CORPUS PUBLISHERS

Journal of Mineral and Material Science (JMMS)

ISSN: 2833-3616

Volume 6 Issue 2, 2025

Article Information

Received date : March 01, 2025

Published date: March 21, 2025

*Corresponding author

Avtandil Okrostsvaridze, Institute of Earth Sciences, Ilia state University, Tbilisi, Georgia

DOI: 10.54026/JMMS/1112

Short Communication

Anomalously High Concentrations of Cobalt in Granite Pegmatites of the Rkvia Variscan Pluton, Dzirula Crystalline Massif, the Caucasus

Rabi Gabrielashvili and Avtandil Okrostsvaridze*

Institute of Earth Sciences, Ilia state University, Tbilisi, Georgia

Abstract

Anomalously high cobalt concentrations have been identified in the granite pegmatites of the Rkvia Variscan Pluton within the Dzirula Massif of Transcaucasus microplate. Seven samples of these pegmatites, analyzed using LA-ICP-MS equipment at Canada's MSALABS laboratory, exhibit cobalt contents ranging from 76 ppm to 205 ppm. The typical concentration of cobalt in felsic igneous rocks is approximately 1 ppm, suggesting that these anomalously high values likely result from post-magmatic hydrothermal alterations. Based on our research, we propose that the elevated cobalt concentrations in these pegmatites were induced by the injection of the cobalt-rich, ultrabasic Buja Intrusive during the Late Triassic period. Consequently, during the hydrothermal transformation of the granite pegmatites, cobalt likely replaced iron and magnesium isomorphically in biotite. It is probable that the cobalt content will increase with depth in the studied pegmatite field. We suggest that the anomalously high cobalt content in microcline-quartz-muscovite pegmatites represents a unique geochemical feature warranting further detailed investigation.

Introduction

In today's global market, the demand for cobalt is increasing rapidly due to its essential role in battery production for electric vehicles. Additionally, cobalt is indispensable in the manufacturing of mobile phones, computers, radars, and other high-tech devices [1]. The average cobalt concentration in the Earth's crust is low (1-4 ppm), leading to its designation as a critical mineral resource by the European Commission in 2017. Cobalt-bearing formations genetically associated with ultrabasic igneous rocks are considered prospective sources of cobalt. However, only a few deposits of this type exist globally, with the Democratic Republic of Congo hosting 50% of the world's known cobalt reserves. Given the limited cobalt reserves in the Earth's crust, this study aims to examine the anomalously high cobalt concentrations- representing a previously unrecognized type - discovered in the granite pegmatites of the Rkvia pluton within the Dzirula Massif and to investigate their probable origin.

Brief Geological Description of the region

The Caucasus Phanerozoic orogenic sisteme is expended over 1200 km between the Black and Caspian Seas, at the NW-SE direction. Currently it is an expression of continental collision between the Arabian and Eurasian lithospheric plates. Three major unites are distinguished in its structure: Greater and Lesser Caucasus folded-trust mobile belts and the Inner Caucasian Microplate. The Pre-Alpine Dzirula Crystalline Massif is exposed in the central part of the Transcaucasian microplate and covers an area of 1200 km^2 (Figure 1). It is mainly composed of Lower Paleozoic granite-migmatite complexes, tonalites, Upper Paleozoic microcline granites, and Triassic orthoclase gabbros (Rikothites) [2]. Upper Paleozoic microcline granites intrude the Lower Paleozoic granite-gneiss complex and tonalites, with the entire rock complex being intersected by Upper Triassic orthoclase-bearing gabbro intrusions, which have limited outcrops within the Dzirula Massif. In contrast to the orthoclase gabbros, the basement massif is characterized by widespread injections of Upper Paleozoic microcline granites, occurring as small veins, intrusions, and plutons. Among these, the thickest and most noteworthy is the Rkvia porphyry pluton.

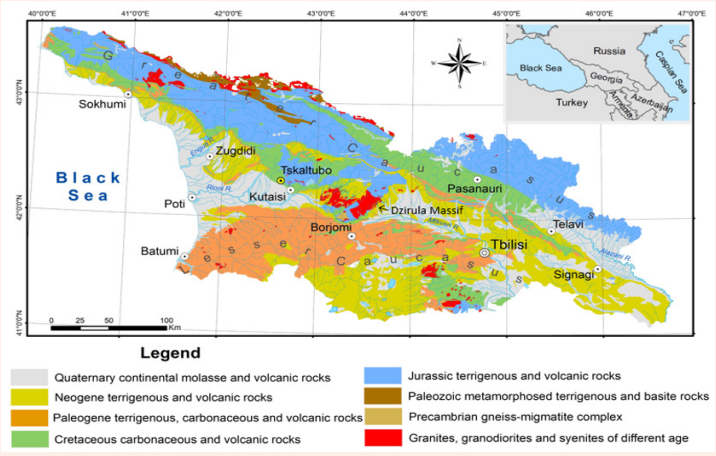

Figure 1: Simplified geological map of Georgia. Dzirula massif in the central part. The map modified after map of Gudjabidze et al. [7].

Rkvia Variscan Pluton

The Rkvia Variscan-generation pluton is situated in the northwestern part of the Dzirula Massif and is incised by the deep canyons of the Buja and Kvirila rivers. It has a sub-latitudinal lenticular shape and spans approximately 65 km² (Figure 2). The pluton is characterized by a heterogeneous structure, with multiple phases of magmatic activity distinguishable within it. The first and primary phase consists of microcline porphyry granites, which constitute 70-75% of the entire pluton. Their crystallization occurred under a temperature regime of 660-690 °C and a total pressure of 7.7-8.7 kbar [3]. The principal minerals in these granites include quartz, albite, microcline, muscovite, and biotite. The I_{Sr} parameter for these rocks ranges from 0.70667 to 0.71460, while the Σ_{Nd} parameter varies from 2.1958 to 9.36967, consistent with granites of crustal origin (S-type granites). These rocks have been dated using the Rb-Sr method to 351±20 million years, confirming their Variscan origin [2].

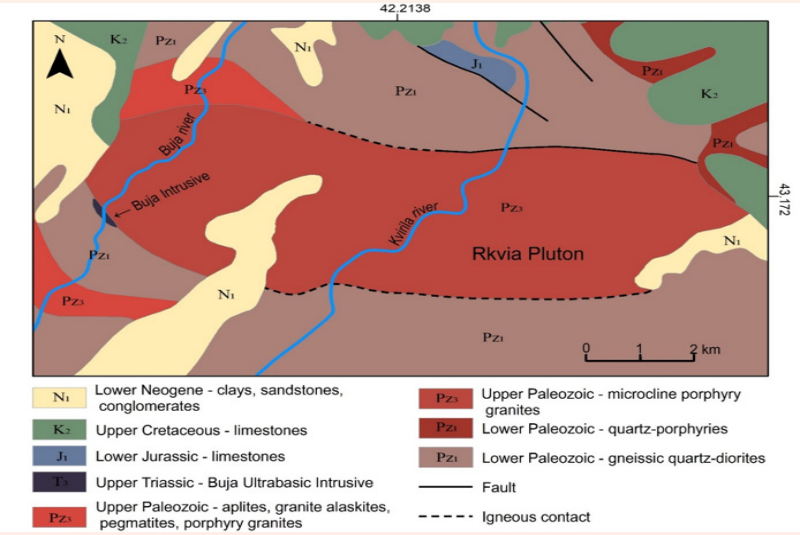

Figure 2: Schematic geological map of Rkvia Pluton, modified According to R Chagelishvili [6].

Granite Pegmatites of Rkvia Pluton

Granite pegmatites are widely distributed throughout the Rkvia Pluton, occurring both as veins and as massive accumulations. Particularly thick fields of these rocks (~2-2.5 km wide) are observed in the western part of the Rkvia Pluton, along both its southern and northern peripheries, where they are exposed in the Md. Buja Canyon. The primary rock-forming minerals of the pegmatites include microcline, quartz, plagioclase, muscovite, and biotite. In these pegmatites, microcline comprise[40] [40] ~0% of the mineral assemblage and is responsible for their characteristic pink color (Figure 3). Three muscovite samples from these pegmatites were dated using the $^{40}Ar/^{39}Ar$–$^{40}Ar/^{39}Ar$ method, yielding an age of 303±2 million years, which corresponds to the late Carboniferous period [2].

Figure 3: Microcline-quartz-muscovite pegmatites of the Rkvia Pluton from Buja river canyon.

Buja Ultrabasic Intrusive

In the bed of the Buja River, along the southern contact zone of the Rkvia Pluton, the ~50 m thick Buja ultrabasic intrusive is exposed [4]. Unfortunately, it is impossible to trace this body in relation to surrounding formations, as both slopes of the valley are covered by deluvial sediments and deciduous forest. The primary minerals of this intrusion are pyroxene, olivine, and basic plagioclase, while hornblende and biotite occur as minor phases. These rocks have a low SiO_2 content, with concentrations in the central part of the intrusion varying from 39% to 42% in the marls. MgO replacement is particularly high, reaching 37% in the central part but decreasing toward the periphery, where it falls to 18-20%. The concentrations of iron-group elements are also elevated, with cobalt contents ranging from 900 ppm to 1100 ppm. The formation of the Buja ultrabasic intrusion is most likely associated with Triassic basic magmatic activity in the Dzirula Massif, which has an Rb-Sr isotopic age of 211±8 Ma [2].

Geochemistry of Buja Pegmatite Valley

We conducted a geochemical study of the Buja pegmatite field at the Canadian MSALABS laboratory using an LA-ICP-MS device with the ICM-230 method. In total, 11 samples from the root array were analyzed (Table 1). Of these, seven samples-20Dz10, 20Dz12, 20Dz14, 20Dz15, 20Dz16, 20Dz18, and 20Dz20 - were collected from the Buja pegmatite field, while the remaining samples (20Dz1 - two-mica granite, 20Dz5 - microcline gabbro, 20Dz7 - quartz diorite, and 20Dz7 - two-mica granite) were obtained from various locations within the Dzirula Massif. As shown in this table, the concentrations of nearly all chemical elements in the analyzed rocks fall within the expected ranges. However, in the Buja granite pegmatites, cobalt concentrations are significantly elevated. In the seven samples analyzed, cobalt content ranges from 76 ppm to 205 ppm. The anomalously high cobalt concentrations are clearly depicted on the variation diagram constructed from these chemical analyses (Figure 4).

Table 1: Contents of some trace elements (in ppm) in granites and pegmatites of the Dzirula massif.

Sample	20Dz1	20Dz5	20Dz7	20Dz8	20Dz 10	20Dz 12	20Dz 14	20Dz 15	20Dz 16	20Dz 18	20Dz 20
Ag	0.04	0.12	0.03	0.02	0.05	0.02	0.11	0.05	0.04	0.04	0.06
As	0.8	5.6	2.4	2.1	2.1	2.4	1.0	0.7	0.8	0.7	0.3
Ba	145	337	1551	178	992	67	31	95	132	146	119
Be	3.03	1.55	1.67	1.54	1.75	6.38	4.23	4.08	4.81	8.00	73.06
Bi	0.22	0.13	0.09	0.04	0.08	1.16	2.40	0.12	0.81	1.20	0.65
Cd	0.10	0.09	0.04	0.05	0.07	0.11	0.17	0.03	0.07	0.05	0.07
Ce	7.31	40.98	97.12	48.79	29.84	5.90	3.38	9.08	5.80	5.45	8.84
Co	0.3	23.6	2.9	0.8	76.6	105.3	87.7	127.8	198.4	205.6	145.3
Cr	38	284	296	371	255	43	125	108	249	382	186
Cs	2.51	0.84	1.99	0.83	0.52	1.82	1.50	1.63	2.69	3.15	2.72
Cu	0.5	6.4	1.40	1.2	116.9	1.8	2.9	9.0	1.1	2.1	1.7
Ga	16.87	13.51	16.71	18.30	11.10	20.37	17.84	20.05	17.36	16.83	17.13
Ge	0.37	0.31	0.4	0.47	0.37	0.41	0.20	0.25	0.35	0.39	0.48
Hf	0.5	3.5	1.4	5.6	1.7	1.7	1.0	0.5	0.9	1.2	0.8
In	0.029	0.053	0.025	0.068	0.048	0.026	0.009	0.041	0.035	0.030	0.029
La	3.6	16.9	49.2	19.1	14.5	2.4	1.5	4.3	2.3	2.6	4.1
Li	11	7.3	10.1	4.8	5.3	6.7	6.7	9.8	8.8	5.5	12.4
Mn	523	729	655	74	1301	1249	1957	231	1062	729	625
Mo	0.10	0.42	0.29	0.16	1.16	0.13	1.44	0.31	0.29	0.28	0.29
Nb	9.5	7.6	5.9	17.2	1.8	15.0	7.8	14.0	8.8	10.4	9.8
Ni	0.8	35.1	4.4	5.0	68.4	1.1	6.4	2.4	3.0	4.2	2.4
P	787	170	258	34	2260	935	832	613	725	788	765
Pb	23.5	11.9	29.6	23.9	12.9	18.8	10.7	12.7	22.9	27.0	20.0
Rb	146.2	85.0	78.6	112.8	53.2	140.7	197.1	112.7	178.8	174.5	170.7

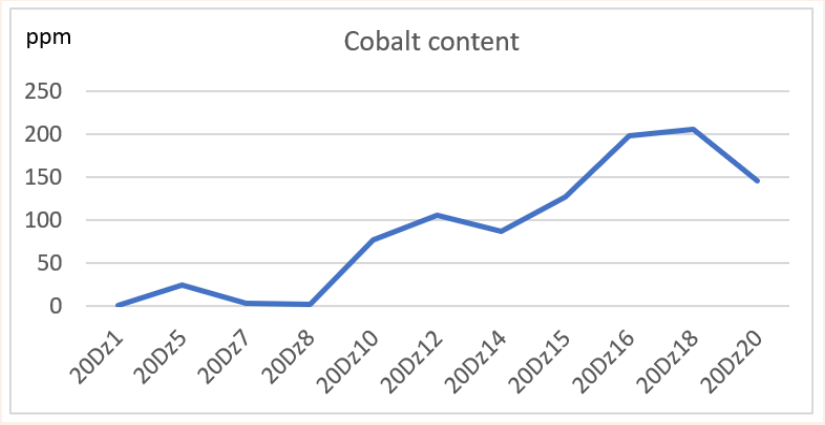

Figure 4: Variation diagram of cobalt content in Buja pegmatites and other rocks from the Dzirula Massif.

This diagram shows that the cobalt concentration in the other rocks of the Dzirula Massif (20Dz1-20Dz8) remains within the normal range. In contrast, the cobalt content in the granite pegmatites of the Buja Valley exhibits a sharp increase, averaging around 100 ppm, with one sample reaching as high as 205 ppm. Analysis of these data suggests that the anomalous increase in cobalt concentration in these rocks was most likely caused by post-magmatic hydrothermal processes.

Cobalt Geochemistry and Ore Depositions

Cobalt (Co), the 27th element in Mendeleev's periodic table, has an atomic weight of 58.9. As is well known, the average cobalt content is highest in ultrabasic rocks, particularly in dunites, where its concentration reaches approximately 110 ppm. In basic rocks, the concentration decreases, dropping to around 47 ppm in basalts, while in acidic igneous rocks, it is lower, varying within 1 ppm. Therefore, it is evident that the cobalt content in Buja felsic pegmatites, which ranges from 76 ppm to 205 ppm in the seven samples analyzed, is significantly anomalous. Cobalt ores are genetically associated with sedimentary and igneous rocks, as well as hydrothermal veins. Only a few large cobalt deposits exist globally, and these are primarily mined for the extraction of cobalt. In most cases, cobalt is extracted alongside copper and nickel. Currently, the largest cobalt deposits have been identified in the Democratic Republic of Congo, where cobalt is concentrated in sedimentary rocks [1].

Discussion

An analysis of the geochemical survey results, along with the available geological data, suggests that the anomalous increase in cobalt concentration in the Late Paleozoic microcline-quartz-muscovite pegmatites can be attributed to the intrusion of an ultramafic pluton into these rocks during the Triassic period, a time when cobalt concentrations were elevated. Evidence of this magmatic activity is exposed on the coeval erosional surface in the form of the Buja ultrabasic intrusive, although smaller veins (~0.5-1.0 m) of similar composition also underlie the southern pegmatite field of Buja. It is possible that beneath this pegmatitic field, a pluton with a strong basic composition and high cobalt content cooled during the Triassic period, leading to the enrichment of the pegmatites with this element.

Regarding the geochemical aspects of these hydrothermal changes, it is well known that cobalt, due to its active chemical properties, is incorporated in large quantities into approximately 30 minerals, and in smaller quantities, it is present in more than 100 other minerals [5]. Primary cobalt minerals occur as sulfides, sulfarsenides, arsenides, and iron oxides. Minerals of economic importance include asbolite, karolite, cobaltite, scolecite, and linite (e.g., Hitzman et al. 2001). Notably, the ionic radii of Co^{2+} and Co^{3+} closely match those of Mg^{2+}, Fe^{2+}, Mn^{4+}, Fe^{3+}, and Ni^{2+}, enabling cobalt to replace these metals in many minerals. In the case of the granitic pegmatites of the Rkvia pluton, it is likely that cobalt ions replaced iron and magnesium ions in the biotites.

Conclusion

Our research has shown that in the southern granitic pegmatites of the Rkvia Variscan pluton of the Dziryuli massif revealed anomalously high cobalt contents, ranging from 76 ppm to 2005 ppm across seven samples. We hypothesize that the anomalous increase in cobalt concentration in these pegmatites was the result of the intrusion of a cobalt-enriched ultrabasic pluton into these rocks during the Triassic period. Consequently, during the hydrothermal transformation of the host rock, cobalt likely replaced iron and magnesium isomorphically in biotite. It is probable that the cobalt content will increase with depth in the studied pegmatite field. We suggest that the anomalously high cobalt content in microcline-quartz-muscovite pegmatites represents a unique geochemical feature warranting further detailed investigation [6,7].

Acknowledgement

This research was supported by the Shota Rustaveli National Science Foundation of Georgia, Grant #. FR-21-10905. We are grateful to Iam Elsea the managing director of Journal of Mineral and Material Science (JMMS), whose unselfish help we are able to publish this article.

References

1. Hitzman MW, Bookstrom AA, Slack JF, Zientek ML (2017) Cobalt-styles of deposits and the search for primary deposits. U S Geological Survey, Virginia, USA.
2. Okrostsvaridze AV, Tormey DR (2013) Phanerozoic continental crust evolution of inner caucasian microplate: The dzirula uplift. Episodes 36(1): 31-38.
3. Okrostsvaridze A, Clarke B, Akhvlediani R (2011) Thermobaric regime of the formation of the dzirula massif rkvia variscan granitoid intrusive. Bulletin of the Georgian National Academy of Sciences 5(3): 79-84.
4. Okrostsvaridze A, Shubitidze L, Chagelishvili R (2006) The first data of basic-ultrabasic intrusive body of the buja canyon (dzirula salient of the inner transcaucasus massif). Bulletin of Georgian National Academy of Sciences 173(3): 5333-5336.
5. Moroni M, Rossetti P, Naitza S, Magnani L, Ruggieri G, et al. (2019) Factors controlling hydrothermal nickel and cobalt mineralization-some suggestions from historical ore deposits in Italy. Minerals 9(7): 429.
6. Chagelishvili R (2006) Petrology and geochemistry of the Rkvia-Beretisa intrusive complex of the Dzirulɔ crystalline massif of the Transcaucasus. Doctoral theses, Tbilisi, Georgia, p. 144.
7. Gudjabidze G, Gamkrelidze I, Abesadze G, et al. (2003) Geological map of Georgia: Georgian State Department of Geology and National Oil Company. Tbilisi, Georgia, scale 1:500,000.