REFERENCES

1. Kucherenko I.V. About phosphorus-magnesium-titanic specialization of gold-bearing beresites // AS USSR Reports. – 1987. – V. 293. – № 2. – P. 443–447.
2. Kucherenko I.V. Theoretical and applied aspects of titan, phosphorus, magnesium geochemistry studying in mesothermal gold deposits. P. 1 // Bulletin of the Tomsk Polytechnic University. – 2004. – V. 307. – № 2. – P. 49–55.
3. Kucherenko I.V. Theoretical and applied aspects of titan, phosphorus, magnesium geochemistry studying in mesothermal gold deposits. P. 2 // Bulletin of the Tomsk Polytechnic University. – 2004. – V. 307. – № 3. – P. 35–42.
4. Kucherenko I.V. Near-ore metasomatim as criterion of genetic uniformity in mesothermal gold deposits formed in blackshale and nonshale substratum // Bulletin of the Tomsk Polytechnic University. – 2005. – V. 308. – № 1. – P. 9–15.
5. Kucherenko I.V. The conception of mesothermal ore-formation in golden-ore areas of southern Siberia folded constructions // Bulletin of the Tomsk Polytechnic University. – 2001. – V. 304. – № 1. – P. 182–197.
6. Rytsk E.Yu., Amelin Yu.V., Krymskiy R.Sh. et al. The Baykal-Muysk belt: age, stages of formation and evolution of crust-formation (U-Pb and Sm-Nd isotope certificates) // Tectonics, geodynamics and processes of magmatism and metamorphism: Materials of the 32 tectonic meeting. – Moscow, 1999. – V. 2. – P. 93–95.
7. Sakharova M.S., Ryakhovskaya S.K., Turchkova A.G. Postcrystallization transformations of gold-quartz units in hydrothermal conditions (experimental data) // Geochemistry. – 1999. – № 5. – P. 486–493.
8. Zaraisky G.P. The influence of acidic fluoride and chloride solutions on the geochemical behaviour of Al, Si and W // Fluids in the Crust: Equilibrium and Transport Properties. – London: Chapman and Hall, 1995. – P. 139–162.
9. Alekseev V.A., Balashov V.N., Zaraysky G.P. Kinematics and modeling of the solution-rock interaction // Petrology. – 1997. – V. 5. – № 1. – P. 42–50.
10. Marakushev A.A. The problem of granite ore-bearing ability // Geology of Ore Deposits. – 1984. – V. 26. – № 5. – P. 3–15.
11. Marakushev A.A., Gramenitskiy E.N., Korotayev M.Yu. Petrologic model of endogenic ore formation // Geology of Ore Deposits. – 1983. – № 1. – P. 3–21.
12. Suk N.I. Behaviour of ore elements in stratified silicate-salt systems // Petrology. – 1997. – V. 5. – № 1. – P. 23–31.
13. Chevychelov V.Yu. Distribution of polymetals among granitoid, fluid-salt and fluid phases // RAS Reports. – 1992. – V. 325. – № 2. – P. 378–381.

Received on 22.01.2007

UDC 552.321.6+552.164

PETROGRAPHY AND MINERALOGY OF ULTRAMAFITES OF OPHIOLITE, SHEETED AND ALKALI-ULTRABASIC COMPLEXES

A.I. Chernyshov

Tomsk State University
E-mail: petro@ggf.tsu.ru

Ultramafites of three formation types: of ophiolite complexes, stratified maphite-ultramafite and alkali-ultrabasic intrusions have been studied. Petrographic and mineralogical features of ultramafites demonstrating their evolution in the process of formation and subsequent superimposed plastic deformation were shown. Geodynamic conditions of their formation were defined by the mineral composition of ultramaphites.

Ultramafites of various formational characteristic, being the studying object, constantly drew attention of many researchers. However the data cited by these authors on petrography and mineralogy of ultramafites did not consider features of their deformation microstructure. Therefore the principle of allocation of their laws in the process of rock plastic flow has been set as a basis of the undertaken mineral-petrographic research of ultramafites.

Ultramafites of ophiolite complexes are presented by metamorphic and cumulative formations. Metamorphic dunites and harzburgites are characterized by significant variety of olivine deformation microstructures, reflecting degree of rock plastic deformations and united in seven consistently formed main types: protogranular, mesogranular, porphyroclastic, porphyrolath, mosaic, mosaic-lath and parquet-like [1, 2]. Transition from one type of microstructures to another is characterized by increase in role of plastic deformation attributes: fracture strips, extinction heterogeneity, changes in margin configuration of olivine grains, degree of their orientation and increase in a role of recrystallized individuals. At the analysis of spatial distribution of deformation types of olivine microstructures in massifs from the center to periphery the general tendency of grain size reduction in rocks has been marked, revealing dynamic metamorphic zoning [1–3]. There is a change in chemical composition of olivine and chrome-spinellid during the process of rock plastic deformations. The orientation of mineral composition change is defined by thermodynamic conditions of their metamorphogenetic transformations which can be fixed in the dominating mechanism of plastic deformation [4]. So, for example, in olivines from dunnites of the Paramskiy massif (northeast Pribaikalye), deformed, mainly, by transmitting sliding, an increase in iron has been distinctly marked (6,0→10,5 % Fa) with increase in deformation degree from protogranular olivine to mosaic-lath. At secondary baking recrystallization a significant decrease of this parameter (up to 3,5 % Fa) in mosaic-parquet-like olivines is marked. With increase in degree of plastic deformations by transmitting sliding in olivine the distortion of crystal lattice occurs and the density of dispositions increases, and the opposite tendency is marked at recrystallization which is connected with processes of dislocation return, polygonization and nucleation [5].

Variations of chrome-spinellid composition in dunites and harzburgites, poorly touched by serpentinization, are also connected with conditions of their high-temperature dynamic metamorphism [1, 6, 7]. Such correlation is most distinctly traced in dunnites. So, for example, for chrome-spinellids from dunnites of the Paramskiy and Shamanskiy massifs (northeast Pribaikalye) with increase in deformations the increase in FeO and Fe_2O_3 content and decrease in MgO and Al_2O_3 content is marked [2]. This trend is in accord with data of other researchers [8] and caused by regressive orientation of metamorphic processes proceeding with increase in oxygen potential [9]. Another tendency is marked in dunnites of the Osipinskiy massif (southeast of East Sayan) [3] where intensive increase of plastic deformations leads to increase in chrome-spinellids of MgO and Al_2O_3 content and reduction of FeO and Fe_2O_3 content, at minimal content and variations Fe_2O_3 which, is obviously, connected with high temperatures of metamorphism at low potential of oxygen.

Olivinites and serpentine-olivine ultrametamorphites, being byproducts of serpentine dehydration, are formed at progressive metamorphism as a result of endomorphic parts of massifs heating along tectonically active zones [3, 4]. Based on features of mineral structure these rocks are close to dunnites which undergone baking secondary recrystallization. They are characterized by presence of recycled olivine with low iron content in which there are no traces of plastic deformations. Chrome-spinellids in ultrametamorphites differ from initial increased chrome content and decreased iron content. A distinctive attribute of ultrametamorphites is abundant impregnation of thin-dispersed magnetite.

Ultramafites of the cumulative series of ophiolite complexes are presented by olivinites and rocks of the wehrlite-clinopyroxenite association. Cumulative ultramafites differ from metamorphogenetic in composition of rock-forming minerals. Olivines in them possess increased ferrous content, and chrome-spinellids are characterized by higher alumina content and iron content and decreased chrome content. Rocks of the wehrlite-clinopyroxenite association differ in non-uniform composition of clinopyroxenite, obviously, reflecting conditions of their formation. These rocks also were a subject to plastic deformations, which is fixed by presence in minerals of non-uniform extinction, fracture strips and attributes of syntectonic recrystallization.

Metamorphic ultramaphites of the studied ophiolite complexes relate to extremely exhausted ultramafites of the harzburgite subtype based on mineral composition. According to composition parameters of coexisting minerals they were formed in paleogeodynamic conditions, mainly of the developed island arches and, less often of primitive island arches [10, 11].

Ultramafites of stratified complexes considered by the example of mafite-ultramafite Yoko-Dovyrenskiy massif (northeast Pribaikalye) are divided on two petrogenetic associations based on character of microstructures – protomagmatic and metamorphogenetic [2, 12]. Protomagmatic rocks is a typical cumulative microstructure with presence of mineral grains of two generations: hypidiomorphic crystals of cumulus and xenomorphic grains of intercumulus. Variations of quantitative parities of cumulus and intercumulus reflect a mode of magmatic melt fractional crystallization. Metamorphogenetic ultramafites have deformation microstructures, the result of the imposed plastic deformations caused, mainly, by syntectonic recrystallization. The following main types are allocated among deformation microstructures based on features of the imposed recrystallization display of attributes: protogranular, mesogranular, porphyrolath and porphyroclast.

Composition of main ore-forming minerals in ultramafites of this complex also reflects conditions of their formation. Olivines are presented by chrysolite. Composition evolution of chrysolite during magmatic differentiation is characterized by consecutive increase of FeO, MnO content and decrease of MgO, NiO content at constant CaO concentration. The subsequent plastic deformations break primary correlation connections, therefore there is an increase of CaO, MgO, MnO content and decrease of NiO. At the same time maximal variations are characteristic for CaO content which are distinctly correlated with degree of olivine plastic deformation.

Chrome-spinellids in ultramafites find essential variations of chemical compound and are presented by wide spectrum from chromepicotite with increased titan content up to chromemagnetite. Their material evolution in vertical section of the massif is expressed in reduction from bottom to top of the magnochromite role and increase of magnetite minals at simultaneous growth of titan content, which is a reflection of the typical magmatic trend caused by fractional crystallization of the system. Chrome-spinellids in plastically deformed ultramafites are characterized by infringement of primary correlation connections between petrogenic components. It is expressed in decrease of concentrations TiO_2, NiO at increase MnO, Fe_2O_3.

Yoko-Dovyrenskiy mafite-ultramafite massif based on structure of coexisting minerals in ultramafites, probably, belongs to intraplatform formations generated on small depths and at low pressure (below 7 kbar) which decreased from the sole to the roof of the massif. Formation temperature of ultramafites considerably varies (1300...800 °C) and reflects conditions of magmatic melt recrystallization as well as imposed plastic deformations.

Ultramafites of alkali-ultrabasic complexes differ from each other by structural-mineralogical features.

In ultramafites of the Gulinskiy massif (northwest of the Siberian platform) protomagmatic and deformation microstructures of olivine have been established, the latter of which have been incorporated into three types: protogramular, porphyroclast and mosaic [4]. Deformation microstructures of olivine in dunnites of the Gulinskiy massif are close to microstructures in metamorphic ultramafites of ophiolite complexes. Olivine in dunnites of the massif corresponds to chrysolite with increased calcium content based on material composition. Variations of its structure reveal connections with microstructure evolution. In a row of microstructures from protomagmatic to protogranular, reflecting the process of bake crystallization, a reduction of iron content is observed. In mosaic olivine, formed on protogranular as a result of plastic deformation, the opposite tendency of the given parameter is observed. Chrome-spinellid in studied dunnites discovers significant variations of chemical compound which is in accordance with change of olivine structure. Paragenesis with chromemagnetite is characteristic for protogranular olivine with the most magnesia, for more ferruterous protomagmatic and mosaic olivine with titanmagnetite. Clinopyroxenes in rocks of the Gulinskiy massif based on material structure essentially differ from clinopyroxenes in other studied complexes by higher content of TiO_2, FeO, Na_2O and lower Cr_2O_3, CaO.

Based on composition of coexisting minerals ultramafites of the Gulinskiy massif belong to intraplatform formations, generated on small depths at high temperature (1500...1000 °C) and low pressure.

Ultramafites of the Inaglinskiy massif (Aldanskiy shield) are presented by metamorphogenic dunnites. They differ from ultramafites of the Gulinskiy massif by greater variety of deformation microstructures and absence of magmatogenic. The established microstructures are subdivided on plastically deformed: protogranular, pegmatoid-porphyroclast, mesogranular, porphyroclast and mosaic types, – and formed as a result of bake secondary recrystallization: pegmatoid, lath, mosaic-lath and idioblast [2, 4].

Microstructural anisotropy of dunnites, caused by plastic deformations and bake recrystallization, finds reflection in chemism of ore-forming variations minerals. With deformation increase from protogranular type to mosaic type the increase in iron content and calcium content of olivine, and in chrome-spinellid accumulation ΣFeO, MnO, TiO_2 and MgO, Al_2O_3, Cr_2O_3 depletion is observed. High-temperature bake recrystallization, which occurred during consolidation stage with formation of idioblast and pegmatoid types of dunnites, facilitated decrease of iron content and calcium content of olivine, and also increase of Cr_2O_3, Al_2O_3 and decrease of ΣFeO, TiO_2 in chrome-spinellids. Rather low-temperature bake postconsolidation recrystallization essentially does not change composition of initial plastically deformed olivines and chrome-spinellids.

The established heterogeneity of material structure in coexisting chrome-spinellids and olivines, obviously, reflects absence of solid-phase balance between them which is consequence of incompleteness of metamorphic exchange reactions between mineral phases. The obtained temperature balance for chrome-spinellids and olivines in the Inaglinskiy massif testifies about their metamorphogenic transformations at temperatures 1000...800 °C.

Clinopyroxenes from metasomatic wherlites and clinopyroxenes based on structure appear very close to metasomatic clinopyroxenes from rocks of wherlite-clinopyroxenite associations of ophiolite complexes but differ in increased TiO_2, Na_2O content anddecreased Al_2O_3, Cr_2O_3, MnO. Composition of clinopyroxenes specifies their formation in conditions of low pressure at increased sodium potential m. With increase of differential pressure, they as well as clinopyroxenes of ophiolite complexes, have undergone plastic deformations.

Conclusion

Petrographic-mineralogical researches testify that ultramafites, being initially heterogeneous formations, have undergone significant structurally-material transformations during multi-stage mantle-core evolution. These metamorphogenic changes are caused, mainly, by high-temperature plastic deformations and find reflection in close hierarchical sequence of microstructural changes of rocks, and also in variations of material structure of main ore-forming minerals.

REFERENCES

1. Goncharenko A.I. Petrostructural evolution of alpinotype hypersubsilicics. – Tomsk: Publishing House of Tomsk University, 1989. – 398 p.
2. Chernyshov A.I., Goncharenko A.I., Gertner I.F., Bether O.V. Petrostructural evolution of ultramafites. –Tomsk: Publishing house of Tomsk University, 1997. – 160 p.
3. Goncharenko A.I., Chernyshov A.I. Deformation structure and petrology of nephrite-bearing hypersubsilicics. – Tomsk: Publishing house of Tomsk University, 1990. – 200 p.
4. Chernyshov A.I. Ultramafites (plastic current, structural and petrostructural heterogeneity). – Tomsk: Charodey, 2001. – 214 p.
5. Chernyshov A.I. Petrostructural evolution of olivines in ultramafites of the Paramskiy and Shamanskiy massifs (Baikal-Muiskiy ophiolite belt) // Geology and geophysics. – 2005. – V. 46. – № 11. – P. 1121–1132.
6. Irvine T.N. Chromian spinel as a petrogenetic indicator. P. I. Theory // Canad J. Earth. Sci. – 1965. – V. 2. – № 6. – P. 648–672.
7. Irvine T.N. Chromian spinel as a petrogenetic indicator. P. 2. Petrologic applications // Canad. J. Earth. Sci. – 1967. – V. 4. – P. 71–103.
8. Makeev A.B., Perevozchikov B.V., Afanasiev A.K. Chromite-bearing ability of Polar Ural. – Syktyvkar, 1985. – 153 p.
9. Malakhov I.A. Petrochemistry of main formational types of ultrasubsilicics. – Moscow: Nauka: 1983. – 207 p.
10. Palandzhan S.A. Typification of mantle peridotites based on geodynamic conditions of formation. – Magadan, 1992. – 104 p.
11. Stupakov S.I., Simonov V.A. Features of ultrasubsilicic mineralogy – criterion of paleogeodynamic conditions of the Altai-Sayanskaya folded area ophiolite formation // Geology and geophysics. – 1997. – № 6. – P. 746–755.
12. Gertner I.F. Petrology of the Yoko-Dovyrenskiy stratified ultramafite-mafite pluton (Northern Pribaikalye): Ph. Dissertation in Geology and Mineralogy. – Tomsk, 1994. – 310 p.

Received on 25.12.2006