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Synthesis of geological, hydrogeological, and geo-touristic features of the Vjosa Watershed

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The paper aims to present the geological settings of Vjosa watershed, situated at the north-western part of Greece and south part of Albania. From a stratigraphic point of view, the geological formations represent a wide variety of rocks, formed from the Triassic to the Quaternary Period. Magmatic rocks, carbonates, terrigenous (flysch and molasse) sediments exposed at spectacular outcrops are actually subject to the erosive activity of the Vjosa River. These sediments are transported and deposited, leading to the formation of Quaternary deposits, comprising of gravels, sands, silts and clays which are characterized by high hydraulic parameters. The geological formations have been classified into different hydrogeological groups based on their lithological, structural, and hydrogeological characteristics. The hydrogeology of the basin includes the hydrogeological framework of groundwater flow systems, as well as the water bearing potential of compact and loose deposits. The paper deals with the spatial distribution of the main features of the considered hydrogeological groups, such as waterbearing potential, quality, and water type. The present morphology is related to the late and neo-tectonic processes. Geological settings and physical geography, accompanied by spectacular natural phenomena, give a significant scientific, didactic, recreational and geo-touristic importance on a local, regional and international level.

Durmishi Ç., Daja S., Ago B., Dindi E., Sinojmeri A., Nazaj Sh, Qorri A. & Muçi R., 2018: Eine Synopsis der geologischen, hydrogeologischen und geotouristischen Eigenschaften des Vjosa Einzugsgebietes.
Der Artikel gibt einen Überblick über den geologischen Aufbau des Einzugsgebietes der Vjosa. In einer stratigraphischen Betrachtung repräsentieren die geologischen Formation ein breites Spektrum von Gestein, das in der Periode Trias bis Quartär gebildet wurde. Magmatisches Gesteine, Karbonate, terrigene Sedimente (Flysch und Molasse) sind den erosiven Kräften der Vjosa und ihren Zuflüssen ausgesetzt. Diese Sedimente werden transportiert und führen zu quartären Ablagerungen aus Schotter, Sanden und Feinmaterial, wie sie für Flüsse mit hoher hydraulischer Dynamik charakteristisch sind.
Die geologischen Formationen wurden an Hand ihrer lithologischen, strukturellen und hydrogeologischen Charakteristika in verschiedene Klassen eingeteilt.
Die Hydrogeologie des Einzugsgebietes umfasst die geologischen Rahmenbedingungen der Grundwasserflüsse sowie die Wasserkapazität der kompakten und lockeren Sedimente.
Die Arbeit bezieht sich auf die räumliche Verteilung der Hauptmerkmale der hydrogeologischen Gruppen, wie z.B. das Potential der Wasserführung, Qualität ??, und geochemischer Wassertypus.
Die gegenwärtige Morphologie des Gebietes ist ein Resultat, spät- und neo-tektonischer Prozesse. Die Geologie und physikalische Geographie mit ihren spektakulären Erscheinungsformen verleiht dem Gebiet einen bedeutenden wissenschaftlichen, didaktischen und geo-touristischen Wert von regionaler und internationaler Bedeutung.

Keywords: Vjosa Watershed, Tectonics, Stratigraphy, Sedimentology, Hydrogeology, Geo-tourism, Albania, Greece.

Introduction

Vjosa Watershed is situated at the north-west of Greece and southern Albania. The actual configuration of the basin is conditioned by the paleogeographic and geodynamic evolution of the Albanides and Hellenides from Mesozoic up to the present day (ShGjSh 1985, Ntokos 2017). Based on the tectonic zonation of Albanides (Al) and Hellenides (Gr), the upstream part extends over 4 tectonic units (Fig. 1): 1 Mirdita (Al) or Sub-Pelagonian Zone (Gr); 2 Krasta – Cukali (Al) or Pindos Zone (Gr); 3 Kruja (Al) or Gavrovo Zone (Gr); 4 Ionian Zone (same name in Albania and Greece). Strike-slips, normal and reverse faults, oriented mainly NNW-SSE, NE-SW and N-S, affect the geological formations. The midstream is developed mainly in the Ionian zone, with some confluents carrying their activity in the Kruja and Krasta zones, while the downstream part extends to the Ionian zone and Peri-Adriatic depression. The stream system started from the upper Pleistocene (Carcaillet et al. 2009), about 150 thousand years ago, and erodes and transports materials from the rocks developed within the abovementioned tectonic units.

Geological settings of the Vjosa Watershed

The upstream section

This section extends from the mountains of Pindos and Grammos in North-Western Greece to Çarshova in Albania (Fig. 2). The following tectonic zones have been described by Papanikolaou & Royden (2007):

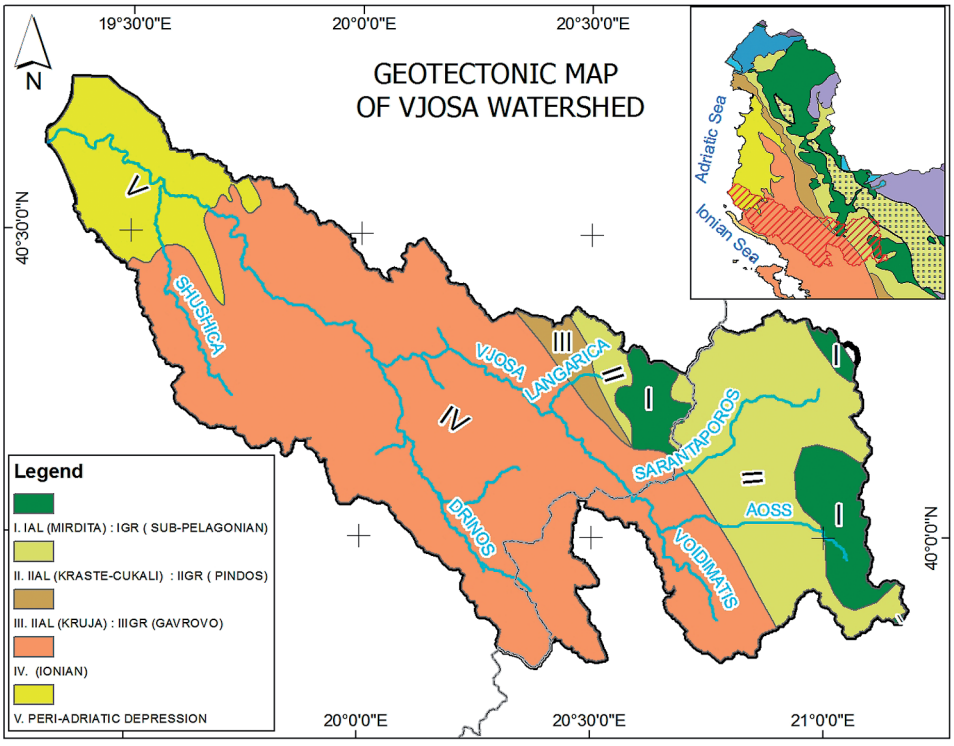

Fig. 1: Tectonic map of the Vjosa Watershed. – Abb. 1: Tektonische Karte des Vjosa-Einzugsgebietes.

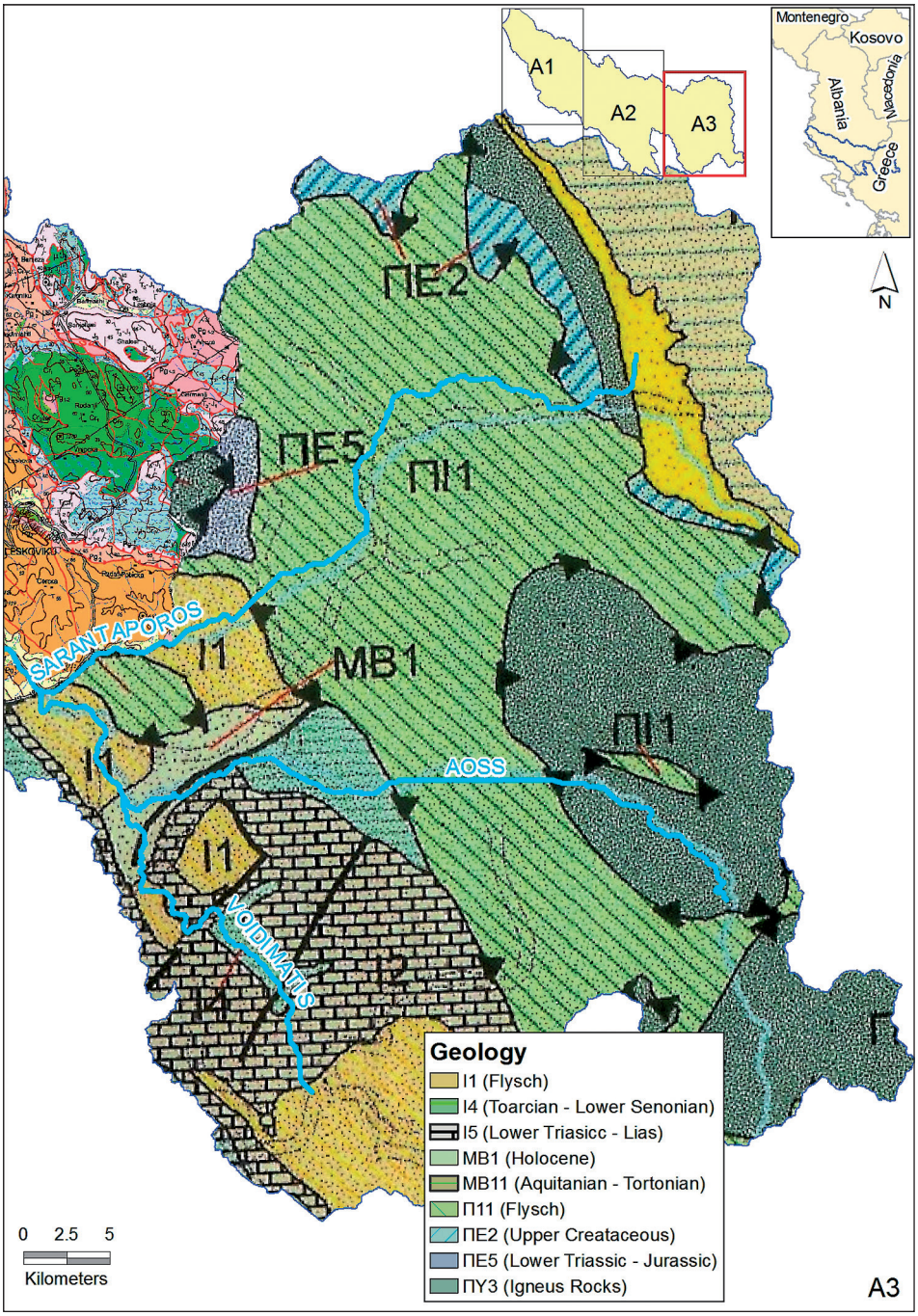

Fig. 2: Geological map of the upstream section-Vjosa Watershed. – Abb. 2: Geologische Karte des Einzugsgebiet der oberen Vjosa.

Mirdita tectonic zone is developed at the eastern part of the watershed with a general orientation NW-SE. This zone is composed mainly of ophiolitic formations (peridotites and serpentinites) and radiolaritic cherts associated to them.

Krasta-Cukali tectonic zone constitutes the most important area of the Greek part of Vjosa. It includes the mountains of Pindos, Lakmos and Athamanien. Paleogeographic studies indicate that this zone is composed of very deep-sea sediments. The oldest geological formations of Pindos zone are dated to Middle Triassic and consist of sandstones, cherts, marls and limestones. In the upper part of the Upper Triassic, an increased presence of cherts and limestones forms a thin-layered structure. Volcanic clasts consisting of andesites, basalts and volcanic tuffsare, are also observed.

The Jurassic formations are characterized by intercalations of thin layers of clayey-siliceous materials and limestones within multicolored cherts. The *first flysch of Pindos zone,* composed of alternation of marls, cherts, sandstones and brecciated limestones, is dated as Lower Cretaceous age. The first flysch is overlaid by thin layered limestones, which constitute an uninterrupted sequence from the Cretaceous up to the Maestrichtian age, where a transition of series composed of alternations of thin-layered limestones, sandstones and shales, precedes the flysch of Danian-Pliocene (locally up to the Upper Eocene), called *second flysch of Kraste-Cukali zone*. This *second flysch of Kraste-Cukali zone*, considered also as the most typical and representative flysch of the Greek territory, consists of rhythmic alternation of sandstones and marls with local conglomerates and limestones. In the clayey-sandstone deposits, sandstone olistholiths are often observed. Tectonic events during this period complicate the sedimentation and lead to the formation of a chaotic mixture called 'wild' flysch.

Kruja tectonic zone characterized by continuous neritic carbonate sedimentation during Triassic to Upper Eocene, is located at the west of Pindos and occurs as tectonic windows at the Valtos mountains. Geological formations involved within this zone are dolomites of Upper Triassic age, neritic limestones of Jurassic – Upper Eocene age with abundant content of fauna fossils and Eocene-Oligocene flysch.

Ionian tectonic zone has a NW-SE orientation and is located west of Kruja zone and is composed of Lower Eocene – Lower Miocene flysch, semi-pelagic limestones of Paleocene – Eocene age, Upper Senonian limestones and the limestones of Jurassic and Upper Cretaceous with radiolarite cherts intercalations and large content of fauna relicts.

The midstream section

This section extends from Çarshova to Poçemi in Albania, mostly in the Ionian zone (ShGjSh 2002, Xhomo et al. 2003) and only some small tributaries (from Çarshova to Kelcyra) belong to the Kruja and Kraste-Cukali zone (Fig. 3).

The **Kruja tectonic** zone consists of carbonate and flysch deposits from the Upper Cretaceous to the Middle Oligocene. The Upper Cretaceous deposits are represented by neritic deposit, consisting of dolomitized limestones at its lower part. In the upper part of the Upper Cretaceous the deposits are represented by bioconstructed limestone *Rudists*. A sedimentary hiatus is observed during the Eocene up to Middle Oligocene. During the Middle Oligocene, due to tectonic movements, the deposit outcropped and consequently the Upper Cretaceous limestones were eroded.

Fig. 3: Geological map of the midstream section -Vjosa Watershed. – Abb. 3: Geologische Karte des Einzugsgebiet der mittleren Vjosa.

Ionian zone represents a series of syncline/anticline structures having a large variety of rock formations dating from Permian to Quaternary (Fig. 4). At the base, the Permian evaporites and shallow carbonates of Triassic ages are situated, continuing with the lower Jurassic dolomites and limestones with algae (low and middle Lias), as well as 'Ammonitico Rosso' facies of upper Lias (Toarian), which characterize the western part of the Ionian Zone. Pelagic turbiditic carbonates with chert intercalations are developed during the middle Jurassic up to late Eocene (Fig. 3). Micritic and biomicritic limestones are dominant during the upper Cretaceous. Flysch deposits took place during the Oligocene and the lower Miocene. Frequent synsedimentary slumps are observed within flysch deposits. During the Miocene marls and clayey marls, sandstones and bioclastic limestones are encountered. Molasses characterize the middle Miocene up to Pliocene age. The molasses are composed of intercalations of conglomerates, sandstones, siltstones and shales. Evaporites are also present.

In the Ionian zone three sub-zones are identified in (ShGjSh 2002, Xhomo et al. 2003):

The **Eastern subzone (Berati belt) –** occupies the eastern part of Ionian zone and is characterized by relatively thick carbonate and flysch deposits of Cretaceous age. Two structural chains can be identified within the Berati belt: 1) the belt of Bureto-Lunxheria-Goliko-Rehova; and 2) the belt of Nemerçka-Terpani-Berati. East of this subzone the Permeti Syncline represents a subsident basin filled by Oligocene flysch and constitutes the transition to the Kruja zone.

Central subzone (Kurveleshi belt) – This subzone extends to the center of Ionian zone and is compiled by a series of syncline/anticline structures, composed of typical pelagic carbonate sediments.

Western subzone (Çika belt) – This sub-zone preserves the general extension of Ionian zone (NW-SE). Its principal characteristic is the presence of almost all facies of dolomites and limestones with algae (Low and Middle Lias) as well as 'ammonitico rosso'facies of Upper Lias (Toarian) instead of cherts with posidonia, found at the other areas of Ionian zones.

Downstream section

This section extends from Poçemi to the Adriatic Sea and extends to the Ionian zone and the Peri-Adriatic depression. In this section only the Quaternary deposits will be described because the Ionian zone deposits (Çika belt) are described in the previous section.

Based on previous studies the quaternary deposits can be divided as follows: 1) glacial and interglacial deposits located mainly in the upstream part; 2) river bed deposits and alluvial fans in the midstream section; and 3) marine and deltaic deposits.

The glacial and interglacial deposits were created during the last glacial cycle continuing during the Holocene till the present days. Abundant glacial and interglacial deposits as well as evidences of interglacial activity are identified in the Pindus area by detailed geomorphological studies carried out by Hughes (2004). These deposits are dated using the radiometric methods as well as the relative geological method, and result as older than 350,000 years B.C.

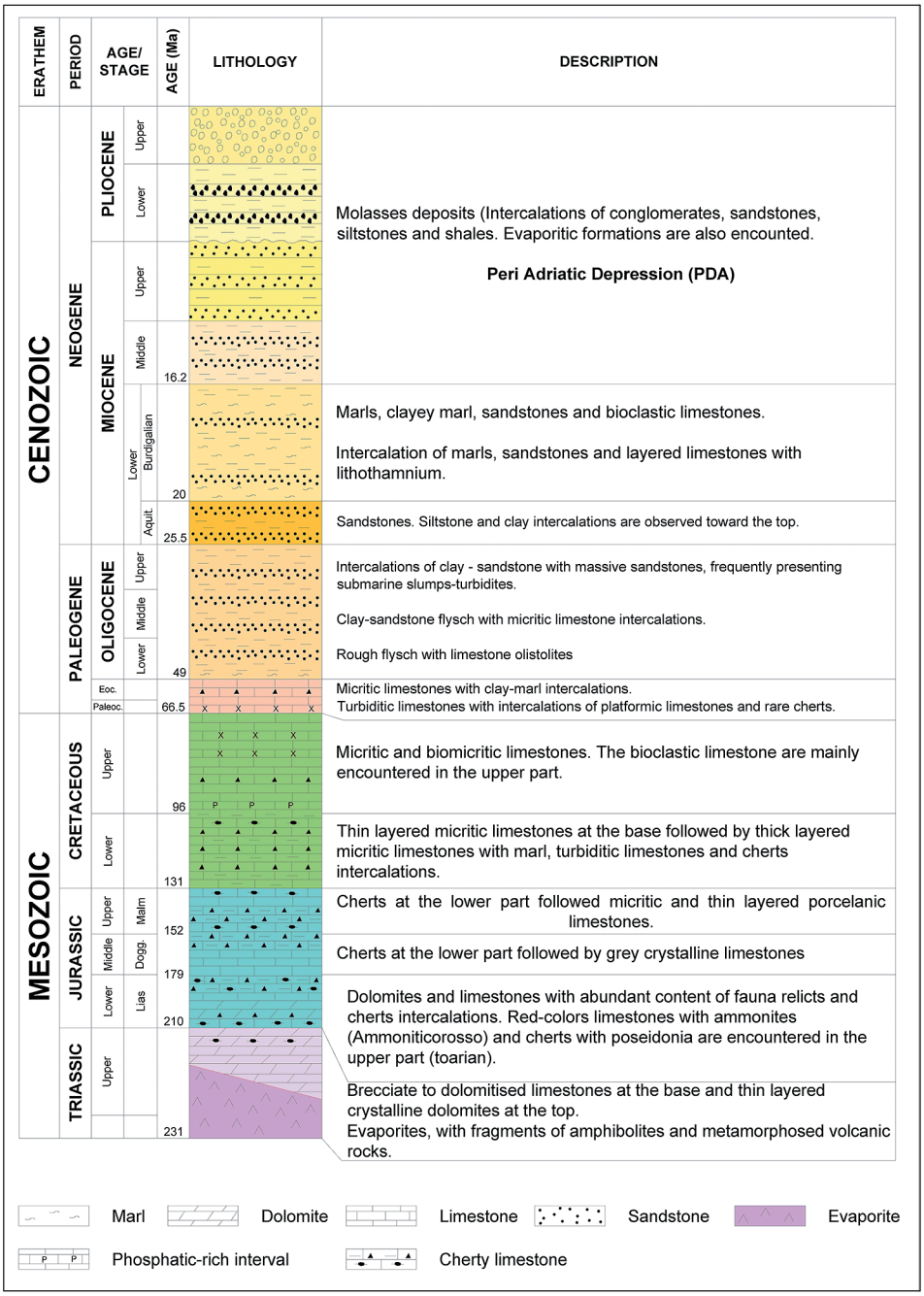

Fig. 4: Litho-stratigraphic column of the Ionian Zone (Albania). – Abb. 4: Die Litho-Stratigraphie der Ionischen Zone (Albanien).

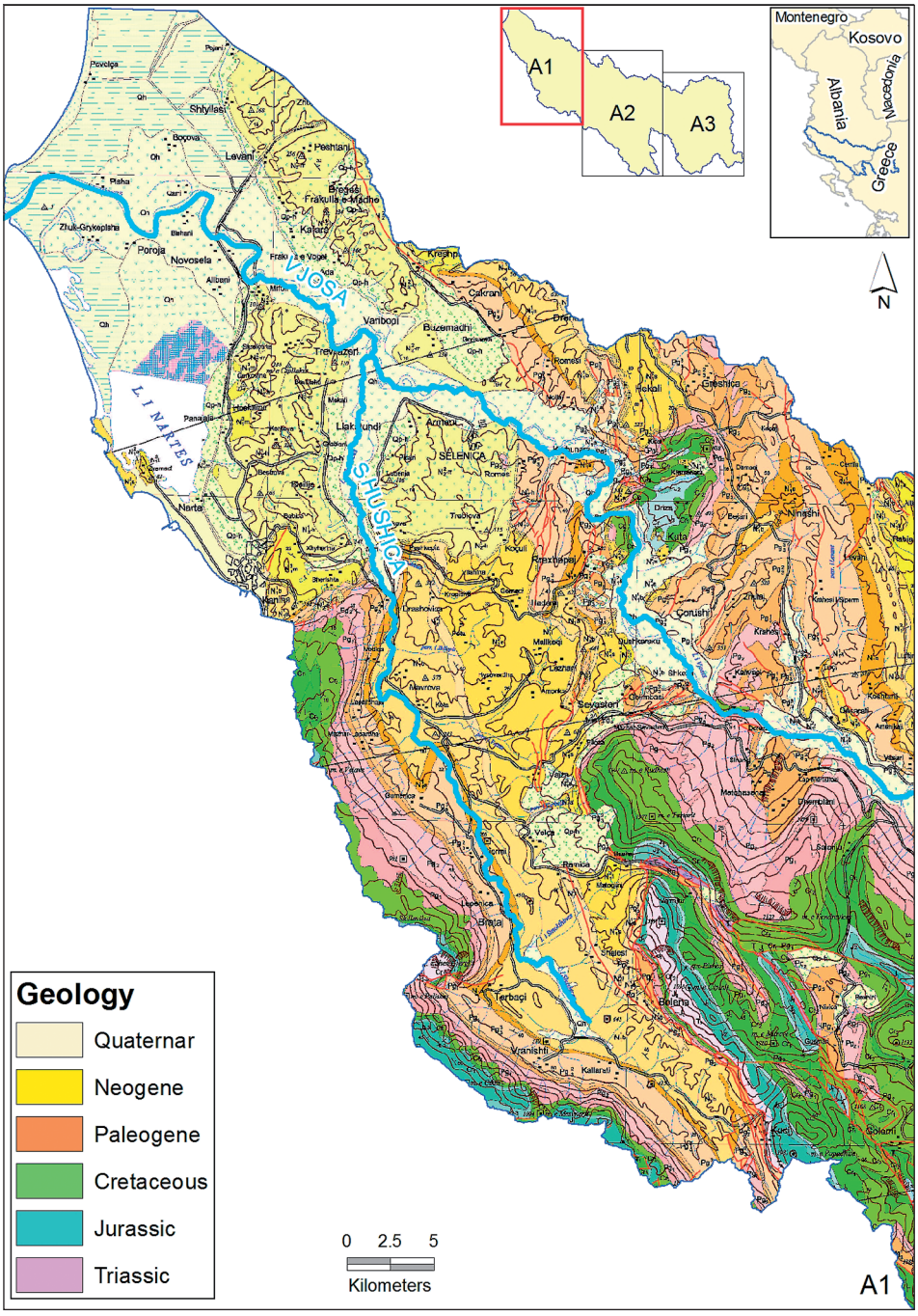

Fig. 5: Geological map of the downstream unit – Vjosa Watershed. – Abb. 5: Geologische Karte des Einzugsgebietes der unteren Vjosa.

In Albania, 11 levels of alluvial terraces are identified. In the Shkumbini and Devolli Valleys, 10 levels of alluvial terraces are fully evidenced (Aliaj et al. 1995, Woodward et al. 2001, 2008, Koçi 2007, Lewin et al. 1991, Carcaillet et al. 2009, Gutierrez 2013). Correlation between the alluvial terraces of Quaternary (Pleistocene – Holocene) and the climate reconstructions show that their formation is mainly controlled by climate changes. Lateral erosion and/or alluvium development occur during the cold and dry periods while vertical erosion and abandonment of channels occur during the hot and wet periods.

In the downstream part of Vjosa, from Poçemi to Mifoli, the actual river bed deposits and the deposits of the fifth alluvial terrace are encountered. From Mifoli to the rivermouth the Pleistocene-Holocene and actual deposits, representing two depositional cycles and having a thickness of 180–200 m, are encountered (Durmishi et al.2004). Sedimentological and petrographic analysis for the actual riverbed sediments have been carried out by Xhemalaj et al. (2000) in fifteen permanent stations along Vjosa and its main tributaries, like Drino, Kardhiqi, Bença and Shushica, starting from the Albanian-Greek border to the Mifoli bridge. The petrographic composition and the dominant grain size of each station are given in Figure 6.

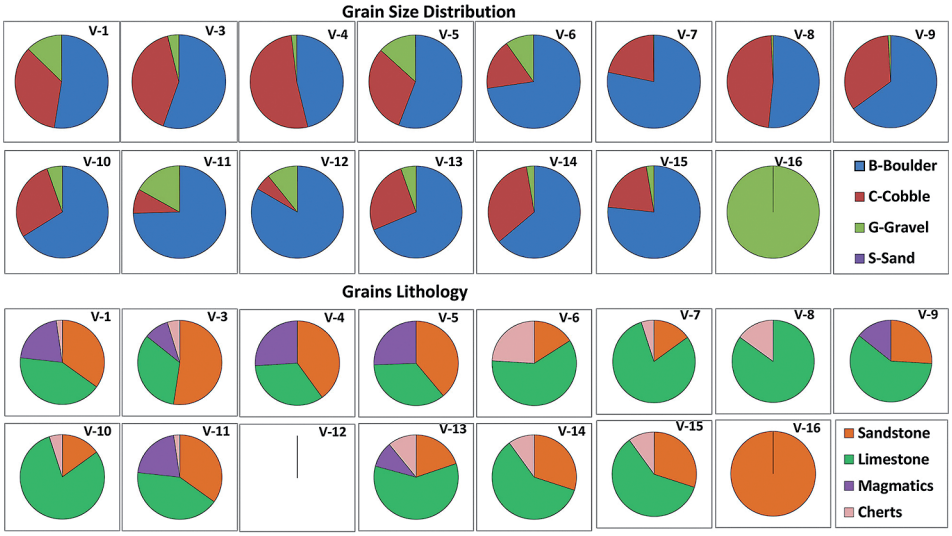

Fig. 6: Petrography and dominant Grain Size of actual sediments along the Vjosa River and its tributaries. – Abb. 6: Petrographie und Korngrößen der Sedimente der Vjosa und ihrer wesentlichen Zuflüsse.

Delta of Vjosa and the dynamics of the shoreline movement (1870–2016)

For the littoral and the Delta of Vjosa, the sedimentological, petrographic and shoreline dynamic analyses were carried out by Durmishi et al. (2004) (Fig. 7, Fig. 8).

The Delta of Vjosa represents the most important area in the Myzeqe lowland, 2/3 of which is a result of delta progradation, during a time lapse of 500 years (Fouache et al. 2010). Previous and archaeological studies show the displacement of the Vjosa mouth

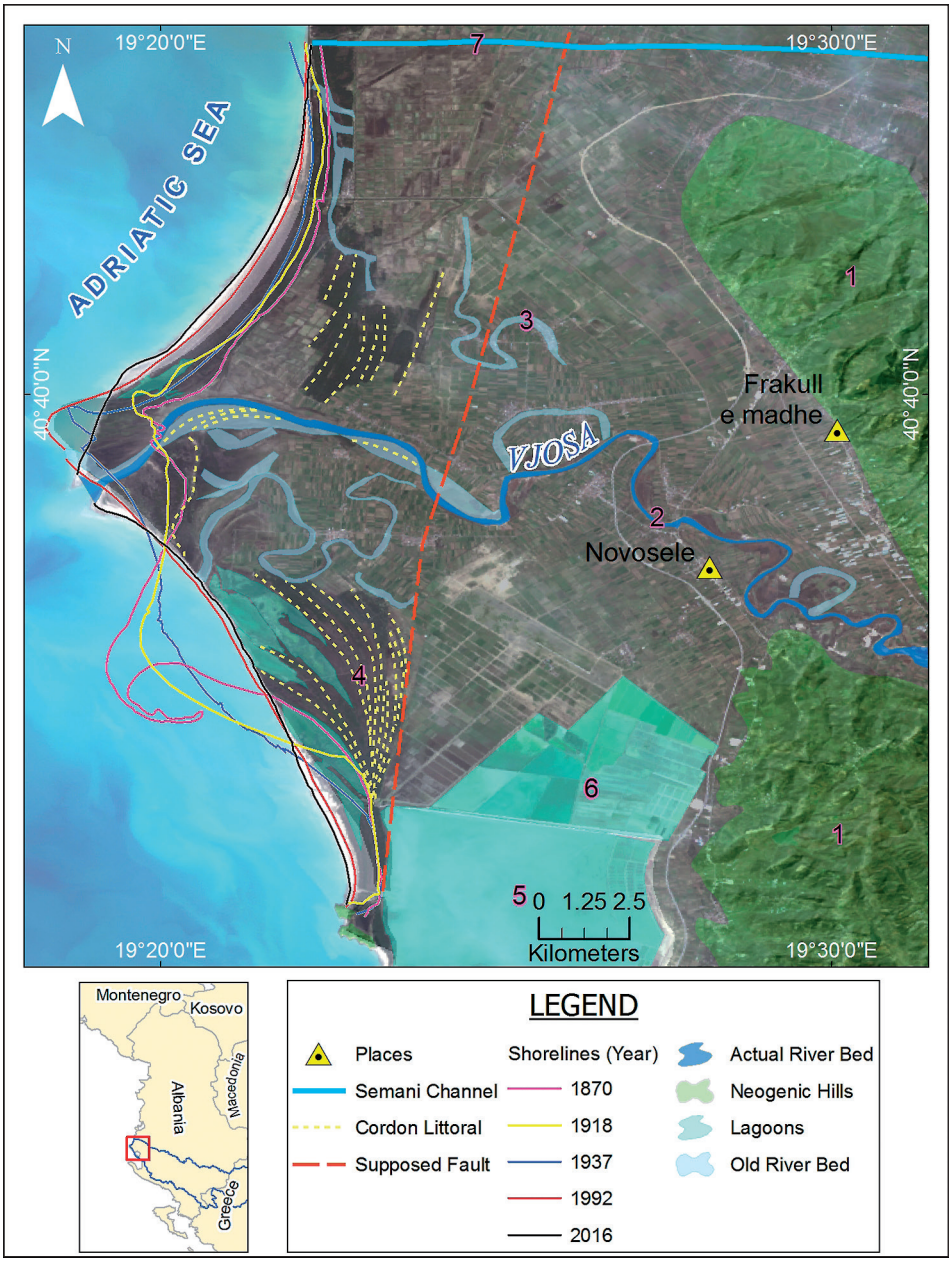

Fig. 7: Delta of Vjosa – shoreline dynamics (1870–2016); 1, Neogene deposits; 2, Actual Vjosa River; 3, Abandoned channel; 4, Ancient beaches and related dunes; 5, Narta Lagoon; 6, Coastal marshes; 7, Semani channel. – Abb. 7: Die Entwicklung des Vjosa-Deltas (1870–2016); 1, neogene Ablagerungen; 2, rezenter Flussverlauf; 3, historische Arme; 4, historische Buchten und Sanddünen, 5, Narta Lagune; 6, Küsten-Marschlandschaft; 7, Semani Arm.

south of its actual location in Vlora Bay (where Narta Lagoon was created) as well as to its north, along the foot of the Frakulla structural ridge, less than 1 km southwest of the ancient city of Apollonia. The Vjosa Delta represents a wave dominated formation, characterized by sand banks, mud flats, salt marshes, reed beds, small lagoons and temporary marshes.

Spatial patterns of the Vjosa Delta are a result of fluvial and marine processes mainly controlled by water and solid discharges as well as oceanographic conditions during the time period from the beginning of Holocene up to today.

Shoreline dynamic analysis, using historical topographic maps from the XIX century up to recently, respectively corresponding to the years 1870, 1918, 1937, 1992, 2007 and 2016, shows the fluctuation of the coastline position. The respective erosion/accumulation rates correspond to the time intervals between the abovementioned years. The results of the analysis demonstrate a dominance of accumulation, which decreases during the time intervals between the years 1992–2007 and 2007–2016, a tendency which would hint towards a possible inversion leading to erosion in the future. The construction of hydropower plants would accelerate this process.

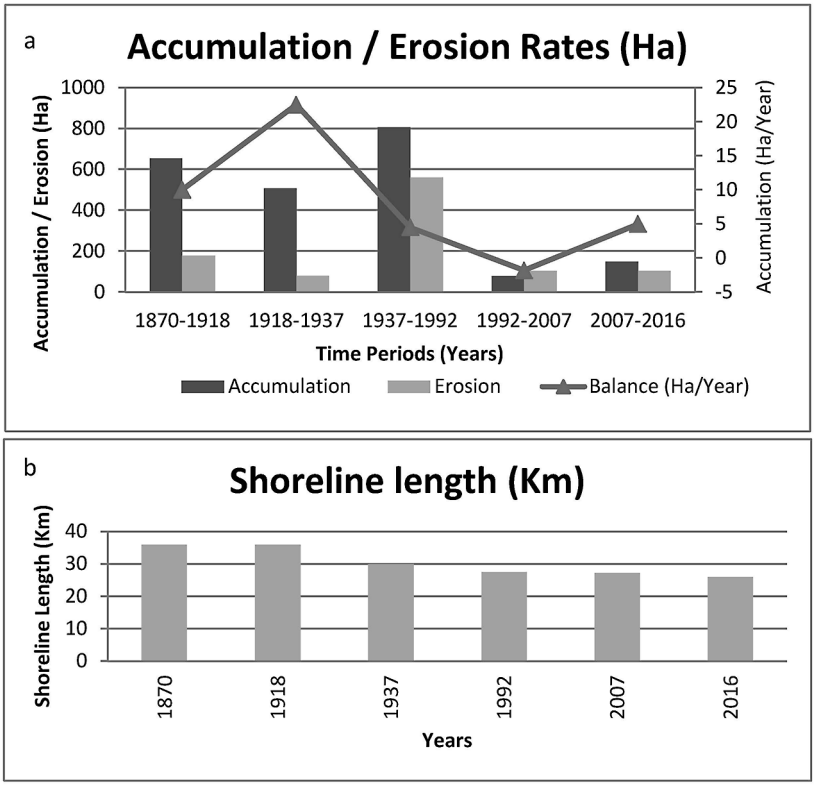

Fig. 8: Shoreline displacement rates (a) and shoreline length (b) during 1870 to 2016. – Abb. 8: Verlagerung der Küstenlinie (a) und Küstenlänge (b) zwischen 1870 bis 2016.

Influence of late and neo-tectonics to the Vjosa Watershed configuration

The present morphology of the Vjosa Watershed – the presence of flattening blocks and almost vertical slopes dividing them, as well as that of fluvial terraces, – is also a consequence of late – and neo-tectonic processes (Aliaj et al. 1998). Stretching neo-tectonic displacements lead to the formation of a mountainous system with peaks more than 2000 m high, interrupted by narrow sinks. The Vjosa Watershed is characterized by pre-Pliocene compression movements, leading to the formation of anticline/syncline complexes, frequently associated to reverse faults even with important displacements towards the west or southwest. As a consequence of these neo-tectonics, the main mountainous complexes over 2000 m high (Nemerçka, Tomorri, Çika, etc.) are formed, which in combination with the lower relief areas correspond to anticline/syncline geological structures.

The eastern flanks of anticline structures are characterized by gentle inclination, with the exception of the complications by backthrust faults. The west flanks of anticlines represent steep slopes associated with colluvial breccias and erosive streams, tributary to Vjosa River.

The contrast between elevated relief and valley sinks is pronounced especially between anticline belts of Berati, Kurveleshi and Çika, and syncline structures of Memaliaj and Shushica. This elevation leads to the outcrops of limestones, while the transversal faults Vlora-Tepelena lead to the sudden disappearance of limestone at its northern side.

Two types of sectors are identified at Vjosa Watershed (Aliaj et al.1998; Carcaillet et al. 2009).

Sectors of continuous and intensive elevation regime associated with the renewing of compressions and thrusts, formed by intensive folding processes during the lower and middle Miocene. Mountain chains such as Nemerçka-Dhembeli-Trebeshina, Lunxheria-Bureto and Kurveleshi are situated there. Sectors of light to middle regime of elevation are detected at the lower relief area, corresponding to the syncline structures, which delineate the separation between anticline structures, Drino, Shushica, etc. valleys, filled by flysch or flyschoidal materials. Several intensive vertical movements are observed during the middle Miocene, but the most important event seems to be the subsidence of the northern part of Ionian zone, leading to the formation of the Peri-Adriatic depression. Serravallian or younger molasses that fill this depression, continue transgressively over older depositions of Ionian and Kruja zones.

Hydrology and Hydrogeology

In this section, only the hydrological and hydrogeological features of the Albanian part of the Vjosa watershed, are described.

Hydrology

The area of Vjosa Watershed is about 6710 km^2 of which 4455 km^2 are included within the territory of Albania and an area of 2805 km^2 belongs to the Greek territory (Ihme 2008). The main tributaries of Vjosa in Greece are Sarandoporos and Voidomare. In the Albanian territory the Vjosa River represents a complex hydrographic network (Pano 1984,

2015). The main tributaries are Drino and Shushica rivers. Shushica has a drainage area of 715 km^2, an average discharge of 24.2 m^3/s and a runoff coefficient of 0.53. Its main tributaries are the torrents of Smokthina, Vajza and Vllahina. Other important tributaries are the Çarshova torrent, Langarica, Lemnica, Dishnica and Zagoria with drainage areas of 90km^2, 337 km^2, 103 km^2, 173 km^2 and 171.6 km^2, respectively. Bença River and the torrents of Luftinje and Salaria are also tributaries of Vjosa.

The average multiannual water discharge of Vjosa River is Q_0=195m^3/s with a runoff coefficient of 0.61. The annual water volume is about 6.2 billion m^3 (Pano 2015) 82 % of which occurs during the wet period (October–May) and 18% during the dry period (June – September). Its alimentation comes from precipitations and the groundwater. The contribution of groundwater to the Vjosa water discharge is about 31% of its total.

The quantity of the precipitations in the Watershed increases from its southeastern to the northwestern part. The average precipitation in the southeastern part varies from 1170 mm/year at Leskoviku to 1290 mm/year to Kelcyra hydro-meteorological station. Higher quantities of rainfalls are observed in the areas corresponding to the mountainous chain of Trebeshina – Dhembeli – Nemerçka, Mali Gjere, Kurveleshi and Çika Mountains. They vary from 1890 mm/year at Gjirokastra to 2300 mm/year at Nivica and Kuçi.

Hydrogeology

The hydrogeological framework of the basin consists of different hydrogeological groups based on rock formations features such as: rocks lithology; structural features; geological formations origin; and geological evolution (ShGjSh 2002, 2015, Dindi 2009, Tab. 1, Tab. 2).

From the hydrogeological point of view four main rock formations are distinguished in the Vjosa watershed:

- Karstic carbonate rock formations originated and structured in different geological periods representing high waterbearing potential aquifers. The groundwater in karstified rocks follows a tortuous path from the recharge areas through karstic systems before discharging. The areas between two river valleys where the massif emerges, as well as river valleys in contact with carbonate formations, serve as recharge zones. Drainage zones, moreover, are composed by the following formations: tectonic contact of flysch with carbonate formations; karstified or fractured rock to erosional basis of the streams; Quaternary Breccias (formations).
- Terrigenous rock formations originated in deep sea, into a turbiditic environment. These deposits represent rythmic intercalations, of claystones, siltstones and sandstones with rare conglomerates. These formations are characterized by a low water bearing potential.
- Sedimentary rock formations of the Neogenic molasses of the Peri-Adriatic Depression represented by intercalations of the sedimentary rocks formed in different sedimentation environments as Fluvial, Deltaic, Littoral, Turbiditic, etc. These deposits are characterized by a moderate water bearing potential.
- Quaternary deposits represent the highest water bearing potential due to their high hydraulic conductivity.

Based on the rock formation types, their hydrologic features and geological structures, the following hydrogeological regions have been distinguished (ShGjSh, 2015, Fig. 9):

Hydrogeological region of the Mirdita tectonic zone: Intrusive Jurassic magmatic rocks with Triassic limestone blocs characterized by a poor waterbearing potential. Springs are encountered along the fractured tectonic lines. Their average discharge varies from 0.3 to 0.5 l/s. Estimated potential recourses are approximately 20 l/s.

Hydrogeological region of carbonate formations of the Krasta–Cukali tectonic zone has a poor water-bearing potential due to the limited presence of the limestones within the flysch formation. The spring yields that drain the massif vary from 0.1–0.4 l/s.

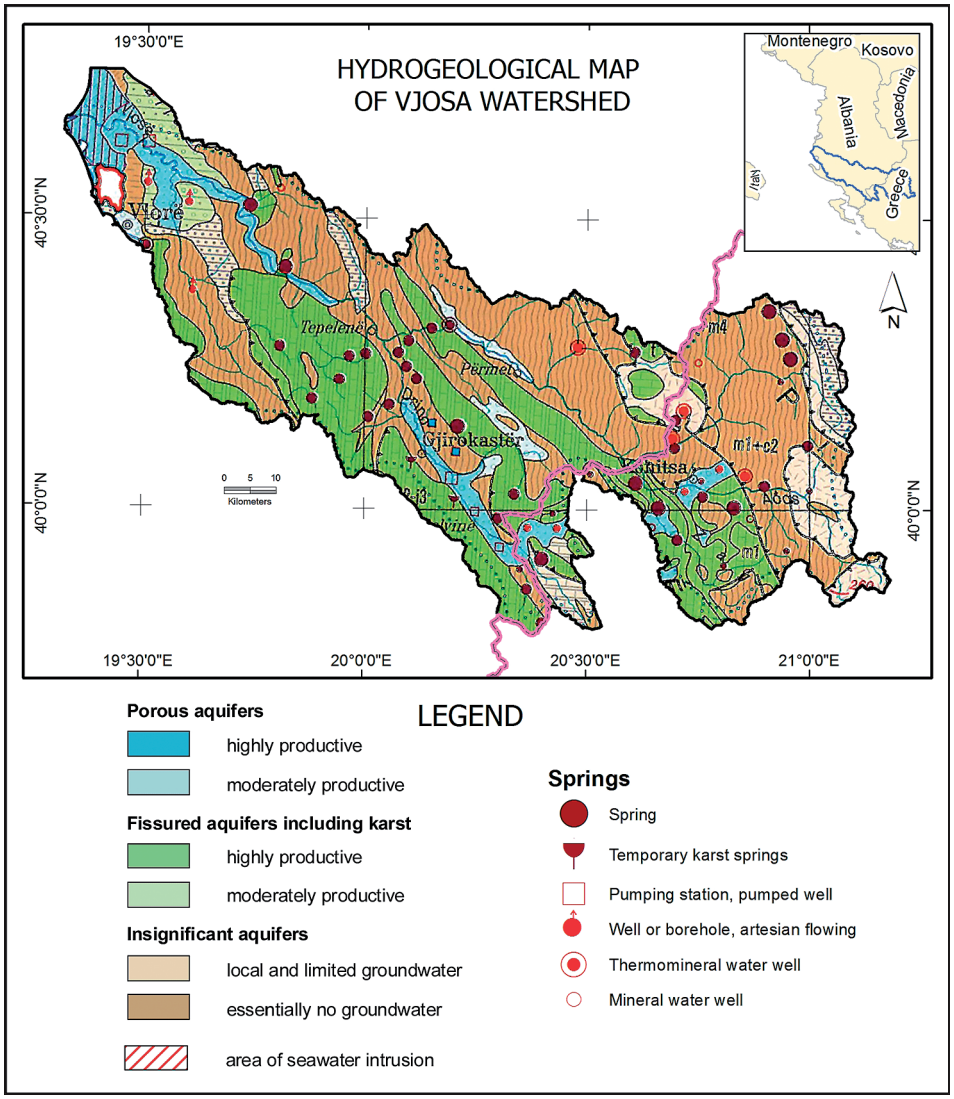

Fig. 9: Hydrogeological map of the Vjosa Watershed. – Abb. 9: Hydrogeologische Karte des Vjosa Einzugsgebietes.

Hydrogeological region of the carbonate formations of the Kruja tectonic zone is represented by small anticline structures outcropping at the eastern side of Permeti syncline. The presence of the thermo mineral sulfide water springs is the relevant feature for this hydrogeological region. (Frashëri et al.2004, Pano 2015). Farther to the south, at Kavasila in Greece, the thermal water occurs.

Hydrogeological region of the carbonate formations of the Berati subzone – Ionian tectonic zone are represented by Trebeshina – Dhembeli – Nemerçka and Shendelli – Lunxheri – Bureto mountain chains. The anticline belt of Berati represents a single karstic reservoir. The most important springs of this region are located in the canyon of Kelcyra, in the eastern flank of the anticline. The biggest spring discharge is1.3 m^3/s.

Hydrogeological region of the Drino depression represents the southern part of Vjosa Watershed and has a northeastern – southwestern extension. The Quaternary deposits have a good hydraulic connection with the Drino River waters. A part of ground waters drains to Mali Gjere Mountain. The average Drino River discharge is Q_0=42.5m^3/s (Lekli station), 22% of which is groundwater contribution. The runoff coefficient of the annual water flow for the entire basin is α_0= 0.53.

Tab. 1: Main physical and chemical characteristics of groundwater related to different tectonic units. – Tab. 1: Die wichtigsten physikalischen und chemischen Charakteristika des Grundwassers in den verschiedenen tektonischen Bereichen.

Tectonic Zone	T (°C)	TDS (g/l)	Hardness (°dH)	Water type
Mirdita	9-14	0.3-0.45	6-10	Ca-Mg-HCO_3.
Krasta-Cukali				
Kruja (Leskovik, Langarice, Lemnice)	29-32			Na-Ca-Cl
Ionian / Berati Subzone (Trebeshine, Dhembel, Nemercke, Shendelli, Lunxheri, Bureto)	8-16	0.7-0.8	6-16	Ca-HCO_3
Ionian / Kurveleshi Subzone (Kurveleshi, Kremanara, Tragjasi)		0.2-0.3	7-12	Ca-HCO_3
Ionian / Kurveleshi Subzone (Mali i Gjere)	11-13	0.1-0.5	7-16	Ca -HCO_3, Springs West side Ca-HCO3-SO4
Ionian / Çika Subzone (Selenica, Vlora)	15-18	0.45-0.50	18-30	Mg-Ca-HCO_3 or Ca–Mg-HCO_3.
Ionian (Vjosa midstream and downstream - Shushica River Valley)	15-16	Changes toward the sea		Mainly HCO_3, Changes toward the sea HCO3-Cl and Cl-HCO3
Ionian (Drino River Valley)	15-16	<0.6	15-20	Mainly Ca-HCO_3
Ionian (Permeti Syncline)	15	0	15-18	Ca-Mg-HCO_3
Delta of Vjosa		< 0.4	8-10	Ca-HCO_3

Hydrogeological region of the carbonate formation t of subzone Kurveleshi- Ionian tectonic zone. This region represents one of the most potential karstic reservoirs of Vjosa watershed, having an area of approximately 580 km^2. The carbonate formations have well-developed cracks and karst, and the springs discharge range from 100 to 1000 l/s. The springs are mostly of tectonic karstic origin. Some of these springs are: Tatzatit, Kalivaçi, Poçemi (795–970 l/), Verniku, Kuçi (Q = 10–100 l/s), Uji i Ftohte – Tepelene (20–200 l/s), Gurra e Picarit, Fterres, Kolonjes, etc. The spring of Viroi with a discharge, ranging from 0 (in the dry period) to 20 m^3/s represent the most important spring of karstic origin. It drains from the eastern side of "Mali i Gjere" massif.

Tab. 2: Hydrochemical characteristics of the main springs. – Tab. 2: Hydrochemische Charakterisierung der wichtigsten Quellen.

Spring	Spring Type (Modified by Durmishi. C.)	Discharge (l/s)	Hydrochemical characteristics			
			TDS (mg/l)	T (°C)	Hardness (°dH)	Water type
Poçemi Springs	Karstic-tectonic (8 springs)	839	287	15	12	Ca -HCO_3
Doreza-Kalivaçi	Karstic-erosional	200	103	12	7	Ca -HCO_3
Tepelena	Karstic	250	162	9,5	9	Ca -HCO_3
Izvori spring	Karstic-tectonic	80-150	-	-	-	-
Vermiku spring	Karstic-tectonic (4 springs)	460	140-165	9-11	7-8	Ca -HCO_3
UjiFtohteTepelena	Karstic-tectonic	100	-	-	-	-
UjiFtohteDrino Valley	Karstic-tectonic (2 springs)	220	180	12	6	Ca -HCO_3
Uji Ftohte- Drino Valley	Karstic spring from quaternary breccias	12	-	-	-	-
Hormova spring	Karstic-tectonic	61	-	-	-	-
Lekli spring	Karstic-tectonic	300	-	-	-	-
Peshtani spring Tepelena	Karstic	300	212	12	8	Ca -HCO_3
Kelcyra Gorge	Karstic-tectonic	-	277	9	10	Ca -HCO_3
Kelcyra Gorge	Karstic	250-300	-	-	-	Ca -HCO_3
Syri Zi, Kelcyra Gorge	Karstic	600-700	-	-	-	-
Lengarica	Tectonic- Karstic (8 thermal springs)	-	-	30	-	Na-Ca -Cl
Viroi	Temporary karstic spring	-	-	11	-	Ca -HCO_3
Petrani spring	Quaternary breccias	9	148	12	7	Ca -HCO_3

Hydrogeological region of the flyschoidal formations and molasses of Peri-Adriatic Depression is represented by the deposits of the "Rrogozhina" formation. This formation is composed of sandstones and conglomerates with relevant water bearing potential, outcropping at the hills of Armeni, Selenica, Buzemadhi, etc. This aquifer is exploited by wells. The water of conglomerates is of good quality, with total dissolved solids (TDS) 0.45–0.7 g/l, and general hardness of 17–20 German degrees.

Hydrogeological region of the formations of Quaternary belonging to the downstream section of Vjosa River and its delta, represented by the aquifer of alluvial deposits of Vjosa River including the entire plain of "Vjosa – Shushica" and "Cakrani". This aquifer is characterized by high hydraulic parameters and high water bearing potential. Water quality is good, but in the western part the quality deteriorates due to sea water intrusion.

Geo-touristic features of the Vjosa watershed

The Vjosa Watershed has a wide variety of ecosystems and landscapes of regional, national and international importance. The landscape of the Vjosa River watershed (especially in the upper and middle parts) is characterized by the presence of a series of geological-geomorphological natural monuments such as: geological structures, river terraces, glacial landscapes, spectacular canyons, narrow valley segments with almost vertical slopes (from 300–400 m to 900–1000 m high) and pure water springs. The characteristic landscapes are associated to a specific biodiversity and grassy vegetation. Forests and hygro-hydrophilic vegetation are also encountered. Habitats expressing all types of vegetation are naturally intertwined.

Protected areas, having different status according to the UCN, are identified in the Vjosa Watershed.

Protected Areas

According to **IUCN/WCMC (1994)** the following protected areas are proclaimed in the Vjosa Watershed:

National Parks (Category II)

The Pindos National Park is located in the northern part of the Pindus Mountains, north of the town of Metsovo and south of Perivoli. The Park of some 7000 ha was established in 1966. There are forests of black pine and beech, and in the higher parts, the Bosnian Pine (*Pinus leucodermis*).

The Vikos–Aoos National Park founded in 1973 is located in northwestern Greece, south of the town of Konitsa, in the west part of Zagoria region. It includes Mount Tymfi, the Vikos Gorge and the Aoos Gorge. It encompasses 126 km^2 of mountainous terrain, with numerous rivers, lakes, caves, deep canyons and dense coniferous and deciduous forests. The core of the NP (3400ha) is the Vikos Gorge, carved by the Voidomatis River, while the Aoos Gorge, mount Tymfi, with its highest peak Gamila 2497 m and a number of traditionally preserved settlements form the park's peripheral zone.

Protected Areas in Albanian territory, according to the International Union for Conservation of Nature (IUCN/WCMC, 1994), have been proclaimed the following areas:

The Hotova-Dangellia National Park is the largest national park in Albania located in Permetiregion, with an area of 34,361 Ha. The Park takes its name from the Hotova Fir, which is considered as one of the most important Mediterranean plant relics of the country. Nevertheless, it encompasses hilly and mountainous terrain composed of limestone and sandstone rocks. Numerous valleys, canyons, gorges, rivers and dense *deciduous* and *coniferous* forests are also present. The park includes 11 natural monuments also.

Nature Monuments (Category III)

In this category the following monuments are included: Postenani Thermal Baths, Vromoneri (Leskoviku) and Benja Thermal Baths, Langarica Canyon (Benja),'Guri Atos' – close to Kutali village,'Guri' of Permeti, 'Bokerima' of Dangellia, 'Uji i Zi' Spring in Kelcyra, Mezhgorani Cave, Piksi Canyon, River Terraces of Nderani village, Nepravishta Spring, Libohova Spring, Viroi Spring, Lekli Cave,'UjiFtohte' spring Tepelena, Nivica Canyon, 'Vurgu' Planes in Çorrushi, Povla Thermal Baths.

The Vjosa-Narta Protected Landscape (Category VI)

It covers a total area of 194.12 km^2, encompassing Narta Lagoon along with the delta of the Vjosa River and its surrounding areas with freshwater wetlands, marshlands, reed beds, woodlands, islands and sandy beaches. It is also listed as an important Bird and Plant Area, because it supports significant bird and plant species.

Natural monuments worth considering in Albanian territory

The Vjosa Watershed encompass important natural monuments of high value still unidentified, not evaluated or cataloged in the network of protected area categories which are endangered by unwise infrastructural, industrial, agro-cultural developments etc. For those natural resources that have not been proclaimed as PAs according to the IUCN, geo-di-

versity studies in the context of geological diversity can contribute to the valorization of specific natural monuments of the Vjosa watershed. The geological diversity studies of the basin have highlighted a series of monuments of different categories according to IUCN, which will enrich the potential values of natural resources and the geo-tourism of Vjosa, at the national and European level.

This paper puts special attention to two of the most important areas (Fig. 10), which should be included in the respective categories of PAs:

The geological structure of Berati belt – Ionian tectonic zone.

This area is oriented SE-NW, and consists of the crests carbonate structures (Jurassic-Cretaceous-Paleogene) of the mountains chains of Dhembeli (from 1280 m to 2050 m a.s.l.) – Trebeshina (from 1085 m to 1307 m) at the eastern flank of the structure, and Lunxheria (from 1722 m to 2185 m) – Shendellia (from 1231 m to1802 m) on the western flank of the structure. This chain is crossed by the geo-monument of Kelcyra Canyon extending from Kelcyra to Dragoti. The mountain-chains are divided by the syncline structure filled by Oligocene terrigenous flysch. In the south-eastern part of the syncline the mountainous valley of Lunxheria is encountered. In this valley, in the area of Sheperi –Nderani (2050 m), the spring of the Zagoria River is located, which joins Vjosa at an elevation of about 150 m (Peshtani area). In the North-Eastern part of this syncline structure (Mezhgorani area) the Mezhgorani torrent originates at an elevation of about 1600 m and flows in the NW-SE direction, joining Vjosa at an elevation of about 155–165 m. In this area, geo-diversity is associated with biodiversity. The most important is the giant natural geomonument canyon of the Vjosa River, with a length of about 20 km, with a valley depth of ranging from 900 m to 1600 m and width ranging from 180 m in Kelcyra, up to 130 m in the Dragoti. In the Kelcyra gorge, the highest elevations are represented by the Qesniku (1280 m) and Dushku (1085 m) mountains, while in the Dragoti gorge the highest elevations are represented by Goliku (1722 m) and Trebeshina (1889 m) mountains. The most spectacular zone of the Vjosa Canyon is the vertical left side of the valley going from an elevation of 160 m (Vjosa River) up to 1000–1040 m, having a width of about 1.5–6 km. From the geological-tectonic point of view, this area represents a carbonate anticline structure composed of the carbonates of Jurassic-Cretaceous-Paleocene and Eocene.

The coexistence between natural elements and geological processes is observed in this area. The presence of the ecosystem and biodiversity of the 'Hija' forest, the outcropping from the anticline structure of the karstic springs of 'Syri Zi – Black Eye' and 'Uji i Zi – Black Water' and small waterfalls along Vjosa valley, are also visible.

Structural "core" of Tepelen Kurveleshi belt – Ionian tectonic zone.

This geo-monument is part of the Ionian tectonic zone – Kurveleshi belt. This area represents a carbonate anticline structure composed by Jurassic, Cretaceous, and Paleogene deposits. The most important part of this geo-monument is the glacial valley of the Bença River, originated during the Quaternary glacial cycles. The river sources of the Bença River are located in the Shtepeza-Lekdushi-Progonati-Gusmari-Nivica mountain belt, in elevations going from 2122 m (Kendervica Mountain) to 1000–1400 m (Progonati plateau). In the upper stream the Bença River has a NW-SE direction. The actual river bed passes through the Jurassic carbonate formations from Nivica to Bença village, following in a SW-NE direction up to Veliqoti village, passing through the Cretaceous carbonate

joining the Vjosa River at an elevation of about 115 m. In this area the glacial valleys of Perrosi, Luzati and Salaria are included. This area also includes a series of geo-monuments, such as the Nivica canyon, the presence of karstic water springs and a series of unexplored karstic caves. In this area the Bença River transverses only the carbonate formations; the water is very clean and the related sediments along the river bed are mainly of carbonate composition.

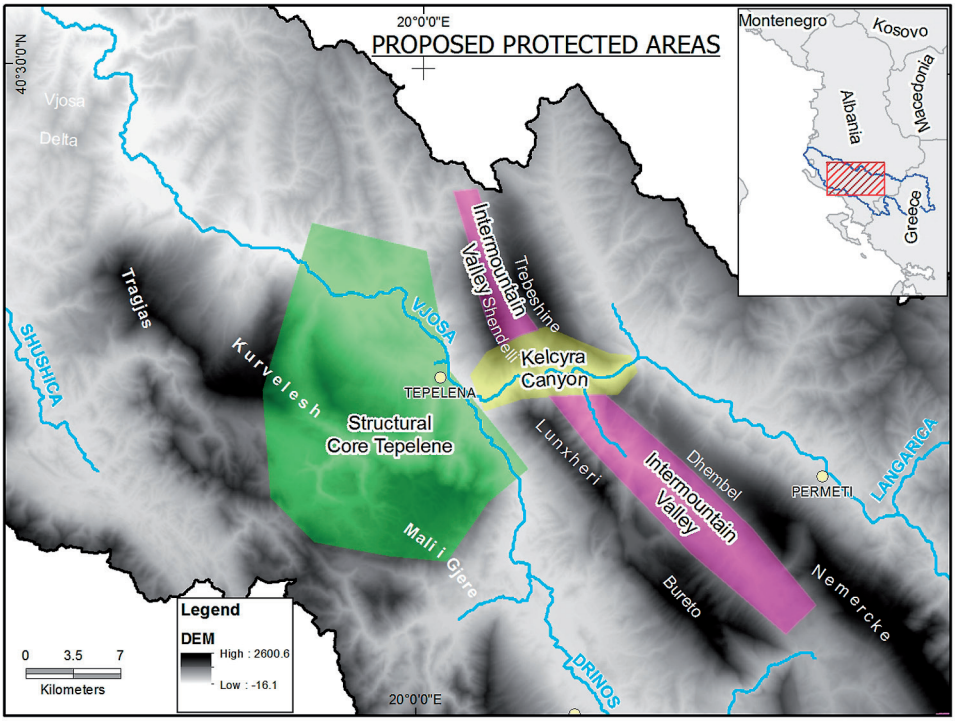

Fig. 10: Proposed new Protected Areas in the Vjosa Watershed (Albanian part). – Abb. 10: Vorschlag für eine Schutzzone des Vjosa Einzugsgebietes.

Conclusions

The Vjosa Watershed is located on the southern part of the Albanides mainly in the Ionian Zone. Along its course, the Vjosa River crosses several geological structures consisting of a succession of anticlines and synclines affected by a series of active tectonic and neotectonic lines, evidencing spectacular outcrops of rocks as well as geodynamic phenomena, representing an area of international interest for geological studies. The carbonate formations, deeply affected by the karst phenomenon, lead to the formation of groundwater flows draining along the Vjosa valley in 47 permanent water springs. The water type of each tectonic zone varies in function of the presence, at local level, of rocks and minerals that condition the chemical composition of the groundwater. The most common type of ground water is calcium bicarbonate (Ca-HCO_3). There is an exception in the coastal plain where the waters of the Quaternary aquifer varies from HCO_3 to HCO_3-Cl up to Cl-HCO_3 type due to the sea water intrusion.

The Vjosa Watershed, at its present natural state, possesses natural resources not yet officially identified or included in the list of Albanian Protected Areas.

The evaluation and the management of these natural resources will contribute in exploring the scientific values, as well as the socio-economic, didactic, recreational and geo-touristic importance of the area, on a local, regional and international level.

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