

MALGORZATA DASZKIEWICZ & GERWULF SCHNEIDER

CHEMICAL AND MINERALOGICAL-PETROGRAPHIC COMPOSITION OF FABRICS FROM MUSAWWARAT ES SUFRA, SUDAN

INTRODUCTION

Laboratory analysis was carried out on 14 fragments of pottery representing 11 fabrics; eight fabrics defined by A. Seiler (Seiler 1999) and three fabrics defined by D. Edwards (Edwards 1999). The analysed ceramic sherds were recovered from excavations conducted at Musawwarat es Sufra by the German Archaeological Mission led by Prof. S. Wenig. Samples were selected for laboratory analysis by I. Gerullat, who is working on a report of the ceramic finds from this site. The aim of this research was to utilise laboratory methods to describe the pottery fabrics which had already been defined on the strength of a macroscopic examination. In addition, the use of quantitative analysis helped assess what exactly was signified by individual fabrics, i.e. whether the diagnostic features used to distinguish between fabrics are associated with technological processes alone (e.g. different firing temperatures and atmospheres, or the techniques used in preparing the ceramic body, in particular its de-aerating) or whether they also bear some relation to the raw materials used.

Ceramics are made by shaping a body which is then hardened by firing. Ceramics made using a clay (marly-clay or clayey-marl) body are known as pottery. The shaping of a clay body and the subsequent setting of this shape is possible thanks to the properties of the clay, which, when suitably crushed and pulverised, becomes plastic when wet, leather-hard when dried and on firing is transformed to a permanent rock-like mass. During drying and firing, when the water which gives the clay its elasticity is lost, the clay shrinks, which may result in scars and cracks forming if a non-plastic component is not added to it. Thus, the pottery formation process results in the plastic parts of the body being distinguishable from the non-plastic parts. In addition to clay minerals, the plastic components may also contain very finely divided minerals e.g. quartz. The pla-

stic part is considered to consist of all minerals of less than 10 mm fraction (i.e. grains of clay fraction and fine silt fraction). Ceramic components of more than 10 mm fraction (medium and coarse silt fraction, sand fraction and fine gravel fraction) make up the non-plastic part of the body. Non-plastic components can be either autogenic in the raw material or allogenic in relation to the deposit (deliberate inclusions added as a requirement of the technological process). During firing the plastic part of the body hardens as a result of the formation of new phases produced by thermal change in the clay minerals. The end result is a product (pottery) made up of a matrix (the hardened plastic part) and non-plastic components within the matrix. When trying to establish the provenance of ancient pottery, it is worth bearing in mind that there are a number of ways in which a ceramic body can be prepared. Geological factors may have dictated that different pottery production centres prepared bodies using the same plastic raw material and the same non-plastic inclusions. Where this was the case, individual workshops can only be identified by technological analysis (e.g. Daszkiewicz et al. 1995). Alternatively, various workshops may have used the same plastic raw material but different non-plastic inclusions, or else different plastic raw material as well as different non-plastic inclusions. It is also possible that different plastic and non-plastic materials were used by an individual workshop depending on the function of the vessel being produced.

Bearing in mind the aforementioned facts, a study of historic pottery ought to encompass analysis of both the body composition and its individual plastic and non-plastic components. This means that a minimum of three analytical methods must be employed (Fig.1):

- chemical analysis, which reveals the geochemical characteristics of both the plastic and non-plastic components of a pottery fabric. It enables the quantity of major and trace elements in the body

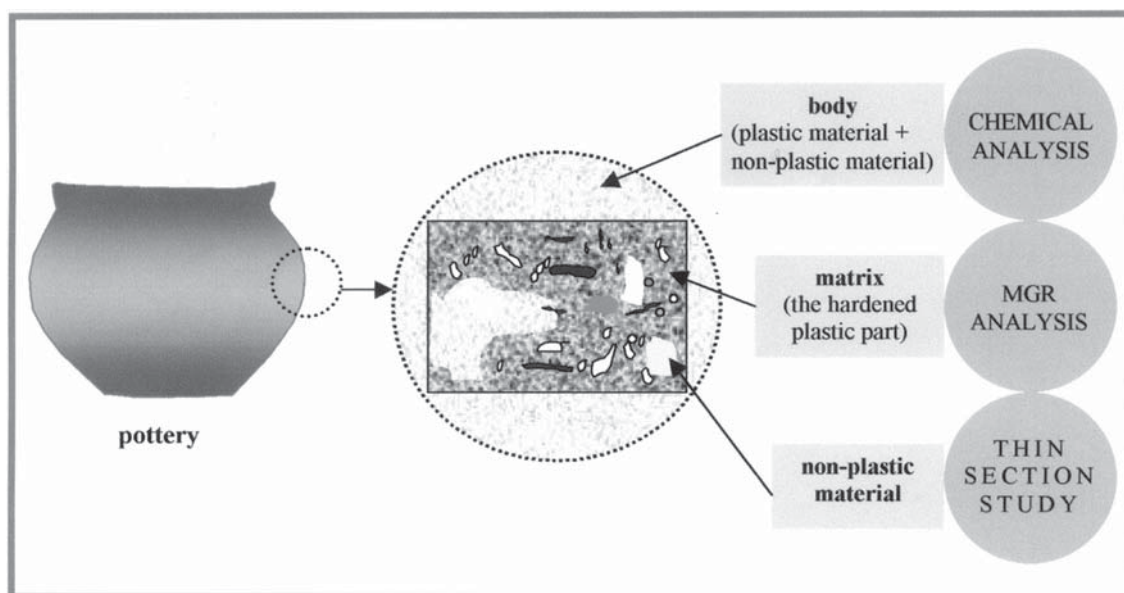


Fig. 1: Diagram showing use of analytical methods.

to be established, although the phases in which individual elements occur cannot be ascertained (giving the major elements as oxides is standard procedure in geochemistry when presenting the results of chemical analysis),

- thin-section studies are used primarily in order to specify the mineralogical-petrographic content and grain size distribution of the non-plastic components of the body. Thin-section analysis can provide only very general information about the matrix due to the resolution of the microscope, the size of the clay minerals making up the plastic part of the body and the fact that they undergo transformation when fired,

- a method for defining the matrix composition. In this study MGR-analysis (Matrix Group by Refiring) was used to identify matrix type in view of the fact that the colour and the thermal behaviour of plastic components during firing is governed by their chemical and phase composition (Daszkiewicz & Schneider 2001). MGR-analysis also enabled the range of original firing temperatures to be calculated.¹⁾

METHODS

MGR-analysis

Nine thin slices were cut from each sample in a plane at right angles to the vessel's main axis. One of these sections was left as an indicator of the sample's original appearance, whilst the remaining eight were fired in a laboratory chamber furnace, each one at a different temperature. Firing was carried out at eight different temperatures: 400, 600, 700, 800, 900, 1000, 1100 and

1200°C in air, static, with a heating rate of 200°C/h and a soaking time of 1h at the peak temperature. The fragments were then glued on to paper.

Chemical analysis

Wavelength-dispersive X-ray fluorescence analysis (Philips PW1400) was used to determine the content of major elements, including phosphorus and a rough estimation of sulphur and chlorine. It was also used to determine a series of fifteen trace elements, six of which, however, could only be ascertained with poor precision. Total iron was calculated as Fe₂O₃. Samples were prepared by pulverising fragments weighing 2-4g (sample size was determined by the number and size of the non-plastic components) having first removed their surfaces and cleaned the remaining fragments with distilled water in an ultrasonic device. The resulting powders were ignited at 900°C (heating rate 200°C/h, soaking time 1h), melted with a lithium-borate mixture (Merck Spectromelt A12) and cast into small discs for measurement. This data is, therefore, valid for ignited samples but, with the ignition losses given, may be recalculated to a dry basis. For easier comparison the major elements are normalised to a constant sum of 100%.

1) The original firing temperature is indicated by that temperature at which the first changes in the refired fragments become visible. This, however, does not apply for grey sherds. The temperature at which they change to a reddish colour depends on the nature of the grey colour, which can be due to reduced iron-oxide or to organic material or both.

Thin-section study

Thin-sections were studied under a polarising microscope. Quantitative analysis by point-counting was not carried out.

RESULTS

In MGR analysis both the behaviour and colour of the sample after refiring at 1100 and 1200°C²⁾ were taken into account when defining different matrix groups. The following types of matrix were identified based on the behaviour of samples when refired at 1200°C³⁾:

- a) sintered (SN) = the sherd is well compacted, it may or may not become smaller in size in comparison to the original sample, whilst its edges remain sharp,
- b) over-fired (ovF) = the sample changes in shape, bloating, however, does not occur nor does the surface of the sample become over-melted,
- c) slightly over-melted (sovM) = over-melting of the sample surface is observed, no change in shape, edges remain sharp,
- d) over-melted (ovM) = the surface of the sample becomes over-melted and its edges rounded,
- e) semi-melted (sMLT) = over-melting of the surface occurs, changes in sample shape are noted (not just rounded edges) but no bloating,
- f) melted (MLT) = the sample becomes spherical or almost spherical in shape,
- g) bloated over-fired (BlovF) = the sample expands in volume but the surface does not become over-melted,
- h) bloated over-melted (BlovM) = the sample expands in volume and its surface is over-melted.

Based on the colour of samples after refiring at 1200°C three fundamental categories of matrix can be identified: non-calcareous, calcareous and mixed matrices. The following criteria were used in matrix category classification:

1. samples were deemed to have a non-calcareous matrix if no calcium silicate or calcium aluminium silicate phases formed during laboratory refiring in air at a temperature of 1200°C, which was indicated by the fact that the samples did not adopt a greenish tint,
2. samples were said to have a calcareous matrix if calcium silicate or calcium aluminium silicate phases formed during laboratory refiring in air at a temperature of 1200°C, indicated by the fact that the samples did become green in colour (or had a greenish tint),

Euclidean distance	MGR group	Sample No.	
	SN1.0	MD2590	-.
2.243E-1	SN4.0	MD2592	-'-.
2.873E-1	SN4.0	MD2596	-'-.
4.098E-1	SN3.0	MD2589	-'-.
5.532E-1	SN1.0	MD2584	-'-GI--.
7.669E-1	ovF1.0	MD2583	GII-'----
1.011E+0	ovF2.0	MD2586	-. I-----.
2.881E-1	ovF2.1	MD2593	-'-.
4.228E-1	ovF3.0	MD2588	-'-.
4.895E-1	ovF4.0	MD2591	-'-GIII I
5.765E-1	sMLT1.0	MD2585	-. I-----'
3.424E-1	ovM1.0	MD2594	-'-GIV-'
1.572E+0	SN2.0	MD2587	-. I-
6.141E-1	SN2.1	MD2595	-'-GV-----'

Fig.4: Dendrogram of multivariate cluster analysis, Euclidean Distance of logged data, Average Link aggregative clustering (Brookhaven Data Handling Programs, Sayre 1975).

3. samples were considered to have a mixed matrix if various irregularly distributed patches of colour were noted in the fabric after refiring. Different colours and shades can be distinguished within each category of matrix. If samples display the same thermal behaviour, colour and shade after refiring this indicates that they were made using the same plastic raw material.

Analysis of the 14 pottery fragments from Musawwarat es Sufra led to the identification of five types of matrix:

- sintered = MD2584, MD2587, MD2589, MD2590, MD2592, MD2595, MD2596 (Fig.2 and Fig.3, Colour Page 90),
- over-fired = MD2583, MD2588, MD2586, MD2593 (Fig.2 and Fig.3, Colour Page 90),
- over-fired partially slightly over-melted = MD2591 (Fig.3, Colour Page 90),
- over-melted = MD2594 (Fig.3, Colour Page 90),
- semi-melted = MD2585 (Fig.2, Colour Page 90).

2) Experience gained from carrying out MGR-analysis on several thousand samples of clay and pottery from numerous sites of various date from Europe, the Near East, Egypt, Sudan and the New World clearly shows that terminating refiring at a lower temperature may lead to erroneous conclusions because, in many instances, after refiring at lower temperatures, even originally very low fired samples may look very similar (or identical) but will differ significantly after refiring at higher temperatures.

3) In order to standardize MGR-analysis reports (by which means it is then possible to compare results from the analysis of other historic pottery assemblages regardless of their date and the type of site they come from) the same categories of matrix type were used in this report as those employed in the classification of 500 pottery sherds from the Fourth Cataract region (Daszkiewicz 2001; Daszkiewicz et al. 2001).



Sample No.	Fabric	Founding place	Matrix categories	Matrix type	Matrix colour	MGR group	Original firing temperature [°C]
MD 2583	A2	KA/94	NC, Fe ⁺⁺	ovF	brown	ovF1.0	700-800
MD 2584	A3	KA/94	NC, Fe ⁺	SN	pale brown	SN1.0	700-800
MD 2585	A5	KA/86	NC, Fe ⁺⁺	sMLT	brown	sMLT1.0	700-800
MD 2586	A6	KA/187	NC, Fe ⁺⁺	ovF	red-brown	ovF2.0	700-800
MD 2587	A7	KA/331,9	NC, Fe ⁺⁺	SN	brownish-red	SN2.0	800-900
MD 2588	B1		NC, Fe ⁺⁺	ovF	milk chocolate	ovF3.0	700-800
MD 2589	B2	KA/94	NC, Fe	SN	brownish-beige	SN3.0	900-1000
MD 2590	H3	GA/372	NC, Fe ⁺	SN	pale brown	SN1.0	800-900
MD 2591	H5		NC, Fe ⁺⁺	sovM/ovF	reddish-brown	ovF4.0/sovM	900-1000
MD 2592	H6	GA/372	NC, Fe ⁺	SN	reddish-brownish	SN4.0	900-1000
MD 2593	A1	KA/79	NC, Fe ⁺⁺	ovF	red-brown	ovF2.1	900-1000
MD 2594	?	GA/247	NC, Fe ⁺⁺	ovM	brown	ovM1.0	700-800
MD 2595	A7	GA/249	NC, Fe ⁺⁺	SN	brownish-red	SN2.1	800-900
MD 2596	B1		NC, Fe ⁺	SN	reddish-brownish	SN4.0	900-1000

Tab.1: List of analysed fabrics and results of MRG-analysis, A1, A2, A3, A5, A6, A7, B1, B2 = fabrics defined by A. Seiler; H3, H5, H6 = fabrics defined by D. Edwards.

All 14 samples belong to one matrix category – they all have an iron-rich non-calcareous matrix. The colour of samples after refiring at 1200°C indicates the presence of a varied content of ferrous compounds staining the matrix. Samples can be divided into groups with a matrix which is either lightly, moderately or strongly coloured by iron compounds. When fired these samples take on various shades of brown and red.

An assessment of the thermal behaviour, colour and shade of refired samples led to the definition of 11 MGR groups (Tab.1). Eight MGR groups consist of only one sample, whilst six samples form pairs making up a further three MGR groups. Samples MD2592 and MD2596 displayed identical thermal behaviour, colour and tint (group SN4.0). Identical thermal properties were also noted for samples MD2584 and MD2590 (group SN1.0), whilst samples MD2586 and MD2593 showed the same thermal behaviour and colour, differing only in tint (groups ovF2.0 and ovF2.1 respectively).

The results of chemical analysis led to the identification of five groups with different geochemical indicators. These groups could be further subdivided into groups of greater similarity (Tab.2, Page 84). Figure 4 presents the results of chemical analysis in the form of a dendrogram of multivariate cluster analysis using Euclidean Distance of logged data and 'Average Link' aggregative clustering (Brookhaven Data Handling Programs, Sayre 1975). This dendrogram was compiled taking into account the following elements: Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, V, Cr, Ni, Zn, Rb, Sr, Y, Ba, La, and Ce.⁴⁾

The dendrogram shows that the Euclidean Distance between samples within any one group is, in most cases, relatively large.

Group I (GI) consists of only those samples which have a matrix that is slightly or moderately coloured by iron compounds and is classified as a SN matrix type. Samples MD2584 and MD2590 are divided by the longest Euclidean Distance in this group, however, they both belong to the same MGR group (SN1.0). This indicates that the same plastic material was used to make the bodies of these samples and that the differences in element content are related to the non-plastic parts of the bodies. The Si content of sample MD2584 is 4% higher than that of sample MD2590, whilst its Al content is lower (Tab.2). This sample, therefore, contains more quartz grains - thin-section analysis illustrates that these samples differ in grain size - sample MD2584 has a greater number of coarse grains of quartz (Tab.3). Other than grains of quartz and polycrystalline quartz both samples contain opaque minerals, conglomerate of quartz with

4) Si = silicon, calculated as SiO₂; Al = aluminium, calculated as Al₂O₃; Ti = titanium, calculated as TiO₂; Fe = iron, total iron calculated as Fe₂O₃; Mn = manganese, calculated as MnO; Mg = magnesium, calculated as MgO; Ca = calcium, calculated as CaO; Na = sodium, calculated as Na₂O; K = potassium, calculated as K₂O; P = phosphorus, calculated as P₂O₅; V = vanadium; Cr = chromium; Ni = nickel; Cu = copper; Zn = zinc; Rb = rubidium; Sr = strontium; Y = yttrium; Zr = zirconium; Nb = niobium; Ba = barium; La = lanthanum; Ce = cerium; Pb = lead; Th = thorium.

Tab.2: Results of chemical analysis by WD-XRF, major elements in per cent by weight, traces in parts per million, loss of ignition at 900°C (LOI), elements in brackets are determined with low precision, bd = below detection limit; - = not analysed. The sulphur (S) and chlorine (Cl) content is not given in this table as it was below the detection limit in all samples.

MGR group	Sample No.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	ppm										LOI	TOTAL					
		% by weight																				%	%					
Chemical group I (GI)																												
SN1.0	MD2590	67.19	1.50	22.13	5.68	0.097	0.95	0.97	0.40	0.85	0.24	133	152	52	39	54	27	104	51	257	17	313	30	96	20	bd	1.93	100.17
SN4.0	MD2592	67.41	1.49	21.76	5.84	0.075	0.91	0.91	0.43	0.93	0.24	150	156	50	38	53	30	96	46	258	19	287	43	94	17	11	1.60	100.92
SN4.0	MD2596	67.87	1.55	21.17	5.77	0.076	0.81	1.04	0.58	0.88	0.26	153	142	56	29	51	22	92	53	275	15	226	39	84	14	bd	5.70	99.72
SN3.0	MD2589	68.76	1.51	21.90	4.61	0.050	0.72	1.11	0.44	0.74	0.15	126	162	42	29	36	24	117	44	268	16	302	28	83	22	bd	1.98	100.26
SN1.0	MD2584	71.00	1.32	18.46	5.26	0.056	0.90	1.43	0.51	0.88	0.19	137	122	43	34	44	20	170	38	256	11	363	21	48	10	bd	4.54	99.63
Chemical group II (GII)																												
ovF1.0	MD2583	67.14	1.34	19.43	6.77	0.050	1.11	1.76	0.52	1.58	0.29	120	126	54	31	65	23	249	38	248	15	811	33	78	17	bd	4.35	99.99
Chemical group III (GIII)																												
ovF2.0	MD2586	68.27	1.34	15.95	7.21	0.109	1.60	2.31	1.07	1.66	0.49	139	142	65	38	81	44	227	46	354	13	420	31	71	16	bd	4.86	100.51
ovF2.1	MD2593	67.91	1.61	16.77	7.19	0.109	1.63	2.32	0.87	1.09	0.51	156	145	66	43	75	33	208	37	381	21	429	27	72	17	bd	2.61	100.35
ovF3.0	MD2588	62.85	1.85	21.46	5.94	0.081	1.78	2.79	1.04	1.86	0.34	146	140	51	37	88	34	270	39	433	23	421	36	113	21	bd	6.29	100.09
ovF4.0/sovM	MD2591	67.67	1.49	14.70	8.32	0.131	2.05	2.70	1.01	1.66	0.27	144	136	68	46	83	45	190	-	331	-	386	-	76	-	-	1.66	100.30
Chemical group IV (GIV)																												
sMLT1.0	MD2585	62.91	1.69	14.81	8.79	0.151	2.30	4.18	1.72	1.59	1.86	161	159	66	35	87	35	401	31	310	20	765	25	57	15	bd	4.78	99.64
ovM1.0	MD2594	62.19	1.73	16.50	9.91	0.122	2.50	3.55	1.57	1.65	0.27	189	164	75	52	91	38	283	36	290	21	466	20	63	19	bd	6.39	100.61
Chemical group V (GV)																												
SN2.0	MD2587	65.41	0.97	18.94	5.73	0.070	0.88	1.04	1.39	5.48	0.10	69	56	33	19	59	149	143	62	537	24	704	81	214	26	24	0.12	100.01
SN2.1	MD2595	62.62	0.84	20.54	6.32	0.050	0.78	1.64	0.91	6.15	0.16	70	44	30	18	70	128	307	53	542	17	1490	84	147	23	14	5.00	100.38



Tab.3: Results of thin-section studies.

Sample No.	Fabric MGR group	Non-plastic material, grain size [mm] and composition				
		main grain fraction	minimal grain fraction	maximal grain fraction		
MD 2590	H3	SN1.0	0.04-0.30	Q, pQ, cng, cng~, OM, Imp, Pl*	0.0125* Q, Mc, OM, Hb*, Px*	0.75 Q~, cng
MD 2592	H6	SN4.0	0.04-0.50	Q, pQ, OM, cng*, org	0.0125* Q, Mc, OM, Hb*, Px*	1.25 Q~
MD 2596	B1	SN4.0	0.04-0.25	Q, pQ, OM, cng*	0.0125* Q, Mc, OM, Hb*, Px*	0.50 Q~
MD 2589	B2	SN3.0	0.025-0.5	Q, Q~, OM, cng~, cng", Bc, Px*	0.0125* Q, Mc, OM, Hb*, Px*	1.40 Q~, pQ, cng~, cng", Bc
MD 2584	A3	SN1.0	0.04-0.30	Q, pQ, cng", OM, Imp, Pl*, org	0.0125* Q, Mc, OM, Hb*, Px*	2.25 Q~, cng"
MD 2583	A2	ovF1.0	0.05-0.50	pQ, Q~, Q, OM, Feagg, Hb*, Px*, Mc*, org	0.0125* Q, OM, Mc, Hb*, Px*	1.5 Feagg
MD 2586	A6	ovF2.0	0.04-0.25	Q, Mc, Ep*, Px, Hb*, Pl*, org	0.02 Q, Hb*, Px, Ep*	0.9 Q~
MD 2593	A1	ovF2.1	0.04-0.25	Q, Mc, Ep*, Px, Hb*, Pl*, org	0.02 Q, Hb*, Px, Ep*	0.5 Q~
MD 2588	B1	ovF3.0	0.04-0.50	Q, grog, agg, Mc, Fs*, Ep*, Hb*, Px*	0.02 Q, OM, Hb*, Px, Ep*	5.0 agg+
MD 2585	A5	sMLT1.0	0.025-0.15	Q, Pl, OM, MC, Px, Hb, Ep, org		0.75 Q~, pQ
MD 2594	?	ovM1.0	0.025-0.12	Q, Pl, OM, MC, Px, Hb, Ep, org		0.50 Q~, pQ
MD 2587	A7	SN2.0	0.05-1.25	Fs, Q~, Hb, org		
MD 2595	A7	SN2.1	0.05-1.50	Fs, Q~, Hb		

* = rare frequency

Q~ = quartz, grains with cracks and gas-liquid inclusions

pQ = polycrystalline quartz

cng = conglomerate of quartz with unidentified white coloured matrix

cng" = conglomerate of quartz with unidentified black coloured matrix

cng~ = unidentified aggregates

agg+ = clay aggregate with very fine material

agg = clay aggregate without non-plastic material

Feagg = iron-rich aggregates

Imp = clay lumps

Bc = clayey-calcareous aggregate after bioclasts

Q = quartz

Pl = plagioclases

Fs = feldspars

Mc = micas

OM = opaque minerals

Hb = hornblende

Px = pyroxenes

Ep = epidote

Sample No.	Geological region - clay	Chemical groups	MGR group	Fabric	Production centre/workshop
MD 2584	I - 1	G I	SN1.0	A3	A/1
MD 2590	I - 1	G I	SN1.0	H3	A/2
MD 2592	I - 1	G I	SN4.0	H6	B/1
MD 2596	I - 1	G I	SN4.0	B1	B/1
MD 2589	I - 1	G I	SN3.0	B2	C/1
MD 2583	I - 2	G II	ovF1.0	A2	D/1
MD 2586	I - 3	G III	ovF2.0	A6	E/1
MD 2593	I - 3	G III	ovF2.1	A1	E/1
MD 2588	I - 3	G III	ovF3.0	B1	F/1
MD 2591	I - 3	G III	ovF4.0/sovM	H5	G/1
MD 2585	I - 4	G IV	sMLT1.0	A5	H/1
MD 2594	I - 4	G IV	ovM1.0	?	H/1
MD 2587	II - 1	G V	SN2.0	A7	X/1
MD 2595	II - 1	G V	SN2.1	A7	X/2

Tab. 4: Final grouping.

unidentified matrix (black or white coloured), clay lumps, fine micas and some fine hornblende and pyroxenes (Fig. 5 and Fig. 6, Colour Page 91). Sample MD2584 was originally fired at 700-800°C, the fractured surface of this sample shows that parts of the matrix are lightly stained by an unburned organic substance. Sample MD2590 was fired at over 800-900°C and displays no evidence of any unburned organic substance. Both samples were probably made at the same production centre but at two different workshops.

A further two GI samples (MD2592 and MD2596) belong to MGR group SN4.0. Their chemical composition is practically the same, as is their non-plastic material composition, consisting of grains of quartz, polycrystalline quartz, conglomerate of quartz with unidentified matrix (white coloured), opaque minerals, fine micas, some pyroxenes and hornblende (Fig. 7, Colour Page 91). These samples differ only in their grain size distribution, sample MD2596 having grains which are a maximum of 0.5mm in diameter (most grains fall within a range of 0.04-0.25mm), whilst sample MD2592 contains individual grains of up to 1.25mm in diameter (most grains measuring 0.04-0.5mm). In both instances, the maximum diameters noted were for quartz grains, which are either cracked or cracked with gas-liquid inclusions. The original firing temperature of both these samples was 900-1000°C. The only vessel whose organic content was not entirely burnt out during firing was that represented by the thick-walled sample MD2592. This phenomenon was particularly noticeable in the middle section of the vessel wall (rapid increase in temperature during firing and short firing time). Both bodies

display a similar degree of compaction. All of these factors suggest that both samples were probably made at the same workshop, the differences in their grain size distribution relating to the function of the given vessel.

The fifth GI sample (MD2589) is notable in having the lowest content of Fe ($\text{Fe}_2\text{O}_3 = 4.61\%$) and slightly higher levels of Cr. Its distinctiveness in thin-section stems from the presence of some clayey-calcareous aggregate after bioclasts. The original firing temperature range for this sample was 900-1000°C.

In comparison to the remaining nine samples, GI samples have the lowest flux content, the highest Al content and a high Si/Zr ratio. Conglomerate of quartz with white firing matrix were noted in each GI sample forming condensed aggregates with a distinct boundary visible between the aggregates and the matrix. No evidence was noted to suggest that these aggregates were plastic at the time when the vessels were formed. Dry aggregates were added to a plastic body in order to serve as non-plastic inclusions. They do not represent the mixture of two different clay raw materials.

The second chemical group (GII) comprises only one sample (MD2583). This sample has an ovF matrix type with non-plastic particles consisting of grains of polycrystalline quartz, quartz, iron-rich aggregates, opaque minerals, fine micas, hornblende and pyroxenes. It was originally fired at 700-800°C, and contains traces of an unfired organic substance.

The next chemical group (GIII) is made up of four samples with an ovF matrix type. Two of these samples (MD2588 and MD2591) constitute

separate subgroups differing from each other in matrix colour. Sample MD2588 has the lowest Si content (63%) in this group, its non-plastic components including quartz, individual fragments of crushed pottery sherds (grog temper) and various round clay aggregates with/without a distinct boundary visible between the aggregates and the matrix (Fig.8, Colour Page 91). This may point to the use of recycling technology, i.e. the use of crushed fragments of vessels which became deformed during the drying stage and were not fired.

Samples MD2586 and MD2593 are very similar to each other and they were probably made at the same workshop.

Chemical group IV (GIV) consists of two samples of the same matrix colour and with the same non-plastic components comprising: quartz, plagioclases, opaque minerals, micas, hornblende, pyroxenes and epidote (most grains fall within a range of 0.025-0.15mm). These samples differ only in their maximal grain size, sample MD2585 having grains which are a maximum of 0.75mm in diameter, whilst sample MD2594 contains individual grains of up to 0.5mm in diameter. In both instances, the maximum diameters noted were for polycrystalline quartz and quartz grains, which are either cracked or cracked with gas-liquid inclusions (Fig.9, Colour Page 91). The original firing temperature of both these samples was 700-800°C. These samples differ slightly in their thermal behaviour, linked to the differences in their chemical composition (Tab.2).

The final chemical group (GVI) is made up of two samples (MD2587 and MD2595). Like GI samples these have a SN matrix type, however, they differ considerably from GI samples in the degree to which the matrix is stained by iron-compounds. They differ from all other samples in their chemical analysis results, these two samples originating from a different geological region to the remaining 12 samples. Both were fired at 800-900°C. The body contained intentional inclusions of feldspars which were most probably produced by the disintegration of rocks such as pegmatite (Fig.10, Colour Page 91). An outcrop of these rocks must have been situated within the vicinity of the workshops where these vessels were made. Slight rounding of the feldspar grains was observed indicating that this is not a material which was intentionally crushed by potters but was extracted by them from a source where the products of weathering of pegmatite were deposited.

CONCLUSIONS

The final results summarised in table 4 led to the following conclusions.

1. The clays used in making the analysed pottery sherds representing 11 different fabrics came from two geologically different regions.

2. Clays from the second of these two regions are characterised by high contents of potassium, rubidium, zirconium, barium, lanthanum and cerium with low contents of vanadium, chromium and nickel. The chromium content is one and a half times greater than that of nickel. Clay deposits of this type were used in the production of only two samples, both of which represent fabric A7.

3. Clays from the first of the two geological regions contrast to those from the first in having twice as high a content of vanadium and nickel, nearly three times as high a content of chromium and a much lower zirconium content (the Si/Zr ratio is twice as high). Chromium content is, on average, nearly three times higher than nickel content. Clay deposits with these geochemical parameters were the raw materials used in the production of 12 pottery sherds (fabrics A1, A2, A3, A5, A6, B1, B2, H3, H5 and H6).

4. Five ceramic groups of similar chemical composition can be identified from the results of chemical analysis.

5. Chemical group I (GI) encompasses five samples, each of which represents a different fabric: A3, B1, B2, H3 and H6. GI samples can be divided into three subgroups based on the results of MGR-analysis. These subgroups most probably represent three different pottery workshops which utilized various layers of the same clay deposit. A characteristic feature of samples belonging to GI is their SN matrix type and the presence of inclusions of conglomerate of quartz with unidentified matrix. Conglomerates having black coloured matrices are turning white when fired in an oxidizing atmosphere.

6. GI samples representing fabrics A3 and H3 were made of the same clay, but contain different quantities and sizes of quartz grains. Fabric A3 was made using a body with a greater quartz content – the sample representing this fabric came from a vessel whose walls were twice as thick as those of the sample representing fabric H3. However, the differences in the ceramic recipes used (the ratio between the matrix and added temper) are large enough to assume that these vessels were produced at two different workshops.

7. GI samples include representatives of fabric B1 and fabric H6 which share the same matrix group and non-plastic materials. These vessels were made at the same workshop using the same

clay raw material and temper. They differ slightly from each other in their grain size distribution which is linked to the technological processes used in their production (and, thus, also to the function of each vessel). Thick-walled vessels (fabric H6) differ from thin-walled vessels (fabric B1) by the presence of coarse grained quartz.

8. One GI sample representing fabric B2 was made of a clay which displayed the smallest degree of staining by iron compounds and could not be grouped with any other sample.

9. Inclusions of white firing conglomerate of quartz noted in samples belonging to GI and representing fabrics A3, B1, B2, H3 and H6 do not evidence the use of a mixture of two different clay raw materials. These aggregates constitute a dry temper which was added to the plastic ceramic body. There was no indication that these aggregates were in a plastic state when the vessel was being shaped.

10. Chemical group II comprises only one sample representing fabric A2.

11. Chemical group III consists of four samples, all of which have an ovF matrix type.

12. GIII samples representing fabrics A1 and A6 were probably produced at the same workshop using the same raw materials and ceramic recipe.

13. The sample representing fabric B1 was made of a clay raw material of the same thermal behaviour as all the other GIII samples, but with a different composition of non-plastic materials. This vessel was made using recycling body technology.

14. Fabric H5 is represented by a single sample forming a separate subgroup of GIII.

15. The two samples making up GIV were most probably made at the same production centre. One of the samples represents fabric A5, the other was not attributed to a certain fabric. Both samples were originally fired at the same temperature: 700-800°C.

16. Two samples representing fabric A7 belong to the same chemical group (GV) but were made using material from different layers of the same clay deposit with the addition of intentional inclusions of coarse-grained feldspars. The ceramic recipes used in making these sherds vary slightly from one another (their matrix to temper ratio), the non-plastic material present in these samples being the product of pegmatite disintegration. The workshop where these vessels were made should be found in a location where outcrops of this rock occur. The non-plastic inclusions were not deliberately crushed but extracted in this state from their parent deposit. Both samples were originally fired within the same temperature range of 800-900°C.

17. Two samples representing fabric B1 are not classified in the same group. They belong to

different chemical and MGR-groups, and were also originally fired at very different temperatures: 700-800°C and 900-1000°C respectively.

18. Nine fabrics were each represented by a single sample, thus it is difficult to draw any conclusions about the consistency of analysis results for these fabrics.

19. No carbonate inclusions were noted in any of the samples analysed, nor were any secondary deposits of carbonate inclusions observed within the pores. The same was also true of both fabric B1 samples - which, according to the fabric description, ought to contain particles of "Kalkstein (z.T. ausgebrannt)" - and of fabric A7 samples. Neither micas nor calcite were observed in the two samples representing fabric A7.

20. The presence of grog was observed in one of the two samples representing fabric B1 (GIII).

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Sample number	Sample before refiring	Sample after refiring in air							
		400°C	600°C	700°C	800°C	900°C	1000°C	1100°C	1200°C
MD 2583									
MD 2584									
MD 2585									
MD 2586									
MD 2587									
MD 2588									
MD 2589									

by M. Daszkiewicz & E. Bobryk, Warsaw 1999

Fig. 2: Chart showing fragments refired in air at eight different temperatures, compared with fragments before refiring: MD2583 = Fabric A2; MD2584 = Fabric A3; MD2585 = Fabric A5; MD2586 = Fabric A6; MD2587 = Fabric A7; MD2588 = Fabric B1; MD2589 = Fabric B2 (fabrics defined by A. Seiler).

Sample number	Sample before refiring	Sample after refiring in air							
		400°C	600°C	700°C	800°C	900°C	1000°C	1100°C	1200°C
MD 2590									
MD 2591									
MD 2592									
MD 2593									
MD 2594									
MD 2595									
MD 2596									

by M. Daszkiewicz & E. Bobryk, Warsaw 1999

Fig. 3: Chart showing fragments refired in air at eight different temperatures, compared with fragments before refiring: MD2590 = Fabric H3; MD2591 = Fabric H5; MD2592 = Fabric H6; MD2593 = Fabric A1; MD2594 = Fabric ?; MD2595 = Fabric A7; MD2596 = Fabric B1 (fabrics H3, H5 and H6 defined by D. Edwards, fabrics A1, A7 and B1 defined by A. Seiler).

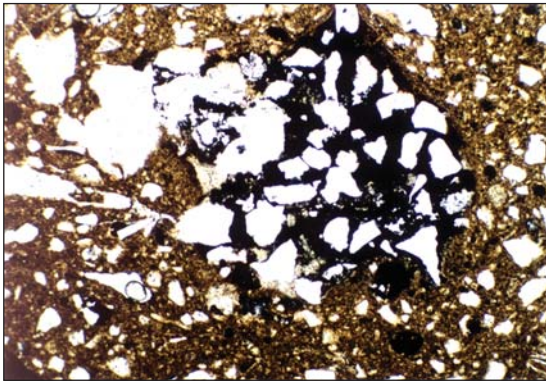


Fig. 5: Micrograph of thin-section image. Sample MD2584, conglomerate of quartz with unidentified black coloured matrix (part of vessel coloured by unburned organic substance); PPL, width of field corresponds to 2.5 mm.

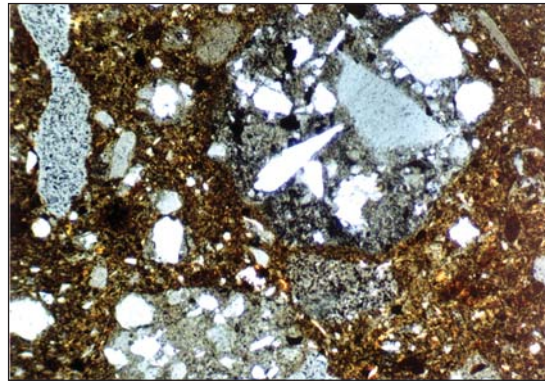


Fig. 6: Micrograph of thin-section image. Sample MD2590, conglomerate of quartz with unidentified white coloured matrix (part of vessel without unburned organic substance); PPL, width of field corresponds to 1.0 mm.

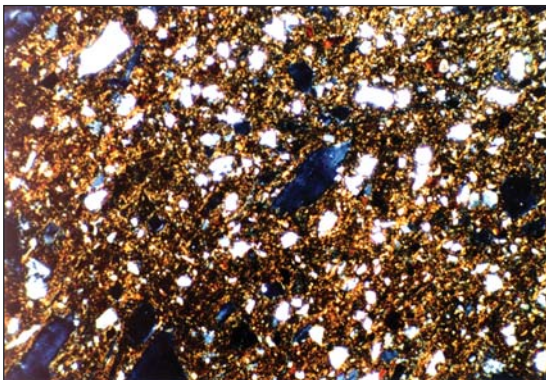


Fig. 7: Micrograph of thin-section image. Sample MD2596, fine grains of quartz, typical thin-section image of samples of B/1 workshop; XPL, width of field corresponds to 2.5 mm.

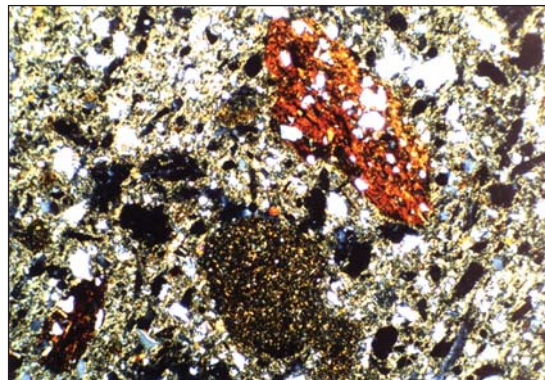


Fig. 8: Micrograph of thin-section image. Sample MD2588, grog temper; XPL, width of field corresponds to 2.5 mm.

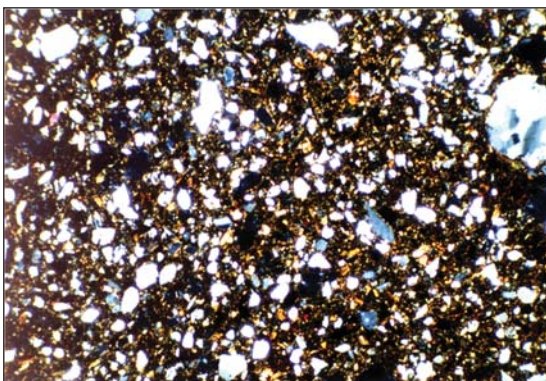


Fig. 9: Micrograph of thin-section image. Sample MD2585, very fine non-plastic material mostly quartz; XPL, width of field corresponds to 2.5 mm.

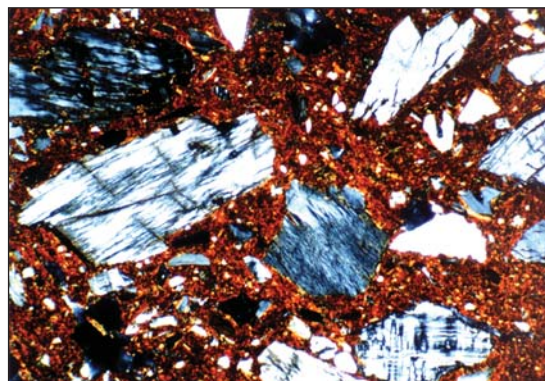


Fig. 10: Micrograph of thin-section image. Sample MD2595, temper of feldspars and quartz; XPL, width of field corresponds to 2.5 mm.

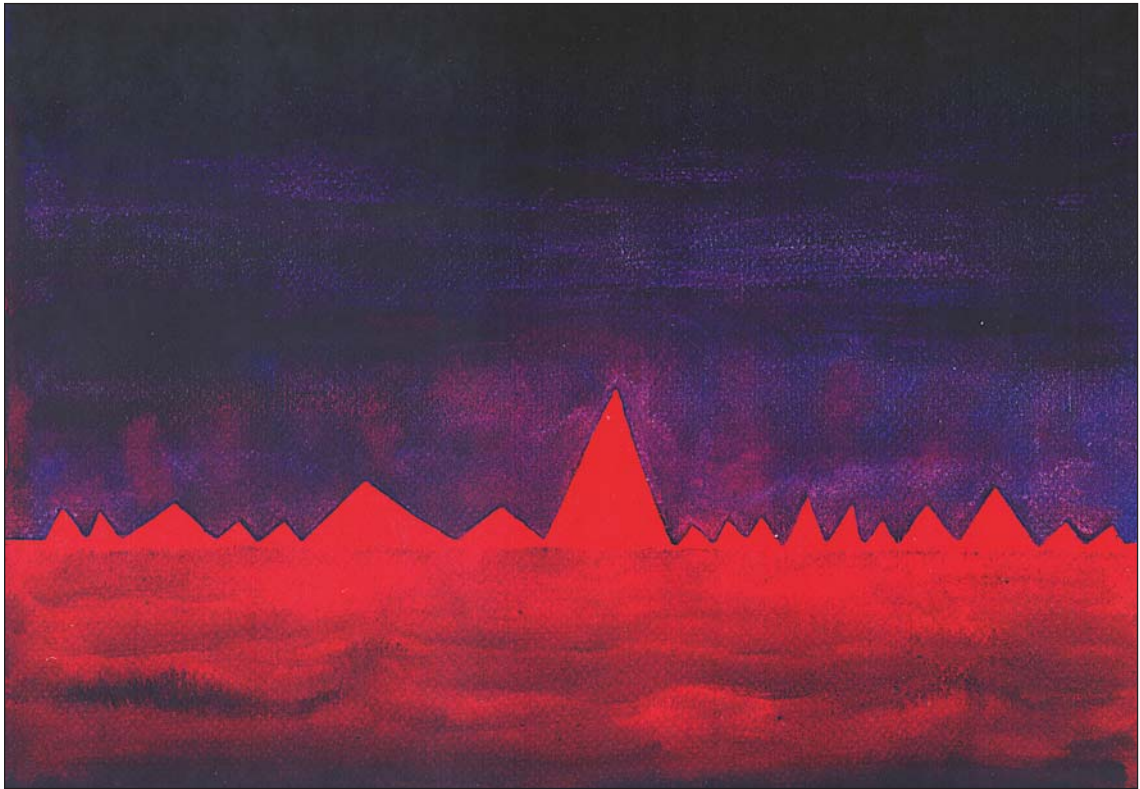


Abb. 8: Rote Pyramiden, Ölkreide, o.J.

Die am Horizont stehenden Pyramiden geben treffend die Szenerie des Pyramidenfeldes von Meroe wieder. Der Schein der untergehenden Sonne beleuchtet die rötliche Wüste und die vor dem Abendhimmel stehende Reihe der Pyramiden.



Abb. 9: Pyramiden, Ölkreide, o.J.

Das Bild gibt eine Kombination von Ansichten und Eindrücken wieder, die beim Besuch eines meroitischen Pyramidenfeldes zurückbleiben. Getürmt, gedrängt, fern und nah zugleich sind die Massive angehäuft.

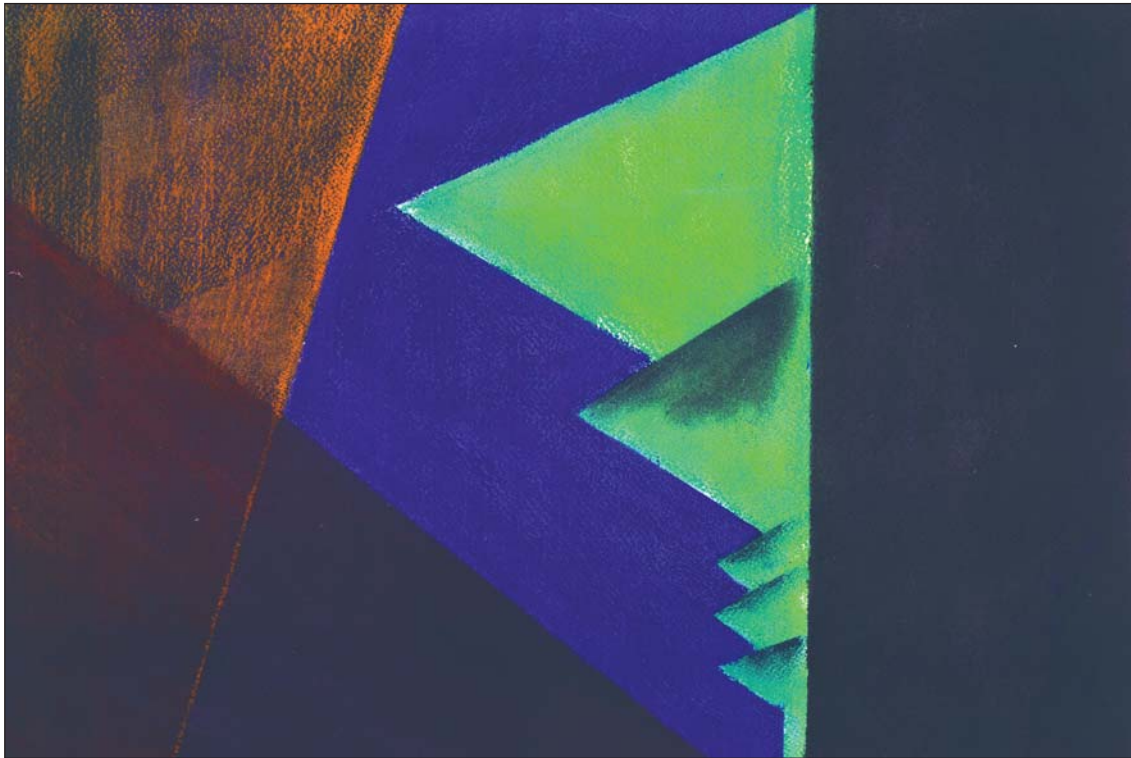


Abb. 10: Grüne Pyramiden,
Ollereide, o.J.
Die Regelmäßigkeit und
Wucht der Pyramiden ist
das Thema dieser Darstel-
lung, in der die anwachsen-
de Größe der Monumente
sich sogar in der Gestaltung
des Himmels fortsetzt.

Abb. 11: Die Dreistadt
Khartoum; Feder und
Aquarell, 1985
Das Motiv der Dreistadt
wird in einer frühen Bil-
drolle bereits entwickelt;
oben Khartoum, rechts
Omdarman,
links Khartoum-Nord,
im Zentrum Tuti-Island.

