Early Mesoproterozoic magmatism in northwestern Lithuania: a new U–Pb zircon dating

Irma Vejelyte[a,b], Svetlana Bogdanova[c] and Grazina Skridlaite[d]

[a] Centre for Physical Sciences and Technology Vilnius, A. Gostauto 9, LT-01108 Vilnius, Lithuania; vejelyte.irma@gmail.com
[b] Present address: ARC Centre of Excellence in Ore Deposits (CODES) and School of Physical Sciences, University of Tasmania, Private Bag 79, Hobart, Tasmania, Australia 7001
[c] Department of Geology, Lund University, Sölvegatan 12, SE-22362 Lund, Sweden
[d] Institute of Geology and Geography, Nature Research Centre, Akademijos 2, LT-08412 Vilnius, Lithuania

Received 29 August 2014, accepted 10 December 2014

Abstract. We present new geochronological evidence of latest Palaeoproterozoic–earliest Mesoproterozoic magmatism in the Telsiai Deformation Zone, NW Lithuania. Employing the laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) at the University of Tasmania, Australia, we demonstrate that a granodiorite, which had previously been considered to belong to the 1850–1820 Ma Kursiai charnockitic batholith, has a U–Pb zircon age of ca 1.62 Ga. The weighted mean Pb^{207}/Pb^{206} age obtained from eight concordant zircon grains is 1625 ± 6 Ma (MSWD = 0.6), while the upper-intercept concordia age is 1619 ± 27 Ma (MSWD = 0.56). Like similar ages of granitoids from several small intrusions in Estonia, this once more indicates extensive melting of the crust at that time. We suggest that both the 1.62 Ga magmatism and the emplacement and crystallization of the large Riga anorthosite–mangerite–charnockite–rapakivi batholith in Latvia and western Estonia at 1580 Ma were far-field feedback effects of the formation of the new Palaeoproterozoic continental crust during the Gothian orogeny at the present SW margin of the East European Craton.

Key words: U–Pb zircon dating, LA-ICP-MS, granodiorite, Lithuania, East European Craton.

INTRODUCTION

Understanding the crustal evolution of the Palaeoproterozoic Svecofennian orogen requires the knowledge of its tectonic structure both in the Baltic/Fennoscandian Shield of Finland and Sweden, and in the Precambrian substratum beneath a ca 2 km thick sedimentary platform cover in the Baltic States on the opposite side of the Baltic Sea. The structure of the Palaeoproterozoic crust in NW Lithuania, in particular, is difficult to unravel and correlate with that in the Shield. One major difficulty is the strong influence of the Riga anorthosite–mangerite–charnockite–rapakivi granite (= AMCG) batholith dated at ca 1580 Ma (Rämö et al. 1996). This is one of the largest among the numerous AMCG and A-type granitoid intrusions with ages between 1650 and 1500 Ma that are widespread in Finland, Sweden, Russian Karelia, Latvia and Estonia. Together these mark the emplacement of voluminous magmas during the latest Palaeoproterozoic and the earliest Mesoproterozoic (Haapala & Rämö 1992; Rämö et al. 1996; Amelin et al. 1997; Andersson et al. 2001, 2002; Söderlund 2006). A similar, but in general somewhat later Mesoproterozoic magmatic activity at 1540–1500 Ma and again 1460 Ma is documented also in Lithuania and Poland (Wiszniewska et al. 2002; Skridlaite et al. 2003; Motuza et al. 2006; Vejelyte et al. 2012).

The object of the present study is a granodiorite from the Velaiciai-2 deep drilling (Vlc-2 drill core) located within the Telsiai Deformation Zone in NW Lithuania (Fig. 1). According to G. Motuza and co-workers (Motuza et al. 2008), this region is occupied by the large Kursiai batholith with a few minor plutons made up of a suite of dominantly charnockitic granitoid rocks (mangerite, enderbite, opdalite, charnockite and granite). Some of these have been dated at ca 1850 to 1820 Ma (Claesson et al. 2001; Motuza et al. 2008), but new geochronological data suggest that granitoids of similar compositions were also emplaced into the Palaeoproterozoic crust much later, at ca 1620 Ma (Vejelyte 2012). Employing the laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) U–Pb method of dating zircon, we thus undertook to test whether also the Vlc-2 rock in NW Lithuania was Mesoproterozoic in age.

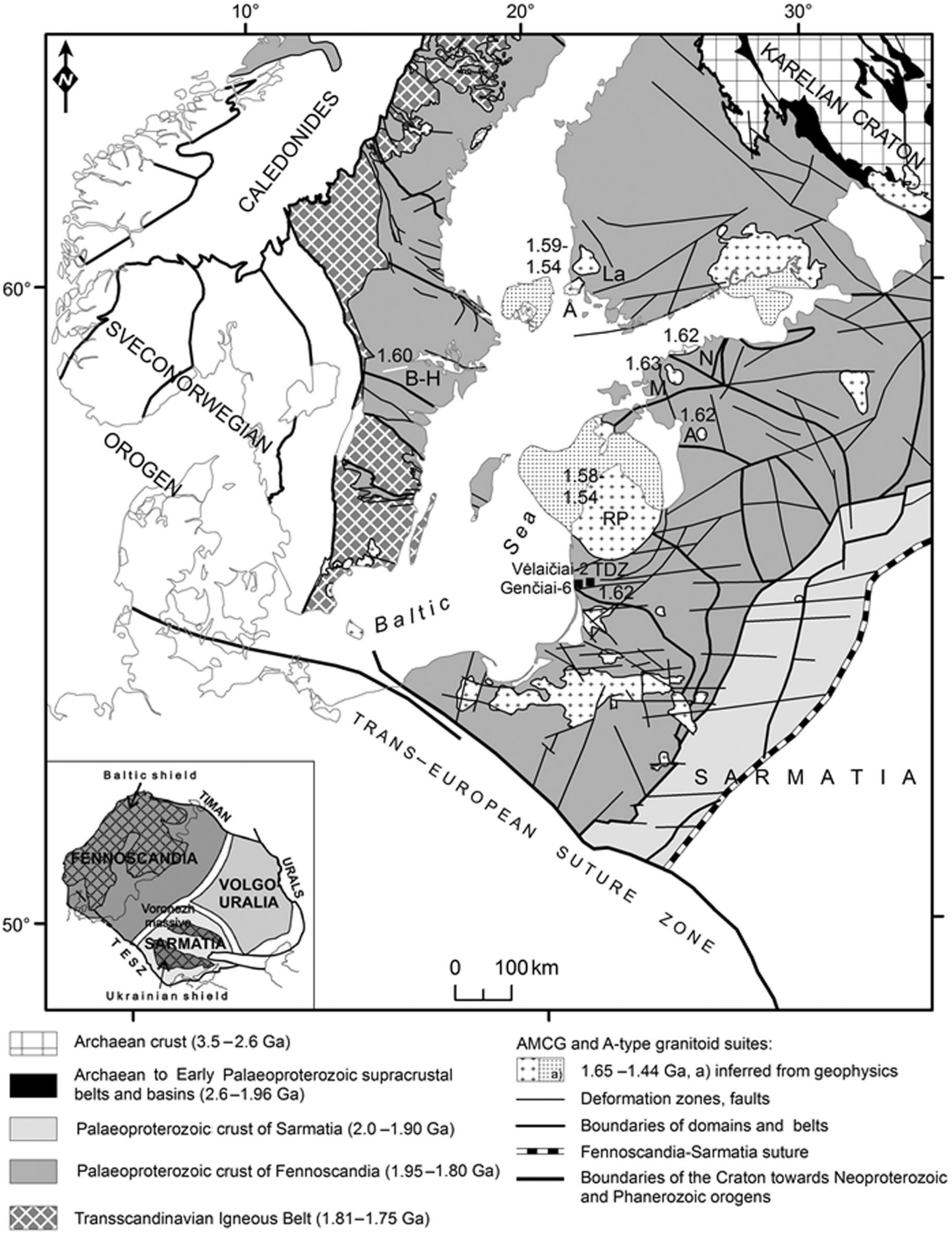

Fig. 1. Major tectonic domains of the crust in the western part of the East European Craton (modified after Bogdanova et al. 2006, 2015, and Skridlaite et al. 2014). The three-segment subdivision of the East European Craton is after Bogdanova (1993). The numbers mark the ages of the involved AMCG and A-type granitoid intrusions in Ga. The letters indicate the following intrusions: A, Abja, Å, Åland, M, Märjamaa, N, Naissaare, B–H, Breven–Hällefors mafic dyke swarm in central Sweden; RP, Riga pluton; TDZ, Telsiai Deformation Zone.

GEOLOGICAL SETTING

The structure and composition of the crust in NW Lithuania were developed during several Palaeoproterozoic and Mesoproterozoic tectonothermal events (Skridlaite et al. 2003, 2007; Motuza et al. 2006; Vejelyte 2012). Metavolcanic and metasedimentary granulites together with dominant plutonic charnockitoid rocks dominate this region, where the 1850–1820 Ma multiphase Kursiai charnockitic batholith has previously been outlined geographically on the basis of numerous drillings and geophysical data (Motuza et al. 2008). Its component intrusions and other similar rocks resemble the WNW–ESE chain of plutons in the southern Bergslagen region of south-central Sweden (Wikström & Andersson 2004; Stephens et al. 2009), which suggests Palaeoproterozoic lithological and structural continuity across the Baltic Sea (Fig. 1). Unlike most of the Berslagen region (though not its southernmost part), however, the Palaeoproterozoic crust in NW Lithuania has been complicated by strong deformation, metamorphism and coeval magmatism between ca 1600 and 1450 Ma, when the E–W-trending Telsiai Deformation Zone (TDZ in Fig. 1) was formed (Vejelyte et al. 2012). This part of Lithuania is close to the ca 1.58 Ga Riga batholith, which constitutes the backbone of the crust in Latvia and northern Lithuania, and has caused arcuate faulting along its periphery (Fig. 1). The presence of distal granitic derivatives of the batholith can therefore be expected in the area. In fact, some minor granitoid intrusions and cross-cutting granite veins resembling the Riga rocks have previously been distinguished also in the charnockitoid wall rocks to the south of the batholith (Bogatikov & Birkis 1973).

Various clinopyroxene- and biotite-bearing granodiorites have previously been described as the Pilsotas phase of the 1850–1820 Ma Kursiai charnockitic batholith (Motuza et al. 2008). They differ from the rest of that batholith in their higher magnetic susceptibilities and produce a strong magnetic anomaly (Motuza et al. 2008). None of these granodiorites have been dated as yet, but a vein of coarse-grained granite cutting the charnockite in the Genciai-6 drilling within the TDZ has yielded a 1622 ± 12 Ma ^{207}Pb/^{206}Pb age (GNC-2-1 in Vejelyte 2012). Similar coarse-grained granitic and amphibole-bearing veins are common among the 1820 Ma Vidmantai-1 drill core charnockitoids.

The Vlc-2 granodiorite was selected for the present study because of its apparent relationship to the still undated Pilsotas phase of the Palaeoproterozoic charnockites and its simultaneously rather numerous similarities with the later granitoids.

SAMPLE DESCRIPTION

The studied ca 50 m long part of the Velaiciai-2 drill core (Vlc-2) from the TDZ (Fig. 1) consists of granodiorites which are cut by a ca 20 cm wide aplitic vein. The studied granodiorite sample (Vlc-2-2) is made up of coarse-grained plagioclase, hornblende, biotite, quartz and microperthitic feldspar. The plagioclase crystals are nearly euhedral and vary between 4 and 6 mm in length. Numerous large (4–5 mm) hornblende crystals and 3 mm long flakes of brown biotite are aligned with each other, which indicates deformation along with magmatic crystallization. Irregularly shaped, more than 5 mm long quartz grains appear strongly elongated. During later mylonitization, the rims of the plagioclase, quartz, hornblende and biotite grains were recrystallized to matrices of minute grains (20–30 µm). Zircon, apatite and magnetite are common accessory minerals (Fig. 2A, B).

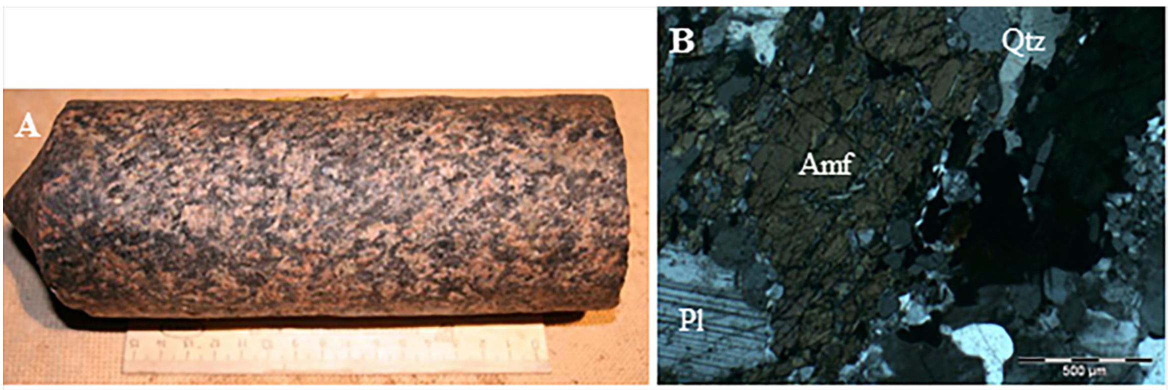

Fig. 2. Dated granodiorite from the Velaiciai-2 drill core (sample Vlc-2-2, depth 2074.4 m). **A**, general view of a hand sample; **B**, cross-polarized microphotograph showing a large amphibole grain (Amf), semi-euhedral plagioclase (Pl), quartz (Qtz) and fine-grained recrystallization and myrmeckitization during deformation.

In relation to the surrounding charnockitoids, the studied Vlc-2 granodiorite is almost identical to the Pilsotas granodiorites (Prm-1, Table 1, Fig. 3A, B) with regard to the major, trace and rare earth element (REE) compositions. All these rocks are ferroan, alkali-calcic and metaluminous, and plot in A-type within-plate settings (Motuza et al. 2008). They differ from the surrounding charnockitoids (Vd1/2183 and Stmb-1) in their lower

Table 1. Whole-rock compositions of the studied rocks. The oxides are given in wt%, while trace and rare earth elements are given in ppm

	Granodiorite	Pilsotas granodiorite	Quartz mangerite granite	Amphibole-bearing vein	Charnockitoids	
	Sample					
	Vlc-2[1]	Prm-2[1]	Edole[2]	Vd1/2535[3]	Vd1/2183[3]	Stmb-1[1]
SiO_2	61.25	61.58	64.54	46.24	62.18	62.94
TiO_2	1.55	1.41	0.53	2.56	1.16	0.74
Al_2O_3	13.78	14.03	13.91	13.97	15.97	14.9
Fe_2O_3	8.41	7.98	6.55	20.2	7.94	8.33
MnO	0.07	0.10	0.13	0.26	0.08	0.09
MgO	2.58	2.04	3.77	5.0	2.01	2.61
CaO	3.44	4.17	2.98	3.55	4.23	0.76
Na_2O	1.94	2.16	2.89	0.28	2.62	1.84
K_2O	4.66	4.64	4.64	5.12	3.16	4.65
P_2O_5	0.48	0.52		0.52	0.33	0.18
LOI	0	0		1.97	0	0
Total	98.16	98.63	99.94	99.67	99.68	98.85
Ba	1142.0	1232.0		608.0	1049.0	981.0
Co	18.1	17.9		58.9	63.2	20.8
Cu	25.4	21.0		82.4	30.2	45.3
Ga	20.3	23.2		36.1	23.8	21.8
Hf	17.9	13.0		18.9	8.46	7.1
Mo	1.4	1.0		1.02	0.69	0.2
Nb	30.0	24.6		38.12	17.83	11.7
Ni	32.3	35.0		64.3	25.0	36.0
Rb	204.2	207.9		195.9	91.93	201.5
Sn	3.0	2.0		2.11	1.38	1.0
Sr	155.8	277.0		71.7	183.0	29.3
Ta	1.8	1.5		2.7	1.28	0.5
Th	30.3	39.1		35.42	8.63	17.4
U	1.6	4.2		1.32	0.5	0.9
V	114.0	108.0		298.0	115.0	90.0
W	0.9	2.0		125.0	396.0	0.1
Y	64.6	66.0		76.4	38.1	65.0
Zn	59.0	88.0		271.0	105.0	102.0
Zr	675.2	424.5		730.0	340.0	251.2
Cs	1.8	3.8		2.96	0.343	0.6
Pb	5.5	11.0		8.04	22.0	2.6
La	119.20	138.50		119.70	62.10	60.1
Ce	247.60	235.20		243.30	128.00	114.5
Pr	28.21	29.07		28.91	14.90	13.75
Nd	103.90	117.10		103.90	57.60	51.0
Sm	16.60	20.70		19.44	10.90	9.9
Eu	2.51	3.02		1.62	2.72	1.48
Gd	13.79	19.61		18.28	10.40	9.32
Tb	2.36	2.24		2.81	1.43	1.5
Dy	12.32	13.24		16.29	7.98	9.13
Ho	2.29	2.53		2.95	1.47	2.11
Er	6.35	6.90		6.48	3.28	6.68
Yb	6.10	5.85		5.06	2.45	6.1
Lu	0.84	0.80		0.83	0.33	0.95

Analyses are from: [1] Motuza et al. (2008); [2] Bogatikov & Birkis (1973); [3] G. Skridlaite, pers. data.

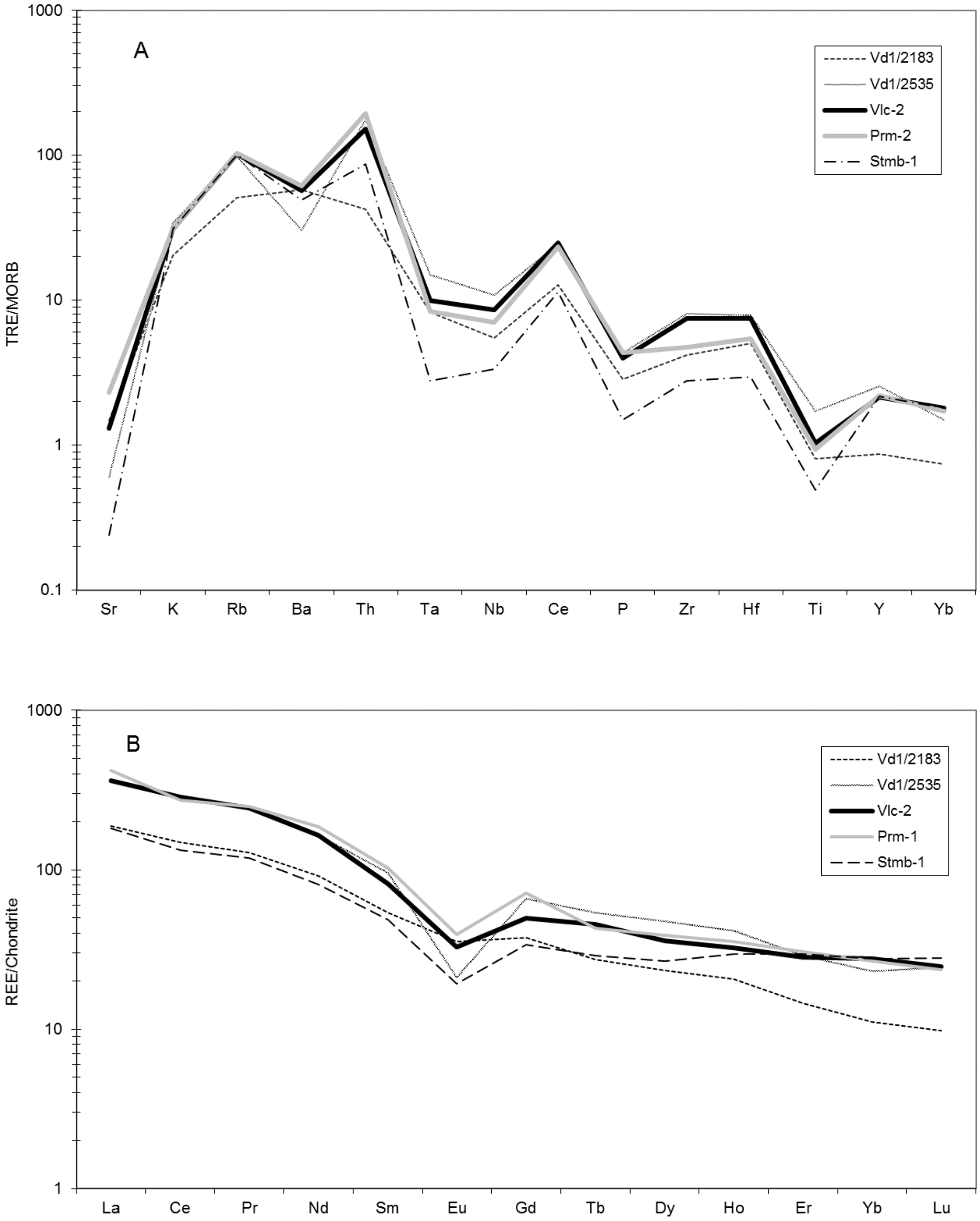

Fig. 3. REE patterns (**A**) and multivariate diagram (**B**) indicating chemical similarity of the dated granodiorite (sample Vlc-2-2) with some granitoids among the Kursiai charnockitoids. Chondrite- and MORB-normalizing values are after Sun & McDonough (1989).

alumina and higher Th and U contents, higher total contents of REEs (particularly light REEs), prominent negative Eu anomalies and quite uniform REE abundance patterns (Table 1, Fig. 3A, B). The Vlc-2 granodiorite has major element contents similar to those of the mangeritic granites in the Riga pluton (e.g. Edole quartz mangerite granite, Table 1; Bogatikov & Birkis 1973). Also the amphibole-bearing vein (Vd1/2535, Table 1) displays very similar REE and trace element patterns.

ANALYTICAL METHOD AND ZIRCON DESCRIPTION

Ten zircon grains from the Vlc-2 granodiorite (sample Vlc-2-2) were analysed by employing the LA-ICP-MS method at the University of Tasmania, Australia. The analyses were performed using a spot size of 34 μm, the results being listed in Table 2. Details of the technique and calibration have been given by Halpin et al. (2014).

The granodiorite contains elongated, well prismatic zircon crystals and rounded zircon fragments ranging between 100 and 210 μm in length (Fig. 4). The internal parts show oscillatory zoning in all cathodoluminescence (CL) images. Microcracks are abundant. Numerous inclusions have been observed in CL images, indicating rapid crystallization of the zircon from the granitoid melt.

DISCUSSION AND CONCLUSIONS

U–Pb zircon age results

As estimated from the ten spot analyses in distinct grains (Table 2; Fig. 5), the concordia upper-age intercept is 1619±27 Ma (MSWD = 0.56). If an analysis of 1670 ± 10 Ma, which we suspect to contain some inherited components, is excluded, the weighted mean $^{207}Pb/^{206}Pb$ age of the eight most concordant values is 1625 ± 6 Ma (MSWD = 0.60). The latter age, which is the most probable, constrains the time of magma emplacement into the Palaeoproterozoic crust of NW Lithuania during the Mesoproterozoic. The obtained U–Pb zircon ages are in good agreement with the age of the 1580 Ma AMCG Riga batholith in Latvia and western Estonia, which is a good example of bimodal felsic and basic magmatism (Rämö et al. 1996; Kirs et al. 2004). Recent baddeleyite datings of the Breven–

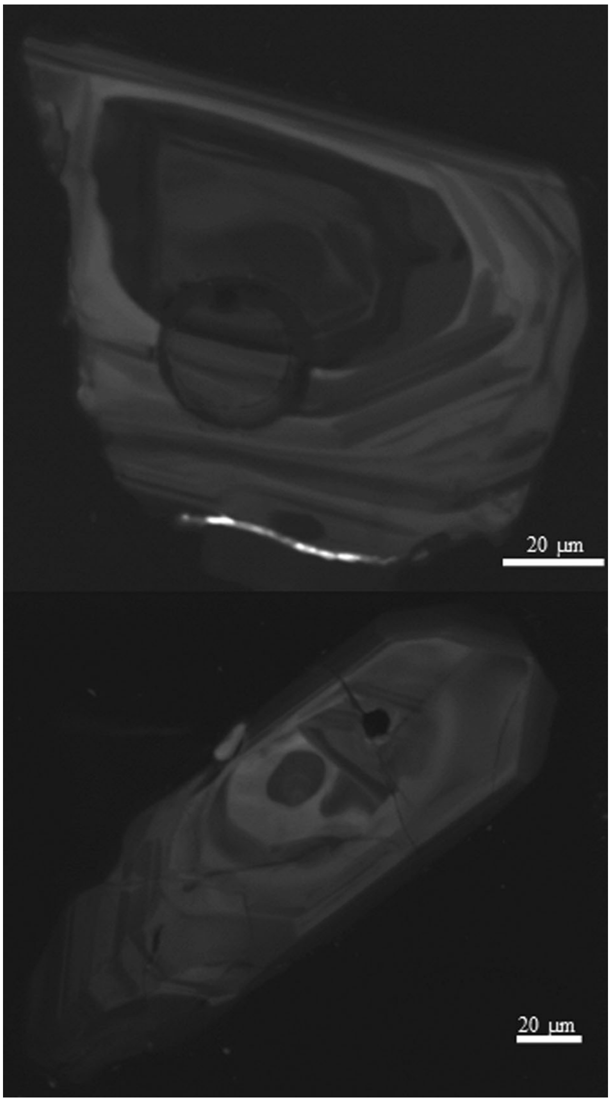

Fig. 4. The dated zircon from the Velaiciai-2 granodiorite (sample Vlc-2-2), NW Lithuania. Circles show the spot of analyses.

Table 2. Isotopic compositions of the zircon grains from the Velaiciai-2 granodiorite (sample Vlc-2-2) obtained by the U–Pb LA-ICP-MS method

Spot	Ratio				Age			
	$^{206}Pb/^{238}U$	σ_1	$^{207}Pb/^{206}Pb$	σ_1	$^{207}Pb/^{206}Pb$	σ_1	$^{206}Pb/^{238}U$	σ_1
AU31A006	0.2904	0.0106	0.1004	0.0125	1632.6	11.6265	1643.6	17.5017
AU31A007	0.2969	0.0097	0.0997	0.0114	1618.9	10.6808	1675.9	16.3332
AU31A008	0.3021	0.0098	0.1025	0.0110	1670.0	10.2115	1701.9	16.7610
AU31A009	0.2950	0.0086	0.1002	0.0059	1627.8	5.5281	1666.6	14.3562
AU31A010	0.2915	0.0089	0.0998	0.0066	1621.3	6.2218	1649.2	14.8382
AU31A011	0.2884	0.0150	0.0992	0.0204	1610.4	19.047	1633.8	24.6305
AU31A012	0.2874	0.0097	0.0994	0.0115	1613.9	10.787	1629.0	15.9538
AU31A013	0.3187	0.0114	0.1001	0.0135	1627.1	12.5914	1783.5	20.4842
AU31A014	0.2969	0.0082	0.1002	0.0062	1628.6	5.8393	1676.1	13.8042
AU31A015	0.2920	0.0124	0.1008	0.0174	1640.0	16.2208	1651.7	20.4853

The $^{207}Pb^{206}Pb$ model = Stacey & Kramers (1975) $^{207}Pb/^{206}Pb$ ratio at the apparent (non-common Pb corrected) $^{206}Pb/^{238}U$ age.

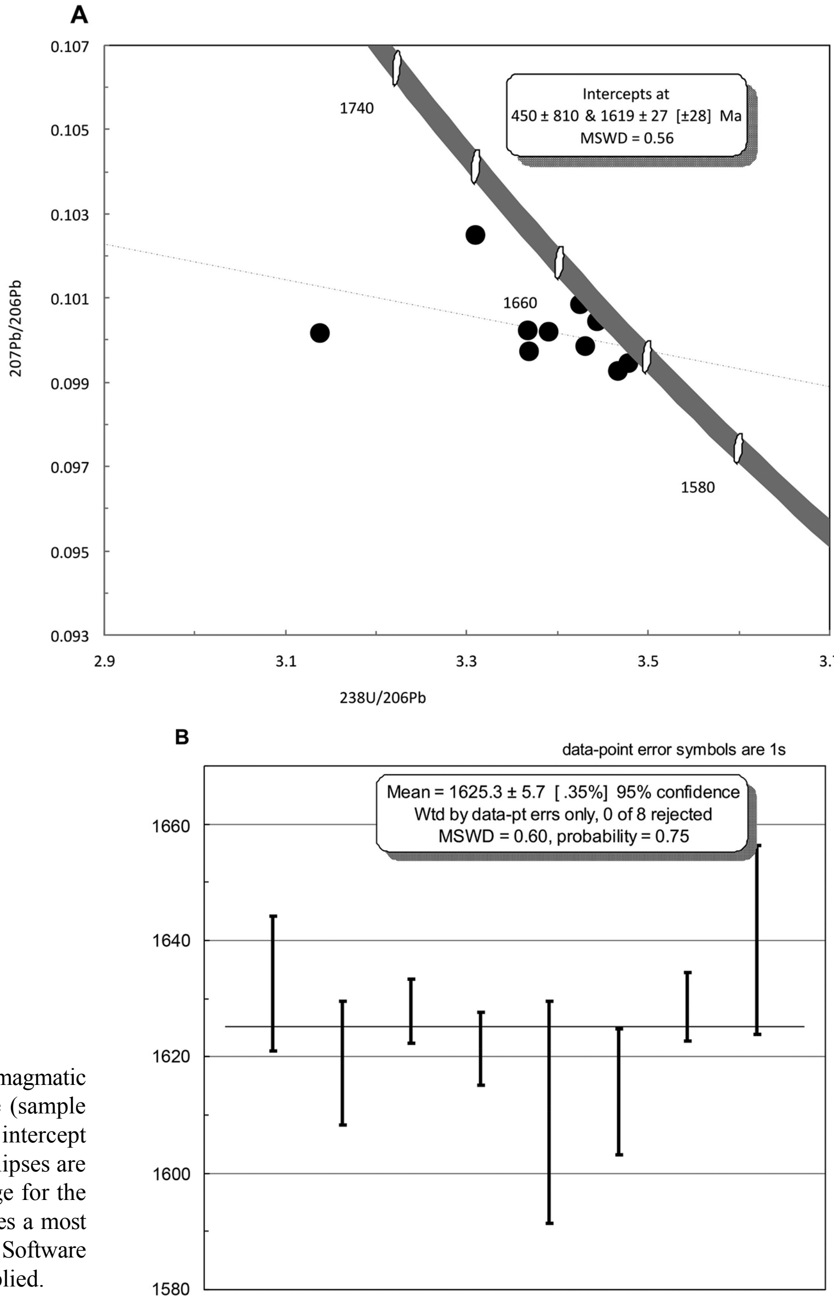

Fig. 5. **A**, Tera–Wasserburg diagram for magmatic zircon from the Velaiciai-2 granodiorite (sample Vlc-2-2), NW Lithuania. The upper age intercept for all analyses is 1619 ± 27 Ma; error ellipses are drawn at 2σ. **B**, the weighted average age for the eight concordant values (Table 2) indicates a most probable magmatism age of 1625 ± 6 Ma. Software Isoplot 3.75 (Ludwig 2012) has been applied.

Hällefors doleritic dyke swarm in south-central Sweden opposite NW Lithuania at ca 1.60 Ga (Söderlund 2006) also indicate the relationship with the Riga magmatism. In consequence, we suggest that the Vlc-2 granodiorite and other similar rocks emplaced at ca 1620 Ma in Lithuania can be interpreted as the earliest phases of the AMCG magmatism that ultimately led to the formation of the slightly later Riga batholith at ca 1580 Ma. The same group also includes the rapakivi-type granite suite located at the northern margins of the main Riga body and farther north in Estonia. These rocks comprise the quite large Märjamaa (1629 ± 7 Ma) and Naissaare (1624 ± 10 Ma) intrusions, three smaller (Neeme, Ereda and Taebla) K-rich granite stocks in northern Estonia and the Abja quartz monzodiorite in the south (Rämö et al. 1996). Like these granitoids, the Vlc-2 granodiorite is different from the Palaeoproterozoic charnockites of the Kursiai intrusion in Lithuania by lacking orthopyroxene but being rich in amphibole and brown biotite, which indicates lower temperatures of crystallization and somewhat higher contents of H_2O. As already stated, geochemically the studied granodiorite has much in common with the Pilsotas granitoids of the Kursiai intrusion and even some rocks within the Riga batholith (Table 1).

These results indicate that the timing and spatial relationships of the magmatic activity at ca 1630–1600 Ma in the crystalline basement of NW Lithuania correlate well with magmatic events in the Baltic States and the Baltic Shield in Sweden, suggesting a number of episodic pulses of magmatism and a prolonged temporal evolution of the Riga batholith.

Magmatism vs metamorphism

A 1.62–1.58 Ga metamorphic event has previously been recognized in western and central Lithuania. The ca 1.82 Ga charnockites from the Vidmantai-1 drill core (Claesson et al. 2001), which is located 24 km to the west of the presently studied Vlc-2 granodiorite, were metamorphosed at 650 °C and 7 kbar at 1.63–1.62 Ga (zircon and monazite ages; Skridlaite et al. 2014). Apart from that, also the charnockites from the Sh3 drill core close to the Pilsotas granodiorites were reworked thermally at ca 1.6 Ga (Skridlaite et al. 2014). Thus it would appear that all these charnockites were affected thermally by the coevally intruding Vlc-2 and Pilsotas(?) granodiorites. The new data also indicate that both in western and eastern Lithuania, which are more than 100 km apart, the 1.63–1.62 Ga heating of the 1.82 Ga charnockites from 600 °C to 700 °C at 4.5–5 kbar and the following near-isobaric cooling were caused by the intrusion of the presently studied granodiorite and related rocks. The previously tentatively assumed wide extent of the 1.63–1.62 Ga magmatism appears confirmed by our data. It is also possible that the semi-simultaneous metamorphism and the shearing of the crust in the Telsiai and similar deformation zones (Vejelyte et al. 2012) occurred at roughly the same time.

Tectonic implications

Korja & Heikkinen (1995) as well as Puura & Floden (1999) suggested that the long-lasting voluminous AMCG magmatism at 1.65–1.50 Ga in the Baltic Shield and beneath the Baltic Sea could have been a result of decompressional melting caused by the extension of the lithosphere and thinning of the crust during post-collisional collapse in the latest Svecofennian. Differently, Åhäll et al. (2000) and Andersson et al. (2002) emphasized the temporal relationship/correlation between the accretionary growth of Baltica towards the present west and episodic pulses of rapakivi magmatism, which were accommodated in discrete N–S-trending belts younging towards the southwest. We agree that the 1.63–1.60 Ga magmatism in Estonia, Finland and Lithuania was in accord with one of the major stages of the Gothian orogeny at 1.62–1.55 Ga. The extension and deformation of the lithosphere and its melting in continental back-arc settings were the most probable causes of that magmatism and the associated metamorphism (Skridlaite et al. 2014).

CONCLUSIONS

We have identified Mesoproterozoic granodiorites within the 1850–1820 Ma Kursiai charnockitic batholith, which makes up most of the Palaeoproterozoic crust in NW Lithuania. The obtained 1625 ± 6 Ma magmatic crystallization age of the Velaiciai-2 granodiorite agrees well with the latest Palaeoproterozoic–early Mesoproterozoic extension of the crust and widespread AMCG and A-type granitoid magmatism in Estonia and Latvia as well as Finland and Sweden in the Baltic Shield. We suggest that all these processes, including the development of the EW-trending Telsiai deformation zone in Lithuania, represent a far-field feedback response of the Palaeoproterozoic continental crust to the Gothian orogeny at the SW margin of the East European Craton.

Acknowledgements. This is a contribution to the project ‘Precambrian rock provinces and active tectonic boundaries across the Baltic Sea and in adjacent areas’ of the Visby Programme of the Swedish Institute and to the European Union’s Structural Funds project ‘Postdoctoral Fellowship Implementation in Lithuania’, supported by the Lithuanian Science Council. Thanks are due to Maya Kamenetsky and Jay Thompson, University of Tasmania, for their assistance with making the mineral analyses. Dzmitry Kurlovich, Minsk State University, Belarus, has helped much with the drawing of the map of the region. J. Kirs and J. Wiszniewska are thanked for their reviews of the manuscript.

REFERENCES

Åhäll, K. I., Connely, J. N. & Brewer, T. S. 2000. Episodic rapakivi magmatism due to distal orogenesis?: Correlation of 1.69–1.50 Ga orogenic and inboard, “anorogenic” events in the Baltic Shield. *Geology*, **28**, 823–826.

Amelin, Y. V., Larin, A. M. & Tucker, R. D. 1997. Chronology of multiphase emplacement of the Salmi rapakivi granite-anorthosite complex, Baltic Shield: implications for magmatic evolution. *Contributions to Mineralogy and Petrology*, **127**, 353–368.

Andersson, J., Söderlund, U., Cornell, D., Johansson, L. & Möller, C. 2001. Reply to discussion on 'Sveconorwegian (-Grenvillian) deformation, metamorphism and leucosome formation in SW Sweden, SW Baltic Shield: constraints from a Mesoproterozoic granite intrusion'. *Precambrian Research*, **106**, 333–337.

Andersson, U. B., Neymark, L. A. & Billström, K. 2002. Petrogenesis of Mesoproterozoic (Subjotnian) rapakivi complexes of central Sweden: implications from U–Pb zircon ages, Nd, Sr and Pb isotopes. *Transactions of the Royal Society of Edinburgh, Earth Sciences*, **92**, 201–228.

Bogatikov, O. A. & Birkis, A. P. 1973. *Dokembrij Zapadnoj Latvii* [*Precambrian Magmatism in Western Latvia*]. Nauka, Moscow, 138 pp. [in Russian].

Bogdanova, S. V. 1993. Segments of the East European Craton In *EUROPROBE in Jablonna 1991* (Gee, D. G. & Beckholmen, M., eds), pp. 33–38. European Science Foundation – Polish Academy of Sciences.

Bogdanova, S., Gorbatschev, R., Grad, M., Guterch, A., Janik, T., Kozlovskaya, E., Motuza, G., Skridlaite, G., Starostenko, V. & Taran, L. 2006. EUROBRIDGE: New insight into the geodynamic evolution of the East European Craton In *European Lithosphere Dynamics* (Gee, D. G. & Stephenson, R. A., eds), *Geological Society, London, Memoirs*, **32**, 599–628.

Bogdanova, S., Gorbatschev, R., Skridlaite, G., Soesoo, A., Taran, L. & Kurlovich, D. 2015. Trans-Baltic Palaeoproterozoic correlations towards the reconstruction of supercontinent Columbia/Nuna. *Precambrian Research*, **259**, 5–33.

Claesson, S., Bogdanova, S. V., Bibikova, E. V. & Gorbatschev, R. 2001. Isotopic evidence of Palaeoproterozoic accretion in the basement of the East European Craton. *Tectonophysics*, **339**, 1–18.

Haapala, I. & Rämö, T. 1992. Tectonic setting and origin of the Proterozoic rapakivi granites of Southeastern Fennoscandia. *Transactions of the Royal Society of Edinburgh, Earth Sciences*, **83**, 165–171.

Halpin, J. A., Jensen, T., McGoldrick, P., Meffre, S., Berry, R. F., Everard, J. L., Calver, C. R., Thompson, J., Goemann, K. & Whittaker, J. M. 2014. Authigenic monazite and detrital zircon dating from the Proterozoic Rocky Cape Group, Tasmania: links to the Belt-Purcell Supergroup, North America. *Precambrian Research*, **250**, 50–67.

Kirs, J., Haapala, I. & Rämö, O. T. 2004. Anorogenic magmatic rocks in the Estonian crystalline basement. *Proceedings of the Estonian Academy of Sciences, Geology*, **53**, 210–225.

Korja, A. & Heikkinen, P. 1995. Proterozoic extensional tectonics of the central Fennoscandian shield: results from the Baltic–Bothnian echoes from the lithosphere experiment. *Tectonics*, **14**, 504–517.

Ludwig, K. R. 2012. Isoplot 3.75. A geochronological toolkit for Microsoft Excel. *Berkeley Geochronology Center, Special Publication*, 5, 10.1016/S0016-7037(98)00059-3.

Motuza, G., Čečys, A., Kotov, A. B. & Salnikova, E. B. 2006. The Zemaičiu Naumiestis granitoids: new evidences for Mesoproterozoic magmatism in western Lithuania. *GFF*, **128**, 209–272.

Motuza, G., Motuza, V., Salnikova, E. & Kotov, A. 2008. Extensive charnockitic-granitic magmatism in the crystalline crust of West Lithuania, *Geologija (Vilnius)*, **61**, 1–16.

Puura, V. & Floden, T. 1999. Rapakivi-granite-anorthosite magmatism – a way of thinning and stabilisation of the Svecofennian crust, Baltic Sea Basin. *Tectonophysics*, **305**, 75–92.

Rämö, O. T., Huhma, H. & Kirs, J. 1996. Radiogenic isotopes of the Estonian and Latvian rapakivi granite suites: new data from the concealed Precambrian of the East European Craton. *Precambrian Research*, **79**, 209–226.

Skridlaite, G., Wiszniewska, J. & Duchesne, J. C. 2003. Ferro-potassic A-type granites and related rocks in NE Poland and S Lithuania: west of the East European Craton. *Precambrian Research*, **124**, 305–326.

Skridlaitė, G., Whitehouse, M. & Rimša, A. 2007. Evidence for a pulse of 1.45 Ga anorthosite–mangerite–charnockite–granite (AMCG) plutonism in Lithuania: implications for the Mesoproterozoic evolution of the East European Craton. *Terra Nova*, **19**, 294–301.

Skridlaite, G., Bogdanova, S., Taran, L. & Baginski, B. 2014. Recurrent high grade metamorphism recording a 300 Ma long Proterozoic crustal evolution in the western part of the East European Craton. *Gondwana Research*, **25**, 649–667.

Söderlund, U. 2006. U–Pb baddeleyite ages of Meso- and Neoproterozoic dykes and sills in central Fennoscandia: a review. In *Dyke Swarms – Time Markers of Crustal Evolution* (Hanski, E., Mertanen, S., Rämö, T. & Vuollo, J., eds), pp. 75–84. Balkema, London.

Stacey, J. S. & Kramers, I. D. 1975. Approximation of terrestrial lead isotope evolution by a two-stage model. *Earth and Planetary Science Letters*, **26**, 207–221.

Stephens, M. B., Ripa, M., Lundström, L., Persson, L., Bergman, T., Ahl, M., Wahlgren, C. H., Persson, P. O. & Wickström, L. 2009. *Synthesis of the Bedrock Geology in the Bergslagen Region, Fennoscandian Shield, South-Central Sweden*. SGU, Sweden, 259 pp.

Sun, S. S. & McDonough, W. F. 1989. Chemical and isotopic systematics of oceanic basalts; implications for mantle composition and processes. In *Magmatism in the Ocean Basins* (Saunders, A. D. & Norry, M. J., eds), *Geological Society of London*, **42**, 313–345.

Vejelyte, I., Bogdanova, S., Yi, K. & Cho, M. 2012. The Paleo- to Mesoproterozoic tectonic and magmatic evolution of the Telsiai and Druksiai-Polotsk deformation zones in the crystalline basement of Lithuania, East European Craton, reconstructed by U–Pb zircon geochronology. In *34th International Geological Congress, Brisbaine, Australia*, Abstract 3163.

Wikström, A. & Andersson, U. B. 2004. Geological features of the Småland–Värmland belt along the Svecofennian margin, part 1: from the Loftahammar to the Tiveden-Askersund areas. In *The Trans-Scandinavian Igneous Belt (TIB) in Sweden: a Review of its Character and Evolution* (Högdahl, K., Andersson, U. B. & Eklund, O., eds), *Geological Survey of Finland, Espoo, Finland. Special Paper*, 37, 22–38.

Wiszniewska, J., Claesson, S., Stein, H., Vander Auwera, J. & Duchesne, J. C. 2002. The north-eastern Polish anorthosite massifs: petrological, geochemical and isotopic evidence for a crustal derivation. *Terra Nova*, **14**, 451–460.

Vara-Mesoproterosoikumi magmatismi ilmingud Loode-Leedus: uued tsirkoonide U–Pb isotoopdateeringud

Irma Vejelyte, Svetlana Bogdanova ja Grazina Skridlaite

On esitatud uus isotoopvanune andmestik Vara-Mesoproterosoikumi magmatismi kohta Loode-Leedu Telsiai tektoonilises vööndis. Kasutades induktiivseotud plasma massispektromeetriat (ICP-MS), on näidatud, et varem 1850–1820 Ma vanuseks peetud Kursiai tšarnokiitse batoliidi granodioriit on tegelikult kivimis olevate tsirkooniterade U–Pb vanuse järgi 1620 Ma vanusega. Kaheksa tsirkooniproovi Pb^{207}/Pb^{206} vanuse kaalutud keskmine on 1625 ± 6 Ma ja määrangute ülemine lõikepunkt on 1619 ± 27 Ma. Kuna ka Eesti aluskord sisaldab lähedase vanusega intrusioone, viitab sellise vanusega magmatismi olemasolu Leedus laiaulatuslikule ülessulamisele. Nii 1620 Ma magmatism kui ka 1580 Ma vanusega Riia anortosiidi, rabakivi ja graniitse batoliidi teke on Ida-Euroopa kraatoni loodeservas toimunud Gooti mäetekkeprotsesside kraatonisisesed ilmingud.