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Luminescence properties of minerals in the Strzegom granites

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Original article

Abstract

This study presents the luminescence properties of minerals occurring in the Strzegom granites using cathodoluminescence in a Scanning Electron Microscope (SEM-CL). Four representative samples of granites from the Strzegom–Sobótka deposits(including the Kostrza, Chwałkow and Graniczna types) were selected for investigation. Their major- and trace-element chemical compositions were adopted from previously published data reported by Panna et al. [1]. The aim of the study was to assess the variability of luminescence activity of rock-forming minerals and to identify potential emission activators based on microphotographic observations and literature data. The results indicate that orthoclase exhibits the strongest luminescence effects, characterized by numerous point-like luminescence centers with yellow, blue and red colors, interpreted as the effect of Mn^{2+} and Fe^{3+} ions, oxygen vacancies, and admixtures of rare earth elements and Zr-rich accessory phases. In contrast, plagioclase rather remained optically inactive in most cases, highlighting the usefulness of SEM-CL for distinguishing feldspar types in granites. The obtained results confirm that cathodoluminescence is a useful tool for the qualitative analysis of structural defects and the distribution of impurities in minerals of the Strzegom granites; however, its interpretation should always be supported by chemical and mineralogical analyses.

Keywords

- quartz
- feldspars
- cathodoluminescence
- Strzegom granites
- rare earth elements

Authors contributions

A – Preparation of the research project
B – Assembly of data for the research undertaken
C – Conducting of statistical analysis
D – Interpretation of results
E – Manuscript preparation
F – Literature review
G – Revising the manuscript

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Introduction

Granite is a deep-seated igneous (plutonic) rock formed as a result of the slow crystallization of silica-rich magma deep beneath the Earth's surface. It is one of the most widespread rock types composing the continental crust [2].

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Conflict of interest

None declared.

Granite is classified as an acidic rock, as illustrated by the QAPF diagram (Quartz–Alkali Feldspar–Plagioclase–Feldspathoids, Figure 1). According to this diagram, typical granites contain 20–60% quartz and are characterized by the dominance of alkali feldspars over plagioclases [3].

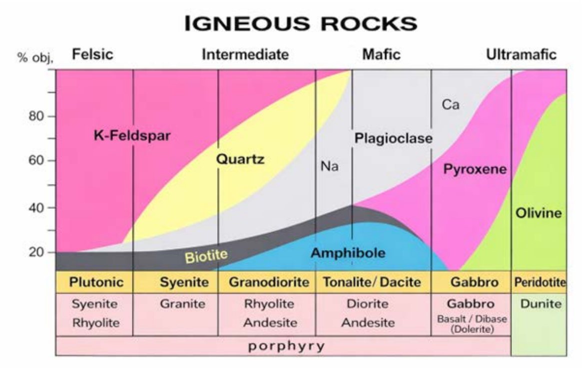

Figure 1. Mineral composition of igneous rocks [4]

Cathodoluminescence plays an important role in studies of rocks and minerals. One of the earliest applications of this method to the analysis of feldspars (the main minerals of granites) was reported by Mariano et al. [5]. They observed differences in the emission wavelengths of electromagnetic radiation released during the luminescence of metasomatic inclusions in feldspar raw materials. This phenomenon manifests itself as color variations of domains visible in magnified images of polished sections.

Subsequent studies demonstrated that the diversity of luminescence colors depends on the presence of active luminescence centers in the samples. Most feldspar minerals exhibit luminescence colors ranging from light blue through green-yellow to red [6].

Cathodoluminescence spectra are commonly characterized by three broad emission regions corresponding to blue (≈420–480 nm), green (≈520–580 nm), and red (≈650–750 nm) wavelengths. These luminescence bands are typically attributed to defect-related centers or impurity ions incorporated within the mineral crystal structure. For example, blue emission is explained by structural defects of the Al–O–Al type, while green emission is associated with the incorporation of activators such as Mn^{2+} and Fe^{3+} into the crystal lattice. Other elements that may influence color variations include Ti, Pb, Cu, Cr, as well as rare earth elements such as Sm^{3+}, Eu^{2+}, and Ce^{3+} [7].

A subtle difference in the identification of feldspars using cathodoluminescence arises from the registration of luminescence emitted by trace elements in the samples. Alkali feldspars are often accompanied by elevated concentrations of rare earth elements, resulting in the emission of infrared radiation [8].

Interesting results were presented by Smith and Brown [9], who analyzed the Eu^{2+} contentin plagioclases (sodium–calcium feldspars). They found that increasing concentrations of this ion correspond to a higher proportion of Ca-rich feldspars, such as bytownite and anorthite. Cathodoluminescence is usually regarded as a method presenting visible radiation effects of samples (electromagnetic radiation in the visible range). It should be noted, however, that some elements emit radiation outside the visible spectrum. Owing to current technical capabilities, radiation intensity beyond the visible range can also be recorded. In such cases, emission intensity is plotted as a function of wavelength, significantly extending the analytical scope of this method [10].

The aim of this study is a comparative analysis of selected granites with respect to the luminescence properties of their constituent minerals. For this purpose, Strzegom granites representing three distinct varieties were examined.

Materials and methods

Representative granite samples originating from the Strzegom region were selected for the study. The material was obtained by crushing granite blocks and was characterized by grain sizes exceeding 20 mm. Several granite varieties occur within the Strzegom massif, with biotite granites constituting the most abundant group. Among these, the Kostrza type is distinguished, including equigranular and porphyritic structural varieties, as well as the Chwałków type [11,12].

Kostrza-type granites occur in the western part of the massif and are monzonitic rocks with porphyritic and fine-grained varieties containing a small number of phenocrysts. This variety is represented by a sample collected from the quarry in Gniewków (sample 1). Chwałków-type granites occur in the eastern part of the massif and contain orthoclase, plagioclases, quartz, and biotite. Samples representing this variety were collected from deposits in Chwałków (sample 2) and Gołaszyce (sample 3). An intermediate variety between the Kostrza and Chwałków types is the Graniczna type, occurring at the northeastern margin of the Strzegom massif and in contact with Kostrza-type granites. These are represented by samples from the Graniczna open pit (sample 4).

The petrographic and geochemical characteristics of these samples were previously described by Panna et al. [1]. From the perspective of this study, the most important analyses are those of major and trace elements, presented in Tables 1 and 2.

Table 1. Major components [in %] of the analyzed samples [1]

Sample	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	MnO	Na_2O	K_2O	P_2O_5	Loss on Ignition	Sum
1	70.95	13.74	2.72	0.31	1.29	0.35	0.05	3.28	4.75	0.10	0.99	98.70
2	70.60	14.93	1.96	0.27	1.39	0.51	0.05	4.09	3.60	0.09	1.27	98.76
3	70.51	15.20	2.76	0.45	2.41	0.94	0.06	3.74	3.27	0.14	0.73	100.20
4	74.98	13.12	2.02	0.26	1.63	0.42	0.05	3.19	4.35	0.09	0.44	100.50

Table 2. Trace elements [ppm] of the analyzed samples [12]

Element	Atomic number	Sample			
		1	2	3	4
Be	4	4	3	3	3
S [%]	16	0.033	0.061	0.022	0.016
Sc	21	5.9	4.7	6.2	4.3
V	23	19	20	43	22
Cr	24	24	17	39	11
Co	27	6	4	8	< 1
Ni	28	6	6	11	7
Cu	29	18	13	18	14
Zn	30	63	57	54	46
As	33	2	< 2	< 2	< 2
Se	34	< 3	< 3	< 3	< 3
Br	35	< 1	< 1	< 1	< 1
Rb	37	270	130	140	200
Sr	38	100	228	343	133
Y	39	34	20	17	26
Zr	40	215	97	144	154
Mo	42	< 2	< 2	< 2	< 2
Ag	47	< 0.5	< 0.5	< 0.5	< 0.5
Cs	55	7.9	< 0.5	2.9	5.1
Ba	56	679	693	736	504
La	57	52.7	22.9	25.9	43.3
Ce	58	99	41	47	80
Nd	60	40	11	20	25
Sm	62	6.7	3.1	3.6	5.2
Eu	63	0.9	0.5	0.5	0.9
Tb	65	< 0.5	< 0.5	< 0.5	< 0.5
Yb	70	3.7	2.1	2.2	2.2
Lu	71	0.55	0.4	0.33	0.38
Hf	72	5.8	2.6	3.3	3.6
Ta	73	2	< 1	< 1	< 1
W	74	< 3	< 3	< 3	< 3
Ir [ppb]	77	< 5	< 5	< 5	< 5
Au [ppb]	79	< 5	< 5	< 5	< 5
Hg	80	< 1	< 1	< 1	< 1
Pb	82	22	19	18	23
Bi	83	< 2	< 2	< 2	< 2

Cathodoluminescence studies were carried out using an FEI Quanta 200 FEG Scanning Electron Microscope operating in low-vacuum mode (LV/ESEM), which enabled the observation of uncoated specimens. Images were recorded using BSE and SE detectors at an accelerating voltage of approximately 10–15 kV and a working distance of 9–12 mm.

The CL signal was used to assess the luminescence properties of selected minerals. The recorded BSE contrast allowed for the differentiation between bright minerals (enriched in heavy elements) and dark minerals (mafic phases). The results were used for the identification and interpretation of the mineralogy of the rock samples.

Results and discussion

The SEM-CL micrograph of sample 1 shows the most abundant luminescence features. Numerous luminescence centers are visible, mainly localized within orthoclase. The emission is point-like and unevenly distributed, suggesting the presence of structural defects and zones enriched in activating impurities. Based on literature data and chemical analyses, the luminescence of orthoclase can be associated with the presence of Mn^{2+} and Fe^{3+} ions as well as oxygen vacancies acting as trapping centers, visualized as yellow points [13].

At the same time, local blue and red luminescence flashes appear in the SEM-CL micrograph of sample 1. The intensity of the blue emission may indicate the presence of zircon and cerium, which is consistent with the chemical analyses showing elevated concentrations of these elements [14,15]. The red luminescence points may be associated with apatite enriched in rare earth elements (REE) and Mn^{2+}, as reported in the literature [15]. However, in the absence of point chemical analyses performed directly on the luminescent centers, this interpretation remains provisional.

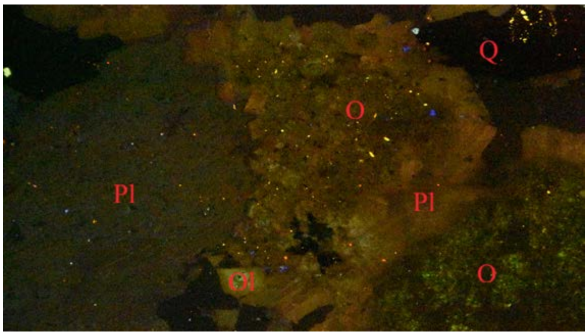

Figure 2. Luminescence centers in orthoclase (sample 1; symbols used: O—Orthoclase, Pl—Plagioclase, Ol—Olivine, Q—Quartz)

In the micrograph of sample 2, plagioclase is present, which—unlike orthoclase—does not exhibit luminescence. The lack of distinct emission indicates that its crystal structure and chemical composition do not favor the formation of active luminescence centers. The dominance of plagioclases (sodium–calcium feldspars) over orthoclase is also confirmed by chemical analyses of major elements, showing higher Na_2O than K_2O contents. Luminescence effects in this sample are mainly concentrated in accessory minerals and in minor amounts of orthoclase, locally generating characteristic yellow luminescence centers. The uneven distribution of point-like light signals may suggest that they are related to the presence of Mn^{2+}, Fe^{3+}, or Ti^{4+} impurities, which are reported in the literature as potential activators of luminescence in accessory phases. However, since no point chemical analyses were performed directly on the luminescence centers, this interpretation should be regarded as tentative, while plagioclase remains largely optically inactive [8].

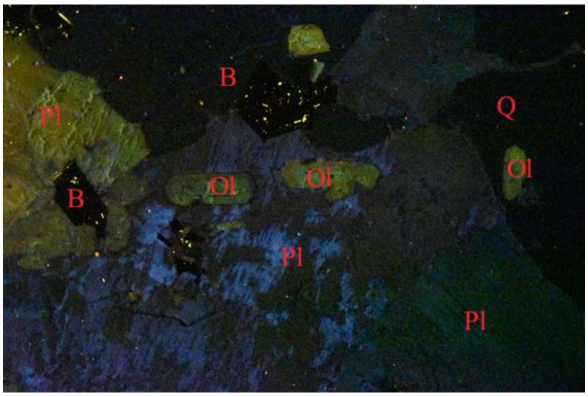

Figure 3. Luminescence centers in accessory minerals (sample 2; symbols used: Pl—Plagioclase, Ol—Olivine, Q—Quartz, B—Biotite)

In the micrograph of sample 3 (Fiure 4), both plagioclase and orthoclase are observed, with the latter exhibiting relatively weak luminescence activity. The emission is limited and diffuse, indicating a small number of defect centers and a relatively low concentration of activating ions in the crystal structure. Individual luminescence points occur mainly within small zones of biotite, which may be associated with local enrichment in elements such as Mn^{2+} or Fe^{3+} acting as luminescence activators [13]. Orthoclase exhibits a brighter appearance compared to other minerals, most likely due to Al–O–Al structural defects. This suggests that the observed luminescence effects result primarily from structural defects rather than from point-like luminescence centers [16]. Rare yellow signals are most probably related to iron activity in biotite, while the remaining red and blue points correspond to active centers described for sample 1 (Figure 2).

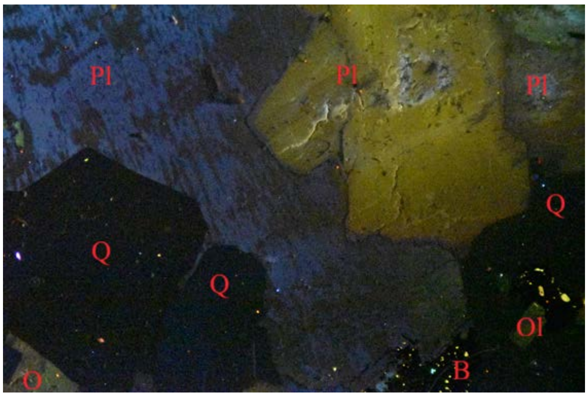

Figure 4. Weak luminescence activity of orthoclase (sample 3; symbols used: O—Orthoclase, Pl—Plagioclase, Ol—Olivine, Q—Quartz, B—Biotite)

In the micrograph of sample 4 (Figure 5), a distinct contrast in luminescence activity between orthoclase and plagioclase is observed. Orthoclase shows intense luminescence in the form of numerous point-like centers with yellow, red, and blue colors, whereas plagioclase remains optically inactive and does not emit a distinct luminescence signal. This differentiation indicates a significant influence of chemical composition and structural defects on the luminescence-generating capacity of minerals. In orthoclase, the observed emission is primarily related to the presence of Fe^{3+} ions acting as luminescence activators and to local oxygen vacancies formed during crystallization. The absence of luminescence in plagioclase confirms that this mineral acts merely as a background phase in the studied samples, while the actual luminescence signal is generated by orthoclase and accessory minerals.

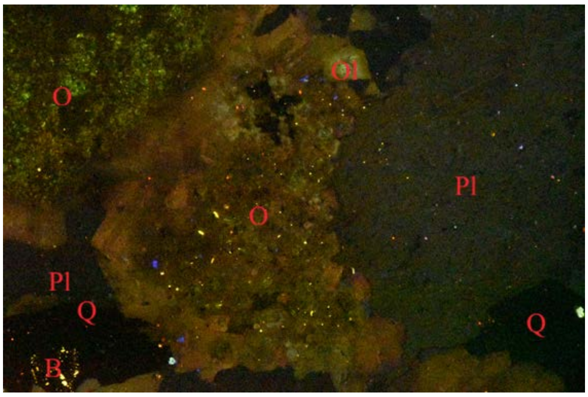

Figure 5. Strong luminescence activity of orthoclase and lack of emission in plagioclase (sample 4; symbols used: O—Orthoclase, Pl—Plagioclase, Ol—Olivine, Q—Quartz, B—Biotite)

Luminescence analyses revealed clear differences in optical activity among the investigated minerals. Orthoclase exhibited the highest emission intensity, whereas plagioclase was generally optically inactive. Accessory minerals (biotite, hornblende) also played a significant role in shaping the luminescence image despite their minor abundance in the samples.

Conclusions

Cathodoluminescence investigations of the Strzegom granites demonstrated that the luminescence activity of individual minerals is highly diversified and closely related to both their chemical composition and the presence of structural defects. The observed luminescence effects are generally consistent with literature data and the results of chemical analyses.

Orthoclase exhibited the highest cathodoluminescence intensity, whereas plagioclase remained optically inactive in most cases. This behavior results from differences in the chemical composition of these feldspars and their ability to incorporate luminescence-activating elements. It should be emphasized, however, that due to the relatively large grain size of the minerals (on the order of several millimeters) and the limited area of microscopic observation, the interpretation of luminescence effects should be regarded as qualitative and local.

Analysis of microphotographs showed that luminescence centers are concentrated in specific minerals, and the observed colors can be attributed to the following mechanisms:

Orthoclase

- yellow luminescence: mainly associated with Mn^{2+} and Fe^{3+} ions acting as activators and with local oxygen vacancies;
- blue luminescence: primarily attributed to Al–O–Al structural defects and to the local presence of rare earth elements (e.g., Ce^{3+}) and Zr-rich accessory phases (e.g., zircon);
- red luminescence: related to the presence of rare earth elements (REE) and Mn^{2+} ions, mainly within fine mineral inclusions (e.g., apatite) associated with orthoclase.

Biotite

- yellow luminescence (local and weak): associated with Fe^{3+} and Mn^{2+} ions; however, the high iron content simultaneously causes partial quenching of emission, making biotite a mineral with limited, point-like luminescence activity.

In summary, cathodoluminescence proved to be a useful tool for the qualitative analysis of the distribution of impurities and structural defects in minerals of the Strzegom granites. The method allows for effective differentiation between potassium feldspars and sodium–calcium feldspars and for the identification of zones enriched in luminescence-activating elements; however, its interpretation should always be supported by chemical and mineralogical analyses.

References

[1] Panna W, Wyszomirski P, Gajek M. Charakterystyka drobnych frakcji ziarnowych z przeróbki granitów strzegomskich pod kątem ich zastosowania do produkcji płytek ceramicznych. Mineral Resources Management. 2015;31(3):59–76. https://doi.org/10.1515/gospo-2015-0031.

[2] Shelly D. Igneous and Metamorphic Rocks Under The Microscope. Classification, Textures, Microstructures and Mineral Preferred Orientations. London: Chapman and Hall; 1993.

[3] Deer WA, Howie RA, Zussman J. An Introduction to the Rock-Forming Minerals. 2nd edition. Harlow: Longman Scientific & Technical; 1992.

[4] Wyszomirski P, Galos K. Surowce mineralne i chemiczne przemysłu ceramicznego. Kraków: AGH. Uczelniane Wydawnictwa Naukowo-Dydaktyczne; 2007.

[5] Mariano AN, Ito J, Ring PJ. Cathodoluminescence of plagioclase feldspars. Geological Society of America Abstracts with Program. 1973;5:726.

[6] Marshall DJ. Cathodoluminescence of Geological Materials. Boston–London: Unwin Hyman; 1988.

[7] Geake JE, Walker G, Telfer DY, Mills AA, Garlick GFJ. Luminescence of lunar, terrestrial, and synthesized plagioclase, caused by Mn^{2+} and Fe^{3+}. Proceedings of the Fourth Lunar Science Conference. Geochimica et Cosmochimica Acta. 1973;3(Suppl. 4):3181–3189.

[8] Götze J, Habermann D, Neuser RD, Detlev DK. High-resolution spectrometric analysis of rare earth elements-activated cathodoluminescence in feldspar minerals. Chemical Geology. 1999;153(1–4):81–91. https://doi.org/10.1016/S0009-2541(98)00153-3.

[9] Smith JV, Brown WL. Feldspar Minerals. Vol. 1 Crystal Structures, Physical, Chemical, and Microtextural Properties. 2nd edition. Berlin–Heidelberg: Springer; 1988.

[10] Homman NPO, Yang C, Malmqvist KG. A highly sensitive method for rare-earth element analysis using ionoluminescence combined with PIXE. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment. 1994;353(1–3): 610–614. https://doi.org/10.1016/0168-9002(94)91734-5.

[11] Majerowicz A. Masyw granitowy Strzegom-Sobótka. Geologia Sudetica. 1972;6(1) 7–96.

[12] Walendowski H. Granity strzegomskie. Nowy Kamieniarz. 2012;58(1):56–57.

[13] Toffolo M, Ricci G, Caneve L, Kaplan-Ashiri I. Luminescence reveals variations in local structural order of calcium carbonate polymorphs formed by different mechanisms. Scientific Reports. 2019;9:16170. https://doi.org/10.1038/s41598-019-52587-7.

[14] Götze, J. (2012). Application of cathodoluminescence microscopy and spectroscopy in geosciences. Microscopy and Microanalysis. 2012:18(6):1270–1284. https://doi.org/10.1017/S1431927612001122.

[15] Kempe U, Götze J. (2002). Cathodoluminescence (CL) behaviour and crystal chemistry of apatite from rare-metal deposits. Mineralogical Magazine. 2002:66(1);151–172. https://doi.org/10.1180/0026461026610019.

[16] Dollfus A, Geake JE. Polarimetric properties of lunar surface and its interpretation: Part 7—Other solar system objects. In: Lunar Science Conference, 6th, Houston, Texas, March 17–21, 1975, Proceedings. Vol. 3. New York: Pergamon Press; 1975. p. 2749–2768.