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DEPLETED SSZ TYPE MANTLE PERIDOTITES IN PROTEROZOIC EASTERN SAYAN OPHIOLITES IN SIBERIA

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N.L. Dobretsov et al. [1985] first described the rock complexes in Eastern Sayan as ophiolites. Ophiolites formed in Dunzhugur island arc and were obducted onto Gargan block, a Neoarchean crystalline basement of the Tuva-Mongolian Massif (TMM), as a single nappe [Khain et al., 2002; Kuzmichev, 2004]. Zircons from plagiogranite were dated at 1021±5 Ma by multigrain TIMS and 1020±1 Ma by Pb-Pb single-grains evaporation method [Khain et al., 2002]. Later [Kuzmichev, Larionov, 2013] analysed 12 grains of detrital zircons from gravelstone of the Dunzhugur formation and obtained ²⁰⁶Pb/²³⁸U ages from 844±8 to 1048±12 Ma. Careful examination of these data shows that ²⁰⁶Pb/²³⁸U ages

for concordant zircons only vary from 962±11 to 1048±12 Ma. Two groups of data give Concordia ages of 974±11 and 1028±10 Ma. Rocks of the Dunzhugur complex are characterized by slightly negative to slightly positive εNd(t) values from -1.0 to +1.5 and Late Palaeoproterozoic depleted mantle Nd model ages of 1.8–1.6 Ga [Sklyarov et al., 2016]. The Dunzhugur complex was intruded by tonalite plutons of the Sumsunur complex dated at 785±11 Ma [Kuzmichev et al., 2001] and 811±7 Ma [Kovach et al., 2012]. These tonalites have strongly negative εNd(t) values from -13.2 to -12.3 and Nd model ages of 2.5–2.4 Ga, suggesting formation of these melts from a mixture of

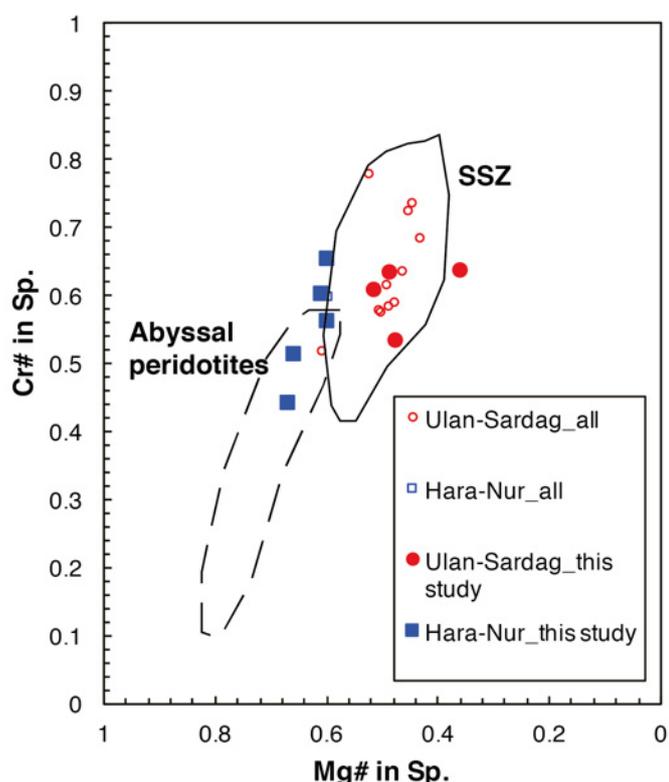


Fig. 1. Diagram of Cr# vs. Mg# of spinel (modified from [Dick, Bullen, 1984]).

Neoproterozoic juvenile and Archaean crustal sources [Kovach et al., 2012].

The Eastern Sayan ophiolites, also named Dunzhugur ophiolites, are composed of several tectonic units/massifs include (1) Ospin (Ospin-Kitoy), (2) Ilchir, (3)

Ulan-Sardag, (4) Hara-Nur, and (5) Dunzhugur from east to west (Fig. 1). Authochton rocks are represented by terrigenous-carbonate deposits of Irkut and Ilchir formations, metamorphosed in green schist to epidote-amphibolite-facies. Ophiolitic peridotites from two localities: Ulan-Sardag (US; one dunite, two harzburgites and one orthopyroxenite) and Hara-Nur (HN; five harzburgites) are studied here.

Geochemistry and geodynamic implications. Two harzburgites from Hara-Nur massif did not undergo metamorphism, whereas metaperidotites and serpentinites underwent metamorphism in lower amphibolite facies. Ulan-Sardag massif is composed of metaperidotites, which formed after serpentinites as a result of prograde metamorphism up to mid-amphibolite facies. Composition of both their relic Sp cores is primary and allows to make petrogenetic investigation. On the diagram of Cr# vs. Mg# of spinel [Dick, Bullen, 1984; Fig. 1], some HN harzburgites locate in abyssal peridotite field, but a few are close to the supra-subduction zone (SSZ) field. All US harzburgites are in the field of SSZ.

Both HN and US harzburgites have negative correlations between Cr# in Sp. and WR Al₂O₃ and CaO indicating degrees of partial melting/melt extraction play a main role in controlling their geochemical features (Fig. 2). US orthopyroxenite has the lowest MgO and La/Yb but highest Al₂O₃ and CaO. Although US dunite has the lowest Al₂O₃, its high CaO and La/Yb suggest that this dunite was readily modified by later metasomatism.

The harzburgites and dunites, resembling subduction zone peridotites, are represented by depletion of MREE with respect to HREE (Fig. 3). In addition, significant enrichments of LILE, LREE and some HFSE are

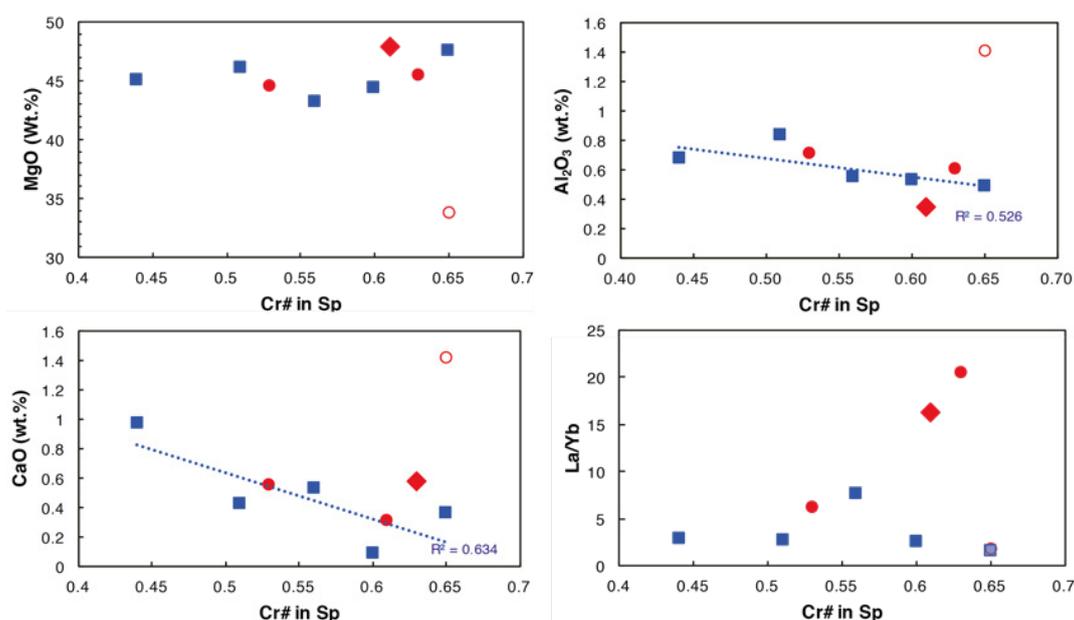


Fig. 2. Diagrams of Cr# in Sp. vs. WR MgO, WR Al₂O₃, WR CaO and WR La/Yb.

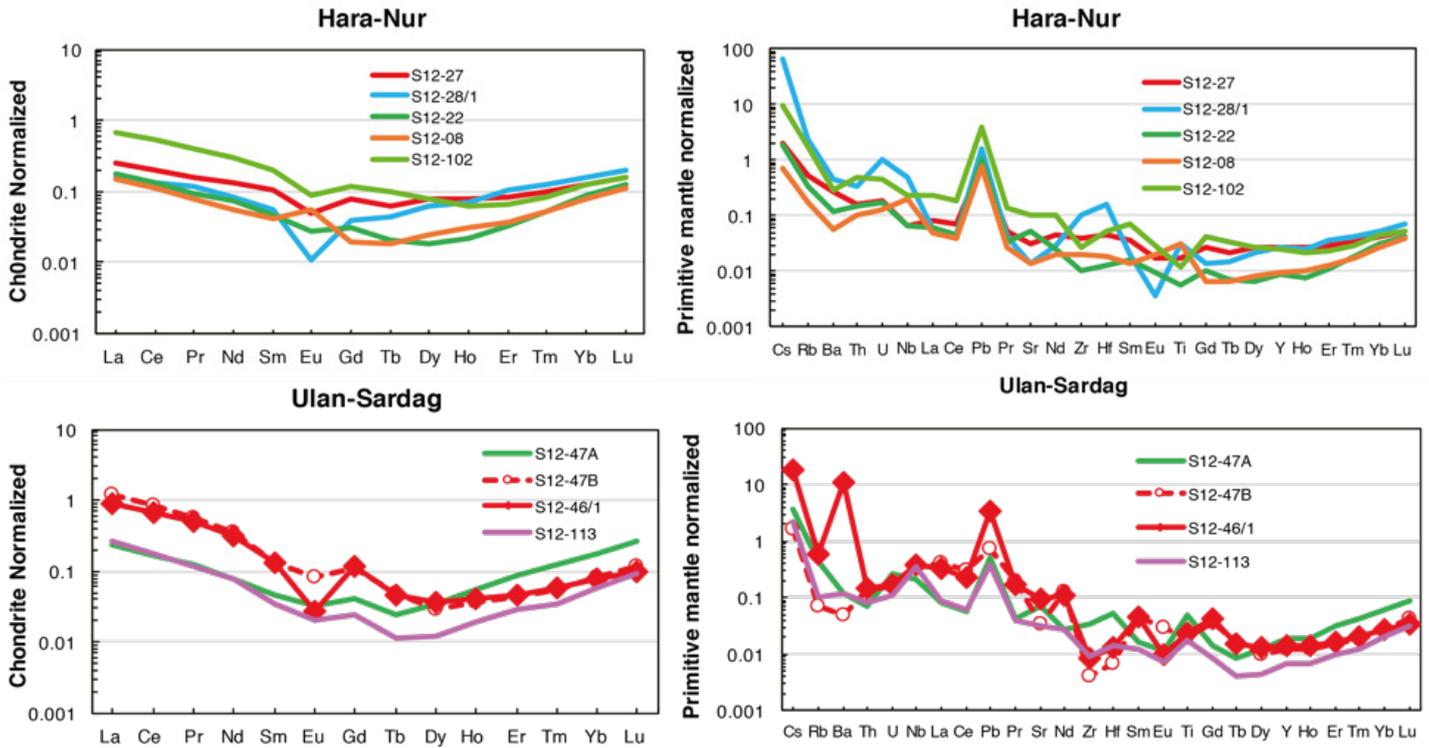


Fig. 3. Chondrite/Primitive mantle-normalized WR trace-element patterns of HN (upper) and US (lower) peridotites.

consistent with a possible interaction of these peridotites with fluids or melts derived from the subducted slab [e.g. Parkinson, Pearce, 1998]. Partial enrichment of LREE and incompatible elements (Ba, Nb and Pb) is believed to result from the interaction of boninitic magmas with peridotites in a mantle wedge. US harzburgites are characterized by more sharper decrease from HREE to MREE with respect to those of US dunite, orthopyroxenite and HN harzburgites. The unmetamorphosed harzburgites and dunite show pronounced positive Ti anomalies. In addition, all rock types show pronounced peaks in Nb and Pb.

The HSE abundances exhibit strongly fractionated patterns for both US and HN harzburgites (Fig. 4). US dunite has enrichments in Os, Ir and Ru and the highest abundance among all. Another US harzburgite (S12-113) also show typical residual pattern. All other harzburgites show the intermediate patterns between residual and melt indicating they had been experienced interaction with later metasomatic melts/fluid. Such melts/fluid metasomatism also caused fractionation among the HSEs. Among them, Os-Ir (both I-PGE), Pt-Ir and Re-Ir covariation in US dunite/harzburgite, Pd-Ir (P-PGE/I-PGE) co-variation for both US and HN peridotites had been modified (Fig. 5).

Dunite, harzburgite and chromitite showing residual PGE patterns (Pd/Ir=0.07–0.62) with low $^{187}\text{Re}/^{188}\text{Os}$ ratios (0.0037–0.0632) yield tMA model ages of 2.38, 1.84, 1.44 and 1.22 Ga ($^{187}\text{Os}/^{188}\text{Os}$ =0.11353–0.11978). A low $^{187}\text{Re}/^{188}\text{Os}$ harzburgite with IPGE-depleted PGE

pattern and one sulfide in dunite yield tMA model ages of 1.38 and 1.53 Ga (Table). The Re–Os isotope compositions of HN and US peridotites yield model age peaks at ~2.38 Ga, ~1.84 Ga and ~1.44–1.22 Ga, which may

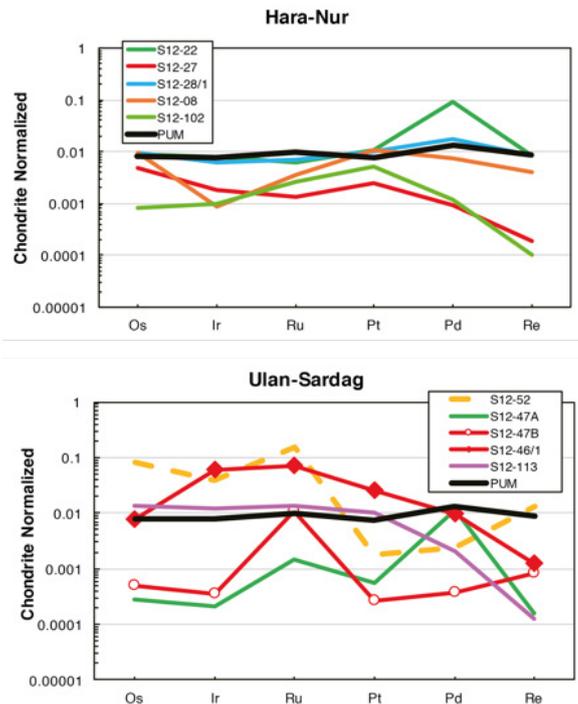


Fig. 4. Chondrite-normalized HSE abundances of US and HN peridotites. Black line shows the composition of primitive mantle after.

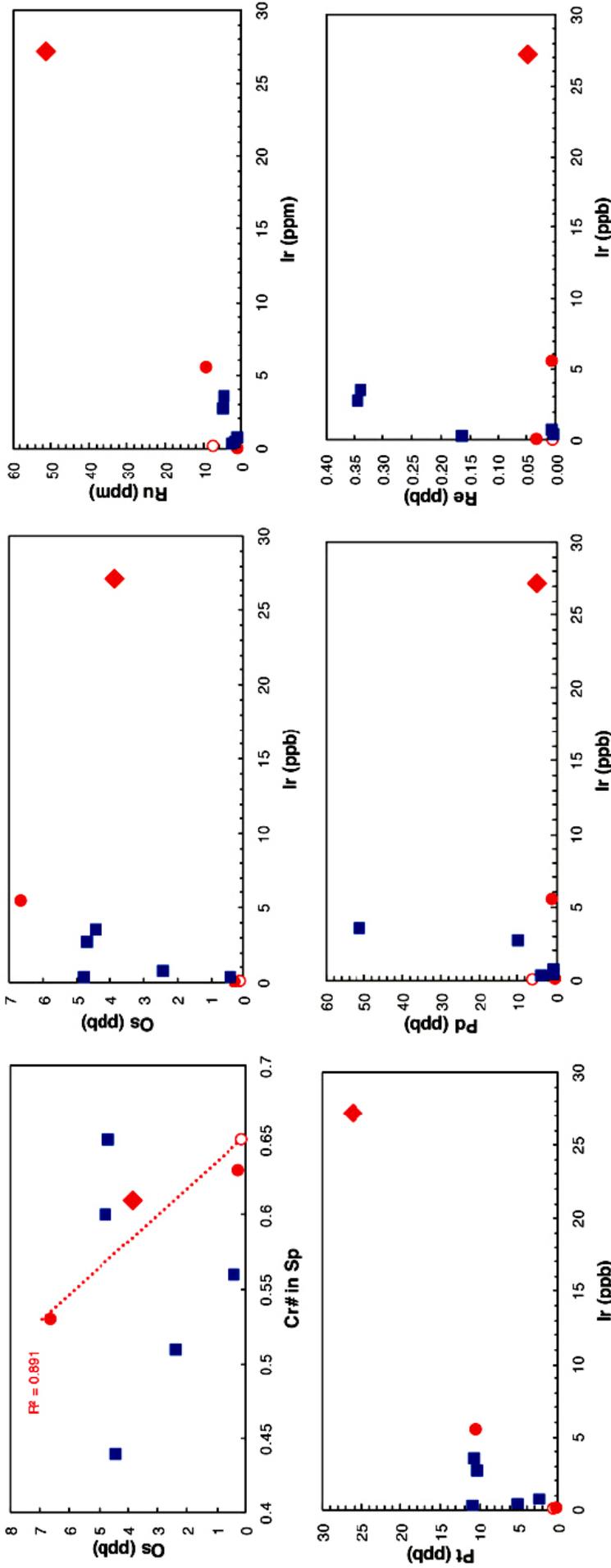


Fig. 5. Bivariate plots of HSEs for US and HN peridotites.

Whole-rock Re-Os isotope compositions of US and HN peridotites

	Lithology	$^{187}\text{Os}/^{188}\text{Os}$	2se	$^{187}\text{Re}/^{188}\text{Os}$	2se	$\gamma_{\text{Os p}}$	$^{187}\text{Os}/^{188}\text{Os i}$ (1020 Ma)	$\gamma_{\text{Os i}}$ (1020 Ma)	T_{RD} (Ma)	2se	T_{MA} (Ma)	2se
Ulan-Sardag												
S12-46/1	dunite	0.1135	0.0000	0.0608	0.0001	-11.4	0.1125	-6.9	2186	1	2380	1
S12-113	harzburgite	0.1151	0.0000	0.0037	0.0000	-10.1	0.1150	-4.8	1834	2	1841	2
S12-47B	harzburgite	0.1235	0.0001	0.6559	0.0007	-3.6	0.1123	-7.1	2215	33	-1184	17
S12-47A	orthopyroxenite	0.1260	0.0001	0.2222	0.0002	-1.6	0.1222	1.2	832	35	620	26
S12-52	chromitite	0.1194	0.0000	0.0632	0.0001	-6.8	0.1183	-2.1	1380	2	1443	2
Hara-Nur												
S12-22	harzburgite	0.1245	0.0000	0.3659	0.0004	-2.8	0.1183	-2.1	1385	11	3758	16
S12-27	harzburgite	0.1198	0.0000	0.0149	0.0000	-6.5	0.1195	-1.1	1211	2	1218	2
S12-28/1	harzburgite	0.1264	0.0000	0.3544	0.0004	-1.4	0.1203	-0.4	1103	9	1545	9
S12-08	harzburgite	0.1184	0.0000	0.1651	0.0002	-7.6	0.1155	-4.4	1764	2	2240	2
S12-102	harzburgite	0.1195	0.0001	0.0507	0.0001	-6.7	0.1187	-1.8	1332	10	1375	10

record major tectonic events prior to and associated with closure of paleo-Asian ocean at the southern margin of the Siberian craton since the late Mesoproterozoic time. The pristine residual signatures, along with the ancient Os model ages older than the Dunzhugur ophiolites cannot be ascribed to recycled (subducted) ancient crustal materials in the lithospheric mantle. Similar crustal event age peaks occur in the South China block/Laurentia, suggesting a connection with the southern Siberian craton before the opening of the Paleo-Asian ocean. Thus, remnant lithospheric fragments stranded by rifting of the ancient continental regions are inferred to occur in the Neoproterozoic Dunzhugur ophiolites as observed in modern ocean basins [O'Reilly *et al.*, 2009].

Conclusion. Mineral chemistry and whole-rock trace and PGE data indicate that formation of the Hara-Nur and Ulan-Sardag peridotites cannot be explained

by a single stage melting event but at least two-stages of melting and re-enrichment processes are needed to explain their geochemical characteristics. Their trace-element patterns are similar to residual peridotites melted in a SSZ environment indicating these depleted harzburgites and dunites are the product of melting and related re-enrichment took place in SSZ. The pristine residual signatures, along with the ancient Os model ages older than the Dunzhugur ophiolites cannot be ascribed to recycled (subducted) ancient crustal materials in the lithospheric mantle. Similar crustal event age peaks occur in the South China block/Laurentia, suggesting a connection with the southern Siberian craton before the opening of the Paleo-Asian ocean. Thus, remnant lithospheric fragments stranded by rifting of the ancient continental regions are inferred to occur in the Neoproterozoic Dunzhugur ophiolites as observed in modern ocean basins.

REFERENCES

- Dick H.J.B., Bullen T., 1984. Chromian spinel as a petrogenetic indicator in abyssal and alpine-type peridotites and spatially associated lavas. *Contributions to Mineralogy and Petrology* 86 (1), 54–76. <https://doi.org/10.1007/BF00373711>.
- Dobretsov N.L., Konnikov E.G., Medvedev V.N., Sklyarov E.V., 1985. Ophiolites and olistostromes of the Eastern Sayan. In: N.L. Dobretsov (Ed.), Riphean – Early Paleozoic ophiolites of Northern Eurasia. Nauka, Novosibirsk, p. 34–58 (in Russian).
- Khain E.V., Bibikova E.V., Kröner A., Zhuravlev D.Z., Sklyarov E.V., Fedotova A.A., Kravchenko-Berezhnoy I.R., 2002. The most ancient ophiolite of the Central Asian fold belt: U-Pb and Pb-Pb zircon ages for the Dunzhugur complex, Eastern Sayan, Siberia, and geodynamic implications. *Earth and Planetary Science Letters* 199 (3–4), 311–325. [https://doi.org/10.1016/S0012-821X\(02\)00587-3](https://doi.org/10.1016/S0012-821X(02)00587-3).
- Kovach V.P., Rytisk E.Yu., Salnikova E.B., Yakovleva S.Z., Fedoseenko A.M., Skopintsev V.G., Lykhin D.A., 2012. New U-Pb (TIMS) geochronological data on age of tonalities of the Sumsunur complex of the Gargan Glyba – to discussion on Palaeozoic organics in ancient sequences of the East Sayan. In: V Russian conference on isotope geochronology. Conference abstracts. Institute of Geology of Ore Deposits, Petrography, Mineralogy and Biochemistry, Russian Academy of Sciences, Moscow, p. 158–160 (in Russian).
- Kuzmichev A.B., 2004. Tectonic History of the Tuva-Mongolian Massif: Early Baikalian, Late Baikalian and Early Caledonian stages. PROBEL-2000, Moscow, 192 p. (in Russian).
- Kuzmichev A.B., Bibikova E.V., Zhuravlev D.Z., 2001. Neoproterozoic (~800 Ma) orogeny in the Tuva-Mongolia massif (Siberia): island arc-continent collision at the northeast Rodinia margin. *Precambrian Research* 110 (1–4), 109–126. [https://doi.org/10.1016/S0301-9268\(01\)00183-8](https://doi.org/10.1016/S0301-9268(01)00183-8).
- Kuzmichev A.B., Larionov A.N., 2013. Neoproterozoic island arcs in East Sayan: duration of magmatism (from U-Pb zircon dating of volcanic clastics). *Russian Geology and Geophysics* 54 (1), 34–43. <https://doi.org/10.1016/j.rgg.2012.12.003>.
- McDonough W.F., Sun S.-S., 1995. The composition of the Earth. *Chemical Geology* 120 (3–4), 223–253. [https://doi.org/10.1016/0009-2541\(94\)00140-4](https://doi.org/10.1016/0009-2541(94)00140-4).
- O'Reilly S.Y., Zhang M., Griffin W.L., Begg G., Hronsky J., 2009. Ultradeep continental roots and their oceanic remnants: A solution to the geochemical “mantle reservoir” problem? *Lithos* 112 (Supplement 2), 1043–1054. <https://doi.org/10.1016/j.lithos.2009.04.028>.
- Parkinson I.J., Pearce J.A., 1998. Peridotites from the Izu-Bonin-Mariana forearc (ODP Leg 125): evidence for mantle melting and melt-mantle interaction in a supra-subduction zone setting. *Journal of Petrology* 39 (9), 1577–1618. <https://doi.org/10.1093/ptro/39.9.1577>.
- Sklyarov E.V., Kovach V.P., Kotov A.B., Kuzmichev A.B., Lavrenchuk A.V., Perelyaev V.I., Shchipansky A.A., 2016. Boninites and ophiolites: problems of their relations and petrogenesis of boninites. *Russian Geology and Geophysics* 57 (1), 127–140. <https://doi.org/10.1016/j.rgg.2016.01.009>.