Conference Paper

Pb, Sr and Nd Isotope Ratios of Permian-Triassic Flood Basalts in the Basement of the West Siberian Plate

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Abstract

Permian-Triassic flood basalts are widespread across an extremely large area of the Siberian plate in the pre-Jurassic basement of the West Siberian plate. We show that Permian-Triassic flood basalts are similar to the trap basalts of the Siberian Platform with regard to geochemical features and Pb, Sr and Nd isotopic composition. Strontium and neodymium isotope ratios indicate the contribution to the formation of the flood basalts of the EM1 reservoir. We will also show a possible contamination of basalt magma by the Palaeozoic island-arc and orogenic rock complexes.

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1. Introduction

Permian-Triassic flood basalts are widespread across an extremely large area of the Siberian plate, particularly in the pre-Jurassic basement of the West Siberian plate in the Middle Urals, in the Timan-Pechora region and in Kuzbass [1-2, 9-10, etc.]. In the pre-Jurassic basement of the West Siberian plate, the flood basalts form rifts and grabens and are present on the surface of the basement [3-5, 11].

However, the Permian-Triassic basalts in the basement of the West Siberian Plate have been studied to a significantly lesser degree than have the trap basalts of the Siberian platform. This is mainly due to the absence of outcrops. Data on the isotopy of lead, strontium and neodymium for the Permian-Triassic basalts in the basement of the West Siberian Plate are almost completely absent. The tasks in this research are to study the geochemical features and the isotope ratios of lead, strontium and neodymium in samples of Permian-Triassic flood basalts from various regions in the West Siberian plate.

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2. Samples and analytical methodology

In this work, we will study samples of Permian-Triassic flood basalts from deep and superdeep boreholes: Yen-Yakhinskaya SG-7, with depths of 6428, 8009 and City8250 m, Tyumenskaya SG-6, with a depth of City6975 m, Urengoiskaya 414-r, with a depth of City5470.54 m (the northern part of West Siberia); Zapadno-Chistinaya 501, with a depth of City3500 m (Yugansk-Koltogorsk zone), Ust-Iuskaya 8000, with a depth of City1794 m, Severo-Shushminskaya 10208, with a depth of City2037 m (the western part of West Siberia), and 27 Lekosskaya, with depths of 2575.5 and 2577, City5 m (the eastern part of West Siberia).

The basalt samples studied are presented as relatively non-altered basalts, which consist of clinopyroxene, plagioclase and altered basalts. In non-altered basalts, the clinopyroxene is diopside – an augite with f 0.26-0.31 % and Wo 44-46%. The plagioclase grains have a zonal structure: The core is labradore (An 62-69) and the margin is andesine (An 35-40). There are rare sanidin grains in basalts with Kfs 0.30-0.47 %, Ab 0.46-0.61 % and An 0.06-0.10 %. An altered basalt consists of albite, prehnite, chlorite, epidote and pumpellyite, and has a relict igneous structure.

All analyses were performed at the Zavaritsky Institute of Geology and Geochemistry UB RAS. The measurement of the chemical composition was conducted by Nadezhda P. Gorbunova using the X-ray fluorescence analyser XRF-1800. The measurement of the elemental composition of rock samples was performed the ICP-MS ELAN-9000 by Dr Daria V. Kiseleva.

Sample preparation was carried out in the class 1000 clean-room facility at the Zavaritsky Institute of Geology and Geochemistry UB RAS. The samples were dissolved in clean Savillex vessels, using a mixture of concentrated HF and HNO_3 at ~120 °C on hotplates over three days, followed by treatment with concentrated HCl at ~120 °C for one day. Prior to the dissolution, each sample was spiked with a mixed ^{147}Sm-^{150}Nd or ^{84}Sr-^{85}Rb spike according to the type of analysis. No spike was used for the Pb isotopic analysis. After the dissolution, the samples were passed through the chromatographic column in order to isolate Nd, Sm, Rb, Sr and Pb. A two-stage column procedure was used for the initial REE isolation on a TRU-spec column and for the final Sm and Nd separation on a LN-spec column [8]. Sr and Rb were isolated using the anion-exchange resin Dowex 50x8 with extra purification of Sr using an Sr-spec resin. Pb isolation was performed using the conventional HBr-HCl technique [6]. The procedural blanks for Sr and Rb were 0.3 ng and 0.05 ng, respectively. The blank correction for Nd, Sm and Pb was not applied due to their low values, which did not exceed 0.01% of the sample concentrations.

All measurements of Nd, Sm and Pb isotope ratios were performed by Neptune Plus (Thermo Finnigan), while Rb and Sr were determined via Triton Plus (Thermo Finnigan) at the Zavaritsky Institute of Geology and Geochemistry UB RAS. Nd and Sm isotope ratios were measured in 3% HNO_3 in static mode, with all data processing being taken off-line. Neodymium samples were run routinely at a ^{142}Nd beam size of ~2 V for 90 cycles. The Analysis of samarium was carried out in 60 cycles. Strontium was loaded in 1 μL 3% HNO_3 with a Ta_2O_5 activator on an Re filament, and was collected in static mode for 90 cycles. Rubidium was analysed in double filament mode from 1 μL 3% HNO_3 load. Data were collected in static mode for 15 cycles. The measurement of lead was performed using the Tl-normalisation technique [14]. Each sample was dissolved in 3% HNO_3 and doped with thallium prior to the analysis in order to obtain a thallium concentration of 25 ppb. Data processing was carried out on-line, including a ^{204}Pb interference correction using the ratio ^{202}Hg/^{204}Hg = 4.350370, and was normalised via the exponential law.

Table 1: Chemical composition (wt%) of Permian-Triassic flood basalts of the basement of the West Siberian plate.

Borehole	Depth, m	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	L.o.i.	Total
ZCh 501	3500	44,26	1,07	18,72	5,69	4,1	0,146	6,56	5,00	2,40	0,11	0,15	12,0	100,19
Yen-Yakh-inskaya SG-7	8009	50,95	0,88	14,78	5,94	4,6	0,178	8,92	5,35	2,86	1,17	0,15	4,0	99,60
	8250	51,01	1,30	14,70	8,54	4,2	0,174	6,50	6,03	2,66	0,26	0,22	4,5	99,92
	7673	44,67	0,98	14,19	6,13	5,2	0,183	5,98	12,12	2,44	0,19	0,25	7,6	99,75

Note: borehole ZCh 501 – Zapadno-Chistinaya 501.

The Merck Nd standard, traceable to SRM NIST Nd_2O_3, was used to access the long-term instrumentation reproducibility yielded in ^{143}Nd/^{144}Nd = 0.511720 ± 15 (1 SD, n = 40). For strontium measurements, NIST SRM 987 was used as a standard, with ^{87}Sr/^{86}Sr = 0.710256 ± 11 (1 SD, n=59). The accuracy and long-term reproducibility of the lead isotope ratio determination was estimated using NIST SRM 981, and yielded ^{204}Pb/^{206}Pb = 0.059061 ± 2, ^{208}Pb/^{206}Pb = 2.16799 ± 5, ^{207}Pb/^{206}Pb = 0.914524 ± 9 (1 SD, n=58). Moreover, the analyses of the geological samples andesite USGS AGV-2 and basalt USGS BHVO-2 were performed on a regular basis and retrieved ^{143}Nd/^{144}Nd = 0.512767± 11 (1 SD, n = 15), ^{87}Sr/^{86}Sr = 0.703974± 47 (1 SD, n = 35) and ^{143}Nd/^{144}Nd = 0.512985±15 (1 SD, n = 20), ^{87}Sr/^{86}Sr = 0.703475± 31 (1 SD, n = 35), respectively. In order to control the sample preparation procedure, a Pb isotopic analysis of AGV-2 was performed and yielded $^{206}Pb/^{204}Pb$ = 18.863 ± 9, $^{208}Pb/^{204}Pb$ = 38.327 ± 19, $^{207}Pb/^{204}Pb$ = 15.615 ± 6 (1 SD, n=13).

Table 2: Element composition (ppm) of Permian- Triassic flood basalts of the basement of the West Siberian plate.

Borehole	U 8000	S 10208	CityUr 414	27 Lekosskaya		SG-6	Yen-Yakhinskaya SG-7				ZCh 501
Depth, m	1794	2037	5470	2577,5	2575,5	6975	6428	8009	8250	7673	3500
Li	4,372	8,470	12,971	4,378	4,507	10,662	8,825	8,2	12,3	11	5,210
Be	1,106	1,228	1,549	0,593	0,732	0,878	1,108	0,8	0,9	1,3	0,371
Sc	19,621	19,211	4,053	18,412	17,795	31,781	16,491	23,8	23,8	20,7	31,446
Ti	9345	8734	5313	5564	5509	15383	12647	4106	5694	5063	4361
V	221,23	235,67	57,822	163,82	164,63	193,25	161,14	106	110	124	160,57
Cr	54,275	15,10	9,043	220,08	209,37	199,35	115,70	189	57	19	132,25
Mn	890,3	1319,0	492,77	752,60	914,84	2080,6	1286,1	618	592	671	811,66
Co	29,01	33,537	10,204	30,098	75,495	53,851	26,439	38	24	44	27,885
Ni	58,49	33,746	8,500	122,91	163,01	57,133	78,231	14	19	12	29,621
Cu	60,66	47,908	18,858	62,180	61,427	83,395	45,742	13	21	21	14,355
Zn	97,39	106,13	64,433	42,888	101,56	139,51	58,645	66	99	83	57,837
Rb	23,219	19,320	46,488	11,634	11,329	0,575	49,019	24	5	3	2,743
Sr	458,64	569,30	974,55	1389,0	1377,1	66,813	65,527	73	441	60	156,64
Y	23,745	21,309	11,702	13,287	14,422	24,406	15,889	22,1	36,7	30,3	20,245
Zr	154,98	169,48	150,66	104,43	103,777	96,950	182,15	86	146	150	95,673
Nb	15,349	13,008	21,152	8,148	7,932	13,748	53,006	7,1	7,8	11,2	4,691
Cd	0,265	0,302	0,218	0,167	0,184	0,198	0,250	0,05	0,07	0,09	0,030
Sn	1,444	1,252	1,717	0,604	0,580	1,002	1,545	1,1	1,9	2,3	1,063
Sb	0,056	0,100	0,495	0,046	0,044	0,063	0,642	0,3	2,6	0,7	0,194
Te	0,005	-	-	-	-	-	-	0,01	0,02	0,04	0,010
Cs	0,553	1,037	0,715	0,107	0,102	0,090	2,393	0,17	0,33	0,14	0,588
Ba	511,21	2808,0	3974,7	836,11	814,07	125,23	357,76	397	338	119	180,94
La	30,346	33,496	31,778	34,321	33,862	11,954	25,485	14,99	19,26	20,18	9,837
Ce	69,406	77,319	60,569	77,599	76,856	28,703	52,645	33,49	43,65	44,67	23,982
Pr	8,488	9,622	7,119	9,502	9,486	3,876	6,086	4,31	5,94	5,65	3,252
Nd	34,445	38,722	25,360	36,916	37,386	17,477	23,503	17,68	25,5	23,25	14,360

Borehole	U 8000	S 10208	CityUr 414	27 Lekosskaya		SG-6	Yen-Yakhinskaya SG-7				ZCh 501
Sm	6,988	7,238	4,565	6,306	6,275	4,556	4,658	4,12	6,53	5,65	3,541
Eu	1,891	2,369	1,520	1,965	1,937	1,643	1,539	1,1	1,56	1,33	0,988
Gd	7,464	8,742	5,946	6,277	6,594	5,718	5,430	4,85	7,33	6,31	3,967
Tb	0,949	0,888	0,525	0,627	0,628	0,874	0,660	0,74	1,2	0,99	0,656
Dy	5,557	4,906	2,756	3,216	3,356	5,372	3,683	4,54	7,3	6,19	4,419
Ho	1,129	1,000	0,538	0,658	0,683	1,114	0,765	0,95	1,58	1,32	0,973
Er	3,319	2,880	1,527	1,844	1,967	3,139	2,111	2,89	4,81	4,07	3,022
Tm	0,487	0,430	0,208	0,258	0,285	0,443	0,307	0,42	0,71	0,63	0,444
Yb	3,250	2,800	1,364	1,745	1,882	2,843	1,940	2,79	4,8	4,27	3,041
Lu	0,502	0,414	0,199	0,267	0,283	0,382	0,298	0,43	0,73	0,65	0,471
Hf	4,468	4,762	4,164	2,785	2,631	3,229	4,515	2,79	4,82	4,55	3,237
Ta	1,067	0,862	1,485	0,496	0,470	1,021	3,809	1,71	1,66	2,95	0,504
Tl	0,108	0,116	0,536	0,018	0,031	0,008	0,271	0,28	0,3	0,15	0,017
Pb	8,919	8,653	19,287	8,516	8,278	2,382	3,794	2,72	7,00	5,17	2,375
Bi	0,026	0,035	0,069	0,006	-	-	-	0,01	0,01	0,01	0,008
Th	3,701	4,096	7,362	2,062	1,956	0,856	3,427	2,96	3,96	5,58	2,156
U	1,587	1,421	7,298	1,737	1,729	0,663	1,202	4,24	5,09	7,91	0,789

Note: boreholes: U 8000 – Ust-Iuskaya 8000, S 10208 – Severo-Shushminskaya 10208, Ur 414 – Urengoiskaya 414-r, SG-6 – Tyumenskaya SG-6, ZCh 501 – Zapadno-Chistinaya 501.

3. Another section of your paper

The samples of Permian-Triassic basalt studied were tholeiitic basalt and picrite-basalt (SiO_2 44-51 wt.%) (Table 1). They varied from a low-potassium to a medium-potassium series, with TiO_2 0.9-1.3 wt.%, Fe/(Fe+Mg) ratio is 0.38-0.51. Flood basalts were characterised by a negative REE trend (La_n/Yb_n ratio is 2, 2-16, 2); the total REE was 73-190 ppm (see Table 2). All samples had a slightly negative Eu-anomaly (Eu_n/Eu_n* 0.68-0.98). The samples were depleted in Rb, Th and Y, and were enriched in U and Ba. Some basalt samples were slightly depleted in Nb and Ta. The Permian-Triassic basalt was characterised by a significant variation in the content of Sr (60-1389 ppm).

The initial isotope ratios by age 250 Ma in the Permian-Triassic flood basalts are $^{206}Pb/^{204}Pb_i$ 17,331–19,536, $^{207}Pb/^{204}Pb_i$ 15,492–15,607, $^{208}Pb/^{204}Pb_i$ 37,541–38,097,

$^{87}Sr/^{86}Sr_i$ 0,704210-0,705211 $^{143}Nd/^{144}Nd_i$ 0,512403-0,512542, εNd is up -1,9 to -4,6 (Table 3).

Table 3: Pb, Sr, Nd isotope ratios of Permian-Triassic flood basalts of the basement of the West Siberian plate.

Borehole	U 8000	S 10208	Ur 414	27 Lekosskaya		SG-6	Yen-Yakhinskaya SG-7			ZCh 501
Depth, m	1794	2037	5470	2577,5	2575,5	6975	6428	8009	8250	3500
Measured:										
$^{206}Pb/^{204}Pb$	18,569	18,511	20,662	18,616	18,644	18,807	18,686	22,070	20,213	19,555
±SE	0,004	0,004	0,005	0,004	0,004	0,004	0,004	0,005	0,005	0,005
$^{207}Pb/^{204}Pb$	15,6106	15,6036	15,6579	15,5354	15,5307	15,6020	15,5434	15,7348	15,6349	15,6567
±SE	0,0004	0,0007	0,0008	0,0004	0,0004	0,0005	0,0004	0,0006	0,0005	0,0007
$^{208}Pb/^{204}Pb$	38,394	38,414	38,457	37,778	37,755	38,165	38,498	38,631	38,133	38,499
±SE	0,001	0,002	0,002	0,001	0,001	0,001	0,001	0,0015	0,0013	0,002
$^{87}Rb/^{86}Sr$	0,1371	0,0885	0,1360	0,0222	0,0224	0,0284				
±2SE	0,0017	0,0011	0,0017	0,0003	0,0003	0,0004				
$^{87}Sr/^{86}Sr$	0,705245	0,705316	0,705031	0,704221	0,704289	0,705312				
±2SE	0,000021	0,000020	0,000020	0,000016	0,000039	0,000019				
$^{147}Sm/^{144}Nd$	0,120224	0,111666	0,106208	0,099707	0,100371	0,154595				
±SE	0,00007	0,00011	0,00014	0,00012	0,00009	0,00086				
$^{143}Nd/^{144}Nd$	0,512599	0,512602	0,512678	0,512705	0,512706	0,512705				
±SE	0,000007	0,000009	0,000005	0,000006	0,000006	0,000049				
Initial:										
$^{206}Pb/^{204}Pb$	18,061	18,044	19,539	18,039	18,054	18,028	17,785	17,355	18,082	18,607
$^{207}Pb/^{204}Pb$	15,5846	15,5797	15,6004	15,5059	15,5004	15,5621	15,4973	15,4933	15,5257	15,6082
$^{208}Pb/^{204}Pb$	38,023	37,990	38,101	37,568	37,550	37,868	37,689	37,613	37,617	37,688
$^{87}Sr/^{86}Sr$	0,704757	0,705001	0,704547	0,704142	0,704210	0,705211				
$^{143}Nd/^{144}Nd$	0,512403	0,512419	0,512504	0,512542	0,512541	0,512452				
εNd	-4,59	-4,27	-2,62	-1,87	-1,88	-3,63				

Note: boreholes as in the Table 2.

4. Discussion and conclusions

In general, the samples of the flood basalts studied are similar to the Permian-Triassic basalts from the basement of the West Siberian plate based on the distribution of REE and some incoherent elements such as [7. 11]. In addition, the basalt samples are geochemically similar to the Permian-Triassic trap basalts of the Siberian platform by [1]. However, the basalt samples studied have a high content of U (up to 7.9 ppm), Ba (up to 3974 ppm) and of Sr (up to 1389 ppm), and have a reduced Y content (12-37 ppm) when compared to Siberian trap basalts. This was reflected in the high values of the ratio Sr/Y, which were up to 105.

Most of the samples were similar to the mantle and lower crustal reservoirs by [15]. The Pb isotope ratios of most of the basalt samples corresponded to the trap basalts of the Siberian platform at diagrams $^{206}Pb/^{204}Pb$ – $^{207}Pb/^{204}Pb$ and $^{206}Pb/^{204}Pb$ – $^{208}Pb/^{204}Pb$ according to [13] (Figure 1). This indicates a common source of basaltic volcanism in these provinces. Samples from the Zapadno-Chistinaya 501 and Urengoiskaya 414-r boreholes differ this field of composition towards the increased ratio of U/Pb. This may be due to the influence of contaminated core material. Both these boreholes are located within the central "axial" zone of the Permian-Triassic rift structures in the basement of the West Siberian Plate. However, in other boreholes in this central "axial" zone (Yen-Yakhinskaya SG-7, Tyumenskaya SG-6), such anomalies are not observed.

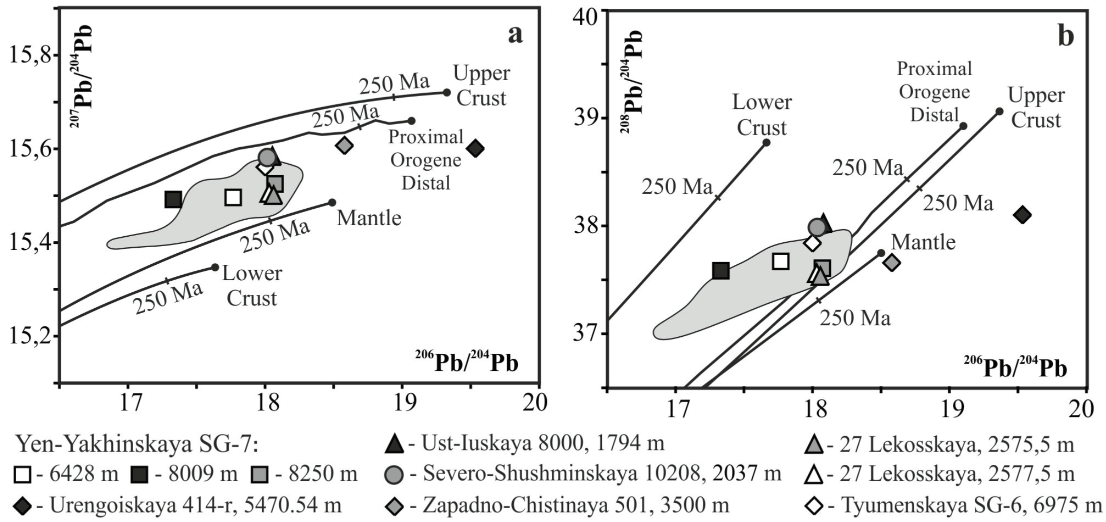

Figure 1: Diagrams $^{206}Pb/^{204}Pb$ – $^{207}Pb/^{204}Pb$ (a) and $^{206}Pb/^{204}Pb$ – $^{208}Pb/^{204}Pb$ (b) for Permian-Triassic flood basalts of the West Siberian plate. Gray field – trap basalts of the Siberian platform by [13]. Reservoirs by [15].

In the diagram $^{87}Sr/^{86}Sr$ – εNd, the points of the Permian-Triassic flood basalts lie along the main mantle trend, mainly in the III quarter (Figure 2). The Permian-Triassic basalts are similar to the field of the trap basalts of the Siberian platform in terms of Sr and Nd isotope ratios. However, the basalts of the West Siberian platform deviate towards the Enriched Mantle 1-st type (EM1). The effect of the EM1 reservoir is shown in the diagram as $^{206}Pb/^{204}Pb$ – $^{207}Pb/^{204}Pb$, particularly for basalts from the

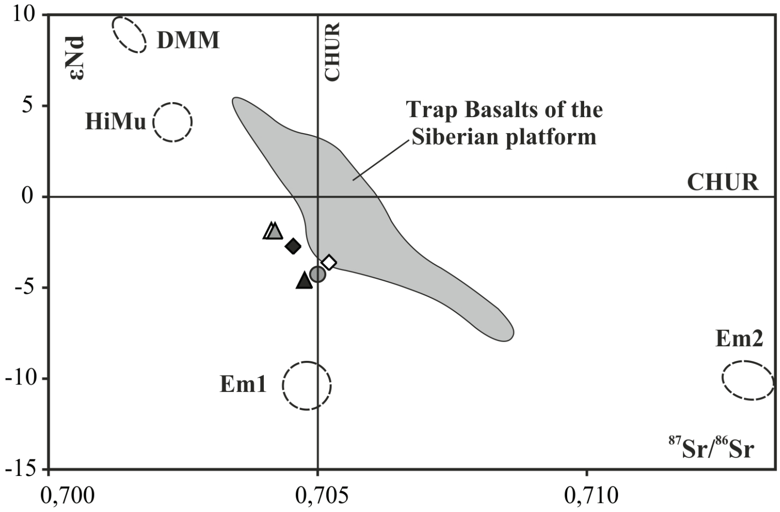

Figure 2: Diagram $^{87}Sr/^{86}Sr$ – εNd for Permian-Triassic basalts of the West Siberian plate. Gray field – trap basalts of the Siberian platform by [12]. Symbols as in the Fig. 1.

Yen-Yakhinskaya SG-7 borehole. This can be explained by the contamination of this basalt magma by the lower continental crust. Similar conclusions have been obtained by other researchers in the study of the traps of the Siberian Platform [12, etc.].

Thus, new data regarding the Pb, Sr and Nd isotope ratios in the Permian-Triassic flood basalts from different regions of the pre-Jurassic basement of the West Siberian Plate are presented in this article. We show that Permian-Triassic flood basalts are similar to the trap basalts of the Siberian platform in terms of geochemical features and Pb, Sr and Nd isotopic composition. Samples from two boreholes incline towards the increased ratio U/Pb. This can be explained by contamination of this basalt magma by the Palaeozoic island-arc and orogenic rock complexes. Strontium and neodymium isotope ratios indicate their contribution to the formation of the flood basalts in the EM1 reservoir.

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