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The source of obsidian artefacts found at East Chia Sabz, Western Iran

Hojjat Darabi [a], Michael D. Glascock [b,*]

[a] Department of Archaeology, Razi University, Kermanshah, Iran
[b] Research Reactor Center, University of Missouri, 1513 Research Park Drive, Columbia, MO 65211, USA

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ABSTRACT

Excavations at the site of East Chia Sabz in western Iran uncovered deposits dating from the 9th through 7th millennium BC showing evidence of obsidian use. A total of twenty obsidian artefacts was found at the site and they were analyzed by X-ray fluorescence and neutron activation analysis. The results show all of the obsidian found at East Chia Sabz came from the Nemrut Dağ source in southeastern Turkey located a distance of almost 750 km from East Chia Sabz. The results and their archaeological implications are discussed.

1. Introduction

The site of East Chia Sabz is a settlement in western Iran containing deposits from the Transitional Neolithic period (ca. 9500–8000 BC). The site was discovered during an archaeological survey inside the reservoir of Seimareh dam in 2007 (Brojeni, 2007) and excavated by an Iranian team under the leadership of H. Darabi in 2009. Evidence shows that East Chia Sabz was occupied from the early 9th–early 7th millennium BC (Darabi et al., 2011). The first season of salvage excavation resulted in identification of seven phases indicating cultural changes through time, mostly attested by lithic industry. Table 1 lists the proportions of chipped stone recovered from the stratigraphic levels of trench #2 (the only trench with complete information) for all seven phases. As the result of analysis of lithic artefacts, a change from flake to blade-bladelet production was observed. The change is accompanied by a transition from use of local chert to flint and then to small amount of obsidian. The latter, thus, was only used in the late (I–III) phases. Twenty obsidian samples from all excavated trenches at East Chia Sabz were submitted to the Archaeometry Lab at the University of Missouri Research Reactor (MURR) for chemical analyses. Analysis of the artefacts by X-ray fluorescence (XRF) indicated that all were chemically similar. However, because the two possible sources – Bingöl A and Nemrut Dağ – have similar chemical fingerprints that are difficult to separate by XRF [although see Orange et al., in press], it was necessary to further analyze the samples by neutron activation analysis (NAA) which gives a more definite result. This article presents the chemical results and discusses them archaeologically.

2. Background

Since the early 1960s, considerable research has been devoted to locating Anatolian obsidian sources and determining chemical fingerprints for them (Rapp and Hill, 1998: 137). Early research was undertaken by Renfrew (1969) who attributed the Anatolian sources for obsidian tools found at Ali Kosh to southeastern Turkey. Subsequently, other researchers using a variety of chemical analytical methods have identified more than 30 possible obsidian sources in Armenia, Azerbaijan, Georgia, and eastern Turkey (Blackman, 1984; Chataigner et al., 1998; Gratuze et al., 1993; Keller et al., 1996; Poupeau et al., 2010). For most of the obsidian sources in this region, the chemical differences between sources are so obvious that artefacts can be easily assigned to their proper sources.

On the other hand, two varieties of obsidian have been identified at Bingöl known as Bingöl A (peralkaline) and Bingöl B (calcalkaline), and at least six different types of peralkaline obsidian have been discovered at Nemrut Dağ. The peralkaline obsidians from Bingöl A and Nemrut Dağ are a distinctive green color and are unlike the obsidian from any other sources in the region. Although

* Corresponding author. Tel.: +1 573 882 5270.
E-mail address: glascockm@missouri.edu (M.D. Glascock).

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Table 1
The proportions of chipped stone recovered from stratigraphic levels of trench #2 at East Chia Sabz.

Phase	Chert	Flint	Obsidian*	Dolomite	Quartzite	Total
1	22	26	4	1	0	53
2	36	62	7	3	0	108
3	107	153	3	0	1	264
4	15	19	0	0	0	34
5	3	3	0	0	0	6
6	17	12	0	0	0	29
7	21	15	0	0	0	36
Total	221	290	14	4	1	530

Note that the only trench for which the proportions of chipped stone are available for all of the phases is trench #2. The 20 obsidian artefacts analyzed in this study came from all trenches at the excavation, were not limited to those from trench #2.

the two source areas are more than 120 km apart as shown in Fig. 1, differentiating between the peralkaline obsidians from Bingöl and Nemrut Dağ has been challenging. Various schemes for separating the sources have been proposed (Chataigner, 1994; Pernicka, 1992; Poidevin, 1998). But, none of the schemes are completely satisfactory. Recently, Frahm (2012) demonstrated that these sources could be successfully differentiated by Electron Microprobe (EMPA) measurements of Al_2O_3, FeO, TiO_2, and Zr; and Orange et al. (in press) used a combination of XRF and SEM-EDS to identify differences between the sources. A study by Coleman (2010) and continued work by M.D. Glascock have demonstrated that high-precision measurements of the trace elements Br, Cs, and Mn by neutron activation analysis (NAA) can be used to differentiate between the sources with more certainty than the other analytical methods employed, thus far.

3. Analytical procedures

The samples were analyzed initially by energy-dispersive XRF with a Bruker III–V+ portable spectrometer at MURR. The spectrometer is equipped with an air-cooled rhodium anode with 140 micron Be window and a thermoelectrically cooled Si–PIN diode detector. The detector has a resolution of 180 eV for the 5.9 keV peak from iron. Beam dimensions are approximately 2 × 3 mm. The X-ray tube was operated at 40 kV using a tube current of about 17 μA and produced a count rate of about 1200 counts per second. Measurement times were 180 s per sample. Instrument calibration was established using data obtained from a series of well-characterized source samples previously analyzed by NAA, XRF, and ICP-MS at MURR (Glascock and Ferguson, 2012). The best measured elements in obsidian by XRF are Rb, Sr, Y, Zr, and Nb.

Because the results from XRF identified the artefacts as having a composition similar to both Bingöl A and Nemrut Dağ, the artefacts were also analyzed by NAA (Glascock et al., 1998) which offers greater precision and accuracy than XRF. Although NAA measurements can determine up to 30 elements, the most useful elements in this study were found to be Br, Cs, and Mn. Information for the additional elements measured by NAA in the sources and artefacts in this study will be presented in a more detailed article being prepared by M.D. Glascock describing the procedures used on obsidian from the Anatolian sources and the artifacts from multiple sites in western Iran.

4. Results

The compositional data for Fe, Rb, Sr, Y, Zr, and Nb measured in the artefacts by XRF are listed in Table 2. Table 3 presents the means

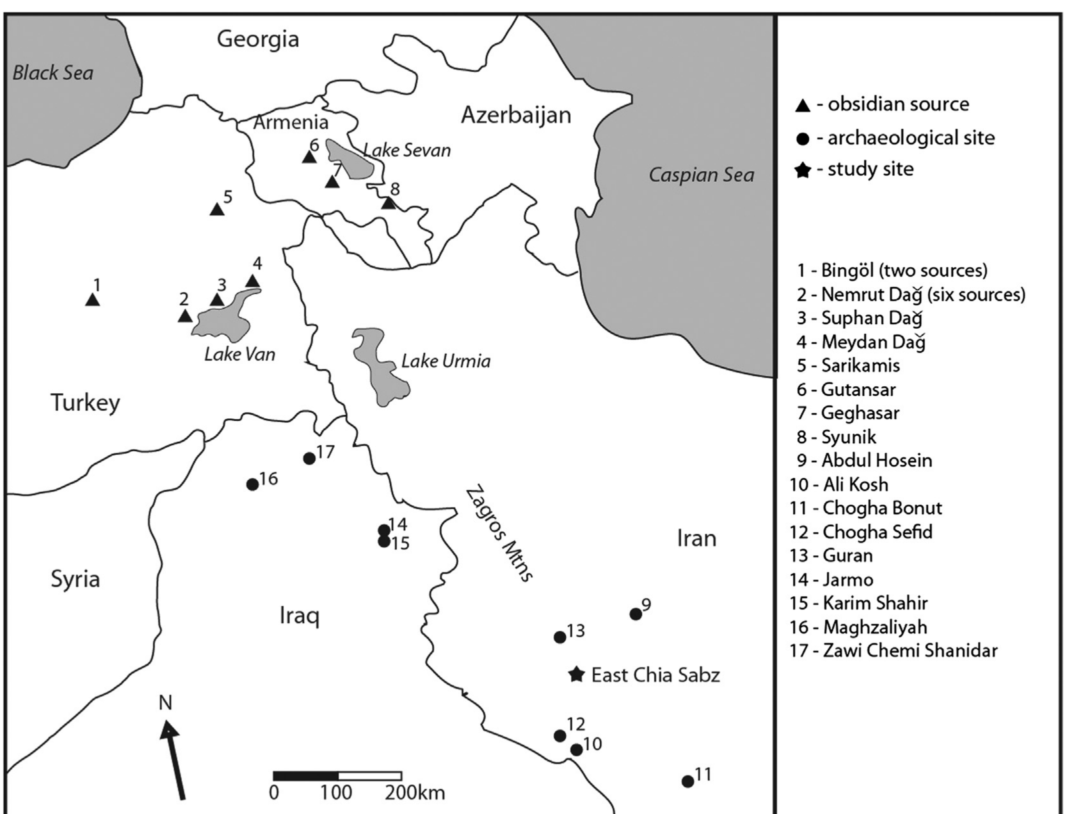

Fig. 1. Map showing locations of major obsidian sources, East Chia Sabz, and other archaeological sites in the Zagros region. Several of the less important obsidian sources are not shown to reduce clutter.

Table 2
Concentrations of elements measured by XRF in obsidian artefacts from East Chia Sabz. Concentrations are given in parts per million unless % is indicated. Elements not detected are indicated by n.d. Fe concentrations are marginally reliable because of the significant differences in thickness compared to the source specimens used to calibrate the XRF spectrometer.

ANID	Fe (%)	Rb	Sr	Y	Zr	Nb
HDI001	2.44	226	4	122	1361	61
HDI002	2.61	237	7	133	1441	63
HDI003	2.41	230	5	127	1409	65
HDI004	2.69	242	1	124	1346	65
HDI005	2.90	234	8	127	1402	64
HDI006	2.48	218	4	114	1337	69
HDI007	2.66	236	2	122	1354	64
HDI008	2.67	233	2	128	1340	61
HDI009	2.61	231	n.d.	144	1428	72
HDI010	2.61	234	4	125	1392	65
HDI011	2.62	224	5	134	1374	60
HDI012	2.52	228	n.d.	135	1488	69
HDI013	2.79	252	2	139	1506	69
HDI014	2.70	252	3	140	1508	70
HDI015	2.60	239	2	125	1365	68
HDI016	2.67	239	1	130	1402	70
HDI017	2.48	232	5	132	1400	70
HDI018	2.51	238	5	139	1520	72
HDI019	3.10	258	6	143	1476	59
HDI020	2.19	226	11	126	1403	72

and standard deviations for samples collected from the Bingöl and Nemrut Dağ subsources. Fig. 2 shows a scatterplot of Rb versus Zr with the artefacts projected against 90% confidence ellipses for the major sources in southeastern Turkey and Armenia. Fig. 2 and the results for elements in common with Frahm (2012) are consistent with the identification of Bingöl A and Nemrut Dağ subsources 2–6 as possible source(s) for the artefacts from East Chia Sabz. However, identification of the precise source from our XRF data is not possible.

The compositional data for Br, Cs, and Mn measured by NAA are listed in Table 4. In addition, the means and standard deviations for the individual subsources at Bingöl and Nemrut Dağ are presented in Table 5. The data for Br and Cs clearly differentiate Bingöl A from all Nemrut Dağ subsources. Fig. 3 shows a scatterplot of Br versus Mn for the data in Tables 4 and 5 comparing the artefacts to source ellipses at the 90% confidence level. The results clearly show that all of the obsidian artefacts from East Chia Sabz came from the Nemrut Dağ-2 subsource. We are confident that our Nemrut Dağ-2 subsource is properly identified as the Nemrut Dağ cluster 2 by Frahm (2012), because the NAA results for Nemrut Dağ-2 include a sample EA25 obtained directly from E. Frahm which has Br = 5.67 ppm, Cs = 7.69 ppm, and Mn = 461 ppm. Thus, the results are in excellent agreement with the attribution of Nemrut Dağ-2 as the source of artifacts found at East Chia Sabz.

5. Discussion

Obsidian is formed in lava flows and as blocks in tuff from explosive volcanic eruptions; it is globally distributed from Alaska to Himalayas (Rapp and Hill, 1998: 137). Throughout the Neolithic of the Old World, however, obsidian was traded and used as a desired raw material to produce stone tools. In the Near East, the most important sources of obsidian are located in Anatolia and the Caucasus which can be grouped into four distinct geographical clusters: central Anatolia, northeast Anatolia, southeastern Anatolia, and the Caucasus (Abdi, 2004: 148). In western Iran, the sources of obsidian lithics were unknown until the 1960s when Renfrew (1969) analyzed the Ali Kosh data attributing them to southeastern Turkey. Renfrew et al. (1968) proposed a model to discuss the nature of obsidian expansion from southeastern Turkey to southwestern Iran, regarding the Central Zagros as an "interaction zone". This idea called the "Down-the Line-Exchange" or "Law of Monotonic Decrement" model was based on the distance between the source and destination (Renfrew and Dixon, 1977: 147–9; Abdi, 2004).

Although the model proposed by Renfrew has been criticized (Wright, 1969: 52), it has indicated a proper way to examine obsidian trade across the Near East. We mention it here to pave the way for our discussion of the possible mechanism for obsidian trade to East Chia Sabz and to emphasize that the information obtained from our archaeological and analytical results is helpful for specifying the nature of the obsidian trade across the eastern wing of the Fertile Crescent.

The Neolithic obsidian artefacts found in western–southwestern Iran are entirely attributed to eastern–southeastern Turkey including the Bingöl and Lake Van areas (i.e. Nemrut Dağ, Meydan Dağ, and Suphan Dağ). As mentioned above, this issue is confirmed through various chemical analyses noted here regarding the East Chia Sabz samples. In addition to East Chia Sabz, obsidian artefacts have been recovered from other sites, including sites from: 1) the Early Neolithic period – Ali Kosh, Chogha Sefid, Chogha Bonut, Abdul Hosein, Genil, and Guran; and 2) the Transitional Neolithic period – Chogha Golan. Because the precise amount of obsidian is unclear at some of the sites, presenting a table is impossible.

Some sites which have obsidian from the beginning of their occupation, such as Ali Kosh and Guran, are so familiar to researchers of Neolithic archaeology that their time span is well known. However, other sites such East Chia Sabz and Chogha Golan show obsidian only in later deposits. This issue could be taken as an indicator to place the sites within a particular time span as obsidian emergence is attributed to sometime between late 8th and early 7th millennium BC in western Iran (Darabi, 2011). However, the three uppermost phases at East Chia Sabz have yielded a small amount of obsidian including tools, debris and even cores showing that raw material was imported as unshaped pieces.

The same phenomenon is regarded for Chogha Sefid in the Deh Luran Plain (Hole, 1977; Renfrew, 1977). In Abdul Hosein and Genil, the obsidian was firstly used from about 1 m above the virgin soil upwards, while the whole deposits of Guran, Chogha Bonut and Ali Kosh yielded the obsidian pieces. The Deh Luran samples were divided into two groups (Renfrew, 1977): 1g (grey) and 4c (light green). Such pieces were also reported from Guran (Mellaart, 1975:87); the Abdul Hosein samples have also been attributed to

Table 3
Means and standard deviations of elements measured by XRF in subsources of obsidian from Bingöl and Nemrut Dağ. Concentrations are given in parts per million unless % is indicated.

ANID	Fe (%)	Rb	Sr	Y	Zr	Nb
Bingöl A ($n = 7$)	3.46 ± 0.11	244 ± 11	4 ± 1	144 ± 5	1470 ± 63	65 ± 4
Bingöl B ($n = 4$)	1.47 ± 0.06	231 ± 6	42 ± 2	28 ± 3	326 ± 13	18 ± 1
Nemrut Dağ-1 ($n = 3$)	1.62 ± 0.024	203 ± 14	3 ± 2	103 ± 7	653 ± 110	60 ± 4
Nemrut Dağ-2 thru 6 ($n = 24$)	3.06 ± 0.82	234 ± 16	3 ± 1	136 ± 12	1451 ± 108	75 ± 8

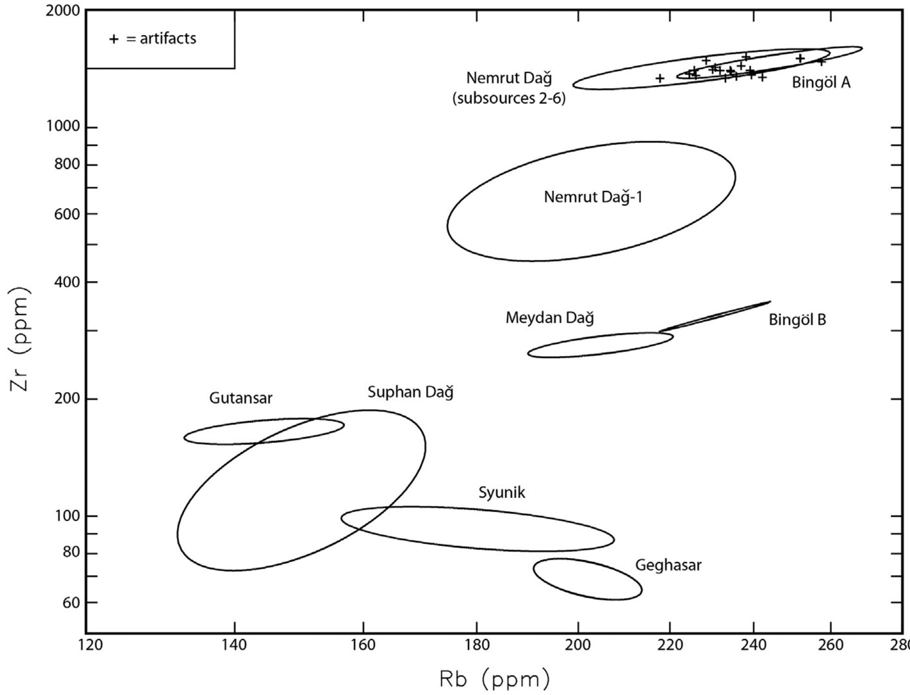

Fig. 2. Log–log scatterplot of Rb versus Zr from XRF for obsidian artefacts from East Chia Sabz projected against 90% confidence ellipses for major sources.

Nemrut Dağ (Pullar, 1990: 12, 113). It should be noted that the presence of a few obsidian pieces at the older sites of Asiab, Karim Shahir and Zawi Chemi Shanidar remains uncertain (Howe, 1983: 44, 115–16; Hole, 1987: 363), though the two latter sites are a shorter distance from southeastern Turkey. In general, it seems likely that obsidian was imported to western Iran as unshaped pieces which then processed to produce the desirable tools on the sites. However, all Early Neolithic sites of the region have not yielded the obsidian samples which could be resulted from a low level of obsidian trading across the region as high-qualified raw materials were easily available to the inhabitants. But, the rate of imported obsidian seems to have increased through time (Watkins, 2008: 156). Such change is quite seen in the Deh Luran plain where the obsidian rate was increased from 1.5% in Ali Kosh phase up to 8% in the succeeding Mohammad Ja'far phase; in western Zagros, the obsidian pieces show a higher use at Maghzaliyah and Jarmo than that of Nemrik, an indicator taken as the signature of younger date for the two former sites (Hole, 1994).

On one hand, debris and even core indicate an on-site production of obsidian tool in the region. On the other hand, the long distance between southeastern Turkey and western Iran with natural obstacles such as mountains and valleys imply an indirect system to import obsidian. Although the precise mechanism of trading is unknown, nomadic peoples might have played an important role in this regard (Darabi, 2011). Then, a kind of middleman trading must have occurred resulting in expansion of the obsidian across the region. Therefore, the most probable way to import the obsidian must be through western Zagros (northern Iraq); needless to say that although northern Zagros is seen as a shorter way no site prior to ca. 6000 BC was found there. It should be mentioned that interactions between two regions of northern Iraq and western Iran are quite implied by the occurrence of "Tadpole Ware" in the succeeding PN period at both regions. Kozlowski (1999: 63) believes that a highly specialized obsidian mining and processing system (mines and workshops) was appeared in a foreign region, perhaps East Anatolia. However, it is not clear that obsidian traded via an administrative organization, though appearance of clay tokens and ritual places could indicate a kind of initial social complexity in neolithic western Iran.

Table 4
Concentrations in parts per million of selected elements measured by NAA in obsidian artefacts from East Chia Sabz.

ANID	Br	Cs	Mn
HDI001	6.13	7.49	457
HDI002	6.00	7.42	460
HDI003	5.35	7.46	467
HDI004	5.70	7.44	468
HDI005	5.96	7.57	455
HDI006	5.53	7.49	441
HDI007	5.77	7.53	460
HDI008	5.50	7.51	465
HDI009	5.98	7.49	465
HDI010	6.10	7.55	461
HDI011	6.55	7.61	465
HDI012	6.00	7.54	457
HDI013	6.52	7.49	468
HDI014	6.00	7.53	473
HDI015	5.77	7.62	465
HDI016	7.72	7.56	458
HDI017	5.98	7.42	468
HDI018	5.79	7.53	460
HDI019	6.29	7.43	457
HDI020	5.80	7.41	452

Table 5
Means and standard deviations in parts per million of selected elements measured by NAA in subsources of obsidian from Bingöl and Nemrut Dağ.

ANID	Br	Cs	Mn
Bingöl A ($n = 7$)	14.4 ± 0.4	14.2 ± 0.2	609 ± 9
Bingöl B ($n = 4$)	2.3 ± 0.2	10.7 ± 0.2	387 ± 150
Nemrut Dağ-1 ($n = 3$)	2.8 ± 0.6	9.1 ± 0.4	379 ± 26
Nemrut Dağ-2 ($n = 9$)	5.3 ± 0.4	7.5 ± 0.2	463 ± 7
Nemrut Dağ-3 ($n = 3$)	4.9 ± 0.2	7.3 ± 0.1	686 ± 39
Nemrut Dağ-4 ($n = 5$)	3.0 ± 0.4	9.2 ± 0.4	774 ± 42
Nemrut Dağ-5 ($n = 1$)	5.3	7.1	727
Nemrut Dağ-6 ($n = 6$)	6.3 ± 0.6	10.1 ± 0.4	1379 ± 26

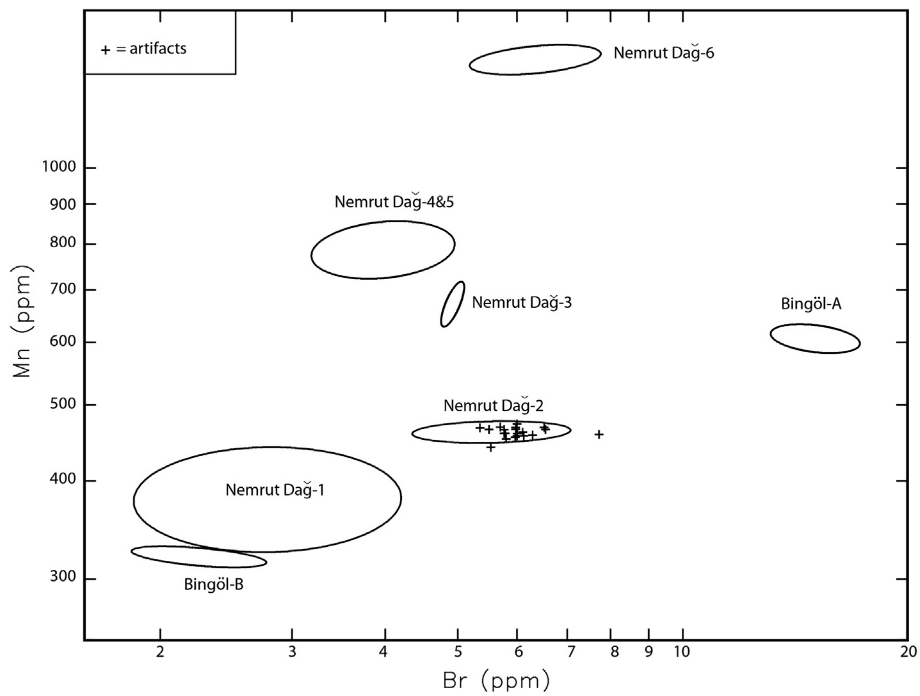

Fig. 3. Log–log scatterplot of Br versus Mn from NAA for obsidian artefacts from East Chia Sabz projected against 90% confidence ellipses for major sources.

6. Conclusion

Based on XRF the Bingöl A and Nemrut Dağ subsources 2–6 were recognized as possible source(s) for the artefacts from East Chia Sabz. But the compositional data for Br, Cs, and Mn were also measured by NAA and determined that all of the obsidian artefacts came from the Nemrut Dağ-2 subsource. These results are clearly consistent with what has already been discussed on the sources of obsidian pieces in the neolithic sites of the region. Moreover, it has been assumed that obsidian must be firstly imported from south-eastern Turkey to northern Iraq and then western Iran. However, obsidian emergence and expansion across western Iran was possibly caused by nomadic peoples who were moving between highlands and lowlands in the Neolithic period.

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