ISSN 1028-334X, Doklady Earth Sciences, 2006, Vol. 406, No. 1, pp. 148–152. © Pleiades Publishing, Inc., 2006.
Original Russian Text © T.A. Osipova, V.M. Gorozhanin, Yu.V. Gol'tsman, V.I. Vinogradov, M.I. Bujakaite, 2006, published in Doklady Akademii Nauk, 2006, Vol. 406, No. 4, pp. 528–532.

GEOCHEMISTRY

Sm–Nd and Rb–Sr Dating of High-Pressure Metagranites in the East Ural Uplift, the Southern Urals

T. A. Osipova[1], V. M. Gorozhanin[3], Yu. V. Gol'tsman[4], V. I. Vinogradov[2], and M. I. Bujakaite[2]

Presented by Academician V. A. Koroteev May 12, 2005

Received May 23, 2005

DOI: 10.1134/S1028334X06010351

The problem of eclogite formation occupies an important place in paleodynamic reconstructions of the geological history of the Urals. To date, the overwhelming majority of researchers have accepted that the eclogite–glaucophane schist complexes in the mobile belt are related to the subduction-related and collisional geodynamic regimes. The age of high-pressure metamorphic rocks and their localization in regional geological structures represent key evidence in deciphering the convergent motions of lithospheric plates at various stages of the mobile belt evolution.

At present, two main areas of high-pressure metamorphic rocks are known in the Urals (Fig. 1). The main belt of eclogites and glaucophane schists extends for 2000 km along the Main Ural Fault both in its hanging and foot walls. The second, Transural belt extends in parallel and at some distance westward of the Denisovsky ophiolite zone [1].

Three age (Late Vendian, Early Devonian, and Late Paleozoic) levels of high-grade metamorphism are currently suggested in the Urals (Table 1).

[1] *Institute of Geology and Geochemistry, Ural Division, Russian Academy of Sciences, Pochtovyi Per. 7, Yekaterinburg, 620151 Russia; e-mail: osipova@igg.uran.ru*

[2] *Geological Institute, Russian Academy of Sciences, Pyzhevskii per. 7, Moscow, 119017 Russia*

[3] *Institute of Geology, Ufa Scientific Center, Russian Academy of Sciences, ul. Karla Marksa 16/2, Ufa, 450000 Russia*

[4] *Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry, Russian Academy of Sciences, Staromonetnyi per. 35, Moscow, 119017 Russia*

The high-pressure metagranites of the Kharlushi Block considered in this communication are situated beyond the main eclogitic belts, but they are also related to a large suture. They occur near the western contact of the Chelyabinsk batholith within a roof pendant close to the Polotsk Suture, which is a thrust fault zone that bounds the main granitic axis of the Urals in the west in the southern segment of the East Ural Uplift (Figs. 1, 2). High-pressure rocks have been found in this locality for the first time.

The metagranites of the Kharlushi Block fit the high-Ca ophiolitic plagiogranites in terms of chemical composition and the distribution of REE and other trace elements. The rocks consist of relatively large (2.0–2.5 mm) quartz grains that make up rounded-lenticular segregations and fine-grained (<1 mm) aggregates of plagioclase ($An_{23–30}$), amphibole, garnet, and epidote, as well as sporadic grains of biotite, white mica (muscovite–phengite series), titanite, apatite, and ilmenite. The chemical compositions of minerals are given in Table 2. Hornblende belongs to high-Al amphiboles of the ferropargasite–hastingsite group and is characterized by low Ti and Mg contents and high Fe and Mn contents typical of amphiboles from silicic rocks. The same chemical features are established for biotite, which is replaced by phengite and chlorite. The Fe/(Fe + Mg) ratio in biotite is always lower than in the coexisting amphibole. Small isometric garnet grains correspond to the high-Ca spessartine–almandine. Garnet reveals a zoning with enrichment in Ca and depletion in Mn from the grain cores toward their margins. The marginal zone occasionally contains quartz inclusions and less abundant inclusions of ore mineral. Garnet is replaced with biotite and chlorite along local fractures. The mineral assemblage of metagranites corresponds to a temperature of 500–536°C and pressure of

~11 kbar [11]. More detailed information on the geology of the Kharlushi Block and mineral and chemical compositions of rocks therein is given in [11]. The K–Ar isochron age of high-Al amphibole from metagranites was estimated at 299 ± 7 Ma [12].

We have dated the aforementioned rocks with Sm–Nd and Rb–Sr methods. The samples for dating were taken near the northwestern outskirts of the Bol'shie Kharlushi Settlement (Fig. 2). The preparation of samples, their chemical treatment, isotopic dilution, and separation of Sm, Nd, Rb, and Sr were carried out using standard techniques. The Sm and Nd isotopic compositions were measured on a Sector 54 Micromass multicollector mass spectrometer (Great Britain) at the Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry. The accuracy of measurements was not worse than ±0.15% and ±0.00001 for $^{147}Sm/^{144}Nd$ and $^{143}Nd/^{144}Nd$ ratios, respectively. The Sr and Rb isotopic ratios were measured on a MAT-260 mass spectrometer at the Geological Institute. The accuracy of measurements of $^{87}Rb/^{86}Sr$ and $^{87}Sr/^{86}Sr$ ratios was ±1% and ±0.0001, respectively. The analytical results are given in Tables 3 and 4 and shown in Fig. 3.

As follows from Fig. 3a, the data points of amphibole, biotite, and garnet fit the Sm–Nd isochron that corresponds to an age of 376 ± 13 Ma. The whole-rock data point lies slightly lower than the isochron, which is probably related to the time when high-Al amphibole and calcic garnet were formed as products of the chemical reaction $An_{40} + Hbl \rightarrow An_{20} + Hbl_{Al} + Grt_{Ca,Fe,Mn}$ at 11 kbar [11] during the high-pressure metamorphic event.

The Rb–Sr measurements of the same sample also yielded the isochron (Fig. 3b) that corresponds to an age of 257 ± 2 Ma, except for the data point of garnet, which lies far apart from the isochron. The Rb–Sr isotopic data most likely record the timing of the last regional thermal event. It should be noted that the obtained Rb–Sr isochron is not controlled by the late rearrangement of the isotopic system of biotite. A similar age of biotite (250–255 Ma) has been obtained with the K–Ar method for biotites from metasomatically altered dike in metaplagiogranite of the Kharlushi Block and from granodiorite of the Chelyabinsk batholith [12, 13].

According to the current interpretation, the formation of the Polotsk Fault Zone was related to the onset of hard collision between the East European and Kazakhstan blocks [14, 15]. It is suggested that this fault zone originated in the Permian [14] or in the late Bashkirian [15]. The estimated Middle Devonian age of high-pressure metamorphism indicates that the Polotsk

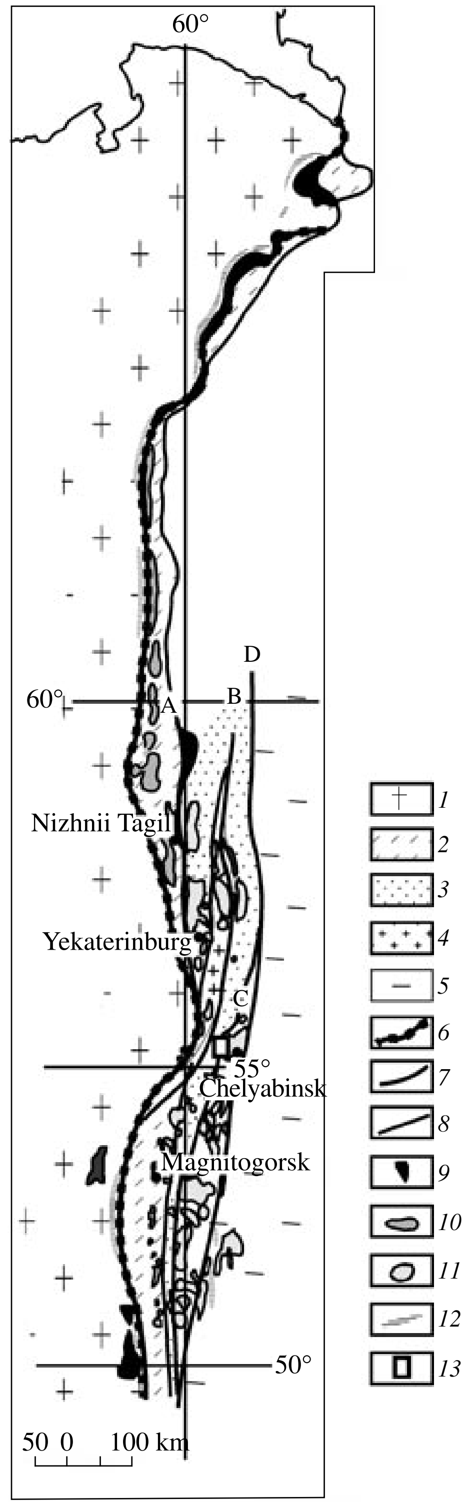

Fig. 1. Occurrences of high-pressure metamorphic rocks in the Urals [1]. The tectonic units of the Middle and Southern Urals are shown after [2]. (*1*) Paleocontinental sector, passive paleomargin; (*2*) island-arc zone; (*3*) continental-margin zone; (*4*) continental zone; (*5*) Transural region, zone transitional to the Kazakhstanides; (*6*) suture of the Main Ural Fault; (*7*) major tectonic sutures (letters in figure): (A) Serov–Mauk, (B) Alapaevsk, (C) Polotsk, (D) Chelyabinsk; (*9*–*11*) igneous complexes: (*9*) ultramafic rocks, (*10*) gabbroids, (*11*) granitoids; (*12*) occurrences of eclogites and glaucophane schists; (*13*) area shown in Fig. 2.

Table 1. Age levels of high-pressure metamorphic rocks in the Urals

Epoch	Complex	Method	Age, Ma	Source
Late Vendian	Beloretsk	K–Ar	590–703	[3]
		Ar–Ar	540–550	
Early Devonian	Maksyutovo	K–Ar, Ar–Ar, Sm–Nd, U–Pb	350–400	[8] [5, 9]
	Marun-Kei Range	Rb–Sr	399, 478, 626	[8]
		Sm–Nd, Rb–Sr	339–366	[5, 9]
	Nerkayus	Ar–Ar	350	[10]
Late Paleozoic	Ufalei	K–Ar	314	[3]
		Ar–Ar	291–308	[3]

Suture has a much older evolutionary history. The convergent regime in the zone trending parallel to the Main Ural Fault was virtually coeval with metamorphism of the main belt of eclogites and glaucophane schists. An interpretation of the geodynamic nature of this regime is beyond the scope of this work and will require special investigations. As a working hypothesis, we suppose that the convergence could have been provoked by the collision between a southern fragment of the abandoned Tagil (?) island arc and the East Ural microcontinent [15].

The hypercollision stage in the evolution of the southern Urals, including the youngest strike-slip displacements along the Polotsk Suture, is probably reflected in the K–Ar age of amphibole (299 Ma, see [12]) and in the Late Permian values based on the Rb–Sr isochron

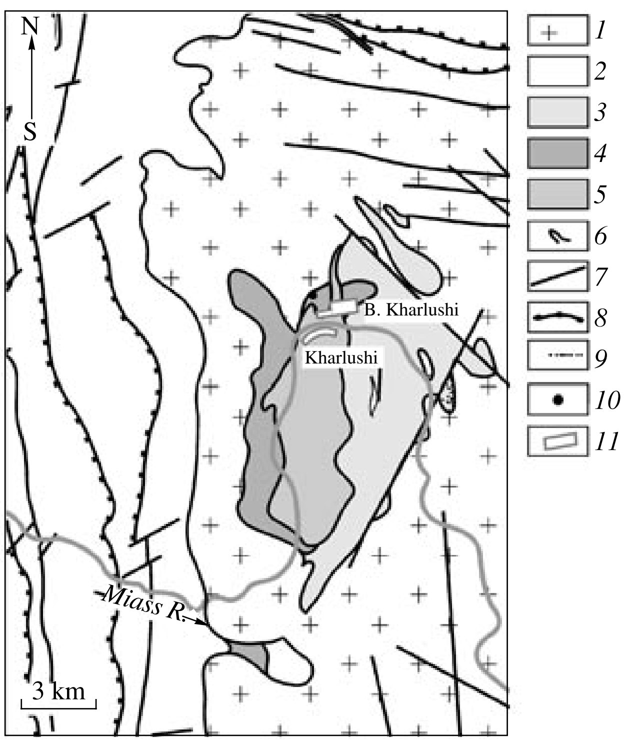

Fig. 2. Geology of the western contact zone of the Chelyabinsk batholith, modified after the data of the Chelyabinsk Territorial Geological Survey. (*1*) Early Carboniferous–Permian granitoids of the Chelyabinsk batholith; (*2*) Lower–Middle Paleozoic metavolcanosedimentary rocks; (*3–5*) Paleoproterozoic metamorphic rocks of the Kharlushi Block: (*3*) crystalline schists and mica gneisses, (*4*) garnet–amphibole and amphibole gneisses, (*5*) apogabbroic amphibolites; (*6*) geological boundaries; (*7*) faults; (*8*) thrust faults; (*9*) hornfels; (*10*) location of samples; (*11*) settlements.

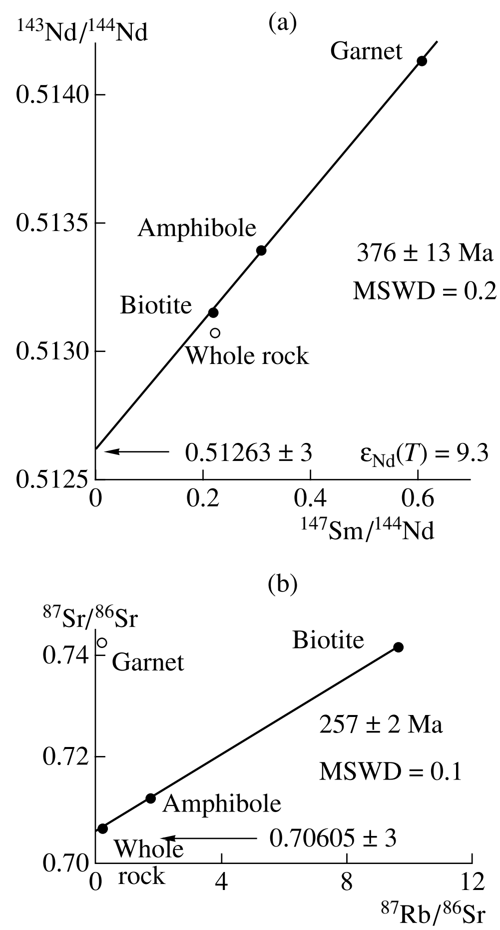

Fig. 3. Isochrons for metagranite from the Kharlushi Block: (a) Sm–Nd and (b) Rb–Sr.

Table 2. Representative microprobe analyses of minerals from metagranites of the Kharlushi Block

Component	Amphibole	Garnet		Biotite	Phengite
	1	2	3	4	5
SiO_2	35.25	36.64	36.52	31.49	49.89
TiO_2	0.32	0.10	0.10	3.07	0
Al_2O_3	18.31	20.18	20.07	18.63	30.79
FeO	25.35	30.76	30.86	27.47	5.62
MnO	0.71	6.18	3.78	0.41	0.05
MgO	4.17	0.94	0.93	5.90	0.43
CaO	10.57	5.66	8.45	0.05	0
Na_2O	1.83	0.23	0.23	0.24	0.2
K_2O	0.75	0.03	0.03	9.20	9.73
Total	97.26	100.72	100.97	96.46	96.71
Si	5.592	2.976	2.953	2.722	3.308
Ti	0.038	0.006	0.006	0.200	0
Al	3.424	1.932	1.913	1.898	2.406
Fe^{2+}	3.363	2.089	2.087	1.986	0.311
Mn	0.095	0.425	0.259	0.030	0.003
Mg	0.986	0.114	0.112	0.760	0.042
Ca	1.797	0.493	0.732	0.005	0
Na	0.563	0.036	0.036	0.040	0.026
K	0.152	0.003	0.003	1.015	0.823
Total	16.01	8.074	8.102	8.656	6.919
Fe/(Fe + Mg)	0.77			0.72	
Alm		65.6	63.2		
Sps		14.2	8.6		
Prp		3.8	3.7		
Grs + Adr		16.4	24.4		

Note: (2, 3) core and margin of the grain, respectively. Formula units of amphibole, garnet and biotite, and phengite were calculated for 23, 12, and 11 oxygen atoms, respectively.

Table 3. Parameters of the Sm–Nd isotopic system of metagranite in the Kharlushi Block

Material	Sm, ppm	Nd, ppm	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	2σ
Whole rock	1.610	4.355	0.2238	0.513073	0.00001
Garnet	1.108	1.101	0.6097	0.514130	0.00006
Biotite	5.674	15.67	0.2194	0.513160	0.00006
Amphibole	5.134	10.06	0.3091	0.513394	0.00001

Note: Uncertainties in the right column are related to $^{143}Nd/^{144}Nd$ ratio; uncertainties of $^{147}Sm/^{144}Nd$ ratio were estimated at 0.15%.

Table 4. Parameters of the Rb–Sr isotopic system of metagranite in the Kharlushi Block

Material	Rb, ppm	Sr, ppm	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	2σ
Whole rock	6.56	67.1	0.228	0.70689	0.0001
Amphibole	3.54	5.92	1.731	0.71235	0.0001
Biotite	329	98.7	9.673	0.74140	0.0002
Garnet	1.48	20.7	0.2076	0.74263	0.0001

Note: Uncertainties in the right column are related to $^{87}Sr/^{86}Sr$ ratio; uncertainties of $^{87}Rb/^{86}Sr$ ratio were estimated at 1%.

and K–Ar biotite dating. In any case, the upper limit of the Polotsk Suture origination is constrained by the age of high-grade metamorphism, which is estimated at 376 Ma.

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research, project no. 04-05-64699.

REFERENCES

1. V. N. Puchkov, Geotektonika **30** (2), 16 (1996) [Geotectonics **30** (2), 97 (1996)].
2. G. B. Fershtater, Geotektonika **26** (6), 3 (1992).
3. U. A. Glasmacher, P. Reynolds, A. A. Alekseev, and V. N. Puchkov, Geol Rdsch. **87**, 577 (1999).
4. A. A. Alekseev, *Igneous Complexes of the Urultau Range* (Nauka, Moscow, 1976) [in Russian].
5. V. S. Shatskii, V. A. Simonov, E. Jagoutz, *et al.*, Dokl. Akad. Nauk **371**, 519 (2000) [Dokl. Earth Sci. **371A**, 534 (2000)].
6. R. J. Beane, J. G. Liou, and J. N. Connely, Geol. Soc. Am. Bull. **110**, 916 (1996).
7. P. Matte, H. Maluski, R. Caby, *et al.*, C. R. Acad. Sci. **317**, 1667 (1993).
8. V. L. Andreichev, in *Proceedings of the 2nd All-Russia Petrographic Conference* (Inst. Geol., Syktyvkar, 2000), Vol. 4, p. 12 [in Russian].
9. J. Glodny, V. Pease, P. Montero, *et al.,* in *Timpebar–Uralides Workshop* (St. Petersburg, 2000), p. 13.
10. K. S. Ivanov, L. A. Karsten, and H. Maluski, in *Proceedings of the 5th International Conference on Subduction Paleozones* (Inst. Geol. Geokhim., Yekaterinburg, 2000), p. 121 [in Russian].
11. G. B. Fershtater, N. S. Borodina, T. A. Osipova, and G. Yu. Shardakova, Zap. Ross. Mineral. Ob-va **131** (3), 1 (2002).
12. T.A. Osipova, B. A. Kaleganov and G. B. Fershtater, in *Yearbook-2000* (Inst. Geol. Geokhim., Yekaterinburg, 2001), p. 196 [in Russian].
13. A. I. Grabezhev, B. A. Kaleganov, and Yu. N. Borovikov, in *Yearbook-1991* (Inst. Geol. Geokhim., Yekaterinburg, 1992), p. 60 [in Russian].
14. P. Bankwitz, E. Bankwitz, and K. S. Ivanov, Freiberg. Forschungsh. **C470**, 1 (1998).
15. V. N. Puchkov, *Paleogeodynamics of the Southern and Central Urals* (Dauriya, Ufa, 2000) [in Russian].