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To cite this version:

Marie Orange, Tristan Carter, François-Xavier Le Bourdonnec. Obsidian consumption at Qdeir 1, a Final Pre-Pottery Neolithic site in Syria: An integrated characterisation study. Comptes Rendus. Palevol, 2019, 18 (2), pp.268-282. 10.1016/j.crpv.2018.08.002 . hal-02077604

C. R. Palevol 18 (2019) 268–282

Contents lists available at ScienceDirect

Comptes Rendus Palevol

www.sciencedirect.com

Human Palaeontology and Prehistory (Prehistoric Archaeology)

Obsidian consumption at Qdeir 1, a Final Pre-Pottery Neolithic site in Syria: An integrated characterisation study

Économie de l'obsidienne à Qdeir 1, site du Néolithique précéramique final en Syrie : étude de caractérisation intégrée

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ARTICLE INFO

Article history:
Received 10 August 2018
Accepted after revision 29 August 2018
Available online 11 December 2018

Handled by Marcel Otte

Keywords:
Obsidian
Geochemical characterisation
Lithic study
Syria
Neolithic
ED-XRF
SEM–EDS

Mots clés :
Obsidienne
Caractérisation géochimique
Étude lithique
Syrie
Néolithique
ED-XRF
SEM–EDS

ABSTRACT

This paper details an integrated characterisation study of a substantial assemblage of obsidian artefacts ($n = 519$) from the Syrian Neolithic site of Qdeir 1 (El Kowm oasis). The results of the chemical characterisation (using ED-XRF and SEM–EDS) have been coupled with the typo-technological data. Such an approach has allowed us (i) to identify four raw materials in the assemblage, namely Bingöl A and Bingöl B from eastern Anatolia, plus Göllü Dağ and Nenezi Dağ from central Anatolia, (ii) to specifically source the distinctive green peralkaline obsidian to Bingöl A (rather than 'Bingöl A and/or Nemrut Dağ'), (iii) to observe that these four raw materials were consumed in a nigh-identical manner, probably worked locally by specialist craftspeople to produce fine pressure flaked blades, and (iv) to hypothesise that the people of Qdeir 1 may have played a key redistributive role in the circulation of obsidian tools, likely supplying the neighbouring village of El Kowm.

RÉSUMÉ

Cet article présente une étude de caractérisation intégrée d'un assemblage d'artefacts en obsidienne ($n = 519$) provenant du site Néolithique de Qdeir 1 (Syrie, oasis d'El Kowm). Les résultats de la caractérisation chimique, menée par ED-XRF et SEM–EDS, ont été couplés aux données de la lecture typo-technologique. Une telle approche nous a permis (i) d'identifier l'utilisation de quatre matières premières au sein de l'assemblage, soit Bingöl A et Bingöl B (Anatolie orientale), ainsi que Göllü Dağ et Nenezi Dağ (Anatolie centrale), (ii) de spécifier l'origine des artefacts de composition peralcaline (Bingöl A), (iii) de montrer

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https://doi.org/10.1016/j.crpv.2018.08.002

que les matières premières en question ont été consommées d'une manière similaire, probablement travaillées localement par des tailleurs « spécialisés » pour produire des lames débitées par pression, (iv) d'argumenter que les habitants de Qdeir 1 ont pu jouer un rôle dans la redistribution des outils en obsidienne, certainement en approvisionnant le village voisin d'El Kowm.

1. Introduction

Obsidian characterisation studies have enjoyed a recent resurgence, the work being employed to engage with a range of major questions in anthropological archaeology (Freund, 2013). Arguably obsidian sourcing is one of archaeological science's greatest success stories, the unique chemical profile of each geological source enabling archaeometers to provenance an artefact's raw material through matching their elemental signatures (Glascock et al., 1998). In this paper, we employ an obsidian characterisation method to reconstruct the nature, direction, and intensity of contact between prehistoric populations in the Near Eastern Neolithic (*cf.* Chataigner, 1994).

Methodologically we follow a recent turn in the development of more integrated characterisation studies that try to maximise the potential of both aspects of an artefact's 'character', *i.e.* working within a '*chaîne opératoire*' framework that considers both elemental composition and typo-technological form (following such work as Briois et al., 1997; Carter et al., 2006; Le Bourdonnec, 2007; Poupeau et al., 2007). Thus instead of talking about 'samples', we reintroduce the terminology of the archaeologist and technologist, discussing how an obsidian from 'source X' may have arrived at the site in the form of 'ready-made unipolar pressure blades', while the obsidian from 'source Y' was procured in the form of 'raw nodules, then knapped on site using an opposed platform percussive blade technology' *inter alia*. Therefore, the integration of these two types of studies leads us to consider the 'consumption' of obsidian in a much more holistic fashion (its overall 'economy'; see Orange et al., 2017).

Another important aspect of this study is the sample size, as until quite recently most characterisation studies tend to be restricted to a handful of artefacts per site (cf. Renfrew et al., 1966), a factor that ultimately limits a project's interpretative potential. Recently there has been a conscious development in obsidian sourcing to characterise larger data sets ('law of large numbers', Shackley, 2005) to enable the analyst to gain a more representative sample of the assemblage and a clearer insight into the nature of procurement and production (see also Mills et al., 2013; Reepmeyer et al., 2011).

In this study, we aimed to (i) compare two different methods for the provenance analysis: an energy dispersive X-ray fluorescence spectrometer [ED-XRF] and a scanning electron microscope with an energy dispersive spectrometer [SEM–EDS], (ii) to limit issues of sampling representativeness by analysing the vast majority of the Qdeir 1 obsidian assemblage (Fig. 1), and (iii) to integrate raw material provenance data with the artefacts' typo-technological characteristics.

A previous paper (Orange et al., 2013) presented the methodological implications of our study, discussing the significance of a combined ED-XRF/SEM–EDS analysis on a large quantity of artefacts from Qdeir 1 and another Syrian Neolithic site, Tell Aswad (Fig. 1). In this paper, we now focus on the results from Qdeir 1, integrating typo-technological observations with the sourcing data to enable a richer characterisation of how obsidian was consumed at the site (the 'obsidian economy'). In turn, we then locate our Qdeir 1 data and conclusions within a broader synchronic regional context, thus allowing us to better understand the role of this community within larger networks of obsidian exchange and dissemination, particularly with regard to its neighbouring site of El Kowm. By extent, our study tackles the question of the importance of nomadic groups during the final Neolithic period (*cf.* Cauvin, 1994).

2. Qdeir 1: a Final PPNB nomadic settlement

The site of Qdeir 1 (Fig. 2) is situated in the El Kowm oasis in northern Syria (Fig. 1), and was first located in 1980 by Olivier Aurenche, with subsequent excavations by the '*Mission d'El Kowm-Mureybet*' directed by Jacques Cauvin (1981), revealing a Final Pre-Pottery Neolithic B [PPNB] settlement dated 7100–5720 cal BC (Stordeur, 1993, 2000; Table 1). Aurenche's survey demonstrated that the El Kowm oasis contains a number of prehistoric settlements (Fig. 1), including El Kowm, Qdeir 1 (Stordeur, 2000) and Umm-el-Tlel (Molist et al., 1992). A larger-scale excavation was initiated in the late 1980s, initially directed by Danielle Stordeur (in 1989, 1991 and 1993), and subsequently by Frédéric Abbès (in 1999, and 2001–2003). The site is estimated to be c. 2000 m^2, of which some 200 m^2 have been excavated (Abbès, 2015). While El Kowm and Qdeir — 8 km apart — were both occupied during the Final PPNB, they displayed sufficient occupational differences to warrant attribution to two distinct cultural facies (Cauvin, 1994). While El Kowm was a village with a long and complex settlement history, with at least five different levels of occupation spanning 7100–4230 cal BC (Stordeur, 2000), Qdeir 1 comprised an exceptionally well preserved nomadic camp, consisting of only a few architectural structures, a semi-permanent camp, and a workshop for the manufacture of flint implements (Abbès, 2015; Besançon et al., 1982; Stordeur and Wattez, 1998). A total of four occupation phases have been defined (*Ibid.*; Gourichon, 2004), two with architectural structures (isolated houses 1

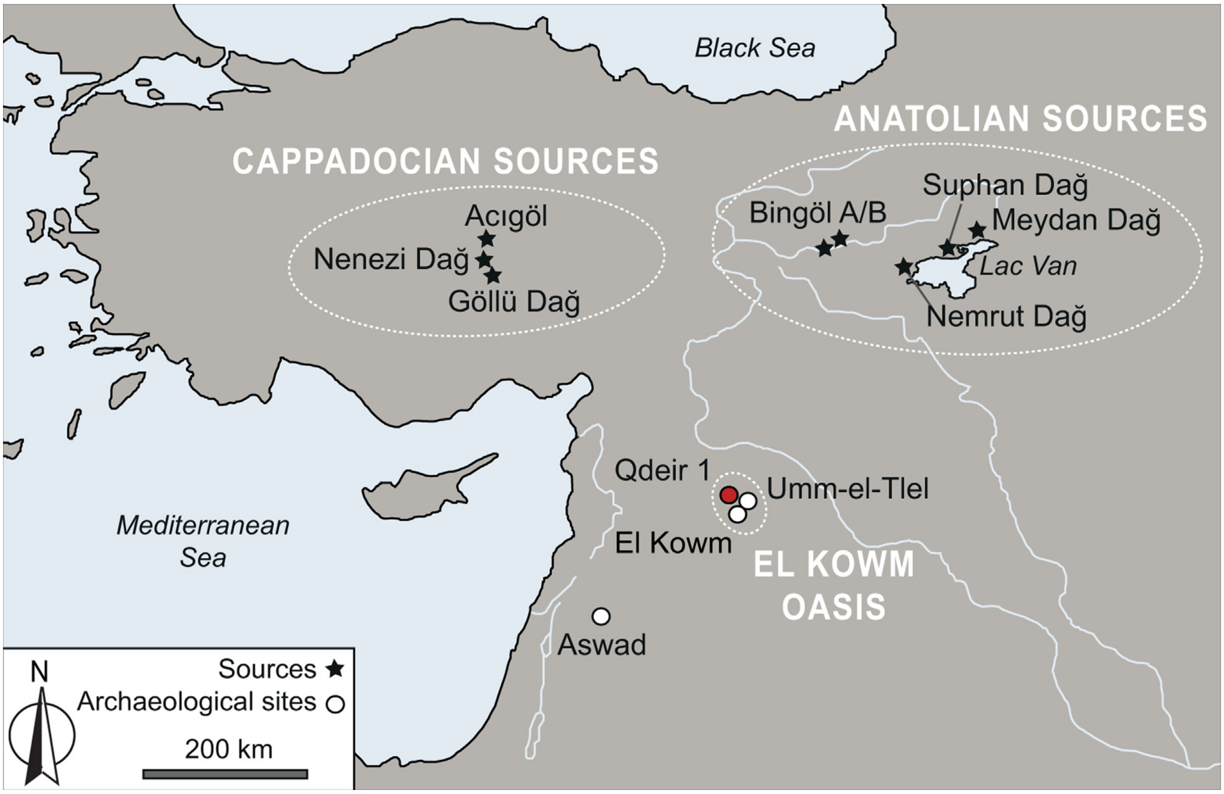

Fig. 1. Map showing the main archaeological sites and obsidian sources mentioned in the text.

Fig. 1. Carte des principaux sites archéologiques et sources d'obsidienne mentionnés dans le texte.

and 2; phases II and IV), and two without (phases I and III). These characteristics led Qdeir 1 to be classified as belonging to some specific facies of the PPNB, the 'desert PPNB'. While distinct in size, location, and nature of occupation, these three sites have all produced evidence for the use of obsidian, an exotic raw material whose closest sources lay hundreds of kilometres to the north in central and eastern Anatolia (Fig. 1); this material was mainly recovered in the form of pressure blades and bladelets (Cauvin and Chataigner, 1998).

Part of the Qdeir 1 chipped stone assemblage was studied and published in the 1980s, albeit with modest attention to the obsidian itself, due to the limited number of artefacts found at this point (Calley, 1986; see also Cauvin, 2000).

3. The Qdeir 1 chipped stone assemblage and sampling protocols

Our study involved the analysis of each artefact that was available to us (the remaining pieces being in Syria), *i.e.* the 519 artefacts coming from the excavation campaigns of 1979–1980, 1989, 1991, 1993, and 2000. While exact figures were unfortunately not available to us (nor likely to be accessible in the near future given the political situation in Syria at the time of writing), the relative proportion of obsidian to flint within the chipped stone assemblage is known to be quite low (F. Abbès, *pers. comm.*). The volume of worked flint per cubic meter has been estimated at > 12,000 pieces, equivalent to 22 kg of raw material (Calley, 1986). Most of this flint appears to have been procured from an outcrop 4 km north-west of Qdeir, an easily accessible source that provided raw nodules of excellent quality (Calley, 1986). The flint was used primarily for the manufacture of bi-directional blades knapped from opposed platform/naviform cores (Calley, 1986; see also Abbès, 2003), a particularly productive technology, with estimates of 26/27 blades and 13/14 bladelets per core (Calley, 1986). Perhaps unsurprisingly, given the proximity of the source, the flint assemblage contains a significant quantity of early-stage reduction knapping debris, with a relatively high proportion of cortical waste (29%, *Ibid.*). As we document below, it is in stark contrast to the obsidian assemblages, which are dominated by end-products and late-stage manufacturing pieces. The relative proportion and range of modified flint implements is greater than that witnessed in the obsidian assemblage, with 31 arrowheads, 156 burins, 108 scrapers, and ten sickle blades reported from the 17,642 artefacts of the GY and GX surveys sectors from the 1980 excavation (Aurenche and Cauvin, 1982). Flint and obsidian seem to be the only raw materials employed by the community to manufacture flaked stone implements, with the exception of one chisel blade executed on greenstone (Aurenche and Cauvin, 1982).

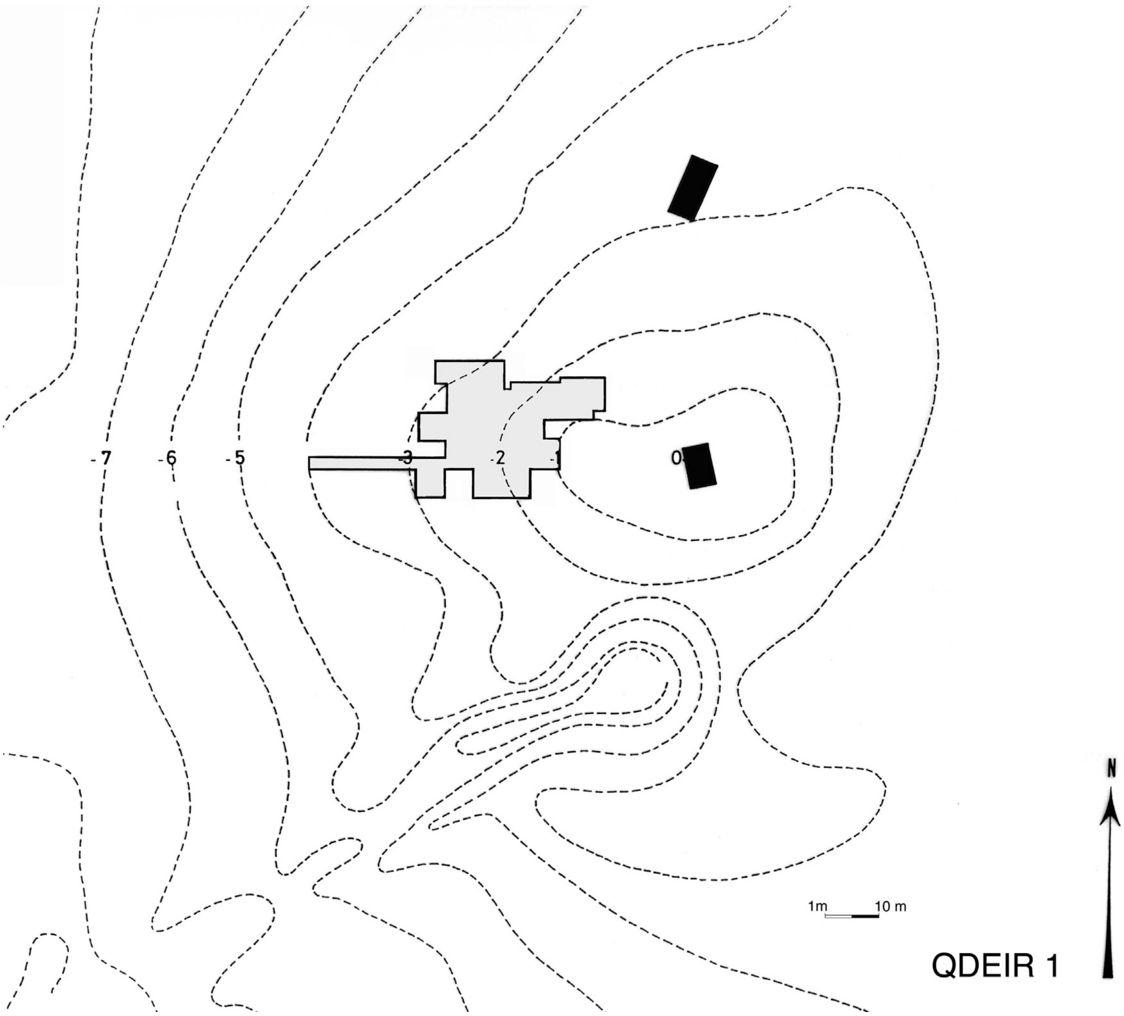

Fig. 2. General map of the Qdeir 1 tell. Courtesy of F. Abbès.

Fig. 2. Plan général du tell de Qdeir 1. Avec la permission de F. Abbès.

Table 1
Radiocarbon dates obtained from the site of Qdeir 1. Data from the BANADORA website [http://www.arar.mom.fr/banadora/] and Stordeur, 1993.

Tableau 1
Dates radiocarbone obtenues pour le site de Qdeir 1, provenant de la base de données en ligne BANADORA [http://www.arar.mom.fr/banadora/] ainsi que de Stordeur, 1993.

Dating reference	Sample location	Calibrated date
Lyon-2338	CAR.EB 96 - US 3	7175–6700 BC
Lyon-2339	CAR.EL76 - Sond. E	7297–6840 BC
Lyon-2340	CAR.EL76 - Sond. E	7176–6702 BC
Ly-2578	nd	7100–5720 BC

4. Obsidian sourcing

In our study, we used two non-destructive geochemical characterisation techniques that have been widely employed for obsidian sourcing in the Mediterranean and Near East, namely SEM–EDS (*cf.* Acquafredda et al., 1999; Le Bourdonnec et al., 2010) and ED-XRF (cf. Carter and Shackley, 2007; Carter et al., 2013; Poupeau et al., 2010). The operating conditions for each method are detailed in an earlier paper (Orange et al., 2013); we present here instead a discussion on the repeatability and accuracy of our measurements (concepts discussed in Frahm, 2011).

4.1. Obsidian characterisation: Using SEM–EDS

4.1.1. Repeatability and accuracy

To assess the repeatability of our SEM–EDS analyses, the geological sample KOM C5 (Kömürcü obsidian source, Göllü Dağ massif) was analysed during every session. Twenty-two measurements, corresponding to the mean of 3 to 5 measurement points, were obtained during this process; these data are reported in Table 2, along with the average, standard deviation, and coefficient of variation (%). The measured values neither significantly vary throughout a single day, nor from one day to another.

Concerning the accuracy of the SEM–EDS, the values obtained for several geological standards (KOM C5,

Table 2
Average (wt %), standard deviation, and variation coefficient (%) for each element assayed by SEM- EDS at the CRP2A on KOM C5 on the 22 measurements. Comparison of Al, Si, Ca, and Fe contents (wt %) of the KOM C5 geological sample measured each morning and evening thorough six complete days of analysis.

Tableau 2
Moyenne (% masse), écart-type et coefficient de variation (%) de chaque élément mesuré par MEB-EDS au CRP2A pour l'échantillon KOM-C5 (22 mesures). Comparaison des teneurs en Na_2O, Al_2O_3, SiO_2, K_2O, CaO et Fe_2O_3 (% masse) pour l'échantillon géologique KOM-C5 mesuré chaque matin et chaque soir au long de six jours complets d'analyse.

All runs ($n = 22$)		Na_2O	Al_2O_3	SiO_2	K_2O	CaO	Fe_2O_3
18/01/12		4.4	13.1	76.8	4.6	0.45	0.61
19/01/12	*Run 1*	4.0	12.9	77.3	4.8	0.43	0.60
	Run 2	4.1	12.8	77.1	4.8	0.49	0.67
20/01/12	*Run 1*	4.1	12.9	77.2	4.7	0.50	0.61
	Run 2	4.6	13.1	76.8	4.4	0.46	0.61
23/01/12		4.4	13.0	76.8	4.6	0.43	0.70
24/01/12	*Run 1*	4.1	12.7	76.9	4.8	0.62	0.70
	Run 2	4.0	12.9	77.0	4.8	0.50	0.74
25/01/12		4.7	13.1	76.7	4.4	0.47	0.58
30/01/12	*Run 1*	4.3	13.0	76.9	4.6	0.43	0.65
	Run 2	4.6	13.4	76.5	4.4	0.53	0.58
31/01/12		4.3	13.5	76.3	4.6	0.61	0.66
01/02/12		4.2	13.0	77.0	4.7	0.42	0.64
02/02/12		4.4	13.0	77.0	4.6	0.45	0.62
03/02/12		4.1	12.9	77.1	4.8	0.47	0.71
06/02/12		4.2	12.9	77.0	4.7	0.46	0.68
02/07/12		4.5	13.1	76.8	4.4	0.44	0.61
04/07/12	*Run 1*	4.1	13.0	77.1	4.7	0.43	0.67
	Run 2	4.3	13.0	77.0	4.6	0.48	0.61
05/07/12		3.9	12.8	77.2	4.9	0.45	0.67
09/07/12	*Run 1*	4.0	12.8	77.0	4.8	0.48	0.74
	Run 2	4.1	12.9	77.0	4.7	0.52	0.67
Average (wt %)		4.2	13.0	76.9	4.7	0.48	0.65
Stand. Dev.		0.2	0.2	0.2	0.2	0.05	0.05
VC (%)		5.0	1.5	0.3	3.4	11.09	7.41

Contents in oxides are in weight per cent (wt %). Each measure of n presented corresponds to the mean of 3 to 5 measurement points on KOM C5.

P35-18B1) were shown to be consistent with previously published values for these standards obtained by PIXE, SEM–EDS (Poupeau et al., 2010), and/or ICP-AES (Bellot-Gurlet, 1998). The accuracy of our SEM–EDS is further detailed in Delerue (2007), Le Bourdonnec et al. (2010), and Poupeau et al. (2010).

4.1.2. Results

A total of 178 artefacts was analysed by SEM–EDS, together with 60 geological samples from various Anatolian obsidian sources, specifically those most likely to be present at the site based on prior analyses of material from Qdeir 1 and pertinent sites from the surrounding area (see Chataigner, 1998; Delerue, 2007; Gratuze et al., 1993 *inter alia*).

The major elemental data generated by the SEM–EDS revealed the existence of three distinct raw material groups (one dominant), as clearly shown by Fe_2O_3 *vs.* SiO_2 and CaO *vs.* SiO_2 binary graphs (Fig. 3). These three groups, easily discriminated by their Fe and Ca contents, correspond to the obsidian sources of Bingöl B and Bingöl A (eastern Anatolia) and Göllü Dağ (Cappadocia). One artefact (KQ80.GX47.62, see Fig. 3) is close to the 90% normal density ellipse of Nemrut Dağ; however, if we look only at the iron content (3.34%), it can clearly be attributed to the Bingöl A source (see Supplementary data). The wide spread of the artefacts' compositional data observed for the sources of Bingöl A and Bingöl B can be explained by the small number of geological samples analysed from these locations ($n = 7$ and $n = 5$ respectively). Alongside the products of these three main chemical groups was a single artefact with a composition of 0.99% in CaO and 1.04% in Fe_2O_3, which can be attributed to the Nenezi Dağ source.

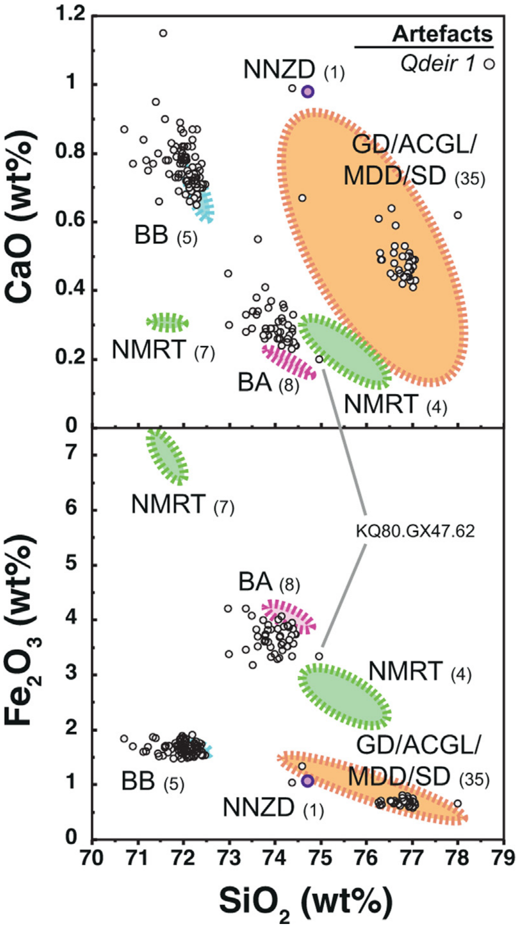

Fig. 3. SEM–EDS ratio plots of SiO_2 *vs.* Fe_2O_3 and SiO_2 *vs.* CaO for Qdeir 1 artefacts and geological source samples (NNZD: Nenezi Dağ; GD: Göllü Dağ; BB: Bingöl B; MDD: Meydan Dağ; SD: Suphan Dağ; ACGL: Acıgöl; NMRT: Nemrut Dağ). Contents in weight per cent. 90% normal density ellipses.

Fig. 3. Diagrammes binaires des rapports SiO_2 *vs.* Fe_2O_3 et SiO_2 *vs.* CaO obtenus par MEB-EDS pour les artefacts de Qdeir 1 et les échantillons géologiques (NNZD : Nenezi Dağ ; GD : Göllü Dağ ; BB : Bingöl B ; MDD : Meydan Dağ ; SD : Suphan Dağ ; ACGL : Acıgöl ; NMRT : Nemrut Dağ). Teneurs exprimées en pourcentage de masse. Ellipses de densité à 90 %.

4.1.3. Problematic results

Only one artefact (KQ80.GY46.33) was excluded from the statistical analysis because of inconsistent results, mainly observed on sodium, potassium, calcium, and iron contents (standard deviation < 1% between different measuring points). This kind of phenomenon, reported in previous studies (Lugliè et al., 2007, 2008; Poupeau et al., 2010), is often unique to the archaeological surface itself,

Table 3
Average (ppm), standard deviation and variation coefficient (%) for each element assayed by ED-XRF at the MAX Lab on RGM-2 (34 measures) and comparison with USGS recommended values (ppm). Comparison of all assayed elements (ppm) of RGM-2 during six days of analysis (two runs per day).

Tableau 3
Moyenne (ppm), écart-type et coefficient de variation (%) de chaque élément mesuré par ED-XRF au sein du MAX Lab pour l'échantillon RGM-2 (34 mesures) et comparaison aux valeurs recommandées par l'USGS (ppm). Comparaison de tous les éléments dosés (ppm) pour RGM-2 au cours de six jours d'analyse (deux exécutions par jour).

All runs (*n* = 36)		Ti	Mn	Fe	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Ba	Pb	Th
01/03/12		1512	306	14,015	6	12	33	17	146	105	26	234	14	825	18	13
14/03/12		1575	294	14,007	2	17	38	17	146	104	25	229	12	828	25	6
15/03/12	*Run 1*	1599	318	14,023	11	14	35	17	147	105	22	234	5	856	20	10
	Run 2	1538	330	13,986	13	22	38	18	148	104	24	238	14	826	23	20
16/03/12	*Run 1*	1541	332	13,953	–	22	39	18	142	108	25	229	9	803	28	17
	Run 2	1552	325	13,944	8	6	41	15	147	108	23	233	8	822	23	20
19/03/12	*Run 1*	1554	344	13,941	–	10	39	15	144	105	25	232	7	791	18	11
	Run 2	1575	320	13,941	5	12	44	17	146	99	25	232	11	792	23	15
27/03/12	*Run 1*	1570	314	14,001	1	5	36	18	150	104	22	238	13	822	19	17
	Run 2	1528	303	14,039	7	18	40	15	144	103	25	234	11	825	22	10
28/03/12	*Run 1*	1534	314	13,986	–	12	37	12	147	103	24	231	9	832	17	12
	Run 2	1499	330	14,052	1	7	41	14	148	102	24	231	11	845	27	12
29/03/12	*Run 1*	1662	335	13,991	2	12	45	12	145	104	27	232	10	821	17	7
	Run 2	1495	338	13,942	6	11	42	21	143	102	25	231	12	787	21	13
	Run 3	1609	321	13,969	7	16	40	19	142	105	25	237	12	792	22	15
04/03/12	*Run 1*	1513	320	13,967	–	10	37	14	146	101	26	231	13	814	21	15
	Run 2	1552	332	13,963	–	22	38	18	144	103	25	231	7	825	21	13
	Run 3	1520	295	14,043	–	5	36	11	143	106	22	228	15	803	24	12
05/04/12	*Run 1*	1565	315	13,978	–	12	39	19	146	106	23	231	9	809	19	12
	Run 2	1520	287	13,963	13	12	44	20	146	105	25	228	13	791	25	13
	Run 3	1480	314	13,942	–	12	37	16	148	104	23	231	11	819	21	10
07/04/12	*Run 1*	1540	311	13,952	3	15	43	19	144	104	26	231	12	806	24	14
	Run 2	1510	312	13,983	9	17	39	13	144	106	24	234	12	794	25	16
09/04/12	*Run 1*	1505	325	13,997	1	14	34	15	145	103	24	230	10	815	23	18
	Run 2	1594	312	13,965	1	17	36	16	146	107	22	228	11	810	21	8
11/04/12	*Run 1*	1533	320	13,905	8	12	39	16	144	106	21	230	11	792	25	7
	Run 2	1537	330	13,932	5	16	36	19	149	104	21	226	7	769	22	15
	Run 3	1538	309	13,987	–	10	37	21	146	107	23	226	8	778	22	11
12/04/12		1524	325	13,953	–	8	41	18	140	105	25	229	8	782	21	13
13/04/12	*Run 1*	1643	324	13,966	–	10	37	16	145	103	23	226	10	794	25	11
	Run 2	1486	358	13,938	–	11	35	15	144	109	23	229	13	787	18	9
	Run 3	1599	323	13,925	11	14	43	17	145	105	27	228	10	783	17	8
14/04/12	*Run 1*	1572	291	13,972	–	8	35	19	148	104	23	224	11	772	24	1
	Run 2	1557	293	13,999	5	12	39	16	144	107	24	232	14	824	23	8
	Run 3	1559	320	14,014	7	16	39	17	145	102	23	229	11	793	23	6
17/04/12		1598	313	13,991	16	17	41	16	148	109	25	231	11	807	24	7
Average (wt%)		1550	318	13,976	6	13	39	17	145	105	24	231	11	806	22	12
Stand. Dev.		42	15	35	4	4	3	2	2	2	2	3	2	20	3	4
VC (%)		3	5	0	54	34	7	15	1	2	6	1	21	3	13	36
USGS values		*1499 ± 38*	273 ± 8	*13,010 ± 280*	4	*9.8 ± 0.8*	*33 ± 2*	*16 ± 1*	*147 ± 5*	*108 ± 5*	*24 ± 2*	*222 ± 17*	9	*842 ± 35*	*20 ± 1*	*15 ± 1*

Element contents are in ppm. Each measure of *n* presented corresponds to one measurement point on RGM-2. USGS values: *recommended values*, information values. ± represents one standard variation.

frequently presenting an alteration of the chemical composition in the surface layers of the glass, due to partial hydration via the soil.

4.2. *Obsidian characterisation: Using ED-XRF*

4.2.1. *Repeatability and accuracy*

The reproducibility of our ED-XRF measurements has been evaluated using the RGM-2 international standard produced by the U.S. Geological Survey (USGS), for which the elemental composition was determined on each of the 36 analytical runs, *i.e.* 36 measurement points (Table 3). The estimated relative standard deviation (%) shows that the range of measurement deviation mostly remains under 20% and drops to less than 10% for the elements of greatest discriminatory power, namely Rb, Sr, Y, Zr, and Ba, indicating a suitable reproducibility of our analyses. We can, however, note that the Ni, Cu, and Th elements, which are not used in our statistical analysis, display higher dispersions (especially for Ni, superior to 50%). As shown by the standard deviation and the variation coefficient (%), we can conclude that our method has a good repeatability over time, by day/week/month.

RGM-2 being an international geological standard, has allowed us to compare our results with USGS recommended values (Table 3). While the instrument generated problematic results for Fe, Zn, Ni, Cu, and Th, we have excellent results for those elements most useful for discriminating the major Anatolian obsidian source products, namely Ga, Rb, Sr, Y, Zr, and Ba.

4.2.2. *Results*

For the 517 artefacts analysed by ED-XRF, a set of fifteen major and trace elements were assayed (Ti, Mn, Fe, Ni, Cu,

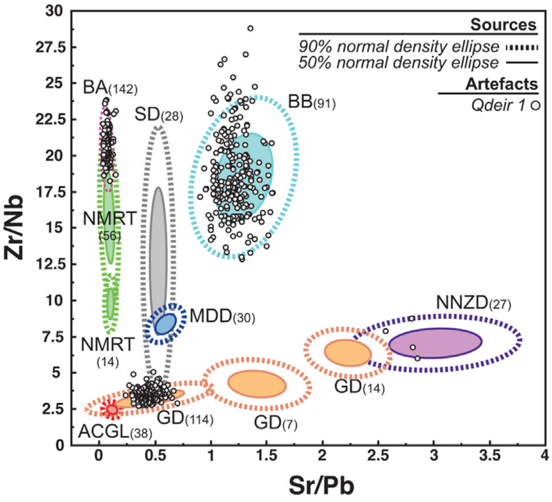

Fig. 4. ED-XRF ratio plot of Sr/Pb *vs.* Zr/Nb for Qdeir 1 artefacts and source samples. Source abbreviations as in Fig. 2.

Fig. 4. Diagramme binaire des rapports Sr/Pb *vs.* Zr/Nb obtenus par ED-XRF pour les artefacts de Qdeir 1 et les échantillons géologiques. Voir abréviations des sources sur la Fig. 2.

Zn, Ga, Rb, Sr, Y, Zr, Nb, Ba, Pb, and Th). The 561 geological source samples employed for this study were previously analysed by the MAX Lab team employing the same analytical conditions as those used for our artefacts (*cf.* Carter et al., 2013).

As with the SEM–EDS analyses, the ED-XRF results indicated the existence of four raw materials, as shown by a ratio diagram (Fig. 4) involving Zr, Nb, Sr, and Pb, four of the most useful elements for the discrimination of obsidian source products in the Near East (Poupeau et al., 2010). Most of the artefacts had a chemical signature that matched source products from Bingöl B (*n* = 230), while others corresponded to the elemental profiles of the Bingöl A/Nemrut Dağ, Göllü Dağ, and Nenezi Dağ sources (*n* = 102, 143, and four respectively). To discriminate between the Bingöl A and Nemrut Dağ sources (see Chataigner, 1994; Frahm, 2012; Orange et al., 2013, regarding this topic), we plotted Y/Nb and Zr/Pb ratios (Fig. 5); this demonstrated that all 102 of Qdeir 1's artefacts made of green peralkaline obsidian came from Bingöl A. The final binary diagram, comparing Zr and Sr contents (Fig. 6), allowed us to demonstrate that the remaining artefacts were made of Cappadocian obsidian from Göllü Dağ and Nenezi Dağ.

4.2.3. *Problematic results*

Amongst the 517 artefacts analysed by ED-XRF, 38 presented irregular values, even after a number of repeat runs. As with the SEM–EDS analysis, these apparently problematic values might be the result of surface irregularities, soil contamination, or partial hydration. But in the case of the ED-XRF analyses, the size of the artefact appears to be the most significant criterion (Davis et al., 2011), with the unattributed pieces tending to be the assemblage's thinnest and/or narrowest pieces (see Fig. 7). The ED-XRF analysis used a non-collimated beam, whereby the diameter of these artefacts was smaller than the incident beam, thus leading to problematic results. Unfortunately, lack of time prevented us installing a new collimator with a narrower beam to re-run these 38 artefacts; all but one (KQ80.GY46.33) were however successfully characterised by SEM–EDS.

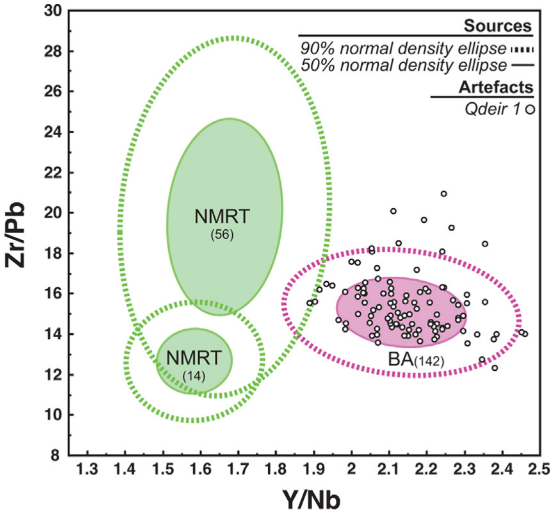

Fig. 5. ED-XRF ratio plot of Y/Nb *vs.* Zr/Pb for Qdeir 1 artefacts and source samples from Bingöl A and Nemrut Dağ. Source abbreviations as in Fig. 2.

Fig. 5. Diagramme binaire des rapports Y/Nb *vs.* Zr/Pb obtenus par ED-XRF pour les artefacts de Qdeir 1 et les échantillons géologiques des sources de Bingöl A et Nemrut Dağ. Voir abréviations des sources sur la Fig. 2.

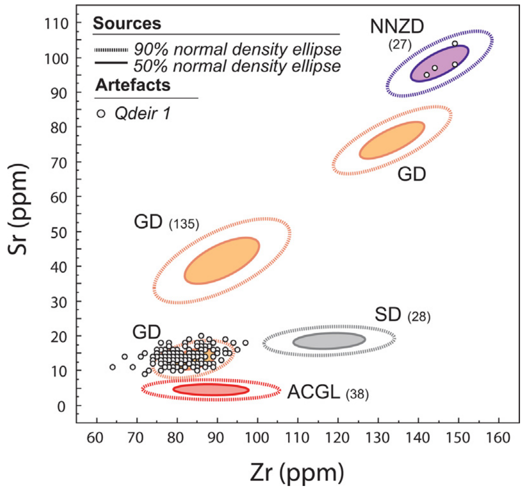

Fig. 6. Zr *vs.* Sr contents determined by ED-XRF for Qdeir 1 artefacts and source samples from Göllü Dağ, Suphan Dağ, Acıgöl, and Nenezi Dağ. Source abbreviations as in Fig. 2.

Fig. 6. Diagramme binaire comparant les teneurs en Zr et Sr obtenus par ED-XRF pour les artefacts de Qdeir 1 et les échantillons géologiques de Göllü Dağ, Suphan Dağ, Acıgöl et Nenezi Dağ. Voir abréviations des sources sur la Fig. 2.

4.3. *Discussion on the sourcing techniques*

This study's aim was to compare two non-destructive archaeometric techniques. We observed that ED-XRF has numerous benefits, not least its ease of use, automation, and speed (only 3 h 30 to analyse 19 samples plus the

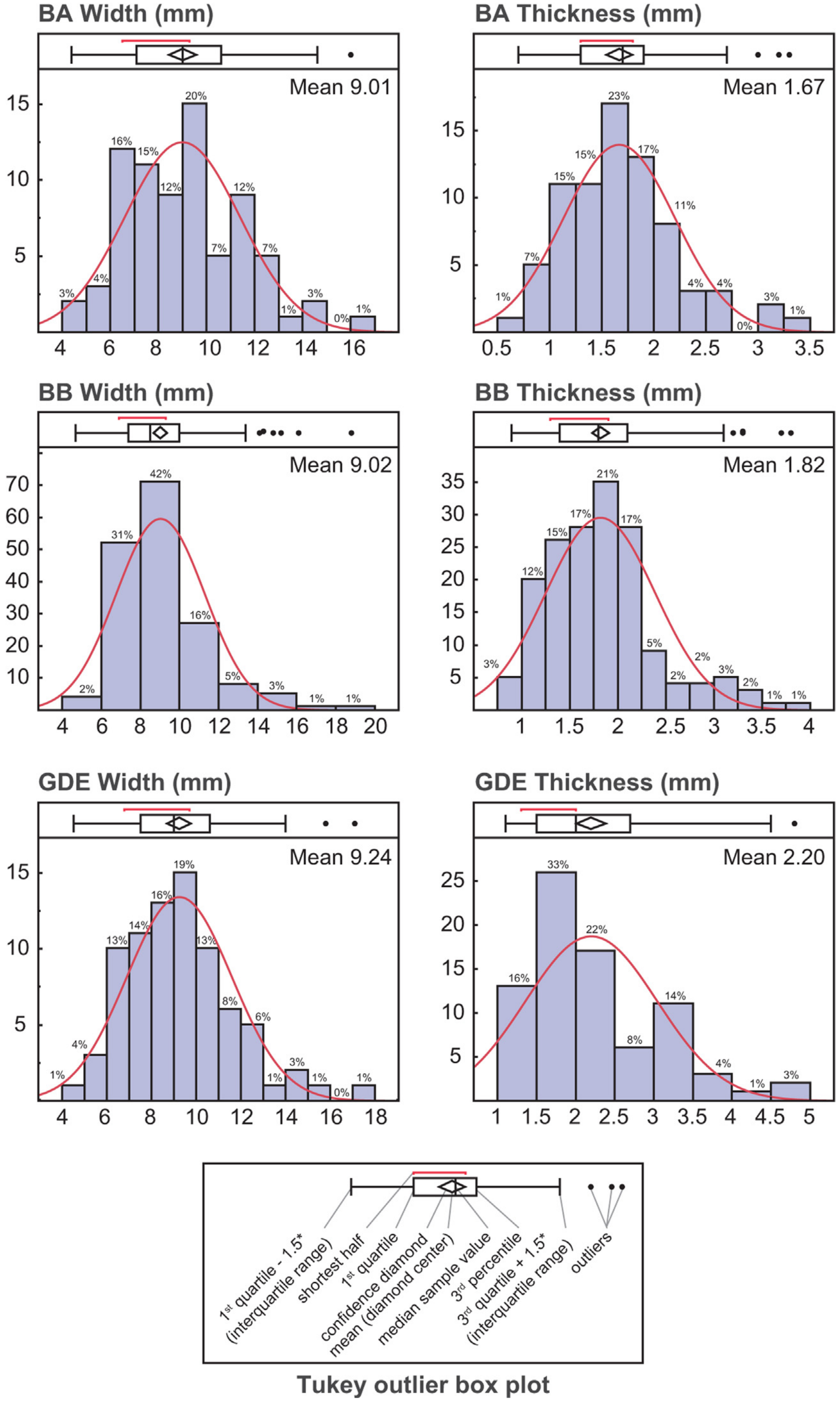

Fig. 7. Histograms representing the width and thickness measures (in mm) of Bingöl A, Bingöl B, and Göllü Dağ artefacts. Data generated from mesial segments and whole blades.

Fig. 7. Histogrammes des mesures de largeur et d'épaisseur (en mm) des artefacts attribués aux sources de Bingöl A, Bingöl B et Göllü Dağ. Données obtenues sur parties mésiales de lames et sur lames entières.

geological standard), while SEM–EDS requires the constant presence of the analyst and takes around 10 hours to analyse 33 samples. Moreover, ED-XRF can successfully discriminate between both peralkaline products of Bingöl A and Nemrut Dağ and calco-alkaline products of Göllü Dağ and Acıgöl in Cappadocia, while SEM–EDS can only distinguish the peralkaline products (see Orange et al., 2013). That said, SEM–EDS also has its strengths, as it too can be used non-destructively, while its controlled beam permits the analysis of the very small artefacts (few micrometres) which can cause problems with ED-XRF. In turn, while the required constant presence of the analyst is time-consuming, it conversely enables each artefact to be carefully staged to provide the best (flattest) analytical surface possible.

5. The typo-technological approach

5.1. Methodology

The artefacts were first sorted by provenance, and then by blank type (flakes, blades, *etc.*) and part (whole, proximal, medial, distal). A variety of attributes were then recorded on the blades, particularly the proximal segments, as a means of obtaining further information on how they were made (*e.g.*, platform type, lip, blank regularity, knapping rhythms, *etc.*), together with a variety of metric information such as length, width, and thickness. All data were recorded in an Excel® database.

5.2. Results

Our SEM–EDS and ED-XRF analyses demonstrated the presence of obsidian from four sources at Qdeir 1, all located over 500 km from the site (Fig. 1). Cumulatively over two thirds of the artefacts were made of raw materials that came from eastern Anatolia, with 245 characterised as Bingöl B products (47%) and 123 as Bingöl A (24%). The rest of the artefacts were made of raw materials from the central Anatolian (south Cappadocian) sources of Göllü Dağ (*n* = 144, 28%) and Nenezi Dağ (*n* = 4, < 1%).

5.2.1. Bingöl B

The 245 artefacts made of Bingöl B obsidian (47% of the total assemblage) are comprised primarily of blades that appear to have been knapped from single platform (unipolar) cores by a pressure technique, as evidenced by the implements' distinctive parallel margins and dorsal ridges, consistent longitudinal thickness, diffuse bulbs, and small platforms (Fig. 8a, b). Analysis of these blades' width and thickness (Fig. 7) was undertaken to examine their standardisation (another characteristic of pressure blades). Most of the data followed a normal distribution indicating the repetitive production of fine prismatic blades of much the same form and size; however, a scatter in the results indicates the presence of wider and thicker blades. On inspection these pieces (KQ89.GYNW82.17 *i.a.*) had the

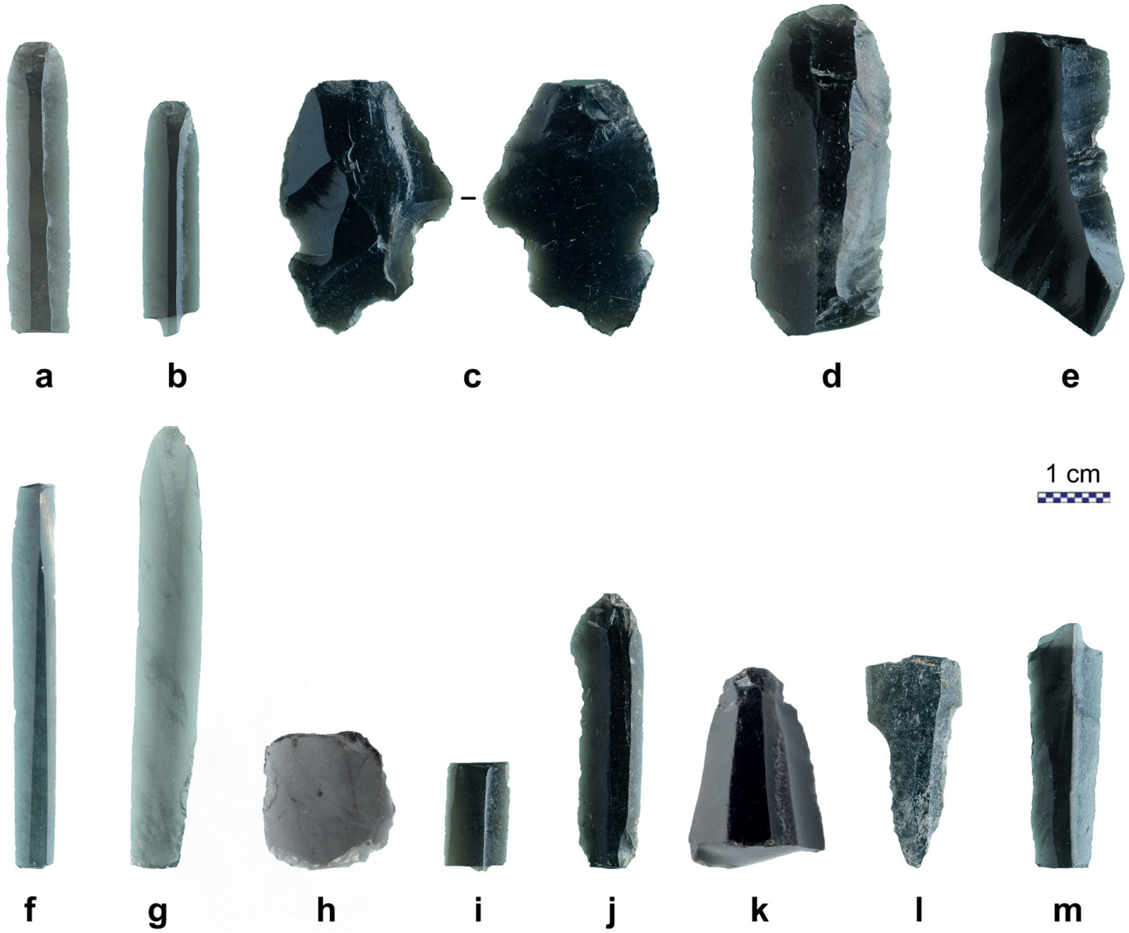

Fig. 8. Photographs of the artefacts from the Qdeir 1 archaeological site discussed in the text (a–m).

Fig. 8. Photographies des artefacts de Qdeir 1 discutés dans le texte (a–m).

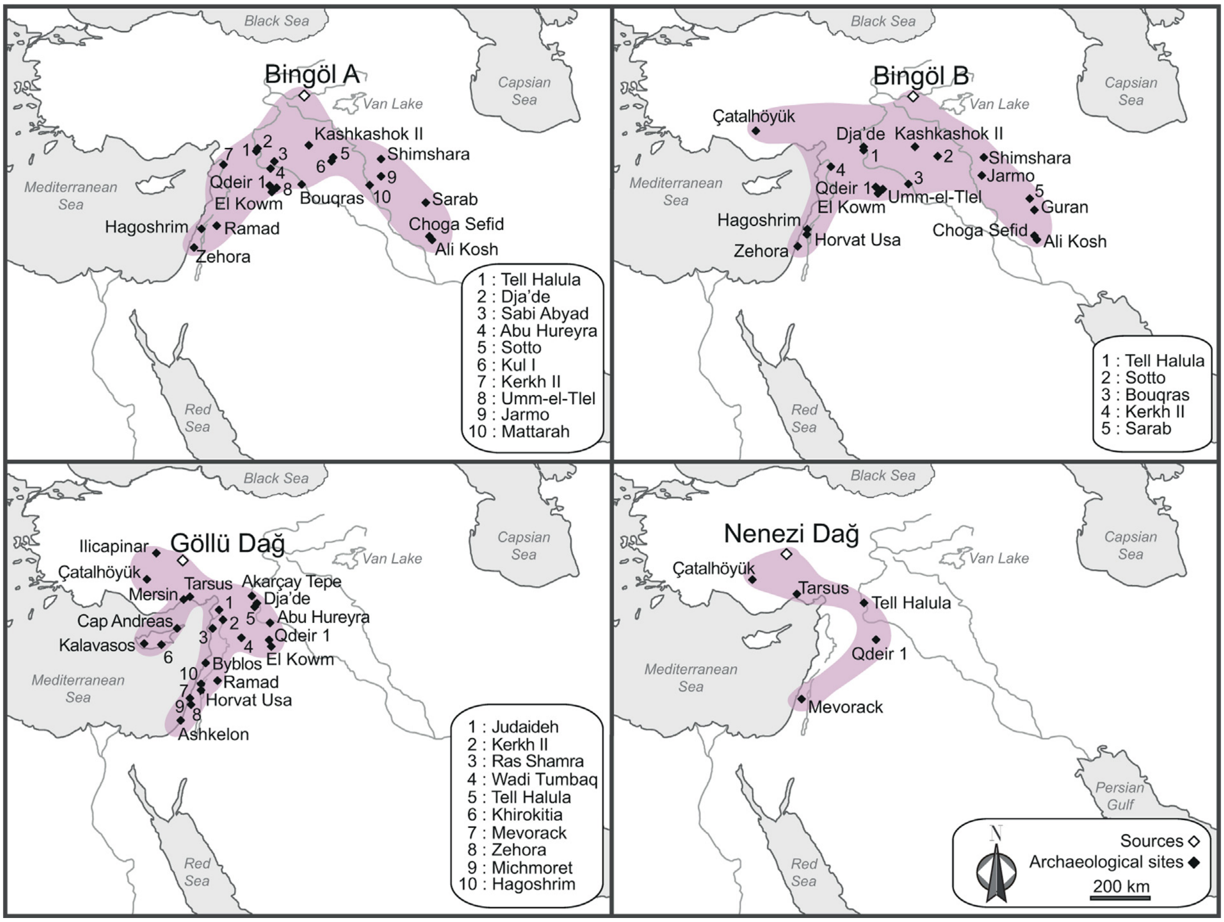

Fig. 9. Maps showing the sites with proof of use of the Bingöl A, Bingöl B, Göllü Dağ, and Nenezi Dağ obsidian during the Final PPNB period.

Fig. 9. Carte des sites ayant démontré l'utilisation d'obsidiennes provenant des sources de Bingöl A, Bingöl B, Göllü Dağ et Nenezi Dağ durant le PPNB final.

characteristics of being knapped by soft stone percussion (again from unipolar cores), i.e. a very thin platform.

Concerning the 'knapping rhythm', *i.e.* the sequence in which the pressure blades were flaked from the core (as evidenced by the stratigraphic relationship of the blades' dorsal scars [cf. Binder, 1984]), the most frequently viewed scheme is 2-1-2' as for the Bingöl A and Göllü Dağ products. If we refer to the study of the lithic assemblage of Tell Sabi Abyad II, a broadly contemporary site some 150 km from Qdeir 1 (Astruc et al., 2007; see Fig. 9), it was argued that the dominance of this type of blades (2-1-2'), with only a few triangular section blades (1-2 or 2-1 rhythm) was indicative of a specific core management strategy. This knapping sequence allows an optimal production of 2-1-2' blades (in essence the most regular prismatic products), together with approximately 20 to 30% of necessary lateral 'technical blades' (*i.e.* "*blades with transversal scars and/or cortical remnants*" that relate to the mode of blade initiation, Astruc et al., 2007: 9). Only the crested blades are generally missing from the Qdeir 1 obsidian assemblage (all sources included); only one was found in the Bingöl B assemblage (KQ89.GYNW81.6).

Of the 179 examples of true prismatic end-products (*plein debitage*), 51 were proximal, 122 were medial, and 6 were distal; none were whole. Based on the number of proximal sections (and different blade-types within the reduction sequence) this assemblage of Bingöl B pressure blades represents a minimum of 51 implements originally. The longest examples measured between 52.0 and 55.4 mm in length. The proximal segments of the pressure blades are distinct in that they have their original platform overhangs removed by tiny flakes and/or abrasion. The platform itself is almost always very thin (< 1 mm), *i.e.* linear, or plain in form. The profile of the medial segments is often straight, while the distal fragments display a slight curvature or even a torsion, and almost always have a pointed termination. The blade cores made of Bingöl B obsidian thus appear to have originally been c. 10–15 cm long, rather narrow (hence the twisted profile of some distal parts), and conical in form, *i.e.* the well-known *'bullet core'* type. This type of nucleus is attested throughout the region in the later PPN periods (10th–8th millennium BC), as for example attested at Abu Hureyra, Tell Halula, and Bouqras (Fig. 9), or closer to Qdeir, at El Kowm, where an example was recycled as a pendant. Obsidian *'bullet cores'* have in fact previously been noted from Qdeir 1 (Kozlowski and Aurenche, 2005: 144), but none were available for our analyses. The general absence of cortical knapping debris, and blade initiation blanks such as crested pieces, suggests strongly that the community procured Bingöl B obsidian in the form of preformed, and part-worked pressure blade cores. Thereafter the major episodes of blade removal occurred on-site, as attested by the presence of end-products, a few maintenance flakes, and a quantity of microchips (F. Abbès, *pers. comm.*). Only one flake related to the initial creation of a core platform was found in the assemblage (KQ93.CS.1; Fig. 8c), a piece that seems to have been imported to the site as a tool (it was retouched into a scraper), rather than evidence for the shaping of cores locally, a stage of the manufacturing process that we feel likely occurred at the quarries, or an intermediary site. One cortical flake was reported at Qdeir (F. Abbès, *pers. comm.*), but the piece was unavailable for analysis.

In general, modified pieces were quite rare, suggesting that the pressure blades may have been employed primarily in their natural, razor-sharp state. Of the 179 Bingöl B blades, only 20 had been retouched (c. 11%), including 18 with simple linear retouch, plus two examples of the distinctive 'corner-thinned' blades made on medial segments. As stated above, while most of the Bingöl B blades were produced by pressure flaking, some appear to have been knapped by soft stone percussion (KQ89.GYNW82.17; Fig. 8d), while one final piece (KQ89.GYNW80.49; Fig. 8e) drives from a third technology, namely a skilled percussive technique from an opposed platform core. This piece, previously attested in the Qdeir 1 flint industry (Calley, 1986), was almost certainly procured ready-made from elsewhere. While opposed platform blades made of obsidian are generally quite rare in the Near East, this technical tradition is known to have been performed at the Kaletepe workshop atop the Göllü Dağ source in southern Cappadocia (Binder and Balkan-Atlı, 2001).

5.2.2. Göllü Dağ

A total of 144 artefacts had chemical signatures that matched those of the southern Cappadocian source of Göllü Dağ (as defined by Binder et al., 2011), *i.e.* 28% of the Qdeir 1 assemblage. The nature of these products is very similar to those made of Bingöl B obsidian, *i.e.* unipolar pressure blades (Fig. 8f, g), with the same type of platform and overhang removal. Aside from the true end-products (*plein débitage*), there are a few 'technical blades' (as defined above) and plunging blades. However, compared to the Bingöl B products the Göllü Dağ pressure blades are slightly less standardised (when one considers the metrical data from medial and whole examples), though most remain very thin (1–2.5 mm; Fig. 7). A smaller proportion of the blades were modified than amongst the Bingöl B products, 11 in total (8%), the pieces mainly modified by simple linear retouch, together with two corner-thinned blades, which were again produced on medial fragments. Following the logic outlined above, this assemblage represents a minimum of 32 Göllü Dağ pressure blades.

The assemblage also includes a flake with an indirect abrupt retouch on its convex distal end, likely a scraper (KQ00.EB86.EF86.1; Fig. 8h).

5.2.3. Bingöl A

One can make much the same observations about the Bingöl A obsidian at Qdeir 1, as we made about the Bingöl B and Göllü Dağ products, with the material dominated by unipolar pressure blades (KQ00.EB81.CS.5; Fig. 8i), with the same type of platform and overhang removal (KQ00.Extnrd.EG107.Z218.5; Fig. 8j). Further insight to the specifics of this technology are provided by a core rejuvenation flake (KQ91.GYNW83.17; Fig. 8k; acute platform angle), probably deliberately broken to obtain a new striking platform with a corrected angle; its entire circumference had been exploited.

A unique tool is observed within the peralkaline products of Bingöl A: a borer, produced on a regular prismatic blade fragment, with convergent backed edges (KQ93.DW86.DZ98.10; Fig. 8l). Once again only a small proportion of the Bingöl A obsidian artefacts were modified ($n = 8$, 7%), including five corner-thinned blades (*e.g.*, Fig. 8j). The metrical data (Fig. 7) show that these blades derive from a single knapping technique (the same as used to work the other raw materials), with thicknesses that ranges from 0.5 and 3.5 mm, with the analysed assemblage comprising a minimum of 39 Bingöl A pressure blades.

5.2.4. Nenezi Dağ

Only four artefacts were made of obsidian from the southern Cappadocian source of Nenezi Dağ, all medial segments of unipolar pressure blades (2 finished products and 2 technical blades). One has a little tongue (KQ89.GYNE65.3; Fig. 8m), like several blade fragments amongst the whole Qdeir 1 assemblage, revealing a deliberate post-manufacture fragmentation of the blade to remove the proximal part. The dimensions of the blades are similar from one another (average width around 9 mm and average thickness around 2.5 mm [see Fig. 7]).

6. The Qdeir 1 results in their broader context

The Qdeir 1 obsidian assemblage thus contains artefacts made of raw materials from both Cappadocia (Göllü Dağ, Nenezi Dağ) and eastern Anatolia (Bingöl B, Bingöl A [Fig. 9]), with the majority coming from the slightly closer Bingöl region (c. 450 km, compared to c. 520 km to the central Anatolian sources). This 'dual access' to both central and Anatolian raw materials is something we have come to associate with later PPNB communities of the northern Levant/Upper Mesopotamia (Cauvin and Chataigner, 1998; Delerue, 2007).

While to an extent we have reaffirmed previous ideas concerning Final PPNB obsidian 'diffusion zones', we also provide new important information as to the form in which these raw materials circulated and how they were subsequently consumed. Our study shows that these four raw materials were worked in essentially the same manner, used to make fine prismatic blades by a skilled pressure technique, with the same modes of core preparation and reduction, leading to the end-products having much the same size and form. Only with the Bingöl B raw material do we have evidence for more than one mode of production, with the pressure technology augmented by a handful of soft hammer percussion blades, and a single larger blade from a skilled percussion opposed platform technique. The standardised nature of the unipolar pressure blades (all materials) is attested by the great regularity of the finished products, and the high ratio of 2-1-2' blades, indicative of a highly skilled practice involving careful control of core preparation and the subsequent knapping sequence. As has been suggested at the nearby, but slightly earlier (middle PPNB) site of Tell Sabi Abyad II (Fig. 9), we might also be dealing with the products of specialist craftspeople (Astruc et al., 2007), although here at Qdeir 1 we do not have evidence for the use of crutch and small lever pressure debitage (Abbès, 2013). As noted previously, only a few obsidian core preparation elements were found in Qdeir (all materials considered), and only one cortical flake was reported. Thus, the first stages of the knapping sequence appear to have been undertaken elsewhere, which leads us to wonder which aspect of this industry would have been most valuable to these people — the exotic raw material (obsidian), or the restricted technical know-how (pressure technique) with which to work it? In sum, while the Qdeir 1 obsidian assemblage contains four different raw materials, there is no reason whatsoever to believe that they were procured via four distinct exchange networks. Instead, it appears far more likely that an intermediary population, perhaps in the Middle Euphrates or further to the northwest (discussed below), were responsible for procuring the different raw materials, and then consuming them within the same pressure-blade tradition. By extent, whomever was responsible for working the obsidian at Qdeir 1, be that a visiting skilled knapper, or a local community member, they too then continued to reduce these cores in the same manner.

Our first point of comparison is with other assemblages from the surrounding sites in the El Kowm basin, namely the El Kowm 2-Caracol village and Umm-el-Tlel 2. At the former site, we also have a mix of obsidian from both eastern and central Anatolian sources, mostly in the form of end-products, again unipolar pressure blades and bladelets (including corner-thinned examples), plus some knapping debris and a single core which appears similar to the example from Qdeir 1 (Cauvin, 2000). At Umm-el-Tlel 2 (Borrell et al., 2013; Molist and Cauvin, 1990), some pressure blades were found but no cores; with only Bingöl B obsidian thus far attested from the site (Gratuze et al., 1993). The fact that El Kowm — the village site — appears to have a more restricted quantity and range of material (no cortical debris for example) than at the nomadic campsite of Qdeir 1, might be taken as evidence to support the theory espoused by V. Gordon Childe in the 1930s that nomadic groups may have 'gravitated' around sedentary villages, supplying them with various non-local products (Childe, 1934). That said, it should be noted that excavations at El Kowm have thus far been limited in nature, and that the known flint workshops have not yet been excavated. Moreover, in Qdeir the excavation technique allowed all microdebitage to be collected, whereas in El Kowm this was not the case (F. Abbès, *pers. comm.*).

If we then consider the Qdeir 1 data in its Final PPNB broader context, then one can point to what appears to be very similar sets of material (raw material and technology) from not only El Kowm and Umm-el-Tlel, but also Abu Hureyra (*pers. obs.*) and the slightly earlier (Middle PPNB) Tell Sabi Abyad II to the north (Astruc et al., 2007). With obsidian representing only a minority component of each of these sites' chipped stone assemblages, and the fact that the material was often being consumed in a distinct manner to how flint was being worked (at Qdeir 1 the flint assemblage essentially relates to a naviform/opposed platform percussion blade technology [Calley, 1986]), one has to consider the idea that these obsidian assemblages could have been produced by one or two non-residential itinerant specialists (cf. Perlès, 1990). One might argue that these itinerants were actually members of the nomadic group who camped at Qdeir 1, perhaps occasionally leaving the group to travel north to access the obsidian quarries of Anatolia, and/or interact with those individuals who could access the distant materials for them.

The fact that at Qdeir 1 — a nomadic campsite — we have evidence for a greater range of knapping debris than its near neighbours suggests that this mobile community may have represented the means by which obsidian was circulated in this local area. While El Kowm has a certain amount of production debris, the Umm-el-Tlel assemblage is comprised exclusively of end-products. Here we might claim that the former community may have represented a more 'attractive' locale for the itinerant specialists to visit, whereas the latter populace only received their tools second-hand, with perhaps a reflection of local power relations and dominance in this arrangement. In theorising 'attractiveness', one might think of the political capital to be gained by an individual/sodality in their ability to attract a character such as the itinerant obsidian worker to their village, the latter potentially an exotic figure of know-how and experience (based on their skilled crafting abilities and their regional travels [cf. Carter, 2007: 100–102; Helms, 1993]). These skilled knappers might be viewed as the minstrels or rhapsodes of their time, the teller-of-tales, relaying cultural traditions as much as they were tool-makers. Their appearance at a village might be seen in terms of a performance (with the all too important host(s) in association), perhaps appearing on a cyclical basis, or drawn to the community to participate in a social gathering/festival surrounding such important occasions as marriage ceremonies, the meeting of far-flung trade partners, or the founding of a lineage's new house.

Further traces of these inter-community networks can be viewed through reference to the specificities of obsidian consumption, as for example evidenced by the common tool-type of the 'corner thinned blade'. These distinctive implements, defined as blades that have deliberately had their corners thinned by retouch initiated from the end (often a medial break), and interpreted as sickle elements (Nishiaki, 1990), are well known from later PPN — Pottery Neolithic sites of the northern Levant/Upper Mesopotamia (Nishiaki, 2000: 205–209, Fig. 8.15). The Qdeir 1 examples (which are mainly made on Bingöl B blades, followed by a few Bingöl A and Göllü Dağ examples) provide a clear link between this community and such Final PPNB contemporaries as Abu Hureyra, Tell Sabi Abyad, Tell Kashkashok II, and Bouqras *inter alia* (Fig. 9). While these tools tend to be made of eastern Anatolian raw materials (exclusively at Bouqras), at both Abu Hureyra and Qdeir 1 there are a few examples made of Göllü Dağ obsidian (Bingöl B is the main material employed at our site, followed by Bingöl A). In sum, our integrated characterisation study indicates closely shared traditions in technical/raw material choices between these sites and suggests a close level of socio-economic interaction amongst these populations, underwritten perhaps via trade partnerships and inter-marriage, in essence what scholars have recently begun to describe as socio-techno 'communities of practice' (for a related discussion of this theme see Carter et al., 2013).

The northern Levant/Upper Mesopotamia is often viewed as a world whose cultural traditions and technical practices were linked to various surrounding regions, its communities' use of both central and eastern Anatolian obsidians taken to be evidence for these peoples' connections with their neighbours to the east and west (Delerue, 2007). Our Qdeir 1 data might indeed be seen as proving links to the east through the presence of a bullet-core which represents a clear connection to the technical traditions of populations in the eastern wing of the Fertile Crescent in the Jezireh and Zagros regions (Kozlowski and Aurenche, 2005: 23, fig. 1.3.5), while wedge-shaped nuclei were the norm in regions to the west (cf. Özdoğan, 1994: 271, fig. 1). Moreover, the Qdeir 1 pressure blades are also much the same size as those from Bouqras (10–12 mm in width), a site that has also produced the same scraper type (Stordeur, 2000).

Links with communities to the south and west are arguably less clear. The claim is usually based upon the common consumption of Cappadocian obsidian by later PPNB northern Levantine/Upper Mesopotamian communities (*e.g.*, Abu Hureyra, Akarçay, Dja'de, Halula, Kerkh II, Ramad), and those living on the Levantine littoral (*e.g.*, Byblos and Ras Shamra [Fig. 9]), southern Levant, Cyprus and central Anatolia (Delerue, 2007, fig. 320). This however is to focus alone on raw materials, an approach we above argued to be reductionist and problematic; the common use of a particular obsidian need not infer any connection between these communities, as there are many different ways in which these raw materials could have been procured and worked by contemporary populations (see Carter et al., 2013). A claim could be made for regional links with regard to shared technical traditions, with Göllü Dağ obsidian also being used to make pressure blades in the southern Levant at this time (Gopher et al., 1998: 645); conversely, with the pressure technique not being introduced into central Anatolia until the mid-seventh millennium BC (Carter, 2011: 12), we have an example of where shared raw material use likely does not indicate inter-regional connections.

7. Future studies

In this paper, we focused on a synchronic vision of the obsidian economy at Qdeir 1; allowing us to improve our understanding of this raw material's consumption by the local community and by extent to further our knowledge as to the use history of various Anatolian obsidian sources during the Final PPNB.

In developing this study, the next obvious step would be to take a diachronic perspective (as at Çatalhöyük for example, see Carter et al., 2006), Qdeir 1 having four occupation phases within the Final PPNB (Stordeur and Wattez, 1998). In turn, if one had access to detailed absolute dates for the periods under consideration, volumetric data of the deposits dug in these phases, plus the counts and weights of obsidian, then one could attempt to reconstruct the amount of obsidian entering the site on an annual basis (*cf.* Cessford and Carter, 2005), which might further help us understand the value regimes surrounding the circulation and consumption of these exotic materials.

A further line of enquiry would be to turn our attention to the other northern Levantine/Upper Mesopotamian sites discussed in this paper (Fig. 9). At present the publications available on these sites' obsidian assemblages do not provide the integrated form of characterisation study that we provide here, whereby most of our discussion has had to focus on patterns of raw material diffusion. However, the use of a common raw material is insufficient evidence to support claims of common cultural traditions and inter-community contact (Carter et al., 2013). Instead, what is required is a more 'thick description' approach that incorporates not only typo-technological considerations (and specificities of how items were modified, as for example with the corner-thinned blades), but also metrical data, such as mean width of prismatic blades. Such a study is in fact currently being undertaken by one of us (TC), with the analysis of 300 artefacts from Abu Hureyra (the data providing many parallels with Qdeir 1), whose results will contribute further to our understanding as to the relationships between these communities.

Acknowledgments

The authors thank Frédéric Abbès for providing access to the Qdeir 1 assemblage and for his precious help during the typo-technological study. We also acknowledge Yannick Lefrais for the management of the SEM–EDS at CRP2A. Brigitte Spiteri and Pierre Machut helped prepare the geological samples for SEM–EDS. The MAX Lab was established and is currently operated by a Canada Foundation for Innovation Leader's Opportunity Fund/Ontario Research Fund. This study was part of Marie Orange's Master's degree research project; her time at the MAX Lab was funded by Aquimob (mobility grant allocated by the "Région Aquitaine"). This project was partly coordinated by the "Université Bordeaux-Montaigne" and supported by the ANR [ANR-10-LABX-52]. Carter's involvement was covered by a Standard Research Grant of the Social Sciences and Humanities Research Council, Canada (*From Neolithisation to state formation: reconstructing interaction networks and the dynamics of socio-economic change through obsidian sourcing in the Aegean & Anatolia 10th–2nd millennia BCE*).

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.crpv.2018.08.002.

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