From near and far: Stone procurement and exchange at Çukuriçi Höyük in Western Anatolia

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Abstract:

The focus of this paper are the stone tools of Çukuriçi Höyük, a prehistoric site situated at the central Aegean coast of Anatolia. The settlement was inhabited from the Neolithic, through the Late Chalcolithic and Early Bronze Age 1 periods, a period lasting from the early 7th to the early 3rd millennium BCE. A long-term interdisciplinary study of the excavated lithics with different scientific methods on various stone materials (thin section analysis, pXRF, NAA, LA-ICP-MS) offer new primary data about the procurement strategies of prehistoric societies from a diachronic perspective. The results will be presented for the first time with an overview of all source materials and their distinct use through time.

The lithic assemblages from Çukuriçi Höyük consist of a considerable variety of small finds, grinding stones and chipped stone tools. The high variability of raw materials within the different categories of tools is remarkable. In addition to stone tools manufactured from sources in the immediate vicinity of the settlement (*i.e.*, mica-schist, limestone, marble, amphibolite, serpentinite), others are of rock types such as chert, which indicate an origin within the broader region. Moreover, volcanic rocks, notably the exceptionally high amount of Melian obsidian found at Çukuriçi Höyük, attest to the supra-regional procurement of distinct rock types. Small stone axes made of jadeite presumably from the Greek island of Syros, also indicate these far-reaching procurement strategies.

The systematic and diachronic analyses of the stone tools found at Çukuriçi Höyük has demonstrated that as early as the Neolithic period extensive efforts were made to supply the settlement with carefully selected raw materials or finished goods procured from distinct rock sources.

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1. Introduction

In this paper, we focus on the procurement of local, regional and supra-regional rock sources for the Neolithic to Early Bronze Age communities that inhabited the site Çukuriçi Höyük in order to assess the accessibility of raw materials from a diachronic perspective. Such investigations allow the reconstruction of socio-cultural developments mirrored in varying resource management strategies. For this purpose, the classification by Andrew W. Kandel and colleagues (Kandel *et al*. 2016: 636) is used which was originally applied for Middle Stone Age societies in Southern Africa to describe the transport distance of rocks based on the proximity of the archaeological site (see Table 1).

Table 1. Transport distance classification (after Kandel *et al*. 2016: 636).

Rock sources	Definition and distance
local	„[…] could be collected on short walks (0-5 km) from a base camp during daily foraging campaigns […]“
regional	„[…] could be collected on longer walks (6-20 km), for example during hunting or foraging trips […]“
supra-regional	„[…] might be collected during extended forays (>20 km), for example during overnight stays or where contact with other groups may have occurred […]“

Although extended mobility has to be assumed already for prehistoric people in this region, especially due to the existence of seafaring communities (Broodbank 2006: 211-220; Horejs 2016; Horejs *et al*. 2015), this classification can be used to point out raw material accessibility of prehistoric coastal societies on a more general level.

1.1. The site Çukuriçi Höyük

The settlement mound of Çukuriçi Höyük is located at the central Aegean coast in Western Turkey. According to the reconstruction of the prehistoric coastline, the settlement can be defined as a coastal site (Stock *et al*. 2013). Subsequent to initial excavations by the Selçuk Müzesi (Evren 1999; Evren & İçten 1998), systematic archaeological investigations at the site, and the vicinity, were conducted between 2006 and 2014 under the licence of the Austrian Archaeological Institute (OeAI). This work was funded by the Austrian Science Fund (FWF) and the European Research Council (ERC; see Horejs 2017 for a presentation of the Çukuriçi Höyük Research Project).

Large parts of the tell settlement were destroyed in the course of modern agricultural activities in the area. However, paleogeographic studies suggest a former settlement size of 200 to 100 meters with 8.5 meters of occupation layers (Stock *et al*. 2015). The settlement phases excavated at Çukuriçi Höyük date from the Neolithic period in the 7th millennium, the Late Chalcolithic period in the second half of the 4th millennium and the Early Bronze Age 1 period in the first quarter of the 3rd millennium BCE, according to the common terminology used in Anatolia (Horejs 2017: 17, fig. 1.5).

Within the distinct occupation levels, various stone tool assemblages produced from a wide range of raw materials have been discovered, including chipped stones, axes, pounders, grinding stones, and mortars. Altogether, *circa* 23790 stone tools were archaeologically investigated (obsidian and chert: *circa* 23000, small finds: *circa* 750, grinding stones and mortars: 40).

2. Local rock sources (0-5 km)

To assess the accessibility and variability of local rock types used by the prehistoric inhabitants of Çukuriçi Höyük, a geological survey in the vicinity of the settlement was conducted, in addition to the examination of published data (Çakmakoğlu 2007: 2, fig. 1a; Wolf 2017: 26, fig. 6.1.3). The regional geology of this area is defined by different tectono-stratigraphical units composed of marble, cherty marble, metavolcanic rocks, phyllites, schists, metabauxites, amphibolites and eclogites.

2.1 Rock and clay sources

Surveys conducted within this project revealed the presence of a variety of local rock sources close to Çukuriçi Höyük in the Derbent Valley (Wolf 2017: 11-16). These detailed studies have shown that the majority of the rock types used for the construction of buildings, as well as the production of tools from the Neolithic period onwards, crop out within a range of 3-4 km from the settlement. Due to gravitational and fluvial transport, stones of different sizes were available in the direct vicinity of the settlement. These local raw materials include different types of carbonate rocks (i.e., marble and schist), as well as quartz, amphibolite, peridotite, gneiss and emery (Wolf 2017: 22-30) (Figure 1). The artefacts made of these rock types have been studied macro- and microscopically to determine the variety of lithotypes used, and to evaluate changes over different settlement phases.

Within occupation layers corresponding to the Early Neolithic period (ÇuHö XIII-XII; n=42), 15 lithotypes have been recorded. In comparison, 37 lithotypes are present for the Late Neolithic period (ÇuHö XI-VIII; n=587), attesting to an increasing diversity in the rock resources used. Interestingly, in the Late Chalcolithic (10 types; ÇuHö VII-Vb; n=23) and Early Bronze Age periods (23 types; ÇuHö Va-III; n=99) a significant reduction of raw material lithotypes can be noted in contrast to the Late Neolithic period (Schwall 2018: 241-243, 564-578; Wolf 2017: 55-59).

For assessing raw material choices, it is necessary to examine the different stone types, their characteristics and use for the production of distinct objects. During the Neolithic period at Çukuriçi Höyük, the high amount of stone beads made of mica schist, quartz-rich mica schist, marble, serpentinized peridotite and peridotite is striking and maybe connected with favoured aesthetic characteristics of the beads (*e.g.*, Wolf 2017: 62-65 for further examples). In the Late Chalcolithic and Early Bronze Age periods, rocks with high hardness and density (*e.g.*, milk quartz, emery, serpentinite, metabasalt) were favoured for pounders or hammerstones. This is especially notable for the use of emery to produce hammerstones, adzes and axes, since the Late Chalcolithic time onwards (*e.g.*, Wolf 2017: 59-62 for further examples).

In general, carbonate rocks-marble, schist (metapelites), ultramafics or metaultramafics (peridotite, amphibolite) and milky quartz are the dominant lithotypes used for the production of stone tools and ornaments at Çukuriçi Höyük, with a decreasing number especially of carbonate rocks-marble (42.9%) and metapelites (21.5%) from the Early Neolithic to the Early Bronze Age (carbonates: 32.2%; metapelites: 7.5%) period. Concerning the Early Bronze Age, the increasing number of emery tools (13.9%), is remarkable since it is in clear contrast to the preceding periods (Neolithic period: max. 3%) (Schwall 2018: 241-243, 564-578; Wolf 2017: 66-67).

The selective choice of emery for the production of extremely tough stone tools during the Late Chalcolithic and Early Bronze Age phases could possibly reflect the need and importance of such materials in the context of a metal working community: For the later occupations at Çukuriçi Höyük extensive metallurgical activities are confirmed. Since the Late Chalcolithic period, in the 4th millennium BCE, the production of arsenical copper is attested and the site evolves into a metal production centre with numerous metallurgical workshops in the settlements ÇuHö IV-III (Horejs & Mehofer 2015; Mehofer 2014).

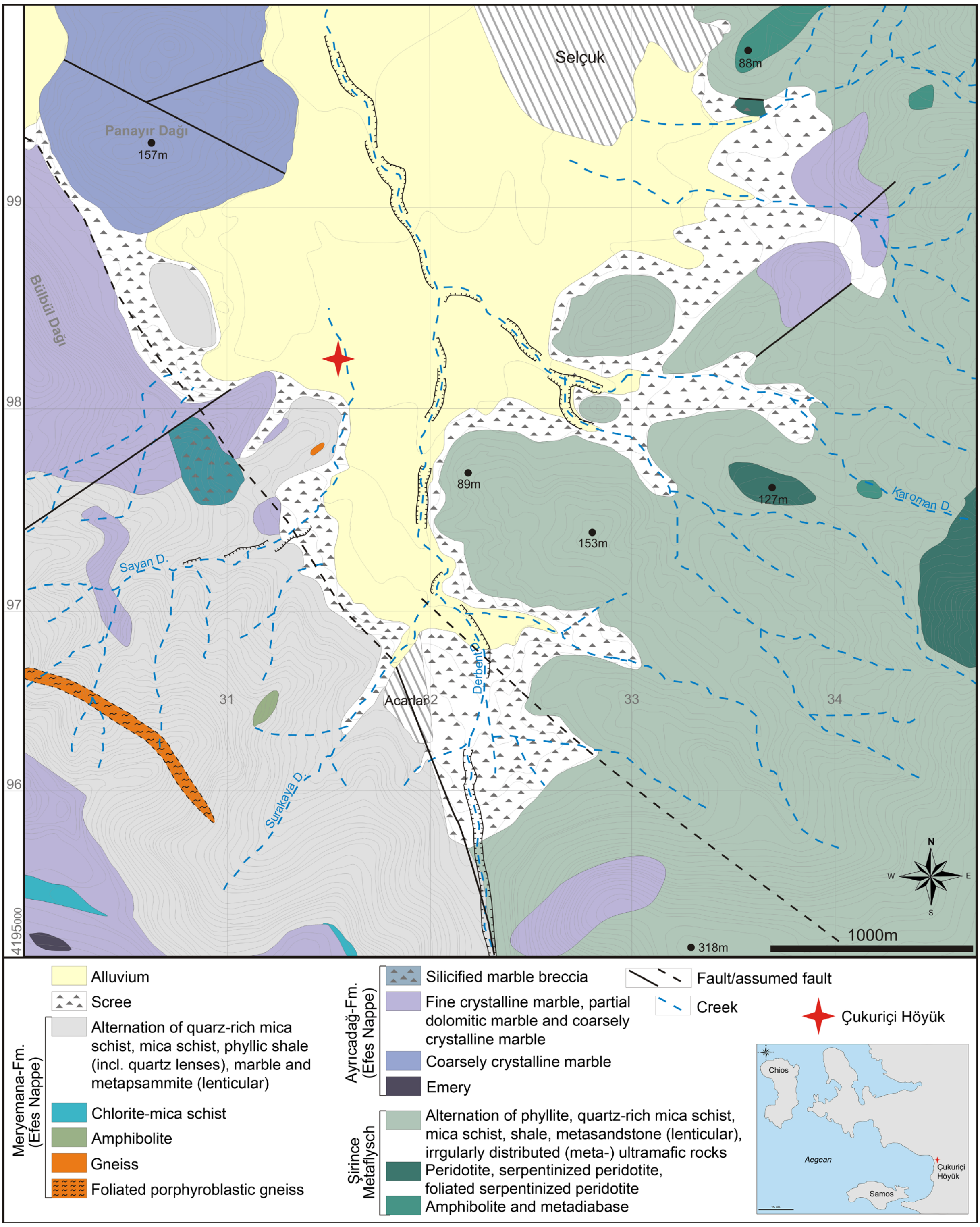

Figure 1. Geological map of the vicinity of Çukuriçi Höyük (map by D. Wolf with modifications after Çakmakoğlu 2007; Vetters 1975).

The detailed characterization of locally and regionally available rock sources likewise provides key data on clay and sediment deposits in the environs of Çukuriçi Höyük, exploited for ceramic production. Comprehensive petrographic investigations of over 500 pottery sherds, originating from all settlement sequences, demonstrate versatile clay compositions. Through examining the relationship of petrographic fabrics to potential raw material sources and the chronology of their occurrence in the archaeological record, it is possible to consider continuity and change in raw material procurement over the occupation period of the site. It thus enables us to examine whether the ceramics consumed at Çukuriçi Höyük are all compatible with local and regional natural resources, or rather point towards an origin from further away (Peloschek 2017).

The rocks dominating the architectural remains of the settlement, mainly schists, are also attested in about 50% of the overall sampled ceramic assemblage, emphasizing the metamorphic character of the native clays. Clays deriving from quartz-muscovite schists have a preponderant role in all recorded settlement phases, whereas actinolite schists are exclusively evident in Neolithic period ceramics. Serpentinite-rich clays have been utilized continuously since the Neolithic period, yet in low quantities (Peloschek 2017). Altogether, ca. 95% of the analysed ceramic items can be attributed to raw material resources in the immediate vicinity of Çukuriçi Höyük (Peloschek 2017: 134, fig. 6.4).

Whilst the majority of the ceramics were produced from local clay sources, the analytical results revealed that 5% of the sampled ceramics originate from supra-regional spheres, attesting to the small-scale exchange of pottery and cultural encounters as early as in the Late Neolithic period (c. 6500-5970 cal. BCE). The majority of these imported wares are defined by clays characterised by volcanic rock fragments, more specifically of rhyolitic-trachytic-dacitic composition, as well as andesites (Figure 2). The closest outcrops of similar rocks are located near Izmir and to its south (Figure 3). Taking into account the existence of prehistoric settlements in the region which are contemporaneous with Çukuriçi Höyük, and considering also stylistic analogies, the assumed provenance determination is plausible. The results fit into increasing site-to-site connectivity within the settlement cluster of the Late Neolithic period as recently discussed by Horejs (2016).

3. Regional rock sources (6-20 km)

A more extended procurement radius is evident for knappable rocks. The excavations, especially in the Neolithic period, yielded numerous chipped stone tools and debris that was made of mixed quality chert.

Due to the absence of chert outcrops in the immediate vicinity of Çukuriçi Höyük, this specific raw material for chipped stone tools had to be procured from sources that were more distant. The chert assemblage from the Neolithic settlement phases of the site was examined according to the Multi Layered Chert Sourcing Approach for material and provenance analyses (Brandl 2016, with further references therein). In an initial step, all chert finds were separated into macroscopic groups, which were microscopically investigated for their homogeneity. Eventually, geochemistry using Laser Ablation-Inductively Coupled-Mass Spectrometry (LA-ICP-MS) was performed on selected samples from the microscopic groups for detailed provenance analysis.

Microscopically, six chert varieties and additional siliceous rocks, *e.g.,* chalcedony, jasper, opal and quartz, were identified. In contrast to chalcedony and jasper, chert is a biogenic siliceous rock, bearing microfossil remains, which can be used for source identification in combination with other analytical techniques. In total, over 1000 chipped stone tools from the lithic assemblage dating to the Neolithic period of Çukuriçi Höyük were investigated in detail.

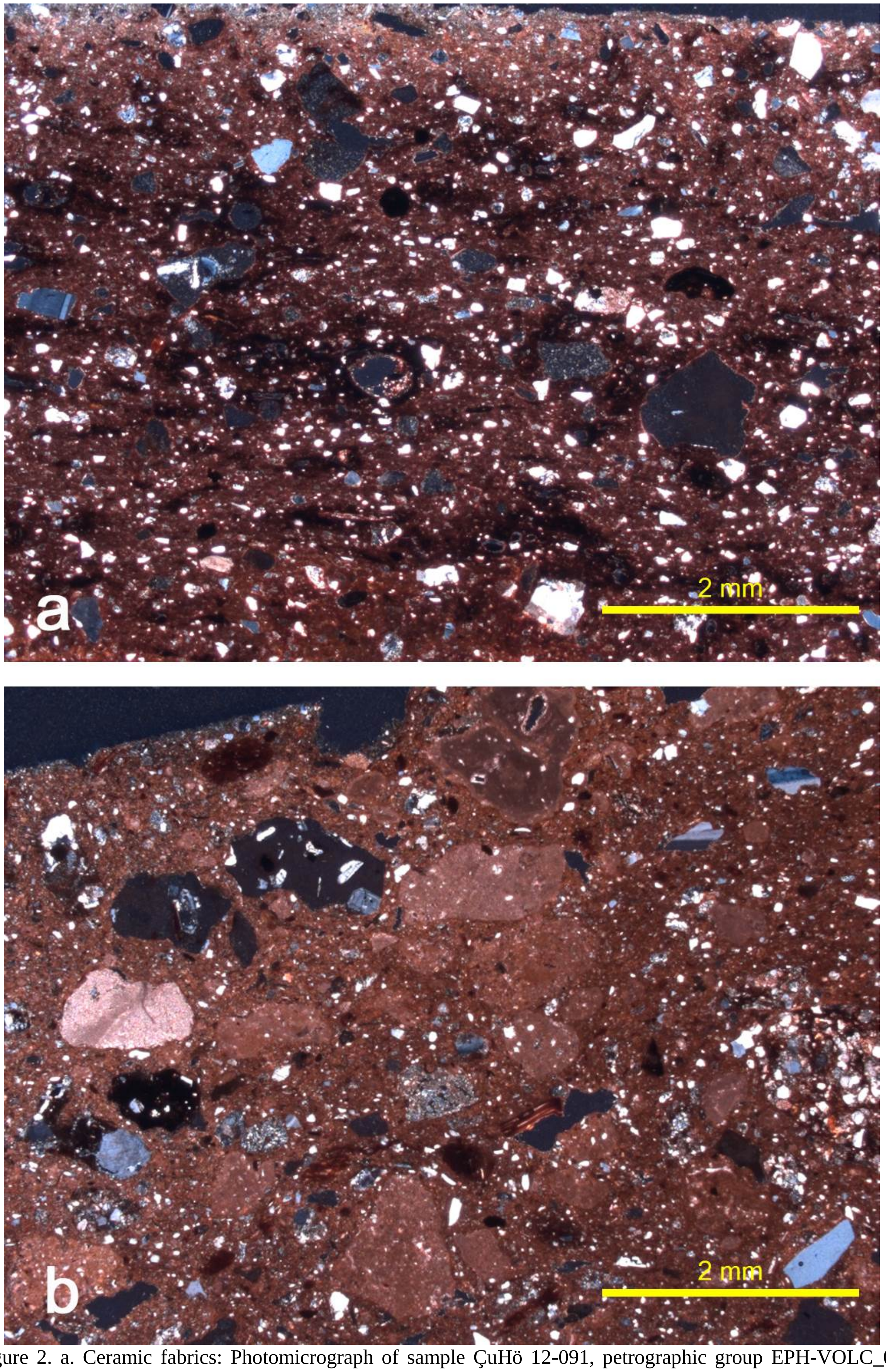

Figure 2. a. Ceramic fabrics: Photomicrograph of sample ÇuHö 12-091, petrographic group EPH-VOLC_08, crossed polars; b. Photomicrograph of sample ÇuHö13-016, petrographic group EPH-VOLC_07, crossed polars. Photos depicting volcanic rock fragments in a glassy matrix (both photos: L. Betina).

Figure 3. The closest volcanic rock sources in the surrounding area of Çukuriçi Höyük (map by D. Wolf based on Akay & Erdoğan 2004; Borsi *et al.* 1972; Ercan *et al.* 1986; Helvacı *et al.* 2009; Innocenti & Mazzouli 1972; Pe-Piper & Piper 2002).

Systematic geological surveys were undertaken in order to locate chert sources in the vicinity of the site and to acquire reference material. The results of the fieldwork indicate only a limited potential of knappable raw materials linked to various geological formations, such as Jurassic limestone containing chert layers, radiolarite from Izmir Flysch context, clear quartz imbedded in Şirince Metaflysch and lacustrine chert from the Kuşadası Formation (Çakmakoğlu 2007). In agreement with the results of microscopic material analyses of the Çukuriçi Höyük chert assemblage, only lacustrine chert turned out to be suitable for the production of chipped stone tools. This is apparent from the fact that no other siliceous rock available from the vicinity of the site (*e.g.*, Jurassic radiolarite or chert) was used for chipped stone tool production. Geologically, lacustrine chert occurs within Neogene limestone formations located close to the present-day coast, which were partly silicified in the course of volcanic (*i.e.*, hydrothermal) activities. The closest sources are situated at the Çanakgöl Tepe approximately 6 km west of Çukuriçi Höyük and at Kuşadası approximately 13 km west of the site. It is important to note here that all chert finds from Çukuriçi Höyük which display remains of their natural surface (*i.e.*, remnants of limestone) indicate for an extraction from the primary host rock context, which is proof that the material was not collected from secondary (river) deposits.

At Çanakgöl Tepe, the chert crops out in layers of up to 10 cm thickness and is, in some parts, of excellent quality for tool production. Additionally, archaeological evidence for prehistoric exploitation is present in the form of knapping debris and hammer stones of various sizes found at the source. Microscopic comparisons between material from this locale and chert from Çukuriçi Höyük display a high correspondence concerning microfossil and non-fossil inclusions, which is indicative of similar depositional developments and can be regarded as source-specific. Consequently, we focused on Çanakgöl chert as geological reference material for geochemical analyses of microscopically distinct chert varieties from Çukuriçi Höyük.

The analysis of the geochemical composition using LA-ICP-MS aims to detect the main-, trace- and ultra-trace element concentrations (-0.1 ppm) in rock materials and is a well-established technique in lithic raw material research (Brandl 2016; Moreau *et al*. 2016; Speakman *et al*. 2007). The comparison of Çukuriçi Höyük and Çanakgöl chert shows that the elements aluminum (Al) and lithium (Li) display the best group assignment and separation (Figure 4). Both elements are indicative of lacustrine versus marine genetic environments; concentrations of both Al and Li are significantly increased in marine cherts due to higher bioproductivity in contrast to lacustrine silicites, which display distinctly lower values (Brandl 2016: 147; Brandl *et al*. 2011: 62).

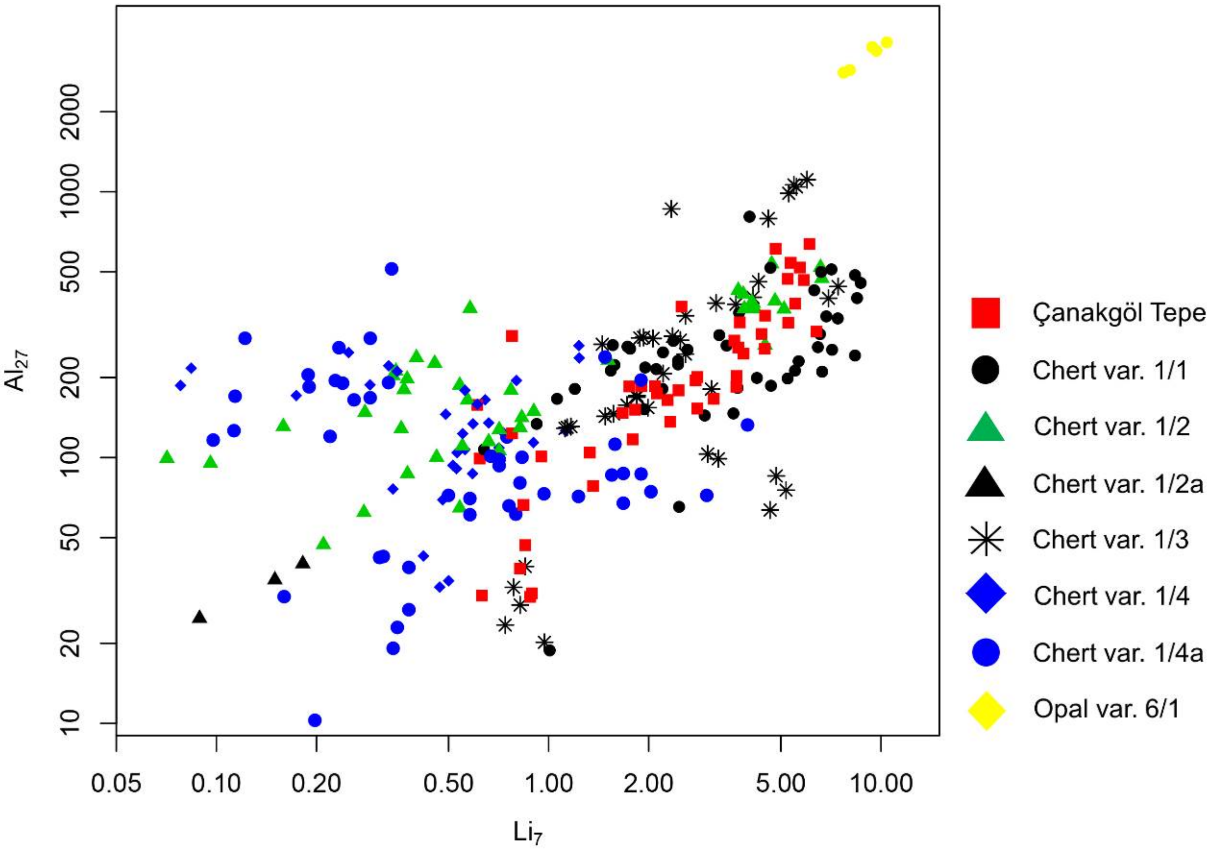

Figure 4. Bivariate Al-Li-scatter plot of the analysed chert samples (graphic by M. Brandl).

The bivariate Al-Li-scatter plot (Figure 4) allows for the assessment that all tested chert varieties from Çukuriçi Höyük are of lacustrine origin (for details on comparable lacustrine materials see Brandl *et al*. 2011: 62). Some Çukuriçi Höyük samples can be assigned to the geochemical Çanakgöl Tepe cluster (chert varieties CH 1/1 and CH 1/3), and others belong to a yet unidentified source area. However, this unidentified source region appears to be geochemically related to the larger Neogene lacustrine source environment (*i.e.*, a Neogene basin) of which Çanakgöl Tepe is a part, as attested by significant overlapping effects of the Al and Li values.

The chert varieties CH 1/1 and CH 1/3, which fit well into the Çanakgöl source cluster, also display the greatest microscopic similarities with Çanakgöl raw materials. The chert variety CH 1/2 is macroscopically and microscopically homogeneous, but geochemically separated into at least two distinct groups. One group (high Al, high Li) seems to belong to the Çanakgöl source cluster, and the other one (lower Al, lower Li) to the unidentified source area indicated above. The variety CH 1/2a also belongs to the latter group, as well as the chert varieties CH 1/4 and CH 1/4a. The opal variety CH 6/1, which was analysed as a control sample, is a clear outlier originating from a source area outside the Neogene basin containing the chert varieties.

These results suggest that the Neolithic inhabitants of Çukuriçi Höyük were procuring chert raw materials on a regional scale from distinct geological environments. One important source area was the coastal region with Çanakgöl Tepe as the most prominent outcrop. The clear evidence for prehistoric raw material exploitation at Çanakgöl Tepe makes this locale the first secured prehistoric raw material quarrying site in the region, if not in coastal western Anatolia. The additional use of materials from deposits which are geologically linked to the Çanakgöl Tepe source area, but are geographically situated in a certain distance, is evidence for the early farming communities' awareness of and engagement with the larger environment in which their site was located. The diversity of non-obsidian raw materials used for chipped stone tool production may also indicate regional exchange networks, as already discussed for pottery (see above). However, this possibility needs to be verified with more data, including results from additional lithic assemblages in the region.

4. Supra-regional rock sources (>20 km)

Supra-regional procurement of distinct materials is assumed for volcanic rocks and jadeite. Especially volcanic glass, obsidian, as well as jadeite indicate far-reaching contacts and the exchange of exotic raw materials.

4.1. Volcanic rocks

4.1.1. Lava

In addition to clay pastes containing volcanic rock fragments, grinding stones made of volcanic rocks were also found during the excavations, dating from the Neolithic period onwards. Due to the lack of further investigation, the total number of grinding stones made of volcanic rocks from other periods remains unclear. Thus, the study had to focus on Early Bronze Age volcanic grinding stones, however, these represent an excellent case study. In general, the use of volcanic rocks for grinding activities is favoured because of the ideal material properties resulting from pores within the rocks combined with their hardness.

In the present study four volcanic rock fragments were identified among the assemblage (n=42) assigned to the Early Bronze Age 1 occupation ÇuHö IV-III(II) of the southern trenches. These were sampled and analysed in detail to determine the provenance of the volcanic rocks used for the grinding stones (ÇuHö IV: 11/**632**/7/1, 11/**692**/7/1; ÇuHö III: 08/**141**/7/101; ÇuHö II: 07/**321**/7/100). Thin sections and geochemical analyses (XRF lab Tuebingen) revealed that the rocks can be classified as trachyte and rhyolite (Table 2) (Wolf 2017: appendix A04-A).

The evaluation of the geochemical analyses includes already published data for the volcanic rock sources from the Aegean islands and Western Anatolia. Additionally, we included samples of volcanic rocks from Hisartepe and Cumaovası (Figure 3) collected in the course of our geological surveys in the surrounding areas of Çukuriçi Höyük (Table 3). In order to assign a possible provenance of the sampled grinding stones, it is necessary to discuss the results of geochemical analyses in detail. The sum of Na_2O+K_2O versus SiO_2 ratios in the ‘total alkali silica’ (TAS) diagram (Le Bas *et al*. 1986) shows that different volcanic rock sources from Chios, Melos and Foça can be excluded (Figure 5). Additionally, the ratios of K_2O and SiO_2 (not shown) reveal that also the Kiraz, Yuntağ, Hisartepe and Balatçık rock sources were not used as material for the grinding stones.

Table 2. Major and trace element composition of the Çukuriçi Höyük grinding stones (normalized; ‘n.d.’ not determined, below detection limit of instrument).

		141	**321**	**632**	**692**
%	SiO_2	69.73	61.15	62.70	67.44
	Al_2O_3	15.63	17.53	18.11	15.31
	Fe_2O_3 (t)	2.12	4.56	3.60	2.44
	MnO	0.02	0.06	0.11	0.07
	MgO	0.39	2.04	1.26	0.30
	CaO	2.41	3.79	1.30	4.00
	Na_2O	3.84	4.13	3.16	3.29
	K_2O	5.35	5.72	8.84	6.31
	TiO_2	0.32	0.64	0.56	0.32
	P_2O_5	0.19	0.39	0.35	0.52
	LOI	0.66	0.56	1.33	1.37
ppm	V	30	94	73	30
	Cr	n.d.	65	n.d.	24
	Co	n.d.	n.d.	n.d.	n.d.
	Ni	59	91	102	79
	Rb	133	184	332	181
	Sr	222	890	256	197
	Y	11	12	31	15
	Zr	248	322	421	242
	Nb	n.d.	n.d.	30	n.d.
	Ba	676	1267	1001	729
	La	73	121	75	68
	Ce	268	388	355	277
	Nd	87	115	133	85
	Sm	7.5	7.9	9.2	6.6
	Eu	0.9	1.9	0.9	0.8
	Yb	n.d.	0.9	n.d.	n.d.
	Zn	n.d.	33	22	n.d.

The major- and trace element compositions (TiO_2 and SiO_2, Al_2O_3 and MgO - see Figure 6a, Sr and SiO_2, Ba [barium] and Zr [zirconium] - see Figure 6b, Y [yttrium] and La [lanthanum] - see Figure 6d) show that the grinding stone samples 141 and 692 plot close to samples from the Cumaovası sources. These volcanic rock deposits are situated around 30 km in the northwest of Çukuriçi Höyük, indicating a potential provenance from these sources.

This result is further supported by the Ce ratios of the grinding stone samples and the newly collected Cumaovası rock samples (Cum8-10), which are significantly higher than the other rock sources and suggest a potential provenance of all sampled grinding stones from this region (see Figure 6c). However, the number of analysed geological samples from the

Cumaovası sources is small, so to place this provenance determination on a sound basis, additional fieldwork is clearly necessary to support these preliminary results.

Table 3. Major and trace element composition of the geological Hisartepe (Hi) and Cumaovası (Cum) samples (normalized; 'n.d.' not determined, below detection limit of instrument).

		Hi18	**Hi19**	**Cum8**	**Cum9**	**Cum10**	**Cum11**	**Cum12**
%	SiO_2	60.26	58.85	70.59	68.56	69.33	77.28	76.93
	Al_2O_3	15.79	15.27	15.87	15.66	15.53	12.35	12.80
	Fe_2O_3 (t)	6.25	5.90	1.59	2.59	3.10	1.00	0.96
	MnO	0.11	0.08	0.02	0.05	0.03	0.04	0.02
	MgO	3.97	4.91	0.40	0.30	0.36	0.12	0.15
	CaO	7.53	8.58	1.38	1.55	1.91	0.29	0.45
	Na_2O	2.94	2.66	3.35	3.66	3.99	3.81	3.59
	K_2O	2.21	2.77	6.38	7.17	5.28	5.06	5.03
	TiO_2	0.78	0.79	0.35	0.39	0.33	0.05	0.06
	P_2O_5	0.16	0.20	0.07	0.08	0.12	0.02	0.02
	LOI	1.03	2.17	0.67	0.98	1.15	0.44	0.99
ppm	V	137.9	173.4	20.7	37.4	25.6	5.2	2.8
	Cr	185.5	324.7	n.d.	7.9	2.0	n.d.	129.8
	Co	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	Ni	18.3	18.4	5.1	17.6	13.0	14.1	11.6
	Rb	67.1	65.1	175.8	208.6	120.1	344.2	224.3
	Sr	649.3	1409.7	208.5	244.1	236.1	3.5	4.1
	Y	13.1	n.d.	7.2	11.2	10.2	22.0	10.9
	Zr	158.6	144.3	248.9	280.2	278.4	94.7	100.6
	Nb	n.d.	n.d.	n.d.	n.d.	n.d.	33.7	16.1
	Ba	744.5	969.2	850.1	827.0	723.7	32.5	21.9
	La	36.5	90.7	72.6	86.7	84.9	23.5	37.1
	Ce	319.3	319.4	364	423	403.3	150.6	169.5
	Nd	125.6	126.1	154.1	184.5	170.8	96.6	117.7
	Sm	4.2	n.d.	n.d.	4.9	6.0	n.d.	4.4
	Eu	1.5	2.3	0.3	0.7	0.9	n.d.	0.2
	Yb	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	Zn	14.8	32.1	n.d.	n.d.	1.2	n.d.	n.d.

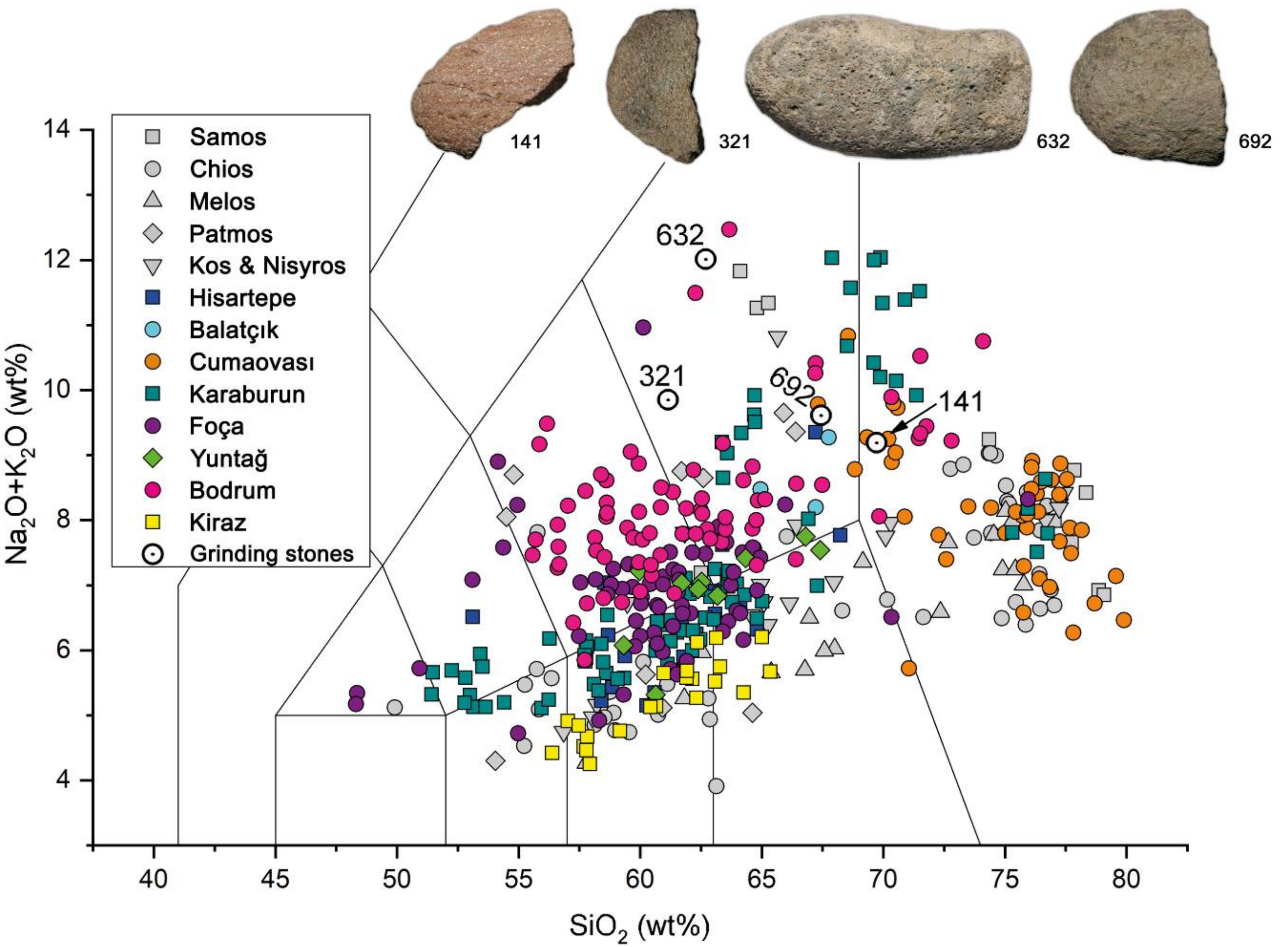

Figure 5. Classification of the grinding stones in the TAS diagram. For references of the data from the compared volcanic regions on the Aegean Islands and Western Anatolia see: *Chios*: Besenecker & Pichler 1974; Mitropoulos *et al*. 1999; Paraskevopoulos 1956; Pe-Piper *et al*. 1994; Robertson & Pickette 2000; *Kos/Nisyros*: Mitropoulos *et al*. 1987; Pe-Piper & Moulton 2008; Wyers & Barton 1987; *Melos*: Fytikas *et al*. 1986; Innocenti *et al*. 1981; Mitropoulos *et al*. 1987; Mitropoulos & Magganas 1988; Mitropoulos *et al*. 1999; *Patmos*: Wyers & Barton 1986; 1987; *Samos*: Paraskevopoulos 1956; Pe-Piper & Piper 2002; 2007; *Balatçık*: Ercan *et al*. 1986; *Bodrum*: Ercan *et al*. 1985; Kurt & Arslan 2001; Pe-Piper & Piper 1989; *Cumaovası*: Innocenti & Mazzuoli 1972; Karacık *et al*. 2013; *Foça*: Akay & Erdoğan 2004; Aldanmaz *et al*. 2000; Innocenti *et al*. 2005; 2010; *Hisartepe*: Ercan *et al*. 1968; *Karaburun*: Agotini *et al*. 2010; Innocenti & Mazzuli 1972; Helvaci *et al*. 2009; Innocenti *et al*. 2005; Karacık *et al*. 2013; Pe-Piper & Piper 1989; *Kiraz*: Bozkurt *et al*. 2008; *Yuntağ*: Ersoy *et al*. 2012 (graphic by T. Gluhak).

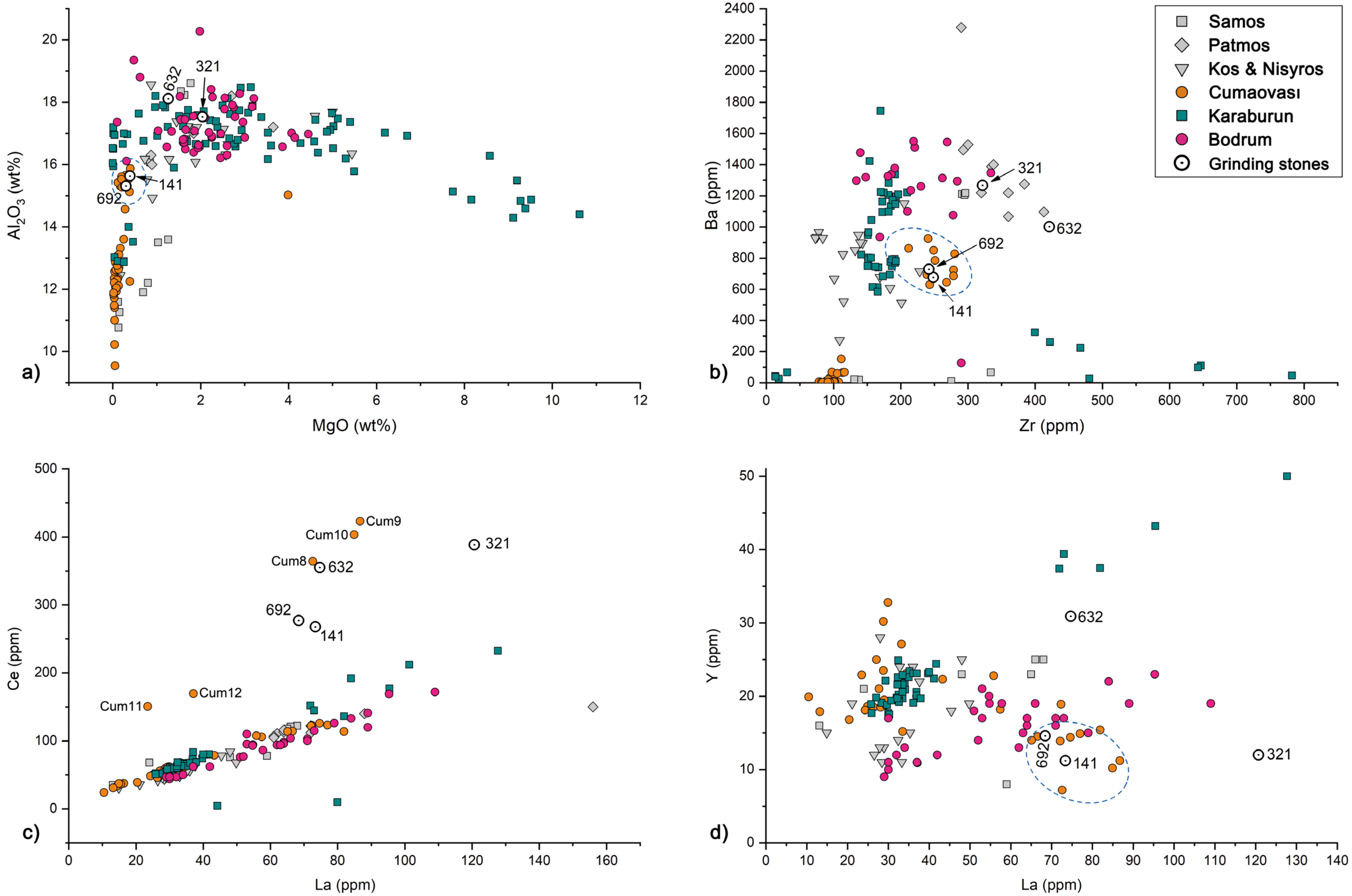

Figure 6. The major- and trace element concentrations (a) Al2O3 and MgO, b) Ba and Zr, c) Ce and La, d) Y and La) of the grinding stones and Cumaovası rocks samples in comparison to the other regions. For references, see Figure 3 (graphic by T. Gluhak).

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4.1.2. Obsidian

Given that the majority of obsidian used for the production of chipped stones at Çukuriçi Höyük originates from far distanced sources, over 280 km away from the site, it can be seen as an exoticum (Bergner *et al*. 2009; Horejs *et al*. 2015: 305-309). The fact that other knappable materials (chert) existed in significantly closer areas did not prevent obsidian becoming the main raw material over the entire site's occupation from the 7th until the 3rd millennium BCE.

Obsidian dominates the chipped stone tool assemblage of Çukuriçi Höyük. It reaches its highest amount by the end of the Late Neolithic comprising 86% of the assemblage, which is exceedingly high when compared to other raw material varieties. Although there is a slight variation in the amounts over time, obsidian remains the dominant raw material during the entire occupation of the site. The only significant shift in the amounts of obsidian used, from 33% to 68%, can be recognised between phases ÇuHö XIII and XII, related to the site foundation in the first half of the 7th millennium BCE (Milić 2018: 79). Extremely high amounts of obsidian at Çukuriçi Höyük (over 80%) were reached after 6500 BCE (ÇuHö XI-VIII; see Figure 7), while a relatively similar trend continued after the hiatus in the site's occupation in the Late Chalcolithic and Early Bronze Age periods.

Figure 7. Çukuriçi Höyük phase X obsidian assemblage made of Melian obsidian (photo by B. Milić).

In total, 263 obsidian artefacts from different Neolithic levels and 64 from the later periods on the site were analysed with the aim of defining their sources. Neolithic samples were analysed by both Neutron Activation Analysis (hereafter NAA) undertaken by E. Pernicka at the Curt-Engelhorn-Center for Archaeometry gGmbH (CEZA) and portable X-ray fluorescence (hereafter pXRF), conducted by L. Betina. The concentration of Fe (iron) and Sc (scandium) was examined in the NAA samples (for method see also Pernicka 1992). Significant counts of Rb (rubidium), Sr (strontium) and Zr (zirconium) were detected by pXRF, compared with geological samples from M. Milić (2014: 290, Tab. 1) and evaluated as described by B. Milić (2018).

The results demonstrate that the majority of the sampled material from the Neolithic period match two sources, Adamas and Dhemenegaki, located on the island of Melos, 280 km from Çukuriçi Höyük (Horejs *et al*. 2015: 305; 314-315; Milić & Horejs 2017: 31). In addition to obsidian from Melos, there are very few samples from the same levels originate from central Anatolian, *i.e.*, Cappadocian, obsidian sources, mainly corresponding to Nenezi Dağ, with a single Göllu Dağ specimen. Moreover, the Late Neolithic occupation layers yielded the rather unique evidence of Yiali obsidian (Milić 2018). These non-Melian samples were previously recognised macroscopically as ‘different’, in terms of colour, translucency and texture, and were therefore selected for provenance studies.

Although preliminary, the main result of our study indicates that during the initial Neolithic phase ÇuHö XIII, which is related to the settlement foundation, exclusively Melian obsidian was used. Cappadocian obsidian was introduced from the beginning of the Late Neolithic on the site and seems to be constantly present, despite its very minor role, from 6500 BCE onwards. This demonstrates the integration of the settlement into new networks. However, it still remains unclear how the obsidian from approximately 650 km arrived from Cappadocia to the site, and what mechanisms of distribution were involved as no certain knapping of this specific obsidian has been attested on the site. The exceptional appearance of Yiali obsidian (c. 140 km far from the site) in the Late Neolithic implies the possible use of this material in Western Anatolia significantly earlier than previously thought (Milić 2018). Moreover, the NAA results of the study of Bergner *et al*. (2009) demonstrated that the reliance on Melian obsidian continued after the Neolithic, in the Late Chalcolithic and Early Bronze Age 1 at Çukuriçi Höyük, since only 3 of 64 post-Neolithic samples matched with Cappadocian sources.

Based on the exceptionally high amount of obsidian at Çukuriçi Höyük in comparison to other contemporaneous sites in the Early Bronze Age (Knitter 2013: 52), it has been suggested that the coastal site of Çukuriçi Höyük was a gateway community for obsidian networks related to Melian sources (Knitter *et al*. 2012: 364, fig. 2). However, we suggest that from the Neolithic Çukuriçi Höyük held a dominant position in the network. A combined study involving the technological aspects of the chipped stone assemblages indicates that the procurement of obsidian from the Cyclades during the Neolithic was likely maintained from the Çukuriçi Höyük settlers themselves and further distributed to other sites (Milić & Horejs 2017: 44). Considering the consistently high obsidian amounts during the long occupation, Çukuriçi Höyük represents a special, if not unique site in the region of western Anatolia regarding obsidian exploitation, with exotic raw material vastly dominating over other varieties used for the chipped stone production.

4.2. Jadeite

In addition to obsidian, supra-regional rock procurement is also indicated by the presence of jadeite as demonstrated by recent investigations on axes from Çukuriçi Höyük (Sørensen *et al*. 2017a). Initial stereomicroscopic studies and analysis using a portable TerraSpec reflexion spectrometer for short wave infrared spectroscopy (SWIR) on two of the Early Bronze Age polished stone axes from Çukuriçi Höyük (ÇuHö I, 08/**501**/3/14, see Figure 8.5; ÇuHö II, 07/**320**/3/1101, see Figure 8.4.), revealed that these axes were made from jadeite. Although, no thin sections could have been produced yet, a second stereomicroscopic investigation of the axe assemblage established three further jadeite axes. The first two jadeite axes (see Figure 8.1-2.) were found in Late Neolithic contexts (ÇuHö XI: 13/**1722**/3/2; ÇuHö IX: 13/**1832**/3/7) dated between c. 6500 and 6200 BCE, whereas the third axe (07/**318**/3/101, see

Figure 8.3.) was found in the Early Bronze Age occupation of ÇuHö IV of the early 3rd millennium BCE. The continuous exploitation of jadeite for axe production at Çukuriçi Höyük raises questions as to where and how this rare and hard raw material was procured and exchanged between prehistoric societies in the Eastern Mediterranean World.

Figure 8. Jadeite axes from Çukuriçi Höyük and below comparisons with geological jadeite samples from Syros: 1: **1722**, ÇuHö XI; sample Syros 36; 2: **1832**, ÇuHö IX, sample Syros 27, 3: **318**, ÇuHö IV; sample Syros 102; 4: **320**, ÇuHö II, sample Syros 29; 5: **501**, ÇuHö I; sample Syros 29 (graphic by L. Sørensen).

To date, three major jadeite sources are known in Europe: Italian Alps, Orhaneli in Turkey, and Syros in Greece. The largest one is located in the Italian Alps, with intensive exploitation and distribution within a major Neolithic network from approximately 5500 to 3700 cal. BCE (Pétrequin *et al*. 2012). It is notable that the examples from Çukuriçi Höyük display a bright milky green colour (see Figure 8.2-5), which resembles the appearance of jadeite from Mount Beigua, Italy. However, the considerable distance and the dating of the layers at Çukuriçi Höyük (c. 6500-6200 cal. BCE) that produced the earliest examples of jadeite axes contradicts a provenance from Italian sources, which were not exploited before 5500 cal. BCE according to Pétrequin & Pétrequin (2012).

A second potential source is located at Orhaneli near Bursa in Turkey (Okay 2002). However, this jadeite is characterised by its purple colour, thus excluding this source for the Çukuriçi Höyük jadeite axes. A third potential source is located on the Cycladic island of Syros in the Aegean, which is approximately 220 kilometres in linear distance from Çukuriçi Höyük. Jadeite boulders can be found on the northern part of Syros within the Kampos area. Until recently this was only considered as a geological site, however, surveys by P. and A.-M. Pétrequin, and by L. Sørensen, revealed several patinated flakes and preforms, which provide the first evidence for prehistoric knapping places around the large jadeite boulders in the Kampos region of Syros (Pétrequin *et al*. 2017). Many of the flakes and preforms were made of a jadeite type having a bright milky green to a paler green colour, thus corresponding to stereomicroscopic descriptions (Sørensen 2017b: 1373-1374) of the jadeite axes from Çukuriçi Höyük (Figure 8). Detailed mineralogical studies are in progress to test this provenance hypothesis.

5. Diachronic assessment of rock procurement at Çukuriçi Höyük

Our investigation of stone artefacts from the prehistoric settlements of Çukuriçi Höyük has revealed the use of local, regional and supra-regional rock sources, through selective rock procurement since the earliest phases of the settlement.

The diachronic approach clearly shows different procurement strategies of carefully selected rock types from the Neolithic to the Early Bronze Age periods. The stones and clays in the direct vicinity (0-5 km) of the tell were continuously exploited during all settlement phases of Çukuriçi Höyük (Figure 9). However, as early as the Neolithic period the more selective choice of distinct rock types is attested by chert from regional deposits as well as volcanic rocks (*e.g.*, obsidian), and jadeite from supra-regional sources. In general, it can be argued that, dependent on the tool type, both material properties for specific tasks, and aesthetic considerations, seem to be the determining factors for raw material selection. Significantly, the continuous procurement of distinct rock varieties, for example obsidian, reveals that far-reaching communication and exchange networks by sea and land must have played an important role since the 7th millennium BCE onwards. This is attested by the especially high amount of obsidian found in the different occupation layers.

As indicated in previous studies, pioneering farming communities at Çukuriçi Höyük were already in possession of a nautical package of knowledge and skills (Horejs 2016). The results of our present study suggest a model of mobile, interconnected maritime communities in the Aegean and bordering regions during the Neolithic period. Experience in extensive sea-faring knowledge since the early stages of the 7th millennium BCE is illustrated by the procurement of obsidian from sources located at a distance of over 280 km, on the island of Melos (Horejs *et al*. 2015). This suggests that Çukuriçi Höyük was participating in an obsidian network, and at least in the Early Bronze Age period 1, had a gateway function for distributing obsidian to the Western Anatolian hinterland (*e.g.*, Knitter *et al*. 2013: 364, fig. 2b).

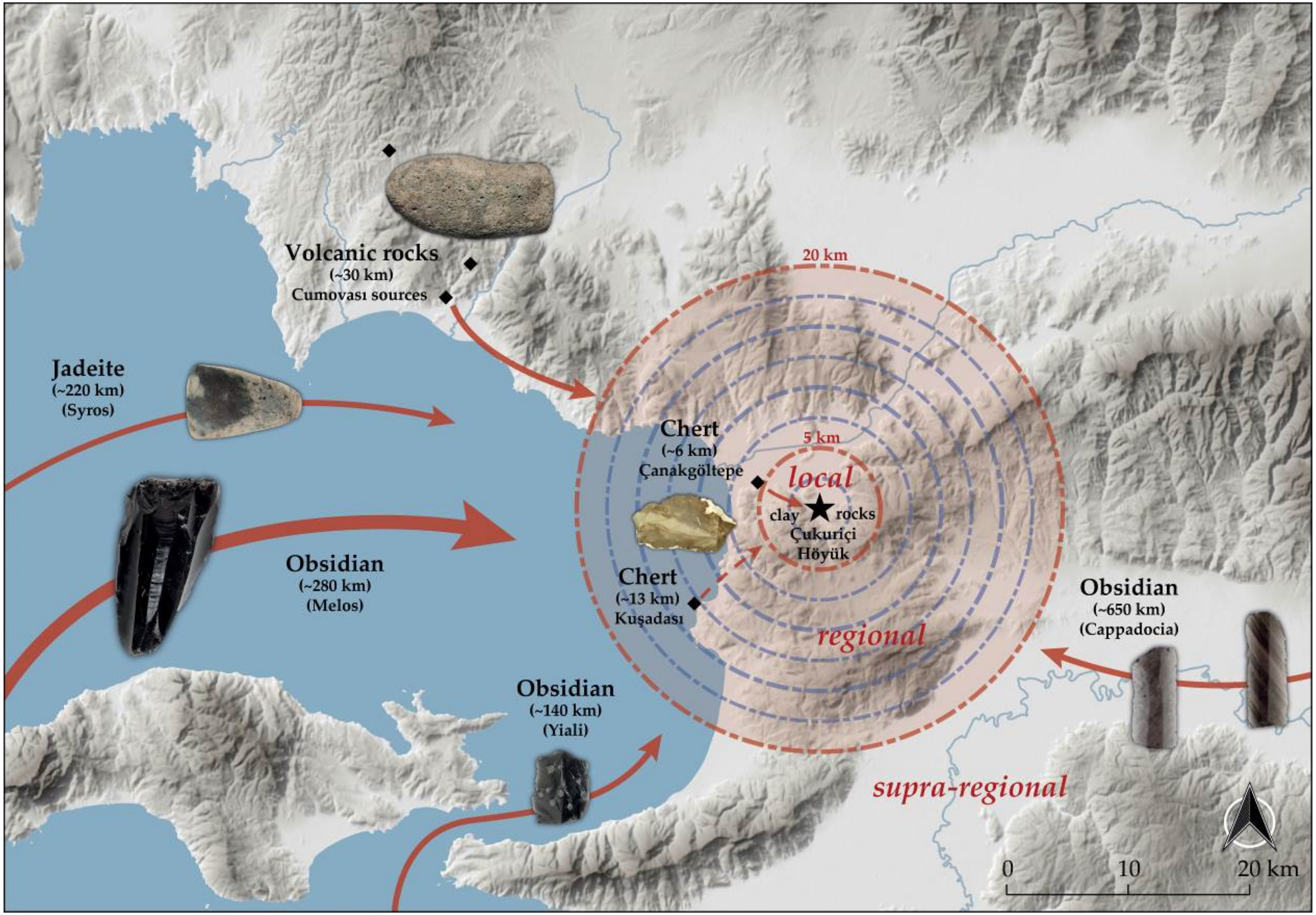

Figure 9. The local, regional and supra-regional rock procurement of the prehistoric settlement Çukuriçi Höyük (map by Ch. Schwall/M. Börner).

On some of their voyages, which must have involved island hopping, these pioneers probably investigated other potential raw materials and different sources of these materials, resulting in the discovery of jadeite on Syros, a very hard raw materials for making axes in the Aegean world. The Syros raw material was continuously exploited from the 7th to the 3rd millennium BCE as suggested by jadeite finds from other Neolithic and Bronze Age sites in the Eastern Mediterranean world (Sørensen *et al*. 2017a). Additionally, the strong maritime character of the communities inhabiting Çukuriçi Höyük is apparent through the use of rock resources closer to the site, such as volcanic rocks and chert, which most likely were also transported over the waterway. This is a reasonable suggestion for heavy implements in particular and considering that Çukuriçi Höyük was a coastal settlement.

As a conclusion, the current study demonstrates the importance and potential of broad-scaled, systematic analytical studies of specific materials, in this case lithic implements, for the assessment of prehistoric exchange and communication systems. Moreover, the diachronic perspective supports our understanding of the nature of procurement systems over time. In the case of Çukuriçi Höyük, specific materials were, in the form of raw or finished products, continuously obtained and used, whereas others played only a role during specific settlement phases. For example, Melian obsidian for chipped stone production, volcanic rocks for grinding stones, and jadeite for axes represent materials that were continuously used by the inhabitants from the Neolithic to the Early Bronze Age period, despite a hiatus of approximately 2500 years at the end of the Neolithic occupation. Conversely, local chert and emery seem to have been only used in different amounts though the entire occupation of the site. This is evidenced by the choice people made for chert during the Neolithic phases and the selection of emery starting with the Chalcolithic period, which presumably can be linked to the introduction of metallurgy. This clearly stresses the high degree of connectivity and exchange of the prehistoric communities at Çukuriçi Höyük and, moreover, expresses the enormous efforts to procure carefully selected, including exotic, lithic raw materials or finished products.

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• This article was submitted and initially published with only the following authors listed: Christoph Schwall, Michael Brandl, Tatjana M. Gluhak, Bogdana Milić, Lisa Betina, Lasse Sørensen, Danilo Wolf, and Barbara Horejs. After publication of the article, the authors observed that they had forgotten to include Maria M. Martinez as an author and requested that she be added to the list of authors. The current version of the article includes Maria M. Martinez. She should be considered an author also for earlier versions of the article that might be in circulation.