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EXTENDING THE SCALE OF OBSIDIAN STUDIES: TOWARDS A HIGH-RESOLUTION INVESTIGATION OF OBSIDIAN PREHISTORIC CIRCULATION PATTERNS IN THE SOUTHERN CAUCASUS AND NORTH-WESTERN IRAN*

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Recent archaeological research has highlighted the potential role of mobile pastoral groups in the diffusion of raw materials and technological innovations between the southern Caucasus and north-western Iran from the Neolithic onwards. Two successive projects, PAST-OBS and SCOPE, were designed to explore this hypothesis through the study of obsidian consumption

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patterns from the Neolithic to the Bronze Age using a flexible analytical strategy that considerably extends the scale of obsidian studies in these regions. By focusing on the exploitation of obsidian at multiple levels—local, regional and interregional—we hope to unravel the complexity of the obsidian networks under study. The aim of this paper is to present (1) a reassessment of the work so far carried out by previous obsidian studies, with a view to homogenizing and to clarifying the nomenclature in use; and (2) an introduction to the PAST-OBS and SCOPE projects in order to initiate a discussion of our preliminary results.

KEYWORDS: CAUCASUS, IRAN, NEOLITHIC, CHALCOLITHIC, BRONZE AGE, OBSIDIAN STUDIES, MOBILE PASTORALISM

INTRODUCTION

The Caucasus, at the crossroads of the Eurasian steppes, Anatolia, Iran and Mesopotamia (Fig. 1), is a region characterized by abundant natural resources—salt, metal ores, water and pasturelands—which developed as a focal point for mobile pastoral communities from the Early Chalcolithic onwards, and perhaps even earlier (Marro 2019). Intense volcanic activity in this area produced numerous obsidian outcrops, more than 20 of which have been identified so far (Fig. 1). Between the Palaeolithic and the Iron Age, most of these outcrops provided relatively accessible, high-quality obsidian for the production of a large variety of tools and weapons (Badalyan *et al*. 2004). Obsidian had indeed a crucial role in the daily life of Prehistoric groups; consequently, it was widely circulated. Owing to its geochemical signature, its distribution is used as an excellent proxy for the study of past circulation networks and exchange systems (Torrence 1986), and the identification of economic hubs and 'communities of practice' (Carter 2014). In the long run, it may also be a useful tool for analysing overarching social structures and political processes (e.g., Moutsiou 2014).

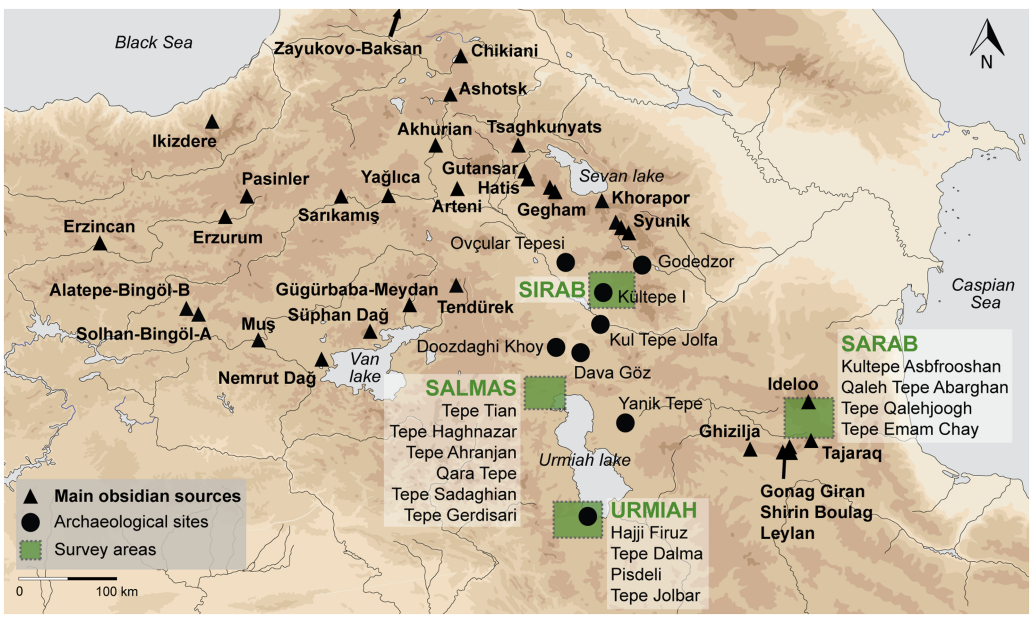

Figure 1 *Location of the archaeological sites mentioned in the text, survey areas and main obsidian sources of the southern Caucasus and eastern Anatolia. [Colour figure can be viewed at wileyonlinelibrary.com]*

After the collapse of the Soviet Union in 1991, Caucasian archaeology gained a new momentum and started to attract the attention of scholars working on the Near East. This impetus favoured new collaborations between local and foreign researchers, thus adding a novel international dimension to ongoing projects. When seen from the perspective of obsidian sourcing studies, one can make a similar observation: until the 1990s, the obsidian sources of the southern Caucasus had received little attention (e.g., Keller *et al*. 1996; Blackman *et al*. 1998; Badalian *et al*. 2001; Barge and Chataigner 2003). The geological field surveys and analytical studies that had flourished since the 1960s were mostly focused on the Mediterranean and Near East (Williams-Thorpe 1995; see also Cann and Renfrew 1964; Keller and Seifried 1990). Besides, the renewed interest in Caucasian archaeology gave rise to new research programmes mainly focused on the study of obsidian assemblages within Armenia, especially from the Neolithic and Bronze Age (Frahm *et al*. 2014, 336). In north-western Iran, the scale of obsidian characterization studies had remained limited to a handful of artefacts, while the existence of potential sources was suspected, but rarely confirmed.

Twenty years later, many new research projects had developed in the south Caucasus, alongside a shift in focus in the scientific agenda of international research, which led to an increased concentration of study on areas neighbouring Armenia. Projects in Georgia (e.g., Le Bourdonnec *et al*. 2012; Neumann *et al*. 2015; Biagi *et al*. 2017), Azerbaijan (e.g., Marro *et al*. 2009, 2010; Lyonnet *et al*. 2012; Helwing *et al*. 2017) and the north-western Caucasus (e.g., Doronicheva and Shackley 2014) have thrived, with a strong emphasis on international and interdisciplinary collaborations.

Despite this second upsurge, current efforts to reconstruct economic flows and interregional dynamics from the correlated analysis of provenance, quantity and use of obsidian still suffer from the heterogeneous character of previous studies. This *heterogeneity* is present at several levels:

- In the sampling strategies, ranging from restricted to exhaustive.
- In the great number of analytical techniques in use and the occasional lack of standard reference materials, which prevents relevant comparisons between the available assemblages (Chataigner 1998).
- In the inconsistency of the nomenclature of the sources.
- In the incitement to undertake obsidian provenance studies in the first place—as a means to an end or as an end to itself (Freund 2013; Carter 2014; Orange *et al*. 2017).
- In the way researchers have approached sourcing studies and managed (or not) to integrate sourcing data in the reconstruction of the *chaînes opératoires* (Orange *et al*. 2017; Campbell and Healey 2018).
- In the disparity in focus between the different regions of the Caucasus and the periods investigated.
- In the uneven information available on the different sources, which may have had an impact on their identification.

Moreover, the nature of archaeological research has often led obsidian studies to be conducted on a site-by-site basis, instead of considering a broader region from the onset (but see Maziar and Glascock 2017 and Maziar in press for a larger scale approach on surveyed sites). Large-scale 'synthetic' studies are thus often conducted post-hoc by 'stitching together' the results emerging from single-site studies.

In this paper, we present an innovative approach adopted in two recent research projects initiated in the framework of the Mission Archéologique du Bassin de l'Araxe (MBA) in an attempt to reduce these heterogeneity issues.

RESEARCH BACKGROUND AND HYPOTHESES

For years, international archaeological research on the emergence of socio-economic complexity in Late Prehistory has focused on the rise of urban entities and city-states in the Near East (e.g., Forest 1996; Frangipane 1996). The Caucasus and other highland areas, on the contrary, have often been considered as backward borderlands (Smith and Rubinson 2003), which major technological and socio-economic innovations only reached in a second step.

But the breakdown of the Soviet Union in 1991 favoured the rise of several international multidisciplinary projects in Armenia, Azerbaijan and Georgia, which have considerably renewed our understanding of past Caucasian cultural dynamics, which may now be analysed from a much broader geographical, but also richer analytical, slant. The origin of several significant innovations in the Middle East has been reconsidered (i.e., extractive metallurgy; Gailhard *et al*. 2017), and the agency of humble social groups, such as pastoral nomads, has been put forward to explain the diffusion of knowledge, raw materials (Gailhard in press) and possibly the circulation of goods towards the lowlands (Helwing in press). Among other consequences, these findings have questioned the common view according to which complex hierarchical societies had risen through mastering the art of metallurgy (Childe 1930; Wailes 1996).

The importance of the Caucasus partly lies in its wealth in natural resources—in particular, obsidian, salt and metal ores, but also water and rich pasturelands—all crucial to Late Prehistoric communities. A new era in the exploitation of these resources emerged from the rise of productive economies (the 'Neolithic way of life'), which in the southern Caucasus developed with no trace of a genesis *c*.6200 BCE, possibly in the wake of human migrations from north-western Mesopotamia (Cucchi *et al*. 2013; Marro *et al*. 2019) or Iran (Lyonnet *et al*. 2012; Nishiaki *et al*. 2015). The processes that led to the introduction of this new way of life into the Caucasus, where Neolithic and Mesolithic groups seem to have co-habited for quite a long time (Marro 2019; Nishiaki *et al*. 2019a), are still unknown. The climatic change prompted by the 8.2 ky BP event (Weninger *et al*. 2006) has been considered as a possible cause for the development of the productive economies observed in the Caucasus *c*.6200 BCE (Sagona 2018). This hypothesis, however, remains tentative, first because the available data are still limited, and second because the different mechanisms invoked to explain the cause-and-effect relationship between climatic change and the rise of Neolithic economies have not been clarified and even appear to be contradictory (Marro 2019).

Recent data retrieved from the valley-settlement of Kültepe I in Nakhchivan (Marro *et al*. 2019) demonstrates that specialized caprine herding was central to the Neolithic economy of the Araxes basin from the onset, exactly as in the Zagros Mountains (e.g., Zeder and Hesse 2000), thus reinforcing the migration-from-Iran hypothesis. In this case, what reasons may have prompted Neolithic groups from Iran to settle in the Caucasus? As a working hypothesis, we first surmised that mobile pastoral groups from north-western Iran were involved in the exploitation of raw materials, in particular obsidian, whose outcrops are concentrated in the Caucasus near rich summer pastures.

With this idea in mind, we launched a new research programme focused on the role of mobile pastoralists in the circulation of obsidian; this programme drew on the many Late Prehistoric campsites that had been found in the Sirab region in Nakhchivan (Bakhshaliyev and Novruzov 2010). The Sirab region (Figs 1 and 2) is located in the southern foothills of the Lesser Caucasus; it is richly endowed with natural resources, in particular metal ores (Gailhard *et al*. 2017, in press) and water sources. Moreover, this region is crossed by the centuries-old transhumance paths linking Urmiah Lake with the summer pastures of the southern Caucasus, some of

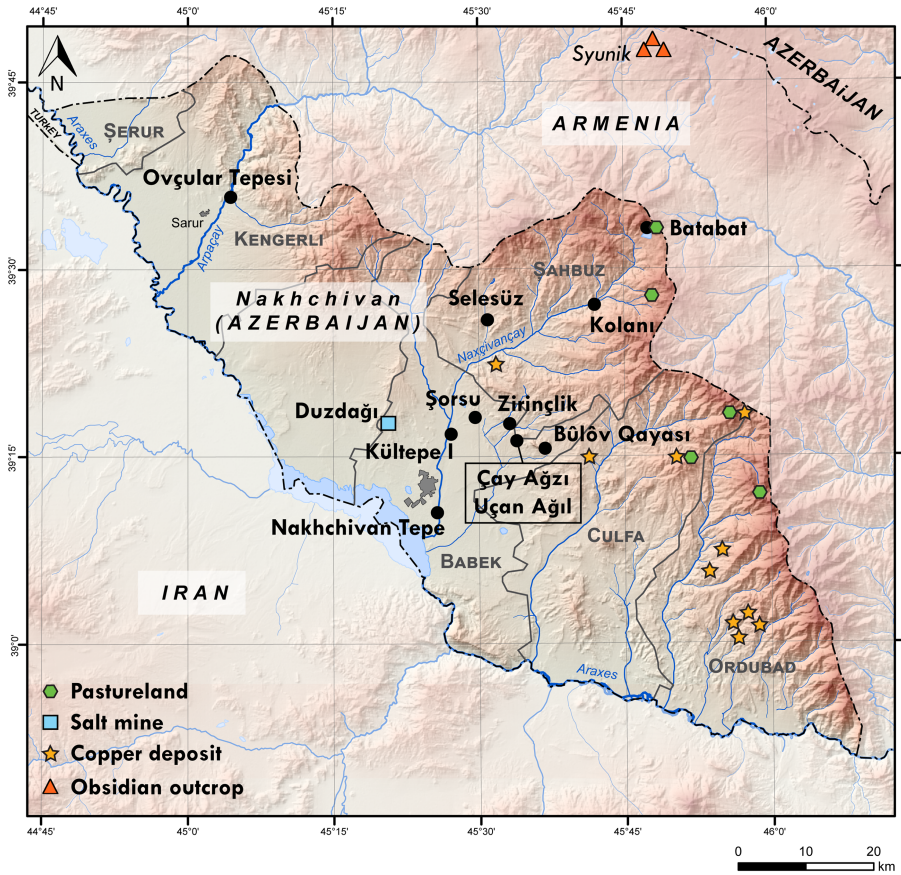

Figure 2 *Detailed map of the main sites investigated in Nakhchivan in the framework of the PAST-OBS and SCOPE projects. Map background: ©O. Barge. [Correction added on 18 April 2021, after first online publication: Credits for Figure 2 have been included in the figure caption.]. [Colour figure can be viewed at wileyonlinelibrary.com]*

which lie close to important obsidian beds, such as those of the Zengezor mountain range (Syunik outcrops). All these characteristics suggest that these sites may have been intermediary camps used during the seasonal migrations between the plateaux of north-western Iran and the upper pastures of the southern Caucasus. As such, they may have been part of a broader economic system relying on the movement of mobile pastoralists, which stretched over the two regions.

PREVIOUS RESEARCH

Obsidian sourcing studies in South-Western Asia

Obsidian studies focusing on Late Prehistoric Caucasia are thriving, but they rely on an heterogenous background. The lack of homogeneity in the sources' nomenclature creates a certain amount of confusion, whereas several sources remain difficult to identify. This is, for example, the case of the '3a' and '3c' groups (Renfrew *et al*. 1966), which are believed to correspond, respectively, to Gügürbaba-Meydan and the outcrops of the Syunik range (Chataigner 1998).

The issues arising from these early data, which are difficult to compare with more recent information, were identified a long time ago (Chataigner 1998), but they sometimes remain an obstacle to the exploitation of this otherwise valuable research.

Confusion also arises from difficulties in the characterization of the sources, in both the Caucasus and the neighbouring regions. Geological studies are still underway: New outcrops have been identified only recently (e.g., Frahm *et al*. 2017; Orange *et al*. 2020), while others have been redefined (Chataigner *et al*. 2014; Robin *et al*. 2016). In particular, the numerous sources of eastern Anatolia present a high degree of complexity requiring further investigation. Other sources remain somewhat enigmatic, the current geopolitical situation in the area preventing further exploration. This is the case of the Kecheldağ group, located north of the Syunik sources, in the Nagorno Karabagh region (Blackman *et al*. 1998). A secondary obsidian deposit, Bartsratumb, was also reported 30 km south of the Syunik outcrops (Karapetyan 1972), but very few samples appear to have been collected and analysed (however, see Supplementary Data 3 in the additional supporting information). The existence, precise location and knapping suitability reported for the Iranian obsidian outcrops also remain uncertain, although recent fieldwork has started to tackle this specific issue in more detail (Niknami *et al*. 2010; Abedi *et al*. 2018a; Orange *et al*. 2020).

Despite these limitations, over 5000 artefacts have been analysed in the last 50 years. For a list of the data published in close to 30 selected publications, see Supplementary Data 1 in the additional supporting information. While this represents a large number of artefacts, it should be noted that these data were obtained from no fewer than 96 sites, encompassing a long time span (Palaeolithic to Iron Age), in a region where obsidian is omnipresent and has been used abundantly. The proportion of the assemblages that have been analysed is rarely representative of the whole industry—a parameter that can only be assessed when the total number of artefacts is indicated. Although the analysis of complete assemblages is still not a general practice, a shift towards exhaustive characterization studies has begun (e.g., Frahm *et al*. 2014; Nishiaki *et al*. 2019b).

Obsidian movement and mobile pastoralists in the literature

The practice of transhumant pastoralism is often cited as a vector for the movement of obsidian, which for some scholars can be seen as the ‘by-product of the pastoral lifestyle’ (Chataigner *et al*. 2010, 392). The Armenian obsidian outcrops are indeed located at high altitude, near the much sought-after summer pasturelands. The excavation of the Chalcolithic levels of Godedzor (Fig. 1) confirms this hypothesis, since it yielded an abundant lithic industry that is almost entirely made of obsidian (98%), together with some painted pottery recalling north-western Iranian assemblages. Animal bones consist mostly of the remains of sheep and cattle, along with a few goats and some game (about 10%); rare architectural remnants are also attested (Chataigner *et al*. 2010). The authors thus interpret Godedzor as a possible seasonal village, where mobile pastoralists coming from north-western Iran (the Urmiah Lake basin) would have camped on their way to and from the obsidian outcrops during their summer migration to the highland pastures (Palumbi *et al*. in press).

Further evidence was brought by the extensive geographical information system (GIS) work carried out by Barge and Chataigner (2003), Chataigner and Barge (2008, 2010). They have defined time–distance models for the procurement of obsidian in Armenia, and created an initial accessibility map based on the provenance of 400 artefacts. Their work identified several factors that could have influenced the choice of deposit (see also Campbell and Healey 2018): the

geographical context of the settlement, the distance to the sources (travel time and 'cost'), the quality and colour of the material, the transhumance routes (seasonal movements) and the axes of communication, the diffusion of other materials (raw materials or finished objects), and the social, cultural and economic contexts (i.e., belonging to a specific network). According to their models, the inhabitants of the Urmiah Lake basin, by following the Araxes valley and Naxçivançay river through to Godedzor, could have reached the Syunik source in eight to 10 days on foot (Chataigner *et al*. 2010). The proposed route follows the centuries-old transhumance patterns observed in these regions (Marro *et al*. 2019). Unsurprisingly, their study places Nakhchivan at the crossroads of the east–west axis following the Araxes valley and the potential north–south path linking north-western Iran to the Kura valley (western Azerbaijan).

Chataigner *et al*. (2010) suggested that, given the regular presence of Syunik obsidian in the Urmiah Lake region from the Chalcolithic onwards, the two regions (the Urmiah Lake basin and Vorotan valley) had specific ties over the long term (391). They also interpreted the rare presence of eastern Anatolian products in the southern Caucasus as evidence that the system involving the circulation of the Syunik obsidian 'was not integrated into the trade networks that crisscrossed northern Mesopotamia and enabled the Lake Van obsidian to be widely diffused' (391). According to them, at least two different obsidian exchange networks would, therefore, exist in the wider southern Caucasus/eastern Anatolia region between the late sixth and the fourth millennia BCE: one would ensure the circulation of the south Caucasian obsidian towards the Urmiah Lake basin, while the other would have transported the obsidian from eastern Anatolia towards western Iran and the Iranian plateau, possibly through northern Iraq (see e.g., Blackman 1984; Darabi and Glascock 2013; Barge *et al*. 2018) and, to a lesser extent, towards the southern Caucasus.

Beside Godedzor, some obsidian from Syunik has been identified in the Urmiah Lake area at Hajji Firuz (in restricted quantity), Pisdeli Tepe and Yanik Tepe (Renfrew *et al*. 1966) (see also Supplementary Data 1 in the additional supporting information), Dava Göz (Late Neolithic to Chalcolithic) (Abedi *et al*. 2018b), Kul Tepe Jolfa (Chalcolithic to Iron Age III) (Khademi Nadooshan *et al*. 2013; Abedi *et al*. 2018c), and on the sites of the Khoda Afarin and Jolfa plains (Neolithic to Iron Age) (Maziar 2015; Maziar and Glascock 2017). The diversity of sources attested in the archaeological assemblages of Kul Tepe Jolfa and Dava Göz, where both Caucasian and eastern Anatolian obsidian have been found, suggests that these sites played an intermediary role in the redistribution of obsidian towards the Urmiah Lake between the Chalcolithic and the Bronze Age (Khademi Nadooshan *et al*. 2013; Abedi *et al*. 2015). In point of fact, Kul Tepe Jolfa is located in the Jolfa Pass, a strategic position acting as a passageway between Iran and Nakhchivan.

However, the evidence pointing to the involvement of mobile pastoralists in the circulation of obsidian and, concomitantly, in the diffusion of technological innovations between north-western Iran and the southern Caucasus (e.g., Thomalsky 2019, in press) is still very limited: to test this hypothesis further, we have both increased the number of sites to be studied and implemented a multi-approach analytical protocol that would make it possible to study obsidian artefacts either in our laboratory or directly in the field.

A DIFFERENT APPROACH TO OBSIDIAN STUDIES: THE PAST-OBS AND SCOPE PROJECTS

Main objectives

The first aim is to trace back the circulation of obsidian artefacts in both areas, namely in Nakhchivan and the Urmiah basin. We first endeavoured to map the connections between the

main Caucasian obsidian outcrops and known sites of the Neolithic, Chalcolithic and the Bronze Age located in the Caucasus and Middle East in order to determine possible changes in interregional dynamics over time. We aim at correlating these changes with the introduction of new techniques, such as new subsistence strategies (Neolithic) or extractive copper metallurgy and the production of wool fabrics (Late Chalcolithic). For example, did the introduction of extractive metallurgy fundamentally change the intensity and overall structure of South-West Asian economic networks between the Neolithic and Chalcolithic? Since major copper deposits are located in proximity to both the Syunik and Gegham obsidian outcrops (Courcier 2010), a focus on the exploitation of copper beds should emphasize the obsidian of Syunik and/or Gegham during the Chalcolithic, at the expense of those not located near the copper deposits (e.g., Arteni). Conversely, the development of wool fabrics during the Late Chalcolithic (Shishlina *et al*. 2003) and the subsequent increase in pastoralism may have led to more diversified strategies in obsidian sourcing (increase in multi-sourcing strategies), since obsidian outcrops and rich pasturelands are attested virtually all over the southern Caucasus and eastern Anatolia.

With these questions in mind, the PAST-OBS and SCOPE projects were set up to analyse the assemblages collected from the sites excavated by the MBA since 2006, but we also proceeded to survey the mountainous areas in search for pastoral sites in the wake of the work initiated by Bakhshaliyev and Novruzov in 2009. The interdisciplinary aspect of these projects relies on collaborations with the Institut de Recherche sur les ArchéoMATériaux (IRAMAT), the Centre National de la Recherche Scientifique (CNRS) and the Université Bordeaux Montaigne in France, the National Academy of Sciences in Nakhchivan, the Tabriz Islamic Art University, and the German Archaeological Institute in Iran, as well as the University of New England and Southern Cross University in Australia.

These research programmes stand out by the scale of their investigation programme: over 70 sites have so far been excavated or surveyed in Nakhchivan and north-western Iran, disclosing several thousands of obsidian artefacts. These sites belong to different categories (e.g., sedentary valley settlements, temporary campsites) and cultural horizons (Neolithic to Bronze Age). To the best of our knowledge, the extent of this obsidian investigation programme is unprecedented in this area. This is an exceptional opportunity to test our hypotheses, but also to gain an in-depth understanding of the circulation networks and of the exploitation, diffusion and consumption patterns of obsidian at the local, regional and interregional scales over the *longue durée*.

Several of the issues identified in previous studies have been addressed in this programme:

- Exhaustivity: Our multi-method strategy ensures the analysis of complete assemblages by relying on several characterization techniques (Orange *et al*. 2017).
- Reconstruction of consumption patterns: We aim to reconstruct the *chaînes opératoires* of each assemblage and each identified obsidian raw material to understand how it was worked and used on different types of sites through time.
- Comparability of the results: The daily measurement of obsidian geological standards makes it possible to evaluate the repeatability, accuracy and precision of the new results.

Addressing the heterogeneous data on the obsidian sources of the area

As a first step, the incredible wealth of available data on the obsidian sources of the Caucasus and eastern Anatolia had to be sorted out. While a considerable amount of information is summarized in both the literature (e.g., Blackman *et al*. 1998; Poidevin 1998; Badalyan *et al*. 2004; Chataigner and Gratuze 2014a) and online (Obsidatabase; Varoutsikos and Chataigner 2010), a

certain amount of confusion is still perceptible when archaeologists refer to obsidian sources. This confusion is mainly due to the variety of names used for each source by different authors (e.g., the names 'Choraphor', 'Khoraphor', 'Khorapor', 'Vardenis', 'Karnyjarykh' and 'Karnyajarich' all designate the same source). Following the work of Mouralis *et al*. (2018), we have set up a standardized nomenclature for the numerous outcrops located in the Caucasus and eastern Anatolia, in collaboration with the GeObs team (https://geobs.univ-rouen.fr/). This nomenclature is presented in Supplementary Data 2 in the additional supporting information with an updated synthesis of the available information on the sources. We hope that this new frame will serve as a reference for future studies and promote comparisons between obsidian sourcing programmes region-wide, and also help clarify the resulting data for specialists working outside this specific field.

The PAST-OBS and SCOPE projects also included the creation of an exhaustive geological database in order to identify the provenance of the obsidian used in Late Prehistoric assemblages. To that effect, we selected over 250 geological samples from the IRAMAT-CRP2A and IRAMAT-CEB collections, which serve as a reference for identifying the provenance of obsidian artefacts. These samples were analysed by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), as well as by portable X-ray fluorescence (pXRF) when the size of the sample made it possible to obtain reliable results (Davis *et al*. 2011). For the complete data from these analyses, see Supplementary Data 3 in the additional supporting information.

First results

So far, a total of 4835 artefacts has been analysed in the framework of these two projects, and more analysis results are underway. This is almost as much as the quantity of obsidian artefacts from the Caucasus analysed over the last 50 years. The preliminary results have revealed several interesting trends, which are outlined below. Given the large number of analyses and the ongoing nature of this programme, these results will be detailed further in a series of forthcoming publications.

Nakhchivan In Nakhchivan, most assemblages reveal the use of several sources, for example, the polysource model described by Badalyan *et al*. (2004). An exceptional diversity appears in the material from the sedentary valley settlements of Ovçular Tepesi, Nakhchivan Tepe and Kültepe I, with the last revealing the use of a dozen different obsidian raw materials during the Neolithic. As in the case of Kul Tepe Jolfa (Abedi *et al*. 2018c), this diversity could be attributed to the key position of these sites, which are located between the obsidian sources and the summer pastures of the uplands, and the winter camps located on the plateaux of north-western Iran, along the communication routes suggested by Chataigner *et al*. (2010).

As observed elsewhere (Badalyan *et al*. 2004), one obsidian type usually predominates in the assemblages belonging to the polysource procurement model (three to six sources in simultaneous use, with one prevailing over the others). In Nakhchivan, initial results show that this main source often corresponds with the closest, that is, Geghasar-Gegham for Ovçular Tepesi, and Syunik on the sites of the Şahbuz, Culfa and Kengerli districts (Fig. 2). This pattern seemingly confirms the observations made by Badalyan (2010: 36) according to which 'geological–geographical realities' were the main drive governing the obsidian procurement system between the sixth and first millennia BCE (i.e., the main source exploited is often the closest). This statement, however, is only partially true: it is not corroborated by the circulation patterns observed at an interregional level during the Neolithic period, for instance, when communities

located in Iran mostly ignore Caucasian outcrops and favour the obsidian from eastern Anatolia (Marro 2019).

In the corpus from Nakhchivan analysed so far, the obsidian from Syunik usually predominates (< 50%), followed by that from Geghasar-Gegham (< 35%) and Gügürbaba-Meydan (about 5%), with the exception of Ovçular Tepesi (Chalcolithic, Early Bronze Age), where 70% of the artefacts were made of obsidian from Geghasar-Gegham. The same sources seem to prevail in north-western Iran (e.g., Dava Göz and Kul Tepe Jolfa (Abedi et al. 2018b, 2018c) (see Supplementary Data 1 in the additional supporting information). A sporadic influx from sources located further west in north-eastern Anatolia (e.g., Erzurum, Pasinler, Yağlıca) and Georgia (Chikiani) is also noteworthy, but the obsidian from each of these outcrops is generally attested by < 1% of the total number of artefacts.

Most importantly, these preliminary analyses have revealed an essential difference in obsidian consumption patterns between the sedentary valley settlements, such as Kültepe I, Ovçular Tepesi and Nakhchivan Tepe (Orange *et al*. in press), and the campsites of the foothills (e.g., Uçan Ağil, Bûlôv Qayasi, Çay Ağzi) (Fig. 2). While the former features the polysource procurement model, the campsites reveal an almost exclusive use of the Syunik outcrops, except for a few artefacts originating from the sources located in eastern Anatolia. These results highlight the dissimilarity in nature and function between valley and mountain sites and suggest that valley settlements may have acted as 'economic hubs' that could have had a central role in redistributing obsidian (Marro *et al*. in press).

While the presence at Ovçular of some obsidian from Chikiani (two artefacts identified so far) confirms previous hypotheses assuming the existence of contacts/networks oriented along a north–south axis, additional east–west interactions are also attested by the non-negligible use of eastern Anatolian products observed on many sites: at Kültepe I for instance, the obsidian from Gügürbaba-Meydan represents up to 10% of the Neolithic assemblage analysed so far.

As concerns the means through which the obsidian from the highlands reached the valley sites, it is still not clear whether this precious staple was brought down from the mountains by mobile pastoralists, or if it was obtained by valley shepherds as they moved up the mountains on their seasonal transhumance. As demonstrated by the work recently carried out in Nakhchivan, mobile pastoralism was indeed practised during the Late Chalcolithic: the analyses of the intra-tooth sequential variation of oxygen ($\delta^{18}O$), carbon ($\delta^{13}C$) and strontium ($^{87}Sr/^{86}Sr$) isotope ratios implemented on the teeth of Chalcolithic sheep, goat and cattle from Ovçular Tepesi have shown that part of the flocks certainly had access to upland pastures during summer (Berthon *et al*. in press). But it is not clear whether these flocks actually ventured as far as the obsidian outcrops of Syunik, since the bioavailable Sr isotope ratios ($^{87}Sr/^{86}Sr$) in the Syunik area are so far unknown.

North-western Iran Compared with Nakhchivan, obsidian consumption in north-western Iranian sites appears to have followed a somewhat different pattern. The analyses so far include the survey assemblages of the Sarab (Orange *et al*. 2020), Lake Urmiah, and Salmas districts (which respectively yielded only 11, 53 and 19 artefacts), as well as the excavated assemblages of Doozdaghi Khoy (40 artefacts) and Tepe Silveh (80 artefacts). From the preliminary results, distinct patterns emerge in the three surveyed areas: the sites located west of Lake Urmiah (Salmas and Urmiah) have revealed an overall predominant use of eastern Anatolian obsidians (Nemrut Dağ, Gügürbaba-Meydan), and a more limited use of the Caucasian sources (Syunik, Gegham). The obsidian from Nemrut Dağ, however, is so far completely absent from the sites located east of Lake Urmiah (Yanik Tepe and Sarab district), whose populations relied on the obsidian from Syunik and Gügürbaba-Meydan, as well as on the local source of Ideloo revealed by recent surveys (Director

A. Abedi) (Orange *et al*. 2020). Interestingly, while the obsidian from Syunik is usually attested in every surveyed area, in the region of Salmas this outcrop is only represented by one artefact, found at Qara Tepe. The obsidian from Gegham, on the other hand, was only used at Tepe Haghnazar and Tepe Ahranjan (Salmas), and at Yanik Tepe (east of Lake Urmiah), but is absent from every other assemblage.

The frequent occurrence of obsidian from the Nemrut Dağ observed west of Lake Urmiah, in comparison with its rare distribution in the southern Caucasus, suggests that this obsidian was brought over by the mobile pastoral groups circulating between Lake Van and Lake Urmiah, possibly through the highland route of Chaldiran. In Nakhchivan, on the other hand, which is located further north and where the main east–west circulation axes follow the Araxes valley, the obsidian from Nemrut Dağ is fairly rare and only illustrated by end-products (blade fragments).

But it must be pointed out that Nakhchivani late prehistoric groups made a steady use of the obsidian from Gügürbaba-Meydan, as shown by the notable quantity of artefacts made of this material on Nakhchivani sites, which might be explained by the relative proximity of Gügürbaba-Meydan to the Araxes valley, since this source is located to the north of Lake Van. The obsidian from Gügürbaba-Meydan certainly prevails in the region of Salmas, which indicates close connections with Lake Van, probably through the Chaldiran route: Considering the proximity of Salmas to the Gügürbaba-Meydan outcrop, the amount of obsidian from this source in the western Urmiah region is, however, not surprising, although one might have expected a larger representation of Caucasian sources, in particular of the Syunik outcrop.

It is clear that our conclusions on the obsidian consumption patterns in north-western Iran are so far limited by the small number of artefacts analysed. Moreover, these artefacts mostly originate from surveys; for this reason, they are difficult to compare with those collected on Nakhchivani sites, which come from surveys and excavations alike.

CONCLUSIONS

Obsidian sourcing studies in the southern Caucasus have long focused on the territory of modern Armenia and produced a plethora of heterogeneous results that have been used to define obsidian diffusion patterns in the wider region. These studies have laid provisional groundwork on which obsidian consumption trends have been analysed and circulation patterns built up. These patterns, however, may be refined if we focus on other key regions of the southern Caucasus and increase the scale and resolution of obsidian studies in the number of both artefacts and investigated sites.

In this regard, the multi-scale (local, regional, interregional), multi-period and exhaustive approach implemented through the PAST-OBS and SCOPE projects has already provided substantial data for a renewed and detailed investigation of the obsidian networks in the Caucasus as a whole. Our comprehensive analysis strategy has revealed the limited but consistent use of eastern Anatolian obsidian in Nakhchivan, which brings to light a so far unknown east–west circulation axis that had not been clearly identified as such because of the limited number of artefacts previously analysed. In Nakhchivan, we highlighted a marked contrast in obsidian procurement patterns between the sedentary valley settlements (high diversity in obsidian raw material procurement), on the one hand, and the temporary campsites of the foothills (low diversity), on the other: This contrast is most likely indicative of a difference in nature and function between these sites. In particular, the sedentary valley settlements may have acted as ‘economic hubs’ through which a diversity of raw materials transited and were redistributed towards neighbouring regions, such as north-western Iran, as illustrated by the omnipresence of the

Syunik obsidian, attested as far as the southern shore of Lake Urmiah. The mobile pastoralists, during their seasonal transhumance to and from the summer pastures, could have supplied such hubs with Caucasian obsidian, while assuring its diffusion further south towards the winter camps (e.g., Urmiah Lake region).

A detailed plotting of the available data on a map, together with more information on obsidian circulation networks, in particular from north-western Iran, are needed before we may prove or disprove the existence of these patterns, and compare them over time. This should be our task in the near future. Our next endeavour will be to study the reduction sequences adopted for every obsidian type identified to reveal the potential differences in consumption patterns for each obsidian source material. We will then be able to compare the *chaînes opératoires* of the obsidian assemblages of Nakhchivan and north-western Iran with those identified on contemporary sites in the Near East (Levant, Mesopotamia) and Anatolia (a synchronic approach) and through time (a diachronic approach). These comparisons will facilitate a renewed understanding of the movement and use of obsidian within South-Western Asia, and help retrace the obsidian networks and their evolution over the *longue durée*.

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REFERENCES

Abedi, A., Mohammadi, V. D., Steiniger, D., and Glascock, M. D., 2018c, The provenance of Kul Tepe obsidian artifacts: Syunik and the highlands of Armenia as possible seasonal pastureland, *Journal of Archaeological Science: Reports*, **21**, 406–12.

Abedi, A., Omrani, B., and Karimifar, A., 2015, Fifth and fourth millennium BC in North-Western Iran: Dalma and Pisdeli revisited, *Documenta Praehistorica*, **XLII**, 321–38.

Abedi, A., Varoutsikos, B., and Chataigner, C., 2018b, Provenance of obsidian artifacts from the chalcolithic site of Dava Göz in NW IRAN using portable XRF, *Journal of Archaeological Science: Reports*, **20**, 756–67.

Abedi, A., Vosough, B., Razani, M., Bagherzadeh Kasiri, M., Steiniger, D., and Ebrahimi, G., 2018a, Obsidian deposits from North-Western Iran and first analytical results: Implications for prehistoric production and trade, *Mediterranean Archaeology and Archaeometry*, **18**, 107–18.

Adler, D. S., Wilkinson, K. N., Blockley, S., Mark, D. F., Pinhasi, R., Schmidt-Magee, B. A., Nahapetyan, S., Mallol, C., Berna, F., Glauberman, P. J., Raczynski-Henk, Y., Wales, N., Frahm, E., Jöris, O., Macleod, A., Smith, V. C., Cullen, V. L., and Gasparian, B., 2014, Early Levallois technology and the lower to middle Paleolithic transition in the southern Caucasus, *Science*, **345**, 1609–13.

Badalian, R., Bigazzi, G., Cauvin, M. C., Chataigner, C., Jrbashyan, R., Karapetyan, S. G., Oddone, M., and Poidevin, J. L., 2001, An international research project on Armenian archaeological sites: Fission-track dating of obsidians, *Radiation Measurements*, **34**, 373–8.

Badalyan, R., 2010, Obsidian of the Southern Caucasus: The use of raw materials in the Neolithic to Early Iron Ages, in *Von Majkop bis Trialeti. Gewinnung und Verbreitung von Metallen und Obsidian in Kaukasien im 4. – 2. Jt. v. Chr., 27-38* (eds. S. Hansen, A. Hauptmann, I. Motzenbäcker, and E. Pernicka), Rudolf Habelt Gmbh, Bonn.

Badalyan, R., Chataigner, C., and Kohl, P. L., 2004, Trans-Caucasian obsidian: The exploitation of the sources and their distribution, in *A view from the highlands: Archaeological studies in honour of C.a. Burney* (ed. A. Sagona), Peeters press, Leuven.

Badalyan, R., Lombard, P., Avetisyan, P., Chataigner, C., Chabot, J., Vila, E., Hovsepyan, R., Willcox, G., and Pessin, H., 2007, New data on the late prehistory of the southern Caucasus: The excavations at Aratashen (Armenia): Preliminary report, in *Les cultures du Caucase (VI^e^–III^e^ millénaires avant notre ère)—leurs relations avec le Proche-orient* (ed. B. Lyonnet), Editions Recherche Sur les Civilisations, CNRS editions, Paris.

Bakhshaliyev, V., and Novruzov, Z., 2010, *Sirabda arxeoloji arastırmalar (archaeological investigations in the Sirab area)*, Oskar, Bakı.

Barge, O., Azizi Kharanaghi, H., Biglari, F., Moradi, B., Mashkour, M., Tengberg, M., and Chataigner, C., 2018, Diffusion of Anatolian and Caucasian obsidian in the Zagros Mountains and the highlands of Iran: Elements of explanation in 'least cost path' models, *Quaternary International*, **467**, 297–322.

Barge, O., and Chataigner, C., 2003, The procurement of obsidian: Factors influencing the choice of deposits, *Journal of Non-Crystalline Solids*, **323**(1-3), 172–9.

Berthon, R., Giblin, J., Balasse, M., Fiorillo, D., and Bellefroid, E., in press, The role of herding strategies in the exploitation of natural resources by early mining communities in the Caucasus, in *On salt, copper, and gold: The origins of early mining and metallurgy in the Caucasus* (eds. C. Marro and T. Stöllner), Maison de l'Orient et de la Méditerranée, Lyon.

Biagi, P., Nisbet, R., and Gratuze, B., 2017, Discovery of obsidian mines on mount Chikiani in the lesser Caucasus of Georgia, *Antiquity*, **91**, e5.

Blackman, M. J., 1984, Provenance studies of middle eastern obsidian from sites in Highland Iran, in *Archaeological chemistry—III* (ed. J. B. Lambert), American Chemical Society, Washington, D.C..

Blackman, M. J., Badalian, R., Kikodze, Z., and Kohl, P. L., 1998, Chemical characterization of caucasian obsidian geological sources, in *L'obsidienne au Proche-orient et au Moyen-orient: du volcan à l'outil* (eds. M.-C. Cauvin, A. Gourgaud, B. gratuze, N. Arnaud, G. Poupeau, and J.-L. Poidevin), Archaeopress, Oxford, England.

Brennan, P. V., 2000, Obsidian from volcanic sequences and recent alluvial deposits, Erzurum District, north-eastern Anatolia: Chemical characterisation and archaeological implications, *Ancient Near Eastern Studies*, **37**, 128–52.

Campbell, S., and Healey, E., 2018, Diversity in obsidian use in the prehistoric and early historic Middle East, *Quaternary International*, **468**, 141–54.

Cann, J. R., and Renfrew, C., 1964, The characterization of obsidian and its application to the Mediterranean region, *Proceedings of the Prehistoric Society*, **30**, 111–31.

Carter, T., 2014, The contribution of obsidian characterization studies to early prehistoric archaeology, in *Lithic raw material exploitation and circulation in prehistory: A comparative perspective in diverse Palaeoenvironments, 2014 Liège* (eds. M. Yamada and A. Ono), 23–33, Belgique. Eraul, Vol. **138**.

Cauvin, M.-C., Balkan, N., Besnus, Y., and Şaroğlu, F., 1986, Origine de l'obsidienne de Cafer Höyük (Turquie): Premiers résultats, *Paléorient*, **12**, 89–97.

Chataigner, C., 1998, Sources des artefacts du Proche orient d'après leur caractérisation géochimique, in *L'obsidienne au Proche-orient et au Moyen-orient: du volcan à l'outil* (eds. M.-C. Cauvin, A. Gourgaud, B. Gratuze, N. Arnaud, G. Poupeau, and J.-L. Poidevin), Archaeopress, Oxford, England.

Chataigner, C., Avetisyan, P., Palumbi, G., and Uerpmann, H.-P., 2010, Godedzor, a late Ubaid-related settlement in the southern Caucasus, in *Studies in ancient oriental civilizations, 63* (eds. R. A. Carter and G. Philip), Oriental Institute of the University of Chicago, Chicago.

Chataigner, C., and Barge, O., 2008, Quantitative approach to the diffusion of obsidian in the ancient northern near east, in *Layers of perception. Proceedings of the 35th international conference on computer applications and quantitative methods in archaeology (CAA), Berlin, 2–6 April 2007* (eds. A. Posluschny, K. Lambers, and I. Herzog), 10, Koll. Vor- u. Frühgesch, Bonn.

Chataigner, C., and Barge, O., 2010, GIS (geographic information system) for obsidian procurement analysis: Pathway modelisation in space and time, in *Von Majkop bis Trialeti: Gewinnung und Verbreitung von Metallen und obsidian in Kaukasien im 4.-2. Jt. v. Chr. Beiträge des Internationalen symposiums in Berlin vom 1.–3. Juni 2006* (eds. S. Hansen, A. Hauptmann, I. Motzenbäcker, and E. Pernicka), Dr Rudolf Habelt GmbH, Bonn.

Chataigner, C., and Gratuze, B., 2014a, New data on the exploitation of obsidian in the southern Caucasus (Armenia, Georgia) and eastern Turkey, part 1: Source characterization, *Archaeometry*, **56**, 25–47.

Chataigner, C., and Gratuze, B., 2014b, New data on the exploitation of obsidian in the southern Caucasus (Armenia, Georgia) and eastern Turkey, part 2: Obsidian procurement from the upper Palaeolithic to the late bronze age, *Archaeometry*, **56**, 48–69.

Chataigner, C., Gratuze, B., Tardy, N., Abbès, F., Kalantaryan, I., Hovsepyan, R., Chahoud, J., and Perello, B., 2020, Diachronic variability in obsidian procurement patterns and the role of the cave–sheepfold of Getahovit-2 (NE Armenia) during the chalcolithic period, *Quaternary International*, **550**, 1–9.

Chataigner, C., Işikli, M., Gratuze, B., and ÇIL, V., 2014, Obsidian sources in the regions of Erzurum and Kars (North-East Turkey): New data, *Archaeometry*, **56**, 351–74.

Cherry, J. F., Faro, E. Z., and Minc, L., 2010, Field survey and geochemical characterization of the southern Armenian obsidian sources, *Journal of Field Archaeology*, **35**, 147–63.

Childe, V. G., 1930, *The bronze age*, Cambridge University Press, Cambridge.

Courcier, A., 2010, Metalliferous potential, metallogenous particularities and extractive metallurgy: Interdisciplinary research on understanding the ancient metallurgy in the Caucasus during the early bronze age, in *Von Majkop bis Trialeti: Gewinnung und Verbreitung von Metallen un obsidian in Kaukasien im 4.-2. Jt. v. Chr. Beiträge des Internationalen symposiums in Berlin vom 1.–3. Juni 2006* (eds. S. Hansen, A. Hauptmann, I. Motzenbäcker, and E. Pernicka), Dr Rudolf Habelt GmbH, Bonn.

Cucchi, T., Kovács, Z. E., Berthon, R., Orth, A., Bonhomme, F., Evin, A., Siahsarvie, R., Darvish, J., Bakhshaliyev, V., and Marro, C., 2013, On the trail of Neolithic mice and men towards Transcaucasia: Zooarchaeological clues from Nakhchivan (Azerbaijan), *Biological Journal of the Linnean Society*, **108**, 917–28.

Danti, M. D., Voigt, M. M., and Dyson, R. H., 2004, The search for the late chalcolithic/early bronze age transition in the Ushnu-Solduz valley, Iran, in *A view from the highlands. Archaeological studies in honour of Charles Burney* (ed. A. Sagona), Ancient near eastern studies, Peeters, Herent.

Darabi, H., and Glascock, M. D., 2013, The source of obsidian artefacts found at east chia Sabz, Western Iran, *Journal of Archaeological Science*, **40**, 3804–9.

Davis, M. K., Jackson, T., Shackley, M. S., Teague, T., and Hampel, J., 2011, Factors affecting the energy-dispersive X-ray fluorescence (EDXRF) analysis of archaeological obsidian, in *X-ray fluorescence spectrometry (XRF) in Geoarchaeology* (ed. M. S. Shackley), Springer New York.

Delerue, S., 2007, *L'obsidienne dans le processus de Néolithisation du Proche-orient (12 000–6500 av. J.-C.)*Unpublished PhD Thesis, Université Michel de Montaigne Bordeaux III, France.

Doronicheva, E., and Shackley, M. S., 2014, Obsidian exploitation strategies in the middle and upper Paleolithic of the northern Caucasus: New data from Mesmaiskaya cave, *PaleoAnthropology*, 565–85.

Doronicheva, E. V., Golovanova, L. V., Doronichev, V. B., Shackley, M. S., and Nedomolkin, A. G., 2019, New data about exploitation of the Zayukovo (Baksan) obsidian source in northern Caucasus during the Paleolithic, *Journal of Archaeological Science: Reports*, **23**, 157–65.

Ercan, T., Şaroğlu, F., and Kuşçu, I., 1996, Features of obsidian beds formed by volcanic activity since 25 million years B. P, in *The proceedings of the 29th international SYmposium on Archaeometry, Ankara 1994* (eds. S. Demirci, A. M. Özer, and G. D. Summers), Ankara, Tübitak.

Forest, J.-D., 1996, L'apparition de l'État en Mésopotamie, *L'État, le pouvoir, les prestations et leurs formes en Mésopotamie ancienne.*, **11**.

Frahm, E., 2012, Distinguishing Nemrut Dağ and Bingöl a obsidians: Geochemical and landscape differences and the archaeological implications, *Journal of Archaeological Science*, **39**, 1436–44.

Frahm, E., 2014, Characterizing obsidian sources with portable XRF: Accuracy, reproducibility, and field relationships in a case study from Armenia, *Journal of Archaeological Science*, **49**, 105–25.

Frahm, E., Feinberg, J. M., Schmidt-magee, B. A., Wilkinson, K. N., Gasparyan, B., Yeritsyan, B., and Adler, D. S., 2016, Middle Palaeolithic toolstone procurement behaviors at Lusakert cave 1, Hrazdan valley, Armenia, *Journal of Human Evolution*, **91**, 73–92.

Frahm, E., Owen Jones, C., Corolla, M., Wilkinson, K. N., Sherriff, J. E., Gasparyan, B., and Adler, D. S., 2020, Comparing lower and middle Palaeolithic lithic procurement behaviors within the Hrazdan basin of Central Armenia, *Journal of Archaeological Science: Reports*, **32**, 102389.

Frahm, E., Schmidt, B. A., Gasparyan, B., Yeritsyan, B., Karapetian, S., Meliksetian, K., and Adler, D. S., 2014, Ten seconds in the field: Rapid Armenian obsidian sourcing with portable XRF to inform excavations and surveys, *Journal of Archaeological Science*, **41**, 333–48.

Frahm, E., Sherriff, J., Wilkinson, K. N., Beverly, E. J., Adler, D. S., and Gasparyan, B., 2017, Ptghni: A new obsidian source in the Hrazdan River basin, Armenia, *Journal of Archaeological Science: Reports*, **14**, 55–64.

Frahm, E. E., 2010, *The Bronze Age obsidian industry at tell Mozan (ancient Urkesh), Syria: Redeveloping electron microprobe analysis for 21st-century sourcing research and the implications for obsidian use and exchange in northern Mesopotamia after the Neolithic*PhD Thesis, University of Minnesota.

Frangipane, M., 1996, *La nascita dello Stato nel Vicino Oriente*, Laterza, Coll. Quadrante 85, Laterza, Rome.

Freund, K. P., 2013, An assessment of the current applications and future directions of obsidian sourcing studies in archaeological research, *Archaeometry*, **55**, 779–93.

Gailhard, N., in press, The invisible movement of metallurgy: The interactions between nomads and metal. some evidence from Nakhchivan (Azerbaijan) during the chalcolithic and the early bronze age, in *On salt, copper, and gold: The origins of early mining and metallurgy in the Caucasus* (eds. C. Marro and T. Stöllner), Maison de l'Orient et de la Méditerranée, Lyon.

Gailhard, N., Bode, M., Bakhshaliyev, V., Hauptmann, A., and Marro, C., 2017, Archaeometallurgical investigations in Nakhchivan, Azerbaijan: What does the evidence from late chalcolithic Ovçular Tepesi tell us about the beginning of extractive metallurgy? *Journal of Field Archaeology*, 1–21.

Ghorabi, S., Glascock, M. D., Khademi, F., and Rezaie, A., 2008, A geochemical investigation of obsidian artifacts from sites in northwestern Iran, *IAOS Bulletin*, **39**, 7–10.

Ghorabi, S., Khademi Nadooshan, F., Glascock, M. D., Noubari-hejabari, A., and Ghorbani, M., 2010, Provenance of obsidian tools from northwestern Iran using X-ray fluorescence analysis and neutron activation analysis, *IAOS Bulletin*, **43**, 14–26.

Gratuze, B., 1999, Obsidian characterization by laser ablation ICP-MS and its application to prehistoric trade in the Mediterranean and the near east: Sources and distribution of obsidian within the Aegean and Anatolia, *Journal of Archaeological Science*, **26**(10), 869–81.

Hejebri Nobari, A., Davoudi, H., Mousavi Kouhpar, S. M., and Mashkour, M., 2017, Subsistence economy during the iron age in northwestern Iran: The case study of Tepe Hasanlu, *International Journal of Humanities*, **24**, 30–48.

Helwing, B., in press, Patterns of early metallurgy on the Iranian plateau, from the beginnings to the end of the bronze age, in *On salt, copper, and gold: The origins of early mining and metallurgy in the Caucasus* (eds. C. Marro and T. Stöllner), Maison de l'Orient et de la Méditerranée, Lyon.

Helwing, B., Aliyev, T., Lyonnet, B., Guliyev, F., Hansen, S., and Mirtskhulava, G. (eds.), 2017, The Kura projects, in *New research on the later prehistory of the southern Caucasus*, Archäologie in Iran und Turan, band 16, Dietrich Reimer Verlag, Berlin.

Innocenti, F., Mazzuoli, R., Pasquaré, G., Serri, G., and Villari, L., 1980, Evolution of the volcanism in the area of interaction between the Arabian, Anatolian and Iranian plates (Lake Van, eastern Turkey), *Journal of Volcanology and Geothermal Research*, **1**, 103–12.

Karapetyan, S. G., 1972, *Structural and compositional features of young Rhyolitic volcanoes in the Armenian SSR, Yerevan*, National Academy of Sciences of the Armenian SSR.

Keller, J., DJerbashian, R., Karapetian, S. G., Pernicka, E., and Nasedkin, V., 1996, Armenian and Caucasian obsidian occurrences as sources for the Neolithic trade: Volcanological setting and chemical characteristics, in *The proceedings of the 29th international Symposium on Archaeometry, Ankara 1994* (eds. S. Demirci, A. M. Özer, and G. D. Summers), Tübitak, Ankara.

Keller, J., and Seifried, C., 1990, The present status of obsidian source identification in Anatolia and the near east, *PACT*, **25**, 57–85.

Khademi Nadooshan, F., Abedi, A., Glascock, M. D., Eskandari, N., and Khazaee, M., 2013, Provenance of prehistoric obsidian artefacts from Kul Tepe, northwestern Iran using X-ray fluorescence (XRF) analysis, *Journal of Archaeological Science*, **40**, 1956–65.

Kobayashi, K., and Sagona, A., 2008, A survey of obsidian sources in the provinces of Erzurum, Erzinca, Rize and Bitlis, 2006, *Arastirma Sonuçlari Toplantisi*, **25**, 185–96.

Le Bourdonnec, F.-X., Nomade, S., Poupeau, G., Guillou, H., Tushabramishvili, N., Moncel, M.-H., Pleurdeau, D., Agapishvili, T., Voinchet, P., Mgeladze, A., and Lordkipanidze, D., 2012, Multiple origins of Bondi cave and Ortvale Klde (NW Georgia) obsidians and human mobility in Transcaucasia during the middle and upper Palaeolithic, *Journal of Archaeological Science*, **39**, 1317–30.

Lyonnet, B., Guliyev, F., Helwing, B., Aliyev, T., Hansen, S., and Mirtskhulava, G., 2012, Ancient Kura 2010–2011: The first two seasons of joint field work in the southern Caucasus, *Archaologische Mitteilungen aus Iran und Turan*, **44**, 11–90.

Madhavi, A., and Bovington, C., 1972, Neutron activation analysis of some obsidian samples from geological and archaeological sites, *Iran*, **10**, 148–51.

Marro, C., 2019, *Avant le Déluge. Connexions et interactions du Caucase à la Mésopotamie du Néolithique à l'âge du bronze*, Unpublished essay—Université de Paris I-Panthéon-Sorbonne.

Marro, C., Bakhshaliyev, V., and Ashurov, S., 2009, Excavations at Ovçular Tepesi (Nakhichevan, Azerbaijan). First preliminary report: The 2006–2008 seasons, *Anatolia Antiqua*, **XVII**, 31–87.

Marro, C., Bakhshaliyev, V., Berthon, R., and Thomalsky, J., 2019, New light on the late prehistory of the South Caucasus: Data from the recent excavation campaigns at Kültepe I in Nakhchivan, Azerbaijan (2012–2018), *Paléorient*, **45**, 81–113.

Marro, C., Bakhshaliyev, V., Le Bourdonnec, F.-X., and Orange, M., in press, A multi-directional bridge? The geo-strategic significance of Nakhchivan during the late chalcolithic (4500–3500 BCE), in *The Caucasus: Bridge between the urban centres in Mesopotamia and the pontic steppes in the 4th and 3rd millennium BC. Proceedings of the Ergebnisse der Caucasus conference, Frankfurt 2018* (eds. L. Giemsch and S. Hansen), Schnell & Steiner.

Marro, C., Bakhshaliyev, V., and Sanz, S., 2010, Archaeological investigations on the salt mine of Duzdagi (Nakhchivan, Azerbaïdjan), *TÜBA-AR, Turkish Academy of Sciences Journal of Archaeology*, **13**, 229–44.

Martirosyan-Olshansky, K., 2018, *Sourcing obsidian artifacts from Masis blur, Armenia*, 19–34, AJNES, XII.

Maziar, S., 2015, Settlement dynamics of the Kura-Araxes culture: An overview of the late chalcolithic and early bronze age in the Khoda Afarin plain, North-Western Iran, *Paléorient*, **41**, 25–36.

Maziar, S., in press, Geographical proximity and material culture; the interplay between Syunik and the southern part of the Araxes river basin in the 6th to the 3rd millennium BC, *Quaternary International.*.

Maziar, S., and Glascock, M. D., 2017, Communication networks and economical interactions: Sourcing obsidian in the Araxes River basin, *Journal of Archaeological Science: Reports*, **14**, 31–7.

Mouralis, D., Massussi, M., Palumbi, G., Akköprü, E., Balossi Restelli, F., Brunstein, D., Frangipane, M., Gratuze, B., Mokadem, F., and Robin, A. K., 2018, The procurement of obsidian at Arslantepe (eastern Anatolia) during the chalcolithic and early bronze age: Connections with Anatolia and Caucasus, *Quaternary International*, **467**(part B), 342–59.

Moutsiou, T., 2014, The obsidian evidence for the scale of social life during the Palaeolithic*,* Oxford, United Kingdom, British archaeological reports: International series 2613.

Neumann, D., Gambashidze, I., Ricci, A., Mindiashvili, G., and Gogochuri, G., 2015, Reassessing the hills. Results of an archaeological field survey on the Akhalkalaki plateau, South Georgia, *Eurasia Antiqua*, 21–44.

Niknami, K. A., Amirkhiz, C. A., and Glascock, M. D., 2010, Provenance studies of chalcolithic obsidian artefacts from near lake Urmia, northwestern Iran using WDXRF analysis, *Archaeometry*, **52**, 19–30.

Nishiaki, Y., Guliyev, F., Kadowaki, S., Alakbarov, V., Miki, T., Salimbayov, S., Akashi, C., and Arai, S., 2015, Investigating cultural and socioeconomic change at the beginning of the pottery Neolithic in the southern Caucasus: The 2013 excavations at Haci Elamxanli Tepe, Azerbaijan, *Bulletin of the American Schools of Oriental Research*, **374**, 1–28.

Nishiaki, Y., Maeda, O., Kannari, T., Nagai, M., Healey, E., Guliyev, F., and Campbell, S., 2019b, Obsidian provenance analyses at Göytepe, Azerbaijan: Implications for understanding Neolithic socioeconomies in the southern Caucasus, *Archaeometry*, **61**, 765–82.

Nishiaki, Y., Zeynalov, A., Mansrov, M., Akashi, C., Arai, S., Shimogama, K., and Guliyev, F., 2019a, The Mesolithic–Neolithic interface in the southern Caucasus: 2016–2017 excavations at Damjili cave, West Azerbaijan, *Archaeological Research in Asia*, 100140.

Orange, M., Abedi, A., Le Bourdonnec, F.-X., Vosugh, B., Ebrahimi, G., Razani, M., and Marro, C., 2020, Consuming local: The new obsidian source of Ideloo (northwestern Iran) and first evidence of use by neighbouring prehistoric communities, *Geoarchaeology.*

Orange, M., Bakhshaliyev, V., Berthon, R., Marro, C. and Le Bourdonnec, F.-X., In press, Polysource procurement at Nakhchivan Tepe (Azerbaijan, chalcolithic): First insights into the obsidian consumption patterns of a Dalma site recently discovered in the southern Caucasus. *In*: Biró, K. & András, M. (Eds). Proceedings of the international obsidian conference*, Sarospatak, Hungary,* 2019.

Orange, M., Le Bourdonnec, F.-X., Bellot-Gurlet, L., Lugliè, C., Dubernet, S., Bressy-Leandri, C., Scheffers, A., and Joannes-Boyau, R., 2017, On sourcing obsidian assemblages from the Mediterranean area: Analytical strategies for their exhaustive geochemical characterisation, *Journal of Archaeological Science: Reports*, **12**, 834–44.

Palumbi, G., Gratuze, B., Harutyunyan, A., and Chataigner, C., 2014, Obsidian-tempered pottery in the southern Caucasus: A new approach to obsidian as a ceramic-temper, *Journal of Archaeological Science*, **44**, 43–54.

Palumbi, G., Guilbeau, D., Astruc, L., Chataigner, C., Gratuze, B., Lyonnet, B., and Pulitani, G., 2018, Between cooking and knapping in the southern Caucasus: Obsidian-tempered ceramics from Aratashen (Armenia) and Mentesh Tepe (Azerbaijan), *Quaternary International*, **468**, 121–33.

Palumbi, P., Kalantaryan, I., Bălăşescu, A., Barge, O., Chahoud, J., Hovsepyan, R., Meliksetian, K., Avetisyan, P., and Chataigner, C., in press, Early pastoralism and natural resource management: Recent research at Godedzor, in *On salt, copper, and gold: The origins of early mining and metallurgy in the Caucasus* (eds. C. Marro and T. Stöllner), Maison de l'Orient et de la Méditerranée, Lyon.

Poidevin, J.-L., 1998, Les gisements d'obsidienne de Turquie et de Transcaucasie: géologie, géochimie et chronométrie, in *L'obsidienne au Proche-orient et au Moyen-orient: du volcan à l'outil* (eds. M.-C. Cauvin, A. Gourgaud, B. Gratuze, N. Arnaud, G. Poupeau, and J.-L. Poidevin), Archaeopress, Oxford, England.

Purschwitz, C., 2018, Chalcolithic and middle bronze age obsidian industries at Karmir Sar: A mountain view on the lithic economies of the southern Caucasus, *Journal of Lithic Studies*, **5**.

Renfrew, C., and Dixon, J. E., 1976, Obsidian in Western Asia: A review, in *Problems in economic and social archaeology* (eds. G. D. G. Sieveking, G. Longworth, and K. E. Wilson), Gerald Duckworth & Co., London, England.

Renfrew, C., Dixon, J. E., and Cann, J. R., 1966, Obsidian and early cultural contact in the near east, *Proceedings of the Prehistoric Society*, **32**, 30–72.

Robin, A.-K., 2013, *Affleurements d'obsidienne dans le massif d'Arteni (Arménie), ressources exploitées par les sociétés néolithiques caucasiennes et proche-orientales: gîtologie, mise en place, morphologie des affleurements*Master, Université Paris 1 Sorbonne.

Robin, A.-K., Mouralis, D., Akköprü, E., Gratuze, B., Kuzucuoğlu, C., Nomade, S., Pereira, A., Doğu, A. F., Erturaç, K. M., and Khalidi, L., 2016, Identification and characterization of two new obsidian sub-sources in the Nemrut volcano (eastern Anatolia, Turkey): The Sıcaksu and Kayacık obsidian, *Journal of Archaeological Science: Reports*, **9**, 705–17.

Sagona, A., 2018, *The archaeology of the Caucasus: From earliest settlements to the iron age*, 541 p, Cambridge University Press, Cambridge World Archaeology: Cambridge. https://doi.org/10.1017/9781139061254

Shishlina, N. I., Orfinskaya, O. V., and Golikov, V. P., 2003, Bronze age textiles from the North Caucasus: New evidence of fourth millennium BC Fibres and fabrics, *Oxford Journal of Archaeology*, **22**, 331–44.

Smith, A. T., and Rubinson, K. S. (eds.), 2003, *Archaeology in the borderlands: Investigations in Caucasia and beyond*, Cotsen Institute of Archaeology, Los Angeles.

Thomalsky, J., 2019, Landscapes of innovation in prehistoric Iran, in *Farr-E Firouz distinguished scholars of cultural heritage of Persia (Vol 5), special edition in honor of Dr. Firouz Bagherzadeh* (ed. S. Aryamanesh), Aryaramna Press, Tehran.

Thomalsky, J., in press, Lithic networks in the Caucasus and Iran. *In*: Hansen S. (ed), *Proceedings of the International Conference 'New Research on the Neolithic in the Circumcaspian Regions*, Tbilisi, 27–30 September 2011.

Torrence, R., 1986, *Production and exchange of stone tools. Prehistoric obsidian in the Aegean*, New York, Cambridge University Press, New York.

Varoutsikos, B., and Chataigner, C., 2010, *Collecter et organiser les données relatives à l'obsidienne préhistorique au Proche-orient et en Transcaucasie*, Premières Rencontres d'Archéologie de l'Institut Français d'Études Anatoliennes—Archéologies et espaces parcourus, Istanbul.

Wailes, B. (ed.), 1996, Craft specialization and social evolution: In memory of V, in *Gordon Childe, New York: University museum monograph 93*, Academic/Plenum, Kluwer.

Weninger, B., Alram-Stern, E., Bauer, E., Clare, L., Danzeglocke, U., Jöris, O., Kubatzki, C., Rollefson, G., Todorova, H., and Van Andel, T., 2006, Climate forcing due to the 8200 Cal yr BP event observed at early Neolithic sites in the eastern Mediterranean, *Quaternary Research*, **66**, 401–20.

Williams-Thorpe, O., 1995, Obsidian in the Mediterranean and the near east: A provenancing success story, *Archaeometry*, **37**, 217–48.

Zeder, M. A., and Hesse, B., 2000, The initial domestication of goats (Capra hircus) in the Zagros Mountains 10,000 years ago, *Science*, **287**(5461), 2254–7.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Detailed currently-available provenance data from archaeological sites of the Southern Caucasus and North-western Iran.

Table S2. Obsidian sources located in the Caucasus and eastern Anatolia and proposed standardized nomenclature.

Table S3. Geochemical compositions obtained by portable X-ray fluorescence (pXRF) and/or laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) on 267 geological samples from Anatolia and the Caucasus.

