Physico-chemical Analyses of Neolithic Pottery from Central Sudan

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Abstract: *The present study sets forth results of physico-chemical analyses carried out on a series of 'Khartoum Neolithic' pottery from two archaeological sites (Islang2 and Nofalab2) excavated by the present writer during July-August 1990. The aims were to discern the lithological provenance and to determine the firing index of these pottery groups. The results of the physico-chemical analyses (Petrographic, X-ray diffraction, X-ray fluorescence and Thermal Expansion Techniques) of the samples examined suggest local manufacture since their temper inclusions and soil samples indicate local derivation. On the other hand, the firing index of the samples suggests the use of similar firing techniques*

1- Introduction:

In the present work the pottery samples analyzed by physico-chemical analyses were derived from two archaeological sites; namely, Islang2 ( ) and Nofalab2 ( ) both of which are located at Khartoum province (Figs. 1-2).

The two sites were test-excavated by the present writer, 1990. The cultural material recovered labelled 'Islang2' and 'Nofalab2' to distinguish it from El-Anwar's earlier work at these localities (see El-Anwar 1981: 42-45).

Islang2 site is located some 28 km north of Omdurman on the west bank of the Nile. It is situated 3.94m above sea level and it lies two kilometers inland on an ancient Nile bank. The site is at present a small one covering m on E-W line. A total area of 200 sq.m. was excavated. The excavated units yielded material culture down to a depth of 50 cm in most places and exceeding that depth (c.60 cm) in rare instances. The archaeological remains are composed of pottery found only in fragmented condition (n = 1312). Zigzag is the most prominent motif. Further frequent motifs include triangles with dots, dotted lines, triangles, incised, combed, scraped, semicircular panels, straight lines and slanting serration. Most of the surfaces are burnished (Pl. 1-b.). The associated lithic industry is characterized by a microlithic-flake.

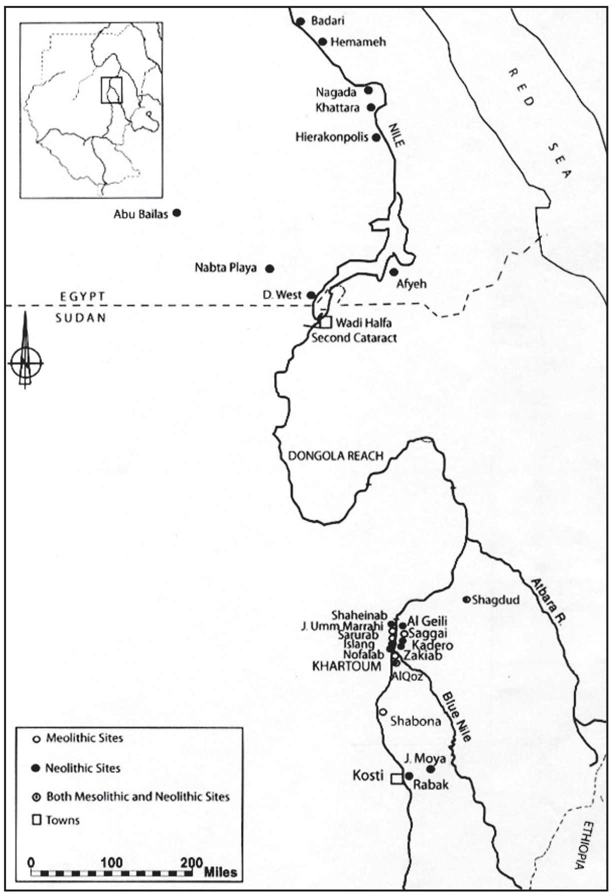


Fig. 1: The Main Mesolithic and Neolithic sites in the central Sudan.

Mollusca and bone remains were found in fragmented condition (Khabir 2006: 117-118).

Two calibrated radiocarbon dates were obtained for this site. The oldest (based on shell) is 4490±150 B.C. (SMU-2575) and the youngest (based on charcoal) is 4330±90 B.C. (SMU-2565)(Khabir 2007: 3-4).

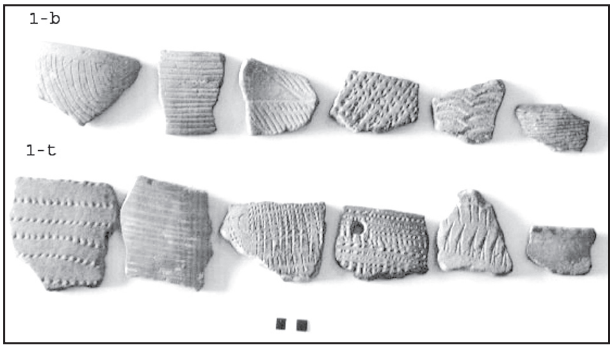
Nofalab2 is also situated on the bank of the Nile about 26 km north of Omdurman (Fig. 1). The site at present is about two meters above the surrounding alluvial plain. Surface finds suggest an estimated occupation of 1200 sq.m. The largest concentration of the material occurred between 20-40 cm below the present day surface. The cultural occupation often reached 70 cm in depth; the cultural material retrieved from Nofalab2 site includes pottery in the form of sherds (n = 2981), most of which was decorated. Vees and zigzag decorative motifs are prevalent along with incised, impressed, dotted lines, triangles, combed and linear impression. Black-topped red ware is scarce. The pottery is burnished and its fabric is sand-tempered (Pl. 1-T.). The lithic industry in association with pottery repertoire is basically microlithic-flake. Some mollusca remains and bones were recorded (Khabir 2006: 118-119).

Two calibrated radiocarbon dates (based on charcoal) were provided; the oldest is 2830±290 B.C. (SMU – 2562) and the youngest is 2705±295 B.C. (SMU – 2561)(Khabir 2007: 5).

2- Objectives and Methodology:

In the present work both physical and chemical methods have been used to determine the lithological provenance and the firing index of the Neolithic pottery derived from Islang2 and Nofalab2 sites in the central Sudan.

Petrographic analysis is used to elucidate the nature of temper and to find criteria diagnostic



Pl.1-b: Nofalab2 Neolithic pottery.
Pl. 1-t: Islang2 Neolithic pottery.

of origin for the pottery in question. It is noteworthy that this method is well known as a useful analytical tool in the study of prehistoric pottery (Peacock 1970 and Shepard 1976). Then section technique has been used as it has several advantages over the powdered sample. It indicates the texture of temper, 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 1976: 139-140).

In order to compare the temper 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).

To further differentiate pottery from the sites investigated and to trace the possible source of raw material used in its manufacture, the chemical composition of the pottery has been identified 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 chemical elements can be determined (Hodges 1981: 25).

Firing conditions of ancient pottery are important because they provide information on the kinds of kilns used, clues to the types of fuels utilized and consequently reveal information about the technological capabilities of the potters with respect to their understanding of the refractory properties of the clay exercised (Title 1972: 323). With these views in mind, a series of physico-scientific analyses (see infra) have been employed in the present work to determine the firing index of the pottery in question.

3- Results:

3.1 Petrographic analysis

Preliminary analysis of Islang2 and Nofalab2 pottery was conducted by the present writer at Southampton University (1990-1995) using a hand-lens (10x) and a binocular microscope (20x). 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 were selected for further analyses by petrographic microscope (80x). 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).

3.1.1 Islang 2 Pottery

Some 27 specimens representing the fabric variations of Islang2 were tested. As a result two main fabrics have been identified and designated as Group A and Group B. The former has been designated into subgroups A1 and A2.

Subgroup A1:

The fabric subgroup is represented by most of the sherds (12 specimens). Non-plastic minerals are almost exclusively quartz amounting to c. 84% at the average in the samples examined and ranging up to 20-40% of any visual field. The remaining non-plastic minerals are either little in amounts or extremely rare. These include iron inclusions (c. 9% of the total), being present at c. 3-8% of any visual field. Feldspars (microcline and plagioclase) are seldom, account c. 5% of the total inclusions and present at 2-5% of the specimen area and totalling c. 3% of the overall minerals. Zircon and hornblende are extremely rare, each is present at 1% of the total minerals.

The non-plastic inclusions are generally subangular or angular (c.78%); subrounded to rounded minerals are occasionally observed (c.22%). The particle size of minerals is generally in the order of 0.300-800 mm across and rarely exceeding that range. In plane polarized light (PPL) the matrix is mostly very pale brown, while under crossed polars (XPOL) is still unistropic and tends to exhibit light brown and yellowish brown shade respectively.

The predominance of quartz grains, the frequent iron inclusions and the scarcity of feldspars are suggestive of sedimentary provenance.

Subgroup A2:

It is represented by rather small group of specimens (7 examples). Non-plastic minerals of quartz being present at 20-35% of any visual field. Feldspar (mainly microcline) is present at c. 10-15% of the specimen area and amounting to c. 26% of the total minerals. Iron oxides are present at 1-3% of the specimen area and 1% of the total inclusions Mica (biotite) and rock fragments are rare (each c. 2% of the total) being evident at 1-2% of any visual field. Zircon is extremely rare (c. 0.5% of the total). It is present at c. 1% of the specimen area.

The grains are mostly (c.83%) subangular to angular. Subrounded grains though present are infrequent (c.17%). Most of the minerals (c.81%) are in the magnitude of 0.300-0.900

mm across. The remaining minerals (zircon and hornblende) exhibit smaller sizes in the order of 0.60-290 mm. The inclusions are generally ill-sorted. The colours of the fabric group are generally similar to that of subgroup A. The only difference is that fabrics rarely display matrices with mid brown colour in PPL and slightly darker brown in XPOL.

An igneous origin could be postulated for this fabric group and the presence of non-polycrystalline quartz, biotite mica and rock fragments is in favour of this assumption.

Group B:

Microcline feldspars (8 specimens) are the dominant components of this fabric group, present at c.20-30% of any visual field and amounting to c.55% of the total minerals. Quartz grains are present with markedly lower proportion (c.30%), occur at c.8-15% of the specimen area. Iron inclusions are frequent (c.14%) comprising c.5-10% of the specimen area. Mica (muscovite and biotite) grains are occasionally present (c.4%) at c.3-5% of any visual field. Rock fragments are absent in comparison with fabric subgroup A2.

Rounding of the minerals is mainly subangular to angular (c.83%). Subroundeed to rounded crystals (c.17%) are often in evidence. Iron oxides are either subangular or subrounded and rarely tend to show rounded crystals. The particle length is generally in the order of 0.200-0.800 mm across. The remaining minerals are in the order of c. 0.02-200 mm. The fabric is mainly ill-sorted due to imperfect mixing. The colour is light/mid brown or pale yellowish brown in PPL and brown, dark brown and yellowish brown, respectively in XPOL.

The suite seems to indicate a source of quartzo-feldspathic rocks. Such rocks are widely known in Sudan and the nearest source to the site area is the Basement Complex outcrop some 35 km north (see Fig. 2).

Nofalab2 Pottery:

Some 23 specimens representing the fabric variations of Nofalab2 site pottery were tested. As a result one main fabric group was identified. This fabric has further been subdivided into two subgroups designated A1 (13 specimens) and A2 (10 specimens).

Subgroup A1:

This fabric is characterized by abundant non-plastic components of quartz (c.80%), being present at c.30-40% of any visual field. Iron inclusions are present in the range of c.5-10% of the specimen area and amounting to 10%

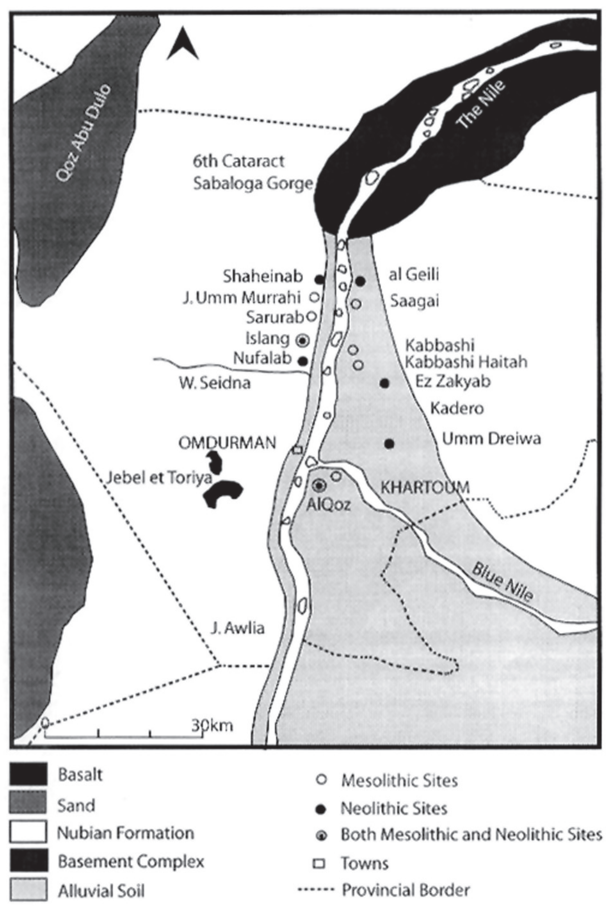


Fig. 2: Distribution of Mesolithic and Neolithic sites in Khartoum Province in relation to geological formations.

of the total minerals. Feldspars (orthoclase, microcline and plagioclase) are rare (c.4%) sparsely distributed in the specimens in the range of c.2-3% of any visual field. Other minerals include biotite (c.2.4%), rock fragments (metamorphic) (c.1.5%), hornblende (c.1%), zircon and epidote (c.1.4%), being present at 1-2% of any visual field.

The minerals are mostly (c.84%) subangular or angular. Subrounded to rounded inclusions though present, are of much lesser percentage (c.18%). It is remarkable that nearly all the iron oxides display subrounded or rounded grains. Quartz sizes fall in the range of 0.060-1 mm across, whereas the remaining minerals show average sizes in the magnitude of 0.60-2 mm across. The texture is ill-sorted due to insufficient kneading. In PPL the matrix ranges from light grayish brown, pale reddish brown, while in XPOL the colour alters to grey brown, reddish and dark brown respectively.

The prevalence of quartz together with frequent iron inclusions in this fabric group favours an origin in or close to exposures of Nubian Sandstone Formation. Nubian Sandstone prevailing in the area of the site is quartz-rich and often highly ferruginous.

Subgroup A2:

Quartz inclusions as in subgroups A1, predominant making up to c.25-40% of any visual field and reaching c. 81% of the total minerals present. Iron inclusions are the second prominent non-plastic minerals (c.10%), being present at c.3-8% of any visual field. Rock fragments occur at c. 1% or less at any visual field and amounting to c.2% of the total minerals.

Most of the grains (c.82%) are subangular or angular, subrounded to rounded minerals are occasionally present (c.18%) and of low to high sphericity. Iron inclusions are nearly all subrounded to rounded. The majority of quartz sizes (c. 60%) are in the range of 0.060-0.380 mm across and the minerals ranging up to 0.700 mm across are fairly frequent. Iron inclusions show sizes in the order of 0.065-0.500 mm across. In PPL the matrix ranges from light or medium brown, pale yellowish brown to light brown, while in the XPOL it appears as brown, dark brown, yellowish brown and medium orange brown respectively.

The fabric subgroup A2 could have a similar origin to subgroup A1. The prevalence of quartz grains and frequent occurrence of iron oxides coupled with the absence of feldspars favour a sedimentary provenance. The Nubian Sandstone exposures prevailing in the area of the site is a source worthy of consideration.

3.2 X-ray diffraction analysis:

Some x-ray diffraction analyses were conducted on four pottery samples from each site: Islang2 (G93-16c, G93-17a) and Nofalab2 (G93-16a, G93-16b). Modern pottery samples from the same area of the two sites (G93-10b) were tested. X-ray diffraction photographs have shown that the samples hold appreciable amounts of quartz inclusions. Modern pottery samples from the same area show slightly higher percentage of plagioclases than the remaining samples, though the presence is weak. Mica is inconspicuous in the pottery samples from Islang2 and entirely absent in the samples from Nofalab2 after firing to 900oC, this mineral is absent in most of the samples. The sole exception are the samples of Islang2 which hold the same proportion of mica after firing.

Unlike the pottery of Islang2 site, the samples from Nofalab2 are devoid of kaolinite. The presence of this clay mineral is apparently weak, identified on the basis of a single diffraction line (7.2Å). Calcite and anatase are not present in the analyzed samples after firing to 900oC for a period of one hour.

3.3 XRFS analysis:

In the present work eleven major elements were analyzed using X-ray fluorescence spectrometric technique (XRFS): SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, BaO (table: 1).

These elements were chosen for two reasons:

a) Major compounds provide information about lithological provenance as well as technology (Palmieri 1987: 225-226), whereas trace elements are sensitive indicators as to geochemical environment and therefore reflecting very specific local sources (Reeves and Brookes 1978: 2).

b) Trace elements are unsuitable for the classification of prehistoric pottery containing appreciable amounts of coarse minerals (Buko 1984: 348).

The results (table: 1) indicate that the chemical composition of all the samples (pottery and clay) from the two sites is silicon-rich. This shows 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 feldspars 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 analyzed samples. Ferric oxide is present in all the samples with less than 10 wght%. The rest of the minerals are generally below 2 wght%.

The results of the chemical analyses outlined above (cf. table: 1) show that the pottery and modern clay samples are comparable. An explanation to this may be that the sources of temper (Nubian Sandstone and Basement Complex) and raw material (Nile silt and alluvial clay) are rather homogenous. The general uniformity of the local geology favours this suggestion.

3.4 Firing Index of the Pottery Samples:

The firing index of the pottery from the two sites (Islang2 and Nofalab2) has been determined using x-ray diffraction (XRD) and thermal expansion (TEP) techniques.

3.4.1 Firing temperature:

3.4.1.1 X-ray diffraction analysis

X-ray diffraction photographs show that the analyzed samples of Islang2 (G93-16c, G93-17a) and Nofalab2 (G93-16a, G93-16b) are characterized by high quartz content. Very fine-grained particles of clay minerals (020), K-feldspar and anatase show weak or very weak occurrence. The absence of the key minerals (montmorillonite, kaolinite, illite … etc.) in most of the samples points to firing temperatures above 300oC, at which montmorillonite disappears and vanishing of kaolinite shows that the firing temperature is above 500oC. The absence of poorly crystallized illite points to firing temperatures above 600oC, whereas vanishing of well-crystallized illite and clay-size muscovite points to firing temperatures exceeding 800oC. However, the only exception, being the weak presence of kaolinite identified on a single sample (G93-17a) derived from Islang2 pottery. After firing to 900oC, all the analyzed samples show development of hematite.

3.4.1.2 Thermal Expansion analysis:

The thermal curve of Islang2 pottery sample (1SG-Sa3) (Fig. 3) tends to show an increase

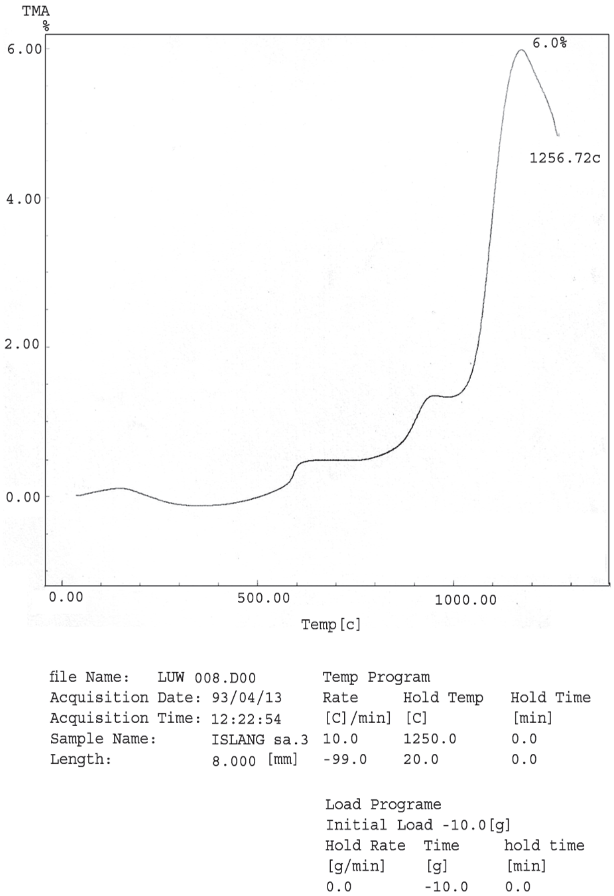


Fig. 3: Thermal curve of Islang2 pottery sample (sa. 3).

in size (the curve represents the linear volume increase of the sample cylinder) of approximately 4.6 to 6.5% with regard to the base line (Van Der Plas, pers. comm. 1994). Such type of curves is typical of clays that are characterized by appreciable amounts of montmorillonite/ illite mixed structure, next to a fair amount of kaolinite, next to a considerable amount of illite (see Grim 1968: 304-305 and Rice 1987: 90-91). Therefore, a firing temperature in the range of 700-800oC could be postulated for Islang2 pottery since above this temperature range the aforementioned minerals become amorphous.

The thermal curve of Nofalab2 pottery (NOF-Sa2) (Fig. 4) indicates a shrinkage after a plateau showing that the firing temperature changes again, a shrinkage followed by an expansion as a result of new formation occurred at a temperature exceeding 1100 B.C. According to literature (Tite 1969: 131-143 and Van Der Pl, pers. comm. 1994), it may have resulted through the interaction of new formed calcite with glass or clay relics. It is equally possible to have resulted from the formation of mullite and spinal. Again, the firing temperature of this sample seems to be less or around 800oC. This is due to the fact that calcite decomposes in a temperature range of c. 650oC-750oC (see Rice 1987: 98).

3.4.2 Firing Time:

The firing time seems rather short as could be inferred from a variety of colours depicted on the Neolithic pottery surfaces of Islang2 and Nofalab2 and the development of hematite after refiring the sherds in an electric oven for one

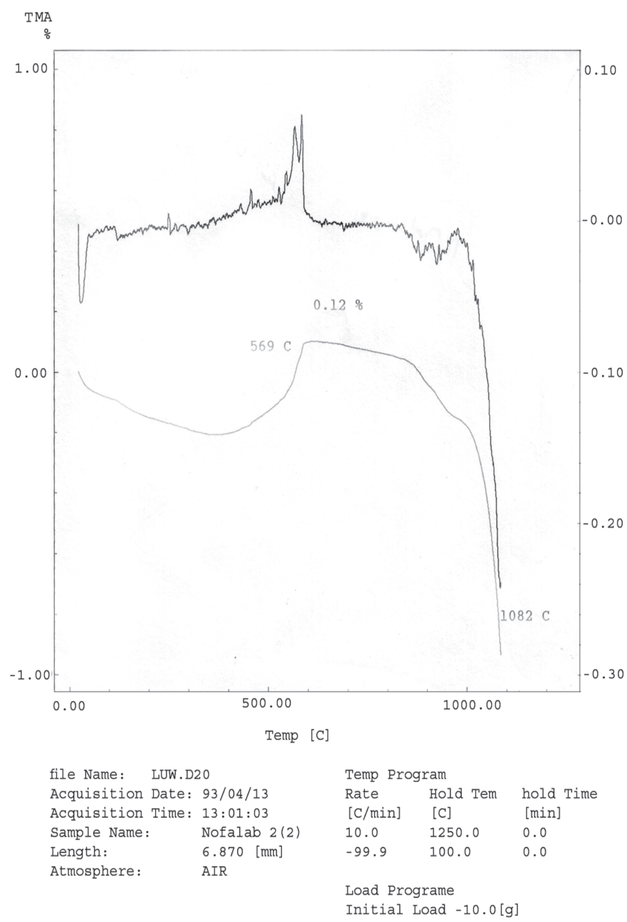


Fig. 4: Thermal curve of Nofalab2 pottery sample (sa. 2).

hour. It is reasonable to suggest that the short firing time of the samples resulted from the use of fast burning fuel such as chaff or grass. On the other hand, the relatively high temperature attained (see supra) makes it highly unlikely that it was obtained during a short period of time without continuous refueling or burning in a simple pit that could allow more control of heat.

3.4.3 Firing Atmosphere

The complete absence of forced-draft kilns at the Neolithic sites in Sudan raises the probability that the pottery of this period was either fired directly on the ground or in simple pits. The unevenly oxidized surfaces of Islang2 and Nofalab2 pottery are considerable in number, reflect fluctuation in firing atmosphere. The pottery of these sites is partially oxidized. This can be deduced from the dark brown cores and the thin oxidation zones at the wall surfaces. The duration of firing which is rather short and the changing atmospheric conditions of these wares do not permit excess of oxygen over that required to burn the fuel and to bring these wares to the highest state of oxidation.

4. Conclusions:

The X-ray diffraction and chemical analyses of the sampled pottery versus local clays from Islang2 and Nofalab2 sites tend to support the results gained from the petrographic analyses that quartz, feldspars and iron inclusions are the most common non-plastic minerals in most of the pottery fabrics. This sedimentary suite (cf. section 3.1.1) suggests a derivation from the Nubian Sandstone Formation prevailing in most of the central and northern Sudan including the sites investigated. On the other hand, fabrics of igneous origin (mainly non-polycrystalline quartz, biotite mica and rock fragments) (cf. section 3.1.1) have been identified. These fabrics seem to have been a derivation from outcrops from Sabaloka Gorge in close proximity to the sampling area (Fig.: 1) where ancient orogenic igneous rocks prevail.

The results of the physico-chemical analyses of the sampled-sites in the present work are consistent with those derived from several Neolithic sites along the Nile and across the Sahara-Sahel. Mineralogical analyses of pottery samples from the central Nile Valley (De Paepe 1991, Francaviglia and Palmieri, 1988; Hays and Hassan 1974; Khabir 1981, 1991; Mohamed-Ali 1982: 36-45, 174-176 and Nordstorm 1972: 33-58) and across the Sahara-Sahel belt (Hays and Hassan 1974; Palmieri 1987; Zedeno and Wendorf 1993) also suggest local manufacture, with their temper inclusions and soil composition indicating local derivation.

The firing index of the samples is of relatively high-grade (800-900oC) despite the fact that the length of firing is inadequate to bring the clay impurities (particularly iron oxide) to the highest state of oxidation. This relatively high firing is a characteristic of well-fired wares. On the other hand, the homogeneity of firing index of the pottery groups tested seems to suggest the use of similar firing techniques.

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ملخص: تسلط هذه الدراسة الضوء على المنشأ (الأصل) الجيولوجي، لعجائن فخار عصر ما قبل التاريخ المتأخر (العصر الحجري الحديث Neolithic ٤٥٠٠-٣٢٠٠ق.م.)، في إقليم الخرطوم بأواسط السودان. وقد أجريت التحليلات الفيزيائية والكيميائية، على عينات من فخار ذلك العصر، أُخِذَتْ من مستوطنتين هما: اسلانج-٢ والنوفلاب-٢ في أواسط السودان. وشملت التحاليل: المجهر البترولوجي، أشعة إكس المشتتة واللصفية، والتحليل الحراري، وذلك في جامعة ساوثهامبتون (بريطانيا)، بهدف 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 العينات باستخدام تقنيات التحاليل نفسها، المشار إليها آنفاً، كما أجريت دراسة تحليلية للعينات باستخدام التحليل الحراري التمددي (TEP) لتحديد مؤشرات الحرق (درجة الحرق، وفترته، وبيئته)، لإعطاء صورة متكاملة ومتماسكة، عن طبيعة المنشأ الجيولوجي للفخاريات موضوع الدراسة وطريقة حرقها. وقد أثبتت التحاليل المختبرية، أنّ العجائن، التي صنعت منها الأواني والأدوات الفخارية، متوافرة محلياً، ما يرجِّح الاحتمال أنّه جرى تصنيعها في المستوطنات ذاتها أو المناطق التي حولها. ومن جهة أخرى، أثبتت مؤشرات الحرق قدرة فخاريّين هذه المستوطنات على التحكم في درجات الحرارة واستخدامها الأمثل لإنتاج فخاريات جيدة الصنع رغم بدائية الأساليب المتبعة.

Note:

Thanks are due to the Department of Archaeology, Khartoum University for allowing me to conduct test-excavations at Islang2 and Nofalab2 sites which are located within the University concession north of Omdurman (1990). The present samples were retrieved from these excavations.

The excavations of Islang2 and Nofalab2 sites were privately financed. Appreciation goes to professor L. Van Der Plas (and his associates) of Wageningen Agricultrual University, Netherlands for the physico-chemical analyses. I am grateful to the Department of Archaeology at Southampton University (Britain) for the facilities put at my disposal while I was performing the petrographic analyses at their laboratories.

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Table 1: XRFS – analysis of major and minor compounds: Neolithic and Modern Pottery, Central Sudan

Locality / Sample	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	P2O5	BaO	L.O.1	Sum
Islang2 (2) – Ne	66.43	1.6	14.46	7.46	0.17	0.98	1.9	3.36	1.29	0.2	0.09	3.99	98.93
Islang2 (9) – Mo	61.72	0.62	19.48	5.28	0.06	0.51	1.28	0.43	6.6	0.56	0.2	3.54	100.2
Nofalab2 (2) – Ne	70.08	0.17	12.77	6.65	0.1	0.87	1.70	0.28	1.22	0.14	0.23	3.92	99.21
Nofalab2 (3) – Mo	71.59	1.16	12.11	6.9	0.09	0.77	1.56	0.57	1.22	0.14	0.17	3.66	99.84