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# Assessing the firing temperature of Uruk pottery in the Middle Euphrates Valley (Syria): Bevelled rim bowls

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ABSTRACT

In geochemical studies on ancient pottery, different methods have been attempted to assess the firing temperature. One of the most successful methods has involved studying mineral phase transformation sequences produced during firing despite the imprecise results usually obtained. The most commonly used methods assess the mineral composition of samples and thermal analysis. In this work, we used optical microscopy, X-Ray Diffraction, Fourier Transform Infrared Spectroscopy and thermal analyses to assess the firing temperature of a particular type of pottery from Mesopotamia. The Middle Uruk phase in Mesopotamia (3600–3500 BCE) has been characterised by the massive production of the so-called bevelled rim bowls (BRB). They are very similar in shape in Mesopotamia and surrounding areas but their production method is unknown, including the little knowledge about their firing temperature although short recent studies have shown that they were probably fired at mild temperatures. We have studied samples from archaeological sites of this period in the Middle Euphrates Valley in Syria. Results indicate very similar mineral composition, probably due to the use of the same raw materials and very similar mineral sequences that can be attributed to the same firing temperature probably below 500–650 °C and below 900 °C for some isolated samples.

## 1. Introduction

In archaeology, ancient pottery is usually studied for assessing manufacturing methods and technologies, trade between locations and cultures and possible uses [1–4]. The production technologies and particularly the determination of the firing temperature has been one of the most problematic points, also referred to as palaeothermometry or archaeothermometry [1,5]. The properties of archaeological pottery depend on original raw materials (composition and grain-sizes), firing conditions, including the maximum temperature reached during firing, heating rate and time and redox conditions and any weathering processes which occurred during burial.

Studies on the firing temperature have suggested that most ancient pottery was fired between 600 and 1300 °C [1,3], although other researchers have proposed milder temperatures below 500 °C [6] or even below 300–400 °C [3], at least for Neolithic and other Prehistoric pottery, as the firing process for pottery production and the assessment of the firing conditions have been a matter of discussion over the last 40 years.

### 1.1. Assessing the firing temperature of ancient pottery

Several methods have been put forward to assess the firing temperature and conditions of ancient pottery. The physical, chemical and mineralogical transformations of raw materials that occurred during firing are typically considered for this purpose. In the '80s, properties such as colour, porosity or density were usually considered for assessing firing conditions. However, these probes are too imprecise and only work below temperatures around 700 °C because several other factors affect these characteristics, including the behaviour of clays and temper used and manufacturing methods [1,7].

Mineral transformations due to decomposition, modification or crystallisation of minerals at increasing temperatures are by far the most common process [1,4,8–12]. This method gives us an accurate but imprecise temperature assessment, as one can improve the precision by combination with other methods. X-Ray Diffraction (XRD) and Fourier Transform Infrared spectroscopy (FTIR) are the most used instrumental methods [1,8–10] to assess the mineral composition of ancient pottery, both being complementary as the first allows mineral identification of crystalline minerals and the second allows identification of bounds

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present in molecules. However, the little knowledge on phase transformation in mineral mixtures [13] occurring at specific temperatures and the effect of other factors, such as firing time and conditions, hinder a more precise assessment of the firing temperature [6].

Alternatively, thermal analyses have been used [1,2,8,9,14], with Differential thermal analysis (DTA) and Thermal gravimetric analysis (TGA) being the most common methods. They assume that when pottery samples are analysed by a second heating, exothermic reactions will occur at temperatures higher than the temperatures reached in the first heating process, (that is assumed to be the firing process [8,15,16]) but also the raw materials used, firing conditions and time affect the behaviour of the samples [6,15–17]. As the weight loss of a ceramic paste during thermal analyses is proportional to the clay content, Drebushchak et al. [6] proposed a dehydroxylation (*m2*)/dehydration (*m1*) ratio and a diagram of the mass loss at *m2* vs. *m1* to assess mild or strong firing conditions and compare samples prepared with the same temper.

Alternatively, other methods such as Electron Spin Resonance (ESR), luminescence, synchrotron radiation induced fluorescence X-Ray absorption near-edge structure analyses or small angle neutron scattering (SANS) [1,18,19] have been used with success but they only work for samples fired at mild temperatures usually (but not all of them) below 600 °C [1,20–22].

## 2. Archaeological background

### 2.1. The Uruk period and the bevelled rim bowls

The Middle and Late Uruk periods (also called Late Chalcolithic 4–5) represent the birth of urban civilisation, that is, the beginning of History when the first known system of writing (proto-cuneiform tablets) was invented [23]. In this period (3600–3100 BCE), the Uruk culture experienced a process of geographical expansion from the South of Mesopotamia to the North (to Eastern Turkey) and East (Iran).

Archaeological sites of the Middle Uruk phase (or Late Chalcolithic 4) are identified because large amounts of a special kind of pottery are found in excavations. These are the so-called “bevelled rim bowls” (referred to as BRB), considered as a “diagnostic fossil” of the Uruk culture (Fig. 1). They are massively produced hand-made bowls, with a similar shape and volume throughout the whole of Mesopotamia. The manufacturing processes and possible trade and function of the BRB are unknown, with several hypotheses being suggested for all these questions, although there is no evidence to support them all [24–34]. Among these open questions, a key point on the manufacture is the temperature attained during firing of the BRB, several hypotheses being proposed and several studies have been published [7,30,34,35].

**Fig. 1.** Aspect of a typical BRB found in archaeological sites of the Middle Uruk phase.

### 2.2. Previous studies on the firing of BRB

The composition of BRB has been studied, with samples from two sites being recently analysed and compared. These were located in a stretch of around 200 km of the Middle Euphrates [33]. From this study, significant homogeneity between sites was observed, concluding that the raw materials have the same provenance or, alternatively, the composition of sedimentary clays in the Middle Euphrates is highly homogeneous.

The firing conditions have briefly been studied from experimental and analytical studies. A simple observation of the pottery paste indicates that they are made of a rich-clay binder and an aggregate (temper or skeleton) of sand and straw [32]. During firing, the straw is lost, the sand aggregate remaining as the skeleton of the paste. In a first experimental approach, Daszkiewicz et al. [7] suggested firing temperatures for BRB from southern Iraq ranging between below 700 °C up to over 1000 °C. Later, Helwing [35], carried out an experimental production of BRB and proposed that the firing temperature was below 600 °C. Recently, based on evidence from X-Ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR) and luminescence analyses on ten samples taken from two nearby archaeological sites of the Middle Euphrates Valley in Syria, the firing temperatures of BRB were apparently 400–550 °C [34]. One wonders whether such a sample is too small to obtain general conclusions about the production technology of BRB in the Middle Euphrates. Thus, the present study attempts to check the conclusion of that paper and extend it to the entire Middle Euphrates, by analysing more samples taken from the same and other archaeological sites of the Syrian Euphrates Valley.

### 2.3. Aim of this work

In this work, we attempt to assess the firing temperature of BRB, at least, in the Middle Euphrates, as a part of a more complete study of the production technology, trade and possible uses of BRB (PAMES project). As they are highly similar in shape and volume, as well as in composition [31–33] in that area, we intend to find evidence of similar production procedures. Thus, up to 63 BRB samples from eight archaeological sites of the Middle Euphrates Valley (Syria) were studied (Fig. 2). Samples come from Jerablus Takhtani, Tell Seikh Hassan, Tell Kosak Shamali and Habuba Kabira in the North-western part of the Middle Euphrates stretch in Syria (near the Turkish borders) and Tell Humeida, Tell Ramadi and Qraya in the South-eastern part of the Euphrates Valley (near the Iraq border). An additional sample from the site of Qasr Shemamok was analysed to compare results, this site being located in the Tigris valley. This comparison would help us to assess if the firing procedures were probably similar at least in the middle Euphrates.

## 3. Methods

### 3.1. Sampling

63 BRB samples from eight archaeological sites were used in this study: Tell Humeida (TH, 30 samples), Tell Ramadi (TR, 8), Tell Seikh Hasan (TSH, 10 samples), Jerablus Takhtani (JT, 10 samples), Habuba Kabira (HK, 2 samples), Qraya (1 sample), Qasr Shemamok (1 sample), and Tell Kosak Shamali (BD7.18.n18, 1 sample). Samples from Tell Humeida, Tell Ramadi and Qraya were recovered by the research team of the PAMES project (‘Archaeological Project Middle Syrian Euphrates’). The other samples were provided by research teams from Europe and Japan.

The sub-samples extracted and used for analysis consist of fragments of the upper part of BRB (near the rim, to minimise the possible effect of temperature differences attained during firing [1,36]). The outermost layer of samples was removed to avoid any contamination of external substances. Approximately 3 g of each sample were scraped off and gently crushed to obtain grains with a diameter below 63 µm.