



ID:

BMRE-25-3075

Title:

Geochemical and Geophysical Relationship of the Potassium-Rich Fenite Zone in Surface and Subsurface Investigations of the Giant Kuluncak (Malatya) Nb-U-REE-Zr-Li Mineralization

Article Type:

Research Article

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Keywords:

Keywords: Fenite, Rare Earth Elements (REE), Niobium (Nb), Uranium (U), Zirconium (Zr)

Abstract:

The Kuluncak (Malatya) district hosts one of the most significant Nb-U-REE-Zr-Li mineralizations in Türkiye, spatially associated with alkaline and carbonatite-related rocks. In this study, geochemical and geophysical investigations were integrated with surface and drillhole data to evaluate the role of fenitization in rare earth element enrichment. The drillhole profiles reveal systematic variations: in marble-hosted sections, light rare earth element (LREE) anomalies occur near-surface zones coupled with KO enrichment, whereas in nepheline syenite-hosted drillholes, REE anomalies are concentrated at intermediate depths (~40-100 m) with heterogeneous distributions. High CaO concentrations, together with fluorite, barite, apatite, and Nb-REE-bearing minerals, confirm a strong carbonatitic contribution. Geophysical anomalies (spectral gamma, magnetic maps) support the geochemical evidence and were used to identify subsurface fenite zones. Comparison with other carbonatite-related systems in Türkiye, such as the Özvatan complex (Kayseri) and Eskisehir, indicates that Kuluncak represents one of the most carbonatite-dominant and LREE-enriched systems in the region. On a global scale, the geochemical features of Kuluncak resemble world-class deposits such as Bayan Obo (China) and Ilímaussaq (Greenland). These findings demonstrate that fenitization and carbonatite-related metasomatism are the principal processes controlling mineralization, highlighting the Kuluncak district as a strategic Nb-REE resource of both national and international importance.

Dear Editor,

I am pleased to submit our manuscript entitled **"Geochemical and Geophysical Relationship of the Potassium-Rich Fenite Zone in Surface and Subsurface Investigations of the Giant Kuluncak (Malatya) Nb-U-REE-Zr-Li Mineralization"** for your consideration for publication in the *Bulletin of the Mineral Research and Exploration (MTA)*.

This study presents integrated geological, geochemical, and geophysical data from the Kuluncak district in Malatya (Türkiye), with a particular focus on potassium-rich fenite zones associated with Nb, U, REE, Zr, and Li mineralization. In the northern part of the region, this mineralization is hosted by alkaline intrusive rocks such as foid syenite, syenite, monzonite, alkali feldspar syenite, sodalite syenite, and nepheline-bearing syenitic rocks. These bodies intrude the neritic oolitic limestones of the Triassic–Early Cretaceous Andırın Formation, providing clear lithological and structural controls on ore formation.

We believe that this study makes a valuable contribution to the literature as it represents one of the few investigations comparing surface (outcrop) samples with drill core samples in the context of rare earth element (REE) exploration. This integrated approach offers new insights into subsurface continuity, mineral zoning, and the exploration potential of similar alkaline systems.

The findings offer valuable insights into the formation mechanisms of alkaline-hosted critical metal deposits and may contribute to future exploration strategies in Türkiye and comparable tectonic environments.

This manuscript is original, has not been published elsewhere, and is not under consideration by another journal.

Thank you very much for your time and consideration.

Sincerely,

Okan PULAT

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Response to Reviewer #1

1. We sincerely thank the reviewer for the detailed and constructive feedback that has significantly improved the overall quality and clarity of our manuscript. We carefully reviewed all the comments and implemented the suggested revisions as outlined below.

2. 1. Replacement of “borehole” with “drillhole”

All instances of the term “borehole” have been replaced with “drillhole” throughout the manuscript, as correctly noted. We agree that “drillhole” is the appropriate term for geological and mineral exploration studies, and this change enhances both precision and consistency in terminology.

3. 2. Copy–paste and formatting errors in oxide values

The “copy-paste” errors in lowercase numerical values for major oxides have been carefully corrected. We have rechecked all oxide data tables and figure captions to ensure full consistency and accuracy.

4. 3. Figure 12 caption

We have reviewed Figure 12 as suggested and confirmed that the caption and contents are now correct and consistent with the figures and text.

5. 4. “Steppe Unit” vs. “Bozkır Unit”

We have accepted the reviewer’s valuable recommendation and retained the name “Bozkır Unit” in all occurrences. The English translation “Steppe Unit” has been removed, as proper geological unit names should not be translated.

6. 5. References in the Conclusions section

We have added the recommended citations to support the relevant international comparisons, specifically Sørensen et al. (2011) for Greenland and Xu et al. (2008) for China. These additions strengthen the scientific grounding of the Conclusions section.

7. 6. General appreciation

We are grateful for the reviewer’s encouraging remarks regarding the expansion of the Discussion section, the inclusion of new figures, and the overall improvement of the paper.

All comments have been addressed, and the revised manuscript has been thoroughly checked for consistency and formatting.

We sincerely appreciate your time, effort, and valuable insights, which have greatly contributed to enhancing the scientific quality of this work. Thank you once again for your constructive evaluation and kind support.

Best regards,

Okan Pulat

Corresponding Author

uncorrected proof

Response to Reviewer #2

We would like to express our sincere gratitude to the reviewer for the positive evaluation and constructive comments.

Comment:

“It is strongly recommended that units be added to the color scale of the magnetic anomaly and potassium distribution maps (Figure 10 (B) and (C)) obtained from geophysical studies. If this deficiency is addressed, the publication is acceptable.”

Response:

We have carefully addressed this recommendation. The units have been added to the color scales of both the magnetic anomaly and potassium distribution maps (Figure 10 (B) and (C)) as suggested. The revised figures now clearly display the respective measurement units, ensuring consistency and clarity in data presentation.

We thank the reviewer once again for this valuable suggestion, which has helped improve the scientific quality and presentation of our manuscript.

Best regards,

Okan Pulat

Corresponding Author

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Keywords: Fenite, Rare Earth Elements (REE), Niobium (Nb), Uranium (U), Zirconium (Zr)

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ABSTRACT

The Kuluncak (Malatya) district hosts one of the most significant Nb–U–REE–Zr–Li mineralizations in Türkiye, spatially associated with alkaline and carbonatite-related rocks. In this study, geochemical and geophysical investigations were integrated with surface and drillhole data to evaluate the role of fenitization in rare earth element enrichment. The drillhole profiles reveal systematic variations: in marble-hosted sections, light rare earth element (LREE) anomalies occur near-surface zones coupled with K₂O enrichment, whereas in nepheline syenite-hosted drillholes, REE anomalies are concentrated at intermediate depths (~40–100 m) with heterogeneous distributions. High CaO concentrations, together with fluorite, barite, apatite, and Nb–REE-bearing minerals, confirm a strong carbonatitic contribution. Geophysical anomalies (spectral gamma, magnetic maps) support the geochemical evidence and were used to identify subsurface fenite zones. Comparison with other carbonatite-

related systems in Türkiye, such as the Özvatan complex (Kayseri) and Eskişehir, indicates that Kuluncak represents one of the most carbonatite-dominant and LREE-enriched systems in the region. On a global scale, the geochemical features of Kuluncak resemble world-class deposits such as Bayan Obo (China) and Ilímaussaq (Greenland). These findings demonstrate that fenitization and carbonatite-related metasomatism are the principal processes controlling mineralization, highlighting the Kuluncak district as a strategic Nb–REE resource of both national and international importance.

1. Introduction

In recent years, the increasing demand for advanced technologies and the ongoing global energy transition have significantly elevated the strategic importance of alkaline rocks and their associated mineralizations. Critical metals such as rare earth elements (REE), niobium (Nb), uranium (U), and lithium (Li) are indispensable components of modern technologies (Lewandowski, 2014). Over the past three decades, there has been a rapid expansion in the use of REEs and their alloys in a wide range of high-tech applications, including computer memory, DVDs, rechargeable batteries, catalytic converters, supermagnets, mobile phones, LED lighting, superconductors, glass additives, fluorescent materials, phosphate binders, solar panels, and magnetic resonance imaging (MRI) systems (Sinhoray, 2022).

Particularly, mineralizations of REE–Nb–U and Th are commonly associated with nepheline syenite–carbonatite complexes, pegmatites, heavy mineral placers, and ion adsorption-type deposits (Goodenough et al., 2016). In Türkiye, such mineralizations linked to alkaline igneous provinces and enriched in REEs and thorium (Th) have been identified in three major regions. Formations associated with Oligocene–Late Miocene volcanic rocks along the Eskişehir–Afyon–Isparta structural trend include the Çanaklı (Burdur) placer deposit, enriched in U, Th, REEs, and heavy minerals such as magnetite, zircon, and rutile (Çimen et al., 2020; Öztürk et al., 2019; Unluer et al., 2023a). In northwestern Anatolia, carbonatite intrusions related to Miocene volcanism have been identified at Arıklı and Nusratlı (Çanakkale), where a ~10 m-thick carbonatite dyke with a potassic fenite aureole clearly cross-cuts the host rocks (Döner et al., 2024; Gülmez et al., 2024; Tunç et al., 2025; Unluer et al., 2024).

The Kuluncak district of Malatya Province is an important metallogenic area with potential for iron, lead, copper, and particularly rare earth element mineralization, and has therefore been the subject of several geological and mineralization studies (Booth et al., 2012; Öztürk et al., 2016, 2019; Camuzoğlu et al., 2017; Çimen et al., 2020; Pulat et al., 2022; Unluer et al., 2023b). These studies have collectively contributed to our understanding of the geological evolution of region, petrographic and geochemical characteristics of igneous, volcanic, and ultrabasic rocks, as well as its mineral potential and metallogenic processes.

Geophysical methods such as magnetic surveys and spectral gamma-ray measurements have been widely employed in the exploration of carbonatite-related and alkaline-hosted mineral systems. Previous studies demonstrated that magnetic lows are commonly associated with fenitization halos due to the breakdown of Fe-

bearing minerals, while gamma-ray spectrometry provides direct information on K, Th, and U enrichment in altered zones (Goodenough et al., 2016; Elliott et al., 2018). In this context, the Nb-U-REE-Zr-Li mineralization associated with alkaline rocks in the northern part of the Kuluncak district (Malatya, Türkiye) represents a significant potential resource. This study aims to elucidate the mineralization processes and assess the ore potential through a comprehensive investigation of the geological and geochemical features of the alkaline rocks in the Kuluncak region. Particular emphasis is placed on understanding the fenitization processes developed in the contact zones between alkaline intrusions and the Triassic–Lower Cretaceous neritic oolitic limestones of the Andırın Formation, and their relationship to mineralization. To achieve this, surface and subsurface data including geochemical analyses, geophysical measurements magnetic and spectral gamma-ray surveys are integrated to characterize the spatial and genetic association between the fenitized zones and mineralization. The outcomes of this study are expected to provide valuable insights into the geological evolution and ore-forming processes of the region and to contribute to guiding future mineral exploration and development efforts.

2. Regional geology

Kuluncak and its surroundings are situated within the Anatolide–Tauride Belt as defined by Okay and Tüysüz (1999), and within the Eastern Taurus Belt according to Özgül (1984). Based on tectonostratigraphic classification proposed by Özgül's (1971), the region falls within the Bozkır Unit.

The basement of the study area is composed of the Triassic–Lower Cretaceous Andırın Formation (dMa), which consists predominantly of neritic oolitic limestones (Metin et al., 2013). This unit is intruded by syenitoid bodies belonging to the Kuluncak Syenitoid Complex (Sy and Syp), dated to the Upper Cretaceous–Paleocene (Çimen et al., 2020). These intrusive rocks cut across the Andırın Formation. Quaternary alluvial fan deposits (Qym) lie above both the Andırın Formation and the syenitoids, with an angular unconformity. These deposits form the youngest sedimentary cover in the area (Figure 1).

2.1. Andırın formation (dMa)

The Andırın Formation forms the basement of the study area and is characterized by a thickly bedded carbonate sequence (Figure 1). It consists predominantly of megalodon-bearing limestones, as well as dolomitic and dolomite-rich limestones that show lateral and vertical transitions with the surrounding units. In its middle and upper levels, the formation commonly comprises medium to thick-bedded, and locally thin-bedded, oolitic limestones.

The stratigraphy includes a succession of rudist-bearing limestone, miliolite, and oolitic limestone, occasionally intercalated with recrystallized limestone and sparse radiolarian limestone, particularly in the middle

sections. Coarse-grained miliolite, dolomitic facies, and local chert laminations are also observed. The uppermost levels are dominated by rudist-rich limestone and miliolitic–oolitic limestone sequences (Metin et al., 2013).

2.2 Kuluncak ophiolite (OKk)

The Kuluncak ophiolite exhibits a complete mantle-to-crust sequence, including tectonites, ultramafic and mafic cumulates, isotropic gabbros, sheet dyke complexes, volcanic units, and sedimentary cover. Tectonites comprise dunite, wehrlite, and harzburgite, while ultramafic cumulates are dominated by wehrlite and clinopyroxenite, and mafic cumulates by olivine gabbro, gabbro, and gabbro. Isotropic intrusions range from gabbro to quartz diorite and plagiogranite. Diabase dykes form the sheet dyke complexes, and volcanic rocks consist mainly of basalt and pyroxene andesite. The overlying sedimentary units cap the sequence, illustrating a fully preserved ophiolitic stacking. (Metin et al., 2013).

2.3 Hasançelebi-Kuluncak syenite (Tphk)

The Kuluncak Syenite represents a suite of deep-seated intrusive rocks, including foid syenite, syenite, quartz syenite, foid monzosyenite, foid monzodiorite, and foid monzogabbro. These rocks display light burgundy to honey-colored hues on fresh surfaces. The largest exposures cover an area of approximately 4 km² and are characterized by equigranular, medium-grained, holocrystalline textures. The light grey to white, medium-grained syenites observed in the Kuluncak outcrops are predominantly alkali feldspar syenites.

A representative sample of foid syenite collected from the Kuluncak region displays a holocrystalline, blocky texture and is composed of alkali feldspar, plagioclase, pyroxene crystals, and pseudomorphs (Metin et al., 2013).

Petrographic investigations have identified various rock types in the area, including alkali feldspar syenite, syenite, foid monzosyenite, foid monzodiorite, foid monzogabbro, foidolite, fels, calc-silicate rocks, vesuvianite–garnet fels, nepheline foidolite, foliite porphyry, microfoliite, sodalite syenite, and garnet-bearing felsic rocks. In particular, sodalite crystals within the foid syenites are large enough to be easily observed with the naked eye (Figure 2).

2.4 Boyalı volcanite (Tpb)

In the Hasançelebi and Kuluncak regions, volcanic rocks referred to as the Boyalı Volcanite are observed exclusively overlying units of the Hekimhan Formation. These volcanic rocks exhibit yellowish-brown, mottled brown, and reddish-brown colors and are characterized by a porphyritic texture. Petrographic analyses have identified the dominant rock type as trachyte, with lesser occurrences of trachyandesite, andesite, and latite (Metin et al., 2013).

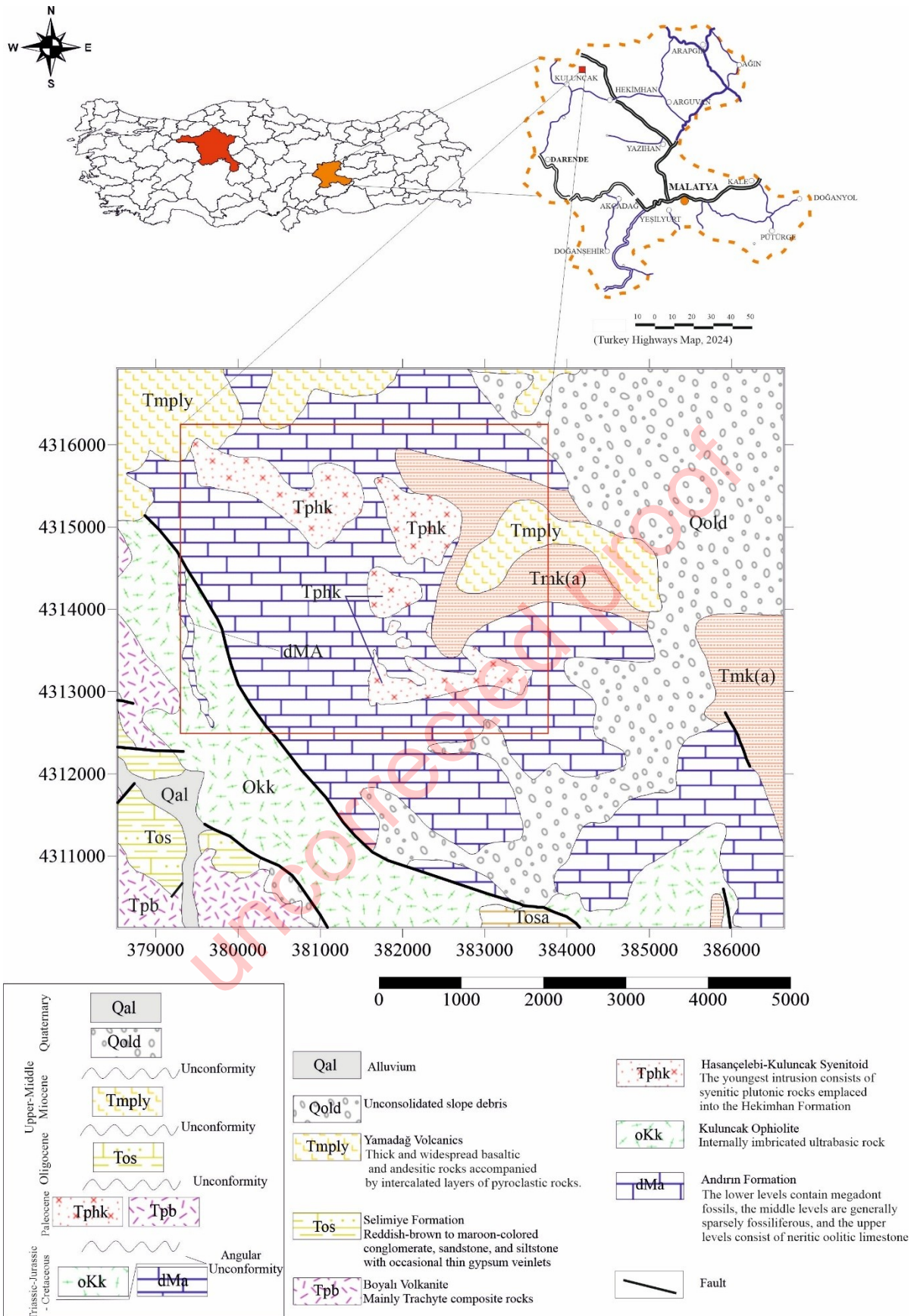


Figure 1- 1/5000 scale location map (red square)



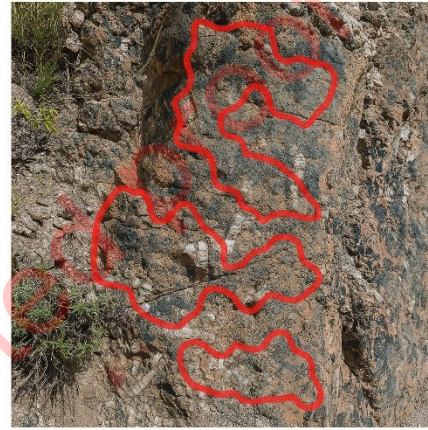
 Fenitized zones



 Fenitized zones



 Fenitized zones



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132 Figure 2- Albite and pyroxene minerals belonging to the fenitic zone (The red area indicates the fenitized zone)

133 3. Materials and Methods

134 3.1 Geochemical methods

135 Geological sampling was conducted in the licensed area covering the Konaktepe, Başören, and Darılı
 136 neighborhoods of the Kuluncak district (Malatya Province). A total of 224 outcrop samples and 4,304 drill-core
 137 samples were collected, with core samples taken at ≤ 1 m intervals and additional sampling performed along
 138 radioactive anomaly zones. All samples were analyzed in TURKAK-accredited laboratories operating under TS
 139 EN ISO/IEC 17025 standards.

140 Lanthanide elements (REEs) were analyzed using ICP–MS, while major and trace elements were determined
 141 by ICP–OES. QA/QC protocols included duplicates, blanks, and certified reference standards to ensure analytical
 142 accuracy and reproducibility.

143 Outcrop sampling was guided by detailed mineral–geological mapping and supported by geophysical surveys.
 144 A total of 224 geochemical samples were collected from both igneous and carbonate rock units, and their analytical

results are summarized in Appendix1. To minimize contamination, all surface samples were excavated from a minimum depth of 50 cm, ensuring the selection of more geochemically stable material. The geochemical results revealed anomalous values for several elements, particularly in zones associated with fenitization and carbonatite-related alteration.

3.2 Geophysical methods

Geophysical investigations included magnetic surveys and spectral gamma-ray measurements (K, U, Th, total irradiance) performed both at the surface and in drillholes. Downhole spectral gamma logging was carried out by the General Directorate of Mineral Research and Exploration (MTA) using a Robertson Geologging Ltd. probe in accordance with ISO 9001:2015 standards. The system measures the gamma spectrum of formations, applies real-time temperature corrections, and provides continuous elemental concentration logs. Appropriate corrections were applied for drillhole conditions such as casing, diameter, density, and drilling fluid.

Gamma-ray spectrometry and magnetic surveys were performed at 4,343 points across an area of 19 km², with data collected at 50 m intervals, and at intermediate points in selected locations. These surveys were designed to support REE exploration and to delineate fenite-related alteration zones. For field measurements, spectral gamma-ray surveys were conducted using a portable NaI(Tl) gamma-ray spectrometer (Georadis GT-40). The instrument records concentrations of K, U, and Th with integrated GPS for spatial referencing. Only key specifications relevant to exploration (energy resolution, measurement duration, and detection range) were considered, while more detailed technical aspects are omitted for brevity (Küçük, 2017).

The instruments used for gamma-ray spectrometry and magnetic surveys, namely the gamma-ray spectrometer and magnetometer, are presented in Figure 3. Based on the acquired geophysical data, potassium distribution maps and magnetic anomaly maps were generated to aid in the interpretation of subsurface structures and mineralized zones (Küçük, 2017). Magnetic surveys were carried out using a proton-precession magnetometer along 50 m-spaced profiles with station intervals of 10–20 m. Standard corrections were applied, including diurnal variation removal using a base station and subtraction of the International Geomagnetic Reference Field (IGRF). Processed data were gridded using minimum curvature interpolation and reduced-to-pole (RTP) transformations. The final magnetic anomaly maps were filtered with upward continuation and first vertical derivative (FVD) techniques to enhance lineaments and structural features associated with fenitization zones.

Comparable methodologies have been successfully applied in REE exploration globally. For instance, in the Kvanefjeld REE–U deposit (Ilímaussaq Complex, Greenland), airborne gamma-ray spectrometry and magnetic surveys were employed to identify uranium and thorium anomalies coinciding with syenitic and nepheline syenitic

units (Sørensen et al., 2011). In Mount Weld (Australia), one of the world's richest REE deposits, high-resolution ground magnetic and radiometric surveys were used to map the carbonatite pipe and fenite aureoles, providing a direct geophysical footprint of REE-bearing zones (Pirajno, 2009; Balaram, 2019). Similarly, in the Araxá and Catalão carbonatite complexes (Brazil), gamma-ray spectrometry has been integrated with magnetic and gravity data to delineate phosphate–niobium–REE mineralization zones (Castor and Hedrick, 2006). In Bayan Obo (China), the largest REE deposit worldwide, extensive magnetic and gravity surveys combined with radiometric data were employed to constrain ore-bearing carbonatite dykes and associated fenitic halos (Xu et al., 2008).

These global analogues demonstrate that magnetic and gamma-ray spectrometric surveys are standard and highly effective geophysical tools in REE exploration, particularly for identifying alkali–carbonate intrusions and fenite alteration zones. The application of these methods in the Kuluncak (Malatya) district is therefore consistent with international exploration strategies and provides robust datasets for targeting Nb–U–REE–Zr–Li mineralization.



Figure 3- Gamma-ray spectrometer (a) and magnetometer instrument (b)

4. Findings

4.1 Geological observations and mineralized features

A detailed mining geology map of the licensed area delineated the boundaries of the Hasançelebi–Kuluncak syenite (Tphk) and the carbonate units of the Andırın Formation (dMa), thereby defining their contact relationship. The spatial association of syenitic intrusions with carbonate rocks indicates that lithological contacts played a key role in the localization of alteration and mineralization zones.

Field studies revealed several distinct vein types (Figures 4–9):

Carbonate veins (possibly carbonatitic) cross-cutting the alkaline igneous rocks.

Carbonate–fluorite veins, indicating localized fluorite mineralization.

Hematitized carbonate veins cutting through nepheline syenites, collectively forming a well-defined mineralized belt.

Pegmatitic veins containing coarse mica, garnet, epidote, and calcite.

Along the margins of this mineralized belt, intense hematitization, carbonation, and clay alteration were observed. These alteration zones are developed both at syenite–carbonate contacts and within younger igneous dykes intruding older intrusive bodies. The cross-cutting relationships suggest that multiple hydrothermal events successively overprinted the alkaline igneous rocks.

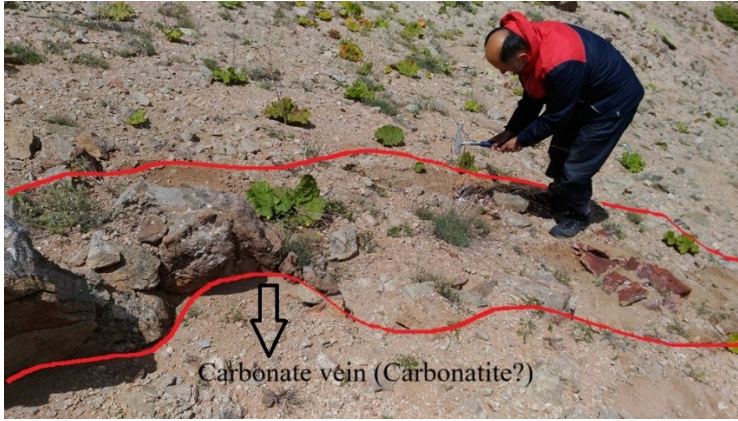
4.2 Hydrothermal alteration and structural controls

The distribution and orientation of mineralized veins demonstrate that ore-forming fluids were strongly influenced by structural features. Hematitized carbonate veins, in particular, define a continuous mineralized belt that reflects structurally controlled fluid flow. The alteration assemblages (hematite + carbonate ± clay) are consistent with hydrothermal metasomatism associated with alkaline–carbonatite systems.

4.3 Exploratory drilling results

In response to geochemical anomalies detected in outcrop samples, an exploratory drilling campaign was conducted in 2019. A total of 15 drillholes were completed, with drilling depths designed to intersect both carbonate–syenite contacts and geophysically anomalous zones. Drill site locations were selected based on the integration of potassium concentration maps and magnetic anomaly maps generated from spectral gamma-ray surveys (Figure 10).

Correlation of geochemical anomalies with geophysical datasets proved effective in guiding drillhole placement. The workflow involved the integration of surface geochemical anomalies, potassium and magnetic anomaly maps, and spectral gamma-ray survey results. Initially, geophysical surveys conducted in 2016 delineated zones of low magnetic intensity and elevated K concentrations. These anomalies were cross-validated with geochemical analyses of surface samples, which revealed enrichment in REE and Nb. The combined interpretation of these datasets was then used to guide the drilling program initiated in 2019, ensuring that drillholes targeted the most prospective zones. Drillhole data confirmed the presence of fenite zones and REE-rich intervals at varying depths, demonstrating that mineralization is not restricted to surface expressions but also extends to the subsurface. The results highlight the significance of combining geochemical and geophysical methods for successful subsurface exploration of REE-bearing alkaline–carbonatite systems.



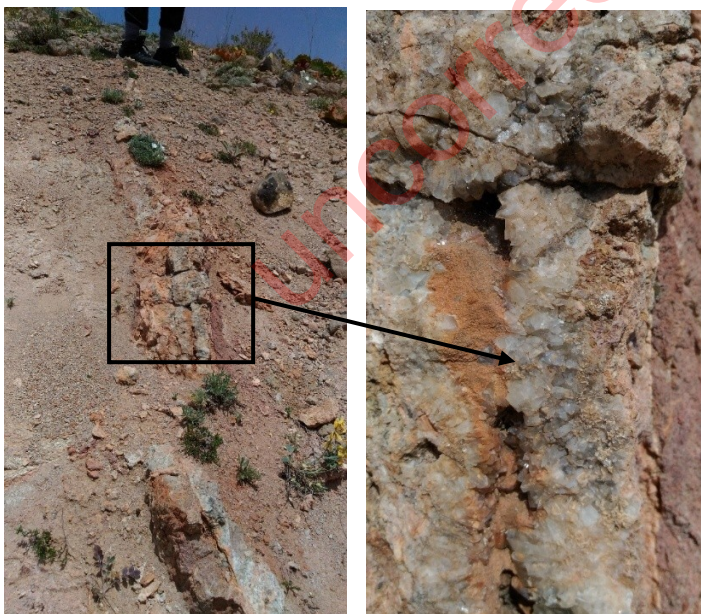
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228 Figure 4- Ferrous carbonate vein cutting foid syenites (thickness between 40-50 cm, extending 10 m)



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230 Figure 5- Ferrous carbonate vein cutting foid syenites (thickness between 1-10 cm, extending 5 m)



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232 Figure 6- Carbonate vein cutting foid syenites (thickness between 10-20 cm, extending 2 m)



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234 Figure 7. Carbonate–fluorite veins, suggesting localized fluorite mineralization

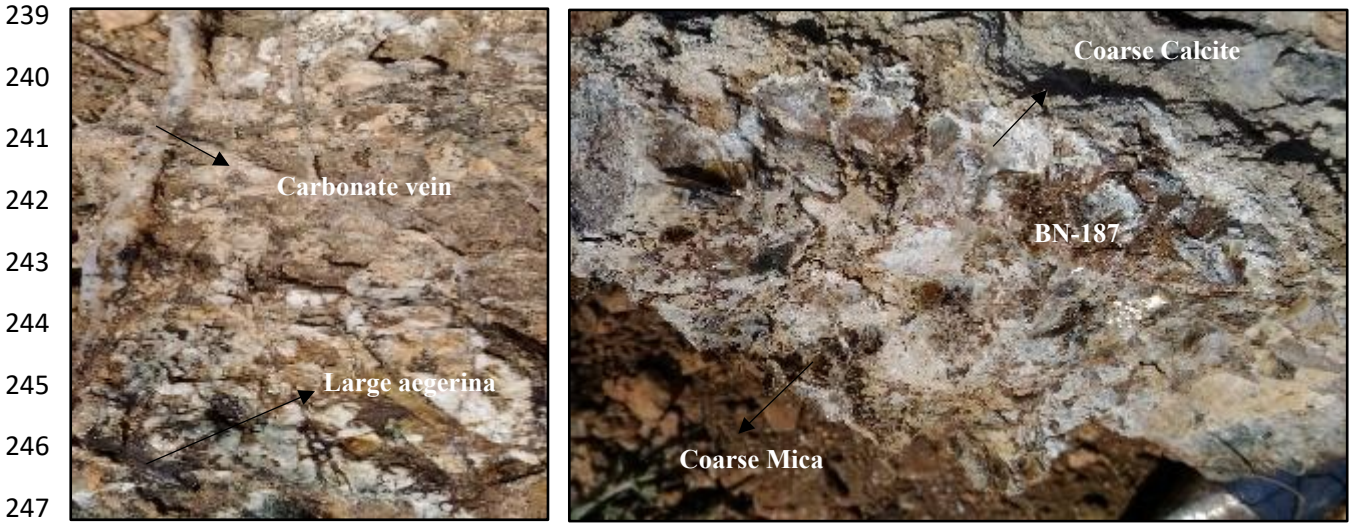


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237 Figure 8- Nepheline syenite (BN-197) and hematitised carbonate veins cutting syenite (BN-196, BN-198)
 238 (Appendix1) (8a), Alkali syenite cut by net-like calcite veins (8b)



Y ₂ O ₃	1462,97	ThO ₂	1321,11
La ₂ O ₃	1665,51	U ₃ O ₈	222,22
Ce ₂ O ₃	1931,44	Ta ₂ O ₅	147,75
Pr ₂ O ₃	132,25	ZrO ₂	19109,37
Nd ₂ O ₃	440,89	Cs ₂ O	2,12
Sm ₂ O ₃	59,14	HfO ₂	130,90
Eu ₂ O ₃	10,42	Nb ₂ O ₅	2144,36
Gd ₂ O ₃	85,29	Rb ₂ O ₂	629,21
Tb ₂ O ₃	12,66	BeO	44,40
Dy ₂ O ₃	104,44	Ga ₂ O ₃	17,47
Ho ₂ O ₃	30,93	Ni ₂ O ₃	7,04
Er ₂ O ₃	122,35	Li ₂ O	370,23
Tm ₂ O ₃	15,99	SrO	257,81
Yb ₂ O ₃	108,17	BaO	218,84
Lu ₂ O ₃	9,10		
Sc ₂ O ₃	1,53		
ΣREE ₂ O ₃	6194,09		

268
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270
271
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Figure 9- In sample no. BN-187 coarse calcite, mica, pyroxene, aegerine nepheline foid syenite

5. Classification of Igneous Rocks and Diagrammatic Interpretations

5.1 Rock classification (Middlemost, 1985)

The classification of igneous rocks in the Kuluncak study area was carried out using the SiO_2 –($\text{Na}_2\text{O} + \text{K}_2\text{O}$) diagram proposed by Middlemost (1985). Both outcrop (Figure 11a) and drillhole (Figure 11b) samples are distributed across a broad compositional spectrum, including foidolite, foid gabbro, foid monzogabbro, foid monzosyenite, foid syenite, monzogabbro, monzodiorite, monzonite, syenite, peridotite–gabbro, gabbro, and gabbroic diorite.

This wide lithological diversity reflects the multiphase magmatic history of the area, consistent with the alkaline–carbonatite association. Drillhole geochemical data (4,304 samples) further confirm that the alkaline intrusive complex includes both silica-undersaturated and silica-saturated facies, with significant compositional variability along different drilling lines.

5.2 Carbonatite variation diagram (Le Bas, 1981)

The distribution of outcrop and drillhole samples was also evaluated using the carbonatite variation diagram of Le Bas (1981). Outcrop samples (Figure 12a) are scattered toward the sövite–alkivite field, whereas drillhole samples (Figure 12b) are more consistently clustered, suggesting a relatively stable compositional trend at depth.

These results indicate that while surface expressions reflect a mixed and heterogeneous composition influenced by weathering and alteration, deeper levels preserve a more homogeneous magmatic character.

5.3 Fenite classification (Höy, 1987; 1988)

The classification of fenite zones was based on the scheme proposed by Höy (1987; 1988). Outcrop samples (Figure 12c) cluster between the albite fenite and pyroxene–amphibole fenite fields, whereas drillhole samples (Figure 12d) are positioned closer to the jambite–alkivite corner, reflecting more intense metasomatic alteration at depth.

This pattern suggests that surface fenitization is more alkali-rich, while at greater depths, fenite zones are enriched in mafic silicate phases (pyroxene and amphibole). Such zonation is consistent with progressive fluid–rock interaction in a carbonatite–alkaline magmatic system.

5.4 Geological implications

The combined use of Middlemost (1985), Le Bas (1981), and Höy (1987; 1988) diagrams provides critical insights into the magmatic and metasomatic evolution of the Kuluncak system:

- The wide compositional range reflects the polyphase nature of alkaline magmatism.

- Carbonatite variation trends confirm the presence of sövite–alkivite associations comparable to other carbonatite-bearing alkaline complexes worldwide.
- Fenite classification demonstrates that metasomatism intensifies with depth, supporting the genetic link between fenitization and REE–Nb–Zr mineralization.

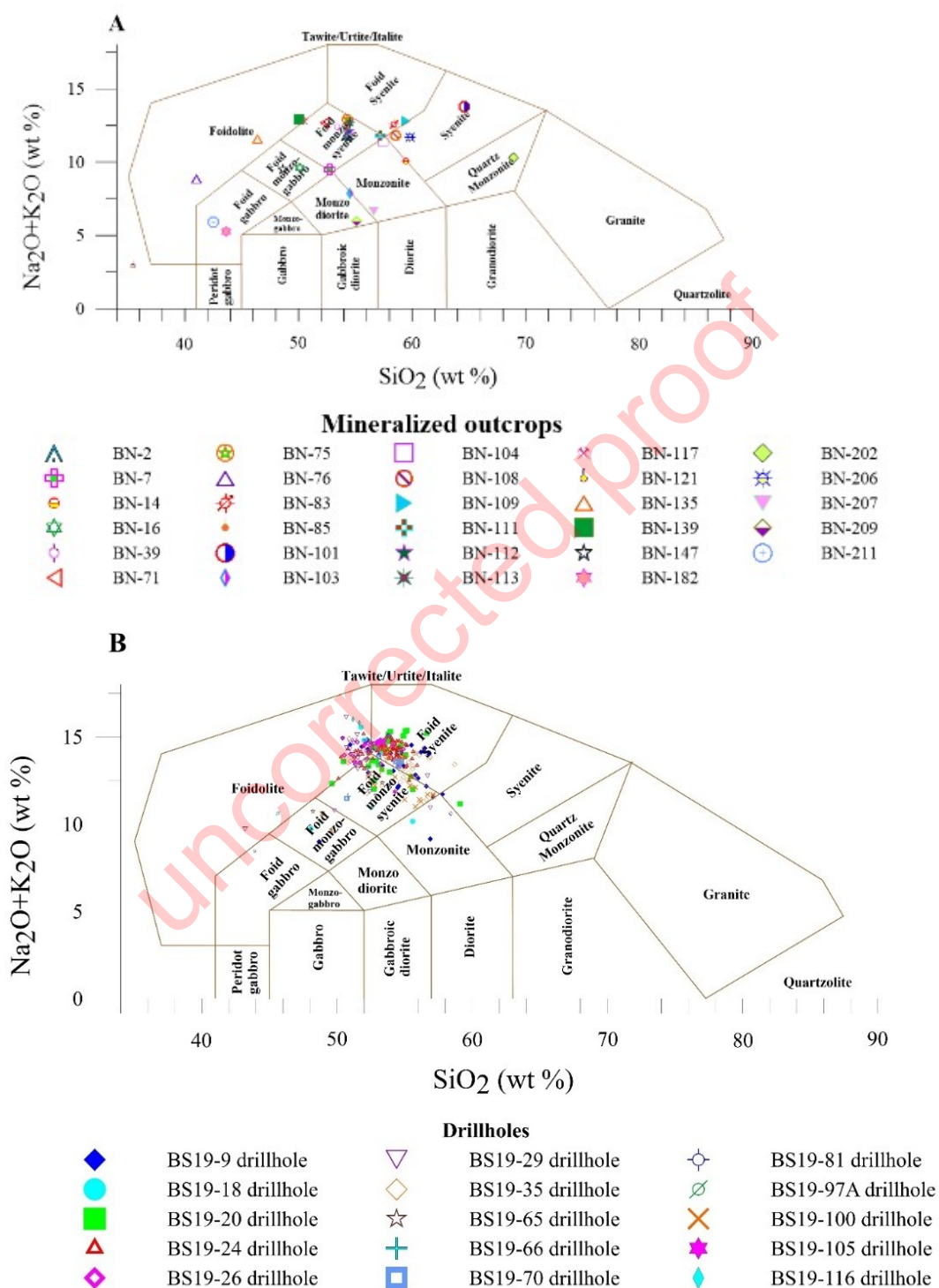


Figure 11- Rock classification of outcrop samples (11a) and drillholes (11b) based on Middlemost (1985)

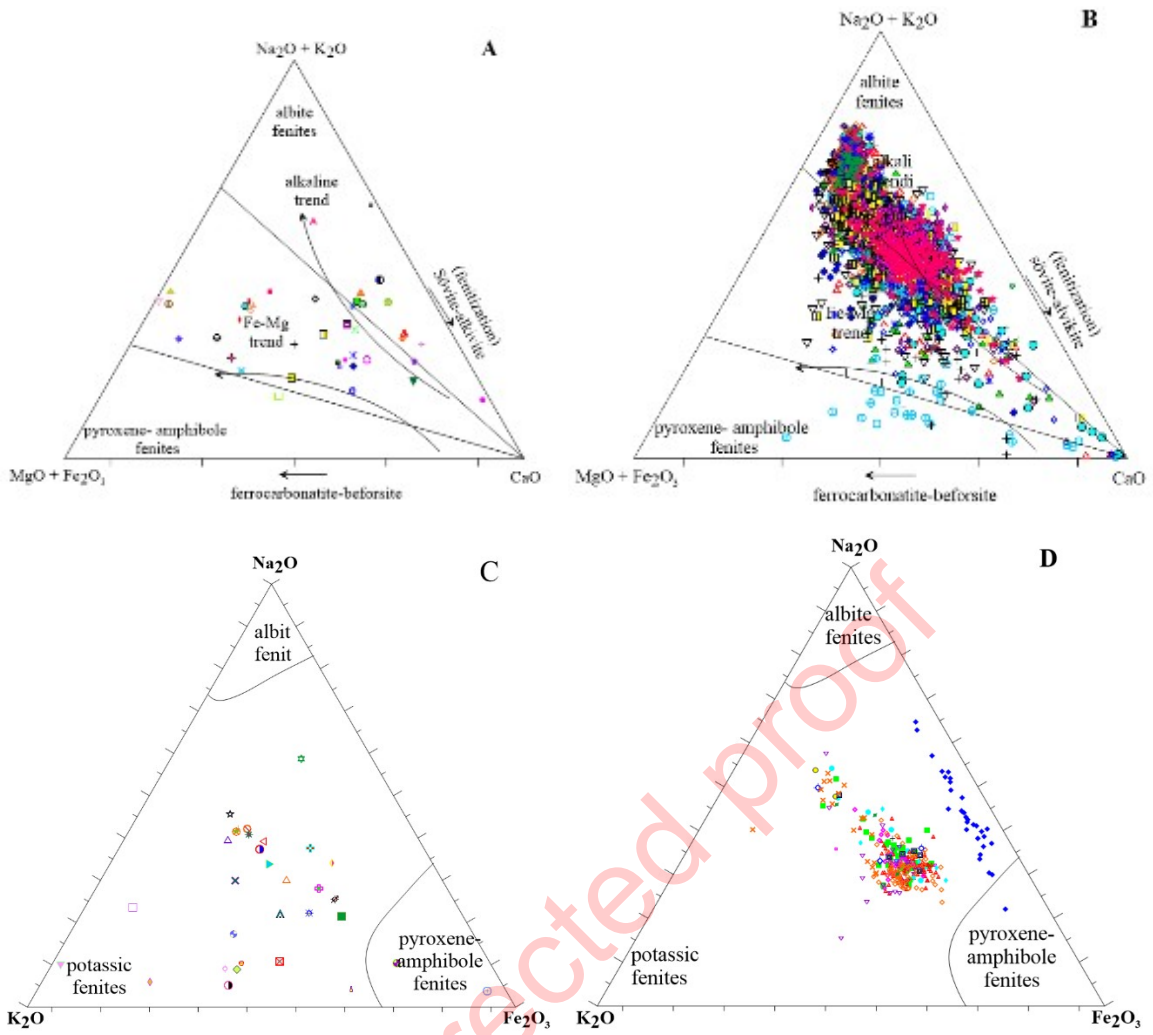


Figure 12- A) Carbonatite variation diagram of outcrop samples based on Le Bas (1981), B carbonatite variation diagram of drillhole samples based on Le Bas (1981), fenite types of outcrop samples and D) fenite types of drillholes (Doner, et al, 2024) based on Höy (1987).

In the diagrams, the outcrop samples tend to cluster near the suvite–alkivite corner, positioned between the albite fenite and pyroxene–amphibole fenite fields (Figure 12C). In contrast, the drillhole samples are predominantly located closer to the jambite–alkivite corner, farther from the albite fenite field and nearer to the pyroxene–amphibole fenite boundary (Figure 12D). Geochemical analysis results of the samples taken from the outcrop in 2016 (Appendix1).

6. Fenitization

Fenite is one of the most notable formations resulting from anorogenic alkaline metasomatism, typically occurring around alkaline complexes within stable continental regions. The term “Fenite” refers to this specific type of hydrothermal alteration and was first described by Brogger (1921) in the Fen carbonatites of Norway.

Fenitization is a type of alkaline metasomatism caused by Na- and/or K-rich fluids during post-magmatic processes in carbonatite or ijolite intrusions. According to Le Bas (1987), “the products of Fenitization are mineralogically syenites and as a result, they have often been misidentified as igneous syenites.” Various nomenclatures have been proposed to classify phenitic rocks. Verwoerd (1966) suggested naming phenitic rocks based on their major mineral constituents followed by the suffix “fenite” (e.g., orthoclase-aegerina-aegerinojite fenite). Kresten (1988) classified fenites into three types:

Hale fenites characterized by initial growth of K-feldspar and sericite; alkali amphiboles may appear at higher temperatures. Vein fenites containing riebeckite and K-feldspar. Contact fenites defined by nearly complete replacement of original minerals by K-feldspar, alkali amphibole, sodium pyroxene, and carbonate (Pirajno, 2019). The spatial extent of fenitisation ranges widely from centimeters up to several kilometers away from the intrusive contact. Fenites commonly associate with hydraulic fracturing and brecciation and display both temporal and spatial mineralogical and chemical variations, resulting in horizontal and vertical zonation patterns. Hydrothermal fluids originating from cooling alkaline magmas or carbonatite intrusions are rich in alkalis and volatile components. These fluids often carry elements not fully retained in the original carbonatitic rocks and thus only incompletely characterize the fenites formed around intrusions (Elliott et al., 2018). Fenitising fluids from evolved and enriched magmas facilitate the formation of REE and Nb micro-mineral assemblages within host rocks (Elliott et al., 2018). These assemblages provide valuable information on magma sources and associated mineral deposits, serving as effective exploration indicators. Fenites typically form extensive three-dimensional halos both vertically and horizontally around intrusions, and thus may be detected at various weathering levels, even where the primary intrusions are not exposed (Elliott et al., 2018). However, mineral resource exploration has traditionally focused on the intrusive alkali and carbonatite complexes themselves, as these constitute the primary hosts and sources for REE and Nb mineralization (Goodenough et al., 2016). Figure 2 illustrates a fenitic zone enriched in coarse orthoclase, albite, and pyroxene crystals, which compositionally resembles syenite but contains nepheline. Additionally, carbonate (possibly carbonatite) veins crosscutting nepheline syenites are shown in Figures 4, 5, 6, 7, 8 and 9. Fenitization in the study area caused by the sodium-and potassium-rich melts interacting with expelled from carbonate rocks. Based on outcrop sampling results, detailed mapping was performed, and exploration

drilling initiated. Drilling targeted zones characterized by relatively low magnetic anomalies and surface hematitization—indicating alteration of iron minerals.

6.1 Fenitization-related changes observed in core samples

Drilling locations were selected on the basis of geochemical anomalies identified from outcrop samples, negative magnetic anomalies, and potassium-rich zones. The spatial distribution of the drillholes is illustrated in Figure 10. Drillholes BS19-65, BS19-100, BS19-105, BS19-116, and BS19-24 are situated in the northwest (Figure 10a), BS19-70, BS19-81, BS19-97A, and BS19-66 in the northeast (Figure 10a), and BS19-29, BS19-9, BS19-18, BS19-26, BS19-20, and BS19-35 in the southern sector of the study area (Figure 10a). The potassium anomaly map is illustrated in Figure 10b, whereas the magnetic anomaly map is displayed in Figure 10c. Three-dimensional block models were generated from the geochemical data obtained from these drillholes to evaluate the relationship between fenitization and mineralization.

Northwestern drillholes (BS19-65, BS19-100, BS19-105, BS19-116, BS19-24): As shown in Figure 13, K₂O values (Figure 13a) are elevated, ranging between 6.73 and 7.82%, whereas Na₂O values (Figure 13b) are relatively low (2.64–7.82%). The combined alkali content (Na₂O + K₂O; Figure 13c) varies from 10.40 to 11.70%. These intervals are characterized by high concentrations of $\Sigma\text{REE}_2\text{O}_3$, Nb₂O₅, ThO₂, and U₃O₈ (Figures 13d–g). In contrast, ZrO₂ values (Figure 13h) are generally low, but they increase where the combined alkali content falls between 8.0 and 10.40%.

Southern drillholes (BS19-29, BS19-9, BS19-18, BS19-26, BS19-20, BS19-35): Figure 14 illustrates that K₂O values are high, while ZrO₂ values (Figure 14h) remain low. Na₂O content (Figure 14b) ranges between 2.23 and 7.82%, accompanied by elevated $\Sigma\text{REE}_2\text{O}_3$, Nb₂O₅, ThO₂, and U₃O₈ values. The highest REE and Nb concentrations correspond to intervals where the combined alkali content varies between 2.23 and 8.49%.

Northeastern drillholes (BS19-70, BS19-81, BS19-97A, BS19-66): According to Figure 15, K₂O values (Figure 15a) exhibit a wide range (0.12–12.49%), while Na₂O values (Figure 15b) also vary considerably (0.10–11.02%). Throughout these cores, high concentrations of $\Sigma\text{REE}_2\text{O}_3$, Nb₂O₅, ThO₂, U₃O₈, and ZrO₂ are present, particularly where the combined alkali content ranges between 0.40 and 15.08%.

Overall, the data reveal that fenitization intensity and associated mineralization vary across the study area: the northwestern section is dominated by K-fenite with elevated REE–Nb–Th–U, the southern section exhibits strong enrichment in both K₂O and REEs, and the northeastern section shows heterogeneous Na–K variations indicative of multiphase hydrothermal activity. These trends emphasize the genetic link between fenitization and REE mineralization in the Kuluncak system.

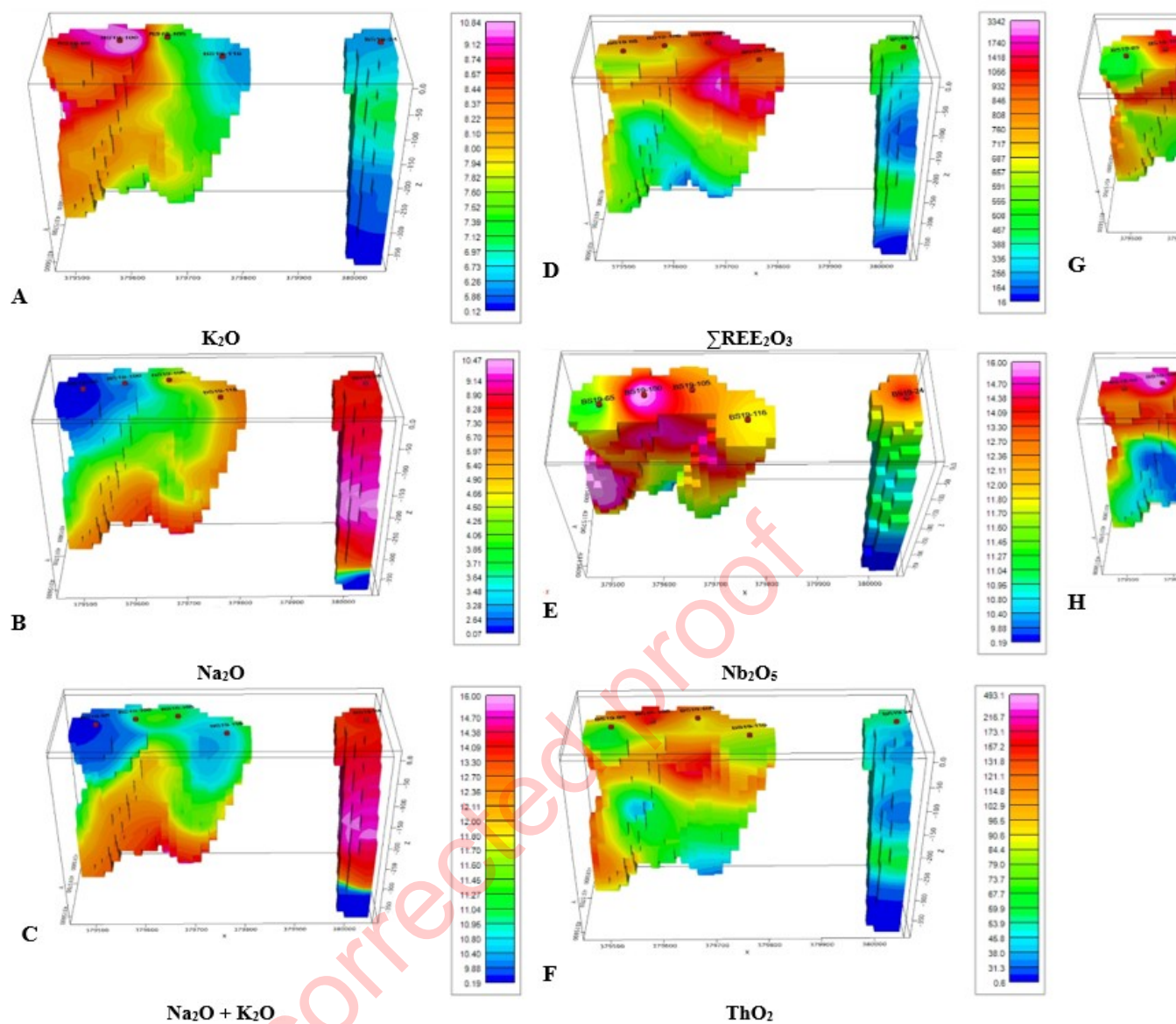


Figure 13- K₂O, Na₂O, Na₂O+K₂O, ΣREE₂O₃, Nb₂O₅, ThO₂, U₃O₈, ZrO₂ distributions of BS19-65, BS19-100, BS19-105, BS19-116

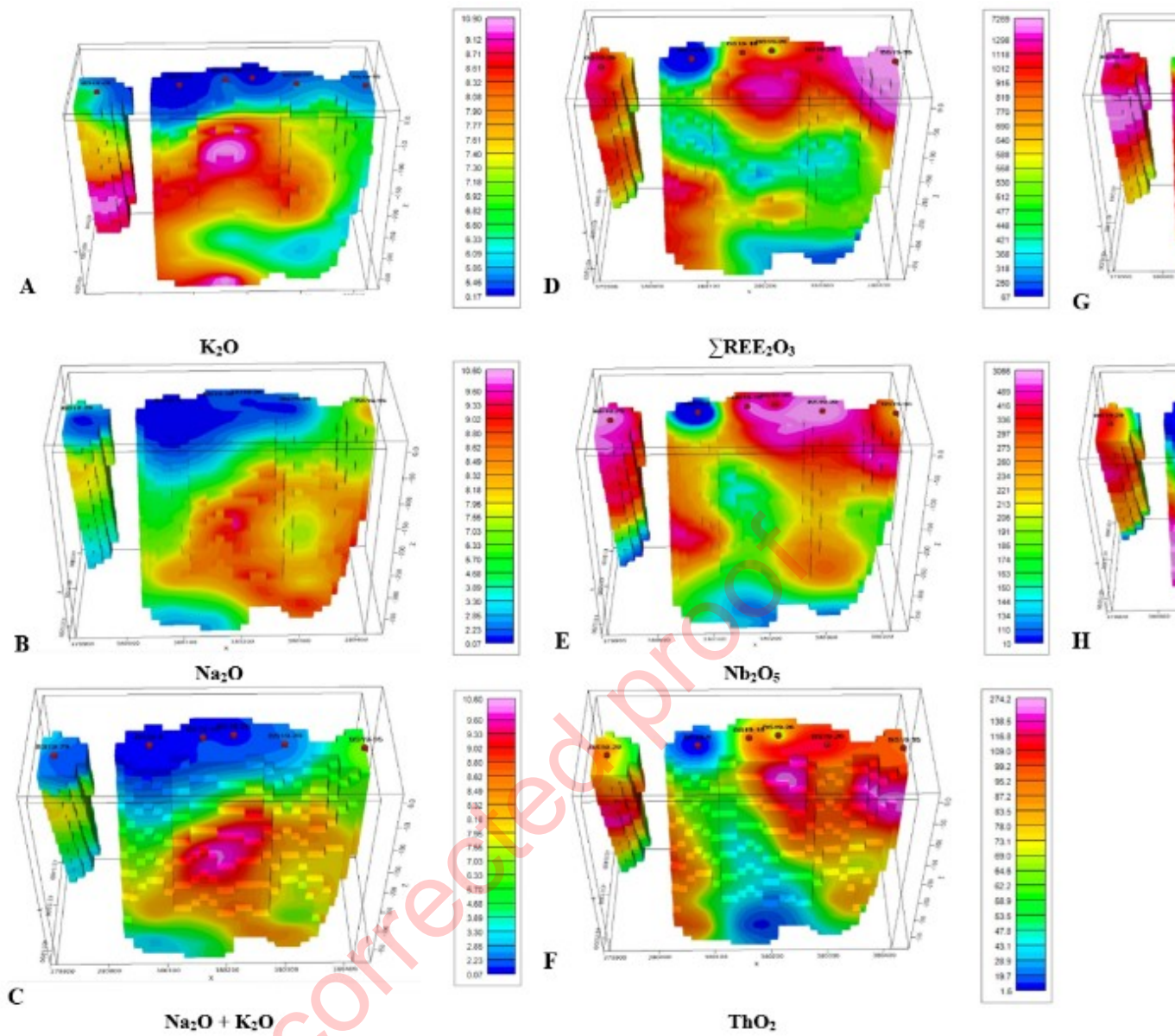


Figure 14- K_2O , Na_2O , Na_2O+K_2O , ΣREE_2O_3 , Nb_2O_5 , ThO_2 , U_3O_8 , ZrO_2 distributions of BS19-29, BS19-9, BS19-18, BS19-26, BS

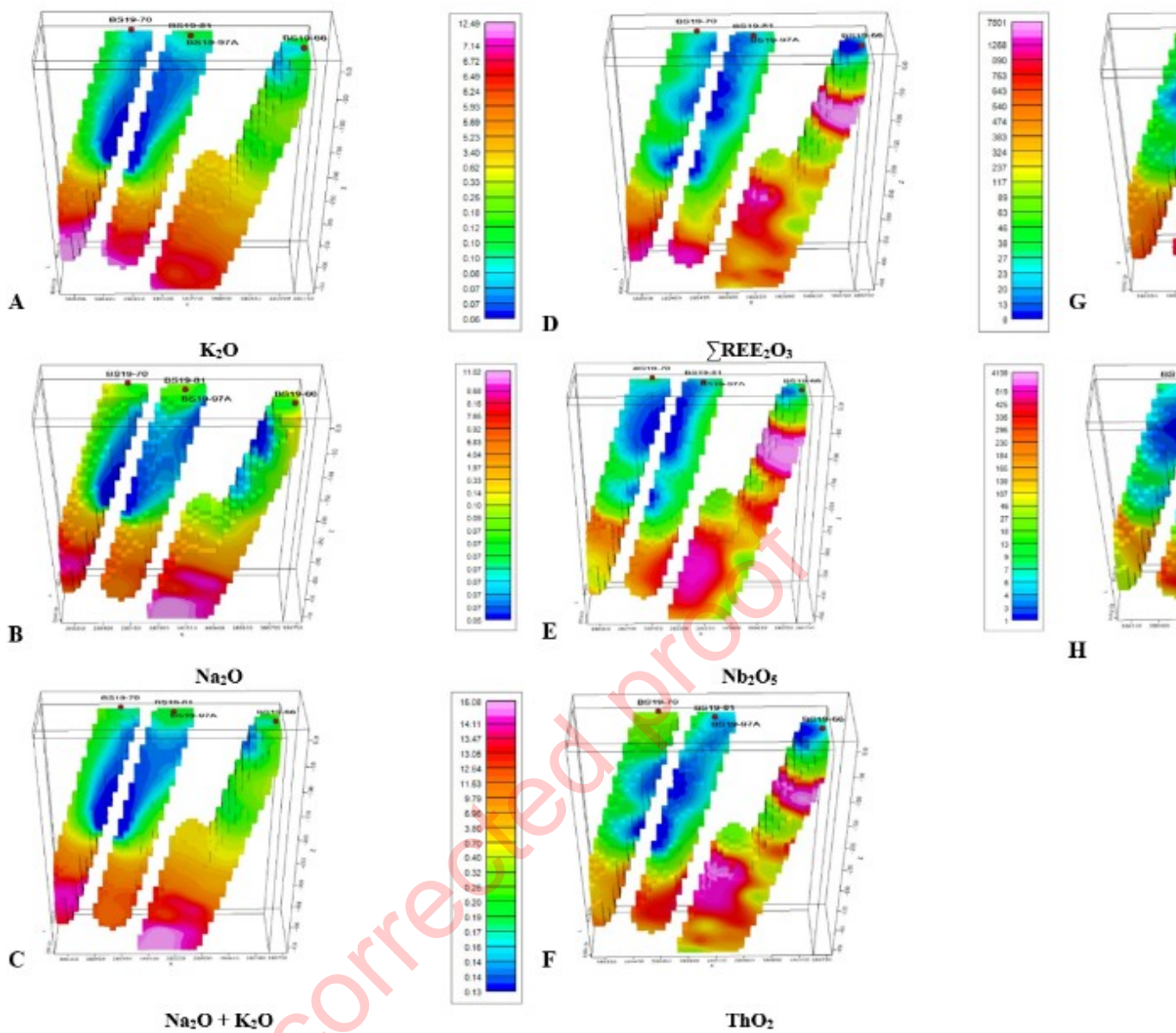


Figure 15- K_2O , Na_2O , Na_2O+K_2O , ΣREE_2O_3 , Nb_2O_5 , ThO_2 , U_3O_8 , ZrO_2 distributions of BS19-70, BS19-81, BS19-97A, BS19-66 d

7. Discussion

The consistently high CaO concentrations in the Kuluncak drillhole profiles provide compelling evidence for a carbonatitic contribution. Carbonatites are typically Ca-rich, dominated by calcite and dolomite, and CaO enrichment, especially within fenite zones, is a well-established geochemical indicator of carbonatite–alkaline magmatic systems (Le Bas, 1987; Woolley & Kempe, 1989). Moreover, the mineral assemblages observed in the study area, including fluorite, barite, apatite, and Nb–REE minerals (e.g., monazite, bastnäsite), are consistent with the paragenetic sequences of known carbonatite systems (Elliott et al., 2018). Together, CaO enrichment and these accessory minerals strongly support the involvement of carbonatitic fluids and metasomatism in Kuluncak mineralization.

The geochemical anomalies also show systematic variations across the north–south profile. In the southern marble-hosted drillholes, Σ LREE anomalies occur at shallow depths coinciding with K₂O enrichment, reflecting fenitization at the carbonatite–marble contact. By contrast, in the northern and northwestern nepheline syenite-hosted drillholes, REE anomalies are concentrated at intermediate depths (~40–100 m) and display heterogeneous distributions. These variations (Figures 13–14–15 and 16–17–18) indicate that the intensity of fenitization and REE mobility is strongly dependent on host lithology and structural position. Notably, Na depletion reflects the breakdown of sodic minerals, whereas K depletion indicates intense potassic alteration and subsequent mobilization (Çimen et al., 2020; Unluer et al., 2023b).

In addition to alteration mapping, magnetic data also provide insights into potential tectonic structures. Lineament analysis of the RTP and FVD magnetic maps reveals several NE–SW and NW–SE trending fault systems that may have acted as fluid conduits, controlling both fenitization and mineralization. These structures coincide with zones of intense alteration and REE enrichment, suggesting that tectonic controls played a significant role in localizing mineralization. Carbonatite–alkaline systems are rare in Türkiye. The Özvatan complex (Kayseri) and the Eskişehir area represent the most significant analogues (Kuşçu and Erler, 1998; Gürer, 1992; Metin et al., 2013, Unluer et al., 2023a). Kuluncak shares similarities with Özvatan in terms of Nb–REE enrichment, but CaO anomalies are more pronounced in Kuluncak, suggesting a stronger carbonatitic contribution. In Eskişehir, fenite zones are more restricted, and LREE–HREE fractionation is weaker than at Kuluncak. Thus, Kuluncak may be considered one of the most carbonatite-dominant systems in Türkiye.

Although the precise sources of mineralizing fluids cannot be directly constrained, comparative insights from previous works (Çimen et al., 2020; Unluer et al., 2023b) are valuable. Our findings are broadly consistent with their interpretations that post-collisional alkaline magmatism and associated hydrothermal fluids played a key role

in mineralization. However, unlike these regional-scale interpretations, the Kuluncak drillhole data provide detailed subsurface evidence of depth-controlled fenitization and localized heterogeneities in anomalies, thereby offering new constraints to complement previous studies.

In conclusion, the Kuluncak system clearly demonstrates carbonatite involvement through CaO enrichment and typical carbonatite mineral assemblages, while showing how fenitization controls LREE-dominant mineralization. When compared with Özvatan, Eskişehir, and global REE deposits such as Bayan Obo (China) and alkaline silicate systems like Ilimaussaq (Greenland), Kuluncak emerges not only as a regionally significant site but also as one of the rare and potentially economic carbonatite-related Nb–REE deposits in Türkiye (Unluer et al.; Çimen et al., 2020; Beard et al., 2023; Yang et al., 2019).

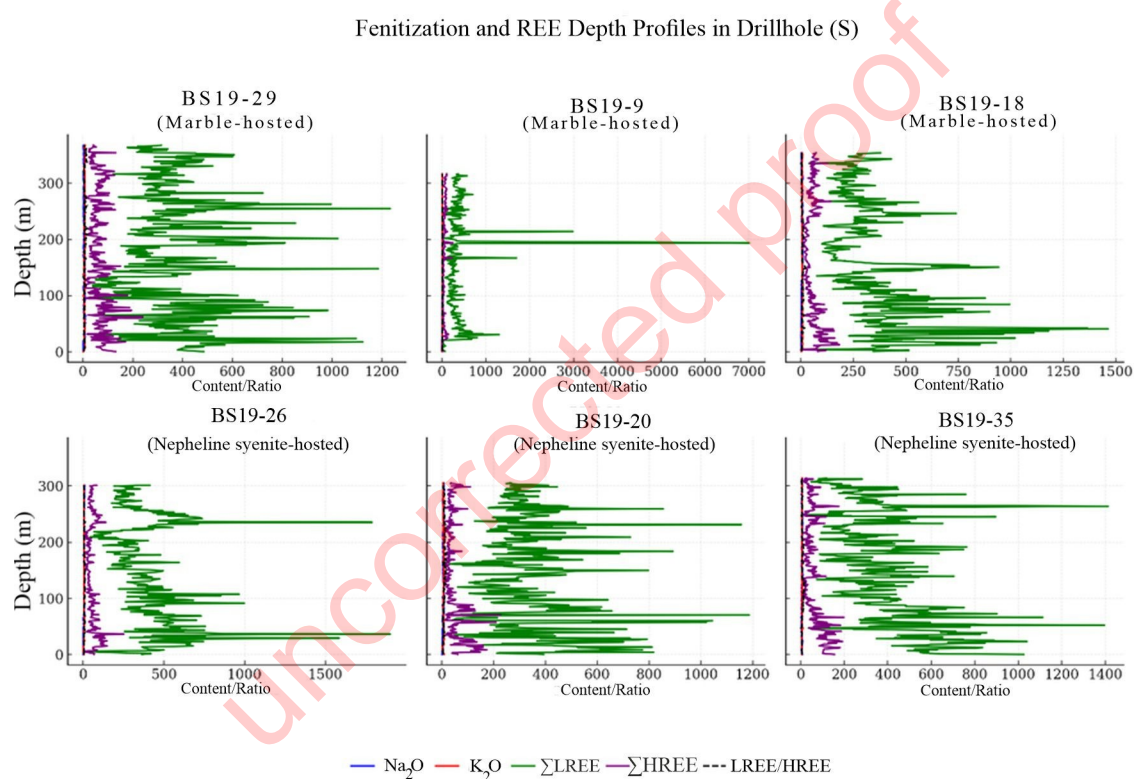
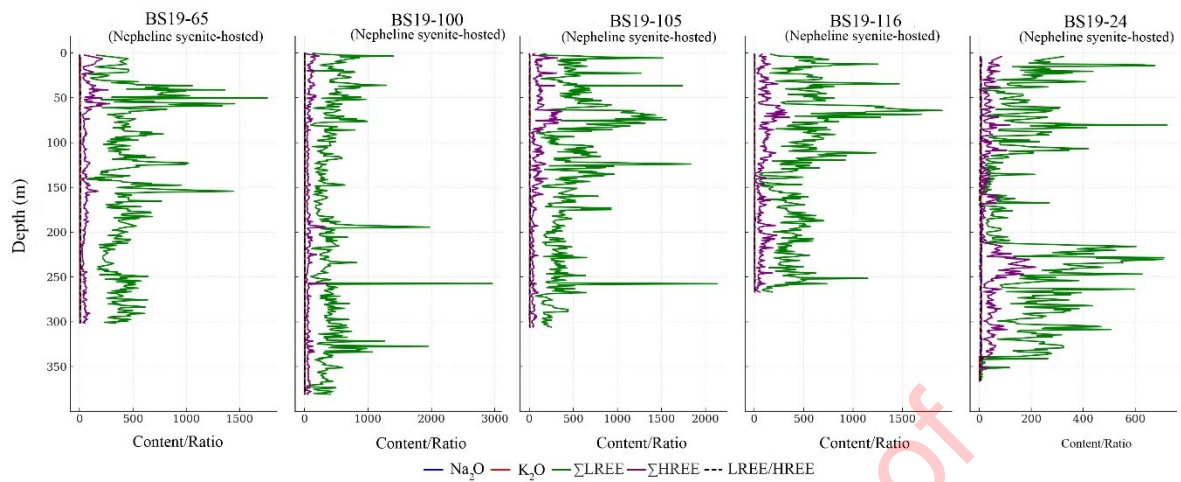


Figure 16. Drillholes BS19-29, BS19-9, and BS19-18 were drilled through marbles, whereas BS19-26, BS19-20, and BS19-35 were drilled through nepheline syenites. Depth profiles of Na₂O (blue), K₂O (red), ΣLREE (green), ΣHREE (purple), and LREE/HREE ratio (black, dashed) are shown for all drillholes. In the marble-hosted drillholes, pronounced K₂O enrichment and associated high ΣLREE values occur in the shallow levels. In contrast, the drillholes drilled through nepheline syenites display REE enrichments at greater depths and in a more scattered manner. These profiles clearly indicate that K-dominant fenitization is the primary process controlling LREE mineralization in the Kuluncak REE deposit.

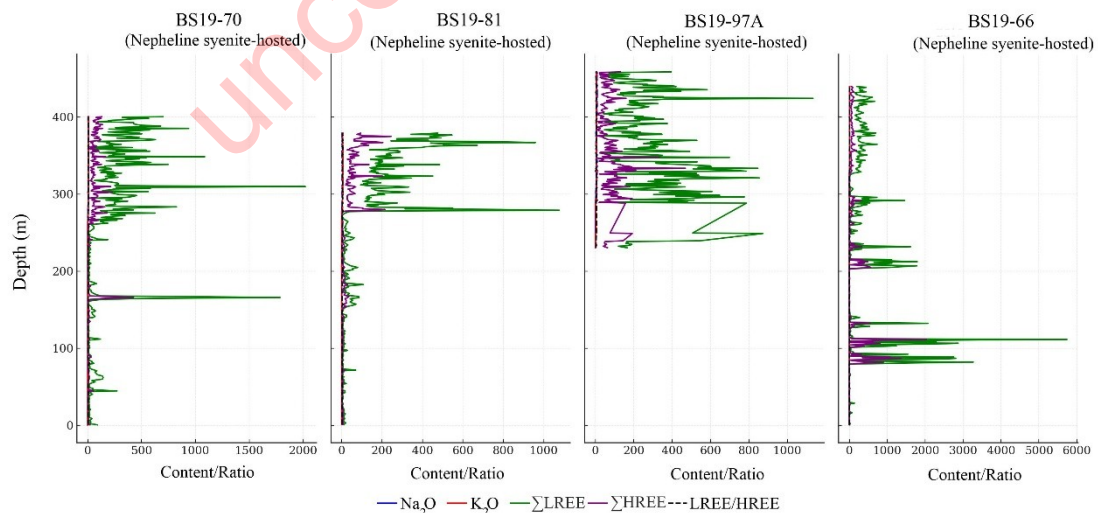
Fenitization and REE Depth Profiles (NW Drillholes, Nepheline syenite-hosted)



441

442 Figure 17. Depth profiles of Na_2O , K_2O , ΣLREE , ΣHREE , and LREE/HREE in drillholes BS19-65, BS19-100,
 443 BS19-105, BS19-116, and BS19-24 drilled through nepheline syenites in the northwestern part of the study area.
 444 The profiles indicate that ΣLREE values increase particularly within K_2O -enriched zones, reflecting the LREE-
 445 dominant character of the mineralization. The concentration of anomalies at intermediate depths (~40–100 m)
 446 suggests that second-stage fenitization related to the metasomatism of nepheline syenites plays a significant role in
 447 controlling REE mineralization.

Fenitization and REE Depth Profiles (NE Drillholes, Nepheline syenite-hosted)



448

449 Figure 18. Depth profiles of Na_2O , K_2O , ΣLREE , ΣHREE , and LREE/HREE in drillholes BS19-70, BS19-81,
 450 BS19-97A, and BS19-66 drilled through nepheline syenites in the northeastern part of the study area. The profiles
 451 show that ΣLREE values increase particularly within K_2O -enriched zones, reflecting the LREE-dominant character

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of the mineralization. The concentration of anomalies at intermediate depths (~40–100 m) suggests that second-stage fenitization related to the metasomatism of nepheline syenites plays a significant role in controlling REE enrichment.

8. Conclusions

Geochemical and geophysical evaluations from the Kuluncak (Malatya) district clearly demonstrate that fenitization and carbonatitic contributions are the primary controls on mineralization. Elevated CaO concentrations, together with typical carbonatite-related mineral assemblages (fluorite, barite, apatite, monazite, bastnäsite, etc.), provide strong evidence for the involvement of carbonatite-derived fluids in the mineralizing system (Elliott et al., 2023; Goodenough et al., 2016).

Drillhole profiles along the north–south transect reveal that the depth of REE enrichment varies depending on the host lithology. In the southern marble-hosted drillholes, LREE anomalies occur at shallow levels and coincide with zones of K₂O enrichment. In contrast, in the northern nepheline syenite-hosted drillholes, REE anomalies are concentrated at intermediate depths (~40–100 m) and display heterogeneous distributions. These findings demonstrate that K-dominant fenitization is the main process controlling LREE mobilization, while Na depletion reflects the breakdown of sodic minerals (Wall et al., 1993; Chakhmouradian & Zaitsev, 2012).

The geochemical block models (Figures 13–15) support these observations:

Figure 13 (northwestern drillholes: BS19-65, BS19-100, BS19-105, BS19-116, BS19-24): High K₂O values (6.73–7.82%), relatively low Na₂O contents (2.64–7.82%), and elevated Na₂O + K₂O (10.40–11.70%) are associated with enrichment in $\Sigma\text{REE}_2\text{O}_3$, Nb₂O₅, ThO₂, and U₃O₈. ZrO₂ remains generally low except for localized increases where total alkali values range between 8.0–10.40%. Figure 14 (southern drillholes: BS19-29, BS19-9, BS19-18, BS19-26, BS19-20, BS19-35): Characterized by high K₂O values and low ZrO₂ concentrations, with enrichment in $\Sigma\text{REE}_2\text{O}_3$, Nb₂O₅, ThO₂, and U₃O₈. The highest REE and Nb concentrations correspond to intervals where total alkali content ranges between 2.23 and 8.49%. Figure 15 (northeastern drillholes: BS19-70, BS19-81, BS19-97A, BS19-66): Show wide variations in K₂O (0.12–12.49%) and Na₂O (0.10–11.02%), with consistently elevated $\Sigma\text{REE}_2\text{O}_3$, Nb₂O₅, ThO₂, U₃O₈, and ZrO₂, particularly where total alkali content ranges between 0.40 and 15.08%.

These geochemical trends confirm that fenitization intensity is directly linked with REE–Nb–Th–U mineralization, and that compositional variability across different drillhole sections reflects localized fluid–rock interaction processes (Elliott et al., 2023; Xu et al., 2008).

At the regional scale, carbonatite-related systems in Türkiye are rare. Comparisons with the Özvatan complex (Kayseri) and the Eskişehir area show that Kuluncak is distinct in its stronger CaO anomalies and more pronounced LREE–HREE fractionation, making it one of the most carbonatite-dominated systems in the country (Özgenç & Kibici, 1994; Çimen et al., 2020).

At the international scale, the Kuluncak system shares similarities with world-class deposits such as Bayan Obo (China; Xu et al., 2008) and Ilímaussaq (Greenland; Sørensen et al., 2011), particularly in its LREE-dominant character, the role of fenitization, and the occurrence of carbonatite accessory minerals.

In conclusion, the Kuluncak district represents not only a regionally significant target but also a strategic Nb–REE deposit with economic potential at the international level, placing it among the rare but highly important alkaline silicate - carbonatite-related systems in Türkiye.

Contribution

Our study was carried out by General Directorate of Mineral Research and Exploration (MTA) under the coordination of the Mineral Research and Exploration within the scope of the REE Potential and Lithium Exploration of the Sofular-Kuluncak-Malatya region in Eastern Anatolia between 2014-2020 and within the scope of the Central and Eastern Anatolia REE Exploration Project since 2018.

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Sample	BN-1	BN-2	BN-3	BN-4	BN-5	BN-6	BN-7	BN-8	BN-9	BN-10	BN-11	BN-12	BN-13	BN-14	BN-15
SiO ₂	50.80	54.20	50.10	49.00	49.80	47.80	52.70	49.90	50.00	54.10	55.00	52.70	53.50	54.50	53.00
Al ₂ O ₃	21.10	15.30	21.70	19.60	21.10	18.90	17.80	16.40	14.70	16.20	15.80	21.10	21.70	22.60	21.10
Fe ₂ O ₃	4.60	8.10	5.40	6.10	4.40	6.30	8.00	9.10	14.90	10.90	11.40	5.50	5.80	6.00	5.60
Na ₂ O	1.10	4.40	1.30	2.80	2.00	2.50	4.90	6.10	1.70	1.70	2.80	1.60	1.60	1.60	6.10
K ₂ O	9.60	7.40	9.00	6.50	5.70	6.10	4.60	2.20	11.20	11.80	9.90	8.90	8.00	7.90	5.80
CaO	5.30	4.60	4.40	7.30	6.90	8.60	3.60	6.10	0.70	0.80	1.30	3.60	2.60	2.80	3.00
MgO	0.20	0.10	0.20	0.20	0.90	0.60	0.50	0.50	0.20	0.20	0.40	0.70	0.90	1.00	0.60
TiO ₂	0.20	0.40	0.20	0.20	0.20	0.20	0.30	0.50	0.10	0.40	0.40	0.20	0.10	0.10	0.20
P ₂ O ₅	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
A.Z	6.45	3.60	6.00	7.75	8.40	7.20	3.95	5.20	4.20	2.65	2.10	5.10	4.95	2.65	4.15
MnO	0.20	0.20	0.20	0.20	0.20	0.30	0.30	0.40	0.20	0.10	0.20	0.20	0.20	0.20	0.20
Y	16.00	40.00	25.00	34.00	31.00	121.00	161.00	296.01	19.00	34.00	21.00	41.00	86.00	225.01	73.00
La	66.00	80.00	41.00	119.00	118.00	273.99	1184.97	826.98	27.00	91.00	66.00	124.00	209.00	85.00	140.00
Ce	103.93	127.77	65.79	170.68	175.44	393.80	1616.18	1142.29	41.95	132.54	93.44	204.05	331.82	254.58	226.93
Pr	7.00	8.00	4.00	10.00	10.00	10.00	108.00	76.00	3.00	9.00	7.00	15.00	25.00	29.00	20.00
Nd	22.00	24.00	15.00	31.00	32.00	81.00	313.99	223.00	9.00	26.00	22.00	45.00	73.00	107.00	49.00
Sm	2.00	3.00	2.00	4.00	4.00	10.00	22.00	21.00	1.00	3.00	3.00	6.00	9.00	17.00	6.00
Eu	1.00	1.00	1.00	1.00	1.00	2.00	3.00	3.00	0.50	1.00	1.00	1.00	2.00	4.00	1.00
Gd	3.00	4.00	3.00	5.00	5.00	12.00	30.00	28.00	1.00	4.00	3.00	7.00	10.00	19.00	7.00
Tb	0.50	0.50	0.50	0.50	0.50	1.00	2.00	3.00	0.50	0.50	0.50	1.00	1.00	3.00	1.00
Dy	1.00	3.00	2.00	3.00	3.00	8.00	11.00	22.00	1.00	3.00	2.00	4.00	7.00	18.00	5.00
Ho	0.50	1.00	0.50	1.00	1.00	2.00	2.00	5.00	0.50	1.00	0.50	1.00	2.00	4.00	1.00
Er	1.00	3.00	1.00	3.00	2.00	6.00	9.00	20.00	1.00	3.00	2.00	3.00	5.00	13.00	4.00
Tm	0.50	0.50	0.50	0.50	0.50	1.00	1.00	3.00	0.50	0.50	0.50	0.50	1.00	2.00	1.00
Yb	1.00	2.00	1.00	2.00	1.00	5.00	6.00	16.00	1.00	2.00	2.00	2.00	4.00	9.00	3.00
Lu	0.50	0.50	0.50	0.50	0.50	0.50	1.00	2.00	0.50	0.50	0.50	0.50	0.50	1.00	0.50
Sc	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
ΣNTEO	226.43	298.77	163.29	385.67	385.44	945.79	3471.66	2687.78	107.95	311.54	224.94	455.55	766.82	791.09	538.93
Th	21.00	184.00	42.00	78.00	50.00	86.00	204.00	236.00	168.00	326.00	163.00	85.00	270.00	31.00	54.00
U	8.02	144.34	13.03	36.09	23.05	101.24	171.41	345.82	59.14	137.33	57.14	28.07	23.05	49.12	36.09
Ta	19.00	153.99	33.00	72.00	31.00	184.99	389.98	445.98	73.00	144.99	60.00	38.00	31.00	83.00	40.00
Zr	435.99	2044.96	675.99	965.98	480.99	1301.97	2721.94	4858.90	551.99	1095.98	769.98	645.99	973.98	2063.96	517.99
Cs	4.00	4.00	2.00	4.00	2.00	4.00	2.00	2.00	1.00	2.00	1.00	5.00	5.00	1.00	35.00
Hf	0.00	11.00	4.00	6.00	3.00	7.00	14.00	27.00	4.00	7.00	4.00	5.00	5.00	12.00	3.00
Nb	153.00	1095.02	205.00	467.01	237.00	1022.02	1962.03	2921.05	541.01	822.01	395.01	198.00	266.00	1288.02	233.00
Rb	219.10	203.95	248.23	193.46	192.29	203.95	259.89	127.03	275.04	303.01	256.39	229.58	241.24	111.88	259.89
Be	10.00	5.00	7.00	13.00	10.00	6.00	6.00	6.00	3.00	4.00	6.00	13.00	11.00	3.00	6.00
Ge	0.00	3.00	2.00	3.00	2.00	3.00	4.00	4.00	3.00	3.00	3.00	2.00	2.00	7.00	2.00
Ga	40.00	49.00	50.00	56.00	41.00	53.00	80.00	82.00	77.00	94.00	55.00	44.00	44.00	51.00	31.00
Ni	1.00	3.00	2.00	4.00	2.00	3.00	13.00	2.00	2.00	1.00	3.00	1.00	1.00	4.00	3.00
Li	184.99	89.99	270.98	133.99	189.98	180.99	132.99	215.98	59.00	61.00	125.99	170.99	172.99	61.00	205.98
Sr	237.00	150.00	160.00	102.00	270.00	288.00	213.00	285.00	64.00	59.00	74.00	318.00	183.00	164.00	357.00
Ba	752.00	352.00	1027.01	370.00	801.00	991.01	473.00	248.00	1371.01	1451.01	1391.01	901.00	966.01	1572.01	787.00
P	215.00	54.00	248.00	77.00	112.00	65.00	132.00	74.00	458.00	420.00	112.00	153.00	269.00	153.00	137.00

Sample	BN-23	BN-24	BN-25	BN-26	BN-27	BN-28	BN-29	BN-30	BN-31	BN-32	BN-33	BN-34	BN-35	BN-36	BN-37
SiO ₂	13.60	34.50	43.10	9.60	30.20	0.30	52.30	22.30	50.00	33.50	35.30	47.80	30.70	51.60	50.50
Al ₂ O ₃	0.60	4.30	9.80	0.70	0.40	0.10	15.30	1.30	22.70	1.40	1.80	22.10	6.10	21.00	19.30
Fe ₂ O ₃	5.90	20.20	13.00	3.50	2.80	0.20	9.80	30.30	5.10	17.80	13.30	4.20	24.50	6.50	6.90
Na ₂ O	0.20	0.20	1.20	0.10	0.10	0.10	2.30	0.10	0.60	1.50	0.70	0.10	0.10	5.80	5.40
K ₂ O	0.20	0.30	5.60	0.10	0.10	0.10	10.90	2.10	6.80	1.10	1.10	7.00	0.80	4.90	4.40
CaO	47.20	32.30	16.70	46.30	35.90	55.00	3.40	17.20	5.50	24.80	30.30	7.20	28.60	3.70	6.10
MgO	1.80	1.10	0.40	1.70	1.00	0.40	0.20	2.80	1.30	2.80	6.90	2.20	1.30	0.80	1.50
TiO ₂	0.10	0.30	0.50	0.10	0.10	0.10	0.40	0.10	0.20	0.40	0.20	0.10	0.50	0.20	0.20
P ₂ O ₅	0.30	0.40	0.10	0.20	0.10	0.10	0.10	0.60	0.10	0.80	0.20	0.10	0.10	0.10	0.10
A.Z	24.45	5.25	8.20	27.70	25.05	43.75	4.10	17.15	7.20	13.45	7.95	8.85	5.10	4.00	4.80
MnO	0.90	0.80	0.60	0.70	0.50	0.10	0.60	0.30	0.10	0.90	0.90	0.20	0.80	0.20	0.20
Y	218.01	199.01	102.00	124.00	196.01	5.00	38.00	220.01	35.00	240.01	211.01	30.00	240.01	63.00	77.00
La	1235.97	212.00	214.00	744.98	669.98	64.00	218.99	197.00	20.00	272.99	176.00	25.00	54.00	126.00	98.00
Ce	1816.42	353.75	331.82	1068.87	901.06	72.47	287.96	321.33	61.02	411.91	282.24	58.16	165.91	204.05	180.21
Pr	117.00	32.00	25.00	67.00	73.00	4.00	28.00	26.00	6.00	31.00	23.00	5.00	22.00	19.00	17.00
Nd	344.99	122.00	75.00	202.00	236.00	10.00	48.00	84.00	26.00	98.00	75.00	20.00	93.00	46.00	45.00
Sm	32.00	20.00	10.00	18.00	25.00	1.00	5.00	15.00	4.00	16.00	12.00	4.00	18.00	6.00	7.00
Eu	5.00	4.00	2.00	3.00	4.00	0.50	1.00	3.00	1.00	3.00	2.00	1.00	3.00	1.00	1.00
Gd	42.00	21.00	12.00	25.00	32.00	1.00	7.00	20.00	5.00	20.00	15.00	4.00	18.00	7.00	8.00
Tb	4.00	3.00	1.00	2.00	3.00	0.50	1.00	3.00	1.00	3.00	2.00	1.00	3.00	1.00	1.00
Dy	18.00	15.00	8.00	10.00	17.00	0.50	4.00	23.00	4.00	21.00	14.00	3.00	20.00	5.00	7.00
Ho	3.00	3.00	2.00	2.00	3.00	0.50	1.00	5.00	1.00	5.00	3.00	1.00	4.00	1.00	1.00
Er	10.00	9.00	6.00	6.00	9.00	0.50	3.00	16.00	2.00	16.00	10.00	2.00	15.00	4.00	5.00
Tm	1.00	1.00	1.00	1.00	1.00	0.50	0.50	2.00	0.50	2.00	1.00	0.50	2.00	1.00	1.00
Yb	5.00	6.00	4.00	2.00	4.00	0.50	2.00	10.00	2.00	14.00	7.00	2.00	9.00	3.00	3.00
Lu	0.50	1.00	0.50	0.50	0.50	0.50	0.50	1.00	0.50	2.00	1.00	0.50	1.00	0.50	0.50
Sc	0.50	1.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	2.00	0.50	0.50	0.50	0.50
ΣNTEO	3853.39	1002.75	794.82	2276.86	2175.05	161.96	646.45	946.83	169.52	1156.41	836.24	157.66	668.41	488.05	452.21
Th	203.00	74.00	146.00	171.00	270.00	1.00	378.00	962.00	10.00	195.00	256.00	10.00	26.00	61.00	66.00
U	76.18	51.12	37.09	57.14	106.25	3.01	36.09	45.11	11.03	33.08	33.08	6.01	30.07	35.08	25.06
Ta	1.00	16.00	54.00	0.50	0.50	0.50	71.00	9.00	18.00	14.00	68.00	13.00	21.00	37.00	32.00
Zr	176.00	631.99	871.98	165.00	188.00	3.00	836.98	5398.89	212.00	1641.97	1759.96	208.00	960.98	639.99	608.99
Co	1.00	1.00	1.00	0.50	1.00	0.50	1.00	4.00	2.00	4.00	2.00	1.00	1.00	4.00	3.00
Cr	3.00	3.00	3.00	0.50	3.00	0.50	28.50	10.00	10.00	13.00	13.00	4.00	5.00	3.00	3.00
Nb	79.00	565.01	465.01	110.00	122.00	4.00	335.01	99.00	78.00	124.00	387.01	86.00	451.01	208.00	176.00
Rb	18.65	17.48	171.31	8.16	5.83	12.82	447.52	236.58	152.67	101.39	102.56	202.78	34.96	216.77	101.39
Be	22.00	7.00	5.00	5.00	4.00	0.50	7.00	65.99	5.00	26.00	28.99	5.00	5.00	8.00	8.00
Ge	3.00	7.00	3.00	2.00	2.00	0.50	2.00	5.00	1.00	5.00	5.00	5.00	7.00	2.00	2.00
Ga	5.00	20.00	28.00	2.00	2.00	1.00	36.00	10.00	44.00	11.00	9.00	29.00	19.00	38.00	33.00
Ni	4.00	5.00	2.00	4.00	5.00	5.00	1.00	15.00	2.00	5.00	5.00	11.00	3.00	2.00	5.00
Li	244.98	183.99	108.99	89.99	69.99	10.00	108.99	2849.77	150.99	805.94	572.95	168.99	93.99	164.99	88.99
Sr	626.00	90.00	533.00	330.00	515.00	251.00	53.00	543.00	219.00	486.00	286.00	120.00	108.00	635.00	358.00
Ba	59.00	21.00	608.00	52.00	69.00	40.00	357.00	124.00	2122.01	85.00	48.00	787.00	66.00	1326.01	753.00

P	1590.00	1354.00	213.00	1173.00	488.00	55.00	66.00	2635.00	87.00	3258.00	720.00	80.00	53.00	121.00	99.00	4
Sample	BN-45	BN-46	BN-47	BN-48	BN-49	BN-50	BN-51	BN-52	BN-53	BN-54	BN-55	BN-56	BN-57	BN-58	BN-59	E
SiO ₂	48.10	50.00	51.60	51.60	53.30	3.10	29.20	49.80	48.00	54.00	51.60	52.80	52.40	53.80	50.30	1
Al ₂ O ₃	13.20	21.40	16.20	20.00	20.50	0.60	1.00	20.80	20.90	17.00	20.70	18.20	18.90	20.00	18.90	1
Fe ₂ O ₃	9.70	3.90	10.90	5.50	5.50	10.20	7.70	5.70	4.60	9.80	6.30	8.80	5.40	5.70	6.30	1
Na ₂ O	2.90	2.00	1.20	1.80	5.80	0.10	0.10	1.90	1.90	5.60	1.70	4.00	2.90	1.80	2.20	1
K ₂ O	3.70	8.70	12.00	8.40	5.60	0.20	0.50	6.30	7.50	4.20	7.20	6.40	8.10	7.40	8.60	1
CaO	13.00	5.70	1.40	5.00	2.70	46.30	36.70	6.90	7.10	3.50	4.00	3.50	5.30	4.00	5.70	1
MgO	3.00	0.30	0.10	0.30	1.10	0.40	6.40	0.30	0.20	0.50	0.90	0.60	0.30	0.60	0.50	1
TiO ₂	0.30	0.20	0.10	0.20	0.20	0.20	0.10	0.30	0.10	0.30	0.20	0.30	0.20	0.20	0.10	1
P ₂ O ₅	0.50	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1
A.Z	4.05	6.20	4.25	6.45	4.55	37.60	16.00	7.05	8.80	3.75	6.70	4.00	5.40	5.45	6.70	1
MnO	0.70	0.40	0.10	0.20	0.20	0.60	0.90	0.30	0.20	0.30	0.30	0.20	0.30	0.30	0.30	1
Y	108.00	34.00	41.00	10.00	50.00	33.00	8.00	64.00	53.00	37.00	62.00	26.00	69.00	93.00	17.00	1
La	351.99	292.99	38.00	53.00	116.00	100.00	64.00	234.99	160.00	151.00	191.00	75.00	322.99	276.99	73.00	1
Ce	478.66	276.52	51.49	71.51	172.58	103.93	74.37	328.00	275.56	195.47	302.26	92.49	445.28	376.63	92.49	2
Pr	31.00	8.00	4.00	5.00	12.00	8.00	5.00	27.00	28.00	13.00	28.00	6.00	39.00	32.00	7.00	1
Nd	81.00	41.00	13.00	15.00	48.00	23.00	13.00	71.00	85.00	38.00	85.00	15.00	109.00	90.00	18.00	1
Sm	9.00	4.00	2.00	2.00	7.00	3.00	1.00	9.00	12.00	5.00	12.00	2.00	14.00	13.00	2.00	1
Eu	2.00	0.80	0.70	0.50	1.40	0.80	0.30	1.90	2.30	0.90	2.20	0.50	2.50	2.50	0.50	1
Gd	13.00	7.00	3.00	2.00	8.00	5.00	2.00	12.00	14.00	7.00	14.00	3.00	16.00	16.00	3.00	1
Tb	1.00	0.60	0.50	0.30	1.10	0.60	0.20	1.30	1.60	0.80	1.60	0.40	1.80	2.00	0.40	1
Dy	9.00	4.00	4.00	2.00	7.00	4.00	1.00	8.00	9.00	5.00	9.00	3.00	10.00	13.00	2.00	1
Ho	2.00	0.90	1.00	0.30	1.30	0.90	0.20	1.70	1.70	1.20	1.80	0.80	2.00	2.70	0.50	1
Er	6.00	3.00	4.00	1.00	4.00	3.00	1.00	6.00	5.00	4.00	6.00	3.00	6.00	9.00	2.00	1
Tm	1.00	0.50	0.50	0.20	0.50	0.40	0.10	0.80	0.50	0.50	0.70	0.30	0.80	1.20	0.20	1
Yb	4.00	3.00	3.00	1.00	3.00	2.00	1.00	5.00	3.00	3.00	4.00	2.00	4.00	7.00	1.00	1
Lu	0.50	0.30	0.30	0.20	0.30	0.20	0.10	0.60	0.20	0.40	0.60	0.20	0.40	0.60	0.10	1
Sc	1.00	0.30	0.30	0.20	0.40	0.60	0.40	0.20	0.20	0.20	0.20	0.20	0.30	0.20	0.20	1
ΣNTEO	1099.15	676.91	166.79	164.21	432.38	288.53	171.67	771.50	651.06	462.46	720.16	229.89	1043.08	935.83	219.39	4
Th	132.00	262.00	131.00	55.00	57.00	18.00	35.00	78.00	40.00	121.00	69.00	37.00	155.00	142.00	88.00	1
U	54.13	44.10	21.05	82.19	27.06	4.01	46.11	32.08	11.03	147.35	10.02	135.32	59.14	31.07	22.05	1
Ta	79.00	23.20	5.50	15.40	5.20	1.60	3.40	13.40	5.10	36.90	6.30	36.60	19.20	15.60	4.90	1
Zr	1177.98	672.99	885.98	407.99	391.99	355.99	225.00	393.99	167.00	1027.98	361.99	647.99	658.99	1045.98	237.00	2
Cs	21.00	6.00	1.00	3.00	8.00	3.00	2.00	2.00	2.00	1.00	2.00	2.00	7.00	6.00	3.00	1
Hf	7.00	5.00	6.00	4.00	3.00	3.00	2.00	3.00	2.00	11.00	3.00	7.00	6.00	8.00	2.00	1
Nb	512.01	729.01	86.00	414.01	152.00	92.00	114.00	264.00	105.00	743.01	126.00	774.01	496.01	393.01	160.00	2
Rb	136.35	390.41	341.46	263.38	299.51	13.98	44.29	248.23	268.04	266.88	237.74	417.21	423.04	167.82	307.67	3
Be	15.00	17.00	3.00	7.00	15.00	18.00	28.00	6.00	6.00	12.00	6.00	15.00	13.00	7.00	7.00	1
Ge	3.00	1.00	2.00	1.00	2.00	2.00	1.00	2.00	1.00	3.00	2.00	2.00	2.00	2.00	2.00	1
Ga	24.00	68.00	79.00	56.00	41.00	26.00	14.00	42.00	39.00	58.00	48.00	75.00	74.00	81.00	57.00	1
Ni	6.00	1.00	3.00	1.00	1.00	136.04	39.01	2.00	2.00	1.00	1.00	2.00	1.00	2.00	2.00	1
Li	244.98	247.98	34.00	118.99	359.97	65.99	96.99	131.99	269.98	133.99	157.99	197.98	209.98	93.99	127.99	1
Sr	221.00	157.00	113.00	135.00	125.00	637.00	540.00	348.00	222.00	185.00	191.00	154.00	356.00	352.00	200.00	1
Ba	159.00	326.00	1535.01	905.00	270.00	1013.01	430.00	1040.01	479.00	826.00	479.00	646.00	1873.01	352.00	40.00	1
P	1752.00	98.00	318.00	111.00	61.00	1220.00	757.00	98.00	54.00	81.00	80.00	41.00	98.00	59.00	49.00	1

sample	BN-67	BN-68	BN-69	BN-70	BN-71	BN-72	BN-73	BN-74	BN-75	BN-76	BN-77	BN-78	BN-79	BN-80	BN-81	
SiO ₂	48.70	49.80	53.20	48.50	53.00	53.90	53.00	52.30	55.70	54.80	50.30	54.30	41.00	53.60	51.30	
Al ₂ O ₃	20.10	16.70	22.60	23.20	20.40	22.60	21.60	19.50	21.10	21.50	21.80	21.40	15.70	21.30	15.50	
Fe ₂ O ₃	4.80	6.80	3.20	3.60	5.20	3.40	3.80	5.30	4.00	3.60	4.10	4.10	3.70	4.50	3.40	
Na ₂ O	1.70	2.30	7.50	8.20	7.10	6.00	6.40	6.60	7.50	6.70	2.20	6.50	1.80	7.30	0.90	
K ₂ O	8.80	9.70	6.30	4.30	5.80	6.70	6.50	6.10	6.60	6.60	6.70	6.40	7.10	6.50	12.30	
CaO	6.70	4.70	1.60	2.80	2.30	1.80	2.00	3.70	1.10	1.70	6.20	2.30	16.60	1.50	8.30	
MgO	0.30	0.50	0.20	0.70	0.40	0.30	0.70	0.50	0.10	0.40	0.60	0.40	0.80	0.40	0.50	
TiO ₂	0.20	0.20	0.10	0.20	0.30	0.10	0.10	0.20	0.10	0.20	0.20	0.20	0.20	0.20	0.20	
P ₂ O ₅	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	
A.Z	8.05	5.75	4.85	7.20	3.90	4.80	5.30	4.45	3.60	3.95	7.25	4.00	12.35	4.15	6.35	
MnO	0.20	0.20	0.10	0.20	0.20	0.10	0.20	0.20	0.10	0.10	0.20	0.20	0.40	0.20	0.20	
Y	64.00	112.00	5.00	73.00	161.00	38.00	63.00	55.00	59.00	89.00	82.00	79.00	59.00	79.00	45.00	
La	47.00	84.00	11.00	114.00	53.00	9.00	28.00	77.00	14.00	15.00	20.00	17.00	24.00	21.00	15.00	
Ce	155.00	147.00	98.00	759.98	173.00	78.00	159.00	192.00	53.00	79.00	91.00	78.00	91.00	106.00	27.00	
Pr	255.54	238.38	148.75	1020.25	225.98	112.51	252.68	301.31	87.72	136.35	134.44	122.05	128.72	156.37	25.74	
Nd	24.00	23.00	12.00	85.00	7.00	8.00	23.00	28.00	7.00	12.00	12.00	10.00	11.00	12.00	2.00	
Sm	70.00	3.00	65.00	231.00	47.00	22.00	66.00	85.00	24.00	38.00	37.00	32.00	34.00	37.00	7.00	
Eu	10.00	9.00	3.00	25.00	6.00	2.00	8.00	13.00	3.00	5.00	5.00	4.00	4.00	5.00	1.00	
Gd	1.90	2.00	0.60	4.20	1.40	0.40	1.50	2.40	0.60	1.00	1.00	0.90	0.90	0.90	0.30	
Tb	11.00	11.00	4.00	32.00	8.00	3.00	9.00	15.00	4.00	5.00	5.00	4.00	5.00	5.00	1.00	
Dy	1.30	1.60	0.30	3.40	1.00	0.30	0.90	1.90	0.40	0.50	0.50	0.50	0.50	0.60	0.20	
Ho	8.00	11.00	2.00	19.00	6.00	1.00	5.00	12.00	2.00	3.00	3.00	3.00	3.00	3.00	1.00	
Er	1.40	2.60	0.30	3.60	1.40	0.30	1.00	2.30	0.50	0.50	0.60	0.60	0.70	0.70	0.40	
Tm	4.00	9.00	1.00	11.00	5.00	1.00	3.00	7.00	1.00	2.00	2.00	2.00	2.00	2.00	1.00	
Yb	0.50	1.20	0.10	1.20	0.80	0.10	0.40	0.90	0.20	0.20	0.30	0.20	0.40	0.30	0.20	
Lu	3.00	6.00	1.00	6.00	5.00	1.00	2.00	5.00	1.00	1.00	2.00	2.00	2.00	2.00	1.00	
Sc	0.30	0.60	0.10	0.50	0.60	0.10	0.20	0.50	0.10	0.20	0.20	0.20	0.30	0.20	0.20	
ΣNTEO	0.20	0.20	0.20	0.30	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	
Th	593.14	549.57	347.34	2316.43	541.38	238.91	559.87	743.50	198.72	298.95	314.24	276.65	307.72	352.27	83.24	
U	43.00	307.00	663.00	75.00	75.00	34.00	59.00	95.00	18.00	29.00	36.00	41.00	53.00	72.00	135.00	
Ta	19.05	130.31	20.05	72.17	36.09	11.03	22.05	42.10	6.01	6.01	6.01	10.02	12.03	12.03	16.04	
Zr	6.00	19.40	3.80	12.60	9.60	3.10	5.50	10.20	2.20	3.60	4.60	4.30	5.00	4.70	3.00	
Cs	185.00	856.98	168.00	1321.97	509.99	206.00	294.99	572.99	182.00	157.00	203.00	211.00	360.99	258.99	198.00	
Hf	2.00	3.00	1.00	2.00	9.00	1.00	1.00	2.00	1.00	7.00	7.00	14.00	6.00	7.00	4.00	
Nb	2.00	6.00	1.00	10.00	5.00	2.00	2.00	5.00	2.00	1.00	2.00	2.00	3.00	2.00	2.00	
Rb	131.00	549.01	75.00	329.01	214.00	66.00	126.00	230.00	46.00	75.00	95.00	95.00	119.00	143.00	101.00	
Be	283.19	341.46	201.62	107.22	266.88	236.58	235.41	144.51	250.56	186.46	230.75	194.62	245.90	192.29	603.68	
Ge	6.00	7.00	6.00	16.00	6.00	6.00	8.00	12.00	4.00	6.00	7.00	7.00	5.00	13.00	6.00	
Ga	2.00	2.00	1.00	2.00	2.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Ni	34.00	65.00	27.00	56.00	42.00	25.00	35.00	49.00	33.00	26.00	31.00	26.00	24.00	26.00	43.00	
Li	2.00	2.00	2.00	2.00	5.00	1.00	3.00	3.00	4.00	4.00	4.00	2.00	2.00	2.00	3.00	
Sr	238.98	181.99	98.99	100.99	174.99	146.99	107.99	49.00	58.00	99.99	117.99	133.99	115.99	273.98	1291.90	
Ba	280.00	280.00	37.00	206.00	346.00	43.00	92.00	455.00	98.00	214.00	278.00	345.00	267.00	204.00	151.00	
P	553.00	892.00	17.00	380.00	713.00	46.00	377.00	748.00	160.00	266.00	482.00	392.00	161.00	92.00	353.00	

Sample	BN-89	BN-90	BN-91	BN-92	BN-93	BN-94	BN-95	BN-96	BN-97	BN-98	BN-99	BN-100	BN-101	BN-102	BN-103	BN-104
SiO ₂	52.80	50.40	43.00	50.40	55.40	57.00	55.60	4.20	57.60	2.60	25.50	2.20	57.60	53.30	57.90	57.90
Al ₂ O ₃	18.90	20.20	17.40	16.80	18.20	18.70	19.10	1.50	19.10	1.00	6.70	0.90	19.90	16.90	15.30	15.30
Fe ₂ O ₃	3.60	1.80	2.70	4.10	4.60	3.40	3.10	14.80	3.70	6.70	5.70	6.60	4.80	5.40	9.70	9.70
Na ₂ O	7.30	8.60	7.00	4.50	6.20	7.20	7.10	0.10	6.30	0.10	0.50	0.10	6.20	4.50	7.30	7.30
K ₂ O	5.30	5.80	2.60	5.10	5.00	4.20	4.90	0.20	5.40	0.10	4.30	0.10	5.60	4.40	4.40	4.40
CaO	4.00	5.10	11.60	7.90	3.90	3.00	3.60	41.10	2.20	48.30	27.00	48.00	1.50	6.10	1.20	1.20
MgO	0.60	0.70	1.10	1.20	0.70	0.60	0.40	1.30	0.50	0.70	1.30	0.70	0.50	1.40	0.40	0.40
TiO ₂	0.20	0.10	0.10	0.20	0.20	0.10	0.10	0.10	0.20	0.10	0.70	0.10	0.20	0.20	0.50	0.50
P ₂ O ₅	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
A.Z	6.90	9.00	13.80	9.40	5.15	5.45	5.65	35.70	4.45	39.85	24.45	40.30	3.20	7.10	2.60	2.60
MnO	0.10	0.10	0.10	0.10	0.20	0.10	0.10	0.70	0.10	0.60	2.30	0.90	0.20	0.20	0.20	0.20
Y	20.00	9.00	150.00	51.00	53.00	7.00	8.00	25.00	12.00	28.00	46.00	21.00	16.00	62.00	27.00	27.00
La	100.00	39.00	202.00	103.00	144.00	45.00	52.00	60.00	70.00	39.00	75.00	19.00	65.00	241.99	41.00	41.00
Ce	155.42	60.07	351.84	162.10	232.65	64.84	75.33	115.37	98.21	47.68	66.75	32.42	110.61	376.63	50.54	50.54
Pr	4.00	5.00	31.00	3.00	21.00	5.00	6.00	4.00	7.00	5.00	6.00	3.00	9.00	32.00	5.00	5.00
Nd	39.00	14.00	92.00	43.00	59.00	13.00	17.00	13.00	22.00	17.00	17.00	9.00	32.00	88.00	15.00	15.00
Sm	5.00	2.00	13.00	6.00	8.00	1.00	2.00	2.00	3.00	3.00	3.00	1.00	4.00	12.00	2.00	2.00
Eu	1.00	0.50	3.00	1.00	2.00	0.50	0.50	0.50	0.50	1.00	1.00	0.50	1.00	2.00	0.50	0.50
Gd	6.00	2.00	17.00	8.00	10.00	2.00	2.00	2.00	3.00	3.00	4.00	2.00	5.00	15.00	3.00	3.00
Tb	0.50	0.50	2.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50	1.00	0.50	0.50	2.00	0.50	0.50
Dy	3.00	1.00	16.00	6.00	7.00	1.00	1.00	2.00	2.00	3.00	5.00	2.00	3.00	10.00	3.00	3.00
Ho	1.00	0.50	4.00	1.00	2.00	0.50	0.50	1.00	0.50	1.00	1.00	0.50	1.00	2.00	1.00	1.00
Er	2.00	1.00	11.00	4.00	5.00	1.00	1.00	2.00	1.00	2.00	4.00	2.00	2.00	6.00	2.00	2.00
Tm	0.50	0.50	2.00	0.50	1.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	1.00	0.50	0.50
Yb	1.00	1.00	9.00	3.00	4.00	0.50	1.00	1.00	1.00	2.00	3.00	1.00	1.00	4.00	2.00	2.00
Lu	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Sc	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
ΣNTEO	339.42	137.07	904.84	393.59	550.65	143.34	168.33	229.87	222.21	153.67	234.24	95.42	251.60	855.63	154.04	154.04
Th	38.00	17.00	103.00	46.00	58.00	27.00	26.00	2.00	44.00	4.00	206.00	2.00	27.00	124.00	29.00	29.00
U	4.01	2.00	14.03	5.01	8.02	5.01	6.01	31.07	9.02	14.03	23.05	7.02	5.01	11.03	69.16	69.16
Ta	25.00	11.00	53.00	27.00	38.00	15.00	15.00	1.00	21.00	0.50	40.00	1.00	21.00	49.00	57.00	57.00
Zr	149.00	85.00	704.99	223.00	276.99	195.00	215.00	281.99	364.99	95.00	110.00	92.00	171.00	189.00	883.98	883.98
Cs	2.00	2.00	1.00	2.00	13.00	13.00	7.00	0.50	10.00	1.00	1.00	0.50	11.00	8.00	14.00	14.00
Hf	1.00	1.00	5.00	2.00	2.00	2.00	2.00	1.00	3.00	0.50	1.00	0.50	2.00	2.00	8.00	8.00
Nb	111.00	57.00	225.00	136.00	173.00	74.00	78.00	7.00	116.00	6.00	438.01	7.00	81.00	215.00	231.00	231.00
Rb	159.66	81.58	123.53	193.46	189.96	159.66	141.01	6.99	144.51	4.66	149.17	3.50	150.34	187.63	283.19	283.19
Be	5.00	4.00	4.00	7.00	5.00	6.00	6.00	5.00	7.00	3.00	8.00	3.00	4.00	7.00	9.00	9.00
Ge	1.00	1.00	1.00	1.00	2.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00
Ga	30.00	17.00	19.00	27.00	27.00	22.00	22.00	32.00	24.00	13.00	53.00	8.00	26.00	25.00	34.00	34.00
Ni	1.00	1.00	2.00	2.00	2.00	3.00	1.00	3.00	5.00	5.00	3.00	3.00	1.00	2.00	2.00	2.00
Li	56.00	65.99	83.99	106.99	102.99	151.99	152.99	18.00	176.99	10.00	31.00	11.00	114.99	142.99	196.98	196.98
Sr	136.00	74.00	167.00	196.00	177.00	123.00	83.00	749.00	100.00	660.00	433.00	525.00	212.00	162.00	66.00	66.00
Ba	627.00	52.00	169.00	509.00	367.00	27.00	29.00	680.00	173.00	80.00	1601.01	31.00	552.00	330.00	147.00	147.00
P	134.00	82.00	96.00	79.00	70.00	73.00	29.00	26.00	109.00	88.00	113.00	42.00	82.00	46.00	27.00	27.00

Sample	BN-111	BN-112	BN-113	BN-114	BN-115	BN-116	BN-117	BN-118	BN-119	BN-120	BN-121	BN-122	BN-123	BN-124	BN-125	BN-126
SiO ₂	58.50	59.40	57.90	57.20	54.40	54.50	53.10	53.40	53.50	50.50	47.70	46.50	43.60	35.40	55.20	55.20
Al ₂ O ₃	16.60	16.80	19.80	19.50	21.90	22.40	17.40	21.70	21.10	24.90	14.50	11.80	12.90	18.60	20.00	20.00
Fe ₂ O ₃	7.60	4.90	4.10	4.30	4.50	3.90	8.30	3.90	4.40	3.00	21.00	14.20	6.60	8.00	2.80	2.80
Na ₂ O	7.30	5.30	6.70	6.90	6.80	7.00	1.10	6.40	6.60	7.70	1.30	0.80	0.80	0.10	0.10	0.10
K ₂ O	4.50	7.50	5.60	4.90	5.30	5.70	12.10	6.30	5.50	5.10	10.30	7.50	9.70	2.80	12.80	12.80
CaO	1.40	2.10	1.40	1.60	1.70	1.10	3.00	2.40	2.90	1.20	0.50	12.00	15.80	17.40	2.70	2.70
MgO	0.30	0.20	0.50	0.50	0.60	0.70	0.50	0.60	0.40	0.60	0.20	0.40	0.30	0.70	0.20	0.20
TiO ₂	0.30	0.30	0.10	0.20	0.10	0.20	0.30	0.20	0.20	0.10	1.00	1.00	0.30	0.30	0.10	0.10
P ₂ O ₅	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
A.Z	2.95	2.80	3.45	4.35	4.00	4.00	3.60	4.70	5.10	6.55	2.60	4.30	8.90	15.55	4.40	4.40
MnO	0.10	0.20	0.10	0.10	0.10	0.20	0.20	0.10	0.10	0.10	0.10	0.70	0.30	0.40	0.10	0.10
Y	40.00	37.00	12.00	16.00	22.00	43.00	71.00	35.00	37.00	26.00	242.01	483.01	77.00	275.01	31.00	31.00
La	84.00	119.00	35.00	33.00	77.00	110.00	204.00	112.00	90.00	87.00	533.99	1838.96	182.00	606.99	110.00	110.00
Ce	144.93	171.63	61.02	58.16	110.61	160.19	165.91	157.33	146.84	126.82	633.12	2486.73	232.65	694.15	153.51	153.51
Pr	14.00	15.00	4.00	5.00	7.00	9.00	9.00	11.00	11.00	10.00	50.00	182.00	26.00	61.00	10.00	10.00
Nd	42.00	43.00	14.00	18.00	20.00	36.00	25.00	35.00	33.00	30.00	111.00	467.99	48.00	159.00	27.00	27.00
Sm	6.00	6.00	2.00	3.00	3.00	6.00	4.00	5.00	5.00	5.00	15.00	56.00	7.00	20.00	4.00	4.00
Eu	1.00	1.00	0.50	1.00	0.60	1.10	0.90	1.00	1.00	1.00	3.00	10.10	1.60	4.00	0.90	0.90
Gd	8.00	7.00	3.00	3.00	4.00	6.00	6.00	6.00	6.00	5.00	22.00	77.00	9.00	28.00	5.00	5.00
Tb	1.00	1.00	0.50	0.50	0.50	0.90	0.90	0.80	0.90	0.60	3.20	9.50	1.20	4.10	0.60	0.60
Dy	6.00	5.00	2.00	3.00	3.00	5.00	6.00	5.00	5.00	4.00	23.00	58.00	8.00	28.00	4.00	4.00
Ho	1.00	1.00	0.50	1.00	0.60	1.10	1.60	1.00	1.10	0.80	5.80	13.00	1.70	6.90	0.80	0.80
Er	4.00	4.00	1.00	2.00	1.90	3.50	5.90	3.30	3.40	2.30	19.80	41.20	5.70	22.60	2.60	2.60
Tm	0.50	0.50	0.50	0.50	0.30	0.50	0.90	0.50	0.50	0.30	2.70	5.40	0.80	3.10	0.40	0.40
Yb	2.00	3.00	1.00	1.00	1.00	3.00	5.00	3.00	3.00	2.00	15.00	30.00	5.00	17.00	2.00	2.00
Lu	0.50	0.50	0.50	0.50	0.20	0.30	0.50	0.30	0.30	0.20	1.30	2.80	0.50	1.50	0.20	0.20
Sc	0.50	0.50	0.50	0.50	0.20	0.20	0.20	0.20	0.20	0.30	0.30	0.40	0.30	0.40	0.20	0.20
ΣNTEO	355.43	415.13	138.02	146.16	251.90	385.79	506.81	376.43	344.24	301.31	1681.22	5762.10	606.45	1931.74	352.21	352.21
Th	39.00	52.00	30.00	25.00	53.00	52.00	207.00	92.00	51.00	36.00	400.00	1556.00	111.00	568.00	74.00	74.00
U	36.09	50.12	15.04	20.05	5.01	13.03	37.09	14.03	11.03	9.02	65.15	48.11	15.04	27.06	56.13	56.13
Ta	86.00	55.00	23.00	32.00	3.00	5.00	28.00	5.00	5.00	3.00	52.00	71.00	10.00	27.00	12.00	12.00
Zr	542.99	468.99	157.00	243.99	280.99	428.99	373.99	475.99	515.99	273.99	2194.95	2718.94	914.98	1680.96	605.99	605.99
Cs	6.00	3.00	9.00	18.00	18.00	16.00	14.00	16.00	30.00	3.00	2.00	9.00	2.00	12.00	2.00	2.00
Hf	6.00	5.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	15.00	25.00	7.00	12.00	4.00	4.00
Nb	242.00	402.01	105.00	145.00	131.00	160.00	615.01	206.00	197.00	96.00	1400.02	1230.02	414.01	577.01	521.01	521.01
Rb	267.07	384.58	221.43	175.98	325.15	368.27	784.32	349.62	363.61	164.32	261.05	242.40	243.57	122.37	344.96	344.96
Be	6.00	3.00	6.00	7.00	11.00	11.00	11.00	14.00	13.00	15.00	8.00	8.00	4.00	11.00	3.00	3.00
Ge	2.00	1.00	1.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00	8.00	8.00	3.00	4.00	1.00	1.00
Ga	31.00	32.00	24.00	27.00	39.00	39.00	63.00	40.00	38.00	42.00	93.00	73.00	65.00	61.00	69.00	69.00
Ni	1.00	1.00	1.00	2.00	8.00	5.00	4.00	2.00	2.00	5.00	22.01	10.00	22.01	9.00	19.01	19.01
Li	144.99	70.99	114.99	177.99	228.98	221.98	778.94	429.97	321.97	268.98	10.00	63.99	54.00	267.98	72.99	72.99
Sr	44.00	53.00	161.00	111.00	179.00	196.00	56.00	192.00	131.00	62.00	180.00	221.00	254.00	155.00	164.00	164.00
Ba	48.00	149.00	60.00	52.00	34.00	30.00	135.00	148.00	59.00	485.00	1140.01	951.00	1240.01	300.00	1247.01	1247.01
P	14.00	94.00	28.00	96.00	85.00	86.00	83.00	98.00	85.00	103.00	337.00	183.00	126.00	72.00	72.00	72.00

Sample	BN-133	BN-134	BN-135	BN-136	BN-137	BN-138	BN-139	BN-140	BN-141	BN-142	BN-143	BN-144	BN-145	BN-146	BN-147	BN-148
SiO ₂	49.60	48.30	54.10	43.50	39.00	46.40	58.30	52.70	52.60	50.00	53.00	50.30	53.80	53.30	55.00	56.00
Al ₂ O ₃	16.70	11.70	20.10	13.00	12.20	11.90	14.40	21.30	22.90	24.40	21.60	20.00	21.30	22.30	22.90	23.00
Fe ₂ O ₃	4.30	4.30	6.80	4.00	7.30	9.50	12.30	5.00	3.90	3.50	4.90	4.00	4.10	4.40	3.00	3.00
Na ₂ O	3.70	1.10	5.40	0.60	1.10	1.20	4.90	5.60	7.00	8.70	6.50	2.30	6.00	5.10	7.30	5.10
K ₂ O	6.90	10.20	5.70	11.60	8.50	10.40	5.70	6.30	4.20	5.80	6.30	6.70	6.70	7.80	5.70	5.70
CaO	10.20	13.20	2.30	15.00	17.50	10.70	1.80	2.10	1.30	1.10	2.60	8.80	2.30	1.50	1.20	1.20
MgO	0.30	0.20	0.90	0.20	0.30	0.50	0.30	1.50	0.50	1.00	0.40	0.40	0.70	0.70	1.00	1.00
TiO ₂	0.30	0.30	0.20	0.30	0.40	0.20	0.30	0.30	0.20	0.10	0.10	0.10	0.20	0.10	0.10	0.10
P ₂ O ₅	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
A.Z	7.35	9.25	3.95	10.40	12.00	7.70	1.60	4.05	4.80	6.60	4.50	7.05	4.40	4.20	3.45	3.45
MnO	0.20	0.30	0.30	0.20	0.30	0.60	0.20	0.30	0.10	0.10	0.20	0.20	0.20	0.20	0.10	0.10
Y	17.00	100.00	30.00	249.01	83.00	91.00	16.00	86.00	68.00	15.00	32.00	67.00	86.00	28.00	8.00	8.00
La	92.00	501.99	164.00	111.00	503.99	281.99	99.00	533.99	200.00	49.00	138.00	282.99	219.99	137.00	81.00	10.00
Ce	122.05	604.52	244.10	162.10	559.70	382.35	126.82	737.06	296.54	78.19	222.17	406.19	371.87	213.58	116.33	20.00
Pr	8.00	44.00	21.00	17.00	40.00	33.00	6.00	26.00	6.00	19.00	31.00	36.00	21.00	8.00	8.00	8.00
Nd	21.00	86.00	52.00	36.00	78.00	75.00	20.00	159.00	62.00	19.00	46.00	69.00	97.00	44.00	19.00	4.00
Sm	3.00	9.00	7.00	7.00	8.00	10.00	2.00	16.00	9.00	3.00	6.00	9.00	14.00	6.00	2.00	2.00
Eu	0.50	1.80	1.40	1.70	1.40	1.90	0.40	2.90	1.70	0.60	1.30	2.10	2.70	1.10	0.30	0.30
Gd	3.00	15.00	8.00	12.00	13.00	13.00	3.00	21.00	11.00	3.00	7.00	11.00	16.00	7.00	2.00	2.00
Tb	0.40	1.60	0.90	2.70	1.30	1.60	0.40	2.10	1.30	0.40	0.90	1.30	2.10	0.80	0.20	0.20
Dy	2.00	9.00	5.00	23.00	8.00	10.00	2.00	11.00	8.00	2.00	5.00	8.00	12.00	4.00	1.00	1.00
Ho	0.50	2.10	1.00	6.50	2.00	2.40	0.50	2.30	1.70	0.50	1.00	1.70	2.40	0.90	0.20	0.20
Er	1.50	7.20	3.00	24.00	6.80	8.20	1.60	7.00	5.50	1.50	3.00	5.40	6.70	2.60	0.70	0.70
Tm	0.20	1.00	0.40	3.60	0.90	1.20	0.20	0.90	0.70	0.20	0.40	0.70	8.00	0.40	0.10	0.10
Yb	1.00	6.00	3.00	22.00	8.00	8.00	2.00	5.00	4.00	1.00	2.00	4.00	4.00	2.00	1.00	1.00
Lu	0.10	0.60	0.30	2.20	0.60	1.00	0.20	0.50	0.40	0.10	0.20	0.40	0.40	0.20	0.10	0.10
Sc	0.20	0.30	0.20	0.50	0.30	0.60	0.20	0.40	0.20	0.30	0.40	0.20	0.20	0.20	0.20	0.20
ΣNTfEO	272.45	1390.11	541.29	680.30	1313.00	921.25	282.31	1647.14	696.04	179.79	484.36	899.99	879.36	468.78	240.13	40.00
Th	69.00	394.00	63.00	644.00	197.00	352.00	96.00	523.00	79.00	36.00	42.00	184.00	56.00	44.00	40.00	40.00
U	54.13	88.21	29.07	92.22	28.07	84.20	19.05	77.18	25.06	9.02	7.02	10.02	9.02	32.08	18.04	18.04
Ta	27.00	35.00	8.00	57.00	47.00	60.00	12.00	14.00	9.00	3.00	5.00	8.00	7.00	6.00	3.00	3.00
Zr	486.99	2070.96	489.99	5904.88	1614.97	2572.95	720.98	942.98	511.99	351.99	239.99	556.99	334.99	264.99	243.99	20.00
Cs	4.00	1.00	1.00	1.00	2.00	3.00	2.00	7.00	1.00	9.00	2.00	2.00	3.00	1.00	10.00	10.00
Hf	4.00	14.00	4.00	40.00	9.00	22.00	7.00	7.00	4.00	3.00	2.00	4.00	2.00	2.00	2.00	2.00
Nb	739.01	1369.02	165.00	692.01	620.01	1437.02	337.01	445.01	216.00	94.00	125.00	282.00	163.00	140.00	109.00	10.00
Rb	312.33	280.86	192.29	473.15	319.32	543.08	237.74	243.57	272.70	262.22	254.06	164.32	284.36	237.74	265.71	20.00
Be	8.00	6.00	8.00	11.00	6.00	21.00	6.00	12.00	9.00	15.00	6.00	11.00	8.00	8.00	10.00	10.00
Ge	2.00	2.00	3.00	2.00	3.00	4.00	5.00	3.00	2.00	2.00	3.00	2.00	3.00	3.00	2.00	2.00
Ga	57.00	60.00	56.00	64.00	37.00	70.00	48.00	48.00	38.00	41.00	37.00	97.00	34.00	44.00	35.00	3.00
Ni	8.00	8.00	28.01	5.00	6.00	5.00	3.00	3.00	2.00	3.00	2.00	2.00	2.00	2.00	2.00	2.00
Li	76.99	53.00	107.99	150.99	67.99	553.96	122.99	86.99	136.99	338.97	103.99	73.99	146.99	72.99	270.98	20.00
Sr	112.00	97.00	156.00	76.00	111.00	113.00	92.00	419.00	87.00	184.00	155.00	412.00	116.00	68.00	303.00	20.00
Ba	211.00	680.00	727.00	464.00	293.00	759.00	173.00	619.00	334.00	145.00	545.00	2537.01	301.00	585.00	28.00	10.00
P	65.00	58.00	60.00	59.00	91.00	171.00	51.00	118.00	69.00	88.00	90.00	76.00	67.00	76.00	69.00	6.00

Sample	BN-157	BN-158	BN-159	BN-160	BN-162	BN-163	BN-164	BN-165	BN-166	BN-167	BN-168	BN-169	BN-170	BN-171	BN-172	BN-173
SiO ₂	5.40	7.30	55.50	54.10	46.90	4.90	29.20	53.30	3.90	19.30	2.40	8.40	29.60	18.30	54.40	5.00
Al ₂ O ₃	1.90	2.70	20.60	21.10	18.00	2.20	9.20	20.20	1.90	7.60	1.00	3.80	0.40	7.00	22.40	1.00
Fe ₂ O ₃	4.50	4.10	4.60	5.00	3.30	5.40	7.80	5.20	5.10	3.00	1.10	1.00	1.10	3.80	3.60	1.00
Na ₂ O	0.20	0.20	6.10	7.30	1.20	0.20	0.20	6.30	0.20	1.10	0.10	0.20	0.10	0.90	7.40	0.00
K ₂ O	0.80	1.30	5.00	4.40	9.50	0.80	7.40	5.20	0.20	2.10	0.10	0.90	0.10	3.00	5.10	0.00
CaO	47.70	46.30	2.60	2.30	11.10	47.00	26.80	3.10	47.00	37.10	52.00	47.70	40.90	38.00	1.40	0.00
MgO	0.50	0.40	0.50	1.00	0.50	0.50	0.40	0.70	1.20	1.00	0.70	0.40	0.30	0.60	0.30	0.00
TiO ₂	0.10	0.10	0.30	0.20	0.10	0.10	0.10	0.20	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.00
P ₂ O ₅	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.20	0.10	0.10	0.00
A.Z	38.05	36.80	4.20	4.20	8.55	37.90	18.00	5.30	39.40	28.10	42.10	37.50	23.40	27.70	4.90	0.00
MnO	0.70	0.60	0.10	0.10	0.10	0.50	0.50	0.20	0.70	0.30	0.20	0.10	0.60	0.60	0.10	0.00
Y	68.00	74.00	157.00	86.00	79.00	138.00	147.00	52.00	329.01	286.01	215.01	63.00	11.00	73.00	11.00	0.00
La	44.00	63.00	347.99	214.00	69.00	68.00	250.99	164.00	47.00	117.00	35.00	82.00	21.00	66.00	25.00	10.00
Ce	81.05	86.77	667.45	384.26	81.05	93.44	374.73	253.63	78.19	182.12	60.07	98.21	18.12	97.26	41.95	20.00
Pr	6.00	7.00	54.00	31.00	5.00	8.00	35.00	12.00	8.00	12.00	6.00	10.00	2.00	7.00	2.00	0.00
Nd	22.00	26.00	174.00	95.00	19.00	30.00	76.00	49.00	64.00	61.00	24.00	38.00	5.00	26.00	8.00	0.00
Sm	4.00	4.00	26.00	13.00	4.00	5.00	12.00	6.00	9.00	11.00	5.00	5.00	1.00	4.00	1.00	0.00
Eu	1.00	1.00	4.00	2.00	1.00	1.00	2.00	1.00	2.00	2.00	1.00	1.00	0.50	1.00	0.50	0.00
Gd	5.00	6.00	28.00	14.00	5.00	7.00	14.00	8.00	13.00	15.00	8.00	6.00	1.00	6.00	1.00	0.00
Tb	1.00	1.00	3.00	2.00	1.00	1.00	2.00	1.00	2.00	3.00	2.00	1.00	0.50	1.00	0.50	0.00
Dy	5.00	6.00	17.00	10.00	6.00	8.00	10.00	5.00	20.00	21.00	13.00	5.00	1.00	6.00	1.00	0.00
Ho	1.00	1.00	3.00	2.00	1.00	2.00	2.00	1.00	5.00	5.00	3.00	1.00	0.50	1.00	0.50	0.00
Er	4.00	4.00	9.00	6.00	5.00	6.00	7.00	4.00	16.00	16.00	12.00	4.00	1.00	4.00	1.00	0.00
Tm	0.50	0.50	1.00	1.00	1.00	1.00	1.00	0.50	2.00	2.00	2.00	0.50	0.50	0.50	0.50	0.00
Yb	3.00	3.00	5.00	4.00	4.00	4.00	5.00	3.00	11.00	12.00	9.00	2.00	0.50	3.00	1.00	0.00
Lu	0.50	0.50	0.50	0.50	0.50	0.50	1.00	0.50	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.00
Sc	4.00	4.00	26.00	13.00	4.00	5.00	12.00	6.00	9.00	11.00	5.00	5.00	1.00	4.00	0.50	0.00
ΣNTfEO	250.05	287.77	1522.95	877.76	285.55	377.95	951.72	566.63	616.19	757.12	401.08	322.21	65.12	300.26	95.95	5.00
Th	6.00	5.00	85.00	58.00	92.00	9.00	343.00	98.00	37.00	19.00	5.00	7.00	2.00	17.00	34.00	0.00
U	16.04	12.03	10.02	16.04	6.01	11.03	16.04	13.03	8.02	6.01	12.03	1.00	23.05	31.07	10.02	0.00
Ta	1.00	1.00	10.00	6.00	4.00	0.50	5.00	7.00	0.50	2.00	0.50	1.00	0.50	1.00	2.00	0.00
Zr	269.99	247.99	415.99	429.99	829.98	281.99	209.00	550.99	57.00	188.00	18.00	88.00	5.00	137.00	271.99	30.00
Cs	1.00	2.00	14.00	20.00	4.00	0.50	1.00	19.00	0.50	2.00	0.50	1.00	1.00	2.00	1.00	0.00
Hf	1.00	1.00	3.00	3.00	6.00	1.00	1.00	3.00	0.50	1.00	0.50	1.00	0.50	1.00	2.00	0.00
Nb	26.00	18.00	256.00	172.00	190.00	15.00	276.00	240.00	10.00	65.00	6.00	25.00	12.00	38.00	62.00	10.00
Rb	50.11	85.07	337.97	355.45	756.35	33.80	397.40	321.65	11.65	89.74	4.66	44.29	10.49	191.13	299.13	30.00
Ge	3.00	6.00	6.00	15.00	14.00	0.00	14.00	5.00	14.00	2.00	14.00	5.00	8.00	5.00	6.00	0.00
Ge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	5.00	10.00	31.00	37.00	49.00	10.00	22.00	30.00	8.00	12.00	4.00	6.00	5.00	17.00	28.00	1.00
Ni	8.00	7.00	3.00	5.00	3.00	5.00	3.00	2.00	7.00	3.00	5.00	8.00	9.00	5.00	2.00	0.00
Li	40.00	46.00	163.99	161.99	1138.91	29.00	18.00	603.95	73.99	58.00	12.00	32.00	17.00	114.99	159.99	1.00
Sr	370.00	216.00	370.00	618.00	285.00	1379.00	215.00	333.00	881.00	584.00	1440.00	47.00	348.00	286.00	99.00	1.00
Ba	67.00	55.00	958.01	1068.01	413.00	87.00	609.00	750.00	29.00	302.00	17.00	66.00	16.00	161.00	113.00	0.00
P	78.00	87.00	97.00	104.00	140.00	73.00	128.00	71.00	72.00	64.00	61.00	85.00	519.00	65.00	61.00	0.00
Sample	BN-180	BN-181	BN-182	BN-183	BN-184	BN-185	BN-186	BN-187	BN-188	BN-189	BN-190	BN-191	BN-192	BN-193	BN-194	BN-195

	SiO ₂	53.00	9.50	55.80	47.40	9.10	1.30	43.60	43.60	52.20	5.90	48.20	19.00	44.90	1.10	1.30
	Al ₂ O ₃	17.90	6.20	20.60	13.60	3.40	0.60	22.20	5.60	16.70	2.20	8.90	6.80	12.80	0.40	0.50
	Fe ₂ O ₃	4.80	7.60	1.40	1.80	0.90	3.40	2.50	2.30	6.50	2.20	16.20	4.20	6.40	2.40	1.70
	Na ₂ O	3.20	0.10	1.70	0.30	0.30	0.10	0.70	0.40	3.20	0.20	4.20	0.80	1.70	0.10	0.10
	K ₂ O	7.80	1.80	11.10	11.40	0.90	0.10	9.20	4.90	1.20	0.90	3.70	3.20	8.20	0.10	0.10
	CaO	6.50	39.50	3.70	13.10	47.60	46.40	10.90	23.20	8.00	48.00	10.10	37.50	15.10	52.80	53.20
	MgO	0.40	0.90	1.00	0.40	8.00	4.40	0.40	0.40	1.20	0.90	0.10	0.30	0.30	0.20	0.10
	TiO ₂	0.30	0.10	0.10	1.20	0.10	0.10	0.10	0.40	0.30	0.10	0.50	0.10	0.20	0.10	0.10
	P ₂ O ₅	0.10	0.10	0.10	0.20	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	A.Z	5.40	33.30	3.80	8.70	36.70	43.45	9.90	13.00	9.90	39.00	6.95	27.40	9.80	42.00	42.35
	MnO	0.10	0.90	0.10	0.20	0.10	0.20	0.10	0.30	0.20	0.60	0.30	0.50	0.20	0.70	0.60
	Y	122.00	48.00	38.00	153.00	106.00	32.00	61.00	1152.03	103.00	37.00	131.00	101.00	76.00	43.00	17.00
	La	266.99	17.00	110.00	343.99	67.00	39.00	17.00	1420.97	264.99	54.00	183.00	70.00	160.00	17.00	15.00
	Ce	380.45	15.26	163.05	434.80	72.47	76.28	24.79	1572.32	373.77	61.02	187.84	80.09	237.42	16.21	17.16
	Pr	37.00	2.00	15.00	33.00	8.00	6.00	2.00	113.00	46.00	6.00	15.00	9.00	21.00	2.00	2.00
	Nd	63.00	8.00	35.00	100.00	31.00	21.00	9.00	377.99	98.00	16.00	38.00	26.00	74.00	10.00	7.00
	Sm	8.00	2.00	5.00	17.00	4.00	3.00	2.00	51.00	15.00	3.00	6.00	5.00	12.00	2.00	1.00
	Eu	2.00	0.50	1.00	3.00	1.00	1.00	0.50	9.00	2.50	0.50	1.10	1.00	2.10	0.50	0.30
	Gd	12.00	3.00	6.00	19.00	6.00	4.00	3.00	74.00	19.00	4.00	10.00	7.00	17.00	3.00	2.00
	Tb	1.00	1.00	1.00	2.00	1.00	1.00	1.00	11.00	2.00	0.50	1.40	1.00	1.60	0.50	0.20
	Dy	10.00	4.00	4.00	14.00	6.00	4.00	5.00	91.00	14.00	4.00	13.00	9.00	11.00	5.00	2.00
	Ho	2.00	1.00	1.00	3.00	1.00	1.00	1.00	27.00	2.40	0.90	2.70	1.90	2.00	0.90	0.40
	Er	8.00	3.00	3.00	10.00	5.00	2.00	4.00	107.00	7.10	2.80	9.30	6.40	5.90	2.80	1.20
	Tm	1.00	0.50	0.50	2.00	1.00	0.50	1.00	14.00	0.90	0.40	1.40	0.80	0.80	0.30	0.20
	Yb	7.00	2.00	2.00	11.00	3.00	2.00	3.00	95.00	4.80	2.30	8.30	4.40	4.40	1.70	0.80
	Lu	1.00	0.50	0.50	1.00	0.50	0.50	0.50	8.00	0.40	0.20	0.80	0.40	0.40	0.20	0.10
	Sc	0.50	0.50	0.50	0.50	1.00	0.50	0.50	1.00	0.30	0.50	0.40	0.20	0.20	0.30	0.20
ΣNTEO		921.94	108.26	385.55	1147.29	313.97	193.78	135.29	5124.32	954.17	193.12	609.24	323.20	625.82	105.41	66.56
	Th	296.00	16.00	95.00	61.00	9.00	33.00	12.00	1161.00	107.00	12.00	123.00	31.00	64.00	3.00	4.00
	U	25.06	5.01	9.02	9.02	2.00	6.01	5.01	188.45	9.02	32.08	44.10	8.02	12.03	7.02	5.01
	Ta	14.00	0.50	4.00	4.00	1.00	1.00	0.50	121.00	9.00	0.90	4.00	1.00	9.00	0.10	0.10
	Zr	520.99	209.00	281.99	462.99	61.00	104.00	41.00	14146.7	919.98	260.99	3632.92	388.99	1042.98	820.98	53.00
	Cs	1.00	1.00	1.00	4.00	1.00	4.00	0.50	2.00	7.00	0.50	0.80	3.00	2.00	0.30	0.40
	Hf	3.00	1.00	2.00	2.00	1.00	1.00	0.50	111.00	5.00	1.00	20.00	2.00	9.00	1.00	0.20
	Nb	513.01	7.00	145.00	684.01	24.00	45.00	4.00	1499.03	310.01	30.00	234.00	48.00	200.00	16.00	5.00
	Rb	358.94	69.92	583.87	926.50	47.78	476.65	11.65	617.66	149.17	43.12	229.58	166.65	447.52	4.66	4.66
	Be	8.00	11.00	9.00	5.00	2.00	13.00	2.00	16.00	15.00	3.00	6.00	8.00	6.00	4.00	2.00
	Ge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50	0.70	4.30	1.10	2.00	0.70	0.50
	Ga	39.00	18.00	36.00	29.00	6.00	30.00	2.00	13.00	49.00	7.00	44.00	21.00	33.00	13.00	11.00
	Ni	3.00	4.00	4.00	2.00	6.00	4.00	41.01	5.00	15.00	6.00	2.00	7.00	5.00	7.00	8.00
	Li	98.99	161.99	300.98	5156.59	55.00	688.95	168.99	171.99	640.95	45.00	327.97	82.99	384.97	7.00	10.00
	Sr	167.00	333.00	112.00	149.00	172.00	246.00	598.00	67.00	461.00	77.00	219.00	53.00	374.00	402.00	51.00
	Ba	302.00	84.00	316.00	686.00	82.00	271.00	147.00	196.00	120.00	118.00	99.00	208.00	144.00	569.00	525.00
	P	100.00	53.00	120.00	673.00	56.00	64.00	92.00	172.00	294.00	320.00	447.00	370.00	227.00	236.00	291.00

529

Sample	BN-202	BN-203	BN-204	BN-205	BN-206	BN-207	BN-208	BN-209	BN-210	BN-211	BN-212	BN-213	BN-214	BN-215	BN-216	BN-217
SiO ₂	60.40	58.10	56.20	58.40	64.40	68.90	45.40	49.70	0.90	59.80	56.60	57.70	55.10	55.20	42.50	59.60
Al ₂ O ₃	15.20	20.00	10.60	19.80	16.20	17.60	12.70	6.90	0.30	19.40	19.40	21.20	20.30	18.50	15.40	20.30
Fe ₂ O ₃	4.30	2.60	8.50	6.30	0.30	1.70	20.30	24.60	2.40	3.90	6.20	5.60	5.60	6.60	3.20	4.20
Na ₂ O	5.70	3.20	6.10	3.00	1.50	9.90	3.00	5.30	0.10	6.30	2.70	2.50	2.70	2.50	2.00	3.10
K ₂ O	4.70	3.50	3.40	4.20	13.50	0.40	5.50	4.60	0.10	5.40	4.00	5.20	3.30	4.40	3.90	4.50
CaO	1.30	4.00	6.60	1.40	2.10	0.20	5.60	5.50	52.50	0.80	3.60	1.50	4.40	4.60	17.60	2.10
MgO	0.40	0.80	0.10	0.70	0.10	0.10	0.30	0.10	0.30	0.30	0.70	0.30	0.50	0.60	0.30	0.70
TiO ₂	0.60	0.30	0.70	0.30	0.10	0.10	0.20	0.40	0.10	0.10	0.10	0.20	0.20	0.20	0.10	0.10
P ₂ O ₅	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
A.Z	2.15	6.65	4.95	5.25	1.70	0.80	6.30	2.50	42.90	3.50	6.20	5.20	7.45	6.80	14.45	4.95
MnO	0.60	0.20	0.40	0.10	0.10	0.10	0.20	0.30	0.50	0.20	0.10	0.10	0.10	0.20	0.20	0.10
Y	271.01	164.00	13.00	118.00	4.00	71.00	123.00	11.00	71.00	19.00	36.00	101.00	74.00	74.00	75.00	72.00
La	1062.98	686.98	30.00	563.99	11.00	431.99	528.99	6.00	8.00	88.00	89.00	457.99	211.00	173.00	92.00	175.00
Ce	1800.21	1036.46	47.68	778.06	14.30	676.03	543.50	7.63	5.72	79.14	147.79	656.96	250.77	249.82	151.61	346.12
Pr	201.00	106.00	5.00	82.00	1.00	81.00	52.00	1.00	1.00	7.00	14.00	71.00	25.00	25.00	19.00	33.00
Nd	473.99	259.00	13.00	254.00	5.00	209.00	159.00	3.00	4.00	17.00	39.00	221.00	47.00	66.00	47.00	104.00
Sm	60.00	33.00	2.00	33.00	1.00	26.00	27.00	1.00	1.00	2.00	6.00	28.00	7.00	10.00	8.00	17.00
Eu	9.60	5.40	0.30	5.30	0.20	3.80	4.50	0.10	0.30	0.50	1.10	4.40	1.10	1.80	1.50	2.90
Gd	79.00	44.00	2.00	41.00	1.00	29.00	34.00	1.00	2.00	3.00	8.00	35.00	10.00	14.00	11.00	21.00
Tb	7.40	4.20	0.30	3.80	0.10	2.30	3.00	0.10	0.50	0.40	0.90	3.40	1.00	1.50	1.40	2.20
Dy	50.00	28.00	2.00	23.00	1.00	13.00	19.00	1.00	6.00	3.00	7.00	22.00	8.00	11.00	11.00	15.00
Ho	8.50	4.50	0.40	3.60	0.10	1.90	3.10	0.20	1.70	0.50	1.20	3.50	1.70	1.90	2.00	2.30
Er	25.40	12.40	1.10	9.50	0.40	5.00	9.10	0.80	7.00	1.60	3.50	9.20	5.90	5.70	5.90	6.20
Tm	3.10	1.40	0.20	1.00	0.10	0.50	1.10	0.10	1.20	0.20	0.50	1.00	0.90	0.70	0.70	0.70
Yb	16.10	6.60	1.30	5.10	0.20	2.60	6.30	1.10	7.30	1.50	2.70	5.00	6.30	3.80	3.60	3.30
Lu	1.40	0.50	0.20	0.50	0.10	0.20	0.60	0.20	0.70	0.20	0.30	0.50	0.60	0.40	0.30	0.30
Sc	0.30	0.20	0.20	0.40	0.20	0.20	0.20	0.10	0.20	0.30	0.20	0.20	0.30	0.20	0.20	0.20
ΣNTEO	4069.99	2392.64	118.67	1922.24	39.70	1553.52	1514.39	34.33	117.62	223.34	357.19	1620.15	650.57	638.81	430.21	801.22
Th	249.00	277.00	8.00	179.00	6.00	177.00	61.00	4.00	23.00	83.00	32.00	170.00	186.00	82.00	31.00	51.00
U	652.55	68.16	2.00	10.02	3.01	3.01	32.08	1.00	3.01	12.03	6.01	5.01	10.02	9.02	6.01	6.01
Ta	197.99	36.00	2.00	9.00	1.00	1.00	2.00	0.50	0.10	3.00	4.00	8.00	9.00	3.00	6.00	6.00
Zr	2331.95	277.99	491.99	414.99	11.00	56.00	233.00	261.99	97.00	372.99	467.99	529.99	827.98	483.99	371.99	240.99
Cs	7.00	17.00	3.00	10.00	11.00	0.70	4.00	3.00	0.10	15.00	2.00	98.00	2.00	17.00	4.00	11.00
Hf	15.00	2.00	4.00	3.00	0.10	0.30	1.00	2.00	0.20	2.00	3.00	4.00	5.00	4.00	2.00	2.00
Nb	4644.08	864.01	377.01	244.00	29.00	45.00	175.00	31.00	4.00	111.00	95.00	192.00	204.00	190.00	81.00	130.00
Rh	244.74	279.70	574.54	340.30	1388.00	11.65	348.46	383.42	1.17	277.37	318.16	502.29	287.83	574.01	240.07	306.50
Be	12.00	15.00	7.00	13.00	2.00	3.00	17.00	2.00	4.00	15.00	6.00	13.00	12.00	11.00	4.00	7.00
Ge	3.60	2.30	2.70	3.30	0.30	1.90	6.20	6.90	0.60	1.10	2.00	2.90	1.90	2.40	1.20	2.20
Ga	83.00	42.00	75.00	41.00	33.00	64.00	52.00	28.00	3.00	32.00	35.00	44.00	45.00	43.00	27.00	36.00
Ni	6.00	4.00	4.00	7.00	2.00	3.00	5.00	2.00	7.00	3.00	2.00	4.00	5.00	4.00	4.00	3.00
Li	131.99	181.99	9174.27	234.98	110.99	11.00	48.00	100.99	2.00	290.98	170.99	416.97	218.98	261.98	185.99	218.98
Sr	187.00	65.00	27.00	68.00	13.00	20.00	38.00	10.00	450.00	298.00	18.00	40.00	52.00	29.00	87.00	37.00
Ba	626.00	158.00	55.00	144.00	105.00	12.00	202.00	48.00	51.00	164.00	66.00	82.00	162.00	144.00	48.00	95.00
P	447.00	352.00	301.00	337.00	216.00	500.00	511.00	299.00	213.00	139.00	302.00	201.00	292.00	227.00	226.00	

uncorrected proof

ANNOTATED MANUSCRIPT

Dear Editor,

In the north of Kuluncak district (Malatya, Türkiye), Nb-U-REE-Zr and Li mineralisation has developed in association with alkaline foid syenite, syenite, monzonite, alkali feldspar syenite, sodalite syenite, and nepheline-bearing syenitic rocks that intrude the neritic oolitic limestones of the Triassic–Lower Cretaceous Andırın Formation. In this study, the relationship between fenitisation and the development of feldspar and pyroxene minerals enriched in sodium and potassium was investigated in the contact zones where this mineralisation is observed, based on surface outcrops and drill core data. The relevant analyses and scientific discussions are presented in the manuscript.

We believe that this work will make a significant contribution to the literature.

Sincerely,

Okan PULAT

uncorrected proof

Figure 1

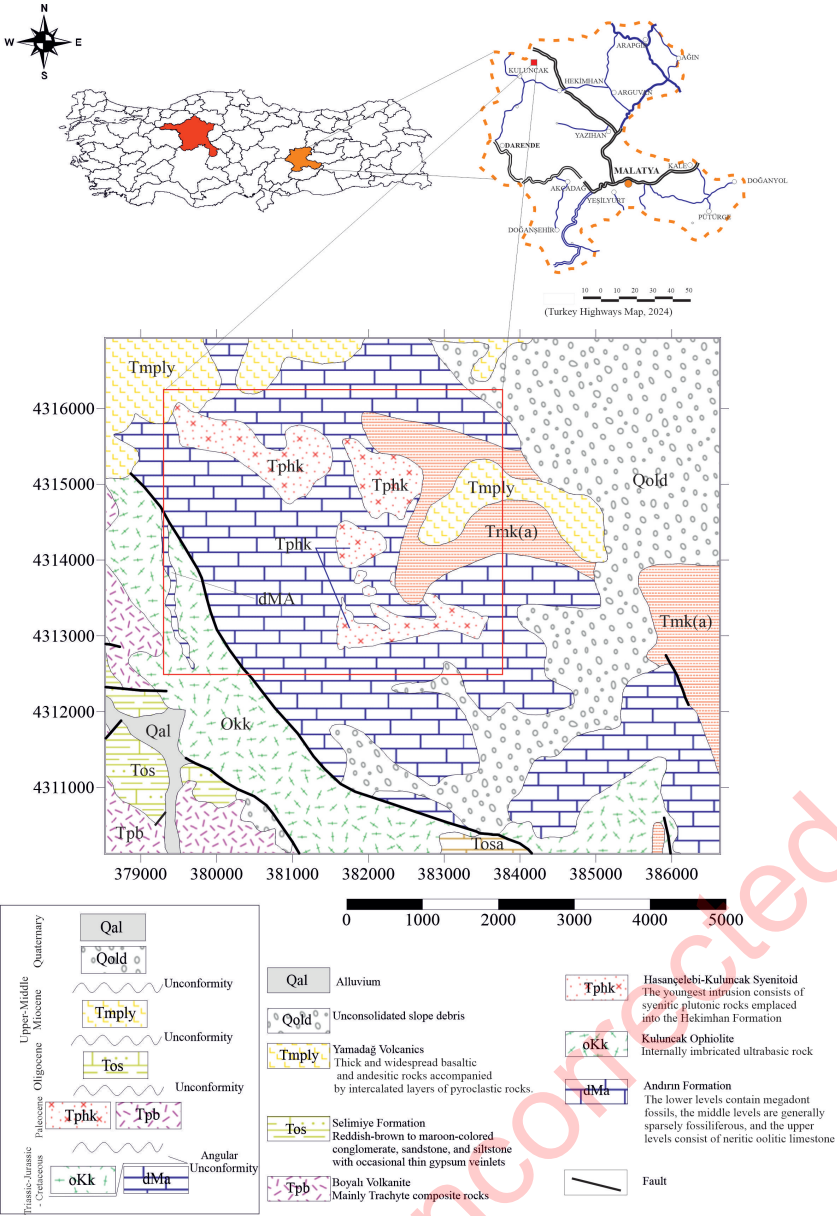


Figure 10

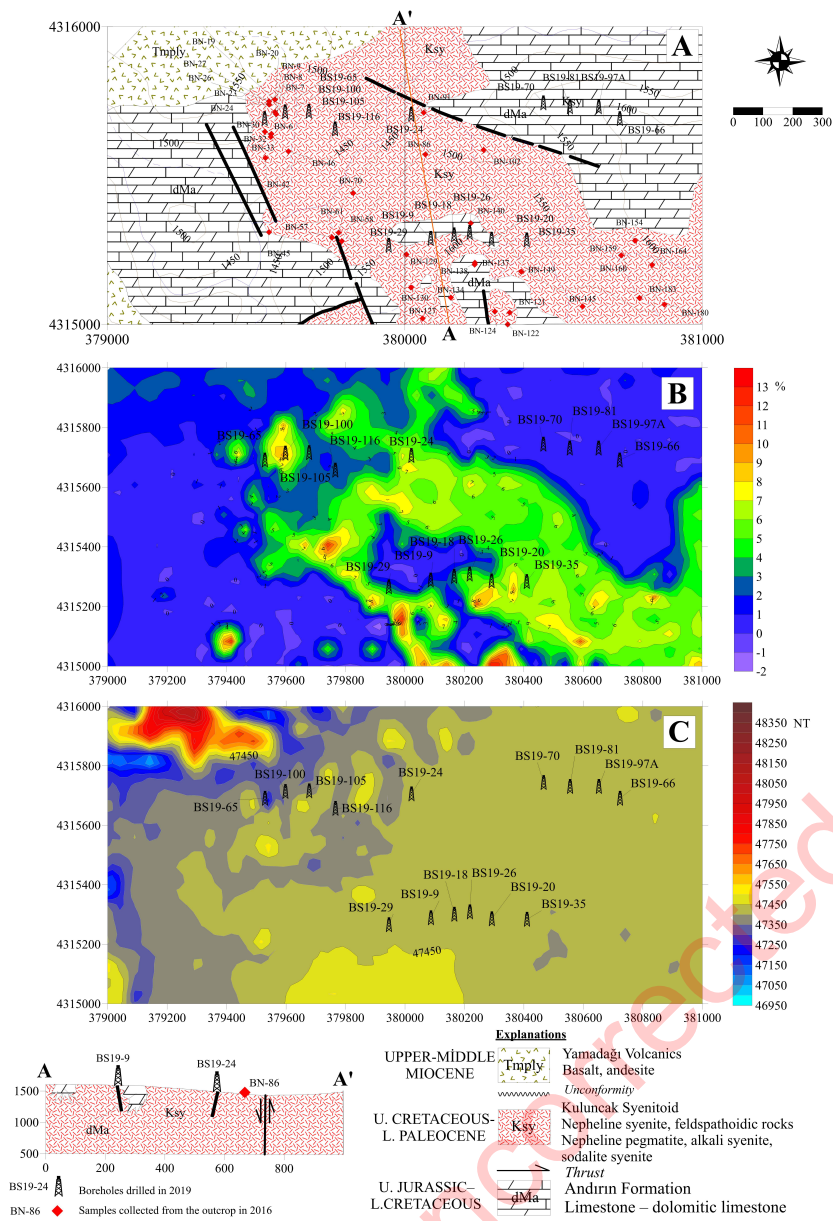


Figure 11

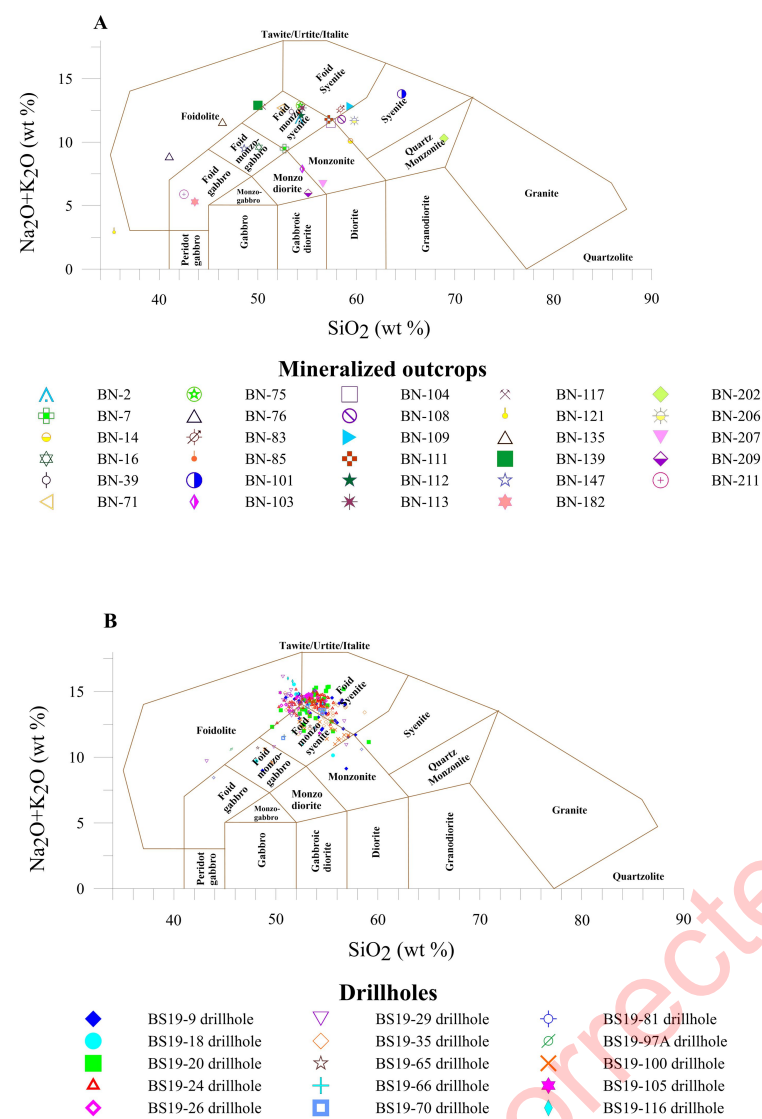


Figure 12

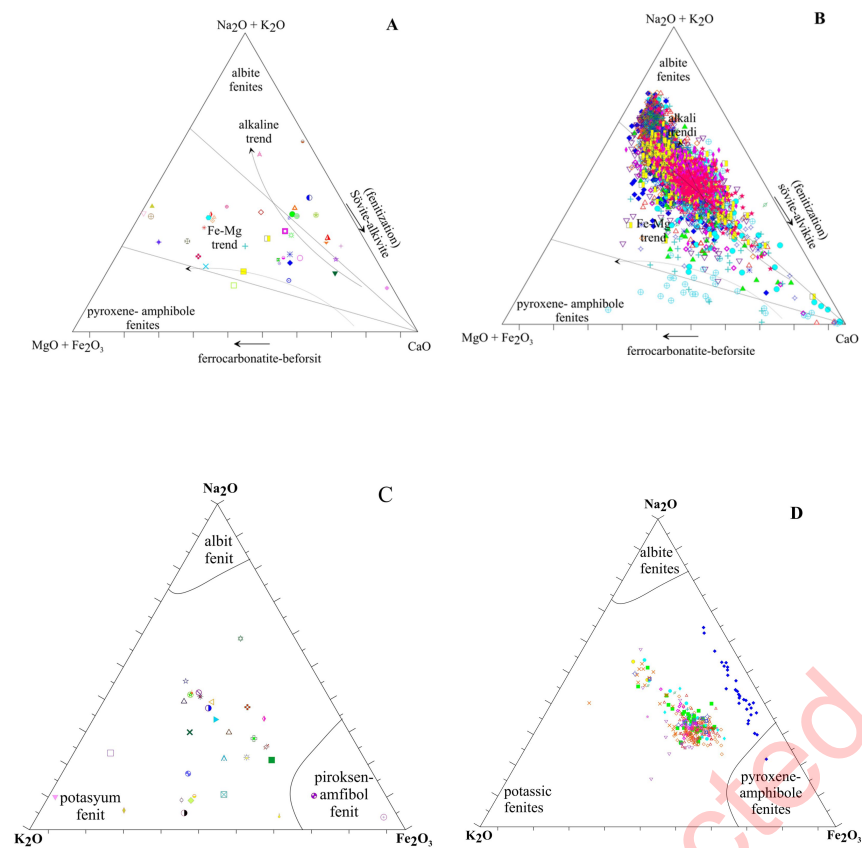


Figure 13

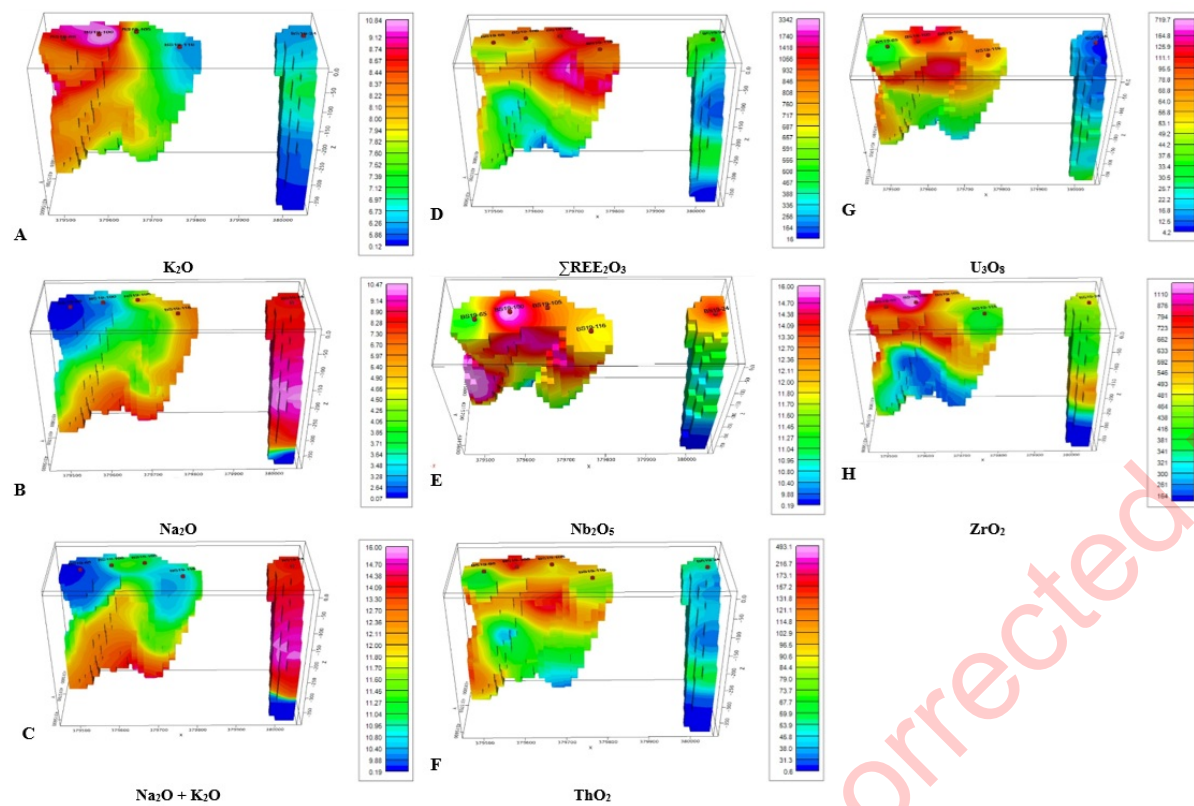


Figure 14

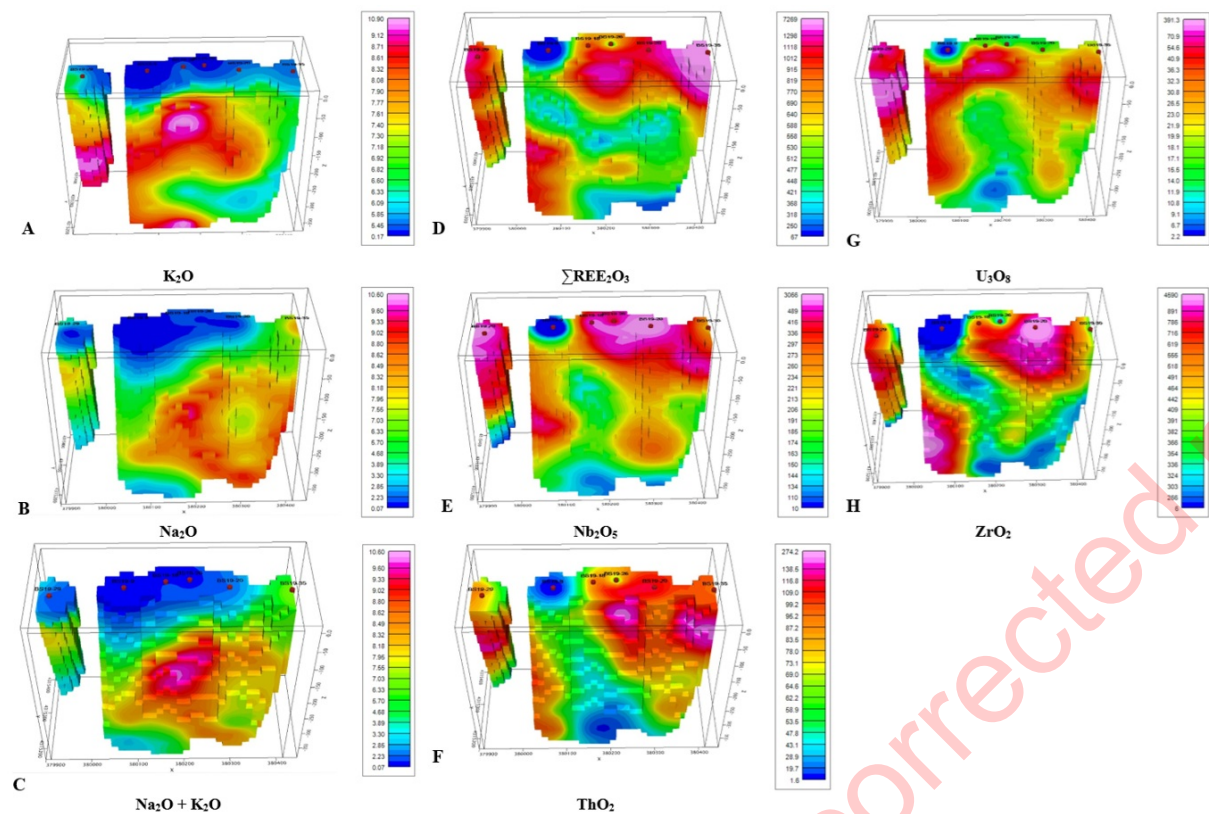


Figure 15

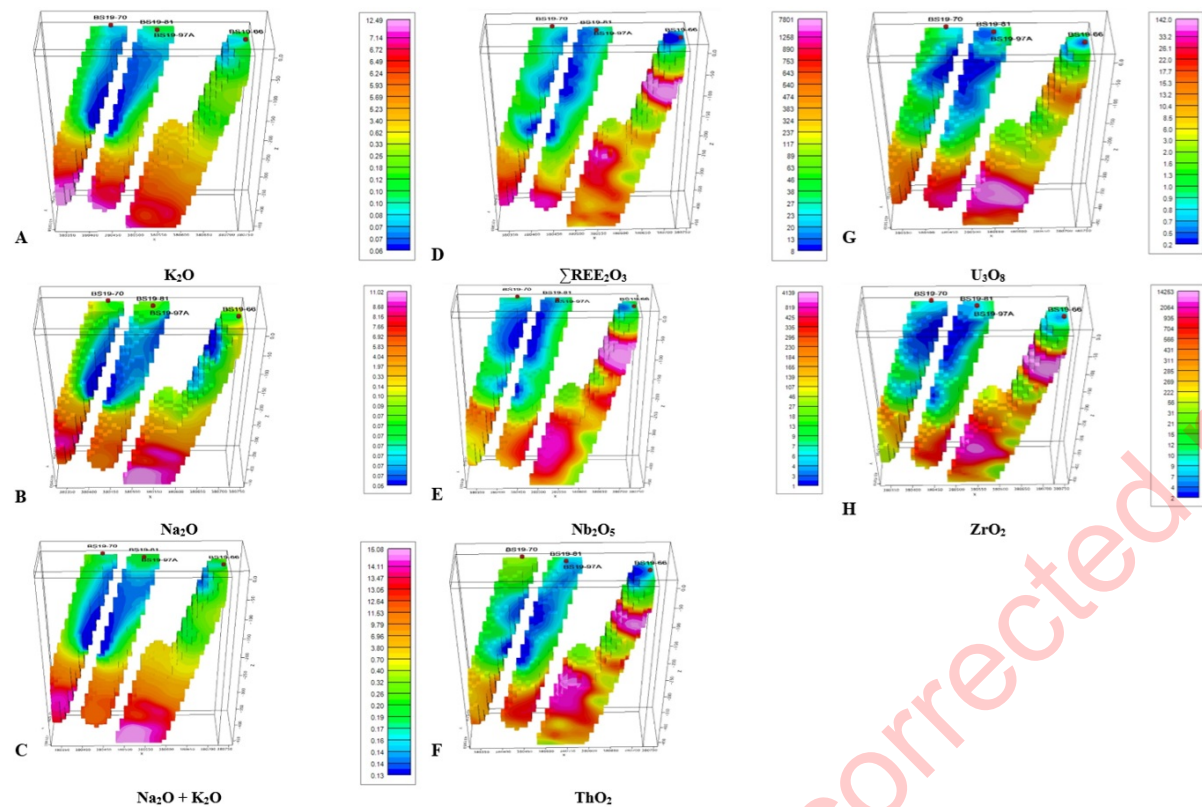


Figure 16

Fenitization and REE Depth Profiles in Drillhole (S)

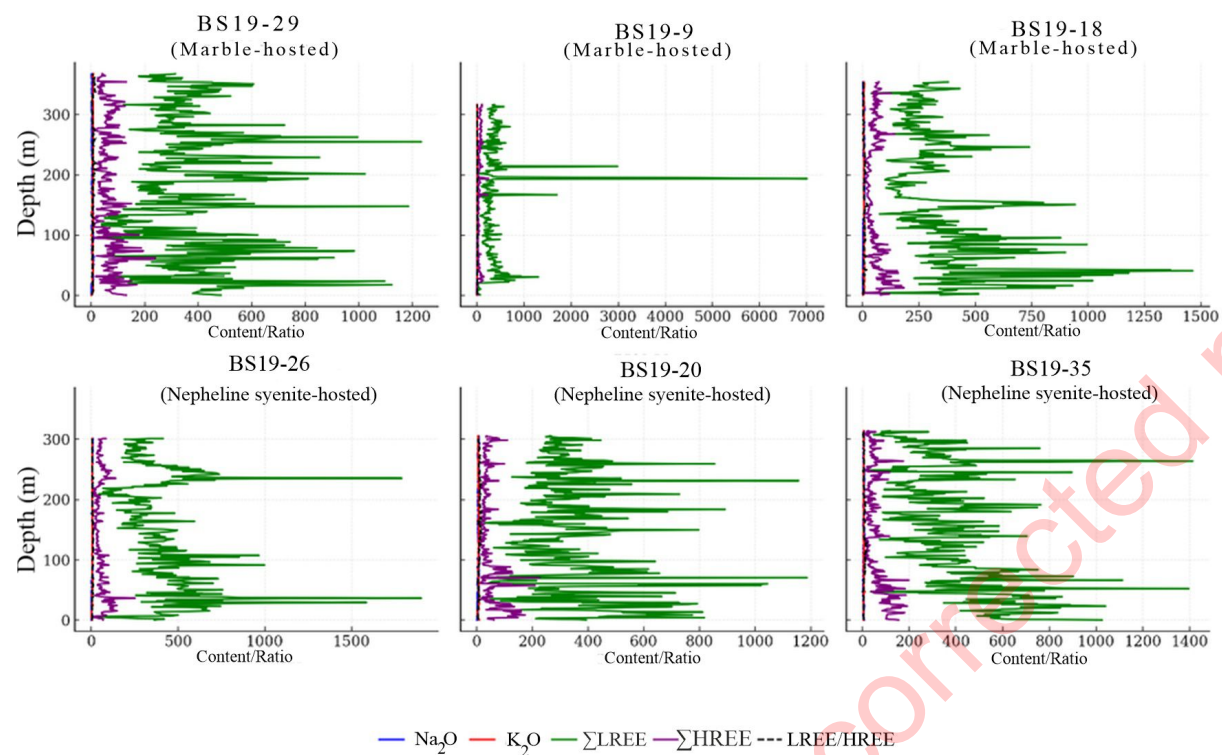


Figure 17

Fenitization and REE Depth Profiles (NW Drillholes, Nepheline syenite-hosted)

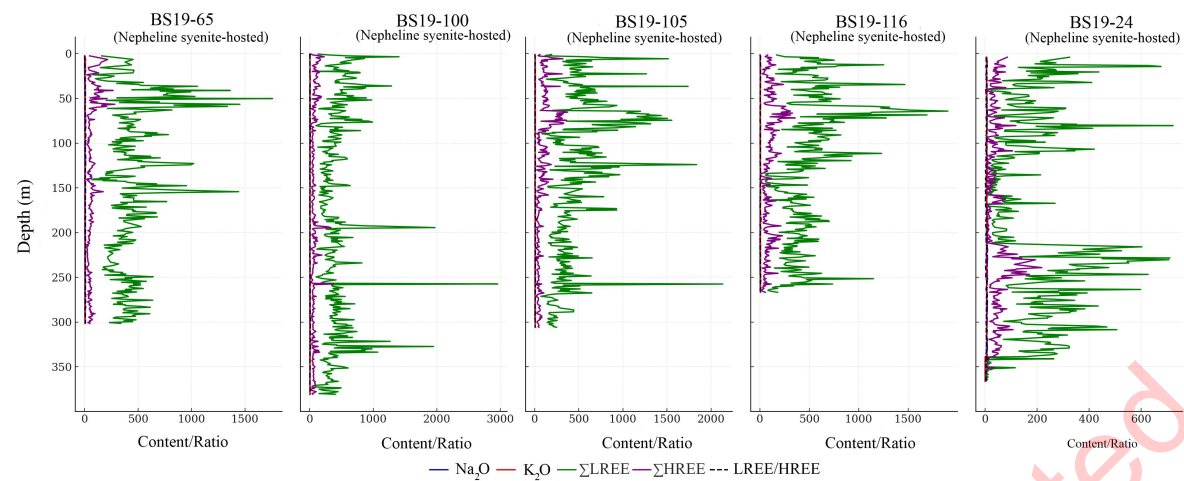


Figure 18

Fenitization and REE Depth Profiles (NE Drillholes, Nepheline syenite-hosted)

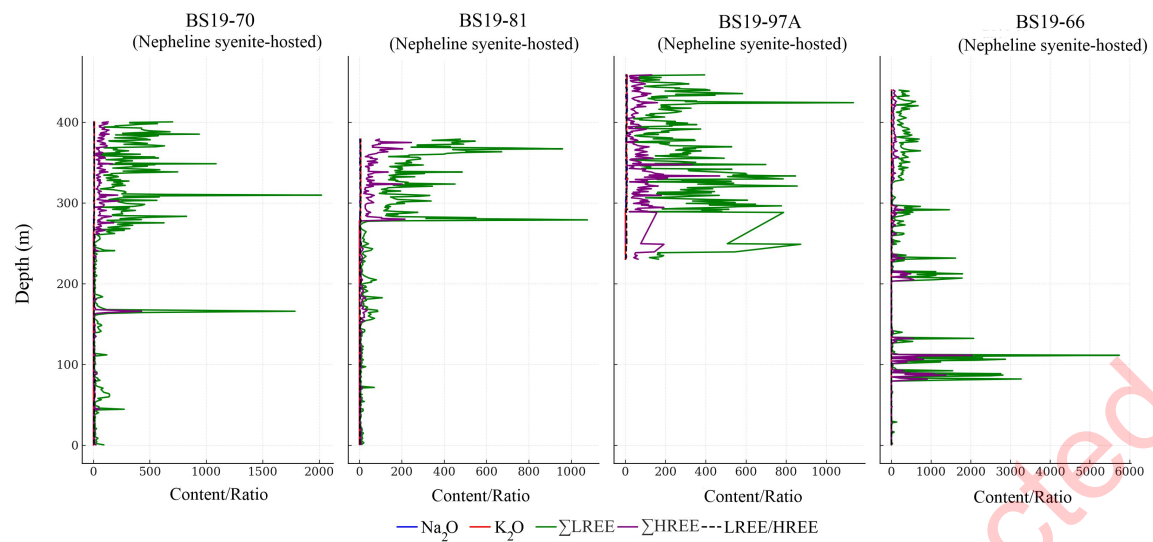


Figure 2



(a)  Fenitized zones

(b)  Fenitized zones



 Fenitized zones



Figure 3



Figure 4

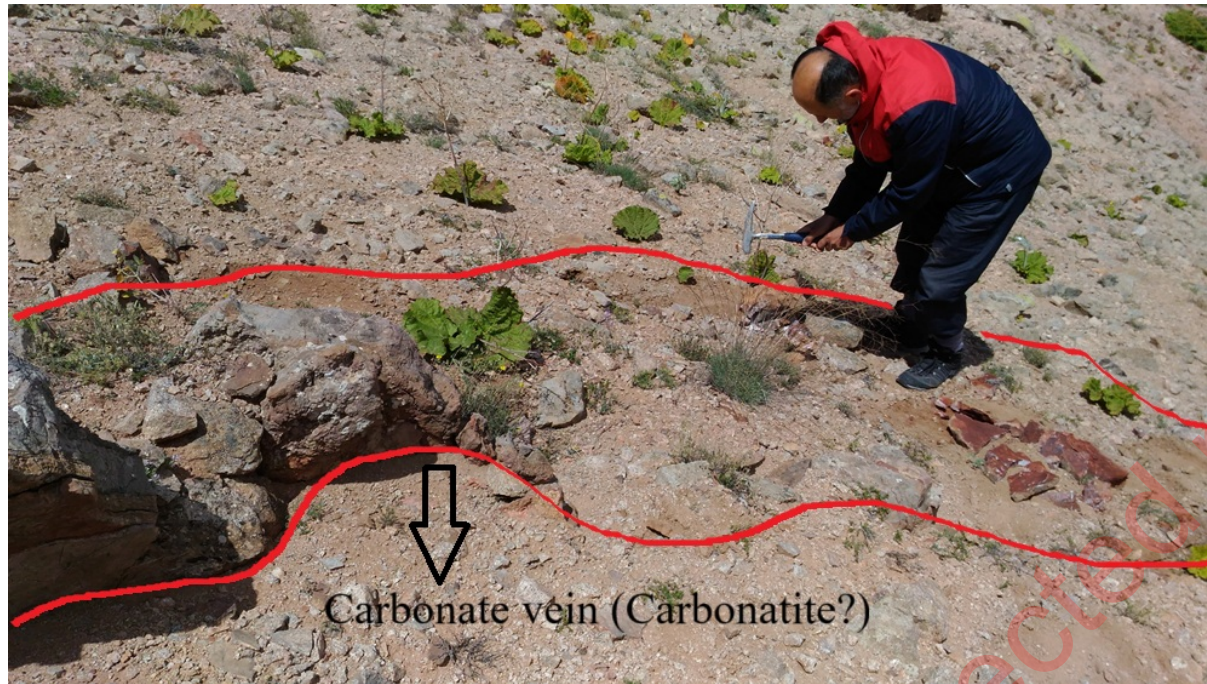


Figure 5



Figure 6



Figure 7



Figure 8



Figure 9



Y ₂ O ₃	1462,97	ThO ₂	1321,11
La ₂ O ₃	1665,51	U ₃ O ₈	222,22
Ce ₂ O ₃	1931,44	Ta ₂ O ₅	147,75
Pr ₂ O ₃	132,25	ZrO ₂	19109,37
Nd ₂ O ₃	440,89	Cs ₂ O	2,12
Sm ₂ O ₃	59,14	HfO ₂	130,90
Eu ₂ O ₃	10,42	Nb ₂ O ₅	2144,36
Gd ₂ O ₃	85,29	Rb ₂ O ₂	629,21
Tb ₂ O ₃	12,66	BeO	44,40
Dy ₂ O ₃	104,44	Ga ₂ O ₃	17,47
Ho ₂ O ₃	30,93	Ni ₂ O ₃	7,04
Er ₂ O ₃	122,35	Li ₂ O	370,23
Tm ₂ O ₃	15,99	SrO	257,81
Yb ₂ O ₃	108,17	BaO	218,84
Lu ₂ O ₃	9,10		
Sc ₂ O ₃	1,53		
ΣREE ₂ O ₃	6194,09		

Sample	BN-1	BN-2	BN-3	BN-4	BN-5	BN-6	BN-7	BN-8	BN-9	BN-10	BN-11	BN-12	BN-13	BN-14	BN-15
SiO ₂	50.80	54.20	50.10	49.00	49.80	47.80	52.70	49.90	50.00	54.10	55.00	52.70	53.50	54.50	53.00
Al ₂ O ₃	21.10	15.30	21.70	19.60	21.10	18.90	17.80	16.40	14.70	16.20	15.80	21.10	21.70	22.60	21.10
Fe ₂ O ₃	4.60	8.10	5.40	6.10	4.40	6.30	8.00	9.10	10.90	10.90	11.40	5.50	5.80	6.00	5.60
Na ₂ O	1.10	4.40	1.30	2.80	2.00	2.50	4.90	6.10	1.70	1.70	2.80	1.60	1.60	1.60	6.10
K ₂ O	9.60	7.40	9.00	6.50	5.70	6.10	4.60	2.20	11.20	11.80	9.90	8.90	8.00	7.90	5.80
CaO	5.30	4.60	4.40	7.30	6.90	8.60	3.60	6.10	0.70	0.80	1.30	3.60	2.60	2.80	3.00
MgO	0.20	0.10	0.20	0.20	0.90	0.60	0.50	0.50	0.20	0.20	0.40	0.70	0.90	1.00	0.60
TiO ₂	0.20	0.40	0.20	0.20	0.20	0.20	0.30	0.50	0.10	0.40	0.40	0.20	0.10	0.10	0.20
P ₂ O ₅	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
A.Z	6.45	3.60	6.00	7.75	8.40	7.20	3.95	5.20	4.20	2.65	2.10	5.10	4.95	2.65	4.15
MnO	0.20	0.20	0.20	0.20	0.20	0.30	0.30	0.40	0.10	0.10	0.20	0.20	0.20	0.20	0.20
Y	16.00	40.00	25.00	34.00	31.00	121.00	161.00	296.01	19.00	34.00	21.00	41.00	86.00	225.01	73.00
La	66.00	80.00	41.00	119.00	118.00	826.98	1184.97	27.00	27.00	91.00	66.00	124.00	209.00	85.00	140.00
Ce	103.93	127.77	65.79	170.68	175.44	393.80	1616.18	1142.29	41.95	132.54	93.44	204.05	331.82	254.58	226.93
Pr	7.00	8.00	4.00	10.00	10.00	76.00	108.00	7.00	3.00	9.00	7.00	15.00	25.00	29.00	20.00
Nd	22.00	24.00	15.00	31.00	32.00	81.00	313.99	223.00	9.00	26.00	22.00	45.00	73.00	107.00	49.00
Sm	2.00	3.00	2.00	4.00	4.00	10.00	22.00	21.00	1.00	3.00	3.00	6.00	9.00	17.00	6.00
Eu	1.00	1.00	1.00	1.00	1.00	2.00	3.00	3.00	0.50	1.00	1.00	1.00	2.00	4.00	1.00
Gd	3.00	4.00	3.00	5.00	5.00	12.00	30.00	28.00	1.00	4.00	3.00	7.00	10.00	19.00	7.00
Tb	0.50	0.50	0.50	0.50	0.50	1.00	2.00	3.00	0.50	0.50	0.50	1.00	1.00	3.00	1.00
Dy	1.00	3.00	2.00	3.00	3.00	8.00	11.00	22.00	1.00	3.00	2.00	4.00	7.00	18.00	5.00
Ho	0.50	1.00	0.50	1.00	1.00	2.00	2.00	5.00	0.50	1.00	0.50	1.00	2.00	4.00	1.00
Er	1.00	3.00	1.00	3.00	3.00	2.00	6.00	9.00	20.00	1.00	3.00	3.00	5.00	13.00	4.00
Tm	0.50	0.50	0.50	0.50	0.50	1.00	1.00	3.00	0.50	0.50	0.50	0.50	1.00	2.00	1.00
Yb	1.00	2.00	1.00	2.00	1.00	5.00	6.00	16.00	1.00	2.00	2.00	2.00	4.00	9.00	3.00
Lu	0.50	0.50	0.50	0.50	0.50	0.50	1.00	2.00	0.50	0.50	0.50	0.50	1.00	0.50	0.50
Sc	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
ΣNTEO	226.43	298.77	163.29	385.67	385.44	945.79	3471.66	2687.78	107.95	311.54	224.94	455.55	766.82	791.09	538.93
Th	21.00	184.00	42.00	78.00	50.00	86.00	204.00	238.00	168.00	326.00	163.00	85.00	270.00	31.00	54.00
U	8.02	144.34	13.03	36.09	23.05	101.24	171.41	345.82	59.14	137.33	57.14	28.07	23.05	49.12	36.09
Ta	19.00	153.99	33.00	72.00	31.00	184.99	389.98	445.98	73.00	144.99	60.00	38.00	31.00	83.00	40.00
Zr	435.99	2044.96	675.99	965.98	480.99	1301.97	2721.94	4858.90	551.99	1095.98	769.98	645.99	973.98	2063.96	517.99
Cs	4.00	4.00	2.00	4.00	2.00	4.00	2.00	2.00	1.00	2.00	1.00	5.00	5.00	1.00	35.00
Hf	0.00	11.00	4.00	6.00	3.00	7.00	14.00	27.00	3.00	7.00	7.00	4.00	5.00	12.00	3.00
Nb	153.00	1095.02	205.00	467.01	237.00	1022.02	1962.03	2921.05	541.01	822.01	395.01	198.00	266.00	1288.02	233.00
Rb	219.10	404.40	248.23	193.46	192.29	203.95	259.89	127.03	275.04	303.01	256.39	229.58	241.24	111.88	259.89
Be	10.00	5.00	7.00	13.00	10.00	6.00	6.00	6.00	3.00	4.00	6.00	13.00	11.00	3.00	6.00
Ge	0.00	3.00	2.00	3.00	2.00	3.00	4.00	4.00	3.00	3.00	3.00	2.00	2.00	7.00	2.00
Ga	40.00	49.00	50.00	56.00	41.00	53.00	80.00	82.00	77.00	94.00	55.00	44.00	44.00	51.00	31.00
Ni	1.00	3.00	2.00	4.00	2.00	3.00	13.00	2.00	2.00	1.00	3.00	1.00	1.00	4.00	3.00
Li	184.99	89.99	270.98	133.99	189.98	180.99	132.99	215.98	59.00	61.00	125.99	170.99	172.99	61.00	205.98
Sr	237.00	150.00	160.00	102.00	270.00	213.00	285.00	74.00	64.00	59.00	74.00	318.00	183.00	164.00	357.00
Ba	752.00	352.00	1027.01	370.00	801.00	991.01	473.00	248.00	1371.01	1451.01	1391.01	901.00	966.01	1572.01	787.00
P	215.00	54.00	248.00	77.00	112.00	65.00	132.00	74.00	458.00	420.00		153.00	269.00	153.00	137.00

Sample	BN-23	BN-24	BN-25	BN-26	BN-27	BN-28	BN-29	BN-30	BN-31	BN-32	BN-33	BN-34	BN-35	BN-36	BN-37
SiO ₂	13.60	34.50	43.10	9.60	30.20	0.30	52.30	22.30	50.00	33.50	35.30	47.80	30.70	51.60	50.50
Al ₂ O ₃	0.60	4.30	9.80	0.70	0.40	0.10	15.30	1.30	22.70	1.40	1.80	22.10	6.10	21.00	19.30
Fe ₂ O ₃	5.90	20.20	13.00	3.50	2.80	0.20	9.80	30.30	5.10	17.80	13.50	4.20	24.50	6.50	6.90
Na ₂ O	0.20	0.20	1.20	0.10	0.10	0.10	2.30	0.10	0.60	1.50	0.70	0.10	0.10	5.80	5.40
K ₂ O	0.20	0.30	5.60	0.10	0.10	0.10	10.90	2.10	6.80	1.10	1.10	7.00	0.80	4.90	4.40
CaO	47.20	32.30	16.70	46.30	35.90	55.00	3.40	17.20	5.50	24.80	30.30	7.20	28.60	3.70	6.10
MgO	1.80	1.10	0.40	1.70	1.00	0.40	0.20	2.80	1.30	2.80	6.90	2.20	1.30	0.80	1.50
TiO ₂	0.10	0.30	0.50	0.10	0.10	0.10	0.40	0.10	0.20	0.40	0.20	0.10	0.50	0.20	0.20
P ₂ O ₅	0.30	0.40	0.10	0.20	0.10	0.10	0.10	0.60	0.10	0.80	0.20	0.10	0.10	0.10	0.10
A.Z	24.45	5.25	8.20	27.70	25.05	43.75	4.10	17.15	7.20	13.45	7.95	8.85	5.10	4.00	4.80
MnO	0.90	0.80	0.60	0.70	0.50	0.10	0.60	0.30	0.10	0.90	0.90	0.20	0.80	0.20	0.20
Y	218.01	199.01	102.00	124.00	196.01	5.00	38.00	220.01	35.00	240.01	211.01	30.00	240.01	63.00	77.00
La	1235.97	212.00	214.00	744.98	669.98	64.00	218.99	197.00	20.00	272.99	176.00	25.00	54.00	126.00	98.00
Ce	1816.42	353.75	331.82	1068.87	901.06	72.47	287.96	321.33	61.02	411.91	282.24	58.16	165.91	204.05	180.21
Pr	117.00	32.00	25.00	67.00	73.00	4.00	28.00	26.00	6.00	31.00	23.00	5.00	22.00	19.00	17.00
Nd	344.99	122.00	75.00	202.00	236.00	10.00	48.00	84.00	26.00	98.00	75.00	20.00	93.00	46.00	45.00
Sm	32.00	20.00	10.00	18.00	25.00	1.00	5.00	15.00	4.00	16.00	12.00	4.00	18.00	6.00	7.00
Eu	5.00	4.00	2.00	3.00	4.00	0.50	1.00	3.00	1.00	3.00	2.00	1.00	3.00	1.00	1.00
Gd	42.00	21.00	12.00	25.00	32.00	1.00	7.00	20.00	5.00	20.00	15.00	4.00	18.00	7.00	8.00
Tb	4.00	3.00	1.00	2.00	3.00	0.50	1.00	3.00	1.00	3.00	2.00	1.00	3.00	1.00	1.00
Dy	18.00	15.00	8.00	10.00	17.00	0.50	4.00	23.00	4.00	21.00	14.00	3.00	20.00	5.00	7.00
Ho	3.00	3.00	2.00	2.00	3.00	0.50	1.00	5.00	1.00	5.00	3.00	1.00	4.00	1.00	1.00
Er	10.00	9.00	6.00	6.00	9.00	0.50	3.00	16.00	2.00	16.00	10.00	2.00	15.00	4.00	5.00
Tm	1.00	1.00	1.00	1.00	1.00	0.50	0.50	2.00	0.50	2.00	1.00	0.50	2.00	1.00	1.00
Yb	5.00	6.00	4.00	2.00	4.00	0.50	2.00	10.00	2.00	14.00	7.00	2.00	9.00	3.00	3.00
Lu	0.50	1.00	0.50	0.50	0.50	0.50	0.50	1.00	0.50	2.00	1.00	0.50	1.00	0.50	0.50
Sc	0.50	1.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	2.00	0.50	0.50	0.50	0.50
ΣNTEO	3853.39	1002.75	794.82	2276.86	2175.05	161.96	646.45	946.83	169.52	1156.41	836.24	157.66	668.41	488.05	452.21
Th	203.00	74.00	146.00	171.00	270.00	1.00	378.00	962.00	10.00	195.00	256.00	10.00	26.00	61.00	66.00
U	76.18	51.12	37.09	57.14	106.25	3.01	36.09	45.11	11.03	33.08	33.08	6.01	30.07	35.08	25.06
Ta	1.00	16.00	54.00	0.50	0.50	0.50	71.00	9.00	18.00	14.00	68.00	13.00	21.00	37.00	32.00
Zr	176.00	631.99	871.98	165.00	188.00	3.00	836.98	5398.89	212.00	1641.97	1759.96	208.00	960.98	638.99	608.99
Cs	1.00	1.00	1.00	0.50	1.00	0.50	1.00	4.00	2.00	4.00	2.00	2.00	4.00	3.00	3.00
Hf	1.00	3.00	6.00	1.00	1.00	0.50	5.00	28.00	1.00	10.00	13.00	1.00	5.00	4.00	3.00
Nb	79.00	565.01	465.01	110.00	122.00	4.00	335.01	99.00	78.00	124.00	387.01	86.00	451.01	208.00	176.00
Rb	18.65	17.48	171.31	8.16	5.83	12.82	447.52	236.58	152.67	101.39	102.56	202.78	34.96	216.77	101.39
Be	22.00	7.00	5.00	5.00	4.00	0.50	7.00	65.99	5.00	26.00	28.99	5.00	5.00	8.00	8.00
Ge	3.00	7.00	3.00	2.00	2.00	0.50	2.00	5.00	1.00	5.00	5.00	5.00	7.00	2.00	2.00
Ga	5.00	20.00	28.00	2.00	2.00	1.00	36.00	10.00	44.00	11.00	9.00	29.00	19.00	38.00	33.00
Ni	4.00	5.00	2.00	4.00	5.00	5.00	1.00	15.00	2.00	5.00	5.00	11.00	3.00	2.00	5.00
Li	244.98	183.99	108.99	89.99	69.99	10.00	108.99	2849.77	150.99	805.94	572.95	168.99	93.99	164.99	88.99
Sr	626.00	90.00	533.00	330.00	515.00	251.00	53.00	543.00	219.00	486.00	286.00	120.00	108.00	635.00	358.00
Ba	59.00	21.00	608.00	52.00	69.00	40.00	357.00	124.00	2122.01	85.00	48.00	787.00	66.00	1326.01	753.00
P	1590.00	1354.00	213.00	1173.00	488.00	55.00	66.00	2635.00	87.00	3258.00	720.00	80.00	53.00	121.00	99.00
Sample	BN-45	BN-46	BN-47	BN-48	BN-49	BN-50	BN-51	BN-52	BN-53	BN-54	BN-55	BN-56	BN-57	BN-58	BN-59

SiO ₂	48.10	50.00	51.60	51.60	53.30	3.10	29.20	49.80	48.00	54.00	51.60	52.80	52.40	53.80	50.30
Al ₂ O ₃	13.20	21.40	16.20	20.00	20.50	0.60	1.00	20.80	20.90	17.00	20.70	18.20	18.90	20.00	18.90
Fe ₂ O ₃	9.70	3.90	10.90	5.50	5.50	10.20	7.70	5.70	4.60	9.80	6.30	8.80	5.40	5.70	6.30
Na ₂ O	2.90	2.00	1.20	1.80	5.80	0.10	0.10	2.10	1.90	5.60	1.70	4.00	2.90	1.80	2.20
K ₂ O	3.70	8.70	12.00	8.40	5.60	0.20	0.50	6.30	7.50	4.20	7.20	6.40	8.10	7.40	8.60
CaO	13.00	5.70	1.40	5.00	2.70	46.30	36.70	6.90	7.10	3.50	4.00	3.50	5.30	4.00	5.70
MgO	3.00	0.30	0.10	0.30	1.10	0.40	6.40	0.30	0.20	0.50	0.90	0.60	0.30	0.60	0.50
TiO ₂	0.30	0.20	0.10	0.20	0.20	0.20	0.10	0.30	0.10	0.30	0.20	0.30	0.20	0.20	0.10
P ₂ O ₅	0.50	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
A ₂ Z	4.05	6.20	4.25	6.45	4.55	37.60	16.00	7.05	8.80	3.75	6.70	4.00	5.40	5.45	6.70
MnO	0.70	0.40	0.10	0.20	0.20	0.60	0.90	0.30	0.20	0.30	0.30	0.20	0.30	0.30	0.30
Y	108.00	34.00	41.00	10.00	50.00	33.00	8.00	64.00	53.00	37.00	62.00	26.00	69.00	93.00	17.00
La	351.99	292.99	38.00	53.00	116.00	100.00	64.00	234.99	160.00	151.00	191.00	75.00	322.99	276.99	73.00
Ce	478.66	276.52	51.49	71.51	172.58	103.93	74.37	328.00	275.56	195.47	302.26	92.49	445.28	376.63	92.49
Pr	31.00	8.00	4.00	5.00	12.00	8.00	5.00	27.00	28.00	13.00	28.00	6.00	39.00	32.00	7.00
Nd	81.00	41.00	13.00	15.00	48.00	23.00	13.00	71.00	85.00	38.00	85.00	15.00	109.00	90.00	18.00
Sm	9.00	4.00	2.00	2.00	7.00	3.00	1.00	9.00	12.00	5.00	12.00	2.00	14.00	13.00	2.00
Eu	2.00	0.80	0.70	0.50	1.40	0.80	0.30	1.90	2.30	0.90	2.20	0.50	2.50	2.50	0.50
Gd	13.00	7.00	3.00	2.00	8.00	5.00	2.00	12.00	14.00	7.00	14.00	3.00	16.00	16.00	3.00
Tb	1.00	0.60	0.50	0.30	1.10	0.60	0.20	1.30	1.60	0.80	1.60	0.40	1.80	2.00	0.40
Dy	9.00	4.00	4.00	2.00	7.00	4.00	1.00	8.00	9.00	5.00	9.00	3.00	10.00	13.00	2.00
Ho	2.00	0.90	1.00	0.30	1.30	0.90	0.20	1.70	1.70	1.20	1.80	0.80	2.00	2.70	0.50
Er	6.00	3.00	4.00	1.00	4.00	3.00	1.00	6.00	5.00	4.00	6.00	3.00	6.00	9.00	2.00
Tm	1.00	0.50	0.50	0.20	0.50	0.40	0.10	0.80	0.50	0.50	0.70	0.30	0.80	1.20	0.20
Yb	4.00	3.00	3.00	1.00	3.00	2.00	1.00	5.00	3.00	3.00	4.00	2.00	4.00	7.00	1.00
Lu	0.50	0.30	0.30	0.20	0.30	0.30	0.10	0.60	0.20	0.40	0.40	0.20	0.40	0.60	0.10
Sc	1.00	0.30	0.30	0.20	0.20	0.60	0.40	0.20	0.20	0.20	0.20	0.20	0.30	0.20	0.20
ΣNTEO	1099.15	676.91	166.79	164.21	432.38	288.53	171.67	771.50	651.06	462.46	720.16	229.89	1043.08	935.83	219.39
Th	132.00	262.00	131.00	55.00	57.00	18.00	35.00	78.00	40.00	69.00	69.00	37.00	155.00	142.00	88.00
U	54.13	44.10	21.05	82.19	27.06	4.01	46.11	32.08	11.03	147.35	10.02	135.32	59.14	31.07	22.05
Ta	79.00	23.20	5.50	15.40	5.20	1.60	0.30	13.40	5.10	36.90	6.30	36.60	19.20	15.60	4.90
Zr	1177.98	672.99	885.98	407.99	391.99	355.99	225.00	393.99	167.00	1027.98	361.99	647.99	658.99	1045.98	237.00
Cs	21.00	6.00	1.00	3.00	8.00	2.00	2.00	2.00	2.00	1.00	2.00	7.00	6.00	6.00	3.00
Hf	7.00	5.00	6.00	4.00	3.00	3.00	2.00	3.00	2.00	11.00	3.00	7.00	6.00	8.00	2.00
Nb	512.01	729.01	86.00	414.01	152.00	92.00	114.00	264.00	105.00	743.01	126.00	774.01	496.01	393.01	160.00
Rb	136.35	390.41	341.46	263.38	299.51	13.98	44.29	248.23	268.04	266.88	237.74	417.21	423.04	167.82	307.67
Be	15.00	17.00	3.00	7.00	15.00	18.00	28.00	6.00	6.00	12.00	6.00	15.00	13.00	7.00	7.00
Ge	3.00	1.00	2.00	1.00	2.00	2.00	1.00	2.00	1.00	3.00	2.00	2.00	2.00	2.00	2.00
Ga	24.00	68.00	79.00	56.00	41.00	26.00	14.00	42.00	39.00	58.00	48.00	75.00	74.00	81.00	57.00
Ni	6.00	1.00	3.00	1.00	1.00	136.04	39.01	2.00	2.00	1.00	1.00	2.00	1.00	2.00	2.00
Li	244.98	247.98	34.00	118.99	359.97	65.99	96.99	131.99	269.98	133.99	157.99	209.98	209.98	93.99	127.99
Sr	221.00	157.00	113.00	135.00	125.00	637.00	540.00	348.00	222.00	185.00	191.00	154.00	356.00	352.00	200.00
Ba	159.00	326.00	1535.01	905.00	270.00	1013.01	430.00	1040.01	479.00	170.00	826.00	479.00	646.00	1873.01	352.00
P	1752.00	98.00	318.00	111.00	61.00	1220.00	757.00	98.00	54.00	81.00	80.00	41.00	98.00	59.00	49.00

Sample	BN-67	BN-68	BN-69	BN-70	BN-71	BN-72	BN-73	BN-74	BN-75	BN-76	BN-77	BN-78	BN-79	BN-80	BN-81
SiO ₂	48.70	49.80	53.20	48.50	53.00	53.90	53.00	52.30	55.70	54.80	50.80	54.30	41.00	53.60	51.30
Al ₂ O ₃	20.10	16.70	22.60	23.20	20.40	22.60	21.60	19.50	21.10	21.50	21.80	21.40	15.70	21.30	15.50
Fe ₂ O ₃	4.80	6.80	3.20	3.60	5.20	3.40	3.80	5.30	4.00	3.60	4.10	4.10	3.70	4.50	3.40
Na ₂ O	1.70	2.30	7.50	8.20	7.10	6.00	6.40	6.60	7.50	6.70	2.20	6.50	1.80	7.30	0.90
K ₂ O	8.80	9.70	6.30	4.30	5.80	6.70	6.50	6.10	6.60	6.60	6.70	6.40	7.10	6.50	12.30
CaO	6.70	4.70	1.60	2.80	2.30	1.80	2.00	3.70	1.10	1.70	6.20	2.30	16.60	1.50	8.30
MgO	0.30	0.50	0.20	0.70	0.40	0.30	0.70	0.50	0.10	0.40	0.60	0.40	0.80	0.40	0.50
TiO ₂	0.20	0.20	0.10	0.20	0.30	0.10	0.10	0.20	0.10	0.20	0.20	0.20	0.20	0.20	0.20
P ₂ O ₅	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
A ₂ Z	8.05	5.75	4.85	7.20	3.90	4.80	5.30	4.45	3.60	3.95	7.25	4.00	12.35	4.15	6.35
MnO	0.20	0.20	0.10	0.20	0.20	0.10	0.20	0.20	0.10	0.10	0.20	0.20	0.40	0.20	0.20
Y	64.00	112.00	5.00	73.00	161.00	38.00	63.00	55.00	59.00	89.00	82.00	79.00	59.00	79.00	45.00
La	47.00	84.00	11.00	114.00	53.00	9.00	28.00	77.00	14.00	15.00	20.00	17.00	24.00	21.00	15.00
Ce	155.00	147.00	98.00	759.98	173.00	78.00	159.00	192.00	53.00	79.00	91.00	78.00	91.00	106.00	27.00
Pr	255.54	238.38	148.75	1020.25	225.98	112.51	252.68	301.31	87.72	136.35	134.44	122.05	128.72	156.37	25.74
Nd	24.00	23.00	12.00	85.00	7.00	8.00	23.00	28.00	7.00	12.00	12.00	10.00	11.00	12.00	2.00
Sm	70.00	3.00	65.00	231.00	47.00	22.00	66.00	85.00	24.00	38.00	37.00	32.00	34.00	37.00	7.00
Eu	10.00	9.00	3.00	25.00	6.00	2.00	8.00	13.00	3.00	5.00	5.00	4.00	4.00	5.00	1.00
Gd	1.90	2.00	0.60	4.20	1.40	0.40	1.50	2.40	0.60	1.00	1.00	0.90	0.90	0.90	0.30
Tb	11.00	11.00	4.00	32.00	8.00	3.00	9.00	15.00	4.00	5.00	5.00	4.00	5.00	5.00	1.00
Dy	1.30	1.60	0.30	3.40	1.00	0.30	0.90	1.90	0.40	0.50	0.50	0.50	0.50	0.60	0.20
Ho	8.00	11.00	2.00	19.00	6.00	1.00	5.00	12.00	2.00	3.00	3.00	3.00	3.00	3.00	1.00
Er	1.40	2.60	0.30	3.60	1.40	0.30	1.00	2.30	0.50	0.50	0.60	0.60	0.70	0.70	0.40
Tm	4.00	9.00	1.00	11.00	5.00	1.00	3.00	7.00	1.00	2.00	2.00	2.00	2.00	2.00	1.00
Yb	0.50	1.20	0.10	1.20	0.80	0.10	0.40	0.90	0.20	0.20	0.30	0.20	0.40	0.30	0.20
Lu	3.00	6.00	1.00	6.00	5.00	1.00	2.00	5.00	1.00	1.00	2.00	2.00	2.00	2.00	1.00
Sc	0.30	0.60	0.10	0.50	0.60	0.10	0.20	0.50	0.10	0.20	0.20	0.20	0.30	0.20	0.20
ΣNTEO	0.20	0.20	0.20	0.30	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Th	593.14	549.57	347.34	2316.43	541.38	238.91	559.87	743.50	198.72	298.95	314.24	276.65	307.72	352.27	83.24
U	43.00	307.00	35.00	663.00	75.00	34.00	59.00	95.00	29.00	38.00	36.00	41.00	53.00	72.00	135.00
Ta	19.05	130.31	20.05	72.17	36.09	11.03	22.05	42.10	6.01	6.01	6.01	10.02	12.03	12.03	16.04
Zr	6.00	19.40	3.80	12.60	9.60	3.10	5.50	10.20	2.20	3.60	4.60	4.30	5.00	4.70	3.00
Cs	185.00	856.98	168.00	1321.97	509.99	206.00	294.99	572.99	182.00	157.00	203.00	211.00	360.99	258.99	198.00
Hf	2.00	3.00	1.00	2.00	9.00	1.00	1.00	2.00	1.00	7.00	7.00	14.00	6.00	7.00	4.00
Nb	2.00	6.00	1.00	10.00	5.00	2.00	2.00	5.00	2.00	1.00	2.00	2.00	3.00	2.00	2.00
Rb	131.00	549.01	75.00	329.01	214.00	66.00	126.00	230.00	46.00	75.00	95.00	95.00	119.00	143.00	101.00
Be	283.19	341.46	201.62	107.22	266.88	236.58	235.41	144.51	250.56	186.46	230.75	194.62	245.90	192.29	603.68
Ge	6.00	7.00	6.00	16.00	6.00	6.00	7.00	12.00	4.00	6.00	7.00	7.00	5.00	13.00	6.00
Ga	2.00	2.00	1.00	2.00	2.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Ni	34.00	65.00	27.00	56.00	42.00	25.00	35.00	49.00	33.00	26.00	31.00	26.00	24.00	26.00	43.00
Li	2.00	2.00	2.00	2.00	5.00	1.00	3.00	3.00	4.00	4.00	4.00	2.00	2.00	2.00	3.00
Sr	238.98	181.99	98.99	100.99	174.99	146.99	107.99	49.99	58.00	99.99	117.99	133.99	115.99	273.98	1291.90
Ba	280.00	280.00	37.00	206.00	346.00	43.00	92.00	455.00	98.00	214.00	278.00	345.00	267.00	204.00	151.00
P	553.00	892.00	17.00	380.00	713.00	46.00	377.00	748.00	92.00	266.00	482.00	392.00	161.00	92.00	353.00

Sample	BN-89	BN-90	BN-91	BN-92	BN-93	BN-94	BN-95	BN-96	BN-97	BN-98	BN-99	BN-100	BN-101	BN-102	BN-103	BN-104
SiO ₂	52.80	50.40	43.00	50.40	55.40	57.00	55.60	4.20	57.60	2.60	25.50	2.20	57.60	53.30	57.90	57.90
Al ₂ O ₃	18.90	20.20	17.40	16.80	18.20	18.70	19.10	1.50	19.10	1.00	6.70	0.90	19.90	16.90	15.30	15.30
Fe ₂ O ₃	3.60	1.80	2.70	4.10	4.60	3.40	3.10	14.80	3.70	6.70	5.70	6.60	4.80	5.40	9.70	9.70
Na ₂ O	7.30	8.60	7.00	4.50	6.20	7.20	7.10	0.10	6.30	0.10	0.50	0.10	6.20	4.50	7.30	7.30
K ₂ O	5.30	3.80	2.60	5.10	5.00	4.20	4.90	0.20	5.40	0.10	4.30	0.10	5.60	4.40	4.40	4.40
CaO	4.00	5.10	11.60	7.90	3.90	3.00	3.60	41.10	2.20	48.30	27.00	48.00	1.50	6.10	1.20	1.20
MgO	0.60	0.70	1.10	1.20	0.70	0.60	0.40	1.30	0.50	0.70	1.30	0.70	0.50	1.40	0.40	0.40
TiO ₂	0.20	0.10	0.10	0.20	0.20	0.10	0.10	0.10	0.20	0.10	0.70	0.10	0.20	0.20	0.50	0.50
P ₂ O ₅	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
A.Z	6.90	9.00	13.80	9.40	5.15	5.45	5.65	35.70	4.45	39.85	24.45	40.30	3.20	7.10	2.60	2.60
MnO	0.10	0.10	0.10	0.10	0.20	0.10	0.10	0.70	0.10	0.60	2.30	0.90	0.20	0.20	0.20	0.20
Y	20.00	9.00	150.00	51.00	53.00	7.00	8.00	25.00	12.00	28.00	46.00	21.00	16.00	62.00	27.00	27.00
La	100.00	39.00	202.00	103.00	144.00	45.00	52.00	60.00	70.00	39.00	75.00	19.00	65.00	241.99	41.00	41.00
Ce	155.42	60.07	351.84	162.10	232.65	64.84	75.33	115.37	98.21	47.68	66.75	32.42	110.61	376.63	50.54	50.54
Pr	4.00	5.00	31.00	3.00	21.00	5.00	6.00	4.00	5.00	5.00	6.00	3.00	9.00	32.00	5.00	5.00
Nd	39.00	14.00	92.00	43.00	59.00	13.00	17.00	13.00	22.00	17.00	17.00	9.00	32.00	88.00	15.00	15.00
Sm	5.00	2.00	13.00	6.00	8.00	1.00	2.00	2.00	3.00	3.00	3.00	1.00	4.00	12.00	2.00	2.00
Eu	1.00	0.50	3.00	1.00	2.00	0.50	0.50	0.50	0.50	1.00	1.00	0.50	1.00	2.00	0.50	0.50
Gd	6.00	2.00	17.00	8.00	10.00	2.00	2.00	2.00	3.00	3.00	4.00	2.00	5.00	15.00	3.00	3.00
Tb	0.50	0.50	2.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50	1.00	0.50	0.50	2.00	0.50	0.50
Dy	3.00	1.00	16.00	6.00	7.00	1.00	1.00	2.00	2.00	3.00	5.00	2.00	3.00	10.00	3.00	3.00
Ho	1.00	0.50	4.00	1.00	2.00	0.50	0.50	1.00	0.50	1.00	1.00	0.50	1.00	2.00	1.00	1.00
Er	2.00	1.00	11.00	4.00	5.00	1.00	1.00	2.00	1.00	2.00	4.00	2.00	2.00	6.00	2.00	2.00
Tm	0.50	0.50	2.00	0.50	1.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	1.00	0.50	0.50
Yb	1.00	1.00	9.00	3.00	4.00	0.50	1.00	1.00	1.00	2.00	3.00	1.00	1.00	4.00	2.00	2.00
Lu	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Sc	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
ΣNTEO	339.42	137.07	904.84	393.59	550.65	143.34	168.33	229.87	222.21	153.67	234.24	95.42	251.60	855.63	154.04	154.04
Th	38.00	17.00	103.00	46.00	58.00	27.00	26.00	2.00	44.00	4.00	206.00	2.00	27.00	124.00	29.00	29.00
U	4.01	2.00	14.03	5.01	8.02	5.01	6.01	31.07	9.02	14.03	23.05	7.02	5.01	11.03	69.16	69.16
Ta	25.00	11.00	53.00	27.00	38.00	15.00	15.00	1.00	21.00	0.50	40.00	1.00	21.00	49.00	57.00	57.00
Zr	149.00	85.00	704.99	223.00	276.99	195.00	215.00	281.99	364.99	95.00	110.00	92.00	171.00	189.00	883.98	883.98
Cs	2.00	2.00	1.00	2.00	13.00	13.00	7.00	0.50	10.00	1.00	1.00	0.50	11.00	8.00	14.00	14.00
Hf	1.00	1.00	5.00	2.00	2.00	2.00	2.00	1.00	3.00	0.50	1.00	0.50	2.00	2.00	8.00	8.00
Nb	111.00	57.00	225.00	136.00	173.00	74.00	78.00	7.00	116.00	6.00	438.01	7.00	81.00	215.00	231.00	231.00
Rb	159.66	81.58	123.53	193.46	189.96	159.66	141.01	6.99	144.51	4.66	149.17	3.50	150.34	187.63	283.19	283.19
Be	5.00	4.00	4.00	7.00	5.00	6.00	6.00	5.00	7.00	3.00	8.00	3.00	4.00	7.00	9.00	9.00
Ge	1.00	1.00	1.00	1.00	2.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00
Ga	30.00	17.00	19.00	27.00	27.00	22.00	22.00	32.00	24.00	13.00	53.00	8.00	26.00	25.00	34.00	34.00
Ni	1.00	1.00	2.00	2.00	2.00	3.00	1.00	3.00	5.00	5.00	3.00	3.00	1.00	2.00	2.00	2.00
Li	56.00	65.99	83.99	106.99	102.99	151.99	152.99	18.00	176.99	10.00	31.00	11.00	114.99	142.99	196.98	196.98
Sr	136.00	74.00	167.00	196.00	177.00	123.00	83.00	749.00	100.00	660.00	433.00	525.00	212.00	162.00	66.00	66.00
Ba	627.00	52.00	169.00	509.00	367.00	27.00	29.00	680.00	173.00	80.00	1601.01	31.00	552.00	330.00	147.00	147.00
P	134.00	82.00	96.00	79.00	70.00	73.00	29.00	26.00	109.00	88.00	113.00	42.00	82.00	46.00	27.00	27.00

Sample	BN-111	BN-112	BN-113	BN-114	BN-115	BN-116	BN-117	BN-118	BN-119	BN-120	BN-121	BN-122	BN-123	BN-124	BN-125	BN-126
SiO ₂	58.50	59.40	57.90	57.20	54.40	54.50	53.10	53.40	53.50	50.50	47.70	46.50	43.60	35.40	55.20	55.20
Al ₂ O ₃	16.60	16.80	19.80	19.50	21.90	22.40	17.40	21.70	21.10	24.90	14.50	11.80	12.90	18.60	20.00	20.00
Fe ₂ O ₃	7.60	4.90	4.10	4.30	4.50	3.90	8.30	3.90	3.90	21.00	14.20	6.60	8.00	8.00	2.80	2.80
Na ₂ O	7.30	5.30	6.70	6.90	6.80	7.00	1.10	6.40	6.60	7.70	1.30	0.80	0.80	0.10	0.10	0.10
K ₂ O	4.50	7.50	5.60	4.90	5.30	5.70	12.10	6.30	5.50	5.10	10.30	7.50	9.70	2.80	12.80	12.80
CaO	1.40	2.10	1.40	1.60	1.70	1.00	2.40	2.90	2.90	1.20	0.50	12.00	15.80	17.40	2.70	2.70
MgO	0.30	0.20	0.50	0.50	0.60	0.70	0.50	0.60	0.40	0.60	0.20	0.40	0.30	0.70	0.20	0.20
TiO ₂	0.30	0.30	0.10	0.20	0.10	0.20	0.30	0.20	0.20	0.10	1.00	1.00	0.30	0.30	0.10	0.10
P ₂ O ₅	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
A.Z	2.95	2.80	3.45	4.35	4.00	4.00	3.60	4.70	5.10	6.55	2.60	4.30	8.90	15.55	4.40	4.40
MnO	0.10	0.20	0.10	0.10	0.10	0.20	0.20	0.10	0.10	0.10	0.10	0.70	0.30	0.40	0.10	0.10
Y	40.00	37.00	12.00	16.00	22.00	43.00	71.00	35.00	37.00	26.00	242.01	483.01	77.00	275.01	31.00	31.00
La	84.00	119.00	35.00	33.00	77.00	110.00	204.00	112.00	90.00	87.00	533.99	1838.96	182.00	606.99	110.00	110.00
Ce	144.93	171.63	61.02	58.16	110.61	160.19	165.91	157.33	146.84	126.82	633.12	2486.73	232.65	694.15	153.51	153.51
Pr	14.00	15.00	4.00	5.00	7.00	9.00	9.00	11.00	11.00	10.00	50.00	182.00	26.00	61.00	10.00	10.00
Nd	42.00	43.00	14.00	18.00	20.00	36.00	25.00	35.00	33.00	30.00	111.00	467.99	48.00	159.00	27.00	27.00
Sm	6.00	6.00	2.00	3.00	3.00	6.00	4.00	5.00	5.00	5.00	15.00	56.00	7.00	20.00	4.00	4.00
Eu	1.00	1.00	0.50	1.00	0.60	1.10	0.90	1.00	1.00	1.00	3.00	10.10	1.60	4.00	0.90	0.90
Gd	8.00	7.00	3.00	3.00	4.00	6.00	6.00	6.00	6.00	5.00	22.00	77.00	9.00	28.00	5.00	5.00
Tb	1.00	1.00	0.50	0.50	0.50	0.90	0.90	0.80	0.90	0.60	3.20	9.50	1.20	4.10	0.60	0.60
Dy	6.00	5.00	2.00	3.00	3.00	5.00	6.00	5.00	5.00	4.00	23.00	58.00	8.00	28.00	4.00	4.00
Ho	1.00	1.00	0.50	1.00	0.60	1.10	1.60	1.00	1.10	0.80	5.80	13.00	1.70	6.90	0.80	0.80
Er	4.00	4.00	1.00	2.00	1.90	3.50	5.90	3.30	3.40	2.30	19.80	41.20	5.70	22.60	2.60	2.60
Tm	0.50	0.50	0.50	0.50	0.30	0.50	0.90	0.50	0.50	0.30	2.70	5.40	0.80	3.10	0.40	0.40
Yb	2.00	3.00	1.00	1.00	1.00	3.00	5.00	3.00	3.00	2.00	15.00	30.00	5.00	17.00	2.00	2.00
Lu	0.50	0.50	0.50	0.50	0.20	0.30	0.50	0.30	0.30	0.20	1.30	2.80	0.50	1.50	0.20	0.20
Sc	0.50	0.50	0.50	0.50	0.20	0.20	0.20	0.20	0.20	0.30	0.30	0.40	0.30	0.40	0.20	0.20
ΣNTEO	355.43	415.13	138.02	146.16	251.90	385.79	506.81	376.43	344.24	301.31	1681.22	5762.10	606.45	1931.74	352.21	352.21
Th	39.00	52.00	30.00	25.00	53.00	52.00	207.00	92.00	51.00	36.00	400.00	1556.00	111.00	568.00	74.00	74.00
U	36.09	50.12	1													

SiO ₂	49.60	48.30	54.10	43.50	39.00	46.40	58.30	52.70	52.60	50.00	53.00	50.30	53.80	53.30	55.00
Al ₂ O ₃	16.70	11.70	20.10	13.00	12.20	11.90	14.40	21.30	22.90	24.40	21.60	20.00	21.30	22.30	22.90
Fe ₂ O ₃	4.30	4.30	6.80	4.00	7.30	9.50	12.30	5.00	3.90	3.50	4.90	4.00	4.10	4.40	3.00
Na ₂ O	3.70	1.10	5.40	0.60	1.10	1.20	4.90	5.60	7.00	8.70	6.50	2.30	6.00	5.10	7.30
K ₂ O	6.90	10.20	5.70	11.60	8.50	10.40	5.70	6.30	6.30	4.20	5.80	6.30	6.70	7.80	5.70
CaO	10.20	13.20	2.30	15.00	17.50	10.70	1.80	2.10	1.30	1.10	2.60	8.80	2.30	1.50	1.20
MgO	0.30	0.20	0.90	0.20	0.30	0.50	0.30	1.50	0.50	1.00	0.40	0.40	0.70	0.70	1.00
TiO ₂	0.30	0.30	0.20	0.30	0.40	0.20	0.30	0.30	0.20	0.10	0.10	0.10	0.20	0.10	0.10
P ₂ O ₅	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
A ₂ Z	7.35	9.25	3.95	10.40	12.00	7.70	1.60	4.05	4.80	6.60	4.50	7.05	4.40	4.20	3.45
MnO	0.20	0.30	0.30	0.20	0.30	0.60	0.20	0.30	0.10	0.10	0.20	0.20	0.20	0.20	0.10
Y	17.00	100.00	30.00	249.01	83.00	91.00	16.00	86.00	68.00	15.00	32.00	67.00	86.00	28.00	8.00
La	92.00	501.99	164.00	111.00	503.99	281.99	99.00	533.99	200.00	49.00	138.00	282.99	219.99	137.00	81.00
Ce	122.05	604.52	244.10	162.10	559.70	382.35	126.82	737.06	296.54	78.19	222.17	406.19	371.87	213.58	116.33
Pr	8.00	44.00	21.00	17.00	40.00	33.00	8.00	62.00	26.00	6.00	19.00	31.00	36.00	21.00	8.00
Nd	21.00	86.00	52.00	36.00	78.00	75.00	20.00	159.00	62.00	19.00	46.00	69.00	97.00	44.00	19.00
Sm	3.00	9.00	7.00	7.00	8.00	10.00	2.00	16.00	9.00	3.00	6.00	9.00	14.00	6.00	2.00
Eu	0.50	1.80	1.40	1.70	1.40	1.90	0.40	2.90	1.70	0.60	1.30	2.10	2.70	1.10	0.30
Gd	3.00	15.00	8.00	12.00	13.00	13.00	3.00	21.00	11.00	3.00	7.00	11.00	16.00	7.00	2.00
Tb	0.40	1.60	0.90	2.70	1.30	1.60	0.40	2.10	1.30	0.40	0.90	1.30	2.10	0.80	0.20
Dy	2.00	9.00	5.00	23.00	8.00	10.00	2.00	11.00	8.00	2.00	5.00	8.00	12.00	4.00	1.00
Ho	0.50	2.10	1.00	6.50	2.00	2.40	0.50	2.30	1.70	0.50	1.00	1.70	2.40	0.90	0.20
Er	1.50	7.20	3.00	24.00	6.80	8.20	1.60	7.00	5.50	1.50	3.00	5.40	6.70	2.60	0.70
Tm	0.20	1.00	0.40	3.60	0.90	1.20	0.20	0.90	0.70	0.20	0.40	0.70	8.00	0.40	0.10
Yb	1.00	6.00	3.00	22.00	6.00	8.00	2.00	5.00	4.00	1.00	2.00	4.00	4.00	2.00	1.00
Lu	0.10	0.60	0.30	2.20	0.60	1.00	0.20	0.50	0.40	0.10	0.20	0.40	0.40	0.20	0.10
Sc	0.20	0.30	0.20	0.50	0.30	0.60	0.20	0.40	0.20	0.30	0.40	0.20	0.20	0.20	0.20
ΣTFeO	272.45	1390.11	541.29	680.30	1313.00	921.25	282.31	1647.14	696.04	179.79	484.36	899.99	879.36	468.78	240.13
Th	69.00	394.00	63.00	644.00	197.00	352.00	96.00	523.00	79.00	36.00	72.00	184.00	56.00	44.00	40.00
U	54.13	88.21	29.07	92.22	28.07	84.20	19.05	77.18	25.06	9.02	42.02	10.02	9.02	32.08	18.04
Ta	27.00	35.00	8.00	57.00	47.00	60.00	12.00	14.00	9.00	5.00	8.00	7.00	6.00	3.00	3.00
Zr	486.99	2070.96	489.99	5904.88	1614.97	2572.95	720.98	942.98	511.99	351.99	239.99	556.99	334.99	264.99	243.99
Cs	4.00	1.00	1.00	1.00	2.00	3.00	2.00	7.00	1.00	9.00	2.00	2.00	3.00	1.00	10.00
Hf	4.00	14.00	4.00	40.00	9.00	22.00	7.00	7.00	4.00	3.00	2.00	4.00	2.00	2.00	2.00
Nb	739.01	1369.02	165.00	692.01	620.01	1437.02	337.01	445.01	216.00	94.00	125.00	282.00	163.00	140.00	109.00
Rb	312.33	280.86	192.29	473.15	319.32	543.08	237.74	243.57	272.70	262.22	254.06	164.32	284.36	237.74	265.71
Be	8.00	6.00	6.00	11.00	6.00	12.00	6.00	9.00	15.00	6.00	11.00	8.00	8.00	8.00	10.00
Ge	2.00	2.00	3.00	2.00	3.00	4.00	5.00	3.00	2.00	2.00	3.00	2.00	3.00	3.00	2.00
Ga	57.00	60.00	56.00	64.00	37.00	70.00	48.00	48.00	38.00	41.00	37.00	97.00	34.00	44.00	35.00
Ni	8.00	8.00	28.01	5.00	6.00	5.00	3.00	3.00	2.00	3.00	2.00	2.00	2.00	2.00	2.00
Li	76.99	53.00	107.99	150.99	67.99	553.96	122.99	86.99	136.99	338.97	103.99	73.99	146.99	72.99	270.98
Sr	112.00	97.00	156.00	76.00	111.00	113.00	92.00	419.00	87.00	184.00	155.00	412.00	116.00	68.00	303.00
Ba	211.00	680.00	727.00	464.00	293.00	759.00	173.00	619.00	334.00	145.00	545.00	2537.01	301.00	585.00	28.00
P	65.00	58.00	60.00	59.00	91.00	171.00	51.00	118.00	69.00	88.00	90.00	76.00	67.00	76.00	69.00

Sample	BN-157	BN-158	BN-159	BN-160	BN-162	BN-163	BN-164	BN-165	BN-166	BN-167	BN-168	BN-169	BN-170	BN-171	BN-172
SiO ₂	5.40	7.30	55.50	54.10	46.90	4.90	29.20	53.30	3.90	19.30	2.40	8.40	29.60	18.30	54.40
Al ₂ O ₃	1.90	2.70	20.60	21.10	18.00	2.20	9.20	20.20	1.90	7.60	1.00	3.80	0.40	7.00	22.40
Fe ₂ O ₃	4.50	4.10	4.60	5.00	3.30	5.40	7.80	5.20	5.10	3.00	1.10	1.00	1.10	3.80	3.60
Na ₂ O	0.20	0.20	6.10	7.30	1.20	0.20	0.20	6.30	0.20	4.10	0.10	0.20	0.10	0.90	7.40
K ₂ O	0.80	1.30	5.00	4.40	9.50	0.80	7.40	5.20	0.20	2.10	0.10	0.90	0.10	3.00	5.10
CaO	47.70	46.30	2.60	2.30	11.10	47.00	26.80	3.10	47.00	37.10	52.00	47.70	40.90	38.00	1.40
MgO	0.50	0.40	0.50	1.00	0.50	0.50	0.40	0.70	1.20	1.00	0.70	0.40	0.30	0.60	0.30
TiO ₂	0.10	0.10	0.30	0.20	0.10	0.10	0.10	0.20	0.10	0.10	0.10	0.10	0.10	0.10	0.10
P ₂ O ₅	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.20	0.10	0.10
A ₂ Z	38.05	36.80	4.20	4.20	8.55	37.90	18.00	5.30	39.40	28.10	42.10	37.50	23.40	27.70	4.90
MnO	0.70	0.60	0.10	0.10	0.10	0.50	0.50	0.20	0.70	0.30	0.20	0.10	0.60	0.60	0.10
Y	68.00	74.00	157.00	86.00	79.00	138.00	147.00	52.00	329.01	286.01	215.01	63.00	11.00	73.00	11.00
La	44.00	63.00	347.99	214.00	69.00	68.00	250.99	164.00	47.00	117.00	35.00	82.00	21.00	66.00	25.00
Ce	81.05	86.77	667.45	384.26	81.05	93.44	374.73	253.63	78.19	182.12	60.07	98.21	18.12	97.26	41.95
Pr	6.00	7.00	54.00	31.00	5.00	8.00	35.00	12.00	8.00	12.00	6.00	10.00	2.00	7.00	2.00
Nd	22.00	26.00	174.00	95.00	19.00	30.00	76.00	49.00	64.00	61.00	24.00	38.00	5.00	26.00	8.00
Sm	4.00	4.00	26.00	13.00	4.00	5.00	12.00	6.00	9.00	11.00	5.00	5.00	1.00	4.00	1.00
Eu	1.00	1.00	4.00	2.00	1.00	1.00	2.00	1.00	2.00	2.00	1.00	1.00	0.50	1.00	0.50
Gd	5.00	6.00	28.00	14.00	5.00	7.00	14.00	8.00	13.00	15.00	8.00	6.00	1.00	6.00	1.00
Tb	1.00	1.00	3.00	2.00	1.00	1.00	2.00	1.00	2.00	3.00	2.00	1.00	0.50	1.00	0.50
Dy	5.00	6.00	17.00	10.00	6.00	8.00	10.00	5.00	20.00	21.00	13.00	5.00	1.00	6.00	1.00
Ho	1.00	1.00	3.00	2.00	1.00	2.00	2.00	1.00	5.00	5.00	3.00	1.00	0.50	1.00	0.50
Er	4.00	4.00	9.00	6.00	5.00	6.00	7.00	4.00	16.00	16.00	12.00	4.00	1.00	4.00	1.00
Tm	0.50	0.50	1.00	1.00	1.00	1.00	1.00	0.50	2.00	2.00	2.00	0.50	0.50	0.50	0.50
Yb	3.00	3.00	5.00	4.00	4.00	4.00	5.00	3.00	11.00	12.00	9.00	2.00	0.50	3.00	1.00
Lu	0.50	0.50	0.50	0.50	0.50	0.50	1.00	0.50	1.00	1.00	1.00	0.50	0.50	0.50	0.50
Sc	4.00	4.00	26.00	13.00	4.00	5.00	12.00	6.00	9.00	11.00	5.00	5.00	1.00	4.00	0.50
ΣTFeO	250.05	287.77	1522.95	877.76	285.55	377.95	951.72	566.63	616.19	757.12	401.08	322.21	65.12	300.26	95.95
Th	6.00	5.00	85.00	58.00	92.00	9.00	343.00	98.00	37.00	19.00	5.00	7.00	2.00	17.00	34.00
U	16.04	12.03	10.02	16.04	6.01	11.03	16.04	13.03	8.02	6.01	12.03	1.00	23.05	31.07	10.02
Ta	1.00	1.00	10.00	6.00	4.00	0.50	5.00	7.00	0.50	2.00	0.50	1.00	0.50	1.00	2.00
Zr	269.99	247.99	415.99	429.99	829.98	281.99	209.00	550.99	57.00	188.00	18.00	88.00	5.00	137.00	271.99
Cs	1.00	2.00	14.00	20.00	4.00	0.50	1.00	19.00	0.50	2.00	0.50	1.00	1.00	2.00	1.00
Hf	1.00	1.00	3.00	3.00	6.00	1.00	1.00	3.00	0.50	1.00	0.50	1.00	0.50	1.00	2.00
Nb	26.00	18.00	256.00	172.00	190.00	15.00	297.00	240.00	10.00	65.00	6.00	25.00	12.00	38.00	62.00
Rb	50.11	85.07	337.97	355.45	756.35	33.80	376.40	321.65	11.65	89.74	4.66	44.29	10.49	191.13	299.51
Be	3.00	4.00	6.00	6.00	15.00	4.00	4.00	14.00	5.00	4.00	1.00	2.00	8.00	5.00	6.00
Ge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ga	5.00	10.00	31.00	37.00	49.00	10.00	22.00	30.00	8.00	12.00	4.00	6.00	5.00	17.00	28.00
Ni	8.00	7.00	3.00	5.00	3.00	5.00	3.00	2.00	7.00	3.00	5.00	8.00	9.00	5.00	2.00
Li	40.00	46.00	163.99	161.99	1138.91	29.00	18.00	603.95	73.99	58.00	12.00	32.00	17.00	114.99	159.99
Sr	370.00	216.00	370.00	618.00	285.00	1379.00	215.00	333.00	881.00	584.00	1440.00	47.00	348.00	286.00	99.00
Ba	67.00	55.00	958.01	1068.01	413.00	87.00	609.00	750.00	29.00	302.00	17.00	66.00	16.00	161.00	113.00
P	78.00	87.00	97.00	104.00	140.00	73.00	128.00	71.00	72.00	64.00	61.00	85.00	519.00	65.00	61.00
Sample	BN-180	BN-181	BN-182	BN-183	BN-184	BN-185	BN-186	BN-187	BN-188	BN-189	BN-190	BN-191	BN-192	BN-193	BN-194
SiO ₂	53.00	9.50	55.80	47.40	9.10	1.30	43.60	43.60	52.20	5.90	48.20	19.00	44.90	1.10	1.30

Al ₂ O ₃	17.90	6.20	20.60	13.60	3.40	0.60	22.20	5.60	16.70	2.20	8.90	6.80	12.80	0.40	0.50
Fe ₂ O ₃	4.80	7.60	1.40	1.80	0.90	3.40	2.50	2.30	6.50	2.20	16.20	4.20	6.40	2.40	1.70
Na ₂ O	3.20	0.10	1.70	0.30	0.30	0.10	0.70	0.40	3.20	0.20	4.20	0.80	1.70	0.10	0.10
K ₂ O	7.80	1.80	11.10	11.40	0.90	0.10	9.20	4.90	1.20	0.90	3.70	3.20	8.20	0.10	0.10
CaO	6.50	39.50	3.70	13.10	47.60	46.40	10.90	23.20	8.00	48.00	10.10	37.50	15.10	52.80	53.20
MgO	0.40	0.90	1.00	0.40	8.00	4.40	0.40	0.40	1.20	0.90	0.10	0.30	0.30	0.20	0.10
TiO ₂	0.30	0.10	0.10	1.20	0.10	0.10	0.10	0.40	0.30	0.10	0.50	0.10	0.20	0.10	0.10
P ₂ O ₅	0.10	0.10	0.10	0.20	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
A.Z	5.40	33.30	3.80	8.70	36.70	43.45	9.90	13.00	9.90	39.00	6.95	27.40	9.80	42.00	42.35
MnO	0.10	0.90	0.10	0.20	0.10	0.20	0.10	0.30	0.20	0.60	0.30	0.50	0.20	0.70	0.60
Y	122.00	48.00	38.00	153.00	106.00	32.00	61.00	1152.03	103.00	37.00	131.00	101.00	76.00	43.00	17.00
La	266.99	17.00	110.00	343.99	67.00	39.00	17.00	1420.97	264.99	54.00	183.00	70.00	160.00	17.00	15.00
Ce	380.45	15.26	163.05	434.80	72.47	76.28	24.79	1572.32	373.77	61.02	187.84	80.09	237.42	16.21	17.16
Pr	37.00	2.00	15.00	33.00	8.00	6.00	2.00	113.00	46.00	6.00	15.00	9.00	21.00	2.00	2.00
Nd	63.00	8.00	35.00	100.00	31.00	21.00	9.00	377.99	98.00	16.00	38.00	26.00	74.00	10.00	7.00
Sm	8.00	2.00	5.00	17.00	4.00	3.00	2.00	51.00	15.00	3.00	6.00	5.00	12.00	2.00	1.00
Eu	2.00	0.50	1.00	3.00	1.00	1.00	0.50	9.00	2.50	0.50	1.10	1.00	2.10	0.50	0.30
Gd	12.00	3.00	6.00	19.00	6.00	4.00	3.00	74.00	19.00	4.00	10.00	7.00	17.00	3.00	2.00
Tb	1.00	1.00	1.00	2.00	1.00	1.00	1.00	11.00	2.00	0.50	1.40	1.00	1.60	0.50	0.20
Dy	10.00	4.00	4.00	14.00	6.00	4.00	5.00	91.00	14.00	4.00	13.00	9.00	11.00	5.00	2.00
Ho	2.00	1.00	1.00	3.00	1.00	1.00	1.00	27.00	2.40	0.90	2.70	1.90	2.00	0.90	0.40
Er	8.00	3.00	3.00	10.00	5.00	2.00	4.00	107.00	7.10	2.80	9.30	6.40	5.90	2.80	1.20
Tm	1.00	0.50	0.50	2.00	1.00	0.50	1.00	14.00	0.90	0.40	1.40	0.80	0.80	0.30	0.20
Yb	7.00	2.00	2.00	11.00	3.00	2.00	3.00	95.00	4.80	2.30	8.30	4.40	4.40	1.70	0.80
Lu	1.00	0.50	0.50	1.00	0.50	0.50	0.50	8.00	0.40	0.20	0.80	0.40	0.40	0.20	0.10
Sc	0.50	0.50	0.50	0.50	1.00	0.50	0.50	1.00	0.30	0.50	0.40	0.20	0.20	0.30	0.20
ΣNTEO	921.94	108.26	385.55	1147.29	313.97	193.78	135.29	5124.32	954.17	193.12	609.24	323.20	625.82	105.41	66.56
Th	296.00	16.00	95.00	61.00	9.00	33.00	12.00	1161.00	107.00	12.00	123.00	31.00	64.00	3.00	4.00
U	25.06	5.01	9.02	9.02	2.00	6.01	5.01	188.45	9.02	32.08	44.10	8.02	12.03	7.02	5.01
Ta	14.00	0.50	4.00	4.00	1.00	1.00	0.50	121.00	9.00	0.90	4.00	1.00	9.00	0.10	0.10
Zr	240.99	209.00	281.99	462.99	61.00	104.00	41.00	14146.7	919.98	260.99	3632.92	388.99	1042.98	820.98	53.00
Cs	1.00	1.00	1.00	4.00	1.00	4.00	0.50	2.00	7.00	0.50	0.80	3.00	2.00	0.30	0.40
Hf	3.00	1.00	2.00	2.00	1.00	1.00	0.50	111.00	5.00	1.00	20.00	2.00	9.00	1.00	0.20
Nb	513.01	7.00	145.00	684.01	24.00	45.00	4.00	1499.03	310.01	30.00	234.00	48.00	200.00	16.00	5.00
Rb	358.94	69.92	583.87	926.50	47.78	476.65	11.65	617.66	149.17	43.12	229.58	166.65	447.52	4.66	4.66
Be	8.00	11.00	9.00	5.00	2.00	13.00	2.00	16.00	15.00	3.00	6.00	8.00	6.00	4.00	2.00
Ge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50	0.70	4.30	1.10	2.00	0.70	0.50
Ga	39.00	18.00	36.00	29.00	6.00	30.00	2.00	13.00	49.00	7.00	44.00	21.00	33.00	13.00	11.00
Ni	3.00	4.00	4.00	2.00	6.00	4.00	41.01	5.00	15.00	6.00	2.00	7.00	5.00	7.00	8.00
Li	98.99	161.99	300.98	5156.59	55.00	688.95	168.99	171.99	640.95	45.00	327.97	82.99	384.97	7.00	10.00
Sr	167.00	333.00	112.00	149.00	172.00	246.00	598.00	218.00	67.00	461.00	77.00	219.00	53.00	374.00	402.00
Ba	302.00	84.00	316.00	686.00	82.00	271.00	147.00	196.00	120.00	118.00	99.00	270.00	144.00	569.00	525.00
P	100.00	53.00	120.00	673.00	56.00	64.00	92.00	172.00	294.00	320.00	447.00	308.00	227.00	236.00	291.00

Sample	BN-202	BN-203	BN-204	BN-205	BN-206	BN-207	BN-208	BN-209	BN-210	BN-211	BN-212	BN-213	BN-214	BN-215	BN-216	BN-217
SiO ₂	60.40	58.10	56.20	58.40	64.40	68.90	45.40	49.70	0.90	59.80	56.60	57.70	55.10	55.20	42.50	59.60
Al ₂ O ₃	15.20	20.00	10.60	19.80	16.20	17.60	12.70	6.90	0.30	19.40	19.40	21.20	20.30	18.50	15.40	20.30
Fe ₂ O ₃	4.30	2.60	8.50	6.30	0.30	1.70	20.30	24.60	2.40	3.90	6.20	5.60	5.60	6.60	3.20	4.20
Na ₂ O	5.70	3.20	6.10	3.00	1.50	9.90	3.00	5.30	0.10	6.30	2.70	2.50	2.70	2.50	2.00	3.10
K ₂ O	4.70	3.50	3.40	4.20	13.50	0.40	5.50	4.60	0.10	5.40	4.00	5.20	3.30	4.40	3.90	4.50
CaO	1.30	4.00	6.60	1.40	2.10	0.20	5.60	5.50	52.50	0.80	3.60	1.50	4.40	4.60	17.60	2.10
MgO	0.40	0.80	0.10	0.70	0.10	0.10	0.30	0.10	0.30	0.30	0.70	0.30	0.50	0.60	0.30	0.70
TiO ₂	0.60	0.30	0.70	0.30	0.10	0.10	0.20	0.40	0.10	0.10	0.10	0.20	0.20	0.20	0.10	0.10
P ₂ O ₅	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
A.Z	2.15	6.65	4.95	5.25	1.70	0.80	6.30	2.50	42.90	3.50	6.20	5.20	7.45	6.80	14.45	4.95
MnO	0.60	0.20	0.40	0.10	0.10	0.10	0.20	0.30	0.50	0.20	0.10	0.10	0.10	0.20	0.20	0.10
Y	271.01	164.00	13.00	118.00	4.00	71.00	123.00	11.00	71.00	19.00	36.00	101.00	74.00	74.00	75.00	72.00
La	1062.98	686.98	30.00	563.99	11.00	431.99	528.99	6.00	8.00	88.00	89.00	457.99	211.00	173.00	92.00	175.00
Ce	1800.21	1036.46	47.68	778.06	14.30	676.03	543.50	7.63	5.72	79.14	147.79	656.96	250.77	249.82	151.61	346.12
Pr	201.00	106.00	5.00	82.00	1.00	81.00	52.00	1.00	1.00	7.00	14.00	71.00	25.00	25.00	19.00	33.00
Nd	473.99	259.00	13.00	254.00	5.00	209.00	159.00	3.00	4.00	17.00	39.00	221.00	47.00	66.00	47.00	104.00
Sm	60.00	33.00	2.00	33.00	1.00	26.00	27.00	1.00	1.00	2.00	6.00	28.00	7.00	10.00	8.00	17.00
Eu	9.60	5.40	0.30	5.30	0.20	3.80	4.50	0.10	0.30	0.50	1.10	4.40	1.10	1.80	1.50	2.90
Gd	79.00	44.00	2.00	41.00	1.00	29.00	34.00	1.00	2.00	3.00	8.00	35.00	10.00	14.00	11.00	21.00
Tb	7.40	4.20	0.30	3.80	0.10	2.30	3.00	0.10	0.50	0.40	0.90	3.40	1.00	1.50	1.40	2.20
Dy	50.00	28.00	2.00	23.00	1.00	13.00	19.00	1.00	6.00	3.00	7.00	22.00	8.00	11.00	11.00	15.00
Ho	8.50	4.50	0.40	3.60	0.10	1.90	3.10	0.20	1.70	0.50	1.20	3.50	1.70	1.90	2.00	2.30
Er	25.40	12.40	1.10	9.50	0.40	5.00	9.10	0.80	7.00	1.60	3.50	9.20	5.90	5.70	5.90	6.20
Tm	3.10	1.40	0.20	1.00	0.10	0.50	1.10	0.10	1.20	0.20	0.50	1.00	0.90	0.70	0.70	0.70
Yb	16.10	6.60	1.30	5.10	0.20	2.60	6.30	1.10	7.30	1.50	2.70	5.00	6.30	3.80	3.60	3.30
Lu	1.40	0.50	0.20	0.50	0.10	0.20	0.60	0.20	0.70	0.20	0.30	0.50	0.60	0.40	0.30	0.30
Σ	0.30	0.20	0.20	0.40	0.20	0.20	0.20	0.10	0.20	0.30	0.20	0.20	0.30	0.20	0.20	0.20
ΣNTEO	4069.99	2392.64	118.67	1922.24	39.70	1553.52	1514.39	34.33	117.62	223.34	357.19	1620.15	650.57	638.81	430.21	801.22
Th	249.00	277.00	8.00	179.00	6.00	177.00	61.00	4.00	23.00	83.00	32.00	170.00	186.00	82.00	31.00	51.00
U	652.55	68.16	2.00	10.02	3.01	3.01	32.08	1.00	3.01	12.03	6.01	5.01	10.02	9.02	6.01	6.01
Ta	197.99	36.00	2.00	9.00	1.00	1.00	2.00	0.50	0.10	3.00	4.00	8.00	6.00	9.00	3.00	6.00
Zr	2331.95	277.99	491.99	414.99	11.00	56.00	233.00	261.99	97.00	372.99	467.99	529.99	827.98	483.99	371.99	240.99
Cs	7.00	17.00	3.00	10.00	11.00	0.70	4.00	3.00	0.10	15.00	2.00	98.00	2.00	17.00	4.00	11.00
Hf	15.00	2.00	4.00	3.00	0.10	0.30	1.00	2.00	0.20	2.00	3.00	4.00	5.00	4.00	2.00	2.00
Nb	444.08	864.01	377.01	244.00	29.00	45.00	175.00	31.00	4.00	111.00	95.00	192.00	204.00	190.00	81.00	130.00
Rb	264.74	279.70	574.54	340.30	1388.00	11.65	348.46	383.42	1.17	277.37	318.16	502.29	273.87	390.41	240.07	306.50
Be	12.00	15.00	7.00	13.00	2.00	3.00	17.00	2.00	4.00	15.00	6.00	13.00	12.00	11.00	4.00	7.00
Ge	3.60	2.30	2.70	3.30	0.30	1.90	6.20	6.90	0.60	1.10	2.00	2.90	1.90	2.40	1.20	2.20
Ga	83.00	42.00	75.00	41.00	33.00	64.00	52.00	28.00	3.00	32.00	35.00	44.00	45.00	43.00	27.00	36.00
Ni	6.00	4.00	4.00	7.00	2.00	3.00	5.00	2.00	7.00	3.00	2.00	4.00	5.00	4.00	4.00	3.00
Li	131.99	181.99	9174.27	234.98	110.99	11.00	48.00	100.99	2.00	290.98	170.99	416.97	218.98	261.98	185.99	218.98
Sr	187.00	65.00	27.00	68.00	13.00	20.00	38.00	10.00	450.00	298.00	18.00	40.00	52.00	29.00	87.00	37.00
Ba	626.00	158.00	55.00	144.00	105.00	12.00	202.00	48.00	51.00	164.00	66.00	82.00	162.00	144.00	48.00	95.00
P	447.00	352.00	301.00	337.00	216.00	500.00	511.00	141.00	299.00	213.00	139.00	302.00	201.00	292.00	227.00	226.00