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# Dating of rock art and the effect of human activity on vegetation: The complementary use of archaeological and scientific methods

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ABSTRACT

One of the main aims of Scandinavian rock art research in recent years has been to identify the culture or society responsible for the imagery. This is of mutual importance, as studies of material culture can shed light on the rock art, while the iconography can be used to understand the contemporary material remains. A major challenge however, has been to determine the exact age of the images, as there are no direct dating materials. In order to overcome this challenge archaeological excavations and palynological analyses have been carried out at Vingen in Western Norway, one of Scandinavia's largest rock art areas. The archaeological and palynological data achieved, as well as loss-on-ignition are independent means for the dating of human activity. Since these methods provided similar results, an indirect connection to the rock art production activity may be inferred. Dates from archaeological contexts indicate a peak of activity between 6900 and 6300 cal. BP, with a potential start 7350 cal. BP and a culmination 6100 cal. BP. Palynological data from three different types of basins have documented forest disturbance in the same time period. Local vegetation reconstructions using the Landscape Reconstruction Algorithm has proved useful to identify anthropogenic-induced land cover changes in the Mesolithic period and a marked reforestation at the transition to the Neolithic period. The applied methods have helped to considerably improve our understanding of past activity and the environment, and demonstrates the potential of archaeological excavations and palynological studies for dating of rock art.



## 1. Introduction

Scandinavia is renowned for its many sites with engraved, pecked or polished rock art, which is also separated into two different traditions, termed *hunters'* and *agrarian* rock art, or lately the *Northern* and *Southern Traditions*. The Northern Tradition is associated with hunter-gather-fisher populations, and normally dated to the Mesolithic and Neolithic time periods. Its iconography is characterised by wild animals, such as red deer, reindeer, elk, bear, and sea mammals, but also anthropomorphic images. The presence of wild animals have led most researchers to associate the Northern Tradition sites in Scandinavia to hunting strategies. However, detailed studies of the iconography at most Northern Tradition sites with anthropomorphic images have shown that these have a number of features that are characteristic for skeletons. It therefore seems more likely that the Northern Tradition rock art was related to mortuary practices, and that the represented wild animals were associated with mortuary or death beliefs (Lødøen, 2014, 2015). During the Late Mesolithic, subsistence along the Norwegian coast seems to have been heavily based on fish and marine resources, which led habitation sites to be concentrated around tidal currents (Bjerck, 2008). This marks a contrast to most of the rock art sites of the Northern Tradition which are located further inland, along fjord systems or at the head of fjords (Lødøen, 2015). Its location thus emphasises a mortuary and perhaps esoteric character for the rock art. The Southern Tradition has been strongly associated with agricultural societies, dated to the Late Neolithic, the Bronze Age and even the Early Iron Age. It is characterised by ship images, domesticated animals, anthropomorphic images, concentric ring figures, spirals, and cup-marks, and could also be associated with mortuary practices, death beliefs and tradition in later periods (Goldhahn, 2016; Lødøen, 2015).

In recent years, Scandinavian rock art research has been occupied with the contemporary context associated with the rock images. Studies of human deposits, occupation and other associated patterns can help to shed light on the rock art, while the rock

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imagery, often seen as narratives, can be used to gain a better understanding of the contemporary archaeological remains. However, the dating of both traditions has always been a challenge, since no direct methods are available, and the indirect methods are all associated with a number of uncertainties generally applying to rock art (e.g. Aubert, 2012; Bednarik, 2001; Whitley, 2005). The prevailing dating method for the Northern tradition has been shoreline displacements and the assumption that the rock art was produced on clean surfaces, close to former shorelines. Following this, geological studies of post-glacial land-uplift have provided a *terminus post quem* dating of previously shore-bound rock art – which in rock art studies far too often is regarded as the real date. The close connection between the rock art and past shorelines has been legitimized by comparisons with the inland locations, where most rock art is found in the close vicinity of water tables of lakes and rivers (Mikkelsen, 1977). It has been argued that the coastal rock art originally had a similar close connection, and therefore that dating the levels of past shorelines will give a convincing dating of rock art at the same altitude. This approach has several weaknesses since variations in the levels chosen for the rock art, due to factors such as wave action or sea splash, may have occurred. Consequently, the dating may vary by hundreds or even thousands of years. In recent years, archaeological excavations in the immediate vicinity of rock art panels have been carried out more frequently, to try to define the age of rock art through dated cultural layers and artefacts. This has been particularly revealing in helping to document the character of the activity at the rock art sites, but we are still left with challenges in terms of contemporaneity: the excavated material could still pre- or post-date the rock art. By carrying out palynological investigations in the vicinity of rock art sites, independent data of activity can be obtained. The palynological and archaeological data can then be unified in order to obtain more accurate datings of the activity associated with the rock art. A pollen diagram may document activity periods and also periods with low or no human impact on the vegetation which can aid to identify the character and frequency of past activity. The challenge posed by this method is being able to separate human activity from natural causes of vegetation change. Traditionally, anthropogenic indicators (Behre, 1981) have been used to identify human activity in pollen diagrams, but activity that does not include animal husbandry or cultivation does not necessarily cause changes in the vegetation that are traceable by pollen analysis. The Landscape Reconstruction Algorithm (LRA) (Sugita, 2007a, 2007b) is an approach that converts pollen percentage data into vegetation cover by taking pollen productivity and dispersal into account. This has been used to reconstruct land-cover changes over time on different spatial scales (e.g. Fyfe et al., 2013; Hultberg et al., 2015; Nielsen and Odgaard, 2010; Nielsen et al., 2012; Marquer et al., 2014; Mehl and Hjelle, 2015; Mehl et al., 2015). By using LRA, a higher degree of vegetation openness has generally been estimated than the openness indicated by pollen percentage data (op. cit.). Of special interest for local studies is that LRA makes it possible to differ between locally produced and long-distance transported pollen. This opens the way to identifying anthropogenic-induced land-cover changes in the past, and may be a fruitful approach for time periods when there are few traditional anthropogenic indicators. As with excavations, the direct link between activity identified in a diagram and the rock art is missing, but one advantage is that a pollen diagram reflects longer time spans and a larger area than a test excavation.

The present paper deals with methodological challenges in the process of dating open rock art sites. Its focus is rock art of the *Northern Tradition*, at the site of Vingen in Western Norway (Figs. 1 and 2). The site contains one of the largest concentrations of rock art in Norway, whose dating has been the subject of debate since its discovery a century ago (Bakka, 1973; Bøe, 1932; Hallström, 1938; Lødøen, 2013). Stylistic comparison with motifs at other sites, and studies of superimpositions and relationships with past shorelines have previously concluded that the rock art was produced in the Early and Middle Neolithic, after 5950 cal. BP, potentially as early as in the Late Mesolithic (Bakka, 1973, 1979).

In order to provide a more detailed chronological framework for the rock art, we present radiocarbon dates from archaeological excavations in the vicinity of rock art panels in combination with palynological investigations. Pollen analyses from two sites within the rock art area and one site just outside the main activity area, have been carried out. Additionally, loss-on-ignition, which gives indications of erosion and, indirectly, human activity, has been measured. The main patterns in the vegetation development have been revealed through ordinations, and land-cover reconstructions have been connected to loss-on-ignition and dates from archaeological contexts. Based on the evidence from these investigations, a solid chronological framework is suggested for the Vingen rock art complex.

## 2. Material and methods

### 2.1. Study area and previous investigations

The Vingen area is located in the Bremanger municipality in the county of Sogn og Fjordane (Fig. 1). A narrow west-east oriented fjord, Vingepollen, separates the main rock art area on the southern side of the fjord from the smaller area of Vingeneset to the north. The usable land for habitation and activity is restricted by the sea at one end, and by steep mountain slopes on the other. In the surrounding area there are several tidal current channels which have attracted habitation in most periods of prehistory due to their marine resources. Vingen, located at a distance to these more resource-rich areas, was inhabited in modern times from the 16th century until the 1930s (Lødøen and Mandt, 2012). In recent decades, Vingen has been used as pastureland for sheep and goats, and a semi-open vegetation of birch, grasslands and heather dominates the area today.

Vingen became officially known as a rock art site in 1912, when the first paper was published (Bing, 1912), and has since then been the subject of detailed documentation (e.g. Bakka, 1973, 1979; Bøe, 1932; Hallström, 1938; Lødøen, 2003, 2013; Lødøen and Mandt, 2012). The area is characterised by a number of east-west oriented ledges, with north- and south-facing rock panels. More than 2200 images are documented on rock panels, boulders and smaller stones (Lødøen and Mandt, 2012). The most common motifs are red deer, animal-headed staffs, and anthropomorphic figures (Fig. 2). The presence of red deer images led earlier researchers to conclude that the site was associated with hunting. More thorough investigations have documented a number of skeleton images at the site, and also a clear distribution of the images, where red deer images are portrayed moving eastward on south facing panels, while red deer and skeletons are depicted as if they were moving westward on the north facing panels. This seems to have been a main, structuring narrative for the area, and also seems likely to be associated with cosmology – and probably mortuary practices – and not exclusively, or at all, to hunting (Lødøen, 2015).

The main focus throughout most of the 20th century has been the character and the distribution of the iconography. A few minor excavations were made in the 1970s, but since the 1990s more methodical approaches have been chosen by prospecting the whole area with systematic test excavations, excavations in the immediate vicinity of rock art panels, including dwelling depressions, and palynological studies (Fig. 1). Three areas of Vingen are included in the palynological study: a small hollow at the *Vingen terrace*

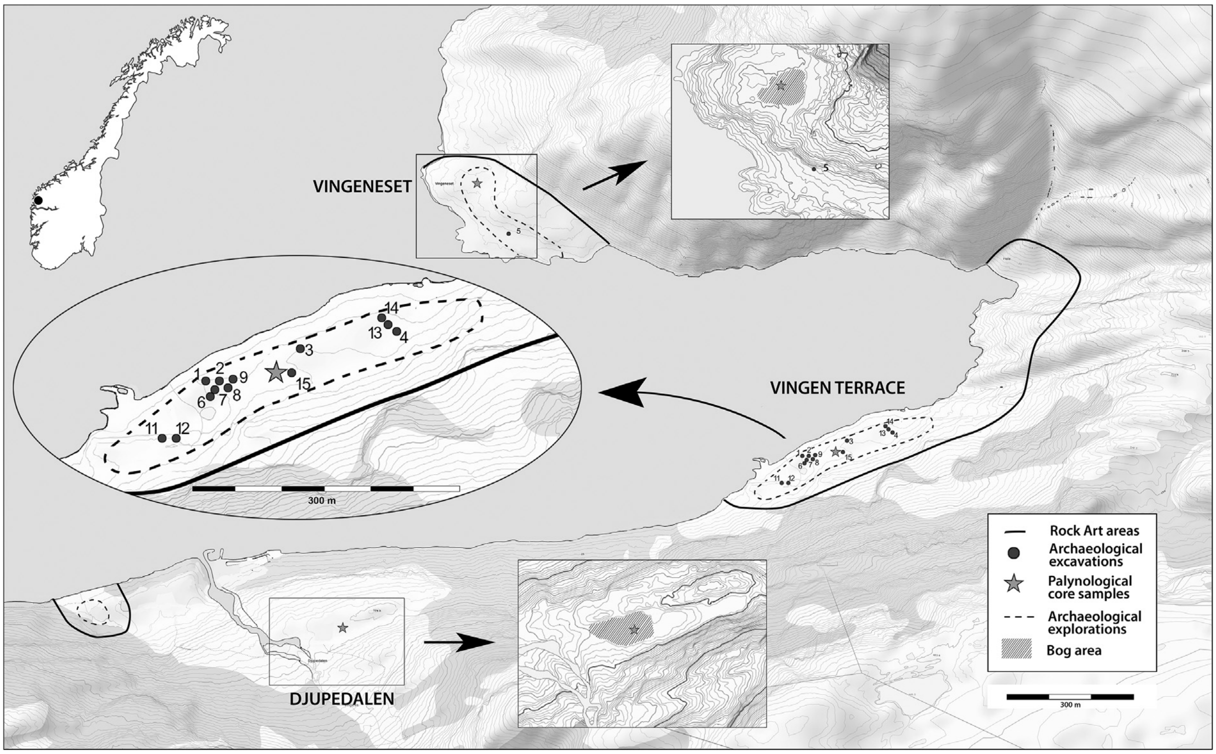


**Fig. 1.** Investigated sites at Vingen, Bremanger, western Norway, with the three study areas Vingen terrace, Vingeneset and Djupedalen. Areas with archaeological test excavations at Vingen terrace and Vingeneset are numbered.

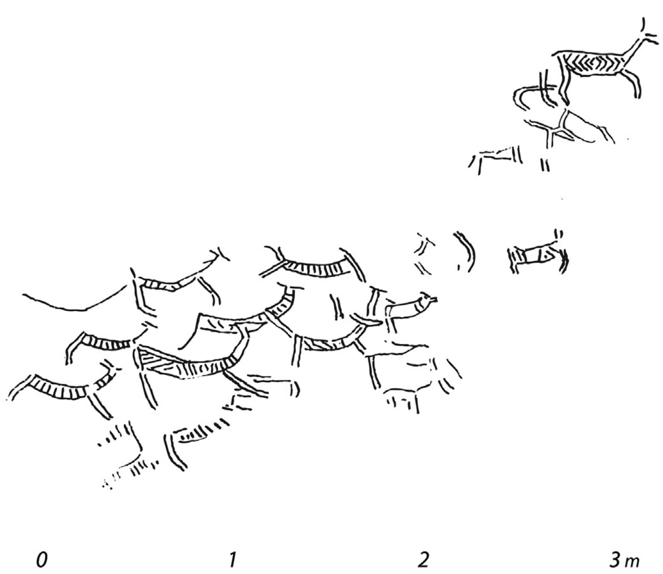


**Fig. 2.** A herd of red deer, for the most depicted as if running eastward. This section is part of the larger south facing *Elva* –panel, one of the innermost rock panels in Vingen.

representing the central rock art area, *Vingeneset* with more dispersed distribution of smaller rock art panels surrounding the bog, and a small infilled lake in *Djupedalen*, on a flat terrace in the terrain to the west of the main rock art area.

The site Vingen terrace (5.3161701 E, 61.8275648N, 14 m a.s.l., radius 5 m) is a hollow covered by Cyperaceae and Poaceae, having open water during rainy periods. It is centrally located within the rock art area, surrounded by boulders and open rock surfaces covered by images. At the border of the hollow, a structure interpreted as a house remain, is found. The site Vingeneset (5.2978168E, 61.8322499N, 15 m a.s.l., radius 22 m) represents the only bog within the rock art area. Some peat cutting have taken place in recent centuries, resulting in a hiatus in the pollen core above the upper analysed sample. *Sphagnum*, *Calluna vulgaris* and *Vaccinium vitis-idaea* are common species on the bog today, with scattered shrubs of *Juniperus communis* and trees of *Sorbus aucuparia*, *Betula pubescens* and *Pinus sylvatica*. The site Djupedalen (5.2946561 E, 61.8221409N, 96 m a.s.l., radius 30 m) is located higher up in the terrain than the two other sites. The previous lake is today mainly a bog with areas of open water. The vegetation varies from open water with *Menyanthes trifoliata*, to *Sphagnum* peat with *Eriophorum angustifolium*, *E. vaginatum*, *Carex* spp., *Drosera rotundifolia*, *Molinia caerulea*, and *Narthecium ossifragum*, and dryer areas with *Calluna vulgaris*, *Andromeda polifolia*, *Erica tetralix*, *Potentilla erecta*, *Succcisa pratensis* and *Juniperus communis*. The bog is surrounded by *Calluna* heathland.

### 2.2. Field work

The archaeological excavations mostly used test-squares (measuring 0.5 × 0.5 m) at a short distance from the rock art panels, where charcoal samples for radiocarbon dating were collected from the profile walls. Nine dwelling depressions were documented by surface visibility in combination with test excavations in the central area. Some of these have been excavated in more detail (Lødøen, 2013).

A pollen core was collected next to the stratigraphically documented profile wall in a test-square at Vingen terrace, and from the central part of the bog at Vingeneset. Both cores were sampled in PVC tubes of 11 cm diameter. At Vingen terrace, the top deposits were interpreted as mixed agricultural layers and the sampled core covers the sequence 23–110 cm, with peat from 41 cm and a thin horizont of charcoal at 59–60 cm. The highest analysed sample is at 63 cm. The core at Vingeneset is 136 cm long and an abrupt change from decomposed peat to fresh *Shagnum* peat at 19 cm below surface, resulted in the level 20 cm being the highest sample analysed. In Djupedalen, three overlapping sediment cores, covering 170–460 cm below surface, were taken from the bog at the northern side of the lake using a 1-m Russian Peat Corer with a chamber diameter of 11 cm. For further information on the stratigraphy, see Figure legends.

The Vingen area is a protected landscape and a cultural heritage site. It was therefore considered of vital importance to ensure that all excavations and coring processes caused as little damage as possible, and also to protect as much of the soil as possible for better methods and associated sampling in the future.

### 2.3. Laboratory methods and radiocarbon dates

In the laboratory, pollen samples with a volume of 1 $cm^3$ were processed using standard procedures with acetolysis and HF-treatment (Fægri and Iversen, 1989). Identification of pollen was based on Fægri and Iversen (1989) and the reference collection of modern pollen at the pollen laboratory, University of Bergen. The pollen diagrams were drawn using the program Core 2.0 (Kaland and Natvik, 1993). Percentages for terrestrial pollen are based on ΣP, the remaining microfossils are calculated based on ΣP + x, where x is the microfossil in question. Black column shows the percentages, grey percentages ×10. Samples for loss-on-ignition (LOI) analysis were dried at 105° C for 24 h, and then ignited at 550° C for 6 h. The results are given as percentages of dry weight.

A total of 41 samples from archaeological contexts and 20 levels from the three pollen cores were radiocarbon dated and calibrated using the Intcal 13 calibration curve (Reimer et al., 2013). The ages were determined at the National Laboratory for Radiocarbon dating at NTNU, Trondheim, Norway, at Ångström Laboratory, University of Uppsala, Sweden, and at Beta Analytic Inc., Miami, USA. Dates are given as calibrated years BP (before 1950). The different results are given in relation to four archaeological time periods: Mesolithic (MESO, until 5950 cal. BP), Neolithic (NEO, 5950–3750 cal. BP), Bronze Age (BA, 3750–2450 cal. BP), and Iron Age (IA, from 2450 cal. BP), following Bergsvik (2002) and Bjerck (2008).

### 2.4. Numerical analyses and land-cover reconstructions

To obtain an estimate of palynological diversity through time, palynological richness was estimated using rarefaction analysis in the RARECEP and RAREPOLL programs (Birks and Line, 1992). The expected number of terrestrial pollen and cryptogam spore taxa was estimated, given that the same number of grains had been counted in all of the samples. The three sites were analysed together, and a base sum of 717 pollen and spores was used.

The main gradients in the vegetation development (based on terrestrial pollen and cryptogam spores) were investigated using ordination in the program CANOCO version 4.5 for Windows (ter Braak and Šmilauer, 2002). Detrended Correspondence Analysis revealed short gradients (<2.0) for all data sets, and Principal Component Analysis (PCA) was carried out (Lepš and Šmilauer, 2003). Loss-on-ignition, microscopic charcoal and estimated palynological richness were treated as supplementary environmental variables in the analysis. Square-root transformation was carried out on the percentage data.

Land-cover reconstructions was carried out for 500-year time windows. The radiocarbon dates from the pollen cores were calibrated using linear interpolation (Vingen terrace) and smoothed spline (Vingeneset and Djupedalen) within the program Clam, R-code for classical age-depth modelling version 2.2 (Blaauw, 2010). Based on the best age estimated for each sample, pollen data was pooled into 500 year intervals. Forest cover in these time windows was estimated using REVEALS (Sugita, 2007a) and LOVE (Sugita, 2007b) within the Landscape Reconstruction Algorithm (LRA). Regional vegetation cover is ideally estimated based on large lakes (≥100ha), but investigations have shown that the model also works for a combination of smaller sites (Sugita et al., 2010; Hjelle et al., 2015; Trondman et al., 2016). Regional vegetation reconstruction was based on the three sites, whereas local reconstructions were made for Vingen terrace and Vingeneset. An estimate of the regional vegetation is needed in order to be able to differentiate between the regional and local pollen component in LRA. REVEALS estimates based on data from Djupedalen and Vingen terrace were used as regional background for Vingeneset in the LOVE reconstructions; Djupedalen and Vingeneset were used as background for Vingen terrace. A total of 21 taxa were included in the analysis (Table 1) and the programs REVEALS.C.v1.5.1.exe and LOVE.v5.1.win64.exe (Shinya Sugita, unpublished programs) were used.

## 3. Results and interpretation

### 3.1. Chronology of the pollen cores

At Vingen terrace, a constant accumulation is indicated from the beginning of peat formation c. 7700 cal. BP until c. 6850 cal. BP, followed by slow accumulation or a potential hiatus between 6850 and c. 5500 cal. BP (Fig. 3). This indicates that a thousand-year period covering the Mesolithic/Neolithic transition is lacking in the pollen record from this site. Deposition of archaeological material does not seem to have affected the accumulation rate, and the date of the top of the cultural layer is confirmed through two dates from the archaeological context (Fig. 4 and Tables 2 and 3). The age-depth model for Vingeneset is based on eight dates of peat (Fig. 3, Table 3). The two AMS-dates of plant remains are treated as outliers in the model. An age-depth model based on these would have resulted in low accumulation rate c. 8300–5000 cal. BP, followed by high accumulation rates over the next 2000 years. There is nothing in the stratigraphy that would indicate such dramatic changes. The two outliers may be explained by re-deposition of old plant

**Table 1**
Relative Pollen productivity estimates (PPE) and fall speed of pollen for the 21 taxa used in LRA. * taxa included in LRA estimates of forest cover (Figs. 9 and 10).

| Taxa | PPE | SE | Fall speed (m/s) | Reference |
|---|---|---|---|---|
| *Alnus** | 3.22 | 0.22 | 0.021 | Hjelle and Sugita (2012) |
| *Artemisia* | 3.48 | 0.20 | 0.025 | Mazier et al. (2012) |
| *Betula** | 3.09 | 0.27 | 0.024 | Mazier et al. (2012) |
| *Calluna vulgaris* | 0.87 | 0.05 | 0.038 | Hjelle and Sugita (2012) |
| *Corylus** | 1.99 | 0.20 | 0.025 | Mazier et al. (2012) |
| Cyperaceae | 1.37 | 0.21 | 0.035 | Hjelle and Sugita (2012) |
| *Fagus** | 0.80 | 0.09 | 0.057 | Hjelle and Sugita (2012) |
| *Filipendula* | 2.81 | 0.43 | 0.006 | Mazier et al. (2012) |
| *Fraxinus** | 1.03 | 0.11 | 0.022 | Mazier et al. (2012) |
| *Juniperus** | 0.79 | 0.21 | 0.016 | Hjelle and Sugita (2012) |
| *Picea** | 1.20 | 0.04 | 0.056 | Hjelle and Sugita (2012) |
| *Pinus** | 5.73 | 0.07 | 0.031 | Hjelle and Sugita (2012) |
| *Plantago lanceolata* | 1.04 | 0.09 | 0.029 | Mazier et al. (2012) |
| *P. major* | 1.27 | 0.18 | 0.024 | Mazier et al. (2012) |
| *P.maritima* | 0.74 | 0.13 | 0.030 | Mazier et al. (2012) |
| Poaceae | 1 | 0 | 0.035 | |
| *Quercus** | 1.30 | 0.10 | 0.035 | Hjelle and Sugita (2012) |
| *Rumex acetosa* | 0.39 | 0.10 | 0.018 | Hjelle and Sugita (2012) |
| *Salix** | 0.62 | 0.11 | 0.022 | Hjelle and Sugita (2012) |
| *Tilia** | 0.80 | 0.03 | 0.032 | Mazier et al. (2012) |
| *Ulmus** | 1.27 | 0.05 | 0.032 | Mazier et al. (2012) |

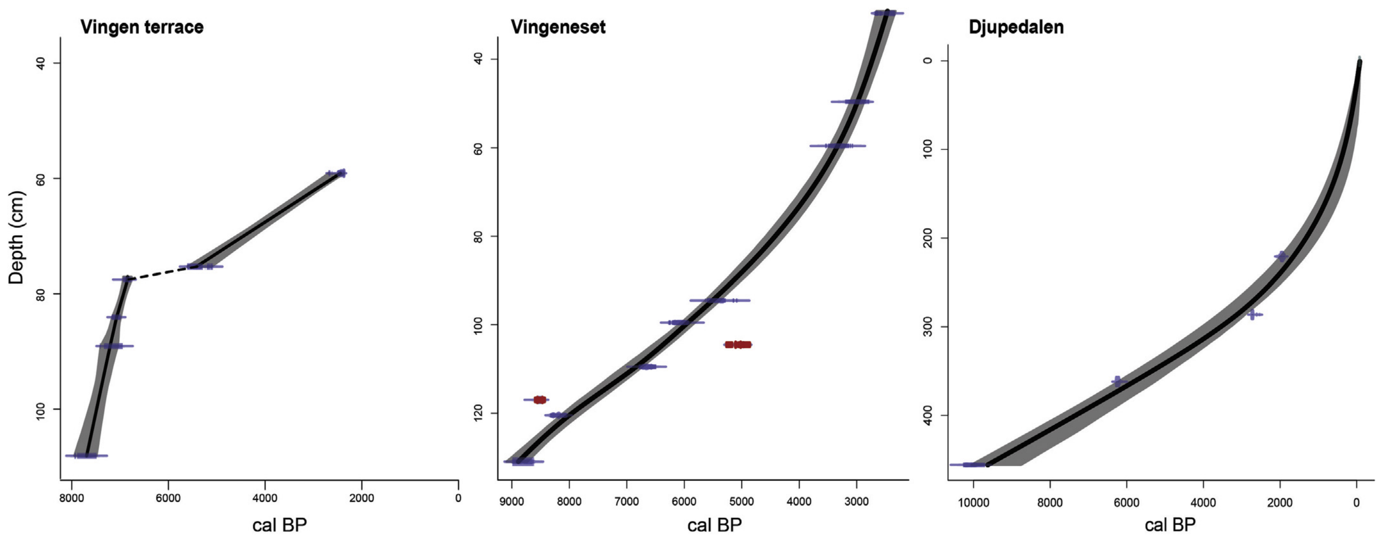


**Fig. 3.** Age depth models for a) Vingen terrace with calibration carried out separately below and above the 75 cm level (see Table 3), b) Vingeneset, and c) Djupedalen.

material, and the presence of young roots. At Djupedalen, a constant sedimentation rate is indicated until c. 2000 cal. BP (Fig. 3, Table 3). From this level to the top, the accumulation rate increases, probably due to a shift from lake sediments to *Sphagnum* peat. The Clam calibrated ages form the basis for the time scales in the pollen diagrams (Figs. 5–7).

### *3.2. Vingen terrace — within the main rock art area*

This area represents the centre of the rock art area, where several larger panels with concentrations of rock art are located in addition to a number of boulders with motifs. Several dwelling depressions have been documented between rock art sites, some of which have been partially excavated (Fig. 1). Radiocarbon dates from the excavated sites are found between 7350 and 6100 cal. BP, with a concentration 6900–6300 cal. BP (Fig. 4, Table 2). Three dates are clearly younger and one date is older. These are supposed to reflect other kinds of activity than rock art production, indicating, contradictory to previous research, exclusively Mesolithic activity. Mesolithic dating is also supported by the archaeological finds; blades, hammer stones, waste flakes, fire cracked rocks, and a diabase chisel, all probably left by the producers and users of the rock art. From investigations of the dwelling depressions, smaller stones with rock art have been documented, indicating more specialized activity, and that these depressions were not necessarily habitation huts. The archaeological data have been described in more detail by Lødøen (2013, 2015).

The pollen core is taken within an archaeological context, reflecting the vegetation prior to, during, and after deposition of the archaeological material at the site (Fig. 5). The site itself is a small hollow which, according to the loss-on-ignition, received minerogenic material from the surroundings during the entire time period included in the study (7700–3200 cal. BP). Marked decreases in loss-on-ignition are found c. 7300, 7150 cal. BP, and 7000 cal. BP, from when LOI is on the same low level until c. 3600 cal. BP.

The pollen diagram reflects open deciduous forest in the Mesolithic, dominated by *Betula* and *Corylus*, with some *Sorbus*, *Prunus padus*, *Salix*, *Viburnum*, and *Juniperus*. *Filipendula* is the dominating herb species, reflecting moist conditions at the sampling site. Herbs such as Poaceae and *Melampyrum* indicate open vegetation. Relatively high values of *Urtica* indicate nitrophilous conditions, and the possibility of human activity. The presence of humans is further indicated by microscopic charcoal and the presence of *Plantago major*, an indicator of trampling. A change towards *Betula* in place of *Corylus*, *Salix* and *Viburnum* as well as an increase in *Filipendula* occurs around 7350 cal. BP. This may reflect forest disturbance followed by local birch expansion. Further disturbance is indicated 7100 cal. BP, when Poaceae, *Urtica* and charcoal increase, several herb taxa are recorded, and macroscopic charcoal is present and dated. Around 6900 cal. BP, *Corylus, Pinus* and *Viburnum* increase, *Betula* decreases, fern spores (Polypodiaceae) have high values, and the maximum value of microscopic charcoal is reached. This is simultaneous with deposition of material from the activity close to the site, and is followed by a period of nearly no accumulation of soil or a hiatus at the site, probably connected to human activity. The next level analysed is c. 5500 cal. BP where pollen from mixed deciduous trees dominates. The first appearance of *Plantago lanceolata* together with other herbs may indicate that the area was sporadically grazed, and microscopic charcoal indicates continued presence of people in the region, also supported by two dates from the archaeological excavations (Table 2). However, the local area seems to have been dominated by shrubs and trees, revealed by the dominance of these and the low values of Poaceae. From c. 4400 cal. BP *Alnus* increases and becomes the dominant deciduous tree.

The PCA of the pollen data (Fig. 8a and b) shows a gradient from *Betula*, *Filipendula*, and *Urtica* on the positive side of the first axis, to *Pinus*, *Alnus* and several herbs on the negative. *Corylus* and *Viburnum* are positively correlated to the second axis, whereas *Vaccinium*, *Empetrum* and Polypodiaceae are found on the negative side. Except for samples T10–T8, all samples from the Mesolithic are found on the positive side of the first axis, separated from samples younger than 7000 cal. BP on the negative side. Charcoal and palynological richness are negatively correlated to the first axis, while LOI is positively correlated to this axis. High palynological richness is estimated in two sample dated to the Mesolithic (T12, 7100 cal. BP and T8, 6850 cal. BP) as well as in T5 (c. 4800 cal. BP) and T4 (c. 4400 cal. BP) dated to the Neolithic (Fig. 5).

Combining all the data, local activity started at latest around 7100 cal. BP and intensified c. 6900 cal. BP. The reason for the low accumulation after 6850 cal. BP is unclear. The constant values of loss-on-ignition does not indicate special disturbances related to a hiatus although the general low values support the presence of people. The continued high values of *Filipendula* do not indicate dry

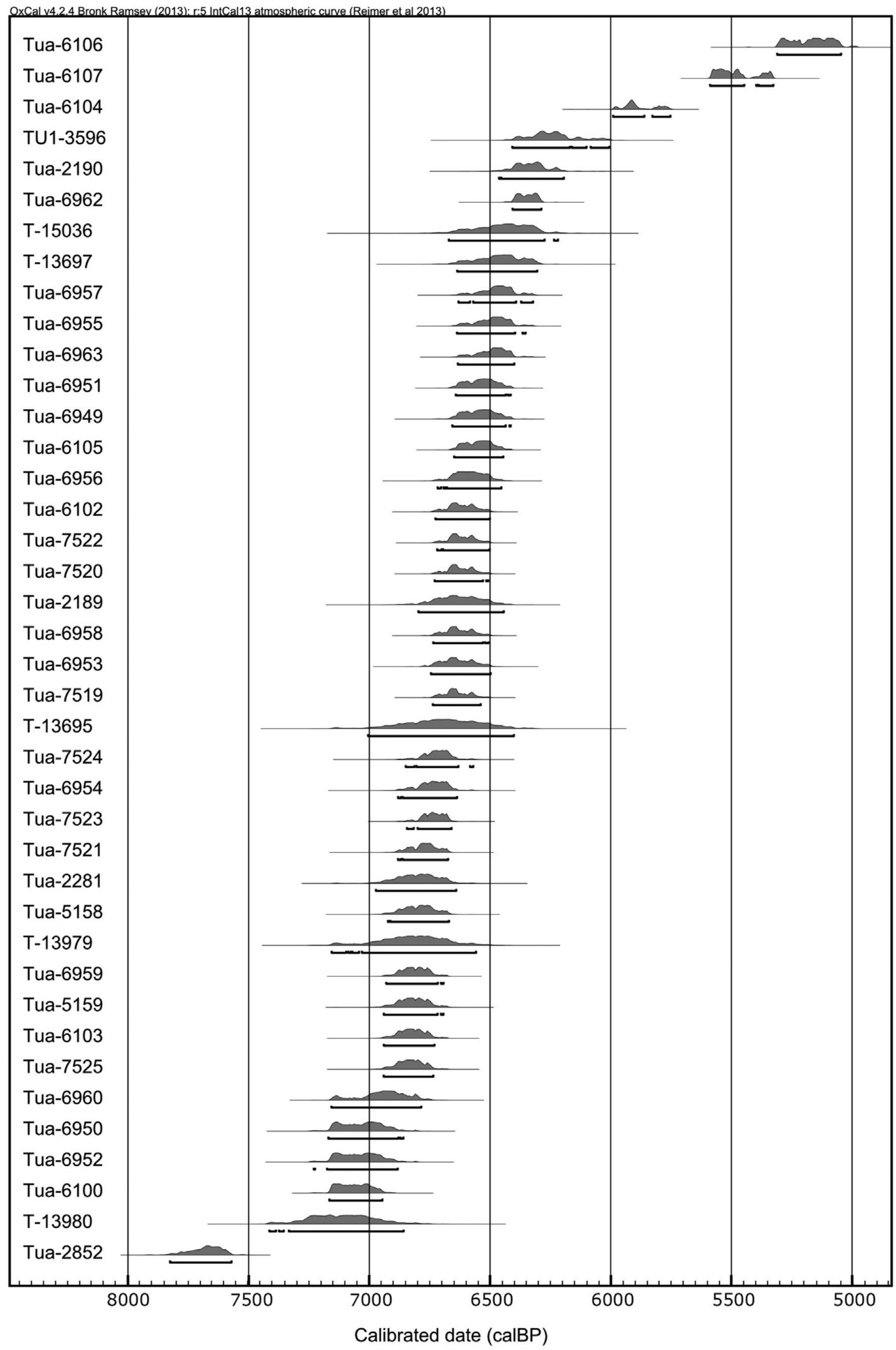


**Fig. 4.** Radiocarbon dates from archaeological excavations at Vingen terrace and Vingeneset. For details, see Table 2.

conditions which could potentially increase the decomposition. It may be that deposition of archaeological material from the nearby site and the presence of people resulted in nearly no accumulation in the period of most intensive activity at Vingen terrace and that peat thereafter developed slowly. This may indicate that the most intensive period was after c. 6850 cal. BP.

### 3.3. *Vingeneset – within the less intensively used rock art area*

Test excavations at Vingeneset have provided some remains from the Late Mesolithic (Fig. 4, Table 2) indicating activity in the vicinity of rock art panels, as well as two Middle Neolithic (5250–4250 cal. BP) sites at some distance to the rock art, which seem to represent later activity than the rock art (Lødøen, 2013). Although less than one hundred images in this area, the distribution follows the larger grand narrative of the area; red deer images mostly depicted on south-facing ledges, oriented as if they are moving eastward.

The pollen diagram (Fig. 6) is in the Mesolithic time period dominated by *Betula* with some *Corylus*, *Salix*, and from ca. 7700 cal. BP also *Alnus*. An open deciduous forest is indicated by the high values of *Melampyrum*, *Filipendula* and Poaceae. Dwarf-shrubs (*Vaccinium*, *Empetrum* and *Calluna*) were probably growing locally together with Cyperaceae. Fluctuations in these as well as in *Alnus*

**Table 2**
Radiocarbon dates from archaeological excavations at Vingen terrace and Vingeneset. Area refers to site location in Fig. 1. Calibrations are carried out using IntCal13 calibration curve (Reimer et al., 2013) within 2 sigma confidence ranges. With the exception of three samples dated to the Neolithic, all dates are Mesolithic (prior to 5950 cal. BP).

| Lab. Ref. | Area (Fig. 1) | Identification of dated charcoal/material | Age ($^{14}$C yr BP) | Age (cal. BP) |
|---|---|---|---|---|
| Tua-6106 | 11 | *Pinus* | 4520 ± 40 | 5310–5047 |
| Tua-6107 | 12 | *Pinus* | 4745 ± 40 | 5588–5328 |
| Tua-6104 | 9 | *Betula, Populus, Salix, Prunus padus, Sorbus, Corylus* | 5145 ± 40 | 5990–5754 |
| TU1-3596 | 5 | *Betula* | 5460 ± 80 | 6407–6009 |
| Tua-2190 | 2 | *Pinus, Corylus, Betula* | 5530 ± 70 | 6453–6197 |
| Tua-6962 | 14 | *Betula* | 5550 ± 40 | 6406–6290 |
| T-15036 | 4 | *Betula, Pinus, Prunus padus/Sorbus* | 5640 ± 105 | 6669–6223 |
| T-13697 | 3 | *Betula, Corylus, Pinus* | 5665 ± 80 | 6635–6308 |
| Tua-6957 | 13 | *Pinus* | 5680 ± 50 | 6631–6324 |
| Tua-6963 | 14 | *Betula* | 5695 ± 45 | 6633–6401 |
| Tua-6955 | 13 | *Betula* | 5695 ± 50 | 6637–6356 |
| Tua-6951 | 13 | *Betula* | 5735 ± 45 | 6642–6416 |
| Tua-6949 | 13 | *Corylus nut shell* | 5740 ± 50 | 6657–6416 |
| Tua-6105 | 10 | *Betula, Populus, Salix, Prunus padus, Sorbus, Corylus* | 5745 ± 40 | 6645–6447 |
| Tua-6956 | 13 | *Pinus* | 5785 ± 50 | 6717–6455 |
| Tua-7522 | 13 | *Corylus nut shell* | 5815 ± 35 | 6719–6505 |
| Tua-6102 | 7 | *Betula* | 5815 ± 40 | 6726–6503 |
| Tua-7520 | 13 | *Corylus* | 5820 ± 35 | 6730–6510 |
| Tua-2189 | 1 | *Pinus, Corylus, Betula* | 5825 ± 75 | 6794–6449 |
| Tua-6958 | 13 | *Pinus* | 5825 ± 40 | 6735–6509 |
| Tua-7519 | 13 | *Salix* | 5830 ± 35 | 6737–6544 |
| Tua-6953 | 13 | *Corylus nut shell* | 5830 ± 50 | 6743–6501 |
| T-13695 | 3 | *Betula, Corylus, Pinus* | 5870 ± 125 | 6993–6408 |
| Tua-7524 | 13 | *Corylus* | 5895 ± 45 | 6829–6638 |
| Tua-6954 | 13 | *Corylus nut shell* | 5910 ± 50 | 6881–6641 |
| Tua-7523 | 13 | *Corylus* | 5915 ± 35 | 6842–6662 |
| Tua-7521 | 13 | *Corylus* | 5945 ± 40 | 6882–6675 |
| Tua-5158 | 15 | *Betula, Corylus, Populus, Salix, Prunus padus, Sorbus* | 5960 ± 50 | 6911–6672 |
| Tua-2281 | 4 | *Betula, Corylus, Salix, Populus, Pinus* | 5960 ± 70 | 6966–6645 |
| T-13979 | 4 | *Betula, Corylus, Pinus* | 5970 ± 105 | 7156–6560 |
| Tua-6959 | 13 | *Pinus* | 5975 ± 40 | 6927–6695 |
| Tua-5159 | 15 | *Betula, Corylus,Populus, Salix, Prunus padus, Sorbus* | 5980 ± 45 | 6940–6695 |
| Tua-6103 | 8 | *Betula, Prunus padus, Sorbus* | 5985 ± 40 | 6937–6734 |
| Tua-7525 | 13 | *Betula* | 5990 ± 40 | 6938–6738 |
| Tua-6960 | 13 | *Pinus* | 6070 ± 60 | 7157–6788 |
| Tua-6950 | 13 | *Corylus nut shell* | 6130 ± 55 | 7170–6863 |
| Tua-6952 | 13 | *Pinus* | 6140 ± 55 | 7175–6884 |
| Tua-6100 | 6 | *Salix/Populus* | 6155 ± 40 | 7164–6950 |
| T-13980 | 4 | *Betula, Corylus, Salix, Populus, Pinus* | 6220 ± 105 | 7414–6811 |
| Tua-2852 | 4 | *Betula, Corylus, Salix, Populus, Pinus* | 6830 ± 70 | 7824–7573 |

and *Betula* between c. 6400–6150 cal. BP, indicate vegetation disturbances. Loss-on-ignition is higher than 90% until c. 6900 cal. BP (although with a small decrease c. 7600 cal. BP), followed by decrease (c. 6600 cal. BP), increase (c. 6400 cal. BP) and a marked decrease to a minimum of around 50% 6200–6000 cal. BP. The amount of organic material then increases, resulting in more than 80% c. 5750 cal. BP and nearly 100% from c. 5600 cal. BP onwards. Increase in minerogenic material is probably caused by erosion due to human activity supported by visible macroscopic charcoal and minerogenic particles in the peat between c. 6250 and 6000 cal. BP. Relatively high values of microscopic charcoal support human activity in the area. During the Neolithic time period deciduous trees dominate with *Betula*, *Alnus*, and *Sorbus* growing on the bog or in the immediate surroundings. *Corylus* was present in the start of the Neolithic, but was less important towards the end. Microscopic charcoal values are high in the Neolithic, possibly related to the Middle Neolithic sites at Vingeneset or sites in other areas. During the Bronze Age the vegetation opened up, and a change from *Betula* to *Pinus* took place. Increases in *Juniperus*, *Calluna*, and several herbs (e.g. Poaceae, *Solidago* type, *Succisa*) and the presence of *Plantago lanceolata*, indicate grazing. Marked increases in *Calluna* and microscopic charcoal reflect heathland development in the Iron Age.

The Vingeneset PCA (Fig. 8c and d) shows a gradient along the first axis from *Betula*, *Corylus*, *Populus* and fern spores on the negative side to *Pinus*, *Juniperus*, *Succisa*, and *Solidago* on the positive. This reflects the importance of *Betula* and *Corylus* in the Mesolithic, where dwarf-shrubs/*Vaccinium* and *Alnus*, respectively, separate the samples along the second axis. Charcoal is negatively correlated to both axes, connected to samples from the Mesolithic and Neolithic. The Bronze Age and Iron Age samples are found along the positive side of the first axis, connected to the increased importance of *Pinus*, *Juniperus*, *Calluna*, and several light demanding herbs, reflecting a new use of the area. LOI and palynological richness are also positively correlated to this axis.

The period between c. 6300 and 6100 cal. BP with a potential start 6600 cal. BP, probably reflect the rock-art production period. Based on the stratgraphy and loss-on-ignition, local disturbance took place at this time. Fluctuations in *Betula*, *Alnus*, dwarf-shrubs and Cyperaceae, indicate vegetation disturbances most probably related to human activity.

### 3.4. Djupedalen – outside the rock art area

Djupedalen represents the outskirts of the rock art area (Fig. 1), where no test excavations have been carried out. Due to its location far from the sea, this area was probably not favourable for human occupation in the Mesolithic. Some smaller panels with rock art are located below this area closer to the shore, with red deer moving eastward.

**Table 3**
Radiocarbon dates from pollen cores at Vingen terrace, Vingeneset and Djupedalen. Calibrations, carried out using the IntCal13 calibration curve (Reimer et al., 2013) in Clam (Blaauw, 2010), are given within 2 sigma confidence ranges, samples marked * represent the archaeological context and is not included in Clam, and samples given in *italic* are treated as outliers in Clam (Fig. 3).

| Lab. Ref. | Depth (cm) | Material dated | Weight | Age ($^{14}$C yr BP) | đ$^{13}$C (o/oo) | Calibrated age (cal. BP) | Archaeological period |
|---|---|---|---|---|---|---|---|
| **Vingen terrace** | | | | | | | |
| Beta-307122 | 59–60 | Peat | – | 2390 ± 30 | −27.5 | 2346–2676 | IA – BA |
| T-16811 | 74–75 | Peat | 10.1 g | 4665 ± 85 | −27.8 | 5063–5590 | NEO |
| TUa-5158* | 75.5–77.5 | Charcoal | – | 5960 ± 50 | – | 6671–6910 | MESO |
| TUa-5159* | 77.5–79.5 | Charcoal | – | 5980 ± 45 | – | 6694–6939 | MESO |
| Beta-408768 | 77.5–78.5 | Charcoal | – | 6010 ± 30 | – | 6757–6939 | MESO |
| Beta-408767 | 84–85 | Charcoal | – | 6180 ± 30 | – | 6992–7167 | MESO |
| T-16812 | 89–90 | Peat | 4.2 g | 6255 ± 80 | −29.1 | 6950–7410 | MESO |
| T-16813 | 108–109 | Peat | 8.0 g | 6815 ± 120 | −28.2 | 7478–7926 | MESO |
| **Vingeneset** | | | | | | | |
| T-16381 | 29.5–30.5 | Peat | 5.5 g | 2420 ± 45 | −29.2 | 2350–2700 | IA – BA |
| T-16382 | 49.5–50.5 | Peat | 4.2 g | 2870 ± 80 | −28.7 | 2794–3210 | BA |
| T-16383 | 59.5–60.5 | Peat | 5.9 g | 3120 ± 85 | −29.0 | 3079–3556 | BA |
| T-15159 | 94.5–95.5 | Peat | 4.4 g | 4710 ± 90 | −30.8 | 5082–5641 | NEO |
| T-15158 | 99.5–100.5 | Peat | 4.8 g | 5295 ± 80 | −30.3 | 5921–6273 | NEO-MESO |
| *TUa-4081* | *104.5–105.5* | *Plant remains* | - | *4410 ± 40* | *−29.1* | *4863–5272* | *NEO* |
| T-15157 | 109.5–110.5 | Peat | 3.0 g | 5840 ± 65 | −30.3 | 6489–6793 | MESO |
| *Tua-4082* | *117–118* | *Plant remains* | - | *7730 ± 50* | *−27.4* | *8421–8591* | *MESO* |
| T-15156 | 120.5–121.5 | Peat | 2.7 g | 7365 ± 60 | −29.7 | 8034–8327 | MESO |
| T-14859 | 131–133 | Peat | 7.1 g | 7930 ± 95 | −29.7 | 8609–8984 | MESO |
| **Djupedalen** | | | | | | | |
| Beta-451878 | 220–221 | Plant remains | 0.028 g | 2020 ± 30 | −27.1 | 1894–2051 | IA |
| Beta-441044 | 285.5–286.5 | Plant remains | 0.024 g | 2590 ± 30 | −26.6 | 2546–2767 | BA |
| Beta-441043 | 361–362 | Plant remains | 0.036 g | 5420 ± 30 | −26.2 | 6188–6287 | MESO |
| T-14860 | 455–460 | Bulk sediment | 7.0 g | 8945 ± 105 | −26.5 | 9692–10,261 | MESO |

Abbreviations: IA (Iron Age), BA (Bronze Age), NEO (Neolithic), MESO (Mesolithic).

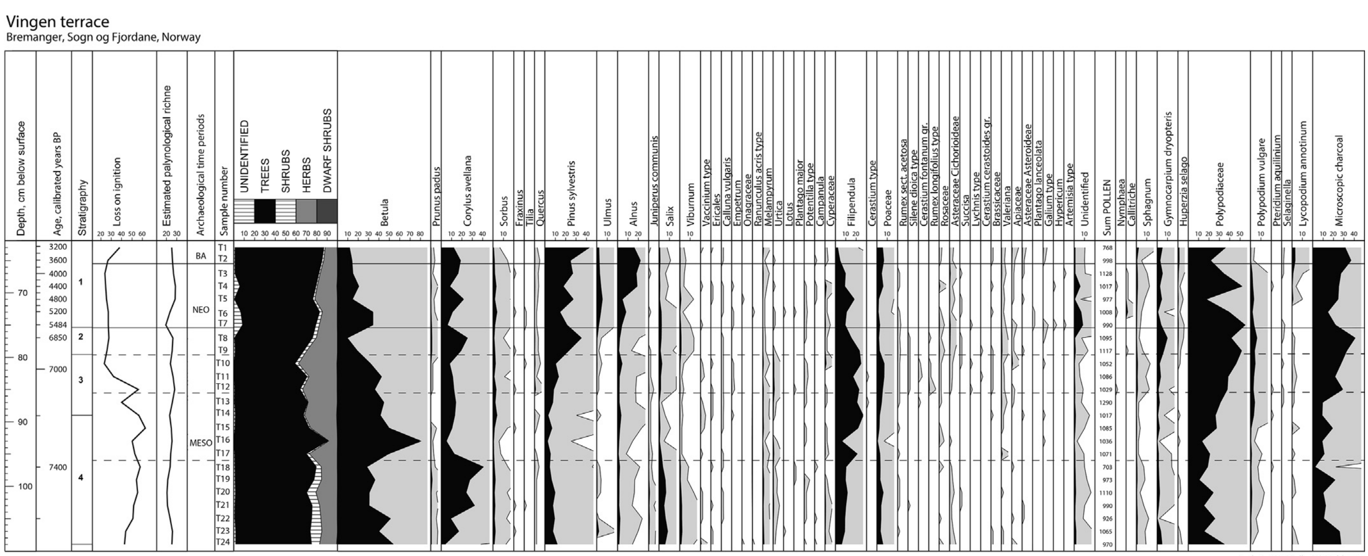


**Fig. 5.** Pollen percentage diagram from the Vingen terrace. Stratigraphy in the pollen core: 1, 60.5–75.5 cm: Decomposed peat; 2, 75.5–79.5 cm: Peat/cultural layer containing stones and charcoal; 3, 79.5–89 cm: Peat containing stones and some charcoal; 4, 89–110 cm: Peat containing macroscopic plant remains. Abbreviations for archaeological time periods: BA (Bronze Age, 3750–2450 cal. BP), NEO (Neolithic, 5950–3750 cal. BP), MESO (Mesolithic, until 5950 cal. BP).

The Djupedalen site is today a bog with some areas of open water. The pollen diagram (Fig. 7) reflects the time period c. 9400–1000 cal. BP. Until c. 9000 cal. BP, the vegetation was dominated by *Betula* with some *Corylus*, *Sorbus* and *Salix*. From that time and through the Mesolithic, mixed forests of *Betula*, *Corylus* and some *Pinus* were growing in the area, a bit later also *Alnus*, and with scattered occurrences of *Populus*, *Sorbus* and *Salix*. The forest was probably open, with species like *Juniperus*, *Calluna*, *Filipendula*, *Melampyrum*, Poaceae and Cyperaceae being constantly present. *Urtica* has scattered occurrences and microscopic charcoal is present, indicating some human activity in the region. From c. 6300 to 5600 cal. BP the tree pollen percentages are at their highest. A gradual opening-up of the forest is indicated through decreasing tree pollen percentages during the Neolithic and Bronze Age. *Pinus* increases with a first maximum c. 4800 cal. BP and a second c. 2600 cal. BP, concurrent with increases in *Calluna* and *Juniperus* and decreases in *Alnus*, *Betula* and *Corylus*. This development continued into the Iron Age, and scattered pollen grains of *Plantago lanceolata* found from the end of the Bronze Age, support heathland development and grazing.

The loss-on-ignition increases until c. 8600 cal. BP, reflecting increased organic production in the lake and development of

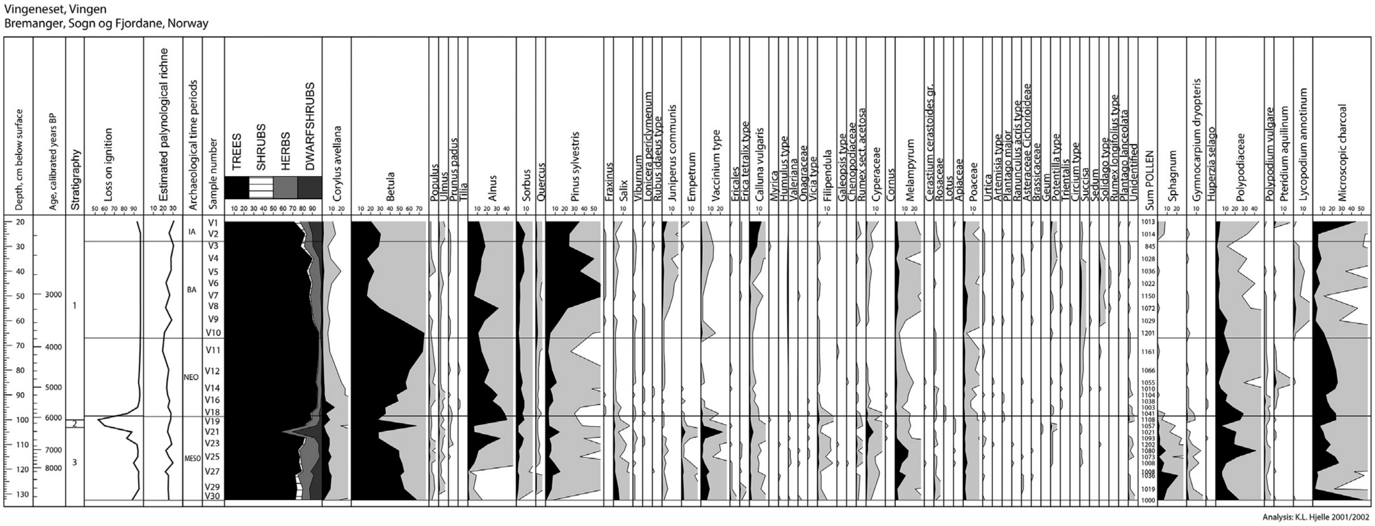


**Fig. 6.** Pollen percentage diagram from Vingeneset. Stratigraphy in the pollen core: 1, 19–100 cm: Peat; 2, 100–103 cm: Peat containing sand and charcoal; 3, 103–133 cm, Peat. Abbreviations for archaeological time periods: IA (Iron Age, from 2450 cal. BP), BA (Bronze Age, 3750–2450 cal. BP), NEO (Neolithic, 5950–3750 cal. BP), MESO (Mesolithic, until 5950 cal. BP).

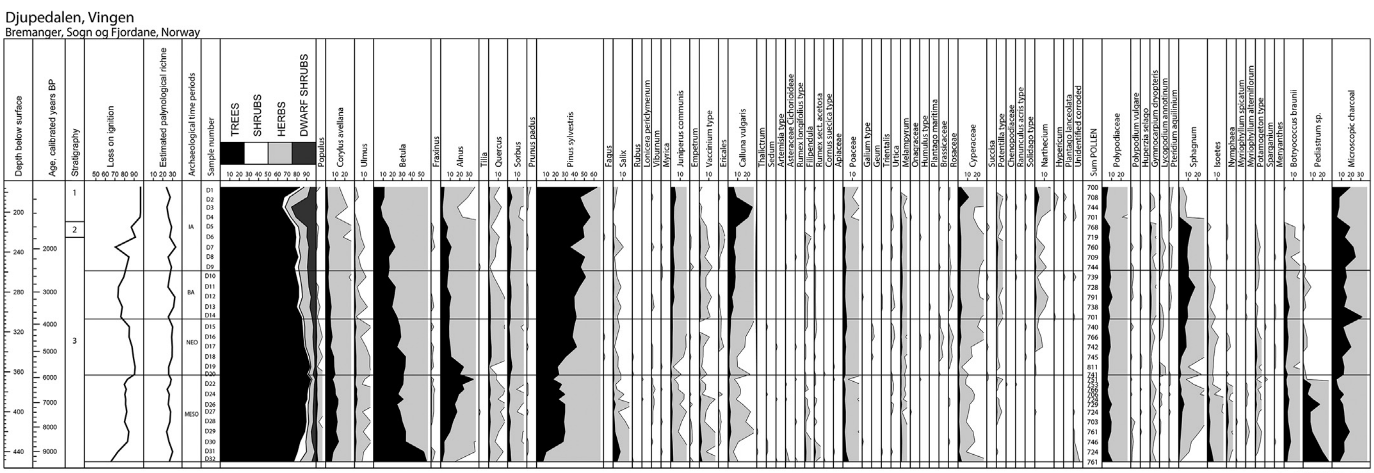


**Fig. 7.** Pollen percentage diagram from Djupedalen. Stratigraphy in the pollen core: 1, 170–214 cm: *Sphagnum* peat with macroscopic plant remains (mosses, twigs); 2, 214–225 cm: Transition gytja – peat; 3, 225–460 cm: Gytja with increasing amount of macroscopic plant remains towards the top. Abbreviations for archaeological time periods: IA (Iron Age, from 2450 cal. BP), BA (Bronze Age, 3750–2450 cal. BP), NEO (Neolithic, 5950–3750 cal. BP), MESO (Mesolithic, until 5950 cal. BP).

vegetation around the lake. From c. 7800 to 6100 cal. BP, slightly lower values may indicate minerogenic input. This is followed by increased loss-on-ignition to around 90% at the transition Mesolithic – Neolithic, probably reflecting infilling of the lake (decreases in *Pediastrum*, *Nymphaea* and *Isoetes*) and the development of a *Sphagnum* peat bog closer to the coring site. A decrease towards 80% takes place during the Neolithic, with further reduction in the Bronze Age. The fluctuations most probably reflect minerogenic input and continued infilling of the lake. From c. 1450 cal. BP the loss-on-ignition is close to 100% and peat developed at the site.

Djupedalen PCA (Fig. 8e and f) shows a gradient from dominance of *Betula*, *Populus*, *Corylus*, and *Ulmus* on the negative side of the first axis, to *Calluna*, *Narthecium*, *Pinus*, and *Juniperus* on the positive side. *Salix*, *Filipendula* and Poaceae are positively correlated to the second axis whereas *Alnus* is found on the negative side. The samples from the Mesolithic and first part of the Neolithic are found on the negative side, separated from the younger samples on the positive. Palynological richness and LOI are negatively correlated, and charcoal is unrelated to them.

### 3.5. Land cover reconstructions

Pollen percentages for trees and shrubs together with reconstructed regional and local forest cover in five hundred year time intervals, are shown in Fig. 9. Generally the pollen percentages are higher than the reconstructed vegetation cover. The regional forest cover is estimated to have been >80% from 9200 to 8200 cal. BP, when all three sites are used in REVEALS. From 8200 to 6200 cal. BP the forest cover is estimated between 70 and 80%, with a minimum 7200–6700 cal. BP. At the end of the Mesolithic (6200–5700 cal. BP) the REVEALS-estimated forest cover increases and is >80% until 4700–4200 cal. BP, from when the regional vegetation gradually opens up, reaching c. 60% 2700–2200 cal. BP.

The local vegetation reconstructions using LOVE indicate more open vegetation at Vingen terrace than at Vingeneset through prehistory (Figs. 9 and 10), in accordance with the density of rock art panels. In the time window 7200–6700 cal. BP, including the period of local activity, the LOVE-estimated forest cover is at its lowest (53%). The period 6700–5700 cal. BP lack data from Vingen

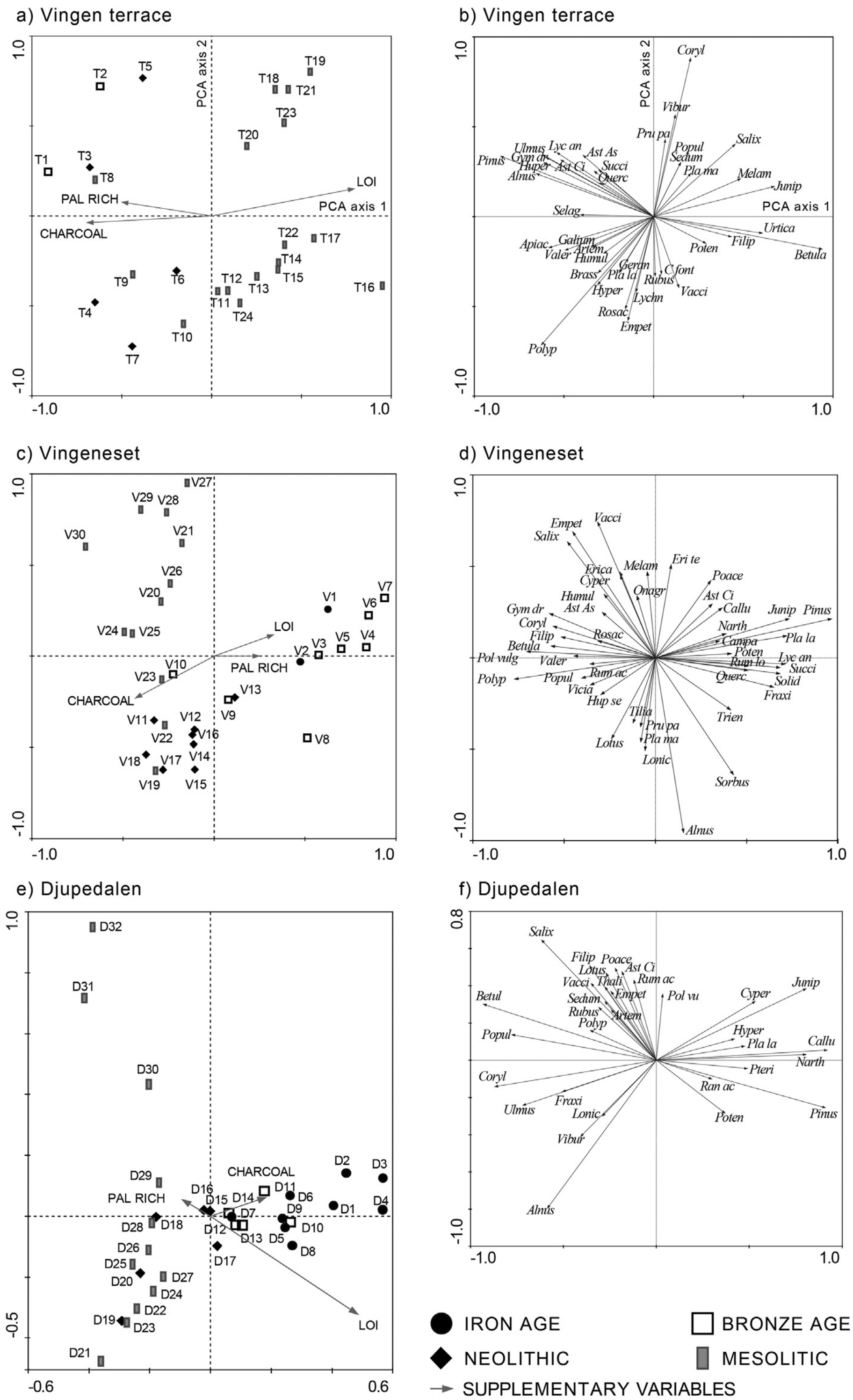


**Fig. 8.** Principal Component Analysis (PCA) scatter plots from the three sites Vingen terrace (a,b), Vingeneset (c, d) and Djupedalen (e, f) showing samples and supplementary environmental variables (a, c, e) and species (b, d, f). Abbreviations: PAL RICH – estimated palynological richness; LOI – loss-on-ignition; Full names for species are given in the pollen diagrams, Figs. 5–7.

terrace. Forest cover close to 70% is estimated from 5700 to 3200 cal. BP, with a period of more open vegetation 4700–4200 cal. BP. At Vingeneset, an open forest is indicated in the Mesolithic, with the lowest LOVE-estimated forest cover 6700–6200 cal. BP (51%), concurrent with the period of lowest loss-on-ignition and forest disturbances. The LOVE-estimated forest cover increases at the end of the Mesolithic, and a quite dense forest (>90% cover) is estimated from 5700 to 3200 cal. BP. In the youngest time window (2700–2200 cal. BP), the forest has again opened up, and a cover of 66% is estimated.

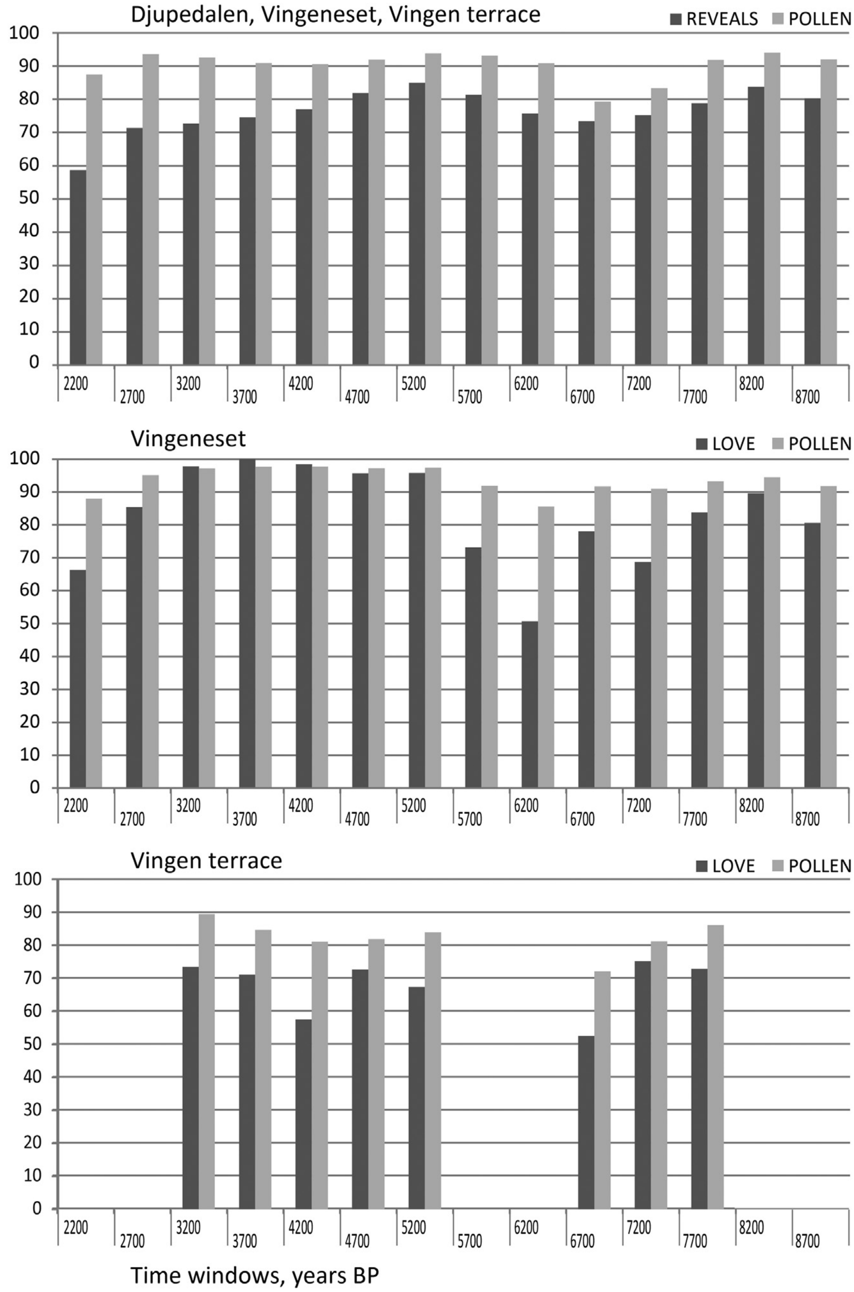


**Fig. 9.** Comparison of LRA-estimates of forest (trees and shrubs) cover and pollen percentages of trees and shrubs, for five hundred year time intervals. REVEALS is used for the three sites Djupedalen, Vingeneset and Vingen terrace, LOVE for Vingeneset and Vingen terrace.

## 4. Discussion

The approach chosen demonstrates clear concurrences between the activity recorded in the pollen cores and the radiocarbon dates from the archaeological contexts (Fig. 10), showing that the main activity – which we assume was also responsible for the rock art production – took place during the last millennium of the Late Mesolithic, and came to an end a few centuries before the end of the Late Mesolithic. Dates from archaeological contexts indicate that the rock art was produced between 6900 and 6300 cal. BP, but suggests that some activity took place as early as 7350 cal. BP and ended 6100 cal. BP. The three pollen diagrams reflect different areas, with the Djupedalen site at some distance from the rock art panels. This basin is larger than the two other sites, implying that it reflects pollen from a wider area, probably including the main rock art area some 800 m away (cf. Hjelle and Sugita, 2012). The sites at Vingeneset and Vingen terrace are smaller and were probably found within forested landscapes in most of the time period studied, justifying local vegetation reconstructions within a radius of maximum 400 m surrounding the sites (cf. Broström et al., 2005; Sugita, 1994). The most distinct signals of activity are found at Vingeneset between c. 6600 and 6100 cal. BP: decrease in loss-on-ignition indicating erosion, human induced vegetation disturbances, and a marked forest opening in the time window 6700–6200 cal. BP estimated by LOVE-reconstructions, an opening on a scale not found in later time periods covered by this study. Loss-on-ignition fluctuates in the Mesolithic, in contrast to the constantly high values in later periods. This may be due to a thinner

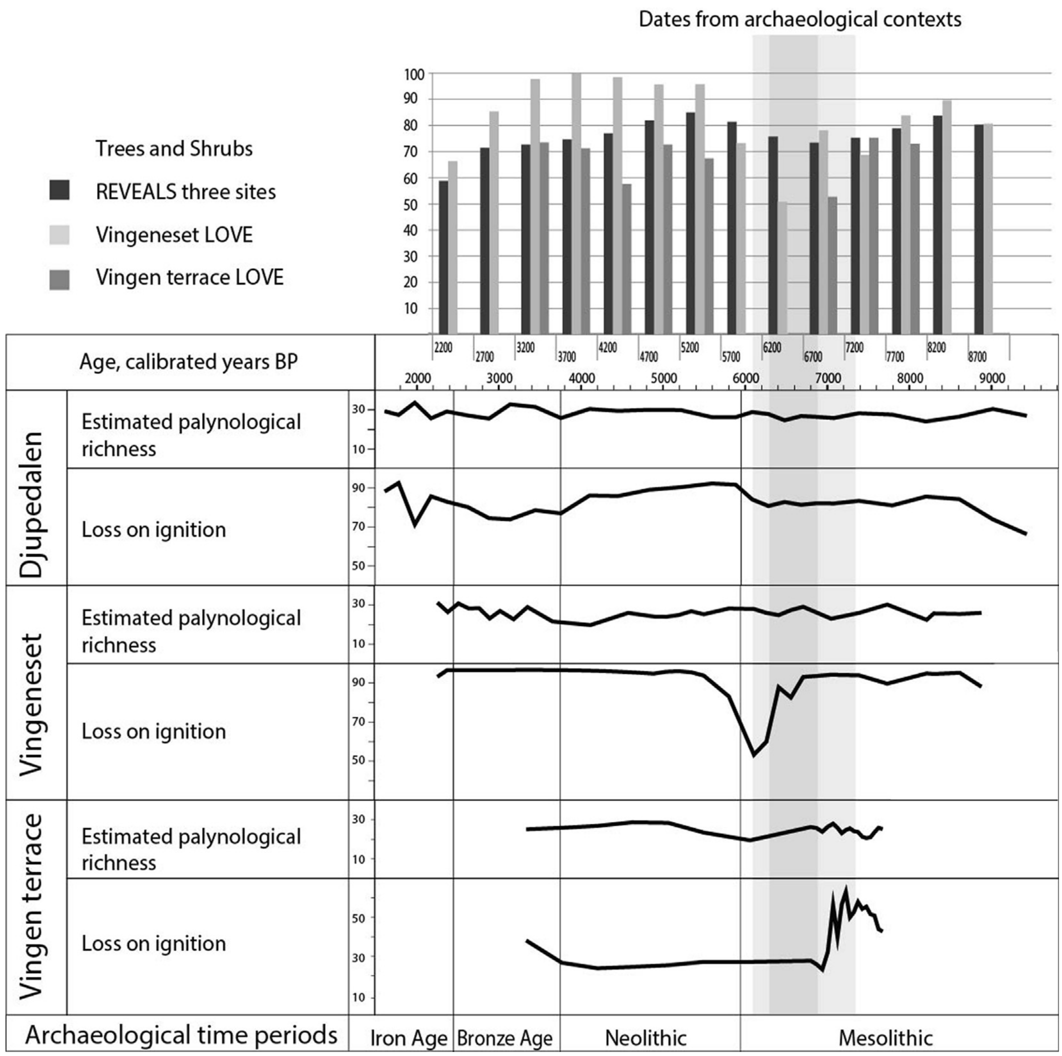


**Fig. 10.** Compiled figure showing REVEALS and LOVE estimated forest cover, loss-on-ignition, and estimated palynological richness through time for the three sites. Vertically, the time periods covered by most radiocarbon dates from archaeological excavations are given (see Fig. 4, Table 2 and the text for further information).

soil cover and shorter distance from a shallow peat bog to the surrounding, probably bare bedrock, than later. However, the higher LOI prior to 6600 cal. BP support the effect of human activity. The activity need not be connected to the production of rock art, but the next phase of pronounced activity at Vingeneset is in the Bronze Age, an age which is less likely for the production of *Northern Tradition* rock art (Sognnes, 2001).

The most pronounced activity at Vingen terrace took place after 7100 cal. BP, with concurrent indications in the loss-on-ignition, macroscopic charcoal, vegetation disturbances and high palynological richness within the time window estimated to have the lowest forest cover using LOVE. The slow accumulation rate at the site after 6850 cal. BP is probably a reflection of continued high human activity for a period of time. This means that the end of the activity is not recorded from Vingen terrace, lacking pollen records for a thousand year time interval. However, LOVE-estimates both at Vingeneset (6200–5200 cal. BP) and Vingen terrace (5700–5200 cal. BP) show high forest cover at the beginning of the Neolithic. This is a strong indication that the rock-art production had come to an end. The presence of microscopic charcoal in both diagrams in the Neolithic and the signs of human activity in the Vingen terrace diagram, probably reflect long-distance transport or sporadic visits to the area from people living in neighbouring areas, such as Skatestraumen or Rugsund, two nearby tidal currents with documented settlement both in the Mesolithic and the Neolithic (Bergsvik, 2002; Bjørkli and Lødøen, 2011).

Also in Djupedalen, a decrease in loss-on-ignition is recorded in the Mesolithic, already 7800 cal. BP, and is quite constant until c. 6300 cal. BP, after which it increases. Although human activity cannot be ruled out, it is reasonable to connect the LOI-values to natural development of the lake. The pollen data shows the highest tree pollen percentages around the Mesolithic/Neolithic transition (5950 cal. BP), followed by a transition from deciduous forest to more open mixed pine forest in the Neolithic. The regional vegetation estimates, combining all three diagrams, indicate lower forest cover between 7700 and 6200 cal. BP than in the centuries prior to and after this time.

One limitation for the local estimated forest cover based on LRA (Sugita, 2007a, 2007b), is that only two sites are available for estimating regional vegetation composition as input data in LOVE. With an increased number of sites, the estimates of the regional vegetation would have been improved, also resulting in improved local vegetation reconstructions. However, combined with the archaeological data the investigation demonstrates the potential of using LOVE for identifying local anthropogenic changes in vegetation cover in the Mesolithic.

Albeit with different intensities and traces, all three palynologically investigated sites reveal signs of human activity in the Late Mesolithic. The effects on the forest composition on the local scale at Vingen terrace and Vingeneset, as well as loss-on-ignition in the Mesolithic time period at these two sites, seem to be too large to be caused by sporadic visits, in concordance with the presence of consistent archaeological material dated to the Late Mesolithic. The variation in signals at the different sites probably reflect activity in several shorter time periods within the larger time frame. It is still not clear what kind of activity that took place in this area, apart from the production of rock art. It is, however, clear from the presence of cultural layers and charcoal concentrations, that firewood was collected and burned. The correspondence between the species of the dated charcoal and the pollen diagrams indicates the use of local vegetation for firewood. The documentation of large numbers of fire cracked rocks that were clearly heated by firewood, in particular at the Vingen terrace, adds to this picture (Lødøen, 2013). Decrease in forest cover may therefore have been caused by the firewood collection. However, also deliberate clearance may have been carried out, in order to secure access and visibility of the rock art.

## 5. Conclusions

The distinct pattern given by the radiocarbon dates from the archaeological sites, pollen analysis, land-cover reconstructions and loss-on-ignition, provide convincing dates for the main activity period in Vingen. The combination of pollen cores from different sites (at different distances from the central rock art area), demonstrate the value of analysing more than one pollen diagram from a relatively small area. The transformation of pollen percentage data to estimates of vegetation cover using LRA was shown to be a further improvement to the methodology for identifying vegetation changes in the Mesolithic, a time period dominated by deciduous forests with few anthropogenic indicators in the pollen diagrams.

The archaeological excavations may not have captured all activity, but have documented human occupation during the last millennium of the Late Mesolithic which came to an end a few centuries before the start of the Neolithic, clearly in line with the impact demonstrated by the pollen cores. At the Vingen terrace, the activity started c. 7100 cal. BP and was high around 6850 cal. BP. At Vingeneset, the main activity have taken place between 6600 and 6100 cal. BP, with lowest estimated tree cover 6700–6200 cal. BP. The archaeological data indicate a main phase between 6900 and 6300 cal. BP. Based on our investigations, we infer that the *Northern Tradition* rock art phase can be dated within the time frame 6900–6100 cal. BP. The rock art production might have been restricted to shorter time frames within this period.

The study demonstrates the high potential of archaeological excavations and palynological investigations for dating of rock art. It also shows a strong correlation between human impact and land-cover changes, which may be of general interest for identification of human-induced land-cover changes in the past.

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