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Upper Cretaceous magmatic suites of the Timok Magmatic Complex

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Abstract. The Upper Cretaceous Timok Magmatic Complex (TMC) developed on a continental crust composed of different types of Proterozoic to Lower Cretaceous rocks. The TMC consists of the magmatic suites: Timok andesite (AT) – Turonian–Santonian, Metovnica epiclastite (EM) – Coniacian–Campanian, Osnić basaltic andesite (AO) and Ježevica andesite (AJ) – Santonian–Campanian, Valja Strž plutonite (PVS) – Campanian and Boljevac latite (LB). The sedimentary processes and volcanic activity of the TMC lasted nearly continuously throughout nearly the whole Late Cretaceous. The sedimentation lasted from the Albian to the Maastrichtian and the magmatism lasted for 10 million years, from the Upper Turonian to the Upper Campanian. The volcanic front migrated from East to West. The volcanic processes were characterized by the domination of extrusive volcanic facies, a great amount of volcanic material, a change in the depositional environment during the volcanic cycle, sharp facial transitions and a huge deposition of syn- and post-eruptive resedimented volcaniclastics.

Key words: Upper Cretaceous, magmatic suite, volcanism, volcanic facies, sediments.

Апстракт. Горњокредни Тимочки магматски комплекс (ТМК) развијен је на континенталној кори изграђеној од различитих стена протерозојске до доњокредне старости. У ТМК се могу издвојити следеће магматске свите: Андезити Тимока (АТ) – турон–сантон, Епикластити Метовнице (ЕМ) – конијак–кампан, Андезитбазалти Оснића (АО) и Андезити Јежевице (АЈ) – сантон–кампан, Плутонити Ваља Стрж (PVS) – кампан и Латити Бољевца (LB). Седиментни процеси и вулканизам у ТМК континуирано трају кроз целу горњу креду. Седиментација траје од алба до мастрихта, а магматизам континуирано 10 милиона година и то од горњег турона до горњег кампана. Вулкански фронт, у току вулканизма, мигрира од истока ка западу, а вулканизам карактерише доминација екструзивних вулканских фација у односу на експлозивне и интрузивне, велике количине емитованог вулканског материјала, честе промене средина депоновања, велике фацијалне разлике и огромне количине син- и пост-еруптивно реседиментованих вулканокластичних наслага.

Кључне речи: Горња креда, магматске свите, вулканизам, вулканске фације, седименти.

Introduction

The Upper Cretaceous volcano-sedimentary complex of the Carpatho–Balkanides belt spreads discontinuously from the northern parts of the Apuseni Mountains and Banat in Romania, over Timok Krajina in eastern Serbia, down to Srednogorie and the Black Sea in Bulgaria. This zone is 1500 km long and 70 km wide. Further on, this complex continues over the Pontides (Turkey) down to the northern parts of Iran. This is the most important active mining area in Europe, belonging to the Tethyan Eurasian Metallogenic Belt (Janković 1977). More recently, this entire province was named the Banatitic Magmatic and Metallogenic Belt (abbreviated as BMMB, Berza *et al*. 1998), or Apuseni-Banat-Timok-Srednogorie Magmatic and Metallogenic Belt (abbreviated as ABTS, Popov *et al*. 2002). Boccaletti *et al*. (1974) and Aiello *et al*. (1977) consider Srednogorie in Bulgaria as a back-arc rift. Geodynamic and tectonic models have also been provided (Hsu *et al*. 1977; Dabovski *et al*. 1991; Vlad 1997; Ciobanu *et al*. 2002 and von Quadt *et al*. 2004, 2005). Recent high precision U/Pb, $^{40}Ar/^{39}Ar$, Re/Os and geochemical data have improved and refined the tectonic models of this area and shed more light on its magmatic activity and metallogeny (Lilov & Chipchakova 1999; von Quadt *et al*. 2002, 2004, 2005; Clark & Ullrich 2004;

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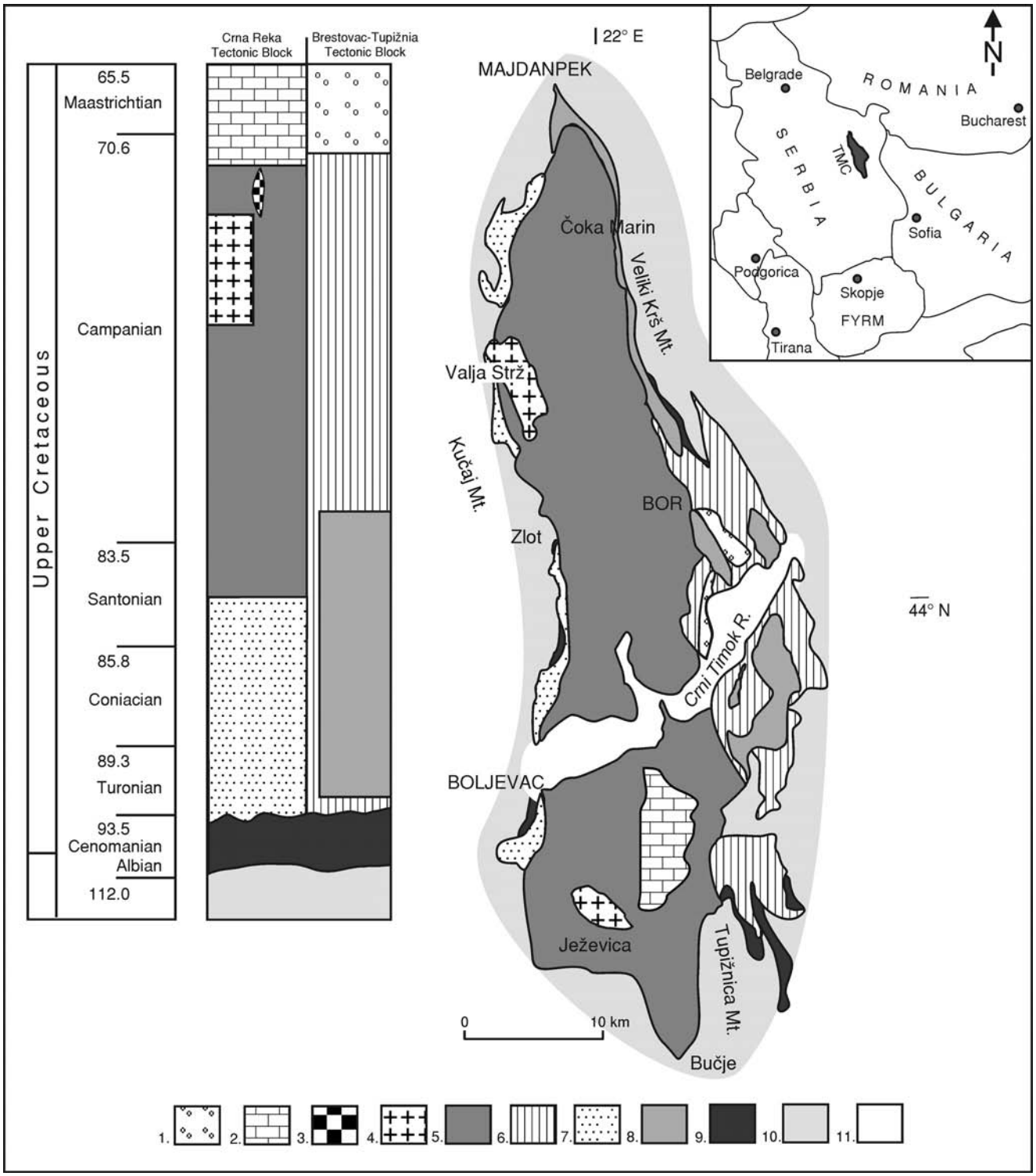

Fig. 1. Schematic geological map and column of the TMC. Legend: **1,** Campanian–Maastrichtian clastite; **2,** Campanian–Maastrichtian reef sediment; **3,** Boljevac latite; **4,** Valja Strž plutonite; **5,** Osnić basaltic andesite and Ježevica andesite; **6,** The epiclastite and the sediment in the BLTB; **7,** Turonian–Maastrichtian sediment in the CRTB; **8,** Timok andesite; **9,** Albian–Cenomanian clastite; **10,** Paleozoic to Lower Cretaceous rock; **11,** Alluvium of the Crni Timok Valley.

HANDLER *et al*. 2004; BANJEŠEVIĆ *et al*. 2006 and ZIMMERMAN *et al*. 2008).

The Upper Cretaceous magmatic activity in eastern Serbia occurred along two subparallel magmatic belts, namely: the Timok Magmatic Complex (TMC) and the Ridanj–Krepoljin belt in the East and West, respectively. The TMC is 85 km long and extends from Majdanpek in the North all the way to the Bučje

Village in the South. It developed on a continental crust composed of different types of Proterozoic to Lower Cretaceous rocks (Antonijević *et al*. 1974). Geotectonically, it belongs to the Getic Nappe (Grubić 1983 and Kräutner & Krstić 2003) or the Kučaj Terrane as part of the complex Carpathian–Balkan Terrane in eastern Serbia (Karamata & Krstić 1996). The Upper Cretaceous rocks of the TMC are overlain by Paleogene, Neogene and Quaternary deposits. Based on continuous geological mapping (Đorđević & Banješević 1997; Banješević 2002 and Banješević *et al*. 2003) and new geological data (Banješević 2006 and Ljubović-Obradović 2008), the TMC is interpreted as a succession of the following magmatic suites (Fig. 1): Timok andesite (AT) – Turonian–Santonian, Metovnica epiclastite (EM) – Coniacian–Campanian, Osnić basaltic andesite (AO) and Ježevica andesite (AJ) – Santonian–Campanian, Valja Strž plutonite (PVS) – Campanian and Boljevac latite (LB). This paper will show a synthesis of the data gathered through many years of geological investigations and a modified version of the TMC units. A first version of the formations was published in the Geological Map and Booklet of the southern part of the TMC (Đorđević & Banješević 1997). The definition of the lithodemic hierarchy in this paper is made according to the recommendations of the North American Stratigraphic Code (by North American Commission on Stratigraphic Nomenclature) and International Stratigraphic Guide (Salvador 1994). In addition, it will provide a volcanological approach to the study of volcanic facies, including the implementation of modern volcanological terminology (*e.g*., Cas & Wright 1987; McPhie *et al*. 1993 and Schmincke 2004).

Geological setting of the TMC

After continuous carbonate sedimentation from the Early Jurassic, a new sedimentation period commenced with the Albian transgression. The new sedimentation processes had clastic character and were related to oscillations of the depositional environment. The sedimentation proceeded with manifestations of Turonian volcanism in the TMC. These Albian–Cenomanian sediments are concentrated along the eastern boundary of the TMC (Fig. 1) and rarely in the central part of the western boundary of the TMC (near Zlot and Boljevac). The Albian clastites transgressively overlie Early Cretaceous rocks (Barremian–Aptian limestones or Aptian carbonate sandstones).

After a hiatus, the Turonian–Senonian evolution commenced with a new sedimentary cycle. The sediments overlie Albian–Cenomanian clastites (Figs. 4 and 6). The lowest part of the sediments contain microfauna (*Helvetoglobotruncana helvetica*), indicating Lower to Middle Turonian age (Ljubović-Obradović 2008). During the Senonian, the whole TMC area shows a considerable difference in the evolution between the eastern (Bor-Lenovac tectonic block – BLTB) and the western (Crna reka tectonic block – CRTB) part (Đorđević & Banješević 1997*,* Fig. 1). Until the Maastrichtian, the first sediments and the epiclastites developed in the BLTB, whereas from the Turonian to the Lower Campanian, andesites originated in this block. In the CRTB, the sediments developed until the Middle Santonian when andesitic and basaltic andesitic volcanism also started. When the volcanism ended, in the Early Campanian, plutonic rock was intruded and the sedimentation continued over a wider area. After the Upper Campanian to the Maastrichtian period, in the central part of the TMC, reef sedimentation commenced (Figs. 1 and 6). On the eastern part of the TMC, in the Upper Campanian, coarse-grained and regressive clastites were deposited (Figs. 1 and 2). This was the period when the TMC uplifted and its existence as an area of active volcanism and marine sedimentation terminated.

Timok andesite (AT)

Name: After the Timok River

Synonyms: "Timazit" – Breithaupt 1860.

"Andesites or volcanites of the I volcanic phase (Timocite)" – Drovenik *et al*. 1962.

"Turonian andesites, Timok andesites, Subvolcanic-hypabyssal rocks of the Borska Reka" – Đorđević & Banješević 1997.

"Banatite volcanites" – Berza *et al*. 1998

"Biotite-hornblende andesite (Timocite)" – Clark & Ullrich 2004.

"Turonian-Campanian andesites" – Banješević 2006.

"Upper Cretaceous volcanics (Phase I)" – Zimmerman *et al*. 2008.

Type locality (Type section): The Timok River locality from the Gamzigradska Banja to the Zvezdan Village. An a additional outcrops are exposed in the Krivelj Village area.

Location, boundaries, lithology and genesis: The AT occur in the eastern parts of the TMC (Fig. 1), where they overlie Cenomanian and Turonian sediments. They are covered by Senonian sediments (Fig. 2) and the EM. Amphibole andesites and trachyandesites of high potassium character predominate. They are light-grey to green-grey rocks, showing a holo- to hypo-crystalline porphyritic texture, sometimes characterized by cm-sized amphibole phenocrysts – Timazit (Breithaupt 1860). Andesine plagioclase, tschermakite amphibole (rarely Mg-hornblende), biotite and clinopyroxene are the main phenocryst phases (in decreasing order of abundance), whereas quartz phenocrysts are very rare. The amount of phenocrysts is usually around 50 % (rarely more than 60 %).

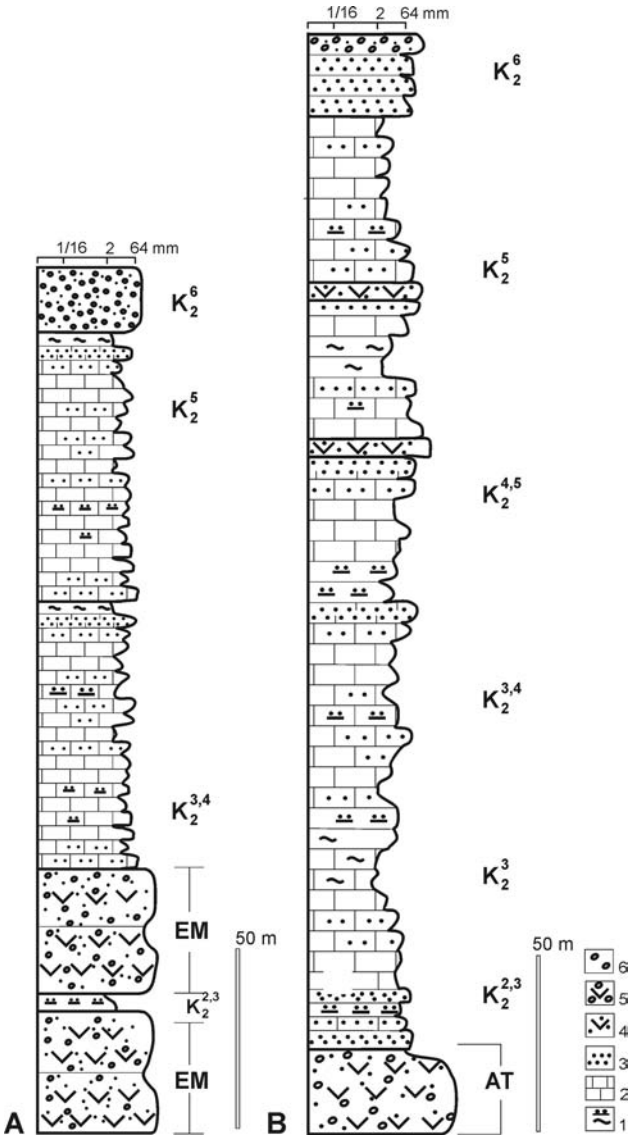

Fig. 2. Schematic geological columns Oštrelj (A) and Slatina (B) south of Bor, with a graphical lithology log. Legend: **AT,** Timok andesite; **EM**, Metovnica epiclastite; **1,** Marl and silty marl; **2,** Limestone; **3,** Sandstone; **4,** Fine-grained volcanoclastite; **5,** Coarse-grained volcanoclastite; **6,** Conglomerate.

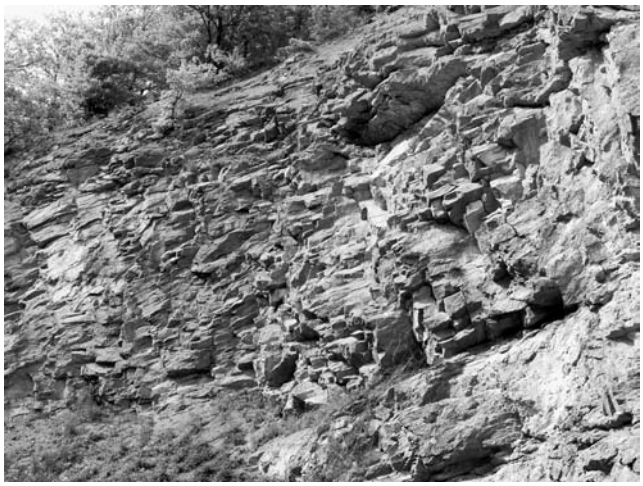

Fig. 3. The central parts of the coherent andesitic lava dome near the Krivelj Village, with columnar jointing.

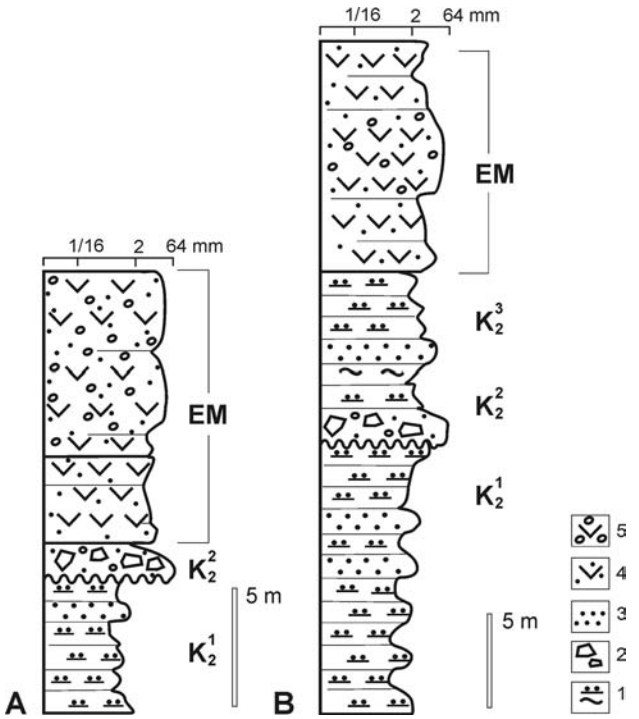

Fig. 4. Schematic geological columns Gamzigradska Banja (A) east of the Metovnica Village and Kravarnik (B) near the Lenovac Village, with a graphical lithology log. **EM,** Metovnica epiclastite; **1,** Marl and silty marl; **2,** Brecia; **3,** Sandstone; **4,** Fine-grained volcanoclastite; **5,** Coarse-grained volcanoclastite.

According to their lithological, volcanological and petrofabric characteristics, the andesites are distinguished into the following facies: lava flows (coherent and autoclastic), lava domes (Fig. 3), shallow intrusions and various volcaniclastic rocks. Completely or partially autobrecciated lava flow facies are predominant, while hyaloclastites are very rare. They have high aspect ratios having thicknesses that sometimes reach several tens of meters and a rather small aerial distribution, commonly < 100 m^2. The autobrecciated lava flows show a clast-supported volcaniclastic texture with subangular to angular clasts up to 30 cm in size, which show almost the same fabric and composition. The matrix is usually subordinated (up to a few vol. %). Lava dome or cryptodome facies are usually exposed on the surface in the range of several square kilometers. At several locations, the central parts of the lava domes are exposed as columnar and rectangular jointed volcanic rocks (Fig. 3). Dykes are usually up to 10 m wide and up to 50 m long. Syn-eruptive and post-eruptive redeposited volcaniclastic rocks

have a great prevalence (here described as Metovnica epiclastite, see below).

Age: According to high precision U/Pb, $^{40}Ar/^{39}Ar$ age (VON QUADT *et al*. 2002 and CLARK & ULLRICH 2004), the AT ranged from 89.0±0.6 to 84.26±0.67 Ma (Upper Turonian to Upper Santonian).

Metovnica epiclastite (EM)

Name: After the Metovnica Village, southern of Bor.

Synonyms: "Pyroclastites or volcanoclastites of the I volcanic phase" – DROVENIK *et al*. 1962.

"Metovnica epiclastics" – ĐORĐEVIĆ & BANJEŠEVIĆ 1997.

"Epiclastics of the Senonian" – ĐORĐEVIĆ 2004–2005.

"Turonian-Senonian epiclastites" – BANJEŠEVIĆ 2006.

Type locality (Type section): The area from the Metovnica Village to the Nikoličevo Village. An a additional localities are near to the open pit in Bor and in the Lenovac-Leskovac Villages area.

Location, boundaries, lithology and genesis: The EM developed in the eastern part of the TMC (Fig. 1) in a shallow marine environment, infilling sharp volcanic bedrocks (ĐORĐEVIĆ & BANJEŠEVIĆ 1997). The rocks are coarse- to fine-grained, massive, coarsely banded, sometimes even laminated (Fig. 5). They are composed of texturally and structurally different fragments deriving from different volcanic facies of the AT. The EM are often interlayed with the sediments (Figs. 2, 5 and 6).

Age: Sometimes, the rocks contain very well preserved Coniacian–Campanian microfauna (ĐORĐEVIĆ & BANJEŠEVIĆ 1997 and ĐORĐEVIĆ 2005).

Osnić basaltic andesite (AO) and Ježevica andesite (AJ)

Name: After the Osnić Village.

Synonyms: "Basaltic andesites or volcanites of the II volcanic phase" – DROVENIK *et al*. 1962.

"Crna Reka andesite-basalt, Dumbrava andesite-basalt, Osnić andesite-basalt, Šarbanovac andesite" – ĐORĐEVIĆ & BANJEŠEVIĆ 1997.

"Pyroxene andesitic and hornblende andesitic volcanic rocks" – BANJEŠEVIĆ *et al*. 2003.

"Hornblende-pyroxene and pyroxene andesite" – CLARK & ULLRICH 2004.

"Senonian basaltic andesite and andesite" – BANJEŠEVIĆ 2006.

"Upper Cretaceous volcanics (Phase II)" – ZIMMERMAN *et al*. 2008.

Type locality (Type section): A section northern of the Osnić Village, from the Metovnica Village to the Šarbanovac Village. An a additional localities are in the area of the Ježevica Mt. and the Brestovačka Banja.

Fig. 5. Fine-grained, massive, banded and laminated epiclastites are interlayed with the sediments.

Location, boundaries, lithology and genesis: The rock suite corresponding to andesite – basaltic andesite of calc-alkaline to tholeiitic character can be distinguished among the Senonian volcanic rocks of the TMC. The first subsuite includes pyroxene basaltic andesite (AO), while the second subsuite comprises amphibole andesite (AJ). Both rock subsuites are located in the central and western parts of the TMC (Fig. 1) and are sometimes closely associated. The AO are predominant. These volcanic rocks are both underlain and overlain by sedimentary rocks (Fig. 6). Field and laboratory studies on several profiles showed that the underlying sediments contain Turonian–Santonian microfauna (Fig. 6), while the overlying sediments are composed of resedimented volcaniclastites, clastitic or reef sediments of Campanian–Maastrichtian age (ĐORĐEVIĆ & BANJEŠEVIĆ 1997).

The pyroxene basaltic andesites are dark grey rocks (Fig. 7) of porphyritic texture, characterized by mm-sized phenocrysts. The structure is most commonly massive and sometimes vesicular. Plagioclase and clinopyroxene are the most abundant phenocrysts, while orthopyroxene and amphibole occur in small amounts or are completely subordinate. The plagioclase contains 42–93 % of An components, therefore these plagioclases are more basic than those occurring in the amphibole andesites and the AT. The amphiboles correspond to tschermakites, rarely to Mg hornblende, and show very primitive, more basic character than the amphiboles in the AT. The clinopyroxene corresponds to augites ($Wo_{40.3–50.2}$-$En_{36.3–45.2}$-$Fs_{11.1–18.1}$), while the rhombic pyroxene is enstatitic in character. The amount of phenocrysts in these rocks rarely reaches 50 vol. %. The groundmass is most often hypocrystalline, but rare holocrystalline varieties also occur.

The amphibole andesites are most frequently massive rocks, rarely with vesicular or banded structure, sometimes with very well exposed tabular or rectan-

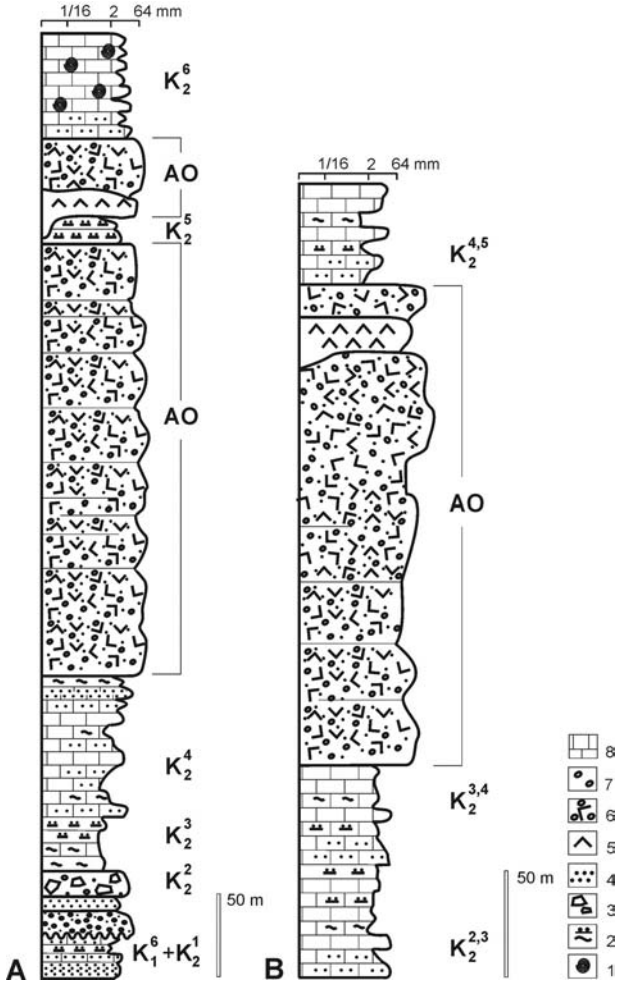

Fig. 6. Schematic geological columns Arnauta (A) northwest of the Osnić Village and Metovnica–Šarbanovac (B) north of the Osnić Village, with a graphical lithology log. **AO,** Osnić basaltic andesite; **1,** Reef fossil; **2,** Marl and silty marl; **3,** Brecia; **4,** Sandstone; **5,** Lava flow; **6,** Fine- to coarse-grained volcanite; **7,** Conglomerate; **8,** Limestone.

gular jointing. Their color varies from grey, pale-green to green-grey. The texture is hypo- to holocrystalline porphyritic, often with a fluidal groundmass. Amphibole and plagioclase phenocrysts are always present, clinopyroxene is subordinate, while orthopyroxene and biotite occur only rarely. The chemical composition of the minerals is very similar to the pyroxene-bearing varieties, except that the plagioclases are more basic in the latter.

The volcanic rocks predominantly occur as lava flow facies (autobreccias and hyaloclastic breccias) and resedimented volcaniclastic deposits. Lava flow facies are up to several meters thick, while their length reaches several hundred meters. The transitions from coherent to autobrecciated parts are usually very sharp (Fig. 7). The fragments are most often angular, rarely subangular, and have a very uniform composition and dimensions. They are rarely coarser than 10 cm in diameter. The hyaloclastites show gradual transitions toward coherent lava flow facies. They are unstratified, poorly sorted rocks, composed of semi-angular to angular fragments of different size – from 1 cm to up to 20 cm. The rock fragments show typical hyaloclastic characteristics, such as chilled margins, tiny normal joints and jig-saw-fit puzzle textures (YAMAGISHI 1991). In addition, there are numerous occurrences of lava lobes and pseudo-pillows (KANO *et al*. 1991). Shallow intrusion facies are represented by necks and dykes. Remnants of the pyroclastic rock deposits are very rare and exposed at only a few localities.

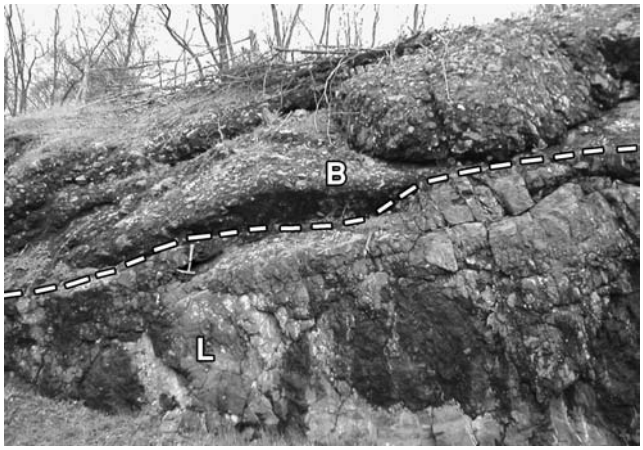

Fig. 7. The coherent pyroxene basaltic andesite lava flow (L) and autobreccia (B) in the upper part. The transitions from coherent to autobrecciated parts are very sharp. The dashed line marks the boundary lava flow and autobreccia.

The resedimented volcanoclastites are mostly stratified volcaniclastic rocks, psamitic to psephitic in grain-size of different origin and type of transport. The sedimentological and lithological characteristics of some deposits are very well exposed, clearly referring to sedimentary types of transportation (mostly debris flow or grain flow). However, for the other deposits, neither transportation type nor material source can be determined. The rock composition is heterogeneous, although there are some layers showing very similar fragment composition. The fragments are semi angular to rounded. The rocks are mostly semi- or well-sorted, but sometimes they can be very poorly sorted, showing typical sedimentary structures: normal and inversed gradation, parallel lamination, rarely also crossed or wave-like lamination.

Age: According U/Pb age zircon analysis, between 82.27±0.35 and 81.79±0.54 Ma. The age of the AO of the dyke from the Brestovac Village to the Brestovačka Banja area was confirmed as Santonian–Lower Campanian (BANJEŠEVIĆ *et al*. 2006).

Valja Strž plutonite (PVS)

Name: After the Valja Strž area.

Synonyms: "Laramian plutonite" – DROVENIK *et al*. 1962.

"Subvolcanic-hypabyssal rocks of Ježevica" – ĐORĐEVIĆ & BANJEŠEVIĆ 1997.

"Hypabyssal and abyssal rocks" – BANJEŠEVIĆ *et al*. 2003.

"Laramide intrusions" – CLARK & ULLRICH 2004.

"Campanian plutonite" – BANJEŠEVIĆ 2006.

"Upper Cretaceous plutons" – ZIMMERMAN *et al*. 2008.

Type locality (Type section): The area of Valja Strž. An a additional locality is in the Ježevica Mountain.

Location, boundaries, lithology and genesis: The PVS occur at the western margin of the TMC (Fig. 1). They are grey to dark-grey rocks of hypidiomorphic granular texture and massive structure (Fig. 8), sometimes showing rectangular jointing. They range in composition from monzodiorite and monzonite to diorite, Q-diorite, granodiorite, syenite and rare gabbro. Generally, the plutonic rocks consist of plagioclase (10–58 vol. % their chemical composition varies from 20 to 46 % An component), potassium feldspar (15 – 37 vol. %), quartz (up to 10 vol. %), amphibole (up to 13 vol. %), biotite (about 11 vol. %), orthopyroxene (3–4 %, rarely around 23 vol. %, $Wo_{26.5–45.7}$-$En_{38.6–56.1}$-$Fs_{12.5–19.5}$), rare clinopyroxene (maximum 2 vol. %) and various accessory minerals (around 3 vol. %) (MAJER 1953; DROVENIK 1959; ĐORĐEVIĆ & BANJEŠEVIĆ 1997 and BANJEŠEVIĆ 2006).

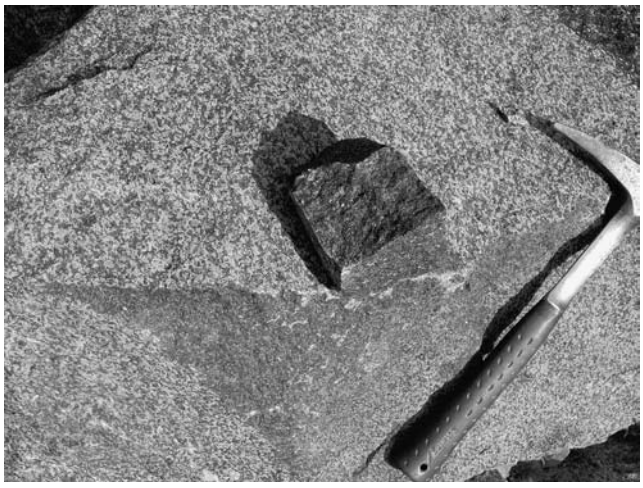

Fig. 8. Grey to dark-grey plutonic rock from Valja Strž with a hypidiomorphic granular texture and a massive structure.

Age: According to U/Pb age zircon analysis, the age of the Valja Strž plutonite is 78.62±0.44 Ma, Upper Campanian age of the PVS was confirmed (VON QUADT *et al*. 2002).

Boljevac latite (LB)

Name: After Boljevac.

Synonyms: "Volcanite of the III volcanic phase" – DROVENIK *et al*. 1962.

"Porphyroid biotite-augite mozonite" – ĐORĐEVIĆ & BANJEŠEVIĆ 1997.

"Alkali basalt of Zlot" – MILOVANOVIĆ *et al*. 2005.

"Latite" – BANJEŠEVIĆ 2006.

"Upper Cretaceous volcanics (Phase III)" – ZIMMERMAN *et al*. 2008.

Type locality (Type section): The outcrops near Boljevac.

Location, boundaries, lithology and genesis: Numerous latitic dykes occur along the western border of the TMC. These rocks crosscut the AO and the AJ. They appear in the form of shallow intrusions (dykes, sills and veins), seldom as lava flows. They are usually small masses, up to several tens of meters long and 3 to 4 meters thick. The rocks are dark-grey, showing very distinctive textures characterized by large, elongated phenocrysts of plagioclase and potassium feldspar, which sometimes exhibit fluidal orientations (Fig. 9). The texture is fine-grained, very fine-grained or hypocrystalline porphyrithic with a microcrystalline, intersertal and pilotaxitic groundmass. The latites consist of plagioclase (53–67 % An), potassium feldspar (61–69 % Or), clinopyroxene and various accessory minerals (MILOVANOVIĆ *et al*. 2005).

Fig. 9. The dark-grey latite south of Boljevac shows very distinctive textures characterized by large, elongated phenocrysts of plagioclase and potassium feldspar, which exhibit fluidal orientation.

Age: The latite crosscut the AO and AJ, however their age is poorly constrained.

Conclusions

Through long-term multidisciplinary and continuous geological investigations, as well as the employment of the volcanic facies concept in the textural and

genetic classification of volcanic deposits, new geological data regarding the petrography and volcanic characteristics of the TMC magmatic and sedimentary rocks are available. The TMC consists of magmatic suites and sedimentary formations. After the Albian–Cenomanian sedimentary cycle, sedimentations lasted continuously from the Lower Turonian to the Maastrichtian. The available lithostratigraphic, paleontological and radiometric data indicate that the Upper Cretaceous magmatism in the TMC lasted more than 10 million years, from the Upper Turonian to the Upper Campanian. In this period, the volcanic front moved from East to West. The volcanic processes were subaerial to marine effusive, hypoabyssal and very rarely explosive in character. It commenced with andesitic to trachyandesitic volcanism (Timok andesite) in the present easternmost parts of the TMC. The volcanic rocks overlay Cenomanian or Lower Turonian sediments. When the volcanic processes ceased in the eastern parts, a new volcanic front opened in the central and western parts of the TMC. The Osnić basaltic andesite and Ježevica andesite overlay sediments containing Turonian–Coniacian microfauna and are overlain by Upper Campanian clastic and reef sediments. The magmatic activity finished with plutonic rocks (Valja Strž plutonite) and latitic dykes (Boljevac latite) in the western parts of the TMC. The termination of volcanic activity in the TMC was followed by subvolcanic processes in the Ridanj–Krepoljin Zone, which is situated more to the west. Deposition of reef sediments and coarse-grained sediments (conglomerates and sandstones) of Upper Campanian–Maastrichtian age certainly represent the end of continual marine development in the TMC area.

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Резиме

Горњокредна свита магматских стена Тимочког магматског комплекса

Рад пружа синтезу података о геолошкој грађи и свити магматских стена Тимочког магматског комплекса (ТМК), добијених дугогодишњим, мултидисциплинарним, континуираним геолошким истраживањима и допуњених савременим концептом вулканских и седиментних фација и генетском класификацијом вулканских наслага. ТМК лежи на континенталној кори изграђеној од

различитих стена протерозојске до доњокредне старости. После седиментног пакета карбонатног карактера који се континуирано таложи од доње јуре, нови седиментациони циклус почиње након албске трансгресије. Интензивно колебање депозиционе средине и знатан прилив теригене компоненте карактеристика је седиментних алб–ценоманских процеса који претходе појави вулканизма у ТМК. Турон–сенонски развој ТМК, после краћег хијатуса, почиње новим седиментационим циклусом. Новонастали седименти транзгресивно леже преко алб–ценоманских кластита и према нађеној микрофауни припадају доњем и средњем турону. Цели простор ТМК даље у сенону показује знатне разлике у развићу источних (борско–леновачки тектонски блок – БЛТБ) и западних (црноречки тектонски блок – ЦТБ) подручја.

У БЛТБ, одвија се таложење седимената и епикластита све до мастрихта и појава вулканизма. Вулканизам претежно андезитског састава (Андезита Тимока), траје од турона до горњег сантона. Вулканска активност је у највећој мери била копнена, субаерског, ефузивног до хипоабисалног карактера. Настају вулканске фације кохерентних и аутофрагментираних лавичних излива, плитке интрузије и реседиментоване вулканокластичне наслаге. Интрузивну фазу прате поствулкански процеси и циркулисања минерализованих раствора који стварају економски најзначајнија порфирска лежишта бакра. Вулканити се еродују и депонују даље од вулканских центара стварајући син- и пост-еруптивне вулканокластичне наслаге – епикластите (Епикластити Метовнице). Ове кластичне стене, псефитске до псамитске гранулације, изграђене су у високом проценту од фрагмената андезита из подлоге. Врло често су замењивани пирокластичним наслагама. На много места епикластити се прослојавају са седиментима. У њима се могу наћи фрагменти хидротермално измењених андезита и микрофауна конијак–кампанске старости .

У ЦТБ, односно у централним и западним деловима ТМК, таложење сенонских седимената у сантону прекида нова вулканска активност андезитског до андезитбазалтског састава. Овај вулканизам (Андезитбазалти Оснића), претежно линеарног ефузивног типа, првобитно се одвија у морским условима. Даљи развој вулканизма карактеришу ефузивне и експлозивне ерупције (Андезити Јежевице). Тада се одлажу велике количине вулканског материјала који највероватније почиње да формира вулканска острва. Вулканизам се одвија у копненим и морским условима. Самим тим издвајају се разноврсне вулканске фације: лавични изливи, аутобрече, хијалокластити, плитке интрузије – дајкови, некови, жице, реседиментовани вулканокластити и ретки пирокластити. У завршним фазама вулканизма у ТМК, утискују се плутонске стене (Плутонити Ваља Стрж) уз изражене поствулканске процесе који су разноврсни по трајању, интензитету и карактеру. Минерализациони и хидротермални процеси појављују се на широком простору. Након или у току ове интрузивне фазе вулкански фронт се помера даље на запад отварајући ново вулкански активно подручје, Ридањско–крепољинску зону. У централним и западним деловима ТМК јављају се и мања лавична тела или плитке интрузије латитског састава (Латити Бољевца), које пробијају андезитбазалте. Старост ових стена још није прецизно одређена.

У горњем кампану, у централним деловима ТМК, подлога од вулканита и велики прилив теригене компоненте у топлу, плитку, морску средину, погодује стварању спрудних седимената. Истовремено, у источним деловима ТМК, почиње таложење дебелог пакета регресивних грубокластичних седимената – ситнозрних пешчара до крупнозрних конгломерата и ретких алевролита. Таложење ових седимената указује на постепено издизање и оплићавање депозиционих простора, чиме се завршава континуирани морски развој у ТМК.