XXXVI INTERNATIONAL BOG (’MOOR’) EXCURSION OF THE
INSTITUTE OF PLANT SCIENCES, UNIVERSITY OF BERN

SOUTHERN AND SOUTH-EASTERN NORWAY

8-13 September 2012

EXCURSION GUIDE

Organised by
Hilary Birks, John Birks, Anne E. Bjune, and Vivian A. Felde

With contributions from
Nancy Bigelow, Steve Brooks, Wenche Eide, John-Arvid Grytnes, Oliver Heiri, Britta Lüder, Asbjørn Moen, Atle Nesje, Mikael Ohlson, Sylvia Peglar, Sakari Salonen, Lotte Selsing, Heikki Seppä, and Rolf Sørensen

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ITINERARY

Day 1 – Sept 8	Oslo – Kisselbergmosen - Askim Leaders: John Birks and Mikael Ohlson Stay overnight at Smaalenene Hotel (http://www.smaalenene-hotell.no).
Day 2 – Sept 9	Ferry Moss – Horten - Siljan – Årum – Vindfjelltunet Leaders: Anne E. Bjune, Mikael Ohlson Stay overnight at Vindfjelltunet (http://www.vindfjell.no/)
Day 3 – Sept 10	Vindfjelltunet – Larvik - Lillesand Leaders: Anne E. Bjune, Rolf Sørensen Stay overnight at Lillesand Hotel Norge (http://www.hotelnorge.no/)
Day 4 – Sept 11	Lillesand – Setesdal – Bykle - Vågslidtun Leaders: John Birks, Hilary Birks Stay overnight at Vågslidtun (http://visithaukeli.org/Aktoer/Vaagslidtun-Hotell).
Day 5 – Sept 12	Vågslidtun – northern Setesdal – Haukeli - Vågslidtun Leaders: Vivian A. Felde, John Birks, Hilary Birks Stay overnight at Vågslidtun
Day 6 – Sept 13	Vågslidtun – Åmot – Rjukan - Gardermoen Leaders: John Birks, Hilary Birks, Anne E. Bjune Return home or stay overnight somewhere near airport

Acknowledgements

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INTRODUCTION TO SOUTHERN AND SOUTH-EASTERN NORWAY

Introduction – John Birks

This excursion is designed to show you recent palaeoecological and ecological studies in southern and south-eastern Norway. Many of these studies concern aspects of forest history and ecology. We will travel as far west as Setesdal, a long valley running from Kristiansand in the south to the edge of the Hardangervidda in the north. Setesdal is an area where several palaeoecological studies have been made or are currently in progress.

The introductory part of this excursion guide provides an introduction to various aspects of Norway's environment (climate, geology, soils) and flora, vegetation, and land-use. It draws extensively on Asbjørn Moen's (1999) masterly *National Atlas of Norway: Vegetation* published by the Norwegian Mapping Authority, Hønefoss (ISBN: 82-7945-000-9 Vegetation). Map numbers refer to the numbers in Moen (1999) which are on the maps in this guidebook. They are not consecutive!

Map 12 shows elevation in Norway and one can see that on this excursion we will almost entirely be below 900-1200 m. Maps 13 and 14 summarise the bedrock geology, Map 15 the superficial deposits, and Map 16 areas rich in nutrients, mainly calcareous phyllitic schist and thick marine deposits.

Aspects of Norway's climate are summarised in Maps 6-11. These maps show the strong gradient in July temperature, length of the growing season, annual temperature and precipitation, and the strong southern and western gradients in January temperature. These regional climate gradients and their regional associated vegetation patterns form the underlying design of the Oslo-to-Trondheim transect of regional-scale pollen sites that we will discuss on Day 1 and of the Setesdal transect of pollen and other palaeoecological sites that we visit and discuss on Days 4 and 5.

Map 19 illustrates the juxtaposition of the major floristic provinces of northern and western Europe in southern and south-east Norway. The five main floristic elements and their associated four floristic sub-elements are also listed.

Representative plant distributions within these main floristic elements are shown in Maps 21-24 (Western), 26-29 (Southern), 31-34 (South-eastern), 36-39 (Eastern), and 41-44 (Alpine and northern boreal). Maps 47 and 48 show the detailed distributions of western species in areas with mild winters (*Erica cinerea, Primula vulgaris*) (0°C, –2°C January isotherms) (Map 47) or in areas with less mild winters (*Luzula sylvatica, Narthecium ossifragum*) (–4°C, –8°C January isotherms) (Map 48).

General temperature limit curves are shown for ten species in relation to the average temperatures of the coldest and warmest months (cf. Iversen's thermal-limits for *Viscum, Hedera*, and *Ilex*).

The potential controls of the distribution of plants with an Eastern distribution and a Southern distribution are discussed in terms of possible physiological constraints. The concept of Respiration sums (Map 50) is a useful measure of growth potential within a particular area and its climate. Maps 51 and 52 show the distribution of *Cornus sanguinea* and *Agrimonia eupatoria* (two species with a south-eastern distribution) in relation to Dahl's respiration sum of 7 and 6, respectively.

Although we will probably not visit any alpine areas, Maps 53-55 and associated text summarise possible controls on the distribution of arctic-alpine plants in Norway.

The typical elevational zonation of vegetation in Norway is summarised on p.34 (Fig. 17).

The six major vegetation zones for western and southern Norway are illustrated in Map 70.

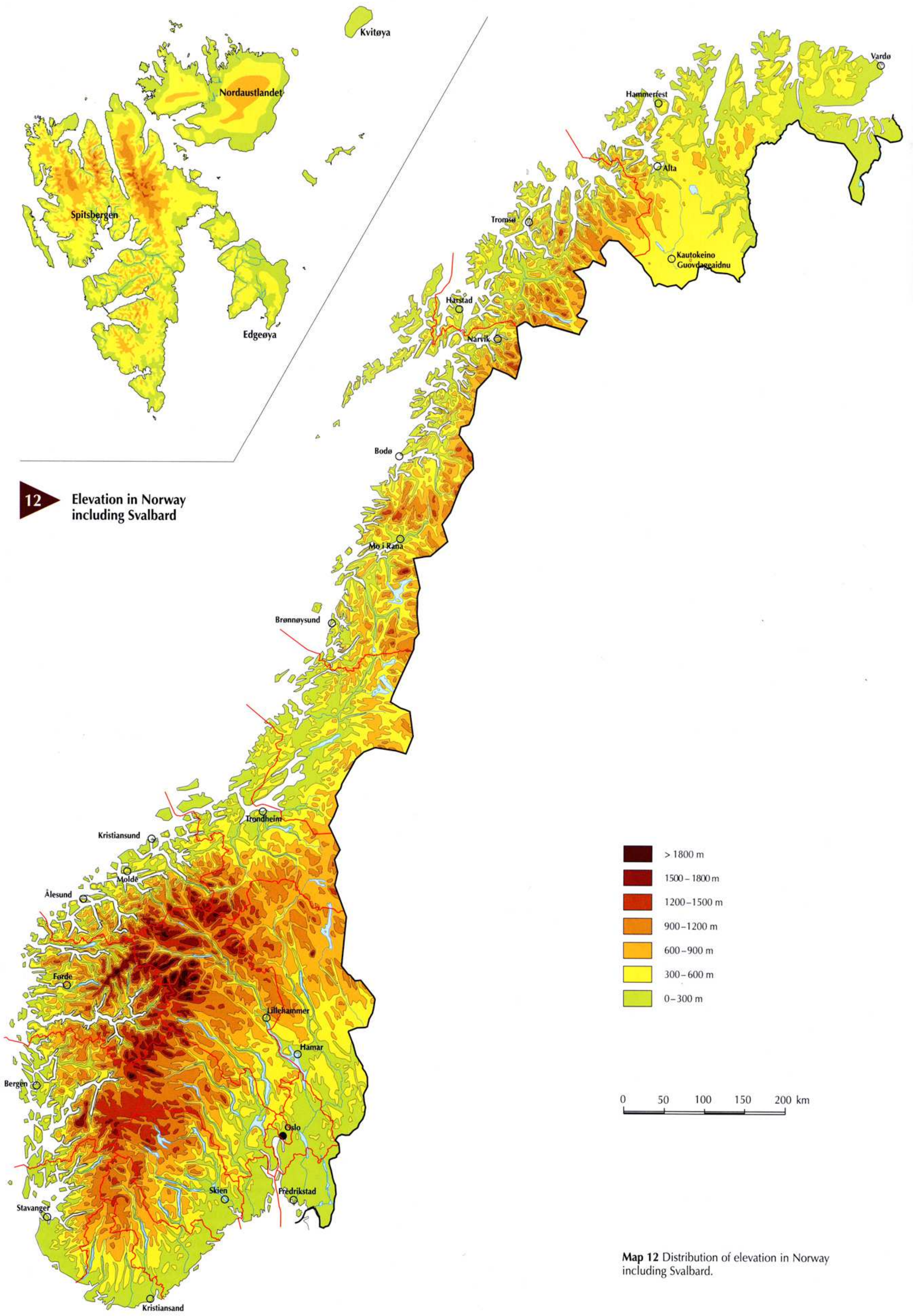
Map 72 shows the distribution of the nemoral zone in Norway and Map 58 the northern limits of the main deciduous-forest trees. Map 73 shows the distribution of the boreo-nemoral zone in Norway and lists some characteristic species. The distribution of the southern boreal zone is illustrated in Maps 75 and 76. On Map 76 isolines of the upper limit of the southern boreal zone are shown with a progressive drop towards the west and the north.

The middle boreal zone, its elevational limits of the upper boundary, and a list of characteristic species are shown in Maps 77 and 78. The distribution of the northern boreal zone and some characteristic species are shown in Map 79. The elevation of the upper woodland limit in Norway is shown in Map 80, whereas the elevation of the climatic coniferous limit is given in Map 81. Maps 82 and 83 and associated text illustrate the low-alpine. Common vegetation zonations in poor- and rich-alpine vegetation are also shown, alongside a list of characteristic middle- and high-alpine species.

Map 88 shows vegetation sections defined primarily on differences in oceanity, whereas Map 95 shows Moen's vegetation ecological regions that combine vegetation zones and vegetation sections to create what he terms 'zonal sections'. Studies on modern pollen assemblages from small lakes in many of these ecological regions show that the regions are **not** distinguishable by their modern pollen assemblages, whereas the vegetation zones (Map 70) generally produce distinctive modern pollen assemblages. The climatic parameters of these zones and sections are also shown.

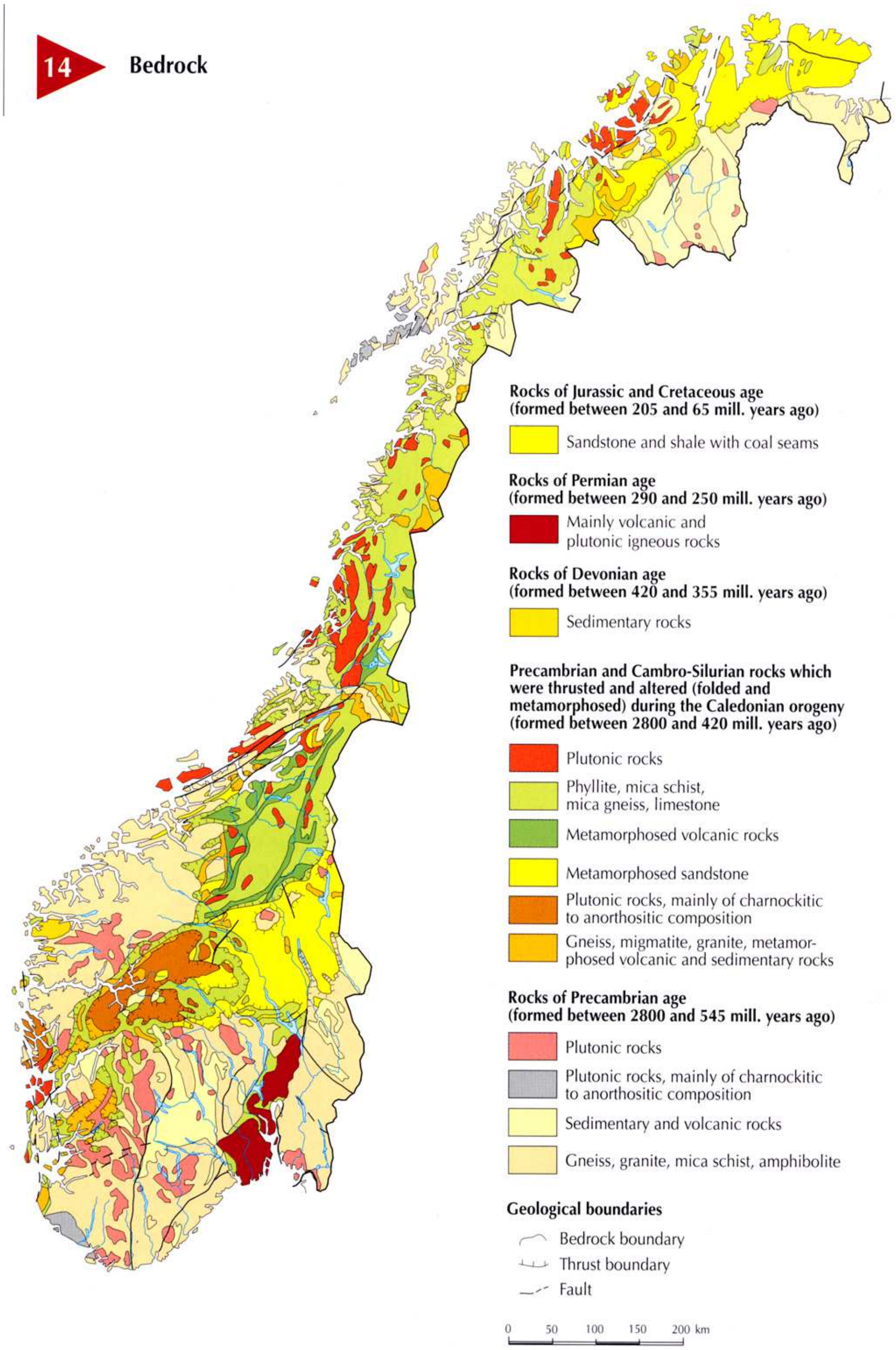
The duration of snow cover and its duration in different zones and sections are show in Map 97. A summary of the frost sums, an important physiological parameter, in the sections and zones is also given.

Turning to land-use and cultural landscapes, Map 99 shows the current distribution of cereal-growing districts in Norway whereas Map 98 shows where fruit-growing districts are. A typical layout of farms, summer dairy farms ('seter'), and hay-barns in Rindal is shown in Map 100 in relation to the main vegetation zones. It illustrates that buildings and barns are confined to the northern boreal or lower zones, but not in the alpine zones.

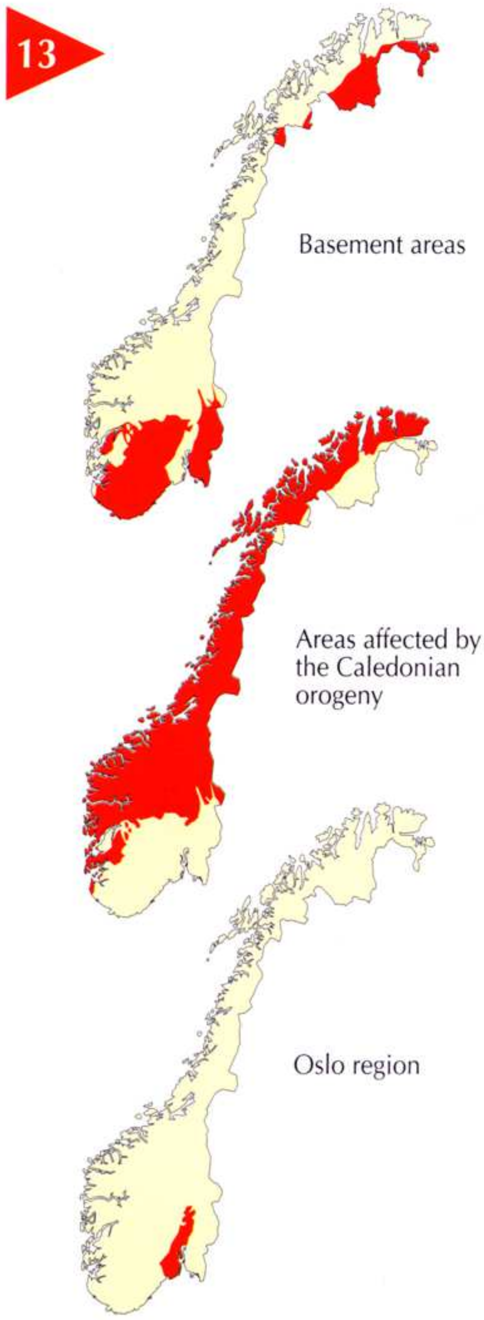


Map 12 Distribution of elevation in Norway and Svalbard.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

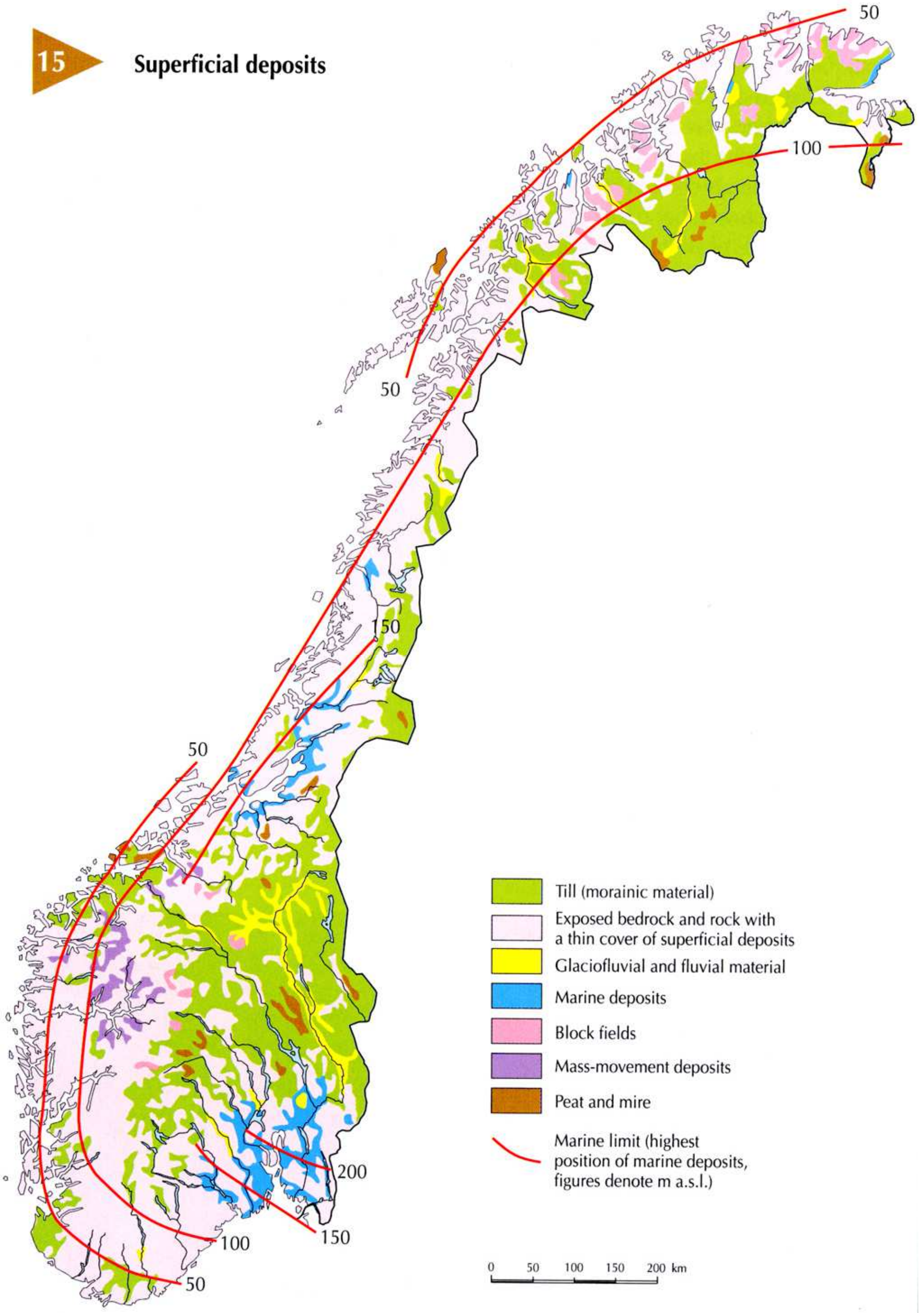


Map 14 The map shows the broad distribution of various kinds of rock in Norway. The rock groups are arranged according to age, the oldest being placed lowermost in the key. The oldest rocks in Norway are some 2800 million years old, the youngest about 100 million years. Precambrian rocks (e.g. gneiss and granite) largely weather slowly, resulting in coarse-grained weathering products which release few mineral nutrients that are important for plant growth. These rocks cover large areas in south-east Norway, the northernmost part of west Norway, outer Trøndelag, outer Troms and Finnmark. During the Cambro-Silurian period, Norway was covered by an ocean. Characteristic rocks from this period are phyllite, mica schist, and metamorphosed limestone (marble). Such rocks, found in a belt from Rogaland to Finnmark, and also in the Oslo region, are often carbonate-rich, or contain other mineral nutrients that are valuable for plant growth. From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

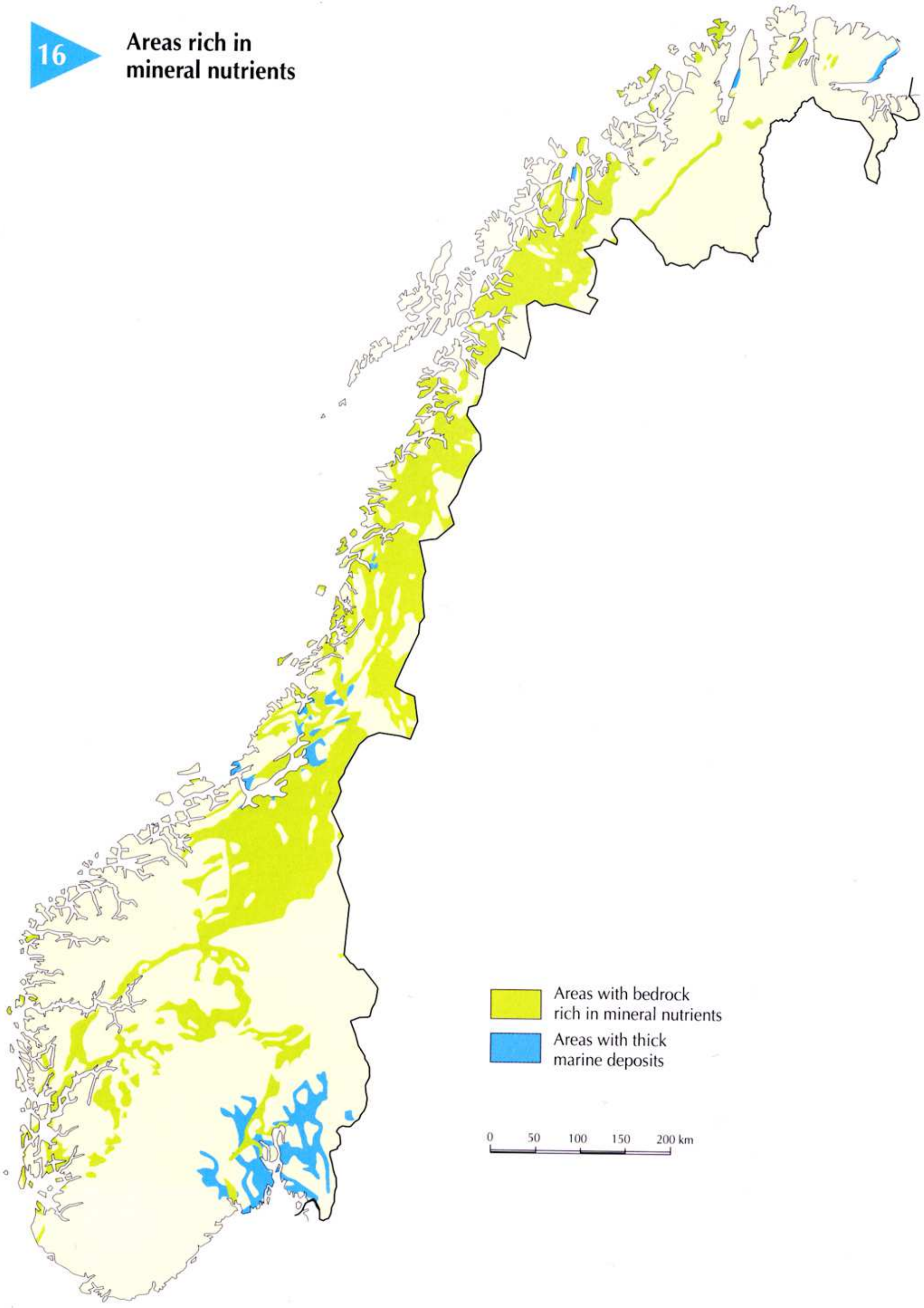


Map 13 These small maps show the Precambrian basement areas, where ancient, hard rock have been little affected by younger earth movements, areas where the Caledonian orogeny has strongly deformed and altered the original bedrock, and the ’Oslo region’ rocks formed by volcanic activity in the Permian era.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

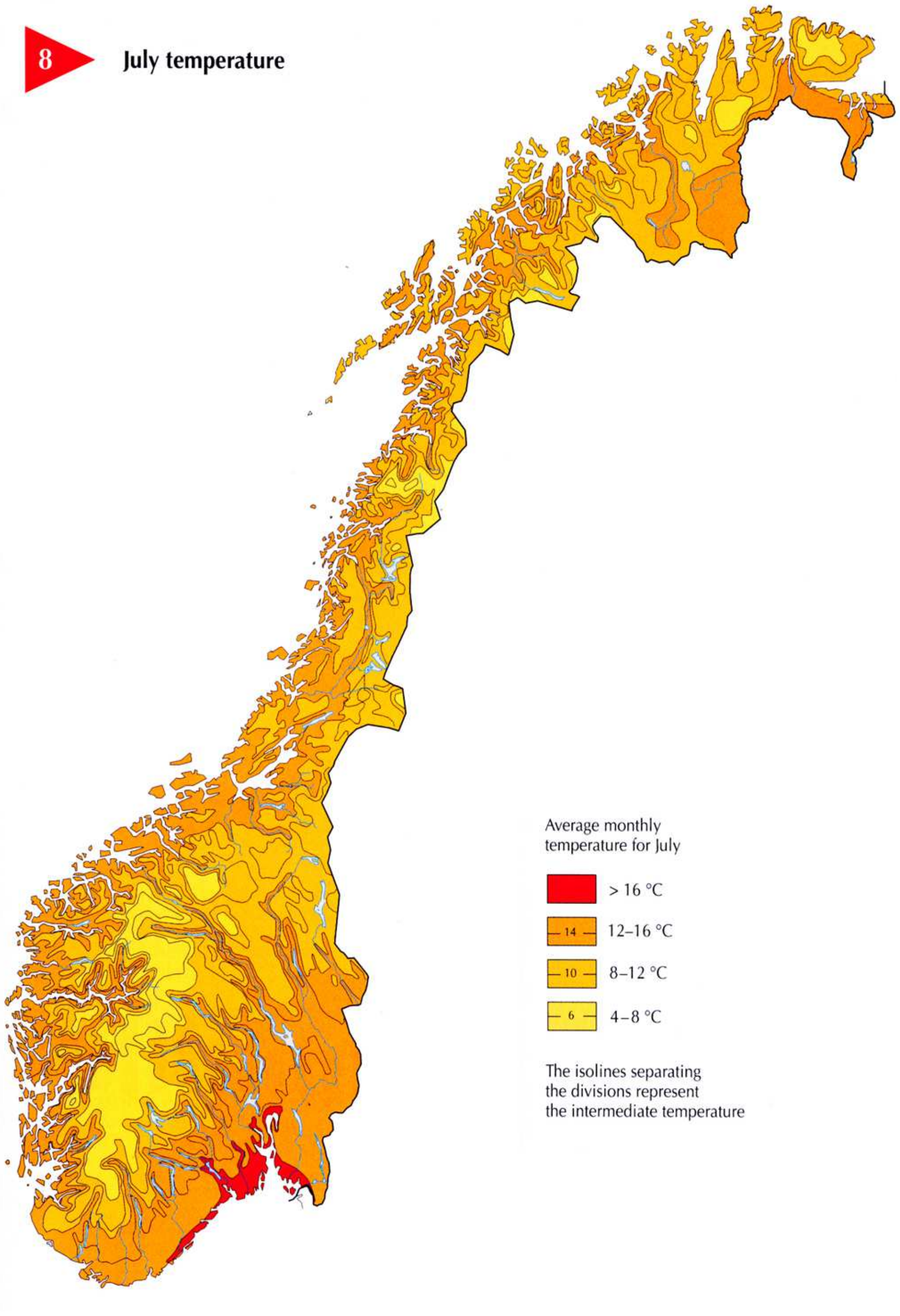


Map 15 The map shows the distribution of seven categories of superficial deposits. Most of the country has a thin cover of morainic material which stems from the last Ice Age. Superficial deposits of considerable thickness are mainly found in the valleys and in lowlands where meltwater rivers at the end of the Ice Age left behind rocks, gravel and sand along their channel, in meltwater lakes and close to the outlet of rivers into lakes and the sea. The very finest material was deposited on the sea floor as clay. When the ice melted, the land rose, and some of the marine deposits now lie on dry land. They are found in the lowlands as far up as the marine limit.
The marine limit, which is the highest level reached by the sea measured by its present-day elevation in the terrain, is shown as lines on the map. It is highest north of Oslofjord where it stands 221 m above present-day sea level at Aker. In the Jæren district in the extreme south-west, it is 20 m a.s.l., at Stad in the extreme west it is a mere 5 m a.s.l., at Trondheim is it about 180 m a.s.l., and Tromsø about 50 m a.s.l., and at Kirkenes about 75 m a.s.l.
From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



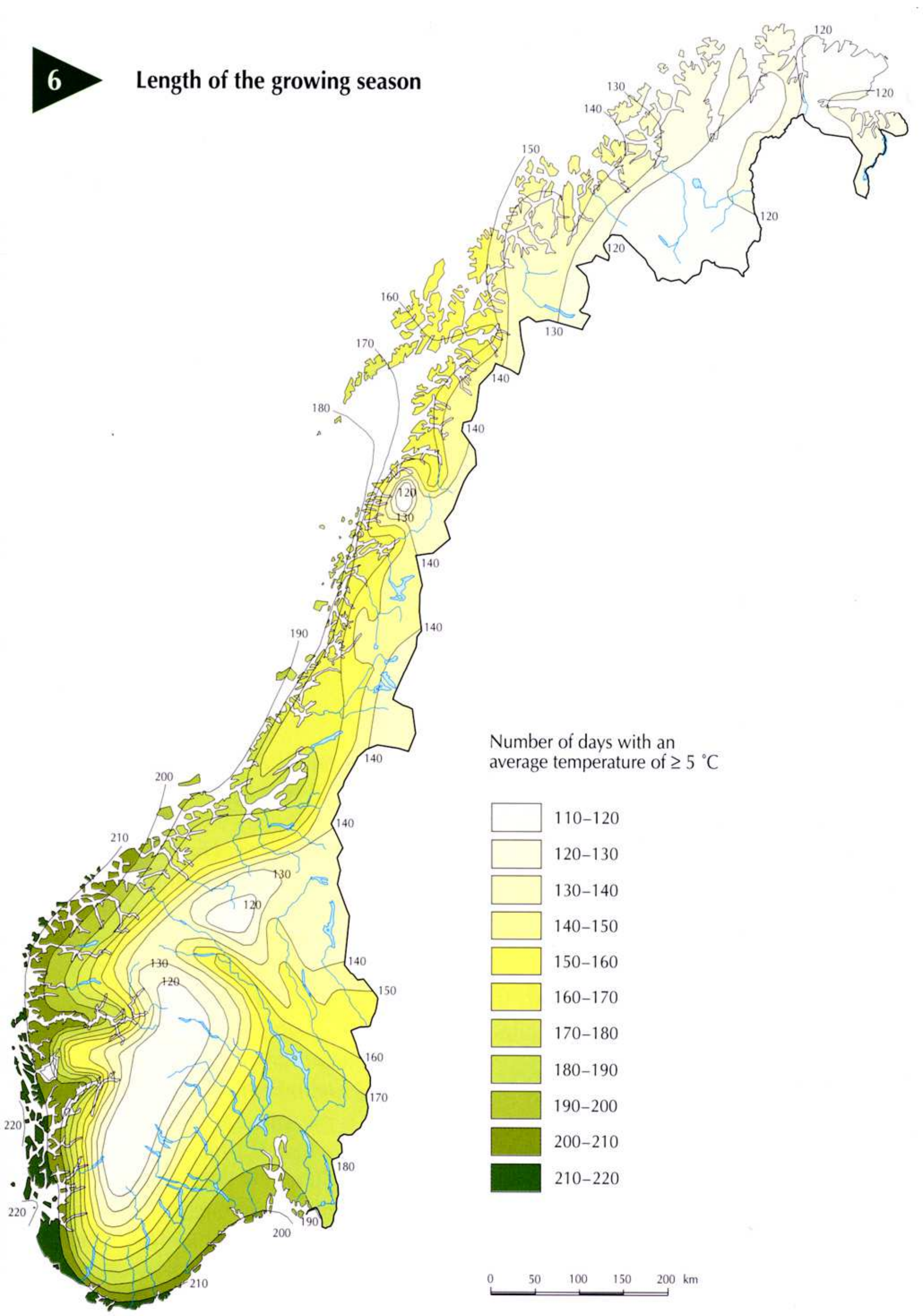
Map 16 This map shows areas with clayey soils, strongly weathered bedrock, and bedrock with a high content of mineral nutrients. The probability of finding 'rich' plant communities with species that are, for example, calcicole will be particularly high is such areas. The map is grossly simplified and is largely based on the previous maps 14 and 15. The bedrock areas that are emphasised also include parts where the bedrock releases relatively few mineral nutrients, such as mica gneiss.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



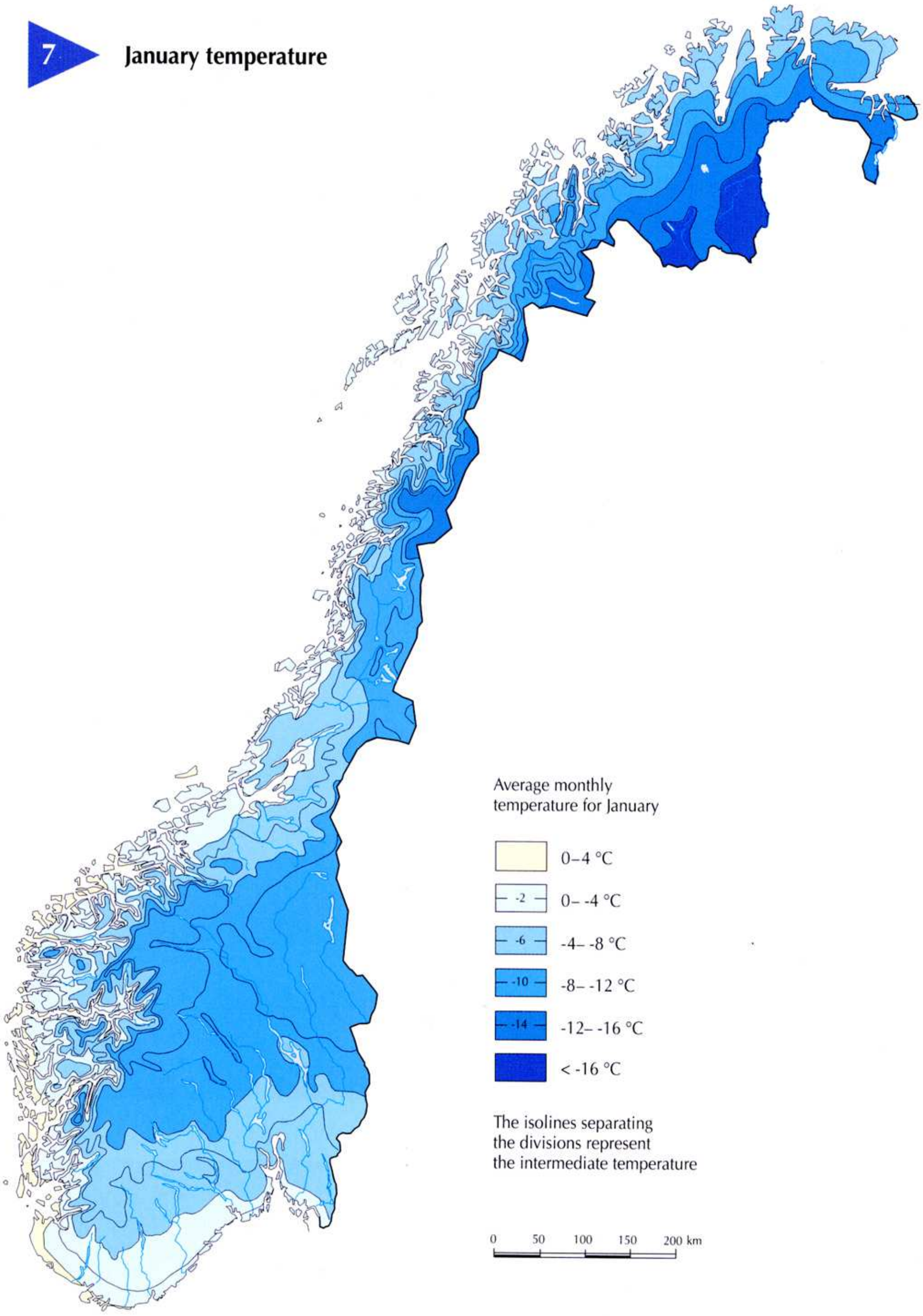
Map 8 In summer, the highest mountainous areas are coldest, recording about 4°C. South-east Norway enjoys the highest temperatures, recoding a July normal temperature in excess of 16°C. The highest average temperature for a month was recorded in Oslo in July 1901 with 22.7°C.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



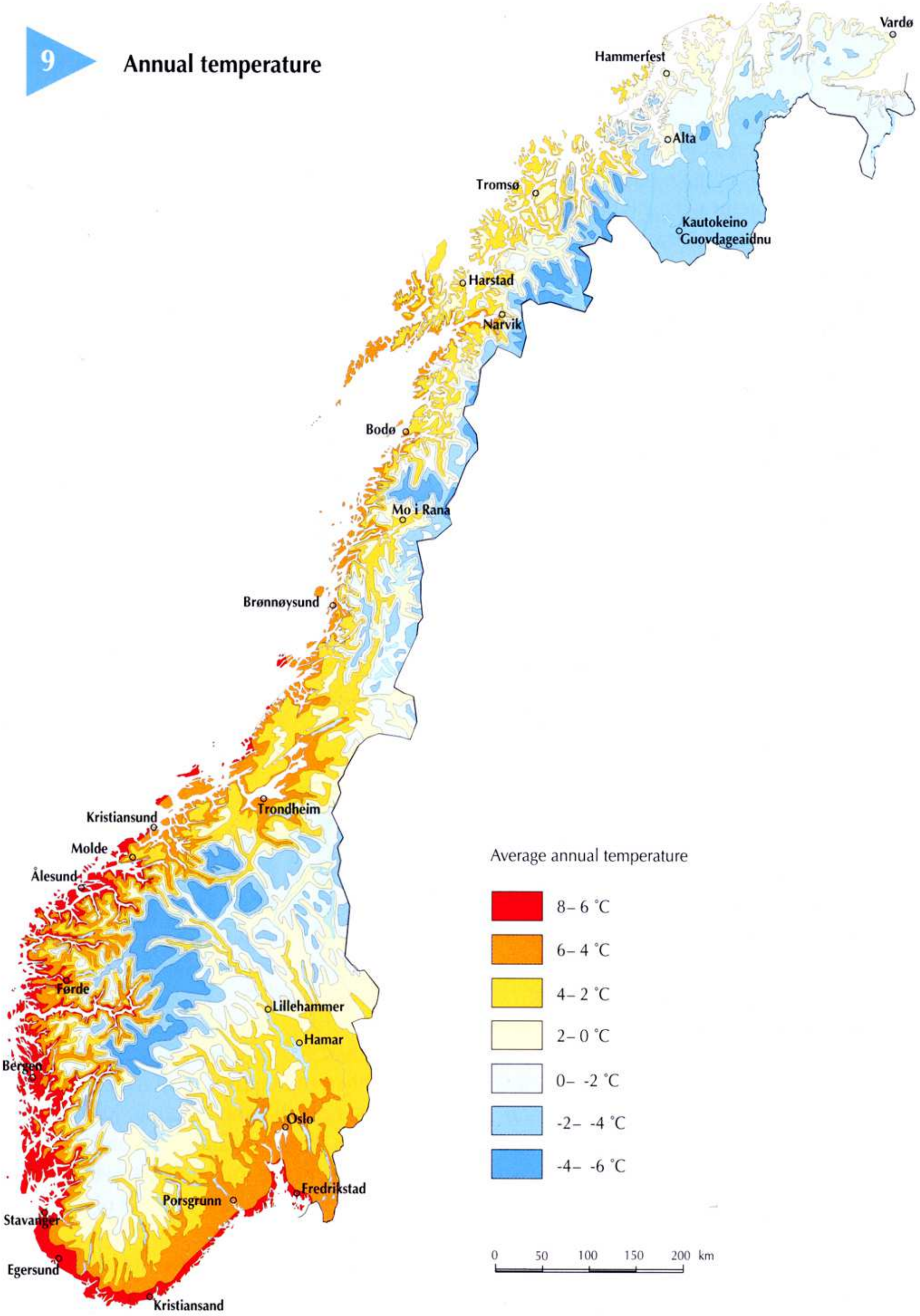
Map 6 The growing season is defined as the period of the year when the normal, round-the-clock temperature exceeds 5°C. The number of days with such conditions provides a measure of its length. This map gives a broad impression of the length of the growing season, based on conditions in lowland areas. It is longest along the coast of west Norway, where it lasts 220 days, and is naturally shorter in upland and northern areas; it last 74 days at Finse (1222 m a.s.l.) in the interior of western Norway.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



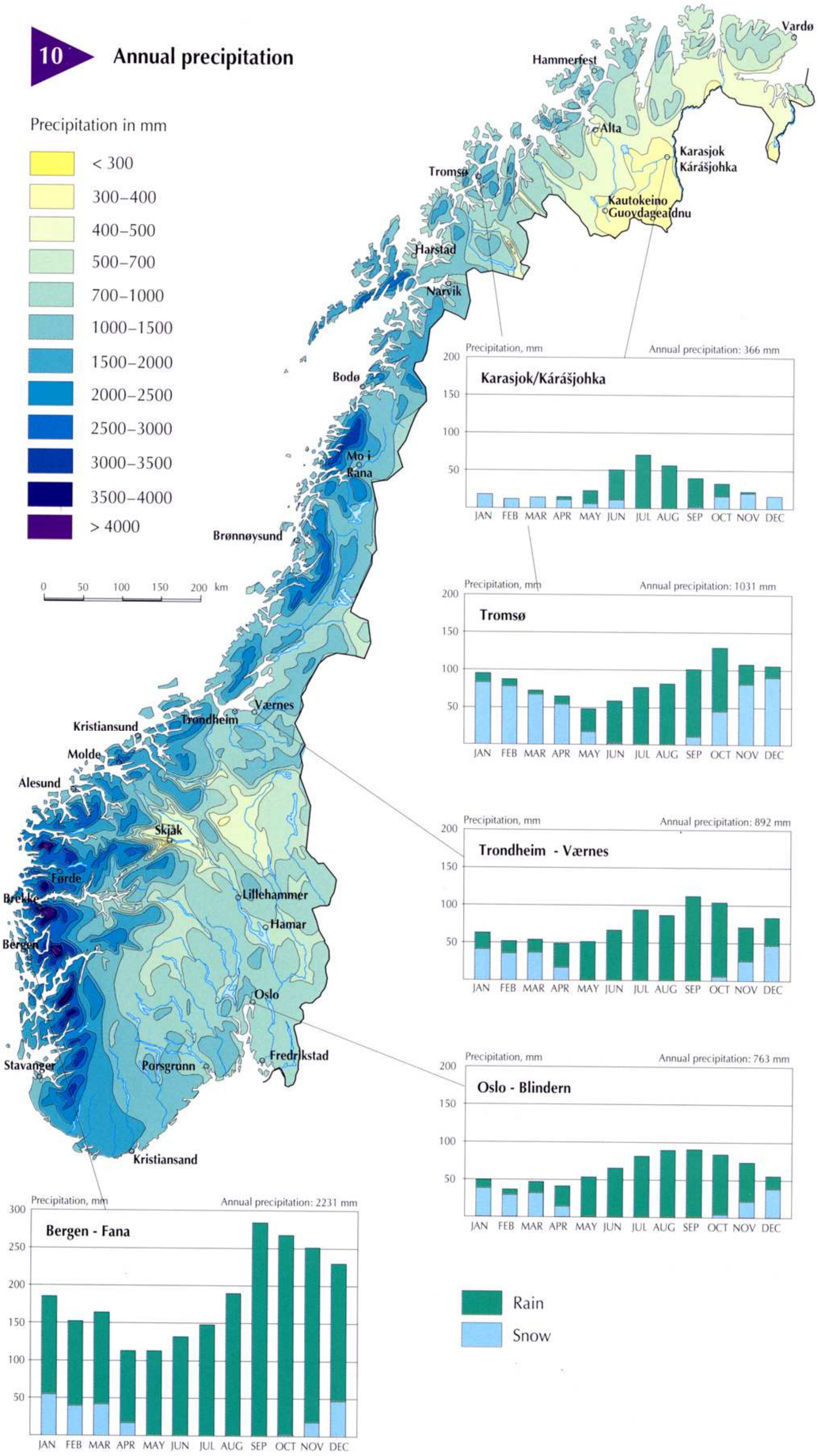
Map 7 There is a great difference in the January temperature between the outer coastal districts of west Norway with 1°C and the upland plateau of Finnmarksvidda in inner Finnmark, the northernmost country in Norway, with –16°C. The lowest average temperature for any month, -27.1°C, was measured at Karasjok on Finnmarksvidda in February 1966.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



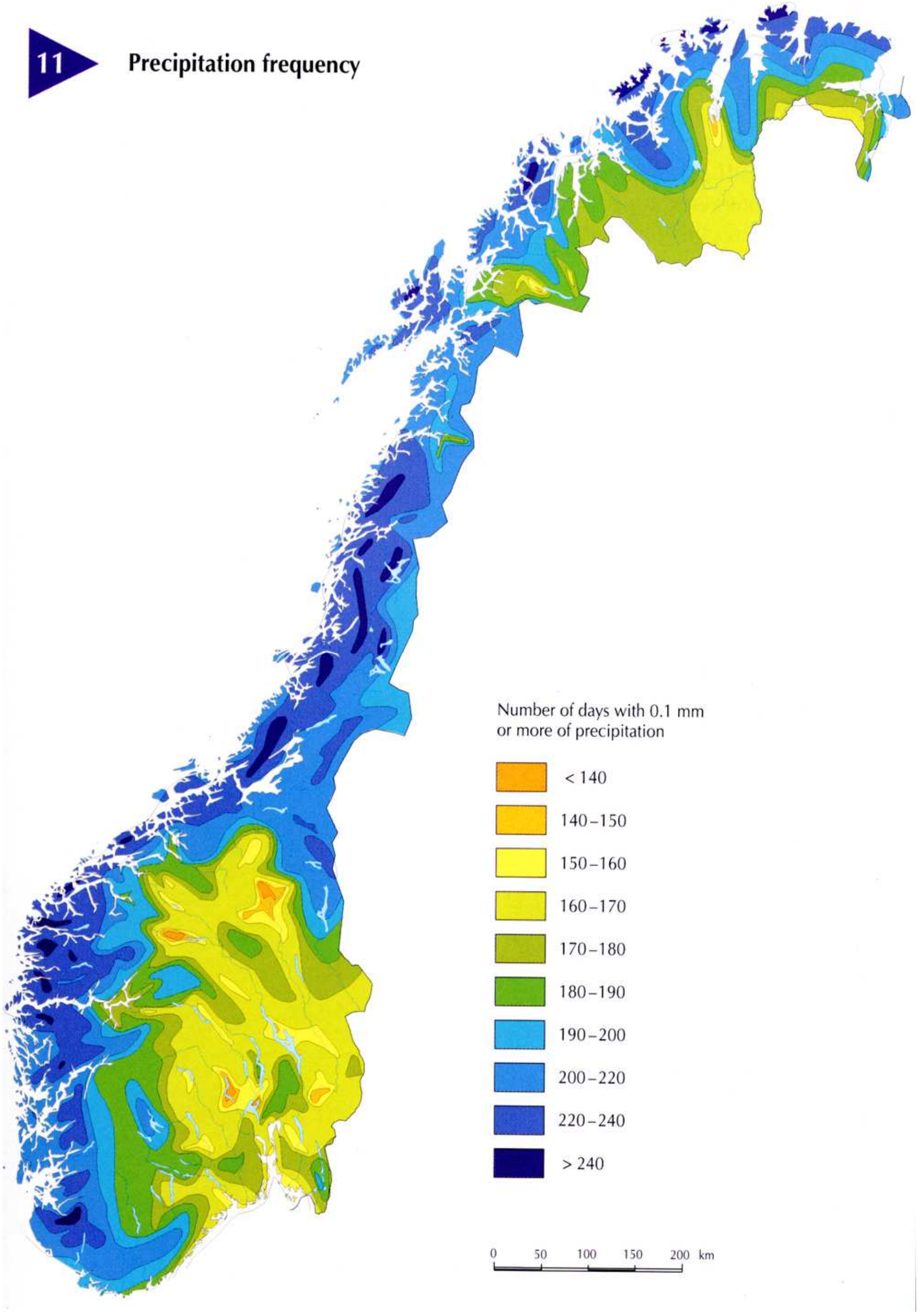
Map 9 Coastal areas in west Norway experience the highest annual temperatures, which exceed 7°C, even though summer temperatures are a little lower there than further inland. Norway's location east of a large and relatively warm ocean and the prevailing westerly winds, result in mild winters near the coast. The mountainous areas are coldest, the highest ones recording about –6°C. On lower ground, it is the inner part of Finnmark that experiences the lowest annual temperature, below –2°C.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



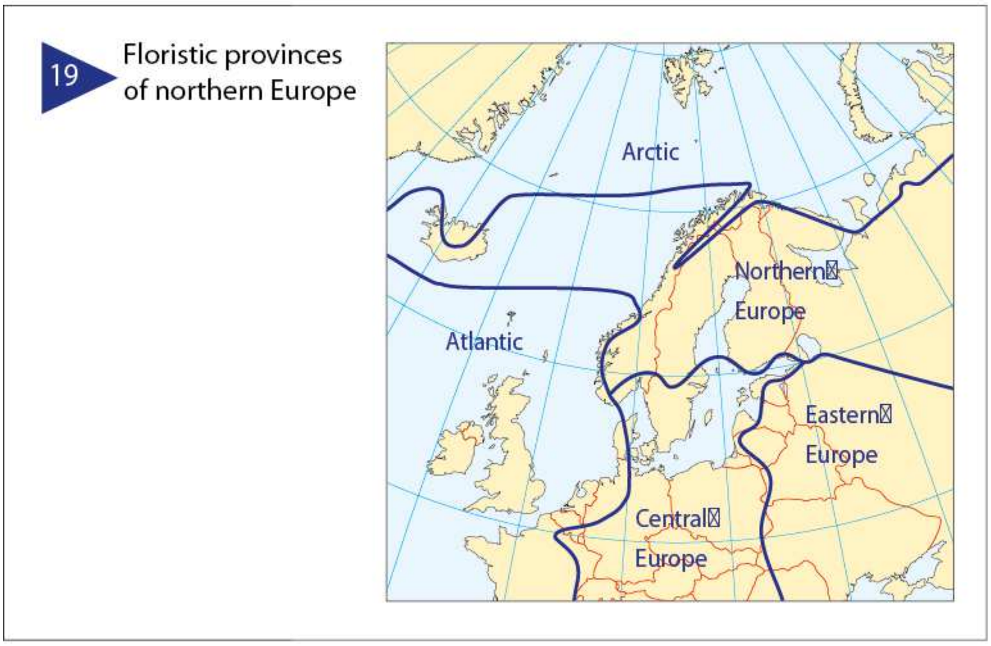
Map 10 The area with the highest precipitation in west Norway, more than 4000 mm per year, is one of the wettest in Europe. On the other hand, the driest areas in the inner valleys of south-east Norway and Troms, recording less than 300 mm per year, are among the driest in western Europe. 1 mm of precipitation means that 1 litre of water has fallen per m^2. The precipitation graphs show how the precipitation varies through the year and the proportion that falls as snow.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



Map 11 The coast from south-east Norway to Varanger in east Finnmark experiences most days with small amounts of precipitation. Precipitation is particularly frequent on the Fosen peninsula in central Norway and the coast of Finnmark, both areas recording more than 250 days with precipitation. The fewest days with precipitation occur in inner parts of Finnmark and Troms, and parts of south-east Norway.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



Map 19 Approximate divisions of the five floristic provinces of northern Europe. Their boundaries are defined on the basis of the distribution of plant species.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

Floristic elements in Norway

The term floristic element is used here to mean a group of species that remain together, i.e. their present-day geographical distribution is approximately the same.

Based on the horizontal and vertical distribution of the species in Scandinavia, Finland and adjacent areas, the Norwegian flora is divided into five floristic elements: western species, southern species, south-eastern species, eastern species and alpine species. This division is based on the five floristic provinces described above. Thus, the most typical species in each element belong to a specific floristic province according to the following main pattern: western species - Atlantic floristic province, southern species - central European floristic province, south-eastern species - eastern European floristic province, eastern species - northern European floristic province, alpine and northern boreal species - arctic floristic province.

It is the species which have a clear distribution pattern in relation to the five main elements in northern Europe that are taken into account. Consequently, species that are widely distributed (e.g. grey alder, downy birch and Scots pine) are not part of any specific floristic element. Shore plants are not included either, even though they have a very clear and limited distribution in northern Europe. Their distribution is, however, controlled by special conditions where they grow, more than by macroclimatic conditions.

Each of the five elements is further subdivided into four floristic sub-elements:

Western species
- strongly western species
- distinctly western species

- weakly western species
- species with a western tendency

Southern species

- strongly southern species
- distinctly southern species
- weakly southern species
- species with a southern tendency

South-eastern species

- strongly south-eastern species
- distinctly south-eastern species
- weakly south-eastern species
- species with a south-eastern tendency

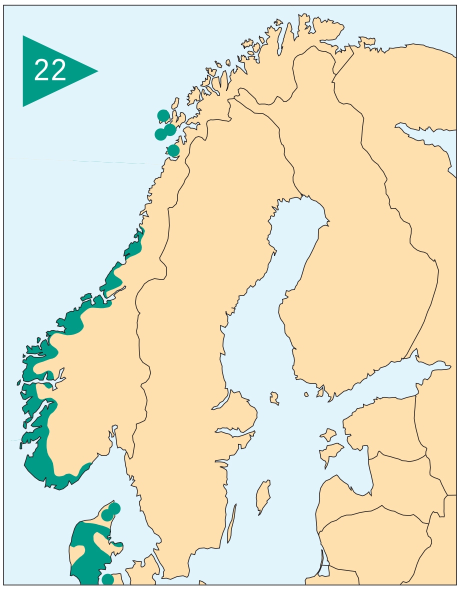
Eastern species

- strongly eastern species
- distinctly eastern species
- weakly eastern species
- species with an eastern tendency

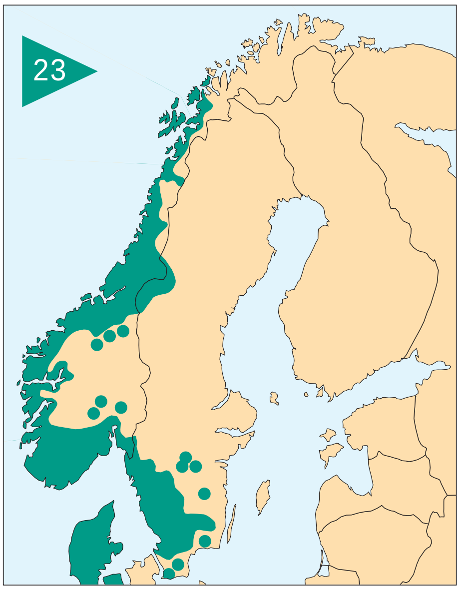
Alpine and northern boreal species

- strongly alpine species
- distinctly alpine species
- weakly alpine and northern boreal species
- species with an alpine and a northern boreal tendency

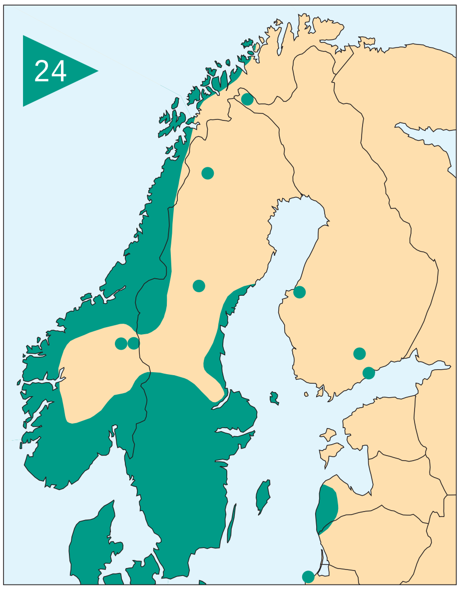
Map 21 Bell heather (*Erica cinerea*)



Map 22 Great wood-rush (*Luzula sylvatica*), a distinctly western species

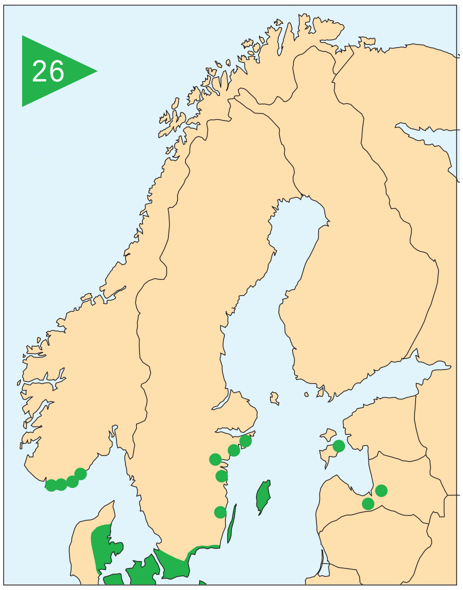


Map 23 Bog asphodel (*Narthecium ossifragum*), a weakly western species

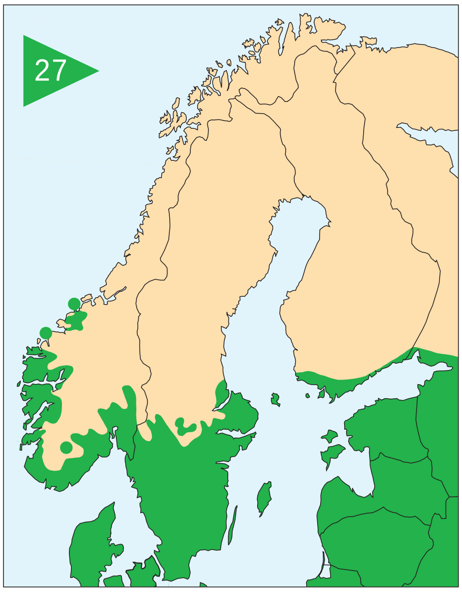


Map 24 Hard-fern (*Blechnum spicant*) with a western tendency

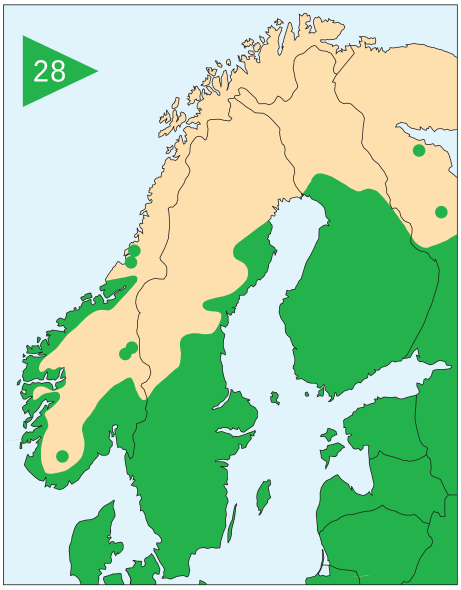
From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



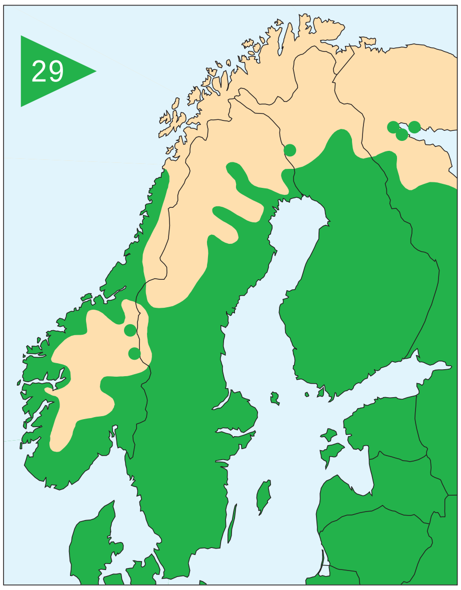
Map 26 Grey sedge (*Carex divulsa*), a strongly southern species



Map 27 Pendunculate oak (*Quercus robur*), a distinctly southern species

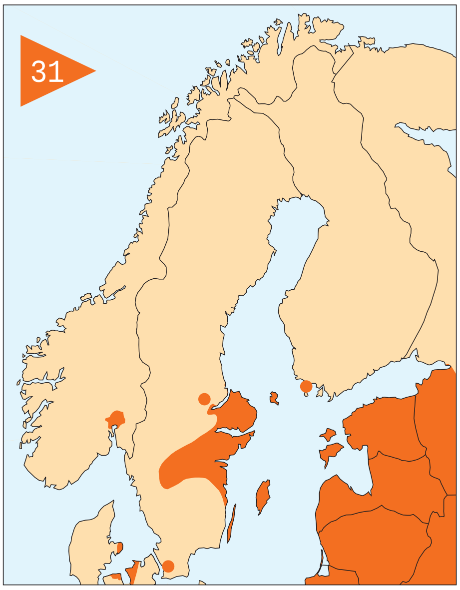


Map 28 Alder (*Alnus glutinosa*), a weakly southern species

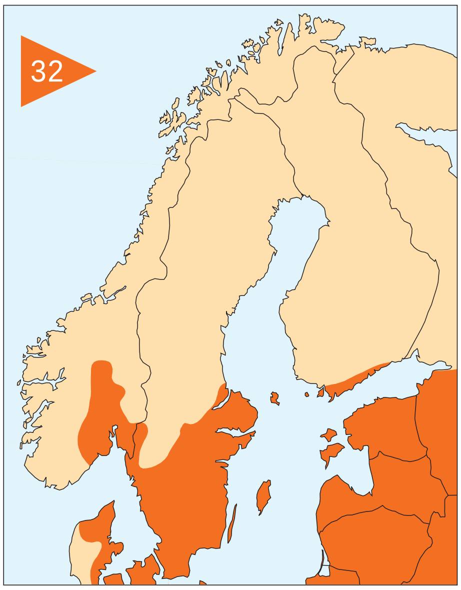


Map 29 Eared willow (*Salix aurita*), a species with a southern tendency

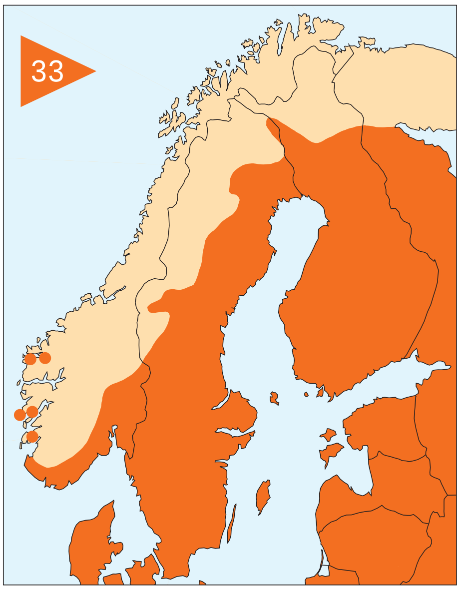
From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



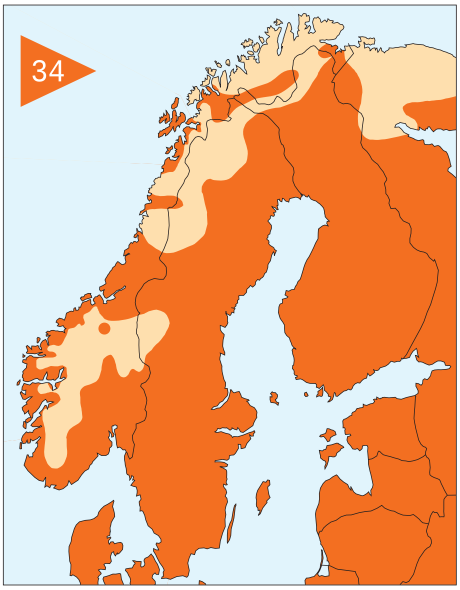
Map 31 Moon carrot (*Seseli libanotis*), a strongly south-eastern species



Map 32 Green strawberry (*Fragaria viridis*), a distinctly south-eastern species

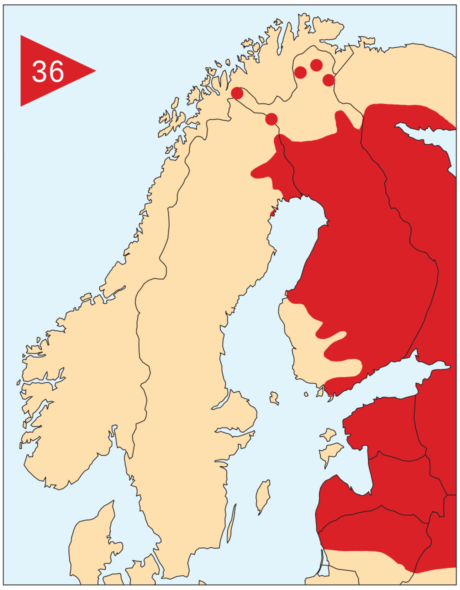


Map 33 Milk-parsley (*Peucedanum palustre*), a weakly south-eastern species

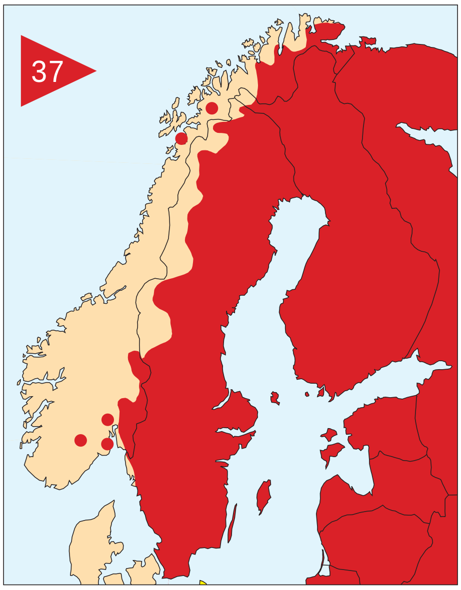


Map 34 Tufted loosestrife (*Lysmachia thyrsiflora*), a species with a south-eastern tendency

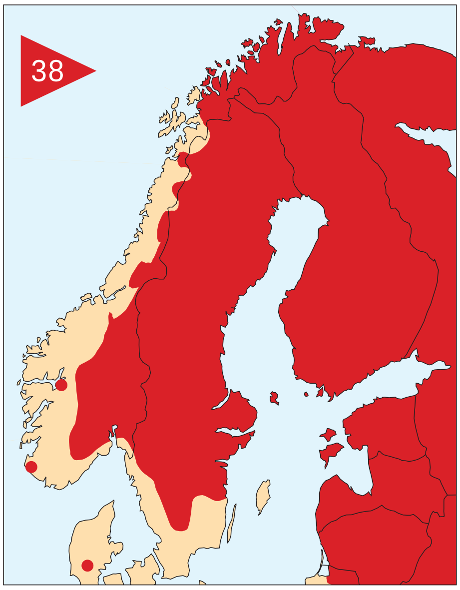
From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



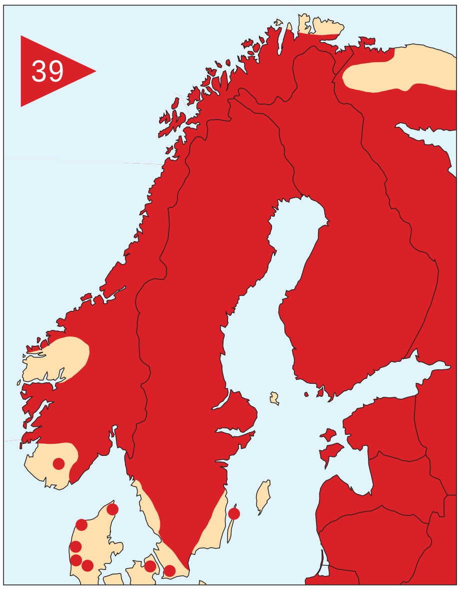
Map 36 Leatherleaf (*Chamaedaphne calyculata*), a strongly eastern species



Map 37 Labrador-tea (*Ledum palustre*), a distinctly eastern species



Map 38 Sceptred lousewort (*Pedicularis sceptrum-carolina*), a weakly eastern species



Map 39 String sedge (*Carex chordorrhiza*), a species with an eastern tendency

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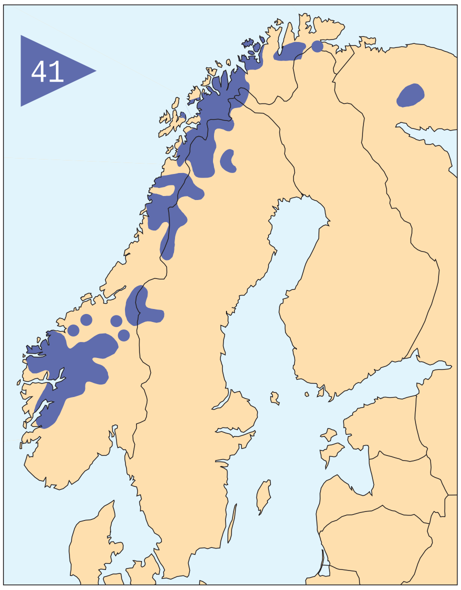
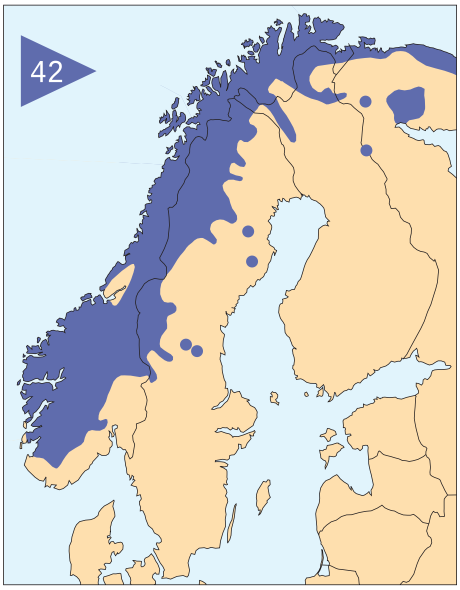
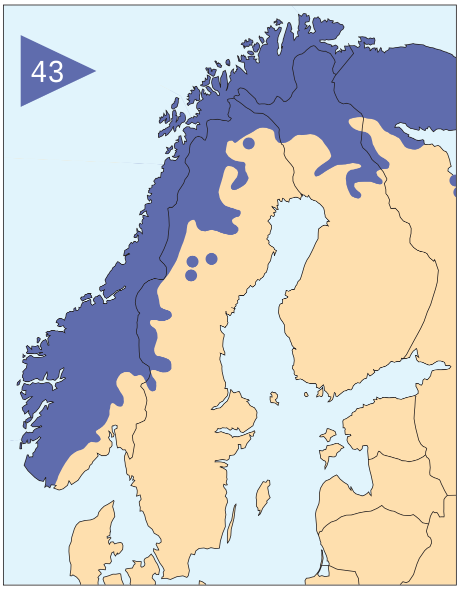


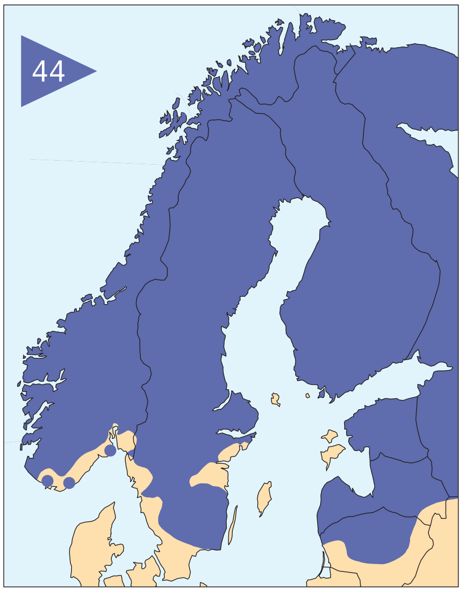
Map 41 Glacier buttercup (*Ranunculus glacialis*), a strongly alpine species



Map 42 Dwarf willow (*Salix herbacea*), a distinctly alpine species



Map 43 Arctic bearberry (*Arctous alpinus*), a weakly alpine species



Map 44 Dwarf birch (*Betula nana*), a species with an alpine tendency

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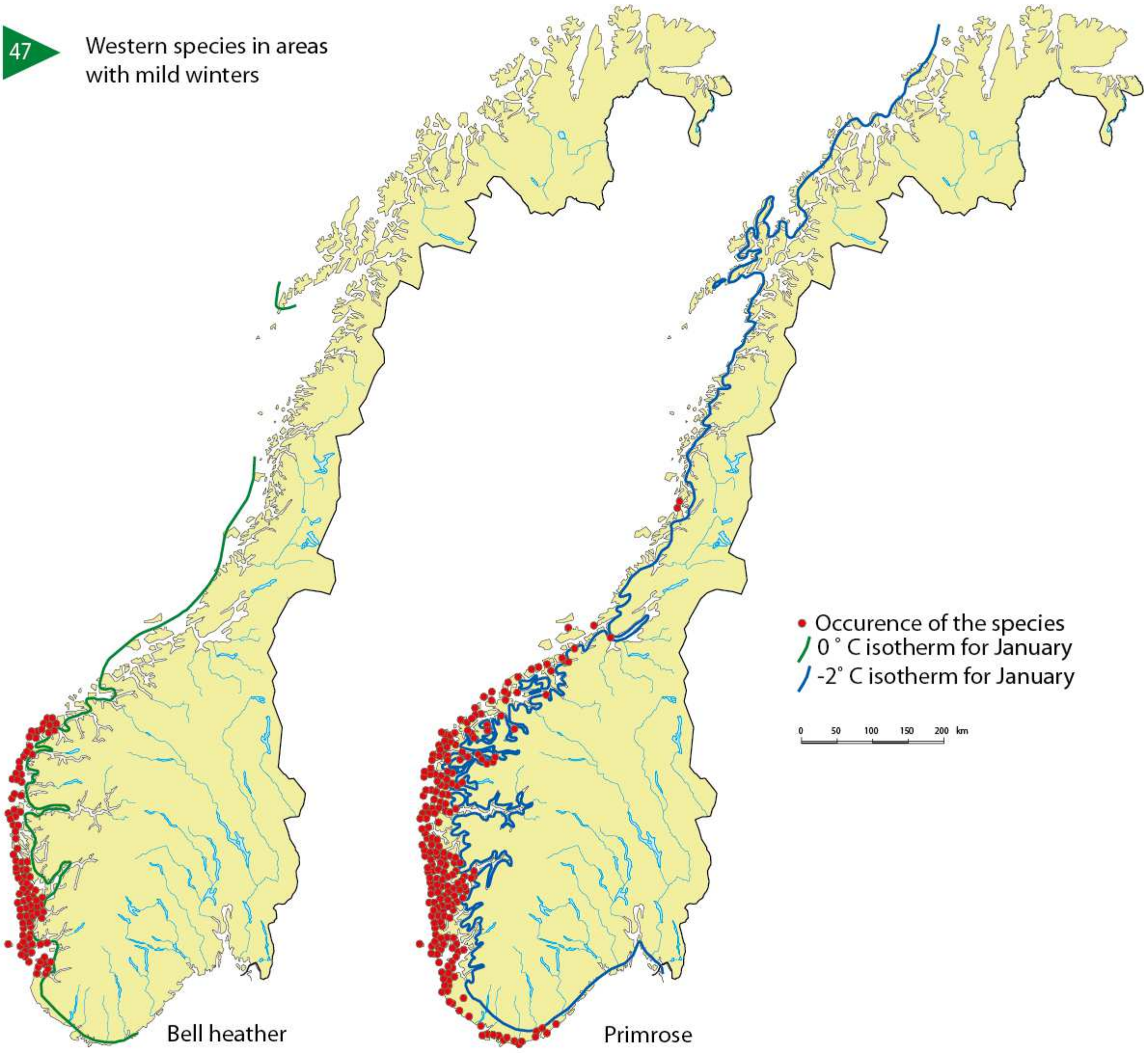
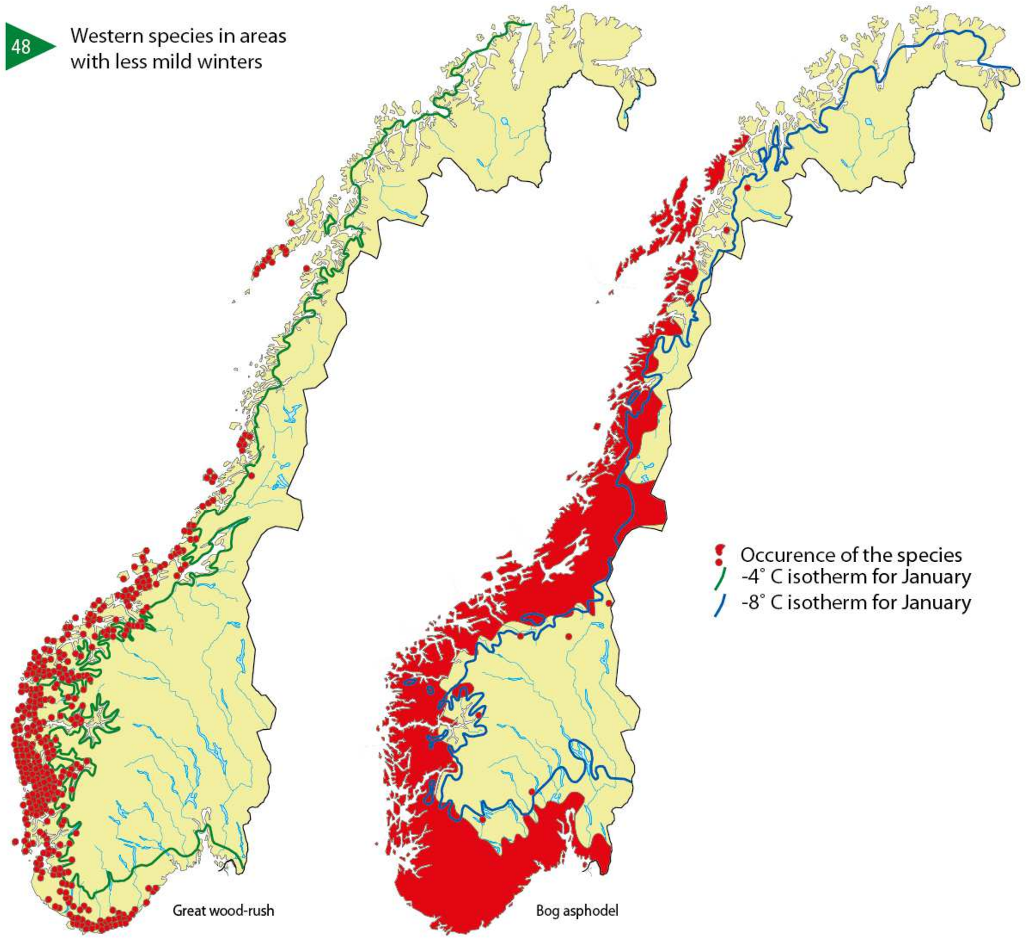


Map 47 Most western species probably have frost as their most important limiting environmental factor. But they have differing degrees of sensitivity for low temperatures. Bell heather (*Erica cinerea*) is found where the average January temperature exceeds 1°C. The 0°C isotherm is shown on the map). Primrose (*Primula vulgaris*) has a somewhat broader distribution because it can withstand lower temperatures somewhat better.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

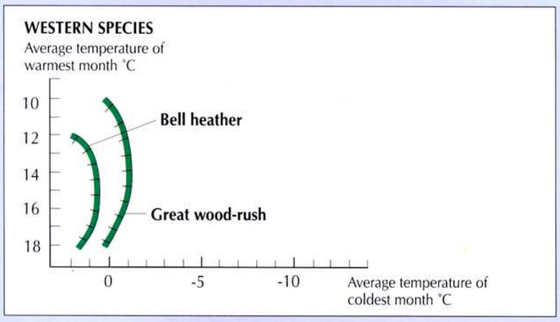


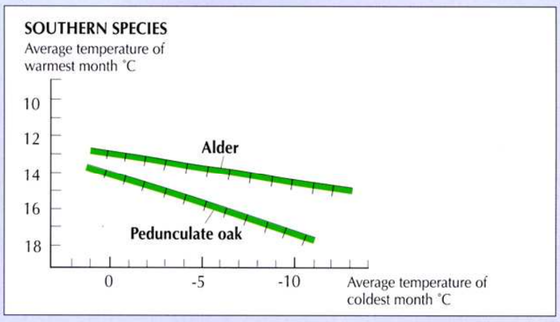
Map 48 These western species place less strict demands on mild winters than bell heather and primrose. The distribution of great wood-rush (*Luzula sylvatica*) roughly coincides with the –4°C January isotherm. Bog asphodel (*Narthecium ossifragum*) has a still wider distribution and is found in areas that are relatively cold in winter, particularly those with much snow. Its distribution is compared here with the –8°C January isotherm.

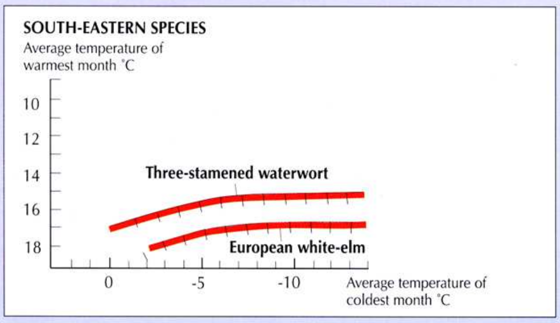
From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

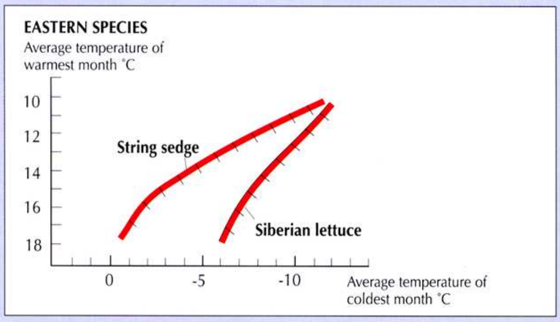
Temperature limit curves for 10 species

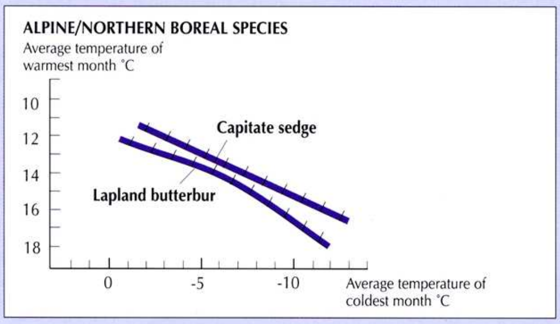
Temperature limit curves like those in Figure 4 (for ivy, holly and mistletoe) are shown here for two species from each of the five floristic elements described on page 41. The curves for these 10 species derive from a work by the Finnish scientist Hintikka (1963) who used a combination of winter and summer temperatures to depict differences in the distribution of plants. He placed all the Scandinavian meteorological stations on a co-ordinate system with the average temperature for the warmest month on one axis and that for the coldest month on the other. When he plotted the distribution data for the various species on this diagram, many of the species could be delimited by a single line, as shown on the figures on the right. The distribution areas are on the side of the line that has teeth.











Western species

Bell heather and great wood-rush (*Erica cinerea, Luzula sylvatica*) belong to the strongly and distinctly western elements, respectively (Maps 21 and 22). Maps 47 and 48 also show the distribution of these species in relation to winter temperature. Holly (*Ilex aquifolium*, see Figure 4) is also a distinctly western species.

Southern species

Pedunculate oak and alder (*Quercus robur, Alnus glutinosa*) belong to the distinctly and weakly southern elements, respectively (Maps 27 and 28). Mistletoe and ivy (*Viscum album, Hedera helix*, see Figure 4) are also distinctly southern species.

South-eastern species

European white-elm and three-stamened waterwort (*Ulmus laevis, Elatine triandra*) belong to the strongly and distinctly south-eastern elements, respectively; the former is not found in Norway (it occurs on Öland and in southern Finland).

Eastern species

Siberian lettuce and string sedge (*Lactuca sibirica, Carex chordorrhiza*) belong to the eastern plants, the former to the strongly eastern element and the latter to the species showing a tendency for an eastern distribution.

Alpine and northern boreal species

Both capitate sedge and Lapland butterbur (*Carex capita, Petasites frigidus*) belong to the weakly alpine and northern boreal species.

The two southern species, pedunculate oak and alder, display the same kind of oblique curve as the three species in Figure 4, except for the lack of a downward-curved vertical portion. Other southern species, like small-leaved lime (*Tilia cordata*), show a similarly shaped curve. Moreover, for such southern species, it is usual for their accumulated heat sum to increase with rising winter temperature when a given July temperature is reached, because their growing season lengthens. The curves for the south-eastern, and especially the eastern, and alpine and northern boreal species, show completely different, in part opposite, trends from the western and southern species. This indicates that completely different climatic factors determine the distribution of these species.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

Eastern distribution

Eastern plants have western limits, i.e. they are delimited towards areas with an oceanic climate. Several alternative physiological reasons have been suggested to account for such boundaries. For instance, winter respiration along the coast is so high that plants with a continental distribution cannot compensate for it by the growth they achieve in the relatively cool summer, or the unstable weather in winter on the coast enhances the risk of the winter dormancy being broken at the wrong time.

The latter hypothesis is based on there being two main ways in which the dormancy is induced and broken, through threshold values for day length or for temperature. The winter temperature in oceanic areas is less predictable than in more continental regions, and Eilif Dahl's hypothesis was that it is most likely that coastal plants enter into and break their dormancy at specific lengths of day. Inland plants, which are adapted to living in a continental climate with more predictable winter temperatures, may instead have temperature thresholds. This hypothesis has been tested by transplanting related coastal and inland plants between an oceanic area (Stavanger) and a more continental one (Ås). The hypothesis was found to be probably correct for some plants since inland plants broke their dormancy at Stavanger during periods of mild weather and were damaged by later frosts, whereas west Norwegian plants remained unaffected by the mild weather. Research is still going on in this field and more work remains to be done before the limiting factors for inland plants have been clarified.

Southern and south-eastern distribution, woodland limits

That low temperatures limit the distribution of plants and that warmth is required for plants to be capable of developing have been common knowledge for a long time, not least here in Norway through the limitations for cultivating such agricultural products as corn, potatoes and fruit. However, warmth can come in many guises, such as a long season with relatively low temperatures (in west Norway), or a short, warm summer (in south-east Norway and inner Finnmark). The accumulated heat sum in the growing season may be identical in areas with a completely different climate.

Eilif Dahl and his co-workers mapped climatic factors which may elucidate the requirements of plants that demand warmth. They did this by calculating respiration (= breathing) sums, which indicate the growth potential present in the climate of an area. Norway spruce (*Picea abies*) was used because of its wide distribution in Scandinavia and Finland and because a great deal was known about its ecology and physiology. The respiration sums reflect the ratio between the net photosynthesis (gross photosynthesis minus photorespiration, i.e. respiration while photosynthesis is taking place) and the respiration in the dark. This indicates how much surplus a plant can produce under the climatic conditions at the locality concerned, a surplus that can be used for growth and reproduction. Map 50 shows isolines for accumulated annual respiration sums.

The respiration hypothesis is based on the production of energy-rich compounds (adenosine triphosphate - ATP) through the respiration, which supply energy to the growth processes of the plants, and which are the most important limiting factors for the growth and development of the plants at low temperatures. These processes are temperature dependent and the temperature is attached importance according to the effect it has on the respiration. Weighted temperature sums for the entire growing season have been calculated on the basis of temperature data from a number of meteorological stations for the normal period of 1931-1960. The respiration which corresponds to 30 days at 10°C is set as one unit.

The most extreme warmth-demanding plants, such as dogwood (*Cornus sanguinea*, Map 51), moon carrot (*Seseli libanotis*) and the other strongly south-eastern species which are limited by a respiration sum of 7, occur in the southern and south-eastern parts of the Nordic countries, in Norway in the far south-east. Somewhat less warmth-demanding species are also found in inner fjord districts of west Norway, for instance agrimony (*Agrimonia eupatoria*, Map 52), which largely fall within the area bounded by a respiration sum of 6. Many of the southern and south-eastern species occur within this isoline.

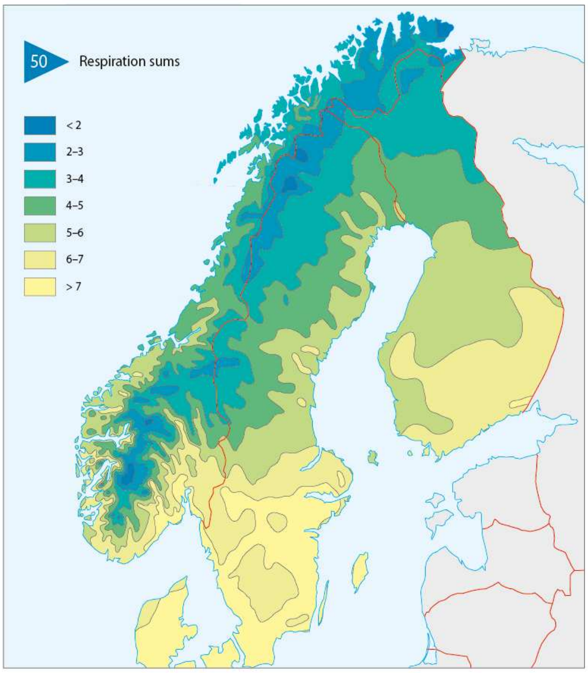
For various southern species, there is good correspondence between the values for the oblique portion of the delimitation lines in Iversen's diagram (page 28 - above) and the respiration sums. Mistletoe is delimited by a respiration sum of 7, ivy and pedunculate oak by 6 and alder by 5.

The respiration sum theory goes a long way towards explaining the relationship between the distribution of the southern plants and the climate, but the question of why some plants require a greater production surplus than others still remains.

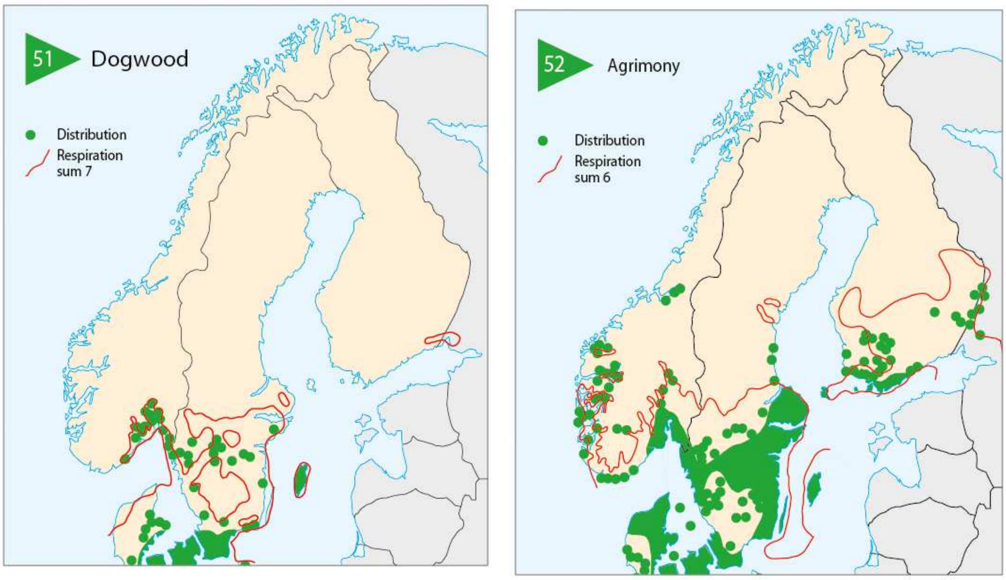
The upper limits of woodland trees (especially Norway spruce, Scots pine and birch) are the distribution limits that have been the object of most investigations in Norway. Because the woodland limit forms an easily visible boundary between wooded regions and treeless mountains, it has always been important in the context of plant geography. The woodland limit is found in every kind of regional division, being used to mark the boundary to either alpine or arctic regions. A close association between the woodland limit and the 10°C isotherm for the warmest month of the year was shown to exist as early as the 19th century. This temperature limit has also been used to distinguish between the cool temperate climate and the arctic and alpine climates on Map 5. Direct comparison with the map of the vegetation formations (Map 56) shows good agreement.

Other workers have used alternative measurements. Helland (1912), for example, found a still better relationship by using the average temperature for the four warmest months of the year (the tetratherm). He found that the limit for birch woodland correlated with a tetratherm of 7.5°C. Corresponding values for grey alder (*Alnus incana*) were 7.7°C, Norway spruce (*Picea abies*) 9.6°C, Scots pine (*Pinus sylvestris*) 10.6°C, wych elm (*Ulmus glabra*) 11.2°C, and most other broad-leaved deciduous trees about 12.5°C. Others have used the tritherm (the average temperature for the three warmest months) to correlate with the woodland limit, and found a good relationship.

With regard to the demand for warmth, physiological investigations have shown that the relationship between growth and temperature is not rectilinear. Most plants grow much more, in relative terms, when the temperature is raised from 20 to 21°C than when it is raised from 10 to 11°C. Hence, since it is the highest temperatures in daytime that are most important for plant growth, at any rate in the lowlands and the southern part of the country, a better relationship seems to exist between the average summer temperature for the warmest month and the woodland limit than between the woodland limit and the average temperature for the summer months. Throughout Norway, there is a close relationship between the average maximum temperature in July of 15.8°C and the limit of birch woodland. The corresponding value for alder woodland is 17.2°C.



Map 50 The possibility for plants to grow and reproduce is strongly dependent upon the temperature. A measure of this, termed here the respiration sum, can be obtained by calculating the accumulated annual respiration measured by comparing with the growth in Norway spruce (*Picea abies*). This map shows the geographical variation in the composite annual respiration sums for the lowest localities in the terrain, based on temperature data. The values range from 7 in the most favourable parts of southern Scandinavia to less than 2 in the climatically most unfavourable regions in eastern Finnmark and the mountains. From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



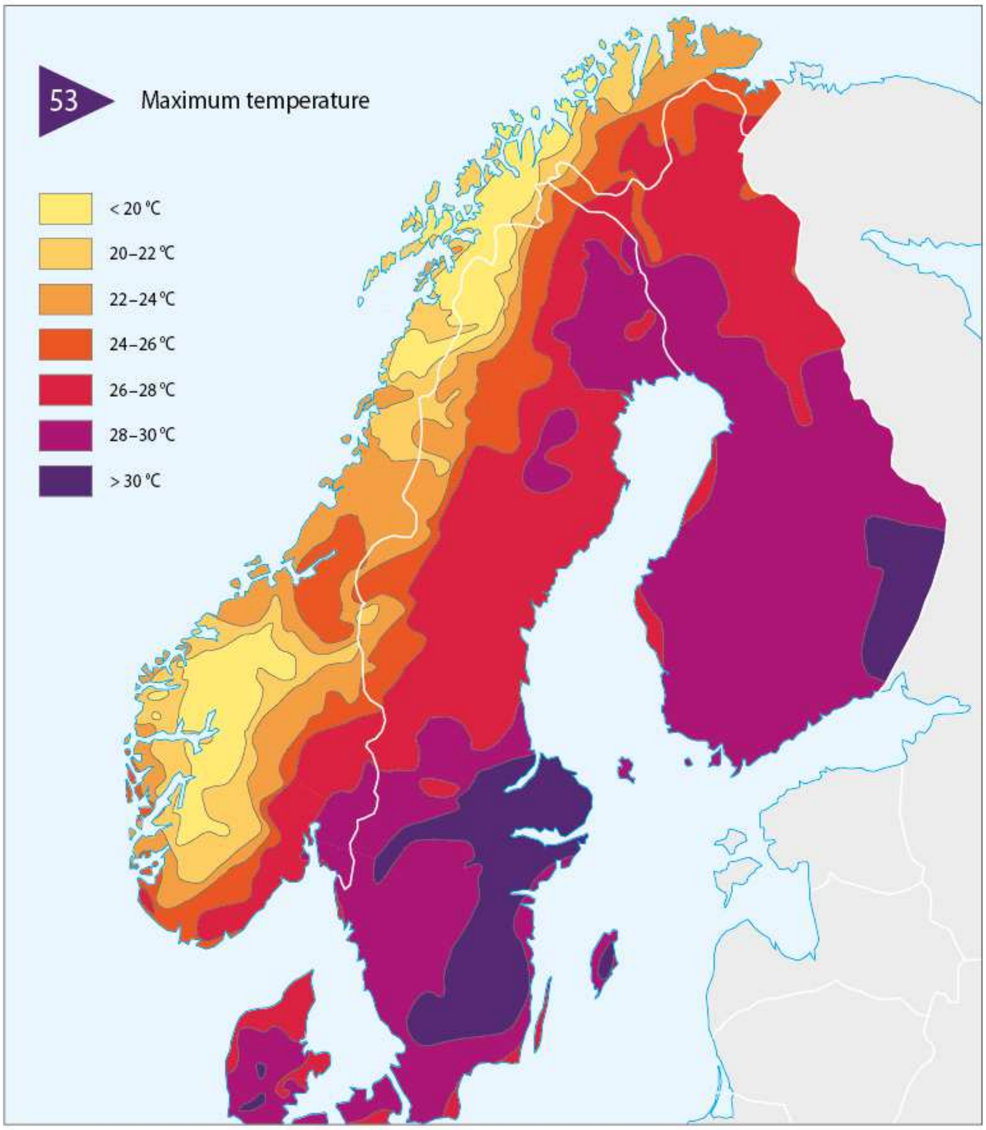
Maps 51 and 52 The plants demanding the greatest amount of warmth occur in southern and south-eastern parts of the Nordic countries. Both dogwood (*Cornus sanguinea*) and agrimony (*Agrimonia eupatoria*) are such warmth-demanding species. Their distributions are compared with the isolines for respiration sums 7 and 6. From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

Arctic and alpine distributions

Not all plants grow best where it is warm; for many alpine and arctic plants it is just the contrary. Even though some also grow in the lowlands, and can often be cultivated in gardens, many quickly die in the lowlands of south Norway. For instance, it is impossible, or almost impossible, to get species such as glacier buttercup, purple saxifrage, dwarf willow and arctic mouse-ear (*Ranunculus glacialis, Saxifraga oppositifolia, Salix herbacea, Cerastium arcticum*) to survive over several years in Oslo without taking special steps. They generally survive the winter well, but slowly die during the summer. It therefore seems that a climatic limitation also exists southwards and towards the lowlands.

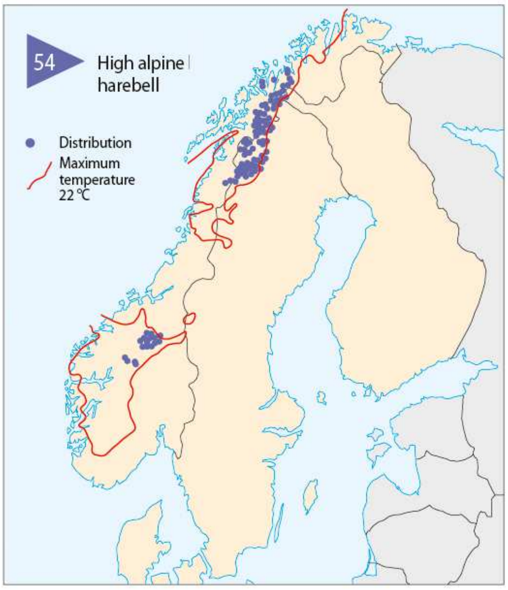
Eilif Dahl and his co-workers tested a hypothesis that alpine plants and other northern plants are limited southwards because they react negatively to particularly high temperatures (maximum temperatures). Initially, Dahl constructed a map showing the expected maximum temperatures for the highest points in the terrain (Map 53). He found clear correlations between isotherms on this map and the distribution of many species. For example, the distribution of many of the most extreme high alpine species, such as high alpine harebell (*Campanula uniflora*) shown on Map 54, fell well within the 22°C isotherm. The distribution of dwarf willow is shown on Map 55 along with the isoline for the maximum temperature of 26°C. Apart from occurrences in a few river valleys, there is a good relationship. River banks become cooled by the draught from the rivers, thereby achieving far lower maximum temperatures than areas away from the river.

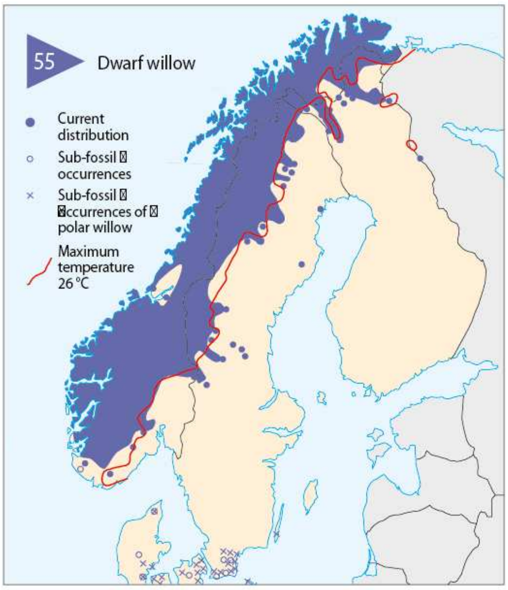
With the help of these maps and climatic data it has been possible to determine which alpine plants have a distribution that correlates with important climatic factors. Dahl's hypothesis (from 1951) was that many alpine plants risk becoming overheated at high temperatures, and later work has confirmed this for some species. A clear correlation has been found between the actual lethal temperature for alpine plants and the isotherms (estimated maximum air temperature) which limit them geographically. The relationship between distribution, isotherms and lethal temperatures has therefore proved to be important for explaining the distribution of many alpine plants, and also many arctic plants and northern seashore plants. Not all these species with an alpine and northern distribution have their range explained in this way. Many species tolerate high temperatures, and it is competition with other species that is decisive for them being unable to survive in lower areas. This is shown by them being able to thrive in gardens in the south, and by scattered occurrences in exceptional, open sites in the lowlands. This applies, for example, to mountain avens, alpine catchfly and rock sedge (*Dryas octopetala, Lychnis alpina, Carex rupestris*) in southern south-east Norway. A very long day is required to initiate flowering in some northern plants (extreme long-day plants), and they are therefore unable to grow outside the Arctic.



Map 53 Estimated maximum temperatures for the highest points in the terrain. The values have been calculated from meteorological station data and recalculated for peaks in the terrain by assuming a constant drop in temperature with height.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

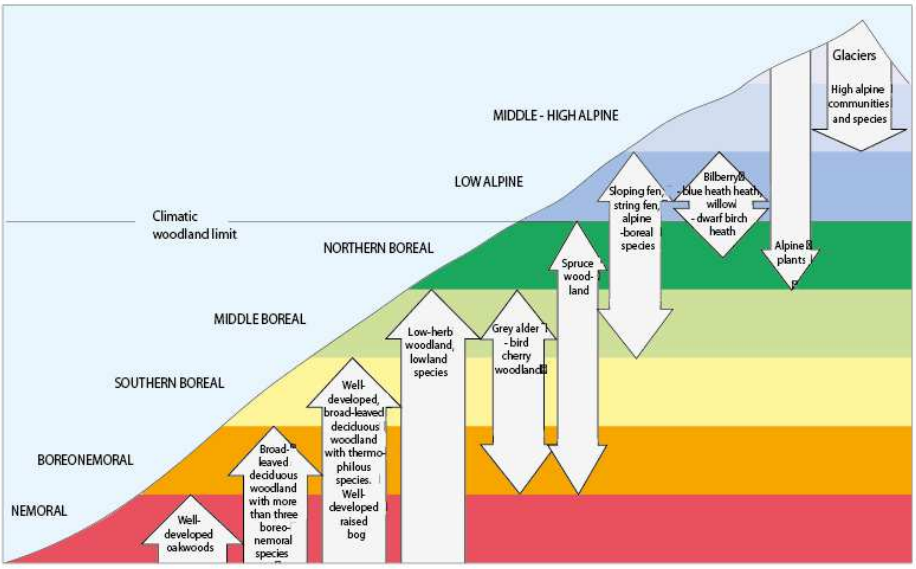




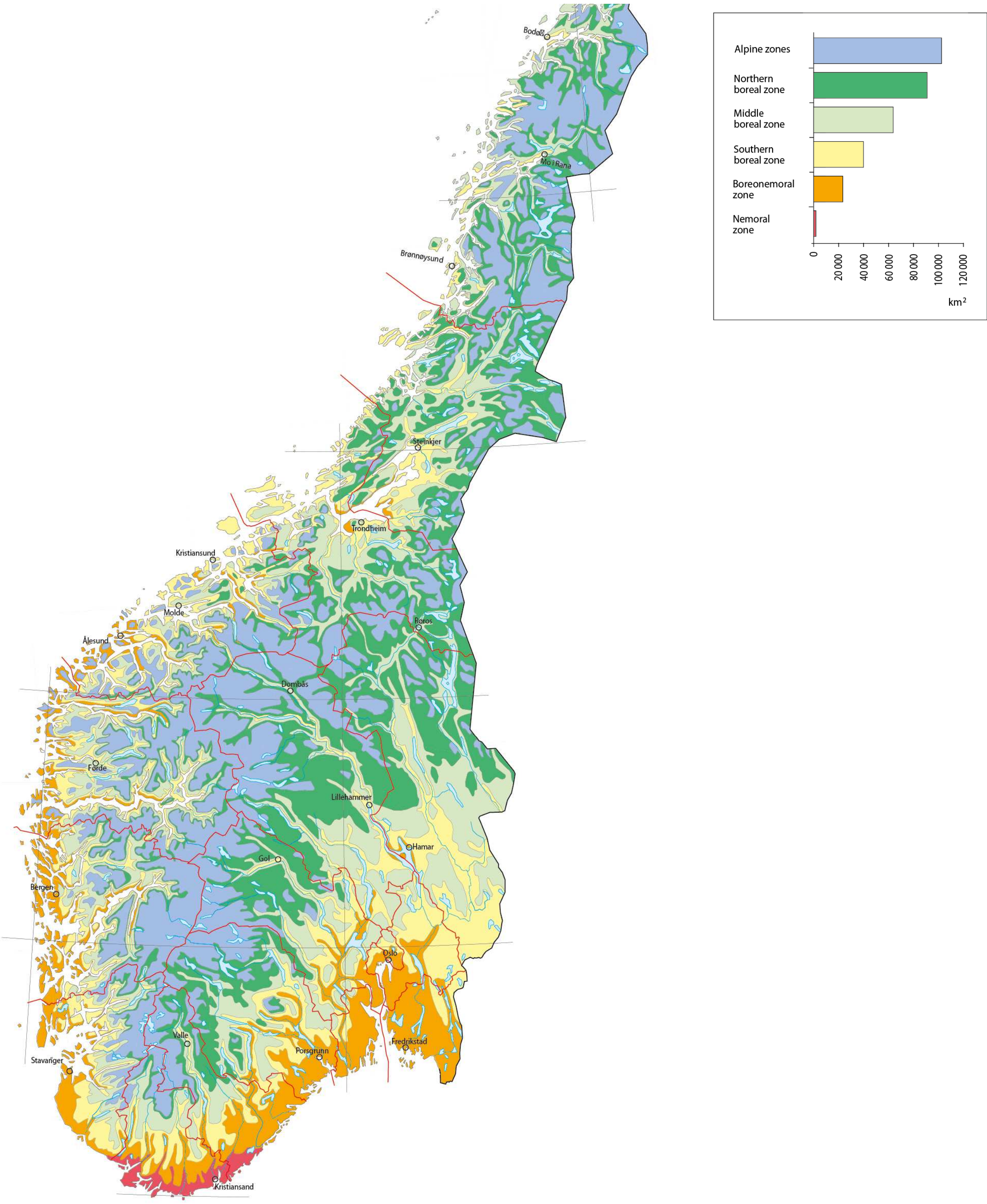
Map 54 High alpine harebell (*Campanula uniflora*) is only 5-10 cm tall and grows on dry, lime-rich, schistose alpine ridges. The species is an exclusive alpine plant that is not found below the woodland limit. In the Dovrefjell mountains (central Norway), where it is locally common, it is found from 1350 m upwards. The species has a bicentric distribution, occurring in the south from Lom to Oppdal and in the north from Saltdal to Kvænangen. Its range falls within the isoline for an estimated maximum temperature of 22°C.

Map 55 Continuous and sporadic distributions of dwarf willow (*Salix herbacea*) compared with the isoline for an estimated maximum temperature of 26°C. All the occurrences east of the line are situated either along river shores or in crevices with a particularly cool local climate. The symbols in southern Scandinavia represent discoveries of sub-fossilised dwarf willow (circles) or the related polar willow (*Salix Polaris*, crosses) from the end of the last glaciation, when these parts of southern Scandinavia had a significantly cooler climate.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



The main criteria for distinguishing the vegetation zones shown schematically. (Moen 1999)

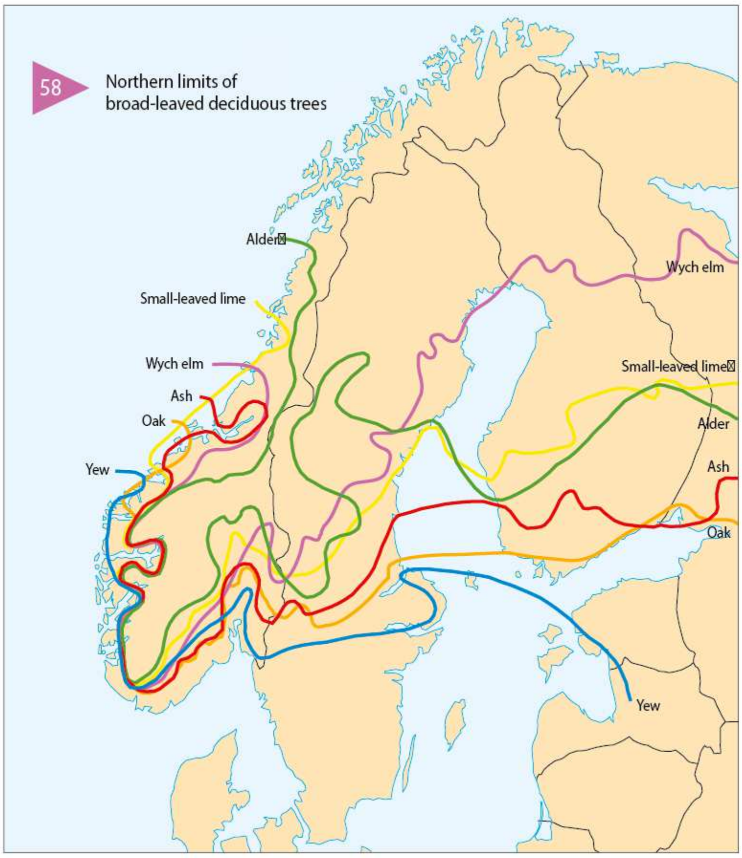


Map 70 The distribution of the vegetation zones is largely determined by the climate, and the units reflect the differing requirements of the plant cover for warmth in summer. The winter temperature also plays an important role for the southernmost zones in Norway, the nemoral and boreonemoral zones.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

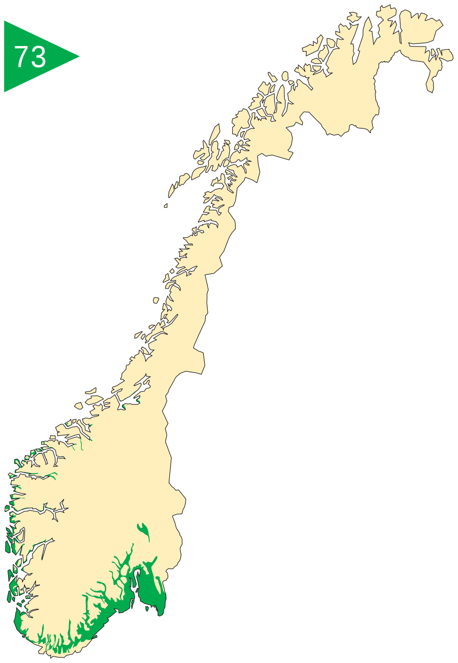
Map 72 The nemoral zone is only found in the lowlands on the southern fringe of south Norway.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



Map 58 The northern limits in Scandinavia and Finland for alder (*Alnus glutinosa*), ash (*Fraxinus excelsior*), oak (*Quercus* spp.), yew (*Taxus baccata*), small-leaved lime (*Tilia cordata*), and wych elm (*Ulmus glabra*). Of these, wych elm grows furthest north in Norway and alder grows furthest north in Sweden and Finland. Small-leaved lime is the next most northern of these six trees. Yew has the most limited occurrence.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



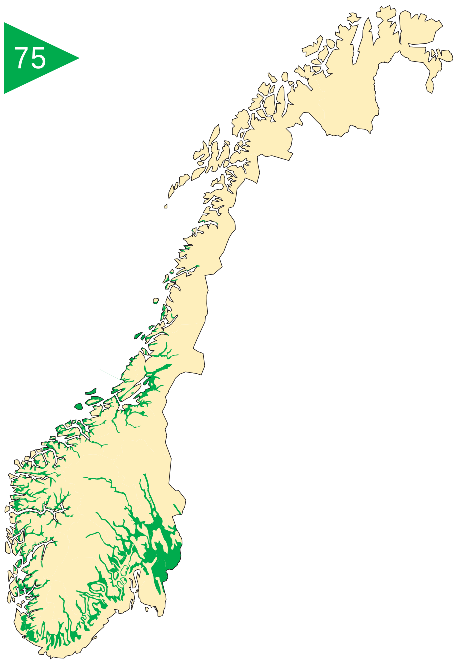
Map 73 The boreonemoral zone is found continuously as far north as Sunnmøre, and also occurs in favourable areas north to Trondheimsfjord.

Boreonemoral species

The boreonemoral zone contains by far the most species of all the vegetation zones in Norway and many of them are only found in this zone. This applies particularly to many south-eastern species occurring in the Oslofjord area. This is related to the extremely limited occurrence of the nemoral zone in this country, since in a wider European context most Norwegian boreonemoral species also occur in the nemoral zone. Species belonging to several floristic elements have their upper limit in the boreonemoral zone.

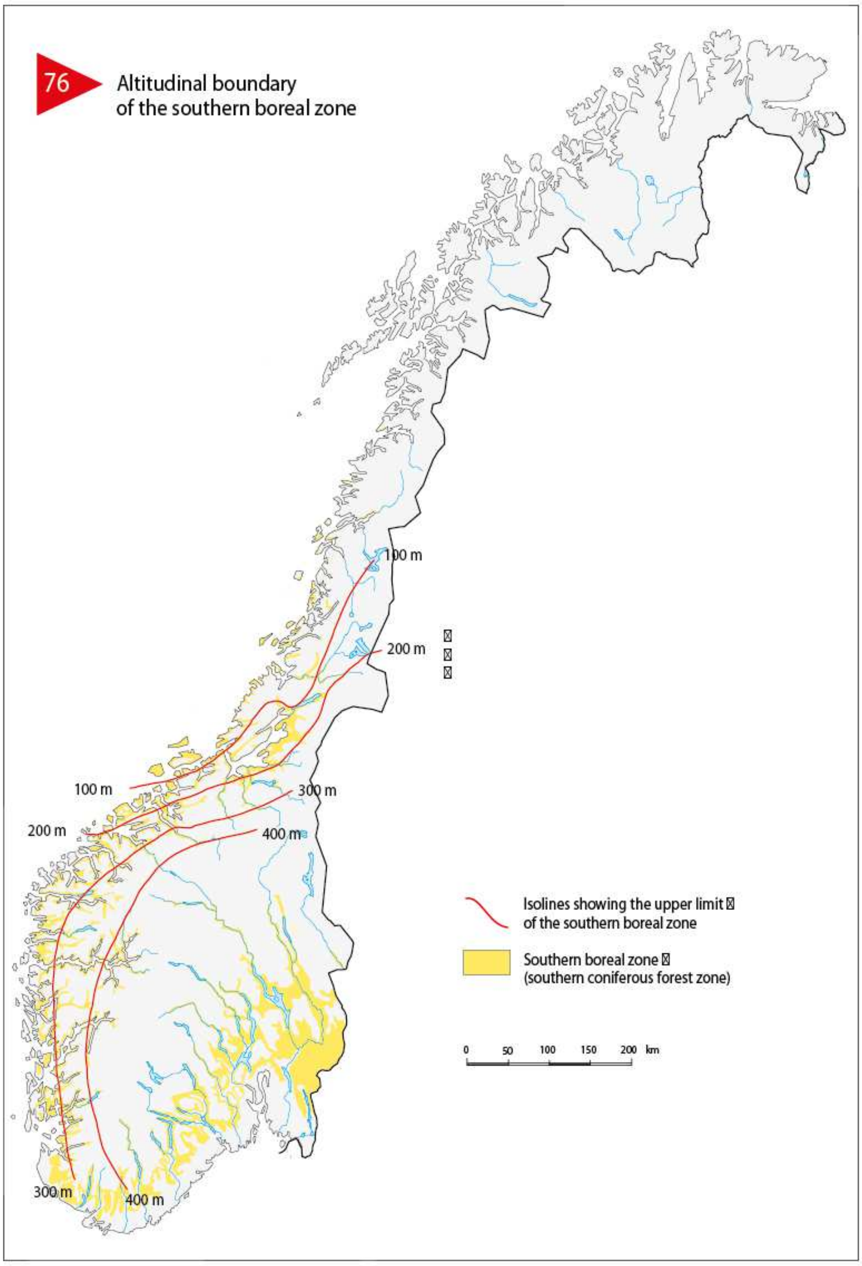
- Strongly western species, including spring squill (*Scilla verna*) and wood bitter-vetch (*Vicia orobus*)
- Distinctly southern species, including bloody crane's bill (*Geranium sanguineum*) and ivy (*Hedera helix*)
- Strongly south-eastern species, including meadow anemone (*Pulsatilla pratensis*) and mountain clover (*Trifolium montanum*)
- Distinctly south-eastern species, including dropwort (*Filipendula vulgaris*) and green strawberry (*Fragaria viridis*). Several species in this element also enter favourable localities in the southern boreal zone.

(Moen 1999)



Map 75 The southern boreal zone occurs continuously in southern Norway as far north as Helgeland (southern Nordland); further north it is found in favourable localities as far as Bodø.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



Map 76 The upper limit of the southern boreal zone in south-east Norway and inner fjord districts of west Norway is situated above 400 m a.s.l. It drops eastwards and northwards, passing below 100 m in north and west of Trondheimsfjorden.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

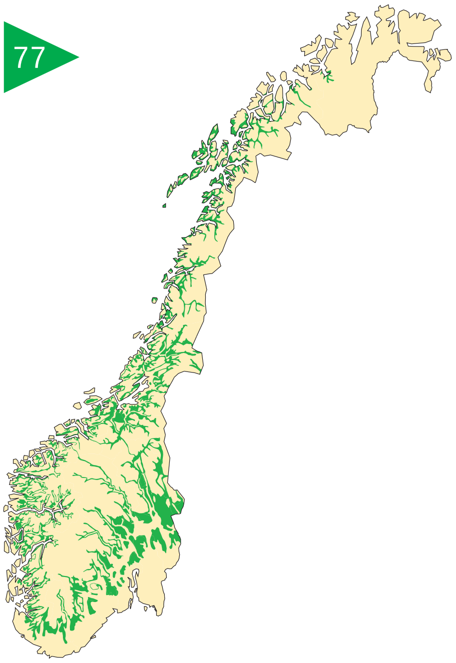
Southern boreal zone species lacking in the middle boreal zone

Species that have their upper or northern limits in the southern boreal zone belong to several floristic elements (page 19). The most important ones are the "weakly southern species". Otherwise, the "distinctly south-eastern species" and most of the "weakly south-eastern species" have their limit in the southern boreal zone. Examples of common species which only occur in the lower or southern parts of the southern boreal zone, but which are found north of Dovre are wild liquorice (*Astragalus glycyphyllos*), shining crane's-bill (*Geranium lucidum*), soft-grasses (*Holcus* spp.), fly honeysuckle (*Lonicera xylosteum*), rue-leaved saxifrage (*Saxifraga tridactylites*), and reflexed stonecrop (*Sedum rupestre*).

Common species which are found almost to the boundary to the middle boreal zone are important for demarcating the southern boreal zone. They include:

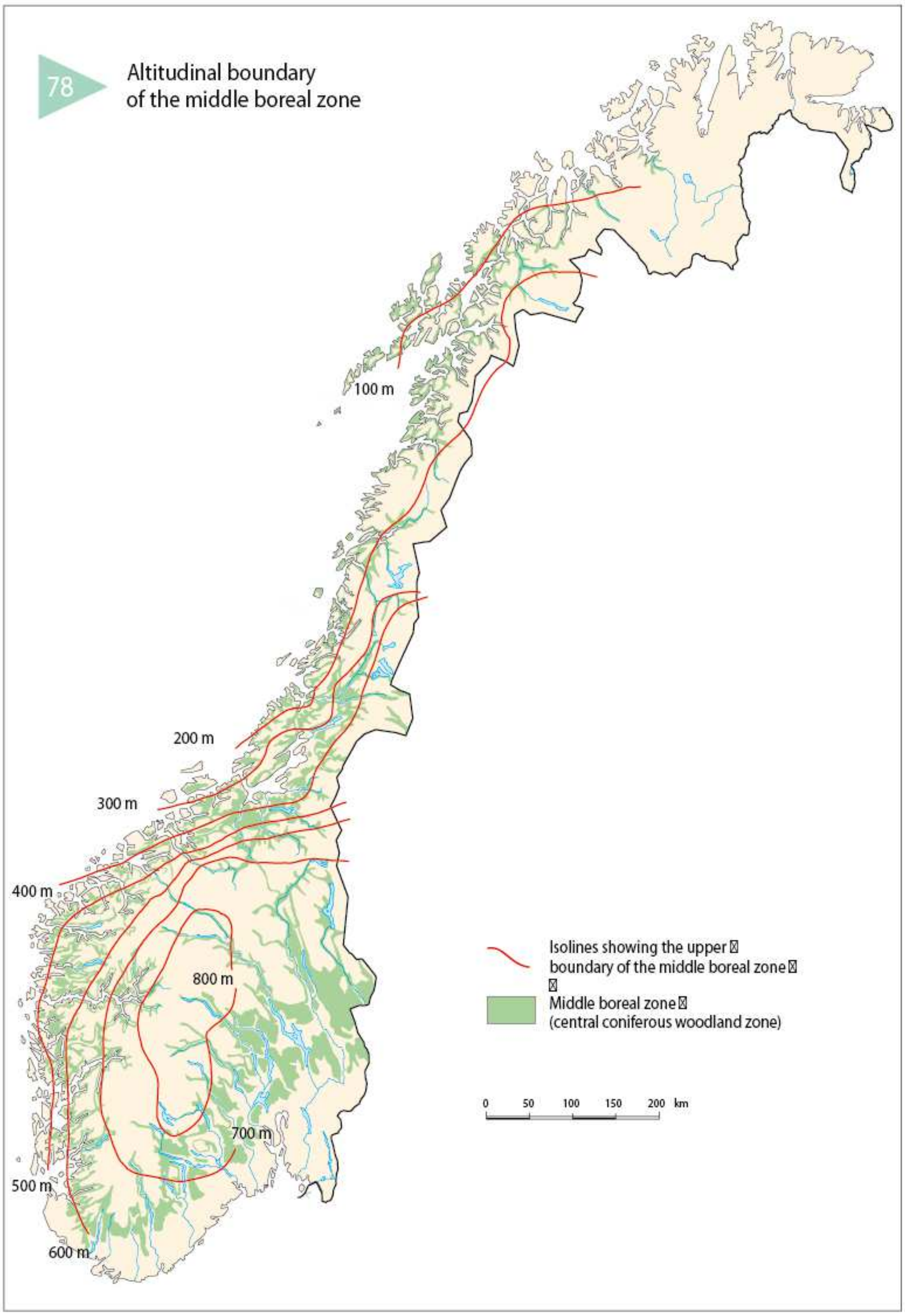
Basil thyme	*Acinos arvensis*
Alder	*Alnus glutinosa*
Lesser burdock	*Arctium minus*
Bristly bellflower	*Campanula cervicaria*
Glaucous sedge	*Carex flacca*
Prickly sedge	*Carex muricata*
Wild basil	*Clinopodium vulgare*
Common whitlowgrass	*Erophila verna*
Alder buckthorn	*Frangula alnus*
Liverleaf	*Hepatica nobilis*
Hop	*Humulus lupulus*
Hairy St John's-wort	*Hypericum hirsutum*
Touch-me-not balsam	*Impatiens noli-tangere*
Yellow iris	*Iris pseudacorus*
Nipplewort	*Lapsana communis*
Bitter-vetch	*Lathyrus linifolius*
Black pea	*Lathyrus niger*
Narrow-leaved everlasting-pea	*Lathyrus sylvestris*
Wall lettuce	*Mycelis muralis*
Wild marjoram	*Origanum vulgare*
Angular Solomon's-seal	*Polygonatum odoratum*
Braun's holly fern	*Polystichum braunii*
Bittersweet	*Solanum dulcamara*
Dark mullein	*Verbascum nigrum*
Great mullein	*Verbascum thapsus*
Guelder-rose	*Viburnum opulus*
Hill violet	*Viola collina*

77



Map 77 The middle boreal zone is found continuously as far north as Troms and also occurs in the lowlands near Alta.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



Map 78 The upper limit of the middle boreal zone in south-east Norway and inner Sognefjord is situated above 800 m a.s.l. and drops westwards and northwards, being below 300 m a.s.l. in north Norway.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

Middle boreal zone species lacking in the northern boreal zone

The middle boreal zone contains relatively few species, since it lacks most of the southern and south-eastern species (page 29), and also the most typical alpine plants. There are substantial floristic differences within the middle boreal zone, not only from the coast to the interior, but also from south to north. Unlike the zones described earlier, the middle boreal zone is found throughout the country. Because of the great distances involved, geographical barriers and historical factors, there are significant differences in the sub-types of middle boreal vegetation. For the southern (weakly thermophilous) species, the distance from southerly dispersal centres to north Norway was substantial after the Ice Age. The lack of species may be explained by them not having succeeded in spreading so far yet, thus failing to fill their potential range. This may, for example, explain the lack of species such as bird's-foot sedge, opposite-leaved golden-saxifrage, lily-of-the-valley, wild cotoneaster and mezereon (*Carex ornithopoda*, *Chrysosplenium alternifolium*, *Convallaria majalis*, *Cotoneaster scandinavicus*, *Daphne mezereum*) north of central Nordland, even though they are common throughout the middle boreal zone further south, and even occur higher up at favourable localities in southern Norway.

Many species are common in southerly zones, but stop in the middle boreal zone, including the following, which are found widely in Norway (+: these usually do not continue right through to the boundary with the northern boreal zone):

Baneberry	*Actaea spicata*
Thale cress	*Arabis thaliana*
Silver birch	*Betula pendula*
+Quaking grass	*Briza media*
Giant bellflower	*Campanula latifolia*
Common yellow-sedge	*Carex demissa*
Fingered sedge	*Carex digitata*
+Long-stalked yellow sedge	*Carex lepidocarpa*
+Greater tussock-sedge	*Carex pulicaris*
Alpine enchanter's-nightshade	*Circaea alpina*
+Hazel	*Corylus avellana*
Broad-leaved willowherb	*Epilobium montanum*
+Broad-leaved helleborine	*Epipactis helleborine*
+Yellow star-of-Bethlehem	*Gagea lutea*
+Woodruff	*Galium odoratum*
Lady's bedstraw	*Galium verum*
Herb-Robert	*Geranium robertianum*
+Wood avens	*Geum urbanum*
Jointed rush	*Juncus articulatus*
Compact rush	*Juncus conglomeratus*
Soft-rush	*Juncus effuses*
Field scabious	*Knautia arvensis*
+Spring pea	*Lathyrus vernus*
Marsh clubmoss	*Lycopodiella inundata*
Ostrich fern	*Matteuccia struthiopteris*
Three-nerved sandwort	*Moehringia trinervia*
+Bog-myrtle	*Myrica gale*
Heath cudweed	*Omalotheca sylvatica*
+Greater butterfly-orchid	*Platanthera chlorantha*
Bracken	*Pteridium aquilinum*
Green-flowered wintergreen	*Pyrola chlorantha*
+Lesser celandine	*Ranunculus ficaria*
+White beak-sedge	*Rhynchospora alba*
+Brown beak-sedge	*Rhynchospora fusca*
+Brown bog-rush	*Schoenus ferrugineus*
Common figwort	*Scrophularia nodosa*
Hedge woundwort	*Stachys sylvatica*
Common meadow-rue	*Thalictrum flavum*
+Wych elm	*Ulmus glabra*
+Wood vetch	*Vicia sylvatica*
Broad-leaved violet	*Viola mirabilis*
+	*Sphagnum cuspidatum*
	Sphagnum rubellum

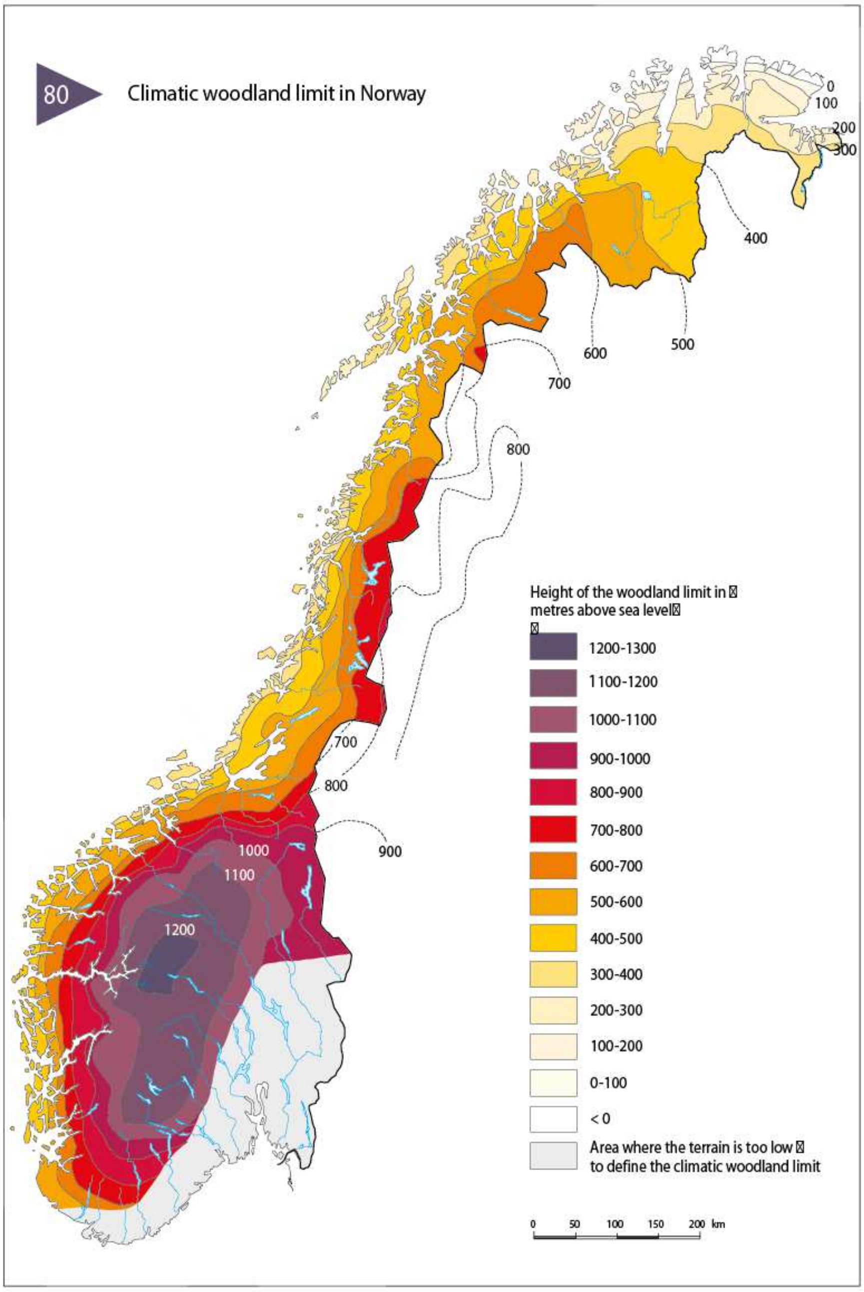
Map 79 The northern boreal zone is found continuously in upland and montane areas from Agder to northern Finnmark.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

Northern boreal zone species lacking in alpine and arctic areas

Many plant species have their upper or northerly limit in the northern boreal zone. A typical feature is that several kinds of trees cease to occur at that boundary, including grey alder (*Alnus incana*), bird cherry (*Prunus padus*), dark-leaved willow (*Salix myrsinifolia*), and bay willow (*S. pentandra*). Norway spruce, Scots pine and aspen (*Populus tremula*) also cease to occur, but birch and rowan (*Sorbus aucuparia*) continue into the southern arctic and low alpine zones, reaching as high as 1500 m in southern Norway. Many of the species listed below (marked +) generally cease to occur somewhat south of, or below, the climatic woodland limit.

Velvet bent	*Agrostis canina*
+Wood anemone	*Anemone nemorosa*
Lady-fern	*Athyrium filix-femina*
+Club sedge	*Carex buxbaumii* ssp. *buxbaumii*
Star sedge	*Carex echinata*
+Tawny sedge	*Carex hostiana*
+Pale sedge	*Carex pallescens*
+Pill sedge	*Carex pilulifera*
+Marsh thistle	*Cirsium palustre*
Sundews	*Drosera* spp.
+Broad-leaved cottongrass	*Eriophorum latifolium*
+Common twayblade	*Listera ovata*
+Water lobelia	*Lobelia dortmanna*
Alternate water-milfoil	*Myriophyllum alterniflorum*
+Wood-sorrel	*Oxalis acetosella*
Herb-Paris	*Paris quadrifolia*
+ meadow-grass	*Poa remota*
Whorled Solomon’s-seal	*Polygonatum verticillatum*
+Broad-leaved pondweed	*Potamogeton natans*
+Bird cherry	*Prunus padus*
+Raspberry	*Rubus idaeus*
	Sphagnum subnitens
Clover	*Trifolium* spp.
+Germander speedwell	*Veronica chamaedrys*
Heath speedwell	*Veronica officinalis*
Tufted vetch	*Vicia cracca*
+Bush vetch	*Vicia sepium*
+Common dog-violet	*Viola riviniana*



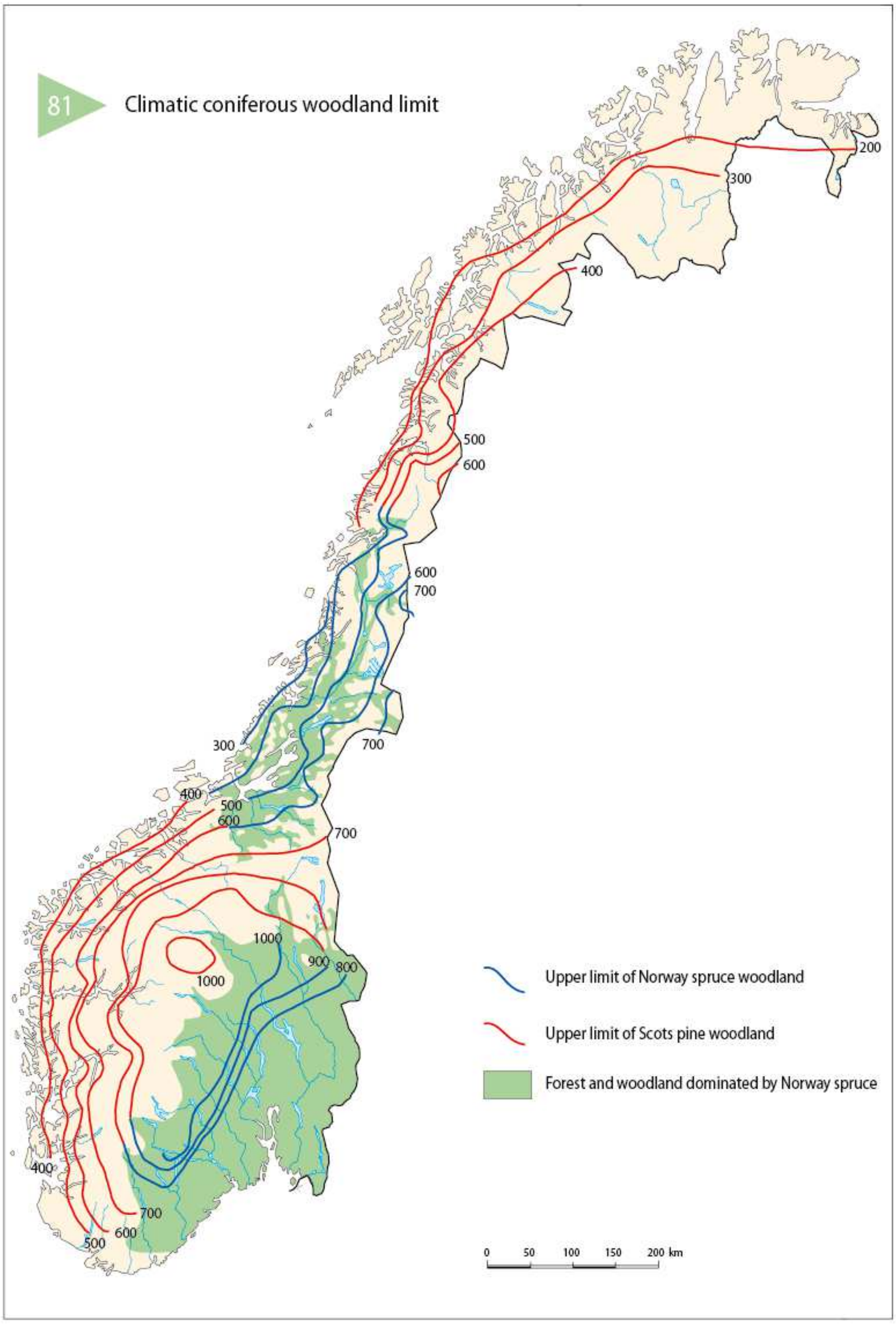
Map 80 This map shows isolines for the climatic woodland limit in Norway and neighbouring countries. The limit corresponds with the boundary between the boreal and arctic/alpine zones. Over most of the country, this is the upper boundary of the northern boreal zone, and upland birch woodland forms the woodland limit over large areas. Western parts of the country (the highly oceanic section) lack the northern boreal zone, and the middle boreal zone borders directly on the low alpine zone. The northernmost past of Finnmark is situated north of the climatic woodland limit and the 0 m isoline demarcates the southern arctic zone. The woodland limit is defined as a line drawn through the uppermost, or northernmost, woodland stands. Where the climate determines the uppermost extent of wood-land, this is the *climatic woodland limit*. Otherwise the *actual woodland limit* may be determined by topographical factors, soil factors, or the impact of humans, and is often situated considerably lower than the climatic woodland limit.

The climatic woodland limit extends significantly higher on south-facing than of north-facing slopes. For instance, on one particularly favourable south-facing slope in the Jotunheimen, birch woodland continues up to 1320 m a.s.l. Such extremes have been avoided, and the height of the climatic woodland limit is placed almost 100 m lower in the area in question.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

The boundary on the map has been drawn at the uppermost occurrence of woodland on flat or gently sloping terrain, facing south or west. For most of the country, topographical maps have been used to find reference points for the climatic woodland limit. In areas with low mountains, the actual woodland limit is usually situated far below the climatic woodland limit, and the demand placed on reference areas has been that the terrain extends more than 100 m higher than the woodland limit. Otherwise, elevational boundaries for vegetation types and individual species have been used to define reference areas. The isolines have been drawn on the basis of a large number of reference areas. Substantial areas in Norway, especially in south-east and southernmost Norway, lack mountainous and hilly areas where the woodland limit can be defined.

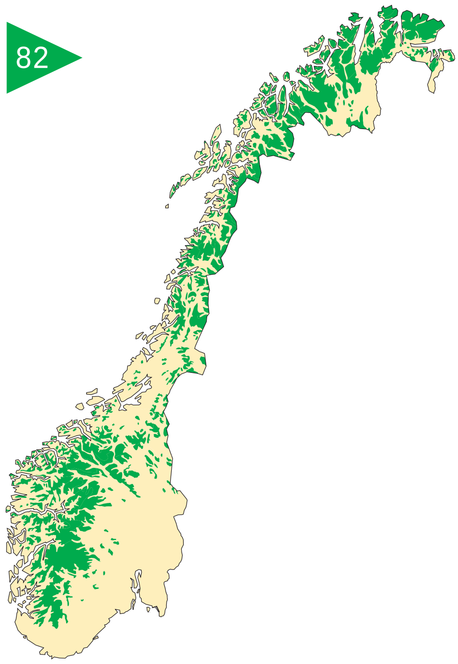
In the Jotunheimen region, the climatic woodland limit is above 1200 m a.s.l. From there it drops in all directions, least towards the east. In central parts of southern Norway, it is around, or higher than, 1000 m a.s.l. In the fjord districts of west Norway, large parts of central Norway, and the interior of north Norway, it is located at about 500-800 m. It is below 400 m in coastal districts from central Norway northwards, particularly in large parts of north Norway.



Map 81 The upper limits of Scots pine and Norway spruce woodlands and forests are shown on the map by isolines. The main areas of spruce forest and woodland are also shown, and within these areas the upper limit for Scots pine is not shown since it was difficult to determine a representative limit owing to the predominance of spruce.
From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

Spruce woodland extends well above 1000 m in the inner valleys of Buskerud and Oppland in the northern part of southern Norway. Pine woodland reaches above 1000 m in central parts of Jotunheimen. The coniferous woodland limit drops in all directs from these central mountainous regions. The northernmost pinewoods are found in Porsanger, in eastern Finnmark.
(Map prepared by Børre Aas and based on research in the early 1960s.)

82



Map 82 Areas above the woodland limit.

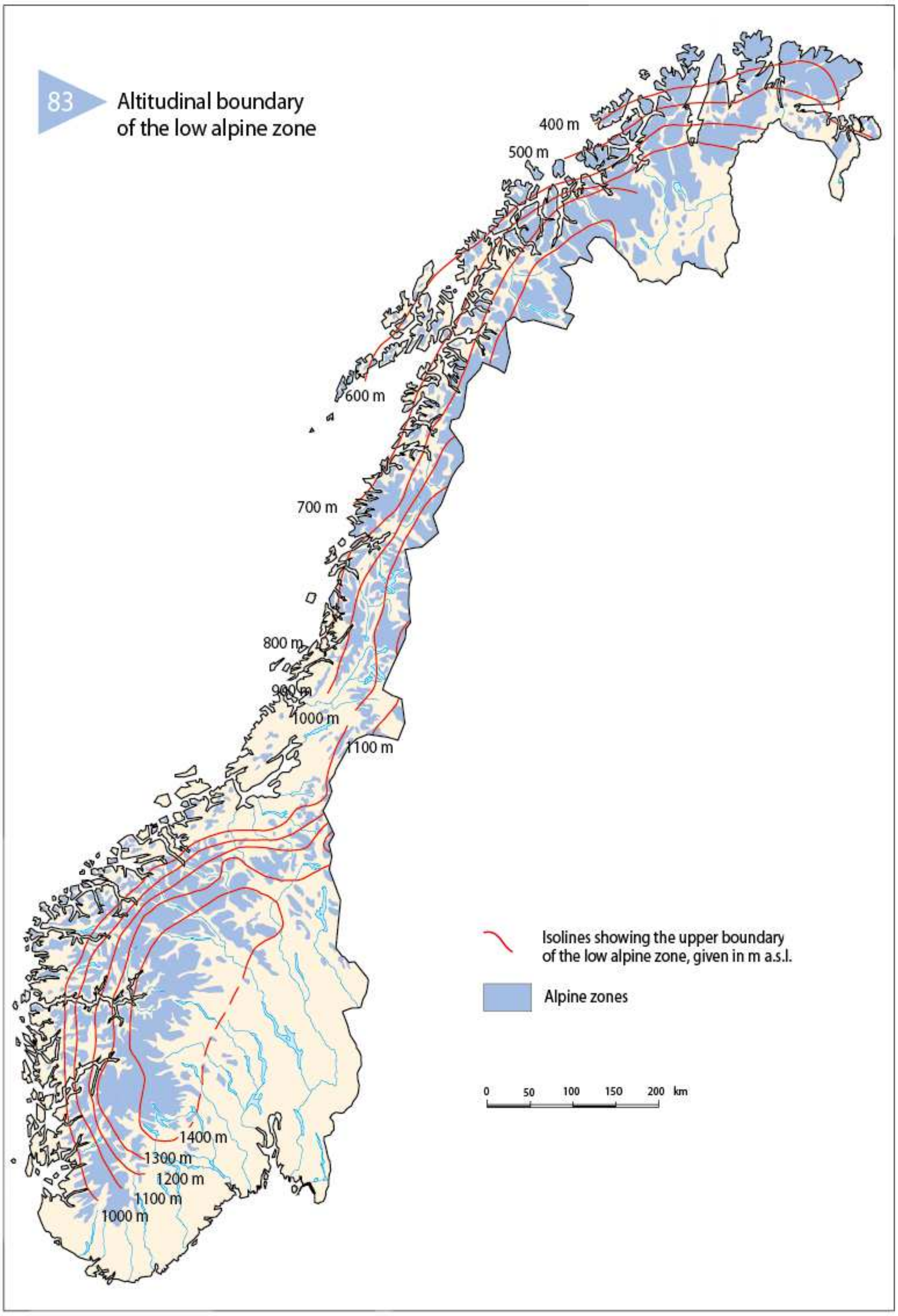
From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

Species whose upper limit is in the low alpine zone

Some species have their main distribution in the northern boreal and low alpine zones, and are lacking or seldom in the middle boreal and middle alpine zones. They include purple gentian (*Gentiana purpurea*), northern stitchwort (*Stellaria borealis*), and mountain hair-grass (*Vahlodea atropurpurea*).

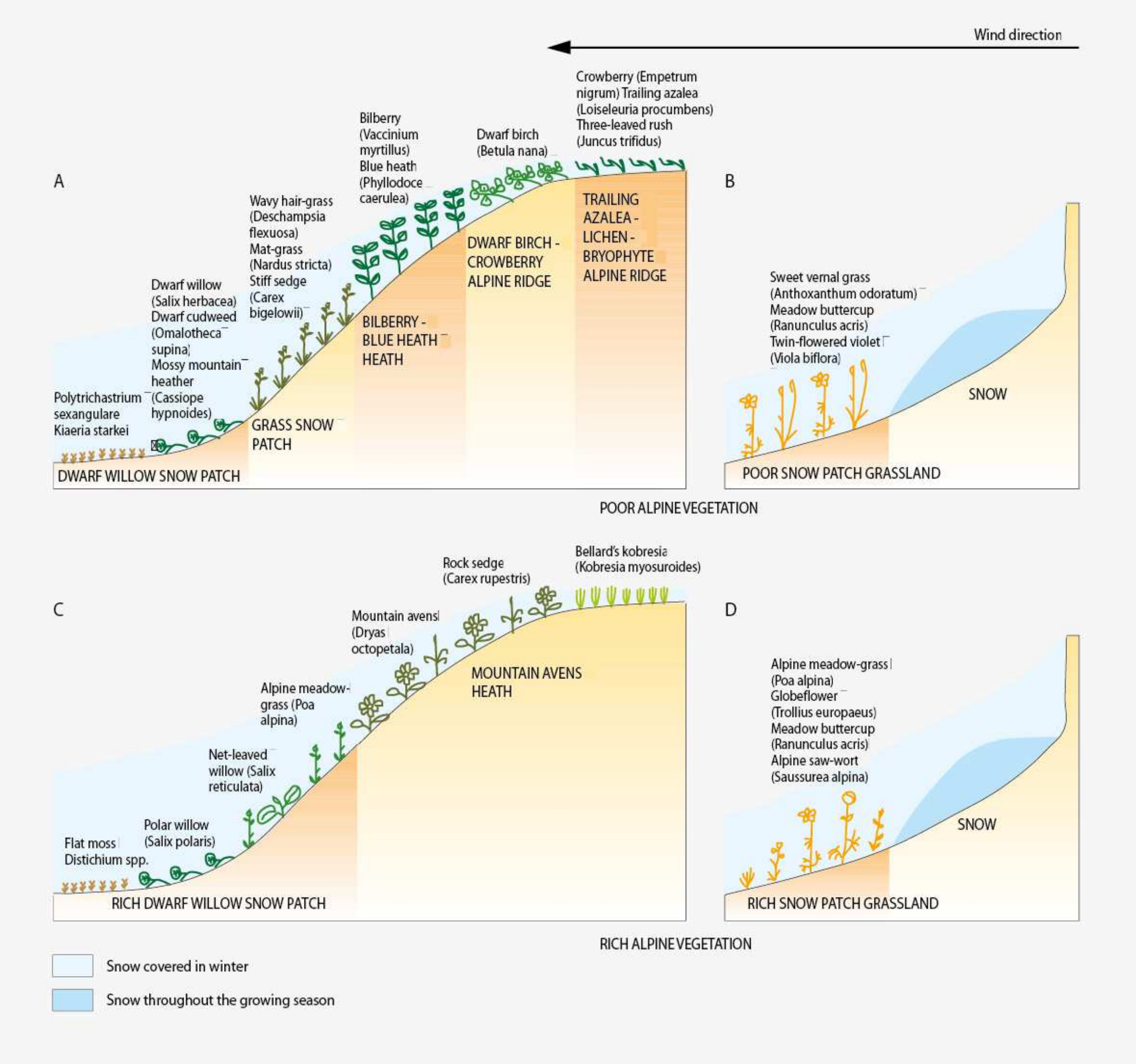
The upper limit of many mire species is in the low alpine zone, including large yellow-sedge (*Carex flava*) and deergrass (*Trichophorum cespitosum*) and most peat mosses (*Sphagnum* spp.). In addition, many species growing on mineral soil have their upper limit in the low alpine zone, including:

Common mouse-ear	*Cerastium fontanum*
Alpine blue-sow-thistle	*Cicerbita alpina*
Northern bedstraw	*Galium boreale*
Water avens	*Geum rivale*
Oak fern	*Gymnocarpium dryopteris*
Thread rush	*Juncus filiformis*
Linnea	*Linnaea borealis*
Lesser twayblade	*Listera cordata*
Beech fern	*Phegopteris connectilis*
Scots pine	*Pinus sylvestris*
White buttercup	*Ranunculus platanifolius*
Yellow-rattle	*Rhinanthus minor* coll.
Halbert-leafed willow	*Salix hastata*
Rowan	*Sorbus aucuparia*
Lesser stitchwort	*Stellaria graminea*
Wood stitchwort	*Stellaria nemorum*
Common valerian	*Valeriana sambucifolia*



Map 83 The alpine areas are coloured. The upper boundary of the low alpine zone is located above 1400 m in the central mountainous region, but drops towards the south, west, and north, and is below 400 m furthest north.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



Schematic presentation of ordinary vegetation types with examples of typical species in profiles from alpine ridges to snow patches in the low alpine vegetation zone. Poor vegetation is found in areas with hard, base-poor rocks, whereas rich alpine vegetation occurs where the bedrock is schistose or base-rich. Alpine ridges have a thin snow cover in winter and quickly become snow free in late winter. Their lee sides have a stable snow cover and quite a long growing season. The ground close to snow patches becomes snow free late, often far into the summer.

Profiles A and C show the situation from an alpine ridge exposed to the weather down to a snow patch. The ridges are generally dry and in profiles A and C the snow patches also dry up in the summer. Here, heathland series vegetation dominates the entire profile. In areas where seepage takes place and the soil is moist throughout the growing season, perhaps the site is located just below a snowdrift (see profile B and D), grassland communities prevail, which may be both riche in species and have a relatively high production. In extreme snow patch locations, where the snow lies particularly far into the growing season, vascular plants are absent and the ground is covered with bryophytes. (Moen 1999)

Species whose upper limit is in the middle alpine zone

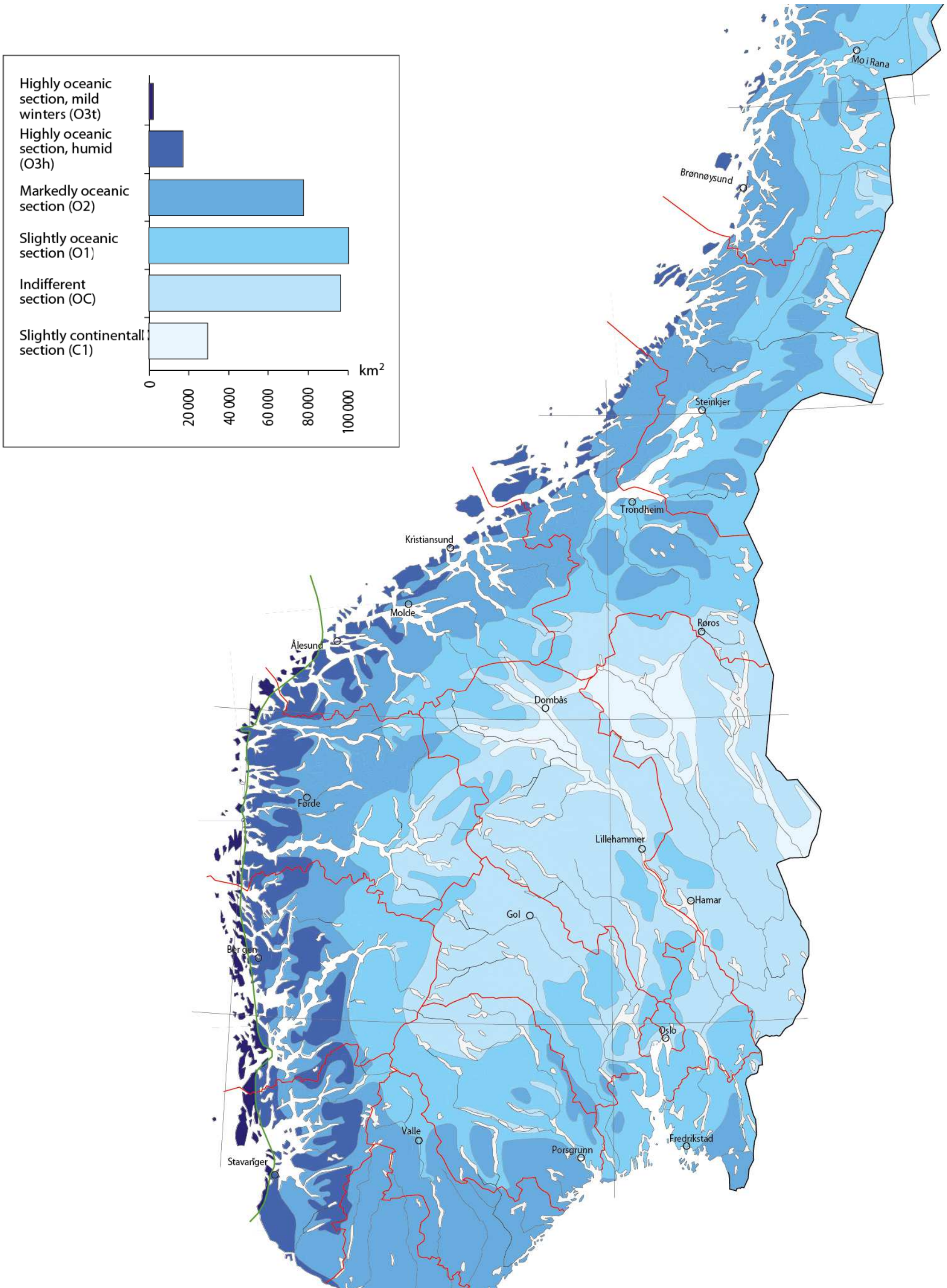
Many species which are common in the low alpine zone, some in the boreal zones, too, cease to occur in the middle alpine zone. They include:

Bearberry	*Arctostaphylos uva-ursi*
Frog orchid	*Coeloglossum viride*
Diapensia	*Diapensia lapponica*
Common cottongrass	*Eriophorum angustifolium*
Hare's-tail cottongrass	*Eriophorum vaginatum*
Alpine crowberry	*Empetrum nigrum* ssp. *hermaphroditum*
Rosebay willowherb	*Epilobium angustifolium*
Wood crane's-bill	*Geranium sylvaticum*
Common juniper	*Juniperus communis*
Mat-grass	*Nardus stricta*
Northern willow	*Salix glauca*
Woolly willow	*Salix lanata*
Downy willow	*Salix lapponum*
Whortle-leaved willow	*Salix myrsinites*
Tea-leaved willow	*Salix phylicifolia*
Red campion	*Silene dioica*
Goldenrod	*Solidago virgaurea*
Bilberry	*Vaccinium myrtillus*
Bog bilberry	*Vaccinium uliginosum*
Cowberry	*Vaccinium vitis-idaea*

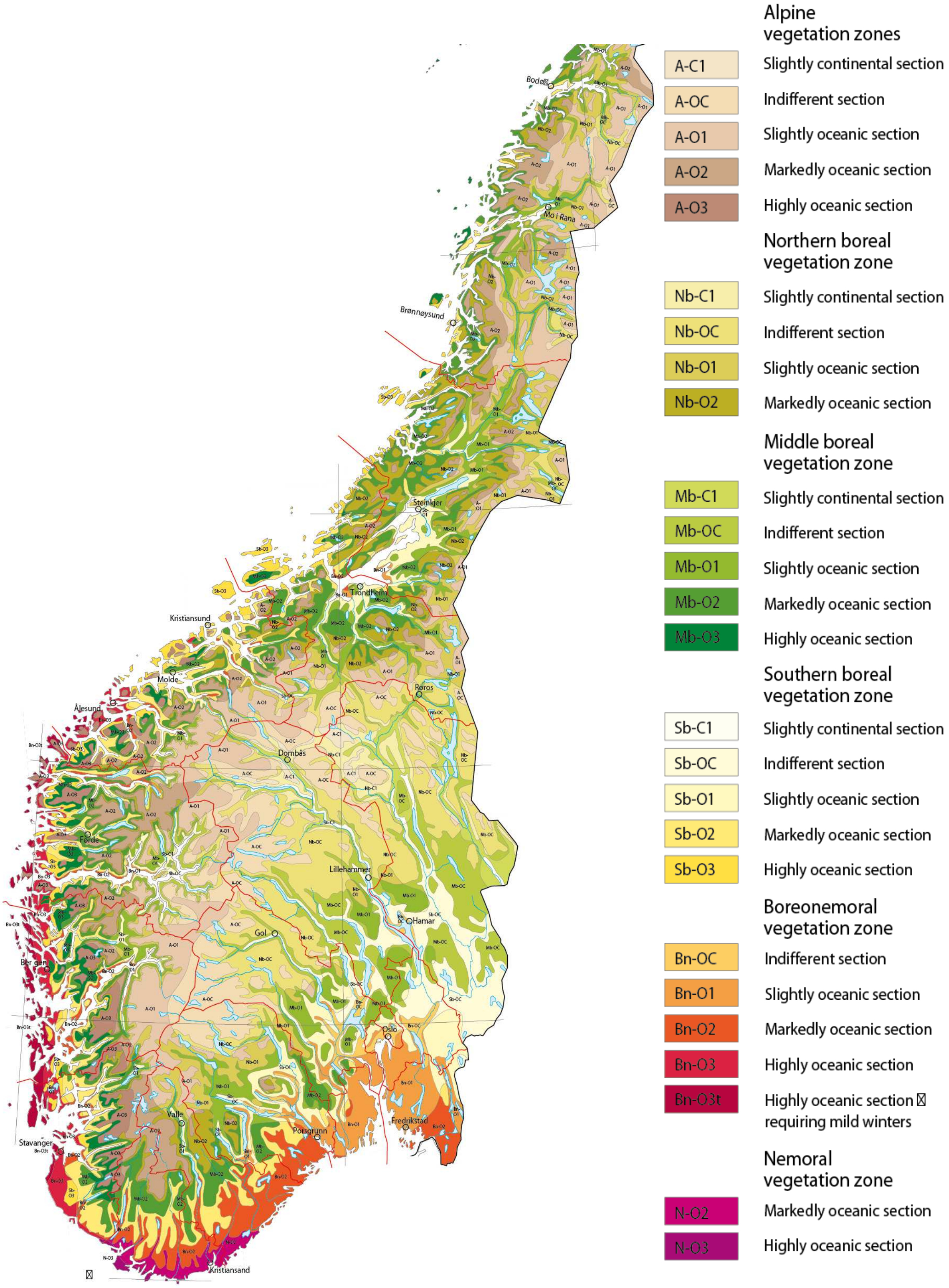
Middle and high alpine species

Some species mainly occur above the low alpine zone:

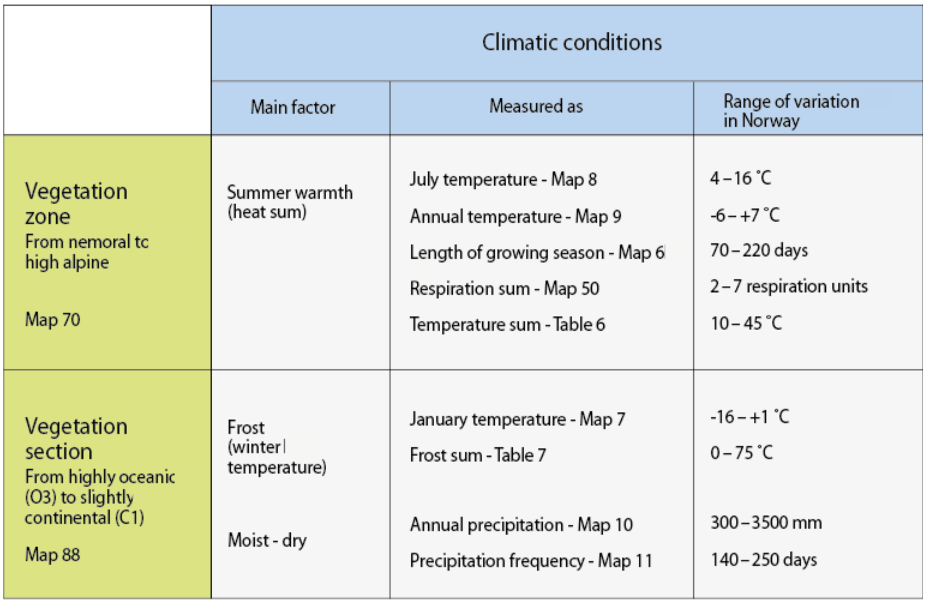
High alpine harebell	*Campanula uniflora*
High alpine cress	*Cardamine bellidifolia*
Nodding sedge	*Carex fuliginosa* ssp. *misandra*
Arctic wood-rush	*Luzula arctica*
Curved wood-rush	*Luzula arcuata* ssp. *arcuata*
Curved wood-rush	*Luzula arcuata* coll.
Spiked snow-grass	*Phippsia algida*
Outspread snow-grass	*Phippsia concinna*
Arctic meadow-grass	*Poa arctica* coll.
Wavy meadow-grass	*Poa flexuosa*
Glacier buttercup	*Ranunculus glacialis*
Tufted pearlwort	*Sagina cespitosa*



Map 88 The vegetation sections show the geographical variation between coast and inland, which, in Norway, largely means from west to east. This variation is related to differences in oceanicity, where the winter temperature (frost) and the moisture in the atmosphere (humidity) are important climatic factors. The vegetation sections are distinguished on the basis of botanical criteria, the distribution of plant species and vegetation types being decisive.
From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

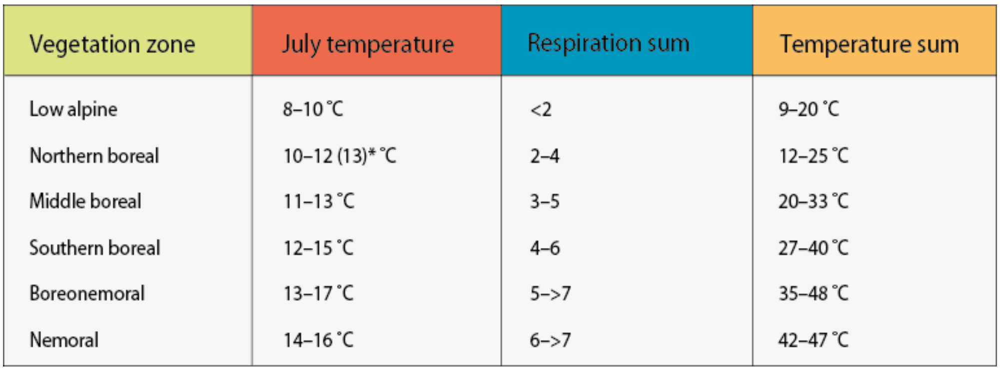


Map 95 The map depicts a combination of the vegetation zone and vegetation section maps of Norway (Maps 70 and 88). The vegetation ecological regions may also be called 'zonal sections'. The 26 vegetation ecological regions are differentiated on purely botanical criteria, the distribution of plant species and vegetation types having been decisive. Because each region is defined according to the variation in both zones (south-north and lowland-highland) and sections (coast-inland), they show significant similarities in vegetation, species composition and ecological conditions. The map is extremely detailed in parts of the country with great regional variations. Because the three alpine zones are not differentiated separately, the five vegetation ecological regions within the alpine areas are the widest, most heterogeneous ones. Some of these alpine units also cover the largest areas. From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



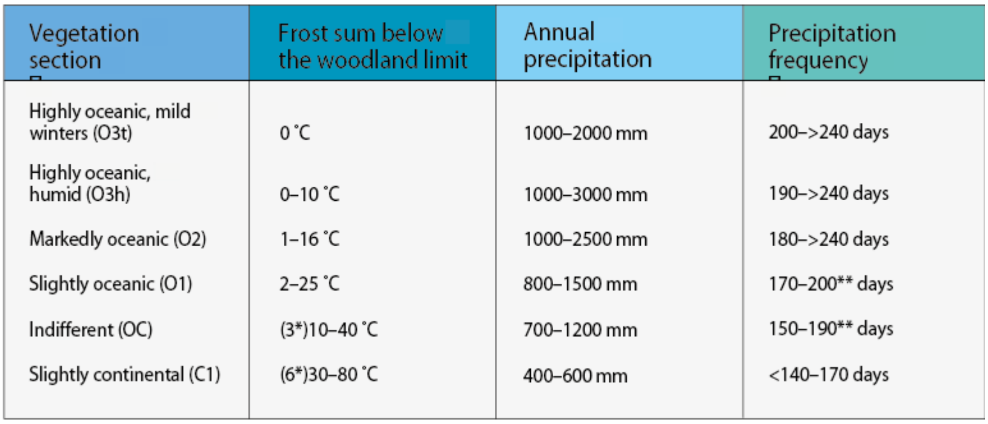
	Climatic conditions		
	Main factor	Measured as	Range of variation in Norway
Vegetation zone From nemoral tc high alpine Map 70	Summer warmth (heat sum)	July temperature - Map 8	4 – 16 °C
		Annual temperature - Map 9	-6 – +7 °C
		Length of growing season - Map 6	70 – 220 days
		Respiration sum - Map 50	2 – 7 respiration units
		Temperature sum - Table 6	10 – 45 °C
Vegetation section From highly oceanic (O3) to slightly continental (C1) Map 88	Frost (winter temperature)	January temperature - Map 7	-16 – +1 °C
		Frost sum - Table 7	0 – 75 °C
	Moist - dry	Annual precipitation - Map 10	300 – 3500 mm
		Precipitation frequency - Map 11	140 – 250 days

Main aspects in the relationship between vegetation zones, sections, climatic factors, and climatic maps. (Moen 1999)



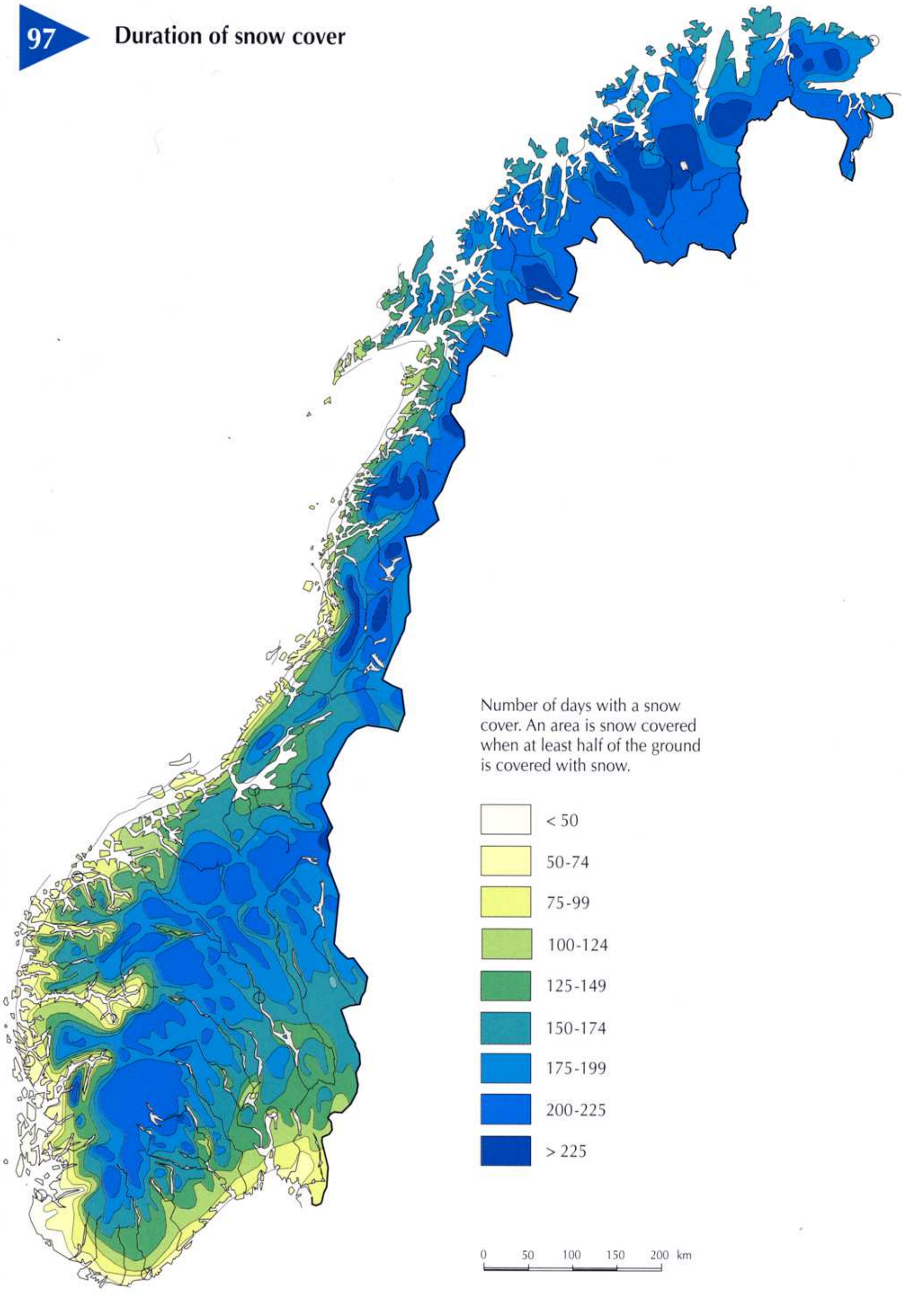
Vegetation zone	July temperature	Respiration sum	Temperature sum
Low alpine	8–10 °C	<2	9–20 °C
Northern boreal	10–12 (13)* °C	2–4	12–25 °C
Middle boreal	11–13 °C	3–5	20–33 °C
Southern boreal	12–15 °C	4–6	27–40 °C
Boreonemoral	13–17 °C	5–>7	35–48 °C
Nemoral	14–16 °C	6–>7	42–47 °C

Features of the climate that are characteristic for the vegetation zones. The values are based on normal temperatures from weather stations. The respiration sums illustrate the growth potential in the climate, where one unit corresponds to the respiration of Norway spruce for 30 days at 10°C. The temperature sums show the sum of all the monthly temperatures that are higher than 5°C for all the months of the year. (* inner Finnmark) (Moen 1999)



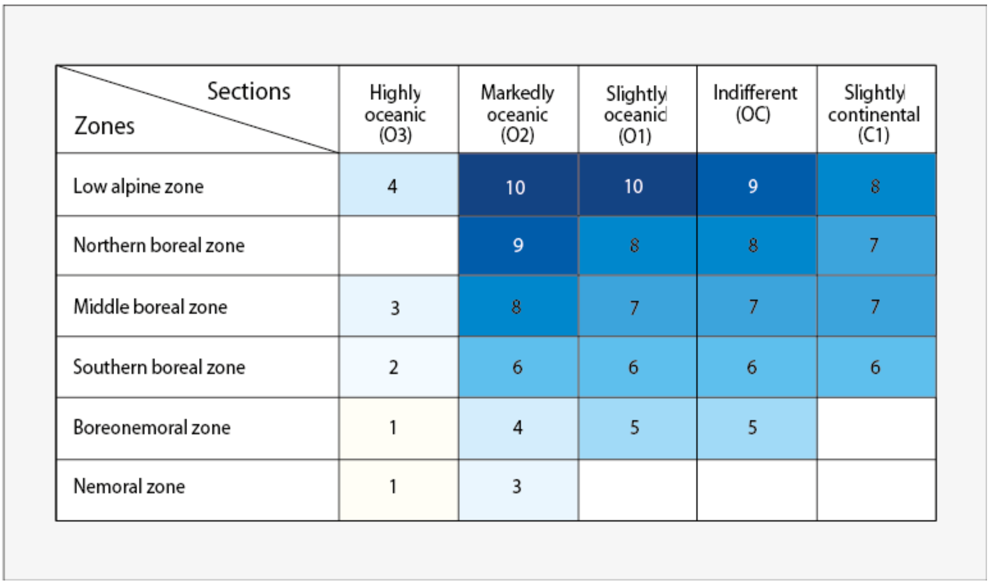
Vegetation section	Frost sum below the woodland limit	Annual precipitation	Precipitation frequency
Highly oceanic, mild winters (O3t)	0 °C	1000–2000 mm	200–>240 days
Highly oceanic, humid (O3h)	0–10 °C	1000–3000 mm	190–>240 days
Markedly oceanic (O2)	1–16 °C	1000–2500 mm	180–>240 days
Slightly oceanic (O1)	2–25 °C	800–1500 mm	170–200** days
Indifferent (OC)	(3*)10–40 °C	700–1200 mm	150–190** days
Slightly continental (C1)	(6*)30–80 °C	400–600 mm	<140–170 days

Features of the climate that are characteristic for the vegetation sections. The frost sum is calculated by adding together all the monthly temperatures that are below 0°C for all the moths of the year. (* values for lowland localities near Sognefjord; ** many more days with precipitation on the coast of Finnmark) (Moen 1999)



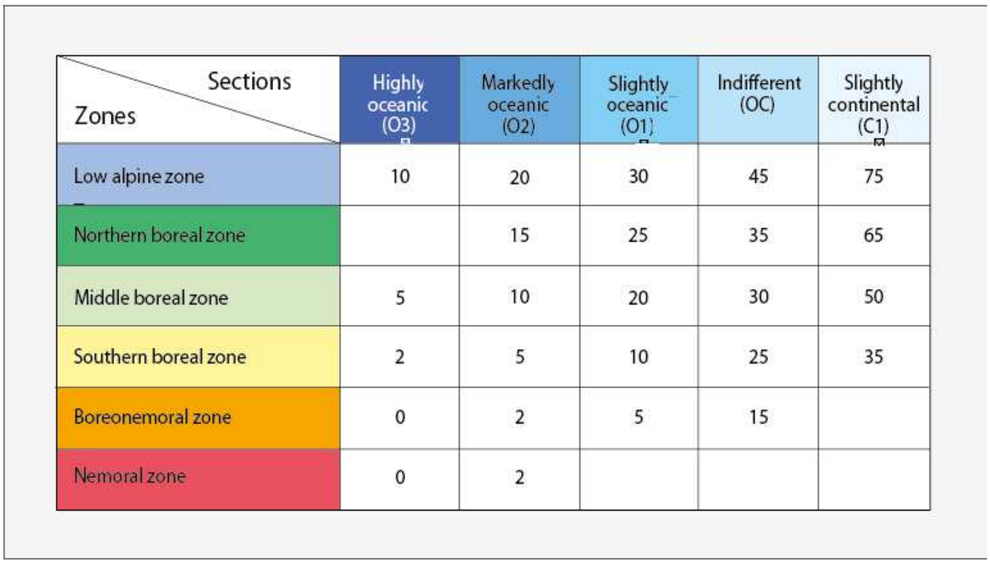
Map 97 The snow influences the vegetation cover in many ways and the distribution of the snow is extremely important for the regional variation in the vegetation. This map shows the number of days with snow-covered ground, mainly based on meteorological data from lowland stations. Higher areas, particularly the mountainous areas immediately inland from the coast from Rogaland to Troms, have a significantly longer duration of snow cover than the map indicates.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



Sections Zones	Highly oceanic (O3)	Markedly oceanic (O2)	Slightly oceanic (O1)	Indifferent (OC)	Slightly continental (C1)
Low alpine zone	4	10	10	9	8
Northern boreal zone		9	8	8	7
Middle boreal zone	3	8	7	7	7
Southern boreal zone	2	6	6	6	6
Boreonemoral zone	1	4	5	5	
Nemoral zone	1	3			

Number of days with snow-covered ground in the vegetation ecological regions of Norway. Each step on the scale represents about 25 days with snow. The lightest shades indicate regions with fewer than 25 days, the darkest those with more than 225 days. Some vegetation ecological regions have considerable variations in snow conditions, and the figure shows an assumed average. (Moen 1999)



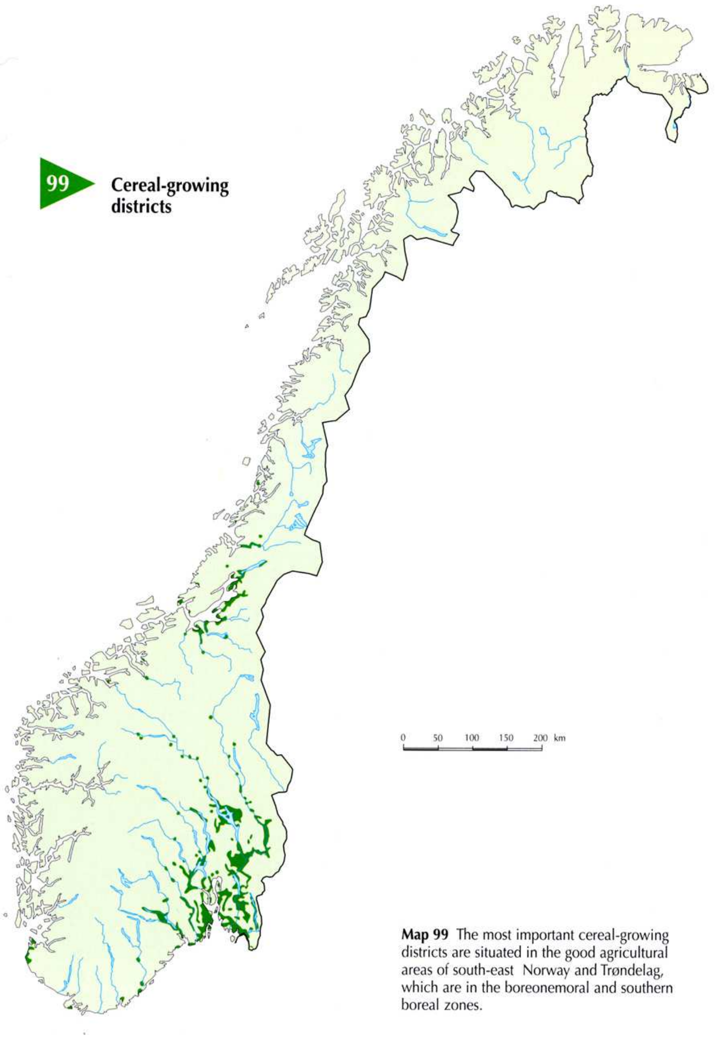
Sections Zones	Highly oceanic (O3)	Markedly oceanic (O2)	Slightly oceanic (O1)	Indifferent (OC)	Slightly continental (C1)
Low alpine zone	10	20	30	45	75
Northern boreal zone		15	25	35	65
Middle boreal zone	5	10	20	30	50
Southern boreal zone	2	5	10	25	35
Boreonemoral zone	0	2	5	15	
Nemoral zone	0	2			

Frost sums in the various vegetation ecological regions. The values represent rounded off averages for at least 10 localities in each region. (Moen 1999)

98 Fruit-growing districts

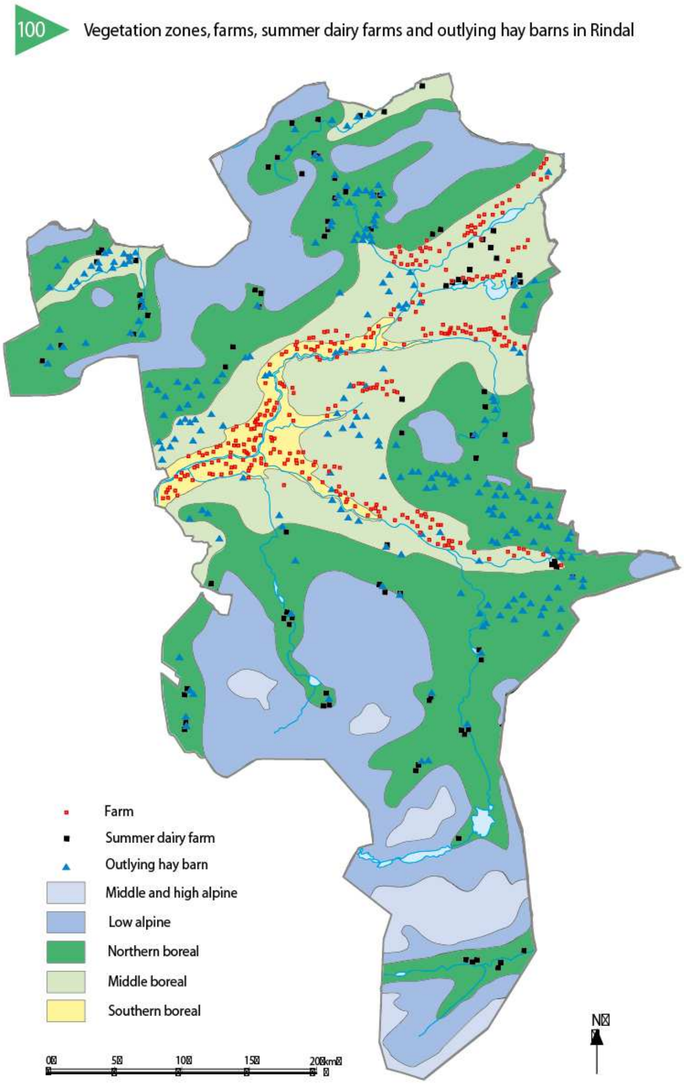
Map 98 The best fruit-growing districts are situated in those parts of the boreonemoral zone in south-east Norway that have the warmest summers, especially Lier and its surroundings in Buskerud, west of Oslo. However,inner parts of west Norway, particularly Hardanger and Sogn, are also important, likewise Sogndal and other parts of the southern boreal zone in west Norway that have the warmest summers.

99 Cereal-growing districts

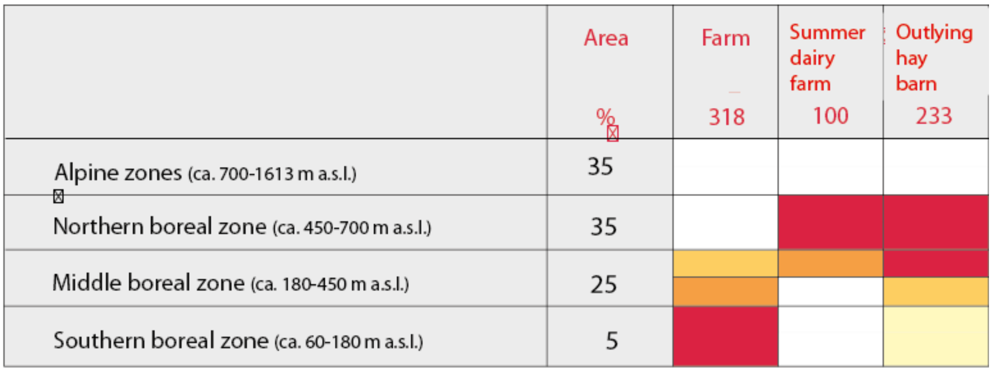


Map 99 The most important cereal-growing districts are situated in the good agricultural areas of south-east Norway and Trøndelag, which are in the boreonemoral and southern boreal zones.

From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



Map 100 Distribution of vegetation zones, farms, summer dairy farms, and outlying hay barns in Rindal, Nordmøre. From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



	Area %	Farm 318	Summer dairy farm 100	Outlying hay barn 233
Alpine zones (ca. 700-1613 m a.s.l.)	35			
Northern boreal zone (ca. 450-700 m a.s.l.)	35		🟥	🟥
Middle boreal zone (ca. 180-450 m a.s.l.)	25	🟨	🟧	🟥
		🟧		🟨
Southern boreal zone (ca. 60-180 m a.s.l.)	5	🟥		🟨

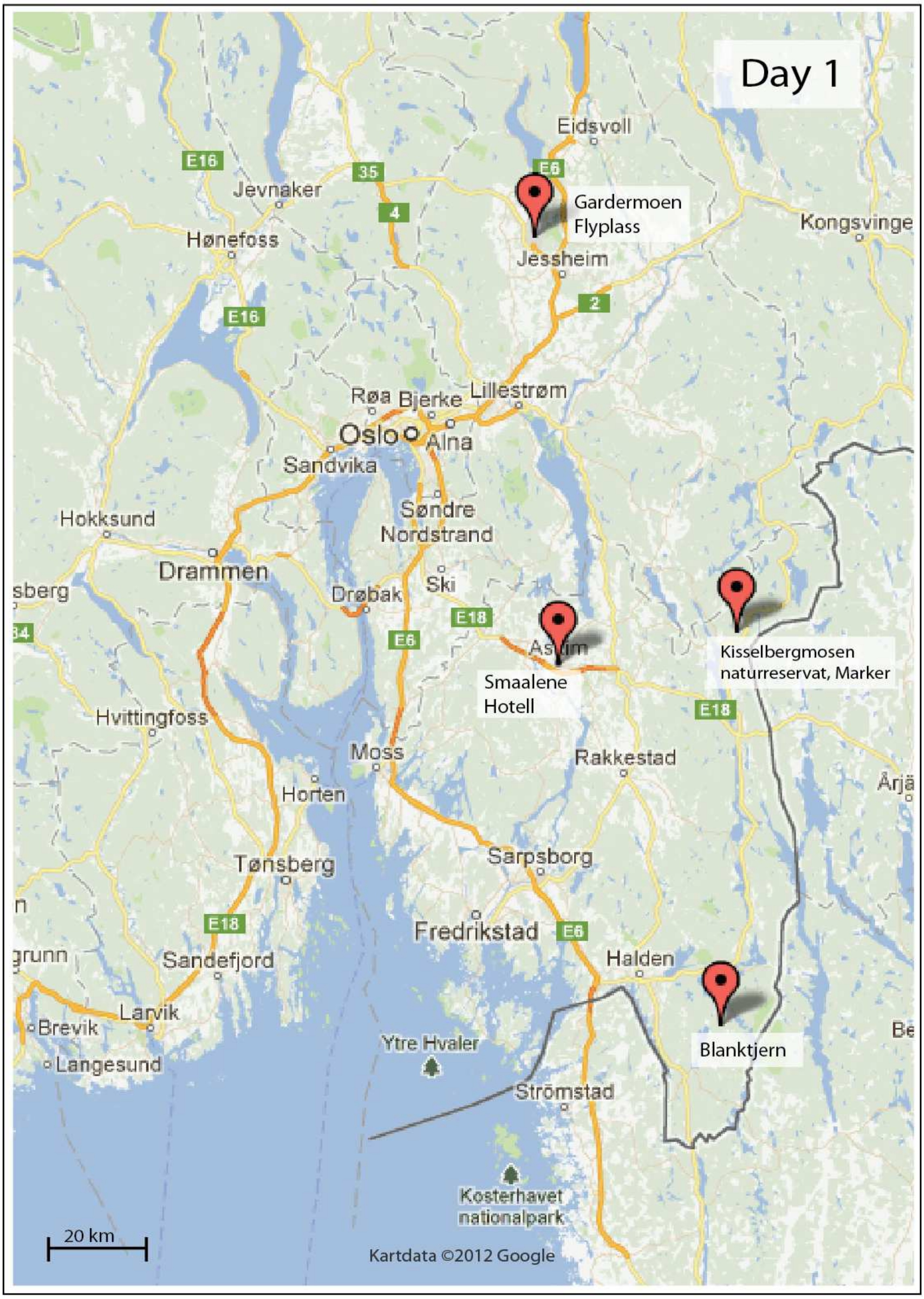
Distribution of vegetation zones, farms, summer dairy farms, and outlying hay barns in Rindal, Nordmøre. Dark red depicts main occurrences, lighter colours depict more seldom occurrence. (Moen 1999)

DAY 1

SØNDRE KISSELBERGMOSEN

BLANKTJERN (MORTTJØNN) (OSLO-TO-TRONDHEIM TRANSECT)

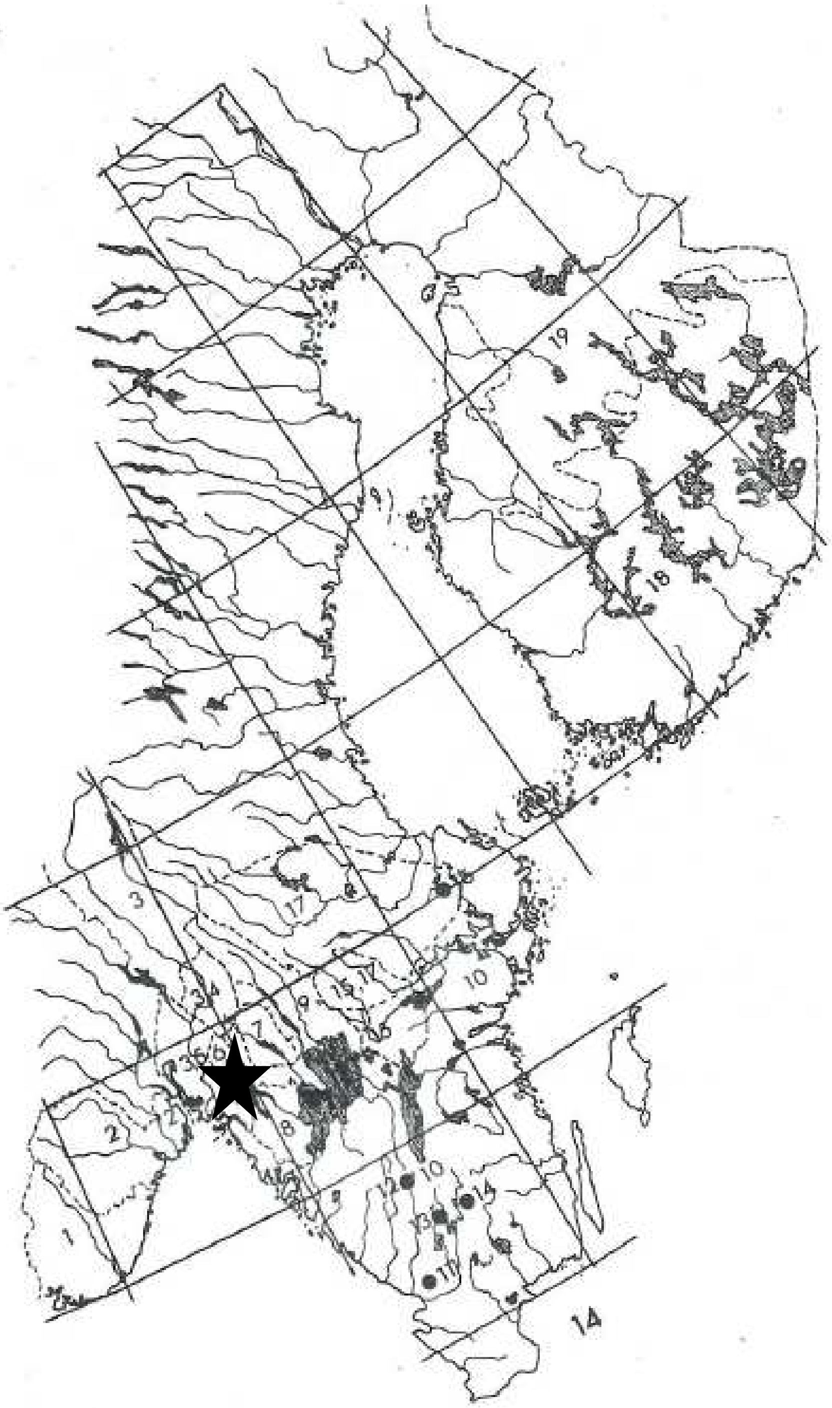
Saturday 8 September 2012


Day 1
Gardermoen Flyplass
Smaalene Hotell
Kisselbergmosen naturreservat, Marker
Blanktjern
Eidsvoll
Jevnaker
Hønefoss
Jessheim
Kongsvinge
Røa
Bjerke
Lillestrøm
Oslo
Alna
Sandvika
Søndre Nordstrand
Hokksund
Drammen
sberg
Drøbak
Ski
Askim
Hvittingfoss
Moss
Horten
Rakkestad
Årjä
Tønsberg
Sarpsborg
Fredrikstad
Halden
Sandefjord
grunn
Larvik
Brevik
Langesund
Ytre Hvaler
Strömstad
Be
Kosterhavet nationalpark
E16
35
4
E6
2
E18
34
20 km
Kartdata ©2012 Google

Søndre Kisselbergmose: general information – Mikael Ohlson

R.H. Økland 1989 - Hydromorphology and phytogeography of mires in inner Østfold, *Opera Botanica* 97.

Fig. 14. Position of areas studied in more important S Fennoscandian works on mire part type distribution. Numbers refer to references in Tab. 4.



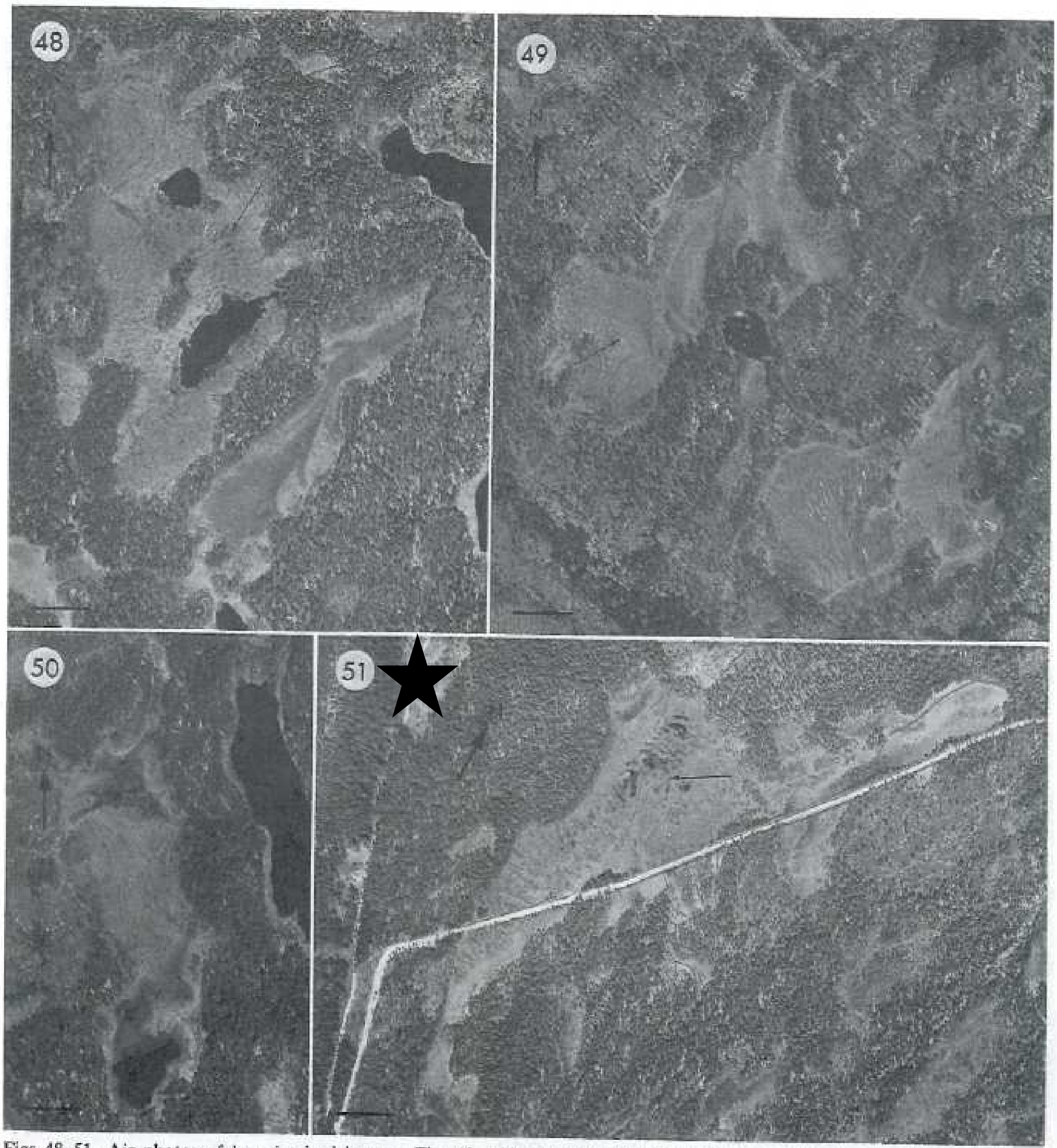
The position of the site (site nr. 6) is marked with a ★

Tab. 4. Investigations used for description of S Fennoscandian distribution of mire component types. Numbers: See Fig. 14.

Nr.	Reference	Geographic position
1	Moen & Pedersen 1981	N: Vest-Agder + Aust-Agder
2	Flatberg 1971	N: Telemark + Vestfold
3	Moen 1970	N: Østfold + Akershus + Oslo + Hedmark
4	Moen 1973b	N: Hedmark: Solør
5	Moen 1976	N: Østfold + Akershus
★ 6	Økland, this paper	N: Akershus SE + Østfold NE
7	Fransson 1972	S: Värmland SW
8	Sjörs 1953	S: Dalsland
9	Sjörs 1977	S: Värmland N + E
10	Granlund 1932, Mörnsjö 1971	S: S Sweden
11	Olausson 1957	S: Halland: Roshultmyren
12	Osvald 1923	S: Småland + Västergötland: Komosse
13	Svensson 1965	S: Småland: Store Mosse
14	Malmer 1962	S: Småland: Åkhultmyren
15	Backéus 1984	S: Närke + Värmland + Västmanland: Örebro län
16	Du Rietz & Nannfeldt 1925	S: Uppland: Ryggmossen
17	Sjörs 1948	S: Bergslagen
18	Eurola 1962	SF: southern part
19	Ruuhijärvi 1960	SF: northern part

Tab. 5. Correspondence between synsegment types in this work and those described by other authors.

This work	Plateau raised bogs	Kermi raised bogs		Plane transitional mires		Soligenous fens	
		unilaterally sloping (K1)	multilaterally sloping (K2)	unilaterally sloping (T1)	multilaterally sloping (T2)	without patterns (A1)	with patterns (A2)
Moen 1985 etc.	Au – plateau raised bogs p.p.	Ae – eccentric raised bogs p.p.	Ak – concentric raised bogs p.p.	Ce – eccentric plane bogs p.p.	Cu – other plane bogs p.p.	Fb – sloping fens, Ff – flat fens	Fs – flark fens
Sjörs 1948 etc. Fransson 1972	Concentrically domed mosses p.p.	Eccentrically domed mosses	Concentrically domed mosses			Sloping (soligenous) fens	flark fens
Ruuhijärvi 1960 Eurola 1962	Plateauhochmoore; Schärenfinnland-Hochmoore	Exzentrische Hochmoore; Küstenfinnland-Kermihochmoore von (1) Satakunta und Süd-Pohjanmaa, (2) Südfinnland	Konzentrische Hochmoore; Küstenfinnland-Kermihochmoore von Bottenwiekküste, Binnenfinnland-Kermihochmoore	Plateauhochmoore p.p. Kermihochmoore p.p.		Lawn aapa mires	Aapa mires with lawn strings and flarks
Aletsee 1967	Plateauhochmoore	Kermihochmoore		Plan-Hochmoore		Niedermoore, Aapamoore	
Dierssen 1982	Plateauhochmoore	Asymmetrische Kermihochmoore	Symmetrische Kermihochmoore p.p.	Plan-Hochmoore		Niedermoore in Hanglage	
Goode & Lindsay 1979						Valley mires	
Malmer 1985						Soligenous fen complex	Aapa fen complex
Mörnsjö 1971	Concentrically domed bog peatland p.p.	Eccentrically domed bog peatland p.p.	Concentrially domed bog peatland p.p.	Eccentrically domed bog peatland p.p.	Concentrically domed bog peatland p.p.	Soligenous peatland	
Olausson 1957	Ombrogene Moore mit Wölbung zentrisch	Ombrogene Moore mit Wölbung Exzentrisch p.p.	Zentrisch p.p	Ombrogene Moore mit Wölbung Exzentrisch p.p.	Zentrisch p.p.	Soligene Moore	
Oswald 1930, 1933	Högmosse p.p.	Högmosse p.p.		Planmosse p.p.		Skålmosse	



Figs 48–51. Air photos of kermi raised bogs. – **Fig. 48.** 200 Gatemosen (upper left), a typical mire complex consisting of unilaterally sloping kermi raised bogs separated by fen soaks. Arrow indicate a segment transitional between patterned sloping fen and kermi raised bog. At lower right, 201 Langmosen, a sloping fen with dark, fan-shaped water tracks dominated by carpets, and lawns along the margins. – Fig. 49. 150 Mire SE of Storemosen (lower right), a unilaterally sloping kermi raised bog with well-developed kermis. 153 Storemosen (upper left), containing a unilaterally sloping kermi raised bog synsegment (indicated by arrow) and a sloping fen synsegment. – Fig. 50. 192 Høgabbortjernmosen, a typical unilaterally sloping kermi raised bog with marginal forest above, distinct kermis, and lower lagg replaced by tarns and extensive topogenous fen carpets. – Fig. 51. 146 S. Kisselbergmosen; asymmetrical, multilaterally sloping kermi raised bog. Highest point (indicated by arrow) surrounded by hollow-pools. – Rules = 100 m. Photos by Fjellanger-Widerøe A/S, published with permission.

Oslo-to-Trondheim (OTT) Transect – John Birks and Sylvia Peglar

This is a transect of nine radiocarbon-dated pollen diagrams from small lakes carefully selected to have no or minimal signs of any significant human activity within their catchment.

The transect runs from the boreo-nemoral region south-east of Oslo (one site), through the southern-boreal region near Hamar (one site), the middle-boreal region near Lillehammer (two sites), the northern-boreal region (one site), the low-alpine region (one site at 1169 m a.s.l.), the middle-boreal (oceanic) region west of the main mountain chain (one site), the southern-boreal (oceanic) region (one site), to the extreme coastal region on the island of Hitra (one site).

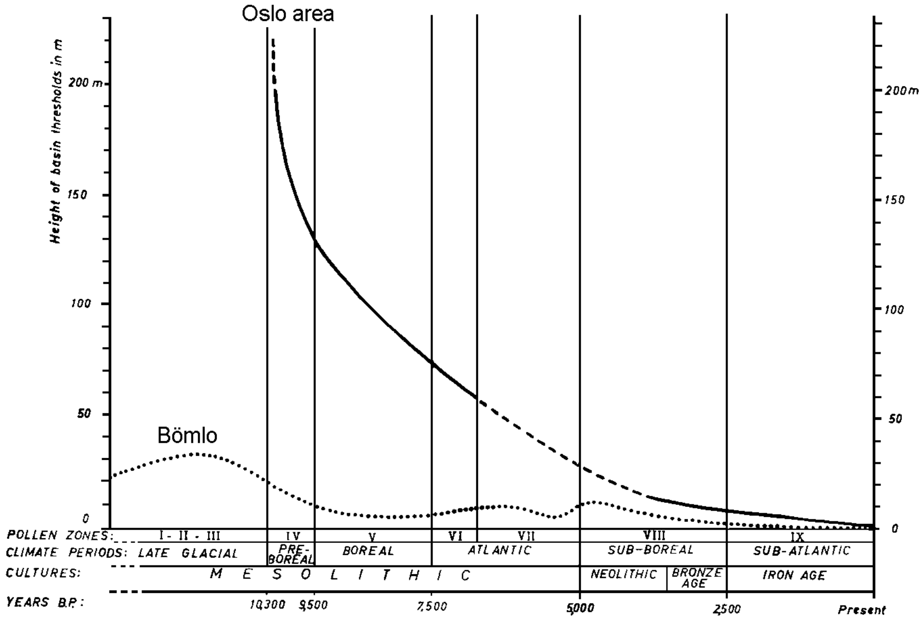
The transect covers a range in mean July temperature of 8.6–15.2°C, mean January temperature of –1.5––14.8°C, and mean annual precipitation of 430–1610 mm.

It thus covers a complex (perhaps too complex) environmental gradient in climate (summer warmth, oceanity), geology, soil, and land-form and hence in vegetation regions.

A set of surface-sediment samples (0–1 cm) were collected from 49 lakes along the transect to assess if the modern vegetation regions produce distinctive modern pollen assemblages. Visual inspection suggests that some but not all vegetation regions have distinctive pollen assemblages (e.g. Coastal, Southern boreal + boreo-nemoral) whereas other regions have very similar assemblages (e.g. northern boreal and low-alpine–northern boreal transition).

On this excursion, we will only have time to visit Blanktjern (mistakenly called Morttjønn in OTT), a small lake at 227 m a.s.l., the southernmost site on the OTT transect. The site today (or at least was in 1999 when we cored it) is in *Pinus sylvestris–Picea abies* forest, with *Alnus glutinosa, Sorbus aucuparia, Betula pendula, B. pubescens, Populus tremula, Salix cinerea, S. aurita, S. caprea,* and *Frangula alnus*. At lower elevations (100–200 m a.s.l.) there are *Quercus robur, Ulmus glabra, Tilia cordata, Fraxinus excelsior, Acer platanoides*, and *Corylus avellana*.

The site is at a higher elevation than we would have liked by a problem with finding undisturbed Holocene sites in this area is the large amount of land-uplift since deglaciation. We only searched for sites above 200 m a.s.l.



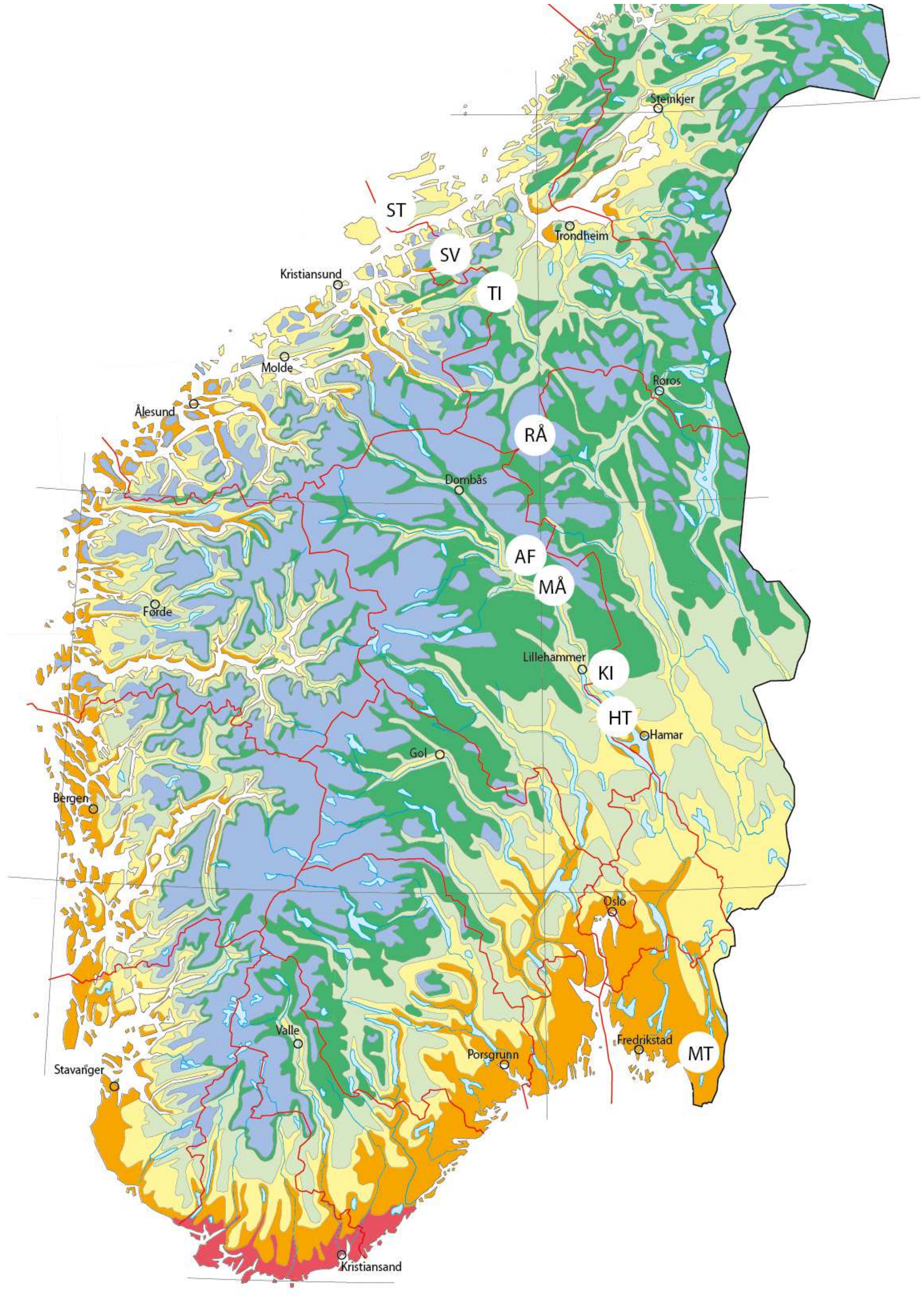
Shore-line displacement near Oslo and Bømlo (western Norway). (Andersen 1965)

We retrieved a 5.2 m core from under 11.6 m of water. The basal 25 cm are deglaciation silts containing no pollen.

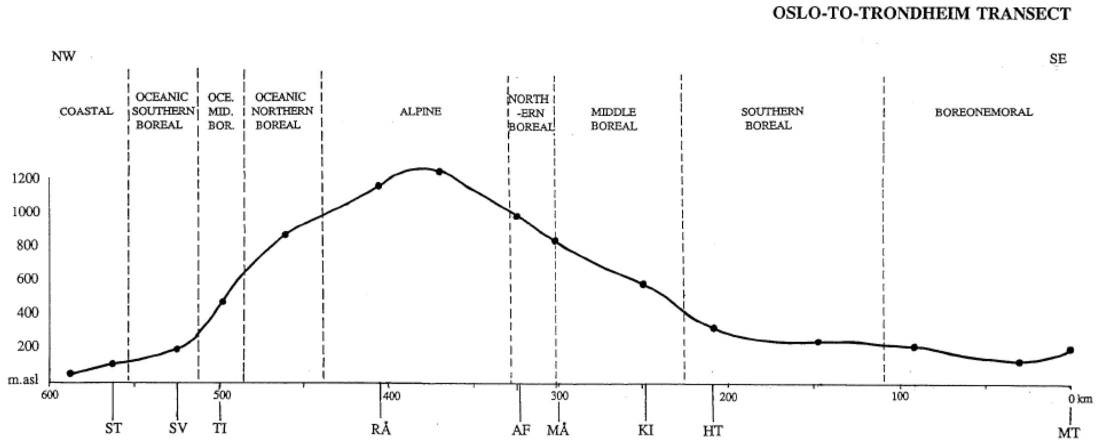
Coring sites along the Oslo-to-Trondheim transect

	
Blanktjern (Morttjern) 227 m, boreo-nemoral, 12 m water depth	Haugtjern, 338 m, southern-boreal, 8.5 m water depth
	
Tjernshaugtjernet (Kinnshaugen), 591 m, middle-boreal, 4.8 m water depth	Måsåtjønnet, 841 m, middle-boreal, 3.3 m water depth

	
Afstjønna, 991 m, northern-boreal, 9.7 m water depth	Råtåsjøen, 1169 m, low-alpine, 8 m water depth
	
Tiåvatnet, 464 m, middle-boreal (oceanic), 7.2 m water depth	Svartvatnet, 183 m, southern-boreal (oceanic), 9.7 m water depth
	
Storsandvatnet, 106 m, coastal, 0.7 m water depth	



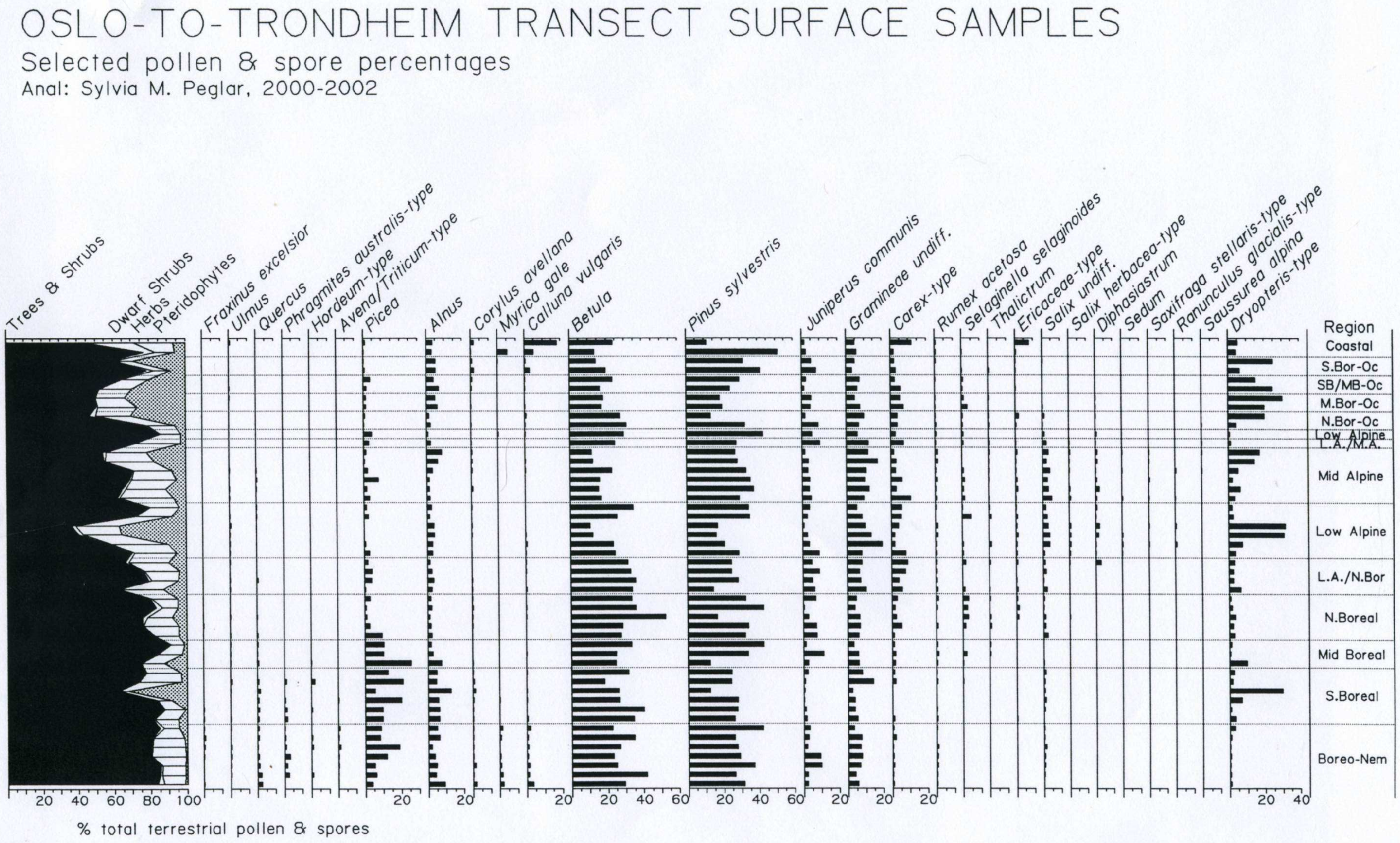
Sites marked on the vegetation map from Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)



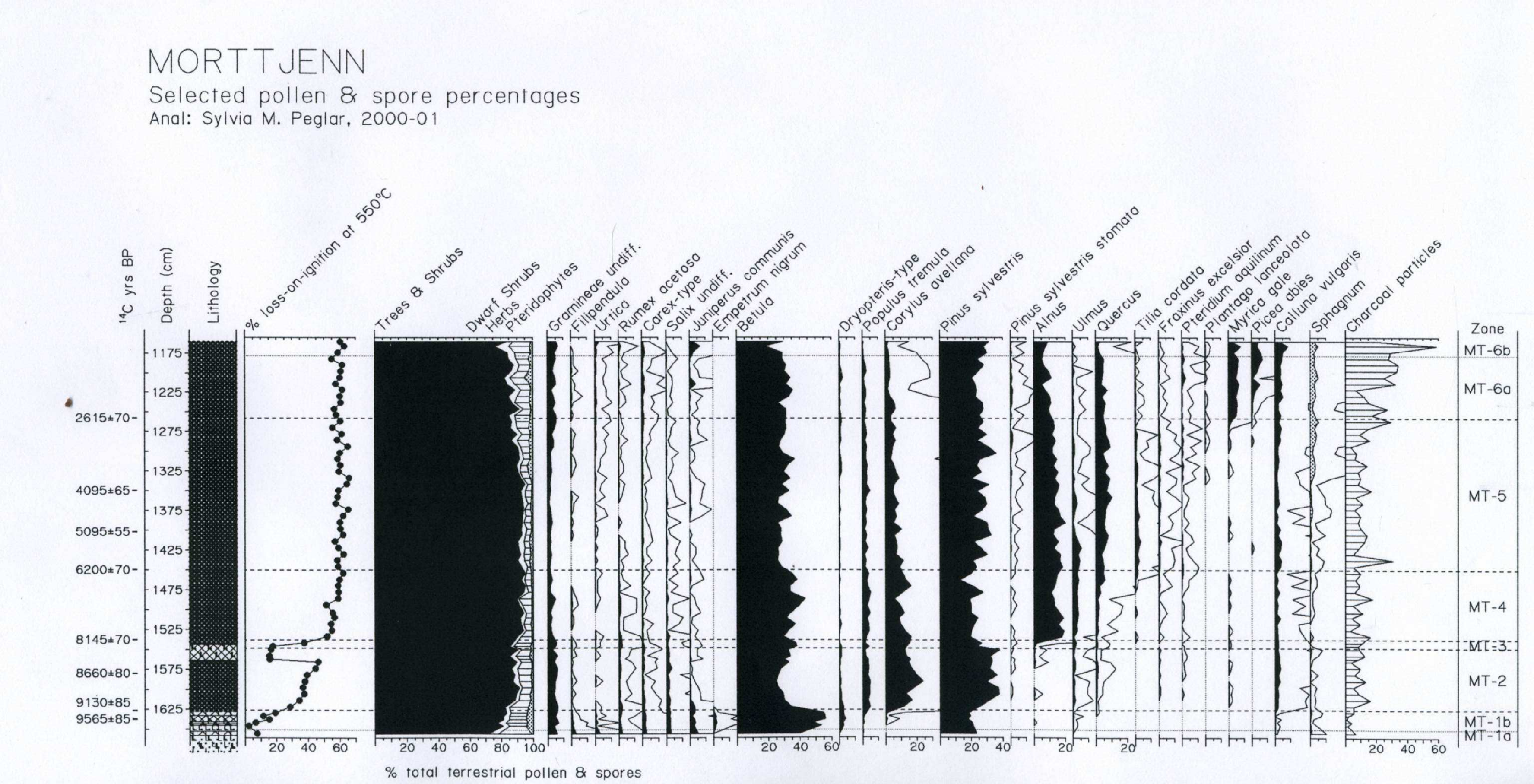
The Oslo-to-Trondheim transect of sites cored in relation to the modern vegetational regions. Site abbreviations follow the Table.

	Altitude	Sediment thickness	Site abbreviation on Transect diagram	Mean July temp. °C	Mean Jan temp. °C	Annual ppt$^{a.}$ (mm)
Boreo-nemoral region						
Morttjenn	227 m	520 cm	MT	15.2	- 4.7	880
Southern-boreal region						
Haugtjern	338 m	242 cm	HT	14.4	- 9.1	570
Middle-boreal region						
Kinnshaugen	591 m	618 cm	KI	12.9	- 10.5	700
Måsåtjørnet	841 m	406 cm	MÅ	11.6	- 14.1	545
Northern-boreal region						
Afstjørna	991 m	357 cm	AF	10.7	- 14.8	430
Low-alpine region						
Råtåsjøen	1169 m	194 cm	RÅ	8.6	- 14.4	450
Middle-boreal (oceanic) region						
Tiåvatnet	464 m	372 cm	TI	11.3	- 7.8	930
Southern-boreal (oceanic) region						
Svartvatnet	183 m	376 cm	SV	12.1	- 2.0	1610
Coastal region						
Storsandvatnet, Hitra	106 m	394 cm	ST	12.6	- 1.5	1600

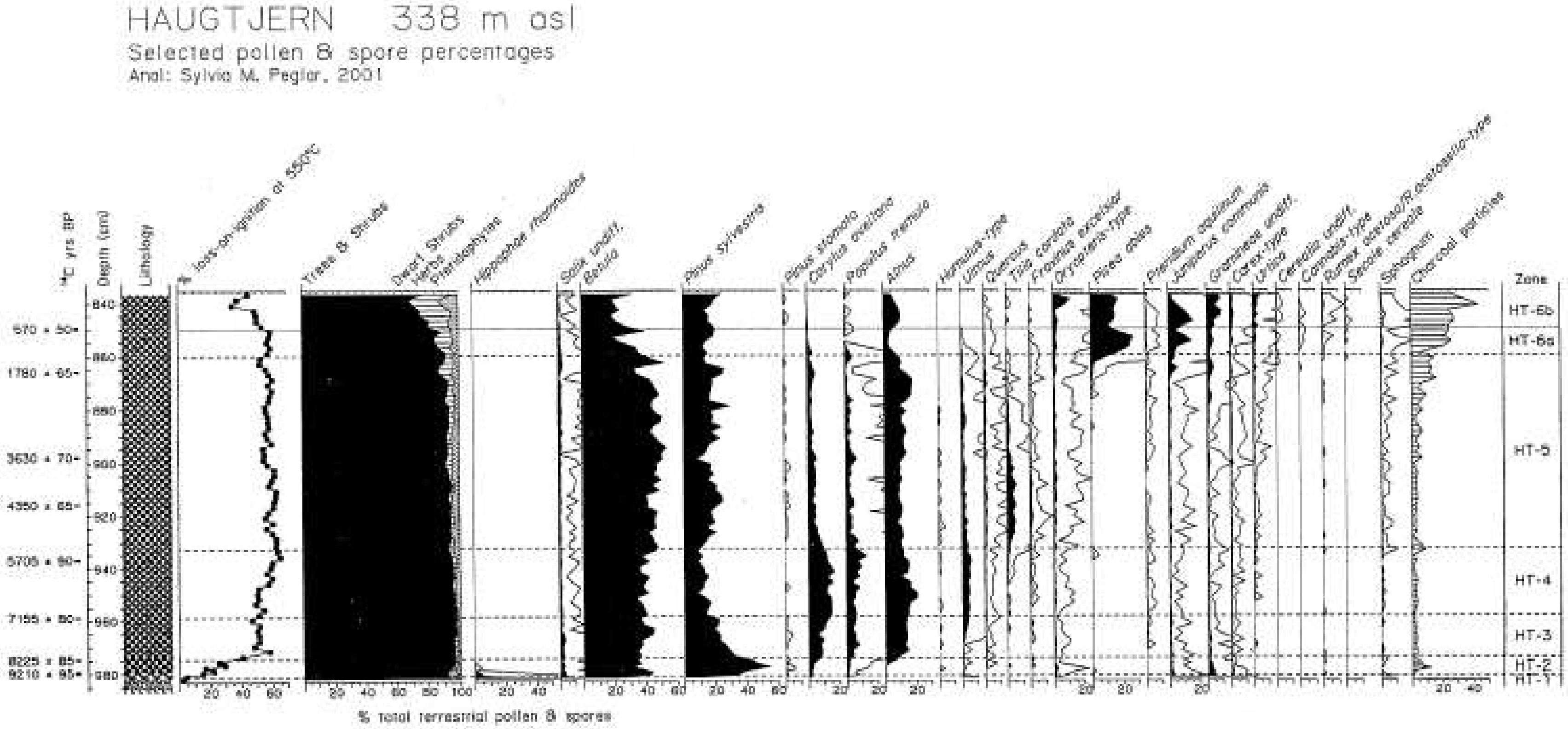
Lakes cored along the Oslo-to-Trondheim transect (arranged in a south-east to north-west order).



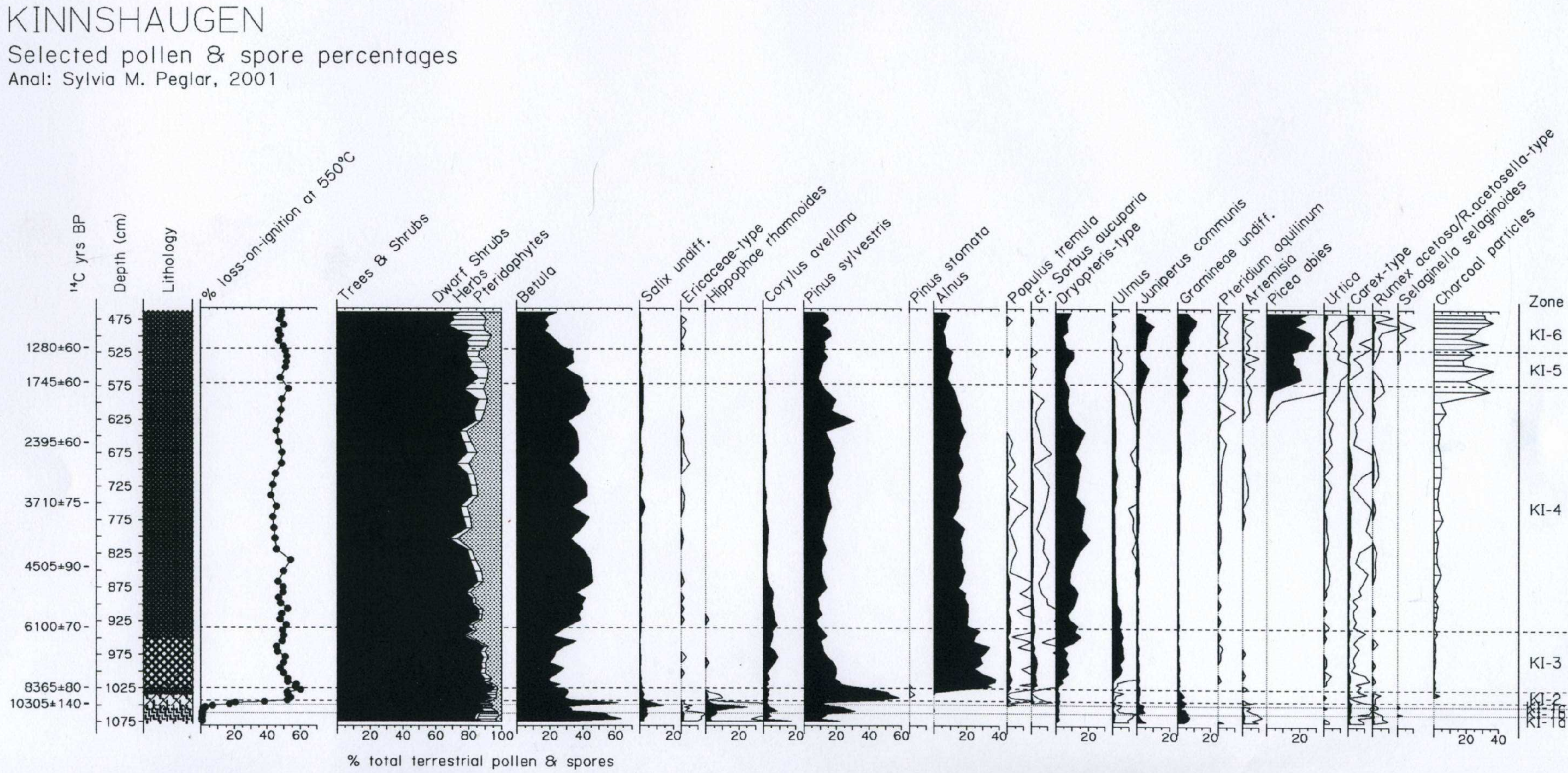
Summary pollen diagram for modern surface-samples (0-1 cm) from 49 lakes along the Oslo-to-Trondheim transect arranged on south-east to north-west transect in relation to modern vegetation region. Within each vegetation region, the sites are arranged attitudinally from south (bottom) to north (top).



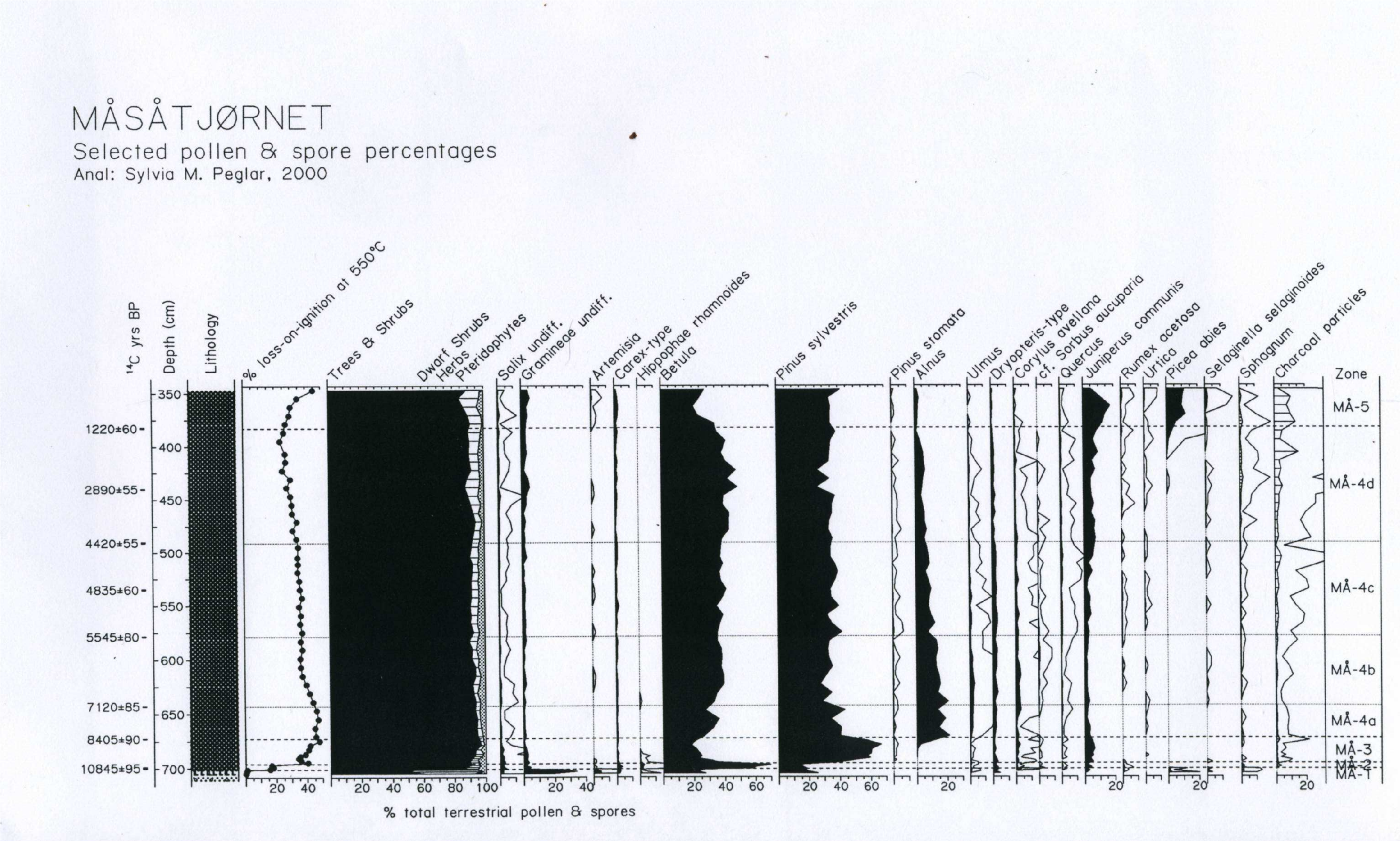
Summary pollen diagram from Morttjern, in the boreo-nemoral region today.



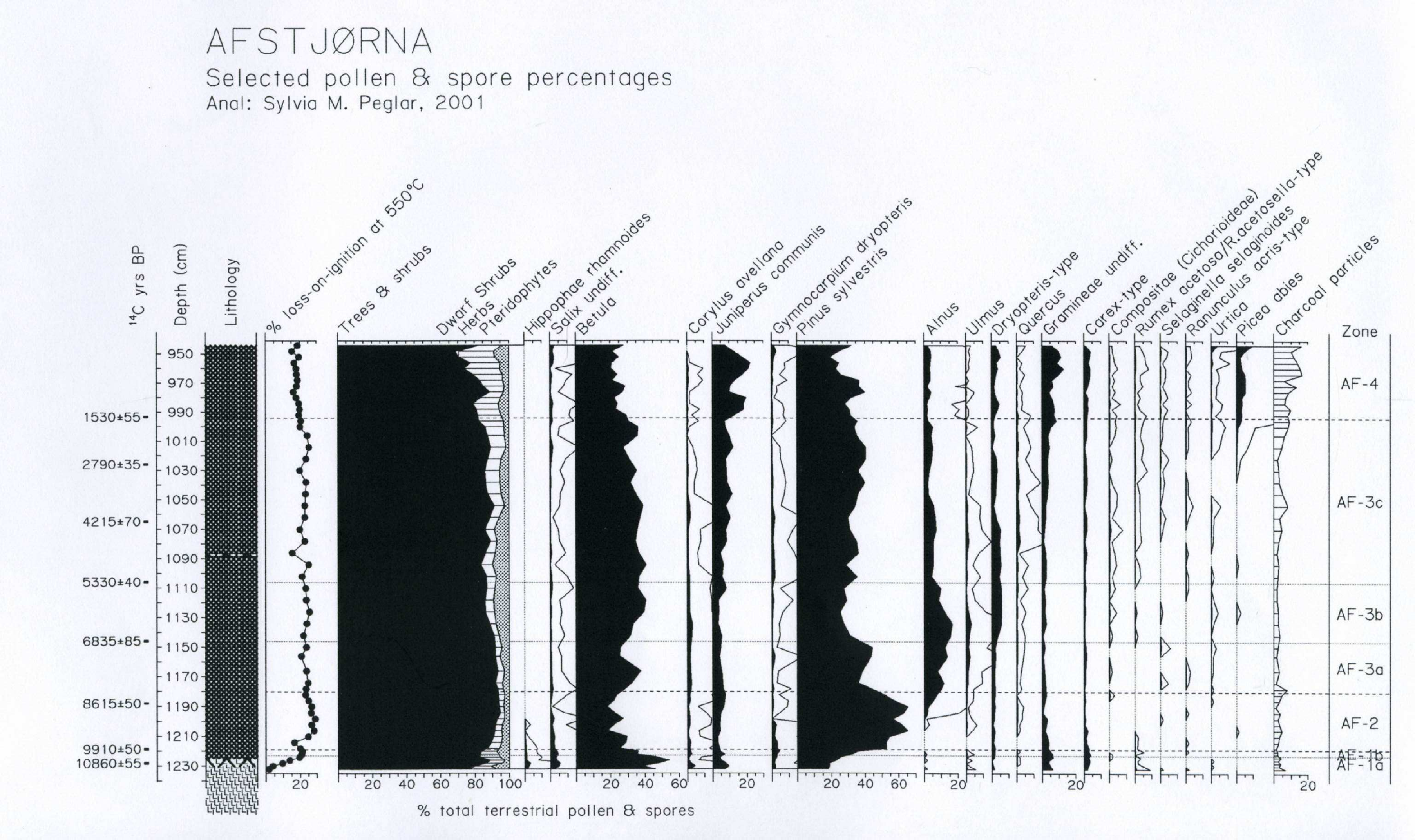
Summary diagram from Haugtjern, in the southern-boreal region today.



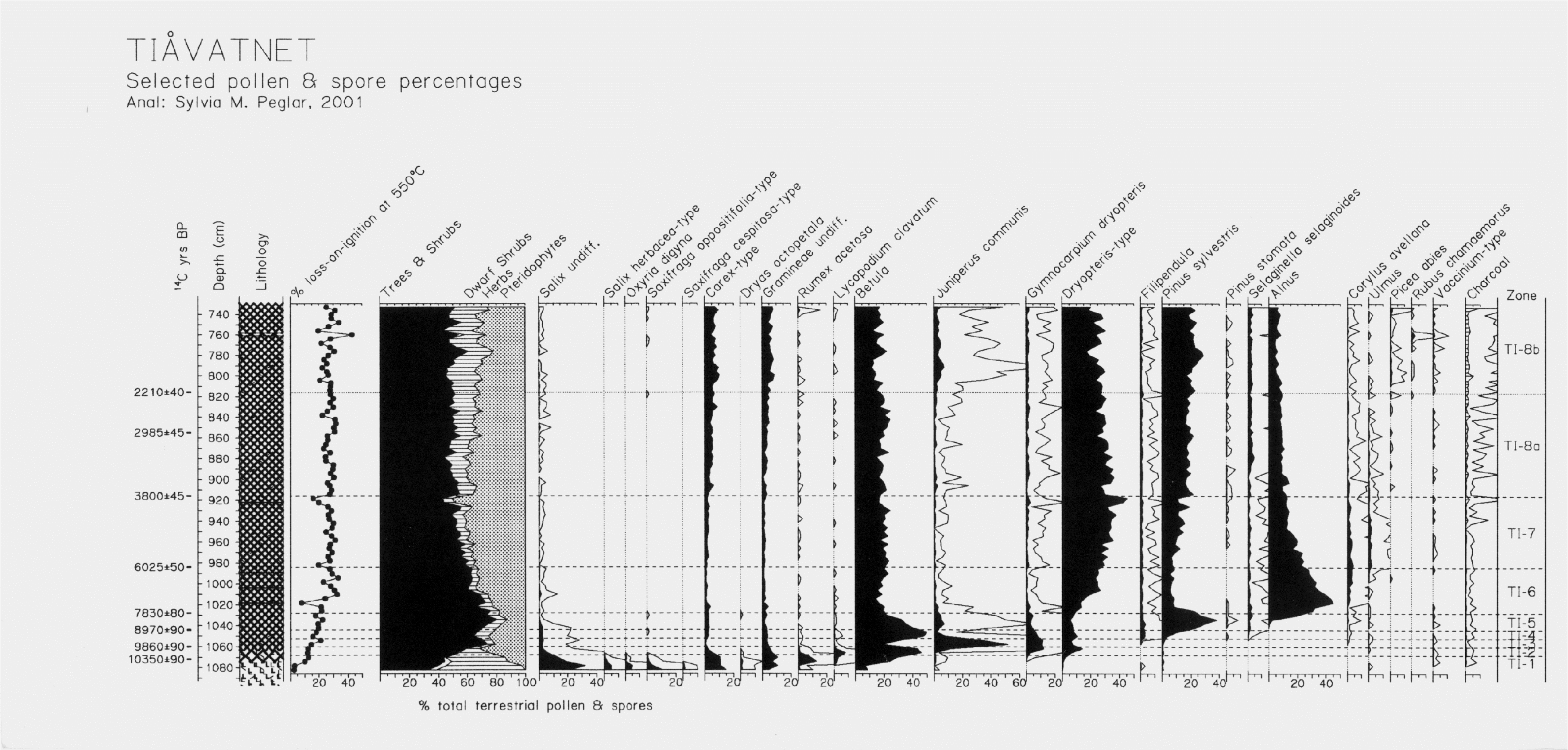
Summary pollen diagram from Kinnshaugen, in the middle-boreal region today.



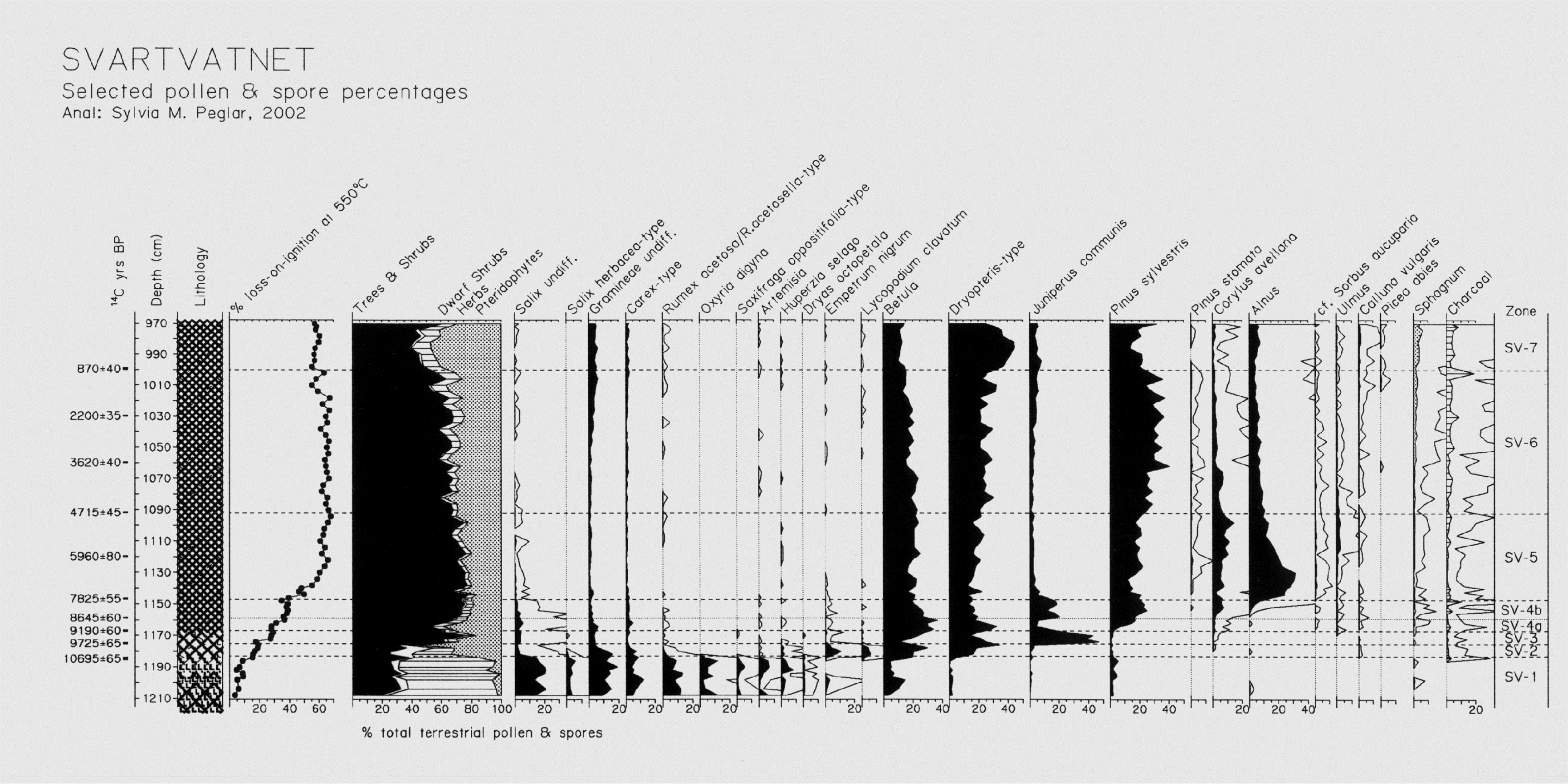
Summary pollen diagram from Måsåtjørnet, in the upper middle-boreal region today.



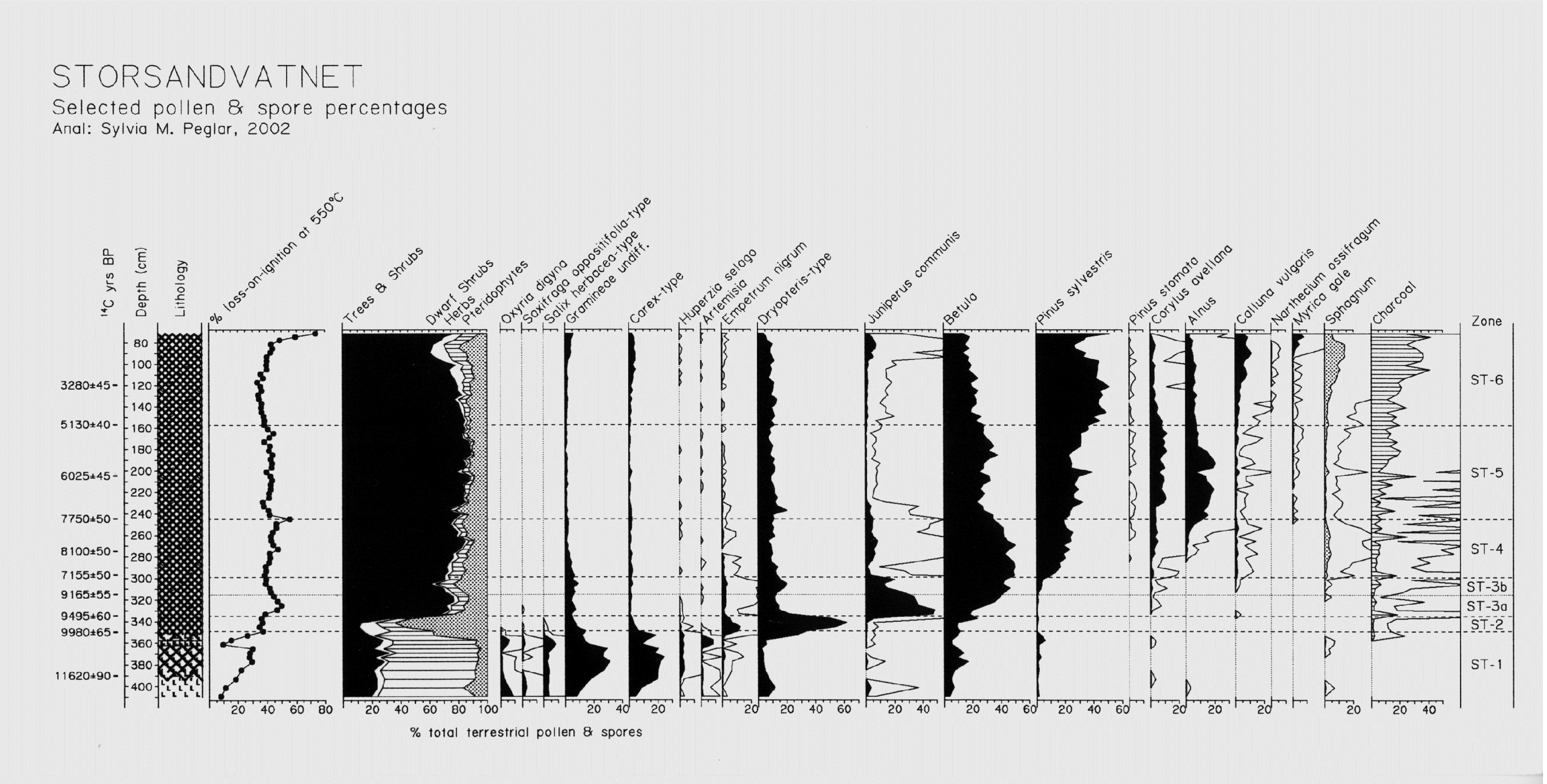
Summary pollen diagram from Afstjørna, in the northern-boreal region today.



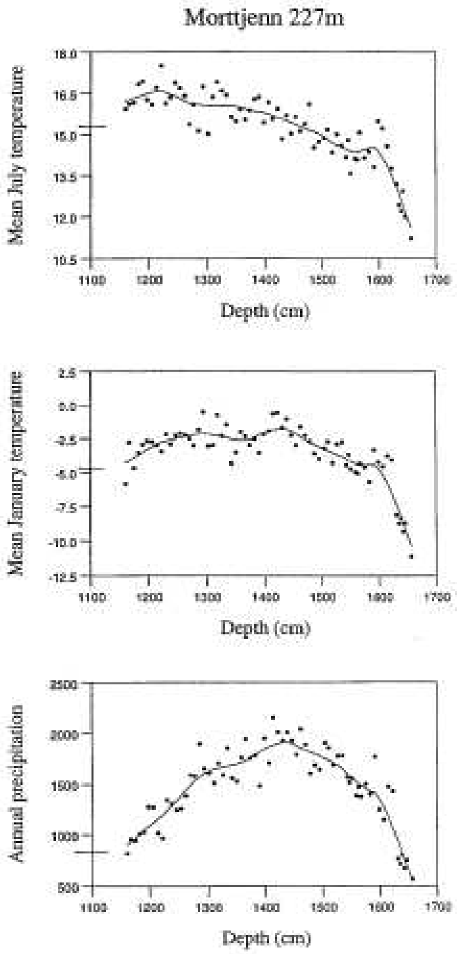
Summary pollen diagram from Tiåvatnet, in the middle-boreal (oceanic) region today.



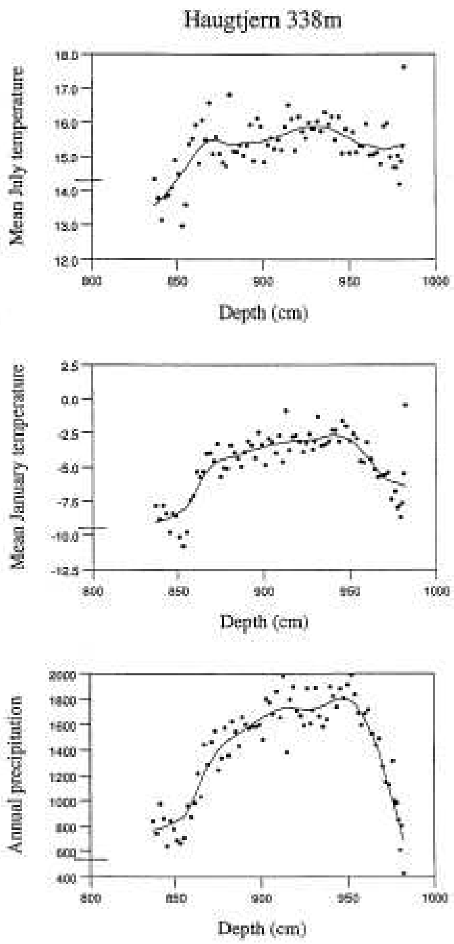
Summary pollen diagram from Svartvatnet, in the southern-boreal (oceanic) region today.



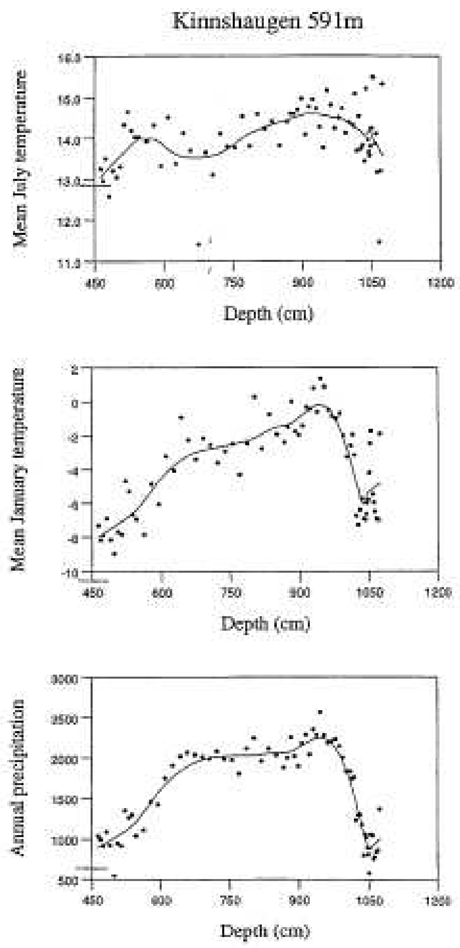
Summary pollen diagram from Storsandvatnet, Hitra, in the coastal region today.



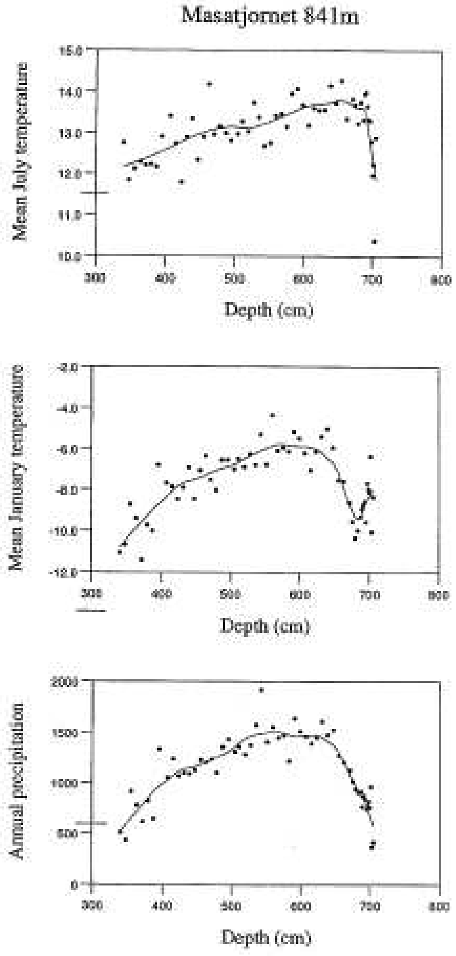
Preliminary reconstructions of mean July and January temperatures (°C) and annual precipitation at Morttjenn, in the boreo-nemoral region today, with a LOESS smoother (span = 0.25) fitted.



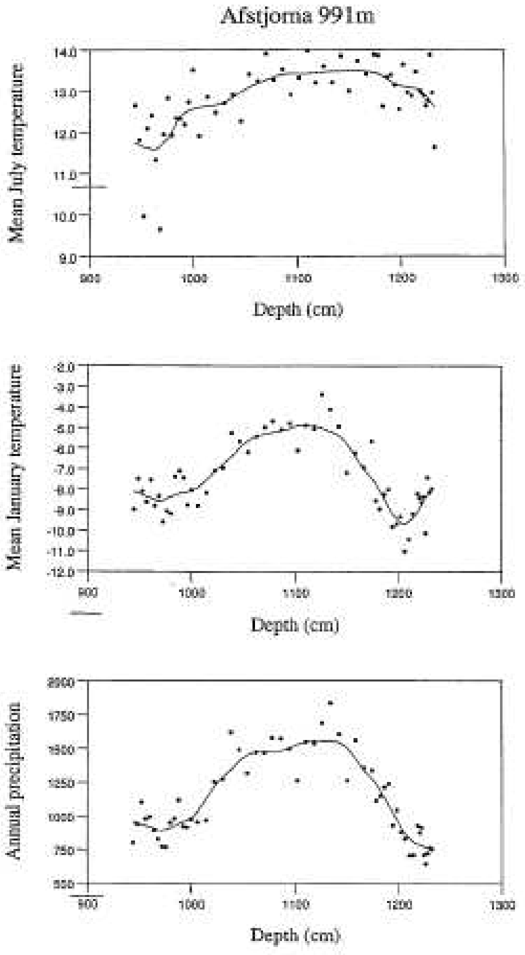
Preliminary reconstructions of mean July and January temperatures (°C) and annual precipitation at Haugtjern, in the southern-boreal region today, with a LOESS smoother (span = 0.25) fitted.



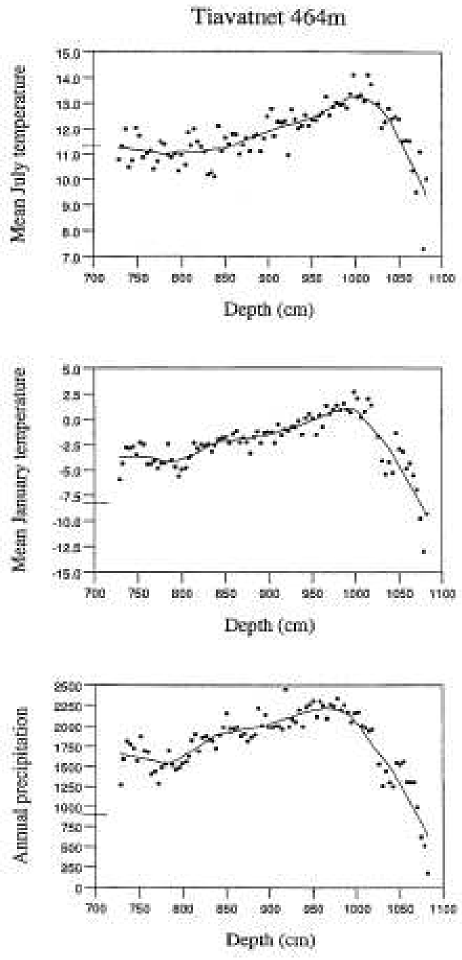
Preliminary reconstructions of mean July and January temperatures (°C) and annual precipitation at Kinnshaugen, in the middle-boreal region today, with a LOESS smoother (span = 0.25) fitted.


Masatjornet 841m

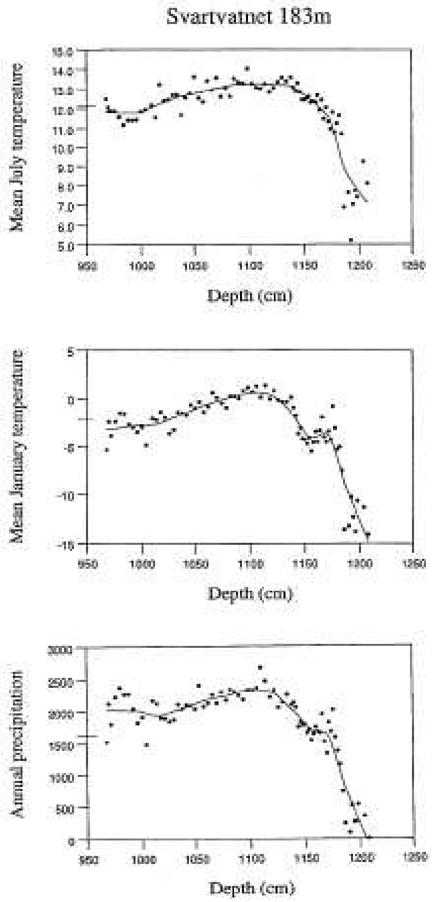
Preliminary reconstructions of mean July and January temperatures (°C) and annual precipitation at Måsåtjørnet, in the upper middle-boreal region today, with a LOESS smoother (span = 0.25) fitted.


Afstjorna 991m

Preliminary reconstructions of mean July and January temperatures (°C) and annual precipitation at Afstjørna, in the northern-boreal region today, with a LOESS smoother (span = 0.25) fitted.

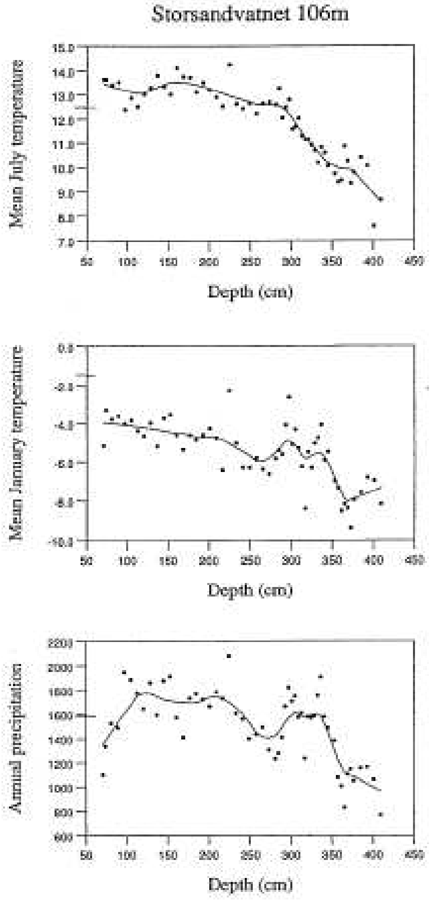

Tiavatnet 464m

Preliminary reconstructions of mean July and January temperatures (°C) and annual precipitation at Tiavatnet in the middle-boreal (oceanic) region today, with a LOESS smoother (span = 0.25) fitted.



Svartvatnet 183m

Preliminary reconstructions of mean July and January temperatures (°C) and annual precipitation at Svartvatnet, in the southern-boreal (oceanic) region today, with a LOESS smoother (span = 0.25) fitted.



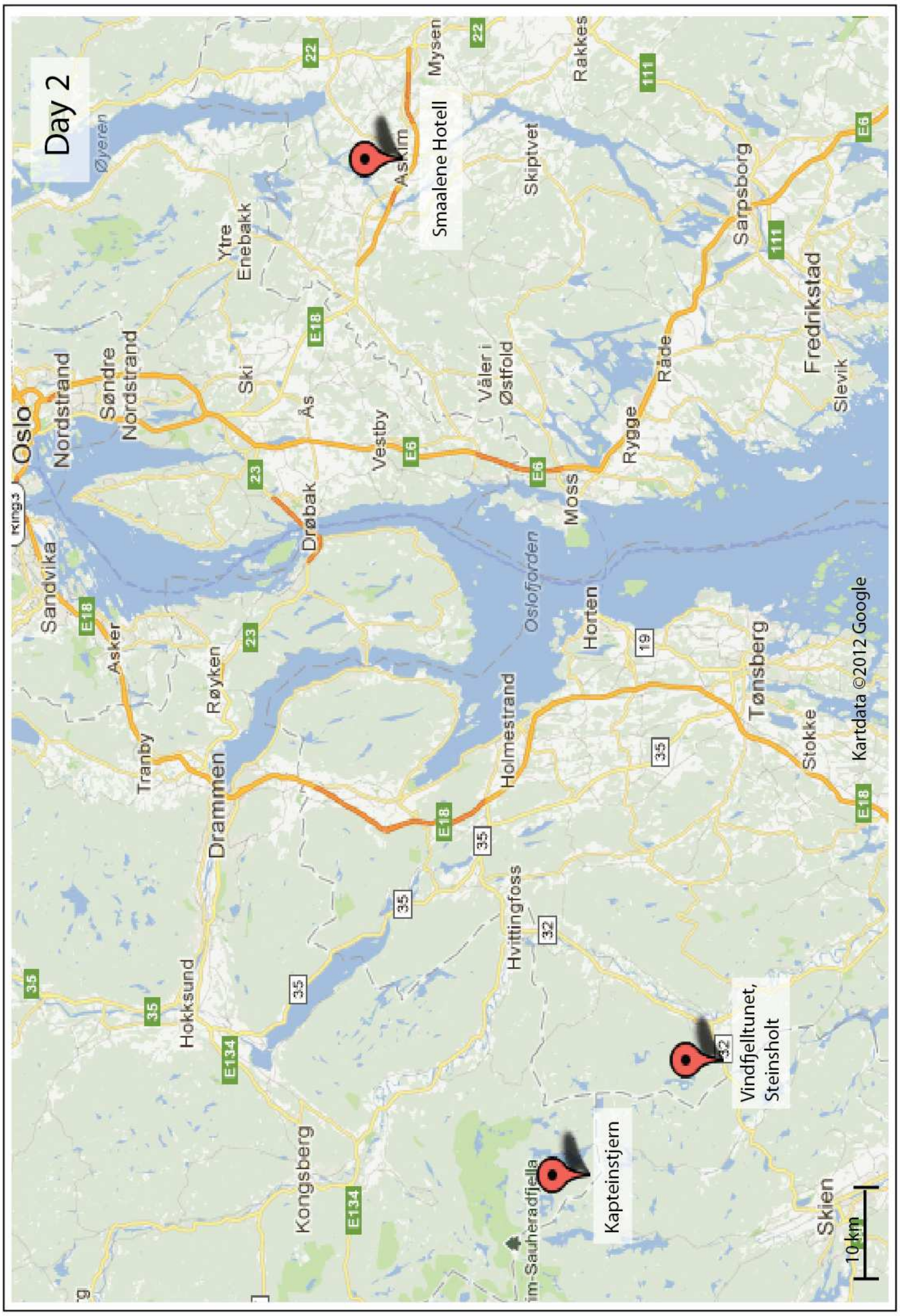
Storsandvatnet 106m

Preliminary reconstructions of mean July and January temperatures (°C) and annual precipitation at Storsandvatnet, in the coastal region today, with a LOESS smoother (span = 0.25) fitted.

DAY 2

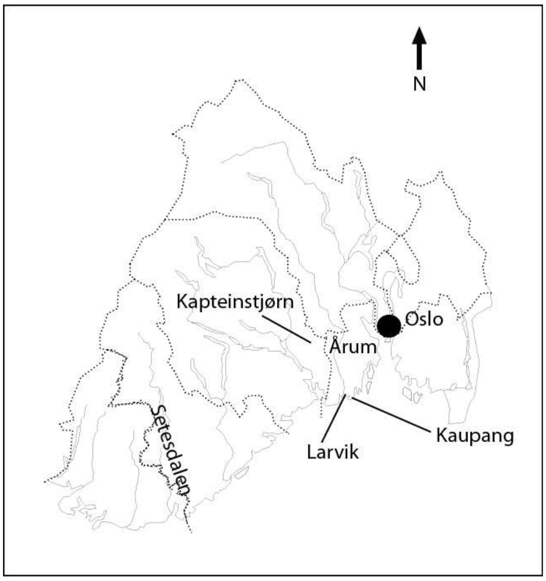
SILJAN – ÅRUM - KAPTEINSTJERN

Sunday 9 September 2012


Day 2
Smaalene Hotell
Askim
Vindfjelltunet, Steinsholt
Kapteinstjern
Oslo
Drammen
Tønsberg
Fredrikstad
Sarpsborg
Moss
Horten
Kongsberg
Skien
Oslofjorden
Kartdata ©2012 Google
10 km

Land-use and ecosystem function in Norwegian forest landscapes

– Anne E. Bjune, Mikael Ohlson and John Birks



The aims of the project "Land-use and ecosystem function in Norwegian forest landscapes" was:

- (i) to analyse how human land-use, biodiversity dynamics, ecosystem function, and abiotic factors interact in Norwegian boreal forests
- (ii) identify scientifically based management strategies that will ensure biodiversity and ecosystem function
- (iii) to analyse the efficiency, risks, and distributional impacts of various policy means to secure biodiversity and to balance the gains between biodiversity functions, moose production, and timber harvest.

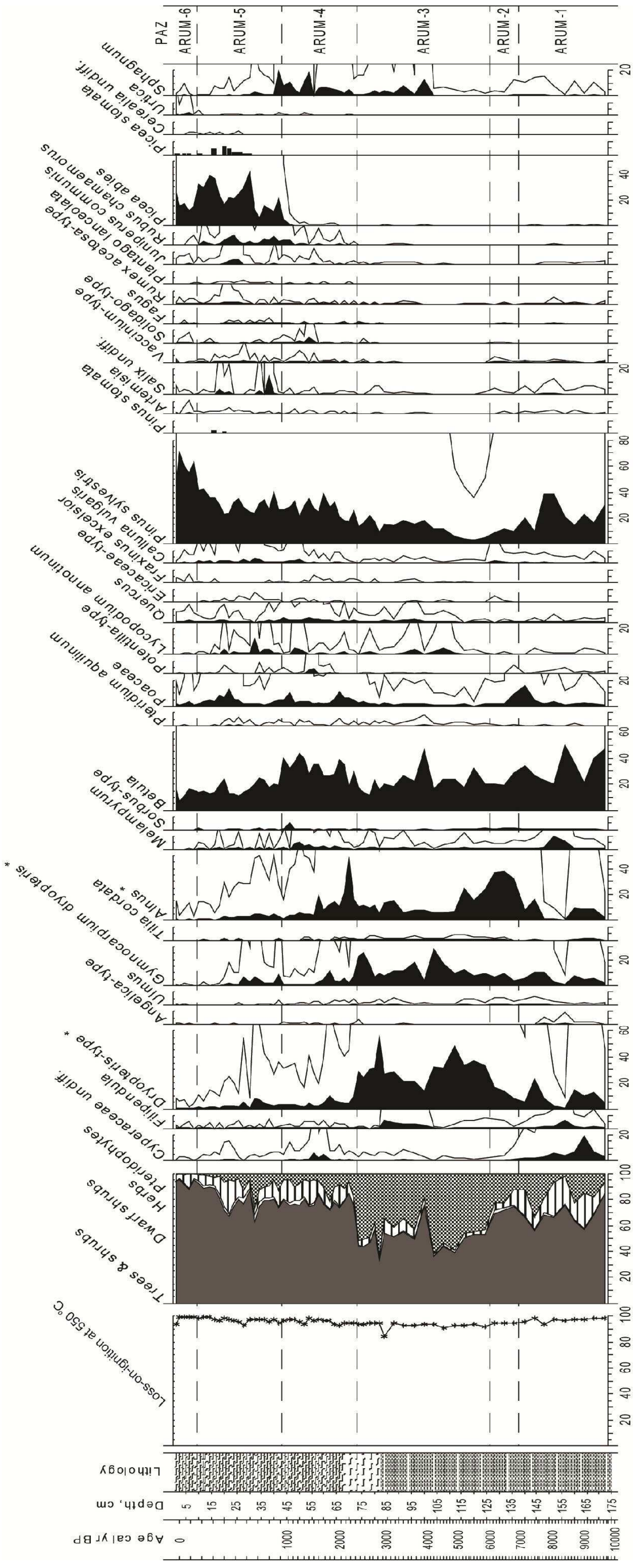
The approach was multidisciplinary and included strong historical and modelling components. The core of the project consisted of competencies in forest ecology, economy, socio-economics, quantitative palaeo-ecology and population biology.

Many, very different sources of information were used to establish and analyse the complex relationships between human use of forests, natural ecosystem dynamics, biodiversity, ecosystem function, and long-term change of forest ecosystems at different spatial- and temporal scales. Observationally, analytically and experimentally assessed measures of habitat distributions, habitat qualities, biodiversity, and ecosystem processes will provide information on present-day ecosystem and landscape properties.

Combinations of several retrospective vegetation history and archaeological methods will provide information on long-term natural changes, human settlement, timber logging, grazing pressure and economical profits were used to be able to analyse patterns in habitats, biodiversity, and ecosystem processes in relation to different main causes to such patterns, e.g. human land-use, landscape history and climatic change.

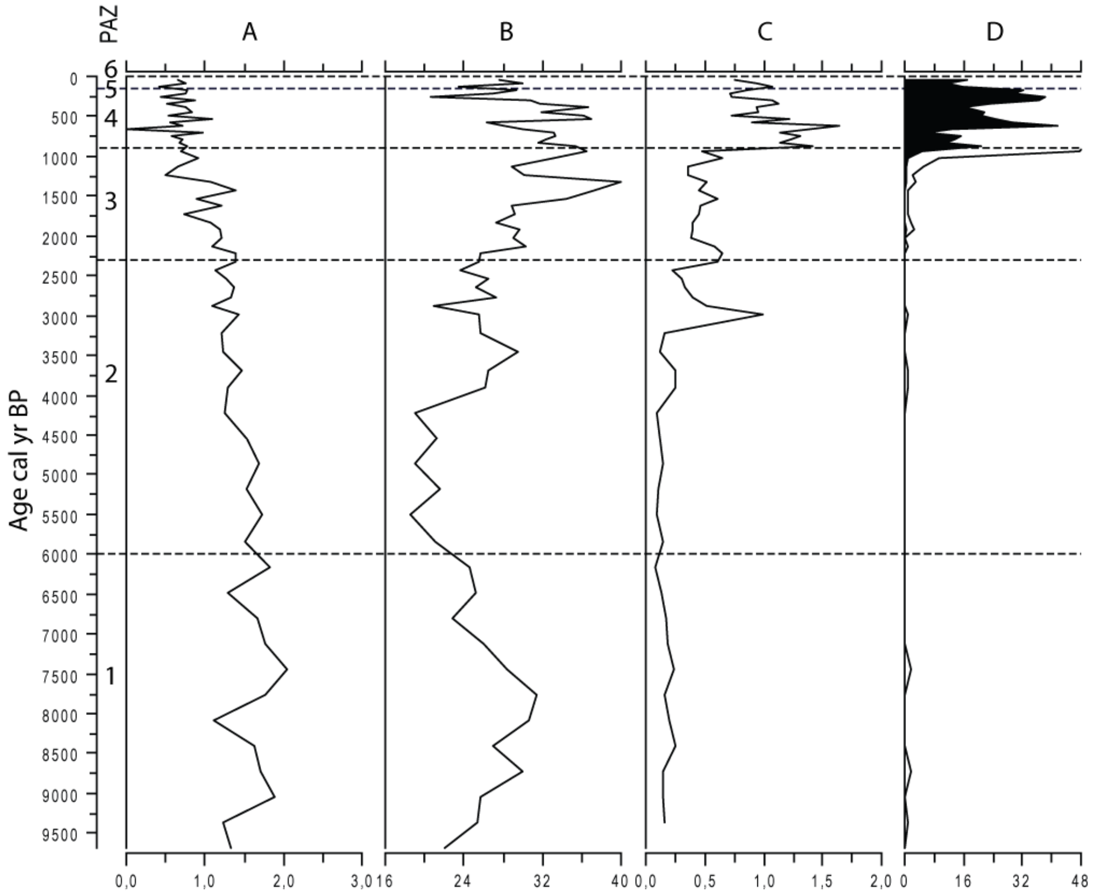
Palaeoecological investigations

The local development and forest history have been studied based on pollen, plant macrofossil, stomata, and charcoal analysis from a small forest hollow situated within an old-growth, closed *Picea abies* forest, rich in epiphytic lichens and wood-decaying fungi in south-eastern Norway. The main aims of this study are to identify the natural development, the disturbance history, and the role of human impact of this forest stand during the last 9650 years. Forest trees have always been dominant in the landscape around the forest hollow. The forest was first dominated by *Betula* and *Pinus sylvestris*, and later these were co-dominant with thermophilous deciduous trees such as *Corylus*, *Fagus*, *Fraxinus excelsior*, *Quercus*, *Tilia cordata,* and *Ulmus*. During the last 1000 years, *Picea abies* (spruce) has become the dominant tree in this area, but its presence can be traced back about 9300 years. The establishment of spruce caused a major shift in the ecosystem. Human impact and fire seem to have been the driving factors to create openings for spruce to establish. Based on estimates of palynological richness, the most diverse pollen assemblages are found in periods with intermediate levels of disturbance (Bjune et al. 2009).



Percentage pollen diagram with selected pollen and spore taxa, loss-on-ignition at 550 °C, and a summary diagram of total terrestrial pollen and spores from the forest hollow at Årum. * Pollen and spore taxa that were removed from the pollen sum. The data are presented on a depth basis with a calibrated age scale, and the hollow silhouettes denote a 10 × exaggeration of the percentage values. The abundance of *Picea abies* and *Pinus sylvestris* stomata are shown as histogram bars (Bjune et al. 2009).

The forest hollow at Årum is situated at 445 m asl and is located within an old-growth, closed *Picea abies* forest with a rich flora of epiphytic lichens and wood-decaying fungi. The study site is part of a forest landscape set-aside on the estate of the Fritzöe Skoger Company. No logging has occurred during the last century and 350 year old Norway spruce trees can be found in the forest. However, selective logging has occurred in the past and the last logging took place in 1909.

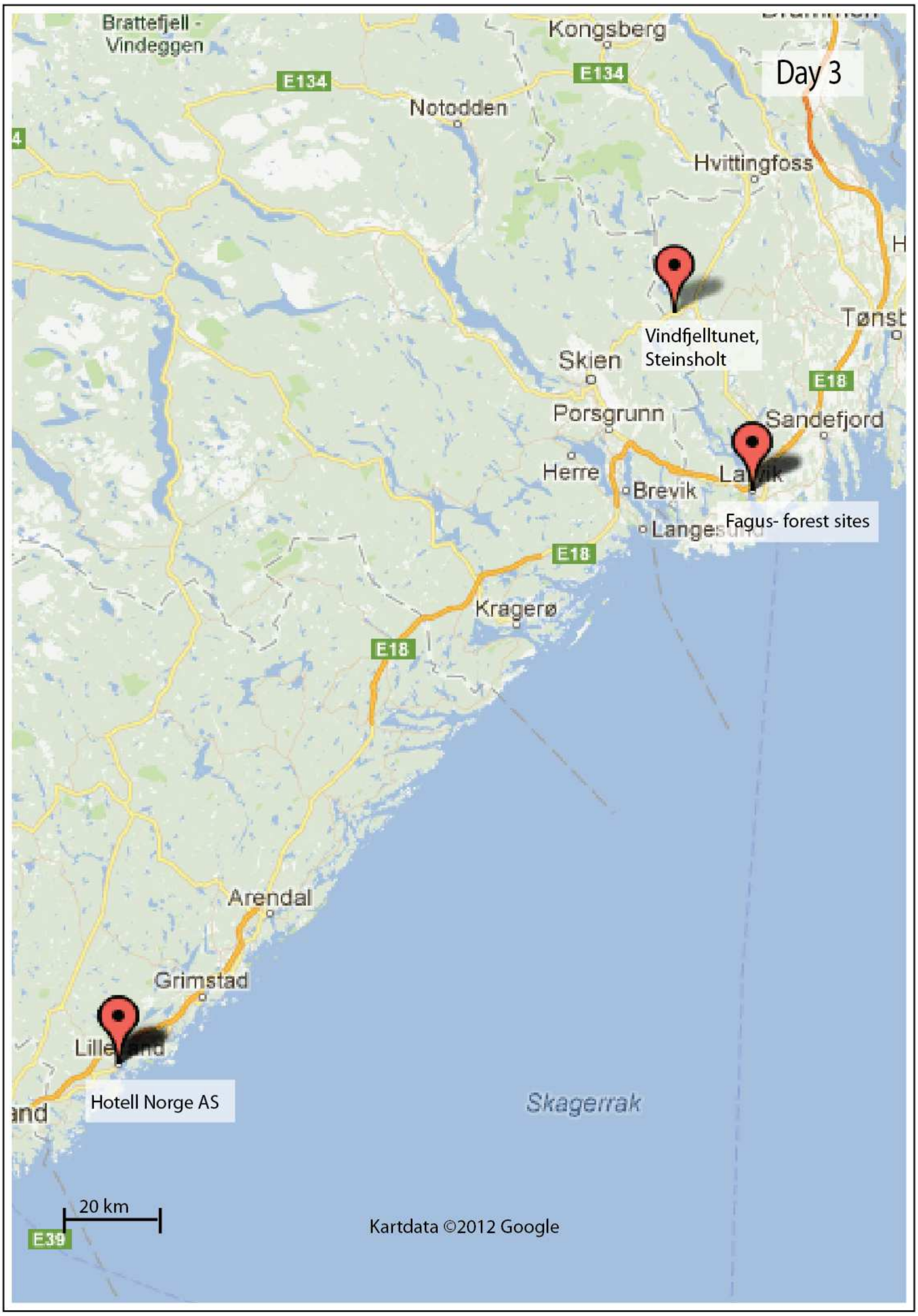


A. Turnover (standard deviation units) **B.** Estimated richness **C.** Rate-of-change, as chord distance per 150 years **D.** *Picea abies* pollen %. The dotted lines represent local pollen assemblage zones (see diagram) (Bjune et al. 2009)

DAY 3

LARVIK

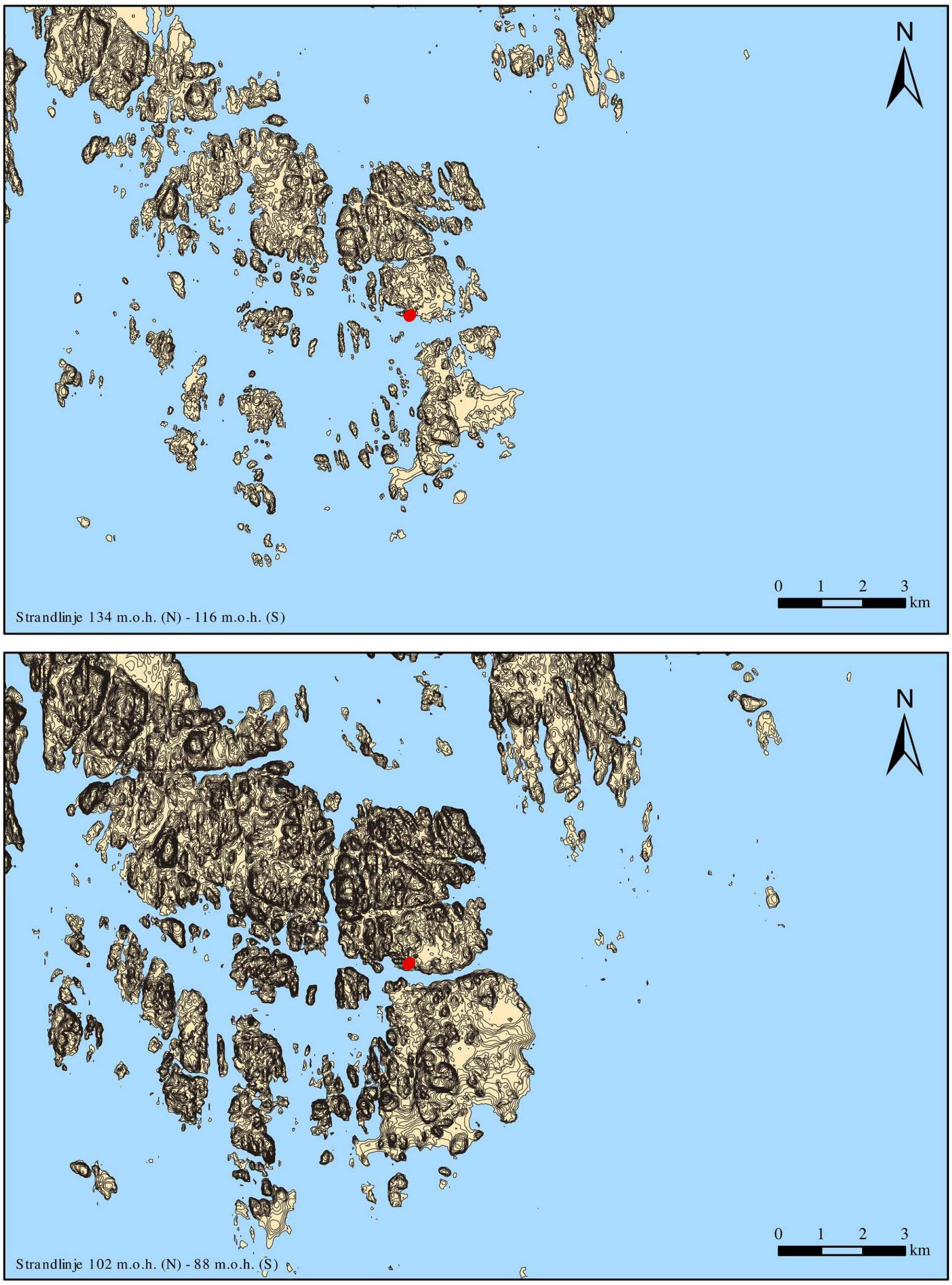
Monday 10 September 2012


Day 3
Vindfjelltunet, Steinsholt
Fagus- forest sites
Hotell Norge AS
20 km
Kartdata ©2012 Google
Brattefjell - Vindeggen
Kongsberg
Notodden
Hvittingfoss
Skien
Porsgrunn
Herre
Brevik
Sandefjord
Kragerø
Arendal
Grimstad
Skagerrak
E134
E18
E39

Development of the Late-Glacial and Early Preboreal landscape and vegetation around the Mesolithic sites at Pauler, Larvik, southeastern Norway.

Rolf Sørensen, Helge I. Høeg, Kari E. Henningsmoen, Göran Skog, Solveig F. Labowsky and Bjørg Stabell

Varia 79 (2012) – Universitetet i Oslo.



Figur 24. Paleo-kart. Øverst: Ca. 11 100 kal. år BP – Nederst: Ca. 10 200 kal. år BP. Rød prikk viser Pauler området. Kartkonstruksjon: Per Persson.
Figure 24. Paleo-map of the Pauler area (red dot). Above: c. 11 100 Cal. BP. Below: c.. 10 200 Cal BP.

Local (regional) Pollen Assemblage Zones (LPAZ) for the Larvik – Porsgrunn districts, South-eastern Norway.

Zone	**Time-interval**	**Calibrated age**	**^{14}C–age BP**	**Characteristic trees and other plants**
8	To the present From spruce immigration; $\mathbf{P}_o$ -	(AD 2000) 1 200 ± 200 -	(AD 1950) ca. 1 200 -	Spruce and beech
7	To spruce immigration, $\mathbf{P}_o$ From first agriculture -	1 200 ± 200 5 700 ± 200 -	ca. 1 200 ca. 5 000 -	Oak, pine, pasture- and other agricultural indicators
6	To first agriculture From linden immigration, $\mathbf{T}_o$ -	5 700 ± 200 7 650 ± 200 -	ca. 5 000 6 700 ± 80 -	Linden, elm and oak (demanding deciduous forests)
5	To linden immigration, $\mathbf{T}_o$ From alder immigration, $\mathbf{A}_o$ -	7 650 ± 200 9 200 ± 200	6 700 ± 80 8 200 + 100 -	Alder and elm
4	To alder immigration, $\mathbf{A}_o$ From hazel immigration, $\mathbf{C}_o$-	9 200 ± 200 10 400 ± 200	8 200 + 100 9 160 ± 65 -	Pine, hazel and elm
3	To hazel immigration, $\mathbf{C}_o$ From buckthorn immigration -	10 400 ± 200 11 100 ± 200	9 160 ± 65 9 700 ± 50 -	Birch and sea buckthorn
2	To buckthorn immigration From basin isolation -	11 100 ± 200 Variable -	9 700 ± 50 Variable -	Birch and pioner plants
1 / M	Marine phase – (to isolation)	Variable	Variable	Variable

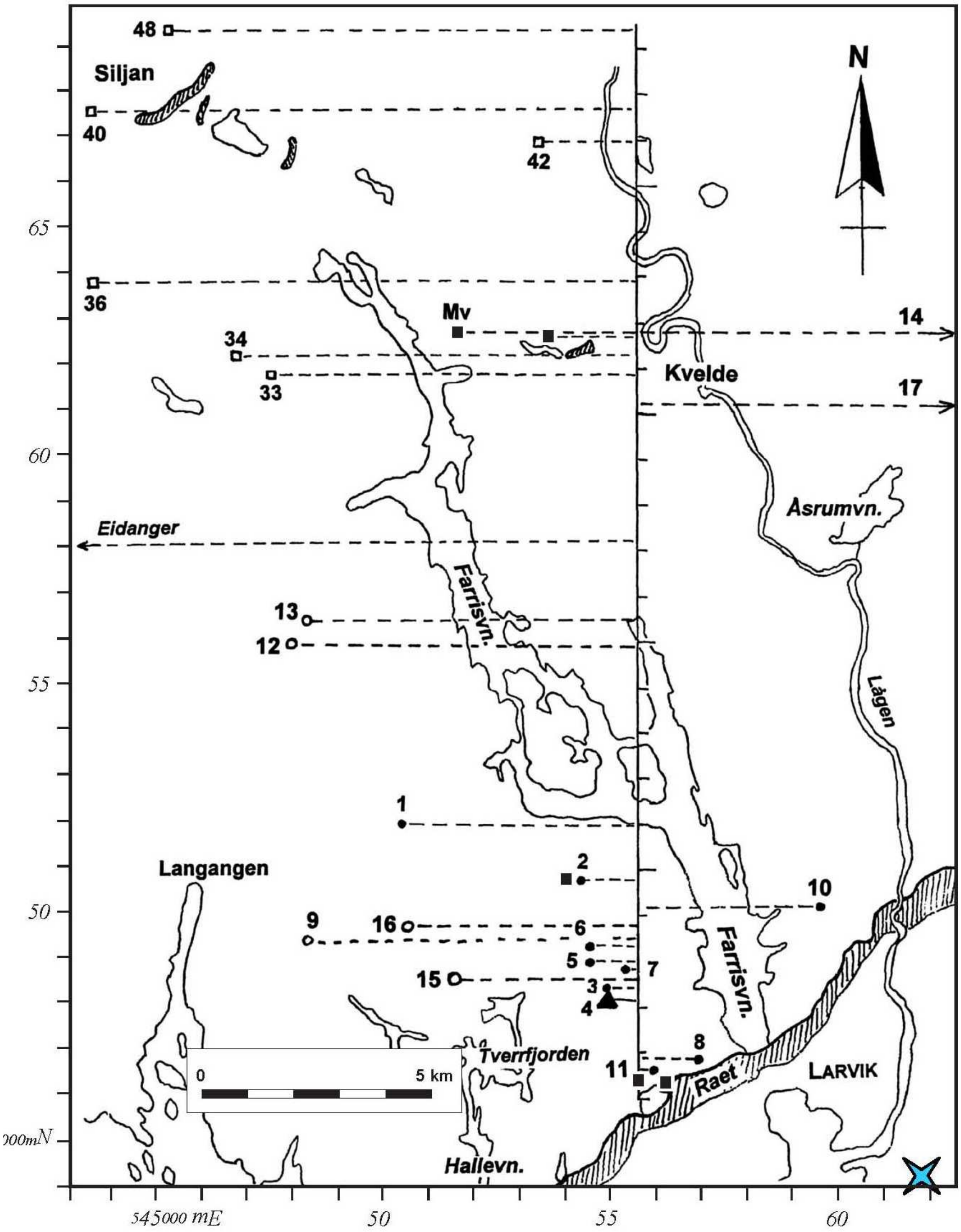
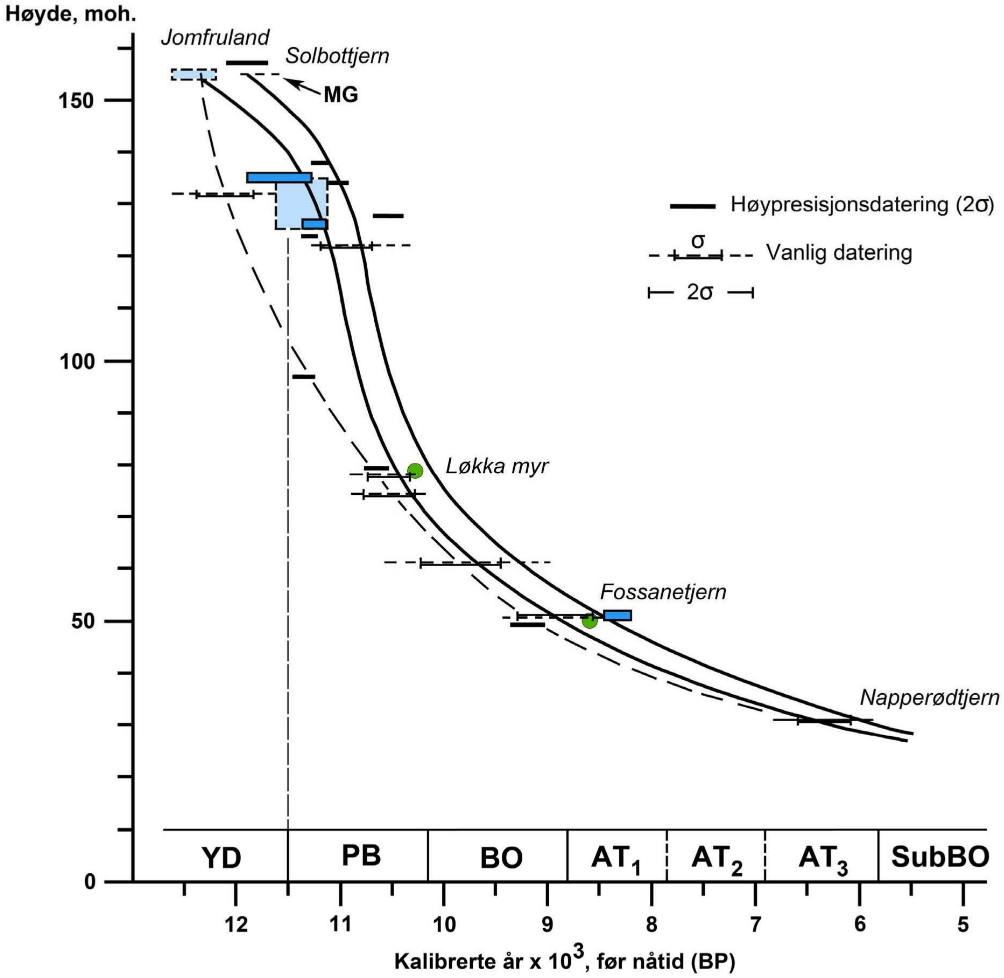


Fig. 2 Studied localities (1 – 10), makes the basis for the sea level curve. Triangle (near locality 3 & 4) represents the highest settlements.
Marine limit (MG) (loc. 33 – 48; is taken from fig. 19 in Bergstrøm 1999).
Black squares are own observations of marine limit near Kvelde, Raet and Stormyr (lok. 2).
Open circles: S = Solumdammen (Henningsmoen 1979), **V =** Vassbotn (Henningsmoen, unpublished).
Star: The Rekkevik-whale



Revised sea level curve for the southern parts of Vestfold (oldest part).
Dotted line: Henningsmoen (1979).

The beech (*Fagus sylvatica)* forests near Larvik – their origin and history

Bjune, A.E., Helvik, I. and Birks, H.J.B.

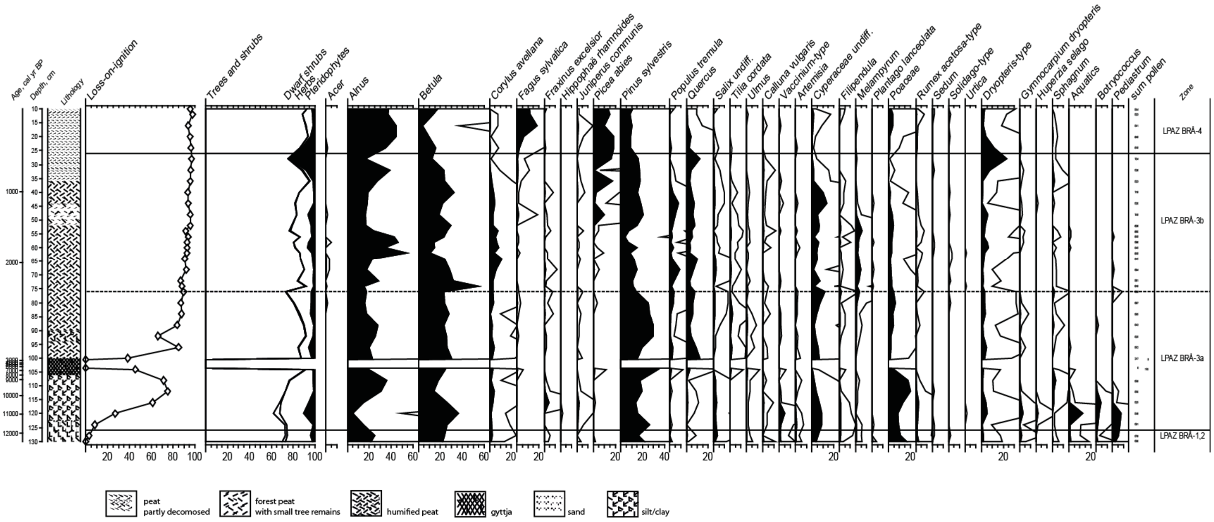
Paper in press in *Vegetation History and Archaeobotany*

By analyzing pollen from two forest hollow sites near Larvik we wanted to obtain a better understanding about the history, origin and development of *Fagus sylvatica* forests. An important part of the study is the examination of processes which led to the establishment of *Fagus sylvatica* and to try to answer whether climate or human activities, or a combination of these, were the driving forces for establishment and development of the local *F. sylvatica* forests. Another hypothesis have been if these are recent plantations.

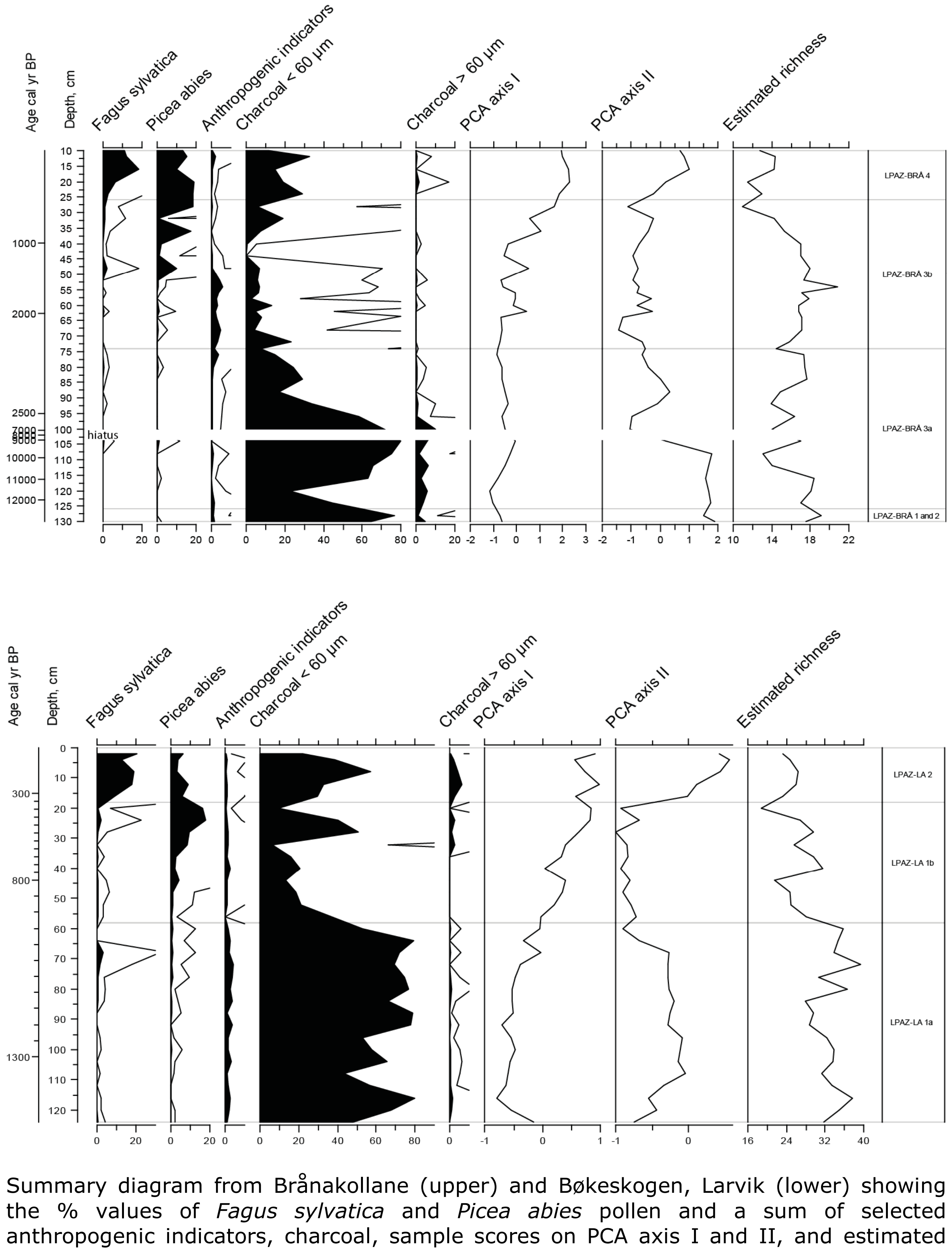
Based on our results, *F. sylvatica* appears to have a long history in the region, from the first occurrence of *F. sylvatica* pollen at *ca.* 9100 cal. B.P. to its local expansion *ca.* 1300 to 1200 cal. B.P..

At the time of local expansion, a shift from a diverse landscape mosaic with many plant taxa present including broad-leaved trees to a less diverse landscape mosaic with *Picea abies* and *F. sylvatica* trees is interpreted from the pollen data.

The long history of *F. sylvatica* suggests that the existing forests are not recent plantations, but implies that these forests are native. The presence of pollen indicative of anthropogenic activity combined with charcoal before the expansion of *F. sylvatica*, as well as comparison with data from nearby sites suggest that the forest development was likely to be a result of human activity and climatic changes, particularly changes in moisture conditions.



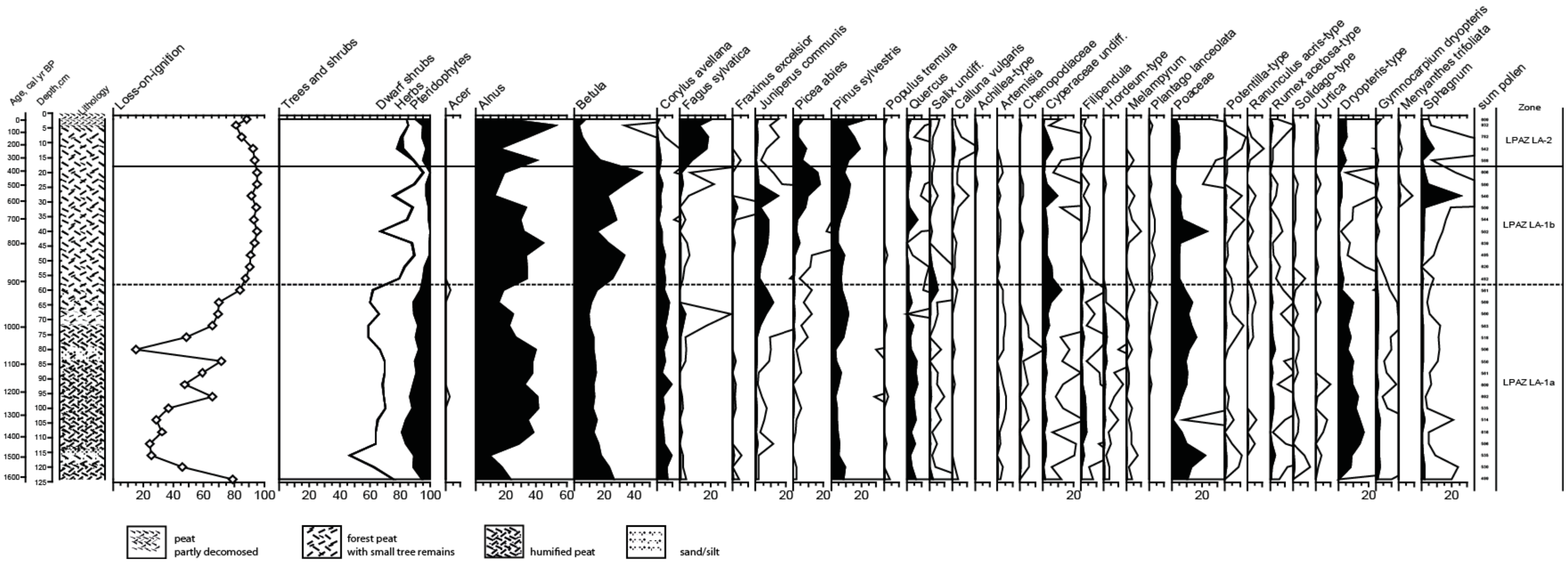
Percentage pollen diagram showing selected pollen and spore taxa from the forest hollow at Brånakollane



Summary diagram from Brånakollane (upper) and Bøkeskogen, Larvik (lower) showing the % values of *Fagus sylvatica* and *Picea abies* pollen and a sum of selected anthropogenic indicators, charcoal, sample scores on PCA axis I and II, and estimated palynological richness (Bjune et al. 2012, in press).

Bøkeskogen, Larvik

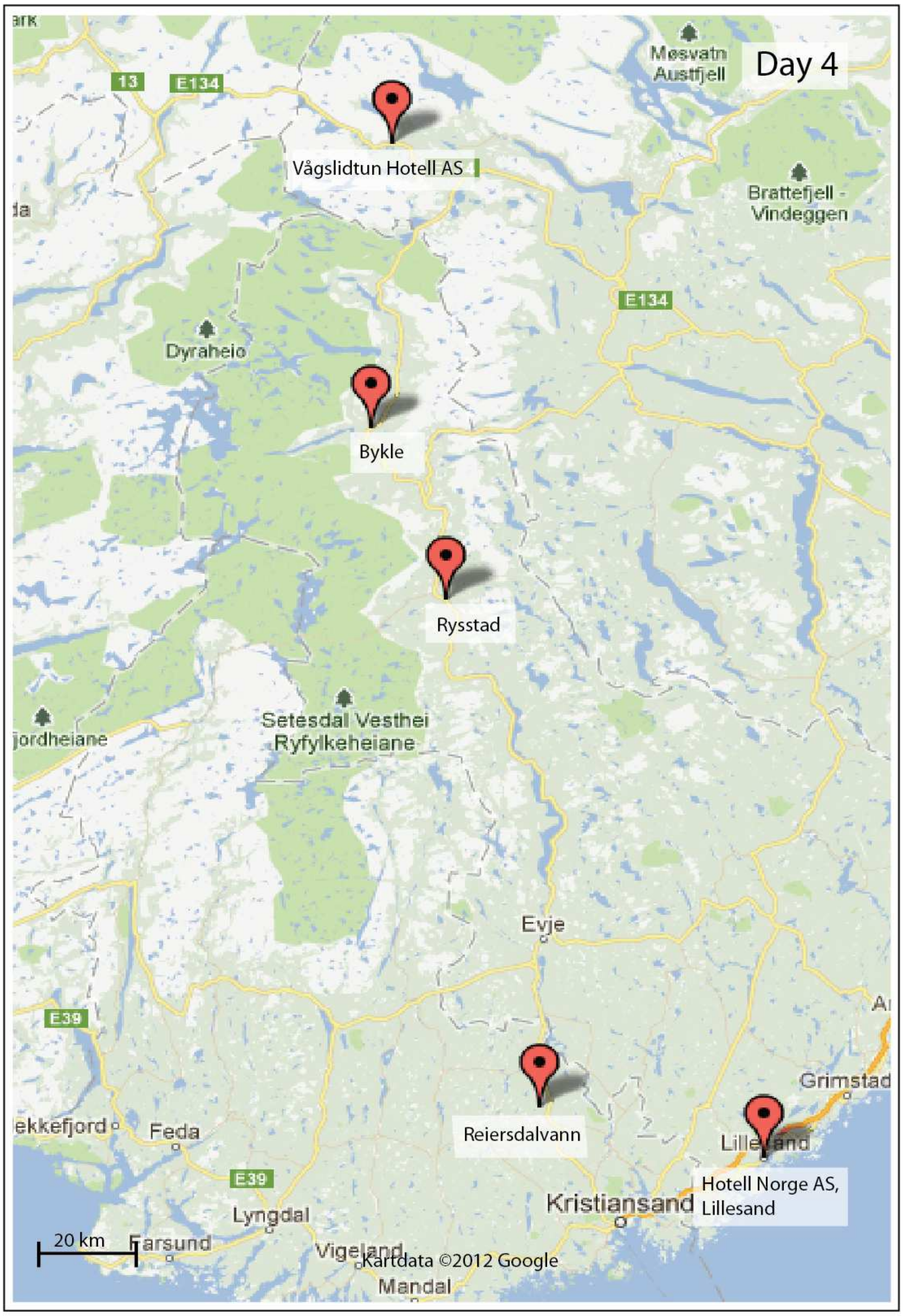
Bjune et al. 2012, in press



DAY 4

SETESDAL (south and central)

Tuesday 11 September 2012


Day 4
Vågslidtun Hotell AS
Bykle
Rysstad
Reiersdalvann
Hotell Norge AS, Lillesand
Møsvatn Austfjell
Brattefjell - Vindeggen
Dyraheio
Setesdal Vesthei Ryfylkeheiane
Evje
Grimstad
Lillesand
Kristiansand
Feda
Lyngdal
Farsund
Vigeland
Mandal
E134
13
E39
20 km
Kartdata ©2012 Google

Setesdal Transect – John Birks and Sylvia Peglar

Introduction

Setesdal is a wonderful ‘natural experiment’ for palaeoecologists and ecologists, as it extends for 200 km from 58°N to nearly 60°N. It lies in two of Moen’s vegetation sections (01 Slightly oceanic; 02 Markedly oceanic), but contains seven vegetation zones. It is thus an ideal area to study biotic responses to changes in temperature independent of changes in annual precipitation.

The Bergen group has prepared ten regional-scale ^{14}C-dated pollen diagrams from ten lakes along Setesdal (Birks 2007). Four of these have been studied for plant macrofossils in conjunction with pollen (Eide et al. 2001). Three of these sites have been studied in detail for chironomids and sediment chemistry (Lüder 2007, Brooks unpublished). Three of the Setesdal lakes were used by Heiri et al. (2003) and Heiri (2004) in his study of within-lake variability of fossil chironomid assemblages in shallow lakes. Most recently Sakari Salonen, Heikkie Seppä, and John Birks have conducted numerical experiments on the effects of selecting different modern calibration-sets for Holocene climate reconstructions. Vivian Felde is currently doing her PhD on modern pollen–vegetation diversity relationships in Setesdal.

In addition, Lotte Selsing from the Museum of Archaeology in Stavanger has published an extensive monograph on people and nature in the mountain area of southern Norway, with particular reference to the Mesolithic (Selsing 2010). As part of an analysis of nuclear and mitochondrial DNA and the genetic structure of *Picea abies* in northern Europe, Tollefsrud et al. (2008, 2009) have examined some spruce populations in Setesdalen.

We have two days in Setesdalen. Today we go to the site Reiarsdalsvatnet (245 m a.s.l) in the boreo-nemoral zone and discuss

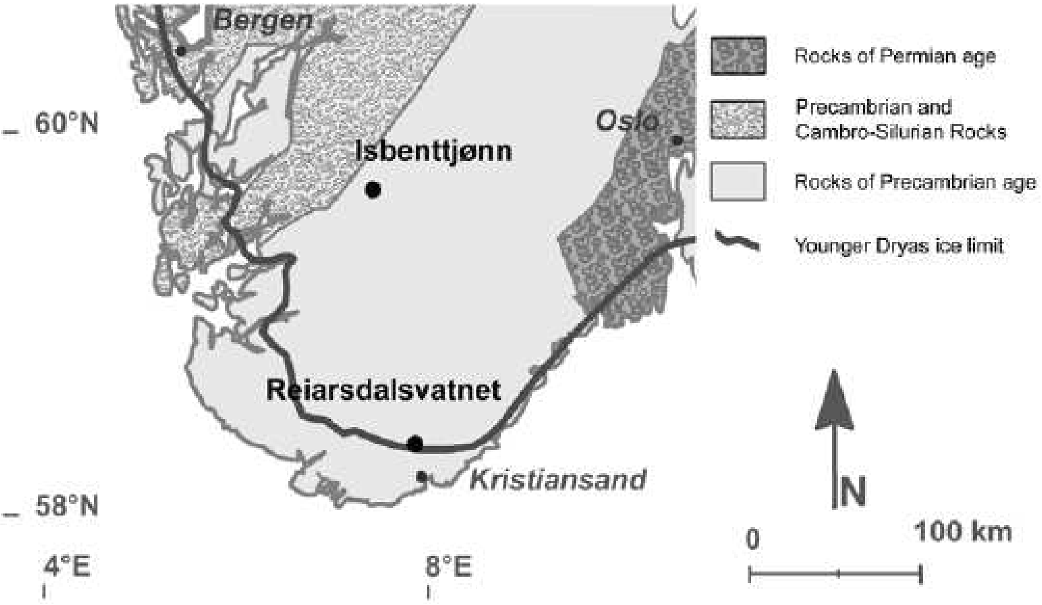
1) modern pollen assemblages in Setesdal
2) Holocene vegetation history of Setesdal as a whole
3) chironomid palaeoecology at Reiarsdalsvatnet
4) reconstruction experiments

Tomorrow we will visit Isbenttjønn (787 m a.s.l) in the northern-boreal zone and Lille Kjelavatn (1000 m a.s.l.) in the sub-alpine zone and discuss

1) chironomid palaeoecogical studies at Isbenttjønn
2) modern pollen-vegetation diversity relationships in Setesdal
3) biotic turnover in the Holocene in Setesdal
4) pollen and macrofossil studies in Setesdal
5) tree migration patterns
6) man in the mountains based on Selsing (2010)
7) Holocene history of the alpine zone and of south Norwegian glaciers.

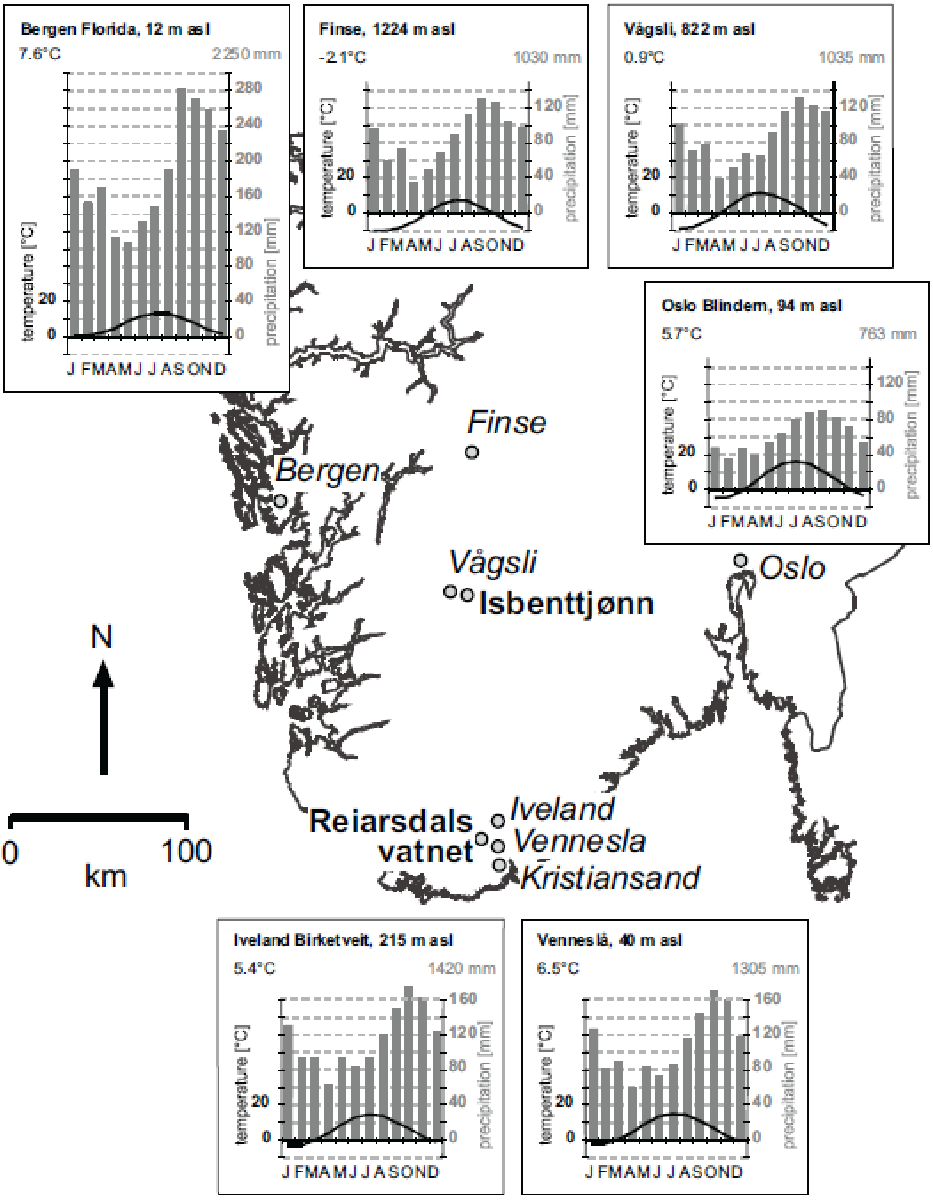
Setesdal geology, climate, vegetation, deglaciation, and archaeology

Setesdal runs over 200 km in a north–south direction from the south coast at Kristiansand to the southern edge of the Hardangervidda plateau at over 1000 m. The bedrock geology of southern Norway is Precambrian Baltic Shield in the south-east and the Norwegian Caledonian in the north and west. All the Setesdalen lakes are located on the old landmass of the central southern Precambrian areas with granite and gneiss as the underlying bedrock (Lüder 2007).



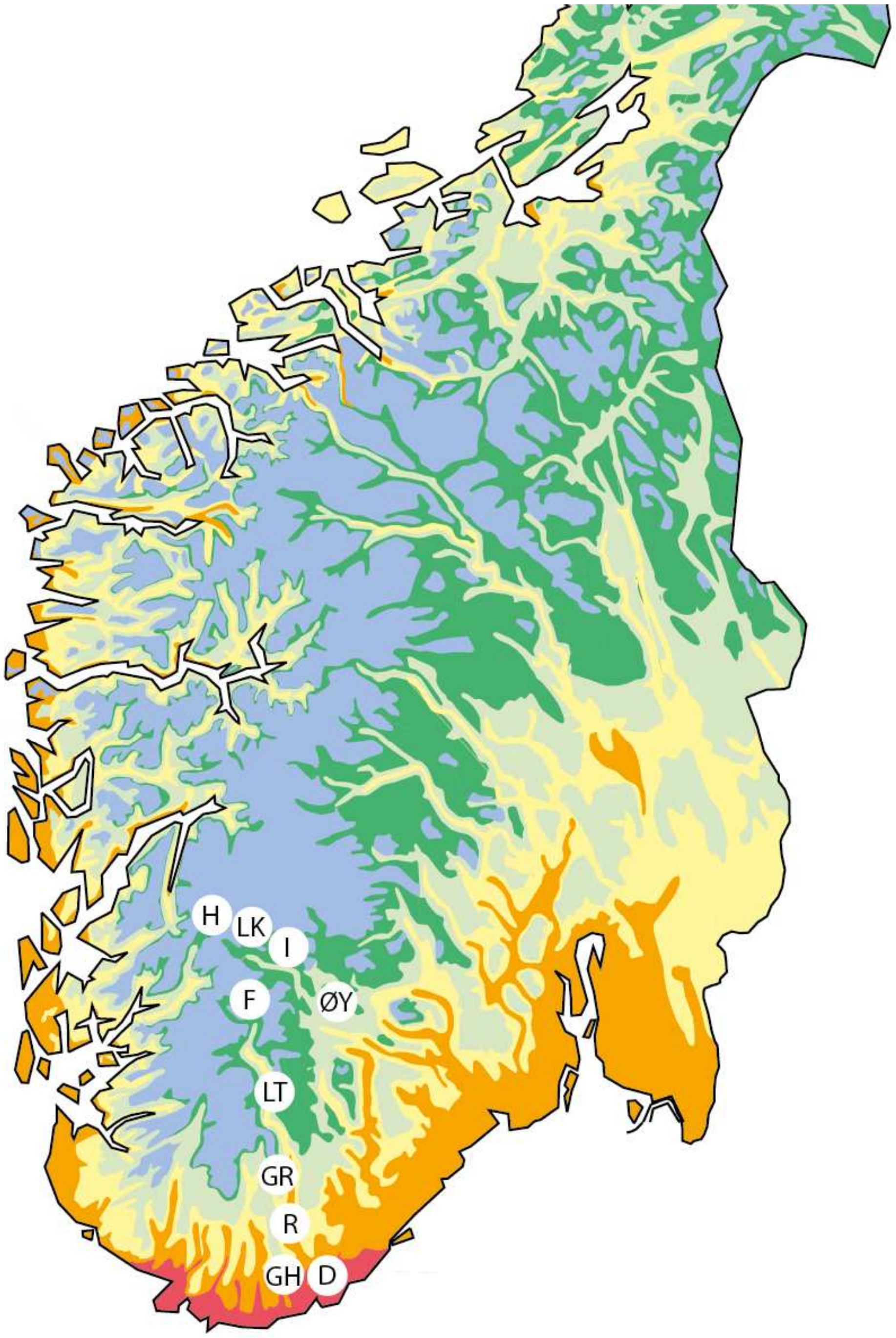
Schematic geological map of southern Norway with the study sites Reiarsdalsvatnet and Isbenttjønn marked. The maximum extent of the Younger Dryas ice-sheet is indicated by the solid line. Modified from Norges Geologiske Undersøkelse (2006), Andersen (1980), Birks (1984), and Moen (1999). (Lüder 2007)

Climatically, Setesdal with its north–south orientation is only marginally affected by the precipitation and oceanity gradients (annual precipitation at Kristiansand 1380 mm and at Vågsli 1067 mm). Most important is the temperature gradient with decreasing summer temperatures from south to north due to increasing elevation.



Map of southern Norway with climate diagrams from Bergen Florida, Finse, Vågslid, Oslo Blindern, Iveland-Birketveit, and Venneslå. The locations of the study sites Reiarsdalsvatnet and Isbenttjønn are indicated. Data from Norsk Meteorologisk Institutt (2006). (Lüder 2007)

The vegetation in the Setesdalen valley falls into seven major zones of Moen (1999) and our pollen sites are situated in these zones.



Setesdal sites marked on the vegetation map from Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

A

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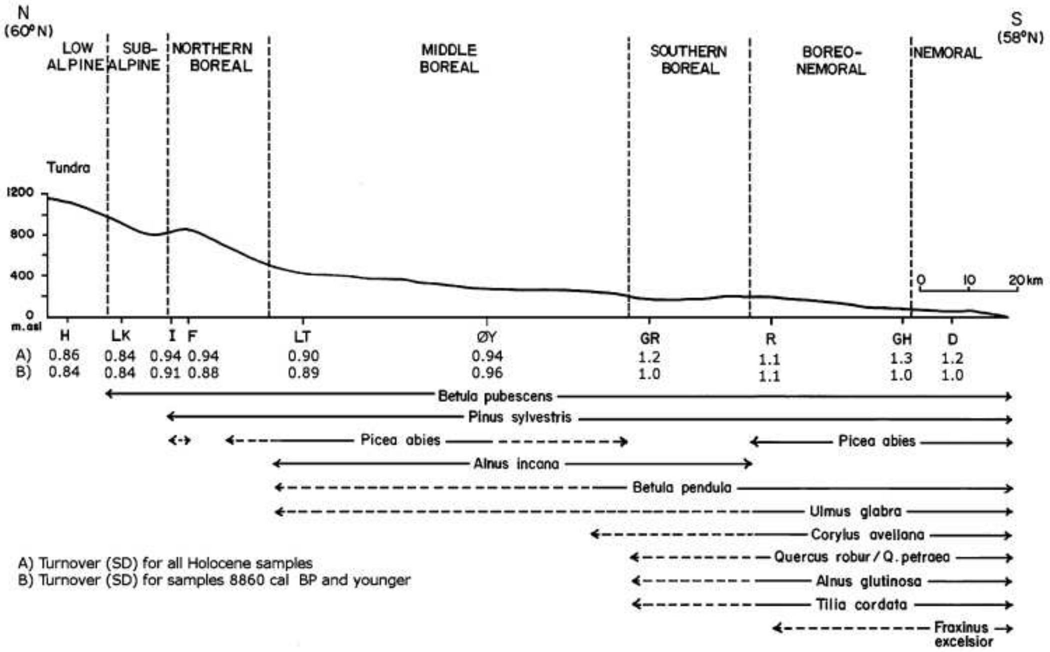


transect through the Setesdal valley in southern Norway showing how altitude varies from south to north, the location of the ten pollen-stratigraphical sequences (H, LK, I, F, LT, ØY, FR, R, GH, D) analysed, the present-day distribution of the major forest trees and shrubs in the valley (= common, = rare), and the estimated palynological compositional turnover (in standard deviation (SD) units) at the ten sites for the Holocene (A) and for the past 8860 cal years (B). (Birks 2007)

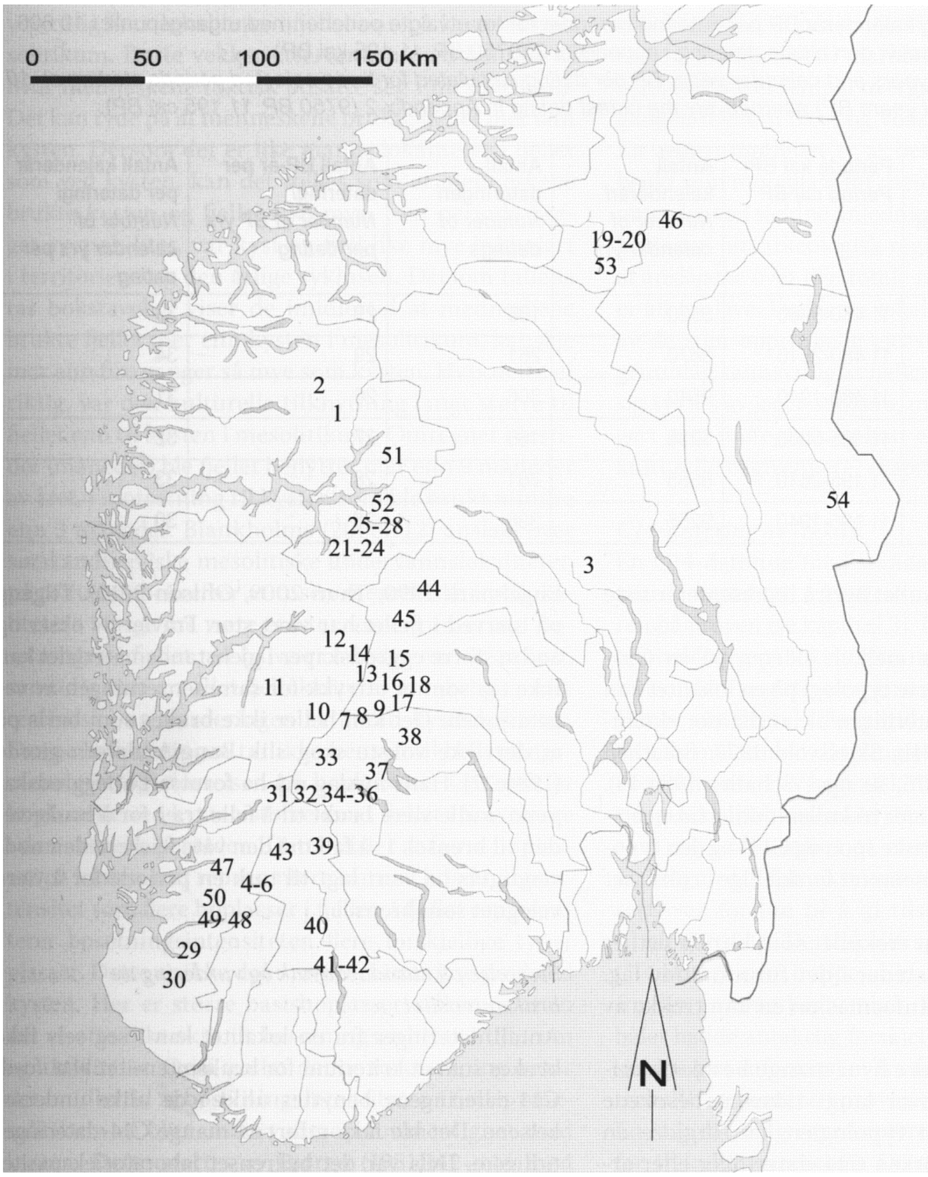
Temperate forest of *Quercus* spp., *Ulmus glabra, Tilia cordata*, and *Fraxinus excelsior* occurs in the extreme southern nemoral zone. Moving northwards and up the valley there is a mixed boreo-nemoral zone with *Pinus sylvestris, Picea abies*, and *Alnus incana*, and local stands of *Quercus* spp., *Ulmus glabra, Tilia cordata*, and *Alnus glutinosa*. This is replaced by the southern and middle boreal vegetation zones with abundant *Pinus sylvestris, Betula pubescens, Alnus incana*, and, locally, *Betula pendula* and *Picea abies*. The northern boreal zone occurs between about 500 m and 800 m above sea-level where *Pinus* and *Picea* become rarer and *Betula* becomes dominant. There is a sub-alpine zone of *Betula pubescens* (strictly part of Moen's northern boreal zone but with no pine or spruce). The elevational tree-line is at about 1000 m a.s.l.

Scandinavia has been extensively glaciated and in the last glacial stage, the Scandinavian ice-sheet reached its maximum between 28 and 22 kyr BP. At that time, the ice-sheet extended beyond the present Norwegian coast. It receded during the early phases of deglaciation, but re-advanced during the Younger Dryas. The Younger Dryas is marked by terminal moraines, so-called Ra-moraines in south Norway (see Geological map on the previous page). The maximum of the Younger Dryas inland ice-sheet may have lasted 100–250 years and the final ice retreat began at about 11500 cal. BP. After the Younger Dryas–Holocene transition, the ice-sheet melted rapidly.

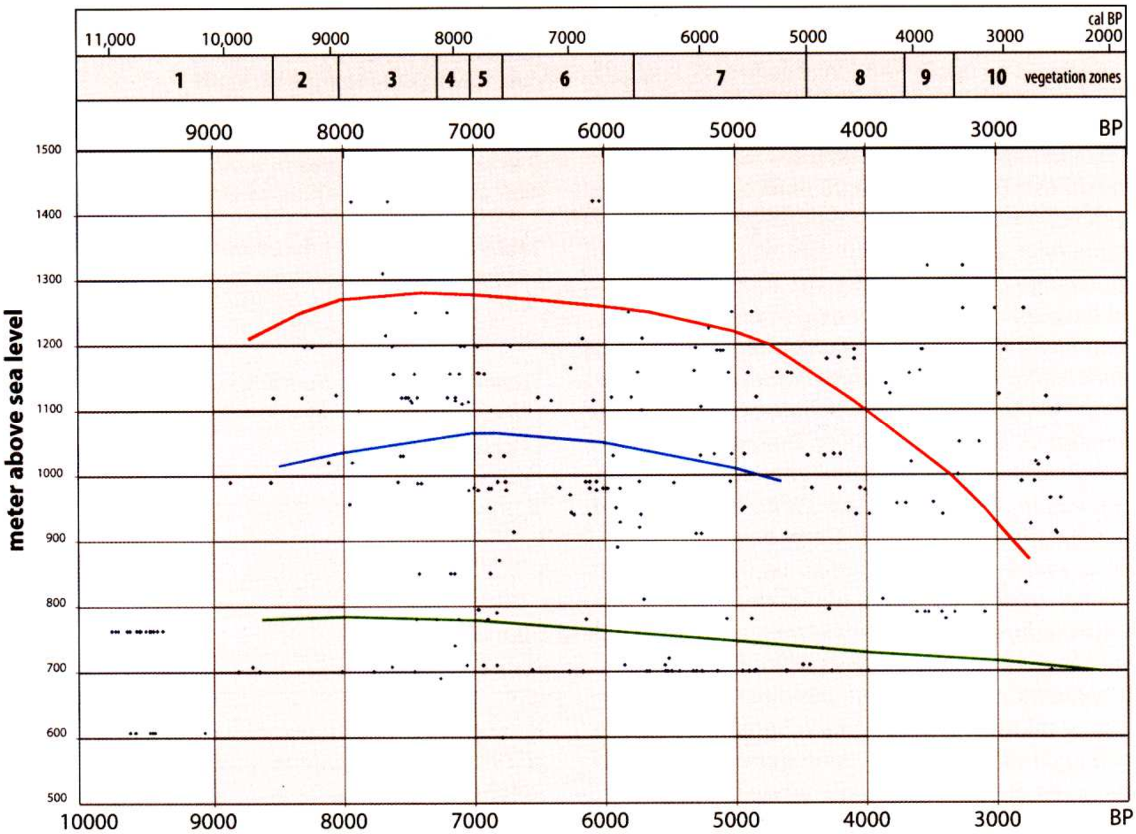
In Setesdal the ice-front was located at the Ra-moraines, at least from the Younger Dryas to Preboreal/Boreal time. Setesdal and the Hardangervidda to the north were deglaciated by about 10000 cal. BP. From fluctuations of the remaining plateau glaciers, several major climate oscillations are detected during the Holocene by Atle Nesje and colleagues (e.g. Dahl and Nesje 1996; Nesje 2009). The major phases of glacial advance are:

Erdalen event	10200 cal. BP
'Finse' event	8500 cal. BP ≡ 8.2 ka event in GRIP and GISP2
Unnamed event	4200 cal. BP
'Little Ice Age'	300-20 cal. BP

Setesdal is rich in archaeological evidence for prehistoric human activity. It is commonly thought that colonisation of the coastal area in southern and western Norway began about 11500 cal. BP, possibly coming via a peninsula on the North Sea shelf and after 10700 cal. BP by sea from Skagen. Only after 10700–10100 cal. BP was migration over land, presumably mainly from southern Sweden. During the Mesolithic (9950–4950 cal. BP), people lived in small groups close to the sea as hunters and gatherers mainly living on marine resources. However, archaeological evidence is also found of Mesolithic settlements in the south Norwegian mountains where people lived by reindeer hunting. In the mountains west of Setesdal, Mesolithic settlements have been dated to between 7900 and 6500 cal. BP. They occur close to lakes or rivers. Trout bones found in settlements between 7000 and 6000 cal. BP indicate that fish were present in the mountain lakes at that time. It is unresolved if migration from the coast to the mountains took place seasonally or if the groups migrated more irregularly over longer distances. In the forested area between the coast and the mountains, especially in the valleys connecting them, numerous transitory sites should have been present but to date only a few have been found. They are generally smaller than the high-mountain sites.

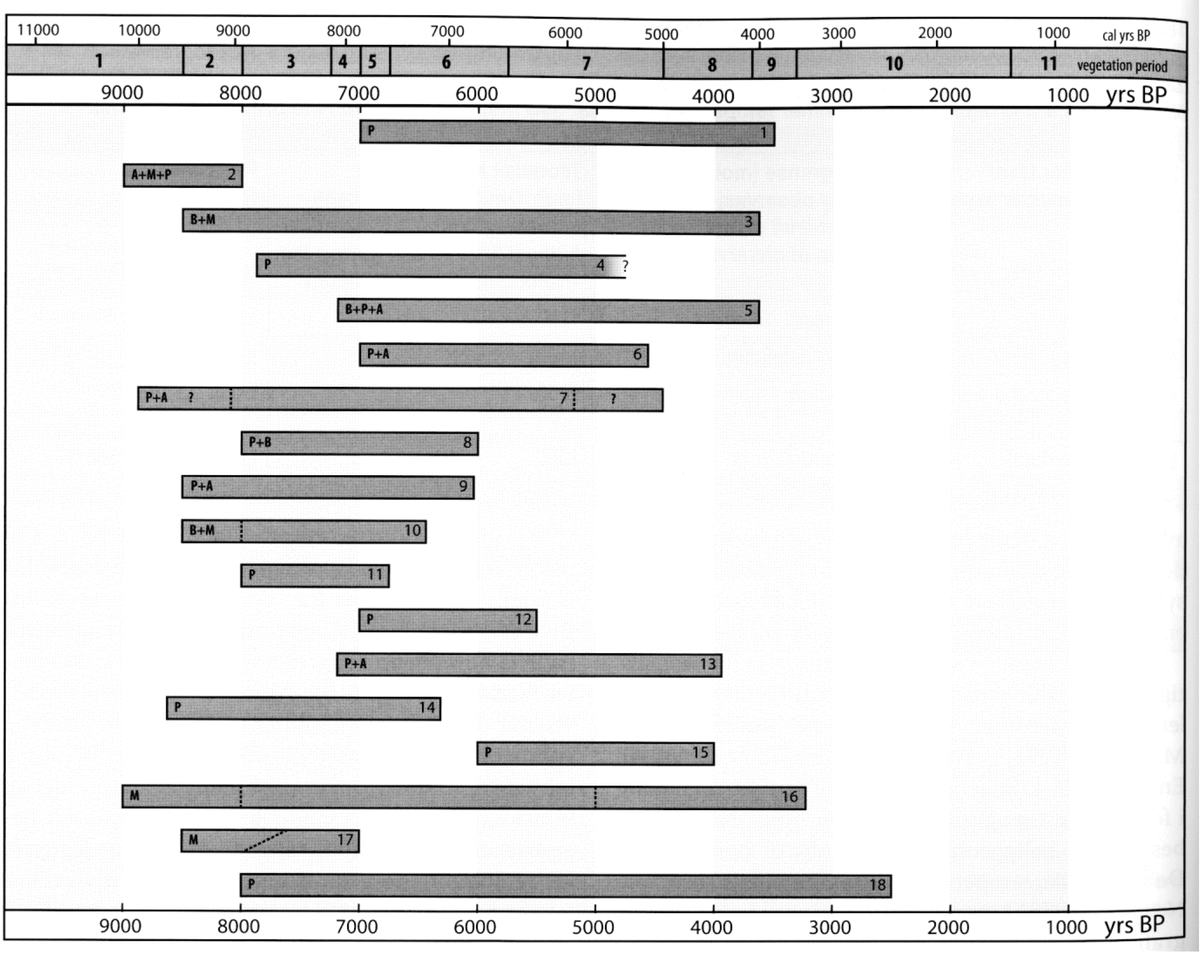


Map of the locations of radiocarbon dated Stone Age sites and areas in the mountain area in south Norway. (Selsing 2010)



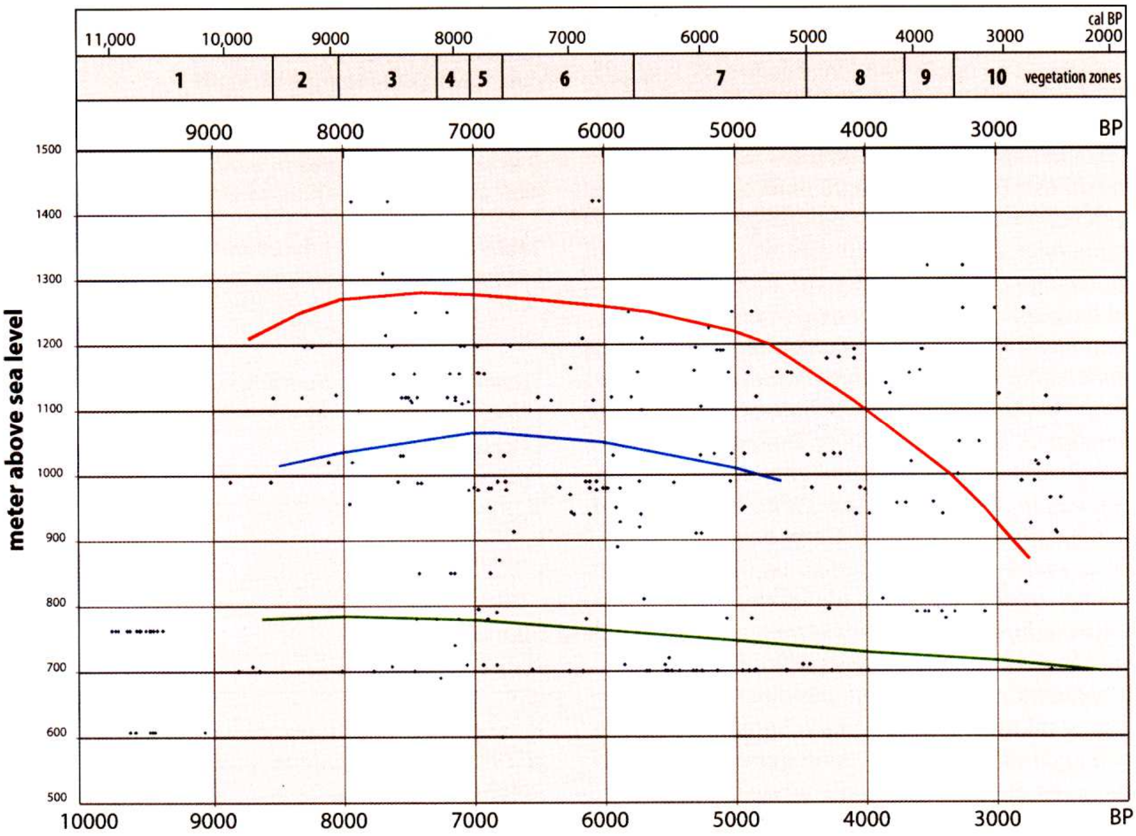
Correlation between the elevation (m a.s.l.) of radiocarbon dated Stone Age sites (marked by small rhombs) and the pine tree limit in the Holocene. South Norway is divided into three geographical areas from west to east. The lower curve represents the area west of the water divide, the middle curve the eastern area where the pine forest limit today declines to the east, and the upper curve – most parts of the mountain area – the area between the two other areas (modified from Selsing 1998). (Selsing 2010)

Tree macrofossils (Selsing 2010) suggest that *Betula* reached 1215 m elevation at 7500 cal. BP (after correction for uplift) whereas *Pinus* reached 1095 m. Today's upper limits 1050 m for *Betula* and 930 m for *Pinus*.



The Holocene 'thermal optimum' in different areas in south Norway. Letters in the bars refer to the main methods used: P = palynology, B = glacier oscillation, M = megafossil, A = other (plant macrofossil, diatom, sedimentology, ecology, Chironomidae, midge. References: 1 Dyraheio (Selsing 2010), 2 Hardangervidda (Moe & Odland 1992), 3 the area around the northern section of Hardangerjøkulen (Dahl & Nesje 1996), 4 Ulvik in Hardanger (Simonsen 1980), 5 Trettetjørn (Bjune 2004, Bjune et al. 2005), 6 Trettetjørn (Larsen et al. 2006), 7 south-western Hardangervidda (Eide 2003a, b), 8 the area around Jostedals Glacier and western Jotunheimen (Matthews & Karlén 1992), 11, eastern Jotunheimen (Gunnarsdottir 1996a, b), 12 Ølstadsetri north of Lesjadalen (Gunnarsdottir 1996b; Gunnarsdottir & Høeg 2000), 13 Råtåsjøen, Dovrefjell (Velle et al. 2005), 14 northern Gudbrandsdalen (Gunnarsdottir 1996a, 1999), 15 Innerdalen, Kvikne, Hedmark (Paus et al. 1987), 16 the mountain area of central south Norway (Aas & Faarlund 1988), 17 the mountain areas of south Norway (Kvamme 1993), 18 the inner part of the areas around the Oslofjord (Hafsten 1956, 1960, 1963). (Selsing 2010)

Selsing (2010) argues that Mesolithic populations were mainly in the sub-alpine zone which was dominated by *Pinus* with some *Betula*. The 'Holocene thermal maximum' started about 8900 cal. BP and the dominance of pine began to decline around 7580 cal. BP and at the same time, there are the first traces of a decline in the forest limit.



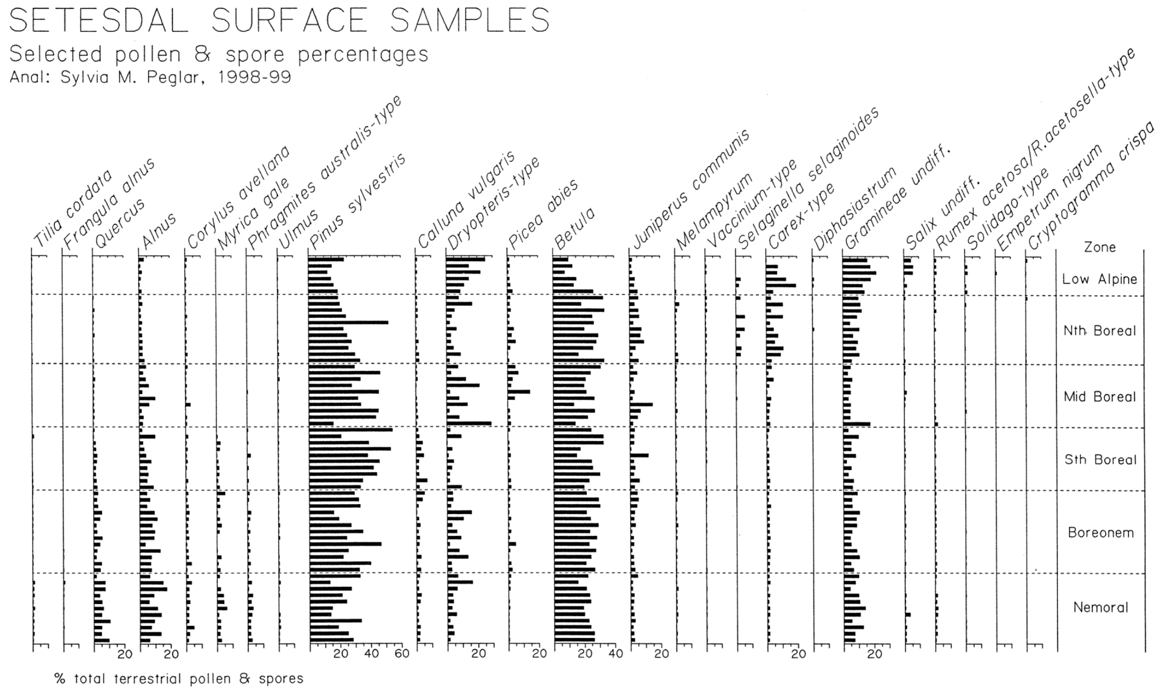
Correlation between the elevation (m asl) of radiocarbon dated Stone Age sites (marked by small rhombs) and the pine tree limit in the Holocene. South Norway is divided into three geographical areas from west to east. The lower curve represents the area west of the water divide, the middle curve the eastern area where the pine forest limit today declines to the east, and the upper curve – most parts of the mountain area – the area between the two other areas (modified from Selsing 1998). (Selsing 2010)

Birch gradually became the dominant tree and sub-alpine birch forest became established during 6480–4970 cl. BP with a declining forest limit and climatic deterioration. From about 4970 cal. BP grazing domestic animals may have influenced the composition of the vegetation and grazing may have hampered tree re-growth. The ‘Holocene thermal maximum’ ended during 4470–3370 cal. BP and the sub-alpine birch forest was more open. The drop in forest limit was considerable from about 4040–3520 cal. BP and low-alpine vegetation expanded as pasturing husbandry increased, resulting in a sub-alpine/low-alpine ‘cultural landscape’ similar to what we see today.

In the lowlands, people probably did not live on agro-pastoral products before about 4200 cal. BP. No bronze artefacts have been found in Setesdal. The onset of iron production in Norway occurred just after 2500 cal. BP. For domestic iron production, bog ore and charcoal locally produced in charcoal kilns were used. Since vast amounts of wood and iron-ore were needed to produce iron, the main areas of iron production were not located close to settlements. Areas around the tree-line were favoured because of the availability of wood and bog ore. In the upper part of Setesdal near Møsvatn (Vinje, Telemark), numerous charcoal kilns and places for iron production have been found and dated to between 1400 and 580 cal. BP. At the end of the Roman Period, farmers had permanently settled in Setesdal and the town of Valle in upper Setesdal became an important trading place for iron and animal skins in the Viking Period.

Modern pollen assemblages in Setesdal – John Birks and Sylvia Peglar

Modern pollen assemblages from the top 0–1 cm of sediment in 61 lakes along the Setesdal transect have been analysed. In general they show that the main zones produce fairly distinctive modern assemblages.



Summary pollen diagram for modern surface samples (0–1 cm) from 61 lakes along the Setesdal valley arranged on a south to north transect in relation to the modern vegetation zones. Within each vegetation zone, the sites are arranged latitudinally from south (bottom) to north (top).

The relationship between these modern pollen assemblages and plant richness will be discussed tomorrow by Vivan Felde.

Coring sites in southern and central Setesdal

Dalandstjørn (Dalane) 40 m, nemoral,
5.2 m water depth

Tvitjønn (Grauthelleren), 80 m, boreo-nemoral,
7.8 m water depth

Reiardalsvatn, 245 m, boreo-nemoral,
9.2 m water depth

Grostjørna, 180 m, southern-boreal,
9.5 m water depth

Øygardstjønn, 665 m, middle-boreal,
12.5 m water depth

Lisletjønn, 520 m, middle-boreal,
7.1 m water depth

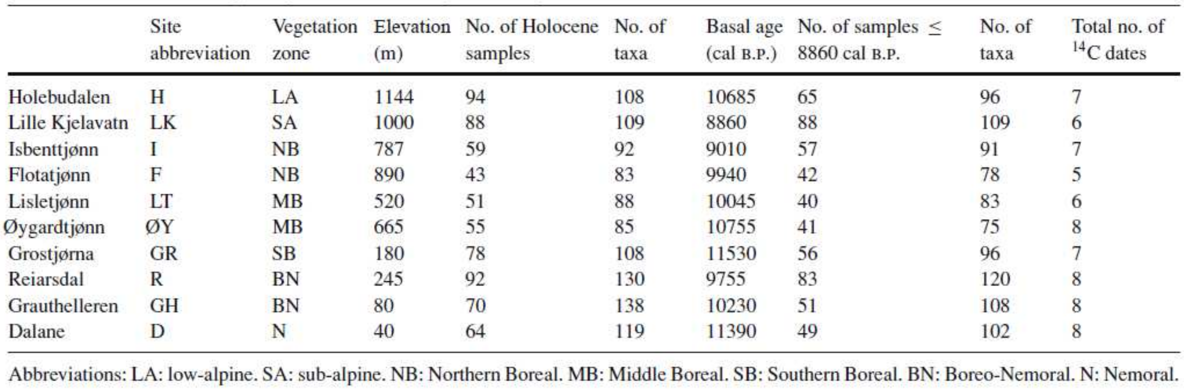
	
Flotatjønn, 890 m, northern-boreal, 6.5 m water depth	

Holocene pollen stratigraphy of the Setesdal valley – John Birks and Sylvia Peglar

Ten small (150–300 m diameter) lakes were selected for detailed pollen-stratigraphical studies along the Setesdal transect in relation to the modern distributional limit of the major tree taxa and the present-day vegetation zones. One site (Isbenttjønn that we will visit tomorrow) had an old deserted farm almost adjacent to the lake. It is now a restored 'holiday' home. There is no other obvious field evidence for intensive human activity in the catchment of the other nine lakes studied. The lakes have few inflow and outflow streams.

Summaries of the ten sites are given below.

Table 1 Summary of the ten sites in Setesdal analysed in terms of site name, abbreviation, vegetational zone, elevation, number of Holocene-age samples and associated pollen and spore taxa, number of samples ≤ 8860 cal years BP and associated taxa, and total number of ^{14}C dates per sequence (Birks 2007)

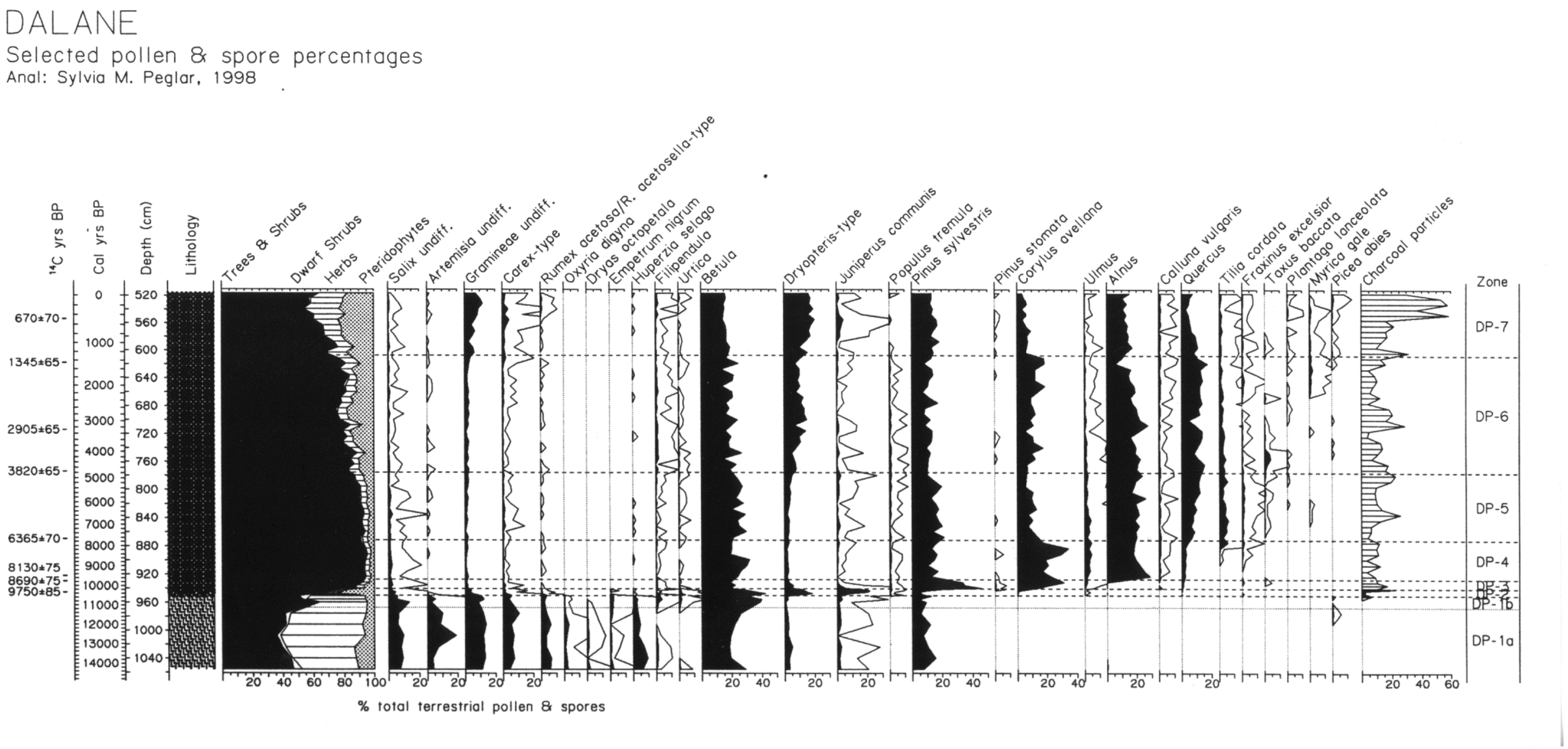


	Site abbreviation	Vegetation zone	Elevation (m)	No. of Holocene samples	No. of taxa	Basal age (cal B.P.)	No. of samples ≤ 8860 cal B.P.	No. of taxa	Total no. of ^{14}C dates
Holebudalen	H	LA	1144	94	108	10685	65	96	7
Lille Kjelavatn	LK	SA	1000	88	109	8860	88	109	6
Isbenttjønn	I	NB	787	59	92	9010	57	91	7
Flotatjønn	F	NB	890	43	83	9940	42	78	5
Lisletjønn	LT	MB	520	51	88	10045	40	83	6
Øygardtjønn	ØY	MB	665	55	85	10755	41	75	8
Grostjørna	GR	SB	180	78	108	11530	56	96	7
Reiarsdal	R	BN	245	92	130	9755	83	120	8
Grauthelleren	GH	BN	80	70	138	10230	51	108	8
Dalane	D	N	40	64	119	11390	49	102	8

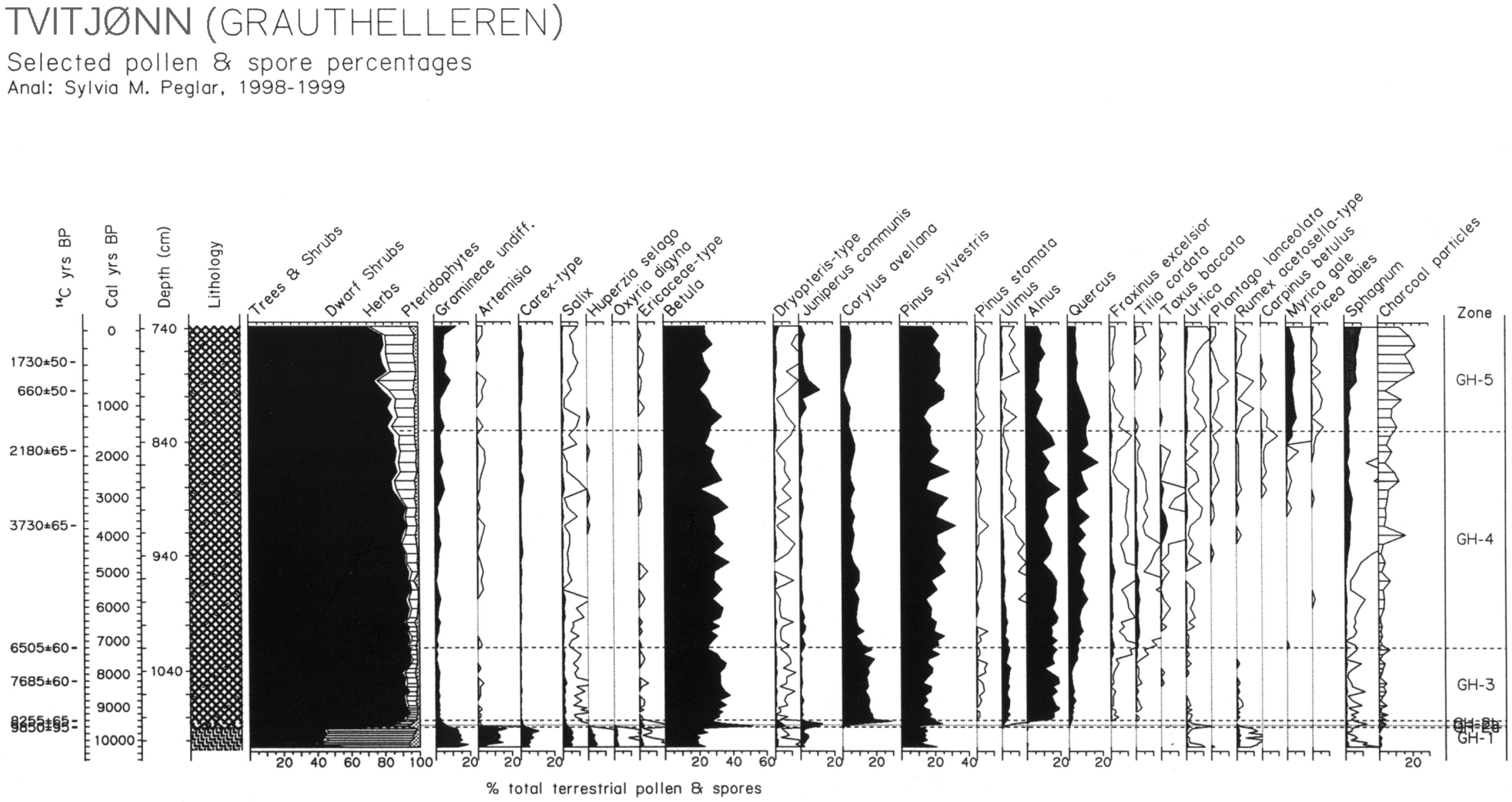
Abbreviations: LA: low-alpine. SA: sub-alpine. NB: Northern Boreal. MB: Middle Boreal. SB: Southern Boreal. BN: Boreo-Nemoral. N: Nemoral.

Table 2 Modern climate data for the ten sites (Birks 2007)

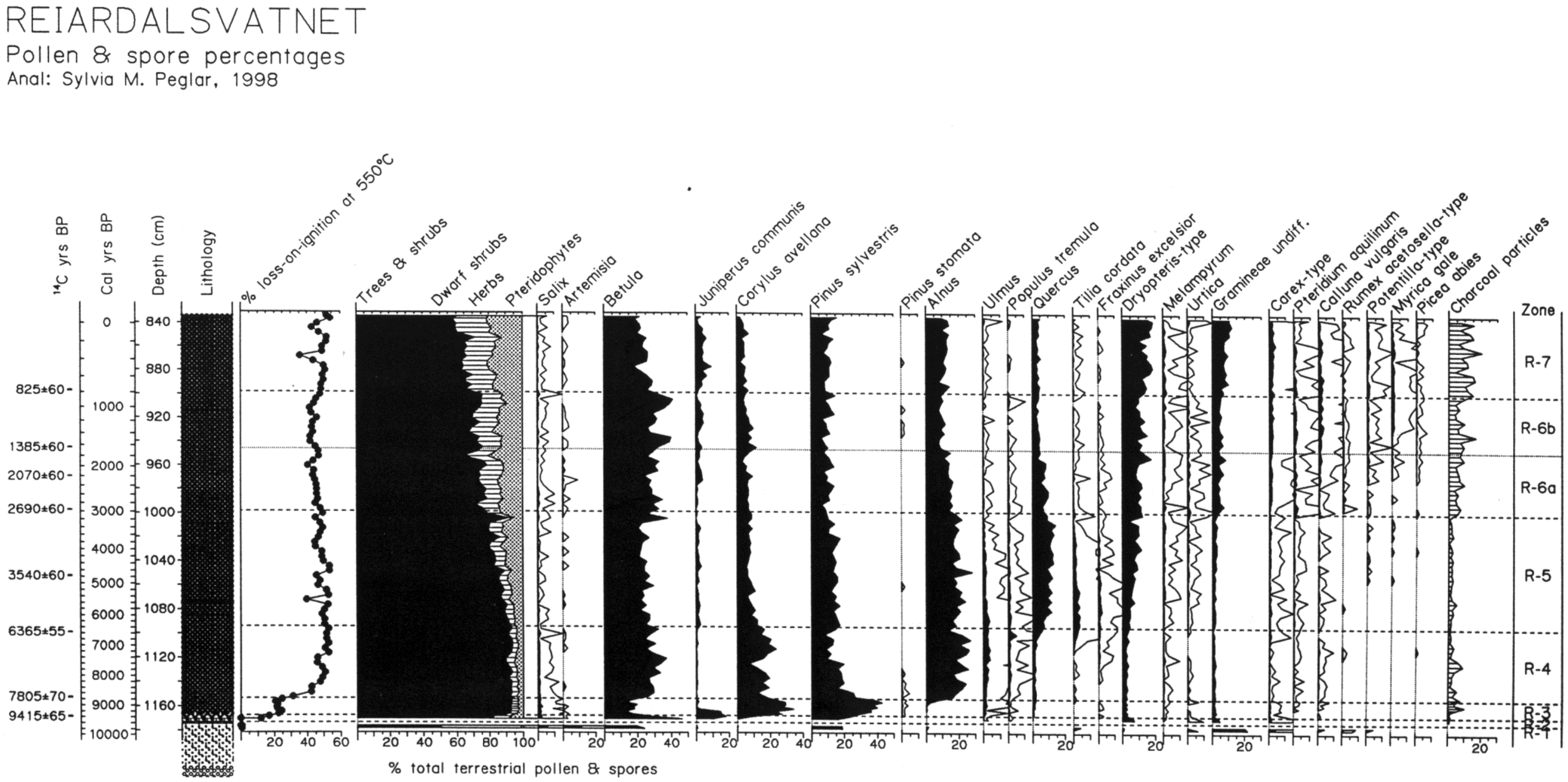
Site	**Elevation (m)**	**Mean July (°C)**	**Mean Jan (°C)**	**Annual pt (mm)**
Holebudalen	1144	8.2	−7.1	900
Lille Kjelavatn	1000	9.3	−6.7	840
Isbenttjønn	787	10.5	−6.3	800
Flotatjønn	840	10.4	−7.6	990
Øygardtjønn	665	12.2	−6.4	1050
Lisletjønn	520	12.9	−5.0	900
Reiarsdalsvatnet	245	14.3	−3.2	1310
Grostjørna	180	15.2	−3.5	1430
Tvitjønn (Grauthelleren)	80	14.5	−1.7	1380
Dalandstjørn (Dalane)	40	14.9	−1.5	1380



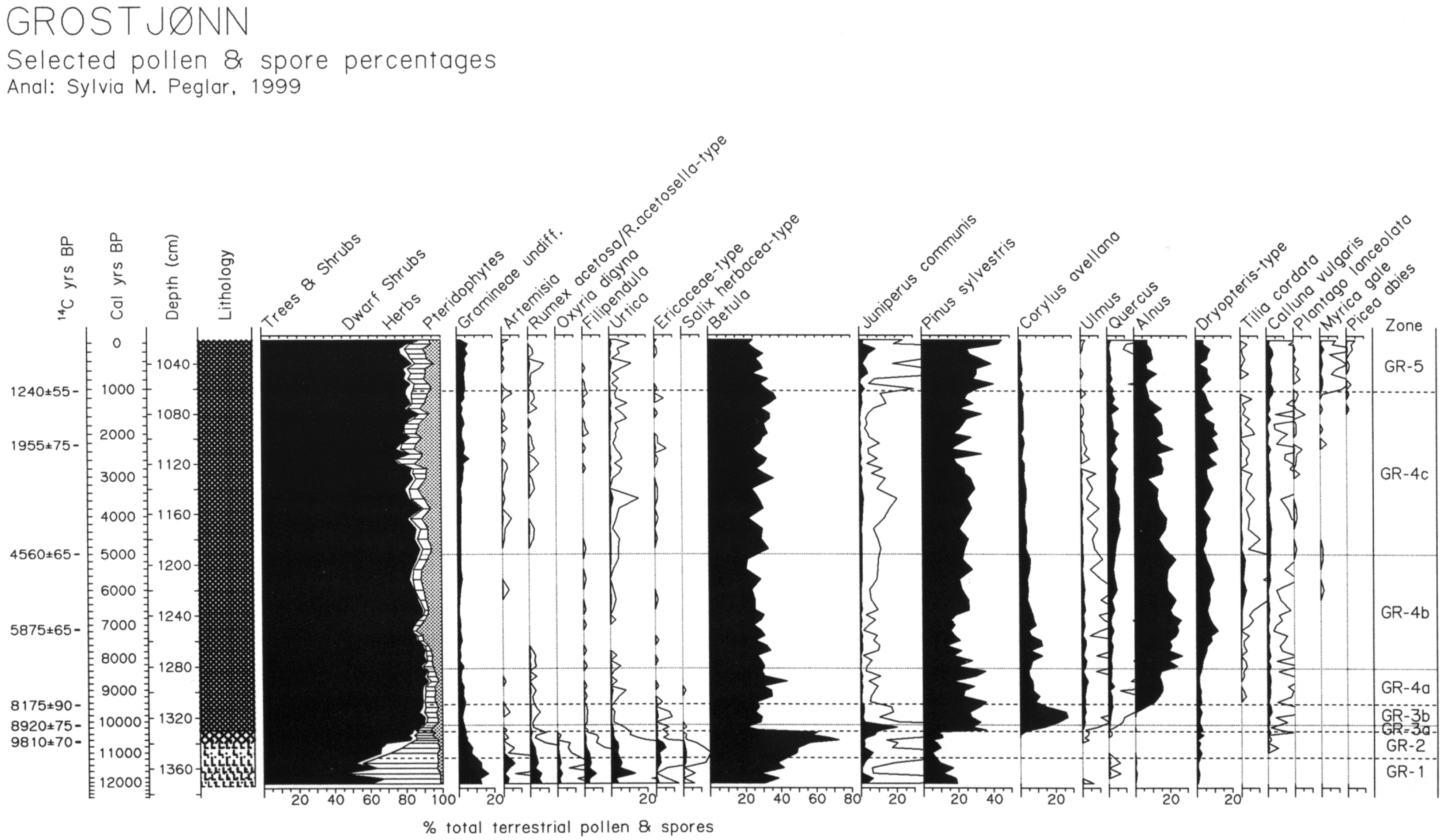
Summary pollen diagram from Dalandstjørn (Dalane) in the nemoral zone



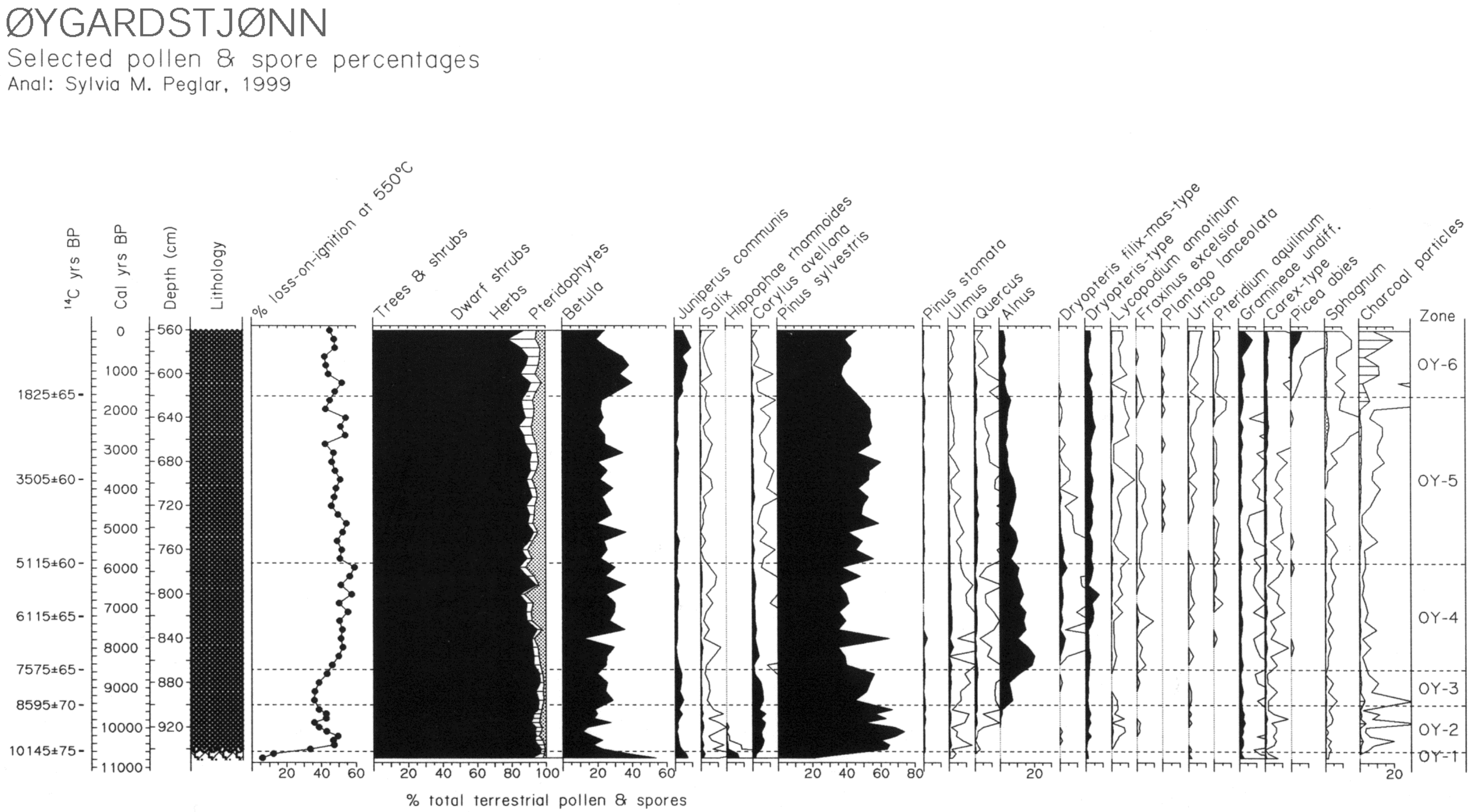
Summary pollen diagram from Tvitjønn (Grauthelleren) in the boreo-nemoral zone



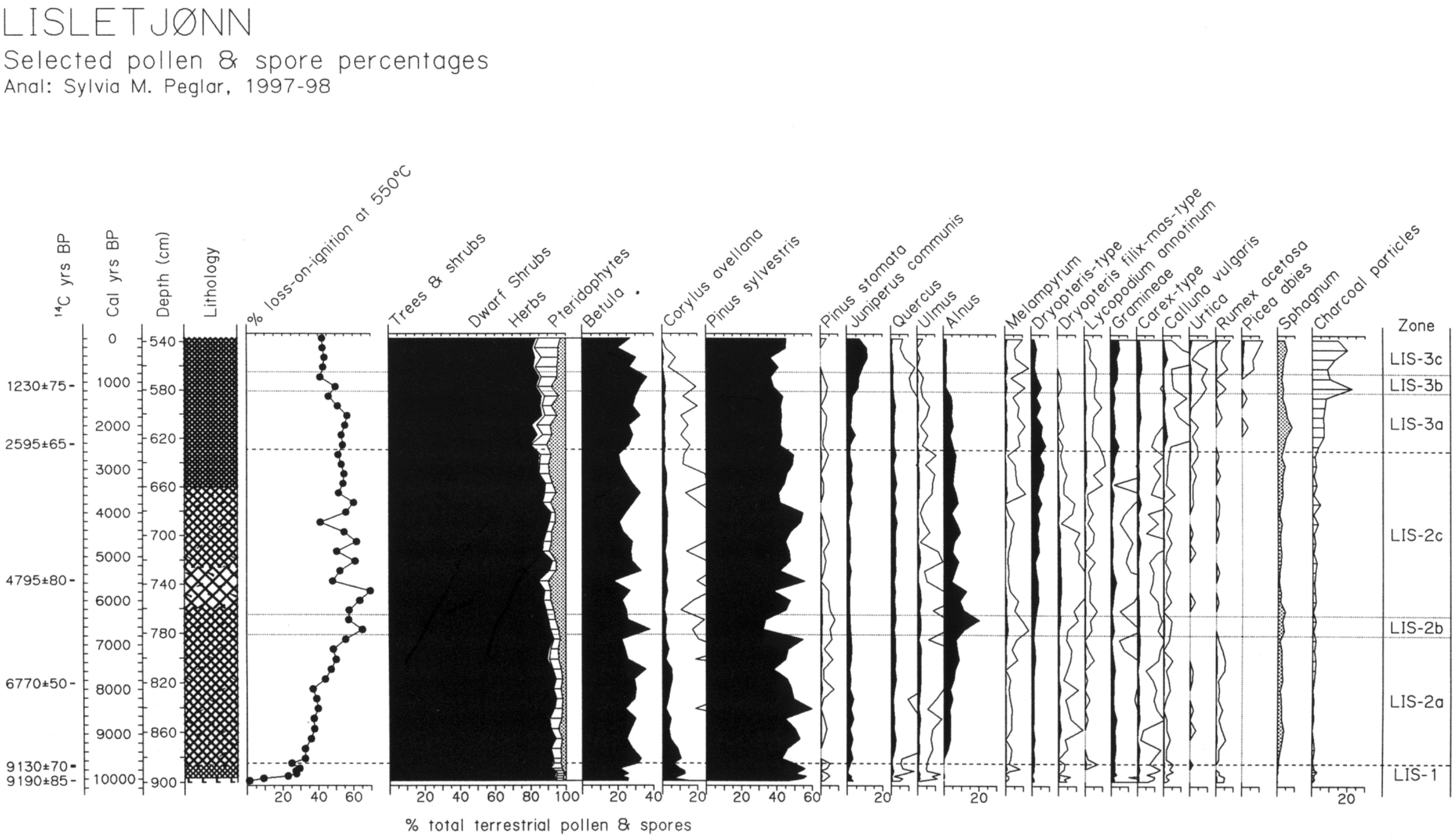
Summary pollen diagram from Reiarsdalvatn in the southern-boreal zone


GROSTJØNN
Selected pollen & spore percentages
Anal: Sylvia M. Peglar, 1999

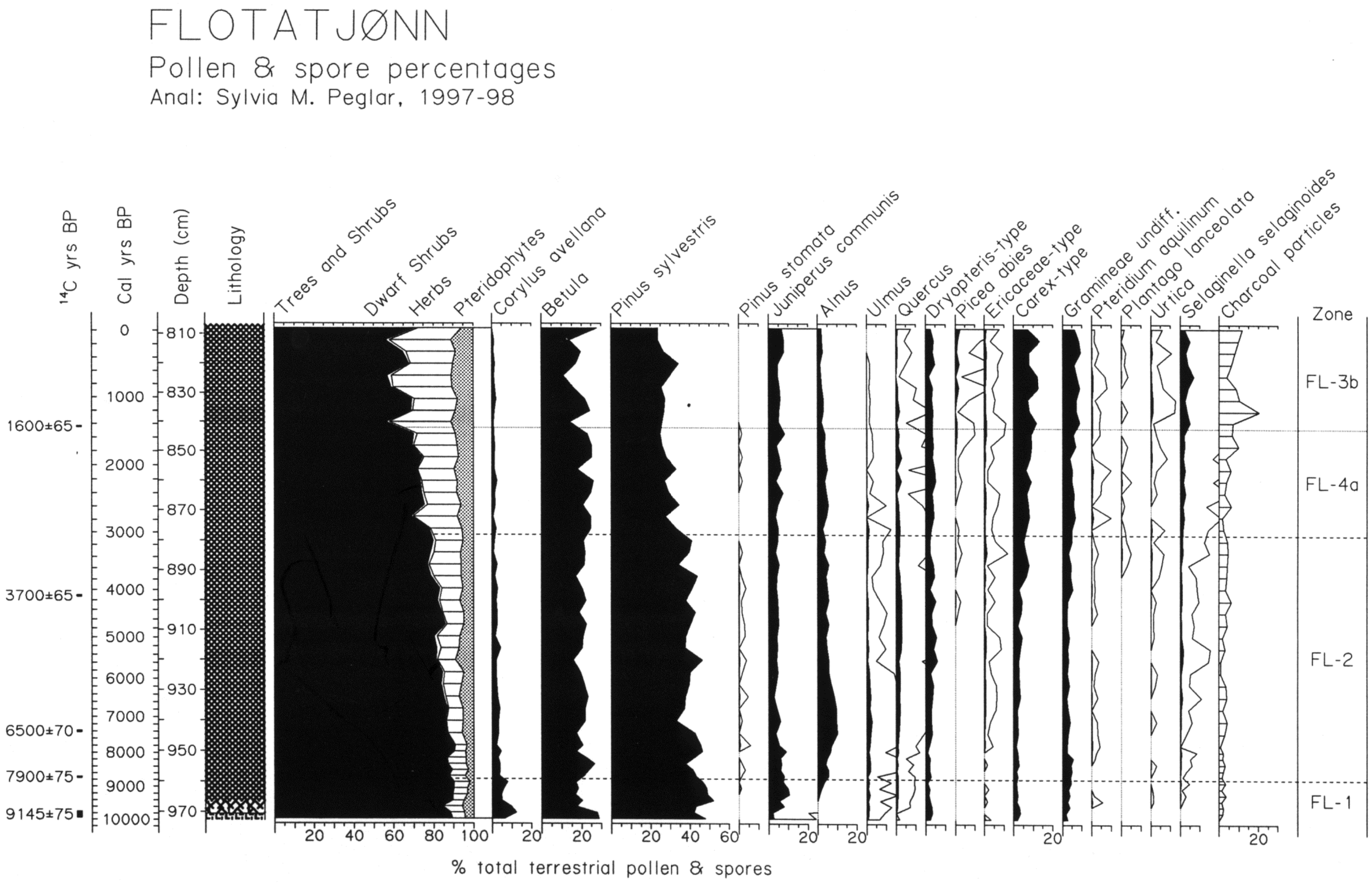
Summary pollen diagram from Grostjørna in the middle-boreal zone



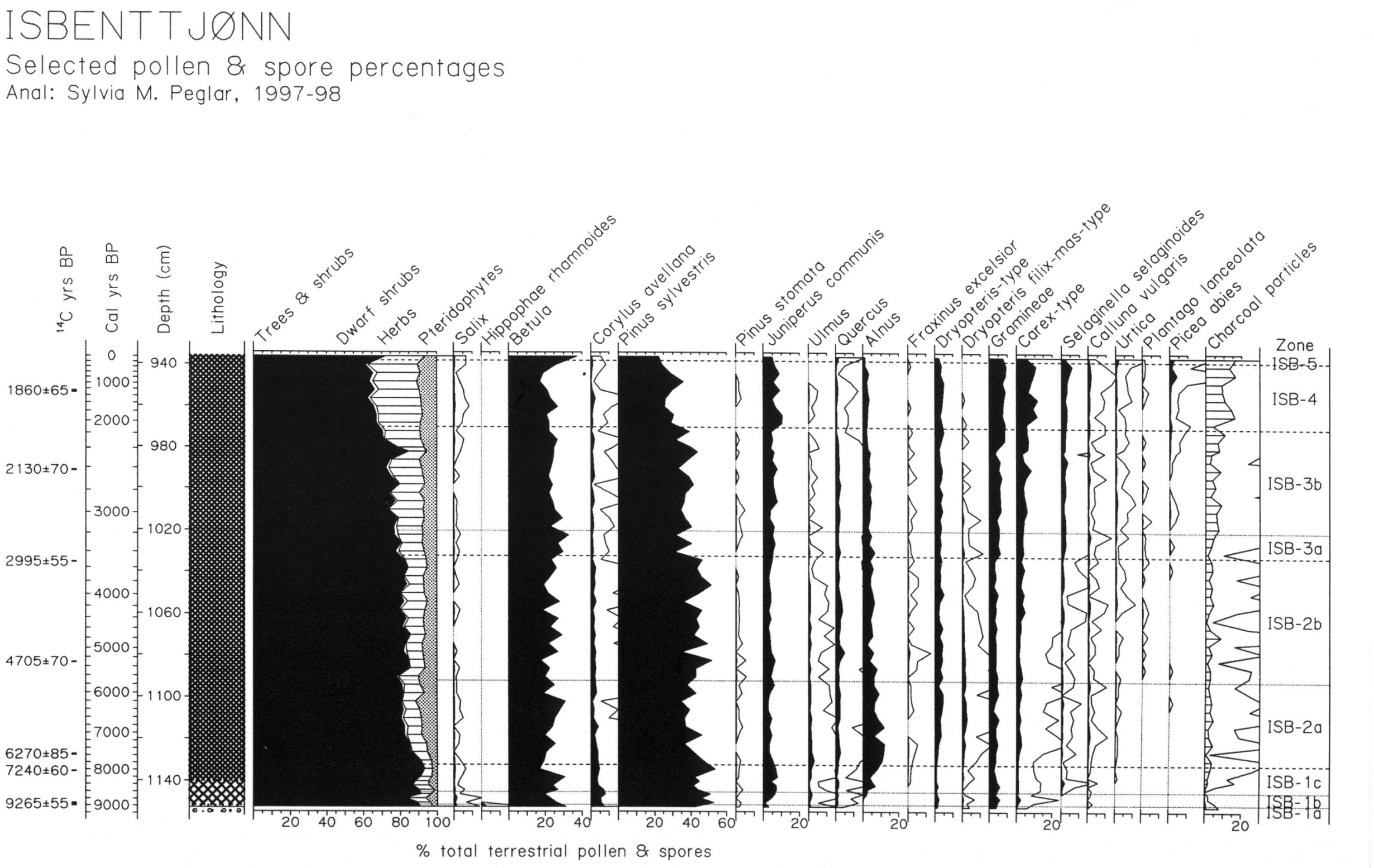
Summary pollen diagram from Øygardstjønn in the middle-boreal zone



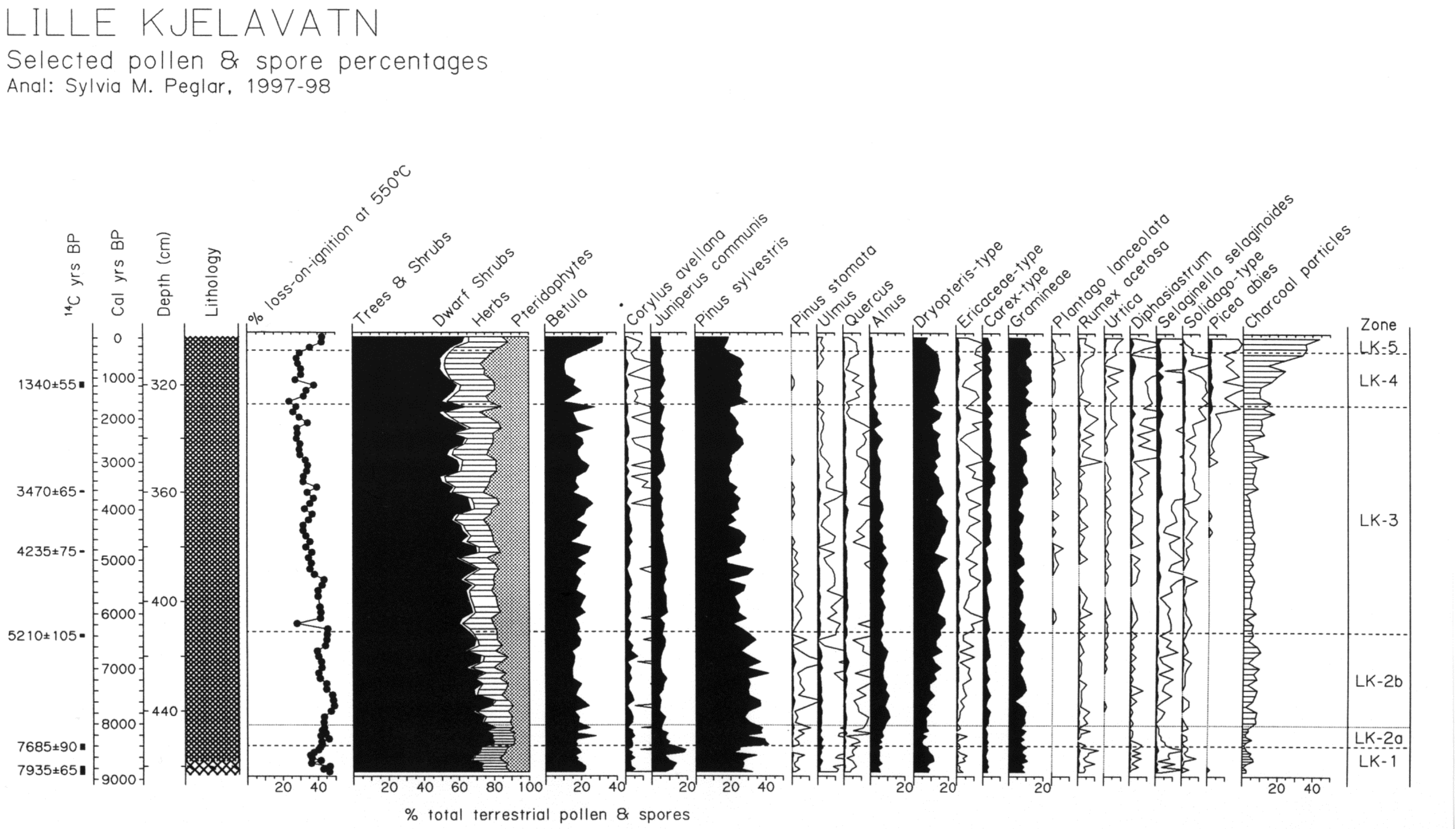
Summary pollen diagram from Lisletjønn in the middle-boreal zone



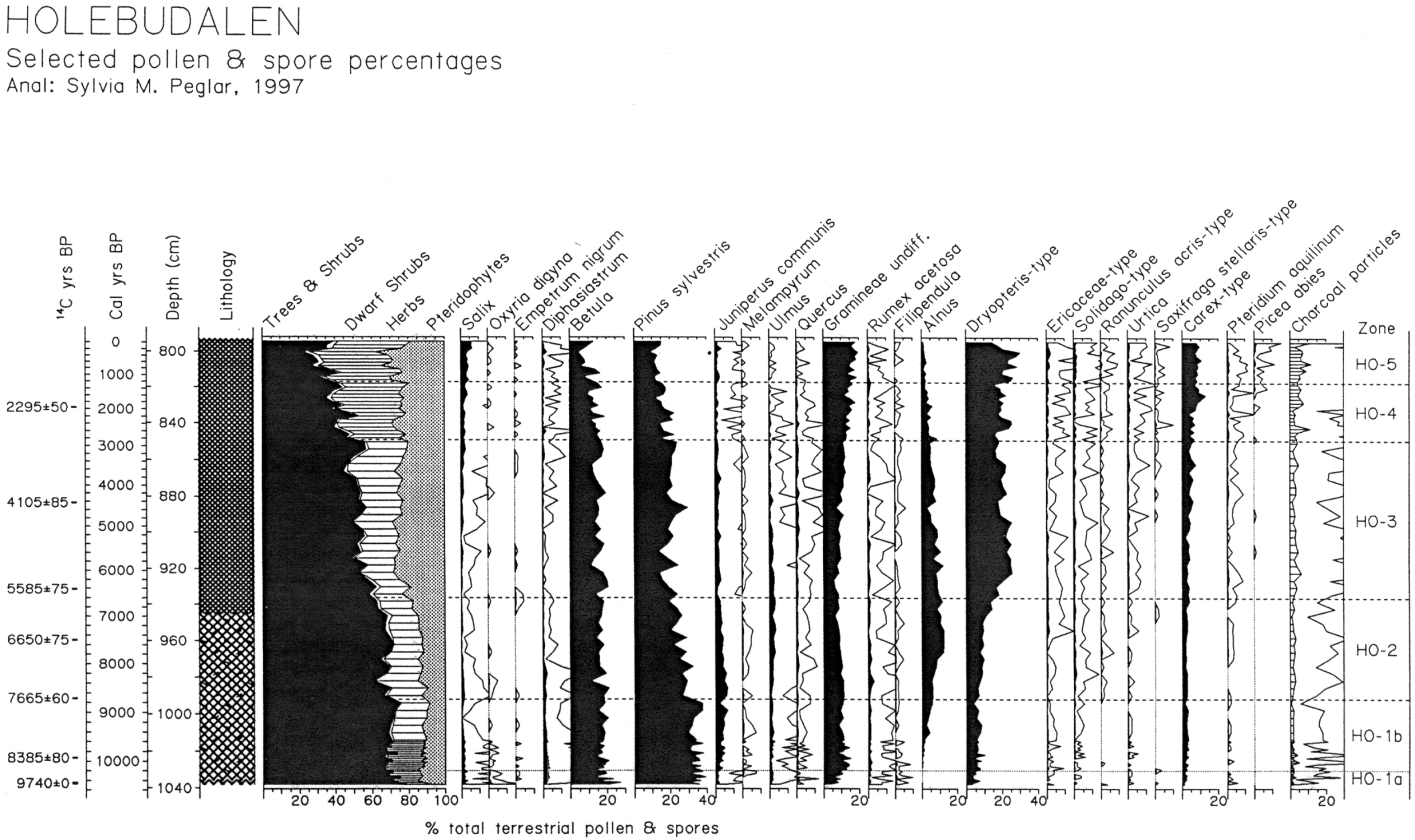
Summary pollen diagram from Flotatjønn in the northern-boreal zone



Summary pollen diagram from Isbenttjønn in the northern-boreal zone



Summary pollen diagram from Lille Kjelavatn in the sub-alpine zone



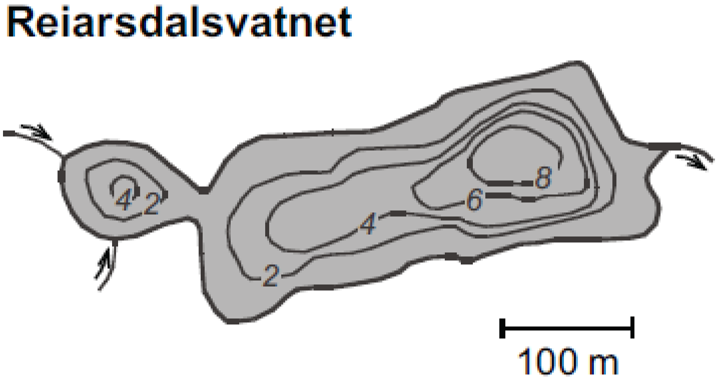
Summary pollen diagram from Holebudalen in the low-alpine zone

Chironomid palaeoecology at Reiarsdalsvatnet

(known as Histøl in Heiri et al. (2003) and Heiri (2004)

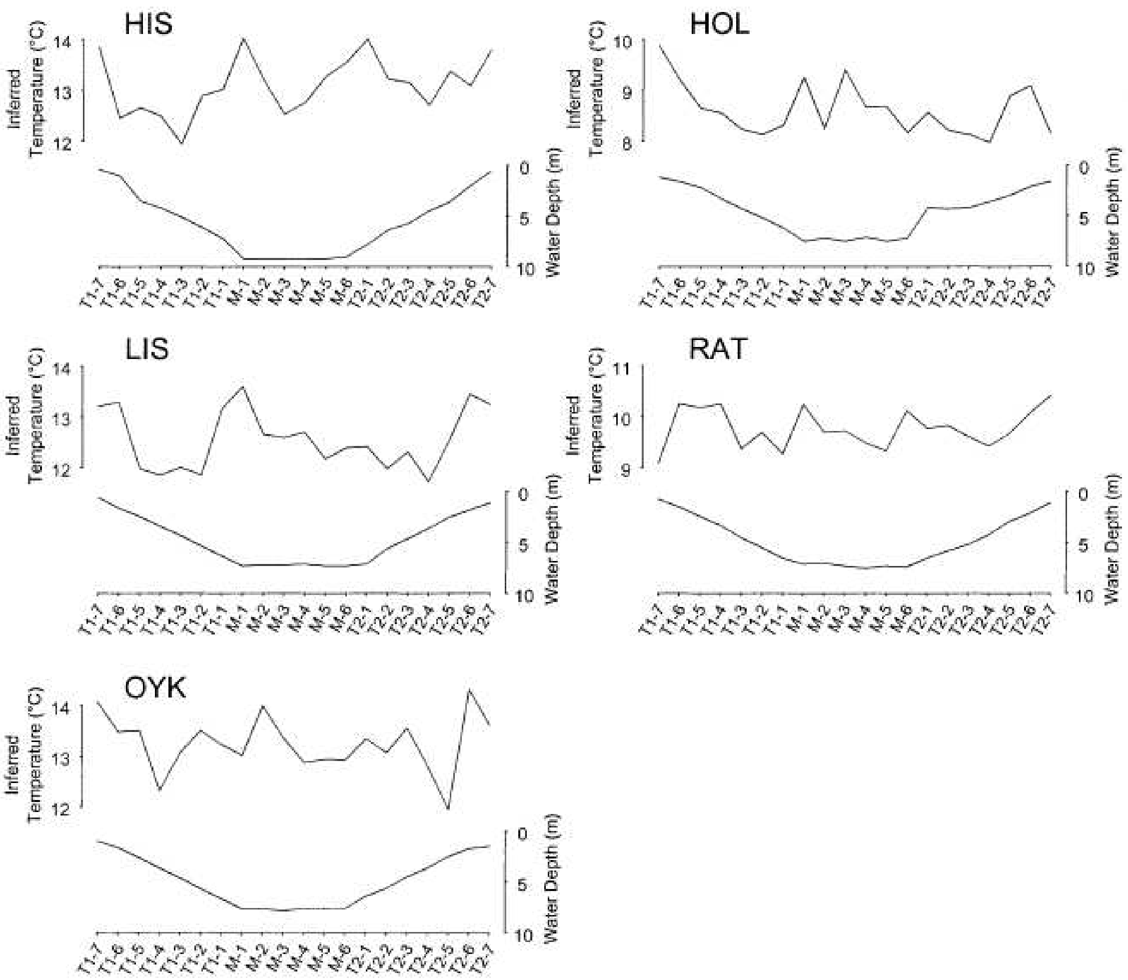
– John Birks, Britta Lüder, and Oliver Heiri

Reiarsdalsvatnet (245 m) is a small lake (ca. 5 ha) with a maximum water depth of 9.2 m. It has a pH of about 5.5 and lies at the transition between the boreo-nemoral and the southern-boreal zones. The south-facing slope is covered with mixed deciduous forest including *Quercus robur, Tilia cordata, Ulmus glabra*, and *Corylus avellana*, whereas the other slopes are covered with mixed coniferous–deciduous forest.

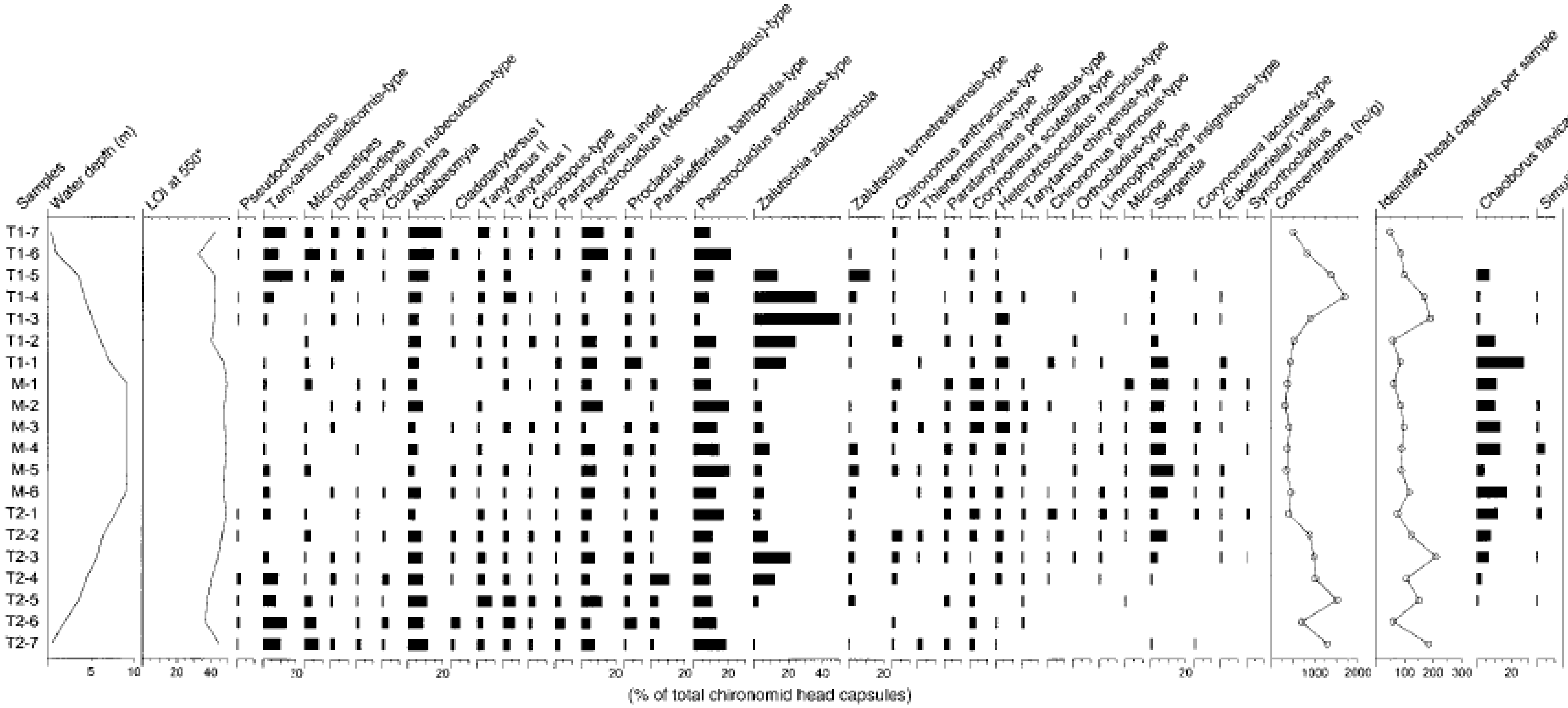


Bathymetric map of Reiarsdalsvatnet. Modified from Heiri (2004). (Lüder 2007)

Using a sampling design of transects from shallow to deep water and several samples in the deep area, Heiri et al. (2003) and Heiri (2004) show that there is relatively little within-lake variation in modern chironomid assemblages away from the very shallow areas. These results are replicated at four other lakes, including Holebudalen and Lisletjønn in Setesdal. This study has been extended by Marianne Presthus Heggen, Oliver Heiri, Hilary Birks, John-Arvid Grytnes, and John Birks to include oribatid mites, plant macrofossils, and Monte Carlo simulations. The results of this work are in press in Journal of Paleolimnology.

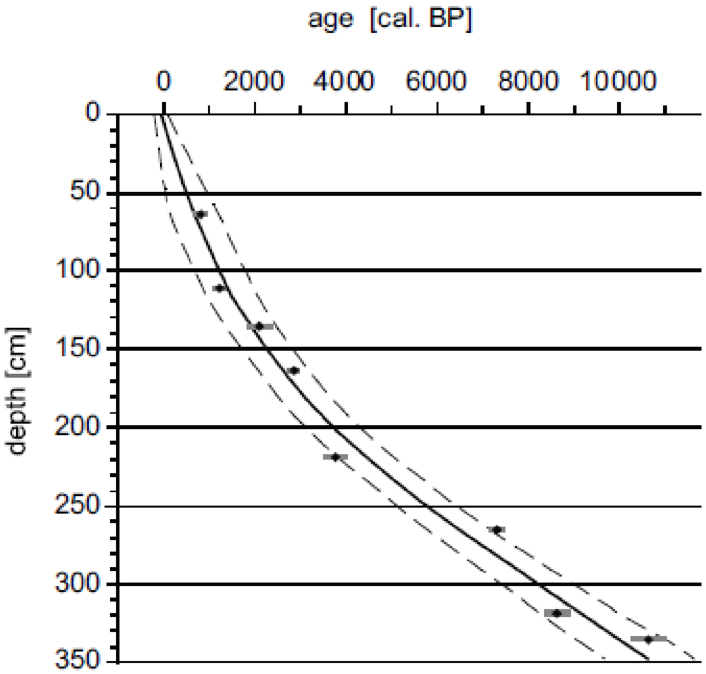


Chironomid-inferred mean July air temperatures and water depth plotted for the 20 samples from each study lake. M refers to the samples taken from the deepest part of the lakes whereas T1 and T2 refer to the two sampling transects. (Heiri et al. 2003)

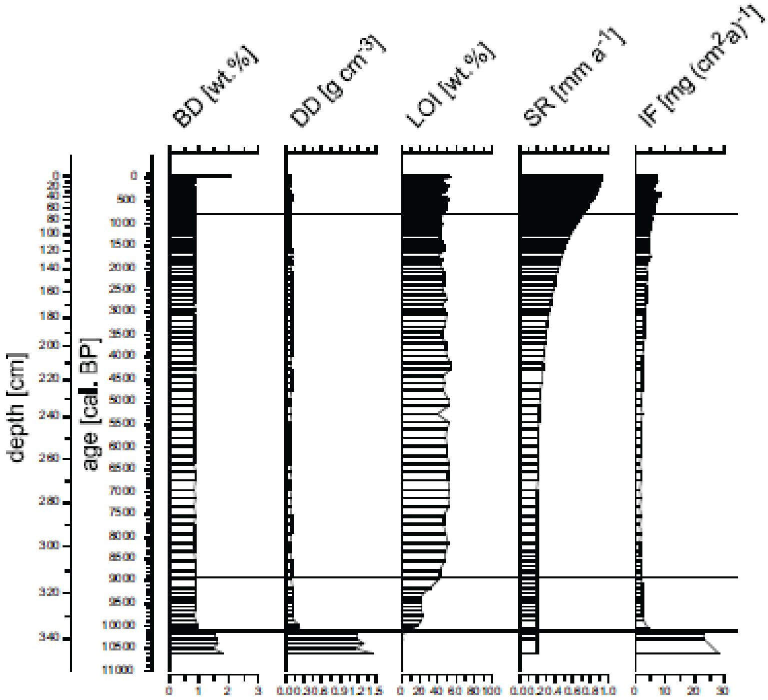


Subfossil chironomid assemblages in the surface sediments of Reiarsdalvatnet (in percentages except where otherwise indicated). M refers to samples taken from the deepest part of the lake basin, and T1 and T2 to the two deep-water transects, respectively. With the exception of *Symorhocladius* and *Orthocladius*-type, only taxa with more than five occurrences and at least 2% maximum abundance are shown. (Heiri 2004)

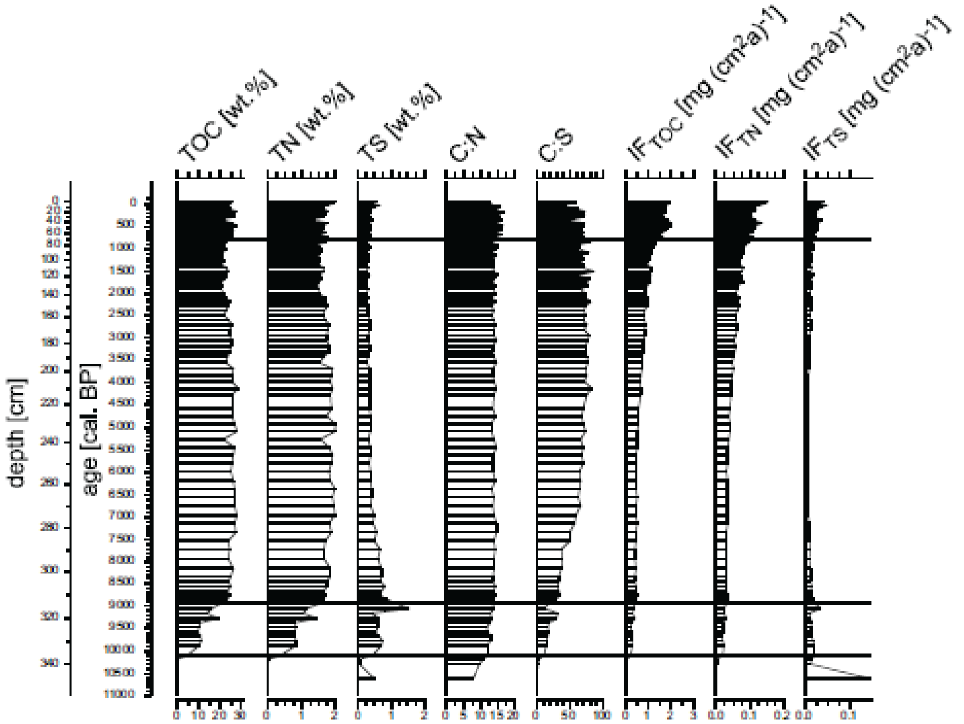
As part of her University of Bremen PhD thesis, Britta Lüder made detailed chironomid stratigraphies from Reiarsdalsvatnet and Isbenttjønn that we will visit tomorrow. Britta used the same cores as were used for pollen analysis. Both sites were chosen for chironomid studies because the catchments of both sites remained forested throughout the Holocene, in contrast to Holebudalen in the low-alpine zone today whose chironomid stratigraphy has been studied by Steve Brooks.



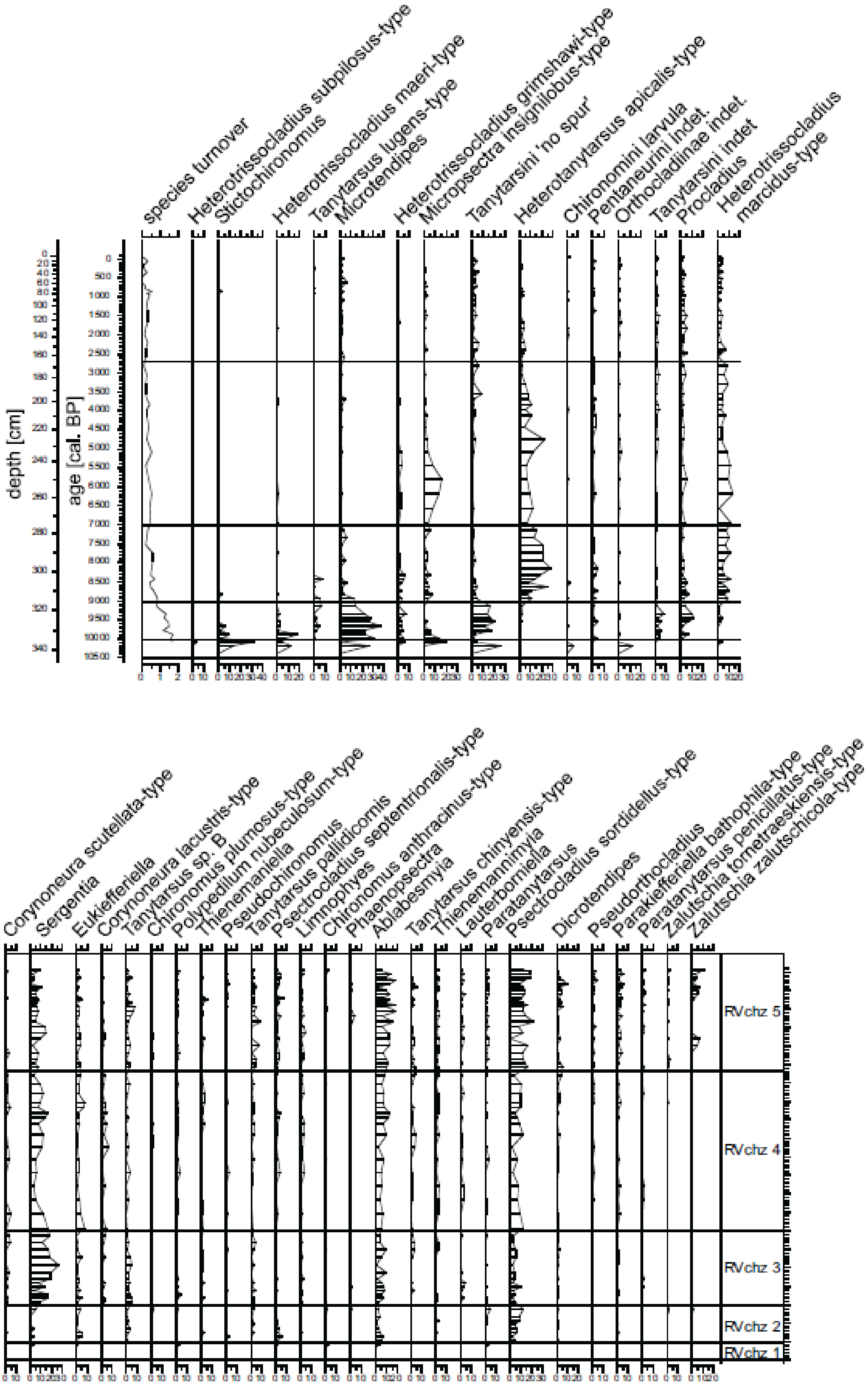
Age-depth model for the Reiarsdalsvatnet profile including 95% confidence intervals (dashed lines), and the calibrated radiocarbon dates (diamonds) with error bars (grey: 95% confidence intervals). (Lüder 2007)



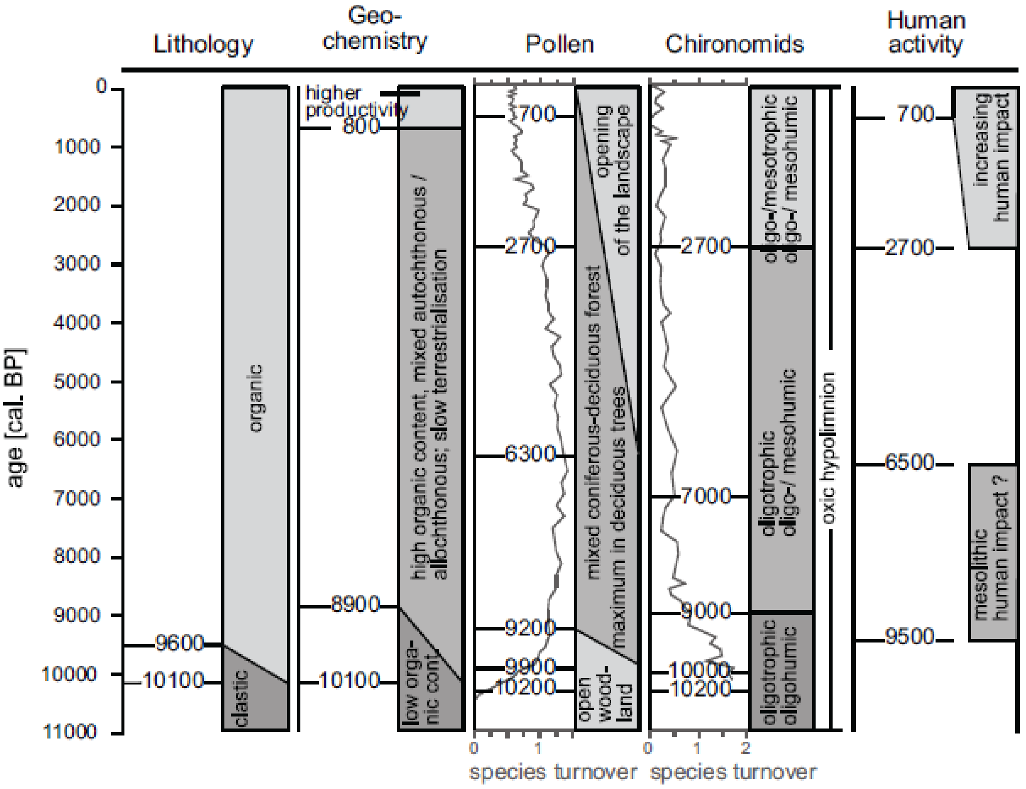
Bulk density (BD), dry density (DD), loss-on-ignition (LOI), sedimentation rates (SR), and total influx (IF) for Reiarsdalsvatnet. Sedimentation zones are indicated by solid lines. (Lüder 2007)



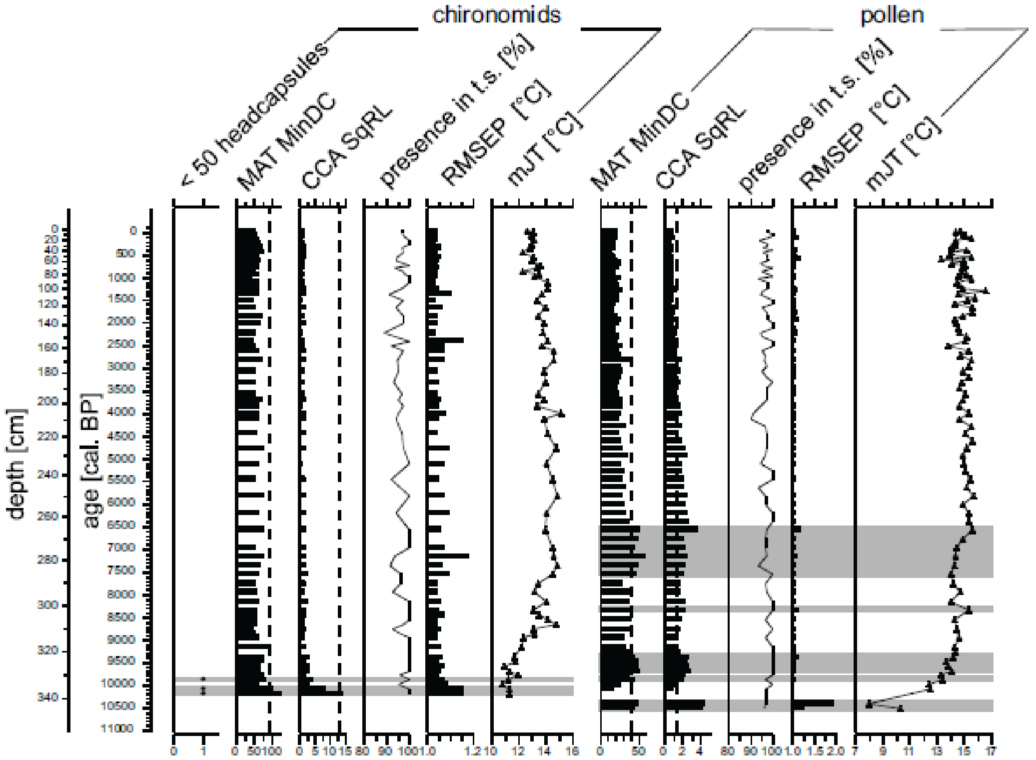
Total organic carbon (TOC), nitrogen (TN), and sulphur (TS), C:N and C:S ratios, and specific influx rates for TOC (IF_{TOC}), TN (IF_{TN}), and TS (IF_{TS}) for Reiarsdalsvatnet. Sediment zones are indicated by solid lines. (Lüder 2007)



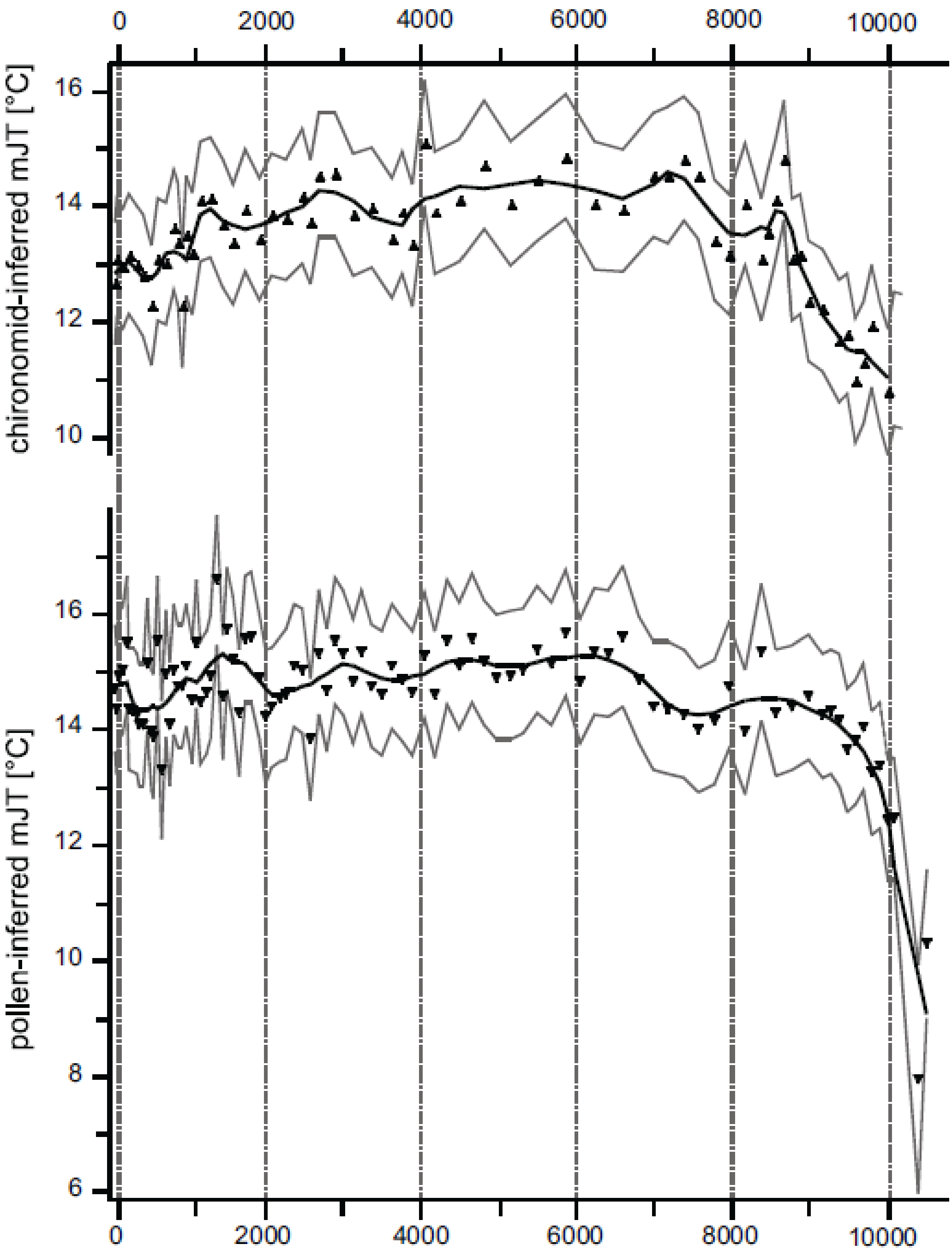
Chironomid percentage diagram of selected taxa (%) sorted by their weighted average with depth, species turnover (DCA axis 1 sample scores (SD)), and local chironomid assemblage zones (RVchz) for Reiarsdalavatnet. (Lüder 2007)



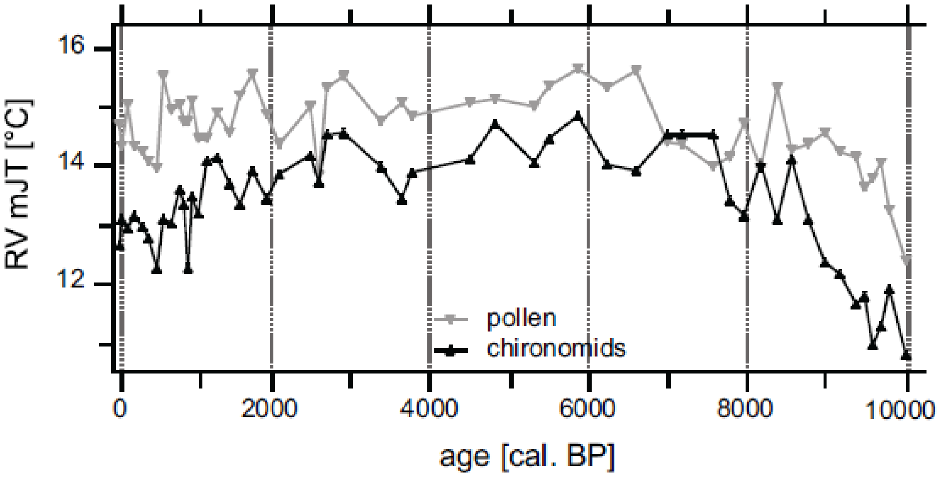
Summary of the ecological development of Reiarsdalsvatnet, reconstructed from the lithological description, geochemical, pollen, and chironomid analyses. Species turnover denotes sample scores of the first DCA axis (SD). (Lüder 2007)



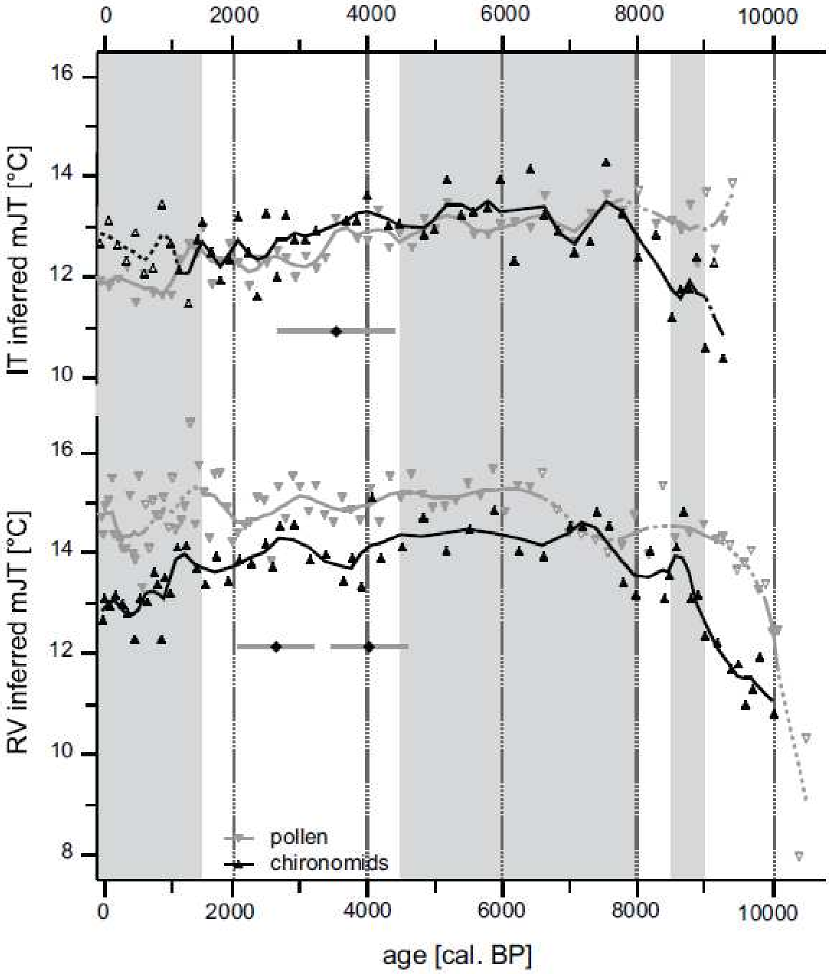
Summary of the sample specific numerical evaluation criteria values for Reiarsdalsvatnet. Areas in grey mark samples omitted from the records of chironomid- and pollen-based temperature reconstructions. MAT MinDC: minimal chi-square distance to the closest modern analogue; CCA SqRl: squared residual distance to the first CCA axis; and 'presence in t.s.': representation of subfossil taxa in the modern training-set. Dashed lines indicate significance level. (Lüder 2007)



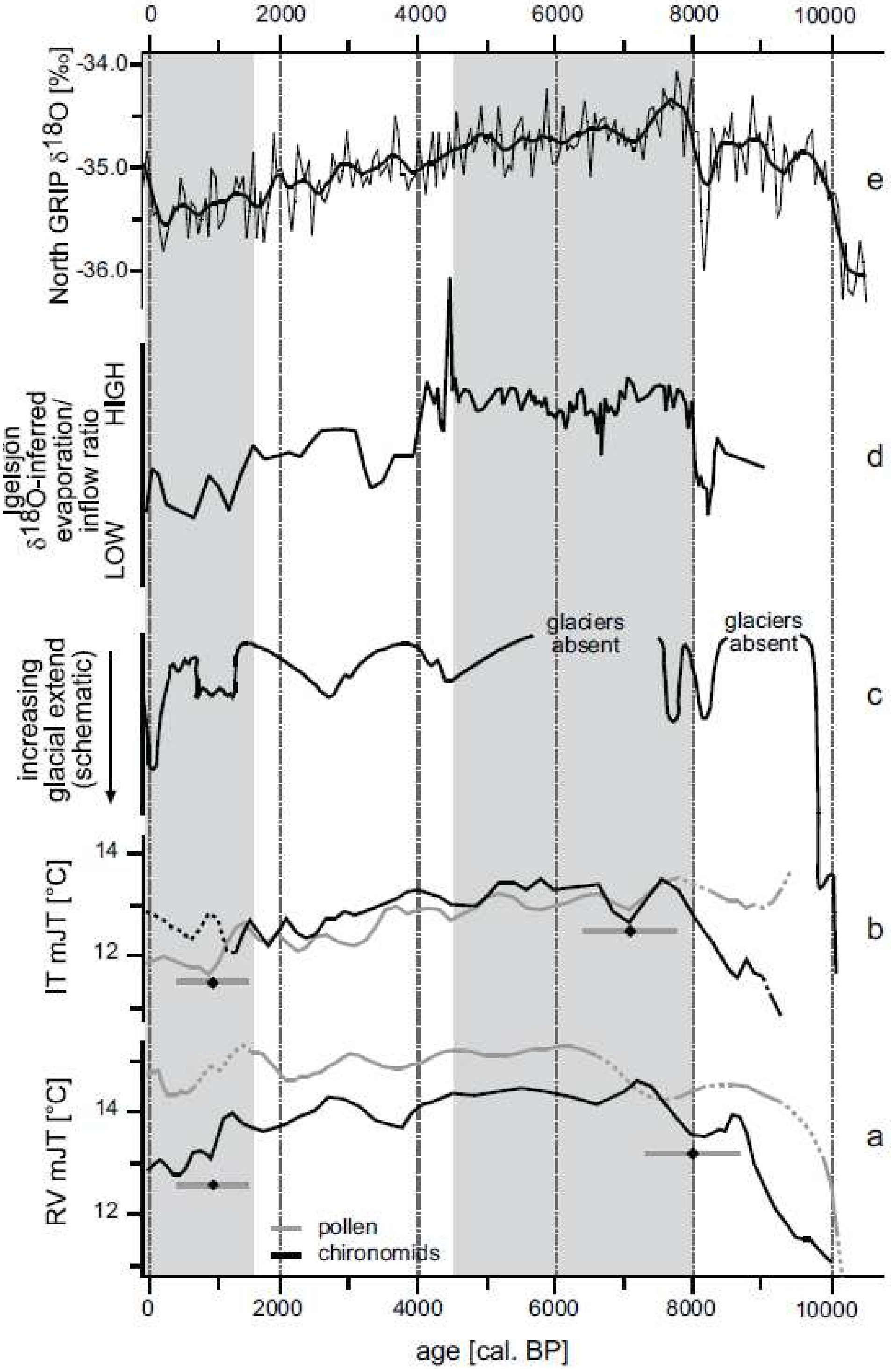
Chironomid- and pollen-inferred mean July temperatures (mJT) for Reiarsdalsvatnet. The reconstructed temperatures for each sample are shown as triangles, the sample-specific error estimates as thin grey lines. Century-scale temperature trends are highlighted by a LOWESS smoother (Bold line). (Lüder 2007)



Chironomid- and pollen-inferred mean July temperatures for selected samples of Reiarsdalsvatnet. To enable a point-wise comparison of the temperatures, only samples with available chironomid- and pollen-inferred temperatures are shown. (Lüder 2007)



Chironomid- and pollen-inferred mean July temperatures (mJT) for Reiarsdalsvatnet (RV) and Isbenttjønn (IT). The reconstructed temperatures are shown as symbols, the century-scales temperature trends are highlighted by a LOWESS smoother (bold line). Phases where the reconstructed temperatures are of lower reliability are marked by dashed LOWESS smoothers and open symbols. Uncertainties of the age-depth model are shown for three samples with the modelled age indicated by black diamonds and the 95% confidence interval by grey bars. (Lüder 2007)



Chironomid- and pollen-inferred mean July temperatures (mJT) for a) Reiarsdalsvatnet (RV) and b) Isbenttjønn (IT), (LOWESS smoothers, dashed parts indicate lower reliability), together with c) a record of Holocene glacier variations at Bjørnbreen, central Jotunheimen, southern Norway (Matthews et al. 2005), d) palaeohydrological changes recorded in the stable isotopes ($\delta^{18}O$ on bulk carbonate) at Igelsjön, southern Sweden (Hammarlund et al, 2003), and e) former ice-surface air temperatures inferred from the $\delta^{18}O$ record in incremental ice layers from North GRIP, central Greenland (Johnsen et al. 2001). Uncertainties of the age-depth models of Reiarsdalsvatnet and Isbenttjønn are shown for four samples with the modelled age indicated by black diamonds and the 95% confidence interval by grey bars. (Lüder 2007)

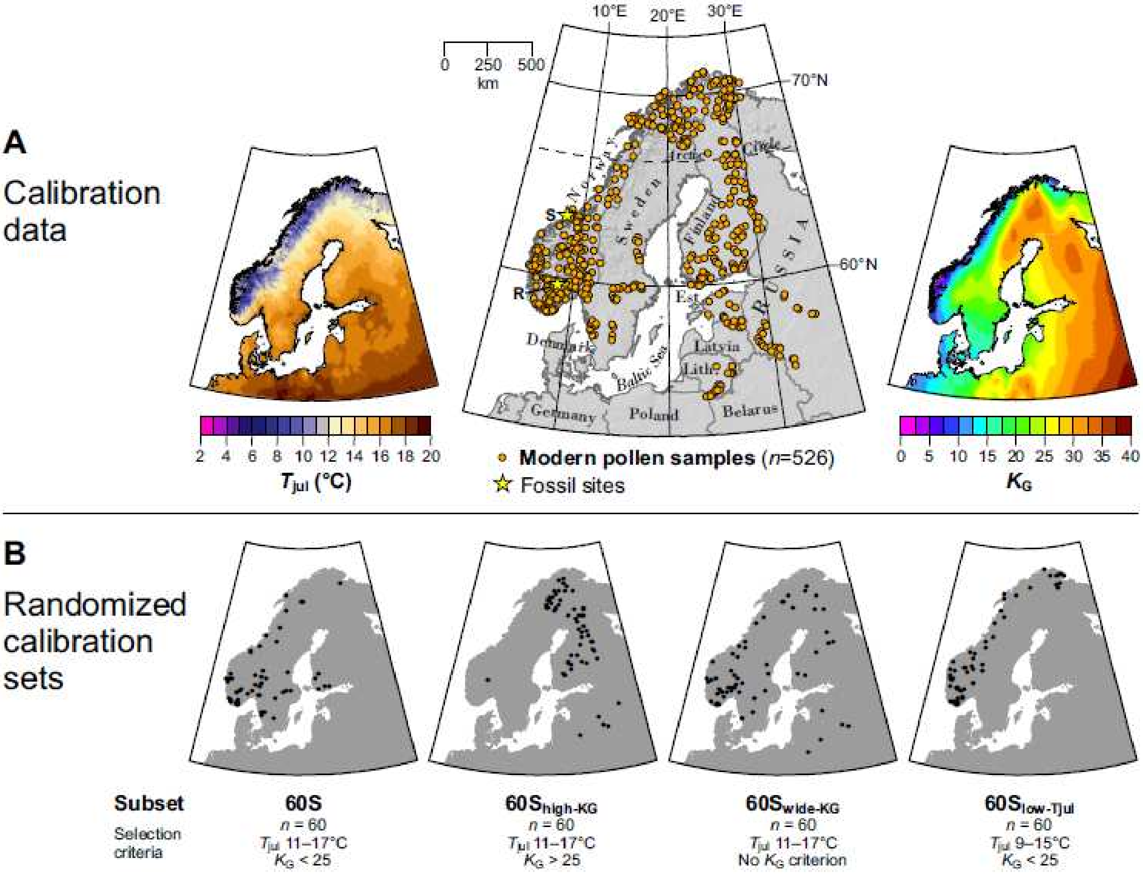
Numerical experiments on choice of calibration data-set in climate reconstructions – Sakari Salonen, John Birks, and Heikki Seppä

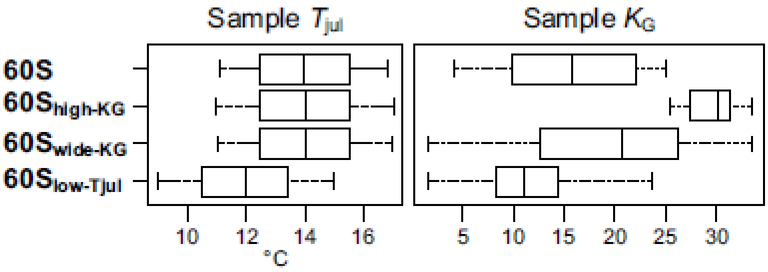
What effect does the choice of a modern-environment calibration-set have on the resulting environmental reconstruction?

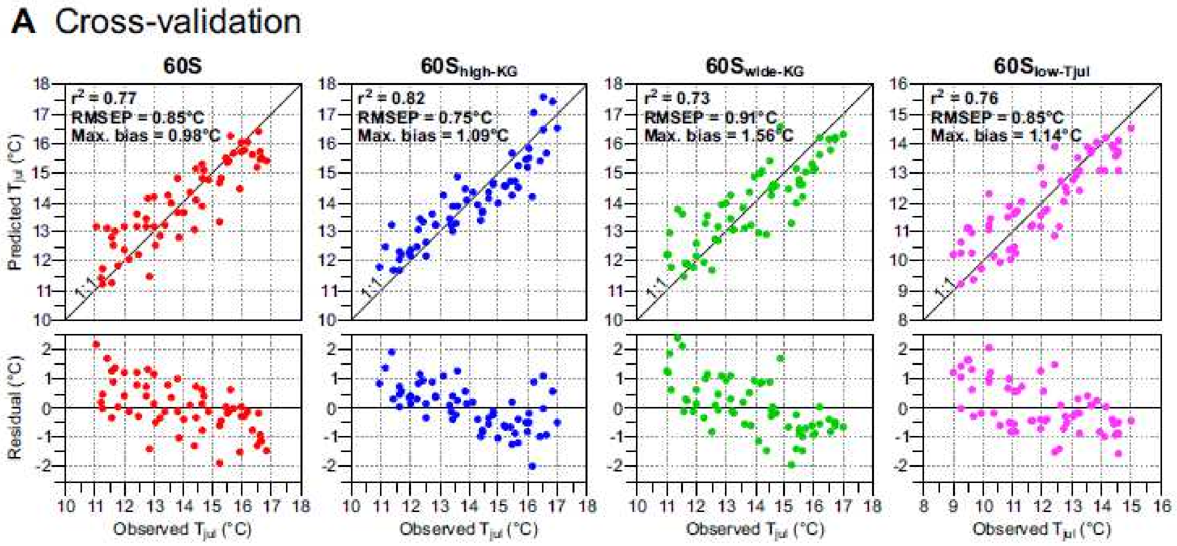
Sakari Salonen et al. (manuscript submitted for publication) have used a modern pollen–climate calibration-set of 526 samples in Scandinavia and the Baltic Countries to reconstruct mean July temperature at Reiarsdalsvatnet in Setesdal and Svartvatnet on the north-western edge of the Oslo-to-Trondheim transect.

Four calibration-sets were used.

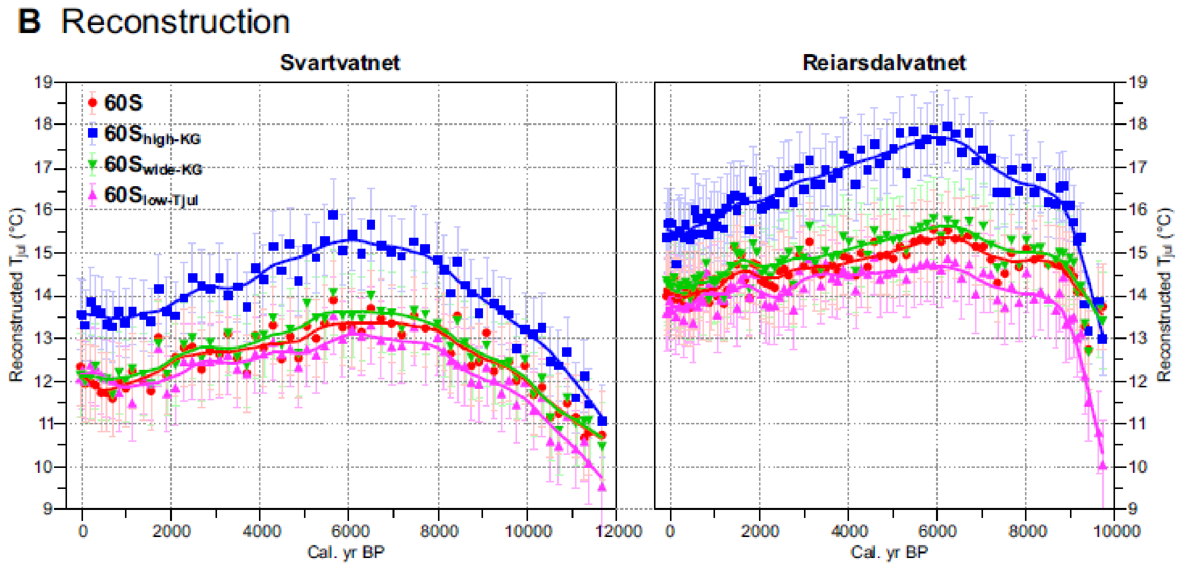
1. 60 sites nearest the two sites, T_{Jul} 11–17°C, Continentality index (Gorczynski) (CGI) <25, 60 S
2. 60 sites, T_{Jul} 11–17°C, CGI >25, 60 $S_{high\text{-}KG}$
3. 60 sites, T_{Jul} 11–17°C, CGI no restriction, 60 $S_{wide\text{-}KG}$
4. 60 sites, T_{Jul} 9–15°C, CGI <25



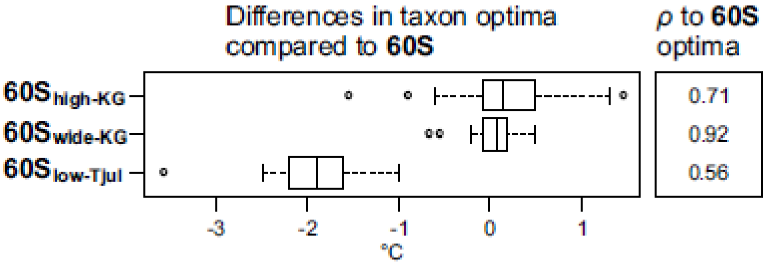




Cross-validation WAPLS for T_{jul}



Reconstructs higher Mean July temperatures when using the $60S_{high-KG}$ training-set, i.e. high continentality.

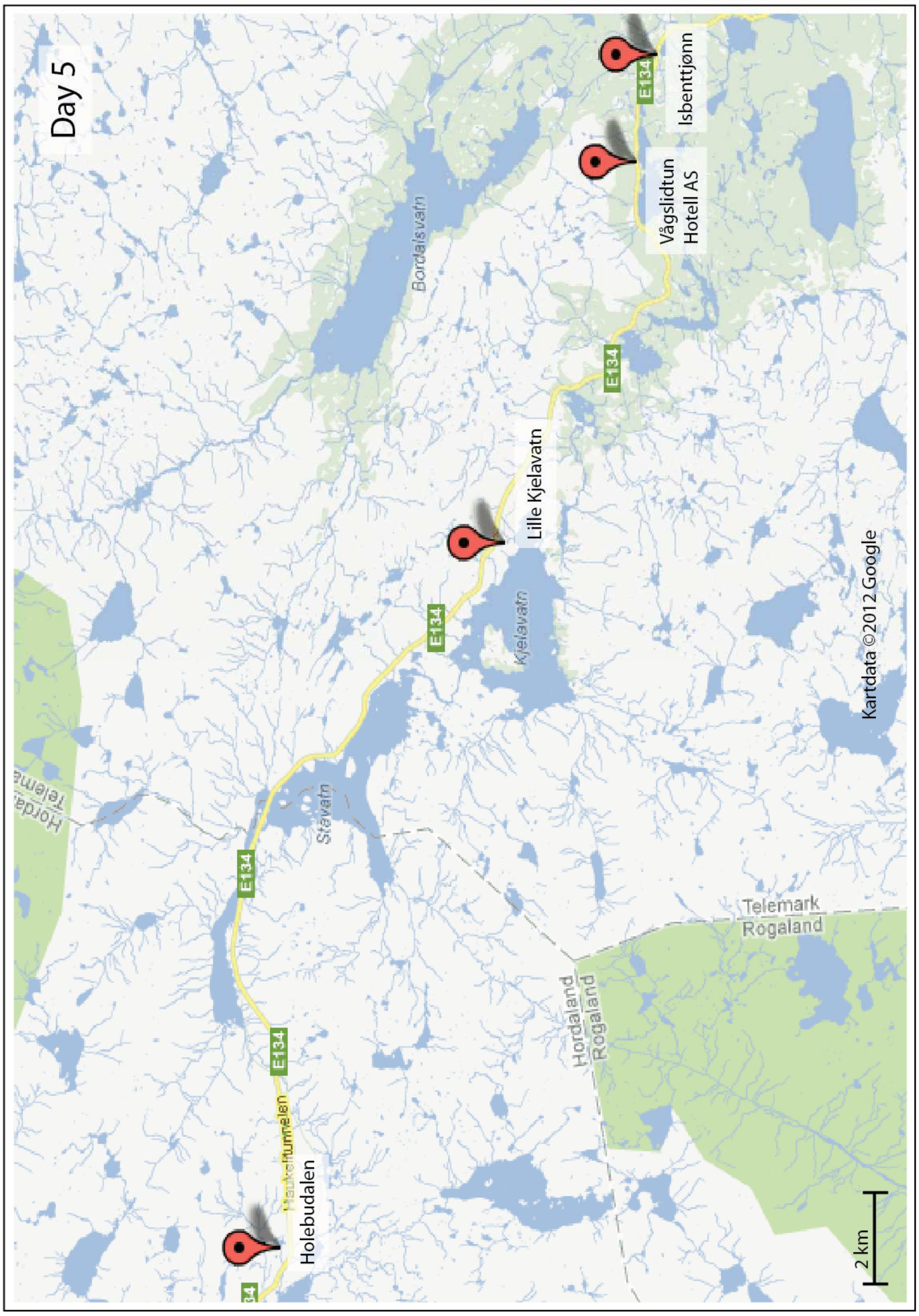


Higher WA optima in high GCI set. (Salonen et al. 2012)

DAY 5

SETESDAL (north)

Wednesday 12 September 2012


Day 5
Isbenttjønn
E134
Vågslidtun Hotell AS
Bordalsvatn
E134
Lille Kjelavatn
E134
Kjelavatn
Kartdata ©2012 Google
Hordaland
Telemark
Stavatn
E134
Telemark
Rogaland
Hordaland
Rogaland
E134
Haukelitunnelen
Holebudalen
2 km

Introduction

Today we are at the northern end of Setesdal in the northern-boreal zone. We will visit Isbenttjønn and the sub-alpine Lille Kjelavatn and, weather permitting, the low-alpine Holebudalen.

We will discuss

1. Chironomid palaeoecological studies at Isbenttjønn
2. Modern pollen-vegetation diversity relationships in Setesdal
3. Biotic turnover in the Holocene in Setesdal
4. Pollen and plant macrofossil studies in Setesdal
5. Tree migration patterns in Setesdal
6. Man in the mountains
7. Holocene history of the alpine zone of south Norwegian glaciers

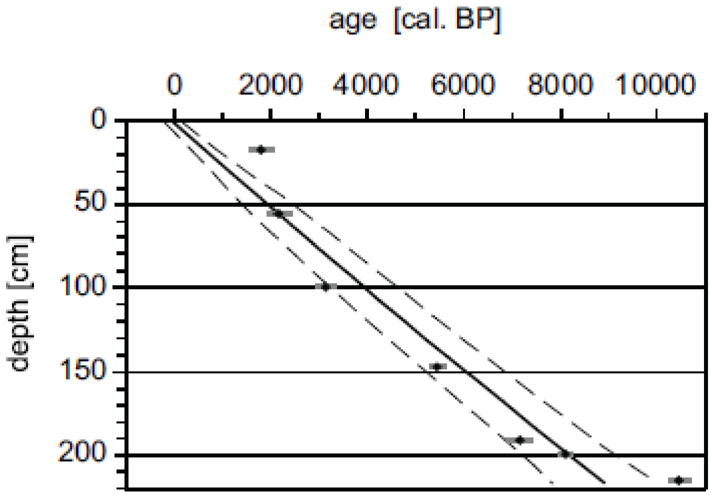
Coring sites in northern Setesdal:

	
Isbenttjønn, 787 m, northern-boreal, 9.4 m water depth	Lille Kjelavatn, 1000 m, sub-alpine, 3.5 m water depth
	
Holebudalen, 1144 m, low-alpine, 8.2 m water depth	

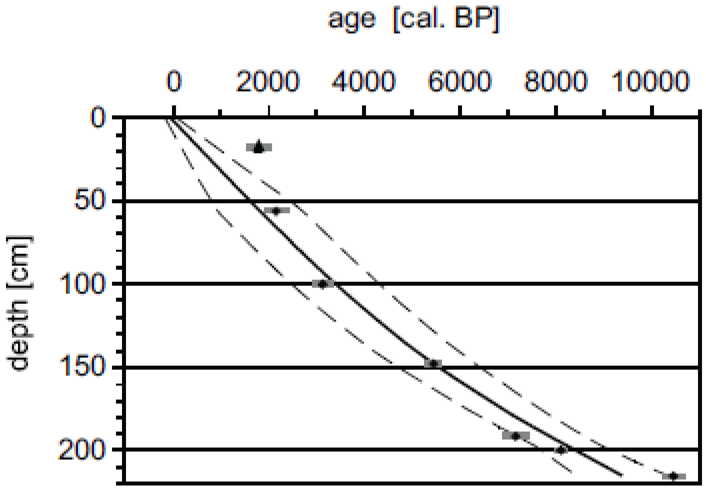
Chironomid palaeoecology at Isbenttjønn and Holebudalen – John Birks, Britta Lüder, Steve Brooks

Isbentjønn 787 m asl, 5 ha, 9.4 m deep, pH 6.4

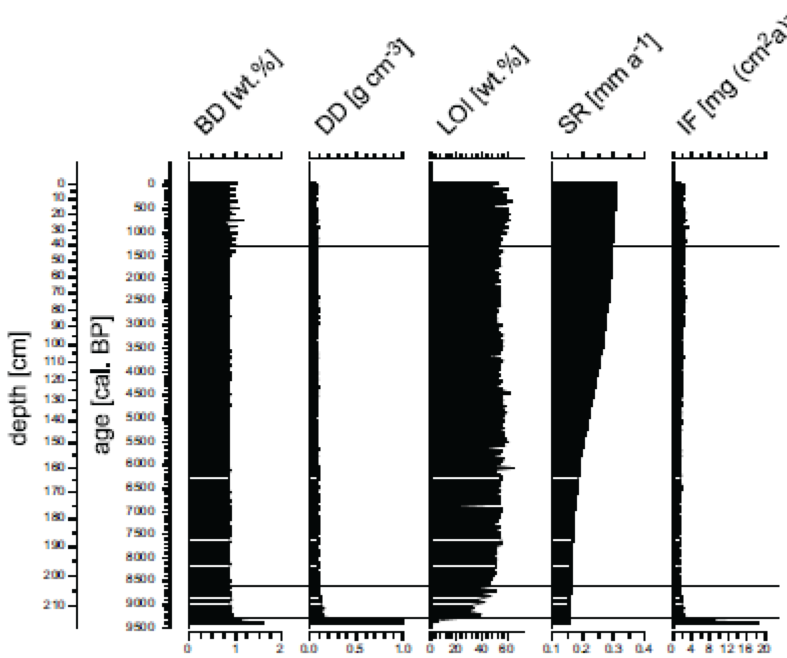
The site is in the upper part of the northern-boreal zone. There are several old huts located on the western shore. They were used as alpine pasture huts ('støl') during the last centuries. In former times, the whole area around the lake was used for pasture by cows and goats whereas sheep pastures were located at higher altitudes. Between 1920 and 1930, the 'støler' were extended to small farms. Pasturing ended in the 1950s and since then the huts have been used as holiday accommodation.



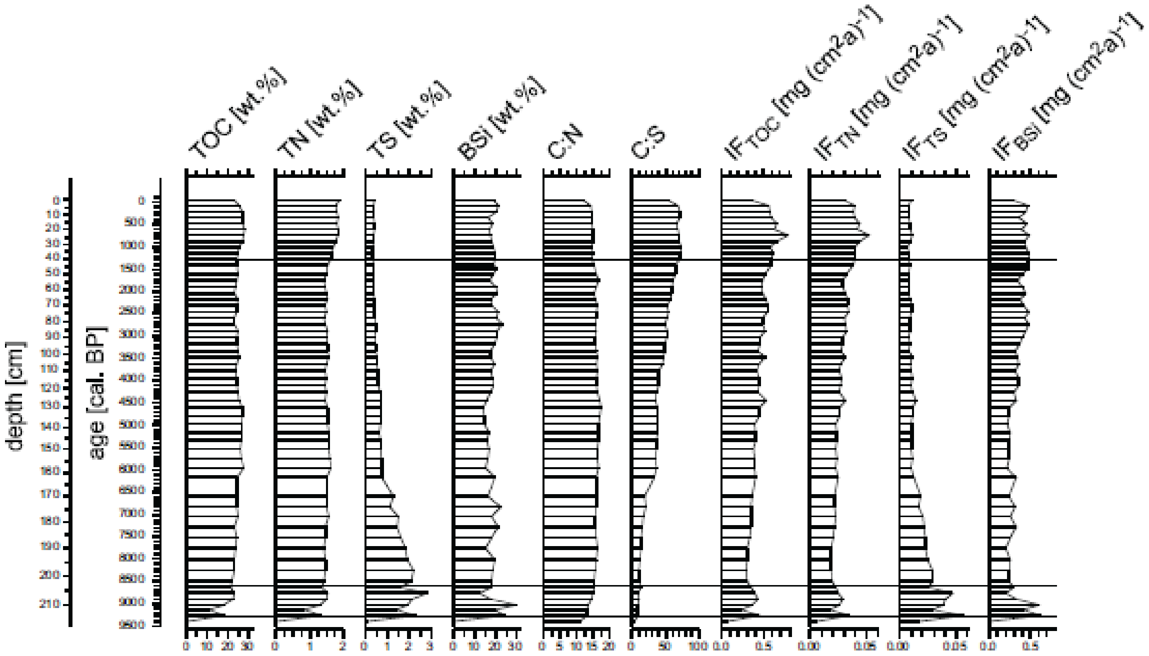
Age-depth model for the Isbenttjønn profile based on seven radiocarbon dates including 95% confidence intervals (dashed lines) and the calibrated radiocarbon dates (diamonds) with error bars (grey; 95% confidence intervals). (Lüder 2007)



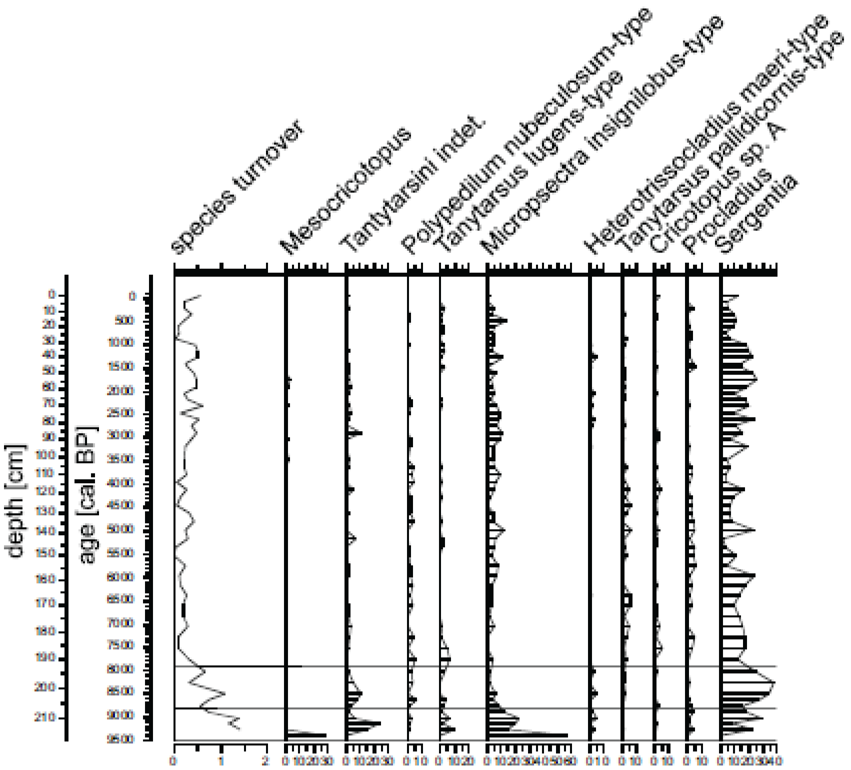
Age-depth model for the Isbenttjønn profile based on six radiocarbon dates (excluding sample I954, triangle) together with 95% confidence intervals (dashed lines) and the calibrated radiocarbon dates (diamonds) with error bars (grey; 95% confidence intervals). (Lüder 2007)



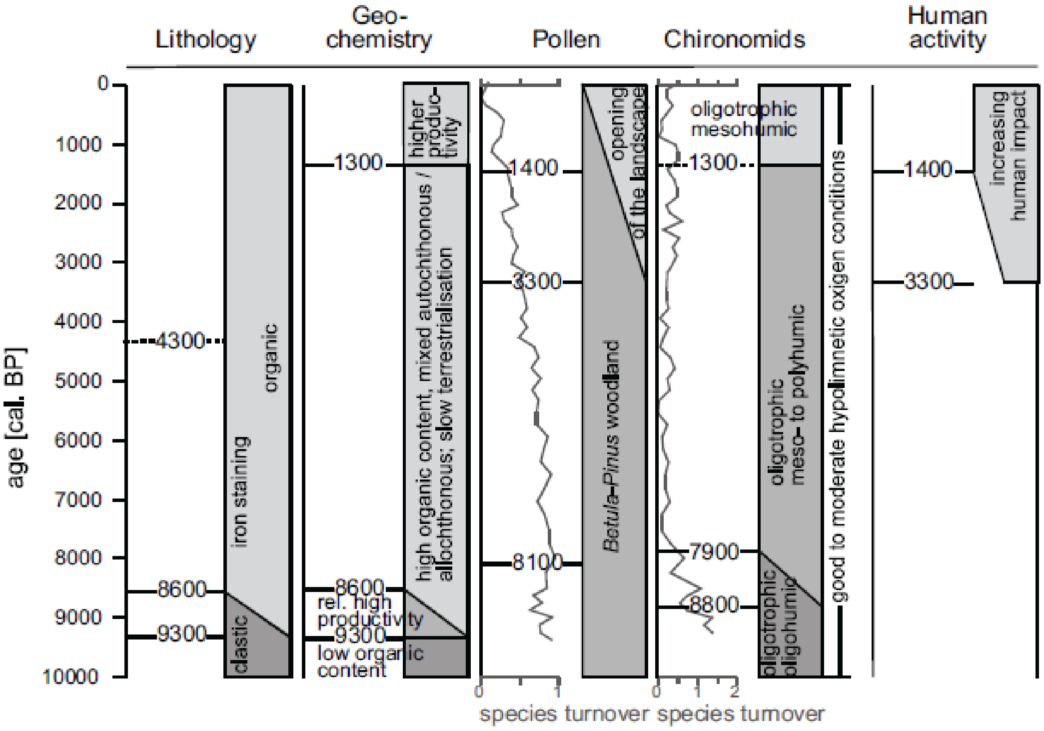
Bulk density (BD), dry density (DD), loss-on-ignition (LOI), sedimentation rates (SR), and sediment influx (IF) for Isbenttjønn. Sedimentation rates are indicated by solid lines. (Lüder 2007)



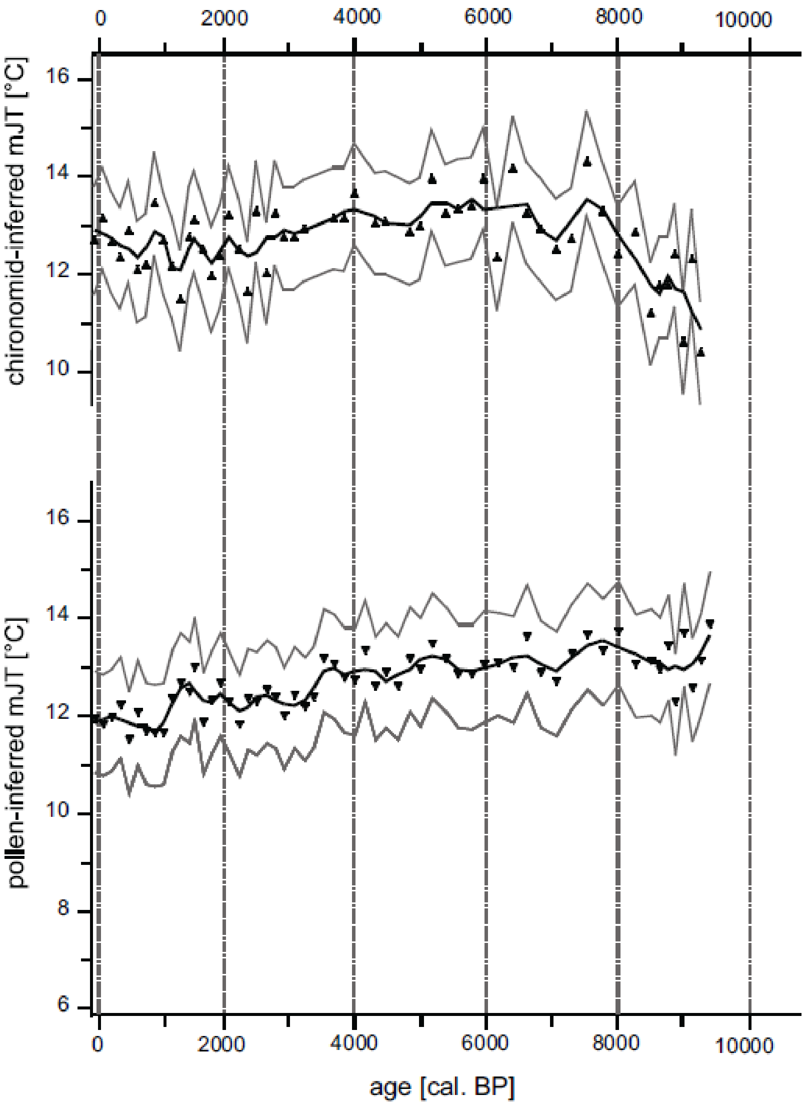
Total organic carbon (TOC), nitrogen (TN), and sulphur (TS), biogenic silica (BSi), C:N and C:S ratios, and specific influx rates for TOC (IF_{TOC}), TN (IF_{TN}), TS (IF_{TS}), and BSi (IF_{BSi}) for Isbenttjønn. Sedimentation rates are indicated by solid lines. (Lüder 2007)



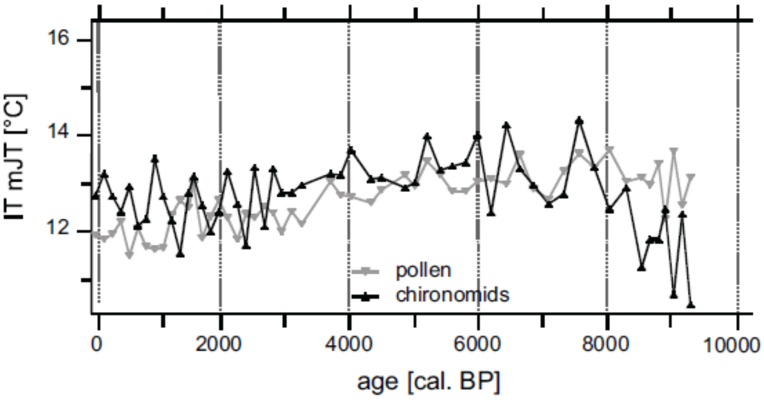
Chironomid percentage diagram of selection taxa (%) sorted by their weighted average with depth, species turnover (DCA axis 1 sample scores (SD)), and local chironomid assemblage zones (ITchz) for Isbenttjønn. (Lüder 2007)



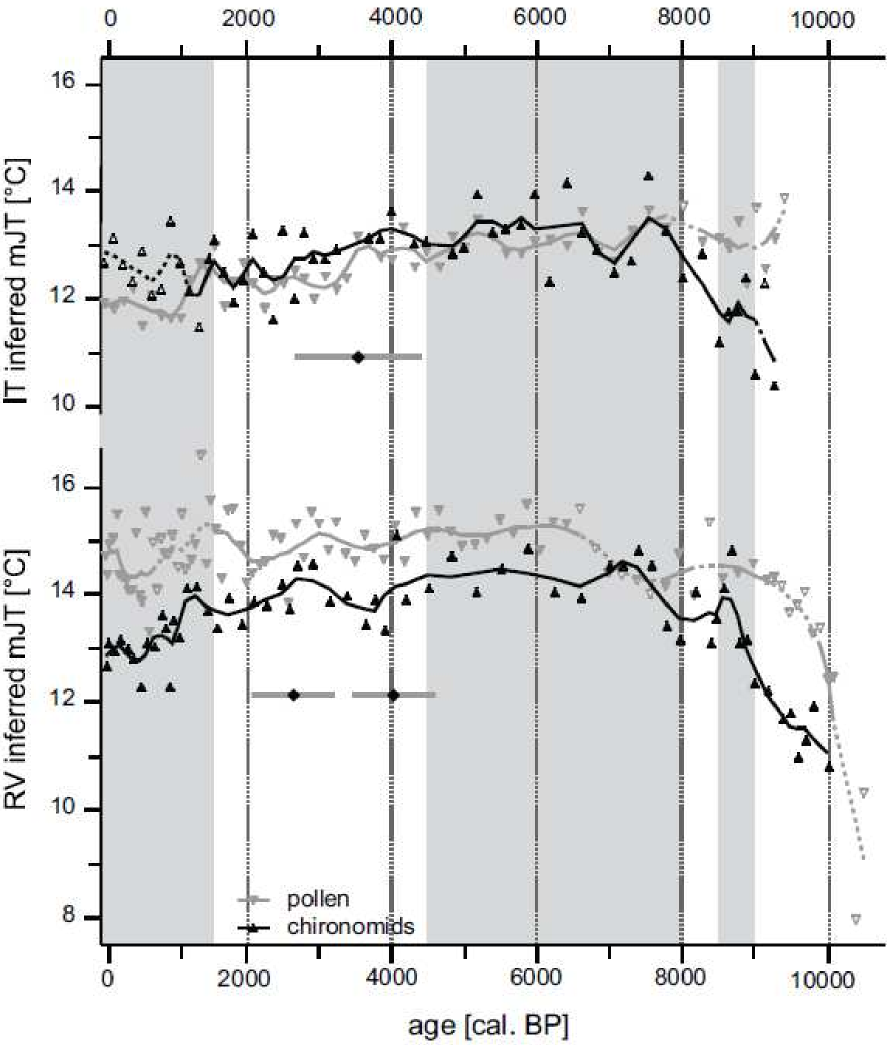
Summary of the ecological development of Isbenttjønn, reconstructed from the lithological description, geochemical, pollen, and chironomid analyses. Species turnover denote sample scores of the first DCA axis (SD). (Lüder 2007)



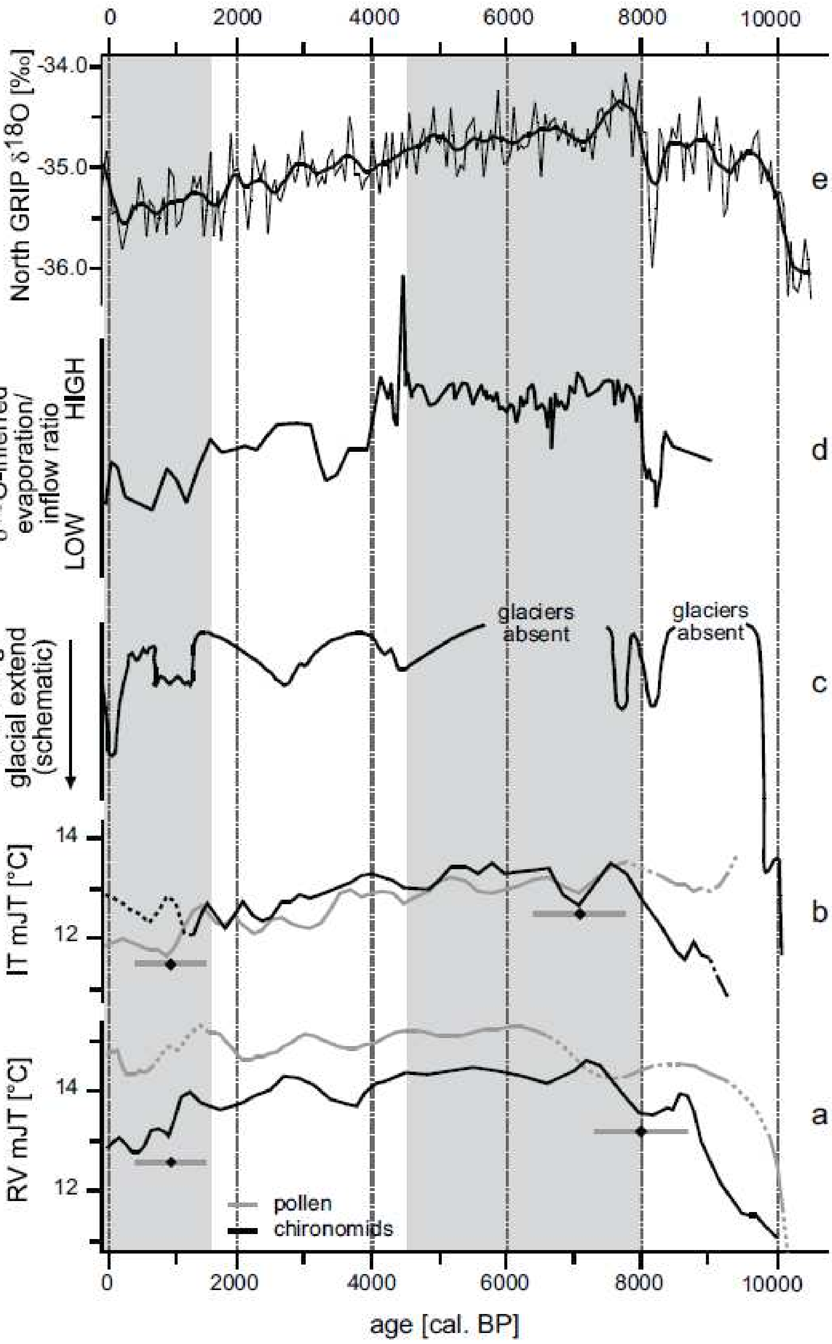
Chironomid- and pollen-inferred mean July temperatures (mJT) for Isbenttjønn. The reconstructed temperatures for each sample are shown as triangles, the sample-specific error estimates as thin grey lines. Century-scale temperature trends are highlighted by a LOWESS smoother (bold line). (Lüder 2007)



Chironomid- and pollen-inferred mean July temperatures for samples from Isbenttjønn. To enable a point-wise comparison of the temperatures, only samples with available chironomid- and pollen-inferred temperatures are shown. (Lüder 2007)



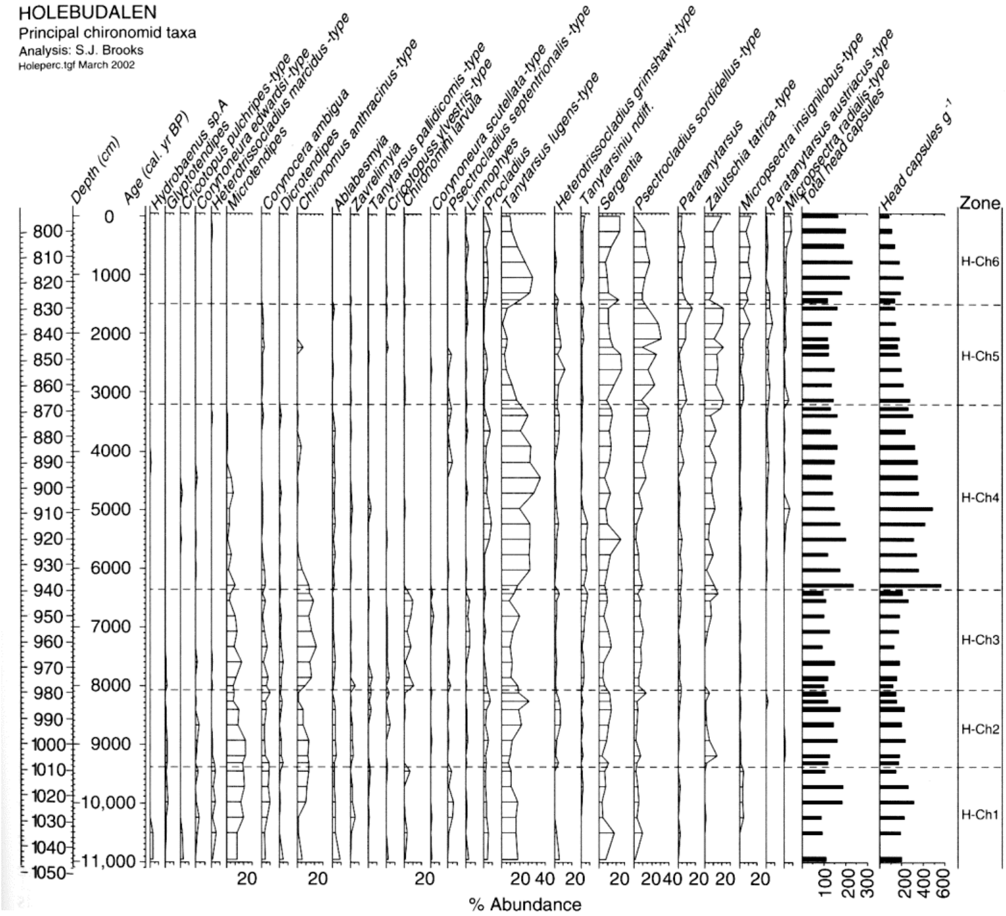
Chironomid- and pollen-inferred mean July temperatures (mJT) for Reiarsdalsvatnet (RV) and Isbenttjønn (IT). The reconstructed temperatures are shown as symbols, the century-scales temperature trends are highlighted by a LOWESS smoother (bold line). Phases where the reconstructed temperatures are of lower reliability are marked by dashed LOWESS smoothers and open symbols. Uncertainties of the age-depth model are shown for three samples with the modelled age indicated by black diamonds and the 95% confidence interval by grey bars. (Lüder 2007)



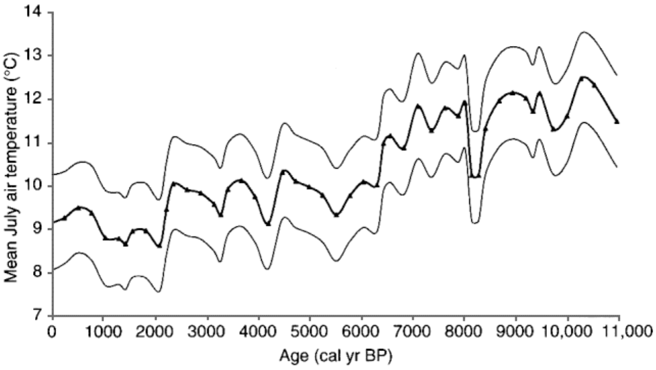
Chironomid- and pollen-inferred mean July temperatures (mJT) for a) Reiarsdalsvatnet (RV) and b) Isbenttjønn (IT), (LOWESS smoothers, dashed parts indicate lower reliability), together with c) a record of Holocene glacier variations at Bjørnbreen, central Jotunheimen, southern Norway (Matthews et al. 2005), d) palaeohydrological changes recorded in the stable isotopes ($\delta^{18}O$ on bulk carbonate) at Igelsjön, southern Sweden (Hammarlund et al, 2003), and e) former ice-surface air temperatures inferred from the $\delta^{18}O$ record in incremental ice layers from North GRIP, central Greenland (Johnsen et al. 2001). Uncertainties of the age-depth models of Reiarsdalsvatnet and Isbenttjønn are shown for four samples with the modelled age indicated by black diamonds and the 95% confidence interval by grey bars. (Lüder 2007)

Holebudalen 1144 m asl, 5 ha, 8.2 m deep, pH 5.2

The results from Isbenttjønn and those from Reiarsdal contrast with the chironomid-inferred temperatures from this low-alpine site at the northern end of the Setesdal transect (Brooks 2003).



Holocene chironomid stratigraphy from Holebudalen (Brooks 2003)



Holocene chironomid-inferred mean July air temperature reconstruction for Holebudalen. The upper and lower trend lines show sample-specific errors calculated by bootstrapping. (Brooks 2003)

There is a very prominent '8.2 cal k yr BP' event and a long-term decline in mean July temperatures from about 8000 cal yr BP to 2000 cal yr BP, broadly similar to the Northern Hemisphere summer insolation record for the last 8000 years. The chironomid temperatures seem too low when one considers the scattered occurrence of *Pinus* macrofossils (Eide et al. 2006) from 10,000 to 8000 cal yr BP and around 2500 cal yr BP which would suggest a mean July air temperature of at least 11°C. There is little correspondence between the Holoebudalen temperature reconstructions and the reconstructed Holocene history of the Hardangerjøkulen glacier (Nesje 2008), but, of course, changes in winter precipitation may influence the glacier responses as well as summer temperatures.

Modern pollen-vegetation diversity relationships in Setesdal –

Vivian Felde, Anne Bjune, John-Arvid Grytnes, John Birks

Estimated pollen and plant richness along the altitudinal gradient in the Setesdal valley

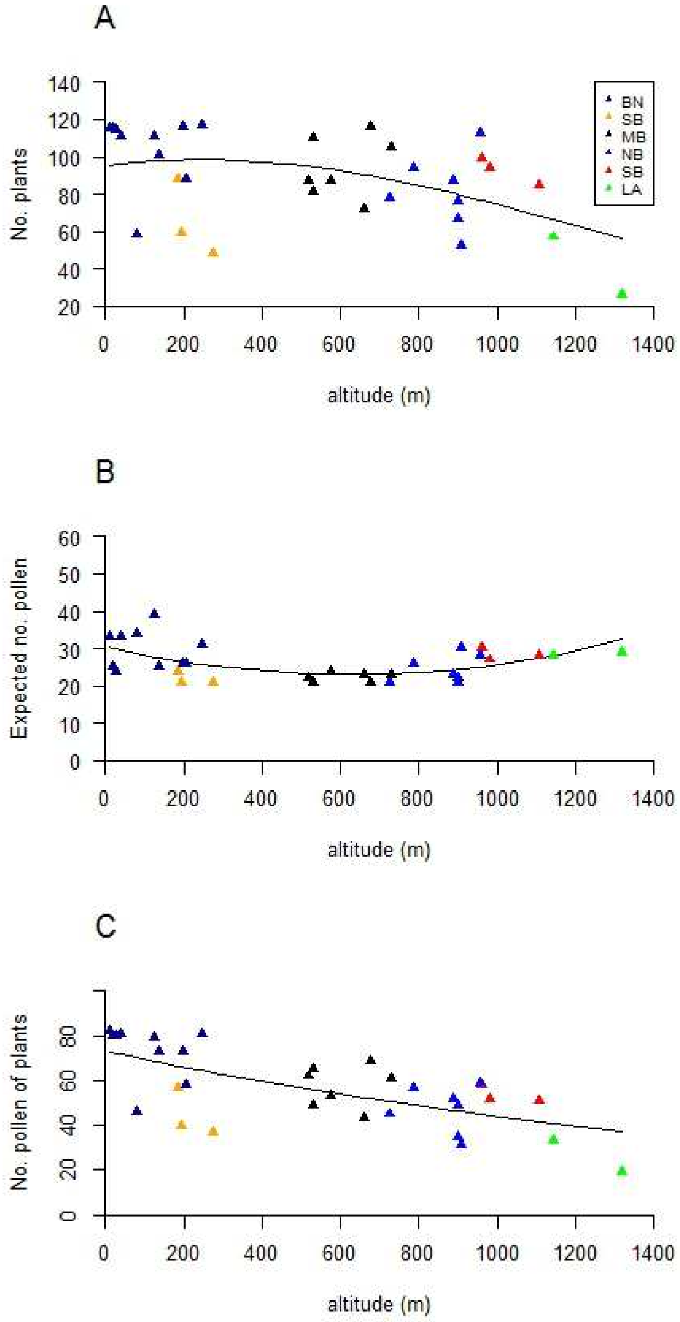


Figure 3a,b,c: Plots of a) plant species, b) expected number of pollen types (rarefaction), and c) pollen types of plant species vs. altitude coded by regions (*BN*= Boreo-nemoral, *SB*=Southern-boreal, *MB*=Mid-boreal, *NB*=Northern-boreal, *SA*=Sub-alpine, *LA*=Low-alpine).

Relationships of plant richness and estimated pollen richness after transformations of raw pollen counts

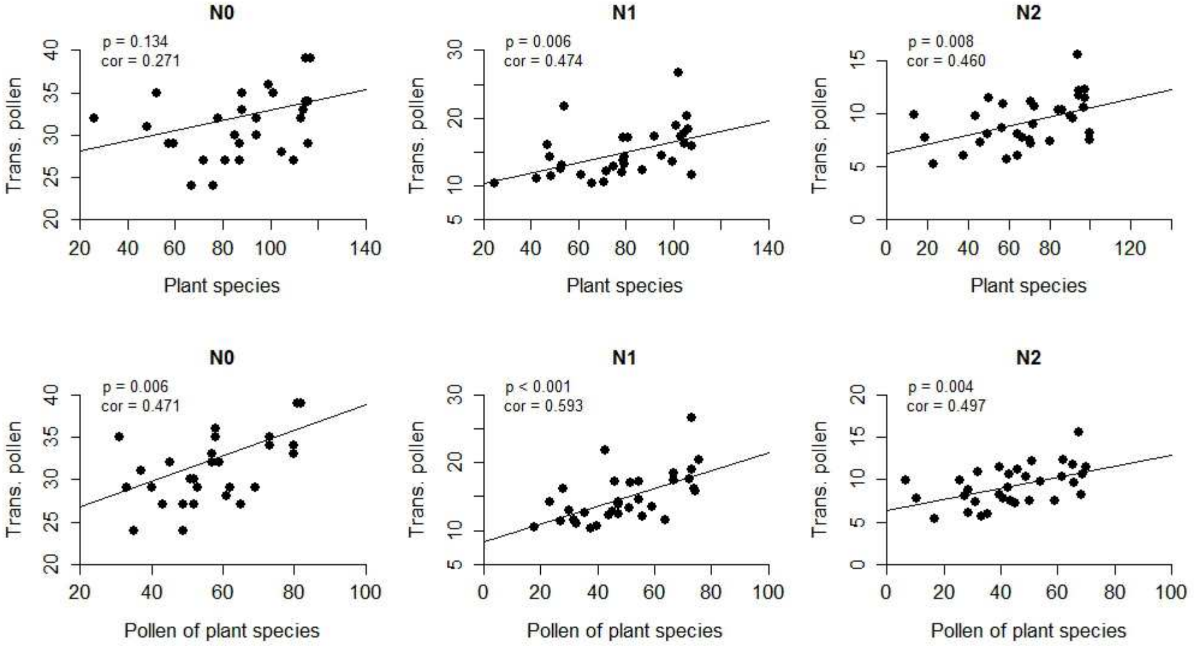


Figure 6: Plots of transformed pollen data (by Andersen's (1978) general correction factors) vs. plant species, pollen of plant species, and untransformed pollen data for *N0*, *N1,* and *N2*.

The relationship of estimated pollen richness along the altitudinal gradient after transformation of raw pollen counts

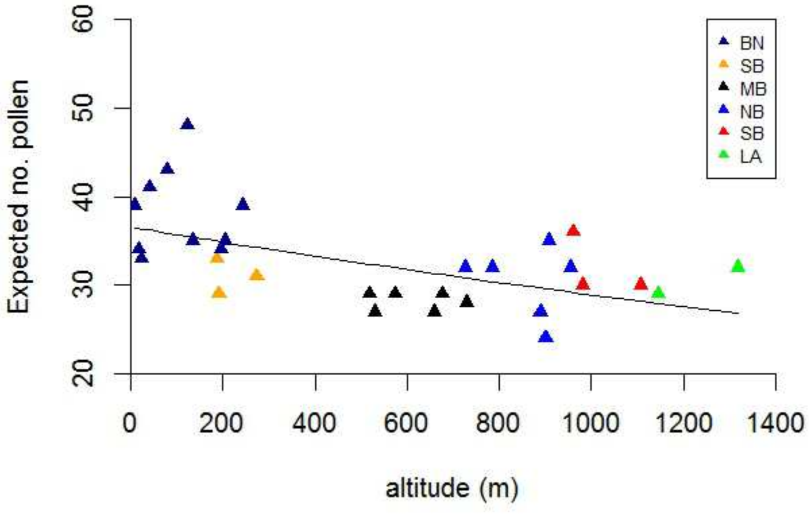


Figure 7: Plot of pollen and spore types (rarefaction) after transformation vs. altitude coded by regions (*BN*= Boreo-nemoral, *SB*=Southern-boreal, *MB*=Mid-boreal, *NB*=Northern-boreal, *SA*=Sub-alpine, *LA*=Low-alpine).

Pollen sample evenness and plant richness before transformation of raw pollen counts

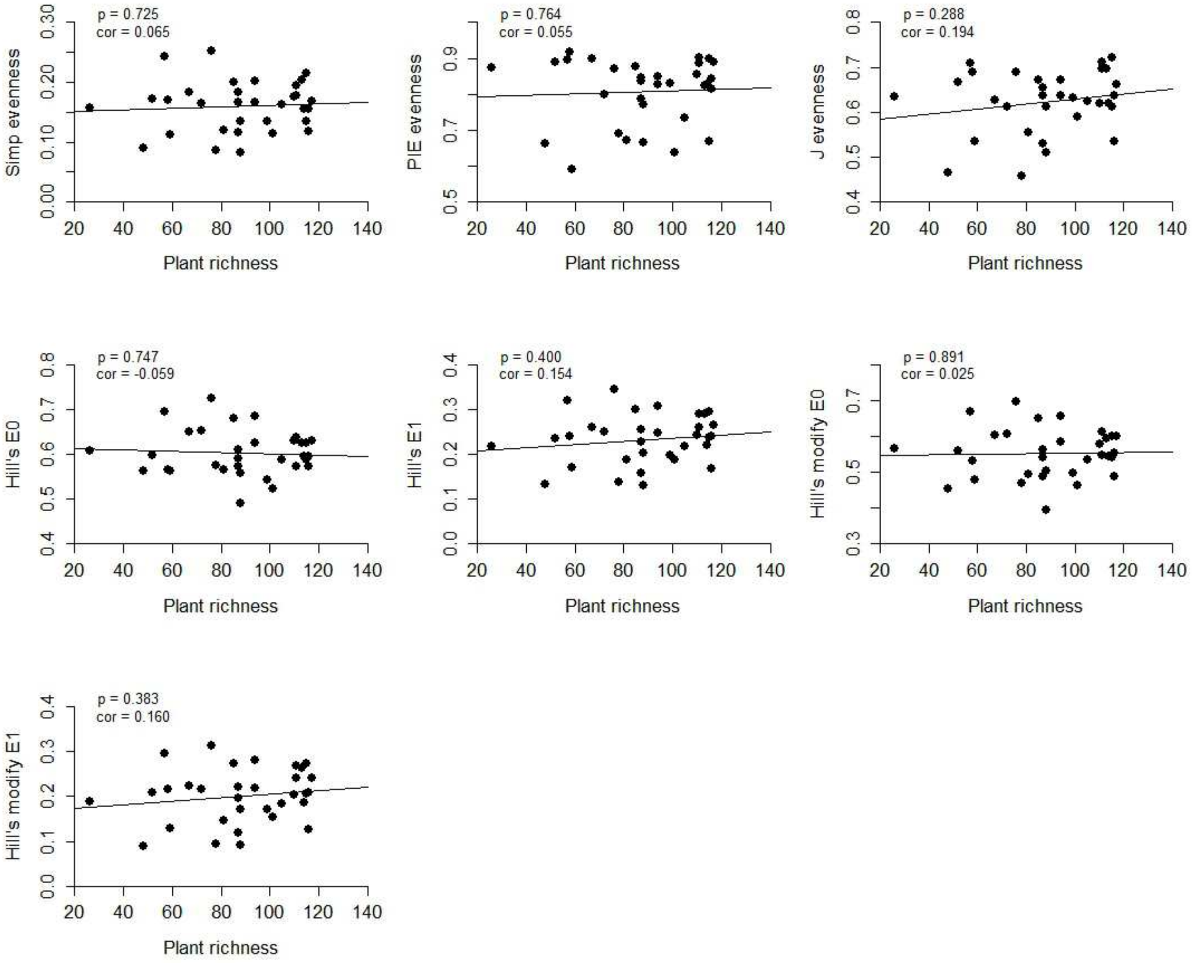


Figure 8: Plots of pollen sample evenness against plant richness before transformations.

Pollen sample evenness and plant richness after transformation of raw pollen counts

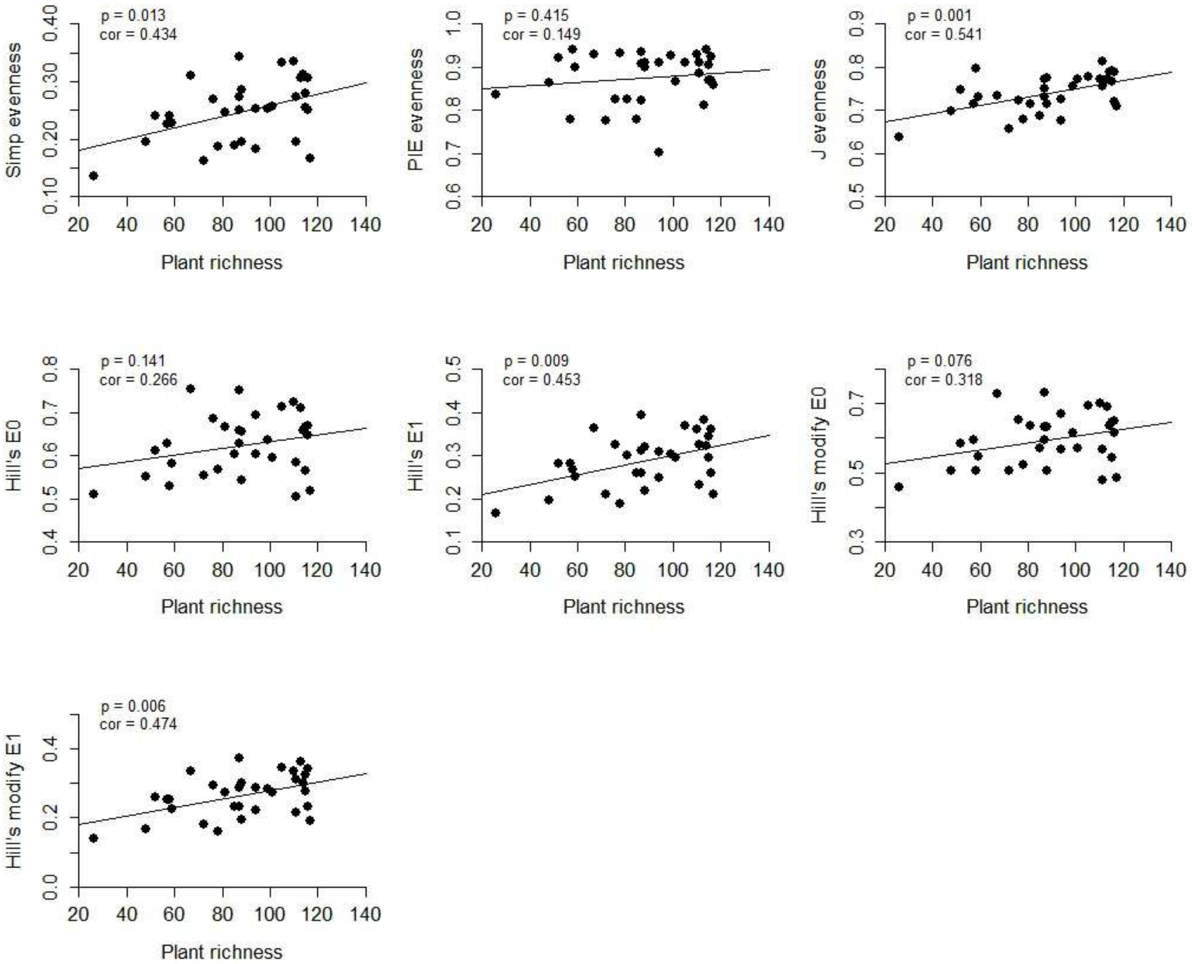
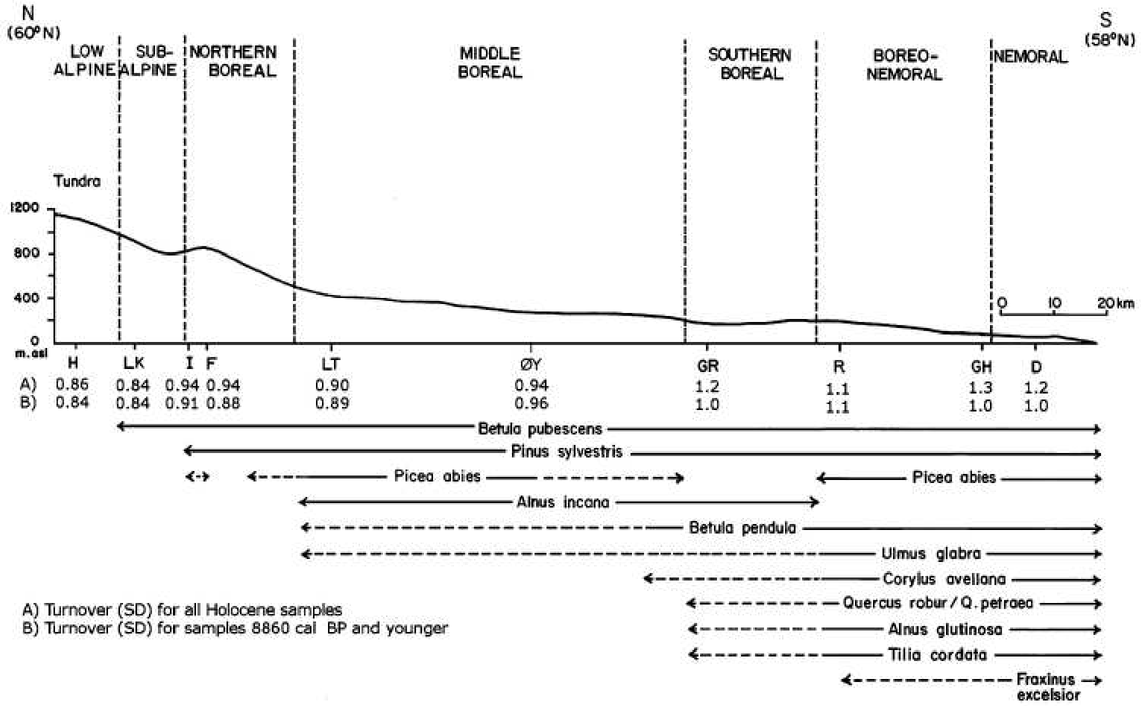


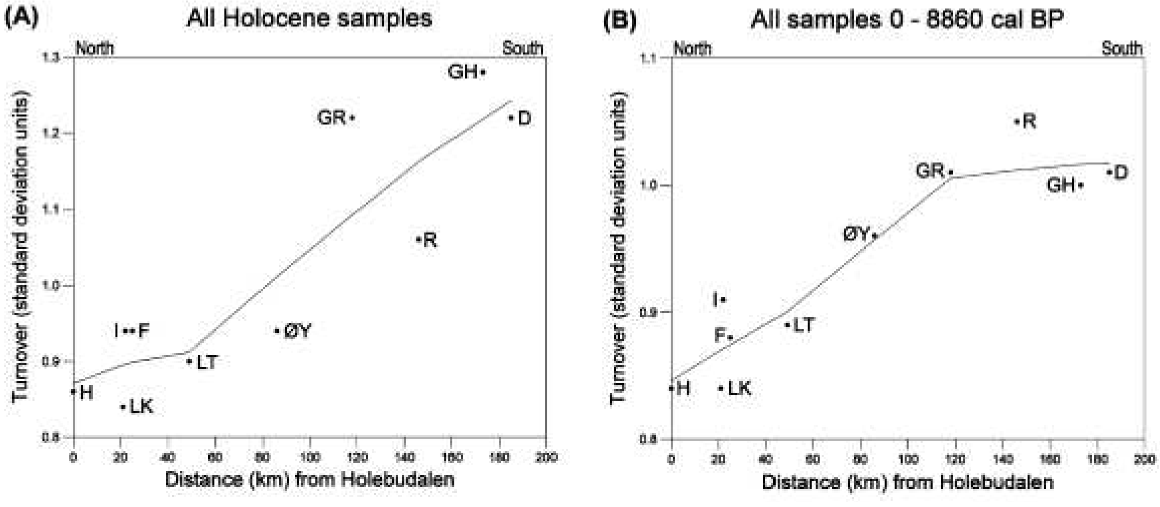
Figure 9: Plots of pollen evenness vs. plant species richness after transformations.

Biotic turnover in the Holocene in Setesdal – John Birks

To summarise the amount of turnover or compositional change in these ten sites, Birks (2007) applied detrended canonical correspondence analysis (DCCA) to each pollen stratigraphy with sample age (or depth) as the sole constraining variable. The analysis was done for each entire sequence and for all samples 8000 cal yr BP or younger.



A transect through the Setesdal valley in southern Norway showing how altitude varies from south to north, the location of the ten pollen-stratigraphical sequences (H, LK, I, F, LT, ØY, FR, R, GH, D) amalysed, the present-day distribution of the major forest trees and shrubs in the valley (→ = common, -→ = rare), and the estimated palynological compositional turnover (in standard deviation (SD) units) at the ten sites for the Holocene (A) and for the past 8860 cal years (B). (Birks 2007)



Plot of palynological turnover (standard deviation units) at the ten sites in the Setesdal Valley. Turnover for the Holocene is shown in A and for the past 8860 cal yr in B. The distance between sites is given as distance from the northernmost site (Holebudalen) to achieve a north-to-south plot comparable to the figure above. The fitted line is a LOESS scatterplot smoother (span 0.60) to highlight the main trends in the plots. (Birks 2007)

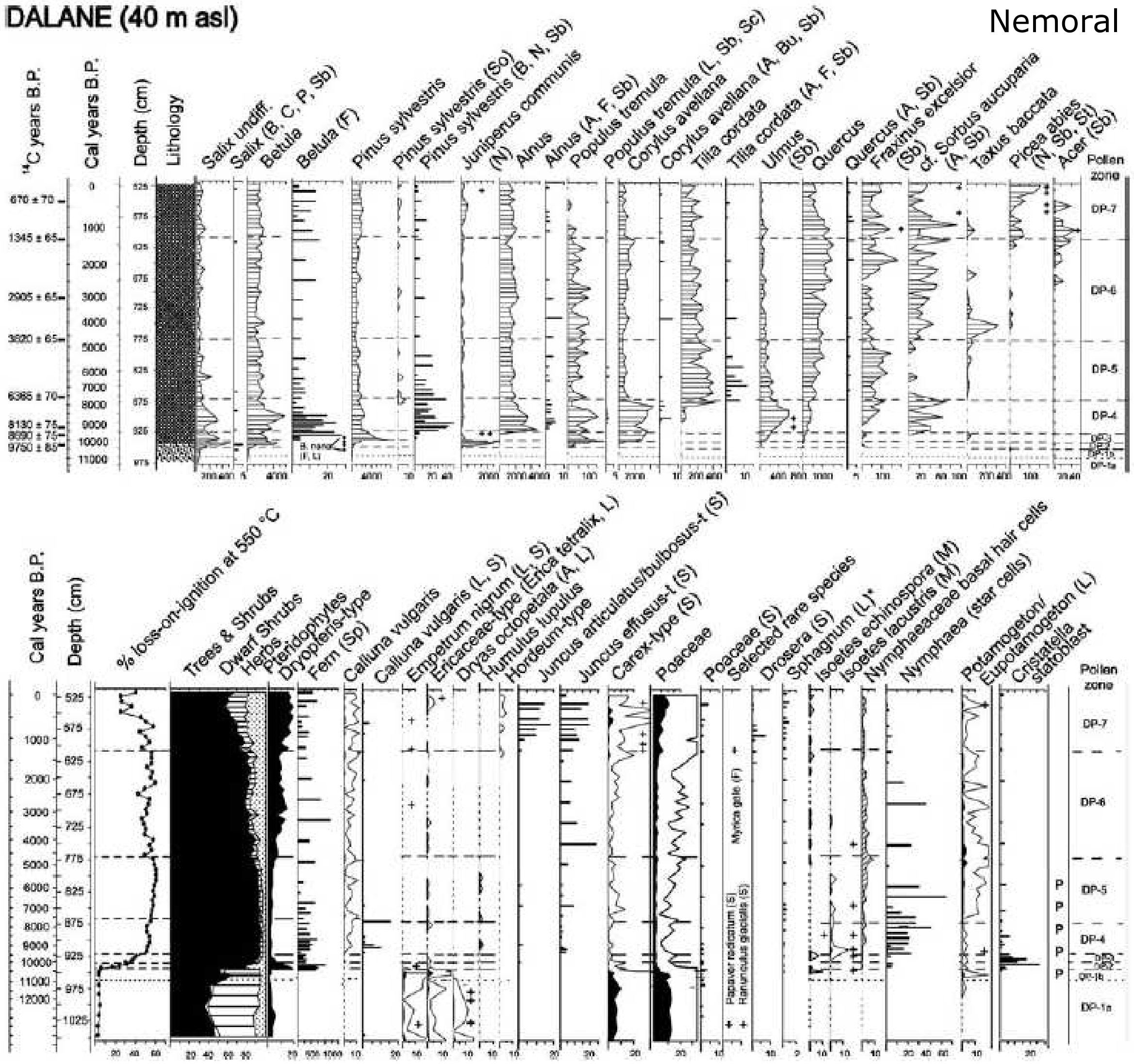
There is a general increase in total turnover as one moves from the low-alpine site at Holebudalen (H) to the southern-boreal site at Grostjørna (GR), and then total turnover does not vary in the southernmost four sites.

Pollen and plant macrofossil studies in Setesdal – Hilary Birks, Wenche Eide, Nancy Bigelow, Sylvia Peglar, John Birks

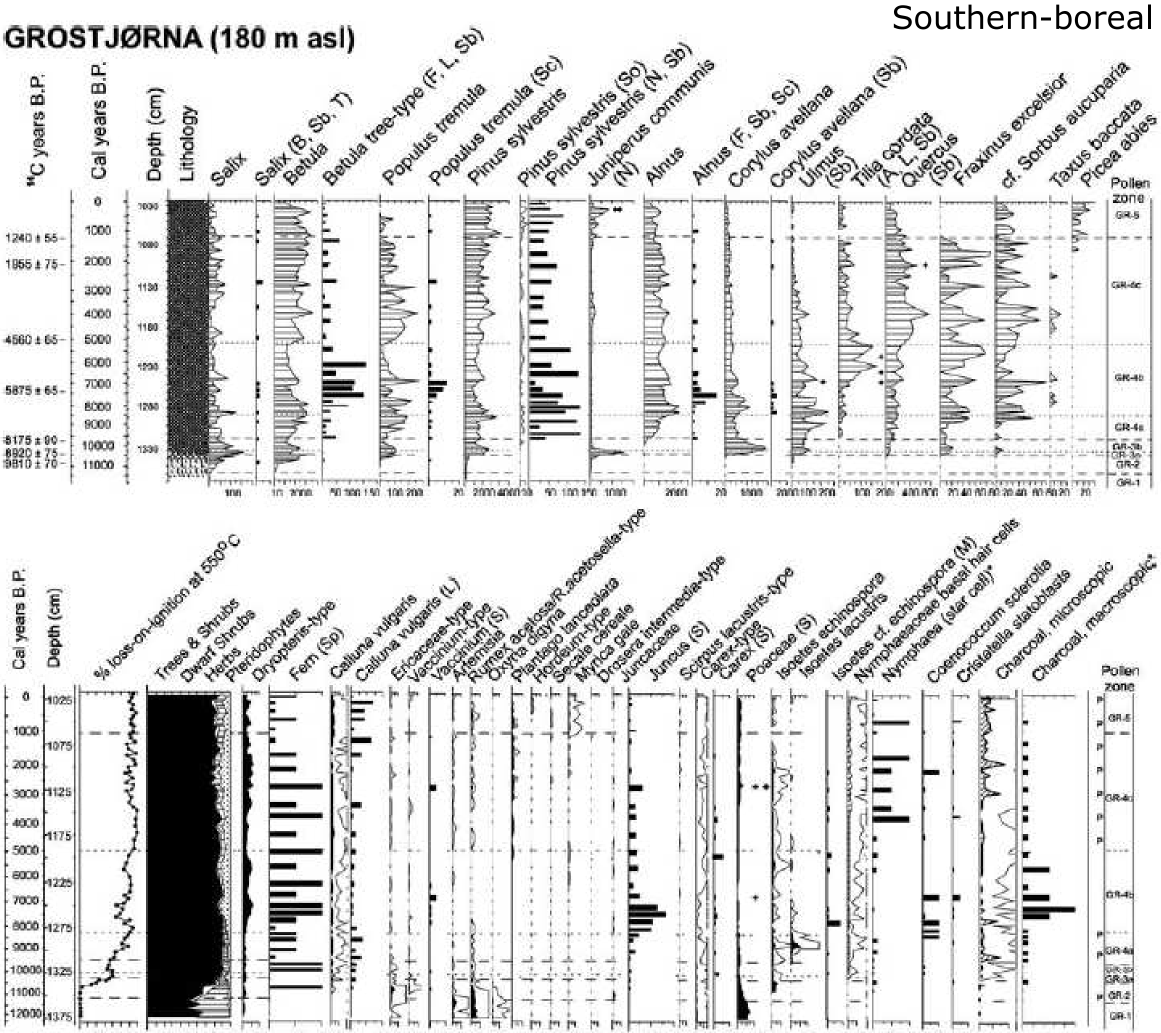
It is now widely accepted that palaeoecological studies in arctic and alpine areas, in northern areas, and in late-glacial situations require **both** pollen analysis and plant macrofossil analysis (Birks and Birks 2000).

Macrofossil analyses have been done at four of the Setesdal sites – Dalane (nemoral), Grostjørna (southern-boreal), Lille Kjelavatn (sub-alpine), and Holebudalen (low-alpine) (Eide et al. 2006).

To permit comparisons between the pollen and the plant macrofossil data, diagrams showing pollen influx (joined curves with horizontal depth bars) and pollen concentrations (histogram) were plotted together. All analyses were done on the same cores.

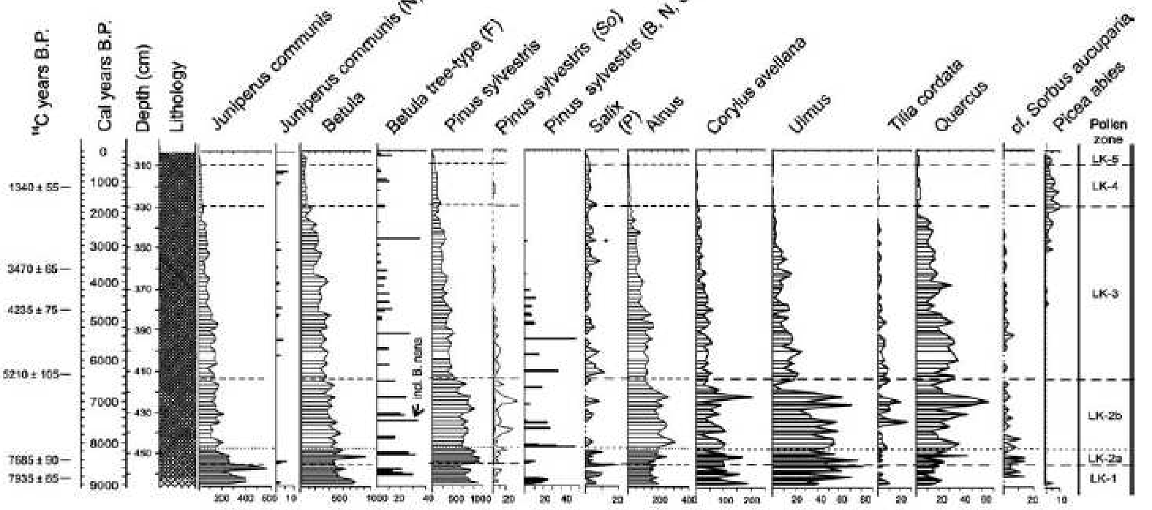


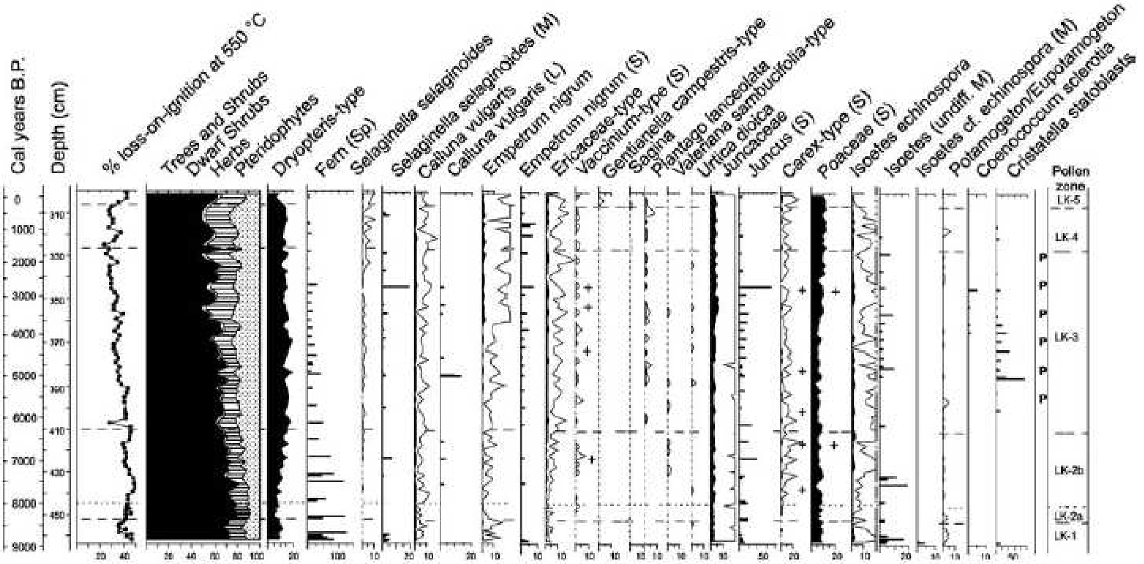
Southern-boreal



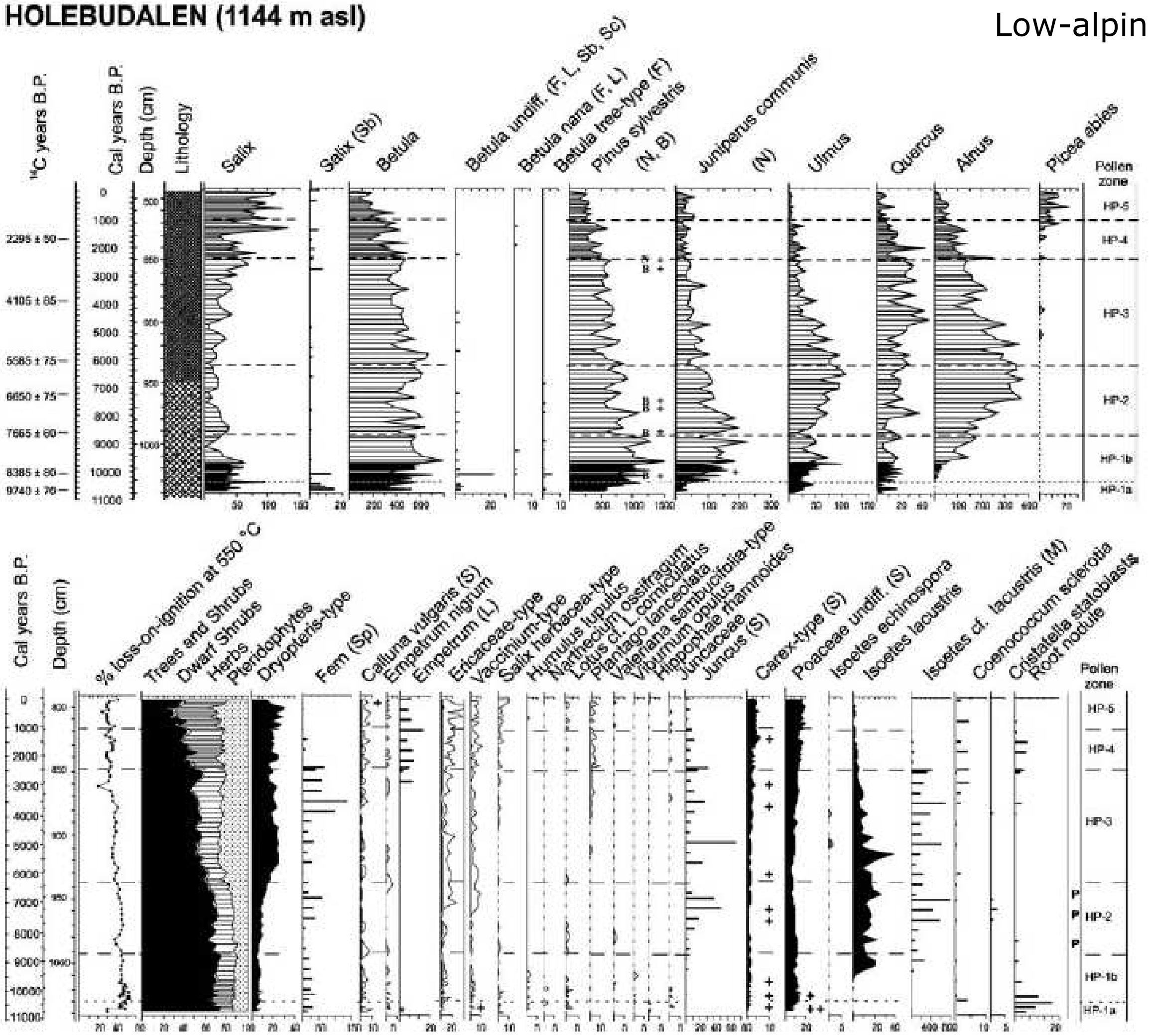
LILLE KJELAVATN (1000 m asl)

Sub-alpine





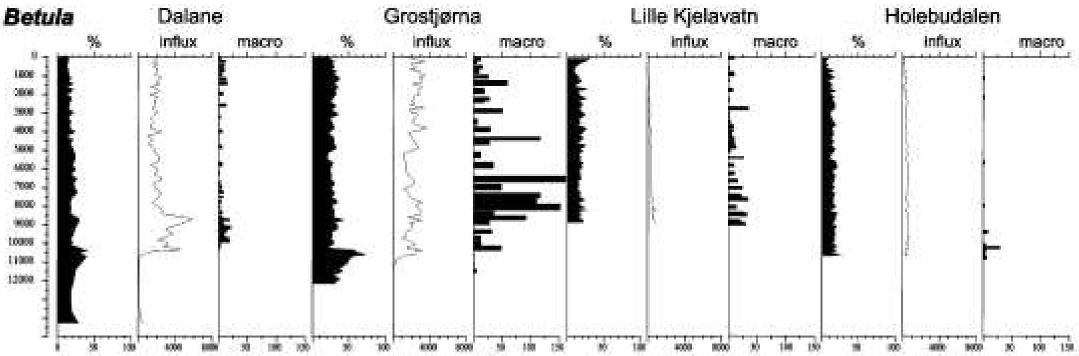
Low-alpine



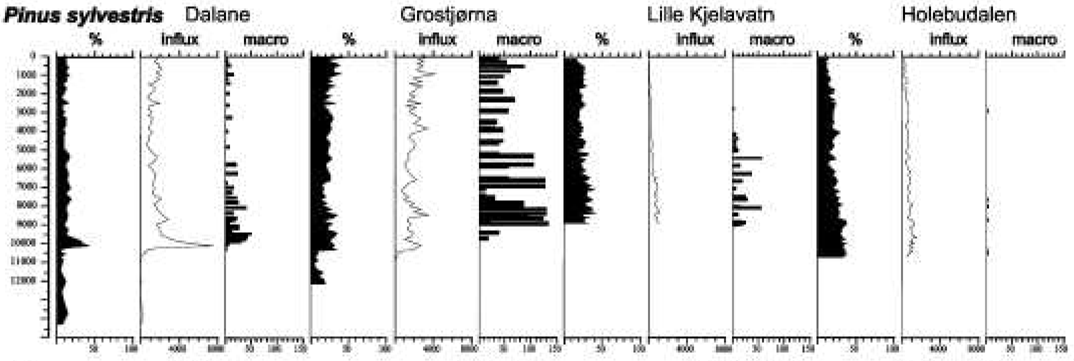
(Eide et al. 2006)

As the emphasis of this study was on tree pollen–tree macrofossil comparisons, a series of diagrams were constructed for the major tree taxa showing pollen percentages, pollen influx, and macrofossil concentrations.

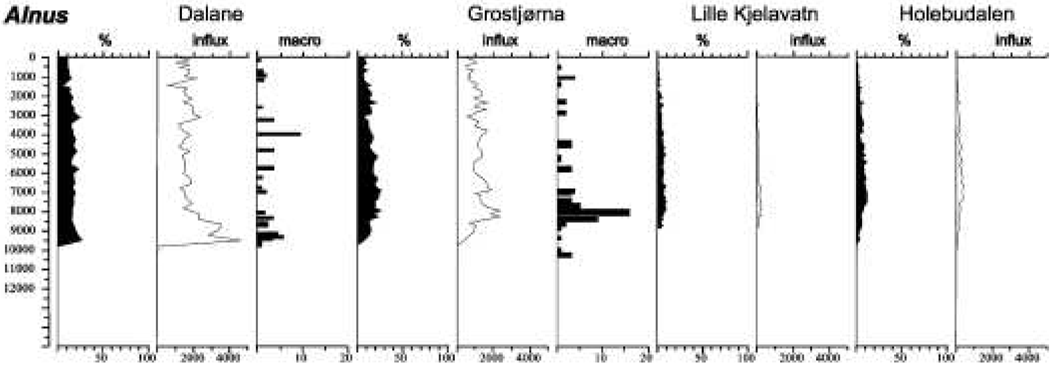
Betula



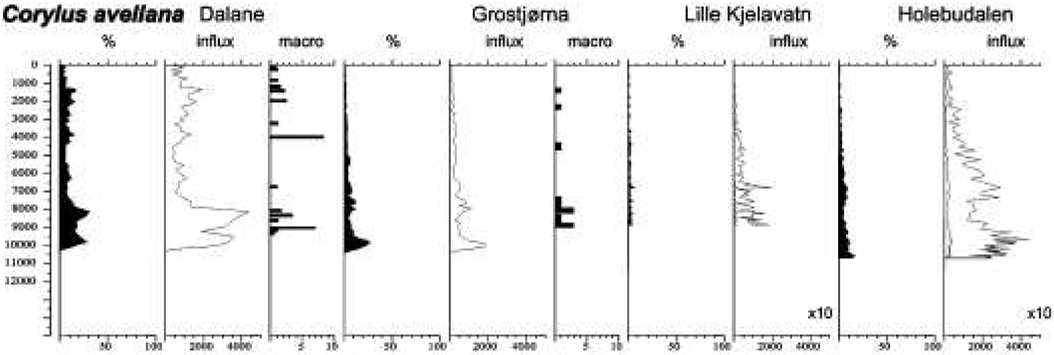
Pinus sylvestris

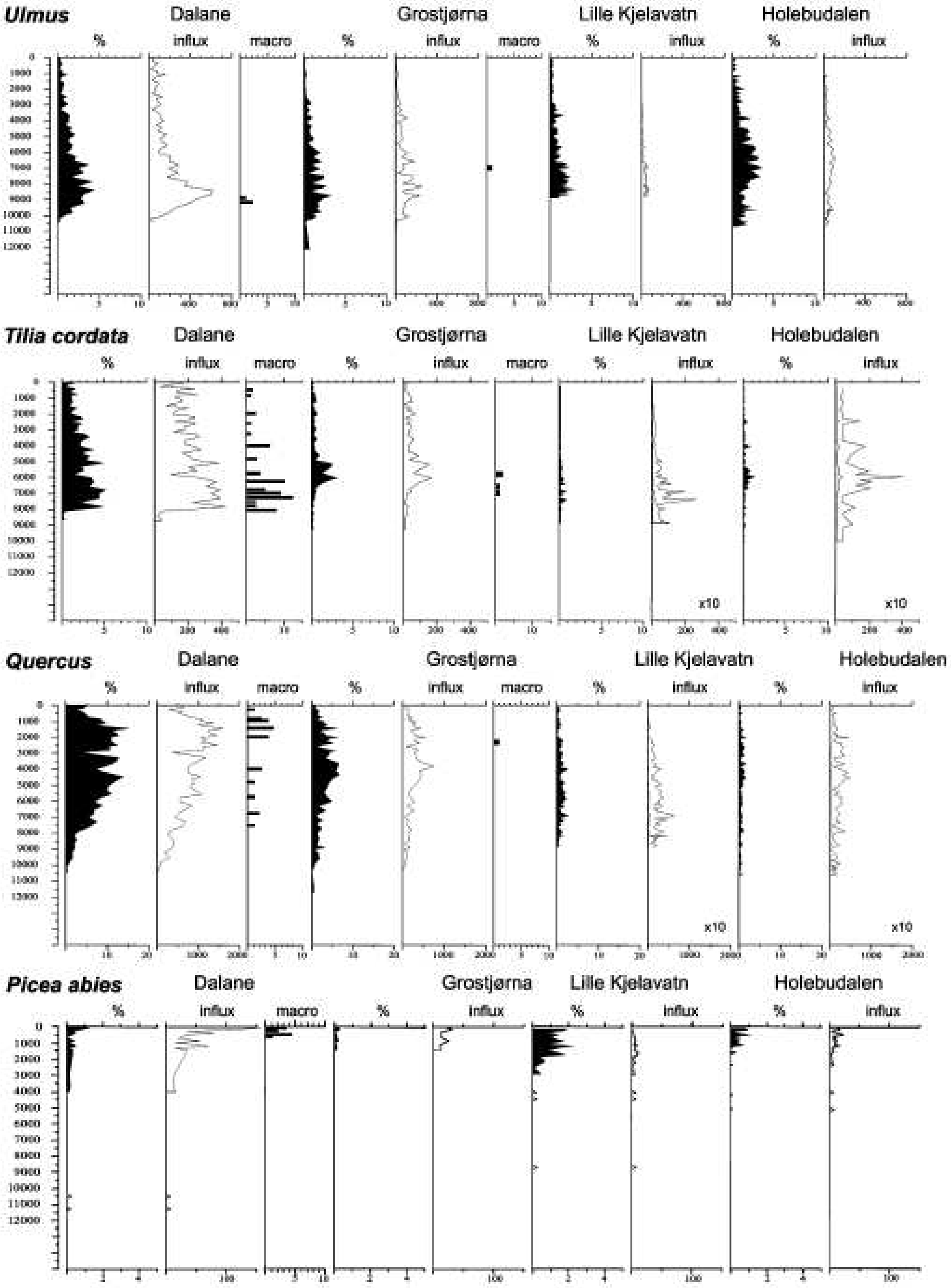


Alnus



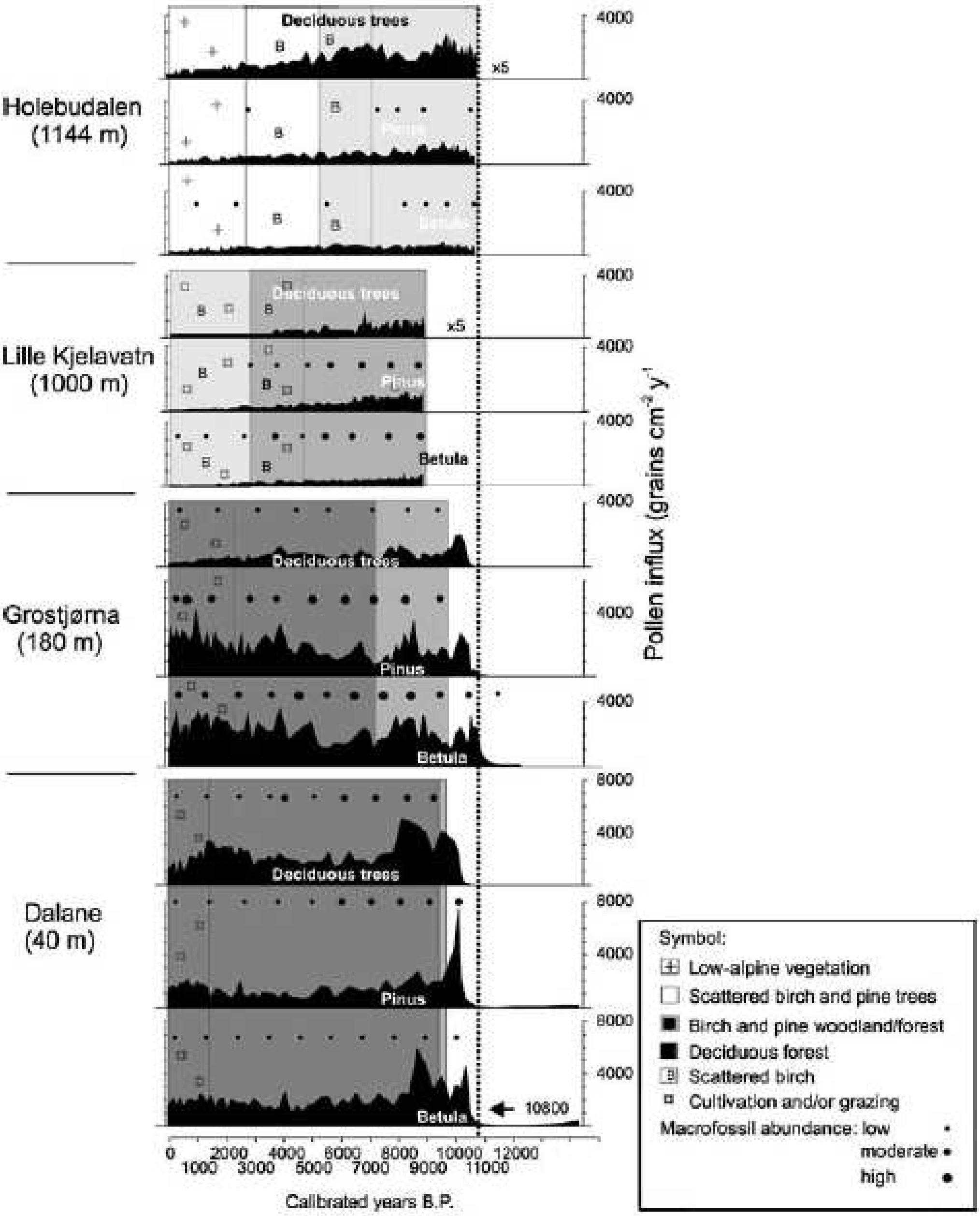
Corylus avellana





(Eide et al. 2006)

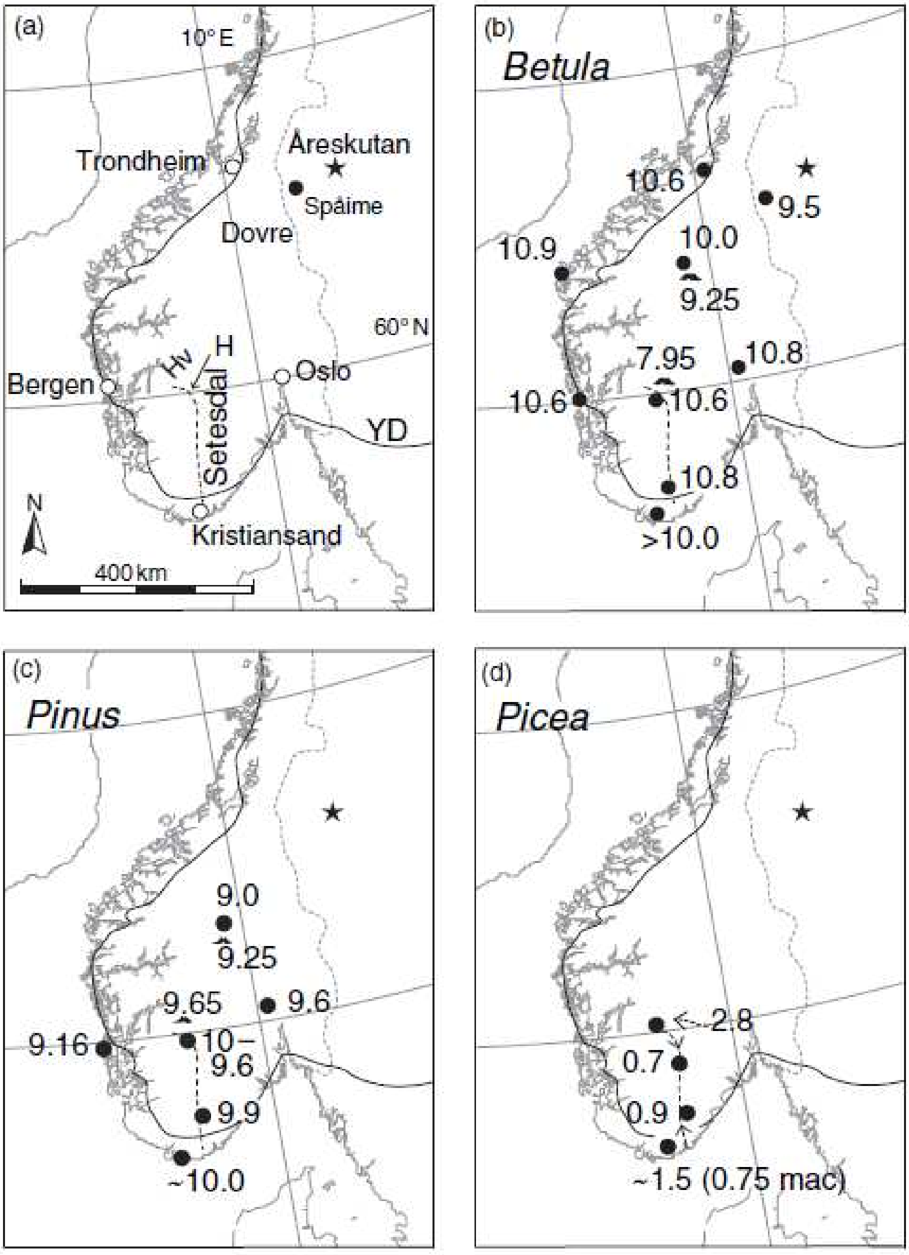
The major vegetational changes are summarised in a time–space diagram arranged on the elevational gradient.



(Eide et al. 2006)

Tree migration patterns in Setesdal – Hilary Birks, John Birks

Given the detailed dated pollen diagrams and, for some sites, plant macrofossil data, it is possible to map out the first pollen or macrofossil increases.



Maps showing the earliest ^{14}C-dated macrofossil/pollen influx increase (black dots) and megafossil records (stump symbol) in the Holocene for *Betula* (b), *Pinus* (c), and *Picea* (d). Ages are given in cal yr BP x 10^{-3}. H=Haukeligrend, Hv=Hardangervidda. Mt Åreskutan is shown by a star. The Younger Dryas (YD) ice re-advance limit is shown. (Birks et al. 2005)

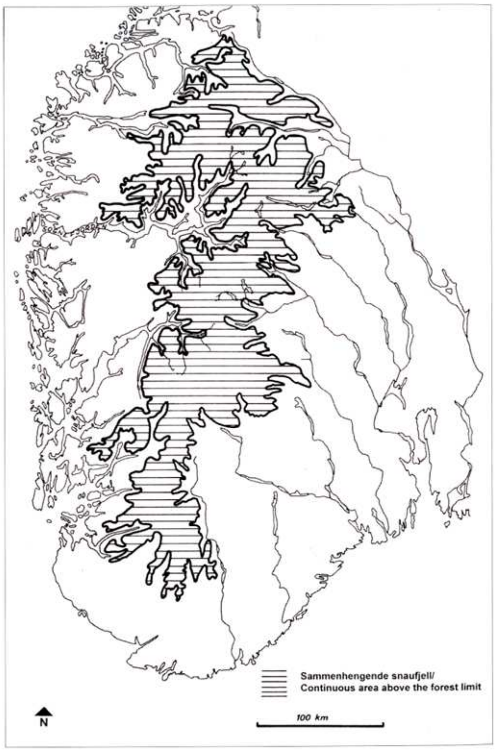
It appears that *Betula* and *Pinus* were rapid colonisers whereas *Picea* appears to have entered Setesdal by at least two routes – from the east via Gungedal and Amot, and from the extreme south. *Picea* in Setesdal thus appears to have two different migrational entries. It is absent in 'native' forest stands in the southern boreal near Grostjørna (see the pollen and macrofossil diagram above). We will discuss the history of *Picea* tomorrow.

Man in the mountains – John Birks, Lotte Selsing

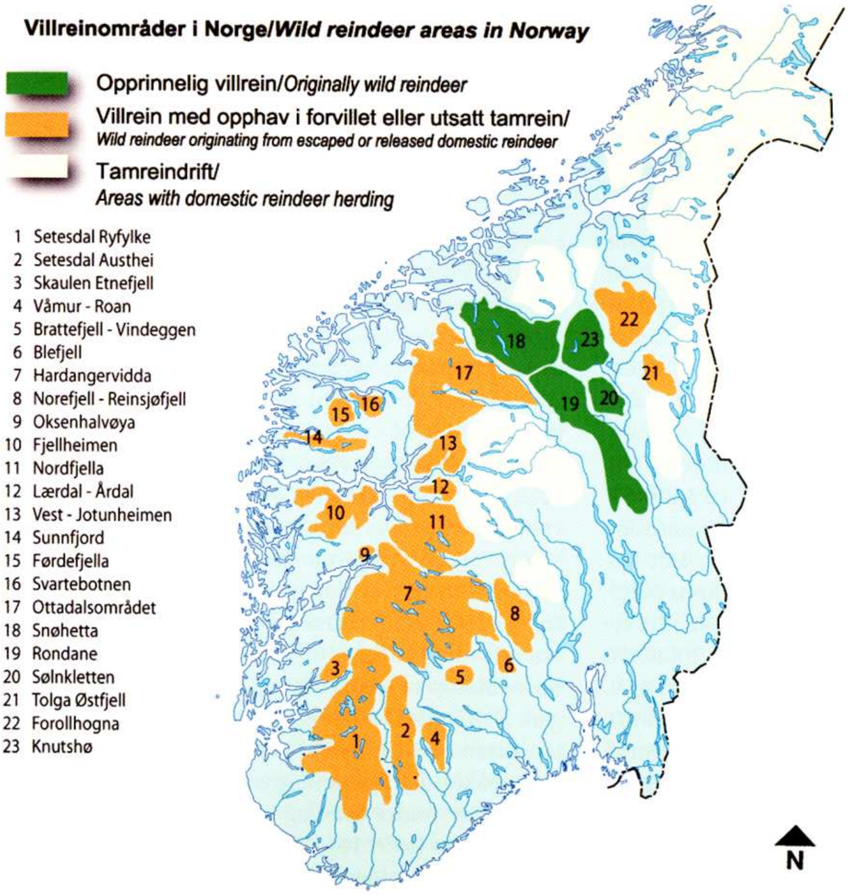
This is based almost entirely on Selsing (2010).

Dates on archaeological finds suggest a continuous presence of people since the late pre-Boreal. Selsing suggests that this homogeneity indicates that hunter-gatherers regularly used the mountain area in an annual cycle. Nearly all the radiocarbon-dated archaeological sites in the mountain area are located below the forest-limit at the time of use. Possibly the sub-alpine forest was a better base than the low-alpine zone to safeguard the regular economic resources needed by the human colonies. The sub-alpine zone probably also had richer and more varied resources than the alpine area ad was the only zone where reindeer, elk, and red deer could be regularly expected. When the forest-limit dropped about 4470–3770 yr BP, the biotopes where settlement sites had been located were poorer and societal safety and integrity weakened. The decline in settlements is well correlated with the decline of high-elevation pine (up to 1095 m) in the sub-alpine zone and the beginning of the descent of the forest-limit. This decline in the forest-limit and the increased area of alpine vegetation probably facilitated an increase in reindeer populations and improved hunting conditions.

Reindeer trails in parts of Dyraheio, Setesdal Vesthei. Dotted line shows the water divide. Modified form Bang-Andersen (2008). (Selsing 2010)



Map of the mountain areas above the forest limit in south Norway today. Modified from Johansen (1978). (Selsing 2010)



Districts and areas with occurrence of reindeer in south Norway are distributed across 24 management areas (Andersen & Hustad 2004).

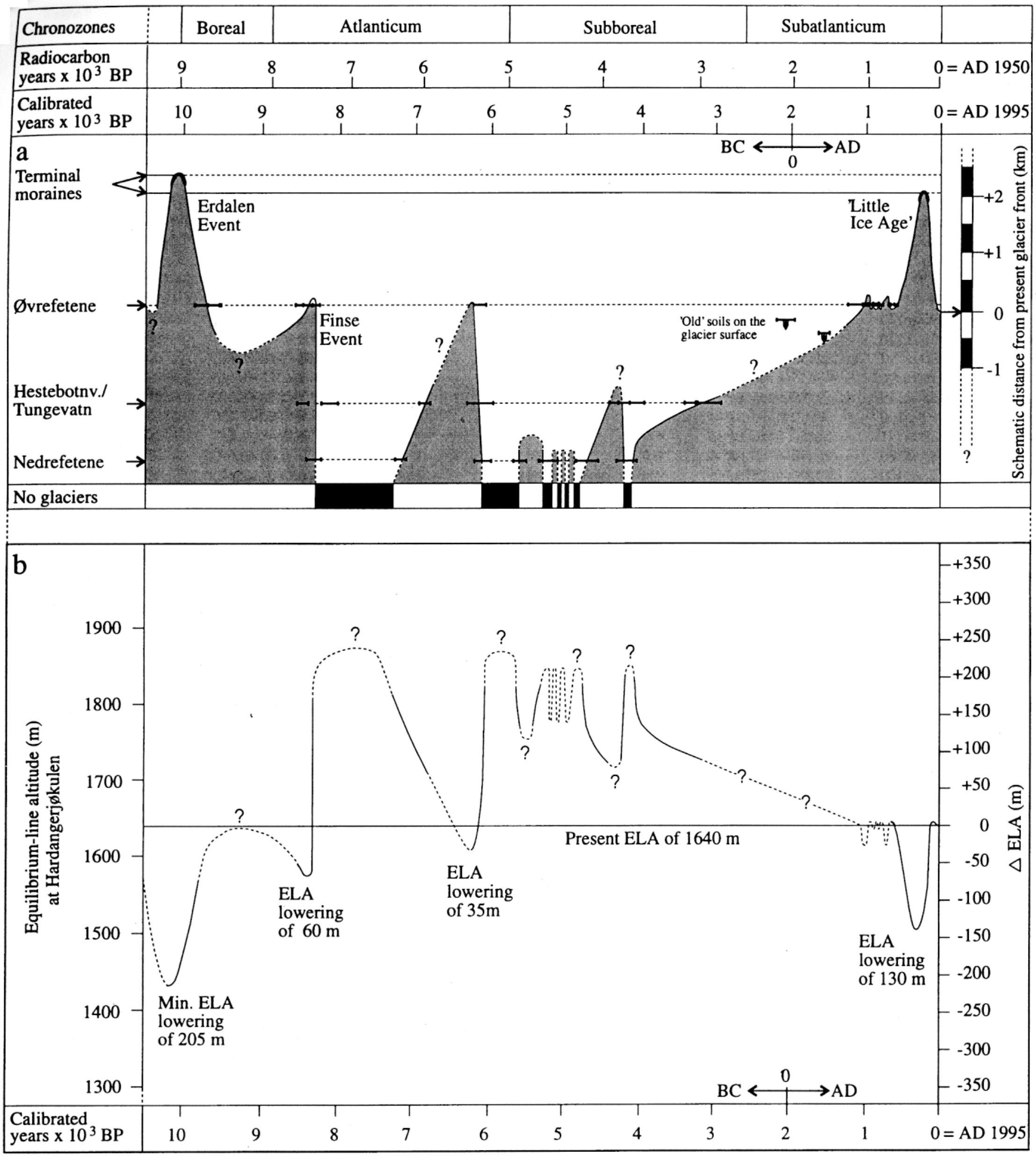
Holocene history of the alpine zone and of south Norwegian glaciers – John Birks, Atle Nesje

The low-alpine zone in the Setesdal area runs from about 1050 m to about 1250 m a.s.l. Its vegetation is similar to sub-alpine birch woodland except that trees are absent. It consists of dwarf-shrub heaths of *Empetrum hermaphroditum, Vaccinium* spp., and *Phyllodoce caerula*; *Salix* scrub; and grass heaths of *Festuca* spp., *Deschampsia flexuosa,* and *Agrostis* spp. Many sub-alpine plants have their upper limits in the low-alpine zone (e.g. *Galium boreale, Geum rivale, Gymnocarpium dryopteris, Linnaea borealis, Listera cordata, Phegopteris connectilis, Sorbus aucuparia, Stellaria nemorus,* and *Valeriana sambucifolia*).

Numerical analysis of floristic composition along an elevational gradient from sea-level to 1700 m a.s.l. in the nearby Aurland area (Odland and Birks 1999) shows that there is no statistically significant change in overall composition at the sub-alpine to low-alpine transition. There is, however, a significant change at the low-alpine to mid-alpine transition with many species not extending into the mid-alpine zone.

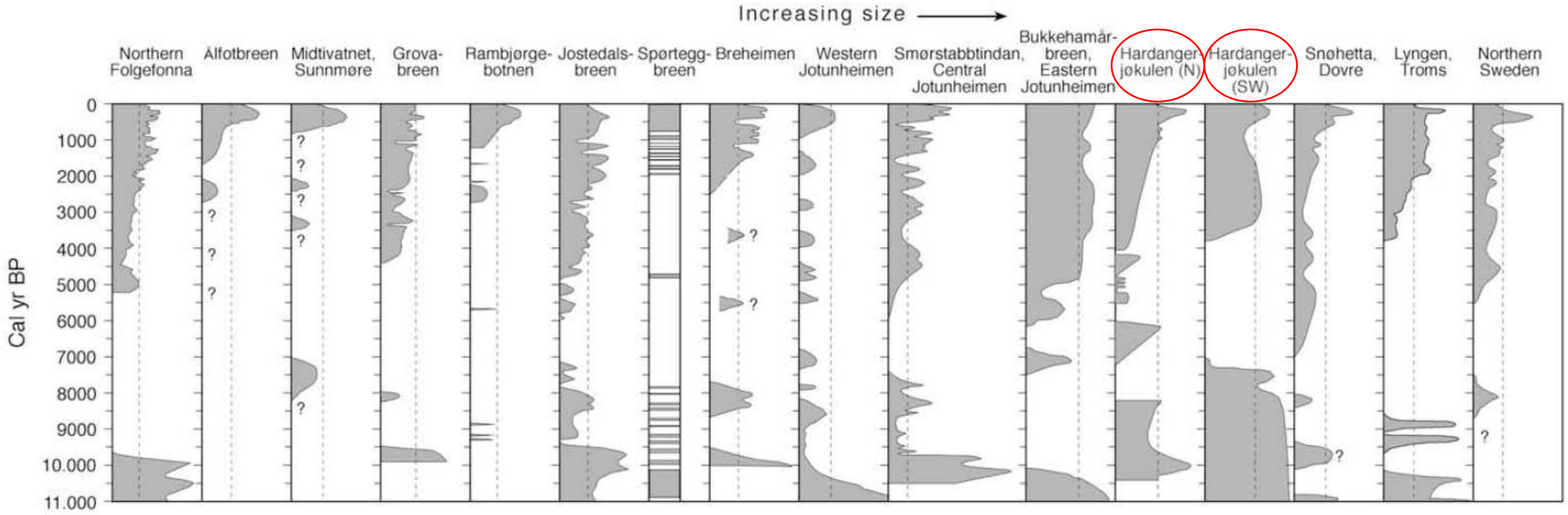
As far as I know, virtually all megafossils of *Pinus* and *Betula* found in the Norwegian mountains occur within what today is the low-alpine zone. It seems likely that the sub-alpine zone extended to the present-day transition between the low-alpine and mid-alpine zones. As Selsing (2010) argues, the sub-alpine and low-alpine zones are, to some extent, cultural landscapes.

Entering the high-alpine (= nival) zone at about 1400 m, the landscape is very barren with isolated vascular plants only, and boulders, snow-beds, and in certain areas, ice-caps or plateau glaciers. The nearest glacier to Setesdal is the Hardangerjøkulen of 73 km^2 and ranges from 1050 to 1860 m. It is the sixth largest glacier in Norway. Dahl and Nesje (1996) reconstructed using stratigraphical sections, moraines, etc., the equilibrium-line altitude (ELA) of the glacier for the last 10,000 years.



(a) Holocene glacier fluctuations at the northern sector of Hardangerjøkulen. The linear timescale is in calibrated years BP, while the corresponding radiocarbon ages are indicated. The calibrated radiocarbon dates (±1σ) used in the reconstruction are shown. The glacier fluctuations are unadjusted for land uplift (modified from Dahl & Nesje 1994). (b) Holocene ELA variations adjusted for land uplift at the northern sector of Hardangerjøkulen. The linear timescale is in calibrated years BP. (Dahl and Nesje 1996)

It is possible that all or parts of the Hardangerjøkulen disappeared in the mid-Holocene, as did several glaciers in Scandinavia (Nesje 2009).



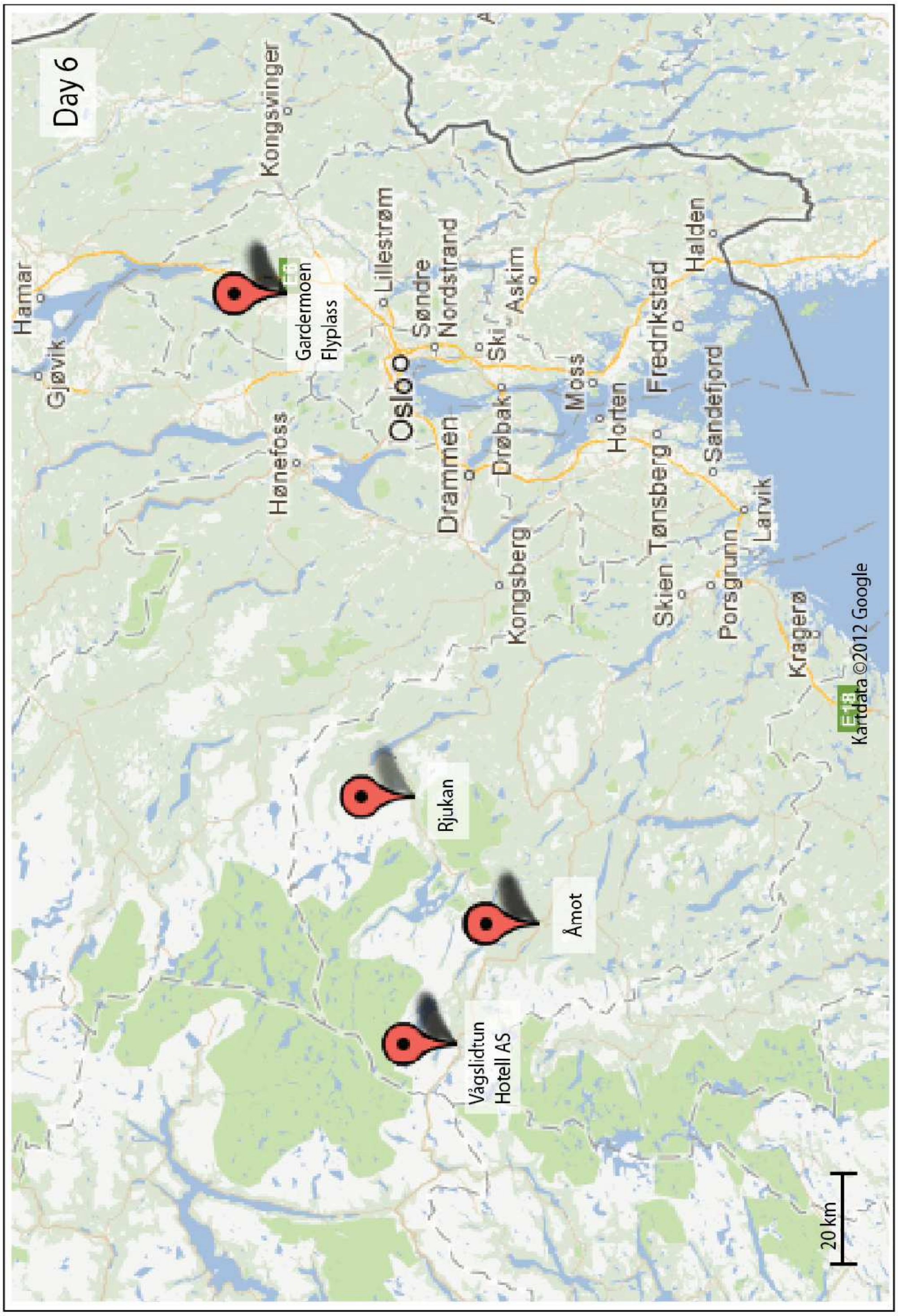
Holocene glacier fluctuations in different parts of Scandinavia (horizontal scale is schematic, not to scale). (Nesje 2009)

DAY 6

PICEA FOREST NEAR ÅMOT

RJUKAN

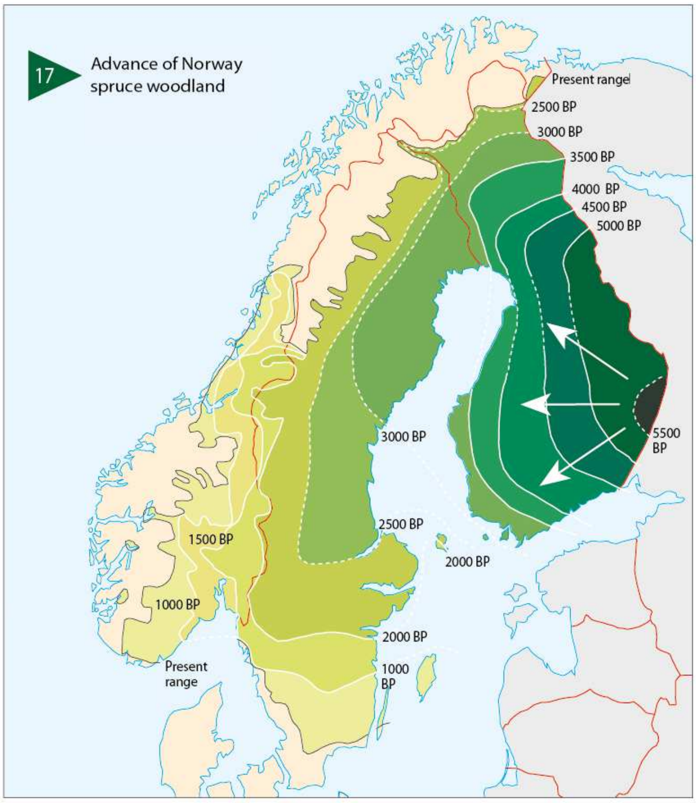
Thursday 13 September 2012


Day 6
Gardermoen Flyplass
Rjukan
Åmot
Vågslidtun Hotell AS
20 km
Kartdata ©2012 Google
Oslo
Hamar
Gjøvik
Kongsvinger
Lillestrøm
Søndre Nordstrand
Askim
Ski
Hønefoss
Drammen
Drøbak
Moss
Horten
Fredrikstad
Halden
Sandefjord
Tønsberg
Larvik
Kongsberg
Skien
Porsgrunn
Kragerø
E18

***Picea abies* in Norway** – John Birks, Hilary Birks

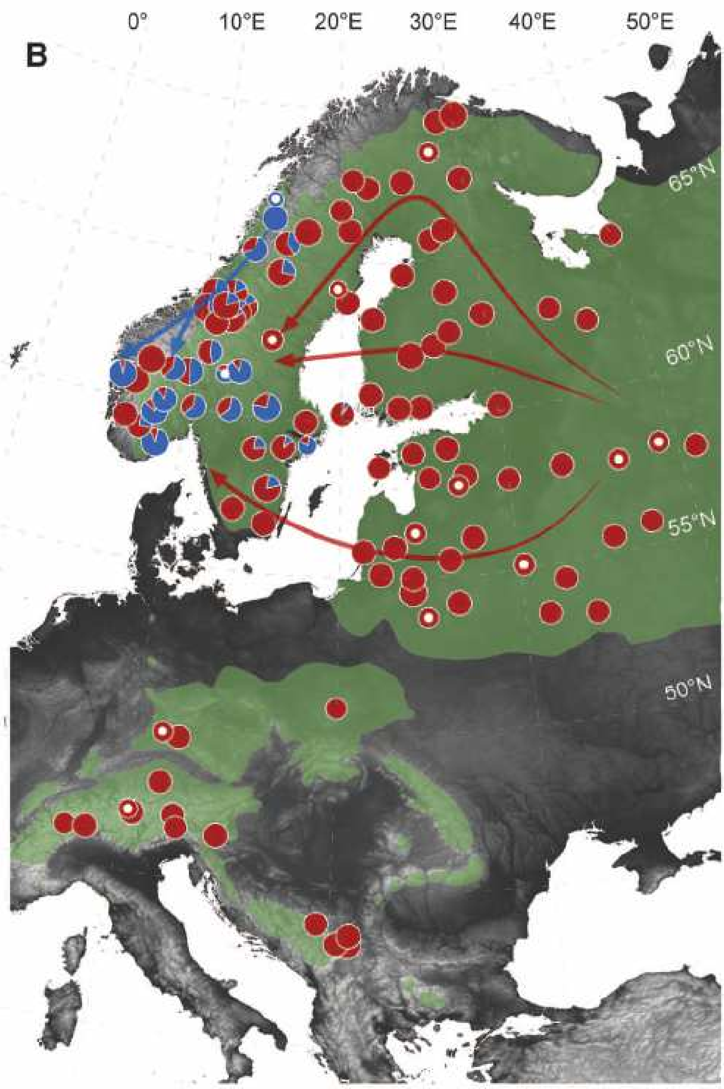
The history of *Picea abies* in Fennoscandia has attracted much scientific study, scientific controversy, and speculation. As Parducci et al. (2011) show, the history of spruce remains as contentious and as controversial as ever.

The general Holocene history of *Picea* in Fennoscandia is of an east-to-west spread.



The main trends in the spread of Norway spruce (Picea abies) from Finland through Sweden into Norway. The data are based on palaeoecological investigations performed during the last decades. From Moen (1999) *National Atlas of Norway: Vegetation* (ISBN: 82-7945-000-9 Vegetation)

Studies of mitochondrial DNA of extant populations of *Picea abies* in northern Europe (Tollefsrud et al. 2008, 2009) indicate a shallow genetic structure consistent with fossil pollen data, suggesting that the vast northern range today was colonised from a single refugium (or many nearby refugia). More recent work (Parducci et al. 2011) shows a deletion of 21 base pairs in some populations, giving two haplotypes – haplotype A confined to Scandinavia and haplotype B in Scandinavia and elsewhere in Europe.



Geographical distribution of mitochondrial mh05 haplotypes A (dark blue circles and B (red circles) in Norway spruce populations. Size of the circle is proportional to population size (centred white dots indicate populations with N < 10). Arrows suggest postglacial movements of the two haplotypes after the LGM. The olive shading shows the natural range of Norway spruce. (Parducci et al. 2011)

On the basis of this deletion, the finding of haplotype A in *Picea* pollen from 6300 yr BP in central Norway and from lake sediments 10,300–6500 yr BP, and of one fragment of chloroplast DNA of *Picea* of about 17,700 yr BP from lake sediment from Endlevatnet on Andøya (northern Norway), Parducci et al. (2011) conclude that "our findings imply that conifer trees survived in ice-free refugia of Scandinavia during the last glaciation, challenging current views on survival and spread of trees as a response to climate changes. ... this has cascading implications for pollen-based inferences of species invasion and migration patterns and rates." Note that there is no native *Picea* (or native *Pinus*) on Andøya today!

Hilary Birks and colleagues have submitted a Technical Comment to *Science* about the Parducci et al. (2011) paper. Hopefully we can discuss our Technical Comment during the Excursion. Working with ancient-DNA and interpreting what, if anything, ancient-DNA from lake sediments means, is not as easy as it may appear.

Returning to Setesdal, the Parducci et al. (2011) map indicates that Setesdal supports both haplotype A (dark blue) and haplotype B (red). Given the two migration routes of *Picea* into Setesdal discussed yesterday, one from the east and one from the south, it would be interesting to investigate mitochondrial DNA of extant *Picea* populations in the southern and northern ends of the valley and to extract ancient-DNA from fossil *Picea* pollen (not lake sediment!) from sites at the two ends of the Setesdal transect.

Setesdal is a palaeoecologist's long-term ecological observatory, abounding in exciting, challenging, and critical questions for palaeoecologists, young and not so young, to try to answer.

Rjukan – John Birks

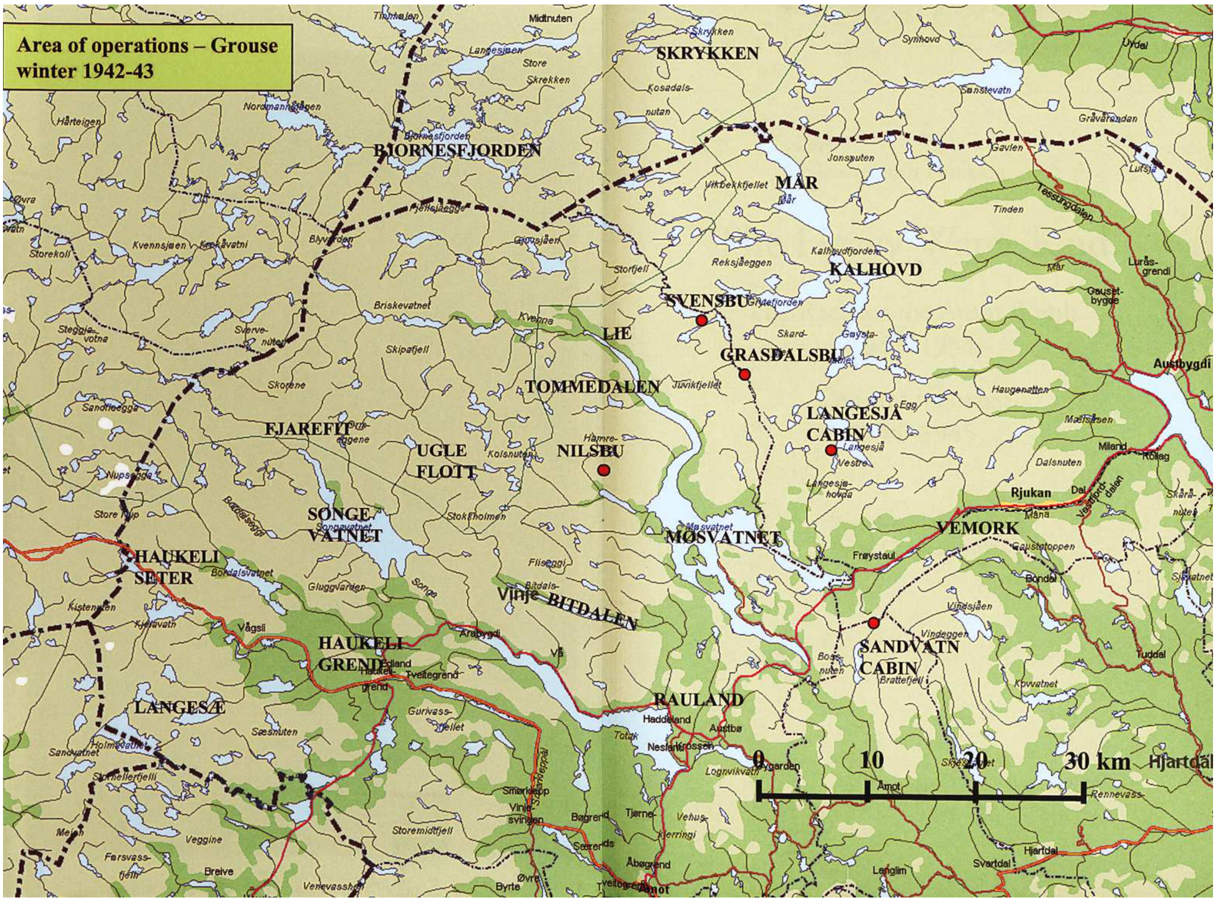
Rjukan is the site of Norwegian heavy-water sabotage undertaken by Norwegian saboteurs during World War II. The sabotage was to prevent the German nuclear energy project from acquiring heavy water (=deuterium oxide) which could be used in the production of nuclear weapons. It took several attempts to sabotage the Norsk Hydro site at Vemork.

The site was built in 1934 and was the first commercial plant capable of producing heavy water as a by-product of fertiliser production with a capacity of 12 tons per year.

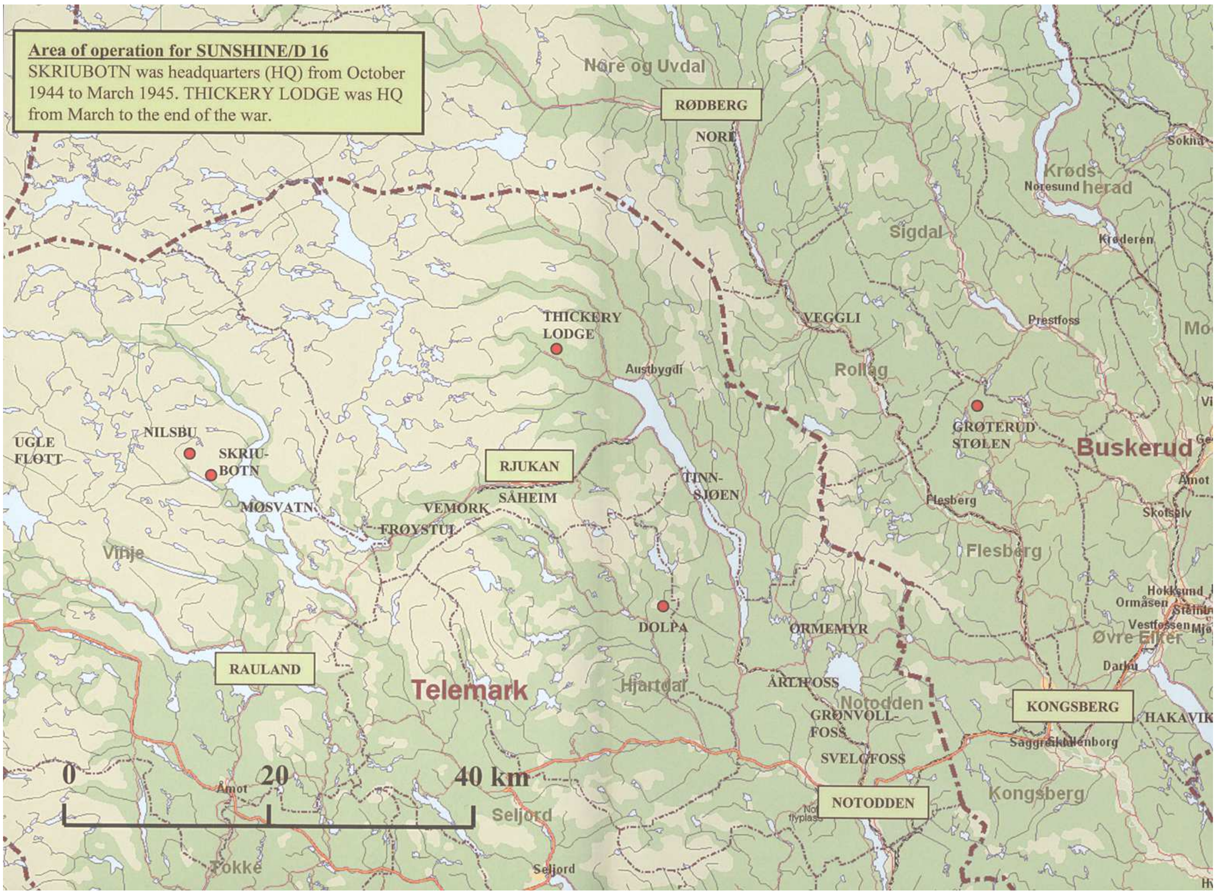
Four operations were required to ensure the destruction of the plant and the loss of the heavy water produced.

1. Operation Grouse – Special Operations Executive successfully parachuted four Norwegians as an advanced team onto the Hardangervidda on 19 October 1942. Over-wintered at Sandvatn Cabin south-east of Møsvatnet.
2. Operation Freshman – unsuccessful operation on 19 November 1942 mounted by British paratroopers who were to rendezvous with Operation Grouse and proceed to Vemork. This attempt failed as military gliders crashed short of their destination along with one of their tugs, a Halifax bomber. All were killed in the crashes or were captured, interrogated, and executed by the Gestapo under Hitler's Commando order. There is a memorial at RAF Skitten in Scotland. The most important consequence of this unsuccessful raid was that the Germans were now alerted to a determined Allied interest in heavy-water production. The Operation Grouse team (later renamed Swallow) had to over-winter on the Hardangervidda, living on moss and lichen and the occasional reindeer.
3. Operation Gunnerside – on 16 February 1943, an additional six Norwegian agents were parachuted in and met up with the Swallow team. The group of 10 attacked the Vemork plant of 27/28 February 1943 and successfully destroyed over 500 kg of heavy water and some equipment. Over 3000 German soldiers searched for the commandos – 4 skied 400 km to Sweden, 2 went to Oslo and join Milorg, and four remained under-cover in the area.
4. Heavy water production resumed in April 1943. The US Air Force started a series of raids, including a raid by 143 B-17 heavy bombers dropping 711 bombs, of which about 600 missed the plant. Germany then decided to abandon the plant and to move the heavy-water stocks and critical components to Germany in February 1944. One of the under-cover agents decided to sabbotage the SF *Hydro* ferry on Tinnsjøen when it would be carrying the railway wagons containing the heavy water. This was achieved on 20 February 1944 with the loss of 14 civilian lives.

We now know that the heavy-water had a pH of 14 but it did not contain high concentrations of D_2O. The barrels contained only about 0.5-1% pure heavy-water. Germany would have needed about 5 tons of heavy water to get a nuclear reactor running, whereas only about 500 kg of heavy water was carried on the ferry *Hydro*, not enough for one reactor let alone the 10+ tons needed for the production of plutonium for a nuclear weapon. Major miscalculations by Werner Heisenberg (as revealed in the Farm Hall transcripts (1945)) might have contributed to Germany giving up the race for an atom bomb so easily. Other German ideas were to develop nuclear-powered U-boats and to produce radioactive poison gas. These were all dropped after the sinking of the SF Hydro on Tinnsjøen.



Area of operations – Grouse winter 1942-43



Area of operation for SUNSHINE/D 16

SKRIUBOTN was headquarters (HQ) from October 1944 to March 1945. THICKERY LODGE was HQ from March to the end of the war.

(Poulsson 2009)

References

Birks HH & Birks HJBB 2000. Future uses of pollen analysis must include macro fossils. *Journal of Biogeography* 27: 31-35.

Birks HJBB 2007. Estimating the amount of compositional change in late-Quaternary pollen-stratigraphical data. *Vegetation History and Archaeobotany* 16: 197-202.

Birks HH, Larsen E & Birks HJBB 2005. Did tree-*Betula* Pinus, and Picea survive the last glaciation along the west coast of Norway? A review of the evidence, in light of Kullman (2002). *Journal of Biogeography* 32: 1461-1471.

Bjune AE *et al.* 2009. The development and local stand-scale dynamics of a Picea abies forest in southeastern Norway. *The Holocene 19*: 1073-1082.

Bjune AE, Helvik I & Birks HJBB 2012. The beech (*Fagus sylvatica*) forests near Larvik – their origin and history. *Vegetation History and Archaeobotany,* in press.

Brooks SJ 2003. Chironomid analysis to interpret and quantify Holocene climate change. In: *Global change in the Holocene*. Eds. Mackay A, Battarbee R, Birks J, Oldfield F. Arnold, UK.

Dahl SO & Nesje A 1996. A new approach to calculating Holocene winter precipitation by combining glacier equilibrium-line altitudes and pine-tree limits: a case stud from Hardangerjøkulen, central southern Norway. *The Holocene* 6: 381-398.

Eide W *et al.* 2006. Holocene forest development along the Setesdal valley, southern Norway, reconstructed from macrofossil and pollen evidence. *Vegetation History and Archaeobotany* 15: 65-85.

Heiri O 2004. Within-lake variability of subfossil chironomid assemblages in shallow Norwegian lakes. *Journal of Paleolimnology* 32: 67-84.

Heiri *et al.* 2003 Effects of within-lake variability of fossil assemblages on quantitative chironomid-inferred temperature reconstruction. *Palaeography, Paleoclimatology, Palaeoecology* 199: 95-106.

Lüder B 2007. *The potential of non-alpine lakes for quantitative palaeotemperature reconstructions based on subfossil chironomids: A comparative palaeolimnological study from southern Norway*. PhD Dissertation, University of Bremen.

Moen A 1999. *Vegetasjonsatlas for Norge*. Statens kartverk, Norge. *National Atlas Norway: Vegetation*. Norwegian Mapping Authority, Norway (ISBN: 82-7945-000-9 Vegetation)

Nesje A 2009. Latest Pleistocene and Holocene alpine glacier fluctuations in Scandinavia. *Quaternary Science Reviews* 28: 2119-2136.

Odland A & Birks HJB 1999. The altitudinal gradient of vascular plant richness in Aurland, western Norway. *Ecography* 22: 548-566.

Parducci *et al.* 2012. Glacial Survival of Boreal Trees in Northern Scandinavia. *Science* 335: 1083-1086.

Selsing L 2010. *Mennesker og natur i fjellet i Sør-Norge etter siste istid med hovedvekt på mesolitikum*. Arkeologisk museum, Universitetet i Stavanger.

Tollefsrud MM *et al.* 2008. Genetic consequences of glacial survival and postglacial colonization in Norway spruce: combined analysis of mitochondrial DNA and fossil pollen. *Molecular Ecology* 17: 4134-4150.

Tollefsrud MM *et al.* 2009. Combined analysis of nuclear and mitochondrial markers provide new insight into the genetic structure of North European *Picea abies*. *Heredity* 102: 549-562.