

The 2021 field season at Kalba: results of the excavations and geo-archaeological surveys

CHRISTOPH SCHWALL, MICHAEL BRANDL, MARIO BÖRNER, SUSANNE LINDAUER,
KATLEEN DECKERS, SIMONE RIEHL, ANJA CRAMER, CHRISTOPH HAUZENBERGER,
EISA YOUSIF & SABAH A. JASIM

Summary

The ongoing fieldwork at Kalba (K4) in the Gulf of Oman focused on the area outside the Early Bronze Age ditch construction and its subsequent use in the later Bronze Age and Iron Age periods. Our previous investigations have exposed a mud-brick wall section in the lower eastern profile of the trench whose function and specific dating were unclear. The excavated superimposed architectural remains in this area indicate that approximately the same spatial dimensions of the sites' central part were continuously enclosed.

Besides environmental studies (archaeobotany, marine reservoir effect) and radiocarbon data, the archaeological material discovered during the investigations extend our knowledge of craft activities on the site. Apart from metallurgy and stone knapping, a fragment of a semi-finished soft-stone vessel attests to local manufacturing of specialized craft products. Based on the artefacts found at Kalba, the geo-archaeological survey was extended. The variety of lithic materials used to produce various objects demonstrates the deliberate choice of particular stone types, and the awareness of the site's inhabitants of local rock deposits. In this context, it is worth considering whether specific rock materials were procured as trade goods by the prehistoric coastal community.

Keywords: United Arab Emirates, Kalba, fieldwork, environmental studies, lithic resources

Introduction

The focus of the 2021 field season at Kalba was the investigation of structures discovered in the eastern sector of trench E1 during the 2019–2020 seasons, in order to locate the exterior retaining wall of the Early Bronze Age ditch outside the Umm an-Nar tower construction (see Schwall et al. 2022: 333–335, figs 4–5; Schwall, Börner & Brandl, in press: fig. 1). So far, mud-brick wall sections in the eastern profile (Schwall, Börner & Meyer 2021: 34, 39, fig. 7) and an activity zone consisting of several fireplaces (Schwall et al. 2022: 334, 336, fig. 6; Schwall, Börner & Brandl, in press) were detected in this area. Radiocarbon dates have confirmed that the fireplaces date to the Early Bronze Age (Schwall et al. 2022: 332, fig. 3; 338, fig. 7b) but the exact chronological position of the mud-brick wall sections remains unclear. However, stratigraphically, all structures belong to a time when the former ditch was no longer in use and filled with sediment. Investigation

of the superimposed architecture from the Bronze Age to the Iron Age I, offers the possibility of gaining deeper insights into the diachronic occupation of the site. For this purpose, an assessment of the environmental conditions and possible changes during the period in question is important and further studies of the archaeobotanical remains and the determination of the local marine reservoir effect were conducted. The systematic geo-archaeological field survey was also continued with the aim of extending the data of chert sources and a variation of lithic resources, in particular jasper, chalcedony, and copper, based on recent finds at Kalba for assessing raw material procurement strategies of the site's inhabitants in a diachronic perspective.

Excavations in trenches E1 and E2

Excavations continued outside the Umm an-Nar tower construction in the eastern sector of trench E1 and in the north-western part of trench E2 (Fig. 1: Area 2021).

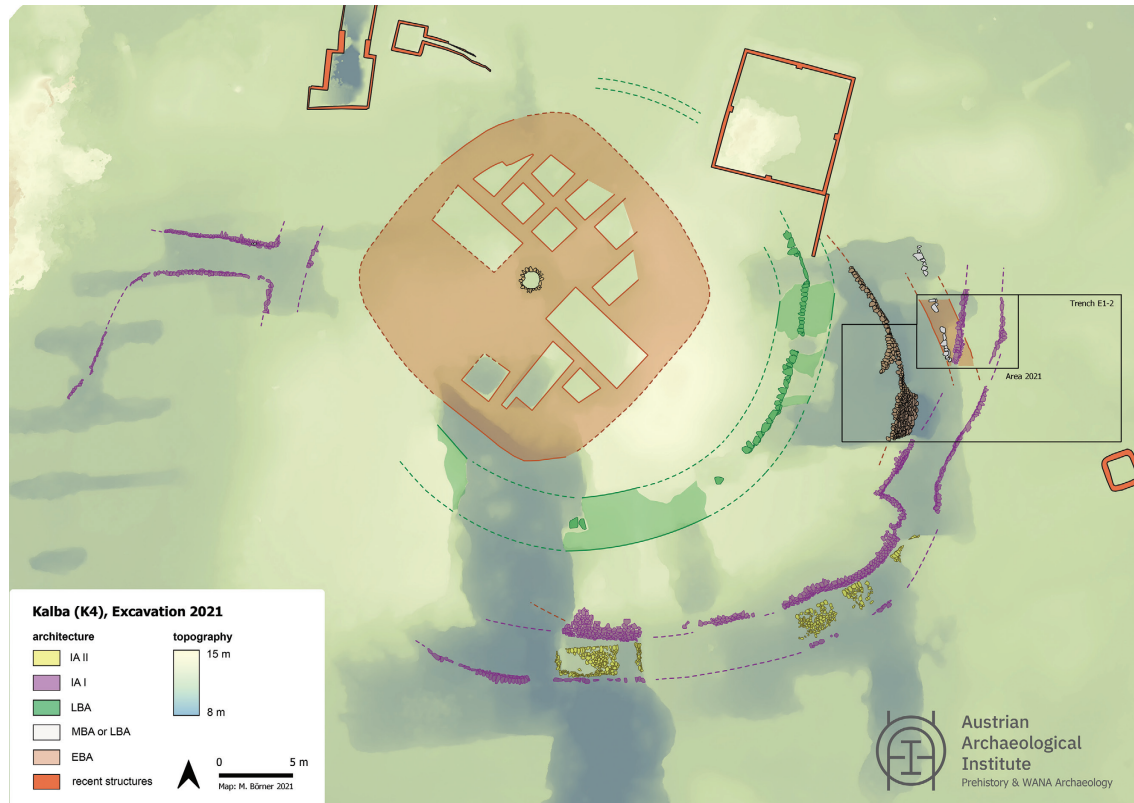


FIGURE 1. An architectural plan of Kalba including the GPR results and the location of the trenches and profiles (map: OeAW-OeAI/M. Börner; GPR data: Eastern Atlas/C. Meyer).

Iron Age occupations

The excavation of the uppermost preserved level with numerous pits found in 2020 was continued in trench E2 (see Schwall et al. 2022: 334; Schwall, Börner & Brandl, in press: fig. 7; Schwall, Börner & Brandl 2022: 62, fig. 1). Most of these pits were filled with stones and the inner walls of the pits were consolidated with stones and pottery sherds. The original surface of the occupation level corresponding to the pits and an associated fireplace (no. 10) was not preserved due to levelling activities during agricultural use as a palm-tree grove and the construction of an associated irrigation system (cf. Schwall, Börner & Brandl 2022: 69, plan 1), and only the lower parts of these installations were preserved. Part of an empty pot found *in situ* may simply indicate that this area was used for cooking and storage purposes. Stratigraphically, however, the pits penetrate into extended levelling layers, which cover the Iron Age I

fortification in the western part of trench E2. Based on pottery fragments found during excavation of the pits, the features can most probably be assigned to the Iron Age II period because the sherds display characteristic decoration (i.e. incised motifs on large storage jars with thick walls and out-turned rims; carinated bowls with criss-cross and zigzag painted decoration; see e.g. Barker 2002: 26–53; Carter 1997: 65, fig. 53; Iamoni 2009; Weeks et al. 2017) for this period (Schwall, Börner & Brandl 2022: 63, fig. 2).

In the western area of the trench, close to trench E1, the continuation of the exterior retaining wall of the Iron Age I fortification (Fig. 2: SU 511), as well as the remains of the interior retaining wall (Fig. 2: SU 416), became visible underneath the levelling layers (see Fig. 1). The fortification was investigated in more detail in the north-western part of the trench. It emerged that both the interior and exterior retaining wall are slightly sloping and create a ditch in between the walls, which

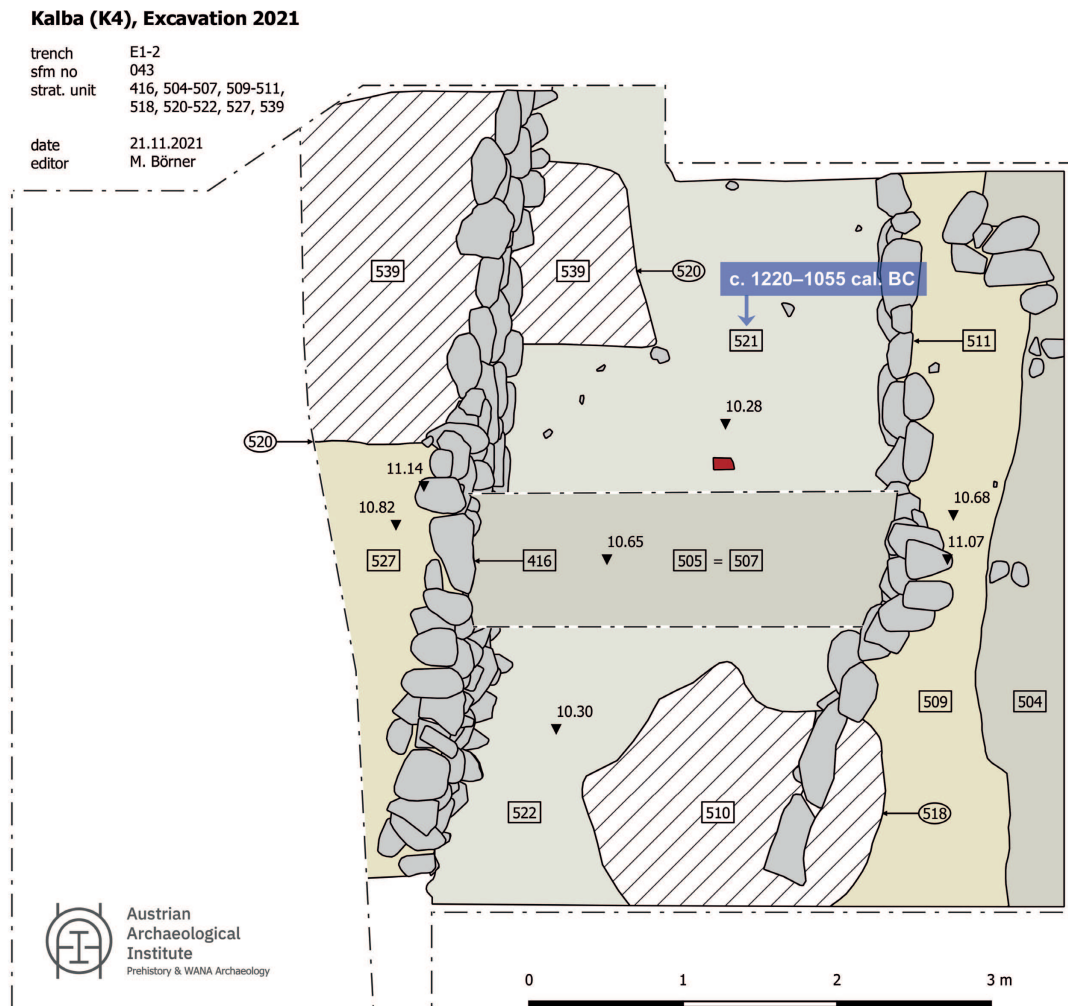


FIGURE 2. A plan of the Iron Age I fortification with retaining walls and ditch in trenches E1-2 (plan: OeAW-OeAI/M. Börner).

was filled with hard, dried clay fragments and blown- or washed-in fine silty and sandy material (Fig. 2: SU 505=507) on an occupation level (Fig. 2: SU 521=522) securely dated by radiocarbon samples to the Iron Age I period (see Fig. 8/b: 55244–45). A stone accumulation as well as hard compact material of the occupation level allow a clear separation of the filling. The filling itself indicates that the ditch was left open and filled with fine-grained sediments sloping in from both retaining walls to the middle of the ditch.

The stones the Iron Age I fortification walls were positioned inside the construction pit SU 528–529 with

clay functioning as mortar (Fig. 2: SU 527 in the west; SU 509 in the east). Radiocarbon dates of charred remains from the pit support the construction in the Iron Age I period (see Fig. 8/b: 55247). It can therefore be assumed, as already observed in the southern profile of trench E1 (Schwall et al. 2022: 332, fig. 3; Schwall, Börner & Brandl, in press: fig. 3), that older occupation layers were removed for the construction of the Iron Age I fortification. This is indicated by two fireplaces (nos. 11 and 12; SU 519, 532), which appeared underneath the remains of levelling layers and, according to radiocarbon dating, are dated to the Middle Bronze Age

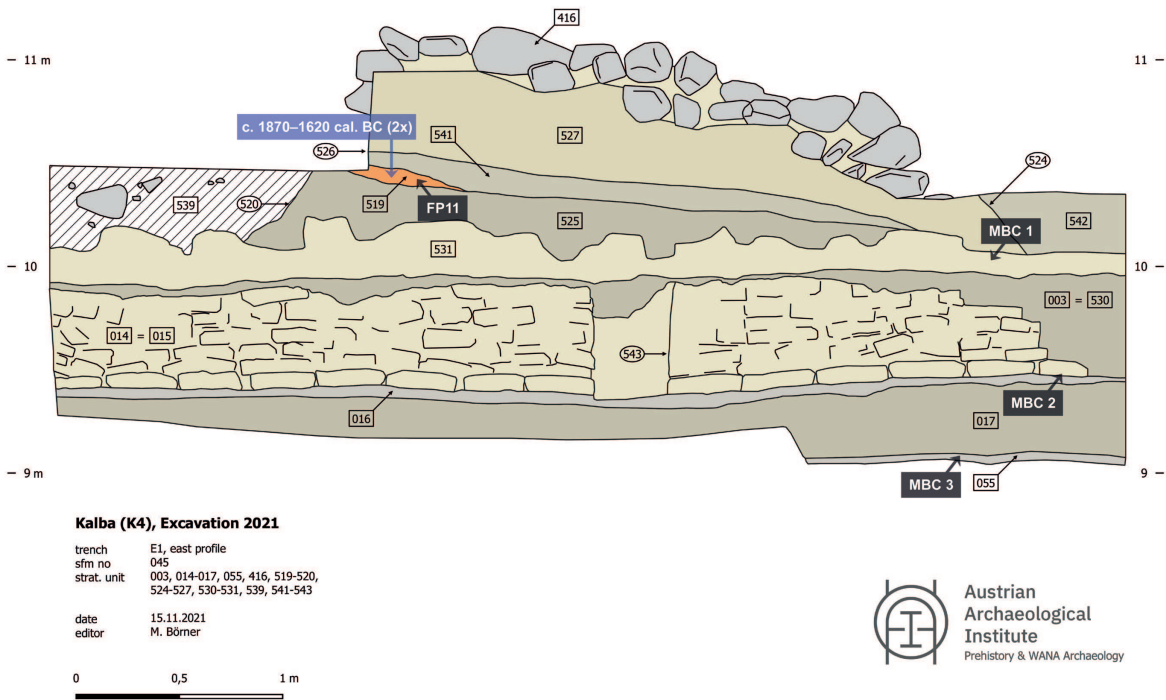


FIGURE 3. Stratigraphy of the east profile in trench E1 (plan: OeAW-OeAI/M. Börner).



FIGURE 4. Profile with the mud-brick wall SU 14=15 (bottom) and the remains of wall SU 531 (top) of MBC 1-2 (photograph: OeAW-OeAI/M. Börner).

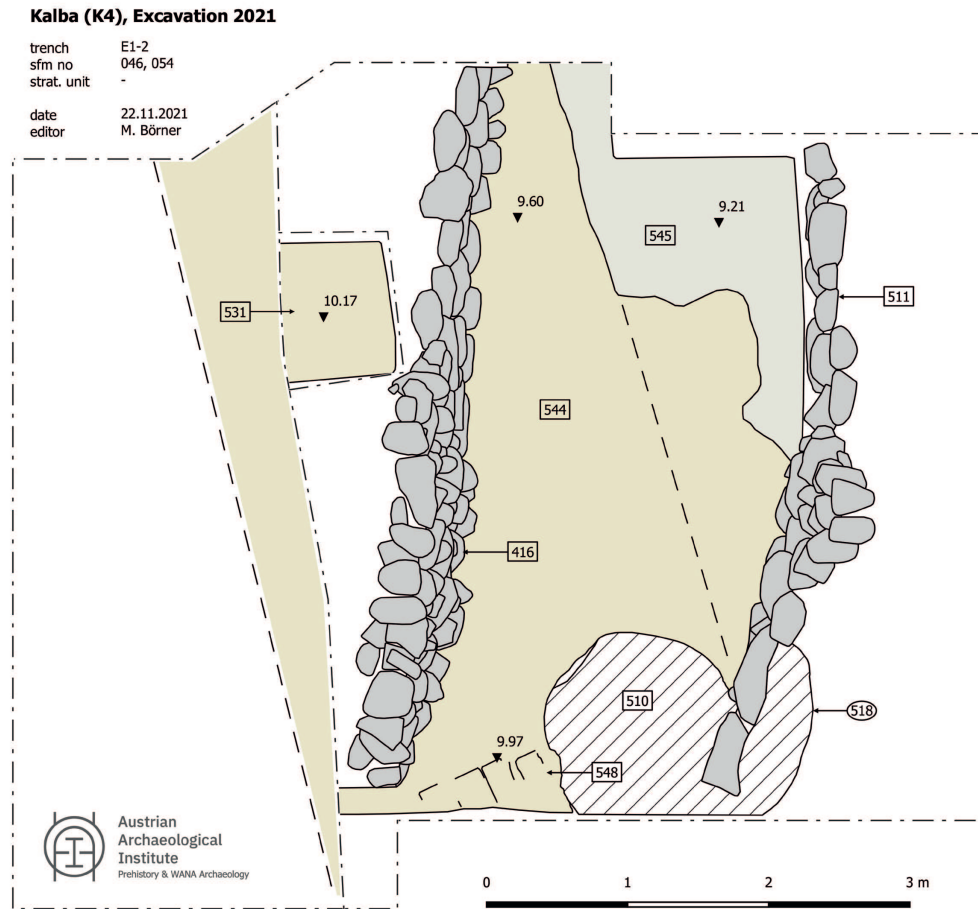


FIGURE 5. Remains of the MBC 1 in trenches E1-2 (plan: OeAW-OeAI/M. Börner).

(see Fig. 8/b: 55243, 55248). Fireplace 11 was situated on an occupation level (Fig. 3: SU 519, 525) attested in the western profile between trenches E1 and E2 (Fig. 4). Additionally, the pit of another fireplace (no. 13; SU 534), radiocarbon-dated to the Late Bronze Age (see Fig. 8/b: 55251), was cut during the construction process of the Iron Age I fortification underneath the north-eastern part of the exterior retaining wall.

Bronze Age mud-brick architecture

Below the Iron Age I fortification and the partially preserved fireplaces of the Late and Middle Bronze Age period, wall structures of two different architectural phases (Mud-brick Complex 1 & 2; see Figs 3 & 4) were detected:

Mud-brick Complex 1 (MBC 1)

Architecture of the first building level was attested underneath levelling layers containing various materials (SU 533, 537–538). Particularly noteworthy is a thick and extended layer mainly consisting of sandy material with pebbles (SU 533), covering an eastward-sloping accumulation of melted mud brick with debris (Fig. 5: SU 544=548; 546) lying on a surface level (Fig. 5: SU 545) in the area underneath the Iron Age I ditch. Radiocarbon dates obtained from material inside the extended levelling layer (SU 533) provide a chronological position in the Middle Bronze Age (see Fig. 8/b: 55250). The mud-brick debris situated below belongs to a mud-brick wall, aligned approximately north-west–south-east (Figs 3–5: SU 531/MBC 1) and partially detected in the trench and

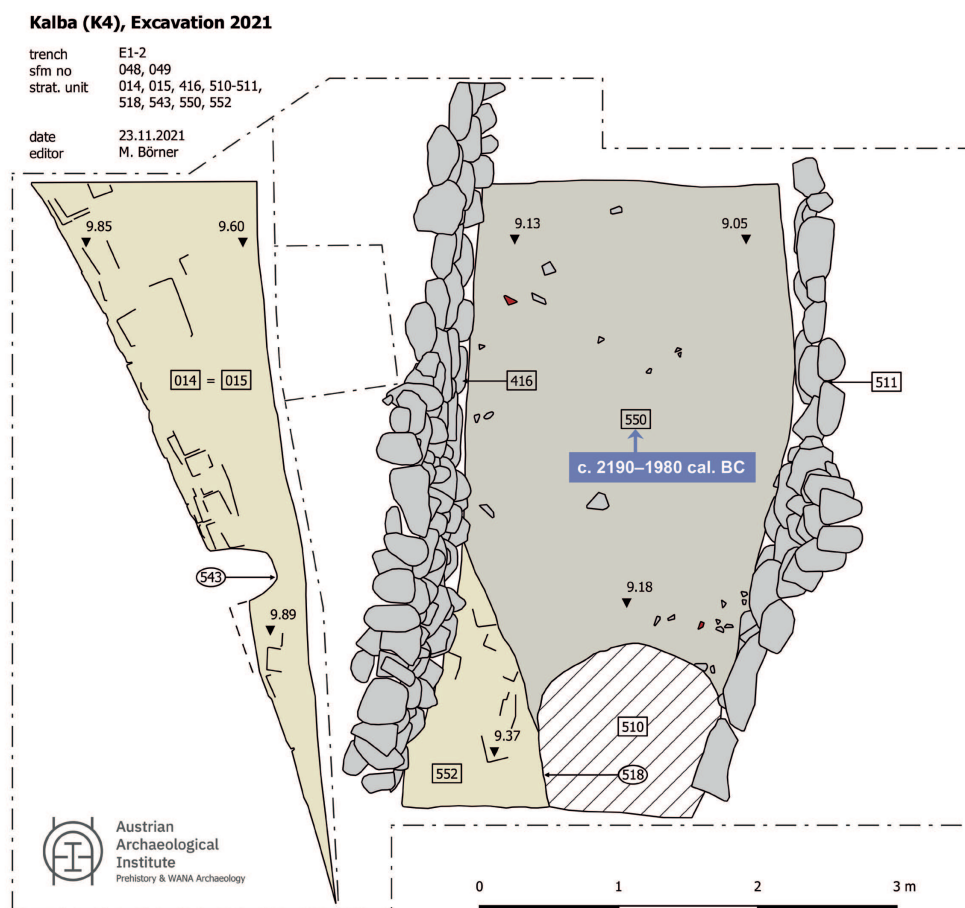


FIGURE 6. Remains of the MBC 2 in trenches E1-2 (plan: OeAW-OeAI/M. Börner).

the western profile between trenches E1 and E2. In the southern area below the Iron Age I ditch, the wall was destroyed by a deep disturbance (Fig. 5: SU 510; SU 518). The remains of the mud-brick wall were preserved up to five courses high, as can be observed in the eastern profile (SU 546). The western profile shows that the north-west-south-east aligned wall was constructed directly onto a levelling layer (Fig. 3: SU 3=530), whereas the remains underneath the Iron Age I ditch were situated on a surface level (Fig. 5: SU 545) with an underlying floor foundation consisting of a stone-clay layer (SU 547). Based on the boundaries of the mud-brick remains in the profiles as well as on the surface level, an assumed width of c.3 m can be reconstructed for the wall. Charcoal from the floor foundation mentioned above provides an Early Bronze Age date (see Fig. 8/b: 55253), which suggests that either MBC 1 can be dated

to the Umm an-Nar period or older material was used for the construction of a floor level in the Middle Bronze Age period.

Mud-brick Complex 2 (MBC 2)

Inside the area underneath the Iron Age I ditch, a slightly eastward-sloping accumulation of melted mud-brick debris (Fig. 6: SU 552) was again attested underneath levelling layers (SU 549, 551) on a surface level (Fig. 6: SU 550). The debris belongs to a mud-brick wall aligned approximately north-west-south-east (Figs 3, 4, & 6: SU 14=15), which was detected in the western profile between trenches E1 and E2 (see Schwall & Jasim 2020: 327; Schwall, Börner & Meyer 2021: 34, 39, fig. 7). The bricks of the western face of the mud-brick wall were preserved up to six courses in height from the surface



FIGURE 7. Possible section of stone wall of the exterior EBA retaining wall detected underneath the MBC 1–2 and the Iron Age I fortification (photograph: OeAW-OeAI/M. Börner).

level (Fig. 3: SU 16). The eastern part of the wall tilts steeply in the direction of the profile that covers the eastern wall face. Inside the wall an roughly semi-circular carved-out interface (Fig. 4 & 6: SU 543) with a diameter of c.40 cm was identified. This negative interface probably belongs to an integrated post supporting the mud-brick wall. The wall can be reconstructed to a minimum width of 1.8 m, based on the boundaries of the detected

structures inside the area underneath the Iron Age I ditch. A radiocarbon date recovered from the surface level (Fig. 6: SU 550) attests to a construction of the wall in the Umm an-Nar period (see Fig. 8/b: 55255).

The wall of MBC 1 can be reconstructed up to c.3 m in width. Additionally, the wall of MBC 2 and its debris indicate a minimum width of 1.8 m. Even though the exact width cannot be determined it is striking that in this area, the walls of three architectural phases (IA I fortification, MBC 1–2; see Fig. 3: SU 416, 531, 14=15), following almost the same direction, are situated above one another. Furthermore, the associated surface levels of both mud-brick complexes do not provide evidence of any domestic features. We therefore tentatively designate the walls of MBC 1 and 2 as sections of enclosure walls.

Possible context of a stone structure underneath the mud-brick complexes

The structures situated below MBC 2, underneath the interior Iron Age I retaining wall, were covered by a levelling layer in the east (SU 553) which was also dated to the Early Bronze Age period (see Fig. 8/b: 55256). In the west, this levelling layer was also detected (Fig. 3: SU 17), covering an occupation level with fireplaces and part of a mud-brick wall excavated in the 2020 season (henceforth MBC 3; see Schwall et al. 2022: 336, fig. 6; Schwall, Börner & Brandl, in press: fig. 6). This horizon can be connected with the occupation level SU 71 excavated in the southern profile (see Schwall et al. 2022: 332, fig. 3; Schwall, Börner & Brandl, in press) and represents the first occupation level after the ditch was filled in front of the interior Early Bronze Age retaining wall. The fireplaces provide radiocarbon dates between c.2280 and 2035 cal. BC (see Schwall et al. 2022: 338, fig. 7/a: 46248, 46254).

Interestingly, inside the former Iron Age I ditch area, no further surface or occupation level has so far been detected below MBC 2. However, a section of a stone structure (SU 555) was uncovered in the south-western corner of the trench below MBC 2 (Fig. 7). The stone structure could either be associated with the steeply eastwards-tilting wall of MBC 2 or represent the preserved top of the exterior Early Bronze Age retaining wall, based on the stone sizes as well as the direction of this structure. Further excavations are necessary to clarify this assumption.

Archaeobotanical remains

Eleven new samples, dating between the Early Bronze Age and Iron Age I, were investigated for their archaeobotanical contents (Fig. 8/a). The samples were hand-picked from selected contexts (see Figs 2, 3 & 6 for the location of the SU and the radiocarbon dates). Charcoals as well as seeds were present. As previous results have shown, the new charcoal remains were dominated by Rhizophoreae, a mangrove clade (see Schwall et al. 2022: 337–340, fig. 7/a). They could not be identified more precisely as Rhizophoreae are not included in the wood identification literature for this wider region (see Jagiella & Kürschner 1987) and moreover are no longer present in this region. They have only recently been reintroduced (Moore, Grizzle & Ward 2013), while *Avicennia marina* is the mangrove species that dominates this region today.

Avicennia charcoal was identified in only one of the new samples, possibly dating to Early/Middle Bronze Age layers. As in previous results from the site, Rhizophoreae appear to have dominated in the past — up until the Late Bronze Age — unlike today (see discussion in Schwall et al. 2022 on the causes for this). A new woody taxon that was not identified previously at the site is *Acacia* sp., which is now quite common in the region. It was present with only one fragment in one Umm an-Nar period sample so far. The mangrove vegetation most likely formed the densest source of wood in the surroundings of the site.

Three fragments of *Phoenix* petiole, dating to Iron Age I, were also newly identified. Date stones were found in the new samples from the Middle Bronze Age onwards. In our previous study it was shown to have been present earlier at Kalba, from the Umm

an-Nar period (see Schwall et al. 2022: 337, fig. 7/a). Date palm was possibly cultivated, as in other areas of the extended cultural complex (e.g. Tengberg 2012; Deckers, Döpper & Schmidt 2019). Two of several cereal fragments date to the Umm an-Nar period, while more clearly identifiable remains date later: *Hordeum vulgare* cf. ssp. *distichum* was found in Middle and Late Bronze Age contexts; while *Triticum aestivum/durum* was found in a sample dating to the Middle Bronze Age, and four unidentifiable Cerealia belong to the Late Bronze Age. The presence of cereals from the Umm an-Nar period onwards fits with the widespread, though not abundant, emergence of agriculture in this region (see e.g. Méry & Tengberg 2009; Tengberg 2012). With present-day average annual rainfall values of c.100 mm, dry farming of cereals is unlikely. While climatic conditions were somewhat wetter during the Bronze Age than they are today (Fleitmann et al. 2007), it is fairly unlikely that conditions were sufficiently favourable for agriculture without irrigation. Apart from a well detected during excavations and dated to the post-Early Bronze Age (see Schwall et al. 2022: 331, 333, fig. 4: SU 42; Schwall, Börner & Brandl, in press; fig. 4; plan 1), so far no evidence of irrigation systems has been found during excavations in the inner part of the settlement mound. Irrigation channels for agricultural use would be expected in the vicinity of the site. However, charcoal found during excavations points to an extended use of the mangroves, which must have been located nearby. In particular, the dominance of the mangrove clade Rhizophoreae suggests that other fresh water must have been accessible in the surroundings of the site at least up until the Late Bronze Age.

Radiocarbon dating and the marine reservoir effect

Thirteen samples of charcoal and marine shell deriving from Early Bronze Age to Iron Age I layers were taken for radiocarbon dating. Charcoal and shells found together in the same layer were used to determine the marine reservoir effect of the respective shells, as described in a previous publication (see Schwall et al. 2022: 340–341). The marine reservoir effect is species-specific as it depends on the habitat and diet of the species of interest. Being a function of the carbon available in seawater, it can also vary over time,

Context	Cultural period	¹⁴ C [2σ cal. BC]	Phoenix petiole	Date stones	Rhizophoreae	Avicennia	Acacia	indet. Dicot	Hordeum cf. distichum	Triticum aestivum/ durum	cf. Cerealia
Post-EBA ditch layers											
MBC 2											
KAL21/553/12/1	Umm an-Nar	2282–2038			1						
KAL21/550/12/1		2192–1980			10		1				<0.5
EBA/MBA layers?											
MBC 1											
KAL21/547/12/4	Umm an-Nar/ Wadi Suq?				2	1		11			
MBA layers											
Fireplace 11											
KAL21/519/12/1	Wadi Suq	1867–1631		1.5					2	2	
Fireplace 12											
KAL21/532/12/1	Wadi Suq	1864–1630		1							
Levelling layer											
KAL21/533/12/1	Wadi Suq	1741–1569			34						
LBA layer											
Fireplace 13											
KAL21/534/12/1	Late Bronze Age	1508–1437		0.5	11				4		3
IA I layers											
Ditch construction and occupation level											
KAL21/528/12/1	Iron Age I	1278–1116	3								
KAL21/521/12/1		1223–1055		<0.3							

FIGURE 8a. Archaeobotanical results of Kalba K4 samples (for ¹⁴C dates see Fig. 8/b; table: University of Tübingen/ K. Deckers, S. Riehl).

depending on the intensity of upwelling of ‘old’ water (¹⁴C-depleted deep seawater), changing sea levels, or ocean circulation. Determining the reservoir effects for each layer separately thus allows the detection of minor changes in the parameters of the oceanic environment. The sample preparation of charcoal and shell samples is described in Lindauer et al. 2017. It must be noted, however, that the shell and charcoal samples used here were each taken from a single context. The statistics are improved with more charcoal and shell samples from each layer, but the results are still useful for supporting environmental data. The measurements were carried

out on a MICADAS-type accelerator mass spectrometer (Kromer et al. 2013) and calibrated using Oxcal 4.4. (Bronk Ramsey 1995) with the IntCal20 dataset (Reimer et al. 2020). The reservoir effect was modelled in Oxcal as described in Lindauer et al. (2017).

Apart from one radiocarbon date (Fig. 8/b: 55254), which is much older than expected, all charcoal and date-stone samples provide ages in the expected calendar age range between the Early Bronze Age and Iron Age I. The single date gained from an undetermined species ranges between 20542 and 20328 cal. BC, is rather difficult to interpret, and might need further attention.

Lab. no. [MAMS]	Sample no.	$\delta^{13}\text{C}$ [‰]	^{14}C age [BP]	Probability 68% [BC]	Probability 95% [BC]	ΔR [yrs]	Material
55243	KAL21/519/11/1	-21.2	3420 ± 18	1746–1687	1867–1631		date stone (<i>Phoenix dactylifera</i>)
55244	KAL21/519/11/2	-23.5	3408 ± 23	1742–1640	1862–1623		barley (<i>Hordeum</i> cf. <i>distichum</i>)
55245	KAL21/521/11/1	-17.7	2947 ± 18	1202–1124	1223–1055		date stone (<i>Phoenix dactylifera</i>)
55246	KAL21/521/11/2-T1	0.0	3600 ± 22	1248–1118	1341–1056	128 ± 55	mollusc (<i>Terebralia palustris</i>)
55247	KAL21/528/11/1	-20.9	2974 ± 23	1257–1128	1278–1116		charcoal (palm tree) (<i>Phoenix petiole</i>)
55248	KAL21/532/11/1	-22.2	3417 ± 18	1745–1645	1864–1630		date stone (<i>Phoenix dactylifera</i>)
55249	KAL21/532/11/2-T1	-1.2	3670 ± 25	1722–1617	1767–1541	-132 ± 50	mollusc (<i>Terebralia palustris</i>)
55250	KAL21/533/11/1	-24.7	3372 ± 19	1687–1623	1741–1569		charcoal (mangrove) (Rhizophoreae)
55251	KAL21/534/11/1	-19.3	3214 ± 18	1503–1451	1508–1437		date stone (<i>Phoenix dactylifera</i>)
55252	KAL21/534/11/2-A1	2.9	3740 ± 24	1507–1407	1582–1335	67 ± 72	mollusc (<i>Anadara uropigimelana</i>)
55253	KAL21/547/11/1	-29.2	3755 ± 24	2267–2136	2282–2041		charcoal (mangrove) (Rhizophoreae)
55254	KAL21/549/11/1	-27.6	18464 ± 58	20489–20383	20542–20328		undetermined
55255	KAL21/550/11/1	-19.6	3689 ± 24	2135–2032	2192–1980		cereal (cf. <i>Cerealia</i>)
55256	KAL21/553/11/1	-24.7	3750 ± 26	2203–2064	2282–2038		charcoal (mangrove) (Rhizophoreae)

FIGURE 8b. Radiocarbon dates from Kalba K4 (n=14). 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).

It could also be the result of relocation, bioturbation, or building practices. Even though we cannot fully interpret the data, we wish to present it for future research and to complete the investigation.

With respect to the reservoir effects, the data for the *Terebralia palustris* shell show a major change within a few centuries. Care must be taken when interpreting these data as each of the respective pairs consists of only one charcoal and one shell fragment. A relocation of one of the shells or charcoals can therefore not be excluded

even if at first sight, the sediment does not show signs of bioturbation, etc. If taken as correct, the change in the reservoir effect can contribute to the interpretation of environmental conditions. In this case, it might be interpreted as a significant change in the amount of upwelling, which would point to a shift either in the wind system, moving the upwelled waters towards Kalba, or in ocean circulation with an increased amount of upwelling between 1864 and 1630 cal. BC (Fig. 8/b: 55249) and 1341 and 1056 cal. BC (Fig. 8/b: 55246). The latter

would contradict the data on upwelling gained from foraminifera in sea sediments (Staubwasser et al. 2002), which point to a constant decline of upwelling from the mid-Holocene to at least the Iron Age period. In addition, changes in rainfall can contribute to changes in the reservoir effect ΔR . Here, a reduction in rainfall would lead to less freshwater input to the estuarine system at Kalba which, depending on the amount of limestone dissolved in fresh water during transport, could lead not only to a reduction in the reservoir effect but also to an increase, if no limestone is transported by fresh water. The reservoir effect for *Anadara* sp. lies between the two *Terebralia palustris* data. It should be noted that the reservoir effect of *Anadara* sp. is usually higher than for *Terebralia palustris* as *Terebralia* sp. has a diet mainly consisting of mangrove leaves, which leads to a mixed atmospheric and marine ^{14}C signal, whereas *Anadara* sp. is a filter feeder resulting in purely marine and therefore older ^{14}C data than contemporaneous *Terebralia* shells (Lindauer et al. 2017). To account for a reliable interpretation of the data, a larger dataset per layer would be advantageous.

In general, the new radiocarbon data confirms previous finds. In combination with all data so far determined at Kalba (Lindauer et al. 2017) and with finds from botanical studies, we can interpret more humid conditions during the early to mid-Holocene, followed by changing climatic conditions towards a more arid environment starting in the Bronze Age until at least Iron Age I. This is also supported, for example, by stalagmite evidence from Hoti cave (northern Oman) where the stalagmites stopped growing during this period, whereas in Qunf cave in the south of Oman they continued to grow during this phase (Fleitsmann et al. 2007; Fleitsmann & Matter 2009).

Lithic raw material studies

Besides copper, chert, and jasper the initiated lithic raw material studies (see Schwall et al. 2022: 341–344) were continued and extended, based on newly discovered artefacts made of chalcedony, volcanic tuff, and soft stone.

Two fragments of a rectangular bead (Fig. 9/a) and a pendant (Fig. 9/b) with a lenticular section and perforated longitudinally and transversally (Schwall, Börner & Brandl 2022: 65, fig. 5) were discovered in a levelling layer (SU 538), dating mainly to the Wadi Suq period

(see Fig. 8/b: 55250). The bead is made of chalcedony and the decorated pendant most likely of heavily weathered volcanic tuff, materials which were also included in our geo-archaeological survey (see below).

Of special interest is a fragment of a semi-finished stone vessel (Fig. 9/c; see Schwall, Börner & Brandl 2022: 66, fig. 8) found in a levelling layer (SU 528) of the Iron Age I period (see Fig. 8/b: 55247). Petrological and mineralogical analyses reveal that chlorite schist was used for its production. The fragment supports the hypothesis of on-site production as briefly mentioned by D. Eddisford and C. Phillips (Eddisford & Phillips 2009: 109; Phillips & Simpson 2018: 50–51, fig. 72) and other than metallurgy, attest to the manufacture of specialized craft products in Kalba.

Geo-archaeological field survey

During the 2021 field campaign the geo-archaeological survey initiated in 2020 (see Schwall et al. 2022: 341–345) was continued, based on various artefacts made of different lithotypes found during excavations at Kalba. The survey focused on the accessibility and use of local and regional lithic raw material sources in the catchment area of Kalba to estimate the raw material procurement strategies of a diachronic, settled prehistoric coastal site in the Gulf of Oman. Based on already published data and available geological maps, possibly suitable formations and outcrops were visited and sampled in a GPS-supported field survey. A sufficient number of geological samples for petrographic and geochemical analyses (i.e. a minimum of twenty individual specimens for siliceous rocks and up to ten for other lithotypes) were collected. The goal of this undertaking was the assessment of the raw material variability as a potential economic factor for the site of Kalba. Apart from chert and copper ore, the 2021 survey concentrated on siliceous rock sources related to materials for which we have archaeological evidence at Kalba (Fig. 10).

Chert

The documentation of chert sources used for chipped stone production was continued in order to build up a comprehensive reference database suitable for in-depth provenance analyses in the working area. Data from the newly recorded chert sources will complete the already

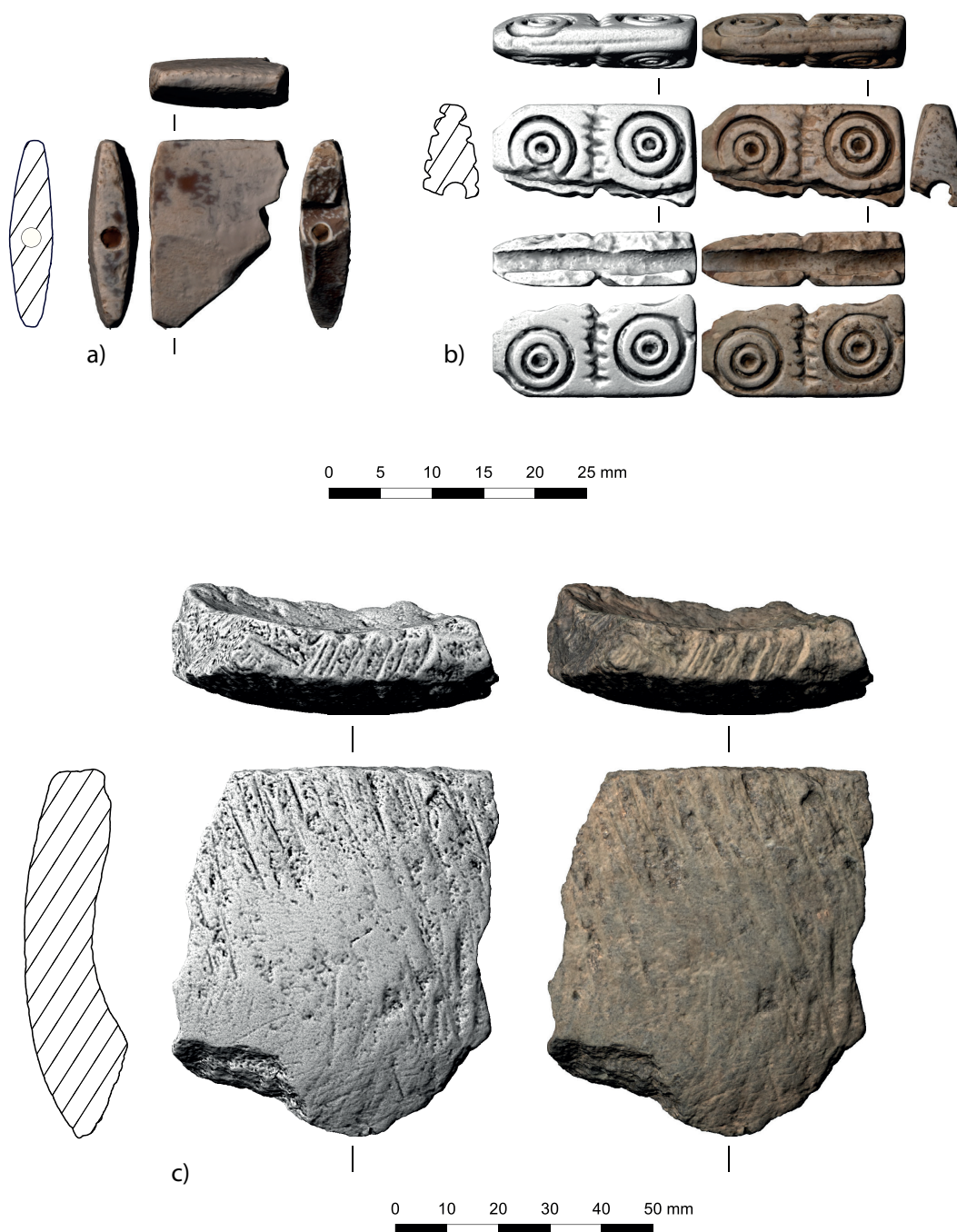


FIGURE 9. 3D models: **a.** a stone bead (KAL21/538/3/1); **b.** a stone pendant (KAL21/538/3/2); and **c.** a semi-finished soft-stone vessel fragment (KAL21/528/3/1). The 3D models were generated with ‘Structure from Motion’ (SfM) technique using Agisoft Metashape. The obtained models were post-processed using GigaMesh (<https://gigamesh.eu>) for calculation of the curvature using the integrated filter MSII and the production of scaled 2D views (documentation/processing/illustration: LEIZA/A. Cramer). This illustration is licensed under CC BY-SA 4.0 (<https://creativecommons.org/licenses/by-sa/4.0/>). The corresponding datasets (3D models and scaled 2D views) are published at <https://doi.org/10.5281/zenodo.7257831>.

established 2020 database. The collected chert samples will be analysed microscopically and geochemically, in order to integrate the results into the database for a refined characterization of locally and regionally available chert raw materials utilized for chipped stone technology at Kalba and the wider catchment area.

Jasper

Jasper occurs in the east of the Buhais mountain range; it displays excellent knapping qualities as reported by M. Uerpmann and colleagues (Uerpmann, Uerpmann & Händel 2008). Since a jasper artefact was also discovered at Kalba, we investigated sources of this material. Several locations situated along ophiolitic faults running from north to south in the west of the coastal mountain ranges were successfully sampled and will provide geochemical information about the variability and potential to differentiate specific outcrops of these visually indistinguishable materials, which were — in addition to chert — widely utilized for chipped stone production during prehistory in the entire region.

Chalcedony, agate, and carnelian

In light of the recent discovery of a stone bead made from chalcedony and a pendant produced from a weathered and compacted former volcanic tuff, which was altered to a clay-rich material, the third aim of the Kalba excavations was the investigation of potential local sources of these kinds of lithic materials. Bound to igneous rocks in the north of the investigation area, inland to the west of Khorfakkan, chalcedony and various multi-coloured cryptocrystalline quartz modifications, such as agate and carnelian along with a wide range of volcanic materials such as tuffs, can be found, as partially reported (see Charpentier et al. 2017). The survey produced a high diversity of materials potentially suitable for stone bead production in this area, and we concentrated on sampling materials macroscopically corresponding to the finds at Kalba. Geochemical analyses of the Kalba stone bead and pendant, applying strictly non-destructive methods, are currently ongoing with the aim of comparing the results to those from the sampled raw materials, testing the hypothesis of bead production using local stone resources.

Overall, the results of our 2021 raw material survey hold the potential to answer questions of local supply and production at Kalba and the wider region, as well as creating a research tool useful for researchers working on stone materials in the north of the south-eastern Arabian Peninsula. Eventually, it is planned to make the petrographic and geochemical data available for the larger research community in an open-access format.

Conclusion

The fieldwork in 2021 at Kalba (K4) produced important results regarding the site's occupation from the third to the first millennium BC in the area outside the Early Bronze Age ditch. Besides the Iron Age I fortification, occupation and surface layers, including the two Mud-brick Complexes (MBC 1 & 2), were excavated. The excavated levels have thus provided us with new insights into the subsequent use of the former Early Bronze Age ditch area and allow us to connect the stratigraphy of the eastern and southern parts of trench E1. Although we have only excavated a small part of the site so far, it is already clear that during the Umm an-Nar period large-scale transformations of the site's inner spatial outline — the construction of a ditch as well as at least one massive mud-brick wall — can be recorded within c.300 years, between 2300 and 2000 cal. BC.

The question arises whether demographic, ecological, or economic factors are responsible for such construction processes in the late Umm an-Nar period and the diachronic occupational development of the site in general. To approach such investigations, a reconstruction of the natural environmental conditions is crucial. For Kalba studies of the botanical remains, as well as the determination of the marine reservoir effect based on radiocarbon data, provide vital results.

As in previous archaeobotanical results from the site, there was a dominance of Rhizophoraceae mangrove vegetation. There is now also evidence for it in the Late Bronze Age. Cereals were found, probably as early as the Umm an-Nar period. They are in line with the emergence of agriculture at several other sites in the region, notwithstanding overall meagre amounts of remains per site. The date stones and date petiole may also indicate palm-tree cultivation.

Investigations on the shell material, if taken as representative, point to changing environmental

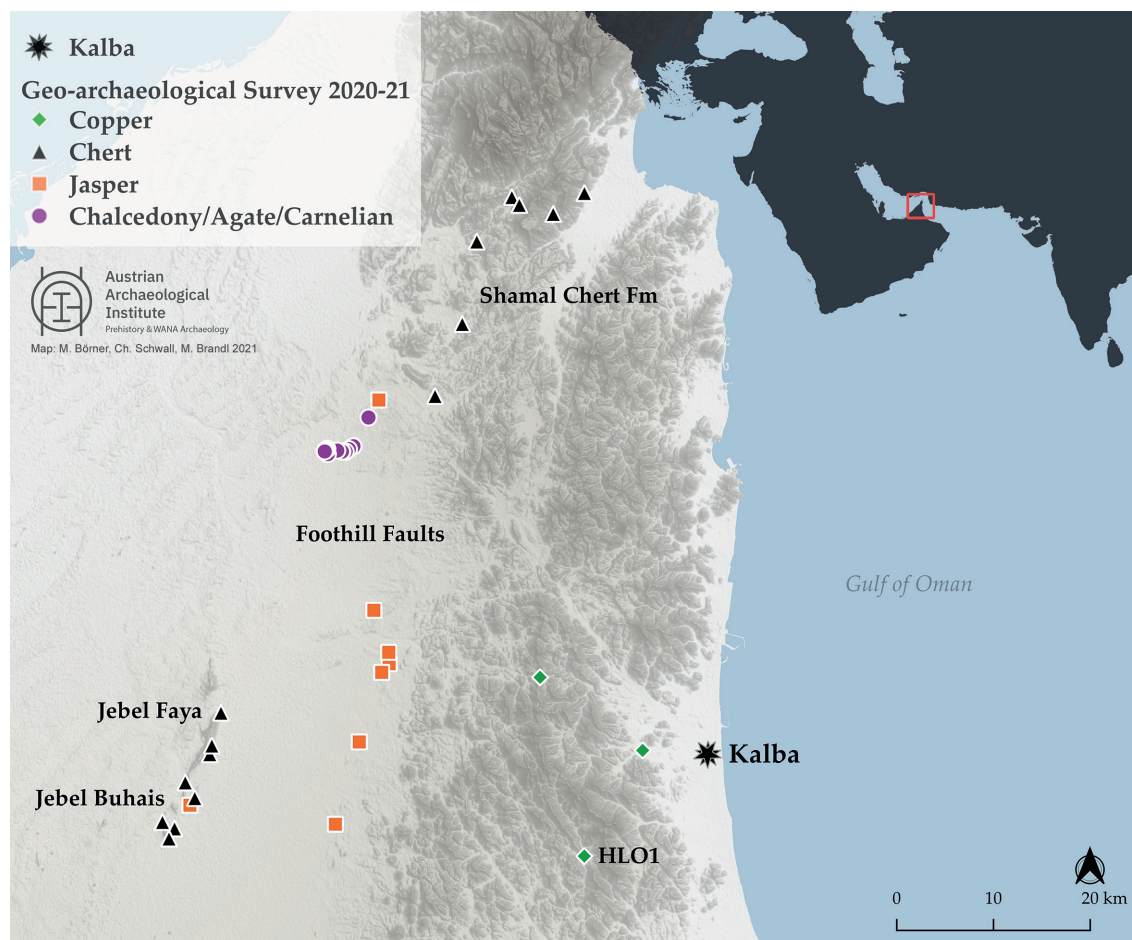


FIGURE 10. A map showing the location of raw material sources sampled during the geo-archaeological surveys 2020–2021 (map: OeAW-OeAI/Ch. Schwall, M. Börner).

conditions. As the estuarine environment is rather complex and lacking reliable statistics, the shell data alone does not allow for an interpretation towards a wetter or a more arid climate. However, in combination with other environmental proxies, we can confirm a more constant climate until the Bronze Age when an environmental change seems to have taken place, lasting until at least the Iron Age I period. This interpretation is so far preliminary as we aim to obtain more data in this context, in order to make an improved link between this microclimate data and the wider context.

Apart from ecological factors, the importance of economic motives, especially the accessible lithic raw material resources, is currently being investigated in detail. Potential candidates under the spotlight

are chert objects, a stone bead, and a stone pendant recovered during excavations, which will help to assess procurement strategies and the significance of lithic raw materials for the prehistoric coastal communities at Kalba. To this end, the systematic geo-archaeological raw material survey was continued and expanded from the Jebel Buhais and Jebel Faya ranges to the north of the Emirates, to broaden the picture of siliceous rock resources suitable for the production of stone objects and tools. In total forty-two different sources of chert, jasper, chalcedony, agate, and carnelian were recorded (Fig. 10).

In this respect, the incised pendant fragment could be of particular interest (see Fig. 9/b). A comparable object with incised decoration of lines and circle

motifs with a central dot was found at Tell Abraq, although its context is unclear (see Potts 2000: front cover). The comparable syntax of the incisions clearly indicates similar motif traditions in the north of the south-eastern Arabian Peninsula. Furthermore, based on the stratigraphic evidence, the object found at Kalba suggests a dating to the Middle Bronze Age. The chronological position is also supported by stylistic evidence. The choice of motifs as well as the syntax resemble the well-known morphology of seals from the Dilmun period (see Crawford 2001: 16–17). Additionally, a seal impression found at Saar (Bahrain; Crawford 2001: 106, K17:76:03) shows an arrangement of incisions comparable with the object from Tell Abraq. Based on similarly shaped objects, such as the pendant found at Bani Bu Hasan in Oman (Frenez et al. 2020: 11, fig. 5), the — presumably — locally produced pendants from Kalba and Tell Abraq show the wide distribution and adoption of motives in the Gulf region and on the south-eastern Arabian Peninsula. This clearly indicates a high degree of connectivity, adoption of motives, and intensification of communication and exchange.

As a preliminary interpretation of our studies, during the final 300 years of the Early Bronze Age the site witnessed major construction and reconstruction events. These are most likely related to ecological and economic diversification and intensification attributed to the ecological niche position, resulting possibly in the aggregation of a large number of people and consequently economic prosperity. Through this combination, Kalba appears to have developed into an important node for the entire region already established during the Early Bronze Age.

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Authors' addresses

Christoph Schwall, Leibniz-Zentrum für Archäologie (LEIZA), Ludwig-Lindenschmit-Forum 1, 55116 Mainz, Germany.
e-mail christoph.schwall@leiza.de

Michael Brandl, Department of Prehistory & Western Asian/Northeast African Archaeology, Austrian Archaeological Institute (OeAI), Austrian Academy of Sciences (AAS), Hollandstrasse 11–13, A-1020 Vienna, Austria.
e-mail michael.brandl@oeaw.ac.at

Mario Börner, Austrian Archaeological Institute (OeAI), Austrian Academy of Sciences (AAS), Hollandstrasse 11–13, A-1020 Vienna, Austria.
e-mail mario.boerner@oeaw.ac.at

Susanne Lindauer, Curt-Engelhorn-Centre Archaeometry gGmbH, D6, 3, D-68159 Mannheim, Germany.
e-mail susanne.lindauer@ceza.de

Katleen Deckers, Institute for Archaeological Sciences, University of Tübingen, Hölderlinstraße 12, 72072 Tübingen, Germany.
e-mail katleen.deckers@uni-tuebingen.de

Simone Riehl, Senckenberg Centre for Human Evolution and Palaeoenvironment (SHEP) and Institute for Archaeological Sciences, University of Tübingen, Hölderlinstraße 12, 72072 Tübingen, Germany.
e-mail simone.riehl@uni-tuebingen.de

Anja Cramer, Leibniz-Zentrum für Archäologie (LEIZA), Lindenschmit-Forum 1, 55116 Mainz, Germany.
e-mail anja.cramer@leiza.de

Christoph Hauzenberger, Institute of Earth Sciences, NAWI Graz Geocenter, University of Graz, Universitätsplatz 2, 8010 Graz, Austria.
e-mail christoph.hauzenberger@uni-graz.at

Eisa Yousif, Sharjah Archaeology Authority, PO Box 5119, Sharjah, United Arab Emirates.
e-mail eisayousif@gmail.com

Sabah A. Jasim, Sharjah Archaeology Authority, PO Box 5119, Sharjah, United Arab Emirates.
e-mail sabah.jasim@gmail.com