of Physical Chemistry B, 108, 3681–3685.

Felsche J. (1968) The alkalí problem in the crystal structure of beta alumina. Zeitschrift für Kristallographie, 127, 94–100.

Galuskin E.V., Galusinka I.O., Widmer R. and Armbruster, T. (2018) First natural hexaferrite with mixed β’-ferrite (β-alumina) and magnetoplumbite structure from Jabel Harmun, Palestinian Autonomy. European Journal of Mineralogy, 30, 559–567.

Galuskin E.V., Krüger B., Galusinka I.O., Krüger H., Nejburt K., Vapnik Ye. and Tomizaki, T. (2019) Gorerite, IMA 2019-080. CNMNC Newsletter No. 52, December 2019, page 892; Mineralogical Magazine, 83, 887–893.

Gray I.E., Madsen, I.C. and Haggerty S.E. (1987) Structure of a new upper-mantle, magnetoplumbite-type titanate mineral from the Prairie Creek (Arkansas) lamproite. American Mineralogist, 72, 633–636.

Gray I.E., Velde, D. and Criddle A.J. (1998) Haggertyite, a new magnetoplumbite-type titanate mineral from the Prairie Creek (Arkansas) lamproite. American Mineralogist, 83, 1323–1329.

Haggerty S.E., Gray I.E., Madsen I.C., Criddle A.J., Stanley, C.J. and Erlank A.J. (1989) Hawthorneite, Ba₃[Ti₄Cr₂Fe₄Mg]O₉·₆, a new metasomatic magnetoplumbite-type mineral from the upper mantle. American Mineralogist, 74, 668–675.

Holtstam D. and Norrestam R. (1993) Lindqvistite, Pb₂MgFe₂O₅·₂₁, a novel hexagonal ferrite mineral from Jakobsberg, Filipstad, Sweden. American Mineralogist, 78, 1304–1312.

Holtstam D. (1994) Mineral chemistry and parageneses of magnetoplumbite from the Filipstad district, Sweden. European Journal of Mineralogy, 6, 711–724.

Holtstam D., Norrestam R. and Sjödin A. (1995) Plumboferrite: new mineralogical data and atomic arrangement. American Mineralogist, 80, 1065–1072.

Holtstam D. (1996) Iron in hibonite: a spectroscopic study. Physics and Chemistry of Minerals, 23, 452–460.
