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Lithostratigraphic column between Nevesinje and Ljubinje including highlights of the karst area characteristics (Southeastern Bosnia & Herzegovina)

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Abstract

The area between Nevesinje and Ljubinje in Eastern Herzegovina is a part the Dinaric massif, where Mesozoic carbonated platform is almost completely preserved. There are also Palaeogene sediments in the area structure, but they are considerably less preserved. However, they are an extraordinary indicator of the more important structures within and a solid base for reconstruction of tectonic occurrences during Neogene and Quaternary.

The purpose of this paper is to provide more information on lithofacies and tectonic terrain structures, including particular karst characteristics. Causes for occurrence and possible development of karst process are issues that are also pointed out (considering the thickness of the carbonated sediments), as well as the directions and development volume of the process.

GEOGRAPHICAL POSITION

The studied area is located in Eastern Herzegovina, between Crvanj Mountain in the north and Popovo Polje in the south. This is the area with high mountains, plateaus and karst fields. It is surrounded by high mountains: Crvanj (highest point 1927 m) and Gatačka Bjelašnica (highest point 1807 m) in the northeast; Viduša (highest point 1419 m) in the east, and Velež (highest point 1969 m) and Snježnica in the west. Popovo Polje is in the south, with particular geomorphology and karst characteristics. The area encompasses approximately 1500 km^2. Significant settlements are Nevesinje and Ljubinje. They are connected relatively well, by partly asphalt roads with Mostar, Stolac and Trebinje.

GEOLOGICAL STRUCTURE

Geologicaly part of Eastern Herzegovina consists of Mesozoic and Cenozoic structures. Previonsly explored rock massifs are the product of sediment deposition. Continual sedimentation lasted in this part of Tethys during Mesozoic, while in the Cenozoic, before the complete withdrawal of the sea, there were some relatively short periods of land and lacustrine environment.

MESOZOIC (Mz)

During Mesozoic era, sedimentation continued through Triassic, Jurassic and Cretaceous.

The map of investigated area

Triassic sediments (T)

There are three forms of Triassic sediments:

Lower Triassic sediments (T_1) are found in the crest of Crvanj mountain range. **Seis Substage** consists of sandstones and sandy limestone with interlayers of clay and marlstones where the following fossils are found: *Anodontophora fassaensis, Claraia claraia i Claraia aurita*. These sediments are approximately 200 m thick. **Campil substage** consists of marlstones, sandstones and limestone, with average thickness of 100 – 200 m. There are the following fossils found: *Myophoria costata, Turbo rectecostatus* etc.

Middle Triassic sediments (T_2) are represented within both forms. **Anisian** (lower middle Triassic stage) is represented by gray and reddish limestone and dolomites, in the western slopes of Crvanj mountain. Gradually, they turn to sheet deposits of limestone, cherts and tuffa of the **Ladinian** stage (upper middle Triassic stage). Thickness of the Anisian carbonate sediment is approximately 250 m, and of discovered part of Ladinian in Zalomka anticline around 50 m.

Upper Triassic sediments (T_3) are found on the western slopes of Crvanj mountain (Zimomor) and by Močila. It is developed as bedded dolomite facies and its thickness being up to 800 m. There are massive and thick bedded dolomites in the Zalomka anticline, that are mostly mixed with dolomite micrites and micrites, with rare occurrences of Megalodones. The thickness of this member is up to 400 m.

Jurassic sediments (J)

Liassic sediments (J_1 – Lower Jurassic) are best represented in Duboki and Fojnica streams, Zalomka river right tributaries. They consist of sheet and bedded limestone, mostly of allochemomicrite type. Cherts are frequent and dolomites are there, but rarely. The characteristic microfossil is *Involutina liassica*, especially for lower and middle Liassic sediment. *Vidalina martana* occurs in the whole pillar transiting into Dogger (middle Jurassic stage). There is an abundant Ammonites fauna within middle Liassic stage (Domerian substage).

Liassic – Dogger sediments ($J_{1,2}$ – Lower to Middle Jurrasic) consists of calcarenites and oolytic limestone, with rare occurrences of dolomites and chert nodules. *Stephanoceras sp.* is found here. There are also bedded biomicrites of Lower Dogger age. Characteristic Dogger type is found in the upmost parts of Dogger: *Protopeneroplis striata*. Thickness of Dogger in this part varies from 60 up to 300 m.

Upper Jurassic sediments (J_3) are represented by light gray and bedded limestone with Nerineas. The following are found: *Ptignatis carpathica, P. pseudobruntruntana* and *Clypeina jurassica*. Limestone thickness of the Upper Jurassic sediments (including nerineas) is around 300 m.

Cretaceous sediments (K)

Lower Cretaceous sediments (K_1) are found in the syncline of Velež mountain, the southwestern part of Nevesinjsko polje, and in Podveležje, from Hum (highest point 1025 m) all the way behind Kokorina. It consists of two structures:

Older $^1K_1$ structure, discovered in Lukavica and Bjelašnica, consists of different types of limestone with dolomites and dolomite limestone. It is characterized by fine deposits of dark gray and brawn layers. There are found: *Campbelliella milesi, Tintinepsella lata*, and Dascycladaceae: *Clypeina jurassica, Pianella anmelata* etc. The thickness of the carbonate is around 300 m.

Younger $^2K_1$ structure of the Lower Cretaceous age takes up more terrain in the northwestern part of Nevesinjsko polje and southern parts of Velež. It comes up in the narrow parts of right bank of Bregava, on the slopes of Hrgud. The most frequent structures are microsparites and limestone with paleodont shells, and in upper parts, layered dolomites and dolomite limestone are noticeable. The thickness of this structure is 300 – 400 m.

Upper Cretaceous sediments (K_2): These sediments have the most important part in the terrain structure. They are characterized by facies changes, vertical and side ones. Carbonated sediments of Upper Cretaceous sediments, thick over 2500 m, are divided into more stratigraphic units:

1. **Alb – Cenomanian** ($K_{1,2}$) sediments, between lower and upper Cretaceous age, are around Popovo Polje. They are developed in the dolomite and dolomite limestone facies. The thickness of these carbonates in this part of the terrain is around 400 m.

2. **Cenomanian – Turonian** ($K_2^{1,2}$) sediments are in the area of Snježnica, in the Bregava canyon, area of Hrgud and Trešanica and outskirts of Dabarsko Polje. Limestone and dolomites with chrondodite and rudites are on the top of Alb – Cenomanian carbonates, with gradual transition. The thickness of these sediments is around 500 m.

3. **Turonian – Senonian** ($K_2^{2,3}$) sediments are around Hrgud, Udrežnje and Snježnica. They are concordantly laid on top of chrondodite carbonates in the thick structure of layered limestone, of white and light gray color. Their thickness is around 450 m.

4. **Senonian** (K_2^3) carbonated sediments are located south of Lukavičko and Dabarsko Polje, and take up more terrain in the surroundings of Ljubinje. They are layered on the Turonian sediments, with gradual transition. In the Senonian stage of this terrain, there are usually two levels: a) **lower parts** ($K_2^{1,2}$) consisting of well layered organic – detrital, micro and cryptocristaline limestone and b) **higher parts** ($K^{2,3}$) represented by well layered various limestone that become massive in their final parts. The thickness of these carbonates is around 500 m.

CENOZOIC (Kz)

The sediments of Paleogene, Neogene and Quaternary belong to this era.

Paleogene (Pc)

Paleogene sediments are in the southwest of Nevesinjsko Polje (Biograd, Magunica, Lukavac), northwest of Dabarsko Polje and west of Ljubinje. There are four Paleogene representatives in this area:

1. **Liburnian sediments** (Pc, E) are represented by brown and dark gray deposited limestone. Limestone is often bituminous. They are discordant to Senonian carbonates and/or other representatives of Upper Cretaceous sediments. Downthrown contact is characterized by the occurrence of bauxite. Their thickness is from a few up to 250 m.

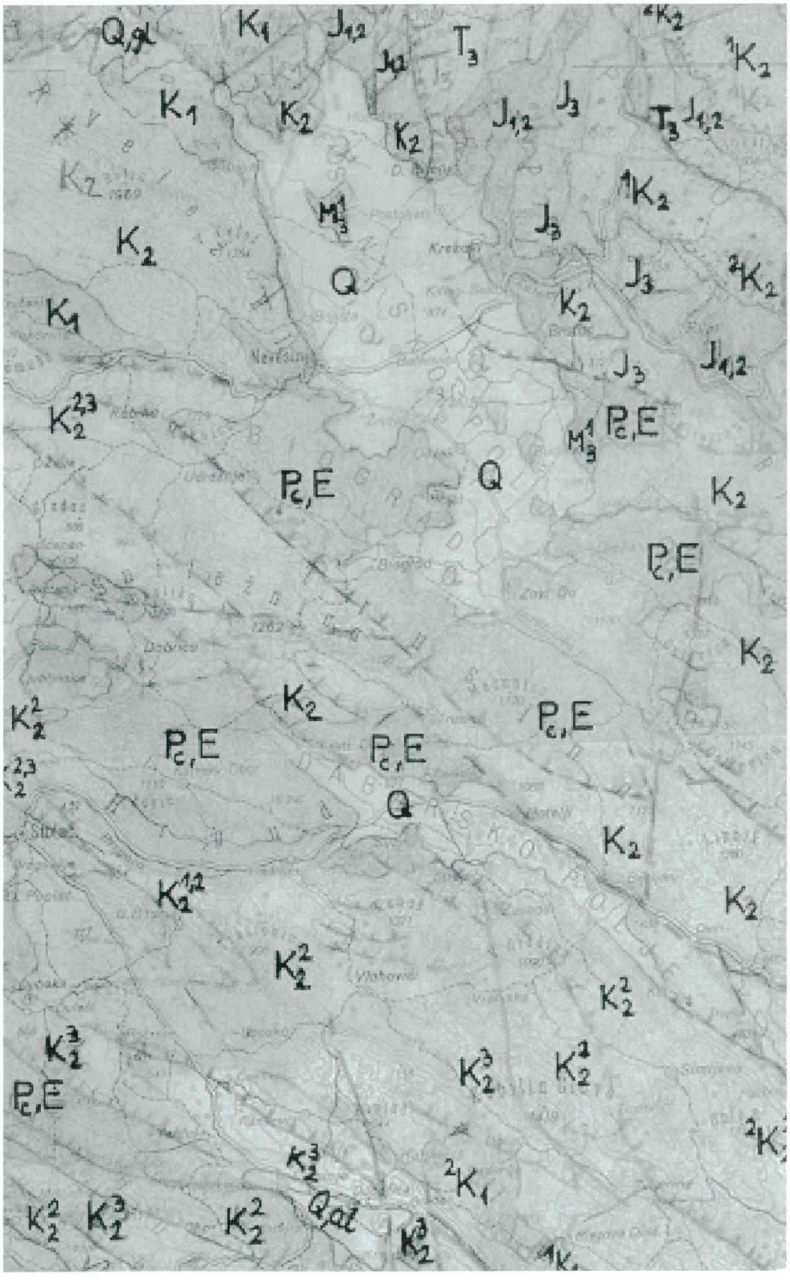
2. **Alveolina – nummulite limestone** ($E_{1,2}$) are concordant on top of Liburnian sediments. These are light gray to white, layered, occasionally massive and compact limestone. Their thickness varies from 100 – 200 m.

3. **Eocen flysch** ($E_{2,3}$) is located in the area of Dabrica, Dabričko and Lukavačko Polje. On the top of the older Cretaceous and Paleogene limestone there are conglomerates, brecciated limestone and large grain sandstone, that are thick up to few tens of meters. There is also bauxite on the downthrown contact. Bauxites are of the economic significance in the area of Dabrica. The thickness of flysch varies from 50 to 200 m.

4. **Promina conglomerates** (E_3, Ol_1) are in the area of Nevesinjsko and Dabarsko Polje. They are lying concordantly on the older flysch. Conglomerates have the characteristics of molasses and synorogenic deposit that would be in accordance with Pyrenean tectogenesis. On this basis, the Upper Eocen and Lower Eocen age of this thick (some places even up to 800 m) carbonated complex has been determined.

GEOLOGICAL MAP
BETWEEN NEVESINJSKO AND LJUBINJE POLJE – EASTERN HERZEGOVINA

3 0 3 6 9 12 km



- Q — Quaternary: alluvial, proluvial, and colluvial deposits
- M_3^1 — Upper Miocene: clay, sandstone, lignite, marl and limestone
- Pc,E — Paleocene-Eocene: Liburnian limestone, flych and Promina conglomerate
- K_2^3 — Upper Cretaceous (Senonian): limestone and marl
- K_2^2 — Upper Cretaceous (Turonian): limestone, marl and dolomite
- $K_2^{1,2}$ — Upper Cretaceous (Cenomanian-Turonian): limestone and dolomite
- K_2 — Upper Cretaceous (inseparabled): limestone, dolomite and marl
- $^2K_1$ — Lower Cretaceus (Barremian-Aptian): limestone, dolomite, marl
- $^1K_1$ — Lower Cretaceous: limestone, dolomite, breccia
- K_1 — Lower Cretaceous (inseparabled): limestone, dolomite, marl
- J_3 — Upper Jurassic (inseperabled): limestone, dolomite, dolomite limestone
- $J_{1,2}$ — Lower to Middle Jurassic: limestone, interbedded dolomite, chert and sandstone
- T_3 — Upper Triassic: limestone and dolomite
- Front of overthrust
- Reverse and normal faults

Neogene (Ng)

This is where lake sediments of Nevesinjsko Polje are. Limnic series starts with basal conglomerates with interlayers of clay. Following are the marls with three layers of coal, 60 cm, 4 m and 1 m thick. The total thickness of marly hanging wall with layers of coal is 80 – 100 m. They are probably of Miocene age, synchronic with upper Miocene sediments in Gacko in the east and Mostar valley in the west.

Quaternary (Q)

These are the youngest sediments in Nevesinjsko Polje and in other parts of this area. They are represented by Moraine structures (slopes of Velež Mountain), limnoglacial sediments (Piskači), proluvial and alluvial covers that are larger in the valley of Zalomka River, and swamp sediments in the fields, and, finally, talus structures in the outskirts of fields.

TECTONICS

From the structural-tectonics point of view, the area belongs mostly to the tectonic unit of Outer Dinarides, namely the High Karst Overthrust. In the northern part it goes into Middle Dinarides, the zone of Paleozoic slate and Mesozoic limestone. However, the area completely belongs to tectonic category of Dinarides that, in the territory of Bosnia and Herzegovina, have the form of total fold, with characteristics of mega-overhrust, folded and moved towards northeast. This is the paradigmatic consequence of the Earth crust dynamics, showed in the Alpide orogenic cycle, due to the collision and underthrust of African plate under the Euro-Asian continent.

Middle Dinarides encompass large structural unit in this area, namely:

- **Anticline Crvanj**, and
- **Anticline of Zalomska river**

Between these two anticlines and Nevesinjsko Polje is the border between Outer and Middle Dinarides. In the northwest, the border goes towards Veliko Rujište (k. 1765 m), where over Porim i Prigradac it goes down to Neretva riverbed. In the southeast, the border between these two mega-structures is characterized by reverse faults with overthrust of Cretaceous onto Palaeogene sediments, and various folded structures.

Within **Outer Dinarides**, in the High Karst Overthrust area there are larger structures of facies:

- Syncline structure of **Velež** Mountain where there are carbonates of lower cretaceous sediments, and the bottom is consisted of Upper Cretaceous and Palaeogene sediments.
- Isoclinally folded complex **Biograd – Snježnica – Hrgud**, that encompasses the terrain between Nevesinjsko and Dabarsko Polje, and
- Tectonic unit **Viduša – Bjelašnica**, that is of a very complicated form. There are structures of Upper and Lower Cretaceous sediments, then carbonates and clastics of Paleogene in its lithofacies content. (Pc, E).

In-depth built of this terrain is consisted of a few large blocks that are divided by deep reverse faults. Along them are Cretaceous carbonates over the Eocen flysch and/or Promina conglomerates. There are parts of anticlines of Lastva and Sitnica in southeastern part, syncline of Žukovica – Gradina, Budoši – Mosko (northwestern part) and Pustipuhe – Ljubinje. West of Ljubinje is isolated unit of Hrasno.

KARST CHARACTERISTICS

Morphology and the surface appearance of the studied area have typical karst characteristics. High **mountain reefs** dominate in the area (above 1500 m). Mountain ranges are characterized by dominant tectonic (Dinarides) lines. They consist of carbonate layers and are marked by bilaterally laid high and steep escarpments towards lower valleys or fields.

Karst plateaus are formed between mountain reefs. They are very characteristic geomorphologic element for this area. They are formed in the tectonically predisposed terrains, and shaped by the processes of corrosion and erosion of the karst, effects of other exogenetic factors, among which the river erosion and lake abrasion possibly have played the major role. South of Nevesinjsko Polje, characteristic morphostructures are structurally erosive plateau Biograd – Udrežnje, then Trusina (without mountain

reef), and parts of Hrgud and Sitnica, where we can find destructed karst plateaus.

Karst fields are paleodepressions between high mountain massifs, or morphostructures of sinking in the areas of longitudinal faults of regional importance. The attached geological map shows three larger karst fields:

- **Nevesinjsko Polje** encompasses the area of 190 km^2. It belongs to the category of the largest karst fields in Eastern Herzegovina. It is located in the area of reverse faults, between the highest mountains in the region: Velež (Botin, 1969 m) and Crvanj (Zimomor, 1921 m). The height of the field bottom ranges from 800 – 850 m.
- **Dabarsko Polje** is located in the zone of deep faults, on the northwest – southeast line. It is formed between Snježnica and Trusina mountains that form its southeastern outskirt, and Hrgud and Sitnica mountains, in the southwest. It is around 20 km long around and wide 3 km the most. It encompasses the area of around 40 km^2.
- **Ljubinjsko Polje** is the smallest of these three fields. It encompasses the area of only 9 km^2. It is located in the area of reverse fault that formed the overthrust of the Upper Cretaceous sediments on the Paleogene and Lower Cretaceous sediments. The bottom of the field is on the 400 – 410 m.

Common characteristics of these fields are:

- They are stairs-like, from north to south;
- The height difference between Nevesinjsko and Dabarsko Polje is almost 500 m, and between Dabarsko Polje and Lubinje 70 – 80 m;
- They are formed during tectogenetic processes in the area of regional faults of Dinarides range;
- They are modeled by the effect of exogenetic factors, where phases of lakes and fluvial erosion, alongside with dominant and long term karst processes, had the most important role;
- On the northern outskirts are springs and wells, and on the south side are abysses, where sometimes the streams are formed with oscillations in the flow;
- Fields are flooded periodically, while in Nevesinjsko Polje, the water accumulations are formed in the northern and southern part;
- Outflow of water from these fields is exclusively underground, which makes them closed karst fields.

Of all karst forms, we often see **karst valleys**, wide 0,5 – 1,0 km. They are smaller than karst fields and larger than sinkholes. **Dry karst river valleys** are extraordinarily characteristic form in this karst. They are especially well developed in the valleys of Bregava and Zalomka rivers.

Among karst micro-forms in this area, there are: **lapies**, **gorges**, **sinkholes**, **natural ceilings**, **holes**, **caves** etc. developed depending on the lythofacies content, structure and influence of the other, mainly exogenetic factors.

Hydrographical network of this area has all the characteristics of the "developed karst". It id underdeveloped and it has networked, dendritic look.

The major streaus in the area are Bregava and Zalomka. Both are tributaries to Neretva River. Bregava is above ground flowing into Nereretva near Čapljina, while Zalomka is an underground tributary (Vrelo Bune). Aside from those, more important (shorter) karst river flows are Dušila in Nevesinjsko Polje, Opačica and Vrijeka in Dabarsko Polje and Bukov potok in Ljubinjsko Polje. They have formed their own underground paths, directed towards Neretva or Bregava, and partly towards Trebišnjica.

River flows are mainly occasional. Only Vrijeka River in Dabarsko Polje is a permanent river flow. Bregava and Zalomka are a combination of permanent and occasional flow. They dry when they get to larger abysses or in the extraordinary dry periods.

The characteristics of this area are wells and springs in the outskirts of crast field and in the river valleys. Their capacity varies in the wide range, depending on the intensity of rainfall. The extreme examples are the springs of Bregava that have the minimum of 2 m^3/s, and maximum over 1000 m^3/s.

CONCLUSION

Karstification process in the Eastern Herzegovina, aside from the one on the surface, is going on in the deep parts of carbonate complex. According to the karst forms and

occurrences, the process is developed in the depths from – 200 up to + 1900 m. Carbonate massive – platform in this area is over 5.000 m thick. Aside from that, tectogenetic processes of folding, faulting and horizontal movements have brought to the smaller blocks of measured in km. We should bear in mind the significant increase in carbonate sediment thickness in the overhrust area. This makes the possibility of exact determination of status and future development of the whole karst process even more complicated. However, it is certain that this process is strong (longitudinal, and in depth), that is has been repeated (with different intensity), but it is permanent, and it is shown as typical "Dinaric karst".

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