MILUSHI Ibrahim, 2015. An 0verview of the Albanian Ophiolite and Related Ore Minerals. *Acta Geologica Sinica* (English Edition), 89(supp. 2): 61-64.

An Overview of the Albanian Ophiolite and Related Ore Minerals

MILUSHI Ibrahim*

Institute of Geosciences, Energy, Water and Environment, Polytechnic University of Tirana, Albania

1 A Short Introduction on the Albanian Ophiolite

Albanian ophiolite (or Mirdita ophiolite) represents a remnant of the Tethyan oceanic lithosphere in the territory of Albania, as an elongated belt from south to the north, about 250 km long and 30-50 km wide. It covers an area of about 4300 km^2 or 1/7 of the territory of Albania and is characterized by a relatively good up to the excellent outcropping. The belt represents a synform structure (Nicolas et al., 1999) with two ultrabasic massif ranges in the western and eastern sides, with approximately N-S striking, often known as western and eastern ultrabasic belts, whereas in the central part are developed the oceanic crust sequences (fig. 1 & 2). Both mantle and oceanic crust sequences reflect significant differences from west towards east. These differences are recorded about 50 years ago (Ndojaj, 1963) and later many researchers (ISPGJ-IGJN, 1983; Kodra et al., 1995; Nicolas et al., 1999; Dilek et al., 2001; Hoeck et al., 2002; Robertson & Shallo, 2000; Dilek et al., 2007; Dilek et al., 2008) have reinforced, with numerous argument, the idea of the existence of two ophiolite types: western and eastern types, but delineating a precise boundary between these two types (known in many cases as belts) has been impossible (Gjata et al., 1996; Dilek et al., 2007). Although, both types of Albanian opiolites display significant differences in their internal structure and pseudostratigraphy, their geochemical affinities are more gradational in contrast to the earlier claims that these ophiolite may have formed in different settings at different times (Dilek et al., 2007). These lateral and vertical changes from MORB to SSZ geochemical affinities for the upper mantle peridotites and crustal units in the west-east section of the Middle Jurassic ophiolite of Albania are related to the oceanic suprasubduction (Beccaluva et al., 1994; Gjata et al., 1996; Dilek et al., 2001; Dilek et al., 2005; Dilek et al., 2008; Morishita et al., 2011). Eastern-type of the Albanian opiolite include all subunits of a typical Penrose-type ophiolite having thickness 10-12 km (Shallo & Dilek, 2003), whereas the western Albanian opiolite type is similar to the architecture of modern slow-spread lithosphere with a reduced and discontinuous oceanic crust (Miranda & Dilek, 2010). Evidence for the occurrence of detachement faults linked to the formation of the Oceanic Core complexes in the Mirdita ophiolite are documented in the Krrabi and Puka massifs (Miranda & Dilek, 2010; Tremblay et al., 2009). The eastern ophiolites are constituted by thick harzburgitic tectonites, followed by dunitic and pyroxenitic cumulates, gabbros and plagiogranites, a well-developed, but not classical, sheeted dyke complex and volcanic sequence that consists of low-Ti basalts and andesites, dacite and rhyodacites. At the top of the ophiolitic sequence there is a relatively thin radiolarian chert formation, which, in turn, is overlain by Jurassic and Lower Cretaceous melange. The western ophiolites are composed of harzburgitic and lherzolitic tectonites, as well as plagioclase-bearing lherzolitic and dunitic cumulates. Relatively thin and discontinuous troctolites and gabbros are directly overlain by High-Ti basalts. A sheeted dyke complex is extremely limited. A characteristic feature for the eastern ophiolite type is the presence of boninite, both as flows and dykes, but which is not exclusivity only for eastern ophiolite since within western type are encountered also rarely boninite dykes (Gjata et al., 1996). The extrusive section at the top of the ophiolite is overlain by 5-20 m thick radiolarian cherts that are late Bajocian-early Bathonian to late Bathonian-early Callovian in age (Marcucci et al., 1994; Kodra et al., 1995; Marcucci and Prela, 1996). Along the western and eastern edges of the ophiolite occur Volcno sedimentary formation which is composed of mid-ocean ridge basalt (MORB) and within-plate alkaline basalts affinities with intercalations of argillaceous-radiolarian shales and mélange in places. Discontinuous exposures of metamorphic sole occur between peridotites and volcano-sedimentary formation. $^{40}Ar/^{39}Ar$ age determinations indicate the formation of metamorphic sole and, thus, the

* Corresponding author. E-mail: *ibrahimmilushi@yahoo*.com

Fig. 1 The location of The Albanian (Mirdita) ophiolite in the Balkan region (Compiled by Joankovic , 1996; Economou , et. al., 1996 and Cina, et al., 1996; modified from Milushi 2014)

possible first emplacement of the ophiolite during Bajocian to Callovian at 161-174 Ma (Vergely et al., 1998; Dimo-Lahitte et al., 2001). Alpine deformation has only slightly affected the Albanian ophiolite as is marked by nealy horizontal Cretaceous limestone overlying ophiolite (Nicolas et al., 1999; Meshi et al., 1999).

2 Mineral Resources Related to the Albanian Ophiolite

Ophiolites of Albania are characterized by a high metallogenic potential. The most important ore minerals are chromite, copper, iron-nickel laterite, titanomagnetite and platinum group elemets (PGE). In the group of non-metallic minerals olivine is most important. It should be emphasized that in a period of over 30 years, until the end of the 90s of last century, were carried out intensive research and prospecting-exploration works that have made possible to accumulate a great information about ore minerals related to the albanian ophiolite (ISPGJ-IGJN, 1983; ISPGJ-IGJN, 1989). Some very brief data on them are presented in the following. Chromite: Ofiolite of Albania is known for a high chromite-bearing potential in the eastern ultrabasic belt (hartzburgite type) and a low potential in western ultrabasic belt (lherzolite type) . In the eastern belt are discovered ore deposits with reserves of over than 1 million tons, where the biggest is Bulqiza-Bater ore deposit (in Bulqiza ultrabasic massif), with about 23 million tons averagely grading over 40% Cr^{203}. The most important ore deposits are located in the mantle section (hartzbugite-dunite sequences), but also in dunite section are encountered significant concentrations of the banding chromite. There are three distinct types of ore: concordant, sub-concordant and discordant, where the most important is the sub-concordant type. Chromite bodies display a great variety in terms of morphology but the most important ones are tabular, lens-like and pencil-like. They are characterized by abundant structural types as disseminated, banding, massive, nodular, antinodular, and orbicular which in the most of cases are characterized by moderate to high deformation. A characteristic feature is the intensive folding in many ore bodies, with spectacular isoclynal folds (i.e Bulqize-Bater deposit). The chromite ore is of metalugical type and rarely refractory in the eastern belt, but in the western belt it is mainly of refractory type and rarely of metalurgical type.

Copper: The most important copper sulphide deposits composed of pyrite-chalcopyrite-sphalerite with contents of gold ans silver are encountered in volcanites of eastern type (SSZ), in basalt andesite and andesite sequence and in its contacts with lower basaltic sequence and with the upper andesitic secuence as well.

In this environment are discovered ore deposits containing up to 12 million tons grading averagely 1.3% Cu (i.e. Munella deposit). Important stockwork mineralization composed of pyrite-chalcopyrite is related to the sheeted duke complex. The copper sulphide ore potential of the western type (MORB-type) is lower, but ore deposits containing up to 2 million tons and grading up to 3.5% Cu are dicovered. The mineralization is maily of pyrite-chalcopyrite massive type and is hosted by pillow lavas and aglomeratic basalts and high-Ti basalts. Mineralizations of quartz-sulphide type composed of chalcopyrite-pyrite-bornite are characteristic for gabbroic section and the area of gabbro-peridotite contacts. The deposits have up 3.5 million tons reserves grading averagely 2.2% Cu. With volcano-sedimentary formation in the basement of ophiolites hosts important massive copper sulphide ore of pyrite-chalcopyrite type. In this formation are discovered pseudo-layering ore deposits up to 5.6 million tons grading averagely 3.3% Cu. A very characteristic feature is the

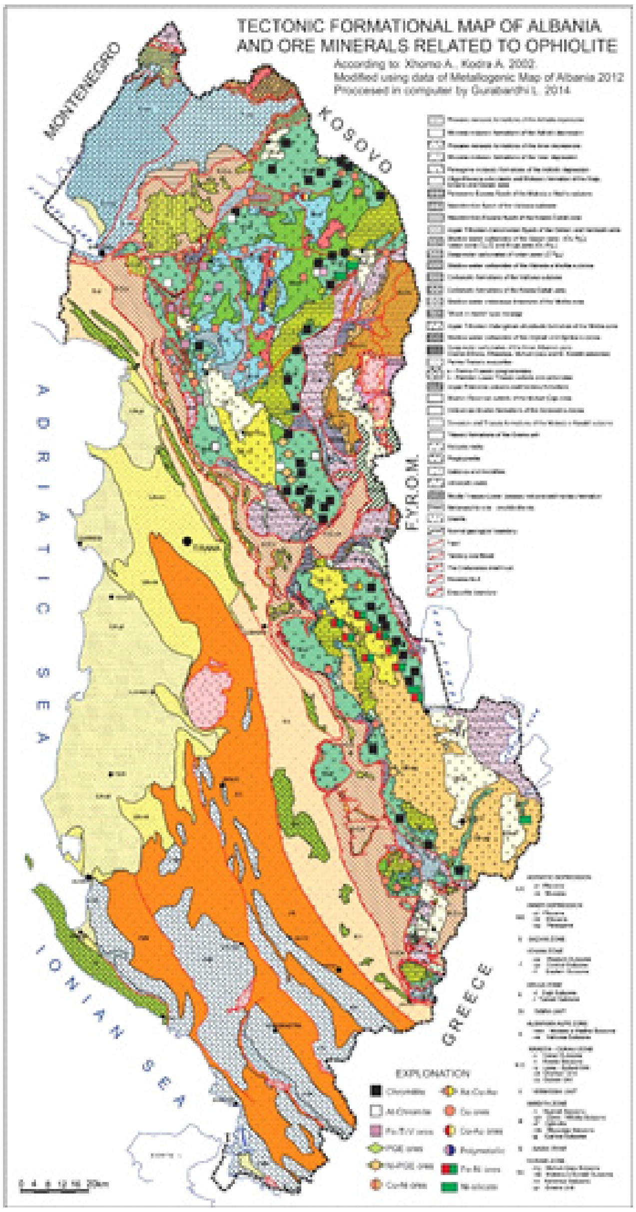

Fig. 2 Tectonic-Formational map of Albania and the main ore minerals related to the ophiolite of Albania. (According to the Geological and Metallogenic Maps of Albania at scale 1/200000)

discovering of one pencil-like deposit followed in strike about 1700 m and containing about 2.5 million ton ore grading averagely 2.1% Cu. Iron-Nickel: Lateritic mineralization of iron-nickel and nickel silicate ores were formed as a result of lateritization of the ultrabasic rocks of the eastern belt during the upper Jurassic which is then covered by limestone of lower and upper Cretaceous. Besides the in situ type deposits types are also distinguished the re-deposited ones. There are identified three large areas of iron-nickel and nickel silicate ores (northern, central and southern) extending, each one, tens km in strike. In each belt are discovered significant reserves and perspective for discovering the new reserves is still open. Titanomagnetite: Several stratiform titanomagnetite deposits located within ferrogabbro occur in the northen part of the western ophiolite. In three deposits are evaluated about 140 million tons ore grading 6% TiO_2, 18% Fe_2O_3 and 0.2-0.3 V_2O_5. Platinum Group Elements (PGE): Four types of PGE mineralizations are distinguished: low Ru, Ir, Os and (Ru+Os+Ir)-(Pt-Pd) related to the mantle chromite; Pd related to low-grade disseminated BMS in transitional dunite; Pt-related to transition dunite-pyroxenite zone which form higer concentrations. Olivine: Sinificant olivine reserves of olivine are discovered in the lower mantle parts of Tropoja ultrabasic massif and in the upper mantle parts of Kuksi ultrabasic massif. The high olivine quality stratification in Tropoja massif is followed in strike about 6 km and thickness is up to 150 m with reserves over 150 million tons and.

References

Beccaluva, L., Coltorti, M., Premti, I., Saccani, E., Siena, F., Zeda, O., 1994. Mid-ocean ridge and supra-subduction affinities in ophiolitic belts from Albania. In: Beccaluva, L. (Ed.), Albanian Ophiolites: State of the Art and Perspectives. Ofioliti, vol. 19, pp. 77-96.

Cina, A., Caslli, H., Goci, L., 1986, Chromites in the ophiolites of Albania. Chromites UNESCO's IGCP-197 project Metallogeny of Ophiolites. Theophrastus Publications S.A. Athens 1996.

Dilek, Y., Furnes, H., Shallo, M., Mortensen, J.K., 2001. Structure, petrology, and geochronology of the Albanian ophiolites and their tectonic evolution within the Neotethyan orogenic belt. EUG XI, European Union of Geosciences, Strasbourg, France. Journal of Conference Abstracts 6 (1), 321.

Dilek, Y., Shallo, M., Furnes, H., 2005. Rift-drift, seafloor spreading, and subduction tectonics of Albanian ophiolites. International Geology Review 47, 147-176.

Dilek, Y., Furnes, H., Shallo, M., 2007. Suprasubduction zone ophiolite formation along the periphery of Mesozoic Gondwana. Gondwana Research 11, 453-475.

Dilek Y, Furnes H, Shallo M (2008) Geochemistry of the Jurassic Mirdita Ophiolite (Albania) and the MORB to SSZ evolution of a marginal basin oceanic crust. Lithos 100:174-209

Dimo-Lahitte, A., Monié, P., Vergély, P., 2001. Metamorphic soles from the Albanian ophiolites: Petrology, $^{40}Ar/^{39}Ar$ geochronology, and geodynamic evolution. Tectonics 20, 78-96.

Economou, M., 1986, Chromite deposits of Greece. Chromites UNESCO's IGCP-197 project Metallogeny of Ophiolites. Theophrastus Publications S.A. Athens 1996.

Gjata, K., Milushi I., Deda, T., Daci, A., 1996. Geological constraints of two ophiolitic belts : evaluation and implications. Convegno Italo Albanese, Georisorse delle ofioliti Albanesi, Tirana, 209-216

Hoeck, V., Koller, F., Meisel, T., Onuzi, K., Kneringer, E., 2002. The Jurassic South Albanian ophiolites: MOR- vs. SSZ-type ophiolites. Lithos 65, 143-164.

ISPGJ-IGJN., 1983, Geological Map of Albania, scale 1:200000. Tirana, Albania.

ISPGJ-IGJN, 1989, Metallogenic Map of Albania, scale 1:200000. Tirana, Albania.

Jankovic, S., 1986, General features of Chromite deposits and major ore districts in Yugoslavia. Chromites UNESCO's IGCP -197 project Metallogeny of Ophiolites. Theophrastus Publications S.A. Athens 1996.

Kodra, A., Gjata ,K., Bakalli F., 1995. The Mirdita oceanic basin from rifting to closure.Workshop on albanian ophiolites and related mineralization. IUGS/UNESCO Modeling Programme. Document du BRGM 244, f. 9-25.

Marcucci, M., Kodra, A., Pirdeni, A., Gjata, Th., 1994. Radiolarian assemblage in the Triassic and Jurassic cherts of Albania. Ofioliti 19, 105-115.

Marcucci, M., Prela, M., 1996. The Lumi i zi (Puke) section of the Kalur cherts: Radiolarian assemblages and comparison with other sections in northern Albania. Ofioliti 21, 71-76.

Meshi, A., Boudier, F., Nicolas, A., Milushi,. 2010. Structure and tectonics of lower crustal and upper mantle rocks in the Jurassic Mirdita ophiolites, Albania. Int Geol Rev, 52(2-3):117-141.

Miranda, AE., Dilek, Y., 2010, Oceanic core complex development in modern and ancient oceanic liyhosphere: gabbro-localized versus peridotite-localized detachment models. The Journal of Geology, 2010, volume 118, p. 95-109

Morishita, T., Dilek, Y., Shallo, M., Tamura, A., and Arai, S., 2010, Insight into the uppermost mantle section of a maturing arc: The Eastern Mirdita ophiolite, Albania: Lithos 124 (2011) 215-226.

Nicolas, A., Boudier, F., Meshi, A., 1999. Slow spreading accretion and mantle denudation in the Mirdita ophiolite (Albania). Journal of Geophysical Research 104, 15155-15167.

Ndojaj, I., 1963, On some problems of magmatism in Albania (in Albanian). Bulitin of Tirana University, Serie of Natural Sciences 2, 3-22.

Robertson, A.H.F., Shallo, M., 2000. Mesozoic-Tertiary tectonic evolution of Albania in its regional Eastern Mediterranean context. Tectonophysics 316, 197-254.

Shallo, M., Dilek, Y., 2003. Development of the ideas on the origin of Albanian ophiolites. In: Dilek, Y., Newcomb, S. (Eds.), Ophiolite Concept and the Evolution of Geological Thought. Geological Society of America Special Paper, vol. 373, pp. 351-364.

Tremblay, A., Meshi, A., Be´dard, JH., 2009, Oceanic core complexes andancient oceanic lithosphere: insights from Iapetan and TethyanOphiolites (Canada and Albania). Tectonophysics 473:36-52

Vergély, P., Dimo, A., Monie, P., 1998. Datation des semelles metamorphiques ophiolitiques d'Albanie par la methode 40Ar/39Ar: Consequences sur le mecanisme de leur mise en place. Comptes Rendus a l'Académie des Sciences 326, 717-722.