Provenance analysis of Roman stone artefacts from sedimentary rocks of the archaeological site near Mošnje, NW Slovenia

Določanje izvora rimskih kamnitih artefaktov iz sedimentnih kamnin z arheološkega najdišča pri Mošnjah, SZ Slovenija

Snježana MILETIČ¹, Sabina KRAMAR², Judita LUX³, Andrej ŠMUC⁴ & Nina ZUPANČIČ⁴

¹Geological Survey of Slovenia, Dimičeva ul. 14, SI–1000 Ljubljana; e-mail: snjezana.miletic@geo-zs.si
²Slovenian National Building and Civil Engineering Institute, Dimičeva ul. 12, SI–1000 Ljubljana, Slovenia; e-mail: sabina.kramar@zag.si
³Institute for the Protection of Cultural Heritage of Slovenia, Regional Office Kranj, Tomšičeva ul. 7, SI–4000 Kranj, Slovenia; e-mail: judita.lux@zvkdls.si
⁴University of Ljubljana, Faculty of Natural Sciences and Engineering, Department of Geology, Aškerčeva ul. 12, SI–1000 Ljubljana, Slovenia; e-mail: andrej.smuc@ntf.uni-lj.si; nina.zupancic@ntf.uni-lj.si

Prejeto / Received 18. 3. 2016; Sprejeto / Accepted 31. 5. 2016; Objavljeno na spletu / Published online 11. 8. 2016

Key words: Roman stone artefacts, clastic sedimentary rocks, limestones, microfacies, provenance, Mošnje, Slovenia

Abstract

This study deals with the macroscopic and microfacies characterisation of Roman stone artefacts excavated in 2006 from a Roman villa rustica near Mošnje (NW Slovenia) with the aim of defining their provenance. A total of 28 representative finds (querns, mortars, whetstones, tooled and rounded stones, a fragment of stone slab, mosaic tesserae and two architectural elements - one with a relief) made of clastic and carbonate sedimentary rocks were examined. Comparison was made with rock samples taken from quarries and gravel bars close to the archaeological site, as well as from larger distance to the site. The majority of artefact sampled is composed of Upper Palaeozoic quartz sandstones, which are found as pebbles in gravel bars close to the archaeological site; while 2 samples were from Quaternary coarse grained clastic rocks which can be found in local glacio-fluvial sediments. Other finds were made of four different Mesozoic shallow-water limestones which outcrop in different areas of Central and SW Slovenia. The nearest Lower Jurassic biopelmicritic limestones are found at the western periphery of Ljubljana in Podutik. Cretaceous miliolid limestones and biocalcarenitic limestones with rudists are common in the successions of the Dinaric Carbonate Platform in SW Slovenia (for example, on the Trieste-Komen Plateau), NE Italy and SW Croatia. This indicates that the limestones for architectural elements, stone mortars and tesserae were brought to Mošnje from distant locations. Smaller stone tools are likely to have been made at the location of the archaeological site from material gathered locally, mostly pebbles from clastic rocks, which were accessible and suitable for tooling.
Introduction

During construction of a section of motorway (Vrba–Peračica) in the Gorenjska region NW Slovenia near the village of Mošnje, a Roman villa rustica was discovered (Fig. 1). The villa was built in the first half, respectively no later than the middle of the 1st century A.D., and had been used until the end of the 2nd century (Lux & SaGaDin, 2012). The villa rustica consisted of five masonry buildings built on the support wall. The largest and best preserved was the easternmost building that contained a residential area with baths. More than six thousand individual artefacts were collected, consisting of tools, jewellery, coins, pottery and other finds; most dating from the period between the 1st and the 4th centuries A.D. (Lux, 2008).

Among numerous stone finds are the querns, whetstones, mortars, two architectural elements – one with a relief and one similar to altar, black and white mosaic and other functional and decorative objects. Despite various archaeological finds of Roman stone artefacts within Slovenia there has been only a small number of publications regarding the provenance of the archaeological stone materials. KRAMAR (2009) published a short review of the stone material from this archaeological site, Košir (2011) analysed pyroclastic rocks finds from the Mošnje site, while similar analysis from other parts of Slovenia include stone material from Emona (Brecelj et al., 1989; Ramovš, 1990; Šasek Kos, 1990; Ramovš, 2002; Ružnar, 2010), studies of querns from Central and Coastal Slovenia (Horvat & Župančič, 1987) and NE Slovenia (Djuric et al., 2005; Djurčić & Müller, 2009; Kramar & Dolenec, 2013).

The aims of the present study were:

- to define and describe the sedimentary rocks used for various artefacts and stone articles found at the villa rustica near Mošnje,

- to compare the stone materials with the samples from quarries and gravel bars close to and further away from the archaeological site in order to determine their provenance.

Geological setting

The archaeological site near Mošnje is located in an intramontane basin known as the Gorenjska Basin (Vrabec & Fodor, 2006). Tectonically the basin is located in the northeastern corner of the Adria-Europe convergent margin, situated at the contact between Southern Alps (northern margin) and External Dinarids (southern margin). The geological basement of the basin and its margins is quite complex; composed of mainly clastic Carboniferous-Permian strata, Mesozoic carbonate rocks and Oligocene to Miocene clastic and volcanoclastic rocks (Grad & Ferjančič, 1974; Grad & Ferjančič, 1976; Buser & Cahen 1978; Buser, 1980). The basin itself is filled with Quaternary alluvial and fluvial deposits from the Sava River and its tributaries. Pebbles found in these deposits are mainly composed of Permian Val Gardena sandstones, Lower Triassic conglomerates, Middle Triassic limestones with cherts and sandstones, Upper Triassic Dachstein limestones and Upper Cretaceous reddish marls (Jurkovšek, 1986; Buser, 2004; Županec & Herlec, 2004).

Materials and methods

A total of 28 stone finds were sampled for petrographic analysis (Table 1). Eighteen of these samples were also microscopically examined (Tables 2, 3). Among sampled finds were querns, whetstones, tooled and rounded stones, stone mortars, a fragment of stone slab, two architectural elements – one with relief, the other similar to altar and black and white mosaic tesserae.

![Fig. 1. Aerial photograph of the archaeological site near Mošnje (Source: author Jože Hanc, archived by the Institute for the Protection of Cultural Heritage of Slovenia in Kranj)](image-url)
In addition, 21 comparative samples, taken from identified potential source areas in vicinity and more distant localities to Mošnje (Tables 4, 5), were used for comparison (Table 6). These potential source areas were determined on the basis of the rock type and the characteristics of the stone artefacts, a detailed review of existing literature on provenance of the Roman stone materials and a review of the geology of the research area (Jurkovšek, 1986; Brečelj et al., 1989; Ramovš, 1990; Ramovš, 2002; Buser, 2004; Županec & Herlec, 2004; Bavec, 2008; Jurkovšek, 2010; Ržinar, 2010).

Potential provenance areas included following localities (Fig. 2, Tables 4, 5):

- in vicinity to the archaeological site pebbles of clastic rocks were taken from the gravel bars of the Sava River near Lancovo (Fig. 2: loc. 1), along with 13 samples of carbonate rocks from the quarries at Brezovica (Fig. 2: loc. 2), Stara Hleva (Fig. 2: loc. 3), and the exploration area Kodrasti vrh (Fig. 2: loc. 4).
- more distant localities included a limestone quarry in Podutik (Fig. 2: loc. 5) near Ljubljana (3 samples) and an Italian limestone quarry Cava Romana (Fig. 2: loc. 6) near Aurisina/Nabrežina, Italy (15 samples).

For all comparative rock samples thin sections were made and the selected carbonate rocks were coloured with the Alizarin-red S dye. Samples were analysed under an optical microscope - Nikon Eclipse E200 in transmitted light. Digital images were taken with a Nikon Coolpix digital camera. Clastic rocks were classified according to Wentworth (1922) and Pettijohn (1973), while carbonate rocks were classified according to Folk (1962) and Dunham (1962) classifications.
Results and discussion

Archaeological samples

The results of analyses of samples indicate the use of a diverse variety of rock material. Two major groups were identified: smaller tools, such as querns and whetstones, mostly made of various medium to coarse-grained quartz sandstones, and mosaic tesserae and larger items, such as architectural elements, made of different limestones (Plate 1, figs. 1–8; Plate 2, figs. 9–16; Plate 3, figs. 17–18).

GROUP 1. Clastic sedimentary rocks (Table 2)

Facies 1.A. Medium to coarse grained quartz sandstones: 20 samples (analysed only macroscopically: PN 779 (quern), PN 1341 (rounded stone), PN 1465 (rounded stone), PN 1514 (whetstone), PN 2734 (rounded stone), PN 2740 (tooled stone), PN 4051 (whetstone), PN 476 (whetstone), PN 6497 (whetstone) and PN 6569 (tooled stone). Microscopically analysed: ANM 159 (quern), ANM 161 (quern), ANM 163 (quern), ANM 164 (quern), ANM 165 (quern), ANM 167 (quern), ANM 174 (tooled stone), ANM 179 (quern), ANM 187 (quern) and ANM 189 (fragment of stone slab).

Macroscopic description—common characteristics: Rock samples are grey to yellowish brown, medium to coarse grained, in places laminated quartz sandstones. Some also contain larger (1–5 mm) grains. Usually these rocks are strongly weathered exhibiting grey-greenish weathered surfaces.

Microscopic description: The rocks structure is mostly heterogeneous, usually composed of 80 % grains and 20 % of matrix. Some are laminated (ANM 159, ANM 161, ANM 167). Grain sizes range from 0.05 to 0.8 mm, only rarely larger grains (2.5–25 mm) are present (ANM 163, ANM 164, ANM 165, ANM 167, ANM 187). They are poorly sorted, sub-angular to angular and elongated to isometric, and show no visible orientation. Often are coated with red haematite. Contacts between the grains are long and concavo-convex. Grains are represented mainly by mono and polycrystalline quartz grains (45–60 % of all), with irregular edges and undulose extinction. Others are lithic grains (25–45 % of all) mostly of igneous rocks, but also grains of slates, siltstones, limestones, sandstones, and cherts are present. These are rare and present only in some samples: micas (10–30 % of all) in ANM 161, ANM 164, ANM 179, ANM 189, feldspars (5–20 % of all) in ANM 161, ANM 165, ANM 179, ANM 187, Fe minerals in ANM 159, ANM 161, ANM 174, ANM 179, ANM 187, and carbonates in ANM 163, ANM 164, ANM 189. The grains are usually bounded by sericite and quartz-sericite matrix or cemented by quartz and/or carbonate. In some samples (ANM 163, ANM 164, ANM 189) the matrix is strongly limonitised. Clay matrix occurs only rarely (ANM 164, ANM 179, ANM 189).

These sandstones are most likely of Upper Palaeozoic age (Plate 1, figs. 1–8; Plate 2, figs. 9–10).

Facies 1.B. Grey medium grained quartz-calcareous conglomerate: (ANM 177 (tooled stone))

Macroscopic description: Grey conglomerate, clast-supported, composed of well-rounded grains of various compositions up to 3 cm in size. Grains are cemented by highly weathered carbonate cement.

Microscopic description: The rock has a grain supported, heterogeneous structure and consists of 80 % of grains and 20 % of partly weathered carbonate (mostly calcite) cement. The grains
| Sample Mark | Name of Rock | Description | Grain Size (mm) | Mineral Composition (Grains) | Other % |
|-------------|--------------|-------------|----------------|-------------------------------|---------|
| ANM 159     | quern        | laminated grey coarse grained lithic-quartz sandstone | 0.07-1.05 (0.7) | Fe minerals 10 | carbonate |
| ANM 161     | quern        | laminated grey medium grained mica-quartz sandstone | 0.05-0.45 (0.25) | Fe minerals 2 | carbonate |
| ANM 163     | quern        | laminated yellow coarse grained lithic-quartz sandstone | 0.05-0.45 (0.25) | feldspars, pyrite, calcite | carbonate |
| ANM 164     | quern        | laminated grey pebbly medium grained quartz conglomerate | 0.05-0.45 (0.25) | feldspars, sericite, clay | carbonate |
| ANM 165     | quern        | laminated yellowish brown medium grained quartzite conglomerate | 0.05-0.45 (0.25) | feldspars, sericite, clay | carbonate |
| ANM 167     | quern        | toolstone | 0.05-0.45 (0.25) | feldspars, sericite, clay | carbonate |
| ANM 169     | fragment of stone | limonitised yellowish brown fine to medium grained mica-feldspar-quartzite breccia | 0.04-0.6 (0.25) | feldspars, sericite, clay | carbonate |
| ANM 186     | quern        | laminated yellowish coarse grained lithic-quartz sandstone | 0.07-2.5 (0.8) | feldspars, pyrite, calcite | carbonate |
| ANM 187     | quern        | grey pebbly coarse grained quartzite conglomerate | 0.07-2.5 (0.8) | feldspars, pyrite, calcite | carbonate |
| ANM 189     | quern        | grey pebbly coarse grained quartz-calcareous conglomerate | 0.07-2.5 (0.8) | feldspars, pyrite, calcite | carbonate |

Table 2. Petrographic characteristics of microscopically analyzed archaeological samples-clastic sedimentary rocks.
Table 3. Petrographic characteristics of microscopically analysed archaeological samples—carbonate sedimentary rocks.

| FACIES | SAMPLE MARK | ARCH. FIND | NAME OF ROCK | BIOCLASTS % | INTRACLASTS % | PELOIDS % | OOLDS % | OTHER | MATRIX OR CEMENT % | MATRIX OR CEMENT /GRAINS RATIO | GRAIN SIZE (mm) |
|--------|-------------|------------|--------------|--------------|---------------|-----------|---------|-------|-------------------|---------------------------|----------------|
| 2.A    | ANM 160     | stone mortar | grey biopelmicritic limestone | 35 | 5 | 60 | indeterminable | geopetal structures, rounded sparry grains, pyrite | micrite - sparite | 35/65 (avg.) | 0.03 - 0.45 |
|        | ANM 170     | architectural element | dark grey pelbiomicritic limestone | 20 | < 10 | 15 | indeterminable | rounded sparry grains 55 %, pyrite | micrite | 70/30 (avg.) | 0.03 - 0.15 (0.7) |
| 2.B    | ANM 185     | stone mortar | white to light grey biocalcarenitic limestone | 30 | 60 | 10 | / | / | micrite, sparite | 60/40 | 0.04 - 1 (0.1) |
|        | PN 6178     | architectural element with relief | white to light grey biocalcarenitic limestone | 30 | 60 | 10 | / | / | micrite, sparite | 60/40 | 0.04 - 1 (0.1) |
| 2.C    | ANM 133     | white tessera | yellowish white to light grey biomicritic limestone | 90 | some | 10 | / | / | micrite 70, microsparite 20, sparite 10 | 70/30 | 0.1 - 0.9 (0.2) |
| 2.D    | ANM 133     | black tessera | laminated dark grey to black bituminous micritic limestone | 80 | / | / | / | organic matter 10 %, pyrite 10 % | microsparite 90, micrite 10 | 90/10 | 0.02 - 0.15 |

Table 4. Petrographic characteristics of microscopically analysed comparative samples—clastic sedimentary rocks.

| PROVENANCE | SAMPLING LOCATION | SAMPLE MARK | NAME OF ROCK | MINERAL COMPOSITION (GRAINS) | MATRIX OR CEMENT % | MATRIX OR CEMENT /GRAINS RATIO | GRAIN SIZE (MM) |
|------------|-------------------|-------------|--------------|-------------------------------|-------------------|---------------------------|----------------|
| Local      | Gravel bar Lancovo (Sava River) | P-1         | laminated dark green very fine to fine grained mica-quartz sandstone | 70 | / | 30 | / | sericite 75, clay 20, carbonates 5 | 15/85 | 0.03 - 0.13 (0.07) |
|            |                   | P-2         | reddish brown fine grained mica-feldspar-quartz sandstone | 60 | / | 15 | feldspars 25 | sericite, clay | 15/85 | 0.03 - 0.2 (0.14) |
|            |                   | P-3         | grey medium grained feldspar-quartz sandstone | 55 | < 10 | 10 | feldspars 25 | sericite - clay 75, Q 25, traces of carbonates | 15/85 | 0.06 - 0.4 (0.25) |
Table 5. Petrographic characteristics of microscopically analysed comparative samples—carbonate sedimentary rocks.

| PROVENANCE          | SAMPLING LOCATION | SAMPLE MARK | NAME OF ROCK                                           | BIOCLASTS % | INTRACLASTS % | PELOIDS % | OODS % | OTHER                                      | MATRIX OR CEMENT % | MATRIX OR CEMENT/GRAINS RATIO | GRAIN SIZE (mm) |
|---------------------|-------------------|-------------|-------------------------------------------------------|--------------|----------------|-----------|-------|--------------------------------------------|-------------------|-------------------------------|-----------------|
| Local               | Brezovica quarry  | B-1         | light grey recrystallised slightly dolomitic pelbiosparite | 70           | some           | 20        |       | recrystallised 10 anhydritisation, dolomitisation | sparite 70, microsparite 20, micrite 10, traces of dolomites | 70/30            | 0.02 - 0.7                   |
| Local               |                    | B-1         | light grey recrystallised slightly dolomitic pelbiosparite to pelbiomicrite | 70           | some           | 20        |       | recrystallised 10 weak dolomitisation      | sparte to micrite, traces of dolomites | 70/30            | 0.02 - 0.7                   |
| Local               |                    | B-2         | light grey recrystallised dolomitic pelbiosparite       | 70           | some           | 20        |       | recrystallised 10 bioturbations            | sparte 70, microsparite 20, micrite 10            | 70/30            | 0.02 - 0.7                   |
| Local               | Kodrasti vrh      | KV-1        | whitish and reddish recrystallised intrasparitic limestone | /            | 20             | /         | /     | calcite grains 80 %, styloletes, karstification | sparite 70, micrite 30                           | 80/20            | variable, up to 0.5          |
| Local               | Stara Hleva       | SH-1        | light grey medium grained calcareous dolomite          | /            | /              | /         | /     | dolomite and calcite grains                | /                | 0/100                        | variable         |
| Distant             | Quarry in Podutik | P-19        | dark grey biopelmicritic limestone                      | 10           | < 10           | highly variable | indeterminable | rounded sparry grains 30 %, pyrite | micrite, fields of sparite | 70/30            | 0.5 - 9                      |
| Distant             |                    | P-26        | grey biopelmicritic limestone                           | 20           | < 10           | 65        | 10    | rounded sparry grains 5 %, pyrite         | micite, partly recrystallisation (sparite)        | 40/60            | 0.02 – 0.2                   |
| Distant             |                    | P-28        | dark grey biopelmicritic limestone                      | 10 - 20      | < 10           | highly variable | indeterminable | rounded sparry grain 10 % | micrite, sparite | 70/30            | 0.5 - 9                      |
| Distant             | Cava Romana (Aurisina) | CR-1    | white to light grey biocalcarencitic limestone         | 30           | 60             | 10        |       | bituminous substance, pyrite              | micrite, sparite | 60/40            | 0.02 – 3 (1)                  |
### Table 6. Overview of analysed stone material from the archaeological site near Mošnje and their related rock type and provenance

| GROUP OF ROCKS | FACIES | SAMPLE MARK | ARCH. FIND | NAME OF ROCK | GEOL. AGE | PROVENANCE |
|----------------|--------|-------------|------------|--------------|----------|------------|
| **1. Clastic sedimentary rocks** | **1.A Medium to coarse grained quartz sandstones** | ANM 159 | quern | laminated grey lithic coarse grained quartz sandstone | P | gravel bars |
| | | ANM 161 | quern | laminated grey medium grained mica-quartz sandstone | C | gravel bars |
| | | ANM 163 | quern | yellow coarse grained lithic-quartz sandstone | C | gravel bars |
| | | ANM 164 | quern | limonitised yellow-brownish coarse grained lithic-quartz sandstone with transition to fine grained quartz conglomerate | P | gravel bars |
| | | ANM 165 | quern | beige pebbly medium grained feldspar-lithic sandstone | P | gravel bars |
| | | ANM 167 | quern | laminated light grey pebbly medium grained lithic-quartz sandstone to medium grained quartz conglomerate | P | Sava River terrace |
| | | ANM 174 | tooled stone | limonitised yellowish brown medium grained lithic-quartz sandstone | P | gravel bars |
| | | ANM 179 | quern | limonitised laminated grey medium grained mica-feldspar-quartz sandstone | C | Quaternary deposits |
| | | ANM 187 | quern | grey pebbly coarse grained quartz sandstone to medium grained conglomerate | P | gravel bars |
| | | ANM 189 | fragment of stone slab | limonitised yellowish brown fine to medium grained lithic-quartz sandstone | P | gravel bars or Sava River terrace |
| | | PN 779 | quern | limonitised green greyish fine to medium grained quartz sandstone | C | gravel bars or Sava River terrace |
| | | PN 1341 | rounded stone | grey medium grained mica-quartz sandstone | C | gravel bars |
| | | PN 1465 | rounded stone | grey medium grained mica-quartz sandstone | C | gravel bars |
| | | PN 1514 | whetstone | limonitised grey medium grained quartz sandstone | C | gravel bars or surrounding deposits |
| | | PN 2734 | rounded stone | limonitised grey medium grained quartz sandstone | C | gravel bars |
| | | PN 2740 | tooled stone | limonitised yellowish brown coarse grained quartz sandstone | C | gravel bars |
| | | PN 4051 | whetstone | limonitised light grey medium grained quartz sandstone | C | gravel bars or surrounding deposits |
| | | PN 6476 | whetstone | limonitised grey medium grained quartz sandstone | C | gravel bars or surrounding deposits |
| | | PN 6497 | whetstone | limonitised yellowish brown fine to medium grained mica-quartz sandstone | P | gravel bars or surrounding deposits |
| | | PN 6569 | tooled stone | greenish grey medium grained quartz sandstone | C | gravel bars |
| | | ANM 177 | tooled stone | grey medium grained quartz-calcareous conglomerate | Q | Sava River terrace |
| | | ANM 186 | quern | dark grey fine grained mica-quartz breccia | Upper Pz | Quaternary deposits |
| **1.B Grey medium grained quartz-calcareous conglomerates** | | ANM 177 | tooled stone | grey medium grained quartz-calcareous conglomerate | Q | Sava River terrace |
| **1.C Dark grey fine grained mica-quartz breccia** | | ANM 186 | quern | dark grey fine grained mica-quartz breccia | Upper Pz | Quaternary deposits |
| **2. Carbonate sedimentary rocks** | **2.A Grey pelobiomicritic limestones** | ANM 160 | stone mortar | grey biopelmicritic limestone | J1 | probably Podutik |
| | | ANM 170 | architectural element | dark grey pelobiomicritic limestone | J1 | probably Podutik |
| | **2.B White to light grey biocalcarenitic limestone** | ANM 185 | stone mortar | white to light grey biocalcarenitic limestone | K2 | the Trieste - Komen Plateau |
| | | PN 6178 | architectural element with relief | white to light grey biocalcarenitic limestone | K2 | the Trieste - Komen Plateau |
| | **2.C Yellowish white to light grey biomicritic limestone** | ANM 133 | white tessera | yellowish white to light grey biomicritic limestone | K2 | probably the Trieste - Komen Plateau |
| | **2.D Laminated dark grey to black limestone** | ANM 133 | black tessera | laminated dark grey to black bituminous micritic limestone | Mz (K2?) | not local |
are poorly sorted, size ranging from 0.05 mm to 10 mm. They are rounded to well rounded, with isometric to elongated forms. Contacts between the grains are point to concavo-convex. Pores comprise approx. 10 % of the rock. Most grains (85 % of all) are comprised of various lithic grains (fossiliferous Mesozoic and Paleogene limestones, Ladinian or Oligocene tuffs, quartz sandstones and other types of rocks). The remaining 15 % is comprised of individual grains of quartz. The rock is partly cemented by coarse grained mostly carbonate (calcite) cement.

Grey medium grained quartz-calcareous conglomerate, probably of Quaternary age (Plate 2, fig. 11).

Facies 1.C. Dark grey fine grained mica-quartz breccia (ANM 186 (quern))

Macroscopic description: Fine-grained dark grey matrix-supported breccia with up to 5 mm large quartz clasts, embedded in the dark matrix with mica flakes.

Microscopic description: Breccia is homogeneous, consisting of 85 % matrix and 15 % of grains. The grains range in size from 0.12 to 0.80 mm, are very well sorted, angular to sub-angular and of different shapes. Quartz grains dominate (60 %), while muscovite and weathered feldspars are subordinate. Matrix is of sericite (75 %) and fine-grained quartz (25 %).

Fine grained mica-quartz breccia, probably of Upper Palaeozoic age (Plate 2, fig. 12).

GROUP 2. Carbonate sedimentary rocks (Table 3)

Facies 2.A. Grey to dark grey biopelmicritic limestones: 2 samples (ANM 160 (stone mortar), ANM 170 (architectural element))

Macroscopic description: The rock is a grey bioclastic micritic limestone, in places cut by calcite veins.

Microscopic description: Sample ANM 160 is heterogeneous wackestone to packstone. Grain to matrix ratio is very variable, but on average 65/35. Grains are up to 0.6 mm in size and composed mainly of peloids (around 60 %) and bioclasts (35 %) with some pyrite crystals while intraclasts occur rarely. Bioclasts are of biserial foraminifera and other small foraminifera (Glomospira?), algae (Thaumathoporella?), mollusc shells and ostracoda. Some are unidentifiable. Also, small rounded sparitic grains are present; some of these are probably ooids. Sample ANM 170 shows similar composition, with average grain to matrix ratio 30/70, however here ostracods (50 %) dominate over other bioclasts, small peloidal grains and micritic intraclasts. The matrix in ANM 170 is micrite, while in ANM 160 micrite and microsparite, in places sparry calcite cement is present.

The observed characteristics indicate shallow-water depositional environment. Absence of age-diagnostic fossils prevents stratigraphic determination of this facies, however, based solely on the microfacies characteristic (cf. O Gorelec, 2011) the rock is tentatively attributed to the Lower Jurassic.

Facies 2.B. White to light grey biocalcarenitic limestone: 2 samples (ANM 185 (stone mortar), PN 6178 (architectural element with relief))

Macroscopic description: White to light grey fine-grained calcarenitic limestone exhibiting shell fragments.

Microscopic description: Limestone is homogeneous packstone to grainstone. Grains are bioclasts of small spherical and biserial foraminifera, sparite-filled rudist shell fragments and echinoderms fragments. They are bounded by micrite to microsparite and in places also by sparite.

Based on the presence of the rudist shells we assigned this limestone to a shallow-water environment of Upper Cretaceous age (Plate 2, figs. 15 & 16).

Facies 2.C. Yellowish white to light grey biomicritic limestone: 1 sample (ANM 133 (white tessera))

Macroscopic description: Yellowish white to light grey homogeneous limestone.

Microscopic description: Limestone is heterogeneous wackestone, composed of 70 % matrix and of 30 % grains. Grains are randomly distributed, without preferred orientation and up to 0.9 mm in size. The majority of grains are miliolid and other foraminifera. Shells, algae fragments and peloids occur rarely. Matrix is micritic and rarely microsparitic. Sparitic infilling of foraminifera moulds is present.

Based on the abundance of miliolids and other shallow-water grains we believe that the limestone was deposited in a shallow water environment and is probably Cretaceous in age (Plate 3, fig. 18).

Facies 2.D. Laminated dark grey to black bituminous limestone: 1 sample (ANM 133 (black tessera))

Macroscopic description: Laminated black to dark grey micritic limestone with transition to homogeneous dark brown micritic limestone. The rock is intersected by 1 mm thick white calcite veins.

Microscopic description: The limestone is homogeneous bioturbated and laminated mudstone. The proportion of matrix approaches 90 %. Lamination is expressed as alternating
bands of 3 mm thick laminae of clear microsparite with 5 mm thick laminae with higher content of organic matter. In some places we noted traces of bioturbation, oriented perpendicular to lamination. Grains are represented by ostracod fragments and rare particles of amorphous organic matter. Small particles of autogenous pyrite are also present. Amorphous organic matter is common and forms streaks and seams roughly parallel to the lamination.

Abundant presence of fine-grained matrix, lamination and high content of preserved organic matter points to the sedimentation in a hydrodynamically quiet anoxic environment. These conditions are typical for sedimentation in restricted lagoonal or deeper-water environments (Plate 3, fig. 17).

Comparative samples

A total of 21 samples with macroscopic petrographic characteristics potentially comparable with artefacts were taken for further examination. Petrographic analyses have shown that 12 of the comparative samples (Plate 3, figs. 19–24, Plate 4, figs. 25–30) from 6 locations (Fig. 2) have certain similarities with the investigated archaeological materials. The results of microscopic analysis of these samples are shown in Table 4 and Table 5, while their significant characteristics are given within the results of comparative analysis in the next subchapter.

**GROUP 1. Clastic sedimentary rocks (Table 4)**

**Samples of local provenance:**
Pebbles of quartz sandstone (3 selected samples from the Sava River gravel bars in Lancovo: P-1, P-2, P-3) (Plate 3, figs. 19–21): P-1 is a laminated dark grey to dark reddish brown medium grained sandstone. P-2 is reddish brown homogeneous fine grained sandstone. P-3 is a homogeneous grey to dark greenish grey medium grained sandstone with light grains of quartz, feldspars and micas. The rocks are of Upper Palaeozoic age.

**GROUP 2. Carbonate sedimentary rocks (Table 5)**

**Samples of local provenance:**
Light grey recrystallised limestone (3 selected samples from the quarry Brezovica pri Kropi: BR-1, B-1, B-2) (Plate 3, figs. 22–24) is heterogeneous with carbonate grains of different sizes and numerous parallel calcitic veins, up to 0.5 cm thick. The limestone is a pelbiosparite i.e. wackestone of Upper Triassic age.

Whitish and reddish recrystallised limestone (1 representative sample from the exploration area Kodrasti vrh: KV-1) (Plate 4, fig. 25) with thick white (Note 3) calcitic veins is recrystallised intrasparite i.e. wackestone of Upper Triassic age.

**Samples of distant provenance:**
Grey micritic limestones (3 selected samples from an abandoned quarry in Podutik: P-19, P-26 and P-28) (Plate 4, figs. 27 - 29) of varying lighter and darker shades with thin calcitic veins, showing individual fossils, with an average size of 3 mm. The rocks are biopelmicrites i.e. grainstones of Lower Jurassic age.

Light grey biocalcarenitic limestone (1 selected sample from the Roman quarry Cava Romana in Aurisina/Nabrežina: Cr-1) (Plate 4, fig. 30) homogeneous in nature with darker fragmented fossils varying from 1 to 3 mm in size in a lighter coarse grained recrystallised carbonate matrix. The rock is a biointrasparite to biointramicrite i.e. packstone to grainstone of Upper Cretaceous age.

---

**PLATE 1**

1. ANM 159: limonitised, grey, coarse grained lithic-quartz sandstone: subangular quartz grains connected with fine grained carbonate cement (+A).
2. ANM 161: laminated, grey, medium grained mica-quartz sandstone: jagged contacts between quartz and lithic grains in quartz-sericite matrix (+A).
3. ANM 163: limonitised, yellow, coarse grained lithic-quartz sandstone: angular lithic and quartz grains are surrounded by limonitised calcitic cement (+A).
4. ANM 164: limonitised, yellowish, coarse grained lithic-quartz sandstone with transition to fine grained quartz conglomerate: quartz grains of different sizes bonded with calcitic cement (+A).
5. ANM 165: beige, pebbly, medium grained feldspar-lithic sandstone: irregular contacts between quartz and different lithic grains in quartz-sericite matrix (+A).
6. ANM 167: laminated, light grey, pebbly, medium grained lithic-quartz sandstone with transition to medium grained quartz conglomerate: quartz and lithic grains with fine grained sericite quartz matrix between them (+A).
7. ANM 174: limonitised, yellowish brown, medium grained lithic-quartz sandstone: quartz and lithic grains of different size (+A).
8. ANM 179: limonitised, laminated, medium grey mica-feldspar-quartz sandstone: different angular grains in sericite matrix (+A).
Provenance analysis of Roman stone artefacts from sedimentary rocks from the archaeological site near Mošnje

PLATE 1
Comparison of archaeological and comparative samples

**GROUP 1. Clastic sedimentary rocks**

**Facies 1.A. Medium to coarse grained quartz sandstones**

Finer-grained clastic rocks, from which querns, whetstones, tooled and rounded stones were made (ANM 159, ANM 161, ANM 163, ANM 164, ANM 165, ANM 167, ANM 174, ANM 179, ANM 187, ANM 189, PN 779, PN 1341, PN 1465, PN 4051, PN 4676, PN 1514, PN 2734, PN 2740, PN 6497, PN 6569), show similarity to the Upper Carboniferous—Lower Permian clastic rocks and the Middle Permian Val Gardena formation. Upper Carboniferous and Lower Permian rocks consist of grey siltstones, grey lithic-quartz sandstones and grey quartz sandstones (Pleničar et al., 2009), while the Val Gardena formation includes red and grey sandstones, shale and conglomerates (SKABERNE, 1995; Buser, 2009). These rocks are found at several locations in NW Slovenia in the Gorenjska region, especially in the South Karavanke and at the hills around Škofja Loka (Grad & Ferjančič, 1976; Buser, 1980). Comparison of the archaeological samples with pebbles collected from gravel bars showed relative similarity in macroscopic characteristics and mineral composition, but they differ in the amount of feldspars (P-2, P-3) and lithic grains. However, due to the rounded shape of some artefacts (Fig. 3) and the presence of even large boulders (of several decimetres in size) of similar sandstones in the surrounding Quaternary fluvial and glacial deposits, we assume that the material for their production was brought from these deposits, located in the close vicinity of the archaeological site. The differences in the composition of the sandstones used to produce the artefacts are considerable and exceed the lateral and vertical facies variations expected in any one quarry, we presume that the material was obtained as pebbles from the gravel bars.

**Facies 1.B and 1.C. Medium grained quartz calcareous conglomerate and fine grained quartz breccia**

The sample of conglomerate (ANM 177, tooled stone) contains clasts of limestones with fossils from the Mesozoic and Paleogene, Ladinian or Oligocene tuff and other rocks of different ages. The variety of centimetre-sized clasts in the partly cemented conglomerate clearly indicates post Oligocene erosion and glacio-fluvial transportation. All of the recognised clast lithologies in the conglomerate occur in the catchment area of the Sava River, so the rock most probably originates from Quaternary glacial and fluvial deposits in the vicinity of Mošnje. Fine grained mica-quartz breccia, from which one quern is made (ANM 186), is presumably of Carboniferous age and such cobbles and boulders can be found in the Quaternary fluvial deposits in the vicinity of the archaeological site as well.

**GROUP 2. Carbonate sedimentary rocks**

**Facies 2.A. Grey pelbiothicritic limestones**

The samples of darker grey stone mortar (ANM 160) and architectural element, similar to altar (ANM 170) (Fig. 4), are made of pelbiothicritic limestones. Microscopic analysis showed that these microfacies belong to the subtidal shallow-water environment located on a carbonate platform.

---

**PLATE 2**

1 AnM 159: grey, pebbly, coarse grained quartz sandstone to medium grained conglomerate: irregular contacts between quartz grains (+A).
2 AnM 161: limonitised, yellowish brown, fine to medium grained lithic-quartz sandstone: quartz and lithic grains in limonitised carbonate cement, which replaces sericite matrix (+A).
3 AnM 162: grey, medium grained quartz calcareous conglomerate: a rounded lithic grain of biomicritic limestone (+A).
4 AnM 163: dark grey, fine grained mica-quartz breccia: smaller quartz grains in fine grained quartz-sericite matrix (+A).
5 AnM 164: grey biopelmicritic limestone: peloids and bioclasts (-A).
6 AnM 165: white to light grey biocalcarenitic limestone: bioclasts, intraclasts and peloids in micritic-microsparitic matrix (-A).
7 AnM 187: grey, pebbly, coarse grained quartz sandstone to medium grained conglomerate: irregular contacts between quartz grains (+A).
8 AnM 189: limonitised, yellowish brown, fine to medium grained lithic-quartz sandstone: quartz and lithic grains in limonitised carbonate cement, which replaces sericite matrix (+A).
9 AnM 177: grey, medium grained quartz calcareous conglomerate: a rounded lithic grain of biomicritic limestone (+A).
10 AnM 160: grey biopelmicritic limestone: peloids and bioclasts (-A).
11 AnM 162: dark grey, fine grained mica-quartz breccia: smaller quartz grains in fine grained quartz-sericite matrix (+A).
12 AnM 163: grey biocalcarenitic limestone: peloids and bioclasts (-A).
Plate 2
According to the geological map of Kranj (Grad & Ferjančič, 1976), shallow–water Upper Triassic and Lower Jurassic limestones exist on the Jelovica Plateau (in the vicinity of the sampling sites of the comparison samples from Kodrasti vrh (KV-1) and Stara Hleva (SH-1)). However they lack any similarity with the investigated artefacts. Furthermore, macroscopic and microscopic characteristics of samples ANM 160 and ANM 170 are in conformance with the samples P-19, P-26 and P-28. The latter were sampled in the vicinity of Podutik near Ljubljana from different Lower Jurassic rock beds, for which such sedimentary depositional environment is proven (Novak, 2003). In addition, Mullner (1879) and after him Ramovš (1980) were supposing the existence of ancient quarries and stone masonry workshops at this location.

**Facies 2.B. White to light grey biocalcarenitic limestones**

The material of the lighter grey stone mortar (ANM 185) and architectural element with relief (PN 6178) is biocalcarenitic limestone containing recrystallised small foraminifera, fragments of rudist shells and echinoderms. The presence of the rudist shells indicates an Upper Cretaceous shallow-water environment of the Dinaric Carbonate Platform. These limestones outcrop in SW Slovenia, NE Italy and SE Croatia. In Aurisina/Nabrežina, near Trieste in Italy, four types of Upper Cretaceous shallow-water limestone from the Dinaric Carbonate Platform are quarried, just as they were in Roman times (Brečelj et al., 1989; Cucchi & Gerdol, 1986). The most similar to the Mošnje samples is a variety called fiorito, which is also found in the Cava Romana quarry. Similar horizons are found in Slovenia as well, in the Lipica formation (Jurkovšek et al., 1996; Ramovš, 2002).

**Facies 2.C. Yellowish white to light grey biomicritic limestones**

The white mosaic tessera (ANM 133) is made of yellowish to greyish white micritic limestone with miliolid and other benthic foraminifer and algae.
Provenance analysis of Roman stone artefacts from sedimentary rocks from the archaeological site near Mošnje

PLATE 3
Their abundance and the presence of other benthic shallow-water organisms indicate a shallow-water subtidal environment on a carbonate platform (Flügel, 2004). Miliolids occur over a wide stratigraphic range; however they show highest abundance in Cretaceous shallow-water limestones of the Dinaric Carbonate Platform. These limestones today outcrop in the External Dinarides of Northeastern Italy, Southern Slovenia and Southwestern Croatia.

**Facies 2.D. Laminated dark grey to black bituminous limestones**

The black mosaic tessera (ANM 133) is of laminated dark grey to black bituminous micritic limestone. Such limestone usually formed in an anoxic–deep or shallow water environment. In the immediate vicinity of the archaeological site we did not find any such rocks. Larger quantities suitable for extraction can be found in the Kras region where shallow-water carbonates containing beds of laminated bituminous limestones with cherts are present within the various Cretaceous formations of Cenomanian–Campanian age (Jurkovšek, 2010). Šribar (1985) has shown that the sedimentary environment for the formation of bituminous limestones in Southwestern Slovenia could also exist in areas of «upwelling» and intertidal coastal areas. However, it must be emphasized that similar sedimentation conditions optimal for development of the laminated bituminous limestones, existed elsewhere at differing times during the Mesozoic. This wide potential area could be reduced in further research by combining geological with archaeological aspects which assume arrival of a mosaist to Mošnje from the area of today’s Italy bringing tesserae with himself.

**Conclusions**

The Roman villa near Mošnje in NW Slovenia was discovered during the construction of a section of motorway (Vrba–Peračica). The numerous stone finds from this archaeological site are comprised of differing stone materials. By microfacies analysis of selected samples, we determined the rock type and attempted to establish the provenance of these materials.

The studied stone artefacts can be divided in to two groups dependent on sedimentary rock type: clastic or carbonate.

Small stone artefacts, such as querns, whetstones and tooled stones, including pebbles with marks, are made of clastic sedimentary rocks (Facies 1.A to 1.C). The rocks are mainly quartz sandstones, most likely of Upper Palaeozoic age, although there are also coarse grained materials like conglomerates and brecias from local Quaternary deposits of the Sava River. Fieldwork and data from the Basic Geological Map (Grad & Ferjančič, 1976), clearly shows that similar rocks are present in the Sava gravel bars and terraces, located in immediate vicinity of the archaeological site. Therefore we propose that these small artefacts were most probably produced locally.

Artefacts made of carbonate rocks tell us a different story. Microscopic analysis and comparison with the carbonate samples, taken local to the archaeological site, and with samples from further afield, indicate that the investigated limestone Roman artefacts were not produced locally. The architectural element and grey stone mortar are made of dark grey pelbiomicritic limestone (Facies 2.A), which is tentatively correlated with Lower Jurassic limestones from the vicinity of Podutik near Ljubljana.

The light grey stone mortar and the architectural element with relief are made of white to light grey Upper Cretaceous biocalcarenitic limestone with rudist shells (Facies 2.B). Similar limestones are characteristic for the Upper Cretaceous successions of the Dinaric Carbonate Platform outcropping in the SW Slovenia, NE Italy and SE Croatia. These limestones were quarried in Roman times near Aurisina/Nabrežina in Italy, and are still quarried today. Similar limestones are also typical for the Lipica formation on the Karst in Slovenia. We presume that the two architectural elements were imported to Mošnje from one of these areas, even though an archaeological aspect based on current knowledge favours the Italian extraction site.

The white and black mosaic tesserae composed of Cretaceous miliolid limestone (Facies 2.C) and dark organic-rich laminated limestone (Facies 2.D), respectively might originate from different horizons of the Cretaceous succession typical for the Dinaric Carbonate Platform. These rocks outcrop on the Trieste–Komen Plateau, but also in some other areas in Slovenia, therefore we cannot unequivocally determine their provenance.

The presented study indicates that in the Roman archaeological site near Mošnje smaller and useful consumable items, such as querns and whetstones, were made from locally sourced materials, easily picked from the ground. Conversely, larger items such as stone mortars, and more prestigious such as architectural elements and tesserae, were obtained by quarrying and imported.

**Acknowledgements**

For assistance in analysis of the samples we express our gratitude to dr. Dragomir Škaberno, dr. Bogdan Jurkovšek and dr. Matevž Novak. Their opinions, comments and advice were greatly appreciated. For preparation of thin sections and technical assistance we would like to thank the technical staff of the Department of Geology, Faculty of Natural Sciences at University of Ljubljana and to Ivan Mesić from the INA d.d. in Zagreb.
Provenance analysis of Roman stone artefacts from sedimentary rocks from the archaeological site near Mošnje

PLATE 4

25 KV-1: whitish and reddish, recrystallised intrasparitic limestone with transition to limestone breccia: calcitic crystals of different size in recrystallised limestone (+A)
26 SH-1: light grey, medium grained calcareous dolomite: xenotopic and hipidiotopic structure of the dolomite (+A)
27 P-19: dark grey biopelmicritic limestone: small rounded sparitic grains in micritic matrix (–A)
28 P-28: dark grey biopelmicritic limestone: microfacies modification, variable amount of peloids (–A)
29 P-26: grey to dark grey biopelmicritic limestone: bioclasts, intraclasts and peloids (–A)
30 Cr-1: white to light grey biocalcarenitic limestone: a shell fragment and intraclasts (+A)
Jurkovšek, B. 1987: Tolmač lista Beljak, Osnovna geološka karta SFRJ, 1:100.000. Zvezni geološki zavod, Beograd: 58 p.

Jurkovšek, B. 2010: Geološka karta severnega dela Tržaško-komenske planote 1:25.000 in tolmač. Geološki zavod Slovenije, Ljubljana: 72 p.

Jurkovšek, B., Toman, M., Ogorelec, B., Šribar, L., Drobine, K., Poljak, M. & Šribar, L. 1996: Formacijska geološka karta južnega dela Tržaško-komenske planote – Kredne in paleogenske kamnine 1:50.000 = Geological map of the southern part of the Trieste-Komen Plateau – Cretaceous and Paleogene carbonate rocks. Geološki zavod Slovenije, Ljubljana: 143 p., incl. Pls. 23, 1 geol. map.

Košir, M. 2011: Izvor pirolastičnih kamnin z arheološkega najdišča Mošnje. Diplomsko delo. Univerza v Ljubljani, NTF, Oddelek za geologijo, Ljubljana: 74 p.

Kramar, S. 2009: Mošnje, arheološko najdišče Pod cesto; Poročilo o petrografskih preiskavah. Restavratorski center, Zavod za varstvo kulturne dediščine Slovenije, Ljubljana: 20 p.

Kramar, S. & Dolenec, M. 2013: Mineraloško-petrografske značilnosti žrmlj. Ljubljana: 51 p.

Kramar, S. & Žužar, i. 2009: Mošnje, arheološko najdišče Pod cesto. Poročilo o petrografskih preiskavah. Restavratorski center, Zavod za varstvo kulturne dediščine Slovenije, Ljubljana: 13–22.

Bavec, M. 2008: Geološka spremljava v okviru varstva naravne dediščine – strukturno tektonske značilnosti na območju trase in spremljavačih objektov na AC Vrba – Černivec (Peračica): interno poročilo. Geološki zavod Slovenije, Ljubljana: 51 p.

Brecelj, A., Legisa, Z. & Vogric, I. 1989: Nabražinski kamnolomi. Tiskarna Graphart, Trst: 151 p.

Buser, S. 1980: Tolmač lista Celovec (Klagenfurt). L: 33–53. Osnovna geološka karta SFRJ, 1:100.000. Zvezni geološki zavod, Beograd: 62 p.

Buser, S. 2004: Geološke značilnosti alpskega prostora. Narava Slovenije – Alpe. Prirodoslovni muzej, Ljubljana: 13–22.

Buser, S. 2009: Geološka karta Slovenije 1:250.000. Zvezni geološki zavod Slovenije, Ljubljana.

Buser, S. & Caijen, J. 1978: Osnovna geološka karta SFRJ, list Celovec (Klagenfurt), 1:100.000. Zvezni geološki zavod, Beograd.

Cucchi, F. & Gerdol, S. (eds.) 1986: I marmi del Carso triestino. Camera di C.I.A.A. di Trieste: 201 p.

Djurčič, B. & Muller, H. W. 2009: White marbles in Noricum and Pannonia: an outline of the roman quarries and their products. In: Jockey, P. (eds.): Leukos Lithos: Ancient marble and stones of the Mediterranean ancient: études interdisciplinaires: Actes du VIIe Colloque International de l’Association for the study of marble and other stones used in antiquity (ASMOSIA). Aix-en-Provence, 12-18 juin 2006 = Leukos lithos: Ancient marble and stones: interdisciplinary studies on Mediterranean: Proceedings of the VIIIth International Conference of the Association for the study of marble and other stones used in antiquity (ASMOSIA). Paris: Maisonneuve & Larose: 111–127.

Djurčič, B., Hebert, B., Hinkcr, C., Hudecček, E., Karl, S. & Muller, H. W. 2005: Marmore römischer Brüche und Steindenkmäler in der Steiermark und in Štajerska. Ergebnisse eines Forschungsprojektes. Fundber. Österr. 43: 365–431.

Dunham, R. J. 1962: Classification of carbonate rocks according to depositional texture. In: Ham, W. E. (eds.): Classification of carbonate rocks. Am. Assoc. Petrol. Geol. Mem. 1. 108–21.

Flügel, E. 2004: Mikrofacies of Carbonate Rocks. Springer Verlag, Berlin: 976 p.

Folk, R.L. 1962: Spectral subdivision of limestone types. In: Ham, W. E. (ed.): Classification of carbonate rocks. American Association of Petroleum Geologists Memoir, 1: 62–84.

Grad, K. & Feriančič, L. 1974: Osnovna geološka karta SFRJ, list Kranj, 1:100.000. Zvezni geološki zavod, Beograd.

Grad, K. & Feriančič, L. 1976: Tolmač za list Kranj, L–33-65, Osnovna geološka karta SFRJ, 1:100.000. Zvezni geološki zavod, Beograd: 70 p.

Horvat, A. & Župančič, M. 1987: Prazgodovinske in rimske žrmlje iz zahodne Slovenije: (prvi rezultati petrografiske analize). Geološki zbornik, 8: 105–110.

Luxe, J. 2008: Nova odkritja, Arheološko najdišče Mošnje. Internet: http://www.zvksd.si/sl/novice/nova-odkrijta/54-/(16/4/2011)

Luxe, J. & Sagadin, M. 2012: Poskus časovne umestitve objekta rimske vile rustike pri Mošnjah. Emona med Akvilejo in Panonijo. In: Županek, B. & Lazar, I. (eds.): Annales Mediteranea. Univerza na Primorskem, Univerzitetna založba Annales, Koper: 311–322.

Müller, A. 1879: Emona, archeologische Studien aus Krain. I.V. Kleinmayr & F. Bamberg. Ljubljana: 20 p.

Novak, M. 2003: Žgornjetriasne in spodnjepoštne plašte na območju Podutika pri Ljubljani. Geologija, 46/1: 65–74, doi:10.5474/geologija.2003.004.

Ogorelec, B. 2011: Microfacies of Mesozoic Carbonate Rocks of Slovenia. Geologija, 54/2 (dodatek/supplement): 136 p., doi:10.5474/geologija.2011.011.

Pleničar, M., Ogorelec, B. & Novak, M. (eds.) 2009: Geologija Slovenije = The geology of Slovenia. Geološki zavod Slovenije, Ljubljana: 612 p.

Pettijohn, F. J.1975: Sedimentary rocks. Harper & Row, New York: 628 p.

Ramovš, A. 1990: Gliniščan od Emone do danes. Geološki zbornik 9, Odsek za geologijo, Ljubljana: 171 p.

Ramovš, A. 2002: Geološko ogotovitev o izvoru kamine menjeda pri Aquilejo in Emono. Arheološki vestnik, 53: 383–384.

Rižnar, I. 2010: Geološka preiskava kamnitih zidov na območju arheološkega najdišča NUK II. Unpublished report, archived by ZVKDS, CPA, Ljubljana: 29 p.

References
ŠKABERNE, D. 1995: Sedimentacijski in postsedimentacijski razvoj Val Grödenske formacije med Cerknim in Žirovskim vrhom = Sedimentary and postsedimentary development of Gröden Formation between Cerkno and Žirovski Vrh. Dissertation thesis, University of Ljubljana: 500 p.

ŠAJN, R. 1998: Geokemične lastnosti urbanih sedimentov na ozemlju Slovenije delo = Geochemical properties of urban sediments on the territory of Slovenia. Dissertation thesis, University of Ljubljana: 251 p.

ŠAŠEL KOŠ, M. 1990: Nauportus antični literarni in epigrafski viri. Nauportus: Literary and Epigraphical Surces, 17–33: 143–159.

ŠRIBAR, L. 1995: Evolucija gornjokredne jadransko-dinarske karbonatne platforme u jugozapadnoj Sloveniji. Magistarski rad. Sveučilište u Zagrebu, Prirodoslovno matematički fakultet, Zagreb: 89 p.

VRABEC, M. & FODOR, L. 2006: Late Cenozoic tectonics of Slovenia: structural styles at the Northeastern corner of the Adriatic microplate. In: PINTER, N., GYULA, G., WEBER, J. & STEIN, S. (eds.): The Adria Microplate: GPS Geodesy, Tectonics and Hazards, NATO Science Series, IV, Earth and Environmental Sciences, 61: 151–168, doi:10.1007/1-4020-4235-3_10.

WENTWORTH, C. K. 1922: A scale of grade and class terms for clastic sediments. Journal of Geology, 30: 377–392.

ŽUPANEC, A. & HERLEC, U. 2004: Prodišča slovenskih alpskih rek. In: TRILAR, T., GOGALA, A. & JERŠEK, M. (eds.): Narava Slovenije – Alpe. Prirodoslovni muzej, Ljubljana: 59–62.
