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Carvajal López, J.C., Hein, A., Glascock, M.D. et al. (1 more author) (2018) Combined petrographic and chemical analysis of water containers and glazed wares in the Early Islamic Vega of Granada (southeast Spain, 6th to 12th centuries CE). Journal of Archaeological Science: Reports, 21. pp. 1130-1140. ISSN 2352-409X

https://doi.org/10.1016/j.jasrep.2017.09.016

Combined petrographic and chemical analysis of water containers and glazed wares in the early Islamic Vega of Granada (southeast Spain, sixth to twelfth centuries CE)

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Abstract:

In this paper petrographic and NAA analyses of two categories of ceramic wares of the early medieval Vega of Granada (southeast Spain) are presented. The vessels analysed include Water Containers and Glazed Wares and were manufactured between the sixth and the twelfth centuries CE. This is the period of the Islamization of Iberia and the emergence of al-Andalus. The studies in this paper offer an opportunity to understand technological, social and economic changes that were part of the pattern of Islamization. The results of this work show that there is a differential pattern of distribution for the samples studied in the eastern and western areas of the Vega and that there is a chronological change in technological variability of the production of the wares under investigation. An earlier period in which this variability is high gave way to a period where the variability is much less and potentially more standardized technological procedures were followed.

Keywords: ceramic petrography, NAA, technological change, Islamization, Iberia

Highlights:

*A combination of petrographic and NAA analysis is used.

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*The samples studied include very similar glazed and unglazed wares.

*The results show geographical and chronological patterns of change.

*The conclusions tie in with other observed patterns of Islamization

1. Introduction

In this paper a study of the process of manufacture and distribution of water containers and glazed wares in the early medieval Vega of Granada is offered. This research was organized and conducted in the context of the Marie Curie project ARANPOT, which aims to shed light on the process of Islamization of the Iberian Peninsula during the Early Medieval period (sixth to twelfth centuries CE). In this project a carefully selected assemblage of contextualized ceramics coming from different excavations in the area of the Vega of Granada, in Southeast Spain, was analysed with a range of different methods in order to document technological change as the process of Islamization unfolded. The final aim is to establish links between the former, technological change, and the latter, Islamization, if possible.

2. Archaeological background and purpose of this study.

The Vega of Granada is a region in southeast Spain over which the River Genil flows after leaving the mountainous range of Sierra Nevada to the east and until it reaches the end of the Vega in Loja, to the west. It has a triangular shape due to the geological history of the region, in which tectonics and isostasy had a relevant role, and it is surrounded by mountain ranges formed during the Alpine orogeny, in which metamorphic and sedimentary rocks are abundant. The geology of the Vega has a complex history: towards the east it is composed of sediments from the geological formations of the mountains of Sierra Nevada, with abundant metamorphic rocks, and an outcrop of a subsidence zone of the Alpine period composed of sedimentary rocks. In the centre and in the west, the clay includes sediments from the hills that surround the Vega to the north, west and south, all containing sedimentary and metamorphic rocks of different facies to those of Sierra Nevada (cf. Carvajal López and Day 2013; 2015).

The Islamization of Iberia occurred between the initial invasion of 711 CE and the formation, development and fall of the Umayyad state of Cordoba from the eighth to the eleventh centuries CE (Chalmeta Gendrón 1994, Manzano Moreno 2006). The Vega of Granada was a very peripheral area with respect to Cordoba, but from the tenth century onward it was integrated into a main route that connected the capital of the state with Almeria, the main port of the Umayyads (Carvajal López 2008). This change in the dynamics of the area of the Vega allows us to look at the impact of different mechanisms of Islamization in the same area. For this, a range of wares coming from seven archaeological sites dated to the period between the sixth and the twelfth centuries CE has been selected. They are, from east to west: Cerro del Castillejo in Nívar, the Albaycín in Granada, Ilbira in Atarfe, Cerro del Molino del Tercio in Salar, Cerro de la Mora in Moraleda de Zafayona, Cerro de la Solana de la Verdeja in Villanueva de Mesía and Manzanil in Loja (Fig 1). More details about these sites can be found in Álvarez García 2009; Carvajal López 2008; 2009; Carvajal López and Day 2013; Jiménez Puertas 2008; Jiménez Puertas et al 2009; Ruiz Jiménez 2008.

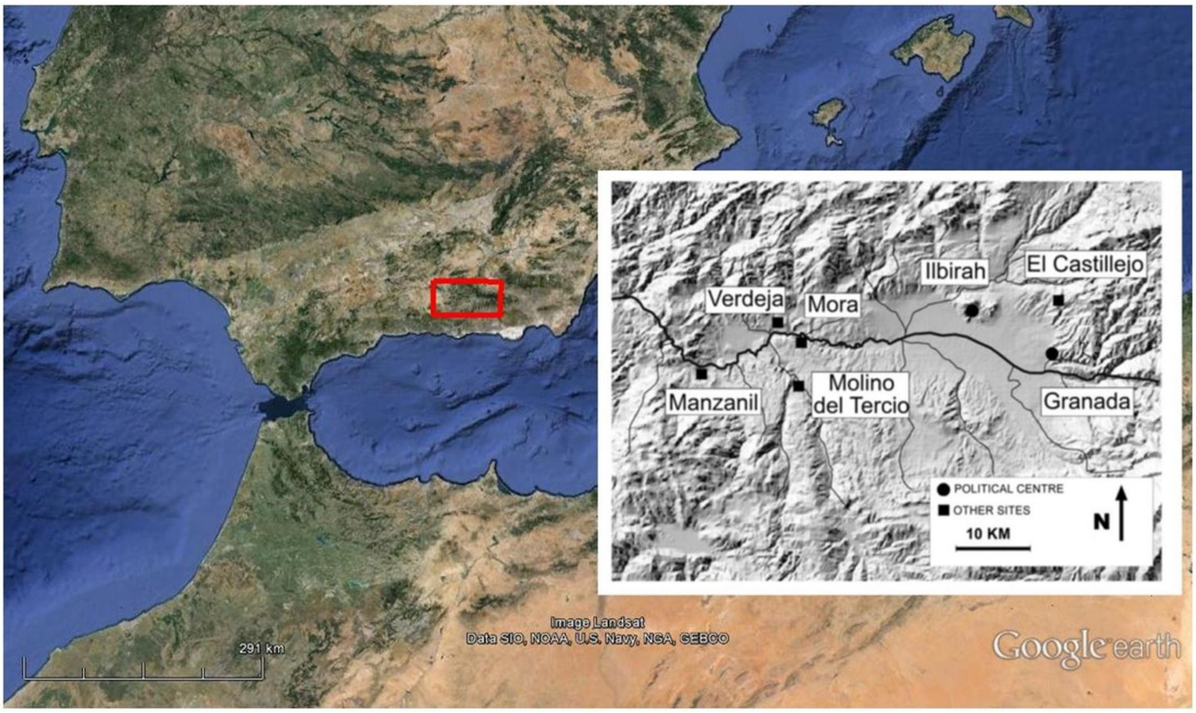

Figure 1: Location of the Vega of Granada and of the sites under analysis

This is not the first pottery study carried out within the framework of ARANPOT. Previously a petrographic and macroscopic study was conducted on cooking pots from the same archaeological deposits and dates mentioned above. The study aimed at micro-provenancing the pots and shedding light on the technological elements of their manufacture. It showed conclusively that in the case of the cooking pots fabric recipes did not substantially change from the pre-Islamic (sixth to seventh centuries CE) to the Islamic period (eighth to twelfth centuries CE), but there were major changes in modelling techniques and in workshop organization. The potters had been initially based in or within the range of each different archaeological site, but the numbers of the study suggest that, with growing relevance of towns from the tenth century, the production from urban workshops tends to overcome the production from the smaller, non-urban centres. This process was developed in four archaeological and historical phases which show increasing standardisation in the process of production and centralisation of their location (that is, potters moved from workshops placed in rural areas to nucleated urban centres of production):

1. Phase I (mid-sixth to late eighth or early ninth centuries CE): Pottery was produced with a wide range of forms and techniques in workshops with only very local distribution.

2. Phase II (late eighth or early ninth centuries to *circa* 925 CE): The variability of forms and techniques is still a feature of this period, but the consolidation of some morphological types is noted. In terms of distribution, the production is still based on dispersed centres, but the movement of pots between the towns of Ilbira and Granada (Albaycín) and from them to other centres is noted.

3. Phase III (*circa* 925 to *circa* 1011 CE): Urban production is clearly attested in the two towns of Ilbira and Granada. Historical data suggest that there is a contraction or even an abandonment of rural centres of pottery production. Apart from Ilbira and Granada, no archaeological occupation is observed in this phase in any of the sites under study in this paper.

4. Phase IV (circa 1011 CE to mid-twelfth century CE): The distribution of the output of the urban workshops of Granada reaches rural places and takes over local production, thus confirming that the model of pottery production and distribution has changed radically since the beginning of the period under consideration (Carvajal López and Day 2013; 2015).

This study was in line with a range of other evidence, like the one that is underlined by the development of irrigation systems in the Vega of Granada (Jiménez Puertas 2007; Carvajal López 2008; Jiménez Puertas and Carvajal López 2011) or the political changes (Carvajal López 2013). All the evidence suggests that initially the Vega was a peripheral and rural area in which the cultural conflict inherent to Islamization was lived and negotiated with ad-hoc mechanisms. From the tenth century onwards, all of the social, economic and political changes in the Vega and in al-Andalus in general brought the area within the scope of interest of the Umayyad government of Cordoba. As a result, Islamization became more of a standardised process, with processes and ideology more under the control of the Cordovan elites and their local allies (Carvajal López 2013).

There is the chance to expand the work done so far with other categories of pottery beyond those of cooking wares, and so to check if the evidence about their production and distribution challenge or confirm the line of work mentioned above. Work has started on another category of pottery coming from the Vega of Granada, the large containers (Carvajal López 2012). This paper proceeds further in this line of work with a study of water containers and glazed ceramics.

3. Materials and methods

This study features a combined petrographic and chemical analysis of two types of ceramics coming from the Vega of Granada, types that have been categorized as Water Containers (Table 1) and Glazed Wares (Table 2). The sherds have been retrieved from excavated and well-contextualised deposits from the same seven archaeological sites in the Vega of Granada mentioned above, and therefore represent the same chronology (sixth to twelfth centuries CE) .

WC1 and related

Sample	Site	E/W	Ph	PF	Ch
1.15	Som	E	II	WC1	-
1.16	Som	E	II	WC1	-
1.24	Tej	E	III	WC1	-
1.25	Tej	E	III	WC1	-
2.13	Nv1	E	I	WC1	B1
2.14	Nv1	E	I	WC1	-
2.15	Nv1	E	I	WC1	A1
2.16	Nv1	E	I	WC1	A1
2.17	Nv1	E	I	WC1	-
2.18	Nv1	E	I	WC1	A1
2.19	Nv1	E	I	WC1	-
2.20	Nv1	E	I	WC1	A1
2.21	Nv1	E	I	WC1	-
2.22	Nv1	E	I	WC1	A1
2.23	Nv1	E	I	WC1	B1
2.24	Nv1	E	I	WC1	B1
4.38	Som	E	II	WC1	A3
4.39	Som	E	II	WC1	A3
4.40	Som	E	II	WC1	A3
4.41	Som	E	II	WC1	A3
4.42	Som	E	II	WC1	-
4.43	Som	E	II	WC1	A3
4.44	Som	E	II	WC1	-
5.8	Som	E	II	WC1	A3
5.10	Som	E	II	WC1	-
5.11	Som	E	II	WC1	-
5.13	Som	E	II	WC1	-
5.14	Som	E	II	WC1	A1
NS47	Tej	E	III	WC1	-
NS95	Nv2	E	IV	WC1	C3
NS96	Nv2	E	IV	WC1	Out
NS97	Nv2	E	IV	WC1	A1
NS98	Nv2	E	IV	WC1	A1
NS99	Nv2	E	IV	WC1	-
NS100	Nv2	E	IV	WC1	Out
NS101	Nv2	E	IV	WC1	A1
NS102	Nv2	E	IV	WC1	A1
NS103	Nv2	E	IV	WC1	C3
NS221	Gr1	E	I	WC1	B1
NS222	Gr1	E	I	WC1	Out
NS223	Gr1	E	I	WC1	A1
NS224	Gr1	E	I	WC1	A1
NS227	Gr1	E	I	WC1	A1
NS229	Gr1	E	I	WC1	A1
NS230	Gr1	E	I	WC1	A1
NS249	Gr2	E	IV	WC1	A1
NS251	Gr2	E	IV	WC1	A3
NS254	Gr2	E	IV	WC1	A1
NS255	Gr2	E	IV	WC1	-
NS256	Gr2	E	IV	WC1	A1
NS257	Gr2	E	IV	WC1	A1
1.27	Man	W	II	WC1	-
4.58	CV	W	I	WC1	Out
4.60	CV	W	I	WC1	A1
4.62	CV	W	I	WC1	D (a)
4.65	CV	W	I	WC1	A1
4.66	CV	W	I	WC1	-
4.67	CV	W	I	WC1	A3
4.68	CV	W	I	WC1	A3
4.77	Man	W	II	WC1	-
4.80	Man	W	II	WC1	B1
4.83	Man	W	II	WC1	B1
4.84	Man	W	II	WC1	B2
4.85	Man	W	II	WC1	B1
4.87	Man	W	II	WC1	B1
4.89	Man	W	II	WC1	-
4.93	Man	W	II	WC1	-
NS146	CM	W	II	WC1	-
NS147	CM	W	II	WC1	-
NS149	CM	W	II	WC1	-
NS150	CM	W	II	WC1	-
NS153	CM	W	II	WC1	-
NS154	CM	W	II	WC1	-
NS188	MZ	W	II	WC1	-
NS190	MZ	W	II	WC1	-
NS191	MZ	W	II	WC1	-
NS193	MZ	W	II	WC1	-
NS194	MZ	W	II	WC1	-
NS199	MZ	W	II	WC1	-
1.29	Man	W	II	WC1 (rel)	-
4.61	CV	W	I	WC1 (rel)	-

WC2-4 and related

Sample	Site	E/W	Ph	PF	Ch
5.9	Som	E	II	WC2	Out
5.12	Som	E	II	WC2	-
NS43	Tej	E	III	WC2	-
NS94	Nv2	E	IV	WC2	-
NS253	Gr2	E	IV	WC2	A1
NS259	Gr2	E	IV	WC2	A1
4.59	CV	W	I	WC2	Out
4.63	CV	W	I	WC2	-
4.69	CV	W	I	WC2	-
4.81	Man	W	II	WC2	B2
4.90	Man	W	II	WC2	-
4.91	Man	W	II	WC2	-
NS143	CM	W	II	WC2	-
NS151	CM	W	II	WC2	-
NS152	CM	W	II	WC2	-
NS157	CM	W	II	WC2	-
NS187	MZ	W	II	WC2	-
NS189	MZ	W	II	WC2	-
NS192	MZ	W	II	WC2	-
NS195	MZ	W	II	WC2	-
NS196	MZ	W	II	WC2	-
NS197	MZ	W	II	WC2	-
NS198	MZ	W	II	WC2	-
NS200	MZ	W	II	WC2	-
4.86	Man	W	II	WC2 (rel)	-
NS144	CM	W	II	WC2 (rel)	-
NS156	CM	W	II	WC2 (rel)	-
NS145	CM	W	II	WC3	-
NS148	CM	W	II	WC3	-
NS155	CM	W	II	WC3	-
1.26	Man	W	II	WC4	-
1.28	Man	W	II	WC4	-
4.64	Man	W	II	WC4	Out
4.78	Man	W	II	WC4	-
4.79	Man	W	II	WC4	Out
4.82	Man	W	II	WC4	B1
4.88	Man	W	II	WC4	Out
4.92	Man	W	II	WC4	-

Table 1: List of WC samples, indicating sites and area of provenance (E/W, eastern or western Vega of Granada), dating (Ph = Phase) and the results of the techniques applied (PF = Petrographic Fabric; Ch = Chemical Group). Sites key: Man = Polígono del Manzanil (Loja), CV = Cerro de la Solana de la Verdeja (Villanueva de Mesía); CM = Cerro de la Mora (Moraleda de Zafayona); MZ = Cerro del Molino del Tercio (Salar); Som = Sombrerete, Ilbira (Atarfe) Phase II; Tej: = Tejoletes, Ilbira (Atarfe) Phase III; Gr1 = Callejón del Gallo, Albaycín, Granada, Phase I; Gr2 = Callejón del Gallo, Albaycín, Granada, Phase IV; Nv1 = Cerro del Castillejo de Nívar, Phase I; Nv2 = Cerro del Castillejo de Nívar, Phase IV. Data key: rel = related sample (in petrography); (a) = associate (chemical analysis); Out = outlier (chemical analysis)

GW1-5 and loner

Sample	Site	E/W	Ph	GC	PF	Ch	Sample	Site	E/W	Ph	GC	PF	Ch
5.21	Tej	E	III	H	GW1	A2	NS119	Nv2	E	IV	G	GW2	-
NS16	Som	E	II	G	GW1	D	NS122	Nv2	E	IV	H	GW2	A2
NS17	Som	E	II	G	GW1	E	NS123	Nv2	E	IV	H	GW2	A2
NS21	Som	E	II	G	GW1	-	NS124	Nv2	E	IV	H	GW2	Out
NS22	Som	E	II	GM	GW1	D	NS125	Nv2	E	IV	H	GW2	A2
NS23	Som	E	II	H	GW1	E (a)	NS126	Nv2	E	IV	H	GW2	Out
NS24	Som	E	II	2C	GW1	-	NS127	Nv2	E	IV	H	GW2	A2
NS26	Som	E	II	G	GW1	-	NS272	Gr2	E	IV	H	GW2	A2
NS29	Som	E	II	G	GW1	A2	NS273	Gr2	E	IV	H	GW2	A2
NS31	Som	E	II	2C	GW1	A2 (a)	NS274	Gr2	E	IV	H	GW2	A2
NS32	Som	E	II	G	GW1	-	NS275	Gr2	E	IV	H	GW2	A2
NS118	Nv2	E	IV	G	GW1	-	NS276	Gr2	E	IV	H	GW2	A2
NS120	Tej	E	III	G	GW1	-	NS277	Gr2	E	IV	H	GW2	A2
NS121	Nv2	E	IV	G	GW1	A2	NS288	Tej	E	III	H	GW2	A2
NS287	Tej	E	III	H	GW1	D	NS289	Tej	E	III	H	GW2	A2
NS291	Tej	E	III	H	GW1	A2	NS290	Tej	E	III	H	GW2	D
5.27	Man	W	II	2C	GW1	C1	NS292	Tej	E	III	H	GW2	Out
NS62	Man	W	II	H	GW1	Out	5.26	Man	W	II	G	GW2	-
NS64	Man	W	II	2C	GW1	-	5.28	Man	W	II	G	GW2	C2
NS68	Man	W	II	G	GW1	-	5.29	Man	W	II	2C	GW2	C1
NS79	Man	W	II	GM	GW1	C1	5.30	Man	W	II	H	GW2	-
NS82	Man	W	II	GM	GW1	C1	NS69	Man	W	II	2C	GW2	-
NS165	CM	W	II	H	GW1	-	NS71	Man	W	II	G	GW2	C2
NS211	MZ	W	II	2C	GW1	-	NS77	Man	W	II	GM	GW2	C1
5.15	Tej	E	III	H	GW2	C3	NS78	Man	W	II	GM	GW2	C1
5.16	Tej	E	III	H	GW2	C3	NS80	Man	W	II	GM	GW2	C2
5.17	Tej	E	III	H	GW2	C3	NS81	Man	W	II	GM	GW2	C1
5.18	Tej	E	III	H	GW2	C3	NS83	Man	W	II	GM	GW2	C1
5.2	Tej	E	III	H	GW2	C3	NS210	MZ	W	II	G	GW2	-
5.22	Tej	E	III	H	GW2	A2	NS73	Man	W	II	G	GW3	-
5.23	Tej	E	III	H	GW2	-	NS74	Man	W	II	G	GW3	-
5.24	Tej	E	III	H	GW2	A2	NS285	Tej	E	III	B	GW4	-
5.25	Tej	E	III	H	GW2	E (a)	NS286	Tej	E	III	B	GW4	-
NS15	Som	E	II	G	GW2	E	NS61	Man	W	II	H	GW5	-

NS20	Som	E	II	H	GW2	-	NS63	Man	W	II	H	GW5	-
NS27	Som	E	II	G	GW1	E	NS209	MZ	W	II	G	GW5	-
NS28	Som	E	II	H	GW2	-	NS25	Som	E	II	H	Loner	-
NS30	Som	E	II	GM	GW2	C3							

Table 2: List of GW samples, indicating sites and area of provenance (E/W, eastern or western Vega of Granada), dating (Ph = Phase), glaze colour (GC) and the results of the techniques applied (PF = Petrographic Fabric; Ch = Chemical Group). Colours key: B = Brown, G = Green, H = Honey, GM = Green and Manganese, 2C = Two-coloured. Sites key: Man = Polígono del Manzanil (Loja), CV = Cerro de la Solana de la Verdeja (Villanueva de Mesía); CM = Cerro de la Mora (Moraleda de Zafayona); MZ = Cerro del Molino del Tercio (Salar); Som = Sombrerete, Ilbira (Atarfe) Phase II; Tej: = Tejoletes, Ilbira (Atarfe) Phase III; Gr1 = Callejón del Gallo, Albaycín, Granada, Phase I; Gr2 = Callejón del Gallo, Albaycín, Granada, Phase IV; Nv1 = Cerro del Castillejo de Nívar, Phase I; Nv2 = Cerro del Castillejo de Nívar, Phase IV. Data key: rel = related sample (in petrography); (a) = associate (chemical analysis); Out = outlier (chemical analysis)

The Water Containers of this paper are jars and small jars made in whitish to pinkish or brownish beige ware, usually with a powdery and soft texture. They must have been used for transportation and service of fluids, mainly water. These wares are found at all of the sites under consideration and they are associated to the whole range of dates. The Glazed Wares of this study, instead, have been dated with certainty from the late ninth century in the Vega of Granada, although some of them could be tentatively dated slightly earlier, in the middle of the same century (Carvajal López 2008; Salinas Pleguezuelo 2013; Salinas Pleguezuelo, Zozaya 2015). That means that they have been documented only from Phase II onwards. The forms of the Glazed Wares include small closed vessels in the earlier period and dishes, lamps and small jars later on. For the purposes of this study, glazed cooking pots have been excluded, as they have been considered as part of a different category of wares (included amongst the cooking wares: see Carvajal López and Day 2013; 2015). There were a number of different colours used for the glazed vessels and different groups have been distinguished on the basis of the colour combinations and applications. Table 3 shows the characteristics used to define those different types.

Glazing Colouration	Featured colours	Dates and sites where it is found	Archaeological Phases
Green Glaze	Olive to dark green	9th to 10th centuries. Found in all archaeological sites under consideration	II
Honey-coloured	Yellowish to greenish	9th to 12th centuries. Found in Cerro del	II-IV

Glaze	honey. Sometimes with black lines of manganese	Castillejo, Ilbira, Albaycín, and Manzanil	
Brown Glaze	Dark brown	9th to 10th centuries. Found in Ilbira and Manzanil	III
Two-Colours Glaze	Usually green on the exterior and brown on the interior, sometimes vice versa	9th to 10th centuries. Found in Ilbira and Manzanil	II
Green and Manganese Glaze	White, black and green, sometimes with purple also	9th to early 10th centuries. Found in Ilbira and Manzanil (there are also abundant later samples, but they have not been analysed in this study)	II

Table 3: Glazing colourations applied to the ceramics considered in this study

A total of 194 sherds were studied by petrographic analysis, including 119 samples of Water Containers and 75 of Glazed Wares. Thin sections of circa 30 microns thickness were made of every sample and they were examined with a polarizing microscope and described according to the methodology developed by Whitbread (1986; 1989; 1995: 369-96; 1996). The petrographic study was combined with neutron activation analysis (NAA) of 104 samples out of the total assemblage from the Vega. The selected samples were chosen in order to represent the main petrographic groups. At NCSR *Demokritos* small fragments of the sherds were cleaned of any traces of glaze and then powdered in an agate mortar. Subsamples of c. 100 mg were then sent to the University of Missouri Research Reactor (MURR) for NAA. The combination of petrographic and elemental analysis was expected to provide a solid, parallel, grouping of the wares under analysis.

4. Results

4.1. Petrography

The petrographic study of the Water Containers reveals four fabrics (see Appendix I), with some related samples to two of the Fabrics. Related samples are those which in general fulfil most criteria to be considered as members of a Fabric, but which differ significantly in a few aspects:

- *Fabric WC1: Fine calcareous fabric with sedimentary and low-grade metamorphic rocks* (n = 79, and 2 related samples).
- *Fabric WC2: Coarse calcareous fabric with sedimentary and low-grade metamorphic rocks* (n = 24, and 3 related samples).
- *Fabric WC3: Coarse calcareous fabric with grog* (n=3).
- *Fabric WC4: Coarse calcareous fabric with micritic limestone* (n=8).

Most of the samples analysed fall within two fabrics, Fabric WC1 and Fabric WC2. They have the same petrological and mineralogical base: a more or less calcareous matrix containing inclusions of micritic limestone, quartz-based sedimentary to low-grade metamorphic rocks and clay pellets and textural features that might suggest clay mixing. The variety within these groups, particularly within Fabric WC1, is extensive and with petrography alone it is not possible to determine if it is the result of similar raw materials and techniques used by a number of workshops or if it is the output of a single centre. The difference between Fabric WC1 and Fabric WC2 is based on the relative texture of the fabric. Although the range of fine to -coarse (like of many other features of these two groups) is so gradual that it does not show a clear separation at any point, it was observed that the coarser samples tended to come from sites of the western part of the Vega of Granada. In the hope of making this trend clear, and with the absence of better criteria, an arbitrary separation between Fabric WC1 and Fabric WC2 was established according to inclusion frequency and grain size. Fabric WC2 comprises those samples that have >20% of inclusions with respect to the matrix and the voids and in which more than 15% of the inclusions belong to the coarse fraction. The rest are classified as Fabric WC1. The distribution of these two groups confirms the impression of divergent geographical patterns for each fabric: whereas Fabric WC1 is quite evenly distributed across all the sites of the Vega of Granada, Fabric WC2 is concentrated mainly on the western part. Two other fabrics, Fabric WC3 and Fabric WC4, have been identified, exclusively related to two western sites, Cerro de la Mora and Manzanil respectively.

As for the Glazed Wares, their study with petrographic analysis indicates five different fabrics and one loner, which is defined as the sample of a fabric that clearly does not fall into any of the defined groups (see Appendix I)

- *Fabric GW1: Fine glazed fabric with sedimentary and low-grade metamorphic rocks*, (n = 24).

- *Fabric GW2: Fine glazed fabric with dominant clay pellets*, (n = 43).
- *Fabric GW3: Fine glazed fabric with micritic limestone and serpentinite*, (n = 2).
- *Fabric GW4: Fine glazed fabric with secondary calcite*, (n= 2).
- *Fabric GW5: Fine glazed fabric with basalt and serpentinite*, (n = 3).
- *Loner: Fine glazed fabric with predominant monocrystalline quartz,* (n = 1).

Fabric GW1 and Fabric GW2 are very similar in terms of composition between themselves and with Fabric WC1 and Fabric WC2: they are fine or very fine and they contain the same range of inclusions: micritic limestone, quartz-based sedimentary to low-grade metamorphic rocks and mudstones and textural features, particularly clay pellets. However, it was observed that the relative proportion of textural features was in some cases a lot larger than in others, and this could be the result of differences in the process of manufacture. As in the former case, the classification was based on measurable features. Groups were separated according to the relative amounts of clay pellets and relevant textural features, which are predominant or dominant in Fabric GW2 and less abundant in Fabric GW1. The other three fabrics, GW3, GW4, and GW5 are formed by very small numbers of samples concentrated in Manzanil and Cerro del Molino del Tercio (GW3 and GW5) and in Ilbira (GW4). Fabrics GW3 and GW5 belong to Phase II, and Fabric GW4 is dated to Phase III.

4.2. Chemical analysis

In order to assess the chemical variability of the ceramics a variation matrix of the dataset was determined following the approach of Buxeda i Garrigós and Kilikoglou (2001). For the statistical evaluation the concentrations of arsenic (As), sodium (Na) and nickel (Ni) were disregarded because of known inhomogeneities or missing values. With the subsequent omission of antimony (Sb), which presents by far the largest variation, the chemical variability of the analysed samples is reduced, with a total variation of 0.899. The small variability affects the definition of the groups, as can be seen in Figures 2 and 3, which present hierarchical clustering and principal component analysis (PCA) of the log-ratio transformed data respectively. Apart from some chemical loners the elemental compositions in general appear to be rather homogeneous, which might indicate that the raw materials used for the ceramics came from a common geological context. This is, however, a far cry from assuming that the ceramics were all locally produced, for example, in the Vega of Granada. In fact, elemental compositions of raw materials from the Vega are probably very similar to raw materials from most of Southeast Iberia and even parts of North Africa, as all these areas have a shared geological history (Sanz de Galdeano 2001; Lhénaff 2001). Many centres could have been producing these wares, which could explain the considerable number of chemical loners. The data were included in the ceraDAT database and further evaluated in order to form chemical groups based on the initial clusters indicated by hierarchical clustering and PCA (Table 4). Therefore, the similarity of individual samples with average compositions of the groups was tested iteratively, in order to decide about the inclusion of new samples or removal of initially included samples. In the case that a sample was found to be similar to a particular reference group but presented differences in only one or two elements its similarity was regarded as 'associate' but its composition was not considered in the evaluation of the group average composition (Hein and Kilikoglou 2011).

Cluster A

In comparison to the other samples, the ceramics in Cluster A present lower concentrations of the lanthanides. This cluster can be divided into three sub-groups: IS-A1, IS-A2 and IS-A3. The main difference between IS-A2 and the other two sub-groups is the higher Sb concentration, which is particularly striking because IS-A2 includes exclusively glazed wares, while IS-A1 and IS-A3 comprise water containers. Group IS-A3 presents generally lower element concentrations, which could be explained by a higher content of non-plastic inclusions in the ceramics, which are low in trace elements.

Cluster B

Cluster B appears to be divided in both the hierarchical clustering (Fig. 2) and the PCA (Fig. 3). Accordingly it forms two sub-groups: IS-B1 and IS-B2. Both groups present comparably low Ca contents and relatively high concentrations of transition metals, lanthanides and actinides. Group IS-B2 presents particularly high concentration of iron (Fe) and Ni and the highest concentrations of europium (Eu), samarium (Sm) and terbium (Tb).

Cluster C

Cluster C, which can also be divided into three sub-groups, appears to be divided in the hierarchical clustering (Fig. 2) with sub-group IS-C1 presenting particularly low concentrations of barium (Ba), caesium (Cs) and rubidium (Rb). Sub-group IS-C3, on the other hand, presents clearly higher Cs and Rb concentrations but a comparably low calcium content.

Cluster D

The composition of Group IS-D is not very different from the sub-groups of Cluster C. The main differences are slightly lower concentrations of lanthanides and actinides.

Cluster E

Group IS-E presents a comparably high calcium content and significantly low concentrations of Fe, scandium (Sc) and uranium (U).

	IS-A1		**IS-A2**		**IS-A3**		**IS-B1**		**IS-B2**		**IS-C1**		**IS-C2**		**IS-C3**		**IS-D**		**IS-E**	
	23 samples		*18 + 1(-) samples*		*9 samples*		*9 samples*		*2 samples*		*8 samples*		*3 samples*		*8 samples*		*4 + 1(-) samples*		*3 + 2(-) samples*	
	average	*stdev*	*average*	*stdev*	*average*	*stdev*	*average*	*stdev*	*average*	*stdev*	*average*	*stdev*	*average*	*stdev*	*average*	*stdev*	*average*	*stdev*	*average*	*stdev*
As	11.3	3.2	15.3	12.6	11.3	1.2	14.6	7.7	16.4	0.7	24.2	4.2	20.0	1.2	15.0	4.2	17.2	8.8	24.5	4.6
Ba	764	288	513	70	811	245	749	140	634	1	507	108	587	114	564	112	503	22	489	87
Ca (%)	7.6	1.8	10.6	2.1	12.4	2.1	5.5	1.7	5.3	1.9	9.0	1.1	8.6	1.4	6.6	1.7	10.2	1.4	11.2	1.7
Ce	78.8	0.7	77.6	0.9	61.0	1.8	100.4	2.2	100.9	0.1	88.0	1.3	83.3	1.3	83.8	1.8	79.1	1.1	69.4	0.9
Co	17.9	1.0	17.6	0.6	13.9	0.6	21.3	1.0	21.0	0.9	16.7	1.4	14.3	1.0	15.0	1.0	16.9	0.8	14.1	0.3
Cr	98	3	99	3	76	2	122	5	122	2	107	4	94	2	89	3	88	1	85	1
Cs	10.4	4.0	9.8	1.1	7.8	0.6	9.1	1.9	8.2	2.0	6.1	1.7	7.1	1.3	14.5	3.0	9.6	2.3	8.1	0.3
Eu	1.34	0.02	1.31	0.02	1.07	0.02	1.48	0.05	1.62	0.04	1.60	0.03	1.50	0.01	1.45	0.03	1.40	0.02	1.33	0.02
Fe (%)	4.46	0.12	4.38	0.08	3.46	0.07	4.84	0.10	5.35	0.15	4.77	0.12	4.17	0.04	3.91	0.08	4.04	0.02	3.69	0.01
Hf	4.3	0.3	4.3	0.3	3.4	0.2	4.9	0.4	5.8	0.4	5.8	0.4	6.0	0.4	6.6	0.7	5.3	0.5	4.9	0.1
La	38.7	0.5	38.7	0.4	30.7	0.9	51.4	0.9	52.8	0.7	44.8	0.9	42.0	0.9	41.9	0.5	39.5	0.6	37.6	0.7
Lu	0.40	0.02	0.40	0.02	0.31	0.01	0.48	0.02	0.50	0.01	0.46	0.02	0.46	0.01	0.44	0.02	0.42	0.02	0.37	0.00
Na (%)	0.41	0.10	0.92	0.35	0.34	0.04	0.32	0.08	0.35	0.12	0.51	0.25	0.33	0.02	0.37	0.03	0.60	0.07	0.50	0.09
Ni	47.4	11.5	49.1	11.3	35.5	10.8	52.0	15.9	83.5	0.0	44.6	4.4	59.1	11.8	55.1	9.0	67.0	16.6	47.7	7.7
Rb	144	8	123	12	106	7	159	22	109	8	58	14	86	6	126	4	119	1	105	2
Sb	1.93	0.35	6.48	2.64	1.30	0.21	1.93	0.17	1.85	0.11	3.32	0.54	3.56	1.05	3.64	1.72	4.66	1.48	2.85	0.34
Sc	15.9	0.4	15.9	0.5	12.4	0.3	19.1	0.6	18.8	0.3	16.0	0.3	13.9	0.3	14.0	0.5	14.7	0.3	13.1	0.1
Sm	6.88	0.08	6.77	0.18	5.41	0.13	8.45	0.21	9.41	0.004	7.90	0.13	7.58	0.04	7.38	0.14	6.89	0.13	6.73	0.12
Sr	670	286	859	309	874	240	726	354	414	76	478	29	410	24	325	68	493	114	513	98
Ta	1.19	0.06	1.13	0.03	0.89	0.06	1.42	0.02	1.45	0.02	1.27	0.04	1.22	0.05	1.24	0.05	1.10	0.04	1.04	0.03
Tb	0.87	0.08	0.86	0.11	0.66	0.03	0.94	0.10	1.22	0.01	1.05	0.05	0.92	0.01	0.94	0.07	1.00	0.05	0.90	0.08
Th	13.0	0.3	12.5	0.3	9.7	0.3	16.6	0.4	16.5	0.4	13.8	0.3	12.7	0.1	13.0	0.3	12.0	0.3	10.8	0.2
U	3.65	0.59	3.47	0.44	2.69	0.22	3.71	0.43	3.70	0.17	2.87	0.22	2.70	0.27	3.03	0.27	2.55	0.08	2.02	0.11
Yb	2.7	0.1	2.7	0.2	2.1	0.1	3.5	0.3	4.0	0.0	3.3	0.1	3.3	0.2	3.2	0.2	2.8	0.1	2.9	0.0
Zn	128	12	110	10	100	8	120	25	97	8	83	18	77	6	88	7	91	4	91	7
Zr	116	13	114	15	88	10	128	17	150	11	143	11	161	1	165	21	137	13	141	4

Table 4: Average composition and standard deviations of the chemical groups formed based on the initial clusters: The concentrations are given in µg/g (ppm) if not indicated elsewise. Key: (-) sample = associate sample.

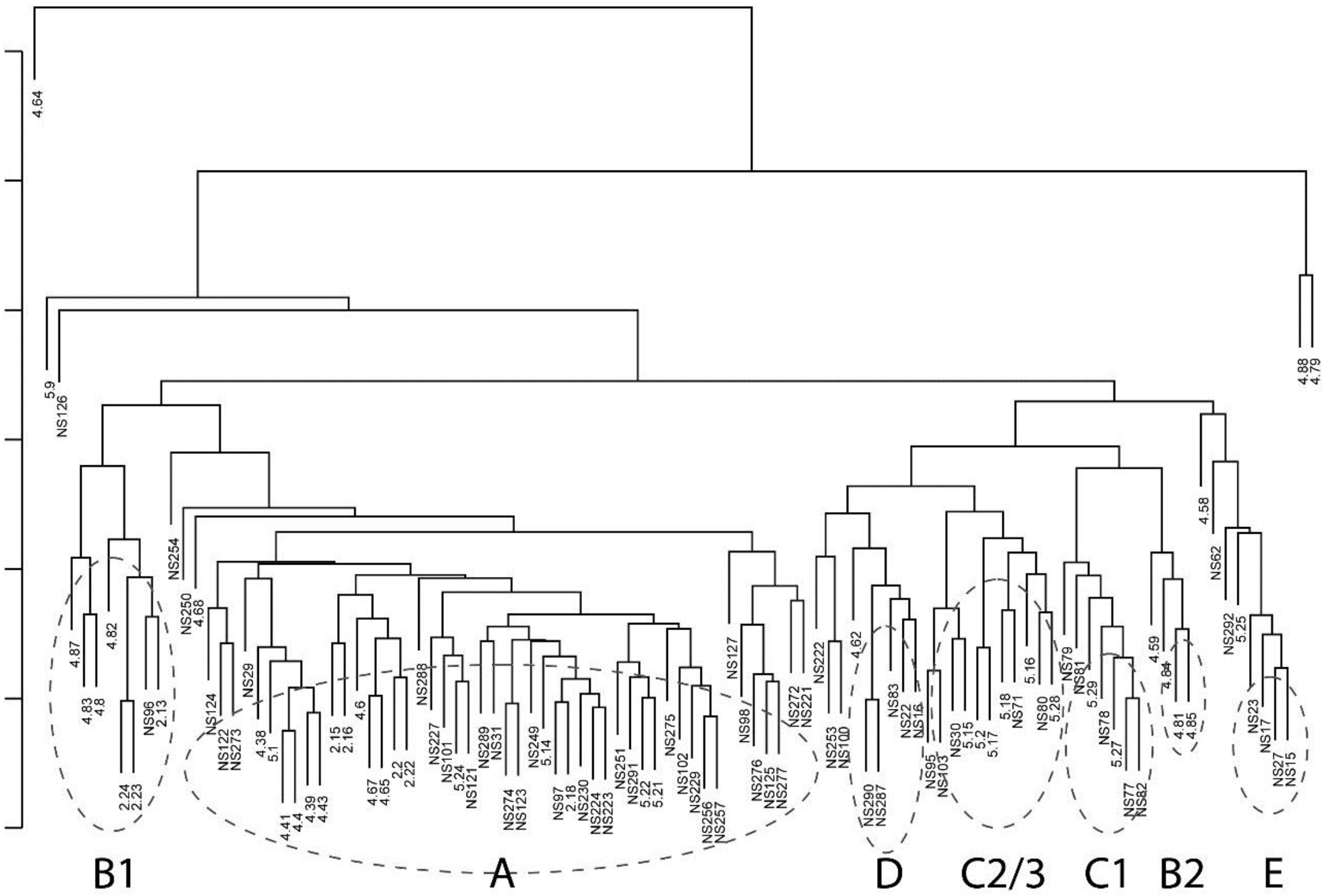

Figure 2: Hierarchical clustering of the log-ratio transformed data with the cerium (Ce) concentration as common divisor, omitting As, Na, Ni and Sb; indicated are the chemical groups, which were formed in the ceraDAT database (Hein and Kilikoglou 2011).

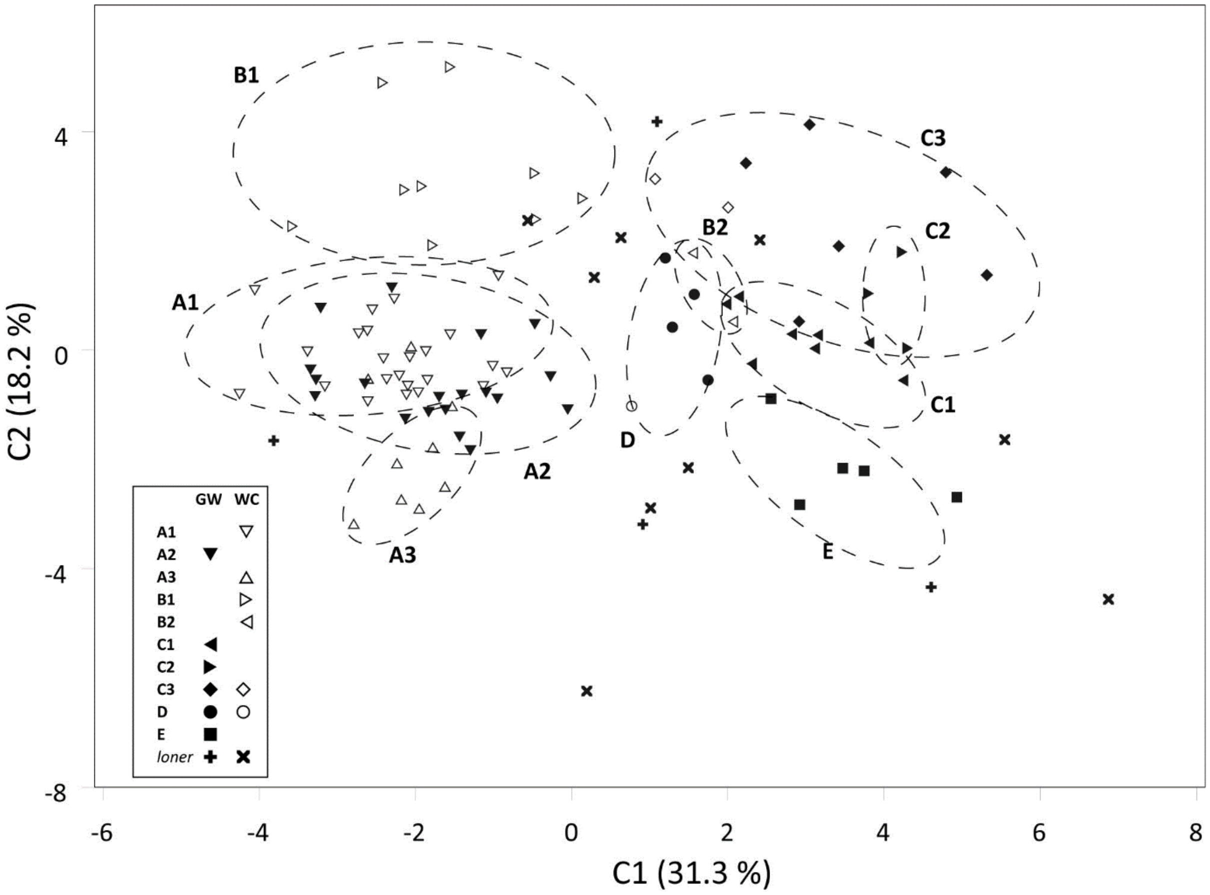

Figure 3: PCA of the log-ratio transformed data with the Ce concentration as common divisor, omitting As, Na, Ni and Sb; presented are the two first principal components covering 31.3% and 18.2 % of the variation, respectively. The ellipses indicate the chemical groups, which were formed in the ceraDAT database, and the symbols indicate the ware types: GW = Glazed Ware; WC = Water Container.

5. Discussion

5.1. Petrographic analysis of Water Containers

The distribution of the samples of Water Containers in Fabrics WC1, WC2, WC3 and WC4 (Table 5) shows a pattern of distinction between the eastern and the western areas of the Vega of Granada. Namely, almost two thirds of all the samples of Fabric WC1 come from sites in the eastern Vega of Granada (El Castillejo, Granada and Ilbira) and almost four fifths of those of Fabric WC2 come from the western part (Cerro de la Mora, Cerro del Molino del Tercio, Cerro de la Verdeja, Manzanil). The pattern of distribution is not conclusive, perhaps due to the difficulty in analytical discrimination between two very similar fabrics, or indeed reflective of the intense exchange of pots over the territory, or a combination of both. However, the pattern does exist and it is consistent with a geographical difference between the east and west in the Vega. The region is divided in two by a diapiric emergence in the area of Láchar, approximately in its centre (Lhénaff 2001: 57). The diapir is a geological intrusion of deformable material (gypsum in this case) forced into the brittle surface rocks. As gypsum is impermeable, the diapir interrupts the east-west direction of the water circulation in the Genil River depression. As a consequence, there is a bottleneck in the area of the diapiric emergence, and that accounts for strong differences in water circulation and humidity in between the east (humid) and the west (dry) (Ocaña Ocaña 1974). The settlement patterns are deeply affected by this. The many villages in the eastern part are concentrated in a variety of locations, yet they avoid the lowest lands because they are prone to flooding. In the west, villages are sparser and usually placed around streams that lead eventually to the Genil River. It is likely that this difference in settlement patterns plays a role in the distribution patterns of the two fabrics.

Fabrics WC3 and WC4 come from the western part, each one from a particular site: Cerro de la Mora and Manzanil respectively. The number of samples in each fabric is too small to extract solid conclusions, but the fabrics are clearly different and therefore they suggest that the petrographic analysis is robust and promising for future research.

There seems to be no general pattern in the distribution of the fabrics across the different chronological phases discussed above, but this is in itself interesting. Fabrics WC1 and WC2 appear in all phases, and particularly in the earlier ones (I and II), but this only reflects the fact that most of the samples have been dated to those phases. Fabrics WC3 and WC4 appear exclusively in Phase II. These chronological links have some consistency with the pattern observed in the study of the cooking pots (Carvajal López and Day 2013; 2015), as will be explored below.

	WC1	**WC2**	**WC3**	**WC4**
W samples	28 (+2 related)	18 (+3 related)	3	8
E samples	51	6	-	-

Table 5: Distribution of fabrics of Water Containers in east (E) and west (W) sites of the Vega of Granada

5.2. Petrographic analysis of Glazed Wares

Unlike the case of the Water Containers, the geographical distribution of the samples in the different fabrics of the Glazed Wares is not distinctive, but instead displays a distinct patterning according to chronology (Table 6). Samples belonging to Fabrics GW3 and GW5 and more than three quarters of the samples belonging to Fabric GW1 are from Phase II, dated between the ninth century and the early tenth century. On the other hand, almost two thirds of those of Fabric GW2 and all members of Fabric GW4 concentrate in Phases III and IV, that is, from the early tenth until the early twelfth century. The change in composition may be best explained by technological development, specifically in the processes of manufacture for this particular type of wares, as also suggested by other data.

	GW1	**GW2**	**GW3**	**GW4**	**GW5**
Phase II (early 9th-early 10th c.)	18	17	2	-	3
Phase III (early 10th-early 11th c.)	4	13	-	2	-
Phase IV (early 11th-mid-12th c.)	2	13	-	-	-
Phases III and IV combined	6	26	-	2	-

Table 6: Distribution of Glazed Wares in the archaeological phases of the Vega of Granada (1 loner is not included in the table).

5.3. Chemical analysis of Water Containers and Glazed Wares.

The two categories of wares under consideration show similar characteristics both in macroscopic and microscopic analyses. As it is reasonable to assume that similar types of clay could have been used for the fabrication of both wares, one of the first questions to address with the chemical analysis was whether significant differences could be established between Glazed Wares and Water Containers based on their elemental composition. The results indicate that both ware types appear generally separated from a chemical point of view. While the two sub-groups in Cluster B comprise exclusively Water Containers, the sub-groups in Clusters C, D and E comprise essentially Glazed Wares apart from a few water containers. This indicates that indeed different clay pastes were used for the fabrication of water containers and for the fabrication of the bodies of glazed ceramics (Table 7).

The apparent exception is Cluster A, which can be sub-divided into three subgroups, with A1 and A3 comprising exclusively Water Containers and A2 composed of Glazed Wares. The main criterion for distinguishing A2 from A1 and A3 is the significantly higher Sb concentration. The observed Sb enrichment in the glazed ceramics, however, is potentially related to contamination of the ceramic body by the glaze. Figure 4 presents the measured Sb and Rb concentrations indicating indeed a general enrichment of antimony in the bodies of glazed wares. The analysis done with SEM-EDS in a related project (see Molera et al forthcoming) did not detect any Sb in the glazes, but the amounts of the elements present in the glaze could have been below the detection limits of the device (T. Pradell, pers. communication). A potential explanation for the presence of the Sb can be its use as opacifier (Kingery and Vandiver 1986: 213) or its presence as an accompanying element in the lead materials used. Thus, despite of the significantly higher Sb concentration in group IS-A2 the use of a common base clay for the production of the ceramics in Cluster A can be assumed.

	Groups	**Frequency**	
		GW	**WC**
GW only	A2	18 (+ 1 associate)	-
	C1	8	-
	C2	3	-
	E	3 (+2 associates)	-
WC only	A1	-	23
	A3	-	9
	B1	-	9
	B2	-	2
Mostly GW	C3	6	2
	D	4	1 associate

Table 7: Association between chemical groups and categories of wares.

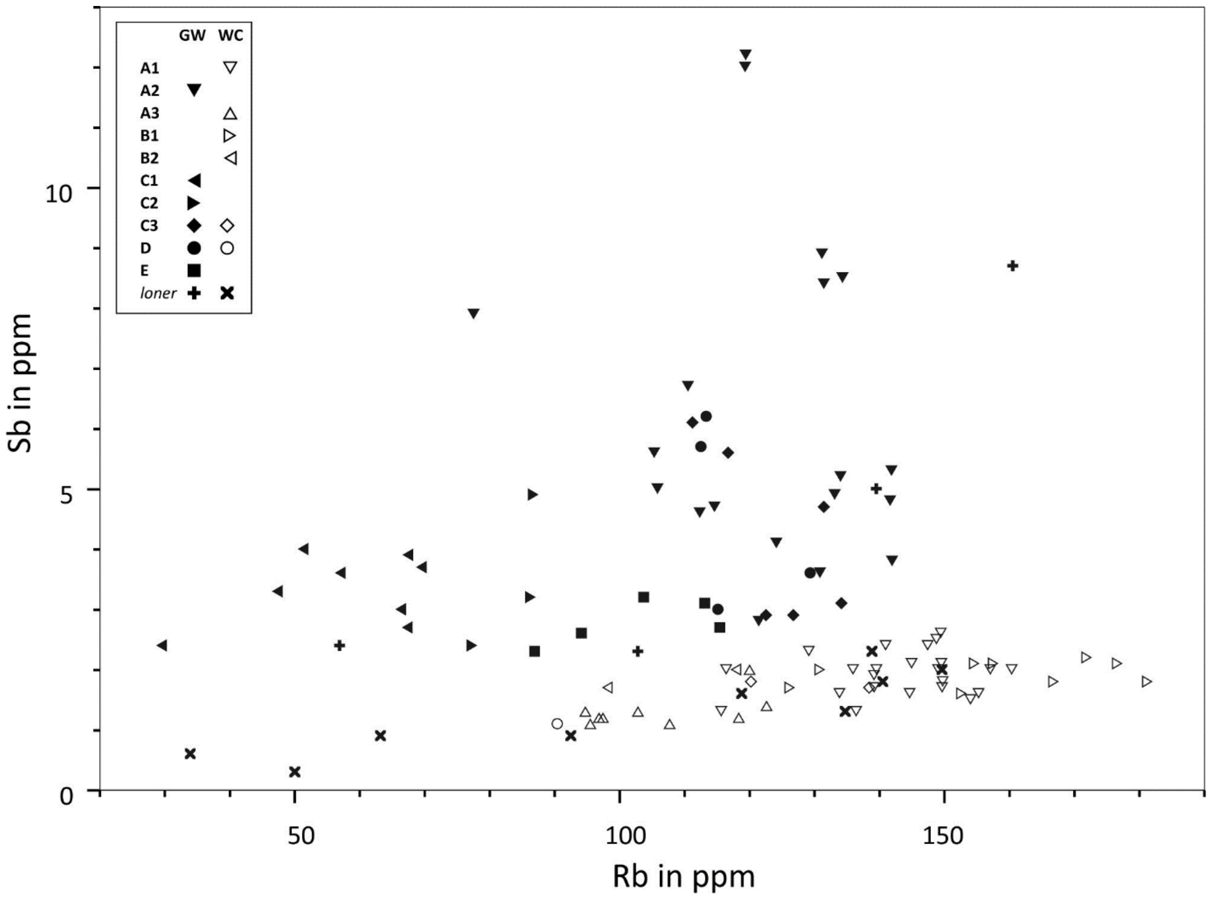

Figure 4: Sb and Rb concentrations of the analysed ceramics, the chemical groups and ware types are indicated with symbols.

In general, however, within the limits set by the categories of wares, the association between petrographic fabrics and chemical groups shown by these data is irregular (Table 8). Chemical groups contain samples of different petrographic fabrics. At the level of subgroups the picture is somewhat clearer. Over 90% (38 of 41 samples) of subgroups A1, A3 and B1 are associated with petrographic fabric WC1 (two samples are associated with WC2 and one sample with WC4) and all components of the Subgroup C2 are members of the petrographic fabric GW2. Subgroups A2, B2, C1 and C3 and Groups D and E are split between various different petrographic fabrics. In the case of groups or subgroups composed of only a few samples (B2, D and E), this may be related to a lack of resolution because of the scarce data available. Subgroup C3 and especially Subgroup A2, with larger numbers of samples, may suggest a changing technical landscape, as we will show below.

Chemical	Petrographic Fabrics

Groups	**WC1**	**WC2**	**WC4**	**GW1**	**GW2**
A1	21	2	-	-	-
A2	-	-	-	4 (+1 associate)	14
A3	9	-	-	-	-
B1	8	-	1	-	-
B2	1	1	-	-	-
C1	-	-	-	3	5
C2	-	-	-	-	3
C3	2	-	-	-	6
D	1 associate	-	-	3	1
E	-	-	-	2 (+1 associate)	1 (+1 associate)
Outliers	4	2	3	1	4

Table 8: Association between chemical groups and petrographic fabrics

The division of the Water Containers petrographic fabrics between the east and west areas of the Vega of Granada is not repeated among the chemical groups (Table 9). The reason may be that only a small number of Water Containers from the west of the Vega has been analysed by NAA and included in one of the chemical groups (of 17 samples selected, 5 were outliers and 12 could be grouped). Of these 12 samples, only two form Subgroup B2, the only one which is exclusively composed by elements of the west of the Vega. The rest of the samples of western Water Containers are included in Subgroup B1, which contains an almost even number of water containers from the east (4) and the west (5) of the Vega, or in Subgroups A1 and A3 and Group D, which are mostly composed of samples from the eastern side of the Vega. With these numbers, it is not possible to offer a robust correlation between the distribution of Water Containers in chemical groups and their provenance. Interestingly, the chemical data of the Glazed Wares can be interpreted according to this geographical pattern: the samples of Glazed Wares in Subgroups A2 and C3 and Groups E and D come exclusively from the east and those belonging to Subgroups C1 and C2 are only from the west.

	Groups	**Frequency**	
		E	W
Only samples from the E	A2	18 (+1 associate) (all GW)	-
	E	3 (+ 2 associates) (all GW)	-
Most samples from the E	A1	21 (all WC)	2 (all WC)
	A3	7 (all WC)	2 (all WC)
	C3	8 (6GW/2WC)	-
	D	4 (all GW)	1 (WC, associate)
Even numbers from the E and the W	B1	4 (all WC)	5 (all WC)
Only samples from the W	B2	-	2 (all WC)
	C1	-	8 (all GW)
	C2	-	3 (all GW)

Table 9: Distribution of chemical groups between the east (E) and west (W) of the study area

At this point it is useful to consider three other patterns of association regarding the Glazed Wares. First, the chronological division of the petrographic fabrics between Phase II on the one hand and Phases III and IV on the other is reflected in the chemical data (Table 10). Subgroups C1 and C2 and Group E are composed of samples dated to Phase II, while most of the samples in Subgroups A2 and C3 date to Phase III or Phase IV. The only exception in this case is Group D, which shows an even distribution between Phases II and III. The lack of definition of this group is due to low sample numbers as noted above.

Chemical Groups (GW only)	**Archaeological Phases**			
	Phase II	**Phase III**	**Phase IV**	**Phase III + IV**
A2	1 (+1 associate)	6	11	17
C1	8	-	-	-
C2	3	-	-	-
C3	1	5	-	5
D	2	2	-	2
E	3 (+1 associate)	1 associate	-	-

Table 10: Distribution of the Chemical Groups of Glazed Wares across archaeological phases

The second association that is worthy of note is that between the chemical groups and the glazing colourations (Table 11). With the exception of the Green-glaze, which is widely distributed across many of the chemical groups, all glazing colours are concentrated around a one or two chemical groups or subgroups. The most relevant cases are the Honey-glazed samples, which are the most numerous component of Subgroups A2 and C3, and the Green and Manganese-glazed samples, the largest component of Subgroup C1.

Chemical Groups (GW only)	**Glazing Colourations**				
	Green	**Brown**	**Honey**	**Green and Manganese**	**Two-Colours**
A2	2	-	15	-	1 associate
C1	-	-	-	6	2
C2	2	-	-	1	-
C3	-	-	5	1	-
D	1	2	-	1	-
E	3	-	2 associates	-	-

Table 11: Association between glazing colourations and chemical groups

The third association to explore is that between petrographic groups, glazing colourations and archaeological phases of the same pots that have been subjected to chemical analysis (Table 12). Most of the Green-glazed wares, the Green and Manganese-glazed wares and the Two-Colour glazes belong to Fabric GW1 and chemical Subgroup C1 or Group E, although there are a number of samples belonging to Fabrics GW2, GW3 and GW5 or Subgroups A1, A2, C2 or Group D. Interestingly, they are almost all dated to Phase II. The other two colours, Honey- and Brown-glazing, belong to the later Phases III and IV, although few examples of the former (not sampled in this study) are documented in Phase II. The Brown glazed-pots are too scarce to comment confidently. As for the Honey-glazed samples, most of them belong to Fabric GW2 and Subgroups A2 or C3, although a small number of them are made of Fabric GW1. They are found in all the sites documented in Phases III and IV. A detailed consideration of all the evidence must take into account that, although Honey coloured-glazed wares are more abundant in this period than Green- and Two Colour-glazed wares, it is the Green and Manganese vessels that have a broader distribution in Phases III and IV; however, they have not been sampled in this study for these phases. Therefore, it is fair to say that the variability in the glazing colourations continues, although there seems to be a certain increase in the homogeneity of the fabrics, at least from the point of view of the Honey-glazed ceramics. On-going research on the glazes has raised similar points (Molera et al. forthcoming).

Glazing Colourations	**Petrographic Fabric**	**Phase II**	**Phase III**	**Phase IV**	**Total**
Honey	GW1	3	2	-	5
	GW2	3	12	12	27
	GW4	2	-	-	2
	GW5	2	-	-	2
Green	GW1	7	1	2	10
	GW2	6		1	7
	GW3	2	-	-	2
	GW5	1	-	-	1
2 colour	GW1	5	-	-	5
	GW2	2	-	-	2

Brown	GW1	-		1	1
	GW2	-	1	-	1
GM	GW1	3	-	-	3
	GW2	6			6

Table 12: Association between colouration of glazes, petrographic fabrics and archaeological phases

6. Discussion

The patterns and associations observed in this study are not as strong as those observed in previous analyses of the cooking pots (Carvajal and Day 2013; 2015), but when the two studies are combined some trends can be noted.

6.1. An east-west distribution pattern?

The results of this study show some significant data that can help us to understand how technical innovations and social changes were deeply interrelated in the context of the early medieval Vega of Granada. The petrographic analysis of the Water Containers suggests an east-west distribution of the fabrics of this category (Table 5), yet it is not conclusive about geographical provenance of the samples of the Glazed Wares. However, the opposite can be said about the chemical analysis. Although inconclusive for the Water Containers, chemistry strongly suggests the same east-west pattern in the Glazed Wares (Table 9). In summary, it can be said that in both cases, Water Containers and Glazed Wares, one of the two analyses points to the existence of an east-west geographical pattern and the other one does not challenge it. It is suggested that further investigation of this pattern may be productive in future analytical programmes.

6.2. Resilience and innovation in Water Containers

The petrographic study of the Water Containers shows that Fabrics WC1 and WC2 are found in all four phases of the study and associated with different sites, whereas Fabrics WC3 and WC4 are found only in Phase II and each one exclusively associated with one site. There are similarities with the patterns found for the fabrics of the cooking pots in previous research of the ARANPOT project (Carvajal López and Day 2013; 2015). The fabrics analysed in that study were clearly linked to particular archaeological sites in the Vega, as is the case with Fabrics WC3 and WC4 in the present study, and the trend of distribution of fabrics between the eastern and the western sides of the Vega points in the same direction. Furthermore, it is significant that the wider variability in fabrics, both in Water Containers and in cooking pots, is documented in Phase II. This seems to confirm the suggestion arising from the study of cooking pots that highlighted Phases I and II as a moment of coexistence of many different techniques to produce the same kinds of pottery. Important divergences between both studies must be noted as well. Unlike in the case of the cooking pots, the details of micro-provenance of the fabrics and therefore the changes in the development of production and distribution of the fabrics of Water Containers cannot be ascertained clearly. This has to do with the limits of the petrographic and chemical analysis in the case of these wares, which are extremely fine and chemically very similar. Another reason is that the representation of samples from the later phases (III and IV) is minor in comparison with that of earlier phases (I and II). This is because this category of wares becomes less abundant in the later phases, as it is progressively substituted by other types of wares, notably Glazed Wares.

6.3. The social impact of Glazed Wares.

Both chemical and petrographic analysis highlight the chronological patterning in the distribution of groups and fabrics of the Glazed Wares samples. In spite of low chemical variability and the fineness of the fabrics, it can be seen that there is also a solid correlation between fabrics, chemical groups and glazing colourations. More research must be conducted here to avoid over-interpretation of the data, but the patterns suggested contribute to an emergent understanding of changes in the society of the early Islamic Vega of Granada.

The correlations observed in Tables 6, 10 and 12 show that the widest range of chemical groups, petrographic fabrics and glazing colouration in Glazed Wares are documented in Phase II, suggesting a variety of production. This may be due to common experimentation with the aim of improving the product. However, it might also be interpreted as evidence of different workshops producing the same type of vessel. Both options are possible and do not exclude each other. Regarding Phases III and IV, the Honey-glazed vessels are the most abundant Glazed Wares, but it is important to consider that these phases are also the period of the wider expansion of the Green and Manganese vessels, which is under-represented in the present assemblage due to limitations in sampling permissions. So, it is fair to say that the variability in the glazing colourations continues, although there seems to be a certain increase in the homogeneity of the fabrics, at least from the point of view of the Honey-glazed ceramics. Therefore, as in Phase II, Phases III and IV show a panorama of innovation. However, in marked contrast to Phase II, the data for these later two phases show more homogeneity in the fabrics used, even though the samples were obtained from three different sites. It is not known at this point if this homogeneity is the product of a concentration of production in a number of workshops in the same area, of the establishment of a common fabric recipe for glazed pottery or of a combination of both causes.

7. Conclusion

The wares analysed in this study have very different production technologies from each other, yet they share some elements of technological history that are also relevant to the cooking pots analysed previously. On the one hand, it is possible to speak of distinctive eastern and western patterns of distribution, especially visible in the earlier Phases I and II. On the other hand, a wider range of technological variability is observed in Phases I and II, whereas Phases III and IV show a technological panorama not devoid of innovation, but with a lower range of variability that possibly correlates with a higher degree of standardisation. Whereas the results of this study are not as conclusive as those of the petrographic analysis of cooking pots, they point in the same direction. We suggest that the ceramic landscape that this study illuminates informs a new understanding of the changing social and economic nature of the period of Islamization in the area of the Vega of Granada.

Acknowledgements

This paper was made possible by the generous funding provided by the project ARANPOT, a Marie Curie Action within the Seventh Framework Programme of the European Union, developed in the University of Sheffield (UK). The chemical analyses conducted at MURR were supported in part by a grant from the US National Science Foundation (#1415403) and were interpreted in the NCSR *Demokritos* (Athens, Greece).

Support and permissions to study ceramics were granted by Mr Isidro Toro Moyano (Director of the Archeological and Ethnological Museum of Granada, for all sites), Delegación de Cultura de la Junta de Andalucia in Granada (for all sites), Prof Antonio Malpica Cuello

(Ilbira), Dr Jose María Martín Civantos (Ilbira), Dr Andrés Adroher Auroux (Granada), Dr Miguel Jiménez Puertas (Castillejo), Mr José J. Álvarez García (Verdeja) and Ms. Ana Ruiz Jiménez (Manzanil).

Our acknowledgement also to the anonymous reviewers and to the guest editor that have made detailed suggestions and comments that have greatly improved the quality of this paper.

References

Álvarez García, J. J. 2009. El yacimiento altomedieval del Cerro de la Verdeja, Huétor-Tájar, Granada. *Anuario Arqueológico de Andalucía, 2004, Vol. I. Granada.* (Vol. I). Seville: Junta de Andalucía, pp. 1550-1562

Buxeda i Garrigós, J. and V. Kilikoglou 2001. Total variation as a measure of variability in chemical data-sets. In:. Van Zelst (ed.): *Patterns and process: a festschrift in honor of Edward V. Sayre*. Suitland, Maryland: Smithsonian Center for Materials Research and Education, pp. 185-198.

Carvajal López, J. C. 2008. *La cerámica de Madīnat Ilbira y el poblamiento altomedieval de la Vega de Granada (siglos VIII-XI)*. Granada: THARG.

Carvajal López, J. C. 2009. Pottery production and Islam in southeast Spain: a social model. *Antiquity 83*: 388-398.

Carvajal López, J. C. 2012. Cooking pots and large containers in the Early Medieval Vega of Granada (Southeast Spain). On the practices of pottery production and the practices that require production of pottery. *Old Potter's Almanach, 17* (2): 7-12.

Carvajal López, J. C. 2013. Islamicization or Islamicizations? Expansion of Islam and social practice in the Vega of Granada (southeast Spain). *World Archaeology, 45* (1): 56-70.

Carvajal López, J. C. and P.M. Day. 2013. Cooking pots and Islamicization in the early medieval Vega of Granada (Al-Andalus, sixth to twelfth centuries). *Oxford Journal of Archaeology, 32* (4): 433-451.

Carvajal López, J. C. and P.M. Day 2015. The production and distribution of cooking pots in two towns of Southeast Spain in the 6th–11th centuries. *Journal of Archaeological Science. Reports 2*: 282-290.

Chalmeta Gendrón, P. 1994. *Invasión e Islamización. La sumisión de Hispania y la formación de al-Andalus*. Madrid: Mapfre.

Hein, A. and V. Kilikoglou 2011. ceraDAT—Prototype of a web-based relational database for archaeological ceramics. *Archaeometry 54* (2): 230–243.

Jiménez Puertas, M. 2007. *Los regadíos tradicionales del territorio de Loja. Historia de unos paisajes agrarios de origen medieval*. Granada: Fundación Ibn al-Jatib.

Jiménez Puertas, M. 2008. Cerámica tardoantigua y emiral de la Vega de Granada. El Cerro del Molino del Tercio (Salar). In A. Malpica and J.C. Carvajal López (eds.), *Estudios de cerámica tardorromana y altomedieval.* Granada: THARG, pp. 163-219.

Jiménez Puertas, M. and J.C. Carvajal López 2011. Opciones sociotécnicas de regadío y secano. El caso de la Vega de Granada. In F. Sabaté (ed.), *Els espais del secà. Actas del IV Curs d'Arqueologia Medieval. Lleida-Algerri, 12-13 Març 2009*. Lleida: Universitat de Lleida, pp. 51-85

Jiménez Puertas, M., J.C. Carvajal López and E.M. Muñoz Waissen 2009. El entorno de El Castillejo de Nívar: el poblamiento y los paisajes en época medieval. In R. G. Peinado Santaella, A. Malpica Cuello and A. Fábregas García (eds.), *Historia de Andalucía. VII Coloquio* (Vol. II. Comunicaciones). Granada: Universidad de Granada, pp. 9-27

Kingery, W.D. and P.B. Vandiver 1986. *Ceramic Masterpieces - Art, Structure and Technology*. New York: The Free Press.

Lhénaff, R. 2001. Géomorphologie du Basin de Grenade. In C. Sanz de Galdeano, J.A. Peláez Montilla and A.C. López Garrido (eds.): *La Cuenca de Granada. Estructura, Tectónica activa, Sismicidad, Geomorfología y dataciones existentes*. Granada: CSIC-Universidad de Granada, pp. 40-58.

Manzano Moreno, E. 2006. *Conquistadores, emires y califas. Los Omeyas y la formación de al-Andalus*. Barcelona: Crítica.

Molera, J., J.C. Carvajal López, G. Molina, T. Pradell forthcoming. Glazes, colorants and decorations in early Islamic glazed ceramics from the Vega of Granada (9th to 12th centuries AD). *Journal of Archaeological Science. Reports*

Ocaña Ocaña, M.C. 1974. *La Vega de Granada. Estudio geográfico*. Granada: Instituto de Geografia Aplicada del Patronato “Alonso de Herrera” (CSIC)-Caja de Ahorros de Granada.

Ruiz Jiménez, A. 2008. *Informe preliminar de la intervención arqueológica puntual en el yacimiento de "El Manzanil", Loja, (Granada), 2008*. Granada: unpublished. Report presented to the Delegación de Cultura de la Junta de Andalucía in Granada.

Salinas Pleguezuelo, E. 2013. Cerámica vidriada de época emiral en Córdoba. *Arqueología y Territorio Medieval,* 20, 67-96.

Salinas Pleguezuelo, E. and Zozaya, J. 2015. Pechina: el antecedente de las cerámicas vidriadas islámicas en al-Andalus. In M. J. Gonçalves; S. Gómez-Martínez (eds.): *Actas do X Congresso Internacional "A Cerâmica Medieval No Mediterrâneo". Silves, 22 a 27 outubro 2012* (Silves: Câmara Municipal de Silves-Campo Arqueológico de Mértola.), pp. 573-76.

Sanz de Galdeano, C. 2001. Localización Geográfica y Geológica de la Cuenca de Granada. Principales Rasgos Estratigráficos. In C. Sanz de Galdeano, J.A. Peláez Montilla and A.C. López Garrido (eds.): *La Cuenca de Granada. Estructura, Tectónica activa, Sismicidad, Geomorfología y dataciones existentes*. Granada: CSIC-Universidad de Granada, pp. 3-9.

Whitbread, I. K. 1986. The characterization of argillaceous inclusions in ceramic thin sections. *Archaeometry 28*: 79-88.

Whitbread, I. K. 1989. A proposal for the systematic descriptions of thin sections towards the study of ancient ceramic technology. In Y. Maniatis (ed.): *Archaeometry. Proceedings of the 25th International Symposium.* Amsterdam: Elsevier, pp. 127-138.

Whitbread, I. K. 1995. *Greek transport amphorae, a petrological and archaeological study*. Oxford: Fitch Laboratory Occasional Paper.

Whitbread, I. K. 1996. Detection and interpretation of preferred orientation in ceramic thin sections. In *Proceedings of the 2nd Symposium of the Hellenic Archaeometric Society (26-28 March 1993). Archaeometrical and Archaeological Research in Macedonia and Thrace*. Athens: Hellenic Archaeometric Society.

Appendices:

Appendix I: Dataset: fabric descriptions, including pictures of all fabrics

APPENDIX I: FABRIC DESCRIPTIONS AND PICTURES

WATER CONTAINERS

Fabric WC1: Fine calcareous fabric with sedimentary and low-grade metamorphic rocks (Fig A1)

Samples: 1.15, 1.16, 1.24, 1.25, 1.27, 2.13, 2.14, 2.15, 2.16, 2.17, 2.18, 2.19, 2.20, 2.21, 2.22, 2.23, 2.24, 4.4, 4.38, 4.39, 4.41, 4.42, 4.43, 4.44, 4.58, 4.60, 4.62, 4.65, 4.66, 4.67, 4.68, 4.77, 4.80, 4.83, 4.84, 4.85, 4.87, 4.89, 4.93, 5.8, 5.10, 5.11, 5.13, 5.14, NS47, NS95, NS96, NS97, NS98, NS99, NS100, NS101, NS102, NS103, NS146, NS147, NS149, NS150, NS153, NS154, NS188, NS190, NS191, NS193, NS194, NS199, NS221, NS222, NS223, NS224, NS227, NS229, NS230, NS249, NS251, NS254, NS255, NS256, NS257

Related: 1.29, 4.61.

Inclusions: 3-15%, eq (equant) & el (elongated), a (angular)-r (rounded), open- or double-spaced, weak alignment of inclusions to margins, unimodal distribution

Coarse fraction:

1-5%, 3.25-0.25 mm

Dominant- Very Few:

Phyllite, el, sa (subangular)-sr (subrounded), <0.1 mm, mode = 0.25 mm. Usually containing large amounts of mica (muscovite, chlorite and biotite identified), but also quartzitic silts and clay.

TFs: Clay pellets and streaks (sample 4.89), eq-el, r-sa, <2.25 mm, mode = 0.25 mm. Sharp to diffuse boundaries, high optical density, discordant to matrix. Contain mainly clay, sometimes quartz-based rocks too (sample 2.21)

Micritic limestone, eq, sr, <2 mm, mode = 0.25 mm. Usually fossiliferous.

Monocrystalline quartz, eq-el, a-sa, <0.5 mm, mode = 0.25 mm. Small grains of monocrystalline quartz with undulose or straight extinction. Sometimes altered minerals are visible in the quartz crystals.

Siltstone-sandstone and metasiltstone-metasandstone ranging into quartzite, eq-el, sa-sr, <2.25 mm, mode = 0.25 mm. The quartz crystals show undulose extinction.

Common- Very Few

Calcareous mudstone, eq-el, sr-sa, <0.25 mm, mode = 0.25 mm. Contain abundant micrite.

TFs: Micrite and clay pellet-streaks (sample 4.89), eq, r, <3.25 mm, mode = 0.5 mm. Diffuse boundaries, low optical density, concordant or discordant to the matrix. Composed of a large amount of micrite and some clay. Sometimes other rocks are included (calcareous mudstones, mica plates)

Serpentinite, eq-el, a-r, <1.25 mm, mode = 0.25 mm. Isolated grains of serpentinite, showing a range of chemical alterations of what quartz-based rocks.

Very Few:

Altered quartz (cordierite?), eq-el, sa-sr, <0.60 mm, mode = 0.25 mm.

Schist, eq, sr, <0.60 mm, mode = 0.25 mm.

Chert, eq-el, a-sa, <0.75 mm, mode = 0.25 mm.

Rare:

Prysmatic amphibole crystal, eq-el, a, <0.25 mm, mode = 0.25 mm.

Serpentinite based on igneous rock, eq, a, 0.60. The original rock is composed of prismatic feldspar and a very altered euhedral mineral with high relief and low birefringence and relic pleochroism and cleavage (amphibole?). Detrital origin.

Fine fraction:

95-99%, 0.25-0.01 mm

Dominant: Clay pellets

    Mica plates (biotite and muscovite identified)

Dominant - Frequent: Monocrystalline quartz

    Opaques

    Micritic limestone

Few: Polycrystalline quartz

    Phyllite grains

Very Few: Serpentinite

    Detritic amphibole from metamorphic origin (euhedral mineral).

    Oolites

Rare: Chert

    Altered quartz (cordierite?)

    Schist grains

Very Rare: Feldspar

    Detritic amphibole from igneous origin (prismatic mineral).

    Epidote

Pyroxene

Matrix: 75-98%

The matrix is calcareous and micaceous. Contamination with secondary calcite is documented in some samples (NS153, NS256, NS257, NS199, 4.84, 4.65). The colour of the matrix usually ranges between red and brown in PPL and in between red and dark reddish brown, sometimes even blackish brown, in XP. There are in many cases small variations in the tone of the colour in between the centre and the margins. Inclusions tend to appear clustered in areas of the matrix, and streaks different clays can be seen, usually in very calcareous samples. There is moderate to high optical activity in all samples, except in 5.11, NS251, NS190, NS193, 1.24 and 4.89, where it is very weak or absent.

Voids: 1-10%

Small vesicles and few meso- to macro-vughs, with a weak to strong alignment to margins, although it is strong in samples 4.42 and NS221. Channels can be seen in samples 4.84, NS154 and 4.83. In some cases they are clearly related to clay pellets that have been weathered, frequently they contain or are surrounded by secondary calcite, more rarely they are related to pellets containing micrite and clay.

Comments:

This fabric is characterised by the presence of sedimentary and low-grade metamorphic rocks of pelitic origin, with a number of textural features that strongly suggest mixing of clays. The variation within the fabric is very high and that probably indicates that it is manufactured in different workshops with a common technical background and similar or the same petrological environment. The firing temperature is in general low, probably in relation to the generally high amount of calcite in the samples. This fabric has the same or very similar petrological background than Fabrics WC2, GW1 and GW2.

Related samples: 1.29, 4.61

These samples have Dominant to Frequent serpentinite (eq-el, r-a, <1.5 mm, mode = 1 mm) and Few to Very Rare polycrystalline quartz showing banding (possibly gneiss, eq-el, a-sa, <1 mm, mode = 0.75 mm). For the rest they fit well within the variability range of the rest of the group.

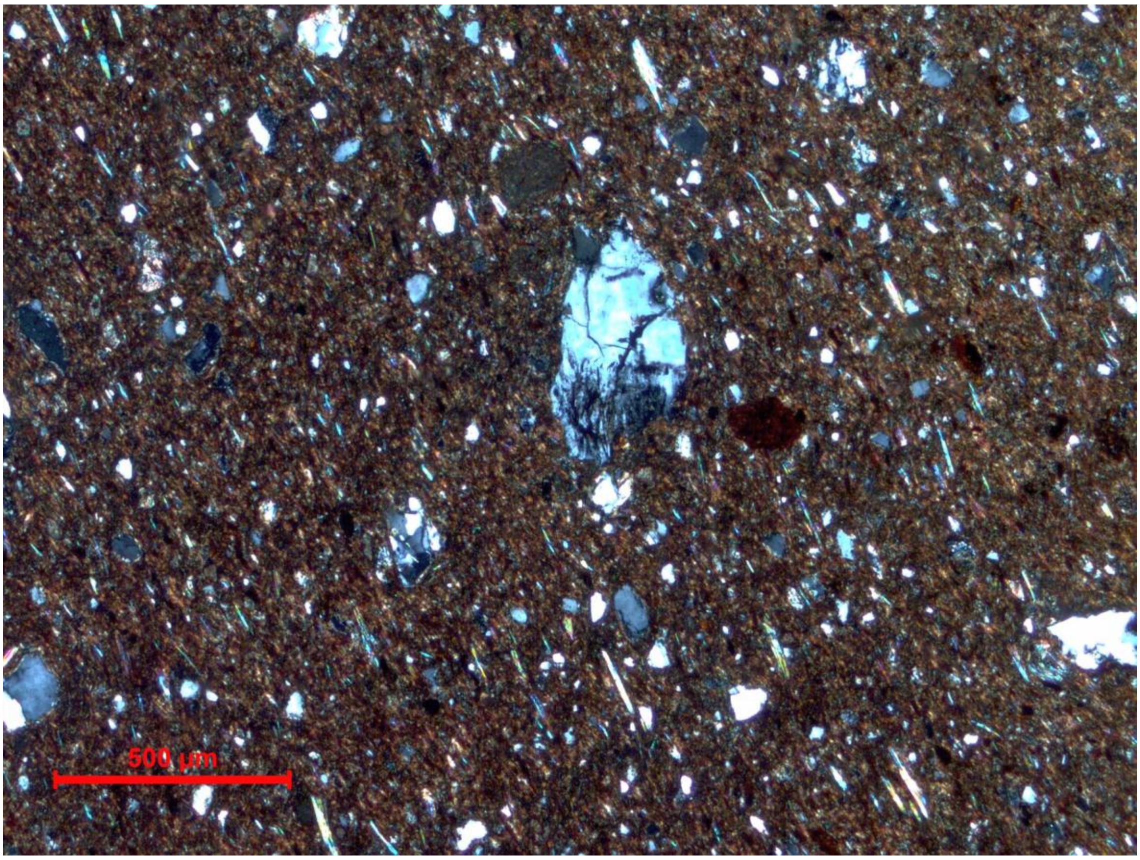

Figure A1: *Fabric WC1: Fine calcareous fabric with sedimentary and low-grade metamorphic rocks* (XP). Showing quartzitic sedimentary rocks and clay pellets over a calcareous and micritic matrix.

Fabric WC2: Coarse calcareous fabric with sedimentary and low-grade metamorphic rocks (Fig A2)

Samples: 4.59, 4.63, 4.69, 4.81, 4.90, 4.91, 5.9, 5.12, NS43, NS94, NS143, NS151, NS152, NS157, NS187, NS189, NS192, NS195, NS196, NS197, NS198, NS200, NS253, NS259

Related: 4.86, NS144, NS156

Inclusions: 20-30%, eq & el, a-r, double-spaced, but there are clusters of close-spaced rocks, weak alignment of inclusions to margins, unimodal distribution

Coarse fraction:

15-35%, 2.75-0.25 mm

Dominant- Common:

Siltstone-sandstone and metasiltstone-metasandstone ranging into quartzite, eq-el, sa-sr, <2.25 mm, mode = 0.5 mm.

Phyllite, el, sa-sr, <2.5 mm, mode = 0.5 mm. Usually containing large amounts of mica (biotite), but also quartzitic silts and clay. Often altered towards serpentinite. Garnet crystals have been documented inside this rock (samples NS253 and 5.9).

Micritic limestone, eq, sr, <2.25 mm, mode = 0.25 mm. Usually fossiliferous, sometimes containing quartz grains.

Dominant-Very Few:

TFs: Clay pellets and arf, rarely streaks, eq-el, r-sa, <1.80 mm, mode = 0.25 mm. Sharp to clear boundaries, high to neutral optical density, discordant to matrix. Contains mainly clay and often quartz-based rocks, more rarely a bit of micrite.

Frequent-Few

Monocrystalline quartz, eq-el, a-sa, <2.75 mm, mode = 0.25 mm. Small grains of monocrystalline quartz with undulose or straight extinction, sometimes showing relic grain boundaries.

Common-Very Few:

Serpentinite, eq-el, a-r, <2.65 mm, mode = 1 mm. Isolated grains of serpentinite, showing a range of chemical alterations of quartz-based rocks and phyllites.

Biotite and muscovite schist, eq-el, a-sa, <2.5 mm, mode = 0.5 mm.

Gneiss, eq-el, sr-sa, <1.5 mm, mode = 1 mm.

Chert, eq-el, sa-sr, <2.35 mm, mode = 0.25 mm.

Very Few:

Altered quartz (cordierite?), eq-el, a-sa, <0.75 mm, mode = 0.25 mm. In some cases contains prismatic pleochroic minerals with high relief (pyroxenes?)

Rare:

Garnet, el, sr, <0.75 mm, mode = 0.5 mm.

Very altered amphibole, el-a, <0.25 mm, mode = 0.25 mm. Euhedral, still pleochroic and showing cleavage.

Plates of biotite, el, sa, 0.30 mm, mode = 0.25 mm.

Rare:

Tabular biotite, el, sa, 0.40 mm, mode = 0.25 mm, altered to chlorite.

Very Rare:

Mudstone, el, sa, 1.5 mm.

Prismatic mineral with low birefringence, fairly high relief, slightly pleochroic and at least one cleavage (andalusite?), el, a, 0.50 mm and 0.75 mm. The largest grain is altered to serpentinite

Fine fraction:

65-85%, 0.25-0.01 mm

Dominant: Clay pellets

Mica plates

Dominant - Frequent: Monocrystalline quartz

Frequent: Opaques

Micritic limestone

Few: Polycrystalline quartz

Phyllite grains

Very Few: Serpentinite

Detritic amphibole

Chert

Rare:

Schist grains

Garnet

Very Rare: Feldspar

Altered quartz (cordierite?)

Matrix: 50-77%

The matrix is usually moderately calcareous and micaceous. The colour of the matrix usually ranges between red (bright red in sample 5.9) and brown in PPL and in between red and dark brown in XP. There are in many cases small variations in the tone of the colour in between the centre and the margins (samples NS94, NS151, 4.59, NS198, 5.12, NS200) or between the inner and the outer margin (samples NS259, NS187, NS152, 4.69, NS196). Inclusions tend to appear clustered in areas of the matrix, and streaks different clays can be seen in samples NS189, NS143. There is moderate to high optical activity in all samples, except in 4.69, NS195, NS157 and 4.63, where it is very weak or absent. Samples NS196 and NS143 have optical activity near one of the margins only.

Voids: 3-20%

Vesicles and meso- to macro-vughs, with a weak to strong alignment to margins. In some cases they are clearly related to clay pellets that have been weathered, sometimes they contain or are surrounded by secondary calcite or they are related to pellets containing micrite and clay.

Comments:

This fabric is characterised by the presence of coarse grains of sedimentary and low-grade metamorphic rocks of pelitic origin. In many cases the clay probably did not require any mixing to be worked, but in some samples there are textural features that strongly suggest mixing of clays, like the streaks of samples NS189 and NS143 and the clay pellets of samples NS195 and NS157. The variation within the fabric is very high and that probably indicates that it is manufactured in different workshops with a common technical background and similar or the same petrological environment. The firing in general reaches low temperatures, probably in relation to the generally high amount of calcite in the samples. This fabric has the same or a very similar petrological background than Fabric WC1, and possibly the same can be said about Fabrics GW1 and GW2.

Related samples: 4.86 and NS156

These samples are characterised by the presence of Dominant monocrystalline quartz, eq-el, a-r, <1.5 mm, mode = 0.25 mm. The particularity is that the majority of the grains of quartz are unusually rounded. However, some of the quartz grains are euhedral and affected by internal mineral (perhaps cordierite). Besides, there is presence of Very Rare calcareous sandstone, eq, r, 1.5 mm, containing the same variety of monocrystalline quartz (rounded and euhedral). All these features suggest tempering with sand.

Related sample: NS144

This sample is characterised by Dominant red clay pellets, eq-el, r, <0.90 mm, mode = 0.25 mm, clear boundaries, rounded, high optical density, discordant to matrix. The same specific variety is red clay pellets is documented in other samples of the main group, but never so abundant. This feature strongly suggest clay mixing.

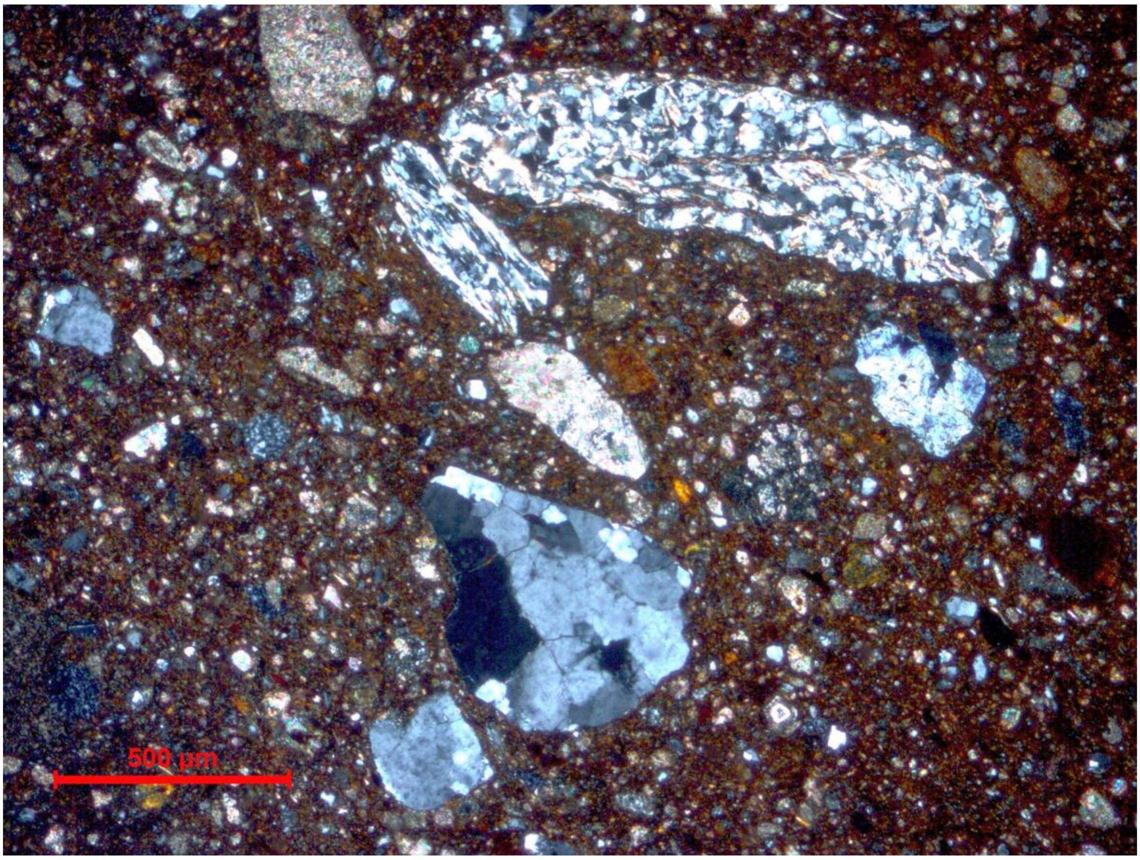

Figure A2: *Fabric WC2: Coarse calcareous fabric with sedimentary and low-grade metamorphic rocks* (XP): Showing coarse grains of phyllite, micritic limestone and polycrystalline quartz that include a possible gneiss in the bottom centre. The matrix is highly calcareous and micaceous.

Fabric WC3: Coarse calcareous fabric with grog (Fig A3)

Samples: NS145, NS148, NS155

Inclusions: 20-30%, eq & el, a-r, close-spaced, moderate alignment of inclusions to margins, unimodal distribution

Coarse fraction:

30-40%, 2.25-0.25 mm

Predominant- Frequent:

TF: Grog, eq-el, a-sr, <2.25 mm, mode = 0.5 mm. Clear to diffuse boundaries, rarely sharp. High to low optical density, discordant to the matrix. Contains more or less calcareous clay and very often monocrystalline quartz, mica and, more rarely, quartz- and mica-based minerals, clay pellets or micritic limestone. Some of these minerals come into the range of the coarse fraction. Sample NS145 contains a piece of grog with an obscured margin. The grog seems to come from a range of different types of pottery.

Frequent-Few:

TF: Clay pellets, eq-el, r-sr, <1.25 mm, mode = 0.25 mm. Diffuse boundaries, low optical density concordant or discordant to the matrix, contains pure clay to high amounts of micrite, sometimes including quartz-based rocks.

Common-Very Few:

Micritic limestone, eq-el, r-sr, <0.75 mm, mode = 0.5 mm.

Very Rare:

Metasandstone grain, el, r, 2 mm. Boundaries in between crystals and the undulose extinction reflect relic grain boundaries.

Monocrystalline quartz, eq, sa, 0.5 mm. Probably originating from a grog fragment.

Fine fraction:

60-70%, 0.25-0.01 mm

Dominant: Clay pellets

Mica plates

Monocrystalline quartz

Frequent: Opaques

Micritic limestone

Few: Polycrystalline quartz

Rare: Phyllite grains

Schist grains

Matrix: 50-65%

The matrix is highly calcareous and micaceous. The colour of the matrix in PPL ranges between brown and reddish brown in the centre and red in the margins; in XP it is reddish brown in the centre towards a more bright red in the margins. Inclusions appear clustered in areas of the matrix, and there are abundant heterogeneity in the clays, probably in cases where clay pellets or grog have collapsed. There is optical activity in the samples, stronger in the redder margins and moderate in the rest of the areas. The exception is the interior margin of sample NS148, where there is no optical activity at all.

Voids: 15-20%

Meso- to macro-vughs, more rarely vesicles and channels with a weak to moderate alignment to margins. In some cases they are clearly related to clay pellets that have been weathered, sometimes they are related to pellets containing micrite and clay.

Comments:

This fabric is characterised by the presence of coarse grog. The variation within the fabric is very low, but they are very few samples. The firing is done in general with low equivalent temperature. This fabric has little relations with other fabrics analysed in this paper.

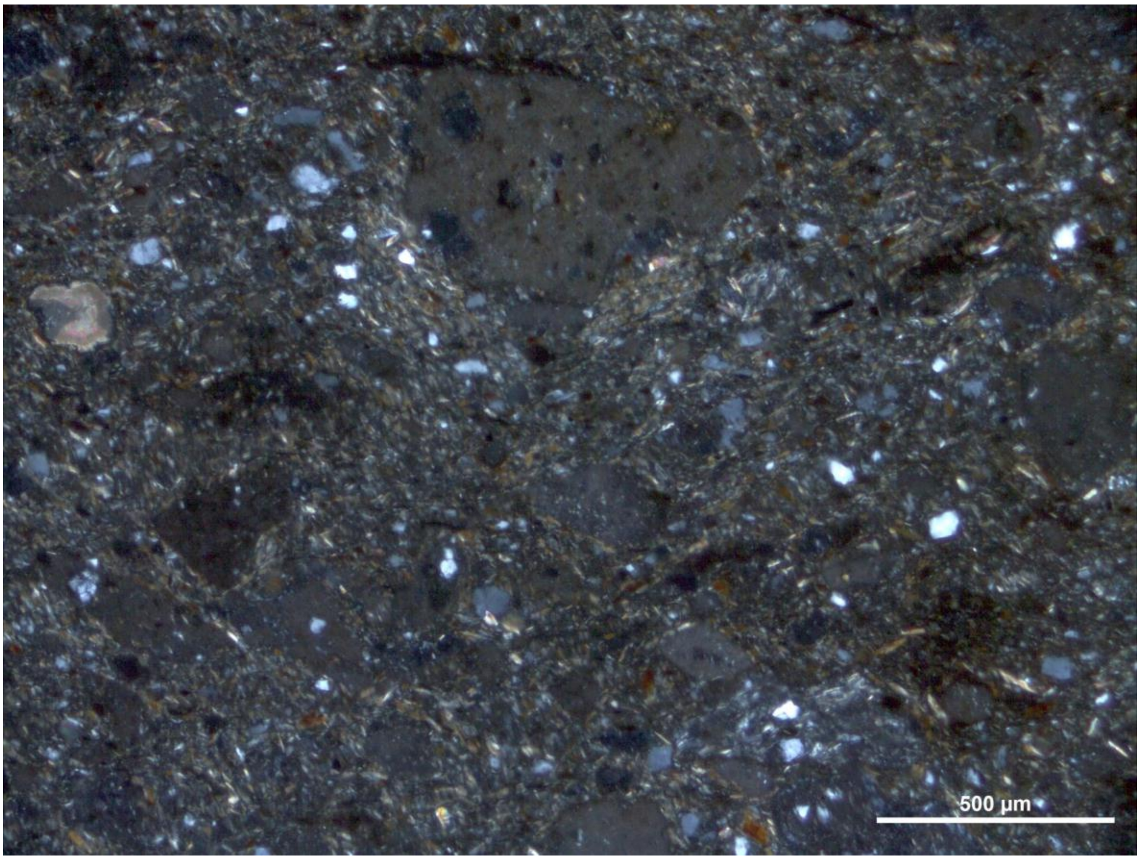

Figure A3: *Fabric WC3: Coarse calcareous fabric with grog* (XP). Showing angular grog fragments and clay pellets over a calcareous matrix

Fabric WC4: Coarse calcareous fabric with micritic limestone (Fig A4)

Samples: 1.26, 1.28, 4.64, 4.78, 4.79, 4.82, 4.88, 4.92

Inclusions: 5-20%, eq & el, a-r, open-spaced or less, weak alignment of inclusions to margins, unimodal distribution

Coarse fraction:

3-10%, 4-0.25 mm

Dominant- Few:

Micritic limestone, eq-el, r-sr, <4 mm, mode = 0.25 mm. In a few cases it is clearly fossiliferous, but in sample 4.64 most of it is, showing particularly angular shapes.

Frequent-Few:

TF: Clay pellets, eq-el, r-sa, <1.25 mm, mode = 0.25 mm. Sharp boundaries, high optical density, discordant to the matrix. Contains clay, micrite, small crystals of calcite and more rarely monocrystalline quartz.

Common-Very Few:

Monocrystalline quartz, eq-el, r-a, <0.60 mm, mode = 0.25 mm. Straight extinction. The largest grains in samples 4.92 and 4.64 show some alteration of the quartz (cordierite?).

Few-Very Few:

Polycrystalline quartz, eq-el, a-sr, <0.40 mm, mode = 0.25 mm.

Very Few:

Serpentinite, el, sa-sr, <1.5 mm, mode = 0.25 mm. Alteration of quartz-based rocks.

Very Rare:

Mica plate (biotite-chlorite), el, a, 0.25 mm.

Prismatic crystal, low birefringence, colourless and slightly pleochroic, high relief, cleavage in one direction (andalusite?), el, a, 0.35 mm.

Fine fraction:

90-97%, 0.25-0.01 mm

Frequent to Very Few: Monocrystalline quartz

Clay pellets

Micritic limestone

Mica plates

Common to Very Few: Opaques

Very Few: Polycrystalline quartz

Matrix: 70-94%

The matrix is highly calcareous and moderately micaceous, although sample 4.64 does not show any mica or even microcrystalline quartz in the matrix or in the fine fraction. There is secondary calcite contamination in samples 4.78, 4.88, 1.28 and 4.79. The colour of the matrix in PPL ranges between brown and dark red; in XP it ranges between reddish brown and dark brown. The matrix is in general homogeneous. There is no optical activity in most samples, except in samples 4.82, 4.92 and 4.64, that have a moderate to strong activity

Voids: 1-10%

Meso- to macro-vughs, more rarely vesicles and planar voids with a weak to moderate alignment to margins. In some cases they are clearly related to clay pellets or micrite limestone that have been weathered.

Comments:

This fabric is characterised by the dominance of micritic limestone. The variation within the fabric is very low. The firing is done in general with high equivalent temperature. This fabric is mostly similar to Fabric WC1.

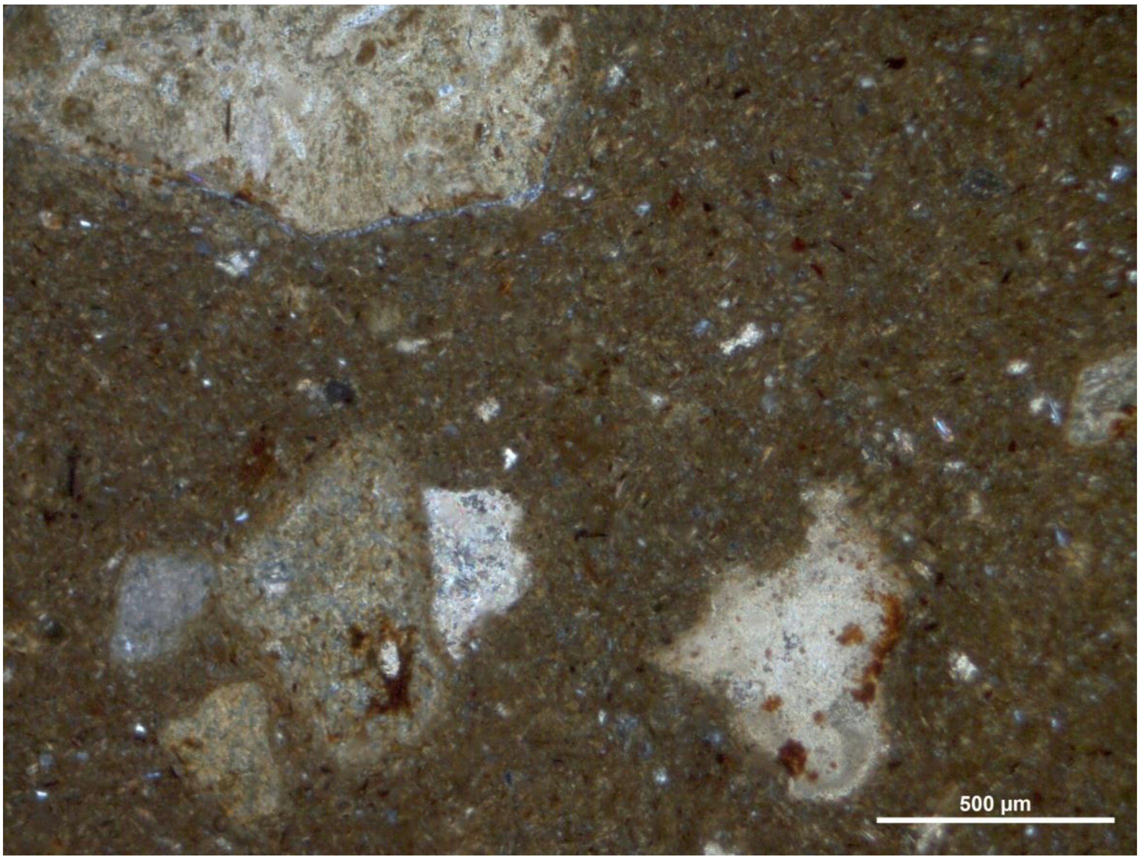

Figure A4: *Fabric WC4: Coarse calcareous fabric with micritic limestone* (XP). Showing subrounded and subangular fragments of micritic limestone over a calcareous matrix.

GLAZED WARES

Fabric GW1: Fine glazed fabric with sedimentary and low-grade metamorphic rocks (Fig A5)

Samples: 5.21, 5.27, NS16, NS17, NS21, NS22, NS23, NS24, NS26, NS29, NS31, NS32, NS62, NS64, NS68, NS79, NS82, NS118, NS120, NS121, NS165, NS211, NS287, NS291.

Inclusions: 5-15%, eq & el, a-r, open-spaced or less, weak alignment of inclusions to margins, unimodal distribution

Coarse fraction:

3-5%, 6-0.25 mm

Predominant-Very Few:

Siltstone-sandstone and metasiltstone-metasandstone ranging into quartzite, eq-el, sa-sr, <1.6 mm, mode = 0.30 mm. The quartz crystals show undulose extinction. Sometimes there are altered minerals inside the quartz, or crystals of altered quartz (cordierite?).

Monocrystalline quartz, eq-el, a-sa, <0.5 mm, mode = 0.25 mm. Small grains of monocrystalline quartz with undulose or straight extinction. Sometimes there are altered minerals inside the quartz.

Frequent to Very Few:

TFs: Micrite and clay pellets-streaks, eq-el, r-sr, <2 mm, mode = 0.5 mm. Diffuse boundaries, always rounded, high to low optical density, discordant or concordant to the matrix. Composed of large amounts of micrite and some clay.

Frequent to Very Few:

TFs: Clay pellets, eq-el, r-sa, <0.65 mm, mode = 0.25 mm. Sharp or clear boundaries, usually rounded, sometimes a bit more angular, high to neutral optical density, discordant to matrix. Contain mainly clay, sometimes quartz-based rocks too.

Common to Very Rare:

Chert, eq-el, a-sr, <1.25 mm, mode = 0.25 mm.

Schist, el, a, <0.75 mm, mode = 0.25 mm.

Few to Very Few:

Micritic limestone, eq-el, a-r, <6 mm, mode = 0.25 mm. Sometimes clearly fossiliferous.

Very Few to Rare:

Altered quartz (cordierite?), eq, a-sa, <0.5 mm, mode = 0.25 mm. Usually monocrystalline, more rarely polycrystalline.

Few to Rare:

Serpentinite, eq-el, sa-r, <0.5 mm, mode = 0.40 mm. Isolated grains of serpentinite, showing a range of chemical alterations of quartz-based rocks.

Phyllite, el, a-r, <0.5 mm, mode = 0.25 mm. Usually containing large amounts of mica (biotite identified), but also quartzitic silts and clay. Sample NS291 contains rounded grains of this rock.

Very Few to Rare:

Mudstone, el, a-sr, <3.5 mm, mode 0.25 mm.

Very Rare:

Olivine, eq, sr, 0.25 mm.

Biotite plaque, el, a, 0.25 mm.

Fine fraction:

95-97%, 0.25-0.01 mm

Dominant: Monocrystalline quartz

Clay pellets

Mica plates (biotite and muscovite documented)

Frequent: Opaques

Few: Polycrystalline quartz

Micritic limestone

Altered quartz (cordierite?)

Very Few: Chert

Serpentinite

Rare: High relief minerals

Phyllite Grains

Oolites

Very Rare: Detritic Amphibole

Matrix: 75-94%

The matrix is usually calcareous and moderately micaceous, but NS22, NS79 and NS211 are particularly non-calcareous and non-micaceous. Contamination with secondary calcite is relatively frequent (samples 5.27, NS24, NS31, NS118, NS121, NS68, NS82, NS17, NS29, NS64 and NS27). The colour of the matrix is usually homogenous, ranging between red and greenish brown in PPL and in between dark reddish brown and dark greenish brown with red or black spots in XP. The only exception is sample NS120, where the margins have red areas and the rest is greenish brown (both in XP and PPL). There is no optical activity in most samples, but NS82, 5.27, 5.21, NS27 and NS121 have moderate optical activity (NS121 only in margins) and NS24, NS165, NS31, NS128 and NS120 have strong optical activity (NS120 only in margins).

Voids: 1-10%

Vesicles, but especially meso- to macro-vughs, more rarely planar voids and channels, usually with strong alignment to margins, sometimes moderate or weak. In some cases they are clearly related to clay pellets that have been weathered, frequently they contain or are surrounded by secondary calcite, more rarely they are related to pellets containing micrite and clay.

Comments:

This fabric is characterised by the presence of sedimentary and low-grade metamorphic rocks of pelitic origin, with a number of textural features that suggest that mixing of clays is at least a possibility. The variation within the fabric is high and that probably indicates that it is manufactured in different workshops with a common technical background and similar or the same petrological environment. The amount of rounded and subrounded quartzitic rocks could reflect the effect of tempering with small amounts of very fine sands. The firing regime seems varied, but its temperature is in general high enough to eliminate or decrease the optical activity in the fabrics. This fabric is in close relationship with Fabric GW2, and probably has the same or a very similar petrological background of Fabrics WC1 and WC2.

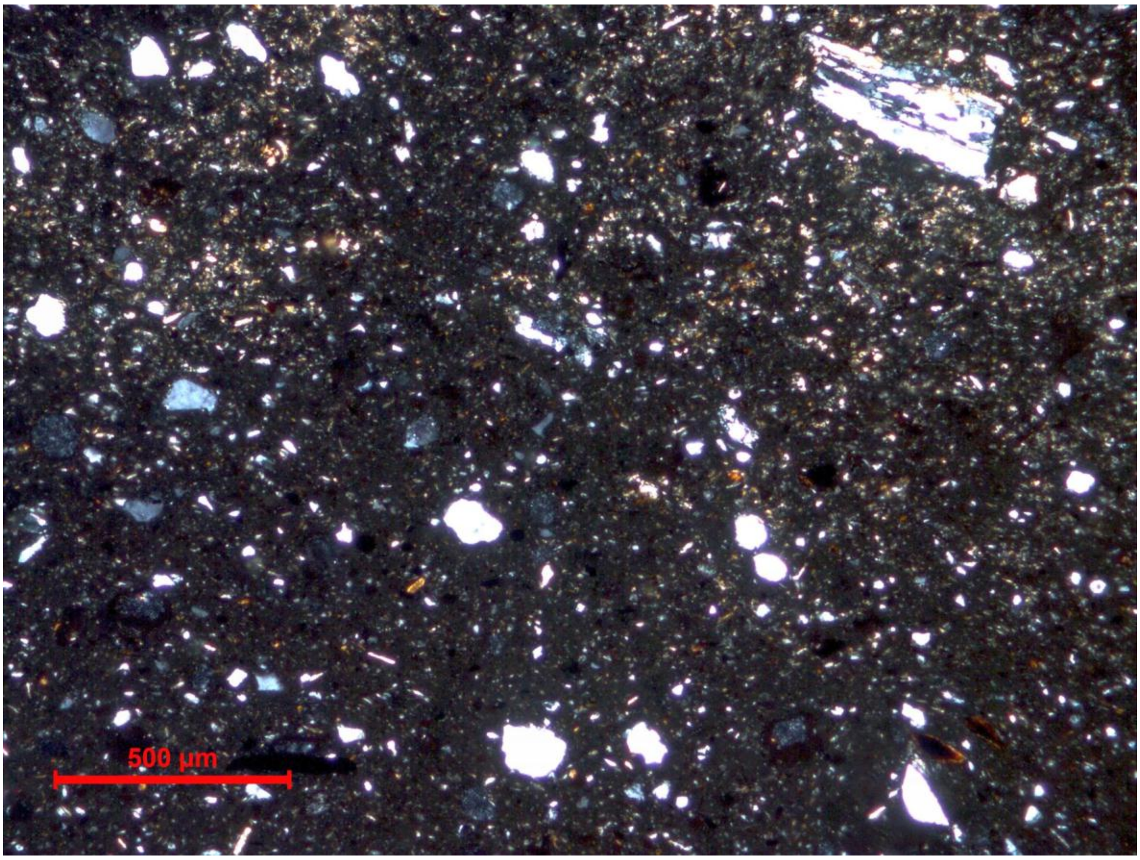

Figure A5: *Fabric GW1: Fine glazed fabric with sedimentary and low-grade metamorphic rocks* (XP). Showing a fragment of phyllite (top right) and fine clay pellets and monocrystalline quartz over a moderately calcareous matrix.

Fabric GW2: Fine glazed fabric with Dominant clay pellets (Fig A6)

Samples: 5.15, 5.16, 5.17, 5.18, 5.20, 5.22, 5.23, 5.24, 5.25, 5.26, 5.28, 5.29, 5.30, NS15, NS20, NS27, NS28, NS30, NS69, NS71, NS77, NS78, NS80, NS81, NS83, NS119, NS122, NS123, NS124, NS125, NS126, NS127, NS210, NS272, NS273, NS274, NS275, NS276, NS277, NS288, NS289, NS290, NS292

Inclusions: 5-35%, eq & el, a-r, open-spaced or less, weak alignment of inclusions to margins, unimodal distribution

Coarse fraction:

3-10%, 1.75-0.25 mm

Predominant-Few:

TFs: Clay pellets and more rarely streaks, eq-el, r-sr, <1.75 mm, mode = 0.25 mm. Sharp or clear boundaries, usually rounded, sometimes a bit more angular, high to neutral optical density, discordant to matrix. Contain mainly clay and sometimes monocrystalline quartz of the same size as the one in the fine fraction. One case (sample 5.23) contains chalcedony grains, others (samples NS274, NS210) contain also grains of polycrystalline quartz, sometimes altered, and one (NS119) contains another similar TF, with more quartz crystals.

Dominant-Rare:

TFs: Micrite and clay pellets and streaks, eq-el, r-sr, <1.25 mm, mode = 0.25 mm. Diffuse boundaries (clay accumulates in the edges usually), always rounded, high to low optical density, discordant to the matrix. Composed of large amount of micrite and some clay, more rarely quartz crystals (sample NS272)

Frequent to Very Few:

Siltstone-Sandstone and metasiltstone-metasandstone ranging into quartzite, eq-el, sa-sr, <1.25 mm, mode = 0.35 mm. The quartz crystals show undulose extinction.

Phyllite, el, a-sr, <0.65, mode = 0.25. Usually containing large amounts of mica (biotite identified), but also quartzitic silts and clay.

Frequent to Rare:

Monocrystalline quartz, eq-el, a-sa, <1.10 mm, mode = 0.25 mm. Shows undulose or straight extinction. Sometimes there are altered minerals inside the quartz.

Serpentinite, eq-el, sa-r, <1.5 mm, mode = 0.25 mm. Isolated grains of serpentinite, showing a range of chemical alterations of quartz-based rocks.

Common to Very Few:

Micritic limestone, ed, a-r, <0.30 mm, mode = 0.25 mm. Sometimes clearly fossiliferous.

Few:

Chert, eq-el, a, <0.60 mm, mode = 0.35 mm.

Few to Very Few:

Mudstone, el, a-sa, <1.30 mm, mode = 0.5 mm.

Few to Rare:

Altered quartz (cordierite?), eq, a-sa, <0.40 mm, mode = 0.25 mm. Usually monocrystalline, more rarely polycrystalline.

Rare:

Schist, el, sa, <0.5 mm, mode = 0.5 mm. Biotite identified in most cases.

Small crystals of calcite, el, a, 0.25 mm.

Very rare:

Grain composed of prismatic pleochroic crystals with reddish brown colour, showing some alteration. Probably epidote or amphibole, eq, sr, 0.25 mm.

Fine fraction:

90-97%, 0.25-0.01 mm

Dominant: Monocrystalline quartz

Clay pellets

Mica plates (biotite and muscovite detected)

Frequent: Opaques

Few: Micrite and clay pellets

Micritic limestone

Oolites

Chert

Polycrystalline quartz

Schist grains

Phyllite grains

Affected quartz (cordierite?)

Rare: Detritic amphibole

Feldspar

Serpentinite

Very Rare: Detritic epidote

Matrix: 55-92%

Non-calcareous to moderately calcareous matrix, with samples NS292, NS119, NS71, 5.15, NS80 being highly calcareous. Sample NS126 has a particularly micaceous matrix, the rest have moderate or very small amounts of mica. Secondary calcite contamination is documented in samples 5.23, NS273, NS272, NS209, NS274, 5.25, 5.30, NS210, 5.18, NS69, 5.22, 5.28, NS81, NS80, NS210. The colour of the matrix ranges between greenish to reddish brown and dark red in PPL. In XP it is dark brown with greenish and reddish tones in different proportions, except for samples NS30, NS126, 5.15, 5.24, 5.17 and 5.20, which are bright red. The matrix is homogeneous in each sample, rarely with variations of colour towards the margins (samples 5.22, 5.16). The optical activity is mostly absent or moderate, except in sample NS122 where it is weak in the centre, and absent in the margins. Samples NS30, NS126, 5.15, NS275, NS80 have strong optical activity.

Voids: 3-10%

Vesicles and meso- to macro-vughs, more rarely planar voids, with strong to moderate alignment to margins. In some cases they are clearly related to clay pellets that have been weathered (vesicles), frequently they contain secondary calcite

Comments:

This fabric is characterised by the abundance of clay pellets, in some cases including micrite, and the presence of low-grade metamorphic rocks of pelitic origin. The variation within the fabric is high and that probably indicates that it is manufactured in different workshops with a common technical background and similar or the same petrological environment. The common technological background probably implies clay mixing with different proportions of similar raw materials. The amount of rounded and subrounded quartzitic rocks could reflect the effect of tempering with small amounts of very fine sands. The firing regime seems varied, but in general the temperature was high enough to decrease the optical activity in the fabrics. This fabric is closely related to Fabric GW1 and has the same or very similar petrological background than Fabrics WC1 and WC2.

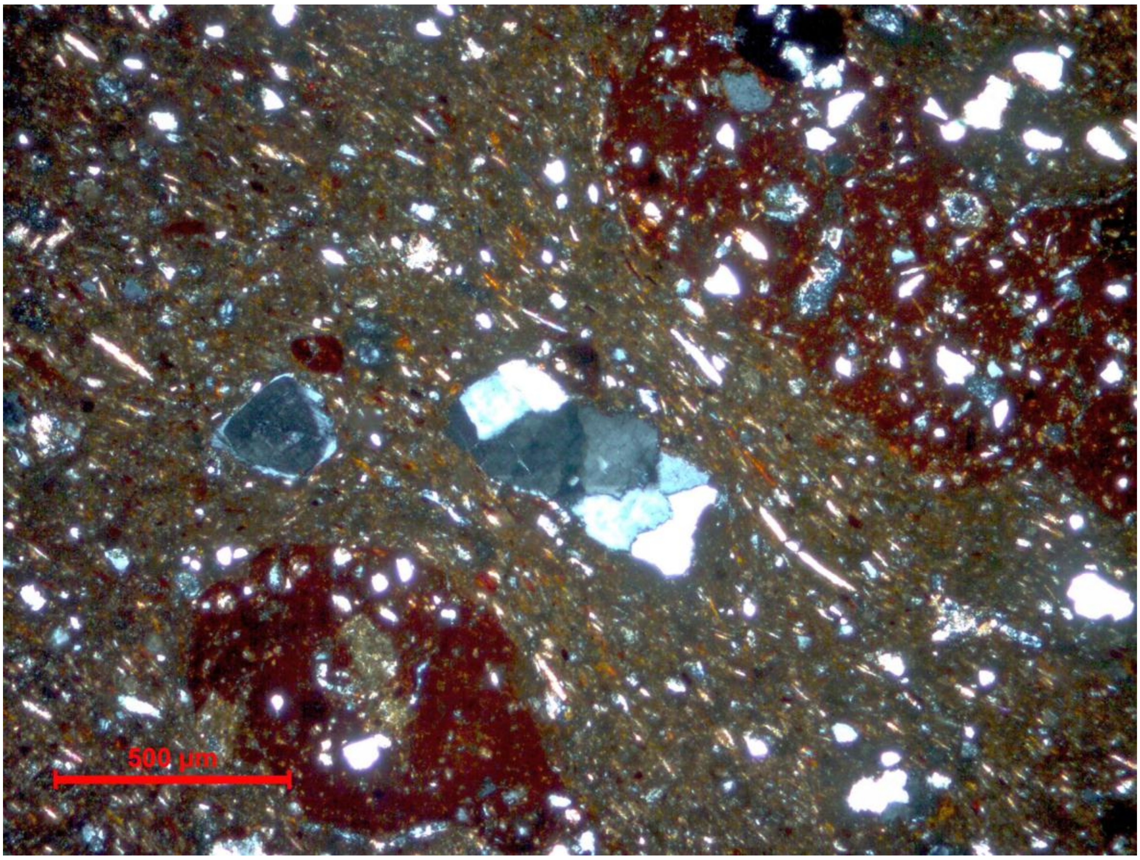

Figure A6: *Fabric GW2: Fine glazed fabric with Dominant clay pellets* (XP). Showing coarse clay pellets (top right, bottom left and bottom right), a grain of polycrystalline quartz and grains of monocrystalline quartz over a calcareous and moderately micaceous matrix.

Fabric GW3: Fine glazed fabric with micritic limestone and serpentinite (Fig A7)

Samples: NS73, NS74

Inclusions: 5-10%, eq & el, sa-r, open-spaced or less, weak alignment of inclusions to margins, unimodal distribution

Coarse fraction:

1-5%, 1.25-0.25 mm

Dominant:

Micritic limestone, ed, a-r, <1.25 mm, mode = 0.25 mm. Fossiliferous.

Frequent:

Serpentinite, eq-el, sa-r, <1 mm, mode = 1 mm. Isolated grains of serpentinite formed from quartz-based rocks

Few:

Monocrystalline quartz, eq, a-sr, <0.65 mm, mode = 0.25 mm. Small grains of monocrystalline quartz with undulose or straight extinction. The largest grain in sample NS73 shows relic grain boundaries.

TFs: Clay pellets, eq-el, r-sr, <0.40 mm, mode = 0.40 mm. Sharp or clear boundaries, high optical density, discordant to matrix. Contains mainly clay and quartz-based rocks.

Very rare:

Phyllite, el, sa, 0.25 mm.

Fine fraction:

95-99%, 0.25-0.01 mm

Dominant: Monocrystalline quartz

Micritic limestone

Mica plates (muscovite documented)

Frequent: Opaques

Clay pellets

Few: Polycrystalline quartz

Affected quartz (cordierite?)

Serpentinite

Rare: High relief minerals

Matrix: 80-94%

Moderately calcareous and micaceous matrix. Sample NS73 shows contamination with secondary calcite. The colour of the matrix in PPL is brown with greenish spots. In XP it is dark greenish brown with areas of more pure brown. The matrix is homogeneous in general. There is moderate optical activity.

Voids: 1-10%

Voids are mostly meso- to macro-vughs, and a few small vesicles. The alignment to the margins is weak. The voids are clearly related to micritic calcite, as it is frequent to find fragments of this rock within them.

Comments:

This fabric is characterised by the presence of micritic calcite and serpentinite. The amounts of these rocks are however very small, and the fabric in general should be considered close to GW1 and GW2 from a petrological point of view (by comparison of the fine fractions of the three fabrics). The particular amounts of micritic calcite and serpentinite may however be indication of a particular recipe or clay origin.

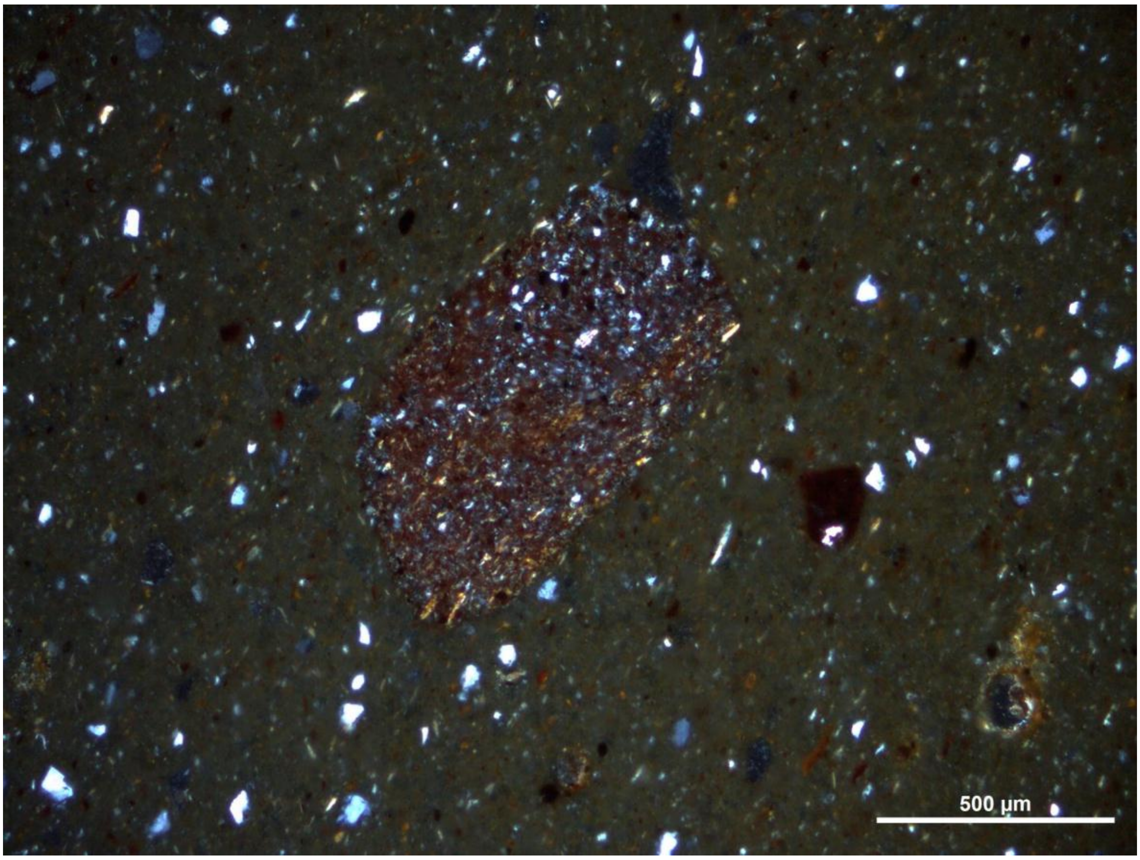

Figure A7: *Fabric GW3: Fine glazed fabric with micritic limestone and serpentinite* (XP). Showing a grain of serpentinite in the centre of the image. There is a small grain of weathered micritic limestone in the bottom right corner.

Fabric GW4: Fine glazed fabric with secondary calcite contamination (Fig A8)

Samples: NS285, NS286

Inclusions: 5-30% (insecure for the amount of secondary calcite), eq & el, a-sr, open-spaced, weak alignment of inclusions to margins, unimodal distribution

Coarse fraction:

3%, 1.5-0.25 mm

Dominant:

Monocrystalline and polycrystalline quartz, eq-el, a-sa, <1.5 mm, mode = 0.25 mm. Small grains of monocrystalline and more rarely of polycrystalline quartz with slightly undulose or straight extinction. Sometimes there are altered minerals inside the quartz.

Frequent:

TFs: Clay pellets, eq-el, r, <0.5 mm, mode = 0.5 mm, clear boundaries, high optical density, discordant with the matrix.

Fine fraction:

97%, 0.25-0.01 mm

Dominant: Micritic limestone (insecure because of the secondary calcite)

Common: Monocrystalline quartz

Few: Clay pellets

Very Few: Biotite plates

Very Rare: Feldspar

Polycrystalline quartz

Phyllite

Matrix: 67-92% (insecure because of the secondary calcite)

Apparently a low calcareous matrix, but with a strong contamination of secondary calcite. It is dark brown in PPL and dark greenish brown with milky spots of dark reddish brown colour in XP. Where there is no secondary calcite it appears homogeneous. Very weak optical activity.

Voids: 3%

Vesicles to macro-vughs, not clearly aligned to margins. In some cases they are clearly related to clay pellets that have been weathered (vesicles), frequently they contain secondary calcite

Comments:

The main feature of this group is the contamination with secondary calcite. It seems to be a non-calcareous clay containing a high amount of micritic and microcrystalline calcite. The fabric recipe is not clear. The temperature reached during firing must have been high, as there is a very weak optical activity.

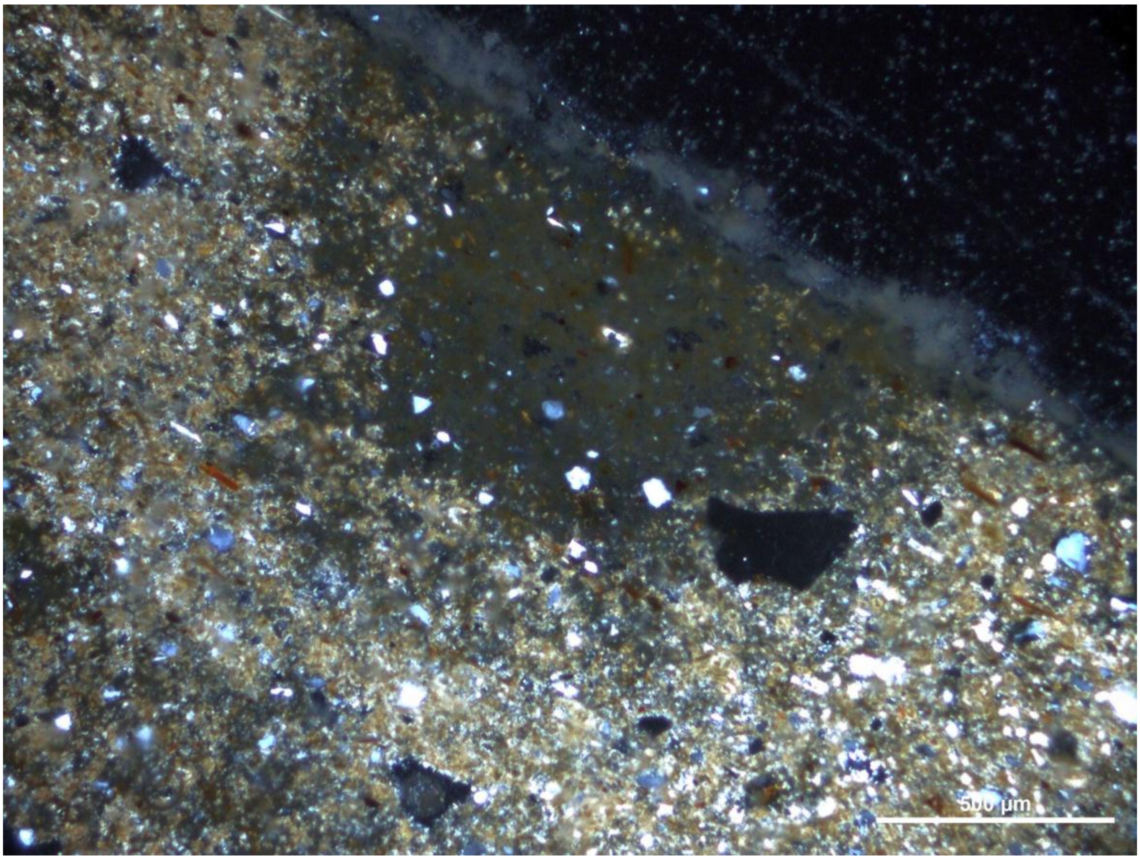

Figure A8: *Fabric GW4: Fine glazed fabric with secondary calcite contamination* (XP). Showing a space of the margin clear of secondary calcite. A non-calcareous fine matrix with abundant fine monocrystalline quartz is visible.

Fabric GW5: Fine fabric with basalt and serpentinite (Fig A9)

Samples: NS61, NS63, NS209

Inclusions: 15-20%, eq & el, a-r, open-spaced or less, weak alignment of inclusions to margins, unimodal distribution

Coarse fraction:

5-7%, 1.75-0.25 mm

Dominant-Few:

TFs: Clay pellets, eq-el, a-r, <1.75 mm, mode = 0.25 mm. Sharp or clear boundaries, high optical density, discordant to matrix. Contain mainly clay, sometimes quartz-based rocks too.

Frequent to Very Few:

Serpentinite, eq-el, sa-r, <0.95 mm, mode = 0.50 mm. Isolated grains of serpentinite, showing alterations of quartz-based rocks.

Common-Few:

Basalt grains, eq-el, r-sa, <0.65 mm, mode = 0.5 mm. Isolated

Altered quartz (cordierite?), eq-el, a-sa, <0.40 mm, mode = 0.40 mm.

Siltstone-sandstone and metasiltstone-metasandstone, eq-el, sa-sr, <0.5, mode = 0.40. The quartz crystals show undulose extinction

Monocrystalline quartz, eq-el, a-sa, <0.5 mm, mode = 0.25 mm. Show undulose or straight extinction.

Few-Very Few:

TFs: Micrite and clay pellets, eq-el, r-sr, <0.25 mm, mode = 0.25 mm. Diffuse boundaries, high to low optical density, discordant to the matrix. Composed of a large amount of micrite and some clay.

Micritic limestone, eq-el, a-r, <0.25 mm, mode = 0.25 mm.

Fine fraction:

93-95%, 0.25-0.01 mm

Dominant: Monocrystalline quartz

Clay pellets

Mica plates (biotite and muscovite documented)

Frequent: Opaques

Polycrystalline quartz

Micritic limestone

Altered quartz (cordierite?)

Serpentinite

Rare: Detritic Amphibole

Chert

Matrix: 75-87%

The matrix is moderately calcareous and micaceous. Sample NS209 has contamination with secondary calcite. The colour of the matrix is dark greenish brown in PPL and dark greenish brown with dark red spots in XP. The samples show moderate to weak optical activity.

Voids: 3-5%

Vesicles and meso-vughs, a few channels. Moderate to weak alignment to the margins. The voids contain frequently secondary calcite.

Comments:

The main feature of this fabric is the documentation of igneous rocks as an important component of the coarse fraction, which makes it unique in this group. The combination of serpentinite and basalt suggest a provenience related to a batolite. Apart from this, the technological elements of the fabric do not seem essentially different to those of the rest of the fabrics.

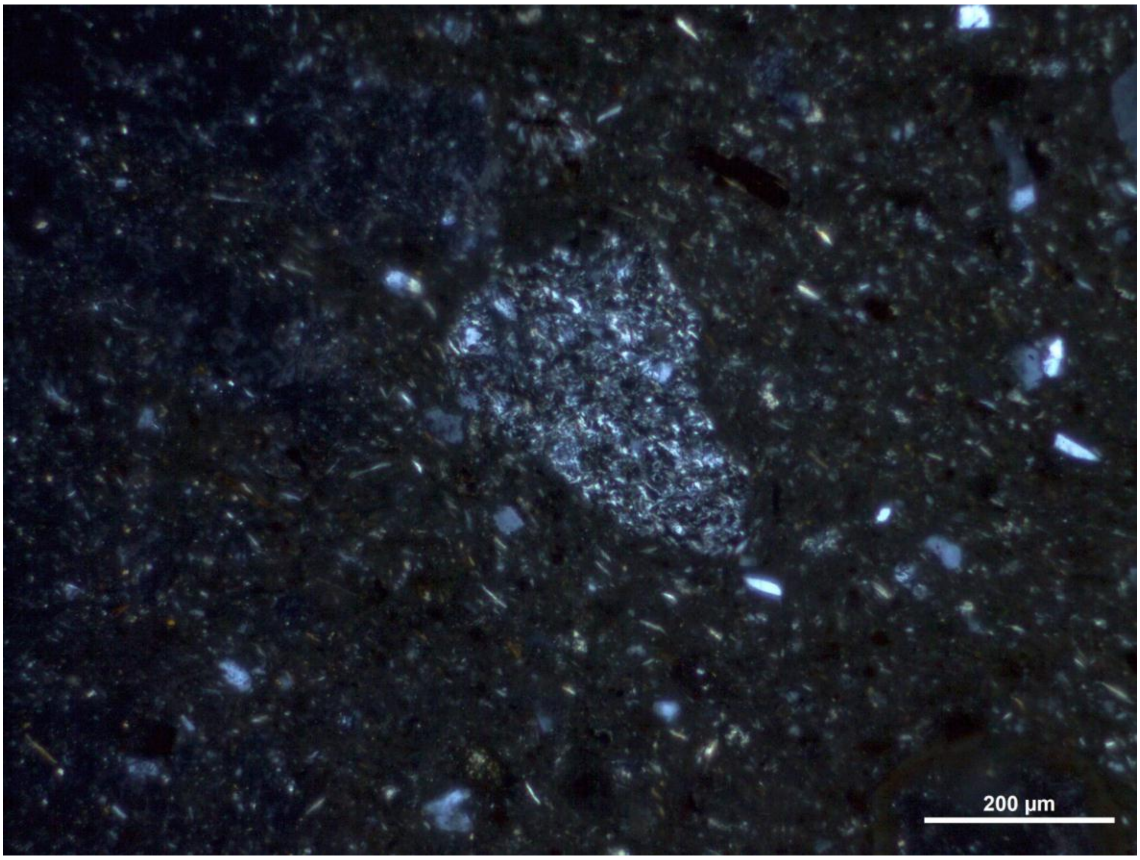

Figure A9: *Fabric GW5: Fine fabric with basalt and serpentinite* (XP). Showing one of the scarce grains of basalt, identifiable because of the microcrystals of feldspar over a glassy matrix

Loner

Sample: NS25 (Fig A10)

Inclusions: 20%, el & eq, sa-sr, single-spaced or less, weak alignment of inclusions to margins, unimodal distribution

Coarse fraction:

5%, 0.5-0.25 mm

Predominant (only):

Monochrystalline quartz, eq-el, sa-sr, <0.5 mm, mode = 0.25 mm. Small grains of monochrystalline quartz with undulose extinction, often with traces of twining similar to that one of plagioclase.

Fine fraction:

95%, 0.25-0.01 mm

Predominant: Monochrystalline quartz

Frequent: TFs: Clay pellets

Few: Opaques

Rare: Detrital epidote

Very rare: Calcareous mudstone

Matrix: 60%

Non calcareous matrix, although there are signs of secondary calcite in margins and near voids. In PPL the colour is dark red to greenish brown in one margin, and in XP it is dark greenish brown colour in the outside margin (with the glaze), dark reddish brown colour with milky spots of greenish brown in the rest of the matrix. Apart from the change of colour, the matrix is very homogeneous. No optical activity at all.

Voids: 20%

Vesicles to macro-vughs and abundant channels. Only channels are somehow aligned to margins. Sometimes there is secondary calcite in the voids.

Comments:

Clay mixing is not clear, the clay pellets seem to be of natural origin. The clay seems to have been very well selected.

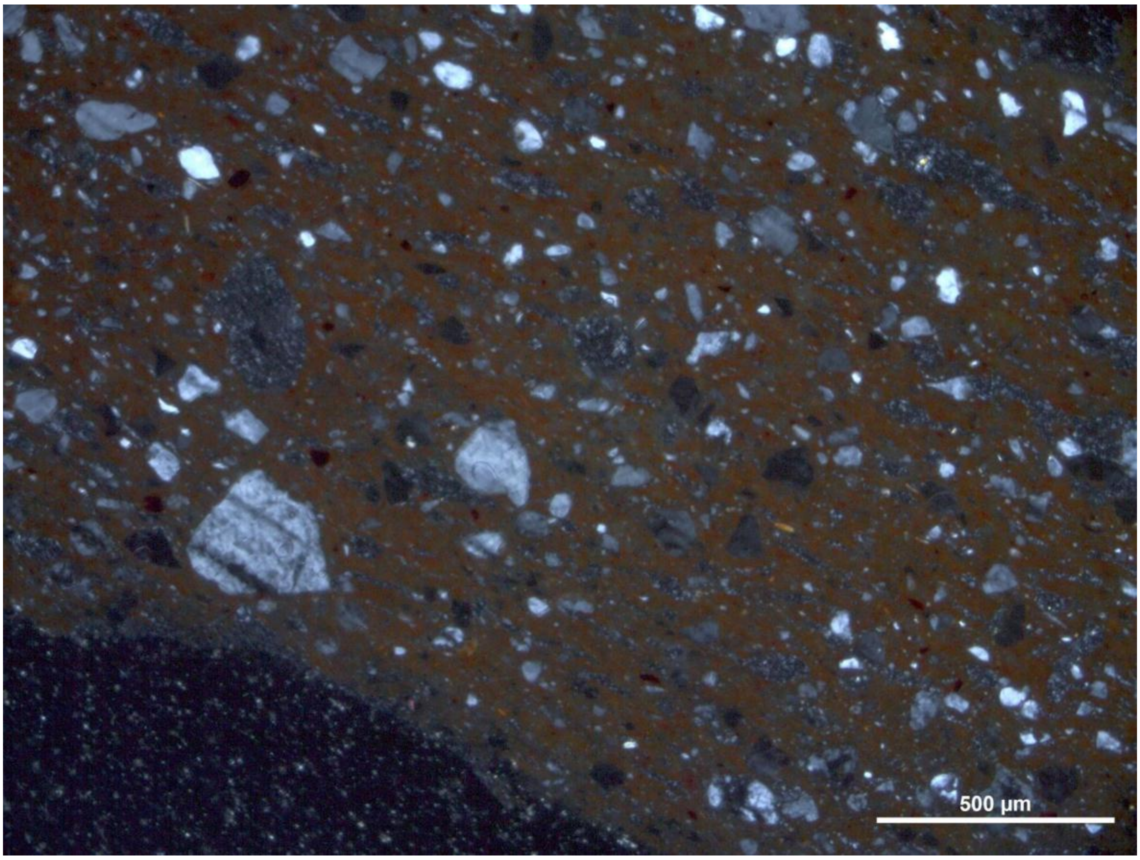

Figure A10: Loner NS25 (XP). Showing a non-calcareous matrix with abundant voids and inclusions of monocrystalline quartz.