Stone Objects from Vindobona (Austria) – Petrological Characterization and Provenance of Local Stone in a Historico-Economical Setting

Rohatsch, Andreas; Kronberger, Michaela; Insulander, Sophie; Mosser, Martin; Hodits, Barbara

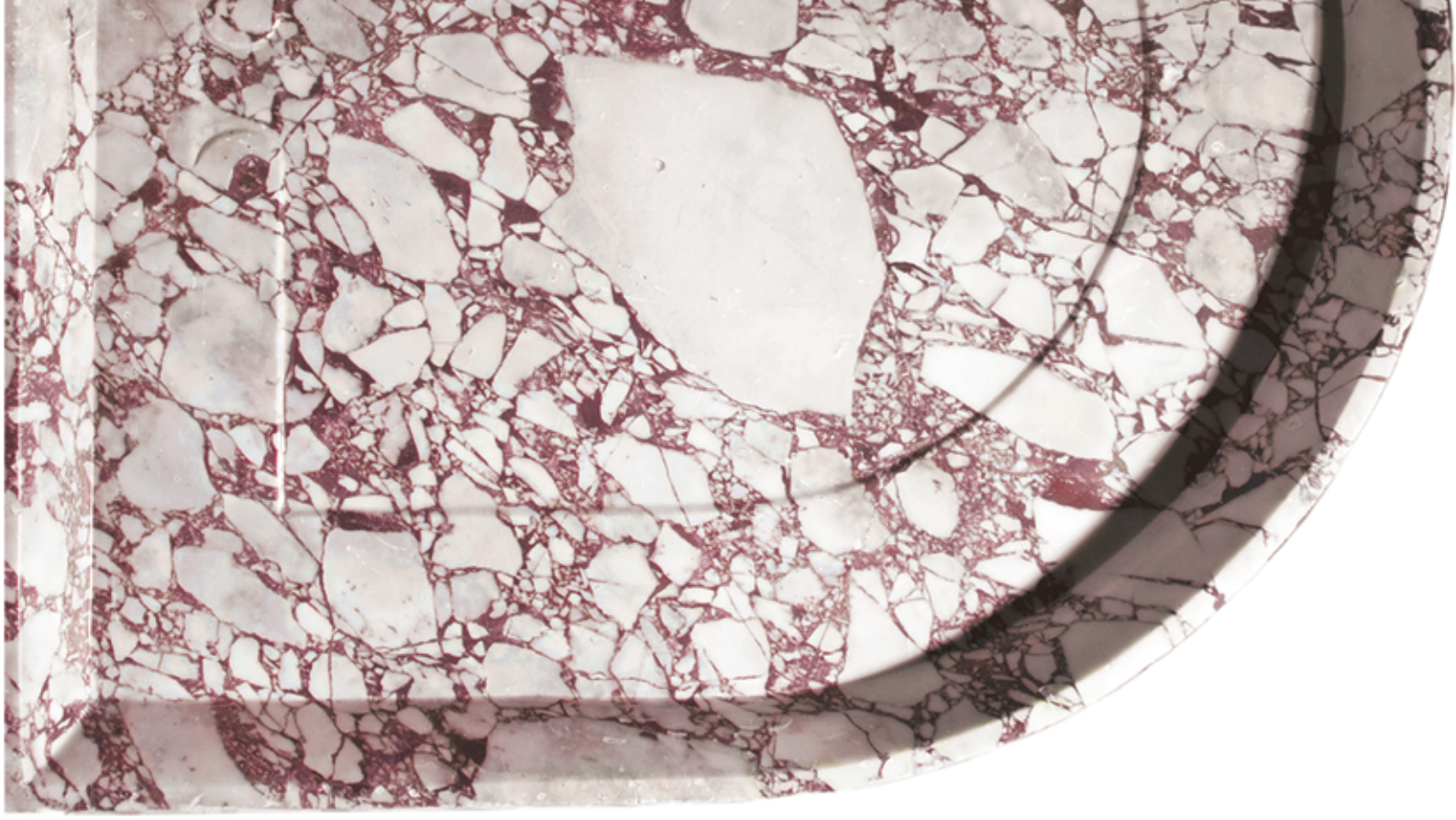
Source / Izvornik: **ASMOSIA XI, Interdisciplinary Studies on Ancient Stone, Proceedings of the XI International Conference of ASMOSIA, 2018, 363 - 372**

Conference paper / Rad u zborniku

Publication status / Verzija rada: **Published version / Objavljena verzija rada (izdavačev PDF)**

https://doi.org/10.31534/XI.asmosia.2015/02.21

Permanent link / Trajna poveznica: https://urn.nsk.hr/urn:nbn:hr:123:587762



ASMOSIA XI

Interdisciplinary Studies on Ancient Stone

PROCEEDINGS

of the XI ASMOSIA Conference, Split 2015

Edited by Daniela Matetić Poljak and Katja Marasović

ARTS ACADEMY IN SPLIT

UNIVERSITY OF SPLIT,
FACULTY OF CIVIL ENGINEERING,
ARCHITECTURE AND GEODESY

Interdisciplinary Studies on Ancient Stone

Proceedings of the XI ASMOSIA Conference (Split 2015)

Publishers:

ARTS ACADEMY IN SPLIT
UNIVERSITY OF SPLIT

and

UNIVERSITY OF SPLIT
FACULTY OF CIVIL ENGINEERING,
ARCHITECTURE AND GEODESY

Technical editor:
Kate Bošković

English language editor:
Graham McMaster

Computer pre-press:
Nikola Križanac

Cover design:
Mladen Čulić

Cover page:
Sigma shaped *mensa* of *pavonazzetto* marble from Diocletian's palace in Split

ISBN 978-953-6617-49-4 (Arts Academy in Split)
ISBN 978-953-6116-75-1 (Faculty of Civil Engineering, Architecture and Geodesy)

e-ISBN 978-953-6617-51-7 (Arts Academy in Split)
e-ISBN 978-953-6116-79-9 (Faculty of Civil Engineering, Architecture and Geodesy)

CIP available at the digital catalogue of the University Library in Split, no 170529005

Association for the Study of Marble & Other Stones in Antiquity

ASMOSIA XI

Interdisciplinary Studies of Ancient Stone

Proceedings of the Eleventh International Conference of ASMOSIA,
Split, 18–22 May 2015

Edited by
Daniela Matetić Poljak
Katja Marasović

Split, 2018

Nota bene
All papers are subjected to an international review.
The quality of the images relies on the quality of the originals provided by the authors.

CONTENT

DOI: https://doi.org/10.31534/XI.asmosia.2015/02.21

STONE OBJECTS FROM VINDOBONA (AUSTRIA) – PETROLOGICAL CHARACTERIZATION AND PROVENANCE OF LOCAL STONE IN A HISTORICO-ECONOMIC SETTING

Andreas Rohatsch[1], Michaela Kronberger[2], Sophie Insulander[3], Martin Mosser[4] and Barbara Hodits[1]
[1] Vienna University of Technology, Institute of Geotechnics, Research Centre of Engineering Geology, Vienna, Austria (andreas.rohatsch@tuwien.ac.at; barbara.hodits@tuwien.ac.at)
[2] Wien Museum, Vienna, Austria (michaela.kronberger@wienmuseum.at)
[3] Institute for the Study of Ancient Culture, Austrian Academy of Sciences, Vienna, Austria (sophie.insulander@oeaw.ac.at)
[4] Department of Urban Archaeology, Vienna, Austria (martin.mosser@stadtarchaeologie.at)

Abstract

The interdisciplinary project *Stone Monuments and Stone Quarrying in the Carnuntum – Vindobona Area* aims to acquire new knowledge about Roman economic and settlement history, art, quarrying and infrastructure through the analysis of archaeological and geological data collections. Based on macroscopic examination of Roman stone objects as well as the analysis of historical maps and airborne laser scans, potential quarrying regions were selected and samples taken.
The main quarrying areas were located near Perchtoldsdorf (Lower Austria) and in Vienna. It seems that after the installation of the Roman legionary garrison, the building material was quarried from the eastern margin of the Eastern Alps, including the Vindobona vicinity. Additionally, it was possible to prove the origin of Neogene algal limestones from the *Leitha Mountains*, which played an important role in sculptured stone monuments.
All investigated lithotypes from the mentioned regions belong to the Austrian stratigraphic stages from Neogene sedimentary rock formations of the Central Paratethys.

Keywords
Vindobona, Roman time monuments, lithological investigation

Introduction, questions and methodological approach

The interdisciplinary project „Stone monuments and Stone Quarrying in the Carnuntum – Vindobona Area"(FWF P 26368-G21; <http://www.oeaw.ac.at/antike/figindex.php?id=390>) investigates the stone monuments in the larger area of the two legionary fortresses of Carnuntum (Petronell/Bad Deutsch-Altenburg in Lower Austria) and Vindobona (ancient Vienna) in the north western part of the Roman province of Pannonia Superior.[1] The aim is to provide an archaeological evaluation of the stone objects and to investigate their geological composition as well as the origin of the rock. The presented paper focuses on the stone monuments from the Vindobona area dating from the 1st to the beginning of the 5th century AD. Since the Roman period, the urban territory of Vienna has been subject to a process of transformation, lasting almost 2000 years. This entailed the continuous reuse of stone objects as valuable construction material – thus it is not surprising that they have been constantly reduced in quantity in the course of time. Nevertheless, about 370 stone monuments originating from Vindobona's sphere of influence are preserved in different collections, especially the Wien Museum.

For an interdisciplinary project, however, this small number can be seen as an opportunity. It allows the historic-cultural classification of more or less all the stone monuments of Vindobona. Specifically chosen case examples from the different object groups can be thus subjected to a more precise geological examination. Thus, in addition to inscription stones, sculpture and architectural ornamentation, it is also possible to explore simpler architectural elements, parts of the infrastructure, building material as well as stone tools with respect to the origin of the stone raw material.

The mapping of the stone inventory in a GIS system and the attempt to reconstruct the ancient terrain enables the visualisation of the individual find-spots of the Roman stone objects as well as their allocation to different historical settlement areas of the legionary base according to object groups (Fig. 1).

During the last years almost 180 archaeological objects of the Vindobona area were examined to get an overview of the preferred lithotypes used for Roman stone objects. An important requirement, deriving also

1 KREMER, KITZ 2016, p. 75–82; KRONBERGER, MOSSER, INSULANDER 2016; ROHATSCH *et al.* 2016.

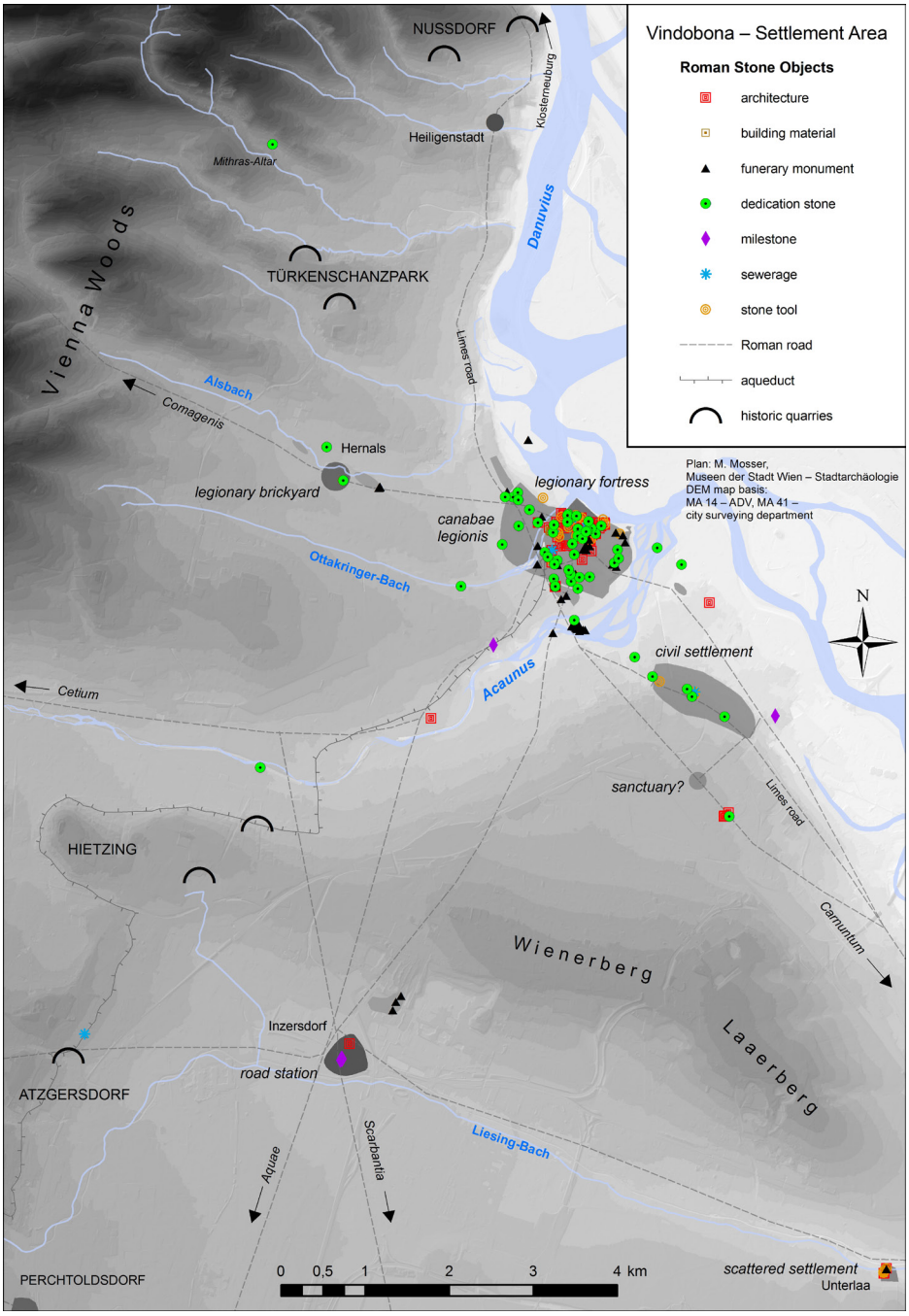


Fig. 1.
Mapped stone objects within the settlement area of Vindobona (plan: M. Mosser, Museen der Stadt Wien – Stadtarchäologie, DEM map basis: MA 14 – ADV, MA 41 – city surveying department, ancient course of the River Danube after ENVIEDAN project [Environmental History of the Viennese Danube 1500-1890])

from the archaeological point of view, is that all investigated objects should be well described, dateable and should be assigned the scientific context of their respective archaeological origin. Only if these fundamental preconditions are fulfilled can a meaningful interpretation of trading connections, economic history and social history be achieved. This constitutes the basis for further questions, such as the localisation of quarries, routes of transportation, chronology, workshops and economic relations.

Corresponding with the topic of the project, the geoscientific focus of this multidisciplinary research is placed on deciphering the petrology and carbonate facies made of Miocene sedimentary rocks on one hand, and on comparing them with the strata outcropping in abandoned quarries on the other. The targeted quarries and pits are especially distributed on the western marginal zone of the *Vienna Basin* and in the north-eastern *Leitha Mountains* within a 45 km radius (= 30 Roman miles) from Vindobona. The about 300 quarries that were exploited in the last 2000 years indicate the importance of these rocks for architecture and sculpture. Nowadays only three active quarries are left: St. Margarethen, Mannersdorf and Aflenz near Leibnitz.

The selection of the quarries for detailed documentation was based on topographical evaluation with emphasis on historical maps from the 18th and 19th

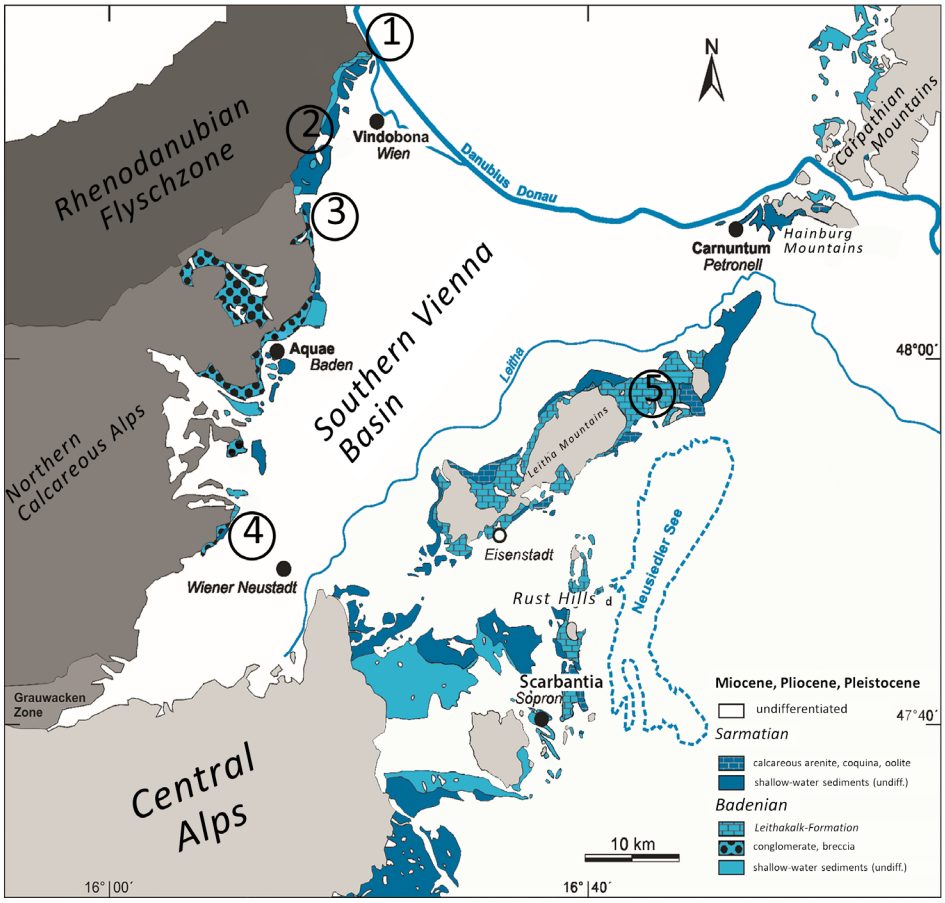


Fig. 2.
Sketch map of the distribution of stones for sculptures, decorations and buildings from the Miocene of the southern *Vienna Basin* and the adjacent *Pannonian Basin* in Austria, which are relevant for Vindobona; locations: 1 – Nussdorf, 2 – Hietzing, 3 – Perchtoldsdorf, 4 – Bad Fischau, 5 – Winden, Jois, Bruckneudorf (plan: modified from Rohatsch, Draganits 2014)

centuries, geological maps and on high resolution airborne laser scans. The archaeological evidence of Roman settlements supplemented the prospection.

In these selected quarries lithological profiles were recorded and representative samples for microscopic, petrophysical, and geochemical analysis were taken. The lithological descriptions, microfacies analyses, determinations and denominations of the samples were carried out with the use of common macroscopic and microscopic methods.[2]

Geological and petrographic fundamentals

Sedimentary rocks from the *Middle Miocene* up to the lower *Late Miocene* (*Langhian – Serravallian - Tortonian*) ranging from about 15.97 to 7.25 my BP[3] can be found in many places in the marginal areas of the *Vienna Basin* as well as in the *Eisenstadt Basin*.[4] The *Vienna Basin* is an important geological element between the *Austrian Eastern Alps* and the *Western Carpathians*. The subsidence of the basin along strike slip faults in connection with a pull-apart mechanism[5], due to the final uplift of the *Eastern Alps* and the *Carpathians* started in the Miocene regional stage of the Lower Badenian accompanied by the transgression of the *Paratethyan Ocean*. The relevant stratigraphically regional stages in Austria span then the *Badenian*, *Sarmatian* and *Pannonian* stages. The lithological inventory includes calcareous arenites, sandstones, limestones, conglomerates and breccia. One of the most common lithotypes, the *Leithakalk*[6], comprises the Badenian coralline red algae (*Corallinaceae*) dominated limestones of shallow water carbonate platforms from the *Western Central Paratethys*[7], distributed around the *Leitha Mountains*, the *Rust-Hills* and other parts of the *Vienna Basin* (Fig. 2).[8] It comprehends the *Leithakalk* faciostratotype of the Badenian regional stage with its

2 DUNHAM 1962; FLÜGEL 2004; FOLK 1959; PETTIJOHN *et al.* 1973; TUCKER, WRIGHT 1990.

3 PILLER *et al.* 2004; GRADSTEIN *et al.* 2012, 183.

4 HÄUSLER *et al.* 2015, 475 493; SCHMID 1968.

5 DECKER *et al.* 2005, 307–322.

6 KEFERSTEIN 1824.

7 KOVÁČ *et al.* 2007; HARZHAUSER, RÖGL 2011; DECKER *et al.* 2005.

8 MOSHAMMER *et al.* 2015; WESSELY *et al.* 2006; SCHÖNLAUB 2005.

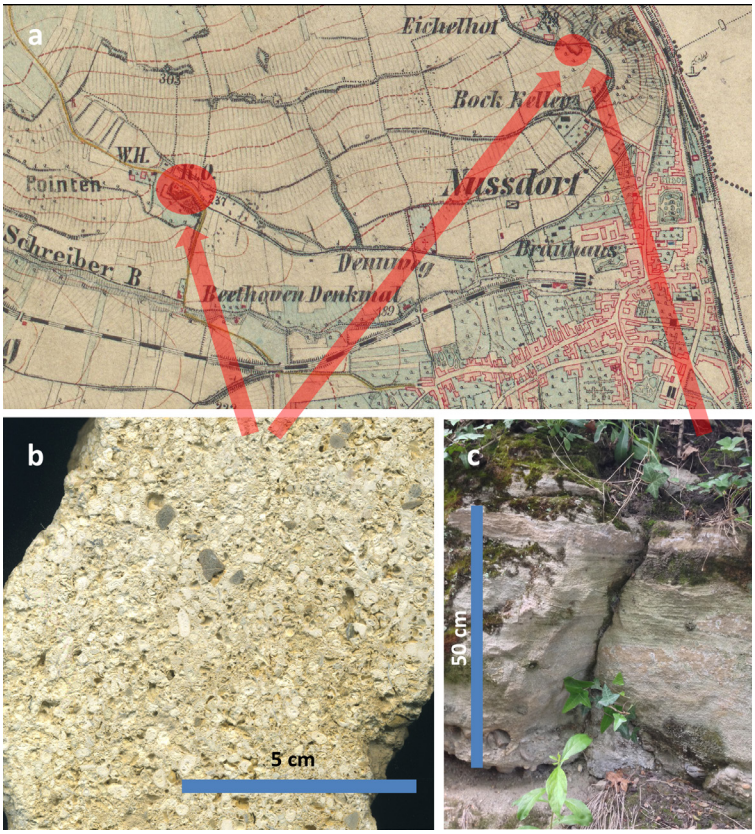


Fig. 3.
Abandoned quarries beyond Nussdorf:
a: detail from the historical map of the 3rd geodetic survey of Austria from 1872 (https://commons.wikimedia.org/wiki/File:Aufnahmeblatt_4657-3c_Heiligenstadt,_Floridsdorf,_Strebersdorf.jpg)
b: sample of Badenian detrital *Leithakalk* (rudstone, biosparite) from the former quarry at the Eichelhof; this type of rudstone mainly consists of debris from coralline red algae beneath debris of Bryozoa, foraminifers, echinoids; pebbles of quartz-arenites from the *Flyschzone* are common (photo: B. Hodits)
c: cross-bedded medium to coarse grained siliciclastic arenite: mainly consisting of angular quartz grains beneath additional debris of coralline red algae and foraminifers; on the bottom of the sandstone sometimes layers of conglomerate, consisting of pebbles from the *Flyschzone* are included (photo: A. Rohatsch)

lateral equivalents of near-shore calcareous sandstones, breccia and conglomerates.[9]

The so-called *detrital Leithakalk* which is an informal name for calcareous arenites and rudstones consisting mainly of debris from coralline red algae comprises the Sarmatian and Pannonian regional stages. Sarmatian oolithic limestones, coquinas and immature sandstones without veritable algal debris content are comparable with the Holíč-Formation and the Skalica-Formation[10]. All these lithotypes have been used extensively as building stones and ornamental stones since at least the late Bronze Age in eastern Austria.

Rock sources of the stone objects in Vindobona – first results

About 180 archaeological objects in the storage place of the *Wien Museum*, the *Römermuseum* and the *Kunsthistorisches Museum* in Vienna, such as gravestones, dedication monuments, architectural parts and milestones have been identified as *detrital Leithakalk* from local quarries along the western border of the *Vienna Basin* as well as from further afield in the *Leitha Mountains*.

The geological hinterland of Vindobona contains a greater variety of natural stone resources and the catchment area for rock used in Vindobona appears to have extended southwards along the Alpine margin via Perchtoldsdorf as far as Bad Fischau. Badenian algal rudstones with or without pebbles of quartz-arenites from the *Rhenodanubian-Flyschzone* and cross-bedded quartz-arenites with accessory debris of coralline algae and foraminifers originate from abandoned quarries near *Nussdorf* in the north of Vienna (Fig. 3).

Very important for the extraction of stones for architecture was the Sarmatian Skalica-Formation which delivered the so called *Atzgersdorfer Stein* and was used for large amounts of building blocks from Roman times to the end of the 19th century. Quarries in Hietzing, Vienna´s 13th district, and in Atzgersdorf (23rd district) were exploited for several hundred years. Gastropod- or bivalve coquinas, oolithic limestones and immature, hybrid arenites are characteristic and simply determinable lithotypes of this formation (Fig. 4).

In order to provide an insight into the current state of research, different case examples, which illustrate the problematic nature of the research as well as showing preliminary tendencies of results, will be presented below.

9 ROHATSCH 2005; STEININGER, PAPP 1978.

10 e.g. HARZHAUSER, PILLER 2004, 65–86; PILLER *et al.* 2004; PILLER, HARZHAUSER 2005, 450–455.

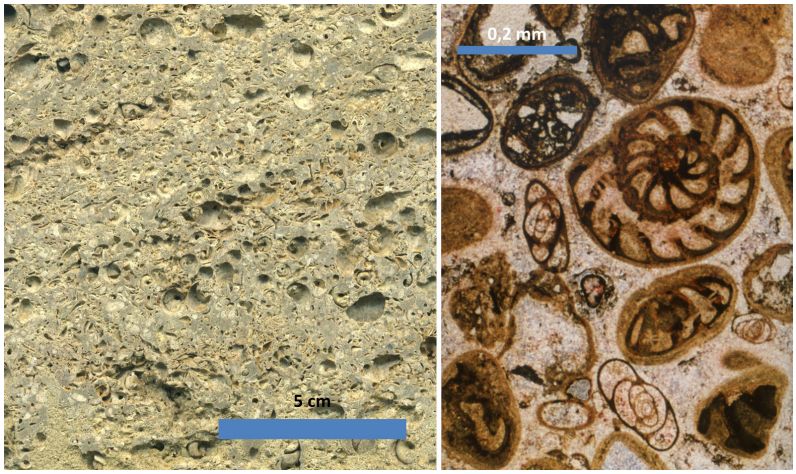


Fig. 4.
Samples from the abandoned quarry of Hietzing (Vienna, 13th district; photos: A. Rohatsch):
a: coquina consisting mainly of endocasts of the Sarmatian gastropods *Pirenella sp.* (rudstone – floatstone, poorly washed biosparite)
b: the thin section (grainstone, biosparite) reveals the embedding fine to medium grained calcareous arenite dominated by foraminifers of the order Miliolida (e.g. *Quinqueloculina sp.* is very common) beneath ooids and siliciclastic detritus from the *Flyschzone*; multiphase diagenetic cementation with dog-tooth calcite and sparry calcite

Example 1: Building material from the Vienna Woods

Starting in 98 AD, the 13th and 14th legion began the construction of the legionary fortress in the area of present Vienna's city centre.[11] There exists a sample of about 30 architectural elements belonging to the fortifications which can be allocated to this period. To these belong a number of facing ashlars and building inscriptions from the fortification wall as well as the profiled base of the *porta principalis sinistra*.[12] According to the petrographic analysis these were made out of rocks predominantly originating from the eastern foothills of the Vienna Woods in the municipal area of present day Vienna, which can be found, for example, in the surroundings of Hietzing, in the Türkenschanzpark and on the Nussberg (Fig.1). This shows the tendency to use nearby quarrying areas with short routes of transportation to bring construction material to the settlement centre.

Example 2: Infrastructural features

According to the current state of research, typical uses of different rock types for various different infrastructural features are already becoming apparent. The massive sewers of the legionary fortress, as high as 2 m, were demonstrably built at the beginning of the legionary camp's construction period at the end of the 1st century AD.[13] This is proved by the continuous use of tiles of the 13th legion for the sewers – the legion which was the first one to work on the legionary fortress. The sewers were covered by manhole cover stones with characteristic drain holes, of which

Fig. 5. Restored Roman manhole cover stone from the sewer of the legionary bath of Vindobona. Wien Museum, Inv.-Nr. MV 93.196/1. (photo: M. Mosser)

seven examples have been found in Vienna (Fig. 5).[14] Five of them were definitely produced from stones extracted along the western border of the *Vienna Basin,* because the breccias predominantly consist of debris of Mesozoic dolomite (*Hauptdolomit*) and limestone (*Dachsteinkalk*). Therefore the *Northern Calcareous Alps* can be assumed as geological hinterland. The predominance of *Hauptdolomit* and *Dachsteinkalk* suggest a northernmost region of the *Northern Calcareous Alps* with a catchment area of the *Frankenfelser-* and *Lunzer Nappe*.[15] Provided that the manhole covers were, in fact, fabricated during the construction period of the legionary fortress, this can be taken as evidence for the early exploitation of quarries south of Vienna, probably from the area of Perchtoldsdorf (see below).

11 KRONBERGER, MOSSER 2015, 242.

12 KAT. VINDOBONA 1978, 172–175 S5–S8; S13–S15; Wien Museum, Inv.-Nr. MV 643. 719. 720. 1703; Kunsthistorisches Museum (KHM) Inv.-Nr. III 1205; MOSSER 2011, 167–183.

13 GIETL, KRONBERGER, MOSSER 2004, 49 tab. 3, Abb. 12.

14 KAT. VINDOBONA 1978, 175 S 16–S 17; Wien Museum, Inv.-Nr. MV 723. 2049. 11937/291. 38060/90. 71531. 93196/1.

15 WESSELY 1983, 27 – 68.

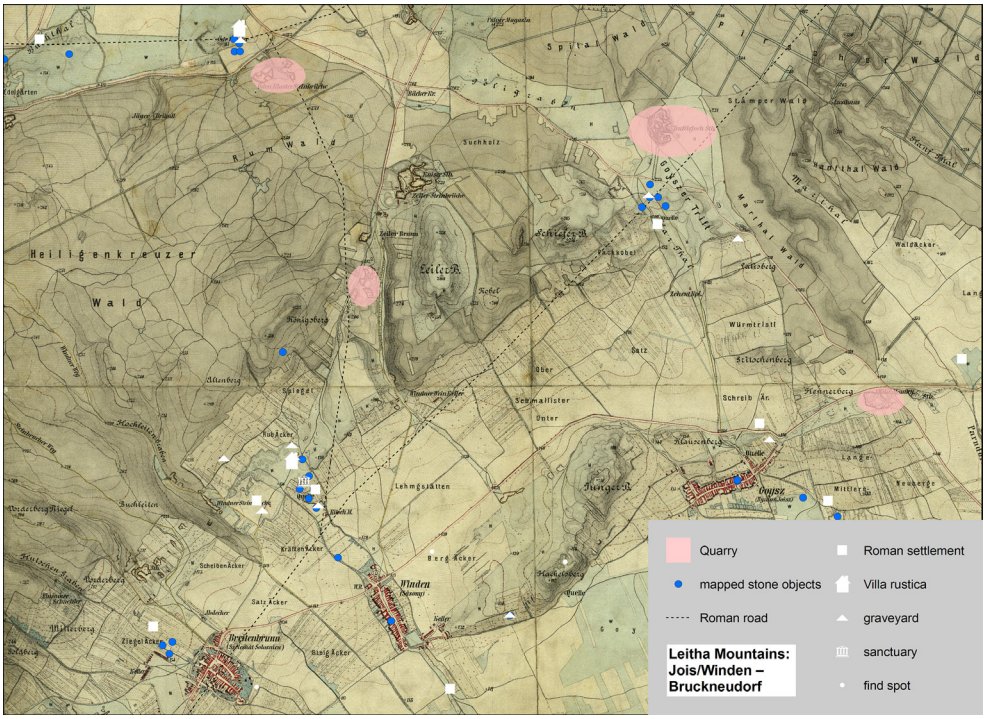


Fig. 6.
Roman settlements (e. g. Edit B. Thomas 1964, 152 ff., 201 ff., René Ployer 2012a, 2012b) and nearby quarries, which were probably used since Roman times (map source: detail from the 3rd geodetic survey of Austria 1873; upload from: http://commons.wikimedia.org/wiki/File:Aufnahmeblatt_4857-2b_Jois_Winden_Breitenbrunn.jpg)

Example 3: Gravestones and altars

For certain types of stone monuments, like tombstones and dedication monuments, it has been proved that there were a large number of imports from quarries in the Leitha Mountains. From those approximately 80 examined objects around one-half was extracted there. One reason for this could be that the Leitha limestone with its finer structure was more suitable for the sculpting of reliefs and inscriptions than the local rocks. But undecorated sarcophagi also have their origin in the *Leitha-Mountains*. So another possibility for these imports could be pre-existing workshops in the *Leitha-Mountains* region or the Carnuntum area whose market extended to Vindobona.

Ancient quarries in the *Leitha Mountains* – first results

Objects made of Sarmatian and Pannonian *detrital Leithakalk* were delivered from ancient quarries in the *Leitha-Mountains*, probably situated in the region between Winden, Jois and Bruckneudorf, and are very similar and comparable to the lithotypes which were used in Carnuntum. Due to the petrographic and geological investigations of the last years[16] the region between Winden, Jois and Bruckneudorf in the northern part of the *Leitha Mountains* is assumed to be an important source area for stones used in Roman architecture, for tombstones and sacred monuments. Some of the quarries are obviously situated near Roman settlements (Fig. 6).[17] The probability that the exploitation of building blocks occurred during Roman times is therefore very high, although antique tool marks are generally not visible in the different extraction walls. The reason for this circumstance is the continuing use of the stone pits up to the early 20th century. The lithological inventory of the regional Miocene stages *Badenian, Sarmatian and Pannonian* in this region includes detrital limestones with different grainsize distributions (grainstone to rudstone/floatstone), degrees of sorting (very well to poor), porosities and strength. All the lithotypes consist predominantly of debris from coralline red algae (*Corallinaceae*), beneath Bryozoans, echinoids and foraminifers (Fig. 7).

Summary: Monument types and quarrying areas

To sum up, the following picture emerges: architectural elements and infrastructure components, which were mostly documented in the legionary fortress area of Vindobona, originate predominantly from local quarries or the western margin of the *Vienna Basin*.

16 e. g. DRAGANITS *et al.* 2008; ROHATSCH 2005; ROHATSCH 2012; ROHATSCH, DRAGANITS 2014; WIEDL *et al.* 2012; WIEDL *et al.* 2013; WIEDL *et al.* 2014.

17 e. g. THOMAS 1964, 152 ff.; 201 ff.; PLOYER 2012a, 2012b.

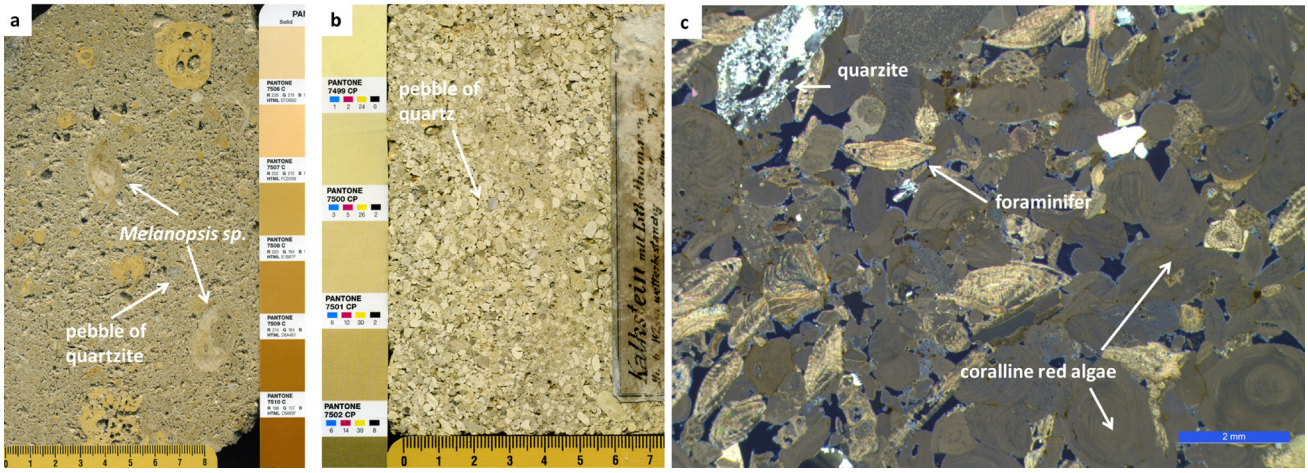


Fig. 7. a: Pannonian detrital Leithakalk (grainstone – packstone, biosparite) predominantly consisting of debris from coralline red algae and foraminifers from an abandoned quarry near Winden with reworked rhodolithes, freshwater gastropods (*Melanopsis sp.*) and pebbles of Quartz and Quartzite (photo: B. Hodits)
b: coarse grained detrital Leithakalk (rudstone, biosparite,) mainly consisting of well-rounded debris from coralline red algae and sporadically pebbles of Quartz and Quartzite (photo: B. Hodits)
c: thin section of b consisting of debris from coralline red algae, foraminifers (e.g. *Amphistegina sp.*); furthermore debris of echinoids, bryozoans and pebbles quartzite are observable (photo: A. Rohatsch)

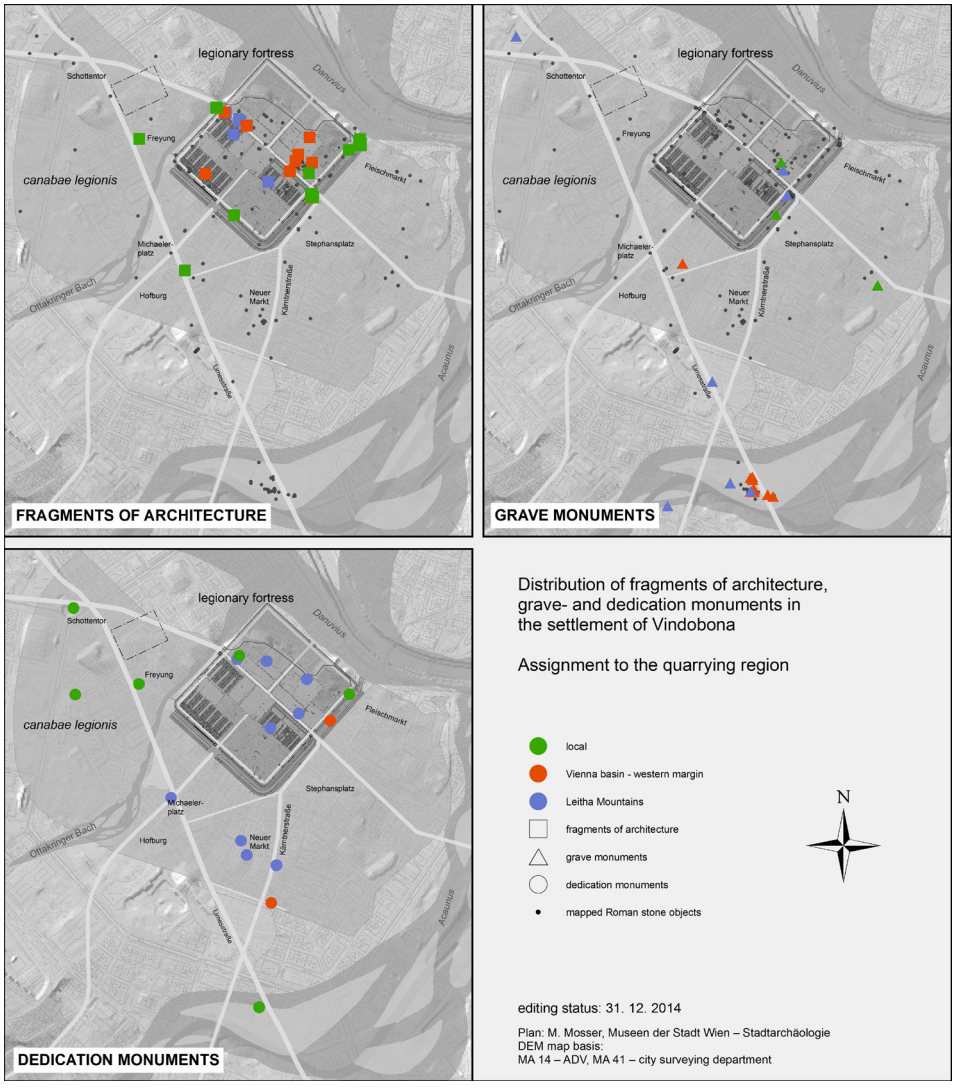


Fig. 8.
Distribution of architectural fragments, dedication monuments and gravestones within the Roman settlement centre of Vindobona. The term "local" designates the quarries of Nussdorf, Türkenschanze and Hietzing. (plan: M. Mosser, Museen der Stadt Wien – Stadtarchäologie; DEM map basis: MA 14 – ADV, MA 41 – city surveying department)

For certain types of stone monuments, like dedication monuments and tombstones, a considerable proportion of imports from quarries in the *Leitha Mountains* can be proved. Rocks from the western margin of the *Vienna Basin* play a lesser role for these types of monuments (Fig. 8).

Analysis by linking various data sources

Petrological characterization offers the possibility of defining quarrying areas for stone monuments on a large scale. However, it is more difficult to locate the actual ancient quarries or the routes of transportation, which were essential for infrastructure. Here a connection of archaeological, geological as well as historical data is needed and therefore constitutes a crucial part of our project. The localisation and verification of Roman find-spots in the surrounding area of potential stone quarries are of great importance. It must be assumed that quarries of significance were established and operated by certain legions, which requires an infrastructure of military nature. The presence of military, then, can be proved through the existence of respective finds in the relevant collections, whose inspection is part of the project. For this purpose all published Roman sites were integrated in a GIS-map of the *Vienna Basin* region as a starting point to enclose the quarry region in question.[18]

Example 4: Verification of a quarrying area

The area surrounding Perchtoldsdorf, 13 km (9 Roman miles) away from Vindobona (Fig. 1) at the western margin of the Vienna Basin meets all the requirements concerning the location of an assumed Roman quarry region. It is situated in the vicinity of a Roman arterial road leading to Vindobona and distinct signs of settlement have been detected.[19] The finding material in the collections, such as tile stamps of all three legions garrisoned in Vindobona or the tombstone of a veteran, is indicative of military context.[20] All these factors make ancient quarrying a possibility.

ACKNOWLEDGEMENTS

We would like to thank Franz Humer and Eduard Pollhammer from the Archaeological Park and Museum in Carnuntum, Gerd Polster and Hannes Herdits from the *Burgenländisches Landesmuseum* in Eisenstadt, Thomas Zalka from the *Burgenländische Landesregierung* and Georg Plattner from the *Kunsthistorisches Museum* in Vienna for the excellent cooperation. We also like to thank our colleagues Gabrielle Kremer, Isabella Kitz and Christian Gugl (Austrian Academy of Sciences, Institute for the Study of Ancient Culture), Ingrid Weber-Hiden (Department of Ancient History, Papyrology and Epigraphy, University of Vienna, Austria), Michael Doneus and Erich Draganits (Institute of Prehistoric and Historical Archaeology, University of Vienna, Austria) and last but not least Maria Heinrich and Beatrix Moshammer (Austrian Geological Survey) for their outstanding teamwork.

18 Important basic literature: TALAA, HERRMANN 2004; PLOYER 2007; PLOYER 2013.

19 TALAA, HERRMANN 2004, 14–76; KRONBERGER, MOSSER 2013, 113–116.

20 KAT. VINDOBONA 1978, 207 S 119; TALAA, HERRMANN 2004, 46–48 Abb. 17.

REFERENCES

DECKER K., PERESSON H., HINSCH R. 2005: "Active tectonics and Quaternary basin formation along the Vienna Basin Transform fault", Quaternary Science Reviews 24, 307–322.

DRAGANITS E., ROHATSCH A., HERDITS H. 2008: „Römersteine entlang der burgenländischen Bernsteinstrasse", in Spuren römischen Lebens im Burgenland, Wissenschaftliche Arbeiten aus dem Burgenland 124, 37-58, Eisenstadt.

DUNHAM R. J. 1962: "Classification of carbonate rocks according to depositional texture", in W. E. HAM, "Classification of carbonate rocks", American Association of Petroleum Geologists Memoir. 1, Tulsa, 108–121.

FLÜGEL E. 2004: "Microfacies of Carbonate Rocks. Analysis, Interpretation and Application", Springer, Berlin, Heidelberg, New York, 2004.

FOLK R. L. 1959: "Practical petrographic classification of limestones", American Association of Petroleum Geologists Bulletin 43, 1–38.

GIETL R., KRONBERGER M., MOSSER M. 2004: „Rekonstruktion des antiken Geländes in der Wiener Innenstadt", Fundort Wien 7, 32–53.

GRADSTEIN F. M., OGG J. G., HILGEN F. J. 2012: On the Geologic Time Scale. - Newsletters on Stratigraphy 45/2, 171–188, Stuttgart.

HARZHAUSER M., PILLER W. E. 2004: "Integrated stratigraphy of the Sarmatian (Upper Middle Miocene) in the western Central Paratethys", Stratigraphy 1, 1, 65–86, text figures 1–12.

HARZHAUSER M., RÖGL F. 2011: "Das Werden der Paratethys", in H. STEININGER, E. STEINER (eds.): Meeresstrand am Alpenrand: Molassemeer und Wiener Becken. Katalog zur Ausstellung des Niederösterreichischen Landesmuseums in Zusammenarbeit mit dem Naturhistorischen Museum und dem Institut für Paläontologie der Universität Wien. Bibliothek der Provinz, 2. Aufl., Weitra, 13–75.

HÄUSLER H., SCHEIBZ J., CHWATAL W., KOHLBECK F. 2015: "Coeval Lower Miocene subsidence of the Eisenstadt Basin an relative updoming of its Austroalpine frame: implications from high-resolution geophysics at the Oslip section (Northern Burgenland, Austria)", Int. J. Earth Sci. (Geol. Rundschau) 104, 475 – 493, Berlin Heidelberg (Springer).

KAT. VINDOBONA 1978: "Vindobona. Die Römer im Wiener Raum". 52. Sonderausstellung des Historischen Museums der Stadt Wien, Karlsplatz, Wien, 1978.

KEFERSTEIN CH. 1828: "Beobachtungen und Ansichten über die geognostischen Verhältnisse der nördlichen Kalk-Alpenkette in Österreich-Bayern", Teutschland geognostisch-geologisch dargestellt 5/3, Weimar, 1–425.

KOVÁČ M., ANDREYEVA-GRIGOROVICH A., BAJRAKTAREVIĆ Z., BRZOBOHATÝ R., FILIPESCU S., FODOR L., HARZHAUSER M., NAGYMAROSY A., OSZCZYPKO N., PAVELIĆ D., RÖGL F., SAFTIĆ B., SLIVA L., STUDENCKA B. 2007: "Badenian evolution of the Central Paratethys Sea: paleogeography, climate and eustatic sea-level changes", Geologica Carpathica 58/6, 579–606.

KREMER G., KITZ I. 2016: "Steindenkmäler und Steingewinnung – Neue interdisziplinäre Forschungen im Rahmen des CSIR Carnuntum", in HUMER F., KREMER G., POLLHAMMER E., PÜLZ A. (eds.): Akten der 3. Österreichischen Römersteintagung in Carnuntum, Wien 2016, 71–85.

KRONBERGER M., MOSSER M. 2013: "Die Straßen von Vindobona", in I. GAISBAUER, M. MOSSER (red.): Straßen und Plätze. Ein archäologisch-historischer Streifzug. Monografien der Stadtarchäologie Wien 7, Wien, 107–155.

KRONBERGER M., MOSSER M. 2015: "Wien – Vindobona", in V. GASSNER, A. PÜLZ (eds.): Der römische Limes in Österreich. Führer zu den archäologischen Denkmälern, Wien, 242–267.

KRONBERGER M., MOSSER M., INSULANDER S. 2016: "Gesteinsbestimmungen an Römersteinen aus Vindobona – Lösungsansätze, erste Ergebnisse und Perspektiven aus archäologischer Sicht", in F. HUMER, G. KREMER, E. POLLHAMMER, A. PÜLZ (eds.): Akten der 3. Österreichischen Römersteintagung in Carnuntum, Wien 2016, 87–99.

MOSHAMMER B., UHLIR Ch., ROHATSCH A., UNTERWURZACHER M. 2015: "Adnet 'Marble', Untersberg 'Marble' and Leitha Limestone—Best Examples Expressing Austria's Physical Cultural Heritage", in G. LOLLINO, A. MANCONI, F. GUZZETTI, M. CULSHAW, P. BOBROWSKY, F. LUINO (eds.): Engineering Geology for Society and Territory - Volume 5. Urban Geology, Sustainable Planning and Landscape Exploitation, 253-257 (Springer).

MOSSER M. 2011: "Befunde im Legionslager Vindobona. Teil VI: Die Lagermauer – Profildokumentation auf der Parzelle Wien 1, Kramergasse 13", Fundort Wien 14, 164–185.

PETTIJOHN F. J., POTTER P. E., SIEVER R. 1973: "Sand and sandstone", Springer, Berlin.

PILLER W. E., EGGER H., ERHART C. W., GROSS M., HARZHAUSER M., HUBMANN B., VAN HUSEN D., KRENMAYR H.-G., KRYSTYN L., LEIN R., LUKENEDER A., MANDL G., RÖGL F., ROETZEL R., RUPP Ch., SCHNABEL W., SCHÖNLAUB H. P., SUMMESBERGER H., WAGREICH M., WESSELY G. 2004: „Die stratigraphische Tabelle von Österreich 2004 (sedimentäre Schichtfolgen)". Kommission für die paläontologische und stratigraphische Erforschung Österreichs der Österreichischen Akademie der Wissenschaften (ÖAW) und Österreichische Stratigraphische Kommission, Wien, 2004, http://palstrat.uni-graz.at/Stratigraphische_Tabelle_von_Oesterreich_2004.pdf.

PILLER W. E., HARZHAUSER M. 2005: "The myth of the brackish Sarmatian Sea", Terra Nova 17, 5, 450–455.

PLOYER R. 2007: "Siedlungsarchäologische Aspekte im Hinterland von Carnuntum. Die ländliche Besiedlung zwischen Leitha und Neusiedler See in römischer Zeit", Carnuntum Jahrbuch 2007, 55–119.

PLOYER R. 2012a: "Das römische Gräberfeld von Mannersdorf am Leithagebirge (NÖ.) als Quelle zur Bevölkerung der Spätantike im Hinterland von Carnuntum", in C. REINHOLDT, W. WOHLMAYR (eds.): Akten des 13. Österreichischen Archäologentages, Klassische und Frühägäische Archäologie Paris-Lodron-Universität vom 25. bis 27. Februar 2010, Wien, 303–310.

PLOYER R. 2012b: "Der Bezirk Neusiedl am See in ur- und frühgeschichtlicher Zeit – Ein archäologischer Überblick", in A. LEHNE (ed.): Österreichische Kunsttopographie 59 – Die Kunstdenkmäler des Politischen Bezirkes Neusiedl am See, Horn, 1–33.

PLOYER R. 2013: "Zur Besiedlung zwischen Steinfeld und Rosaliengebirge während der römischen Kaiserzeit", in R. LANG, M. MEHOFER, R. PLOYER, N. SCHINDEL, A. STEINER, Ein Opferplatz der römischen Kaiserzeit aus dem südlichen Niederösterreich. Römisches Österreich 36, Wien, 296–303.

ROHATSCH A. 2005: "Neogene Bau- und Dekorgesteine Niederösterreichs und des Burgenlandes", in B. SCHWAIGHOFER, W. EPPENSTEINER (eds.): Nutzbare Gesteine von Niederösterreich und Burgenland, "Junge" Kalke, Sandsteine und Konglomerate, Mitteilungen Institut für Angewandte Geologie, Universität für Bodenkultur, Wien, 9–56.

ROHATSCH A. 2012: "Verwendung und gesteinsphysikalische Eigenschaften burgenländischer Leithakalke", Wissenschaftliche Arbeiten aus dem Burgenland 142, Begleitband zur Ausstellung "Als das Burgenland noch am Meer lag", Eisenstadt, 38–50.

ROHATSCH A., DRAGANITS E. 2014: "Herkunftsbestimmung an den Gesteinen des römischen Gräberfeldes von Halbturn", in N. DONEUS (ed.): Das kaiserzeitliche Gräberfeld von Halbturn, Burgenland, Teil 2 Intention, Abfall oder Zufall – naturwissenschaftliche Untersuchungen, Monografien des Römisch-Germanischen Zentralmuseums 122, 2, Mainz, 701–715.

ROHATSCH A., MOSHAMMER B., HODITS B., DRAGANITS E., HEINRICH M. 2016: "Steindenkmäler und Steingewinnung im Raum Carnuntum-Vindobona – Vorstellung des geologischen Teils eines interdisziplinären Projektes", in F. HUMER, G. KREMER, E. POLLHAMMER, A. PÜLZ (eds.): Akten der 3. Österreichischen Römersteintagung in Carnuntum, Wien 2016, 177–183.

SCHMID H. 1968: "Das Jungtertiär an der SE-Seite des Leithagebirges zwischen Eisenstadt und Breitenbrunn (Burgenland)", WAB, 41, 74 S., Eisenstadt (Bgld. Landesmuseum).

SCHÖNLAUB H. P. (ed.) 2000: "Geologie der österreichischen Bundesländer – Burgenland". Geologische Bundesanstalt, Wien.

STEININGER F., PAPP A. 1978: 9. "Faziesstratotypus: Gross Höflein NNW, Steinbruch „FENK", Burgenland (Österreich)", in A. PAPP, I. CICHA, J. SENES, F. STEININGER (red.): Chronostratigraphie und Neostratotypen Bd. VI. M4 Badenien (Moravien, Wielicien, Kosovien), Bratislava, 194–199.

TALAA D., HERRMANN I. 2004: "Spätantike Grabfunde in der niederösterreichischen Thermenregion (Bezirke Mödling und Baden)", Römisches Österreich 27, Wien.

THOMAS E. B. 1964: "Römische Villen in Pannonien". – Beiträge zur pannonischen Siedlungsgeschichte, Akadémiai Kiadó, Budapest.

TUCKER M. E., WRIGHT V. P. 1990: "Carbonate Sedimentology", Blackwell Sci. Publ., London.

WESSELY G. 1983: "Zur Hydrodynamik im südlichen Wiener Becken und seiner Randzone", Mitteilungen österreichische geologische Gesellschaft, 76, 27 – 68, Wien.

WESSELY G., DRAXLER I., GANGL G., GOTTSCHLING P., HEINRICH M., HOFMANN T., LENHARDT W., MATURA A., PAVUZA R., PERESSON H., SAUER R. 2006: "Geologie der österreichischen Bundesländer – Niederösterreich", Geologische Bundesanstalt, Wien.

WIEDL T., HARZHAUSER M., PILLER W. E. 2012: "Facies and synsedimentary tectonics on a Badenian carbonate platform in the southern Vienna Basin (Austria, Central Paratethys)", Facies, DOI 10.1007/s10347-011-0290-0, Springer, Berlin, Heidelberg.

WIEDL T., HARZHAUSER M., KROH A., ĆORIĆ S., PILLER W. E 2013: "Ecospace variability along a carbonate platform at the northern boundary of the Miocene reef belt (Upper Langhian, Austria)", Palaeogeography, Palaeoclimatology, Palaeoecology 370, 232–246, http://dx.doi.org/10.1016/j.palaeo.2012.12.015.

WIEDL T., HARZHAUSER M., KROH A., ĆORIĆ S., PILLER W. E. 2014: "From biologically to hydrodynamically controlled carbonate production by tectonically induced paleogeographic rearrangement (Middle Miocene, Pannonian Basin)", Facies, DOI 10.1007/s10347-014-0408-2, Springer, Berlin, Heidelberg.