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GEOCHEMISTRY

Age of Lamprophyres of the Middle Timan: First Rb–Sr Data

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Dating of lamprophyres from magmatic complexes of the Middle Timan that are probably genetically linked to Timan diamonds is a problem of considerable importance. Up to now, the age of magmatism of this region was mainly defined by K–Ar determinations obtained in the 1970s and 1980s. In this work, we attempted for the first time to study the Rb–Sr systematics of the rocks of Middle Timan.

Subalkaline basic rocks of the dike series have a wide areal distribution and belong to the lamprophyre group. These rocks are confined to deep-seated, long-lived faults of NE-strike that is transverse to the general Timan northwestern extension of plicative and disjunctive structures. Host rocks are sandstones and clay shales of the Chetlas and Bystrin groups. In the development area of lamprophyres, the sediments of the Chetlas Group form a gently SW-dipping monocline complicated by small gentle folds. Beds commonly dip 10°–20°, becoming steeper near the Central Timan fault zone. The rocks of the Bystrin Group are deformed into simple folds whose limbs dip up to 40° [2, 5].

The lamprophyres compose hundreds of bodies (predominant dikes and a few stocks) that show no spatial relation to intrusive magmatism. They form several fields with the largest Kos'yu (Fig. 1) and Bobrovskoye fields with the area of approximately 1000 km^2 in the southeastern part of the Chetlas Kamen [2, 5].

Lamprophyres are holocrystalline porphyritic rocks with phenocrysts of brown mica of phlogopite–annite–siderophyllite–eastonite series, clinopyroxene, amphibole, occasional olivine, and no feldspars. Their characteristic structural feature is equal amounts of femic and felsic minerals in a fine-grained groundmass, which contains rounded, occasionally dissolved or corroded phenocrysts of mafic minerals, autholiths, and xenoliths of the surrounding rocks.

In terms of chemistry (Table 1) and mineralogy, the rocks are ascribed to the kersantite–spessartite series [3]. More than 95 rock-forming and accessory minerals having typomorphic features were identified in the lamprophyres. Accessory minerals in the lamprophyres and surrounding metasomatites are similar to those of the Middle Devonian diamondiferous conglobreccias of the Ichet'yu occurrence [4], which indicates a genetic link of lamprophyres with bedrock sources of Timan diamonds. Postcrystallization transformations of the lamprophyres were caused by autometasomatism (phlogopitization, amphibolization) and hydrothermal processes.

Carbonatites spatially related to the lamprophyres and localized in the same fault zones are the younger rocks. Their possible age established by phlogopite K–Ar dating is 600 ± 30 Ma [1], which can be considered as the approximate age of the lamprophyres. To specify this assumption, we carried out Rb–Sr dating of core material from five boreholes, one of which was drilled in the Kos'yu dike field and others in Bobrovskoye field. Whole-rock samples and a single phlogopite separate from spessartite were analyzed.

The Rb and Sr contents were analyzed in one aliquot by isotopic dilution and using separate ^{87}Rb and ^{84}Sr tracers. The samples were decomposed in a mixture of HF + HCl at a temperature of about 120°C using special Teflon inserts. The separation of Rb and Sr was carried out by means of eluent chromatography using columns (internal diameter of 7 mm) filled with 5 cm^3 of DOWEX 50 × 8 resin (200–400 mesh) and 2 *N* HCl as an eluent. The Rb and Sr laboratory blanks were no more than 2.0 and 0.5 ng.

The Rb and Sr isotopic composition was analyzed in the one-beam mode on a MI-1201T spectrometer with a two Re filament ion source; Re filaments were prelim-

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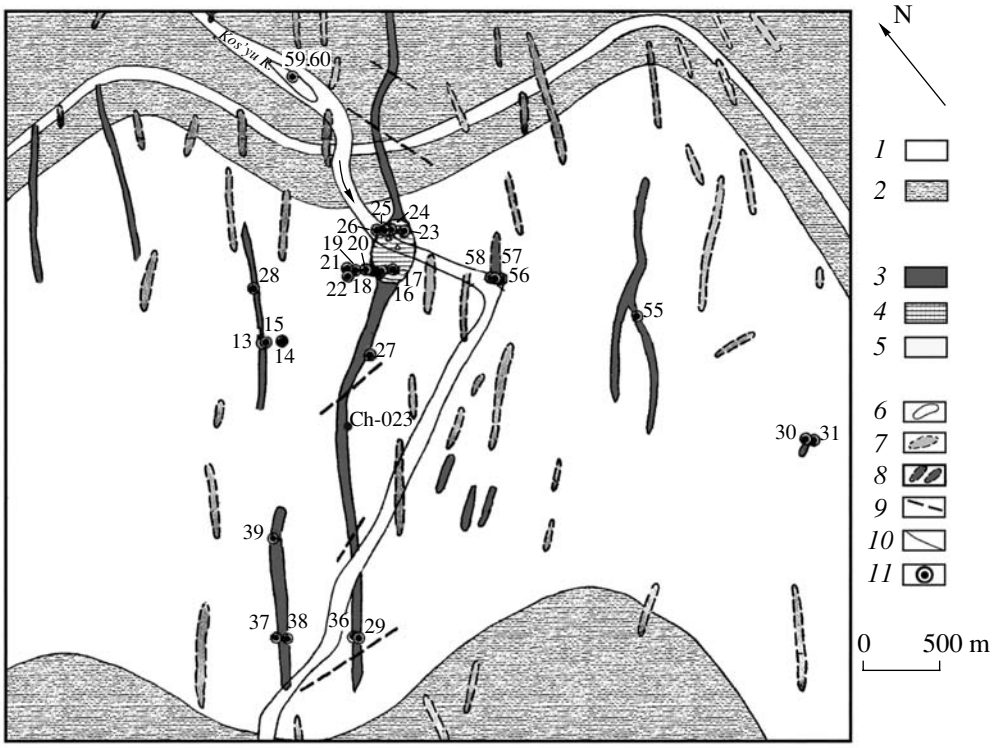

Fig. 1. Distribution scheme of the magmatic bodies in the central part of the Kos'yu field (Diamond Hill area). Compiled after materials of the Ukhta GRE. (*1, 2*) Upper Proterozoic deposits of the Upper Subformation of the Chetlas Formation ($PR_2čt_2$): (*1*) quartz and feldspar–quartz sandstones, their fenitized varieties, and quartzites; (*2*) mudstones and siltstones, (*3–5*) Magmatic rocks: (*3*) lamprophyre dikes (kersantites) and their breccias, (*4*) Kos'yu carbonatite massif, (*5*) diabase dikes; (*6–8*) lamprophyre bodies: (*6*) exposed at the surface, (*7*) unexposed; (*8*) inferred from geophysical data; (*9*) faults, (*10*) geological boundaries, (*11*) boreholes and their numbers.

inarily annealed to remove admixtures. The measured $^{87}Sr/^{86}Sr$ ratios were normalized to $^{86}Sr/^{88}Sr = 0.1194$, with no correction for fractionation. During measurements, the $^{87}Sr/^{86}Sr$ ratio in the SRM-987 strontium isotopic standard was 0.71023 ± 6 (12 analyses, 2σ). Here, in Table 2 and in the text, the errors in measured and initial $^{87}Sr/^{86}Sr$ ratios are given in the last digits. The measurement error of $^{87}Sr/^{86}Sr$ is $\pm 1.5\%$ (2σ). Isochron parameters were calculated using the ISOPLOT program [6]. The error in age determinations reported in Table 2 and in the text corresponds to $\pm 2\sigma$.

Analytical data are reported in Table 2 and given in Fig. 2, where most experimental data points define two parallel straight lines. The best results were obtained for four lamprophyre samples from a dike recovered by borehole 55 within the Kos'yu field. Their age is 827 ± 31 Ma at $(^{87}Sr/^{86}Sr)_0 = 0.70416 \pm 22$ and MSWD = 0.3. The data points of samples 102/55 and 186/99 from two dike bodies of Bobrovskoye field together with samples from borehole 55 form an isochron with practically the same parameters: $t = 819 \pm 19$ Ma; $(^{87}Sr/^{86}Sr)_0 = 0.70421 \pm 16$, MSWD = 0.3. The initial Sr ratio definitely indicates the mantle source of the protolith and the absence of postcrystallization alteration.

Less reliable results were obtained for lamprophyres from two other dikes of Bobrovskoye field, which were recovered in boreholes 116 and 157. Three data points from samples 116/33.5, 116/47.0, and 157/17.7 from an isochron with an age of 826 ± 24 Ma at $(^{87}Sr/^{86}Sr)_0 = 0.70693 \pm 24$ and MSWD = 1.2. The comparison of the parameters of two isochrons showed that the studied rocks have the same ages, while the more radiogenic Sr isotopic composition in lamprophyres of the age of 826 Ma is caused not by postmagmatic alteration of the rocks, but by significant crustal contamination of the initial magmatic melt.

The data points of two lamprophyre samples (spessartite taken at a depth of 37 m from borehole 116 and kersantite Ch-023 from the dike exposed at the surface), mica separate (sample 116/37m), and metasomatite (sample 186/89) are not plotted on the obtained isochrons. Instead, they define another regression line, which presumably marks the time of postcrystallization alteration of lamprophyres. Actually, this line defines an age of $t = 523 \pm 24$ Ma at $(^{87}Sr/^{86}Sr)_0 = 0.71099 \pm 36$ Ma; MSWD = 2.5. Omitting the data point of sample 186/89 from calculations practically does not affect the isotopic–geochronometric characteristics: $t = 530 \pm 10$ Ma;

Table 1. Chemical composition of lamprophyres of the Middle Timan (wt %)

Component	55/29.2	55/38.7	55/46.3	55/172	102/55	186/99	116/33.5	116/47	157/17.7	116/37	Ch-023	186/89
SiO_2	42.62	40.88	34.18	36.08	47.10	37.10	38.76	40.88	43.80	40.76	36.46	40.83
TiO_2	1.40	1.60	1.52	0.94	1.35	1.78	1.79	1.45	1.65	1.89	1.45	1.50
Al_2O_3	7.96	8.70	9.79	8.18	10.05	9.84	9.24	8.05	10.40	7.39	7.07	9.29
Fe_2O_3	5.44	4.46	6.86	3.79	2.47	2.90	5.10	2.61	3.05	5.67	6.50	1.95
FeO	4.89	5.12	3.53	4.07	9.70	6.95	3.86	5.38	6.52	3.69	2.51	6.81
MnO	0.16	0.14	0.18	0.22	0.42	0.14	0.19	0.15	0.15	0.15	0.09	0.08
MgO	19.15	18.46	16.02	20.04	12.41	11.05	18.16	16.83	15.58	12.91	21.09	13.41
CaO	8.87	11.46	15.63	11.06	4.71	12.29	14.97	13.43	8.63	19.21	10.65	10.41
Na_2O	1.00	0.67	0.66	1.91	2.71	0.63	0.54	0.35	1.69	0.54	0.67	0.42
K_2O	2.99	2.66	2.87	2.89	2.54	4.16	1.73	3.20	3.02	0.60	1.96	2.88
Cr_2O_3	0.28	0.24	0.05	0.08	0.13	0.09	0.17	0.14	0.13	0.07	0.14	0.09
NiO	0.07	0.04	0.01	0.05	0.04	0.03	0.04	0.03	0.04	0.01	0.06	0.03
P_2O_5	0.43	0.39	0.67	1.05	0.28	0.60	0.42	0.15	0.52	0.37	0.87	0.39
S_{tot}	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.04	0.00	0.00	0.00
CO_2	0.98	1.35	3.77	6.20	2.85	8.38	1.31	4.10	1.49	3.04	4.90	7.12
H_2O^-	0.64	0.50	0.39	0.42	0.45	0.44	0.52	0.56	0.54	1.14	0.64	0.41
H_2O^+	3.03	3.13	3.61	2.73	2.65	3.44	3.04	2.50	2.57	2.49	4.67	4.25
L.O.I.	4.65	4.98	7.77	9.35	5.95	12.26	4.87	7.16	4.60	6.67	10.21	11.78
Total	99.95	99.80	99.74	99.71	99.86	99.82	99.84	99.92	99.82	99.93	99.73	99.87

Note: The numerals in the nominator are the borehole number, the denominator denotes the depth; (186/89) metasomatite. (116/37) spessartite, other samples are kersantites.

Table 2. Rb and Sr isotopic characteristics of the lamprophyres of the Middle Timan

Point numbers in Fig. 2	Sample	Rb, ppm	Sr, ppm	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Age, Ma	$(^{87}Sr/^{86}Sr)_0$
1	55/29.2	105.2	417.4	0.730	0.71275 ± 16	819 ± 19	0.70421 ± 16
2	55/38.7	100.6	574.9	0.506	0.71015 ± 8		
3	55/46.3	121.4	901.3	0.390	0.70882 ± 18		
4	55/172	87.2	1127.0	0.224	0.70678 ± 12		
5	102/55	152.3	365.1	1.208	0.71828 ± 14		
6	186/99	189.0	245.4	2.232	0.73031 ± 22		
7	116/33.5	71.7	497.3	0.418	0.71191 ± 16	826 ± 24	0.70693 ± 24
8	116/47	139.9	269.2	1.506	0.72475 ± 18		
9	157/17.7	122.5	565.6	0.627	0.71425 ± 15		
10	116/37	25.1	1235.7	0.059	0.71144 ± 16	530 ± 10	0.71099 ± 11
11	116/37m	256.3	317.6	2.342	0.73754 ± 17		
12	Ch-023	51.7	742.5	0.202	0.71248 ± 17		
13	186/89	155.8	144.0	3.139	0.73409 ± 11		

$(^{87}Sr/^{86}Sr)_0 = 0.71099 \pm 11$; MSWD= 0.2. Close ages were obtained by K–Ar dating of phlogopite and orthoclase from metasomatic and hydrothermal rocks associated with carbonatites [1].

Thus, the first Rb–Sr isotope data were obtained on lamprophyres of the Middle Timan. Study of the core material from boreholes in the Kos'yu and Bobrov dike fields made it possible to establish that the alkali mag-

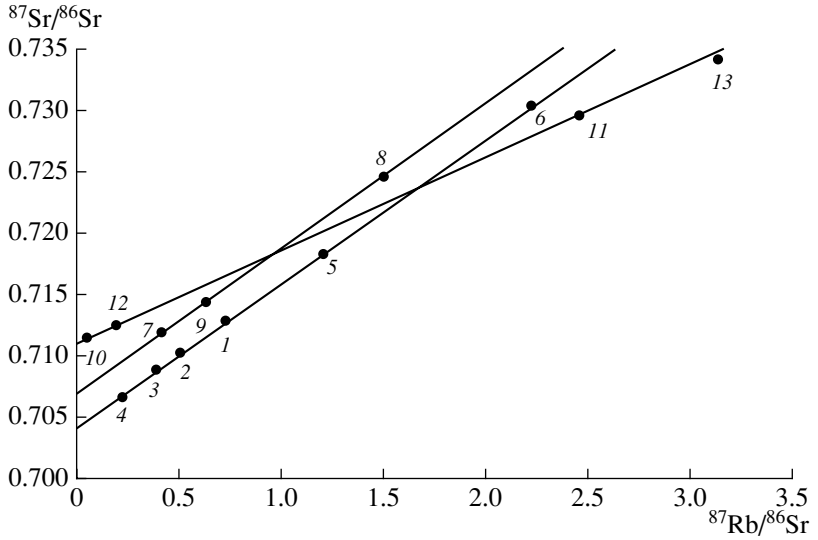

Fig. 2. Rb–Sr diagram for lamprophyres of the Middle Timan. Numbers are the same as in Table 2. See the text for explanation.

matic rocks were formed in the Neoproterozoic at 820 Ma, which confirms their within-plate (pre-Timanian) origin. Local postcrystallization transformations of lamprophyres took place in the Early Cambrian (530 Ma) after Timanide orogeny.

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