Arne Anderson Stamnes and Egil Lindhart Bauer

16 Geophysical Surveys

This chapter presents the geophysical surveys of Avaldsnes carried out by several actors between 2004 and 2013 and discusses the surveys' results. An important part of the discussion is a quantitative and qualitative comparison of the geophysical data compiled and archaeological discoveries made during the field campaign. Such comparisons have seldom been performed on Norwegian material. This work will therefore lead to discussions of the different surveys' usability for planning archaeological excavations, enabling suggestions for improvements in the quality of geophysical data and methods for data processing so that archaeologically relevant anomalies under similar conditions can be more easily distinguished. The GPR surveys, most notably the survey conducted by the Vienna Institute for Archaeological Science (VIAS) in 2009, revealed a high number of clearly defined, archaeologically significant anomalies; the data was easily applied both prior to and during excavation. Several of the other surveys proved difficult to interpret, as the data lacked spatial detail or was muddled by large amounts of stones, waterlogged soil, or the effects of magnetic geology of volcanic origin. However, during reprocessing and reinterpretation of the data with the excavation results at hand, it became clear that the various surveys have provided significantly more information than was appreciated by geophysicists and archaeologists before the excavation commenced. That the excavation results needed to be known in order to recognise relevant archaeological features illustrates the difficulty of interpreting geophysical data. Such data must be tried against a number of hypotheses for the site in question. Otherwise, the sheer amount of data can be overwhelming and impractical to utilise. Furthermore, the data must be used not only prior to, but also during excavation, and the excavation staff and the geophysics technicians must be able to discuss data and excavation results throughout a project's lifespan. By evaluating data and adjusting methods, targeted investigations can be carried out in relevant areas, rendering the field campaign more effective.

The large quantity of geophysical surveys carried out at Avaldsnes allows thorough evaluation of the different methods by comparing the collected data with the excavation results from the 7,715 m^2 excavation areas from the investigations from 1992–2012 combined. One of the main aims of the evaluation is to review the various geophysical methods' applicability under the geological and archaeological conditions encountered at Avaldsnes. As the surveys were carried out by different parties and with different goals, methods, and equipment, a thorough evaluation is possible. This chapter presents this evaluation as a reference for further development of geophysical survey strategies for archaeological purposes, including for determining how best to apply geophysical methods under the ruling survey conditions elsewhere. One of the main advantages to geophysical surveys is that they enable the on-site archaeological staff to conduct targeted investigations. Thus, a key point in the evaluation of the geophysical methods is how readily the various geophysical data could be interpreted by the on-site staff, both prior to and during excavation. The following discussion involves features in areas 1, 2, 5, 6, and 8 (Bauer and Østmo, Fig. 5.2) at Avaldsnes – areas with features exemplifying relevant possibilities and limitations related to the geophysical surveys applied at the site. For a discussion of surveyed areas and features not mentioned here, please refer to the geophysical reports (Sandnes and Eide 2004; Persson 2006; Smekalova and Bevan 2009; Barton 2010).

16.1 Geophysical surveying at Avaldsnes – a brief history

A complete overview of all the geophysical surveys at Avaldsnes is given in Tables 16.1–2, as well as Figure 16.1.

Initiated by Karmøy Municipality, the first geophysical survey at Avaldsnes was conducted in August 2004 by the georadar manufacturing company 3-d Radar AS using a prototype of their Step-Frequency ground-penetrating radar (GPR) system. The data quality was restricted by the equipment's limitations coupled with water-saturated ground and standing surface water. The current, fourth-generation commercially available system features sensitivity, signal quality, and processing software that are significantly enhanced compared with the prototype used in 2004. The report contains selected time-slices and GPR sections (Sandnes and Eide 2004; Eide, personal comm. 2013).

Likewise initiated by Karmøy Municipality, a geophysical survey was conducted in April 2006 by GeoFysica, managed by Kjell Persson, using a Malå Geoscience GPR system with a 500-MHz antenna and a Geonics EM38 electromagnetic induction meter. The report contains combined contoured and greyscale plots for the EM data; the GPR data was presented as contoured horizontal depth slices and selected GPR sections (Persson 2006). It is uncertain what methods were used for positioning and mapping the surveyed areas.

Following the ARM Project's first application to excavate in 2009, the Directorate for Cultural Heritage required that survey methods and the testing and development of geophysical technology be systematically non-destructive. The Project arranged with three different parties to carry out new surveys: the Museum of Natural History and Archaeology at the Norwegian University of Science and Technology (NTNU) in collaboration with the Irish company Earthsound Associates performed the most extensive survey, while Moesgård Museum/Geosight and the Vienna Institute for Archaeological Science (VIAS) surveyed limited parts of the planned excavation areas.

In connection with Dr Natascha Mehler's project "HANSA: The Hanseatic Expansion in the North Atlantic", VIAS conducted a GPR survey of the northern part of Area 2 in April 2009. Using a Sensors and Software Noggin system with a 500-MHz GPR antenna, the project collected georeferenced horizontal time-slices and generously shared the results with the ARM Project. Analyses of the provided images indicated a traverse interval of 0.25 m; no other technical information is available. The method used for positioning the surveyed area is unknown, but the accurate size and correlation with known archaeological features indicate a high-level GPS or total station.

In June 2009, US-based Geosight, in collaboration with Moesgård Museum in Denmark, performed a total field magnetometer survey, combined with an EM38 and earth resistance survey. The report contained data plots with contours and colour plots, apparent gradiometer plots, depth-, mass-, and shape-modelling, and estimates of selected anomalies (Smekalova and Bevan 2009). The positioning was based on the grid set by VIAS.

Earthsound Associates performed a geophysical survey on behalf of the Museum of Natural History and Archaeology (NTNU) in August 2009. The survey had four phases: 1) a reconnaissance magnetic susceptibility survey performed with a Bartington MS 2 with the MS2D loop probe, 2) a fluxgate gradiometer survey performed with a Geoscan Research FM 256, 3) an earth resistance survey performed with a Geoscan RM 15 and a TRS/CIA twin probe array, and 4) a detailed GPR and Earth Resistivity Tomography survey performed with a GSSI Sir 3000 system with a 400 MHz antenna (Barton 2010). NTNU returned to conduct post-excavation GPR surveys in 2013, intended to map the extent of archaeological features investigated during the 2011 and 2012 excavations in Areas 1 and 8. The results from this investigation are presented exclusively in this chapter and are not available in a separate report. Positionings were obtained by total station and a differential GPS.

Tab. 16.1: Summary of survey institutions, methods, and areas covered by the various surveys. The last three of the six were commissioned by the ARM Project.

	MS	Magnetometer	GPR	EMI	ER	Total
3d-radar AS (2004)	–	–	4,410 m²	–	–	4,410 m²
GeoFysica (2006)	–	–	1,669 m²	1,851 m²	–	3,520 m²
VIAS (2009)	–	–	4,000 m²	–	–	4,000 m²
Moesgård/Geosight (2009)	–	4,870 m²	–	801 m²	–	5,671 m²
Earthsound Associates/NTNU (2009)	26,863 m²	22,000 m²	9,745 m²	–	3,213 m²	63,641 m²
NTNU (2013)	–	–	2,449 m²	–	–	2,449 m²

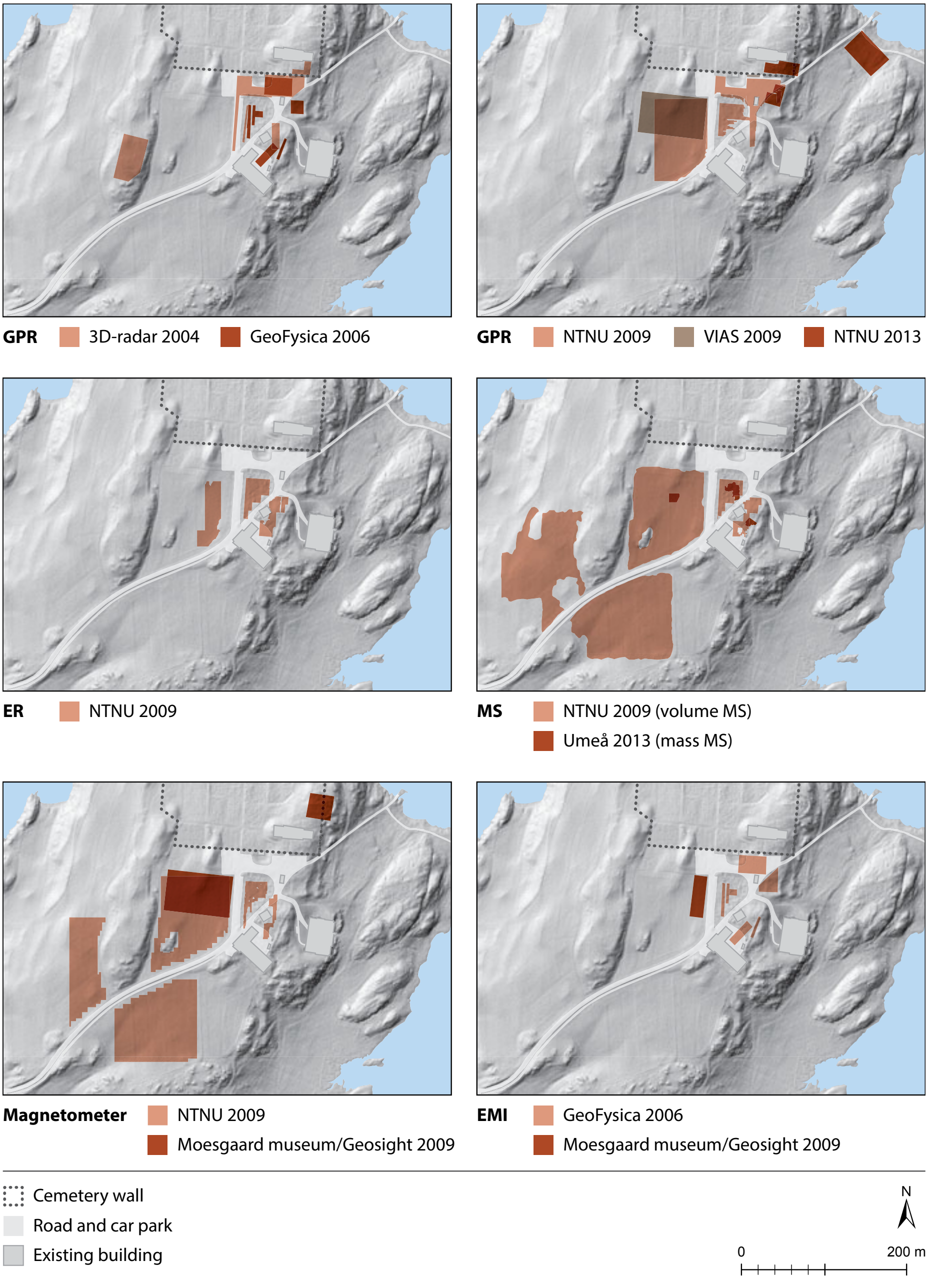

Fig. 16.1: Map of all geophysical surveys carried out at Avaldsnes 2004–13 (Tab. 16.1). Illustration: A. A. Stamnes, I. T. Bøckman, MCH.

Tab. 16.2: Overview of the various survey setups, GPR frequencies, instruments and manufacturers used at Avaldsnes.

Survey setups				
GPR	**Crossline**	**Inline**	**GPR frequencies**	**Instrument and manufacturer**
3d-radar 2004	0.09 m	0.05 m	?	3d-radar Geoscope mark 1 prototype
GeoFysica 2006	0.5 m, 1 m and 5 m	0.03 m	500 Mhz	Malå Ramac
VIAS 2009	0.25 m	?	500 Mhz	Sensors and Software Noggin GPR
NTNU 2009	0.5 m, 1 m and 5 m	0.02 m	400 Mhz	GSSI Sir-3000
NTNU 2013	0.25 m	0.025 m	400 Mhz	
ER	**Crossline**	**Inline**	**Electrode spacing**	
NTNU 2009	0.5 m	0.5 m	0.5 m/1 m	Geoscan Research RM 15 and Tr/CIA Resistivity meter
MS				
NTNU 2009	5 m/2 m	5 m/2 m		Bartington MS2 with the D field probe
Umeå 2013	1 m	1 m		Bartington MS3 with the MS2B probe
Magnetometer				
NTNU 2009	0.5 m	0.125 m		Geoscan Research FM256
Moesgaard Museum/Geosight 2009	0.5 m	0.2 m in average (reading every 0.2 second)		GEM Overhauser GSM-09WG
EMI				
GeoFysica 2006	0.5 m	0.5 m		EM38
Moesgaard Museum/Geosight 2009	1 m and 0.5 m	1 m, 0.5 m		EM38

16.2 Linking geophysical data sets

The geophysical surveys performed at Avaldsnes from 2004 to 2013 provided data sets from different areas, using different methods and equipment. Only the surveys from 2009 onwards were directly related to the ARM Project, and only the 2009 and 2013 NTNU surveys were part of an overarching geophysical survey strategy. However, all surveys are evaluated here, including those from 2004 and 2006 as they covered areas subsequently excavated in 2011 and 2012.

Accuracy is essential when comparing geophysical data with excavation results. Data of high spatial detail is required for identifying small archaeological features. All reports from the above-mentioned surveys contain maps and data plots, usually with discussions of selected anomalies and observations, their origin, and their potential archaeological significance. However, each field crew documented their survey location using different survey equipment with inherent variations in accuracy. Consequently, georeferencing for an effective comparison of the data sets was a challenge, as most of the geophysical survey reports did not contain georeferenced maps or additional information in GIS or CAD format of either geophysical data or archaeological interpretations of anomalies. The 2009 VIAS GPR survey provided georeferenced depth-slices, which in turn were very helpful in georeferencing the survey data and interpretations from the 2009 Moesgaard/Geosight survey, which was collected on the same grid (Smekalova and Bevan 2009). The GeoFysica data was difficult to georeference due to the low resolution of the maps published in the report (Persson 2006), while we observed some discrepancies in the 2009 NTNU dataset (Barton 2010). For the latter two surveys, grid-plot sizes did not always match those presented in the reports, and for the 2009 NTNU survey anomalies in GPR survey time-slices performed in different directions in the same area did not always correspond. Such discrepancies required data repositioning to ensure accuracy, taking as reference points mainly those anomalies visible in several or all data sets. We have strived to the best of our ability to identify and compensate for any inherent discrepancies that might introduce errors.

16.3 Geophysical survey methods, interpretation, and data comparison

Magnetic methods involve measuring various magnetic properties, including the topsoil magnetic susceptibility (volume MS or K) or the mass magnetic susceptibility (mass MS or χ) of soil samples, as well as field-based mapping with a magnetometer or gradiometer (an array of two magnetometer sensors used to measure changes in the vertical component of the Earth's magnetic field; the dual sensors overcome the problem of diurnal variations in the magnetic field). Typically, such methods are useful for detecting activity such as burning, metalworking, accumulated soil, or magnetic material. For an in-depth description of the magnetic methods, see Gaffney and Gater (2003), Dalan (2008), and Aspinall (et al. 2009).

Electrical measurements are taken to map local changes in the ground's electrical properties. Typically, a ditch is conductive as it can retain water, while stones or hard-packed areas tend to be electrically resistive as they do not retain water. By mapping changes in electrical resistance over an area or along depth-sections in the ground, archaeological features can be located. For further information on electrical survey methods, see Clark (1996), Gaffney and Gater (2003), and Schmidt (2013).

Electromagnetic techniques involve use of ground penetrating radar (GPR) and electromagnetic induction (EMI). A GPR transmits electromagnetic energy, often referred to as radio waves, into the ground. By measuring this energy's return time and strength, reflective sources can be mapped in section and plan. A GPR survey is usually performed with traverses laid out parallel to each other with a set spacing. Each measured traverse provides a GPR section of all reflectors along the traverse; by surveying parallel traverses, a three-dimensional data set is established. A map of the magnitude of all reflections at a certain depth is called a time slice. For more detailed information on GPR in archaeology see Conyers (2012; 2013) and Goodman and Piro (2013).

Electromagnetic induction (EMI) is a method of simultaneously measuring both apparent magnetic susceptibility (EMI MS or in-phase) and apparent electrical conductivity (EMI EC or quadrature phase) in the ground. The instrument generates a magnetic field that magnetises particles in the soil. The quantity of this magnetisation is measurable as apparent magnetic susceptibility. The electrical currents in the ground caused by the instrument's magnetic field produce a secondary magnetic field, the strength of which is related to the ground's apparent electrical conductivity. For further information on the principles of EMI, see Clark (1996), De Smedt (2013), and De Smedt (et al. 2013).

16.4 Pre-excavation survey: Area 1

Excavations in Area 1 revealed building remains from A10 and A14 (Østmo and Bauer, Ch. 7:108–17, 126–8) and the remains of stone foundations from the post-medieval rectory at Avaldsnes. In Area 1's south-eastern corner, a medieval ruin (A12) with walls up to 110 cm high lay covered by garden soil from the rectory. Other notable features were a subterranean passageway and a stone-built well of post-medieval origin. Due to the extensive timespan of prehistoric and historic activities in Area 1, many of the archaeological features have truncated and disturbed one another. In addition, there have been massive recent disturbances related to various post-medieval activities as well as the construction of a car park in the area south of the cemetery wall.

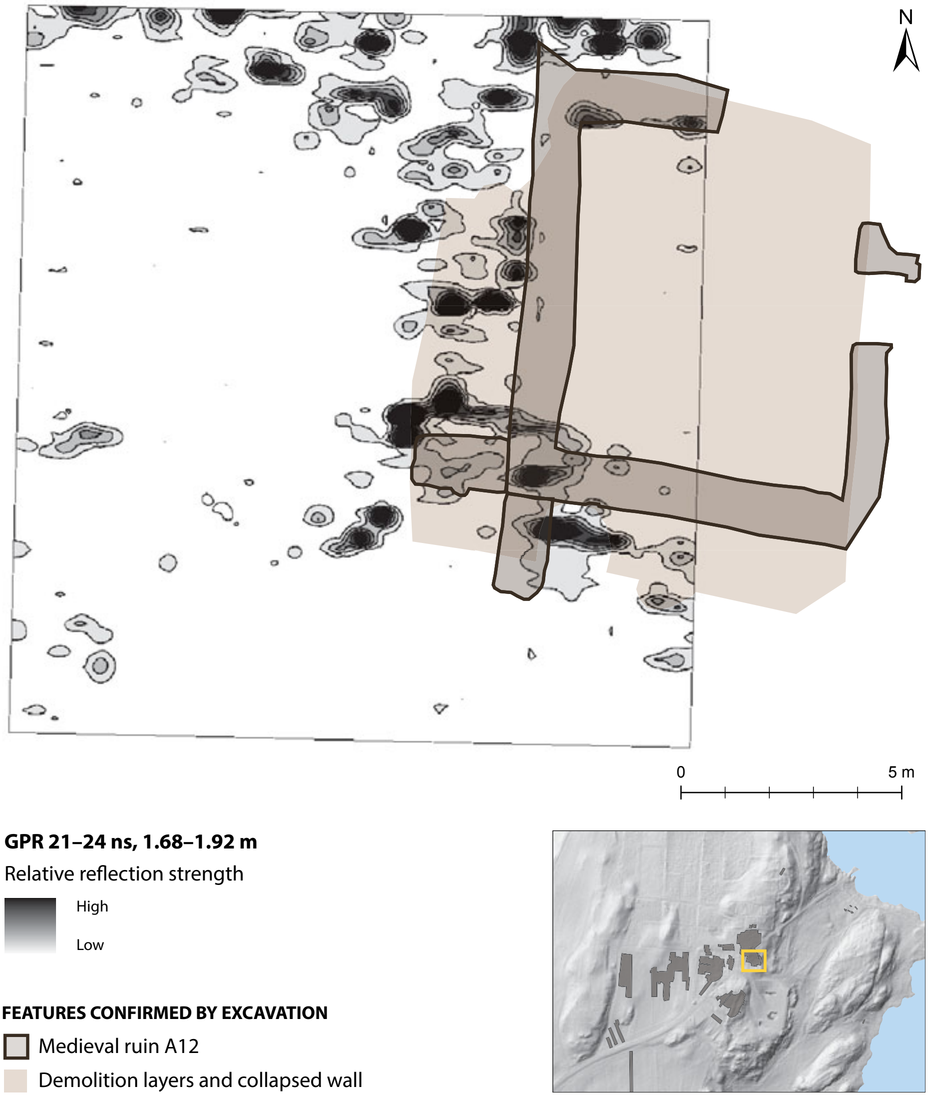

Fig. 16.2: Comparison of Persson's GPR time slice and excavations results in south-eastern part of Area 1.
Illustration: A. A. Stamnes, I. T. Bøckman, MCH. Plot from GPR; GeoFysica 2006 (Persson 2006).

Among the modern disturbances were a ditch for a high-voltage cable cutting through the area between the rectory remains and building A10/A14 (Bauer, Fig. 15.7).

Stone walls from A12 (Bauer, Ch. 14) were visible in the GPR data as a linear north–south anomaly breaking eastwards (Fig. 16.2; Persson 2006:fig. 17). The orientation of the building's southern and western walls in the data diverged somewhat from the wall exposed during excavation. This might be because the walls were obscured by

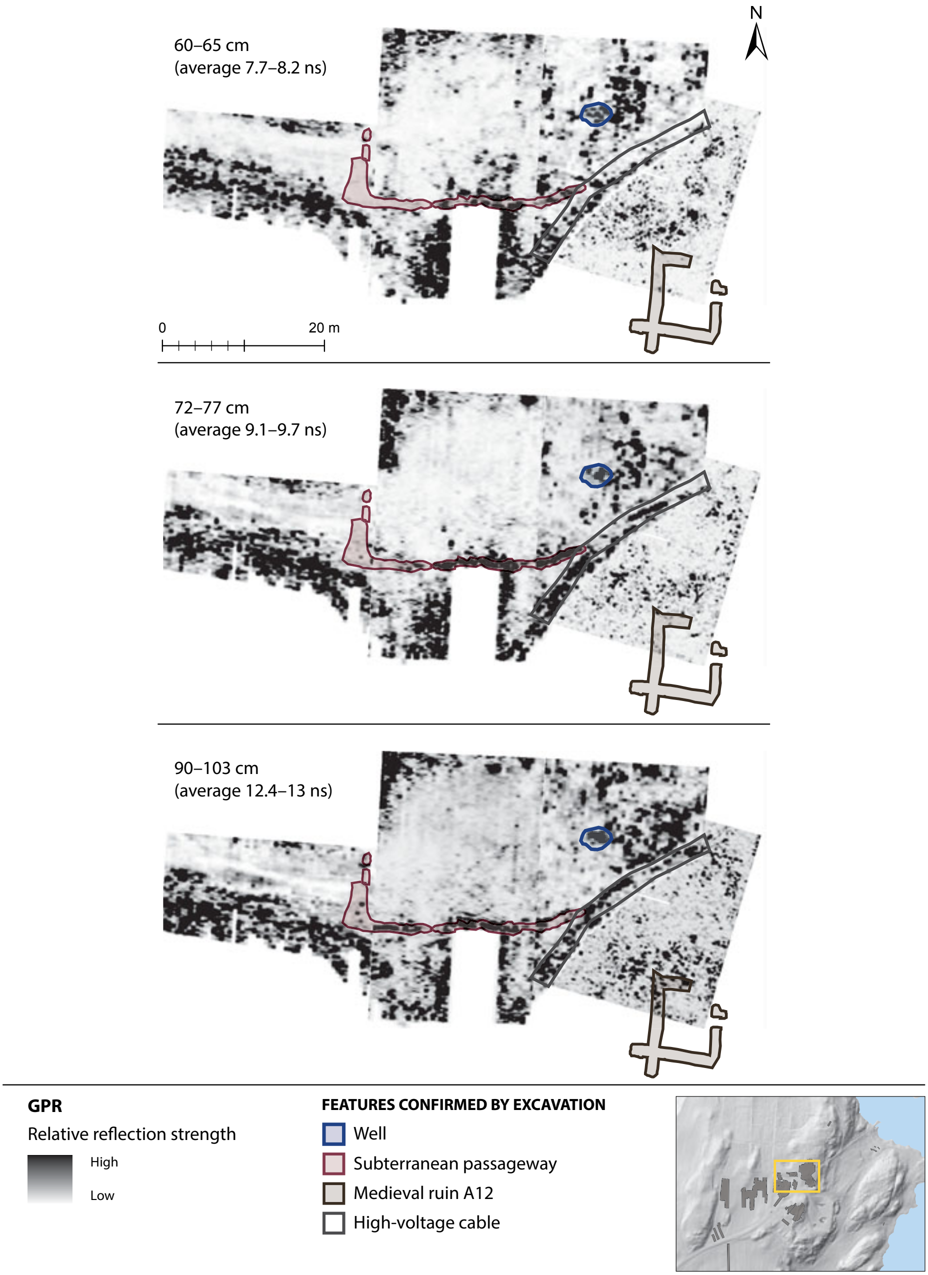

Fig. 16.3: Maps showing GPR reflections at different depths of the medieval ruin, the subterranean passageway, the stone-built well, and the high-voltage cable. Also notice the low reflectivity strength in the central part of Area 1.
Illustration: A. A. Stamnes, I. T. Bøckman, MCH. Plot from GPR, Earthsound Associates/NTNU (Barton 2010) and NTNU 2013.

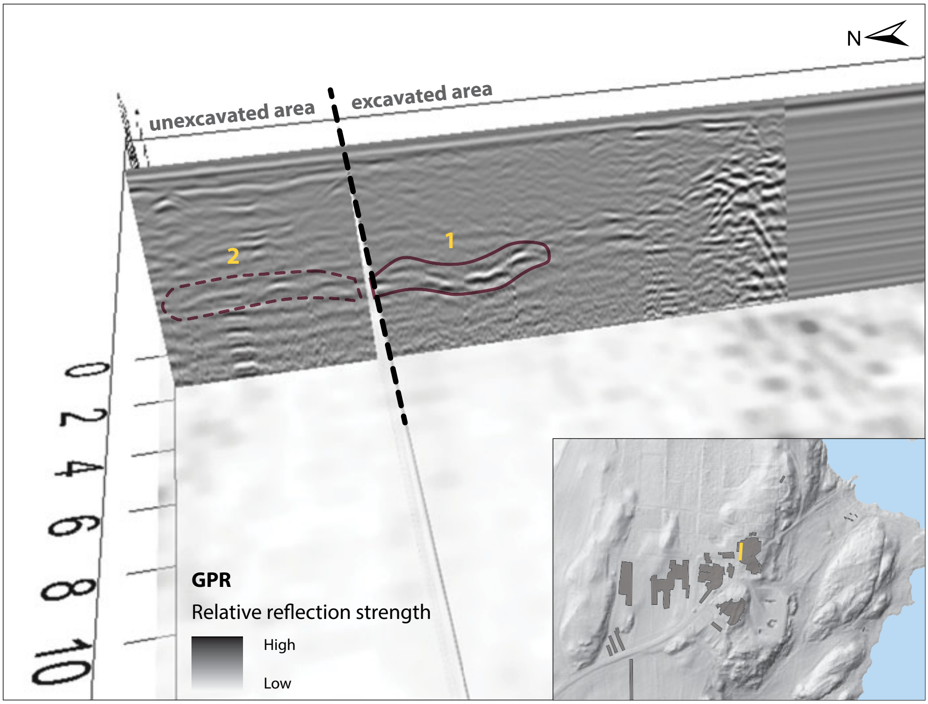

Fig. 16.4: The dashed line denotes the northern edge of the 1986 excavation.
No. 1 is a strong curved reflection coinciding with the subterranean passageway exposed in 1986.
No. 2 might be reflections from a northward continuation of the passageway. Illustration: A. A. Stamnes, I. T. Bøckman, MCH. Plot from GPR, Barton 2010.

stone-filled demolition deposits or, alternatively, due to a grid-positioning error or sources of error introduced during data collection, for instance inconsistent walking speed.

In 1986, excavations revealed a medieval subterranean passageway constructed of stone slabs, running across Area 1 towards St Óláfr's Church. The re-deposited soil and gravel in the trenches were uncovered during the 2011 excavation. This re-deposited material also showed in the GPR data (Barton 2010). Tracing the passageway in the GPR data, it is apparent that the feature lies deeper in the west than in the east (Figs. 16.3–4). In the east, the passageway lies at a depth of approximately 50 cm, while in the west it dips down to approximately 110 cm. This corresponds to the estimated depth based on photographs from the 1986 excavation (Bauer, Fig. 14.11). It is possible to trace a northward continuation of the passageway in the GPR data (Fig. 16.4), which is indicated by a strong reflection in the GPR profile at the expected depth that is not visible in the neighbouring profiles (Fig. 16.5). The reflection probably derives from the flagstones that covered the passageway and the re-deposited material from the 1986 excavation. The hard-packed gravel surface also attenuates

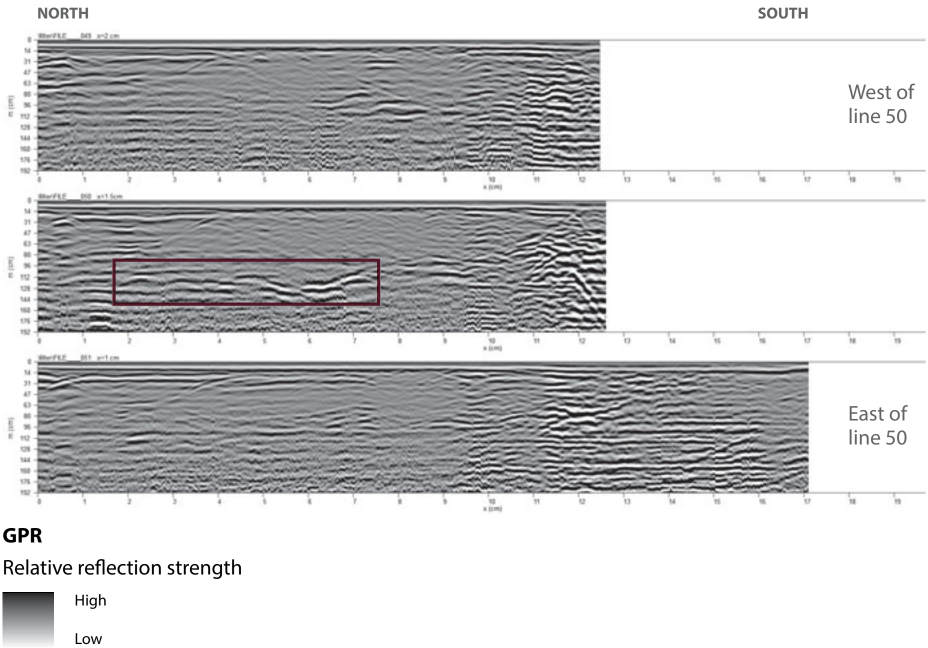

Fig. 16.5: GPR radargram showing the GPR reflection from the possible northward continuation of the passageway.
Illustration: A. A. Stamnes, I. T. Bøckman, MCH.

part of the signal, yielding a lessened response in this particular area visible in all profiles in Figure 16.5, while still giving a strong response from what we interpret as the northern continuation of the passageway.

A circular, stone-built well with infilling dated to the 18th–20th centuries (Beta-319021) is clearly visible in the GPR data from the central part of Area 1. This feature presents itself as a strong reflection visible at the same place in time slices from multiple depths of the collected dataset (Figs. 16.3 and 16.6). The excavation showed that the well's diameter was larger in its upper part, narrowing slightly towards the bottom at a depth of approximately two metres. The GPR data show an area of strong reflections in the shape of hyperbolas and layer disruptions down to similar depths. Stones made up the well's walls and the backfill within. The backfill was more reflective than the walls, indicating increased water content in the backfill. This is plausible, considering the purpose of a well: to retain water.

The Iron Age hall building (A10) (Østmo and Bauer, Fig. 7.5) was discovered in the north-eastern part of Area 1, and was identified by a central hearth, several postholes, and a 16.5-metre-long wall ditch cut directly into bedrock. The wall ditch was not observable in the initial processing of the NTNU data (Barton 2010), so several processing steps were attempted to enhance it. The wall ditch ran roughly north to south, while the data was collected both north to south and east to west. Since the ditch lay

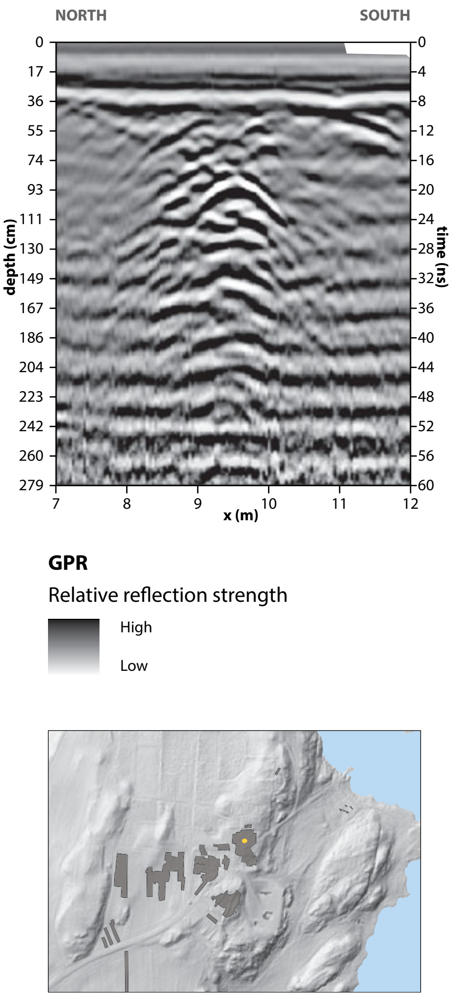

Fig. 16.6: GPR radargram showing the GPR reflection from the stone-built well (A11062). Illustration: A. A. Stamnes, I. T. Bøckman, MCH.

shallow and was only 30–50 cm wide, the reprocessing focused on a higher frequency range (285–750 MHz) – the processing of different frequency ranges has been suggested as a means of improving image resolution and extracting additional information from GPR data (Grealy 2006). After reprocessing, parts of the ditch became visible as a weak geophysical contrast, seen as a 40–50 cm wide linear anomaly stretching over approximately three meters, which could be seen in three five-centimetre-thick time slices, and only in the dataset collected perpendicular to the feature (Fig. 16.7). This demonstrates how easily certain features can be overlooked in the data interpretation process. While other, more recent features could be seen, such as anomalies relating to electrical cables and water pipes, as well as an older pathway or road leading towards the church, the geophysical contrast of the wall ditch was indistinct under the current survey conditions. The geophysical properties between the cut and

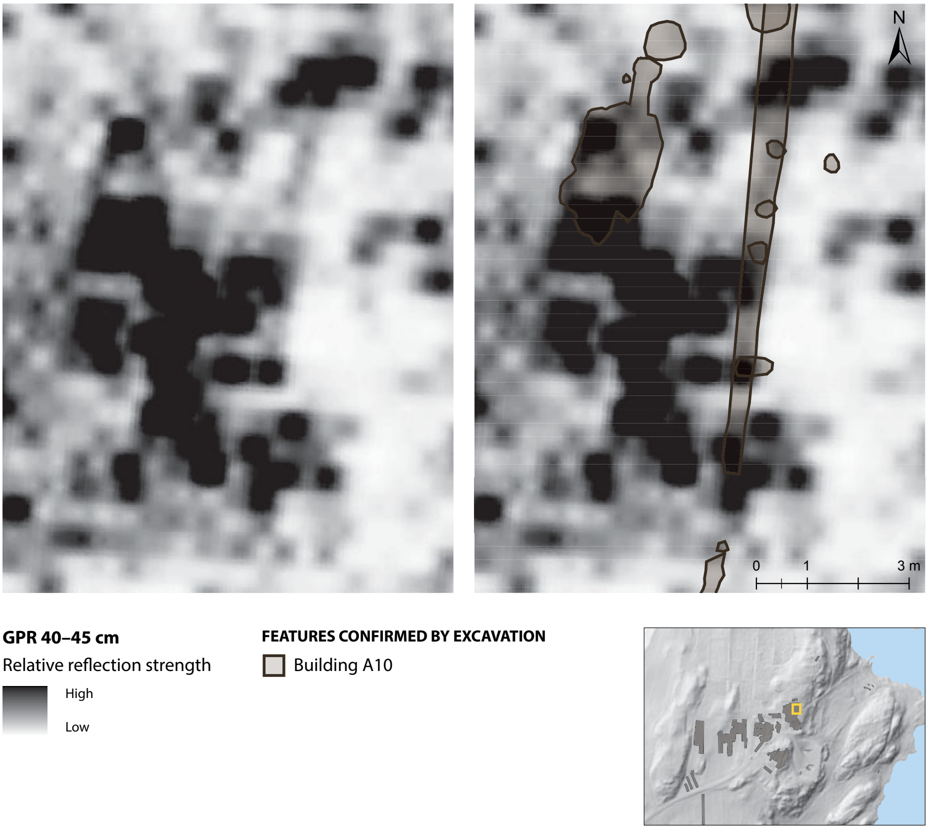

Fig. 16.7: Building A10 remains in the reprocessed GPR dataset collected east to west. Few of the excavated postholes and none of the hearths are visible in the selected time slice.
Illustration: A. A. Stamnes, I. T. Bøckman, MCH. Plot from GPR, Earthsound Associates/NTNU 2009 (Barton 2010).

the fill were apparently too similar to yield a strong geophysical contrast. The focusing of the GPR signals' higher-frequency range helped identify the wall ditch in the GPR data. As the wall ditch lay relatively shallow, another possibility would have been to test a higher-frequency antenna in the field; this was not done. As seen in Figures 16.3 and 16.5, we observe that the car park has in parts an attenuating surface cover, which reduces the geophysical contrast in the areas beneath it. Survey conditions such as water content or saturation in the ground, surface materials, and salting are all factors that can alter signal attenuation and impact the resulting degree of success of positive identification of archaeological features; these conditions may have played a role for this specific feature. While attention is more easily given to linear, rectangular, and/or repeating observations while interpreting geophysical data, it is possible that an interpreter would not recognize this particular anomaly as an archaeologically relevant feature due to its comparatively weak contrast.

The GPR surveys from Area 1 exemplify the detectability of various feature types, although there were some discrepancies between the survey data and the excavated features, for instance regarding exact location or shape. At similar sites, proper examination of the collected data calls for processing the data at different frequency ranges and/or using a higher-frequency antennae; this practice additionally increases the potential to locate vague or shallow features such as the wall ditch cut into bedrock and leads to a higher survey resolution by decreasing the line spacing between each traverse. As the footprint of the GPR signal from a 500-Mhz centre frequency antenna is approximately 25 cm in diameter under typical survey conditions, a traverse interval of 25 cm or less is needed to avoid spatial aliasing (David et al. 2008). An even higher sample resolution might be recommend depending on the expected size of the archaeological features present; it is advisable to apply a survey methodology that ensures at least two traverses within a single feature. To ensure that two data transects intersect a feature of 20 cm in diameter, two traverses with a traverse interval of 10 cm are needed. The depth of investigation and the potential footprint of the GPR signal are frequency dependent (David et al. 2008; Conyers 2013) and must also be taken into consideration along with the expected size of archaeological features present. Also, if time allows, gathering GPR data in several directions could yield additional positive results. This example shows that perpendicular lines improved the possibility to detect this ditch. As the sample interval is usually lower in the inline direction (i. e. sampling along the survey line) compared to the crossline interval, this method will yield a greater quantity of information along the line than between the lines. In the case of a linear wall, the feature can easily be missed with a course crossline resolution running parallel to the feature. By contrast, the feature has a much higher chance of being detected if the data was collected perpendicular to it. Certain processing software can be used to combine GPR data collected in various survey directions for optimal information gain.

16.5 Pre-excavation survey: Area 2

Excavations in Area 2 showed that colluvial deposits up to 130 cm thick had amassed through centuries of cultivation, forming a large prehistoric field. Micromorphological analyses have demonstrated ploughing and fertilisation using animal dung and charcoal, as well as other burnt material (Macphail and Linderholm, Ch. 17:401–3). Numerous archaeological features, including cooking pits and postholes, were cut into different levels of the colluvial deposits and the subsoil. The colluvium was homogeneous with scarcely any stones. Thus, stones where present were indicative of archaeological features, for instance cooking pits. The earliest cultural deposits in the field had traces of burning prior to agricultural activity. The wall ditch from a Bronze Age building (A11) was cut into this deposit. In the eastern part of Area 2, the soil was shallow with stony bedrock appearing just below the topsoil.

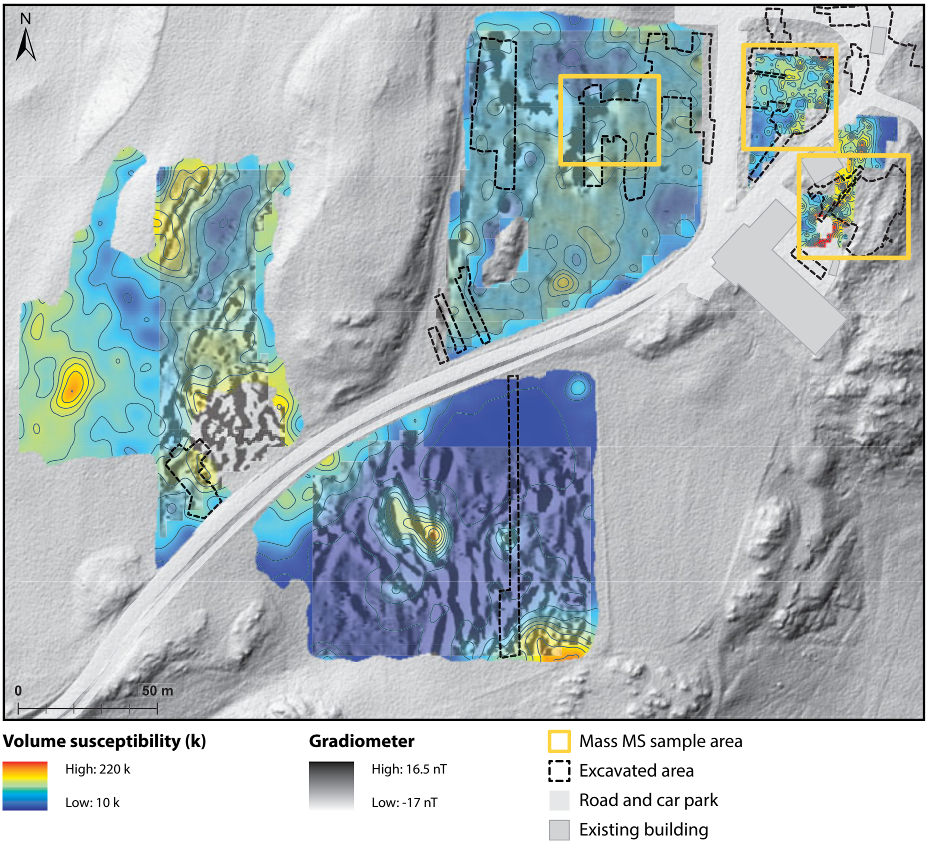

Fig. 16.8: Map showing all topsoil volume susceptibility (k) values measured at Avaldsnes as well as the apparent influence of the geology on the gradiometer results.
The yellow boxes illustrate areas from which mass susceptibility samples have been analysed (Macphail and Linderholm, Ch. 17). Illustration: A. A. Stamnes, I. T. Bøckman, MCH. Plot from topsoil MS survey, Earthsound Associates/NTNU 2009 (Barton 2010).

The main surveys in Area 2 involved magnetic susceptibility (MS), earth resistance, GPR, electromagnetic imaging, and magnetometry (Figs. 16.1 and 16.8). A trend of topsoil MS values elevated relative to those of the surroundings was detected running north-east to south-west in the survey area in Area 2. The values ranged from 60 to 120 K, corresponding closely with the thicker cultivation deposits identified by the VIAS GPR survey and confirmed by excavation as a prehistoric field with thick homogeneous cultivation deposits amassed through centuries of cultivation. The area also included several cooking pits buried at various depths (Figs. 16.8, 16.10, and 13.1). The high topsoil MS values continued south-west from the survey area. While the excavation was not carried out further to the south-west, the presumption that the high values are related to thick cultivation deposits has indicated that the area of cultivation deposits did in fact extend further to the south-west from the excavation area. Areas with concentrations of cooking pits were not similarly distinct, despite their presumed high MS values caused by heat-exposed stones. Areas of thinner soil cover above the natural subsoil tended to register low MS values. This is the opposite of areas 3 and 4, where the gradiometer data indicates geological influence closer to the surface in areas with high MS values. This conclusion is supported by the gradiometer data plots from the same areas, which shows a spatial correlation between relatively high MS values and the extremely strong influence from the natural bedrock in the gradiometer data (Figs. 16.8, 16.10).

It seems likely that the south-west to north-east trend of enhanced MS values in Area 2 is related to prehistoric agricultural activity – especially in areas within this prehistoric field with thicker cultivation deposits above the natural subsoil (Bauer and Østmo, Ch. 8:145). Factors that are known to enhance the magnetic susceptibility of soils include enhancement of soil by material of increased magnetic susceptibility (for instance fertilisers or the spread of domestic waste on the fields), redox processes, and biological decomposition, which fosters the growth of bacteria capable of altering iron minerals from less magnetic into more magnetic types (Dalan and Banerjee 1996; Dearing 1999; Evans and Heller 2003; Dalan 2006; Linderholm 2007; Dalan 2008). The enhanced MS values observed at Avaldsnes can be explained by the effect of fertilising where material with an increased magnetic susceptibility has been added to the soil over time. Alternatively, the values may be the result of biological decomposition of plough soil or the ploughing of cooking pits, which caused the mixing of enhanced magnetic material from both cooking pits and redox-altered topsoil into the upper soil strata over time. The southward continuation of this activity into Area 3 is invisible in the MS data, as there is a clear difference in the topsoil MS readings between the northern and southern side of the road separating Areas 2 and 3. No observable change in deposits or features appeared during excavation to explain this. Because the differing values roughly corresponded with the areas separated by the present-day road, the variation in magnetic response was presumed to be the result of activities after construction of the road. Alternatively, the difference might be caused by varying geology or the introduction of soil from different locations in the two areas (Barton 2010:27). The mass MS samples from the excavation showed increased values in the area containing cooking pits to the north-west of building A11; furthermore, the samples indicated the possible presence of a ploughed-out hearth within the building. All these samples were taken from the same soil matrix and horizon, at the base of the histic topsoil (Macphail and Linderholm, Fig. 17.6.b).

The various magnetic susceptibility schemes performed at Avaldsnes provide the chance to compare the topsoil MS with the magnetic analysis of soil samples taken from the archaeological deposits, and thereby enable an investigation of whether magnetic soil enhancement observed in the topsoil had a spatial variation similar to that of the archaeological deposits. Comparison between the pre-excavation survey of topsoil MS and the mass MS from the excavations (Tab. 16.3) showed a modest

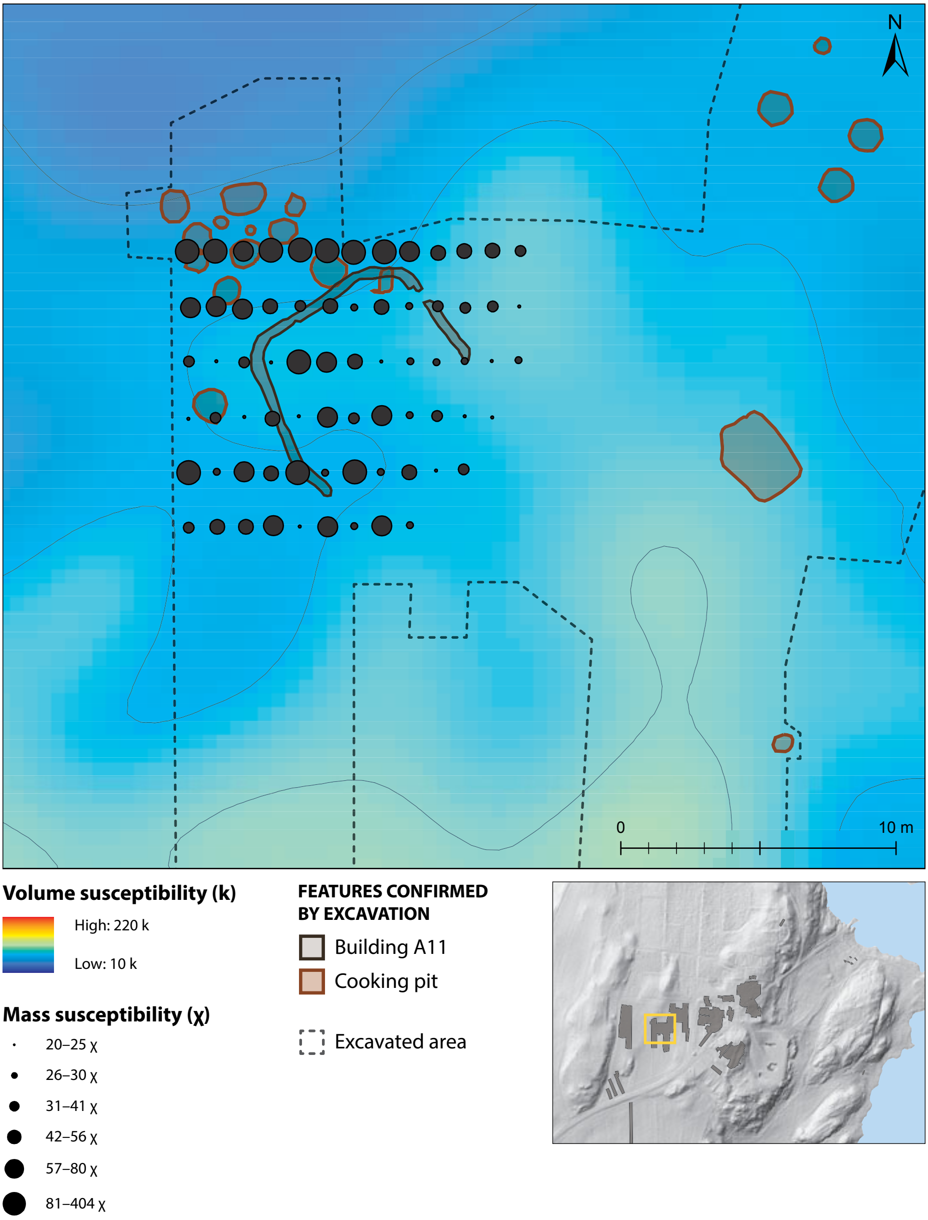

Fig. 16.9: Comparison of topsoil volume susceptibility (k) and the mass susceptibility (χ) samples taken during excavation.
Illustration: A. A. Stamnes, I. T. Bøckman, MCH. Plot from MS survey, Earthsound Associates/NTNU 2009 (Barton 2010; Macphail and Linderholm, Ch. 17).

Tab. 16.3: Calculated correlation between the volume MS and the mass MS from areas 2, 5, and 6, with calculated percentage of the variation in the volume MS that could be explained by the mass MS.

Area	Correlation method	Correlation	Coefficient of determination	Percentage explained
2	Pearson's product-moment correlation coefficient (r)	−0.30	r^2	9 %
	Spearman's rank correlation coefficient (ρ)	−0.52	ρ^2	27 %
5	Pearson's product-moment correlation coefficient (r)	0.36	r^2	13 %
	Spearman's rank correlation coefficient (ρ)	0.41	ρ^2	17 %
6	Pearson's product-moment correlation coefficient (r)	0.03	r^2	0.1 %
	Spearman's rank correlation coefficient (ρ)	0.10	ρ^2	1.0 %

to moderately negative correlation (Taylor 1990:37), meaning that as the topsoil MS values increased, the mass MS values decreased moderately. This is the opposite of what should be expected if anthropogenic material had been transported up through the deposits by bioturbation and ploughing to be detected in the top 6–8 cm – that is, within the active range of the Bartington MS 2 used to measure topsoil MS. The variation coefficient is low: 9–27 % (Tab. 16.3). A possible explanation is that the overburden's thickness, which in the area with the concentration of cooking pit was approximately 70 cm thick, prevented delimitation of the activity area by means of topsoil MS alone. Furthermore, varying data density from the topsoil MS and the mass MS sampling scheme could introduce additional errors, as data points were not collected from the same geographical position. A proper interpolation with ordinary kriging was performed. Kriging is a method of exact interpolation, returning the same value of the initial measurement at the same location in the resulting interpolation map. This makes the method very well suited for the interpolation at hand (Isaaks and Srivastava 1989); such a method should reduce the impact of dissimilar sample density on the correlation. At Avaldsnes, the survey conditions under which topsoil MS measurements were taken were considered quite uniform, without rough ground or varied vegetation cover. Therefore, the survey conditions should not have any significant impact on the final results. An MS section through the entire sequence of deposits showed declining mass MS values from top to bottom, which is more typical for undisturbed natural soils. Consequently, even if the mass MS sampled from the archaeological deposits indicated a distinction between anthropogenic activities in plan, this was not evident in the section from the same area (Linderholm and Wallin 2013).

Tab. 16.4: Measures of magnetic variability of the available fluxgate gradiometer.

Location	Mean	Standard Deviation	Variance	Interquartile Range
Avaldsnes – Area 2	2.59	27.44	753	6.2
Avaldsnes – Area 3	−1.47	37.42	1400	27.2
Avaldsnes – Area 4	−1.02	40.38	1631	19.8
Avaldsnes – Area 5	1.46	27.6	762	10
Avaldsnes – Area 6	−0.28	43.22	1868	19.8
Veøy (reference site)	−0.54	13.49	182.0	11.0
Gustad (reference site)	−0.26	2.04	4.2	1.5

Data from Avaldsnes and two reference sites in other parts of Norway (Stamnes 2011; Solli and Stamnes 2013). Original values are in nanotesla (nT).

Local geology influences geophysical measurements in various ways, with the amount of magnetic minerals in the ground affecting the likelihood of positively identifying archaeological features (Evans and Heller 2003; Aspinall et al. 2009; Bonsall et al. 2014). Different soils and geologies contain various amounts of magnetic minerals that can, in turn, be altered into more magnetically enhanced iron minerals. The background geology in itself can be very magnetic to the point of saturating the sensor, thereby making it impossible to detect subtler, potentially significant archaeological features (Aspinall et al. 2009). A quantification of the magnetic variation in the fluxgate gradiometer datasets is therefore helpful to understanding the local geology's effect on the survey results. Such quantification involves a comparison of statistical parameters for measuring variability, or spread of variables, such as standard deviation (std), variance, and interquartile range (IQR) as explained by Isaaks and Srivastava (1989:16–23). In advance of the 2009 Earthsound/NTNU survey, the geological implications for geophysical magnetic prospectivity were considered uncertain, as the magnetic response from metamorphic bedrock depends on the parent material from which the bedrock has been transformed – that is, the bedrock's original type before exposure to heat and pressure through metamorphic processes. As previous investigations in Norway have shown, a significant magnetic response from the bedrock does not necessarily preclude a magnetic response due to sub-surface archaeology (Barton 2010:8).

Table 16.4 presents calculated values indicating the relative variation of on-site magnetism at the various areas surveyed at Avaldsnes as compared with two reference sites. Presumably, high variability is caused by background geology or potential anthropogenic activity. The Geological Survey of Norway (NGU 2014) classifies the drift geology at Avaldsnes as shallow moraine material from magmatic bedrock. The bedrock in the area is characterised by the Geological Survey of Norway (NGU) as alkali basaltic greenstone of volcanic origin, volcanic meta-sandstone rich in iron manganese, quartz slate of metamorphic origin, and chert (NGU 2014). Compared with the two reference sites, particularly Gustad, the magnetic variability in the gradiometer data is very high in all areas at Avaldsnes. Veøy's bedrock is metamorphic, and Gustad's is sedimentary. Avaldsnes' bedrock, by contrast, is magmatic and volcanic, which can probably explain some of the variability. The calculated values for magnetic variability demonstrate quantitatively the effect of the bedrock at Avaldsnes on the gathered fluxgate gradiometer information. These values are suitable for use as a reference when planning or analysing magnetic geophysical information from other sites. Evidently, the presence of magmatic and volcanic bedrock of volcanic origin was not known to the surveyors at the time of the survey; rather, they considered it to be metamorphic.

Tab. 16.5: Calculated threshold values in nanotesla (nT) for areas 2, 5, and 6 at Avaldsnes, and the two reference locations.

Threshold values	Avaldsnes Area 2	Avaldsnes Area 5	Avaldsnes Area 6	Veøy	Gustad
±2 std above mean	−52.3/+57.5	−66.8/+68	−86.7/+86.2	−27.5/+26.4	−4.3/+3.8
±1 std above mean	−24.9/+30.0	−33/+34.4	−43.5/+42.9	−14.0/+13.0	−2.3/+1.8
±1/2 std above mean	−11.1/+16.3	−16.2/+17.5	−21.9/+21.3	−7.3/+6.2	−1.3/+0.8
±1/4 std above mean	−4.3/+9.5	−7.8/+9.1	−11.1/+10.5	−3.9/+2.8	−0.8/+0.25
±1/6 std above mean	−2.1/+7.3	−5.1/+6.4	−7.6/+7.1	−2.8/+1.8	−0.6/+0.1
±1/8 std above mean	−0.9/+6.0	−3.5/+4.9	−5.7/+5.1	−2.2/+1.1	−0.52/−0.01
±1/10 std above mean	−0.2/+5.3	−2.7/+4.0	−4.6/+4.0	−1.9/+0.8	−0.46/-0.06

The strength categories for magnetic response values follow Hargrave (2006).

Interpretation of the fluxgate gradiometer datasets were based on the values presented in Table 16.5, with the shape and size of the fluxgate gradiometer anomalies compared with the visualised fluxgate gradiometer datasets. Out of 213 anomalies within Area 2 with a value stronger than 5.3 nanotesla (or 1/10 std above mean), only five had a shape, size, or position comparable to that of the excavated features. The general impression is that the collected data is highly influenced by the bedrock, which created very high or low readings (Figs. 16.8 and 16.10; Tab. 16.4). This consequently rendered it impossible to identify archaeological structures based solely on the gradiometer data, as the magnetic variability resulting from the geology was so strong that the general background noise was much greater than the magnetic enhancement of any archaeological features (Tabs. 16.4–5). Further analyses of the data – that is, comparison of the excavated features' location with the contour lines visualising change in the measured nT values – allowed the shape of a few additional cooking pits to be outlined. This brought the count of verified anomalies of archaeological origin to 11 – still only about 5 % of all the anomalies and 7 % of the total number of excavated features.

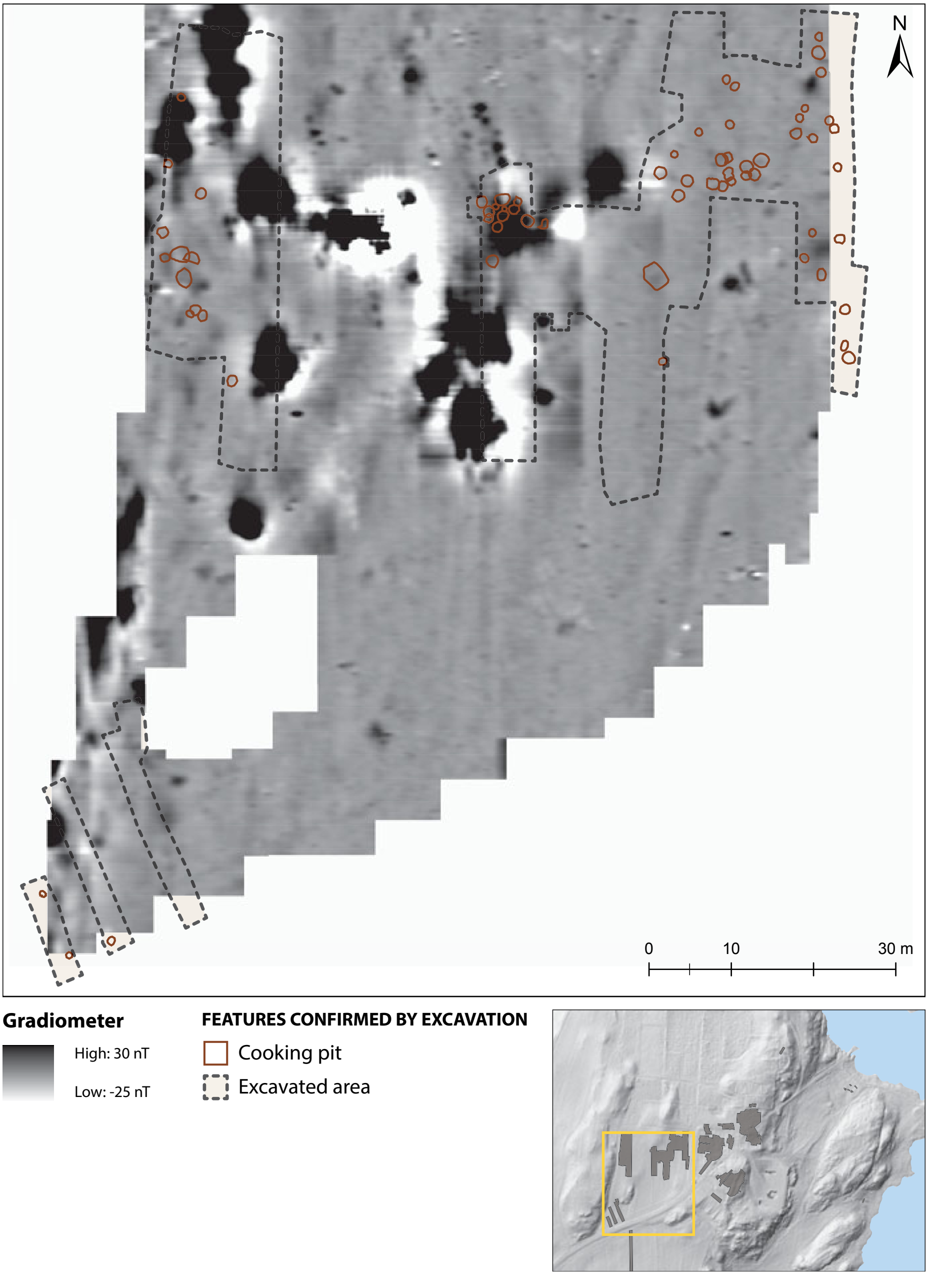

Fig. 16.10: Gradiometer data from Area 2 and excavated cooking pits.
Plotted in ±1 Standard Deviation (see Table 16.5). Illustration: I A. A. Stamnes, I. T. Bøckman, MCH.
Plot from gradiometer survey, Earthsound Associates/NTNU 2009 (Barton 2010).

The maximum nT values from the identified cooking pits ranged from 3.3 to 8.6. As the mean value of the survey was 2.6 nT, the cooking pit values ranged from only 0.7 to 6 nT above the mean, limiting a proper archaeological interpretation of the dataset. The nT values were not particularly high, demonstrating that even accounting for the descriptive statistics values, the magmatic bedrock of alkali basaltic greenstone, meta-sandstone, quartz slate, and chert creates high background variation. Such background variation reduces the value of gradiometer mapping methods. Thick colluvial deposits further decreased the likelihood of detecting magnetic contrast from buried archaeological features.

Similarly to the gradiometer data collected by NTNU (Barton 2010), the Moesgård/Geosight magnetometer survey was affected by strong magnetic disturbance from the background geology. The report presents a map of 82 objects in which the potential mass and depth of the anomalies are modelled (Smekalova and Bevan 2009). Of these, 31 anomalies lay within the area excavated in 2011. During excavation, six anomalies were classified as caused by geological variations. Seven of the anomalies corresponded with archaeological features – a 28 % co-location. As 123 archaeological features (excluding the stakeholes) were identified within the excavation area, these seven co-located anomalies equal 5.7 % of the excavated features within the survey area.

In Moesgaard/Geosight's magnetometer and EMI surveys, which measure detailed magnetic susceptibility, only two anomalies were identified: F1 and F4 (Smekalova and Bevan 2009). F4 lay in the north-eastern corner of Area 2. No archaeological features were exposed in the vicinity of F4 during excavation. Smekalova and Bevan (2009) suggest that the surface could have been burned, thus enhancing the subsoil's magnetic susceptibility. Another interpretation is that the overburden is shallower in the area; hence, the magnetic bedrock is closer to the surface. F1 is visible in the EMI survey, in the magnetometer data from Smekalova and Bevan (2009), the gradiometer data from Earthsound Associates/NTNU 2009 (Barton 2010), and vaguely in the VIAS GPR and earth resistance data from Earthsound Associates/NTNU 2009 (Barton 2010) – the latter constituting reasonable evidence to suspect it to be an archaeological feature (Fig. 16.11). Smekalova and Bevan (2009) provide a detailed analysis and modelling of the anomaly. It is located within the area of a survey trench from 1992 (Hemdorff 1993) but lay deeper than the exposed level. A reasonable interpretation is that the anomaly is a large cooking pit, similar to cooking pit A3889 (Bauer, Ch. 13:257) but with a greater magnetic enhancement.

The earth resistance data collected with a twin probe array by NTNU in 2009 (Barton 2010) from Area 2 (Fig. 16.12) mainly reflected soil thickness, having low earth resistance values in areas with thick cultivation deposits and relatively high values in areas where the overburden was shallow. A few anomalies coincided with excavated cooking pits – especially the large cooking pit A3889 which yielded a maximum reading of 141 Ω compared with the surrounding soil matrix of approximately 133 Ω. (On cooking pits: Bauer, Ch. 13). No clear shapes in the geophysical data were recog-

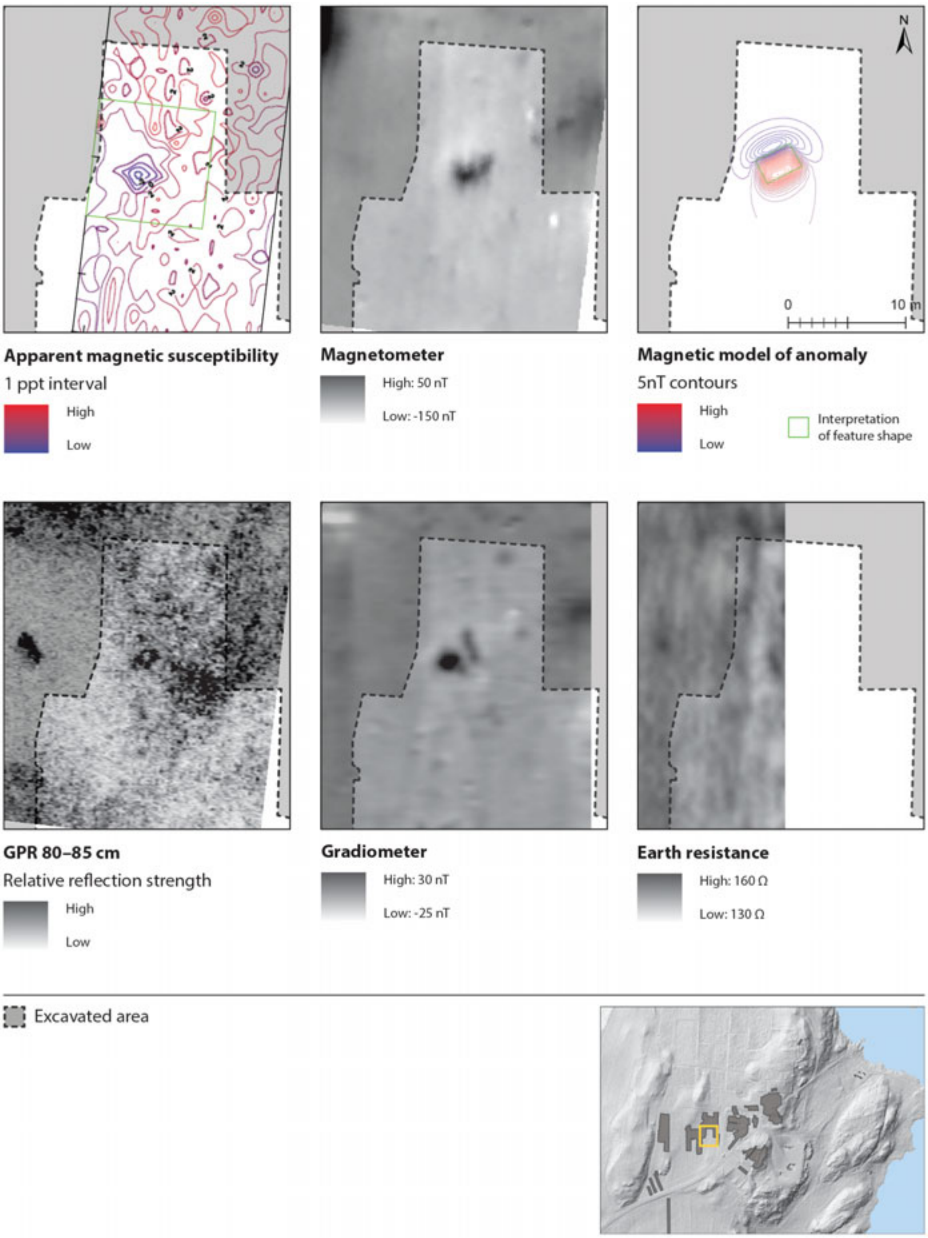

Fig. 16.11: The anomaly denoted as F1 by Smekalova and Bevan (2009) as identified in their EMI (MS), magnetometer data and modelling, compared with the VIAS GPR data, and gradiometer and earth resistance data from Earthsound Associates/NTNU 2009 (Barton 2010).
All the anomalies included in this figure were visible in several depth slices, increasing the likelihood that they are man-made constructions collocated at the same spot over several depths.
Illustration: A. A. Stamnes, I. T. Bøckman, MCH.

nised as archaeologically significant prior to excavation. The western edge of the 1992 survey's trench (Hemdorff 1993) was visible. Another resistance anomaly – denoted as F1 in the EMI and magnetometer data from the Moesgaard/Geosight survey – coincided with a GPR anomaly identified outside the excavated trenches (Fig. 16.11). The earth resistance survey was performed with 1-metre probe separation, which could in theory be affected by features situated as deep as 1–1.5 m, depending on the features' conductivity. Sampling at 0.5 m x 0.5 m is generally considered to provide an adequate spatial resolution (Gaffney and Gater 2003; David et al. 2008; Schmidt 2009). Knowing that the overburden's thickness was ±70 cm in places, any features within this soil volume should still be within detectable depth for a probe spacing of 1 m. The fact that no features were clearly identified indicates either suboptimal survey conditions, poor resistivity contrasts of the archaeological features, or a depth of investigation lower than was indicated.

Numerous anomalies observed in 36 georeferenced GPR time slices in high spatial resolution from Area 2, supplied by VIAS, corresponded closely with archaeological features discovered during subsequent excavation. Among the numerous geophysical surveys at Avaldsnes, the VIAS survey provided the most relevant results (Tab. 16.6). Twenty-one GPR profiles, collected by NTNU in 2009, were used in tandem with the VIAS time slices for visualising sections across anomalies. This helped with categorising and understanding the results. The interpretation was made after the excavation ended, but without taking known archaeological features into account when isolating geophysical anomalies (Fig. 16.13).

The VIAS GPR time slices showed 121 anomalies of various sizes and at different depths. The excavation trenches encompassed 78 of these anomalies, while 43 anomalies remain in the ground without verification through excavation. A sharp positive contrast clearly delimited several of the anomalies, especially those situated in areas with thick and homogeneous cultivation deposits. Certain excavated features, such as small stones and stakeholes, cannot be expected to be visible due to their small size (i. e. diameter <0.1 m). Other archaeological deposits were likewise not expected to be visible due to their large and often irregular size, the weak geophysical contrast at interfaces, and the limitation of examining GPR data in time slices alone. Such features are consequently excluded from the statistics. There were 123 excavated archaeological features within the GPR survey area (excluding stakeholes and deposits). Twenty-four of these (i. e. 20 %) were identified in the GPR data during initial interpretation made by the authors of this chapter, as mentioned above (Tab. 16.6 and Fig. 16.13).

The archaeological feature type proving easiest to identify was cooking pits (Tabs. 16.6–7, and Fig. 16.13). The GPR data showed such stone-rich features as dark anomalies corresponding to the size and shape of the excavated cooking pits. The comparison demonstrated that cooking pits had to be of some size and contain a certain amount of stones in order to be visible in the time slices. Most of the cooking pits cut into homogeneous cultivation deposits cleared of stones, hence the pronounce contrast between the cooking pits and the surrounding soil (Tab. 16.7 and GPR sections

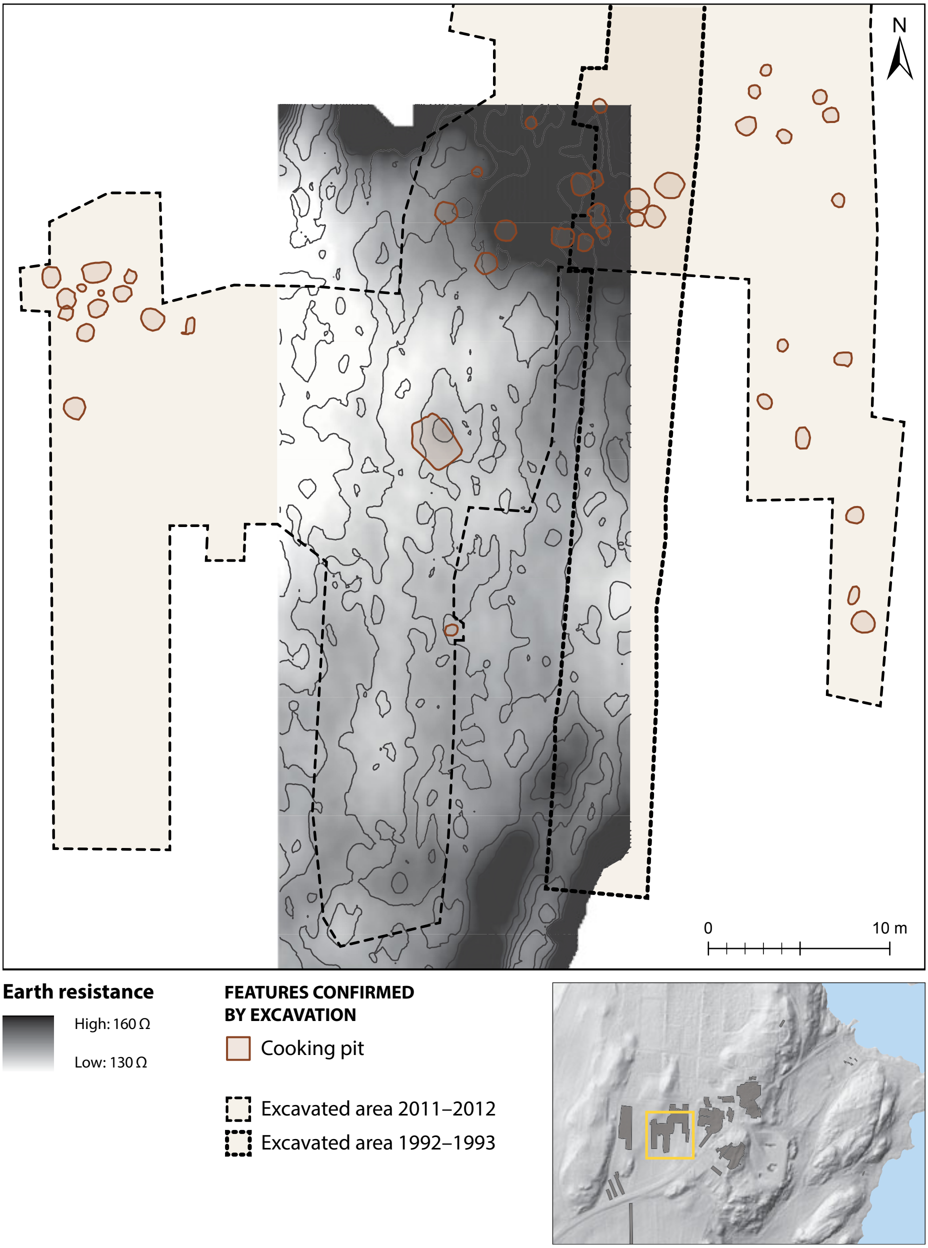

Fig. 16.12: Earth resistance data and excavated cooking pits.
Illustration: A. A. Stamnes, I. T. Bøckman, MCH.
Plot from earth resistance survey, Earthsound Associates/NTNU 2009.

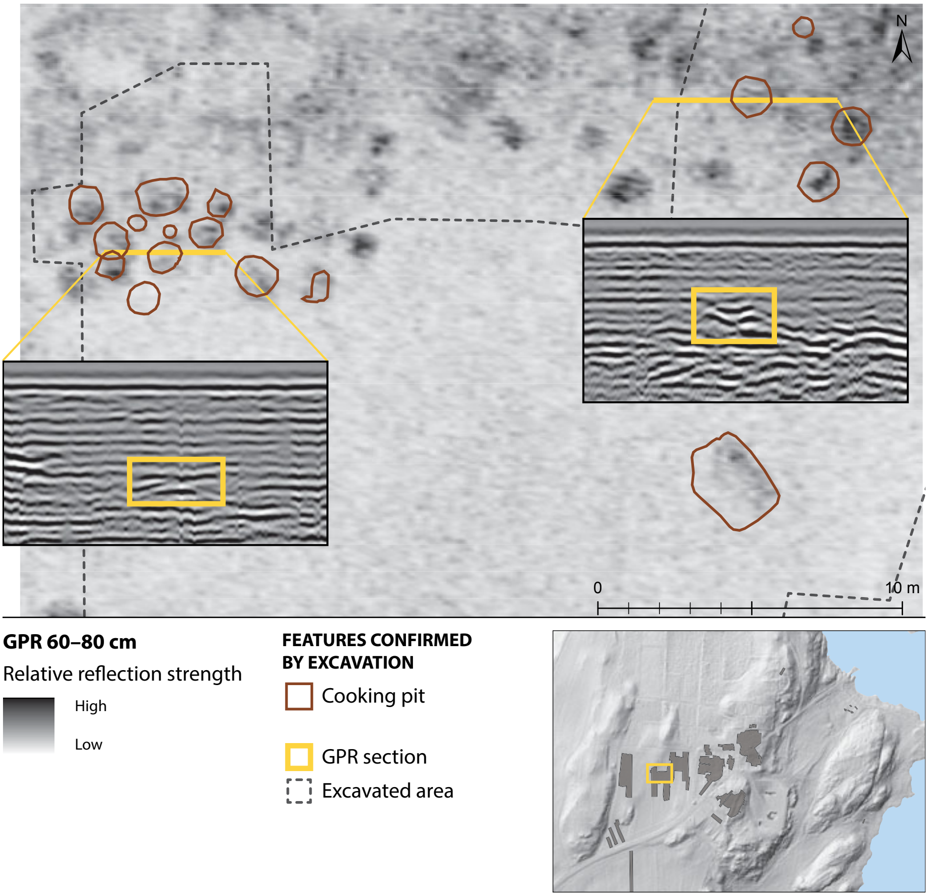

Fig. 16.13: Comparison of the average GPR reflection strength of the VIAS time slices from a depth of 60–80 cm against GPR sections across some of the excavated cooking pits.
Illustration: A. A. Stamnes, I. T. Bøckman, MCH. Plot from Earthsound Associates/NTNU 2009 (Barton 2010).

in Fig. 16.13). The cooking pits lay mainly in the outskirts of the cultivated surface or where the cultivation deposits were rather shallow. Fortunately, the deposits were still thick enough to provide geophysical contrast to the cooking pits. The cultivation deposits' extent and depth were clearly visible in the time slices, mainly due to their sharp contrast to the stony and gravelly subsoil and bedrock below. The same subsoil camouflaged cooking pits and other features dug into it, due to similar signatures. Table 16.7 demonstrates how easily identifiable cooking pits were when dug into different deposit types. This comparison suggests that several of the 43 anomalies identified outside of the excavation areas might be of archaeological significance, and that it is reasonable to assume that several of the anomalies situated within the cultivation deposits might be additional cooking pits.

Tab. 16.6: Comparison of GPR interpretation against excavated features.

Feature type	Number of excavated features within the GPR survey area	Number of features positively identified in the GPR data	Percentage correlation
Cooking pit	54	23	43 %
Charcoal concentration	4	0	0 %
Removed clearing cairn	1	0	0 %
Stone	24	1	4 %
Concentration of stones	2	0	0 %
Imprint after stone removal	18	0	0 %
Posthole	17	0	0 %
Ditch/wall ditch	3	0	0 %
Anomalies identified below excavated depth*	0	12	
Total number of archaeological features	123	24	20 %
Total interpreted GPR anomalies within excavation area (*anomalies below excavated depth excluded)	66	24	36 %

Numbers are based on the contrast in the GPR time slices and a visual comparison of anomalies and excavated archaeological features to confirm whether the two were of comparable size and shape.

We followed up on this by examining the typical features missed in the initial interpretation. Of the 17 postholes, only four contained stones used for bolstering the post, and all 17 had a backfill of sand or silt. A visual comparison left none of the postholes detectable in the time slices, indicating that the backfill of sand or silt did not create a detectable geophysical contrast. The postholes had a diameter of 0.45 m ± 0.2 m and a depth rarely greater than 0.25 m, which typically would be covered by only 1–2 GPR profiles. Of the 31 cooking pits missed in the initial interpretation, at least eight were visible in the time slices, but many were located in the intersection between the bottom of the cultivation deposits and the more stony subsoil. This camouflaged the pits and rendered them less pronounced, as the subsoil generally had a high signal reflection. Eight of the overlooked cooking pits had a backfill of sand, charcoal, and burnt clay – but no stones. The cooking pits indicated in the initial interpretation covered an average area of 0.96 m^2 in plan, and the excavated cooking pits had an average depth of 0.23 m. The missed features had a smaller area on average – 0.65 m^2 – and an average depth of 0.18 m. Both measurements were slightly less than for the identified cooking pits. We were not able to identify the ditches when re-examining the data. We also observed several anomalies outside the excavated areas. Based on size and previous experience, we interpret as many as 25 of these anomalies as cooking pits. Two of the features are of size comparable to that of the large cooking pit A3889.

Tab. 16.7: The visibility in the GPR data of cooking pits dug into subsoil and cultivation deposits.

Local deposit context of cooking pits	Number of exposed cooking pits	Number of anomalies observed in GPR data	Percentage of excavated cooking pitsvisible in the GPR data
Subsoil	27	5	19 %
Cultivation deposit	27	18	67 %
Sum	**54**	**23**	**43 %**

The geophysical surveys from Area 2 demonstrate that several factors, such as local geology, thickness and homogeneity of deposits, and prehistoric and historic activities at the site, affect the interpretable results. High-definition GPR surveys excel in locating features containing stones within thick cultivation deposits otherwise cleared of stones. MS surveys are better suited to gathering information about activity areas than to locating individual features. While gradiometer surveys usually are used to distinguish and locate individual features than activity areas, this was not the case in Area 2 at Avaldsnes. Here, the magnetic surveys were susceptible to background variation of geological origin, thereby complicating the interpretation of the data. Moreover, thick deposits covering archaeological features decreased the magnetic contrast from such features, limiting their detectability.

16.6 Pre-excavation survey: Area 5

The prehistoric field extended into Area 5 from Area 2. The cultivation deposits were shallower in Area 5, however: between 30 cm and 100 cm. A concentration of cooking pits were cut into the cultivation deposits in the area's western half; on top of this was a stone-paved walkway from a later, medieval complex. A broad ditch running north to south and turning gradually towards the north-east demarcated the prehistoric field from the remains of an Iron Age longhouse (A13). A 19 × 8 m stone packing covered most of the building remains. Two modern ditches for metal pipes were cut through the central part of the excavation area, and recent digging activity and refuse dumping has disturbed the area's north-eastern part.

The mass MS sampled during excavation (Fig. 16.14) were all taken from the same archaeologically defined deposit and showed two concentrations of distinctly increased value in the north-west and the south-east, respectively. In the north-west, the values increased towards the concentration of cooking pits. The south-eastern area of increased values was located in the south-eastern part of the longhouse and could be caused by Iron Age household activities. Alternatively, these could be traces of the metalwork activity from neighbouring Area 6, approximately 30 m to the south-

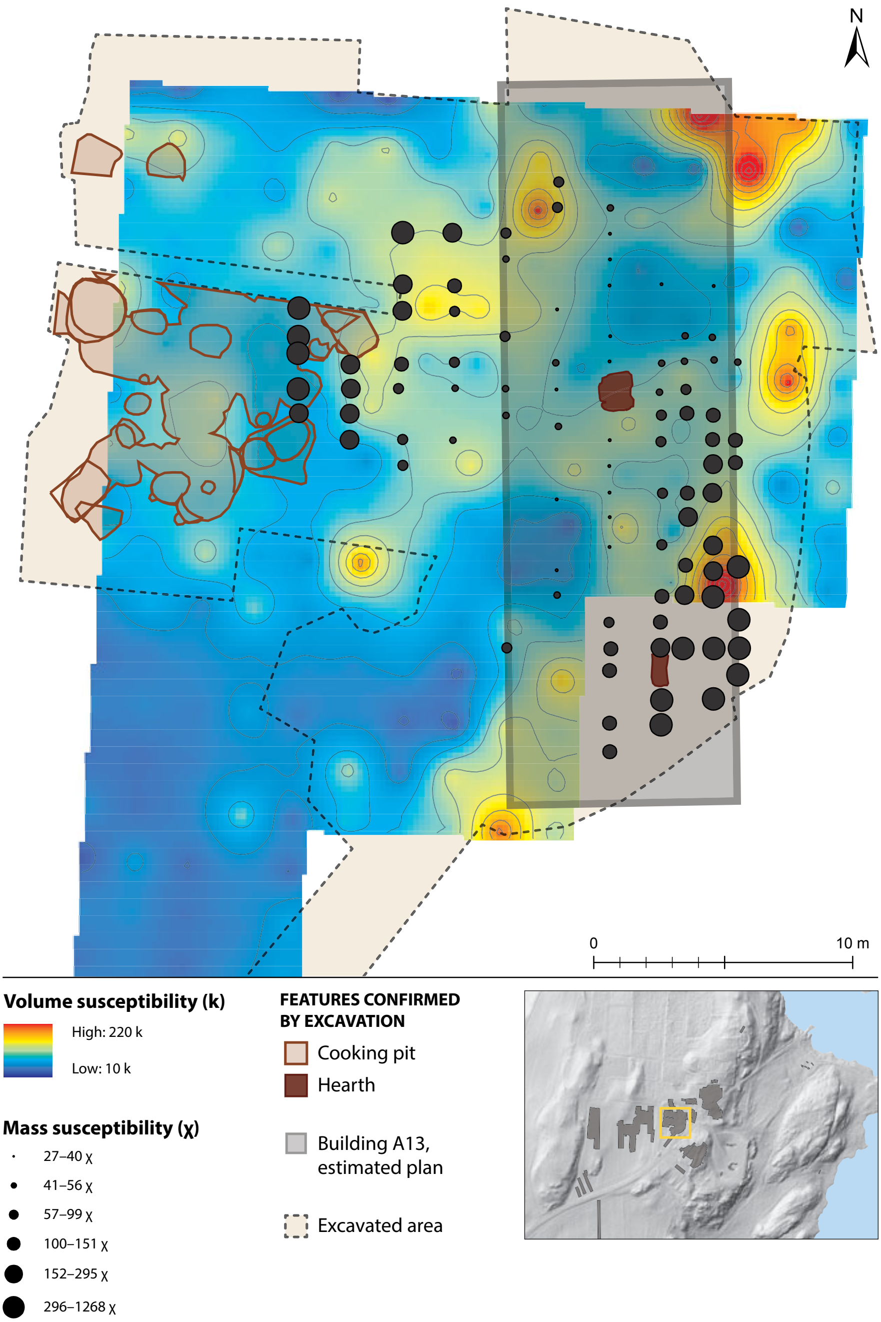

Fig. 16.14: Comparison of topsoil volume MS (k) and the mass MS (χ) sampled during excavation. Illustration: A. A. Stamnes, I. T. Bøckman, MCH. Plot from MS survey reprocessed by A. A. Stamnes, based on samples from Earthsound Associates/NTNU 2009 (Barton 2010), analysed by Linderholm and Wallin (2013).

east, which possibly extended this far. Furthermore, charcoal fertilisation – identified in micromorphological thin-sections (Macphail and Linderholm, Ch. 17:402) – of the cultivated surface probably contributed to the magnetic enhancement of the topsoil. A heightened response in the eastern part of the area with topsoil MS samples seemed to correspond to the longhouse's location. Another area of heightened topsoil MS values north-east of the longhouse might be due to modern activity, leaving the collocation with the longhouse a mere coincidence. As seen in Table 16.3, Area 5 showed a correlation of 0.36 to 0.41, which is within the range of a moderate correlation. The relationship between these two measurements is limited, as only 13–17 % of the variation in the mass MS could be explained by the topsoil volume MS values. The mass MS sampled during excavation was better suited to identify activity areas, but topsoil MS gave some indication of these areas.

The fluxgate gradiometer data (Fig. 16.15) showed several areas of strong magnetic response, particularly in the eastern part of Area 5. The heightened values can be explained by modern refuse and disturbances and shallow bedrock. The response in the area's western part was lower compared with that in the eastern, probably due to thicker cultural deposits associated with the prehistoric field. A dipolar, almost beaded linear anomaly in the gradiometer data corresponds with the location of the modern ditch mentioned above. The response accords with what could be expected from the modern metal pipe excavated there. This interpretation was also noted in the geophysical report (Barton 2010:17). A few anomalies were identified within the cooking pit concentration in Area 5's western part, but the lack of a clear delineation made it difficult to relate any of these anomalies to specific archaeological features. Neither the building elements from the longhouse, the stone packing, the stone-paved walkway, nor the curving ditch were visible in the fluxgate gradiometer data. All values, except the mean, were slightly higher compared to those of Area 2, supporting the hypothesis of modern disturbance and geology influencing the results from Area 5 (Tabs. 16.4–5). Interestingly, the EMI (MS) data from GeoFysica indicated a possible area of increased response, which in the report was interpreted as an area of burning (Persson 2006). This area coincided well with the excavated cooking pits in the western part of Area 5 (Fig. 16.16).

The earth resistance survey data showed that Area 5's northern part (the northern third of the surveyed area) had low resistance while the southern generally had higher resistance (ER data in Fig. 16.16). A linear, 1.5–2.5 m wide low-resistance anomaly cutting through both the high and low resistance areas proved to be the same modern pipe ditch as mentioned above. The cut for this pipe was only 0.3–0.5 m wide, however. This reveals how the earth resistance measurements, rather than revealing the ditch itself, indicated the width of the area drained for moisture around the ditch. This demonstrates the potential impact of drainage ditches on the preservation of nearby archaeological features and deposits.

Neither the stone packing nor the stone-paved walkway were visible in the earth resistance data. The stone packing was exposed 30–50 cm below the topsoil and

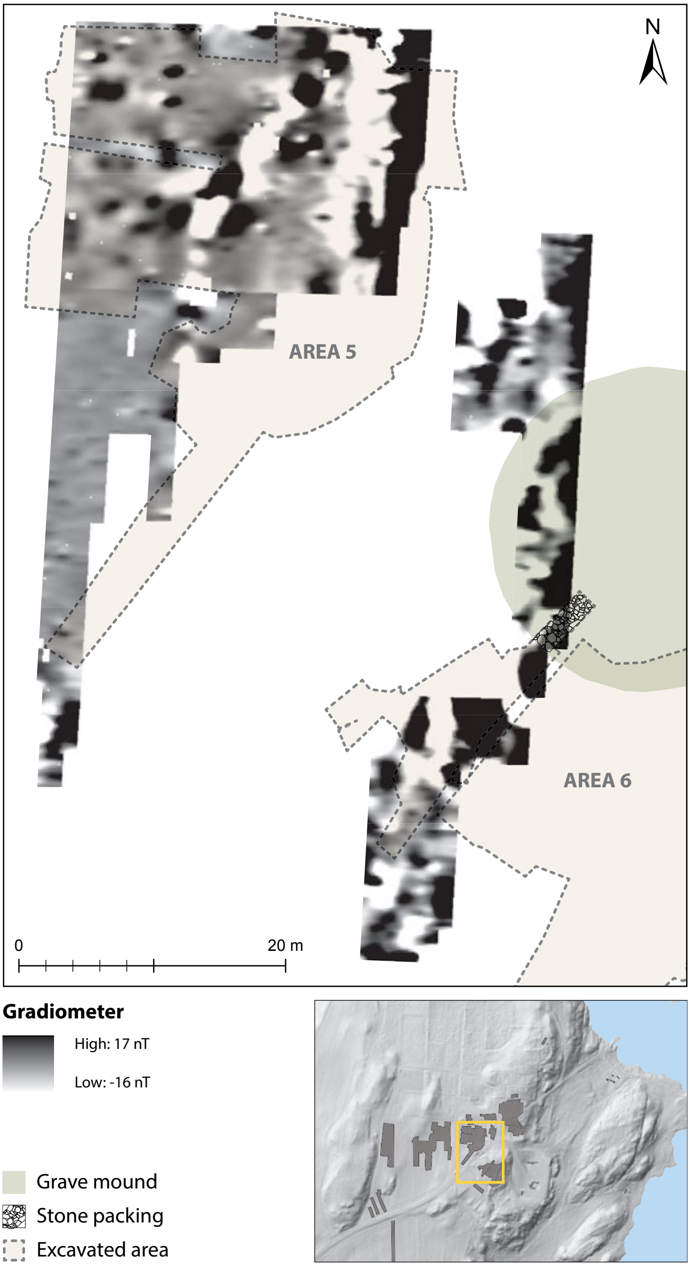

Fig. 16.15: Gradiometer plot from Areas 5 and 6,
as collected by Earthsound Associates/NTNU 2009 (Barton 2010).
Illustration: A. A. Stamnes, I. T. Bøckman, MCH.

was 15–20 cm thick. The stone-paved walkway was of similar thickness and lay at a depth of approximately 30 cm. Both features should have been within detectable depth. Stone-filled features are expected to have a relatively high resistance, but hard-packed soil surrounding the features might have created a suboptimal electrical resistance contrast to the stones at the time of the survey. The data showed outlines of old test trenches and pits (Hafsaas 2006), but none of the ditches or postholes associated with the longhouse were contrasted in the earth resistance data, perhaps due to the overlying stone packing. Neither the cooking pit concentration nor the prehistoric ditches were visible, in the case of the latter possibly because the modern drainage ditch cutting into the ditch drained away moisture, leaving the feature without visible electrical contrast to its surroundings. Some anomalies detected in the earth resistance data were left unexcavated, including a linear, low-resistance anomaly in the area's south-western part and a 9 × 6.5 m rectangular area of high resistance – possibly a compact surface. Further west, five low-resistance anomalies, each approximately 60 cm in diameter, lay evenly spaced (Fig. 16.17). While these features could be prehistoric pits, it is also possible that they are remnants of removed bushes or other modern-day garden flora.

The 2009 GPR survey by Earthsound Associates/NTNU covered only part of Area 5 (Fig. 16.16). The interpretations in the geophysical report focused on the drainage ditch also visible in the earth resistance and gradiometer data, as well as a rectangular feature in the north-west (Barton 2010). The rectangular feature proved to be the medieval stone-paved walkway (Fig. 16.16). The stone-paved walkway was not visible in the GPR data in the northernmost part of the area, at the edge of the car park. This is difficult to explain, as the feature was clearly visible further south. Possibly, the conductivity contrast within the present-day garden that made up Area 5 was different from that in the gravel-covered car park in Area 1. Alternatively, variation in ground coupling between the GPR antenna and the ground could have altered the amount of transmitted energy, affecting the potential geophysical contrast of features. The data in Area 5 was collected perpendicular to the walkway, while the direction of data collection in Area 1 was oriented parallel to the direction of the walkway.

By reprocessing the data, another linear feature could be correlated with the exposed modern drainage ditch further east. With a traverse interval of 1 m between each mapped GPR transect, features less than 2–3 m in diameter are not expected to be noticeable. Linear features perpendicular to the traverse direction, as well as extensive constructions and coherent continuous deposits, could theoretically be visible. However, for identifying archaeological features such as cooking pits, surveys with a traverse interval of 1 m or more are arguably ineffective. Although described as a Phase 4 GPR survey, intended to further define and refine archaeological features (Barton 2010), the choice of 1-metre transects seems inappropriate when considering the size of typical archaeological features such as cooking pits and postholes that could be expected and were in fact excavated within Area 5. Ideally, a line spacing of 0.25 m or less should have been chosen to identify archaeological features smaller

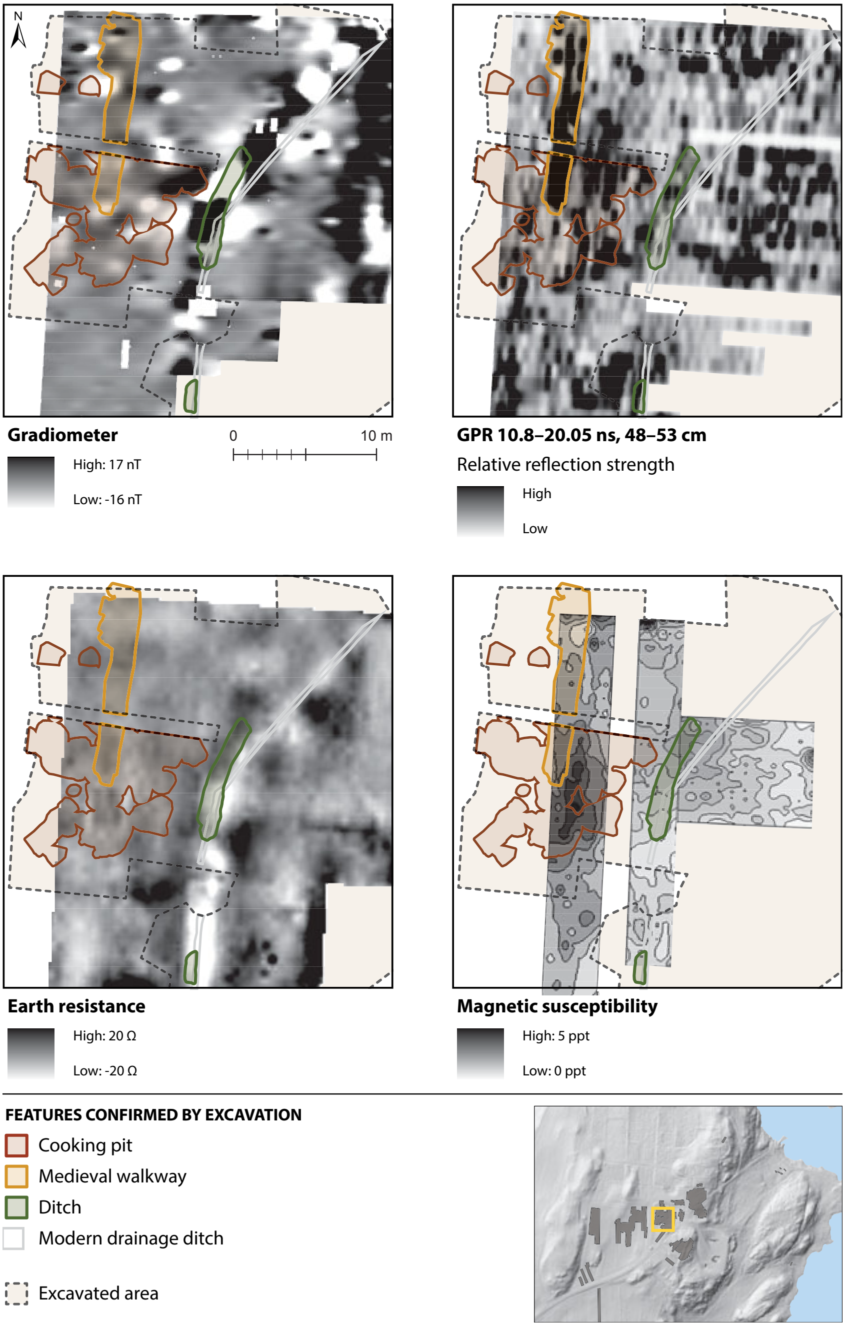

Fig. 16.16: Comparison of various geophysical responses in the north-western part of Area 5. Illustration: A. A. Stamnes, I. T. Bøckman, MCH. Plot from gradiometer, GPR, and ER collected by Earthsound Associates/NTNU 2009 (Barton 2010); EMI (MS) collected by GeoFysica 2006 (Persson 2006).

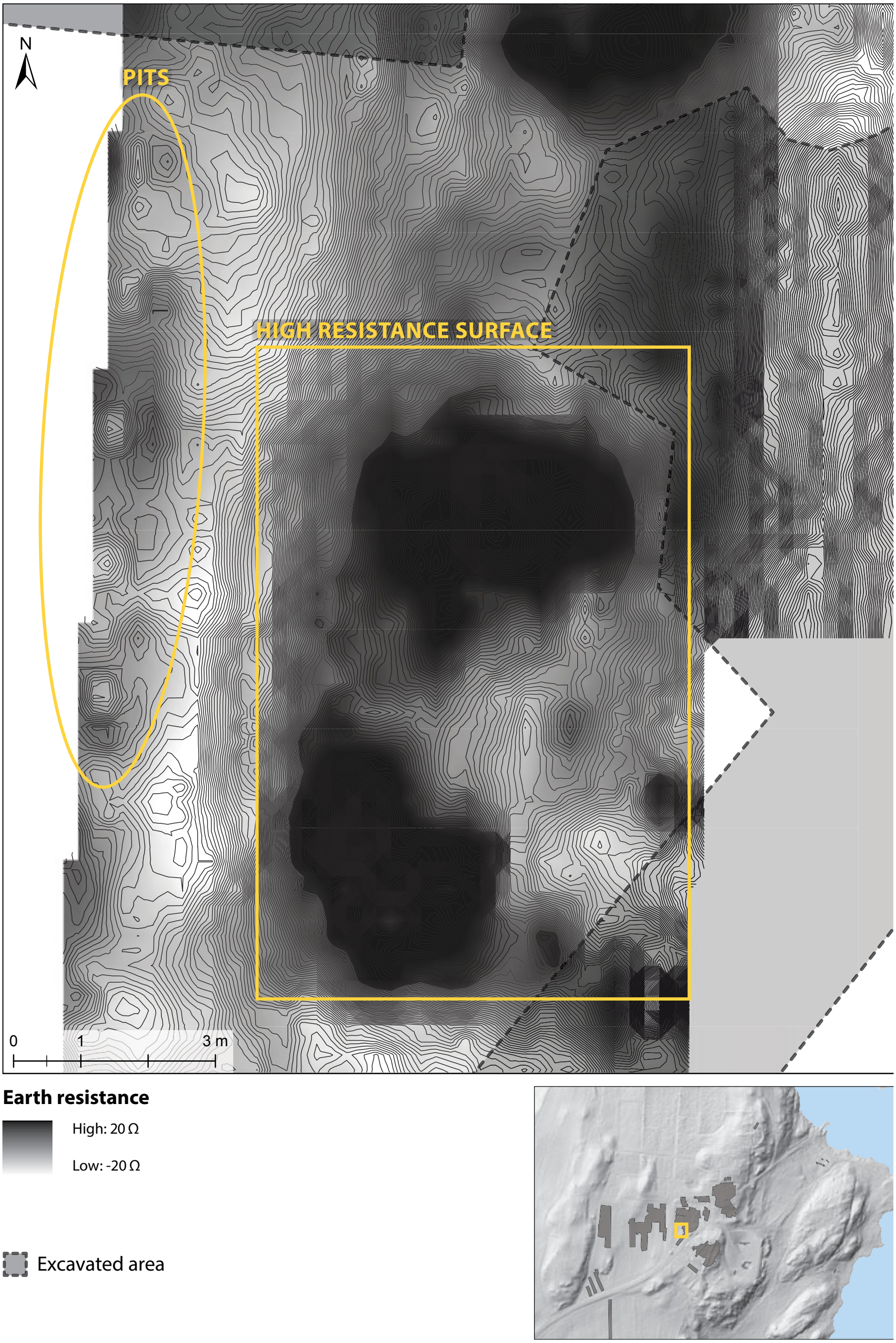

Fig. 16.17: Earth resistance plot over the south-western part of Area 5. Data collected by Earthsound Associates/NTNU 2009 (Barton 2010). Illustration: A. A. Stamnes, I. T. Bøckman, MCH.

than 0.5 m in diameter (David et al. 2008; Conyers 2013). The reason for the line spacing choice is not known, but may be related to time constraints or lack of information of the size of the archaeological features that were to be expected at the site. In Area 5, ditches and pipes gave clear linear responses in the GPR time slices, while the stone packing was not detectable even though some highly reflective areas were visible in its general location. The examination of the GPR profiles from these areas do not reveal any clear layers that can be easily explained by the presence of this stone packing. Most of the stones in the stone packing were fist-sized or smaller and loosely packed, seemingly not creating enough geophysical contrast to be detectable either by GPR or earth resistance measurements, at least not at the interval spacing used and with the current antenna centre frequency of 400 Mhz.

The surveys carried out in Area 5 illustrate how modern features, refuse, drainage, and disturbances, as well as shallow bedrock make it difficult to discern whether anomalies are related to archaeological features or later activity. This is problematic for sites such as Avaldsnes, which has an extensive history – particularly for Area 5, which is and has been part of the main farmyard for most of the site's history. Interestingly, the EMI survey mapping's apparent magnetic susceptibility produced encouraging results, indicating and roughly delimiting an area of cooking pits, even under such difficult survey conditions.

16.7 Pre-excavation survey: Area 6

Area 6's close proximity to the modern-day farmyard, road, car park, and housing was expected to result in spurious, high MS readings. Intrusion into the Kjellerhaug grave mound is known from historical sources. The topsoil MS showed a low enhancement zone on the central and eastern parts of Kjellerhaug, interpreted as an intact or less disturbed part of the mound (Fig. 16.18). South of the mound are several zones with high values. The zones are not connected, and the source of these high values could vary. The ground is rough and disturbed, with evidence of modern disturbances (Barton 2010). The measured χ values of the mass MS samples extracted during excavation showed a log-normal distribution with a single extreme reading and a cluster of readings in the range of 1000–2000 χ. A random distribution of sample values would lead to a normal distribution, which is not noticed here. Instead, they are log-normally distributed, interpreted by Linderholm and Wallin (2013) as a sign of human influence as the measured values are skewed. Such high values are usually associated with presence of metal or highly magnetic igneous rock. The mass MS data suggested two areas of particular interest, of which one contained the above-mentioned extreme value. This area coincided with features and deposits containing hammer slag, suggesting that metalworking and dispersion of waste related to this activity caused the high values (Linderholm and Wallin 2013). A furnace and a corn-drying kiln were also

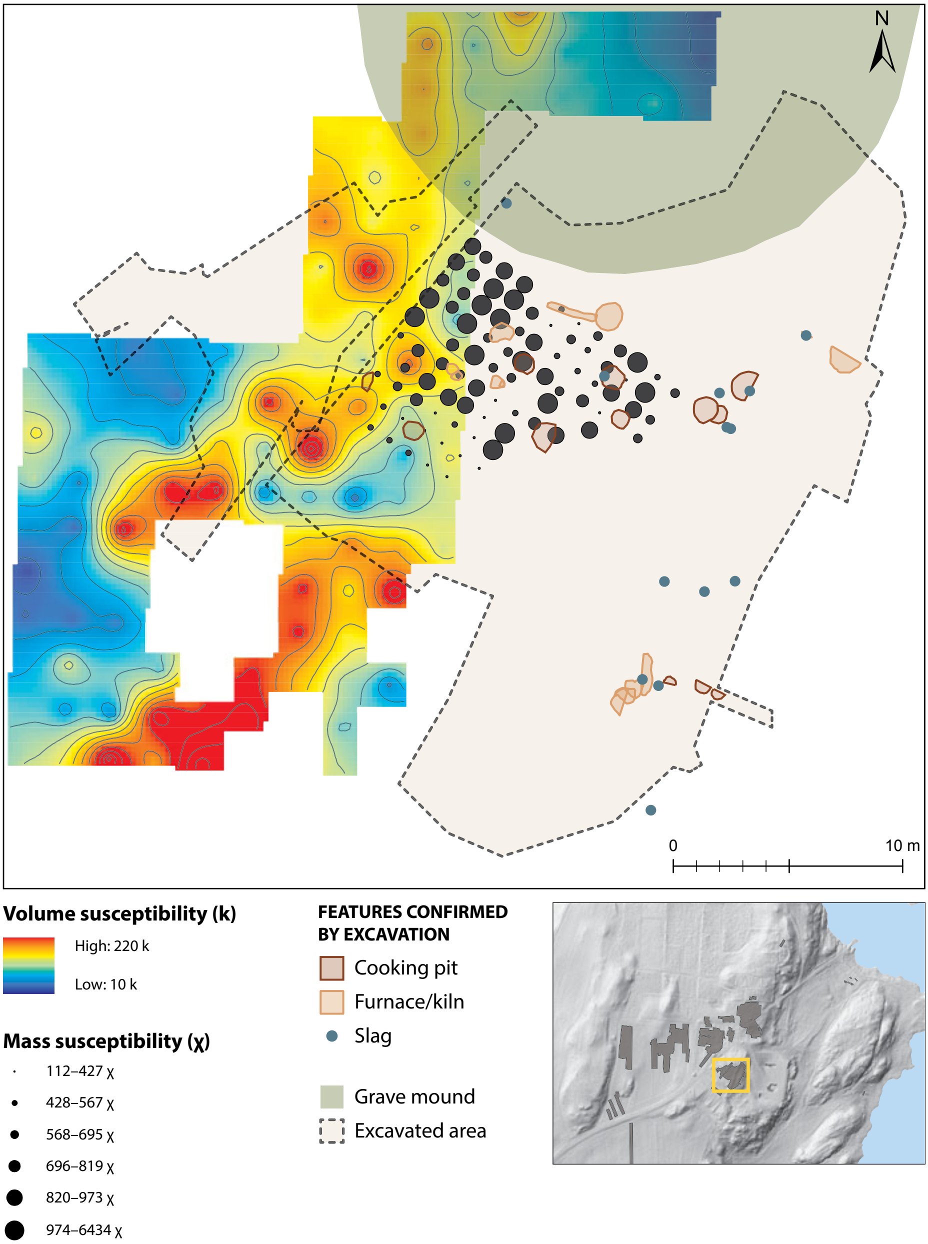

Fig. 16.18: Topsoil volume susceptibility (k) vs. sampled mass susceptibility (χ) in Area 6. Illustration: A. A. Stamnes, I. T. Bøckman, MCH. Plot from MS surveys, Earthsound Associates/NTNU 2009 (Barton 2010) and Linderholm and Wallin (2013).

excavated in this area (Østmo, Ch. 9:159) – features associated with activities that can explain the areas of mass MS enhancement. The areas of enhancement observed in the mass MS data sets are interpreted as reasonable sizes of work zones, and it is plausible that the MS response reflects metalworking and the connected, unintentional spread of waste products in the area (Linderholm and Wallin 2013). The MS survey therefore provided additional spatial information regarding the production and processing activities in this area.

The correlation between volume and mass MS was very low, only 0.03–0.1, and with a correlation coefficient of only 0.1–1 % (Tab. 16.2), even though the topsoil MS was sampled relatively densely, in a 2 × 2 m grid. We had assumed that a higher spatial sampling rate would increase the spatial correlation. The correlation between such activity areas delineated by mass MS and the topsoil MS readings was weak or simply absent. In combination with the modern disturbance to the topsoil, this weak correlation made it difficult to use the topsoil MS readings to delineate the production and processing activities that were excavated. The mass MS, on the other hand, was more useful for delineating activity areas.

The fluxgate gradiometer survey covered only a small part of the excavated area, and did not cover significant archaeological features such as the corn-drying kiln or the palisade (Fig. 16.15; Østmo, Ch. 11). The exposed stone packing in the southern part of the Kjellerhaug grave mound was partially included. The rather strong negative magnetic signal observed in this area can probably be attributed to the stones' magnetic properties. A similar signal within the average survey depth of the gradiometer indicated that the stone packing continued to the north-west. The mound's boundary is suggested by the strong negative values occurring roughly where the construction is visible on the surface.

The resistance data did not reveal anomalies related to excavated archaeological features, except for the stone packing in the grave mound, but even this feature did not show a high contrast (Fig. 16.19). By relating high contrast to the presence of stones or compacted soil, it is probable that the rectangular area near the modern building by the south-western edge of Kjellerhaug represents a disturbance caused by foundation work for the building. Furthermore, a 3.5 × 3.3 m low-resistance area west of the mound's top indicates a filled-in hole from a possible grave-plundering event. The north-eastern part of the mound has very low earth resistance readings, coinciding with the possible location of a potato cellar dug into the mound in the early 19th century.

The lack of correlation between topsoil MS and mass MS in Area 6 demonstrates a limitation of such surveys. Furthermore, magnetic susceptibility can be caused by metal or igneous rock, thus in certain instances necessitating ground-based observations to confirm archaeologically relevant activity areas. Pre-excavation survey areas at any given site do not always cover what subsequent excavation proves to be the most relevant areas for investigation. Small survey areas can furthermore hinder the interpretation of anomalies, as the high- or low-value areas cannot be delineated.

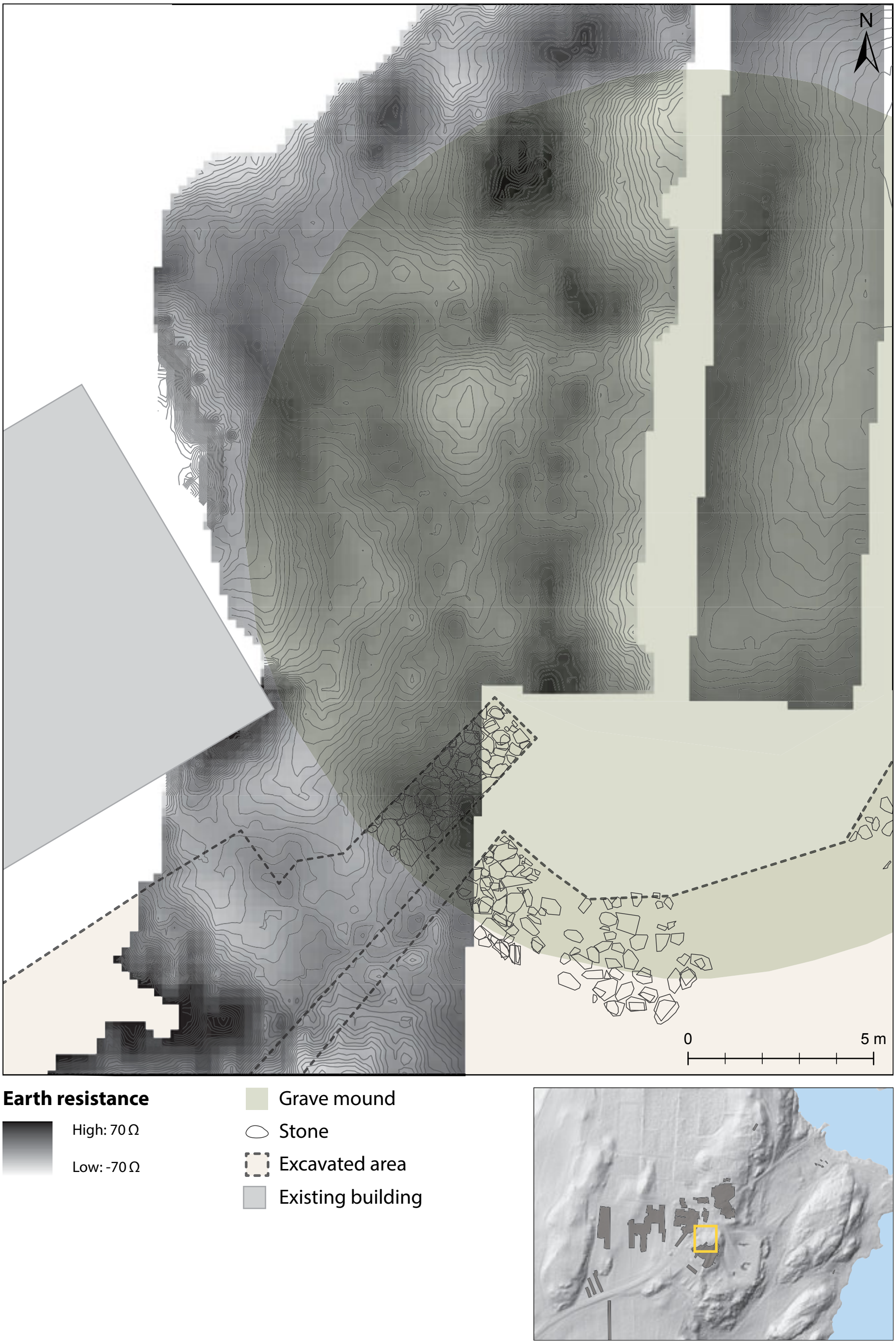

Fig. 16.19: Earth resistance measurements in Area 6.
Illustration: A. A. Stamnes, I. T. Bøckman, MCH. Plot from ER survey, Earthsound Associates/NTNU 2009 (Barton 2010).

16.8 Post-excavation survey: Area 1

From 4–7 November 2013, post-excavation GPR surveys were carried out in the northern and south-eastern parts of Area 1 and in Area 8 (Fig. 16.1) to address some unanswered questions from the excavations. The knowledge of archaeological features in the vicinity facilitated the positioning of the survey areas to cover presumed features in the unexcavated areas.

Area 1's northern part was inside the cemetery partly surveyed with GPR in 2004; however, wet conditions at that time had obscured any possible features, so the 2004 survey was without clear results (Sandnes and Eide 2004:14). In the 2013 GPR survey, we hoped to find remains of a construction extending from the southern chancel wall, towards the medieval ruin (A12) discovered in the south-eastern part of Area 1. Such a feature was suggested by the excavation of the medieval ruin (Bauer, Ch. 14:298). Another motive for the survey was to attempt to locate an octagonal construction, 6.8 m in diameter – perhaps a vestry – rumoured to have stood 16 paces south of the church (Hansen 1800:259).

The processed GPR data showed a number of high-reflective anomalies from several depths. All anomalies and interpretations are overlaid on a selected time slice in Figure 16.20. The ground was water-saturated after heavy rainfall and yielded little contrast between the soil and low reflective anomalies. Still, three approximately 2 × 1 m anomalies of east–west orientation, presumably graves, lay relatively shallow (40 cm at most). This interpretation is based on the clear geophysical contrast, shape, and orientation of the anomalies. One of the identified graves has a grave slab on the surface, while the two others visible on the time slice in Figure 16.20 do not. Figure 16.21 shows a GPR time slice through both the visible grave slab and the interpreted grave just east of it. A right-angled anomaly adjoining the chancel's south-eastern corner at a roughly 45-degree angle is probably the remains of foundations for some form of construction. An approximately rectangular area of north–south orientation of high-reflective anomalies just south of the surveyed area's central point could be the remains of a hard-packed surface or stones associated with a foundation. Such an interpretation is difficult to establish without excavation, as the anomalies' size and shape are not continuous.

Other anomalies might also represent remains of foundations or walls. A linear anomaly ran from east to west in the survey area's eastern part. The line is parallel to the church, possibly contextually related to it or another feature in the cemetery. Another line of continuous anomalies extends for approximately 9.5 m at a right angle from chancel's south-eastern corner, before turning westwards for about 5 m and then south again. This line seemingly coincided with a topographic break in the landscape, forming a roughly squared terrace. However, as suggested by Bauer (Ch. 14:296), it is possible that the anomalies from the point where the line turns westwards is actually remains of the above-mentioned octagonal building. Two, possibly three, segments of an angled line can be suggested, of which the two northernmost are the easiest to

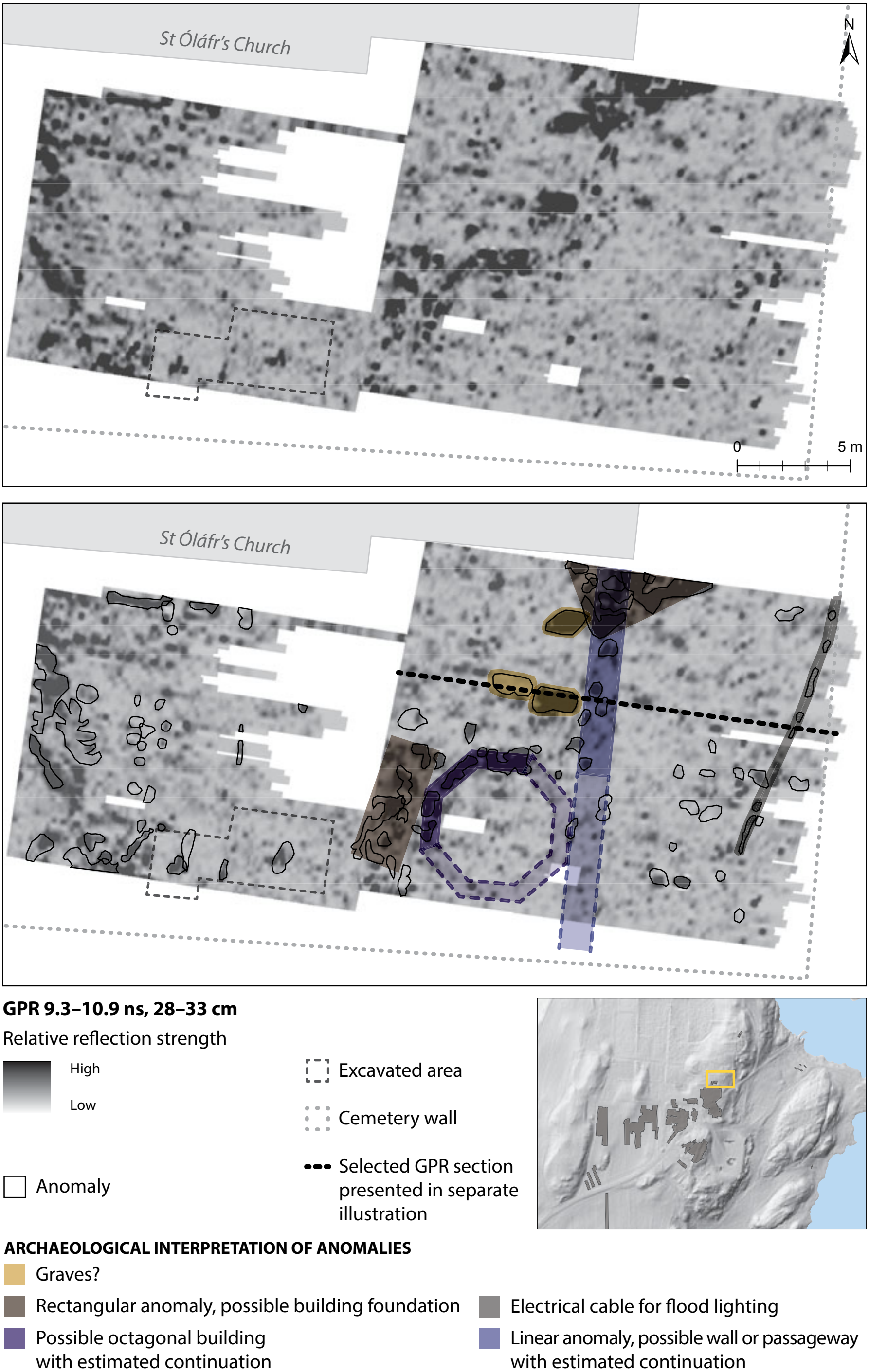

Fig. 16.20: The authors' interpretation of the GPR data collected in 2013. Illustration: A. A. Stamnes, I. T. Bøckman, MCH.

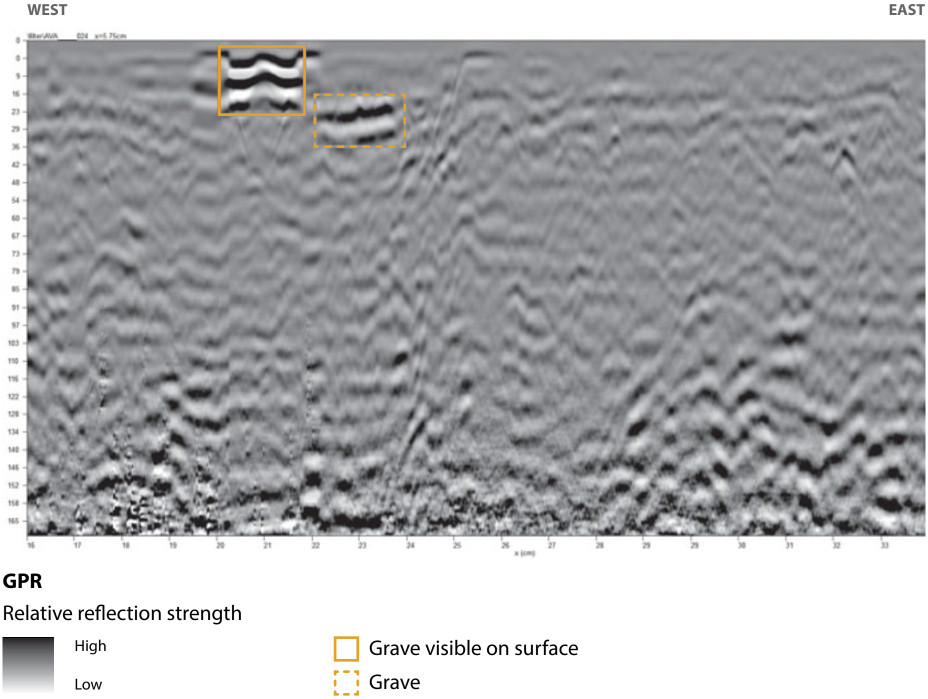

Fig. 16.21: GPR profile showing two of the graves: a shallow grave to the west and a grave at a lower depth to the east.
Illustration: A. A. Stamnes, I. T. Bøckman, MCH.

distinguish. These segments are c. 2.5 metres long. The northernmost segment runs parallel to the chancel, while the other lies to the west, at a 45-degree angle. The third, vaguer, segment runs perpendicular to the chancel wall and might represent the western wall segment of the octagonal building.

The 2013 survey included the area immediately to the north of the medieval ruin (A12), to discern how far north this construction continued (Fig. 16.1). Excavations had demonstrated that stone rubble from different phases of the post-medieval rectory buildings complicated the stratigraphy in the area. At the time of the survey, the site had been backfilled to cover and protect the partly exposed ruin. The surfaces exposed during the excavation were covered by 20–40 cm of soil.

The time slices showed large amounts of strong reflective material in the central part of the survey area (Fig. 16.22). As the excavation revealed stone rubble and building material from the post-medieval rectory, it is reasonable to assume that most of the strong reflective anomalies are related to these building remains. Several rows comprised of individual anomalies indicated foundations. At least one of these rows corresponded with stones left in situ after excavation. This row could be part of a building or a room. Possible building foundations might be traced further outside of

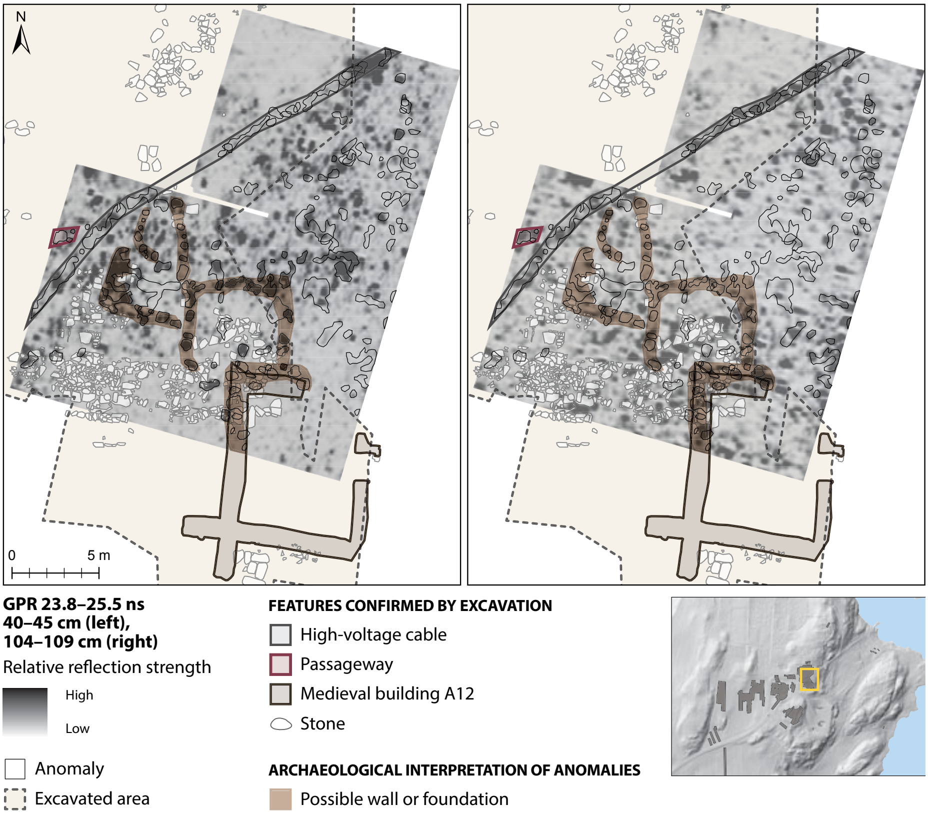

Fig. 16.22: The authors' interpretation of the GPR data collected in 2013.
Two different time slices are overlaid with an archaeological interpretation of the GPR data. The passageway can be traced going further westwards in another GPR dataset (Fig. 16.3). Illustration: A. A. Stamnes, I. T. Bøckman, MCH.

the excavated area. The feature's alignment corresponds roughly with the medieval ruin, suggesting that these anomalies might be related to the medieval ruin or constructions associated with it. Apart from these observations, it was generally difficult to discern distinct patterns in the anomalies, even when comparing the excavated features with GPR time slices and profiles. We interpret these observations as indicators of additional building rubble and building material remaining adjacent to the excavated areas. The geophysical response is similar to the known stones left in situ but is still relatively chaotic.

The only clearly continuous row of anomalies is the high-voltage cable mentioned in connection with the subterranean passageway (above, pp. 337–8). While the passageway's eastern end was visible (Figs. 16.22–3, western edge), no linear trend indicating a continuation of the passageway east of the high-voltage cable could be distinguished in the time slices by following the observed response from the passage-

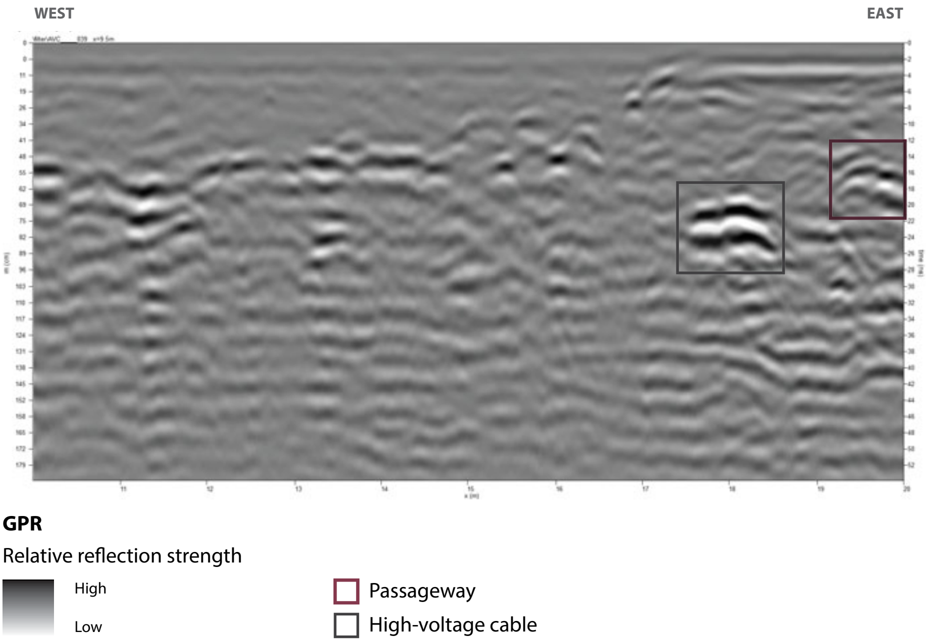

Fig. 16.23: GPR profile showing the geophysical response from the subterranean passageway and the high-voltage cable.
Illustration: A. A. Stamnes, I. T. Bøckman, MCH.

way into this area in the adjacent GPR sections. This could mean that the passageway actually ended there; alternatively, the high-voltage cable could have been laid in the passageway, effectively camouflaging this feature.

A few anomalies are visible in the GPR sections as very distinct areas of reflection, possibly representing substantial constructions. Alternatively, the heavy rainfall at the time of the survey led to bedrock depressions being filled by water, which in turn can create increased geophysical contrasts complicating interpretation. From the excavation on the terrace in Area 1's eastern part the bedrock is known to lie at approximately 0.2–0.3 metres below the surface, but the GPR profiles indicate increased thickness of deposits down towards the edge of the terrace to the east (Figs. 16.24–5). The yellow line in Figure 16.24 is drawn along a layer of strong reflections corresponding with known bedrock depths to the west.

The depth to the bedrock was relevant in order to estimate how far the building remains could extend downwards (Fig. 16.25). In the survey area's central part, which was not excavated after having stripped away the turf, the depth to the bedrock seems to be 30–40 cm and maybe as little as 20 cm in the northern part. At the area's eastern edge it might be as deep as 65–75 cm, while in the south-eastern corner the depth seems to be as much as 85–125 cm. Earlier excavations with subsequent backfilling of soil have, however, made it hard to judge the depth.

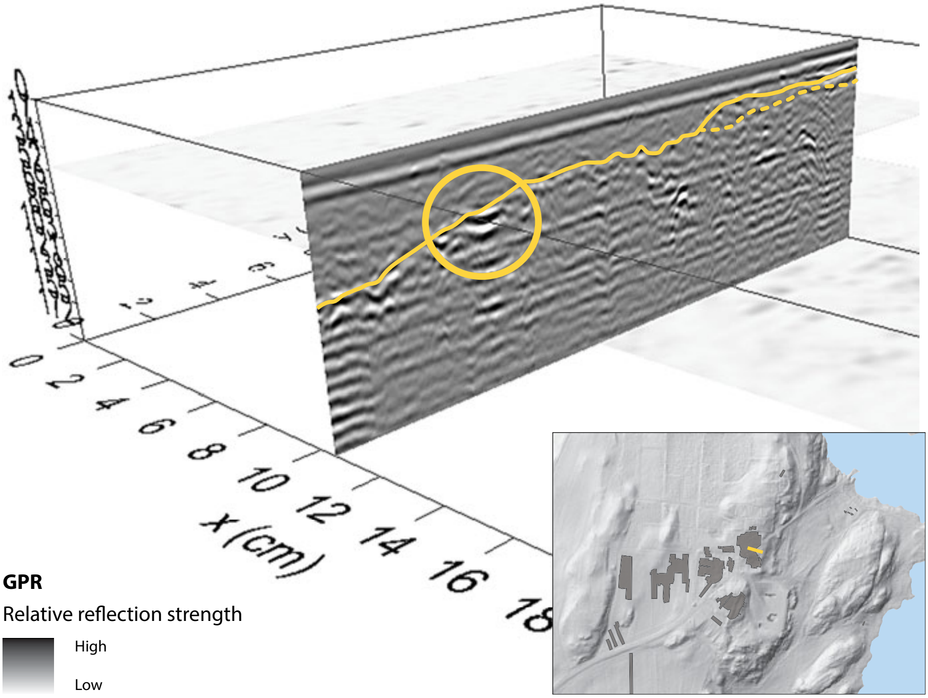

Fig. 16.24: A possible effect of standing water in a bedrock depression.
The yellow line shows an interpretation of the depth to bedrock along the collected GPR transect. Illustration: A. A. Stamnes, I. T. Bøckman, MCH. Plot from GPR survey, NTNU 2013.

The post-excavation survey from Area 1 demonstrated that even when information from previously excavated areas and features allows specific hypotheses to be investigated, poor survey conditions, such as water-saturated ground or large amounts of stones in the ground, can result in GPR surveys that are less informative than expected.

16.9 Post-excavation survey: Area 8

Area 8 lay at the bottom of the slope below St Óláfr's Church and was the site for a two-phased boathouse (A40) from the Roman Iron Age and Migration Period (Bauer, Ch. 10). The boathouse was investigated in 2012 by digging narrow trenches across the remains, which were covered by colluvial cultivation deposits (Bauer Ch. 10:188). A modern gravel path covered the boathouse's presumed opening towards the beach. No pre-excavation geophysical surveys existed from Area 8. The aims of the 2013 GPR survey were to investigate whether any other boathouses could be identified and to

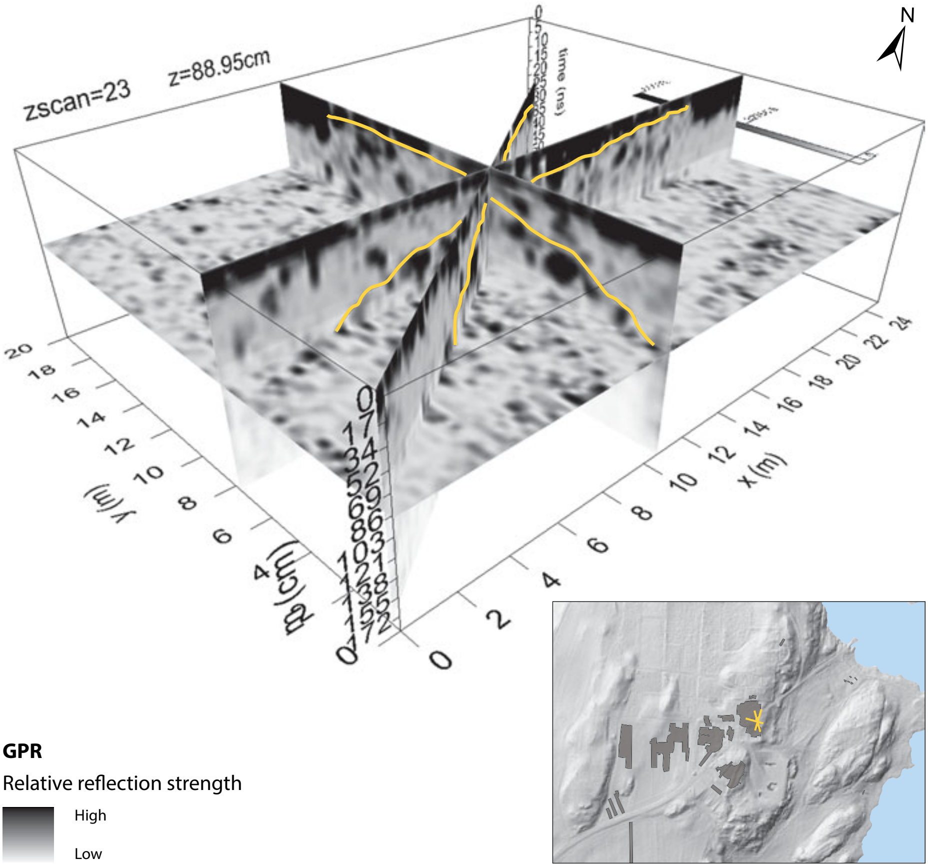

Fig. 16.25: GPR data showing the varying depths to bedrock.
Illustration: A. A. Stamnes, I. T. Bøckman, MCH. Plot from GPR survey, NTNU 2013.

delimit and identify additional constructional features of the partly excavated boathouse.

The most distinct results from the GPR survey was the location of four modern ditches (Fig. 16.26), probably containing plastic tubes similar to the two identified in the excavated trenches (Bauer, Ch. 10:188). The ditches ran in two parallel pairs, one pair from south-west to north-east and the other pair west-northwest to east-southeast. No other boathouses could be identified within the survey area. It was furthermore difficult to identify any pattern in anomalies possibly representing postholes, as there were many positive reflections. It was likewise difficult to observe already-excavated postholes and stratigraphical observations in the GPR profiles. No stone walls were identified, but in some places the excavated turf walls showed as stronger reflecting areas. In the centre of the boathouse was an area with stronger reflection at a depth of approximately 0.5 m, coinciding relatively closely with the depth of the floor deposits.

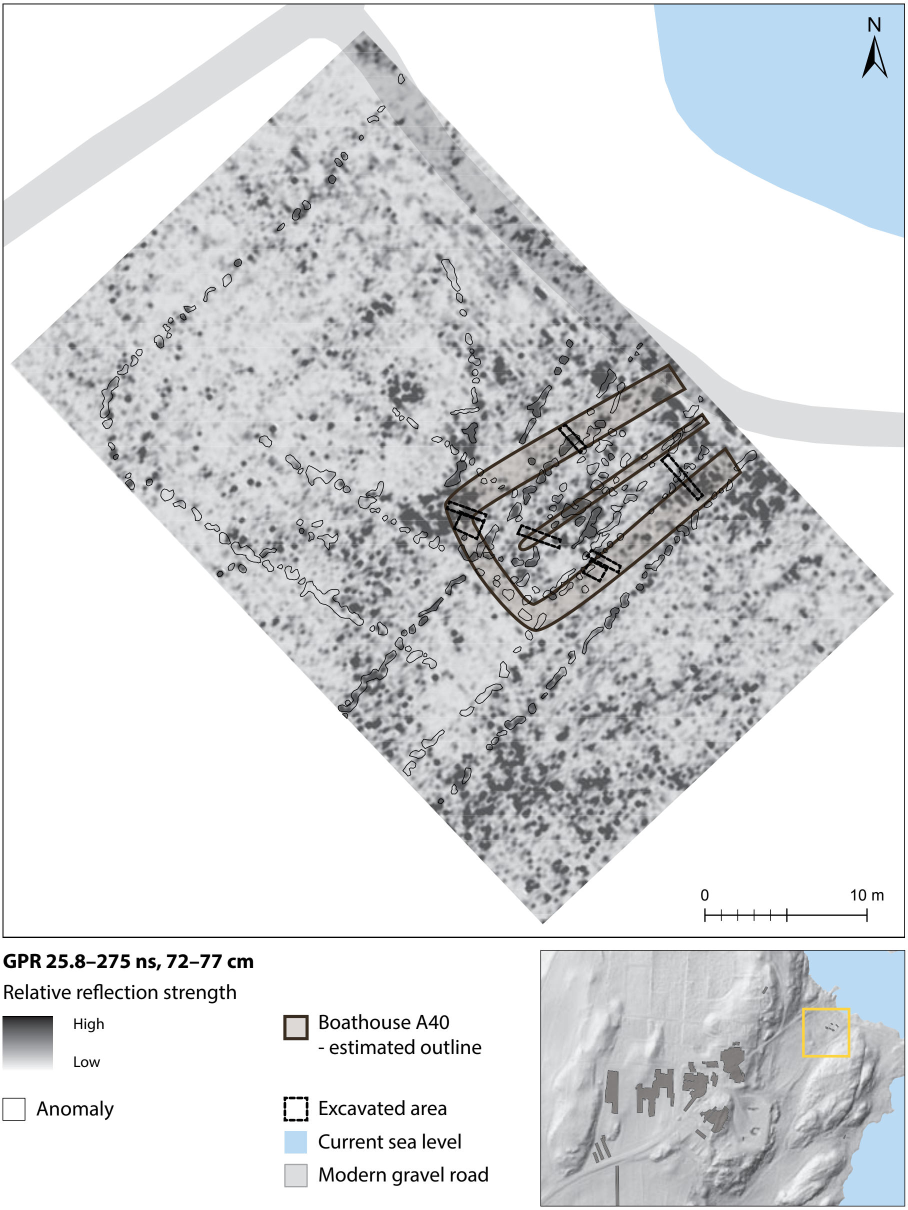

Fig. 16.26: Map showing Area 8 with all identified anomalies, both modern and those interpreted as archaeologically significant, on a background of a selected GPR depth slice (72–77 cm below the surface).
Several anomalies are not visible in this slice, but appear either above or below. All the anomalies included in this figure were visible in several depth slices, increasing the likelihood that they are a man-made construction collocated at the same spot over several depths. The estimated outline of boathouse A40's wall banks is not visible in the data. Illustration: A. A. Stamnes, I. T. Bøckman, MCH. Plot from GPR survey, NTNU 2013.

This area extends beyond the relatively narrow excavation trench, but did not form a continuous area of increased signal reflection. Around this area, particularly in the south-west, a curve of slightly stronger reflection seemed to make up the gable end of the boathouse. However, this did not correspond with the location of the excavated wall banks. It is more likely, therefore, that this curvature is a natural formation, or possibly represents the remains of an older boathouse in a slightly different location.

The post-excavation GPR survey from Area 8 unfortunately was unable to address the unanswered questions from the excavation. The GPR profiles showed only minor geophysical contrasts in areas with known archaeological information, with seemingly high attenuation in the uppermost deposits consisting mainly of water-saturated sand and silt. Drier conditions might have improved the results, but there was not an opportunity to repeat the survey at a later stage under different conditions – a valuable lesson for GPR surveys at similar sites in western Norway.

16.10 Evaluation of the geophysical surveys and methods

Generally, the experiences from Avaldsnes show that GPR data was more applicable during excavation than the magnetometer, magnetic susceptibility, and earth resistance data, mainly because GPR anomalies were easily comparable to excavated archaeological features. For field personnel lacking training in interpreting the various data sets, the 'what you see is what you get' nature of GPR time slices is more readily understandable to the untrained eye. The detailed GPR datasets supplied by VIAS from Area 2 were particularly useful during excavation. Following an initial phase of excavation where systematic connections between GPR data and excavated features were discovered, more limited and targeted investigations could be performed, saving work and time.

Certain features, such as stone-free postholes and stakeholes, were invisible in the GPR data; in order to avoid missing entire categories of cultural remains, investigations were based on other criteria as well, such as topography and results from earlier test trenching. By correlating the anomalies' depth within the trench areas with the exposed level of the trenches, the staff could predict with great accuracy the location of archaeological features, which proved to fit well with this dataset. However, stony subsoil or bedrock camouflaged anomalies to a certain extent by providing similar resistance as dug-down, stone-rich features.

For areas with a high density of modern disturbances it was difficult to distinguish archaeological features. This was particularly prevalent in parts of Area 1, where deposits were shallow, compact, and packed with gravel. Certain features, such as the subterranean passageway, stones related to buildings, and several cable ditches, showed clearly in the GPR data. Still, prior to excavation, there was no way of telling whether anomalies were of modern or prehistoric origin. Certain excavated features were even invisible in the GPR data. Such experiences caused the field staff to doubt the surveys' reliability, simply noting anomalies before proceeding with excavation as normal. Other times, the field staff missed certain distinct features in the geophysical data altogether, for example the stone-paved walkway in Area 5. This oversight seemed strange, as the construction was 25 metres long and up to 1.5 metres wide; however, the GPR time slice in the geophysical survey report (Barton 2010:fig. 12.9.1) showed only a single depth slice (no. 10). The walkway was partly visible in four of the other slices (nos. 5–8) not presented in the map. When the GPR data was reprocessed and georeferenced for the presentation of this chapter, the walkway appeared more clearly, as a linear anomaly visible at several depths (Fig. 16.16). This demonstrates the importance of access to digital files with georeferenced data plots and to an interpretation of the data from the survey, allowing the field staff to continuously select which slices to view, thereby focusing on different depths of the surveyed area, rather than only the depth considered to contain relative features by the geophysicist prior to excavation. It also demonstrates the need for strong communication with trained professionals who can provide adequate data processing and geophysical and archaeological interpretations as well as support and advice throughout the archaeological planning and excavation process.

The data from the survey methods other than GPR were more difficult to interpret for the field staff prior to and during excavation. In the magnetometer data, for instance, the shapes of anomalies do not fit the exposed archaeology. While geophysical responses can be different in size and shape to that of their source features, this is not necessarily a surprise to a trained expert. Rather, it demonstrates the complications in understanding such datasets for field staff untrained in interpreting geophysical data. Often, anomalies corresponded better with geological formations than with exposed archaeological features. Hence, the field staff tended to consider certain data irrelevant when determining the placement of excavation trenches. At Avaldsnes, it was evident that the magnetic bedrock restricted the usefulness of this survey method as well as the magnetometer and resistance data. In Area 2, for instance, the areas of enhanced responses were too large to allow the identification of any relation to specific archaeological features. Heightened signals might stem either from large activity areas or simply from geology, but such conclusions were impossible to draw before excavation. In hindsight, it seems plausible that the heightened topsoil magnetic susceptibility response in Area 5's eastern part corresponded with the area for the excavated longhouse, but prior to excavation it was not possible to discern any occupation area here. The high magnetic susceptibility might equally well have been due to modern disturbances.

The pre-excavation geophysical survey data from Area 6 demonstrated another issue: the survey areas were long and narrow, rendering difficult the attempts to gain an overview of the larger context of the anomalies. The topsoil magnetic susceptibility survey showed high values, but as in the other excavation areas, the meaning of this was unclear. There were high values in the area's northern and southern parts alike; as the latter consisted mostly of modern infilling, there was no reason to interpret the high values in the north as anything else prior to excavation. The general impression is that the topsoil MS at Avaldsnes only partly reflected archaeological observations. Again, geology and modern disturbances probably factored into this, while colluvial deposits in Area 2 would have inhibited the transportation of anthropogenically influenced material upwards towards the topmost deposits. At the same time, the extent of the deeper colluvium and cultivation deposits could be made out in the topsoil MS. Our impression is also that the mass MS collected from soil samples from deposits undisturbed by modern activity was useful in understanding and spatially delimiting past activity areas.

Another potentially problematic factor is the direction of data collection. As seen, for instance, regarding the wall ditch in Area 1, certain features are only visible if the data collection runs perpendicular to them. As it is rarely possible to predict the type and alignment of features and to perform surveys accordingly, performing a GPR survey in only one direction could induce false negatives, leading to important information being missed. Moreover, obstacles and the physical layout of the survey areas often dictate which direction the data collection can be performed. Further, it is essential that the surveys' traverse interval is sufficiently narrow to detect small archaeological features. This boils down to a question of time and money. Good communication between the geophysical service provider and the project management is essential when designing a survey methodology for the site.

Each geophysical survey method has its inherent advantages and limitations, all of which have to be taken into account when planning the survey methodology for a site. In hindsight, some of the choices that were made for Avaldsnes seem inappropriate. GPR traverses with a line spacing of 1 m or 0.5 m seem too coarse to properly detect minor archaeological features such as postholes and small pits. GPR is considered to be the most detailed survey method of all methods applied at Avaldsnes; perhaps for this very reason, the method was not utilised to its full potential. We noticed an improvement in the resolution when reprocessing the data from building A10 in Area 1 to focus on a higher frequency range (285–750 Mhz), but this was a trade-off between potential survey depth and resolution. With GPR, applying a lower frequency will lose spatial resolution but gain potential depth of investigation (Conyers 2013). For magnetic methods using passive magnetometer sensors, any decrease in line spacing will improve the data resolution, thereby increasing the potential to properly characterise and interpret observed anomalies. The choice of inline and crossline spacing should therefore match expected features in detail and size (Schmidt and Marshall 1997). Such details are not always known before commencing a survey, but estimates should nevertheless be taken into account. The magnetometer surveys performed at Avaldsnes had a crossline spacing of 0.5 m, which was deemed sufficient considering that these surveys were performed with hand-carried instruments. Current practice within European archaeological prospecting favours the use of towed magnetometer sensor arrays, which allows for the potential of increased effective spatial resolution and survey speed without losing area coverage.

While magnetic bedrock compromised the magnetometer results at Avaldsnes, we still advocate that geophysical surveys should be performed by utilising several complementary geophysical methods. At Avaldsnes, we identified in some geophysical datasets archaeological features that were invisible in others. This fact is widely demonstrated and recognised by geophysical practitioners in archaeology (e. g., Clark 1996; Gaffney et al. 2002; Gaffney and Gater 2003; Kvamme et al. 2006; David et al. 2008; Watters 2009; Trinks et al. 2010; Stamnes 2010; Viberg et al. 2011; Gaffney et al. 2012; and Trinks et al. 2014). Furthermore, the use of EMI methods is known to provide positive results within an area of strongly magnetic bedrock, as observed for instance over cooking pits in Area 5 and feature F1 in Area 2. Tests in Ireland have shown promising results from EMI surveys over very wet or dry soils and high and low magnetic bedrock that might otherwise impose difficulties for more conventional geophysical survey methods (Bonsall et al. 2013). This indicates that the future use of multi-depth EMI systems in archaeological geophysical surveys in Scandinavia could compensate for some of the difficulties observed at Avaldsnes, including thick topsoils and magnetic bedrock.

Several of the geophysical survey reports from Avaldsnes accentuate an inherent problem with their usability. As the surveys are usually carried out prior to excavation (several of them even before the ARM Project was established), the geophysical reports contain unconfirmed interpretations. Data comparison is often complicated by inherent discrepancies with regards to positioning between the surveys, hence the necessity for clear and concise information on survey locations in a digital format. Furthermore, the most apparent anomalies are not always archaeologically significant. It is essential that, along with the report, the geophysical service provider make available depth slices and data plots as high-resolution digital files, thus enabling the excavation staff to study them and quickly alternate between them, consequently increasing the likelihood of spotting anomalies in different areas, both prior to and during excavation. The geophysical technicians should be supplied with excavation plans containing information on the types of features to expect, based on survey excavations, written sources, or previous experience. Communication between the geophysical technicians and the excavation staff should be maintained throughout the excavation phase and even during post-excavation, as interpretations are tested and revised. Such communication, including interpretative assistance, should be included in the standard contract upon entering into collaborative work. Such two-way feedback would facilitate the development of the application and usability of geophysical survey methods for archaeological fieldwork with regard to evaluating initial data interpretations, understanding the influence of background environmental conditions, and reinterpreting the data during and after excavation.

Geophysical survey equipment quickly improves and grows more sophisticated in tandem with archaeologists' experience in interpreting survey results. Thus, while several of the geophysical surveys at Avaldsnes unfortunately proved of meagre importance for locating significant archaeological features, the sheer number of surveys has allowed the methods to be evaluated and put to use for precisely this purpose: to educate archaeologists in the use of these methods.

16.11 Conclusion

The main aim of this chapter was to review the applicability of the various geophysical methods under the geological and archaeological conditions encountered at Avaldsnes. This was achieved by comparing the various geophysical data with the archaeological features, as well as with geoarchaeological and geochemical information gathered during the excavation. In this way, the evaluation of the applicability of the various geophysical survey methods performed at Avaldsnes can serve as important reference material for future survey campaigns. The evaluation has demonstrated possibilities as well as pitfalls, highlighting various aspects to be considered in advance of commissioning and planning geophysical surveys – geological information, choice of methods, and survey resolution.

At Avaldsnes, the geological bedrock is mainly magmatic of volcanic origin, with a moraine drift geology derived primarily from this magmatic bedrock. This geological situation created very magnetic subsoil with a high variability, which in turn renders difficult any positive archaeological identification by means of the available magnetometer and gradiometer datasets. Bedrock close to the surface obscured or made invisible any archaeological features; only in a few isolated instances did we notice any semblance of archaeology (for instance feature F1 in Fig. 16.11). Site delineation with topsoil magnetic susceptibility sampling, while difficult at Avaldsnes due to the geological conditions and modern disturbance, did however reveal information of geoarchaeological significance; for instance, the main area of cultivation deposits in Area 2. The mass susceptibility collected from soil samples in less disturbed contexts, on the other hand, created a useful source of information for delineation and understanding of past activity areas.

The mapping of apparent magnetic susceptibility by the use of EMI sensors was more successful in delineating sources of firing; for instance, the area of cooking pits in Area 5 and feature F1 in Area 2. Further investigations on the potential of EMI surveys in areas with magnetically enhanced bedrock are encouraged.

The earth resistance sampling revealed a series of pits in Area 5 as well as information on the drainage effect on the surrounding soils from a modern day pipeline. Earth resistance data could also be used to reveal geoarchaeological information on soil thickness in Area 2, but the stone packing and medieval walkway in Area 5 remained undetected.

Of all methods applied, it is clear that ground penetrating radar (GPR) produced the most usable results at Avaldsnes: data from Area 2 was instrumental in locating cooking pits in an area of thick homogeneous deposits from prehistoric cultivation. The positive identification of these anomalies as cooking pits did not become eminent before excavation, as any magnetic contrast was not detectable. While it is possible that cooking pits might have a clearer magnetic contrast on sites with a less magnetic geological background, it is clear that at Avaldsnes, excavation was the key to identifying geophysical anomalies as cooking pits. The early positive identification of cooking pits within cultivation deposits in Area 2 made it possible to limit excavation areas to those containing such features and to apply the knowledge derived from comparing the geophysical results with field observation during the excavation campaign. While several other observations of archaeological features were visible in other parts of the Avaldsnes site, it also became obvious that interpreting GPR data from stratigraphically complex conditions partly disturbed by modern-day activity was a difficult task. Archaeological observations of stone walls were difficult to distinguish from background 'clutter', as with building A12. The earlier GPR survey campaigns furthermore involved a traverse interval of 50 and 100 cm between each transect, which in hindsight clearly limited the GPR surveys' usability.

At Avaldsnes, the use of magnetometers and gradiometers could probably have been omitted without significant loss to the total amount of geophysical information, had the geological conditions been known at an early date. It might be advisable, however, to explore the potential of other non-intrusive methods such as multi-receiver EMI or high resolution multi-receiver and multi-channel GPR systems.

Generally, clearly communicated objectives for geophysical surveys, including descriptions of expected archaeological features and details of background geology and other information, will facilitate in designing an optimal survey strategy for any given site. Absent such objectives or theses for the site, the large volume of collected data can be difficult to utilise. On the other hand, despite the use of relevant theses and objectives, the site's survey conditions will ultimately play a major part in the produced result.

The communication between the excavation staff and the geophysical technicians should be maintained throughout and after the excavation to help with specific interpretations and for planning and prioritising the excavation work and evaluating results. Such contact would be mutually beneficial for developing geophysical surveys methods for use in archaeological fieldwork. It is the authors' hope that the experiences from Avaldsnes can further improve geophysical survey methods' application in archaeological survey or excavation projects.

References

Icelanders are listed according to their first name. Ä, Æ, Å, and Á are alphabetised as A, while Ö, Ø, Ǫ, and Ó are alphabetised as O. Bibliographical abbreviations are listed pp. XIII–XIV.

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Appendix I: The ARM Project Council, Advisory Group, Staff, and Authors

The Project Council

The ARM Project Council, scheduled to meet twice annually, is a forum for contact and information-sharing between the ARM Project and its main funder, Karmøy Municipality. The Council's role is to ensure that the project is conducted within contract and budget, making no decisions regarding the project itself. Council members are appointed by University of Oslo (UiO, up to 6 members) and Karmøy Municipality (KM, up to 6 members).

Professor Emeritus Knut Helle, University of Bergen (appointed by UiO, 2007–15)
Head of Research Mads Ravn, Archaeological Museum, University of Stavanger (appointed by UiO, 2007–11)
Professor Siv Kristoffersen, Archaeological Museum, University of Stavanger (appointed by UiO, 2011–17)
Archaeologist Frans-Arne Stylegar, Vest-Agder County Council (appointed by UiO, 2007–17)
Associate Professor Torun Zachrisson, University of Stockholm (appointed by UiO, 2007–17)
Professor Dagfinn Skre, Museum of Cultural History, University of Oslo (UiO, 2007–17)
Mayor Kjell Arvid Svendsen, Karmøy Municipality (appointed by KM, 2007–17)
Mayor Aase Simonsen, Karmøy Municipality (appointed by KM, 2011–15)
Mayor Jarle Nilsen, Karmøy Municipality (appointed by KM, 2015–17)
Chief administrative officer Arnt Mogstad, Karmøy Municipality (appointed by KM, 2007–13)
Chief administrative officer Sigurd Eikje, Karmøy Municipality (appointed by KM, 2013–17)
County Mayor Janne Johnsen, Rogaland County Council (appointed by KM, 2011–15)
Head of Culture, Egil Harald Grude, Rogaland County Council (appointed by KM, 2007–10)
Marit Synnøve Vea, Karmøy Municipality (appointed by KM, 2007–17)
Sigurd Steen Aase, Haugesund (appointed by KM, 2007–17)
The Directorate for Cultural Heritage has appointed an observing member of the Project Council: Advisor Bjørn-Håkon Eketuft Rygh (2007–13) and Senior Advisor Atle Omland (2013–17).

The Advisory Group

The task of the Advisory Group has been to offer scholarly support to the project. As the project entered the excavation phase in 2011, new members were appointed to strengthen the competence on excavation methods and strategies. The members have been:

Head of Culture, Egil Harald Grude, Rogaland County Council (2007–10)
Professor Emeritus Knut Helle, University of Bergen (2007–10)
Researcher Olle Hemdorff Archaeological Museum, University of Stavanger (2011–10)
Professor Mads Kähler Holst, Århus University (2011–17)
Professor Frode Iversen, Museum of Cultural History, University of Oslo (2007–10)
Professor Lars Jørgensen, National Museum of Denmark (2011–16)
Researcher John Ljungkvist, Uppsala University (2011–17)
Archaeologist Trond Meling, Rogaland County Council (2011–15)
Dr. Arnfrid Opedal, Stavanger (2007–10)

Associate Professor Unn Pedersen (2011–2019)
Archaeologist Lars Pilø, Oppland County Council (2007–17)
Researcher Morten Ramstad, University of Bergen (2011–17)
Archaeologist Frans-Arne Stylegar, Vest-Agder County Council (2007–17)
Marit Synnøve Vea, Karmøy Municipality (2007–10)
Associate Professor Torun Zachrisson, University of Stockholm (2007–10)

The Project Staff

Geir Ove Åmodt, Operator, mechanical excavator (2011–12)
Egil Lindhart Bauer, Excavation manager (2011–14)
Ingvild Tinglum Bøckman, Field archaeologist, GIS specialist, Project assistant (2011–19)
Rebecca Cannell, Field archaeologist (2011–12)
Marianne Hem Eriksen, Field archaeologist (2011)
Magnar Mojaren Gran, Field archaeologist (2011–12)
Christoffer Hagberg, Field archaeologist (2012)
Hans Christian Hauge, Operator, mechanical excavator (2011)
Silje Lillevik, Field archaeologist (2011)
Knut Steinar Løften, Operator, mechanical excavator (2011)
Tor-Geir Løften, Operator, mechanical excavator (2012)
Stella Macheridis, Field archaeologist (2012)
Jessica Leigh McGraw, Field archaeologist (2011–12)
Erlend Norlie, Field archaeologist (2012)
Mari Arentz Østmo, Head of excavations, PhD candidate (2007–18)
Maryon Evelyn Østvik, Field archaeologist (2011)
Josefine Kristin Sandvik, Field archaeologist (2012)
Anja Nordvik Sætre, GIS specialist (2011–12)
Andreas Skredsvik, Field archaeologist (2011–12)
Syver Smukkestad, Field archaeologist (2011–12)

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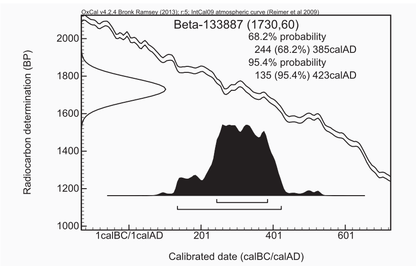
Appendix II: Radiocarbon Dates

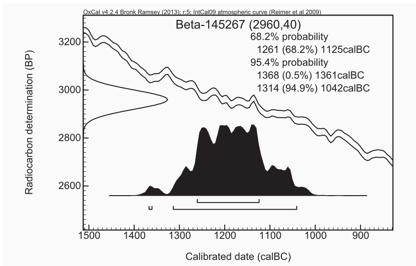
All radiocarbon datings from the ARM excavations 2011–12 have been calibrated according to OxCal v4.2.3 (Reimer et al. 2009); they are listed by laboratory numbers, and with their respective calibration curves. Pre-2011 datings (in italics) have been recalibrated. Datings on material from previous excavations on courtyard sites (Iversen, Ch. 26) are listed separately (pp. 889–97). Prefixes in each dating's laboratory number indicates laboratory and dating method – see Abbreviations (pp. XIII–XIV).

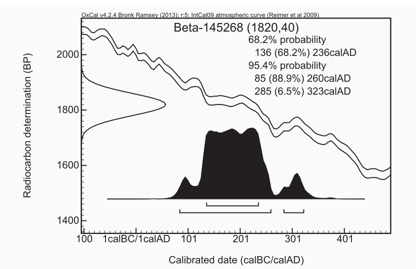
When referred to in the text, datings are given in terms of the one sigma (68.2 % probability) unless otherwise stated. If the one sigma spans more than one time interval, only the start of the earliest and end of the most recent is indicated. For example, for the dating Beta-304876 where the one sigma spans the two periods AD 214–61 and 280–326, this is written as AD 214–326.

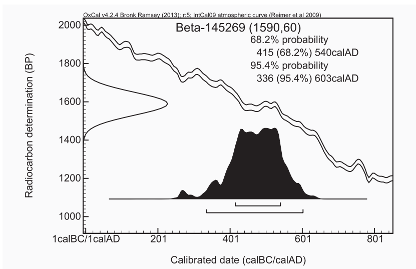
Avaldsnes and Vicinity

LAB NO.	SITE, SAMPLE NO.	MATERIAL	RADIO-CARBON AGE BP	CALIBRATED 1 SIGMA	CALIBRATED 2 SIGMA	CONTEXT
Beta-133887	Avaldsnes		1730 +/– 60	AD 244–385	AD 135–423	Grave 2000: structure 1
Beta-145267	Avaldsnes		2960 +/– 40	BC 1261–1125	BC 1368–1361, 1314–1042	Cultivation deposit 2000: layer 5
Beta-145268	Avaldsnes		1820 +–/ 40	AD 136–236	AD 85–260, 285–323	Grave 2000: structure 2
Beta-145269	Avaldsnes		1590 +/– 60	AD 415–540	AD 336–603	Grave 2000: structure 4

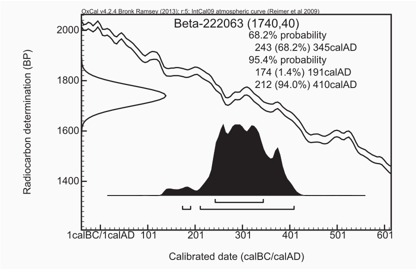


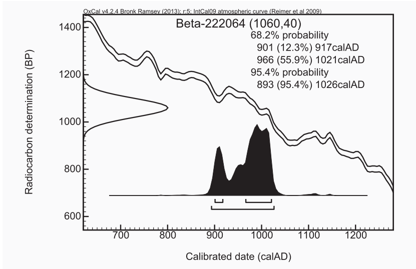


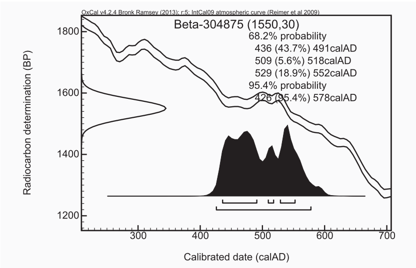


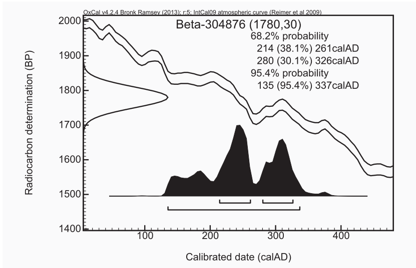


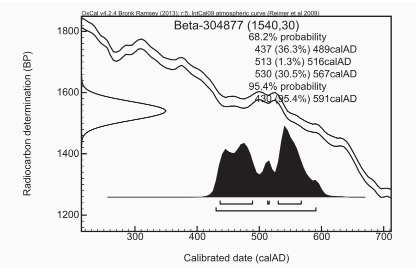
LAB NO.	SITE, SAMPLE NO.	MATERIAL	RADIOCARBON AGE BP	CALIBRATED 1 SIGMA	CALIBRATED 2 SIGMA	CONTEXT
Beta-222063	Avaldsnes 2006/19–1	Charred material	1740 +/ – 40	AD 243–345	AD 174–191, 212–410	Hearth A8957, A10
Beta-222064	Avaldsnes 2006/19–2	Charred material	1060 +/ – 40	AD 901–917, 966–1021	AD 893–1026	Posthole A18687, A14
Beta-304875	Avaldsnes 1546	Betula	1550 +/ – 30	AD 436–491, 509–518, 529–552	AD 426–578	Cooking pit A2046
Beta-304876	Avaldsnes 1552	Betula	1780 +/ – 30	AD 214–261, 280–326	AD 135–337	Cooking Pit A3889
Beta-304877	Avaldsnes 1555	Betula	1540 +/ – 30	AD 437–489, 513–516, 530–567	AD 430–591	Cooking pit A5031
Beta-304878	Avaldsnes 1721	Betula	3270 +/ – 40	BC 1608–1570, 1561–1501	BC 1637–1447	Cultivation deposit A4216
Beta-304879	Avaldsnes 1566	Betula	1660 +/ – 30	AD 347–371, 377–423	AD 259–295, 321–436, 491–509, 518–529	Hearth A8957, A10
Beta-319014	Avaldsnes 39	Hordeum vulgare	2150 +/ – 30	BC 350–311, 209–159, 134–117	BC 356–286, 235–250, 234–91, 72–60	Cooking pit A9568
Beta-319015	Avaldsnes 61	Hordeum vulgare	2190 +/ – 30	BC 356–286, 234–201	BC 365–176	Cooking pit A18656
Beta-319016	Avaldsnes 76	Avena	940 +/ – 30	AD 1035–1052, 1080–1152	AD 1025–1160	Stakehole A18736, A14

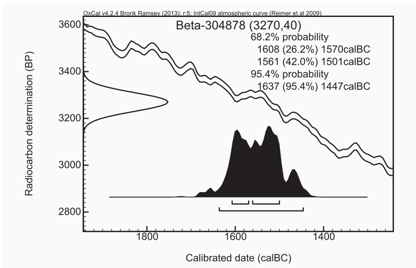

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Beta-222063 (1740,40)
68.2% probability
243 (68.2%) 345calAD
95.4% probability
174 (1.4%) 191calAD
212 (94.0%) 410calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

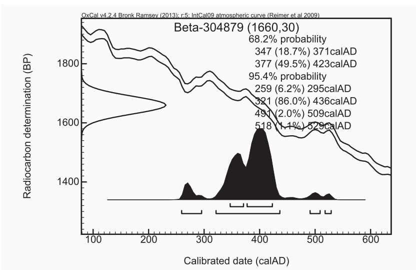

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Beta-222064 (1060,40)
68.2% probability
901 (12.3%) 917calAD
966 (55.9%) 1021calAD
95.4% probability
893 (95.4%) 1026calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

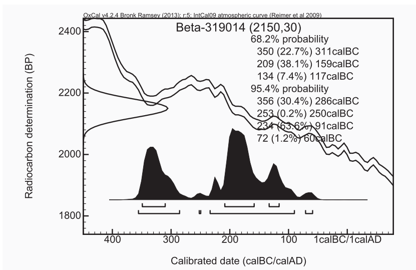

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Beta-304875 (1550,30)
68.2% probability
436 (43.7%) 491calAD
509 (5.6%) 518calAD
529 (18.9%) 552calAD
95.4% probability
426 (95.4%) 578calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

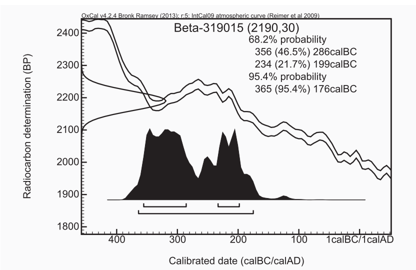

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Beta-304876 (1780,30)
68.2% probability
214 (38.1%) 261calAD
280 (30.1%) 326calAD
95.4% probability
135 (95.4%) 337calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

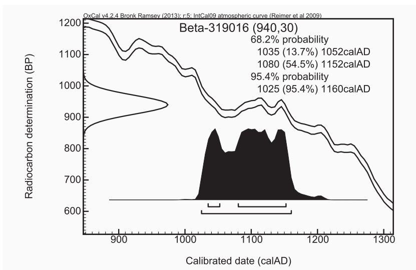

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Beta-304877 (1540,30)
68.2% probability
437 (36.3%) 489calAD
513 (1.3%) 516calAD
530 (30.5%) 567calAD
95.4% probability
430 (95.4%) 591calAD
Radiocarbon determination (BP)
Calibrated date (calAD)


OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Beta-304878 (3270,40)
68.2% probability
1608 (26.2%) 1570calBC
1561 (42.0%) 1501calBC
95.4% probability
1637 (95.4%) 1447calBC
Radiocarbon determination (BP)
Calibrated date (calBC)

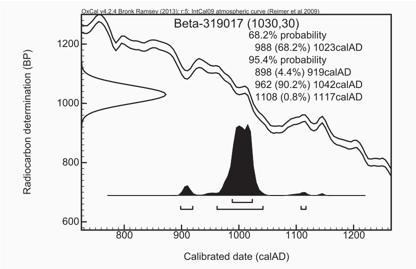

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Beta-304879 (1660,30)
68.2% probability
347 (18.7%) 371calAD
377 (49.5%) 423calAD
95.4% probability
259 (6.2%) 295calAD
321 (86.0%) 436calAD
491 (2.0%) 509calAD
518 (1.1%) 529calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

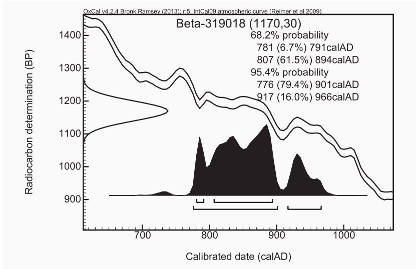

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Beta-319014 (2150,30)
68.2% probability
350 (22.7%) 311calBC
209 (38.1%) 159calBC
134 (7.4%) 117calBC
95.4% probability
356 (30.4%) 286calBC
253 (0.2%) 250calBC
234 (63.6%) 91calBC
72 (1.2%) 60calBC
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

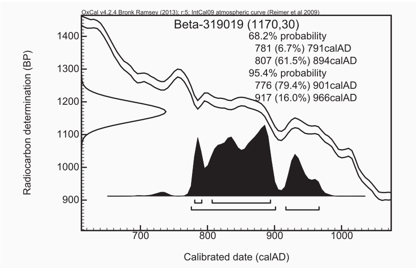

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Beta-319015 (2190,30)
68.2% probability
356 (46.5%) 286calBC
234 (21.7%) 199calBC
95.4% probability
365 (95.4%) 176calBC
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

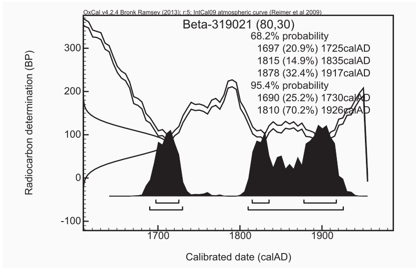

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Beta-319016 (940,30)
68.2% probability
1035 (13.7%) 1052calAD
1080 (54.5%) 1152calAD
95.4% probability
1025 (95.4%) 1160calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

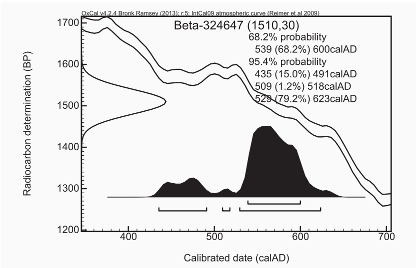
LAB NO.	SITE, SAMPLE NO.	MATERIAL	RADIOCARBON AGE BP	CALIBRATED 1 SIGMA	CALIBRATED 2 SIGMA	CONTEXT
Beta-319017	Avaldsnes 75	Betula	1030 +/– 30	AD 988–1023	AD 898–919, 962–1042, 1108–1117	Posthole 19799, A14
Beta-319018	Avaldsnes 91	Hordeum vulgare	1170 +/– 30	AD 781–791, 807–894	AD 776–901, 917–966	Posthole A10197
Beta-319019	Avaldsnes 98	Hordeum vulgare	1170 +/– 30	AD 781–791, 807–894	AD 776–901, 917–966	Pit A20476
Beta-319021	Avaldsnes 126	Corylus avellana nutshell	80 +/– 30	AD 1697–1725, 1815–1835, 1878–1917	AD 1690–1730, 1810–1926	Well A11062
Beta-324647	Avaldsnes 129	Populus	1510 +/– 30	AD 539–600	AD 435–491, 509–518, 529–623	Possible floor, A28805, A40
Beta-324648	Avaldsnes 130	Alnus	1720 +/– 30	AD 258–299, 319–355, 366–381	AD 245–397	Posthole A31295, A40
Beta-324650	Avaldsnes 132	Betula	1590 +/– 30	AD 426–465, 482–533	AD 411–543	Conduit A30325, A40
Beta-324651	Avaldsnes 135	Betula	1550 +/– 30	AD 436–491, 509–518, 529–552	AD 426–578	Posthole A31003, A40
Beta-332885	Avaldsnes 473	Alnus	3490 +/– 30	BC 1878–1840, 1828–1770	BC 1895–1739, 1705–1700	Hearth A46300, A13
Beta-333047	Avaldsnes 412	Salix/ populus	3560 +/– 30	BC 1952–1880	BC 2016–1997, 1980–1869, 1847–1775	Posthole A48787, A13

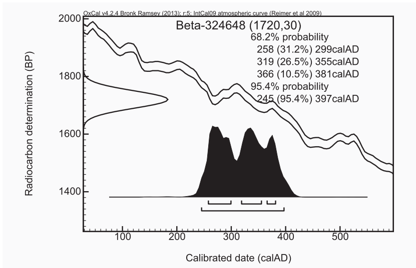

Beta-319017 (1030,30)
68.2% probability
988 (68.2%) 1023calAD
95.4% probability
898 (4.4%) 919calAD
962 (90.2%) 1042calAD
1108 (0.8%) 1117calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

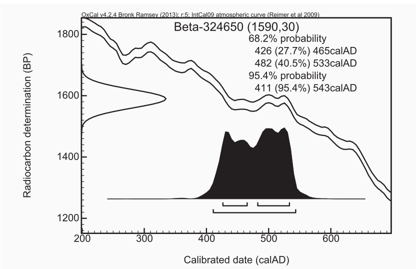

Beta-319018 (1170,30)
68.2% probability
781 (6.7%) 791calAD
807 (61.5%) 894calAD
95.4% probability
776 (79.4%) 901calAD
917 (16.0%) 966calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

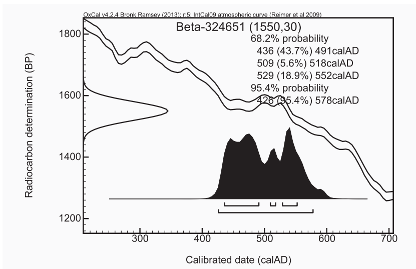

Beta-319019 (1170,30)
68.2% probability
781 (6.7%) 791calAD
807 (61.5%) 894calAD
95.4% probability
776 (79.4%) 901calAD
917 (16.0%) 966calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

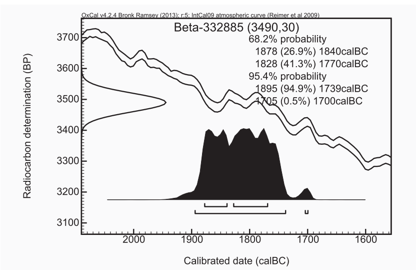

Beta-319021 (80,30)
68.2% probability
1697 (20.9%) 1725calAD
1815 (14.9%) 1835calAD
1878 (32.4%) 1917calAD
95.4% probability
1690 (25.2%) 1730calAD
1810 (70.2%) 1926calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

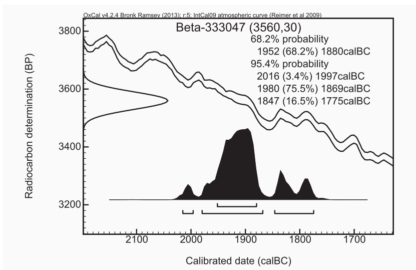

Beta-324647 (1510,30)
68.2% probability
539 (68.2%) 600calAD
95.4% probability
435 (15.0%) 491calAD
509 (1.2%) 518calAD
529 (79.2%) 623calAD
Radiocarbon determination (BP)
Calibrated date (calAD)


Beta-324648 (1720,30)
68.2% probability
258 (31.2%) 299calAD
319 (26.5%) 355calAD
366 (10.5%) 381calAD
95.4% probability
245 (95.4%) 397calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

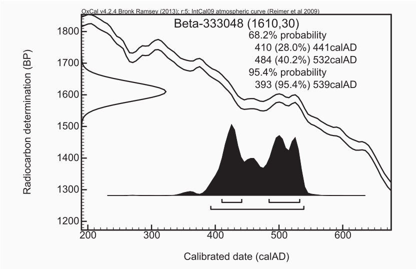

Beta-324650 (1590,30)
68.2% probability
426 (27.7%) 465calAD
482 (40.5%) 533calAD
95.4% probability
411 (95.4%) 543calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

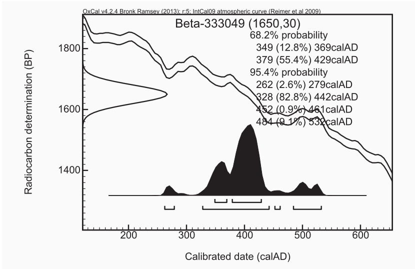

Beta-324651 (1550,30)
68.2% probability
436 (43.7%) 491calAD
509 (5.6%) 518calAD
529 (18.9%) 552calAD
95.4% probability
426 (95.4%) 578calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

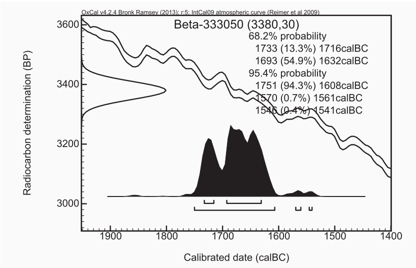

Beta-332885 (3490,30)
68.2% probability
1878 (26.9%) 1840calBC
1828 (41.3%) 1770calBC
95.4% probability
1895 (94.9%) 1739calBC
1705 (0.5%) 1700calBC
Radiocarbon determination (BP)
Calibrated date (calBC)

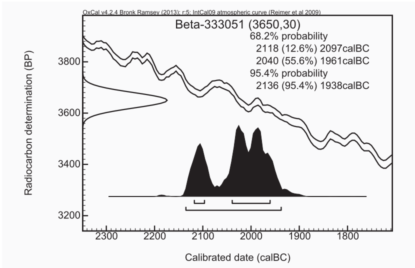

Beta-333047 (3560,30)
68.2% probability
1952 (68.2%) 1880calBC
95.4% probability
2016 (3.4%) 1997calBC
1980 (75.5%) 1869calBC
1847 (16.5%) 1775calBC
Radiocarbon determination (BP)
Calibrated date (calBC)

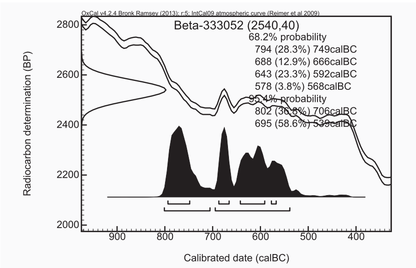
LAB NO.	SITE, SAMPLE NO.	MATERIAL	RADIOCARBON AGE BP	CALIBRATED 1 SIGMA	CALIBRATED 2 SIGMA	CONTEXT
Beta-333048	Avaldsnes 320	Betula	1610 +/ – 30	AD 410–441, 484–532	AD 393–539	Posthole A46673, A13
Beta-333049	Avaldsnes 313	Hordeum vulgare	1650 +/ – 30	AD 349–369, 379–429	AD 262–279, 328–442, 452–461, 484–532	Posthole A46796, A13
Beta-333050	Avaldsnes 304	Alnus	3380 +/ – 30	BC 1733–1716, 1693–1632	BC 1751–1608, 1570–1561, 1546–1541	Charcoal concentration A42891
Beta-333051	Avaldsnes 279	Betula	3650+/ – 30	BC 2118–2097, 2040–1961	BC 2136–1938	Impression of removed stone A44121
Beta-333052	Avaldsnes 216	Hordeum vulgare	2540 +/ – 40	BC 794–749, 688–666, 643–592, 578–568	BC 802–706, 695–539	Charcoal deposit A39717
Beta-347958	Avaldsnes 1720	Humus	2960 +/ – 30	BC 1257–1236, 1216–1129	BC 1293–1109, 1104–1056	Cultural deposit A9601
Beta-435314	Avaldsnes 475	Quercus	1858 +/ – 30	AD 128–215	AD 85–235	Hearth A46300, A13
T-1771	Taksdal	Quercus	2360 +/ – 100	BC 749–687, 666–643, 591–578, 565–360, 275–260	BC 772–343, 325–204	Ard, S8749
T-4015	Madla	Bog butter	1500 +/ – 40	AD 536–621	AD 434–492, 508–519, 528–644	Bog butter, S9457
T-5129	Salhushaug -	Pinus	1470 +/ – 80	AD 440–450, 460–490, 530–660	AD 410–700	Wooden spade from grave mound

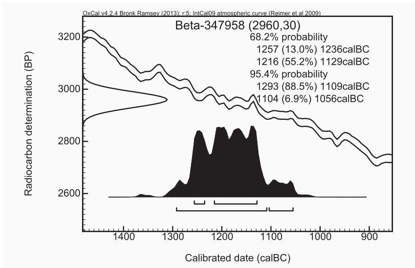

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Beta-333048 (1610,30)
68.2% probability
410 (28.0%) 441calAD
484 (40.2%) 532calAD
95.4% probability
393 (95.4%) 539calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

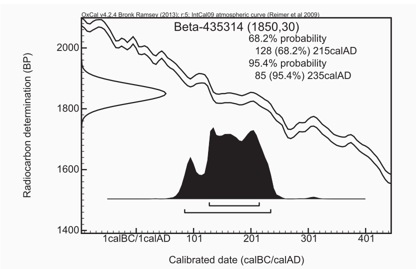

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Beta-333049 (1650,30)
68.2% probability
349 (12.8%) 369calAD
379 (55.4%) 429calAD
95.4% probability
262 (2.6%) 279calAD
328 (82.8%) 442calAD
452 (0.9%) 461calAD
484 (9.1%) 532calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

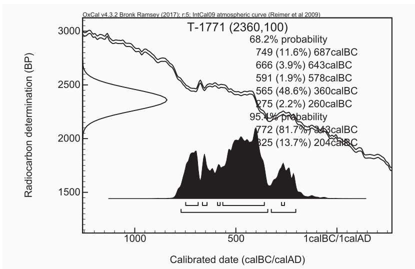

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Beta-333050 (3380,30)
68.2% probability
1733 (13.3%) 1716calBC
1693 (54.9%) 1632calBC
95.4% probability
1751 (94.3%) 1608calBC
1570 (0.7%) 1561calBC
1546 (0.4%) 1541calBC
Radiocarbon determination (BP)
Calibrated date (calBC)

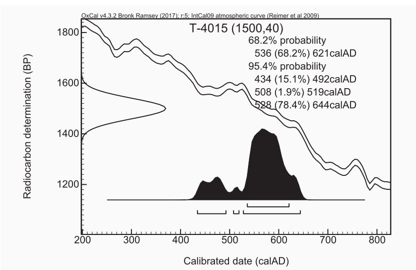

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Beta-333051 (3650,30)
68.2% probability
2118 (12.6%) 2097calBC
2040 (55.6%) 1961calBC
95.4% probability
2136 (95.4%) 1938calBC
Radiocarbon determination (BP)
Calibrated date (calBC)

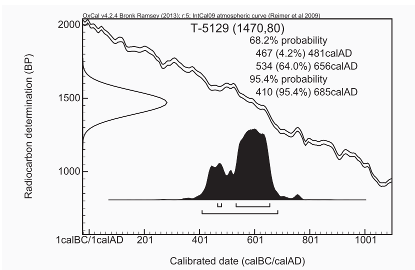

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Beta-333052 (2540,40)
68.2% probability
794 (28.3%) 749calBC
688 (12.9%) 666calBC
643 (23.3%) 592calBC
578 (3.8%) 568calBC
95.4% probability
802 (36.8%) 706calBC
695 (58.6%) 539calBC
Radiocarbon determination (BP)
Calibrated date (calBC)


OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Beta-347958 (2960,30)
68.2% probability
1257 (13.0%) 1236calBC
1216 (55.2%) 1129calBC
95.4% probability
1293 (88.5%) 1109calBC
1104 (6.9%) 1056calBC
Radiocarbon determination (BP)
Calibrated date (calBC)

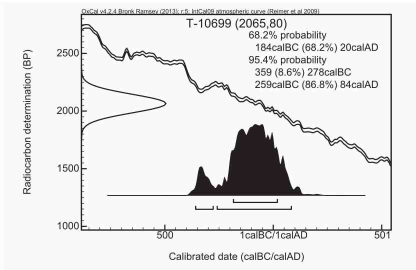

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Beta-435314 (1850,30)
68.2% probability
128 (68.2%) 215calAD
95.4% probability
85 (95.4%) 235calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

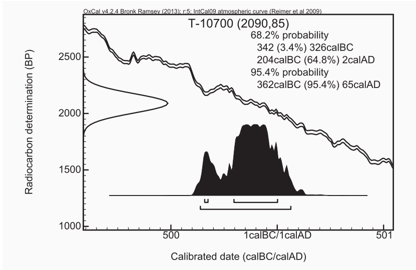

OxCal v4.3.2 Bronk Ramsey (2017); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
T-1771 (2360,100)
68.2% probability
749 (11.6%) 687calBC
666 (3.9%) 643calBC
591 (1.9%) 578calBC
565 (48.6%) 360calBC
275 (2.2%) 260calBC
95.4% probability
772 (81.7%) 343calBC
325 (13.7%) 204calBC
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

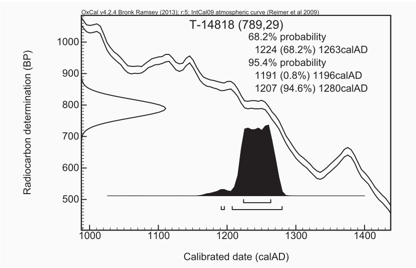

OxCal v4.3.2 Bronk Ramsey (2017); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
T-4015 (1500,40)
68.2% probability
536 (68.2%) 621calAD
95.4% probability
434 (15.1%) 492calAD
508 (1.9%) 519calAD
528 (78.4%) 644calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

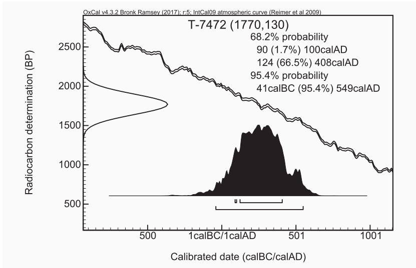

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
T-5129 (1470,80)
68.2% probability
467 (4.2%) 481calAD
534 (64.0%) 656calAD
95.4% probability
410 (95.4%) 685calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

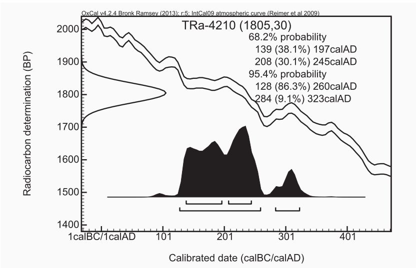
LAB NO.	SITE, SAMPLE NO.	MATERIAL	RADIOCARBON AGE BP	CALIBRATED 1 SIGMA	CALIBRATED 2 SIGMA	CONTEXT
T-7472	Bø	Skeletal remains (human)	1770 +/ – 130	AD 90–100, 124–408	AD 41–549	Skeletal remains (human), S10968
T-10699	Avaldsnes	Betula, Salix, Corylus	2065 +/ –80	BC 184–AD 20	BC 359–278, 259–84	Hearth 1992:35
T-10700	Avaldsnes	Betula, Salix	2090 +/ – 85	BC 342–326,BC 204–AD 2	BC 362–AD 65	Hearth (1992: 31)
T-14818	Gloppehavn -	Unknown	789 +/ – 29	AD 1224–1263	AD 1191–1196, AD 1207–1280	Shipwreck in Gloppehavn P. #
Tra-4210	Avaldsnes 274	Alnus	1805 +/ – 30	AD 139–197, 208–245	AD 128–260, 284–323	Cooking pit A44603
TRa-4211	Avaldsnes 9	Corylus avellana nutshell	1720 +/ – 25	AD 258–298, 320–351, 368–380	AD 250–392	Cooking pit A3646
TRa-4213	Avaldsnes 11		2215 +/ – 30	BC 361–349, 317–272, 262–208	BC 378–202	Impression of removed stone A4079
TRa-4214	Avaldsnes 14	Hordeum vulgare	1590 +/ – 30	AD 426–465, 482–533	AD 411–543	Cooking pit A1425
TRa-4216	Avaldsnes 24	Corylus avellana nutshell	1695 +/ – 30	AD 263–277, 330–399	AD 256–304, 314–416	Cooking pit A5049
TRa-4217	Avaldsnes 23	Salix	1560 +/ – 25	AD 436–491, 509–518, 529–542	AD 427–558	Cooking pit A5263

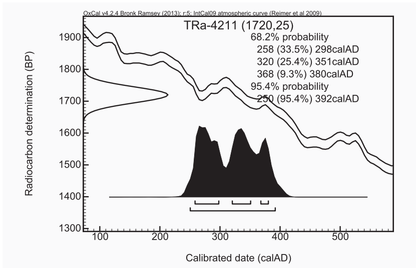

OxCal v4.2.4 Bronk Ramsey (2013); r:5: IntCal09 atmospheric curve (Reimer et al 2009)
T-10699 (2065,80)
68.2% probability
184calBC (68.2%) 20calAD
95.4% probability
359 (8.6%) 278calBC
259calBC (86.8%) 84calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

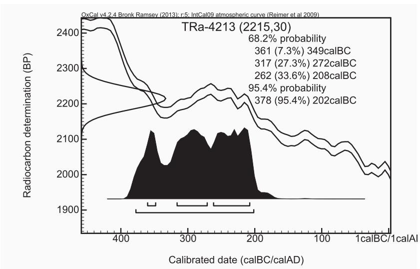

OxCal v4.2.4 Bronk Ramsey (2013); r:5: IntCal09 atmospheric curve (Reimer et al 2009)
T-10700 (2090,85)
68.2% probability
342 (3.4%) 326calBC
204calBC (64.8%) 2calAD
95.4% probability
362calBC (95.4%) 65calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

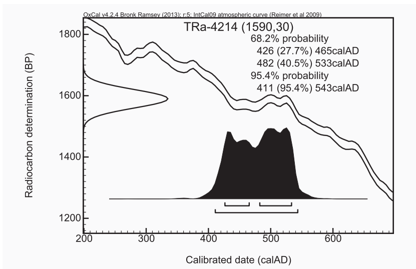

OxCal v4.2.4 Bronk Ramsey (2013); r:5: IntCal09 atmospheric curve (Reimer et al 2009)
T-14818 (789,29)
68.2% probability
1224 (68.2%) 1263calAD
95.4% probability
1191 (0.8%) 1196calAD
1207 (94.6%) 1280calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

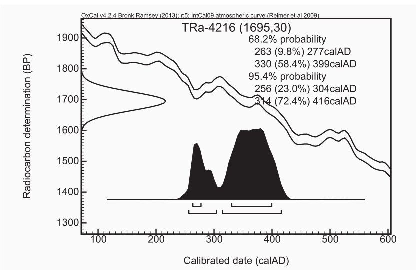

OxCal v4.3.2 Bronk Ramsey (2017); r:5: IntCal09 atmospheric curve (Reimer et al 2009)
T-7472 (1770,130)
68.2% probability
90 (1.7%) 100calAD
124 (66.5%) 408calAD
95.4% probability
41calBC (95.4%) 549calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

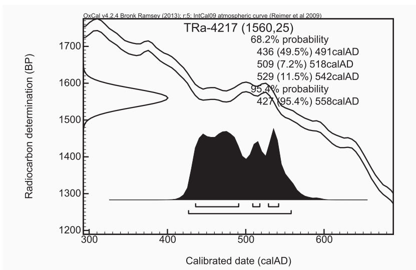

OxCal v4.2.4 Bronk Ramsey (2013); r:5: IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4210 (1805,30)
68.2% probability
139 (38.1%) 197calAD
208 (30.1%) 245calAD
95.4% probability
128 (86.3%) 260calAD
284 (9.1%) 323calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)


OxCal v4.2.4 Bronk Ramsey (2013); r:5: IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4211 (1720,25)
68.2% probability
258 (33.5%) 298calAD
320 (25.4%) 351calAD
368 (9.3%) 380calAD
95.4% probability
250 (95.4%) 392calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

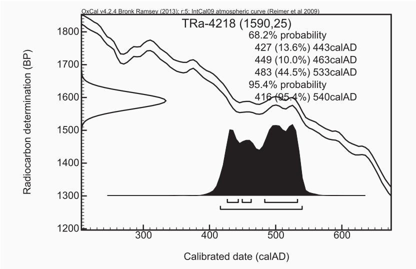

OxCal v4.2.4 Bronk Ramsey (2013); r:5: IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4213 (2215,30)
68.2% probability
361 (7.3%) 349calBC
317 (27.3%) 272calBC
262 (33.6%) 208calBC
95.4% probability
378 (95.4%) 202calBC
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

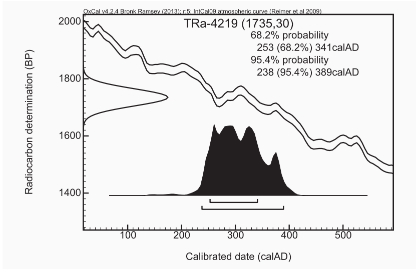

OxCal v4.2.4 Bronk Ramsey (2013); r:5: IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4214 (1590,30)
68.2% probability
426 (27.7%) 465calAD
482 (40.5%) 533calAD
95.4% probability
411 (95.4%) 543calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

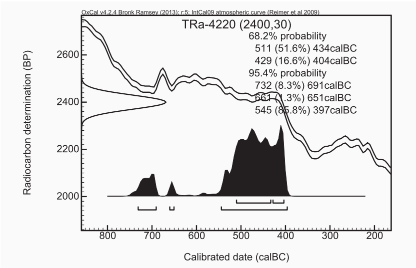

OxCal v4.2.4 Bronk Ramsey (2013); r:5: IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4216 (1695,30)
68.2% probability
263 (9.8%) 277calAD
330 (58.4%) 399calAD
95.4% probability
256 (23.0%) 304calAD
314 (72.4%) 416calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

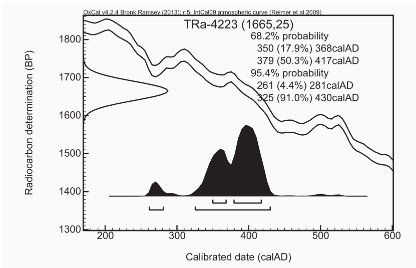

OxCal v4.2.4 Bronk Ramsey (2013); r:5: IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4217 (1560,25)
68.2% probability
436 (49.5%) 491calAD
509 (7.2%) 518calAD
529 (11.5%) 542calAD
95.4% probability
427 (95.4%) 558calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

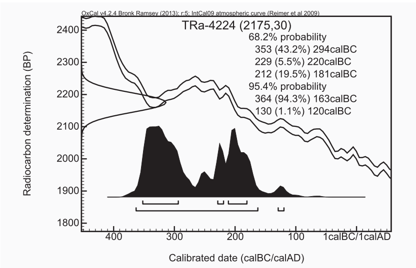
LAB NO.	SITE, SAMPLE NO.	MATERIAL	RADIOCARBON AGE BP	CALIBRATED 1 SIGMA	CALIBRATED 2 SIGMA	CONTEXT
TRa-4218	Avaldsnes 27	Corylus avellana nutshell	1590 +/ – 25	AD 427–443, 449–463, 483–533	AD 416–540	Cooking pit A5376
TRa-4219	Avaldsnes 25	Salix/ populus tremula	1735 +/ – 30	AD 253–341	AD 238–389	Cooking pit A5541
TRa-4220	Avaldsnes 29	Corylus avellana nutshell	2400 +/ – 30	BC 511–434, 429–404	BC 732–691, 661–651, 545–397	Posthole A5815
TRa-4223	Avaldsnes 30	Pinus	1665 +/ – 25	AD 350–368, 379–417	AD 261–281, 325–430	Cooking pit A5504
TRa-4224	Avaldsnes 36	Betula	2175 +/ – 30	BC 353–294, 229–220, 212–181	BC 364–163, 130–120	Cooking pit A9150
TRa-4225	Avaldsnes 37	Betula	2150 +/ – 30	BC 350–311, 209–159, 134–117	BC 356–286, 253–250, 234–91, 72–60	Cooking pit A9533
TRa-4226	Avaldsnes 43	Corylus avellana nutshell	3490 +/ – 35	BC 1879–1838, 1831–1767	BC 1907–1737, 1711–1696	Posthole A10500
TRa-4227	Avaldsnes 49	Betula	2195 +/ – 30	BC 356–286, 234–201	BC 367–181	Cooking pit A12577
TRa-4228	Avaldsnes 50	Salix	3460 +/ – 30	BC 1875–1843, 1818–1798, 1780–1738, 1708–1698	BC 1881–1729, 1720–1692	Cooking pit A4193
TRa-4229	Avaldsnes 47	Betula	2055 +/ – 30	BC 151–140, 112–37, 29–22, 11–2	BC 169–AD 5,AD 12–17	Cooking pit A1640

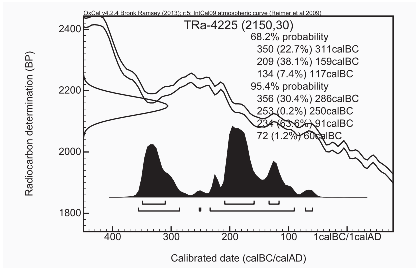

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4218 (1590,25)
68.2% probability
427 (13.6%) 443calAD
449 (10.0%) 463calAD
483 (44.5%) 533calAD
95.4% probability
416 (95.4%) 540calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

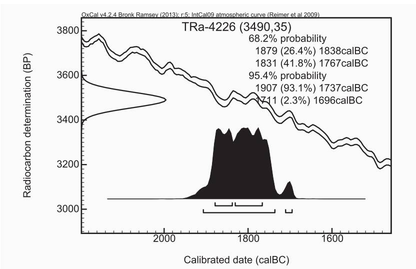

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4219 (1735,30)
68.2% probability
253 (68.2%) 341calAD
95.4% probability
238 (95.4%) 389calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

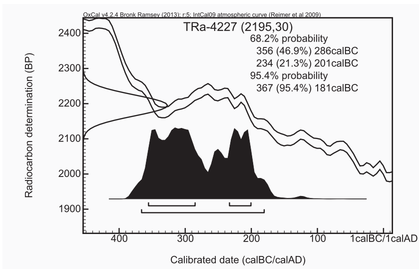

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4220 (2400,30)
68.2% probability
511 (51.6%) 434calBC
429 (16.6%) 404calBC
95.4% probability
732 (8.3%) 691calBC
661 (1.3%) 651calBC
545 (85.8%) 397calBC
Radiocarbon determination (BP)
Calibrated date (calBC)

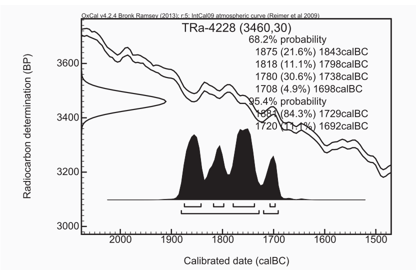

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4223 (1665,25)
68.2% probability
350 (17.9%) 368calAD
379 (50.3%) 417calAD
95.4% probability
261 (4.4%) 281calAD
325 (91.0%) 430calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

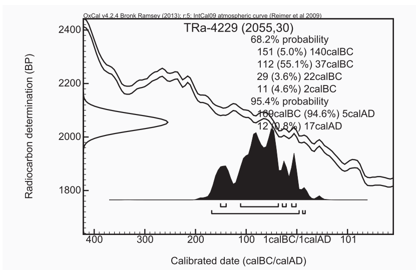

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4224 (2175,30)
68.2% probability
353 (43.2%) 294calBC
229 (5.5%) 220calBC
212 (19.5%) 181calBC
95.4% probability
364 (94.3%) 163calBC
130 (1.1%) 120calBC
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)


OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4225 (2150,30)
68.2% probability
350 (22.7%) 311calBC
209 (38.1%) 159calBC
134 (7.4%) 117calBC
95.4% probability
356 (30.4%) 286calBC
253 (0.2%) 250calBC
234 (63.6%) 91calBC
72 (1.2%) 60calBC
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

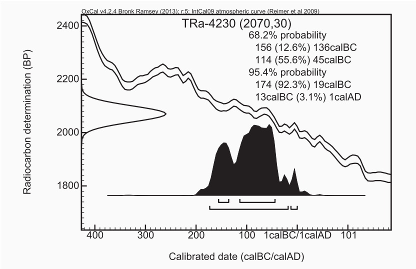

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4226 (3490,35)
68.2% probability
1879 (26.4%) 1838calBC
1831 (41.8%) 1767calBC
95.4% probability
1907 (93.1%) 1737calBC
1711 (2.3%) 1696calBC
Radiocarbon determination (BP)
Calibrated date (calBC)

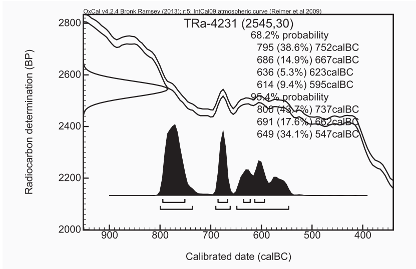

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4227 (2195,30)
68.2% probability
356 (46.9%) 286calBC
234 (21.3%) 201calBC
95.4% probability
367 (95.4%) 181calBC
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

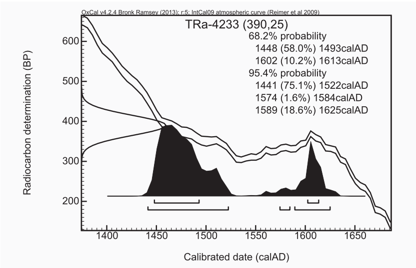

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4228 (3460,30)
68.2% probability
1875 (21.6%) 1843calBC
1818 (11.1%) 1798calBC
1780 (30.6%) 1738calBC
1708 (4.9%) 1698calBC
95.4% probability
1881 (84.3%) 1729calBC
1720 (11.1%) 1692calBC
Radiocarbon determination (BP)
Calibrated date (calBC)

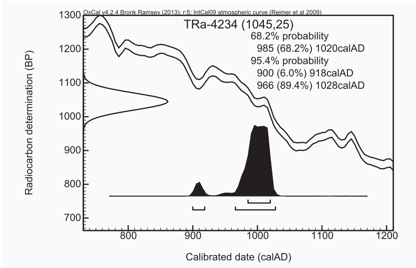

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4229 (2055,30)
68.2% probability
151 (5.0%) 140calBC
112 (55.1%) 37calBC
29 (3.6%) 22calBC
11 (4.6%) 2calBC
95.4% probability
169calBC (94.6%) 5calAD
12 (0.8%) 17calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

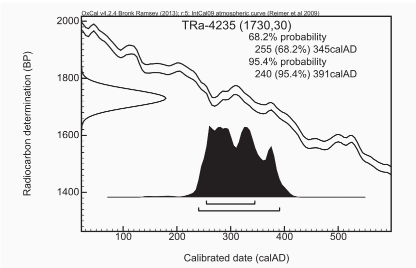
LAB NO.	SITE, SAMPLE NO.	MATERIAL	RADIOCARBON AGE BP	CALIBRATED 1 SIGMA	CALIBRATED 2 SIGMA	CONTEXT
TRa-4230	Avaldsnes 53	Betula	2070 +/ – 30	BC 156–136, 114–45	BC 174–19,BC 13–AD 1	Cultivation deposit A103
TRa-4231	Avaldsnes 54	Corylus avellana nutshell	2545 +/ – 30	BC 795–752, 686–667, 636–623, 614–595	BC 800–737, 691–662, 649–547	Cultivation deposit A5882
TRa-4233	Avaldsnes 82	Salix	390 +/ – 25	AD 1448–1493, 1602–1613	AD 1441–1522, 1574–1584, 1589–1625	Floor layer A6488
TRa-4234	Avaldsnes 89	Betula	1045 +/ – 25	AD 985–1020	AD 900–918, 966–1028	Discarded A19788
TRa-4235	Avaldsnes 74	Betula	1730 +/ – 30	AD 255–345	AD 240–391	Hearth A5793, A10
TRa-4236	Avaldsnes 86	Quercus	1720 +/ – 30	AD 258–299, 319–355, 366–381	AD 245–397	Hearth A8957, A10
TRa-4237	Avaldsnes 69	Betula	1720 +/ – 30	AD 258–299, 319–355, 366–381	AD 245–397	Posthole A18745, A10
TRa-4238	Avaldsnes 87	Betula	1070 +/ – 30	AD 903–915, 969–1016	AD 895–925, 936–1021	Posthole A19839, A14
TRa-4239	Avaldsnes 1953	Betula	385 +/ – 25	AD 1450–1495, 1602–1615	AD 1444–1523, 1574–1626	Possible post-hole A19880
TRa-4240	Avaldsnes 80	Betula	930 +/ – 25	AD 1041–1058, 1073–1109, 1116–1154	AD 1030–1161	Hearth A8957, A10

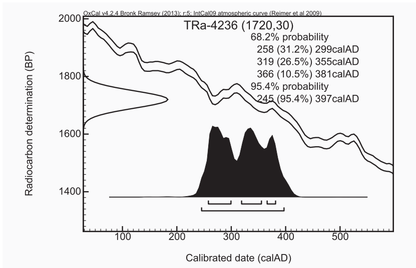

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4230 (2070,30)
68.2% probability
156 (12.6%) 136calBC
114 (55.6%) 45calBC
95.4% probability
174 (92.3%) 19calBC
13calBC (3.1%) 1calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

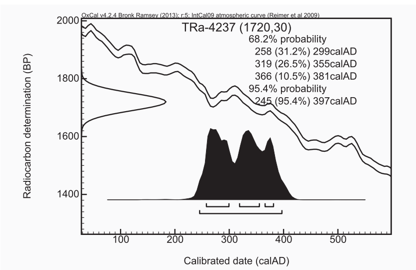

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4231 (2545,30)
68.2% probability
795 (38.6%) 752calBC
686 (14.9%) 667calBC
636 (5.3%) 623calBC
614 (9.4%) 595calBC
95.4% probability
806 (43.7%) 737calBC
691 (17.6%) 662calBC
649 (34.1%) 547calBC
Radiocarbon determination (BP)
Calibrated date (calBC)

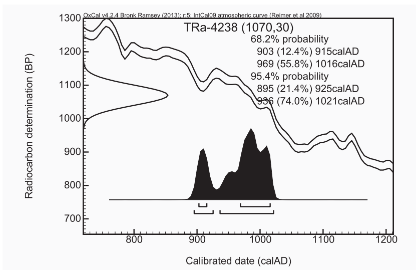

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4233 (390,25)
68.2% probability
1448 (58.0%) 1493calAD
1602 (10.2%) 1613calAD
95.4% probability
1441 (75.1%) 1522calAD
1574 (1.6%) 1584calAD
1589 (18.6%) 1625calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

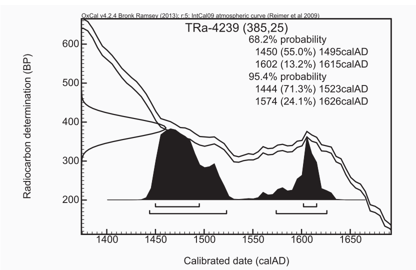

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4234 (1045,25)
68.2% probability
985 (68.2%) 1020calAD
95.4% probability
900 (6.0%) 918calAD
966 (89.4%) 1028calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

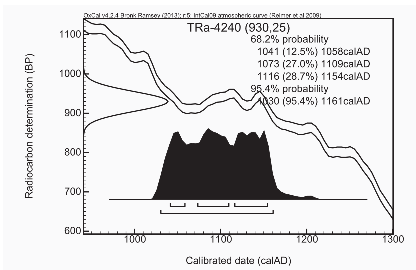

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4235 (1730,30)
68.2% probability
255 (68.2%) 345calAD
95.4% probability
240 (95.4%) 391calAD
Radiocarbon determination (BP)
Calibrated date (calAD)


OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4236 (1720,30)
68.2% probability
258 (31.2%) 299calAD
319 (26.5%) 355calAD
366 (10.5%) 381calAD
95.4% probability
245 (95.4%) 397calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

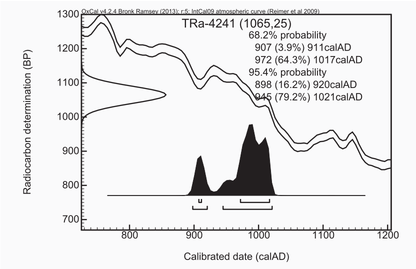

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4237 (1720,30)
68.2% probability
258 (31.2%) 299calAD
319 (26.5%) 355calAD
366 (10.5%) 381calAD
95.4% probability
245 (95.4%) 397calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

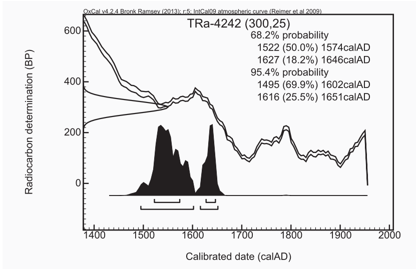

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4238 (1070,30)
68.2% probability
903 (12.4%) 915calAD
969 (55.8%) 1016calAD
95.4% probability
895 (21.4%) 925calAD
936 (74.0%) 1021calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

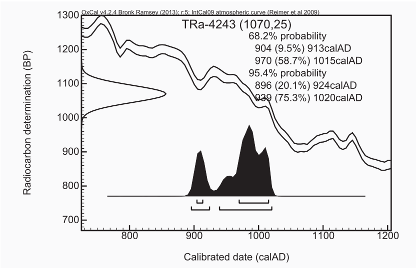

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4239 (385,25)
68.2% probability
1450 (55.0%) 1495calAD
1602 (13.2%) 1615calAD
95.4% probability
1444 (71.3%) 1523calAD
1574 (24.1%) 1626calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

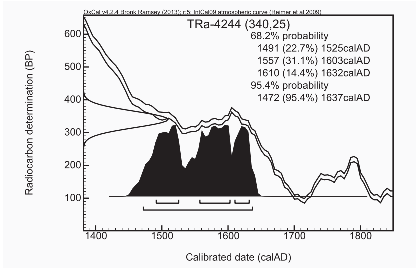

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4240 (930,25)
68.2% probability
1041 (12.5%) 1058calAD
1073 (27.0%) 1109calAD
1116 (28.7%) 1154calAD
95.4% probability
1030 (95.4%) 1161calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

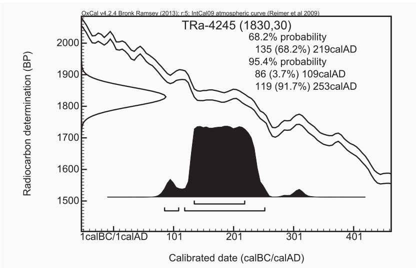
LAB NO.	SITE, SAMPLE NO.	MATERIAL	RADIOCARBON AGE BP	CALIBRATED 1 SIGMA	CALIBRATED 2 SIGMA	CONTEXT
TRa-4241	Avaldsnes 88	Betula	1065 +/ – 25	AD 907–911, 972–1017	AD 898–920, 945–1021	Posthole A19829, A14
TRa-4242	Avaldsnes 93	Betula	300 +/ – 25	AD 1522–1574, 1627–1646	AD 1495–1602, 1616–1651	Wall ditch A9231, A10
TRa-4243	Avaldsnes 65	Betula	1070 +/ – 25	AD 904–913, 970–1015	AD 896–924, 939–1020	Posthole A18677, A14
TRa-4244	Avaldsnes 72	Betula	340 +/ – 25	AD 1491–1525, 1557–1603, 1610–1632	AD 1472–1637	Floor layer A20326
TRa-4245	Avaldsnes 122	Betula	1830 +/ – 30	BC 135–AD 219	AD 86–109, 119–253	Post impression A20921
TRa-4246	Avaldsnes 109	Betula	1760 +/ – 30	AD 236–264, 275–333	AD 144–150, 170–193, 211–384	Discarded, A19860
Ua-45327	Avaldsnes 127	Salix/ populus	1459 +/ – 30	AD 582–637	AD 553–649	Posthole A25343, A41
Ua-45328	Avaldsnes 171	Betula	110 +/ – 30	AD 1692–1728, 1812–1891, 1908–1920	AD 1681–1763, 1801–1938	Old ground surface A27331, A46
Ua-45331	Avaldsnes 195	Betula	1662 +/ – 30	AD 347–371, 377–421	AD 259–296, 321–435, 493–507, 520–527	Construction layer A25526, A20
Ua-45332	Avaldsnes 149	Betula	1606 +/ – 30	AD 414–441, 456–460, 484–532	AD 396–540	Charcoal concentration A32030

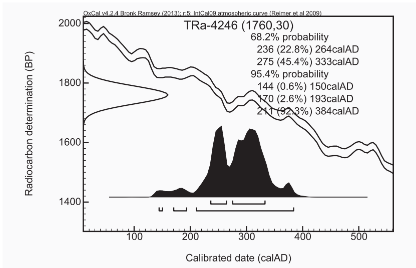

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4241 (1065,25)
68.2% probability
907 (3.9%) 911calAD
972 (64.3%) 1017calAD
95.4% probability
898 (16.2%) 920calAD
945 (79.2%) 1021calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

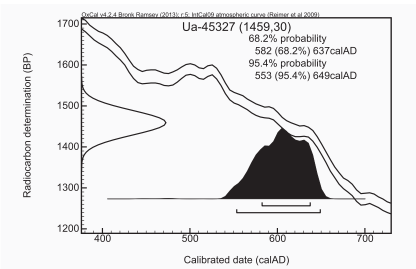

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4242 (300,25)
68.2% probability
1522 (50.0%) 1574calAD
1627 (18.2%) 1646calAD
95.4% probability
1495 (69.9%) 1602calAD
1616 (25.5%) 1651calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

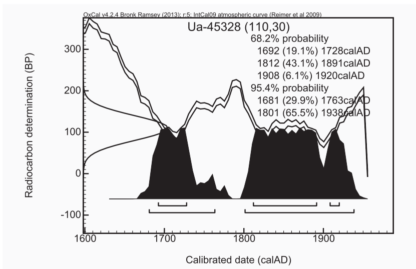

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4243 (1070,25)
68.2% probability
904 (9.5%) 913calAD
970 (58.7%) 1015calAD
95.4% probability
896 (20.1%) 924calAD
939 (75.3%) 1020calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

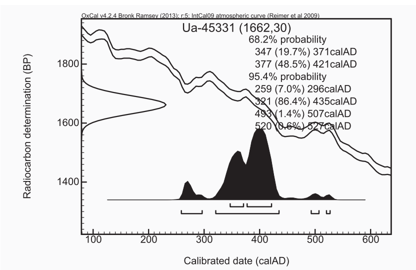

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4244 (340,25)
68.2% probability
1491 (22.7%) 1525calAD
1557 (31.1%) 1603calAD
1610 (14.4%) 1632calAD
95.4% probability
1472 (95.4%) 1637calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

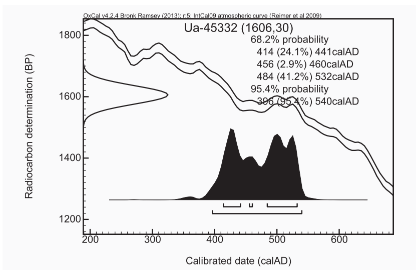

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4245 (1830,30)
68.2% probability
135 (68.2%) 219calAD
95.4% probability
86 (3.7%) 109calAD
119 (91.7%) 253calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)


OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TRa-4246 (1760,30)
68.2% probability
236 (22.8%) 264calAD
275 (45.4%) 333calAD
95.4% probability
144 (0.6%) 150calAD
170 (2.6%) 193calAD
211 (92.3%) 384calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

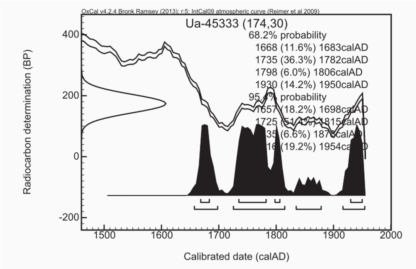

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45327 (1459,30)
68.2% probability
582 (68.2%) 637calAD
95.4% probability
553 (95.4%) 649calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

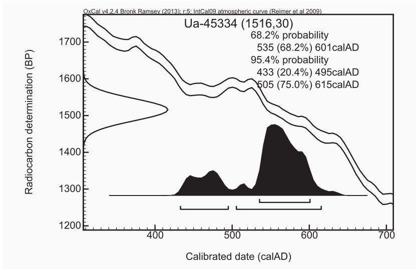

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45328 (110,30)
68.2% probability
1692 (19.1%) 1728calAD
1812 (43.1%) 1891calAD
1908 (6.1%) 1920calAD
95.4% probability
1681 (29.9%) 1763calAD
1801 (65.5%) 1938calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

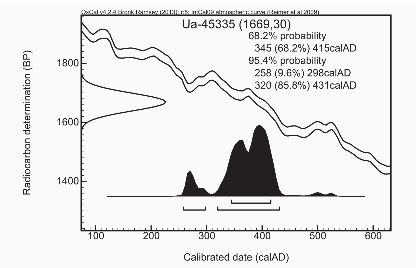

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45331 (1662,30)
68.2% probability
347 (19.7%) 371calAD
377 (48.5%) 421calAD
95.4% probability
259 (7.0%) 296calAD
321 (86.4%) 435calAD
493 (1.4%) 507calAD
520 (0.6%) 527calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

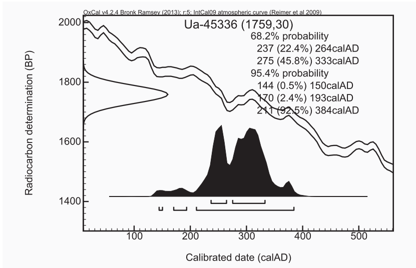

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45332 (1606,30)
68.2% probability
414 (24.1%) 441calAD
456 (2.9%) 460calAD
484 (41.2%) 532calAD
95.4% probability
396 (95.4%) 540calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

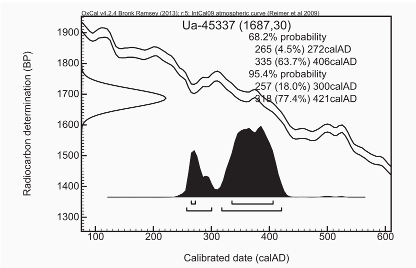
LAB NO.	SITE, SAMPLE NO.	MATERIAL	RADIOCARBON AGE BP	CALIBRATED 1 SIGMA	CALIBRATED 2 SIGMA	CONTEXT
Ua-45333	Avaldsnes 192	Betula	174 +/ – 30	AD 1668–1683, 1735–1782, 1798–1806, 1930–1950	AD 1657–1698, 1725–1815, 1835–1878, 1916–1954	Posthole A32087
Ua-45334	Avaldsnes 287	Salix/ populus	1516 +/ – 30	AD 535–601	AD 433–495, 505–615	Oven A37744
Ua-45335	Avaldsnes 196	Betula	1669 +/ – 30	AD 345–415	AD 258–298, 320–431	Cooking Pit A37846
Ua-45336	Avaldsnes 200	Corylus	1759 +/ – 30	AD 237–264, 275–333	AD 144–150, 170–193, 211–384	Oven A37770
Ua-45337	Avaldsnes 220	Corylus	1687 +/ –30	AD 265–272, 335–406	AD 257–300, 318–421	Oven A39340, A401438
Ua-45338	Avaldsnes 245	Betula	1283 +/ – 30	AD 677–721, 741–770	AD 661–779	Construction layer A25526, A20
Ua-45339	Avaldsnes 238	Betula	1760 +/ – 30	AD 236–264, 275–333	AD 144–150, 170–193, 211–384	Waste layer A35150
Ua-45340	Avaldsnes 286	Alnus	1669 +/ – 30	AD 345–415	AD 258–298, 320–431	Cooking pit A44578
Ua-45343	Avaldsnes 467	Betula	1628 +/ – 30	AD 389–437, 489–530	AD 350–368, 380–536	Posthole A49699
Ua-45344	Avaldsnes 1916	Betula	617 +/ – 30	AD 1299–1326, 1344–1370, 1380–1394	AD 1293–1401	Ditch A18206

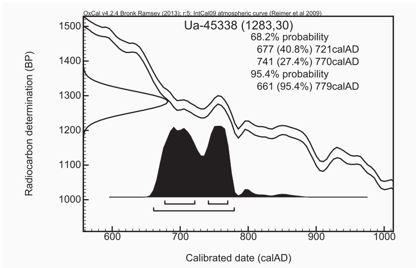

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45333 (174,30)
68.2% probability
1668 (11.6%) 1683calAD
1735 (36.3%) 1782calAD
1798 (6.0%) 1806calAD
1930 (14.2%) 1950calAD
95.4% probability
1657 (18.2%) 1698calAD
(6.6%)
(19.2%) 1954
Radiocarbon determination (BP)
Calibrated date (calAD)

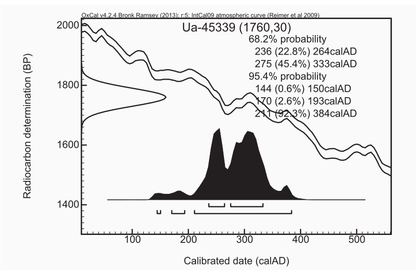

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45334 (1516,30)
68.2% probability
535 (68.2%) 601calAD
95.4% probability
433 (20.4%) 495calAD
505 (75.0%) 615calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

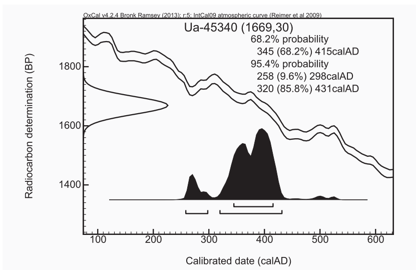

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45335 (1669,30)
68.2% probability
345 (68.2%) 415calAD
95.4% probability
258 (9.6%) 298calAD
320 (85.8%) 431calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

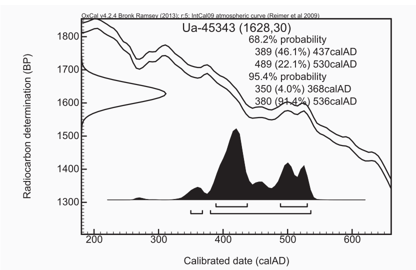

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45336 (1759,30)
68.2% probability
237 (22.4%) 264calAD
275 (45.8%) 333calAD
95.4% probability
144 (0.5%) 150calAD
170 (2.4%) 193calAD
211 (92.5%) 384calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

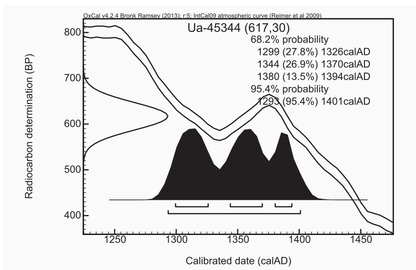

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45337 (1687,30)
68.2% probability
265 (4.5%) 272calAD
335 (63.7%) 406calAD
95.4% probability
257 (18.0%) 300calAD
318 (77.4%) 421calAD
Radiocarbon determination (BP)
Calibrated date (calAD)


OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45338 (1283,30)
68.2% probability
677 (40.8%) 721calAD
741 (27.4%) 770calAD
95.4% probability
661 (95.4%) 779calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

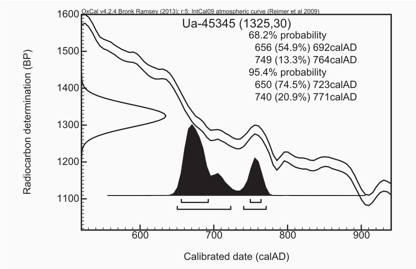

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45339 (1760,30)
68.2% probability
236 (22.8%) 264calAD
275 (45.4%) 333calAD
95.4% probability
144 (0.6%) 150calAD
170 (2.6%) 193calAD
211 (92.3%) 384calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

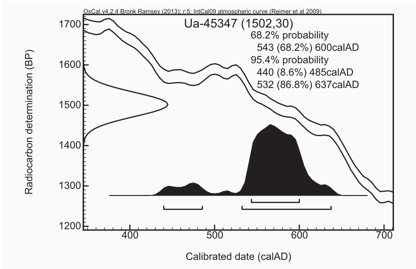

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45340 (1669,30)
68.2% probability
345 (68.2%) 415calAD
95.4% probability
258 (9.6%) 298calAD
320 (85.8%) 431calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

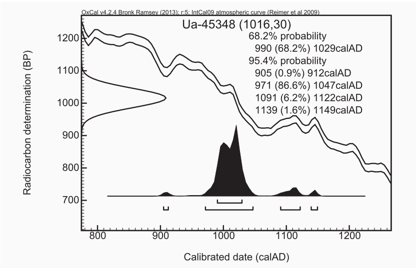

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45343 (1628,30)
68.2% probability
389 (46.1%) 437calAD
489 (22.1%) 530calAD
95.4% probability
350 (4.0%) 368calAD
380 (91.4%) 536calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

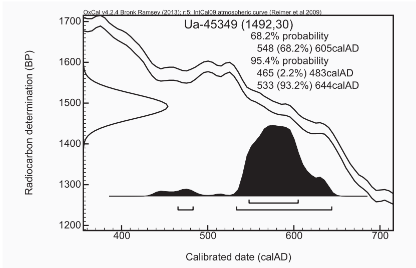

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45344 (617,30)
68.2% probability
1299 (27.8%) 1326calAD
1344 (26.9%) 1370calAD
1380 (13.5%) 1394calAD
95.4% probability
1293 (95.4%) 1401calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

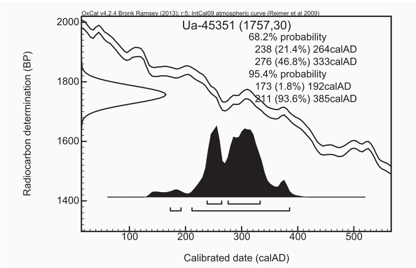
LAB NO.	SITE, SAMPLE NO.	MATERIAL	RADIOCARBON AGE BP	CALIBRATED 1 SIGMA	CALIBRATED 2 SIGMA	CONTEXT
Ua-45345	Avaldsnes 407	Betula	1325 +/ – 30	AD 656–692, 749–764	AD 650–723, 740–771	Posthole A50691
Ua-45347	Avaldsnes 471	Salix/ populus (round-wood)	1502 +/ – 30	AD 543–600	AD 440–485, 532–637	Hearth A48640, A13
Ua-45348	Avaldsnes 418	Betula	1016 +/ – 30	AD 990–1029	AD 905–912, 971–1047, 1091–1122, 1139–1149	Posthole A48560
Ua-45349	Avaldsnes 425	Salix/ populus	1492 +/ – 30	AD 548–605	AD 465–483, 533–644	Posthole A46825
Ua-45351	Avaldsnes 374	Prunus	1757 +/ – 30	AD 238–264, 276–333	AD 173–192, 211–385	Cooking pit A52790
Ua-45352	Avaldsnes 376	Salix/ populus	3447 +/ – 35	BC 1871–1845, 1812–1803, 1776–1731, 1719–1692	BC 1883–1683	Posthole A47199
Ua-45354	Avaldsnes 190	Hordeum vulgare	2111 +/ – 30	BC 182–92,BC 67–64	BC 338–330, 204–47	Activity surface/culti-vation deposit A25600
Ua-45355	Avaldsnes 183	Avena	21 +/ – 30	AD 1707–1719, 1826–1833, 1886–1912	AD 1696–1726, 1813–1837, 1844–1852, 1876–1919	Burned deposit A35555
Ua-45356	Avaldsnes 246	Hordeum vulgare	2201 +/ – 30	BC 358–337, 331–283, 257–245, 235–204	BC 376–193	Cooking pit A40222
Ua-45357	Avaldsnes 254	Hordeum vulgare	1749 +/ –30	AD 243–265, 272–335	AD 220–389	Cultivation deposit A34995

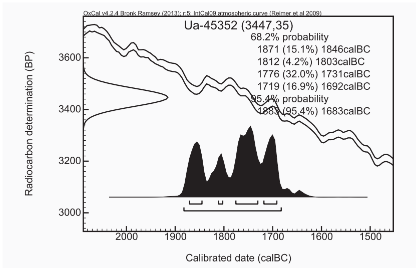

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45345 (1325,30)
68.2% probability
656 (54.9%) 692calAD
749 (13.3%) 764calAD
95.4% probability
650 (74.5%) 723calAD
740 (20.9%) 771calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

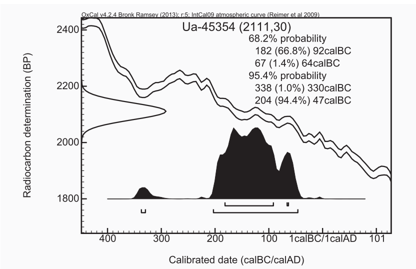

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45347 (1502,30)
68.2% probability
543 (68.2%) 600calAD
95.4% probability
440 (8.6%) 485calAD
532 (86.8%) 637calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

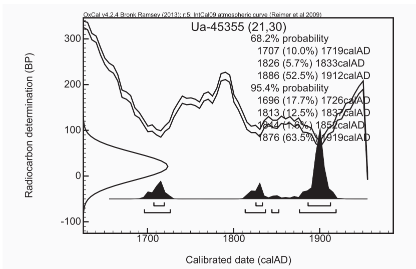

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45348 (1016,30)
68.2% probability
990 (68.2%) 1029calAD
95.4% probability
905 (0.9%) 912calAD
971 (86.6%) 1047calAD
1091 (6.2%) 1122calAD
1139 (1.6%) 1149calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

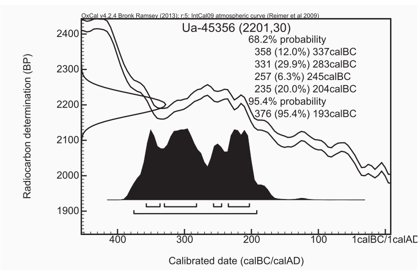

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45349 (1492,30)
68.2% probability
548 (68.2%) 605calAD
95.4% probability
465 (2.2%) 483calAD
533 (93.2%) 644calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

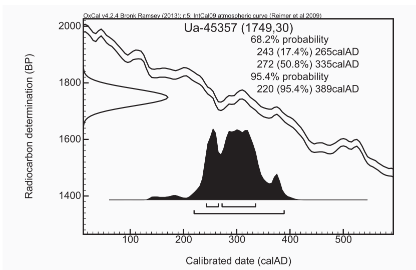

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45351 (1757,30)
68.2% probability
238 (21.4%) 264calAD
276 (46.8%) 333calAD
95.4% probability
173 (1.8%) 192calAD
211 (93.6%) 385calAD
Radiocarbon determination (BP)
Calibrated date (calAD)


OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45352 (3447,35)
68.2% probability
1871 (15.1%) 1846calBC
1812 (4.2%) 1803calBC
1776 (32.0%) 1731calBC
1719 (16.9%) 1692calBC
95.4% probability
1883 (95.4%) 1683calBC
Radiocarbon determination (BP)
Calibrated date (calBC)

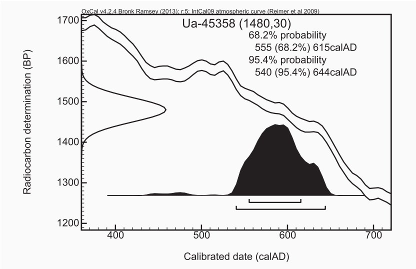

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45354 (2111,30)
68.2% probability
182 (66.8%) 92calBC
67 (1.4%) 64calBC
95.4% probability
338 (1.0%) 330calBC
204 (94.4%) 47calBC
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

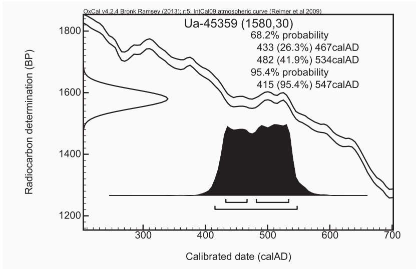

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45355 (21,30)
68.2% probability
1707 (10.0%) 1719calAD
1826 (5.7%) 1833calAD
1886 (52.5%) 1912calAD
95.4% probability
1696 (17.7%) 1726calAD
1813 (12.5%) 1837calAD
1844 (1.6%) 1852calAD
1876 (63.5%) 1919calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

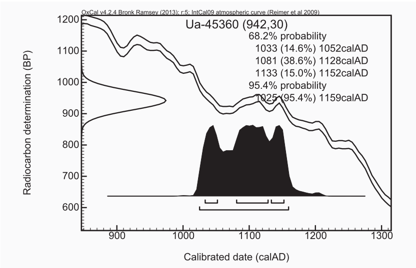

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45356 (2201,30)
68.2% probability
358 (12.0%) 337calBC
331 (29.9%) 283calBC
257 (6.3%) 245calBC
235 (20.0%) 204calBC
95.4% probability
376 (95.4%) 193calBC
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

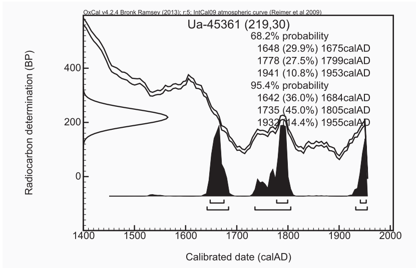

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45357 (1749,30)
68.2% probability
243 (17.4%) 265calAD
272 (50.8%) 335calAD
95.4% probability
220 (95.4%) 389calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

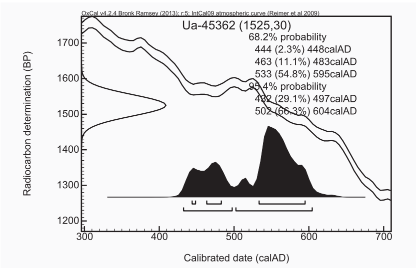
LAB NO.	SITE, SAMPLE NO.	MATERIAL	RADIOCARBON AGE BP	CALIBRATED 1 SIGMA	CALIBRATED 2 SIGMA	CONTEXT
Ua-45358	Avaldsnes 273	Hordeum vulgare	1480 +/– 30	AD 555–615	AD 540–644	Cooking pit A44483
Ua-45359	Avaldsnes 276	Hordeum vulgare	1580 +/– 30	AD 433–467, 482–534	AD 415–547	Cooking pit A44432
Ua-45360	Avaldsnes 289	Hordeum vulgare	942 +/– 30	AD 1033–1052, 1081–1128, 1133–1152	AD 1025–1159	Oven A44031
Ua-45361	Avaldsnes 296	Corylus avellana nutshell	219 +/– 30	AD 1648–1657, 1778–1799, 1941–1953	AD 1642–1684, 1735–1805, 1932–1955	Burned deposit A45350
Ua-45362	Avaldsnes 348	Hordeum vulgare	1525 +/– 30	AD 444–448, 463–483, 533–595	AD 432–497, 502–604	Posthole A48688, A13
Ua-45363	Avaldsnes 332	Hordeum vulgare	1558 +/– 30	AD 434–493, 507–520, 527–544	AD 425–567	Posthole A45557, A13
Ua-45364	Avaldsnes 329	Hordeum vulgare	1096 +/– 30	AD 898–921, 945–986	AD 890–1014	Posthole A12036
Ua-45365	Avaldsnes 355	Hordeum vulgare	1117 +/– 30	AD 894–906, 911–972	AD 828–840, 866–996, 1006–1013	Posthole A50604
Ua-45366	Avaldsnes 333	Hordeum vulgare	1125 +/– 30	AD 890–905, 912–971	AD 783–788, 818–843, 860–991	Posthole A12060
Ua-45367	Avaldsnes 340	Hordeum vulgare	1126 +/– 30	AD 890–904, 913–970	AD 783–788, 817–843, 860–991	Posthole A51007

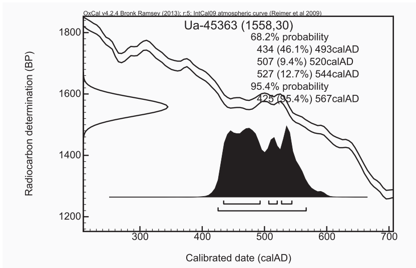

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45358 (1480,30)
68.2% probability
555 (68.2%) 615calAD
95.4% probability
540 (95.4%) 644calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

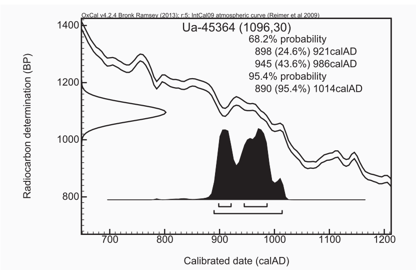

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45359 (1580,30)
68.2% probability
433 (26.3%) 467calAD
482 (41.9%) 534calAD
95.4% probability
415 (95.4%) 547calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

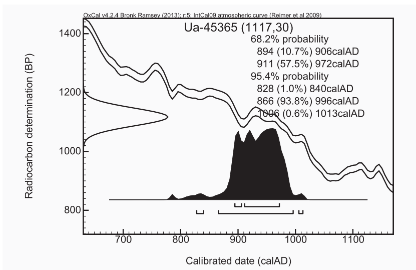

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45360 (942,30)
68.2% probability
1033 (14.6%) 1052calAD
1081 (38.6%) 1128calAD
1133 (15.0%) 1152calAD
95.4% probability
1025 (95.4%) 1159calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

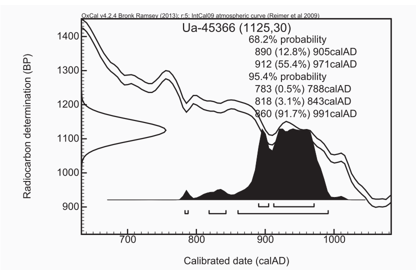

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45361 (219,30)
68.2% probability
1648 (29.9%) 1675calAD
1778 (27.5%) 1799calAD
1941 (10.8%) 1953calAD
95.4% probability
1642 (36.0%) 1684calAD
1735 (45.0%) 1805calAD
1933 (14.4%) 1955calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

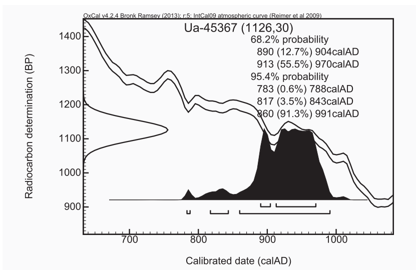

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45362 (1525,30)
68.2% probability
444 (2.3%) 448calAD
463 (11.1%) 483calAD
533 (54.8%) 595calAD
95.4% probability
432 (29.1%) 497calAD
502 (66.3%) 604calAD
Radiocarbon determination (BP)
Calibrated date (calAD)


OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45363 (1558,30)
68.2% probability
434 (46.1%) 493calAD
507 (9.4%) 520calAD
527 (12.7%) 544calAD
95.4% probability
425 (95.4%) 567calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

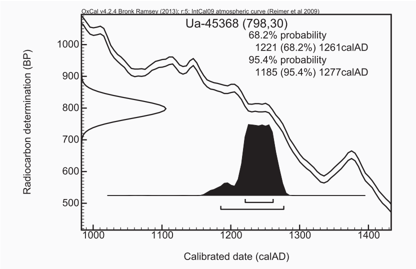

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45364 (1096,30)
68.2% probability
898 (24.6%) 921calAD
945 (43.6%) 986calAD
95.4% probability
890 (95.4%) 1014calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

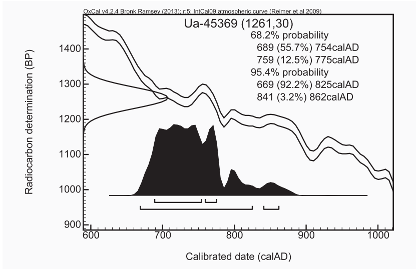

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45365 (1117,30)
68.2% probability
894 (10.7%) 906calAD
911 (57.5%) 972calAD
95.4% probability
828 (1.0%) 840calAD
866 (93.8%) 996calAD
1006 (0.6%) 1013calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

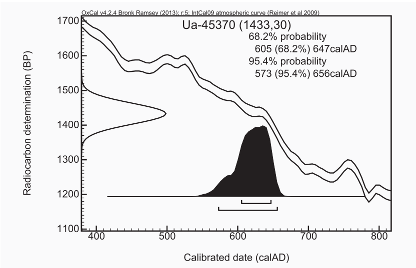

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45366 (1125,30)
68.2% probability
890 (12.8%) 905calAD
912 (55.4%) 971calAD
95.4% probability
783 (0.5%) 788calAD
818 (3.1%) 843calAD
860 (91.7%) 991calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

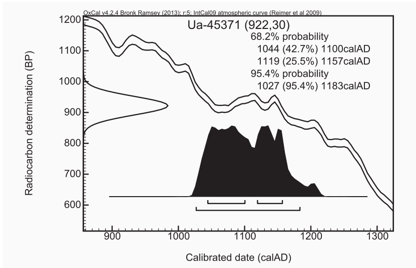

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45367 (1126,30)
68.2% probability
890 (12.7%) 904calAD
913 (55.5%) 970calAD
95.4% probability
783 (0.6%) 788calAD
817 (3.5%) 843calAD
860 (91.3%) 991calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

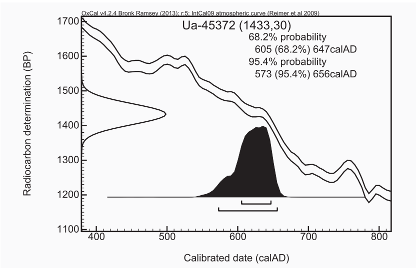
LAB NO.	SITE, SAMPLE NO.	MATERIAL	RADIOCARBON AGE BP	CALIBRATED 1 SIGMA	CALIBRATED 2 SIGMA	CONTEXT
Ua-45368	Avaldsnes 343	Hordeum vulgare	798 +/ – 30	AD 1221–1261	AD 1185–1277	Layer A12780
Ua-45369	Avaldsnes 439	Hordeum vulgare	1261 +/ – 30	AD 689–754, 759–775	AD 669–825, 841–862	Posthole A10161
Ua-45370	Avaldsnes 410	Hordeum vulgare	1433 +/ – 30	AD 605–647	AD 573–656	Posthole A49884
Ua-45371	Avaldsnes 414	Hordeum vulgare	922 +/ – 30	AD 1044–1100, 1119–1157	AD 1027–1183	Posthole A46764
Ua-45372	Avaldsnes 432	Hordeum vulgare	1433 +/ – 30	AD 605–647	AD 573–656	Posthole A50677
Ua-45373	Avaldsnes 419	Hordeum vulgare	1143 +/ – 30	AD 872–905, 911–971	AD 781–791, 807–980	Posthole A49724
Ua-45374	Avaldsnes 391	Hordeum vulgare	1605 +/ – 30	AD 415–441, 456–460, 484–532	AD 397–540	Posthole A46847
Ua-45375	Avaldsnes 413	Hordeum vulgare	1780 +/ – 30	AD 214–261, 280–326	AD 135–337	Posthole A50424
Ua-45376	Avaldsnes 417	Hordeum vulgare	1137 +/ – 30	AD 882–905, 912–971	AD 781–790, 809–985	Ditch A12178
Ua-45377	Avaldsnes 334	Hordeum vulgare	1137 +/ – 30	AD 882–905, 912–971	AD 781–790, 809–985	Cooking pit A10438

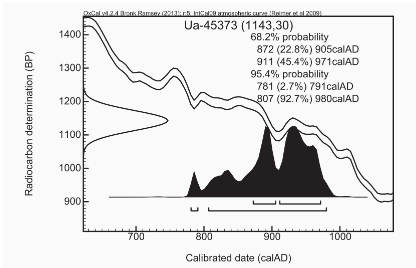

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45368 (798,30)
68.2% probability
1221 (68.2%) 1261calAD
95.4% probability
1185 (95.4%) 1277calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

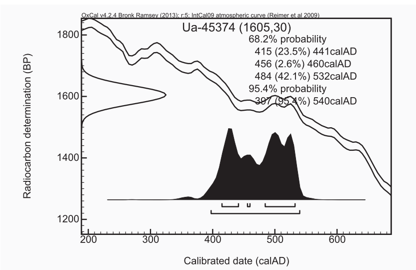

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45369 (1261,30)
68.2% probability
689 (55.7%) 754calAD
759 (12.5%) 775calAD
95.4% probability
669 (92.2%) 825calAD
841 (3.2%) 862calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

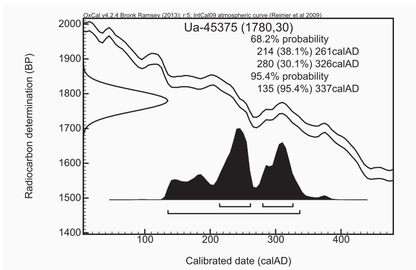

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45370 (1433,30)
68.2% probability
605 (68.2%) 647calAD
95.4% probability
573 (95.4%) 656calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

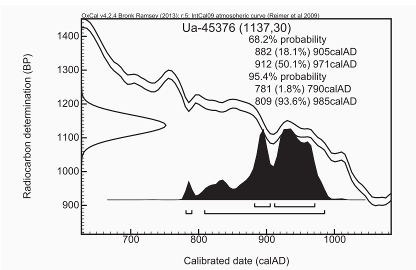

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45371 (922,30)
68.2% probability
1044 (42.7%) 1100calAD
1119 (25.5%) 1157calAD
95.4% probability
1027 (95.4%) 1183calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

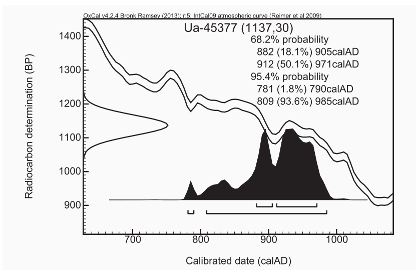

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45372 (1433,30)
68.2% probability
605 (68.2%) 647calAD
95.4% probability
573 (95.4%) 656calAD
Radiocarbon determination (BP)
Calibrated date (calAD)


OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45373 (1143,30)
68.2% probability
872 (22.8%) 905calAD
911 (45.4%) 971calAD
95.4% probability
781 (2.7%) 791calAD
807 (92.7%) 980calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

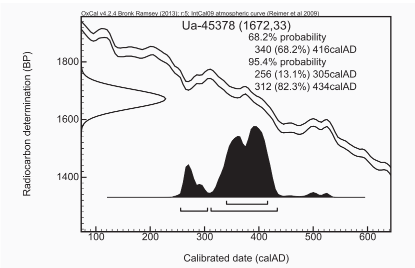

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45374 (1605,30)
68.2% probability
415 (23.5%) 441calAD
456 (2.6%) 460calAD
484 (42.1%) 532calAD
95.4% probability
397 (95.4%) 540calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

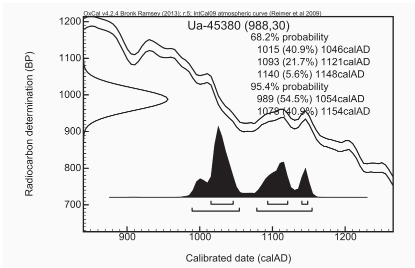

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45375 (1780,30)
68.2% probability
214 (38.1%) 261calAD
280 (30.1%) 326calAD
95.4% probability
135 (95.4%) 337calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

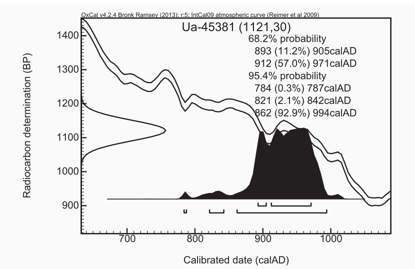

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45376 (1137,30)
68.2% probability
882 (18.1%) 905calAD
912 (50.1%) 971calAD
95.4% probability
781 (1.8%) 790calAD
809 (93.6%) 985calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

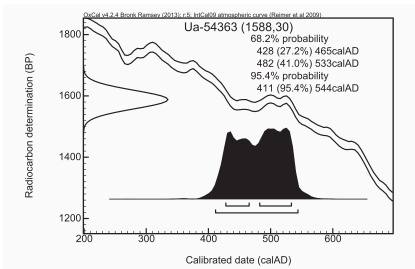

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-45377 (1137,30)
68.2% probability
882 (18.1%) 905calAD
912 (50.1%) 971calAD
95.4% probability
781 (1.8%) 790calAD
809 (93.6%) 985calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

LAB NO.	SITE, SAMPLE NO.	MATERIAL	RADIOCARBON AGE BP	CALIBRATED 1 SIGMA	CALIBRATED 2 SIGMA	CONTEXT
Ua-45378	Avaldsnes 385	Avena	1672 +/ – 33	AD 340–416	AD 256–305, 312–434	Posthole A46437
Ua-45380	Avaldsnes 450	Hordeum vulgare	988 +/ – 30	AD 1015–1046, 1093–1121, 1140–1148	AD 989–1054, 1078–1154	Posthole A52453
Ua-45381	Avaldsnes 382	Hordeum vulgare	1121 +/ – 30	AD 893–905, 912–971	AD 784–787, 821–842, 862–994	Posthole A53576
Ua-54363	Avaldsnes 332	Hordeum vulgare	1558 +/ – 30	AD 428–465, 482–533	AD 411–533	Posthole A45557, A13



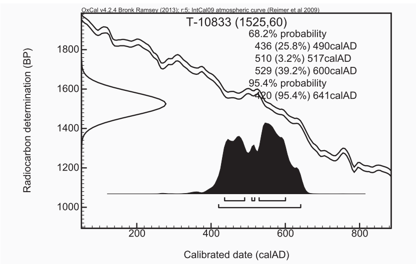


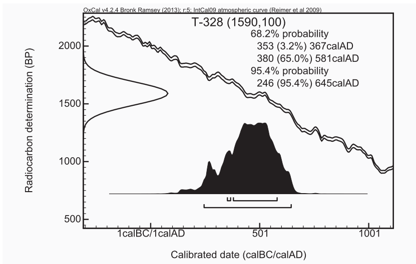


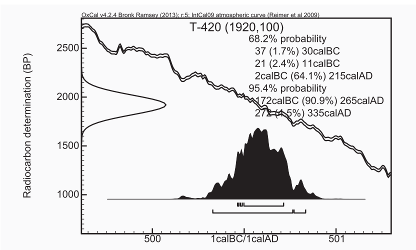


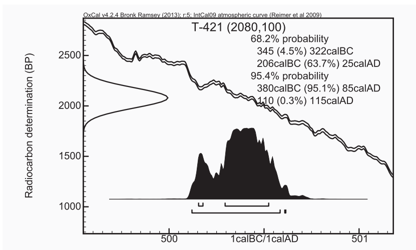
Courtyard Sites

LAB NO.	SITE, SAMPLE NO.	MATERIAL	RADIOCARBON AGE BP	CALIBRATED 1 SIGMA	CALIBRATED 2 SIGMA	CONTEXT
T-328	Klau-haugane	Charcoal	1590 +/– 100	AD 353–367, 380–581	AD 246–645	Building 21, wall trench
T-420	Klau-haugane	Charcoal	1920 +/– 100	BC 37–30, 21–11, BC 2–AD 215	BC 172–AD 265, AD 272–335	Building 21, hearth
T-421	Klau-haugane	Charcoal	2080 +/– 100	BC 345–322, BC 206–AD 25	BC 380–AD 85, AD 110–115	Building 21, hearth
T-10833	Leksaren	Betula, salix	1525 +/– 60	AD 436–490, 510–517, 529–600	AD 420–641	Building 12, hearth 3

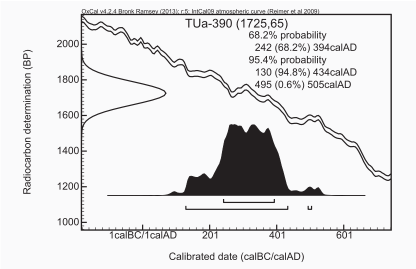


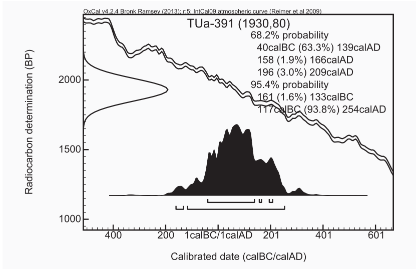


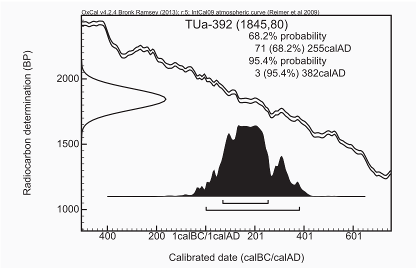


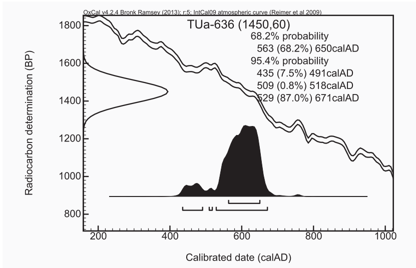


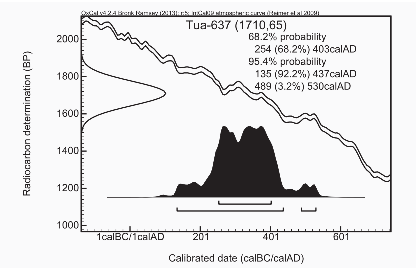
LAB NO.	SITE, SAMPLE NO.	MATERIAL	RADIOCARBON AGE BP	CALIBRATED 1 SIGMA	CALIBRATED 2 SIGMA	CONTEXT
Tua-390	Leksaren	Betula	1725 +/ – 65	AD 242–394	AD 130–434, 495–505	Building 9, heart 11
Tua-391	Leksaren	Betula	1930 +/ – 80	BC 40– AD 139, 158–166, 196–209	BC 161–133, BC 117–AD 254	Building 9, layer
Tua-392	Leksaren	Food residue	1845 +/ – 80	AD 71–255	AD 3–382	Building 12
Tua-636	Leksaren	Betula	1450 +/ – 60	AD 563–650	AD 435–491, 509–518, 529–671	Building 2, hearth 6
Tua-637	Leksaren	Bark	1710 +/ – 65	AD 254–403	AD 135–437, 489–530	Building 15, culture layer
Tua-638	Leksaren	Betula	1605 +/ – 70	AD 387–544	AD 259–297, 321–600	Central mound
Tua-639	Leksaren	Food residue	1705 +/ – 45	AD 259–296, 322–395	AD 235–427	Building 2
Tua-640	Leksaren	Food residue	2705 +/ – 130	BC 1109–1105, 1070–1065, 1056–761, 682–671	BC 1260–1228, 1221–510, 436–426	Building 2
Tua-641	Leksaren	Food residue	2010 +/ – 65	BC 93–AD 67	BC 181–AD 126	Buildng 9
Tua-642	Leksaren	Food residue	1620 +/ – 65	AD 383–538	AD 256–302, 316–576	Building 15

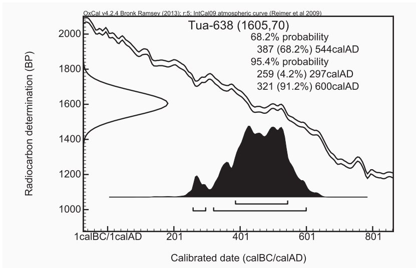

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TUa-390 (1725,65)
68.2% probability
242 (68.2%) 394calAD
95.4% probability
130 (94.8%) 434calAD
495 (0.6%) 505calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

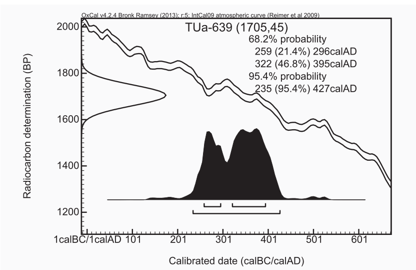

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TUa-391 (1930,80)
68.2% probability
40calBC (63.3%) 139calAD
158 (1.9%) 166calAD
196 (3.0%) 209calAD
95.4% probability
161 (1.6%) 133calBC
117calBC (93.8%) 254calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

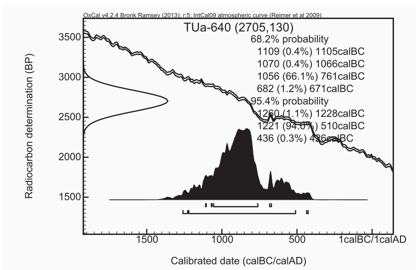

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TUa-392 (1845,80)
68.2% probability
71 (68.2%) 255calAD
95.4% probability
3 (95.4%) 382calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

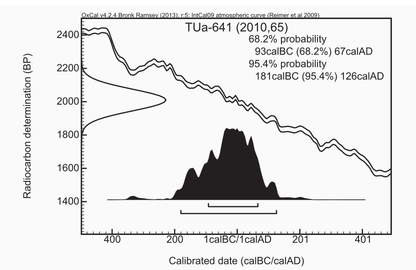

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TUa-636 (1450,60)
68.2% probability
563 (68.2%) 650calAD
95.4% probability
435 (7.5%) 491calAD
509 (0.8%) 518calAD
529 (87.0%) 671calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

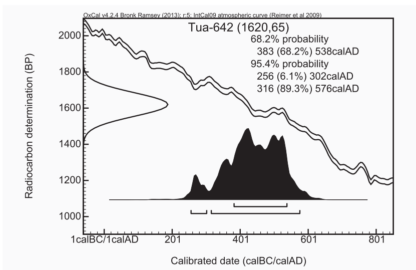

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Tua-637 (1710,65)
68.2% probability
254 (68.2%) 403calAD
95.4% probability
135 (92.2%) 437calAD
489 (3.2%) 530calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)


OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Tua-638 (1605,70)
68.2% probability
387 (68.2%) 544calAD
95.4% probability
259 (4.2%) 297calAD
321 (91.2%) 600calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

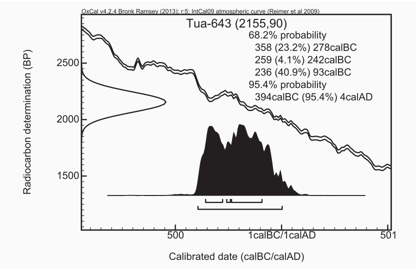

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TUa-639 (1705,45)
68.2% probability
259 (21.4%) 296calAD
322 (46.8%) 395calAD
95.4% probability
235 (95.4%) 427calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

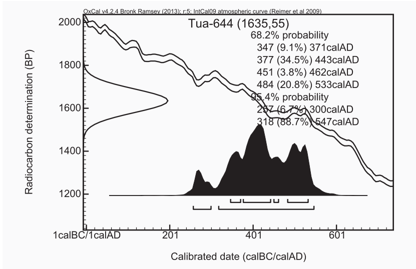

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TUa-640 (2705,130)
68.2% probability
1109 (0.4%) 1105calBC
1070 (0.4%) 1066calBC
1056 (66.1%) 761calBC
682 (1.2%) 671calBC
95.4% probability
1260 (1.1%) 1228calBC
1221 (94.0%) 510calBC
436 (0.3%) 426calBC
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

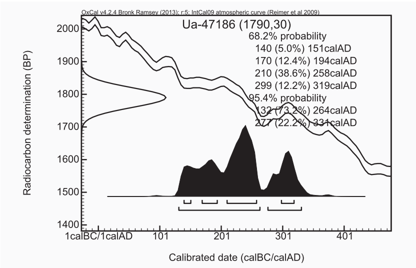

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
TUa-641 (2010,65)
68.2% probability
93calBC (68.2%) 67calAD
95.4% probability
181calBC (95.4%) 126calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

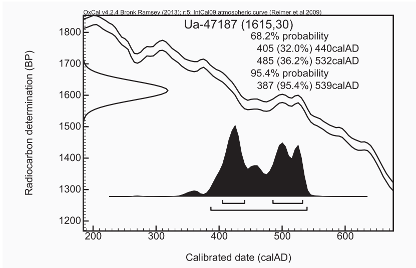

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Tua-642 (1620,65)
68.2% probability
383 (68.2%) 538calAD
95.4% probability
256 (6.1%) 302calAD
316 (89.3%) 576calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

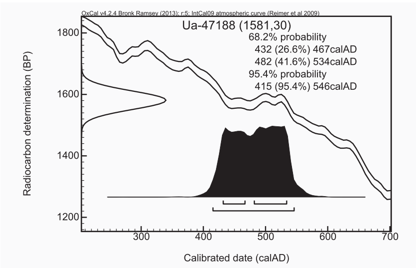
LAB NO.	SITE, SAMPLE NO.	MATERIAL	RADIOCARBON AGE BP	CALIBRATED 1 SIGMA	CALIBRATED 2 SIGMA	CONTEXT
Tua-643	Leksaren	Food residue	2155 +/ – 90	BC 358–278, 259–242, 236–93	BC 394– AD 4	Building 15
Tua-644	Leksaren	Food residue	1635 +/ – 55	AD 347–371, 377–443, 451–462, 484–533	AD 257–300, 318–547	Central mound
Ua-47186	Øygarden	Betula	1790 +/ – 30	AD 140–151, 170–194, 210–258, 299–319	AD 132–264, 277–331	Building 2, hearth 8
Ua-47187	Øygarden	Bark, betula	1615 +/ – 30	AD 405–440, 485–532	AD 387–539	Building 3, cultural deposit 1
Ua-47188	Øygarden	Betula	1581 +/ – 30	AD 432–467, 482–534	AD 415–546	Building 4, cultural deposit 5
Ua-47189	Øygarden	Betula	1917 +/ – 40	AD 29–38, 51–129	AD 1–215	Building 5, cultural deposit 7
Ua-47190	Øygarden	Bark, betula	1451 +/ – 31	AD 613–653	AD 582–664	Building 6, cultural deposit 15
Ua-47191	Øygarden	Betula	1851 +/ – 30	AD 128–216	AD 85–235	Building 7, cultural deposit 3
Ua-47192	Øygarden	Bark	1869 +/ – 30	AD 83–140, 150–170, 194–210	AD 74–226	Building 8, cultural deposit 7
Ua-47193	Øygarden	Bark	1828 +/ – 30	AD 136–223	AD 86–108, 120–245, 307–312	Building 8, cultural deposit 12

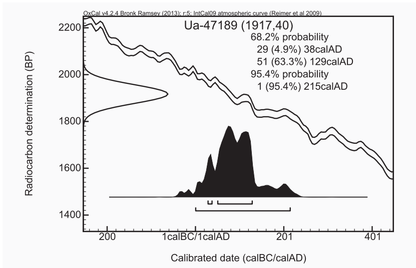

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Tua-643 (2155,90)
68.2% probability
358 (23.2%) 278calBC
259 (4.1%) 242calBC
236 (40.9%) 93calBC
95.4% probability
394calBC (95.4%) 4calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

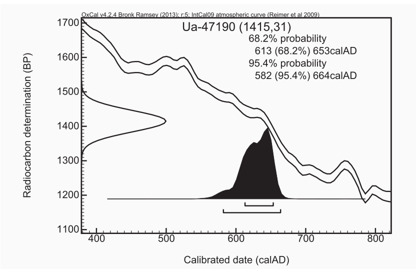

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Tua-644 (1635,55)
68.2% probability
347 (9.1%) 371calAD
377 (34.5%) 443calAD
451 (3.8%) 462calAD
484 (20.8%) 533calAD
95.4% probability
207 (6.7%) 300calAD
318 (88.7%) 547calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

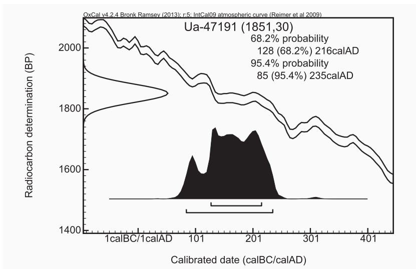

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47186 (1790,30)
68.2% probability
140 (5.0%) 151calAD
170 (12.4%) 194calAD
210 (38.6%) 258calAD
299 (12.2%) 319calAD
95.4% probability
132 (73.2%) 264calAD
277 (22.2%) 331calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

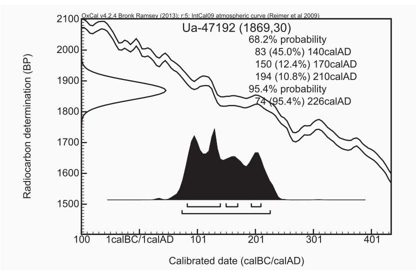

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47187 (1615,30)
68.2% probability
405 (32.0%) 440calAD
485 (36.2%) 532calAD
95.4% probability
387 (95.4%) 539calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

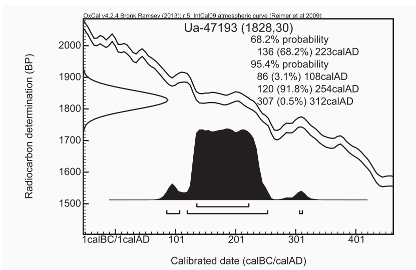

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47188 (1581,30)
68.2% probability
432 (26.6%) 467calAD
482 (41.6%) 534calAD
95.4% probability
415 (95.4%) 546calAD
Radiocarbon determination (BP)
Calibrated date (calAD)


OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47189 (1917,40)
68.2% probability
29 (4.9%) 38calAD
51 (63.3%) 129calAD
95.4% probability
1 (95.4%) 215calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

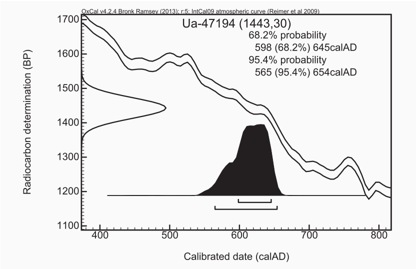

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47190 (1415,31)
68.2% probability
613 (68.2%) 653calAD
95.4% probability
582 (95.4%) 664calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

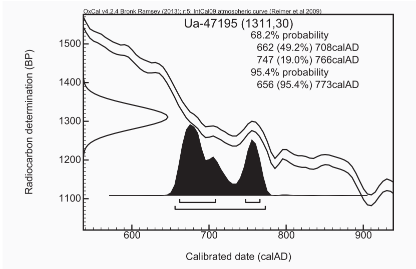

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47191 (1851,30)
68.2% probability
128 (68.2%) 216calAD
95.4% probability
85 (95.4%) 235calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

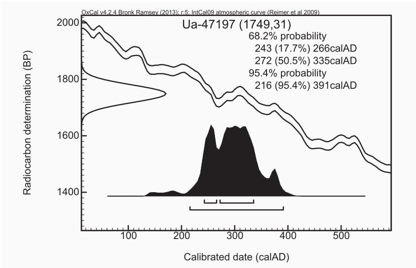

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47192 (1869,30)
68.2% probability
83 (45.0%) 140calAD
150 (12.4%) 170calAD
194 (10.8%) 210calAD
95.4% probability
74 (95.4%) 226calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

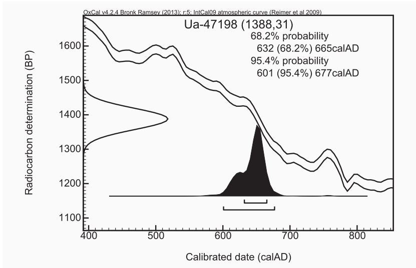

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47193 (1828,30)
68.2% probability
136 (68.2%) 223calAD
95.4% probability
86 (3.1%) 108calAD
120 (91.8%) 254calAD
307 (0.5%) 312calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

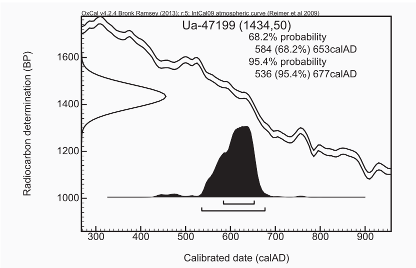
LAB NO.	SITE, SAMPLE NO.	MATERIAL	RADIOCARBON AGE BP	CALIBRATED 1 SIGMA	CALIBRATED 2 SIGMA	CONTEXT
Ua-47194	Øygarden	Betula	1443 +/– 30	AD 598–645	AD 565–654	Building 10, hearth 20
Ua-47195	Klau-haugane	Corylus	1311 +/– 30	AD 662–708, 747–766	AD 656–773	Building 1, cultural deposit 3
Ua-47197	Klau-haugane	Betula	1749 +/– 31	AD 243–266, 272–335	AD 216–391	Building 3, hearth 125
Ua-47198	Klau-haugane	Betula	1388 +/– 31	AD 632–665	AD 601–677	Building 4, Cultural layer 10
Ua-47199	Klau-haugane	Bark	1434 +/– 50	AD 584–653	AD 536–677	Building 4, Cultural layer 76
Ua-47200	Klau-haugane	Betula	1414 +/– 31	AD 613–654	AD 582–664	Building 4, hearth 132
Ua-47201	Klau-haugane	Betula	1210 +/– 31	AD 776–872	AD 693–748, 765–892	Building 10, Cultural layer 238
Ua-47202	Klau-haugane	Betula	1831 +/– 30	AD 135–217	AD 86–109, 120–252	Building 10, Cultural layer 238
Ua-47203	Klau-haugane	Betula	1511 +/– 30	AD 538–601	AD 434–492, 508–518, 528–622	Building 13, cultural layer 33
Ua-47204	Klau-haugane	Betula	1763 +/– 30	AD 235–264, 277–331	AD 140–154, 167–195, 210–360, 365–384	Building 16/17, cultural layer 255

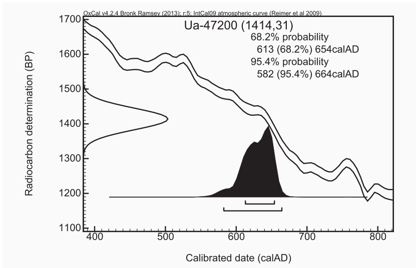

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47194 (1443,30)
68.2% probability
598 (68.2%) 645calAD
95.4% probability
565 (95.4%) 654calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

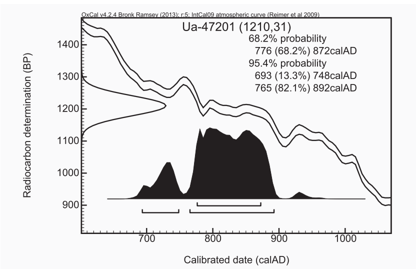

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47195 (1311,30)
68.2% probability
662 (49.2%) 708calAD
747 (19.0%) 766calAD
95.4% probability
656 (95.4%) 773calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

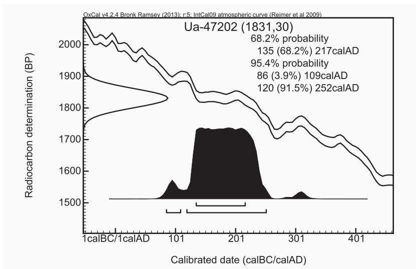

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47197 (1749,31)
68.2% probability
243 (17.7%) 266calAD
272 (50.5%) 335calAD
95.4% probability
216 (95.4%) 391calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

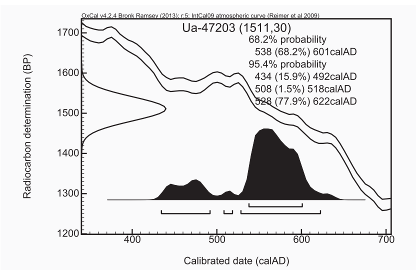

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47198 (1388,31)
68.2% probability
632 (68.2%) 665calAD
95.4% probability
601 (95.4%) 677calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

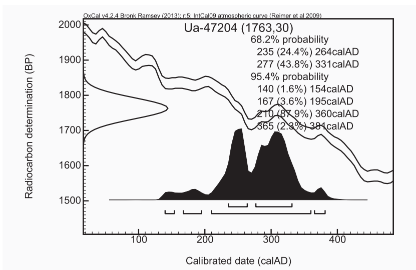

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47199 (1434,50)
68.2% probability
584 (68.2%) 653calAD
95.4% probability
536 (95.4%) 677calAD
Radiocarbon determination (BP)
Calibrated date (calAD)


OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47200 (1414,31)
68.2% probability
613 (68.2%) 654calAD
95.4% probability
582 (95.4%) 664calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

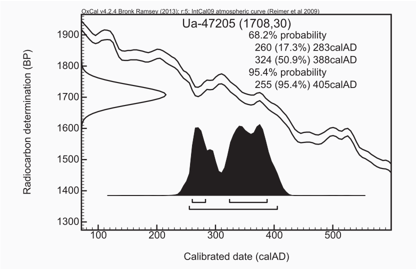

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47201 (1210,31)
68.2% probability
776 (68.2%) 872calAD
95.4% probability
693 (13.3%) 748calAD
765 (82.1%) 892calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

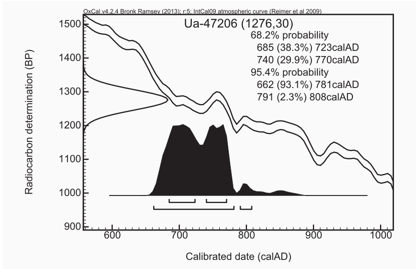

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47202 (1831,30)
68.2% probability
135 (68.2%) 217calAD
95.4% probability
86 (3.9%) 109calAD
120 (91.5%) 252calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

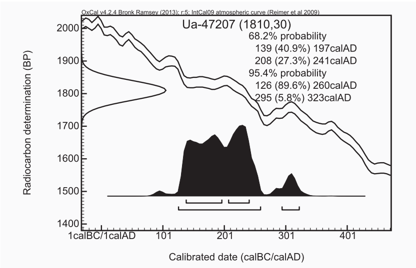

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47203 (1511,30)
68.2% probability
538 (68.2%) 601calAD
95.4% probability
434 (15.9%) 492calAD
508 (1.5%) 518calAD
528 (77.9%) 622calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

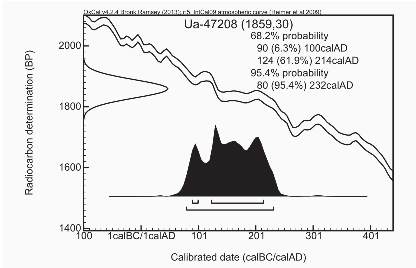

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47204 (1763,30)
68.2% probability
235 (24.4%) 264calAD
277 (43.8%) 331calAD
95.4% probability
140 (1.6%) 154calAD
167 (3.6%) 195calAD
210 (87.9%) 360calAD
365 (2.3%) 381calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

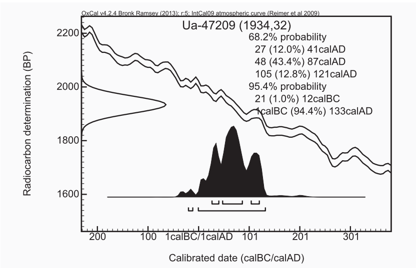
LAB NO.	SITE, SAMPLE NO.	MATERIAL	RADIOCARBON AGE BP	CALIBRATED 1 SIGMA	CALIBRATED 2 SIGMA	CONTEXT
Ua-47205	Klau-haugane	Corylus	1708 +/ – 30	AD 260–283, 324–388	AD 255–405	Building 16/17, post-hole 287
Ua-47206	Klau-haugane	Betula	1276 +/ – 30	AD 685–723, 740–770	AD 662–781, 791–808	Building 19, cultural layer 1
Ua-47207	Leksaren	Betula	1810 +/ – 30	AD 139–197, 208–241	AD 126–260, 295–323	Building 3, cultural layer 4
Ua-47208	Leksaren	Betula	1859 +/ – 30	AD 90–100, 124–214	AD 80–232	Building 3, cultural layer 182
Ua-47209	Leksaren	Betula	1934 +/ – 32	AD 27–41, 48–87, 105–121	BC 21–12, BC 1–AD 133	Building 4, cultural layer 67
Ua-47210	Leksaren	Betula	1775 +/ – 31	AD 217–263, 277–330	AD 136–341	Building 5, cultural layer 47
Ua-47211	Leksaren	Bark	1652 +/ – 32	AD 346–372, AD 377–428	AD 261–281, 325–442, 451–462, 484–533	Building 6, charcoal…
Ua-47212	Leksaren	Betula	1608 +/ – 31	AD 412–441, 455–460, 484–532	AD 392–540	Building 7, hearth 25
Ua-47213	Leksaren	Betula	1762 +/ – 32	AD 234–265, AD 274–334	AD 140–153, 168–195, 210–382	Building 8, cultural layer 23

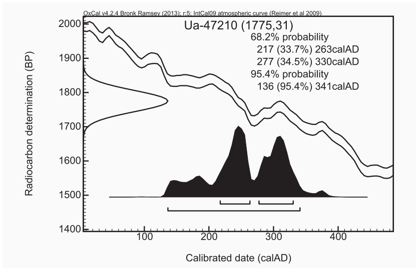

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47205 (1708,30)
68.2% probability
260 (17.3%) 283calAD
324 (50.9%) 388calAD
95.4% probability
255 (95.4%) 405calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

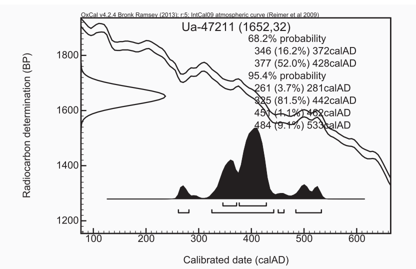

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47206 (1276,30)
68.2% probability
685 (38.3%) 723calAD
740 (29.9%) 770calAD
95.4% probability
662 (93.1%) 781calAD
791 (2.3%) 808calAD
Radiocarbon determination (BP)
Calibrated date (calAD)

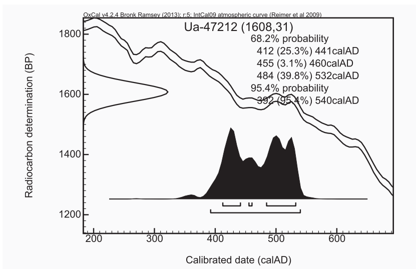

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47207 (1810,30)
68.2% probability
139 (40.9%) 197calAD
208 (27.3%) 241calAD
95.4% probability
126 (89.6%) 260calAD
295 (5.8%) 323calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)

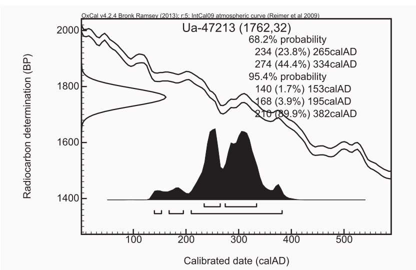

OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47208 (1859,30)
68.2% probability
90 (6.3%) 100calAD
124 (61.9%) 214calAD
95.4% probability
80 (95.4%) 232calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)


OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47209 (1934,32)
68.2% probability
27 (12.0%) 41calAD
48 (43.4%) 87calAD
105 (12.8%) 121calAD
95.4% probability
21 (1.0%) 12calBC
1calBC (94.4%) 133calAD
Radiocarbon determination (BP)
Calibrated date (calBC/calAD)


OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47210 (1775,31)
68.2% probability
217 (33.7%) 263calAD
277 (34.5%) 330calAD
95.4% probability
136 (95.4%) 341calAD
Radiocarbon determination (BP)
Calibrated date (calAD)


OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47211 (1652,32)
68.2% probability
346 (16.2%) 372calAD
377 (52.0%) 428calAD
95.4% probability
261 (3.7%) 281calAD
325 (81.5%) 442calAD
451 (1.1%) 462calAD
484 (9.1%) 533calAD
Radiocarbon determination (BP)
Calibrated date (calAD)


OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47212 (1608,31)
68.2% probability
412 (25.3%) 441calAD
455 (3.1%) 460calAD
484 (39.8%) 532calAD
95.4% probability
392 (95.4%) 540calAD
Radiocarbon determination (BP)
Calibrated date (calAD)


OxCal v4.2.4 Bronk Ramsey (2013); r:5; IntCal09 atmospheric curve (Reimer et al 2009)
Ua-47213 (1762,32)
68.2% probability
234 (23.8%) 265calAD
274 (44.4%) 334calAD
95.4% probability
140 (1.7%) 153calAD
168 (3.9%) 195calAD
210 (89.9%) 382calAD
Radiocarbon determination (BP)
Calibrated date (calAD)