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Ceramics as indicators of Late Bronze Age environments at Zürich-Alpenquai (Switzerland)

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Abstract: Lake-dwellings in the northern Alpine region are renowned for their extraordinary organic preservation. In addition to organic remains, thousands of ceramic sherds are also recovered. This paper addresses ceramic sherds from the Late Bronze Age site Zürich-Alpenquai, and assesses over 2000 sherds for indications of erosion and abrasion in addition to quantifying sherd size and plotting the spatial distribution of these factors. Recording such wear patterns can provide indications of deposition practices in addition to environmental conditions pre- and post-deposition. In this manner the study of ceramic remains from wetland sites for abrasion can complement environmental studies addressing conditions at the time of artefact deposition, and contribute to discussions of influences for lake-settlement abandonment.

Keywords: Lake-dwelling, ceramic abrasion, deposition context, environmental conditions, wetland archaeology

1 Introduction

Excavations and investigations at the lake-dwelling site Zürich-Alpenquai between 1999 and 2001 produced a large corpus of material from a relatively limited excavation area of 60 m^2 (Künzler Wagner 2005). In addition to organic materials, stone- and metalwork, over 170 kg of ceramic material was recovered. Stratigraphic and dendrochronological analysis indicates that the site was occupied throughout the entire Hallstatt B period (*c.* 1050 – 800 BC; Figure 1), though some periods of occupation hiatus occurred, dividing settlement into several phases (Künzler Wagner 2005, Betschart 2004, Huber 2005, Kotai 2005). The ceramic material has been typologically divided between the various phases of occupation, dependent upon their stratigraphic position, and stylistic and technical attributes (Künzler Wagner 2005, Roth 2005).

It is generally assumed that lakeshore settlements, such as Zürich-Alpenquai, were abandoned during periods of unfavourable climate as a direct result of climatic deterioration and rising lake water levels (*e.g.* Künzler Wagner 2005, Menotti 2001), but other influences, such as depletion of resources in the settlement region could also have influenced abandonment (*e.g.* Arbogast *et al.* 2006). Despite the well documented evidence for a climatic decline at the end of the Late Bronze Age (*e.g.* Magny 2004), there has been some recent debate as to how synchronous such changes in lake-level were across the broader Circum-Alpine region (Bleicher 2013). In fact, the number of lake-dwellings extant in Zürich Bay could be seen as an indicator both in favour of, and arguing against a climatically driven model. On the one hand, it could be

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suggested that settlements were moving around because of fluctuating water levels, with the number of sites reflecting the lake-dwellers desire to reside near the water's edge but recurrent relocation of sites to respectively higher or lower areas. On the other hand, Zürich Bay – especially along the lake foreshore – is relatively flat with a slight height gradient (see GIS models in Menotti 2001), and it must be questioned how effective such a relocation might have been over the short term – especially if it is assumed that the lake-dwellers could comprehend mid and long term patterns of change. Furthermore, ceramic and metalwork typological evidence (in addition to dendrochronological dating) suggests that some settlements – such as Zürich-Alpenquai and Zürich-Wollishofen Haumesser – were broadly contemporaneous (Mäder 2001a).

A recent multi-disciplinary assessment of environmental indicators using samples recovered during the 1999-2001 excavations sought to clarify the inundation–abandonment hypothesis for the various Late Bronze Age settlement phases at Zürich-Alpenquai (Wiemann *et al.* 2012, sample locations marked in Figure 3). The environmental assessment by Wiemann *et al.*, can, to a degree, be seen as suggesting somewhat contradictory conclusions. This partially arises from the competing scales of the primary forms of analysis employed in the paper: micromorphology, botanic micro-remains (pollen) and botanic macro-remains (seeds). Even though the different techniques exploited the same profile samples, they identify factors affecting different scales. Micromorphological analysis primarily identifies conditions within the immediate location of the sample: influences from the sample location – for example anthropogenic trampling, sweeping/cleaning, inundation, conflagration – relate specifically to the location of the sample, and conditions even a few meters away could be very different. Botanic macro-remains reflect a broader scale, likely reflecting the plant species found within the proximity of the village, with remains either brought in through deliberate economic activities (crop processing), accidental carry in (*e.g.* foot traffic) and natural ingress (*e.g.* windblown, water borne). Pollen remains potentially provide the broadest scale of environmental interpretation, reflecting a landscape and environment significantly larger than the settlement. When combined, the three disciplines can provide a significant insight to the environment of a particular location, traversing the small to the broad scale. What can be seen in the example of Zürich-Alpenquai (Wiemann *et al.* 2012) is some correlation between the indicators for a drier and more open environment (based on plant species from pollen and macro-remains) with less influence of the lake (absence of stratified lake-marl in micromorphological samples) during early stages (Layer 1.3) of settlement phase D, turning towards a wetter environment during the latter stages (Layer 1.2.1) (Figure 1).

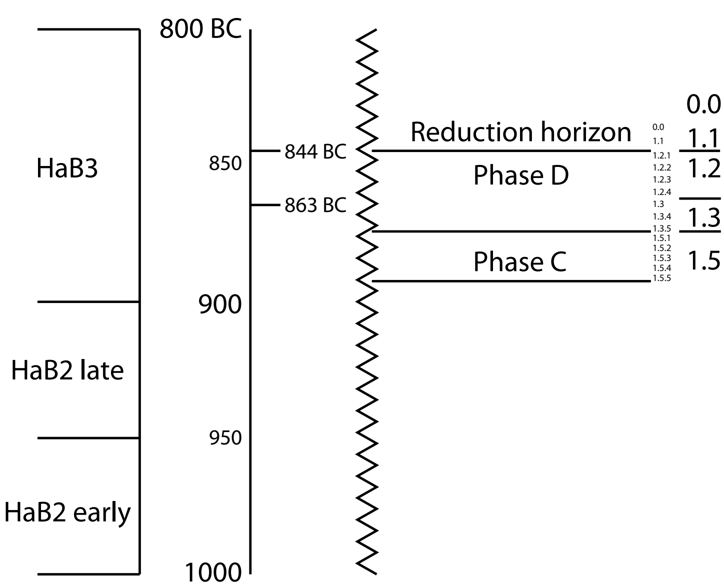

Figure 1. Dating and chronological setting (Hochuli *et al.* 1998), and phase definition, dendrochronological dates (844 and 863 BC), and stratigraphic layer sequence of Zürich-Alpenquai Phases C and D (after Künzler Wagner 2005). Zigzag line denotes separation of absolute dates and stratigraphic layers.

As a supplementary material culture study to the assessment of Wiemann *et al.* (2012), ceramic remains from Settlement Phase D were examined for indications of erosion in order to establish potential deposition conditions. Given the number of lake-dwellings known in the region of Zürich Bay both studies may provide useful insights which can be transferred to other Late Bronze Age sites in the area, but this case- or test-study is a stand-alone assessment of the remains from the limited area excavation of Zürich-Alpenquai without consideration of ceramics from other sites.

2 Methods

Over 2000 sherds were studied by the author at the Zürich Cantonal Archaeology department, Dübendorf, Zürich (Kantonsarchäologie Zürich, the conductors of the 1999-2001 excavations and holders of the ceramic assemblage). All sherds were visually assessed along their edges for erosion/abrasion according to a four point classification system (Table 1), following that proposed by Edwards (2009, see also Sánchez-Polo, Blanco-González 2014), which is itself an elaboration of a system proposed by Sørensen (1996). Any evident adherences to the ceramic surfaces were also noted (as indicators of relatively protected deposition conditions), as were traces of secondary burning – which may be of interest for considerations of the processes of settlement abandonment, such as deliberate destruction by fire – and particularly evident surface erosion. Furthermore, the approximate (nearest cm) maximal and minimal dimensions of the sherds were recorded by visual estimation. Although specific features and points of interest were photographed, a policy of complete and comprehensive photographic recording was not undertaken. During the recording of sherds it became apparent that individual sherds—particularly the larger ones—could have multiple levels of erosion along their edge (Figure 2). In this event each level of erosion was recorded.

Table 1. Recording system employed to categorise states of erosion of sherds (*cf.* Edwards 2009).

Value / Class	State	Characteristics
1	No or very little abrasion	Fresh breaks – snug refit joins; Sharp edges; Surface flush to edge
2	Low abrasion	Small gaps visible on refit edges, Slight wear on edges; Surface near flush to edge
3	Medium abrasion	Refits blunted; Blunt edges; Surface receding from edge
4	High abrasion	Rounded edges; Surfaces receded from edge

Varying levels of cleaning had previously been undertaken on the ceramics. Those items which had previously been studied and reassembled (Künzler Wagner 2005) were well – and carefully – cleaned during the previous studies, ensuring that the sherds were free of lake sediment *etc.*, but with intact adherent residue (where applicable). In contrast, many of the sherds which were not re-assembled appeared to have undergone relatively little post-excavation cleaning, in some cases retaining slight visible adherences of lake sediment. There were no signs of over-cleaning on the sherds (aggressive brush marks, *etc.*) and the expertise and skills of the excavation team and conservation team must be sufficiently trusted to assume that minimal damage/abrasion will have occurred post-excavation to the sherds; such damage must, however, always be considered a possibility – but again, no aggressive cleaning marks were observed.

Closely associated to the issue of post-excavation (cleaning) damage is the consideration of the ceramic fabric. Identification and classification of the ceramic fabric was undertaken by Künzler Wagner (2005) for the primary publication of the 1999-2001 excavation, and so was not repeated for this study. Ceramics were classified as fine, coarse-fine, fine-coarse, or coarse wares (as at other contemporary sites – Nagy 1999). The temper, primarily quartz with other minerals such as verrucano, was assessed through visual examination of the sherd edges, and where possible, on eroded surfaces, with classification in to a nine category quantitative-qualitative matrix (Künzler Wagner 2005, 27). The wall thickness of the relative types was variable, but with predominance of 5 mm for fine ceramics, 6 mm for coarse-fine, 7 mm for fine-coarse, and 8-10 mm for coarse (Künzler Wagner 2005, 27-28). Essentially different grades of ceramic were internally

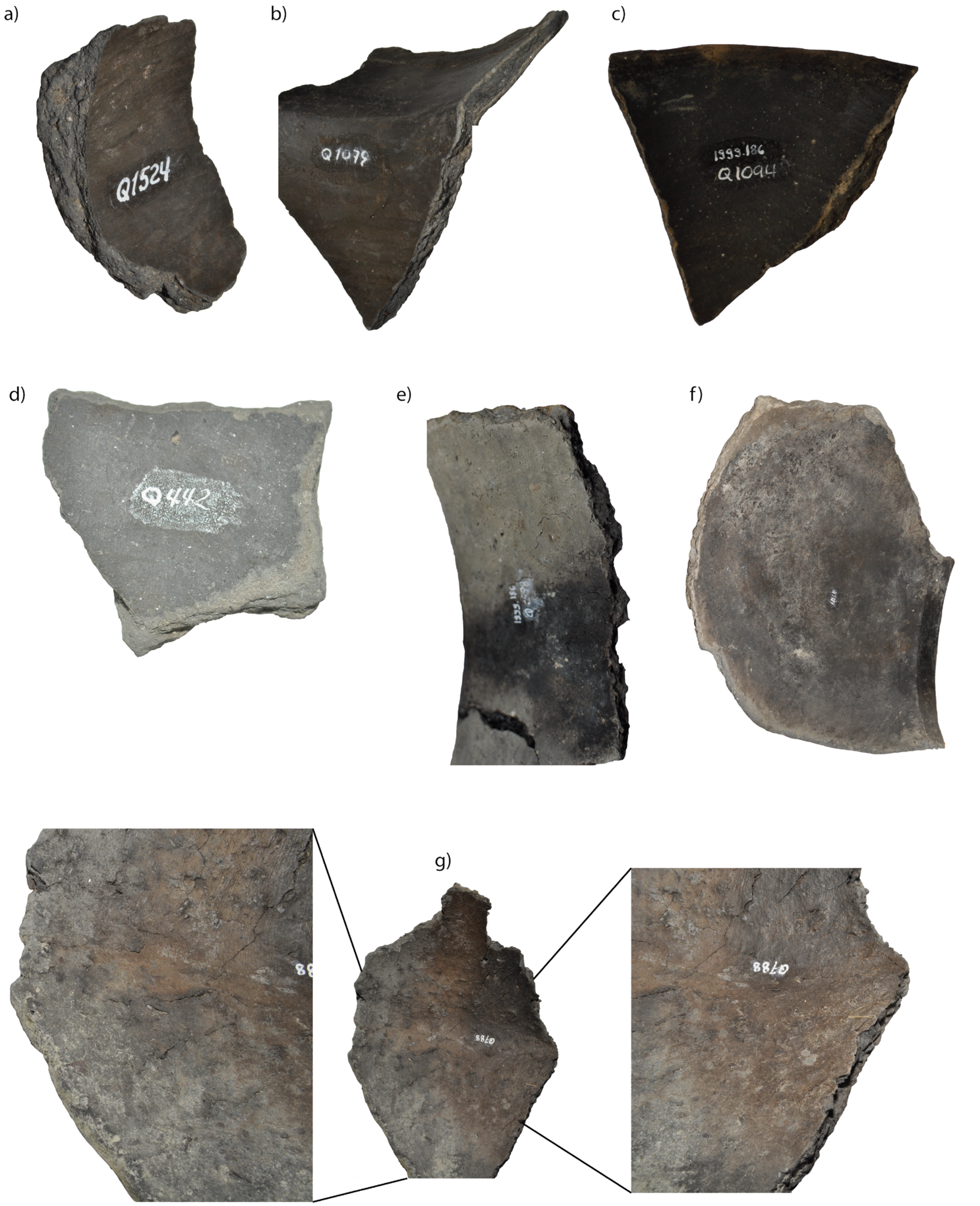

Figure 2. Differing states of erosion/abrasion on ceramic sherds from Zürich-Alpenquai. a, b, c: No or little erosion (Classes 1 and 2), d; Heavy erosion (Class 4); e: Mixed erosion – Classes 2 (right edge) and 3 (upper edge); f: Mixed erosion – Classes 2 (lower right edge), 3 (left edge) and 4 (lower edge); g: Mixed erosion – Classes 1 & 2 (right enlargement) and 3 & 4 (left enlargement) (Photographs by the author, with permission of Zürich Cantonal Archaeology department).

homogenous in terms of production and firing, excluding the few instances of secondary firing/burning, and so the potential variation in erosion and abrasion arising from differing fabric types, as well known (*e.g.* Cunliffe 1995), is expected to be minimal.

Documentation with the majority of sherds identified the grid square and layer in which they were excavated, though for some material collected in the excavation campaign this was unavailable. Ceramics relating to settlement Phase D were primarily selected for study as this relates to the final phase of site occupation visible in the archaeological record – higher levels of stratigraphy have been lost through erosion processes within the lake – and also formed a significant point of interest in the research of Wiemann *et al.* (2012), to which this study can be seen as supplementary insights from material culture studies. It should be re-iterated that the relatively small size of the formally excavated area at Zürich-Alpenquai – 60 m^2 – compared to the potential size of the full Late Bronze Age settlement (28,000m^2 – Künzler Wagner 2005, 8) ensure that the ceramic study provides only a small glimpse in to the settlement conditions. It would be interesting to conduct similar studies at more fully excavated sites, for instance Greifensee-Böschen (Eberschweiler *et al.* 2007) or Ürschhausen-Horn (Gollnisch-Moos 1999, Nagy 1999), but this would not provide directly comparable results; each site had its own specific environmental setting with unique characteristics. Thus, the ceramic study presented here may serve as a case- or test-study to provide a model for future analysis at other sites.

Using the context information associated with the sherds, and published site plans (Künzler Wagner 2005), information recorded from the ceramics has been plotted in a GIS program (ArcGIS 10.1) to provide spatial distributions of sherd quantities, size, and erosion state. Layer groups 1.2, 1.3, and 1.5 are strongly represented in the ceramic record, partly as a result of excavation classification (*i.e.* layer 1.4 is not detailed in the stratigraphy, see Künzler Wagner 2005, 11-20), partly due to the emphasis of this study on layers relating to occupation phase D (specifically layers 1.2 and 1.3), and significantly reflecting those layers as substantial cultural deposits with many ceramics. In accordance with the research focus, only a small sample of ceramics from temporally subsequent layers 0.0 and 1.1, and preceding layer 1.5 (occupation phase C) were studied, in order to assess any differences in erosion state in layers assumedly more strongly affected be recent erosion (0.0, 1.1) or ancient inundation (1.5).

3 Results and spatial analysis

Of a total 2116 recorded sherds, 1082 were recorded with co-ordinate information, which was extended to 1842 based on the assumption that sherds with the same number originate from the same grid location. Provenance layer information was available for the vast majority of sherds, with layers identified through publication or archive label for 1919 of the pieces (Table 2). The highly variable quantity of sherds per layer does provide some hindrance for the direct comparison of erosion state between layers, which is partly countered by the removal of low representation layers from the analysis (see above). Inter-layer variability in sherd count does not affect the interpretation of intra-layer variation in the distribution of erosion and abrasion indicators, which may suggest, for example, areas of refuse dumping and deposition practices in addition to the prevailing environmental conditions at the time of deposition.

Table 2. Count of sherds per layer.

Layer	Phase	Number of sherds
N/A	N/A	203
0.0	Reduction	7
1.1	Reduction	6
1.2	D	583
1.3	D	1146
1.4	? (not listed in phase definition, see Figure 1)	8
1.5	C	163
Total number of sherds		**2116**

For 205 of the sherds it was not possible to directly observe the edges—due to reconstruction of the parent vessel—but their successful joining to other sherds and appearance of the reconstructed vessel suggests an edge value at maximum ‘2’ (see Table 1). Including these 205 sherds, the vast majority of pieces show little signs of erosion/abrasion; 1572 sherds are classified as either class 1 or class 2. The remaining sherds are divided between those showing only moderate or high levels of erosion (respectively class 3; 231 sherds and class 4; 50), and those showing multiple states (Table 3; Figure 2). In order to reduce data categories and clarify data display, where sherds display multiple states of erosion/abrasion they are categorised at the highest observed state (Table 3). Such category ‘binning’ reduces the potential miss-representation arising from separate classification of each potential multi-state abrasion, and brings the categorisation back in to accordance with similar ceramic studies (*e.g.* Edwards 2009, Sánchez-Polo, Bianco-González 2014).

Table 3. Count of sherds per erosion class (see Table 1).

Edge erosion class	Number of sherds	Highest edge erosion class	No. sherds at highest erosion class
1	68	1	68
1 + 2	64	2	1504
1 + 2 + 3	5	3	470
1 + 3	2	4	74
1 + 4	1		
2	1440		
2 + 3	232		
2 + 3 + 4	10		
2 + 4	1		
3	231		
3 + 4	12		
4	50		
Total	**2116**	**Total**	**2116**

Indications of surface erosion and secondary burning were rare among the studied materials. In general, the coarse ceramics are significantly more brittle along their edge than the fine ware, resulting in both a greater appearance of erosion (as large pieces of temper easily come away from the broken edges) and also an uncertainty as to whether such damage is ancient or more recent. However, considering the absence of aggressive cleaning marks on the sherds (see above), and the absence of small detached pieces of fabric within the sherd packaging during examination, and visual appearance of the sherd edges, the occurrence of fresh/recent edge reduction on the coarser sherds is considered to have had minimal influence upon the erosion/abrasion scoring system employed.

In terms of spatial distribution, concentrations of ceramics are visible in the north-western and south-eastern areas of the excavation (Figure 3). The potential size of sherds (taken as maximum * minimum length to give cm^2, and grouped into size ranges 1: 1-2; 2: 3-10; 3: 11-19; 4: 20-49; 5: >49 cm^2), is relatively evenly distributed across the excavation area, with size group 2 generally being most abundant. There is, however, a slightly weaker presence of group 2, and corresponding stronger presence of group 3, in the southern region of the excavation (Figure 3). It is recognised that this method of size calculation will produce a maximum possible estimate and assume that all sherds are rectangular. In reality many are triangular, and so will be significantly less than this value. However, all sherds are treated the same, so the dataset is internally consistent in the application of this over estimation. Erosion/abrasion class 2 is uniformly high across the entire area, but higher levels of erosion occur more frequently on the southern and south-western edges of the excavation than the more northerly and easterly areas squares, though it is important to remember that the southern area of excavation is double the size of the northern area (Figure 4).

Dividing the dataset further by provenance layer, layers 0.0, 1.1, and 1.4 (see Table 2) contain relatively few sherds and so are of limited use for spatial differentiation. Comparing layer groups 1.2, 1.3, and 1.5, there is a spatial segregation between layers 1.2 and 1.3 / 1.5, with numerous sherds from layer 1.2 in the north-western sector but none in the south-eastern. From layers 1.3 and 1.5, there are sherds from both regions (Figure 5). Regardless of provenance layer, in the well-populated grid squares size group 2 and erosion state 2 are again the most frequent (Figure 6).

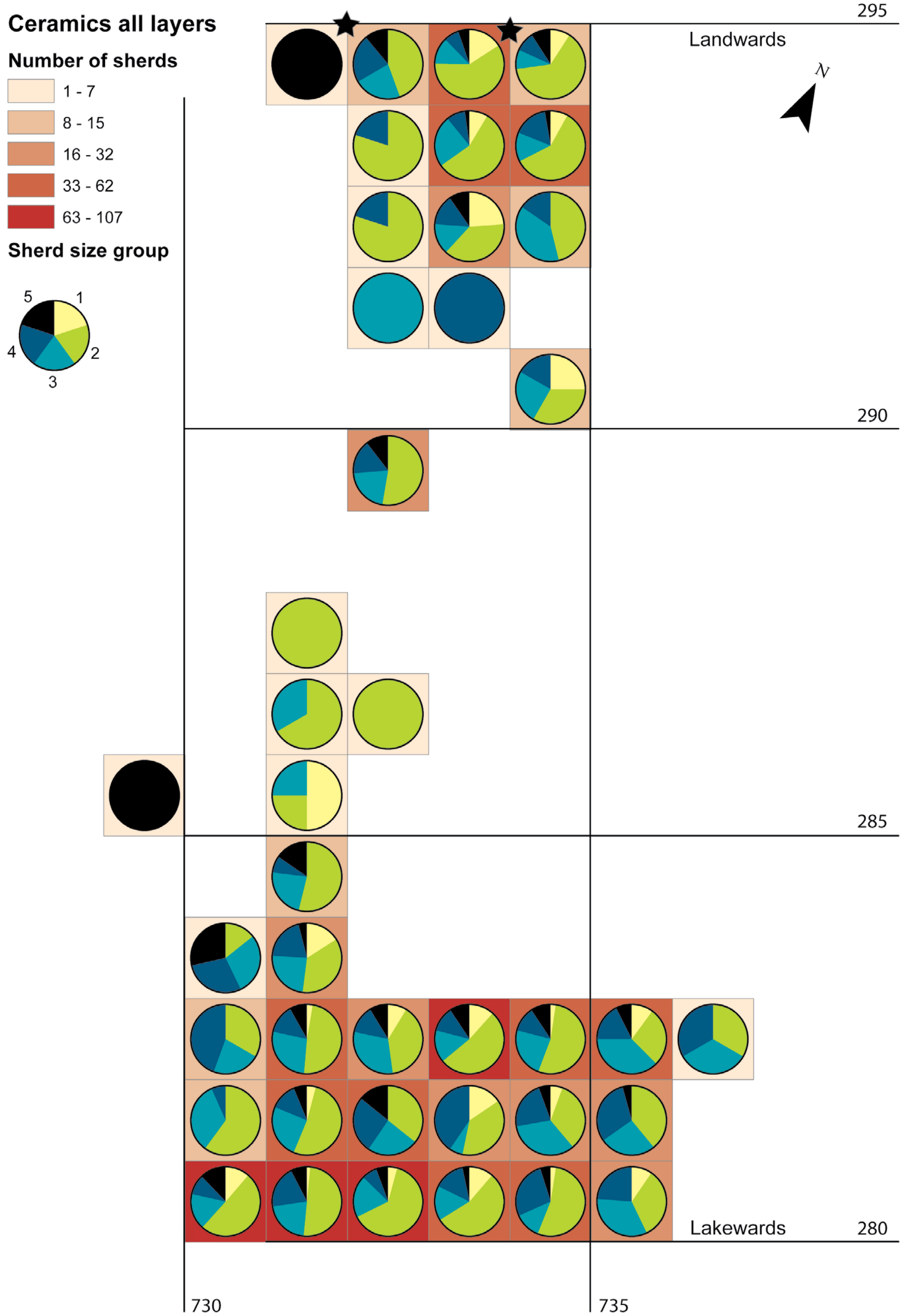

Figure 3. Count of sherds per layer (red background) and size of sherd (1 = 1 – 2 cm², 2 = 3 – 10; 3 = 11 – 19; 4 = 20 – 49; 5 = > 49) per excavated grid square. Approximate sample locations used by Wiemann *et al.* 2012 marked with star. Grid lines relate to co-ordinate system set out during excavation (Künzler Wagner 2005).

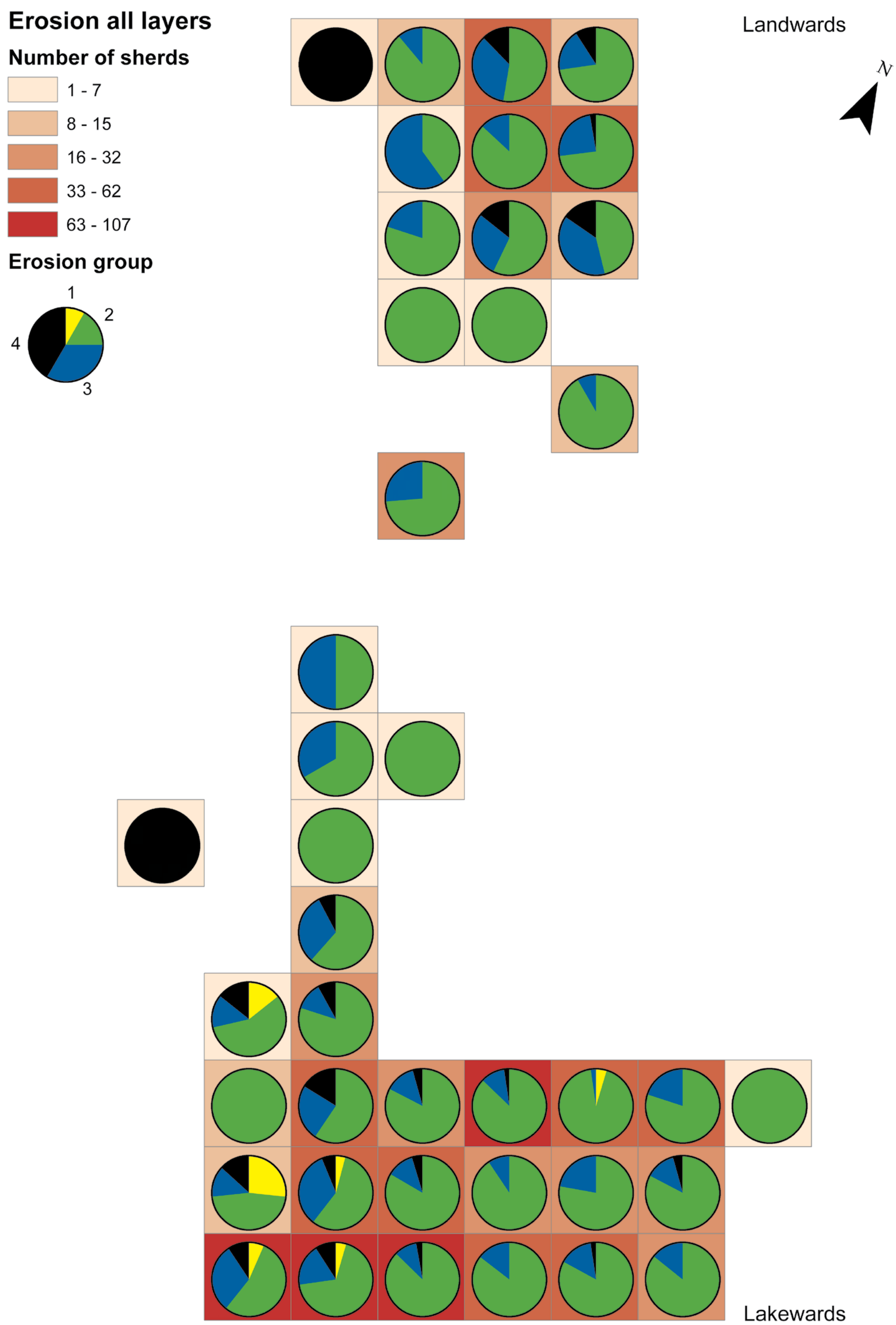

Figure 4. State of erosion/abrasion of sherds by excavated grid square.

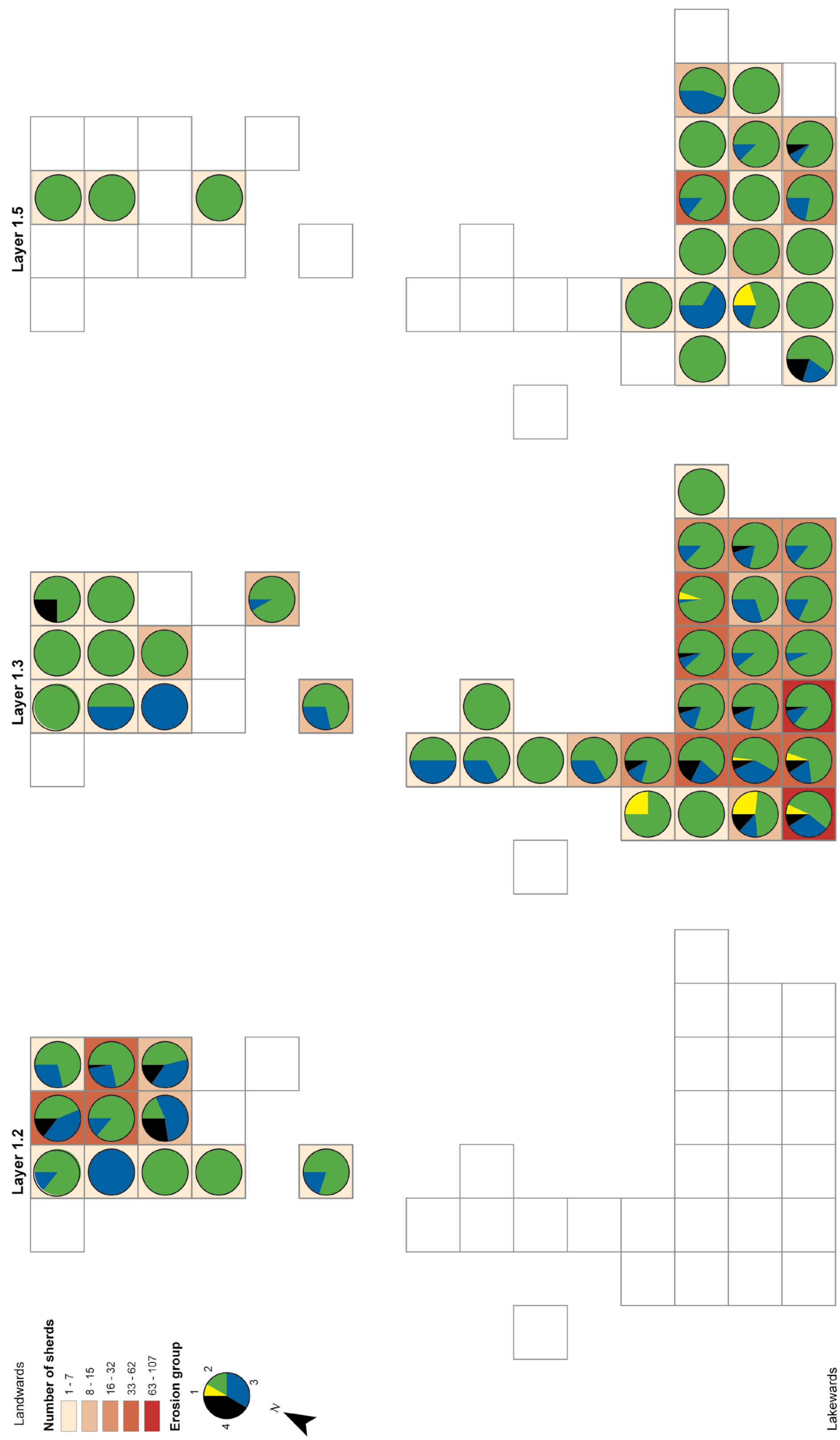

Figure 5. Comparison of erosion state of sherd by layer, for layers 1.2, 1.3, and 1.5.

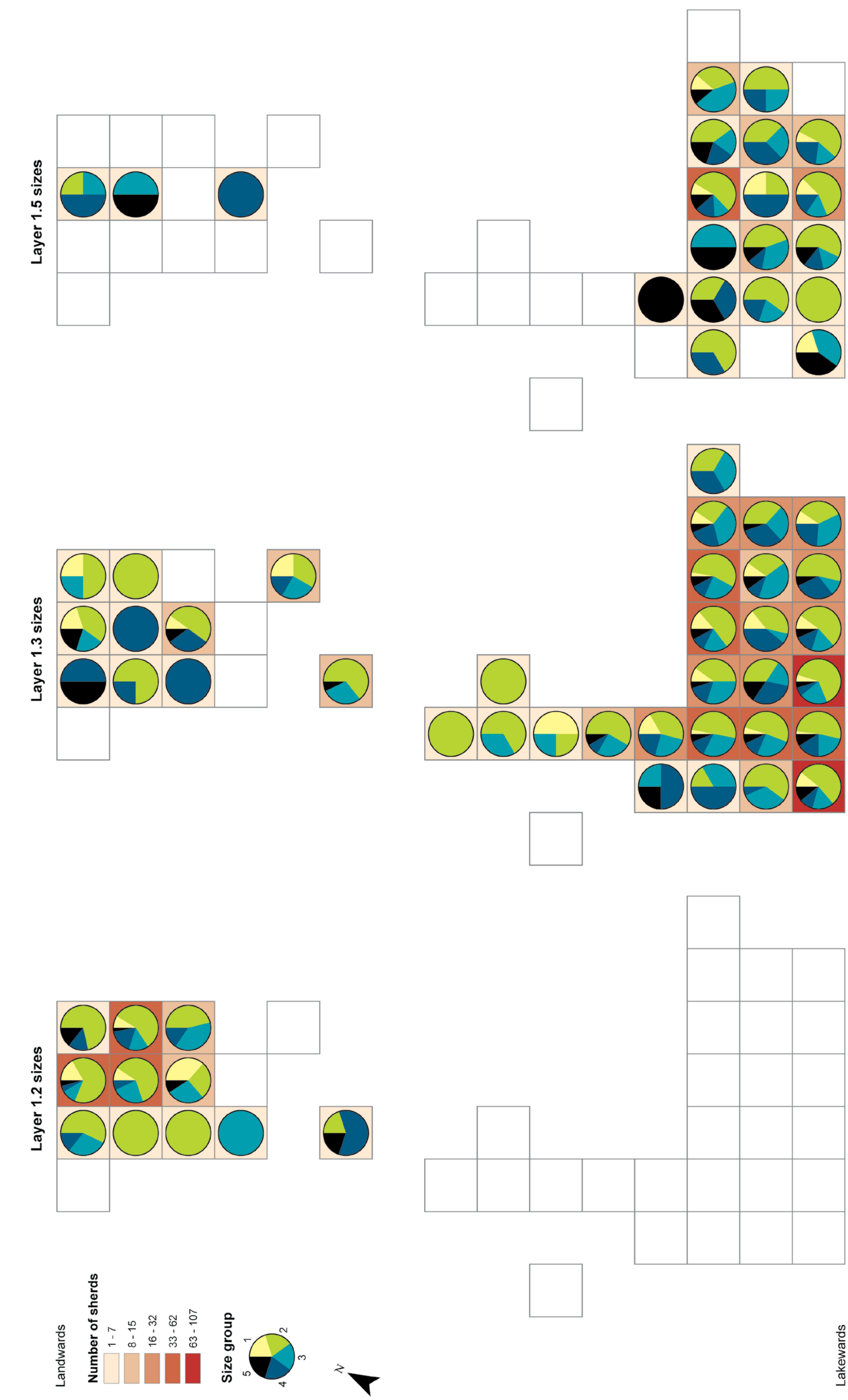

Figure 6. Comparison of sherd size by layer, for layers 1.2, 1.3, and 1.5. Size groups as Figure 3.

4 Discussion

The analysis of ceramic sherds from Zürich-Alpenquai draws upon the environmental research (Wiemann *et al.* 2012) and previous ceramic studies from the site (Künzler Wagner 2005, Betschart 2004, Huber 2005, Kotai 2005, Roth 2005). It is with reference to these previous phases of research that the results of the present study can be placed in context, and also generate potential new – and occasionally contradictory – insights.

From the previously refitted vessels (data collected from published material, see Künzler Wagner 2005) it is possible to observe some of the inter-layer refits; these demonstrate that the majority of refits occur between sub-layers of the same cultural layer – *i.e.* various sub-definitions of layers 1.2 and 1.3 – with relatively few between different primary layers (Figure 7). This suggests that the layers are largely un-disturbed (at least layers 1.2 and 1.3) with generally limited post depositional re-distribution of sherds within the stratigraphy; the number of inter-level refits (19) is far outweighed by the number of intra-level joins (82).

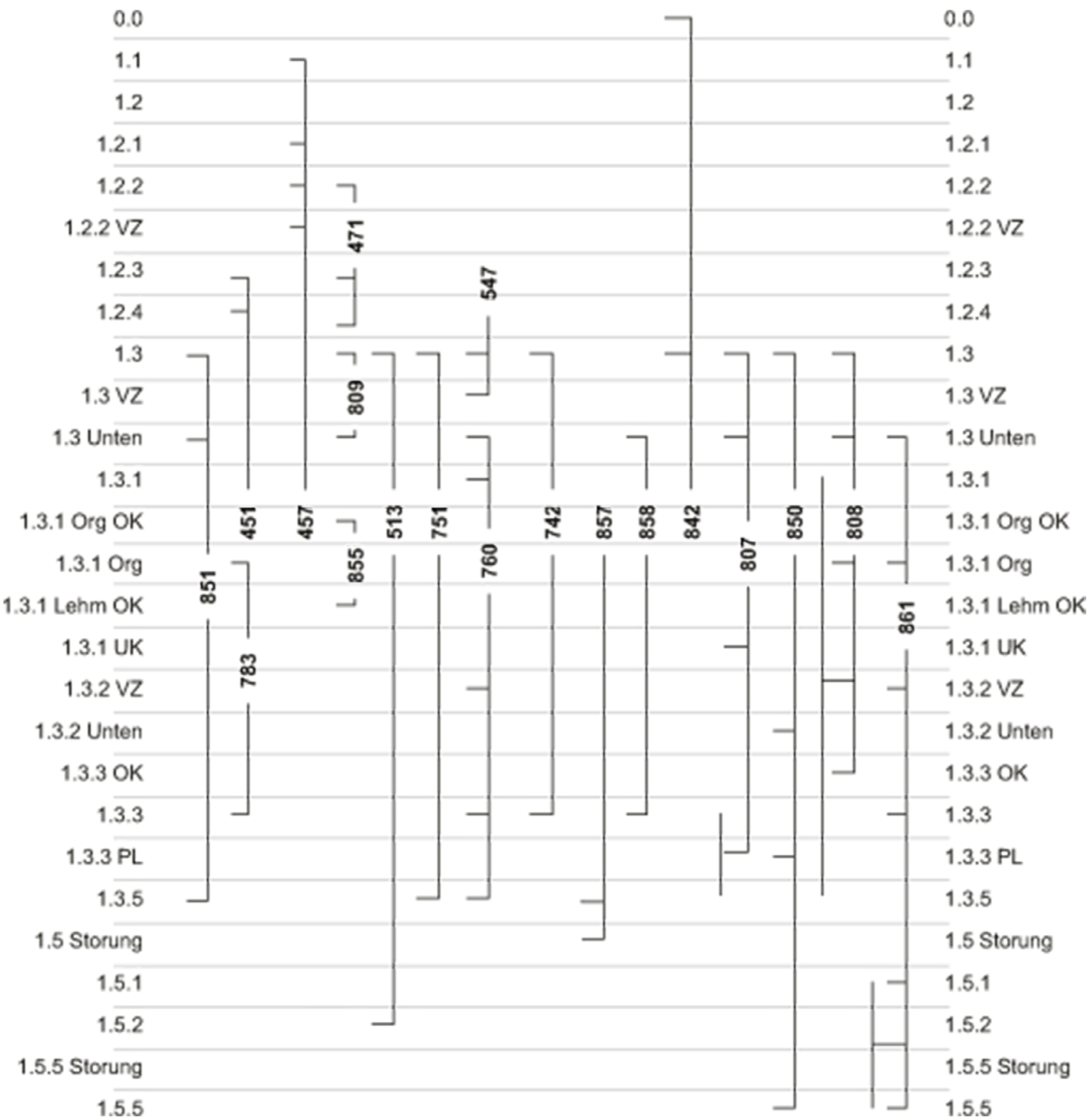

Figure 7. Inter-layer ceramic refits from occupation phase D at Zürich-Alpenquai (data from Künzler Wagner 2005).

Increased rates of higher erosion states on the southern and western edges of excavation, and in the upper stratigraphy (layers 0.0 and 1.1), can be partially explained through the early 20th century dredging excavation exposing some of the stratigraphy to the well documented natural and recent anthropogenic erosion which has occurred across the site (Künzler Wagner 2005, Büro für Archäologie 1976).

To provide an assessment of whether any correlation occurs between the sherd size (grouped into ordinal ranges as detailed above) and erosion state (Table 1, grouped into maximal state observed: Table 3), Kendall's *Tau* C correlation test was run, on both the full ceramic assemblage dataset and a reduced dataset consisting of sherds only from layers 1.2, 1.3, and 1.5. Kendall's *Tau* C was chosen as an appropriate method to identify correlation between ordinally scaled data with an un-equal number categories in the series (4 erosion and 5 size). Furthermore, *Tau* C has been successfully applied in previous archaeological studies of ceramic fragmentation and abrasion (*e.g.* Edwards 2009, see also Fletcher, Lock 1991), demonstrating its efficiency and applicability to such studies. The result of the calculation can vary between -1 and +1, with either extreme indicating a, relative, negative or positive correlation, while values closer to 0 indicate no correlation between the two procesees (Fletcher, Lock 1991). The results, -0.04 for the complete data set (Table 4) and -0.05 for the reduce data from layers 1.2, 1.3, and 1.5 (Table 5), suggest that there is no significant correlation between sherd size and erosion state; the processes causing ceramic fragmentation and erosion were likely separate and unrelated.

Table 4. Calculation of Kendall's *Tau* C correlation, for ceramic sherds from all layers. N = total number of frequencies (sherds); k = smaller number of rows or columns (erosion classes – 4); P = sum of each cell multiplied by sum of all frequencies to below and right; Q = sum of each cell multiplied by sum of all frequencies to below and left.

Edge/Size	**1**	**2**	**3**	**4**	**5**	**Total**
1	2	18	15	11	22	**68**
2	94	621	264	297	228	**1504**
3	24	198	90	97	61	**470**
4	14	35	10	5	10	**74**
Total	**134**	**872**	**379**	**410**	**321**	**2116**
P calculation						
Edge/Size	1	2	3	4	5	
1	3832	19116	10470	3289	0	
2	47564	169533	45672	21087	0	
3	1440	4950	1350	970	0	
4	0	0	0	0	0	
Q calculation						
Edge/Size	1	2	3	4	5	
1	0	2376	14790	14850	38478	
2	0	23598	71544	110187	107844	
3	0	2772	4410	5723	3904	
4	0	0	0	0	0	
N	**2116**			Tau **C =**	**(2k(P-Q))/ (N2(k-1))**	
k	**4**					
P	**329273**					
Q	**400476**			Tau **C =**	**-0.04241**	

Table 5. Calculation of Kendall's *Tau* C correlation, for ceramic sherds from layers only with a substantial quantity of ceramic sherds, and direct relevance to the phases of occupation (*i.e.* layers 1.2, 1.3, and 1.5). Equation as detailed for Table 4.

Edge/Size	**1**	**2**	**3**	**4**	**5**	**Total**
1	2	18	15	10	18	**63**
2	81	559	241	254	183	**1318**
3	23	191	85	83	53	**435**
4	14	35	10	4	5	**68**
Total	**120**	**803**	**351**	**351**	**259**	**1884**
P calculation						
Edge/Size	1	2	3	4	5	
1	3406	16524	8730	2410	0	
2	37746	134160	34945	14732	0	
3	1242	3629	765	415	0	
4	0	0	0	0	0	
Q calculation						
Edge/Size	1	2	3	4	5	
1	0	2124	13545	12390	28440	
2	0	20683	63383	90932	81435	
3	0	2674	4165	4897	3339	
4	0	0	0	0	0	
N	**1884**			Tau **C =**	**(2k(P-Q))/ (N2(k-1))**	
k	**4**					
P	**258704**					
Q	**328007**			Tau **C =**	**-0.05206**	

The absence of strong indicators for erosion or abrasion on many of the sherds suggests that they were not subjected to significant levels of post deposition re-working. Essentially, following deposition the ceramics were relatively quickly buried in a secure matrix and not exposed to significant or substantial weathering or trampling action. Those sherds which display multiple stages of erosion may have been partially exposed to the elements upon deposition—for example in the upper layers of a waste midden—but could also represent the partial exposure of sherds to the underwater erosional environment (particularly anchor chains or following dredging work) at any point post deposition until the time of excavation (*cf.* Künzler Wagner 2005).

Relating the indications for—or lack of—erosion on the ceramics from Zürich-Alpenquai back to previous environmental research from the site (micromorphological analysis, plant macro-remains and pollen analysis, Wiemann *et al.* 2012), it is possible to theorise some aspects of ceramic deposition and preservation at the site.

The combined micromorphological and botanical analyses, suggest no lakemarl is present within the main layers of cultural phase D (stratigraphic layers 1.3 and 1.2) and that there may not have been standing water over the site—at least in the position of the samples (Wiemann *et al.* 2012). The upper portions of layer 1.2 (sub-layers 1.2.2 and 1.2.1) contained ceramic sherds with evidence of secondary firing, and the intrusions of lake marl, which may have been introduced through soil and sediment erosion processes

(Wiemann *et al.* 2012). Evidence of secondary fired ceramics, charcoal and charred wooden remains have often been taken as indications that lake-dwellings were destroyed in "catastrophic fires" (*e.g.* Künzler Wagner 2005, Schmidheiny 2003, Gollnisch-Moos 1999, Nagy 1999, Eberschweiler 2007). However, such an event is unclear at Zürich-Alpenquai (Künzler Wagner 2005, 63), as can also be demonstrated by the fact that the majority of macro-botanical remains were preserved in an uncharred state (Wiemann *et al.* 2012, 68); in the case of widespread destruction by fire it would be reasonable to expect a high percentage of charred plant remains. Evidence for secondary burning of ceramics does not reflect on the environmental conditions within the proximity of the site, but rather the processes of abandonment – were the 'catastrophic fires' deliberate events of destruction or accidental occurrences? The few indications for secondary burning observed do not provide substantial evidence for either scenario, but the subject of how settlements were abandoned is worthy of future consideration and can draw much from ethnographic studies (*e.g.* Deal 1985, Hayden, Cannon 1983).

Both plant macro-remains and pollen analysis suggest that during cultural occupation phase D the settlement ground and environment was moist—but not covered by standing water (Wiemann *et al.* 2012, 79-82). However, the general level of organic preservation at the site (see Künzler Wagner 2005) indicates that even though the settlement may not have been covered by standing water, it was very moist, and may have been more like a 'boggy' or 'peaty' environment (Wiemann *et al.* 2012). A general decline in plant residues in the upper stratigraphy of layer 2 (layer 1.2.3 and above) possibly indicate a relocation of the settlement further along the shoreline (Wiemann *et al.* 2012, 81, Mäder 2001a, 20).

With these considerations in mind, the ceramics present in layers relating to cultural phase D were deposited in a moist and humid, but not submerged, environment (Wiemann *et al.* 2012). For them to have been preserved in a non-eroded condition requires that they were not exposed on the ground surface to trampling, by humans or animals, or weathering processes for any extended duration. It is not reasonable to argue that only ceramics relating to phases of abandonment (or immediately prior to), and thus largely un-exposed to potential trampling abrasion but subject to potential to rapid covering (through inundation, vegetal growth, collapsing building debris *etc.*), have been retained in the archaeological record and thereby explain the relatively un-abraded state of sherds. Protection from abrasion could have arisen if ceramic sherds were collected into general refuse heaps, or intact vessels were intentionally buried in the ground (*i.e.* placed depositions). Such depositions/middens could also occur with the disposal of waste through the house floor (either above water or 'dry' ground), as has been detailed at, for instance, Arbon-Bleiche 3 (Jacomet *et al.* 2004, Leuzinger 2000, Menotti 2012, 313-315). These under-structure deposits would be protected from trampling and weathering, and would rapidly be covered in new layers of waste, providing a protective environment for any ceramics located there. The predominantly damp, but not necessarily submerged ground conditions (Wiemann *et al.* 2012) may have aided in the preservation of sherds in a relatively intact state, even if they were exposed on the surface and subject to trampling. If the ground was moist the sherds may have been pressed into the ground upon initial deposition, and thereby partially protected from any subsequent trampling or crushing actions (bearing in mind that the micromorphological analysis suggest no trampling occurred, at least in the location of the micromorphological sampling). The relative high frequency of small sized sherds, < 3 cm^2 (size group 1), may suggest that some larger sherds were broken (potentially by trampling or crushing actions) into several smaller pieces. However, experimental fragmentation studies using replica vessels in a variety of breakage scenarios would be required to provide an indication for the expected frequencies of sherd size (*e.g.* Chapman, Gaydarska 2007).

The apparent lack of trampling indicators in the micromorphological analyses – for example the survival of large charcoal pieces – does not entirely exclude the potential of ceramic trampling (Wiemann *et al.* 2012), as the micromorphological analyses were conducted on samples from single spot locations, whereas the ceramic sherds are from the broader settlement/excavation extent. This returns us to the previously detailed dichotomy between the ceramic assemblage analysis addressing a much broader area than the specific location interpretation provided by the micromorphological analysis. It is quite possible that some of the ceramics were exposed to trampling action, which is not recognised in the micromorphological analysis due to the specific location factor. It is also worth noting that the Kendall *Tau* C analysis indicates that the sherd size and edge erosion are not directly linked; the processes causing the edge erosion were likely not the same processes influencing the sherd size. Thus, it is eminently possible that some sherds were exposed to initial trampling or crushing into a protective matrix, directly reducing their size, but not affecting the edge erosion/abrasion state. Separation of size reduction and erosion processes instead reflects that the sherds were not exposed to prolonged weathering and/or trampling/crushing, which would have concurrently abraded edges and reduced sizes.

From a distribution perspective it is, in some ways, 'unfortunate' that such a large portion of the site was excavated by dredger in the early 20th century. Although "hut" locations have been proposed through the densities of objects found in specific locations and loam and clay deposits (Künzler Wagner 2005, Mäder 2001a, Mäder 2001b, Viollier *et al.* 1924), it has meant that possible middens and other depositions have gone unrecognised. Potential activity areas with a loam base identified in the south-eastern area (Grid 734-737/280-282.5) during the 1999-2001 excavation, show particular concentrations of objects and ceramics–including some with indications of secondary firing (Künzler Wagner 2005), suggesting they may have been multi-purpose work places or 'houses'. If the suggestion that these loam deposits represent the base of hearths or, according to the occurrence of pile shoes, building floors (Künzler Wagner 2005, 56-63), is at least tentatively accepted then the concentrations of ceramics outside of the pile shoe/loam perimeter could represent vessels stored outside of the building (as identified at the Late Bronze Age lake-settlement Ürschhausen-Horn, Lake Nussbaum, see Nagy 1999), or waste deposits created through the routine cleaning of building interiors and floors—which would potentially include sherds of broken ceramics. While this does not directly relate to the environmental conditions in proximity to the Zürich-Alpenquai settlement at its time of occupation or abandonment, the distribution of ceramics may provide indications of the settlement structure and the abandonment processes (*e.g.* Hayden, Cannon 1983). Thus, it is possible that if distribution of ceramics does indicate some external storage of ceramics then a) comparable social practices to those seen at Ürschhausen-Horn existed at Zürich-Alpenquai, and b) it is possible to indirectly infer that the houses were not situated above standing water (*cf.* Wiemann *et al.* 2012).

5 Conclusions

Over 2000 ceramic sherds from the Late Bronze Age lake-dwelling Zürich-Alpenquai were assessed for indications of erosion/abrasion and categorised according to their condition edge condition and physical size, with the intention of contributing to discussions of the depositional environment within the settlement–factors which have recently been detailed from an environmental archaeology perspective. Previous studies have noted the limited erosion visible on ceramics from the site, but did not provide qualitative or quantitative details. Utilising classification systems similar to those employed by other ceramic abrasion studies, the sherd edge condition was classified into four groups of erosion/abrasion. This study is in agreement with that of Künzler-Wagner (2005) in that there are relatively few indicators of erosion, and on those sherds which do show such signs it is difficult to ascertain whether this occurred shortly after deposition or more recently following exposure of the cultural layers on the lake-bed. Ceramic refits between layers relating to the last phase of cultural occupation (Phase D) suggest, however, that relatively little mixing has occurred between these deposits. Thus, the absence of erosion and abrasion indicators becomes more interesting due to the implications that this creates about their initial deposition.

The lack of erosion and abrasion suggests that the sherds were relatively quickly covered following their deposition; this could have occurred in midden heaps, if sherds were incorporated into household waste, or after short periods of exposure to trampling on moist ground. Environmental indicators suggest that the settlement area was moist/wet ground but not permanently submerged, which would have provided good preservation conditions once sherds had been pressed into the ground. There appears to be no correlation between sherd size and edge condition, suggesting that the fragmentation and erosion processes were discrete events. Some sherds, and also largely complete vessels, show several classes of erosion on different edges; this could be the result of ancient or modern erosion following exposure of the deposit on the lake bed (such as by anchor chains from boats at the modern day boat house) or following deposition of sherds in waste middens in an occupied environment. While it is not presently possible to differentiate between these eventualities, it is inconceivable that ceramics were not accidentally broken during the prehistoric occupation of the settlement Zürich-Alpenquai, and those sherds must have been deposited somewhere; perhaps they were thrown into the nearby lake, or maybe they were collected into waste deposits within the perimeter of the settlement in a broadly humid but not over standing water environment. It is likely that instances of erosion caused during both prehistoric occupation and post abandonment environmental erosion are represented in the ceramic record excavated from Zürich-Alpenquai. The size of sherds is unrelated to their state of erosion or abrasion, suggesting that the processes of fragmentation and abrasion were not correlated. The size range of sherds, from *c*. 1 cm^2 to intact substantial vessels, with the majority falling below 19 cm^2, and their relatively uniform distribution over the excavated area (particularly within stratigraphic layers) suggests that similar processes of fragmentation were occurring across the site. Some of the smaller sherds may have arisen from primary breaking and/or trampling in the humid ground conditions, but such action is a single possibility which is not seen in the micromorphological record.

The ceramic material with recorded context information excavated during the late 20th century forms a small portion of the total ceramic assemblage from Zürich-Alpenquai, with many pieces recovered with limited context data during dredging in the early 20th century. Unfortunately this information cannot be recovered, and so hypotheses have to be built from the smaller body of material. Indeed, the relatively small area of site excavated (60 m^2) means that the insights gained from the ceramic assemblage provide only a small snapshot, and cannot be taken as representative of the entire settlement, just as the micromorphological evidence from previous studies provides information on a very specific location. Thus, the suggestions here are only hypotheses, and the general lack of comprehension of the complex taphonomic processes (which can vary across very short distances) at the site, and indeed the majority of other wetland sties, hinder the production of hard conclusions. Nevertheless, the ceramic study has provided another avenue of research, and demonstrates that material culture, and in particular ceramic, studies can contribute to the discussion of potential climatic/environmental influences for the cyclical and/or terminal abandonment of lake- and lakeshore villages.

Looking towards the future, one potential avenue for research, which would be of benefit to lake-dwelling and ceramic studies in Switzerland and Europe as a whole, is the experimental (re)construction/replication of vessels in assorted shapes and forms using various clay sources and tempers with the specific intention of breaking them to observe fracture patterns. Given the wide range of vessel types and shapes, and variability in fabric materials, this would be a major undertaking, but following general fabric schemes—*i.e.* coarse, coarse-fine, fine, fine-coarse—and focussing on the most frequently encountered forms would reduce the workload somewhat; the results would certainly be informative and offer a new insight as to environment conditions and deposition/disposal practices within these settlements, and at other sites across Europe.

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