Chapter

Investigation of the Usability of Pseudoleucites in Central Anatolia Alkali Syenites as Industrial Raw Materials

Zeynel Başibüyük and Gökhan Ekincioğlu

Abstract

Pseudoleucite syenite is a magmatic rock, which is rarely found in the foidolite rock group. With respect to the compositions of similar alkali feldspars as sodium potassium aluminosilicates, feldspathoid minerals are normally characterized by silica deficiency. Pseudoleucite syenite formed from alkaline (sodium and potassium)-rich and silica-poor magmas. In this study, intrusion-related distributions, mineralogical and petrographical properties, and mineral chemistry of pseudoleucites in İsahocalı (Kırşehir) alkali syenites from Central Anatolia Granitoids have been investigated, and magnetic enrichment processes have been carried out on their crushed and grinded samples. As a result of the enrichment of pseudoleucite syenites with a high amount of K_2O + Na_2O (12.25 + 5.61 wt.%), via dry magnetic separator, the obtained data demonstrated that pseudoleucites in İsahocalı Alkali syenites can be used as industrial raw material in sectors such as ceramics, agriculture, cement industries, etc.

Keywords: usability of pseudoleucite, industrial raw material, ceramics, İsahocalı alkali syenites, Kırşehir, Central Anatolia

1. Introduction

Leucite is a rock-forming mineral composed of potassium and aluminum tectosilicate $K[AlSi_2O_6]$. Its crystals have the form of tetragonal but it is isotropic, because of its pseudocubic system [1]. Pseudoleucites are intergrowths of two or more minerals: leucite, nepheline, and K-feldspar; nepheline and feldspar; or analcite, nepheline, and feldspar; or alteration products of these, thought to be pseudomorphing leucite in igneous rocks [2].

In the Central Anatolia Granitoids, studied pseudoleucite syenites, which are feldspathoid igneous rocks, appear as light colored, coarse crystalline, and compositionally silica-poor. They can also be classified as foid syenite, consisting of pseudoleucite (leucite + nepheline + orthoclase) and aegerine-augite minerals.

Recent studies have shown that foid syenitic rocks containing feldspathoid minerals can be used as starting materials for the production of glass, ceramics, and paint. The lack of free silica, high alkaline and alumina content, high melting power, and narrow melting range of foid syenites are the properties that are desired in the glass industry. In addition, they provide high resistance to weather conditions, as well as the use of roof particles, road materials, stone pavements, as well as concrete aggregate and asphalt production. Other potential use areas are artificial fertilizer, refractory, cement mortar, and paper [3, 4].

The İsahocalı (Kırşehir) area in Central Anatolia includes pseudoleucite syenites. Such alkaline syenite intrusions in the region, which is the main objective of this study, offer irregularly shaped outcrops reaching up to 1 km^2. In the vicinity of the study area, there are also nephelite syenites, which are produced by B & S Invest CO. B & S Invest CO, via magnetic enrichment operations. After the magnetic enrichment, the iron-containing minerals are removed and the sodium and potassium-rich industrial raw materials are marketed to the ceramic industry.

The aim of this study is to investigate the usability of sodium- and potassium-rich pseudoleucites in İsahocalı (Kırşehir) alkali syenites from the Central Anatolia Granitoids.

2. Materials and methods

In this study, the spread of pseudoleucite syenites in the İsahocalı (Kırşehir) area has been mapped. Then samples were taken from these intrusions for laboratory studies. In order to determine the mineralogical and petrographic properties of the pseudoleucite syenites samples obtained from the field, thin sections were prepared in the Thin Section Laboratory of the Department of Geological Engineering of the Engineering Faculty of the University of Ahi Evran.

Pseudoleucite syenite samples were grinded by a crusher and ball mill at B&S Yatırım AŞ laboratory. As the enrichment method, magnetic enrichment was carried out to remove the iron-bearing minerals in the grinded samples. The chemical analyses of the samples were carried out by the XRF-method before and after enrichment studies. As a result of chemical analysis, their sodium, potassium, and iron values were compared.

3. Geology

The Central Anatolia, in which the study area is located, consists of several continental blocks separated from each other by ophiolitic suture zones (**Figure 2**). These tectonic belts are, from the north to the south, Pontid Continent, Intra-Pontide suture, Sakarya Continent, Ankara-Yozgat-Erzincan suture (Central Anatolian Metamorphites), and the Kırşehir Continent (Central Anatolian Metamorphics) (**Figure 1**), and the continental blocks developed as a result of Pan-African, Hercynian, and Cimmerian orogenies and remained as the continental basement during the Neo-Tethyan evolution [5]. The Neo-Tethys Ocean was opened by rifting of these continental bases along two lines in Lias, so that the Intra-Pontid and Ankara-Yozgat-Erzincan Ocean branches developed [6]. At the beginning of the Late Cretaceous, a subduction started along the entire Pontide belt [6]; in other words, the northern branch of Neo-Tethys began to subduct under the Pontide. During this period, the greatest ophiolitic nappes including Refahiye Complex, which is the oldest unit of the study area, was settled on Anatolide-Tauride continent [6, 7]. In the Paleocene-Early Eocene, the northern branch of the Neo-Tethys was completely closed and the continent-continent collision [6] took place [8].

The oldest level in the study area consists of Paleozoic Middle Anatolian Metamorphics consisting of schist, gneiss, amphibolite, and marbles. Seymen (1981)

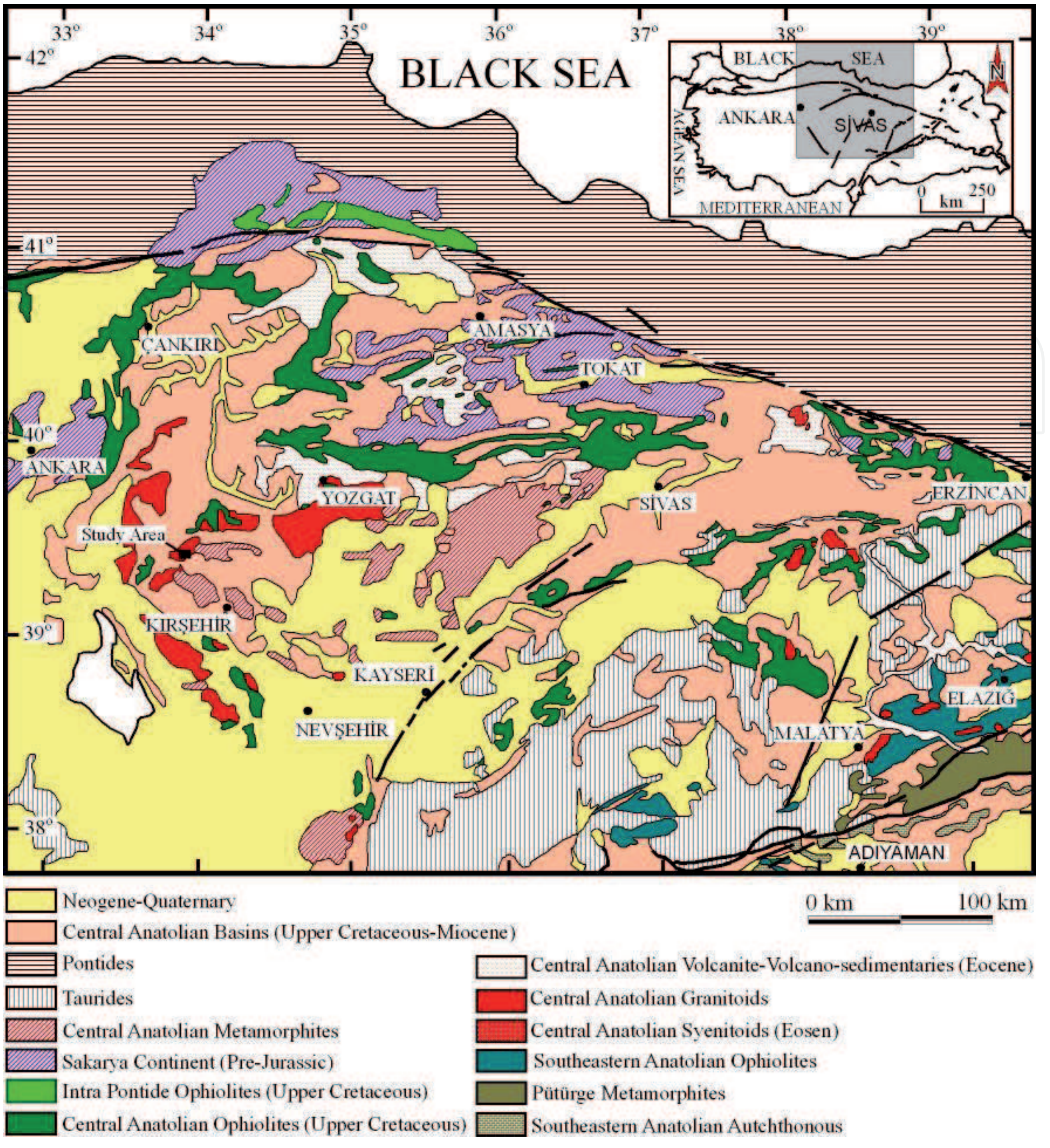

Figure 1.
The regional geological map of the study area [7–11].

divided the unit into three formations in his study [12]. These are from the old to the young, Kalkanlıdağ, Tamadağ, and Bozçaldağ formations. In the Upper Cretaceous, the Central Anatolian Volcanites with dacite-rhyolite-rhyodacite composition and the Upper Cretaceous-Paleocene granite-syenite-monzonite composition of the Central Anatolian Granitoids were cut by coeval units. All these units are unconformably overlain by Lower-Middle Eocene-Quaternary sedimentary units (**Figure 2**).

The igneous rocks in the region and its vicinity are defined as Central Anatolian Granitoids by Erler and Bayhan (1995) [13]. These rocks with granite, syenite, and monzonite composition are Upper Cretaceous-Paleocene aged [14, 15]. Central Anatolian Metamorphics and Central Anatolian Granitoids are covered by Eocene—Quaternary aged, marine, and terrestrial rock units. These units consist of alternation of conglomerate, sandstone, siltstone, claystone, limestone, and occasionally tuff and gypsiferous levels, from old to young, formations defined as Baraklı Formation, Arzilar Limestone Member, Meşeköy Formation, Kozaklı Limestone Member, Kızılırmak Formation, travertine, and alluvium [15–17].

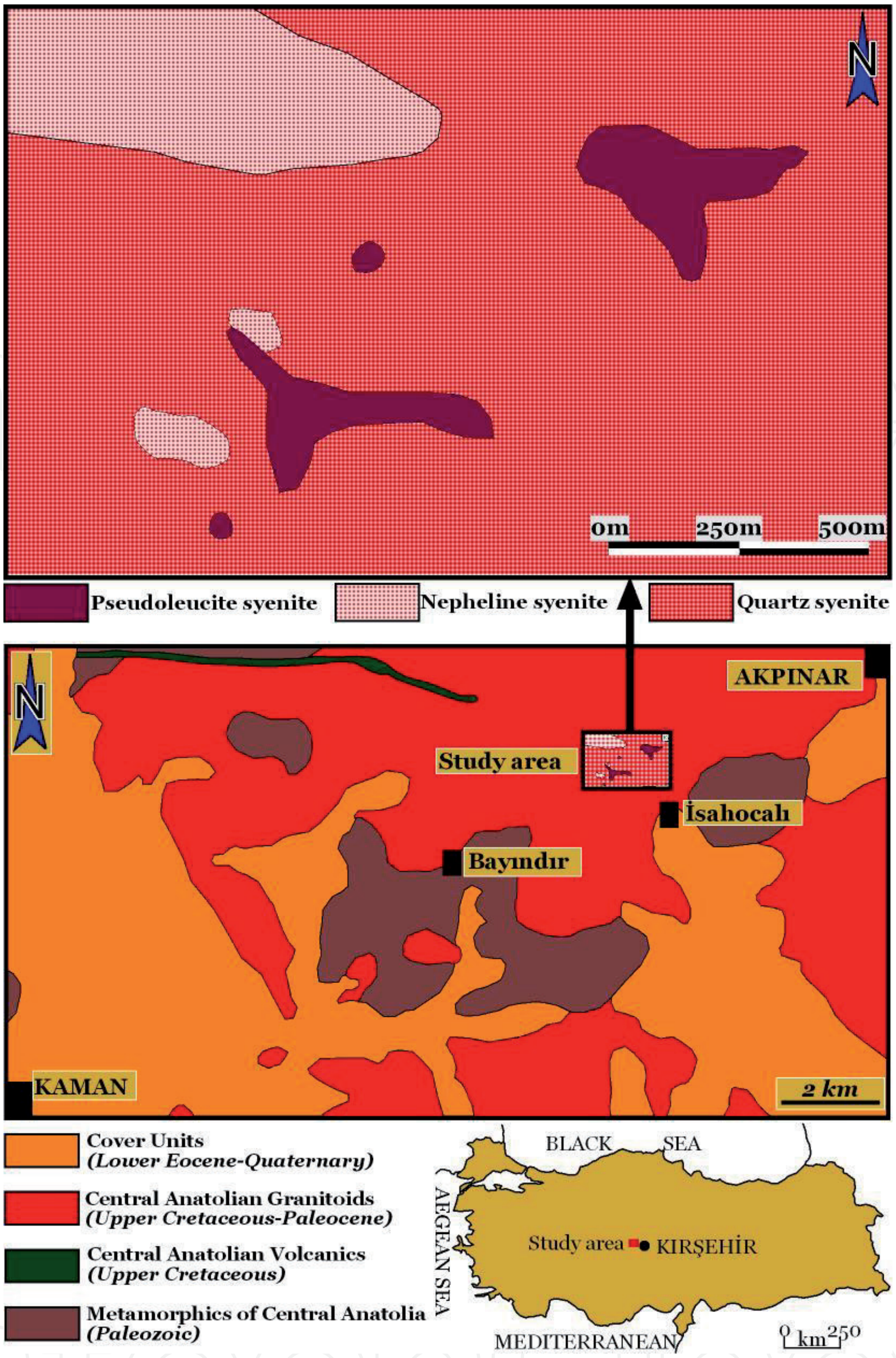

Figure 2.
Geological map of the study area [16].

4. Findings

4.1 Field studies

İsahocalı (Kırşehir) pseudoleucite syenites [18] in Central Anatolian Granitoids are spread along a line extending in the NE–SW direction in the region. They are topographically exposed at the high level of the area. The units have a hard, compact, and massive structure and do not contain alteration. Two dominant colors of intrusions are distinct in the region. At the southwest (SW) end of the study area, they appear as darker color due to the enrichment in the mafic mineral contents, whereas in other locations they have lighter color due to the decrease in mafic mineral content (**Figure 3**). The cooling cracks are also observed in the unit (**Figure 4**).

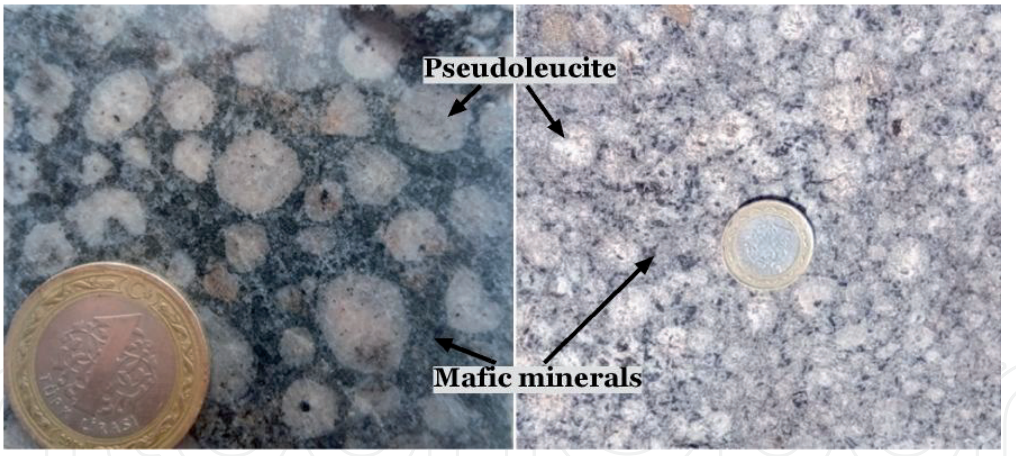

Figure 3.
Pseudoleucite syenite different color selections observed depending on the mafic mineral contents.

Figure 4.
Cooling cracks observed in pseudoleucite syenites.

4.2 Laboratory works

Within the scope of laboratory studies, İsahocalı (Kırşehir) pseudoleucite syenite samples (**Figure 5**) have been processed in the Materials and methods section. The data obtained are given in mineralogical petrographic investigations and ore preparation and enrichment processes.

4.2.1 Mineralogical petrographic investigations

The leucite mineral is derived from magmas with high potassium and low silica contents. It is a typical magmatic mineral, which solidifies as late stage crystals. On the other hand, pseudoleucite generally coexists with potassium feldspar, nepheline, and small amounts of sodalite, kankrinite, and/or zeolite. At the same time, pseudoleucite is defined as a collection of crystals in both volcanic and plutonic rocks showing a leucite crystal structure [19, 20]. As a result of thin section studies, the rock with holocrystalline hypidiomorphic granular texture in the study area, pseudoleucite (leucite + nepheline + orthoclase), aegirine, aegirinaugite, and opaque minerals were determined (**Figures 6** and 7).

At the same time, opacification-type alterations were observed in mafic minerals. According to its mineralogical contents, rock is named foid syenite, which is defined in foidolite rock group from feldspathoid rocks (**Figure 8**).

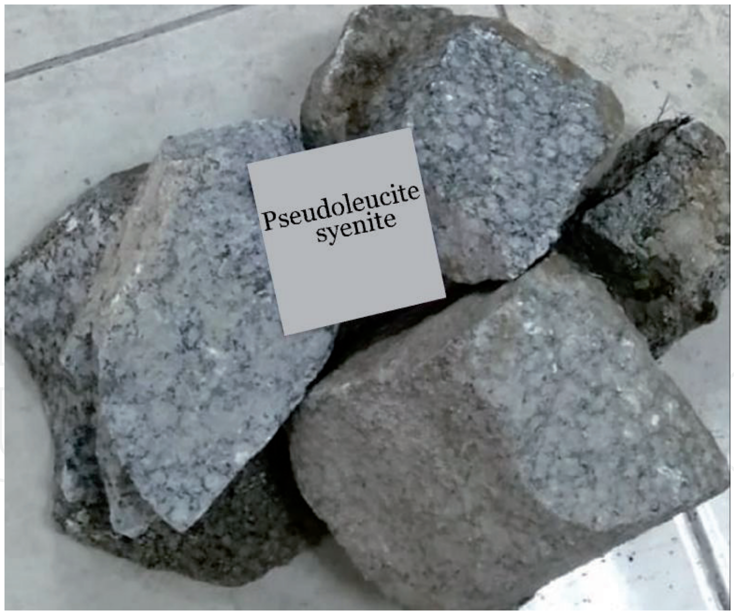

Figure 5.
View of pseudoleucite samples taken from land.

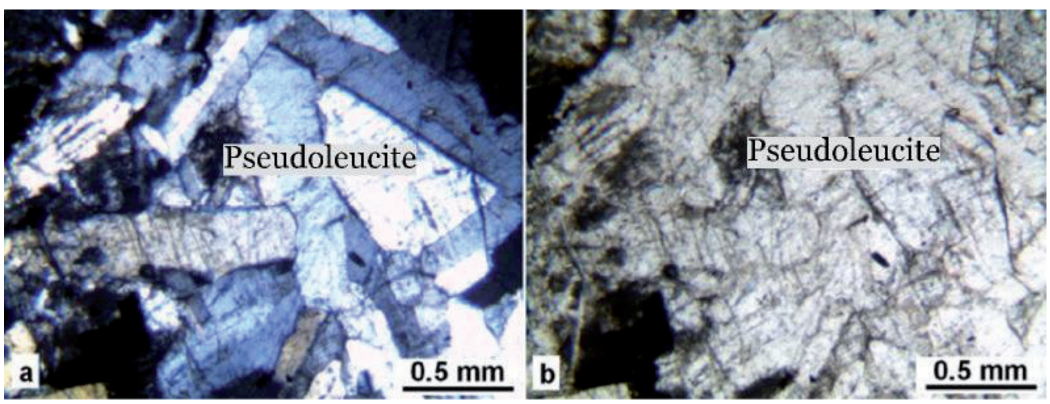

Figure 6.
Leucious prismatic leucite, nepheline, and orthoclase minerals in pseudoleucite.

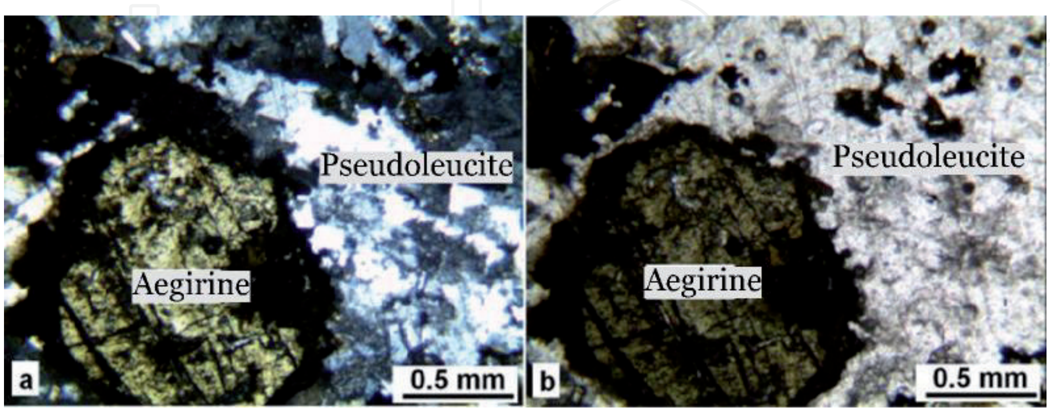

Figure 7.
Euhedral aegirine mineral in pseudoleucite syenite rock.

Similarly, according to the results of chemical analysis (**Table 1**), the rock is classified in the total alkali silica (TAS) diagram. According to the TAS diagram, the analyzed sample with 56.52 wt.% SiO_2 and 15.71 wt.% Na_2O + K_2O contents is plotted in the field of foid syenites (**Figure 9**).

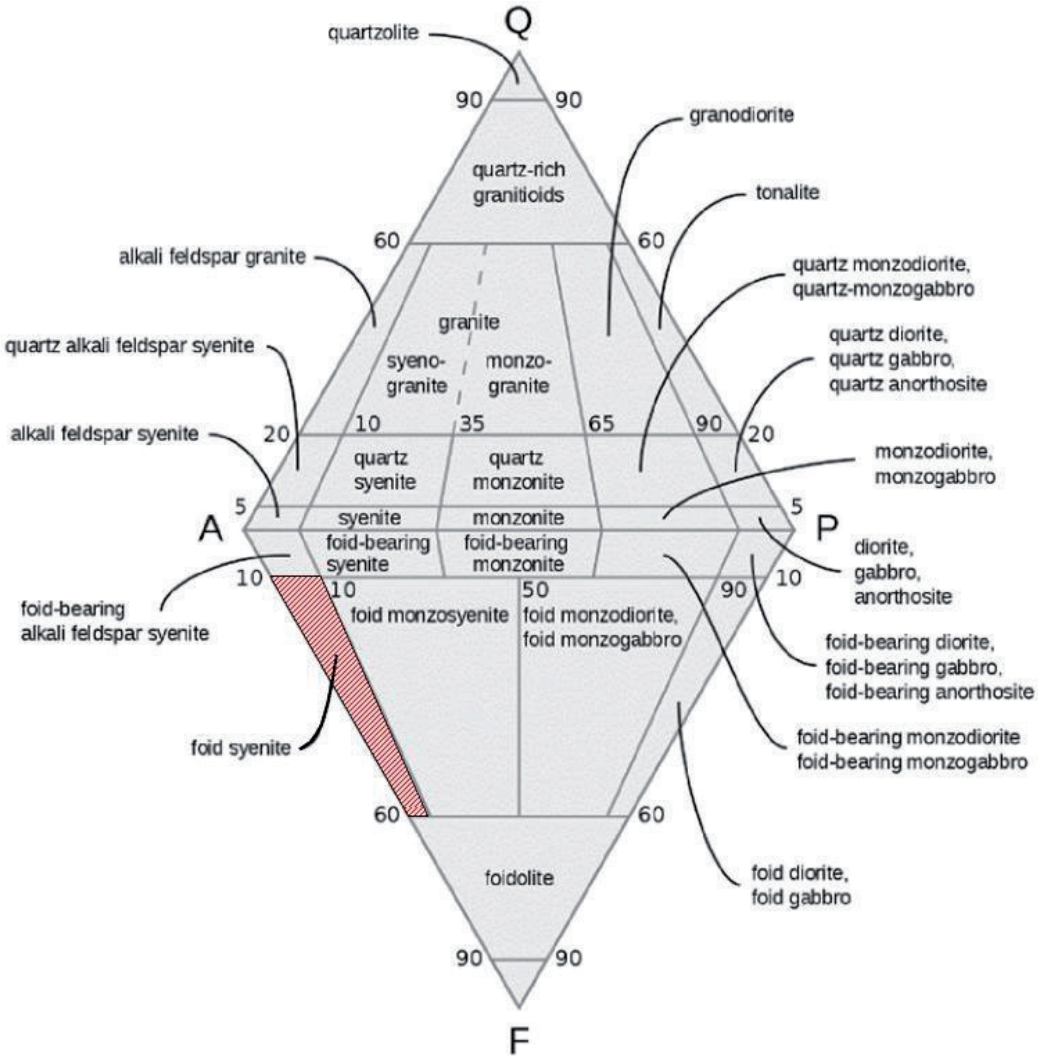

Figure 8.
Modal QAPF classification of magmatic rocks [21].

Chemical content (wt.%)		
	Before enrichment %	**After enrichment %**
SiO_2	56.52	57.54
Al_2O_3	21.01	21.56
K_2O	11.13	12.24
Fe_2O_3	3.11	0.43
CaO	2.02	1.03
Na_2O	4.58	5.61
MgO	0.26	0.04
TiO_2	0.21	0.09
MnO	0.004	0.001
LOI	1.12	1.27

Table 1.
Results of chemical analysis (wt.%) of studied samples.

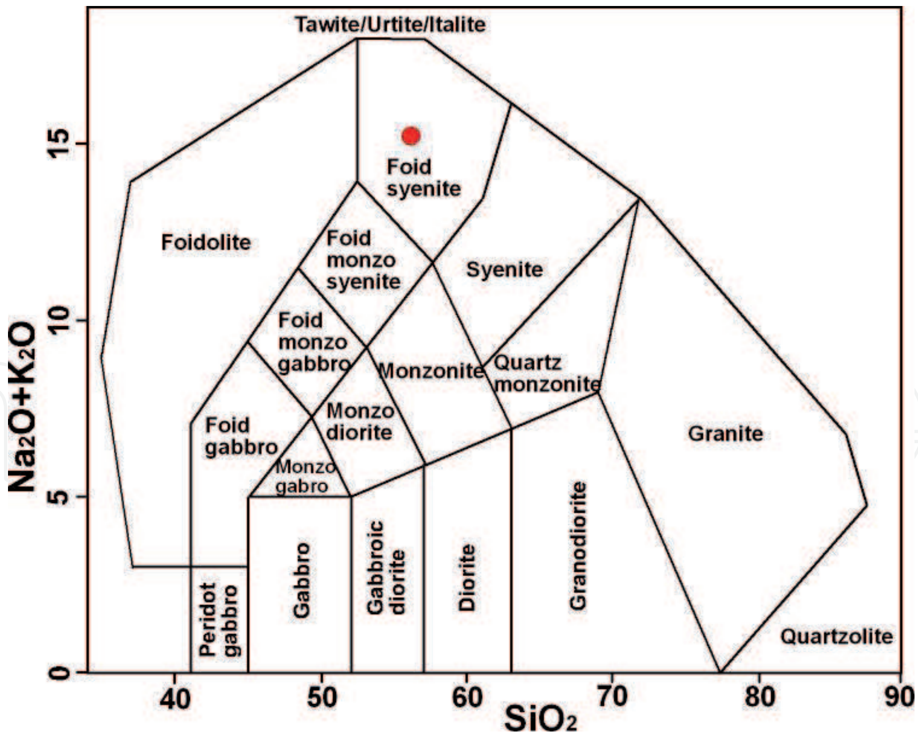

Figure 9.
TAS diagram of analyzed sample in magmatic rock classification [23].

Bayhan conducted investigations around the study area and stated that the mineralogical composition of the alkaline igneous rocks in the region was formed by orthoclase, plagioclase, leucite, nozean, nepheline, cancrinite, aegirinaugite, amphibole, and biotite minerals [22]. We concluded that converting of leucite, nepheline, and orthoclase minerals form euhedral pseudoleucite crystals in these intrusions.

4.2.2 Ore preparation and enrichment processes

4.2.2.1 Sample preparation

Within the scope of this study, approximately 40 kg of sample was provided to represent the study area. Pseudoleucite syenite samples brought to the laboratory were reduced to less than −1 mm size using jaw and hammer crushers. The appearance of the obtained samples after size reduction operations is given in **Figure 10**.

After crushing operations, sample reduction operations were carried out. Then, magnetic enrichment experiments were performed. The appearance of the product obtained after magnetic enrichment is given in **Figure 11**.

4.2.2.2 Magnetic enrichment

Magnetic separation experiments were carried out by Aksa Magnet magnetic separator with 9000 Gauss. The enrichment process was carried out under dry conditions. Magnetic separation was carried out once in the magnetic separator with 5000 gr sample. Then, 2470 gr pseudoleucite concentration was obtained. Chemical analysis of these samples was performed by the Oxford Instruments X-Supreme brand XRF device before and after magnetic separation processes. The results of the analysis are given in **Table 1**.

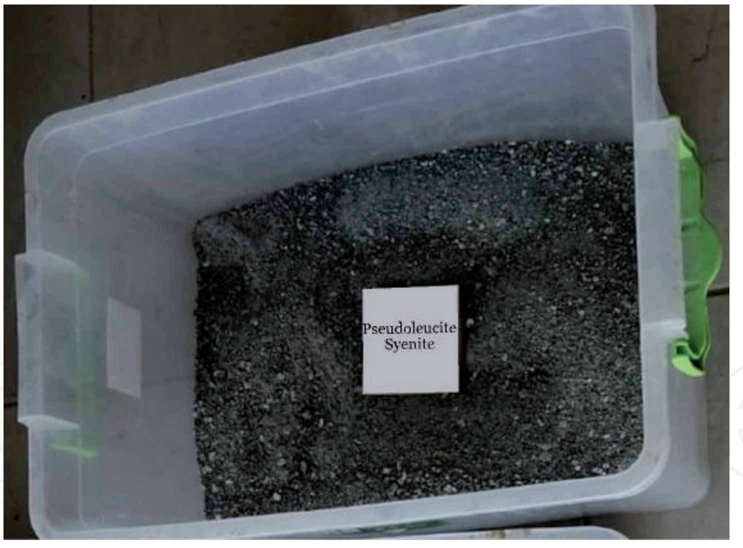

Figure 10.
The appearance of the obtained samples after size reduction operations.

Figure 11.
The appearance of the product obtained after magnetic enrichment.

5. Results

In this study, the usability of pseudoleucites in alkali syenites from İsahocali region (Kırşehir) in Central Anatolia as a raw material in glass and ceramics sectors has been investigated. Within the scope of the study, approximately 40 kg of sample was provided to represent the studied intrusions. Pseudoleucite syenite samples were reduced to less than −1 mm size using jaw and hammer crushers. After crushing and grinding processes, magnetic enrichment experiments were performed. For this purpose, the samples were subjected to magnetic separation process in the dry magnetic separator. $Na_2O + K_2O$ (15.71 wt.%) and Fe_2O_3 (3.11 wt.%) contents were determined in pseudoleucite syenites prior to the magnetic enrichment process. In terms of the analytical result performed after enrichment processes, their $Na_2O + K_2O$ contents increased (17.76 wt.%) and Fe_2O_3 content (0.43 wt.%) decreased. It was observed that the iron-containing minerals could be removed after the separation process.

We claimed that high concentrations of iron minerals in İsahocalı (Kırşehir) pseudoleucite syenites can easily remove via magnetic enrichment processes under optimum enrichment conditions. It is suggested that the concentrated $Na_2O + K_2O$-rich product obtained after magnetic enrichment can be added to the economy as a high quality product and can be used in different sectors of industry with the necessary tests and investigations. The nepheline syenites produced in the Kırşehir region are used in cement and ceramic industry [23, 24]. More detailed tests on the availability of pseudoleucite syenites in the glass and ceramics industry are recommended.

Acknowledgements

The authors would like to thank BS Investment Inc. for their support in carrying out this study.

Conflict of interest

The authors declare no conflict of interest.

Author details

Zeynel Başibüyük[1] and Gökhan Ekincioğlu[2]*

1 Department of Geological Engineering, Faculty of Engineering and Architecture, Kırşehir Ahi Evran University, Kirşehir, Turkey

2 Department of Mining and Mineral Extraction, Kaman Vocational School, Kırşehir Ahi Evran University, Kirşehir, Turkey

*Address all correspondence to: gokhanekincioglu@gmail.com

References

[1] Karakaya Çelik M, Mineraloji Ö. Bizim Büro; 1993. p. 276 (in Turkish)

[2] Hesselbo SP. Pseudoleucite from the Gardar of South Greenland. Bulletin of the Geological Society of Denmark. 1986;**35**:11-17

[3] VT ML. Nepheline Syenite. In: Kogel JE, Trivedi NC, Barker JM, Krukowski ST, editors. Industrial Minerals & Rocks. 7th ed. Colorado: Published by Society for Mining, Metallurgy, and Exploration, Inc.; 2006. pp. 653-670

[4] Haner S, Demir M. Nefelinli Siyenit: Bir Gözden Geçirme. Jeoloji Mühendisliği Dergisi. 2018;**42**(1): 107-120 (in Turkish)

[5] Tüysüz O. Karadeniz'den orta anadolu'ya bir jeotravers: Kuzey neo-tetisin tektonik evrimi. Türkiye Petrol Jeolojları Derneği Bülteni. 1993;**5**:1-33 (in Turkish)

[6] Şengör AMC, Yılmaz Y. Tethyan evolution of Turkey: A plate tectonic approach. Tectonophysics. 1981;**75**:181-241

[7] Göncüoğlu MC, Dirik K, Kozlu H. Pre-alpine and alpine Terranes in Turkey: Explanatory notes to the Terrane map of Turkey. Ed.D. Papanikolaou, F.P. Sassi, IGCP project No:276 final volume: Terrane maps and Terrane descriptions. Annales Géologiques Des Pays Helléniques. 1997;**37**:515-536

[8] Başıbüyük Z, Yalçın H. Minerology, petrography and origin of hydrothermal alteration in eocene magmatites in central anatolia (Sivas-Turkey). Bulletin of The Mineral Research and Exploration. 2019;**158**:143-166

[9] Bingöl E. 1/2.000.000 ölçekli Türkiye Jeoloji Haritası. Maden Tetkik ve Arama Yayını, Ankara; 1989 (in Turkish)

[10] Tüysüz O, Karadeniz'den Orta Anadolu'ya Bir Jeotravers: Kuzey Neo-Tetisin Tektonik Evrimi. Türkiye Petrol Jeolojları Derneği Bülteni. 1993;**5**:1-33. (in Turkish)

[11] Görür N, Tüysüz O, Şengör AMC. Tectonic evolution of the Central Anatolian Basins. International Geology Review. 1998;**40**:831-850

[12] Seymen İ. Kaman (Kırşehir) dolayında Kırşehir masifinin stratigrafisi ve metamorfizması. TJK Bülteni. 1981;**24**(2):101-108 (in Turkish)

[13] Erler A, Bayhan H. Orta anadolu granitoidlerinin genel değerlendirilmesi ve sorunlari. Hacettepe Üniversitesi Yerbilimleri. 1995;**17**:49-67

[14] Otlu N. Kortundağ-Baranadağ Arası (D Kaman, KIRŞEHİR) Plütonik Kayaçlarının Petrolojik İncelenmesi; Cumhuriyet Üniversitesi Fen Bilimleri Enstitüsü; 1998 (in Turkish)

[15] Boztuğ D, Güney Ö, Heizler M, Jonckheer RJ, Tichomirowa M, Otlu N. 207Pb-206Pb,40Ar-39Ar and fission-track geothermochronology quantifying cooling and exhumation history of the Kaman-Kırşehir region intrusions, Central Anatolia, Turkey. Turkish Journal of Earth Sciences. 2009;**18**(1):85-108

[16] Kara H, Dönmez M. 1:100.000 ölçekli açınsama nitelikli Türkiye jeoloji Haritaları serisi, Kırşehir–G 17 paftası. MTA yayınları; 1990 (in Turkish)

[17] Otlu N, Boztuğ D. The coexistence of the silica oversaturated (ALKOS) and undersaturated alkaline (ALKUS) rocks in the Kortundağ and Baranadağ plutons from the central Anatolian alkaline plutonism, E Kaman/NW

Kırşehir, Turkey. Turkish Journal of Earth Sciences. 1998;**7**:241-257

[18] Ilbeyli N. Field, petrographic and geochemical characteristics of the Hamit alkaline intrusion in the central Anatolian crystalline complex, Turkey. Turkish Journal of Earth Sciences. 2004;**13**(3):269-286

[19] Deer WA, Howie RA, ve Russman J. Rock Forming Minerals. London: Longmans; 1965

[20] Lünel AT, Akman O. Hamitköy, Kaman, Kırşehir bölgesinde bulunan psodolosit oluşuğu ve basınç göstergesi olarak kullanımı. Maden Tetkik ve Arama Dergisi. 1985;**103**:103-104

[21] Streckeisen A. IUGS subcommission on the systematics of igneous rocks. Classification and nomenclature of volcanic rocks, lamprophyres, carbonatites, and melilite rocks. Recommendations and suggestions. Neues Jahrbuch für Mineralogie Abhandlungen. 1978;**134**:1-14

[22] Bayhan H. Geochemistry and genetic interpretation of alkaline rocks in the Bayındır-Akpınar (Kaman) area. Geological Bulletin of Turkey. 1988;**31**:59-70

[23] Le Maitre RW, Bateman P, Dudek A, Keller J, Lameyre J, Le Bas MJ, et al. Classification of Igneous Rocks and Glossary of Terms: Recommendations of the International Union of Geological Sciences Subcommission on the Systematics of Igneous Rocks. Oxford: Blackwell Scientific; 1989

[24] Kıymet D, Kadıoğlu YK. Nefelin siyenitlerin seramik sanayinde kullanılma potansiyeli: Buzlukdağ örneği. Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi. 2018;**24**(6):1209-1219