

PLAGIOCLASE COMPOSITION ON THE VITOSHA PLUTON (BULGARIA) BY X-RAY MAPS

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Abstract

Electron microscopy X-ray elemental analysis is used to characterize the plagioclase composition of the Vitosha pluton. The Vitosha pluton crops out in the western part of the Srednogorie structural zone. The plutonic body is composed of abyssal gabbros and anorthosites, hypabyssal monzonites, syenites and late veins of granosyenitic composition. The major rock-forming mineral phases are plagioclase, K-feldspar, amphibole and clinopyroxene. Common accessory minerals include apatite, titanite, magnetite, ilmenite and zircon. Secondary minerals are epidote, tourmaline, chlorite, actinolite, adularia and clay minerals. Plagioclase crystals characterized by compositional zoning are typical of the Vitosha pluton.

Key word: Vitosha pluton, plagioclase, gabbro, monzonite, syenite

INTRODUCTION

Electron microscopy X-ray elemental analysis is used to characterize the plagioclase composition of the Vitosha pluton. The Vitosha pluton crops out in the western part of the Srednogorie structural zone (Fig.1). The plutonic body is built from hypabyssal gabbro, anorthosite, monzonite, syenite and vein granosyenite intrusions. The plutonic complex introduce volcanic rocks and it is cut by post plutonic dyke rocks. The rocks span a range of SiO₂ from about 45 to 79 wt%.

Geological setting

The Vitosha pluton built the nucleus of the Vitosha Mountain with most high peaks and descending to the W-NW into Tertiary sediments of the Pernik kettle. The Vitosha Mountain is located south of Sofia and covers an area of about 200 km²; and the size of the Vitosha pluton is about 120 km². The high water-shed and western slopes of the mountain are made up of Upper Cretaceous intrusive rocks (Vitosha pluton), while Upper Cretaceous volcanic, subvolcanic, volcano-sedimentary rocks crop out in the other slopes. (Fig. 1)

In a structural aspect the Vitosha Mountain is situated in the easternmost part of the Viskjar-Vitosha synclinerium (Gochev et al., 1970) – part of the Sofia complex trough of the West Srednogorie (Bonchev, 1971). The Vitosha pluton, along with the Plana and Gucal plutons to the southeast, is considered to be part of the Marica neointrusive zone (Dabovski, 1968). However, this interpretation is still under debate.

Starting with Ami Boué (1840) until today the Vitosha pluton is a focus for research by mineralogists, petrologists, structural geologists, geophysicists and ore geologists.

The rocks from the Vitosha pluton have been studied in detail by Str. Dimitrov (1942). According to the latter it consists of 4 phases: gabbroic rocks (gabbro, anorthosites), monzonites, leucosyenites and granosyenites. In the contact between the gabbro and monzonite he determined monzodiorites and quartzdiorites, which he interpreted as hybrid rocks formed by magma mixing. Pegmatite dykes cut each of them and granosyenite-aplitic rocks cut volcanic rocks suggesting that the intrusion is younger. Str. Dimitrov (1951) interpreted the "andesite veins" as xenoliths within the gabbro and the Upper Cretaceous magmatism as a volcano-plutonic triad: volcanite – plutonite – magmatite dykes. He interprets this Upper Cretaceous magmatism as a Laramian tectonic magmatic intrusive phase.

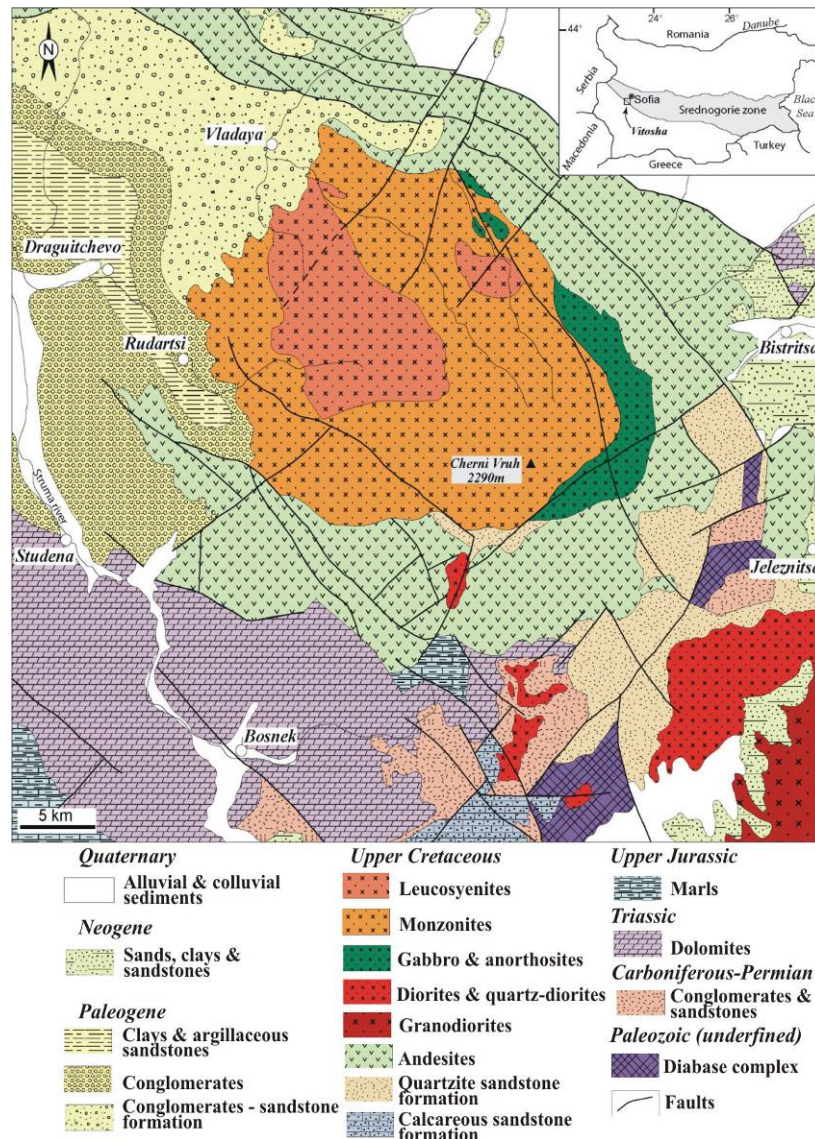


Fig. 1 Geological map of Bulgaria in scale 1:100 000, Pernik map sheet (editor I. Zagorchev, 1994), with authors processing

ANALYTICAL METHODS

Major elements in plagioclases were analysed using JEOL JSM 6390 with Oxford Instruments INCA energy dispersive X-ray spectrometer. Electron microprobe operated at 20 kV accelerating voltage, 30 nA beam current. Standards for: Na, Si, Ti, Al, Fe, Ca, K, Ba are natural minerals. For Na is aegirine – α line; Si – quartz with α line; Ti – rutile with α line; Al – corundum with α line; Fe – hematite with α line; Ca – wollastonite with α line; K - potassium feldspar with α line; Ba – barite with α line. Standards for: Cr, Mn, Mg are synthetic minerals. Cr is chromite with α line; Mn – tefoid with α line; Mg – periclase with α line.

X-ray maps are 16-bit, 256 gray-scale images depicting the distribution of major elements. Characteristic X-ray signals generated by the interaction of an electron beam and the sample were detected and then recorded as digital images. X-ray maps were obtained by energy dispersive spectroscopy (EDS). Images were collected using an accelerating potential of 20kV, a beam current of 10-20nA, and a 1-2 μ m focused electron beam. EDS analysis produces qualitative chemical results. A 16-bit gray-scale (256-shades) digital image was produced for each element.

Trace element analyses, including REE, were carried out by Excimer Laser Ablation ISP – MS (Elan 6000) of lithium tetraborate pellets. The laser beam is focused onto the surface of a solid sample. The intense energy of the beam ablates a small amount of the sample, which is swept by high-purity Ar into an inductively coupled plasma-mass spectrometer for determination of analyze mass abundance. The maximum output energy of the laser is 70 mJ per pulse at 10 Hz with beam size of 0.8 X 0.5 mm, a pulse width of 5.9 ns at 1064 nm and a pulse-to-pulse stability of better than 10% at 70mJ. The laser repetition rate can be varied from 2 to 20Hz. The LAMTRACE program developed by S. E. Jackson was used data reduction. Each analysis used in this paper is the average of at least 3 points.

Petrology

Typically, the plagioclases are idiomorphic, polylamellae twinned crystals. Different zoning types have been recognized: normal zonation. The microanalyses classified plagioclase according to Or-Ab-An diagram (Smith, 1974). The anorthite composition decreases with increasing fractionation of the magmas. (Fig. 2)

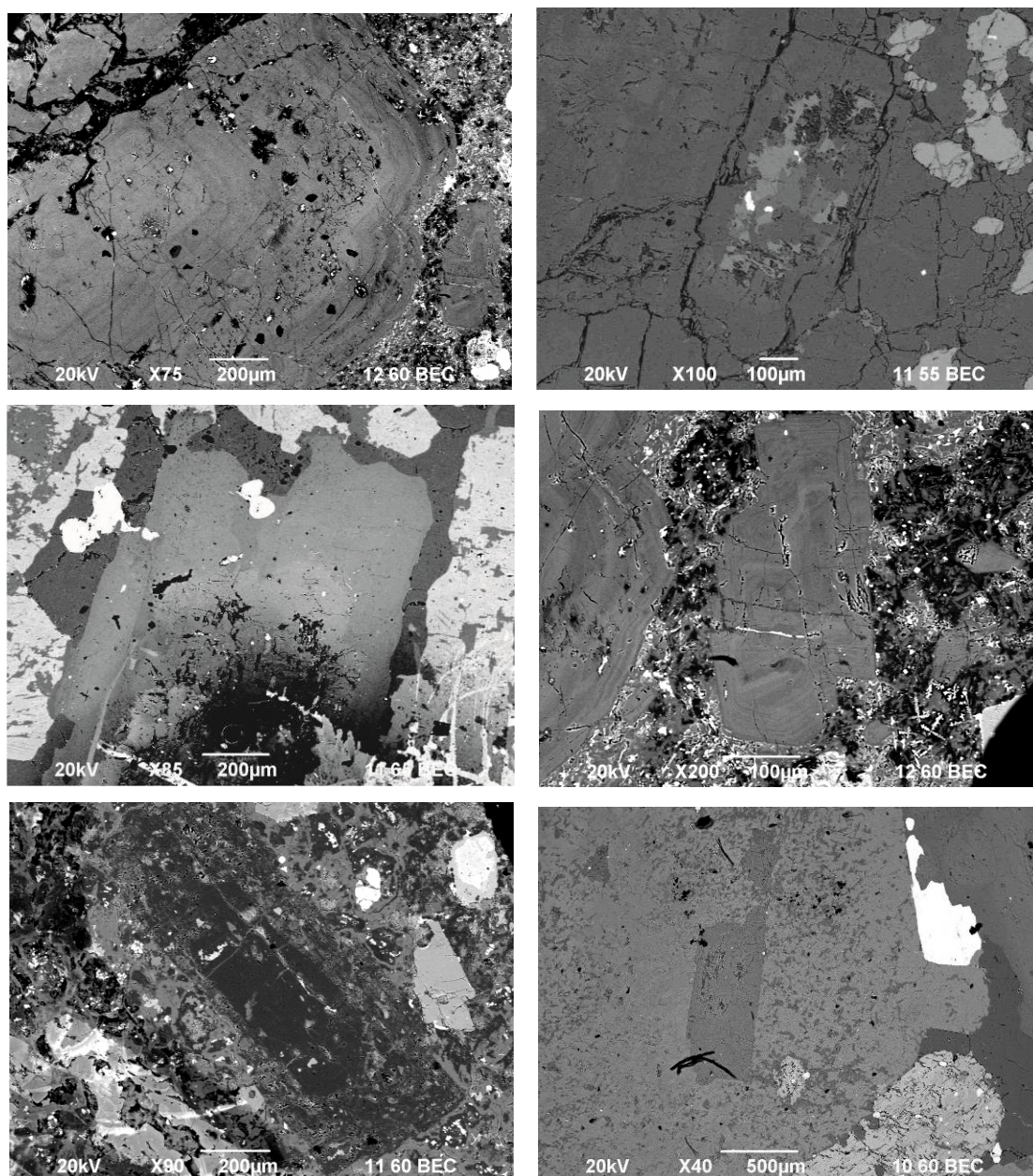


Fig. 2 Plagioclase crystal in Backscattered electron image

Plagioclase feldspars span much of the crystallization history of the Vitosha pluton. It is the most abundant mineral. It occurs in all types of the Vitosha pluton. They have different compositions in the different rock types. In gabbro the plagioclases are labradorites - bytownites. In monzonites and syenites they are oligoclases-andesines (Fig 3, Tab.1).

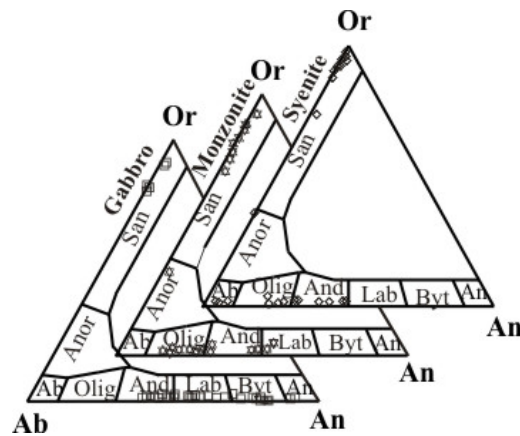


Fig. 3 Feldspar classification diagram (after Smith, 1974)

We use elemental X-ray maps provide an alternative method for mineral identification and chemical characterisation for the plagioclase feldspar. The maps of Ca, Na, Al, K together with the BSE image are presented in Fig. 4. The zonations vary according to their chemical composition, core is Ca rich and darker rim is Na rich. The rim portions display higher Si and Na concentrations and lower Al and Ca concentrations. In most of the samples, plagioclase presents Ca concentration at the core higher than at rim identifying a normal crystallization from high to low temperature.

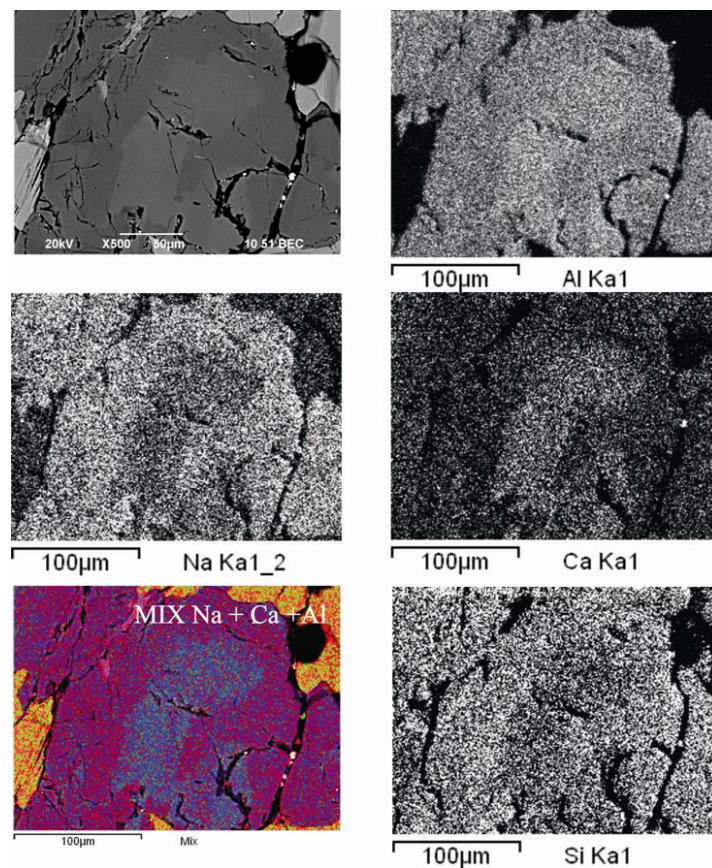


Fig. 4 X-ray maps showing Na, Ca, Si and Al zonation

Geochemistry

Primitive mantle normalized rare-earth element (REE) patterns for plagioclase (Tab. 2a, Tab. 2b and 2c) show that highly calcic plagioclase $> \text{An}_{78}$ has greater light REE /heavy REE ratio than less calcic plagioclase, An_{60-75} , suggesting that higher LREE/HREE ratio is inherent to plagioclase. Sr, Ba, Hf can also discern parentages as their abundances in plagioclase. These relationships help to distinguish between the effects of fractionation of trace elements in plagioclase and their primary abundances due to intrinsic concentrations in their magma sources. In the all samples the LREE/HREE ratios are high; this ratio increases as plagioclase evolves to lower An compositions. Hf and Ba can also be useful, because they are relatively enriched in calcalkaline magmas, however, Ba is sensitive to modification by secondary alteration processes. The best expressions for identifying parentage use are the Sr and Ba abundances, because Sr concentrations increase in feldspars with increasing of SiO_2 .

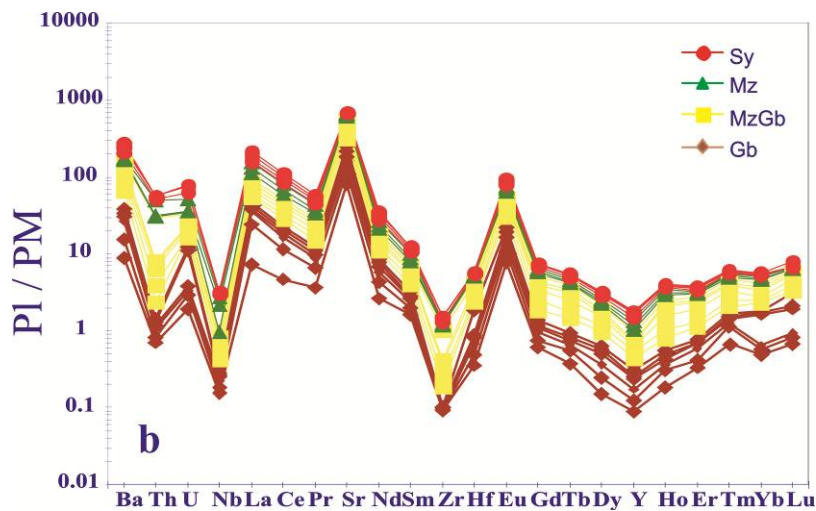


Fig. 5 Plagioclase against Primitive mantle (normative value Sun and McDonough, 1989)

Chondrite-normalized REE diagram for plagioclase (Fig. 6) shows that all analyses have significant positive Eu anomalies. In gabbro $\text{Eu}/\text{Eu}^* = 2.41 - 6.63$, in monzogabbro $\text{Eu}/\text{Eu}^* = 1.84 - 4.93$, in monzonite $\text{Eu}/\text{Eu}^* = 1.92 - 5.43$, in syenite $\text{Eu}/\text{Eu}^* = 1.43 - 7.37$

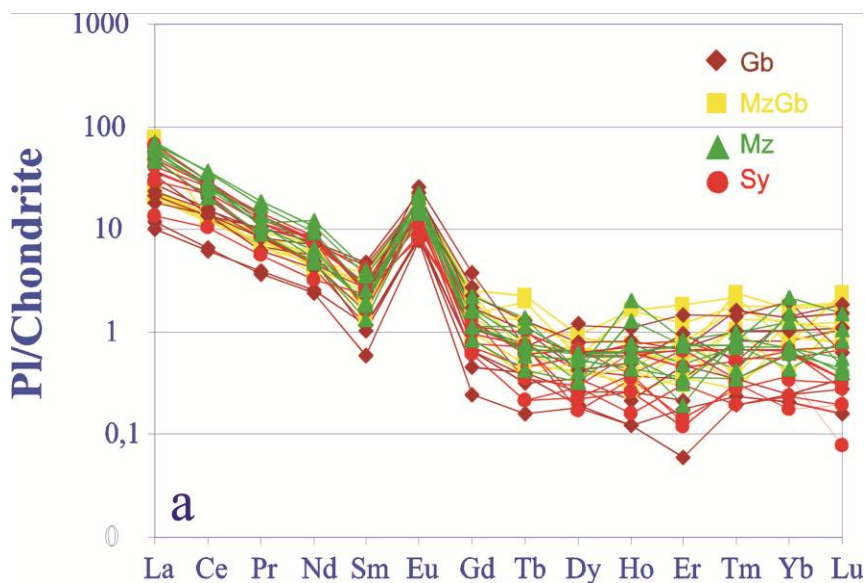


Fig. 6 Plagioclase against Chondrite (normative value Sun and McDonough, 1989)

Table 1 Mineral analyses of representative plagioclase from the Vitosha pluton.

№	52	54	44	45	51	148	149	162	163	170	176
SiO ₂	51,94	52,61	47,01	44,36	46,55	61,23	55,80	65,87	67,31	59,38	59,93
TiO ₂	0,05	0,06	0,00	0,00	0,03	0,00	0,05	0,00	0,00	0,03	0,03
Al ₂ O ₃	29,06	29,05	32,51	32,34	33,12	25,27	28,62	21,64	21,67	27,42	27,49
Cr ₂ O ₃	0,02	0,00	0,05	0,00	0,00	0,01	0,02	0,04	0,02	0,02	0,01
FeO	0,90	0,31	0,32	0,35	0,26	0,16	0,17	0,25	0,06	0,18	0,17
MnO	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,02	0,00
MgO	0,08	0,07	0,16	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00
CaO	12,16	12,31	17,13	16,33	17,06	6,09	9,99	1,80	1,97	7,17	7,57
Na ₂ O	4,77	4,85	1,87	2,45	2,05	8,07	5,80	10,66	10,40	7,32	7,50
K ₂ O	0,14	0,14	0,03	0,07	0,05	0,51	0,25	0,05	0,17	0,23	0,22
BaO	0,02	0,01	0,01	0,03	0,02	0,01	0,00	0,03	0,00	0,00	0,01
Total	99,15	99,40	99,09	95,93	99,16	101,36	100,69	100,35	101,61	101,76	102,94
An	58	58	83	78	82	29	48	9	10	35	36

Table 2a REE analyses of representative plagioclase from the Vitosha pluton

№	52	54	44	45	51	148	149	162	163	170	176
B	15,7	7,63	21,0	13,44	4,98	5,52	10,89	6,36	20,37	76,76	63,50
Sc	0,54	0,36	4,21	0,43	0,18	0,33	0,41	0,25	0,31	0,46	1,12
Ti	0,02	0,02	0,05	0,02	0,01	0,01	0,02	0,00	0,00	0,01	0,01
V	2,86	1,48	59,36	2,20	0,60	0,54	0,65	0,42	0,35	1,28	11,13
Cr	29,5	41,5	43,28	53,13	9,55	3,82	8,81	8,35	70,53	12,01	15,70
Co	4,9	0,71	18,89	0,61	0,37	0,19	0,15	0,10	0,19	0,32	0,00
Ni	10	4,29	6,83	4,67	2,50	1,16	2,64	4,03	3,96	4,43	2,54
Cu	4,24	3,06	543,7	4,36	35,60	0,57	1,77	0,56	1,32	12,69	15,20
Zn	12,9	12,2	29,81	10,6	5,54	6,90	6,76	1,27	2,14	11,68	20,13
Rb	1,27	2,4	3,61	0,20	0,94	3,74	2,37	3,49	6,11	23,43	5,30
Sr	124	1267	1573	1729	740	186	1102	319	369	536	535
Y	0,44	0,38	0,89	0,39	0,21	0,28	0,60	0,02	0,05	0,46	0,65
Zr	0,88	3,05	1,65	0,75	0,03	0,04	0,80	0,06	0,12	0,20	0,44
Nb	0,09	0,05	0,32	0,08	0,01	0,10	0,07	0,03	0,05	0,06	0,65
Cs	0,09	0,05	0,17	0,04	0,07	0,29	0,25	0,44	2,21	1,04	0,60
Ba	148	157	54,00	61,26	28,79	9,84	159,72	2,19	11,97	103,96	37,45

Table 2b REE analyses of representative plagioclase from the Vitosha pluton

№	52	54	44	45	51	148	149	162	163	170	176
La	5,02	10,19	5,10	5,77	2,53	0,29	9,01	0,02	0,02	13,04	14,95
Ce	8,32	8,31	9,66	8,98	3,86	9,84	14,47	0,02	0,03	14,54	20,59
Pr	0,77	0,79	2,86	0,90	0,34	12,31	1,13	0,02	0,01	1,08	1,48
Nd	2,39	2,64	3,27	3,43	1,28	16,02	3,55	0,06	0,15	2,56	4,05
Sm	0,33	0,48	0,30	0,59	0,12	1,20	0,56	0,12	0,23	0,27	0,41
Eu	1,08	1,11	1,08	1,26	0,47	3,21	1,11	0,03	0,05	1,04	1,02
Gd	0,37	0,15	0,49	0,46	0,08	0,25	0,22	0,11	0,05	0,27	0,25
Tb	0,06	0,03	0,05	0,02	0,01	0,70	0,02	0,01	0,03	0,03	0,02
Dy	0,20	0,12	0,38	0,13	0,07	0,11	0,12	0,10	0,16	0,13	0,12
Ho	0,07	0,02	0,05	0,03	0,01	0,02	0,04	0,01	0,01	0,05	0,03
Er	0,19	0,10	0,26	0,14	0,03	0,07	0,12	0,08	0,08	0,10	0,06

Table 2c REE analyses of representative plagioclase from the Vitosha pluton

№	52	54	44	45	51	148	149	162	163	170	176
Tm	0,30	0,02	0,03	0,02	0,01	0,01	0,01	0,02	0,02	0,02	0,02
Yb	0,19	0,08	0,26	0,21	0,03	0,04	0,11	0,06	0,14	0,23	0,12
Lu	0,04	0,02	0,03	0,04	0,00	0,01	0,01	0,02	0,02	0,02	0,01
Hf	0,15	0,07	0,11	0,13	0,02	0,04	0,04	0,08	0,13	0,10	0,03
Ta	0,05	0,10	0,04	0,03	0,00	0,00	0,02	0,01	0,01	0,04	0,02
Pb	13,97	10,11	10,23	10,80	4,65	0,02	19,91	4,54	7,28	12,98	15,95
Th	0,12	0,10	0,35	0,09	0,01	0,01	0,12	0,02	0,03	0,21	0,63
U	0,05	0,05	0,08	0,04	0,06	14,58	0,12	0,02	0,02	0,49	0,14

CONCLUSION

The Vitosha pluton formed by fractional crystallization as revealed by this detailed investigation of plagioclase zonation.

1. Plagioclases span much of the crystallization history throughout the magmatic series, generally decreasing in anorthite component from basic to acid plutonic varieties.
2. Plagioclases core are Ca and Al rich and the rim is Na and Si rich.
3. Chondrite-normalized REE diagram for plagioclase shows higher LREE/HREE ratio.

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