Report for the Joint Use/Research of the Institute for Planetary Materials, Okayama University for FY2024

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Category: ☑International Joint Research ☐General Joint Research ☐Joint Use of Facility ☐Workshop

Name of the research project: Geochemical and isotopic characteristics of Early Carboniferous volcanic complexes of the Southern Urals

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Research report:

Research purpose

The main goal of the project was to identify geochemical and isotopic features of riftogenic magmatism at the stage of terranes accretion to the East European craton. For this purpose we planned to conduct analyses of volcanic rocks from Magnitogorsk and Ui River zones (the westernmost ones) of the Southern Urals.

Planned analyses:

1. XRF analysis for major elements (20–25 samples).
2. ICPMS analysis for trace elements (20–25 samples).
3. Sr, Nd, Pb, and Hf isotopic analyses (20–25 samples).

Actually conducted research

In the 2024 project, samples from the western part of the Southern Urals, Magnitogorsk zone, were mainly studied with a few samples from the nearby Ui River narrow suture zone. During May-July 2024 we conducted the following analyses:

1. Major element compositions for 10 samples (6 from Magnitogorsk zone and 4 from Ui River zone) by XRF (table 1). The LOI values for most samples vary between 0.24-3.23 and only for 1 sample (6230/1) it is 7.25 mass percent.

	704	706	706/3	6219/1	6230/1	9917	1633/1	1634	1635	1640/2
Zone	Magnitogorsk						Ui River			
SiO2	71,63	71,19	68,33	71,95	51,91	56,24	49,66	55,32	73,92	71,86
TiO2	0,57	0,28	0,52	0,16	2,19	2,00	2,86	1,84	0,20	0,41
Al2O3	14,47	13,91	14,13	12,28	13,73	14,56	14,25	13,79	12,14	12,84
Fe2O3	2,67	3,89	3,89	3,36	9,01	9,68	13,35	11,72	2,79	4,23
MnO	0,02	0,15	0,08	0,08	0,12	0,18	0,42	0,24	0,01	0,01
MgO	0,66	0,83	1,37	0,70	3,80	2,99	5,09	2,25	0,28	0,13
CaO	0,22	0,12	1,27	0,99	6,18	5,00	4,73	5,04	0,07	0,02
Na2O	6,89	7,26	3,44	3,89	4,68	5,20	5,56	4,41	2,50	3,09
K2O	0,63	0,11	3,11	3,91	0,06	1,91	0,44	1,77	6,81	5,38
P2O5	0,09	0,02	0,08	0,01	0,78	0,46	0,75	0,87	0,01	0,02
LOI	1,34	1,61	3,23	2,06	7,25	1,28	2,77	2,24	0,24	1,07
Total	99,19	99,36	99,44	99,37	99,72	99,49	99,87	99,49	98,97	99,07

Table 1. Major oxides (wt.%) in volcanic rocks from the Southern Urals.

2. Trace element compositions for 17 samples (13/4 Magnitogorsk zone/Ui River zone, respectively) by ICP-MS, 8 for basaltic samples (table 2) and 9 for felsic ones (table 3).

	703/1	2809	2812	2815/1	6230/1	9917	1633/1	1634
Zone	Magnitogorsk						Ui River	
Cs	1,06	0,65	0,13	0,28	0,29	0,06	0,10	0,89
Rb	17,75	10,20	2,92	10,57	0,72	33,08	5,86	33,72
Ba	199,23	162,61	91,33	105,08	31,88	318,36	393,75	421,56
Th	1,18	2,18	3,55	0,79	2,52	7,06	0,99	2,75
U	0,38	0,60	0,80	0,30	0,70	1,90	0,44	1,27
Nb	3,87	6,47	7,03	2,60	9,88	10,75	6,93	11,68
Ta	0,25	0,41	0,43	0,17	0,61	0,68	0,43	0,68
La	8,52	11,49	15,93	6,39	21,01	24,59	13,30	22,45
Ce	22,74	28,25	37,95	16,57	57,26	61,39	35,51	58,08
Pb	4,34	5,45	7,78	2,29	2,62	3,34	3,56	5,93
Pr	3,31	3,99	5,07	2,44	8,18	8,18	5,13	8,06
Sr	358,14	284,42	284,17	316,60	116,35	167,44	211,96	308,47
Nd	16,51	19,16	23,57	12,36	38,48	36,39	25,78	38,84
Zr	125,79	160,64	111,30	74,57	220,35	254,99	88,45	234,89
Hf	3,24	4,32	2,93	2,17	5,24	6,37	2,94	5,95

Sm	4,42	5,06	6,08	3,52	9,33	8,84	7,03	9,81
Eu	1,64	1,76	2,12	1,33	2,77	2,24	2,36	3,19
Gd	5,68	6,45	7,09	4,33	9,78	9,59	8,22	11,18
Tb	0,91	1,03	1,19	0,72	1,46	1,60	1,34	1,77
Dy	5,87	6,68	7,76	4,61	8,23	10,11	8,36	11,19
Y	28,84	32,96	38,04	22,75	36,55	50,27	39,74	55,45
Ho	1,21	1,38	1,57	0,94	1,61	2,06	1,67	2,29
Er	3,37	3,81	4,37	2,62	3,92	5,62	4,31	6,29
Tm	0,48	0,54	0,60	0,37	0,53	0,78	0,57	0,89
Yb	3,06	3,44	3,84	2,34	3,39	4,91	3,50	5,66
Lu	0,46	0,51	0,54	0,34	0,47	0,68	0,45	0,81

Table 2. Trace elements (ppm) in basaltic volcanic rocks from the Southern Urals.

	704	**706**	**706/3**	**1647**	**2937**	**6213**	**6219/1**	**1635**	**1640/2**
Zone	**Magnitogorsk**							**Ui River**	
Cs	0,02	0,08	0,43	0,30	0,06	0,10	0,13	0,72	0,21
Rb	1,57	14,21	65,95	125,33	126,45	50,98	74,37	64,87	68,69
Ba	33,64	55,90	333,41	479,01	16,56	431,59	155,24	417,17	176,48
Th	10,06	15,59	12,34	15,35	21,37	12,26	19,02	6,95	10,76
U	3,15	5,00	3,66	2,73	5,33	3,69	4,67	3,19	3,01
Nb	13,89	21,11	20,15	29,02	26,38	18,12	23,03	15,59	16,22
Ta	0,90	1,38	1,22	1,83	2,04	1,09	1,46	0,94	1,01
La	35,29	64,52	46,25	69,99	44,40	50,53	57,01	34,55	42,19
Ce	77,88	149,21	107,70	165,82	109,47	122,03	128,02	78,94	92,56
Pb	5,89	2,55	10,46	5,60	5,49	27,75	3,38	2,66	4,51
Pr	9,20	18,37	12,95	20,07	13,05	14,82	14,97	10,27	12,29
Sr	53,60	48,92	187,76	41,06	23,91	60,20	32,06	24,76	12,16
Nd	37,20	75,85	51,65	80,52	52,82	58,98	58,87	42,96	51,77
Zr	509,81	728,47	757,93	977,06	535,80	596,53	523,24	471,04	541,58
Hf	12,62	18,45	18,37	23,74	17,97	14,68	15,08	11,76	13,02
Sm	7,87	16,20	10,58	17,58	12,22	13,31	12,26	9,96	12,44
Eu	1,18	2,18	1,54	2,31	0,50	2,07	0,77	1,48	2,15
Gd	8,12	15,38	10,45	17,27	13,37	13,71	11,87	10,85	14,85
Tb	1,44	2,68	1,93	3,03	2,70	2,57	2,15	2,11	2,84
Dy	9,96	19,05	13,46	19,71	19,23	17,16	14,81	14,58	19,55
Y	56,32	111,85	75,53	103,02	118,74	96,69	84,52	82,16	110,42

Ho	2,17	4,32	2,92	4,19	4,40	3,79	3,23	3,17	4,26
Er	6,47	13,44	8,93	12,47	13,52	11,57	9,93	9,28	12,79
Tm	1,01	2,03	1,37	1,94	2,08	1,84	1,55	1,39	1,95
Yb	6,82	13,94	9,54	13,52	13,68	12,63	10,79	9,21	12,97
Lu	1,03	2,07	1,46	2,04	2,00	1,91	1,63	1,35	1,94

Table 3. Trace elements (ppm) in felsic volcanic rocks from the Southern Urals.

3. Sr (table 4) and Pb (table 5) isotopic compositions for 17 and 16 samples, respectively, by TIMS (13/4 and 12/4 Magnitogorsk zone/Ui River zone, respectively).

	Sample	Zone	87Sr/86Sr	2σ
Basaltic	703/1	Magnitogorsk	0,704464	0,000006
	2809	Magnitogorsk	0,704985	0,000006
	2812	Magnitogorsk	0,705670	0,000006
	2815/1	Magnitogorsk	0,703888	0,000006
	6230/1	Magnitogorsk	0,704963	0,000008
	9917	Magnitogorsk	0,706893	0,000006
	1633/1	Ui River	0,705163	0,000007
	1634	Ui River	0,705738	0,000005
Felsic	704	Magnitogorsk	0,705270	0,000004
	706	Magnitogorsk	0,709209	0,000004
	706/3	Magnitogorsk	0,710346	0,000007
	1647	Magnitogorsk	0,748209	0,000009
	2937	Magnitogorsk	0,777833	0,000007
	6213	Magnitogorsk	0,716696	0,000007
	6219/1	Magnitogorsk	0,738137	0,000007
	1635	Ui River	0,740927	0,000007
	1640/2	Ui River	0,768001	0,000004

Table 4. Sr ratios in the volcanic rocks from the Southern Urals.

	Sample	Zone	206Pb/204Pb	207Pb/204Pb	208Pb/204Pb
Basaltic	703/1	Magnitogorsk	18,423225	15,577075	38,201597
	2809	Magnitogorsk	18,698866	15,605546	38,589611
	2812	Magnitogorsk	18,634851	15,611105	38,515796
	2815/1	Magnitogorsk	18,591426	15,595195	38,351337

	6230/1	Magnitogorsk	19,447534	15,637364	39,234768
	9917	Magnitogorsk	20,423812	15,692061	40,346898
	1633/1	Ui River	18,491175	15,591446	38,280473
	1634	Ui River	18,892821	15,621288	38,408500
Felsic	704	Magnitogorsk	19,941115	15,670993	39,790509
	706	Magnitogorsk	25,443730	15,943315	45,141135
	706/3	Magnitogorsk	19,357169	15,632579	39,194048
	1647	Magnitogorsk	19,731491	15,658689	41,055370
	2937	Magnitogorsk	21,929830	15,772333	42,180041
	6213	Magnitogorsk	18,554927	15,584855	38,346338
	1635	Ui River	22,285468	15,813704	40,776551
	1640/2	Ui River	19,774798	15,663157	39,810053

Table 5. Pb ratios in the volcanic rocks from the Southern Urals.

We did not manage to conduct Nd and Hf isotopic analyses due to lack of time and technician problems.

List of equipment have been used:

(1) XRF: Axios Advanced (major elements)
(2) ICPMS: Thermo Scientific iCAP TQ (trace elements)
(3) TIMS: Thermo Scientific TRITON Plus (Sr and Pb isotopes)

Research outcomes

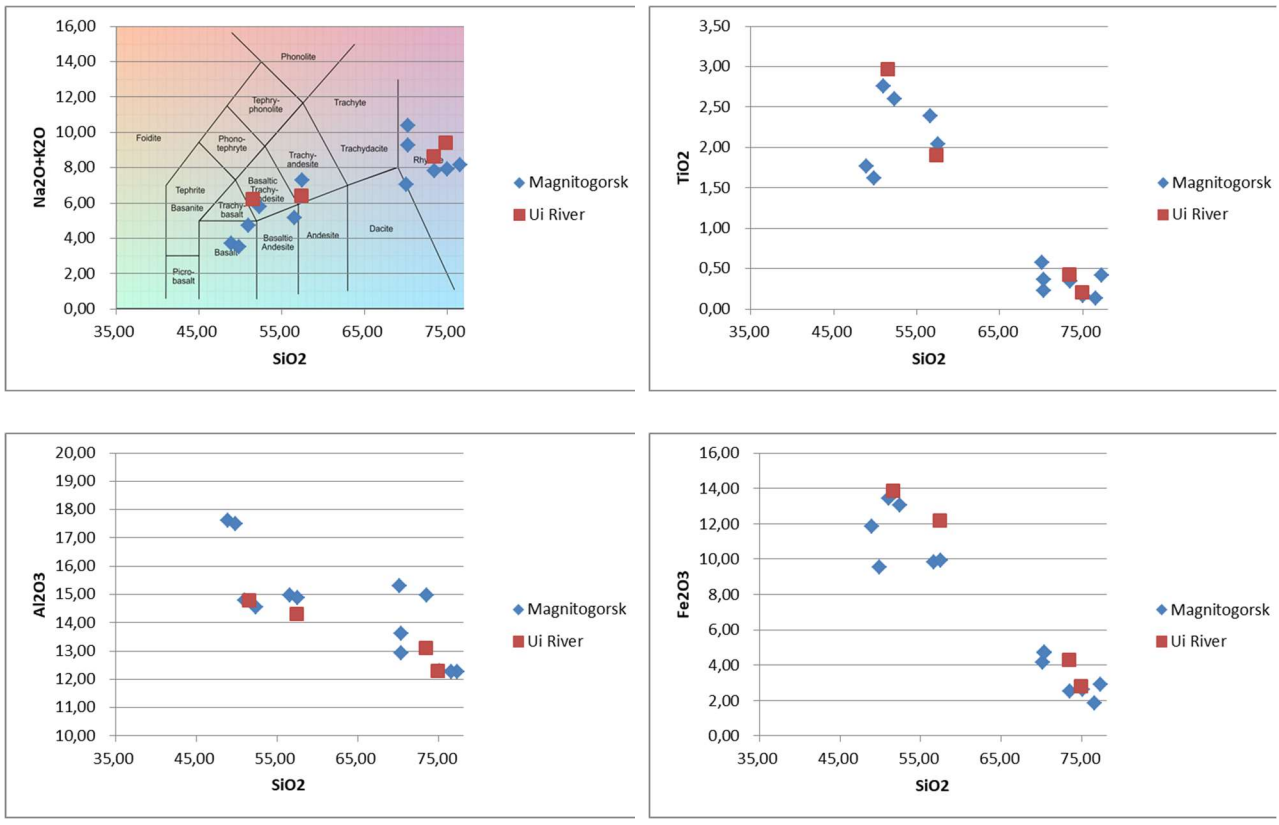
To complete dataset for major elements we used 7 analyses that were conducted in the laboratory of Miass, Russia, Russian Academy of Science. All results recalculated to dry residue are presented in table 6.

Sample	Lab	Zone	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O
703/1	Miass	Magnitogorsk	48,95	1,77	17,61	11,85	0,14	6,67	9,32	2,86	0,85
2809	Miass	Magnitogorsk	52,37	2,60	14,54	13,07	0,20	3,87	7,56	5,57	0,21
2812	Miass	Magnitogorsk	51,03	2,76	14,78	13,43	0,27	4,62	8,39	4,51	0,22
2815/1	Miass	Magnitogorsk	49,89	1,62	17,50	9,55	0,14	6,81	10,98	3,01	0,49
6230/1	IPM	Magnitogorsk	56,62	2,39	14,98	9,83	0,13	4,14	6,74	5,11	0,06
9917	IPM	Magnitogorsk	57,53	2,05	14,89	9,90	0,19	3,05	5,12	5,32	1,95
704	IPM	Magnitogorsk	77,24	0,42	12,28	2,89	0,03	0,60	0,12	6,32	0,11
706	IPM	Magnitogorsk	73,52	0,35	14,97	2,51	0,03	0,77	0,06	6,99	0,80
706/3	IPM	Magnitogorsk	70,12	0,57	15,30	4,16	0,08	1,50	1,24	3,58	3,45
1647	Miass	Magnitogorsk	70,31	0,23	12,94	4,72	0,08	0,39	0,94	3,61	6,78

2937	Miass	Magnitogorsk	76,60	0,13	12,27	1,85	0,04	0,26	0,71	3,70	4,44
6213	Miass	Magnitogorsk	70,30	0,36	13,63	4,71	0,13	0,71	0,92	4,93	4,31
6219/1	IPM	Magnitogorsk	75,04	0,16	12,28	2,63	0,08	0,72	1,16	3,66	4,26
1633/1	IPM	Ui River	51,54	2,97	14,79	13,85	0,43	5,28	4,91	5,77	0,45
1634	IPM	Ui River	57,40	1,91	14,30	12,16	0,25	2,33	5,22	4,58	1,84
1635	IPM	Ui River	74,87	0,21	12,30	2,83	0,01	0,29	0,07	2,53	6,89
1640/2	IPM	Ui River	73,35	0,42	13,10	4,32	0,01	0,13	0,02	3,16	5,49

Table 6. Major oxides (wt.%) in volcanic rocks from the Southern Urals recalculated to dry residue.

All Ui River zone samples and a part of Magnitogorsk zone are moderately alkaline volcanics. The rest of Magnitogorsk zone samples are normal alkaline. The rocks from the Magnitogorsk and Ui River zones comprise a significant portion of high-Ti basalts, with the TiO2 content varying between 2 and 3 wt. %. Two magmatic series are identified based on the existence of statistically different linear correlations in binary plots (fig. 1).



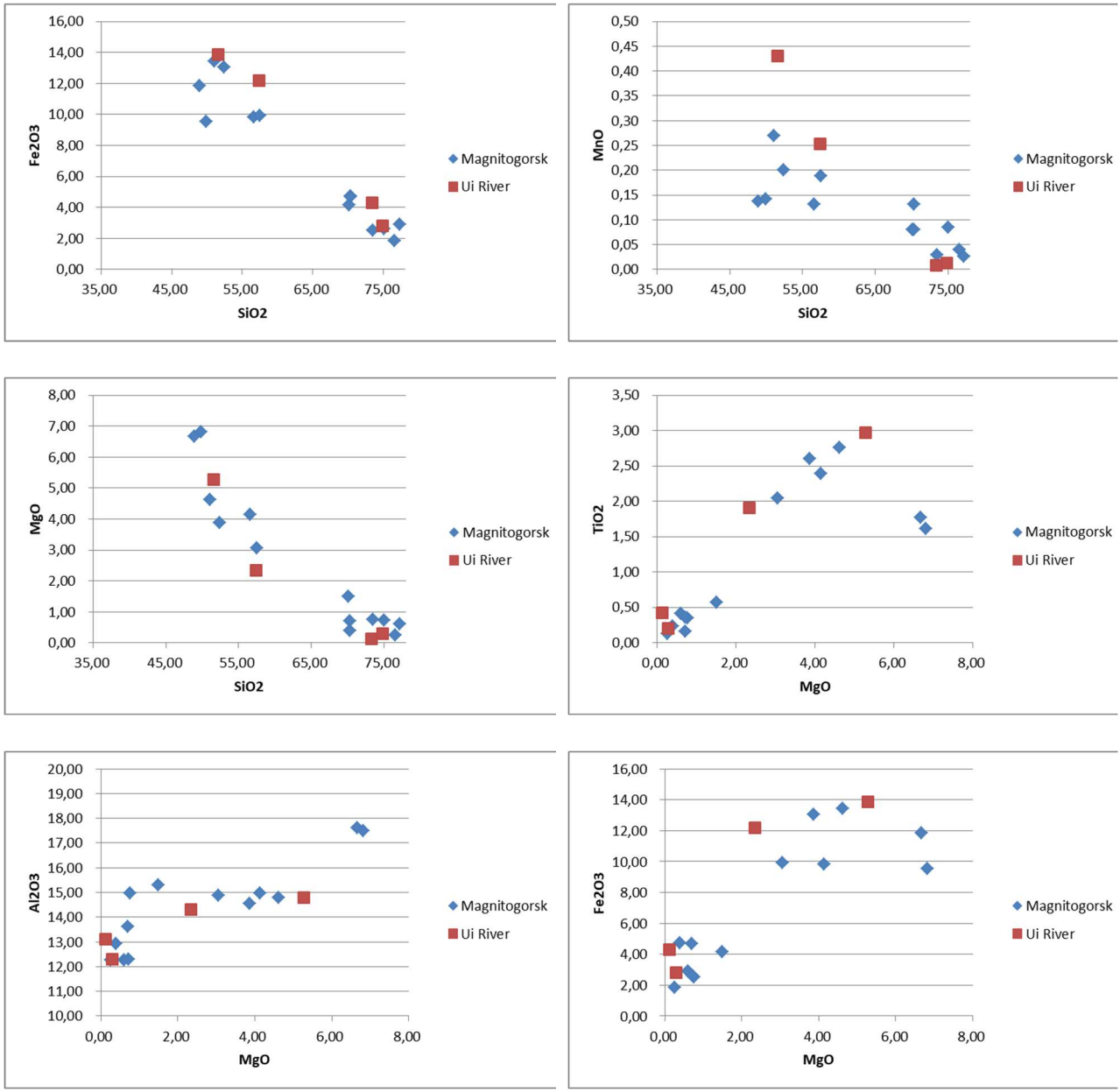


Fig. 1. Harker diagrams (wt %) of volcanic rocks from the Southern Urals. TAS fields after (Le Maitre, 2002).

Abundance patterns of trace element (fig. 2, 3) indicates that the sources of mafic to intermediate magmas have affinities of E-MORB and OIB sources. Minor effect of IAB sources are inferred from Ta-Nb anomaly and enriched in HREE.

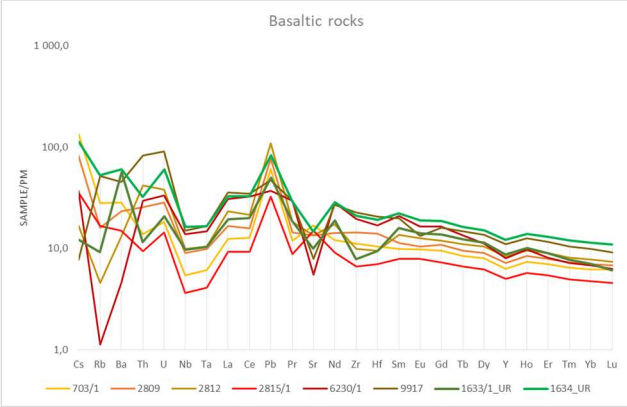


Fig. 2. Trace element plots for basic volcanic rocks of the Southern Urals. The contents are normalized to the primitive mantle composition, after (Sun, McDonough, 1989).

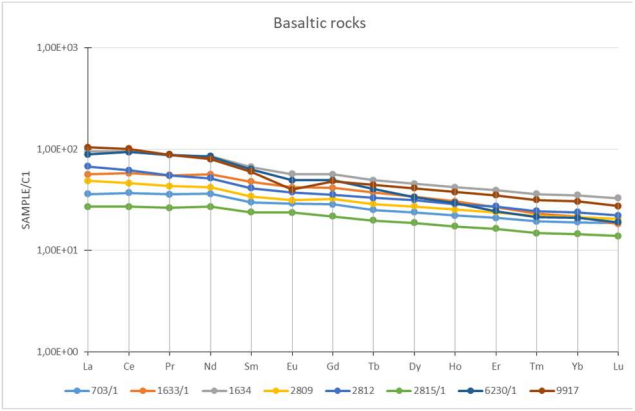


Fig. 3. REE plots for basic volcanic rocks of the Southern Urals. The contents are normalized to the C1 chondrite composition, after (Sun, McDonough, 1989).

Silicic rocks are inferred to have been derived by the involvement of proto-crustal rocks from their element abundance patterns akin to upper continental crust (UCC) with strong enrichments of incompatible elements, especially REE (fig. 4, 5).

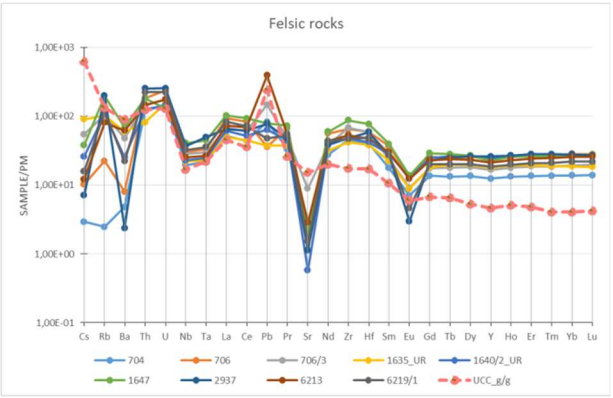


Fig. 4. Trace element plots for felsic volcanic rocks of the Southern Urals. The contents are normalized to the primitive mantle composition, after (Sun, McDonough, 1989). The composition of the upper continental crust (UCC) after (Rudnick and Gao, 2003).

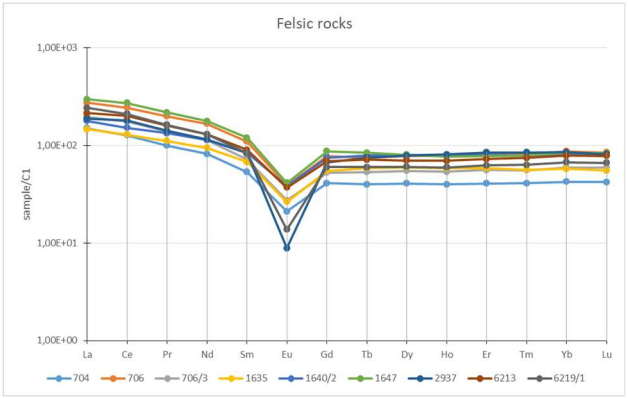


Fig. 5. REE plots for basic volcanic rocks of the Southern Urals. The contents are normalized to the C1 chondrite composition, after (Sun, McDonough, 1989).

The age corrected 87Sr/86Sr ratios of the basalts range from 0,703724 to 0,705126, and those of the felsic rocks from 0,705923 to 0,751857 (table 4, fig. 6). Anomalously high 87Sr/86Sr signatures could be attributed either to post-magmatic secondary alteration or to the involvement of Precambrian crust blocks in the source of magma generation.

The age corrected 206Pb/204Pb ratios are 18,074–18,535 and the age corrected 207Pb/204Pb ratios are 15,561–15,592 (table 5, fig. 7). Generally, samples from Magnitogorsk and Ui River zones lie on a linear trend (except 1 that flies away from the main group), suggesting the involvement of common two magma sources.

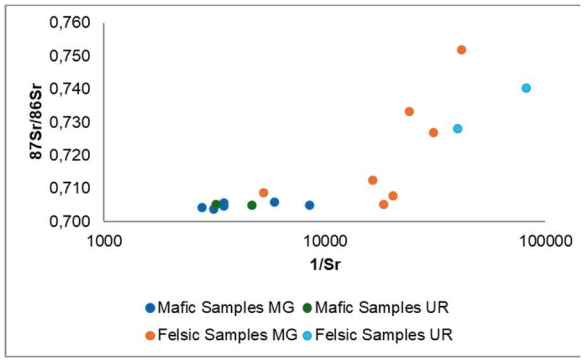


Fig. 6. 87Sr/86Sr vs 1/Sr diagram. MG – Magnitogorsk Zone, UR – Ui River Zone.

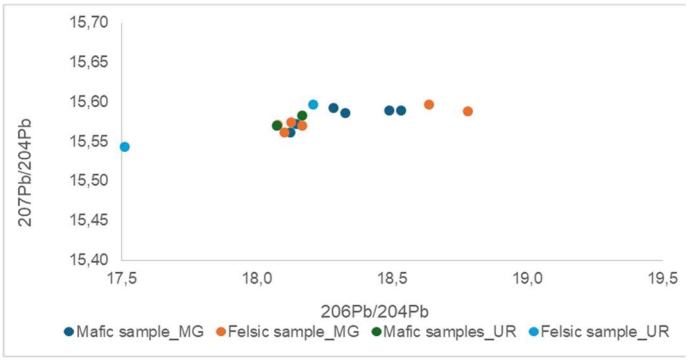


Fig. 7. 207Pb/204Pb vs 206Pb/204Pb diagram. MG – Magnitogorsk Zone, UR – Ui River Zone.

These results are valuable to understand magmatic processes and source characteristics in limited temporal and spatial scales within the western region in Southern Ural zone. For more deep understanding of the magma generation processes additional isotope analyses (Nd and Hf) are needed.

References

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