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Petrology of the Rocks Composing the Shuakhevi HPP Engineering Structure

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Abstract

The petrology of the rocks in the Adjaristskali River basin in the territory of Shuakhevi HPP engineering buildings has been studied. The petrographic, mineralogical and geochemical features of the rock material of the Middle Eocene Burnati and Kintrishi suites have been studied using both traditional and modern methods. This research confirmed that the mentioned suites are composed of basalt, andesite-basalt and trachybasalt tuffs, tuff-breccias and lavas. These rocks have been investigated for the first time from a geochemical point of view. They were established to be rocks of tholeiitic and calc-alkaline composition of high-K shoshonite origin. The rocks of both suites are characterized by boninitic composition, which is typical for the geodynamic conditions of young island arcs; their origin is related to back-arc tectonic conditions.

Keywords: Shuakhevi hydropower plant, Adjaristskali River, petrology, geochemistry

Introduction

The study area is located in the Adjara-Trialeti folded zone of the Lesser Caucasus fold system in the Adjaristskali River basin (Gamkrelidze, 2000). The basin is composed of volcanic-sedimentary rocks from the middle Eocene Burnati and Kintrishi suites. The engineering structures of the Shuakhevi HPP are located in the territory of these suites.

Petrographic and mineralogical studies of the rocks of the mentioned suites were performed in the last century for geological surveying, and the results are presented mainly as archival materials. The studies included only macroscopic and microscopic studies of rocks and minerals and analysis of the chemical composition of the material—only silicate analysis. However, no other kind of analytical research has been conducted within the framework of the abovementioned suites.

During the implementation of the Shuakhevi HPP project, a detailed study of the rocks in the HPP building area was needed. Our goal was to perform a complex study of the Burnati and Kintrishi volcanogenic-sedimentary suites. During geological field work and engineering-geological research, rich factual material was obtained, which was studied using both traditional and modern analytical equipment and methods. In addition to detailed petrographic and mineralogical studies, geochemical research has also been conducted. As a result, this work presents a detailed petrological characterization of the rocks composing the Kintrishi and Burnati suites.

Study Area

The research area, which covers ≈170 km2, is located in the mid-stream of the Adjariskali River gorge (right tributary of the Chorokhi River) (Fig. 1). It is structurally located in the central (axial) and southern subzones of the Adjara-Trialeti folded zone of the Lesser Caucasus fold system (Gamkrelidze, 2000). The geological study of the territory was carried out mainly in the first half of the twentieth century and included regional geological, geomorphological, hydrogeological and petrographic issues (Meffert, 1933; Gamkrelidze, 1949; Beliankin & Eremeev, 1935; Beliankin et al., 1935). On the basis of studies conducted in the 1960s and 1970s (Laliev et al., 1970; Zirakadze, 1967, 1969, 1973), three suites were distinguished in the Middle Eocene volcanic formations: 1. Zekari (≈1500 m), 2. Kintrishi (≈600-700 m) and 3. Burnati (≈400 m). The mentioned volcanogens are calc-alkaline rocks represented by andesite-basaltic tuffs, limburgites, trachytes, trachyandesites and trachybasalts. In the upper parts, massive tuff breccias, lavas, lava breccias and tuffs are also found (Lordkipanidze & Nadareishvili, 1964; Lordkipanidze & Zakariadze, 1974). Lordkipandze and Nadareishvili (1964) dated the mentioned suites to the Middle Eocene.

As a result of processing the literary materials found during the design of engineering structures of the Shuakhevi HPP, it was established that the petrography and mineralogy of the suites composing the territory of the project engineering buildings were studied only at the level of rock identification, and analytical studies were limited only to silicate analysis of rocks.

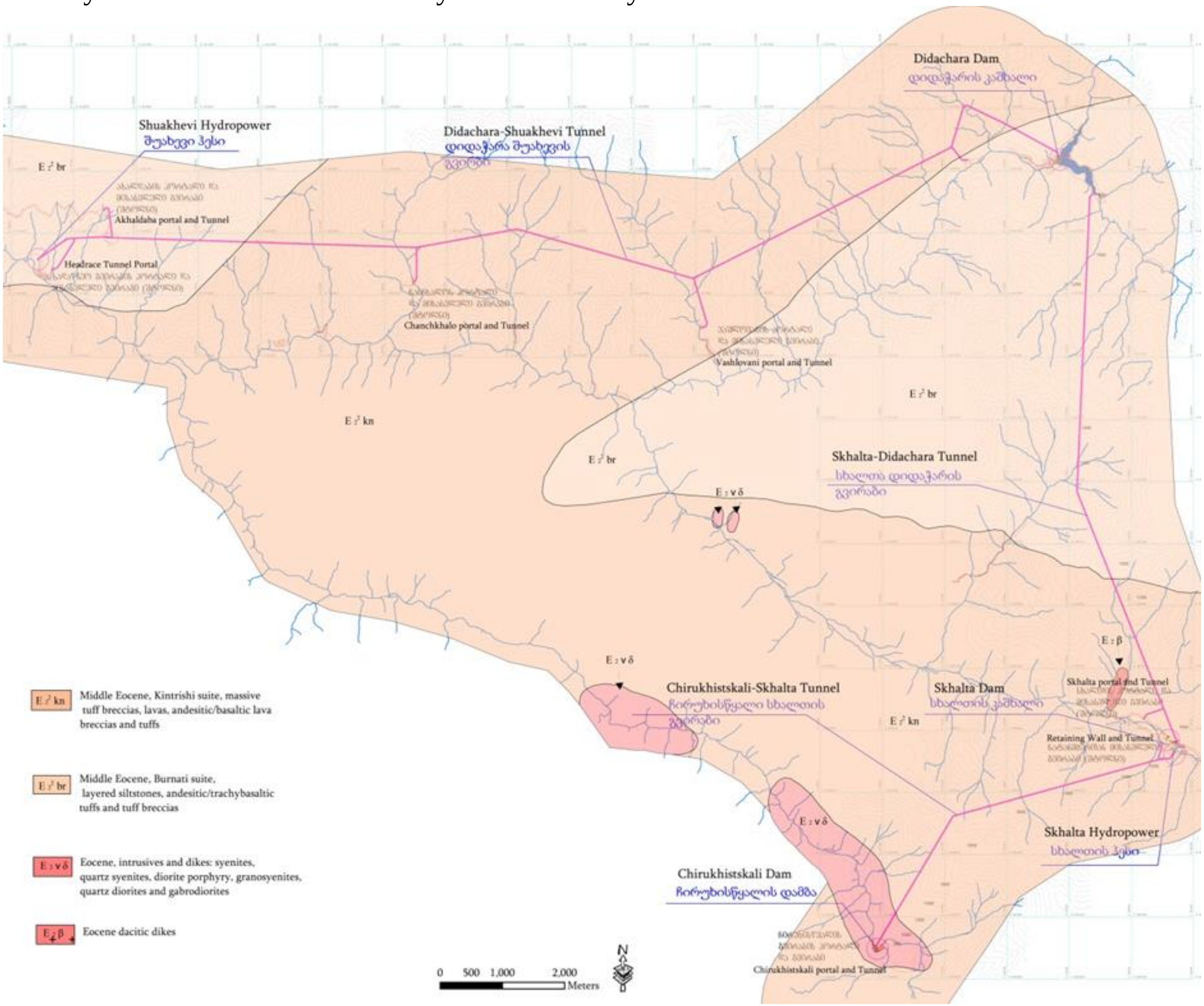


Figure 1. Geological map of the study area

Methods and Materials

The research methodology includes both traditional and modern analytical methods. Field work was carried out in the Adjaristskali River basin, as well as in its tributaries, the Skhalta and Chirukhistskali River valleys. Samples were collected from all key locations of Shuakhevi HPP engineering buildings (Table 1). During the field work, reference sections were selected, rock samples were collected, sampling was accomplished using GPS technologies, the points were plotted on geological and topographic maps of different scales, photographs of interesting areas of exposure were taken, informative charts were drawn on the spot, and deformation structures were measured using a geological compass. At the next stage, systematization/sorting/selection of collected and searched material was performed; at the Laboratory of Complex Geological Research of the Al. Janelidze Institute of Geology, thin sections were prepared. At the same institute, a microscopic description of thin sections was carried out using a polarizing microscope, and petrographic characterization was accomplished.

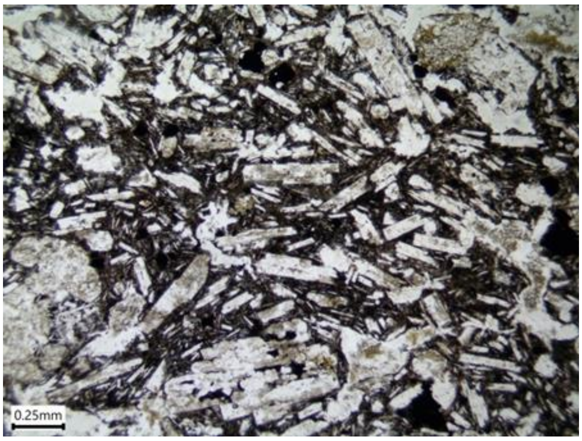
Table 1. Coordinates of sampling points selected for geochemical analysis from the territory of the Shuakhevi HPP engineering buildings

Sample №	Name	Coordinates	
		X	Y
1-18	Didadjara impounding reservoir	0279569	4615174
2-18		0279659	4615085
3-18		0279714	4615069
4-18	Northern portal of Skhalta tunnel, Adjaristskali basin, left bank	0279891	4614651
5-18		0280021	4614603
6-18		0279986	4614686
7-18	Didadjara impounding reservoir, the Ghorjomi and the Adjaristskali Rivers confluence	0279357	4615293
8-18	Left bank of Didadjara dam	0279357	4615293
9-18	Diakonidze tunnel gallery	0277819	4615130
10-19	Skhalta impounding reservoir	0281192	4605977
11-19		0280984	4605986
12-19		0280984	4605986
13-19		0280735	4606159
14-19		0281029	4605761
15-19	Chirukhi impounding reservoir	0276460	4602529
16-19		0276461	4602527
17-20	Didadjara Central tunnel (village Chanchkhalo)	0268899	4613369
18-20	Shuakhevi HPP building	0262935	4613648

For geochemical studies, the 18 most typical samples were chosen from several hundred samples. Analysis of major components, REs and REEs was performed at the Complex Laboratory of Geological Research of the Al. Janelidze Institute of Geology of Iv. Javakhishvili Tbilisi State University. The sample chips were finely powdered using a RETSCH RS200 vibrating mill. Major and trace element concentrations were determined by X-ray fluorescence (XRF) spectrometry using a SPECTROSCOUT X-ray spectrometer with a Cu-Rh X-ray tube.

Results

The samples for petrographic study were collected in the Adjaristskali River basin, as well as in its tributaries, the Skhalta and Chirukhistskali River valleys. Microscopically, the studied rocks were divided into two types. In particular, the main rock-building minerals of the Burnati suite are plagioclase (0.2-1 mm), pyroxene (0.2-0.8 mm in size) and hornblende (0.1-0.9 mm in size). Among the secondary minerals, calcite replaces plagioclase, and chlorite, which is an alteration product of hornblende, is notable. Zeolite and ore minerals also occur in the rock. The main rock mass is represented by volcanic glass. The rock is characterized by a porphyry structure. Petrographic characterization confirmed that the rocks composing the Burnati suite are tuffs and tuff breccias with andesite-basalt and trachy-basalt compositions (Fig. 2).



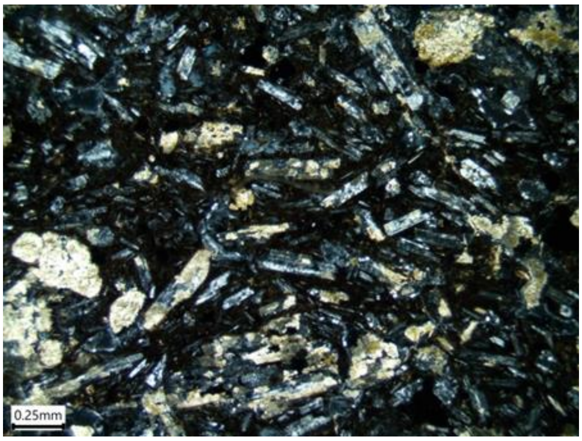


Figure 2. Burnati suite tuff of trachy-basalt composition, PPL and XPL

The main rock-building minerals of the Kintrishi suite are plagioclase (0.3-1.2 mm), which is sometimes fine grained, and pyroxene (0.3-0.6 mm). In addition to plagioclase chloritized hornblende (0.3-1 mm), andesites are notable. Among the secondary minerals, calcite, which substitutes for plagioclase, and chlorite, which is the alteration product of hornblende, are rather remarkable. Zeolite and ore minerals also occur in the rock. Volcanic glass represents the main mass of the rock. The rock is characterized by a porphyry structure. In andesites, volcanic glass is chloritized. In addition, in the rock, tuff fragments with andesite-basaltic compositions are observed. Petrographic characterization verified that the rocks composing the Kintrishi suite are tuffs, tuff breccias and lavas of andesite basaltic composition (Fig. 3).

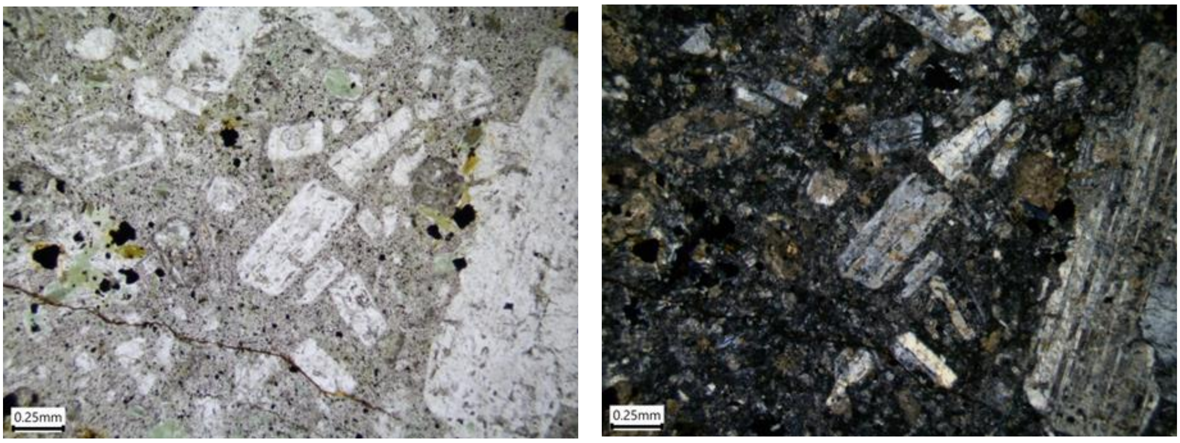


Figure 3. Kintrishi suite tuff-breccia of andesite-basaltic compositions, PPLs and XPLs

We conducted geochemical studies of tuffs, tuff breccias and lavas with andesite-basalt and trachybasalt compositions from the Burnati and Kintrishi suites (Table 2).

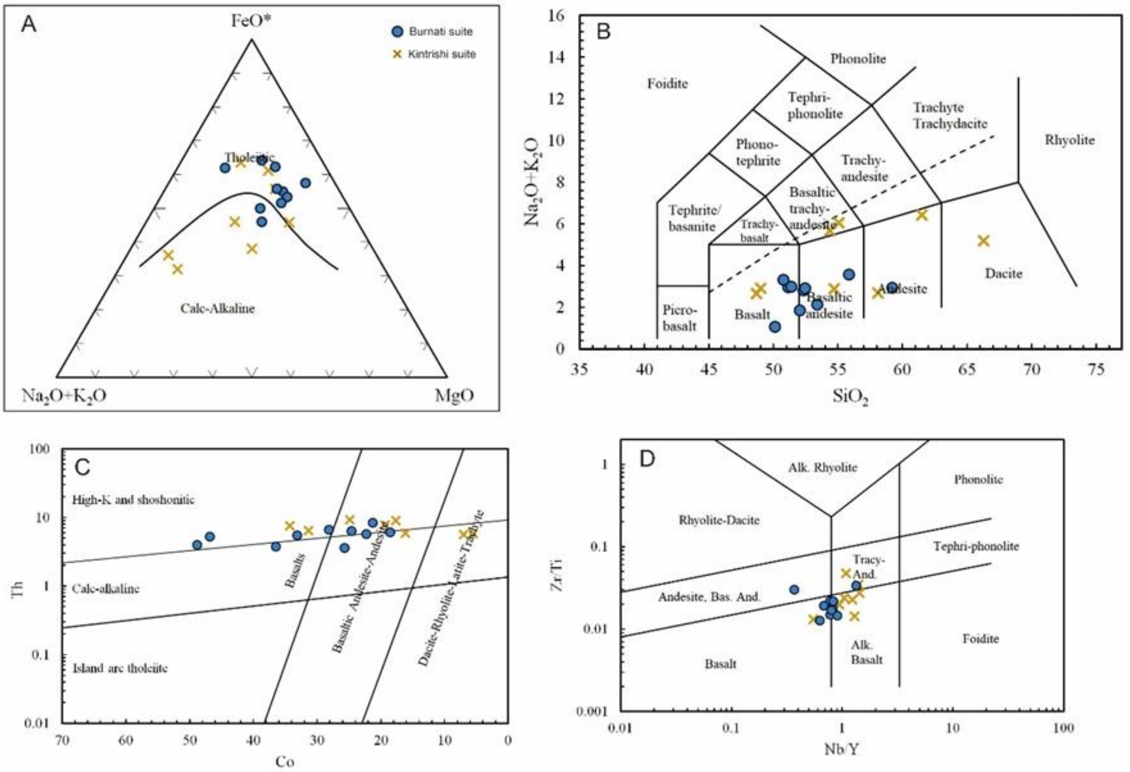


Figure 4. Classification discrimination diagrams: A – AFM (Irvine & Baragar, 1971); B - Na_2O+K_2O vs. SiO_2 (Le Bas et al. *1986); C - Th vs. Co (Hastie* et al.*, 2007); D - Zr/Ti vs. Nb/Y (Pearce, 1996)*

On the Na_2O+K_2O - FeO - MgO diagram (Irvine & Baragar, 1971; Fig. 4A), most of the figurative symbols representing the rocks of the Burnati suite are located in the tholeiitic field, and only two symbols plot in the calc-alkaline field; as for the rocks of the Kintrishi suite, their symbols are equally distributed in the tholeiitic and calc-alkaline fields. On the Na_2O+K_2O *vs* SiO_2 diagram (Le Bas et al. 1986; Fig. 4B), the symbols indicating the rocks of the Burnati suite were equally distributed in the basalt and andesite-basalt fields, while those of the Kintrishi suite were scattered in the andesite-basalt and basalt-trachyandesite fields; only in one case did the symbol fall into the dacitic field. On the Th *vs*. Co diagram (Hastie et al. 2007; Fig. 4C), the figurative symbols representing the rocks of both suites are located along the dividing line of the high-K shoshonite and calc-alkaline fields, with a well-defined increase in acidity. According to the Zr/Ti *vs*. Nb/Y diagram (Pearce, 1996; Fig. 4D), the Burnati suite rocks are equally distributed in the alkaline basalt and basalt field, and the Kintrishi suite rocks are equally distributed in the alkaline basalt and trachyandesite field.

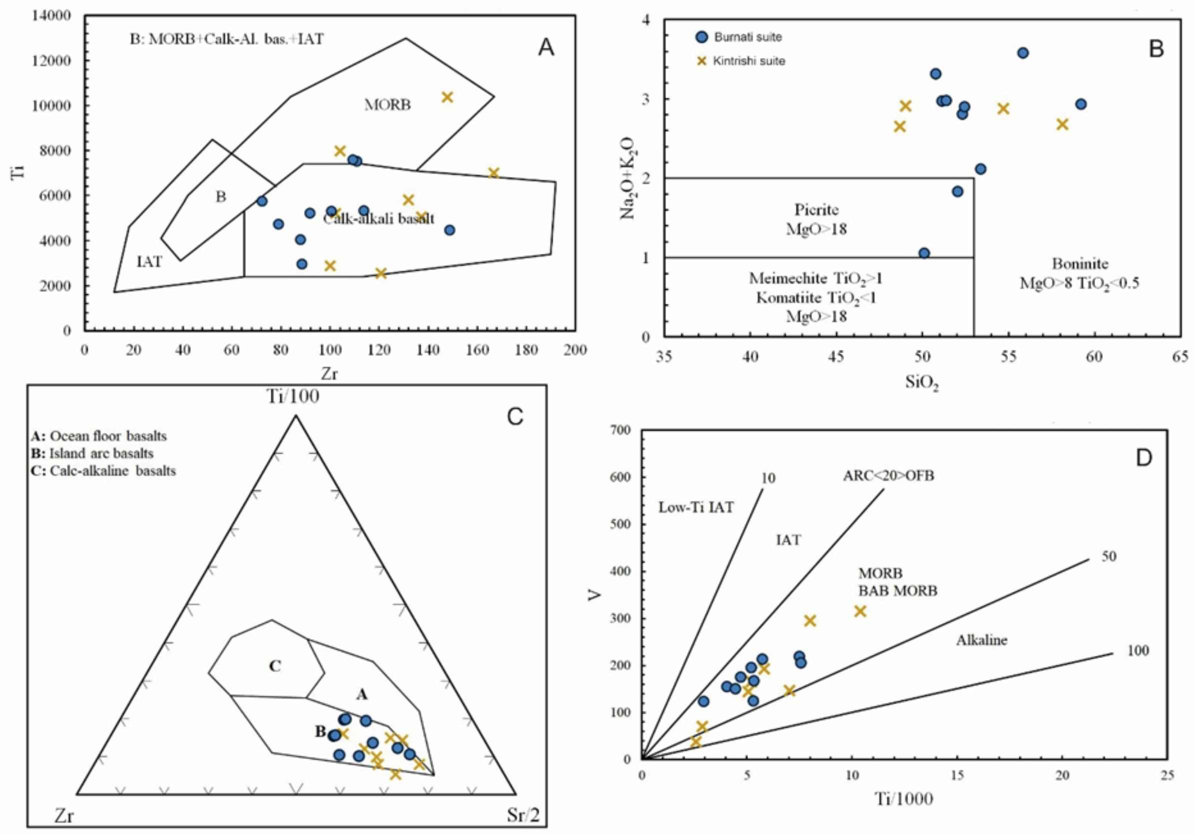


Figure 5. Tectonic diagrams: A – Ti vs. Zr (Pearce, Cann, 1973); B – Na_2O+K_2O vs. SiO_2 (Le Bas et al. 2007); C – Zr vs. Ti/100 vs. Sr/2 (Pearce, Cann, 1973); D – V vs. Ti/1000 (Shervias, 1982)

On the Ti vs. Zr tectonic classification diagram (Pearce, Cann, 1973; Fig. 5A), the rocks of the Burnati and Kintrishi suites occur within the calc-alkaline basalts field. On the Na_2O+K_2O vs SiO_2 diagram (Le Bas et al. 2007; Fig. 5B), the rocks of both suites are also situated in the boninites field. Boninites are known to be characteristic of the geodynamic conditions of young island arcs. According to the Zr vs. Ti/100 vs. Sr/2 diagram (Pearce, Cann, 1973; Fig. 5C), the rocks of both suites are island arc formations, and according to the V vs. Ti/1000 diagram (Shervias, 1982; Fig. 5D), the rocks belong to the back-arc formations.

Table 2. Results of the XRF analysis of the volcanogenic-sedimentary rocks of the Adjaristskali River. Note: №1-18 – 9-19 and №18-20 Burnati suite; №10-19 – 16-19 and №17-20 Kintrishi suite

Symbol	1-18	2-18	3-18	4-18	5-18	6-18	7-18	8-18	9-18	10-19	11-19	12-19	13-19	14-19	15-19	16-19	17-20	18-20
SiO_2	41.08	41.46	41.20	40.93	42.08	40.77	42.02	40.16	44.77	54.86	48.24	51.69	43.02	49.63	39.20	42.89	48.14	51.95
TiO_2	1.25	1.26	0.96	0.87	0.68	0.89	0.79	0.89	0.75	0.43	1.17	0.48	0.87	0.84	1.33	1.73	0.97	0.49
Al_2O_3	15.08	15.18	14.90	13.96	15.98	15.56	16.16	15.47	12.54	15.68	17.06	15.59	15.80	15.15	16.02	18.07	14.12	16.75
Fe_2O_3	9.11	9.40	8.59	5.87	6.31	7.02	7.28	6.56	6.91	2.93	7.43	3.26	6.91	6.08	8.18	9.53	6.55	4.87
MnO	0.09	0.36	0.14	0.24	0.13	0.09	0.10	0.14	0.18	0.05	0.10	0.06	0.07	0.14	0.11	0.22	0.11	0.09
MgO	5.05	2.98	4.37	3.18	3.83	4.31	2.91	3.98	1.37	0.88	3.71	1.56	1.71	4.89	4.18	3.71	5.40	3.13
CaO	5.83	5.95	7.32	12.62	7.97	6.55	9.73	11.82	10.52	3.39	5.35	5.76	7.74	6.11	8.09	8.84	6.21	7.70
Na_2O	1.92	0.54	1.54	1.08	0.35	0.22	0.32	0.31	1.53	2.54	2.15	2.53	0.48	1.50	1.17	0.14	2.51	0.63
K_2O	0.47	1.68	0.85	1.59	1.32	2.03	1.16	0.54	1.34	1.75	2.88	2.86	1.79	0.78	1.16	2.20	2.78	1.94
P_2O_5	0.45	0.41	0.33	0.27	0.17	0.30	0.26	0.30	0.26	0.26	0.59	0.29	0.29	0.28	0.56	0.80	0.66	0.19
V	218.1	205.4	212.5	194.9	154.8	167.3	175.2	124.6	149.9	37.78	146.9	70.71	165.6	144.1	294.8	315.3	192.90	123.2
Cr	169.1	111.3	105.2	88.44	58.45	92.74	87.57	78.85	65.36	15.34	98.83	14.31	76.73	56.59	83.10	28.41	89.19	45.55
Co	46.82	48.85	36.48	22.27	33.16	24.61	25.69	28.19	21.30	5.54	24.89	7.02	16.14	17.64	34.32	31.39	19.38	18.55
Ni	86.41	89.35	72.43	40.29	41.16	63.62	52.78	42.16	38.92	1.83	44.56	2.65	27.96	31.83	32.50	36.45	41.15	22.58
Rb	6.63	26.45	12.67	29.31	21.07	29.83	17.75	7.21	23.89	22.97	52.94	40.86	30.82	11.17	25.63	40.40	50.53	26.69
Sr	385.1	387.7	331.1	686.2	264.60	347.90	510.40	473.60	463.40	686.20	696.80	474.90	343.50	651.90	753.00	896.60	1083.00	342.70
Y	14.89	18.28	11.88	9.91	9.16	13.02	9.36	13.42	11.43	5.03	14.39	5.28	9.67	8.84	15.31	18.89	10.14	13.64
Zr	110.9	109.2	72.31	91.71	87.93	113.8	79.00	100.6	148.8	120.6	166.60	99.99	102.20	137.20	104.10	147.70	131.80	88.48
Nb	11.61	16.54	7.51	8.19	7.13	10.84	7.47	9.19	15.25	5.45	15.05	7.39	9.07	12.70	8.35	24.39	12.48	5.06
Mo	0.64	0.66	0.63	0.62	0.59	0.61	0.62	0.61	0.63	0.53	0.64	0.54	0.60	0.60	0.64	0.70	0.63	0.59

Cs	5.73	5.86	5.77	5.50	5.73	5.87	6.46	5.40	5.79	4.96	6.02	9.72	5.30	5.16	5.86	6.72	6.14	5.63
Ba	210.5	337.70	211.20	314.70	160.00	201.20	275.70	233.90	295.30	515.80	368.70	420.10	129.70	293.00	207.00	575.30	886.70	782.60
La	9.19	32.52	9.43	8.57	26.19	21.35	18.32	110.80	9.36	9.16	9.63	9.28	8.90	26.85	26.78	42.23	23.13	21.94
Ce	46.20	65.12	39.32	18.62	52.93	40.96	30.12	152.10	93.97	81.52	65.21	59.94	30.81	53.68	45.44	87.61	38.29	24.92
Nd	104.4	53.43	82.37	42.69	62.10	60.59	74.03	20.05	51.59	42.07	106.50	56.42	86.90	64.70	102.7	150.5	95.95	61.32
Hf	2.70	1.39	1.29	1.27	1.19	1.22	1.28	1.25	1.27	1.03	3.13	1.07	1.22	1.20	1.35	3.18	1.29	1.14
W	1.61	1.65	1.59	1.55	1.47	1.49	1.56	1.54	1.55	1.25	1.58	1.30	1.51	1.47	1.64	2.78	1.57	1.40
Th	5.28	4.00	3.75	5.76	5.49	6.31	3.62	6.63	8.39	5.83	9.24	5.63	5.89	9.01	7.53	6.40	7.76	6.09
U	0.65	0.87	0.73	0.94	0.77	0.86	0.81	1.78	1.69	0.75	1.44	1.18	0.85	1.43	0.93	1.09	1.13	0.84

Conclusion

As a result of the research, it was established that

- The Burnati suite within the study area is composed of tuffs and tuff breccias of basalt, andesite basalt and trachybasalt, while the Kintrishi suite is composed of tuffs, tuff breccias and lavas of andesite basaltic composition;
- The rocks of both suites are characterized by similar geochemical characteristics; they have tholeiitic and calc-alkaline compositions, although the rocks of the Burnati suite are mostly characterized by tholeiitic compositions;
- According to the lithological composition, they are calc-alkaline rocks of high-K shoshonite origin;
- The majority of the rocks of both suites are characterized by boninitic compositions that are typical of the geodynamic conditions of young island arcs; their origin is related to back-arc tectonic conditions.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

All authors provided critical feedback and helped shape the research, analysis and manuscript.

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