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Zurich-Alpenquai: a multidisciplinary approach to the chronological development of a Late Bronze Age lakeside settlement in the northern Circum-Alpine Region

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Abstract

The Alpenquai lake-dwelling is located on Lake Zurich, and can be considered as one of the rare Late Bronze Age lake-dwellings with a pronounced organic-rich cultural layer in the northern Circum-Alpine region. Within a larger research project, investigating the final abandonment of the lakeshores in the Circum-Alpine area at the end of the Late Bronze Age, this settlement has been investigated using a multidisciplinary research design. Combining micromorphology, archaeobotany, palynology, archaeozoology and material culture studies, the formation of the site is reconstructed, and the reasons for its final abandonment are sought. A highly dynamic lake system that caused a lake water level rise before 900 BC, a regression in the second half of the 9th century BC, and a later transgression, could be detected. The settlement appears to have been established during the lake regression, and abandoned during the transgression, proving a high degree of environmental adaptation by its inhabitants.

Keywords: lake-dwellings, Switzerland, Bronze Age, multidisciplinary approach, site formation, abandonment

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Introduction

The 3500-year long lake-dwelling tradition of the Circum-Alpine lakes cannot be seen as a continuous event. The precise chronology established by radiocarbon and dendrochronological dating techniques reveals phases of occupation and phases of abandonment (Magny 2004; Billamboz 2004). Climate change is typically mentioned as a trigger factor for those occupational cycles, but cultural factors should be considered as well (Pétrequin and Bailly 2004; Menotti 2003). However, the reason why the lake-dwellings disappeared within the Circum-Alpine region towards the end of the 7th century BC (Gollnisch-Moss 1999, Köninger 2001) is still a subject of scientific dispute.

A Swiss National Science Foundation (SNSF) multidisciplinary research project ('The End of the Lake-dwelling Phenomenon: Cultural *vs* Environmental Change') has been established at the Institute of Prehistory and Archaeological Science (IPAS), Basel University, to shed some light on this long-debated topic. As part of the project two samples from the Late Bronze Age site of Zurich-Alpenquai have been studied, incorporating micromorphology, plant macroremains, pollen and archaeozoological analysis. To evaluate the preservation of artefacts and possible cultural influences, an assessment of the material culture has also been conducted.

This article focuses on the following research questions:

- What was the interaction between the lake and the settlement environment?
- What happened during the last settlement phase(s) of Zurich-Alpenquai?
- Why was the settlement abandoned?
- How was the settlement integrated in the regional/interregional settlement/cultural context?

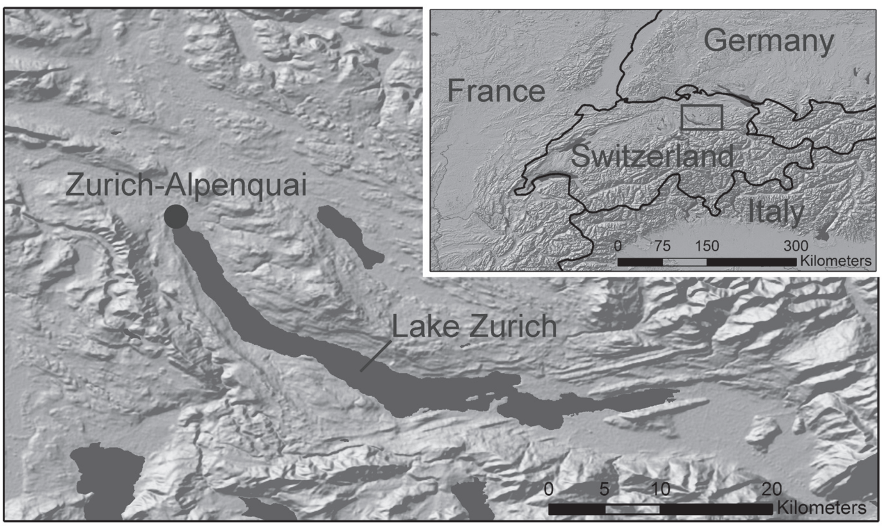

Figure 1. Location of the Lake Zurich area in Switzerland and location of the site Zurich-Alpenquai at the northwestern tip of Lake Zurich (Map created with base map from ESRI Data and Maps Media Kit 9.3, SRTM global shaded relief data and River/Lake Overlays).

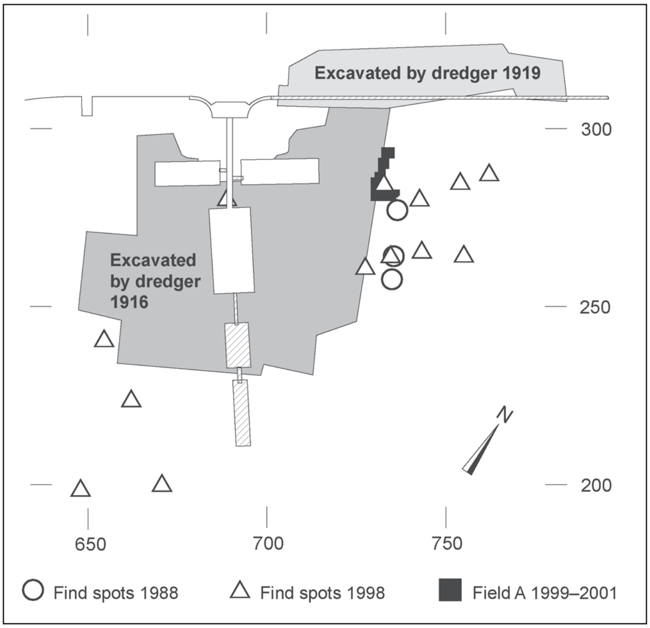

Figure 2. Plan of the Zurich-Alpenquai site with boat houses on jetty in the central part of the 1916 excavations. Grid size = 50m (© Kantonsarchäologie Zürich/Amt für Städtebau der Stadt Zürich).

The Zurich-Alpenquai lake-dwelling site

Zurich-Alpenquai was discovered during the construction of boathouses in 1916. The Swiss National Museum, under the direction of Ferdinand Blanc, collected large quantities of archaeological material by dredging the area. Similar studies were made when the quay was shifted further into the lake, in 1919. The most important result of these 'excavations' was that Blanc found 34 'hut locations' (concentrations of rocks and finds) and two cultural layers (Betschart 2001, 10).

Underwater archaeological investigations in the 1960–70s helped to determine the extent of the settlement and established that, despite the extensive dredging, the settlement area had been preserved. Furthermore, the cultural layers were observed more directly, and Blanc's observation of two cultural layers was confirmed (Büro für Archäologie 1976). The extensive underwater survey of 1988 revealed the damage pattern of the dredging, and a large area of exposed cultural layers. The inventory of the Zurich lakeside settlements, initiated in 1996, confirmed that the cultural layers were severely damaged and rescue excavations were carried out from 1999 to 2001 (Büro für Archäologie 2000). The excavation included a total of 60m^2 in the north-eastern area of the previously dredged area (Figure 2). Subsequently, the exposed areas were covered with protective geotextiles. Samples examined in the present work were taken during the 1999–2001 excavation campaign (Q622 and Q651; Figure 3).

A detailed report of the 1999–2001 campaign including dating information has been published by Künzler Wagner (2005). The stratigraphic sequence of the two profiles relevant to this study can be summarized as follows (see Figures 4, 5 and 6):

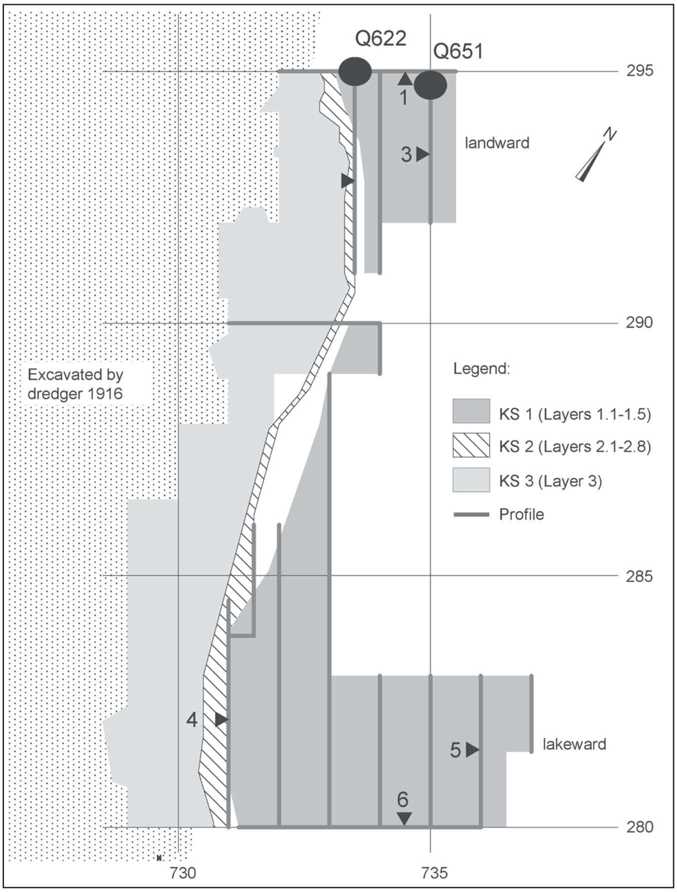

Figure 3. Plan of the 1999–2001 excavations with sample locations (dots). Grid size = 5m. (© Kantonsarchäologie Zürich/Amt für Städtebau der Stadt Zürich).

- Layer 3: Organic rich cultural layer above lake marl 0.4. Dendrodated to 1041 and 979 BC (dates from perforated base-plates). Attributed to settlement phase A.
- Layer 2.8: Mixture of lake marl and organic remains that can hardly be distinguished from the lake marl SE 0.3. Dendrodated to 976 BC (perforated base-plate). Phase A.
- Layer 2.7: Localised mixture of lake marl and organic remains. No dendrodates. Phase A.
- Layer 2.6: Organic layer with charcoal and woodworking debris. No dendrodates. Phase A.
- Layer 2.5: Gray and loamy sand. No dendrodates. Attributed to settlement phase B.
- Layer 2.3: Organic rich layer with woodworking debris and charcoal. No dendrodates. Phase B.
- Layer 2.1: Layer containing few organic remains, but very rich in charcoal and burnt pottery fragments. The dendrodate of 978 BC for a perforated base-plate in this layer can be considered a *terminus post quem* for the beginning of phase B. Regional pottery typology places building activities of phase B within the mid-10th century BC. Phase B (Sample Q622).

- Layer SE 0.2: Lake marl layer. No dating information. (Samples Q622 and Q651).
- Layer 1.5: Loam and sand mixed with organic remains. No perforated base-plates or vertical timbers were dated from this layer. Some piles dated to between 900 and 860 BC are stratigraphically combined with 1.5. Attributed to settlement phase C (Samples Q622 and Q651).
- Layers 1.3 and 1.2: Organic rich layers with woodworking debris and charcoal. One piece of construction timber from layer 1.3 is dated to 863 BC. It cannot be said whether the vertical lying timber with the youngest date of 844 BC belongs to layers 1.3–1.2 or to 1.1. Attributed to settlement phase D (Samples Q622 and Q651).
- Layer 1.1: Sandy layers with gravel and eroded pottery fragments. Mixed with modern debris (Sample Q651).

The stratigraphy of Zurich-Alpenquai essentially consists of two separate cultural layers (3–2.5 and 1.5–1.1) separated by lake marl (SE 0.2). A subdivision into four phases (A–D) has been made according to macroscopic and archaeological characteristics (Künzler Wagner 2005, 11–18; see Figure 4). With the analysed samples Q622 and Q651, the entire stratigraphic sequence of Alpenquai is not recorded.

Zurich-Alpenquai is a very important site as, besides the investigations of the reworked Late Bronze Age layer of Zurich-Mozartstrasse, it is the only Late Bronze Age culture layer of the lower Lake Zurich basin investigated using a multidisciplinary approach (i.e. archaeology and natural science).

Material and methods

Two monolith samples (Q622 and Q651), 50–60cm long, taken during excavation campaign 1999–2001, were used for the multidisciplinary investigations during the first three years of the SNSF project. Sub-sampling and treatment were undertaken on a disciplinary specific basis:

- For micromorphological analysis the monolith sub-samples were cut into blocks 0.25m long, air-dried, impregnated with an acetone-diluted epoxy resin, and then cut with a diamond saw. Fourteen glass covered thin sections (48 × 48mm), cut from the blocks, were prepared by Th. Beckmann (Gifhorn, Germany).
- For macrobotanical analysis a total of 26 samples were prepared from the two monoliths Q622 and Q651, and subsequently processed following the standard methodology of IPAS Basel. The wet-sieving was done with mesh sizes of 4, 2, 0.5 and 0.25mm (Brombacher and Hadorn, 2004; Jacomet and Kreuz, 1999; Jacomet *et al*. 1989).
- The 26 samples for pollen analysis were taken from the same sediment samples used for botanical macroremain analysis, and processed at the Institute of Plant Sciences, University of Bern (Moore *et al*. 1991).

The micromorphology slides were examined optically using a Leitz DM-RXP microscope (magnification of up to 630×) in plane-polarized light (PPL), crossed-polarized light (XPL), oblique-incident light (OIL), and also using UV-fluorescence (UVL) (Stoops 2003).

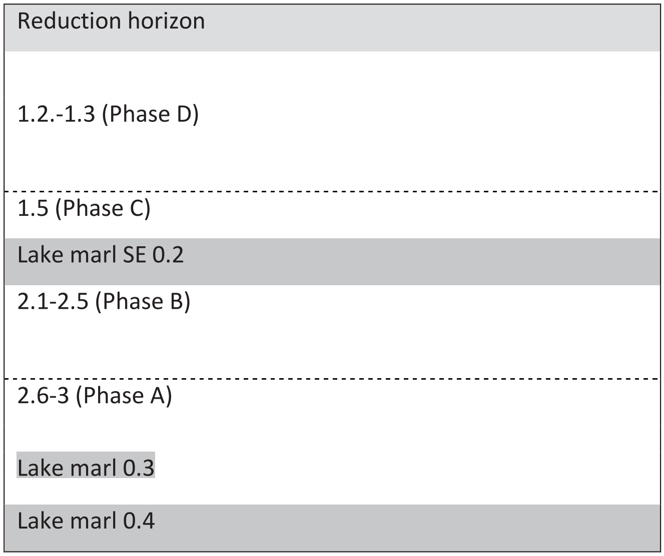

Figure 4. Schematic representation of the site stratigraphy. The dotted lines indicate the phase limits. (After Künzler Wagner 2005, ©Kantonsarchäologie Zürich/ Amt für Städtebau der Stadt Zürich).

The plant remains from all fractions were analysed with a stereo microscope (Leica MZ6, 6.3–40× magnifications), and the determination of plant residues was performed using the reference collection of IPAS (e.g. Cappers *et al*. 2006; Jacomet 2006; the nomenclature of plant taxa follows Aeschimann and Heitz 2005). To improve the comparability of results, the absolute counted value (residues in the complete sample) were unified to the number of residues per litre of sediment volume (= concentration of remains per litre of sample volume). The study of the 0.25mm fraction was omitted, because the analysis of individual fractions did not lead to the identification of new taxa. The identified plant species were then divided into groups based on their current ecological niche (Brombacher and Jacomet 1997). Amongst them, the riverine vegetation was of special interest, therefore divided into sub-groups according to the depth of water and degree of aggradation (aquatic plants/marsh plants/plants of wet grassland/shore pioneers; see Jacomet 1985).

Pollen samples were analysed using 400× and sometimes 1000× magnification, leading to the identification of up to 600 pollen grains per layer (pollen counting performed with TAXUS, and graph plotting with TGView 2.0.2). The pollen types were then divided in ecological groups.

To be comparable with the other studies, also archaeozoological material needed to be linked to stratigraphic layers. The 5303 animal bone fragments, published by E. Wettstein in 1924 did not, unfortunately, qualify, as they were 'excavated' by dredging. Only animal bones recovered during the underwater excavations of 1970 and 1999–2001 could be analysed.

The analysed bones (Table 2) are from field A, located northeast of the excavation area of 1916 (Figure 2). These are fewer than those collected in 1916 (the excavated area is much smaller), but about 90% of the total number (2145) could be attributed to one of the four settlement phases (with sub-layers). The excavation surface covered

Samples Q651 and Q622; Zurich-Alpenquai **Vertical thin sections; size 48×48 mm; thickness *c.* 30µm**				
Layers				
	Phase B	SE 0.2	Phase C	Phase D
Microstructure	massive with vughs	massive with vughs	complex	complex
Groundmass c/f limit: 5µm				
mineral	frequent subangular quartz (f.s.–c.s.)	few angular quartz (f.s.–c.s.)	common angular quartz (f.s.–c.s.)	few angular quartz (f.s.–c.s.)
organic	common tissue residues (c.s.)	few tissue residues (c.s.)	fine material, cell and tissue residues	consists chiefly of organic material
micromass	yellowish speckled clay; undifferentiated b-fabric	grey micrite; crystallitic b-fabric	grey micrite; crystallitic b-fabric	brown amorphous organic material (in zones)
Special features	diatoms, chunks of loam with crust, charcoal	few rounded loam aggregates, oogonia, mollusc shells	common loam aggregates, charcoal, bone fragments	gelified organic material, charcoal, dopplerite, fungal spores, dung fragments

f.s. = fine sand size, m.s. = medium sand size; c. s. = coarse sand size; g. s. = gravel size

Table 1. Summarized micromorphological description of Zurich-Alpenquai samples Q622 and Q651.

c. 60m^2 for the two youngest phases (C and D), whereas the two older ones (A and B) consisted of a narrow strip along the border of the 1916 excavation. It is important to point out that unlike micromorphological, macrobotanical, and pollen analyses, the archaeozoological finds cover the entire stratigraphic sequence.

Results

Micromorphology

The sample Q622 comprises the uppermost part of settlement phase B, the dividing lake marl SE 0.2 and settlement phases C and D (Figure 5). While in phase C significant amounts of lake marl can be seen, phase D consists of a loose organic layer with high quantities of charcoal. Sample Q651 only contained settlement phases C and D (Figure 5). The microstratigraphy of both samples is quite similar, therefore the results of micromorphological analyses (from both samples) are presented together (Table 1).

CULTURAL LAYER PHASE B (ONLY Q622)

Layer 2.1 contains little organic material, chunks of loam, wood, and a relatively large amount of charcoal. Due to the presence of burned pottery and a clay-ash mixture on top of the layer, a burning event can be presumed (Künzler Wagner 2005, 14). A tripartition of this layer is apparent at the micromorphological scale. The yellowish-grey (PPL) or

		n	g	Excavation
Phase D	total	1519	10332.4	1999
	layer 1.2	99	905.4	
	layer 1.3	1420	9427	
Phase C	layer 1.5	268	1649.6	1999
Phase A/B	total	198	2467.5	
	phase A	101	1237.8	1999
	phase A/B	61	1083.2	1970
	phase B	36	146.5	1999
Total		1985	14449.5	

Table 2. Number and phase distribution of the analysed animal bones (n = number; g = weight in grams).

dark grey (XPL) layer 2.1.1 is the first layer from which samples have been subjected to thin section analysis. Essentially, it consists of loam (or aggregated loam chunks) with a significant proportion of unsorted sand – the clay shows a speckled b-fabric. A thin crust on one of the loam aggregates shows a gradual colour change (from black to yellowish/white) towards the centre (Figure 7), which can be interpreted as the effect of a conflagration. Layers 2.1a and 2.1b provide a rather heterogeneous mixture of loam chunks, organic material, quartz sand and some rock fragments. Unlike 2.1.1, they also include a higher quantity of charcoal (up to 10%). In particular, layer 2.1b shows an increased organic content, and, with a coarse/fine ratio of 6:4 it has, by far, a larger share of fine material than layer 2.1a (8:2 ratio). Finally, diatoms in layer 2.1a indicate water influence.

Lake marl SE 0.2

Lake marl SE 0.2 can be considered a sequence of layers with an increasing proportion of micrite, which represents an accumulation of biochemically precipitated carbonates (Freytet and Verrecchia 2002). At the beginning of the sequence in SE 0.2b, still a high percentage of clay has been mixed with micrite, and no alignment of the components is detectable. In SE 0.2a, lake marl has become the dominant material, replacing clay, which occurs as multitude of small, rounded chunks. Moreover, Oogonia of chara demonstrate clear input from the lake, and the anthropogenic influence recedes in favour of a limnic dominated milieu. The lake marl is banded (and includes a large number of diatoms), suggesting calm and undisturbed conditions. It is possible that rounded chunks of loam, and the few organic remains, may have been eroded away and transported there from a nearby settlement.

Cultural layer phase C

The anthropogenically introduced components (charcoal, organic remains) rise noticeably from layers 1.5.5 and 1.5.2 to 1.5.1. A higher clay and sand content (in combination with a change of the coarse/fineratio from 1:9 (in the lake marl), to about 4:6 in 1.5.1), may indicate sediment input from surrounding building activities.

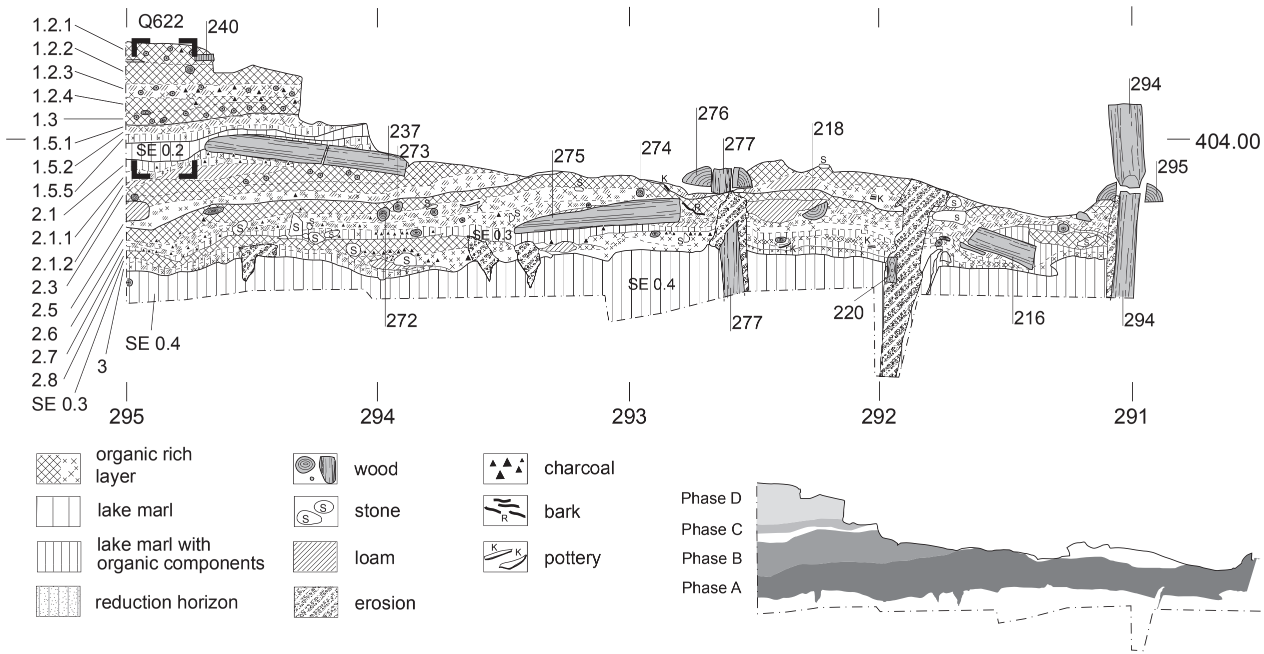

Figure 5 (above). Profile 2 with sample Q622. Grid size = 1m (© Kantonsarchäologie Zürich/Amt für Städtebau der Stadt Zürich).

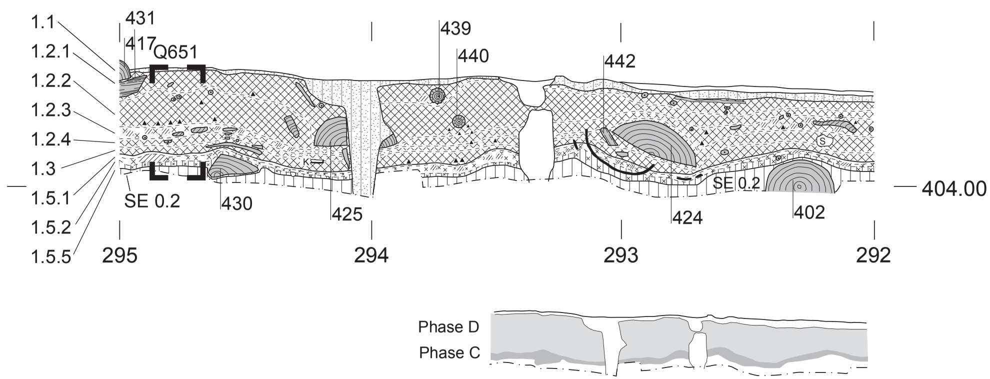

Figure 6 (left). Profile 3 with sample Q651. Grid size = 1m (© Kantonsarchäologie Zürich/Amt für Städtebau der Stadt Zürich).

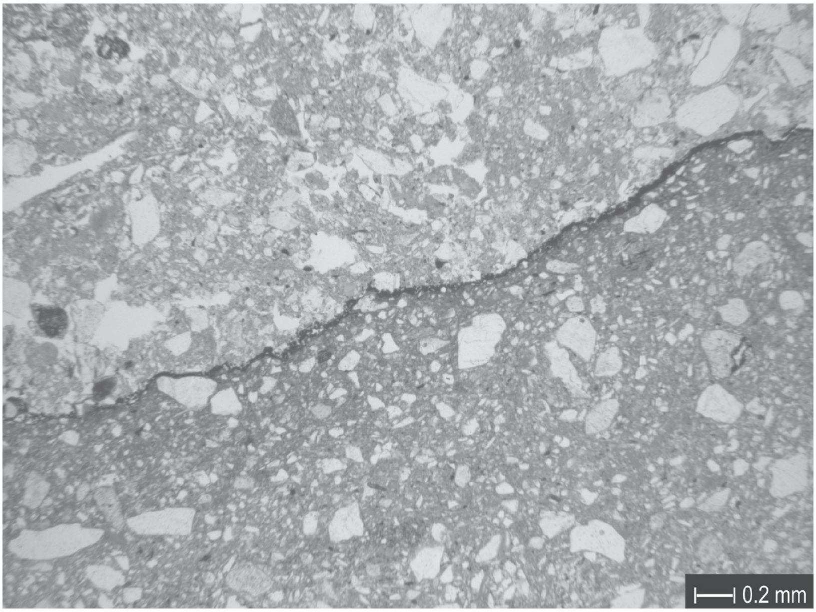

Figure 7. Photomicrograph of burnt loam chunk with surface crust in phase B (lower part of the picture). The loam in the upper part was not burned (plain polarized light).

Cultural layer phase D

Following a mixed layer of organic material and lake marl (1.3), there is a sharp transition to an entirely carbonate-free organic layer, which comprises unsorted sand and loam aggregates – this layer, and the succeeding organic one (1.2.4), have a large amount of amorphous fine organic material (detritus). The amount of detritus appears to increase at the top of the sample, which is associated with the occurrence of decay products (gelification of organic material and formation of dopplerite, an organic substance related to humic acid; Stolt and Lindbo 2010; Figure 8). Most intriguing is the complete absence of lake marl in the sedimentation of these layers.

Layer 1.2.3 differs significantly from the aforementioned organic-rich cultural layers with a relatively balanced ratio of fine mass to coarse components. This ratio shifts to such an extent that components of the coarse fraction prevail significantly. The sediment is rather looseley packed, but, in places, there are areas with amorphous organic fine material mixed with sand – the layers consist mainly of charcoal (up to 40%). The wood residues appear poorly preserved, while macro remains such as mistletoe and moss seem to be in better state of preservation. Despite the high amount of charcoal, some wood and other macro remains do not appear to be burned, indicating a secondary position of the charcoal (e.g. a midden deposition). The position of the samples lies within the activity zone of a hearth that can be attributed to settlement phase D (Künzler Wagner 2005, 62–63). The archaeological evidence is not clear, but the sample location might resemble the midden of a nearby house.

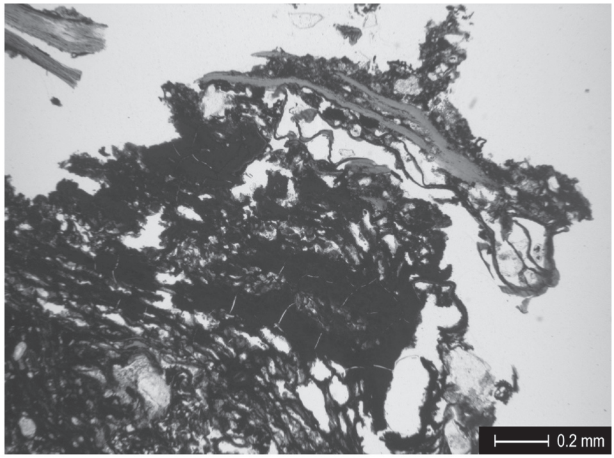

Figure 8. Photomicrograph of gelified organic matter in phase D in the center of the picture. The cracks have formed during the air drying of the sample (plain polarized light).

Similar observations could be made for the upper layers of phase D, while in 1.2.2 more amorphous organic fine material (partly gelified) is present. Large pieces of charcoal, burned twigs and pottery fragments with traces of secondary firing are indicators for burning activities. Although organic and inorganic fractions of biogenic origin clearly dominate, a continuous input of quartz sand (possibly related to the River Sihl, or nearby delta deposits) can also be observed. Layer 1.2.2 in Q651 is slightly different to that in Q622, particularly with reference to sand content, which increases to 20% with 40% organic material. This suggests a later disturbance of the sample – a phenomenon that can be seen in the palynological results as well.

Layer 1.2.1 is the uppermost cultural layer in the two profiles: a marked transition occurs to a very compact layer of fine organic material, which, however, has a larger proportion of fine/medium sand (under higher magnification it is evident that the fine material contains high levels of micro-charcoal). Zones of poorly preserved organic material, with some phosphates, indicate dung input into this layer. In sample Q651 part of this layer contains lake marl and a lot of sand, which is possibly the result of increased erosion/disturbance in the upper part of the sample; this marks the transition to the reduction horizon 1.1 (not included in the thin section analysis).

Macrobotanical analysis

With the exception of layer 1.1 (reduction horizon) the plant remains (e.g. opium poppy, flowers, petals of clover, etc.) show exceptionally good preservation (Figures 9 and 10). The plant remains are predominantly uncharred (90% of all residues). Grains and threshing residues as well as weed diaspores are predominant amongst the few charred remains.

The concentration of plant residues per litre of sediment (in cultural layers) can be considered very high, ranging between 5000 and almost 20000 units. The lake marl and the reduction horizon have a concentration of 400 to 2500 plant residues per litre. Local and regional settlement activities are apparent in all layers (including the lake marl SE 0.2); with the highest concentrations of cultivated/gathered plants, weeds, and

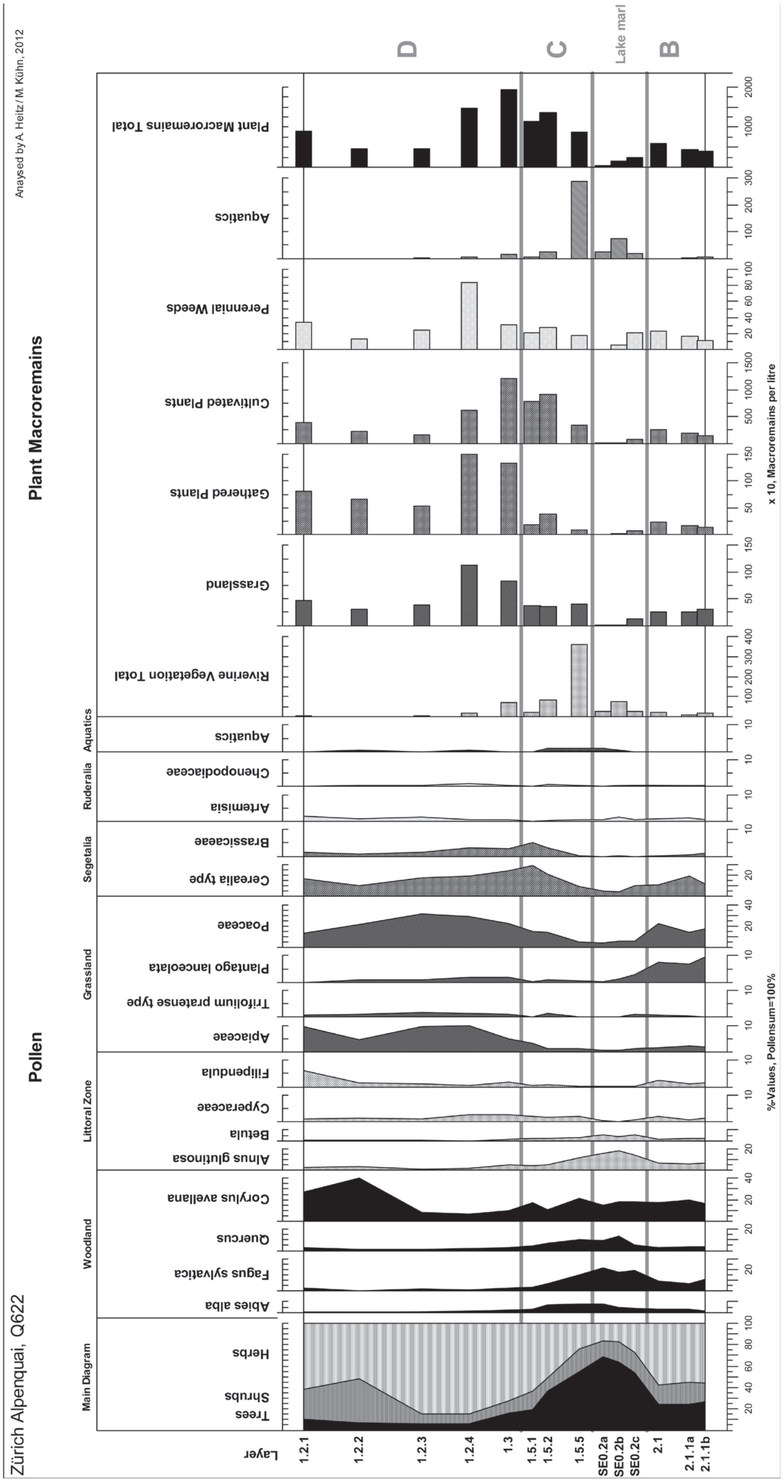

Figure 9. Sample Q622. Summary diagram of pollen and plant macroremain-analysis.

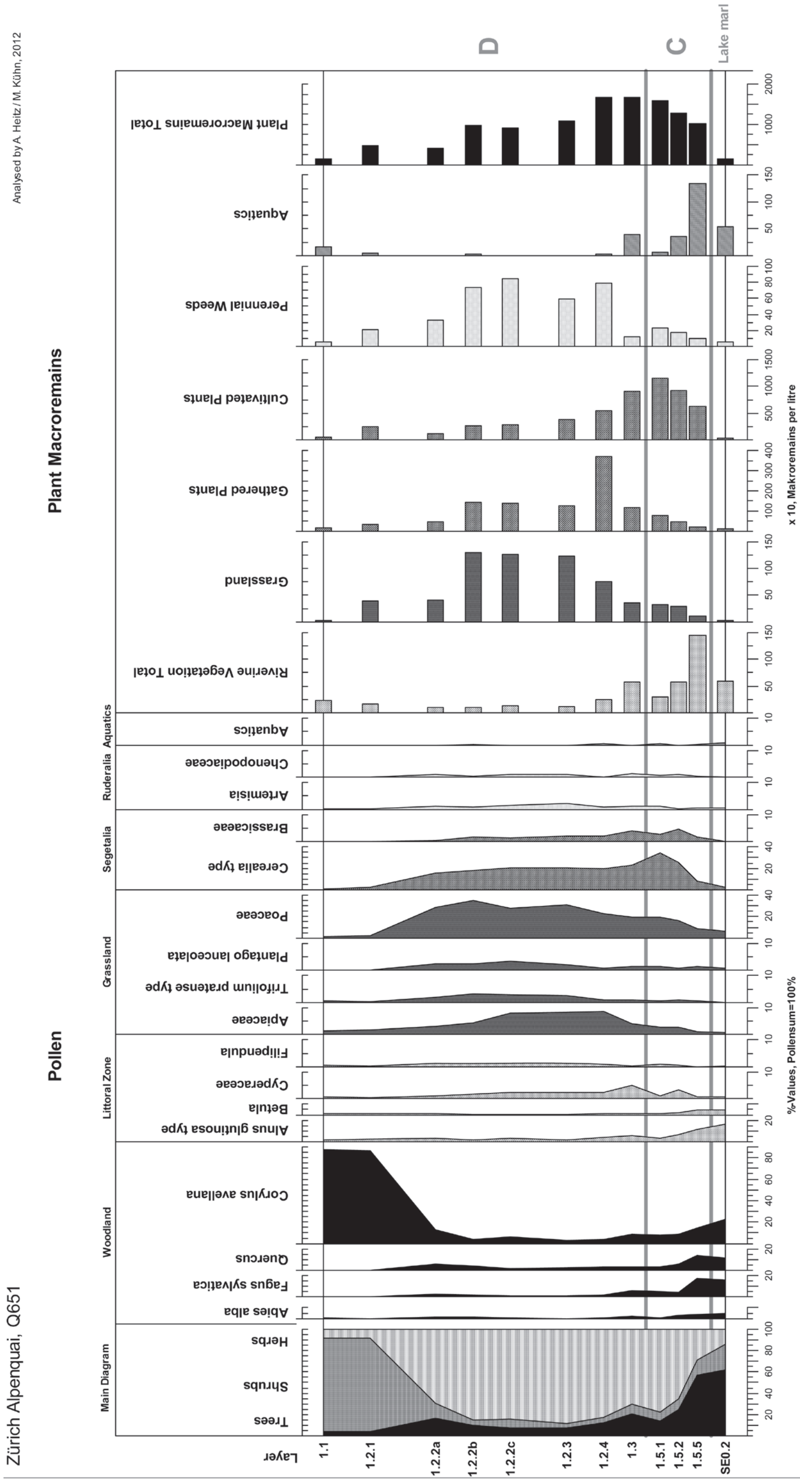

Figure 10. Sample Q651. Summary diagram of pollen and plant macroremain-analysis.

grassland species in the second half of occupational phase C, and at the beginning of phase D (see also Künzler Wagner 2005).

In general, the percentage of gathered plants is not very significant. The proportion of cultivated plants is 35% to 80% of all plant remains in the cultural layers, with ½ to ¾ of all cultivated plants being cereals. The following cereal types, in order of importance, were identified: barley (*Hordeum vulgare*), spelt (*Triticum spelta*), common millet (*Panicum miliaceum*), emmer (*Triticum dicoccum*), einkorn (*Triticum monococcum*), naked wheat (*Triticum nudum*), individual rachis segments could be assigned to hexaploid bread wheat (*Triticum aestivum*), and foxtail millet (*Setaria italica*). Pulses are represented by garden pea (*Pisum sativum*), broad bean (*Vicia faba*), and lentil (*Lens culinaris*). Numerous examples of the oil plant opium poppy (*Papaver somniferum*), the oil and fibre plant oil flax (*Linum usitatissimum*), and even the spice dill (*Anthum graveolens*) were present.

A great diversity of species is found within wild plants; and in particular, open area species (e.g. ruderal area, grassland) are well represented. They include many taxa of Mediterranean origin, e.g. bur chervil (*Caucalis platycarpos*), sharp-leaved fluellen (*Kickxia elatine*), small-flowered catchfly (*Silene gallica*), ivy-leaved toadflax (*Cymbalaria muralis*), common chicory (*Cichorium intybus*), and woad (*Isatis tinctoria*), which might have been also used as a dyestuff (Hall 1995; Zech-Matterne and Leconte 2010).

Similar to other Late Bronze Age sites, at Alpenquai we also have the presence of indicator species for meadows (for instance, cow parsley (*Anthriscus sylvestris*), hogweed (*Heracleum sphondylium*), common mouse-ear (*Cerastium fontanum*), red clover (*Trifolium pratense*), oxeye daisy (*Chrysanthemum leucanthemum*)), as well as for pastures (e.g. crested dog's-tail (*Cynosurus cristatus*), white clover (*Trifolium repens*), selfheal (*Prunella vulgaris*), creeping cinquefoil (*Potentilla reptans*), greater plantain (*Plantago major*), creeping buttercup (*Ranunculus repens*)) (Jacomet and Brombacher 2009; Jacomet and Karg 1996). All of this points to a mixed use of grassland both for pasturing and hay making for winter fodder (Kühn *et al.* submitted).

Cultural layer phase B (only Q622)

The presence of indicators for terrestrialization, wet grassland and even aquatic plants suggests a pronounced zonation of the vegetation along the lake shore, which was affected by wave action. Grassland plants attest the use of surrounding pasture land for both grazing, and for obtaining herbs and/or grass hay.

Lake marl SE 0.2

A lake transgression is reflected by a distinct increase in aquatic plants, whereas crop residues and weeds indicate the submersion and reworking of cultural layers.

Cultural layer phase C

Aquatic plants, shore pioneer vegetation, and indicator species for terrestrialization continue to be very well represented in layers 1.5.5 and 1.5.2, suggesting lake-level fluctuations, with peaks of aquatic plants, during low-water periods (*cordons littoraux* in French), common in phase C.

Cultural layer phase D

Gathered plants increase in importance while crop residues decline throughout phase D. The lowermost layer 1.3 shows a high degree of similarity to the uppermost layer of phase C 1.5.1. Phase D is also characterised by a change to wet grassland on damp ground without standing water; particularly striking is the increase in grassland, especially expressed by indicators for mowing (larger quantities of flower parts of *Trifolium pratense* and related taxa), at the expense of perennial ruderal weeds and riparian vegetation, which may indicate a change in use of the area. This conversion could be related to animal husbandry, proven by an increase of dung remains from indefinite ruminants (including sheep/goat) in the layers of phase D. A slight increase is also observed in indicators for eutrophication (bur-marigold (*Bidens*), knotgrass species (*Polygonum minus, P. hydropiper*), and meadowsweet (*Filipendula ulmaria*)). Towards the end of Phase D a general decline of plant residues and a small increase in water plants can be observed.

Reduction horizon (only Q651)

The importance of water plants increases within the reduction horizon; however, those plants are significantly less than in the lake marl SE 0.2, and layer 1.5.5.

Pollen analysis

The two pollen diagrams (Q622 and Q651, Figures 9 and 10) were collected 1.5m apart, on the landside area of the settlement (Figure 3). The two charts show very rich pollen layers in good correlation, allowing us to make positive conclusions regarding the depositional environments, the formation of the layers and the vegetation surrounding the settlement.

Cultural layer phase B (Diagram Q622 only)

In all three analysed samples *Alnus* and *Fagus* are the most common tree species – high values of *Plantago lanceolata* are also present. The latter are not only local accumulations, but they also occur simultaneously in a nearby pollen diagram taken in 1976 (AQ1–1976: Heitz-Weniger 1978), and may confirm the occurrence of extensive meadows, or can be interpreted as pioneer vegetation on fallow land, which could indicate a temporary abandonment of the settlement. The good level of pollen preservation may be an indication of damp ground during sedimentation.

Lake marl SE 0.2

The lake marl layer has a typical pollen spectrum compared to similar layers from other sites with high levels of tree pollen. The range reflects the surrounding forest vegetation between the two settlement phases. Dominant is *Fagus*, followed by *Quercus*, *Abies* (the most frequent conifer), *Corylus*, and *Fraxinus* (basically a mixed beech forest with sparse fir growth which possibly surrounded the subsequent settlement). The layer also contains charcoal particles and some herb pollen (typical for cultural layers), indicating a wash out of material from the cultural layer, and underwater sedimentation.

Cultural layer phase C

The two graphs show consistently balanced pollen spectra without local accumulations. In the lowest layer (1.5.5), both diagrams show very rich tree pollen (as usual in lake marl), indicating natural sedimentation in water. However, the amount of tree pollen declines towards the upper part of phase C, despite the cultural layer being influenced by the lake throughout the period. Reed vegetation can also be recognized, but its origin is probably located on the lakeshore, away from the settlement. The uppermost layer (1.5.1) contains a lot of pollen grains, which have been brought in the lake-dwelling perimeter by people. The water has a less discernible influence on this part of the layer.

Cultural layer phase D

In this layer, tree pollen has low values, while herb pollen occurs in high numbers across a large variety of species, which bear no signs of water-influenced sediment mixing. However, the depositional environment must have been constantly wet, as confirmed by the good state of pollen preservation.

The values of cereals, Brassicaceae, and of *Fallopia* show a declining profile, while ruderalia, grasses and grassland species increase slightly, indicating a further opening of forests and a development of meadows. *Filipendula* and Poaceae are better represented in the upper part of D, and are combined with slightly decreasing sedge values, whereas the reed areas appear to be developing into wet grasslands, possibly indicating a terrestrializiation of the area. In addition to the frequent pollen of *Trifolium pratense* in phase D, an extraordinarily high value of Apiaceae and biodiverse non-tree pollen indicate an open landscape. The settlement is located on moist, but not flooded ground; reed indicators and aquatic plants are almost completely missing.

In both profiles (Q622 and Q651), layer 1.2.3 has, in addition to molluscs and loam, significant charcoal remains and very high values of grassland pollen, pointing again to an open landscape.

The two graphs differ in layer 1.2.2: high values of *Corylus* are present only in profile Q622, but in the overlying horizon 1.2.1, the high values are shown on both charts. A local accumulation or a mixing with the overlying sediment (1.1) would be conceivable – this has also been suggested by Künzler Wagner (2005).

Reduction horizon 1.1 (only Q651)

The high *Corylus* values, with low levels of tree pollen and cereals, are exceptional. The spectrum resembles some dung samples from Alpenquai (Kühn *et al*. submitted) and Arbon-Bleiche 3 (Brombacher and Hadorn, 2004). The horizon must be interpreted as dung layer, or as the storage of hazel twigs brought into the settlement during spring. The hazel, a very important source of food for humans and livestock, certainly benefited and gained importance through the increasing openness of forests and farming activity in the Late Bronze Age and Iron Age.

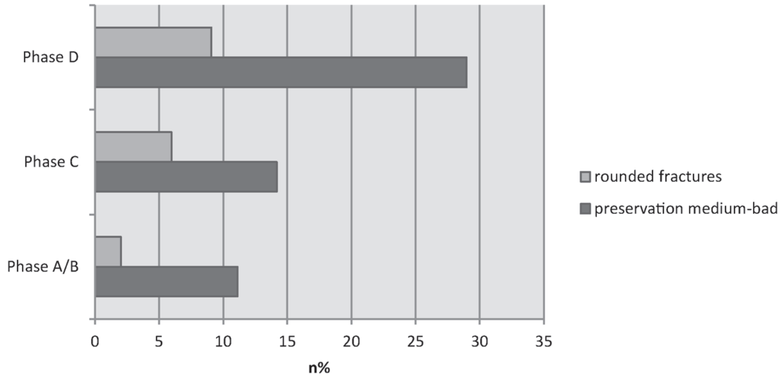

Figure 11. Distribution of animal bones with rounded fractures and medium-bad preservation by phase (percent by number).

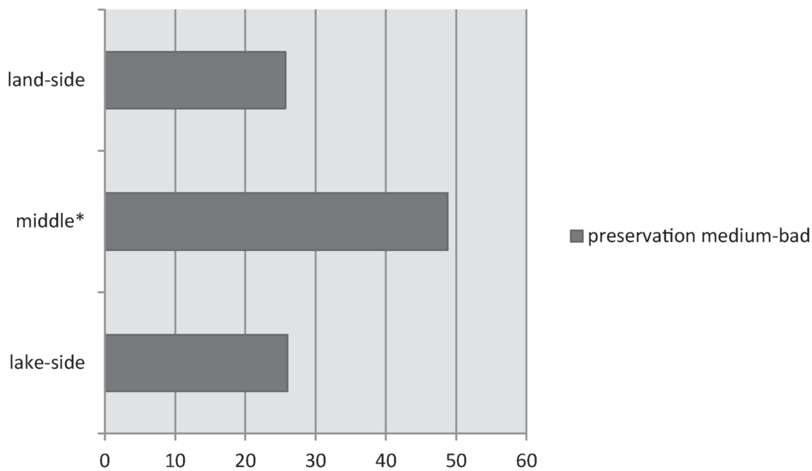

*Figure 12. Spatial distribution of medium-bad preserved animal bones. *middle = intermediate part of the excavated zone.*

Archaeozoology

TAPHONOMY

In general, bone surface preservation is good. From a stratigraphical point of view, the preservation deteriorates steadily from the lower to the upper phases (older to younger periods), and the numbers of bones with rounded fracture edges increases (Figure 11). Even considering the sub-layers in phases C and D, increasing levels of deterioration can be observed. Interestingly, there is no difference in preservation between the landward and the lakeside parts of the excavation area, as opposed to the bones of the middle area, which show markedly worse preservation (Figure 12); the

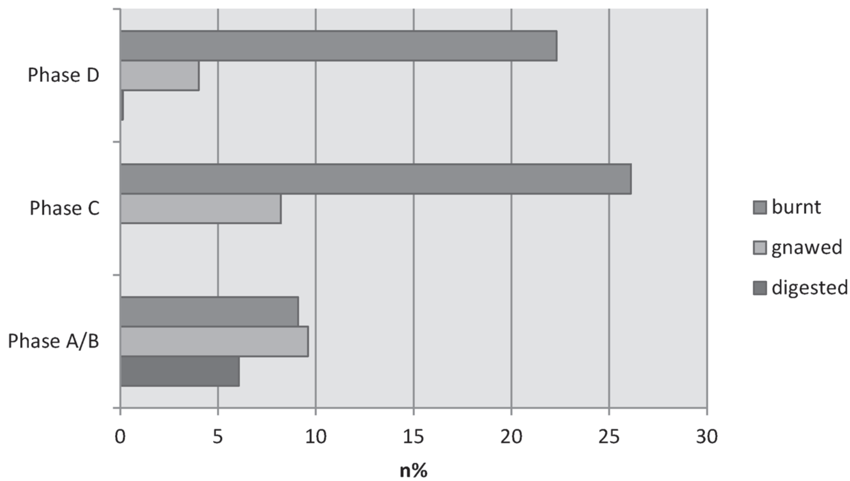

Figure 13. Distribution of burnt, gnawed, and digested bones by phase (percent by number).

reason for this is still unknown. The proportion of burnt, gnawed and digested bones displays a clear difference between phases A/B and C/D (Figure 13).

The interpretation of this taphonomic pattern is twofold:

- There is a deteriorating effect from bottom to top, possibly linked to the devastation of the layers caused by boat anchor chains, which resulted into the exposure of cultural layers (Künzler Wagner 2005, 8–9).
- There is a marked difference to be observed between phases A/B and C/D. The interlying lake marl already indicates that there was no settlement activity on the lakeshore during the high water level of the lake. After the settlers had returned to the shore and rebuilt the settlement, the activity zone (indicated by the higher percentage of burnt, gnawed and digested bones) changed, becoming slightly different than in the previous occupation.

Species representation and skeleton part distribution

As to be expected in the Late Bronze Age, the domestic species significantly outweigh the wild animals (Tables 3 and 4; Schibler and Studer 1998, 175). Considering meat consumption, represented by the weight of the animal bones, there is hardly any difference to be observed between the various phases, and the consumption of cattle meat is well predominant. There is a slight but continuous increase of cattle, and a decrease of sheep/goat between phases A/B and layer 1.2 of phase D (Figure 14). The species representation by number of fragments displays quite a difference between phases A/B and C/D, with a considerably higher proportion of sheep/goat, and smaller proportion of domestic pig in the earlier phases (Figure 15). There is also a statistically significant difference between phase C and the two sub-layers of phase D. The analysis

	Phase A/B		Phase C		Phase D	
	n	g	n	g	n	g
Bos taurus	58	1251.8	62	985.3	451	6465.5
Capra hircus			1	9.1	5	40
wahrscheinlich *Capra hircus*	1	8.9	1	13.6	5	45.9
Ovis aries	2	51.1	3	13.6	23	196.8
wahrscheinlich *Ovis aries*	6	19.1	3	34.7	17	146.2
Ovis aries/Capra hircus	63	236	48	132	198	752.7
total *Ovis a./Capra h.*	72	315.1	56	203	248	1181.6
Sus domesticus	25	333.1	60	238.8	280	1529.2
Equus caballus	1	411.2	3	55.6	7	140.9
Canis familiaris	13	85.1			2	19.1
total domestic animals	169	2396.3	181	1482.7	98.8	9336.3
*Cervus elephus**					6	51.5
Sus scrofa	1	7.9			2	68.3
Canis lupus	1	0.6				
Castor fiber					4	18.7
Lepus europaeus			1	1.3		
Salmo salar/Salmo trutta lacustris	1	0.6				
total wild animals	3	9.1	1	1.3	12	138.5
total domestic and wild animals	172	2405.4	182	1484	1000	9474.8
Cervid/Bovid big	1	4	5	49.8	28	189.1
Sus domesticus/Sus scrofa	3	25.5	2	12.2	15	111.7
Vulpes vulpes/Canis familiaris					1	0.3
Aves sp.					1	0
indet.	7	7.7	15	7.8	179	73.8
indet. size *Lepus*			1	0	1	0.1
indet. size *Ovis/Capra*	5	2.4	18	7.3	85	31.3
indet. size *Ovis/Capra/Sus*			3	3.5	3	4.9
indet. size *Sus*	2	3.4	11	9.8	23	27.1
indet. size *Bos/Cervus*	8	19.1	30	74	180	349.4
total indet.	22	32.6	78	102.4	471	486.6
Gallus gallus					1	1.5
Homo sapiens					1	63
Total	198	2467.5	267	1648.4	1518	10327

Table 3. Distribution of animal species by phase (n = number; g = weight in grams).

of skeleton part distribution is somewhat hampered by the fact that only small sample sizes are available. As far as the interpretation is concerned, there seems to be a slightly different composition for phases A/B, compared to C/D.

In conclusion, taphonomic processes confirm that the material of phase A/B represents a different settlement to the one in the phases C and D. Some differences can also be observed between the later phases, even though they are not as marked as the ones between phases A/B and C/D.

Phase D	*layer 1.3*		*layer 1.2*	
	n	g	n	g
Bos taurus	428	5960	23	505.5
Capra hircus	5	40		
Capra hircus?	5	45.9		
Ovis aries	21	189.7	2	7.1
Ovis aries?	15	124.5	2	21.7
Ovis aries/Capra hircus	191	740.3	7	12.4
Sus domesticus	263	1430.9	17	98.3
Equus caballus	7	140.9		
Canis familiaris	2	19.1		
total domestic animals	937	8691.3	51	645
Cervus elephus (without antler)	3	21.4	3	30.1
Sus scrofa	1	11.7	1	56.6
Castor fiber			4	18.7
Lepus europaeus				
total wild animals	4	33.1	8	105.4
total domestic and wild animals	941	8724.4	59	9474.8

Table 4. Animal species distribution within phase D only, by sub-phases (n = number; g = weight in grams).

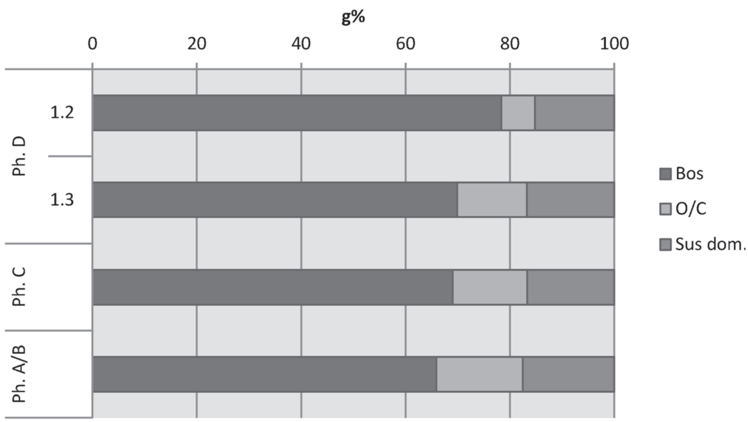

Figure 14. Meat consumption represented by the weight of animal bones (percent by weight; Bos = cattle, O/C = ovicaprids, and Sus dom. = pigs).

Material Culture Studies

The material culture remains from Zurich-Alpenquai divulge information regarding two aspects of the settlement and its inhabitants: environmental conditions and inter-regional social connections. Regarding the first of these aspects, the distribution of organic material culture is of relevance, whereas for the second, metal- and glass-work are informative. The excavations of 1999–2001 revealed numerous, non-structural, organic materials, such as basket work, tools, a wooden container, and a knife with

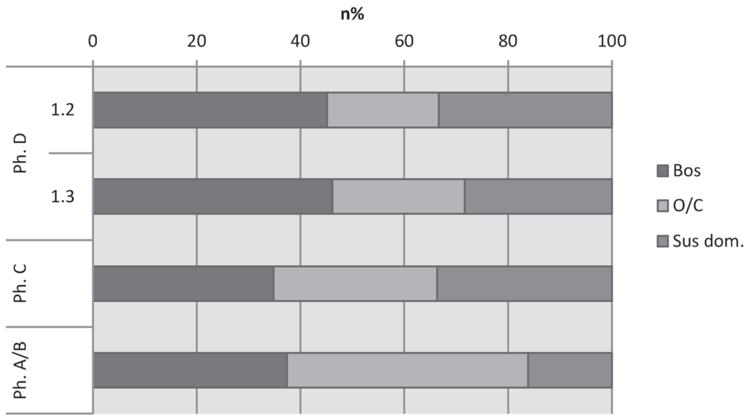

Figure 15. Representation animal species by bone fragments (percent by weight; Bos = cattle, O/C = ovicaprids, and Sus dom. = pigs).

intact handle and binding (Künzler Wagner 2005). Although frequently found in lakeshore settlements and wetland contexts, these materials, particularly basketry, are very rarely preserved in terrestrial contexts (Adovasio 2010). Unfortunately, comparative evidence regarding the degradation rate of basketry in waterlogged and dry sediments is currently unavailable, but the very survival of this material, and the condition of the knife handle, suggest that they were either deposited in a wet environment, or were waterlogged shortly after deposition. The distribution of these pieces across the extent of the settlement area suggests that there were waterlogged conditions throughout the site.

Two glass beads recovered during the excavations of the early 20th century, unfortunately without find context information, are of the *Pfahlbauperlen* type (Haevernick 1978). Comparable pieces are known from numerous lake settlements in the northern Circum-Alpine region, including Zurich-Wollishofen Haumesser and Zug-Sumpf. While these beads are distributed widely across the northern Circum-Alpine region, particularly around Lake Neuchâtel, and are dispersed in decreasing quantity to northern Europe (Jennings 2012), the only known manufacturing centres for them are in the Po Plain, northern Italy (Angelini *et al*. 2006; Bellintani and Stefan 2008). Thus, it is evident that the communities of Zurich-Alpenquai were connected, either indirectly or directly, to communities in the Po Plain, for example at Frattesina. The largest concentration (>200) of these beads, north of the Alps, is at the 11th-century BC lake-settlement Hauterive-Champréveyres, Lake Neuchâtel (Rychner-Faraggi 1993). They occur in fewer numbers (<10) in many other lake settlements in the northern Circum-Alpine region, and continue in circulation until the 9th century BC, for example at Ürschhausen-Horn (Gollnisch-Moos 1999). The presence of beads in the Alpine valleys, e.g. at Montlingerberg and Tec Nev (Haevernick 1978; Della Casa 2000), suggests the route along which these beads may have travelled from the Po Plain, though the concentration at Hauterive-Champréveyres may indicate that this settlement acted as a regional distribution centre. As a result, direct contact between Zurich-Alpenquai and northern Italy cannot be ascertained simply through the presence of these beads, but contact chains may have linked the two.

Metalwork pieces, such as the well-publicised bridal gear piece in the form of a horse, a combined cheek piece/bit assemblage, and Jenišovice cups (Mäder 2001) indicate cultural connections to northern and eastern central Europe. Furthermore, an axe mould from the site would apparently manufacture socketed axes of a style more widespread in the Carpathian Basin than in the Circum-Alpine region (Primas 2004, 125). Conspicuous by their absence are large metal objects of northern Italian influence. Unlike in the Lake Neuchâtel and Lake Geneva regions, no razors of north Italian/Proto-Villanovan form are known (Jockenhövel 1971; 1980; Bianco Peroni 1979). The horse shaped cheek piece shows some possible connections to northern Italian forms, in that these pieces are rare outside of the Italian peninsula; however, they are generally typologically and stylistically later than the object from Alpenquai (von Hase 1969).

Combining the indications from the metalwork and glass beads, it is possible that the community at Zurich-Alpenquai was not connected directly to communities of the southern Alpine region and Po Plain, but was indirectly linked through longer chains of communication via other settlements – possibly including those in western Switzerland.

Discussion

In general, the results of micromorphology, macrobotanical and pollen analysis support each other quite well, and allow cross-discipline statements regarding site formation and the development of vegetation in the vicinity of the Late Bronze Age settlement Zurich-Alpenquai to be made. The results of archaeozoology and material culture studies are slightly constrained by their lower resolution. Both disciplines struggle with the scarcity of stratified remains, and therefore, their results can only be partially combined with the other disciplines involved.

The analysis of animal bones detected a modern destructive influence from above caused by the anchor chains of private boats. The same effect can be observed (although to a lesser extent) in the micromorphological and palynological analysis; this is quite obvious as the bones were collected throughout the excavation area, while the two monolith samples were taken from better preserved parts of the settlement. The evidence of building structures is generally poor (Künzler Wagner 2005); therefore little can be said about the construction of the houses, except that they used the common lake-dwelling building technique of eastern Switzerland, which includes piles and perforated base-plates (see Menotti 2012, 132–137). Plant macroremains, pollen, loam in the micromorphology thin-sections and animal bones in the archaeological layers clearly reflect the influence of anthropogenic inputs.

Compared to other Late Bronze Age sites in eastern Switzerland, Zurich-Alpenquai is notable for its low proportion of cattle and the comparatively high proportion of sheep/goat. This is especially interesting in light of the nearby lake-settlement Zurich-Grosser Hafner, which is (partially) contemporaneous to Zurich-Alpenquai (Künzler

Wagner 2005, 8). In fact, Zurich-Grosser Hafner has the lowest proportion of sheep/goat, and the highest of domestic pigs of all the eastern Switzerland lake-side dwellings. Whether this is due to a different function of the settlements, taphonomy, or particular excavation issues, cannot be fully determined.

Main characteristics of the different phases

- Pollen and macroremains in the cultural layers of phase B indicate the presence of extended cleared areas and of grassland (Jacomet and Brombacher 2009). This phase is definitely followed by a rising lake level and the erosion of the cultural layer. The low organic content, a dominance of loam chunks, and the evidence of diatoms in thin-section analysis support this statement. If we combine micromorphological and archaeological analyses (Künzler Wagner 2005, 14), this situation can be interpreted as an eroded burning horizon.
- The subsequent lake marl layer SE 0.2 reflects the increasing water influence (transgression of the lake). Cultivated plant remains indicate a mixing of the sediment with part of the cultural layer, or in-wash from neighbouring settlements. The banded lake marl layer attests a rather calm deposition, with a water level high enough to prevent that layer from being influenced by wave action. This intermediate hiatus is well known for eastern Switzerland and the Lake of Constance region (Schöbel 2010).
- Cultural layer phase C is continuously affected by the lake. Only in the upper horizon does the water influence start to decline.
- A further opening of the forests and an increase in meadow land is clearly detected in cultural layer phase D. This matches the slight increase of cattle, shown by animal bone analyses. A lesser influence of water correlates with a dryer period, which is also observed in Ürschhausen-Horn from *c*. 870–850 BC (Gollnisch-Moos 1999, 146).

Development towards a more terrestrial environment

In general, a tendency to a rather drier environment can be detected at the beginning of phase D. This period of terrestrialization is even more clearly shown by the contemporaneous layers in pollen diagram AQ1–1976 from the border of the settlement (Heitz-Weniger 1978). The pollen spectrum contains a peak of vesiculate pollen (*Abies*, *Picea*, *Pinus*), which accumulates on the banks, as well as high values of Cyperaceae. It is therefore clear that profile AQ1–1976 corresponds to the flooded area of the settlement and the reed belt, while the two samples (Q622 and Q651) of the newly investigated area come from the landward of that line (Figure 2). Phases of terrestrialization on the shores of lower Lake Zurich are documented several times, from the Corded Ware period onwards (Pressehaus, AKAD, Heitz, unpubl. report).

The continuing decline of diaspores of aquatic plants (signs of terrestrialization), and a simultaneous increase of indicators for wet grassland and shore pioneer vegetation can be seen as the development of a less flooded area near the settlement. This is supported by the complete absence of lake marl in the micromorphological analysis. The increase of perennial ruderal and grassland plants, especially mowing indicators ('hay'), as well as regularly occurring dung, argue for a change in animal husbandry within the site, with ruminants (sheep/goat) becoming more predominant.

From layer 1.2.3, a general decline in plant residues is documented, which may indicate a slight relocation of the settlement, from the original settled area.

Flooding of the settlement

The slight increase of water plant diaspore in the upper layer of phase D (1.2.1) and in the reduction horizon suggests a new rise of the lake level, which may have ultimately led to the abandonment of the settlement. The previously analysed core AQ1–1976 also shows that the lake level indeed rose between the latest phase of the Late Bronze Age (Ha B3) and the Roman period. Alluvial forests with *Alnus* and *Betula* began to expand, and at least the periphery of the settlement was flooded again significantly. Consequently, an occupational hiatus in the upper limit of the cultural layer (today's 'reduction horizon') is presumed. The results are supported by the observations of Blanc (in the early 20th century), who believed in a settlement shift towards the shore in the recent settlement phase (Mäder 2001, 20) (see layer 1.2.3, above).

The results obtained at Zurich-Alpenquai are consistent with the hiatus in lakeside settlements commonly explained with climate deterioration (with consequent flooding and lake level fluctuations) in the northern Circum-Alpine region of central Europe in the later half of the 9th century BC (Magny 2004; Speranza *et al*. 2000; Haas *et al*. 1998; van Geel and Renssen 1998; also Jacomet 1985; Heitz-Weniger 1978). This climatic instability may have led to the abandonment of the lakeshores, and have triggered the emergence of new forms of settlement and subsistence strategies. However, the theory of (supra-) regional phases of high or low lake levels driven by solar activity as the main forcing factor has been recently contested (Bleicher 2013, but see Magny *in press*). Further support for this interpretation can be found in the contemporaneous settlement Ürschhausen-Horn (Lake Nussbaum; Switzerland), which is believed to have been abandoned in connection with the rising water level of Lake Nussbaum (Haas and Hadorn 1998; Gollnisch 1998). In recent research, however, there is general agreement that not only climatic influences, but also aspects of culture and new forms of communication have contributed to the change in lifestyle (Pétrequin and Bailly 2004; Jennings 2012). The results of the material culture study show that the settlement was integrated in an interregional settlement/cultural system. Unfortunately the data are not precise enough to identify changes in this integration pattern between the different phases.

Conclusions

The results clearly show that the environment of the four occupational phases of Zurich-Alpenquai was subject to continuous transitions. From phase A to the end of phase D, only *c*. 200 years elapsed, including a significant lake-level transgression, just before 900 BC (layer SE 0.2). In the course of phase D, a subsequent regression of the lake can be observed, leaving a humid, but not flooded environment. A last transgression is finally noticeable in the rather damaged most-recent layer (1.2.1). This dynamic development of the settlement can be summarized as follows:

- A highly dynamic lake/settlement relationship during the final period of Late Bronze Age could be detected – this corresponds to similar oscillation of Lake Nussbaum and Lake Constance.
- The older settlement phases are heavily influenced by the lake which showed a continuously changing water level
- The last recorded settlement phase (phase D) can be considered as a relatively dry period, without any influence of the lake
- The very last settlement phase might be related to the dendrodate 844 BC, but was eroded already during a later lake-level change

Zurich-Alpenquai shows a very dynamic occupational pattern throughout the various phases. The slight relocation of the settlement shown in the second last stratigraphic layer (1.2.3), and the final abandonment argued by the last layer (1.2.1) reflect contradicting, yet stereotypical environmental-deterministic explanations as to why the settlement was abandoned. Climate deterioration with consequent lake-level transgression towards the second half of the 9th century BC, may lead us to accept the easiest explanation for the final abandonment. However, the partial absence of the crucial last occupational layer (nevertheless associated with a reliable dendrochronological date (844 BC) from a house component), leads us to wonder as to whether there is more to it than meets the eye. We have certainly seen examples of lake-dwellers' resilience towards climatic and lake-level variations before (see Arbogast *et al*. 2006; Menotti 2009), but maybe in this case, the climate component did play an important role. However, the ultimate reasons why the settlement was left for good, still remain shrouded in mystery, and must be sought elsewhere!

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