UPPER CRETACEOUS DEPOSITS OF THE POŽEŠKA GORA MT. (CROATIA)

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Upper Cretaceous deposits of the Požeška gora Mts. (Croatia) formed as the result of interaction between tectonic movements, volcanism and sedimentation in conditions characteristic for moderately deep to deep sea environments. Uninterrupted Santonian-Maastrichtian succession starts with breccias and coarse-grained sandstones which grade into laminated siltstones sandstone and lamellar to thick-bedded limestones. Granite, granophyre and rhyolite fragments are predominant detrital grains in breccias and sandstones all derived from local source-area. The youngest meso to mega-scale folds in Cretaceous sediments show an E-W strike, although bedding poles are scattered due to older deformations.

Key words: paleostress, resedimentation, granite, rhyolite, Upper Cretaceous deposits, Požeška gora Mt., Croatia

INTRODUCTION

Upper Cretaceous deposits of Požeška gora Mt. can be found in tectonically separated blocks, mainly in its central part (Fig. 1). Going from the west they first crop out southwest of Brestovac-Požeški village (Fig. 1. a) in spring flows of Bukovica and Maglaj stream. At this locality they are brought to the north over Ottnangian
clastic deposits along the south-dipping reverse fault, whereas from the south they are unconformably overlain by the Paleocene (?) conglomerates of Škrabučnik stream. Further to the east, Upper Cretaceous deposits are south of Požega, in the valley of Vučjak stream (Fig. 1, b) and its south tributaries. Here they outcrop in a core of a dome-like structure and are transgressively overlain by Ottnangian deposits. Westward of Pleternica, the Upper Cretaceous sediments build up the wider surroundings of Luke stream (Fig. 1, c), where the complete Upper Cretaceous column is preserved and accessible. To the north they are brought on top of rhyolites and Ottnangian sediments by the south-dipping reverse fault, while from the south and west they are unconformably overlain by Ottnangian and Paleocene (?) Škrabučnik stream sediments, respectively.

KOCH (1919) considered that the Upper Cretaceous sediments in the Vučjak stream are equivalents to Upper Cretaceous deposits of the Žumberak, Samoborsko gorje and Medvednica mountains of NW Croatia. He believed that the volcanic rocks exposed at Požeška gora are the products of post-Cretaceous eruptions, most probably of Late Miocene age. First paleontological data which confirmed Upper Senonian age of marls and limestones of Požeška gora Mt. were given by D. NEDELA-DEVIDE (1957). Globotruncana lapparenti lapparenti BROTZEN and G. l. tricarinata QUEREAU were found in grey to pinkish limestones (Seoce – Sv. Jelena – Vrhovci profile) and clayey limestones of Luke stream valley, yielding Turonian-Maastrichtian age (POLŠAK, 1971). G. l. bulloides VOGLER was determined in lamellar limestone yielding Campanian-Maastrichtian age while G. arca CUSHMAN proved Campanian age of limestones rocks (Grimani in JAMICIĆ et al., 1985). The top-most member of the Upper Cretaceous column of the Požeška gora Mt. is represented by a thick-bedded limestone deposit. In this limestone, remains of Hippurites (Orbignia) lapeirousei GOLDFUS, and sections of Radiolites and Bournonia were found. Based on these determinations, done by Mamižić (JAMICIĆ et al., 1985), the reef limestone is also confirmed to belong to Campanian-Maastrichtian. Upper Cretaceous sediments are unconformably overlain by coarse-grained clastic rocks wich are largely expand

Fig. 1. Geological map of part of the Požeška gora Mt.; 1 – granites, 2 – rhyolites, 3 – basic rocks, 4 – Upper Cretaceous deposits, 5 – conglomerates of Škrabučnik stream, 6 – conglomerates, sandstones, siltstones and marls (Ottnangian), 7 – biocalcareinites, calcarenites, marls, tuffites, sandstones and bituminous marls (Badenian-Sarmatian), 8 – limestones, marls, sandstones, sands and silts (Panonian-Pontian), 9 – sands, silts, gravels, clays and marls (Pliocene), 10 – bed strikes, 11 – normal boundary, 12 – unconformity, 13 – fault, 14 – sinistral fault, 15 – gravity fault, 16 – reverse fault, 17 – syncline, 18 – anticline, 19 – overthrust syncline. Stereographic projections (lower hemisphere Schmidt net) of fault systems, principal paleostress axes (5-, 4-, 3- stars indicate orientations of, σ1, σ2, σ3 respectively) and main extension/compression as black arrows (values of stress tension are given in Tab. 1). 1d and 2d – granites of Gradski Vrhovci quarry, 1e and 2e – rhyolites on Vesela Dervišaga local road, 3a – bed poles (144 data) of Cretaceous rocks, 3b – poles of axial plane cleavage (67 data) in Upper Cretaceous deposits and 3c – bed poles (120 data) in Tertiary deposits.
in the area of Škrabutnik village. Prevailing coarse-grained rocks sandstones with rare occurrences of muscovite siltstones (Šparica et al., 1980). The same authors described the Upper Cretaceous limestones in the Luke stream valley and Golo brdo area but a scarce microfauna did not allow a more detail age determination. Also, in the area of Bukovača they reported about flysch sequences characterised by alternation of marls, sandstones, clayey limestones, calcarenites and conglomerates. Pamić & Šparica (1983) proposed that the volcanic rocks of Požeška gora Mt. are of the same age as the interstratified sediments the being the products of multiphase volcanic activity. Alkali feldspar granites in the area of Požeška gora Mt. are widely discussed by Pamić, (1987); Pamić et al., (1988) and Belak et al., (1992*). Pamić et al. (1988) applied radiometric Rb/Sr method dating on granites and rhyolites and obtained Campanian-Maastrichtian age, 71.5 ± 2.8 Ma for three granite and two rhyolite samples. The same authors suggested that basalts of the Požeška gora Mt. have a different source than that of granites and rhyolites. Later, however, Pamić et al. (1989) concluded that mafic and acidic rocks represent a typical bimodal volcanic association made up of the same proportion of alkali feldspar rhyolites and ophitic metabasalts. According to Halamić et al. (1990), Halamić (1992) Upper Cretaceous sediments and acidic magmatic rocks are cross-cut by diabase veins. Halamić et al. (1993) claimed that coarse-grained clastics of rhyolitic and granitic fragments represent continental sediments deposited in semi-arid conditions. Supposing that such conditions occurred in the area after the Cretaceous time, they assumed that these breccias are of Lower to Middle Oligocene age. Belak et al. (1998) concluded that the mafic of Požeška gora Mt. are of Upper Cretaceous-Paleogene age, being younger than the granite-rhyolite complex and even younger than the Upper Cretaceous deposits.

Jamičić (1995) gave an overview of the tectonic events for the area of the Slavonian Mts. and based on study of Cretaceous stratigraphic profiles he concluded that acidic volcanic rocks of Požeška gora Mt. are older than Senonian.

METHODOLOGY

On the Luke stream locality, in the left tributary valley and in the local road trench (Fig. 1, c), separate geological cross sections were recorded while the rock sampling was completed in order to determine composition of breccias and sandstones and their structural characteristic. Additional sampling and observations were done on other localities as well namely at Brestovac-Požeški and Vučjak, (Figs. 1a and 1b); respectively. At the same time structural measurements and determination

of structural elements and their classification according to their shape and genesis was completed too. In granites of Gradski Vrhovci village (Fig. 1, d) fault systems with kinematics indicators of tectonic transport direction were recorded. Detailed structural measurements are also performed on outcrops along a local road in rhyolites (Fig. 1, e). Slip directions along fault planes are determined following criteria proposed by HANCOCK (1985) and PETIT (1987). Recorded fault-slip data have been used to calculate orientation of principal stress axes ($\sigma_1$, $\sigma_2$, $\sigma_3$) by means of computer generated statistical analysis. Relative and succession of deformational events were determined based on the presence or absence of particular structural elements in Pre-Tertiary and in Tertiary rocks. Age relations are also confirmed by correlation between recorded structures and structures documented in the surrounding Slavonian Mts. where a sequence deformational event is clearly established (JAMIČIĆ, 1983, 1995a, 1995b; JAMIČIĆ et al., 1985; PRELOGOVIĆ et al., 1995).

RESULTS

Petrographic data

Based on previous investigations, collection and processing on new field structural and petrographic data, the sequence of Upper Cretaceous deposits of Požeška gora Mt. has been reconstructed and presented in a schematic stratigraphic column (Fig. 2). The majority of data refers to the valleys of Luke stream and its left tributary (Fig. 1, c) where the road trench opened a continuous profile throughout the Upper Cretaceous deposits.

The Lower parts of the column are reconstructed based on data collected in the Bukovica stream valley and its right tributary Popova valley (Fig. 1, a), and in the immediate vicinity of Gradski Vrhovci quarry (Fig. 1, d and Fig. 3), located in alkali feldspar granites. Here these granites are unconformable overlain by coarse-grained clast-supported breccias (Fig. 4), which also occur in the area of Bukovica and Vučjak stream, at the very center of the Požeška city, as well as on the northern slopes of Požeška gora Mt south-southeast of Požeška.

These breccias are composed of sub-angular to sub-rounded fragments of granophyres, alkali-feldspar reddish coloured granites, cherts and rhyolites, up to 10 mm in size. Matrix is semi-coarse-grained sandstone. Thickness of these bressias is not determined due to a strong tectonic reduction.

Also, on most of studied localities, coarse-grained sandstones of the same composition as these breccias are rarely found. However, within the area of Luke stream valley (Fig. 1, c) along the local road, an outcrop of coarse to fine-grained sandstones which grade into, laminated siltstones, lamellar limestone and, finally into thick-bedded limestone of Upper Cretaceous age is visible. This succession is schematically shown in the stratigraphical column of Fig. 2.

Due to the matrix colour, coarse-grained sandstones are light reddish. Microscopic observations showed particles of quartz, K-feldspar, quartzite, fragments of chert, alkali-feldspar granite and granophyre (Fig. 5a) and fragments of rhyolites
Fragments of volcanic glass and clusters of muscovite with sporadic quartz grains are also present. The reddish colour originates from limonite dispersed in matrix. Together with coarse-grained sandstones, fine-grained greyish sandstones occur, which gradually become predominant in the column. Their composition is almost the same as that of the coarse-grained sandstones. Towards the top of this sequence, the ratio of acidic intrusive and effusive rock particles gradually decreases, while quartz, poly-crystalline quartz and sporadically chert fragments prevail. K-feldspar, muscovite, chloritised biotite and some scarce particles of plagioclase occur as well.

Sandstones gradually changes into laminated siltstones of grey to dark grey colour, which in turn grade into laminated limestone. The age of this level is determined on the basis of numerous findings of Globotruncanaidae as Campanian-Maastrichtian (PAMić & ŠPARICA, 1983; Grimani in JAMić et al., 1985). Lamellar limestone overlies concordantly the siltstones (Fig. 2). The thickness of the limestone beds

![Schematic lithostratigraphic column](image)
range from one to five centimetres while the pile thickness is around 80 meters. The top-most member of the Upper Cretaceous column of the Požeška gora Mt. is a thick-bedded limestone deposited. The total thickness of this limestone is approximately 60 meters. In this limestone, the remains of species *Hippurites* (*Orbignia* *lapeirousei* GOLDFUS were found, as well as sections of *Radiolites* and *Bournonia*. According to analysis done by MAMUŽIĆ et al. (1985), the reef limestone also belongs to Campanian-Maastrichtian, while POLŠAK (1971), on the basis of rudist community, determined Upper Cretaceous age.

Coarse-clastic rocks unconformably overlie the Upper Cretaceous beds (Fig. 2) with their maximal extent west of Škrabutnik village. The prevailing rocks are conglomerates and to a lesser extent sandstones with very rare occurrences of muscovite siltstones (ŠPARICA et al., 1980). These non-carbonate sediments lack fossil re-

![Alkali feldspar granites, Gradski Vrhovci quarry.](image)
cords. However, due to their unconformable relationship with Cretaceous rocks and their being surrounded with Middle-Miocene deposits, it is reasonable to expect their age within the Paleocene-Eocene range.

Structural observations

Deformation history of the Požeška gora Mt. is characterised by faulting and folding during the Late Cretaceous and Tertiary times. Based on structural studies the sequence of deformation events and a new perception of tectonic evolution of Požeška gora Mt. area is proposed in this paper.

The recent tectonic setting of the Požeška gora Mt. is characterized by E-W strike of the major stratigraphic unit shaped during the Tertiary and Quaternary times. This resulted from regional stress which, in the southern part of the Pannonian basin was characterised by N-W direction of the greatest principal stress axis (JAMILIĆ, 1995a, 1995b; PRELOGOVIC et al., 1995). Two tectonic events were determined by geological mapping and structural measurements in the Upper Cretaceous rocks of Požeška gora Mt. (Fig. 1, D1 and D2) which were controled by stress fields characterised by almost perpendicular orientation of the greatest principal stress axes (σ1).

Succession of tectonic events in the Upper Cretaceous of the Požeška gora Mt. and dating of these events is hereby shown through structural determinations and data obtained from key outcrops.

Fig. 4. Normal grading of clast-supported breccia into coarse-grained sandstone.
Upper-Cretaceous-Paleogene structures

Older tectonic events (D1) is supposed to be related to the Laramian phase of the Alpine orogeny which in this part of the Pannonian area marks the termination of the Late Cretaceous sedimentary cycle and the Late Cretaceous uplift (JAMICIĆ, 2007). Fig. 5. Micrographs (N+, 5X) of semi coarse-grained sandstones composed of particles of quartz, polycrystalline quartz, chert, alkali-feldspar granite, granophyre and rhyolite. a) Popova valley locality b) Luke stream locality.
1985, 1988, 1993, 1995a, 1995b, 2000, 2004; Marinčić, 1995). During this tectonic phase pre-Tertiary rocks of the Požeška gora Mt. were affected by the E-W directed compression, and N-S directed extension.

New paleostress data from the Upper Cretaceous rocks exposed at were obtained the Požeška gora Mt. by measuring orientation of striae lineation on fault planes.

In granitic and rhyolitic rocks of Early Cretaceous (?) age as well as in the Upper Cretaceous deposits (Fig. 1), fault systems were recorded characterized by kinematic indicators that indicate reverse and normal sense of tectonic transport. Due to their brittle characteristics, granitic rocks were heavily crushed into blocks of maximum 1/4 of cubic meter in size. Only one generation of striae has been recorded on fault planes characterised by reverse sense of slip. Two systems of brittle structures were determined in the field. The first one corresponds to reverse faults of approximate N-S strike (NNE-SSW), as a result of E-W directed (Tab. 1), while the other one is represented by faults with normal character of tectonic transport of separated blocks. Data for reverse faults recorded in granites are shown in Fig. 1, 1d and for the consequent normal faults (Fig. 1, 2d). In rhyolitic rocks outcropping in the NE part of the Požeška gora Mt. (Figs. 1, 7), reverse faults prevail (Fig. 1, 1e). These faults indicate a stress field characterized by E-W directed compression (Tab. 1) that resulted in predominantly eastward tectonic transport of rhyolites. In rhyolitic rocks the consequent faults of normal character are present (Fig. 1, 2e).

In the Upper Cretaceous deposits during the Cretaceous and Paleogene tectonic events, monoclinic folds with N-S strike were formed (Jamičić et al., 1985). The process is often followed by sigmoidal folding of siltstone beds and laminated limestones along the axial plane cleavage (Fig. 6). The strike of the cleavage is N-S with plane inclination in the 20–80° range (Fig. 1, 3b).

**Tertiary-Quaternary structures**

During the Tertiary to Middle Miocene times, the area of Slavonian Mts. Was affected by the regional extension. During Middle to Late Miocene the same region was affected by a N-S compression. The main structural elements formed during this last deformational event (D2) are reverse faults with E-W strike. In the Cretaceous and Miocene sediments normal, monoclinic, and overturned folds of E-W strike were formed (Fig. 1) with northern vergence, accompanied by a conjugate pair of NE-SE striking sinistral and NW-SE striking dextral faults. Maximal horizontal offset along sinistral faults is maximum 500 meters where this can be seen. Although the bedding poles of the Cretaceous beds of the Požeška gora Mt. are scattered (Fig. 1, 3a) due to older deformation (D1), a folded structure of E-W strike is detectable. Miocene sediments (Fig. 1, 3c) have clear E-W strike with northern vergence.

**CONCLUSIONS**

Upper Cretaceous deposits of the Požeška gora Mt., on the basis of micro- and macrofossils are of Santonian-Campanian-Maastrichtian age. The continuous sequence
of sediments starting from coarse-grained sandstones and breccias, over siltstones and laminated limestones is revealed. Sandstones and breccias contain sub-angular to angular fragments of granites, granophyres and acidic volcanic rocks. They do not contain the fragments of mafic rocks exposed at the Požeška gora Mt., thus indicating that the mafic volcanism was not active during the deposition of the Upper Cretaceous clastic rocks. Since the acidic magmatic rocks were re-sedimented into sandstones and breccias, it is certain that they are older than Santonian-Campanian-Maastrichtian. It is hard to establish how much older then the Santonian granites and acidic volcanic

**Tab. 1.** Paleostress tensors computed from fault-slip data

<table>
<thead>
<tr>
<th>Locality</th>
<th>Coordinate</th>
<th>Lithology</th>
<th>Age of rocks</th>
<th>Figure</th>
<th>S</th>
<th>N</th>
<th>$\sigma_1$</th>
<th>$\sigma_2$</th>
<th>$\sigma_3$</th>
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<td>Gradski</td>
<td>x=6472321</td>
<td>granite</td>
<td>Lower Cretaceous?</td>
<td>Fig.1, 1d</td>
<td>R</td>
<td>13</td>
<td>108</td>
<td>9</td>
<td>198</td>
</tr>
<tr>
<td>Vrhovci</td>
<td>y=5017743</td>
<td>granite</td>
<td>Lower Cretaceous?</td>
<td>Fig.1, 2d</td>
<td>N</td>
<td>8</td>
<td>171</td>
<td>72</td>
<td>36</td>
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<td>Fig.1, 1e</td>
<td>R</td>
<td>32</td>
<td>292</td>
<td>7</td>
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<tr>
<td>Vrhovci</td>
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<td>Fig.1, 2e</td>
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$S=$ state of stress (N=normal, R=reverse), $N=$ number of faults used for paleostress calculation. $\sigma_1, \sigma_2, \sigma_3$ trend (as azimuth) and plunge (in degrees) of stress axes.
rocks can be, but it can be said that the radiometric age (Pamić et al., 1988) is a consequence of warming and it is lower than the exact age of their formation. The subsequent warming is the result of tectonic deformational processes that took place at the transition from Upper Cretaceous to Paleogene when this area together with other Slavonian Mts. Experienced compression an E-W directed.

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SAAZETAK

Gornjokredne naslage Požeške gore (Hrvatska)

D. Jamičić


Na brečama slijede krupnozrnati pečenjaci koji su zbog veziva svijetlocrvene boje. U njihov sastav ulaze čestice kvarca, K-feldspata, kvarcita, fragmenti rožnjaka,

Jamičić, D.: Upper Cretaceous deposits of the Požeška gora Mt. (Croatia)
te čestice kiselih intruziva (alkalijsko-feldspatski granit i granofir) i efuziva (riolit). Zatim, dolaze čestice vulkanskog stakla i nakupine muskovita sa i bez zmna kvarca. Javljuju se i sitnozrnati pješćenjaci stive boje koji u slijedu stupa postupno prevaldavaju. Fosilni ostaci nisu zapaženi u ovom nivou gornjokrednih naslaga.

Pješćenjaci postupno prelaze u laminirane siltite stive do tamnosive boje. Unutar njih se javljaju i pelagički biomikriti s laminiranim gradom. Starost ovog nivoa je na temelju nalaza brojnih globostruk-ruleda određena kao kampan-mastiht.

Na siltitima kontinuirano dolaze pločasti vapnenci. Debljina slojeva vapnenaca se kreće od 1 do 5 cm. I u ovom paketu vapnenaca nađene su globostruk-rulede kampan-mastihtske starosti.

Završni član, u stupu gornjokrednih naslaga Požeške gore, su debelo uslojeni vapnenci.

Na gornjokrednim naslagama diskordantno nalijepaju krupnoklastične naslage čije je najveće rasprostranjenje zapadno od sela Škrabutnik. Prevladavajuće stijene su konglomerati, te podređeno pješćenjaci, a vrlo rijetko dolaze i tinjasti siltiti. To su bezkarbonatne naslage u kojim nisu nađeni fosilni ostaci, ali je zbog njihovog diskordantnog odnosa spram gornjokrednih naslaga i položaja u odnosu na okolne srednjomiocenske naslage realno za pretpostaviti da im se starost kreće u rasponu paleocen-eocen.

Dačišnji strukturno-tektonski sklop Požeške gore oblikovan je tijekom gornje krede i tercijara. Ustanovljena su dva tektonska događaja (D1 i D2) čije su glavne ose stresa (c115) međusobno okomite. Stariji tektonski događaj vezan je za kraj mezozojskog sedimentacijskog ciklusa koji je u ovom dijelu panonskog prostora završio postkrednim izdizanjem u vrijeme laramijske faze alpinske orogeneze. Predtercijarne stijene su pri kraju gornje krede došle pod utjecaj lateralne kompresije, koja djeluje na pravac istok-zapad, koju prati značajno tektonsko suženje prostora i ekstenzijski procesi u smjeru S-J. U granitnim i rioditnim stijenama i gornjokrednim naslagama su tijekom ove kompresijske deformacijske procesa oblikovani rasjedni sustavi čiji linearni elementi tektonskog transporta ukazuju na reverzno kretanje odvojenih blokova uz pojavu pratečih normalnih rasjeda.

U gornjokrednim naslagama su tijekom kredno-paleogenskih tektonskih događaja oblikovane i bore monoklinalnih procesa. Glavni strukturni elementi nastali u ovom događaju (D2) su reverzni rasjedi pružanja Z-I. U krednim i miocenskim sedimentima se zapažaju normalne, kose i prebačene bore pružanja Z-I sjeverne vergencije te lijevi rasjedi pružanja SI-J. Konjugirani sustavi desnih rasjeda (SZ-JI) su također zapažani, no u značajno podređenoj mjeri. Horizontalni pomaci uz lijeve rasjede su do maksimalno 500 metara.

Kako su kisele magmatske stijene pretalozene u pješćenjak i breča, to je sigurno da su one starije od razdoblja kampan – mastiht. Koliko su graniti i rioditi stariji od...
kampana za sada je teško ustanoviti, no može se reći da je radiometrijska starost (71.5 mil. god.) posljedica naknadnih zagrijavanja i s tim u svezi njihovog podmlađivanja.

Naknadno zagrijavanje je uzrokovano snažnim tektonskim deformacijskim procesima na prijelazu gornje krede u paleocen, kada je ovaj prostor, kao i ostale slavonske planine, pod utjecajem kompresije na pravcu Z-I.