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with some contribution of F. Koller

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FIELD TRIP FT5

"THE SOUTHERN ALBANIAN OPHIOLITES"
(27TH-29TH OF SEPTEMBER 2014)

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Part I: Geological Introduction

1. Ophiolites in southeastern Europe

The western part of the Balkan Peninsula shows two NNW-SSE trending zones characterized by ophiolite bodies (Fig. 1). The western one, known as the Dinaride Ophiolite Zone in the north and the Albanide-Hellenide Ophiolite Zone in the south respectively, is bordered to the west by the Adriatic (Dinaride) carbonate platform and other units which are interpreted as parts of the rifted margin of the Adriatic (Apulian) continent (Robertson et al. 2009). The eastern zone, generally termed the Vardar Zone, adjoins the metamorphic continental-derived Serbo-Macedonian composite unit to the east. Both ophiolite-bearing units are separated in the north by a small, elongated continental fragment called the Drina-Ivanjica Zone (DIZ in Fig. 1), and further south by the Korabi-Pelagonian Zone (KPZ in Fig. 1). Two other continental fragments are the Jadar block and the small, elongated Kopaonik unit. Both are situated within the Vardar Zone (Robertson & Karamata 1994, Karamata 2006, Schmid et al. 2008, Robertson 2012, Bortolotti et al. 2013).

The interpretation of the two ophiolite-bearing zones and their relation to the neighboring continental fragments is crucial in understanding the geodynamic evolution of the whole area. Without going into details, there are basically two models in discussion to explain the situation. The first considers the Dinaride-Albanide-Hellenide ophiolites as representing a separate oceanic domain, that was already open during the Triassic and started to close during the Middle to Late Jurassic as inferred from the cooling ages of the metamorphic sole (MS). In the former Yugoslavia, the metamorphic sole is not precisely dated but ages from Kimmeridgian to Tithonian (Karamata 2006) have been reported. This model, including several variations, has been inferred by researchers such as Beccaluva et al. (1994), Shallo (1996), Rassios & Smith (2000), Robertson & Shallo (2000), Smith & Rassios (2003), Saccani & Photiades (2005), Karamata (2006), Rassios & Dilek (2009), Robertson et al. (2009) and Robertson (2012).

The second model envisages the small continental fragments of the Drina-Ivanjica unit and the Korabi-Pelagonian unit as parts of the Adriatic continental margin. Consequently, the Dinaride-Albanide-Hellenide zone is regarded as being part of the Vardar Ocean and having originated east of the Drina-Ivanjica and Korabi-Pelagonian units. This model postulating only one ocean is elaborated by Schmid et al. (2008) and takes into account older models advocating a ‘one ocean’ model (see also Bernoulli & Laubscher 1972, Bortolotti et al. 2005, 2013, Gawlick et al. 2008 and Ferrière et al. 2012).

2. Geological overview of the Dinarides, Albanides and Hellenides

The Albanian ophiolites are restricted to the “Dinaride-Albanide-Hellenide” ophiolite belt and comprise mainly ultramafics. The crustal section is rare and of small extent. Complete ophiolite sections including significant volcanic sequences are found only in few areas, e.g., in former Yugoslavia at Rzav, between the ultramafic massifs of Zlatibor and Varda (Pamić & Desmons 1989), in Albania between the Puka and Krrabi massifs in the west and the Kukes, Luri and Tropoja massifs in the east (Shallo 1990), and in Greece (in the Pindos, Vourinos and Othris; see Smith 1993 for an overview).

Whereas the ultramafic massifs in the Vardar Zone the ophiolites are uniformly built up of spinel harzburgites (Bazylev et al. 2009), the Dinaric ophiolite belt consists of lherzolites, harzburgites and plagioclase peridotites. The massifs of Čavka, Bosanski Ozren, Borja and Konjuh in former Yugoslavia (1, 2, 3 and 4 in Fig. 1) consist almost entirely of fertile and variably depleted lherzolites. Small harzburgite bodies with chromite segregations are found only in the Konjuh massif. The Zlatibor massif also consists to a large extent of spinel lherzolite and plagioclase lherzolite. Harzburgites are restricted to the western and the southwestern part of the massif. The small Bistrica

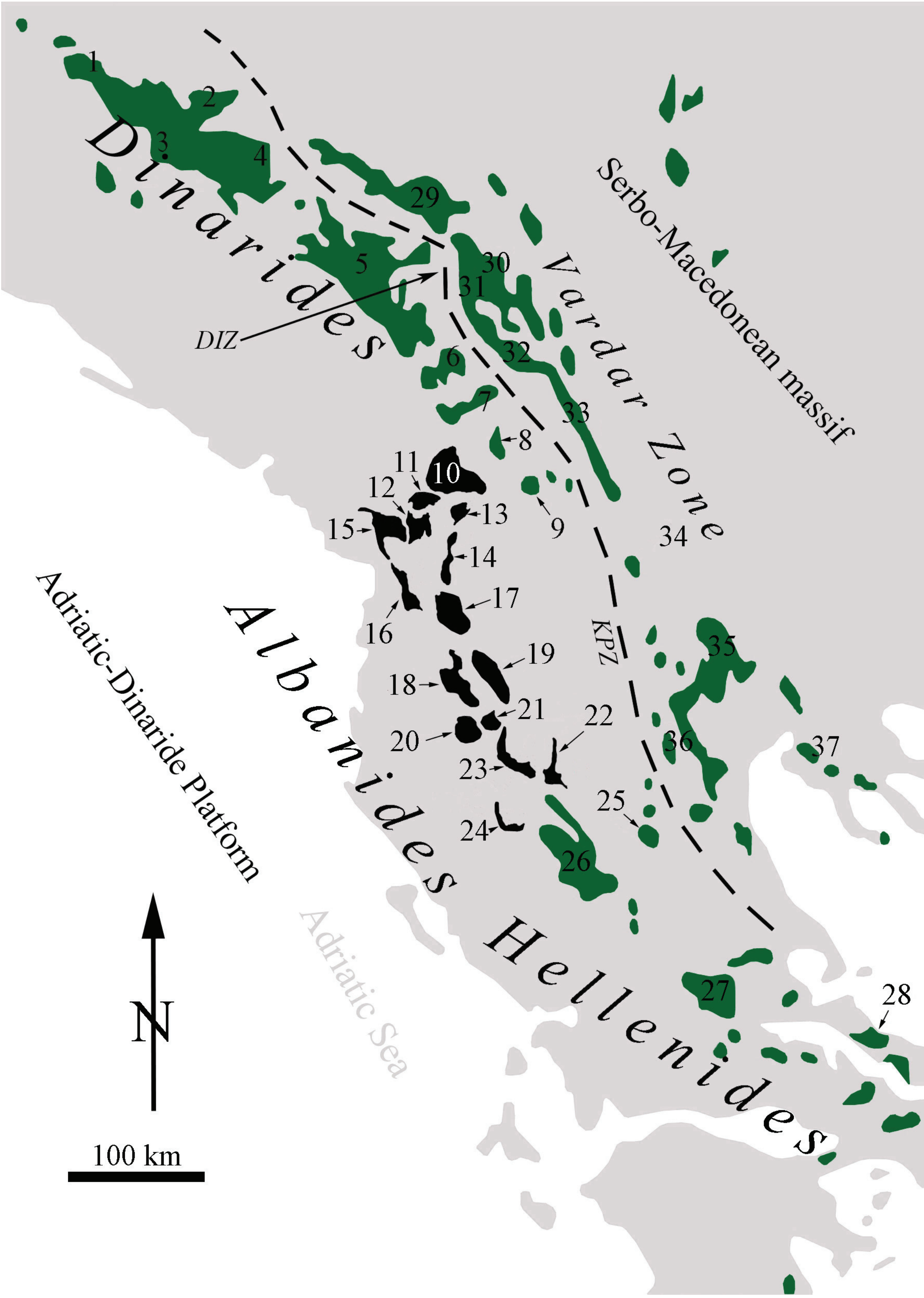


Figure 1. Distribution of ophiolites in the Dinaride, Albanide and Hellenide (1 – Čavka; 2 – Bosanski Ozren; 3 – Borja; 4 – Konjuh; 5 – Zlatibor; 6 – Bistrica; 7 – Sjenički Ozren; 8 – Orahovac; 9 – Brezovica; 10 – Tropoja; 11 – Krrabi; 12 – Puka; 13 – Kukes; 14 – Luri; 15 – Gomsiqe; 16 – Skenderbeu; 17 – Bulqize; 18 – Shpati; 19 – Shebenik; 20 – Devolli; 21 –Vallamara; 22 – Morava and Bitincka; 23 – Voskopoja; 24 – Rehove; 25 – Vourinos; 26 – Pindos; 27 – Othris; 28 – Evvia) and the Vardar Zone (29 – Maljen; 30 – Troglav; 31 – Stolovi; 32 – Trnava; 33 – Banjska; 34 – Poinja; 35 – Guevgueli; 36 – Vermion; 37 – Chalkidiki). In black, Albanian ophiolites. The dashed line in the center of the map follows the Drina-Ivanjica Zone (DIZ) in the north, and Korabi-Pelagonian Zone (KPZ) in the south. Image modified from Smith & Spray (1984) and Bazylev et al. (2009).

massif is built up of lherzolites with harzburgitic layers, crosscut by clinopyroxene + garnet veins.

The Sjenički Ozren massif contains spinel lherzolite and plagioclase lherzolite in equal amounts. It is crosscut by gabbroic dikes and small gabbroic intrusions. The southernmost ophiolites situated in Kosovo, i.e. at Orahovac and Brezovica (Bazylev et al. 2003), consist predominantly of harzburgites. Along the Skodra-Peç line, the Dinaride ophiolite belt shows a Z-like changing trend from NW-SE to NE-SW and back to NW-SE. Starting from here, to the south, the Dinaride ophiolite belt is divided into what is called the eastern and the western belt respectively (Shallo 1992), forming the Albanide

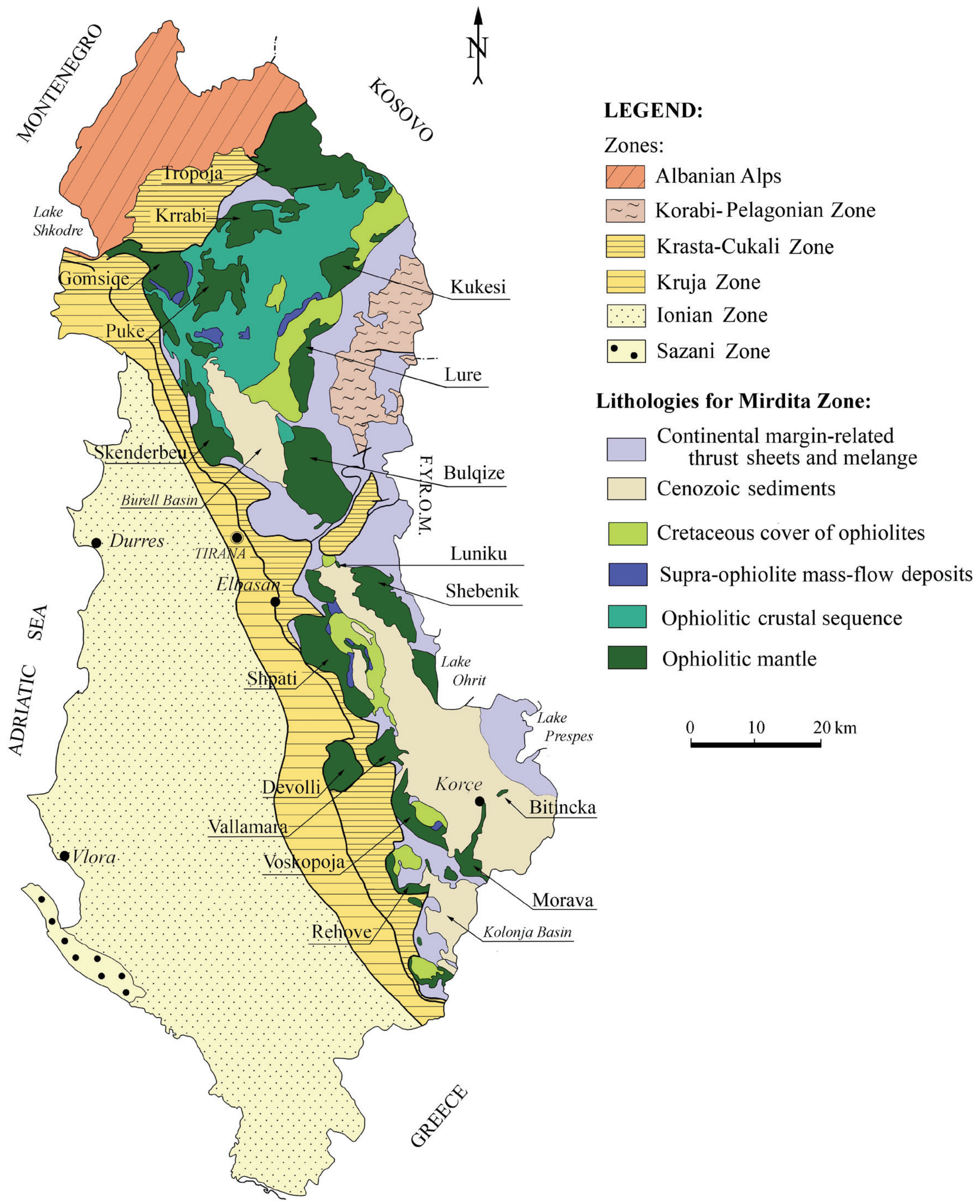


Figure 2. Simplified geological map of Albania, with the main tectonic units and the main ophiolite massifs (modified, from Robertson et al. 2012; based on Xhomo et al. 2002).

ophiolites (Figs. 1 and 2).

The eastern belt is thought to consist entirely of harzburgites and the western belt of lherzolites. Whereas the eastern belt is indeed made up of harzburgitic massifs (Kukes, Luri, Bulqize and Shebenik), the western belt is more diverse. The massifs of Krrabi and Puka are lherzolitic, but contain a high amount of harzburgites. The Gomsiqe massif is to a large extent lherzolitic. Further to the south, the Skenderbeu and Shpati massifs are partly lherzolitic, partly harzburgitic. The massifs of Vallamara and Devolli are exclusively harzburgitic. Only the Voskopoja and the accompanying small massifs are predominantly lherzolitic. All massifs of the western belt show variable amount of plagioclase lherzolites.

3. Ophiolites

Before discussing particulars of the ophiolites in Southern Albania, we will give a short insight into the overall geological structure of Albania and in particular how the ophiolites fit into it. For simplicity, we will adopt here the view that the Albanian ophiolites originated between the Adriatic continent and the Korabi-Pelagonian unit. This is a view held by many scientists, e.g., Shallo et al. (1990), Aliaj & Meço (1994), Beccaluva et al. (1994), Robertson & Shallo (2000), Shallo & Dilek (2003), Saccani & Photiades (2005), Rassios & Dilek (2009), Robertson et al. (2009) and Robertson (2012). The following description is based on Robertson & Shallo (2000).

The outermost and westernmost zone of Albania is called the Sazani Zone (Meço & Aliaj 2000) and is part of the Apulian carbonate platform (Figs. 2 and 3). The successions range from Cretaceous to Eocene, overlain by the Miocene molasse. The stratigraphic column of the Ionian Zone (Fig. 3) covers sediments from Triassic to Eocene. The latter are unconformably overlain by Lower Miocene sediments. The west directed thrusting ended in the Early Miocene. The Kruja Zone (KZ), continuing to the east (Figs. 2 and 3), is characterized by Cretaceous platform carbonates passing into pelagic carbonates and Late Eocene and Miocene turbidites, respectively. These sequences are unconformably overlain by Middle Miocene shallow water to terrestrial sediments. A sight over the Kruja Zone will be possible at field stop 16 (Bulcari). The innermost unit of the Apulian margin is the Krasta-Cukali Zone (KCZ). The sedimentation starts in the Triassic with volcaniclastics, cherts and deep water limestones. The sequence continues with deep water successions through the Mesozoic and ends with Paleocene to Early Eocene turbidites (Theodori et al. 1993). The Krasta-Cukali Zone (Fig. 3) was overthrust by the ophiolitic units during the Eocene. An overview of the KCZ will be possible at field stop 14 (Nikollara).

The Korabi Zone is part of the Drina-Ivanica–Pelagonian continent (DIZ and KPZ in Fig. 1). The deepest stratigraphic units are Early Paleozoic volcanics and sediments, metamorphosed during the Variscan orogeny. Their age is confirmed partly

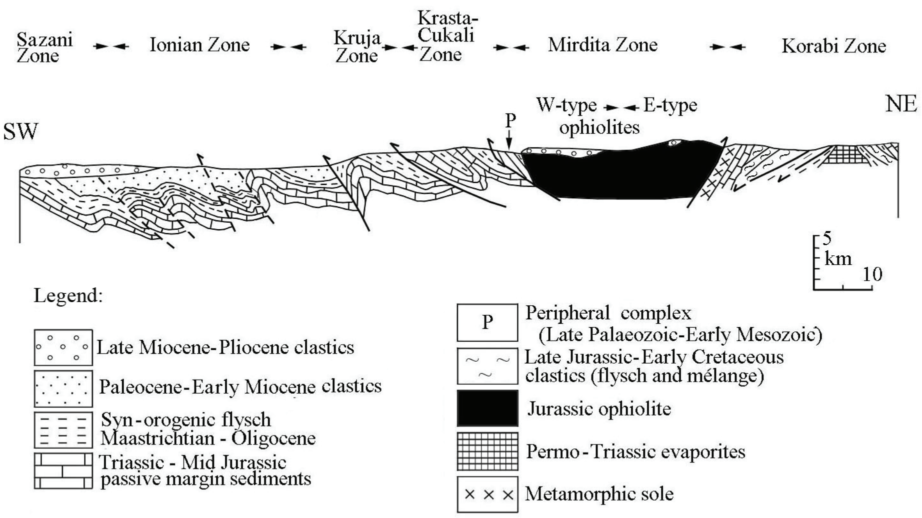


Figure 3. Geological profile across central Albania showing the relation of various geological units (modified from Robertson & Shallo 2000).

Figure 4. Shpati massif: lherzolite outcrops near Gaferi. (Photo by V. Hoeck).

by fossils and partly by radiometric age dating. The sedimentation continues with Permo-Triassic sandstones and conglomerates, followed by an Early to Middle Triassic volcanic-sedimentary sequence. The Late Triassic–Early Jurassic is represented by shallow water carbonates changing into deep water carbonates and radiolarites during the Middle Jurassic. The latter are overlain by ophiolite-derived sediments and later on by Cretaceous neritic limestones.

3.1. Southern Albanian ophiolitic massifs

In the following chapters we will focus on the Southern Albanian ophiolites. However, the corresponding rock types in Northern Albania (Shallo 1992, 1994, Bortolotti et al. 1996, 2002, 2005, Nicolas et al. 1999, Saccani et al. 2004, 2011, Dilek et al. 2008) will be addressed as well. The Southern Albanian ophiolitic massifs are: Shpati (SOM), Shebenik (SBOM), Devolli and Vallamara (DVOM), Voskopoja (VOM), Morava (MOM) and Bitincka (BOM) (Fig. 2). SOM, DVOM, VOM (including Rehove) and MOM are assigned to the western belt, whereas SBOM and BOM are assigned to the eastern belt, respectively. The small ophiolitic massif at Rehove will be discussed together with VOM. A very small ophiolitic massif north of Librazhd, i.e. Luniku, is included in the map from Fig. 2 but is not discussed further. Firstly, we will look briefly into the Southern Albanian ophiolite massifs and subsequently discuss the overall features of their pseudostratigraphy, including the Peripheral complex and the sedimentary cover.

3.1.1. Shpati ophiolitic massif

The SOM (Figs. 1, 2 and 4) extends over 35 km, trending NW-SE from north of Kutermani village to the Kukuri village in the south. The SOM is crossed in its northern part, from west to east, by the Shkumbini River, thus separating a small, 10 km long promontory in the NW – the Kutermani massif. The SOM is ~11 km wide just south of the Shkumbini River, and narrows down to 2 km at its central part. A small and elongated accompanying massif, located east of the main Shpati body and separated from the latter by Cretaceous and Eocene sediments, is also included here in the main SOM. It contains significant basic extrusives and will be visited during the field stops 4 (Stravaj A) and 5 (Stravaj B).

The pseudostratigraphy of the Shpati ophiolitic massif (Fig. 5) starts with a subophiolitic mélange - occasionally separated from the mantle tectonites by small occurrences of metamorphic sole which is at least partly incorporated in the subophiolitic mélange. The lower part of the mantle section is built up of clinopyroxene-bearing harzburgites with local dunite lenses. It is followed upwards by lherzolites, occasionally containing websterite dikes. The uppermost part of the ultramafic section consists mainly of plagioclase-bearing lherzolite crosscut by gabbros. After a thin plutonic sequence consisting of olivine-clinopyroxene gabbros, MORB-type lavas follow. The ophiolite sequence ends with coarse grained sediments including breccias and conglomerates which are in turn overlain by ophiolite-derived fine grained clastic sediments. The age of the sediments ranges from Late Jurassic to Early Cretaceous. The small Kutermani massif is entirely harzburgitic. It has no crustal cover and is directly overlain by molasse sediments. Outcrops in the Shpati massif will be visited at field stops 4 (Stravaj A) and 5 (Stravaj B).

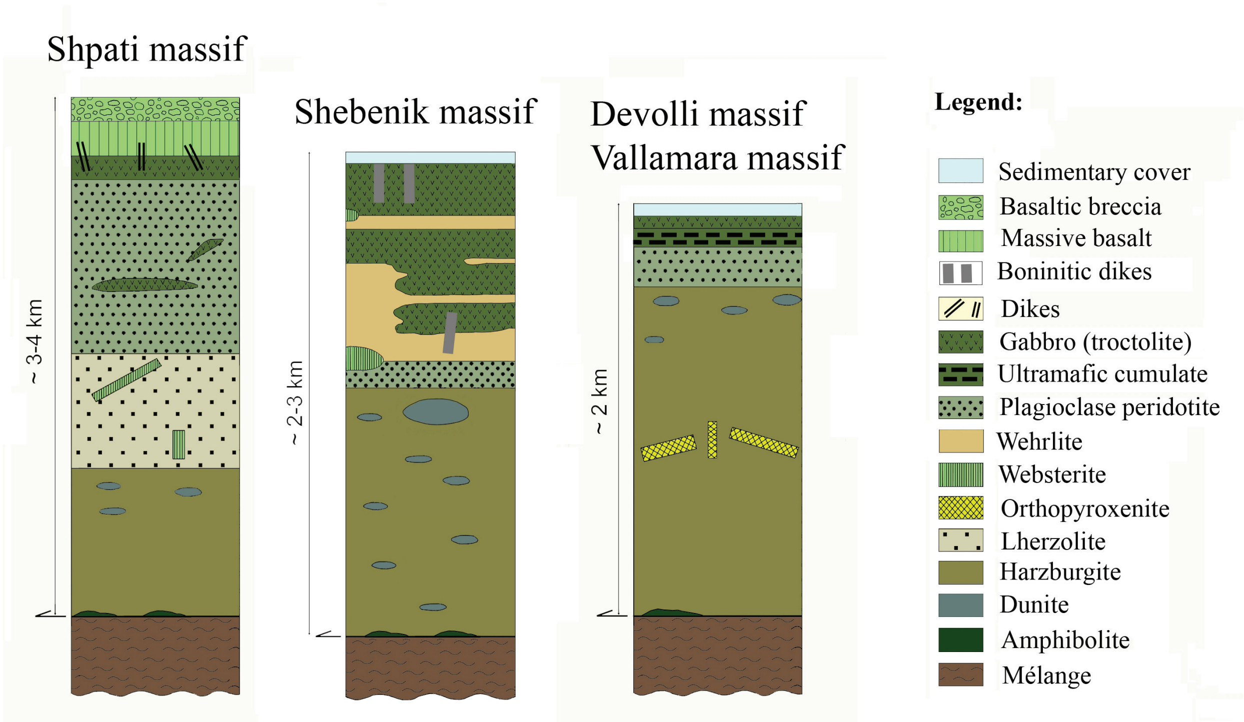


Figure 5. Stratigraphic columns through Shpati, Shebenik and Devolli-Vallamara ophiolitic massifs. The Shpati and Devolli-Vallamara columns are modified from Koller et al. (2006). The Shebenik column is modified from Bébien et al. (1998).

3.1.2. Shebenik ophiolitic massif

The SBOM is located east of the Shpati massif (Figs. 1 and 2), from which it is separated by Paleogene and Neogene molasse sediments of the Albanian-Thessalian Trough. The SBOM forms mountains with elevations above 2,300 m (Fig. 6). In the classical division of the western and eastern ophiolite belts, the SBOM is assigned to the latter (Shallo 1994, Bébien et al. 1998). It follows a NNW to SSE trend and extends over almost 30 km from Zgosti, north of Librazhd, to the town of Pogradec. The area extending south of Perrenjasi, along the shoreline of Lake Ohrid, is sometimes termed the 'Pogradec massif'. The northern and southern parts of the SBOM are separated by Mesozoic and Quaternary sediments. In the central part, the SBOM is approximately 11 km wide and narrows down to 4 km near Qafe Thane.

Above a thin subophiolitic mélange and remnants of a metamorphic sole, the mantle section is built up of harzburgites (Fig. 5) including chromite-bearing dunite lenses. The latter have led to Cr-mining activities (Beqiraj et al. 1995, 2000, Quintiliani et al. 2006, Kocks et al. 2007, Onuzi et al. 2012). To the west and northwest, plagioclase-bearing peridotites occur. A plutonic section consisting of clinopyroxene gabbro, wehrlite, olivine gabbro, troctolite and websterite is occasionally preserved (Bébien et al. 1998). A few boninitic dikes crosscut the plutonic section. So far no effusive section has been found. The SBOM is separated from the Upper Triassic platform limestones to the east, by high angle faults. Outcrops of chromite-bearing peridotites in the Shebenik massif (Pogradec) will

Figure 6. Shebenik massif (in the background). (Photo by V. Hoeck).

be seen during field stop 8 (Pojska).

3.1.3. Devolli and Vallamara ophiolitic massifs

The DVOM (Figs. 7 and 8) are located between the Shpati massif to the NW and the Voskopoja massif to the SE (Figs. 1 and 2). Similar to the Shebenik massif, the DVOM are comprised of clinopyroxene-bearing harzburgites as the main mantle constituent. However, the DVOM are not seen as part of the eastern ophiolite belt but are assigned rather to the western belt. In contrast to most of the ophiolitic massifs in Albania, the DVOM do not have an elongated shape, but have an almost isometric shape instead. Additionally, they form an ophiolitic 'promontory' towards the west (Fig. 2).

A small mélange basement and a thin metamorphic sole are often displaced by near vertical faults, in particular at the W and NW border of the Devolli massif. The main body consists of clinopyroxene-

Figure 7. Devolli massif, with harzburgite outcrops. (Photo by C. Ionescu).

Figure 8. Vallamara massif. (Photo C. Ionescu).

bearing harzburgites crosscut by orthopyroxenite dikes (Fig. 5). Lherzolites are extremely rare. Plagioclase-bearing peridotites are found on top of the mantle section of both massifs, mainly at their southern side. Locally, thin mafic and ultramafic cumulates end the sequence. Whether the Mesozoic sediments occurring in the area are part of the subophiolitic mélange or primary cover remains questionable. The Eocene sediments separating the two massifs are part of the Krasta-Cukali Zone, on which both massifs rest tectonically. Rocks in the Devolli massif will be visited during field stop 15 (Devolli).

3.1.4. Voskopoja ophiolitic massif

The Voskopoja ophiolitic massif (Figs. 1, 2 and 9), one of the largest in Southern Albania, is assigned to the western ophiolitic belt. It extends over 30 km from north of the Devolli River (Strelca village) to the southern tip of the Korça graben, i.e. south of the town of Korça. It is slightly bent, striking NE-SW in its northern part, N-S in the central part, and changes to a NW-SE strike in the south. The VOM continues towards the SE into the Morava massif without clear boundaries, beneath the Pliocene and Quaternary sediments of the Korça graben. Westwards the VOM is partly fault-bounded, partly steeply thrust onto the mélange zone. The latter contains variable sized blocks of highly altered serpentinite and large blocks of Triassic-Jurassic carbonate rocks in a serpentinite-derived sandy-silty matrix. The mélange and the VOM are overthrust onto the Eocene flysch sediments of the Krasta-Cukali Zone. Elongated lenses of amphibolites, micaschists and marbles near Pasha Tepe indicate a tectonic doubling of the ultramafic sequence. Whereas the lower unit comprises exclusively highly serpentinized peridotites, the tectonically higher unit contains a thin crustal cover consisting of gabbros and basalts.

The Rehove massif is very similar in lithology, mineralogy and chemistry to the Voskopoja massif and is therefore included in the VOM description. The stratigraphic column through the VOM is displayed in Figure 10. The ultramafic part consists of ~90 vol.% lherzolite and plagioclase lherzolites and ~10 vol.% harzburgites. This applies to the ultramafics in both tectonic slivers separated by the metamorphic sole. The ultramafics are highly serpentinized, therefore their original mineralogy is difficult to recognize. In thin sections, most ultramafics can be assigned to lherzolites. In the upper parts, the ultramafics are crosscut by several gabbroic dikes.

The crustal section is only preserved to a small extent, mainly in the southern and central parts of the Voskopoja ophiolites. It starts with small occurrences of wehrlites, troctolites and clinopyroxene gabbros. The latter are sometimes crosscut by basaltic dikes. A sheeted-dikes section is missing. However, some large basalt clasts in the volcanic section show chilled margins. Above the gabbroic sequence, often fault bounded, there is a MOR-type basaltic section, with basaltic breccias, lava flows and pillow lavas. The volcanic section is covered by sediments which eventually may also rest directly on ultramafics. In the southern part of the VOM, the sedimentary sections reach more than 400 m in thickness (for more details, see Chapter 3.8 'Sediments above the ophiolites').

The Voskopoja ophiolite is the only massif in Southern Albania built up predominantly by lherzolites and plagioclase lherzolites, with only

Figure 9. Voskopoja massif. (Photo by C. Ionescu).

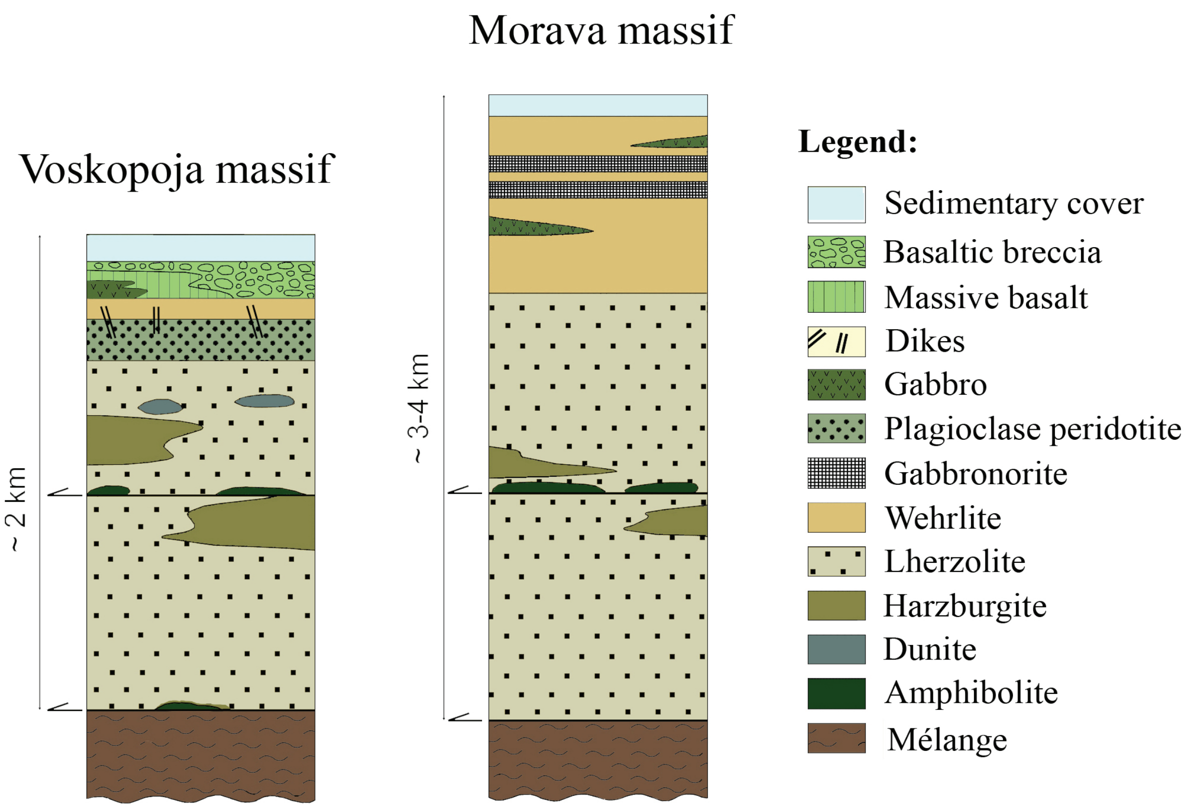


Figure 10. Stratigraphic columns through the Voskopoja and Morava ophiolitic massifs (from Koller et al. 2006, modified).

minor harzburgites. In this respect, it resembles the Gomsiqe massif in Northern Albania, which is also included in the western belt. Outcrops in the Voskopoja massif will be visited at field stops 11 (Shipcka), 12 (Ura Verbes) and 13 (Gjinikas).

3.1.5. Morava ophiolitic massif

The MOM is a small, elongated-shaped ophiolite body trending from NNE to SSW, located east of the town of Korça (Figs. 1, 2 and 11). This orientation contrasts to the more northern massifs, with a general NW-SE trend. The Morava massif extends over 22 km from Dishnica in the north to south of the village of Nikolica. In general, the massif is less than 1–1.5 km in width. The width reaches up to 6 km only in the extreme south.

The internal structure of the Morava massif is very similar to that of the Voskopoja massif. Near Boboshtica, the MOM is also divided by a metamorphic sole into two parts. The metamorphic sole consists of amphibolite, marble and micaschist. At the base of the lower unit, no metamorphic sole has been found so far. Above a subophiolitic mélange, lherzolite is a dominant rock type (Fig. 10). Some minor layers of clinopyroxene-bearing harzburgite occur. The higher unit has a composition similar to the VOM. It is overlain by plagioclase-peridotite which contains several layers of clinopyroxene gabbro and clinopyroxene-orthopyroxene gabbro, as well as crosscutting gabbro dikes. No effusive section has been found so far. A sedimentary sequence crops out in the east, near Boboshtica, deposited directly on highly serpentinized peridotites. Plagioclase peridotite outcrops in the Morava massif will be seen during field stop 10 (Barçi).

Figure 11. The town of Korça at the foothills of the Morava massif. (Photo by C. Ionescu).

3.1.6. Bitincka ophiolitic massif

The Bitincka ophiolitic massif (Fig. 2) is located ENE of Korça, at the eastern rim of the so-called 'Devolli graben' (Meço & Aliaj 2000). It occurs in partly fault-bounded erosional windows. The individual units have a maximum length of 2 km and are only a few hundred meters in width. The BOM consists entirely of highly serpentinized harzburgites and contains several NiFe-rich laterite deposits which are due to Cretaceous weathering processes. Laterite outcrops will be seen during field stop 9 (Kapshtica).

3.2. The Peripheral complex

The deepest of the ophiolite-related units is the so-called 'Sedimentary periphery' (Shallo 1990, 1992, Shallo & Dilek 2003). Robertson & Shallo (2000) termed it as 'Peripheral complex' (PC). It refers to a predominantly Mesozoic succession, which is widely distributed in the immediate vicinity of the large ophiolite bodies. The individual units of the PC display variable stratigraphic ranges. A compiled and complete stratigraphic log covering various sections was constructed by Shallo (1992) and Shallo & Dilek (2003). It is reproduced, slightly modified, in Figure 12. This synthetic stratigraphic section is very similar to that of the Korabi Zone, as shown by Robertson & Shallo (2000). It contains, at the base, Lower Paleozoic, slightly metamorphosed sediments covered by a Permo-Triassic sequence, with sandstones, conglomerates, volcanics and radiolarites. The latter occur also as large blocks in the mélange (see Chapter 3.3. 'Subophiolitic mélange') where they were dated as Middle-Late Triassic by Marcucci et al. (1994), Chiari et al. (1996) and Gawlick et al. (2008). Limestones locally identified as Hallstatt type (Gawlick et al. 2008) are also Mid-Triassic. Upper Triassic to Lower Jurassic neritic limestones are followed by pelagic carbonate rocks e.g. Toarcian *Ammonitico rosso,* and cherts. This sequence is in several places overlain by Tithonian to Lower Cretaceous ophiolitic debris flows and flysch-like sediments containing Tithonian-Early Cretaceous *calpionellids*. Similar sequences are widely distributed in comparable positions in Greece, as well as in the former Yugoslavia adjacent to the Dinaride ophiolites. They are interpreted, for example by Robertson & Shallo (2000) and Gawlick et al. (2008), as passive margin successions.

Two conclusions can be drawn from the stratigraphic log of the ophiolitic Peripheral complex (Fig. 12). First, the Middle Triassic volcanics (volcano-sedimentary rocks) contain preferentially MOR-like and mildly alkaline basalts which, combined with the Middle Triassic cherts, are indicative of an oceanic crust or at least the opening of an ocean. However, more SiO_2-rich volcanics such as trachytes, andesites, dacites and rhyolites occur as well (Carossi et al. 1996; Meço & Aliaj 2000). Based on these findings, the Middle

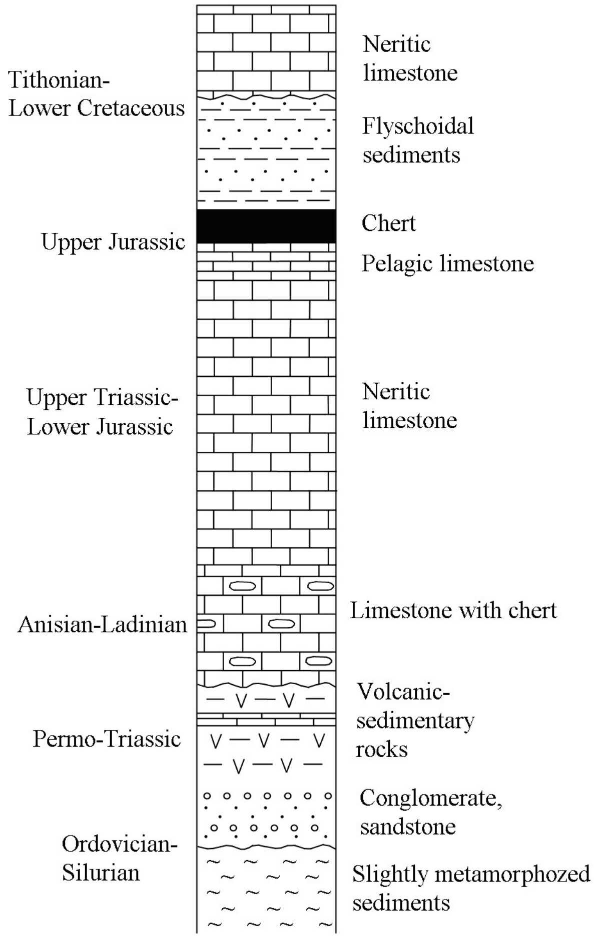


Figure 12. Stratigraphic column of the Peripheral complex (redrawn and modified, from Shallo et al. 1990 and Shallo & Dilek, 2003).

Triassic volcanics were interpreted as reflecting the opening of the Dinaric-Albanian-Hellenic ocean which lasted until the Middle Jurassic (Gawlick et al. 2008).

The second conclusion is that the whole sequence of the Peripheral complex indicates a passive margin. Robertson & Shallo (2000) pointed out that it may be compared on the one hand with the Krasta-Cukali Zone (located in the west), and the Korabi Zone (located in the east). However, the KCZ developed continuously from the Triassic into the Eocene, while the Korabi Zone contains a package of Upper Jurassic to Lower Cretaceous ophiolite-derived debris flows.

3.3. Subophiolitic mélange

The subophiolitic mélange is widely distributed beneath various ultramafic massifs and their metamorphic soles in Southern as well as in

Northern Albania. The most extensive mélange areas occur on the western side of the ophiolites. To the east, the mélange is partly destroyed by late high angle faults. The Albanian subophiolitic mélanges meet the criteria enlisted in the definition of mélange by Festa et al. (2012): “a body of mixed rocks containing blocks (exotic and native) that are derived from different stratigraphic units or sequences, different tectonic units, various paleogeographic domains and/or dissimilar metamorphic zones”. Mélanges are mappable units, several kilometers wide, with a fine-grained matrix, consisting of shale or siltstone, resedimented serpentinite or detrital chert. They show a typical ‘block-in-matrix’ structure, with blocks of variable size and age, derived from various environments. The blocks include ultramafics, basalts, gabbros and other magmatic rocks of Middle Triassic age, Middle Triassic radiolarites, Middle Triassic to Upper Triassic limestones, and occasionally metamorphics which are probably derived from the metamorphic sole. Additionally, sandstones and even fragments of sediments typical for those deposited on top of the ophiolites occur (Bortolotti et al. 1996). The size of the blocks varies over a short distance, from less than 1 m to tens of meters and even kilometers. The latter are mainly considered to be nappe-size fragments of the Peripheral complex. The mélange occurrences are not, or only very slightly, metamorphosed, showing sometimes an inverted metamorphic gradient towards the metamorphic sole. The mélange should be situated structurally between the Peripheral complex and the ultramafic massifs.

Mélanges are not uncommon in the Dinaride-Albanide-Hellenide ophiolite belt. Occurrences have been described in Serbia (Robertson & Karamata 1994) and Greece, such as the Avdella Mélange beneath the Pindos ophiolites (Jones & Robertson 1991, 1994) or the Agios Nikolaos Formation beneath the Vourinos ophiolites (Ghikas et al. 2010).

In Northern Albania Bortolotti et al. (1996) introduced the term ‘Rubik complex’ for the subophiolitic mélange. It consists of “an assemblage of block and/or thrust sheets of (1) Triassic–Jurassic, mainly carbonate sequence, (2) Triassic basalts with intercalations of radiolarites (‘volcano-sedimentary sequence’), (3) serpentinites, and (4) Late Jurassic-Early Cretaceous Simoni Mélange and Firza Flysch”. The Rubik complex includes therefore blocks from the volcano-sedimentary sequence of the Peripheral complex (Fig. 12), and additionally some slices from sediments deposited on top of the ophiolites (Kalur cherts, Simoni Mélange and Firza Flysch). These terms are discussed in chapter 3.8 ‘Sediments above ophiolites’, in this excursion guide. For more details, the reader is referred to Bortolotti et al. (1996). Mélange outcrops will be seen at field stops 1 (Miraka A), 2 (Miraka B), 6 (Qafe Thane) and 7 (Lini).

3.4. Metamorphic sole

Most of the massifs are underlain by a metamorphic sole extending over a limited length of few meters to few kilometers. The MS in Southern Albania does not exceed a few tens of meters in thickness and shows no metamorphic gradient. In the northern massifs the thickness increases to several hundred meters, therefore it is possible to calculate variable PT conditions across (Carosi et al. 1996). Commonly, the metamorphic sole is sandwiched by the mantle tectonites above and the subophiolitic mélange below. Sometimes it is difficult to decide whether the MS is already incorporated into the subophiolitic mélange or whether it is in its original position. Metamorphic soles occur on both sides of the ophiolitic belts, i.e. their eastern side as well as their western side. The metamorphic sole underlying the eastern belt can be followed over larger distances and is generally thicker than in the western belt.

In Southern Albania the metamorphic sole consists mainly of amphibolites, some metapelites and additionally metamorphosed carbonate rocks. The most important metamorphic assemblages present both in the north and in the south of Albania (Carosi et al. 1996; Dimo-Lahitte et al. 2001) within the amphibolites, are:

a) hornblende + plagioclase + clinozoisite;

b) hornblende + plagioclase + clinopyroxene;

c) hornblende + plagioclase + clinopyroxene + garnet;

d) quartz + plagioclase + biotite + muscovite +

garnet.

Minor compounds such as FeTi oxides and late alteration products are not included in this list of assemblages. It is not quite clear whether clinopyroxene overgrown by hornblende represents a relic of the magmatic stage or was formed by an earlier high T event. Apart from the mineral assemblage (d), Dimo-Lahitte et al. (2001) were able to identify in Northern Albania metasedimentary parageneses formed at high PT:

e) garnet + clinopyroxene ± orthopyroxene + plagioclase + quartz;

f) garnet + kyanite + plagioclase + biotite + muscovite + quartz.

The temperatures calculated at various pressures (0.2 to 0.5 GP) are similar (Carosi et al. 1996, Dimo-Lahitte et al. 2001 and our own unpublished data), and range for assemblage (a) from 550 ºC to 700 ºC, for assemblage (b) from 680 ºC to 750 ºC, for assemblage (c) from 600 ºC to 750 ºC and for assemblage (d) from 500 ºC to 700 ºC. No PT gradient can be seen from these temperature ranges. The values vary according to the geothermometric models, and depend on the composition of the phases which were believed to be in equilibrium. Dimo-Lahitte et al. (2001) report 800–860 ºC and 0.9–1.1 GPa for assemblage (e), and 625–700 ºC and 0.7–0.9 GPa.

The protoliths of amphibolites are mainly basalts and basaltic andesites and include the whole chemical spectrum from E-type MORBs to N-type MORBs, and from OIB to highly depleted basalts (Beqiraj et al., 1996). This is consistent with the assumption that amphibolites of the metamorphic sole were derived mainly from the Middle Triassic volcano-sedimentary sequence. At least a small part of the protoliths originate most likely from the Middle Jurassic volcanics.

The metamorphic sole provides a unique opportunity to shed light on the problem of the emplacement of the ophiolites (Hacker 1990; Hacker et al. 1996, Wakabayashi & Dilek 2000) because of the combination of PT data with age dating. After some attempts to date the metamorphic sole in Albania by K-Ar (Beqiraj et al. 1996) ^{40}Ar-^{39}Ar (Gjata et al. 1992, Vergély et al. 1998, Bébien et al. 2000) and Sm-Nd (Gjata et al. 1992), Dimo-Lahitte et al. (2001) published a large comprehensive ^{40}Ar-^{39}Ar study with over 20 age dates from metamorphic sole amphibolites from the north as well as from the south of Albania. This study corroborates earlier dating and revealed a 175–165 Ma age, i.e. Middle Jurassic (Aalenian to Callovian). Similar ages have been reported from Greece in the south to former Yugoslavia in the north (for details see the compilation by Smith 1993, Karamata 2006, Bortolotti et al. 2013). The Middle Jurassic ages are thought to mark the onset of the emplacement of the Dinaride-Albanide-Hellenide ophiolites.

A general decrease in the age of the metamorphic soles, from south to north of Albania, has been inferred by Vergély et al. (1998) and Dimo-Lahitte et al. (2001). Metamorphic sole outcrops in the Voskopoja massif will be seen during field stop 13 (Gjinikas).

3.5. Mantle peridotites

The mantle peridotites are composed of harzburgites, lherzolites and plagioclase peridotites, and contain several dunite lenses. The massifs from the western ophiolite belt are built up by harzburgites and lherzolites (see also Nicolas et al. 1999). It appears that in the deeper parts of the massifs harzburgite prevails, whereas the higher parts are lherzolitic in composition. The plagioclase peridotites are restricted to the uppermost part of the mantle column (compare with data by Tremblay et al. 2008 for Northern Albania).

The ophiolitic massifs from the eastern belt, including the massifs of Devolli and Vallamara (which are part of the western belt), consist almost entirely of harzburgites. Lherzolites are extremely rare. Again, at the top of the mantle tectonite column plagioclase peridotites occur. Dunite lenses are found in both harzburgites and lherzolites but are more frequent in the eastern belt massifs. The modal composition of peridotites plotted in an olivine-orthopyroxene-clinopyroxene diagram is shown in Fig 13a for the western belt (without DVOM) and in Fig. 13b for the eastern belt (including DVOM). Spinel is a minor phase. All ultramafic rocks are serpentinized to various degrees, ranging from not serpentinized at all or very slightly serpentinized (e.g., harzburgites in the Devolli massif - field stop

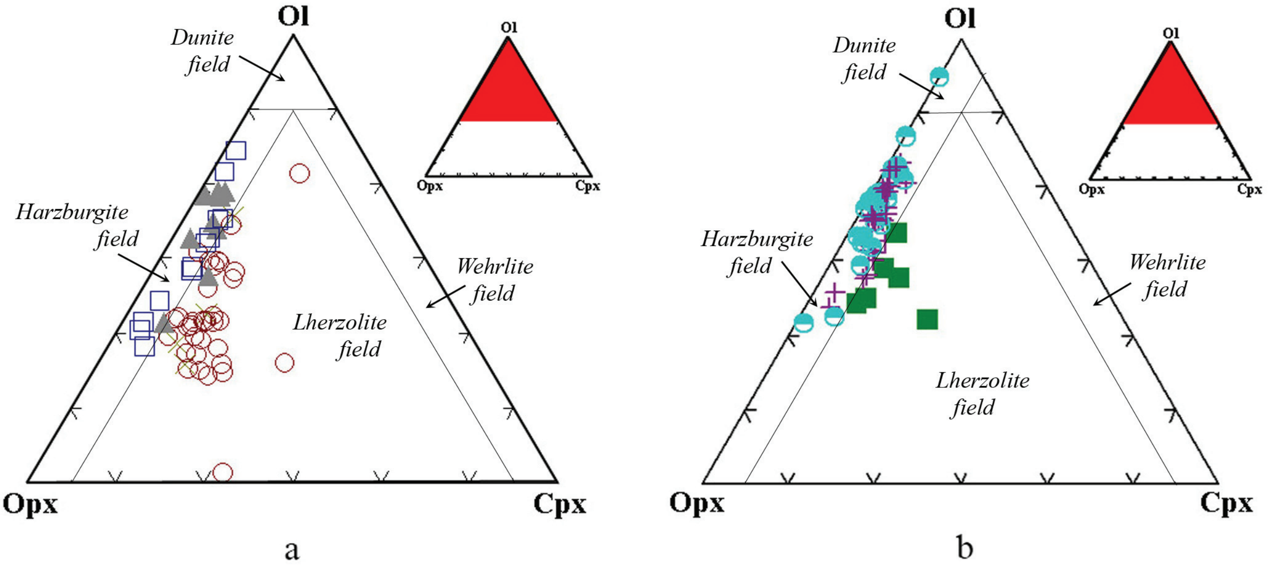


Figure 13. The modal composition of peridotites from (a) the western belt (Voskopoja, Rehove, Morava and Shpati massifs) and (b) the eastern belt (Devolli, Vallamara, Shebenik and Bitincka massifs), plotted in the olivine (ol)-orthopyroxene (opx)-clinopyroxene (cpx) diagram. Symbols: red open circle for VOM and MOM lherzolite, blue open square for VOM harzburgite, grey full triangle for SOM harzburgite, grey x for SOM lherzolite; green square for DVOM lherzolite, blue half filled circle for SBOM and BOM harzburgite, purple cross for DVOM harzburgite.

15) to totally serpentinized (e.g., harzburgites in the Voskopoja massif). The latter may contain 13-16 mass% LOI.

The ultramafics show a porphyroclastic texture and often a clear foliation. Large orthopyroxene porphyroclasts display clinopyroxene exsolution lamellae. Chromite and more rarely clinopyroxene can be found as porphyroclasts. Between the clasts, fine grained olivine, orthopyroxene, clinopyroxene and often spinel occur. They equilibrated at T >950 ºC, probably within the spinel field. Occasionally a pargasitic hornblende is also present. Magnesiohornblende and actinolitic to tremolitic amphiboles are late products, overgrowing clinopyroxene at lower temperature. Similar textures are also common in plagioclase peridotites. Plagioclase is associated with the fine grained olivine - clinopyroxene - orthopyroxene assemblage and shows remnants of spinel as inclusions. It is mostly altered but some fresh parts are still preserved.

Geochemically, lherzolites and plagioclase peridotites have higher Al_2O_3 and CaO but lower MgO content than harzburgites. This is highlighted in the MgO/SiO_2 versus Al_2O_3/SiO_2 diagram (Fig. 14), the ultramafics, as a whole, which follow a linear trend parallel to the so-called 'terrestrial array' (Niu 2004, Paulick et al. 2006, Deschamps et al. 2013). It indicates either depletion from fertile lherzolite to depleted harzburgites, or vice versa, enrichment from depleted harzburgites to fertile lherzolite. All analyses fall within the field of abyssal peridotites defined by Niu (2004), ranging from fertile to depleted chemistry. The boundary between lherzolites and plagioclase peridotites on one side and harzburgite on the other side is

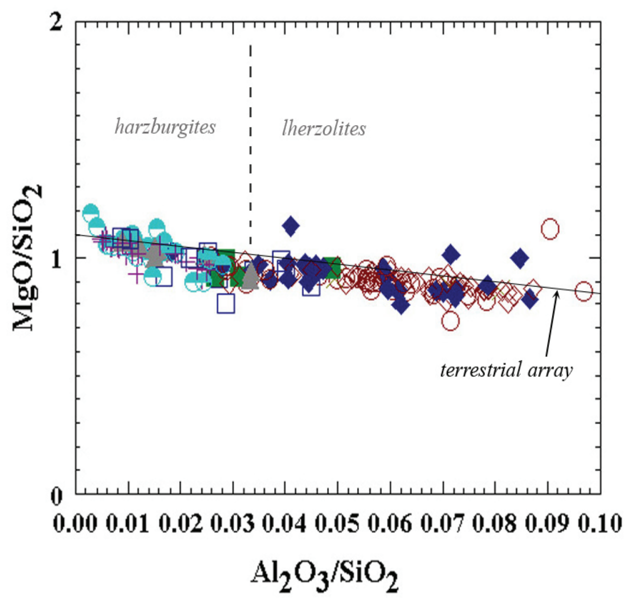


Figure 14. MgO/SiO_2 versus Al_2O_3/SiO_2 diagram for peridotites from all massifs, showing a trend parallel to the 'terrestrial array' of Niu (2004), Paulick et al. (2006) and Deschamps et al. (2013).

around 0.03 Al_2O_3/SiO_2 corresponding to ~1.5 mass% Al_2O_3.

The REE of lherzolites (in particular those from the Voskopoja massif) show two distinct patterns (Fig. 15a). The first one exhibits a strong depletion of the LREE, a flat MREE pattern and HREE values at ~0.7–2 times chondrite. The $(Ce/Yb)_N$ ratios between 0.01 and 0.05 indicate a strong fractionation of the REE. Such strongly depleted LREE patterns were observed elsewhere in the Dinaride Ophiolite Zone (Lugović et al. 1991). The second type shows a spoon-shaped pattern, with $(La/Nd)_N$ from 1 to 3 and enrichment from MREE to HREE. A positive Eu anomaly occurs occasionally. The overall concentration of the MREE and HREE is smaller than in the first type. Plagioclase peridotite resembles the first type of REE and trace element patterns of lherzolites.

Harzburgites (e.g., those from Devolli and Vallamara massifs) have a typical U-shaped REE pattern (Fig. 15b), which can be divided into two groups, each with different overall enrichment. The first group has around 0.1 (chondrite-normalized) for the LREE and HREE and 0.01 for the MREE. Some patterns exhibit a positive Eu anomaly. Among other trace elements, a positive Sr anomaly (not shown in diagrams) is observed. The second group is more enriched in LREE and HREE, around 1, and MREE 0.3–0.5 times chondrite (Fig. 15b). For this group the Sr anomaly is weak, a positive U anomaly relative to the Th value is visible. Harzburgites from other massifs can be assigned to one or the other of these groups.

The chemistry of minerals reflects the general differences in overall geochemistry among lherzolites, harzburgites and plagioclase peridotites. Ti and Al are the best elements to distinguish clinopyroxene from different type of rocks (see also Müntener et al. 2010). Those from harzburgite have the lowest TiO_2, with concentrations of <0.1 mass%. In clinopyroxene from lherzolites the TiO_2 content goes up to 0.4 mass% and the Al_2O_3 content reaches up to 7.5 mass%. The clinopyroxene in plagioclase peridotite is very similar in chemistry to that from lherzolite with a TiO_2 concentration up to 1 mass%. The maximal Al_2O_3 content is around 5 mass%.

The orthopyroxene in lherzolite is separated from that in harzburgite by the lower Cr_2O_3 at the same Al_2O_3 content. In plagioclase peridotites the Cr versus Al trend follows that from harzburgites. The TiO_2 content of orthopyroxene of plagioclase peridotite is, to a large extent, significantly higher than that of the harzburgite and the lherzolite.

X_{Mg} in olivine varies in all peridotite types between 0.89 and 0.91. At X_{Cr} <0.55 the plagioclase peridotite spinel is identical with lherzolitic spinel as regards the X_{Mg} and X_{Cr}. At X_{Cr} >0.55 it shows a lower X_{Mg} compared with the harzburgite spinels. TiO_2 in plagioclase peridotite spinel varies from 0.2 to 1 mass%. At high Al content the TiO_2 is identical with that of lherzolite spinel but at lower Al, the TiO_2 is significantly larger than that of the harzburgite spinel.

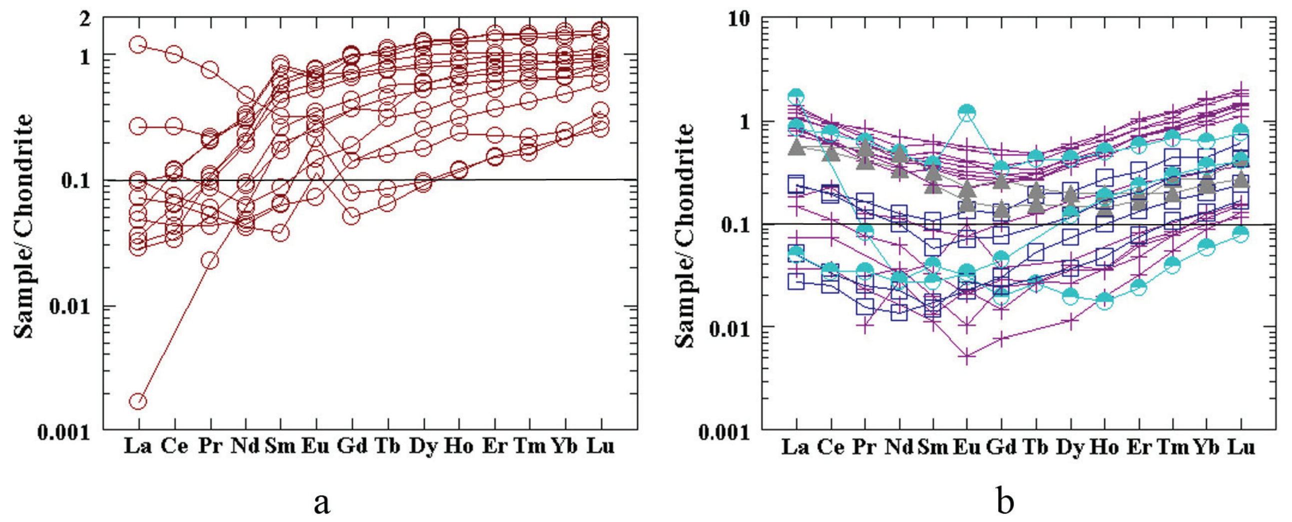


Figure 15. REE of peridotites: a) Lherzolites from VOM, b) Harzburgites from DVOM (purple cross), VOM and MOM (blue open square), SOM (grey triangles) and SBOM (blue half-filled circle).

Amphibole occurs in all lithologies. It is rarer in harzburgite and lherzolite, but common in plagioclase peridotite. In harzburgite and lherzolite, amphibole is mainly magnesiohornblende, actinolite or tremolite, whereas in plagioclase peridotite, pargasite and edenite are common.

Combining geochemistry, textural evidence, mineral chemistry and the overall structure of ophiolites, the following tentative scenario for peridotite evolution can be envisaged:

a) Partial melting of the peridotites at variable degree leaving more or less refractory peridotites ranging from lherzolites to harzburgites during an older geological event;
b) Upwards migration of asthenospheric melt and interaction with older peridotites in the spinel-peridotite(?) facies;
c) Equilibration of second generation of orthopyroxene-olivine-clinopyroxene at high T (>950 ºC). Break down of spinel in plagioclase field and formation of pargasite(?);
d) Cooling and low T metamorphism of peridotites, leading to formation of magnesiohornblende and actinolite-tremolite.

3.6. Plutonic section

The plutonic rocks in Albanian ophiolitic massifs comprise ultramafic cumulates (dunites, wehrlites), and various gabbros (Koller et al. 2006). The ultramafic cumulates are more or less serpentinized, however layering and magmatic textures are still recognizable. Olivine, clinopyroxene and orthopyroxene cumulate in mm- to cm-thick layers. Pyroxene layers alternate with partly or totally serpentinized olivine layers. Chromite often shows magmatic embayment. Olivine and chromite are overgrown by clinopyroxene or orthopyroxene. The plutonic rocks contain also plagioclase (transformed into prehnite or hydrogarnet) and an amphibole (magnesiohornblende to pargasite) of possible magmatic origin.

The olivine gabbro (troctolite) and the cumulate gabbro differ from the ultramafic cumulates by an higher amount of plagioclase and lack of orthopyroxene. Often olivine is overgrown by clinopyroxene. Troctolite consists of olivine and plagioclase, whereas cumulate gabbro contains also clinopyroxene and often shows layering (Fig. 16). Olivine is highly serpentinized, plagioclase is replaced by low-T alteration minerals and clinopyroxene changes into amphiboles.

The isotropic gabbros, gabbronorites and pyroxenites form dikes and stocks, ranging from a few meters to tens of meters in size, within lherzolites and harzburgites. The isotropic gabbros consist mainly of clinopyroxene and plagioclase, sometimes olivine. Orthopyroxene is found in low amounts in the Devolli and Shpati

Figure 16. Cumulate gabbro in the Morava massif (Photo by V. Hoeck).

gabbros, but is common in gabbronorites from Morava ophiolites. Generally clinopyroxene is transformed into an amphibole with a composition from magnesiohornblende to actinolite. Pargasite is rare. Most of the plagioclase is altered into albite and prehnite. There is no spinel, but ilmenite and Ti-magnetite occur frequently. Among the low-T alteration products are also chlorite, serpentine and zeolite.

The gabbroic dikes and lenses from the ultramafics and ultramafic cumulates reveal rodingitization, e.g., replacement of plagioclase by hydrogrossular and prehnite.

3.7. Volcanic sequence

In the Southern Albania ophiolites extrusives are rare and occurrences are comparatively small. Only in the Shpati massif at Stravaj and in the Voskopoja massif (including the small Rehove massif) do they form mappable outcrops, up to several hundred meters in length (Hoeck et al. 2002). The mode of occurrence of the volcanics is highly variable. Massive basalt flows and pillow lavas occur, but most of the basalts are brecciated. They can be found rarely as individual dikes cutting lherzolites and gabbros. In larger blocks, remnants of sheeted dikes, as well as pillow lavas, are recognizable.

Most of the basalts are holocrystalline. About 80–85 vol.% of the basalts contain phenocrysts, the rest are aphyric. Phenocrysts formed from plagioclase alone, plagioclase + clinopyroxene, and rarely from olivine alone and olivine + plagioclase. There is a large variety of textures such as ophitic, subophitic, intersertal and intergranular. Glass is restricted to brecciated pillow lavas. Olivine is mostly altered, forming chlorite-bearing pseudomorphs, locally with chromite inclusions. Clinopyroxene plots within the augite field. Plagioclase is normally zoned, with An_{94} in the core and An_{40} at the rim (Hoeck et al. 2002). Spinels have a high X_{Cr} at a given X_{Mg} compared to lherzolites, and a significantly higher X_{Mg} compared to cumulates and gabbros. Amphibole shows a wide range of composition including tschermakite, magnesiohornblende and actinolite. Most of amphiboles were formed from clinopyroxene during alteration. Other secondary minerals include chlorite, serpentine, titanite, prehnite and zeolites.

The overwhelming majority of volcanics are basalts, according to the TAS diagram. Only a few appear as basaltic andesites. The MgO value from 7 to 13 mass% indicates some fractionation. The TiO_2 content typically ranges from 0.5 to 3 mass%.

Regarding the trace elements and the REE, two groups of basaltic lavas (including dikes) have been distinguished. The first group displays a typical MORB signature, with a slightly convex-up pattern in chondrite-normalized diagrams (Hoeck et al. 2002). The HFSE are close to unity in rock/MORB spider diagrams. In the V versus Ti diagram (Shervais, 1982) basalts plot entirely within the MORB field. They are identical with the MOR basalts described from northern Albania (Bortolotti et al. 1996, 2002, 2013, Saccani et al. 2004, 2011, Saccani & Photiades 2005, Dilek et al. 2008). However, a small but significant negative Nb and Ta anomaly is visible in the spider diagrams. This negative anomaly is generally interpreted as a supra-subduction signature (Hoeck et al. 2002).

The second group includes basalts, intermediate between MOR and SSZ basalts. They show, at least partly, a more pronounced negative Nb-Ta anomaly and additionally depletion in Zr, Ti and Y. The most significant difference from MOR basalts (the first group) is the strong depletion of LREE. Such intermediate basalts are described also in Northern Albania and the Hellenides (Bortolotti et al. 2002, 2013, Saccani et al. 2004, 2011, Saccani & Photiades 2005). Finally, basalt from Luniku, with even significantly lower Ti, Zr, Y and Nb content, can be classified as boninite.

3.8. Sediments above ophiolites

The Jurassic Mirdita ophiolites are covered in many places by sedimentary sequences. The sediments have a special importance as they may provide information on “ophiolite emplacement, including tectonic setting, palaeoenvironment and the timing of events” (Robertson et al. 2012).

In Northern Albania the sedimentary cover of ophiolites includes Bajocian-Middle Callovian/Oxfordian radiolarian cherts – the so called ‘Kalur cherts’ (Marcucci et al. 1994, Marcucci & Prela

1996, Chiari et al. 2002), and debris flows above. The latter, known as 'Simoni Mélange', has a typical 'block-in-matrix' structure and contains blocks with a wide lithological range, e.g., ultramafics, sandstones, limestones, radiolarites, basalts and even granitoid rocks (Bortolotti et al. 1996, Kodra et al. 1996). This succession is followed by Late Tithonian to Late Valanginian pelagic limestones (Gardin et al. 1996) interbedded with calcareous turbidites ('Firza Flysch'), overlain by Barremian to Albian platform limestones with conglomerates at the base (Bortolotti et al. 1996).

In Southern Albania the sediments on top of the ophiolites were recently described in six profiles in the Shpati, Voskopoja (including Rehove), Morava and Luniku massifs by Robertson et al. (2012). The following description is based on this paper. The thickness and the lithology change rapidly between the individual profiles. As well, the basement of the sediments is different, including mylonitic lherzolites, pillow lavas, siliceous shales and serpentinites. Radiolarites are rare, either on top or interbedded with pillow lavas. Above radiolarites or siliceous shales where present, there are ophiolite-derived breccias and conglomerates. The clasts range from well-rounded to angular and comprise all ophiolitic lithologies. The thickness of breccias and conglomerates reaches up to several hundred meters. Higher up in the succession, they become finer grained and better stratified. Siltstones and sandstones become increasingly more frequent. The fine-grained clastic sediments are interbedded with argillaceous limestones which eventually grade into pelagic limestones. The thick breccias were deposited by various mechanisms, varying from rock fall to debris flows, during or shortly after the ophiolite emplacement. The overlaying pelagic *calpionellid* limestones become upwards shallow-water limestones often interbedded with conglomerates. The whole sequence is covered by transgressive Aptian-Albian limestones.

3.9. Emplacement age of ophiolites

Based on findings related to radiolarites at Miraka, Gawlick et al. (2008) envisage a Triassic (Late Anisian) ocean basement, i.e. "the oldest known Mesozoic ocean floor remnant in the western part of the Neotethys Ocean". Consequently, in the Dinaride-Albanide-Hellenide zone the ocean floor started to form during the Middle Triassic (Gawlick et al. 2008) and continued up to the Middle Jurassic, over ~75 Ma. Radiolarites on top of the ophiolitic sequence range up from Bajocian to Callovian/Oxfordian (Marcucci et al. 1994, Marcucci & Prela 1996, Chiari et al. 2002). The fossils in the pelagic limestones (see previous chapter) indicate an Early Tithonian to Valanginian age. However, the metamorphic soles (Dimo-Lahitte et al. 2001 and references therein) were dated to between 174 and 159 Ma and interpreted as the onset of the ophiolite emplacement. These datings indicate that ophiolite emplacement in Albania started while radiolarites were deposited, i.e. during the Middle Jurassic (Bajocian). The emplacement was most likely completed after the deposition of radiolarites and before the onset of shallow water sediments during the Tithonian (Robertson et al. 2012).

Part II: Field Stops

The excursion will visit the following field stops (Fig. 17): Miraka A, Miraka B, Librazhd, Stravaj A, Stravaj B, Qafe Thane, Lini, Pojska, Kapshtica, Barçi, Shipcka, Ura Verbes, Gjinikas, Nikollara, Devolli and Bulcari. Three cultural stops, at Elbasan, Korça and Voskopoja, are included as well.

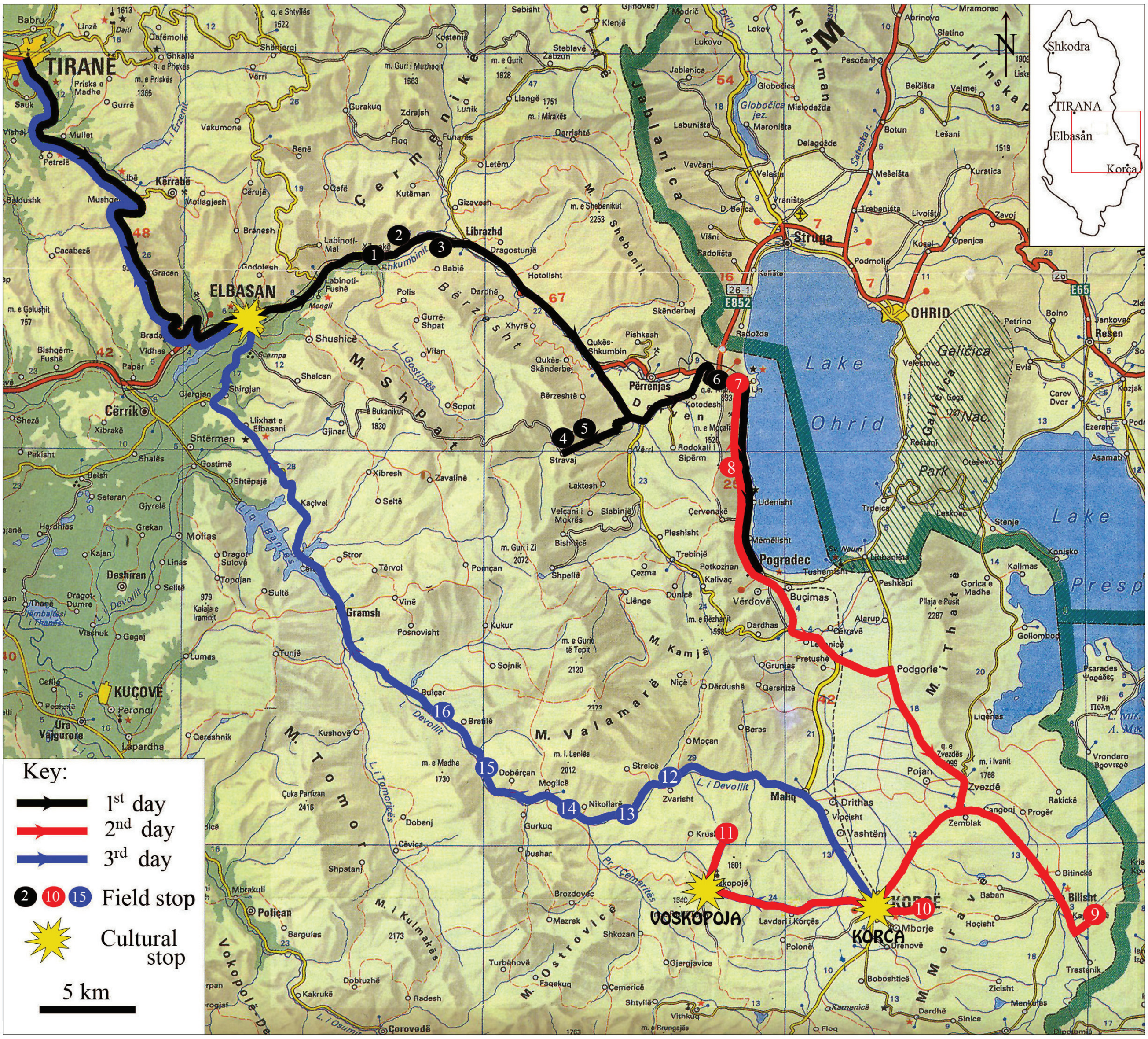


Figure 17. The itinerary of the FT5 excursion and the location of the field stops: 1 – Miraka A; 2 – Miraka B; 3 – Librazhd; 4 – Stravaj A; 5 – Stravaj B; 6 – Qafe Thane; 7 – Lini; 8 – Pojska; 9 – Kapshtica; 10 – Barçi; 11 – Shipcka; 12 – Ura Verbes; 13 – Gjinikas; 14 – Nikollara; 15 – Devolli; 16 – Bulcari. The insert in the upper right shows the position of the map within Albania. Map from 'Albania, road map & tourist guide' by Inter Map Inc., modified.

Day 1 (Saturday, September 27th, 2014): From Tirana to Pogradec

Cultural stop - Elbasan

***Location**: center of Albania, on the Shkumbini River, about 35 km SE of Tirana (Fig. 17).*

***Coordinates**: N 41°06.728' and E 20°04.805'; Elevation: 130 m.*

With almost 130,000 people, Elbasan is one of the largest cities of Albania. Over time, it has had several names: Neokastron, Novigrad and Terra Nuova (http://en.wikipedia.org/wiki/Elbasan).

The settlements in this area date back to Antiquity. One of the most outstanding historical buildings in the area is a fortress built by the Turks in the 15th century, which is still preserved in the center of the city (Fig. 18a,b). The fortress is crosscut by Via Egnatia – a road across the Balkan Peninsula, built by the Romans in the 2nd century A.D. It was paved, 6 m wide, and its traces can be followed in modern day Albania, the FYROM, Greece and Turkey (the European part). Within the fortress, is the famous Turkish bath of Sinan Pasha (19th century).

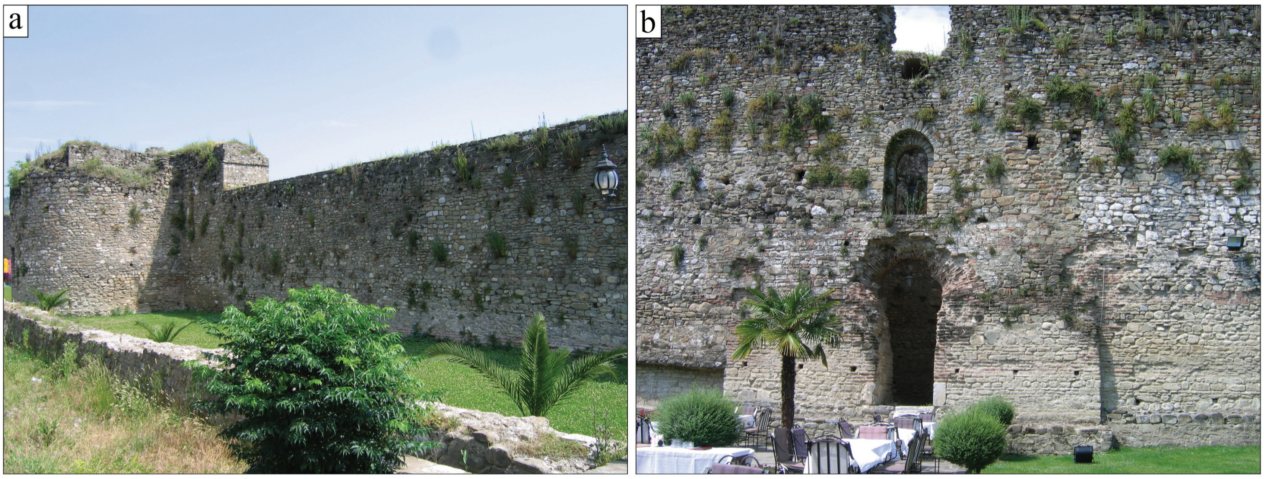


Figure 18. a) The fortress in Elbasan; b) Detail of the inner yard of the fortress. (Photos C. Ionescu).

Field stop 1 - Miraka A (Shpati massif): *Mélange beneath ultramafics*

***Location**: Shkumbini River, ~12.5 km ENE of Elbasan (Figs. 17 and 19).*

***Coordinates**: N 41°09.776' and E 20°13.868'; Elevation: 190 m.*

The outcrop at Miraka shows the subophiolitic mélange with a typical 'block-in-matrix' structure, i.e. a large variety of blocks of all sizes in an ophiolite-derived coarse matrix. The clasts derive from various Triassic environments and have variable size and age. Poorly sorted, more or less rounded pebbles and boulders as well as small blocks are dominant (Fig. 20). The clast lithologies include ultramafics, basalts, gabbros, and radiolarites, as well as limestones. The size of the blocks varies from <1 m to several meters, tens of meters and sometimes even kilometers.

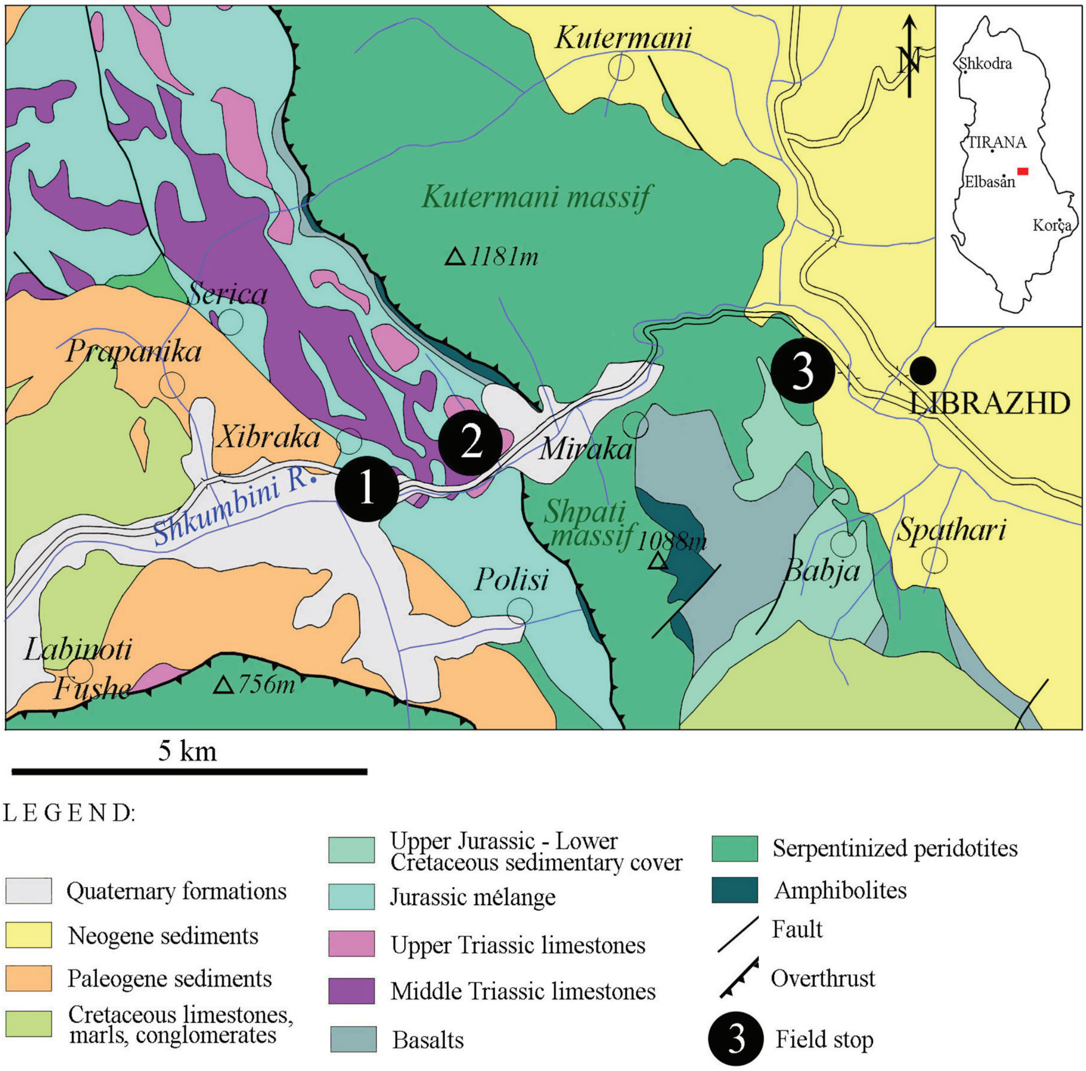


Figure 19. Simplified geological map of the Librazhd area (Shpati and Kutermani massifs), with the location of the field stops: 1 – Miraka A, 2 – Miraka B, and 3 – Librazhd. Geology after Xhomo et al. (2002) and Onuzi et al. (unpublished) modified. The insert in the upper right shows the position of the map within Albania.

Figure 20. Mélange outcrop along the Shkumbini River (field stop 1 - Miraka A), showing poorly sorted, rounded clasts of ophiolites in an ophiolite-derived black matrix. (Photo by K. Onuzi).

Field stop 2 - Miraka B (Shpati massif): Triassic radiolarites and limestones in mélange

Location: about 13 km ENE of Elbasan, along the Shkumbini River, on the road from Elbasan to Librazhd, at the railway tunnel (Figs. 17, 19 and 21).

Coordinates: N 41°09.983' and E 20°14.215'; Elevation: 200 m.

This outcrop is part of the Jurassic mélange (Xhomo et al. 2002) consisting of several blocks of Triassic gabbros and basalts covered by Triassic radiolarites. Furthermore, there are blocks of Jurassic radiolarites and Upper Triassic hemipelagic limestones. According to Gawlick et al. (2008), the most important rocks at Miraka are gabbros and basalts overlain by "12 m thick cherty shales and radiolarites, and finally bedded hemipelagic limestones" (Figs. 22 and 23). A Middle to early Upper Triassic age was determined for the radiolarites and a Carnian to Norian age for limestones (Gawlick et al. 2006, 2008).

In the outcrop, Middle Jurassic radiolarite-derived matrix was found (Fig. 21). Further on, there are also large blocks of thick bedded Upper Triassic limestone. The latter has a grey to light grey color and consists of massive, as well as algae limestones. The stratigraphic range of the sediments has been determined based on fossil content, i.e. foraminifera, algae, bivalves and corals. Fig. 23 shows the open marine Miraka column, dated by radiolarians and conodonts.

Based on findings related to radiolarites at Miraka, Gawlick et al. (2008) envisage a Triassic (Late Anisian) ocean basement, i.e. "the oldest known Mesozoic ocean floor remnant in the western part of the Neotethys Ocean". Consequently, in the Dinaride-Albanide-Hellenide zone the ocean floor started to form during the Middle Triassic. Gawlick et al. (2008) interpret the Mirdita ophiolites as part of the Vardar Ocean thrust more than 150 km to the west onto the internal Albanides.

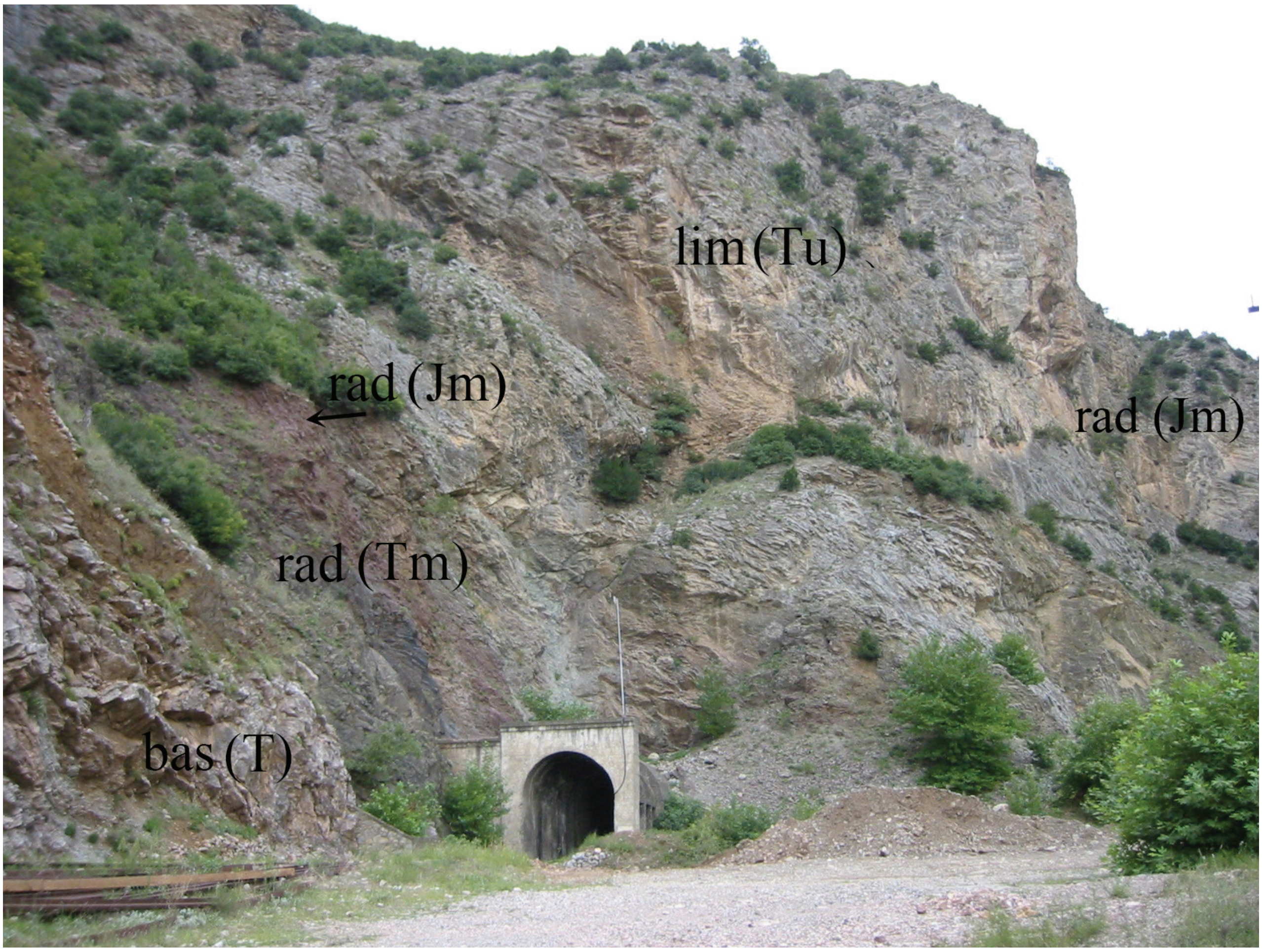


Figure 21. Triassic basalts – bas(T) covered by Middle to Upper Triassic radiolarites – rad(Tm). The outcrop shows small blocks of Middle Jurassic radiolarite – rad(Jm) and a large block of Upper Triassic hemipelagic limestone – lim(Tu). From Gawlick et al. (2008), modified; Photo by courtesy of H.-J. Gawlick).

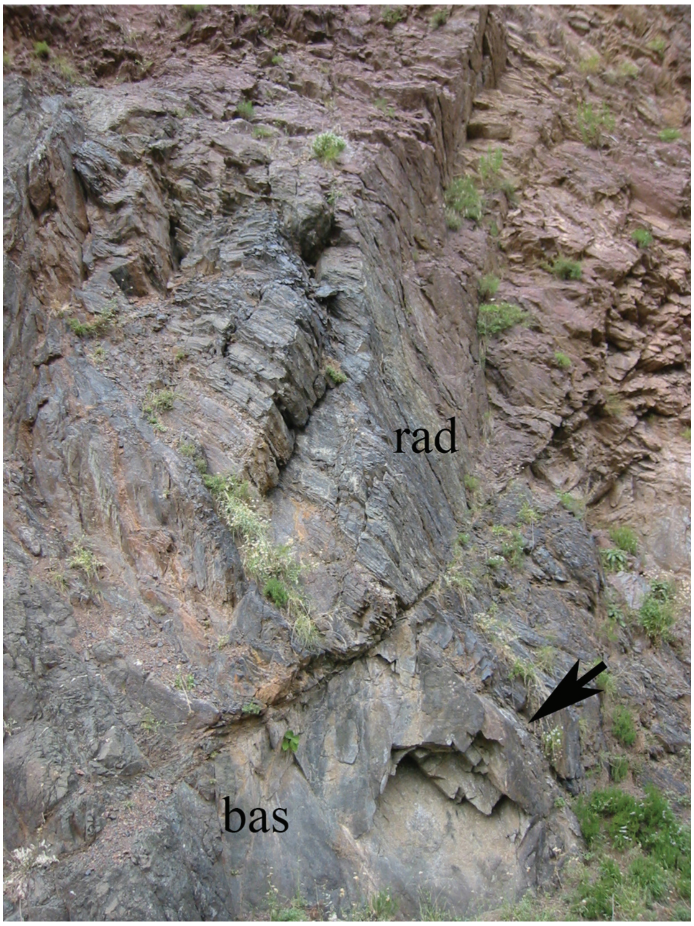
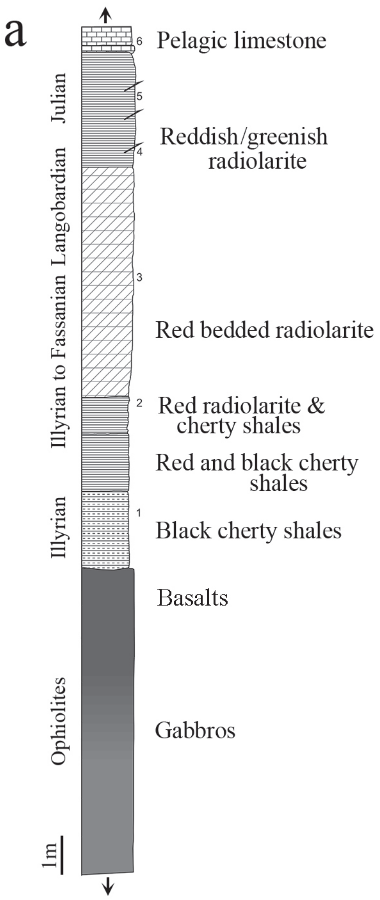


Figure 22. Close-up view of Middle Triassic radiolarites (rad) covering the Triassic basalts (bas), at Miraka. The arrow points to the contact. From Gawlick et al. (2008) modified; Photo by courtesy of H.-J. Gawlick.



b

6	*Metapolygnathus polygnathiformis*
5	*Annulotriassocampe sulovensis* *Muelleritortis expansa* *Pseudostylosphaera nazarovi* *Tritortis disperalis* *Tritortis kretaensis* *Vinassaspongus subsphaericus*
4	*Latium cf. paucum* *Triassocampe cf. deweveri* *Muelleritortis cochleata* *Muelleritortis expansa* *Spongoserrula fluegeli*
3	*Pararuesticyrtium cf. illyricum* *Pararuesticyrtium (?) cf. trettoense* *Pseudostylosphaera langobardica* *Welirella cf. weveri*
2	*Eptingium cf. japonicum* *Pseudostylospaera sp.* *Spongostephanidium sp.* *Triassocampe cf. scalaris* *Triassocampe cf. transita*
1	*Eptingium japonicum* *Parasepsagon cf. praetetracanthus* *Pseudoertlispongus cf. hermi* *Pseudostylospaera sp.* *Triassosponogosphaera cf. multispinosa*

Figure 23.
a) Stratigraphic column at Miraka;
b) The fossil content at several levels of the column (1 to 6). From Gawlick et al. (2008), simplified; Draw by courtesy of H.-J. Gawlick.

Field stop 3 - Librazhd (Shpati massif): Backthrust of serpentinites onto molasse

***Location**: around 2 km NW of Librazhd, along the road from Elbasan to Librazhd (Figs. 17 and 19).*

***Coordinates**: N 41°11.272' and E 20°17.727'; Elevation: 245 m.*

Along the Shkumbini River, the overthrust of Shpati massif ultramafics onto the molasse sediments of the Librazhd Basin are exposed (Fig. 24a). The ultramafics are highly serpentinized peridotites. Beneath the thrust line the sediments are highly deformed (Fig. 24b).

The molasse sediments include mostly clastic sediments, i.e. sandstones and conglomerates, as well as mudstones. The 'Librazhd Reddish Formation' of Serravallian age (Fig. 25) is the lowest and thickest part of the Librazhd intramontane basin. It formed by a marine transgression coming from the northwest (Meço & Aliaj 2000). It is deposited on ophiolitic ultramafic rocks in the north and Eocene-Aquitanian sediments in the south. The 'Librazhd Reddish Formation' has a variable thickness, ranging from ~180 m to ~500 m and consists of conglomerates and sandstones with rare intercalations of mudstone (Fig. 25; Meço & Aliaj 2000).

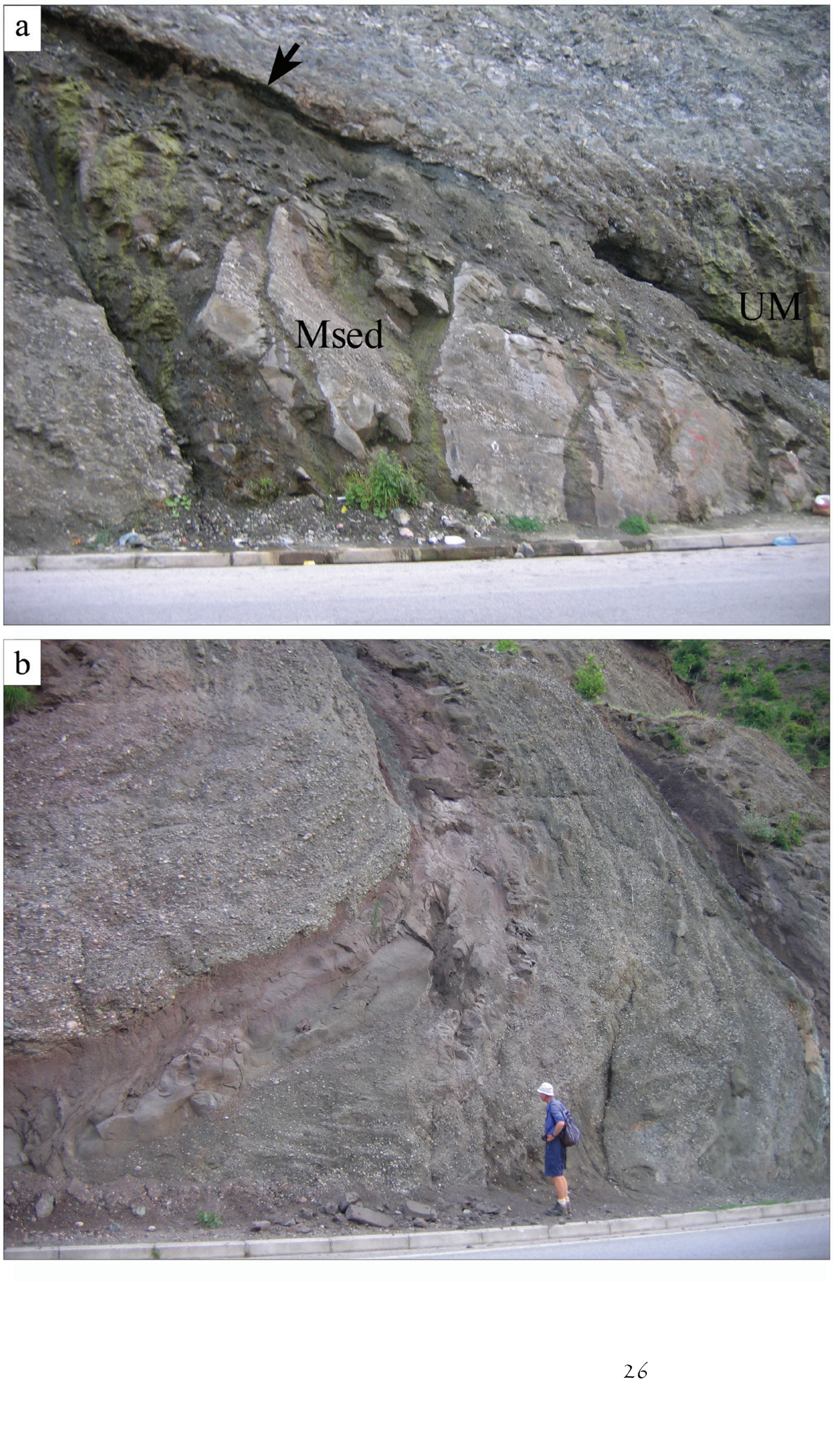


Figure 24.
a) Overthrust of serpentinized ultramafics (UM) of the Shpati massif to the east, over the molasse sediments (Msed), i.e. the Librazhd Reddish Formation; the black arrow marks the overthrust plane;
b) Detail of folded and overturned molasse sediments beneath serpentinites of the Shpati massif. (Photos by V. Hoeck).

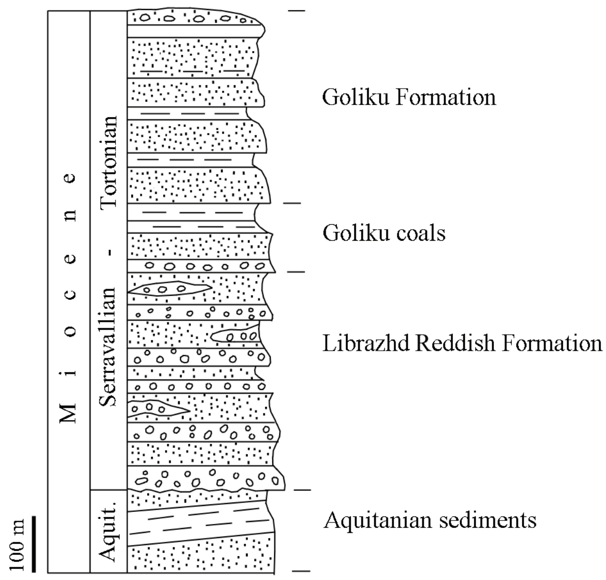


Figure 25. Stratigraphic column of the Miocene molasse in the Librazhd Basin (redrawn and modified column by Pashko 1996 - fide Meço & Aliaj 2000).

Field stop 4 - Stravaj A (Shpati massif): Basalts and dolerite dikes

Location: village of Stravaj, about 35 km SSE of Librazhd (Figs. 17 and 26).

Coordinates: N 41°00.608' and E 20°24.591'; Elevation: 780 m.

The village of Stravaj is bordered by steep slopes in the north and soft slopes to the south (Fig. 27a). On the slopes, small concrete cupolas – relics of one-person bunkers from the communist period - were still preserved in 2009 (Fig. 27b). The outcrop shows the uppermost part of the ophiolite sequence (Havancsák et al. 2012), with

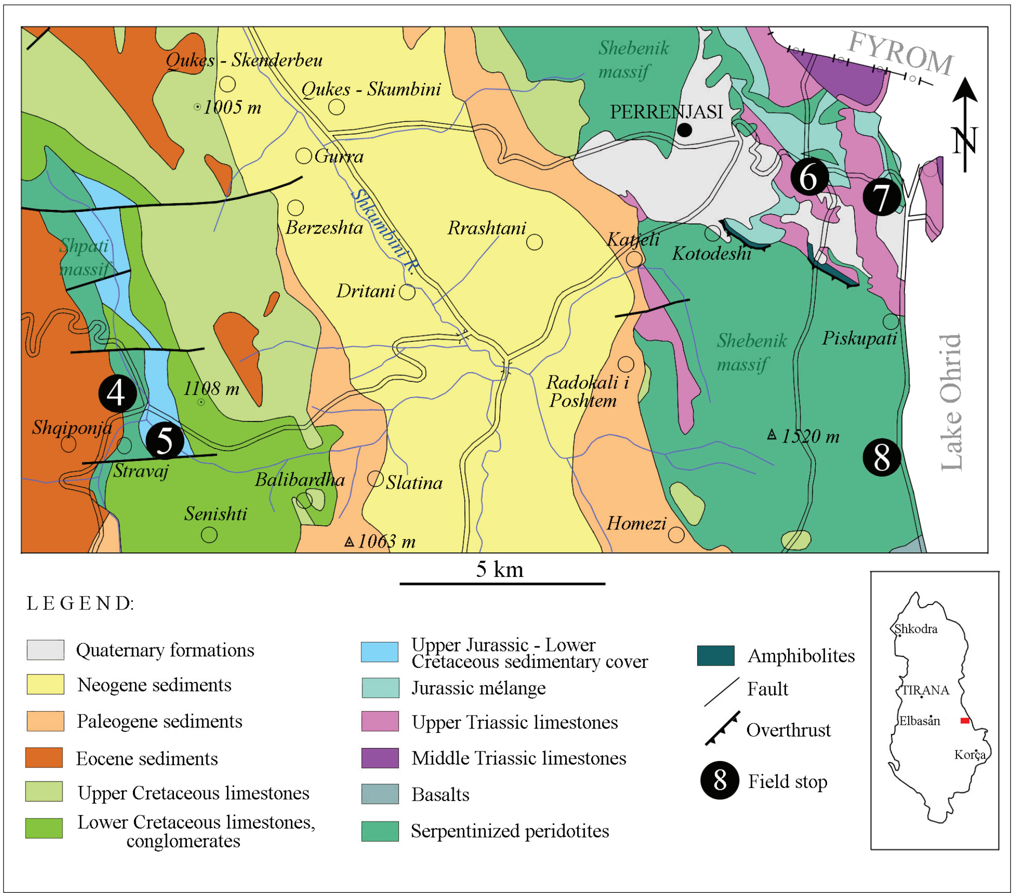


Figure 26. Simplified geological map of the Shpati and Shebenik massifs, with the locations of the field stops
4 – Stravaj A,
5 – Stravaj B,
6 – Qafe Thane,
7 – Lini
and
8 – Pojska.
Geology after Xhomo et al. (2002), modified. The insert in the lower right shows the position of the map within Albania.

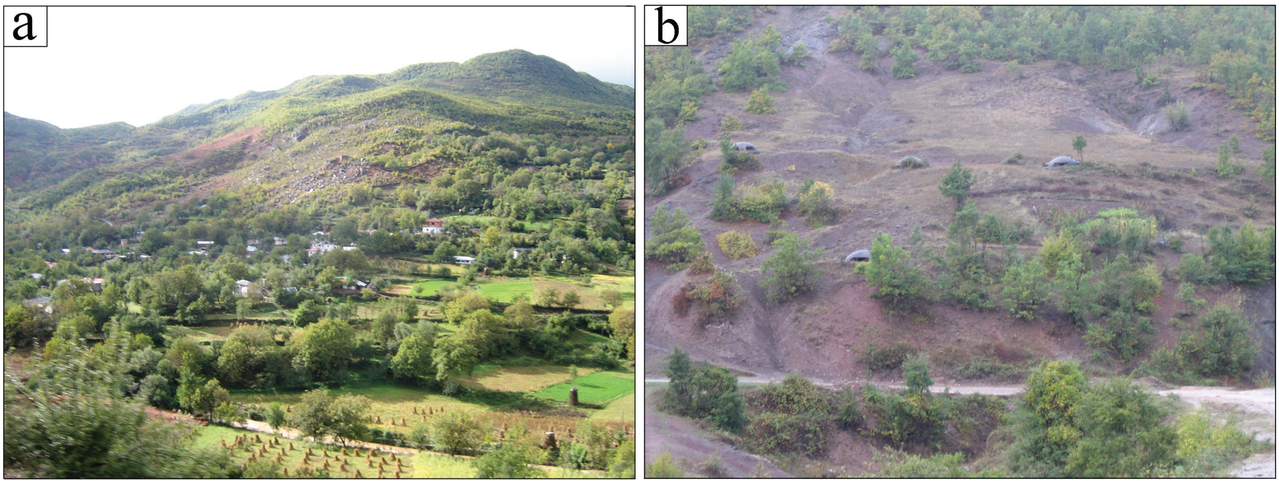


Figure 27. a) Stravaj village and the Shpati massif seen from field stop 5; b) Remnants of the communist era: concrete one-person bunkers on the slopes facing Stravaj village. (Photos by C. Ionescu).

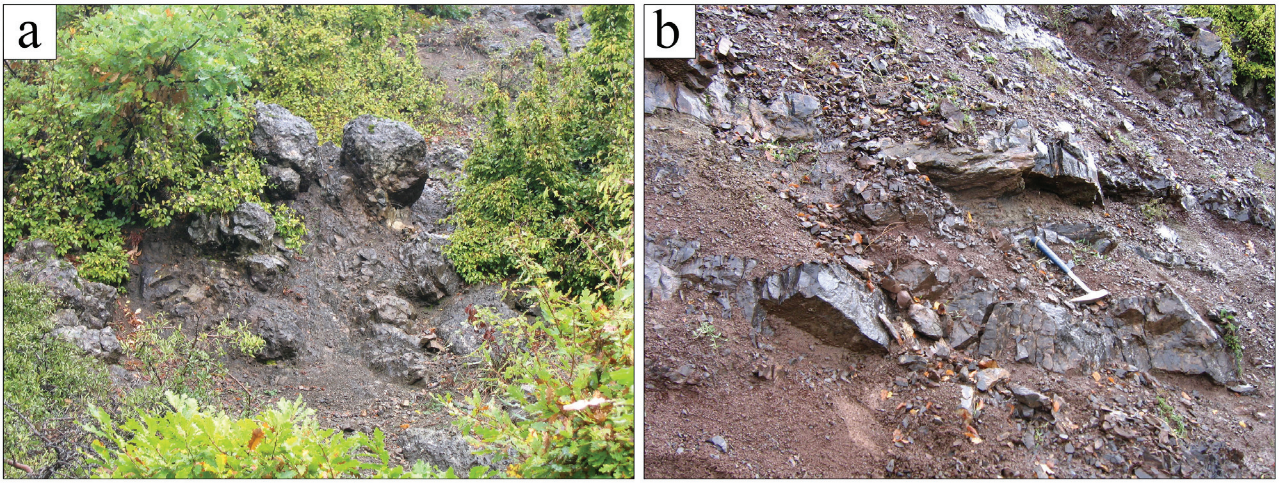


Figure 28. a) Basaltic pillow lava at Stravaj; b) Dolerite dikes in pillow lavas, evidenced by erosion. (Photos by C. Ionescu).

pillow basalts and pillow breccia, crosscut by dolerite dikes (Fig. 28a,b). The breccias consist of basaltic clasts, fragments of volcaniclastic siltstone made up of plagioclase and clinopyroxene, chlorite and fragments of altered hyaloclastite (Robertson et al. 2012). The pillows are overlain by red siliceous shales (see field stop 5 - Stravaj B).

The dolerite dikes within the pillows have a high Ti MOR chemical signature whereas other dikes further to the north, in the same massif, are more depleted. The latter are dikes crosscutting gabbros or peridotites. Both basalts types (see Chapter 3.7 'Volcanic sequence') are found among the pillow and massive lava flows, indicating that both MOR and SSZ types erupted more or less simultaneously.

Field stop 5 - Stravaj B (Shpati massif): Sediments above ophiolites

Location: in the village of Stravaj, a few hundred meters east of field stop no. 4 (Figs. 17 and 26).

Coordinates: N 41°00.465' and E 20°25.256'; Elevation: 730 m.

A large outcrop in Stravaj exhibits sedimentary cover of the volcanics seen at field stop 4. The sequence includes (Robertson et al. 2012) at the bottom, reddish siliceous shales a few meters-thick (Fig. 29a,b), directly covering the pillow basalts. They grade into serpentinite-derived sandstone followed by serpentinite-derived conglomerate and calcite-cemented conglomerate (with basalt, gabbro, dolerite and neritic limestone clasts, and detrital serpentinite as matrix). After several meters without any outcrop, conglomerate appears again and grades into pebbly sandstone with clasts of fossiliferous micritic limestone. This is followed by volcaniclastic sandstone with pebbly conglomerate intercalations which become more frequent upwards in the sequence. The sequence ends with reddish bioclastic limestones, of Early Cretaceous age (Robertson et al. 2012).

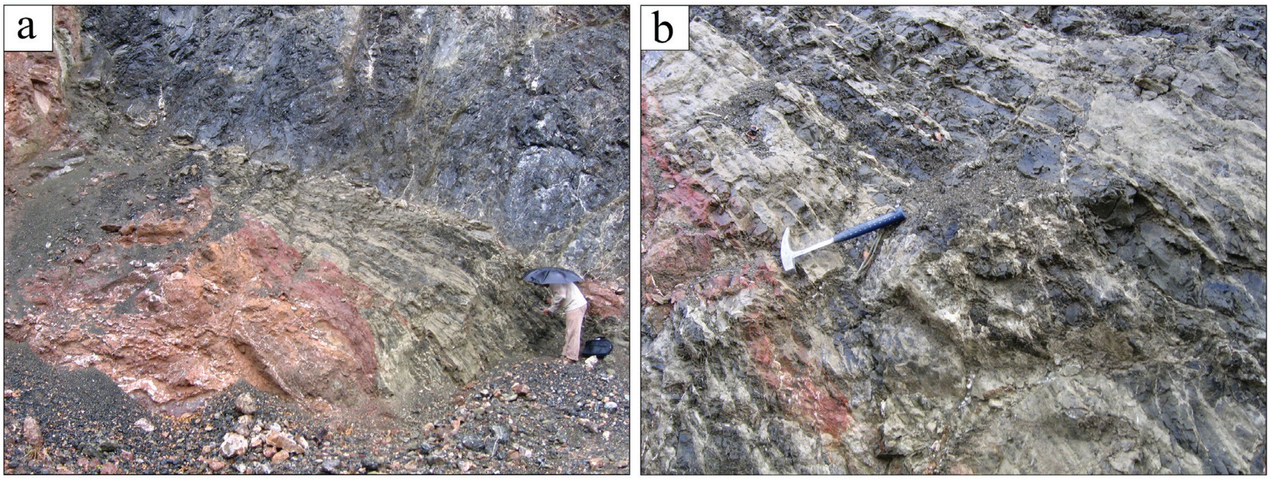


Figure 29. Sedimentary cover of ophiolites at Stravaj B: a) Sequence of reddish and greenish ophiolitic sandstones; b) Detail of the sandstones. (Photos by C. Ionescu).

Field stop 6 - Qafe Thane: Geological overview

***Location**: About 7.5 km E of Perrenjasi, at the Qafe Thane pass (Figs. 17 and 26).*

***Coordinates**: N 41°03.917' and E 20°36.533'; Elevation: 930 m*

The stop at Qafe Thane pass offers an overview of mélange formations overthrust by the Shebenik massif, at the eastern side of the ophiolite belt. Looking towards Lake Ohrid (Fig. 30) shows the Lini peninsula and various Triassic and Jurassic formations. The mountains in the background east of Lake Ohrid represent the Korabi-Pelagonian Zone. Towards the west, the Shpati ophiolitic massif, its Late Cretaceous limestone cover and the molasse zone can be seen.

Figure 30. Lake Ohrid seen at field stop 6 - Qafe Thane pass. (Photo by K. Onuzi).

Day 2 (Sunday, September 28th, 2014)
From Pogradec to Korça

Field stop 7 - Lini (Shebenik massif): Mélange

Location: around 10 km E of Perrenjasi, along the road from Elbasan to Librazhd, 2.5 km east of field stop no. 6 (Figs. 17 and 26).

Coordinates: N 41°03.797' and E 20°37.887'; Elevation: 780 m.

In an outcrop at Lini (Fig. 29a,b), a similar subophiolitic mélange formation to that at field stop 1 (Miraka, on Shkumbini River) occurs. The structure is of 'block-in-matrix' type, with blocks of various size (from cm to km) and nature (ultramafics, gabbros, limestones, sandstones, basalts and radiolarites) embedded in a fine-grained matrix (Fig. 31a,b). The latter consists of ophiolite-derived material mixed with fine-grained clastic sediments (mudstone, siltstone). In particular, the white Upper Triassic limestone blocks are visible in the brown matrix (Fig. 31b).

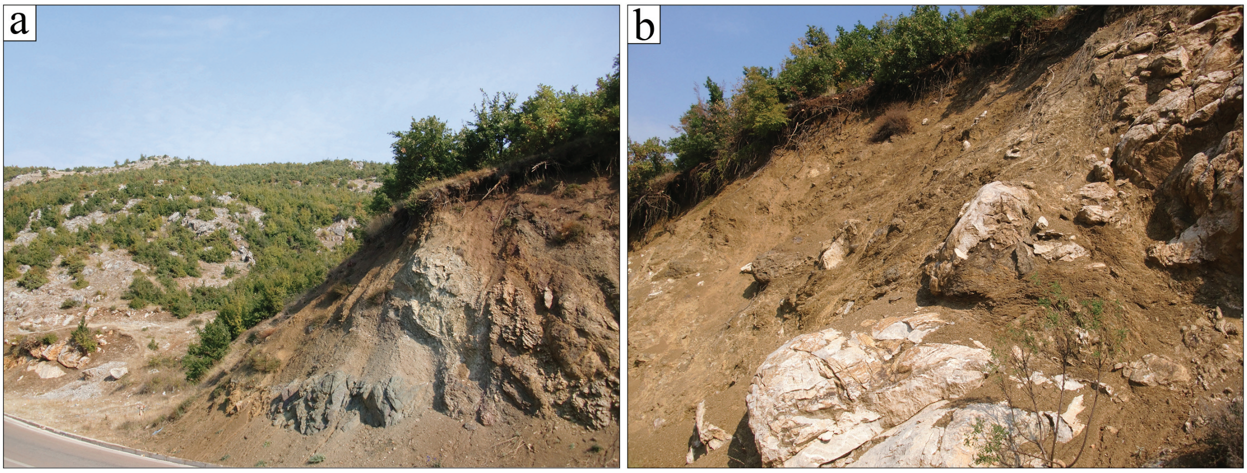


Figure 31. Mélange at Lini with: a) Ultramafic small blocks (greenish, lower part of the outcrop) and b) Upper Triassic limestone blocks (white) in an ophiolite-derived matrix (dark brown). (Photos by K. Onuzi).

Field stop 8 - Pojska (Shebenik massif): Ultramafics with chromite

Location: along the road from Perrenjasi to Pogradec, ~11 km NNW of Pogradec (Figs. 17 and 26).

Coordinates: N 41°01.155' and E 20°38.167'; Elevation: 720 m.

Albania is well known for chromite deposits associated with ultramafics in ophiolites (Beqiraj et al. 1995, 2000, Masi et al. 1998, Hallaci et al. 2004, Quintiliani et al. 2006, Hoxha 2007). The deposits in the Shebenik massif (Kocks et al. 2007), contain chromite mineralizations in the dunite lenses hosted by massive harzburgite (Fig. 32). At Pojska, the harzburgites are coarse grained rocks, serpentinized in places, composed of mainly olivine and orthopyroxene, with low amounts of clinopyroxene and Cr-spinel. Dunite lenses are variable in thickness, from a few centimeters to several meters and occur at several levels within the harzburgites.

Chromite occurs either as disseminated grains or concentrates in lenses, nodules and pseudo-layers, i.e. podiform bodies. The Cr_2O_3 exceeds 4 mass% (Onuzi et al. 2012). Chromite grains are in the range of 1 mm in size. Ore was exploited here until 1996, when the mining activity was closed down.

Figure 32.
Ultramafics with chromite-bearing dunite at Pojska. (Photo by K. Onuzi).

Field stop 9 - Kapshtica (Bitincka massif): Fe-Ni deposit

***Location**: around 29 km E of Korça and 3 km E of town of Bilishti, along the road from Korça to Greece (Figs. 17 and 33).*

***Coordinates**: N 40°36.683' and E 21°01.250'; Elevation: 1000 m.*

The Kapshtica deposit in the Bitincka massif is among the Fe-Ni rich laterite occurrences in Albania. The Ni deposits from the Bitincka massif contain an estimated resource of 35.6 Mt, with an average of 1.2 mass% Ni (Thorne et al. 2012). According to these authors, in the 2006–2011 period ~120,000 t of ore were extracted in the Bitincka mines alone. The ore bodies are aligned over 1 km along a N-S direction and dip steeply towards the east. The unexploited reserves in Kapshtica total almost 20 Mt, with 1.25 mass% Ni, 43 mass% Fe and 0.04 mass% Co on average (National Agency for Natural Resources Albania, 2007).

Here we will follow the detailed description provided by Thorne et al. (2012) regarding the Fe-Ni ore in Kapshtica. The Fe- and Ni-rich concentrations are located between Jurassic ultramafics (at the base) and the Eocene sedimentary cover (Fig. 34a,b). The ultramafics consist of highly serpentinized peridotites, which have most likely been emerged since the Early Cretaceous (Thorne et al. 2012). Due to weathering in a warm tropical to sub-tropical climate, laterite horizons formed at the expense of peridotites, most likely until Eocene. The

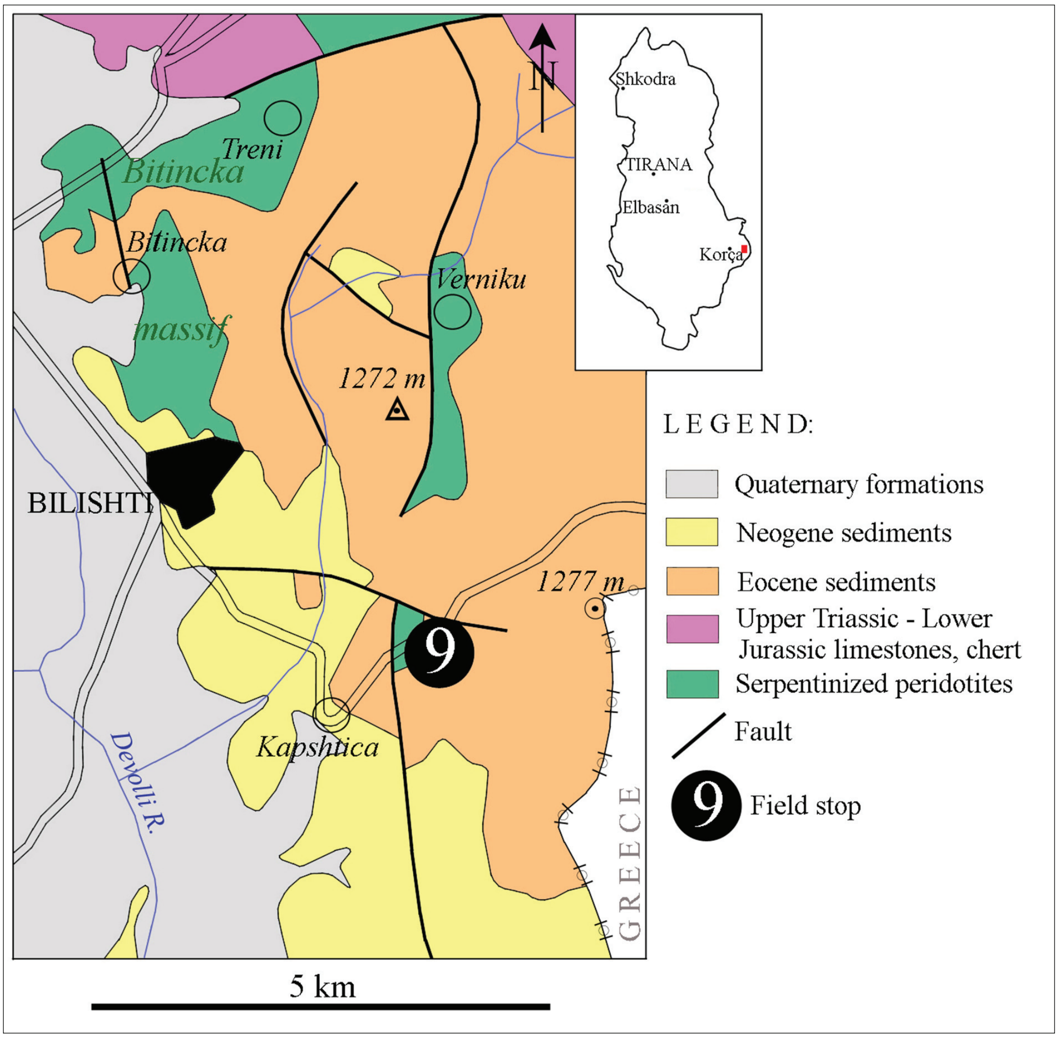


Figure 33. Simplified geological map of the Bitincka massif, with the location of field stop 9 – Kapshtica. Geology after Xhomo et al. (2002), modified. The insert in the upper right shows the position of the map within Albania.

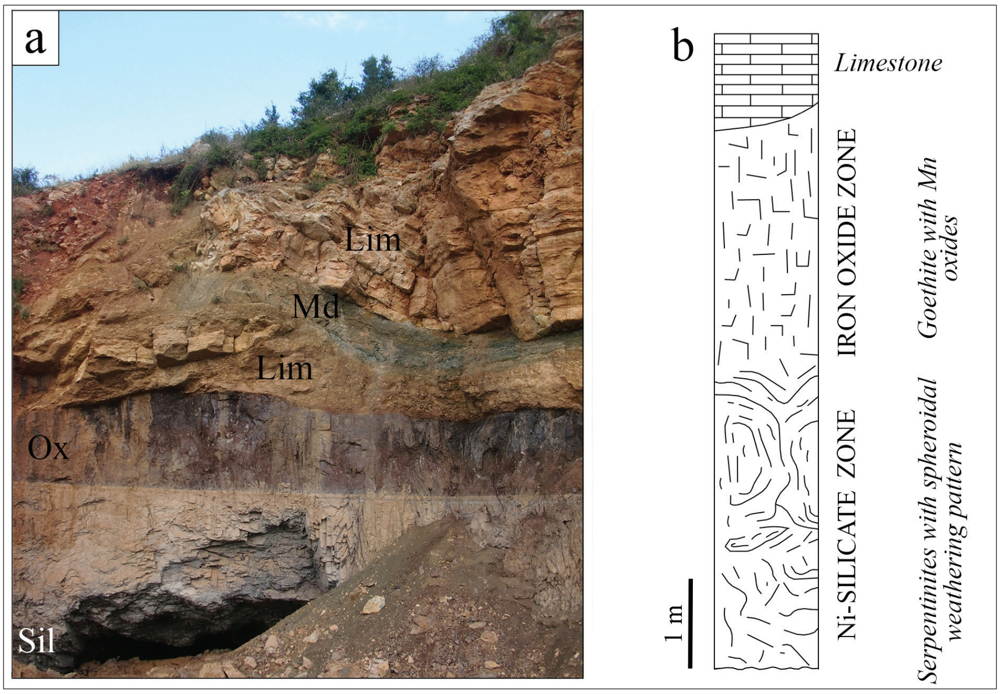


Figure 34. a) Fe-Ni rich lateritic horizons at Kapshtica; photo by K. Onuzi; b) Geological profile through the Fe-Ni rich laterite; modified and redrawn from Thorne et al. (2012). Abbreviations: Sil – Ni-silicate zone, Ox – Oxide zone, Lim – Limestone, Md – Mudstone.

maximum age of lateritization is constrained by the age of the limestone cover (Molla et al. 1994).

The laterite formation consists of two zones (Fig. 34a,b). The lower zone is the so-called 'Ni-silicate zone' (NSZ), while the upper is termed the 'iron oxide zone' (IOZ). The 1–5 m thick NSZ shows characteristic spheroidal weathering, with fresh serpentinite cores up to 2 m in diameter, surrounded by decimeter-thick red to orange alteration rims. The NSZ is made of montmorillonite, with scattered relics of chromite, serpentinized olivine and pyroxene. Calcite and sometimes garnierite veins occur as well. The NSZ has up to 1.5–2 mass% Ni, ~10 mass% Fe_2O_3 and ~30 mass% SiO_2 (Thorne et al. 2012).

The thickness of the IOZ is variable, between ~2 m and maximum 4 m. The iron oxide zone consists mainly of goethite, with scattered chromite grains. It is crosscut by numerous fissures, on which microcrystalline quartz and manganese oxides are deposited. The Ni content of the IOZ ranges between 0.25 and 1.5 mass%, Fe_2O_3 is up to 80 mass%, and SiO_2 up to 5 mass% (Thorne et al. 2012).

Above the NSZ and IOZ there is a layer with reworked serpentinite material mixed with red clay, overlain by Cenozoic limestones, mudstones and conglomerates.

Field stop 10 - Barçi (Morava massif): Geological overview and plagioclase peridotites

***Location**: around 4 km E of Korça, on a hill with a cross (Figs. 17 and 35).*

***Coordinates**: N 40°36.633' and E 20°48.84'; Elevation: 1340 m.*

The outcrop which was opened along a new road built on the hill east of Korça in the Morava massif (Fig. 36a) shows massive plagioclase peridotites crosscut by faults and fissures. Gabbro dikes, a few centimeters to several

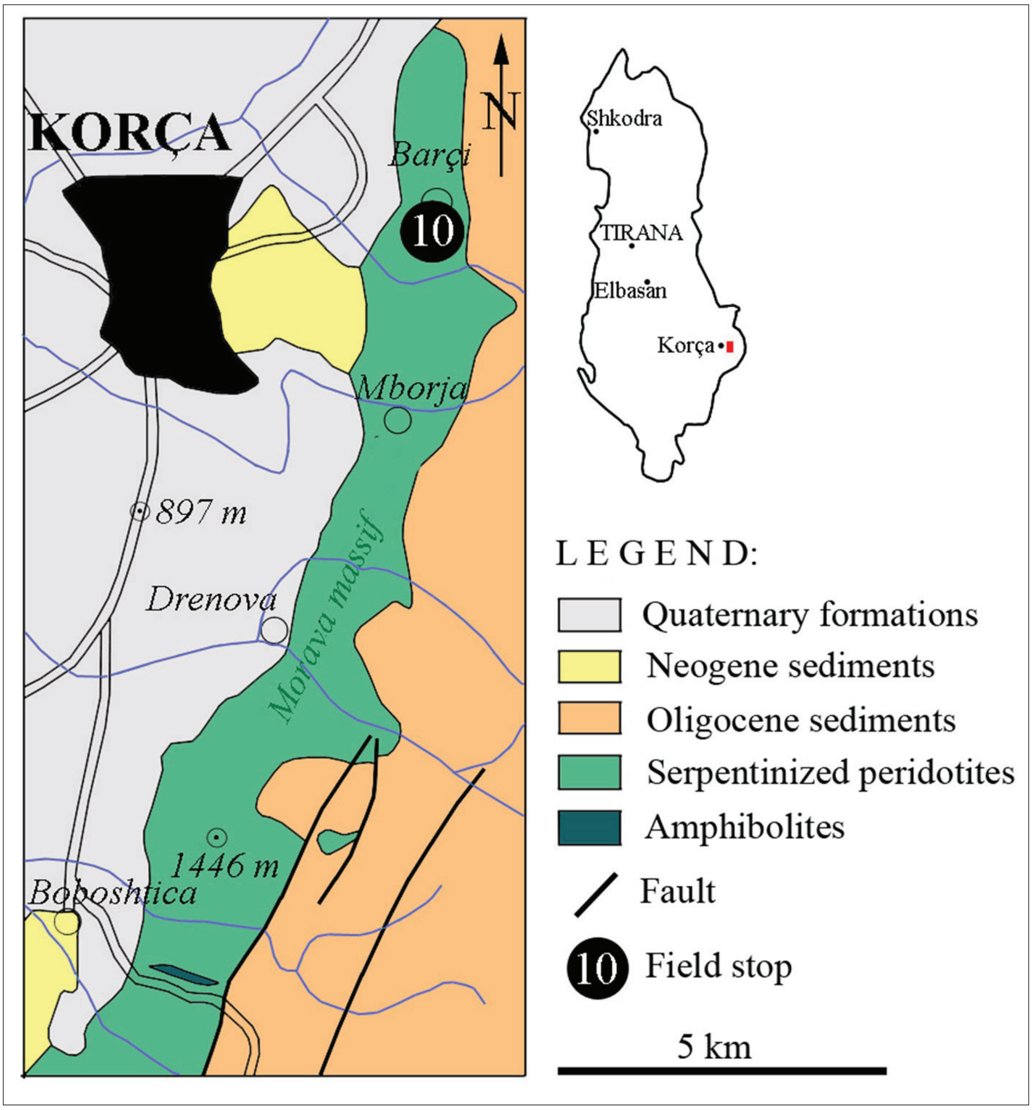


Figure 35.
Simplified geological map of the Morava massif, with the location of field stop 10 – Barçi and the cultural stop at Korça. Geology after Xhomo et al. (2002), modified. The insert in the upper right shows the position of the map within Albania.

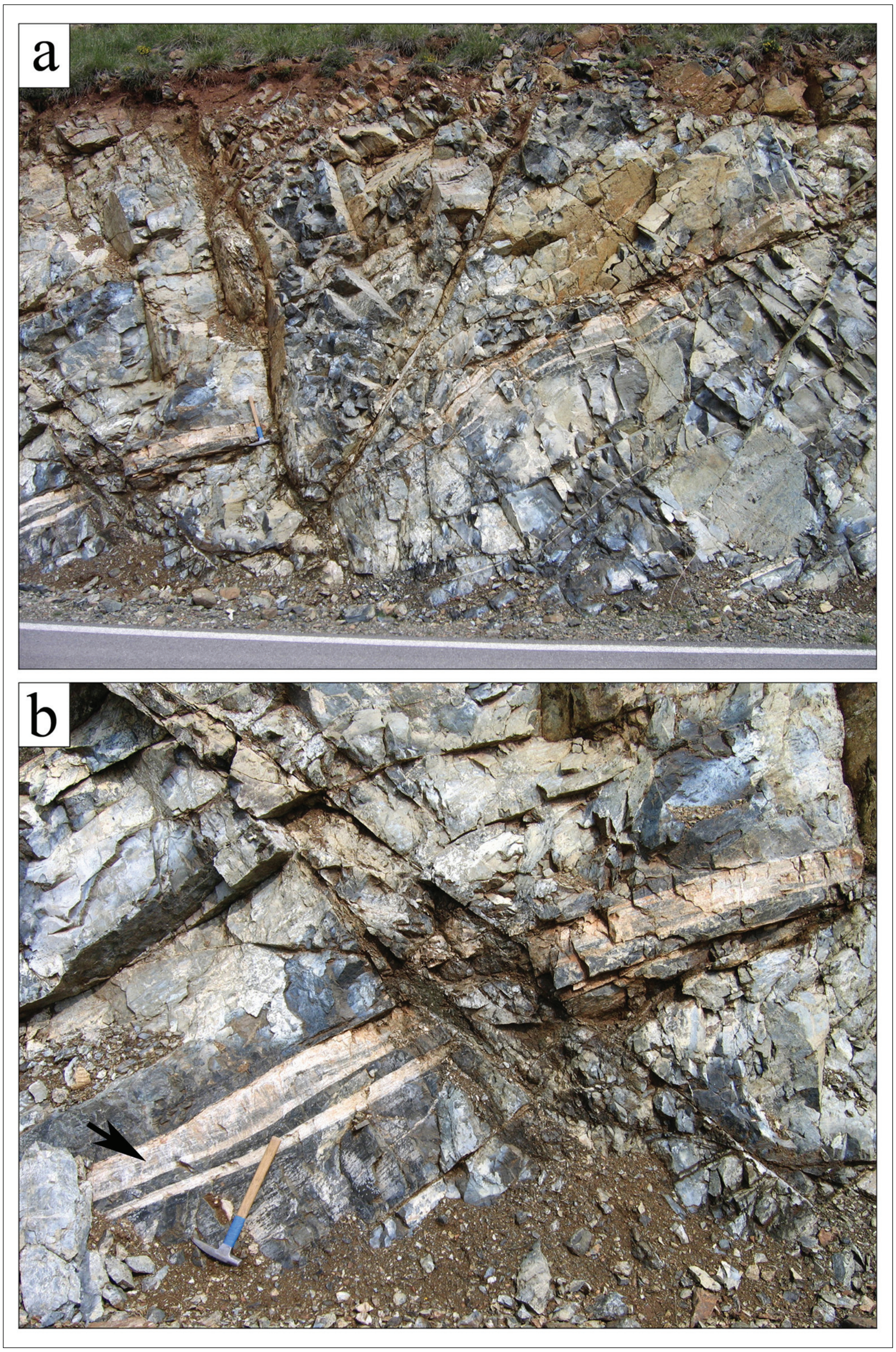


Figure 36.
a) Outcrop of plagioclase peridotite along the road, in the north of the Morava massif, near Barçi;
b) Close-up view of plagioclase peridotites with gabbro dikes (marked by arrow). (Photos by V. Hoeck).

decimeters in thickness, appear frequently (Fig. 36b).

Field stop 10 allows for an overview of the Korça graben (Fig. 37). The Korça graben is filled with Pliocene to Quaternary sediments. The Korça graben is bordered by the Morava massif covered by molasse sediments to the east, and the Voskopoja massif, Cretaceous limestones and Cenozoic molasse sediments to the west. It is separated further north from the Ohrid graben by a steep, north dipping fault.

The age of the molasse sediments on top of the Morava massif ranges from the Oligocene to the Miocene (Fig. 38). The succession starts with a basal conglomerate on top of the ultramafics (Meço & Aliaj 2000). This is followed above by the Drenova Formation with mudstones, siltstones, sandstones and coal-bearing strata. The latter were mined south of Korça near the village of Drenova. The Drenova Formation is overlain by a sequence of fine-grained clastic sediments, with coral-bearing calcareous rocks. The younger formations are built up by siltstones, sandstones, mudstones and calcareous mudstones (marls).

Figure 37. The Korça graben and the city of Korça seen from field stop no. 10. In the background, the Voskopoja massif. (Photo by V. Hoeck).

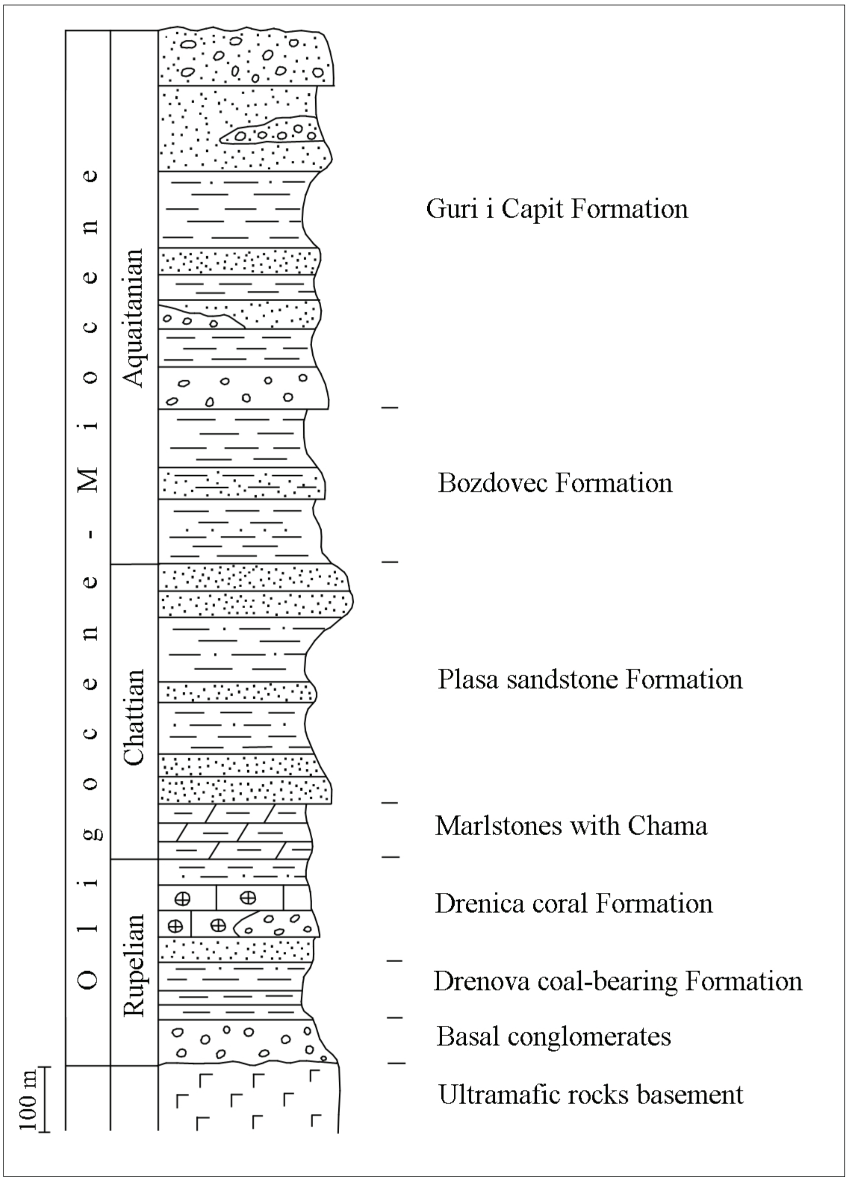


Figure 38.
Stratigraphical column of Oligocene-Miocene molasse sediments on top of the Morava massif (redrawn and modified column by Pashko 1996 – fide Meço & Aliaj 2000).

Field stop 11 - Shipcka (Voskopoja massif): basalts

***Location**: around 4 km north of Voskopoja (Figs. 17 and 39).*

***Coordinates**: N 40°39.750' and E 20°35.750'; Elevation: 1250 m.*

The northeasternmost part of the Voskopoja massif shows one of the rare volcanic sequences associated with the ophiolitic massifs in Southern Albania. The outcrop extends for tens of meters along a country road (Fig. 40). Geologically, the nature of the outcropping rocks is still debated. There are massive lavas, dikes, and rocks ranging from breccias to conglomerates. Petrographically, various basalts (aphyric as well as pyroxene-phyric and plagioclase-phyric), dolerites and microgabbros are found. The rocks may represent the transition zone from gabbros to volcanic sequence or even poor remnants of a sheeted dike complex.

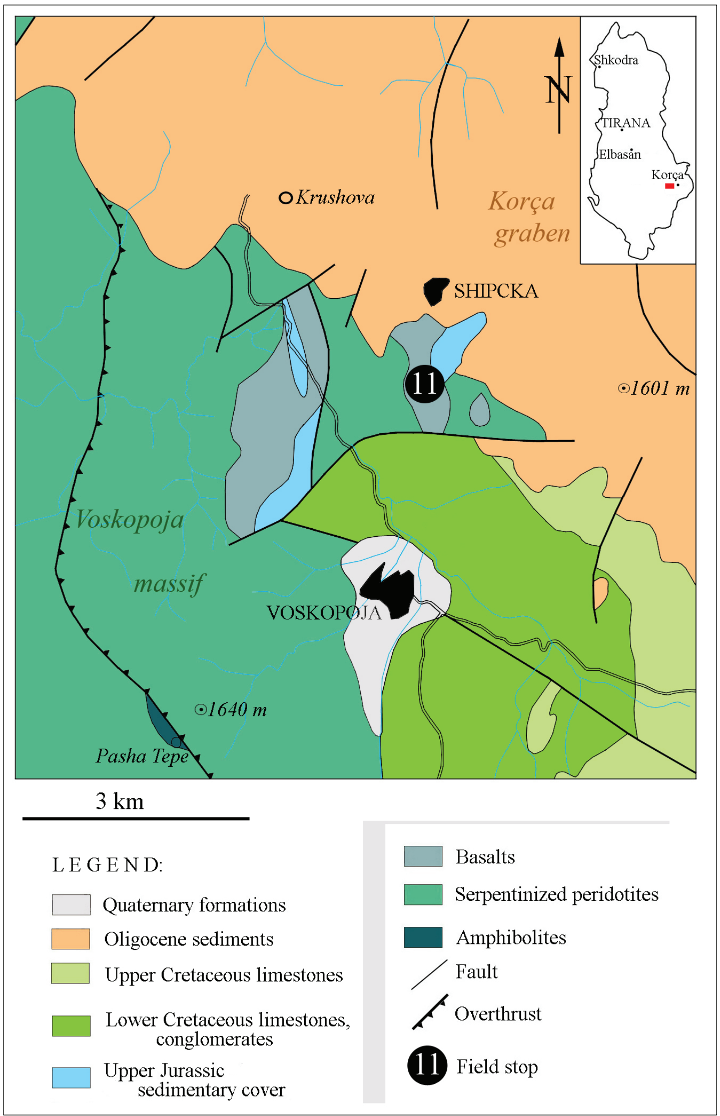


Figure 39.
Simplified geological map of the Voskopoja massif, with the location of field stop 11 – Shipcka and the cultural stop in Voskopoja. Geology after Xhomo et al. (2002), modified. The insert in the upper right shows the position of the map within Albania.

Figure 40. Basalts and gabbros at Shipcka, in the Voskopoja massif. (Photo by K. Onuzi).

Cultural stop: City of Voskopoja

***Location**: ~17 km W of Korça (Figs. 17 and 39).*

***Coordinates**: N 40°38.016' and E 20°35.416'; Elevation: 1200 m.*

The city of Voskopoja has been documented since the 18th century (Fig. 41a) when it had more than 30,000 inhabitants, mostly Aromanians. It is also called Moscopole, Moscopoli or Moscopolis. In the 18th century, Voskopoja had the first printing press in the Balkans outside of Istanbul (http://en.wikipedia.org/wiki/Moscopole), schools and numerous churches. The city was destroyed by Turks led by Ali Pasha at the end of the 18th century. Most of the eighteen orthodox churches from the 17th-18th, some decorated with colorful frescos, are ruins. Only six churches are more or less well preserved and restored (Fig. 41b-d). Nowadays, Voskopoja, a small mountain village, is regarded as a 'holy land' by local Orthodox Christians.

Figure 41. Voskopoja: a) Commemorative plaque displaying an engraving of the town in 1742; b) A 17th century Orthodox church; c) & d) Orthodox church with walls decorated with frescos. (Photos by C. Ionescu).

Cultural stop: Korça

***Location:** SE part of Albania, in the Korça, graben (Figs. 17, 35 and 37).*

***Coordinates:** N 40°37.105' and E 20°46.645'; Elevation: 860 m.*

The sixth largest city in Albania, with more than 100,000 people, Korça is located in the flat plain (850 m altitude) of the Korça graben, filled in with Pliocene to Quaternary sediments.

Churches belonging to the Christians (Fig. 42), Islamic mosques as well as several historical buildings are found in the town. The Museum of Medieval Art displays, among other artworks, a collection of 14th-15th century icons (Franceschi et al. 2011).

Figure 42. Main Orthodox church in Korça. (Photo by C. Ionescu).

Day 3 (Monday, September 29th, 2014)
From Korça to Tirana

Field stop 12 - Ura Verbes (Voskopoja massif): Ultramafics with chromite

***Location**: 16 km W of Maliq along the Devolli River valley along the road from Korça to Elbasan (Figs. 17 and 43).*

***Coordinates**: N 40°43.363' and E 20°32.661'; Elevation: 700 m.*

The Devolli River, after leaving Lozhani towards the west, crosscuts the northern part of the Voskopoja massif (Fig. 44a). The ultramafic rocks (peridotites) are serpentinized to various degrees. It is one of the rare occurrences of lherzolite-dominated ophiolitic massifs substantially enriched in chromite-bearing dunites (Fig. 44b). The chemical composition of the chromite ore includes 14–30 mass% Cr_2O_3, 8–17 mass% Al_2O_3, and 25–32 mass% MgO, as well as various amounts of Pt-group elements (Onuzi et al. 2012).

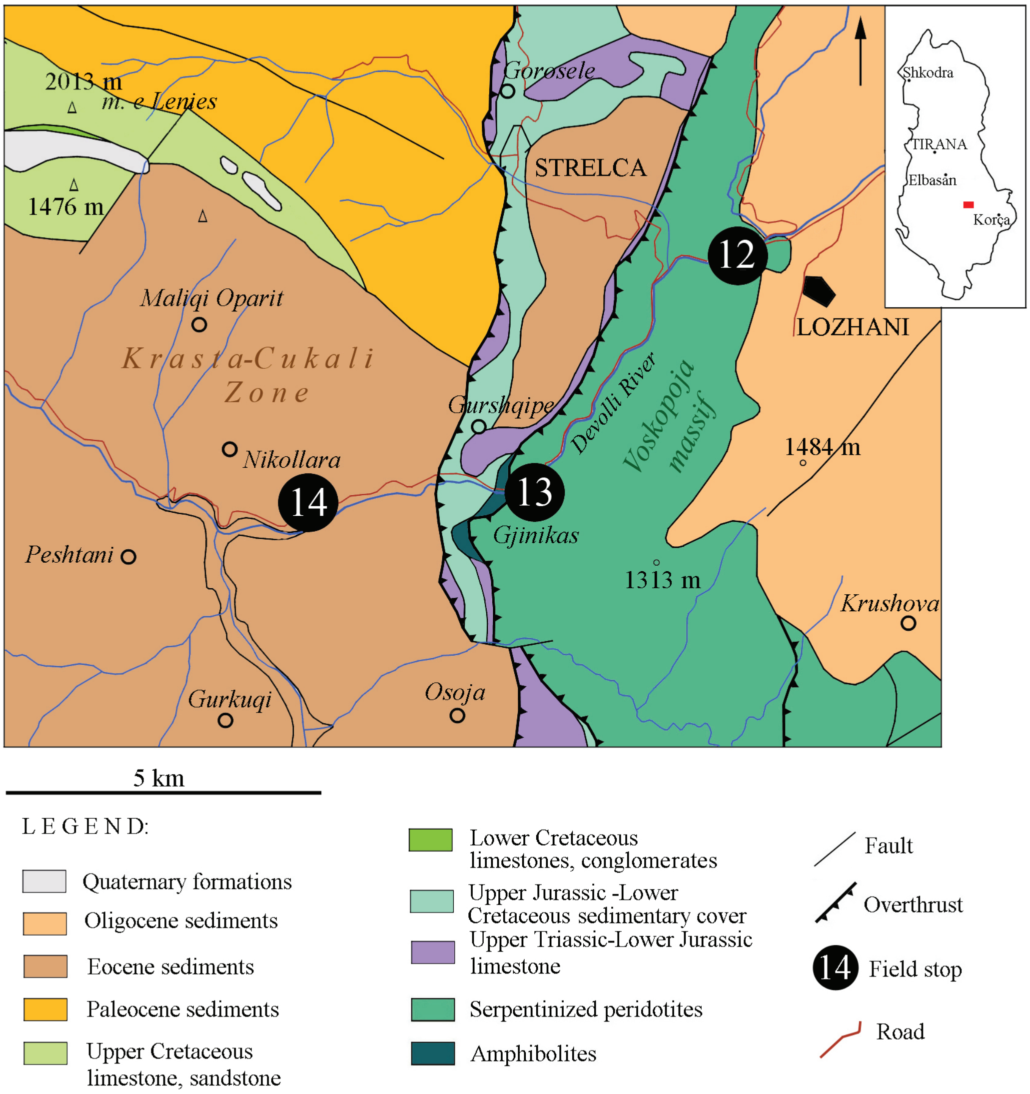


Figure 43. Simplified geological map of the Voskopoja massif and the Krasta-Cukali Zone, with the location of field stops 12 – Ura Verbes, 13 – Gjinikas and 14 – Nikollara. Geology after Xhomo et al. (2002) and Onuzi et al. (unpublished), modified. The insert in the upper right shows the position of the map within Albania.

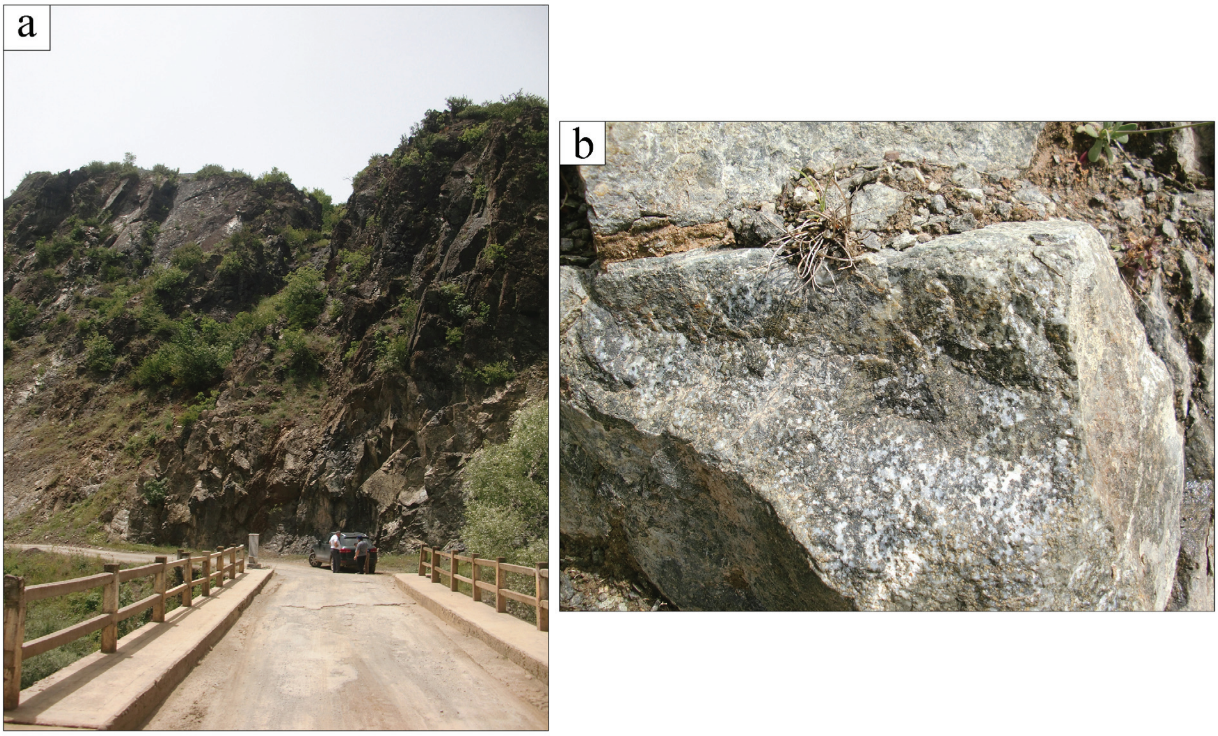


Figure 44.
a) Outcrops of serpentinized peridotites with chromite at Ura Verbes, along the Devolli River (Voskopoja massif);
b) Chromite-bearing dunite; chromite grains as dark spots in the image. The block is ~30 cm in diameter. (Photos by K. Onuzi).

Field stop 13 - Gjinikas (Voskopoja massif): Metamorphic sole

***Location**: ~6 km SW from field stop no. 12, along the road from Korça to Elbasan (Figs. 17 and 43).*

***Coordinates**: N 40°41.480' and E 20°30.014'; Elevation: 650 m.*

The outcrop at Gjinikas, along the Devolli River, shows a thin metamorphic sole 'sandwiched' between Upper Jurassic-Lower Cretaceous limestone and serpentinized peridotites (Fig. 45). Amphibolites of the metamorphic sole display foliation.

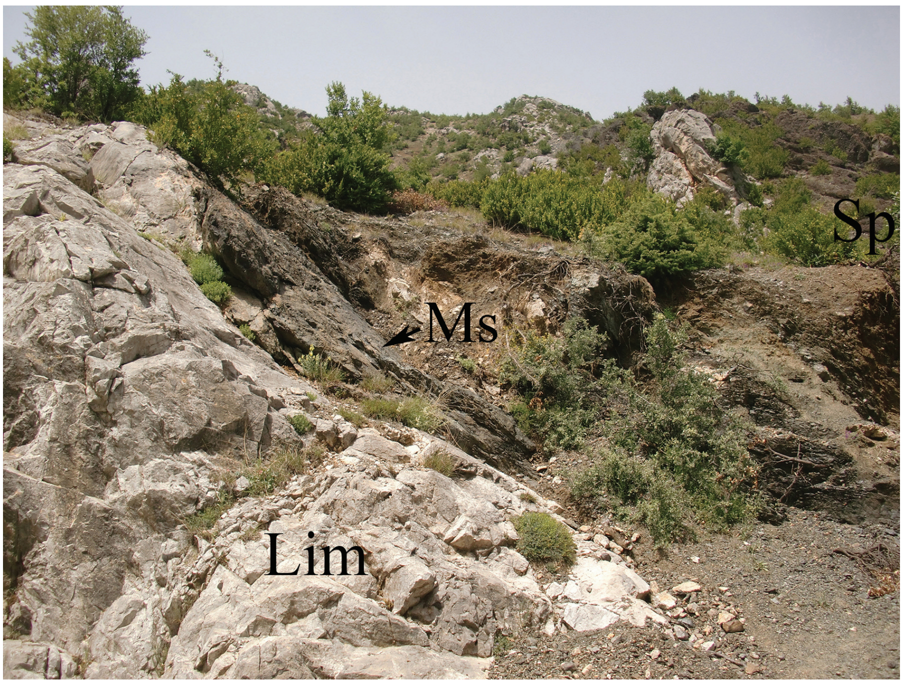


Figure 45. Outcrop of metamorphic sole (Ms) between Upper Triassic-Lower Jurassic limestones (Lim) and serpentinized peridotites (Sp). (Photo by K. Onuzi).

Field stop 14 - Nikollara: Geological overview of the Krasta-Cukali Zone

***Location**: Nikollarë village on the Devolli River, around 4 km W of field stop 13, along the road from Korça to Elbasan (Figs. 17 and 43).*

***Coordinates**: N 40°41.217' and E 20°27.417'; Elevation: 560 m.*

The stop in Nikollara provides an opportunity to have a brief look at the Krasta-Cukali Zone (Fig. 46a,b) which consists here of Cenozoic sediments, i.e. Paleocene to Eocene flysch formations and conglomerates.

The KCZ is the innermost unit of the Apulian margin. The sedimentation in the KCZ begins with Triassic volcaniclastics, radiolarites and limestones. The deep water formations continued until the end of Mesozoic. In Paleocene to Early Eocene turbidites were formed. During the Eocene, the ophiolites were thrust over the KCZ.

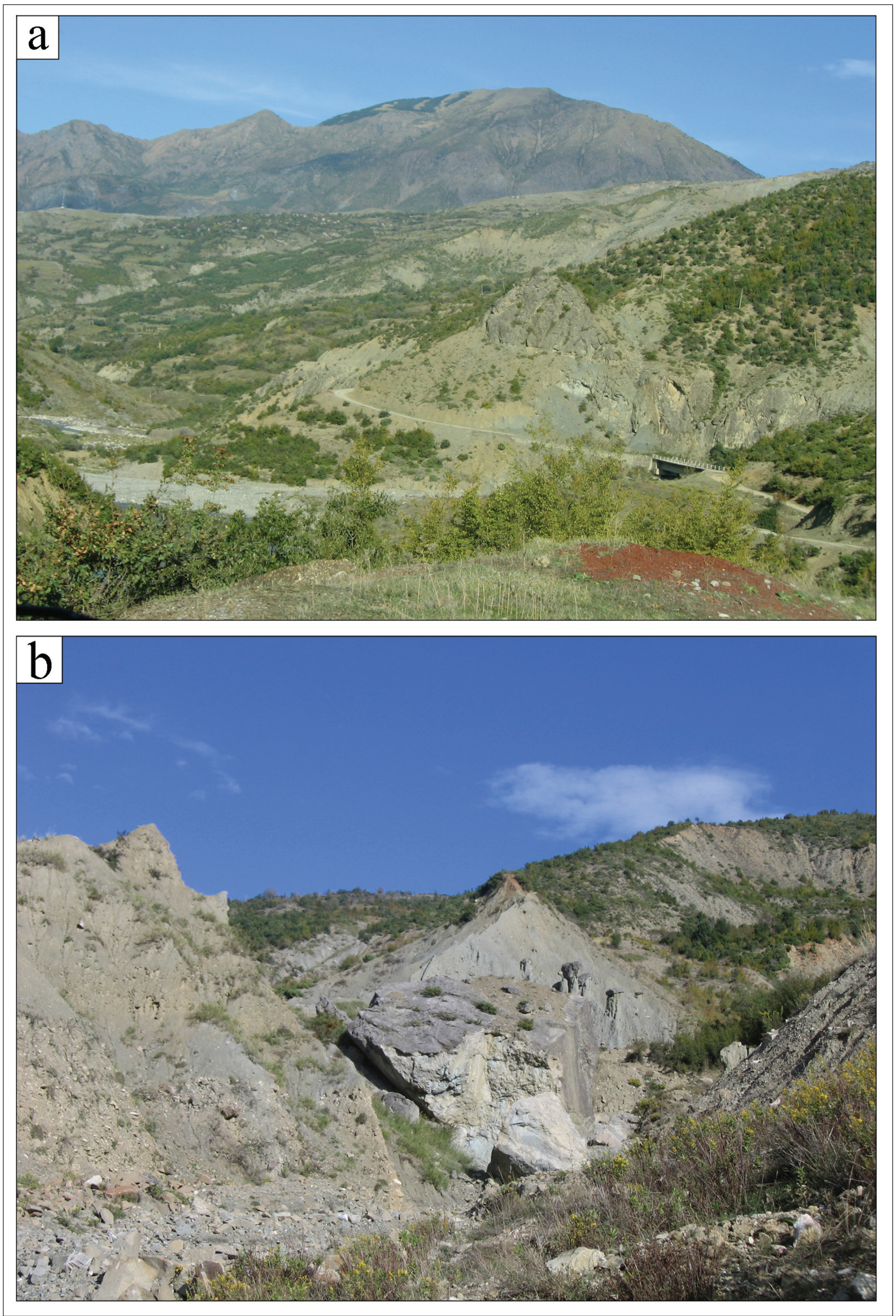


Figure 46.
a) Overview of the Krasta-Cukali Paleocene to Eocene flysch formation and conglomerates; in the background: the Devolli massif;
b) Erosion witnesses in flysch sandstones of the Krasta-Cukali Zone. (Photos by C. Ionescu).

FIELD STOP 15 - DEVOLLI: HARZBURGITE WITH ORTHOPYROXENITE DIKES

***LOCATION**: DEVOLLI GORGES, AT 15 KM NW OF VILLAGE OF NIKOLLARA (FIGS. 17 AND 47).*

***COORDINATES**: N 40°45.654' AND E 20°19.247'; ELEVATION: 500 M.*

The spectacular Devolli gorges (Fig. 48a) are cut through the peridotite massif by the Devolli River. The almost continuous line of outcrops along the narrow, unpaved road perched on the steep slopes of the mountain, shows fresh massive clinopyroxene-bearing harzburgites, frequently crosscut by orthopyroxenite dikes (Fig. 48b).

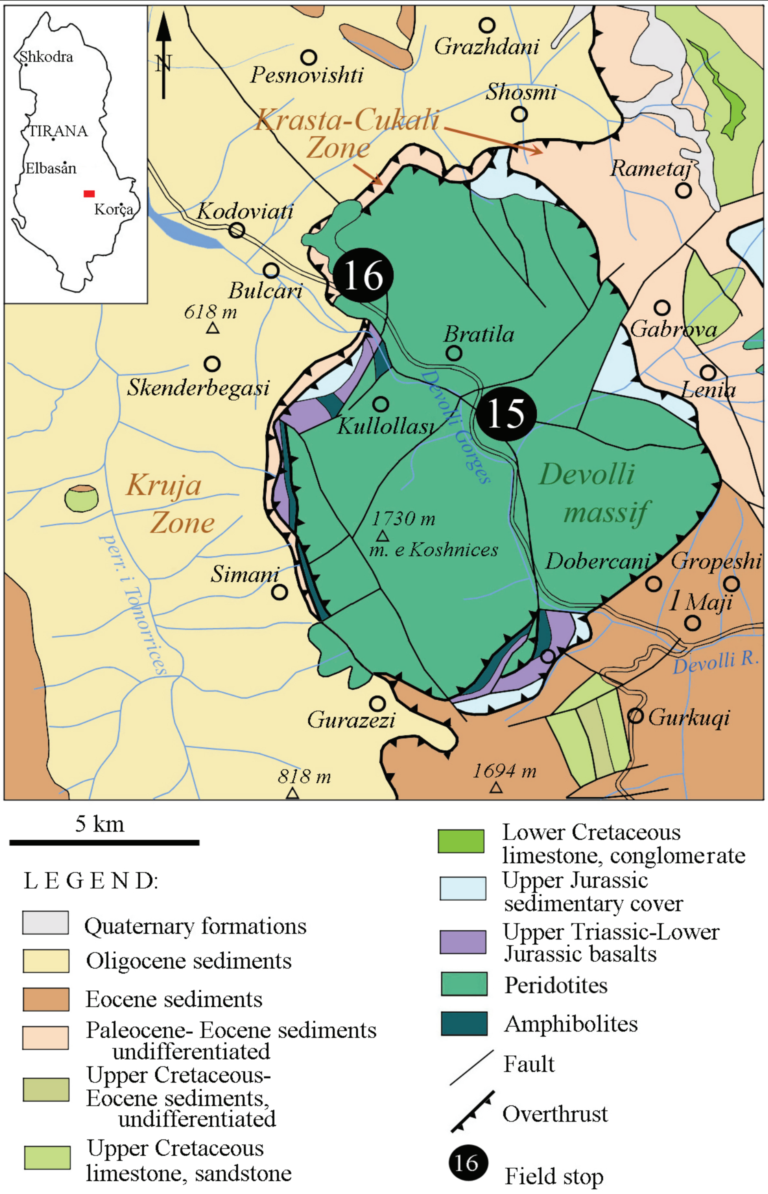
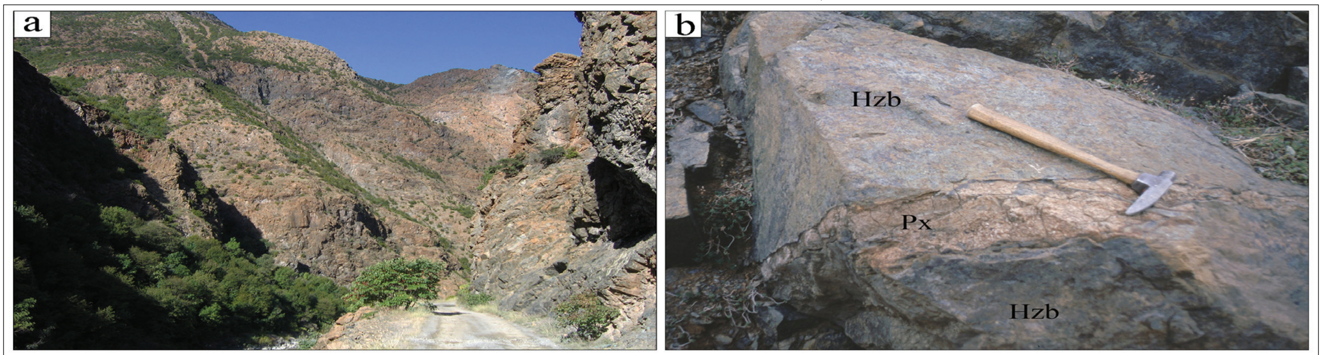


Figure 47. Simplified geological map of the Devolli massif and Kruja Zone, with the location of field stops 15 – Devolli and 16 – Bulcari. Geology after Xhomo et al. (2002), modified. The insert in the upper left shows the position of the map within Albania.

Figure 48.
a) Devolli Gorges crosscutting the peridotitic (harzburgitic) Devolli massif;
b) Pyroxenite dike (Px) in harzburgite (Hzb). (Photos by V. Hoeck).



Field stop 16 - Bulcari: Geological overview of the Kruja zone

Location: *~4 km NW of the village of Bratila and ~2 km E the village of Bulcari* (Figs. 17 and 47).

Coordinates*: N 40°47.167' and E 20°17.450'; Elevation: 450 m.*

This stop offers a view of the boundary between the harzburgitic Devolli massif overthrusting a thin sequence of the Krasta-Cukali Zone to the east and southeast, and the Kruja Zone towards the northwest (Figs. 2, 49a,b and 50).

The KCZ consists of Cretaceous platform carbonates and Paleocene-Eocene pelagic carbonates overlain by Oligocene-Lower Miocene turbidites (flysch) and Middle Miocene shallow water to terrestrial sediments. Mt. Tomor (Figs. 49a and 50) appears as an anticline with a core of Upper Cretaceous platform limestones enveloped by Eocene pelagic limestones and Oligocene flysch.

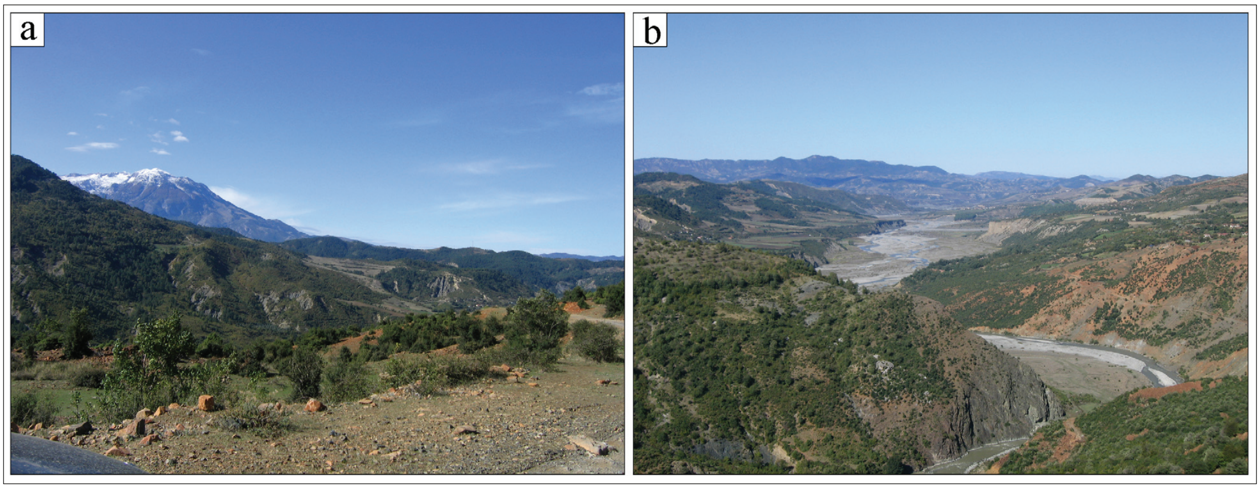


Figure 49. Exit from the Devolli gorges: a) A view of Mt. Tomor behind the last hills of the Devolli massif; b) View towards the NW, over the wide valley of the Devolli River and the sediments of the Kruja Zone. (Photos by C. Ionescu).

Figure 50. View of Mt. Tomor behind the sediments of the Kruja Zone. (Photo by C. Ionescu).

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