American Mineralogist, Volume 62, pages 403-410, 1977

Classification and nomenclature of the pyrochlore group

D. D. Hogarth

Department of Geology, University of Ottawa
Ottawa, Canada K1N 6N5

Abstract

The IMA Subcommittee on Nomenclature of the Pyrochlore Group recommends the following classification and nomenclature:

- **Group**: pyrochlore \([A_{x-n}B_{n}O_{2n+1}OH_{n}]^{x−n} \cdot pH_{2}O\]
- **Subgroups**: pyrochlore, microilute, betafite
- **Species**: pyrochlore, kathpyrochlore, bariopyrochlore, ytropyrochlore, ceriopyrochlore, plumbopyrochlore, uranopyrochlore (pyrochlore subgroup); microilute, stannomicroilute, bariomicroilute, plumbomicroilute, bismutomicroilute, uratimicroilute (microilute subgroup); yitrobetaite, plombetafite, betafite (betaite subgroup).

Subgroups are divided according to \(B\)-atoms (Nb, Ta, Ti) and species according to \(A\)-atoms (K, Sn, Ba, REE, Pb, Bi, U). Forty-eight names related to the pyrochlore group should be dropped, and five type specimens should be reinvestigated.

Introduction.

The pyrochlore group comprises a series of cubic oxides containing essential amounts of niobium, tantalum, or titanium. Pyrochlore itself was described by Wöhler in 1826, microilute by Shepard in 1835, and “hatchettolite” by Smith in 1877. The remaining members were all described in the present century.

Prior to the late 1950’s, Dana’s System of Mineralogy (Palache et al., 1944, p. 747–757) provided the accepted classification of the pyrochlore minerals. In this classification pyrochlore–microilute was described as a series, and nine similar minerals were appended as “likely members” of this series. Betaite and “djalmaite” (ibid, p. 803–805) were excluded, but with the cautionary statement that “considerable uncertainty” exists concerning their relationship with pyrochlore and microilute. These two minerals were later shown, chemically and structurally, to retain the pyrochlore structure with many of the larger cation sites unfilled (Borodin and Nazarenko, 1957; Hogarth, 1961).

In the 1960s and 1970s many new analyses of pyrochlore minerals were published, revealing a wide range of compositions and leading to many new mineral names. In the same period several schemes of classification were proposed including those of Ginzburg et al. (1960), van der Veen (1963), and Bonshtedt-Kupletskaya (1966). Adding to this growing complexity, the literature continued to perpetuate mineral “species” of questionable validity, such as blomstrandite, ellsworthite, and chalcolamprite, and synonyms such as mendeleevite and betaite, neontantalite and microilute, koprite and pyrochlore. Clearly a need existed for a universally accepted, rational classification and a revised nomenclature.

In view of this need, the IMA Commission on New Minerals and Mineral Names, at the request of the chairman Dr. Michael Fleischer, established a Subcommittee on Pyrochlore Nomenclature. A. H. van der Veen, Arnhem, Netherlands, was appointed chairman in August, 1966, and he, in turn, selected the following members:

1. **Subcommittee, voting members**
   - E. M. Bonshtedt-Kupletskaya, Moscow, U.S.S.R.
   - T. Deans, London, England (Secretary)
   - M. Guépin, Paris, France
   - D. D. Hogarth, Ottawa, Canada
   - Akira Kato, Tokyo, Japan
   - L. Van Wambecque, Brussels, Belgium

---

1 For the IMA Subcommittee on Nomenclature of the Pyrochlore Group.

2 Died July, 1974

3 Retired Feb., 1976
The pyrochlore group comprises those multiple cubic oxides having the following characteristics:
(a) essential amounts of niobium, tantalum, and titanium, either individually or in combination,
(b) the space group $Fd	ext{3}m$,
(c) the pyrochlore structure as defined by Gaertner (1930) and Brandenberger (1931), and
(d) the general formula $A_2^+\cdot B_{1-x}O_4(\text{OH},\text{F})_{x-1/2}$.

In the case of metamict minerals, compositional equivalents which produce the pyrochlore phase on ignition (preferably in vacuum or inert atmosphere) are admitted to the scheme. Isostructural minerals, such as antimonates of the stibiconite series and tungstates related to ferritungstate, are excluded.

Three subgroups are recommended, based on the atomic proportions of the $A$-atoms Nb, Ta, and Ti.

The recommended subgroups are:

- **Pyrochlore Subgroup** in which $\text{Nb} + \text{Ta} > 2\text{Ti}$ and $\text{Nb} > \text{Ta}$.
- **Microlite Subgroup** in which $\text{Nb} + \text{Ta} > 2\text{Ti}$ and $\text{Ta} > \text{Nb}$.
- **Betalite Subgroup** in which $2\text{Ti} > \text{Nb} + \text{Ta}$.

The above compositional limits for the subgroups were adopted because of a natural clustering of compositions and a relative scarcity of titanium-rich analyses (see Fig. 1). Titanium-rich species range from 33 to 55 percent Ti, where $\text{Nb} + \text{Ta} + \text{Ti} = 100$ atom percent. Analyses reporting larger amounts of titanium may represent mixtures. In contrast, most pyrochlores and microlites fall in the range 70–100 percent Nb and Ta, respectively. Subdivision of the pyrochlore group according to the predominance of Nb, Ta, and Ti atoms would therefore restrict the titanium subgroup to few examples, and would cause wide variations of compositions in the pyrochlore subgroup. Accordingly, it was eventually ruled that any mineral with $2\text{Ti} > \text{Nb} + \text{Ta}$ belongs to the betalite subgroup.

Within the subgroups, individual species are defined with respect to $A$-atoms (i.e., Na, Ca, K, Sn, Ba, REE, Pb, Bi, U) in the following manner:
- (a) Na-Ca members. Sodium or calcium, but no other $A$-atom, shall exceed 20 percent of the total $A$-atoms present, and
- (b) other members. One or more $A$-atoms other than Na or Ca shall exceed 20 percent of the total $A$-atoms present.

The figure 20 percent corresponds favorably with recent practice in describing betalite, uranopyrochlore, and uranmicrolite, the most common species after pyrochlore and microlite.

The proposed classification is based on total $A$-ions (excluding oxonium), not on $A$-sites available. Thus deficiency of $A$-cations or filling of vacant $A$-sites by oxonium does not affect the classification.

Special rules apply in the case of lanthanides and yttrium. Although no example is known in the pyrochlore group of a single rare-earth element exceeding 20 percent of the $A$-atoms, several rare earths may occur together in significant amounts. When their total exceeds 20 percent of the total $A$-atoms, the Subcommittee recommends that the mineral be given separate species status. The well-known tendency for the rare earths to be predominantly of the cerium group (light lanthanides La – Eu, styled $\Sigma\text{Ce}$), or the yttrium group (Y + heavier lanthanides $\Sigma\text{Y}$), also prevails, and has created a further twofold subdivision.

**Nomenclature and species**

The current 16 species of the pyrochlore group recommended in this study are listed and defined in
Table 1. Their names reflect the decision to adopt chemical names in preference to “orthodox” names. Thus uranopyrochlore replaces hatchetolite, uranmicrolite replaces djalmaitite, etc. Applicability of the Levinson nomenclature (Levinson, 1966) was referred to, but not recommended by the Commission. The root names for species of the Nb- and Ta-rich subgroups, as also the names of the subgroups themselves, are derived from the “orthodox” names of the Na-Ca members. However, as no Na-Ca member has been definitely established for the Ti-rich subgroup, the Subcommittee recommends that betafite, the most common member, be used as root name for this subgroup.

The bismuthomicrolite of Zalashkova and Kukharchik (1957) was considered as a new species but rejected by the Subcommittee because it contained insufficient Bi (4 atom % of the A-ions). The Subcommittee recommends this name be used for the bismuth member of the microlite subgroup as defined in the preceding section and first described (as west-grenite) by Knorr and Morse (1963).

The use of additional adjectival prefixes is optional, and should normally be restricted to the A-atom next in abundance after the principal constituent, following Palache et al. (1944, p. 43). Thus bariopyrochlore from the type locality can be called strontian bariopyrochlore (Ba 44%; Sr 32% of the A-atoms present).

Recommended names are given below. Note that, with the approval of the Commission, six new names are introduced: kalipyrochlore, bariopyrochlore, ytropyrochlore, ceripyrochlore, stannomicrolite, and baromicrolite. Bismutomicrolite is redefined.

Species of the pyrochlore group
Pyrochlore (Wöhler, 1826)

<table>
<thead>
<tr>
<th>Subgroups defined by 8 atoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nb, Ta, Ti</td>
</tr>
<tr>
<td>Na + Ca, but no other A-atoms &gt; 20% total A-atoms</td>
</tr>
<tr>
<td>Species defined by A-atoms</td>
</tr>
<tr>
<td>K</td>
</tr>
<tr>
<td>Sn</td>
</tr>
<tr>
<td>Ba</td>
</tr>
<tr>
<td>REE**</td>
</tr>
<tr>
<td>Pb</td>
</tr>
<tr>
<td>Bi</td>
</tr>
<tr>
<td>U</td>
</tr>
<tr>
<td>REE = Y + (La - Lu), and for purposes of species definition, REE counts as one A-atom.</td>
</tr>
<tr>
<td>** ZY = Y + (Gd - La), ZCe = La - Eu.</td>
</tr>
</tbody>
</table>

Fig. 1. The three subgroups of the pyrochlore group. Compositions are plotted atomically from data in Bonshtedt-Kupetskaya (1966). Minerals no longer included in the group (minerals with the samarskite phase, “hatchetolite” from Hybla, Ontario, and “titanpyrochlore” from Tangen, Norway) are not plotted.
Kalipayrochlore (described but not named by Van Wambke, 1965, p. 9-15)
Bariopyrochlore (name replaces pandaita, q.v.)
Ytropyrochlore (Kupriyana, unpublished; described as obruchevite by Kupriyana et al., 1964, anal. 63)
Cerrapyrochlore (name replaces mazgacite, q.v.)
Plumbopyrochlore (Skorobogatova et al., 1966)
Uranopyrochlore (Holmquist, 1896; name replaces hatchettolite, q.v.)

Species of the microlite subgroup
Microlite (Shepard, 1835)
Sutraonicmicrolite (name replaces sukulaite, q.v.)
Bariomicrolite (name replaces tsieboorite, q.v.)
Plumbomicrolite (Hey, 1964, p. 1147; based on Saffranikoff and Van Wambke, 1961)
Bismutonicmicrolite (name replaces westgrenite, q.v.)
Uranonicmicrolite (Strunz, 1957; name replaces djamaite, q.v.)

Species of the betaflite subgroup
Ytrobetaflite (Kalita, 1959)
Plumbobetaflite (Guzneev et al., 1969)
Betaflite (Lacroix, 1912b)

Synonyms, doubtful and discredited names, and species not belonging to the pyrochlore group

The many synonyms and other names associated with the pyrochlore group are listed alphabetically below, and discussed in light of the proposed nomenclature.

Alanobetaflite (Kawai, 1960) may possibly belong to the pyrochlore group and betaflite subgroup, with unusual gross substitution of Al and some Sn and U. More data are needed.

Azopyrrhite (Hubbard, 1886) probably belongs to the pyrochlore group, but as quantitative analyses are lacking, the mineral cannot be classified or renamed at this time.

Bloomstrandite (Lindström, 1874) has been assumed to belong to the pyrochlore group. It is possibly uranopyrochlore, but adequate analyses are lacking and new data are desirable.

Calciosamarskite (Ellsworth, 1928) has the composition of uranian ytropyrochlore, but the mineral is metamict, and proof that it belongs to the pyrochlore group is lacking. Van Wambke (1970) suggests that a somewhat similar metamict mineral from Zaire may be yttrian uranopyrochlore with a high proportion of Fe³⁺ in its B-positions. Further study seems desirable before deciding the status of this mineral.

Ceruanopyrochlore (Lin et al., 1973) is a cerian pyrochlore. The name should be dropped.

Chalcolamprite (Flink, 1898; 1901) contains a “large number of microscopical inclusions” (Flink, 1901, p. 163) and apparently represents an impure pyrochlore. The 10.86 percent SiO₂ may be due to impurities. The name should be dropped.

Colubromicrolite (Villiers, 1941) is an unnecessary synonym of pyrochlore. The name should be dropped.

Djamaite (Guimarães, 1939) is a synonym for uranmicrolite. The name should be dropped.

Ellsworthite (Walker and Parsons, 1923a) conforms to the new definition of uranopyrochlore. The name should be dropped.

Endecolite (Flink, 1901) is probably an impure pyrochlore. The few tiny analysed crystals “were scraped” from aegirine. The 11.48 percent weight loss in HF and H₂SO₄ was assumed to be SiO₂, essential to the composition of the mineral. The name should be dropped.

Fluorochlore (Hermann, 1850) is an early synonym of pyrochlore, not used by later writers. The name should be dropped.

Haddamite (Shepard, 1870) is assumed to be a synonym of microlite, but analyses are lacking. The name should be dropped.

Hatchettolite (Smith, 1877) is a synonym of uranopyrochlore. The name should be dropped.

Hydrochlore (Hermann, 1850) is an early synonym of pyrochlore, not used by later writers. The name should be dropped.

Hydropriochlore (Ivanov et al., 1944) is probably an altered metamict pyrochlore. The name should be dropped.

Kopite (Knop, 1875) is a poorly defined variety of pyrochlore. The type specimen is not available, but most specimens from the type locality are pyrochlore (see Van Wambke, 1964, p. 67 for analyses). Jakob’s analysis (Brandenberger, 1931) shows 9.73 percent Fe₂O₃, and contamination is suspected. The name should be dropped.

Marignacite (Weidmann and Lenher, 1907) is a synonym of cerian pyrochlore. The name should be dropped.

Mendelevite or mendelevite (Vernadskii, 1914; 1923) is a synonym of betaflite. The accepted analysis (see Chukhrov and Bonshheid-Kupletskaya, 1967, p. 175-176, anal. 9) conforming to the redefinition of this species, although the proportion of uranium is little above the necessary minimum. The name should be dropped.
Metasimosomite (Simpson, 1938, p. 88; Bowley, 1939; Taylor, 1939, p. 93) is a synonym of microtilite. The name should be dropped.

Mumellite (Van Wambeke, 1970) is a synonym of plumbomicrolite. The name should be dropped.

Neotantalite (Termier, 1902) has long been recognized as either microtilite or a closely-related mineral. The original analysis (by Pisan) showed Fe and Mn as the principal A-atoms and the absence of Ca. Re-examination of Termier’s type material by Gasperini (1972) showed the mineral to be metamict microtilite with large deficiencies in the A-ions, which may be filled by Ba, Pb, U, and Ca. Fe and Mn were present as impurities. The name should be dropped.

Niobpyrochlore (Machatschki, 1932) is an unnecessary synonym for pyrochlore. The name should be dropped.

Niobtantalpyrochlore (Machatschki, 1932), implying a composition with Nb = Ta, must be renamed either pyrochlore or microtilite, according to the analysis. The name should be dropped.

Nuloite (Lokka, 1928), a mixture of yttropyrochlore and other niobium oxide minerals relates to wikitite (q.v.), must be discredited as a species. Obruchevite (Kalita, 1957) is a name later shown to have been given to two different species (Gorzhevskaya and Sidorenko, 1969). One of these, brown obruchevite, after heating to 700°C, crystallized to the sanhreite S phase (q.v.). The other, black obruchevite, was subsequently renamed yttropyrochlore (Kuprianova, 1970, unpublished). The Soviet Union’s Commission of New Minerals (KNM) and Mineralogical Terminology have recommended the name yttropyrochlore replace this type of obruchevite.

Pandaitite (Jäger et al., 1959) is a synonym for baripyrrochlore. The name should be dropped.

Priaocite (Yurk, 1941, p. 24), previously regarded as an altered pyrochlore (Dzhun, 1963), has been shown to belong to the sanarskite group (Gorzhevskaya and Sidorenko, 1974) and must be excluded from the pyrochlore group.

Pyrochlore-microtilite (Beus et al., 1962), implying a composition with Nb = Ta must be renamed either pyrochlore or microtilite, according to the analysis.

Pyrochlore-wikitite (Strunz, 1957), being a mixture, must be discredited; see wikitite, below.

Pyrhrite (Rose, 1839, p. 562; 1842, p. 383-385) belongs to the pyrochlore group, but cannot be classified because the type material has not been analyzed. The name should be dropped.

Rijkeboerite (van der Veen, 1963) is a synonym for barionmicrotilite. The name should be dropped.

Saniresite (Lacroix, 1912a) has the composition of a plumbian uranopyrochlore (see Van Wambeke, 1970, p. 138). However, although this mineral is metamict, apparently with octahedral habit, it recrystallizes on heating (Gorzhevskaya et al., 1966; Gorzhevskaya and Sidorenko, 1971) to a phase, “S”, related to synthetic UTaO6S (Gasperini, 1965) and lesser amounts of a pyrochlore phase. The name should be dropped.

Scheteligite (Björlykke, 1937) may possibly belong to the betaifite subgroup, with complex substitution by Y, Mn, Sh, W, Bi, but more data are needed.

Silicate-wikitite (Strunz, 1957) must be discredited, being a mixture; see wikitite.

Sibionmicrotilite (Quensel and Berggren, 1938) must be discredited, being a mixture of microtilite, sibiontantalite, and stibnite (see Rosin and Westgren, 1938).

Sukulaite (Vorma and Siivola, 1967) is a synonym for stannomicrolite. The name should be dropped.

Tangentite (Gagarin and Cuomo, 1949) was a name presumptuously given to titanium-rich “betaifites” from Norway (Tangen quarry near Kragerø). Two of the analyses correspond to betaifite, and one to the tinanian equivalent of pyrochlore. Recently W. L. Griffin, of the Mineralogisk Museum, Oslo, has shown that the specimens analyzed were mixtures (see titanopyrochlore). The name is discredited.

Tantalbetaifite (Kalita and Bykova, 1961) is a synonym for betaifite. The name should be dropped.

Tantalohatchettolite (Villiers, 1941) is a synonym for uranmicrolite. The name should be dropped.

Tantalo-obruchevite (van der Veen, 1963), intended for the yttrium-rich member of the microtilite group, has not been found.

Tantalytrichlorite (Machatschki, 1932) is a synonym of microtilite. The name should be dropped.

Titanbetaifite (Ginzburg et al., 1960) is a synonym of betaifite as redefined above. The name should be dropped.

Titanmicrolite (Strunz, 1966, erroneously ascribed to van der Veen, 1963), with Ti > Ta > Nb, has not been found.

Titano-obruchevite (van der Veen, 1963) is a synonym of yttrobetaifite, and the name must be discarded.

Titanopyrochlore (Machatschki, 1932) was named as a hypothetical titanium equivalent of pyrochlore. One of the analyses by Björlykke (1931, anal. 3), from the Tangen Quarry near Kragerø, Norway, conforms to a dominantly calcian member of the betaifite subgroup. W. L. Griffin (correspondence, April 1974) made a microprobe analysis of Björlykke’s specimen
and found it to be composed of at least five different phases. A "hatchettolite" from Hybla, Ontario (Walker and Parsons, 1923b, anal. 1) approaches titanpyrochlore in bulk, but the material is inhomogeneous (Hogarth, unpublished data). The name should be dropped.

Westgrenite (Knoering and Mrose, 1963) is a synonym of bismutomicrolite. The name should be dropped.

Wiktite (Ramsay, 1899, p. 379) and α- and β-wiktite (Ant-Wuorinen, 1936) are mixtures of yttropyrochlore or other members of the pyrochlore group with euxenite and silicates (Fauquier, 1960; Beus and Kalita, 1961) and must be discredited (see also pyrophyllite and silicate-wiktite).

Yttrﻯnophytolite (Kalita, 1959) has insufficient uranium to be classified as uranopyrochlore. It is synonymous with yttropyrochlore. The name should be dropped.

Zirconolite and niobozirconolite from U.S.S.R. (Borodin et al., 1956; 1960) are synonymous with zirkelite (Hussak and Prior, 1985). Parker and Fleischer (1968, p. 31) have listed niobozirconolite as a member of the "pyrochlore-batite-microlite series," but its monoclinic symmetry excludes it from the pyrochlore group (Pudovkina et al., 1974).

Conclusions

The proposed scheme of classification permits the addition of new species to the group when data become available. In naming these minerals, we recommend a chemical nomenclature, as outlined above. The following minerals or variants are poorly defined: aluminobatite, azopyrhyrite, blomstrandite, caucasosamarskite, schetelitite. Type materials should be reinvestigated, and their mineralogical status confirmed.

Acknowledgments

The Subcommittee gratefully acknowledges the help of Dr. Michael Fleischer, past-Chairman of the IMA Commission of New Minerals and Mineral Names, and Professor Glauco Gottardi, the present secretary of the Commission. Much assistance was given by the All-Union Mineralogical Society of the USSR, especially by Professors V. A. Frank-Kamenetskii, Chairman of the Soviet Union's Commission of New Minerals and New Mineral Names, and E. K. Lazarenko, Chairman of the Commission on Mineralogical Terminology and Nomenclature. Dr. W. L. Griffin, Curator of the Mineralogical Museum, Oslo, kindly microprobed Tanger "titanpyrochlore." H. R. Stacey, of the Geological Survey of Canada, read the manuscript and made valuable suggestions for its improvement. Publication expenses were paid by a National Research Council of Canada Operating Grant (A 2122) made to D. D. Hogarth.

References


HOGARTH: THE PYROCHLORE GROUP


(1965) A study of some niobium-bearing minerals of the

133


Manuscript received, January 19, 1977; accepted for publication, January 24, 1977.

Appendix: Table 2. Pyrochlore-group minerals described since 1977

<table>
<thead>
<tr>
<th>Name</th>
<th>Idealized formula</th>
<th>Abstract in American Mineralogist</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Bariobetaufite]¹</td>
<td>Ba₂(Nb,Ti)₂(O,OH)₂</td>
<td>[Knudsen, 1989]</td>
</tr>
<tr>
<td>Ca₂[Ti,Fe]₂(O,OH)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natroblasteanite*⁴</td>
<td>(Na,Fe)Ta₂O₆</td>
<td>Voloshin et al. <em>AM 67,</em> 413–414 (1982)</td>
</tr>
<tr>
<td>Stibioberlange*</td>
<td>(Si,Fe)Ta₂O₆</td>
<td>Voloshin et al. <em>AM 69,</em> 407–408 (1984)</td>
</tr>
<tr>
<td>Stibibiobetaufite*⁵</td>
<td>(Si,Fe)Ta₂O₆</td>
<td>Cherty et al. <em>AM 66,</em> 1278 (1981)</td>
</tr>
<tr>
<td>Stibibiobetaufite*⁶</td>
<td>(Si,Fe)Ta₂O₆</td>
<td>Groat et al. <em>AM 73,</em> 1499 (1988)</td>
</tr>
<tr>
<td>Stontiopyrochlore¹</td>
<td>Sr₂Nb₂O₇</td>
<td>Lapin et al. <em>AM 73,</em> 930 (1988)</td>
</tr>
<tr>
<td>Thoribiopyrochlore¹</td>
<td>Th₂Nb₂O₇</td>
<td>Gaidukova &amp; Zborik (1962)¹</td>
</tr>
</tbody>
</table>

Symbols: approved by Commission on New Minerals and Mineral Names, IMA

¹ name disagrees with IMA recommendations, cestbitantite = stibibiobetaufite, natroblasteanite = bismutoberlange
² data not submitted to IMA for approval