

GEOLOGY

## New Data on the Precambrian Age of Marunkeu Eclogites (Polar Urals)

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The age of eclogites (Precambrian or Middle Paleozoic) constituting the Marunkeu Block remains one of the key geological problems of the Polar Urals. It is crucial for dating subduction responsible for crystallization of eclogites.

The Marunkeu Block is located on the eastern limb of the northern Polar Urals segment of the central Uralian Uplift (Fig. 1). The Marunkeu Block includes different (in lithology and genesis), highly metamorphosed rocks (eclogites associated with ultramafics, migmatites, and garnet amphibolites) that are confined to the axial zone of the block corresponding to the southeastern part of the synonymous ridge (Slyudyanaya Gorka area). The flanks are composed of gneisses, feldspar amphibolites, and amphibole and micaceous schists. In the northern part, amphibolites and glaucophane schists are dominant rocks, while eclogites are missing. Widespread are lithology-variable blastomylonites and migmatites with signs of multiphase granitization and metasomatism. The block has tectonic contacts with the Upper Riphean greenschist volcanosedimentary Nyarovei Group [1, 2].

The Precambrian age of eclogites from the Marunkeu Block was established in the 1970s–1980s based on the dating of their minerals by the K–Ar and Pb–Pb methods [1, 2]. The maximal values for zircons and phlogopite were estimated at 1.70, 1.54 and 1.56 Ga, respectively. In addition, six K–Ar dates ranging from 626 to 605 Ma were obtained for amphiboles and biotite. Most of the ages obtained for minerals from the

rocks constituting the Marunkeu Block correspond to the Paleozoic with the maximum value at 360 Ma [3].

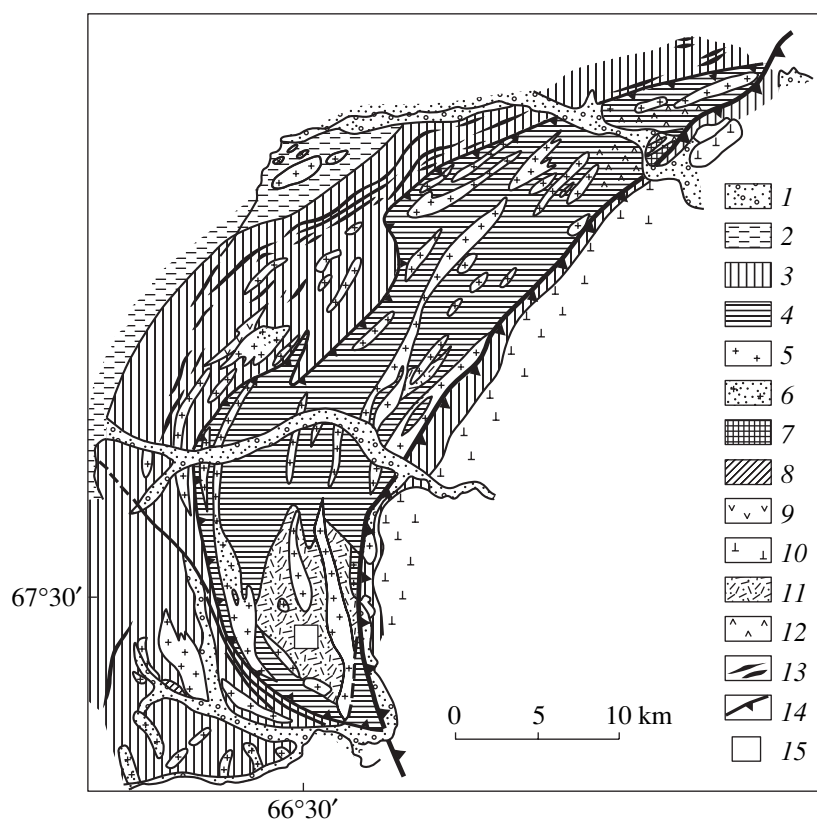
Recently, a different point of view has been suggested for the age of eclogites. The Sm–Nd mineral isochron method yielded  $366 \pm 8.6$  Ma [4] (hereinafter accuracy corresponds to  $2\sigma$ ). Similar values ranging from  $352 \pm 5$  to  $360 \pm 3$  ( $355.5 \pm 1.4$  on average) were established using Rb–Sr mineral isochrons for eclogites and amphibolites [5]. In recent works, these data are interpreted as the timing of eclogites. The Sm–Nd and Rb–Sr ages are beyond doubt, although they do not necessarily correspond to primary crystallization of eclogites. In both cases, we examined rocks containing white mica, which could be a product of their subsequent transformation rather than primary eclogite crystallization. The multiple development of muscovite in the Marunkeu Block is indicated by K–Ar ages of this mineral ranging from 482 to 207 Ma [3]. This is also indicated by the name of the maximal eclogite distribution area (Slyudyanaya Gorka, i.e., Micaceous Hill), where exploration works for muscovite were carried out. We examined only mica-free eclogites. In addition, we also attempted to date ultramafics occurring among eclogites. All the samples were taken in the Slyudyanaya Gorka area. Table 1 presents data on the chemical composition of rocks. Table 2 shows isotopic compositions of Rb, Sr, Sm, and Nd. Isotopic ages were determined in line with respective techniques at the geochronological laboratories of different institutions of the Russian Academy of Sciences [3, 6, 7].

We analyzed eclogite from Mt. Ryzhaya (sample 360). The Rb–Sr age determined for the whole-rock and kyanite and karyinite fractions is  $1.54 \pm 0.15$  Ga (Fig. 2). The data point of garnet is located away from the general trend. The age of the rock + garnet pair is  $629 \pm 39$  Ma at  $(^{87}\text{Sr}/^{86}\text{Sr})_0 = 0.70542 \pm 21$ . The Sm–Nd experimental data define an isochron with the age of  $1.54 \pm 0.14$  Ga (Fig. 3). The data point of garnet deviates from the isochron, although less significantly as

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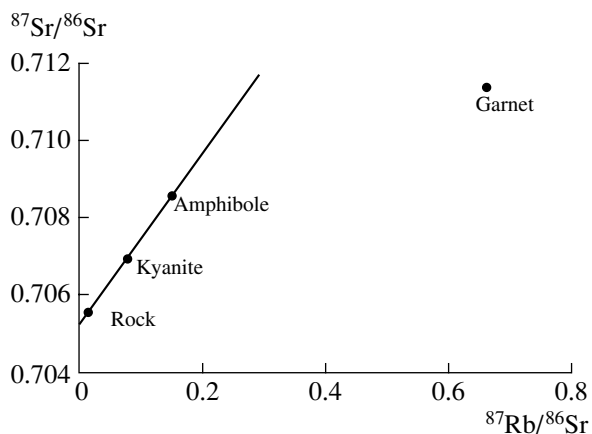
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**Fig. 1.** Schematic geological map of the Marunkeu Block (modified after [1]). (1) Quaternary sediments; (2) Paleozoic formations; (3) Nyarovei Group (conglomerates, schists with interbeds of quartzites, sandstones, marbles, and volcanics); (4) Marunkeu Complex (alternating amphibolites, gneisses, granite gneisses, and eclogites); (5) granites, plagiogranites, and gneissic granites; (6) granitoids with fluorite; (7) felsite porphyres; (8) diorites; (9) gabbro, gabbro diabases, and diabases; (10) Syumkeu ultramafics; (11) eclogite distribution areas; (12) rocks with glaucophane; (13) quartz-graphite schists; (14) dislocation zones; (15) Mt. Slyudyanaya area.

compared with the Rb–Sr system. The age estimated for the rock + garnet pair is  $1.30 \pm 0.07$  Ga.

The data obtained confirm the assumption that mica is responsible for rejuvenation of host rocks. For greater confidence, we examined an additional eclogite



**Fig. 2.** The Rb–Sr diagram for eclogite of sample 360:  $t = 1540 \pm 150$  Ma,  $(^{87}\text{Sr}/^{86}\text{Sr})_0 = 0.70521 \pm 22$ , MSWD = 0.002.

specimen (sample 366, Mt. Konicheskaya). The Rb–Sr age for the whole-rock, kyanite, and omphacite is estimated at  $1.61 \pm 0.07$  Ga (Fig. 4). As in the case of sample 360, the garnet data point appeared to deviate from the isochron. The age calculated from experimental data on garnet and whole-rock obtained for both samples is  $604 \pm 11$  Ga at  $(^{87}\text{Sr}/^{86}\text{Sr})_0 = 0.70542 \pm 21$  and MSWD = 0.97. The Sm–Nd age of sample 366 and garnet is  $1.68 \pm 0.07$  Ga (Fig. 3). The behavior of the Rb–Sr and Sm–Nd systems in garnet implies that conditions of the secondary transformation of eclogites during the Riphean–Vendian transition period were sufficient for resetting of the Rb–Sr system and the Sm–Nd system experienced partial changes.

The age of the Marunkeu eclogites can also be estimated using the data on their probable protoliths represented, in the opinion of some researchers [8], by meta-granites, gneisses, and amphibolites. Their Pb–Pb age determined for single zircon grains ranges from 690 to 350 Ma, which implies the age of the Marunkeu Complex to be younger than 700 Ma.

We carried out the Sm–Nd analysis of whole-rock samples of ultramafics from Mt. Ryzhaya and a nameless hill southeast of Mt. Peridotitovaya. The insignifi-

**Table 1.** Chemical composition of eclogites and ultramafics, wt %

Component	Eclogites		Ultramafics			
	Sample 360	Sample 366	Sample 350/1	Sample 357	Sample 359	Sample 362/1
SiO <sub>2</sub>	43.78	46.78	40.49	42.87	41.55	49.98
TiO <sub>2</sub>	0.18	0.09	0.21	0.09	0.23	0.72
Al <sub>2</sub> O <sub>3</sub>	22.28	24.62	6.30	13.74	9.63	14.80
Fe <sub>2</sub> O <sub>3</sub>	1.40	1.00	3.64	1.58	4.28	3.27
FeO	4.79	3.24	8.44	7.12	8.96	8.23
MnO	0.13	0.09	0.26	0.13	0.25	0.19
MgO	11.41	8.02	32.97	23.79	25.23	8.47
CaO	12.05	12.05	3.14	7.64	5.31	11.82
Na <sub>2</sub> O	1.44	2.52	0.69	0.93	0.89	1.90
K <sub>2</sub> O	0.31	0.05	0.13	0.04	0.17	0.23
P <sub>2</sub> O <sub>5</sub>	0.04	0.02	0.03	0.01	0.04	0.12
L.O.I.	2.02	1.41	3.38	1.43	2.53	0.93
Total	99.83	99.89	99.68	99.37	99.07	100.66

**Table 2.** Contents and isotopic compositions of Rb, Sr, and Nd in eclogites and ultramafics

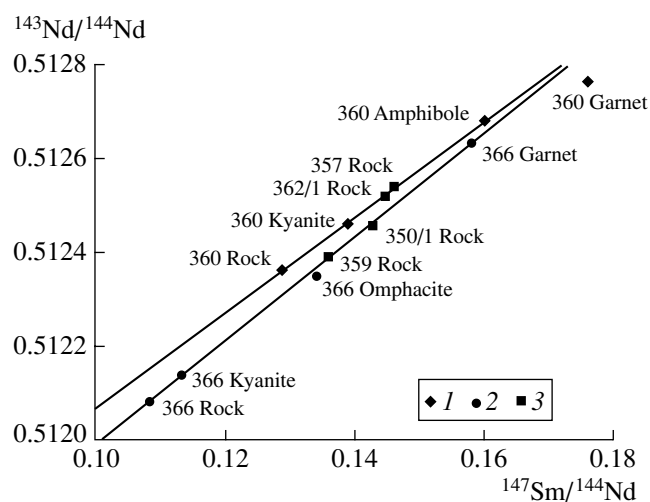
Material	Rb, ppm	Sr, ppm	<sup>87</sup> Rb/ <sup>86</sup> Sr	<sup>87</sup> Sr/ <sup>86</sup> Sr	Sm, ppm	Nd, ppm	<sup>147</sup> Sm/ <sup>144</sup> Nd	<sup>143</sup> Nd/ <sup>144</sup> Nd
Sample 360								
Rock	3.1	560.5	0.016	0.70556 (14)	1.00	4.70	0.12891	0.512364 (13)
Amphibole	5.2	99.3	0.151	0.70855 (22)	0.16	0.62	0.16017	0.512680 (25)
Kyanite	0.9	32.0	0.078	0.70694 (30)	0.14	0.62	0.13916	0.512460 (24)
Garnet	3.2	14.0	0.660	0.71134 (27)	0.13	0.44	0.17605	0.512767 (6)
Sample 366								
Rock	1.6	163.4	0.029	0.70579 (9)	0.59	3.31	0.10843	0.512082 (21)
Omphacite	5.0	51.2	0.280	0.71164 (31)	0.20	0.90	0.13398	0.512353 (12)
Kyanite	1.3	62.6	0.061	0.70653 (9)	0.25	1.36	0.11329	0.512141 (18)
Garnet	3.7	6.3	1.678	0.71994 (12)	0.41	1.55	0.15804	0.512634 (13)
Ultramafic samples (whole-rock)								
350/1					2.22	9.38	0.14281	0.512458 (18)
357					0.20	0.83	0.14610	0.512537 (14)
359					0.66	2.93	0.13606	0.512390 (13)
362/1					2.67	11.15	0.14480	0.512521 (17)
		Not determined						

Note: Determination accuracy of <sup>87</sup>Sr/<sup>86</sup>Sr and <sup>143</sup>Nd/<sup>144</sup>Nd ratios in parentheses (2σ) corresponds to the last two significant digits. The accuracy of the <sup>87</sup>Sr/<sup>86</sup>Sr and <sup>147</sup>Sm/<sup>144</sup>Nd ratios is ±1.5 and ±0.3%, respectively.

cant range of <sup>147</sup>Sm/<sup>144</sup>Nd values makes the age assessment difficult. The arrangement of experimental data points in the eclogite Sm–Nd diagram indicates, however, that data points of ultramafics coincide with isochrons compiled for individual eclogite samples (Fig. 3). It is conceivable that the primary Sm–Nd system of ultramafics was distorted during eclogitization and the rocks are older (probably, Early Proterozoic).

Thus, all the geochronological data derived from different isotopic systems provide sufficiently reliable

evidence for primary crystallization of eclogites of the Marunkeu Block most likely during the Early–Late Proterozoic transition period. The tectonic juxtaposition of different-age eclogites cannot be ruled out as well. Some researchers [9–11 and others] suggest the existence of the Proto-Uralian ocean east (in recent coordinates) of the Uralian margin of the East European paleocontinent during the Riphean or some interval of this period. The Vendian was marked by the collision that gave way to rifting in the terminal Cam-



**Fig. 3.** The Sm–Nd diagram for eclogites from (1) sample 360 and (2) sample 366 and (3) ultramafics. Sample 360:  $t = 1540 \pm 130$  Ma,  $(^{143}\text{Nd}/^{144}\text{Nd})_0 = 0.51106 \pm 12$ ,  $\epsilon_{\text{Nd}} = +8.0$ , MSWD = 0.11; sample 366:  $t = 1690 \pm 63$  Ma,  $(^{143}\text{Nd}/^{144}\text{Nd})_0 = 0.510874 \pm 57$ ,  $\epsilon_{\text{Nd}} = +8.3$ , MSWD = 0.92.

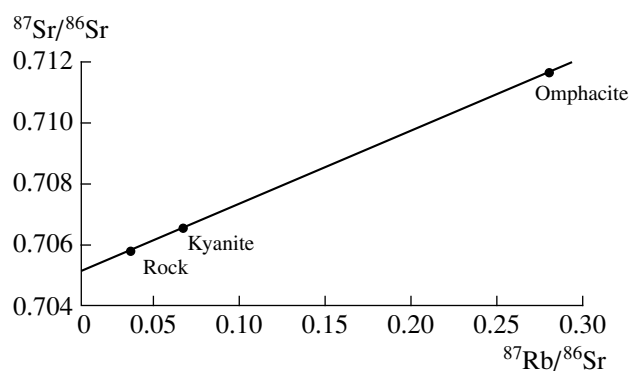
brian–initial Ordovician and opening of the Paleo-Uralian ocean.

#### ACKNOWLEDGMENTS

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#### REFERENCES

1. N. G. Udovkina, *Eclogites of the Polar Urals: Evidence from the Southern Marunkeu Ridge* (Nauka, Moscow, 1971) [in Russian].
2. N. G. Udovkina, *Eclogites of the USSR* (Nauka, Moscow, 1985) [in Russian].



**Fig. 4.** The Rb–Sr diagram for eclogite from sample 366:  $t = 1620 \pm 81$  Ma,  $(^{87}\text{Sr}/^{86}\text{Sr})_0 = 0.70512 \pm 7$ , MSWD = 0.21. The garnet data point with the abscissa of 1.768 is not shown.

3. V. L. Andreichev, *K–Ar, Rb–Sr, Sm–Nd, and Pb–Pb Isotopic–Geochronological Systems in Eclogites of the Marunkeu Block, Polar Urals* (Geoprint, Syktyvkar, 2003) [in Russian].
4. V. S. Shatsky, B. A. Simonov, E. Yagoutz, et al., *Dokl. Earth Sci.* **371A**, 534 (2000) [*Dokl. Akad. Nauk*, **371**, 519 (2000)].
5. J. Glodny, H. Austrheim, J. F. Molina, et al., *Geochim. Cosmochim. Acta* **67**, 4353 (2003).
6. T. B. Bayanova, *Age of Reference Geological Complexes in the Kola Region and Duration of Magmatic Processes* (Nauka, St. Petersburg, 2004) [in Russian].
7. A. V. Maslov, Yu. L. Ronkin, M. T. Krupenin, et al., *Geochem. Int.*, **42**, 561 (2004) [*Geokhimiya* **42** (4), 1 (2004)].
8. J. Glodny, V. Pease, P. Montero, et al., *Geol. Soc. Mem. London*, No. 30, 87 (2004).
9. S. G. Samygin and A. M. Leites, in *Regularities in the Formation of the Structure of Continents in the Neogen* (Nauka, Moscow, 1986), pp. 87–105 [in Russian].
10. V. A. Dushin, *Magmatism and Geodynamics of the Paleozoic Segment of the Northern Urals* (Nauka, Moscow, 1997) [in Russian].
11. V. N. Puchkov, *Geotectonics* **31**, 294 (1997) [*Geotektonika* **31** (4), 30 (1997)].