Obsidian-tempered pottery in the Southern Caucasus: a new approach to obsidian as a ceramic-temper

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1. Obsidian and ceramics a combined approach

In the Southern Caucasus, obsidian-tempered ware has been found in several sites that date from the Chalcolithic period. So far studies concerning this specific ceramic group have been limited to traditional morphological or decorative classifications and, more rarely, petrographic analyses. In fact, studies on obsidian-tempered ceramics have never considered the contribution, in terms of acquisition and use of the obsidians related to different craft-activities, tool knapping and ceramic production. Its multiple use might imply coexisting forms of acquisition according to a much broader spectrum of functions than those so far hypothesized.

The results from the chemical analysis of such artefacts have been questioned in the past (Barone et al., 2010) because obsidian employed in ceramics could show significant modifications in its chemical composition caused by the firing of the vessels. Here we present a new approach linked to the analysis of trace elements of the obsidians that were used as a ceramic-temper. Laser Ablation High Resolution Inductively Coupled Plasma Mass Spectrometry was used to assess the concentration of critical chemical elements, the origin of the raw-materials and the stability of the ceramic artefacts. These results do not show any sensitivity in the concentration of trace elements such as Ba, Zr, Y and Nb to controlled firing at several temperatures.

This new approach is a breakthrough in obsidian provenance studies and also in tracing the circulation of artefacts such as vessels and the goods therein. As such, it provides a new perspective on the different uses of obsidian; not just for knapping but also for ceramic production. Its multiple use might imply coexisting forms of acquisition according to a much broader spectrum of functions than those so far hypothesized.

Firstly, such analyses can tell us if the obsidian-tempered pottery was locally produced or was imported from nearby regions. Another set of questions that will be addressed in this work concerns the function of the obsidian-tempered pottery and the cultural meanings attached to these ceramics.

So far the selective use of obsidians as an intentional temper in the ceramics rarely occurs outside of the Caucasus with the exception of sporadic examples from the Aegean (Katsarou et al., 2002).

Despite this dearth of information, we decided to undertake this pioneering research as we were aware of the potential that this new application offers to future research on the production and
circulation of obsidian and of ancient ceramics and on the still little understood social, economic and cultural developments of the chalcolithic communities of the Southern Caucasus.

While the experimental part of this work will mainly focus on the chalcolithic ceramics from the site of Aratashen in Armenia (Fig. 1), we also decided to analyse some samples of obsidian-tempered ceramics from the Middle Bronze Age site of Geghakar in Southern Armenia (Fig. 1) to further verify the reliability of the analyses of the obsidian temper.

2. The Chalcolithic period in Armenia and in the Caucasus

The concept of Chalcolithic period is still rather difficult to define in the Southern Caucasus both in socio-cultural and chronological terms.

Within the framework of an absolute chronology, the Chalcolithic period should be dated between the very beginning of the fifth and the middle of the fourth millennium BC.

There have been several attempts to subdivide this long time span (Kiguradze and Sagona, 2003; Lyonnet, 2007), but so far the only subdivision that seems founded on current archaeological data is the Early Chalcolithic, corresponding to the first half of the fifth millennium BC, and documented in very few sites like Mentesh Tepe in Azerbaijan, Aknashen in the Ararat plain (Badalyan et al., 2010) and Sioni in Georgia, and that of a Middle–Late Chalcolithic (dating between the second half of the fifth and the first half of the fourth millennium BC) which is widely identified in a large number of sites.

This bipartite periodization basically corresponds to that originally proposed by Kiguradze (2000) when he subdivided the South Caucasian Chalcolithic into an early phase, known as Early-Sioni, and a more recent phase called Late-Sioni. This terminology is named after the eponymous site of Sioni in Eastern Georgia (Fig. 1) (Menabde and Kiguradze, 1981; Kiguradze and Sagona, 2003), which was also the first site where a large amount of dark coloured and obsidian-tempered ceramics was noticed (Kiguradze, 2000; Sagona and Zimansky, 2009).

With the term Sioni are often grouped together Chalcolithic chaff-tempered, obsidian-tempered and grit-tempered ceramics of the Southern Caucasus and adjacent areas (such as Eastern Turkey and North Iran). Nevertheless, due to the dearth of publications featuring quantitative ceramic analyses, the quantitative occurrence of these different ware groups within the “Sioni” ceramic horizon is still very difficult to estimate. However, according to the present data, it seems that in the chalcolithic sites of the Caucasus, the chaff-tempered pottery is much more common than the obsidian-tempered pottery, while the quantitative occurrence of the grit-tempered ceramics remains to be evaluated.

The Chalcolithic has generally been considered as the period during which social and productive complexity first emerged among the communities of the Southern Caucasus (Palumbi, 2011).

This seems to be confirmed by an increased capacity to systematically exploit a broad range of natural resources located in different ecological niches (from lowlands to mountains) which is reflected in the settlement pattern, which comprised permanent, seasonal (camp-sites) and temporary occupations (caves and shelters). This increased socio-economic complexity was not only visible in some activities related to “primary” production, such as pastoralism (Chataigner et al., 2010) and wine-making (Areshian et al., 2012), but also in craft production. The quantitative increase in the number of metal artefacts in arsenical copper (Courcier, 2007, 2012), also supports a theory that there was a growth in specialised metallurgical skills.

One of the most distinguishable features of chalcolithic period pottery in the Southern Caucasus is the large-scale production of vegetal or chaff-tempered ceramics. A similar phenomenon is also recorded in the fifth millennium BCE in Eastern Anatolia, Northern Syria and Northern Mesopotamia, where it has been linked to radical transformations in the modes and volume of ceramic production (Truffelli, 1997; Marro, 2010, 2012). The use of chaff-tempered ceramics has been interpreted as a response to an increased demand for ceramic containers, possibly fulfilled by a growing productive specialisation (Palmieri, 1985). This is because plant-tempering allows for quicker drying and faster firing of the
ceramic vessels and lower firing temperatures (Arnold, 1985) and thus could have been more “cost effective” and might have been designed to reduce the times and energy needed to manufacture of the vessels (Akkermans, 1988; Akkermans and Schwartz, 2003). The data available in the Southern Caucasus does not allow us to assess whether the large-scale production of chaff-tempered ceramics in the Chalcolithic period resulted from the same premises as in the surrounding Near Eastern regions.

This experimental work was mainly designed to focus on the obsidian-tempered ceramics from the site of Aratashen in Armenia. However, we believe that by starting to focus on issues related to the production, function and circulation of obsidian-tempered ceramics, it will also allow us to increase our understanding of the relationship between obsidian-tempered and chaff-tempered ceramics and could thus allow us to shed light on the still little understood aspects of complexity related to ceramic production in the Chalcolithic communities of the Southern Caucasus.

3. The site of Aratashen (Armenia)

Located in the Ararat plain, near the valley of the Kasakh river, Aratashen is a small artificial mound, less than a hectare of which is preserved, which was excavated by a joint French–Armenian expedition between 1999 and 2005 in the framework of the “Mission Caucase” project (Badalyan et al., 2004) (Fig. 2).

The cultural sequence stretches between the first half of the sixth and the second half of the fifth millennium BCE with three main phases of occupation. The earliest, Aratashen II (5900–5500 BCE), which relates to the Neolithic period, is characterised by a set of superimposing circular dwellings built in pisé or mud-brick, closely recalling the architecture of the Shulaveri-Shomu Tepe cultural horizon that are typical of the contemporary settlements of the Kura river valley in Georgia and Azerbaijan. The archaeological assemblage of Aratashen II features a very rich bone and obsidian blade industry and the absence of ceramics, apart from few imported sherds of Halaf painted pottery.

The following phase, Aratashen I, which also relates to the Neolithic period, developed in strong continuity with phase II in terms of bone and lithic industries. The main change is the appearance of locally produced ceramics mainly belonging to the grit-tempered tradition (Badalyan et al., 2007; Palumbi, 2007).

The latest occupation at Aratashen is phase 0 and relates to the Chalcolithic period. It was heavily eroded by agricultural works (Badalyan et al., 2007) and no architectural remains have been found. The excavation of these remains yielded obsidian artefacts and a large amount of ceramics that can be attributed – both in terms of its technological and typological aspects, to the middle-late phase of the Chalcolithic (Badalyan et al., 2007; Palumbi, 2007).

3.1. The obsidians from Aratashen

There are many sources of obsidian across the Southern Caucasus (Arteni, Tsaghkunyats, Ashotsk, Gutansar, Hatis, Geghasar, Khorapor, Syunik, in Armenia; Chikiani, in Georgia; Kechaldag, in Azerbaijan) and in the neighbouring Kars plateau and Van basin (Yağlıca, Sarıkamış, Pasinler, Meydan Dağ, Nemrut Dağ) in Eastern Turkey (Fig. 1).

Excavations of the two Neolithic levels of Aratashen have produced an abundance of lithic tools in obsidian (more than 20,000 artefacts), although flint was extremely rare (less than 10 artefacts); the Chalcolithic level (0) produced only a few observant artefacts (Badalyan et al., 2004, 2007). Provenance analyses carried out by Blackman (Blackman et al., 1998; Badalyan et al., 2004) and Gratuze (Chataigner and Gratuze, 2013a,b) have shown that a wide range of obsidian sources was exploited (Arteni, Gutansar, Hatis, Geghasar, Sarıkamış, Meydan Dağ), but that one of these sources (Arteni) clearly predominated (about 60% of the supply) (Badalyan, 2010).

The absence of obsidians from the Georgian source of Chikiani makes the obsidian acquisition pattern of the Neolithic and Chalcolithic levels of Aratashen significantly different from the contemporary sites in Georgia where the Chikiani source predominates (Badalyan et al., 2004; Badalyan, 2010).

3.2. The ceramic production from Aratashen in the chalcolithic period (level 0)

Chaff-tempered ware is the most prominent type of ceramic production from Aratashen level 0; the quantitative data, based on a corpus of 316 sherds from a sample of selected stratigraphic units, shows that the vegetal or chaff-tempered pottery predominates at 86% (274 sherds) while the obsidian-tempered pottery constitutes the second most common group (31 sherds or 10% of the assemblage).

3.2.1. Chaff-tempered pottery

The petrographic analyses carried out on 47 samples by means of a Polarized Microscope with magnifications 3.7×, 9×, 20×...
recognised that two main varieties of clay-paste were employed:
- clay-paste with litho- (basalts, andesites and rhyodacites), crystallo- and vitroclastic components
- clay-paste with virtually no coarse impurities, in which crystals and vitroclastic materials correspond to the psammitic fraction of clay paste.

The content of pores and voids in these clays varies between 20–25% and 35–40%, and this suggests an increase in the intentional organic temper. In general this pottery was fired hastily and somewhat irregularly; the cross-sections are characterised by grey cores, thus confirming quick firing processes. The presence of an isotropic opal in diatoms allows us to hypothesise that the firing temperatures of the chaff-tempered ceramics were not higher than 550–600 °C. Often the surfaces of these ceramics are characterised by a comb-scraping treatment, but decorations are rare and are limited to motifs in relief or small knobs. The predominating quantity of this ware group at Aratashen in level 0 and the strong correspondence of their clays with the geological composition of the area surrounding the site strongly suggest that chaff-tempered ware was locally produced.

3.2.2. Obsidian-tempered pottery

The obsidian-tempered pottery forms an easily identifiable ware-group that stands out clearly from the chaff-tempered ceramics in terms of the composition of the paste.

According to the petrographic analyses (Arutyunyan and Mnatsakanyan, 2010: 215–218), this group is characterized by a clear predominance of vitroclastic material (obsidian) ranging between 14% and 22% (from scattered to dense) and 35–37% (very dense) of the total of the inclusions. The size of the obsidian grains reaches up to 3–5 mm and they are clearly distinguishable thanks to their glassy glitter. The obsidians observed in the petrographic analyses show different structural and textural types:

c. Greyish, smoky and translucent obsidian with a spotty distribution of gas—liquid inclusions (Table 1, sample AR.99.C.55).
d. Colourless obsidian with vesicular texture and rare microphenocrysts of plagioclase (Table 1, sample AR.99.C.46b).

In association with the obsidian, small amounts (3–4%) of vitroclastic materials (basalts, quartzites, etc) and vegetal temper were also added to the clay. The clacey component of these ceramics retains an intact non-vitrified primary structure and is characterised by stable paragenesis clay-minerals, volcanic glass and diatoms. This paragenesis points to clay masses corresponding to the sandy and ashly diatomaceous clays of the lower quaternary period largely widespread in the Ararat plain.

The firing temperatures of the obsidian-tempered ceramics should be higher than the chaff-tempered ceramics. Considering that the appearance of secondary cracks in obsidian (Fig. 3b) corresponds to 600–700 °C and that vitrification is weak, we can assume that the firing temperatures did not go beyond 750 °C. All the obsidian-tempered ware diagnostic sherds from Aratashen came from medium and small sized jars. The surfaces of these vessels, which were all hand-made, have a wide range of colours (Table 1) and are either smoothed or irregularly burnished and are often

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Macroscopic description of the corpus of sampled obsidian-tempered sherds from Aratashen.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sample</strong></td>
<td><strong>Shape</strong></td>
</tr>
<tr>
<td>AR.99.C.46a</td>
<td>Body sherd</td>
</tr>
<tr>
<td>AR.99.C.46b</td>
<td>Jar</td>
</tr>
<tr>
<td>AR.99.C.46c</td>
<td>Jar</td>
</tr>
<tr>
<td>AR.99.C.53</td>
<td>Body sherd</td>
</tr>
<tr>
<td>AR.99.C.54</td>
<td>Body sherd</td>
</tr>
<tr>
<td>AR.99.C.55</td>
<td>Body sherd</td>
</tr>
<tr>
<td>AR.04.Kb.501a</td>
<td>Body sherd</td>
</tr>
<tr>
<td>AR.04.Kb.501b</td>
<td>Body sherd</td>
</tr>
<tr>
<td>AR.04.Kb.501c</td>
<td>Body sherd</td>
</tr>
<tr>
<td>AR.04.Kb.502</td>
<td>Body sherd</td>
</tr>
<tr>
<td>AR.05.S.351.1</td>
<td>Jar</td>
</tr>
<tr>
<td>AR.05.T.451</td>
<td>Jarlet</td>
</tr>
<tr>
<td>AR.05.W.650</td>
<td>Body sherd</td>
</tr>
<tr>
<td>AR.05.W.651</td>
<td>Body sherd</td>
</tr>
</tbody>
</table>
A final distinguishing feature of this ware-group is the presence of distinctive decorations applied on the rim (small circular impressions, rows of tiny comb-impressions) (Figs. 4b and 5) which are completely different in terms of techniques from those of the chaff-tempered ceramics.


Fig. 4. Photographs of obsidian-tempered ceramics. a) Sample AR.99.C.53. High concentrations of fine-fluid medium and large transparent obsidians. b) Sample AR.05.S.351. Fine obsidian inclusions visible on the external and internal surface of the sherd. The rim shows typical comb-impressed decorations.

Fig. 5. Different decorative motifs applied on the rims of the obsidian-tempered ceramics from Aratashen. Comb-pressed (a), incised (b, c, e), circular impressions (d).

4. Obsidian-tempered ceramics in the Southern Caucasus

At Aratashen, chaff-tempered and obsidian-tempered ceramics are different in terms of their clays, temper, firing temperatures and decorative repertoires. The low quantities of the obsidian-tempered ceramics in comparison to the chaff-tempered pottery, and the affinities that the former shared with analogous productions from other chalcolithic sites of the Southern Caucasus have often prompted archaeologists to interpret the Aratashen obsidian-tempered ceramics as having been produced elsewhere.

Obsidian-tempered ceramics, dark-coloured, with combed surfaces and consistently decorated with incisions on the rims, such as parallel oblique lines and circular impressions, were particularly common at the site of Sioni (Menabde and Kiguradze, 1981; Kiguradze and Sagona, 2003), and were also found at Bodorna (Ramishvili, 1982), and Delisi (Tbilisi, 1978) in Georgia.

Further east, in Azerbaijan, obsidian-tempered pottery, which is also characterised by incised decorations on the rims, and considered as “kitchen pottery”, was retrieved in level III of Mentesh Tepe, which dates to the second half of the fifth millennium BC (Lyonnet and Guliyev, 2012: 101), and in Toiretepe (Petrun, 1973).

Going south, at Ovçular Tepesi, in Nakhchivan, during the same period as Mentesh Tepe, sporadic examples of obsidian-tempered ceramics have been found, with characteristic comb impressions (Marro et al., 2011: 74, Pl VII: 1; Gülçür and Marro, 2012: 311, 318, 320).

Some fragments of obsidian-tempered ceramics, with combed surface treatment and incised decorations on the rims, were also found at the site of Hazine Tepe in Eastern Turkey (Marro and Özfirat, 2003: 390, Pl. IV).

Both at Mentesh Tepe and Ovçular Tepesi, the obsidian-tempered pottery was found sporadically, or made up only a minor part of the production, mainly consisting of chaff-tempered
ceramics. In later periods, the presence of obsidian in ceramics is largely seen in the Early Bronze and Middle Bronze Age ceramics of Sos Höyük in Eastern Turkey (Kibaroglu et al., 2011). However, in this case, the very small dimensions (less than 1 mm) of the obsidian inclusions suggest that their presence in clays was not intentional.

In Armenia the presence of obsidian as a mineral temper is also recorded in the Early Bronze Age ceramics of Shengavit, Mokhakour, Berka, Artashavan (Navasardyan, 1990). In the Middle Bronze, Late Bronze and Early Iron Ages, obsidian-tempering is found in the ceramics from the kurgans 1 and 7 at Trialeti in Georgia (Zhorzhikashvili and Gogadze, 1974), burial 2 of kurgan 1 at Khachbulag in Azerbaijan (Dzhafarzade, 1976), and from Geghakar (Arutyunyan and Badalyan, 2008: 106) and Akhtamir in Armenia (Van As and Jacobs, 1996–1997). In fact, in volcanic regions such as in the Southern Caucasus, volcanic clays, normally employed in pottery production, may naturally contain obsidian particles. However, in the case of the obsidian-tempered ceramics from Aratashen, the quantity, the dimensional variability and the angular shapes of the obsidian inclusions (Figs. 3c and 4) strongly suggest that obsidian was ground or crushed and intentionally added to the clay as a temper.

The intentional use of the obsidian tempering process at Aratashen inspired a set of experimental analyses on 13 obsidian-tempered sherds (Table 1) in order to answer a variety of archaeological and geomorphic questions.

5. The analyses of the obsidian-tempered pottery

5.1. Sample preparation and characterisation of the inclusions

Before analysis, the ceramic sherds were polished on their surfaces and cross-sections in order to visualise the largest possible number of mineral inclusions. To prevent any pollution of the argon carrier gas flow during the ablation process, the sherds were also cleaned in an ultrasonic bath to remove microscopic dust particles produced by polishing. Finally, the obsidian inclusions were mapped by studying the polished surfaces with a binocular microscope. Between five to ten inclusions from each sherd were selected for analysis and were circled with a pencil to facilitate their identification during the ablation (Fig. 6). The selection of obsidian inclusions was made in order to cover the largest variability of colours and texture, even though these elements alone are not diagnostic to discriminate among the several Anatolian and Southern Caucasian obsidian sources (Chataigner and Gratuze, 2013a).

5.2. LA-ICP-MS analysis

The analysis of the obsidian inclusions was conducted at the Centre Ernest-Babelon of the IRAMAT (Orléans) using Laser Ablation High Resolution Inductively Coupled Plasma Mass Spectrometry (LA-HR-ICP-MS). The standard analytical protocol developed for obsidian analysis (Chataigner and Gratuze, 2013b) has been adapted to the very small size of the inclusions under study. This is the reason why the diameter of the ablation pits was reduced, according to the width of the obsidian inclusions, to the interval between 40 μm and 80 μm instead of the 60 μm–100 μm interval.

The other critical parameter is the thickness of the obsidian inclusions which, owing to the fact that they were inserted in a ceramic paste, is unknown. Consequently, in order to avoid overshooting the inclusions, the laser pulse frequency was reduced to 5 Hz and the analytical time was reduced from 70 to 55 s (15 s for pre-ablation and 40 s for analysis). Despite these changes, thinner inclusions were occasionally overshoot and for this reason the evolution of the signal during ablation always has to be carefully checked. In the case of overshooting, the calculation protocol developed to study concentration profiles in glass was applied (Gratuze, 2013). This protocol allowed us to calculate the concentrations of the obsidian inclusion separately from the different layers of the ceramic paste crossed during the ablation process.

The signal recorded from chemical elements such as calcium and iron, which shows the largest possible variation while passing from obsidian to clay, is the most useful in controlling the evolution of the signal (Fig. 7). However when the inclusion was too thin to obtain a confident signal, but large enough to be moved under the laser, the ablation was conducted in the line mode on its surface. (Fig. 8). The determination of concentration in both ablation modes (pit and line) on the same inclusion shows that the results are not affected by the selected ablation process. To avoid side contamination effects, the analyses were carried out in the middle of the inclusions. When possible the largest obsidian inclusions were selected for analysis, however, analyses of very small inclusions were also carried out (Fig. 9).

5.3. Representativity of the results

Before trying to relate the obsidian inclusions that were analysed to specific volcanic outcrops, we wanted to be sure that the chemical fingerprint of the obsidian had not been modified during the firing of the ceramics. This is because, according to Barone (Barone et al., 2010) volcanic glasses found as inclusions in ceramics show chemical modifications due to interaction with the clayey groundmass during firing. However, the work carried out by Barone mainly focuses on major elements and not on minor and trace elements. More particularly, the authors mention increases in lime, silica and alumina and losses of soda and potash. Using standard rock and mineral classification diagrams, they conclude that volcanic glasses are not useful in identifying production and provenance areas.

![Fig. 6. Sample AR.99.C46.c after the analysis.](image)
In order to check if the obsidian employed as a temper in the ceramics are subject to chemical modifications and how these changes modify their chemical fingerprint, we implemented an experimental procedure by adding different types of obsidian as a temper to a commercial clay (SG579 from Ceradel — www.ceradel.com/ — 67.5% SiO₂, 16.8% Al₂O₃, 6.9% CaO, 4.8% MgO, 2% K₂O, 1.1% TiO₂, 0.6% Fe₂O₃ recommended firing temperature range 1000–1150 °C) that was fired at several controlled temperatures.

The obsidian selected for this experimental part of our study comes from the outcrops of Tsaghkunyats 1 and 2, Chikiani, Arteni 2 and 3, Syunik, Yaglica Dağ and Meydan Dağ. These obsidian samples have the advantage of covering a large range of concentrations of the most useful elements used in provenance studies (Sr, Zr and Ba) and are also among the most common obsidians exploited for the production of tools not only at Aratashen, but also more generally in Eastern Anatolia and the Southern Caucasus.

These experimental obsidian-tempered ceramic pastes were fired for 6 h in an electric furnace at temperatures of 750, 950 and 1150 °C. We are aware that these firing parameters could not reproduce the ancient archaeological firing conditions for several reasons. First of all, because according to the petrographic analyses lower firing temperatures, probably not higher than 750 °C, were reached at Aratashen to fire the obsidian-tempered ceramics, and secondly because the ancient firing atmospheres were certainly different from those of an electric furnace. However, we decided to reach higher firing temperatures in order to increase the probability of chemical interactions between the obsidian and the surrounding clay and also to reach the recommended firing temperature of the industrial clay.

In the future, we plan to undertake new experiments by using a wood fire with longer firing sessions in order to check if the presence of ashes in the firing atmosphere and longer firing sessions may modify the chemical interactions between obsidian inclusions and clayey groundmass.

It was observed that all the obsidian inclusions fired above 950 °C show evidence of melting and degassing (expanded structure) and sometimes slight changes of colour were noticed (from colourless to brown). Nonetheless, no physical changes were observed for most of the obsidians fired at 750 °C. The chemical characterization of the obsidian inclusions contained in the experimental pastes that were fired at 750 °C and 950 °C was conducted with the same analytical protocol used for the archaeological sherds.
Eight analyses of each obsidian type were carried out: two on original obsidian samples coming from the natural outcrops, three on the inclusions that were fired with clay at 750 °C and three on inclusions fired with clay at 950 °C. As much as possible, both large and smaller inclusions were characterized.

The results match Barone’s observations for the major elements; in our study losses of Na and Al were mainly observed as well as an increase of K and Ca (Fig. 10). Modification of composition was also observed for some light minor and trace elements such as Li, Mg and Ti but also Rb and, to a minor extent, Sr (Fig. 11). However no systematic change in concentration was observed for heavier minor and trace elements and more specifically for rare earths elements.

Thus, the results show that the Ba–Zr and Y/Zr–Nb/Zr diagrams that we employ to differentiate the Armenian and Anatolian obsidian outcrops (Chataigner and Gratuze, 2013a, b) do not exhibit any significant drifts. According to these results and, as discussed later also for Aratashen and Geghakar ceramics, these diagrams are still effective to identify the provenance of the obsidian used as a temper in the ceramics (Figs. 12 and 13).

5.4. Obsidian inclusion sourcing

Sixteen ceramic sherds, 13 from Aratashen and 3 from Geghakar, were analysed representing a total of 130 analysed mineral inclusions (Table 2). At first, from 4 to 6 inclusions were analysed per sherd; some sherds were then re-analysed once or twice more. The final corpus of analysed obsidian inclusions consists of 114 inclusions for Aratashen (103 obsidian and 14 other minerals) and 23 inclusions for Geghakar (22 obsidian and one other mineral) (Table 2). Except for one sherd from Aratashen (AR 651), obsidian inclusions are largely present in the selected corpus of sherds and are easily recognisable under the binocular microscope.

5.4.1. The obsidian-tempered ceramics from Aratashen

As shown in the Ba–Zr and Nb/Zr–Y/Zr diagrams (Figs. 14 and 15), most of the inclusions from Aratashen originate from the outcrops of Tsaghkunyats (1 & 2) and Arteni (2 & 3). Seven of the studied sherds show the exclusive presence of Tsaghkunyats obsidian. Tsaghkunyats (predominant) and Arteni inclusions are found in 4 other sherds. One of the sherds (n 501 C) contains only obsidian from Arteni, while the last one (n 54) shows both Meydan Dag and Arteni (predominating) (Fig. 1).

5.4.2. The obsidian-tempered ceramics from Geghakar

Two slightly distinct obsidian compositions were identified for Geghakar. One of them matches the composition of Khorapor...
(Vardenis), while the other shows higher concentrations in barium and rare earth elements which are similar to those encountered for obsidians occurring in the Syunik region (Table 3; Fig. 14). As mentioned elsewhere (Chataigner and Gratuze, 2013b), these obsidian sources can be differentiated on the basis of their Nb/Zr and Y/Zr ratios. The picture in Fig. 15 shows that the obsidians from Geghakar do not match those of the Syunik complex but are closer to those from Khorapor (Fig. 1).

### 6. Discussion of the results

The first and most important result of this work is that the obsidian used as a clay-temper for ceramic production can be analysed for provenance studies.

The analyses of the ceramics from Aratashen show that obsidian employed as a temper in the ceramic-paste came from several outcrops (Tsaghkunyats, Arteni and Meydan Dag) (Fig. 1) and also identified two different patterns of obsidian-tempering.

The first pattern was multi-source (samples Aratashen 46c, Aratashen 501a, Aratashen 502 and Aratashen 54), with obsidian from different outcrops (Tsaghkunyats + Arteni; Arteni + Meydan Dag). The Arteni and Meydan Dag obsidian was brought to Aratashen mainly for tool-knapping, but they were also used as a temper for ceramics. It seems likely that the process of crushing and mixing the different obsidian later added to the clay took place in situ and therefore it is reasonable to suggest that these ceramics were locally produced.

The second pattern of obsidian-tempering was mono-source: Tsaghkunyats (Aratashen 351/1; AR 451; AR 46a; AR 46b; AR 55; AR 650, AR 651) or Arteni (Aratashen 501b, AR 501c). The use of the Arteni source is not surprising, as at Aratashen the main supply of obsidian for the lithic industry comes from this outcrop. The

<table>
<thead>
<tr>
<th>N. of studied inclusions</th>
<th>Tsaghkunyats 1</th>
<th>Tsaghkunyats 2</th>
<th>Arteni 2</th>
<th>Arteni 3</th>
<th>Meydan Dag</th>
<th>Khoraphor 1</th>
<th>Khoraphor 2</th>
<th>Other minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aratashen 1</td>
<td>117</td>
<td>36</td>
<td>26</td>
<td>2</td>
<td>34</td>
<td>5</td>
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<td>Geghakar</td>
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Fig. 14. Binary diagram of the Zr–Ba contents of the analysed archaeological and experimental inclusions and of their related outcrops.
exclusive diffusion of the Arteni obsidian in Armenia and in the Araxes valley (Badalyan, 2010) could argue in favour of a local production at Aratashen.

Unlike Arteni, the obsidian from Tsaghkunyats was not exploited for tool-knapping but it was only employed for ceramic tempering. This inconsistency can be explained if we consider that although small pebbles of obsidian from Tsaghkunyats were easily available in the river Kasakh, which flows in the proximity of Aratashen, their dimensions (1–4 cm long) were of no use as a raw material for tool knapping.

However, the fact that, according to chemical analyses, Tsaghkunyats obsidian was also used in other Chalcolithic sites, such as Artashat in the Ararat plain, Tisiteli Gorebi in Eastern Georgia (Badalyan, 2010) and Mentesh Tepe in Western Azerbaijan (Astruc et al., 2012), could not definitely exclude an exogenous origin of these sherds. Consequently, the analysis of the clays of the obsidian-tempered ceramics from other Chalcolithic sites of the Southern Caucasus and the comparison with those from Aratashen, remains necessary to define the provenance (local or imported) of the Aratashen ceramics.

Fig. 15. Binary diagram of the Nb/Zr–Y/Zr ratios in the analysed archaeological and experimental inclusions and of their related outcrops.

Table 3
Average composition of the studied inclusions according to their assigned provenance. Major and minor elements (Si, Al, Na, K, Fe, Ca, Mg, Ti and Mn) are expressed as weight % of oxide, other elements are given in part per million (1 ppm = 0.0001%).

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<th>Group</th>
<th>Average (n)</th>
<th>Li</th>
<th>B</th>
<th>Na₂O</th>
<th>MgO</th>
<th>Al₂O₃</th>
<th>SiO₂</th>
<th>K₂O</th>
<th>CaO</th>
<th>Sc</th>
<th>TiO₂</th>
<th>MnO</th>
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<th>Zn</th>
<th>Rb</th>
<th>Sr</th>
<th>Y</th>
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<td>75.6%</td>
<td>4.7%</td>
<td>0.58%</td>
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<td>0.081%</td>
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<td>0.018%</td>
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<td>0.5%</td>
<td>0.06%</td>
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<td>0.013%</td>
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We would like to move further from these first results to show how our data may contribute to a broader understanding of the obsidian-tempered ceramics in their context of production and use.

The selection of the Tsaghkunyats obsidian for pottery production and not for tool-making, may shed new light on the dynamics of acquisition and use of the obsidians at Aratashen. These data point to the fact that the obsidian supply at Aratashen was multi-purpose, by fuelling two different craft-activities, namely tool-making and ceramic production, and that the patterns of acquisition related to these activities were only partially overlapping. This suggests that these two different activities could have been carried out separately at Aratashen both in spatial (different areas) and possibly also in social terms (by different individuals).

Finally, a last set of questions concerns the function and meaning of the obsidian-tempered ceramics both at Aratashen and in the Southern Caucasus.

The hypothesis that these ceramics were employed as kitchen-pottery, and consequently were related to preparation and cooking of food, as suggested for Mentesh Tepe (Lyonnet and Guliyev, 2012), needs to be proved. Whether the presence of obsidian as temper was related to a good conductivity of this volcanic material, this remains to be confirmed and it is an issue that will be addressed more specifically in future works.

What is more, if the interpretation of this pottery as “kitchen-ware” proves to be correct, it still has to be explained how and why a ceramic production strongly linked to the household sphere, crossed the local communitarian boundaries and connected, culturally and technologically, the rest of the chalcolithic communities of the Southern Caucasus in the fifth millennium BCE.

The obsidian-tempered ceramics from Aratashen shared a large set of technical similarities (gritty pastes and dark colours) as well as decorative techniques and repertoires (incised and impressed decorations of lines and circles invariably applied on the rims) with those from other chalcolithic sites of the Southern Caucasus (e.g. Sioni in Georgia, Mentesh Tepe, and Ovchular Tepesi in Azerbaijan). So far, these analogies have been interpreted as the result of the provenance of the obsidian-tempered ceramics from one single region or site (Sioni). But our study allows us to suggest that these ceramics, with their own specific techniques and decorative codes, belonged to a unitary and broadly shared tradition of ceramic manufacture throughout the region.

The present experimental and pioneering work, by laying the foundations for a new double perspective on research—that on the provenance of obsidians employed as a ceramic-temper and that on the circulation of ceramics that were tempered with obsidian—has already addressed some intriguing patterns of complexity linked to the social, productive and cultural world of the Chalcolithic communities of the Southern Caucasus.

Acknowledgements

We would like to express our gratitude to Pierre Lombard and Ruben Badalyan, directors of the excavations at Aratashen, for allowing this study on the ceramics from the site. We are also indebted to Ruben Badalyan and Tommaso Prosperi for the critical final revision of the work, to Frédéric Abbes for crunching the obsidians, to Alain Bernet for cutting the archaeological samples and to Marie Le Mièvre for her encouragement and advice in the early phases of the research. This work was conceived and partially realised while Giulio Palumbi was fellow at the Collegium de Lyon, Institut d’Études Avancées.

References


