

Kalba: new insights into an Early Bronze Age trading post on the Gulf of Oman

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Summary

The fieldwork conducted at the coastal site of Kalba on the Gulf of Oman revealed continuous occupation from the Early Bronze Age to the Iron Age (c.2500–600 BC), and the significance of trade networks on the south-eastern Arabian Peninsula from the third millennium BC onwards. The renewed investigations at Kalba focus especially on the occupation during the Umm an-Nar period in order to gain insights into the origins and developments of these trading networks. In this context, the excavations concentrate on a highly promising section in the east of the settlement, including a massive Early Bronze Age retaining wall that represents the base of the Umm an-Nar tower constructed above. The recent fieldwork revealed interesting results regarding the construction of this stone wall with an exterior ditch and the subsequent use of this area in later periods.

Besides archaeobotanical and radiocarbon analyses, chert and copper artefacts from the excavations and potential raw material sources are of special interest. Results of material analyses illustrate the significance of mineral resources for the settlement. This indicates that Kalba could have functioned as a trading post connecting maritime and inland trade routes leading into the inner region of the Arabian Peninsula.

Keywords: United Arab Emirates, Kalba, Early Bronze Age, material studies, trading post

Introduction

Following earlier renewed field investigations in 2019 (Schwall & Jasim 2020; Schwall, Börner & Meyer 2021), systematic excavations at Kalba began in 2020. The main goals during the 2020 field season were to gain more detailed information about the stratigraphic sequence between the third and first millennia BC as well as the Early Bronze Age occupation. Of special interest was the construction of the massive retaining wall, which functions as the base of the Umm an-Nar tower. Furthermore, systematic sampling and analysis of the artefacts from Kalba as well as the potential raw material sources of copper in the nearby Al-Hajar mountain range (Wādī al-Ḥilo) as well as chert in the Rub al-Khali desert (Jebel Buhais mountain range) was undertaken. The aim of these analyses was to investigate procurement strategies of mineral resources and the regional significance of the site Kalba (K4) within the framework of known surveyed and/or excavated Umm an-Nar sites on the south-eastern Arabian Peninsula (Fig. 1 with Map Appendix).

Excavations in trench E1 & E2

At the eastern part of the site, the excavations in trench E1 (8 x 9 m; see Fig. 2) continued inside (western sector) and outside (eastern sector) of the Early Bronze Age retaining wall to provide insights into the stratigraphic relations between the present surface level and archaeological horizons extending down to the foundation of the massive Bronze Age wall. For this purpose, the entire southern profile was cleaned and documented (Fig. 3). The inner Iron Age I retaining wall (Fig. 3: SU 24) as well as layers possibly related to Bronze Age occupations were identified and attest to the subsequent use of the interior and exterior area of the Early Bronze Age retaining wall during later periods. Interestingly, at c.1.7 m below the current surface level, a fireplace (no. 2; Fig. 3: SU 19) was detected upon extended levelling layers (Fig. 3: SU 18, 20, 28, 85) covering sediments associated with the Early Bronze Age retaining wall in the western section of the profile.

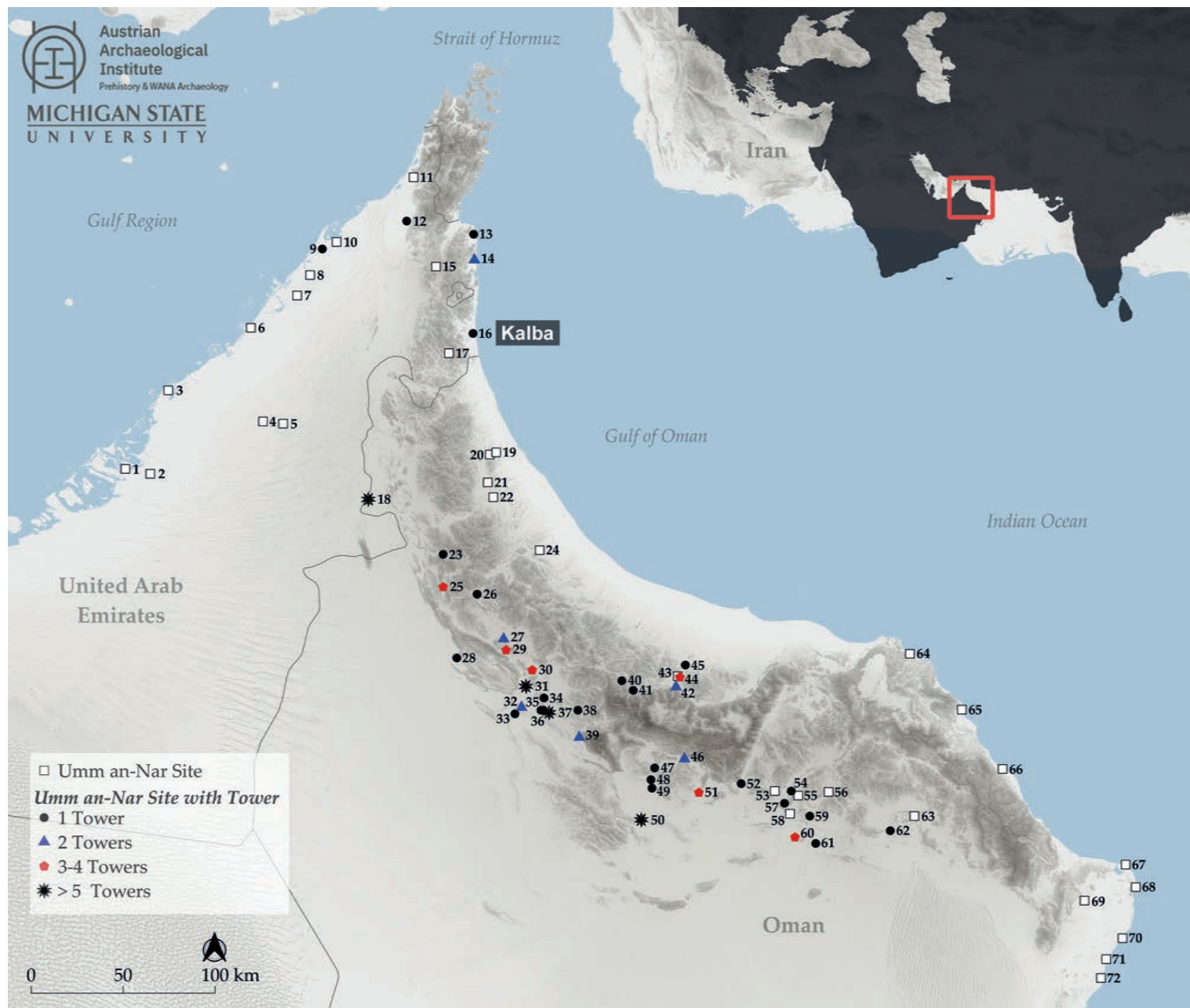


FIGURE 1. Surveyed and/or excavated Umm an-Nar sites on the Oman peninsula (for references see Map Appendix; map: OeAW-OeAI/M. Börner, C. Schwall; MSU/C. Cable).

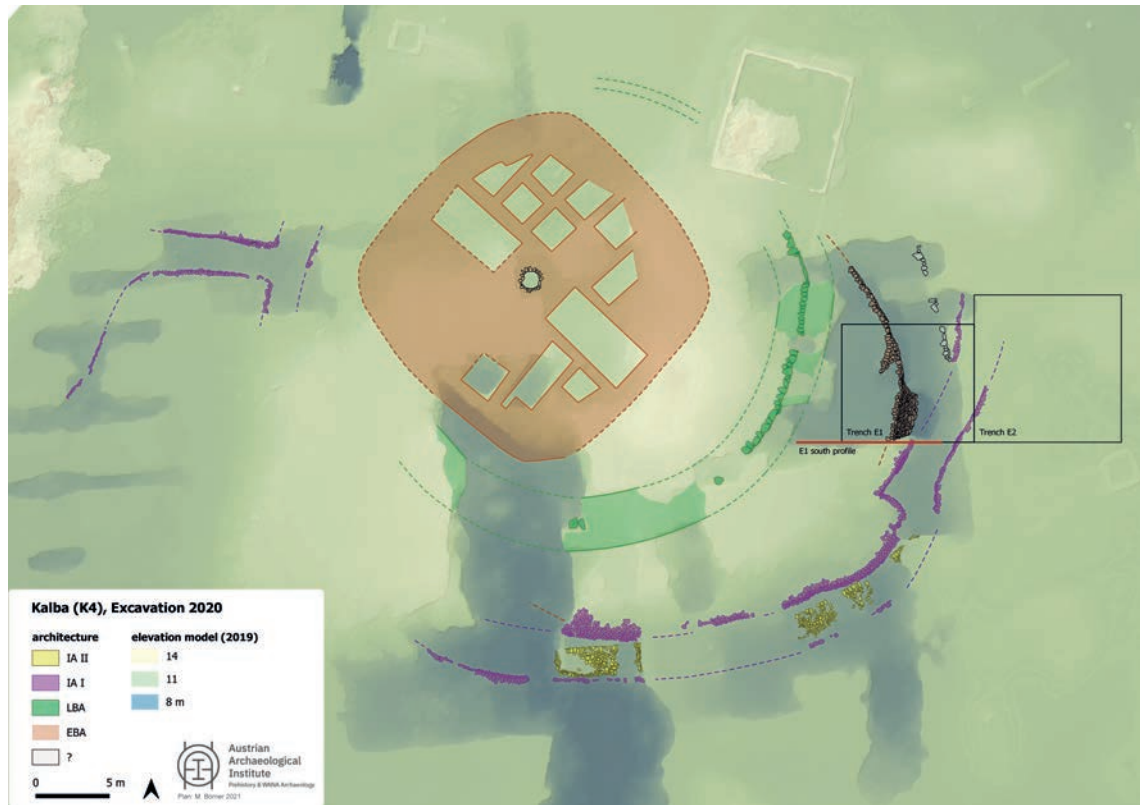


FIGURE 2. Topographical plan of the site including the recorded architectural remains and the locations of trenches E1 & E2 (map: OeAW-OeAI/M. Börner).

Trench E1, western sector (Fig. 4)

The continued excavations in this part of the trench revealed an earlier occupation level (for the younger level see Schwall & Jasim 2020: 326–327, fig. 6; Schwall, Börner & Meyer 2021: 33–34, 38, fig. 6), consisting of a horizontally extending stone layer (SU 44), two fireplaces (nos. 4–5; Fig. 4: SU 35, 45), and one circular pit (Fig. 4: SU 43, 50, 58). Inside the pit, a stone accumulation was discovered on top of the fill, consisting mainly of ashy material, burnt clay fragments, and charcoal, leading to the assumption that the pit was also used as a fireplace (no. 9). This occupation level (Fig. 4: SU 46–48) is cut by a pit (Fig. 4: SU 42, 49), originating from later occupation layers in the north-western part of this area. Additionally, this level provides important information about the construction of the Early Bronze Age retaining

wall (Fig. 4: SU 7). The northern and southern profiles (see Fig. 3) and the exposed occupation level clearly indicate that the Early Bronze Age occupation layer attested in the trench was partially cut off along its eastern part during the construction of the wall. The north and south profiles clearly show a thick sloping layer in the eastern part of the western sector. After the removal of the cultural layers, the angled stone facade of the retaining wall was erected and the remaining space between the stones in the west and the earlier occupation layers still in place was filled in (Fig. 4: SU 6, 78, 87, 94). Therefore, the assumption of the 2019 season that older occupation layers were dug away during the course of the wall construction could be confirmed and recorded in detail (see Schwall & Jasim 2020: 326; also for the structures in SU 4–5).

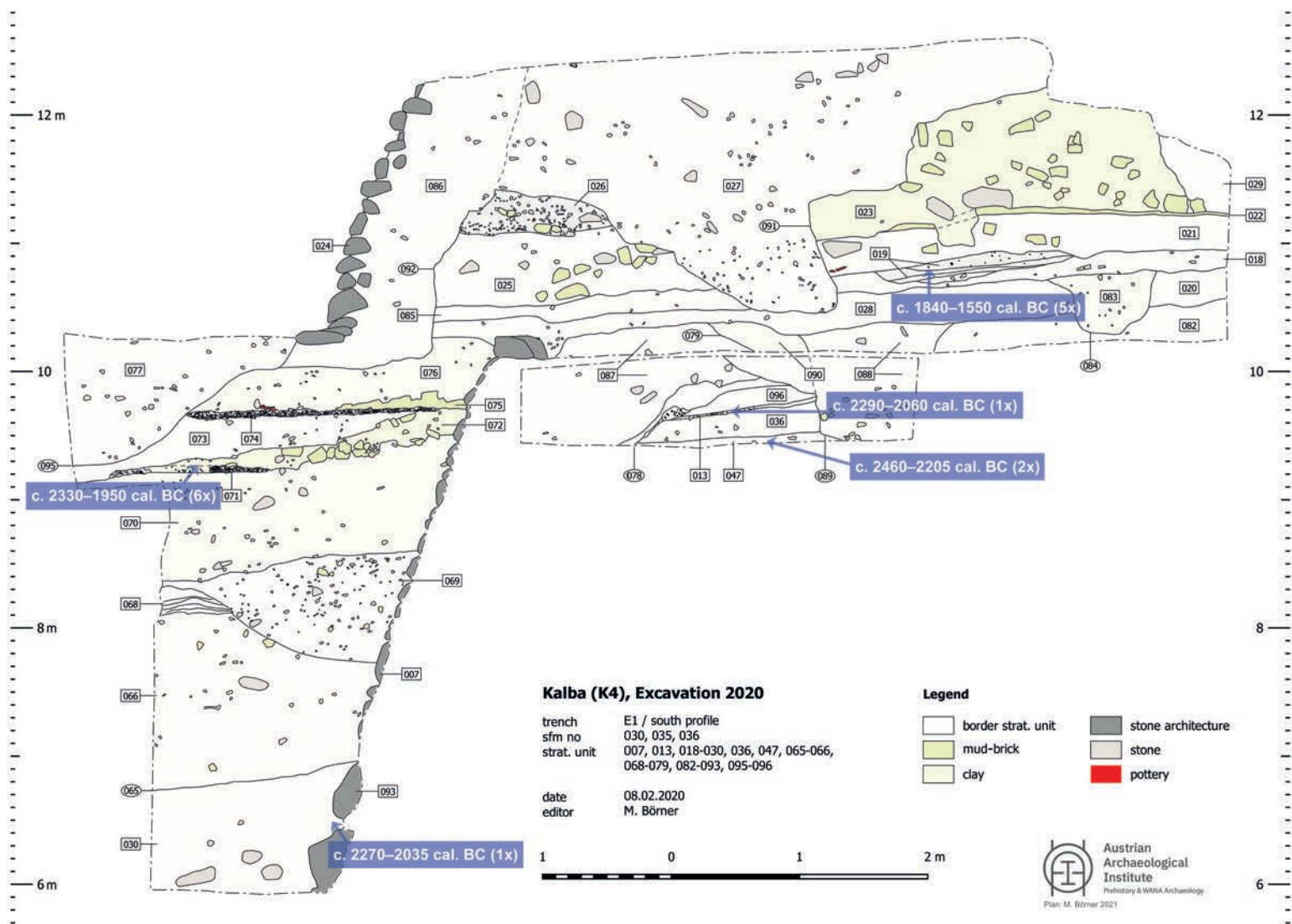


FIGURE 3. Stratigraphical sequence of the south profile in trench E1 with the position of the radiocarbon samples and their cal 2σ results. The presented dates correspond to the maximum possible time spans of the distinct contexts and occupation levels obtained from botanical and molluscs samples. For individual data see Figure 7/b (plan: OeAW-OeAI/M. Börner, C. Schwall).

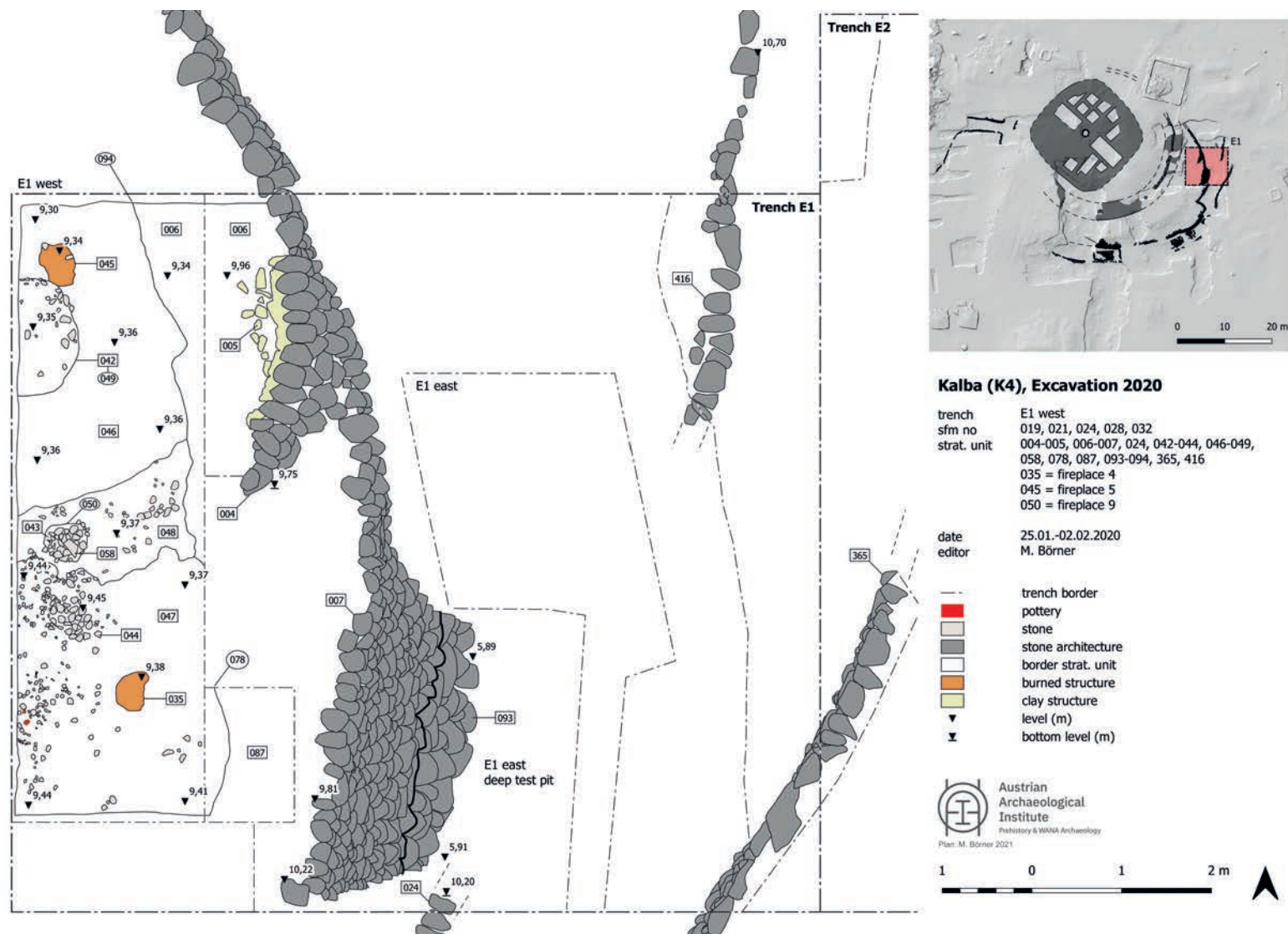


FIGURE 4. A plan showing the detected occupation level as well as the layers in the course of the construction of the Early Bronze Age retaining wall in the western sector of trench E1 (plan: OeAW-OeAI/M. Börner).

Trench E1, eastern sector (Figs 5–6)

The investigations outside the Early Bronze Age retaining wall focused on its construction and possibly associated occupation levels. Excavations in the deep test pit were continued, resulting in a 6.7 m stratigraphic sequence of the southern profile (see Fig. 3). Inside the deep test pit, the end of the visible and accurately positioned stone facing was reached. At a depth of c.3.3 m, the layout of the stones became less organized, indicating a clear change in the wall's construction technique (Fig. 5). This was illustrated by numerous gaps filled with sediment between the facing stones in the lower section of the wall. Although the base of the stone construction was not reached in the deep trench, it can be assumed that this section of the wall represents its foundation, which was levelled and prepared before the construction of the representative wall. Due to the restricted space, the excavations were stopped at a depth of 4.30 m below the uppermost preserved stone row of the Early Bronze Age retaining wall. The assumption that the foundations of the wall were reached is supported by the southern profile of the deep test pit. It shows a clear occupation level belonging to the exterior area (see Fig. 3: SU 65). Interestingly, the depth of this level below the uppermost preserved stone row of the retaining wall slopes down from 3.3 to 3.5 m. Therefore, it can safely be assumed that a related ditch was situated in front of the wall, which is also attested by thick filled-in sediments (see Fig. 3: SU 66, 69–70) indicating that the ditch was rapidly closed since there is no evidence of blown- or washed-in sediments separating individual filling phases. This is additionally supported by the change in the construction technique of the Early Bronze Age retaining wall at a depth of 3.3 m (see Fig. 3). Today, therefore, the visible part of this monumental wall has a preserved height of at least 3.45 m with a steep slope of 56°.

Outside the Early Bronze Age retaining wall, further excavations continued in an area adjacent to the north of the deep test pit in order to gain more insights into the stratigraphy and subsequent use of this area during later periods. During these excavations, an occupation level (Fig. 6: SU 37, 55) was detected, defined by four differently sized fireplaces (nos. 3, 6–8; Fig. 6: SU 41, 53, 64, 62) with stone and mud-brick installations, partially cut by later fireplaces. The pits of the fireplaces are

oval- to pear-shaped with one wider and one narrower end. The internal installations consist most probably of three stones, which were positioned roughly vertically at the edge of the wider end of the pit following an axial alignment. At the centre of the three stones, a mud brick was vertically placed on its long side. Inside the pits, numerous remains of charcoal, carbonized date stones, fish bones, and molluscs were discovered. Therefore, the preliminary assumption is that this area was used for cooking activities, presumably related to a mud-brick structure (Fig. 6: SU 32) already exposed in the eastern profile of trench E1. Stratigraphically, this area is connected to an occupation level (see Fig. 3: SU 71) recorded in the south profile of trench E1.

Trench E2

The aim was to investigate the Early Bronze Age occupation layers outside the retaining wall in detail, based on the results obtained in trench E1. In order to achieve this, the excavation area was extended towards the east of trench E1 and trench E2 (10 x 10 m; see Fig. 2).

After removing the uppermost layer of topsoil and disturbed horizons containing only mixed material, a level with numerous pits was uncovered. Nearly all of these pits were filled with stones and the interior walls of the pits were consolidated with stones and pottery sherds. Due to levelling activities from the time when this area was used for a palm-tree plantation with constructions of an associated irrigation system, the original surface of the occupation level corresponding to the pits was not preserved. Stratigraphically, however, the pits are penetrating layers covering the architecture of the Iron Age I fortification (Fig. 6: SU 24, 365, 416) and the pits must therefore date to a younger occupation of the site. Numerous fragments of grinding stones and pottery sherds found during the excavation of the pits allow a preliminary assignment to a settlement presumably of the Iron Age II period, since the pottery displays characteristic decoration of this period (i.e. criss-crossed incised motifs). In the western area of trench E2, immediately adjacent to trench E1, the continuation of the exterior retaining wall (Fig. 6: SU 365) of the Iron Age I fortification as well as partially preserved remains of the interior retaining wall (Fig. 6: SU 416) were detected (see Fig. 2).

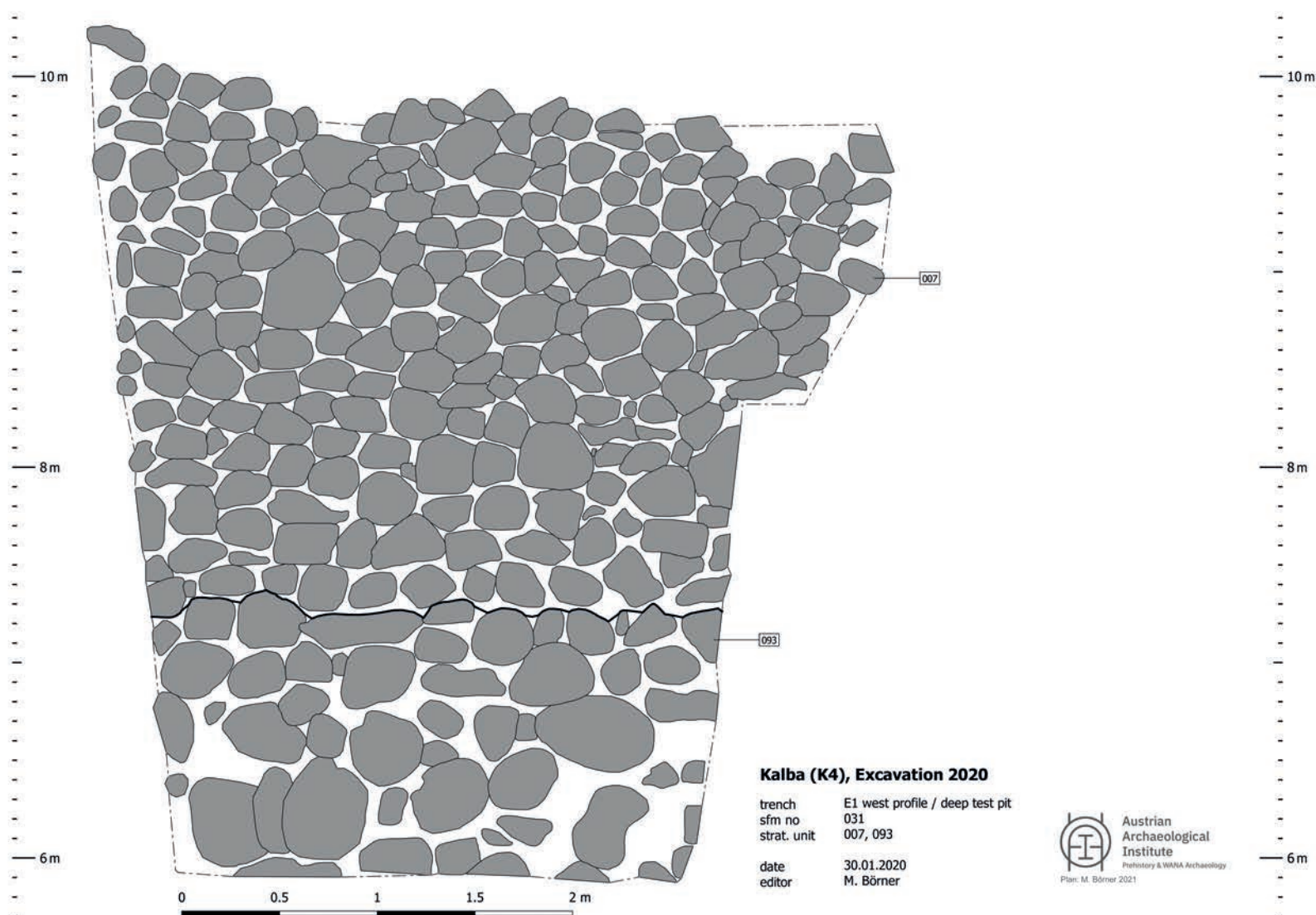


FIGURE 5. A schematic plan of the interior Early Bronze Age retaining wall in the deep test pit (plan: OeAW-OeAI/M. Börner).

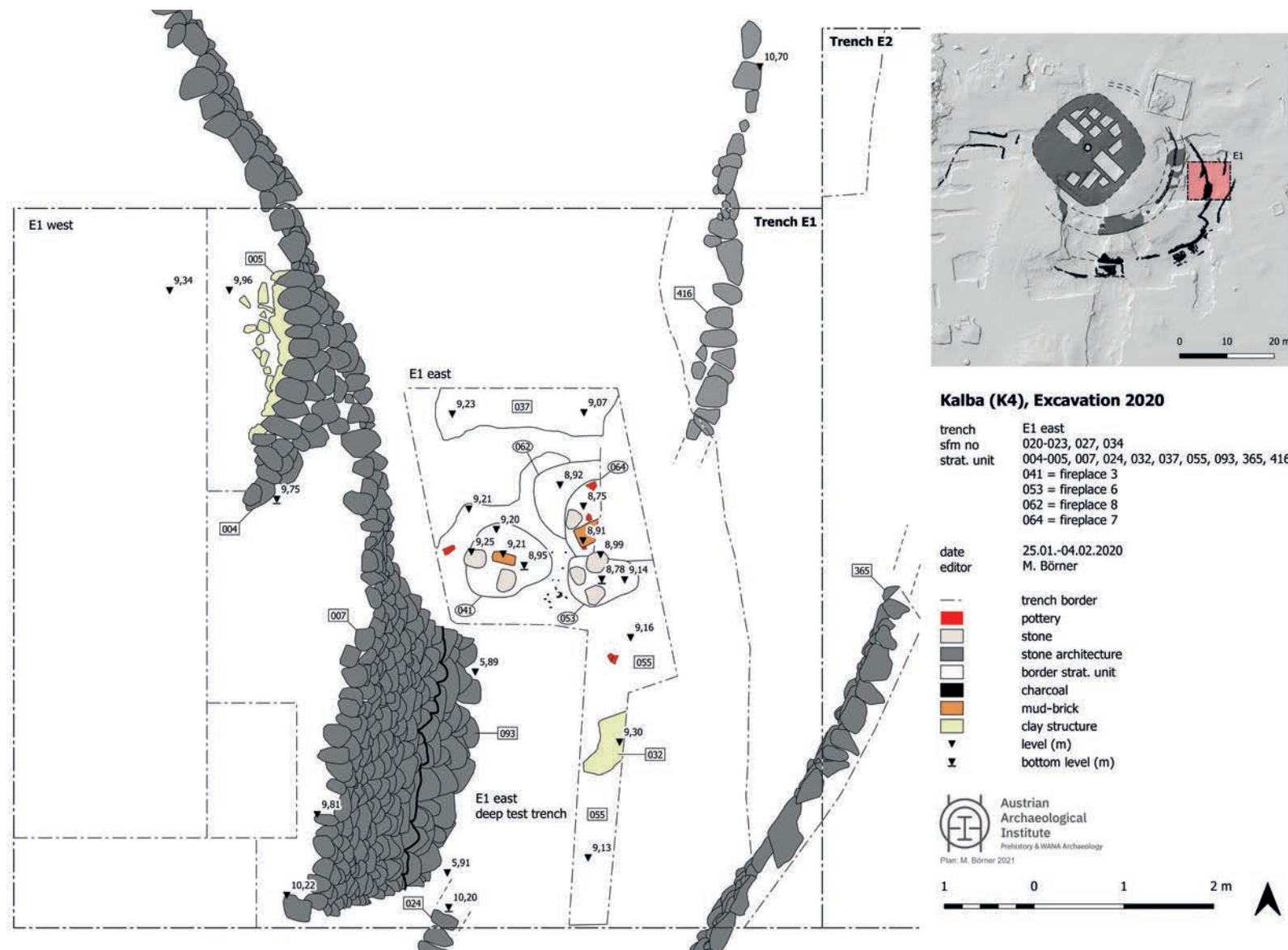


FIGURE 6. A plan showing an occupation level with a fireplace area outside the former Early Bronze Age retaining wall in the eastern sector of trench E1 (plan: OeAW-OeAI/M. Börner).

Archaeobotanical remains

Twenty hand-picked samples from nine contexts, mostly fireplaces (nos. 1–3, 5–7, 9), but also a foundation layer (SU 30) and a levelling layer (SU 31), were

investigated for their archaeobotanical remains. A total of 212 charcoal fragments and date-stone fragments representing at least twenty-three dates were identified (see Fig.7/a). The charcoals were analysed using standard methodology consisting of the investigation

Context	Cultural period	¹⁴ C [2σ cal. BC]	Phoenix petiole	Date stones	Rhizophoreae	Avicennia
Pre-EBA retaining wall and ditch layers						
Fireplace 9						
KAL20/59/11/1	Umm an-Nar	2455–2205			16	
KAL20/59/12/3					11	
KAL20/43/12/1						4
Fireplace 5						
KAL20/45/11/1	Umm an-Nar	2463–2236			1	
KAL20/45/12/1					2	
Levelling layer						
KAL20/31/11/1	Umm an-Nar				2	
KAL20/31/12/1					3	
Fireplace 1						
KAL19/10/14/1	Umm an-Nar	2289–2061				1
EBA-retaining wall foundation						
KAL20/30/11/1	Umm an-Nar	2270–2035		0.3		
EBA fireplace area (nos. 3, 6–8)						
Fireplace 7						
KAL20/67/11/1	Umm an-Nar	2280–2041			17	
KAL20/67/12/1					2	1
Fireplace 6						
KAL20/51/11/1	Umm an-Nar				1	
KAL20/51/12/1				0.75	11	
Fireplace 3						
KAL20/34/11/1	Umm an-Nar			0.3		
KAL20/34/12/1				0.4	4	
KAL20/40/11/1		2202–2034		0,6		
KAL20/40/12/4				15	10	
KAL20/40/12/6			4	3	122	
MBA layers						
Fireplace 2						
KAL20/19/11/1	Wadi Suq	1750–1616		1		
KAL20/19/12/1				1		

FIGURE 7. Results of the archaeobotanical, radiocarbon and metallurgical analyses. **a.** Results of the archaeobotanical analysis of Kalba K4 samples (n=212; for ¹⁴C dates see Fig. 7/b; table: University of Tübingen/K. Deckers);

Lab. No. [MAMS]	Sample No.	$\delta^{13}\text{C}$ [‰]	^{14}C Age [BP]	Probability 68% [BC]	Probability 95% [BC]	ΔR [yrs]	Material
42622	KAL19/10/14/1	-24.5	3772 ± 25	2276–2142	2289–2061		charcoal (mangrove) (<i>Avicennia marina</i>)
46242	KAL20/19/11/1	-23.8	3397 ± 25	1737–1632	1751–1616		date stone (<i>Phoenix dactylifera</i>)
46243	KAL20/19/11/2	-22.8	3385 ± 25	1732–1626	1746–1613		date stone (<i>Phoenix dactylifera</i>)
46244	KAL20/19/22/1-T1	-1.7	3738 ± 25	1739–1636	1843–1579	-150.9 ± 52.2	mollusc (<i>Terebralia palustris</i>)
46245	KAL20/19/22/1-T2	-5.4	3700 ± 26	1736–1635	1821–1561	-150.9 ± 52.2	mollusc (<i>Terebralia palustris</i>)
46246	KAL20/19/22/1-T3	-4.8	3673 ± 26	1735–1633	1811–1551	-150.9 ± 52.2	mollusc (<i>Terebralia palustris</i>)
46247	KAL20/30/11/1	-24.5	3734 ± 28	2199–2047	2270–2035		date stone (<i>Phoenix dactylifera</i>)
46248	KAL20/40/11/1	-23.7	3726 ± 27	2197–2043	2202–2034		date stone (<i>Phoenix dactylifera</i>)
46249	KAL20/40/22/1-T1	-4.5	4153 ± 25	2201–2052	2250–2016	-72.8 ± 55.0	mollusc (<i>Terebralia palustris</i>)
46250	KAL20/40/22/1-T2	-3.6	4086 ± 25	2197–2051	2233–1996	-72.8 ± 55.0	mollusc (<i>Terebralia palustris</i>)
46251	KAL20/40/22/1-A1	-1.6	4131 ± 24	2205–2056	2330–1947	-66.1 ± 90.5	mollusc (<i>Anadara uropigimelana</i>)
46252	KAL20/45/11/1	-25.0	3873 ± 24	2451–2297	2463–2236		charcoal (mangrove) (Rhizophoreae)
46253	KAL20/59/11/1	-26.1	3843 ± 22	2343–2211	2455–2205		charcoal (mangrove) (Rhizophoreae)
46254	KAL20/67/11/1	-27.3	3753 ± 21	2203–2137	2280–2041		charcoal (mangrove) (Rhizophoreae)
46255	KAL20/67/22/1-T1	-2.2	4108 ± 21	2198–2051	2240–2001	-72.8 ± 55.0	mollusc (<i>Terebralia palustris</i>)

FIGURE 7. Results of the archaeobotanical, radiocarbon and metallurgical analyses. **b.** Radiocarbon dates from Kalba K4 (n=15). Terrestrial samples were calibrated using OxCal 4.4 with the IntCal20 dataset. Reservoir effect ΔR for shells modelled in Oxcal 4.4 with Marine20 (table: CEZA/S. Lindauer) ;

Lab. No. [MAMS]	Sample No.	Cu	Fe	Co	Ni	As	Se	Ag	Te
202191	KAL19/2/21/1	100	<0.05	<0.01	0.02	<0.005	0.038	0.004	0.008
202193	KAL20/2/21/2	99	0.14	0.03	0.54	0.49	0.017	0.009	0.007
202194	KAL20/2/21/3	100	0.18	0.01	0.08	0.005	0.036	0.029	0.015
202195	KAL20/2/21/4	96	3.7	0.01	0.06	0.018	0.045	<0.002	0.016

FIGURE 7. Results of the archaeobotanical, radiocarbon and metallurgical analyses. **c.** chemical compositions of the copper artefacts from Kalba as determined with energy-dispersive X-ray fluorescence. All data are given in mass percent. Zn was below 0.1% in all samples; Sn, Sb, Pb, and Bi were below 0.005% in all samples (table: CEZA/E. Pernicka) ;

Lab. No. [MAMS]	Sample No.	Cu	As	Sb	Co	Ni	Ag	Au	Zn	Sn	Se	Te	Pb	Bi
202197	HLO20/1/25/2	13.7	12	<0.5	380	130	11	0.02	120	33	<2	6.6	126	<0.007
202198	HLO20/1/25/3	7	12	0.45	53	80	<2	0.016	58	<91	0.8	3.7	58	<0.002
202199	HLO20/1/25/4	10	1	<0.4	95	71	<2	0.009	29	<140	<2	24	<0.006	<0.002

FIGURE 7. Results of the archaeobotanical, radiocarbon and metallurgical analyses. **d.** Chemical composition of the copper ore samples from Wādī al-Ḥilo as determined with neutron activation analysis. Pb and Bi were determined with ICP-MS from dissolved sample aliquots. All data are given in µg/g except for copper in mass percent. Fe was below 0.8% in all samples (table: CEZA/E. Pernicka);

Lab. No. [MAMS]	Object	Sample No.	²⁰⁸ Pb/ ²⁰⁶ Pb	²⁰⁷ Pb/ ²⁰⁶ Pb	²⁰⁶ Pb/ ²⁰⁴ Pb	²⁰⁸ Pb/ ²⁰⁴ Pb	²⁰⁷ Pb/ ²⁰⁴ Pb	Figure
202191	metal slag	KAL19/2/21/1	2.0904	0.84992	18.278	38.209	15.535	8a4
202193	metal slag	KAL20/2/21/2	2.0865	0.84644	18.404	38.399	15.578	8a2
202194	metal slag	KAL20/2/21/3	2.0871	0.84596	18.456	38.520	15.613	8a3
202195	needle/ wire	KAL20/2/21/4	2.0756	0.83863	18.646	38.702	15.637	8a1
202197	copper ore	HLO20/1/25/2	2.0846	0.84353	18.530	38.627	15.631	8a5
202198	copper ore	HLO20/1/25/3	2.0870	0.84544	18.467	38.541	15.612	8a6

FIGURE 7. Results of the archaeobotanical, radiocarbon and metallurgical analyses. **e.** Lead isotope ratios of the copper objects from Kalba and the copper ore samples from Wādī al-Ḥilo (table: CEZA/E. Pernicka).

of transversal, tangential, and radial sections using incident light microscopy and magnifications varying between 60x and 500x depending on the diagnostic features that were investigated.

The charcoals were strongly dominated by *Rhizophoreae*, a mangrove clade, but they could not be identified more precisely due to a lack of literature and reference material. However, it is possible that they represent *Rhizophora mucronata*. Only a few fragments of *Avicennia marina* and *Phoenix* petiole were identified.

Although mangrove is today present in the Kalba region, it is dominated by *Avicennia marina* while *Rhizophora mucronata* has only recently been reintroduced (Moore, Grizzle & Ward 2013). Both these mangrove taxa are adapted to different environments, with *Avicennia marina* more to salt-water conditions, while *Rhizophora* more to fresh-water conditions (Spalding, Blasco & Field 1997). Palynological research has indicated overall changes in the mangrove vegetation in southern Arabia, with a strong abrupt increase in the *Avicennia/Rhizophora* ratio in Kwar al Jaramah in Oman shortly before 2000 BC, while this

change took place further south in Filim only around 1000 BC and more gradually. It has been argued that these vegetation changes could be related to increased aridity due to the rain belt moving to the south in different stages (Lézine et al. 2017). Archaeobotanical remains from Tell Abraq show a similar trend in an increased *Avicennia/Rhizophora* ratio from the third to first millennium BC, that is, from Umm an-Nar to the Iron Age (Tengberg 2005). Although the climate became increasingly drier from c.3000 BC onwards (Lézine et al. 2017), the strong dominance of *Rhizophoreae* in Kalba may be related to more favourable conditions with possibly enhanced summer rainfall compared to today. Tengberg (2005) however argues that the decrease of *Rhizophora* was likely also related to human impact causing salinization and coastal landscape evolution. She stresses that climatic drying alone was not responsible for the current absence of *Rhizophora* since they were present at later archaeological sites in the region, for example at Kush in the nineteenth to thirteenth century BC. People at Kalba appear to have used the mangrove *Rhizophoreae* vegetation as their

main fuel source, indicating the importance of coastal resources (cf. Phillips & Mosseri-Marlio 2002).

Besides two mangrove taxa, the only other taxon identified so far is *Phoenix*, represented by at least twenty-three stones and four petiole fragments. This is of interest since it concerns the question of agriculture, which started to play a role in the subsistence economy at that time (Cleuziou & Costantini 1980; Willcox & Tengberg 1995; Méry & Tengberg 2009; Tengberg 2016; Nathan Staudt 2017). *Phoenix* remains have been found at several sites in the greater Middle East (e.g. Tengberg 2012; Deckers, Döpper & Schmidt 2019) and it was possibly cultivated, considering the presence, though meagre, of other crops like barley and free-threshing wheat at some sites of this period (see e.g. Méry & Tengberg 2009; Tengberg 2012). Unfortunately, the charcoal from wild date palm cannot be differentiated from the cultivated one and wild date palm has been found in the Hajar mountains of Oman that are a relict population of domesticated lineages (Gros-Balthazard et al. 2017). The few unfragmented date stones at Kalba may perhaps provide further information on this issue after morphometrical analysis (Gros-Balthazard et al. 2016). No other cultivated crops have been found at Kalba thus far.

Radiocarbon dating and marine reservoir effect

In total, fifteen radiocarbon samples (date stones, molluscs, and charcoal) were taken from selected contexts of the excavations in trench E1, in order to capture a broader chronological variety from the Early Bronze Age to the Iron Age period (see Figs 3, 7/b).

The samples were measured at the Curt-Engelhorn-Centre of Archaeometry, Mannheim, Germany. The date stone and the charcoal samples were pre-treated to remove contaminations such as carbonates and soluble humic acids. The shell samples underwent an acid leaching step to remove any contamination attached to the outer surfaces of the shell material. Prior to measurement, all samples were converted to gaseous CO₂ before being reduced to elemental carbon by addition of hydrogen with iron as catalyst. The samples were then pressed into targets and measured in a MICADAS system (Kromer et al. 2013). All procedures are described in more detail by Lindauer et al. (2017).

Charcoal and shell samples with definite correlation can then be used to derive a reservoir age and a reservoir effect of the shell material. The reservoir effect needs to be considered for shells, because marine organisms tend towards older ages than their terrestrial counterparts. The ocean can store large amounts of carbon for periods of over 1000 years during which a significant fraction of the radiocarbon decays. The ¹⁴C-depleted waters are then taken up by the marine organisms. This leads to apparently older calendar ages of marine shells and other species. For this site, we used IntCal20 and Marine20 calibration curves as references (Reimer et al. 2020; Heaton et al. 2020).

The evaluation of the radiocarbon dates in combination with the stratigraphy provided interesting results indicating that older occupation layers inside E1 (western sector) were cut off in the course of the construction of the retaining wall (see Fig. 3; Fig. 7/b: 42622, 46252–46253). One sample taken from the foundation of the wall suggests a construction during the late third millennium BC, although it remains an open question whether this sample could have been dislocated from older layers during the construction process (see Fig. 3; Fig. 7/b: 46247). However, the construction during the late third millennium BC is supported by absolute dates from the fireplace area outside the Early Bronze Age retaining wall which are roughly contemporary with the foundation level of the wall c.3 m deeper (Fig. 7/b: 46247–46251, 46254–46255). This evidence supports the assumption that the ditch in front of the retaining wall has been in use just for a short period during the late Umm an-Nar period. However, it is not known why the ditch was refilled after a rather short period. The activity zones in the area of the former ditch clearly point to a domestic space outside the Early Bronze Age retaining wall which was still visible during these times. So far, the date stone and the charcoal samples from Early Bronze Age contexts range between c.2460 and 2035 cal. BC. Absolute dates for the levelling of the Umm an-Nar retaining wall and related layers in this area of the settlement are provided by fireplace 2 (date stones: 1751–1613 cal. BC; molluscs: 1843–1551 cal. BC) inside the southern profile corresponding to the Wadi Suq period (see Fig. 3; SU 19; note that in Fig. 3 the age ranges refer to the complete age span covered partially by multiple samples from distinct features whereas the individual data is presented in Fig. 7/b). Therefore, the

stratigraphy of the south profile of trench E1 indicates a hiatus of c.300 years. However, it is not clear if the site was temporarily abandoned or older settlement layers of the Wadi Suq period were dug away in the course of levelling activities in this area.

Regarding the marine reservoir effect at Kalba (ΔR , Fig. 7/b), the shells indicate a change between the Early (-72.8 ± 55.0 yrs) and Middle (-150.9 ± 52.2 yrs) Bronze Age. The decreasing reservoir effect reflects a declining sea level or at least a certain variation in ocean circulation patterns. Together with other climate proxies it can also point to an increasingly drier climate during c.2500–1600 cal. BC (see Lindauer et al. 2017: 112–115 for a trend of the reservoir effect in older periods).

Lithic raw material studies

Besides the favourable geographical location of the site of Kalba, the repeated occupation from the Early Bronze Age to the Iron Age (c.2500–600 BC) raises the question of whether there are other reasons for such a settlement continuity. In this context, chert and copper artefacts from the excavations at Kalba are of special interest. Since deposits of copper and chert are not located in the direct vicinity of the settlement, questions arise about the provenance of these artefacts and/or raw materials, and how they might have arrived at Kalba.

In an attempt to shed some light on these factors, selected samples of copper and chert artefacts from Kalba were taken for further analyses. Additionally, raw material samples from copper and chert sources were collected in order to establish the potential provenance of the archaeological material.

Metallurgical analyses

The abundant copper deposits in south-eastern Arabia, especially in the Al-Hajar mountains, are well-known copper sources of the Bronze Age (see Hauptmann 1985; Weeks 2003: 7–14; Begemann et al. 2010; Salzmann 2019: 35–36; 110, fig. 15.1). Known copper deposits are located c.15 km (as the crow flies) from Kalba in Wādī al-Ḥilo (Fig. 1: 17; Fig. 10). Previous research at the copper smelting site of HLO1 demonstrated that this location was already known and used during the Umm an-Nar period (Kutterer & Jasim 2009: 249–250; Kutterer 2013: 163–164; Kutterer, Neureiter & Jasim 2013: 192,

fig. 8; 195). For this reason, besides samples of copper objects and slag from Kalba (Fig. 8/a: 1–4), copper ore samples (Fig. 8/a: 5–6) were taken from the copper mineralization near the Bronze Age site of Wādī al-Ḥilo. Although the samples from Kalba derive from mixed contexts, they could address the question of whether or not raw material from the copper deposits of Wādī al-Ḥilo was processed at Kalba during prehistoric times.

The analytical methods used were described in detail by Nørgaard, Pernicka and Vandkilde (2019) and by Kuleff and Pernicka (1995). The analysed metal objects consist of rather pure copper matching the copper ores from Wādī al-Ḥilo (Fig. 7/c–d), especially concerning the silver and nickel concentrations as well as the low lead concentrations. Of interest is the presence of tellurium, which may indicate the general type of mineralization in south-east Arabia, chemically resembling the copper deposits on Cyprus. For the latter Cyprian deposits, selenium and tellurium are indicative and at least indirectly attested by relatively high concentrations in copper oxide ingots (Rehren & Northover 1990). Also significant in this respect are the very low concentrations of antimony whereas the low cobalt concentrations in the objects compared to the ores could indicate smelting of the ores at relatively high oxygen partial pressure. Incidentally, the very low concentrations of lead in the ore and slag samples also match the regional geological context with rocks consisting mainly of gabbro and harzburgite (see Ministry of Energy 2006). Moreover, in one ore sample from Wādī al-Ḥilo the lead concentration was so low that it was not possible to determine the lead isotope ratios.

The match between the analysed objects and the copper ores from Wādī al-Ḥilo is corroborated by the lead isotope ratios as shown in Figures 7/e and 8/a–b, which were compared with those of copper ores from Oman, Iran, Jordan, and Cyprus, the most likely source regions. The ores from Jordan can safely be excluded as well as the ores from the Iranian plateau, although there is some overlap and very few analyses are yet available from this large region.

The ore samples from Wādī al-Ḥilo and also the metal objects from Kalba correspond to the signatures of the copper deposits in Oman. Only the fragment of a needle or wire (Fig. 7/e: 202195; 8/a: 1) matches with signatures from Iran and Cyprus. However, the lead and gold

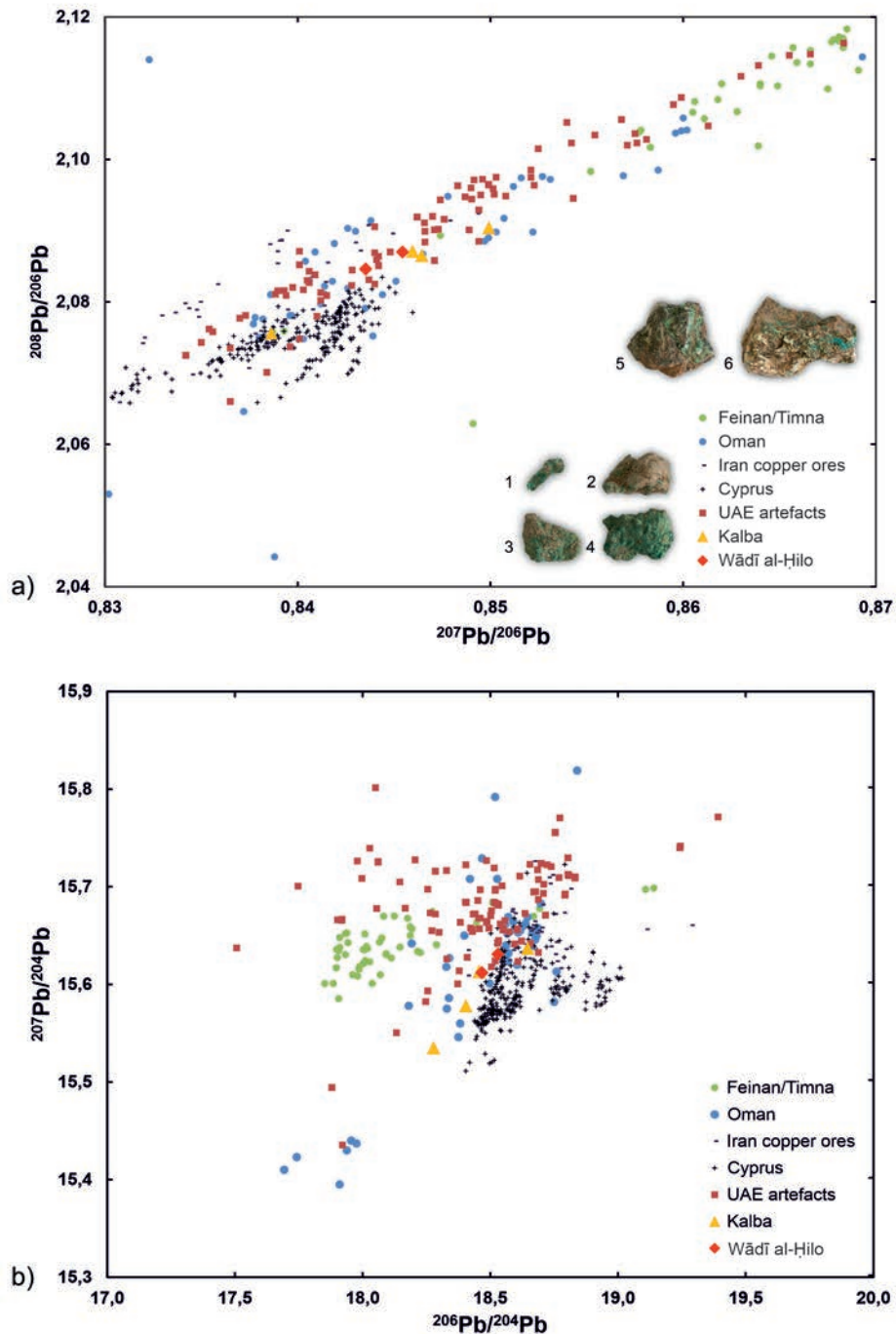


FIGURE 8. **a.** Traditional representation of the lead isotope ratios of objects from Kalba (1: fragment of a needle/wire; 2-4: slags) and ore samples from Wādī al-Ḥilo (5-6) compared with published data of the copper deposits in Oman (Begemann et al. 2010; Prange 2001) on Cyprus (Gale et al. 1997), in Iran (Pernicka et al. 2011; van Ham-Meert et al. 2019) and the Arabah (Gale et al. 1990; Hauptmann et al. 1992); **b.** lead isotope diagram most often used in geochemistry. In addition to the ore data the lead isotope ratios of objects from sites in the UAE (Weeks 1999; 2003) are plotted (graphics: CEZA/E. Pernicka).

concentrations of copper from Cyprus are mostly higher and silver contents are lower (Begemann et al. 2001). Therefore, a provenance from Cyprus can be excluded.

Comparing the lead isotope results with published signatures of artefacts from sites in the UAE, specific trends become visible (Fig. 8/b). The Early Bronze Age artefacts from the UAE are more variable in their lead isotope ratios indicating several different copper sources whereas the signatures from Kalba and from Wādī al-Ḥilo correspond most closely to the deposits from Oman. Ore deposits of the Al-Hajar mountains therefore provide the best reference signatures, but it cannot be excluded that the fragment of the needle or wire was made of copper from Iran. More samples from copper sources in Iran would be needed to substantiate this assumption.

Chert analyses

In contrast to copper ore, chert sources are not available in the immediate catchment area of Kalba. Preliminary

studies show that chert-bearing deposits are located in the northern Rub al-Khali desert, in the Jebel Buhais mountain range and the western foothills of the Al-Hajar mountains (see Ministry of Energy 2006; Uerpmann, Uerpmann & Händel 2008: 68, fig. 19). Material reported from Jebel al-Ma'taradh and Suhaila (Charpentier et al. 2017) do not correspond with any of the chert types found at Kalba and were therefore not included in the study. These deposits are located c.50 km (as the crow flies) from Kalba and at the inner range of the western mountains, which would clearly indicate contacts with the inland south-eastern Arabian Peninsula (Fig. 9). To gain reference data for the chert artefacts from Kalba (eight specimens) and determine their provenance, a geo-archaeological field survey of chert deposits was initiated. Both archaeological artefacts and the collected geological material will be analysed according to the 'Multi-Layered-Chert-Sourcing-Approach', a multi-analytical technique for securely tracing the origin of chert artefacts back to their geological deposits (Brandl 2016; Brandl et al. 2018). While the case study of

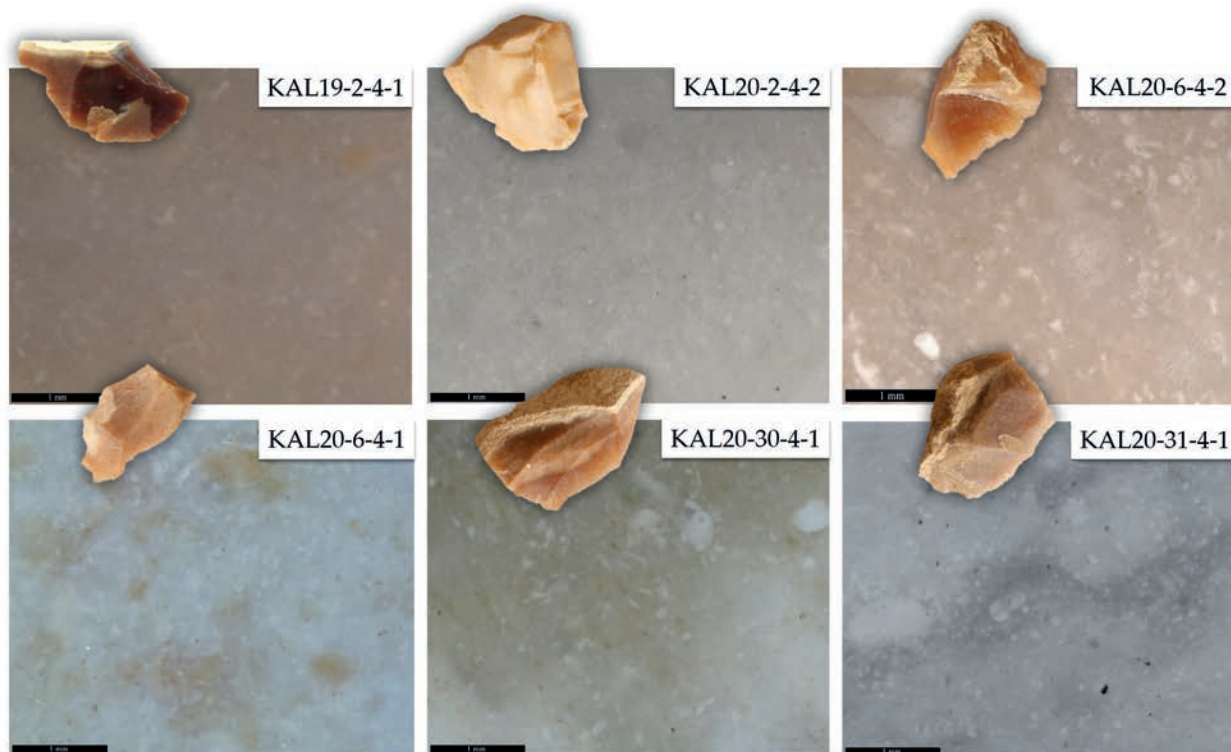


FIGURE 9. Microphotographs of selected chert artefacts from Kalba providing microfacies information (graphic: OeAW-OeAI/M. Brandl).

Kalba is the starting point, this undertaking will allow for the development of a reference database of chert sources, which can be used to study their exploitation and distribution patterns on a larger scale. Fieldwork in 2020 concentrated on the Jebel Buhais mountain range, since M. Uerpmann and colleagues determined this source region as the most relevant for this part of the UAE (Uerpmann, Uerpmann & Händel 2008).

In the course of this initial survey, eight distinct source localities at Jebel Faya and Jebel Buhais were sampled (Fig. 9). The main geological chert-bearing unit within the Buhais range is the Late Cretaceous Simsim formation, where chert nodules are primarily associated with banked limestone (Abd El-Gawad et al. 2010: fig. 10). All sampled locations showed traces of intensive chert extraction and on-site lithic workshops. Additionally, first stereomicroscopic microfacies analyses (Affolter 2002; Aydın & Brandl 2019; Brandl 2016) coupled with geochemistry of the chert artefacts from Kalba (Early Bronze Age: 4; Early Bronze to Iron Age: 2), one from the site HLO1 in Wādī al-Ḥilo and the collection of raw material samples from Jebel Faya North and South, Jebel Buhais North, West and East revealed an origin of all investigated artefacts from Jebel Buhais East and North, and Jebel Faya North (Fig. 9). The publication of the results of these in-depth studies is currently in preparation. These preliminary results illustrate the high potential of a systematic investigation of the entire Buhais range and the larger catchment for future sourcing attempts also including archaeological materials from various sites in the UAE.

Discussion and conclusion

The fieldwork at Kalba (K4) in trench E1 produced important results regarding the site's stratigraphy and its chronological sequence, especially the late Umm an-Nar and the Wadi Suq periods. Furthermore, additional information about the construction of the Early Bronze Age retaining wall with a ditch in the exterior part of the settlement was obtained in the western sector of the trench. The stratigraphy in combination with the radiocarbon dates clearly demonstrate that older occupation layers were dug away in the course of its construction. In this context, it can be assumed that the retaining wall must be seen in context with the minimum 3.5 m deep ditch (preserved and excavated

depth). A so-called tower construction with an attached exterior ditch is not unusual during the Umm an-Nar period on the south-eastern Arabian Peninsula (Döpper 2018a: 125–128). So far, the ditch has partially been captured over a length of c.2.7 m in the southern part of trench E1 (see Fig. 4). Therefore, both the length and depth fits to the general pattern of ditches attached to towers that are several metres in width and commonly 2 to 5 m deep (Döpper 2018a: 127). In the case of the ditch at Kalba, the radiocarbon dates of its construction and the subsequent use of the area for domestic purposes (fireplaces) indicate that the ditch lost its function after a relatively short period. The reason for the relatively short use of this construction can only be hypothesized. The activity zone in the area of the former ditch indicates a change in use, which could possibly be seen in connection with an expansion of the settlement area. Further excavations outside the tower complex will provide important information on this topic. However, the location of the tower construction at Kalba near the coast would have certainly been a recognizable landmark and raises the question about the significance of the site in Early Bronze Age times.

Despite a trend towards an increasingly drier climate indicated by the marine reservoir effect from Early to Middle Bronze Age times, botanical analyses revealed that wood used at the site mainly consisted of mangrove which, unlike today, was dominated by Rhizophoraceae and may relate to somewhat wetter conditions in the third millennium BC than today. Moreover, the only possible cultivated plant species attested so far is date, represented by petiole and stones.

Besides the location of an ecological niche with favourable conditions in Early Bronze Age times, the availability and accessibility of raw material deposits could be a possible explanation for the establishment of the settlement close to the seashore in the Gulf of Oman. To address this question, initial systematic analytical studies on copper and chert artefacts found during our excavation at Kalba in combination with surveyed copper ore (Wādī al-Ḥilo) and chert deposit samples (Buhais range) were conducted for determining their provenance.

The metallurgical analyses of the objects from Kalba indicate that the copper from the deposits in the Al-Hajar mountains were used. Due to the similar lead isotopic signature of distinct copper ore deposits (cf. Begemann

et al. 2010: 148, fig. 3), the copper artefacts cannot be assigned to an exact source, yet it is not surprising that two samples from Kalba plot closely to ore samples from Wādī al-Ḥilo. Thus, at least a partial origin from deposits 15 km away can be assumed (Fig. 10). The results of the chert analyses are clearer. It shows that the majority of the objects from Kalba can be assigned to the deposits of the Buhais range 50 km away based on their microfacies information and chemistry. An undetermined jasper flake requires more reference material from deposits which will be surveyed during our next fieldwork.

In general, the region of Kalba seems to have been well embedded in third-millennium BC trading

networks evidenced by imports found at different sites. Pottery and a soft-stone vessel found inside tomb K2 attest contacts with Iran and Mesopotamia as early as the mid-third millennium BC (David-Cuny & Phillips 2008; Eddisford & Phillips 2009: 108–109). Additionally, the investigations at K4 yielded imported pottery from Mesopotamia, Bahrain, Iran, and the Indus region (Eddisford & Phillips 2009: 108–109). Besides imports, the scientific analyses of copper and chert support the assumption that Kalba played an active role in regional and interregional trade networks. Taking the new data into account, the accessibility of suitable mineral sources seems to have contributed to the establishment of this

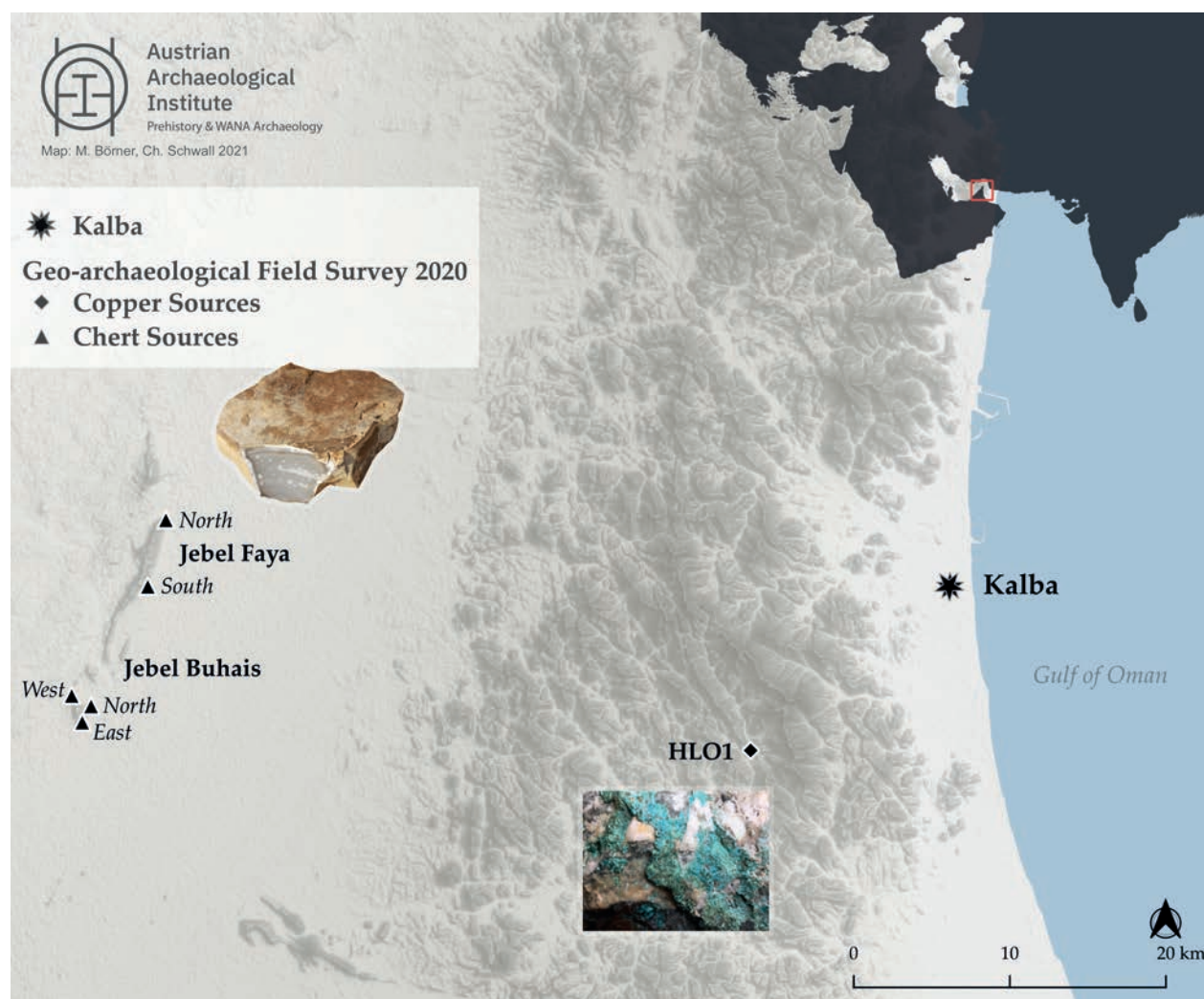


FIGURE 10. A map showing the sampled raw material sources during the geo-archaeological field survey (photo: OeAW-OeAI/M. Börner, C. Schwall).

diachronic settlement. Therefore, Kalba seems to have functioned as a trading post and node between maritime and inland trade routes, connecting the Arabian coast with the inner regions of the Arabian Peninsula.

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Map Appendix

1. Umm an-Nar (Excavation – Frifelt 1995); **2. Abu Dhabi Airport** (Excavation & Survey – de Cardi 1997; Beech, Kallweit & Hellyer 2004); **3. Ghanadah** (Excavation – al-Tikriti 1985); **4. Saruq al-Hadid** (Excavation – Weeks et al. 2019: 15–16); **5. al-Ashoosh** (Excavation – Contreras et al. 2016); **6. al-Sufouh** (Excavation – Benton 1996); **7. al-Qusays** (Excavation – Taha 2003); **8. Mowaihat** (Excavation – Phillips 2007); **9. Tell Abraq** (Excavation – Potts 1990; 1991; 2000); **10. Ed-Dur** (Excavation – Phillips 2007: 5); **11. Shimal** (Excavation & Survey – Franke-Vogt & Velde 1987: 80; Velde 1990: 376; Cleuziou 2003: 137); **12. Khatt/Nud Ziba** (Visible structures – Kennet & Velde 1995); **13. Rul Dhadnah** (Survey – Ziolkowski 2020: 30–31); **14. Bidya** (Excavation & Survey – al-Tikriti 1989); **15. Asimah** (Excavation – Vogt 1994); **16. Kalba** (Excavation – Eddisford & Phillips 2009; Schwall & Jasim 2020); **17. HLO1** (Excavation – Kutterer & Jasim 2009; Kutterer 2013: 163–164); **18. Hili** (Excavation & Survey – Cleuziou 1980; 1982; Méry 2013); **19. Fizh 1/WAJAP 63** (Survey – Düring & Botan 2018: 21–23); **20. WAJAP 50** (Survey – Düring & Botan 2018: 23); **21. Zahra 1** (Excavation – Costa & Wilkinson 1987: 97–99; Düring

& Botan 2018: 19–20); **22. WAJAP 2** (Survey – Düring & Botan 2018: 23); **23. Arjan** (Survey – Cable & Thornton 2013: 390, table 20.1); **24. Dahwa** (Excavation – al-Jahwari et al. 2018); **25. Qumayra** (Survey – Costa 2006; Cable & Thornton 2013: 389, table 20.1; Rutkowski 2021: 2, fig. 1); **26. Wadi Hareem** (Survey – Dumitru 2019: 152, table 5.1); **27. Abu Suwaih** (Survey – Dumitru 2019: 150, table 5.1); **28. Shukur** (Survey – Cable & Thornton 2013: 389, table 20.1); **29. al-Safri** (Survey – Cable & Thornton 2013: 389, table 20.1; Harrower et al. 2014; Dumitru 2019: 151, table 5.1); **30. Khadil** (Survey – Cable & Thornton 2013: 389, table 20.1; Dumitru 2019: 153, table 5.1); **31. al-Hasi** (Survey – Kondo et al. 2014: 229–231); **32. ad-Dariz** (Survey – Cable 2012: 308, table 14; Cable & Thornton 2013: 389, table 20.1); **33. al-Araqi** (Survey – Cable & Thornton 2013: 389, table 20.1); **34. al-Zebah** (Excavation – Schmidt 2018); **35. Wahrah Qala** (Survey – Cable 2012: 308, table 14; Cable & Thornton 2013: 389, table 20.1); **36. al-Khutm** (Survey – Cable 2012: 307, table 14; Cable & Thornton 2013: 388, table 20.1); **37. Bat** (Excavation & Survey – Cable 2012: 307, table 14; Cable & Thornton 2013: 388, table 20.1); **38. Banah** (Survey – de Cardi, Collier & Doe 1976: 170; Cable & Thornton 2013: 388, table 20.1); **39. Amlah** (Excavation – de Cardi, Collier & Doe 1976: 166–167; Schreiber 1998: 40; Döpper 2018b: 90); **40. al-Maidan** (Survey – Cable & Thornton 2013: 388, table 20.1); **41. Yika** (Survey – Cable & Thornton 2013: 388, table 20.1; Kennet, Deadman & al-Jahwari 2016: 160); **42. Rustaq** (Survey – Kennet, Deadman & al-Jahwari 2016: 159–160); **43. Wadi Far 1** (Survey – Hastings, Humphries & Meadow 1975: 10); **44. al-Tikha** (Survey – Kennet, Deadman & al-Jahwari 2016: 159); **45. Falaj al-Shurah** (Survey – Kennet, Deadman & al-Jahwari 2016: 159–160); **46. Tanuf** (Survey – de Cardi, Collier & Doe 1976: 160–161; Cable & Thornton 2013: 387, table 20.1); **47. al-Ghubra** (Survey – Orchard & Stranger 1994: 82–83); **48. Wihi al-Murr** (Survey – de Cardi, Collier & Doe 1976: 163; Cable & Thornton 2013: 387, table 20.1); **49. Sufayha** (Survey – Cable & Thornton 2013: 387, table 20.1); **50. Bisya** (Excavation & Survey – Cable & Thornton 2013: 387–388, table 20.1; Degli Esposti 2016: 665–667); **51. Firq** (Survey – Schreiber 2007: 198–199; Cable & Thornton 2013: 386–387, table 20.1); **52. Izki** (Survey – Schreiber 2007: 129–130; Cable & Thornton 2013: 386, table 20.1); **53. al-Qaryatain** (Survey – al-Jahwari 2008: 457–458; al-Jahwari, Douglas & Hesein 2020: 283); **54. al-Ghoryeen** (Excavation & Survey – Cable & Thornton 2013: 386,

table 20.1; al-Jahwari, Douglas & Hesein 2020); **55. al-Fulayj** (Survey – al-Jahwari 2008: 446–451; al-Jahwari, Douglas & Hesein 2020: 283); **56. ar-Rawdhah** (Survey – al-Jahwari 2008: 482–484; al-Jahwari, Douglas & Hesein 2020: 283); **57. Khadra Bani Dafa'a** (Survey – al-Jahwari 2008: 526–529; al-Jahwari, Douglas & Hesein 2020: 283); **58. al-Khuraish** (Survey – al-Jahwari 2008: 451; al-Jahwari, Douglas & Hesein 2020: 283); **59. al-Maysar** (Excavation – Hastings, Humphries & Meadow 1975: 18; Weisgerber 1980: 94–95; 1981: 198–203; Hauptmann 1985: 116; Orchard & Stanger 1994: 84, ann. 42); **60. al-Khashbah** (Survey – Weisgerber 1980: 99–100; al-Jahwari 2008: 466–478; Cable & Thornton 2013: 386, table 20.1); **61. al-Fath** (Survey – Cable & Thornton 2013: 386, table 20.1); **62. Ibra** (Survey – Cable & Thornton 2013: 386, table 20.1); **63. al-Batin** (Survey – Yule & Weisgerber 1996: 141); **64. Bandar Jissa** (Excavation – Thornton et al. 2018: 548–552); **65. Quriyat** (Survey – Ibrahim & ElMahi 2000: 120, 122; Cleuziou 2003: 137); **66. Bimmah** (Survey – Ibrahim & ElMahi 2000: 120, 122; Cleuziou 2003: 137); **67. Ras al-Hadd** (Excavation – Cattani et al. 2019); **68. Ras al-Jinz** (Excavation – Azzarà 2018; Azzarà & De Rorre 2018; 2019); **69. al-Ayn** (Excavation – Blin 2007; 2012; Cleuziou 2009: 733); **70. ar-Ruways** (Survey – Cleuziou 2009: 733; 2003: 137); **71. as-Suwayh** (Excavation – Méry & Marquis 1998; Cleuziou 2003: 137; 2009: 733); **72. Asilah** (Survey – Cleuziou 2009: 733; 2003: 137).

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