Palimpsests and Palaeolithic living floors around the well of Hummal (Syria). A taphonomical approach combining lithic and microstratigraphical analysis.

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Introduction

Time, depth and the durable proprieties of the material record give archaeologists the chance to explore distinct past human activities. But the time and its relationship with the factual world has an immense impact on archaeological interpretation of the ancient human survival strategies. The investigation of the temporal and spatial properties of archaeological material, the resolution of datasets and the active role of site formation processes led archaeologists and geologists to review the perception of archaeological records (Binford 1977, 1980; Schiffer 1972, 1983, 1987). It was identified that the archaeological material and its spatial distribution can be frequently transformed not only during but also after human occupation. The notion of 'palimpsest' (Binford, 1981, 1987; Villa, 1982; Bailey 2007) and 'living floor' (Clark 1954; Leroi-Gourhan & Brézillon, 1956, 1972; Leakey, 1971; Bordes 1975) have been introduced into archaeological sciences to describe the complexity of site formation processes and their impact on archaeological remnants. The concept of 'palimpsest' in general refers to successive depositional events incorporating the remains of several occupations and 'living floors' to a single episode of site use. Some researchers suggested that a very small occupation scatter with distinct vertical and horizontal boundaries may be a sign of limited occupation period, representing probably a specialized activity area (Villa 1976; Delagne *et al.* 2006) and that the authenticity of 'living floor' can be verified through refitting of artefacts (Villa 2004). The concept of palimpsest has a long tradition in archaeology but its definition is not unified. Some archaeologists view it only as a limitation because they have to rely on the incomplete material record, some others focus on the opportunity to observe the long term trends and recognize full range of palimpsests established and their impacts on our considerations of the past human life (e.g., Foley 1981; Bailey, 2007; Malinsky-Buller *et al.* 2011). Therefore the understanding of the actions that affect the formation processes of the site is crucial for interpretations of temporal resolution of archaeo logical material.

In this paper we present Hummalian occupation horizons based on combined archaeological and micromorphological examination. We investigate formation processes and their impact on archaeological data in the Early Middle Palaeolithic stratigraphical section of eastern and western parts of the Hummal site in the El-Kowm region, Syria.

layer	6a	6b	6c-2	7a	7c
excavated surface (m^2)	10	14	2	14	18
volume (m^3)	0.2	0.1	0.7	0.2	0.4
density (item per m^3)	241	2682	137	19	50
fauna (artefacts ≥ 2cm)	6	51	6	13	29
lithics (artefacts ≥ 2cm)	476	3704	186	41	332

Table 1: *Artefact density in Hummalian layers.*

Currently the archaeological sequence for the Hummalian industry (layers 6a, 6b, 6c, 7a and 7c) is well established being stratigraphically inserted in between Yabrudian and Levallois-Mousterian (Wojtczak 2011, 2014; 2015a, b; Wojtczak *et al.* 2014) and dated to around 200 ka (Richter 2006; Richter *et al.* 2010). The site was occupied repeatedly, resulting in layers with variable densities of the archaeological remains. This seems to be the effect of differing intensities of occupation, but also because of the limited extent of the excavation. Two of the Hummalian archaeological levels (layers 6a and 6b) show high densities of flint artefacts, where the complete sequence of tool manufacture, maintenance and recycling activities took place on the site. At the same time three archaeological layers (layer 6c-2, 7a and 7c) with a much lower density of artefacts, show vastly differing patterns from those mentioned previously (Tab. 1). Thus the Hummalian assemblages offer different archaeological contexts, and embody varied activities of their human producers at the site giving the opportunity to discuss the site formation processes, the diverse environmental conditions in which these layers have been formed and artefacts deposited.

Preservation of the archaeological record

The preservation of the archaeological record depends strongly on the environment and site formation processes. Semi-arid milieus are exposed to three main types of weathering: physical, chemical and biogenic. Mechanical weathering of rocks is driven by temperature changes, precipitations and pressure. Chemical reactions between the sediment and water cause dissolution and re-precipitation of calcium carbonate and silica, influenced by the pH (Pümpin 2003; Le Tensorer *et al.* 2007; Karkanas 2017). During stable phases, plant covers develop and pedogenesis starts, resulting in bioturbation due to root growth and burrows from termites and rodents. Ferric precipitations and gypsum crystals can form in cracks due to percolating rainwater and high evaporation rates, which can be the result of soil formation and/or post-sedimentary processes, in turn amplified by the high evaporation rates (Karkanas 2017). Deflation, cryoturbation and erosion near bodies of water influence the preservation of lithic artefacts and bones, which makes some of the archaeological and archaeozoological analyses problematic (Roberts & Mitchell 1987). In addition fire events were a frequent natural occurrence (Alperson-Afil *et al.* 2007), however, their thermal effects into the sediments is in general very low (Bellomo 1993; Mallol *et al.* 2013). Flints with distinct burning features were most probably the result of human activities, as experiments and archaeological observations showed that severely overheated flints are the best marker of non-structured surface hearths, which could be also overprinted or destroyed by intensive trampling (Sergent *et al.* 2006). Human and animal trampling can also damage artefacts to a high extent (Behrensmayer *et al.* 1986; McBrearty *et al.* 1998; Thiébaut 2007; Miller 2017). Regarding flint artefacts, another important aspect is the development of patina, which seems to be a complex process depending on many factors, e.g. the flints' mineralogical composition and the moisture regime (Bäsemann 1987). Repetitive experiments carried out by the author in El-Kowm confirms that the modification of the surface of Paleogene flint commonly used in Palaeolithic period is perceived after only a few weeks laying on the surface and being exposed to sun light; the typically black flints gradually lost their shiny aspect and developed a white discoloration.

The site and its surroundings

The El-Kowm oasis is located 450m above sea level in the Syrian steppe between Rasafa, Palmyra, and Deir el Zor (Fig. 1). The region is a 20km long depression bordered by the Anti-Lebanon Mountains in the west, and the Euphrates River in the east. The southern limit of the El-Kowm area is covered by the northern Palmyrides, in the north emerges the Jabal Bishri. In the past as today, the open landscape between the mountain ranges offers an ideal path for migrating herds, which meant an abundance of ambush sites for hunting gazelles. The area is characterised by the presence of many artesian springs related to faults in the substratum and by high quality Lower Eocene flint outcrops. The springs continually attracted humans to the same places, accumulating cultural remains of occupations over long periods. Generally, the preservation of artefacts at the spring sites is excellent, for Palaeolithic open-air sites. This is due to the occasional rapid build-up of fine sediments within and near the springs. Carbonate precipitations during active periods of the springs led frequently to the formation of a well mound, where wind depositions and deflation also played major roles. In this environment, remains of human activities have occasionally been preserved. Until today inhabitants of the El-Kowm area dig new wells on these raised mounds, bringing archaeological sequences, such as Hummal, to light, to be identified by archaeologists (Besançons *et al.* 1982).

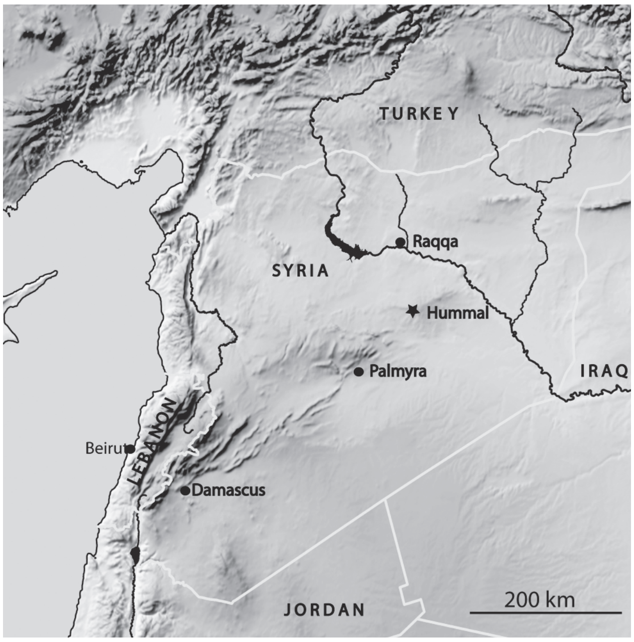

Figure 1: *Map of the region.*

The Hummal site, also called Bir Onusi, is a spring mound formed around an artesian well. Spring mounds are circular volcano-like structures, formed due to strong evaporation of mineralized water leading to calcareous or gypsiferous precipitations around sources of artesian waters often formed near *sabkhas* (saltpans). The activity of the well plays a major role in the sediment formation of the site: during active phases, carbonatic sediments precipitate in the pool, and organic layers can develop. During inactive phases, the mound dries out and degrades due to water and wind erosion and re-depositions occur. In this environment, calcrete or gypcrete may build up at or near the ground surface, tufa and travertine can form and aeolian dunes develop (Roberts & Mitchell 1987).

Today, Hummal is a discrete well mound of sediments built up during the Quaternary. The spring was fed by an aquifereous geological layer under pressure, where water could flow out along tectonic faults in the bedrock, and form a pool in a karstic setting. For more than 780,000 years, the well was active; a geological sequence investigated paleomagnetically by J.J. Villalain indicates the boundary of Brunhes-Matuyama for the Lower Palaeolithic at the base of the stratigraphy. The artesian well was active until the early 1980s (oral communication J.-M. Le Tensorer and A. Onusi, owner of the spring). As a result of changing water supply over time, due to wet and arid periods, the size of the pool and the water level changed, which in turn influenced the conservation of the archaeological levels (Ismail-Meyer 2009). There are indicators that suggest the spring was much less active from the Holocene onwards. The well mound suffered deflation and aeolian accumulations of silt and gypsum-rich sand covered the Pleistocene morphology of the site (Pümpin & Jagher 2004).

Palaeoclimatic information for inland areas, like El-Kowm, during the Pleistocene is still lacking but data from central Mediterranean lacustrine and marine sequences indicate important climate oscillations that caused the formation of submarine sapropel during periods of higher rainfall (Kroon *et al.* 1998, Aritztegui *et al.* 2000). Marine cores have identified twelve humid periods during the last 500,000 years. Isotopic records from cave deposits (speleothems) in the Mediterranean coastal regions attest to these changes in precipitation as well as temperature fluctuations (Bar-Matthews *et al.* 2000; Bar-Matthews *et al.* 2003). The climate of the Levant and north-eastern Africa is influenced by the interaction of Atlantic/Mediterranean frontal system and the African/West Asian monsoonal systems. Recorded data show that during warm interglacial periods, when the Mediterranean frontal and monsoonal systems are stronger and almost overlapped, the area became particularly humid and wet. Conversely at the glacial maxima, the whole area is much cooler and drier. In between these extremes, there are also locally occurring dry and warm interstadial phases and cool and humid glacial intervals (Almogi-Labin *et al.* 2004). It is unknown how strongly the paleoclimate in the El-Kowm area was influenced by these climatic fluctuations, but it seems that the lower temperatures and increased precipitation slowed evaporation and led to thicker vegetation cover, which possibly had an effect on the karsts system. The water supply of the well was probably not only controlled by climate, but also by tectonic systems, causing significant faulting in the bedrock (Turberg 1999; Pümpin & Jagher 2004).

Today, the Syrian steppe is characterised by a Mediterranean climate, with two main seasons: dry and rainy. The annual rainfall is irregular and unpredictable, with precipitation in this area varying wildly from one year to another. Alongside this irregular rainfall, increased evaporation, extremely low humidity and constant wind effect must also be considered. In addition, the thin soils of this arid zone do not readily hold water. Most of the water from the rainfall drains off into the wadis to the southeast and then into the alluvial plain of Qsar al Hair or *sabkhas*. Drinkable water is only available in the wadis for a few days after heavy rain. This shows the importance of the numerous natural springs in enabling permanent settlement in this arid steppe. The majority of the recognised natural springs in El-Kowm were epithermal artesian wells, highly saturated with mineral salts, and a water temperature of around 27-28°C (Margueron 1998). Many of them were semi-permanent and must have flowed for a very long period. Nowadays, these water reserves are unsustainably exploited for irrigation; all the natural springs have dried out, and the water table has fallen from the subsurface to a depth between 40 and 75 metres.

The stratigraphy

Surface excavations of the Hummalian layers began in 2001 and continued until 2005 (Fig. 2) and restarted again in 2009 and 2010. Altogether the excavated area covers 28m². The stratigraphic sequences were recorded in the East, West and South sectors and are well correlated, although there are also some differences, e.g. complex 6c appears only in the eastern zone.

This study includes archaeological artefact analyses from five archaeological layers and micromorphological investigation from a profile block sample (HU 34/1, Fig. 3), integrating stratigraphical description and interpretations, on-site fieldwork observations and geoarchaeological descriptions of the profiles in the western and eastern sector.

From a geoarchaeological view, the layers of Hummal are rich in micritic carbonates, precipitated directly from the well's water (Freytet & Verrecchia 2002). In some areas, cemented carbonates formed,

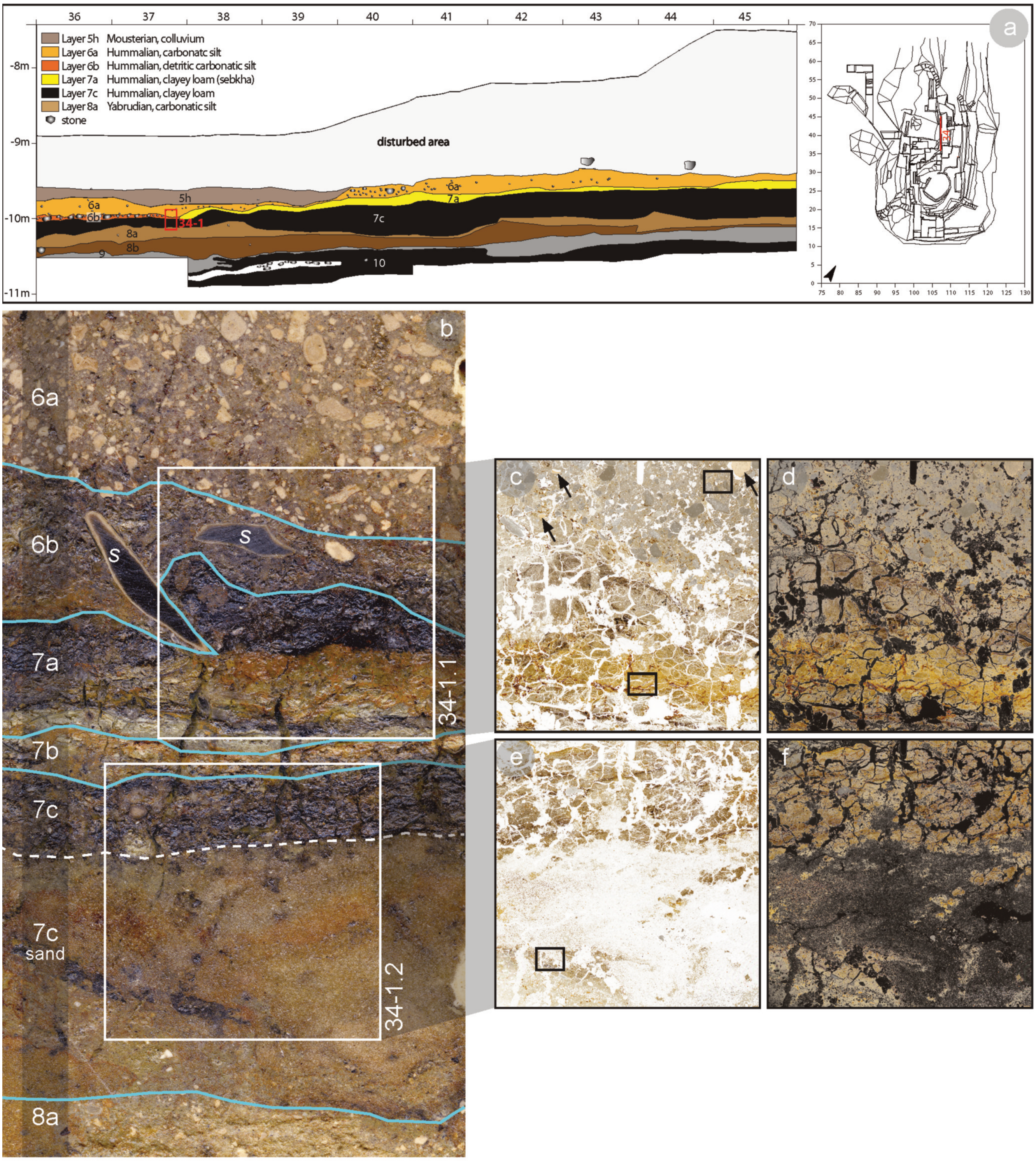

Figure 3: *a) Profile 34 from sector West with the archaeological layers 10 to 5h. The micromorphological sample 34/1 is marked in red. The inlet in the righter upper angle shows an overview over the excavated area from the site Hummal with profile 34 marked in red. b) Polished section of the sample 34/1 with the archaeological layers noted on the left side and the position of the thin sections 34/1.1 and 34/1.2 marked in white. Note the two flint artefacts (s) in layer 6b, showing a beige patina. c) The scanned thin section 34/1.1; pore space appears in white, the black rectangles show the positions of the microphotographs in Fig. 7, the black arrows point to bone fragments (the two flint artefacts don't appear in the section). d) Same as Fig. 3c, pore space coloured in black; the brown and yellow coloured clay from layers 7a and 6b can be better recognized, as also the beige carbonatic silt layer 6a rich in grey, rounded carbonates on top. e) Scanned thin section 34/1.2; pore space appears in white, the black rectangle shows the position of the microphotograph in Fig. 7. f) Same as Fig. 3e, pore space coloured in black; note the sand and the finely layered brownish clay from layer 7c (macroscopically seen as black clay), on top of the sand.*

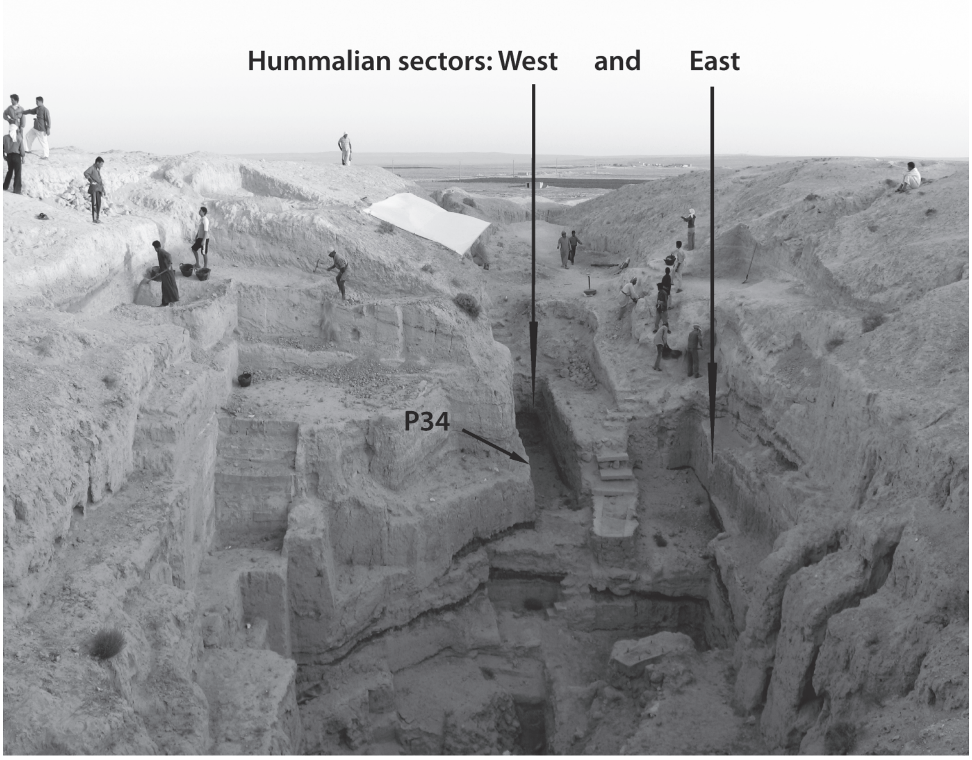

Figure 2: *General view of the site Hummal in 2005, towards north. Note the black coloured clay layers 7 and 10 within the profiles.*

as travertine. Reworked fragments of these carbonates can often be found within the micritic carbonates. Aeolian quartz sand, trapped in the depression of the well, is also part of the sediments. Further, green and black clays can be observed, forming rare and very distinct layers. Water level probably fluctuated according to climatic changes and tectonic processes (Meyer 2001; Pümpin & Jagher 2004). The relevant layers are described from the base upwards (Fig. 3a):

Hummalian sand αh

In the heart of the well, massive sand deposits of several metres have been found. A single unit of well-sorted quartz sand, rich in generally well preserved lithic artefacts and also faunal remains; locally it forms cemented sandstones.

Layer 7

Situated on Yabrudian Layer 8, this deposit is a complex series of clays of varying thickness (5 to 40cm). It contains four sub-levels of which three (7a, b and c) are presented here.

Layer 7c: Laminated black and green clay with thin organic bands laminations. An intercalation of well-sorted medium sand showing shiny grain surfaces (sand αh) was observed. In other places, this sand forms dunes reaching a thickness of 20cm (Fig. 4). Lithic artefacts, bones (some burnt), and small fragments of carnivore coprolite were found. Archaeologically, it is the richest sub-level in terms of artefact density. The majority of stone artefacts have been collected from eastern part of excavation beyond sand concentrations (micro-dunes), none however were found inside such a micro-dune.

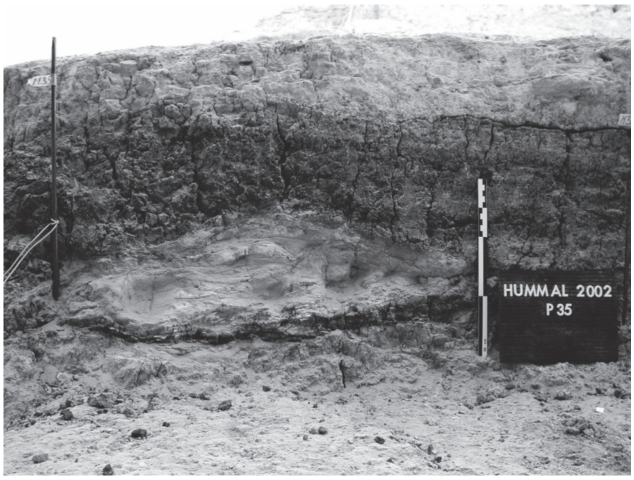

Figure 4: *Micro-dune discovered in layer 7c in the East sector (profile 35).*

Layer 7b: Reddish, sterile sand which sometimes forms accumulations up to 20cm thick. The micromorphological sample comprises a thin green clay layer with well-rounded quartz sand, organic intercalations and ferric precipitations.

Layer 7a: Layered green and black clay with quartz sand, organic intercalations and rich in ferric precipitations, containing a small number of lithic artefacts and faunal remains.

Layer 6c

The compact carbonate silt, approximately 30cm thick, was only observed in the eastern profile, from where it thinned out and could not be identified on the western and southern part of the excavation. It is subdivided into two sub-levels: 6c-1 and 6c-2.

Layer 6c-2: Brown-grey calcareous silt, which forms a hard freshwater carbonate crust in some places. In an area of just two square metres, lithic material, a number of small bones (including a felid bone), three fragments of ostrich shell and also equid teeth were collected. The flint artefacts are very well conserved and still presenting sharp edges.

Layer 6c-1: Compact, white calcareous loam with carbonate fragments. Only a few lithic items were collected in the upper part of this layer, and presented the same patination visible on pieces from layer 6b, with which it abutted.

Layer 6b

This layer consists of heterogeneous clay merging into a detritic carbonate with a maximum thickness of 14cm with no clear stratigraphic subdivision. On its surface, a thick layer of flints oriented horizontally with a high proportion of patinated and damaged artefacts mixed with better-conserved pieces was observed.

Layer 6a

Layer 6a consists of an unstratified detritic calcareous silt rich in rounded carbonate fragments. The layer has an average thickness of 15cm. Relatively few lithic artefacts were found and several artefacts are broken and show signs of edge damage.

Methods

To elucidate site formation processes, the successive deposition of sediments and archaeological material, during Hummalian period, we refer to the following factors: archaeological levels defined in the field by clear upper and lower boundaries, spatial distribution of artefacts, their conservation, and micromorphological investigations.

The study of the lithic artefacts was undertaken using attribute analysis and spatial distribution using GIS (Wojtczak 2014). For the micromorphological analyses, the oriented soil block HU 34/ was taken from the west profile section comprising archaeological layers 6a to 8a. In the laboratory, the sample was cast in epoxy resin under vacuum and cut using a diamond saw. Polished sections and two thin sections were produced (Beckmann 1997). The thin sections were described after Bullock *et al.* (1985). Sediment facies have been applied after the system established during the field campaigns (Meyer, 2001; Ismail-Meyer, 2009).

Layer formation processes, an archaeological perspective

The Hummal site is huge and until now only a small section of it has been excavated. The observations presented here are merely a first step toward the understanding of the site. The assembly of a single archaeological layer embodies a temporal component, whose duration is very difficult if not impossible to estimate. The period between the deposition of the first and last artefacts in the archaeological assemblages seems to include more than one occupation, only rarely are clear-cut and defined phases of occupation observable. Evidence from flint artefacts and Hummalian layers show that humans repetitively visited the site, and that each consecutive occupation may have left knapping waste and animal bones behind. Within the Hummalian horizons the evidence of reuse of lithic artefacts from older occupations is apparent; e.g. double patinated specimens scavenged from the same or older cultural horizons. This suggests that during the Hummalian period humans considered the dispersed, surface flint material from previous settlements as a source of raw material. This in turn points to the conditions in which the archaeological material was discarded and to possible explanations for differences in preservation. It points also to low sedimentation rates between occupation events.

Sand αh

The lithic artefacts from Layer αh are well preserved. Some are broken but do not present any edge crushing. 40% present blunt edges, while the edges of the rest are fresh and sharp. Some are covered by a faint white veil and 40% show a glossy, varnished-like surface (Fig. 5). Similar glossy flints have been noted on several spring mound sites in North Africa and the Levant and have been the subject of a number of studies. Masson (1982), who reported a similar phenomenon in other complexes from El-Kowm, describes it as a patina formed through either wind or water action. Jagher (1990) proposed that the agent causing the chemical destruction of the surface of the glossy flints from Hummal was warm, strongly sulphated groundwater. Further, he also put forward that the transition between patina and fresh break clearly shows that the gloss does not consist of a mineral base but was most likely generated by an erosion of the surface and then mechanical formation. However, Meeks (*et*

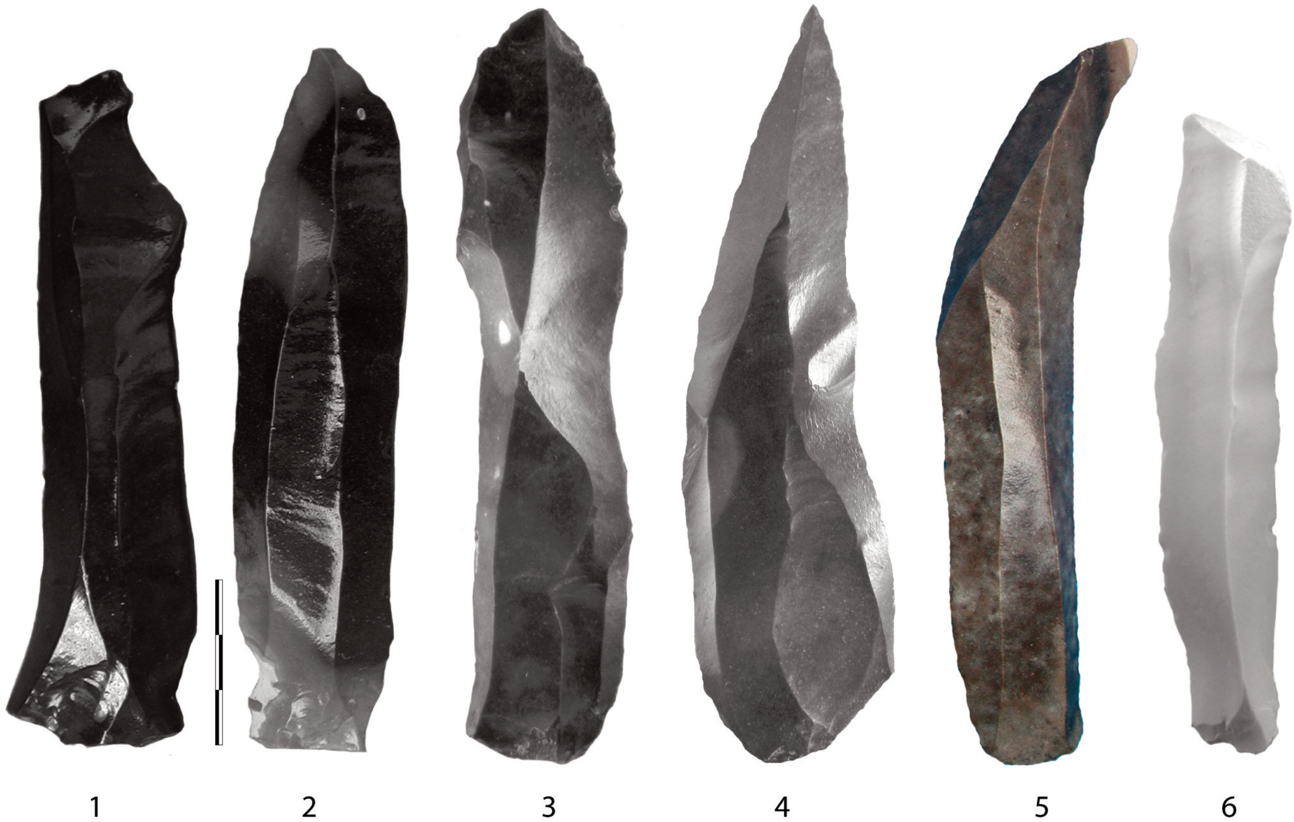

Figure 5: *Artefacts from sand αh; 1, 2) blades showing glossy patina; 3-6) well preserved blades (height of scale; 3cm).*

al. 1982) and Shackley (1988) contradict these results, arguing that such a glaze is a true chemical deposit associated with exceptional circumstances existing in artesian spring mounds ('glazed flints'). Proper observations agree with this interpretation and designate the glaze as secondary silica varnish. This hypothesis is supported by the fact, that there is clear evidence for neoformation of authigenic quartz cristals within these type of layers (Le Tensorer *et al.* 2007, 633).

Layers 7a and 7c

The lithic artefacts from layers 7a and 7c are well preserved. Nearly all were found in a sub-horizontal position in accordance with the inclination of layer. They do not show any edge damage, but at the same time a number of blades are fragmented. Several pieces demonstrate an orange patination, originating from iron oxide deposits. The majority of faunal material came from the western part and is highly fragmented. As a result, the number of identified bones is low. Furthermore, the surface preservation and edge sharpness of bones suggest that the burial took place relatively rapidly and that post-depositional forces were responsible for the destruction of the bones. It is possible that the observed organic intercalations became highly compressed over time owing to sediment overload. This would account for the high degree of bone fragmentation and also the breakup of several blades. These layers may correspond to short-term occupation during which blanks were at least partially produced and maintained on-site. Additionally, in Level 7c a small debitage workshop was excavated in a single square meter. All uncovered pieces, mainly composed of chips, were collected. They are slightly patinated, but still present sharp edges. It was possible to make a major refitting task (Wojtczak 2014; Wojtczak & Demidenko in preparation). Lithic specimens from this workshop were lying in horizontal position in three cm thick sediment. All others flakes from the same archaeological layer were found a few centimetres above or below this and randomly dispersed around them, showing no connection to the workshop. This confirms that the surface on which the flint knapper was working was quickly covered and therefore we can speak of an in situ position, possibly a single episode of site use, even a true 'living floor'. Interestingly, directly beneath the workshop a micro-sand dune of about 5m2 has been uncovered, possibly a dry zone in the surrounding swamp in which the knapper chose to work.

Layers 6c-1 and 6c-2

In Layer 6c-2 nearly all artefacts were found in a sub-horizontal position, similar to the inclination of the layer. 20% of lithic items present a grey patina. All are well preserved. Their sharp edges remain and thus seem to have been covered soon after deposition. Additionally, in Layer 6c-2 the high percentage of retouched pointed blades may suggest a task-specific location. The high percentage of small debris and chips come principally from tool production or tool re-sharpening. Layer 6c-1 contains only a few lithic pieces that present an identical patination to that visible in Layer 6b.

Layers 6a and 6b

Hummal's Layers 6a and 6b show the following characteristics: high density of artefacts, the presence of almost all stages of lithic production, evidence of on-site maintenance, the presence of many highly retouched specimens, and the frequency of recycling, with the majority of cores being exhausted and discarded at the site. These facts give hints for an intense occupation phase, with repeatedly used activity areas. The state of preservation of the artefacts from layers 6a and 6b indicates that taphonomic processes such as alteration was important, and also explains the small number of preserved bones, the majority of which are teeth. The majority of artefacts from both layers were broken. It seems that the lithic layers lay exposed on the surface for a certain time creating the possibility of a scenario of lithics from overlapping occupations and activity zones. The lithic material from both layers represents a single technological tradition.

Numerous burnt flints were collected from Layer 6b. The thermally altered artefacts were found in three main concentrations, around which other flints, burnt and unburnt, were distributed. In addition, the micromorphological analysis shows the presence of charcoal in layers 6a and 6b (Meyer 2001). This could point to the existence of hearths in layer 6b, which might easily have been overprinted by intensive trampling.

Nearly all the objects were found in a sub-horizontal position in concordance with the layer inclination. The white-grey patination of the lithic objects in both layers is homogenous. Some animal bones and two fragments of ostrich shell were also collected.

In Layer 6a, 90% of blades are broken and several artefacts show signs of edge damage (Fig. 6). The lithic collection of Layer 6b as a whole is characterised by the same state of alteration. Its patina is rather strong, homogeneous and of a white-grey colour. 65% of blades and 3% of flakes have undergone mechanical breakage. 18% of all artefacts show crushing or a series of pseudo-retouch removals. The three phenomena - erosion, mechanical breakage and crushing - are related to the post-depositional processes. The presence of the broken blanks observed at the time of the excavation, the fragments of which were easily refitted, also suggests mechanical disturbances to the artefacts. In the same way, some refitting of the broken elements made on 4m2 of the excavation testifies to a displacement of less than 1m, and thus an *in situ* breakage, probably mechanical in nature. However, time constraints meant that a systematic refitting of all broken artefacts was not possible. The bad preservation of the artefacts could be due to the effect of long-term exposure on the surface (low sedimentation rate) in addition to being trampled. Several experiments have shown that trampling can cause severe damage to artefacts. It leads to breakage, crushing, pseudo-retouch and vertical and horizontal displacement (McBrearty *et al.* 1998; Thiébaut 2007; Miller *et al.* 2010). In the case of the artefacts from layers 6a and 6b, breakage, crushing and pseudo-retouch are evident. Cryoturbation could cause similar damage, but this process has never been identified within the Hummalian sequences. The occurrence of a high degree of fragmentation in the faunal remains also lends weight to the trampling hypothesis (Frosdick, n.d).

Figure 6: *Blade from layer 6b, with strong crushing visible (height of scale; 3cm).*

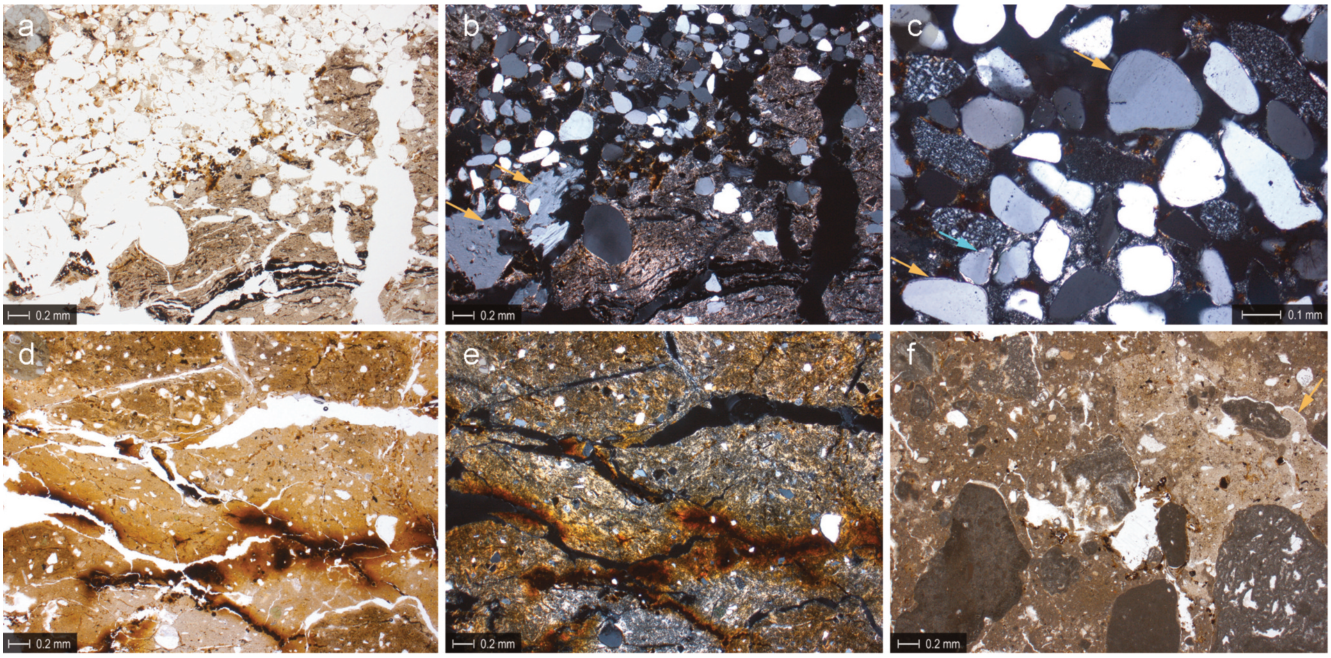

Figure 7: *a) Microphotograph from layer 7c in transmitted light (position see rectangle in Fig. 3e); at the base a brown coloured clay (macroscopically seen as black clay) with a black organic intercalation and the sand rich layer towards the top (quartz grains and pore space appear transparent). b) Same as Fig. 7a, with crossed polarizers; the birefringent clay appears in mottled beige, quartz grains in white to dark grey and pore space in black. Note the big secondary gypsum crystals (arrows). c) Detail from the glazed sand in layer 7c with crossed polarizers; two quartz grains show silica covering (orange arrows), other grains have a clay coating (blue arrow). Note also the chert sand grains with their mottled greyish-black appearance between the quartz grains. d) Microphotograph from layer 7a in transmitted light (position see the lower rectangle in Fig. 3c); the yellowish clay (macroscopically seen as green clay) shows strong ferric staining and precipitations following the cracks. The uppermost brownish clay contains highly fragmented, dark coloured organic matter. e) Same as Fig. 3d with crossed polarizers; the birefringence of the clay and their reticulated orientation due to shrinking/swelling of the clay can be recognized. f) Microphotograph from layer 6b in transmitted light (position see upper rectangle in Fig. 3c); the grey carbonate fragments are embedded in a brownish carbonate silt matrix; note also the beige clay aggregate on the right side (arrow).*

Layer 6b appears identical in all the sectors excavated and is easy to locate due to the regular presence of pebbles and blocks of limestone and travertine. These blocks although eroded were certainly brought into the site by hominids, as the type (limestone) and size of rock are not found naturally at this location and form an imitation of a living floor.

Layer formation processes reconstructed by micromorphology

The site formation processes of layers 7 and 6 can be described as follows (Fig. 3, 7).

Layer 7 and sand αh

The formation of the clay layer 7 involves several reflections:

- Clay formation: Layer 7 is rich in clay minerals belonging to the smectite group (Fig. 7a, b). This special typ of swellable clay can be formed in a milieu with strong evaporation and waters rich in magnesium and showing pH below 8. They may stem from an arid sabkha environment (Stängele 1997).
- Glazed sand formation: Microscopic observations show that the glazed quartz sand is covered by very thin silica rim (see Fig. 7c). This covering, a phenomenon also observed in other well mounds (see above; Shackley 1988), formed most probably due to water oversaturated in dissolved silica, when under high temperatures and neutral pH silica recrystallizes under high-pressure within the spring. Owen (1975) reports silica gel formation (gelatinous silica) under high temperature and elevated pressure, covering surfaces in slightly acidic milieus.

In fact, the two phenomena of clay accumulation and the occurrence of glazed sand are related to each other; the latter is only found below or inside layer 7, forming thin intercalations and small dunes (Fig. 4), and in the centre of the well (sand **α**h). Furthermore it is obvious, that from the carbonate depositional environment of layer 8a - a colluvium comprising rounded carbonate fragments - to the clay sedimentation in layer 7c, a major depositional change has occurred. This change is possibly caused by the colluvium formation or a change in water supply. However, the formation of carbonates stopped, or a drop in pH led to their dissolution. The origin of the clay itself could go back to aeolian processes (the next sabkha lies in 9km distance), or *in situ* precipitation in a magnesium-oversaturated milieu under neutral pH. Aeolian transport is attested by the sand, originating from a geological marine beach sand deposit (Meyer 2001; Pümpin 2003). Signs for *in situ* clay formation are its very fine layering, the fact that clay is not a usual component of the Hummal sediments, and the actual pH of the Hummal clays lying between 6.7 and 7.1 (the pH ranges of carbonate layers are 7.5 to 8.5; Meyer 2001). During clay accumulation, organic layers developed - most probably due to peat growth - possibly leading to a drop in pH (Fig. 7a, b) (Karkanas 2017).

Sand accumulation is connected to reinforced aeolian sand input, which could be related to climatic changes (missing plant cover during dry phases and/or stronger wind action?) or due to arrested sedimentation; when no other sediments form in the spring mound, sand may accumulate over time and form dunes around the well, a phenomenon observed in Tunisia (Roberts & Mitchell 1987). In fact, the fine layering of the clays could point to very slow clay accumulation (Meyer 2001). The glazed covering the grains seems to have developed *in situ*, as sand from other layers in Hummal does not show this varnish. It probably formed within the spring's water, oversaturated with silica. The sand then dried out, observed by red ferric precipitations within the sand followed by an occupation phase.

The glazed sand αh originated from layer 7, and has been translocated into the well in one or several very short events lacking strong water action, as the sands are very pure with no eroded sediments within, besides the flint artefacts. In the middle of the well, a further phase of silica precipitation led to the formation of cemented sand and glazed artefacts (Fig. 5.1-2). Clay accumulation restarted after the sand translocation (Fig. 7d, e) and continued until the formation of layer 6c. Organic matter decay and perhaps dissolution of carbonate led to sediment subsidence, causing *in situ* breakage of artefacts and bones within the clay.

To conclude: not all the processes which led to clay and sand accumulation are as yet well understood, but it is obvious, that a major change in the depositional environment occurred after the accumulation of the colluvium 8a.

Layer 6a, b and c

Layer 6c was formed under humid, carbonate rich freshwater conditions within the pool of the well. The biggest part of this layer has been eroded, leading to the formation of layer 6b, rich in reworked clay aggregates (from layer 7) and eroded carbonates (from layer 6c) (Fig. 7f). On the surface, huge quantities of artefacts were found; there are no signs that this layer is the result of a lag formation, as fine-grained particles are still present within the sediment. The deposition of layer 6a, a further colluvium, eroded parts of layer 6b and led to the formation of micrite sediment with rounded carbonate fragments. Strong ferric precipitations and impregnations in layer 7a point to a hiatus. It is not clear whether this hiatus is connected to the transition from layer 7a to 6c/6b or from layer 6b to 6a (Fig. 7d, e).

Reconstruction of the site formation processes

Archaeological observations offer the possibility of reconstructing human actions within the analysed layers, as short-term knapping workshops or intensively used living floors. Micromorphology can give information about the long-term environment during the formation of the layers connected to climate and/or tectonic changes, which led to changes in water regime. The major site formation processes can be described as follows:

Clay and peat built up formed during a warm climatic phase in a swampy environment (Layer 7). Aeolian sands accumulated within the pool of the well and got varnished with silica in a watery environment (Layer 7c). After regression, humans were present and at least one knapping workshop indicates a short occupational event, with quick burial of the artefacts. A major event (shifting dunes?) led to dislocation of huge quantities of sand including many artefacts, into the central part of the well. Furthermore, the artefacts and stratigraphic observations connect this event to layer 7; also Le Tensorer (2004: 229) placed this event between the Yabrudian layer 8 and the Hummalian layer 7. Water from the spring, rich in dissolved silica, led to the formation of cemented sand in the heart of the well. In layer 7c, the remaining artefacts were most likely protected by a covering of still water or vegetation (peat?), as very small flint splinters could be refitted together. From the plant layers, only very tiny organic intercalations within the clays have been preserved. Loss of sediment volume due to organic matter degradation and sediment subsidence perhaps enhanced by carbonate dissolution led to *in situ* breakage of artefacts and bones.

A water regime change stopped the clay formation and freshwater limnic carbonates precipitated within the well, leading to the formation of layer 6c. An important erosive event led to truncation of the major part of layer 6c, including parts of layer 7 and leading to the accumulation of the colluvium 6b, which in places has been slightly reworked during phases of changing water table. In drier parts on the gravelly surface of this layer, humans were present, leading to accumulations of patinated and broken artefacts. We suppose that part of the artefacts were exposed over longer periods on the surface and have been altered by animal and human trampling. Discrete signs of soil formation and surface weathering on some artefacts support this assumption. From the micromorphological point of view, layer 6b does not correspond to a typical lag deposit, as fine-grained sediments are still present. It can be concluded that the formation of layer 6b was initially influenced by an erosive event, removing part of layer 7 and layer 6c. Subsequently, sedimentation was affected by successive human occupation episodes over a longer period (thousands of years?), in which artefacts accumulated and were embedded, but without leaving real living floors or sterile intercalations. Therefore this layer can be regarded as a palimpsest. The colluvium 6a led to removal of a part of layer 6b and micrite sediment containing carbonate fragments was deposited. Probably a similar process on the surface of layer 6a is seen to that of 6b, as there further flint artefacts were found with identical overprints as from layer 6b.

Conclusions

This small scale study of five Hummalian layers from their eponymous site show how important it is to correlate observations from several disciplines and to get to a more precise interpretation of site formation processes, where natural regimes, single events and anthropogenic activities are highly interwoven to a complex pattern. Not all the natural processes could be precisely defined, but it turns out that major environmental changes had a big influence on preservation pattern of the flint artefacts and bones. The artefacts of this well mound illustrate on one hand very short events, being perfectly preserved without any erosional processes, and on the other the development of true palimpsests. Both patterns can give some indications about time spans encountered in this complex stratigraphy, i.e. very short-term and medium-term settlement patterns. The sediments themselves, where precipitation and dissolution phenomena were the major factors, must be seen as long-term buildups. Conversely, erosion and sediment dislocation processes with major influence seem to be the results of probably short-termed or even single natural events. The balance of these processes was strongly bound to the water supply of the artesian spring.

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