Statistical analyses of Late Cretaceous clastic deposits from Mali Potok Creek (Medvednica Mt., Northern Croatia)

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Original scientific paper

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Abstract

Statistical analyses were applied to the Late Cretaceous clastic deposits exposed along the flanks of the Mali Potok creek in Medvednica Mt., as an auxiliary tool in order to help determining the source of pebbles, depositional processes and position within the sedimentary basin. Particularly interesting is the comparison of the conglomerate matrix with the overlying sandstone. Matrix grain size exhibits normal distribution, with most abundant fractions between 0.125 and 0.5 mm and sorting coefficient 2.14. Sandstones are grain-supported, well sorted, with coefficient value 1.55. Asymmetrical distribution, with domination of small-sized clasts between 0.032 and 0.125 mm in diameter characterizes these deposits. Such distribution is in concordance with interpretation of sandstones as synorogenic turbidites. Clastic succession from Mali Potok Creek can be well compared with contemporaneous deposits in the wider area, particularly with recently studied clastic succession in the vicinity of the Medvedgrad Castle.

Keywords: Clastic deposits, statistics, Santonian-Campanian, Medvednica Mt., Croatia

1. Introduction

Late Cretaceous clastic deposits near the Medvedgrad Castle in the Medvednica Mt. (Northern Croatia) were recently studied in order to estimate their reservoir potential (**Sremac et al., 2018, submitted**). Contemporary clastic deposits crop out in Mali Potok Creek, south from the Medvedgrad succession (**Figure 1**). Clastic succession transgressively lies over the Palaeozoic low-metamorphic rocks. A continuous transition from conglomerates into sandstones, shales, and finally pelagic argillaceous limestones at this outcrop was first studied by **Kudrnovski (1993)**, while the neighbouring clastic deposits of the same age were described by several authors (**Crnjaković, 1979; Marinčić et al., 1995; Pavelić et al., 1995**).

Conglomerates are polymictic, clast- to matrix-supported with clasts of cobble, pebble and even boulder size, upto 75 cm in diameter. Clasts are commonly elongated in shape, well-rounded and often arranged parallel to the bedding plane. Most of the clasts originate from the nearby uplifted land, but some carbonate clasts are derived from skeletons of contemporary benthic biota. Matrix is of similar composition as the overlying sandstones.

The main purpose of this research was to compare the modal composition and size distribution of conglomerate matrix and overlying sandstones, and to find differences and similarities with the recently studied neighbouring locality near Medvedgrad.

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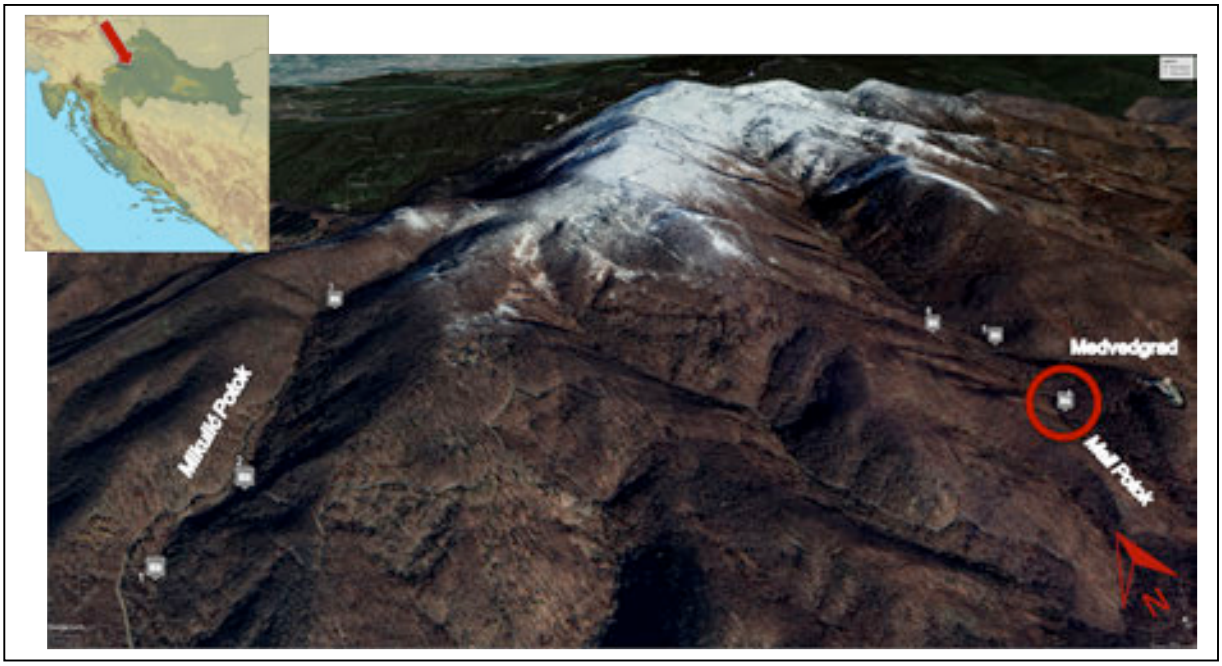

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Figure 1: Position of exposures of Late Cretaceous conglomerates in the vicinity of Medvedgrad Castle. Locality Mali Potok Creek encircled (Google Earth, August 2018).

2. Methods

A detailed sedimentological log was reconstructed in the field (**Figure 2**). Pebbles were counted, sorted by lithology and measured in the field. Their lithology was more detailed studied after the preparation of thin sections. Heavy minerals probes and roentgen analysis were performed in the Department of Geology, Faculty of Science. Grain size distribution in conglomerate matrix and in sandstones was calculated and presented by simple Microsoft Excel tools. Sorting coefficient was obtained from the simple **Equation 1**:

$$So=SQRT(Q3/Q3) \quad (1)$$

with SQRT as square root function, Q_1 being the smallest grain size and Q_3 being the largest grain size.

Figure 2: Details from the studied succession in the Mali Potok Creek: **a.** conglomerates; **b.** sandstones; **c.** overlying Scaglia limestone. Hammer size 33 cm.

3. Results

Conglomerates comprise clasts varying in size from 0.4 to 75 cm. According to the granulometric analysis provided in the field, by counting the 10 largest clasts in a layer (**Bluck, 1967**), pebbles (4-64 mm in diameter) and cobbles (64-256 mm) prevail. Average maximum clast size varies from layer to layer. It can be concluded that conglomerates comprise all size-groups of clasts, from pebbles, through cobbles, up to the boulders. Most of the clasts are well-rounded, although there are also angular fragments (**Figure 2a**). Smaller clasts are generally less rounded. Rounded clasts are in most cases elongate in shape, with longer axes parallel to the bedding planes. Exceptionally, in some layers longer axes are obliquely positioned towards the bedding planes. In basal horizons conglomerates are clast-supported, but the amount of matrix soon reaches 15%.

Terrigenous siliciclastic material prevails over the carbonate clasts. Green-coloured rocks were observed as the most abundant among the clasts. Microscopic analyses have shown the lithologies of low-metamorphic schists (quartz-chlorite, quartz-epidote and epidote-chlorite schists), spilites and, sporadically, diabases. White quartz clasts are clearly visible in the field, and other clasts belong to the quartzites, cherts, shales and siltites. Carbonate grains are autigenic, mostly comprised of skeletons of corallinaceans, corals, bivalves, echinoderms and large benthic foraminifera. Matrix is of sand to silt size. Sand-sized clasts make up to 98% of matrix (**Table 1, Figure 3**). Average diameter of matrix grains (median) is 0.26 mm (**Figure 4**). Sorting coefficient is 2.14, pointing to the poor sorting (**Müller, 1967**).

Table 1: Conglomerate matrix and sandstone grain size from Mali Potok Creek

	CONGL. MATRIX	SANDSTONE
GRAIN SIZE [mm]	PERCENTAGE OF GRAINS	PERCENTAGE OF GRAINS
2-4	1.1	0.5
1-2	9	1.2
0.5-1	19.1	0.5
0.25-05	21.9	2.2
0.125-0.25	31.6	8.4
0.063-0.125	15.1	40.1
0.032-0.063	2.2	39.2
0.016-0.032	0	7.9
	100	100

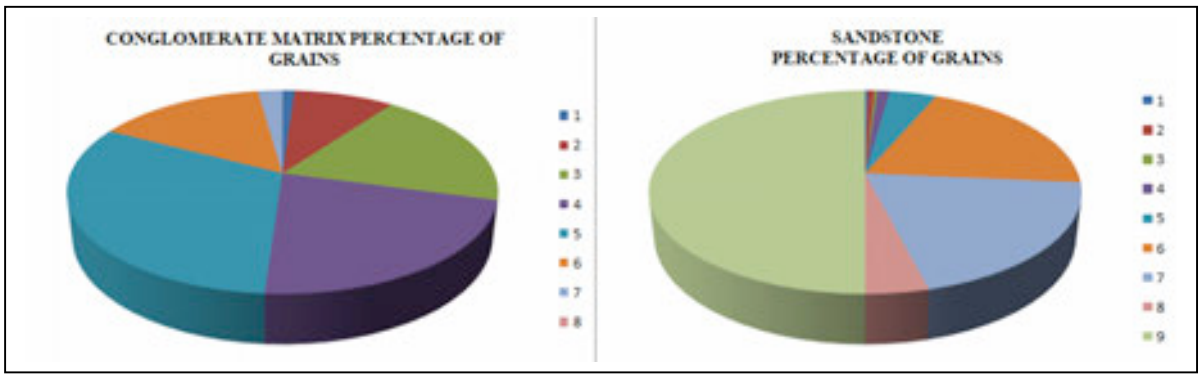

Figure 3: Comparison of grain size distribution in Late Cretaceous conglomerates and sandstones of Mali Potok Creek: Fractions: 1. 2-4 mm; 2. 1-2 mm; 3. 0.5-1 mm; 4. 0.25-5 mm; 5. 0.125-0.25 mm; 6. 0.063-0.125; 7. 0.032-0.063; 8. 0.016-0.032 mm.

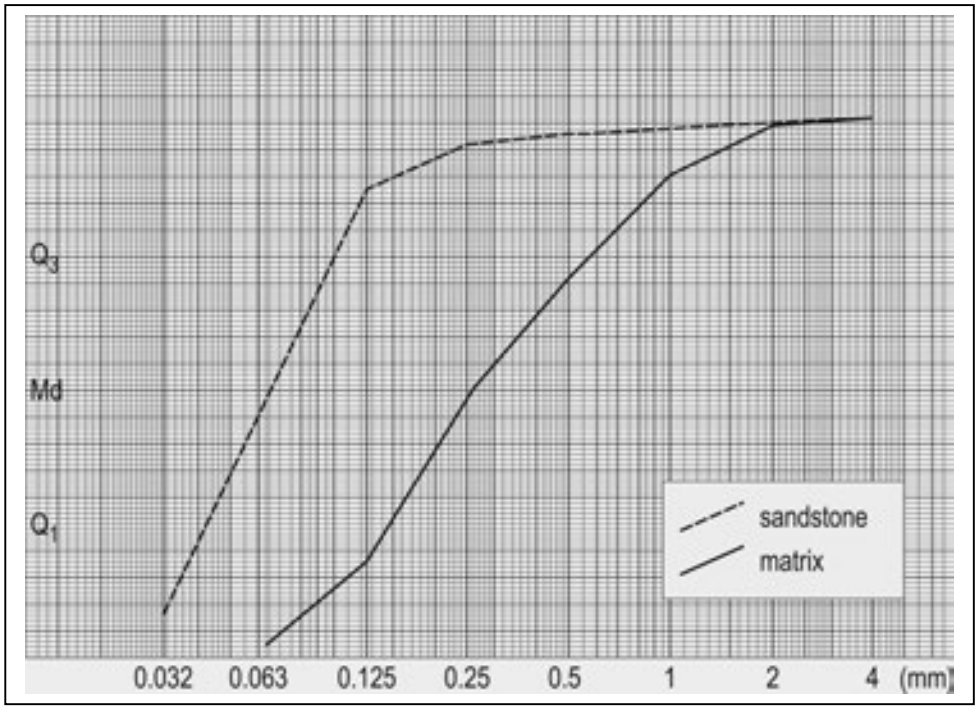

Figure 4: Results of granulometric analyses of conglomerate matrix and sandstones of Mali Potok Creek (**Kudrnovski, 1993**).

Sandstones overly the conglomerates forming a ca. 2.5 m thick horizon. Freshly cut, sandstones are dark-brown in colour. They are strongly tectonized and break up into irregular platty particles parallel to bedding planes (**Figure 2b**). Some layers are cross-lamminated (**Kudrnovski, 1993**). Sandstones are clast-supported, with fine-grained detritic matrix. Silt-sized grains dominate (**Table 1, Figure 3**). Grain size median is 0.067 mm (**Figure 4**), and sorting coefficient is calculated as 1.55, defining the rock as medium-sorted (**Müller, 1967**). Larger clasts are better rounded, while sand-sized clasts are angular or semi-rounded.

Modal composition of sandstones exhibits high percentage of quartz and rocks, with addition of feldspar and plagioclase (**Table 2, Figure 4**). Rock fragments comprise spilite, quartz-chlorite schist, quartzite and shale (**Kudrnovski, 1993**).

Table 2: Modal composition of Late Cretaceous sandstone from Mali Potok Creek.

GRAIN TYPE	%
QUARTZ	44.45
PLAGIOCLASE	1.7
FELDSPAR	1.7
ROCKS-VOLCANIC	8.8
ROCKS-METAMORPHIC	27.4
ROCKS-SEDIMENTARY	17.6

Heavy minerals compose 4.93% of the total sample weight (**Kudrnovski, 1993**). Epidote and opaque minerals are the most common, also with significant amount of chlorite (**Table 3, Figure 5**). Roentgen analyses proved the presence of visually determined epidotes and recorded the presence of titanite, not previously recognized among transparent heavy minerals (**Kudrnovski, 1993**).

Table 3: Composition of heavy minerals in Late Cretaceous sandstone from Mali Potok Creek.

HEAVY MINERALS	
GRAINS	**PERCENTAGE**
OPAQUE	37.5
CHLORITE	13.4
EPIDOTE	43.2
UNKNOWN	5.9
	100

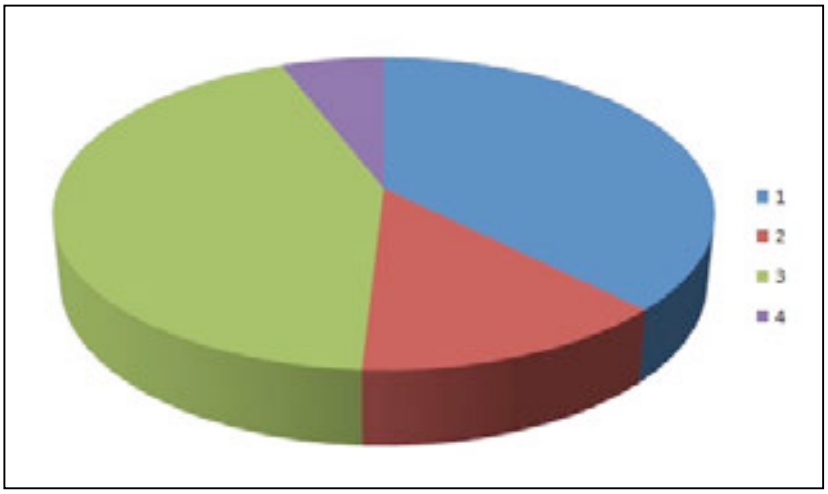

Figure 5: Distribution of heavy minerals in Late Cretaceous sandstone from Mali Potok Creek.1. opaque minerals; 2. chlorite; 3. epidote; 4. unknown.

A combined matrix and cement supports are present in sandstones. Matrix is silt-sized, composed of quartz and phylosilicate minerals (mostly micas). Mica grains are folded, indicating the compaction processes during the diagenesis. Deformed grains originate from shales, slate an phyllites, present as common clasts in underlying conglomerates. Carbonate cement occurs sporadically. According to the common classification (**Pettijohn et al.1972**), sandstones can be classified as lithic greywackes. In upper horizons, sandstones are overlain by shales and, finally, by pelagic Scaglia limestone, comprising the pelagic foraminifera of Late Cretaceous age (**Kudrnovski, 1993 and references therein**).

4. Discussion and conclusions

Terrigenous component of the studied clastic deposits in Mali Potok Creek in most cases originates from low-metamorphic Palaeozoic bedrocks, widely present in the studied area. These rocks are also the source of the mineral grains present in sandstones. Less frequent clasts composed of magmatic rocks are derived from the Mesozoic ophiolitic complex, also present in the wider area.

Lithological features and modal composition of conglomerates indicate their deposition from debris flows, as previously suggested by several authors (e.g., **Crnjaković, 1979; Marinčić et al., 1995; Pavelić et al., 1995**). A possible alluvial and/or deltaic palaeoenvironment was discussed by these authors, but **Sremac et al. (2018, submitted)** rather suggest short-term flows, transporting the material from the uplifted proto-Medvednica along collapse zones into the shelves and surrounding depressions.

Sandstones and shales are generally considered as synorogenic flysch deposits (e.g. **Lužar-Oberiter et al., 2012 and references therein**) reflecting the sinking of the Gosau-type basin (**Borojević Šoštarić et al., 2012**). Such interpretation is in accordance with modal composition of the studied clastic deposits, with rather common grain-size distribution within the conglomerate matrix, and asymmetrical distribution in overlying sandstones (**Figure 6**).

Sremac et al. (2018, submitted) consider the age of the clastic sequence as the Upper Santonian, as the pelagic Scaglia limestone comprise the Uppermost Santonian to Early Campanian microfauna. They also discuss the porosity and permeability of conglomerates and point to the possible importance of Cretaceous clastic deposits as reservoir rocks.

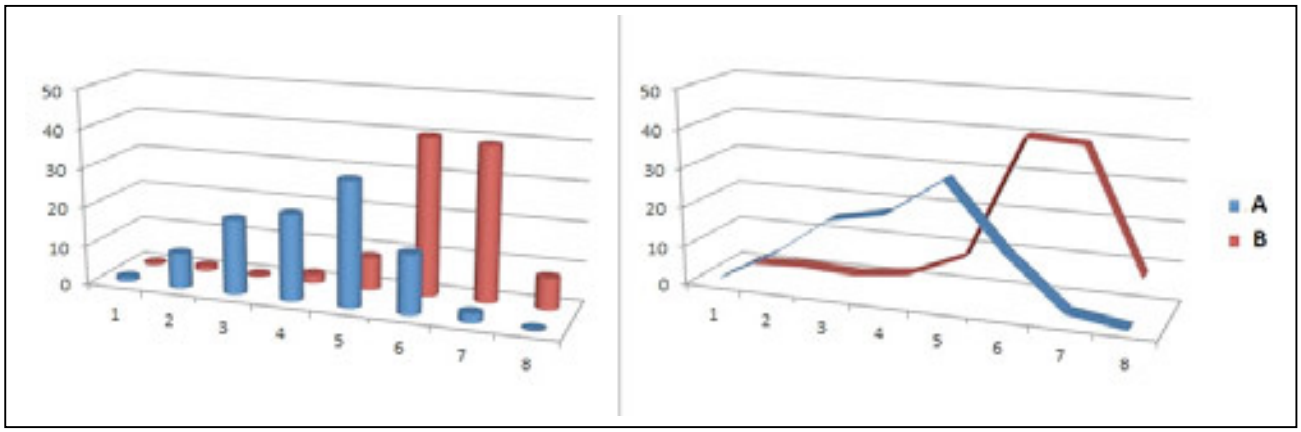

Figure 6: A comparison of grain size distribution (size categories 1-8 vs. percentage 0-50) in conglomerates (A, blue colour) and sandstones (B, red colour). Rather normal distribution is present in conglomerate matrix, while significant assimetry, with higher percentage of fine-grained fraction is visible in sandstones. Size categories as in **Figure 2**.

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Abstract in Croatian

Statistička analiza gornjokrednih klastičnih naslaga iz Malog Potoka na Medvednici (Sjeverna Hrvatska)

Statistička analiza načinjena je za gornjokredne klastične naslage na području Malog Potoka u Medvednici. Slijed naslaga pokazuje postupni prijelaz iz konglomerata u pješčenjake i šejlove, na kojima leže glinoviti Scaglia vapnenci. Konglomerati su polimiktni, klast- do matriks-potporni, s klastima veličine šljunka, valutica, sve do gromada. Klasti su izdužena oblika, dobro zaobljeni, često orijentirani paralelno slojnoj plohi. Većina klasta potječe iz naslaga okolne izdignute podloge, no ima i karbonatnih skeleta morskih organizama. Konglomeratni matriks je slična sastava kao pješčenjaci, koji leže u krovini. Veličina zrna pokazuje normalnu distribuciju, s najviše zrna u frakcijama između 0,125 i 0,5 mm i koeficijentom sortiranosti 2,14. Pješčenjaci imaju zrnsku potporu i dobro su sortirani, s koeficijentom 1,55. Asimetrična raspodjela, uz dominaciju sitne frakcije, između 0,032 i 0,125 mm, karakterizira ove naslage. Takva je raspodjela u suglasju s interpretacijom njihova postanka, kao sinorogenetskih turbidita. Na temelju planktonskih foraminifera iz najmlađeg dijela slijeda, Scaglia vapnenaca, određena je starost naslaga od santona do kampana. Slijed se može dobro usporediti sa sličnim naslagama na širem području, a osobito s nedavno istraženim profilom u okolici Medvedgrada. Na temelju dobivenih vrijednosti poroznosti i propusnosti konglomerata i nepropusne krovine zaključeno je da bi ove naslage trebalo detaljnije istražiti kao moguće ležišne stijene.

Ključne riječi: klastične naslage, statistika, santon-kampan, Medvednica, Hrvatska.