ANTÆUS

31-32

The present volume
is dedicated to Professor

László Török

former editor of the journal
Mitteilungen des Archäologischen
Instituts / Antaeus
on his seventieth birthday

ANTÆUS
31-32

Communicationes ex Instituto Archaeologico
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ABBREVIATIONS

AAWG	Abhandlungen der Akademie der Wissenschaften in Göttingen
ActaAntHung	Acta Antiqua Academiae Scientiarum Hungaricae (Budapest)
ActaArchCarp	Acta Archaeologica Carpathica (Kraków)
ActaArchHung	Acta Archaeologica Hungarica Academiae Scientiarum Hungaricae (Budapest)
Agria	Az Egri Múzeum Évkönyve (Eger)
AKorr	Archäologisches Korrespondenzblatt (Mainz)
Alba Regia	Alba Regia. Annales Musei Stephani Regis (Székesfehérvár)
AntikTan	Antik Tanulmányok (Budapest)
AnthrKözl	Anthropológiai Közlemények (Budapest)
APA	Acta Praehistorica et Archaeologica (Berlin)
AP	Arheološki Pregled (Beograd)
AR	Archeologické Rozhledy (Praha)
ArchA	Archaeologia Austriaca (Wien)
ArchÉrt	Archaeologiai Értesítő (Budapest)
ArchHung	Archaeologia Hungarica (Budapest)
Arrabona	Arrabona. A Győri Xantus János Múzeum Évkönyve (Győr)
AV	Arheološki Vestnik (Ljubljana)
AVANS	Archeologické výskumy a nálezy na Slovensku (Nitra)
Balcanica	Balcanica. Annuaire de l' Institut des Etudes Balkaniques (Beograd)
BÁMÉ	A Béri Balogh Ádám Múzeum Évkönyve (Szekszárd)
BMMK	A Békés megyei Múzeumok Közleményei (Békéscsaba)
BRGK	Bericht der Römisch-Germanischen Kommission (Berlin)
BudRég	Budapest Régiségei (Budapest)
BVbl	Bayerische Vorgeschichtsblätter (München)
CA	Советская археология (Москва)
CommArchHung	Communicationes Archaeologicae Hungaricae (Budapest)
DA	Deutsches Archiv für Erforschung des Mittelalters
EAZ	Ethnographisch – Archäologische Zeitschrift (Berlin)
EMÉ	Az Egri Múzeum Évkönyve (Eger)
FMSt	Frühmittelalterliche Studien. Jahrbuch des Instituts für Frühmittelalterforschung der Univesität Münster (Berlin)
FolArch	Folia Archaeologica (Budapest)
FontArchHung	Fontes Archaeologici Hungariae (Budapest)
FÖ	Fundberichte aus Österreich (Wien)
GDV	Germanische Denkmäler der Völkerwanderungszeit (Franfurt a. M.)
Germania	Germania. Anzeiger der Römisch-Germanischen Kommission des Deutschen Archäologischen Instituts (Mainz)
Grada	Grada (Beograd)
HOMÉ	A Herman Ottó Múzeum Évkönyve (Miskolc)
Hortus	Hortus Artium Medievalium. Journal of the International Research Center for Late Antiquity and Middle Ages (Zagreb)
IzdanjaHAD	Izdanja, Hrvatsko arheološko društvo (Zagreb)
JAMÉ	A nyíregyházi Jósa András Múzeum Évkönyve (Nyíregyháza)
JMV	Jahresschrift für mitteldeutsche Vorgeschichte (Saale)
JPMÉ	A Janus Pannonius Múzeum Évkönyve (Pécs)
JRGZM	Jahrbuch des Römisch-Germanischen Zentralmuseums (Mainz)
KJb	Kölner Jahrbuch für Vor- und Frühgeschichte (Köln)

MAGW	Mitteilungen der Anthropologischen Gesellschaft (Wien)
MBV	Münchner Beiträge zur Vor- und Frühgeschichte (München)
MFMÉ	A Móra Ferenc Múzeum Évkönyve (Szeged)
MFMÉ-StudArch	A Móra Ferenc Múzeum Évkönyve – Studia Archaeologica (Szeged)
MGH	Monumenta Germaniae Historica (Hannover – Berlin)
MittArchInst	Mitteilungen des Archäologischen Instituts der Ungarischen Akademie der Wissenschaften (Budapest)
MÖAG	Mitteilungen der Österreichischen Arbeitsgemeinschaft für Ur- und Frühgeschichte (Wien)
MPK	Mitteilungen der prähistorischen Kommission der Österreichischen Akademie der Wissenschaften (Wien)
Ősrégészeti Levelek	Ősrégészeti Levelek (Budapest)
NMMÉ	Nógrád Megyei Múzeumok Évkönyve (Salgótarján)
PA	Památky Archeologické (Praha)
PreAlp	Preistoria Alpina (Trento)
PrilInstArheolZagrebu	Prilozi Instituta za arheologiju u Zagrebu (Zagreb)
PZ	Prähistorische Zeitschrift (Berlin – New York)
RégFüz	Régészeti füzetek (Budapest)
RGA	Reallexikon der Germanischen Altertumskunde (Berlin)
RKM	Régészeti Kutatások Magyarországon–Archaeological Investigations in Hungary (Budapest)
SASTUMA	Saarbrücker Studien und Materialien zur Altertumskunde (Saarbrücken)
Savaria	Savaria (Szombathely)
SbNM	Sbornik Narodného Musea (Praha)
SCIVA	Studii şi Cercetări de Istorie Veche şi Arheologie (Bucureşti)
SlA	Slovenská Archeológia (Bratislava)
SMK	A Somogy megyei Múzeumok Közleményei (Kaposvár)
SP	Starohrvatska prosvjeta (Split)
StCom	Studia Comitatensia (Budapest)
StudArch	Studia Archaeologica (Budapest)
StudPraehist	Studia Praehistorica (Sofia)
ŠZ	Študijné Zvesti Archeologického Ústavu Slovenskej Akademie Vied (Nitra)
VAH	Varia Archaeologica Hungarica (Budapest)
VAMZ	Vjesnik Arheološkog Muzeja u Zagrebu (Zagreb)
VHVO	Verhandlungen des historischen Vereins für Oberpfalz und Regensburg (Regensburg)
VMMK	A Veszprém Megyei Múzeumok Közleményei (Veszprém)
WMMÉ	A Wosinsky Mór Múzeum Évkönyve (Szekszárd)
WPZ	Wiener Prähistorische Zeitschrift (Wien)
ZalaiMúz	Zalai Múzeum (Zalaegerszeg)
ZAM	Zeitschrift für Archäologie des Mittelalters (Köln)
ZgČ	Zgodovinski časopis (Ljubljana)
ZGy	Zalai Gyűjtemény (Zalaegerszeg)

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HAJNALKA HEROLD

THE CERAMIC 'TABLEWARE' OF THE CAROLINGIAN PERIOD IN ZALAVÁR, SOUTH WEST HUNGARY

1. Archaeological background

The ceramics analysed and presented here belong to the very distinct group of the so-called polished yellow ceramics, representing the best-quality ceramics of the Carolingian Period (9th century A.D.) found in the fortified settlement of Zalavár in South West Hungary *(fig. 1)*.[1] Their reddish-yellow colour and fine-grained fabrics are very different from the rest of the predominantly brownish-black, coarse-grained ceramics found at the site. The polished yellow ceramics were made, similarly to all other early medieval ceramic vessels of the site, on a slow potter's wheel (also called turntable). Similar yellow ceramics are known from the same period from different parts of Central and Eastern Europe, in a region ranging from today's Austria to Bulgaria. The polished yellow ceramics are also known under the names 'ceramics of antique tradition' and 'ceramics of the type Zalavár-Keszthely'.

The polished yellow ceramic vessels are mostly flasks *(fig. 2)*, but there are also some amphora-like vessels with two handles *(fig. 3)* and a variety of other special forms (lids, small pots, bowls) in very small numbers. Because of their special colour and fabrics, which were of high quality for the regions and period concerned, their function is likely to have been connected to the consumption (and perhaps storage) of precious substances. The use of these vessels in contexts connected to fire (cooking, baking) is not likely. The most frequent vessel shapes (flasks and amphorae) imply that they were first of all used for liquid substances. Similarities to the golden vessels of the Nagyszentmiklós treasure (Sînicolaul Mare/Sânnicolau Mare, Romania)[2]

fig. 1. Location of the site of Zalavár

[1] For recent summaries of archaeological research in Zalavár see *B. M. Szőke:* Zalavár. RGA Bd. 35 (2007) 833–842, Taf. 18–19; *B. M. Szőke:* New findings of the excavations in Mosaburg/Zalavár (Western Hungary), in: J. Henning (ed.): Post-Roman towns, trade and settlement in Europe and Byzantium, Millennium-Studien Vol. 5/1 The Heirs of the Roman West, Berlin – New York 2007, 411–428.

[2] E. g. *T. Kovács (ed.):* The Gold of the Avars. The Nagyszentmiklós treasure. Exhibition in the Hungarian National Museum, Budapest, 24 March – 30 June 2002. Budapest 2002.

regarding colour and shapes possibly suggest that the polished yellow ceramics imitated such golden vessels, but this hypothesis needs to be verified by further research.

The nature of the connections between the polished yellow ceramics of the 9th century A.D. presented here and the yellow ceramics from the Avar Khaganate of the 8th century A.D.[3] has not yet been completely explained. Common to both ceramic groups is the yellow colour and the difference in quality compared to other contemporary ceramic vessels. However, the Avar yellow ceramics of the 8th century were made on a quick potter's wheel, as opposed to the polished yellow ceramics that were made on a slow potter's wheel/turntable. The repertoire of the vessel forms of the Avar yellow ceramics includes shapes, e. g. mugs with circular handles and jugs with a spout, that are at present not known from the polished yellow ceramics. No clear morphological border can, however, be drawn between the flasks of the two groups. Incised and stamped ornaments are at present only known from the polished yellow ceramics of the 9th century and painted ornaments have only been documented on vessels of the Avar yellow ceramics of the 8th century, but in both groups only very few vessels are decorated. It makes the differentiation of the two groups difficult that the surface of the vessels of the Avar yellow ceramics can also be polished.

It is not intended and also not possible to resolve this research problem in the present article, it is only intended here to point out the existence of these two groups. The most secure criterion for differentiating the Avar yellow ceramics of the 8th century and the polished yellow ceramics of the 9th century remains the identification of the vessel forming method: vessels turned on a quick potter's wheel typically belong to the Avar yellow ceramics and vessels made on a slow wheel/turntable generally belong to the polished yellow ceramics. Further research can shed more light on the connection between these two groups.

The primary goal of the investigations published in the present article is to find and characterise the groups of the polished yellow ceramics of the 9th century A.D. in order to obtain information about the standard and the framework of production and their changes through time and to establish the possibility for a later archaeometric (chemical, mineralogical, microstructural) comparison with similar ceramics from different sites and

fig. 2. Polished yellow flask from Zalavár

fig. 3. Polished yellow amphora from Zalavár

[3] *D. Bialekova:* Žltá keramika z pohrebísk obdobia avarskej ríše v Karpatskej kotline (Die gelbe Keramik aus den awarenzeitlichen Gräberfeldern im Karpatenbecken). SlA 14 (1967) 5–76; *É. Garam:* A késő avar kori korongolt sárga kerámia (Die spätawarenzeitliche schnellgedrehte gelbe Keramik). ArchÉrt 96 (1969) 207–237.

regions. The investigation methods applied include thin section analysis, XRF, XRD and scanning electron microscopy.

The present project is part of a series of projects for the investigation of the polished yellow ceramics. In the framework of this project series hitherto samples from Zalavár (Hungary), Mikulčice, Břeclav-Pohansko, Uherské-Hradiště – Otokarova ulice (Czech Republic),[4] Gars-Thunau (Austria) and Pliska (Bulgaria)[5] have been analysed. In this paper the results concerning the samples from Zalavár are presented.[6]

2. Investigated samples

50 samples of archaeological ceramics from Zalavár were investigated by thin section analysis, X-ray fluorescence analysis and X-ray diffraction analysis. Twelve of these samples were also investigated by scanning electron microscopy. (For data on the origin of the investigated samples of archaeological ceramics see *Tab. 1*)

In addition to the samples of archaeological ceramics seven (fired) clay samples from the site were also analysed by thin section analysis, X-ray fluorescence analysis, X-ray diffraction analysis and scanning electron microscopy (only petrography and XRF of clay samples presented here).[7]

sample number	petrographic group	excavation feature
3	1	01/2001
4	1	01/2001
6	1	01/2001
7	1	01/2001
8	1 (+SEM)	01/2001
9	1 (+SEM)	01/2001
10	1 (+SEM)	01/2001
11	1	01/2001
12	1	01/2001
20	1	01/2001
25	1	20/2001

sample number	petrographic group	excavation feature
1	2	01/2001
13	2	01/2001
15	2	01/2001
19	2	01/2001
21	2 (+SEM)	01/2001
22	2	01/2001
26	2	20/2001
27	2	20/2001
28	2 (+SEM)	20/2001
29	2 (+SEM)	20/2001
30	2	20/2001
33	2	20/2001
45	2	04/1999
46	2	04/1999
48	2	04/1999
49	2	04/1999
50	2	04/1999

sample number	petrographic group	excavation feature
2	3 (+SEM)	01/2001
5	3	01/2001
14	3	01/2001
16	3	01/2001
17	3	01/2001
18	3 (+SEM)	01/2001
23	3	01/2001
24	3 (+SEM)	01/2001
31	3	20/2001
32	3	20/2001
41	3	04/1999
43	3	04/1999
47	3	04/1999

sample number	petrographic group	excavation feature
34	4 (+SEM)	34/2000
35	4	34/2000
36	4	34/2000
37	4	04/1999
38	4 (+SEM)	04/1999
39	4	04/1999
40	4	04/1999
42	4	04/1999
44	4 (+SEM)	04/1999

Tab. 1. List of the investigated samples of archaeological ceramics; samples also analysed by scanning electron microscopy are marked by (+SEM)

[4] *H. Herold:* Frühmittelalterliche Prunkkeramik aus Mikulčice, Mähren – Archäometrische Analysen und ihre Interpretation, in: L. Poláček (ed.): Das wirtschaftliche Hinterland der frühmittelalterlichen Zentren, Internationale Tagungen in Mikulčice VI, Spisy Archeologického Ústavu AV ČR Brno 31, Brno 2008, 299–311, 428–429.

[5] *H. Herold:* Dünnschliffanalysen frühmittelalterlicher Keramik aus Pliska, Bulgarien. Unpublished project report, Vienna 2004; to be published as an appendix to the Ph.D. thesis of V. P. Vasileva at the Johann Wolfgang Goethe University, Frankfurt am Main.

[6] A part of the research results on the polished yellow ceramics published in the current article has been presented in *H. Herold:* The „polished yellow" ceramics of the Carolingian Period (9th century AD): Samples from Zalavár, South–West Hungary, in: S. Y. Waksman (ed.): Archaeometric and Archaeological Approaches to Ceramics. Papers presented at EMAC ´05, 8th European Meeting on Ancient Ceramics, Lyon 2005. BAR International Series 1691, Oxford 2007, 137–144.

[7] The clay samples were mixed with water, formed into brick-shaped pieces (of ca. 10×6×2 cm) and fired in an electric oven in an oxidising atmosphere. The samples were put into the cold oven, heated up to 700 ˚C in 270 minutes, kept at 700 ˚C for 15 minutes and left to cool down in the closed oven.

3. The geology of the surroundings of Zalavár[8]

The site of Zalavár lies on a flat sand-dune in an area that was covered by swamp before the regulation of the River Zala, flowing west and south-west of the site. The sand-dune is only slightly higher than its surroundings. The area around the sand-dune consists of peat layers formed during the Holocene.

West of the site the River Zala deposited sediments in the Holocene; further west of the river there is a north-south loess plateau from the Pleistocene, divided by various small creeks in east-west directions. Along the creeks a number of sand/clay deposits from the Pliocene can be found.

East of the site another north-south loess plateau from the Pleistocene is situated. Within the various loess plateaus as well as within the peat areas east of the site there are a number of sand/clay deposits from the Pliocene. The Holocene deposits of the River Zala, flowing into Lake Balaton, can also be found east of the site of Zalavár.

North of Lake Balaton there are river sands from the Pleistocene and dolomite from the Triassic. The nearest surface outcrops of Miocene layers (limestone, clays, marls) can be found about 25 km north-east of the site, north of Lake Balaton.

4. Ceramic types by petrography

On the basis of the petrographic analysis by polarising microscopy four different groups of the archaeological ceramics were distinguished. Groups 1–3 have practically the same mineralogical composition (quartz, alkali feldspars, low grade metamorphic rock fragments, small amounts of plagioclase, muscovite mica, grains of opaque phases, practically no carbonates; epidote, tourmaline, rutile, zircon and garnet as accessory minerals; for details see the description of the petrographic groups in the Appendix), they can only be differentiated by their texture (group 1: fine-grained, well sorted; group 2: coarse-grained, poorly sorted; group 3: mid-coarse grained, poorly sorted; see also *fig. 4*).

The mineralogical composition of group 4 is differentiated from that of groups 1–3 by a relatively large amount of carbonates. Group 4 also has a texture different from all of the other three groups (very fine matrix with a small number of large non-plastic inclusions).

5. Ceramic types by X-ray fluorescence analysis

Groups 1–3 of petrography cannot be distinguished by X-ray fluorescence analysis (*Tab. 2*; total iron measured as Fe^{3+}; see also the plot of archaeological samples in *fig. 8*), which supports the conclusion from the petrographic analysis that these three groups have a very similar mineralogical composition and are only different in their texture. Group 4 differs first of all in its CaO and SiO_2 content and also in some trace elements from groups 1–3. Thus the results of the XRF analysis strengthen the results of the polarising microscopy, but do not provide a basis for the quantitative separation of groups 1–3.[9]

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[8] See also the Geological Map of Hungary 1:200 000, Sheets L-33-XII Veszprém and L-33-XVIII Kaposvár.

[9] The XRF measurements were performed on a Philips PW 2400 machine equipped with a Rh tube. Major elements (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P) and trace elements (Ba, Cr, Cu, Nb, Ni, Pb, Rb, Sr, Y, Zn, Zr) of 57 samples (50 samples of archaeological ceramics and 7 fired clay samples) were analysed. Analyses were performed on glassy tablets for both major and trace elements. Glassy tablets were prepared by starting with about 3 g of powdered sample dried for 6–8 hours at 110 °C and calcined at 1000 °C for one hour. Samples were weighed after each step in order to calculate the loss on ignition (LOI). 0.700 g of calcined powder was then mixed with 0.350 g of Li fluoride and 6.650 g of Li tetraborate, put into a Pt crucible and melted at 1150 °C for 10 min using a Philips Perl'X-2 machine. Calibration of major and trace elements was made on 50 standards. Analytical reproducibility and detection limits for major and trace elements after standard analyses are reported in *S. DiPierro:* Domestic Production versus pottery exchanges during the Final Neolithic: Characterization of the Auvernier-cordé ceramics of the Portalban and Saint Blaise settlements, Western Switzerland. PhD Thesis. University of Fribourg, Switzerland 2002.

group	sample	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	P2O5	SUM	Ba	Cr	Cu	Nb	Ni	Pb	Rb	Sr	Y	Zn	Zr	H2O	LOI
		wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	wt%	wt%
1	Z03	65,48	0,83	17,99	7,02	0,07	1,94	1,46	0,56	3,08	0,89	99,50	667	131	31	15	64	32	157	194	27	111	193	1,26	2,07
1	Z04	64,90	0,82	17,73	7,41	0,09	1,92	1,82	0,54	2,91	1,25	99,57	750	121	26	16	72	42	155	223	24	116	194	2,07	3,05
1	Z06	64,80	0,78	17,39	7,45	0,07	1,98	1,99	0,53	2,75	1,32	99,24	733	119	34	15	75	29	151	195	28	117	186	3,04	3,95
1	Z07	65,49	0,83	18,57	6,98	0,07	2,10	1,03	0,93	3,07	0,24	99,47	585	125	42	17	88	29	166	168	27	111	191	0,41	0,81
1	Z08	65,00	0,82	18,27	7,09	0,08	2,05	1,36	0,53	3,09	0,65	99,11	649	125	29	18	73	29	166	190	27	117	184	0,86	1,69
1	Z09	65,38	0,83	18,39	6,97	0,07	2,06	1,15	0,48	3,12	0,43	99,03	592	132	29	16	70	32	164	174	28	112	188	0,50	1,15
1	Z10	64,98	0,79	17,54	7,43	0,07	1,97	1,87	1,03	2,81	1,25	99,92	720	120	37	15	70	29	148	200	31	111	189	2,49	3,59
1	Z11	65,24	0,82	18,34	7,09	0,07	2,04	1,35	0,51	3,00	0,58	99,23	637	121	70	18	80	30	164	188	27	113	183	0,81	1,40
1	Z12	64,84	0,79	17,38	7,35	0,07	1,93	1,87	0,57	2,97	1,38	99,34	729	119	31	16	71	30	150	190	28	122	188	2,66	3,68
1	Z20	64,29	0,78	17,28	7,52	0,08	1,97	2,10	0,52	2,87	1,54	99,11	704	127	27	16	77	26	150	217	29	116	187	3,09	4,49
1	Z25	65,44	0,85	18,73	6,73	0,05	1,96	1,29	0,50	2,94	0,69	99,33	607	127	27	17	76	32	152	152	26	98	190	2,20	3,11
2	Z01	72,12	0,69	14,87	5,49	0,08	1,60	0,81	0,83	2,61	0,14	99,38	462	100	17	14	85	31	132	105	27	92	181	0,32	0,70
2	Z13	71,54	0,67	14,06	5,33	0,16	1,30	1,75	0,84	2,61	1,17	99,59	659	92	19	13	54	23	121	210	22	94	180	1,92	2,95
2	Z15	69,49	0,77	15,87	5,80	0,12	1,66	1,30	0,59	2,87	0,59	99,23	599	104	25	17	56	24	142	175	28	95	214	0,90	1,76
2	Z19	69,06	0,75	15,81	5,68	0,10	1,73	1,74	0,83	2,78	0,38	99,03	582	103	15	16	58	23	148	170	30	99	199	0,95	2,07
2	Z21	69,22	0,75	15,77	5,55	0,11	1,70	2,01	0,76	2,72	0,56	99,31	631	102	17	16	56	23	139	181	32	100	193	1,41	3,03
2	Z22	67,70	0,74	15,46	6,73	0,08	1,78	2,29	0,75	2,64	0,92	99,26	642	100	21	15	67	24	139	169	29	105	201	2,81	4,28
2	Z26	69,29	0,78	15,51	6,17	0,09	1,61	1,23	0,73	2,79	0,72	99,08	591	104	18	17	64	27	134	137	31	84	205	1,64	2,32
2	Z27	69,36	0,79	15,69	6,22	0,10	1,64	1,23	0,69	2,80	0,66	99,33	591	107	25	16	69	27	143	139	30	90	203	1,56	2,05
2	Z28	69,49	0,78	15,66	6,05	0,09	1,64	1,19	2,05	2,85	0,62	100,57	582	112	22	16	71	27	140	130	29	90	209	1,67	2,31
2	Z29	70,41	0,72	14,93	5,93	0,06	1,58	1,33	1,97	2,64	0,50	100,21	550	94	22	15	98	23	124	128	28	74	194	1,86	2,73
2	Z30	69,54	0,79	15,65	6,26	0,11	1,75	1,05	0,91	2,79	0,48	99,47	507	102	38	17	63	22	136	126	32	92	206	0,85	1,26
2	Z33	71,25	0,70	15,23	5,35	0,08	1,59	1,36	1,85	2,71	0,59	100,87	516	102	23	15	66	22	118	130	17	74	188	1,97	2,86
2	Z45	70,86	0,65	14,55	5,50	0,06	1,65	1,55	1,57	2,58	0,74	99,90	792	97	260	14	76	21	127	164	23	105	187	2,45	3,27
2	Z46	70,10	0,79	15,11	4,77	0,07	1,83	2,56	1,52	2,51	0,38	99,82	636	100	50	16	53	31	133	189	19	97	213	0,68	1,26
2	Z48	69,92	0,72	16,13	6,14	0,12	1,95	1,26	1,67	2,60	0,29	100,96	581	113	26	14	63	29	134	136	22	91	176	0,35	0,68
2	Z49	71,05	0,68	14,54	5,29	0,10	1,49	1,59	1,39	2,51	1,23	100,09	1081	106	97	15	60	29	120	216	16	112	185	1,49	2,34
2	Z50	73,83	0,62	13,87	5,04	0,06	1,36	0,89	1,51	2,23	0,14	99,70	641	90	19	12	54	25	117	111	12	82	155	0,30	0,85
3	Z02	68,06	0,87	17,30	5,64	0,12	1,95	1,40	0,66	3,13	0,26	99,55	587	121	24	16	60	36	166	140	29	114	197	0,35	0,94
3	Z05	66,73	0,83	16,74	5,79	0,06	1,97	3,09	0,75	2,51	0,42	99,04	592	105	16	15	54	24	134	190	31	100	191	0,50	1,87
3	Z14	69,23	0,76	15,94	5,82	0,10	1,65	1,14	1,20	2,87	0,41	99,29	653	109	13	18	68	22	145	158	30	99	201	0,44	0,90
3	Z16	65,42	0,85	18,14	6,12	0,06	2,14	1,88	0,39	3,17	1,12	99,46	661	123	29	17	87	24	178	199	27	137	169	2,95	3,99
3	Z17	67,83	0,83	15,71	5,50	0,12	1,78	2,53	0,68	2,87	1,18	99,22	720	99	34	17	63	23	144	208	26	122	198	2,24	3,95
3	Z18	66,24	0,77	17,16	6,17	0,09	1,98	1,81	1,15	3,21	1,35	100,11	758	123	31	15	63	25	157	197	19	118	158	2,30	3,29
3	Z23	67,58	0,85	15,86	5,52	0,10	1,78	2,70	0,69	2,82	1,20	99,27	743	101	16	17	63	25	148	212	26	121	202	2,20	3,90
3	Z24	68,01	0,83	15,54	5,55	0,09	1,76	2,51	0,71	2,73	1,14	99,03	729	104	18	16	61	23	146	208	26	115	203	2,28	3,82
3	Z31	67,81	0,85	16,03	6,40	0,07	1,82	2,12	0,79	2,71	0,36	99,12	516	108	33	17	119	34	129	117	26	95	217	2,27	3,92
3	Z32	67,05	0,85	16,15	6,25	0,10	1,77	2,07	1,36	2,80	0,71	99,26	609	106	91	17	82	32	131	136	28	93	222	2,32	3,64
3	Z41	62,13	0,88	18,82	7,35	0,10	2,32	3,44	1,31	2,98	0,35	99,87	736	122	29	16	71	32	156	172	26	107	188	0,60	1,65
3	Z43	63,22	0,89	19,13	6,97	0,09	2,32	3,34	1,39	3,02	0,32	100,88	788	117	29	17	66	30	153	172	26	111	183	0,59	3,39
3	Z47	65,97	0,91	17,76	6,15	0,08	2,03	2,55	1,65	2,82	0,70	100,81	756	140	52	18	67	29	138	192	25	104	219	0,91	1,86
4	Z34	58,98	0,85	19,08	7,38	0,10	2,33	5,25	0,54	2,88	1,41	99,01	872	112	26	18	68	40	151	309	30	120	160	2,06	4,53
4	Z35	58,83	0,79	18,49	7,46	0,10	2,24	5,87	1,95	2,85	1,26	100,04	884	124	27	17	72	27	149	293	36	117	164	1,88	5,39
4	Z36	56,16	0,82	17,74	9,15	0,10	2,33	7,09	0,53	2,73	2,10	98,99	1007	121	23	18	80	24	146	348	30	134	166	3,44	7,84
4	Z37	58,89	0,81	18,37	7,56	0,10	2,44	6,33	0,46	2,90	1,07	99,15	882	119	121	16	68	30	152	283	31	134	144	1,26	3,99
4	Z38	59,48	0,81	18,73	7,25	0,11	2,60	5,57	1,39	3,04	0,86	100,05	908	126	41	17	71	35	160	250	23	126	138	0,95	3,05
4	Z39	56,93	0,79	18,52	7,33	0,12	2,94	7,15	1,23	2,98	0,96	99,19	1118	130	56	15	72	35	153	269	24	127	131	1,16	4,28
4	Z40	59,03	0,80	18,76	7,40	0,13	2,68	5,82	1,15	2,99	1,11	100,10	1145	129	51	17	68	34	159	265	22	121	134	1,15	3,34
4	Z42	57,61	0,82	18,49	7,08	0,14	2,66	7,77	1,36	3,03	1,60	100,83	1200	103	43	18	71	34	150	353	22	122	149	2,13	5,79
4	Z44	57,27	0,80	17,97	6,95	0,12	2,91	8,06	1,58	2,89	1,12	99,89	972	125	50	16	70	33	147	295	22	117	148	1,38	5,95
clay sample	ZT01	71,74	0,93	13,96	5,31	0,11	1,90	2,25	1,75	2,45	0,14	100,70	625	111	21	17	45	23	118	106	27	76	326	0,56	2,13
clay sample	ZT02	85,05	0,49	7,47	2,07	0,06	0,65	1,16	1,55	1,51	0,25	100,32	311	54	9	11	18	12	67	89	9	32	163	0,16	0,62
clay sample	ZT03	79,29	0,43	10,60	3,96	0,04	1,16	1,65	1,47	1,86	0,18	100,72	313	64	16	8	43	24	85	91	19	52	109	0,46	1,24
clay sample	ZT04	73,58	0,52	7,91	2,38	0,05	2,54	9,94	1,55	1,53	0,21	100,31	341	51	14	11	20	19	61	156	8	39	190	0,32	7,05
clay sample	ZT05	83,53	0,53	8,22	2,77	0,04	0,77	1,42	1,56	1,62	0,32	100,89	532	44	13	9	21	14	70	92	9	51	152	0,25	0,73
clay sample	ZT06	79,93	0,46	7,93	3,38	0,06	0,91	3,65	1,46	1,56	0,53	99,95	299	50	7	9	22	11	65	140	9	35	134	0,32	2,06
clay sample	ZT07	79,21	0,54	8,98	3,65	0,07	1,04	3,09	1,68	1,71	0,59	100,68	465	60	55	11	32	36	76	131	8	99	161	0,42	1,37

Tab. 2. Numeric data from the X-ray fluorescence measurements of the samples from Zalavár

Groups 1–3 of petrography have a similar chemical composition and thus cannot be distinguished by XRF. Group 4 can well be differentiated from groups 1–3 chemically, first of all on the basis of its higher CaO content.

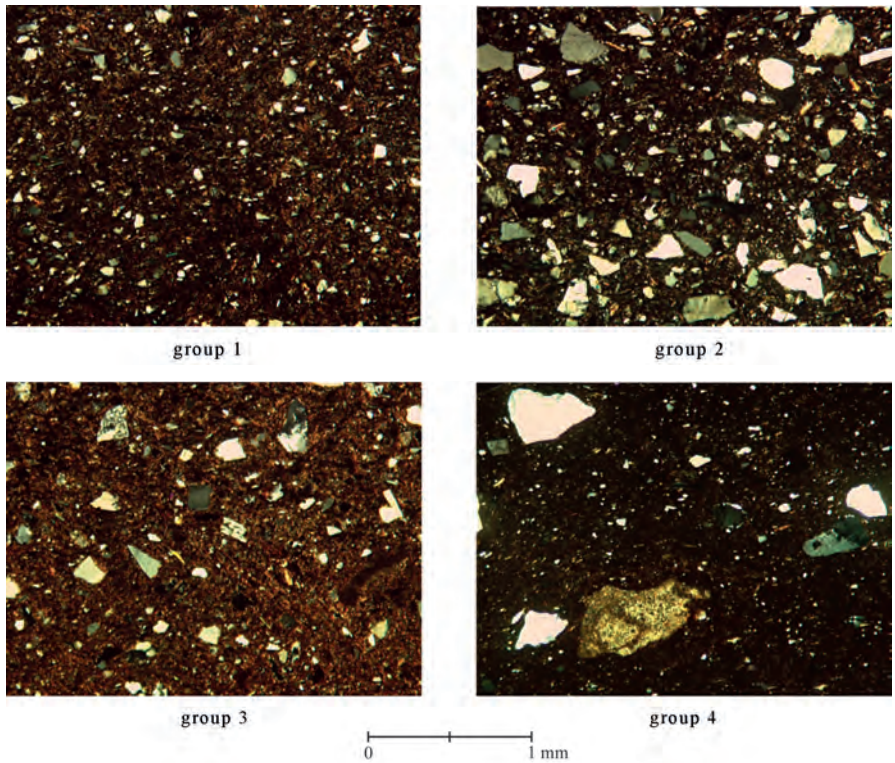

fig. 4. The four groups of the polished yellow ceramics from Zalavár in the polarising microscope; under crossed polars, areas shown equal 2.6×1.8 mm. Groups can mainly be differentiated on the basis of micromorphological criteria

(samples shown: group 1: Z08; group 2: Z01; group 3: Z18; group 4: Z39)

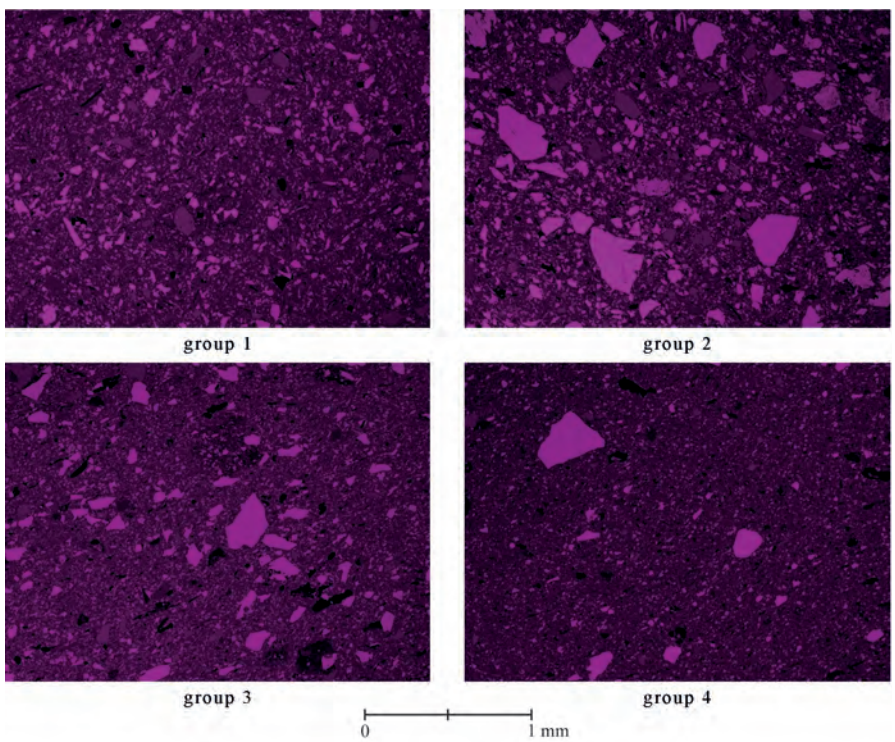

fig. 5. The four groups of the polished yellow ceramics from Zalavár by scanning electron microscopy

Si mappings from SEM EDX (the more violet the particles are, the more Si they contain: the bright violet particles are quartz, the mid-violet particles are feldspars); between 800–1200 quartz particles could be detected in the areas of 2.6×1.8 mm shown here (samples shown: group 1: Z08; group 2: Z28; group 3: Z02; group 4: Z38)

6. Ceramic types by scanning electron microscopy, micromorphology

The groups 1–3 of petrography cannot be distinguished by X-ray fluorescence analysis; they can only be separated on the basis of their microstructure. In order to separate them on a reliable basis, we need quantified data of their microstructure. The problems of the quantification of microstructural data in polarising microscopy are well known: under crossed polars grains of the same mineral can have different colours and grains of different minerals can show the same colour. This makes a digital quantitative micromorphological analysis of polarising microscope pictures almost impossible.

To avoid the above described optical problems when quantifying micromorphological data from the polarising microscope, scanning electron microscopy was used.[10] On a SEM image all particles are shown in different shades of grey according to the atomic weight of their constituents. Moreover it is possible to produce mappings of the distribution of chemical elements within the sample. The images obtained in the SEM are thus best suitable for a digital quantitative analysis and allow the recording of different features of grain size and shape. Therefore a quantitative differentiation between groups of samples on a micromorphological basis is possible.

In the present project mappings of the chemical element Si were selected for the micromorphological analysis *(fig. 5)*. Each of the 12 samples was measured at two different places; the measured area was 2.6×1.8 mm in all cases. The subsequent image analysis was performed using the free UTHSCSA ImageTool program (developed at the University of Texas Health Science Center at San Antonio, Texas and available from the Internet from http://ddsdx.uthscsa.edu/dig/download.html). Various measures of quartz grains were

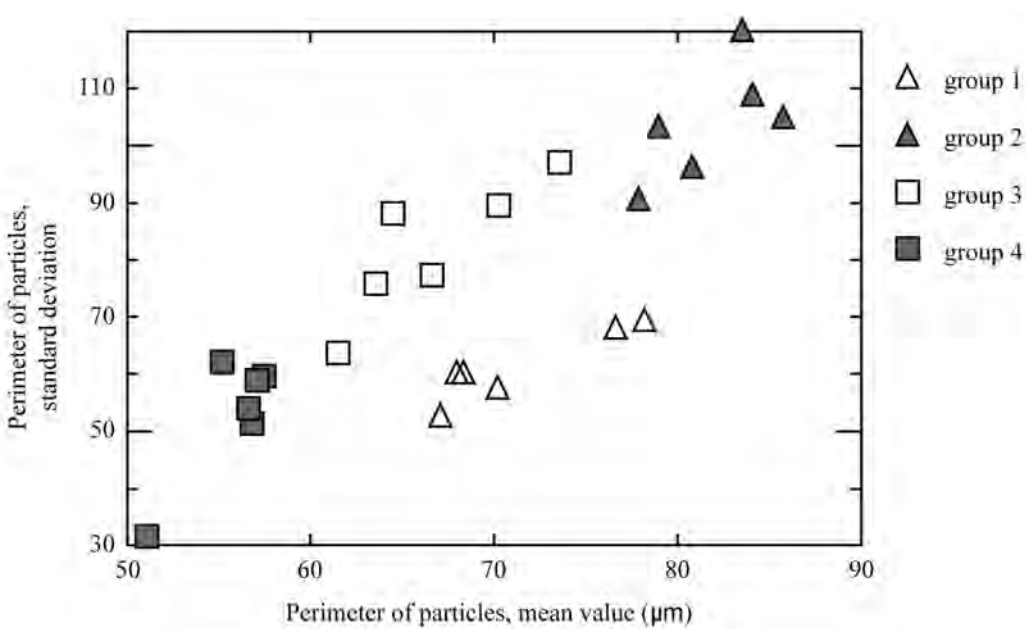

fig. 6. The four groups of the polished yellow ceramics from Zalavár

Bivariate plot of the perimeter of the measured quartz grains in the archaeological samples; mean value of perimeter in each sample against standard deviation of perimeter in each sample; perimeter measured in µm. The plot makes a separation of groups 1–3 possible on the basis of micromorphological criteria; these groups cannot clearly be separated on the basis of chemical data

[10] A scanning electron microscope from FEI (Focused Electrons and Ions) XL 30 Sirion FEG was used with various settings.

	1a	1b	2a	2b	2c	2d	3a	3b	3c	3d	4a	4b
Chlorite	■		■				■	■			■	
Illite+Muscovite	■	■	■	■	■		■	■	■	■	■	■
Feldspar	■	■	■	■	■	■	■	■	■	■	■	■
Quartz	■	■	■	■	■	■	■	■	■	■	■	■
Calcite			■	■				■	■		■	■
Estimated T ºC	< 650	650–850	< 650	650–750	650–850	~850–900	< 650	< 650	650–750	650–850	< 650	650–750
Samples	Z06, Z10, Z12, Z20, Z25	Z03, Z04, Z07, Z08, Z09, Z11	Z22, Z29	Z19, Z21	Z01, Z13, Z15, Z26, Z27, Z28, Z30, Z33, Z45, Z48, Z49, Z50	Z46	Z16, Z18	Z24, Z31, Z32	Z02, Z05, Z17, Z23, Z47	Z14, Z41, Z43	Z36	Z34, Z35, Z37, Z38, Z39, Z40, Z42, Z44

Tab. 3. Phase composition and estimated firing temperature of the four groups of the polished yellow ceramics from Zalavár

Groups 1–3 are rather heterogeneous concerning the estimated firing temperature on the basis of XRD analyses; group 4 shows the most homogeneous picture in this respect.

recorded (area, perimeter, major axis length, minor axis length etc.). The plot of the perimeter of quartz grains (mean value against standard deviation in each sample, *fig. 6*) shown here makes a separation of groups 1–3 possible on the basis of micromorphological criteria. This novel methodology for quantitative micromorphological analysis developed in the present project does not only solve the research question set to the micromorphological analysis in the Zalavár project, but also provides a perspective for answering further micromorphological questions in future projects.

7. Firing temperature and vitrification by X-ray diffraction analysis and scanning electron microscopy

On the basis of the phase composition of the samples of archaeological ceramics detected by XRD the firing temperature was estimated *(Tab. 3)*.[11] Groups 1–3 of the archaeological ceramics are rather heterogeneous concerning the firing temperature estimated, group 4 shows the most homogeneous picture in this respect. This means that the potters producing the vessels belonging to group 4 are likely to have had a better control over the firing process than the potters of the groups 1–3.[12]

The samples of group 4 show a higher degree of vitrification in the scanning electron microscope than the samples of the groups 1–3 (samples Z02 and Z39 shown in *fig. 7*). This is probably due to the higher Ca-content of group 4 (shown also by X-ray fluorescence analysis), Ca acting as a flux in the firing process.

[11] The temperature estimation was based on data from *M. Maggetti – H. Westley – J. Olin:* Provenance and Technical Studies of Mexican Majolica Using Elemental and Phase Analysis, in: J. B. Lambert (ed.): ACS Advances in Chemistry, Series, No. 205, Archaeological Chemistry III, American Chemical Society, 1984, 175, Fig. 12; and *W. Noll:* Alte Keramiken und ihre Pigmente. Studien zu Material und Technologie, Stuttgart 1991, 99, Abb. 21.

[12] The Powder XRD measurements were performed with a Philips PW1800 X-ray diffractometer (40mA/40kV, Cu-Kα radiation, 2 Theta 2–70°, step size 0.020º 2 Theta, time per step 1 sec, PC-APD diffraction software). The samples were ground in a tungsten-carbide mill. For the identification of the peaks the freeware MacDiff was used (Version 4.2.5, Rainer Petschick, Johann Wolfgang Goethe University, Frankfurt am Main, Germany).

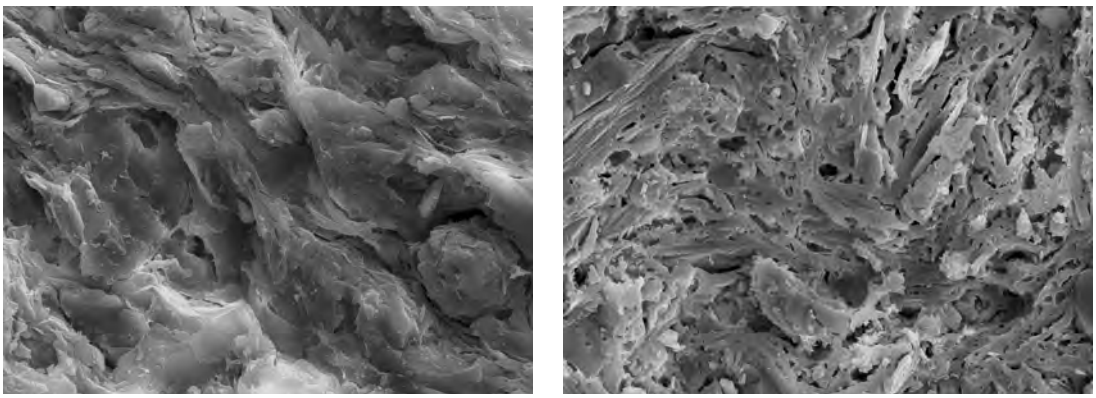

fig. 7. Scanning electron microscopy images of the internal structure of samples Z02 (group 3) and Z39 (group 4)

Longer side of images represents 65 µm. Sample Z39 of group 4 shows a higher degree of vitrification in the SEM than sample Z02 of group 3. This is probably due to the higher Ca-content of group 4.

8. Provenance of the archaeological ceramics by X-ray fluorescence analysis and petrography

In order to investigate a possible local provenance of the archaeological ceramics six clay samples were taken from the site of Zalavár and one clay sample (ZT 1) at a distance of 2 km from the site. Since the clay samples are much coarser (higher Si-content) than the archaeological ceramics, the data from the X-ray fluorescence analysis is plotted below as ratios of elements in order to eliminate the dominance of Si. (For the numeric results of the XRF analysis see *Tab. 2*, for details of the XRF analysis see footnote 9.)

Both main and trace elements show that raw material with a chemical composition similar to the four groups of archaeological ceramics is available at and in the vicinity of the site *(fig. 8)*. Clay samples ZT1–3 and ZT5 are well compatible with groups 1–3 of the archaeological ceramics; clay samples ZT6–7 are well compatible with group 4 of the archaeological ceramics. Clay samples ZT2–7 were collected directly at the site and thus allow a provenance of the archaeological ceramics local to the site itself; clay sample ZT1 was, however, collected 2 km east of the site and is still compatible with the archaeological ceramics. How large the area is, where sediments of a similar composition occur, can only be defined by analysing more clay samples from the greater vicinity of the site.

Results from petrographic analysis confirm the above results of the XRF measurements. The clay samples ZT1–3 and ZT5 are well comparable to groups 1–3 of the archaeological ceramics also on the basis of their mineral composition. The clay samples are, however, somewhat coarser gained and also contain more non-plastic components and heavy minerals than the archaeological ceramics. The largest particles in the clay samples are sandstone fragments. Such grains are not present in the archaeological ceramics; furthermore there are also less large quartzite grains in the archaeological ceramics than in the clay samples. This can be a result of levigation when preparing the raw materials for the archaeological ceramics.

Group 4 of the archaeological ceramics is richer in carbonates than the formerly mentioned clay samples ZT1–3 and ZT5. Thus these clay samples are unlikely to have been the raw material of group 4. The clay samples ZT4 and ZT6–7 contain carbonates. Although their grain size is much coarser than that of group 4, they show that there are also sediments containing carbonates at the site of Zalavár. Furthermore the shell fragments contained in clay sample ZT4 are very similar to those identified in a number of samples of group 4 of the archaeological ceramics. Therefore a local provenance seems to be possible also for group 4 of the archaeological ceramics, not only from a chemical, but also from a petrographic point of view.

9. Results

The conducted analyses (thin-section analysis, XRF, XRD, scanning electron microscopy) have shown that the 50 investigated samples of archaeological ceramics can be divided into four groups. Of these four groups groups 1–3 have a similar mineralogical and elemental composition and differ mainly in textural parameters. These differences can best be shown by means of digital micromorphological analyses of element mappings in the SEM. On the basis of the investigated samples it seems, however, that these three groups are part of a 'continuous textural set', i.e. it is difficult to draw exact borders between the groups. This can either be interpreted as a raw material source with slightly different types of raw materials exploited or as somewhat different clay preparation techniques used.

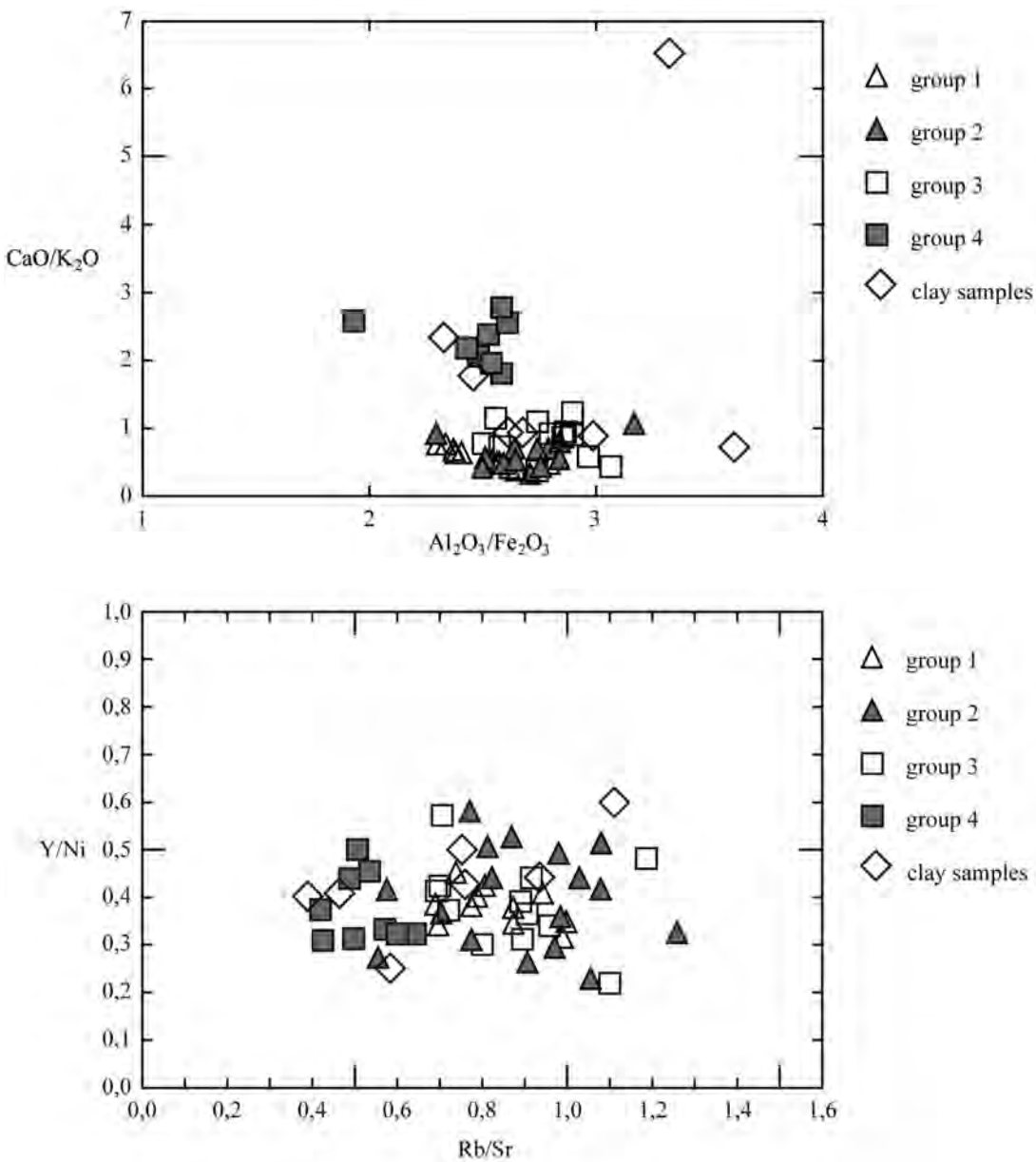

fig. 8. The four groups of the polished yellow ceramics and the clay samples from Zalavár by X-ray fluorescence analysis

Here the plots of Al_2O_3/Fe_2O_3 against CaO/K_2O and Y/Ni against Rb/Sr. Both main and trace elements show that raw material with a chemical composition similar to the four groups of archaeological ceramics is available at the site

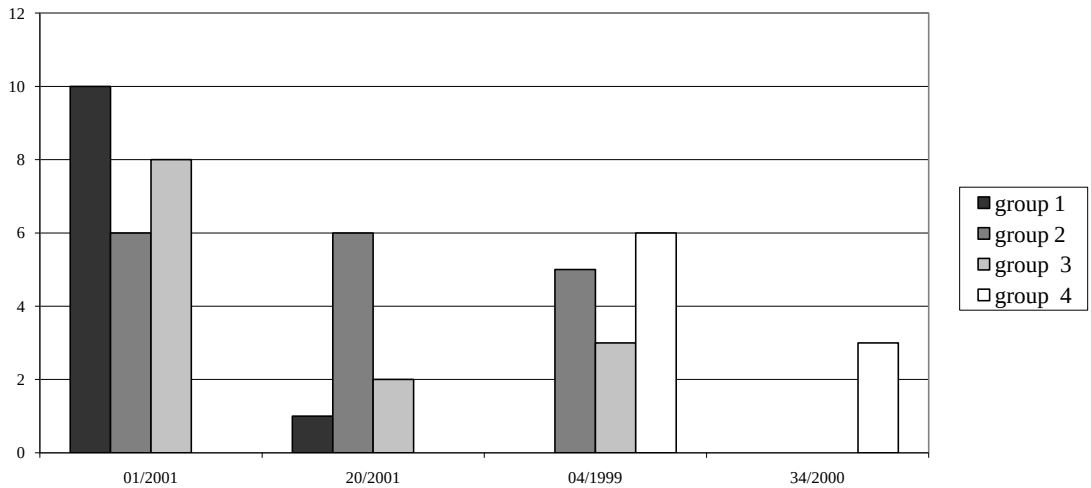

fig. 9. The distribution of the petrographic groups in those four settlement features of Zalavár where the samples originate from (settlement features 01/2001, 20/2001, 4/1999 and 34/2000; see also *Tab. 1*)

For each of the three groups a set of macroscopic criteria can be defined, which makes it possible to assign potsherds with no archaeometric analysis with a great certainty to the groups defined by archaeometric methods. A comparison with the full archaeological record is thus made possible and could clarify if the groups 1–3 are more likely to have been produced simultaneously or if they are more likely to represent phases of a continuously changing production. Group 4 diverges from the above three groups in mineralogical-, chemical- as well as in textural parameters. Again, a comparison with the full archaeological record can clarify if group 4 is more likely to have been produced simultaneously with groups 1–3 using a different raw material source or if group 4 represents a different chronological phase than groups 1–3. The distribution of the petrographic groups in those four settlement features of Zalavár where the samples originate from *(Tab. 1* and *fig. 9)* seems to suggest a chronological difference between the groups, especially in the case of group 4. However, this hypothesis needs to be verified by the analysis of the full archaeological record. The investigated clay samples show that a local provenance is possible for all four groups of the polished yellow ceramics in Zalavár.

From a methodological point of view it can be concluded that the digital micromorphological analysis carried out on the basis of element mappings in the scanning electron microscope does add an extra dimension to the investigations and allows the analysis of features which are not accessible by other means.

When comparing the results of the archaeometric investigations of the polished yellow ceramics from Zalavár to previous archaeometric analysis of this special ceramic type, it can be seen that the analysis of polished yellow ceramics from Mikulčice and other sites in Moravia[13] brought somewhat different results concerning the size and provenance of the petrographic groups than the investigation of the samples from Zalavár presented above. In Miklučice the analysed samples formed small and petrographically very distinct groups (eight groups from 21 samples in Mikulčice compared to four groups from 50 samples in Zalavár). Some of the petrographic groups in Mikulčice must have been imported to the site, whereas in Zalavár a local provenance of all four petrographic groups is possible.

[13] *H. Herold:* Frühmittelalterliche Prunkkeramik aus Mikulčice, Mähren – Archäometrische Analysen und ihre Interpretation, in: L. Poláček (ed.): Das wirtschaftliche Hinterland der frühmittelalterlichen Zentren, Internationale Tagungen in Mikulčice VI, Spisy Archeologického Ústavu AV ČR Brno 31, Brno 2008, 299–311, 428–429.

The investigation of single samples from Břeclav-Pohansko and Uherské-Hradiště-Otokarova ulice, carried out parallel to the investigation of samples from Mikulčice,[14] showed that samples from the same petrographic group can be found at different Moravian sites. This suggests that the vessels of the polished yellow ceramics were transported within Moravia (by trade or in other ways, e. g. as part of gift exchange). Similar information is currently not available for the region of Zalavár, as samples from other sites in the region have yet to be investigated with archaeometric methods.

The results of the archaeometric investigations from Zalavár and Moravia suggest a more standardised and larger scale ceramic production of the polished yellow ceramics in Zalavár than in Mikulčice. Further investigations can show if these differences are only restricted to the production of the polished yellow ceramics or if they are also a sign of general differences between the two sites (and their '*Hinterlands*') in terms of production processes, trade connections and the organisation of economy.

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Appendix: Description of petrographic groups

1. Archaeological ceramics

Group 1

Samples: 3, 4, 6, 7, 8, 9, 10, 11, 12, 20, 25

matrix:

colour (plane polarised light):

the thin sections have a brownish black – dark brown (HUE 10YR 3/2–3/3) colour on the inside and in the middle and an oxidised outer zone (inside, middle and outside are relative to the position of the thin section to the ceramic vessel) with a bright reddish brown – reddish brown colour (HUE 5YR 5/8–4/8); there is a narrow brown transition zone (HUE 7.5YR 4/3–4/4) between the two parts

colour (crossed polars) and optical properties:

all thin sections have an anisotropic matrix; less anisotropic in the outer zone (colour under crossed polars: bright reddish brown – HUE 2.5YR 5/6–5/8) than in the inner part (colour under crossed polars: orange – HUE 7.5YR 6/6–6/8)

[14] *idem*

non-plastic components:

quartz: mostly monocrystalline, subangular grains with uniform or weakly undulatory extinction, most abundant mineral in the thin sections

plagioclase: very few grains, with polysynthetic twinning

alkali feldspar: few grains with inclusions, very few grains with perthitic structure

mica: mostly muscovite

opaque phases: grains of opaque phases are present

rock fragments: (very fine-grained texture, very few rock fragments) mica schist (muscovite), quartzite (often with muscovite, in some cases with hematite), feldspar (alkali feldspar and/or plagioclase) + quartz (with undulatory extinction) associations, chert, clay pellets

heavy minerals: epidote, tourmaline, rutile, zircon, garnet

amount, size and shape of particles:

the amount of particles >15 μm is ~25–30 vol%

mean grain size ~100 μm, maximum grain size ~300 μm

non-plastic inclusions are well sorted by size

grains are mostly subangular with straight borders

no preferred orientation of particles can be observed

shape, size and orientation of voids:

larger (length: up to 1000 μm) voids with different, mostly elongated shapes (no preferred orientation), from organic material(?), ash(?); there is an oxidised zone (brown, reddish brown) on the border of these voids

apart from these voids the thin sections have a compact structure

Group 2

Samples: 1, 13, 15, 19, 21, 22, 26, 27, 28, 29, 30, 33, 45, 46, 48, 49, 50

matrix:

colour (plane polarised light):

- four thin sections (15, 26–28) have a brownish black – dark brown colour (HUE 10YR 3/2–3/3) on the inside and in the middle and an oxidised outer zone with a bright reddish brown – reddish brown colour (HUE 5YR 5/8–4/8); there is a narrow brown transition zone (HUE 7.5YR 4/3–4/4) between the two parts
- seven thin sections (1, 13, 22, 29, 30, 33, 49) have a brownish black – dark brown colour (HUE 10YR 3/2–3/3) on the inside and in the middle and an oxidised outer third with a bright reddish brown – reddish brown colour (HUE 5YR 5/8–4/8)
- one thin section (46) has a black colour (HUE N2) on the inside third and oxidised outer two thirds with a bright reddish brown – reddish brown colour (HUE 5YR 5/8–4/8)
- five thin sections (19, 21, 45, 48, 50) have an oxidised inside and outside with a bright reddish brown – reddish brown colour (HUE 5YR 5/8–4/8) and a grey, dark grey, black zone (HUE N4/N3/N2) in the middle; the thickness of these zones is different in each thin section

colour (crossed polars) and optical properties:

- two thin sections (46, 48) have an isotropic matrix with a reddish black, very dark reddish brown colour (HUE 7.5R 2/1–2/2) in the zones which show a grey/black colour in plane polarised light, and an isotropic dark reddish brown (HUE 10R 3/2–3/3) matrix in the zones which show a reddish brown colour in plane polarised light
- all other thin sections have an anisotropic matrix; less anisotropic in the zones that show a bright reddish brown – reddish brown colour in plane polarised light (colour under crossed polars: bright reddish brown – HUE 2.5YR 5/6–5/8) than in the parts showing a brownish black – dark brown colour in plane polarised light (colour under crossed polars: orange – HUE 7.5YR 6/6–6/8)

non-plastic components:

quartz: mostly monocrystalline, subangular grains with uniform or weakly undulatory extinction, most abundant mineral in the thin sections, few polycrystalline grains with undulatory extinction

plagioclase: very few grains, with polysynthetic twinning

alkali feldspar: few grains with inclusions, very few grains with perthitic structure, very few grains with microcline structure

mica: mostly muscovite

opaque phases: grains of opaque phases are present
carbonates: very few monocrystalline carbonate grains
rock fragments: mica schist (muscovite), quartzite (often with muscovite, in some cases with hematite), feldspar (alkali feldspar and/or plagioclase) + quartz (with undulatory extinction) associations, chert, sandstone, siltstone, (very few) micritic carbonates, (very few) carbonates with larger crystals
heavy minerals: epidote, rutile, tourmaline, zircon, garnet, amphibole
amount, size and shape of particles:
the amount of particles >15 μm is ~40–45 vol%
mean grain size ~300 μm, maximum grain size ~1000 μm
non-plastic inclusions are moderately well sorted by size
grains are mostly subangular with straight borders
elongated particles are aligned parallel to the outside/inside of the potsherds
shape, size and orientation of voids:
larger (length: up to 1000 μm) voids with different, shapes (no preferred orientation), from organic material(?), ash(?); there is an oxidised zone (brown, reddish brown) on the border of these voids
elongated smaller voids (length up to ~250 μm) oriented parallel to the outside/inside of the potsherd

Group 3
Samples: 2, 5, 14, 16, 17, 18, 23, 24, 31, 32, 41, 43, 47
matrix:
colour (plane polarised light):
– three thin sections (14, 41, 43) have a yellowish gray colour (HUE 2.5YR 6/1–5/1) on the inside and in the middle and an oxidised outer zone with a bright brown colour (HUE 7.5YR 5/8)
– one thin section (2) has a brownish black colour (HUE 10YR 3/1) on the inside and in the middle, a bright brown colour (HUE 7.5YR 5/8) on the outside and a thin dull yellow orange (HUE 10YR 6/4) zone between the two parts
– one thin section (5) has a black colour (HUE N 2) on the inside and in the middle and a thin dark brown (HUE 10YR 3/3) zone on the outside
– five thin sections (17, 23, 24, 31, 32) have a bright brown colour (HUE 7.5YR 5/8) on the outside and a dark brown – brownish black (HUE 10YR 3/3–2/3) colour on the inner two-thirds
– three thin sections (16, 18, 47) have a bright brown (HUE 7.5YR 5/6–5/8) zone of different thickness on the in- and outside and a dark brown – brownish black (HUE 10YR 3/3–2/3) zone in the middle
colour (crossed polars) and optical properties:
– three thin sections (14, 41, 43) have a reddish black, very dark reddish brown (HUE 7.5R 2/1–2/2) isotropic matrix in the zones which show a gray colour in plane polarised light and an anisotropic dark reddish brown (HUE 5YR 3/6) colour in the zones which are bright brown in plane polarised light
– one thin section (2) has an anisotropic brown – dark brown (HUE 7.5YR 4/6, 3/4) colour in the parts which are brownish black in plane polarised light, a part of the clay pellets in the thin section have a reddish black – very dark reddish brown (HUE 7.5R 2/1–2/2) colour and are isotropic, the zones which are dull yellow orange in plane polarised light show an anisotropic bright reddish brown colour (HUE 5YR 5/8) under crossed polars
– one thin section (5) has a weakly anisotropic brownish black (HUE 5YR 2/1–2/2) matrix in the zone which has a black colour in plane polarised light and an anisotropic bright reddish brown (HUE 5YR 5/8) matrix in the zone which has a dark brown colour in plane polarised light
– five thin sections (17, 23, 24, 31, 32) have a bright brown (HUE 7.5 YR 5/8) anisotropic matrix in the parts which are dark brown – brownish black in plane polarised light and a bright reddish brown (HUE 5YR 5/8) anisotropic matrix in the parts which are bright brown in plane polarised light
– three thin sections (16, 18, 47) have a reddish brown (HUE 5YR 4/8) anisotropic matrix
non-plastic components:
quartz: mostly monocrystalline, subangular grains with uniform or weakly undulatory extinction, most abundant mineral in the thin sections, few polycrystalline grains with undulatory extinction
plagioclase: very few grains, with polysynthetic twinning
alkali feldspar: few grains with inclusions, very few grains with perthitic structure, very few grains with microcline structure

mica: mostly muscovite
opaque phases: grains of opaque phases are present
carbonates: very few monocrystalline carbonate grains
rock fragments: (few rock fragments) quartzite (often with muscovite, in some cases with hematite), mica schist (muscovite), feldspar (alkali feldspar and/or plagioclase) + quartz (with undulatory extinction) associations, clay pellets, chert, sandstone, micritic carbonates, carbonates with larger crystals, (extremely rarely) shell fragments
heavy minerals: epidote, tourmaline, rutile, zircon, amphibole
amount, size and shape of particles:
the amount of particles >15 μm is ~20–25 vol%
mean grain size ~200 μm, maximum grain size ~1000 μm
non-plastic inclusions are poorly sorted by size
grains are mostly subangular with straight borders
elongated particles are in very few cases aligned parallel to the outside/inside of the potsherds
shape, size and orientation of voids:
larger (length: up to 1000 μm) voids with different, shapes (no preferred orientation), from organic material(?), ash(?); there is an oxidised zone (brown, reddish brown) on the border of some of these voids
round and elongated smaller voids (length up to ~250 μm), usually not oriented in a special direction

Group 4
Samples 34, 35, 36, 37, 38, 39, 40, 42, 44
matrix:
colour (plane polarised light):
all thin sections have a bright reddish brown (HUE 2.5YR 5/8, HUE 5YR 5/8) outer zone and a brownish gray – brownish black (HUE 5YR 4/1, HUE 5YR 3/1) inner zone; the thickness of the zones varies between 1/4 brownish gray/brownish black, 3/4 bright reddish brown (sample 39); 1/3 brownish gray/brownish black, 2/3 bright reddish brown (samples 36, 38); 1/2 brownish gray/brownish black, 1/2 bright reddish brown (samples 35, 37, 44); 2/3 brownish gray/brownish black, 1/3 bright reddish brown (samples 34, 40, 42)
colour (crossed polars) and optical properties:
the matrix of all samples is anisotropic; the parts that are brownish gray/ brownish black in plane polarised light show a brown – orange (HUE 7.5YR 4/4, HUE 7.5YR 6/8) colour under crossed polars, the parts that are bright reddish brown in plane polarised light have a reddish brown – dark red (HUE 2.5YR 4/8–HUE 10R 3/6) colour under crossed polars
non-plastic components:
quartz: mostly monocrystalline, subangular grains with uniform or weakly undulatory extinction, very few polycrystalline grains with undulatory extinction
plagioclase: very few grains, with polysynthetic twinning
alkali feldspar: very few grains, partly with inclusions, some grains with perthitic or microcline structure
mica: small amounts, mostly muscovite
opaque phases: grains of opaque phases are present
carbonates: few monocrystalline carbonate grains
rock fragments: (fine grained matrix with very few larger grains, very few rock fragments) quartzite (partly with hematite), feldspar (alkali feldspar and/or plagioclase) + quartz (with undulatory extinction) associations, micritic carbonates, shell fragments, carbonates with larger crystals, clay pellets
heavy minerals: (very few heavy mineral grains) garnet, epidote, tourmaline, zircon, rutile
amount, size and shape of particles:
the amount of particles >15 μm is ~10–20 vol%
mean grain size ~200 μm, maximum grain size ~1500 μm
non-plastic inclusions are very poorly sorted by size
shape of grains can be from well rounded to subangular with straight borders
no preferred orientation of particles can be observed

shape, size and orientation of voids:

larger (length: up to 1000 μm) voids with different, shapes (no preferred orientation), from organic material(?), ash(?); there is an oxidised zone (brown, reddish brown) on the border of some of these voids

smaller voids with a rounded shape are present (length up to ~250 μm)

2. Clay samples

Clay sample 1

matrix: colour (plane polarised light/crossed polars): reddish brown (HUE 2.5YR 4/6) / dark reddish brown (HUE 2.5YR 3/6); optical properties: anisotropic

non-plastic components:

quartz: mostly monocrystalline, subangular grains with uniform or weakly undulatory extinction, most abundant mineral in the thin sections

plagioclase: very few grains, with polysynthetic twinning

alkali feldspar: few grains with inclusions, very few grains with perthitic structure

mica: mostly muscovite

opaque phases: grains of opaque phases are present

rock fragments: (very few rock fragments) quartzite (often with muscovite, in some cases with hematite), feldspar (alkali feldspar and/or plagioclase) + quartz (with undulatory extinction) associations, chert, (few) micritic carbonates

heavy minerals: epidote, garnet, tourmaline, rutile, zircon, amphibole

amount, size and shape of particles:

the amount of particles >15 μm is ~25–30 vol%

mean grain size ~100 μm, maximum grain size ~300 μm

non-plastic inclusions are moderately well sorted by size

grains are mostly subangular with straight borders

Clay sample 2

matrix: colour (plane polarised light/crossed polars): bright brown (HUE 7.5YR 5/6) / yellowish brown (HUE 10YR 5/6); optical properties: anisotropic

non-plastic components:

quartz: mostly monocrystalline, subangular grains with uniform or weakly undulatory extinction, most abundant mineral in the thin sections, few polycrystalline grains with undulatory extinction

plagioclase: very few grains, with polysynthetic twinning

alkali feldspar: few grains with inclusions, very few grains with perthitic structure, very few grains with microcline structure

mica: mostly muscovite

opaque phases: grains of opaque phases are present

rock fragments: quartzite (often with muscovite, in some cases with hematite), mica schist (muscovite), feldspar (alkali feldspar and/or plagioclase) + quartz (with undulatory extinction) associations, chert

heavy minerals: tourmaline, epidote, garnet, zircon, rutile, amphibole

amount, size and shape of particles:

the amount of particles >15 μm is ~45–50 vol%

mean grain size ~400 μm, maximum grain size ~1300 μm

non-plastic inclusions are moderately sorted by size

grains are mostly subangular with straight borders

Clay sample 3

matrix: colour (plane polarised light/crossed polars): bright brown (HUE 7.5YR 5/6) / yellowish brown (HUE 10YR 5/6); optical properties: anisotropic

non-plastic components:

quartz: mostly monocrystalline, subangular grains with uniform or weakly undulatory extinction, most abundant mineral in the thin sections, few polycrystalline grains with undulatory extinction

plagioclase: very few grains, with polysynthetic twinning
alkali feldspar: few grains with inclusions, very few grains with perthitic structure, very few grains with microcline structure
mica: mostly muscovite
opaque phases: grains of opaque phases are present
rock fragments: quartzite (often with muscovite, in some cases with hematite), chert, sandstone, (extremely few) micritic carbonates
heavy minerals: epidote, tourmaline, amphibole, rutile, garnet, zircon
amount, size and shape of particles:
the amount of particles >15 μm is ~45–50 vol%
mean grain size ~400 μm, maximum grain size ~1300 μm
non-plastic inclusions are moderately sorted by size
grains are mostly subangular with straight borders

Clay sample 4
matrix: colour (plane polarised light/crossed polars): yellowish brown (HUE 10YR 5/6) / orange (HUE 10YR 6/8); optical properties anisotropic
non-plastic components:
quartz: mostly monocrystalline, subangular grains with uniform or weakly undulatory extinction, most abundant mineral in the thin sections, few polycrystalline grains with undulatory extinction
plagioclase: very few grains, with polysynthetic twinning
alkali feldspar: few grains with inclusions, very few grains with perthitic structure, very few grains with microcline structure
mica: mostly muscovite
opaque phases: grains of opaque phases are present
carbonates: monocrystalline carbonate grains
rock fragments: quartzite (often with muscovite, in some cases with hematite), mica schist (muscovite; very few pieces), feldspar (alkali feldspar and/or plagioclase) + quartz (with undulatory extinction) associations, chert, sandstone, micritic carbonates, carbonates with larger crystals, siltstone, shell fragments, clay pellets
heavy minerals: epidote, tourmaline, rutile, garnet, zircon
amount, size and shape of particles:
the amount of particles >15 μm is ~50–55 vol%
mean grain size ~400 μm, maximum grain size ~4000 μm
non-plastic inclusions are poorely sorted by size
grains are mostly subangular with straight borders

Clay sample 5
matrix: colour (plane polarised light/crossed polars): orange (HUE 7.5YR 6/8) / bright brown (HUE 7.5YR 5/8); optical properties: anisotropic
non-plastic components:
quartz: mostly monocrystalline, subangular grains with uniform or weakly undulatory extinction, most abundant mineral in the thin sections, few polycrystalline grains with undulatory extinction
plagioclase: very few grains, with polysynthetic twinning
alkali feldspar: few grains with inclusions, very few grains with perthitic structure, few grains with microcline structure
mica: mostly muscovite
opaque phases: grains of opaque phases are present
carbonates: monocrystalline carbonate grains
other: one large slag(?) piece from glass production(?)
rock fragments: quartzite (often with muscovite, in some cases with hematite), mica schist (muscovite; very few pieces), chert
heavy minerals: garnet, epidote, tourmaline, zircon, rutile, amphibole

amount, size and shape of particles:
the amount of particles >15 μm is ~45–50 vol%
mean grain size ~300 μm, maximum grain size ~1500 μm
non-plastic inclusions are moderately sorted by size
grains are mostly subangular with straight borders

Clay sample 6

matrix: includes some larger carbonate-rich clay pellets that have no clear borders to the matrix, it is not clear whether these are non-plastic inclusions or represent a carbonate-rich part of the clay matrix; colour (plane polarised light/crossed polars): dark reddish brown (HUE 5YR 3/6) / reddish brown (HUE 5YR 4/8); optical properties: anisotropic

non-plastic components:

quartz: mostly monocrystalline, subangular grains with uniform or weakly undulatory extinction, most abundant mineral in the thin sections, few polycrystalline grains with undulatory extinction

plagioclase: very few grains, with polysynthetic twinning

alkali feldspar: few grains with inclusions, very few grains with perthitic structure, very few grains with microcline structure

mica: mostly muscovite

opaque phases: grains of opaque phases are present

carbonates: (very few) monocrystalline carbonate grains

rock fragments: quartzite (often with muscovite, in some cases with hematite), mica schist (muscovite; very few pieces), feldspar (alkali feldspar and/or plagioclase) + quartz (with undulatory extinction) associations, chert, sandstone, micritic carbonates

heavy minerals: garnet, epidote, tourmaline, zircon, rutile, amphibole

amount, size and shape of particles:
the amount of particles >15 μm is ~45–50 vol%
mean grain size ~300 μm, maximum grain size ~1500 μm
non-plastic inclusions are moderately sorted by size
grains are mostly subangular with straight borders

Clay sample 7

matrix: colour (plane polarised light/crossed polars): bright reddish brown (HUE 5YR 5/8) / brown (HUE 7.5YR 4/6); optical properties: anisotropic

non-plastic components:

quartz: mostly monocrystalline, subangular grains with uniform or weakly undulatory extinction, most abundant mineral in the thin sections, few polycrystalline grains with undulatory extinction

plagioclase: very few grains, with polysynthetic twinning

alkali feldspar: few grains with inclusions, very few grains with perthitic structure, very few grains with microcline structure

mica: mostly muscovite

opaque phases: grains of opaque phases are present

other: one large slag(?) piece from glass production(?)

rock fragments: quartzite (often with muscovite, in some cases with hematite), mica schist (muscovite; very few pieces), feldspar (alkali feldspar and/or plagioclase) + quartz (with undulatory extinction) associations (very few pieces), chert, clay pellets, spikes of the sea urchin, sandstone

heavy minerals: garnet, epidote, tourmaline, zircon, rutile, amphibole

amount, size and shape of particles:
the amount of particles >15 μm is ~45–50 vol%
mean grain size ~300 μm, maximum grain size ~1300 μm
non-plastic inclusions are moderately sorted by size
grains are mostly subangular with straight borders