Significance of Baddeleyite for Paleoproterozoic PGE Deposits with Pt-Pd and Cu-Ni Reefs (North-Eastern Fennoscandian Shield): New Results of U-Pb and LA-ICP-MS Studies

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Abstract

Baddeleyite is a significant mineral successfully applied in the U-Pb geochronology for the precise dating of mafic rocks from layered intrusions with the platinum group element (PGE) and Cu-Ni mineralization. The Fennoscandian Shield hosts several layered Pt-Pd, Co-Cr-Ni, and Ti-V occurrences in the Northern (Karelian) and Southern (Karelian-Finnish) belts. The aim of this study is to estimate the content and distribution of rare earth elements (REE) in baddeleyite and to calculate temperatures (?,??) of the U-Pb system closure and baddeleyite crystallization compared to zircon from Cu-Ni and Pt-Pd deposits in the north-eastern Fennoscandian Shield. For the first time, baddeleyite crystals from Cu-Ni (Monchepluton) and Pt-Pd (Monchetundra) reefs of the Monchegorsk ore area have been studied in situ by the laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) to measure the U-Pb age of formation and the REE content.

Index terms— baddeleyite; layered intrusions; U-Pb analysis; laser ablation inductively coupled

1 Introduction

addeleyite is a valued mineral for the U-Pb dating of PGE deposits (Bayanova, 2006;Mungall et al., 2016). Compared to zircon, it is more reliable for precise U-Pb dating of deposits in the north-eastern Fennoscandian (Baltic) Shield, since it is genetically magmatic. In contrast, zircon can be metamorphic, hydrothermal or occur as xenocrysts. The study of the trace element composition of zircon is a common practice, while geochemical characteristics of baddeleyite are poorly studied and contradictory. Thus, the value of Ce-anomaly varies, and the Eu-anomaly is absent in some analyses **??**Reischman et al., 1995; **??**ircon, 2003;Schaltegger et al., 2017). Also, recent studies limelight the crucial role of baddeleyite in the reconstruction of the supercontinents breakup in the history of the Earth's evolution **??**Bayanova et In Paleoproterozoic PGE layered intrusions, baddeleyite is found in Pt-Pd and Cu-Ni deposits of the Monchegorsk ore area (Fig. 1). The aim of this study is (i) to estimate the REE content and distribution in baddeleyite, (ii) to calculate temperatures (?,??) of the U-Pb system closure and baddeleyite crystallization compared to zircon from Cu-Ni and Pt-Pd deposits in the Monchegorsk ore area, hosting the recently discovered Pt-Pd Vurechuayvench deposit (north-eastern Fennoscandian Shield, Russia).

2 II.

3 Resources and Techniques

Baddeleyite was extracted from gabbroanorthosites with the Pt-Pd mineralization in the middle of the Monchetundra massif (Fig. 1). The age of baddeleyite was estimated (Nerovich et al., 2014) by the U-Pb method at 2476±5 Ma and 2471±3 Ma (Fig. 2, Table 1). Stacey and Kramers (1975).

The REE content and distribution in baddeleyite were estimated by the following technique. The method of the electron (LEO-1415) and optic (LEICA OM 2500 P, camera DFC 290) spectroscopy was used to study the morphology of samples. Points for local analyses on baddeleyite crystals were selected based on the study of their back-scattered electron (BSE) and cathodoluminescence (CL) images.

Contents of REE and other elements were estimated in situ by ICP-MS on an ELAN 9000 DRC-e (Perkin Elmer) quadrupole mass spectrometer equipped with a 266 nm UP-266 MA?RO laser (New Wave Research). LA-ICP-MS was performed using argon with a repetition rate of 10 Hz, pulse duration of 4 ns, the energy density of 14-15 J/cm 2 at a spot with a diameter of 35-100 µm or using scanning "in a line" (length 35-70 µm), monitoring and measuring produced craters. NIST 612 glass with the known concentrations of REE, U, Ti, and Th of 40 ppm was used for external calibration as a multi-point calibration forced through the origin after blank correction (Pearce et al., 1997, Certificate of Analysis, 2012). NIST SRM 610 sample (450 ppm concentration) was used to check the accuracy of estimations (Yuan et al., 2004; **??**ochum et al., 2011). The laser beam diameter was changed, while the rest parameters were stable: from 35 to 240 µm (point sampling) and from 20 to 155 µm (r = 0.999) (scanning "in a line"). As for calibration standards, measurements of the elements were in the range of 15% relative deviations. Determination limits were within 0.01 ppm, a diameter of the laser beam of 155 µm. It complies with the available data (Yuan et al., 2004). This technique was tested, using analyses of internationally approved standard zircon samples 91500, TEMORA 1, Mud Tank, and inter-laboratory cross-checks (Boynton, 1984).

4 III.

5 Results

Table 2 and Figure 3 provide new data on the contents of REE and other elements in baddeleyite from Pt-Pd occurrences of the Monchetundra massif.

Baddeleyite from vein pegmatites with the gabbronorite composition from the Monchepluton with Cu-Ni reefs (Mt. Nyud, Terrace deposit) was studied. Its U-Pb age was estimated at 2505±5 Ma (Bayanova, 2006). Figures 4 and 5 display new LA-ICP-MS data on baddeleyite, which was measured along and across its section. IV.

6 Conclusion

For the first time, the provided research revealed a direct relation between the REE content in baddeleyite and the formation of Pt-Pd and Cu-Ni reefs. The higher concentrations of ?REE in baddeleyite, the higher temperatures of the U-Pb systematics closure and formation are. Pt-Pd reefs are likely to occur under such conditions. Cu-Ni reefs form at lower temperatures of the U-Pb systematics closure and crystallization of accessory minerals. These occurrences display low ?RE? and a wide range of LREE concentrations (Table 2).

V.

7 Funding

The research has been funded by grants of the Russian Foundation for Basic Research, Note: 1-baddeleyite from gabbronorite -anorthosite, 2 -baddeleyite from medium-to coarse -grained leucogabbronorite, 3-sample gabbronorite composition. Temperature of zircon and baddeleyite crystallization is calculated according to [3].

from vein pegmatites of the

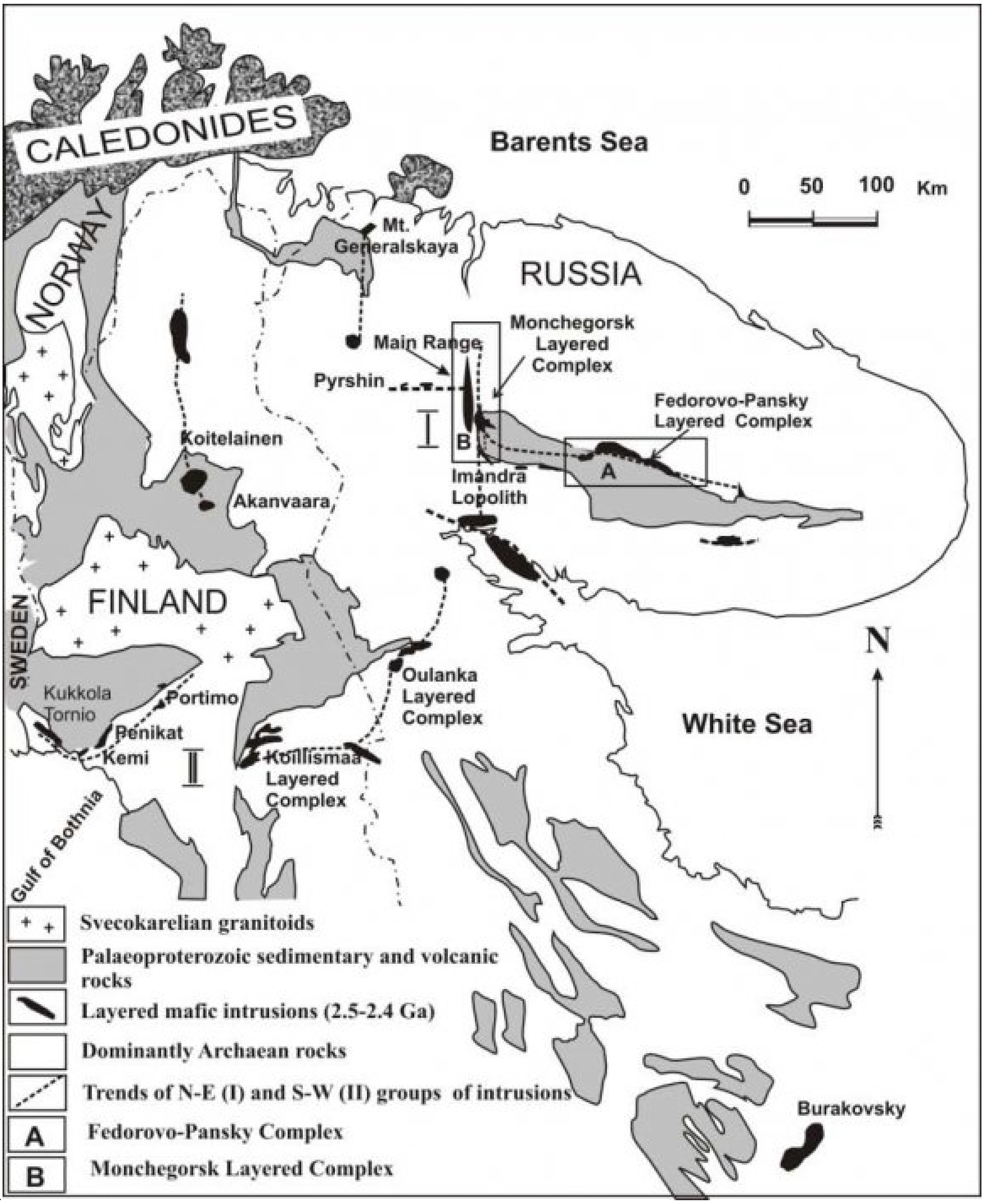

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Figure 1: Fig. 1 :

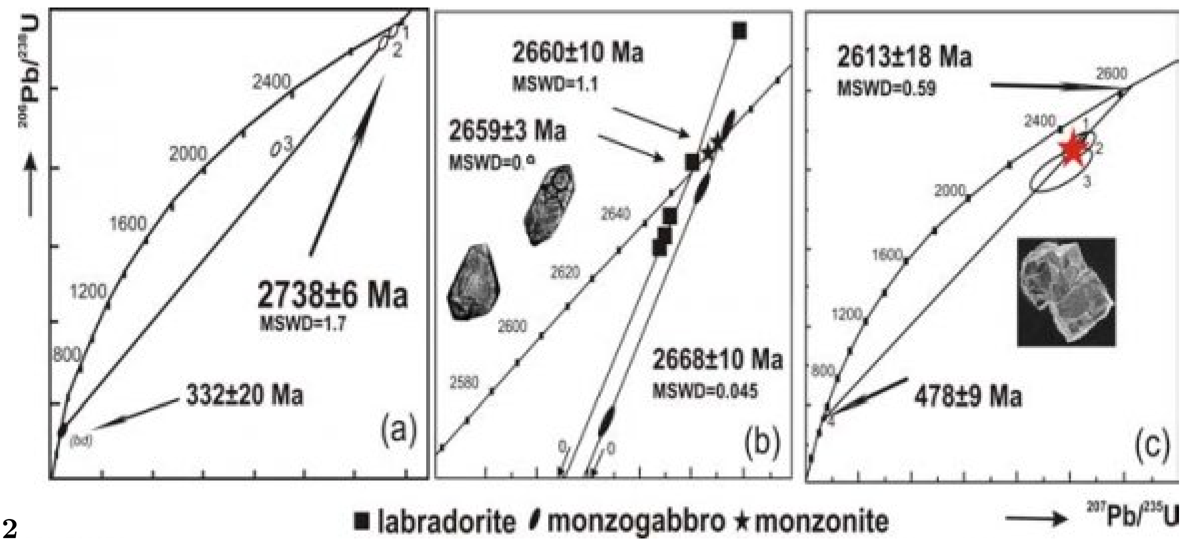

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Figure 2: Fig. 2 :

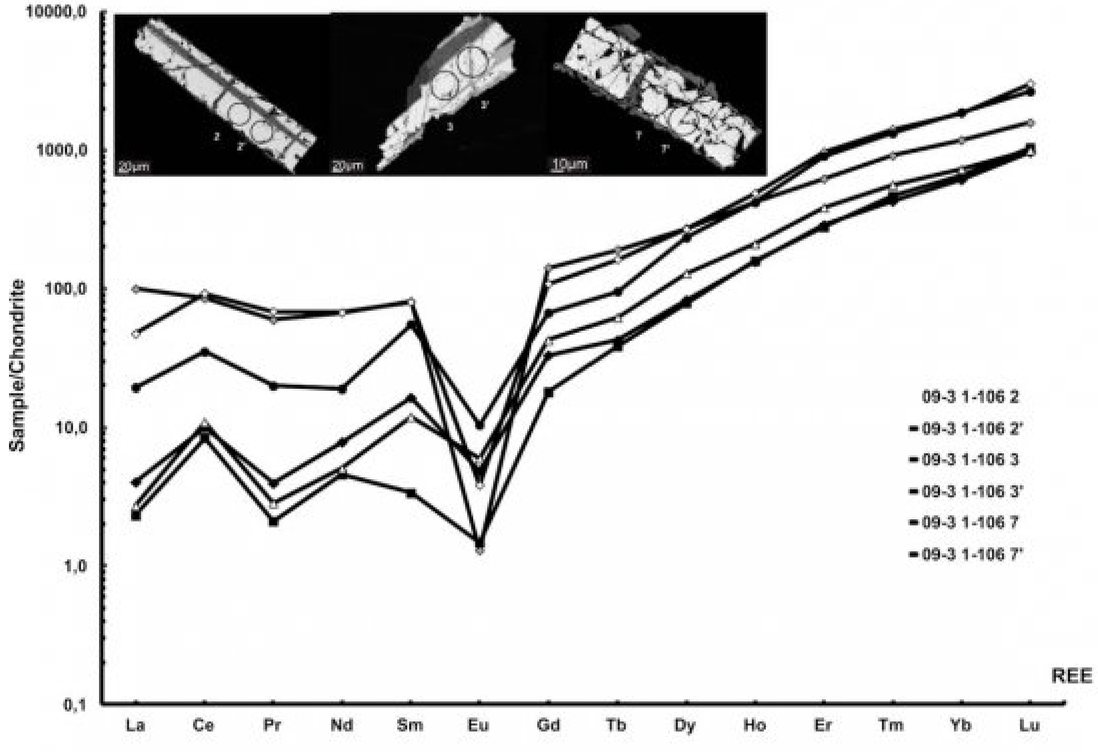

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Figure 3: Fig. 3 :

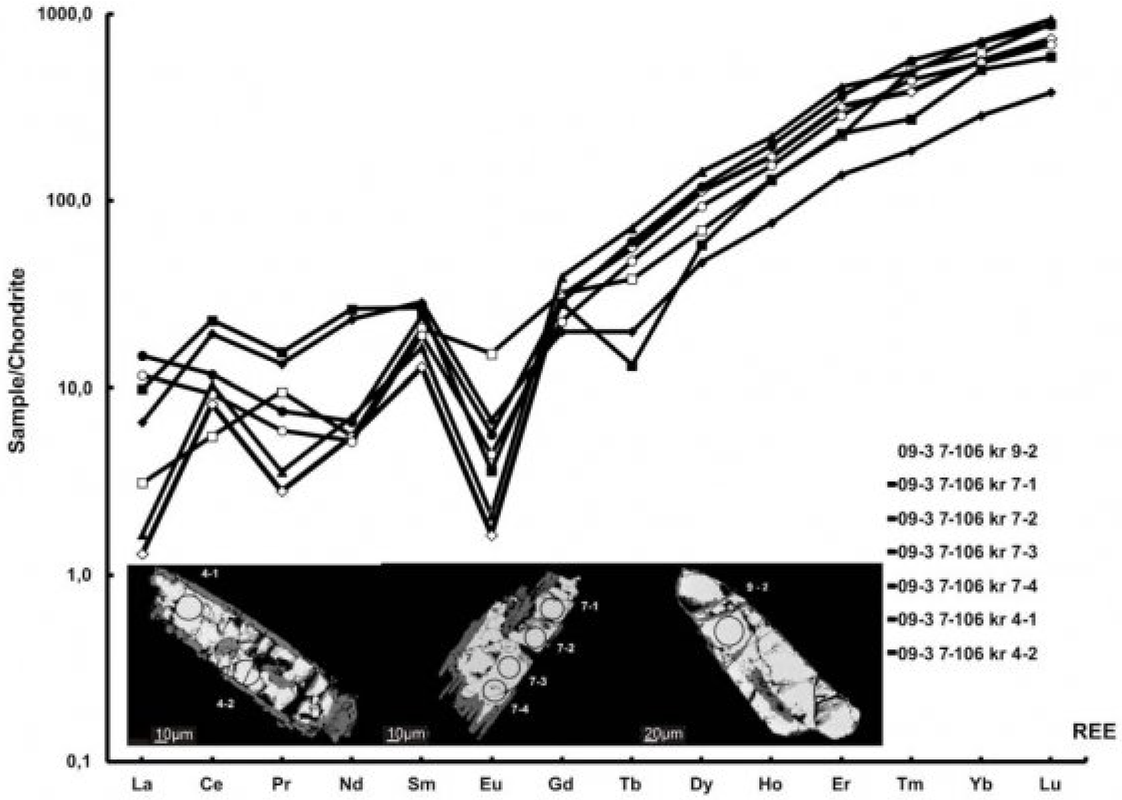

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Figure 4: Fig. 4 :

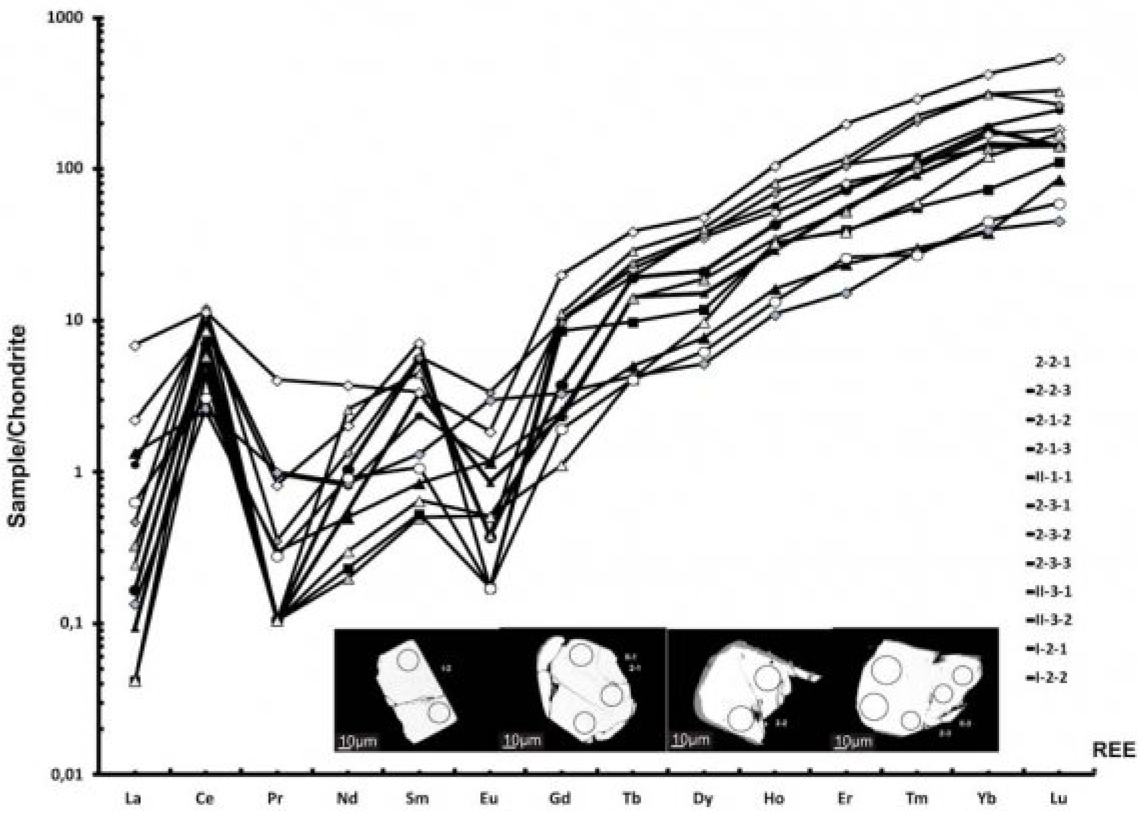

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Figure 5: Fig. 5 :

Figure 6:

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Sample, No.	Weighted sample, mg	Contents, ppm Pb	U	Isotope composition of Pb *		Isotope ratio and age, Ma ** 206 P
	for baddeleyite and gabbronorite -anorthosite (medium-to coarse-grained, partly amphibolized)					
1	0.25	94.48	114.75	86	3.3003 2.2134	9.92226 0.450763 2500
2	0.20	57.60	123.14	570	5.5602 11.459	9.08165 0.417879 2430
3	0.25	30.09	67.86	557	5.6496 8.0718	8.19067 0.385383 2392
		for baddeleyite from medium-to coarse-grained gabbronorite-anorthosite				
1	0.50	110.70	244.90	1478	5.9187 23.690 9.504470 0.429716 2460	
2	0.35	152.60	359.10	3510	6.1640 35.011 9.119096 0.413367 2441	
3	0.50	60.479	136.81	830	5.5615 13.663 8.820570 0.400447 2453	
4	0.20	98.025	246.35	1539	6.3461 24.580 8.368770 0.382377 2437	

*[Note: * The ratios are corrected for blanks of 0.8 ng for Pb and 0.04 ng for U and mass discrimination 0.12 ± 0.04%. *]*

Figure 7: Table 1 :

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18-35-00246,

Figure 8: Table 2 :

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