Title: Use of phosphorus mapping in assessing coastal activity zones of an Icelandic multi-period site of Vatnsfjörður.

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Abstract: This paper presents the results of phosphorus mapping conducted on a number of coastal activity zones on the multi-period, archaeological farm site of Vatnsfjörður, northwest Iceland. The aim of the study was to detect the exact levels and extents of shorelines contemporary with the archaeological site's activities and to use sea-level change to establish a relative chronology of coastal activity zones. Absolute dating of the coastal zones and sea-level changes was achieved by integrating an existing sea-level curve with a novel tephrochronology-based curve, created for the purpose of this research. Results were projected onto a detailed digital terrain model of the area in order to reconstruct the extent of the coastline contemporary with human activity in the respective zones. A significant component of the research was an attempt to develop the existing approach to phosphorus mapping results interpretation. This has resulted in an improved methodology that can be applied to the dynamic and challenging environments of coastal sites worldwide.
Dear Editor,

Please find attached for your kind review our revised version of a manuscript entitled “Use of phosphorus mapping in assessing coastal activity zones of an Icelandic multi-period site of Vatnsfjörður”.

Look forward to your favourable consideration.

Most sincerely,
Łukasz Mikołajczyk

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Graphical Abstract (for review)
Multi-period Icelandic site with long and complex history of coastal area use
Phosphorus mapping of coastal activity zones
Detection of extent of past, site-contemporary shorelines
Integration of sea-level change data and tephrochronology to reconstruct ancient shorelines
Dear Editor,

We would like to thank the reviewers again for their comments. We addressed them all in the manuscript:

- Misspelt ‘Phosphorous’ was corrected to ‘Phosphorus’ in the manuscript and in all submitted materials
- Sign ‘µ’ was replaced with ‘x’ in manuscript, captions and tables
- Shorter version of a title was used
Use of phosphorus mapping in assessing coastal activity zones of an Icelandic multi-period site of Vatnsfjörður.

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1. Introduction

Coastal zones of archaeological sites grant insight into a very specific set of past human behavioural practices. At the same time, they also present research challenges, such as shore displacement, which have consequences for past human activities and require specialised methodologies to understand. Phosphorus (P) mapping, very popular as an archaeological prospection method worldwide (Holiday and Gartner 2007 with references; Rypkema et al. 2007; Sarris et al. 2004; Viberg 2013), also has been suggested as a tool for identifying shorelines contemporary to human activity conducted in proximity to the water in the areas with raised shorelines (Arrhenius 1945; Broadbent 1979; Florin 1948; Halén 1994; Löfstrand 1974; Nunez 1977, 1978; Schnell 1932; Siiriäinen 1982; Simonsen and Lysnes 1968; Sundström and Darmark 2005; Sundström et al. 2006; Ilves and Darmark 2011, Ilves 2012). The method assumes that human activity in the coastal zone causes P enrichment of soil by means of continuous deposition of P-rich excreta and waste materials. On coastal sites, the shoreline provides a fixed border to the site, restricting the deposition of P-rich materials and affecting P distribution, which would normally decrease gradually in all directions as one move away from the core of the site. Water, as a special type of border, not only creates a limit for P deposition but also causes redeposition by tide and wave activity and has been found to cause distortions to the normal P distribution in the form of sudden drops or high-amplitude variations. The very existence of such distortions in P distribution maps at sites close to a former shoreline indicates the probable location of the former shoreline and points towards the sites being ‘water-bound’ (for details, method history and wider discussion see: Ilves and Darmark 2011). This methodology, with further development described in this paper, was therefore deemed appropriate for answering questions about the character of coastal activity zones and associated sea levels at the site of Vatnsfjörður, in the Icelandic Westfjords.

2. The site

The farm of Vatnsfjörður is located in the Vatnsfjörður fjord, in northwest Iceland, and has been continuously occupied from the 10th century to modern day. The site consists of three components: the Viking-age settlement area, the medieval to early modern farm mound and an extensive coastal zone (Milek 2011: 17-22). The coastline in the Vatnsfjörður area is not stable. Glacio-isostatic crustal movement and glacio-eustatic sea-level rise are responsible for relative sea-level (RSL) change in the area, first rising to at least 1 m above present-day levels in the mid-Holocene, then gradually falling to the present-day level (Norðdahl and Pétursson 2005; Lloyd et al. 2009).

The archaeological coastal zone at Vatnsfjörður stretches c. 1500 m along the shoreline and consists of three pronounced subzones, all of which still bear visible traces of intensive use in the past (Fig. 1).
In zone A, two archaeological structures were identified near an early 20th-century building on the shoreline (Mikołajczyk and Gardela 2010: 42-44). One of these was a building ruin in the form of two 9 m long, turf-built, parallel walls, in which two phases were recognised, divided by a tephra layer from the Hekla volcano dated to 1693 AD (Mooney et al. 2012: 57-63). The early phase's construction technique and the turf material used resemble the Viking Age buildings at the nearby settlement site, but otherwise it is not possible to date it. Both the form of the ruin and associated finds, consisting mostly of cut and dismantled clenched nails, suggest that the building might have functioned as a boathouse. Unfortunately, there was little internal stratigraphy in the structure, making it impossible to attribute the finds to a particular phase or to confirm its function. This building is currently located 50 m from the shoreline and its use as a boathouse is debatable as the second structure in this zone – a dry-stone bank 100 m long and c. 0.7 m high – obstruct the building's access to water (Fig. 1A) (Mikołajczyk and Gardela 2010: 42-44; Mooney 2011: 74-75). The H-1693 tephra layer was found in presumably in situ patches on the inner side of the stone bank, suggesting that it was erected before 1693 AD and thereby sheltered the tephra layer from the erosion. No other datable material has been retrieved from the area.

Zone B, located at the southernmost edge of Vatnsfjörður, is dominated by a ruin of a massive, 15 m long, U-shaped building (Fig. 1B) (Mikołajczyk and Gardela 2010: 48). It has been excavated (Mooney et al. 2012: 49-50, Mooney 2013: 40-48), but despite the detailed information on its construction method, characterised by a very robust, 1.5 m thick, stone-lined, turf wall, its function and date remain unknown because it yielded neither datable material nor any other finds, and its internal floor layer is very thin and non-diagnostic (Mikołajczyk 2013). The shape of the building is similar to boathouse constructions, but its orientation parallel to the modern shoreline seems to contradict the hypothesis that it was a boathouse. There is, however, an elongated depression in front of the structure. Long test trenches excavated across this linear depression as part of this study revealed that it was a dried-out stream bed, which, if sea levels were higher, could have been an inlet and channel facilitating watercraft access to the structure. The structure is stratigraphically below the H-1693 tephra layer, but it has so far not been possible to date it more precisely. In addition, there are three other ruins in the northern part of the same zone, all of which are in a very poor state of preservation (Fig. 1B). Two of them are c. 6 m long, U-shaped, overlapping boathouse-like structures and the third is a small, rectangular, stone-lined structure with walls abutting a natural bedrock outcrop. All three were test trenched as part of this study and were found to pre-date the H-1693 tephra.

Zone C has a 6 m long V-shaped ruin consisting of the foundations of a de-constructed dry-stone wall, with a visible keel mark in the beach in front of it (Fig. 1C). Nearby, to the north of this ruin, a narrow stone-built sea wall or quay foundation has been documented (visible in the aerial photograph in Fig. 1), but with no cultural layers detected around its base (Mikołajczyk and Gardela 2010: 50). Both structures are interesting because, unlike the other structures discussed above, they are close to the modern shoreline. No datable materials have been retrieved from the area.

3. Methodology

3.1. Sampling strategy
All three of Vatnsfjörður’s coastal zones were subject to P transect mapping in order to determine whether past activities at these sites had been bounded by water, and, if so, to pinpoint the location of the sites’ seaward boundaries, and, based on sea-level change models, the likely dates of their occupation (Fig. 1, Tab. 1). Each transect sampling line was also placed in a particular location in order to solve a specific research problem related to that activity area.

In Zone A (Fig. 1A), Line 1 was stretched from the entrance of the building towards the shoreline, crossing the stone-built bank in order to clarify its possible relation with both phases of the boathouse-like building, and with changing sea levels.

In Zone B (Fig. 1B), Line 2 was placed between the northwest wall of the U-shaped building and the shoreline in order to seek evidence for shore-related activity areas, and to assess whether the different preservation conditions of ruins in this area was related to their chronology. Line 3 was placed between the mouth of the U-shaped structure and the linear depression to its southeast to test the hypothesis that the structure’s unusual orientation was related to the presence of a stream and an inlet to the sea, which would have facilitated the movement of boats into the building. Line 4 was located across Line 3, between the mouth of the U-shaped building and the present shoreline, in order to help compare and correlate the results of Lines 2 and 3.

In Zone C (Fig. 1C), Line 5 was positioned between the mouth of the V-shaped building and the shoreline, where the keel-mark was located, in order to confirm that the site’s activities were water-bounded and to help determine their date.

In order to distinguish between anthropogenic enrichment and natural P levels, as well as analyse the way natural P was distributed on the coastal zone of Vatnsfjörður, two control sampling lines (controls 1 and 2) were placed in an area between Zones B and C, where there were no visible traces of human activity (Fig. 1).

From each of these transect lines, P samples were taken from 0.2 m x 0.2 m shovel test pits placed 0.5 m apart, except in Line 1 in Zone A, where the interval was 1 m because the slope to the present shoreline was very gentle. Every sampling point was recorded with the use of a Trimble DGPS unit, with 1 cm accuracy. Special care was taken to sample soil strata recognised as corresponding to the archaeological structures. However, due to the thinness of the soil and the patchiness of the only chronological marker on the site, the H-1693 tephra layer, in some cases, samples had to be taken at an arbitrary depth of 0.05 m below the dense grass root mat. All sample lines with the exception of the support lines (4 and controls 1 and 2) were duplicated by the placement of two parallel lines 0.5 m apart in order to make it possible to catch erroneous P results (significant outliers), but as all sub-lines were well correlated, the results given in the paper present an average of the two respective values (Tab. 1).

3.2 Sample analysis
The choice of the most suitable P extraction method was dictated by the Fe-rich and allophone-rich character of Icelandic Andosols, which gives them characteristically high (generally >90%) P retention (Arnalds et al. 1995; Arnalds 2004). While citric acid extraction is normally suitable for anthropogenic P enrichment assessment (Engelmark and Linderholm 1996), difficulties obtaining available P from Icelandic soils (Bolender 2003: 42; 2006: 126; Simpson et al. 2002: 433) led to a trial for this study in which both 550°C-ignited (total P) and non-ignited (organic P) samples were compared. In comparison to the well distributed results from the ignited subset, readings from the unignited samples were fairly random, and as a result the decision was made to conduct all P analyses on ignited samples. Samples were oven-dried, pulverized, screened (1 mm) and ashed for 4 hours at 550°C. Subsequently, 1 g of each sample was extracted in 5 ml of 2% citric acid (0.1M) on a shaker board for 15 hours and left to settle for another 5 hours. The extract (0.25 ml), filtered if necessary, was then mixed with 1 ml of a solution of sulphuric acid and ammonium heptamolybdate in a water solution (17.5% (3.28M) and 0.25% (0.02M) respectively), 0.25 ml of a mixture of sodium sulphite and hydroquinone water solution (9.5% (0.72M) and 0.19% (0.01M) respectively) and 20 ml of deionised water. The sample solution was then heat treated for 5 hours at 50°C and the intensity of the samples’ blue colour was analysed with the use of a HITACHI U-1100 spectrophotometer (calibrated with standards) at a wave length of 620 nm. Results were calculated to reflect the P concentration in parts per million (ppm).

3.3. Methodological developments

In Ilves and Darmark (2011) a particular conceptual approach was adopted in the use of the P distribution as the tool for establishing the archaeological sites’ connection to water and the investigations concentrated on identifying ‘contact zone’ and not the exact ‘border’ between the site and water. Thus, just the question of whether the site was shore-bound was investigated. Authors had no ambition for exploring the relation between the site and landscape in general and hitherto, the suggested method as it stands does not allow for fully answering the questions posed in this article. For this reason, as a methodological improvement to the P distribution model, we propose an approach suited for identifying shorelines contemporary to site’s activity. The proposed method uses the concept of ‘events’ – discrete points in space, in particular the point at which the undisturbed P readings typical of terrestrial sites met the readings that had clearly been distorted by the presence of water at least at some point in the year (showing drastic drops or alteration of anomalously high and low P values; see Ilves and Darmark 2011). Our assumption is that the highest elevation distorted P value in each zone indicates the level of the high spring tide when the site was first occupied. The method is not precise enough to detect yearly variation, but it is sufficient to make use of the local sea-level change curve to date the extent of coastal activity zones.

Another methodological development introduced in this study concerns a novel way of quantifying and interpreting P results in coastal environments, particularly the rapid, high amplitude P changes that seem characteristic of the contact zone between human activity areas and the water (Ilves and Darmark 2011, based on Löfstrand 1974: 98-101). In order to achieve a more unequivocal method of identifying these anomalous events in the P distributions, we introduce a ‘change index’ (ΔP). For every sample point a ΔP is calculated: the difference between that P value and the next one up (in terms of elevation relative to current sea level) in the sampling line (the highest elevation sample in every line is automatically given a ΔP value of 0). In this way, for every sampling line a ΔP curve has
been produced that shows where in the linear dataset a significant change in P values occurs and how rapid this change was. The higher the ΔP, the more drastic the P change from the previous sampling point.

Deciding on a threshold above which a given ΔP value reflected a significant enough P change to indicate the contact point between the activity zone and the water proved to be problematic. Assessment of statistical significance of ΔP values gave a very low threshold value, which was deemed not selective enough for successful interpretation. Thus, in order to define a threshold of ‘practical significance’, previously published datasets (Ilves and Darmark 2011; Ilves 2012) were reanalysed with the use of the new ΔP index and the results compared with these authors’ original interpretations. In most cases, P value change was interpreted as significant at the point where the respective ΔP value was above the level of $\bar{X} + \sigma$ (mean value + standard deviation) of a given sampling line and this value has therefore been applied as a significance threshold in the current research (Tab. 1). Points yielding ΔP values exceeding this relative threshold value were marked as ‘events’ where the P change was considered drastic enough to indicate the contact zone between a human activity area and the water. Although the described approach allows for rather objective identification of events, their final interpretation has to be supported with the observations of the local $\bar{X}$ of P values.

4. Results and discussion

Analysis of control lines 1 and 2 revealed significantly lower P and $\bar{X}P$ values than the activity areas in Zones 1 and 2, with P values generally <3000 ppm, and $\bar{X}P$ 1700-1800 ppm (see Tab. 1, Figs 2-3). This is to be expected, since the control lines were located some distance from the visible human activity areas in Zones 1, 2 and 3, where activities may have been expected to contribute to the input of P-rich organic matter or ash into the soil. However, rather than showing an even distribution across the transects, the P values in both control lines dropped unexpectedly at 3.0-3.1 and 2.5-2.7 m a.s.l.. These sudden drops in P differ from the pattern we have come to associate with the border between human activity zones and the sea, where the P values at elevations above the initial drastic P-drop tend to be higher and steadier, and the P values at elevations below the initial P-drop, where soils remained in regular contact with water, tend to remain distorted and highly variable (e.g. Ilves and Darmark 2011, and Figs. 3 and 5, below). It seems likely, therefore, that these two events mark exceptionally violent storm events, in which the waves reached 3.0-3.1 and 2.5-2.7 m above current sea level respectively, and at which points the P in the natural A horizon was disturbed.
In Zone A, three events were identified in sampling line 1 in which ΔP values exceeded the threshold for that particular line (Fig. 4). In Event 1, a drop in P was recorded at an elevation of 3.13 m a.s.l., which was followed by three high variance values, causing a slight lowering of local xP (local mean P). In Event 2, a drop in P was recorded at an elevation of 2.83 m a.s.l., just on the seaward side of the stone-built bank, this time causing a drastic drop in local xP, which was again followed by three readings of high variance. In Event 3, a sudden rise in P was recorded at an elevation of 2.38 m a.s.l., not followed by any notable change of variance, but causing a slight rise in the local xP.

[Fig. 4]

The most straightforward event to interpret is Event 2, as its P distribution follows the pattern expected for the border between a P-enriched activity area and a water body. The event caused the local xP to drop to a level comparable with the control values (Figs. 2-3), suggesting no anthropogenic enrichment in the area on the sea-ward side of the stone-built bank; at the same time it points towards intense human activity within the zone sheltered by the bank. In this zone, the boundary between the water and the site seems to have coincided with the location of the bank, and the process of erecting and maintaining the bank seems to have happened on the very edge of the water. This would explain why the test trench through the stony bank did not reveal any buried soil layers, but showed that the bank was built of the same shattered beach stones it was resting on (Mooney 2011: 74-75).

Event 1 is more complicated to interpret. If analysed separately, it would readily be interpreted as the earliest point at which the activity area associated with two-walled structure bordered the sea; however, when analysed in the context of the whole line, it seems surprising that the later activity on site, linked with Event 2, did not mask or overwrite this boundary with subsequent P enrichment. On the other hand, the event caused a notable drop in the local xP and cannot be ignored. It is notable that the elevation of Event 1, at 3.13 m a.s.l., coincides with the elevation of the putative storm high water mark interpreted on the basis of the drastic drop in P noted in control lines 1 and 2. We therefore suggest that while Event 1 might represent the highest elevation and earliest date at which this activity zone was used, it is also possible that it represents an unusual storm event, and that subsequent activity in Zone 1 was not intensive enough to fully replenish former P levels – although these came close to what they were before Event 1.

Event 3, despite crossing the ΔP significance threshold, is most likely to be a continuation of the P distortion spread after Event 2. This is supported by the fact that Event 3 represents a very localised rise of P values, without any consequences for the subsequent P readings, and with a very weak influence on the local xP of the lowest elevation samples (Fig. 4).

4.2. Zone B

Zone B was sampled with three lines. In Line 2, which was located between the northeast wall of the U-shaped structure and the current shoreline, there were two events identified, but no high variance readings were registered (Fig. 5). In Event 1, a drop in P was recorded at an elevation of 2.87 m a.s.l.,
causing a dramatic decrease in local $\bar{x}P$ among the subsequent readings (the adjacent readings at a slightly lower elevation). In Event 2, a slight drop was recorded close to the edge of the vegetation cover on the shoreline, but this may be excluded from our analysis as its $\Delta P$ value barely crossed the significance threshold and its location on the very edge of the sampling line is probably responsible for the drop in $P$. The $\bar{x}P$ of all the samples taken at a lower elevation than Event 1 is still higher than both control $\bar{x}$ values, which suggests that the area continued to be used even after the sea level associated with its original use had dropped. As will be seen below, this accords well with the results from the other two lines in Zone 2.

In Line 3, which stretched from the mouth of the U-shaped building towards, and over, the dry stream bed, three events were identified (Fig. 5). In Event 1, a prolonged drop in $P$ concentration was noted at an elevation of 2.46 m a.s.l., which was associated with a massive drop in local $\bar{x}P$ of the following (slightly lower elevation) readings. In Event 2, a slight rise in $P$ concentration was recorded at an elevation of 2.28 m a.s.l., which did not introduce any change to the local $\bar{x}P$ of subsequent readings. And finally, in Event 3, a rise in $P$ was recorded at an elevation of 2.20 m a.s.l. (note that the elevation of the sampling line was rising slightly at this point, after reaching a low of 2.00 m a.s.l. in the middle of the dry stream bed). Local $\bar{x}P$ values that were reduced to the level of the control samples after Event 2 became high again after event 3, and, at levels of around 2500 ppm, exceeded the $P$ concentration of most of the control samples. Event 2 is considered the least significant of these events because it had no influence on the subsequent readings, and should probably be considered one of several high amplitude variations in $P$ visible around the dry stream bed (Fig. 5).

The results from Line 3 suggest that the area in front of the U-shaped structure, where the shallow stream entered the sea, was indeed a small inlet of the sea while the structure was in use. As the sea level dropped, the mouth of the shallow stream moved further to the east and entered the sea at a lower elevation, while the opposite bank of the stream in this location became part of the activity area associated with the U-shaped structure and received greater $P$ enrichment.

The difference in the elevations of the first events recorded in Lines 2 and 3 are interesting and require explanation. Event 1 in Line 2, which occurred at 2.87 m a.s.l., records earlier activity at the site than Event 1 in Line 3, which occurred at 2.46 m a.s.l. It is likely that Line 2 has registered the earlier side of the activity zone, which was linked with the heavily eroded and probably older ruins north of the U-shaped structure. Line 3, on the other hand, seems to show a slightly later activity area immediately in front of the entrance to the U-shaped structure, which was associated only with the use of this structure, when it faced a small sea inlet.

In Line 4, which stretched from the mouth of the structure to the shoreline directly to its east, only one event was identified (Fig. 6). After this event, which occurred at an elevation of 2.29 m a.s.l., $\bar{x}P$ was lowered to the control level. A close look at Fig. 6 shows that, regardless of the threshold
significance, this event should probably be associated with the start of the dramatic drop in P at an elevation of around 2.40 m a.s.l., bringing it in close correspondence to Event 1 from Line 3.

4.3. Zone C

Zone C was sampled with a single line (Line 5), which registered two events (Fig. 6) between the mouth of the V-shaped structure and the present shoreline. Event 1 was a rise in P at the very beginning of the line, where the ground was still flat within the mouth of the structure, and it must be associated with human activities rather than the boundary between the site and the sea. Event 2, on the other hand, was a pronounced drop in P at an elevation of 2.19 m a.s.l., which heavily influenced \( \bar{x}P \) of subsequent readings between the structure and the shore adjacent to the keel mark. Although the trend in the line is clearly visible, the P values are in general surprisingly low (\( \bar{x}P < 700 \) ppm), far below the control \( \bar{x}P \) (see Tab. 1 and summary Fig. 3). As the \( \Delta P \) values of this line are comparable with other sampling lines in the area there is no reason to doubt the credibility of the sampling line. Instead, the low P values in Zone C raise the possibility that area where the control lines were placed did in fact receive some P enrichment, even though they were a significant distance from Zone B. Possible reasons for this are discussed further below.

[Fig. 6]

4.4. Chronology of activity zones

An attempt was made to date the events in the sampling lines using the relative sea-level change curve for Vatnsfjörður that had been generated by Lloyd and Dickens (2009) on the basis of changes in the foraminifera assemblage in the nearby isolation basin of Sveinhusavatn. However, when the RSL change rate of 0.86 m/ka was first applied to the elevation and P data discussed above, it resulted in 4th-century, pre-Viking-age date for the earliest use of the Vatnsfjörður shoreline (Tab. 2).

Because of this incompatibility with the known date of the occupation of the nearby farm, and indeed the colonisation of Iceland in c. 870 AD, an attempt was made to refine the RSL change model using the H-1693 tephra layer, which was found in most of the sampling points along the coastline. Volcanic tephra accumulates only where there is sufficient vegetation cover to shelter the particles from wind erosion (Dugmore and Newton 2012: 46), and tephra will be disturbed or washed away when deposited on bare rocks or gravel within the tidal area. Therefore, our study assumed that the lowest elevation at which tephra was registered on every sampling line represents the lowest elevation of the coastal vegetation in 1693 AD, when the tephra was deposited. Today the coastal vegetation limit at Vatnsfjörður is at the elevation of the current high spring tide mark, therefore, the difference in elevation between the current vegetation limit and the lowest edge of tephra layer is indicative of the RSL change that has occurred between 1693 and the present day.

Elevation of the lower extent of the H-1693 tephra was measured in seven different locations along the Vatnsfjörður coast and the mean value calculated was 2.12 m a.s.l. (\( \sigma=0.03 \)). The present elevation of the vegetation limit was measured in 46 locations along the same stretch of coast and the mean value was 1.69 m a.s.l. (\( \sigma=0.07 \)). The difference between these measurements, 0.46 m
(σ=0.08), reflects the RSL change between 1693 and the present. Those calculations were used to approximate a new RSL change rate of 1.4 m/ka and a new RSL change curve was produced. Although RSL change is rarely a linear process and two chronological markers are inadequate to calculate a comprehensive model, we found that the refined RSL change curve provided a much more realistic guide to the approximate dates of the coastal activity zones in the Vatnsfjörður area.

Using the new chronological model, the dates assigned to the events discussed above span the 11th to 17th centuries, which corresponds remarkably well with the known dates of the settlement site (Tab. 2). By projecting this RSL change model onto a precise digital terrain model of the Vatnsfjörður coastline based on a DGPS survey conducted for this study, the past shorelines contemporary with the events identified as activity zone borders have been reconstructed (Fig. 7).

5. Conclusions

The results of the study reveal a rather complex picture of coastal use at Vatnsfjörður. It seems that the activity zones were not in use simultaneously but in a sequence, probably losing their primary maritime functions as the marine regression advanced. Zone A was the first zone put to use, in the 11th century, when this area formed a small peninsula suitable for one building. Finds from the boathouse-like structure, as well as the P results indicating water-bound activity, strongly suggest that Zone A was one of the first landing sites of the farm, and support the interpretation of the structure as a late Viking-age boathouse. Two centuries later, in the 13th century, a stone bank was built around the area, possibly as a protection from storms. This separated the site from the direct maritime context. The post-1693 phase of the structure did not left any P traces on the shoreline, indicating that the function of the structure had changed. The first phase of the water-bound activity in Zone B is dated to the 13th century and may actually be linked in time with the cessation of the use of Zone A as a landing site. The activity in Zone B seems first to have been concentrated in the area’s northern part, around the poorly preserved V-shaped structures, which may be presumed to be boathouses. Contemporary with the erection of the most prominent building in this area, the U-shaped structure, a new phase of water-bound activity left detectable P traces in front of the structure, dated to the 15th century. This date matches the distinctively robust, stone-lined character of the structure’s walls, which closely resemble the walls of the post-medieval domestic buildings on the Vatnsfjörður farm mound. At this time the area in front of the structure was a shallow inlet of the sea, making it easily accessible by watercraft. Although this does not confirm the function of the U-shaped structure, it makes it more likely that it was used as a boathouse. There is some P evidence that this zone was used for the next two centuries, and that the open, grassy area east of the Zone B might also have been used occasionally and less intensively as an activity area. In the 17th century,
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the landing place was moved to Zone C, where a new structure, presumably a boathouse, was built using dry-stone foundations instead of turf – a more modern choice of building materials.

The methodologies that were used and developed for this study were very successful. P transect mapping for the purpose of detecting site-contemporary shorelines, combined with RSL change data refined using tephrochronology, provided interesting results that closely complemented the archaeological data. More importantly, these new techniques enabled us to build independent and far more complex narratives about ephemeral, difficult-to-interpret and difficult-to-date buildings and activity areas on the Vatnsfjörður shoreline than had hitherto been possible. This has important and exciting implications for the potential of other coastal sites throughout Iceland, and indeed all coastal countries where reliable RSL change data are available or tephrochronology provides a viable dating method for soils.

6. Acknowledgements

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7. Literature


6. Acknowledgements

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7. Literature


Löfstrand, L., 1974. Yngre stenålderns kustboplatser, Undersökningarna vid Ās och studier I den gropkeramiska kulturens kronologi och ekologi, Aun 1, Uppsala.


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Figure 5
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