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Contribution of GIS and digital archaeology to the interpretation of stratigraphic relations on the Bronze Age site al-Khidr, Failaka island, State of Kuwait¹

Imagery analyses of trenches 22S and 22T – case study

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Al-Khidr site on Failaka island, State of Kuwait, was excavated from 2004 till 2008 by the Kuwaiti – Slovak Archaeological Mission (fig. 1; for published results of research, including history of research and other details see Barta *et al.* 2007, 69–73; Barta *et al.* 2008, 121–134; Benediková/Barta 2009, 43–56; Benediková *et al.* 2008; Benediková *et al.* 2010a; Hajnalová/Miklíková/Belanová-Štolcová 2009, 197–202, some can be retrieved from <http://www.kuwaitarchaeology.org/publications.html>). The site is dated to the Bronze Age and culturally belongs to the Early and possibly also to the Middle (?) Dilmun period (Benediková/Barta 2010b, 320).

The stratigraphic analysis of the site based on the field observations was already presented (Benediková/Barta 2009, 47–54; Barta/Benediková/Ďuriš 2010, 32–37). The major occupation of the settlement took place during the Bronze Age (stratigraphic layers III and IV), later the site was occasionally used during the period between c. 50 to 400 AD (stratigraphic layer II) and during the Islamic Period (stratigraphic layer I; Ib for the Middle Islamic, Ia for the Late Islamic Period²; Benediková/Barta 2009, 54; Barta/Benediková/Ďuriš 2010, 36–37).

The Bronze Age development of the site was portrayed in the following stratigraphic layers: al-Khidr IIIa, IIIb is represented by the uppermost layer of architectural remains, i.e. by buildings on rectangular ground plans with recognizable rebuilding; al-Khidr IIIc or III/IV or IV³ was observed as shell deposits with bituminous and/or gypsum-like admixtures. This layer is related either to pre-building activities of the uppermost horizon, or to post-depositional processes after the earliest settlement ceased, or it can be seen as an independent stratigraphic layer reflecting different activity on the site; al-Khidr IV⁴ or V⁵ represents the lowermost layer of architectural remains with structures on oval or irregular layouts.

The Bronze Age occupation horizon was the subject of here presented digital imagery analyses⁶.

The paper presents the results of the stratigraphic analysis of the northern part of excavated KH-1 mound (trenches 22S and 22T; figs. 2–4) that represents c. one third of the exposed area on the site. The analysis is based on the GIS and digital archaeology approaches. Originally, starting the excavations, it was intended to develop a geodatabase of the sources exposed and retrieved from the site, i.e. the geodatabase of the discovered immovable and portable monuments that would enable the reconstruction of the settlement's development from the point of view of gradual deposition of the anthropogenic sediments (including *in situ* remains, portable objects, palaeoenvironmental material, and – in the ideal case – also C14 dates; Štolc/Bartík 2010, 275–283). After all the sources were in detail studied and analysed, the overall Harris matrix was supposed to be generated from inputted data and interpreted

¹ Manuscript prepared in 2011, revised in 2014.

² The layers were labelled from the top to the bottom, i.e. layer I lays on the top of the cultural sequence, layer IV at its bottom.

³ The labelling of this horizon might be rather confusing (without solving its relation to the uppermost or lowermost horizon, or conversely its independence from both). If it is related to the pre-building activities within al-Khidr III, it must be labelled as al-Khidr IIIc. If it represents the post-depositional processes after the lowermost settlement was abandoned, it should be called al-Khidr III/IV or al-Khidr post-IV. If it is an independent stratigraphic layer, i.e. an independent Bronze Age layer, it should be labelled as al-Khidr IV, below which is al-Khidr V (Benediková/Barta 2009, 55; Barta/Benediková/Ďuriš 2010, 37).

⁴ If the above layer is al-Khidr IIIc or III/IV (post-IV; Benediková/Barta 2009, 55; Barta/Benediková/Ďuriš 2010, 37).

⁵ If the above layer is al-Khidr IV (Benediková/Barta 2009, 55; Barta/Benediková/Ďuriš 2010, 37).

⁶ The paper was supposed to be published as a chapter in prepared revised edition (Benediková *et al.* 2011) of above quoted monograph (Benediková *et al.* 2010a), that was, unfortunately, not printed.

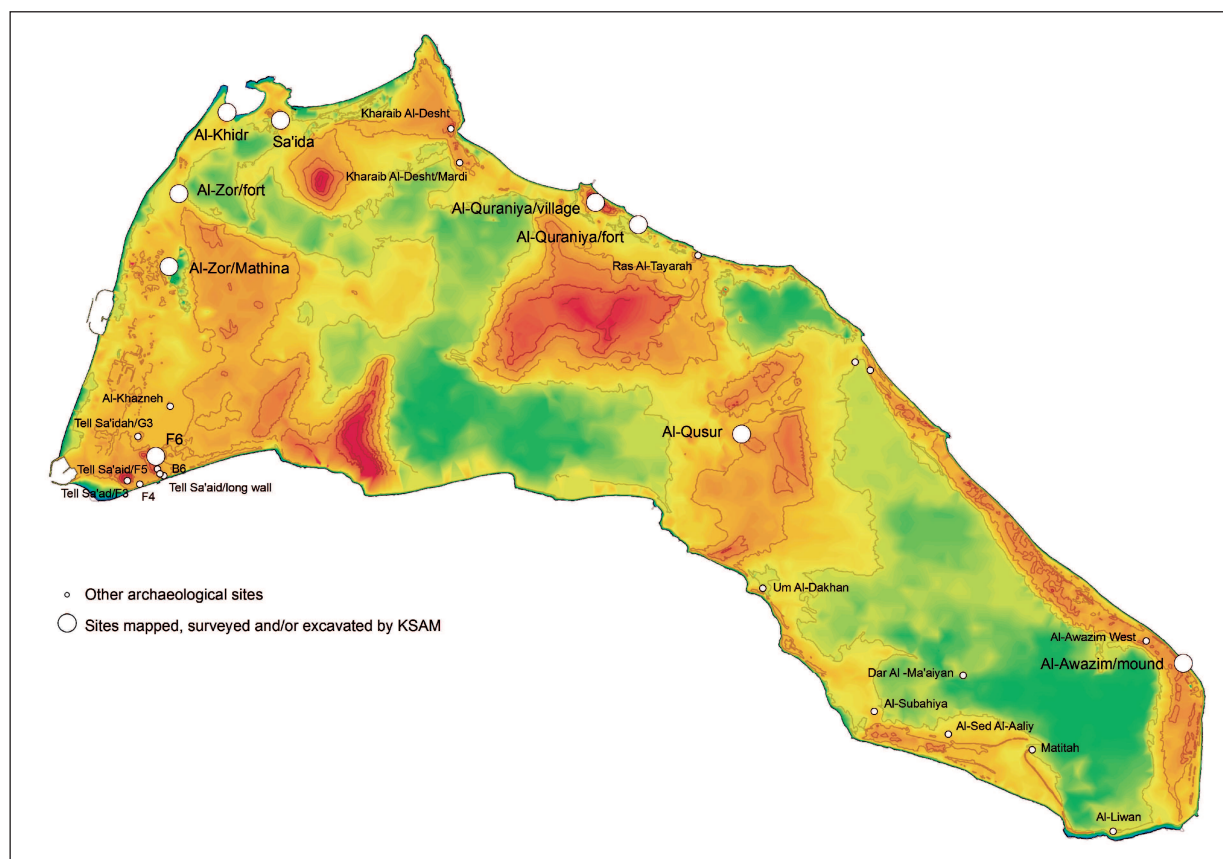


Fig. 1. Failaka island with known archaeological sites (picture: M. Bartík; after *Benediková/Barta 2010a*, fig. 3a).

afterwards. At the present stage of research, however, the Harris matrix have not yet been extracted, instead the basic imagery analysis of data with corresponding basic interpretation could have been done, as shown below. It has to be noted that the system of documentation of the site during the excavations and its interconnection with the geodatabase was designed so that it allows for checking and correcting possible errors occurred during the field works by the excavators or during the primary registration of the materials or during the digitalization of the sources, even after excavations were finished and without access to the *in situ* remains in field (*Barta/Benediková 2010*, 19–21; *Benediková et al. 2010b*, 21–28; *Benediková/Đuriš 2010*, 28–32).

As shown on fig. 6, the 5 cm stratigraphic slices were derived from 1:50 and 1:20 digitized plans of trenches 22S and 22T, which were drawn in field during the 2004–2008 seasons and digitized in 2009. All feature types, besides so called *collected units*⁷, are displayed in order of their occurrence in different stratigraphic slices. All the features shown in the particular slice were required to interfere (cut) with the elevation of the slice. Features discovered below or residing completely above the slice elevation are not visualized. For the sake of more complex view of feature details in individual slices, both 2D and 3D views have been provided for each slice. 2D views capture basic spatial collocation of the features observed at certain elevation. Furthermore, 3D views bring information on the thickness of individual features. Due to the limitations of ArcGIS 9.2 (a geodatabase processing software employed in this project), the upper and lower feature surfaces could be approximated only by flat planes. This property of the system may occasionally introduce minor ambiguities, when visualizing vertically tilted or folded features, which overlap both horizontally as well as vertically. In particular, in 3D views, such a configuration of features may falsely hide some parts of the overlapped features, which, however, can be correctly detected and interpreted by looking at associated 2D views.

⁷ *Collected unit* feature type defines an archaeological layer without a distinctive attribute, unlike e.g. shell layer, plaster layer, bitumen layer, etc.

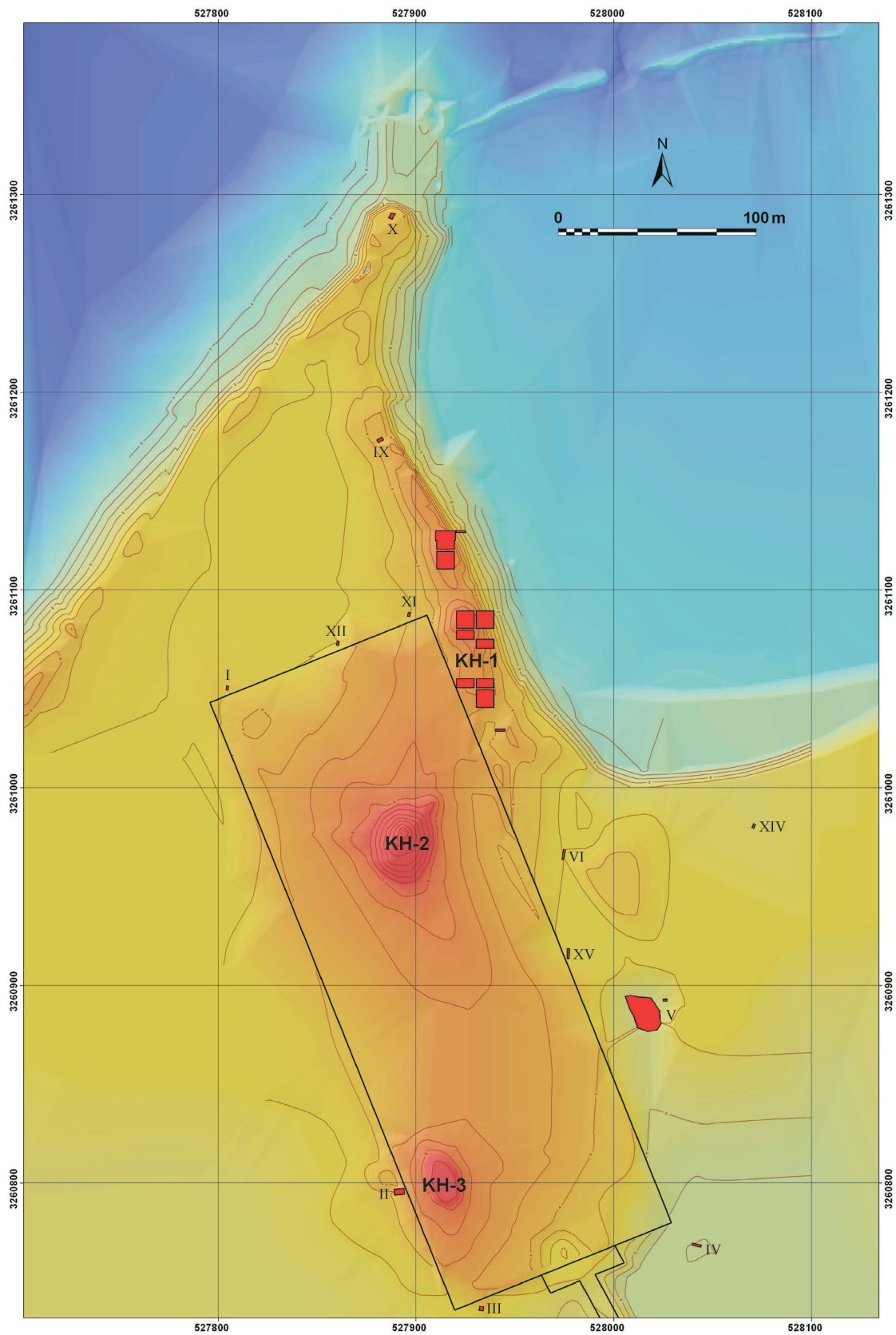


Fig. 2. Al-Khidr. 3D model of the site with marked excavated areas (red colour; Roman numerals label soundings I–XV excavated in 2004–2008; soundings VII and VIII were involved into 24AA trench; picture: M. Bartík/J. Al-Shemali/L. Benediková; after *Barta/Benediková 2010*, fig. 8).

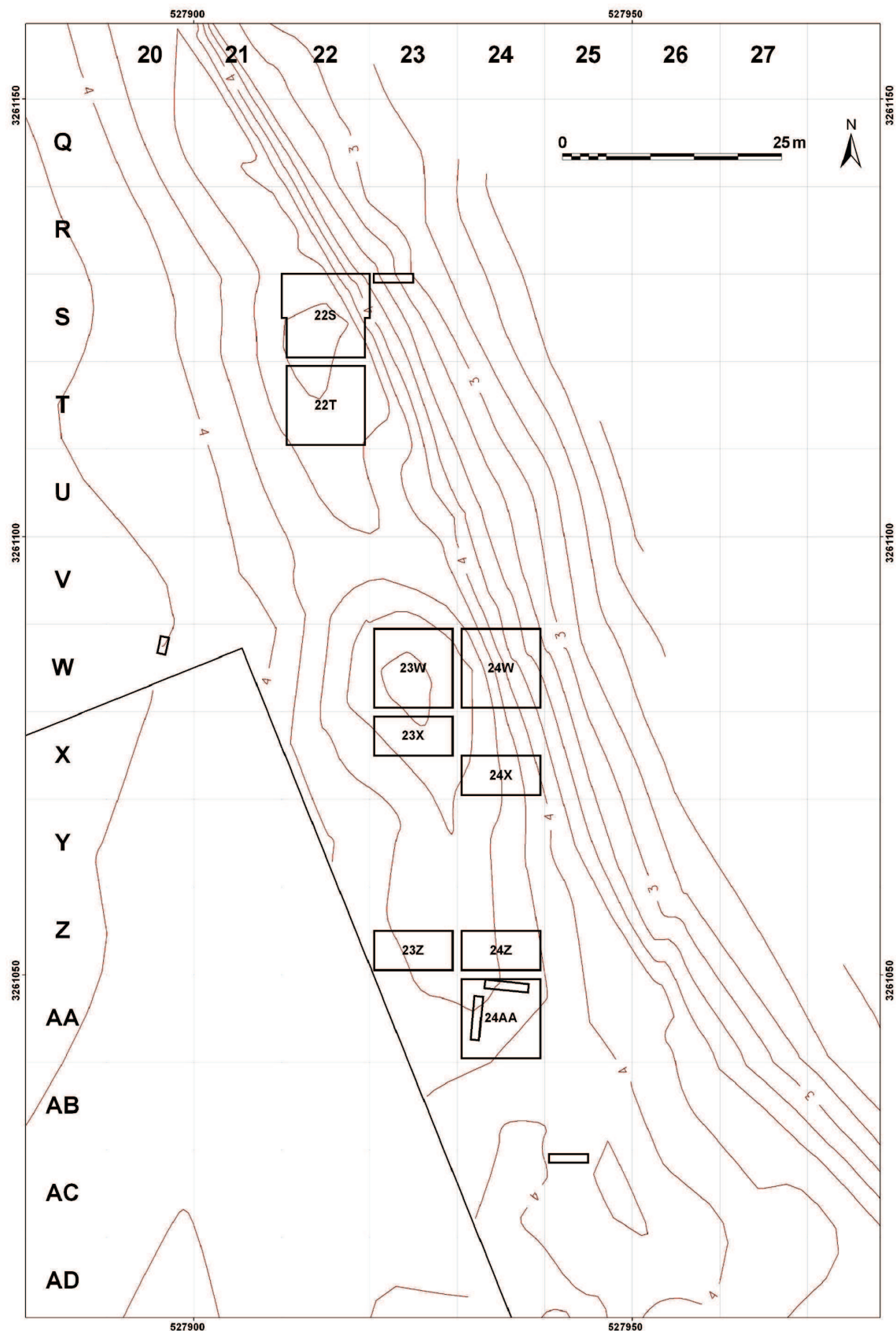


Fig. 3. Al-Khidr. Topographic plan of the mound KH-1 with labelled exposed trenches (picture: M. Bartík/J. Al-Shemali; after Barta/Benediková 2010, fig. 10).

The stratigraphic slices start at elevation 3.70 m a.s.l., what is the lowest point with discovered archaeological features (the soundings to the natural layers were excluded from this analysis; for general stratigraphy of the site including natural strata see *Benediková/Barta 2009, 47–54; Barta/Benediková/Ďuriš 2010, 32–37*). The topmost elevation for the slices is 5 m a.s.l. that is the topmost layer where the archaeological remains appear and that corresponds also with the topmost elevation of the top soil in this part of the site (note that some *in situ* remains were partially exposed on the surface; see *Benediková/Barta 2009, 47; Barta/Benediková/Ďuriš 2010, 34*).

Based on a thorough inspection of 5 cm stratigraphic slices (fig. 6), 5 generalised stratigraphic layers were defined based on the changes of occurring feature types throughout the whole stratigraphic sequence. For these slices, the relations of selected feature types of a key importance for the development of the Bronze Age settlement according to the field observations (see *Barta/Benediková/Ďuriš 2010, 32–37*) are shown in figs. 7–9. Moreover, in fig. 10, the distribution of small finds related to the stone walls and stone concentrations is displayed.

Similarly to the construction of 5 cm stratigraphic slices, also the generalized stratigraphic layers comprise only those features, which interfere within the given elevation range (e.g. 4.20–4.40 m a.s.l.). Features discovered below the lower bound of the layer or residing completely above the upper bound are not visualized. In other words, the stratigraphic layers, as shown in figs. 7–9, unite all the features appearing at 5 cm slices they include.

Speaking of the *stone concentrations* category, stone walls that could not have been surely defined during the field works by trenchmasters, can be hidden under this feature type. Some of them are contoured on below images within the stone concentrations category. On the contrary, *stone wall* feature type includes exclusively such features that were clearly to be interpreted as the regular walls already in field.

The generalized stratigraphic layers were defined as follows (figs. 6–10):

- 3.70–4.20 m a.s.l.: the lowest layer founded on the natural sandy sediment with irregular stone remains in the south-western part of 22S, with bitumen and plaster layers c. in the centre of 22T, and with traces of the bottoms of the storage jars in the south-eastern part of 22S and north-eastern part of 22T that, although dug into this layer, belong to the subsequent generalised layer. The break of this lowest generalised layer was defined at 4.20 m, although there are implication speaking for the borderline between this and subsequent layer between 4.15 and 4.30. Nevertheless, the stone remains without clear ground plan (“irregular” ground plans) are for the first time overlaid by bitumen layer right at 4.20, and all the storage jars from the subsequent layer in the south-eastern part of 22S and north-eastern part of 22T are for the first time visible at this height, too. Small finds are distributed in the western parts of the trenches that might indicate completely destroyed, but originally existing architecture or activity area.
- 4.20–4.40 m a.s.l.: most of the storage jars visible⁸; architectural remains on the rectangular ground plan appear in 22S and in the south-western part of 22T; bitumen layer covering the irregular stone remains in 22S visible, followed by mixed and shell layers in the western part of 22S that completely covered the irregular remains; however, in the west of 22T the irregular remains, probably still belonging to the lowest layer, are still visible; so-called kiln in the north-western part of 22S appear; shell layer, perhaps a levelling horizon for the new architectures appear in the south-western part of 22T; other, perhaps remains of levelling horizons (plaster and mixed layers in the centre of 22T) appear. Small finds are distributed over whole area of excavated trenches.
- 4.40–4.50 m a.s.l.: closed rectangle of 22S architecture with stone walls and stone concentrations south to it; shell layer north to 22S architecture appears; storage jars gradually disappear from the plans (what does not mean they do not occur in this layer, only they were not dug into this layer); solid plaster layer in the north-eastern corner of 22T, and new stone concentrations in the north-western part of 22T appear. Small finds seem to concentrate in the south-east of 22S and north-east of 22T, what corresponds with distribution of the storage jars.

⁸ Storage jars in the south-eastern part of 22S and north-eastern part of 22T seem to form a rectangular pattern south to 22S rectangular architecture. The orientation of this rectangular pattern corresponds with the orientation of the rectangular architectures in 22S and 22T. This might indicate the presence of another structure, probably of other than stone-plaster construction, related to the architecture in 22S (covered or uncovered area reserved for the storage jars). It also means, as already stated, that the storage jars belong to one of the higher generalised layers.



Fig. 4. Al-Khidr, mound KH-1. A general overview of unearthed architectural remains (all stratigraphic layers; picture: M. Bartík/L. Benediková; after *Barta/Benediková/Ďuriš* 2010, fig. 26).

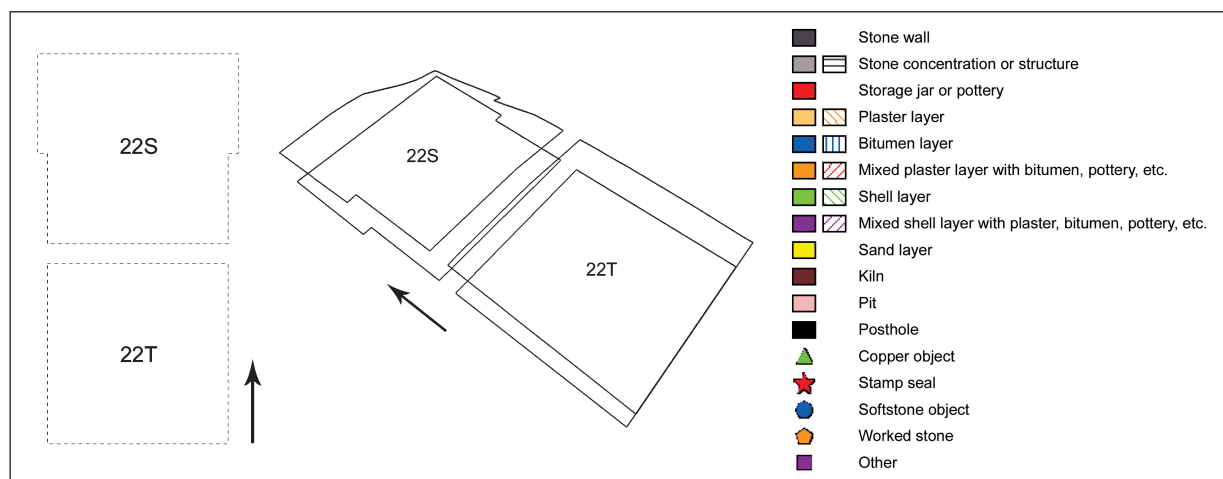


Fig. 5. Al-Khidr. Legend for figures 6–11 (picture: S. Štolc/M. Bartík/L. Benediková).

- 4.50–4.80 m a.s.l.: additions to the stone walls and stone concentrations in the southern and south-eastern part of 22S; distinctive shell layer in the north of 22S still visible; denser and overlying stone concentrations, without clear ground plans, however, in whole area of 22T (they looked like damaged during the post-depositional processes). Small finds are distributed similarly to previous layer, but are less in number.
- 4.80–5.00 m a.s.l.: only stone concentrations and stone walls present, together with bitumen layer in the centre of 22T (right at 4.80, not higher) and very few of storage jar remains. Small finds are just very few in the north-east of 22T.

Five generalised layers can be interpreted partially in accordance with the chronological sequence as presented regarding the field observations (see above, with references). The lowest layer (stratigraphic layer IV at elevation 3.70–4.20/4.40 m a.s.l.) would represent the initial stage of the settlement activities on al-Khidr. Only very indistinctive architectural and portable monuments are preserved from this stage of the settlement what can be explained by their massive destruction during the subsequent settlement activities. Contrary to the idea supposing three stratigraphic layers of the Bronze Age settlement and counting with middle stage interpreted as a dumping area for unspecified activities on the shore, it now seems that after the initial stage of the Bronze Age settlement, the solid settlement with buildings on rectangular ground plans was built represented by two sub-phases (sub-layers) – IIIb (the lower and the first one at elevation 4.20/4.40–4.50) and IIIa (the second one at elevation 4.50–4.80 m a.s.l.). During the sub-phase IIIa the rebuilding and refurbishments on the settlement took place as it can be assumed from the most complicated and dense occurrence of stone walls and stone concentrations within the trench plans, that did not change the general orientation and appearance of the architectural ground plans as they had existed and survived from the previous layer, however (for more about rebuilding and refurbishments see *Benediková/Barta 2009*, 52–53; *Barta/Benediková/Đuriš 2010*, 36, figs. 27–42).

The images of generalized layer 4.20–4.40 m a.s.l. would show the last remains of the initial (present at 3.70–4.20/4.40 m a.s.l.), as well as bottom remains of IIIb layer (present at 4.20/4.40–4.50 m a.s.l.). The layer 4.80–5.00 m a.s.l. (post-IIIa) would picture already abandoned settlement remains where no activities took place (as the modern era analogy from Failaka island the al-Zor village with dilapidating buildings and their original inventory can be quoted; for more examples see *Benediková et al. 2010c*, 284–297).

The layer division as defined above is also supported by both horizontal and vertical distributions of the small finds (figs. 10, 11). Besides spatial shifting and changes in the density of the finds from west to east of the trenches (with more specific concentrations as already referred to above; fig. 10), also the density of individual small find types with respect to the elevation of their discovery show the similar picture (fig. 11). Moreover, the latter picture helps understand and refine the interpretation of IIIb and IIIa layers and of their relationship. In particular, the IIIa sub-phase can be viewed as less intensive, showing perhaps a kind of regress of the site activities. The peak of occurrence of the most common (copper and softstone objects), as well as of distinctive (stamp seals) small finds can be seen at elevation 4.40–4.50 m a.s.l., i.e. during IIIb sub-phase (fig. 11). During IIIa sub-phase, the worked stones have reached the

peak of their occurrence. This can be explained by the change of the activities within the settlement and perhaps by a kind of regress that would be accompanied by refurbishment, but not by the complete change of the settlement pattern (see above; for objects from the site see *Benediková et al. 2010d*, 54–181).

It has to be stressed out that despite the variations from the original interpretation of the site based on the field observations, the GIS methods are offering similar data interpretation (two main stages of settlement development, although without the hypothetically suggested middle horizon represented by shell and bitumen layers in above quoted works), although much clearer picture can be presented. From methodological point of view, the possibility to define the period of abandoned settlement (post-IIIa layer) can be seen as very interesting and inspiring.

It has to be kept in mind, that presented results, are derived from the analysis of the stratigraphic situation in the northern part of the excavated area only (as the case study) and it might be refined or updated after other segments of the site will be processed in the similar way. The central part of the site is specially promising for further detailing of here presented chronological sequence. Paired with the detailed stratigraphic and portable material analyses, the methods as presented here show high potential for giving a very clear view of al-Khidr settlement during the Bronze Age.

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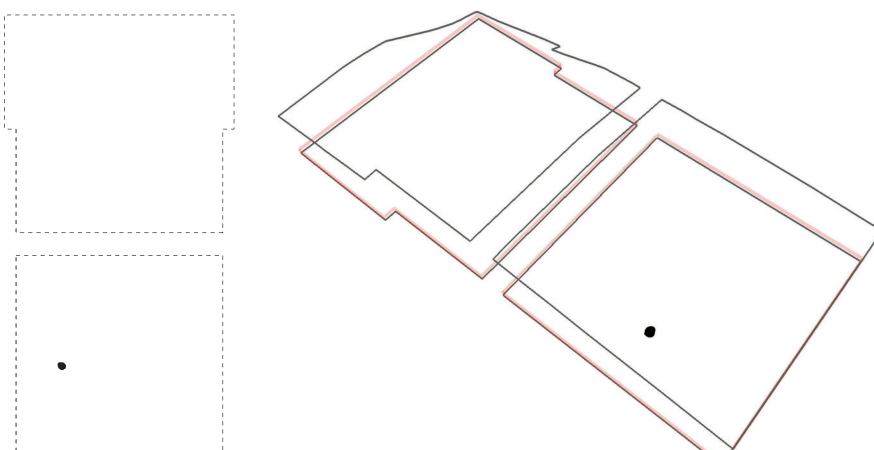
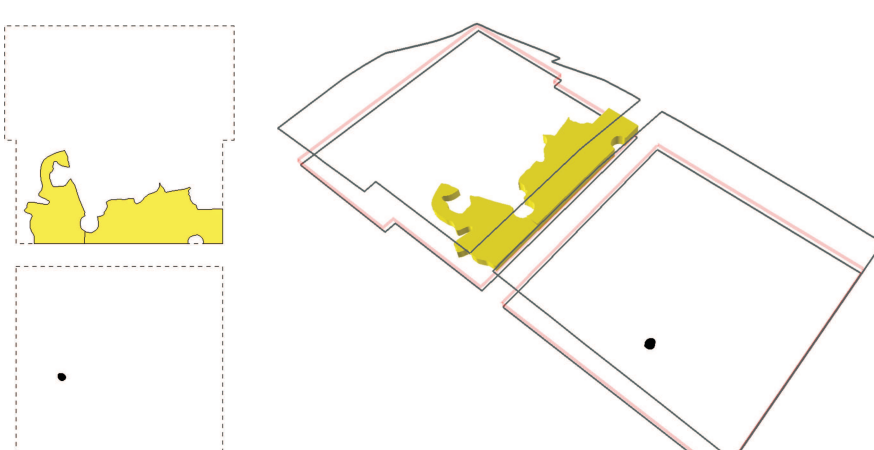
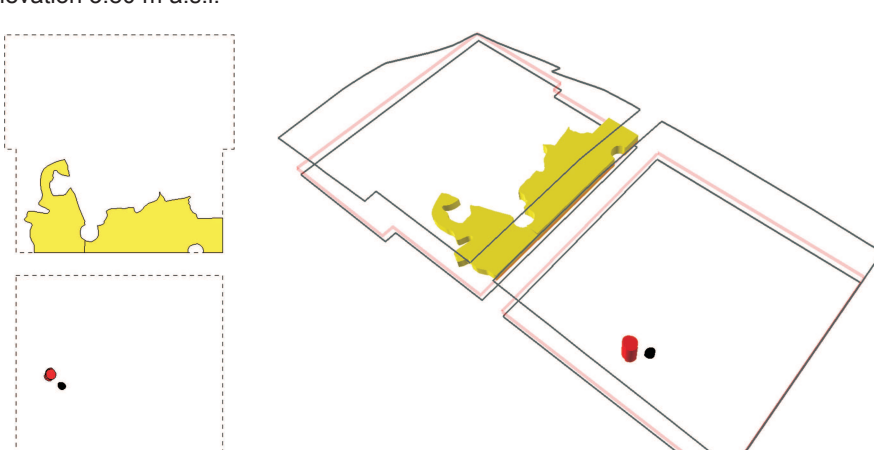
Stratigraphic slice	Stratigraphic layer
<p>Elevation 3.70 m a.s.l.</p> 	<p>Al-Khidr IV</p>
<p>Elevation 3.75 m a.s.l.</p> 	<p>Al-Khidr IV</p>
<p>Elevation 3.80 m a.s.l.</p> 	<p>Al-Khidr IV</p>

Fig. 6. Al-Khidr. Stratigraphic slices (top and 3D views) of trenches 22S and 22T with associated stratigraphic layers (picture: S. Štolc/M. Bartík/L. Benediková).

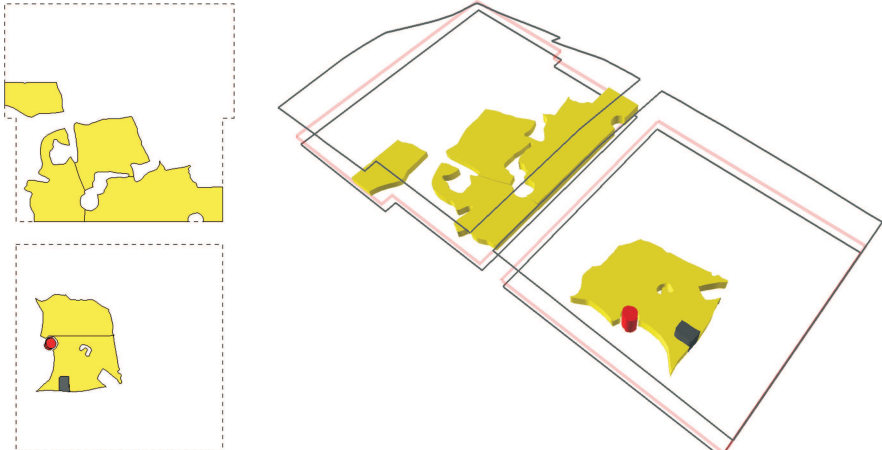
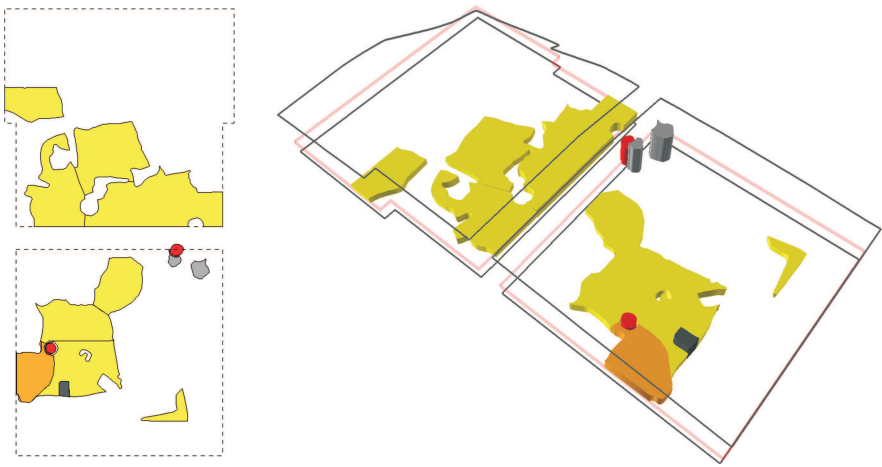
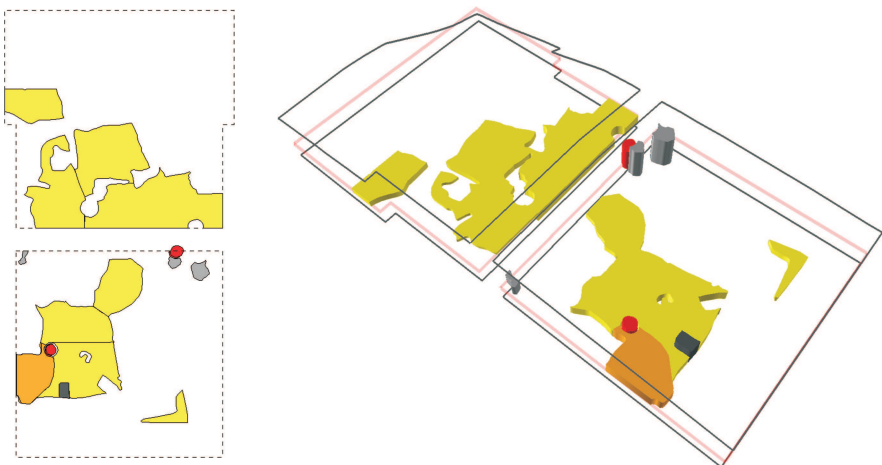
Stratigraphic slice	Stratigraphic layer
<p>Elevation 3.85 m a.s.l.</p> 	<p>Al-Khidr IV</p>
<p>Elevation 3.90 m a.s.l.</p> 	<p>Al-Khidr IV</p>
<p>Elevation 3.95 m a.s.l.</p> 	<p>Al-Khidr IV</p>

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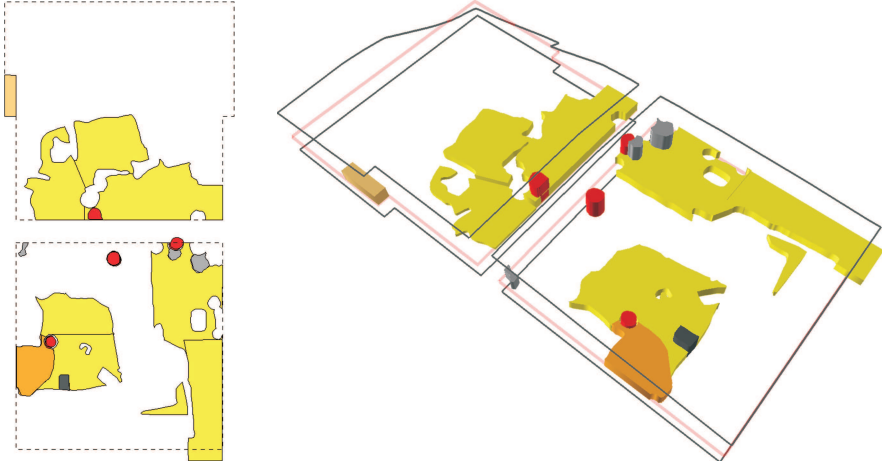
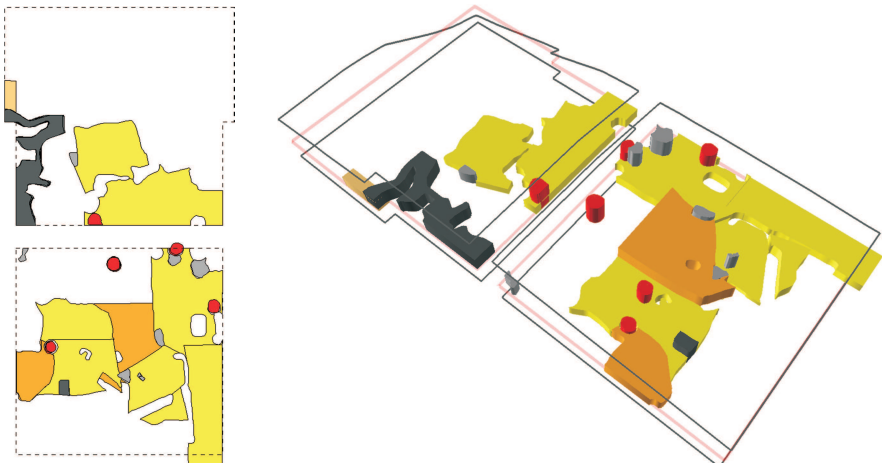
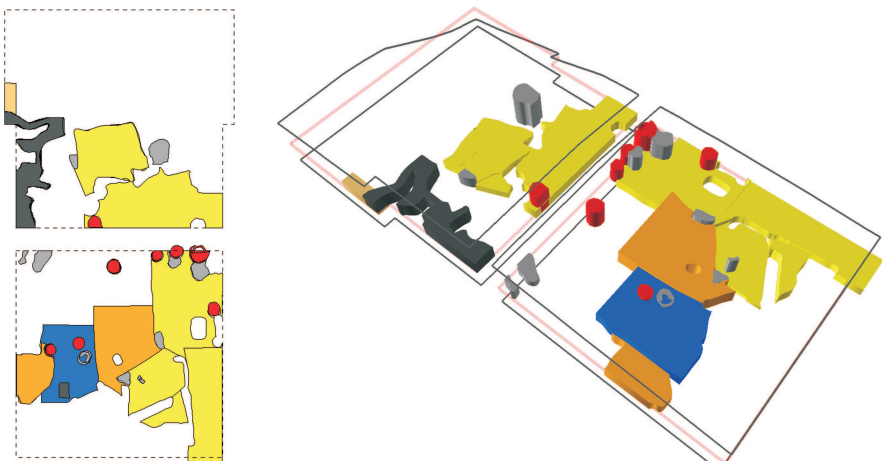
Stratigraphic slice	Stratigraphic layer
<p>Elevation 4.00 m a.s.l.</p> 	<p>Al-Khidr IV</p>
<p>Elevation 4.05 m a.s.l.</p> 	<p>Al-Khidr IV</p>
<p>Elevation 4.10 m a.s.l.</p> 	<p>Al-Khidr IV</p>

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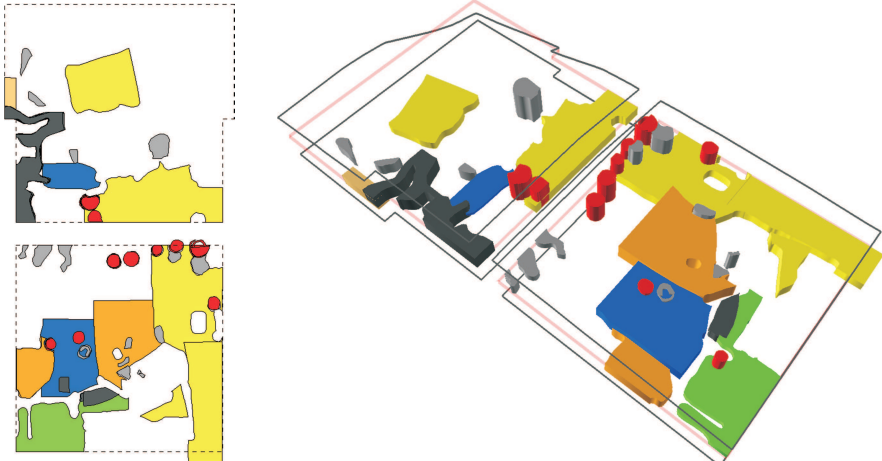
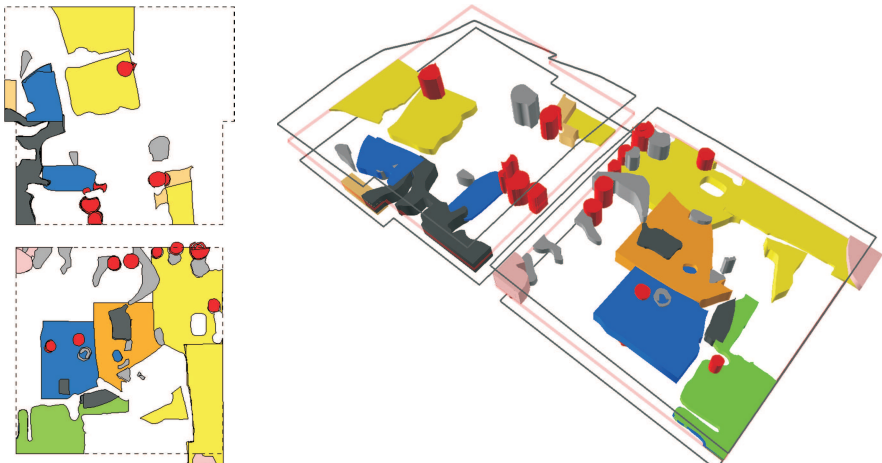
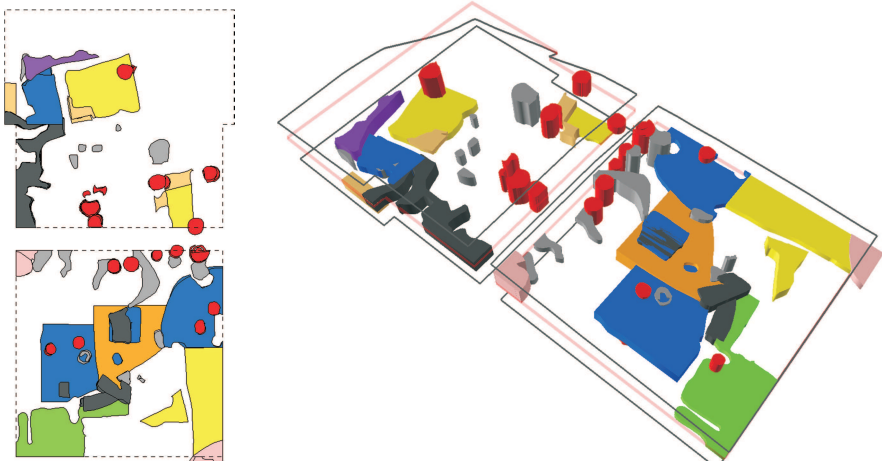
Stratigraphic slice	Stratigraphic layer
<p>Elevation 4.15 m a.s.l.</p> 	<p>Al-Khidr IV</p>
<p>Elevation 4.20 m a.s.l.</p> 	<p>Al-Khidr IV and IIIb</p>
<p>Elevation 4.25 m a.s.l.</p> 	<p>Al-Khidr IV and IIIb</p>

Fig. 6. Al-Khidr. Stratigraphic slices (top and 3D views) of trenches 22S and 22T with associated stratigraphic layers (picture: S. Štolc/M. Bartík/L. Benediková).

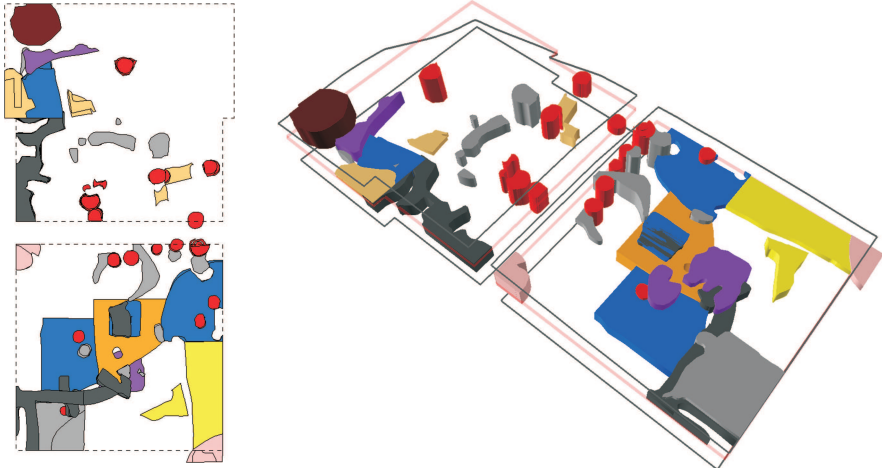
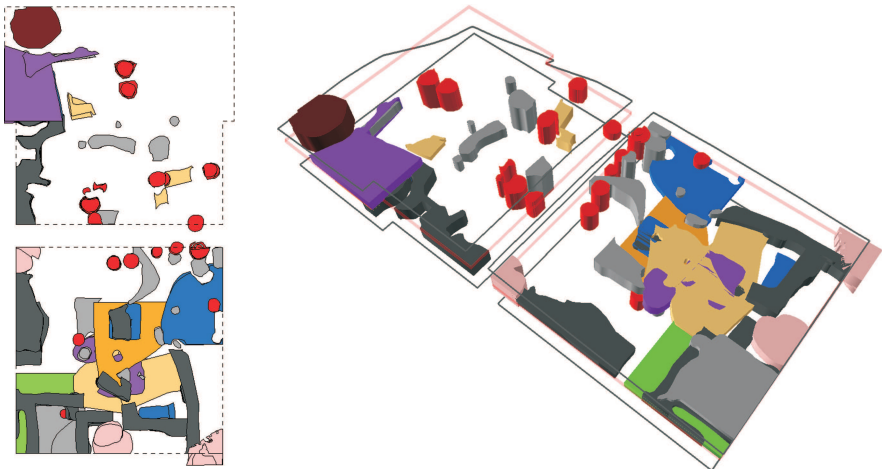
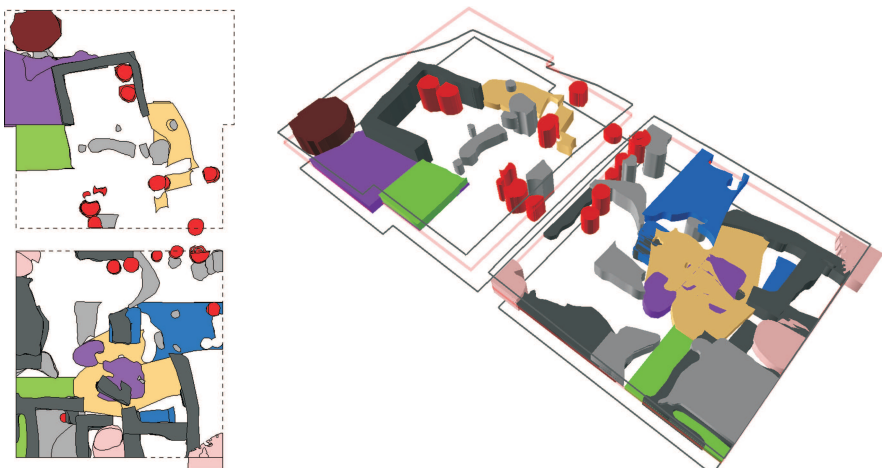
Stratigraphic slice	Stratigraphic layer
<p>Elevation 4.30 m a.s.l.</p> 	<p>Al-Khidr IV and IIIb</p>
<p>Elevation 4.35 m a.s.l.</p> 	<p>Al-Khidr IV and IIIb</p>
<p>Elevation 4.40 m a.s.l.</p> 	<p>Al-Khidr IIIb</p>

Fig. 6. Al-Khidr. Stratigraphic slices (top and 3D views) of trenches 22S and 22T with associated stratigraphic layers (picture: S. Štolc/M. Bartík/L. Benediková).

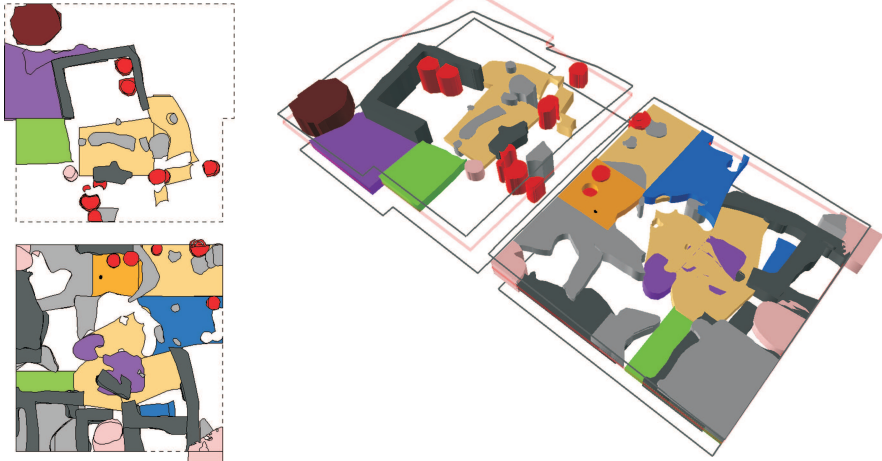
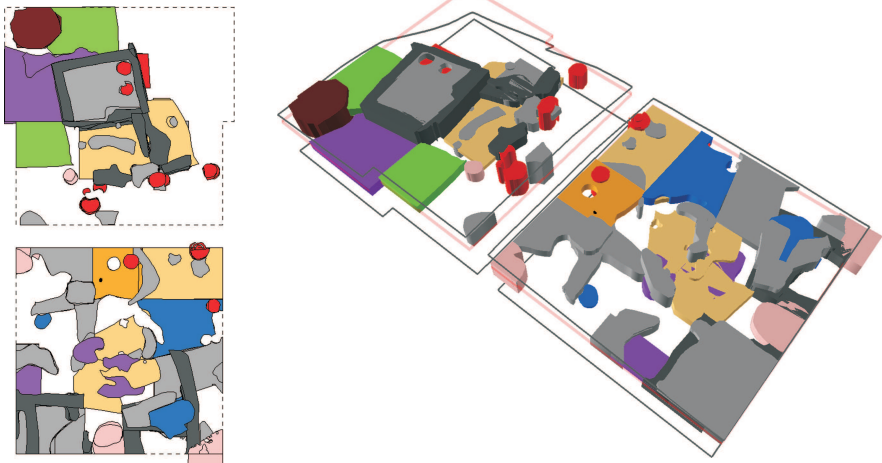
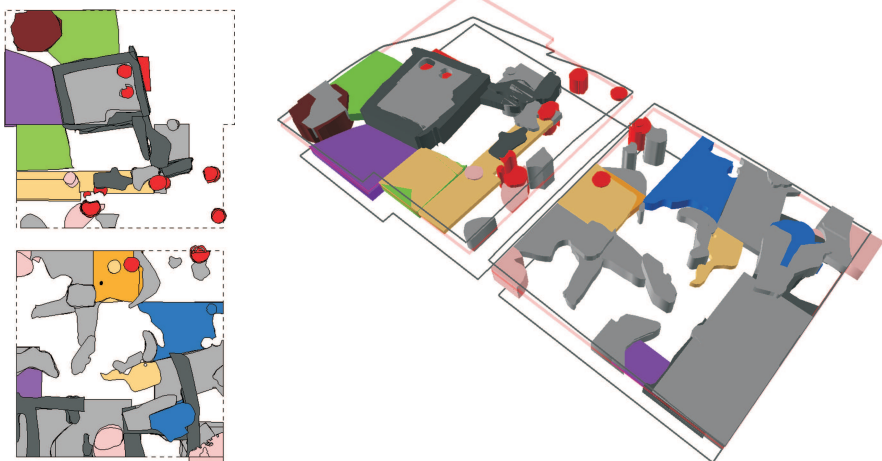
Stratigraphic slice	Stratigraphic layer
<p>Elevation 4.45 m a.s.l.</p> 	<p>Al-Khidr IIIb</p>
<p>Elevation 4.50 m a.s.l.</p> 	<p>Al-Khidr IIIb and IIIa</p>
<p>Elevation 4.55 m a.s.l.</p> 	<p>Al-Khidr IIIa</p>

Fig. 6. Al-Khidr. Stratigraphic slices (top and 3D views) of trenches 22S and 22T with associated stratigraphic layers (picture: S. Štolc/M. Bartík/L. Benediková).


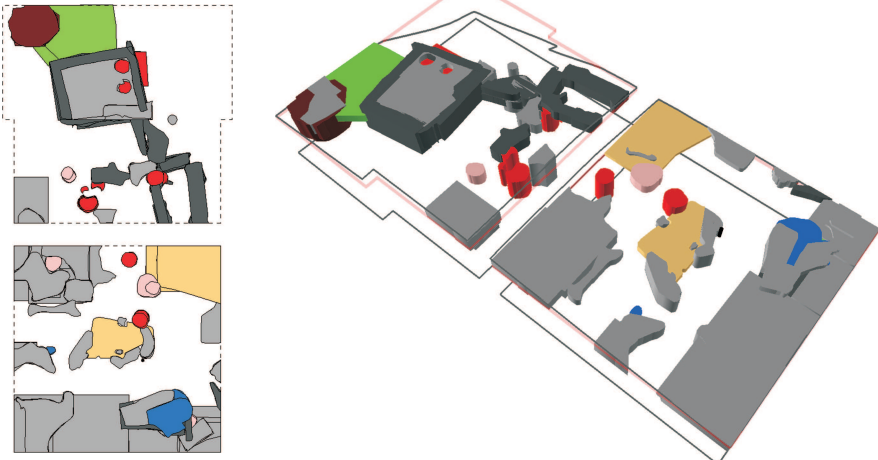
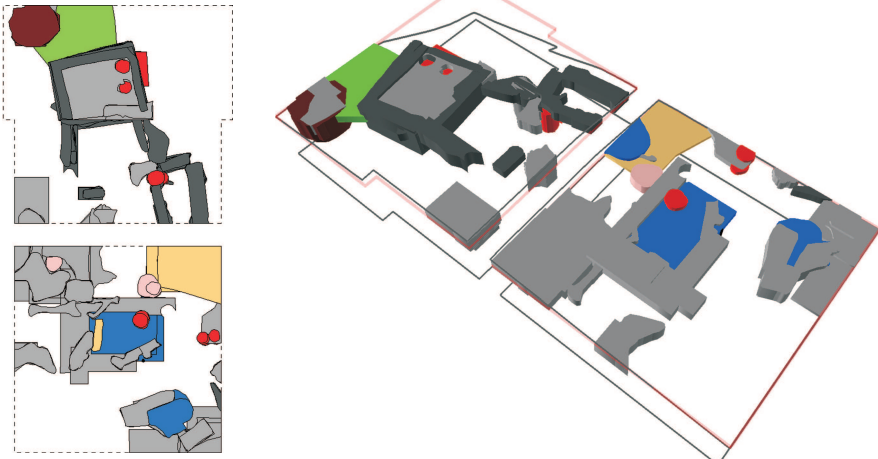
Stratigraphic slice	Stratigraphic layer
<p>Elevation 4.60 m a.s.l.</p> 	<p>Al-Khidr IIIa</p>
<p>Elevation 4.65 m a.s.l.</p> 	<p>Al-Khidr IIIa</p>
<p>Elevation 4.70 m a.s.l.</p> 	<p>Al-Khidr IIIa</p>

Fig. 6. Al-Khidr. Stratigraphic slices (top and 3D views) of trenches 22S and 22T with associated stratigraphic layers (picture: S. Štolc/M. Bartík/L. Benediková).

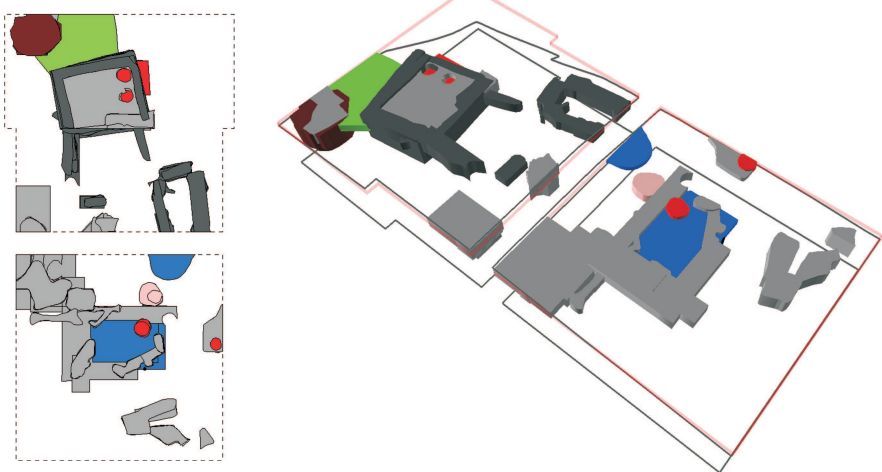
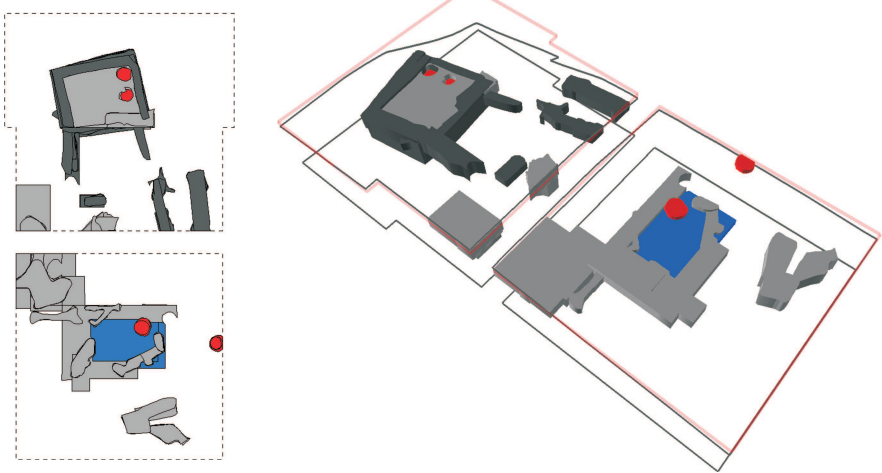
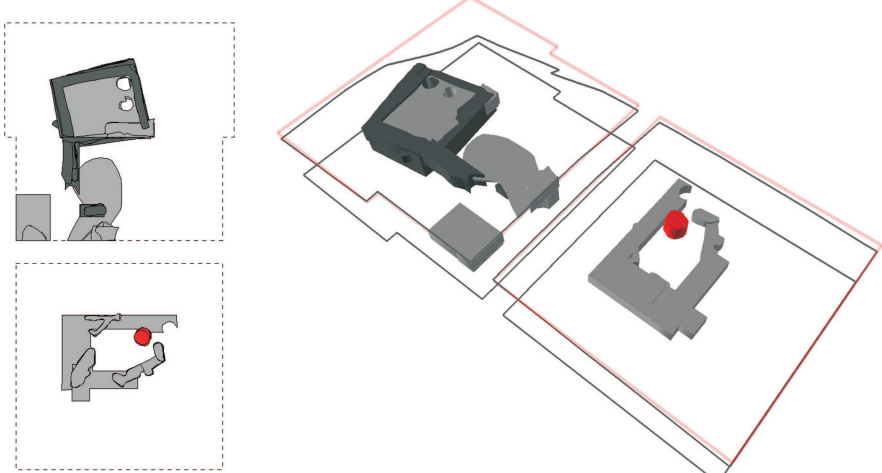
Stratigraphic slice	Stratigraphic layer
<p>Elevation 4.75 m a.s.l.</p> 	<p>Al-Khidr IIIa</p>
<p>Elevation 4.80 m a.s.l.</p> 	<p>Al-Khidr post-IIIa</p>
<p>Elevation 4.85 m a.s.l.</p> 	<p>Al-Khidr post-IIIa</p>

Fig. 6. Al-Khidr. Stratigraphic slices (top and 3D views) of trenches 22S and 22T with associated stratigraphic layers (picture: S. Štolc/M. Bartík/L. Benediková).

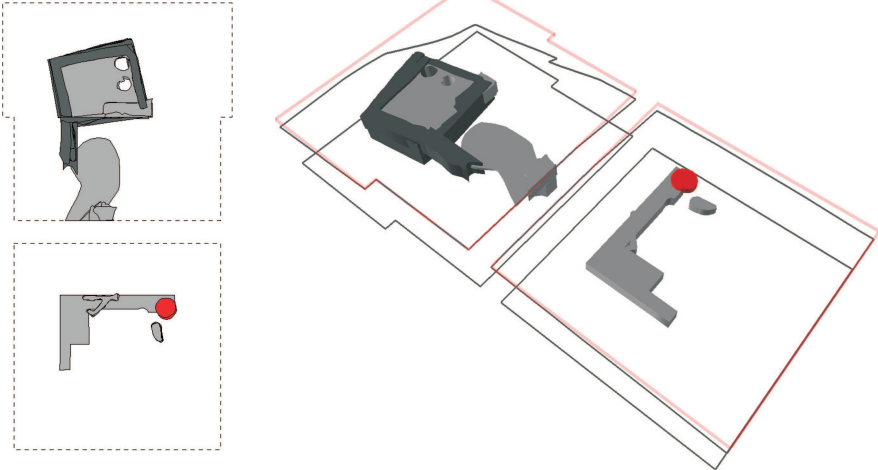
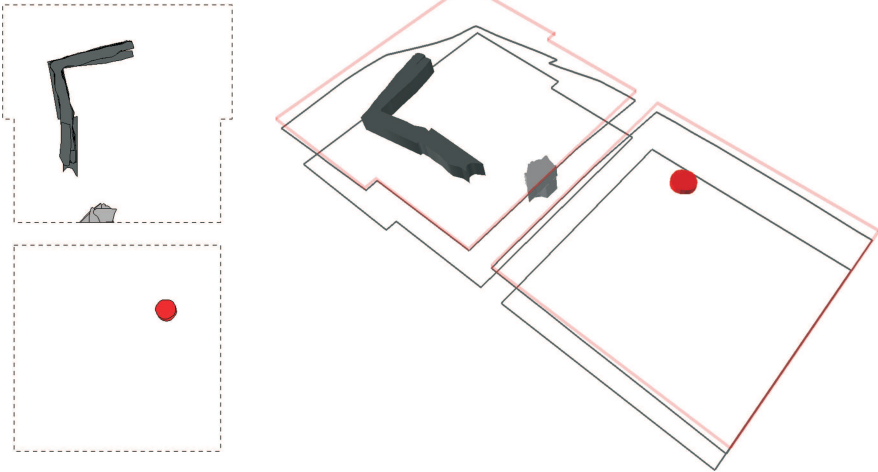
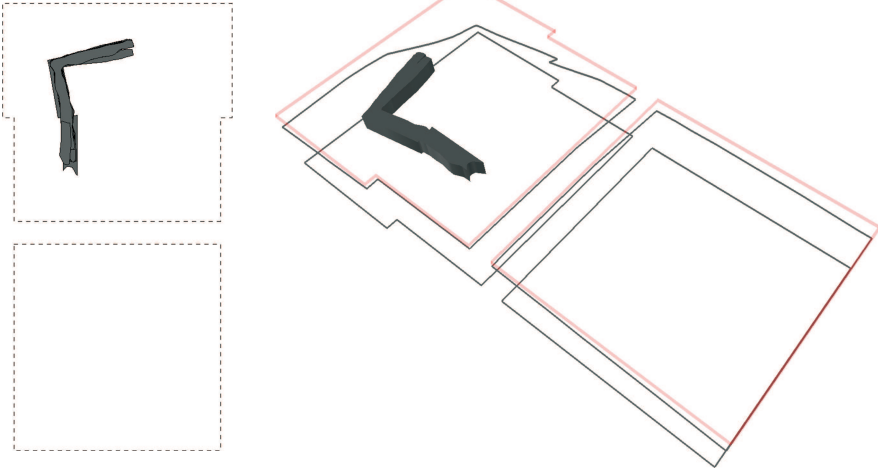
Stratigraphic slice	Stratigraphic layer
<p>Elevation 4.90 m a.s.l.</p> 	<p>Al-Khidr post-IIIa</p>
<p>Elevation 4.95 m a.s.l.</p> 	<p>Al-Khidr post-IIIa</p>
<p>Elevation 5.00 m a.s.l.</p> 	<p>Al-Khidr post-IIIa</p>

Fig. 6. Al-Khidr. Stratigraphic slices (top and 3D views) of trenches 22S and 22T with associated stratigraphic layers (picture: S. Štolc/M. Bartík/L. Benediková).



Fig. 7. Al-Khidr. Trenches 22S and 22T. Stone walls, stone concentrations and storage jars relations (picture: S. Štolc/M. Bartík/L. Benediková).

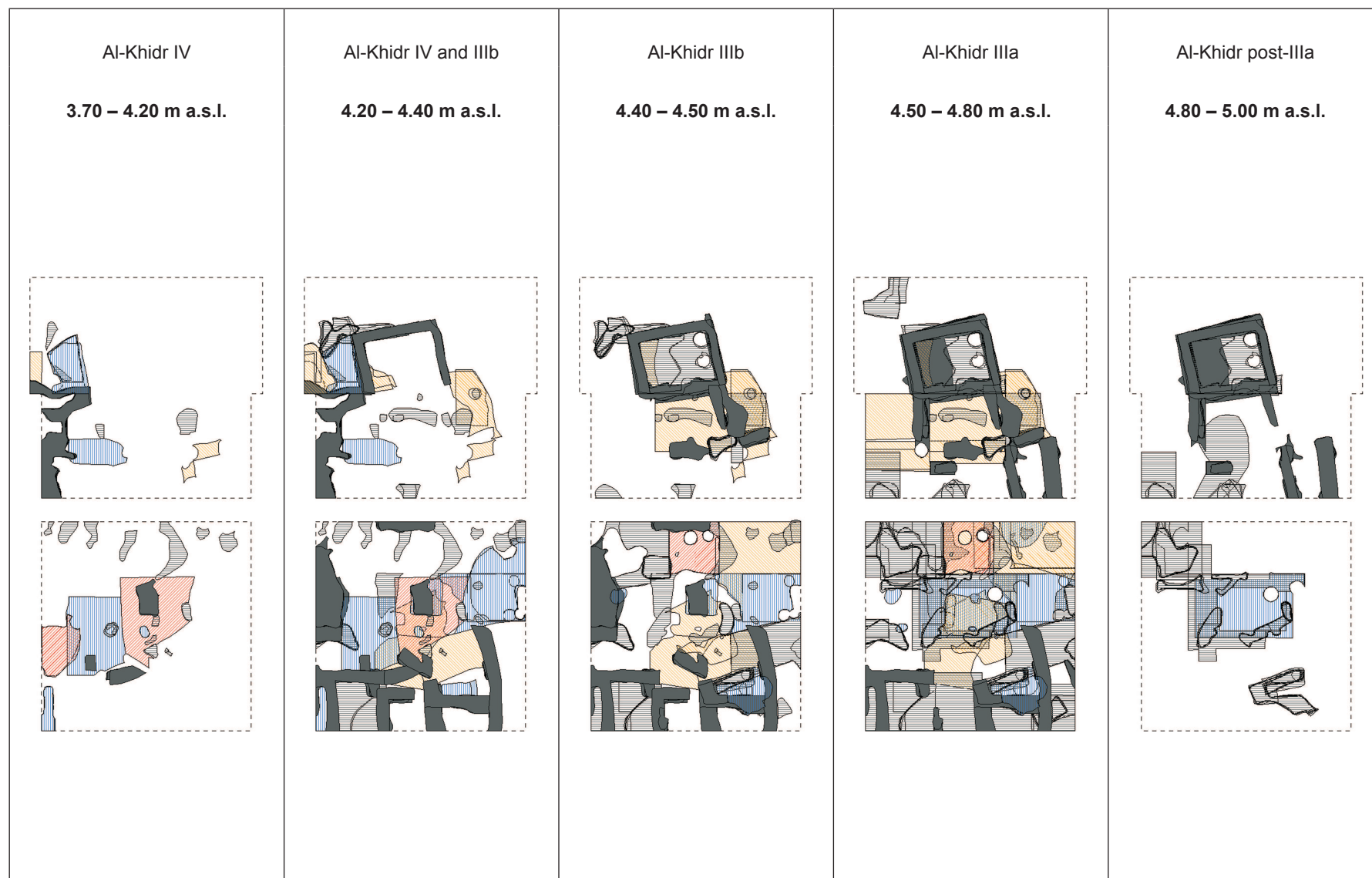


Fig. 8. Al-Khidr. Trenches 22S and 22T. Stone walls, stone concentrations, plaster and bitumen layers relations (picture: S. Štolc/M. Bartík/L. Benediková).

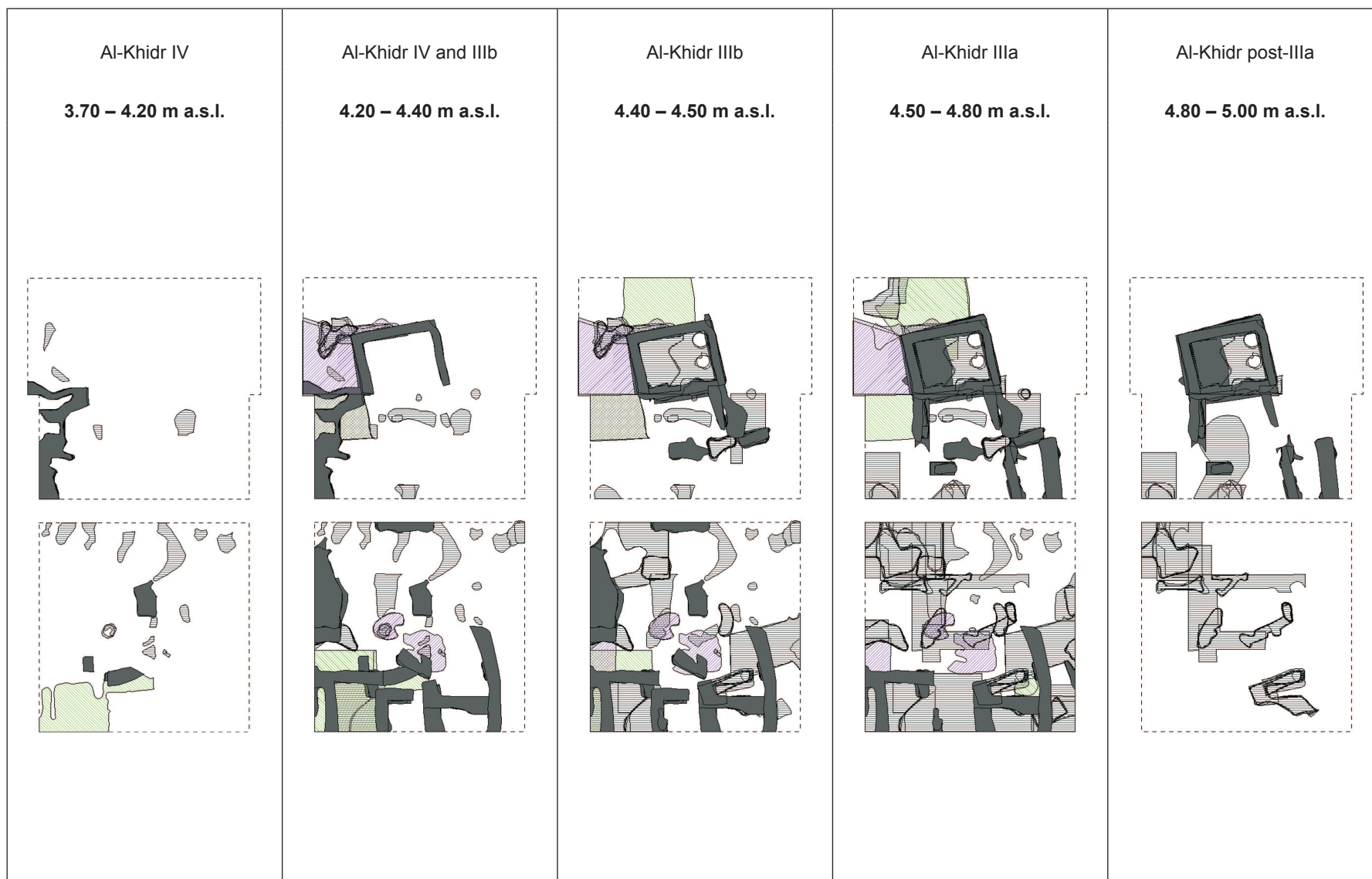


Fig. 9. Al-Khidr. Trenches 22S and 22T. Stone walls, stone concentrations, shell layers and mixed shell-pottery-bitumen layers relations (picture: S. Štolc/M. Bartík/L. Benediková).

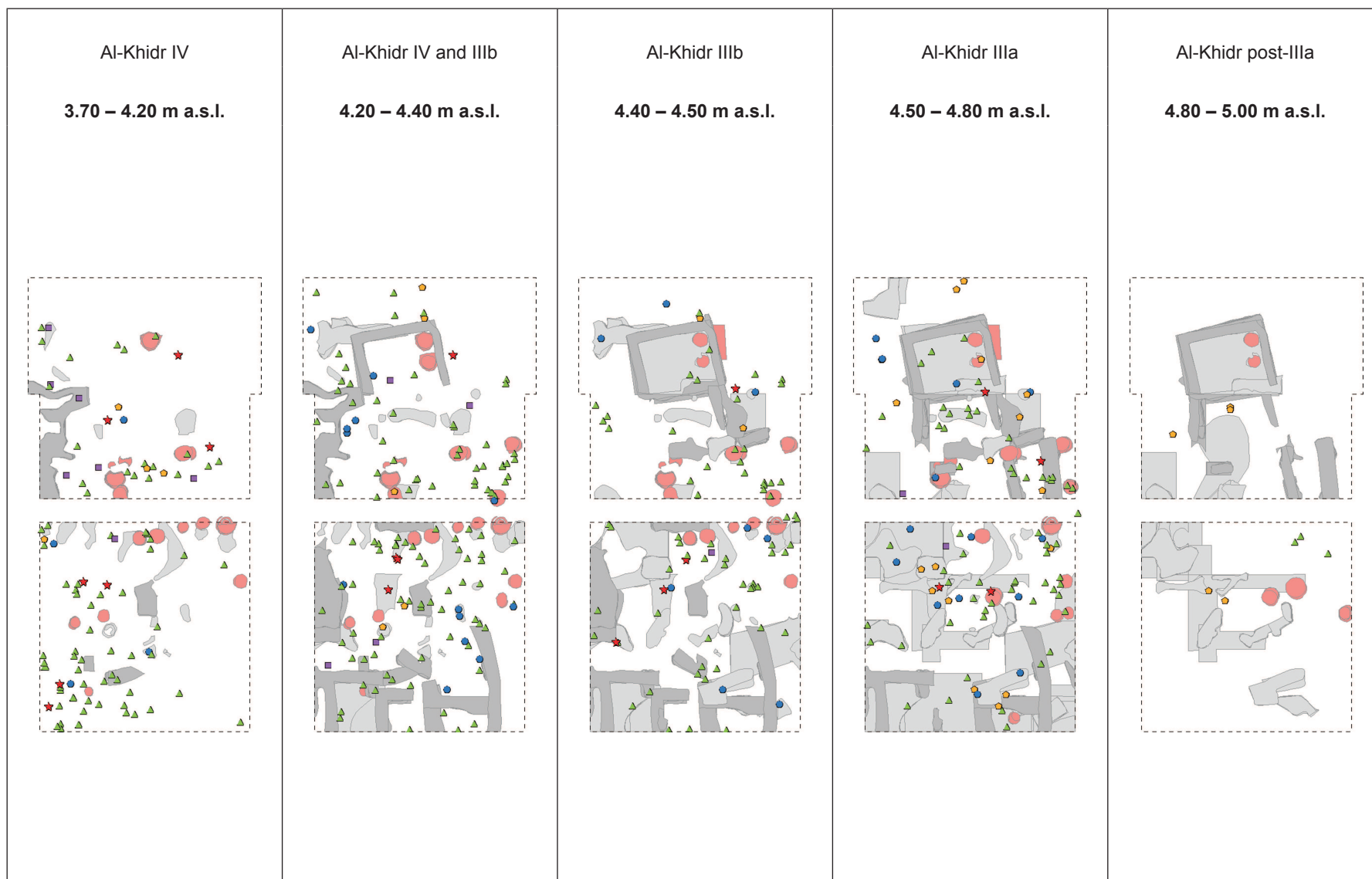


Fig. 10. Al-Khidr. Trenches 22S and 22T. Small finds distribution in the relation to the stone walls, stone concentrations and storage jars (picture: S. Štolc/M. Bartík/L. Benediková).

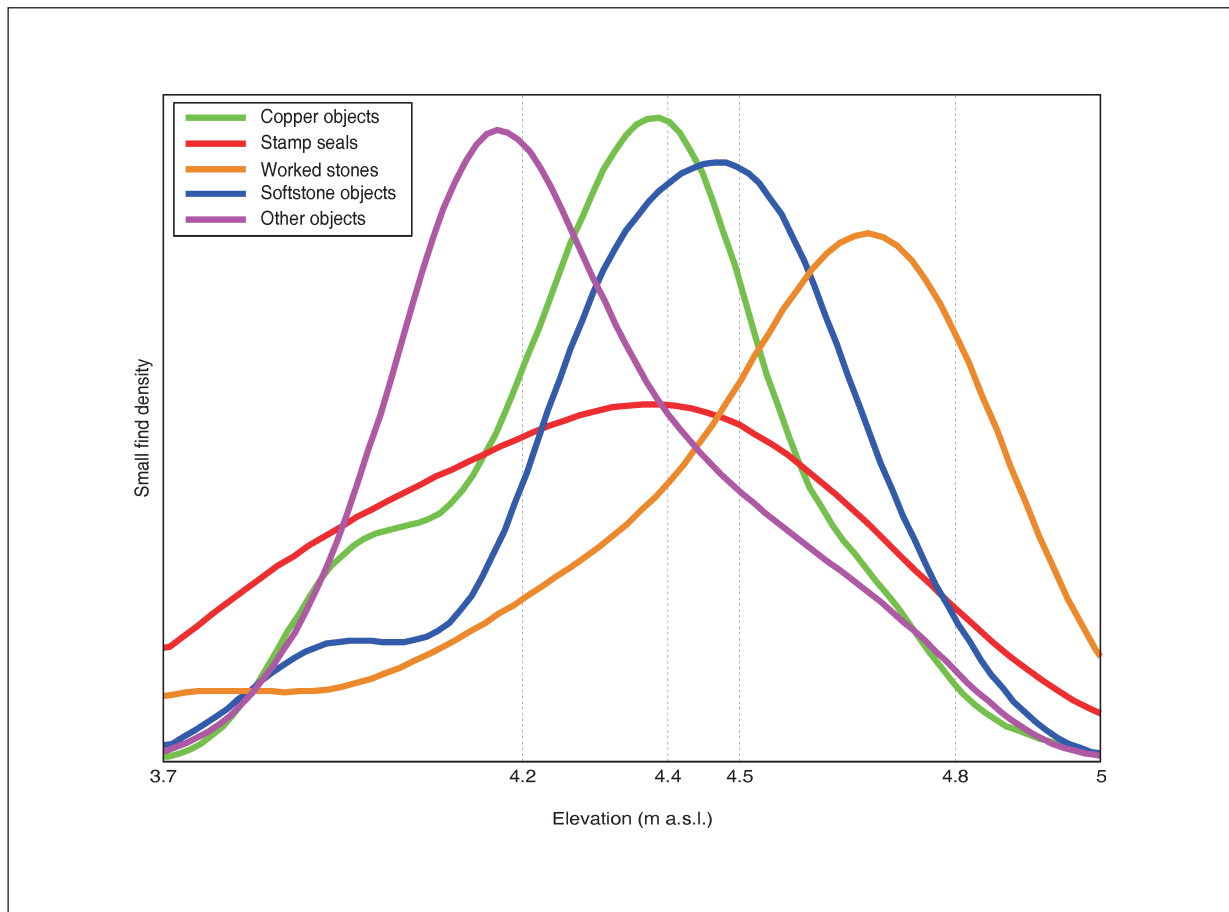


Fig. 11. Al-Khidr. Distributions of the small finds discovered in trenches 22S and 22T. Dashed lines stand for borders of 5 generalized stratigraphic slices as defined for 22S and 22T according to the *in situ* remains (picture: S. Štolc).