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Zirconolite: A Review of Localities Worldwide, and a Compilation of its Chemical Compositions

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Abstract

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Disciplines

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Comments

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Zirconolite: a review of localities worldwide, and a compilation of its chemical compositions

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SYNOPSIS. A compilation of the chemical data and brief review of the mineral zirconolite, essentially $CaZrTi_2O_7$, is presented. A total of 321 chemical analyses, 169 previously unpublished, from 39 of the 46 known terrestrial localities, and covering 10 rock types are tabulated. A brief description of the minerals associated with zirconolite is outlined for each locality. Data from all zirconolite-bearing lunar rocks have also been compiled. The recently published nomenclature scheme for zirconolite is employed throughout.

INTRODUCTION

Zirconolite, although a relatively rare accessory mineral, is found in a wide range of rock types and geological environments. To date, zirconolite has been reported from 46 terrestrial localities and from 13 lunar samples: it has not been reported in meteorites. The chemical composition of natural zirconolite can vary extensively, with the main substitutions involving rare earth elements, actinide elements, niobium and iron. Synthetic zirconolite is a major component in SYNROC, a synthetic polyphase titanate ceramic designed to immobilise high-level radioactive waste.

In this paper, we compile and tabulate all reported chemical data for natural zirconolites, including new, and previously unpublished analyses: we group zirconolites into specific rock types or paragenetic types, and denote those samples that are stored in the collections of the Mineralogy Department, The Natural History Museum, London.

NOMENCLATURE

In the literature, several minerals with stoichiometries close to $CaZrTi_2O_7$, but with different crystal structures, have been reported and this has led to confusion in the nomenclature of these minerals. The compound $CaZrTi_2O_7$ can exist as three superstructures with monoclinic, orthorhombic and trigonal symmetries (Rossell, 1980), each being a polytype (White, 1984), subsequently redefined as polytypoids (Bayliss *et al.*, 1989). However, the original type material, polymignite (Berzelius, 1824), zirkelite (Hussak & Prior, 1895) and zirconolite (Borodin *et al.*, 1956) are metamict and their structures cannot be unambiguously defined. Further problems in identification and characterisation have arisen, in part because the frequent occurrence of actinide elements in the structure may render the mineral partially or totally metamict, and in part because the often small grain size does not allow for routine crystallographic techniques to be employed. These nomenclature problems have been addressed by Nickel & Mandarino (1987) and most recently by Bayliss *et al.* (1989), who summarized the crystallographic and chemical characteristics of these minerals, detailed their historical documentation, and rationalized their nomenclature.

Under the Bayliss *et al.* (1989) IMA-approved nomenclature scheme, **zirconolite** is the non-crystalline (metamict) mineral, or the mineral with undetermined polytypoid of $CaZrTi_2O_7$; **zirconolite-3O** is the three-layered orthorhombic polytypoid of $CaZrTi_2O_7$; **zirconolite-3T** is the three layered trigonal polytypoid of $CaZrTi_2O_7$; **zirconolite-2M** is the two-layered monoclinic polytypoid, or aristotype (White, 1984) of $CaZrTi_2O_7$; **zirconolite** is polymignite (metamict), and **zirkelite** is the cubic mineral with formula $(Ti,Ca,Zr)O_{2-x}$. Smith & Lumpkin (1993) have subsequently described two additional polytypes which appear to be supercells of the zirconolite-2M and 3T structures (zirconolite-4M and -6T, respectively).

CHEMICAL COMPOSITION

Zirconolite has five cation-acceptor sites, these being Ca in 8-coordination, Zr in 7-coordination, and three distinct Ti sites: Ti(I) and Ti(III) are both 6-coordinate, and Ti(II) is 5-coordinate (Gatehouse *et al.*, 1981; Mazzi & Munno, 1983). In natural (and synthetic) zirconolites, a wide range of cation substitutions can occur (e.g. Ringwood, 1985), ranging in ionic size from 0.051nm (Ti^{4+}) to 0.112nm (Ca^{2+}) – ionic radii data from Shannon (1976) – and charge from 2+ (Mg) to 6+ (W). Predominant substitutions are: the rare earth elements including Y (REE) and actinide (ACT) elements for Ca: Hf for Zr; and Nb, Fe, Ta, Mg and W for Ti. In natural zirconolites the chemical variation is extensive; of the major components, CaO ranges from 1.83 to 16.54%, ZrO_2 from 22.82 to 44.18%, and TiO_2 from 13.56 to 44.91% (Table 1). Up to 79% of the Ca site can be replaced by other cations (e.g. analyses A4, L11, Table 3), and up to 65% of the Ti site (analysis C69, Table 3).

ZIRCONOLITE LOCALITY DETAILS

In Table 2, details of zirconolite from terrestrial and lunar localities are presented in terms of their host rock (or paragenetic type) and corresponding analysis numbers, together with references relating both to the first report for that occurrence, and to the sources of the analytical data. Full chemical analyses, where available, are given in Table 3.

Kimberlite. Raber & Haggerty (1979) report zirconolite from three localities in South Africa. All their microprobe analyses are presented in Table 3 (K1 to K3); however, two analyses (K1 and K2) have significantly higher ZrO_2 values than all other zirconolites reported. The number of Zr cations for these analyses, recalculated on the basis of 7 oxygens, exceed the theoretical value by >50% and >100%. It seems probable therefore, that these analytical data are in error, or that the minerals analysed are not zirconolite. Calzirtite has been suggested as a possible alternative mineral for one of these questionable phases (Kogarko *et al.*, 1991). Analyses K1 and K2 are thus omitted from comparative data of zirconolites (such as in Table 1).

Zirconolite described by Raber & Haggerty (1979) is very fine-grained, associated with baddeleyite, ± zircon, ilmenite, armalcolite and calcite, and is considered to have been formed as a secondary mineral due to infiltration of, and reaction with, a carbonatitic fluid.

Ultrabasic Rocks. Zirconolite has been described from two ultrabasic cumulate complexes – Laouni, Algeria (Lorand & Cottin, 1987) and Rhum, Scotland (Williams, 1978).

At Laouni zirconolite occurs as compositionally homogeneous, discrete grains up to 200μm in diameter, in plagioclase-rich adcumulates. Although baddeleyite also occurs in this intrusion, it is located in cumulates richer in trapped intercumulus liquid. Analyses U1–U2 (Table 3) are from Lorand & Cottin (1987).

In the layered, ultrabasic complex of Rhum zirconolite occurs as a rare, late-stage accessory mineral, associated with apatite, baddeleyite and zircon, predominantly in olivine-rich mesocumulates – i.e. those cumulates with a relatively high proportion of trapped (and fractionated) magma. The microprobe analysis (U3, Table 3) is from Fowler & Williams (1986).

Gabbro Pegmatite. Harding et al. (1982, 1984) describe accessory zirconolite (reported as 'zirkelite'), with acicular habit, from a gabbro pegmatite of Tertiary age at St. Kilda, Scotland. The pegmatite consists essentially of ferroaugite, ferroedenite, chlorite, magnetite, Mn-rich ilmenite, quartz and alkali feldspar. Associated with zirconolite are the accessory minerals biotite, epidote, allanite, titanite, apatite and zircon. The pegmatite is considered to have formed from the last residues of basaltic (tholeiitic) liquid from which the major Mg-minerals and feldspars of the Glen Bay Gabbro had previously precipitated.

The zirconolite analysis tabulated here (G1, Table 3) is from Fowler & Williams (1986). Harding *et al.*'s (1982) original analysis totals only 91%, as it excludes many of the heavy REE, Hf and Ta.

Since the ΣREE^{3+} exceeds 50% of the Ca site cations, it is *sensu strictu* a rare earth mineral, and following the Bayliss & Levinson (1988) nomenclature guidelines, this mineral can be classified as **zirconolite-(Y)** [subject to approval from the CNMMN].

Syenite. Zirconolite has been described from four syenite localities.

At Glen Dessarry, Scotland (Fowler & Williams, 1986), zirconolite occurs as an accessory mineral in a rock consisting of aegirine augite, edenitic amphibole, hypersolvus alkali-feldspar, orthoclase, albite and biotite. Zirconolite, typically <10μm in diameter, is enclosed by alkali feldspar phenocrysts and associated with Fe-Ti oxides, titanite, allanite, apatite and zircon. The microprobe analysis (S1, Table 3) is from Fowler & Williams (1986).

Zirconolite is reported in the alkaline intrusions of the Arbarastakh massif, Aldan, Russia, where segregations of zirconolite occur in [a] '. . . micatized large-grained pyroxenite . . .' with accessory apatite and ilmenite (Borodin *et al.*, 1960). In Table 3, analyses S2 (Borodin *et al.*, 1960) and S3 (Gaidukova *et al.*, 1962) are wet chemical determinations on mineral separates; analysis S4 (Wark *et al.*, 1973) is a microprobe analysis of a separate zirconolite grain.

Zirconolite (described as 'polymignite') was reported from the syenite pegmatites of Fredicksvärn, S. Norway by Berzelius (1824), and was a mineral separately analysed by Brögger (1890) using 'classical' wet chemical techniques (S5, Table 3). It also occurs at Langesundfjord, near Larvik in coarse-grained syenite pegmatites (S6 and S7, Table 3 – previously unpublished microprobe data).

Zirconolite (reported as 'polymignite') was described from a 'sanidinite' at Campi Flegrei, Italy (Mazzi & Munno, 1983). No analysis is included in Table 3, because the total of the reported analysis is low. Material is no longer available for analysis (Munno pers. comm., 1992).

Nepheline Syenite. At Pine Canyon, Utah, USA, zirconolite was found as an accessory mineral associated with hibonite, perovskite and pseudobrookite (Agrell *et al.*, 1986). The rock-forming minerals include corundum, nepheline and Mg-hercynite. Analyses (NS1-NS6, Table 3) are previously unpublished wavelength-dispersive microprobe data (CTW).

At the Elk Massif, Poland, zirconolite and Nb-zirconolite are reported in an association with apatite, fluorite and pyrochlore in agpaitic nepheline syenite pegmatites (Dziedzic, 1984). The major minerals of the pegmatites are microcline, nepheline, aegirine, arfvedsonite, and more rarely eudialyte. No analytical data are given for the zirconolite.

At Chikala, Chilwa Alkaline Province, Malawi, zirconolite occurs also as an accessory mineral, up to 0.3mm in size, in a nepheline syenite (sample number BM1980,P23(1), Platt *et al.*, 1987 – microprobe analyses NS7-NS11, Table 3). The rock-forming minerals are alkali feldspar, nepheline, biotite, apatite and an opaque oxide phase.

At Tchivira, Angola, niobian zirconolite is reported as intimately crystallized with wöhlerite from nepheline syenite rocks of the alkaline complex (Mariano & Roeder, 1989). Analyses NS11 to NS16 are previously unpublished microprobe data of **zirconolite-(Y)** [see above] from Tchivira.

At Pilanesberg, Transvaal, South Africa (Lurie, 1986), zirconolite occurs as an accessory mineral (A.N. Mariano, personal communication, 1993). No analytical data is reported.

At Tre Croci, near Vetralla in the Vico Volcanic complex of the Roman Comagmatic Province, Latium, Italy, crystalline epitaxial zirconolite occurs as an accessory mineral associated with baddeleyite, zircon and rare thorian hellandite in a sanidinitic ejectum with nepheline and sodalite (G.C. Parodi, personal communication, 1993). Analyses NS17 to NS21 are previously unpublished microprobe data from this locality.

Carbonatite. Carbonatites, with sixteen reported occurrences of zirconolite, seem to be the most common host rock type for this mineral. In the Kola Peninsula, Russia, zirconolite occurs in four separate carbonatite complexes where detailed descriptions, including studies on crystal morphology and crystal chemistry, is given in Bulakh & Ivanikov (1984).

In the Afrikanda complex, Kola, zirconolite is described from the amphibolitized and fenitized pyroxenites (Borodin *et al.*, 1956) In Table 3 analyses C1–C3 are wet chemical analyses; C1–C2 from Borodin *et al.* (1956) and C3 from Bulakh *et al.* (1960). C4 is a microprobe analysis (Wark *et al.*, 1973).

At Vuoriyarvi, Kola, zirconolite was first described as zirkelite (Bulakh *et al.*, 1960), then '. . . tentatively described as a niobium variety, niobozirconolite' (Borodin *et al.*, 1960). It is associated with apatite-magnetite rocks (accompanying carbonatites, Zhuravleva *et al.*, 1976), accumulating predominantly in apatite, and was also observed replacing hatchettolite (Kapustin, 1980). Analyses C5–C7 (Table 3) are unpublished wavelength-dispersive microprobe data (CTW) on separate grains (BM1970,39); C8–C11 are wet chemical analyses: C8–C9 from Borodin *et al.* (1960), C8 and C11 quoted in Kapustin (1980); C10 is from Bulakh *et al.* (1960).

Bulakh *et al.* (1960) refer to zirconolite from the Sayan Province, Russia. Analysis C12 (Table 3) is a wet chemical analysis from Bulakh *et al.* (1960).

At Seblyavr, Kola, niobozirconolite was initially identified as zirkelite (Bulakh *et al.*, 1960) and is described as '. . . the typical mineral of the process of amphibolization-dolomitization confined to carbonatite . . .' (Kapustin, 1980). The mineral is partly metamict, it has good symmetry habit and displays complicated twinning (Bulakh *et al.*, 1960). Associated minerals are apatite, clinohumite, tetraferriphlogopite, pyrrhotite and richterite. Analysis C13 (Table 3) is a wet chemical analysis from Bulakh *et al.* (1960).

At Kovdor, Kola, zirconolite is associated with zones of carbonatization, Kapustin (1980). C14–C16 (Table 3) are wet chemical analyses: C14–C15 from Kapustin (1980), and C16 from Kukharenko *et al.* (1965). Analyses C17–C34 are unpublished wavelength-dispersive micropobe data (CTW), on chemically-zoned zirconolite grains in a thin section of carbonatite. Associated minerals are baddeleyite and U-Ta-rich pyrochlore (Williams, in press).

At Schryburt Lake, Ontario, Canada, zirconolite occurs intergrown with calzirtite, baddeleyite, and U-rich pyrochlore (Williams & Platt, in preparation). Microprobe analyses (C35–C58, Table 3), show significant variations in ΣREE_2O_3 and Nb_2O_5. Some of the grains have ΣREE^{3+} >50% of the Ca site, and, with Nd as the most abundant REE, this mineral can be classified as **zirconolite-(Nd)**, following Bayliss & Levinson (1988), and subject to approval from the CNMMN.

At Santiago Island, Cape Verde Republic, non-metamict **zirconolite-2M** occasionally up to 2mm in diameter, occurs as an accessory mineral, often associated with pyrochlore, in apatite-rich sövite, beforsite and glimmerite rocks of the Canafistula carbonatitic plug (Silva, 1979; Silva & Figueiredo, 1980). Analysis C59 (Table 3) is the wavelength-dispersive microprobe analysis from Silva & Figueiredo (1980).

At Phalaborwa, South Africa, zirconolite was first described by Verwoerd (1986) from the carbonatite. Analyses C60–C64 (Table 3) are unpublished wavelength-dispersive microprobe analyses by CTW on sample BM1988,260, kindly provided by Prof. G. Bayer (ETH, Zürich). In this rock, zirconolite is associated with baddeleyite and zircon, the latter mineral probably having crystallized at a later stage. Analyses C65–C66 are unpublished microprobe data (from Bochon University) from Prof. G. Bayer.

At Sokli, Finland, zirconolite (reported as zirkelite) was originally described by Vartiainen (1980) from hydrothermal phoscorites. The crystals have apparently formed '. . . at the expense of pyrochlore and occur around and as inclusions in pyrochlore . . .', and are also found as separate prisms. Analyses C67–C70 (Table 3) are unpublished wavelength-dispersive microprobe data from Dr. I. Hornig-Kjarsgaard (pers. comm., 1992), analysed at the University of Mainz.

At Kaiserstuhl, Germany, zirconolite occurs with calzirtite, baddeleyite, Nb-perovskite and pyrochlore (Keller, 1984). Analyses C71 and C72 are wavelength-dispersive microprobe analyses (Keller, 1984; Sinclair & Eggleton, 1982).

In the Hegau volcanic province, Germany, zirconolite (described as 'Nb-zirconolite') is a typical accessory mineral in the carbonatitic tuffs (Keller *et al.*, 1990). Analyses C73–C88 (Table 3), are unpublished wavelength-dispersive microprobe analyses (CTW) of eight grains from a heavy mineral separate provided by Prof. J. Keller (Freiburg).

At Prairie Lake, Ontario, Canada, niobian zirconolite is reported in association with wöhlerite, pyrochlore, betafite and niobian perovskite (Mariano & Roeder, 1989). A microprobe analysis provided by Dr A.N. Mariano of six major elements is shown in Table 3 (C89).

At the Cummins Range Carbonatite, Kimberley Area, Western Australia, accessory zirconolite occurs in an apatite-amphibolite rock. Qualitative analysis of the zirconolite showed the presence of Ca, Zr, Ti and minor Fe, but with Nb absent (Dr. A.N. Mariano, personal communication, 1993).

At Howard Creek, British Columbia, Canada (Woolley, 1987; p.16), zirconolite is associated with zircon, magnetite and diopside in an apatite calcite carbonatite (Dr. A.N. Mariano, personal communication, 1993). There is no analytical data.

At Catalao, Goias, Brazil (Woolley, 1987; p.179), zirconolite is associated with apatite and phlogopite in a calcite carbonatite (Dr. A.N. Mariano, personal communication, 1993). There is no analytical data.

At Araxá, Minas Gerais, Brazil (Woolley, 1987; p.66), zirconolite occurs as prismatic crystals with anastase in a glimmerite, and also with pyrochlore, baddeleyite and apatite in a calcite carbonatite (Dr. A.N. Mariano, personal communication, 1993). There is no analytical data.

Metasomatic Rocks. Zirconolite has been reported from metasomatic rocks at nine localities, although analyses from only seven of these have been published.

In the Mt. Melbourne Volcanic Field, Victoria Land, Antarctica, zirconolite occurs as isolated grains with a maximum grain diameter of 0.08mm within ultra-potassic veins in a mantle xenolith from a basanite host (Hornig & Wörner, 1991). The major vein-forming minerals are leucite, plagioclase, nepheline, Mg-ilmenite, apatite and titaniferous mica. Analyses M1-M7 (Table 3) are selected from Hornig & Wörner (1991) as being the least 'contaminated' by adjacent silicate minerals.

At the contact between granodiorite with gneisses and marbles in the Bergell aureole, Switzerland/Italy, chemically discontinuously-zoned zirconolite is observed, typically 30–40μm in diameter, associated with allanite and titanite, in a skarn (Gieré, 1986; Williams & Gieré, 1988). The major minerals of the skarn are calcite, spinel, phlogopite and anorthite. The microprobe analyses M8–M22 (Table 3) are unpublished data (CTW) of eleven grains from three discrete zones, the averages of which are published in Williams & Gieré (1988).

In the Oetztal-Stubai complex, Austria, within polymetamorphic metacarbonates, zirconolite and baddeleyite occur in several mineral assemblages consisting of chlorite, ilmenite, apatite, spinel, phlogopite, titanian clinohumite, olivine, calcite, dolomite and diopside (Purtscheller & Tessadri, 1985). Analyses M23–M27 (Table 3) are the wavelength-dispersive microprobe analyses given by Purtscheller & Tessadri (1985).

In the Adamello contact aureole, Italy, compositionally-zoned and corroded zirconolite occurs in two zones within a Ti-rich vein in dolomite marbles at the contact with a tonalite intrusion (Gieré, 1990a). In the phlogopite zone, zirconolite is always found associated with phlogopite and calcite (±dolomite), and occasionally with geikelite, rutile and fluorapatite. In the titanian clinohumite zone, zirconolite occurs with titanian clinohumite, spinel, calcite, dolomite, pyrrhotite, geikelite, fluorapatite and minor secondary chlorite. A detailed mineralogical and chemical description is given in Gieré & Williams (1992), and analyses M28-M66 (Table 3) are wavelength-dispersive microprobe analyses from Gieré (1990b).

At Koberg Mine, Bergslagen, Sweden, yttrian zirconolite occurs as anhedral grains, predominantly 20-30μm in diameter, in an altered phlogopite-rich sample associated with a marble skarn (Zakrzewski *et al.*, 1992). The low analytical totals (analyses M67-M94, Table 3) suggest the zirconolite is hydrated (Zakrzewski *et al.*, 1992).

At the agpaitic alkaline syenite complex of Lovozero, Kola, zirconolite (reported as 'zirkelite') has been described in a mineral assemblage including rosenbuschite, from the contact metasomatic rocks of the massif (Semenov *et al.*, 1963). Analyses M95-M96 (Table 3) are the wet chemical data of Semenov *et al.* (1963).

In a dolomitic marble from the Neichi mine, Iwate Prefecture, Japan zirconolite is associated with geikelite and baddeleyite, forsterite and spinel (Kato & Matsubara, 1991). The composition of zirconolite is close to the theoretical composition (analyses M97-M98, Table 3, from Kato & Matsubara (1991).

At Sør Rondane, Antarctica, Grew *et al.* (1989) report zirconolite (qualitative analysis only, *cf.* p. 119) from a marble affected by metasomatic processes which had introduced rare metals. Associated minerals include dissakisite-(Ce) (Grew *et al.*, 1991), calcite, dolomite, phlogopite, chlorite, ilmenite-geikelite and spinel.

Rekharskiy & Rekharskaya (1969) discovered zirconolite (reported as zirkelite) intergrown with jordisite and abundant metasomatic pyrite, as veins in zones of altered trachytic to rhyolitic volcanic rocks. Locality details are not reported.

Kinny & Dawson (1992) report the occurrence of zirconolite, as a rare accessory phase associated with zircon and baddeleyite, in a veined and metasomatised harzburgite xenolith from Kimberley, southern Africa. The metasomatism is MARID-related (Kinny & Dawson, 1992) and considered to be associated with kimberlite magma. Analysis M99, Table 3, is the unpublished mean of 6 microprobe analyses (Prof. J.B. Dawson, pers. comm., 1993).

Rubin *et al.* (1993) report zirconolite occurring as inclusions in phlogopite in one sample of a complex skarn from the Ertsberg District of Irian Jaya, Indonesia. No analytical details are given.

Placer Deposit. Zirconolite is reported as millimetre-sized crystals from two placer deposits.

At Jacupiranga, Sao Paulo, Brazil, zirconolite (named as the new mineral 'zirkelite'), is found with baddeleyite and perovskite in the heavy mineral fraction from pyroxene sands of '. . . the decomposed magnetite-pyroxenite of Jacupiranga . . .' (Hussak, 1895; Hussak & Prior, 1895; see also Pudovkina *et al.*, 1974). Analyses P1, P2 are unpublished wavelength-dispersive microprobe analyses (CTW) of separate grains (80142). The wet chemical analysis given in Hussak & Prior (1895) is not included here, as the chemical separation techniques employed in the analysis could only provide qualitative data for ZrO_2 and TiO_2.

In Sri Lanka, zirconolite (reported as 'zirkelite') was observed from two 'gem gravel' localities in the Sabaragamuwa Province: at Walaweduwa in the Bambarabotuwa district, and in southern Sabaragamuwa (Blake & Smith, 1913). Analyses P3, P4 (Table 3) are from Bambarabotuwa, and P5-P7 from Sabaragamuwa; analyses P8, P9 are microprobe data from Lumpkin *et al.* (1986); analysis P10 is an unpublished (CTW) wavelength-dispersive microprobe analysis of several grains (BM1905,361).

'Other' Rock Types. Sapphirine Granulite: Zirconolite occurs as acicular grains in a mineral assemblage including sapphirine, spinel, enstatite and minor phlogopite from a sapphirine granulite nodule sampled from a xenolith-rich norite wall zone in the Archaean Vestfold Hills, east Antarctica (Harley, 1994). The zirconolite is considered to have been a relatively early crystallising phase during the melt crystallisation history of the entrapped granulite xenolith. Analyses SG1-SG3 (Table 3) are from Harley (1994).

Alnöite: Thin (1 μm) rims of zirconolite (no compositional details given) are reported as overgrowing a baddeleyite crystal from the île Bizard alnöite, Québec, Canada (Heaman & Le Cheminant, 1993). Although the baddeleyite crystals are considered to be mantle-derived xenocrysts, the associated overgrowths, which include perovskite and melilite as well as zirconolite, are considered to have formed after exposure to the alnöite magma.

Lunar. Zirconolite has been observed in several lunar samples, (*cf.* review by Frondel, 1975). Data from the literature are presented as analyses L1-L13 (Table 3). It occurs in coarse-grained basalts (Apollo 11, 15 and 17), in a feldspathic

Table 1 Range of chemical variation in natural zirconolite

	Terrestrial*		Lunar		
	Maximum	Minimum	Maximum	Minimum	Theoretical composition
CaO	16.54	01.83	10.70	02.63	16.5
REE_2O_3	23.66	0.00	31.98	04.74	
PbO	00.80	00.00	02.19	00.00	
ThO_2	22.28	00.00	02.34	00.00	
UO_2	23.98	00.00	01.16	00.00	
ZrO_2	44.18	22.82	45/40	29.80	36.3
HfO_2	01.13	00.00	01.34	00.00	
TiO_2	44.91	13.56	34.60	25.48	47.2
MgO	03.04	00.00	01.15	00.00	
Al_2O_3	03.47	00.00	01.60	00.35	
FeO	10.20	00.00	11.40	04.23	
Fe_2O_3	09.58	01.08	–	–	
Nb_2O_5	27.00	00.19	04.34	00.00	
Ta_2O_5	05.83	00.00	00.40	00.00	
WO_3	01.44	00.00	–	–	

*Excluding kimberlite analyses K1 and K2 (see text)

Table 2 Details of zirconolites from terrestrial and lunar occurrences

Rock type	Sample locality	Country	Analysis number	Reference (Occurrence)	Reference (Analytical data)
Kimberlite	Monastery	South Africa	K1	Raber and Haggerty (1979)	Raber and Haggerty (1979)
Kimberlite	Mothae	South Africa	K2	Raber and Haggerty (1979)	Raber and Haggerty (1979)
Kimberlite	Kimberley	South Africa	K3	Raber and Haggerty (1979)	Raber and Haggerty (1979)
Ultrabasic	Laouni	Algeria	U1-U2	Lorand and Cottin (1987)	Lorand and Cottin (1987)
Ultrabasic	Rhum (+)	Scotland	U3	Williams (1978)	Fowler and Williams (1986)
Gabbro Pegmatite	St. Kilda	Scotland	G1	Harding *et al.* (1982)	Fowler and Williams (1986)
Syenite	Glen Dessarry	Scotland	S1	Fowler and Williams (1986)	Fowler and Williams (1986)
Syenite	Arbarastakh, Aldan	Russia	S2–S4	Borodin *et al.* (1960)	Borodin *et al.* (1960, S2); Gaidukova *et al.* (1962), S3); Wark *et al.* (1973, S4)
Syenite	Fredericksvärk (*)	Norway	S5	Berzelius (1824)	Brögger (1890)
Syenite	Langesundfjord (+)	Norway	S6–S7	Brögger (1890)	CTW (unpubl. data)
Syenite	Campi Flegrei	Italy	–	Mazzi and Munno (1983)	–
Nepheline Syenite	Pine Canyon, Utah	U.S.A.	NS1–NS6	Agrell *et al.* (1986)	CTW (unpubl. data)
Nepheline Syenite	Chilwa Island (+)	Malawi	NS7–NS11	Platt *et al.* (1987)	Platt *et al.* (1987)
Nepheline Syenite	Elk Massif	Poland	–	Dziedzic (1984)	No analytical data
Nepheline Syenite	Tchivira	Angola	NS12–NS17	Mariano and Roeder (1989)	CTW (unpubl. data)
Nepheline Syenite	Pilanesberg, Transvaal	South Africa	–	Mariano (pers. comm., 1993)	No analytical data
Nepheline Syenite	Tre Croci, Latium	Italy	NS18–NS22	Parodi (pers. comm., 1993)	CTW (unpubl. data)
Carbonatite	Afrikanda, Kola (**)	Russia	C1–C4	Borodin *et al.* (1956)	Borodin *et al.* (1956, C1, C2); Bulakh *et al.* (1960, C3); Wark *et al.* (1973, C4)
Carbonatite	Vuoriyarvi, Kola(+)	Russia	C5–C11	Borodin *et al.* (1960)	CTW (unpubl. data, C5–C7); Borodin *et al.* (1960, C8, C9); Bulakh *et al.* (1960, C10); Kapustin (1964, C11)
Carbonatite	Sayan Province	Russia	C12	Gaidukova *et al.* (1962)	Gaidukova *et al.* (1962)
Carbonatite	Seblyavr, Kola	Russia	C13	Bulakh *et al.* (1960)	Bulakh *et al.* (1960)
Carbonatite	Kodvor, Kola (+)	Russia	C14–C34	Kukharenko *et al.* (1965)	Kapustin (1980, C14, C15); Kukharenko *et al.* (1965, C16); CTW (unpubl. data, C17–C34)
Carbonatite	Schryburt Lake (+)	Canada	C35–C58	Williams and Platt (in prep.)	CTW (unpubl. data)
Carbonatite	Santiago Island	Cape Verde Republic	C59	Silva (1979)	Silva and Figueiredo (1980)
Carbonatite	Phalaborwa(+)	South Africa	C60–C66	Verwoerd (1986)	CTW (unpubl. data); G. Bayer (unpubl. data)
Carbonatite	Sokli	Finland	C67–C70	Vartianen (1980)	Hornig-Kjarsgaard (unpubl. data)
Carbonatite	Kaiserstuhl	Germany	C71–C72	Keller (1984)	Keller (1984, C71); Sinclair & Eggleton (1982, C72)
Carbonatite	Hegau	Germany	C73–C88	Keller *et al.* (1990)	CTW (unpubl. data)
Carbonatite	Prairie Lake, Ontario	Canada	C89	Mariano and Roeder (1989)	Mariano (unpubl. data)
Carbonatite	Howard Creek, B.C.	Canada	C90–C135	Mariano (pers. comm., 1993)	CTW (unpubl. data)
Carbonatite	Cummins Range, Kimberly	W. Australia	–	Mariano (pers. comm., 1993)	No analytical data
Carbonatite	Catalao, Goias	Brazil	–	Mariano (pers. comm., 1993)	No analytical data
Carbonatite	Araxá, Minas Gerais	Brazil	C136–C161	Mariano (pers. comm., 1993)	CTW (unpubl. data)
Metasomatic	Mt. Melbourne	Antartica	M1–M7	Hornig and Wörner (1991)	Hornig and Wörner (1991)
Metasomatic	Bergell (+)	Switzerland/Italy	M8–M22	Gieré (1986)	Williams and Gieré (1988)
Metasomatic	Oetzal-Stubai	Austria	M23–M27	Purtscheller and Tessadri (1985)	Purtscheller and Tessadri (1985)
Metasomatic	Adamello (+)	Italy	M28–M66	Gieré (1990a)	Gieré (1990b)
Metasomatic	Koberg, Bergslagen (+)	Sweden	M67–M94	Zakrzewski *et al.* (1992)	Zakrzewski *et al.* (1992)
Metasomatic	Lovozero, Kola	Russia	M95–M96	Semenov *et al.* (1963)	Semenov *et al.* (1963)
Metasomatic	Neichi, Iwate Prefecture	Japan	M97–M98	Kato and Matsubara (1991)	Kato and Matsubara (1991)
Metasomatic	Sør Rondane	Antarctica	–	Grew *et al.* (1989)	No analytical data
Metasomatic	?	Former USSR	–	Rekharskiy and Rekharskaya (1969)	No analytical data
Metasomatic	Kimberley	South Africa	M99	Kinny and Dawson (1992)	Dawson (unpubl. data)
Metasomatic	Irian Jaya	Indonesia	–	Rubin *et al.* (1993)	No analytical data
Metamorphic	Vestfold hills	East Antarctica	SG1–SG3	Harley (1994)	Harley (1994)
Alnöite	ile Bizard, Quebec	Canada	–	Heaman and LeCheminant (1993)	No analytical data
Placer (1)	Jacupiranga (***) (+)	Brazil	P1–P2	Hussak (1895); Hussak and Prior (1895)	CTW (unpubl. data) (3)
Placer (2)	Sabaragamuwa Province (+)	Sri Lanka	P3–P10	Blake and Smith (1913)	Blake and Smith (1913, P3–P7); Lumpkin *et al.* (1986, P8–P9); CTW (unpubl. data, P10)
Lunar	Apollo 11 Landing Site	Moon	L1–L4	Lovering and Wark (1971)	Wark *et al.* (1973)
Lunar	Apollo 12 Landing Site	Moon	L5	Busche *et al.* (1972)	Busche *et al.* (1972)
Lunar	Apollo 14 Landing Site	Moon	L6–L7	Busche *et al.* (1972)	Busche *et al.* (1972); Wark *et al.* (1973)
Lunar	Luna 20 Landing Site	Moon	L8	Roedder and Weiblen (1973)	Roedder & Weiblen (1973)
Lunar	Apollo 15 Landing Site	Moon	L9–L11	Brown *et al.* (1972)	Brown *et al.* (1972); Wark *et al.* (1973)
Lunar	Apollo 16 Landing Site	Moon	–	Lovering and Wark (1974)	No analytical data
Lunar	Apollo 17 Landing Site	Moon	L12–L13	Meyer and Boctor (1974)	Meyer and Boctor (1974)

(*) type POLYMIGNITE
(**) type ZIRCONOLITE
(***) type ZIRKELITE
} now all renamed as zirconolite (see Bayliss *et al.*, 1989)
(+) In BMNH collection
(1) Heavy mineral fraction from pyroxene sand; (2) Heavy mineral fraction from alluvial deposits: two separate localities; (3) Analysis from Hussak & Prior (1895) not included as method used could not adequately distinguish Ti from Zr.

Table 3 Chemical analyses of zirconolites

	K1	K2	K3	U1	U2	U3	G1	S1	S2	S3	S4	S5	S6	S7	NS1	NS2	NS3	NS4	NS5	NS6	NS7
MgO	1.20	0.31	0.49	0.19	0.20	0.35	0.06	0.07	0.53	0.43	0.14	0.16	0.07	0.13	-	-	-	-	-	-	0.05
Al2O3	0.13	0.04	0.23	0.59	0.50	0.31	0.09	0.27	2.23	-	0.10	0.19	0.27	0.19	0.44	0.48	0.50	0.50	0.44	0.42	0.43
SiO2	-	-	-	-	-	0.25	0.10	0.29	1.18	0.76	-	0.45	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	3.25
CaO	10.11	9.09	11.10	10.67	11.15	10.80	4.05	9.05	12.03	11.28	12.61	6.98	12.60	7.34	10.05	10.24	10.17	10.21	10.66	10.31	1.83
TiO2	29.16	16.70	40.48	35.67	35.73	35.76	29.03	28.80	32.25	22.04	31.57	18.90	21.50	20.94	32.50	33.26	34.23	33.90	33.68	33.93	24.80
Cr2O3	1.10	0.06	0.09	0.05	0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MnO	0.11	0.15	0.11	-	0.16	-	-	0.15	0.12	-	-	1.32	0.43	0.65	0.10	0.03	0.01	0.13	0.03	0.04	0.54
FeO	6.94	2.38	5.15	4.85	4.87	5.14	8.26	7.70	2.85	4.53	2.30	2.08	7.84	7.93	5.76	5.65	5.62	5.68	5.65	5.46	4.56
Fe2O3	-	-	-	-	-	-	-	-	3.44	3.39	2.78	7.66	-	-	-	-	-	-	-	-	-
Y2O3	-	-	-	2.50	2.45	2.04	8.11	0.67	-	-	0.28	2.26	0.30	1.60	2.10	2.01	1.96	1.90	1.75	1.76	3.70
ZrO2	51.12	71.27	41.91	43.58	44.18	37.60	31.33	31.35	35.75	32.32	33.54	29.71	29.83	27.79	35.18	36.19	35.48	35.84	37.29	36.22	27.30
Nb2O5	-	-	-	0.22	0.25	0.35	1.29	2.71	4.25	13.65	4.80	11.99	19.72	12.53	1.86	1.89	1.86	1.91	2.20	2.02	6.90
La2O3	-	-	-	0.02	0.01	0.17	0.52	0.91	-	-	0.19	5.13	0.95	1.30	0.26	0.28	0.28	0.31	0.35	0.31	0.34
Ce2O3	-	-	-	0.18	0.13	0.92	2.83	3.25	3.36	4.62	1.57	5.91	2.31	5.54	0.92	1.01	0.93	1.05	1.29	1.08	1.57
Pr2O3	-	-	-	0.15	0.13	0.19	0.63	0.28	-	-	0.28	-	0.20	0.69	0.25	0.28	0.20	0.25	0.23	0.15	0.41
Nd2O3	-	-	-	0.17	0.25	1.28	4.66	1.29	-	-	1.52	-	0.53	2.55	2.43	2.21	2.30	2.26	2.24	2.05	3.61
Sm2O3	-	-	-	-	-	0.55	1.33	0.28	-	-	0.49	-	0.04	0.40	0.53	0.48	0.49	0.49	0.44	0.41	0.98
Eu2O3	-	-	-	-	-	-	0.29	0.15	-	-	-	-	<.1	<.1	0.05	0.08	0.16	0.12	0.12	0.11	0.26
Gd2O3	-	-	-	-	-	0.53	1.63	0.10	-	-	0.18	-	<.1	0.33	0.49	0.59	0.48	0.40	0.49	0.54	1.09
Tb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dy2O3	-	-	-	-	-	0.48	1.83	-	-	-	0.22	-	<.1	0.35	0.43	0.40	0.36	0.46	0.41	0.32	1.12
Ho2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Er2O3	-	-	-	-	-	0.18	0.96	-	-	-	0.39	-	<.1	0.19	0.21	0.14	0.19	0.24	0.25	0.13	0.52
Tm2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yb2O3	-	-	-	-	-	0.13	0.87	-	-	-	-	-	-	-	0.19	0.22	0.36	0.24	0.17	0.27	0.60
Lu2O3	-	-	-	-	-	-	-	-	-	-	0.04	-	-	-	-	-	-	-	-	-	-
HfO2	-	-	-	0.34	0.57	0.80	0.92	0.31	-	-	0.55	-	0.68	0.46	0.57	0.69	0.66	0.77	0.57	0.57	0.40
Ta2O5	-	-	-	-	-	0.23	0.16	0.26	0.09	1.75	0.75	1.35	1.08	0.95	0.02	0.21	0.14	0.12	0.05	0.09	0.77
WO3	-	-	-	-	-	-	-	-	-	-	-	-	<.1	0.16	-	-	-	-	-	-	-
PbO	-	-	-	-	-	-	-	0.29	-	-	0.15	0.39	<.1	<.1	-	-	-	-	-	-	-
ThO2	-	-	-	0.41	0.59	0.48	0.45	8.22	0.37	2.50	1.70	3.92	0.20	4.19	2.64	2.12	2.05	1.95	1.28	1.09	7.37
UO2	-	-	-	-	0.06	0.18	0.21	2.86	0.10	0.86	0.70	-	0.11	1.95	1.31	0.78	0.77	0.58	0.37	0.36	1.82
(Na,K)2O	-	-	-	-	-	-	-	-	0.24	0.29	-	1.36	-	-	-	-	-	-	-	-	-
H2O	-	-	-	-	-	-	-	-	1.65	1.38	-	0.28	-	-	-	-	-	-	-	-	-
"Others"	-	-	-	-	-	-	-	-	0.12	0.32	-	0.15	-	-	-	-	-	-	-	-	-
TOTAL	99.87	100.00	99.56	99.59	101.28	98.72	99.61	99.26	100.56	100.12	96.85	100.19	98.71	98.17	98.29	99.24	99.20	99.31	99.96	97.64	94.22
											cations to 7 oxygens										
Ca2+	0.667	0.637	0.698	0.690	0.713	0.716	0.295	0.654	0.774	0.789	0.865	0.513	0.871	0.553	0.694	0.695	0.687	0.690	0.713	0.701	0.139
(Y+REE)3+	0.000	0.000	0.000	0.091	0.089	0.163	0.660	0.177	0.074	0.110	0.119	0.361	0.105	0.347	0.202	0.194	0.192	0.192	0.189	0.179	0.398
Pb2+	-	-	-	-	-	-	-	0.005	-	-	0.003	0.007	0.000	0.000	-	-	-	-	-	-	-
Th4+	-	-	-	0.006	0.008	0.007	0.007	0.126	0.005	0.037	0.025	0.061	0.003	0.067	0.039	0.031	0.029	0.028	0.018	0.016	0.119
U4+	-	-	-	-	0.001	0.002	0.003	0.043	0.001	0.012	0.010	-	0.002	0.031	0.019	0.011	0.011	0.008	0.005	0.005	0.029
SUM Ca2+	0.667	0.637	0.698	0.788	0.810	0.888	0.965	1.006	0.854	0.949	1.022	0.942	0.981	0.998	0.954	0.931	0.920	0.918	0.926	0.901	0.685
Zr4+	1.534	2.272	1.199	1.283	1.285	1.134	1.040	1.031	1.046	1.029	1.047	0.993	0.939	0.953	1.106	1.118	1.091	1.102	1.135	1.121	0.945
Hf4+	-	-	-	0.006	0.010	0.014	0.018	0.006	-	-	0.010	-	0.013	0.009	0.010	0.012	0.012	0.014	0.010	0.010	0.008
SUM Zr4+	1.534	2.272	1.199	1.289	1.295	1.148	1.058	1.037	1.046	1.029	1.057	0.993	0.951	0.962	1.117	1.131	1.103	1.116	1.145	1.131	0.953
Ti4+	1.349	0.821	1.786	1.620	1.603	1.664	1.486	1.461	1.455	1.082	1.520	0.974	1.043	1.107	1.576	1.585	1.623	1.607	1.581	1.619	1.324
Si4+	-	-	-	-	-	0.015	0.007	0.020	0.071	0.050	-	0.031	-	-	-	-	-	-	-	-	0.231
Mg2+	0.110	0.030	0.043	0.017	0.018	0.032	0.006	0.007	0.047	0.042	0.013	0.016	0.007	0.014	-	-	-	-	-	-	0.005
Mn2+	0.006	0.008	0.005	-	0.008	-	-	0.009	0.006	-	-	0.077	0.023	0.039	0.005	0.002	0.001	0.007	0.002	0.002	0.032
Fe2+	0.357	0.130	0.253	0.245	0.243	0.266	0.470	0.434	0.143	0.247	0.123	0.119	0.423	0.466	0.311	0.299	0.296	0.299	0.295	0.290	0.271
Fe3+	-	-	-	-	-	-	-	-	0.155	0.167	0.134	0.395	-	-	-	-	-	-	-	-	-
Al3+	0.009	0.003	0.016	0.042	0.035	0.023	0.007	0.021	0.158	-	0.008	0.015	0.020	0.016	0.033	0.036	0.037	0.037	0.032	0.031	0.036
Cr3+	0.054	0.003	0.004	0.002	0.002	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nb5+	-	-	-	0.006	0.007	0.010	0.040	0.083	0.115	0.403	0.139	0.372	0.575	0.398	0.054	0.054	0.053	0.054	0.062	0.058	0.221
Ta5+	-	-	-	-	-	0.004	0.003	0.005	0.001	0.031	0.013	0.025	0.019	0.018	0.000	0.004	0.002	0.002	0.001	0.002	0.015
W6+	-	-	-	-	-	-	-	-	-	-	-	-	0.001	0.003	-	-	-	-	-	-	-
SUM Ti4+	1.885	0.996	2.107	1.932	1.916	2.014	2.019	2.040	2.153	2.022	1.950	2.025	2.112	2.062	1.980	1.980	2.013	2.008	1.973	2.002	2.135
TOTAL	4.085	3.904	4.004	4.009	4.021	4.050	4.042	4.083	4.053	4.000	4.029	3.960	4.045	4.021	4.051	4.041	4.036	4.041	4.045	4.034	3.773

	NS8	NS9	NS10	NS11	NS12	NS13	NS14	NS15	NS16	NS17	NS18	NS19	NS20	NS21	NS22	C1	C2	C3	C4	C5	C6
MgO	0.18	0.13	0.09	0.11	3.09	3.04	3.53	2.92	3.30	2.95	<.05	0.08	<.05	<.05	0.05	0.45	0.50	-	0.10	0.37	0.70
Al2O3	0.75	0.89	0.68	0.56	2.97	2.97	3.43	2.89	2.94	2.64	0.26	0.19	0.26	0.29	0.25	1.03	1.04	0.76	0.09	<.05	<.05
SiO2	<.07	<.07	<.07	<.07	0.17	0.12	2.02	0.15	0.13	0.17	<.05	0.08	0.09	0.07	0.06	2.05	4.50	-	-	<.05	<.05
CaO	7.22	8.08	8.43	10.03	4.08	4.12	3.87	4.38	3.64	4.14	7.06	7.24	6.64	9.15	7.53	11.05	10.79	12.01	11.44	11.23	11.50
TiO2	26.00	27.20	27.80	28.30	32.18	32.30	30.79	32.12	31.77	32.44	24.72	22.35	27.45	26.00	24.57	31.69	29.91	27.50	30.43	15.42	15.01
Cr2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MnO	0.50	0.28	0.28	0.21	<.05	<.05	<.05	<.05	<.05	<.05	0.98	1.04	0.87	0.75	0.78	0.06	0.13	-	-	0.55	0.54
FeO	8.32	7.96	8.47	7.66	1.03	1.03	1.00	0.98	0.95	1.05	8.25	8.46	7.55	7.81	8.21	-	0.36	-	2.84	7.41	7.28
Fe2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.49	4.60	5.83	3.15	-	-
Y2O3	3.83	3.23	3.33	1.84	9.37	9.38	8.85	9.27	9.36	8.14	1.16	0.78	1.66	0.49	1.13	-	-	-	0.31	0.32	0.26
ZrO2	27.30	28.80	29.20	29.40	33.09	32.97	32.09	32.82	32.49	31.85	29.30	26.00	31.46	32.27	30.90	32.84	31.17	35.26	32.96	28.91	28.72
Nb2O5	8.10	8.30	8.20	9.60	0.39	0.34	0.52	0.47	0.25	0.50	3.29	6.04	2.63	5.35	5.97	3.26	2.86	2.50	4.71	24.66	23.79
La2O3	0.40	0.53	0.54	0.64	0.26	0.27	0.23	0.24	0.28	0.43	0.56	0.57	1.03	0.83	1.04	-	-	-	0.32	0.25	0.32
Ce2O3	1.85	2.54	2.97	3.23	1.91	1.94	1.74	1.66	2.00	2.90	3.62	3.43	7.31	4.46	5.62	6.22	6.00	3.77	2.85	1.41	1.50
Pr2O3	0.43	0.49	0.56	0.47	0.35	0.40	0.37	0.30	0.39	0.55	0.47	0.40	0.98	0.40	0.45	-	-	-	0.56	0.31	0.42
Nd2O3	3.97	3.98	4.49	3.96	2.81	2.89	2.57	2.55	2.98	3.88	1.60	1.28	3.79	1.17	2.28	-	-	-	2.17	1.32	1.23
Sm2O3	0.79	0.76	0.78	0.61	1.14	1.14	1.07	1.04	1.25	1.29	0.31	0.19	0.65	0.14	0.45	-	-	-	0.59	0.72	0.38
Eu2O3	0.30	0.33	0.35	0.31	0.11	0.08	0.07	0.09	0.15	0.13	-	-	-	-	-	-	-	-	-	-	-
Gd2O3	0.86	0.86	0.84	0.44	1.62	1.67	1.52	1.55	1.79	1.60	0.20	0.17	0.28	<.15	0.33	-	-	-	0.13	0.23	0.22
Tb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dy2O3	0.99	0.75	0.75	0.36	1.95	1.90	1.79	1.92	2.04	1.55	-	<.2	-	<.2	-	-	-	-	0.18	0.38	0.28
Ho2O3	-	-	-	-	-	-	-	-	-	-	-	<.2	-	<.2	-	-	-	-	-	-	-
Er2O3	0.41	0.35	0.40	0.13	0.91	0.89	0.84	0.92	0.91	0.64	-	-	-	-	-	-	-	-	0.41	0.20	<.16
Tm2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yb2O3	0.49	0.39	0.31	0.22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HfO2	0.43	0.44	0.59	0.81	0.34	0.29	0.33	0.37	0.25	0.44	0.39	0.28	0.88	0.34	0.34	-	-	0.25	0.39	0.75	0.47
Ta2O5	0.69	0.59	0.33	0.70	<.1	<.1	<.1	<.1	<.1	<.1	-	0.39	-	<.25	-	-	-	-	-	1.08	1.10
WO3	-	-	-	-	0.47	0.44	0.40	0.43	0.42	0.38	-	<.25	-	<.25	-	-	-	-	-	-	-
PbO	-	-	-	-	0.28	0.23	0.21	0.20	0.23	0.17	<.1	<.1	<.1	<.1	<.1	-	-	-	0.24	0.31	0.31
ThO2	4.32	1.62	0.89	0.38	0.52	0.59	0.56	0.54	0.65	0.66	11.25	9.55	4.10	1.95	5.21	0.58	0.46	5.57	2.51	3.43	3.41
UO2	0.98	0.57	0.28	0.13	0.47	0.49	0.52	0.55	0.47	0.31	5.20	10.91	1.19	8.22	4.48	1.53	1.75	2.90	1.00	1.04	0.29
(Na,K)2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.37	0.46	-	-	-	-
H2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.35	5.66	3.15	-	-	-
"Others"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	0.13	-	-	-	-
TOTAL	99.11	99.07	100.56	100.10	99.48	99.49	98.33	98.34	98.65	98.80	98.62	99.43	98.82	99.69	99.65	101.03	100.32	99.50	97.38	100.30	97.73
											cations to 7 oxygens										
Ca2+	0.524	0.573	0.589	0.692	0.276	0.279	0.259	0.299	0.250	0.284	0.542	0.565	0.489	0.662	0.558	0.737	0.725	0.855	0.797	0.804	0.837
(Y+REE)3+	0.386	0.369	0.391	0.301	0.555	0.559	0.514	0.539	0.578	0.566	0.220	0.190	0.411	0.190	0.296	0.142	0.138	0.092	0.178	0.125	0.115
Pb2+	-	-	-	-	0.005	0.004	0.004	0.003	0.004	0.003	0.000	0.000	0.000	0.000	0.000	-	-	-	0.004	0.006	0.006
Th4+	0.067	0.024	0.013	0.006	0.007	0.008	0.008	0.008	0.009	0.010	0.184	0.158	0.064	0.030	0.082	0.008	0.007	0.084	0.037	0.052	0.053
U4+	0.015	0.008	0.004	0.002	0.007	0.007	0.007	0.008	0.007	0.004	0.083	0.177	0.018	0.123	0.069	0.021	0.024	0.043	0.014	0.015	0.004
SUM Ca2+	0.992	0.975	0.997	1.000	0.850	0.857	0.792	0.856	0.848	0.867	1.029	1.089	0.982	1.005	1.005	0.909	0.894	1.073	1.030	1.003	1.015
Zr4+	0.903	0.930	0.929	0.923	1.019	1.016	0.979	1.019	1.013	0.993	1.024	0.923	1.055	1.063	1.042	0.997	0.953	1.142	1.044	0.942	0.952
Hf4+	0.008	0.008	0.011	0.015	0.006	0.005	0.006	0.007	0.005	0.008	0.008	0.006	0.017	0.007	0.007	-	-	0.005	0.007	0.014	0.009
SUM Zr4+	0.911	0.938	0.940	0.938	1.025	1.021	0.985	1.026	1.018	1.001	1.032	0.929	1.072	1.069	1.049	0.997	0.953	1.147	1.052	0.957	0.961
Ti4+	1.326	1.355	1.364	1.370	1.529	1.535	1.448	1.538	1.527	1.560	1.333	1.224	1.419	1.320	1.278	1.484	1.410	1.373	1.487	0.775	0.767
Si4+	-	-	-	-	0.011	0.008	0.126	0.010	0.008	0.011	0.000	0.006	0.006	0.005	0.004	0.128	0.282	-	-	-	-
Mg2+	0.018	0.013	0.009	0.011	0.291	0.286	0.329	0.277	0.315	0.281	0.003	0.009	-	-	0.005	0.042	0.047	-	0.010	0.037	0.071
Mn2+	0.029	0.016	0.015	0.011	-	-	-	-	-	-	0.060	0.064	0.051	0.043	0.046	0.003	0.007	-	-	0.031	0.031
Fe2+	0.472	0.441	0.462	0.412	0.054	0.055	0.052	0.052	0.051	0.056	0.495	0.515	0.434	0.441	0.475	-	0.019	-	0.154	0.414	0.414
Fe3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.257	0.217	0.291	0.154	-	-
Al3+	0.060	0.070	0.052	0.043	0.221	0.221	0.253	0.217	0.222	0.199	0.022	0.016	0.021	0.023	0.020	0.076	0.077	0.060	0.007	-	-
Cr3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nb5+	0.248	0.248	0.242	0.279	0.011	0.010	0.015	0.014	0.007	0.015	0.107	0.199	0.082	0.163	0.187	0.092	0.081	0.075	0.138	0.745	0.731
Ta5+	0.013	0.011	0.006	0.012	-	-	-	-	-	-	-	0.008	-	0.001	-	-	-	-	-	0.020	0.020
W6+	-	-	-	-	0.008	0.007	0.006	0.007	0.007	0.006	-	0.002	-	0.003	-	-	-	-	-	-	-
SUM Ti4+	2.165	2.153	2.150	2.138	2.125	2.122	2.229	2.114	2.137	2.129	2.019	2.042	2.013	1.998	2.014	2.081	2.140	1.799	1.951	2.022	2.034
TOTAL	4.068	4.066	4.087	4.076	4.000	4.000	4.006	3.996	4.003	3.997	4.080	4.061	4.067	4.073	4.068	3.987	3.987	4.019	4.033	3.982	4.011

	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27
MgO	0.36	-	-	0.36	-	0.70	-	0.21	0.36	-	0.49	0.39	0.80	0.55	0.74	0.76	0.27	0.39	0.27	0.58	0.72
Al2O3	<.05	-	-	0.70	-	0.04	0.96	0.70	-	3.47	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
SiO2	<.05	-	-	-	-	-	1.23	-	-	-	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
CaO	11.36	10.78	11.00	9.59	10.12	10.71	10.22	10.00	9.59	10.12	11.99	12.43	10.82	12.22	10.72	11.47	12.66	12.72	12.74	12.30	11.00
TiO2	16.84	22.00	18.19	18.30	16.32	14.08	20.00	18.30	16.32	14.86	18.14	18.95	17.25	17.39	16.54	14.70	23.67	21.05	23.54	18.68	17.00
Cr2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MnO	0.49	-	0.38	-	-	-	-	-	-	-	0.21	0.20	0.30	0.21	0.27	0.26	0.10	0.13	0.05	0.20	0.25
FeO	7.91	5.16	6.00	5.37	2.02	5.56	3.19	5.37	2.02	4.00	7.43	7.54	7.57	7.59	7.77	7.27	6.79	7.31	7.10	7.66	7.66
Fe2O3	-	1.48	1.11	2.72	3.46	1.08	4.81	2.72	3.46	2.88	-	-	-	-	-	-	-	-	-	-	-
Y2O3	0.21	-	-	-	-	-	-	-	-	-	0.22	0.23	0.05	0.14	0.17	0.09	0.15	0.23	0.13	0.25	0.18
ZrO2	31.44	22.82	25.00	27.35	28.40	34.39	33.42	27.35	28.40	32.94	30.23	31.19	28.81	29.00	29.27	28.64	30.71	30.53	31.18	30.29	28.84
Nb2O5	21.26	27.00	24.84	16.17	24.40	24.11	11.25	22.47	24.81	19.65	19.45	19.21	19.01	21.15	19.85	20.68	13.97	17.45	14.54	18.25	19.51
La2O3	0.14	-	-	-	-	-	-	-	-	-	0.26	0.33	0.25	0.15	0.45	0.17	0.37	0.17	0.26	0.21	0.34
Ce2O3	1.44	3.97	4.00	3.71	2.79	1.40	6.10	3.71	2.79	3.06	1.44	1.64	1.52	1.52	1.40	0.97	1.46	1.62	1.42	1.61	1.65
Pr2O3	0.25	-	-	-	-	-	-	-	-	-	0.22	0.35	0.38	0.11	0.19	0.16	0.30	0.39	0.14	0.41	0.20
Nd2O3	1.49	-	-	-	-	-	-	-	-	-	1.15	1.42	1.13	1.30	1.40	0.82	1.12	1.15	1.31	1.56	1.40
Sm2O3	0.33	-	-	-	-	-	-	-	-	-	0.24	0.32	0.32	0.30	0.31		0.29	0.18	0.33	0.20	0.30
Eu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gd2O3	0.31	-	-	-	-	-	-	-	-	-	0.16	0.25	0.21	0.18	0.22	0.14	0.23	0.26	0.24	0.34	0.27
Tb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dy2O3	<.15	-	-	-	-	-	-	-	-	-	<.15	0.18	0.20	0.18	0.22	<.15	<.15	0.18	<.15	0.18	0.23
Ho2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Er2O3	<.16	-	-	-	-	-	-	-	-	-	<.15	<.15	<.15	<.15	<.15	<.15	<.15	<.15	<.15	<.15	<.15
Tm2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HfO2	0.56	-	-	0.29	0.46	-	0.64	0.29	0.46	-	0.56	0.52	0.52	0.49	0.48	0.48	0.66	0.70	0.62	0.72	0.43
Ta2O5	0.67	0.41	2.00	0.87	1.24	-	1.50	0.43	2.74	2.08	2.56	1.58	1.75	2.47	2.46	4.97	1.70	2.03	1.66	3.27	1.73
WO3	-	-	-	-	-	-	-	-	-	-	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25
PbO	0.25	-	-	-	-	-	-	-	-	-	0.12	<.1	0.18	<.1	<.1	<.1	<.1	<.1	<.1	0.20	0.20
ThO2	4.20	2.79	2.90	2.72	2.51	2.05	2.73	2.72	2.51	3.21	2.89	1.39	6.26	2.48	5.42	5.51	2.21	1.18	1.36	1.09	4.39
UO2	<.1	-	0.40	-	3.20	2.51	0.96	-	3.20	1.82	0.67	0.54	0.13	0.72	0.23	0.28	0.63	0.41	0.56	0.40	0.39
(Na,K)2O	-	0.9	1.4	2.16	1.26	0.52	-	1.46	2.27	0.89	-	-	-	-	-	-	-	-	-	-	-
H2O	-	2.42	2.48	-	2.88	2.62	-	3.3	1.13	2.72	-	-	-	-	-	-	-	-	-	-	-
"Others"	-	-	0.98	-	-	0.64	-	-	-	0.41	-	-	-	-	-	-	-	-	-	-	-
TOTAL	99.51	99.73	100.68	90.31	99.06	100.41	97.01	99.03	100.06	102.11	98.43	98.66	97.46	98.15	98.11	97.37	97.29	98.08	97.45	98.40	96.69

cations to 7 oxygens

	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27
Ca2+	0.812	0.755	0.799	0.748	0.748	0.778	0.730	0.727	0.699	0.719	0.860	0.881	0.799	0.879	0.788	0.854	0.895	0.897	0.895	0.880	0.814
(Y+REE)3+	0.104	0.095	0.099	0.099	0.071	0.035	0.149	0.092	0.070	0.074	0.094	0.114	0.101	0.095	0.109	0.060	0.098	0.101	0.094	0.117	0.115
Pb2+	0.004	-	-	-	-	-	-	-	-	-	0.002	-	0.003	-	-	-	0.001	0.001	0.001	0.004	0.004
Th4+	0.064	0.041	0.045	0.045	0.039	0.032	0.041	0.042	0.039	0.048	0.044	0.021	0.098	0.038	0.085	0.087	0.033	0.018	0.020	0.017	0.069
U4+	-	-	0.006	-	0.049	0.038	0.014	-	0.048	0.027	0.010	0.008	0.002	0.011	0.004	0.004	0.009	0.006	0.008	0.006	0.006
SUM Ca2+	0.985	0.891	0.949	0.892	0.907	0.882	0.935	0.861	0.856	0.868	1.011	1.024	1.004	1.022	0.985	1.006	1.036	1.022	1.018	1.022	1.008
Zr4+	1.023	0.727	0.827	0.971	0.955	1.137	1.086	0.905	0.942	1.065	0.987	1.006	0.969	0.949	0.979	0.971	0.988	0.979	0.997	0.986	0.971
Hf4+	0.011	-	-	0.006	0.009	-	0.012	0.006	0.009	-	0.011	0.010	0.010	0.009	0.009	0.010	0.012	0.013	0.012	0.014	0.008
SUM Zr4+	1.034	0.727	0.827	0.977	0.965	1.137	1.099	0.911	0.951	1.065	0.998	1.016	0.979	0.958	0.988	0.980	1.000	0.992	1.008	1.000	0.980
Ti4+	0.845	1.081	0.927	1.002	0.847	0.718	1.003	0.934	0.835	0.741	0.913	0.942	0.894	0.878	0.853	0.768	1.174	1.041	1.160	0.938	0.883
Si4+	-	-	-	-	-	-	0.082	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg2+	0.036	-	-	0.039	-	0.071	-	0.021	0.036	-	0.049	0.038	0.082	0.055	0.076	0.079	0.027	0.038	0.026	0.058	0.074
Mn2+	0.028	-	0.022	-	-	-	-	-	-	-	0.012	0.011	0.018	0.012	0.016	0.015	0.006	0.007	0.003	0.011	0.015
Fe2+	0.442	0.282	0.340	0.327	0.117	0.315	0.178	0.305	0.115	0.222	0.416	0.417	0.436	0.426	0.446	0.423	0.375	0.402	0.389	0.428	0.442
Fe3+	-	0.073	0.057	0.149	0.180	0.055	0.241	0.139	0.177	0.144	-	-	-	-	-	-	-	-	-	-	-
Al3+	-	-	-	0.060	-	0.003	0.075	0.056	-	0.271	-	-	-	-	-	-	-	-	-	-	-
Cr3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nb5+	0.642	0.798	0.761	0.532	0.761	0.739	0.339	0.689	0.763	0.589	0.589	0.574	0.593	0.642	0.615	0.650	0.417	0.519	0.431	0.551	0.609
Ta5+	0.012	0.007	0.037	0.017	0.023	-	0.027	0.008	0.051	0.037	0.047	0.028	0.033	0.045	0.046	0.094	0.030	0.036	0.030	0.059	0.032
W6+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUM Ti4+	2.004	2.241	2.144	2.127	1.927	1.901	1.946	2.152	1.977	2.003	2.026	2.012	2.056	2.057	2.051	2.029	2.028	2.044	2.039	2.044	2.055
TOTAL	4.023	3.859	3.920	3.997	3.799	3.921	3.979	3.924	3.784	3.936	4.034	4.052	4.038	4.038	4.024	4.014	4.064	4.059	4.065	4.067	4.043

	C28	C29	C30	C31	C32	C33	C34	C35	C36	C37	C38	C39	C40	C41	C42	C43	C44	C45	C46	C47	C48
MgO	0.62	0.30	0.56	0.54	0.60	0.48	0.65	0.59	0.31	0.37	0.33	0.30	0.47	0.27	0.22	0.12	0.48	0.32	0.21	0.10	0.19
Al2O3	<.05	<.05	<.05	<.05	<.05	<.05	<.05	0.19	0.11	0.09	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	0.09
SiO2	<.05	<.05	<.05	<.05	<.05	<.05	<.05	0.27	0.48	0.43	<.05	0.05	<.05	0.05	0.05	0.27	0.16	0.28	0.27	0.32	0.07
CaO	11.20	11.85	11.41	12.12	11.67	12.25	11.12	9.97	9.19	7.77	10.70	10.39	10.68	11.75	11.78	5.95	10.49	7.50	5.79	6.01	9.11
TiO2	17.81	22.77	18.12	18.72	16.75	17.18	17.00	18.97	29.12	27.36	23.20	21.07	18.34	22.04	22.52	22.66	19.39	21.25	22.40	23.20	25.93
Cr2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MnO	0.26	0.34	0.20	0.16	0.28	0.20	0.26	0.36	0.20	0.31	0.13	0.34	0.47	0.33	0.21	0.57	0.40	0.44	0.55	0.63	0.21
FeO	7.66	6.79	7.41	7.46	7.39	7.40	7.65	7.06	6.77	6.98	6.98	7.72	6.74	6.82	7.37	7.50	8.22	8.03	7.90	7.20	7.48
Fe2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Y2O3	0.27	0.18	0.24	0.31	0.17	0.15	0.30	0.46	1.28	1.40	0.53	0.58	0.56	0.45	0.49	1.18	0.61	0.99	1.26	1.53	1.08
ZrO2	29.72	30.72	30.26	31.24	29.07	29.86	29.44	30.67	32.78	32.07	30.51	29.72	30.73	30.68	30.15	28.85	28.87	29.16	28.36	29.10	30.33
Nb2O5	20.19	14.47	17.59	18.04	21.21	20.78	20.12	13.36	2.82	3.71	13.10	15.39	18.92	13.92	15.48	9.49	17.75	13.56	9.11	9.17	9.91
La2O3	0.30	0.18	0.27	0.40	0.33	0.22	0.37	0.11	0.45	0.60	0.19	0.26	0.32	0.24	0.14	0.53	0.37	0.33	0.53	0.52	0.33
Ce2O3	1.58	1.46	1.85	1.62	1.27	1.47	1.76	1.68	5.03	5.75	2.09	2.47	2.15	1.75	2.09	5.53	2.64	3.82	5.27	4.84	3.29
Pr2O3	0.34	0.41	0.36	0.48	0.26	0.17	0.23	0.46	1.10	1.08	0.27	0.42	0.38	0.34	0.57	1.31	0.41	0.96	1.25	1.20	0.89
Nd2O3	1.45	1.16	1.45	1.49	1.14	1.14	1.75	1.91	4.99	6.15	2.25	2.91	2.03	1.71	2.49	7.10	3.22	5.20	7.27	7.71	4.54
Sm2O3	0.34	0.18	0.30	0.40	0.21	0.35	0.23	0.50	1.03	1.17	0.61	0.58	0.43	0.43	0.60	1.96	0.90	1.49	1.90	2.32	1.33
Eu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gd2O3	0.26	0.35	0.32	0.34	0.30	0.18	0.33	0.16	0.91	0.89	0.46	0.53	0.41	0.36	0.40	1.07	0.40	0.82	1.25	1.56	0.79
Tb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dy2O3	0.16	<.15	<.15	0.19	<.15	<.15	0.20	0.21	0.45	0.49	0.30	0.29	0.19	0.22	0.25	0.72	<.15	0.52	0.57	0.97	0.56
Ho2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Er2O3	<.15	<.15	<.15	<.15	<.15	<.15	<.15	<.15	<.15	<.15	0.22	0.15	0.19	<.15	<.15	0.26	<.15	0.15	0.20	0.19	0.22
Tm2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yb2O3	-	-	-	-	-	-	-	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18
Lu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HfO2	0.38	0.67	0.72	0.72	0.56	0.55	0.54	0.63	0.57	0.45	0.70	0.75	0.57	0.67	0.67	0.42	0.72	0.65	0.58	0.56	0.65
Ta2O5	1.78	2.78	3.99	3.91	1.61	2.80	2.20	0.39	0.29	0.30	<.25	0.56	1.04	0.59	0.66	0.32	<.25	0.42	<.25	<.25	<.25
WO3	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25
PbO	0.17	<.1	<.1	<.1	<.1	<.1	<.1	0.45	<.1	<.1	0.23	<.1	0.25	0.37	0.19	<.1	<.1	<.1	<.1	<.1	<.1
ThO2	3.95	2.46	2.85	2.04	4.09	2.26	4.01	6.20	<.1	0.12	0.93	2.44	0.64	0.83	1.45	0.76	1.58	1.51	0.54	0.36	0.77
UO2	0.14	1.07	0.46	0.24	0.51	0.51	0.35	1.37	0.10	0.34	2.04	0.59	2.13	2.06	0.41	0.49	0.03	0.19	0.51	0.45	0.53
(Na,K)2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
"Others"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	98.58	98.14	98.36	100.42	97.42	97.95	98.51	95.97	97.98	97.83	95.77	97.51	97.64	95.88	98.19	97.06	96.64	97.59	95.72	97.94	98.30
											cations to 7 oxygens										
Ca2+	0.807	0.840	0.828	0.856	0.850	0.882	0.808	0.752	0.654	0.565	0.779	0.755	0.776	0.855	0.835	0.452	0.765	0.556	0.445	0.452	0.651
(Y+REE)3+	0.116	0.098	0.122	0.127	0.095	0.094	0.129	0.144	0.377	0.443	0.173	0.205	0.168	0.139	0.175	0.511	0.216	0.363	0.514	0.538	0.322
Pb2+	0.003	-	-	-	-	-	-	0.009	-	-	0.004	-	0.005	0.007	0.003	0.002	0.001	0.002	0.001	0.002	-
Th4+	0.060	0.037	0.044	0.031	0.063	0.035	0.062	0.099	-	0.002	0.014	0.038	0.010	0.013	0.022	0.012	0.024	0.024	0.009	0.006	0.012
U4+	0.002	0.016	0.007	0.004	0.008	0.008	0.005	0.021	0.001	0.005	0.031	0.009	0.032	0.031	0.006	0.008	0.000	0.003	0.008	0.007	0.008
SUM Ca2+	0.989	0.991	1.000	1.017	1.016	1.017	1.005	1.025	1.033	1.015	1.002	1.006	0.991	1.044	1.041	0.985	1.006	0.947	0.977	1.005	0.993
Zr4+	0.975	0.991	0.999	1.004	0.964	0.978	0.974	1.053	1.062	1.062	1.011	0.983	1.017	1.016	0.972	0.998	0.958	0.983	0.992	0.997	0.987
Hf4+	0.007	0.013	0.014	0.014	0.011	0.011	0.010	0.013	0.011	0.009	0.014	0.015	0.011	0.013	0.013	0.009	0.014	0.013	0.012	0.011	0.012
SUM Zr4+	0.982	1.004	1.013	1.018	0.975	0.989	0.985	1.066	1.073	1.071	1.025	0.998	1.028	1.029	0.985	1.006	0.972	0.996	1.004	1.008	0.999
Ti4+	0.901	1.133	0.923	0.928	0.857	0.868	0.867	1.004	1.455	1.398	1.186	1.075	0.936	1.125	1.120	1.209	0.992	1.105	1.208	1.225	1.301
Si4+	-	-	-	-	-	-	-	0.019	0.032	0.029	-	0.003	-	0.003	0.003	0.019	0.011	0.019	0.019	0.022	0.005
Mg2+	0.062	0.030	0.057	0.053	0.061	0.048	0.066	0.062	0.031	0.037	0.033	0.030	0.048	0.027	0.022	0.013	0.049	0.033	0.022	0.010	0.019
Mn2+	0.015	0.019	0.011	0.009	0.016	0.011	0.015	0.021	0.011	0.018	0.007	0.020	0.027	0.019	0.012	0.034	0.023	0.026	0.033	0.037	0.012
Fe2+	0.431	0.376	0.420	0.411	0.420	0.416	0.434	0.416	0.376	0.396	0.397	0.438	0.382	0.387	0.408	0.445	0.468	0.464	0.474	0.423	0.417
Fe3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Al3+	-	-	-	-	-	-	-	0.016	0.009	0.007	-	-	-	-	-	-	-	0.002	0.003	-	0.007
Cr3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nb5+	0.614	0.433	0.538	0.538	0.652	0.631	0.617	0.425	0.085	0.114	0.403	0.472	0.580	0.427	0.463	0.304	0.546	0.424	0.295	0.291	0.299
Ta5+	0.033	0.050	0.073	0.070	0.030	0.051	0.041	0.007	0.005	0.006	-	0.010	0.019	0.011	0.012	0.006	0.003	0.008	-	0.001	0.003
W6+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.001	-	-	0.004	-	-
SUM Ti4+	2.055	2.041	2.022	2.009	2.036	2.025	2.040	1.971	2.004	2.005	2.026	2.048	1.992	2.000	2.039	2.031	2.091	2.080	2.061	2.011	2.064
TOTAL	4.027	4.036	4.035	4.045	4.027	4.031	4.030	4.062	4.110	4.091	4.053	4.052	4.011	4.073	4.065	4.023	4.069	4.024	4.042	4.024	4.056

	C49	C50	C51	C52	C53	C54	C55	C56	C57	C58	C59	C60	C61	C62	C63	C64	C65	C66	C67	C68	C69
MgO	0.08	0.18	0.28	0.30	0.44	0.28	0.38	0.35	0.27	0.29	0.36	<.05	<.05	<.05	<.05	<.05	0.17	0.15	1.06	1.07	1.13
Al2O3	<.05	<.05	<.05	0.09	<.05	<.05	<.05	0.12	<.05	0.09	0.14	<.05	<.05	<.05	<.05	<.05	-	-	0.13	0.15	0.18
SiO2	0.22	0.15	0.23	0.31	0.25	0.19	0.16	0.46	0.17	0.19	0.06	<.05	<.05	<.05	<.05	<.05	-	0.13	0.05	0.03	0.03
CaO	8.06	6.93	5.84	7.35	10.70	9.78	8.99	8.71	6.20	8.37	12.10	12.36	12.02	11.48	9.75	11.31	11.28	12.07	10.32	9.18	9.09
TiO2	21.68	21.84	20.49	22.90	21.09	23.64	22.28	20.51	22.69	27.24	24.95	36.15	35.39	34.68	34.33	35.71	34.93	34.45	14.14	14.10	14.40
Cr2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MnO	0.36	0.47	0.59	0.32	0.31	0.27	0.25	1.07	0.65	0.33	0.28	0.19	0.21	0.21	0.35	0.26	-	-	-	-	-
FeO	7.03	7.46	7.34	7.80	7.87	7.04	7.75	6.56	7.11	6.66	6.53	6.49	6.85	6.57	10.20	6.32	-	-	8.89	7.27	8.56
Fe2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.88	6.64	-	-	-
Y2O3	0.99	1.41	1.06	0.95	0.58	0.51	0.75	0.48	1.10	1.43	0.50	0.32	0.32	0.17	0.36	0.28	-	0.45	0.24	0.41	0.34
ZrO2	28.10	29.49	28.68	29.50	29.79	30.00	29.54	32.62	30.51	32.42	31.07	35.15	33.71	34.55	31.65	33.67	32.90	32.23	26.17	26.08	26.76
Nb2O5	12.84	10.53	10.97	11.91	16.84	13.21	13.55	13.82	8.78	5.15	12.39	0.19	0.29	0.23	0.38	0.19	-	0.45	18.50	17.01	16.50
La2O3	0.32	0.36	0.89	0.34	0.28	0.23	0.33	0.19	0.68	0.38	0.15	<.07	0.13	0.11	<.07	<.07	-	-	-	-	-
Ce2O3	4.00	4.13	6.99	3.78	2.56	2.95	3.24	1.99	5.06	3.50	1.29	0.74	0.91	0.77	1.04	0.77	-	0.33	1.59	2.42	1.31
Pr2O3	0.70	1.05	1.60	0.92	0.44	0.66	0.91	0.61	1.00	0.84	0.24	<.14	<.14	<.14	<.14	<.14	-	-	-	-	-
Nd2O3	5.33	5.91	7.56	5.51	3.22	3.89	4.16	2.04	6.62	4.51	1.26	0.57	0.85	0.75	1.08	0.61	-	0.95	-	-	-
Sm2O3	1.43	1.89	1.59	1.46	0.89	0.98	1.43	0.49	1.64	1.15	0.57	0.33	0.36	0.27	0.31	0.26	-	-	-	-	-
Eu2O3	-	-	-	-	-	-	-	-	-	-	0.17	-	-	-	-	-	-	-	-	-	-
Gd2O3	1.02	1.12	1.04	0.87	0.57	0.59	0.83	0.26	0.99	0.98	0.34	0.32	0.17	0.23	0.33	0.23	-	-	-	-	-
Tb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dy2O3	0.58	0.68	0.56	0.61	0.35	0.25	0.30	0.69	0.67	0.57	0.22	0.28	0.21	0.26	0.33	0.15	-	-	-	-	-
Ho2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Er2O3	0.23	0.37	0.26	<.15	0.28	<.15	<.15	<.15	<.15	<.15	0.21	<.16	<.16	<.16	<.16	<.16	-	-	-	-	-
Tm2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yb2O3	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	0.06	-	-	-	-	-	-	-	-	-	-
Lu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HfO2	0.79	0.59	0.73	0.66	0.76	0.64	0.47	0.60	0.42	0.59	0.42	0.51	0.70	0.85	0.55	0.76	1.22	0.90	1.08	0.76	0.70
Ta2O5	<.25	0.30	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	1.81	<.2	0.39	<.2	0.32	<.2	-	-	5.67	5.68	5.83
WO3	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25	<.25		<.2	<.2	<.2	<.2	<.2	-	-	-	-	-
PbO	0.23	0.14	<.1	0.14	0.11	0.14	<.1	0.23	<.1	0.10	0.10	0.65	0.33	0.68	0.17	0.21	-	-	-	-	-
ThO2	1.85	1.07	0.13	1.88	0.50	0.55	1.72	3.67	1.73	1.73	1.44	3.46	4.18	4.03	5.58	3.67	4.36	4.85	5.89	7.65	10.80
UO2	1.14	0.42	0.31	0.46	0.48	0.97	0.24	0.49	0.10	0.25	2.07	1.41	1.44	1.51	1.87	1.68	1.37	1.44	-	-	-
(Na,K)2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
"Others"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	96.98	96.49	97.14	98.06	98.31	96.77	97.28	95.96	96.39	96.77	98.73	99.11	98.46	97.34	98.59	96.09	93.11	95.04	93.73	91.81	95.63
											cations to 7 oxygens										
Ca2+	0.605	0.525	0.449	0.540	0.761	0.705	0.657	0.643	0.472	0.611	0.846	0.829	0.818	0.792	0.676	0.780	0.783	0.830	0.804	0.739	0.713
(Y+REE)3+	0.375	0.442	0.567	0.366	0.223	0.250	0.299	0.171	0.463	0.341	0.121	0.060	0.070	0.060	0.083	0.056	0.000	0.045	0.052	0.083	0.048
Pb2+	0.004	0.003	-	0.003	0.002	0.003	0.001	0.004	-	0.002	0.002	0.011	0.006	0.012	0.003	0.004	-	-	-	-	-
Th4+	0.029	0.017	0.002	0.029	0.008	0.008	0.027	0.058	0.028	0.027	0.021	0.049	0.060	0.059	0.082	0.054	0.064	0.071	0.097	0.131	0.180
U4+	0.018	0.007	0.005	0.007	0.007	0.015	0.004	0.008	0.002	0.004	0.030	0.020	0.020	0.022	0.027	0.024	0.020	0.021	-	-	-
SUM Ca2+	1.031	0.994	1.023	0.945	1.001	0.981	0.988	0.883	0.965	0.984	1.020	0.969	0.975	0.944	0.871	0.917	0.867	0.966	0.953	0.953	0.941
Zr4+	0.959	1.017	1.004	0.986	0.965	0.985	0.982	1.095	1.056	1.076	0.989	1.073	1.044	1.084	0.999	1.057	1.040	1.009	0.927	0.956	0.955
Hf4+	0.016	0.012	0.015	0.013	0.014	0.012	0.009	0.013	0.009	0.012	0.008	0.009	0.013	0.016	0.010	0.014	0.023	0.016	0.022	0.016	0.015
SUM Zr4+	0.975	1.029	1.019	0.999	0.979	0.997	0.991	1.108	1.066	1.089	0.997	1.082	1.057	1.099	1.010	1.071	1.062	1.025	0.950	0.972	0.970
Ti4+	1.141	1.162	1.106	1.181	1.053	1.197	1.142	1.062	1.212	1.395	1.225	1.702	1.691	1.678	1.672	1.729	1.702	1.663	0.773	0.797	0.793
Si4+	0.015	0.011	0.017	0.021	0.017	0.013	0.011	0.032	0.012	0.013	0.004	-	-	-	-	-	-	0.008	0.004	0.002	0.002
Mg2+	0.008	0.019	0.030	0.031	0.044	0.028	0.039	0.036	0.029	0.029	0.035	0.001	0.002	0.002	0.002	0.002	0.016	0.014	0.115	0.120	0.123
Mn2+	0.021	0.028	0.036	0.019	0.017	0.015	0.014	0.062	0.039	0.019	0.015	0.010	0.011	0.011	0.019	0.014	-	-	-	-	-
Fe2+	0.412	0.441	0.441	0.447	0.437	0.396	0.442	0.378	0.422	0.379	0.356	0.340	0.364	0.354	0.552	0.340	-	-	0.540	0.457	0.524
Fe3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.336	0.321	-	-	-
Al3+	-	-	-	0.007	0.002	-	-	0.010	0.002	0.007	0.011	-	-	-	-	-	-	-	0.011	0.013	0.016
Cr3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nb5+	0.406	0.337	0.356	0.369	0.506	0.402	0.418	0.430	0.282	0.159	0.366	0.005	0.008	0.007	0.011	0.005	-	0.013	0.608	0.578	0.546
Ta5+	0.004	0.006	0.003	0.001	0.003	0.001	0.002	0.004	0.003	-	0.032	-	0.007	0.003	0.006	0.003	-	-	0.112	0.116	0.116
W6+	0.001	0.005	-	-	0.001	0.003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUM Ti4+	2.010	2.008	1.988	2.076	2.079	2.056	2.068	2.014	2.000	2.001	2.044	2.058	2.083	2.054	2.263	2.094	2.054	2.019	2.163	2.083	2.120
TOTAL	4.016	4.031	4.030	4.020	4.059	4.034	4.047	4.005	4.031	4.074	4.061	4.109	4.114	4.097	4.143	4.082	3.984	4.010	4.065	4.009	4.031

	C70	C71	C72	C73	C74	C75	C76	C77	C78	C79	C80	C81	C82	C83	C84	C85	C86	C87	C88	C89	C90
MgO	0.52	0.85	-	0.30	0.32	0.52	0.48	0.30	0.37	0.45	0.34	0.33	0.32	0.31	0.36	0.35	0.40	0.29	0.31	-	0.28
Al2O3	0.03	-	-	0.39	0.41	0.19	0.20	0.27	0.28	0.39	0.36	0.36	0.34	0.27	0.25	0.29	0.30	0.40	0.45	-	0.08
SiO2	0.18	-	-	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	-	<.05
CaO	11.16	11.38	12.50	12.57	12.39	12.31	12.33	12.74	12.80	12.05	12.62	12.93	13.11	12.68	12.72	12.52	12.53	12.57	12.89	12.65	10.55
TiO2	19.79	13.56	22.70	28.25	28.39	20.13	20.35	25.20	24.96	27.17	27.40	27.01	28.01	25.47	24.99	24.64	24.59	29.25	29.78	19.13	26.09
Cr2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MnO	-	0.94	0.20	0.17	0.14	0.43	0.39	0.26	0.24	0.26	0.23	0.18	0.21	0.21	0.30	0.19	0.32	0.16	0.21	0.40	0.18
FeO	8.16	7.41	2.28	6.32	6.18	7.72	7.91	6.88	7.20	6.81	6.51	6.54	6.24	7.01	7.12	6.93	7.09	6.08	5.98	7.90	7.89
Fe2O3	-	-	5.32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Y2O3	0.46	-	-	0.41	0.34	0.24	0.37	0.35	0.29	0.35	0.37	0.18	0.32	0.35	0.35	0.30	0.30	0.35	0.32	-	0.60
ZrO2	27.35	30.51	34.80	35.91	36.33	31.18	31.18	34.03	33.87	35.47	35.19	35.38	35.76	33.31	33.75	33.40	33.29	35.89	36.00	30.42	31.77
Nb2O5	15.68	22.07	15.70	7.27	7.57	17.34	17.70	12.28	12.36	8.68	9.61	9.43	8.67	11.37	12.08	12.34	12.59	7.35	6.99	22.29	8.47
La2O3	-	-	-	<.1	<.1	0.13	0.24	0.15	0.11	<.1	0.16	0.14	0.12	0.14	0.13	0.19	<.1	0.15	<.1	-	0.18
Ce2O3	2.49	0.77	0.90	0.53	0.53	0.95	0.81	0.53	0.65	0.49	0.54	0.80	0.43	0.79	0.75	0.60	0.72	0.54	0.49	-	1.39
Pr2O3	-	-	-	<.2	0.43	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	0.33	<.2	<.2	-	0.24
Nd2O3	-	1.10	-	0.50	0.47	0.80	0.85	0.72	0.56	0.62	0.85	0.74	0.61	0.65	0.64	0.64	0.70	0.55	0.51	-	1.52
Sm2O3	-	0.27	-	<.15	0.20	0.25	0.25	0.18	0.24	0.16	0.17	0.16	<.15	0.17	0.28	0.17	0.26	0.19	<.15	-	0.43
Eu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.14
Gd2O3	-	-	-	<.15	0.15	0.19	0.21	<.15	<.15	<.15	<.15	<.15	<.15	<.15	0.15	0.22	<.15	<.15	0.21	-	0.35
Tb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dy2O3	-	-	-	<.18	<.18	0.31	0.19	0.24	0.19	0.19	<.18	0.19	<.18	<.18	<.18	0.31	0.20	<.18	<.18	-	0.19
Ho2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Er2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.07
Tm2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HfO2	0.40	-	-	0.27	0.19	0.37	0.37	0.35	0.25	0.13	0.26	0.21	0.31	0.30	0.27	0.15	0.45	0.24	0.12	-	0.48
Ta2O5	0.21	3.08	-	1.66	1.58	1.79	1.92	1.62	1.77	1.73	1.71	1.87	1.75	1.70	1.72	1.83	1.74	1.47	1.52	-	2.63
WO3	-	-	-	<.25	0.30	<.25	<.25	<.25	<.25	<.25	0.29	<.25	<.25	0.25	<.25	<.25	<.25	<.25	<.25	-	<.1
PbO	-	-	-	<.1	<.1	<.1	<.1	<.1	0.17	<.1	<.1	<.1	<.1	0.27	<.1	0.11	<.1	<.1	<.1	-	<.1
ThO2	5.57	5.13	4.10	1.90	1.67	2.53	2.17	1.81	1.67	1.56	1.94	1.62	1.25	1.72	1.96	1.99	2.27	1.62	1.48	-	6.28
UO2	-	1.22	1.40	0.98	0.79	1.40	1.32	0.97	1.06	1.14	0.84	0.97	0.94	0.90	1.08	0.87	1.24	1.07	0.97	-	1.01
(Na,K)2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
"Others"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	92.00	98.29	99.90	97.43	98.38	98.78	99.24	98.88	99.04	97.65	99.39	99.04	98.39	97.87	98.90	98.04	99.32	98.17	98.23	92.79	100.80
											cations to 7 oxygens										
Ca2+	0.847	0.839	0.850	0.861	0.842	0.868	0.864	0.872	0.876	0.827	0.854	0.879	0.887	0.877	0.873	0.869	0.862	0.851	0.868	0.911	0.742
(Y+REE)3+	0.082	0.053	0.021	0.038	0.054	0.074	0.072	0.054	0.050	0.046	0.052	0.054	0.039	0.053	0.057	0.060	0.061	0.045	0.040	0.000	0.126
Pb2+	-	-	-	-	-	-	-	-	0.003	-	-	-	-	0.005	-	0.002	-	-	-	-	-
Th4+	0.090	0.080	0.059	0.028	0.024	0.038	0.032	0.026	0.024	0.023	0.028	0.023	0.018	0.025	0.029	0.029	0.033	0.023	0.021	-	0.094
U4+	-	0.019	0.020	0.014	0.011	0.020	0.019	0.014	0.015	0.016	0.012	0.014	0.013	0.013	0.015	0.013	0.018	0.015	0.014	-	0.015
SUM Ca2+	1.019	0.991	0.950	0.941	0.931	1.000	0.987	0.967	0.968	0.912	0.945	0.970	0.957	0.973	0.974	0.972	0.974	0.935	0.943	0.911	0.976
Zr4+	0.945	1.024	1.077	1.120	1.124	1.000	0.994	1.061	1.055	1.108	1.084	1.095	1.101	1.049	1.054	1.055	1.042	1.106	1.104	0.997	1.017
Hf4+	0.008	-	-	0.005	0.003	0.007	0.007	0.006	0.005	0.002	0.005	0.004	0.006	0.006	0.005	0.003	0.008	0.004	0.002	-	0.009
SUM Zr4+	0.953	1.024	1.077	1.125	1.127	1.007	1.001	1.067	1.060	1.111	1.088	1.099	1.107	1.055	1.059	1.058	1.050	1.111	1.106	0.997	1.026
Ti4+	1.055	0.702	1.084	1.358	1.354	0.996	1.000	1.211	1.199	1.309	1.301	1.289	1.330	1.237	1.204	1.200	1.187	1.391	1.408	0.967	1.288
Si4+	0.013	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg2+	0.055	0.087	-	0.029	0.030	0.051	0.047	0.029	0.035	0.043	0.032	0.031	0.030	0.030	0.034	0.034	0.038	0.027	0.029	-	0.027
Mn2+	-	0.055	0.011	0.009	0.008	0.024	0.022	0.014	0.013	0.014	0.012	0.010	0.011	0.011	0.016	0.010	0.017	0.009	0.011	0.023	0.010
Fe2+	0.484	0.427	0.121	0.338	0.328	0.425	0.432	0.368	0.385	0.365	0.344	0.347	0.330	0.379	0.381	0.375	0.381	0.321	0.314	0.444	0.433
Fe3+	-	-	0.254	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Al3+	0.003	-	-	0.029	0.031	0.015	0.015	0.020	0.021	0.029	0.027	0.027	0.025	0.021	0.019	0.022	0.023	0.030	0.033	-	0.006
Cr3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nb5+	0.502	0.687	0.451	0.210	0.217	0.516	0.523	0.355	0.357	0.251	0.274	0.271	0.248	0.332	0.350	0.361	0.365	0.210	0.199	0.677	0.251
Ta5+	0.004	0.058	-	0.029	0.027	0.032	0.034	0.028	0.031	0.030	0.029	0.032	0.030	0.030	0.030	0.032	0.030	0.025	0.026	-	0.047
W6+	-	-	-	-	0.005	-	-	-	0.003	-	0.005	-	-	0.004	-	-	-	-	-	-	-
SUM Ti4+	2.115	2.015	1.920	2.002	2.000	2.058	2.074	2.025	2.044	2.042	2.024	2.007	2.004	2.044	2.035	2.036	2.042	2.013	2.021	2.111	2.062
TOTAL	4.088	4.031	3.947	4.068	4.058	4.066	4.062	4.059	4.071	4.065	4.058	4.076	4.067	4.071	4.068	4.065	4.066	4.059	4.070	4.020	4.064

	C91	C92	C93	C94	C95	C96	C97	C98	C99	C100	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111
MgO	0.33	0.35	0.32	0.32	0.31	0.31	0.33	0.33	0.40	0.40	0.47	0.47	0.47	0.49	0.48	0.46	0.47	0.44	0.45	0.36	0.32
Al2O3	0.08	0.07	0.09	0.08	0.06	0.08	0.07	0.05	0.07	0.08	0.06	0.05	0.06	0.07	0.05	0.06	0.06	0.06	0.06	0.05	0.06
SiO2	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
CaO	10.37	10.17	10.33	10.52	10.55	10.00	8.76	9.39	9.15	9.15	8.36	8.29	8.24	8.17	8.09	8.37	8.42	8.42	8.43	7.83	9.61
TiO2	25.50	25.20	25.13	24.87	24.77	24.43	23.18	23.75	23.91	24.19	24.14	24.29	24.27	24.37	24.43	24.55	24.66	24.60	24.41	24.82	25.43
Cr2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MnO	0.17	0.20	0.18	0.17	0.16	0.37	0.98	0.27	0.23	0.22	0.26	0.30	0.30	0.30	0.30	0.26	0.28	0.25	0.26	0.73	0.47
FeO	7.83	7.80	7.81	7.86	7.88	7.78	6.87	7.78	7.98	7.95	8.00	7.94	7.95	7.94	7.95	7.91	7.85	7.96	7.94	6.63	7.35
Fe2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Y2O3	0.54	0.48	0.48	0.51	0.49	0.57	0.58	0.56	0.50	0.53	0.38	0.37	0.38	0.35	0.35	0.37	0.36	0.38	0.37	0.71	0.54
ZrO2	31.61	31.08	31.50	31.28	31.07	30.83	30.82	30.46	29.86	29.89	29.34	28.86	29.10	28.85	28.99	28.84	28.40	28.96	28.79	30.81	31.68
Nb2O5	8.50	8.37	8.81	9.39	9.54	8.83	8.58	8.68	8.17	8.06	7.06	6.75	6.91	6.75	6.47	6.61	7.01	6.78	6.98	6.11	7.75
La2O3	0.18	0.16	0.15	0.15	0.17	0.18	0.16	0.18	0.16	0.14	0.08	0.07	0.06	0.06	0.06	0.07	0.09	0.08	0.09	0.17	0.16
Ce2O3	1.27	1.20	1.18	1.16	1.22	1.36	1.33	1.29	1.13	1.08	0.76	0.71	0.67	0.67	0.64	0.71	0.71	0.72	0.72	1.40	1.18
Pr2O3	0.23	0.22	0.24	0.18	0.17	0.23	0.16	0.25	0.20	0.17	0.12	0.10	0.08	0.09	0.08	0.11	0.14	0.15	0.12	0.17	0.13
Nd2O3	1.42	1.34	1.34	1.29	1.34	1.51	1.50	1.47	1.29	1.21	0.94	0.85	0.83	0.78	0.77	0.87	0.83	0.88	0.88	1.72	1.32
Sm2O3	0.40	0.36	0.37	0.37	0.35	0.42	0.42	0.42	0.35	0.37	0.27	0.26	0.23	0.21	0.24	0.24	0.24	0.24	0.23	0.46	0.38
Eu2O3	0.12	0.11	0.13	0.11	0.12	0.13	0.13	0.13	0.11	0.13	0.08	0.09	0.09	0.08	0.05	0.08	0.09	0.08	0.09	0.18	0.14
Gd2O3	0.31	0.29	0.28	0.27	0.31	0.35	0.36	0.30	0.30	0.30	0.24	0.19	0.20	0.21	0.20	0.18	0.22	0.21	0.21	0.41	0.32
Tb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dy2O3	0.17	0.12	0.14	0.14	0.17	0.16	0.15	0.16	0.16	0.12	0.08	0.05	0.05	0.06	0.03	0.07	0.08	0.08	0.06	0.20	0.12
Ho2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Er2O3	0.05	0.04	0.05	0.05	0.07	0.06	0.07	0.08	0.07	0.06	0.06	0.05	0.03	0.05	0.03	0.04	0.04	0.04	0.04	0.09	0.05
Tm2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HfO2	0.49	0.45	0.49	0.46	0.48	0.47	0.47	0.44	0.46	0.43	0.50	0.46	0.45	0.46	0.48	0.44	0.49	0.48	0.48	0.40	0.40
Ta2O5	2.92	2.88	3.02	3.28	3.50	3.71	3.69	3.55	2.91	2.76	2.02	1.77	1.72	1.58	1.55	1.59	1.64	1.56	1.61	2.08	2.58
WO3	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
PbO	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
ThO2	7.36	8.41	7.88	7.50	7.12	7.68	8.50	9.16	11.21	11.38	15.14	15.70	16.02	16.23	16.32	15.37	15.16	15.26	15.46	11.63	8.69
UO2	1.03	0.91	0.84	0.95	0.86	0.83	1.01	1.06	1.41	1.49	2.10	2.27	2.36	2.43	2.49	2.42	2.65	2.27	2.42	1.80	1.16
(Na,K)2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
"Others"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	100.88	100.22	100.75	100.89	100.71	100.29	98.11	99.75	100.02	100.11	100.45	99.89	100.50	100.20	100.07	99.63	99.87	99.91	100.09	98.73	99.84
cations to 7 oxygens																					
Ca2+	0.734	0.728	0.734	0.745	0.749	0.718	0.650	0.686	0.672	0.671	0.623	0.622	0.615	0.612	0.607	0.627	0.629	0.629	0.630	0.585	0.692
(Y+REE)3+	0.116	0.108	0.108	0.105	0.110	0.125	0.127	0.124	0.110	0.106	0.079	0.072	0.070	0.068	0.066	0.073	0.073	0.076	0.074	0.144	0.110
Pb2+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Th4+	0.111	0.128	0.119	0.113	0.107	0.117	0.134	0.142	0.175	0.177	0.239	0.250	0.254	0.258	0.260	0.245	0.240	0.242	0.245	0.185	0.133
U4+	0.015	0.013	0.012	0.014	0.013	0.012	0.016	0.016	0.022	0.023	0.032	0.035	0.037	0.038	0.039	0.038	0.041	0.035	0.038	0.028	0.017
SUM Ca2+	0.976	0.977	0.973	0.977	0.978	0.973	0.926	0.968	0.978	0.977	0.974	0.979	0.976	0.975	0.972	0.982	0.984	0.981	0.987	0.942	0.951
Zr4+	1.019	1.013	1.018	1.009	1.003	1.008	1.041	1.013	0.998	0.997	0.994	0.984	0.988	0.983	0.990	0.984	0.966	0.984	0.979	1.049	1.038
Hf4+	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.008	0.010	0.009	0.009	0.009	0.010	0.009	0.010	0.010	0.009	0.008	0.008
SUM Zr4+	1.028	1.021	1.028	1.017	1.012	1.017	1.051	1.021	1.007	1.006	1.004	0.994	0.997	0.992	0.999	0.992	0.976	0.994	0.988	1.057	1.045
Ti4+	1.267	1.266	1.253	1.237	1.234	1.232	1.208	1.218	1.233	1.245	1.261	1.278	1.271	1.280	1.286	1.291	1.293	1.289	1.280	1.303	1.284
Si4+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg2+	0.032	0.035	0.031	0.031	0.031	0.031	0.034	0.034	0.040	0.041	0.049	0.049	0.049	0.051	0.050	0.048	0.049	0.046	0.047	0.037	0.032
Mn2+	0.009	0.012	0.010	0.010	0.009	0.021	0.058	0.015	0.013	0.013	0.015	0.018	0.018	0.018	0.018	0.015	0.016	0.015	0.015	0.043	0.027
Fe2+	0.433	0.436	0.433	0.435	0.436	0.436	0.398	0.444	0.457	0.455	0.465	0.465	0.463	0.464	0.465	0.463	0.458	0.464	0.463	0.387	0.413
Fe3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Al3+	0.006	0.005	0.007	0.006	0.005	0.006	0.006	0.004	0.006	0.006	0.005	0.004	0.005	0.006	0.004	0.005	0.005	0.005	0.005	0.004	0.005
Cr3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nb5+	0.254	0.253	0.264	0.281	0.286	0.268	0.269	0.268	0.253	0.249	0.222	0.214	0.217	0.213	0.205	0.209	0.221	0.214	0.220	0.193	0.235
Ta5+	0.052	0.052	0.054	0.059	0.063	0.068	0.069	0.066	0.054	0.051	0.038	0.034	0.033	0.030	0.030	0.030	0.031	0.030	0.031	0.040	0.047
W6+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUM Ti4+	2.054	2.058	2.052	2.058	2.063	2.062	2.041	2.049	2.058	2.060	2.054	2.061	2.056	2.062	2.058	2.061	2.073	2.061	2.059	2.006	2.043
TOTAL	4.059	4.057	4.053	4.053	4.054	4.052	4.018	4.038	4.044	4.043	4.032	4.034	4.029	4.030	4.029	4.036	4.033	4.036	4.034	4.006	4.040

	C112	C113	C114	C115	C116	C117	C118	C119	C120	C121	C122	C123	C124	C125	C126	C127	C128	C129	C130	C131	C132
MgO	0.31	0.29	0.27	0.31	0.28	0.44	0.46	0.49	0.48	0.44	0.48	0.35	0.44	0.45	0.47	0.46	0.47	0.47	0.42	0.40	0.31
Al2O3	0.06	0.07	0.07	0.07	0.08	0.06	0.07	0.05	0.05	0.05	0.05	0.07	0.07	0.06	0.06	0.06	0.06	0.07	0.06	0.06	0.07
SiO2	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
CaO	10.44	10.43	10.42	10.17	9.85	8.13	7.95	7.87	7.99	8.23	8.00	9.67	9.24	8.67	8.29	8.18	8.25	8.22	8.27	8.78	10.47
TiO2	25.87	25.69	25.59	25.00	23.85	24.35	24.06	23.95	24.08	24.61	24.03	24.79	24.96	24.59	24.46	24.57	24.27	24.59	24.31	24.24	24.83
Cr2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MnO	0.16	0.17	0.13	0.16	0.17	0.28	0.33	0.31	0.32	0.28	0.29	0.18	0.21	0.24	0.28	0.26	0.29	0.29	0.27	0.24	0.17
FeO	7.84	7.85	7.81	7.88	7.47	7.89	7.95	7.95	7.90	7.95	8.00	7.82	7.87	7.98	7.96	7.88	8.02	7.92	7.91	7.92	7.88
Fe2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Y2O3	0.52	0.53	0.56	0.47	0.48	0.36	0.37	0.39	0.36	0.35	0.34	0.39	0.33	0.41	0.35	0.37	0.37	0.38	0.35	0.42	0.50
ZrO2	31.35	31.51	31.39	31.28	30.16	29.02	28.36	28.44	28.39	29.17	28.39	29.97	30.06	29.22	28.71	28.80	28.35	28.34	28.29	29.32	30.94
Nb2O5	8.36	8.16	8.60	8.41	8.69	6.51	6.67	6.67	6.77	6.43	6.56	8.26	7.24	6.89	6.75	6.71	6.81	6.61	6.62	7.56	9.35
La2O3	0.17	0.18	0.18	0.15	0.16	0.08	0.07	0.06	0.07	0.08	0.06	0.12	0.10	0.10	0.07	0.08	0.08	0.08	0.07	0.11	0.15
Ce2O3	1.23	1.37	1.41	1.20	1.20	0.70	0.65	0.64	0.63	0.70	0.61	0.93	0.81	0.88	0.71	0.72	0.70	0.69	0.68	0.92	1.19
Pr2O3	0.20	0.25	0.24	0.21	0.15	0.15	0.13	0.10	0.14	0.12	0.08	0.14	0.13	0.14	0.16	0.15	0.13	0.08	0.06	0.13	0.22
Nd2O3	1.38	1.52	1.57	1.34	1.34	0.88	0.79	0.83	0.77	0.85	0.78	1.04	0.92	1.03	0.82	0.86	0.80	0.84	0.82	1.02	1.28
Sm2O3	0.37	0.43	0.43	0.37	0.34	0.24	0.25	0.25	0.22	0.25	0.23	0.30	0.23	0.29	0.24	0.24	0.22	0.24	0.25	0.31	0.35
Eu2O3	0.11	0.13	0.12	0.11	0.11	0.08	0.07	0.09	0.07	0.07	0.09	0.09	0.08	0.10	0.08	0.08	0.07	0.08	0.09	0.10	0.10
Gd2O3	0.32	0.33	0.31	0.28	0.28	0.21	0.21	0.20	0.21	0.20	0.20	0.22	0.18	0.25	0.20	0.19	0.19	0.20	0.22	0.27	0.28
Tb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dy2O3	0.19	0.20	0.18	0.16	0.14	0.07	0.05	0.07	0.03	0.04	0.04	0.09	0.06	0.09	0.06	0.05	0.06	0.06	0.06	0.11	0.16
Ho2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Er2O3	0.06	0.05	0.07	0.05	0.05	0.04	0.03	0.05	0.05	0.05	0.02	0.03	0.05	0.04	0.03	0.03	0.04	0.05	0.05	0.06	0.06
Tm2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HfO2	0.39	0.44	0.49	0.50	0.48	0.48	0.48	0.50	0.46	0.46	0.47	0.48	0.47	0.45	0.46	0.45	0.51	0.49	0.45	0.45	0.44
Ta2O5	2.78	2.64	2.77	2.95	3.06	1.47	1.57	1.65	1.67	1.41	1.60	2.12	1.92	1.80	1.50	1.46	1.58	1.46	1.59	2.14	3.41
WO3	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
PbO	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
ThO2	7.51	6.94	6.34	8.35	7.94	15.96	16.37	16.59	16.40	15.69	16.53	10.98	12.83	13.75	15.77	15.74	15.87	15.90	15.64	13.15	7.15
UO2	0.95	0.89	1.21	0.90	0.85	2.31	2.58	2.57	2.55	2.49	2.64	1.54	1.89	2.03	2.44	2.50	2.71	2.65	2.57	2.01	0.93
(Na,K)2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
"Others"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	100.57	100.09	100.16	100.32	97.15	99.69	99.45	99.70	99.60	99.93	99.47	99.59	100.09	99.45	99.88	99.82	99.83	99.70	99.07	99.71	100.24
											cations to 7 oxygens										
Ca2+	0.739	0.742	0.740	0.728	0.729	0.611	0.602	0.596	0.604	0.616	0.606	0.705	0.677	0.646	0.622	0.613	0.621	0.618	0.625	0.651	0.746
Y+REE3+	0.113	0.124	0.126	0.109	0.111	0.075	0.070	0.072	0.068	0.072	0.065	0.086	0.075	0.087	0.072	0.073	0.071	0.072	0.071	0.090	0.107
Pb2+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Th4+	0.113	0.105	0.096	0.127	0.125	0.255	0.263	0.267	0.263	0.249	0.266	0.170	0.200	0.217	0.251	0.250	0.254	0.254	0.251	0.207	0.108
U4+	0.014	0.013	0.018	0.013	0.013	0.036	0.040	0.040	0.040	0.039	0.041	0.023	0.029	0.031	0.038	0.039	0.042	0.041	0.040	0.031	0.014
SUM Ca2+	0.979	0.984	0.980	0.977	0.977	0.977	0.976	0.974	0.976	0.976	0.979	0.984	0.980	0.981	0.982	0.976	0.987	0.985	0.988	0.980	0.975
Zr4+	1.011	1.020	1.015	1.019	1.016	0.993	0.977	0.980	0.976	0.994	0.979	0.995	1.002	0.990	0.979	0.982	0.970	0.969	0.973	0.990	1.003
Hf4+	0.007	0.008	0.009	0.010	0.009	0.010	0.010	0.010	0.009	0.009	0.010	0.009	0.009	0.009	0.009	0.009	0.010	0.010	0.009	0.009	0.008
SUM Zr4+	1.018	1.029	1.024	1.029	1.025	1.003	0.987	0.990	0.986	1.003	0.989	1.004	1.012	0.999	0.988	0.991	0.980	0.979	0.983	0.999	1.011
Ti4+	1.286	1.283	1.276	1.256	1.239	1.285	1.279	1.272	1.277	1.293	1.278	1.269	1.283	1.285	1.286	1.293	1.281	1.297	1.290	1.263	1.242
Si4+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg2+	0.030	0.029	0.027	0.031	0.029	0.046	0.048	0.052	0.051	0.046	0.050	0.036	0.045	0.047	0.049	0.048	0.049	0.049	0.044	0.041	0.031
Mn2+	0.009	0.009	0.007	0.009	0.010	0.016	0.020	0.018	0.019	0.017	0.017	0.011	0.012	0.014	0.017	0.015	0.017	0.017	0.016	0.014	0.010
Fe2+	0.433	0.436	0.433	0.441	0.432	0.463	0.470	0.470	0.466	0.465	0.473	0.445	0.450	0.464	0.466	0.461	0.471	0.465	0.467	0.459	0.438
Fe3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Al3+	0.005	0.005	0.005	0.006	0.007	0.005	0.006	0.004	0.004	0.004	0.004	0.005	0.006	0.005	0.005	0.005	0.005	0.006	0.005	0.005	0.005
Cr3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nb5+	0.250	0.245	0.258	0.254	0.271	0.206	0.213	0.213	0.216	0.203	0.210	0.254	0.224	0.216	0.213	0.212	0.216	0.210	0.211	0.237	0.281
Ta5+	0.050	0.048	0.050	0.054	0.057	0.028	0.030	0.032	0.032	0.027	0.031	0.039	0.036	0.034	0.028	0.028	0.030	0.028	0.031	0.040	0.062
W6+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUM Ti4+	2.064	2.055	2.056	2.050	2.045	2.050	2.066	2.062	2.065	2.055	2.063	2.059	2.055	2.065	2.064	2.061	2.068	2.071	2.064	2.058	2.068
TOTAL	4.060	4.067	4.060	4.056	4.047	4.030	4.028	4.026	4.026	4.033	4.031	4.048	4.047	4.046	4.035	4.028	4.036	4.034	4.035	4.037	4.055

	C133	C134	C135	C136	C137	C138	C139	C140	C141	C142	C143	C144	C145	C146	C147	C148	C149	C150	C151	C152	C153
MgO	0.31	0.30	0.32	0.08	0.11	0.11	0.12	0.23	0.33	0.37	0.52	0.33	0.40	0.25	0.10	0.15	0.19	0.32	0.23	0.14	0.21
Al2O3	0.09	0.07	0.10	0.05	0.06	0.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	0.08	0.08
SiO2	<.05	<.05	<.05	0.10	0.10	0.09	0.07	<.05	<.05	<.05	<.05	<.05	<.05	<.05	0.11	0.06	0.20	0.18	<.05	<.05	<.05
CaO	10.56	10.50	10.17	13.50	13.03	13.24	12.96	10.87	9.49	9.81	8.69	10.09	8.90	9.20	10.42	9.85	9.46	8.20	8.81	12.67	12.19
TiO2	24.80	24.81	25.79	37.16	36.00	36.30	35.99	29.16	24.81	24.54	23.71	27.14	25.68	28.97	32.93	31.63	30.46	28.52	28.33	32.29	30.69
Cr2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MnO	0.15	0.16	0.16	<.05	0.05	<.05	0.10	0.15	0.30	0.30	0.41	0.29	0.29	0.23	0.07	0.16	0.16	0.25	0.24	0.11	0.15
FeO	7.87	7.87	8.04	4.09	4.59	4.26	4.58	6.72	7.42	7.23	7.43	6.89	7.29	6.89	6.26	6.49	6.83	7.12	7.17	5.31	5.76
Fe2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Y2O3	0.56	0.52	0.54	0.28	0.29	0.36	0.34	0.58	0.65	0.55	0.68	0.62	0.55	0.46	0.34	0.37	0.48	0.59	0.57	0.62	0.56
ZrO2	31.07	30.98	30.83	37.20	36.56	36.58	36.92	31.90	29.60	29.54	29.21	29.76	29.53	30.97	32.96	31.80	32.32	30.47	30.30	33.32	33.17
Nb2O5	9.35	9.14	7.77	1.92	2.42	2.32	2.17	7.46	11.59	12.34	11.78	9.00	8.39	5.60	2.43	2.81	3.71	4.65	5.24	5.70	5.98
La2O3	0.17	0.14	0.15	0.17	0.18	0.18	0.20	0.42	0.58	0.51	0.49	0.46	0.54	0.86	1.00	0.92	0.84	0.77	0.77	0.11	0.11
Ce2O3	1.25	1.19	1.21	1.32	1.59	1.43	1.48	3.25	4.19	3.77	4.26	3.33	4.10	5.66	5.89	5.92	5.83	6.20	5.80	1.18	1.28
Pr2O3	0.25	0.17	0.17	0.20	0.25	0.23	0.19	0.61	0.72	0.75	0.79	0.60	0.71	0.86	0.83	0.88	0.80	1.06	0.86	0.23	0.23
Nd2O3	1.45	1.32	1.40	0.99	1.09	1.04	1.04	2.85	3.66	3.29	3.97	2.96	3.65	3.52	2.98	3.34	3.63	4.86	4.19	1.26	1.29
Sm2O3	0.40	0.39	0.40	0.13	0.20	0.23	0.19	0.53	0.69	0.73	0.85	0.62	0.70	0.48	0.33	0.43	0.60	0.79	0.62	0.36	0.36
Eu2O3	0.13	0.12	0.15	0.06	0.05	0.06	0.05	0.06	0.21	0.18	0.17	0.15	0.19	0.16	0.08	0.11	0.14	0.22	0.19	0.14	0.10
Gd2O3	0.32	0.29	0.32	0.12	0.12	0.16	0.15	0.38	0.46	0.45	0.52	0.46	0.46	0.32	0.13	0.21	0.30	0.43	0.35	0.28	0.30
Tb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dy2O3	0.20	0.15	0.15	0.12	0.13	0.15	0.09	0.20	0.29	0.27	0.33	0.24	0.27	0.23	0.09	0.14	0.19	0.25	0.18	0.26	0.23
Ho2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Er2O3	0.04	0.05	0.05	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	0.12	<.1
Tm2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HfO2	0.43	0.48	0.46	0.70	0.82	0.73	0.78	0.64	0.70	0.65	0.65	0.74	0.66	0.73	0.66	0.70	0.63	0.67	0.68	0.77	0.81
Ta2O5	3.61	3.37	2.40	0.25	0.21	0.23	0.25	0.38	0.58	0.63	0.49	0.46	0.46	0.39	0.06	0.19	0.20	0.18	0.37	0.41	0.52
WO3	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	0.11	<.1	0.16	<.1	0.13	<.1	<.1	0.13	<.1	<.1	<.1	<.1	<.1
PbO	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
ThO2	6.63	7.20	7.87	0.54	1.06	0.89	0.91	2.09	2.46	2.26	3.33	3.33	4.74	2.82	0.67	1.19	1.83	1.92	2.85	1.10	1.82
UO2	0.78	0.93	1.09	0.12	0.25	0.13	0.29	0.30	0.27	0.36	0.15	0.56	0.48	0.25	0.18	0.05	0.00	0.13	0.18	0.29	0.56
(Na,K)2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
"Others"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	100.38	100.13	99.54	99.09	99.14	98.75	98.85	98.79	99.11	98.54	98.61	98.02	98.13	98.84	98.53	97.51	98.78	97.76	97.92	96.75	96.41
cations to 7 oxygens																					
Ca2+	0.750	0.749	0.729	0.877	0.855	0.869	0.853	0.756	0.679	0.702	0.632	0.720	0.650	0.656	0.720	0.696	0.666	0.595	0.638	0.865	0.845
Y+REE3+	0.119	0.109	0.115	0.077	0.089	0.088	0.086	0.214	0.282	0.258	0.301	0.232	0.280	0.306	0.277	0.298	0.309	0.376	0.336	0.107	0.109
Pb2+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Th4+	0.100	0.109	0.120	0.007	0.015	0.012	0.013	0.031	0.037	0.034	0.051	0.051	0.074	0.043	0.010	0.018	0.027	0.030	0.044	0.016	0.027
U4+	0.011	0.014	0.016	0.002	0.003	0.002	0.004	0.004	0.004	0.005	0.002	0.008	0.007	0.004	0.003	0.001	0.000	0.002	0.003	0.004	0.008
SUM Ca2+	0.980	0.981	0.980	0.963	0.962	0.971	0.955	1.006	1.002	1.000	0.987	1.012	1.011	1.008	1.010	1.012	1.002	1.002	1.021	0.994	0.989
Zr4+	1.005	1.006	1.007	1.101	1.093	1.093	1.106	1.010	0.964	0.962	0.966	0.967	0.981	1.004	1.037	1.022	1.035	1.006	0.999	1.035	1.047
Hf4+	0.008	0.009	0.009	0.012	0.014	0.013	0.014	0.012	0.013	0.012	0.013	0.014	0.013	0.014	0.012	0.013	0.012	0.013	0.013	0.014	0.015
SUM Zr4+	1.013	1.015	1.015	1.113	1.107	1.106	1.120	1.022	0.977	0.975	0.979	0.981	0.994	1.018	1.049	1.035	1.047	1.018	1.012	1.049	1.062
Ti4+	1.237	1.243	1.298	1.695	1.659	1.672	1.663	1.424	1.246	1.233	1.210	1.360	1.316	1.449	1.598	1.568	1.505	1.451	1.440	1.547	1.494
Si4+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.007	0.004	0.013	0.012	-	-	-
Mg2+	0.030	0.030	0.031	0.008	0.010	0.010	0.011	0.022	0.032	0.036	0.053	0.033	0.041	0.025	0.010	0.014	0.019	0.032	0.024	0.014	0.020
Mn2+	0.008	0.009	0.009	0.000	0.003	0.000	0.005	0.008	0.017	0.017	0.023	0.016	0.017	0.013	0.004	0.009	0.009	0.015	0.014	0.006	0.008
Fe2+	0.436	0.438	0.450	0.208	0.235	0.218	0.235	0.365	0.414	0.404	0.422	0.384	0.416	0.383	0.338	0.358	0.375	0.403	0.405	0.283	0.312
Fe3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Al3+	0.007	0.005	0.008	0.004	0.004	0.003	-	-	-	-	-	-	-	-	-	-	-	-	-	0.006	0.006
Cr3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nb5+	0.281	0.275	0.235	0.053	0.067	0.064	0.060	0.219	0.350	0.373	0.361	0.271	0.258	0.168	0.071	0.084	0.110	0.142	0.160	0.164	0.175
Ta5+	0.065	0.061	0.044	0.004	0.003	0.004	0.004	0.007	0.011	0.011	0.009	0.008	0.009	0.007	0.001	0.003	0.004	0.003	0.007	0.007	0.009
W6+	-	-	-	-	-	-	-	-	0.002	-	0.003	-	0.002	-	-	0.002	-	-	-	-	-
SUM Ti4+	2.064	2.061	2.076	1.976	1.988	1.978	1.983	2.045	2.072	2.073	2.081	2.073	2.059	2.045	2.029	2.042	2.034	2.059	2.050	2.026	2.025
TOTAL	4.058	4.058	4.071	4.052	4.058	4.055	4.057	4.073	4.051	4.048	4.046	4.065	4.064	4.071	4.087	4.090	4.083	4.080	4.083	4.070	4.076

	C154	C155	C156	C157	C158	C159	C160	C161	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
MgO	0.19	0.15	0.13	0.22	0.15	0.11	0.11	0.16	0.38	0.31	0.29	0.36	0.49	0.48	0.50	<.04	0.09	<.04	<.04	<.04	<.04
Al2O3	0.10	0.10	0.09	0.09	0.08	0.11	0.10	0.10	0.53	0.53	0.54	0.58	0.70	0.58	0.72	0.71	0.67	0.60	0.64	0.65	0.54
SiO2	<.05	0.10	<.05	<.05	0.24	0.08	<.05	<.05	0.15	0.14	0.42	0.27	0.40	0.21	0.44	0.09	0.13	0.09	0.09	0.11	0.07
CaO	12.38	12.68	12.35	12.13	12.65	12.67	12.87	12.72	12.36	12.18	12.53	12.02	13.15	12.95	14.72	13.11	13.52	14.94	14.44	12.93	14.06
TiO2	31.37	31.50	31.34	30.67	32.27	32.60	32.74	31.85	29.91	30.73	30.21	29.78	33.15	34.03	36.85	36.85	37.99	38.79	39.24	37.21	39.76
Cr2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MnO	0.07	0.11	0.12	0.15	0.09	0.10	0.05	0.08	-	-	-	-	-	-	-	<.05	<.05	<.05	<.05	0.06	<.05
FeO	5.62	5.34	5.34	5.81	5.16	5.14	5.16	5.33	6.18	5.85	6.18	6.15	4.93	4.74	3.93	-	-	-	-	-	-
Fe2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.07	4.73	3.96	4.54	5.29	4.21
Y2O3	0.55	0.45	0.58	0.52	0.60	0.53	0.56	0.56	0.58	0.67	0.01	0.70	0.55	1.15	0.24	0.58	0.69	0.31	0.48	1.07	1.16
ZrO2	34.94	33.69	33.42	34.10	34.17	33.81	33.84	34.13	32.62	32.08	35.92	32.40	29.73	30.35	28.55	35.26	34.17	34.32	35.77	33.13	33.47
Nb2O5	5.34	5.30	5.75	6.15	5.40	4.90	5.28	5.48	10.53	9.66	9.39	9.83	10.29	8.72	11.08	0.44	0.51	0.45	0.37	1.07	0.34
La2O3	0.13	0.11	0.12	0.11	0.13	0.12	0.12	0.12	-	-	-	-	-	-	-	0.18	0.15	0.15	0.17	0.16	0.12
Ce2O3	1.15	1.07	1.19	1.24	1.13	1.11	1.18	1.24	3.71	3.78	2.40	4.03	2.20	1.95	0.45	1.46	1.03	1.06	1.35	1.02	1.01
Pr2O3	0.19	0.20	0.18	0.17	0.23	0.23	0.22	0.23	-	-	-	-	-	-	-	0.17	<.09	<.09	0.13	0.11	<.09
Nd2O3	1.14	1.02	1.25	1.14	1.14	1.16	1.19	1.19	-	-	-	-	-	-	-	0.68	0.61	0.47	0.77	1.17	0.79
Sm2O3	0.32	0.31	0.36	0.35	0.30	0.32	0.35	0.30	-	-	-	-	-	-	-	0.15	0.36	0.13	0.29	0.38	0.25
Eu2O3	0.08	0.11	0.12	0.10	0.11	0.13	0.04	0.08	-	-	-	-	-	-	-	-	-	-	-	-	-
Gd2O3	0.29	0.23	0.32	0.30	0.29	0.26	0.32	0.29	-	-	-	-	-	-	-	0.19	0.22	0.16	0.21	0.44	0.19
Tb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dy2O3	0.21	0.18	0.20	0.20	0.22	0.21	0.23	0.25	-	-	-	-	-	-	-	0.32	0.13	<.12	<.12	0.38	0.33
Ho2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Er2O3	<.1	<.1	0.10	<.1	<.1	<.1	<.1	<.1	-	-	-	-	-	-	-	0.16	0.19	<.12	<.12	0.33	0.30
Tm2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<.1	<.1	<.1	<.1	<.1	0.27
Lu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HfO2	0.82	0.78	0.79	0.80	0.87	0.73	0.78	0.77	0.49	0.39	0.72	0.45	0.23	0.35	0.34	0.52	0.68	0.32	0.55	1.00	0.65
Ta2O5	0.45	0.35	0.41	0.53	0.32	0.43	0.36	0.39	-	-	-	-	-	-	-	<.1	<.1	<.1	<.1	<.1	<.1
WO3	<.1	<.1	<.1	0.15	<.1	<.1	0.13	<.1	-	-	-	-	-	-	-	1.44	1.16	0.53	0.91	0.90	0.92
PbO	0.14	<.1	<.1	0.13	<.1	<.1	<.1	<.1	-	-	-	-	-	-	-	<.1	<.1	<.1	<.1	<.1	<.1
ThO2	1.66	0.98	1.17	2.03	0.95	1.13	0.94	1.22	0.61	1.04	0.17	1.47	1.90	1.96	1.25	0.61	2.37	0.26	0.60	2.43	1.07
UO2	0.40	0.33	0.34	0.46	0.24	0.29	0.21	0.34	-	-	-	-	-	-	-	0.37	0.91	0.22	0.19	1.55	0.20
(Na,K)2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
"Others"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	97.54	95.08	95.64	97.52	96.71	96.17	96.77	96.84	98.05	97.36	98.78	98.04	97.72	97.47	99.07	98.36	100.31	96.76	100.74	101.39	99.71
cations to 7 oxygens																					
Ca2+	0.845	0.878	0.855	0.833	0.860	0.867	0.874	0.869	0.828	0.820	0.826	0.810	0.864	0.854	0.928	0.851	0.865	0.963	0.905	0.830	0.893
Y+REE3+	0.098	0.090	0.106	0.100	0.100	0.098	0.101	0.103	0.104	0.109	0.054	0.116	0.067	0.082	0.017	0.090	0.080	0.058	0.077	0.119	0.104
Pb2+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.001	0.001	0.000
Th4+	0.024	0.014	0.017	0.030	0.014	0.016	0.014	0.018	0.009	0.015	0.002	0.021	0.027	0.027	0.017	0.008	0.032	0.004	0.008	0.033	0.014
U4+	0.006	0.005	0.005	0.006	0.003	0.004	0.003	0.005	-	-	-	-	-	-	-	0.005	0.012	0.003	0.002	0.021	0.003
SUM Ca2+	0.976	0.987	0.985	0.971	0.976	0.986	0.992	0.994	0.941	0.945	0.883	0.947	0.958	0.963	0.962	0.954	0.989	1.028	0.994	1.004	1.015
Zr4+	1.086	1.062	1.053	1.066	1.057	1.052	1.046	1.061	0.994	0.983	1.078	0.993	0.889	0.911	0.819	1.041	0.995	1.007	1.021	0.968	0.968
Hf4+	0.015	0.014	0.015	0.015	0.016	0.013	0.014	0.014	0.009	0.007	0.013	0.008	0.004	0.006	0.006	0.009	0.012	0.005	0.009	0.017	0.011
SUM Zr4+	1.101	1.076	1.068	1.080	1.072	1.066	1.061	1.075	1.003	0.990	1.091	1.002	0.893	0.917	0.825	1.050	1.007	1.013	1.030	0.986	0.979
Ti4+	1.503	1.531	1.523	1.478	1.539	1.565	1.561	1.527	1.406	1.453	1.398	1.408	1.529	1.575	1.631	1.678	1.706	1.756	1.727	1.677	1.773
Si4+	-	0.006	-	-	0.015	0.005	-	-	0.009	0.009	0.026	0.017	0.025	0.013	0.026	0.005	0.008	0.005	0.005	0.007	0.004
Mg2+	0.018	0.014	0.013	0.021	0.014	0.010	0.011	0.016	0.035	0.029	0.027	0.034	0.045	0.044	0.044	-	0.008	-	0.002	-	-
Mn2+	0.004	0.006	0.006	0.008	0.005	0.005	0.003	0.004	-	-	-	-	-	-	-	-	-	0.001	-	0.003	0.002
Fe2+	0.299	0.289	0.289	0.312	0.273	0.275	0.273	0.284	0.323	0.308	0.318	0.323	0.253	0.244	0.193	-	-	-	-	-	-
Fe3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.231	0.213	0.179	0.200	0.239	0.188
Al3+	0.008	0.008	0.007	0.006	0.006	0.008	0.007	0.008	0.039	0.039	0.039	0.043	0.051	0.042	0.050	0.051	0.047	0.043	0.044	0.046	0.038
Cr3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nb5+	0.154	0.155	0.168	0.178	0.155	0.141	0.151	0.158	0.298	0.275	0.261	0.279	0.285	0.243	0.295	0.012	0.014	0.012	0.010	0.029	0.009
Ta5+	0.008	0.006	0.007	0.009	0.006	0.007	0.006	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-
W6+	-	-	-	0.003	-	-	0.002	-	-	-	-	-	-	-	-	0.023	0.018	0.008	0.014	0.014	0.014
SUM Ti4+	1.994	2.015	2.013	2.015	2.014	2.017	2.015	2.004	2.111	2.112	2.070	2.105	2.188	2.161	2.239	2.000	2.013	2.004	2.002	2.015	2.027
TOTAL	4.071	4.077	4.067	4.067	4.063	4.068	4.067	4.073	4.055	4.047	4.044	4.054	4.039	4.041	4.026	4.004	4.009	4.045	4.025	4.004	4.021

	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34
MgO	<.04	0.09	<.04	<.04	<.04	<.04	0.18	<.04	<.04	0.30	0.56	0.63	0.22	0.31	0.93	0.75	0.59	1.21	1.21	0.16	0.14
Al2O3	0.52	0.62	0.56	0.74	0.72	0.76	0.68	0.67	0.62	0.98	1.12	1.14	0.80	0.82	1.24	1.17	1.39	0.64	0.79	1.28	1.39
SiO2	0.16	0.11	<.05	<.05	<.05	<.05	<.05	<.05	<.05	0.06	0.10	0.08	-	-	<.06	<.06	<.06	<.06	<.06	0.18	0.22
CaO	15.28	15.21	14.44	11.38	10.59	12.07	7.67	9.53	8.84	13.39	12.24	10.97	13.94	13.78	8.86	9.74	10.68	12.20	12.11	14.05	14.44
TiO2	41.21	41.60	39.97	34.54	32.34	33.62	29.57	30.67	29.62	35.52	25.86	31.12	40.91	42.64	29.43	31.61	33.48	33.21	32.18	39.35	41.59
Cr2O3	-	-	-	-	-	-	-	-	-	0.01	-	-	-	0.02	-	-	-	-	-	-	-
MnO	<.05	<.05	<.05	<.05	<.05	0.09	0.09	0.07	0.09	0.01	-	-	-	0.04	0.19	0.13	0.12	0.10	0.12	0.07	<.05
FeO	-	-	-	-	-	-	-	-	-	3.12	4.93	5.36	1.28	2.38	4.30	3.48	2.79	1.96	2.26	1.72	1.01
Fe2O3	3.16	3.27	3.73	6.32	7.02	5.70	8.40	7.42	7.91	-	-	-	-	-	-	-	-	-	-	-	-
Y2O3	0.29	0.42	0.70	3.08	2.92	3.13	6.71	6.91	8.07	2.10		3.08	0.18	0.14	0.22	0.22	0.20	0.94	1.19	0.42	0.18
ZrO2	34.41	35.71	33.97	31.01	30.54	32.14	28.53	30.97	28.10	35.35	34.72	35.15	38.64	35.71	26.85	29.37	30.70	30.28	29.44	33.74	33.80
Nb2O5	0.40	0.30	0.50	1.96	1.59	1.93	1.51	2.03	1.68	5.94	16.47	5.71	1.63	2.49	0.85	0.81	0.51	1.98	2.16	0.51	0.43
La2O3	0.18	0.19	0.17	0.15	0.07	0.10	<.07	<.07	<.07	-	-	-	-	-	0.12	0.23	0.17	0.14	0.07	0.28	0.21
Ce2O3	0.98	0.94	0.31	0.66	0.99	1.34	0.16	0.33	0.21	0.56	0.15	0.46	0.21	0.22	1.34	1.18	1.48	1.68	1.77	1.48	1.33
Pr2O3	0.10	0.10	<.09	0.21	0.15	0.21	<.09	<.09	<.09	-	-	-	-	-	<.14	<.14	<.14	0.38	0.39	0.24	<.14
Nd2O3	0.45	0.52	0.57	1.20	1.22	1.74	0.42	0.72	0.54	0.04	0.32	0.11	-	-	0.65	0.65	0.71	1.88	2.38	0.94	0.70
Sm2O3	<.12	<.12	0.28	0.62	0.57	0.54	0.49	0.57	0.58	0.17	-	0.21	0.04	0.03	<.14	<.14	<.14	0.52	0.65	<.14	<.14
Eu2O3	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-	-	-	-	-	-	-	-
Gd2O3	0.16	<.15	0.51	0.80	0.61	0.61	0.79	0.95	0.96	0.41	-	0.32	0.06	0.07	<.16	<.16	<.16	0.42	0.48	<.16	<.16
Tb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dy2O3	<.12	<.12	<.12	0.61	0.68	0.52	1.67	1.36	1.87	0.34	0.31	1.01	0.09	0.07	<.16	<.16	<.16	0.29	0.45	<.16	<.16
Ho2O3	-	-	-	-	-	-	-	-	-	-	0.30	-	0.21	-	-	-	-	-	-	-	-
Er2O3	<.12	<.12	0.19	0.47	0.39	0.34	1.38	0.85	1.37	-	-	-	-	-	<.17	<.17	<.17	<.17	<.17	<.17	<.17
Tm2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yb2O3	<.1	<.1	<.1	0.43	0.31	0.24	1.02	0.72	0.90	-	-	-	-	-	<.18	<.18	<.18	<.18	<.18	<.18	<.18
Lu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HfO2	0.50	0.50	0.57	0.74	0.36	0.78	0.66	0.70	0.47	0.69	0.68	0.71	0.77	0.39	0.37	<.24	<.24	0.70	0.85	0.40	<.24
Ta2O5	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	0.25	0.95	0.46	-	0.15	<.27	<.27	<.27	<.27	<.27	<.27	<.27
WO3	0.83	0.58	0.74	0.57	0.56	0.96	1.24	0.86	0.76	-	-	-	-	-	0.55	0.81	<.3	<.3	<.3	<.3	<.3
PbO	<.1	<.1	<.1	<.1	<.1	<.1	0.18	<.1	<.1	0.11	-	-	-	-	-	-	-	-	-	-	-
ThO2	0.22	0.21	1.75	1.87	4.88	0.76	1.01	1.20	1.16	0.39	1.65	1.38	0.01	0.21	17.07	15.09	13.62	7.49	6.44	4.00	2.73
UO2	0.14	0.02	0.27	1.88	3.43	0.75	7.18	2.89	3.81	0.02	0.86	0.81	0.07	0.20	5.93	3.87	2.91	2.56	2.58	1.47	0.79
(Na,K)2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
"Others"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	98.99	100.39	99.23	99.24	99.94	98.33	99.54	99.42	97.56	99.76	101.22	98.78	99.06	99.67	98.90	99.11	99.35	98.58	97.52	100.29	98.96
										cations to 7 oxygens											
Ca2+	0.958	0.939	0.917	0.757	0.721	0.807	0.540	0.651	0.624	0.857	0.803	0.734	0.873	0.852	0.660	0.701	0.748	0.847	0.853	0.903	0.915
Y+REE3+	0.052	0.055	0.067	0.211	0.208	0.226	0.363	0.353	0.424	0.098	0.022	0.148	0.018	0.012	0.062	0.058	0.063	0.155	0.186	0.078	0.054
Pb2+	-	0.000	0.001	-	-	-	0.003	0.001	0.001	0.002	-	-	-	-	-	-	-	-	-	-	-
Th4+	0.003	0.003	0.024	0.026	0.071	0.011	0.015	0.017	0.017	0.005	0.023	0.020	0.000	0.003	0.270	0.231	0.203	0.110	0.096	0.055	0.037
U4+	0.002	0.000	0.004	0.026	0.048	0.010	0.105	0.041	0.056	0.000	0.012	0.011	0.001	0.003	0.092	0.058	0.042	0.037	0.038	0.020	0.010
SUM Ca2+	1.015	0.997	1.012	1.020	1.048	1.055	1.026	1.063	1.123	0.963	0.860	0.913	0.892	0.869	1.084	1.047	1.057	1.150	1.173	1.055	1.016
Zr4+	0.982	1.004	0.981	0.939	0.946	0.978	0.914	0.963	0.903	1.030	1.037	1.070	1.102	1.005	0.911	0.962	0.979	0.957	0.943	0.987	0.975
Hf4+	0.008	0.008	0.010	0.013	0.007	0.014	0.012	0.013	0.009	0.012	0.012	0.013	0.013	0.006	0.007	-	-	0.013	0.016	0.007	-
SUM Zr4+	0.990	1.012	0.991	0.952	0.953	0.992	0.926	0.976	0.912	1.042	1.048	1.082	1.114	1.011	0.918	0.962	0.979	0.970	0.959	0.994	0.975
Ti4+	1.814	1.803	1.781	1.612	1.546	1.578	1.461	1.471	1.469	1.596	1.191	1.461	1.799	1.850	1.540	1.596	1.647	1.619	1.590	1.775	1.849
Si4+	0.009	0.006	0.001	-	0.001	-	-	0.001	-	0.004	0.006	0.005	-	-	-	-	-	-	-	0.011	0.013
Mg2+	-	0.008	0.004	0.005	0.002	-	0.018	0.004	-	0.027	0.051	0.059	0.019	0.027	0.096	0.075	0.058	0.117	0.118	0.014	0.012
Mn2+	0.001	-	0.002	0.001	0.002	0.005	0.005	0.004	0.005	0.001	-	-	-	0.002	0.011	0.007	0.007	0.005	0.007	0.004	-
Fe2+	-	-	-	-	-	-	-	-	-	0.156	0.252	0.280	0.063	0.115	0.250	0.195	0.153	0.106	0.124	0.086	0.050
Fe3+	0.139	0.142	0.166	0.295	0.336	0.268	0.415	0.356	0.393	-	-	-	-	-	-	-	-	-	-	-	-
Al3+	0.036	0.042	0.039	0.054	0.054	0.056	0.053	0.050	0.048	0.069	0.081	0.084	0.055	0.056	0.102	0.093	0.107	0.049	0.061	0.091	0.097
Cr3+	-	-	-	-	-	-	-	-	-	0.000	-	-	-	0.001	-	-	-	-	-	-	-
Nb5+	0.011	0.008	0.013	0.055	0.046	0.054	0.045	0.059	0.050	0.160	0.456	0.161	0.043	0.065	0.027	0.025	0.015	0.058	0.064	0.014	0.011
Ta5+	-	-	-	-	-	-	-	-	-	0.004	0.016	0.008	-	0.002	-	-	-	-	-	-	-
W6+	0.013	0.009	0.011	0.009	0.009	0.016	0.021	0.014	0.013	-	-	-	-	-	0.010	0.014	-	-	-	-	-
SUM Ti4+	2.023	2.018	2.017	2.031	1.995	1.976	2.017	1.959	1.978	2.017	2.053	2.057	1.979	2.118	2.036	2.005	1.986	1.955	1.965	1.994	2.033
TOTAL	4.028	4.027	4.021	4.003	3.996	4.022	3.969	3.998	4.013	4.022	3.961	4.052	3.985	3.998	4.038	4.014	4.021	4.075	4.097	4.042	4.023

	M35	M36	M37	M38	M39	M40	M41	M42	M43	M44	M45	M46	M47	M48	M49	M50	M51	M52	M53	M54	M55
MgO	0.59	0.81	0.27	1.07	0.07	0.86	0.47	0.22	1.03	0.78	0.49	1.48	0.30	1.34	0.20	2.20	1.22	0.80	1.24	1.98	2.60
Al2O3	1.26	0.85	1.68	0.82	1.37	0.50	0.92	1.37	0.72	1.09	1.35	0.94	0.74	0.98	0.81	0.58	0.91	1.33	0.97	0.54	1.32
SiO2	<.06	0.20	0.18	<.06	0.11	0.40	0.07	0.11	<.06	<.06	<.06	<.06	<.06	<.06	<.06	<.06	<.06	<.06	<.06	<.06	<.06
CaO	10.18	7.94	12.83	9.87	14.49	7.48	13.02	13.58	7.37	12.19	13.11	12.24	16.54	10.90	16.10	9.35	8.68	10.48	9.88	9.96	9.25
TiO2	32.42	28.16	38.24	33.13	40.83	30.18	40.15	39.45	31.03	35.02	39.85	33.15	42.94	34.88	44.91	28.75	32.50	33.20	32.25	31.31	29.40
Cr2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MnO	0.17	0.26	<.05	<.05	<.05	0.16	0.07	<.05	0.11	0.09	<.05	0.09	<.05	0.14	<.05	0.11	0.09	0.27	0.23	0.19	0.19
FeO	3.34	4.26	1.74	3.12	0.97	4.58	2.02	1.46	4.64	2.77	1.88	2.68	1.10	2.44	0.72	2.24	3.23	2.74	2.60	2.46	2.51
Fe2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Y2O3	0.24	0.17	0.42	1.34	0.45	2.00	0.75	0.32	2.44	0.85	0.45	1.10	0.42	0.96	0.30	0.25	1.83	0.60	0.68	0.37	0.25
ZrO2	27.58	27.63	31.55	28.32	34.59	24.50	28.53	31.66	28.96	31.01	30.66	29.24	31.44	30.18	31.80	27.67	25.50	30.26	30.71	27.76	27.63
Nb2O5	0.79	0.93	0.52	2.35	0.42	3.50	1.60	0.67	3.20	1.60	0.90	2.25	0.91	2.29	0.83	1.78	2.37	0.97	1.38	2.16	1.82
La2O3	0.26	0.15	0.15	0.28	0.21	0.40	<.07	0.16	0.54	0.28	0.20	0.28	<.07	0.26	<.07	<.07	0.41	0.36	0.23	<.07	<.07
Ce2O3	1.21	1.10	1.22	2.40	1.16	3.68	1.12	1.00	3.92	2.01	1.21	1.80	0.70	1.83	0.26	0.59	3.82	2.64	2.02	0.90	0.63
Pr2O3	0.28	<.14	<.14	0.40	0.20	0.72	<.14	<.14	0.61	0.34	<.14	0.27	<.14	0.34	<.14	<.14	0.63	0.41	0.22	<.14	<.14
Nd2O3	1.08	0.52	0.86	2.48	0.88	4.00	1.10	0.54	4.90	2.17	1.05	2.54	0.52	2.21	0.15	0.52	4.09	1.92	1.59	0.70	0.50
Sm2O3	0.19	<.14	<.14	0.76	0.28	1.08	0.24	<.14	1.47	0.59	0.27	0.80	0.16	0.59	<.14	0.17	1.18	0.32	0.33	0.17	<.14
Eu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gd2O3	<.16	<.16	<.16	0.53	0.21	1.01	0.25	<.16	1.08	0.43	0.21	0.61	0.21	0.51	<.16	<.16	0.95	0.24	0.25	<.16	<.16
Tb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dy2O3	<.16	<.16	<.16	0.54	<.16	0.69	0.19	<.16	0.83	0.40	0.29	0.43	<.16	0.40	<.16	<.16	0.67	0.17	<.16	<.16	<.16
Ho2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Er2O3	<.17	<.17	<.17	0.28	<.17	0.30	<.17	<.17	0.33	0.19	<.17	0.21	<.17	0.18	<.17	<.17	0.25	<.17	<.17	<.17	<.17
Tm2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yb2O3	<.18	<.18	<.18	0.20	<.18	0.20	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18
Lu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HfO2	<.24	0.49	0.30	1.09	<.24	0.65	1.03	<.24	0.94	0.75	0.25	0.29	0.64	0.88	0.74	0.66	0.83	0.31	<.24	0.53	0.55
Ta2O5	<.27	<.27	<.27	<.27	<.27	<.27	<.27	<.27	<.27	<.27	<.27	<.27	<.27	<.27	<.27	0.41	<.27	<.27	<.27	0.41	<.27
WO3	1.00	0.75	<.3	0.37	<.3	1.02	<.3	1.04	0.43	0.42	<.3	<.3	<.3	<.3	<.3	<.3	<.3	0.51	0.88	<.3	<.3
PbO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ThO2	12.81	15.37	4.81	7.08	1.30	6.32	3.94	3.69	4.44	5.23	5.37	6.36	0.67	6.09	0.80	8.47	6.38	7.47	6.26	7.00	6.92
UO2	6.97	9.20	3.82	2.69	0.78	3.32	2.24	2.26	2.41	2.88	2.64	2.89	1.08	2.52	0.59	14.66	2.48	4.54	8.21	13.61	14.04
(Na,K)2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
"Others"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	100.37	98.79	98.59	99.12	98.32	97.55	97.71	97.53	101.40	101.09	100.18	99.65	98.37	99.92	98.21	98.41	98.02	99.54	99.93	100.05	97.61
cations to 7 oxygens																					
Ca2+	0.727	0.603	0.848	0.693	0.924	0.552	0.859	0.890	0.519	0.818	0.852	0.841	1.042	0.739	1.001	0.698	0.624	0.731	0.694	0.715	0.679
Y+REE3+	0.081	0.052	0.064	0.228	0.077	0.367	0.088	0.048	0.407	0.171	0.084	0.195	0.047	0.174	0.018	0.041	0.351	0.163	0.133	0.056	0.037
Pb2+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.002	-	-	-	-	-
Th4+	0.194	0.248	0.068	0.106	0.018	0.099	0.055	0.051	0.066	0.075	0.074	0.093	0.009	0.088	0.011	0.134	0.097	0.111	0.093	0.107	0.108
U4+	0.103	0.145	0.052	0.039	0.010	0.051	0.031	0.031	0.035	0.040	0.036	0.041	0.014	0.035	0.008	0.227	0.037	0.066	0.120	0.203	0.214
SUM Ca2+	1.106	1.048	1.032	1.066	1.029	1.069	1.033	1.021	1.028	1.103	1.046	1.170	1.112	1.037	1.037	1.103	1.110	1.070	1.040	1.081	1.039
Zr4+	0.896	0.955	0.950	0.904	1.004	0.822	0.856	0.945	0.929	0.947	0.907	0.915	0.902	0.932	0.900	0.940	0.835	0.960	0.982	0.907	0.924
Hf4+	-	0.010	0.005	0.020	-	0.013	0.018	-	0.018	0.013	0.004	0.005	0.011	0.016	0.012	0.013	0.016	0.006	-	0.010	0.011
SUM Zr4+	0.896	0.964	0.955	0.925	1.004	0.835	0.875	0.945	0.946	0.960	0.911	0.920	0.913	0.948	0.912	0.953	0.851	0.966	0.982	0.917	0.934
Ti4+	1.625	1.500	1.775	1.632	1.828	1.562	1.859	1.816	1.534	1.649	1.817	1.599	1.899	1.661	1.960	1.506	1.641	1.625	1.590	1.578	1.515
Si4+	-	0.014	0.011	-	0.007	0.028	0.004	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg2+	0.059	0.086	0.025	0.104	0.006	0.088	0.043	0.020	0.101	0.073	0.044	0.141	0.026	0.126	0.017	0.228	0.122	0.078	0.121	0.198	0.266
Mn2+	0.010	0.016	-	-	-	0.009	0.004	-	0.006	0.005	-	0.005	-	0.008	-	0.006	0.005	0.015	0.013	0.011	0.011
Fe2+	0.186	0.252	0.090	0.171	0.048	0.264	0.104	0.075	0.255	0.145	0.095	0.144	0.054	0.129	0.035	0.130	0.181	0.149	0.143	0.138	0.144
Fe3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Al3+	0.099	0.071	0.122	0.063	0.096	0.041	0.067	0.099	0.056	0.081	0.097	0.071	0.051	0.073	0.055	0.048	0.072	0.102	0.075	0.043	0.107
Cr3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nb5+	0.024	0.030	0.015	0.070	0.011	0.109	0.045	0.019	0.095	0.045	0.025	0.065	0.024	0.066	0.022	0.056	0.072	0.029	0.041	0.065	0.056
Ta5+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.008	-	-	-	0.007	-
W6+	0.017	0.014	-	0.006	-	0.018	-	0.016	0.007	0.007	-	-	-	-	-	-	-	0.009	0.015	-	-
SUM Ti4+	2.019	1.983	2.037	2.046	1.996	2.118	2.125	2.051	2.055	2.005	2.078	2.026	2.055	2.062	2.090	1.983	2.093	2.005	1.997	2.039	2.099
TOTAL	4.021	3.995	4.024	4.036	4.030	4.022	4.032	4.017	4.029	4.068	4.035	4.116	4.080	4.047	4.040	4.039	4.054	4.041	4.020	4.037	4.072

	M56	M57	M58	M59	M60	M61	M62	M63	M64	M65	M66	M67	M68	M69	M70	M71	M72	M73	M74	M75	M76
MgO	1.49	2.37	2.27	1.98	2.28	0.75	2.14	1.98	2.31	2.68	2.22	0.52	0.53	0.37	0.32	0.37	0.30	0.34	0.24	0.21	0.32
Al2O3	0.91	0.86	0.47	0.33	0.43	1.46	0.52	0.63	0.70	0.70	0.80	0.35	0.40	0.38	0.25	0.30	0.21	0.19	0.23	0.26	0.28
SiO2	<.06	<.06	<.06	<.06	<.06	0.18	<.06	<.06	<.06	<.06	<.06	0.39	0.39	0.33	0.26	0.28	0.23	0.26	0.28	0.19	0.26
CaO	9.79	9.55	9.33	8.92	9.48	11.86	9.42	9.35	9.07	10.06	10.51	7.21	7.40	8.33	7.49	7.23	7.37	7.16	7.46	8.99	7.52
TiO2	33.50	29.79	29.73	26.39	29.94	35.87	30.31	28.68	29.50	30.66	30.62	26.36	26.33	29.24	28.04	26.72	26.75	26.96	26.58	29.01	27.36
Cr2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MnO	0.24	0.24	<.05	0.20	0.09	<.05	0.19	0.13	0.19	0.14	0.10	0.72	0.78	0.60	0.64	0.63	0.82	0.87	1.10	0.59	0.79
FeO	2.12	2.29	1.99	4.23	2.34	2.10	1.89	3.21	2.36	2.15	2.22	6.08	6.63	6.26	6.67	7.14	6.90	6.54	5.79	6.54	6.36
Fe2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Y2O3	1.13	0.27	0.18	0.08	0.17	0.38	0.18	1.06	0.44	0.28	0.24	4.51	3.55	3.76	4.40	4.62	5.26	5.10	4.88	3.22	4.58
ZrO2	30.90	29.99	29.77	25.96	30.46	32.40	31.85	24.34	27.76	26.65	26.05	28.95	29.23	30.16	29.16	29.33	29.15	29.05	29.12	29.92	28.66
Nb2O5	2.22	1.75	2.20	1.64	1.62	0.74	1.37	2.34	1.85	1.89	1.78	2.77	2.65	2.04	2.73	2.32	3.85	3.52	3.07	2.10	2.76
La2O3	0.23	<.07	<.07	0.09	0.12	0.34	<.07	0.09	0.09	<.07	0.12	0.21	0.34	0.18	0.18	0.08	0.14	0.19	0.13	0.25	0.14
Ce2O3	1.69	0.58	0.59	0.39	0.73	1.99	0.61	1.75	0.81	0.66	0.86	1.61	2.45	2.62	2.17	1.63	1.88	1.75	1.70	2.69	1.68
Pr2O3	0.45	<.14	<.14	<.14	<.14	0.25	0.18	0.36	<.14	<.14	<.14	0.19	0.33	0.40	0.52	0.52	0.32	0.39	0.34	0.45	0.29
Nd2O3	1.93	0.54	0.45	0.21	0.66	1.72	0.97	2.11	0.88	0.60	0.68	3.21	3.20	3.03	3.36	3.09	3.47	3.27	3.22	3.31	3.09
Sm2O3	0.50	0.16	<.14	<.14	<.14	0.22	<.14	0.57	0.26	0.14	0.20	1.24	0.99	1.11	1.01	1.13	1.41	1.57	1.29	0.94	1.14
Eu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gd2O3	0.39	<.16	<.16	<.16	<.16	0.30	<.16	0.56	0.24	<.16	0.21	1.49	1.07	1.07	1.14	1.22	1.48	1.36	1.43	0.87	1.28
Tb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dy2O3	0.31	<.16	<.16	<.16	<.16	<.16	<.16	0.38	0.17	0.16	0.16	1.22	0.85	0.70	0.78	1.02	0.96	0.99	1.03	0.53	0.96
Ho2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Er2O3	<.17	<.17	<.17	<.17	<.17	<.17	<.17	<.17	<.17	<.17	<.17	0.34	0.36	0.23	0.48	0.53	0.49	0.37	0.40	0.25	0.51
Tm2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yb2O3	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	<.18	0.42	0.16	0.47	0.41	0.42	0.42	0.30	0.31	0.23	0.42
Lu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HfO2	0.52	0.51	0.59	0.58	0.70	0.39	0.54	0.41	0.48	0.65	0.30	0.52	0.85	0.87	0.98	0.82	0.85	0.69	0.74	1.04	0.51
Ta2O5	<.27	<.27	0.41	<.27	<.27	<.27	<.27	0.36	0.56	<.27	0.31	<.15	<.15	<.15	0.15	0.27	0.32	0.25	0.20	<.15	<.15
WO3	<.3	<.3	<.3	0.85	<.3	<.3	<.3	0.69	<.3	<.3	<.3	0.34	0.49	0.65	0.71	0.58	0.35	0.35	0.26	0.78	0.37
PbO	-	-	-	-	-	-	-	-	-	-	-	0.20	0.21	0.16	0.18	0.37	0.18	0.26	0.21	<.10	0.29
ThO2	6.40	8.25	8.98	5.96	8.39	4.92	7.04	7.30	8.06	7.62	8.24	1.53	3.05	1.43	1.45	1.96	0.94	0.84	1.46	0.74	1.78
UO2	5.64	12.26	13.98	23.98	12.14	4.01	11.81	14.66	13.23	15.10	13.16	0.97	1.39	0.78	1.12	1.43	0.59	0.54	0.75	0.37	1.21
(Na,K)2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
"Others"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	100.36	99.41	100.94	101.79	99.55	99.88	98.99	100.96	98.96	100.14	98.78	91.35	93.63	95.17	94.60	94.01	94.64	93.11	92.22	93.48	92.56
											cations to 7 oxygens										
Ca2+	0.674	0.690	0.675	0.679	0.687	0.794	0.679	0.693	0.667	0.727	0.767	0.557	0.564	0.610	0.559	0.549	0.552	0.542	0.572	0.666	0.573
Y+REE3+	0.165	0.041	0.032	0.021	0.043	0.121	0.051	0.182	0.076	0.050	0.063	0.421	0.378	0.371	0.407	0.411	0.452	0.442	0.431	0.351	0.408
Pb2+	-	-	-	0.003	-	-	-	-	0.002	-	-	0.004	0.004	0.003	0.003	0.007	0.003	0.005	0.004	-	0.006
Th4+	0.094	0.127	0.138	0.096	0.129	0.070	0.108	0.115	0.126	0.117	0.128	0.025	0.049	0.022	0.023	0.032	0.015	0.014	0.024	0.012	0.029
U4+	0.081	0.184	0.210	0.379	0.183	0.056	0.177	0.226	0.202	0.226	0.199	0.016	0.022	0.012	0.017	0.023	0.009	0.008	0.012	0.006	0.019
SUM Ca2+	1.013	1.041	1.054	1.178	1.042	1.040	1.015	1.215	1.073	1.120	1.157	1.022	1.017	1.018	1.010	1.022	1.032	1.012	1.043	1.034	1.035
Zr4+	0.969	0.986	0.980	0.899	1.005	0.987	1.045	0.821	0.929	0.876	0.865	1.018	1.014	1.005	0.991	1.014	0.994	1.002	1.017	1.009	0.995
Hf4+	0.010	0.010	0.011	0.012	0.014	0.007	0.010	0.008	0.009	0.013	0.006	0.011	0.017	0.017	0.019	0.017	0.017	0.014	0.015	0.021	0.010
SUM Zr4+	0.978	0.996	0.991	0.911	1.018	0.994	1.055	0.829	0.939	0.889	0.871	1.028	1.031	1.022	1.010	1.031	1.011	1.015	1.032	1.029	1.005
Ti4+	1.620	1.510	1.509	1.410	1.523	1.685	1.534	1.492	1.523	1.554	1.569	1.429	1.409	1.503	1.469	1.425	1.407	1.433	1.431	1.508	1.464
Si4+	-	-	-	-	-	0.011	-	-	-	-	-	0.028	0.028	0.023	0.018	0.020	0.016	0.018	0.020	0.013	0.019
Mg2+	0.143	0.238	0.228	0.210	0.230	0.070	0.215	0.204	0.236	0.269	0.225	0.056	0.056	0.038	0.033	0.039	0.031	0.036	0.026	0.022	0.034
Mn2+	0.013	0.014	-	0.012	0.005	-	0.011	0.008	0.011	0.008	0.006	0.044	0.047	0.035	0.038	0.038	0.049	0.052	0.067	0.035	0.048
Fe2+	0.114	0.129	0.112	0.251	0.132	0.110	0.106	0.186	0.135	0.121	0.126	0.367	0.394	0.358	0.389	0.423	0.404	0.387	0.347	0.378	0.379
Fe3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Al3+	0.069	0.068	0.037	0.028	0.034	0.108	0.041	0.051	0.057	0.056	0.064	0.030	0.034	0.031	0.021	0.025	0.017	0.016	0.019	0.021	0.024
Cr3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nb5+	0.065	0.053	0.067	0.053	0.050	0.021	0.042	0.073	0.057	0.058	0.055	0.090	0.085	0.063	0.086	0.074	0.122	0.113	0.099	0.066	0.089
Ta5+	-	-	0.008	-	-	-	-	0.007	0.010	-	0.006	-	-	-	0.003	0.005	0.006	0.005	0.004	-	-
W6+	-	-	-	0.016	-	-	-	0.012	-	-	-	0.006	0.009	0.011	0.013	0.011	0.006	0.006	0.005	0.014	0.007
SUM Ti4+	2.023	2.013	1.961	1.979	1.974	2.004	1.948	2.033	2.030	2.066	2.051	2.050	2.062	2.060	2.069	2.060	2.058	2.066	2.018	2.057	2.062
TOTAL	4.014	4.049	4.006	4.069	4.034	4.039	4.018	4.077	4.042	4.075	4.079	4.101	4.110	4.101	4.090	4.112	4.102	4.093	4.092	4.120	4.102

	M77	M78	M79	M80	M81	M82	M83	M84	M85	M86	M87	M88	M89	M90	M91	M92	M93	M94	M95	M96	M97
MgO	0.45	0.22	0.17	0.37	0.65	0.28	0.96	1.33	0.95	0.39	0.36	0.32	0.24	0.34	0.19	0.35	0.34	0.20	-	-	0.39
Al2O3	0.23	0.34	0.17	0.32	0.40	0.19	0.54	0.74	0.57	0.29	0.25	0.27	0.25	0.21	0.21	0.19	0.19	0.10	-	1.89	-
SiO2	0.59	0.21	0.09	0.16	0.52	0.26	0.86	0.93	0.81	0.23	0.28	0.28	0.12	0.16	0.14	0.37	0.26	0.28	-	2.94	-
CaO	7.78	8.40	7.70	7.31	6.92	7.81	7.29	7.55	8.20	7.13	7.52	8.14	7.24	7.44	7.64	8.47	7.32	8.75	6.58	8.71	15.83
TiO2	26.95	28.00	27.24	27.87	26.51	26.47	27.00	27.52	28.18	27.67	27.48	28.38	27.75	27.29	27.35	27.16	27.38	27.51	28.12	33.12	45.72
Cr2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MnO	0.94	0.84	0.78	0.68	0.64	1.03	0.97	0.59	0.87	0.63	0.85	0.58	0.71	0.75	0.63	2.00	0.88	1.99	-	-	-
FeO	6.21	5.27	6.64	7.02	7.10	5.17	5.71	7.02	5.77	6.71	6.74	6.58	6.58	6.85	6.70	3.63	5.96	3.10	-	1.50	-
Fe2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.58	1.87	1.50
Y2O3	4.99	3.13	4.97	4.83	5.08	4.49	5.21	4.01	4.02	5.02	4.97	4.18	4.95	5.39	5.19	5.18	5.09	5.24	3.28	0.85	-
ZrO2	28.56	30.12	29.13	29.89	28.11	29.18	29.00	29.37	30.23	29.65	29.74	30.06	28.59	28.71	28.86	28.84	28.81	28.71	31.04	32.86	36.70
Nb2O5	3.94	2.02	3.71	2.50	2.60	2.44	3.06	2.37	1.83	2.47	3.81	2.60	2.49	3.17	3.72	2.49	2.78	3.12	6.40	4.43	-
La2O3	0.21	0.32	0.13	0.15	0.12	0.18	0.11	0.17	0.31	0.10	0.20	0.19	0.16	0.13	0.13	0.10	0.15	0.11	0.57	0.57	-
Ce2O3	1.74	2.99	1.74	1.42	1.14	1.77	1.31	2.10	2.10	1.18	1.82	2.11	1.61	1.41	1.63	1.27	1.58	1.30	3.68	3.53	-
Pr2O3	0.37	0.61	0.29	0.49	0.41	0.24	0.27	0.35	0.46	0.34	0.47	0.40	0.30	0.42	0.25	0.29	0.36	0.10	0.90	0.73	-
Nd2O3	3.15	3.18	3.26	2.99	2.67	3.01	2.70	3.13	3.11	2.92	3.39	3.15	2.80	2.89	3.21	2.82	3.22	2.50	3.28	1.77	-
Sm2O3	1.20	0.91	1.27	1.31	1.21	1.27	1.03	0.97	1.01	1.11	1.10	0.96	1.18	1.08	1.23	1.20	1.32	0.87	1.38	0.37	-
Eu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.28	0.06	-
Gd2O3	1.36	0.94	1.40	1.51	1.53	1.39	1.41	1.16	1.13	1.50	1.37	1.14	1.43	1.41	1.51	1.50	1.44	1.22	1.14	0.27	-
Tb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.13	0.03	-
Dy2O3	0.98	0.75	0.92	1.20	1.21	0.92	0.90	0.79	0.76	1.12	0.90	0.94	1.09	1.11	0.97	1.07	1.10	1.08	0.78	0.19	-
Ho2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.10	0.02	-
Er2O3	0.43	0.34	0.42	0.60	0.50	0.46	0.46	0.39	0.43	0.43	0.41	0.42	0.50	0.47	0.48	0.55	0.55	0.42	0.44	0.06	-
Tm2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	-	-
Yb2O3	0.40	0.23	0.34	0.35	0.27	0.32	0.30	0.39	0.18	0.45	0.28	0.43	0.55	0.43	0.44	0.55	0.55	0.41	0.20	0.02	-
Lu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	-	-
HfO2	0.80	0.90	0.80	0.78	0.77	1.13	0.59	0.69	0.72	0.93	0.80	0.75	1.00	0.78	0.77	0.87	0.70	0.54	-	-	-
Ta2O5	0.46	0.12	0.20	<.15	<.15	<.15	<.15	<.15	<.15	<.15	<.15	<.15	<.15	<.15	<.15	<.15	<.15	<.15	-	-	-
WO3	0.23	0.51	0.30	0.67	0.42	0.65	0.77	0.14	0.39	0.69	0.67	0.65	0.44	0.26	0.05	0.28	0.21	0.25	-	-	-
PbO	<.10	0.27	0.24	0.40	0.80	0.16	0.30	0.21	0.21	0.27	0.17	0.19	0.29	0.43	0.21	0.19	0.78	0.22	-	-	-
ThO2	0.73	1.97	0.66	2.25	2.35	2.39	2.33	1.18	1.39	2.31	1.20	1.56	2.25	2.26	1.23	2.07	1.74	2.19	0.60	0.97	-
UO2	0.65	0.78	0.46	1.49	2.10	1.63	1.87	0.72	1.01	1.58	0.75	0.97	1.89	1.72	0.99	1.89	1.16	2.43	-	0.11	-
(Na,K)2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.02	1.87	-
H2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.20	-
"Others"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.08	-
TOTAL	93.35	93.37	93.03	96.56	94.03	92.84	94.95	93.82	94.64	95.12	95.53	95.25	94.41	95.11	93.73	93.33	93.87	92.64	99.62	100.02	100.14
											cations to 7 oxygens										
Ca2+	0.583	0.633	0.582	0.541	0.527	0.601	0.540	0.556	0.601	0.533	0.555	0.600	0.548	0.559	0.576	0.644	0.556	0.666	0.459	0.573	0.959
Y+REE3+	0.424	0.372	0.426	0.416	0.414	0.410	0.394	0.373	0.373	0.406	0.421	0.386	0.420	0.427	0.434	0.423	0.443	0.394	0.412	0.196	0.000
Pb2+	-	0.005	0.005	0.007	0.015	0.003	0.006	0.004	0.004	0.005	0.003	0.004	0.006	0.008	0.004	0.004	0.015	0.004	-	-	-
Th4+	0.012	0.032	0.011	0.035	0.038	0.039	0.037	0.018	0.022	0.037	0.019	0.024	0.036	0.036	0.020	0.033	0.028	0.035	0.009	0.014	-
U4+	0.010	0.012	0.007	0.023	0.033	0.026	0.029	0.011	0.015	0.025	0.011	0.015	0.030	0.027	0.015	0.030	0.018	0.038	-	0.002	-
SUM Ca2+	1.029	1.054	1.030	1.022	1.027	1.079	1.005	0.962	1.015	1.006	1.009	1.029	1.040	1.057	1.049	1.134	1.060	1.138	0.880	0.784	0.959
Zr4+	0.974	1.034	1.002	1.006	0.974	1.022	0.977	0.984	1.008	1.009	0.999	1.009	0.985	0.981	0.990	0.997	0.995	0.994	0.986	0.983	1.012
Hf4+	0.016	0.018	0.016	0.015	0.016	0.023	0.012	0.014	0.014	0.019	0.016	0.015	0.020	0.016	0.015	0.018	0.014	0.011	-	-	-
SUM Zr4+	0.990	1.052	1.018	1.021	0.989	1.046	0.989	0.998	1.022	1.028	1.014	1.024	1.005	0.997	1.005	1.015	1.009	1.005	0.986	0.983	1.012
Ti4+	1.417	1.482	1.445	1.447	1.416	1.430	1.403	1.422	1.449	1.452	1.423	1.469	1.474	1.439	1.447	1.449	1.459	1.470	1.378	1.528	1.944
Si4+	0.041	0.015	0.006	0.011	0.037	0.019	0.059	0.064	0.055	0.016	0.019	0.019	0.008	0.011	0.010	0.026	0.018	0.020	-	0.180	-
Mg2+	0.047	0.023	0.018	0.038	0.069	0.030	0.099	0.136	0.097	0.041	0.037	0.033	0.025	0.036	0.020	0.037	0.036	0.021	-	-	0.033
Mn2+	0.056	0.050	0.047	0.040	0.039	0.063	0.057	0.034	0.050	0.037	0.050	0.034	0.042	0.045	0.038	0.120	0.053	0.120	-	-	-
Fe2+	0.363	0.310	0.392	0.405	0.422	0.311	0.330	0.403	0.330	0.392	0.388	0.379	0.389	0.402	0.394	0.215	0.353	0.184	-	0.077	-
Fe3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.470	0.086	0.064
Al3+	0.019	0.028	0.014	0.026	0.034	0.016	0.044	0.060	0.046	0.024	0.020	0.022	0.021	0.017	0.017	0.016	0.016	0.008	-	0.137	-
Cr3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nb5+	0.125	0.064	0.118	0.078	0.083	0.079	0.096	0.074	0.057	0.078	0.119	0.081	0.080	0.100	0.118	0.080	0.089	0.100	0.189	0.123	-
Ta5+	0.009	0.002	0.004	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W6+	0.004	0.009	0.005	0.012	0.008	0.012	0.014	0.002	0.007	0.012	0.012	0.012	0.008	0.005	0.001	0.005	0.004	0.005	-	-	-
SUM Ti4+	2.081	1.984	2.050	2.057	2.107	1.960	2.101	2.196	2.091	2.052	2.068	2.048	2.047	2.054	2.045	1.948	2.028	1.928	2.037	2.132	2.041
TOTAL	4.100	4.090	4.098	4.101	4.123	4.085	4.094	4.156	4.128	4.086	4.091	4.101	4.091	4.108	4.099	4.097	4.097	4.071	3.903	3.899	4.012

	M98	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	SG1	SG2	SG3	L1	L2	L3	L4	L5	L6
MgO	-	0.71	0.37	2.34	3.04	1.33	1.08	1.96	2.32	2.43	1.89	2.50	2.65	2.65	0.36	0.58	0.72	0.65	0.01	0.03
Al2O3	-	0.12	0.22	-	-	-	2.26	-	0.67	0.81	0.42	2.50	2.73	2.74	1.60	1.14	1.34	1.07	0.48	0.43
SiO2	-	-	-	-	-	-	-	-	-	-	<.05	0.10	0.11	0.12	1.90	1.08	0.27	1.74	-	0.25
CaO	16.41	9.80	11.10	6.87	6.78	8.55	9.35	8.18	8.31	8.60	5.47	4.68	4.23	4.62	10.70	4.60	8.60	7.31	2.63	3.55
TiO2	45.87	21.00	22.30	29.50	30.95	36.26	36.06	34.87	29.00	30.20	21.70	32.50	32.95	32.92	28.30	26.90	34.60	32.61	25.48	27.48
Cr2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.59	0.44	0.52	0.56	0.07	0.24
MnO	-	0.28	0.26	0.03	-	-	-	-	0.07	0.05	0.08	-	-	-	0.03	-	-	0.11	-	0.08
FeO	-	7.16	7.37	4.07	4.42	4.72	4.65	3.73	-	-	4.97	0.84	0.81	0.88	4.30	6.50	5.90	5.95	9.06	7.44
Fe2O3	0.76	-	-	-	-	-	-	-	3.50	2.25	-	-	-	-	-	-	-	-	-	-
Y2O3	-	0.19	0.24	1.08	0.40	-	-	-	0.26	0.32	0.88	8.21	9.09	8.79	2.60	7.30	4.00	3.06	7.80	10.53
ZrO2	36.56	31.40	33.20	30.73	32.56	34.19	32.64	35.27	28.30	28.10	28.01	34.34	34.17	34.96	45.40	40.70	40.20	37.21	33.60	32.78
Nb2O5	-	9.98	11.20	-	-	-	-	-	2.61	2.24	2.92	0.14	-	-	0.46	0.40	0.63	1.85	2.75	1.62
La2O3	-	0.06	0.04	-	-	-	-	-	0.12	0.05	0.38	0.23	0.23	0.24	-	-	-	0.09	0.19	0.29
Ce2O3	-	0.74	1.17	2.68	1.40	0.32	0.83	-	0.28	0.62	2.11	2.45	1.87	1.99	0.48	2.11	0.33	0.76	1.64	1.63
Pr2O3	-	0.20	0.25	-	-	-	-	-	0.11	0.14	0.31	0.58	0.44	0.45	-	-	-	0.07	0.55	0.43
Nd2O3	-	1.03	1.19	-	-	-	-	-	0.33	0.42	1.50	3.27	2.69	2.96	0.56	3.30	0.63	0.79	3.08	2.13
Sm2O3	-	0.30	0.36	-	-	-	-	-	-	-	0.34	1.37	1.17	1.30	0.22	-	-	0.36	1.74	1.08
Eu2O3	-	0.08	0.12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<.01	0.13	0.09
Gd2O3	-	0.32	0.43	-	-	-	-	-	-	-	0.24	1.79	1.78	1.78	0.45	1.92	0.42	0.25	2.00	1.45
Tb2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.13	0.37	0.42
Dy2O3	-	0.17	0.06	-	-	-	-	-	-	-	0.30	1.69	1.87	1.70	-	1.61	0.67	0.79	2.64	2.09
Ho2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<.01	0.37	0.38
Er2O3	-	-	-	-	-	-	-	-	-	-	0.15	0.75	0.88	0.77	-	-	-	0.72	1.43	1.48
Tm2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<.01	0.01	0.11
Yb2O3	-	-	-	-	-	-	-	-	-	-	-	0.39	0.55	0.39	0.43	-	-	0.67	0.54	1.24
Lu2O3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.21	0.33	0.44
HfO2	-	0.70	0.66	-	-	-	-	-	0.67	0.67	0.69	0.65	0.70	0.67	-	0.47	0.28	0.72	1.11	0.89
Ta2O5	-	2.75	1.76	-	-	-	-	-	0.20	0.20	<.15	0.02	-	-	-	-	-	0.12	0.19	0.16
WO3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PbO	-	0.16	0.09	0.38	-	-	-	0.44	0.44	0.43	0.61	-	-	-	-	0.23	0.48	0.52	0.45	0.22
ThO2	-	14.00	8.65	20.44	18.78	8.33	8.51	0.23	19.50	18.00	22.28	0.61	0.56	0.44	0.83	0.46	0.44	1.19	0.35	0.60
UO2	-	0.86	0.36	1.06	0.65	4.66	2.08	14.31	1.58	1.90	2.67	0.28	0.52	0.36	-	0.21	0.22	0.30	0.40	0.14
(Na,K)2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H2O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
"Others"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	99.60	102.01	101.40	99.18	98.98	98.36	97.46	98.99	98.27	97.43	97.92	99.89	100.00	100.73	99.21	99.95	100.25	99.81	99.40	99.70
											cations to 7 oxygens									
Ca2+	1.000	0.719	0.788	0.511	0.490	0.588	0.633	0.567	0.607	0.627	0.444	0.318	0.285	0.309	0.705	0.320	0.558	0.483	0.196	0.259
Y+REE3+	0.000	0.077	0.094	0.108	0.049	0.008	0.019	0.000	0.030	0.042	0.180	0.551	0.553	0.541	0.130	0.455	0.172	0.200	0.643	0.684
Pb2+	-	0.003	0.002	0.007	-	-	-	0.008	0.008	0.008	0.012	-	-	-	-	0.004	0.008	0.009	0.008	0.004
Th4+	-	0.218	0.130	0.323	0.288	0.122	0.122	0.003	0.303	0.279	0.384	0.009	0.008	0.006	0.012	0.007	0.006	0.017	0.006	0.009
U4+	-	0.013	0.005	0.016	0.010	0.067	0.029	0.206	0.024	0.029	0.045	0.004	0.007	0.005	-	0.003	0.003	0.004	0.006	0.002
SUM Ca2+	1.000	1.030	1.019	0.965	0.837	0.784	0.803	0.784	0.972	0.985	1.066	0.882	0.853	0.862	0.847	0.789	0.747	0.713	0.859	0.958
Zr4+	1.014	1.048	1.073	1.040	1.072	1.071	1.005	1.112	0.942	0.933	1.035	1.062	1.050	1.065	1.361	1.291	1.188	1.119	1.140	1.087
Hf4+	-	0.014	0.012	-	-	-	-	-	0.013	0.013	0.015	0.012	0.013	0.012	-	0.009	0.005	0.013	0.022	0.017
SUM Zr4+	1.014	1.062	1.086	1.040	1.072	1.071	1.005	1.112	0.955	0.946	1.050	1.073	1.062	1.077	1.361	1.299	1.193	1.132	1.162	1.105
Ti4+	1.962	1.081	1.112	1.540	1.571	1.751	1.713	1.696	1.488	1.546	1.237	1.549	1.561	1.546	1.308	1.315	1.576	1.512	1.333	1.406
Si4+	-	-	-	-	-	-	-	-	-	-	-	0.006	0.007	0.007	0.117	0.070	0.016	0.107	-	0.017
Mg2+	-	0.072	0.037	0.242	0.306	0.127	0.102	0.189	0.236	0.247	0.214	0.236	0.249	0.247	0.033	0.056	0.065	0.060	0.001	0.003
Mn2+	-	0.016	0.015	0.002	-	-	-	-	0.004	0.003	0.005	-	-	-	0.002	-	-	0.006	-	0.005
Fe2+	-	0.410	0.409	0.236	0.249	0.253	0.246	0.202	-	-	0.315	0.045	0.043	0.046	0.221	0.353	0.299	0.307	0.527	0.423
Fe3+	0.033	-	-	-	-	-	-	-	0.180	0.115	-	-	-	-	-	-	-	-	-	-
Al3+	-	0.010	0.017	-	-	-	0.168	-	0.054	0.065	0.038	0.187	0.203	0.202	0.116	0.087	0.096	0.078	0.039	0.035
Cr3+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.029	0.023	0.025	0.027	0.004	0.013
Nb5+	-	0.309	0.336	-	-	-	-	-	0.081	0.069	0.100	0.004	-	-	0.013	0.012	0.017	0.052	0.086	0.050
Ta5+	-	0.051	0.032	-	-	-	-	-	0.004	0.004	-	-	-	-	-	-	-	0.002	0.004	0.003
W6+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUM Ti4+	1.994	1.950	1.956	2.020	2.126	2.132	2.228	2.087	2.046	2.049	1.908	2.027	2.062	2.048	1.838	1.917	2.095	2.151	1.995	1.954
TOTAL	4.008	4.042	4.061	4.026	4.035	3.986	4.037	3.983	3.973	3.980	4.025	3.983	3.978	3.987	4.046	4.006	4.034	3.995	4.015	4.017

	L7	L8	L9	L10	L11	L12	L13	THEORETICAL
MgO	0.10	1.15	-	<.01	0.12	-	-	
Al2O3	0.50	0.67	-	0.35	0.46	0.37	0.84	
SiO2	-	0.62	-	0.13	0.10	0.29	0.37	
CaO	3.20	6.15	3.29	3.17	3.21	2.75	2.85	16.54
TiO2	27.10	29.62	26.60	25.71	27.01	28.70	26.60	47.13
Cr2O3	0.50	0.50	-	<.01	-	-	-	
MnO	0.30	-	-	-	-	0.13	-	
FeO	11.40	4.23	8.67	7.71	9.00	10.30	9.97	
Fe2O3	-	-	-	-	-	-	-	
Y2O3	10.40	7.70	10.80	7.87	12.80	12.80	12.00	
ZrO2	30.80	30.06	29.80	36.98	29.94	31.50	31.70	36.33
Nb2O5	-	4.34	-	2.34	-	4.25	3.99	
La2O3	0.60	0.08	0.20	0.13	0.27	0.02	-	
Ce2O3	1.90	0.84	1.72	1.23	2.29	1.05	1.11	
Pr2O3	0.70	0.32	1.38	0.40	1.01	0.32	0.26	
Nd2O3	3.30	1.04	7.04	2.94	4.79	1.21	2.31	
Sm2O3	1.70	0.55	2.04	1.49	0.65	0.73	1.14	
Eu2O3	0.40	<.01	0.01	0.12	0.02	-	-	
Gd2O3	2.10	0.33	1.44	1.74	0.95	2.34	1.75	
Tb2O3	0.30	0.24	1.19	0.32	0.46	0.19	0.08	
Dy2O3	0.90	1.59	2.06	2.10	3.19	-	-	
Ho2O3	0.20	0.03	1.27	0.15	1.16	0.95	0.88	
Er2O3	-	1.01	2.11	0.94	1.14	0.90	1.17	
Tm2O3	-	0.20	0.26	<.01	0.83	0.24	0.3	
Yb2O3	-	1.03	0.46	0.25	0.76	0.50	0.71	
Lu2O3	-	0.36	-	0.26	-	-	-	
HfO2	-	0.86	1.20	1.34	1.03	0.71	0.77	
Ta2O5	-	0.40	-	0.24	-	0.05	0.13	
WO3	-	-	-	-	-	-	-	
PbO	-	2.19	-	0.45	-	-	-	
ThO2	-	2.34	-	0.33	-	0.06	0.14	
UO2	-	1.16	-	0.33	-	-	-	
(Na,K)2O	-	-	-	-	-	-	-	
H2O	-	-	-	-	-	-	-	
"Others"	-	-	-	-	-	-	-	
TOTAL	96.40	99.61	101.54	99.02	101.19	100.36	99.07	100.00
				cations to 7 oxygens				
Ca2+	0.239	0.433	0.247	0.233	0.237	0.194	0.205	1.000
Y+REE3+	0.681	0.436	0.910	0.570	0.879	0.635	0.650	0.000
Pb2+	-	0.039	-	0.008	-	-	-	-
Th4+	-	0.035	-	0.005	-	0.001	0.002	-
U4+	-	0.017	-	0.005	-	-	-	-
SUM Ca2+	0.921	0.959	1.157	0.822	1.116	0.829	0.858	1.000
Zr4+	1.048	0.963	1.017	1.239	1.005	1.009	1.039	1.000
Hf4+	-	0.016	0.024	0.026	0.020	0.013	0.015	-
SUM Zr4+	1.048	0.980	1.041	1.265	1.025	1.023	1.054	1.000
Ti4+	1.423	1.464	1.400	1.328	1.398	1.418	1.345	2.000
Si4+	-	0.041	-	0.009	0.007	0.019	0.025	-
Mg2+	0.010	0.113	-	-	0.012	-	-	-
Mn2+	0.018	-	-	-	-	0.007	-	-
Fe2+	0.666	0.233	0.507	0.443	0.518	0.566	0.560	-
Fe3+	-	-	-	-	-	-	-	-
Al3+	0.041	0.052	-	0.028	0.037	0.029	0.067	-
Cr3+	0.028	0.026	-	-	-	-	-	-
Nb5+	-	0.129	-	0.073	-	0.126	0.121	-
Ta5+	-	0.007	-	0.004	-	0.001	0.002	-
W6+	-	-	-	-	-	-	-	-
SUM Ti4+	2.185	2.064	1.907	1.886	1.972	2.166	2.120	2.000
TOTAL	4.154	4.003	4.105	3.973	4.113	4.018	4.031	4.000

peridotite (Apollo 12), in lithic fragments (Apollo 14, LUNA 20), and in a metamorphosed breccia (Apollo 16). Zirconolite is often associated with baddeleyite as small discrete crystals, no larger than 50μm in diameter, and is considered to have crystallised at a late stage from interstitial liquids in the lunar basalts (e.g. Busche *et al.*, 1972).

Lunar zirconolites are generally rich in Y and heavy-REE when compared with terrestrial zirconolites (Lovering & Wark, 1974; Kochemasov, 1980; Fowler & Williams, 1986). The majority of the lunar zirconolites have $\Sigma REE^{3+} > 50\%$ of the Ca site, and with Y being the dominant REE, these may be considered as **zirconolite-(Y)**.

DISCUSSION AND CONCLUSION

Zirconolite occurs as an accessory mineral only, generally less than 0.1mm in diameter, but from a wide variety of rock types. Its small size and low modal abundance means that it can be easily overlooked using traditional optical microscopy. However, with the increasing accessibility of analytical scanning electron microscopes (usually with a backscatter electron detector attached), zirconolite, even if present at a very low modal abundance, will be readily observed, because its backscatter component is considerably higher than the majority of the rock-forming minerals. It is probable therefore, that the number of zirconolite occurrences will increase significantly in the near future.

It is also evident that zirconolite is often zoned, and/or finely intergrown with other minerals, and early bulk chemical analyses were unable to characterise fully the chemical variability of this mineral. Microprobe analyses, together with a detailed SEM investigation, is therefore essential in any study. It is generally recommended that microprobe analysis is performed using wavelength-dispersive means, because zirconolite can accommodate more than 30 elements at the 0.1 to 1.0 wt.% concentration level (which in energy-dispersive electron microprobe analysis is close to, or below, the detection limit), However, quantitative analysis of sub-micron zones has been successfully undertaken using an energy-dispersive analytical transmission electron microscope (Lumpkin *et al.*, 1994).

As can be seen from the data for natural zirconolite, the range of elements substituting, and the degree of substitution are extensive. The most commonly occurring elements, and therefore the minimum that should be reported in any microprobe analysis of zirconolite are: Mg, Al, Si, Ca, Ti, Mn, Fe, Y, Zr, Nb, Hf, Ta, W, Pb, Th, U and of the REE, La, Ce, Pr, Nd, Sm, Gd.

It should also be noted that Cr and Zn are present in some zirconolites: Cr predominantly from lunar samples, and Zn occasionally from metasomatic samples (e.g. Zakrzewski *et al.*, 1992). H_2O has been reported in wet chemical analyses of separated grains (e.g. Borodin *et al.*, 1960; Bulakh *et al.*, 1960), and has also been inferred from low analytical totals of microprobe data (e.g. Platt *et al.*, 1987; Zakrzewski *et al.*, 1992). Na and K, although also quoted in some wet chemical analyses of separated grains, have not been observed in microprobe analyses. It is probable therefore, that Na and K are *not* present to any significant extent in zirconolite. It is of note also, that Sr and Ba generally do not occur in natural zirconolite, and Pb only rarely does so. These elements might have been expected to substitute more readily for Ca, but it appears that the Ca structural site does not easily accommodate 2+ cations larger than Ca. The valency state of Fe in zirconolite is unclear: where measured directly on mineral separates, both FeO and Fe_2O_3 are present.

It is evident that zirconolite, although invariably occurring only as an accessory or 'trace' mineral in a range of rock types, is able to accommodate many incompatible elements, such as REE, ACT, Nb, Zr, Hf, Ta to concentration levels whereby it can become a major repository for these elements. As such, it has the potential for playing a significant role in the petrological/geochemical evolution of those rock-types in which it crystallizes. Several studies have provided evidence that zirconolite can reflect changes in the composition of the fluid during its evolutionary history, both in metasomatic systems (Williams & Gieré, 1988; Gieré & Williams, 1992), and in magmatic fractionation processes (Platt *et al.*, 1987).

It is hoped that this review and compilation will prove useful as a comparative database for geologists who discover zirconolite in their samples, and also to material scientists working on various SYNROC projects, in order that they can compare laboratory-based experiments on synthetic zirconolite with studies of the natural forms of zirconolite.

This database is available in a computerised format from CTW. We would be grateful also to receive any additional analytical data and/or material from new occurrences of zirconolite, in order to periodically update this database.

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