New data on geology, petrochemistry and geochemistry of rocks of the Nizhnetarlashkynsky ultramafite massif (Western Sangilen, Eastern Tuva)

Ch K Oidup 1, F P Lesnov 2, Ye K Druzhkova 1

1 Tuvinian Institute for Exploration of Natural Resources of SB RAS, Internatsionalnaya, 117 a, Kyzyl, 667007, Russia
2 Institute of Geology and Mineralogy of SB RAS, Ac. Koptyuga ave, 3, Novosibirsk, 63009, Russia

E-mail: oydup_ch@mail.ru, lesnovfp@list.ru

Abstract. Mafic-ultramafic massifs of Tuva territories are located both within linear belts tracing deep faults and as “disordered” areas associated with some belts suffered the later fold-block dislocations. Sometimes fragments of mafic-ultramafic bodies are present in granitoidal intrusive as xenogenic blocks of various sizes. Areal location of ultramafic massifs is particularly observed in the east of Tuva within the Khamsarynsky structural-formational zone as well as in the structures of the Tuvinian-Mongolian middle massif. Geochemical features of the ultramafic massif rock variety studies are continued for obtaining convincing conclusions on their formational affiliation. Ultramafic massifs of Tuva have isolated single data in terms of the geochemical characteristics which requires a purposeful work in this direction. The present paper summarizes for the first time petro-geochemical characteristics of dunites of the Nizhnetarlashkynsky ultramafic massif and fragments of individual picritic dikes among them.

Areal location of ultramafic massifs is not uncommon; their location is particularly known in the east of Tuva within the Khamsarynsky structural-formational zone as well as in structures of the Tuvan-Mongolian middle massif among the highly-metamorphic deposits of the Proterozoic. One of such mafite-ultramafite bodies is the Nizhnetarlashkynsky ultramafite massif located within the Western Sangilen as well as some new data on geology, petrochemistry and geochemistry presented below.

The Nizhnetarlashkynsky ultramafite massif is outcropped both sides of the mid-channel valley of the Tarlashkyn river (50°26'58,28" N; 95°9'57,16" E). Antalusite-sillimanite and cordierite-bearing crystalline schists and gneisses of the Mugursky suite (Proterozoic) outcropped within the massif. This ultramafic massif contacts the Pravotarlashkynsky gabbroid complex on the right bank of the river, and it contacts the Bashkhymugursky granitoid massif in the northeast and east. There are many small blocks of marbles and marble limestones (the Morensky suite) as well as bodies of leucogranites among the ultramafic rocks.

The Nizhnetarlashkynsky ultramafite massif is mainly composed of dunites where olivine grains and multiple grains are usually found in the talc-carbonate-serpentine matrix. Dunites have the following quantitative mineral composition (%): olivine (55–85), serpentine represented by chrysotile (15–40), carbonate (<1), talc (<1), chrome-spinel (up to 5), magnetite (1). Olivine content is about 90% in the composition of small lens-like separations. Olivine grains usually have an elongated one-axis shape. Serpentinites are present in the massif including dunites which form a narrow submeridionally oriented strip on the left-bank of the (southern) part of the massif. They have the following composition (%): serpentine — 60%, olivine relics — up to 35%, clay mineral on olivine — 5%, chrome-spinel (2), carbonate (1), talc and tremolite (singular occurrence case).

Dunites of the described massif have the following average chemical composition according to the 9 analyses results carried out using X-ray fluorescence method (wt%): SiO₂ (37,18), TiO₂ (0,05),
Elements

| Numbers of samples | Samal massif |
|--------------------|--------------|
| La                 | 0.017        |
| Ce                 | 0.041        |
| Pr                 | 0.01         |
| Nd                 | 0.026        |
| Sm                 | 0.006        |
| Eu                 | 0.003        |
| Gd                 | 0.001        |
| Tb                 | 0.005        |
| Dy                 | 0.007        |
| Ho                 | 0.005        |
| Er                 | 0.011        |
| Tm                 | 0.007        |
| Yb                 | 0.006        |
| Lu                 | 0.002        |
| Sum (La/Yb)        | 1.0674       |
| (Eu/Ea)            | <0.1         |
| Rb                 | <0.1         |
| Sr                 | 0.74         |
| Y                  | <0.1         |
| Zr                 | 1.63         |
| Nb                 | <0.05        |
| Cs                 | 0.007        |
| Ba                 | 0.58         |
| Hf                 | 0.013        |
| Ta                 | <0.002       |
| Th                 | 0.014        |
| U                  | 0.005        |

0.27-1.60 g/t which is much higher than the average total content of these impurities in dunites from the Samal (Oman) massif (Table 1).
Chondrite-normalized REE patterns of all the dunite samples from the Nizhnetarlashkynsky massif have a negative slope and parameter values $(\text{La/Yb})_n>1$ which show their enrichment with light elements. Parameter values $(\text{Eu/Eu}^*)_n$ for all these dunite samples are $<1$ which indicates on europium spent (Figure 2).

Abnormally high levels of light REE in the studied dunites which are not characteristic of restitogenic ultramafites are causally related to the presence of structureless impurity of these elements added by epigenetic fluids and concentrated in intergranular and intragranular rock microcracks. Decreased values of Rb, Ba, K, Nb, La, Ce, Pb and ratios Nb/Ta, Zr/Hf, U/Th, Ce/Yb of the initial mantle indicate the belonging of dunites (olivinites) of this massif to the depleted mantle.

It will be remarked that a small rock fragment of dunite indurite massif determined by us as a picrite was found among the dunites of the investigated massif at parameters (50°26'58.4" N; 95°10'4.02" E). Xenoliths of spinel lherzolites were found as part of the kamtonite dikes of the Agardagsky complex within the neighboring Pravotarlashkynsky gabbroid complex among the granitoids of the Bashkhymugursky massifs and inclosing antalusite-sillimanite cordierite-containing shales and gneisses of the Mugursky suite [2]. Such formations were found for the first time among dunites. This macroscopically black fine-grained rock has a massive texture and poikilitic structure and has the following quantitative-mineral composition (%): clinopyroxene (35), olivine (30 %), serpentine (20), green spinel (10–15), ore mineral (1), carbonate (<1). There are inclusions of olivine and green spinel sized within 0.01–0.1 mm in clinopyroxene oikocrystallized within 0.7–1.5 mm. In some sample parts fine-grained rock structure is changed to coarse-grained light rock with the same mineral composition but containing singular occurrence of green spinel. It was found that the picrites from the Nizhnetarlashkynsky massif are close to them for TiO₂, FeO, MgO, CaO, Na₂O and K₂O content but more depleted than SiO₂ and Al₂O₃ (Table 2).
Table 2. Chemical composition of picrites from the Nizhnetarlashkynsky massif, wt. %

| Components | Spl.14-8 | Spl.14-1 | The composition of picrites (literary data) |
|------------|----------|----------|---------------------------------------------|
| SiO₂       | 34.25    | 35.53    | 39.0–43.5                                   |
| TiO₂       | 0.34     | 1.57     | 0.3–1.5                                     |
| Al₂O₃      | 11.57    | 11.36    | 3.5–8.5                                     |
| Fe₂O₃      | 11.58    | 15.53    | 3.0–6.5                                     |
| FeO        | n.d.     | n.d.     | 3.5–13.5                                    |
| MnO        | 0.16     | 0.22     | 0.1–0.3                                     |
| MgO        | 30.51    | 28.29    | 20.0–32.0                                   |
| CaO        | 5.16     | 5.05     | 2.5–7.5                                     |
| Na₂O       | 0.15     | 0.21     | 0.2–0.5                                     |
| K₂O        | 0.05     | 0.16     | 0.1–0.5                                     |
| P₂O₅       | 0.01     | 0.10     | n.d.                                        |
| BaO        | 0.01     | 0.01     | n.d.                                        |
| SO₃        | 0.17     | 0.08     | n.d.                                        |
| V₂O₅       | 0.017    | 0.077    | n.d.                                        |
| Cr₂O₃      | 0.210    | 0.200    | n.d.                                        |
| NiO        | 0.142    | 0.096    | n.d.                                        |
| LOI        | 6.13     | 1.66     | n.d.                                        |
| Sum        | 100.44   | 100.15   | n.d.                                        |

Note. Analyzes were performed in the Analytical Center of IGM SB RAS by the RFA method.

In comparison with picrate chemical composition according to the Mountain Encyclopedia [Internet]. Picrites differ from the surrounding dunites by higher parameter value 100*FeO/FeO+MgO but much lower compared to N-MORB basalts. The graphs of the normalized N-MORB basalts of the petrochemical parameters of the studied picrites are like negatively inclined lines complicated by positive and negative anomalies of moderate intensity (Figure 3).

Figure 3. Graphs of normalized on N-MORB basalts of petrochemical parameters of picrites of the Nizhnetarlashkynsky massif (according to Table 2).
The two analyzed picrite samples differ according to the total REE content, in both cases sufficiently high REE is observed (Table 3).

| Elements | Spl. 14-8 | Spl. 14-1 |
|----------|-----------|-----------|
| La       | 0.42      | 1.65      |
| Ce       | 0.89      | 4.50      |
| Pr       | 0.14      | 0.74      |
| Nd       | 0.90      | 5.00      |
| Sm       | 0.34      | 1.96      |
| Eu       | 0.18      | 0.30      |
| Gd       | 0.59      | 2.50      |
| Tb       | 0.10      | 0.54      |
| Dy       | 0.62      | 3.80      |
| Ho       | 0.13      | 0.91      |
| Er       | 0.50      | 2.80      |
| Tm       | 0.081     | 0.47      |
| Yb       | 0.70      | 3.10      |
| Lu       | 0.10      | 0.57      |
| Sum      | 5.69      | 28.82     |
| (La/Yb)n | 0.41      | 0.36      |
| (Eu/Eu*)n| 1.22      | 0.41      |

Note. Analyzes were performed in the Analytical Center of IGM SB RAS by the ICP-MSc method with acid decomposition in an autoclave of the MARS-5 system (performed by I.V. Nikolaeva).

Figure 4. Chondrite-normalized REE patterns of picrites of the Nizhnetarlashkynsky massif (according to Table 3)

Positively inclined distribution spectra of REE content normalized in chondrites have a similar configuration but they differ in position on the diagram as well as in the character of the Eu anomalies due to differences in the level of their accumulation (Figure 4). The resulting data can be assumed that the investigated picrites form one of the tectonically disintegrated dikes cutting the dunites of the Nizhnetarlashkynsky massif.

Nemtsovich has distinguished the Agardagsky dike complex within the Western Sangilen represented by lamprophyres and essexite diabases[3]. These dykes were further studied by [4] etc. and after by [2]. Dykes break through heterochronous metamorphic and magmatic formations and often contain deep xenoliths. It can be assumed that this xenolith is also a substance of the lithospheric mantle according to the geological position of the Nizhnetarlashkynsky ultramafic massif.

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