Fluidizate-Explosive Occurrences in Ophiolites as Indicator of the Subduction Zone Activity: The Urals Example

V.R. SHMELEV*

Institute of Geology and Geochemistry, Vonsovsky str. 15, 620016, Ekaterinburg, Russia

1 Abstract

It is known that the formation of oceanic crust occurs in different geodynamic settings, accompanying by the emergence of mantle-magmatic ophiolite complexes having a distinctive properties. In the process of mantle-crustal evolution of the ophiolites are undergoing significant changes with the formation of peculiar (on structure and composition) rocks, sometimes with unusual mineral paragenesis. The presence of such rocks in mélange tectonic zones greatly complicates to determine their origin. In the Ural folded belt (length more than 2,000 km) separating the East European Platform and the West Siberian sedimentary basin, ophiolites are widespread forming a chain of mafic-ultramafic massifs (Fig. 1) located in the allochthonous position with mélange at the bottom (Puchkov, 2013). With the Urals ophiolites are associated occurrences of eclogites, jadeites, ruby and other rocks of unclear nature, sometimes regarded as potentially diamondiferous.

Such formations of unclear genesis include the associating with ophiolites metabasites of higher alkalinity composing the body in the mantle peridotites of the mélange Main Uralian Fault (MUF) zone (Shmelev, 2005). By this time they are determined in different parts of the fault zone, but most completely are known in the SubPolar Urals, where are distinguished under the name of Sertynya alkaline-ultramafic complex, which is located just 25 km east of Hartes kimberlitic complex (Fig. 1). Formally, its affiliation to diamond-bearing associations is confirmed by finding of grains and fragments of natural diamond in the weathering crust.

A detailed study of the rock complexes shows that in reality they have a polygenic nature, combine the elements of proper magmatic and fluidizate-explosive formations, the appearance of which was interfaced with the processes at the slab-mantle wedge boundary in subduction zones. Polygenic nature of the rocks is reflected in the existence of three interrelated structural-geological units: (1) bodies and dikes of uniform metadiabases and dense fine-grained
metadolerites (lamprophyres), (2) fluidal-brecciated
dolerites ("tuff breccias") and (3) structural weathering
crust with angular or rounded fragments (blocks) of
metadolerites and serpentinites. The rocks have
experienced rodingitization and permeated with net of
veins a vesuvianite composition. The host peridotite
matrix (harzburgites and dunites) has undergone
serpentinization and chloritization. Structural
relationships give grounds for distinguishing in the
history of the complex formation the magmatic proper
(dolerite dyke and lamprophyre intrusion) and infiltration
fluidizate-explosive (metasomatic transformation of
dolerite) stages.

Peculiarities of petrography and mineralogy of rock
complexes does not allow to compare them with
lamproites and kimberlites. Metadiabases demonstrate
relics of ophitic structure, as primary paragenesis is
completely replaced by aggregate of chlorite, zoisite and
leucoxene. Dolerites (lamprophyres) have a uniform
fine-grained or porphyry structure with phenocrysts of
clinopyroxene, brown amphibole and leucoxene (sphene),
which are immersed in a fine-scaly aggregate of light
green mica. In the rocks amphibole, garnet and vesuvian
are present. Clinopyroxene corresponds to augite with
moderate content of titanium and alumina (up to 3.5
wt.%), showing a normal magmatic zonation in
composition. Mica previously wrongly called as
phlogopite, actually has an extremely ferrous
composition and corresponds to biotite (annite).
Amphibole is presented by magmatic titaniferous
tschermakite hornblende and metamorphic (bluish)
variety of sodium-calcium composition (taramite).
Garnet is presented by exceptionally grossular of
rodingite type. Mineralogy of weathering crust reveals
similar features, but in the samples it is marked the
presence of muscovite, orthoclase and weakly ferrous
diopside. An important feature of the weathering crust is
the presence of shear surfaces on minerals, resulting in
fracturing due to internal stress, confirming the explosive
nature of protolith.

The bulk chemical composition of rocks is
characterized by significant variations in the content of
silica (30-46 wt.%) and alkalis (0-6.5 wt.%). These
metabasites have consistently a low magnesia number
and high titanium oxide content (1.5-3.0 wt.%). Side by
side with these have been established the uniform slope
REE distribution trends similar to the trend of oceanic
basalts N-MORB type (Fig. 2). The level of trace
element compositions does not depend on variations in
the alkalinity of the rocks, but clearly correlates with the
titanium content. Unlike them the Hartes kimberlites
demonstrate the distribution with deficit of HREE, and
the level of the elements content is correlated with the
alkalinity of rocks (Mahotkin et al., 1998).

Another important geochemical feature of the
Sertynya complex rocks is a regular behavior of the
mobile LILE elements (Cs, Rb, Ba, K). In the varieties of
rocks with mica enriched by alkalis, it is recorded extremely
high level of LILE, exceeding the level of contents in N-MORB basalts at 10-10000 times! In the
metabasites varieties with low level of alkalinity, LILE
content is sharply (except Cs) reduced to minimum
values (Fig. 2). The observed pattern of the element
distribution is undoubtedly the result of postmagmatic
fluid-metasomatic alteration of the original rocks.

Fig.2. N-MORB-normalized trace element patterns of the
fluidizate-explosive rocks of the Urals (normalization values
from Sun and McDonough, 1989).

Tectonic position and the primary composition
characteristics of the metadolerites give reason to
consider them as fragments of the ophiolite sheeted dike
complex (Shmelev, 2005). The famous dike complexes
in the ophiolite massifs of the MUF zone (east of
mélangé) belong to suprasubduction formations of
Paleozoic age. However the obtained mainly ancient
U-Pb zircon dating (up to Archean inclusive) for
metadolerites of the Sertynya complex, make it possible
to assume its Vendian-Early Cambrian (530-617 Ma) age.
It permits to compare the Sertynya metabasites with the
Vendian metaophiolites of the MUF zone in the Middle
Urals (Petrov et al., 2010). It is noteworthy that similar
age datings (520-550 Ma) are also established for
kimberlites of the Hartes complex located to the west of
ophiolites. Therefore, the presence of the Vendian-Cambrian ophiolite of MOR-type in the MUF
mélange zone, "changing" to the east of Ordovician
ophiolites SSZ-type, seems quite possible.

The obtained data allow to suggest an original
interpretation of nature of the Urals fluidizate-explosive
formations considering the process specifics in the
subduction zones (Bebout and Barton, 2002). According
to this model, the pre-Ordovician (?) oceanic crust has undergone transformations and deformations on the slab-mantle wedge boundary during the subduction. As a result of slab dehydration it occurred a flow of aqueous fluids, which were enriched with the extracted from sedimentary rocks the LILE elements and percolated through the mantle substrate with dolerite dyke complex. Interaction with them led to the formation of chlorite-zoisite and/or mica (biotite-bearing) fluidizates and in the presence of a gas phase - fluidizate-explosive breccias with subsequent development of weathering crust. In the surrounding peridotites an explosive process is marked by the formation of pseudokimberlite breccias.

Fluidized-explosive occurrences in mantle peridotites of mélange zones should be considered as indicators of the subduction slab-mantle interaction at relatively shallow levels involving enriched LILE fluids (without melts participation), rising as the front from the subduction zone. In this interpretation, there is no need to appeal to the alkaline-ultramafic or lamproit-kimberlite hypothesis of the genesis of these formations, however, the question of their potential diamondiferous remains to be open. The proposed interpretation of the fluidizate-explosive occurrences makes it possible to comprehend that in reality the mélange is a complex formation with signs of not only collisional (as usually is considered), but also of earlier subduction events.

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References