

A new programme of obsidian characterization at Çatalhöyük, Turkey

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Abstract

This paper details the chemical sourcing of 135 obsidian artefacts from Çatalhöyük, a Neolithic site in central Anatolia, the trace-elemental analyses being undertaken in two laboratories using ICP-MS, ICP-AES and LA-ICP-MS. The material is assigned to three sources in Cappadocia: Göllü Dağ-east, Nenezi Dağ and Acıgöl West. The various interrelationships of technology, raw material and date are considered, the data suggesting an increased reliance upon the Nenezi Dağ source in the latter part of the Early Neolithic, a shift that coincides with, and is related to, the introduction of new blade technologies.

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1. Introduction

Located in central Anatolia's Konya Plain the famous Neolithic community of Çatalhöyük lacked a local supply of conchoidally fracturing stone, whereby its large and varied lithic industry is based on resources procured from afar [15,25]. Most of the chipped stone tools were made of obsidian (Table 1), despite the fact that the nearest sources lay 120 miles to the north-east amongst the volcanoes of Cappadocia (Fig. 1). While the origin of Çatalhöyük's limnic quartzites, radiolarites and flint continues to be debated, there have been recent advances in the location and characterization of Anatolia's numerous obsidian sources, providing a solid basis for archaeological provenience studies and the

investigation of prehistoric exchange and other forms of cultural interaction [20]. This work inspired our sourcing project, which in turn forms part of a 'new wave' of Mediterranean, Anatolian and Near Eastern obsidian sourcing studies (cf. [30,35,56]).

In 1999 a major programme of obsidian characterization was initiated to investigate the long-term use of obsidian at Çatalhöyük. This is an ongoing project, involving more than one laboratory and analytical technique; this paper presents our first set of results from the trace-elemental analysis of 135 pieces of worked obsidian.

This is an ongoing project, involving more than one laboratory and analytical technique. This paper presents our first set of results from the trace-elemental analysis of 135 pieces of worked obsidian, that have provided important new data concerning the diachronic relationship between lithic technology and raw material at Çatalhöyük. We also forward a methodology that integrally locates a characterization study within the overarching *chaîne opératoire* analysis of a site's obsidian

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Table 1
Relative proportion of raw materials in Çatalhöyük chipped stone assemblages from the 1995–1999 excavations (by count)

Level	Total	Obsidian	% of total	'Flint'	% of total
Pre-XII.D	893	867	97.1	26	2.9
Pre-XII.C	1487	1373	92.3	114	7.7
Pre-XII.B	4809	4566	95	243	5
Pre-XII.A	5648	5355	94.8	293	5.2
XII	972	924	94.4	55	5.6
XI	248	238	96	10	4
X	6110	5907	96.7	203	3.3
IX	11,476	11,070	96.5	406	3.5
VIII	25,142	24,835	98.8	307	1.2
VII	5870	5793	98.7	77	1.3
North VIII–VII	1543	1517	98.3	26	1.7
North VII–VI	113	110	97.4	3	2.6
KOPAL	306	291	95.1	15	4.9

assemblage. The artefacts came from the 1995–1999 excavations, with 128 from the Neolithic east mound (henceforth Çatalhöyük East) and seven from the Early Chalcolithic west mound (henceforth Çatalhöyük West). The analyses were undertaken at two laboratories in France and Britain, employing three analytical techniques, namely: (1) Poupeau and Bressy of the Groupe de Géophysique Nucléaire, UMR 5025 of the *Centre National de la Recherche Scientifique* [CNRS], Université Joseph Fourier, Grenoble employing solution nebulisation Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) and Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES), and (2) Pearce of the Institute of Geography and Earth Sciences, University of Wales, Aberystwyth, employing Laser Ablation Inductively Coupled Plasma Mass Spectroscopy (LA-ICP-MS).

2. Background

This is not the first provenance study involving Çatalhöyük's obsidian, with 20 artefacts characterised in the past 35 years by three different projects (Table 2). In the 1960s Renfrew analysed four blades by Optical Emission Spectroscopy, three of which fell within his 'Group 1e-f', associated with the northern Cappadocian source of Acıgöl [49]. The fourth artefact was sourced to Armenia ('Group 1g'), a result considered to be counterintuitive by the analysts, who cautioned that it might 'conceivably be an anomalous and exceptional product of a nearer source' [49, p. 33]. Using the same technique, Wright analysed three pieces of obsidian from Çatalhöyük East and three from Çatalhöyük West [58]. Four artefacts, including all the Chalcolithic material, were sourced to Acıgöl, while the obsidian employed for two of the East mound blanks was claimed to be from Çiftlik in southern Cappadocia. Lastly, Keller and Seifried characterised 10 artefacts from Çatalhöyük (contexts unknown), the obsidian again being sourced to the Çiftlik region [34]. More specifically, their technique of X-ray Fluorescence allowed them to determine that six were made of obsidian from the mountain of Nenezi Dağ, while four originated from nearby 'Göllüdağ-Kömürcü' (Fig. 1). Chataigner has since argued that the six artefacts attributed to Acıgöl by Renfrew and Wright could in fact be from Nenezi Dağ, as both sources fell within their Group 1e-f [22, pp. 279–285]. We return to this issue below.

Traditionally obsidian sourcing has been employed to gain a clearer image of cultural interaction and the socio-economic complexity of prehistoric societies (cf. [48 (pp. 38–51),50,58]). Yet more often than not, interpretations have been forwarded on the basis of a handful of samples, whose descriptions rarely extend beyond an object/lab number,

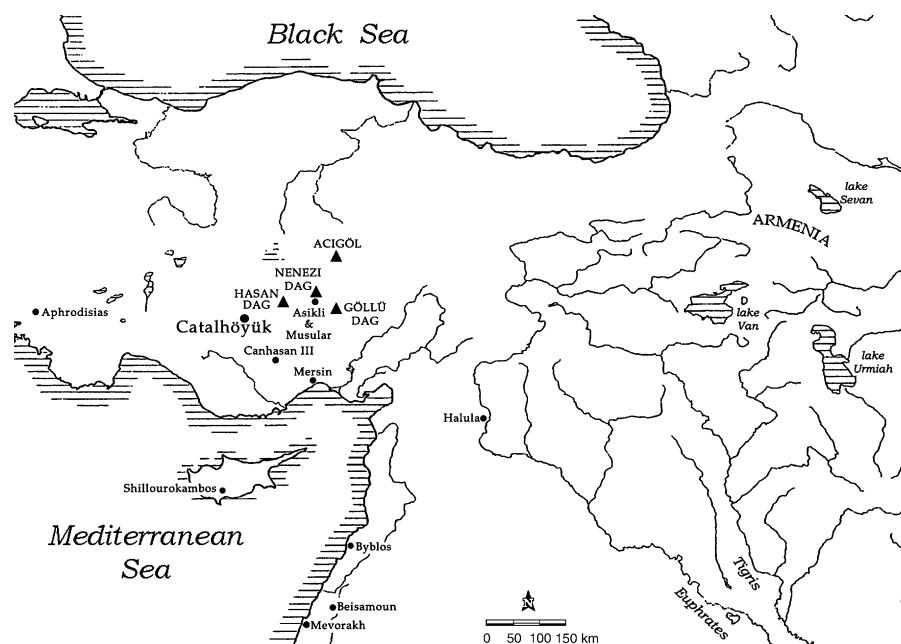


Fig. 1. Map showing main sites mentioned in text (M. Milić).

Table 2
Obsidian from Çatalhöyük sourced prior to 1999

Sample	Level	Context	Object	Source	Method	Analysts
41	Neolithic	East Mound	Blade	Armenia (Group 1g)	OES	Renfrew et al.
42	Neolithic	East Mound	Blade	Acigöl (Group 1e-f)	OES	Renfrew et al.
43	Neolithic	East Mound	Blade	Acigöl (Group 1e-f)	OES	Renfrew et al.
280	Neolithic	East Mound	Blade	Acigöl (Group 1e-f)	OES	Renfrew et al.
643	Chalcolithic	West Mound	?	Acigöl (Group 1e-f)	OES	Wright
644	Chalcolithic	West Mound	?	Acigöl (Group 1e-f)	OES	Wright
645	Chalcolithic	West Mound	?	Acigöl (Group 1e-f)	OES	Wright
646	Neolithic	East Mound	?	Çiftlik (Group 2b?)	OES	Wright
647	Neolithic	East Mound	?	Acigöl (Group 1e-f)	OES	Wright
648	Neolithic	East Mound	?	Çiftlik (Group 2b?)	OES	Wright
6 pieces	?	?	?	Nenezi Dağ	XRF	Keller and Seifried
4 pieces	?	?	?	Göllüdağ-Kömürcü	XRF	Keller and Seifried

OES – Optical Emission Spectroscopy; XRF – X-ray Fluorescence; data from Refs.[34,49,58].

largely ignoring their context, form, or technological characteristics. It is extremely important to appreciate the potential distinctions in how these obsidians were exchanged, transformed, conceptualised and valued through time (cf. [28,51]). To talk about the trade or consumption of ‘obsidian’ alone is problematic; as archaeologists we need to document the nature of our samples: raw material, preform, or end product. One recent set of studies has started to bring some of these issues together in a most informative way, namely the work of archaeologists and archaeometrists at the Kaletpepe blade workshop (Aceramic Neolithic) located atop the Kömürcü obsidian outcrop of the Göllü Dağ-East source [8,17]. This research has produced a techno-typological characterization of the workshop’s industries (naviform and unipolar prismatic blades) and the geo-chemical signature of the source material. When these data are integrated with trace-element analysis of obsidian artefacts from contemporary Levantine sites such as Mureybet and Cheikh Hasan, one can start to discuss the trade of large, black, shiny, razor-sharp projectiles (amongst other products), rather than talking simply about the exchange and movement of Göllü Dağ-East ‘obsidian’ [2,8 (p. 244, fig. 6),22 (pp. 288–289)]. It is this type of analytical strategy, where archaeometric data are located within a *chaîne opératoire* framework, that we wish to forward.

3. Aims

The aims of our programme are manifold, with samples selected to examine a number of variables relating to raw material, time, space and modes of consumption. We wish to document Çatalhöyük’s relationship with the obsidian sources through time (level-by-level), and to search for spatial patterning in consumption (building-by-building), as rights of access to an outcrop could have been based on household, or kinship affiliations (cf. [32 (pp. 227–228),55 (pp. 52–57)]). A further line of enquiry is to investigate if distinct knapping traditions relate to specific outcrops; for this reason, each artefact chosen for analysis has been described in detail and illustrated for publication alongside the results, an unfortunately all too rare occurrence in provenience studies; a representative

sample is presented here (Fig. 2), with all line-drawings available online [59]. Finally, we are also interested in the potential for visually discriminating between the obsidians, on the basis of the sample’s colour, banding, translucency, inclusions and texture. Such a broad range of questions has necessarily involved taking a large number of samples, following recent trends elsewhere, as for example with c. 400 pieces from the La Mana Pre-Hispanic site in Ecuador [45] and the thousands from Puerto Escondido in Honduras (S. Shackley pers. comm.). To consider each of the questions outlined above is beyond the scope of a single paper; we here focus on the diachronic interrelationship between technology and source.

4. Sampling strategy

The occupation sequence at Çatalhöyük East spans the Aceramic (Level Pre-XII.A–D) to Early Neolithic (Levels XII–0), a duration of approximately 1200 years, from c. 7400 to 6200 cal BC (Level Pre-XII.D–Level II, Levels I and 0 are not dated yet [21,53]). The Çatalhöyük East material that forms the basis of this paper comes from the North, South and Summit Areas (Fig. 3), spanning Levels IX–III (Table 3), a period of approximately 500 years [21]. Seven distinct obsidian industries have thus far been defined in the Neolithic assemblages (see below); unfortunately it was not possible to sample each of them in this study. For instance, most of the finely retouched material, such as projectiles, was not selected for analysis, as such pieces are – understandably – not allowed to be exported for destructive analysis. To this end we are investigating the possibility of sub-sampling on-site and the use of portable non-destructive techniques (cf. [39]), so that we may eventually source Çatalhöyük’s mirrors, spearheads, beads and other ‘museum pieces’.

5. ICP-MS and ICP-AES analyses of 100 samples at CNRS

5.1. Analytical procedure

Regarding the 100 artefacts analysed at CNRS (Grenoble), major and trace element concentrations were determined

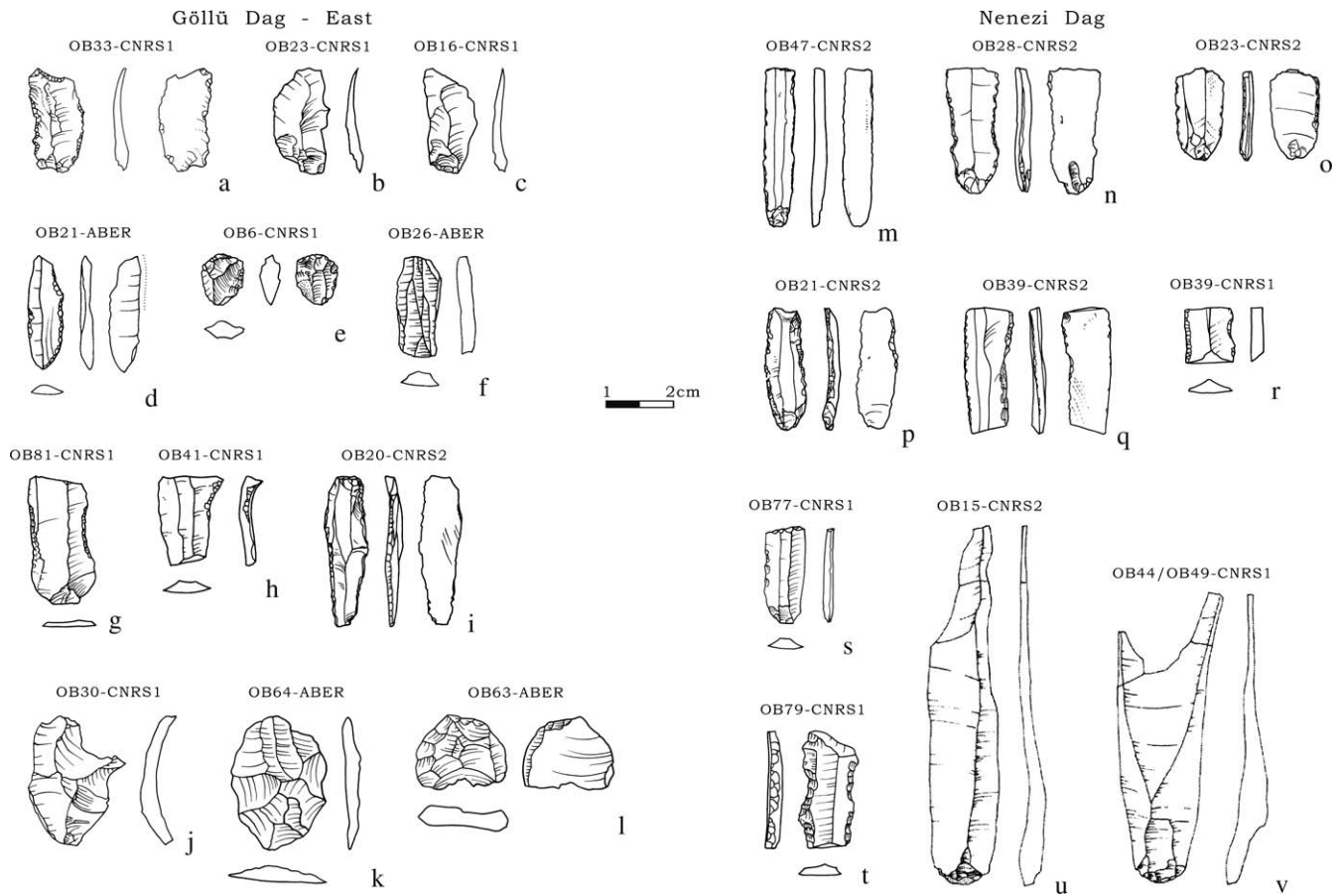


Fig. 2. Representative sample of obsidian industries sampled; source-by-source (G. Der Aprahamian, M. Milić and J.G.H. Swogger).

using, respectively, ICP-AES and ICP-MS, following the procedure described by Barrat et al. [9]. The accuracy of major and trace element concentrations is better than 5% (probably better than 3% for all REEs), except for W and Cs (10–30%

for the lowest concentrations) based on various standards and sample duplicates. Small slices were taken from each piece using either a thin diamond saw or a diamond wire saw. To minimize eventual surface contamination/alteration

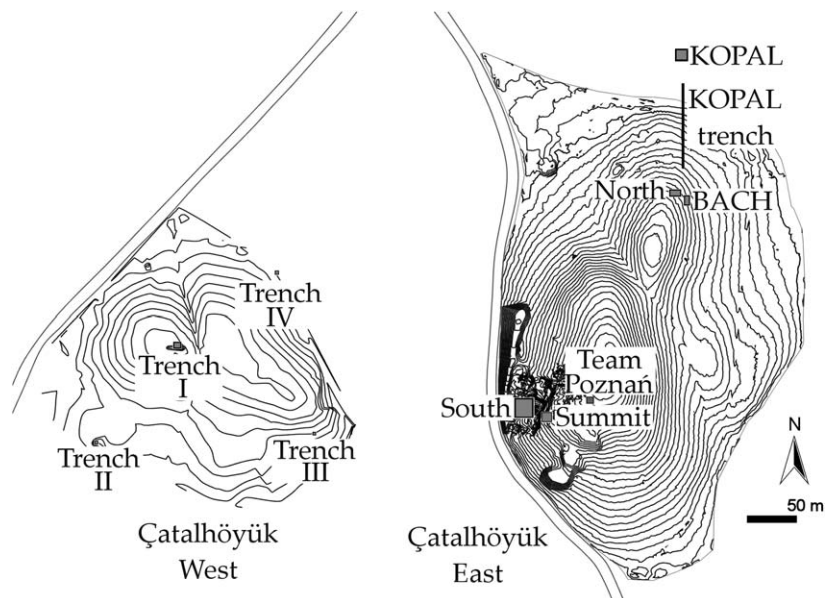


Fig. 3. Plan of Çatalhöyük showing areas of excavation mentioned in text.

Table 3
Temporal and spatial distribution of the 135 artefacts analysed by CNRS and Aberystwyth

Mound Level	Samples	Area	Building	Space
East IX	5	South	2	
East VIII	16	South		114, 115, 150
East VIII–VII	10	North	1/5, 5	154–157
East VII	15	South	—	105–109, 112–113
East VII–VI	79	North	1	Various
East VIB	1	South	—	160
East III	2	Summit	10	Various
West E. Chalcolithic I–II	7	—	25	Various

biases in analyses, each slice was crushed between thick books of paper sheets in order to obtain internal fragments. To ensure a representative sample was taken, about 100 mg of such millimetre-sized chips were carefully selected under a stereomicroscope, checking the freshness of their surfaces. In order to obtain a mother solution they were then dissolved in Teflon beakers with high-purity hydrofluoric acid under controlled-atmosphere conditions.

For ICP-AES analyses of Al, Fe, Mn, Mg, Ca, Na, K, Ti and P, daughter solutions with different degrees of dilution were prepared. Four solutions of appropriate dilutions were prepared from pure element solutions for calibration purposes. Twenty-seven trace elements: Co, Rb, Sr, Y, Zr, Nb, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Pb, Th, U were measured by ICP-MS from a single diluted daughter solution. Several solutions of geo-chemical standard reference materials (RGM-1, BIR-1, BHVO-1, SRM-278) were prepared in the same way. All these solutions were spiked with a thulium reference solution [10]. In order to take into account interferences in the REE, pure solutions of Sm–Eu–Gd–Tb, Pr–Nd, Ce and Ba were also analysed. Finally, to compensate for instrumental drift, one unspiked standard (BHVO-1) was analysed after each set of four samples. Element contents were then calculated following Bellot-Gurlet et al. [11].

For provenance determination the data generated from the artefacts were compared with those previously obtained in the laboratory from obsidian samples of various geological sources. The trace element data are presented conventionally in diagrams of normalized element abundances (cf. [22,46]); the norm selected is the composition of the upper continental crust [52].

5.2. Data

The trace element normalized abundances of the 100 artefacts are presented in Fig. 4. It is clear that two compositional groups are present comprising 55 and 45 samples, respectively. In Fig. 4a, the compositions of the 55 artefacts defining the largest group are reported along with geological obsidians from the ‘Göllü Dağ-East’ region (four and five samples from the Kömürçü and Kayırlı-East outcrops, respectively); the artefacts show a clear affinity with the ‘Göllü Dağ-East’ type compositional group of Cauvin et al. [18,19]. The major

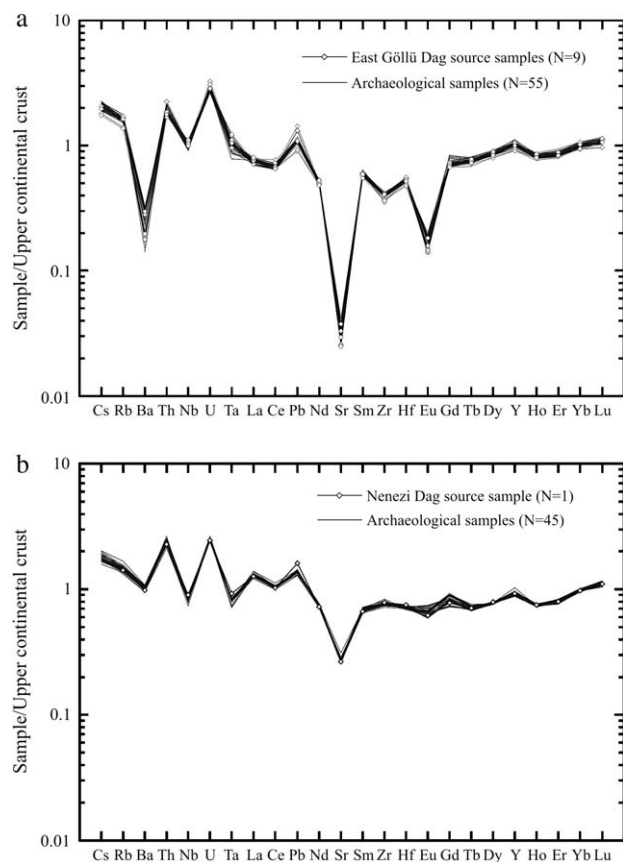


Fig. 4. Relative trace element abundances for 100 artefacts analysed at CNRS. (a) Relative trace element abundances for artefacts with a Göllü Dağ-east composition. (b) Relative trace element abundances for artefacts with a Nenezi Dağ composition.

element contents of the artefacts (Table 4) are also in agreement with that of the Göllü Dağ-East obsidians. As it is not possible from the 36 element contents to discriminate obsidians of the Kömürçü outcrops from those of Kayırlı-East, we attribute a Göllü Dağ-East origin to the 55 artefacts analysed. In Fig. 4b, the compositions of the 45 artefacts with another composition are compared to that of one geological sample from the Nenezi Dağ volcano. As above, from both the similarity of trace (Fig. 4) and major elemental (Table 4) contents of these obsidians with that measured from Nenezi Dağ (see also [20]), we assign them an origin from this volcano.

6. LA-ICP-MS analysis of 35 samples at Aberystwyth

6.1. Analytical procedure

The analysis of 35 samples performed by laser ablation (LA)-ICP-MS at Aberystwyth involved each flake of obsidian having five separate spectra acquired from it for 40 separate elements. Spectra are acquired by burning a small volume of material from the sample (‘ablating’) using a high-intensity ultraviolet pulsed laser beam and analysing the vaporised material in the ICP-MS. The resulting ablation craters are

Table 4
Element contents determined by CNRS using ICP-MS and ICP-AES for the 55 artefacts associated with a Göllü Dağ-east-type compositional group, the 45 artefacts associated with a Nenezi Dağ-type compositional group and sample OBC 38 of Acıgöl West affinity

Çatal Höyük-Gollu Dag East																				
	OB 99 1	OB 99 6	OB 99 7	OB 99 8	OB 99 9	OB 99 10	OB 99 11	OB 99 12	OB 99 13	OB 99 14	OB 99 16	OB 99 18	OB 99 19	OB 99 20	OB 99 23	OB 99 30	OB 99 31	OB 99 32	OB 99 33	OB 99 34
Al ₂ O ₃	13.07	12.96	12.86	12.87	12.69	12.60	12.59	12.58	12.65	12.89	12.65	12.68	12.41	12.54	12.50	12.49	12.68	12.57	12.60	12.58
Fe ₂ O ₃	0.78	0.73	0.73	0.73	0.76	0.72	0.71	0.73	0.73	0.74	0.75	0.73	0.72	0.75	0.75	0.77	0.76	0.76	0.73	0.75
MnO	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.06	0.06	0.07	0.06	0.06	0.06
MgO	0.09	0.09	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.05	0.05	0.06	0.06	0.06	0.05	0.05
CaO	0.56	0.59	0.58	0.55	0.59	0.58	0.61	0.58	0.61	0.58	0.57	0.56	0.60	0.55	0.57	0.57	0.56	0.56	0.56	0.55
Na ₂ O	3.59	3.50	3.63	3.65	3.56	3.54	4.13	4.15	4.12	4.15	4.10	3.97	3.92	3.96	3.93	3.97	3.92	3.87	3.93	4.18
K ₂ O	4.25	4.35	4.19	4.23	4.31	4.25	4.52	4.28	4.20	4.63	4.42	4.44	4.51	4.33	4.48	5.31	4.53	4.46	4.27	4.40
TiO ₂	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Co	0.20	0.17	0.19	0.17	0.18	0.19	0.18	0.19	0.21	0.19	0.16	0.16	0.24	0.16	0.15	0.16	0.16	0.15	0.21	0.13
Rb	180	177	185	185	175	178	181	179	175	179	176	170	178	183	177	177	171	172	177	177
Sr	12.7	12.2	12.9	14.5	12.4	11.4	12.3	12.8	12.3	12.8	12.5	12.4	13.2	10.4	13.0	12.7	10.6	12.3	9.81	12.8
Y	22.5	22.6	23.0	23.1	21.9	22.5	22.7	22.5	22.1	22.5	22.8	22.0	23.4	24.5	23.0	23.2	22.5	22.2	23.2	22.3
Zr	78.1	76.1	78.7	79.0	75.8	76.0	76.7	77.1	76.1	75.6	77.2	75.8	77.8	77.6	77.4	78.2	74.6	76.7	74.4	75.6
Nb	23.6	23.9	25.4	25.4	23.8	22.9	24.6	24.1	24.1	23.1	25.0	23.7	25.7	26.9	24.1	25.7	24.6	24.4	25.5	23.6
Cs	8.06	8.01	8.27	8.38	7.81	8.03	8.02	8.00	7.92	8.21	7.86	7.66	7.27	7.62	7.31	7.32	7.10	7.07	7.48	7.25
Ba	170	157	173	176	165	139	158	167	161	170	162	164	167	113	174	166	128	164	102	170
Hf	3.17	3.17	3.12	3.11	3.05	3.04	3.14	3.17	3.14	3.03	3.08	3.08	3.12	3.22	3.12	3.19	3.04	3.04	3.12	2.97
Ta	2.07	2.27	2.35	2.33	2.15	1.98	2.30	2.23	2.27	1.73	2.30	2.22	2.38	2.51	1.92	2.44	2.33	2.33	2.44	1.90
W	3.35	3.51	3.64	3.60	3.30	3.18	3.42	3.51	3.58	3.03	3.31	3.17	3.46	3.62	3.03	3.57	3.46	3.43	3.61	2.82
Th	21.8	21.3	22.4	22.7	21.4	21.4	22.0	22.1	21.6	22.7	21.6	21.2	22.0	22.1	22.8	22.5	20.6	21.2	21.4	21.6
U	20.6	20.7	20.8	21.1	19.9	19.6	19.9	20.3	20.2	19.8	19.4	19.2	19.8	19.7	19.6	20.0	19.3	19.6	19.5	19.3
La	7.86	7.86	7.95	7.97	7.80	7.95	7.95	7.78	7.77	7.79	7.73	7.57	7.86	8.17	8.00	7.90	7.48	7.43	7.89	7.60
La	22.5	21.7	22.9	23.4	21.7	21.5	22.3	22.1	21.6	22.9	22.2	21.6	22.8	22.5	23.5	23.1	21.3	22.2	21.0	22.9
Ce	43.3	42.0	44.4	45.2	42.3	42.3	43.7	42.9	41.8	44.9	43.5	42.3	44.0	44.0	46.4	44.9	41.3	42.9	41.5	44.8
Pr	4.33	4.23	4.43	4.50	4.24	4.19	4.31	4.27	4.25	4.53	4.31	4.20	4.36	4.44	4.58	4.45	4.18	4.28	4.19	4.48
Nd	13.1	13.0	13.4	13.7	12.7	12.8	13.0	12.8	12.9	13.6	13.3	12.8	13.4	13.6	14.0	13.5	12.8	13.2	13.0	13.6
Sm	2.69	2.64	2.69	2.76	2.53	2.55	2.57	2.63	2.63	2.70	2.64	2.58	2.75	2.79	2.79	2.75	2.54	2.67	2.62	2.71
Eu	0.16	0.15	0.15	0.16	0.15	0.14	0.15	0.15	0.15	0.16	0.15	0.16	0.16	0.13	0.16	0.16	0.13	0.15	0.12	0.17
Gd	2.59	2.58	2.62	2.65	2.55	2.61	2.62	2.65	2.62	2.71	2.70	2.63	2.70	2.70	2.73	2.68	2.59	2.68	2.68	2.67
Tb	0.49	0.48	0.50	0.50	0.49	0.49	0.50	0.49	0.48	0.49	0.50	0.48	0.49	0.52	0.50	0.50	0.48	0.47	0.49	0.49
Dy	3.03	2.99	3.00	3.02	2.93	2.97	2.94	2.95	2.94	3.01	3.03	2.93	3.07	3.17	3.09	3.05	3.01	2.91	3.06	2.91
Ho	0.66	0.66	0.66	0.65	0.63	0.64	0.65	0.65	0.65	0.64	0.65	0.63	0.66	0.68	0.67	0.66	0.65	0.64	0.68	0.64
Er	1.96	2.00	1.96	1.99	1.93	2.01	1.97	1.93	1.94	1.87	1.96	1.90	1.97	2.05	1.99	2.03	1.90	1.91	1.98	1.88
Yb	2.19	2.15	2.18	2.16	2.17	2.18	2.19	2.15	2.20	2.17	2.15	2.10	2.26	2.35	2.22	2.24	2.17	2.14	2.24	2.16
Lu	0.35	0.35	0.35	0.34	0.34	0.35	0.34	0.34	0.34	0.34	0.34	0.33	0.36	0.37	0.36	0.36	0.34	0.34	0.35	0.34

Çatal Höyük-Gollu Dag East

	OB 99	35OB 99	36OB 99	37OB 99	41OB 99	51OB 99	67OB 99	72OB 99	73OB 99	78OB 99	80OB 99	81OB 99	88OB 99	89	OB 3	OB 4	OB 5	OB 6	OB 8	OB 9	OB 10
Al ₂ O ₃	12.64	11.59	12.61	12.65	12.82	12.76	12.80	12.89	13.00	12.63	12.45	12.25	12.63	12.50	12.44	12.67	10.17	11.66	12.73	12.82	
Fe ₂ O ₃	0.74	0.68	0.73	0.87	0.79	0.81	0.78	0.81	0.79	0.81	0.82	0.77	0.81	0.72	0.66	0.66	0.69	0.64	0.80	0.74	
MnO	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.06	0.06	0.08	0.05	0.06	0.06	
MgO	0.06	0.05	0.05	0.05	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.02	0.03	0.03	0.02	0.03	0.03	0.03	0.04	0.05	
CaO	0.59	0.52	0.58	0.56	0.54	0.57	0.55	0.56	0.56	0.55	0.53	0.53	0.56	0.50	0.57	0.50	0.50	0.64	0.79	0.69	
Na ₂ O	4.07	3.19	3.41	5.04	4.38	4.36	4.41	4.43	4.33	4.39	4.37	4.34	4.32	4.28	3.96	3.89	3.02	3.66	3.84	3.95	
K ₂ O	4.47	3.97	3.92	4.84	4.32	4.67	4.75	4.45	4.63	4.46	4.39	4.42	4.77	4.20	4.35	4.40	3.14	3.37	4.32	3.82	
TiO ₂	0.05	0.04	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.05	0.05	0.05	0.07	0.06	0.06	0.06	
Co	0.17	0.14	0.11	0.18	0.15	0.22	0.15	0.16	0.17	0.20	0.31	0.19	0.27	0.11	0.11	0.11	0.09	0.09	0.09	0.13	
Rb	177	184	186	190	192	200	190	185	199	185	183	171	177	183	177	181	181	185	190	182	
Sr	12.8	9.57	10.0	11.6	9.74	13.6	9.58	12.9	9.85	11.9	13.6	11.8	13.3	9.15	11.7	12.2	12.3	10.3	10.7	9.16	
Y	23.2	24.2	24.1	21.9	22.8	22.7	22.4	21.6	24.6	23.4	22.7	21.9	21.9	22.7	21.7	22.2	21.8	22.5	23.5	22.6	
Zr	78.7	75.8	74.1	77.2	74.3	81.3	73.7	78.1	77.6	79.0	80.2	73.3	77.8	75.7	77.3	79.0	78.2	76.8	75.3	73.1	
Nb	25.3	26.2	24.8	24.5	25.0	25.0	24.4	23.8	26.1	25.6	25.1	23.5	24.6	25.2	24.1	24.7	24.5	24.8	26.0	25.0	
Cs	7.63	8.08	8.13	8.26	7.77	8.17	7.47	7.14	8.24	7.40	7.09	8.20	8.29	7.63	7.31	7.49	7.52	7.70	8.17	7.67	
Ba	168	98	103	143	105	181	104	174	85	108	176	152	171	104	161	168	171	130	78	98	
Hf	3.14	3.16	3.13	3.14	3.11	3.07	3.10	3.07	3.00	3.10	2.99	2.95	2.97	3.07	3.04	3.03	3.03	3.04	3.05	3.02	
Ta	2.29	2.39	2.02	2.25	2.40	2.22	2.39	2.27	2.15	2.33	2.19	2.16	2.21	2.41	2.25	2.27	2.25	2.32	2.48	2.39	
W	3.48	3.58	3.03	3.55	3.27	3.83	3.77	3.60	2.98	3.28	3.10	3.24	3.29	3.50	3.35	3.37	3.35	3.49	3.66	3.46	
Pb	22.1	22.0	22.5	22.5	22.8	21.4	22.3	22.5	22.9	23.2	22.9	22.5	22.6	22.1	22.0	21.9	22.0	21.5	21.6	21.8	
Th	20.4	20.0	19.8	20.7	20.2	20.5	19.8	20.3	19.3	19.4	19.5	19.7	19.7	22.8	23.4	22.9	23.0	22.7	22.8	22.0	
U	7.88	8.27	8.47	8.11	8.36	7.76	8.50	8.10	8.20	7.95	7.51	7.55	7.55	8.48	8.08	8.01	8.01	8.09	8.54	8.39	
La	22.8	22.0	22.4	22.9	22.3	23.8	21.6	22.7	22.5	22.2	22.9	22.2	22.5	22.1	23.5	23.6	23.4	22.8	22.2	21.6	
Ce	44.1	43.0	44.9	44.0	43.4	46.1	42.1	43.6	43.7	43.2	44.3	41.9	43.2	42.0	43.8	43.9	43.9	42.9	42.7	41.1	
Pr	4.38	4.33	4.50	4.42	4.35	4.53	4.25	4.35	4.34	4.32	4.39	4.29	4.30	4.30	4.45	4.44	4.44	4.35	4.35	4.23	
Nd	13.4	13.3	13.9	13.4	13.3	13.6	13.1	13.2	13.3	13.2	13.2	12.9	13.1	13.3	13.7	13.7	13.7	13.5	13.5	13.1	
Sm	2.65	2.66	2.75	2.70	2.67	2.68	2.69	2.58	2.76	2.71	2.62	2.61	2.63	2.83	2.77	2.79	2.78	2.85	2.90	2.77	
Eu	0.16	0.12	0.13	0.15	0.14	0.17	0.14	0.17	0.12	0.14	0.18	0.16	0.18	0.14	0.16	0.17	0.16	0.15	0.13	0.13	
Gd	2.78	2.80	2.86	3.04	3.20	3.12	3.15	3.05	3.16	3.13	3.04	3.06	2.98	2.76	2.73	2.77	2.79	2.80	2.86	2.83	
Tb	0.49	0.51	0.52	0.48	0.51	0.49	0.50	0.48	0.52	0.52	0.50	0.51	0.49	0.49	0.48	0.48	0.48	0.50	0.52	0.51	
Dy	2.96	3.14	3.22	2.99	3.07	2.98	3.10	2.96	3.06	3.08	2.92	2.97	2.88	3.11	3.00	3.01	3.00	3.11	3.22	3.13	
Ho	0.65	0.69	0.69	0.64	0.66	0.64	0.66	0.64	0.67	0.66	0.63	0.64	0.62	0.68	0.65	0.64	0.65	0.67	0.70	0.69	
Er	1.97	2.07	2.07	1.96	2.02	1.90	2.01	1.94	1.97	1.97	1.86	1.89	1.82	2.07	2.00	2.03	2.02	2.05	2.17	2.11	
Yb	2.23	2.36	2.37	2.21	2.28	2.19	2.29	2.21	2.26	2.26	2.15	2.18	2.14	2.34	2.24	2.24	2.24	2.26	2.37	2.28	
Lu	0.35	0.37	0.37	0.35	0.35	0.34	0.35	0.35	0.36	0.34	0.33	0.34	0.34	0.36	0.34	0.34	0.34	0.35	0.36	0.35	

(continued on next page)

Table 4 (continued)

	Çatal Höyük-Gollu Dag East															Çatal Höyük-Nenezi Dag				
	OB 11	OB 12	OB 13	OB 14	OB 16	OB 17	OB 18	OB 20	OB 26	OB 29	OB 40	OB 42	OB 44	OB 45	OB 50	OB15	OB17	OB 99 39	OB 99 40	OB 99 44
Al ₂ O ₃	12.68	12.52	12.40	12.63	12.66	12.64	12.45	12.54	12.61	12.50	12.58	12.61	12.70	13.15	12.71	13.68	13.72	13.80	13.95	14.04
Fe ₂ O ₃	0.70	0.77	0.78	0.78	0.89	0.68	0.80	0.85	0.68	0.67	0.69	0.70	0.80	0.78	0.76	1.15	1.16	1.28	1.28	1.32
MnO	0.06	0.06	0.06	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06
MgO	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.17	0.17	0.17	0.18	0.18
CaO	0.61	0.63	0.65	0.49	0.50	0.49	0.50	0.52	0.50	0.52	0.49	0.49	0.49	0.50	0.49	1.15	1.14	1.15	1.22	1.23
Na ₂ O	3.79	3.93	4.02	4.05	4.11	4.02	4.06	4.00	3.47	4.19	4.09	4.10	4.12	4.08	4.00	4.23	4.41	5.32	5.19	5.07
K ₂ O	4.50	3.47	4.52	4.22	3.82	4.23	3.81	4.10	4.38	3.83	3.96	4.06	3.43	4.25	3.40	4.45	4.26	4.81	4.63	4.60
TiO ₂	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.12	0.12	0.12	0.14	0.15
Co	0.10	0.09	0.09	0.19	0.09	0.15	0.18	0.17	0.17	0.16	0.11	0.14	0.14	0.10	0.11	0.62	0.63	0.71	0.68	0.66
Rb	177	182	180	195	181	174	175	187	191	185	185	182	179	185	179	148	151	188	165	165
Sr	12.0	10.8	8.7	12.9	12.1	11.2	10.8	12.5	10.2	12.4	12.1	12.6	11.8	12.1	10.8	91.2	92.4	108	95.3	95.7
Y	21.7	22.1	22.3	22.6	20.4	20.7	20.1	22.3	22.9	22.0	22.0	21.7	21.1	22.0	21.4	20.1	20.4	22.7	19.8	20.0
Zr	77.6	75.3	73.6	81.4	73.7	73.5	73.8	80.2	76.8	78.2	78.2	76.7	75.8	78.5	74.3	137	140	158	142	144
Nb	24.0	24.5	25.1	25.9	23.2	23.7	24.0	25.6	25.8	25.2	24.7	24.1	24.0	24.7	24.1	19.9	19.9	22.4	20.3	19.9
Cs	7.33	7.57	7.98	8.27	7.38	7.12	7.17	7.42	7.87	7.60	7.74	7.73	7.23	7.37	6.91	6.46	6.61	7.47	6.97	6.29
Ba	167	128	98	179	171	159	160	176	125	170	169	167	170	171	141	526	532	597	556	567
Hf	2.95	2.96	3.02	3.03	3.01	3.01	2.93	3.10	3.15	3.10	3.05	2.99	3.02	3.09	3.00	4.08	4.19	4.08	4.32	4.27
Ta	2.23	2.30	2.42	2.22	1.97	2.29	2.24	2.30	2.36	2.35	2.17	2.16	2.27	2.26	2.29	1.77	1.75	1.62	1.83	1.80
W	3.34	3.38	3.45	4.01	3.48	3.62	3.62	3.74	4.11	4.03	3.51	3.41	3.53	3.62	3.72	2.91	2.85	2.84	3.25	3.29
Pb	21.5	21.5	22.0	21.7	23.6	22.2	21.7	21.7	22.8	22.9	22.7	22.5	21.6	21.9	21.3	25.8	25.7	28.4	27.7	27.6
Th	23.4	22.2	22.6	20.8	23.0	22.2	21.6	20.4	21.4	22.0	21.0	21.0	20.8	20.7	20.7	22.8	23.1	25.1	25.2	24.5
U	7.91	8.04	8.54	7.61	8.75	8.20	8.30	7.53	8.37	8.21	8.08	7.99	7.85	7.86	7.84	6.73	6.77	6.95	7.09	7.26
La	24.4	22.3	21.8	23.8	22.7	22.5	21.1	23.4	22.6	23.5	23.3	23.0	23.0	23.4	22.2	36.2	36.4	41.8	38.6	38.5
Ce	45.3	42.1	41.4	44.8	43.7	42.4	42.0	43.9	43.1	44.3	43.9	43.2	43.2	44.1	41.7	63.3	64.0	71.6	66.7	66.7
Pr	4.56	4.28	4.23	4.49	4.36	4.27	4.04	4.43	4.42	4.48	4.41	4.32	4.39	4.42	4.27	6.07	6.09	6.69	6.43	6.31
Nd	13.9	13.2	13.2	13.6	13.2	13.2	12.4	13.6	13.6	13.8	13.5	13.3	13.4	13.5	13.3	18.5	18.5	20.1	19.4	19.2
Sm	2.77	2.73	2.79	2.77	2.71	2.68	2.55	2.77	2.86	2.81	2.72	2.70	2.74	2.79	2.77	2.92	2.89	3.13	3.02	3.01
Eu	0.17	0.14	0.13	0.16	0.16	0.15	0.15	0.17	0.14	0.15	0.15	0.15	0.16	0.16	0.15	0.53	0.53	0.60	0.58	0.59
Gd	2.77	2.77	2.78	2.70	2.56	2.67	2.53	2.75	2.91	2.73	2.71	2.72	2.57	2.63	2.54	3.10	3.14	3.39	3.29	3.43
Tb	0.48	0.49	0.50	0.47	0.47	0.46	0.44	0.46	0.49	0.47	0.47	0.47	0.47	0.49	0.48	0.47	0.47	0.46	0.46	0.47
Dy	2.97	3.02	3.11	2.99	2.96	2.95	2.85	3.01	3.16	3.05	2.99	3.00	2.94	3.00	3.03	2.69	2.73	2.73	2.67	2.70
Ho	0.64	0.66	0.68	0.64	0.63	0.63	0.61	0.64	0.67	0.66	0.64	0.64	0.64	0.66	0.65	0.59	0.59	0.59	0.59	0.59
Er	1.98	1.99	2.10	1.97	1.94	1.92	1.87	1.96	2.08	2.03	1.98	1.94	1.97	2.03	1.98	1.79	1.85	1.75	1.87	1.80
Yb	2.17	2.22	2.30	2.15	2.13	2.15	2.08	2.17	2.27	2.18	2.21	2.15	2.16	2.23	2.20	2.10	2.12	2.22	2.19	2.18
Lu	0.33	0.34	0.35	0.34	0.34	0.34	0.33	0.35	0.37	0.36	0.34	0.34	0.33	0.34	0.34	0.35	0.34	0.37	0.35	0.36

Çatal Höyük-Nenezi Dag

	OB 99 45	OB 99 46	OB 99 47	OB 99 48	OB 99 49	OB 99 59	OB 99 75	OB 99 76	OB 99 77	OB 99 79	OB 99 82	OB 99 83	OB 1	OB 2	OB 7	OB 15	OB 19	OB 21	OB 22	OB 23
Al ₂ O ₃	13.86	14.60	13.95	13.76	13.99	13.99	14.07	13.88	13.97	13.80	13.86	13.66	13.99	14.08	13.75	13.26	13.61	13.82	13.79	13.82
Fe ₂ O ₃	1.23	1.26	1.18	1.23	1.23	1.20	1.26	1.24	1.21	1.23	1.25	1.22	1.26	1.28	1.29	1.23	1.29	1.25	1.09	1.10
MnO	0.06	0.06	0.06	0.06	0.06	0.05	0.07	0.06	0.05	0.05	0.06	0.06	0.07	0.06	0.06	0.07	0.07	0.07	0.07	0.07
MgO	0.16	0.16	0.15	0.15	0.15	0.14	0.14	0.14	0.13	0.14	0.15	0.14	0.17	0.16	0.16	0.15	0.16	0.16	0.15	0.15
CaO	1.15	1.16	1.15	1.12	1.15	1.14	1.12	1.13	1.14	1.13	1.12	1.19	1.03	1.54	1.17	1.11	1.17	1.16	1.18	1.18
Na ₂ O	5.11	4.81	4.70	4.80	4.60	4.49	4.76	4.72	4.51	4.61	4.63	4.61	4.35	4.08	4.02	4.29	4.30	4.30	4.32	4.43
K ₂ O	4.61	4.53	4.29	4.42	4.42	4.27	4.58	4.38	4.19	4.03	4.11	4.31	4.72	4.42	4.29	4.11	3.75	4.16	4.06	3.83
TiO ₂	0.11	0.12	0.12	0.11	0.10	0.10	0.12	0.11	0.12	0.12	0.12	0.12	0.12	0.13	0.12	0.13	0.13	0.13	0.13	0.13
Co	0.60	0.72	0.73	0.69	0.56	0.72	0.67	0.63	0.65	0.73	0.76	0.68	0.68	0.67	0.59	0.70	0.76	0.73	0.78	0.70
Rb	167	166	168	171	165	166	167	156	158	160	163	153	171	170	158	169	164	160	168	162
Sr	98.9	98.0	99.1	101	96.5	98.2	98.5	95.6	97.5	98.8	100.6	94.0	98.5	97.6	92.8	92.9	95.5	93.6	98.2	94.3
Y	20.5	20.4	20.3	20.7	20.2	20.3	20.1	20.2	20.2	20.6	21.1	19.9	21.3	21.1	20.0	19.9	20.5	20.1	20.8	20.2
Zr	144	145	145	148	141	143	149	143	144	146	149	142	154	153	145	147	148	145	151	145
Nb	19.6	20.6	20.3	21.2	18.5	20.4	20.6	20.6	20.8	21.1	21.1	20.4	22.2	22.1	19.8	21.5	21.2	20.7	21.7	20.7
Cs	7.16	7.22	7.22	7.40	6.38	6.44	6.36	6.39	6.43	6.09	6.26	5.88	6.83	6.83	6.35	7.15	6.42	6.30	6.57	6.23
Ba	568	570	570	580	556	560	574	548	558	561	572	552	598	599	558	581	574	565	585	572
Hf	4.15	4.22	4.18	4.20	4.15	4.19	4.31	4.09	4.12	4.16	4.08	4.08	4.03	4.06	4.13	4.12	4.23	4.18	4.21	4.26
Ta	1.60	1.83	1.77	1.77	1.57	1.77	1.79	1.76	1.78	1.89	1.78	1.75	1.76	1.77	1.74	1.83	1.85	1.79	1.83	1.79
W	2.68	3.16	3.07	3.12	2.39	2.82	3.33	3.12	3.13	3.04	2.86	3.04	3.08	3.09	3.00	3.72	3.46	3.40	3.48	3.50
Pb	27.8	27.8	27.6	27.5	27.9	27.4	27.4	27.9	28.3	28.8	28.3	28.0	26.0	25.9	26.9	26.4	27.4	27.4	26.9	27.4
Th	24.4	25.0	24.3	24.3	24.1	23.9	24.0	24.0	24.1	23.9	23.9	23.9	27.4	27.1	28.2	25.6	25.6	25.9	25.2	26.2
U	7.09	7.19	6.99	7.01	6.97	6.96	7.14	6.99	7.06	6.78	6.82	6.84	6.90	6.80	7.13	6.82	6.99	7.07	6.85	7.19
La	39.5	38.9	39.1	39.9	38.4	38.2	39.2	37.4	37.8	37.8	38.5	37.7	41.3	41.3	38.5	38.4	39.3	38.7	40.1	39.1
Ce	67.8	66.9	67.5	67.9	67.3	66.4	67.5	65.0	64.8	65.6	67.1	65.4	68.4	68.3	64.9	66.0	66.3	65.5	67.5	66.4
Pr	6.49	6.41	6.43	6.46	6.36	6.37	6.43	6.14	6.17	6.22	6.38	6.22	6.56	6.53	6.28	6.26	6.39	6.32	6.54	6.41
Nd	19.6	19.2	19.3	19.4	19.2	19.2	19.4	18.8	18.7	18.9	19.0	18.6	19.9	19.8	19.1	18.8	19.4	19.2	19.6	19.5
Sm	3.03	3.01	3.00	3.03	3.07	3.01	3.05	2.96	2.98	2.95	2.99	2.95	3.22	3.24	3.20	3.06	3.13	3.09	3.17	3.20
Eu	0.58	0.59	0.59	0.58	0.59	0.59	0.59	0.57	0.57	0.58	0.59	0.58	0.58	0.58	0.57	0.59	0.61	0.63	0.66	0.64
Gd	3.39	3.40	3.34	3.39	3.45	3.41	3.53	3.40	3.37	3.43	3.45	3.41	2.97	3.02	2.98	3.11	3.14	3.16	3.23	3.23
Tb	0.46	0.46	0.47	0.46	0.47	0.46	0.47	0.47	0.47	0.48	0.49	0.48	0.46	0.46	0.47	0.43	0.44	0.44	0.44	0.45
Dy	2.73	2.66	2.68	2.68	2.70	2.68	2.74	2.67	2.67	2.71	2.67	2.65	2.74	2.77	2.78	2.69	2.79	2.77	2.80	2.79
Ho	0.59	0.59	0.59	0.58	0.58	0.58	0.61	0.58	0.59	0.59	0.58	0.59	0.60	0.60	0.60	0.58	0.59	0.59	0.60	0.60
Er	1.87	1.86	1.80	1.85	1.80	1.83	1.82	1.76	1.78	1.79	1.80	1.79	1.90	1.90	1.92	1.82	1.86	1.86	1.86	1.89
Yb	2.20	2.21	2.20	2.21	2.20	2.14	2.19	2.10	2.16	2.17	2.18	2.13	2.22	2.20	2.22	2.11	2.20	2.15	2.17	2.21
Lu	0.36	0.36	0.36	0.36	0.35	0.35	0.36	0.35	0.34	0.34	0.34	0.35	0.35	0.35	0.35	0.35	0.35	0.36	0.36	0.36

(continued on next page)

Table 4 (continued)

	Çatal Höyük-Nenezi Dag																				Acigöl W
	OB 24	OB 25	OB 27	OB 28	OB 30	OB 31	OB 32	OB 33	OB 34	OB 35	OB 36	OB 37	OB 38	OB 39	OB 41	OB 43	OB 46	OB 47	OB 48	OB 49	OB 38
Al ₂ O ₃	13.61	13.63	13.77	13.86	13.78	13.34	12.95	13.15	12.77	13.65	13.45	13.53	13.29	14.05	13.56	14.09	13.84	13.71	13.76	13.60	
Fe ₂ O ₃	1.21	1.04	1.14	1.08	1.04	1.07	1.08	1.09	1.09	1.09	1.10	1.02	1.12	1.06	1.13	1.20	1.05	1.17	1.17	1.10	
MnO	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.07	0.07	
MgO	0.15	0.15	0.15	0.15	0.14	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.16	0.15	0.16	0.17	0.16	0.17	0.16	0.16	
CaO	1.17	1.14	1.16	1.22	1.15	1.16	1.24	1.25	1.23	1.20	1.20	1.18	1.20	1.20	1.17	1.13	1.13	1.16	1.12	1.16	
Na ₂ O	3.98	3.89	4.43	4.37	4.40	4.40	4.48	4.44	4.48	4.44	4.45	4.40	4.41	4.34	4.36	4.24	4.51	4.56	4.37	4.39	
K ₂ O	3.85	4.00	4.22	3.99	3.49	3.86	3.92	3.93	3.83	3.80	4.01	3.94	3.98	4.00	4.01	3.28	3.84	4.28	3.76	3.83	
TiO ₂	0.13	0.13	0.13	0.13	0.12	0.13	0.14	0.13	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.13	
Co	0.73	0.75	0.74	0.79	0.72	0.65	0.61	0.67	0.67	0.62	0.59	0.65	0.64	0.68	0.66	0.65	0.63	0.60	0.65	0.71	
Rb	160	162	166	165	164	162	167	155	161	155	160	158	156	168	166	176	162	162	164	170	167
Sr	94.1	95.3	97.0	97.0	95.9	93.5	95.8	90.5	92.6	90.2	91.5	91.3	90.3	97.0	95.7	99.9	94.4	94.5	96.0	99.7	1.47
Y	19.9	20.5	20.6	20.3	20.4	20.3	20.5	19.4	19.9	19.4	19.7	19.7	19.4	20.6	20.5	20.8	20.3	20.3	20.3	21.1	19.9
Zr	144	147	149	149	147	147	149	140	143	139	141	141	139	149	147	150	147	145	147	152	47.1
Nb	20.7	20.8	21.5	21.6	21.5	21.3	21.6	20.3	20.5	19.8	20.3	20.2	19.8	21.6	21.0	21.8	20.6	20.6	21.0	21.5	20.9
Cs	6.18	6.26	6.58	6.60	6.20	6.68	6.95	6.29	6.42	6.30	6.64	6.57	6.57	6.81	6.76	7.03	6.34	6.31	6.37	6.54	
Ba	565	571	580	584	580	564	582	556	565	555	558	553	553	586	579	590	568	560	570	579	2.96
Hf	4.21	4.22	4.29	4.26	4.18	4.13	4.13	4.17	4.17	4.18	4.21	4.20	4.22	4.20	4.26	4.01	4.19	4.20	4.06	4.18	2.04
Ta	1.81	1.78	1.85	1.87	1.84	1.85	1.81	1.82	1.80	1.80	1.77	1.79	1.78	1.84	1.82	1.82	1.81	1.75	1.78	1.79	1.50
W	3.53	3.46	3.64	3.73	3.71	3.24	3.19	3.28	3.17	3.14	3.18	3.19	3.20	3.32	3.28	3.40	3.32	3.20	3.26	3.26	
Pb	28.2	27.3	27.8	28.5	27.5	26.9	27.7	28.4	27.9	27.9	27.8	27.8	27.4	28.1	28.1	27.0	27.2	27.2	27.5	27.2	27.6
Th	26.4	26.1	25.9	26.8	26.1	26.4	26.5	26.5	25.9	26.2	25.8	25.8	25.9	25.9	25.9	25.8	24.9	25.3	25.2	24.9	13.5
U	7.29	7.11	7.14	7.39	7.29	7.14	7.20	7.20	7.20	7.18	7.17	7.11	7.12	7.38	7.36	7.16	6.97	7.06	7.10	6.92	6.09
La	38.6	39.3	40.1	39.7	39.7	39.3	40.0	38.8	39.0	38.4	38.6	38.4	38.6	40.2	39.8	40.5	39.7	38.7	39.2	39.9	7.83
Ce	65.9	66.3	67.7	68.1	67.5	65.7	67.3	65.7	66.1	64.8	65.4	64.9	65.1	68.1	67.7	69.1	66.5	65.5	66.4	68.2	16.5
Pr	6.36	6.42	6.55	6.50	6.47	6.37	6.50	6.33	6.37	6.29	6.31	6.29	6.28	6.52	6.52	6.56	6.44	6.31	6.37	6.58	2.04
Nd		19.5	19.9	19.7	19.6	19.3	19.4	19.2	19.3	19.2	19.2	19.2	19.3	19.8	19.7	19.8	19.6	19.3	19.4	19.9	7.35
Sm	3.12	3.18	3.22	3.20	3.21	3.10	3.13	3.13	3.13	3.12	3.11	3.10	3.09	3.20	3.18	3.14	3.22	3.10	3.13	3.17	2.00
Eu	0.65	0.65	0.63	0.62	0.62	0.53	0.53	0.53	0.53	0.53	0.54	0.52	0.52	0.55	0.55	0.56	0.57	0.57	0.56	0.57	0.022
Gd	3.21	3.21	3.11	2.96	2.99	2.97	2.99	2.99	3.05	3.11	3.08	3.08	3.07	3.21	3.16	2.81	2.75	2.81	2.79	2.82	2.14
Tb	0.45	0.45	0.44	0.45	0.45	0.44	0.44	0.44	0.44	0.44	0.44	0.43	0.43	0.45	0.45	0.44	0.45	0.45	0.45	0.45	0.41
Dy	2.71	2.78	2.79	2.79	2.80	2.70	2.69	2.75	2.76	2.76	2.70	2.73	2.71	2.76	2.75	2.66	2.75	2.71	2.70	2.77	2.86
Ho	0.60	0.60	0.61	0.61	0.60	0.59	0.59	0.60	0.60	0.60	0.59	0.59	0.58	0.60	0.60	0.59	0.61	0.60	0.60	0.62	0.62
Er	1.88	1.88	1.92	1.91	1.87	1.85	1.85	1.87	1.90	1.89	1.87	1.86	1.86	1.88	1.89	1.86	1.90	1.85	1.84	1.88	1.86
Yb	2.19	2.22	2.20	2.21	2.21	2.15	2.17	2.21	2.20	2.20	2.15	2.18	2.18	2.21	2.21	2.19	2.24	2.20	2.15	2.20	2.20
Lu	0.37	0.37	0.37	0.37	0.36	0.35	0.35	0.35	0.36	0.36	0.36	0.35	0.35	0.36	0.35	0.34	0.35	0.35	0.34	0.35	0.35

typically 25 μm in diameter and about 50 μm deep, and are virtually invisible to the naked eye. The analysis of each sample requires no preparation with the flakes of obsidian being placed directly into the ablation chamber of the laser ablation system. The analysis of each flake takes approximately 5 min. Full details of the analytical methods are given in Pearce et al. [43] and references therein.

Analyses were calibrated against the NIST 610 ‘Trace elements in Glass’ reference material using concentrations taken from Pearce et al. [42]. To produce quantitative trace-element analyses, LA-ICP-MS requires the knowledge of at least one element in the unknown to act as an internal standard (usually SiO_2 in rhyolitic materials). As no concentrations were known for any elements in the obsidian flakes analysed, a value of 69.895% was assumed for SiO_2 (the same concentration as in the NIST 610 reference material) to act as the internal standard, and to give approximate concentrations. Because of this estimate of the internal standard, the reported concentrations cannot be used directly for comparison (as they are calculated using this assumed value of the internal standard, and not the true concentration). Ratios of one element to another (e.g. Zr/Y, Zr/Nb or any other element pair), however, are correct (as the ratios are independent of the actual concentration), and these can be used in identifying groups within the data (Fig. 5). Similarly triangular discrimination diagrams plot the relative proportions of three elements, and can also be used in provenance/correlation studies (Fig. 6). To avoid any possible confusion, here only plots of the data are presented, the approximate concentration data from which they are derived is not presented, but would be available from the authors if needed.

LA-ICP-MS offers one advantage over solution analytical methods in that it is easy to identify in the analysis the presence of any mineral inclusions. Analyses that have ablated into invisible sub-surface micro-phenocryst phases (such as feldspar, zircon or apatite) in the obsidian can be easily recognised because of anomalous concentrations of Sr, Zr and LREE for example [41,43]. These analyses can be removed from the data sets so that only the glassy component of the obsidian is considered in the comparisons.

6.2. Data

Two distinct groups can be observed in the data, representing the southern Cappadocian sources of Nenezi Dağ ($n = 6$) and Göllü Dağ-East ($n = 28$), while a third chemical type is represented by one sample alone (Figs. 5 and 6). The first group comprises seven samples that form a clear grouping with high Zr/Nb and high Zr/Y ratios (Fig. 5), and correlate directly with the Nenezi Dağ group as identified at CNRS by Poupeau and Bressy: OB27, OB54, OB57, OB65, OB70, OB74, OB85. The second group of samples form the main cluster of analyses with 28 samples, and correlate with the Göllü Dağ-East analyses of CNRS: OB2, OB3, OB4, OB5, OB21, OB22, OB24, OB25, OB26, OB28, OB29, OB42, OB43, OB50, OB52, OB53, OB55, OB56, OB58, OB61, OB62, OB63, OB64, OB66, OB68, OB69, OB71, OB90.

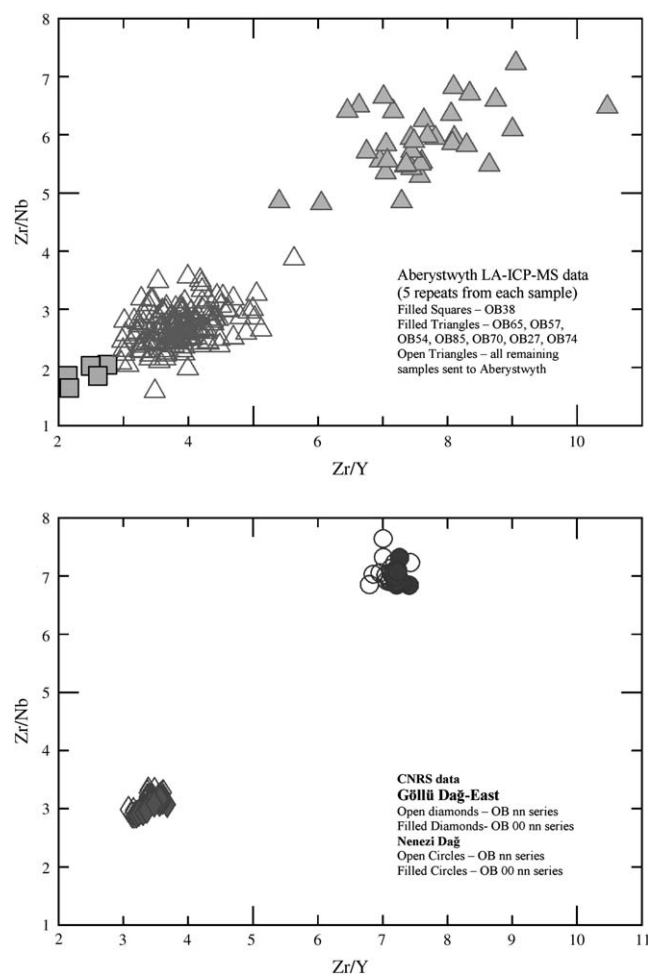


Fig. 5. Element/element ratio discrimination diagrams using Zr/Y vs. Zr/Nb determined by LA-ICP-MS at Aberystwyth.

There are some minor subdivisions evident in this second group that may merit further investigations, for example samples OB71, OB87 and OB4 often cluster together on many of the discriminant diagrams, having relatively low Ba. These variations form the cluster at the low Ba end of the main group of samples in Fig. 6. These may be subtle variations on the main groupings, but at present with only a few of each group present it is hard to be precise in defining these groups, if indeed they are real. These sub groups are clearly related geochemically (similar trace element ratios, etc.) and are likely to have originated from a very similar source, such as a series of lava flows from the same volcano, and may thus be a reflection of subtle compositional differences between such flows. Without comparative material from individual sources, it is not possible to be certain about the causes of this variation.

Finally, sample OB38-ABER identified initially by the LA-ICP-MS analyses at Aberystwyth stands alone in having the lowest Zr/Y and Zr/Nb ratios (Fig. 5), and having high Rb and Zr relative to low Ba (Fig. 6). It is clearly distinct from all other samples analysed by LA-ICP-MS and does not correlate with the Nenezi Dağ or Göllü Dağ-East sources. Further analyses by solution ICP-MS (Delerue, Milton and Poupeau) confirm the low Zr/Y and Zr/Nb of this sample. The sole

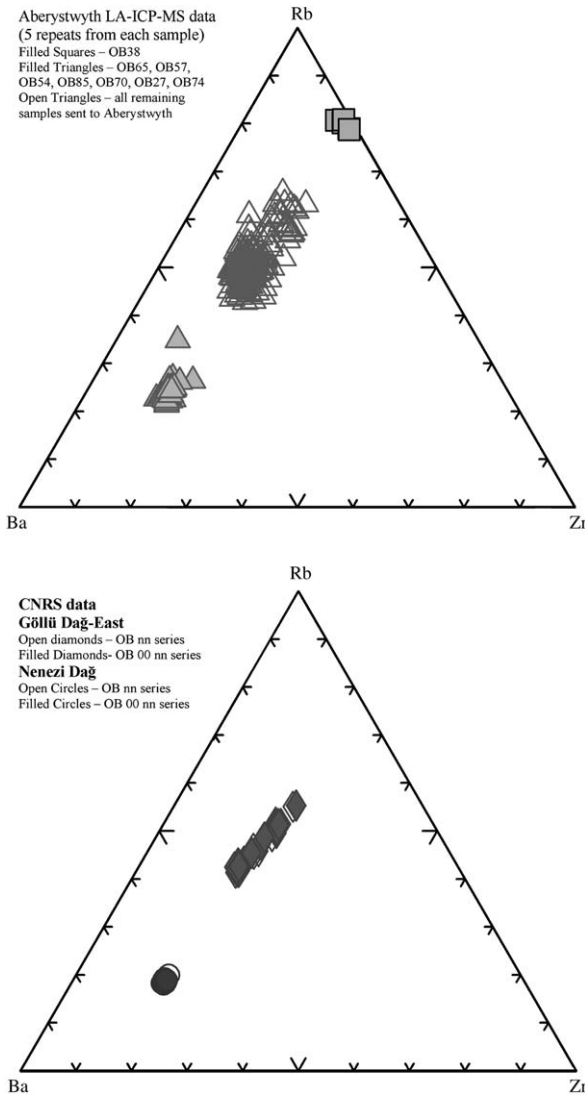


Fig. 6. Trace element discrimination diagram for obsidian flakes using Rb, Zr and Ba determined by LA-ICP-MS at Aberystwyth.

origin, with which this artefact shows strong affinities, in particular from its Sr, Zr and Ba contents, is with the geological obsidians of the Açıgöl West area (Table 5).

7. Discussion

Perhaps invariably, the data generated by our analyses have spawned more questions than they answered. Focusing for the time being on what we have learnt, it can be stated that all of the samples thus far analysed have a chemical signature congruent with a Cappadocian source (Tables 5 and 6). At present, the trace-elemental data allow us to assign the vast majority of them with some confidence to the ‘two’ southern sources of Göllü Dağ-East (*n* = 83) and Nenezi Dağ (*n* = 51), while one piece is believed to have come from Açıgöl West in northern Cappadocia (OB38-ABER). We refer to ‘two’ southern sources, but the Göllü Dağ-East signature, as defined by Poidevin in 1998 [46, pp. 115–121] actually represents three

Table 5
Source of Çatalhöyük obsidian by level

Level	Samples	Göllü Dağ-east	Nenezi Dağ	Açıgöl West
E. Chalcolithic I–II	7	3	4	–
III	2	–	2	–
VIB	1	1	–	–
VII–VI	79	38	40	1
VII	15	13	2	–
VIII–VII	10	8	2	–
VIII	16	15	1	–
IX	5	5	–	–
Total	135	83 (61.5%)	51 (37.8%)	1 (0.7%)

separate obsidian flows (Kayırlı-East, Kömürcü and Sirça Deresi) that could not be geochemically discriminated by the participant laboratories employing the analytical techniques described above (though see [29]).

Our new data thus corroborate Keller and Seifried’s assertions that Çatalhöyük was procuring obsidian from Göllü Dağ-East and Nenezi Dağ [34], as indeed were numerous other Aceramic and Early Neolithic settlements in central Anatolia and beyond. These include Canhasan III (Konya plain), Aşıklı Höyük and Musular (Cappadocia), Mersin (Cilicia), Shillourokambos (Cyprus), Byblos and Halula (Syria), Beisamoun (southern Jordan) and Mevorakh (coastal Israel) [22, pp. 285–292, figs. 5a-b, 7a-b]. For the (Late) Chalcolithic, the Aphrodisias in southwest Turkey has also produced obsidian from Göllü Dağ-East and Nenezi Dağ [13]. The issues of exactly how and when these sources were exploited, and Çatalhöyük’s position within the various modes of procurement and exchange, are crucially important questions that unfortunately lie beyond this paper’s scope and will be dealt with elsewhere.

While only one artefact is sourced to Açıgöl West (OB38-ABER) the piece is significant, not least for perhaps serving to rescue the earlier assignment of artefacts to the north Cappadocian outcrops [49,58]. It remains the case, however, that limited evidence exists for the exploitation of this obsidian, with only a handful of artefacts sourced tentatively to Açıgöl West, from Aceramic Neolithic Aşıklı Höyük (Cappadocia), Late Chalcolithic Aphrodisias (SW Turkey) and Bronze Age

Table 6
Source of Çatalhöyük obsidian by level and industry

Level	Obsidian industries						
	1	2	3	4	5	6	7
IX	●	–	–	ns	ns	ns	●
VIII	●	–	–	●	▲	–	●
VIII–VII	ns	–	–	ns	ns	–	●
VII	●	–	–	▲?	▲?	–	●
VII–VI	● ▲	–	–	● ▲	● ▲	–	● ▲?
VIB	●?	–	–	ns	?	–	ns
III	?	–	–	ns	▲	–	ns
Early Chalcolithic I–II	?	–	–	ns	● ▲	–	?

● – Göllü Dağ-east; ▲ – Nenezi Dağ; industries 2 and 3 not represented after Pre-Level XII.A, industry 6 not sampled/not represented after Level IX; uncertain whether industries 1 and 7 continue in later levels.

Hasek Hüyük (Middle Euphrates [22, pp. 279–285, Table 2]). As with Göllü Dağ-East, the Acıgöl West geo-chemical ‘source’ currently subsumes a number of distinct outcrops, namely: Karnıyarık, Kuzeytepe, Kalecitepe, Güney Dağ, Koru Dağ-North/South and “Acıgöl crater” [46, p. 113, fig. 6].

Turning to the negative evidence, we still lack evidence for obsidian coming from Çatalhöyük’s closest source, Hasan Dağ (Fig. 1), the mountain occasionally visible from the site, its double-peaks allegedly represented in a wall painting from Shrine VII, 14 [38, pp. 176–177, pl. 59–60]. Mellaart claimed that the mountain’s depiction symbolized the significance accorded the source of Çatalhöyük’s obsidian, ‘from which the site probably derived much of its wealth’ [38, p. 177]. It has since become clear, however, that the obsidian at Hasan Dağ is difficult to access and possesses a poor conchoidal fracture habit; moreover, analyses have failed to link any archaeological obsidian to this mountain, suggesting that it may never have been exploited [17 (p. 252), 22 (pp. 292–293)]. Nor have our analyses provided any corroborative evidence for Renfrew’s alleged piece of Armenian obsidian, though we have little problem with the idea that such material might be recovered at Çatalhöyük (particularly from the later levels).

Since our analyses were run, matters have become somewhat more complicated, with renewed work at the sources demonstrating that at least 10 spatially and geologically distinct outcrops exist on the Göllü Dağ massif [31], as opposed to the six discussed originally by Poidevin (Göllü Dağ-East and West [46, pp. 115–121]). Furthermore, it is claimed that a more fine-tuned discrimination of the sources can be achieved through combined geo-chemical, geo-chronological and structural analyses, with four groups distinguished thus far. Of significance to this paper, is the claim that Kaletepe-Erikli dere Birtlikeler and Ekinlik can now be discriminated, outcrops that were previously subsumed in the Göllü Dağ-East field; most of the known Neolithic workshops cluster around these outcrops (two of which were once termed ‘Kömürücü’ [31]). Some of the current authors have subsequently interrogated our data further, the results provisionally suggesting a potential separation of our old Göllü Dağ-East field, however we need an increased compositional data-bank of geological samples (not least matching the newly mapped outcrops), before we can further develop these important lines of enquiry [47].

7.1. The relationship between technology and source through time

The above statements offer only the simplest appraisal of our new data, for there are far more nuanced patterns that one can observe in Çatalhöyük’s consumption of these obsidians, particularly when one considers the artefacts’ technology and date. Studies of the chipped stone from the 1995–1999 excavations, spanning Level Pre-XII.D–Level V–IV, have demonstrated that obsidian was circulating in different forms and being worked by various techniques at any one time [15]. This evidence for parallel *chaînes opératoires* is a recurrent feature of Çatalhöyük’s obsidian assemblages; the nature

of production and tool-types change through time, but technological variability is a constant throughout the site’s history. Seven industries have thus far been documented, a proportion of which were sampled in the current analysis (data summarised in Tables 5 and 6).

7.1.1. Industry 1

Çatalhöyük’s dominant industry from its basal levels (Level Pre-XII.D), up to at least Level VI.B; the manufacture of small, un-standardized blades and blade-like flakes from opposed platform cores (Fig. 2a–e), a relatively low-skilled percussive technique that was performed locally. The tradition is documented at other central Anatolian sites, including Canhasan III (Aceramic Neolithic [15]). Many pieces from this industry were characterised, including end-products, cores and rejuvenation material, from Level IX (OB31, OB 33, OB34), Level VIII (OB3, OB20, OB21, OB23, OB24, OB90), Level VII (OB6, OB7, OB9, OB10, OB14, OB16), Level VII–VI (OB5, OB8, OB56, OB42-ABER, OB43-ABER, inter alia) and Level VI.B (OB1), all being sourced to Göllü Dağ-East. Only Level VII–VI produced *industry 1* blades and cores made from Nenezi Dağ obsidian (OB37-CNRS2, OB38-CNRS2).

7.1.2. Industry 2

Regular prismatic microblades/microliths manufactured on-site during Level Pre-XII.B–D, part of a central Anatolian Aceramic Neolithic tradition (cf. [3 (pp. 142–143), 5 (p. 82 & fig. 2.4–6)]), albeit one that ultimately has an Epi-Palaeolithic heritage [14, 33]. None of these products were analysed.

7.1.3. Industry 3

Long blade-like burin spalls flaked from the margins of non-local scrapers and projectiles; similar material is reported from Aşıklı Höyük in Cappadocia (Aceramic Neolithic [4, p. 211 & fig. 11.10]). None of these ‘edge blades’ were sourced.

7.1.4. Industry 4

Bipolar prismatic blades of non-local manufacture. This ‘industry’ subsumes a number of different knapping traditions through time, the lack of associated cores making it difficult to offer further subdivisions. Examples made from Göllü Dağ-East obsidian are attested in Level VIII (OB2, OB26 [Fig. 2f]), while in Level VII–VI we have evidence that both south Cappadocian obsidians were used to make bipolar blades (Göllü Dağ-East – OB36-CNRS1, OB20), with the Nenezi Dağ samples (e.g. OB25) including large fine naviform products from a hoard (OB15/OB44, OB49-CNRS1 [Fig. 2u, v]); the latter raw material is further represented by an *industry 4* rejuvenation flake from Level VII (OB15).

During the Aceramic Neolithic we know that bipolar blades were being produced at both settlements (e.g. Aşıklı Höyük [1]) and quarries, the latter evidenced by excavations at Kaletepe sector P, atop Göllü Dağ’s Kömürücü outcrop [6 (pp. 194–199), 7 (p. 136)]. For the Early Neolithic period things are less clear due to a lack of excavated data. Surface surveys have, however, recorded concentrations of opposed platform

cores on Nenezi Dağ and at Bitlikeler (Göllü Dağ), an apparently long-lived workshop on the Kayırlı flow [7, pp. 135–137, figs. 4.1 & 12]; the new Çatalhöyük characterization data suggest that these assemblages may, in part, date to the 7th millennium BC (Level VIII–VII). Arguably our results take on a further significance at this juncture, as they allow us to start to indirectly describe the nature of production at the sources, offering information as to what was being manufactured and when.

7.1.5. Industry 5

Unipolar prismatic blades (pressure and skilled percussion) whose manufacture is almost certainly non-local up to Level VI.A [24]; the varying widths of these products suggests that this ‘industry’ again includes a number of different techniques. Analysis indicates *industry 5* blades are represented in both obsidians, their lips usually removed by flaking, suggesting that certain knapping traditions were not raw material specific. Samples sourced to Göllü Dağ-East (Fig. 2g–i) came from Level VIII (rejuvenation flake [OB27]), Level VII–VI (rejuvenation flake and blades [OB3, OB5, OB29, OB63]) and Çatalhöyük West (Early Chalcolithic II [OB81-CNRS1]). Most of the Level VII–VI examples were made of Nenezi Dağ obsidian (OB47-CNRS2, OB28, OB23, OB31, inter alia), while Level III (OB75) and Çatalhöyük West (Early Chalcolithic I [OB77-CNRS1, OB 79-CNRS1]) produced unipolar blades made from the same raw material (Fig. 2m–t).

As with the opposed platform blade technologies, our best (excavated) evidence for unipolar blade production in central Anatolia comes from Aceramic Neolithic sites, both settlement (e.g. Aşıklı Höyük [1]) and quarry workshops, not least Kaletepe sector P on Göllü Dağ [6 (pp. 199–200), 8 (p. 249 & 253, figs. 7 & 11.1)]. Surface concentrations of single platform regular prismatic blade cores have also been found at Bitlikeler (Kayırlı outcrop) and Nenezi Dağ [4, 135–137, Table 1].

7.1.6. Industry 6

Level Pre-XII.D–B (Aceramic Neolithic) produced a series of large, flat flakes used to make scrapers. These pieces may derive from a distinct reduction sequence, or could be by-products from a large bipolar blade industry. Parallels are known from Aşıklı Höyük and other Cappadocian sites of similar date (cf. [14, p. 215 & figs. 4, 5 & 7]); none were sampled.

7.1.7. Industry 7

Up to Level VI.B, most of Çatalhöyük’s obsidian entered the site in the form of thick part-worked flakes – some worked into side-scrapers – that were likely knapped at the quarries; most complete examples come from hoards [26]. These ‘quarry flakes’ again embody more than one *chaîne opératoire*, with some representing biface preforms, while others became the cores for *industry 1*. Most of the *industry 7* samples were characterised as being made of Göllü Dağ-East obsidian (Fig. 2j–l), with a possible biface preform from Level IX (OB30), possible biface thinning flakes from Levels VIII and VIII–VII (OB4, OB58, OB 66), fragmentary ‘quarry flakes’ from Level VII (OB11, OB13, OB19, OB89), biface thinning flakes (OB64)

and broken ‘quarry flakes’ (OB10, OB40-CNRS2, OB35-CNRS1) from Level VII–VI. These results were perhaps to be expected. Large flakes/scrapers have been recovered found on the surface at the Kayırlı (Bitlikeler workshop) and Kömürçü outcrops [17, pp. 257–264, figs. 7 & 12], while a workshop producing biface preforms has been investigated at Kaletepe sector M (Kömürçü) has long been suggested at the source of the Çatalhöyük hoard material [6 (pp. 200–201, fig. 7), 17 (p. 270)]; we have now provided the archaeometric data to prove the link. Interestingly, Level VII–VI also produced a few possible *industry 7* ‘quarry flakes’ sourced to Nenezi Dağ (OB35-CNRS2, OB33, OB49-CNRS2).

8. Conclusions

Even allowing for the fact that the 135 artefacts neither represent all of the industries thus far defined, nor all of the excavated levels, it remains apparent that significant temporal and technological differences existed in Çatalhöyük’s exploitation of Cappadocia’s raw materials (Tables 5 and 6). Firstly, Göllü Dağ-East obsidian enjoys a long history of use and dominates the earlier assemblages, almost 90% of those artefacts analysed from Levels IX to VII ($n = 41/46$, 89%). In contrast, there is a marked upswing in the use of Nenezi Dağ obsidian approximately half-way through the Early Neolithic occupation sequence, constituting just over half of the samples from Level VII–VI and later ($n = 46/89$, 52%). Moreover, there is a technological component to this pattern, because the increased consumption of Nenezi Dağ obsidian correlates directly with unipolar pressure-flaked blade technology (*industry 5*) becoming the mainstay industry at Çatalhöyük. Significantly, this shift coincides with a number of other changes at the site around Level VI.B in lithic, ceramic and building technologies [24, 36 (pp. 295–296), 37 (p. 172)]; we return to this issue below.

8.1. Modes of consumption: Levels IX–VII

During Levels IX to VII the Göllü Dağ-East obsidian(s) embody a number of distinct *chaînes opératoires*, the raw material entering the site in different forms and being consumed in different ways. Much of Çatalhöyük’s obsidian arrived as large, thick, largely decorticated flakes that had been knapped at the Kayırlı and Kömürçü outcrops [17, pp. 257–264, figs. 7 & 12] and then transported in bulk to the site (*industry 7*), where they were buried in intramural hoards [26]. When retrieved from their sub-floor caches the flakes were knapped to produce the small blades and blade-like flakes of *industry 1*, our dominant ‘in house’ tradition at pre-Level VI.B Çatalhöyük. The biface preforms almost certainly came from Kaletepe sector M [6, pp. 200–201, fig. 7], their final shaping into spearheads occurring within the houses. While none of our *industry 7* samples came from hoards, we feel confident that future analyses will demonstrate that most of these ‘quarry flakes’ are made of Göllü Dağ-East obsidian; indeed, most of the related *industry 1* material from Levels IX to VII contexts were provenanced to this source.

While *industry 1* represents the primary mode of consuming Göllü Dağ-East obsidian(s) during this period, the raw material was also being used in other traditions, as evidenced by the two bipolar prismatic blades (*industry 4*) from Level VIII. The lack of associated manufacturing debris suggests that these blades arrived ready-made, having possibly been knapped at the quarries; the Bitlikeler workshop is perhaps the likeliest origin given that Kaletepe seems to have mainly operated at an earlier date [7 (pp. 136–138, fig. 12),36]. The only diagnostic piece of Nenezi Dağ obsidian from Levels IX to VII is a rejuvenation flake from a bipolar prismatic blade core (Level VIII); the nucleus itself had almost certainly been prepared and reduced at a quarry workshop (see [7, pp. 135–136, fig. 4.1]).

8.2. Modes of consumption: Levels VII–VI to Early Chalcolithic I–II

We turn now to the major changes in obsidian procurement post Level VII, specifically Çatalhöyük's increased reliance upon the Nenezi Dağ source. Only 11% ($n = 5/46$) of the Levels IX to VII artefacts analysed were characterised as being made of Nenezi Dağ obsidian, a figure that leaps to just over 50% of the Level VII–VI to Early Chalcolithic samples (Tables 5 and 6). Significantly, this period not only witnesses a major change in source exploitation, but also a radical shift in knapping traditions [24]. It is contended that these changes in procurement and production were related integrally.

In 1999 Conolly discussed a 'profound change' in obsidian consumption at Çatalhöyük after Level VI.B, with a shift from flake- to blade-based assemblages and a concurrent transformation in blade technology from percussion to pressure-flaking, with manufacture furthermore becoming a more exclusive affair [24]. It was claimed that the shift to pressure-flaked blade production related to contemporary agricultural intensification (which required a more appropriate toolkit), while at the same time representing a medium for the creation of social distinction in the community. The latter argument drew on a wealth of literature that has documented this technology's highly skilled nature (cf. [27,54]) and the potential social ramifications for the adoption of a craft that patently lends itself to specialization (cf. [23]). Our programme of obsidian sourcing has produced data that require a reappraisal of these arguments.

The first point to make is that we are no longer talking about just a change in knapping technology; this is a dual shift, a new tradition based on a raw material that had previously witnessed little use at Çatalhöyük. Ergo, we have here evidence for a radical realignment of procurement and production strategies, involving greater interaction with those people working at the Nenezi Dağ quarry workshops. Secondly, it is now clear that we are not dealing with a simple 'early: flake industry/late :: blade industry' dichotomy, as numerous industries existed in tandem at any one time (blades also being a component of our Aceramic Neolithic assemblages). Thirdly, while unipolar prismatic blade industries do indeed become the mainstay mode of production in Çatalhöyük's later levels, the situation is more complex than envisaged originally, with recent work indicating that these blades were being made not only by

pressure-flaking, but also percussion techniques [16]. While both sets of end-products are of similar size and share technical features such as lip removal by flaking, their manufacture would have involved different tool kits, motor habits and arguably levels of skill (cf. [44]). In future we have to distinguish these traditions, where possible. Fourthly, the 2004 excavations further suggested that the new technology's introduction may have a spatial as much as a temporal character, i.e. that there may have been 'hot spots' in terms of where these blade industries were first introduced at Çatalhöyük, with other parts of the community lagging behind [16].

These more nuanced perspectives on technical change half-way through Çatalhöyük's Early Neolithic sequence do not in themselves answer why the shifts occurred in the first place. It is at this point that we rapidly become frustrated by the lack of excavation data pertaining to this period from the Cappadocian sources and other central Anatolian sites, as research in these areas tends to have been biased towards the Aceramic Neolithic and the region's links with the Near East (cf. [12]). Ultimately we may be witnessing the effect of some form of "external dynamism" [53, p. 18], with the emergence of a new form of interaction between central Anatolian populations (not least members of the Çatalhöyük community) and peoples living in Cilicia, south-eastern Anatolia and the northern Levant, where unipolar blade technologies were well established prior to their major impact at post Level VI.B Çatalhöyük (cf. [40]).

9. Final comments

While one of this project's strengths is its sample size, there remains room for improvement with regard to the sampling strategy itself. Some of these issues can be rectified relatively easily, for instance filling the chronological lacunae and sampling each of the industries. In turn, one could have a more even distribution of material amongst the various buildings within each level. Arguably, these are all minor considerations in the context of what we claim should be the structuring principle of a meaningful sampling strategy: it is only *after* one has undertaken a full technological and typological analysis and gained an in-depth understanding of an assemblage that one is justified in selecting artefacts for sourcing.

There has been a habit in obsidian provenience studies to select relatively insignificant debris for export to laboratories, largely due to limitations on the movement and/or destruction of 'museum quality' finds. We essentially followed this tradition, our samples dominated by relatively inconspicuous, small and broken flakes, albeit selected carefully on the basis of their date, context and visual characteristics. Unfortunately, many of these artefacts are technologically undiagnostic and cannot be assigned to specific industries. With hindsight, we appreciate that this approach was flawed and that we need to target samples that can be related directly to our various traditions. The amount of time and money spent undertaking a sourcing project is not insignificant, from the selection of the obsidian, its recording and illustration, via the paperwork associated with exporting the material, the time expended in sample preparation, the running costs of the instrumentation,

to the analysis and presentation of the data. As such the archaeologist shoulders a great responsibility in making sure that the intellectual return on this investment is maximised.

It was stressed at the outset that this paper represents the results from our first set of analyses and deals with only some of our research foci; much work remains. Indeed, the next stage of Çatalhöyük's obsidian characterization programme has already commenced, involving new laboratories and analytical techniques. The ramifications for an inter-laboratory approach, and the use of more than one analytical technique, are important issues that do not fit the remit of this paper and will, in due course, be explored more fully elsewhere. We note, however, that while the application of LA-ICP-MS (see also [41,45,57]) cannot produce quantitative trace element concentrations in the absence of an internal standard, accurate trace element data can be produced to give accurate element/element ratios for sourcing and discrimination. Incompatible trace element ratios (e.g. Zr/Y, Zr/Nb) determined by LA-ICP-MS at Aberystwyth are in the same range as those obtained at Grenoble, particularly when the possibility of contamination of the bulk obsidian analyses by mineral inclusions is considered (see above). Pearce et al. [41,43] discuss the issues surrounding the comparison of bulk glass analyses with microanalyses. LA-ICP-MS is also a rapid and essentially non-destructive method technique (the analysis of each flake takes about 5 min) and requires no sample preparation (grinding, acid digestion, dilution, etc.) and thus has great value in archaeological studies where material is precious. Thus, with permission to export samples, we should be able to characterise each of our traditions; until such inclusive analyses have been undertaken, the reader should be aware of the biases in the data presented in this paper.

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