# "NIOBOLOPARITE":
# A RE-INVESTIGATION AND DISCREDITATION*

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ABSTRACT

A study of "nioboloparite" samples from the Khibina massif, Kola Peninsula, Russia, demonstrates that the majority is merely calcian niobian loparite-(Ce), niobian calcian loparite-(Ce) or niobian loparite-(Ce). The minerals do not differ in structure or significantly, with respect to their composition, from common loparite-(Ce) that occurs as a primary mineral throughout the Khibina complex. They differ from common loparite-(Ce) in that they are zoned from a Nb-enriched core to a margin enriched in rare-earth elements and depleted in Nb. This zonation trend is the opposite of that developed during crystallization of primary loparite and is considered to reflect reaction of primary relatively Nb-rich loparite with late-stage *REE*-enriched fluids. One sample of "nioboloparite" from a pegmatite vein in ijolite–urtite is a lanthanian lueshite characterized by enrichment of La over Ce. The term "nioboloparite" does not correspond to a distinct mineral species and must be discredited.

*Keywords:* perovskite, "nioboloparite", loparite, lueshite, Khibina complex, Russia.

SOMMAIRE

D'après une étude d'échantillons de "nioboloparite" provenant du massif de Khibina, sur la péninsule de Kola, en Russie, il s'agit simplement, dans la plupart des cas, de loparite-(Ce) calcique niobienne, de loparite-(Ce) niobienne calcique, ou bien de loparite-(Ce) niobienne. Les échantillons ne diffèrent pas sensiblement de la loparite-(Ce) commune, qui est répandue dans le massif de Khibina, ni par leur structure, ou de façon importante, dans leur composition. Il s'en distinguent toutefois par leur zonation, allant d'un coeur enrichi en Nb à une bordure appauvrie en Nb et enrichie en terres rares. Cette zonation est contraire à celle qui se développe au cours de la cristallisation primaire de la loparite. Elle résulterait plutôt d'une réaction de la loparite niobienne primaire avec une phase fluide tardive enrichie en terres rares. Un exemple de "nioboloparite" provenant d'un filon de pegmatite dans l'unité à ijolite–urtite est en fait un échantillon de lueshite lanthanifère, contenant plus de La que de Ce. D'après nos données, le nom "nioboloparite" ne correspond pas à une espèce minérale distincte; nous en proposons ici la radiation.

(Traduit par la Rédaction)

*Mots-clés:* pérovskite, "nioboloparite", loparite, lueshite, complexe de Khibina, Russie.

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*Unfortunately, this paper was accepted for publication and set into type before the IMA Commission on New Minerals and Mineral Names was given an opportunity to review a proposal to discredit nioboloparite. The editor regrets this oversight, and urges authors wishing to change mineral nomenclature to submit proposals to the CNMMN before sending their manuscripts to editors of journals for publication.

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## INTRODUCTION

Loparite $[Na(Ce,La)Ti_2O_6]$, the rare-earth-element-rich member of the perovskite group of minerals, is common in the peralkaline nepheline syenites of the Khibina complex, Kola Peninsula, Russia. A mineral enriched in Nb relative to the amounts found in most examples of loparite from Khibina was named "nioboloparite" by Tikhonenkov & Kazakova (1957).

Although the name has been widely used, especially in the Russian mineralogical literature, and is found in most mineral lexicons, it has never been approved as a valid mineral species by the Commission on New Minerals and Mineral Names (CNMMN) of the International Mineralogical Association.

Subsequently, "nioboloparite" has been reported from several more localities in the Khibina and the adjacent Lovozero massif (Shliukova & Unanova 1972, Semenov 1972, Sokolova 1972, Kozyreva & Men'shikov 1974, Kostyleva-Labuntsova et al. 1978), and as a late-stage mineral overgrowing perovskite in an ultramafic lamprophyre from the Schryburt Lake carbonatite complex, Ontario (Platt 1994).

As a part of a comprehensive investigation of perovskite-group minerals from the Khibina and Lovozero alkaline complexes (Mitchell & Chakhmouradian 1996, Chakhmouradian et al. 1995, 1996), we considered it important to re-investigate "nioboloparite" from the type locality at the Eudialyte Pass between Mt. Kuel'por and Mt. Kukisvumchorr. The objective of this investigation was to determine if "nioboloparite" is a useful mineral name; Platt (1994) and Mitchell (1996) have recently suggested that it is merely niobium-rich loparite and unlikely to be a distinct mineral species.

## GEOLOGICAL SETTING

The geology and petrogenesis of the Khibina complex have been described by Eliseev et al. (1939), Zak et al. (1972), Galakhov (1966), Sørensen (1970), and Arzamastsev (1994). This pluton is the largest body of nepheline syenite in the world (1327 km² at the current erosion level). The Khibina massif is now believed to be a multiphase intrusive complex consisting of derivatives of nephelinitic and alkali-basaltic magmas (Arzamastsev 1994). Both parental magmas were available between 377 and 362 Ma; the Khibina massif is contemporaneous with the emplace-ment of the Lovozero, Afrikanda and other alkaline plutons in the Kola–Karelian province (Kramm et al. 1993). The emplacement of the separate intrusive series was tectonically controlled by the Middle Paleozoic Kovdor – Khibina – Lovozero – Ivanovka fault zone (Orlova 1993, Arzamastsev 1994). On the basis of field observations (Galakhov 1966, Arzamastsev 1990) and isotopic data (Kramm et al. 1993), it is believed that emplacement of peridotites, pyroxenites, melilitolites and other rocks derived from the nephelinitic parental magma preceded the emplace-ment of nepheline and alkali syenites. The former rocks are present mainly as xenoliths in the latter, which comprise the bulk of the Khibina pluton.

The major intrusive series, from the margin of the massif inward, are: leucocratic coarse-grained massive nepheline syenite (khibinite), trachytic khibinite, a layered complex of melteigite, ijolite, urtite and asso-ciated apatite-nepheline rock, poikilitic eudialyte nepheline syenite (rischorrite) and associated juvite, medium-grained nepheline syenite (liavochorrite), massive foyaite, and trachytic foyaite.

Most petrologists consider that the above sequence corresponds to the order of emplacement (Eliseev et al. 1939, Zak et al. 1972), although some geologists view the layered complex as remnants of an earlier intrusion derived from the nephelinite magma (e.g., Arzamastsev 1990, 1994). Pegmatites, occurring as simple unzoned to multistage differentiated bodies, are known in all major intrusive series of the massif. Their distribution, textural, structural features and mineralogy have been described in detail by Slepnev (1962), Tikhonenkov (1963), and Kostyleva-Labuntsova et al. (1978).

## OCCURRENCE OF "NIOBOLOPARITE"

The type locality of "nioboloparite" consists of a 6-meter-thick pegmatite vein emplaced in pyroxene rischorrite (nepheline syenite with large laths of microcline that poikilitically enclose euhedral grains of nepheline). In this vein, the mineral occurs only in the natrolite-rich central zones, where it is accompanied by aegirine, pyrochlore, murmanite, lamprophyllite, lorenzenite and other accessory phases. "Nioboloparite" forms cubo-octahedral crystals and interpenetration twins (Tikhonenkov & Kazakova 1957).

Subsequently, "nioboloparite" has been found in: (1) an arfvedsonite–feldspar vein emplaced in the Proterozoic country rocks that host the Khibina massif (Shliukova & Unanova 1972), (2) an aegirine vein in rischorrite, Khibina (Shliukova & Unanova 1972), (3) a pegmatite vein in ijolite–urtite, Khibina (Sokolova 1972, Kostyleva-Labuntsova et al. 1978), (4) a natrolite-bearing vein in micaceous rischorrite, Khibina (Kozyreva & Men'shikov 1974), (5) natroli-tized urtite and an unspecified rock from the Lovozero massif (Semenov 1972).

These occurrences show that, except for the specimen found by Shliukova & Unanova (1972) in the vein emplaced in country rocks, all examples of "nioboloparite" from Khibina occur in rocks genetically related to the melteigite – urtite – rischorrite series. In common with the type locality, they occur in highly differentiated pegmatite bodies, commonly in their central late-stage zones, and are associated with acicular aegirine, natrolite, sodalite, wadeite, nenadkevichite, mangan-neptunite and other minerals that apparently formed at the latest stages of the evolution of pegmatites.

Samples of material identified as "nioboloparite" on the basis of their occurrence and paragenesis, investigated in this study, were taken from the following localities: Khb–62: an aegirine–albite vein in rischorrite, Mt. Eveslogchorr; Khb–91: an

aegirine – sodalite – microcline vein in ijolite–urtite, Kukisvumchorr mine; Khb–92: from the type locality for "nioboloparite", Eudialyte Pass; Khb–93: an aegirine–microcline–natrolite vein in rischorrite, Mt. Kukisvumchorr; Khb–94: a sodalite-bearing vein in rischorrite, Mt. Kaskasnyunachorr. The specimens studied exhibit a broad variation in morphology, from ordinary "fluorite-law" intergrowths to inter-penetration twins of cubo-octahedral individuals, separate untwinned cubo-octahedra and cubo-dodecahedral crystals.

We attempted, without success, to locate either the holotype material studied by Tikhonenkov & Kazakova (1957) or the original investigators. The holotype material has not been deposited in any of the official depositories of new minerals in Russia (Fersman Mineralogical Museum; State Geological Museum, Moscow; the Mineralogical Museum of the Mining Institute, St. Petersburg; Mineralogical Museum of the Ilmeny State Reserve, Miass). Samples of the holotype also could not be located in the Mineralogical Museum of the Geological Institute of the Kola Science Centre, Apatity, which normally retains specimens of new minerals discovered at Khibina.

As the type locality for the holotype material is geographically and geologically well characterized, we obtained samples (Khb–92) from this locality; we believe this material to be identical to that examined by Tikhonenkov & Kazakova (1957).

### ANALYTICAL METHODS

All mineral compositions were determined by X-ray energy-dispersion spectrometry (EDS) using a Hitachi 570 scanning electron microscope equipped with a LINK ISIS analytical system incorporating a Super ATW Light Element Detector (133 eV FwHm Mn$K$) at Lakehead University. EDS spectra of loparite crystals were acquired for 300 seconds (live time) with an accelerating voltage of 20 kV and beam current of 0.86 nA. X-ray spectra were collected and processed with the LINK ISIS–SEMQUANT software package. Full ZAF corrections were applied to the raw X-ray data. The following well-characterized standards were employed for the determination of loparite composi-tions: Khibina loparite (Na, La, Ce, Pr, Nd, Nb, Ti), Magnet Cove perovskite (Ca, Fe), synthetic $SrTiO_3$ (Sr), $BaSiO_3$ (Ba) and metallic Th and Ta. A multi-element standard for the rare-earth elements ($REE$) was used, as experience has shown that this gives more accurate data than single $REE$ standards when using EDS spectrum-stripping techniques. However, peak profiles used for the analytical X-ray lines were obtained using single $REE$ fluoride standards. The accuracy of the method was cross-checked by wave-length-dispersion electron-microprobe analysis of sample Khb–91 using an automated CAMECA SX–50

microprobe located at the University of Manitoba using methods described by Mitchell & Vladykin (1993).

With few exceptions, in which the composition varies dramatically within the same grain, back-scattered electron imagery of the samples studied, at the low beam-currents used for the analyses, did not reveal any heterogeneity in the distribution of the major elements. However, line scanning plus analysis undertaken at different points within each apparently homogeneous grain of loparite revealed that some zoning is present. Consequently, each loparite grain was analyzed in several places to ensure that the complete compositional range present was determined.

Mitchell (1996) has demonstrated that the compo-sitions of most naturally occurring perovskite-group minerals can be expressed in terms of relatively few end-member compositions, namely: $CaTiO_3$ (perovskite), $Na(REE)Ti_2O_6$ (loparite), $NaNbO_3$ (lueshite), $SrTiO_3$ (tausonite), $PbTiO_3$ (macedonite), $Ca_2Fe^{3+}NbO_6$ (latrappite), $Ca_2Nb_2O_7$, $REE_2Ti_2O_7$, $CaThO_3$, $CaZrO_3$, $KNbO_3$ and $BaTiO_3$. Compositional data were recalculated into these perovskite-group end-

TABLE 1. REPRESENTATIVE COMPOSITIONS OF LOPARITE-(Ce)

| Wt% | 1 C | 1 R | 2 C | 2 R | 3 C | 3 R | 4 C | 4 R | 5 C | 5 R |
|---|---|---|---|---|---|---|---|---|---|---|
| $Nb_2O_5$ | 10.22 | 17.84 | 10.31 | 34.80 | 20.56 | 26.45 | 22.27 | 18.54 | 14.41 | |
| $Ta_2O_5$ | 0.58 | 0.01 | 0.72 | 0.96 | 0.37 | 0.65 | 0.50 | 0.25 | 0.21 | |
| $TiO_2$ | 38.86 | 36.02 | 39.15 | 24.96 | 32.12 | 31.91 | 34.35 | 35.09 | 36.99 | |
| FeO | 0.22 | 0.08 | 0.38 | n.d. | 0.03 | n.d. | n.d. | 0.08 | 0.18 | |
| $ThO_2$ | 0.68 | 1.94 | 0.42 | 1.14 | 0.68 | 0.79 | 0.98 | 2.04 | 2.35 | |
| $La_2O_3$ | 10.54 | 9.48 | 11.33 | 8.28 | 10.31 | 9.68 | 10.80 | 11.87 | 12.31 | |
| $Ce_2O_3$ | 18.46 | 15.20 | 19.50 | 11.64 | 18.36 | 14.58 | 15.63 | 16.81 | 18.02 | |
| $Pr_2O_3$ | 2.53 | 1.39 | 1.09 | 1.12 | 2.13 | 0.54 | n.d. | 0.65 | 0.55 | |
| $Nd_2O_3$ | 3.67 | 2.64 | 3.31 | 1.55 | 3.69 | 2.11 | 2.21 | 1.48 | 1.62 | |
| CaO | 3.67 | 3.38 | 4.17 | 1.36 | 0.50 | 2.28 | 2.00 | 1.88 | 1.79 | |
| SrO | 2.23 | 3.59 | 1.74 | 1.36 | 0.95 | 1.82 | 1.67 | 1.92 | 1.88 | |
| $Na_2O$ | 7.89 | 8.90 | 8.23 | 11.84 | 10.06 | 10.52 | 10.25 | 9.76 | 8.91 | |

| | 99.56 | 100.49 | 100.39 | 99.00 | 99.76 | 101.33 | 100.55 | 100.37 | 99.21 | |

Structural formulae based on 3 oxygens

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Nb | 0.135 | 0.230 | 0.134 | 0.453 | 0.274 | 0.335 | 0.284 | 0.241 | 0.193 | |
| Ta | 0.005 | – | 0.006 | 0.007 | 0.003 | 0.005 | 0.004 | 0.002 | 0.002 | |
| Ti | 0.851 | 0.771 | 0.847 | 0.541 | 0.711 | 0.671 | 0.728 | 0.758 | 0.803 | |
| Fe | 0.005 | 0.002 | 0.009 | – | 0.007 | – | 0.002 | 0.005 | | |
| Th | 0.005 | 0.013 | 0.003 | 0.008 | 0.005 | 0.005 | 0.006 | 0.013 | 0.016 | |
| La | 0.113 | 0.099 | 0.120 | 0.088 | 0.112 | 0.100 | 0.112 | 0.126 | 0.134 | |
| Ce | 0.197 | 0.158 | 0.205 | 0.123 | 0.198 | 0.149 | 0.161 | 0.177 | 0.195 | |
| Pr | 0.027 | 0.014 | 0.011 | 0.012 | 0.023 | 0.005 | – | 0.007 | 0.006 | |
| Nd | 0.038 | 0.027 | 0.034 | 0.016 | 0.039 | 0.021 | 0.022 | 0.015 | 0.017 | |
| Ca | 0.114 | 0.103 | 0.129 | 0.042 | 0.016 | 0.068 | 0.060 | 0.058 | 0.057 | |
| Sr | 0.038 | 0.059 | 0.029 | 0.023 | 0.016 | 0.029 | 0.027 | 0.032 | 0.032 | |
| Na | 0.445 | 0.492 | 0.459 | 0.661 | 0.574 | 0.571 | 0.560 | 0.544 | 0.511 | |

End member compositions (mol.%)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $CaThO_3$ | 0.61 | 1.80 | 0.37 | 1.20 | 0.68 | 0.78 | 0.96 | 1.96 | 2.30 | |
| $SrTiO_3$ | 5.14 | 8.49 | 3.90 | 3.64 | 2.41 | 4.56 | 4.15 | 4.70 | 4.69 | |
| $Ce_2Ti_2O_7$ | 7.03 | 4.04 | 5.20 | 4.54 | 8.24 | 5.17 | 2.65 | 2.61 | 3.91 | |
| $NaNbO_3$ | 9.49 | 16.46 | 9.38 | 36.89 | 20.58 | 26.20 | 21.86 | 17.84 | 14.13 | |
| $CaTiO_3$ | 15.01 | 12.97 | 16.89 | 5.53 | 1.67 | 9.77 | 8.23 | 6.55 | 5.95 | |
| Loparite | 62.71 | 56.23 | 64.28 | 48.21 | 66.42 | 53.52 | 62.15 | 66.34 | 69.03 | |

1 Khb–92; 2 Khb–57, loparite from a microcline vein in rischorrite, Mt. Kaskasnyunachorr; 3 Khb–93; 4 Khb–94; 5 Khb–62. C = core, R = rim. n.d. = not detected. Total Fe is expressed as FeO.

TABLE 2. REPRESENTATIVE COMPOSITIONS OF
LANTHANIAN LUESHITE

| | C | I | R | | C | I | R |
|---|---|---|---|---|---|---|---|
| Wt.% | | | | Structural formulae(O=3) | | | |
| $Nb_2O_5$ | 43.64 | 41.45 | 41.69 | Nb | 0.550 | 0.528 | 0.530 |
| $Ta_2O_5$ | 0.56 | 0.25 | 0.45 | Ta | 0.004 | 0.002 | 0.003 |
| $TiO_2$ | 21.91 | 22.50 | 22.78 | Ti | 0.460 | 0.475 | 0.481 |
| FeO | 0.02 | 0.03 | n.d. | Fe | 0.005 | 0.007 | - |
| $ThO_2$ | 4.68 | 4.62 | 3.49 | Th | 0.030 | 0.030 | 0.022 |
| $La_2O_3$ | 7.50 | 7.15 | 7.37 | La | 0.077 | 0.074 | 0.077 |
| $Ce_2O_3$ | 5.34 | 7.10 | 7.37 | Ce | 0.055 | 0.073 | 0.076 |
| $Pr_2O_3$ | n.d. | 0.60 | 0.75 | Pr | - | 0.006 | 0.007 |
| $Nd_2O_3$ | 0.30 | 0.79 | 1.24 | Nd | 0.003 | 0.008 | 0.013 |
| CaO | 2.00 | 1.62 | 1.44 | Ca | 0.060 | 0.049 | 0.043 |
| SrO | 2.07 | 1.85 | 1.78 | Sr | 0.034 | 0.031 | 0.029 |
| $Na_2O$ | 12.52 | 12.68 | 12.00 | Na | 0.677 | 0.691 | 0.655 |
| | 100.35 | 100.74 | 100.33 | | | | |

| Endmember components (mol.%) | | | |
|---|---|---|---|
| $CaThO_3$ | 3.28 | 3.18 | 2.48 |
| $SrTiO_3$ | 3.70 | 3.24 | 3.23 |
| $CaTiO_3$ | 3.32 | 2.07 | 2.34 |
| Loparite | 29.76 | 34.70 | 38.36 |
| $NaNbO_3$ | 59.94 | 56.80 | 53.59 |

Sample Khb–91; C = core, I = intermediate, R = rim. Total Fe
expressed as FeO, n.d. = not detected. All data obtained by
wavelength dispersion electron microprobe analysis.

members using an APL program for PC following
methods suggested by Mitchell (1996).

X-ray-diffraction (XRD) powder patterns (Cu
radiation) were obtained with a Philips 3710
diffractometer at Lakehead University operated in
the scanning mode at 40 kV and 30 mA. Unit-cell
parameters were calculated from the patterns using the
least-squares method.

COMPOSITIONAL DATA

Representative compositions of the loparite samples
analyzed are given in Tables 1 and 2. Recalculation
of the data into perovskite-group end-member
compositions (mol.%) indicates that all samples are
essentially members of the ternary solid-solution series
perovskite ($CaTiO_3$) – lueshite ($NaNbO_3$) – loparite
(Na,*REE*)$Ti_2O_6$. In the recalculation procedure, all
*REE* as treated as forming compounds that are
isomorphous with $NaCeTi_2O_6$. As other components,
*e.g.*, $SrTiO_3$ and $CaThO_3$ are negligible, the majority of
the data may be plotted in the ternary system $CaTiO_3$ –
$NaNbO_3$ – $NaCeTi_2O_6$ (Fig. 1). As a consequence of
the dominance of La over Ce (see below), sample
Khb–91 is plotted in the ternary system $CaTiO_3$ –
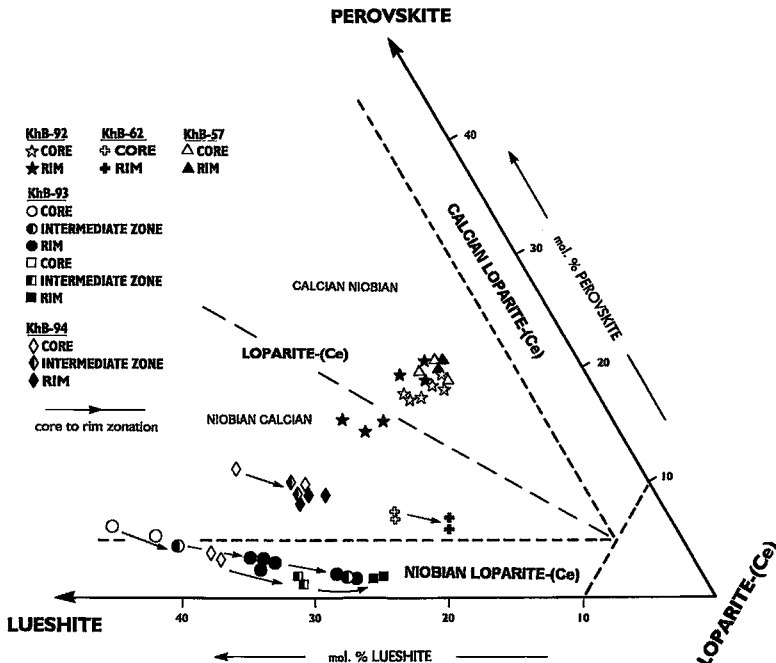$NaNbO_3$ – $NaLaTi_2O_6$ (Fig. 2).



FIG. 1. Compositions of "niboloparite" (Khb–62, Khb–92–94) analyzed in this study
plotted (mol.%) in the ternary system perovskite ($CaTiO_3$) – lueshite ($NaNbO_3$) –
loparite-(Ce) (Na*REE*$Ti_2O_6$). Sample Khb–57 is representative of primary magmatic
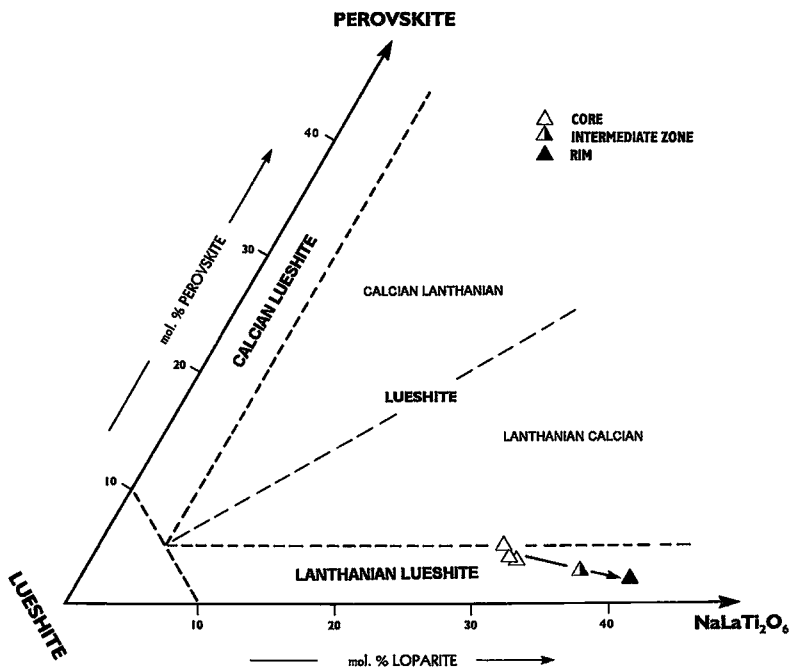perovskite from Khibina nepheline syenite.

FIG. 2. Compositions of lanthanian lueshite plotted (mol.%) in the ternary system perovskite ($CaTiO_3$) – lueshite ($NaNbO_3$) – $NaLaTi_2O_6$.

### "Nioboloparite" Khb–92

The "nioboloparite" from the type locality is weakly zoned (Fig. 1) and is unlike all other samples of "nioboloparite" analyzed in this study. In terms of its composition, the material is ordinary loparite-(Ce) with an average Nb content of 11 wt.% $Nb_2O_5$. Within the crystals, areas that are locally enriched in Nb occur adjacent to fractures in the core region (up to 13.1 wt.%), and at the margin of the grains (up to 17.8 wt.%). The Ce:La ratio ranges from 1.5 to 2.7.

Figure 1 compares the composition (Table 1, anal. 11) of loparite (Khb–57) from an aegirine–microcline vein found within Khibina rischorrite with that of Khb–92. These data demonstrate that the latter is not significantly different in composition from the common loparite of the Khibina complex.

Our data are not in accord with the high $Nb_2O_5$ plus $Ta_2O_5$ (26.3 wt.%), $K_2O$ (0.8 wt.%), MgO (0.2 wt.%), $Fe_2O_3$ (0.9 wt.%) and $H_2O$ (0.8 wt.%) contents originally reported for holotype "nioboloparite" by Tikhonenkov & Kazakova (1957). We attribute this discrepancy, in part (see below), to the fact that Tikhonenkov and Kazakova were restricted, by the analytical methods available to them, to bulk analyses of samples. Examination of our samples with BSE-

imagery reveals that many of the crystals of Khb–92 contain fractures that are filled with natrolite. In addition, many crystals are overgrown with diverse Na–*REE*–Ti–Nb silicates. Consequently, we consider that the bulk compositional data may reflect the presence of these mineral inclusions and overgrowths. However, it is also possible that the high Nb and Ta contents reported by Tikhonenkov & Kazakova (1957) result from analytical errors.

### Other samples of "nioboloparite"

Samples Khb–62, Khb–93 and Khb–94 show pronounced zonation from a Nb-enriched core to a Nb-depleted margin enriched in light rare-earth elements (*LREE*) (Table 1, Fig. 1). All crystals examined are Ce-rich, with Ce/La values ranging from 1.3 to 1.8. Although there are significant variations in major-element content within and between samples, all compositions obtained plot within the ternary system $CaTiO_3$ – $NaNbO_3$ – $NaCeTi_2O_6$ (Fig. 3). Core-to-rim zonation trends for individual crystals are distinct and plot close to the $NaNbO_3$ – $NaCeTi_2O_6$ join (Fig. 3). Sample Khb–93 exhibits the most extensive zonation, and evolves from niobian calcian loparite-(Ce) to niobian loparite-(Ce).
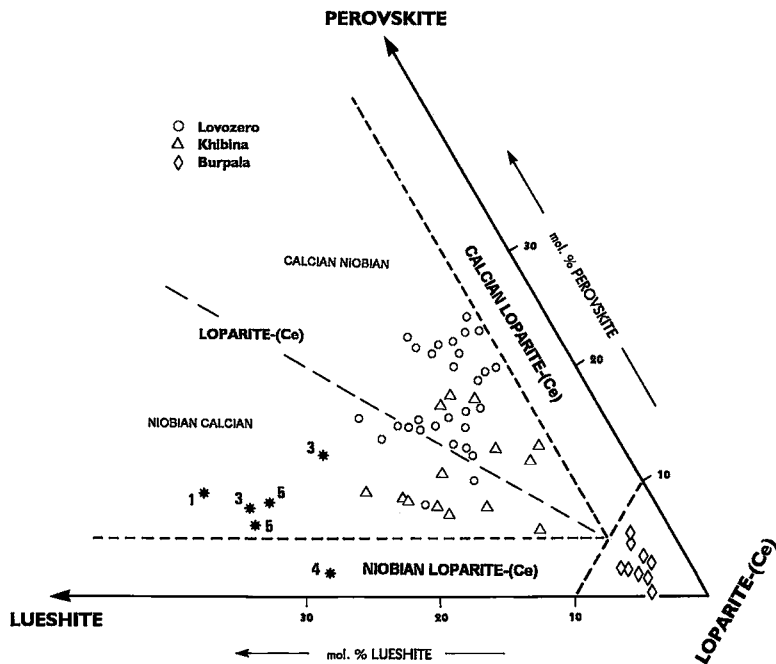
FIG. 3. Previously published compositions of "nioboloparite" from the Khibina and Schryburt Lake complexes plotted (mol.%) in the ternary system perovskite (CaTiO$_3$) – lueshite (NaNbO$_3$) – loparite-(Ce) [Na($REE$)Ti$_2$O$_6$]. Numbered compositions (*) are from: 1 Tikhonenkov & Kazakova (1957), 2 Shliukova & Unanova (1972), 3 Semenov (1972), 4 Platt (1994). Also shown are representative compositions of primary magmatic loparite-(Ce) from the Lovozero (Mitchell & Chakhmouradian 1996), Khibina and Burpala complexes (authors' unpubl. data).

*"Nioboloparite" Khb–91*

This sample is compositionally distinct from all other samples of "nioboloparite" examined, as it is characterized by high Na and Nb contents coupled with La > Ce and Nb > Ti (Table 2). The Ce/La value ranges from 0.6 in the core to 1.0 at the margin. With respect to the predominance of La over Ce, this sample is unlike all previously studied $REE$-bearing perovskite-group minerals in which Ce > La (Khomyakov 1972, Haggerty & Mariano 1983, Bel'kov *et al.* 1988, Kozyreva *et al.* 1991, Chakhmouradian *et al.* 1995, Mitchell 1996). Accordingly, the hypothetical perovskite-group compound dominating the $REE$-based solid solutions in this mineral is considered to be NaLaTi$_2$O$_6$ rather than NaCeTi$_2$O$_6$. This La end-member has recently been synthesized by Mitchell (1996) and shown to have the orthorhombic perovskite structure.

Figure 2 and Table 2 indicate that the bulk of Khb–91 perovskite is best regarded as lanthanian lueshite rather than a La-rich variety of niobian

loparite. The zonation trend is similar to that observed for niobian loparite-(Ce), *i.e.*, Nb depletion coupled with $REE$ enrichment (Fig. 1). The trend is subparallel and close to the lueshite – loparite join in Figure 2 as a consequence of the very low CaTiO$_3$ (<10 mol.%) contents. The trend of increasing Ce/La values from core to margin suggests that ultimately the zonation trend might culminate with the formation of niobian loparite-(Ce). However, such loparite would differ substantially from the common loparite of the Khibina complex and the niobian loparite-(Ce) described above with respect to its low CaTiO$_3$ contents.

X-RAY DIFFRACTION

Although the actual symmetry of natural and synthetic loparite is orthorhombic, deviation from the ideal cubic structure is small (Hu *et al.* 1992, Mitchell 1996), and for our purposes XRD patterns may be indexed in the cubic system. Table 3 indicates that "nioboloparite" Khb–92 (type locality) and Khb–93 give XRD patterns that are very similar to that of

TABLE 3. X-RAY POWDER-DIFFRACTION DATA FOR
LOPARITE-(Ce)

| hkl | 1 | | 2 | | 3 | | 4 | |
|-----|---|---|---|---|---|---|---|---|
| | I | d | I | d | I | d | I | d |
| 100 | | | 5* | 3.906 | 21 | 3.913 | 10 | 3.853 |
| 110 | 100 | 2.76 | 100 | 2.752 | 100 | 2.766 | 100 | 2.742 |
| 111 | | | 7 | 2.248 | 3 | 2.252 | 8 | 2.238 |
| 200 | 60 | 1.951 | 35 | 1.945 | 43 | 1.955 | 45 | 1.939 |
| 210 | | | 2 | 1.735 | 2 | 1.750 | | |
| 211 | 60 | 1.592 | 38 | 1.588 | 34 | 1.594 | 29 | 1.584 |
| 220 | 40 | 1.378 | 10 | 1.376 | 10 | 1.380 | 22 | 1.372 |
| 300 | | | | | 1 | 1.301 | <1* | 1.301 |
| 310 | 30 | 1.235 | 14 | 1.231 | 9 | 1.234 | 13 | 1.228 |
| 311 | | | <1 | 1.174 | | | <1* | 1.171 |
| 222 | 10 | 1.125 | 3 | 1.124 | 2 | 1.126 | 3 | 1.121 |
| 321 | | | 13 | 1.040 | 9 | 1.042 | 11 | 1.038 |
| $a_o$ | 3.905 | | 3.8921(4) | | 3.9011(5) | | 3.8817(7) | |
| $V_o$ | | | 58.96(2) | | 59.37(2) | | 58.49(3) | |

1-3 "nioboloparite":1,(Tikhonenko & Kazakova 1957);2, Khb-92
3, Khb-93; 4 loparite Khb-57. $a_o$ = pseudocubic unit cell (Å)
$V_o$ = pseudocubic cell volume (Å³). Lines with (*) are broad.

common loparite Khb–57. Note that as a consequence of the compositional variation recognized in the samples, the pseudocubic unit-cell parameters and volumes listed in Table 3 actually correspond to their mean values. However, comparing the data in Tables 1 and 3, it is clear that an increase in the unit-cell dimensions of loparite correlates positively with increasing Na and Nb contents. This is because these elements have significantly larger ionic radii than the light *REE* and Ti, which they isomorphically replace.

A comparison of our data with those obtained by Tikhonenkov & Kazakova (1957) suggests that the XRD pattern of the holotype "nioboloparite" sample was perhaps inaccurately measured, as these authors reported a unit-cell parameter that far exceeds that of sample Khb–93, which contains similar amounts of Nb (mean $Nb_2O_5$ content of 28.6 wt.%, estimated from 25 analyses of four grains). Regardless, it is evident that all material termed "nioboloparite" does not differ in structure from that of common loparite, and thus cannot be regarded as a polymorph or polytype of the latter.

DISCUSSION

The data obtained in this study show that the majority of the "nioboloparite" samples from different occurrences associated with the melteigite – urtite – rischorrite series of the Khibina massif are merely members of the perovskite – lueshite – loparite-(Ce) solid-solution series (Fig. 1). Our data are in accord

with the bulk compositions of "nioboloparite" reported in previous studies (Fig. 3), although our sample Khb–91 is unusual in being La-enriched and is essentially lanthanian lueshite (Fig. 2).

With the exception of the "nioboloparite" from the type locality, core-to-rim zonation is from Nb-rich to Nb-depleted, *LREE*-enriched compositions. This zonation trend is contrary to that found in the majority of primary loparitic perovskite from Khibina and Lovozero nepheline syenites (Mitchell & Chakhmouradian 1996). It is also unlike compositional trends found in the pseudobinary system nepheline – loparite, in which loparite becomes richer in Nb and Sr and poorer in *REE* with decreasing temperature (Veksler *et al.* 1985). These data suggest that this contrary trend in zonation is not magmatic, but reflects the reaction of relatively Nb-rich primary niobian calcian loparite and niobian loparite with late-stage *REE*-rich fluids.

Sample Khb–92, considered to be representative of the holotype material, exhibits a weak normal zonation trend from calcian niobian loparite-(Ce) to niobian calcian loparite-(Ce), and is apparently identical to common primary loparite in the Khibina nepheline syenites (Figs. 1, 3).

Figure 3 shows that the sample analyzed by Tikhonenkov & Kazova (1957) is, in terms of its bulk composition, niobian calcian loparite-(Ce). Its composition is similar to that of our sample Khb–94, but differs significantly from that of Khb–92 (Fig. 1). As this material was obtained from the holotype locality and there is no possibility that it is a mislabeled specimen derived from elsewhere, we conclude that "nioboloparite" from the type locality must exhibit a range of composition.

CONCLUSIONS

It is shown above that, with one exception, all samples that have been termed "nioboloparite" are merely members of the perovskite – lueshite – loparite-(Ce) ternary solid-solution series. They exhibit no compositional or structural characteristics that set them apart from other samples of niobium- and calcium-bearing loparite. Although samples of the holotype are no longer available for examination, we are satisfied that we have obtained from the type locality material representative of the holotype. We have not described these samples as a neotype, as we conclude that the name "nioboloparite" (*sensu* Tikhonenko & Kazakova 1957) serves no purpose and must be abandoned as a mineral name, as the majority of "nioboloparite", is in reality, calcian niobian loparite-(Ce), niobian calcian loparite-(Ce) or niobian loparite-(Ce).

The discreditation of the name "nioboloparite" has been approved by the Commission on New Minerals and Mineral Names of the International Mineralogical Association.

The Nb-rich, La-dominant perovskite-group mineral recognized in this work is not "nioboloparite", but is actually a Na- and Nb-rich member of the lueshite – Na(La,Ce)Ti$_2$O$_6$ solid-solution series that is best termed lanthanian lueshite.

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