Lithological Provenance of Prehistoric Ceramics from the Central Sudan: A physico-chemical Approach

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Abstract: *The present study sheds lights on the provenance of prehistoric ceramics from four archaeological sites in th central Sudan (**lat. 14º 50' - 16º - 30' N; long. 32º 18' - 38º 54' E; fig. 1**). To elucidate the nature of temper and clay matrix used in the production of these ceramics and to discern their lithological provenance, a series of physico-chemical analyses (petrographic, X-ray diffraction, X-ray fluorescence and Goethite Norm techniques) were used. Moreover, unfired clays that might have been used to make these ceramics were examined to get an impression of the composition in terms of mineralogy of the original clays utilized. The results of the physico-chemical analyses of the pottery samples recovered from the investigated-sites suggest local manufacture as their temper inclusions and soil samples indicate local derivation.*

Introduction:

Provenance studies are commonly used in many researches, besides pottery including obsidian and stone artifacts (e.g. Bradely and Suthern 1990: 117-122). These are very important in ancient pottery studies, and the critical first step in studying pottery production is to determine where artifacts were produced. In a historic period this does not pose a great difficulty since the presence of documents and known kiln-sites indicate the location of pottery source (Shepard 1956: 165-168 and Rice 1987: 413). In prehistoric periods information of the location of production-sites, the types of pottery fabricated and the organization of production are of great importance (Rice 1987: 413).

Pottery provenance studies can be conducted using three approaches: firstly there are studies whose primary aim is to evaluate the usefulness of various research techniques, making use of several tests upon the empirical data. The work of Van der Leeuw (1976) on the Neolithic pottery in Netherlands and medieval pottery (dated ca. 600-1200 A.D.) on the Eurphates in northern Syria is an example of this approach.

The second approach involves various types of analyses including petrological, chemical, mineralogical, thermic, etc. A model of composition is established for local production. Some archaeologists believe that it is possible by this way to establish precise standards of raw material composition with geological data and to isolate samples of unidentified provenance. The work of Hulthen on the Neolithic and Iron Age pottery in Denmark and Germany can be taken as an example to represent this line of investigation (see Hulthen 1977).

The third approach, which is applied more widely, parallels detailed studies of both ceramics and raw material of a region via a series of physico-scientific analyses. The work of Nordstrom on the early and middle Nubian pottery from Sudanese Nubia illustrates this line of research (see Nordstrom 1979: 33-93). It is noteworthy that the present research has adopted this type of investigation as it provides a coherent picture about the criteria diagnostic of the origin for the pottery in question.

In the present work the analyzed pottery samples were derived from four archaeological sites; namely Sarurab2 (***15º 56' N, 32' 32º E***) and Shabona (***14^{o} 38' N, 32^{o} 16' E***) which are affiliated to the Khartoum Mesolithic tradition (ca. 7000 - 5000 B.C.). The other two sites include Shaheinab (***16^{o} 03' N, 32^{o} 33' E***) and Nofalab 2 (***15^{o} 52' N, 32^{o} 32' E***) and belong to the Khartoum Neolithic tradition (c. 4500 - 3500 B.C.) (see the map, fig.1 and infra).

The mineralogical analyses described here were based on pottery samples unearthed from the present writer own excavations at Sarurab2 and Nofalab2 sites or made available to him from a series of excavated Mesolithic (Shabona) and Neolithic (Shaheinab) sites on the White Nile (***13-14^{o} 50' N, 32^{o} 18' E***) and Khartoum (***15-16^{o} 14' N, 32^{o} 34' E***) districts respectively.

The Mesolithic pottery (Sarurab2 and Shabona) is characterized by the diagnostic wavy line decorations (Arkell 1949) whereas the Neolithic one (Arkell 1953) is distinguished by triangular and fish-scale patterns. Further frequent decorations include impressed straight, incised and zigzag designs (see Pls. 1, 2 & 3).

It is to be noted that the pottery samples of the Mesolithic and Neolithic sites are generally hard of coarse grained-fabric and well-fired. The surface colour is mainly reddish brown with various shades (***2.5YR 5/4; 5YR 5/3, 5YR 5/8, 7.5YR 6/4***) Munsell soil colour chart 1975). The sole exception, is the surface colour of the Mesolithic pottery which is mostly pale brown (***10YR 6/3 Munsell***). The fractures are mainly coloured in shades of grey (***2.5YR - N3/0, 5YR 5/1, 5YR 4/1, 7.5YR 3/1, 10YR 3/1***) or dark grey (***2.5YR - N 4/0, 5YR - N 3/0, 7.5YR - N 4/0***) colours.

2- Methodology:

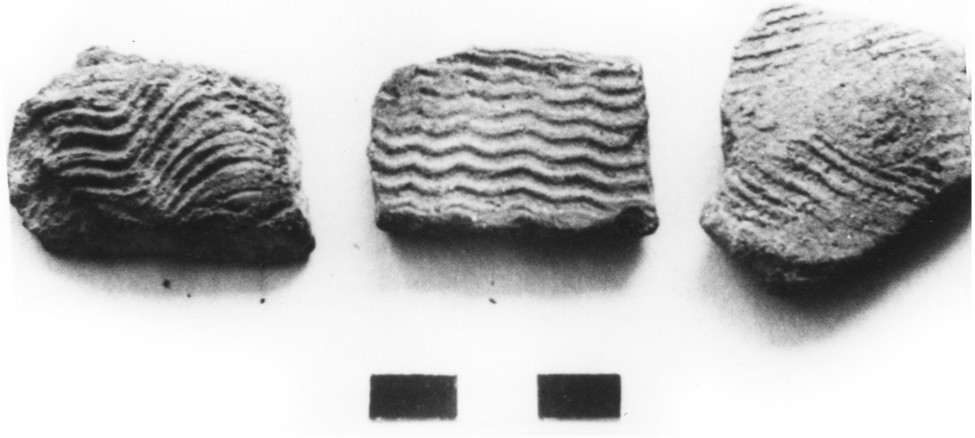
In the present research both physical and chemical methods have been used to determine the lithological provenance of the Mesolithic and Neolithic ceramics derived from four archaeological sites in the central Sudan (see supra).

Petrographic analysis is used to determine the origin of temper utilized in forming ceramics. It is noteworthy that this method is widely applicable and useful analytical tool in the study of prehistoric ceramics (Shepard 1965 and Peacock 1970). Ancient ceramics are studied with petrographic microscope either in thin section or in powdered form.

Thin section has been used here as it has several advantages over a powdered sample. It indicates the texture of paste, the proportion of inclusions, the size and shape of grain, the relationship and proportions of different minerals. Moreover, thin section can be utilized for both quantitative and qualitative studies (Shepard 1956: 139-140).

In order to compare the tempering inclusions with that of the paste, X-ray diffraction (XRD) has been used. This technique is utilized to obtain qualitative information on clay mineralogy and rarely used to obtain quantitative data (Weymouth 1973: 33). As the thin-section technique has a drawback that it does not permit the study of clay mineralogy of pottery and since clay mineralogy varies in different deposits (e.g. montmorillonite, kaolinite, illite, ...etc.), the XRD can, theoretically, be used to characterize pottery (Peacock 1970: 380).

In order to further differentiate pottery from the sites investigated and to trace the possible source of raw material utilized in its manufacture, the chemical composition of the pottery has been determined using X-ray fluorescence spectrometric technique (XRFS). This method is of a particular value in distinguishing between wares that appear identical under the microscope. It gives no indication of the minerals in the body, though the proportion of the



Pl. 1: Wavy-line Decoration: Khartoum Mesolithic Tradition.

Pl. 2: Zigzag-dotted Decoration: Khartoum Mesolithic Tradition.

Pl. 3: Triangular Decoration: Khartoum Neolithic Tradition.

chemical elements can be determined (Hodges 1981: 25).

Goethite norm technique was used to determine the original fine earth fractions which might have been present in pottery prior to firing. It is worth mentioning that pottery can be regarded as a metamorphosed sedimentary rock, hence it can be argued that ceramics are best approached in a manner similar to that in the geological study of the parent raw material (Peacock 1977: 26). This technique provides the petrologist with a set of hypothetical mineral assemblages that are petrogrphically comparable and similar to certain mineral assemblages found in rock specimens. It can also lead us to know the mineral assemblages of a specific parent rock if it has been changed without the removal or addition of material into 'stable' mineral assemblage of the various soil horizons (Plas and Schuylenborgh 1970: 365).

3- Results:

3.1 Petrographic analysis

Preliminary analysis of Sarurab2, Shabona, Shaheinab and Nofalab2 ceramics was conducted by the present writer at the Geology department of Khartoum University (1980) using a hand-lens (10 X) and a binocular microscope (20 X). The aim was to make broad fabric classifications and to reduce the number of thin sections required. The potsherds representing the fabric variables of each site (Sarurab2, N=18; Shabona, N=12; Shaheinab N=15; Nofalab2, No=14) were selected for further analysis by petrographic microscope (80 X). The samples represent all the fabric variations and the range of the main decoration styles diagnostic of time periods found at each sampled-site. Thin sections were prepared of standard thickness (0.03 mm.).

The petrographic results can be classed into three main fabric groups (see fig.2):

Fabric 1: This is the most common fabric group (47% of the total). It is characterized by high quartz content reaching 70% in the bulk of the samples. Feldspar is generally little amounting to 5-13% in most samples. Accessory minerals which include zircon, epidote, tourmaline and hypersthene are present in a haphazard disribution in all the thin sections examined, being in the magnitude of 1% or less. Samples of this fabric were derived from Sarurab2 (N=8 sherds), Shabona (N=7 sherds), Shaheinab (N=7 sherds), and Nofalab2 (N=6 sherds) sites.

Fabric 2: This fabric denotes an igneous source (33.5% of the total). It is characterized by high content of microcline and perthite (ca. 67%) with relatively low mounts of non-plastic quartz (ca. 5-37%). The fabric is represented by samples from Sarurab2 (N=6 sherds), Shaheinab (N=4 sherds), Nofalab2 (N = 5 sherds), and Shabona (N=5 sherds) sites.

Fabric 3: It represents a mixed lithography (ca. 19% of the total samples). It has a distinctive appearance under the polarized microscope, mainly composed of abundant polycrystalline quartz and K-feldspar (igneous source) coupled with varying amounts of hornblende, muscovite, muscovite mica and/or rock fragments (metamorphic source) suggestive of mixture of tempering inclusions from igneous and metamorphic sources. It has been identified in the composition of ceramics from Sarurab2 (N=4 sherds), Shaheinab (N=4 sherds), and Nofalab (N=3 sherds) sites.

3.2 X-ray diffraction analysis

Pottery and clay samples of the four sites were studied with X-ray diffraction at the department of soil science and geology at Wageningen National University, Netherlands, 1980 (table: 1, fig.3). The samples were treat-

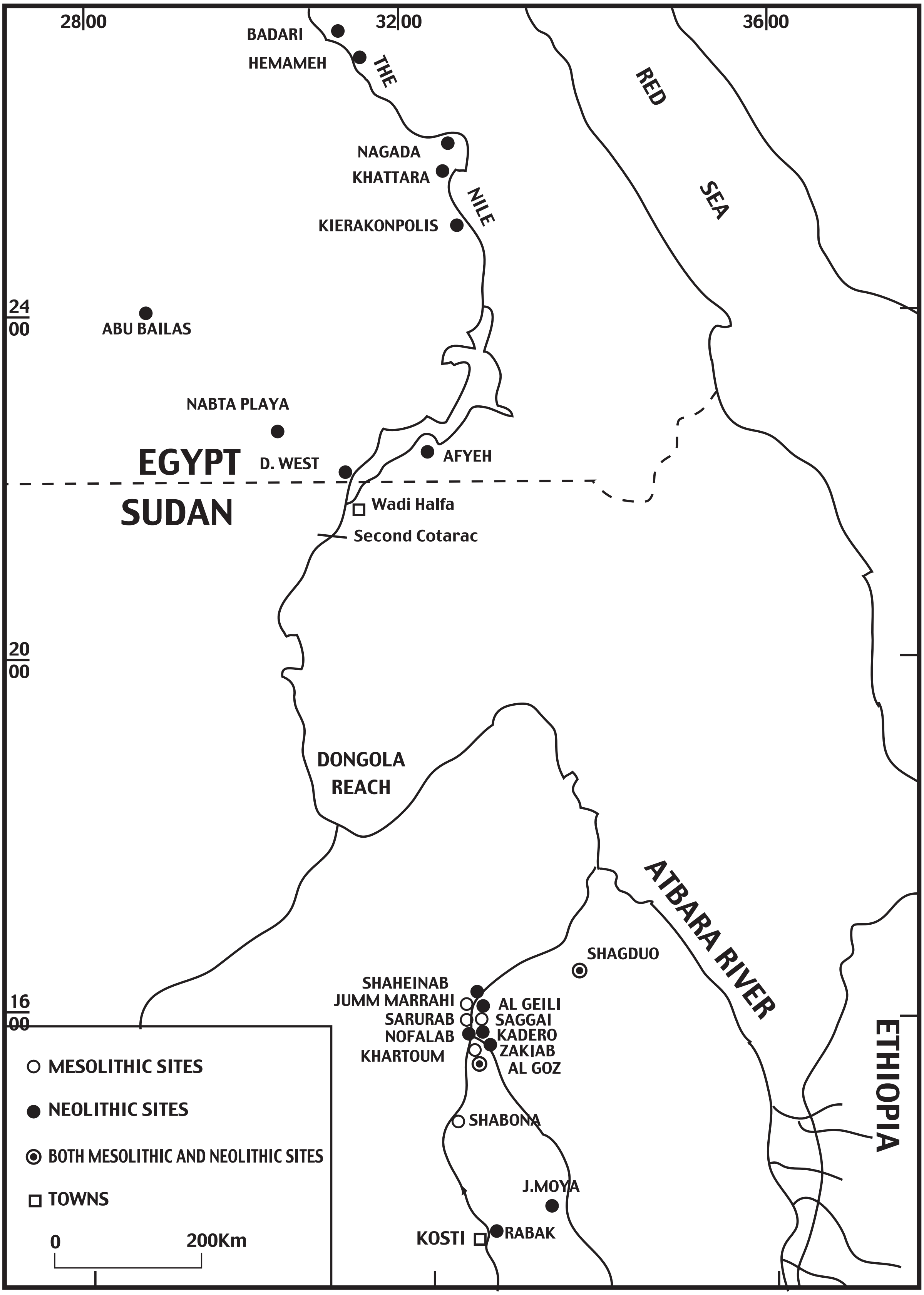


Fig.1: The Main Mesolithic and Neolithic Sites in the Central Sudan.

ed as follows: the smaller fraction than 0.002 mm, was separated after a pretratment with H2O2 (removal of organic material) and acetic acid (removal of carbonate). The suspension of the sample was brought on a ceramic holder and the sample was turned into a Mg-clay (see table:1).

3.2.1 Pottery samples

The results of X-ray diffraction analysis indicate that quartz is a chief mineral component of the samples analyzed and it was detected in appreciable amounts. Other clay minerals including montmorillonite, kaolinite, illite and chlorite are found only in the form of traces. This immediately shows that the firing temperature of the wares examined is higher than 800 C. These clay minerals have undergone structural changes at different firing temperatures and some of them become amorphous at a temperature exceeding this degree.

3.2.2 Clay samples

3.2.2.1: The Nofalab clay shows a pronounced 1.4 mn and a pronounced 0.7 nm peak. Treatment with glycol shows a shift of much of 1.4 mn peat at 1.8 nm indicating the prescence of montmorillonite. The 1.0 peak of micas and illite is not sharp but rather weak. The 0.7 peak of kaolinite is sharp and well-developed. Therefore, Nofalab clay is a kaolinite-montmorillonite clay.

3.2.2.2: The Sarurab clay shows much the same pattern as the Nofalab one. The mount of kaolinite, however, is much higher than in the Nofalab clay.

3.2.2.3: The Shaheinab clay differs from the former two samples in showing very small amounts of kaolinite and mica. This feature is also characteristic of the Shabona clay. Remarkably, the amount of mica-type clay minerals in all the samples is approximately similar.

4- Chemical properties of the samples:

4.1: Chemical information on the exchangeable anions and cations and pH. values (table: 2).

The chemical properties of the clay samples used by the present day potters were determined by the present writer at the department of soil science, Khartoum University (1981).

4.1.1: pH. of the samples (table 2)

The pH. of the clay samples was determined using pH. meter immersed in solution of a fixed buffer (9.2). The saturation paste was prepared by adding soil of a known quantity to the paste consistency and saturation extract was sucked using a vaccum. Solution of soil to water ratio of 1:5 was prepared in order to measure the pH. of the soil suspension. The results (table: 2) show that the pH. values are above 7.0 denoting alkaline clays.

4.1.2: Soluble salts and Metallic Ions

Carbonate, bicarbonate (insoluble salts), calcium and magnesium (metallic ions) were determined using the Titration method whereas sodium and potassium were obtained by flame photometer (table: 3).

4.2: X-ray fluorescence spectrometric analysis

In the present work ten major elements were analyzed: SiO_2, Al_2O_3, FeO, Mno, MgO, CaO, KO, HO, Tio and Po (table: 3, fig.4). These elements were chosen for the following reasons:-

(a) Major compounds provide information on tempering material and hence on lithological provenance as well as technology (Palmieri 1987: 225-226) whereas trace elements are sensitive indicators as to geochemical environ-

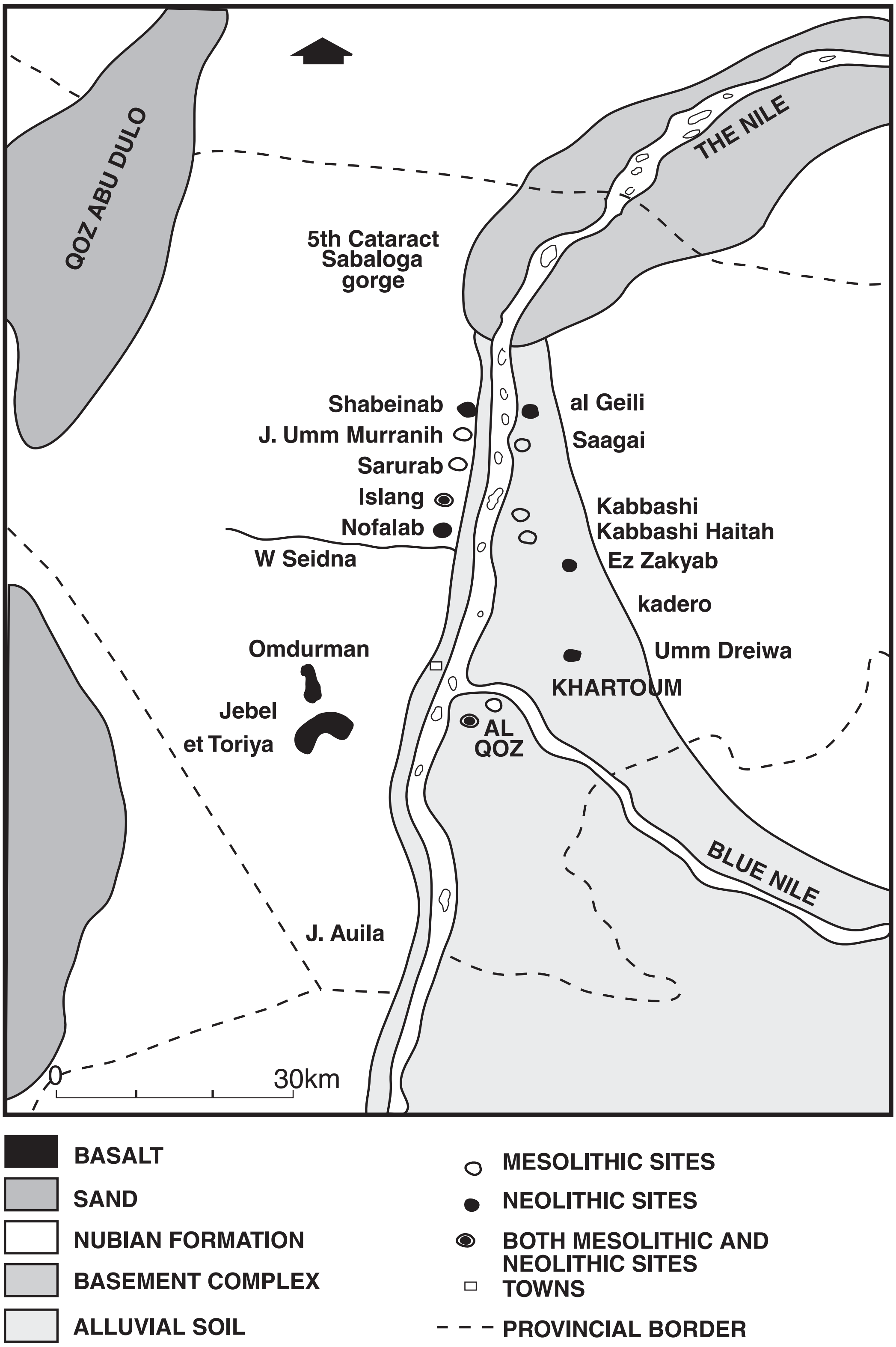


Fig. 2: Distribution of Mesolithic and Neolithic sites in Khartoum Province, in relation to the geological formations (after Mohamed Ali, A. S. 1982: 39 with some modifications).

	1.4 mm Montm	1.0 Mm Mica/illite	0.7 mm Kaolinite	0.343 Quartz	1.8 mm Montm.
Sarurab2	64.83	9.43	25.72	8.58	**
Shaheinab	81.25	12.34	6.4	4.45	**
Shabona	77.49	11.40	11.11	8.72	**
Nofalab2	76.29	12.35	11.35	5.81	**

P.A.P. = Proportional area percentage according to Porringa (1967).

Table 1: P.A.P. X-ray analysis of the ‹2 u.m fractions of the samples.

ment (Reeves and Brookes 1978: 2) and therefore reflecting very specific local sources.

(b) Trace elements composition appears to be unsuitable for the classification of prehistoric ceramics containing appreciable amounts of coarse minerals (Buko 1984: 348).

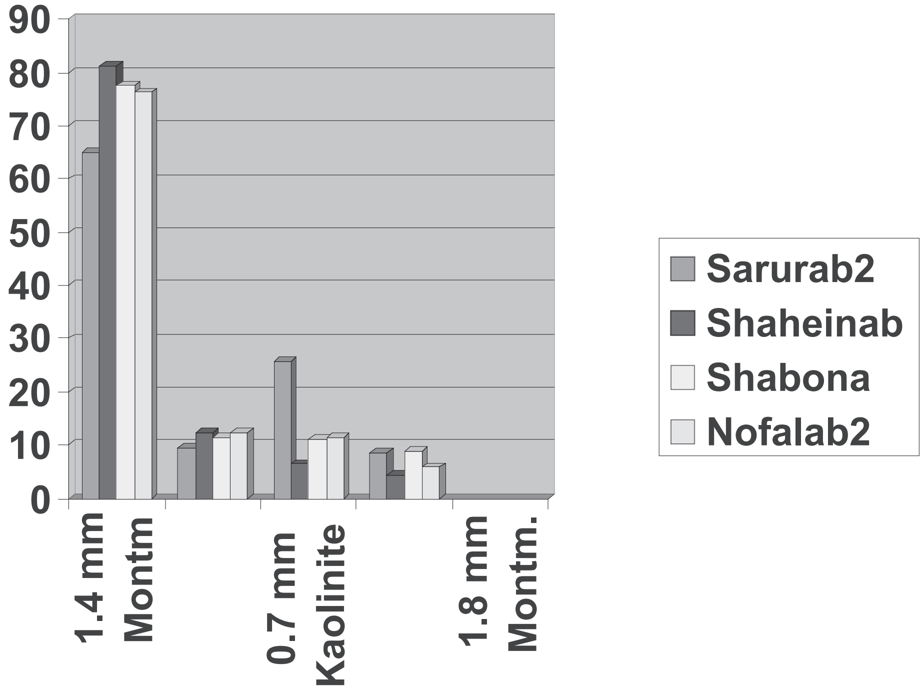
The samples were processed with a highly automized Philips X-ray fluorescence apparatus model PW104 which is computer-controlled. The results (table: 3) indicate that the chemical composition of all the samples is silicon-rich. When silicon oxide (SiO_2) is high it is probable that free quartz content will be high and this is the most common impurity of clays (Wilson 1927: 44).

Aluminum (Al_2O_3) which is a rough index of feldspar occurs mainly in the form of feldspar, feldspathoids and to a lower extent may be of amphiboles and pyroxenes (Jeffery 1975: 94). The percentages of aluminum are comparable in almost all the samples and all of which are below 16wght %. Ferric oxide (Fe_2O_3) is present in all the samples with less than 10wght %. Ferrous (FeO) and sodium (Na_2O) oxides were not calculated. The rest of the mineral oxides including manganese (MnO), magnesium (MgO), calcium (CaO), potassium (K2O), titanium (TiO_2) and Phosphorous (P_2O_5) are generally below 2wght %.

5. Goethite Norm analysis:

A useful method for the comparison of clay samples and samples of sherds is the calculations of the so-called norm composition (cf-section 2). The tables 4 and 5 give the results in terms of goethite norm (composition of the clay and of the fine earth fractions) and 800 C ceramic norm (composition of the sherds and the matrix) (fig.5).

Table no. 4 lists two ceramic norms that minerals quartz, sanidine, anorthite, spinel, rutile Q; Or; An; Geh; Mull; Ru; Hm norm as-



P.A.P. = Proportional area percentage according to Porringa (1967).

Fig. 3: P.A.P. X-ray analysis of the < 2 u.m Fractions of the samples.

sumes the minerals quartz, sanidine, anorthite, gehlenite, mullite, rutile and hematite to be formed or present in the sherd Q; Or; An; Geh; Mull; Ru; Hm norm assumes the minerals quartz, sanidine, anorthite, gehlenite, mullite, rutile and hematite to be the result of the firing process. Before choosing these norms, the chemical analyses of a few samples were used in a computer programme that calculates the thermodynamically stable mineral assemblages under circumstances determined by the operator. The programme is a modification of Brown and Skinner (1979).

Firing under oxidizing circumstances at a pressure of 1 bar and a temperature of 800 C, theoretically produces the minerals of quartz, enstatite, andalusite, sanidine, anorthite, anantase and hematite. As enstatite and andalusite never occur in ceramic products, mullite and spinel were used instead. Another aspect of the norm conclusions is inherent in the chemical analyses (table: 3). As NaO content was not altered, plagioclases could not be determined. Anorthite, the calcium endmember of the plagioclase group is calculated instead on the basis of the available CaO. Then the two ceramic norms (composition of the sherd and the matrix) will be matched against the clay samples to see whether the norm minerals are similar or different and the implication(s) of this phenomenon.

5.1: Ceramic norm of the clay samples and the sherds (table 4)

Differences and similarities can be observed between the norm mineral composition of the clay samples and the potsherds. Similarities between the norm minerals of Shaheinab and Nofalab sherds and that of clays are outnumbering the differences. Percentages of quartz, sanidine, anorthite, rutile and hematite in the sherds as compared to the clays are similar, whereas mullite and spinel exhibit marked dif-

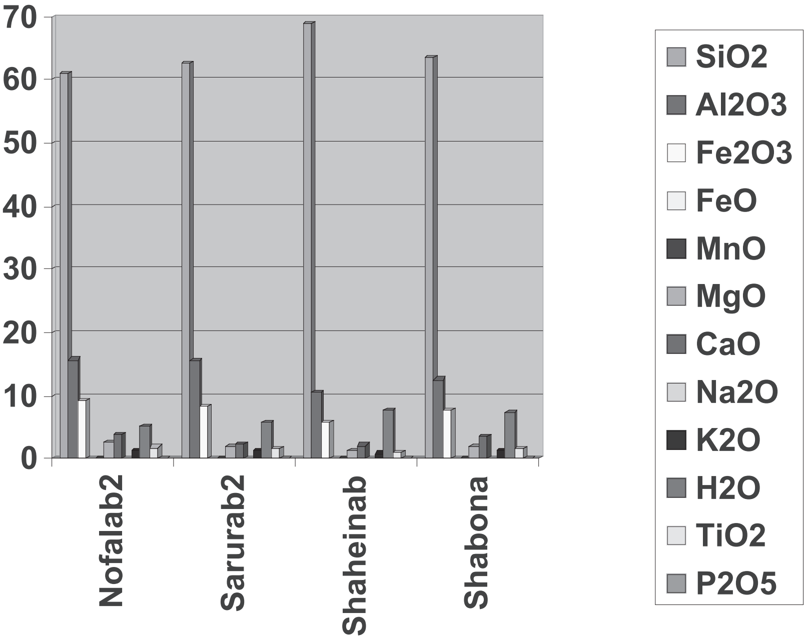


Fig. 4: Chemical composition of the samples in weight percentages.

Sample	PH paste	PH water	CO3	HCO3	Cl	Mg	Na	Ca	K
Nofalab2	8.0	8.7	0.0	4.7	5.25	5.4	55.0	3.8	2.5
Sarurab2	8.1	8.5	o.o	7.9	5.4	4.6	46.2	3.7	1.2
Shaheinab	8.1	8.4	o.o	6.8	8.1	4.4	33.7	3.3	4.5
Shabona	8.1	8.3	o.o	5.5	5.7	4.3	16.5	2.3	4.8

Exchangable ion m.e./1.

Table 2: Chemical Information on the samples.

ferences before firing to 800 C. On the other hand, the proportions of norm minerals of the sherds in comparison with clays of Sarurab2 and Shabona are different.

5.2: Ceramic Norm of the Matrix (table 5)

Before firing the percentages of the norm minerals of the sherds versus clays are different. After firing to 800 C at a pressure of 1 bar, the norm minerals of both sherds and clays are comparable.

6- Discussion:

6.1: It is difficult from the petrological results outlined above to pinpoint any characteristic groups with certainty. However, the petrographic analysis indicates that most of the Mesolithic and Neolithic ceramics analyzed in the present work are mainly characterized by quartz grains, little or absence of feldspar (mainly microcline and plagioclase) and mica. This suite (Fabric 1) suggests a derivation from Nubian sandstone formation prevailing in most parts of northern and central Sudan including the sites investigated (see Whiteman 1971: 58).

Considerable number of the analyzed sherds reveal igneous source (33%). This is indicated by the occurrence of appreciable quantities of microcline, perthite and low amounts of non-plastic quartz in the composition of fabric 2 (cf. section 3.1). The igneous origin for the Khartoum Province samples (Sarurab2, Shaheinab and Nofalab 2) seems to lie within the rocks of Sabaloka Basement Complex at the sixth cataract (fig. 2). On the other hand, the nearest likely source for the igneous fabric of Shabona ceramics (White Nile) lies ca. 200 km. to the north at Sabloka Gorge north of Khartoum (fig. 2). This seems to suggest either a high degree of mobility by at least a segment of dwellers of Shabona site or the presence of some sort of exchange mechanism via some mobile groups (hunters and gatherers) who might have played the role of middlemen between the folks inhabiting the areas along the strip of the Nile in Khartoum and White Nile regions during the prehistoric era.

Fabric of mixed lithography (igneous and

Chemical	Nofalab2	Sarurab2	Shaheinab	Shabona
SiO_2	61.03	62.50	68.93	63.54
Al_2O_3	15.73	15.66	10.54	12.61
Fe_2O_3	9.31	8.22	5.85	7.78
FeO	n.d.	n.d.	n.d.	n.d.
MnO	0.15	0.12	0.18	0.13
MgO	2.58	1.90	1.29	1.91
CaO	3.82	2.30	2.20	3.60
Na_2O	n.d.	n.d.	n.d.	n.d.
K_2O	1.41	1.49	0.94	1.34
H_2O	5.12	5.84	7.69	7.44
TiO_2	1.86	1.65	1.13	1.68
P_2O_5	0.26	0.23	0.10	0.17
	101.27	99.93	98.85	100.20

Table 3: Chemical composition of the samples in weight percentage.

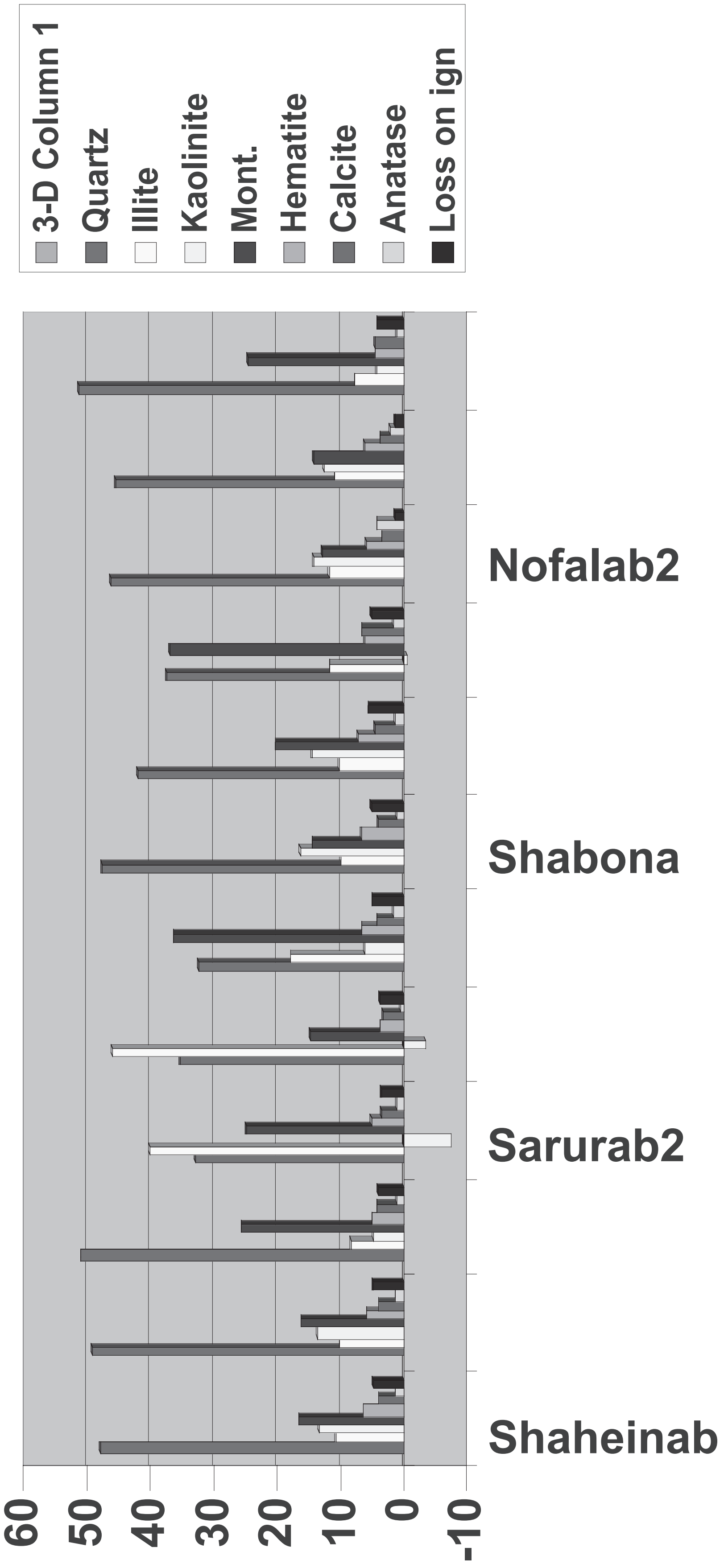


Fig. 5: Goethite norm of the clay samples and sherds.

Sample	Shaheinab			Nofalab2			Sarurab2			Shabona		
	Sherd 1	Sherd 2	Clay	Sherd 3	Sherd 4	Clay	Sherd 5	Sherd 6	Clay	Sherd 7	Sherd 8	Clay
Quartz	47.82	49.21	50.93	46.23	45.41	51.31	32.90	35.29	32.32	47.60	41.89	37.42
Illite	10.68	10.06	8.39	11.77	10.82	7.69	40.07	45.89	17.77	9.83	10.26	11.63
Kaolinite	13.45	13.59	4.79	14.22	12.59	4.39	-7.58	-3.41	6.24	16.31	14.53	-0.45
Mont.	16.46	16.17	25.59	12.82	14.22	24.67	24.91	14.66	36.20	14.33	20.16	36.85
Hematite	6.36	5.79	4.96	5.98	6.18	4.49	5.07	3.64	6.64	6.72	7.21	6.24
Calcite	3.94	3.98	4.14	3.39	3.62	4.56	3.47	3.33	4.16	4.05	4.62	6.59
Anatase	1.28	1.21	1.19	4.21	2.21	1.14	1.15	0.59	1.67	1.17	1.33	1.72
Loss on ign	4.89	4.88	4.11	1.38	1.35	4.17	3.49	3.78	5.03	5.19	5.50	5.15
Matrix												
Quartz	36.42	36.54	32.54	37.12	35.57	33.44	20.54	16.75	20.85	36.45	33.90	15.47
Illite	13.04	12.53	11.55	12.39	13.46	10.65	29.01	33.86	14.93	11.93	11.65	15.71
Kaolinite	16.36	17.00	6.51	18.37	17.73	7.61	3.88	16.72	7.29	19.81	16.59	-0.60
Mont.	20.08	20.21	35.25	16.64	15.33	33.01	34.25	21.54	42.35	17.32	22.87	49.76
Hematite	7.74	7.24	6.82	7.14	9.32	5.24	6.96	5.36	7.76	8.16	8.20	8.43
Calcite	4.80	4.97	5.69	4.48	3.88	5.31	3.77	4.90	4.87	4.91	5.26	8.91
Anatase	1.56	1.51	1.64	1.55	1.38	1.38	1.57	0.87	1.96	1.42	1.52	2.32
Loss on ign	5.96	6.10	5.64	5.86	3.76	5.74	5.17	7.06	5.89	6.31	6.27	6.96

Table 4: Goethite norm of the clay samples and sherds.

metamorphic sources) has been confined to Khartoum Province sherds (Sarurab2, Shaheinab and Nofalab2) (cf. section3.1). This fabric seems too have been a derivation from outcrops at Sabaloka Gorge in close proximity to the sampling area (fig. 2) where ancient orogenic igneous and metamorphic rocks prevail.

6.2: X-ray diffraction results of ceramics versus the local clays are highly heterogeneous. On the basis of these results it is difficult to discern any characteristic groupings. The X-ray analysis of pottery samples shows the absence of the key minerals (e.g. montmorillonite, kaolinite, illite, chlorite...etc.). In the meantime the modern local clays of the sampled-sites hold appreciable fine earth fractions of montmorillonite. The result is in accord with the abundance of montmorillonite clays in the recent sediments of central Sudan. These clays are characterized by predominant or large amounts of minerals of montmorillonite group with small amounts of kaolinite, traces of quartz and mica are detectable (see Buursink 1971: 192 and Vail 1982: 92).

6.3: XRFS analysis shows that the chemical content of all the samples (cf. table:4) from Khartoum and White Nile regions is characterized by silicon rich sand. SiO2 concentration reaches ca. 64 wght% at the average. The high silicon concentration is suggestive that the composition of the analyzed pottery samples (temper and matrix) is characterized by high amounts of incorporated quartz grains resulting from the prevalence of Nubian Sandstone Formation in the two regions that form the case study of this research. The rest of the minerals have been identified in much lesser amounts, most of which are below 2 wght%.

6.4: It appears from the Goethite norm calculations (tables: 4&5) that the clay minerals of the potsherds and clay samples are dissimilar. The percentage of illite minerals of Sarurab2 pottery are higher than that of other samples, they are even not comparable to that of the clay of the region suitable for pot making. Moreover, in each of the comparison one or two norm minerals of the sherds do not compare well with the norm minerals of the clay. It can be postulated from this evidence that the clay samples were not used in preparing the pottery in question (see the diagram, fig. 6). It is equally possible that the clays analyzed are not used as such for pottery making. Certain pretreatment is done and the clays are mixed with temper (dung) as can be observed from the present day local potters of the areas investigated. The aim is to counteract excessive shrinkage and to ensure uniform drying and hence lessening the probability of cracking. It seems more likely that the ceramics of the Sarurab2, Shaheinab, Nofalab2 (Khartoum Province) and Shabona (White Nile region) might have been tempered prior to firing. The abundance of angular and sub-angular non-plastic mineral inclusions in the composition of the sampled-sherds strengthens the probability that they have been added as temper. If that is the case, then this difference in the mineralogical composition between sherds and clays is not a conclusive evidence that they are not related. Pretreatment may cause either decrease or increase of the percentage of particular minerals in the sherds as compared to the clay matrix depending on whether or not the pretreatment material added contains the mineral in question.

7. Conclusions:

7.1: The present physico-chemical analyses indicate that X-ray diffraction (cf. section 3.2) and chemical analyses (cf. sections 4.1, 4.2) tend to support the results gained from petrographic analyses (cf. section 3.1) that quartz, feldspar and iron inclusions are the most common non-plastic minerals in most of the Meso-

Minerals	Shaheinab			Nofalab2			Sarurab2			Shabona		
	Sherd 1	Sherd 2	Clay	Sherd 3	Sherd 4	Clay	Sherd 5	Sherd 6	Clay	Sherd 7	Sherd 8	Clay
Quartz	50.96	51.37	52.12	53.13	51.63	54.80	37.51	29.10	*44.78	50.65	49.99	37.93
Sanidine	9.69	9.33	8.56	8.6	8.81	7.92	21.38	25.46	*11.08	8.90	8.69	11.80
Anorthite	14.19	14.70	16.76	14.14	13.96	13.47	11.06	14.65	14.38	14.58	15.61	*26.61
Mullite	10.25	10.24	*4.82	11.7	10.40	*5.70	12.55	18.65	*8.86	11.31	9.61	*-0.46
Spinel	4.01	4.02	*7.01	3.19	5.66	*9.61	6.78	4.35	*8.45	3.47	4.58	*10.04
Rutile	1.66	1.61	1.74	1.21	1.16	1.6	1.66	0.93	*2.08	1.52	1.62	2.50
Hematite	9.24	8.73	8.99	8.3	8.48	6.9	9.04	6.86	*10.37	9.58	9.90	11.59
Ceramic Norm: Q; Or; An; Geh; Mull; Ru; Hm.												
Quartz	50.31	50.84	48.94	50.46	55.1	51.6	33.14	28.19	39.64	50.66	49.09	34.03
Sanidine	9.69	9.33	8.55	9.31	8.7	9.2	21.37	25.46	*11.13	8.90	8.69	11.80
Anorthite	6.10	6.11	*10.67	7.27	7.2	8.3	10.32	6.62	12.91	5.28	6.97	*15.28
Mullite	3.13	3.37	*1.50	4.89	3.9	4.5	-1.08	3.03	-1.06	3.84	3.28	3.44
Spinel	19.87	20.01	19.60	18.67	13.9	15.86	25.53	28.90	25.27	20.22	20.45	21.37
Rutile	1.66	1.61	1.74	1.98	1.78	1.91	1.66	0.93	2.09	1.52	1.62	2.50
Hematite	9.24	8.73	8.99	8.01	9.43	8.68	9.05	6.86	10.02	9.58	9.90	11.58

Ceramic norm. Q; Or; An; Mull; Ru; Hm.

* Denotes differences in composition between sherds and clays.

Table 5: Cdramic norms of the matrix of the samples arrived by subtraction of the Q-content arrived at by point counting analysis.

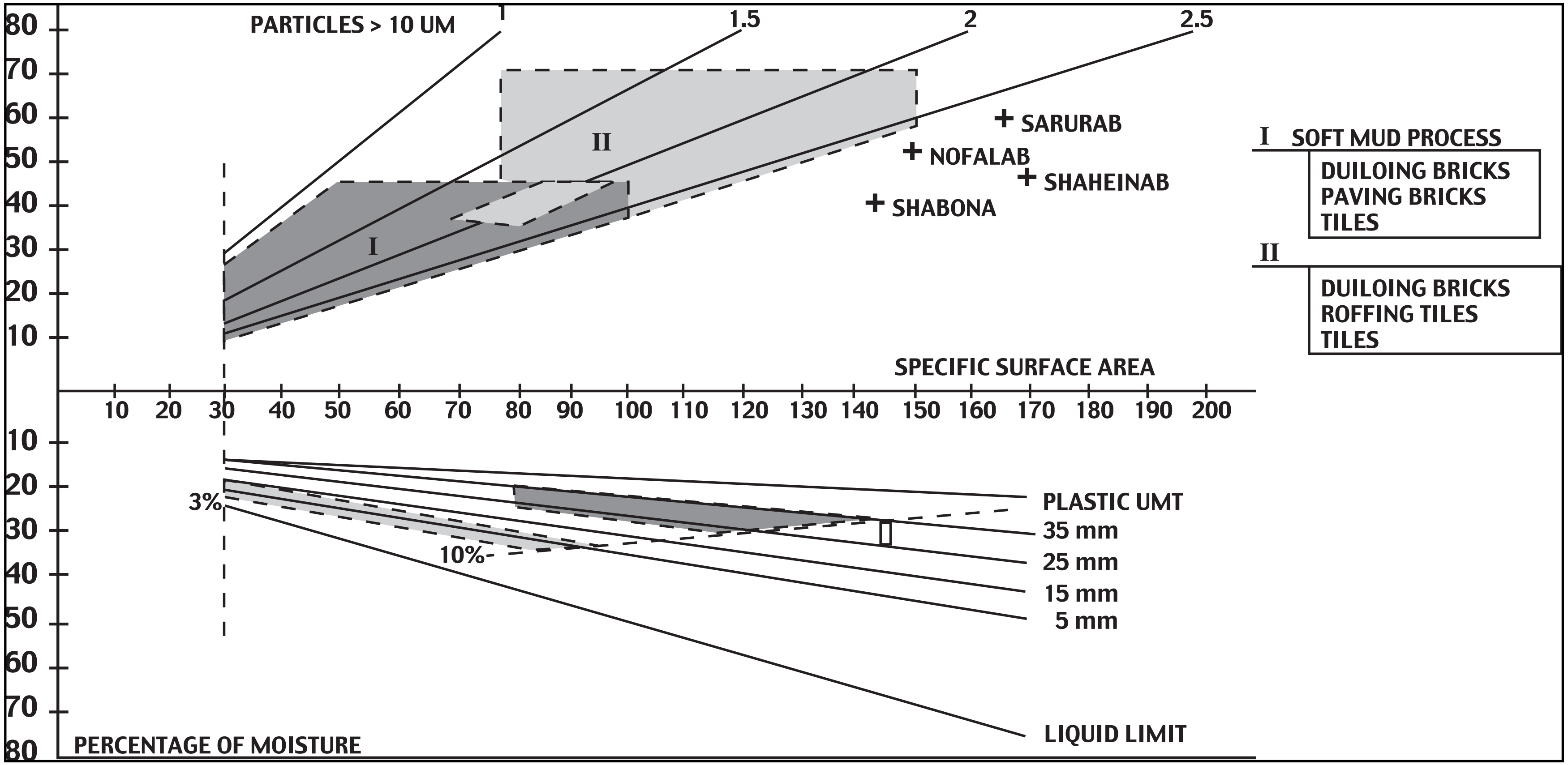


Fig. 6: The Position o the Four Clays under Discussion in a Suitability Diagram.

lithic and Neolithic ceramic fabrics from Khartoum and White Nile regions. On the other hand, the Goethite norm analyses (cf. section 5) provide information suggestive that the fine earth fractions of all the samples analyzed hold appreciable proportions of quartz-rich illite kaolinitic clay. This seems to add credibility to the results obtained by petrographic, X-ray and chemical analyses all of which are advocating the mineralogical and/or chemical homogeneity of the samples examined.

7.2: Temporal differences in ceramic paste composition, if any, is imperceptible from the physico-chemical results of the present work.

7.3: Despite the marked homogeneity of the physico-chemical analyses the analyzed Mesolithic, Neolithic and the local clayey samples are relatively less differentiated in terms of their clay mineralogy (X-ray diffraction and chemical results) than they are on the basis of their tempering material (petrography).

7.4: The results of the overall data set indicate that the analyzed pottery fabrics have mineral assemblages consistent with that present in the locally available clays.

7.5 Mineralogical analyses of the samples-sets performed in the present research coupled with the analyzed samples from Khartoum Province (Francavigli and Palmieri 1983: 191-205; Khabir, 1987: 45-46 nd Chlodnicki 1989: 369-373); the Western Butana (De Paepe 1991: 261-266) and northern Sudan (Nordstrom 1972: 33-49; Hays and Hassan 1974: 71-79) suggest local manufacture as the pottery inclusions and/or clay composition indicate local derivation. Given the uniformity in geology and clays in the immediate areas of the investigated sites (see supra) the probability that the Mesolithic and Neolithic ceramics in the central Sudan were locally made becomes much more likely.

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ملخّص: تسلط هذه الدراسة، الضوء على المنشأ (الأصل) الجيولوجي، لعجائن فخار عصر ما قبل التاريخ المتأخر، (العصرين الميزوليثي - Mesolithic والنيوليثي Neolithic 7000-3500 ق. م)، في إقليمي الخرطوم والنيل الأبيض، في وسط السودان. وقد أجريت العديد من التحليلات الفيزيائية والكيميائية، على عيّنات من فخار ذلك العصر، أُخِذَتْ من أربع مستوطنات هي: السروراب -٢ ، الشهيناب ، النوفلاب -٢ وشابونا، في أواسط السودان. وشملت التحاليل: بالمجهر البترولوجي ، أشعة أكس المشتتة، واللصفية، وتقنية الجيوسايت، وذلك في جامعتي الخرطوم (السودان)، وفاخنين (هولندا)، بغية التعرف على طبيعة العجينة (Clay) والشوائب المضافة (Temper)، المستخدمة في صناعة ذلك الفخار. وفضلاً عن ذلك، فقد جرى تحليل الطين غير المحروق، الصالح لصناعة الفخار، المتوافر في منطقة العيّنات، باستخدام تقنيات التحاليل نفسها، المشار إليها آنفاً، لإعطاء صورة متكاملة ومتماسكة، عن طبيعة المنشأ الجيولوجي للفخاريات موضوع الدراسة. وقد أثبتت التحاليل المختبرية، أنَّ العجائن، التي صنعت منها الأواني والأدوات الفخارية، متوافرة محلياً ؛ ما يرجِّح الاحتمالَ أنَّه جرى تصنيعها في المستوطنات ذاتها، أو المناطق التي حولها.

Note:

Thanks are due to the Department of Archaeology, Khartoum University for allowing me to conduct test-excavations at Sarurab2 (1978) and Nofalab2 (1990) sites. The present analyzed samples were retrieved from these excavations.

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