The Budakalász Travertine Production

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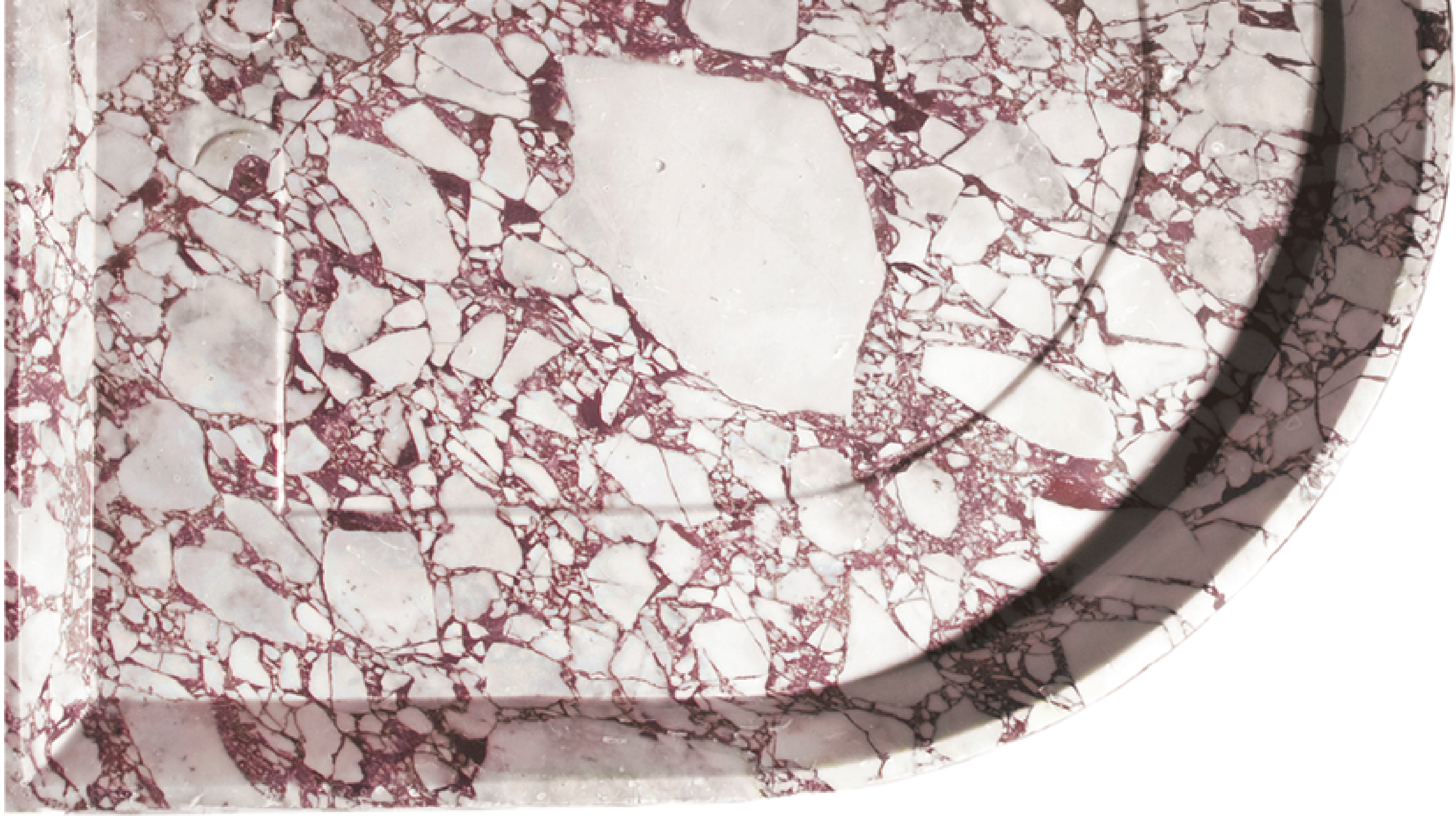

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CONTENT

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THE BUDAKALÁSZ TRAVERTINE PRODUCTION

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Abstract

The stone monuments from the Roman towns along the Danube include a wide range of sepulchral, votive and architectural pieces made of the travertine quarried in the Buda Hills. The representative quarries of this rock are located at Budakalász, on the slope of the Monalovác Hill north of *Aquincum*, and in the Kápolna Hills (north of Budapest), while another small and abandoned (Roman) travertine quarry lies in Budapest, on Gellért Hill. From at least the Flavian times to the 4th century, the products made in the quarry(ies) and in the Aquincum workshops were transported southwards, down the Danube as far as Viminacium. From Mursa onwards, travertine products were transported alongside those of Eastern Alpine marble coming down the Drava River. The two productions were the only ones of interprovincial importance in Noricum, Pannonia and Upper Moesia.

Keywords
Budakalász travertine, stone production, Danube

General remarks

The production, products and their distribution considered in our analysis are strongly marked by the geological and geographical conditions of Pannonia where the Romans quarried and used Budakalász travertine. The specific isolation of the Pannonian Basin, enclosed within the Alps, the Carpathians and the Dinarids[1] (Fig. 1), determined the routes and modes of heavy load transport. With the preference for waterways – sea and rivers – for such transport[2], white and coloured Mediterranean marbles could only reach Pannonia across the Black Sea and up the Danube, a route that led through the treacherous gorges of the Iron Gates[3]. This meant that Mediterranean marbles were only exceptionally used in Pannonia and north-western Upper Moesia, mostly for imperial (palace in *Sirmium*[4]) or religious (Isaeum in *Savaria*[5]) architecture, occasionally also for cult and imperial images (*Aquincum*[6], *Mursa*[7], *Scarbantia*[8]). Consequently, the Roman towns in Pannonia were completely dependent on the local and regional resources, preferably situated near navigable waterways – the main ones including the Danube, the Raab/Raba, the Zala-Balaton-Sió, the Drau/Drava/Dráva, the Sava and the Drina. The distance from the quarry to the town was determined by specific geographic conditions, but only rarely exceeded 20 kilometres.

There are two main rock types suitable for stonemasonry in Pannonia and its periphery: Neogene rocks of Badenian and Sarmatian age, and the much rarer travertine. The former were extensively used in the Roman towns in Pannonia and north-western Upper Moesia, and mostly occur all along the margins of the Pannonian Basin (Fig. 2)[9] as whitish to yellowish, more or less porous detritic limestone and sandstone with carbonate cement. The latter, less extensively used rock is Pliocene and Pleistocene travertine that occurs in several locations within the Transdanubian Range Unit[10]. In the western Pannonian Basin, these rocks are

1 LÓCZY, STANKOVIANSKY, KOTARBA 2012.

2 See CAMPBELL 2012; SCHEIDEL, MEEKS, WEILAND 2012; RUSSEL 2013, 105-110.

3 ŠAŠEL 1973; for literary description see JÓKAI 1872 and MAGRIS 1986.

4 DJURIĆ *et al.* 2006.

5 MEZŐS 2005, 253, fig. 2.

6 KÉRDŐ 1999, 270.

7 DJURIĆ, MÜLLER, FILIPOVIĆ 2009, 10.

8 MÜLLER 2001.

9 The map was generated from the geological maps of Yugoslavia, Austria, Hungary and Romania. Special thanks to Edisa Lozić for her commitment.

10 KELE *et al.* 2003; KELE 2009.

Fig. 1. Map of the Roman Empire with the Pannonian area marked (courtesy of: Digital Atlas of the Roman Empire)

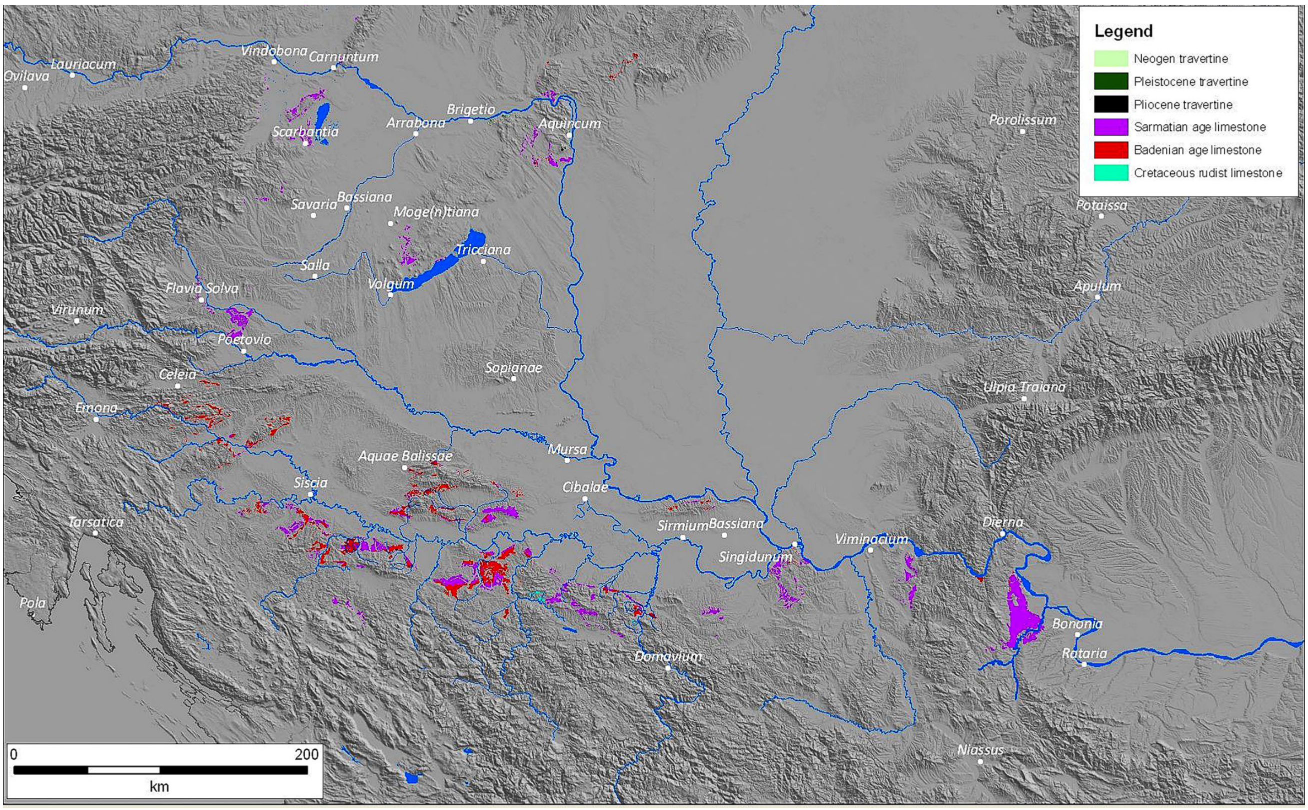

Fig. 2. Map of Pannonia with the occurrence of limestones of Badenian and Sarmatian age (drawing: E. Lozić)

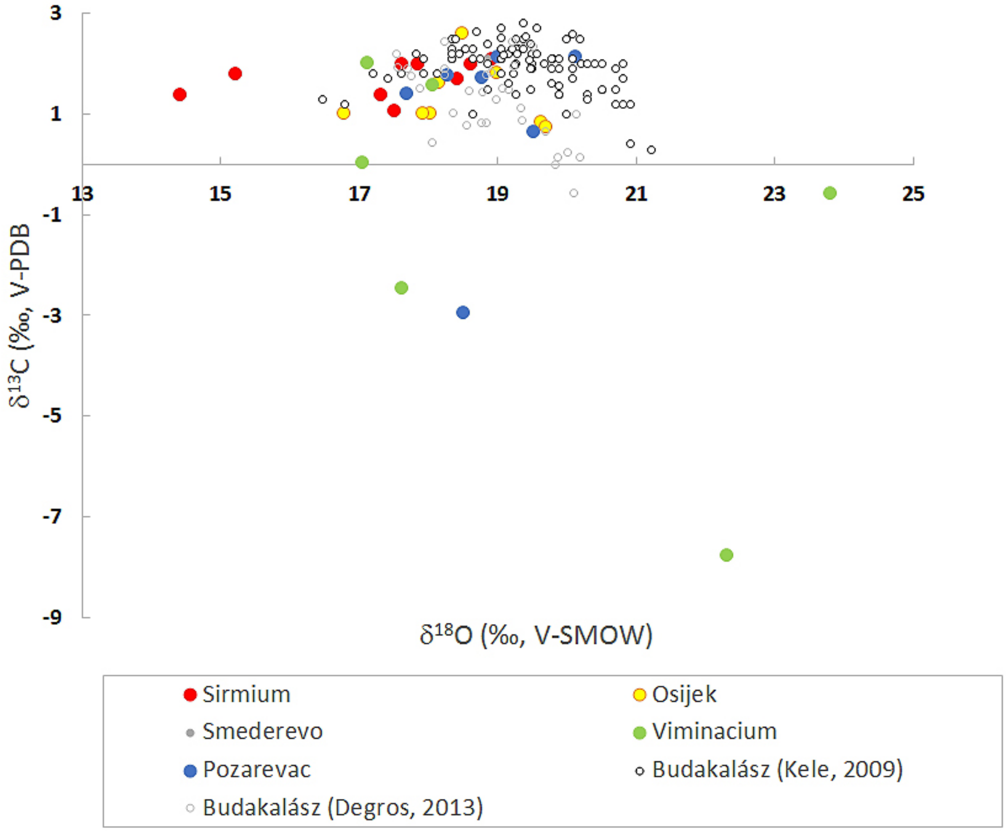

Fig. 3. Results of 13C and 18O stable isotope analysis (drawing: S. Kele). Among the mapped samples the VIM 25 (door threshold) sample shows a possible provenance from the Gerecse Hills (Süttő quarry) where the travertines have negative d13C values in general (KELE 2009, fig. 6.6-1). Mixing with soil carbonate and diagenesis can also cause negative δ13C values

complemented or substituted for by sandstone of *Oligocene* age and with Eastern Alpine marble[11].

The rocks that exceeded local or regional importance and were used in the Roman towns across Pannonia were quite rare. The most important one was certainly Eastern Alpine marble from Gummern in Austria[12]. It has been confirmed that it first appeared in Pannonian and Moesian towns in the Flavian period[13]. In the post-Trajanic time, it was joined on the Pannonian markets by the marble quarried on Pohorje in Slovenia, both persisting to and including the 4th century[14]. The distribution of the finished and semi-finished marble products is tied almost exclusively to river transport, principally along the Drau/Drava and the Danube.

11 Observations based on mesoscopic examination of the objects in the lapidaria of the Arheološki muzej Zagreb, Pokrajinski muzej Ptuj Ormož and the Savaria Múzeum Szombathely.

12 MÜLLER 2007; DJURIĆ, MÜLLER 2009.

13 DJURIĆ *et al.* 2006, 115-116; DJURIĆ, MÜLLER, FILIPOVIĆ 2009, 10.

14 DJURIĆ *et al.* 2006, 115-117.

Travertine

Methods[15]

All carbonate samples were powdered and homogenised using an agate mortar and pestle. The powders were then analysed using the continuous flow technique with the H_3PO_4 digestion method[16]. $^{13}C/^{12}C$ and $^{18}O/^{16}O$ ratios of CO_2 generated by acid reaction were measured using a Thermo Finnigan Delta Plus XP continuous flow mass spectrometer equipped with an automated GasBench II (Thermo Fisher Scientific Inc., Waltham, Massachusetts, USA). The results are expressed in the δ-notation [$\delta = (R_1/R_2 - 1) \times 1000$] where R_1 is the $^{13}C/^{12}C$ or $^{18}O/^{16}O$ ratio in the sample and R_2 is the corresponding ratio of the standard Vienna Pee Dee Belemnite (V-PDB), in parts per thousand (‰). Duplicates of standards and samples reproduced to better

15 Analysis carried out at the Institute for Geological and Geochemical Research, Hungarian Academy of Sciences, Budapest.

16 ROSENBAUM, SHEPPARD, 1986; SPÖTL, VENNEMANN, 2003.

Samples / Objects	$\delta^{18}O$ (V-PDB)	$\delta^{18}O$ (V-SMOW)	$\delta^{13}C$ (V-PDB)
SRM 38	-16.0	14.4	1.4
SRM 59	-13.2	17.3	1.4
SRM 61	-12.2	18.4	1.7
SRM 73	-15.2	15.2	1.8
SRM 146	-11.9	18.6	2.0
SRM 227	-11.7	18.9	2.1
SRM 270	-13.0	17.5	1.1
SRM 279	-12.9	17.6	2.0
SRM 301	-12.7	17.8	2.0
OSJ 01	-12.4	18.1	1.6
OSJ 05	-11.0	19.6	0.8
OSJ 06	-13.7	16.8	1.0
OSJ 08	-11.6	19.0	1.8
OSJ 09	-12.5	18.0	1.0
OSJ 10	-10.9	19.7	0.8
OSJ 14	-12.6	17.9	1.0
OSJ 15	-12.1	18.5	2.6
SMD 01	-11.7	18.9	2.1
VIM 04	-13.4	17.1	2.0
VIM 08	-12.9	17.6	-2.5
VIM 20	-6.9	23.8	-0.6
VIM 25	-8.4	22.3	-7.8
VIM 40	-13.5	17.0	0.0
VIM 42	-12.5	18.0	1.6
POZ 01	-12.8	17.7	1.4
POZ 03	-11.1	19.5	0.7
POZ 04	-12.0	18.5	-2.9
POZ 06	-11.8	18.8	1.7
POZ 09	-12.3	18.3	1.8
POZ 11	-11.6	19.0	2.2
POZ 12	-10.5	20.1	2.2

Fig. 3a. Results of 13C and 18O stable isotope analysis

than ±0.1 ‰, for both the O and C isotopes. No other methods were employed.

The other rock of presumed interprovincial importance is the limestone determined as Lithotype 2b during our analyses of the rocks used at Sirmium[17]. The analysis of the ^{13}C and ^{18}O stable isotopes in 31 samples[18] revealed it to be Pleistocene travertine quarried today at Budakalász[19] (Fig. 3), on the slope of Monalovác Hill, north of Aquincum, and in the Kápolna Hills, north of Budapest[20]. The quarry on Monalovác Hill lies at an altitude of 240-250 meters, and is approximately 800 meters long and 15-20 meters high. To the south of Aquincum, on Gellért Hill (Budapest)[21], a smaller Roman quarry was excavated in 1993-94[22]. The Roman products made of Pleistocene travertines from the Buda Hills have not yet been analysed in detail and are temporarily treated here under the common name of Budakalász travertine.

Travertines in the Pannonian Basin have been studied for almost one hundred years, making their genesis and characteristics quite well known[23]. They mainly occur in the Transdanubian range, more precisely the Bakony, Gerecse and Buda Hills (Fig. 4). The gradual uplift of this area from the Miocene onwards caused erosion and subsequent exposure of the Triassic-Eocene carbonate rocks in the area[24]. Meteoric waters penetrated the exposed carbonate sequences and then ascended as thermal waters due to the above-average geothermal gradient in the basin area. During their ascent, the thermal waters mixed with cold karstic waters, causing a strong corrosive effect. Reaching the surface, these highly saturated waters deposited travertines. This occurred at the margins of the mountains, mainly along the NW–SE trending normal faults. As the Danube formed a series of river terraces below the thermal springs, travertine deposits covered the slopes and steps between the terraces[25].

Mathieu Degros[26] recently described several facies of the travertine in the Budakalász quarry, distinguished on the basis of porosity and other sedimentary structures, and accordingly interpreted their depositional environment. This travertine varies in colour, from almost pure white to brown. The different colours have also been

17 RIŽNAR, JOVANOVIĆ 2006; DJURIĆ *et al.* 2006; DJURIĆ *et al.* 2007.

18 Nine (9) from Sremska Mitrovica (SRM 38, 59, 61, 73, 146, 227, 270, 279, 301), eight (8) from Osijek (OSJ 1, 5, 6, 8, 9,10, 14, 15), one (1) from Smederevo (SMD 1), six (6) from Viminacium (VIM 4, 8, 20, 25, 40, 42) and seven (7) from Požarevac (POZ 1, 3, 4, 6, 9, 11, 12).

19 KELE *et al.* 2003; for this Roman quarry see TORMA 1984.

20 TÖRÖK *et al.* 2013.

21 KELE *et al.* 2009.

22 PETŐ 1998; another ancient quarry (from the Árpád period?) lies in the area of Pomáz-Holdvilágárok, KOREK 1984.

23 SCHEUER, SCHWEITZER 1988; KELE 2009.

24 GOLDSCHEIDER *et al.* 2010; NÁDOR 1993.

25 NÁDOR 1993.

26 DEGROS 2013; see also DEGROS *et al.* 2016.

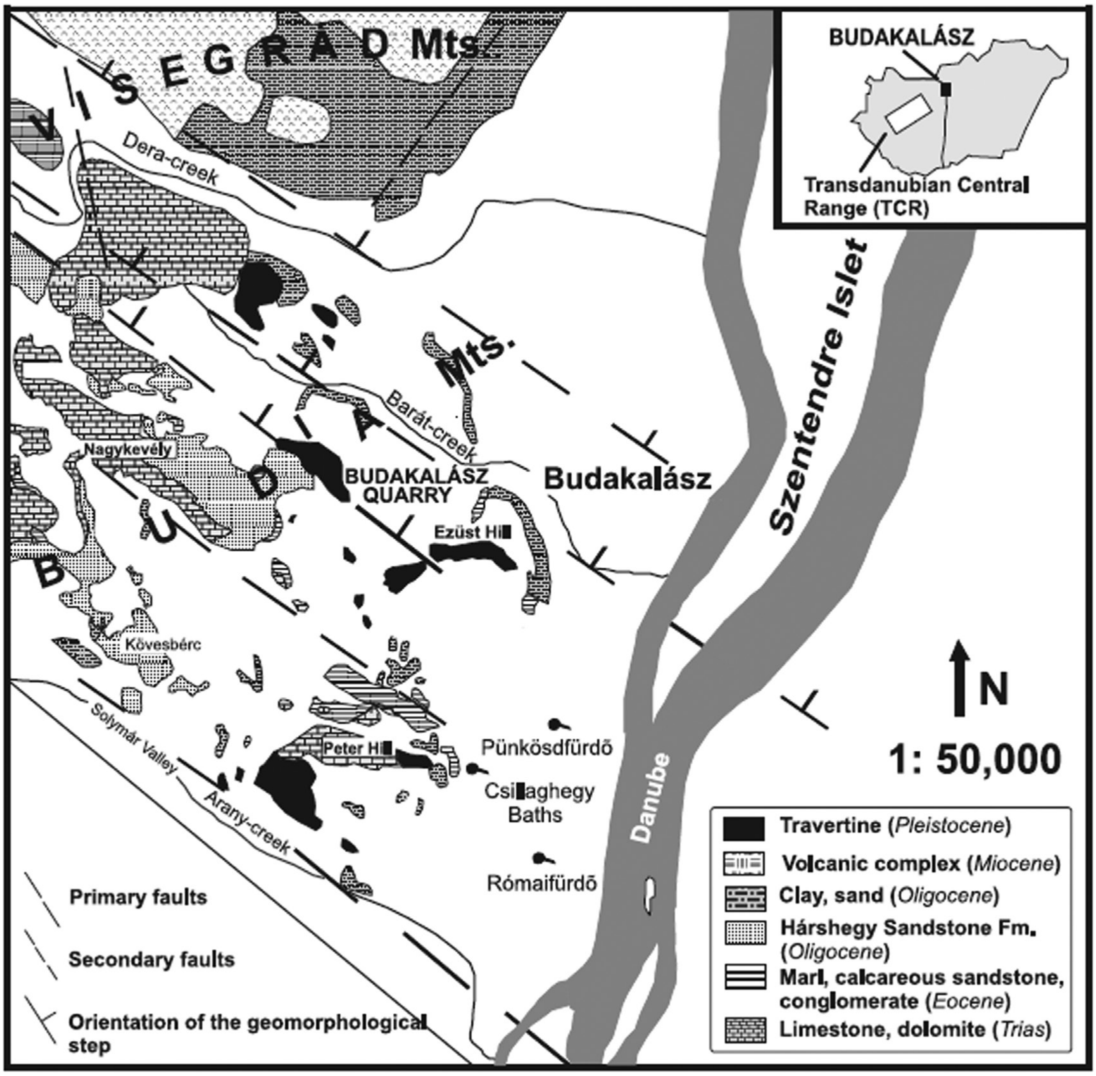

Fig. 4. Map of the occurrence of travertine in the Buda Hills (after: KELE *et al.* 2003)

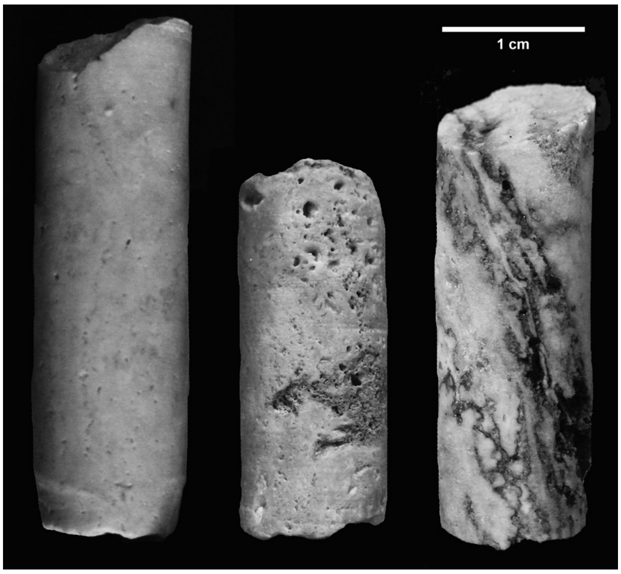

Fig. 5. Core samples of travertine of different characteristics as observed on the monuments from Sremska Mitrovica (photo: I. Rižnar)

identified on the monuments from Sremska Mitrovica[27] (Fig. 5), but these have not yet been classified according to the characteristics of individual facies.

One of the most important limiting factors in working with travertine is certainly the tectonically induced cleavage. Budakalász travertine formed very recently[28] and has not been exposed to long-lasting tectonic activity; it is therefore not deformed and is without fractures. It is well cemented and has a very high flexural and compressive strength; the massive variety is actually almost as good as marble in terms of the requirements of the stonemasons. It was valued according to its colour and porosity, with the most sought-after varieties being almost white in colour, while those of the most massive appearance and almost non-porous were particularly suitable for statuary.

27 RIŽNAR, JOVANOVIĆ 2006.

28 In geological terms, the age of Budakalász travertine is roughly 570 – 270 ky. KELE 2009.

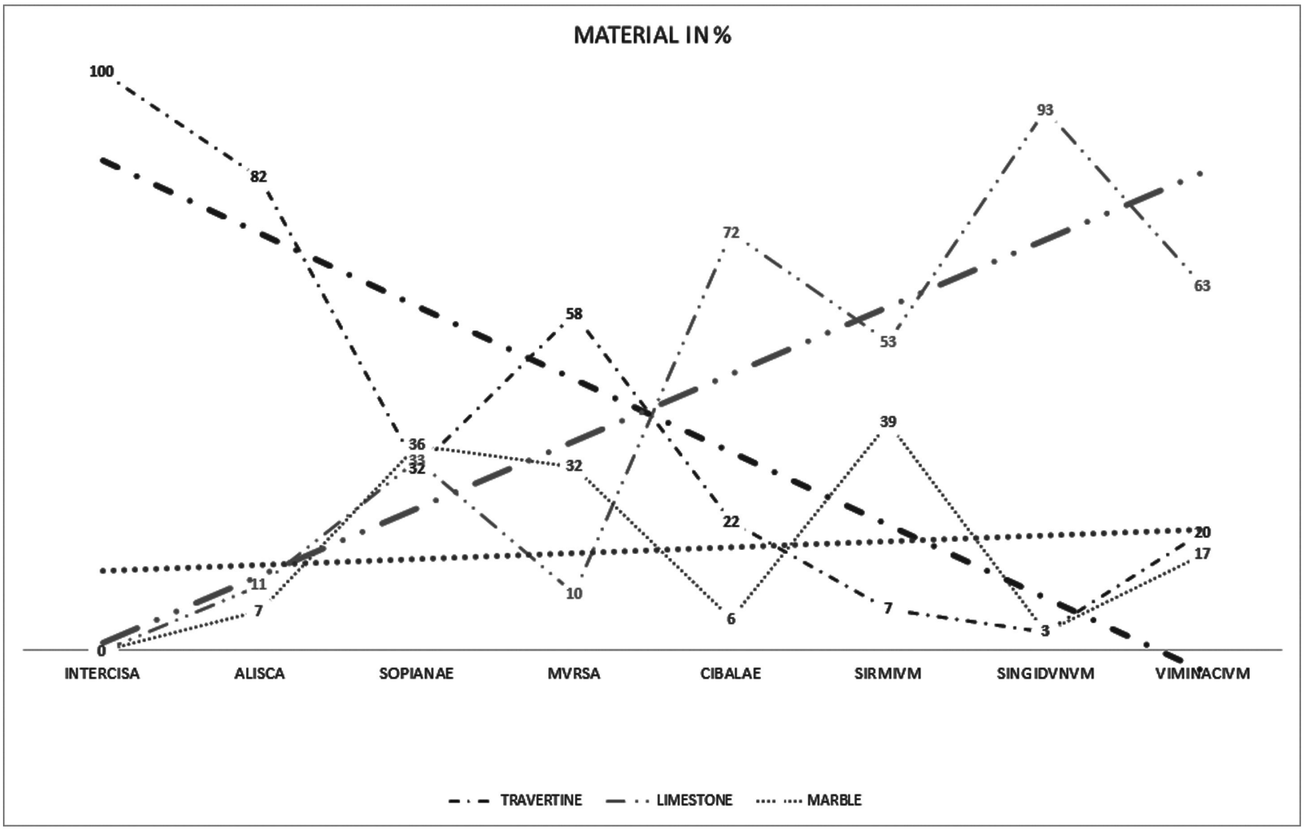

Fig. 6. Numbers of the documented travertine, limestone and marble products in the centres along the Danube and their general trends (drawing: B. Djurić)

In Aquincum, practically all stone monuments are made of travertine[29]. The situation is similar in the centres down the Danube[30]: all of the 78 documented monuments at *Intercisa* (Dunaújváros) are of travertine, 82% of the 44 monuments at *Alisca* (*Szekszárd*-Őcsény*)*, 32% of the 76 monuments at *Sopianae* (*Pécs)*, 57% of the 93 monuments at *Mursa* (Osijek), 27% of the 18 monuments at *Cibalae* (Vinkovci), 8% of the 403 monuments at *Sirmium* (Sremska Mitrovica), 3% of the 61 monuments at *Singidunum* (Belgrade) and 20% of the 108 monuments at *Viminacium* (Kostolac). As the distance from Aquincum down the Danube grows, other stones appear alongside travertine, namely local or regional limestones and Alpine marbles. Interestingly, travertine more or less prevails over other stones or is present in significant quantities all the way down to Mursa, where it meets a strong presence of Alpine marbles coming down the Drava[31]. In nearby Sopianae, a variety of regional limestone that is almost absent in Mursa covered one third (33%) of the town's needs, while one third was taken up by marble and just one third by travertine. Down the Danube from Mursa, local and regional limestones prevail (Cibalae 72%, Sirmium[32] 53%,

29 SZIRMAI 2003; a brief mesoscopic verification of the stones used for the monuments in the lapidarium of the Aquincumi Múzeum in Budapest was carried out in 2013, confirming an absolute predominance of travertine.

30 A mesoscopic verification of the stones used for the monuments in the lapidaria of the Intercisa Múzeum Dunaújváros, Wosinsky Mór Megyei Múzeum Szekszárd, Janus Pannonius Múzeum - Régészeti Múzeum Pécs, Narodni muzej Beograd, Muzej u Smederevu, Narodni muzej Požarevac and the stone collection at the site of Viminacium was carried out in 2014-15. For the permission and help we would like to thank Ernyey Katalin from Budapest, Farkas Lajos, Buza Andrea and Keszi Tamás from the Intercisa Múzeum Dunaújváros, Ódor János from the Múzeum Szekszárd, Veselinka Ninković from the Narodni muzej Beograd, Tatjana Gačpar and Ljiljana Nikolić from Smederevo Museum, Dragan Jacanović from the National Museum in Požarevac, Miodrag Korač and Emilija Nikolič from the SANU Archaeological Institute, Belgrade.

31 DJURIĆ, MÜLLER, FILIPOVIĆ 2009; a large quantity of the Alpine marble monuments in the area between castellum Alisca and Sopianae might point to their transport along the Zala-Balaton-Sió waterway.

32 The limestone from the Dardagani quarry and from another, as yet unknown, quarry.

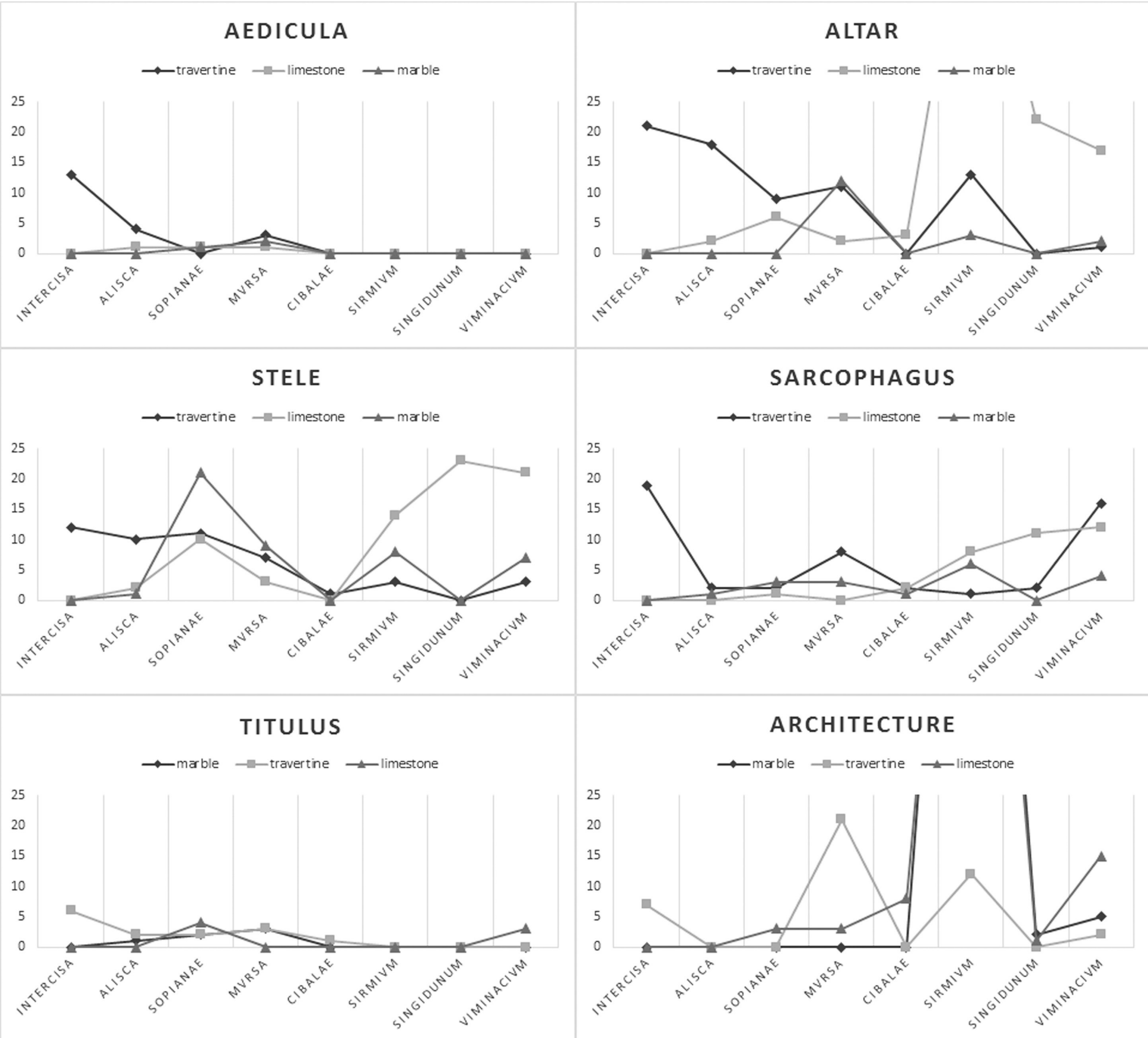

Fig. 7. Occurrence of the travertine, limestone and marble in different products in the centres along the Danube (drawing: B. Djurić)

Singidunum[33] 93%, Viminacium[34] 63%), accompanied by travertine and marble in almost equal shares. The general trend in the use of travertine in the centres along the Danube is clearly descending with the distance from the source, whilst marble is more or less evenly represented (Fig. 6). This is true at a general level, while a closer look at the different types of products shows a slightly but significantly different picture (Fig. 7).

33 The limestone from the Tašmajdan quarry.

34 Limestone of as yet unknown provenance.

Products

Aediculae, the most representative and expensive sort of composite sepulchral architecture in Pannonia, are known mainly in Aquincum[35] and the nearby areas south of it[36], with only rare pieces reaching their farthest point at Mursa[37]. The distribution model of these monuments follows the same economic logic already observed in Noricum in the aediculae of Alpine marbles[38].

35 For the stone products in Aquincum see NAGY 1971; for the sepulchral architecture there see ERTEL 1999.

36 DJURIĆ 2012, 43-45, fig. 2.

37 POCHMARSKI, FILIPOVIĆ 1997.

38 KREMER 2001.

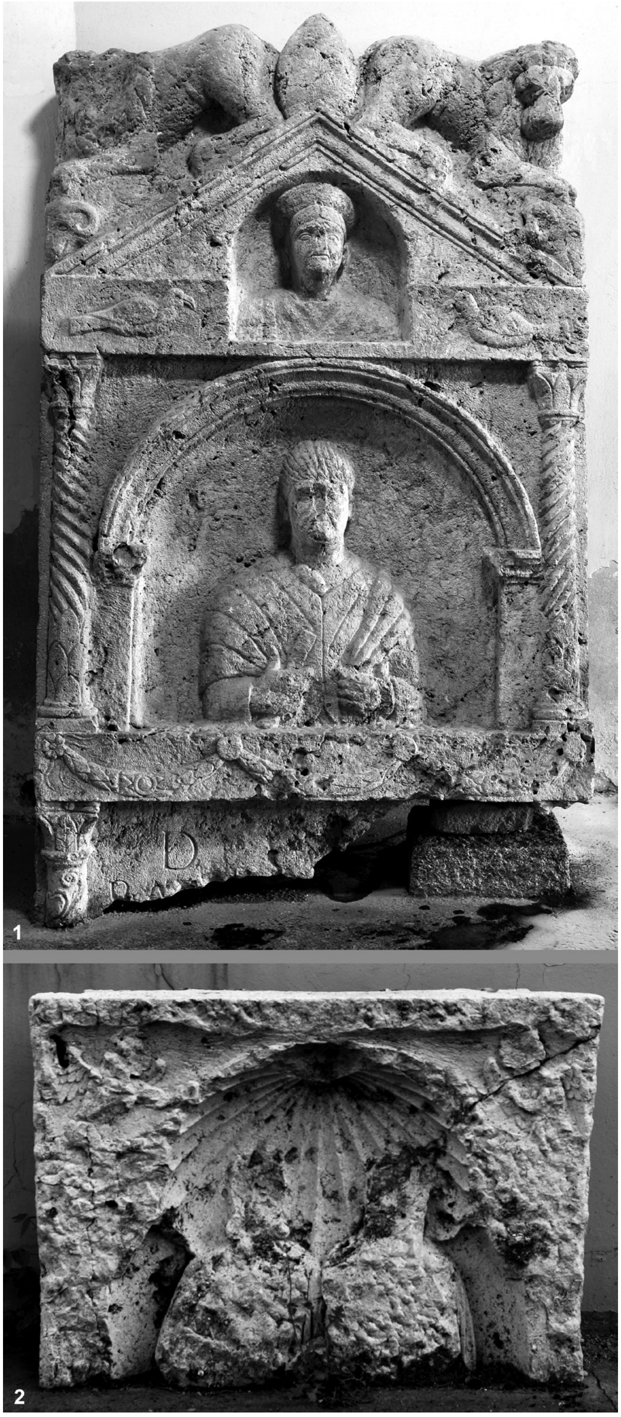

Fig. 8. A stela with the portrait under the arch (1-Sirmium) (sample SRM 146) and a stela with the portrait under the arch in the shell niche (2-Viminacium) (sample POZ 12) (photo: B. Djurić)

Simple monolithic sepulchral monuments such as **stelae** show a markedly different distribution. From the late Flavian time onwards, travertine stelae are present in all centres along the Danube quite evenly and together with the marble stelae represent the most prestigious examples of this monument type in local cemeteries. Their general forms demonstrate an affiliation with the quarry workshops at Budakalász and Aquincum, suggesting trading in semi-finished or even fully finished products. We may assume this affiliation in at least two series (Fig. 8): of the portrait stelae with the portrait under an arch (*Aquincum*[39], *Intercisa*[40] and *Sirmium*[41]) and the portrait stelae with the portrait(s) under the arch in a shell niche (*Aquincum*[42], *Intercisa*[43] and *Viminacium*[44]).

Votive and sepulchral **altars** made of travertine were very popular in all centres along the Danube, but their occurrence from Mursa to Viminacium diminishes rapidly in favour of those made of local or regional limestones. The situation in Sirmium[45] is typical in this respect.

The most significant and widely spread products of the Budakalász/Aquincum workshops are **sarcophagi**[46]. Their distribution down the Danube to Viminacium[47] demonstrates the popularity and prestige ascribed to these products that were competing on the markets there with the sarcophagi of Alpine marbles[48]. The prevailing general form of the receptacles was the same for both the travertine and the marble sarcophagi, marked by a tripartite front panel incorporating a sunken and moulded central field intended for the inscription; only a small number have a flat front panel. This general quarry form was diversified by applying different decorative motifs to the moulded frame of the central field, in most cases the different forms of the Norico-Pannonian volute. Recently, Erwin Pochmarski described several variants of these motifs in Intercisa[49] and Aquincum[50] and noted that his Types 3a

39 Three stelae: NAGY 2007, No. 22; LUPA 4677; NÉMETH 1999, No. 172.

40 BARKÓCZI *et al.* 1954, No. 5; NAGY 2007, No. 23.

41 DAUTOVA 1983, No. 6.

42 NÉMETH 1999, 51 No. 133.

43 BARKÓCZI *et al.* 1954, No. 95; LUPA 3972.

44 LUPA 5398.

45 DJURIĆ *et al.* 2007.

46 On the sarcophagi from Aquincum and Intercisa see: POCHMARSKI 2011; 2014; POCHMARSKI, POCHMARSKI-NAGELE 2013.

47 See DAUTOVA-RUŠEVLJAN 1983; ĐORĐEVIĆ 1989-90.

48 DJURIĆ 2001.

49 POCHMARSKI E., POCHMARSKI-NAGELE M. 2013.

50 POCHMARSKI 2014.

Fig. 9. Sarcophagi with Type 3a (1-Mursa /sample OSJ 14/, 2-Singidunum, 3-Viminacium /sample POZ 04/) and Type 7 decoration (4-Mursa, 5 /sample VIM 40/ and 6-Viminacium /sample POZ 09/) (photo: B. Djurić)

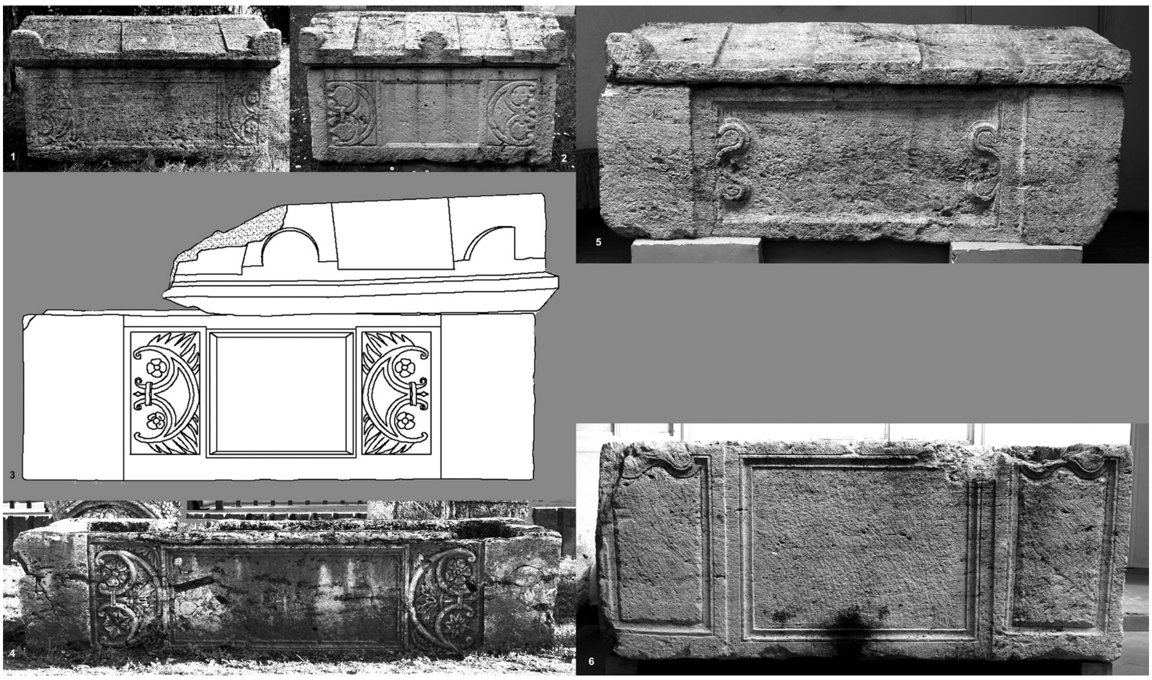

Fig. 10. Sarcophagi with the pelta-type decoration (1-Intercisa, 2-Siscia, 3 and 4-Viminacium /sample POZ 03/), a sarcophagus with the simple Norico-Pannonian decoration (5-Mursa /sample OSJ 09/) and a sarcophagus of the Poetovian type (6-Mursa /sample OSJ 08/) (photo: B. Djurić)

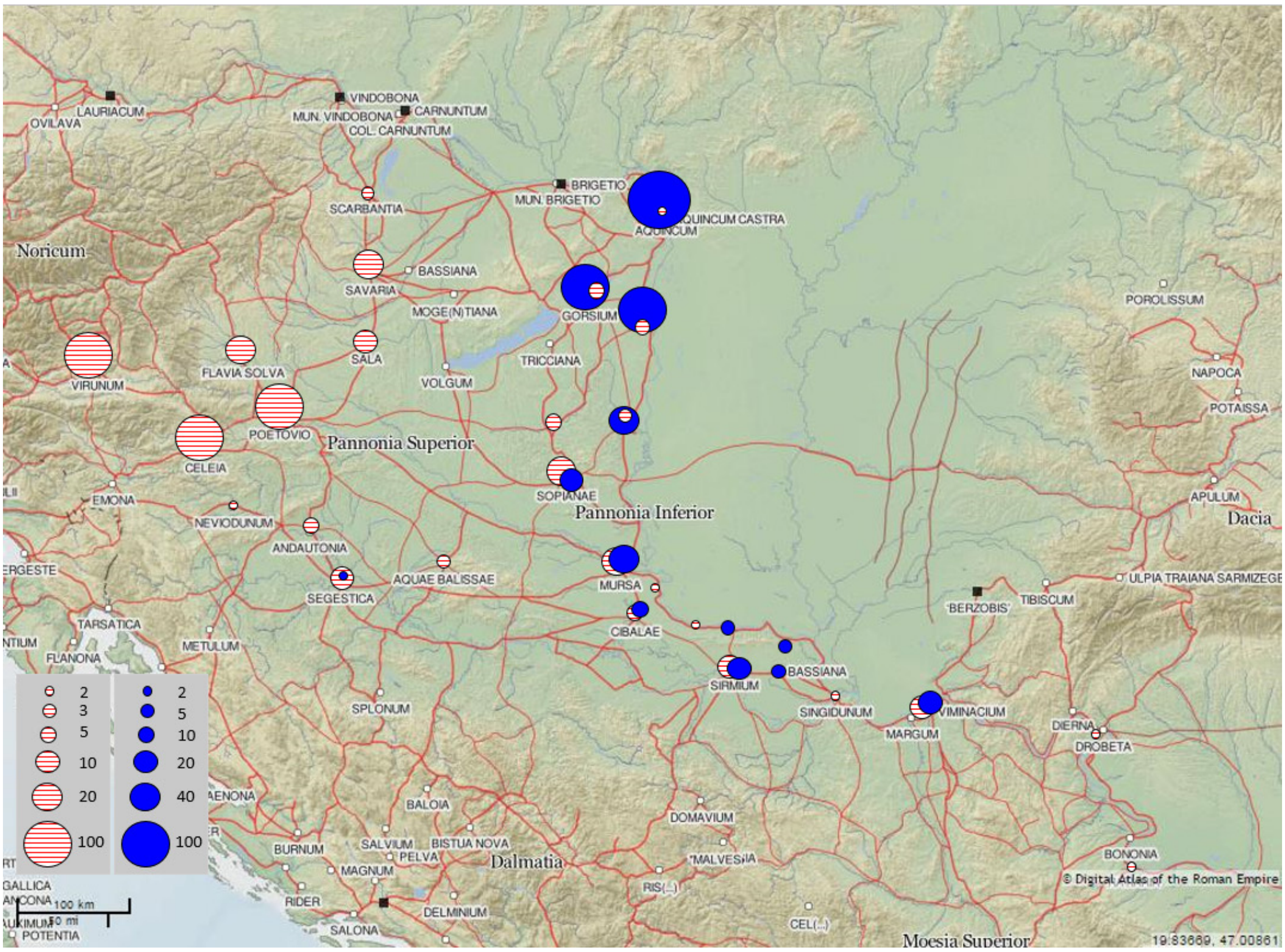

Fig. 11. Distribution map of the products made of Eastern Alpine marble and of Budakalász travertine (drawing: B. Djurić)

and 7 were the most popular[51]. The examples found along the Danube between Aquincum and Viminacium confirm his findings (Fig. 9; Fig. 10). They also show, quite clearly, that sarcophagi were mainly traded in the quarry condition to be finished later[52]. One sarcophagus from Mursa[53] is clearly a travertine imitation of a marble sarcophagus, and was probably made in Mursa from a block of travertine or possibly just finished there, because the moulded lateral fields of the front panel are executed in the manner typical of the Poetovian type of marble sarcophagus.

Blocks of travertine were also used to build the Roman bridge across the Drava at Mursa[54], which suggests that travertine was traded along the Danube even as blocks and architectural elements. The poor state of research into the architectural remains prevents us from drawing any conclusions, but evidence from the Roman centres along the Danube does suggest that Budakalász travertine played a significant role in the construction activities in the area.

The general distribution of the stones used in the Pannonian and Upper Moesian centres clearly shows that the prestigious (sepulchral) monuments of Budakalász travertine successfully complemented those of Alpine marbles (Fig. 11). The question that remains open is the degree to which the quarry workshops in the Buda Mountains were related to the Alpine quarry workshops; certain forms and motifs on their products as well as the quality of their execution suggest that some kind of interaction existed[55].

51 POCHMARSKI 2014, 415, fig. 9.

52 One of the best examples is the Jonah sarcophagus from Belgrade; POP-LAZIĆ 2002, 21-22.

53 GÖRICKE-LUKIĆ 2000, 36-37.

54 FILIPOVIĆ 2004, 160; blocks of this bridge were lifted and brought to the Muzej Slavonije, Osijek, during the cleaning campaign of the Drava riverbed in 1985.

55 See DJURIĆ 2012.

BIBLIOGRAPHY

BARKÓCZI L., ERDÉLYI G., FERENCZY E., FÜLEP F., NEMESKÉRI J., ALFÖLDI M. R., SÁGI K. 1954: Intercisa I., (Dunapentele - Sztálinváros), Geschichte der Stadt in der Römerzeit, Budapest.

CAMPBELL B. 2012: Rivers and the Power of Ancient Rome. University of North Carolina Press, Chapel Hill.

DAUTOVA-RUŠEVLJAN V. 1983: Rimska kamena plastika u jugoslovenskom delu provincije Donje Panonije. Savez arheoloških društava Jugoslavije, Novi Sad.

DEGROS M. 2013: Sedimentological-Petrological Study and Reservoir Characterisation of the Budakalász Travertine Carbonates (Buda Mountains, Hungary), Leuven (PhD thesis).

DEGROS M., HANNES C., SOETE J., CLAES S., KELE S., MINDSZENTY A., TÖRÖK A., SWENNEN R. 2016: "Geobody architecture, genesis and petrophysical characteristics of the Budakalász continental carbonates, Buda Hills (Hungary)", Quaternary International (submitted).

DJURIĆ B. 2001: "Production of marble sarcophagi in Poetovio", Budapest régiségei 34, 47-62.

DJURIĆ B. 2012: "Mitološki prizori na noriških in panonskih sepulkralnih spomenikih", Keria 14, 41-54.

DJURIĆ B., DAVIDOVIĆ J., MAVER A., MÜLLER H. W. 2006: "Stone use in Roman towns: resources, transport, products and clients: case study Sirmium: first report", Starinar 56, 103-137.

DJURIĆ B., DAVIDOVIĆ J., MAVER A., RIŽNAR I. W. 2007: "Stone use in Roman towns: resources, transport, products and clients: case study Sirmium: second report", Starinar 57, 83-99.

DJURIĆ B., MÜLLER H. W. 2009: "White marbles in Noricum and Pannonia: an outline of the roman quarries and their products", in ASMOSIA VIII, 111-127.

DJURIĆ B., MÜLLER H. W., FILIPOVIĆ S. 2009: "Karakteriziranje mramornih spomenika Murse", Osječki zbornik 29, 9-18.

ĐORĐEVIĆ M. 1989-90: "Rimski kameni sarkofazi iz Viminaciuma", Viminacivm 4-5, 133-147.

ERTEL Ch. 1999: "Konstruktive Bauteile von römischen Grabbauten im Aquincum-Museum", Budapest régiségei 33, 197-241.

FILIPOVIĆ S. 2004: "Colonia Aelia Mursa", in M. ŠAŠEL-KOS, P. SCHERER (eds.): The autonomous towns of Noricum and Pannonia. Pannonia II. NMS, Ljubljana, 2004, 157-168.

GOLDSCHEIDER N., MÁDL-SZŐNYI J., ERŐSS A., SCHILL E. 2010: "Review: Thermal water resources in carbonate rock aquifers", Hydrogeology Journal 18/6, 1303-1318.

GÖRICKE-LUKIĆ H. 2000: Sjeveroistočna nekropola rimske Murse, HAZU, Zagreb-Osijek.

JÓKAI M. 1872: Az arany ember (The Golden Man), Pest.

KELE S. 2009: Investigations on freshwater limestones from the Carpathian-Basin: paleoclimatological and sedimentological studies. Eötvös Loránd University, PhD Thesis, Budapest (in Hungarian). (http://real-phd.mtak.hu/28/1/kele_sandor_2009_doktori_ertekezes.pdf).

KELE S., SCHEUER GY., DEMÉNY A., SHEN C.-C., HONG-WEI C. 2009: "U-series dating and isotope geochemical study of the Gellért Hill (Budapest) travertine", Central European Geology, 52/3-4, 199-224.

KELE S., SZABÓ C., VASELLI O., MINISSALE A. 2003: "Stable isotope geochemistry of Pleistocenetravertine from Budakalász (Buda Mts, Hungary) ", Acta Geologica Hungarica 46/2, 161-175.

KÉRDŐ K. 1999: "Beitrage zur Materialuntersuchung der Aquincumer Marmordenkmäle", Budapest régiségei 33, 269-277.

KOREK J. 1984: "Pomáz Árpád-kori kőbány kőbányászata. The Pomáz quarry from Árpád-Period", in J. GÖMÖRI (ed.): Iparrégészeti kutatások = Research in industrial archaeology and archaeometry in Hungary, Veszprém, 1982. A Magyar Tudományos Akadémia Veszprémi Akadémiai Bizottságának, Veszprém, 55-60.

KREMER G. 2001: Antike Grabbauten in Noricum. Katalog und Auswertung von Werkstücken als Beitrag zur Rekonstruktion und Typologie. Sonderschriften des Österreichischen Archäologischen Institutes 36, Wien.

LÓCZY D., STANKOVIANSKY M., KOTARBA A. (eds.) 2012: Recent Landform Evolution. The Carpatho-Balkan-Dinaric Region, Springer, Dordrecht.

LUPA: www.ubi-erat-lupa.org.

MAGRIS C. 1986: Danubio, Garzanti, Milano.

MEZŐS T. 2005: "A szombathelyi Iseum helyreállítás-története és új elvi rekonstrukciója", Építés - Építészettudomány 33, 245-287.

MÜLLER H. W. 2001: "Herkunftbestimmung von römischen Marmorobjekten aus der Gegend des Balaton", Balácai Közlemények 6, 245-254.

MÜLLER H. W. 2007: "Der Marmor von Gummern und seine Bedeutung für die römischen Provinzen Pannonien, Norikum und Rätien", in V. HÖCK, F. LANG, W. WOHLMAYR (eds.): Akten zum 2. Österreichischen „Römerstein-Treffen" 2006 in Salzburg, Phoibos Verlag, Wien, 33-36.

NÁDOR A. 1993: "Palaeokarsts and long-term karst evolution of the Buda Mountains, Hungary", Bulletin de la Société géographique de Liège 29, 139-143.

NAGY M. 2007: Lapidárium. Magyar Nemzeti Múzeum, Budapest.

NAGY T. 1971: "Kőfaragás és szobrászat Aquincumban. Taille de pierre et sculpture à Aquincum", Budapest Régiségei 22, 103-160.

NÉMETH M. 1999: Vezetö az Aquincumi Múzeum. Budapesti Történeti Múzeum, Budapest.

PETŐ M. 1998: "A gellérthegyi kôbánya. The Gellért hill quarry", Budapest Régiségei 32, 123-133.

POCHMARSKI E. 2011: "Ikonographische und chronologische Probleme der Sarkophage aus Aquincum", Anodos 11, 247-268.

POCHMARSKI E. 2014: "Die Sarkophagwerkstätten von Aquincum und Brigetio", Acta Archaeologica Academiae Scientiarum Hungaricae 65, 405-426.

POCHMARSKI E., FILIPOVIĆ S. 1997: "Eine Gruppe Dionysischer Reliefs aus Mursa (Osijek) ", Osječki zbornik 22-23, 33-44.

POCHMARSKI E., POCHMARSKI-NAGELE M. 2013: "Die Sarkophage von Intercisa", in N. CAMBI, G. KOCH (eds.): Sepulkralna skulptura zapadnog Ilirika i susjednih oblasti u doba Rimskog Carstva: zbornik radova s međunarodnog simpozija održanog od 27. do 30. rujna 2009, Split = Funerary sculpture of the Western Illyricum and neighbouring regions of the Roman Empire : proceedings of the International Scholarly Conference held in Split from September 27th to the 30th 2009, Književni krug, Split, 281-301.

POP-LAZIĆ S. 2002: "Nekropole rimskog Singidunuma", in M. POPOVIĆ (ed.): Singidunum 3, Arheološki institut, Beograd.

RIŽNAR I., JOVANOVIĆ D. 2006: "Stone material of regional provenance from Sirmium", Starinar 56, 139-152.

ROSENBAUM J., SHEPPARD S. M. F. 1986: "An isotopic study of siderites, dolomites and ankerites at high temperatures", Geochimica et Cosmochimica Acta 50, 1147-1150.

RUSSEL B. 2013: The economics of the Roman stone trade, OUP, Oxford.

SCHEIDEL W., MEEKS E., WEILAND J. 2012: "ORBIS: The Stanford Geospatial Network Model of the Roman World" on http://orbis.stanford.edu/orbis2012/ORBIS_v1paper_20120501.pdf.

SCHEUER GY., SCHWEITZER F. 1988: Freshwater limestones of the Gerecse and Buda Hills. Földrajzi Tanulmányok 20, Akadémiai Kiadó, Budapest 1988 (in Hungarian).

SPÖTL C., VENNEMANN T. W. 2003: "Continuous-flow isotope ratio mass spectrometric analysis of carbonate minerals. Rapid Communication", Mass Spectrometry 17, 1004-1006.

SZIRMAI K. 2003: "Die Steinbearbeitung in Aquincum", Forschungen in Aquincum 1969-2002, Aquincum nostrum II.2, 233-244.

ŠAŠEL J. 1973: "Trajan's Canal at the Iron Gate", Journal of Roman Studies 63, 80-85.

TORMA I. 1984: "Római kori kőbánya Budakalász határában / Roman quarry near the village Budakalász", in J. GÖMÖRI (ed.): Iparrégészeti kutatások = Research in industrial archaeology and archaeometry in Hungary, Veszprém, 1982. A Magyar Tudományos Akadémia Veszprémi Akadémiai Bizottságának, Veszprém, 39-49.

TÖRÖK Á., ÜNNEP V., BALÁZS A., MINDSZENTY A., KELE S. 2013: "A kápolna-hegyi édesvízi mészkőkúp komplex szedimentológiai, geokémiai és geofizikai vizsgálata (Budai-hegység). Complex sedimentological, geochemical and geophysical study of the Kápolna-hegy spring-cone (Buda Hills, Hungary) ", Bulletin of the Hungarian Geological Society 143/3, 251-264.