

Classification and nomenclature of the pyrochlore group

D. D. HOGARTH¹

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 $[A_{2-m}B_2O_6(O,OH,F)_{1-n} \cdot pH_2O]$
Subgroups pyrochlore, microlite, betafite
Species pyrochlore, kalipyrochlore, bariopyrochlore, ytropyrochlore, ceriopyrochlore, plumbopyrochlore, uranpyrochlore (pyrochlore subgroup); microlite, stannomicrolite, bariomicrolite, plumbomicrolite, bismutomicrolite, uranmicrolite (microlite subgroup); ytrobetafite, plumbobetafite, betafite (betafite 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, microlite 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-microlite was described as a series, and nine similar minerals were appended as "likely members" of this series. Betafite and "djalmaite" (*ibid*, p. 803-805) were excluded, but with the cautionary statement that "considerable uncertainty" exists concerning their relationship with pyrochlore and microlite. 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 Ginz-

burg *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 betafite, neotantalite and microlite, koppite 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.²
T. Deans, London, England (Secretary)³
M. Gasperin, Paris, France
D. D. Hogarth, Ottawa, Canada
Akira Kato, Tokyo, Japan
L. Van Wambeke, Brussels, Belgium

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

² Died July, 1974

³ Retired Feb., 1976

(2) *Commission observers, non-voting*

M. Fleischer, Washington, D.C., U.S.A. until Feb., 1968

C. Guillemin, Orléans, France

M. H. Hey, London, England since Feb., 1968

The Subcommittee functioned almost entirely by correspondence. In general, their criteria were based on published information, but in two cases, members re-examined type specimens. Certain decisions required a vote, and in the few instances when opinions of members were equally divided, the chairman cast the deciding vote.

At the outset, members were faced with the choice of recommending "orthodox" names, often well-established and of deserving origin, or appropriate chemical names. After detailed consideration, the Subcommittee and later the Commission ruled in favor of a chemical nomenclature.

The Subcommittee submitted its first complete report to Dr. Fleischer in December 1971. He, in turn, distributed copies to affiliated societies for comments and suggestions, which were forwarded to the Subcommittee in November 1973. A revised report was then submitted in August 1974, and its recommendations were ratified by the Commission in 1975 and 1976. The present report summarizes the reports of the Subcommittee (unpublished, prepared by T. Deans), incorporates suggestions and decisions taken by the Commission, and represents the final conclusions of the Subcommittee.

Classification

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 $Fd3m$,

(c) the pyrochlore structure as defined by Gaertner (1930) and Brandenberger (1931), and

(d) the general formula $A_{2-m}B_2O_6(O,OH,F)_{1-n} \cdot pH_2O$.

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 ferritungstite, are excluded.

Three subgroups are recommended, based on the atomic proportions of the *B*-atoms Nb, Ta, and Ti. The recommended subgroups are:

Pyrochlore Subgroup in which $Nb + Ta > 2Ti$ and $Nb > Ta$,

Microlite Subgroup in which $Nb + Ta > 2Ti$ and $Ta \geq Nb$,

Betafite Subgroup in which $2Ti \geq Nb + Ta$.

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 $Nb + Ta + Ti = 100$ 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 $2Ti \geq Nb + Ta$ belongs to the betafite subgroup.

Within the subgroups, individual species are defined with respect to *A*-atoms (*viz* 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 betafite, uranpyrochlore, 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 $La \rightarrow Eu$, styled ΣCe), or the yttrium group ($Y +$ heavier lanthanides $Ga \rightarrow Lu$, styled ΣY), 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 uranpyrochlore replaces hatchettolite, uranmicrolite replaces djalmaite, 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 westgrenite) by Knorring and Mrose (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,

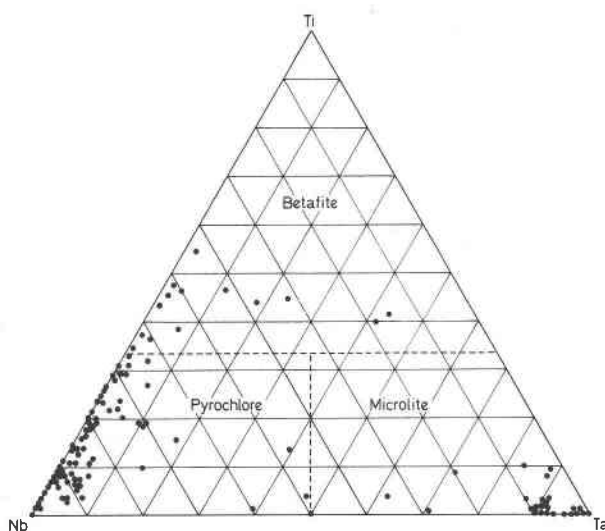


Fig. 1. The three subgroups of the pyrochlore group. Compositions are plotted atomically from data in Bonshtedt-Kupletskaya (1966). Minerals no longer included in the group (minerals with the samiresite phase, "hatchettolite" from Hybla, Ontario, and "titanpyrochlore" from Tangen, Norway) are not plotted.

with the approval of the Commission, six new names are introduced: kalipyrochlore, bariopyrochlore, ytropyrochlore, ceriopyrochlore, stannomicrolite, and bariomicrolite. Bismutomicrolite is redefined.

Species of the pyrochlore group

Pyrochlore (Wöhler, 1826)

Table 1. The pyrochlore group

SUBGROUPS defined by B atoms v/z Nb, Ta, Ti		PYROCHLORE Nb+Ta>2Ti Nb>Ti	MICROLITE Nb+Ta>2Ti Ta>Nb	BETAFITE 2Ti>Nb+Ta	
SPECIES defined by A-atoms v/z K, Sn, Ba, REE, Pb, Bi, U	Na+Ca, but no other A-atoms >20% total A-atoms	pyrochlore	microlite		
	One or more A-atoms, other than Na or Ca, >20% total A-atoms Species named by most abundant A-atom, other than Na or Ca	K	kalipyrochlore		
		Sn		stannomicrolite	
		Ba	bariopyrochlore	bariomicrolite	
		REE*	ytropyrochlore (ΣY>ΣCe)** ceriopyrochlore (ΣCe>ΣY)		ytrobetafite (ΣY>ΣCe)
		Pb	plumbopyrochlore	plumbomicrolite	plumbobetafite
		Bi		bismutomicrolite	
		U	uranpyrochlore	uranmicrolite	betafite

*REE = Y + (La + Lu), and for purposes of species definition, REE counts as one A-atom.
** ΣY = Y + (Gd + Lu); ΣCe = La + Eu.

Kalipyrochlore (described but not named by Van Wambeke, 1965, p. 9–15)

Bariopyrochlore (name replaces pandaite, *q.v.*)

Yttropyrochlore (Kupriyanova, unpublished; described as obruchevite by Kupriyanova *et al.*, 1964, anal. 63)

Ceripyrochlore (name replaces marignacite, *q.v.*)

Plumbopyrochlore (Skorobogatova *et al.*, 1966)

Uranpyrochlore (Holmquist, 1896; name replaces hatchettolite, *q.v.*)

Species of the microlite subgroup

Microlite (Shepard, 1835)

Stannomicrolite (name replaces sukulaite, *q.v.*)

Bariomicrolite (name replaces rijkeboerite, *q.v.*)

Plumbomicrolite (Hey, 1964, p. 1147; based on Sa-fiannikoff and Van Wambeke, 1961)

Bismutomicrolite (name replaces westgrenite, *q.v.*)

Uranmicrolite (Strunz, 1957; name replaces djalmaite, *q.v.*)

Species of the betafite subgroup

Yttrobetafite (Kalita, 1959)

Plumbobetafite (Ganzeev *et al.*, 1969)

Betafite (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.

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

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

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

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

Ceruranopyrochlore (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.

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

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

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

Endeolite (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.

Fluochlore (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 *uranpyrochlore*. The name should be dropped.

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

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

Koppite (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 Wambeke, 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 *ceripyrochlore*. The name should be dropped.

Mendelyevite or *mendelejevite* (Vernadskii, 1914; 1923) is a synonym of *betafite*, the accepted analysis (see Chukhrov and Bonshtedt-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.

Metasimpsonite (Simpson, 1938, p. 88; Bowley, 1939; Taylor, 1939, p. 93) is a synonym of *microlite*. The name should be dropped.

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

Neotantalite (Termier, 1902) has long been recognized as either *microlite* or a closely-related mineral. The original analysis (by Pisani) showed Fe and Mn as the principal A-atoms and the absence of Ca. Reexamination of Termier's type material by Gasperin (1972) showed the mineral to be metamict *microlite* 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 \approx Ta, must be renamed either *pyrochlore* or *microlite*, according to the analysis. The name should be dropped.

Nuolaite (Lokka, 1928), a mixture of yttropyrochlore and other niobium oxide minerals relates to *wiikite* (*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 *samiresite* S phase (*q.v.*). The other, black obruchevite, was subsequently renamed *yttropyrochlore* (Kupriyanova, 1970, unpublished). The Soviet Union's Commission of New Minerals (KNM) and Mineralogical Terminology have recommended the name *yttropyrochlore* replace this type of *obruchevite*.

Pandaite (Jäger *et al.*, 1959) is a synonym for *bariopyrochlore*. The name should be dropped.

Priazovite (Yurk, 1941; 1956, p. 24), previously regarded as an altered pyrochlore (Dzhun, 1963), has been shown to belong to the *samaraskite* group (Gorzhevskaya and Sidorenko, 1974) and must be excluded from the pyrochlore group.

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

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

Pyrrhite (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 *bariomicrolite*. The name should be dropped.

Samiresite (Lacroix, 1912a) has the composition of a *plumbian uranpyrochlore* (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 UTa_3O_{10} (Gasperin, 1965) and lesser amounts of a pyrochlore phase. The name should be dropped.

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

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

Stibiomicrolite (Quensel and Berggren, 1938) must be discredited, being a mixture of *microlite*, *stibio-tantalite*, and *stibnite* (see Rosén and Westgren, 1938)

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

Tangenite (Gagarin and Cuomo, 1949) was a name presumptuously given to titanium-rich "betafites" from Norway (Tangen quarry near Kragerø). Two of the analyses correspond to *betafite*, and one to the titanian 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.

Tantalbetafite (Kalita and Bykova, 1961) is a synonym for *betafite*. 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 microlite group, has not been found.

Tantalpyrochlore (Machatschki, 1932) is a synonym of *microlite*. The name should be dropped.

Titanbetafite (Ginzburg *et al.*, 1960) is a synonym of *betafite* 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 *yttrbetafite*, and the name must be discarded.

Titanopyrochlore (Machatschki, 1932) was named as a hypothetical titanian equivalent of *pyrochlore*. One of the analyses of Bjørlykke (1931, anal. 3), from the Tangen Quarry near Kragerø, Norway, conforms to a dominantly calcian member of the betafite subgroup. W. L. Griffin (correspondence, April 1974) made a microprobe analysis of Bjørlykke'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 (Knorring and Mrose, 1963) is a synonym of *bismutomicolite*. The name should be dropped.

Wiikite (Ramsay, 1899, p. 379) and α - and β -*wiikite* (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 *pyrochlore-wiikite* and *silicate-wiikite*).

Yttrohatchettolite (Kalita, 1959) has insufficient uranium to be classified as *uranpyrochlore*. 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, 1895). Parker and Fleischer (1968, p. 31) have listed *niobozirconolite* as a member of the "pyrochlore-betafite-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: aluminobetafite, azorpyrrhite, blomstrandite, calciosamarskite, scheteligite. 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 Mineralogisk Museum, Oslo, kindly microprobed Tangen "titanpyrochlore." H. R. Steacy, 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

- Ant-Wuorinen, J. (1936) Der Wiikite und seine chemische Zusammensetzung. *Bull. Comm. géol. Finlande*, 115, 213-229.
- Beus, A. A., and A. P. Kalita (1961) Recent data on the so-called wiikite. *Dokl. Akad. Nauk SSSR*, 141, 705-708. (In Russian).
- , E. A. Severov, A. A. Sitnin and K. D. Subbotin (1962) Albitized and greisenized granites (apogranites). *Izvest. Akad. Nauk SSSR*, Moscow, 194 p. (In Russian).
- Bjørlykke, H. (1931) Ein Betafitmineral von Tangen bei Kragerø. *Norsk Geol. Tidsskr.*, 12, 73-88.
- (1937) Mineral paragenesis of some granite pegmatites near Kragerø, southern Norway. *Norsk Geol. Tidsskr.*, 17, 1-16.
- Bonshtedt-Kupletskaya, E. M. (1966) Systematization of the pyrochlore-microlite mineral group. *Zap. Vses. Mineral. Obshchestva* 95, 134-144. (In Russian).
- Borodin, L. S., A. V. Bykova, T. A. Kapitonova and Yu. A. Pyatenko (1960) New data on zirconolite and its niobian variety. *Dokl. Akad. Nauk SSSR*, 134, 1188-1191. (In Russian).
- and I. I. Nazarenko (1957) Chemical composition of pyrochlore and isomorphic replacements in the $A_2B_2X_7$ molecule. *Geokhimiya*, No. 4 [for 1957], 278-295. (In Russian with English summary).
- , — and T. L. Richter (1956) The new mineral zirconolite—a complex oxide of the AB_3O_7 type. *Dokl. Akad. Nauk SSSR*, 110, 845-848. (In Russian).
- Bowley, H. (1939) Simpsonite (sp. nov.) from Tabba Tabba, Western Australia. *J. R. Soc. W. Aust.* 25, 89-92.
- Brandenberger, E. (1931) Die Kristallstruktur von Koppit. *Z. Kristallogr.*, 76, 322-334.
- Chukrov, F. and E. M. Bonshtedt-Kupletskaya, Eds. (1967) *Mineralogy*, Vol 2, Pt. 3, Nauka Press, Moscow. (In Russian).
- Dzhun, V. S. (1963) New data on the characteristics of priazovite. *Dopovidi Akad. Nauk URSR*, 10, 1379-1384. (In Ukrainian with summaries in Russian and English).
- Ellsworth, H. V. (1928) A mineral related to samarskite from the Woodcox Mine, Hybla, and from Parry Sound, Ontario. *Am. Mineral.*, 13, 63-68.
- Fauquier, D. (1960) Sur la "wiikite" et la "loranskite." *C. R. Acad. Sci.*, 250, 3032-3034.
- Flink, G. (1898) Berättelse om en mineralogisk resa i Syd-Grönland sommaren 1897. *Medd. Grönland*, 14, 221-262.
- (1901) On the minerals from Narsarsuk on the Firth of Tunugdliarfik in southern Greenland. *Medd. Grönland*, 24, 7-180.
- Gaertner, H. R. von (1930) Die Kristallstrukturen von Loparit und Pyrochlor. *Neues Jahrb. Mineral., Beil.-Band*, 61, Abt. A, 1-30.
- Gagarin, G. and J. R. Cuomo (1949) Algunas proposiciones sobre nomenclatura mineralógica. *Comun. inst. nac. invest. cienc. nat. del Museo Argentino Cienc. Natl. "Bernardino Rivadavia," Cienc. geol.*, 1, No. 5, 21 p.
- Ganzev, A. A., A. F. Efimov, and G. V. Lyubomilova (1969) Plumbobetafite, a new variety in the pyrochlore group. *Trudy Mineral. Muz. Akad. Nauk SSSR*, 19, 135-137. (In Russian).
- Gasperin, M. (1965) Synthèse et données cristallographiques d'un oxyde double de tantalite et d'uranium. *C. R. Acad. Sci.*, 261, 3417-3419.
- (1972) Contribution à l'étude de l'état métamictite: la "néotantalite", une espèce discréditée. *Bull. Soc. fr. Minéral. Cristallogr.*, 95, 451-457.
- Ginzburg, A. I., S. A. Gorzhevskaya, E. A. Erofeeva and G. A. Sidorenko (1960) Titanium-tantalum-niobates. *Geol. Mes-*

- torozhd. Redk. Elem. Nauchn.-Issled. Inst. Mineral. Syrya, 10, 168 p. (In Russian).
- Gorzhevskaya, S. A., G. P. Lugovskoi and G. A. Sidorenko (1966) Siberian samiresite. *Geol. Mestorozhd. Redk. Elem. Vses. Nauchn.-Issled. Inst. Mineral. Syrya*, 30, 51–71. (In Russian).
- and G. A. Sidorenko (1969) The obruchevite problem. *Trudy Mineral. Muz. Akad. Nauk SSSR*, 19, 138–145. (In Russian).
- , — (1971) The structural type samiresite. *Roentgenogr. Mineral. Syrya*, 8, 49–62. (In Russian).
- , — (1974) Products of samarskite alteration. *Trudy Mineral. Muz. Akad. Nauk SSSR*, 23, 72–77. (In Russian).
- Guimarães, C. P. (1939) Djalmita, um novo mineral radioactivo. *Annaes Acad. Brasil. Ciências*, 11, 347–350.
- Hermann, R. (1850) Untersuchungen über die Zusammensetzung der Tantalzerze. *J. Prakt. Chem.*, 50, 164–200.
- Hey, M. H. (1964) Twenty-third list of new mineral names. *Mineral. Mag.*, 33, 1125–1160.
- Hogarth, D. D. (1961) A study of pyrochlore and betafite. *Can. Mineral.*, 6, 610–633.
- Holmquist, P. J. (1896) Synthetische Studien über die Perowskit- und Pyrochlormineralien. *Bull. Upsala Univ., Inst., Geol.*, 3, 181–266.
- Hubbard, L. L. (1886) Ueber Azor-Pyrrhite und Zirkon von Laacher See sowie Pyrrhit und Azorit von San Miguel. *Verh. Naturhist. Ver. preuss. Rheinland, Sitz.*, 43, 214–220.
- Hussak, E. and G. T. Prior (1895) Lewisite and zirkelite, two new Brazilian minerals. *Mineral. Mag.*, 11, 80–88.
- Ivanov, A. A., I. B. Borovskii and I. A. Yaroshch (1944) Pyrochlore from the Vishnevye Mountains, Urals. *Zap. Vses. Mineral. Obshch.*, 73, 56–58. (In Russian with English summary).
- Jäger, E., E. Niggli and A. H. van der Veen (1959) A hydrated barium-strontium pyrochlore in a biotite rock from Panda Hill, Tanganyika. *Mineral. Mag.*, 32, 10–25.
- Kalita, A. P. (1957) Composition of obruchevite, a hydrated uranium-yttrium variety of pyrochlore. *Dokl. Akad. Nauk SSSR*, 117, 117–120. (In Russian).
- (1959) New data on some minerals in the Alakurtti Vein No. 1. *Trudy Instit. Mineral. Geokhim. Kristalloghim. Redk. Elem.*, 2, 164–172. (In Russian).
- and A. V. Bykova (1961) Tantalum betafite from the Ladoga pegmatites. *Trudy Inst. Mineral. Geokhim. Kristalloghim. Redk. Element.*, 7, 104–107. (In Russian).
- Kawai, T. (1960) Chemical studies on minerals containing rare elements from the Far East: No. 54. Betafite from former Kaijo, near Mukden, Manchuria. *Nippon Kagaku Zasshi*, 81, 1219–1220. (In Japanese).
- Knop, A. (1875) Über "Koppit" von Kaiserstuhl. *Neues Jahrb. Mineral.*, 50, 66–69.
- Knorring, O. Von and M. E. Mrose (1963) Westgrenite and waylandite, two new bismuth minerals from Uganda (abstr.). *Geol. Soc. Am. Spec. Pap.*, 73, 256–257.
- Kupryanova, I. I., M. I. Volkova and Z. I. Goroshchenko (1964) Rare earth minerals in a molybdenite deposit in the European U.S.S.R. *Trudy Mineral. Muz. Akad. Nauk SSSR*, 15, 123–133. (In Russian).
- Lacroix, A. (1912a) Sur un groupe de niobo-tantalites cubiques (radioactifs) des pegmatites de Vakinankaratra. *Bull. Soc. fr. Minéral.*, 35, 84–92.
- (1912b) Quelques nouvelles observations sur les minéraux uranifères de la province de l'Itasy, Madagascar. *Bull. Soc. fr. Minéral.*, 35, 233–235.
- Levinson, A. A. (1966) A system of nomenclature for rare-earth minerals. *Am. Mineral.*, 51, 152–158.
- Lin, Teh-Sung, Wen-Hsing Hung and Tse-Min Shih (1973) Ceruranopyrochlore—a new variety of pyrochlore. *Geochimica*, 1, 39–45. (In Chinese).
- Lindström G. (1874) Blomstrandit, ett nytt uranmineral från Nohl. *Geol. Fören. Förh.*, 2, 162–164.
- Lokka, L. (1928) Über Wiikite. *Bull. Comm. géol. Finlande*, 82, 68 p.
- Machatschki, F. (1932) Die Pyrochlor-Romeit-Gruppe. *Chem. Erde*, 7, 56–76.
- Palache, C., H. Berman and C. Frondel (1944) *System of Mineralogy of . . . Dana, 7th ed.*, Vol. 1, John Wiley and Sons, New York.
- Parker, R. L. and M. Fleischer (1968) Geochemistry of niobium and tantalum. *U.S. Geol. Surv. Prof. Pap.*, 612.
- Pudovkina, Z. V., L. S. Dubakina, S. I. Levedeva and Yu. A. Pyatenko (1974) Study of Brazilian zirkelite. *Zap. Vses. Mineral. Obshch.*, 103, 368–372. (In Russian).
- Quensel, P. and T. Berggren (1938) Minerals of the Varuträsk pegmatite. XI. The niobate-tantalate group. *Geol. Fören. Förh.*, 60, 216–225.
- Ramsay, W. (1899) A third list of new mineral names. *Mineral. Mag.*, 13, 363–381.
- Rose, G. (1839) Beschreibung einiger neuen Mineralien des Urals. *Pogg. Ann. Phys. Chem.*, 48, 551–572.
- (1842) *Mineralogische-geognostische Reise nach dem Ural, dem Altai und dem Kaspischen Meere*, Vol. 2, Verlag Sanderschen Buchhandlung, Berlin.
- Rosén, O. and A. Westgren (1938) On the structure and composition of minerals belonging to the pyrochlore-atopite group and an X-ray analysis of disintegrated stibiomicrolite. *Geol. Fören. Förh.*, 60, 226–235.
- Safiannikoff, A. and L. Van Wambeke (1961) Sur une terme plombifère du groupe pyrochlore-microlite. *Bull. Soc. fr. Minéral. Cristallogr.*, 84, 382–384.
- Shepard, C. U. (1835) Microlite, a new mineral species. *Am. J. Sci.*, 27, 361–362.
- (1870) Unknown mineral (microlite?) in Haddam columbite. *Am. J. Sci.*, 50, 93–94.
- Simpson, E. S. (1938) Annual Report of the Chemical Branch. *Rep. Dept. Mines. W. Aust. for 1937*, 86–96.
- Skorobogatova, N. V., G. A. Sidorenko, K. A. Dorofeeva and T. I. Stolyarova (1966) Plumbopyrochlore. *Geol. Mestorozhd. Redk. Elem. Vses. Nauchn.-Issled. Inst. Mineral. Syrya*, 30, 84–95. (In Russian).
- Smith, J. L. (1977) Examination of the American minerals, No. 6. *Am. J. Sci.*, 13, 359–369.
- Strunz, H. (1957) *Mineralogische Tabellen*, 3rd ed. Akademische Verlagsgesellschaft, Leipzig.
- (1966) *Mineralogische Tabellen*, 4th ed. Adademische Verlagsgesellschaft, Leipzig.
- Taylor, L. E. R. (1939) X-ray studies of simpsonite. *J. Roy. Soc. W. Aust.*, 25, 93–97.
- Termier, P. (1902) Sur la néotantalite, espèce minéral nouvelle. *Bull. Soc. fr. Minéral.*, 25, 34–38.
- van der Veen, A. H. (1963) A study of pyrochlore. *Nederlands Geol. Mijnbouwkd. Gen. Verh.*, Geol. Ser., 22, 188 p.
- Van Wambeke, L. (1964) Géochimie minérale des carbonatites du Kaiserstuhl. In *Les Roches Alcalines et les Carbonatites du Kaiserstuhl*. Euratom publication EUR 1827, d,f,e, 65–91.
- (1965) A study of some niobium-bearing minerals of the

- Lueshe carbonatite deposit (Kivu, Republic of Congo). *Eurotom Rep.*, 2110e, 31 p.
- (1970) Alteration processes of some of the complex titanio-niobo-tantalates and their consequences. *Neues Jahrb. Mineral., Abh.*, 112, 117-149.
- Vernadskii, V. I. (1914) Study of some radioactive mineral deposits of Russia during the summer of 1914. *Bull. Acad. Imp. Sci. (6th Ser.)*, 8, 1353-1384. (In Russian).
- Vernadsky, W. J. [Vernadskii, V. I.] (1923) La mendelejevite, nouveau minéral radioactif. *C. R. Acad. Sci.*, 176, 993-994.
- Villiers, J. E. de (1941) Columbomicrolite from Eshowe, Natal. *Am. Mineral.*, 26, 501-506.
- Vorma, A. and J. Siivola (1967) Sukulaite— $Ta_2Sn_2O_7$ —and wodginitite as inclusions in cassiterite in the granite pegmatite in Sukula, Tammela, in S. W. Finland. *Bull. Comm. géol. Finlande*, 229, 173-187.
- Walker, T. L., and A. L. Parsons (1923a) Ellsworthite and associated minerals from Hybla, Ontario. *Univ. Toronto Studies, Geol. Ser.*, 16, 13-20.
- , —— (1923b) Hatchettolite and associated minerals from Hybla, Ontario. *Univ. Toronto Studies, Geol. Ser.*, 16, 21-24.
- Weidmann, S. and V. Lenher (1907) Marignacite, a new variety of pyrochlore from Wausau, Wisconsin. *Am. J. Sci.*, 23, 287-292.
- Wöhler, F. (1826) Ueber den Pyrochlor, eine neue Mineral Species. *Pogg. Ann. Phys. Chem.*, 7, 417-428.
- Yurk, Yu. Yu (1941) Priazovite, a new mineral. *Dopov. Akad. Nauk URSS*, 3, 15-22. (In Ukrainian).
- (1956) *Redkie mineraly pegmatitov Priazovya*. Izdatel. Akad. Nauk URSS (Inst. Geol. Nauk), Kiev. 68 p. (In Russian).
- Zalashkova, N. E. and M. V. Kukharchik (1957) Bismuto-microlite—a new variety of microlite. *Trudy Inst. Mineral. Geokhim. Kristallokhim. Redk. Elem.* 1, 77-79. (In Russian).

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