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Obsidian provenance analyses at Göytepe, Azerbaijan:
Implications for understanding Neolithic socioeconomies in the Southern Caucasus

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Abstract
This paper presents a provenance analysis of the Neolithic obsidian assemblages from the early-middle 6th millennium BC settlement at Göytepe, Azerbaijan. The study is unique in that (1) it involves a complete, non-selected obsidian assemblage (901 artefacts) from one particular area of the site; (2) the material is derived from a well-stratified sequence of ten securely radiocarbon-dated architectural levels; and (3) the use of an extraordinarily wide range of sources (more than 20) was identified by provenance analysis using energy dispersive X-ray fluorescence. The results revealed a previously unknown diachronic change in obsidian use in the region, suggesting the occurrence of significant socioeconomic changes during the Late Neolithic of the Southern Caucasus.

Keywords: Southern Caucasus; Shomutepe-Shulaveri culture; Neolithic socioeconomy; obsidian; energy dispersive X-ray fluorescence; pXRF

INTRODUCTION

Provenance research relating to obsidian artefacts from Neolithic sites has greatly advanced in Near and Middle Eastern archaeology since the early 1960s, making it possible to identify not only the sources from which Neolithic communities exploited obsidian, but also how exchange and communication networks developed in the period of increasing social complexity (Cauvin *et al*. 1998; Carter *et al*. 2013; Freund 2013 and references therein). In comparison, research on Neolithic obsidian use in the Southern Caucasus, a region situated north of the Middle East across the modern countries of Armenia, Azerbaijan and Georgia, is still in its early stages. Despite the existence of numerous obsidian sources in the Lesser Caucasus Mountains (Fig. 1), systematic and controlled characterisation research began only in the early 1990s (e.g. Keller and Seifried 1990; Keller *et al*. 1996). Earlier provenance research was based on rather simple methods using a combination of visual observations and some refractive indices (Chataigner 1995:

137). While it was suggested that the Neolithic communities of the southern Caucasus obtained obsidian mostly from local nearby sources, confirmation required advanced physio-chemical analyses.

With the new use of instrumental neutron activation (INAA), fission track (FT) and X-ray fluorescence analyses (XRF), more comprehensive and systematic research appeared on the chemical composition of obsidian artefacts and sources (Poidevin 1998; Blackman *et al*. 1998; Chataigner *et al*. 2003). In 1998, a corpus of more than 30 sources in the Near East then known was compiled with characterisation data (Cauvin *et al*. 1998). Based on the results of those data and other research, obsidian sources known to have contributed to most of the Neolithic obsidian artefacts from the Southern Caucasus were defined and the dominant sources for each settlement were also evaluated (Badalyan *et al*. 2004). Further, subsequent research revealed that Neolithic communities of the region rarely used obsidian from sources in southeastern Turkey such as Nemrut Dağ and Bingöl, which were the primary sources for northern Mesopotamian communities to the south (Arimura *et al*. 2010; Frahm 2012). On the other hand, some southern Caucasian obsidian has recently been identified at sites in southeastern Turkey and northwestern Iran but only after the later part of the Pottery Neolithic period (Glascock 2009; Nadooshan *et al*. 2013; Campbell and Healey 2016; Frahm et al. 2016; Mouralis *et al.* 2018). The provenance analysis of obsidian artefacts from Armenian sites has now been extended to a wider range of periods, covering the Palaeolithic to Iron Age (Chataigner and Gratuze 2014a, b). Most recently, research using portable X-ray fluorescence (pXRF) instruments has also been implemented, allowing rapid sourcing of a much larger number of geological and archaeological samples. However, the quantity of Neolithic artefacts thus far analysed is limited (Frahm 2013; Frahm *et al*. 2014; cf. Martirosyan-Olshansky 2015).

These developments have established a promising foundation on which the temporal and spatial variability of obsidian exchange/exploitation strategies among the southern Caucasian Neolithic communities can be understood. However, further research is needed. First, the number of Neolithic sites with securely provenanced obsidian data remains low, limited to a handful of sites, such as Aratashen and Masis Blur in Armenia (Badalyan *et al*. 2004; Chataigner and Gratuze 2014b; Martirosyan-Olshansky 2015) and Mentesh and Kamiltepe in Azerbaijan (Lyonnet *et al*. 2012), reflecting the small number of systematic Neolithic excavations in the region. Second, the chronological control of the archaeological samples is not precise enough for detailed interpretation. All these sites represent settlements signifying the emergence of a full-fledged food production economy in the region. This period, belonging to the early half of the 6th millennium BC, is known to have involved significant cultural developments

(Nishiaki *et al*. 2013, 2015a, b), thus requiring provenance analysis to be conducted under strict chronological control. Third, the studies conducted to date are mostly dependent on archaeological samples selected from the entire excavated assemblages, often through unknown criteria. Fourth, the number of obsidian artefacts analysed from each Neolithic site has, in most cases, been limited to dozens of pieces.

This paper aims to contribute to our knowledge of obsidian artefacts from the Neolithic Southern Caucasus by providing new provenance data from the Pottery Neolithic site of Göytepe, Azerbaijan (Fig. 1; Guliyev and Nishiaki 2012, 2014). Because the site has a well-defined stratigraphic sequence with 14 architectural levels in the 11 m of cultural deposits, which are securely radiocarbon dated to the early-middle 6th millennium BC (Nishiaki *et al*. 2015a), results have revealed a previously unrecognised temporal change in obsidian use during this period. This study involves a stratified obsidian artefact assemblage (10 levels; 901 pieces) excavated from a single area of the site, and is the first such attempt in obsidian research of the southern Caucasus.

MATERIALS AND METHODS

The Neolithic mound of Göytepe, approximately 145 m in diameter and 11 m in height, is situated on the left bank of the Middle Kura Valley, approximately 10 km east of Tovuz, western Azerbaijan (Fig. 1). It is one of the largest Neolithic mounds in the region known to date. The excavations have been carried out by a large-scale Azeri-Japanese joint mission since 2008, resulting in the recovery of an 11 m thick Neolithic cultural sequence founded on virgin soil (Fig. 1; Guliyev and Nishiaki 2012, 2014; Nishiaki *et al*. 2015a). The sequence consists of 14 architectural levels, each characterised by a dense distribution of circular mudbrick houses connected by curvilinear walls. All archaeological records, including architecture, pottery, lithic artefacts, ground stones, and bone tools indicate that they belong to the Shomutepe-Shulaveri culture of the Pottery Neolithic, which represents the first food producing socioeconomy in the Middle Kura and the Upper Araxes Valleys (Narimanov 1987). The entire sequence has been firmly dated by more than 50 radiocarbon dates to a period of 5650 to 5460 cal BC, the late phase of this culture. This high-resolution cultural stratigraphy has been established by a Bayesian analysis providing a unique opportunity to study cultural developments in a Shomutepe-Shulaveri Neolithic society (Nishiaki *et al*. 2015a, 2018).

A large number of lithic artefacts have been recovered from this site. More than 5000 have been studied thus far, among which about 70% are made of obsidian (Nishiaki and Guliyev in press). Non-obsidian raw materials consist of flint, tuff, andesite, mud-stone and others, all considered locally available. The proportion of obsidian shows little change through the sequence. Obsidian was used mainly for production of blades and blade tools. Large single-platform blade cores, with regular blade removal scars showing the use of pressure debitage, were recovered. As at other Shomutepe-Shulaveri settlements (Hansen *et al*. 2006), burinated and/or splintered pieces are common in the retouched tool assemblages. Other tools include retouched blades, sickle elements, denticulates, notches, and a small number of transverse arrowheads. The rare occurrence of flakes with cortex indicates that obsidian was brought to the site in a more or less decorticated condition (Table S1).

The material analysed here is from Square 4B (10 × 10 m), located at the northeast corner of the main excavation area (Fig. 1). This square is covers the longest occupational sequence thus far exposed at this mound, while the excavations of the other squares have revealed latest levels only (Levels 5–1). Excavated between 2009 and 2013, this square was divided into two lengthways sections (each area 5 × 10 m) oriented north-south, designated 4BI (west) and 4BII (east). After both areas were excavated to the top of Level 11 in 2010, the excavations continued to underlying levels in a small square of 2 × 2 m at the northeast corner of 4BII only. The virgin soil was reached below Level 14 in 2013 (Fig. 1). All the obsidian pieces recovered from 4BI and 4BII were available for this study. They comprise a collection of 901 specimens, covering Levels 14 to 5. According to the radiocarbon chronology, this sequence represents a period of approximately 150 years dated to 5650 to 5500 cal BC (Nishiaki *et al*. 2018).

For geochemical source identification all 901 artefacts were subjected to analysis using a desktop ED-XRF spectrometer (JEOL, model JSX-3100s) at the Center for Obsidian and Lithic Studies (COLS) of Meiji University, Tokyo, following the protocol developed there (Kannari *et al*. 2014). The X-ray intensity of 13 elements, Na, Mg, Al, Si, K, Ca, Ti, Mn, Fe, Rb, Sr, Y and Zr, were measured. Due to the incomplete collection of geological reference samples available, however, the artefacts were only geochemically grouped based on the X-ray intensity ratios of several elements without calibrating their absolute values or identifying their sources. The method for evaluating elemental data followed Mochizuki (1997). This approach allowed the identification of 17 compositional groups, two of which had sub-groups.

Then, in order to identify their specific geological origins, 213 artefacts were selected for a second set of analyses. The samples were randomly selected from each group to ensure that each geochemical group was represented (Table S2). This analysis was conducted using a portable X-ray fluorescence (pXRF) instrument (Thermo Scientific Niton XL3t 980 GOLDD+) at the Manchester Obsidian Laboratory (MOL) in the University of Manchester, UK. In accordance with the procedures previously established (Campbell and Healey 2016), concentrations of 15 elements were measured: Al, Si, K, Ca, Ti, Mn, Fe, Zn, Rb, Sr, Y, Zr, Nb, Ba and Pb. The values of each element were calibrated to a set of 16 international standards, including NIST-278 (obsidian), BIR-1 (basalt), BCR-2 (basalt), JR-1 (obsidian), JR-2 (obsidian), RGM-2 (rhyolite) and W-2a (diabase). The reference data set used for comparison and source attribution was the Manchester pXRF source set v3.62, which includes 1306 individual specimens from almost all the geological sources in Anatolia and Southern Caucasus. These source samples have been analysed using the same pXRF instrument and the same analytical procedures. Published source data from other analytical programmes was used for comparison when appropriate.

RESULTS

1. Grouping of archaeological samples by ED-XRF analysis

Fig. 2 shows the clusters of archaeological samples based on the ED-XRF analysis (intensity ratios of X-ray fluorescence). It indicates that the artefacts can be assigned to 17 distinct groups (A to Q) with Groups A and I each sub-divided into two sub-groups, giving a total of 19 distinct compositions. A bivariate plot of Sr/(Rb+Sr+Y+Zr) to Zr/(Rb+Sr+Y+Zr) clearly distinguishes 12 clusters of artefacts (Fig. 2-1). Those with lower values for Zr cannot be clearly distinguished on this plot but can be separated into 7 groups on a Fe/Mn to Sr/Rb plot (Fig. 2-2). This grouping was confirmed by other elemental combinations. Six samples, which fall between the 19 groups were not categorised.

2. Source identification by pXRF

The artefacts analysed by pXRF were assigned to 20 sources using bivariate plots of calibrated values of measured elements, by ratioed element pairs and by multivariate analysis (discriminant analysis and principal components analysis) in a series of steps which confirmed or eliminated potential sources. This was done independently of the categorisation by the qualitative ED-XRF analysis. Most of the names of obsidian sources used in this paper correspond directly to those used by other researchers but additional description is needed for a few sources. Geological obsidian named Kars Akbaba and Kars city in this study was collected by Katsuji Kobayashi in his 2002 survey (Kobayashi *et al*. 2003). The former was collected in a form of rolled cobbles at a secondary deposit about 3 km north of the village of Akbaba, southwest of Kars city. Its chemical composition is similar to the Kars Arpaçay reported by Frahm (Frahm 2010; Frahm et al. 2016), which is from a secondary deposit along the Kars/Arpaçay river, and it was previously published as Kars Arpaçay (Campbell and Healey 2017). The latter was collected in the city of Kars also in the form of rolled cobbles. The location of its original geological source is unknown but its composition can be distinguished from Kars Akbaba and Kars Digor. Our Sarıkamış 1 has similar composition to Sarıkamış South by Chataigner and Gratuze (2014a) and Sarıkamış 2 to their Sarıkamış North. Our Pokr Arteni 1 and 2 respectively corresponds to Pokr Arteni Group 1 and Group 2 by Frahm (2014), who has related them respectively to Arteni 2 and Arteni 3 of Chataigner and Gratuze (2014a).

The initial step in source attribution, using a simple Rb to Nb scatterplot, allowed us to eliminate 12 sources (most Cappadocian and Southeast Anatolian sources including those of peralkaline obsidian) (Fig. S1-1). After omitting these sources a plot of Sr/(Rb+Sr+Y+Zr) to Zr/(Rb+Sr+Y+Zr) was helpful in providing initial attribution of Göytepe artefacts to 10 sources (İkizdere 1, Sarıkamış 1, Kars city, Chikiani, Mets Arteni, Pokr Arteni 2, Tsagkunyats Damlik, Hatis 1, Geghasar and Spitakasar) and eliminated further 12 sources (Fig. 3-1). For the remaining samples, an Sr vs. Fe plot allowed assignment of three groups to Pokr Arteni 1, Gutansar and Tsaghkunyats (Ttvakar) and elimination of another two sources (Fig. S1-2). For the next step, on a Rb/(Rb+Sr+Y+Zr) to Zr/(Rb+Sr+Y+Zr) plot, three groups can be attributed to Syunik 2 (Mets Qarakhach), Sarıkamış 2 (Group 1) and Sarıkamış 2 (Group 2), while Syunik 2 (Sevkar) can be excluded (Fig. 3-2). Sarıkamış 2 (Group 2) plots close to Pasinler but their separation was confirmed when other combinations of elements, such as Nb/Zr to Rb/(Rb+Sr+Y+Zr), are used (Fig. S1-1, 2). Finally, two groups can be separated and assignable to Pasinler and Kars-Akbaba 2 on a Nb/Zr to Rb/(Rb+Sr+Y+Zr) plot (Fig. S1-3). In addition to these source attributions, İkizdere 1 can be separated to two sub-groups as represented in Figs. 3-1 and 3-2. Two samples match MOL geological samples of İkizdere 1 and were assigned to İkizdere 1 (Group 1) and another five samples show a slight but distinct separation from this group and thus were sub-categorised as İkizdere 1 (Group 2). The Syunik (unspecified) group includes those which belong to the Syunik 2 group but the sub-source (i.e. Syunik 2 (Mets Qarakhach), Syunik 2 (Sevkar), or a third sub-group) cannot be identified.

Across all the scattergrams described above there are two compositional groups of Göytepe obsidian which do not correspond to any source samples currently in the Manchester source reference set. One of them can be attributed to Tsaghkunyats (Arqayasar/Kamakar) through comparison with published data of geological obsidian (Chataigner and Gratuze 2014a,b; Frahm 2017; Frahm et al. 2017). The other group of four samples form a tight cluster but does not match any known sources (including the recently found source of Ptghni: Frahm et al. 2017) and is currently left as an unknown group which we have designated MOL Unknown 1. It is also difficult to assign sources for four other samples which do not make an exact match to any sources. However, one of them (GTOB-1004) is probably from Syunik 1 or Geghasar. Another sample (GTOB-0078) might be from Kars city but has a problematically low Zn, making it difficult to categorise with confidence, and has provisionally been identified as 'uncategorised but probably from Kars/Sarıkamış area'. The other two (GTOB-0438 and GTOB-0726) were not categorised into any groups and cannot be associated with any particular sources and were classified as 'uncategorised'.

3. Correlation of the results between ED-XRF and pXRF

The results of the source identification by pXRF analysis can be closely correlated with the geochemical groups established by ED-XRF analysis. The pXRF analysis of the samples taken from the ED-XRF Groups A to Q indicate that each group could be attributed to a single source, except for Groups B, G and I (Table S2). Group B could be separated into two sources and Group G and Group I could be separated into sub-sources.

There was already a hint that the 200 artefacts classified by ED-XRF as Group B could be separated to two groups. The 30 artefacts from Group B analysed by pXRF confirm that they can be split into Sarıkamış 2 (Group 2) (11 artefacts) and Kars Akbaba 2 (19 artefacts) with some confidence (Figs. 3-1 and 3-2). The two groups plot closely together but the division is fairly consistent in multiple plots using a range of elemental values. Based on this division, most of the 170 samples not analysed by pXRF can also be divided into two groups on a scattergrams of X-ray intensities (Fig. 4). However, several samples fall on the border of two clusters and cannot be reliably differentiated on the basis of simple bivariable plots. Therefore, discriminant analysis was used to provide final sub-divisions for Group B. The assignations of the 30 Group B artefacts analysed by pXRF were used to define the initial groups for discriminant analysis, using seven elements that are well-detected in the ED-XRF analysis and where preliminary analysis indicated that they showed useful variation for this group: Ti, Mn, Fe, Rb, Sr, Y and Zr. For the 30 Group B artefacts already assigned to separate groups, the ED-XRF data classified them in the same way, with an r^{2-} score of 0.981, suggesting a strong level of correlation. These discriminant functions were then used to classify the artefacts not re-analysed by pXRF. In the large majority of cases, the predicted group membership carried a high degree of confidence. In only 4 cases was it less than 0.8. While we acknowledge that there are a few marginal cases, this indicates that differentiation into two groups can be considered robust.

In Group G, 14 out of 17 members were analysed by pXRF, of which 12 were attributed to Syunik 2 (Mets Qarakhach) and the other two identified as a general Syunik 2 group: Syunik 2 (unspecified). Three samples were not analysed by pXRF but a plot of their X-ray intensities with the samples already assigned to source allows two to be assigned to Syunik 2 (Mets Qarakhach) and one to Syunik 2 (unspecified) (Fig. 4). For Group I, 10 out of 11 members of this group were analysed by pXRF. They were separated into Pokr Arteni 1 (1 artefact) and Pokr Arteni 2 (10 artefacts). The other sample which was not analysed by pXRF could also be attributed to Pokr Arteni 2, again on an X-ray intensity plot with the other samples (Fig. 4). On the other hand, Group I', which was provisionally separated from Group I by ED-XRF qualitative analysis, was attributed to Pokr Arteni 2 by pXRF, as with the majority of the Group I obsidian. Among the six samples uncategorised by ED-XRF analysis, two correspond to İkizdere 1 (Group 1) according to pXRF, one to 'uncategorised but probably Kars/Sarıkamış area', one to 'Syunik 1 or Geghasar'; the other two remain 'uncategorised'.

The correlation of the results of the ED-XRF and pXRF analyses demonstrate a close match which is robust and reliable. On this basis we are able to attribute the obsidian from Square 4B at Göytepe to at least 20 sources as summarised in Table 1. Three sources predominate accounting for more than 500 artefacts or 56.2% of the obsidian used; the major suppliers are Geghasar (27.1%), Kars Akbaba 2 (17.9%) and Sarıkamış 1 (11.2%). Seven other sources (Sarıkamış 2 (Group 1), Sarıkamış 2 (Group 2), Mets Arteni, Chikiani, Tsaghkunyats (Ttvakar), Tsaghkunyats (Damlik) and Gutansar) contributed 34.0%, each consisting of more than 20 pieces, while another 10 sources contributed only a small percentage.

DISCUSSION

Considering the small database of obsidian provenance data for Neolithic artefacts in the southern Caucasus, the results from Göytepe represent a significant addition to our knowledge. Our analyses have characterised one of the largest Neolithic obsidian collections from the region and is the first systematic provenance study conducted on a stratified Neolithic assemblage from a single site. The results lead to a more refined understanding of obsidian exploitation and use during the Shomutepe-Shulaveri cultural phase of the Pottery Neolithic of the Southern Caucasus. Particularly important is that the entire assemblage from one particular area of the site (Square 4B) has been provenanced, allowing statistical analysis of the results.

First, the results indicate that all the identified sources are confined to the southern Caucasus (Armenia and Georgia) and the northeastern Anatolia. No evidence was found for the use of obsidian from the southeastern Anatolian sources such as those at Nemrut Dağ and Bingöl (southeastern Anatolia), which were widely circulated in the Middle East during the Neolithic. In this regard, our results support the previous finding (Arimura *et al*. 2010), which suggested that the Shomutepe-Shulaveri communities developed its own distinct obsidian trade/exploitation network.

Second, the results revealed that a wide range of sources were utilised at Göytepe. The analysis identified the use of obsidian from at least 20 sources, or 14 source areas. The variety is larger than that shown in previous analyses from other Shomutepe-Shulaveri settlements. For example, at Aratashen an analysis (LA-ICP-MS) of 30 artefacts indicates the intensive use of obsidian from five sources: Arteni (15), Gutansar (5), and Sarıkamış (8), followed by Hatis (1) and Gegham (Geghasar) (1), all of which are accessible within a 100 km radius from the settlement (Chataigner and Gratuze 2014b). Likewise, at Masis Blur (Armenia), 171 artefacts were provenanced and six source areas were identified , using pXRF (Martirosyan-Olshansky 2015). The results also show the use of the nearby sources such as Gutansar (59), Arteni (58), Spitaksar (35), Hatis (14), and Sarıkamış (5). However, the excavator suggests that the source areas could be divided into 'possibly as many as 13' sources (Martirosyan-Olshansky 2015). On the northern side of the Lesser Caucasus Mountains in Azerbaijan provenance data is available from Mentesh, situated only 10 km east of Göytepe. There 43 artefacts have been provenanced and at least nine sources documented: Gegham (Geghasar) (18), Tsaghkunyats (8), Chikiani (3), Syunik (2), Gutansar (1), Arteni (1), and Sarıkamış (10) (Lyonnet *et al*. 2012). Although this mound contains Shomutepe-Shulaveri Neolithic levels on virgin soil, its densest occupations belong to the Chalcolithic and the excavators admit that the samples might represent a mixed assemblage. Further, reference to the LA-ICP-MS analysis at the contemporary Pottery Neolithic site of Kamiltepe on the Mil plain (Fig. 1) is also useful. It shows that the 13 artefacts analysed consisted of obsidian from Syunik (8), Gegham (Geghasar) (4) and Gutansar (1) (Lyonnet *et al*. 2012).

The greater diversity of sources at Göytepe undoubtedly relates to the significantly larger sample size but at the same time it may also reflect the peculiarities of the assemblage. Göytepe is located farther from the obsidian sources than the Armenian sites or Kamiltepe. The nearest sources for Göytepe are situated in central Armenia, about 100 km to the south and west. Interestingly, the results from neighbouring Mentesh also indicate a relatively broad diversity of sources (7) considering the number of artefacts analysed, although the sample is mixed with Chalcolithic material. It seems that Neolithic communities further from sources may have obtained obsidian materials from more diversified sources. We suggest that different patterns of obsidian exploitation and exchange relate to the distance between the settlements and sources.

Third, it is notable that much more of the obsidian used at Göytepe came from areas to the west and southwest (Geghasar in the southern Caucasus Mountains and the Sarıkamış and Kars regions in northeast Anatolia) rather than from the northwest (Khrami region), upstream from the Kura Valley. Settlements belonging to the Shomutepe-Shulaveri culture are densely distributed on the Ganja-Ghazakh plain and in the Khrami region along the Middle Kura Valley. Traditionally, these two regions are thought to have shared numerous cultural traits, as represented by the two eponymous sites of Shomutepe in the Ganja-Ghazakh plain and Shulaveris Gora in the Khrami plain. Neolithic communities in the Ganja-Ghazakh region may have procured obsidian from sources near the Khrami region, namely, Chikiani, about 150 km to the east of Göytepe. However, the present analysis demonstrates that the use of obsidian from Chikiani at Göytepe was quite low (6.9%). Similarly at Mentesh obsidian from Chikiani forms only 7.0% of the analysed artefacts, indicating that obsidian acquisition by the communities in the Middle Kura Valley of Azerbaijan was focused on the Lessor Caucasus Mountains, where several sources are concentrated in a relatively confined region, rather than at a single source upstream in the valley.

Given the distance between Göytepe and the nearest obsidian sources (Fig. 1-1), one may postulate that the Neolithic societies obtained obsidian through not only exchange but also direct acquisition. Procurement may have also been associated partly with transhumance, or seasonal travel associated with animal husbandry (Chataigner and Barge 2008; Chataigner and Gratuze 2014b). Many obsidian sources in Armenia are located in the high mountains, often higher than 2000 m above sea level, which are snow-covered in winter but provide pastures suitable for migrating shepherds in the summer. According to the GIS travel cost analysis by Chataigner and Barge (2008), societies on the Ganja-Ghazakh plain could have been within travelling distance of the obsidian sources in the mountains. Although no direct support for this hypothesis has been obtained at Göytepe, the architectural evidence may be relevant. The preservation of the architectural remains and floors is exceptionally good, including still usable materials and tools on the living floors. The repeated examples of such remains suggest the frequent abandonment of the settlement on several occasions during its occupation. Likewise, the outstanding preservation of the buildings may also reflect an intentional, intermittent abandonment for the purposes of seasonal movement (Guliyev and Nishiaki 2012: 77; Nishiaki et al. 2018).

Fourth, this study revealed a clear diachronic change in obsidian use at Göytepe during the late phase of the Shomutepe-Shulaveri culture (Fig. 5-1 and Table S3). The frequencies of different sources in each level point to two chronological phases. The earlier phase (Levels 14 to 8) contains a higher proportion of Sarıkamış and Kars Akbaba (northeastern Anatolia) obsidian, accounting for about half of the total. The later phase (Levels 7 to 5) shows a sharp decline in the proportion of obsidian from these sources, whereas the proportion from Geghasar, south of Lake Sevan, increases. In addition, the use of obsidian from Tsaghkunyats (Damlik) and Tsaghkunyats (Ttvakar), sources located west of the site, gradually declines and the use of obsidian from Syunik, to the south, slightly increases. Our Bayesian analysis of radiocarbon dates shows that the change occurred approximately 5520 cal. BC (Nishiaki *et al*. 2018). Investigating the factors influencing this shift would be interesting for future research.

The frequent use of Armenian sources at Göytepe is not surprising considering that they are geographically close, but the regular use of obsidian from northeastern Anatolia, at least 200 km and up to 450 km from Göytepe, is remarkable in the earlier chronological phase (Fig. 5-1, Table S3). This perspective seems to differ from the common sense prediction that many Neolithic communities in the region would have mainly obtained obsidian from sources closer to the settlement. To investigate what might underlie this issue, the general techno-morphological categories of the respective *chaîne opératoires* were compared by source (Fig. 5-2; Table S4; northeastern Anatolia: Sarıkamış and Kars Akbaba; central Armenia: Geghasar, Damlik, Ttvakar, Arteni), because the category might be related to the distance to the source (e.g. more finished tools for obsidian from remote sources and more cores and debitage for closer sources; see Nishiaki and Nagai 2011). However, the artefacts of northeastern Anatolian and central Armenian obsidian show virtually the same pattern (Fig. 5-2), the only notable difference being related to chronology. Both assemblages contain more retouched tools in the later phase. This does not necessarily mean that obsidian was brought to the site in the form of finished products, because the assemblages contain obsidian cores and knapping debris that attest to local core reduction

(Nishiaki and Guliyev in press). The provenance study at Mentesh also demonstrated local reduction of obsidian cores, even from the remote northeastern Anatolian sources (Lyonnet *et al*. 2012: 173). The increase of retouched tools in the later phase, including use-damaged and recycled tools, therefore, may reflect a more intensive use of obsidian tools within the settlement. Although this issue warrants more detailed research, the transport and use of obsidian from both remote and nearby sources appears virtually the same during this period.

The relationship between distance and frequency of use modelled by Renfrew *et al*. (1968; also see Renfrew and Bahn 2008: 376–377) cannot easily be applied to the pattern uncovered at Göytepe. In this regard, results of a detailed geoarchaeological survey on the Ararat plain provide a useful suggestion. As revealed at Aratashen and Masis Blur, the regional communities also exploited obsidian from the relatively distant sources in northeastern Anatolia, as well as from much closer sources in central Armenia. Relying upon the survey results, Chataigner and Gratuze (2014b: 15) suggest two ways by which the obsidian from northeastern Anatolia might have been obtained. One is that the secondary cobbles transported from the region around obsidian sources at Sarıkamış North by the Kars River, down to its confluence with the Akhurian River and further down were exploited. The second is that the obsidian was obtained through exchange with the inhabitants of the Sarıkamış region. The hypothetical meeting point proposed is the region of Tuzluca, located at the edge of the Ararat plain, where natural salt could have been extensively exploited in the Neolithic. Whichever strategy was used, it suggests that the procurement of obsidian from northeastern Anatolia by the inhabitants of Göytepe, who may have frequented the Ararat plain as part of a transhumance cycle, was not necessarily associated with long distance travel, but took place within central Armenia. This hypothesis is supported by the data from Göytepe discussed above, where no distinctive differences in reduction strategies were identified for obsidian from remote and nearby sources.

Future studies are required to investigate the shift in obsidian use from northeastern Anatolia to central Armenian sources, as this change might also be related to other developments in social relations. Comparison of the diachronic changes in obsidian use with those reflected in other archaeological data at Göytepe will be useful. In this regard, it is worth remembering the change in the site's pottery assemblage (Nishiaki *et al*. 2015a). The use of pottery in the lowest levels was rare, accounting for about 10–20% of the total number of sherds and flaked stone artefacts. The proportion jumped from Levels 8 to 7, when the number of sherds reached approximately 50% and eventually became more common than lithics in the later levels. In addition, the use of mineral-tempered pottery in the earlier phase was gradually replaced by the use of plant-tempered pottery from Level 8 onwards. Further, the variation in vessel types also increased remarkably, now consisting of bowls and jars as well as necked jars, plates and painted ceramics (Nishiaki *et al*. 2015a).

The significant increase in pottery use and the diversity of vessel types, and the change of the temper types have also been reported in the later levels of Aratashen and Akhnashen (Badalyan *et al*. 2004). Not only the employment of similar manufacture and decoration styles in pottery production, but development patterns are also similar across the Lessor Mountains, indicating the existence of some social network among the Neolithic communities. Obsidian acquisition probably played a major role in developing the network. It is likely that important changes were occurring in the network during the late phase of the Shomutepe-Shulaveri culture, at some 5520 cal. BC. Dramatic changes in the exploited sources of obsidian also occurred in this period. To further investigate this issue, it will be necessary to conduct an extensive comparative study of the Neolithic assemblages from Göytepe with the central Armenian and northeastern Anatolian regions. Unfortunately, few Neolithic settlements have been reported in detail from northeastern Anatolia.

CONCLUSIONS

This paper reports the first results of our provenance analysis of obsidian assemblages from the Pottery Neolithic site of Göytepe. The number of artefacts provenanced, the non-arbitrary nature of the sample selection and the high chronological resolution of this study are unique among Neolithic obsidian studies in the region. The provenance analysis yielded previously unknown results that enrich our understanding of the socioeconomic structure of Neolithic communities of the Southern Caucasus. The diachronic change is particularly significant; the shift in emphasis from the use of sources in northeastern Anatolia to those in central Armenia, indicates a change in social networks and/or raw material procurement strategies during the late phase of the Shomutepe-Shulaveri culture. Further research is needed to investigate the socioeconomic background for this change, as it was likely associated with other aspects of Neolithic lifeways.

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Captions for figures and tables

Fig. 1. The location of obsidian sources and Neolithic sites mentioned in the text (above). The plan and stratigraphy of Göytepe. The stratigraphy shows a north-south section of the ten main excavation squares. The vertical scale is twice the size of the horizontal scale (below).

Fig. 2. Scatterplots of elemental intensity ratios measured by ED-XRF for Göytepe obsidian artefacts from Square 4B.

Fig. 3. Scatterplots of elemental concentration ratios measured by pXRF for Göytepe obsidian artefacts from Square 4B.

Fig. 4. Scatterplots of elemental intensity ratios by ED-XRF analysis to show the sub-division of the Groups B, G and I obsidian.

Fig. 5. Stratigraphic changes in the use of obsidian at Göytepe. 1: Frequencies by level; 2: Frequencies of the technological categories of obsidian by different sources and phases at Göytepe.

Table 1. The results of provenance analysis of Göytepe obsidian artefacts.

Fig. S1 Scatterplots of elemental concentration ratios measured by pXRF for Göytepe obsidian artefacts from Square 4B.

Table S1. The obsidian artefacts excavated from Square 4B at Göytepe.

Table S2. The correlations between the compositional groups by ED-XRF qualitative analysis and the source attributions by pXRF analysis.

Table S3. Stratigraphic changes in the use of obsidian from different sources at Göytepe.

Table S4. Stratigraphic changes in the use of obsidian at Göytepe. Frequencies of the technological categories of obsidian by different sources and phases at Göytepe.

Table S5. Elemental compositions (in ppm) of 213 obsidian artefacts from Göytepe as determined by pXRF.

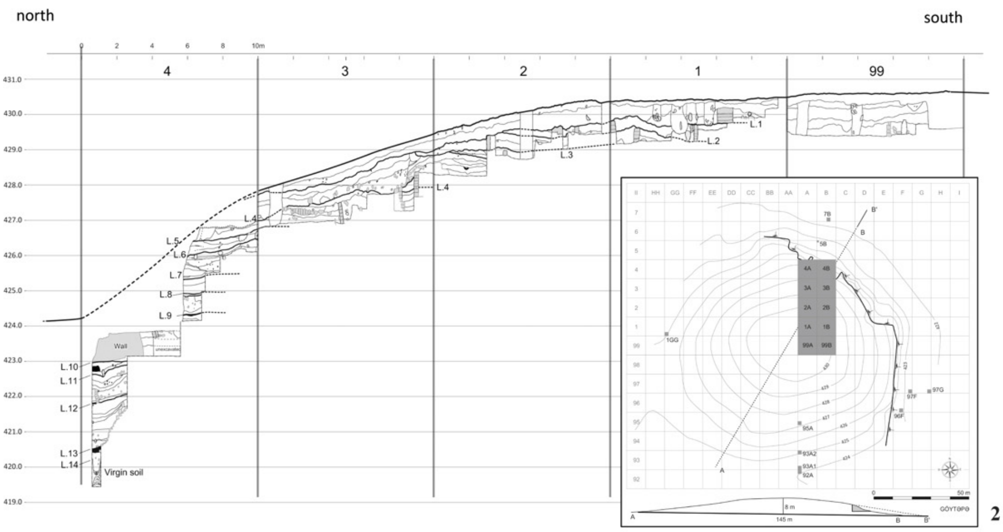


Fig. 1. The location of obsidian sources and Neolithic sites mentioned in the text (above). The plan and stratigraphy of Göytepe. The stratigraphy shows a north-south section of the ten main excavation squares. The vertical scale is twice the size of the horizontal scale (below).

Fig. 2-1 Sr/(Rb+Sr+Y+Rb) vs Zr/(Rb+Sr+Y+Rb) : X-ray intensity

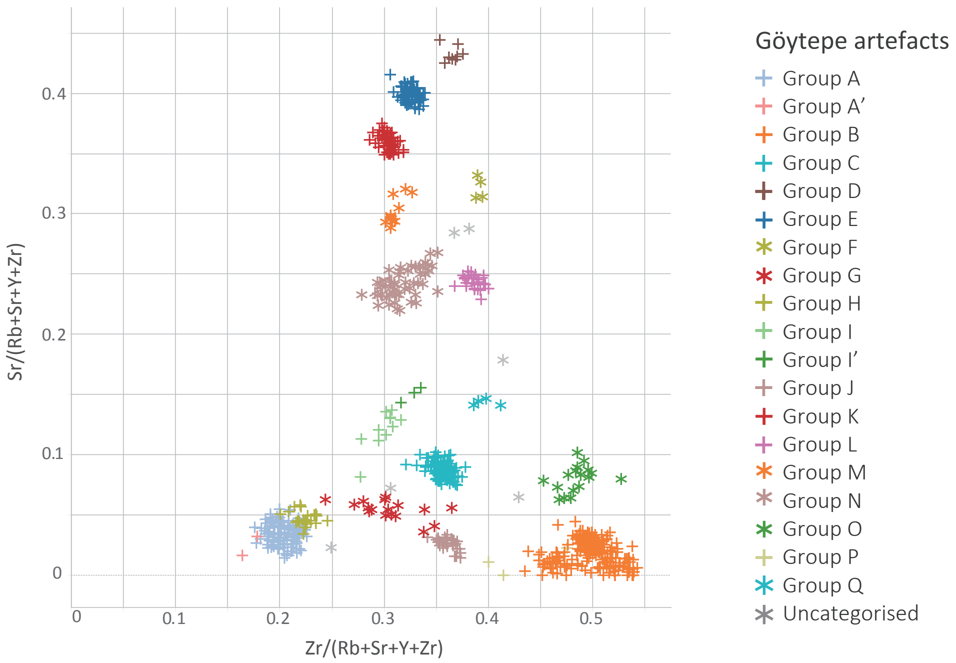


Fig. 2-2 Fe/Mn vs Sr/Rb : X-ray intensity

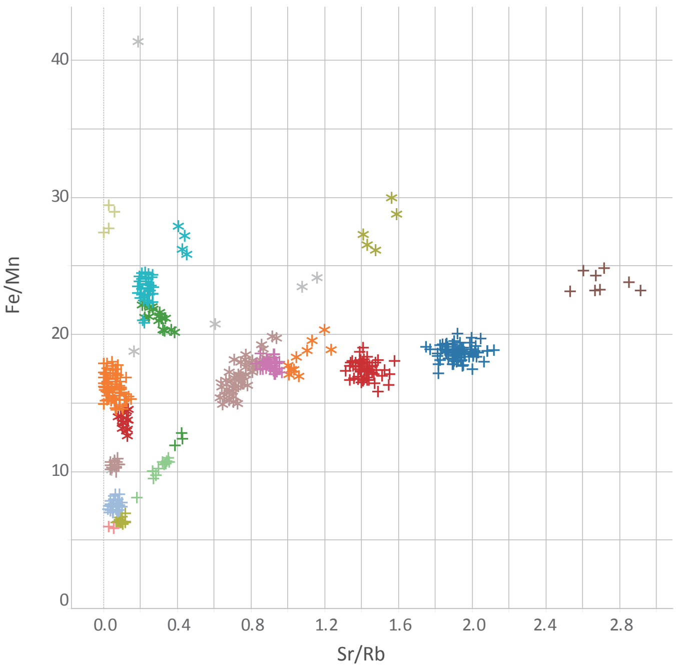


Fig. 3-1 Sr/(Rb+Sr+Y+Rb) vs Zr/(Rb+Sr+Y+Rb)

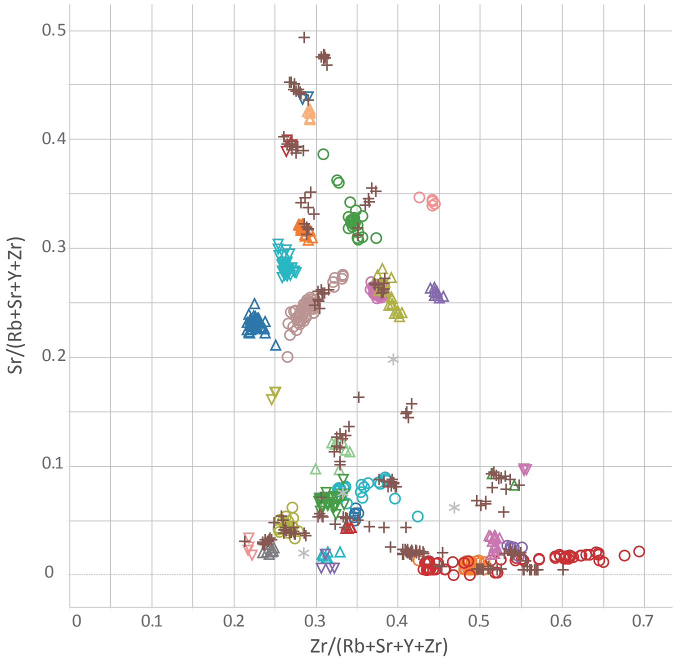


Fig. 3-2 Rb/(Rb+Sr+Y+Rb) vs Zr/(Rb+Sr+Y+Rb)

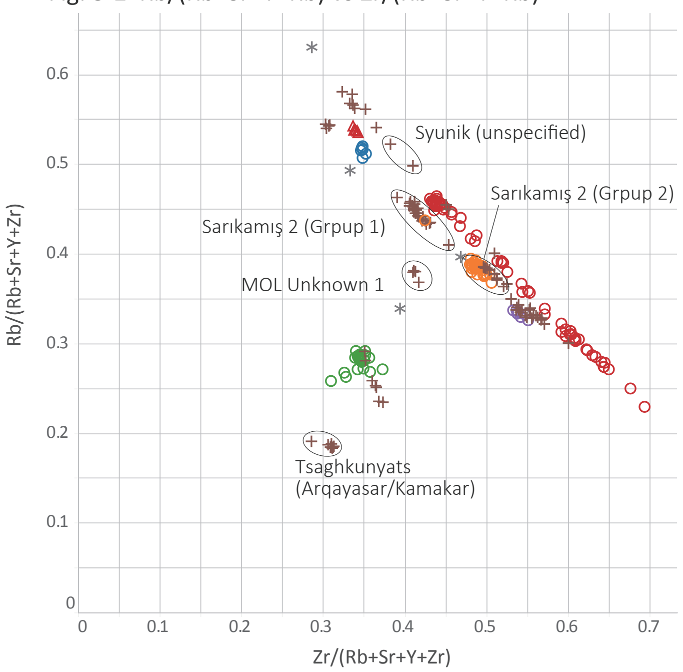
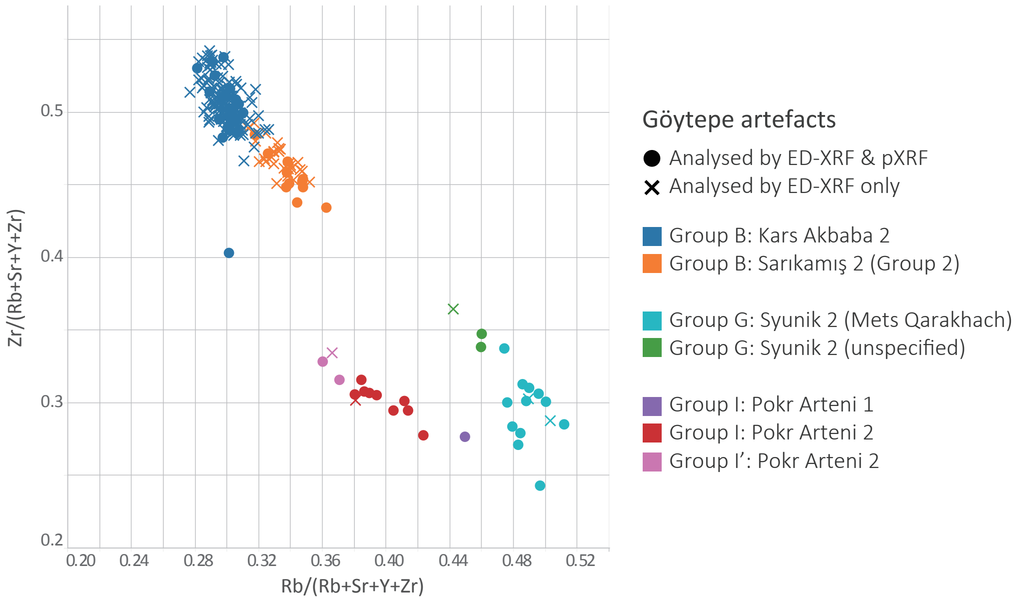
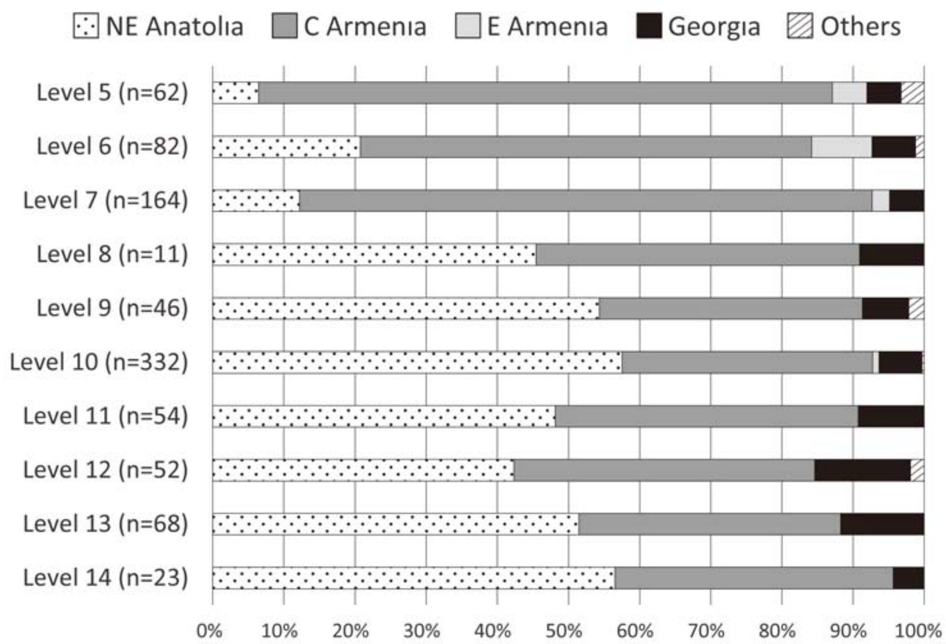


Fig. 4-1 Zr/(Rb+Sr+Y+Rb) vs Rb/(Rb+Sr+Y+Rb) : X-ray intensity





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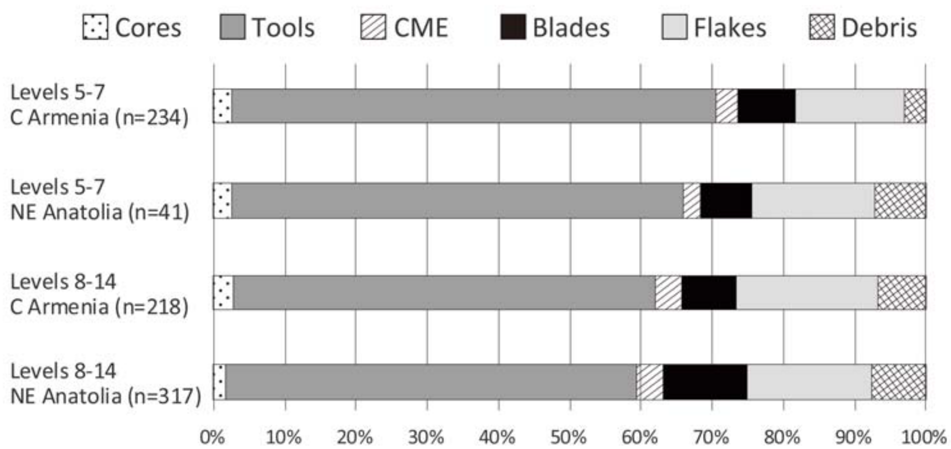

2

Fig. 5. Stratigraphic changes in the use of obsidian at Göytepe. 1: Frequencies by level; 2: Frequencies of the technological categories of obsidian by different sources and phases at Göytepe.

Table 1. The results of provenance analysis of Göytepe obsidian artefacts.

Source	Surface	L.5	L.6	L.7	L.8	L.9	L.10	L.11	L.12	L.13	L.14	Total	%
İkizdere 1 (Group 1)				1							1	2	0.2%
İkizdere 1 (Group 2)			1				3			1		5	0.6%
Pasinler							1	3				4	0.4%
Sarikamis 1		1		2		12	63	8	8	6	1	101	11.2%
Sarıkamış 2 (Group 1)		1	4	4	1	2	10	2	2	2	1	29	3.2%
Sarıkamış 2 (Group 2)			5	6	1	1	18		2	5	1	39	4.3%
Kars Akbaba 2	1	2	7	6	3	7	88	12	7	20	8	161	17.9%
Kars city				1		3	7	1	3	1	1	17	1.9%
Uncategorised but Kars/Sarıkamış area							1					1	0.1%
Chikiani	1	3	5	8	1	3	20	5	7	8	1	62	6.9%
Mets Arteni				2		1	8	4	5	1		21	2.3%
Pokr Arteni 1				1								1	0.1%
Pokr Arteni 2		1	3	8			1					13	1.4%
Tsaghkunyats Ttvakar		2	8	5	2	4	28	6	3	6	4	68	7.5%
Tsaghkunyats Damlik	1	2	4	6		1	24	3	3	7	2	53	5.9%
Tsaghkunyats Arqayasar/Kamakar		1				1	3	1	1		1	8	0.9%
Gutansar		2	1	9	1	2	12	1	5	2		35	3.9%
Hatis 1		2		5		2	1	1				11	1.2%
Geghasar	3	40	34	96	2	6	40	7	5	9	2	244	27.1%
Spitakasar			2									2	0.2%
Syunik 1 or Geghasar							1					1	0.1%
Syunik 2 (Mets Qarakhach)	1	2	6	3			2					14	1.6%
Syunik 2 (Unspecified)		1	1	1								3	0.3%
MOL Unknown 1		1	1				1		1			4	0.4%
Uncategorised		1				1						2	0.2%
Total	7	62	82	164	11	46	332	54	52	68	23	901	100%

Fig. S1-1 Rb vs Nb

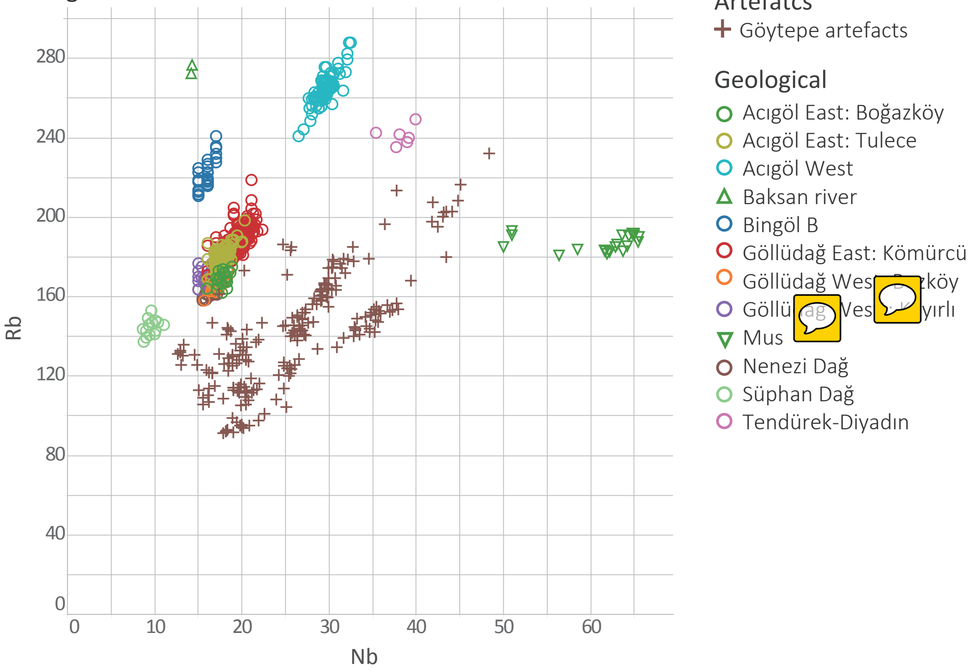

Fig. S1-2   Sr vs Fe

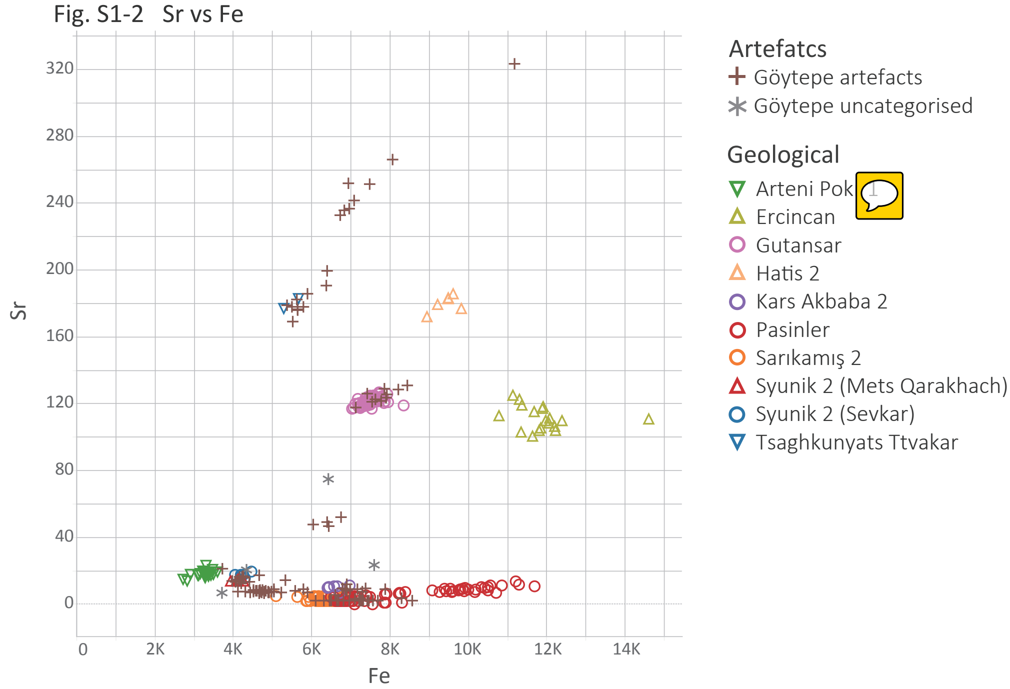

Fig. S1-3 NB/Zr vs Rb/(Rb+Sr+Y+Zr)

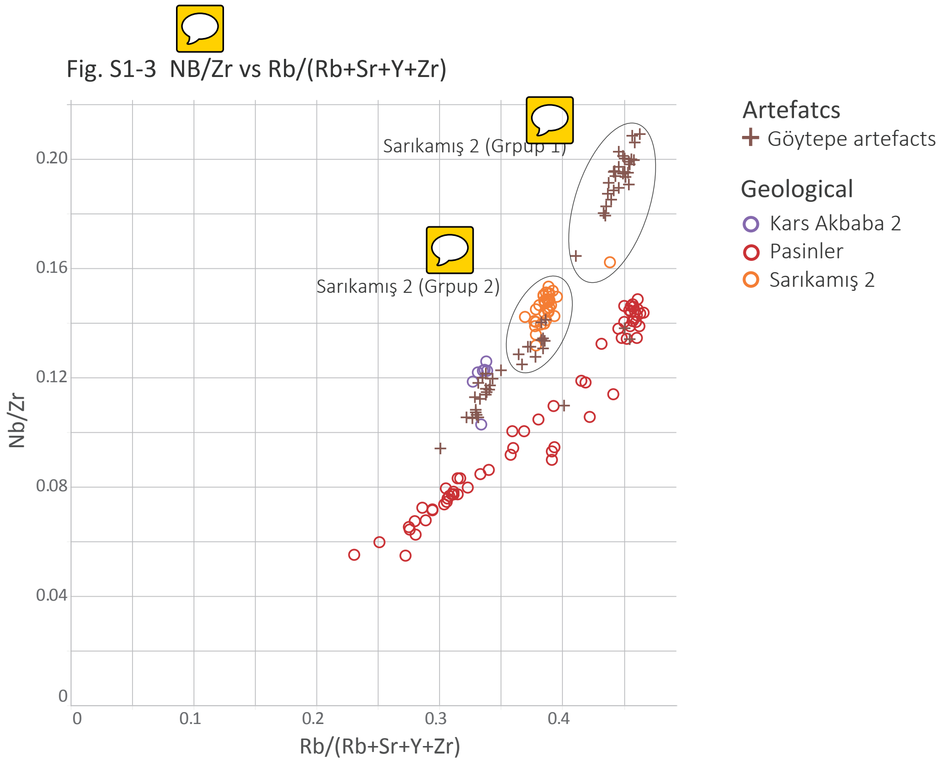

Table S1. The obsidian artifacts excavated from Square 4B at Göytepe.

Levels	Surface	Level 5	Level 6	Level 7	Level 8	Level 9	Level 10	Level 11	Level 12	Level 13	Level 14	Total (%)
Cores			2	8			9	2		2		23 (2.6)
Core management elements	1		5	4			12	4	3	2	1	32 (3.6)
Cortical flakes				1								1 (0.1)
Partially cortical flakes						1	4	1		1	1	8 (0.9)
Flakes	1	8	18	23		12	58	9	9	17	4	159 (17.6)
Partially cortical blades			2				3					5 (0.6)
Blades	1	5	1	16	1	5	35	6	4	2	3	79 (8.8)
Debris		1	4	5	1	5	21	4	2	5	1	49 (5.4)
Retouched tools	4	48	50	107	9	23	190	28	34	39	13	545 (60.5)
Total	7	62	82	164	11	46	332	54	52	68	23	901 (100.0)

Table S2. The correlations between the compositional groups by ED-XRF qualitative analysis and the source attributions by pXRF analysis.

Compositional groups by ED-XRF	Number of samples analysed by ED-EXF	Number of samples selected for pXRF	Ikizdere 1 (Group 1)	Ikizdere 1 (Group 2)	Pasinler	Sarikamis 1	Sarikamis 2 (Group 1)	Sarikamis 2 (Group 2)	Kars Akbaba 2	Kars city	Uncat. Kars/Sar. area	Chikiani	Mets Arteni	Pokr Arteni 1	Pokr Arteni 2	Tsaghkunyats Damlik	Tsaghkunyats Ttvakar	Tsaghkunyats (Arqayasarr)	Hatis 1	Gutansar	Spitakasar	Geghasar	Syunik 1 or Geghasar	Syunik 2 (Mets Qarakhach)	Syunik 2 (Unspecified)	MOL Unknown 1	Uncategorised
Group A	244	10																				10					
Group A'	2	1																			1						
Group B	200	30						11	19																		
Group C	101	10				10																					
Group D	8	8																8									
Group E	68	10															10										
Group F	5	5		5																							
Group G	17	14																						12	2		
Group H	21	17											17														
Group I	11	10												1	9												
Group I'	3	2													2												
Group J	29	28					28																				
Group K	53	10														10											
Group L	35	10																		10							
Group M	11	10																	10								
Group N	62	10										10															
Group O	17	15								15																	
Group P	4	3			3																						
Group Q	4	4																								4	
uncategorised	6	6	2								1												1				2
Total	901	213	2	5	3	10	28	11	19	15	1	10	17	1	11	10	10	8	10	10	1	10	1	12	2	4	2

Table S3. Stratigraphic changes in the use of obsidian from different sources at Göytepe.

Levels	NE Anatolia	C Armenia	E Armenia	Georgia	Others	Total
Level 5 (n=62)	4	50	3	3	2	62
Level 6 (n=82)	17	52	7	5	1	82
Level 7 (n=164)	20	132	4	8		164
Level 8 (n=11)	5	5		1		11
Level 9 (n=46)	25	17		3	1	46
Level 10 (n=332)	191	117	3	20	1	332
Level 11 (n=54)	26	23		5		54
Level 12 (n=52)	22	22		7	1	52
Level 13 (n=68)	35	25		8		68
Level 14 (n=23)	13	9		1		23
Surface (n=7)	1	4	1	1		7
Total	359	456	18	62	6	901

Table S4. Stratigraphic changes in the use of obsidian at Göytepe. Frequencies of the technological categories of obsidian by different sources and phases at Göytepe.

	Cores	Tools	CME	Blades	Flakes	Debris	total
Levels 8-14 NE Anatolia (n=317)	5	183	12	37	56	24	317
Levels 8-14 C Armenia (n=218)	6	129	8	17	43	15	218
Levels 5-7 NE Anatolia (n=41)	1	26	1	3	7	3	41
Levels 5-7 C Armenia (n=234)	6	159	7	19	36	7	234
Total	18	497	28	76	142	49	810

Table S5. Elemental compositions (in ppm) of 213 obsidian artefacts from Göytepe as determined by pXRF.

Sample		Al	Si	K	Ca	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Pb
GTOB-0283	Ikizdere 1 (Group 1)	73851	365880	60697	6431	809	301	6188	37.7	115.1	123.1	18.1	138.6	16.9	934	20.6
GTOB-1173		76714	386000	43899	5978	877	387	6480	40.6	113.1	128.3	19.5	141.3	15.0	1105	20.9
GTOB-0015	Ikizdere 1 (Group 2)	77941	363691	64972	6625	1024	292	7393	41.5	109.1	148.6	18.0	158.1	15.6	970	18.5
GTOB-0137		76104	375134	44795	6855	1041	342	7672	36.0	105.7	158.7	18.3	167.9	15.5	1159	14.4
GTOB-0388		73832	369255	42167	6533	955	368	7061	34.2	110.4	144.6	17.6	153.0	16.1	1111	20.4
GTOB-0492		78292	391243	44951	6903	1002	236	7532	33.4	113.9	155.5	16.9	163.6	16.2	779	13.0
GTOB-1161		80779	398974	42239	6915	1021	461	7701	44.8	106.9	161.0	18.9	166.7	16.2	1503	25.1
GTOB-0049	Pasinler	74828	394245	45217	3028	569	206	7219	33.7	184.9	3.3	36.3	186.2	25.7	-181	29.0
GTOB-0461		79311	408010	49396	3276	726	206	8304	36.2	183.3	3.5	37.3	233.1	25.6	-181	29.3
GTOB-0468		75131	397075	45858	2982	558	206	7222	39.0	186.3	3.5	35.7	184.4	24.7	-136	29.1
GTOB-0217	Sarikamis 1	70245	364893	40691	3641	569	311	5235	32.5	125.7	25.3	24.7	113.7	13.0	649	28.2
GTOB-0286		73178	386183	51393	3823	696	199	5394	25.8	130.8	24.2	24.0	118.2	14.6	186	22.8
GTOB-0428		73539	387429	50642	3978	579	199	5503	22.7	131.0	25.0	24.7	117.8	12.6	280	23.5
GTOB-0460		75777	400808	44118	3785	587	199	5432	26.0	136.0	24.5	24.8	117.5	13.3	260	24.6
GTOB-0573		75784	399476	42805	3825	566	233	5274	29.1	131.8	24.2	23.9	115.6	12.9	356	26.7
GTOB-0598		96750	518889	66649	5479	842	236	8476	39.3	173.0	33.4	30.4	142.9	20.3	62	31.8
GTOB-0606		74694	394558	44201	3934	653	279	5504	28.9	132.7	25.5	24.3	119.0	13.0	463	24.9
GTOB-1047		75971	402491	43448	3801	591	199	5186	28.3	130.2	24.0	24.6	117.2	13.2	280	24.2
GTOB-1137		88171	475036	56456	4763	757	199	7071	31.7	161.1	30.7	27.5	136.0	17.4	62	30.7
GTOB-1141		87359	455079	54914	4929	672	231	6289	26.6	146.9	28.3	26.3	129.3	16.6	171	25.0
GTOB-0003	Sarikamis 2 (Group 1)	76137	401567	44653	3111	546	471	4972	48.9	169.4	7.4	45.0	151.2	29.9	-180	33.7
GTOB-0033		71121	370339	41315	3041	515	522	4733	54.9	163.7	8.6	41.7	149.4	29.2	-149	29.0
GTOB-0104		73618	379549	52692	3068	485	619	4429	62.7	156.3	7.3	42.6	144.7	28.5	32	35.0
GTOB-0117		74130	385699	42043	2995	531	544	5572	58.6	165.8	8.0	43.4	164.2	29.4	-48	32.1
GTOB-0167		77031	406865	45460	3112	558	471	5220	51.2	176.5	7.3	44.9	156.6	31.3	-180	33.3
GTOB-0294		91818	490738	59432	3718	700	667	6892	76.1	213.6	11.7	56.0	180.4	37.7	-181	42.1
GTOB-0306		76726	402081	41544	2900	512	491	4596	55.3	166.8	8.0	42.6	150.8	29.4	-180	30.2
GTOB-0324		74155	389463	41500	2886	524	611	4662	60.0	159.3	8.2	43.4	156.7	28.2	42	34.0
GTOB-0354		75442	395857	42901	3154	547	511	4886	53.4	164.3	7.6	43.0	149.6	30.0	-102	28.8
GTOB-0391		74877	395713	43676	3067	508	536	5033	52.3	174.4	7.8	43.2	157.5	31.5	-180	30.7
GTOB-0423		76151	397545	42563	2984	492	544	4775	51.6	163.2	6.8	42.9	150.5	30.3	-137	30.2

Sample		Al	Si	K	Ca	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Pb
GTOB-0472		79301	416633	44470	3009	525	512	4789	56.8	169.4	7.7	44.1	167.9	30.7	-180	33.0
GTOB-0488		73651	386613	40867	2853	515	618	4679	59.0	160.3	8.3	43.9	154.5	29.0	-55	31.5
GTOB-0508		73629	387893	40991	2825	504	510	4565	54.7	159.8	7.9	41.5	152.8	29.8	-137	28.0
GTOB-0520		73928	381622	67793	4407	485	462	4505	52.7	166.2	8.6	43.0	148.5	29.6	-180	29.1
GTOB-0522		75124	396664	44973	3023	512	468	4880	55.6	165.5	7.2	45.0	161.0	30.8	-180	28.4
GTOB-0548		77636	412308	44672	3044	520	529	4914	55.9	172.0	7.2	44.8	153.0	31.9	-180	28.8
GTOB-0566		72276	370478	37550	2700	477	523	4120	55.2	152.2	7.4	40.2	142.0	26.9	-16	27.4
GTOB-0583		84274	452241	64622	3704	621	543	5790	65.1	196.3	9.2	46.4	176.4	36.4	-180	33.5
GTOB-0601		76098	400197	45173	3003	508	485	4652	59.2	166.6	6.6	42.5	153.7	29.7	-145	30.6
GTOB-0610		76915	404872	42840	2990	509	512	4730	53.8	163.2	7.3	43.8	151.9	30.8	-148	28.8
GTOB-0690		75951	395736	40850	2908	486	579	4601	57.5	162.6	8.0	42.8	148.6	28.9	-106	33.7
GTOB-0701		71837	373234	39458	2823	497	585	4306	57.5	153.6	7.4	41.8	145.1	27.3	38	27.8
GTOB-1061		80991	422409	45163	3104	530	578	5038	62.2	174.5	9.1	43.7	157.1	30.0	-71	33.4
GTOB-1063		78234	408880	42161	3087	511	576	4686	58.5	163.3	7.7	43.7	157.0	29.1	-54	28.9
GTOB-1082		74595	389498	41803	2855	477	576	4664	58.7	160.7	8.3	42.8	150.9	29.2	-40	33.3
GTOB-1101		73834	384179	52537	2925	502	505	4505	53.5	158.2	7.5	43.1	149.0	29.1	-145	26.5
GTOB-1167		76865	403138	44180	2926	524	519	4833	57.1	163.9	8.2	46.0	181.1	29.8	-130	30.3
GTOB-0265	Sarikamis 2 (Group 2)	75910	400119	46042	2786	498	447	7228	64.1	156.0	2.2	45.4	214.0	28.1	-180	27.0
GTOB-0363		75225	393163	56359	2874	492	455	6960	58.6	152.0	2.2	42.8	217.8	27.2	-180	27.2
GTOB-0530		74400	391689	42056	2568	431	520	6309	60.1	143.2	2.2	42.3	197.7	26.0	-98	28.3
GTOB-0535		73056	385620	41913	2644	434	498	6477	61.7	145.6	2.2	42.4	187.4	25.0	-180	29.3
GTOB-0588		74658	395299	42984	2683	459	479	6644	61.7	149.6	2.2	42.6	196.7	26.3	-180	26.5
GTOB-0637		75447	390646	68319	2857	427	382	6105	57.8	148.4	2.2	43.0	190.6	26.9	-180	28.2
GTOB-0684		72170	381375	41865	2678	440	562	6490	64.3	145.3	2.2	41.5	189.2	24.7	-136	31.4
GTOB-0691		85021	457826	52892	3239	634	531	8570	75.6	177.9	2.2	50.5	234.0	32.8	-180	33.5
GTOB-1036		77373	404653	46844	2749	429	506	6464	63.9	149.5	2.2	42.3	201.8	25.7	-180	30.3
GTOB-1098		77439	412704	44193	2844	447	437	6678	60.6	150.9	2.2	44.0	195.8	26.3	-180	27.0
GTOB-1168		80629	427700	46317	2703	482	416	7308	58.1	157.7	2.2	47.7	225.7	29.0	-180	28.5
GTOB-0146	Kars Akbaba 2	72053	373838	41204	2448	522	519	7215	60.4	140.1	2.2	43.9	243.1	25.6	-180	29.5
GTOB-0155		73119	381572	41221	2548	484	558	7220	62.9	141.9	2.2	44.4	242.1	25.8	-180	32.6
GTOB-0238		80599	407458	44018	3010	628	600	6782	64.8	140.7	9.7	42.9	223.5	27.2	-16	33.5
GTOB-0307		78409	407195	43246	2432	530	562	7458	68.2	140.1	2.2	44.0	280.3	26.4	-103	30.0
GTOB-0372		79632	413842	48578	3798	612	423	6598	56.7	138.2	5.4	43.4	233.7	26.4	-181	26.2

Sample		Al	Si	K	Ca	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Pb
GTOB-0543		78709	412394	49556	3342	699	492	7870	68.2	160.0	9.0	46.1	242.2	29.7	-180	30.5
GTOB-0551		75270	392910	48275	2564	501	506	7280	64.1	142.8	2.2	44.1	233.2	26.8	-180	30.1
GTOB-0567		84346	429888	47719	3115	656	640	7376	60.2	149.1	9.4	45.6	248.5	26.9	-56	31.9
GTOB-0609		74195	388538	43355	2557	522	504	7411	65.0	140.6	2.2	44.9	249.3	26.3	-180	27.8
GTOB-0612		70771	360808	38522	2708	544	469	5896	65.2	126.7	7.1	39.5	209.6	24.8	-35	23.8
GTOB-0698		73807	382194	43163	2751	552	536	7096	63.1	140.0	3.2	43.3	234.5	26.4	-43	35.1
GTOB-1012		78769	406101	60447	3288	665	504	7300	65.7	146.8	7.7	42.8	230.6	27.6	-147	24.2
GTOB-1015		77561	395574	43285	2971	606	630	6847	66.2	140.4	9.2	42.8	227.2	27.3	46	30.2
GTOB-1054		77377	403261	43765	2589	501	494	7554	64.7	145.4	2.2	43.4	251.2	27.0	-180	30.3
GTOB-1059		78236	407743	44549	3015	642	468	6972	58.8	143.9	8.9	42.5	227.0	26.6	-180	25.9
GTOB-1089		77458	399493	50646	3401	630	541	7165	69.6	145.2	9.1	42.5	233.6	26.6	-47	30.6
GTOB-1097		74706	394997	42596	2592	505	414	6819	57.6	143.2	2.2	43.0	233.0	27.0	-180	21.4
GTOB-1132		74342	384350	42130	2802	504	572	7689	68.7	145.7	2.2	45.4	246.2	26.0	-51	30.8
GTOB-1169		75233	387906	42507	2905	619	507	6888	58.3	140.6	7.9	43.4	224.8	26.1	-180	26.8
GTOB-0001	Kars city	75796	370246	42438	4472	590	415	9006	55.1	134.6	25.3	38.3	198.5	20.2	176	22.9
GTOB-0064		79626	381558	42439	4866	673	518	10047	60.7	130.9	38.0	39.6	252.3	20.1	210	24.0
GTOB-0077		80500	384475	59898	5500	642	490	10158	57.5	138.5	35.4	40.2	226.9	21.9	123	24.8
GTOB-0236		79130	387758	42348	4438	570	474	8958	59.0	136.3	27.8	39.3	208.9	19.3	253	26.3
GTOB-0240		92400	456298	53615	5460	681	537	12132	73.1	171.2	34.1	45.7	246.4	25.2	-5	37.7
GTOB-0301		75379	357694	41906	4716	646	568	9599	62.4	125.0	39.7	38.5	216.9	18.9	419	29.5
GTOB-0491		75855	366572	44906	5030	682	562	10694	68.4	137.1	41.8	39.9	236.9	21.7	159	27.5
GTOB-0515		80007	394683	44262	4563	604	445	9360	59.2	138.8	27.4	40.6	212.6	20.1	135	28.0
GTOB-0714		79084	380558	43116	4757	614	546	9879	65.1	134.4	35.0	39.3	237.2	20.6	368	29.2
GTOB-1009		78094	366721	40023	4597	626	636	9734	70.0	130.7	40.4	38.5	236.9	20.5	535	29.0
GTOB-1030		79131	390083	46574	4634	595	483	9829	62.0	143.3	25.8	41.5	236.3	20.5	173	27.8
GTOB-1035		80904	386772	42468	4790	644	619	9873	64.7	128.3	38.9	38.7	238.2	19.7	378	24.3
GTOB-1040		81673	391678	43118	4876	689	555	9884	63.9	128.3	38.9	39.0	228.3	20.5	284	24.7
GTOB-1136		81679	387243	43315	5190	726	604	10263	67.4	132.8	40.5	38.8	223.6	19.7	470	28.7
GTOB-1157		79029	378883	42780	4858	700	658	9919	66.6	127.5	38.0	38.7	223.7	20.8	628	28.2
GTOB-0078	Uncat. Kars/Sari. area	76604	402242	47702	4291	922	199	7573	21.1	150.0	23.5	27.3	176.5	17.5	29	24.7
GTOB-0020	Chikiani	71930	365299	42065	4882	624	281	4704	36.1	126.7	78.1	17.5	97.4	19.4	481	19.0
GTOB-0081		78007	395255	44548	5219	642	393	5056	36.1	129.8	84.0	18.9	101.5	18.9	510	21.7
GTOB-0359		85345	437107	58281	6277	776	283	6161	38.7	146.8	98.4	18.6	114.2	22.3	178	22.9

Sample		Al	Si	K	Ca	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Pb
GTOB-0408		75684	384420	50853	5347	667	235	5116	31.2	130.6	90.0	17.5	104.9	18.9	418	20.5
GTOB-0600		75982	384891	42474	4857	617	454	4700	45.2	129.0	80.7	18.9	97.3	18.4	744	22.3
GTOB-0643		78566	398584	45069	5165	656	407	5111	43.2	131.2	88.3	16.7	105.3	17.4	629	22.2
GTOB-0655		77120	387767	53014	5189	611	433	4828	39.4	126.4	82.7	18.5	98.8	18.5	701	23.6
GTOB-1074		77673	397127	44067	5097	645	380	5050	43.0	122.5	87.3	18.2	105.2	18.5	641	21.3
GTOB-1114		78094	394765	44830	5116	657	389	4947	39.8	126.0	86.9	18.4	104.2	17.9	586	19.9
GTOB-1118		75342	381391	42373	5129	624	311	4661	34.6	121.3	82.5	17.4	98.0	16.6	619	18.0
GTOB-0136	Tsaghkunyats Damlik	73992	372019	40767	5735	606	403	4978	31.5	108.7	147.3	17.6	100.2	17.9	638	25.3
GTOB-0139		75877	381472	41696	6148	664	327	5181	19.7	114.4	150.4	16.2	106.9	19.7	391	21.9
GTOB-0427		79659	403734	43589	6570	636	287	5189	20.2	115.9	158.4	16.4	111.8	19.9	324	21.9
GTOB-0481		75859	383660	47586	6014	676	277	5083	28.3	113.0	150.4	16.1	100.8	19.0	396	26.4
GTOB-0632		81381	417724	46288	6663	668	242	5494	26.5	118.7	162.3	17.4	105.3	21.0	150	22.8
GTOB-0699		79241	396185	41840	6176	609	385	5053	32.8	111.6	151.0	16.0	103.3	19.7	677	26.1
GTOB-1069		79248	396954	45283	6074	594	317	5062	29.1	114.0	155.5	16.2	113.4	19.0	468	24.5
GTOB-1085		77698	394557	42147	6213	631	316	5218	29.0	112.7	155.6	16.6	105.8	19.5	472	25.2
GTOB-1122		76713	385999	42412	6322	632	376	5144	33.1	114.1	154.3	16.1	108.2	19.0	539	23.0
GTOB-1146		77554	393755	41579	6263	653	245	5136	29.5	114.0	150.1	16.3	104.2	19.6	404	20.9
GTOB-0006	Tsaghkunyats Ttvakar	84683	425332	43207	5730	665	390	5885	22.9	100.8	185.8	14.4	117.6	22.6	453	32.2
GTOB-0430		76167	381910	44147	5543	649	474	5498	30.0	95.0	178.2	16.4	113.3	19.8	718	30.9
GTOB-0536		83076	423031	46312	6050	681	239	6400	17.0	108.3	199.5	14.6	118.8	24.0	228	26.8
GTOB-0578		81002	393135	54338	5870	642	413	5795	30.5	95.7	177.9	15.7	118.4	20.0	712	30.9
GTOB-0616		78824	395522	41905	5642	625	340	5644	19.1	95.1	176.5	16.1	109.4	20.8	516	29.1
GTOB-0662		74132	363762	55895	6503	610	424	5374	31.4	94.1	179.2	15.5	108.8	20.0	828	28.8
GTOB-0703		81840	414402	46166	6033	727	288	6369	25.1	104.2	190.7	15.6	121.3	25.1	231	29.6
GTOB-1024		77722	391295	41771	5570	644	474	5644	31.2	93.6	176.1	15.0	110.1	20.1	800	33.3
GTOB-1126		74886	375517	61282	5861	636	238	5620	25.7	97.7	182.4	14.8	107.9	21.9	325	25.4
GTOB-1150		75401	379006	40051	5342	707	342	5525	28.2	91.6	169.1	15.0	103.5	19.0	557	23.3
GTOB-0105	Tsaghkunyats (Arqayasar	76619	378245	41388	6071	796	409	6721	32.4	92.4	233.1	16.5	155.7	18.3	1052	26.9
GTOB-0175	/Kamakar)	88339	424046	59218	6853	835	393	8070	34.3	105.7	266.4	15.4	173.9	20.5	660	28.8
GTOB-0198		77643	381289	46777	6473	843	282	6953	26.0	92.0	236.9	14.6	155.3	18.1	716	26.9
GTOB-0241		108246	527797	65352	9755	1271	424	11178	41.4	125.5	323.7	19.2	186.9	26.0	278	37.6
GTOB-0431		76977	379165	41287	6632	818	412	6823	35.5	91.3	235.6	14.5	152.8	17.8	950	26.6
GTOB-0471		80577	402284	49267	7043	900	291	7483	25.7	98.9	251.6	16.4	161.8	18.9	547	23.8

Sample		Al	Si	K	Ca	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Pb
GTOB-1033		77667	385084	43634	6664	777	247	7079	31.3	93.1	241.5	14.5	156.2	18.4	768	28.3
GTOB-1170		82134	394133	70759	9159	775	270	6939	29.9	96.9	251.8	14.8	163.9	19.4	558	28.9
GTOB-0083	Mets Arteni	72273	370805	40686	3872	395	624	3046	42.7	152.6	11.0	31.4	68.9	35.7	-27	25.9
GTOB-0091		75494	388841	40686	3817	386	577	2890	41.5	151.2	10.6	31.3	72.2	35.3	-180	19.4
GTOB-0119		65835	332688	36501	3904	366	613	2728	43.4	142.4	12.5	30.0	64.8	34.7	-22	24.5
GTOB-0193		75700	387518	42607	3869	371	595	2901	40.7	150.5	10.0	31.0	72.5	34.8	-180	21.3
GTOB-0453		72037	371717	39225	3692	374	643	2772	40.5	142.3	13.6	30.3	64.7	35.2	-11	23.1
GTOB-0511		77668	403245	42191	3896	395	574	2961	39.1	156.6	10.0	31.4	80.0	37.7	-180	18.1
GTOB-0565		81886	430122	61770	4456	425	609	3407	46.5	168.2	13.7	32.4	71.1	39.4	-180	16.0
GTOB-0569		72442	372273	41317	3824	382	639	2875	45.7	148.1	10.3	33.0	76.6	35.3	-47	22.6
GTOB-0629		72762	376315	41671	3985	380	579	2982	42.0	154.9	10.4	32.5	69.7	35.4	-180	22.0
GTOB-1010		75805	391958	47507	3932	375	565	2891	39.6	152.4	10.7	32.6	70.2	36.9	-180	19.7
GTOB-1011		76444	391583	45156	3693	368	592	2815	38.7	143.9	9.7	31.9	67.9	34.7	-180	21.0
GTOB-1016		78688	407104	43034	4074	363	543	2975	36.7	153.6	10.4	31.5	72.3	37.9	-180	19.6
GTOB-1031		75974	397977	43527	4289	426	505	3024	35.9	153.2	11.8	32.6	74.2	37.3	-180	15.5
GTOB-1044		76364	389552	50174	4482	409	563	2909	40.3	151.4	10.9	31.5	68.6	35.9	-180	19.9
GTOB-1055		77863	400453	41992	3956	378	586	2822	43.2	147.2	10.3	31.2	70.7	35.6	-180	22.6
GTOB-1072		76122	393033	41051	3935	384	709	2868	40.4	153.8	11.7	31.4	70.1	35.1	38	21.1
GTOB-1110		78247	402396	48266	4023	384	514	2863	37.6	155.9	10.2	31.6	74.3	36.7	-180	20.4
GTOB-0268	Pokr Arteni 2	80404	425438	48186	4170	549	450	3725	36.3	149.0	21.1	33.8	90.2	33.2	-181	20.7
GTOB-0244		71061	370639	43092	4142	604	400	4029	29.2	120.6	37.7	24.1	94.0	24.2	124	18.5
GTOB-0290		78495	411627	46430	4185	588	416	3864	30.4	133.9	28.5	26.1	92.6	28.6	-37	17.8
GTOB-0297		79265	409618	42450	4191	613	469	4099	37.0	113.9	46.2	23.6	99.9	24.8	429	23.0
GTOB-0302		75790	396465	43591	4028	569	524	3862	38.9	123.9	34.2	24.3	90.8	25.5	265	22.0
GTOB-0325		75035	388489	43147	4124	559	433	3714	34.9	125.4	30.4	25.5	86.4	24.9	136	18.3
GTOB-0382		72682	382026	42869	3924	549	374	3631	27.4	125.2	32.0	24.4	87.6	25.5	109	19.0
GTOB-0449		72996	378944	41909	3930	513	461	3396	33.6	123.9	27.5	25.1	86.4	25.1	154	21.0
GTOB-0641		74106	388616	43105	3993	532	463	3630	40.7	121.5	33.6	24.4	86.4	25.6	265	22.4
GTOB-0674		73981	387928	43699	4008	530	362	3686	32.2	123.5	31.2	24.2	88.0	25.7	41	17.6
GTOB-0678		75668	391322	44066	4230	575	533	3901	37.4	120.1	34.6	24.6	90.6	25.4	378	22.8
GTOB-0729		72403	380223	48203	4536	596	350	3988	28.4	128.5	36.7	24.4	92.9	26.5	34	17.4
GTOB-0253	Gutansar	77708	380003	39325	6980	1056	468	7776	42.2	143.1	121.9	24.9	179.1	33.0	153	19.7
GTOB-0303		75763	372229	38728	6766	1035	605	7545	42.4	139.2	121.0	25.4	172.2	31.6	391	20.1

Sample		Al	Si	K	Ca	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Pb
GTOB-0373		72336	357437	42951	6878	1067	481	7927	32.5	144.7	125.8	24.6	174.1	32.9	193	19.3
GTOB-0448		74801	360796	43332	6667	1027	548	7419	41.6	134.6	126.2	24.4	177.9	30.9	425	23.2
GTOB-0495		79745	400254	42827	7492	1143	475	8437	38.8	149.8	130.9	26.3	184.8	34.2	30	18.0
GTOB-0586		78319	380559	43096	6737	973	569	7121	41.4	140.3	117.6	23.6	172.4	32.8	418	21.0
GTOB-0608		81548	401176	39748	7079	1067	547	7905	36.5	143.7	123.8	24.8	180.5	33.0	246	19.7
GTOB-1042		79205	391879	42238	7074	1050	449	8214	38.4	152.0	128.3	22.9	179.2	34.8	63	12.6
GTOB-1046		79954	392668	40903	7335	1079	516	7845	40.8	145.1	129.3	23.7	184.5	34.2	186	20.1
GTOB-1123		79287	384190	39095	6827	1020	606	7632	46.8	141.0	122.5	24.0	178.4	33.5	446	19.7
GTOB-0243	Hatis 1	85714	418344	45633	7761	738	418	7039	34.2	112.8	131.2	20.0	109.5	21.3	304	19.3
GTOB-0318		76520	375307	36405	6888	631	513	5845	34.1	105.1	112.2	20.3	100.7	19.9	697	22.7
GTOB-0327		75060	373150	38397	7097	647	351	6156	29.7	111.5	117.9	18.6	97.2	21.2	248	20.6
GTOB-0435		74543	369842	37387	6779	558	343	5247	32.9	107.9	103.1	19.0	94.2	20.7	423	21.8
GTOB-0437		77216	383303	41316	6953	623	376	5751	28.6	114.4	108.4	23.8	99.8	20.2	263	20.5
GTOB-0480		77230	380401	54590	6510	619	376	5519	33.0	111.7	106.6	19.3	96.1	20.6	419	22.6
GTOB-0563		77892	387436	41096	7800	713	379	6708	28.0	113.3	125.2	19.4	103.7	21.7	206	17.0
GTOB-0590		75658	362363	65192	7769	643	421	5957	36.9	109.4	117.1	19.7	100.8	20.4	410	19.1
GTOB-0672		77871	388291	40358	7053	610	383	5740	22.9	112.5	107.0	19.7	97.7	20.4	286	19.1
GTOB-0680		79251	393852	40455	7015	647	378	5933	28.8	116.3	111.5	18.9	98.7	22.0	251	21.8
GTOB-0256	Geghasar	73524	381643	41516	4228	417	465	3014	27.3	202.8	9.5	23.4	74.6	43.5	-180	31.2
GTOB-0338		73345	368326	61772	5662	424	584	2968	26.8	195.2	10.3	23.7	74.0	42.5	-20	32.9
GTOB-0439		77037	402524	42494	4325	420	533	3088	29.5	207.4	9.9	23.5	76.9	41.8	-180	29.4
GTOB-0499		79280	414020	67249	5301	465	456	3373	28.7	232.2	9.8	25.8	83.2	48.3	-180	29.4
GTOB-0581		79320	413815	44270	4533	454	461	3095	17.2	216.4	9.9	23.3	76.7	45.1	-180	26.9
GTOB-0611		74047	387019	42532	4357	415	424	2949	18.1	202.6	8.9	23.9	72.5	43.2	-180	28.3
GTOB-1017		74724	387403	43679	4165	413	563	2981	33.2	200.2	10.0	22.6	74.8	43.1	-127	29.8
GTOB-1070		73452	379555	54185	4507	408	404	3012	17.3	203.0	9.6	23.5	75.0	44.1	-180	23.8
GTOB-1121		76127	396636	41268	4258	433	481	2991	27.2	197.9	9.9	22.6	75.2	41.8	-180	28.5
GTOB-1171		77005	401030	42309	4381	421	543	3076	29.7	208.3	10.3	24.0	75.7	44.8	-180	27.7
GTOB-0381	Spitakasar	75057	380516	40919	4080	376	715	2873	32.8	179.9	8.4	21.9	57.1	43.4	-115	33.7
GTOB-1004	Syunik 1/Geghasar	75820	403141	42376	3387	496	430	3700	30.5	212.9	6.9	21.5	96.2	33.9	-181	33.5
GTOB-0221	Syunik 2 (Mets Qarakhach)	75249	405400	47169	4017	641	199	4653	26.3	185.0	17.1	14.4	109.4	32.7	-180	29.4
GTOB-0222		74290	394359	43829	3753	593	236	4238	25.7	178.7	16.9	14.4	104.7	32.1	-180	25.5
GTOB-0273		74691	396965	40947	3655	494	352	4083	28.3	143.5	14.0	26.2	79.8	18.4	-12	19.0

Sample		Al	Si	K	Ca	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Pb
GTOB-0342		75069	401637	40377	3441	502	333	4164	21.6	142.5	14.9	26.3	80.3	18.7	-34	14.6
GTOB-0343		73455	387453	42691	3652	567	428	4056	31.2	178.7	13.4	13.5	103.6	30.5	-91	32.9
GTOB-0353		75220	398726	40259	3395	480	409	3975	26.2	140.7	13.9	24.5	79.7	18.3	52	17.6
GTOB-0412		73484	388702	44591	3760	591	293	4263	27.2	179.1	16.1	11.7	112.1	31.7	-180	31.7
GTOB-0441		75069	400222	41276	3374	488	359	4069	29.8	144.2	14.5	25.3	81.5	18.4	5	15.6
GTOB-0666		81280	442639	52770	4300	699	234	5324	29.6	179.2	14.6	16.5	120.9	34.5	-180	28.0
GTOB-0697		76707	405143	43870	3819	592	350	4214	29.9	174.3	16.1	14.8	104.8	30.3	-180	30.7
GTOB-0710		74781	396377	44482	3736	558	332	4137	30.5	175.0	14.2	14.5	97.3	30.4	-145	30.0
GTOB-0718		76047	400849	44532	3784	579	325	4166	29.3	178.0	16.2	14.4	105.8	30.5	-117	24.1
GTOB-0399	Syunik 2 (unspecified)	72963	387215	43713	3522	552	341	4409	28.7	154.9	13.6	15.1	127.4	29.9	-180	22.9
GTOB-0669		71806	378492	42349	3607	565	440	4191	33.6	147.3	12.4	14.3	107.8	28.2	-4	29.5
GTOB-0063	MOL Unknown 1	75368	390263	40336	5081	818	276	6426	31.0	123.2	46.8	20.1	133.7	15.9	473	20.0
GTOB-0367		74524	375528	56452	5816	877	199	6753	28.7	121.8	52.0	19.3	137.8	16.2	386	16.4
GTOB-0411		75849	394436	40528	4984	818	362	6403	30.5	125.5	49.2	19.2	135.0	14.9	624	21.5
GTOB-1076		74739	387773	38610	4882	787	247	6034	32.8	121.7	47.7	20.1	131.4	16.6	445	15.4
GTOB-0438	Uncategorised	79203	404746	41693	5972	946	250	6404	30.4	128.3	75.0	26.1	148.6	17.3	285	17.4
GTOB-0726	Uncategorised	75520	391057	62100	3684	491	206	4320	29.5	137.4	21.0	27.3	92.4	13.2	240	24.5