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AGE AND GEOCHEMICAL CHARACTER OF PLAGIOMICROCLINE GRANITE VEINS IN THE ABJA GABBRO-DIORITIC MASSIF

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The Svecofennian complexes of the burried crystalline basement of Estonia often contain mostly vein-like plagiomicrocline granite bodies of different thickness and shape. By texture the granites are varigrained, more rarely pegmatoid or medium-grained. Their mineralogical composition varies from microcline granite to plagioclase-microcline ones being also charnockitic in the areas of granulitic stage of regional metamorphism. Chemically the granites belong to subalkaline series (Irvine, Baragar, 1971). The rocks are most often correlated with the late — and postkinematic plagiomicrocline granites of the Fennoscandian Shield, which have the ages between 1.85–1.75 Ga. (Nurmi and Haapala, 1986, Andersson, 1991). Similar varigrained K-rich vein-like bodies of plagio-microcline granite intersect also the gabbro-diorites of the Abja massif in Southern Estonia (Fig. 1). The stock under the Paleozoic sedimentary cover 480 m thick was tracked geophysically and opened by the drill core 92 (Puura et al. 1983).

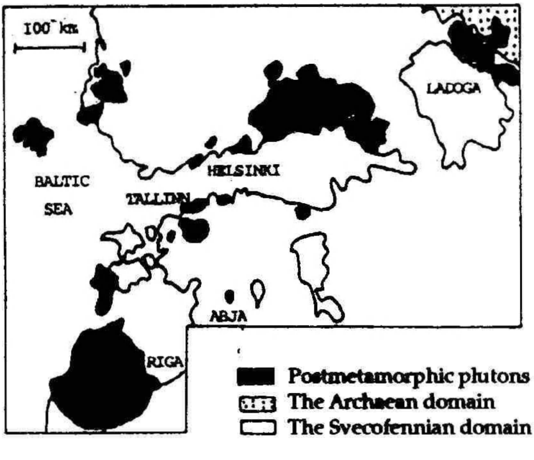

Fig. 1. Map, showing the location of Abja gabbro-dioritic stock in Estonian crystalline basement.

Table 1. Chemical composition of the rocks from drill core 92 (Abja)

Sample	925948	926150	926254	926306	926336	925875	925890	926203	926300
	1	2	3	4	5	6	7	8	9
SiO_2	45.34	50.00	49.44	50.80	51.74	67.12	68.80	73.26	71.92
TiO_2	2.04	2.14	2.14	2.06	1.88	0.42	0.48	0.11	0.18
Al_2O_3	13.04	13.02	13.74	13.02	13.02	13.52	13.63	12.96	13.50
$Fe_2O_3^+$	16.32	13.93	14.64	13.58	13.22	4.79	1.93	1.42	2.26
MnO	0.20	0.14	0.17	0.19	0.16	0.04	0.03	0.02	0.03
MgO	4.74	3.92	4.31	3.79	4.01	0.93	1.26	0.13	0.43
CaO	8.14	7.12	6.88	6.82	6.15	1.51	1.75	1.21	1.69
Na_2O	2.88	3.25	3.16	3.32	3.16	2.50	2.50	2.68	3.41
K_2O	2.58	3.20	3.12	3.18	3.09	7.25	6.65	7.33	6.05
P_2O_5	3.58	1.98	2.04	1.88	1.80	0.18	0.15	0.02	0.08
Total	98.86	98.70	99.64	98.64	98.23	98.26	97.18	99.14	99.55

Sample	925948	926150	926254	926306	926336	925875	925890	926203	926300
	1	2	3	4	5	6	7	8	9
F	0.457	0.331	0.508	0.507	0.589	0.123	–	0.017	0.058
CO_2	0.62	0.62	0.67	0.54	0.62	0.40	–	0.44	0.23
LOI	1.39	0.93	1.26	1.18	1.45	0.98	0.60	0.76	0.66
Pb	55	60	39	57	57	62	–	70	98
Rb	61	62	80	87	86	197	–	185	150
Sr	1423	1586	850	959	1290	608	–	923	1150
Nb	24	19	23	22	27	70	–	16	16
Zr	224	279	356	356	353	330	–	93	184
Ti	12230	12829	12829	12350	11271	2518	2878	659	1079
Y	65	56	66	64	67	119	–	39	36
Th	14	16	16	26	21	111	–	42	67
U	9	6	10	11	10	10	–	6	15

Notes:

+Total iron as Fe_2O_3

Samples 1–5 as gabbro-diorites, 6–9 as plagiomicrocline granites.

Major elements: wet chem. an., trace elements: XRF method. Chem. Lab. Geol. Surv. Estonia

Table 2. U-Pb analytical results of zircons from the gabbo-diorites and granites from the drill core 92 (Abja)

N	Fraction (mkm)	Concentration (ppm)		Measured			Atomic ratios		Age (Ma)
		U	Pb	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{206}Pb$	$^{208}Pb/^{206}Pb$	$^{206}Pb/^{238}U$	$^{207}Pb/^{206}Pb$	$^{207}Pb/^{206}Pb$
Sample 926064, interval 606.4–610.0 m. Gabbro-diorite, weakly gnessic									
1.	80-200	267.7	74.07	4015	0.1029	0.2081	0.2433	3.351	1624
2.	200-250	250.6	69.82	6140	0.1019	0.2244	0.2431	3.360	1628
Sample 926110, interval 611.0–617.0 m. Gabbro-diorite, weakly gneissic									
3.	80-200	237.9	70.39	3855	0.1032	0.2693	0.2484	3.439	1632
4.	200-250	194.5	63.85	1175	0.1114	0.3291	0.2620	3.622	1629
5.	80-200+	216.3	83.22	241.7	0.1569	0.4296	0.2620	3.622	1629
Sample 92575, intervals 587.5–589.5, 620.3–620.7, 630.0–630.3, 603.4–604.0 m. Plagiomicroline granite, varigrained									
6.	Slightly coloured	2057	579	4954	0.10193	0.11430	0.26863	3.6770	1610.5
7.	Mediumcolured	2590	636	1535	0.10671	0.11401	0.23160	3.1251	1583.8
8.	Dark-coloured, opaque	3589	686	743.5	0.11280	0.11754	0.17665	2.2974	1514.6
9.	Residues of 7 and 8	248.9	163	620.2	0.11963	0.14659	0.59157	7.9607	1578.7

+ – abrasive treatment

Fraction 9 – residues of the fractions 7 and 8, were processed during 30 minutes in fluoric acid at 210°C

Abja gabbro-diorites

The gabbro-diorites from the Abja drill core form the greenish-grey mediumgrained rock with massif or weakly gneissic texture. Containing SiO_2 about 45–52 wt% the rock nevertheless has the mineralogical composition of quartz-diorite (Puura et al, 1983, Table 32). Of specific character is also the enrichment with the accessory apatite and titanomagnetite. Geochemically the rock belongs to alkaline series with K_2O content of 2.6–3.2 wt%. It is enriched with the P, F, Ti and incompatible trace elements such as Ba, Sn, Zr, Th, REE (Table 1) (Petersell, Kirs 1992).

The isotope age of the gabbro-diorite was determined by the U-Pb method of zircon in the laboratory of Vassiliostrov Association "Ostrov" by IGGD in St. Petersburg under the supervision of Dr. O. A. Levchenkov. Decomposition of zircon and extraction of Pb and U were performed by Krogh's method (Krogh, 1973). Pollution with laboratory Pb and U did not exceed 0.2 and 0.1 ng. The content of Pb and U isotopes was measured by means of the mass spectrometer Finnigan MAT, model 261. Fractionation coefficient of this device is 0.001 to 1 per unit of atom mass. Error by measuring the isotopic ratios 206Pb/238U and 207Pb/235U was up to 1.0%. Establishing of isotopic relations, finding of their analytical points in the concordia plot and calculation of isochronous ages were performed according to Ludwig (Ludwig, 1980).

By calculating the age the following constant values were used: $\lambda_{238} = 0.155125 \times 10^{-9}$ years^{-1}, $\lambda_{235} = 0.984850 \times 10^{-9}$ years^{-1}, 238U/235U=137.88. In meaning of correctional lead the isotopic composition calculated by the model of Stacey and Kramers (Stacey, Kramers, 1975) was used.

Zircons fractionated were translucent with the pale pink (brownish) colour and idiomorphic prismatic habit. Some crystals were weakly zoned. Most grains had dimensions about 0.05–0.3 mm with the elongation less 1.5. Rarely tiny inclusions were detected.

The age of Pb, obtained by single determinations from zircon, as well as the concordant age, were very similar, respectively 1.624–1.632 Ga and 1.635 ± 7 Ga (Table 2, Fig. 2).

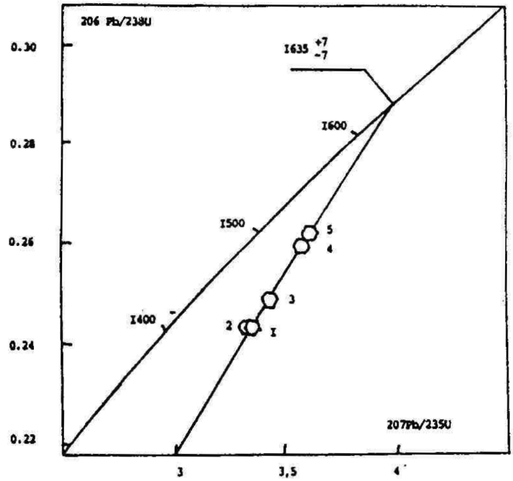

Fig. 2. Concordia plot of U-Pb zircon data on Abja gabbro-diorite.
1–5 – fractions from Table 2.

Veins of plagiomicrocline granite

Gabbroids in the Abja drill core are intersected by five veins of varigrained plagiomicrocline granite, forming an angle of about 40–50° with the vertical line. The thickness of these veins seems to range within 0.2–3.4 m. The rock is fine- to mediumgrained, in places containing coarser K-feldspar crystals which give to it a slightly porphyritic appearance. The mineralogical composition of granite is predominantly as follows: microcline (40–60%), plagioclase (20–30%), quartz (20–25%), biotite (5%). Accessory minerals are represented by apatite, zircon, monazite, orthite and magnetite.

For the isotope age dating rock samples were taken from the drill core 92 at dephts of 577.5, 620.3 and 630.0 ± 0.5 m and were combined into one sample. At the same dephts samples were taken for the determination of major and trace elements in the rock.

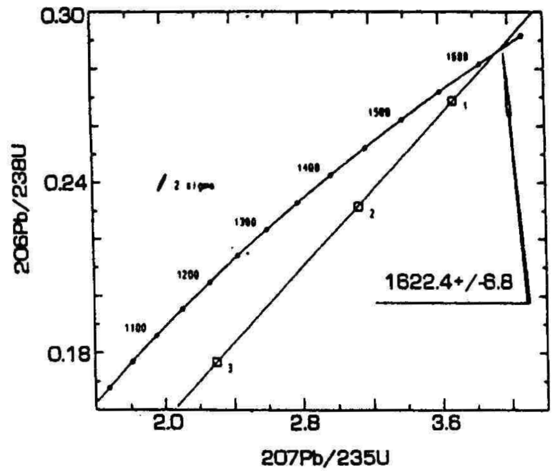

Fig. 3. Concordia plot of U-Pb zircon data on Abja vein granite.
1–3 – fractions from Table 2 (see text).

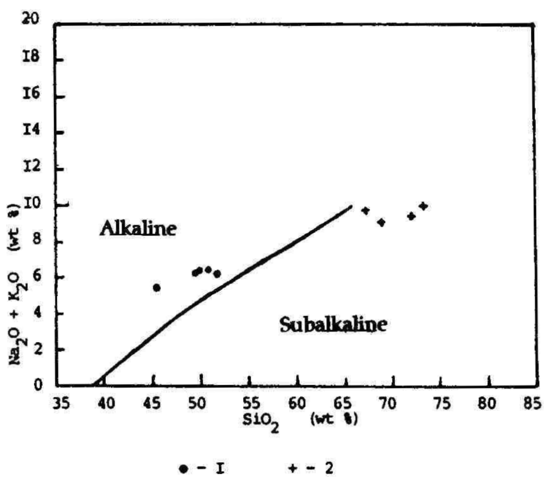

Fig. 4. Compositions of Abja gabbro-diorites (1) and plagiomicrocline granites (2) plotted in Na_2O+K_2O vs. SiO_2 diagram (Irvine and Baragar, 1971).

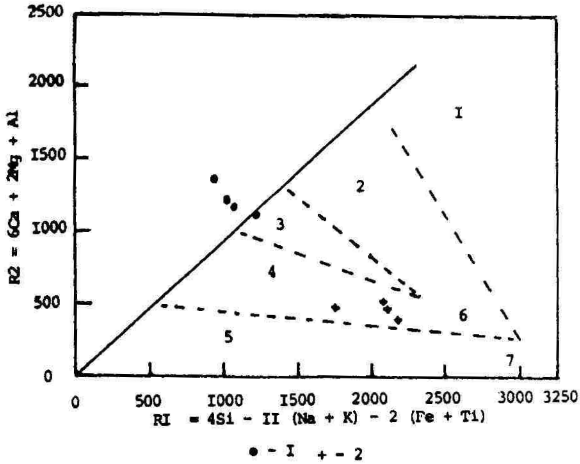

Fig. 5. Compositions of Abja gabbro-diorites (1) and plagiomicrocline granites (2) plotted in de la Roche multicationic RI vs. R2 diagram (Batchelor and Bowden, 1985)
1 – Mantle Fractionates, 2 – Pre-plate Collision, 3 – Post-collision Uplift, 4 – Late-orgenic, 5 – Anorogenic, 6 – Syn-collision, 7 – Post-orogenic

The sample for the isotope age was crushed to 0.25 mm. Zircon, separated from it using the ordinary mineralogical methods, constituted pieces of crystals of one generation broken mechanically.

The isotope age dating was performed also in the above-mentioned laboratory in St. Petersburg under the supervision of Dr. O. A. Levchenkov. The colour of zircons analyzed changed from colourless translucent to dark-brown opaque (Table 2). For the analysis three portions were weighed having different colours: slightly coloured translucent, medium-coloured semi-opaque and dark-coloured opaque. The residues of the two last fractions were processed during 30 minutes in fluoric acid on the temperature of 210°C to investigate of more crystallized mineral parts having less destroyed isotope systems (Krogh, Davis, 1975).

All three zircon fractions of different translucency, separated for the analysis, had a very high U-content exceeding 2000 ppm (Table 2). Radioactive decomposition of U and Th caused considerable metamictisation of crystals finding its expression in lowering of double refraction coefficient. This was the reason for partial loss of radiogenic Pb. There can be observed direct relation between the U-content in zircon and Pb loss.

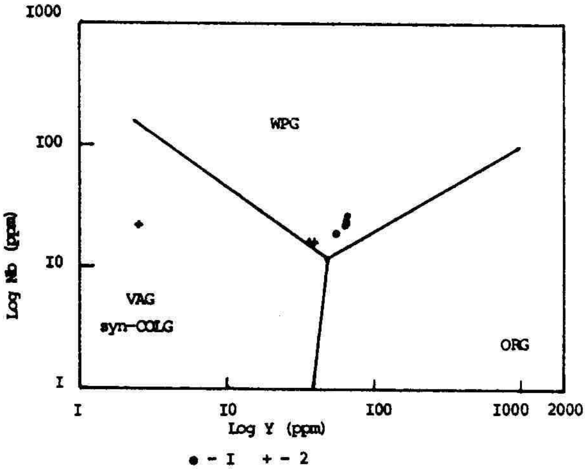

Fig. 6. Compositions of Abja gabbbro-diorites (1) and plagiomicrocline granites (2) plotted in Nb vs. Y diagram (Pearce et al; 1984).
WPG – within plate granites, VAG – volcanic arc granites, syn-COLG – syncollision granites, ORG – ocean ridge granites.

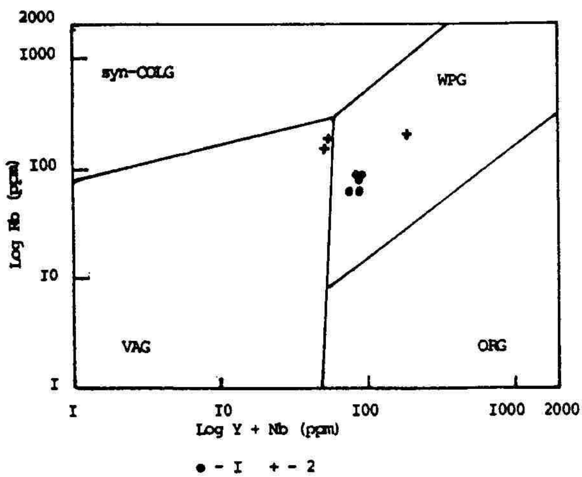

Fig. 7. Compositions of Abja gabbro-diorites (1) and plagiomicrocline granites (2) plotted in Rb vs. (Y+Nb) diagram (Pearce et al; 1984). The fields as in Fig. 7.

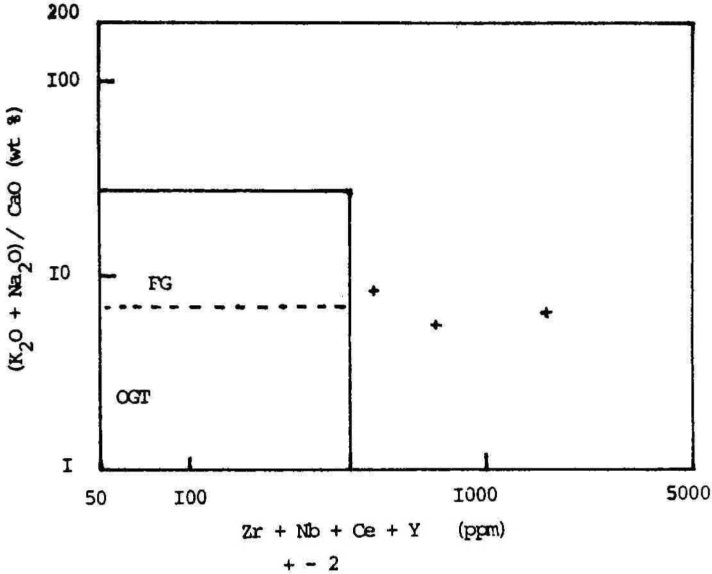

Fig. 8. Compositions of Abja plagiomicrocline granites (2) plotted in $(K_2O + Na_2O)/CaO$ vs. (Zr + Nb + Ce + Y) diagram (Whalen et al; 1987).
FG – fractionated I-type granites, OGT – unfractionated M-, S-, I-type granites.

By the data of analysis of three zircon fractions an isochron was constructed dating the age of zircon occuring in granites as 1622 ± 6 million years (Fig. 3). The fourth fraction was left out of consideration. During its processing with fluoric acid subtraction of U in relation to Pb took place whereas the 207 Pb and 206 Pb ratio remained the same. The Pb-Pb age in different zircon fractions ranges within 1514.6–1610.5 million years, being lower at higher U content in the samples (Table 2).

The contents of major and trace elements in granites were established at the chemical laboratory of the Geological Survey of Estonia, using the classical chemical and XRF methods, respectively, under the supervision of the chemist M. Kalkun (Table 1). The granites under consideration are highly alcalic, particulary rich in K (Table 1). On the SiO_2-alkalies diagram (Irvine, Baragar, 1971) their composition fall into the transition zone from subalkaline to alkaline field (Fig. 4). On the de la Roche R1-R2 multicationic diagram (Fig. 5) (Batchelor and Bowden, 1985) the compositions of vein granites lie on the trend of late orogenic granitoid series, lieing closely to the field of syn-collisional granites (i.e. towards the minimum melting composition formation of it in many cases coincides with the plate collision event in time). It is worth to note that, the compositions of Estonian subplatform (or rapakivi formation) K-granites (Petersell, Kirs 1992, Table 1), postorogenic age of which has been firmly documented (1.62–1.63 Ga, Kirs et al, 1991), lie exactly on this latter field of this diagram.

Characteristic to Abja vein granites is also high content of U, Th, Sr and Pb. The specific location of the composition points of the plagiomicrocline granites on various tectono-magmatic discrimination diagrams, such as Nb-Y, (Fig. 6), Rb-(Nb+Y) (Fig. 7) (Pearce et al. 1984) and $(K_2O + Na_2O)/CaO$ – – (Zr + Nb + Y + Ce*) (Fig. 8) (Whalen et al. 1987) allows to connect them with the granitoids of a tensional tectonic regime. Their geochemical parameters are quite close to granitoids of the rapakivi formation of the Estonian crystalline basement, first of all to rocks of the Naissaare stock. The age of the latter is also about 1.626±13 Ga (Kirs et al., 1991). However, the geochemical data refer to a more less fractionated character (lower Rb/Sr ratios, greater difference from a granitic minima) as to a more restricted (and various) extent of source rock melting (little higher, but uneven content of incompatible elements) for Abja vein granites in comparison with the Estonian subplatform K-granites forming an independent stocks.

Conclusions

The data above show the existence of such type plagiomicrocline vein granites in Estonian crystalline basement which have clearly younger age, than Svecofennian, together with the geochemical characteristics proper to anorogenic type magmatic rocks. However to distinct them from the widespread Svecofennian so-called lateorogenic plagiomicrocline granites it demands more detailed geochemical investigations. Considering this, the greatest attention should be paid on alkali-rich ($Na_2O + K_2O = 7 - 10$ wt%) veined bodies of plagiomicrocline

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* unpublished data V. Petersell

granite known from the boreholes of Are (171), Häädemeeste (172), Viljandi (91) and also from Seliste (173) borehole. In the last case, the isotopic age of granites determined by the K-Ar method from biotite is 1.545 Ga and 1.540 Ga (Puura, 1974). The pegmatoid varieties of plagiomicrocline granite, having a low isotopic age determined by the K-Ar method from biotite, have been recorded also from the drill cores in North-Eastern Estonia (Jõhvi II – 1.440 Ga, Kabala – 1.683 Ga, etc.) and also from Northern Estonia (Hirvli 8 – 1.345 Ga, F109 – 1.654 Ga) (Puura, 1974).

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ABJA GABRO-DIORIITSE MASSIIVI PLAGIOMIKROKLIINGRANIIDI SOONTE VANUS JA GEOKEEMILINE ISELOOM

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Resümee

Eesti aluskorra svekofenni kivimikompleksides on sageli soonelised mikrokliin- või plagiomikrokliingraniidi kehad. Neid rööbistatakse Fennoskandia kilbi hilis- osalt ka post-kinemaatiliste graniitidega, mille vanus kõigub vahemikus 1,85–1,75 miljardit aastat. Sellised eriteralise plagiomikrokliingraniidi sooned levivad ka Abja puursüdamikus 92 kohati gneisilist tekstuuri ilmutavas gabro-dioriidis (mineraloogiliselt kvartsdioriidis).

Gabbro-dioriidist eraldatud tsirkooni vanuseks saadi U-Pb isokroonmeetodil 1635 ± 7 ma (tabel 2, jn. 2). Geokeemiliselt on gabrokivimites kõrgenenud K, P, F, Ti, Zr, TR jt. nn. mittekaasnevate elementide sisaldus, mis on väga iseloomulik postorogeenseile magmakivimeile.

Abja soonelise plagiomikrokliingraniidi tsirkoonid annavad isokroon-vanuseks 1622 ± 6 ma. (jn. 3). Multikatioonsel RI-R2 diagrammil (jn. 5) langevad graniidiproovide koostispunktid graniitse ülessulamise miinimumi koostise lähedale. Rabakivigraniitidega võrreldes viitavad Abja soongraniidi geokeemilised andmed aga nii lähtekivimi ülessulamise kui ka tekkinud magma väiksemale fraktsioneerituse astmele.

Toodud andmed näitavad, et Eesti aluskorra kivimeis on Svekofenni orogeneesist selgelt nooremad, valdavalt plagiomikrokliingraniitse koostisega sooned. Sellele viitavad ka V. Puura esitatud soonelist tüüpi graniitide biotiidist K-Ar meetodil saadud isotoopvanused (Puura, 1974).