XXVI BOG ('MOOR') EXCURSION

OF THE INSTITUTE OF PLANT SCIENCES,

UNIVERSITY OF BERN

WESTERN AND CENTRAL NORWAY

August 17 - 24 2002

EXCURSION GUIDE

Contributions from

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Botanical Institute, University of Bergen, August 2002

ITINERARY

Sunday 18 August	Bergen - Lygra Heath Centre - Kotedalen - Mongstad - Måløy Overnight in Måløy Leaders: Mons Kvamme, Peter Emil Kaland, Kari Loe Hjelle, Jorunn Larsen, Sylvia Peglar
Monday 19 August	Måløy - Kråkenes - Skattestraumene - Vingen - Måløy Overnight in Måløy Leaders: Hilary Birks, Sylvia Peglar, Kari Loe Hjelle
Tuesday 20 August	Måløy - Briksdalsbreen - Stryn Glacier Museum - Lom - Sletten Overnight at Sletten Leaders: Atle Nesje, John Birks
Wednesday 21 August	Sletten - Råtåsjøen - Gåvålisætra - Kongsvoll - Drivdalen - Sletten Overnight at Sletten Leaders: John Birks, Wenche Eide, Jorunn Larsen, Sylvia Peglar, Gina Clarke
Thursday 22 August	Sletten - Brurskardtjønn - Bøvertun - Sognefjell Overnight at Sognefjellshytta Leaders: Anne Bjune, John Birks, Jorunn Larsen
Friday 23 August	Sognefjell - Bøvertun - Leirdalen - Storbreen - Kyrkja - Sognefjell Overnight at Sognefjellshytta Leaders: John Birks, Anne Bjune
Saturday 24 August	Sognefjell - Aurland - Voss - Håvrå - Bergen Overnight in Bergen Leaders: John Birks, Hilary Birks, Kari Loe Hjelle

ACKNOWLEGEMENT

The printing costs for this Excursion Guide have been covered by a generous grant from the Olaf Grolle Olsens Legat Printing Fund.

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17.-18. August
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Johan Blytts vei 30, N-5096 Bergen
tel: (+ 47) 55 20 80 70

18.-20. August
Norlandia Måløy Hotell, Måløy
tel: (+ 47) 57 84 94 00

20.- 22. August
Sletten Fjellgard, Dalholen
tel: (+ 47) 62 49 31 08

22.-24. August
Sognefjellshytta, Bøverdalen
tel: (+ 47) 61 21 29 34

24.-25. August
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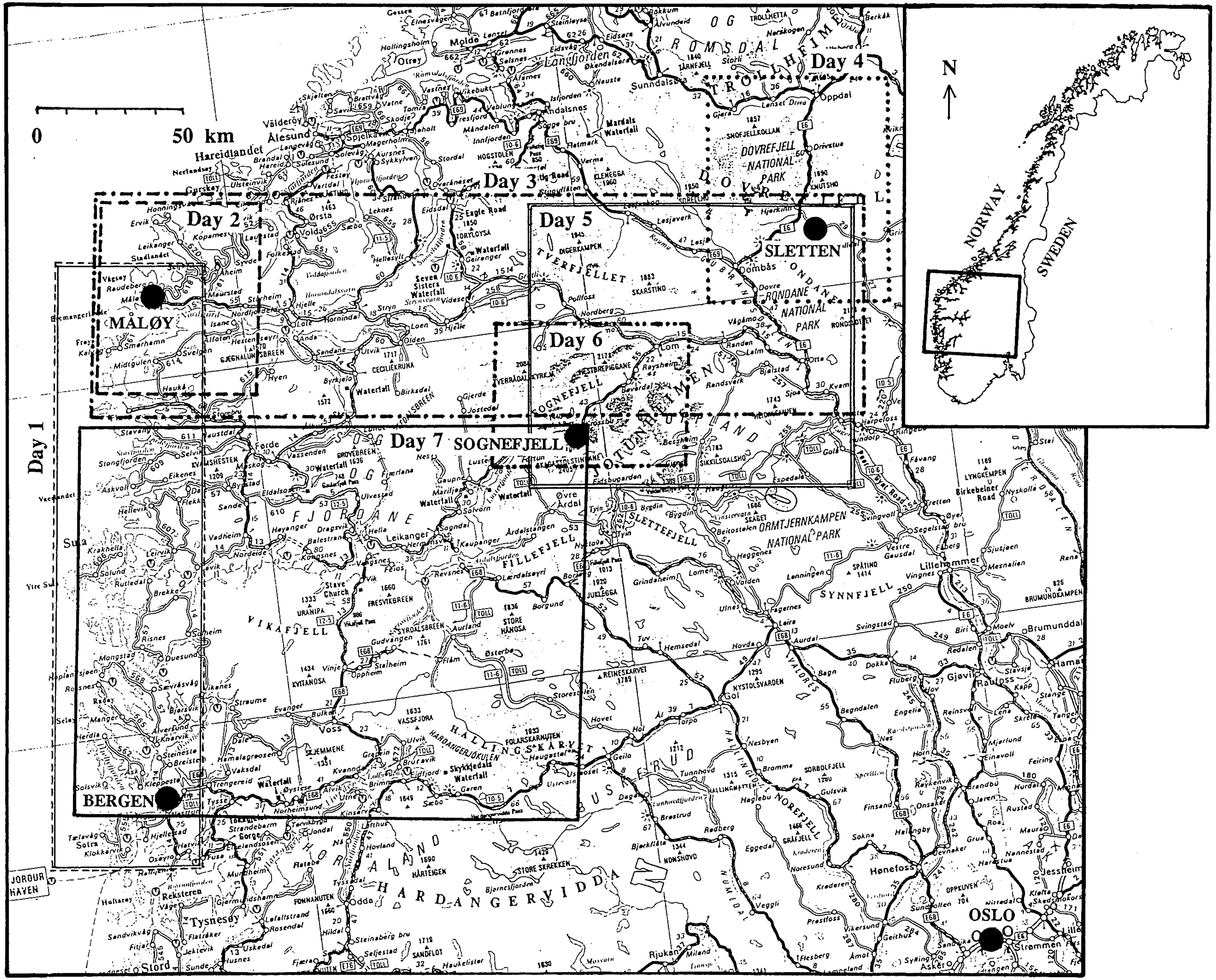
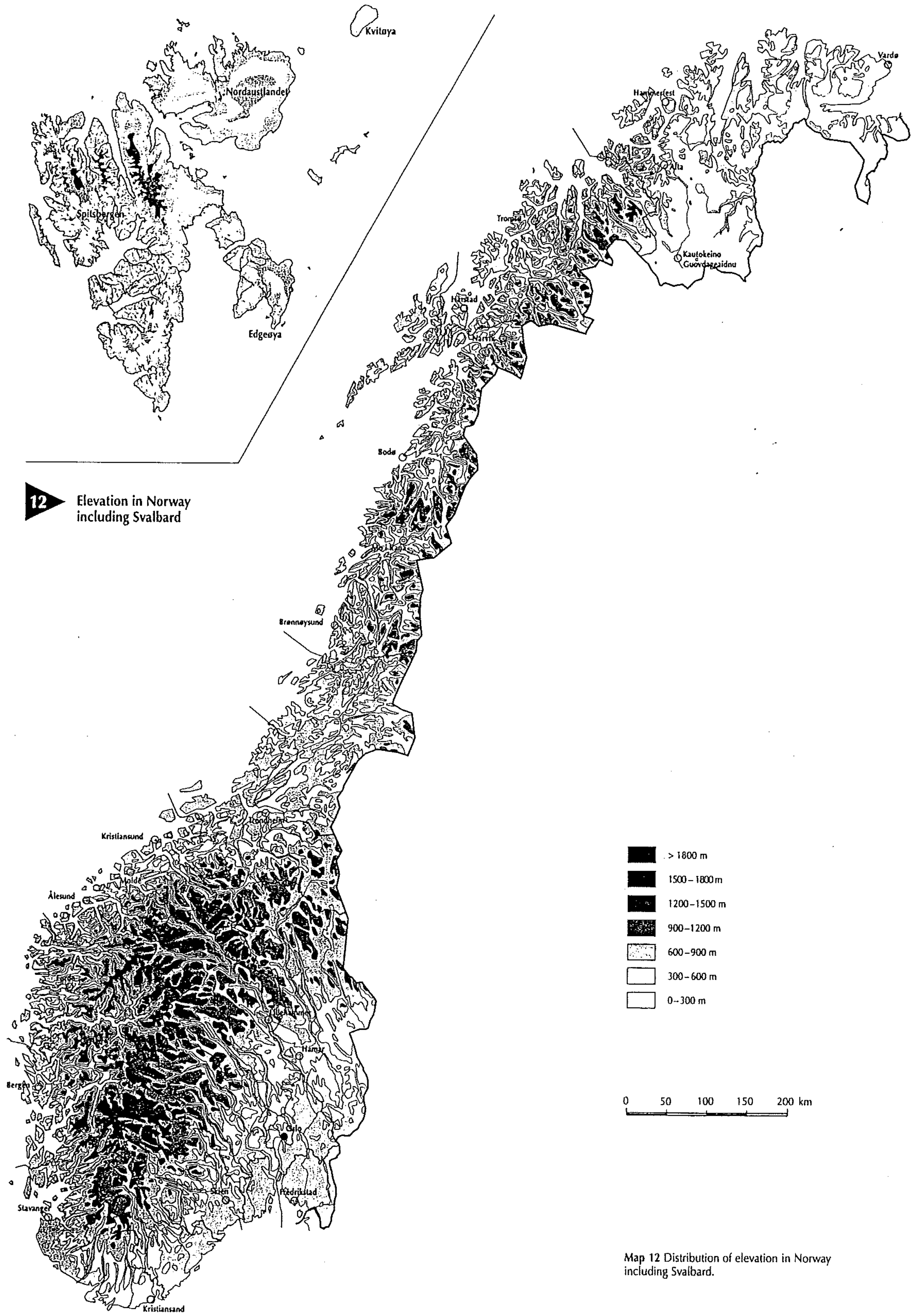
INTRODUCTION TO

WESTERN AND CENTRAL NORWAY

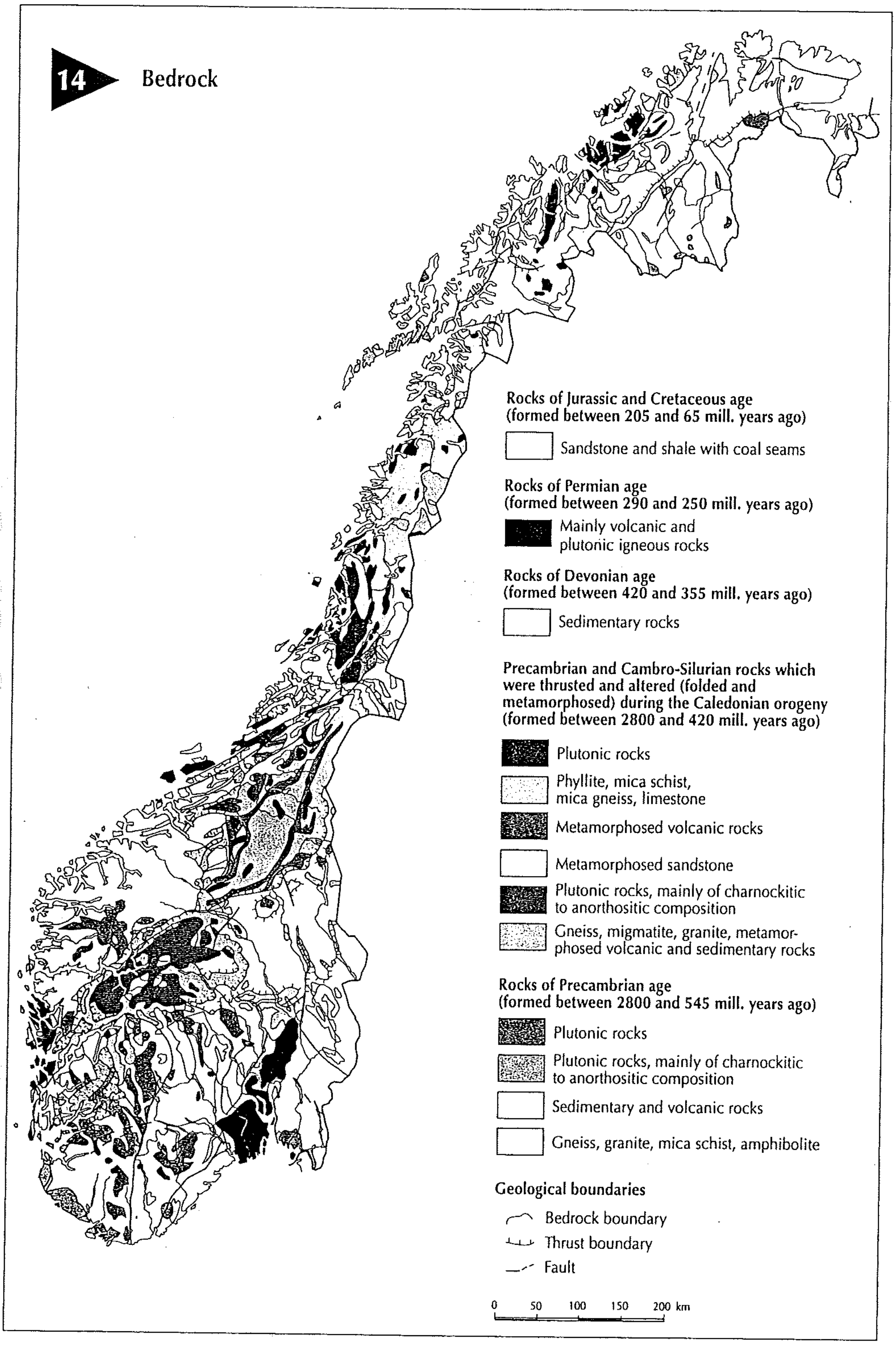


0
50 km
Day 1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7
MÅLØY
SLETTEN
SOGNEFJELL
BERGEN
OSLO
N
NORWAY
SWEDEN

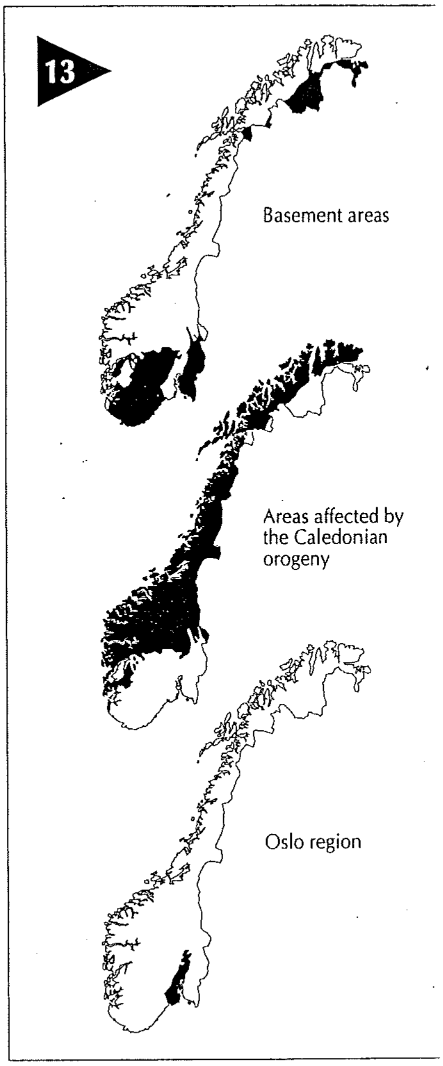
12 Elevation in Norway including Svalbard



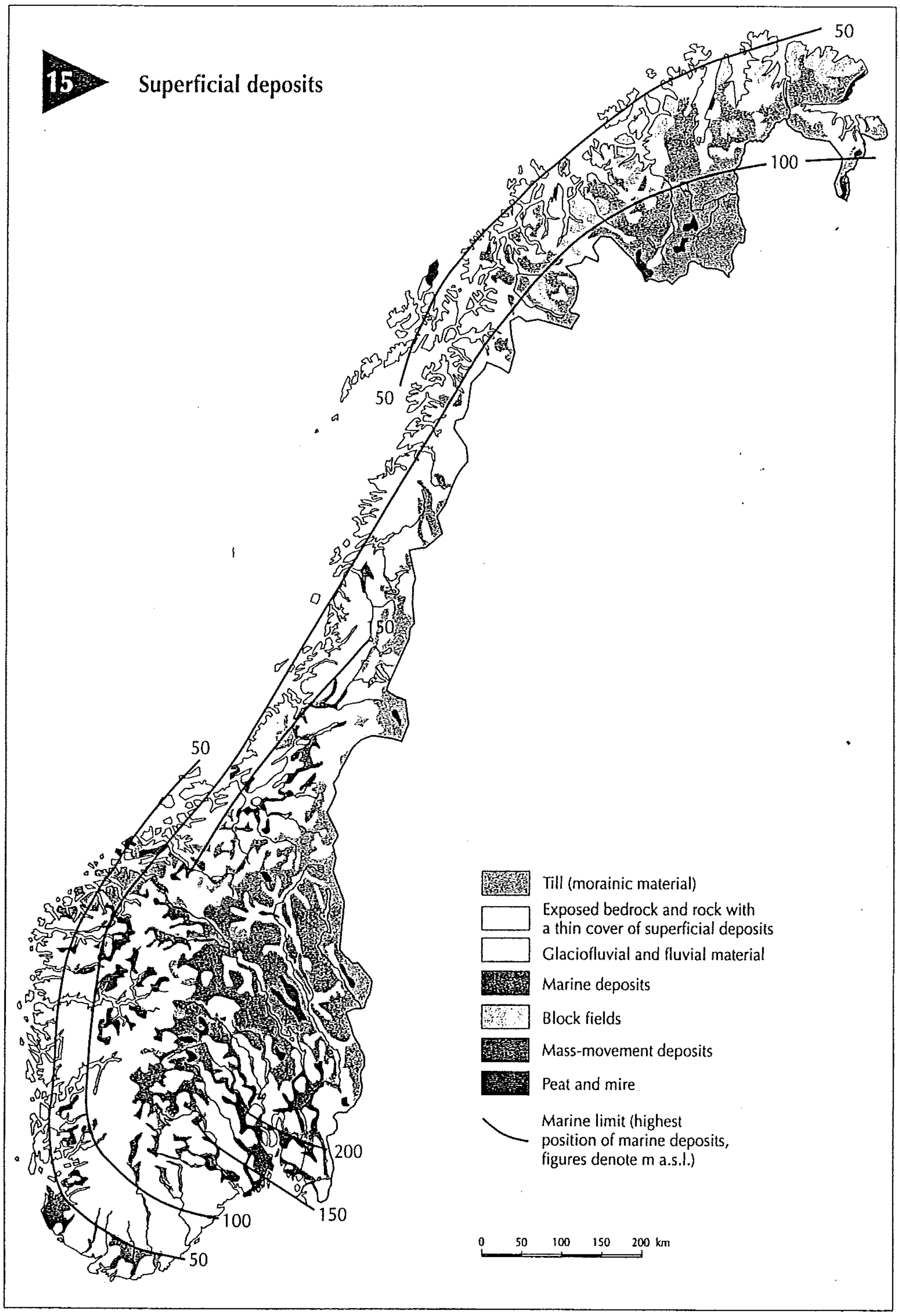
Map 12 Distribution of elevation in Norway including Svalbard.



Map 14 The map shows the broad distribution of various kinds of bedrock 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. Precambrian rocks (e.g. gneisses and granites) 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 northern 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.

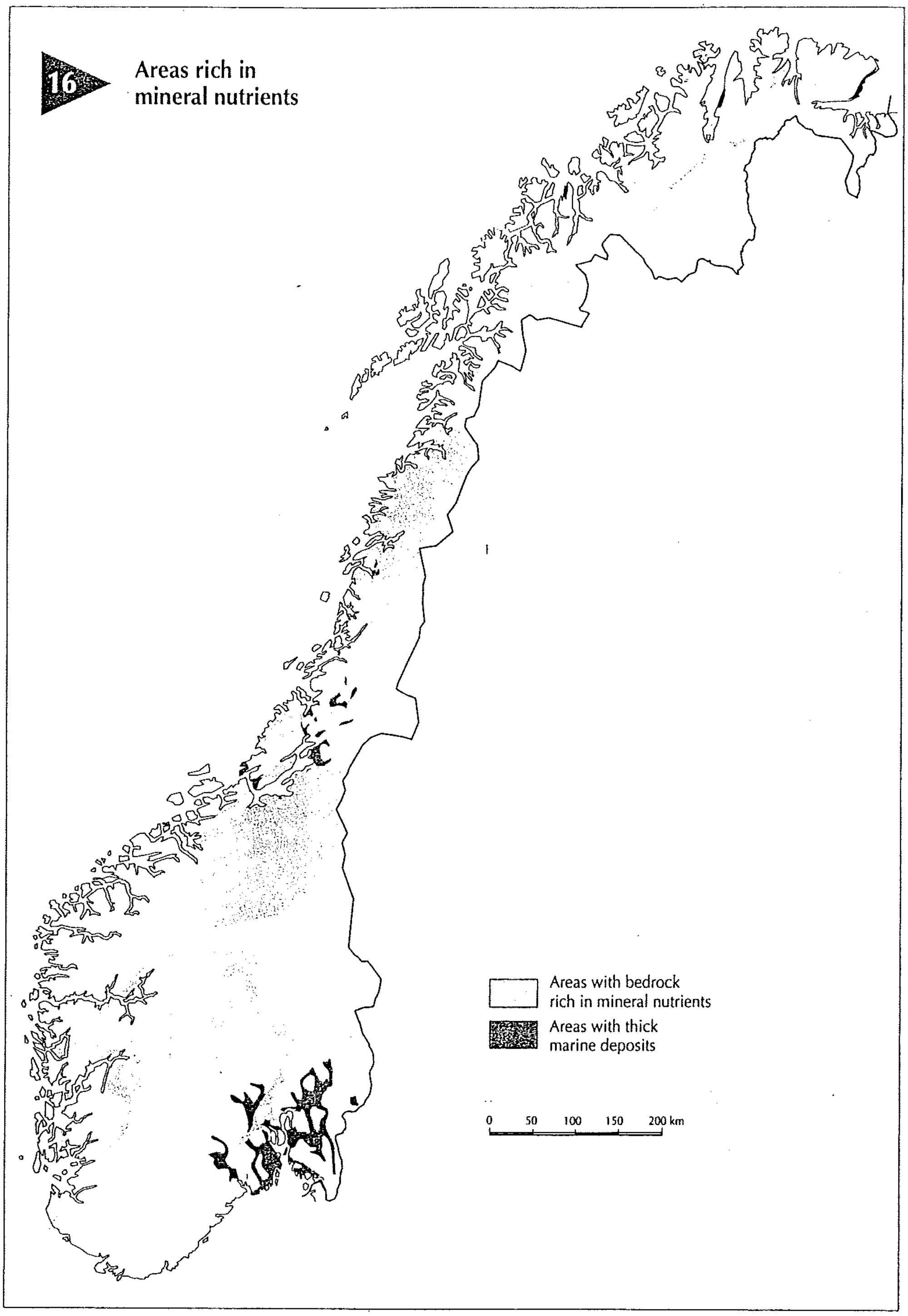


Map 13 The small maps show the Precambrian basement areas, where ancient, hard rocks have bee little affected by younger earth movements, areas where the Caledonian orogeny (mountain building episode) has strongly deformed and altered the original bedrock, and the 'Oslo region' rocks forme by volcanic activity in the Permian era.



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.

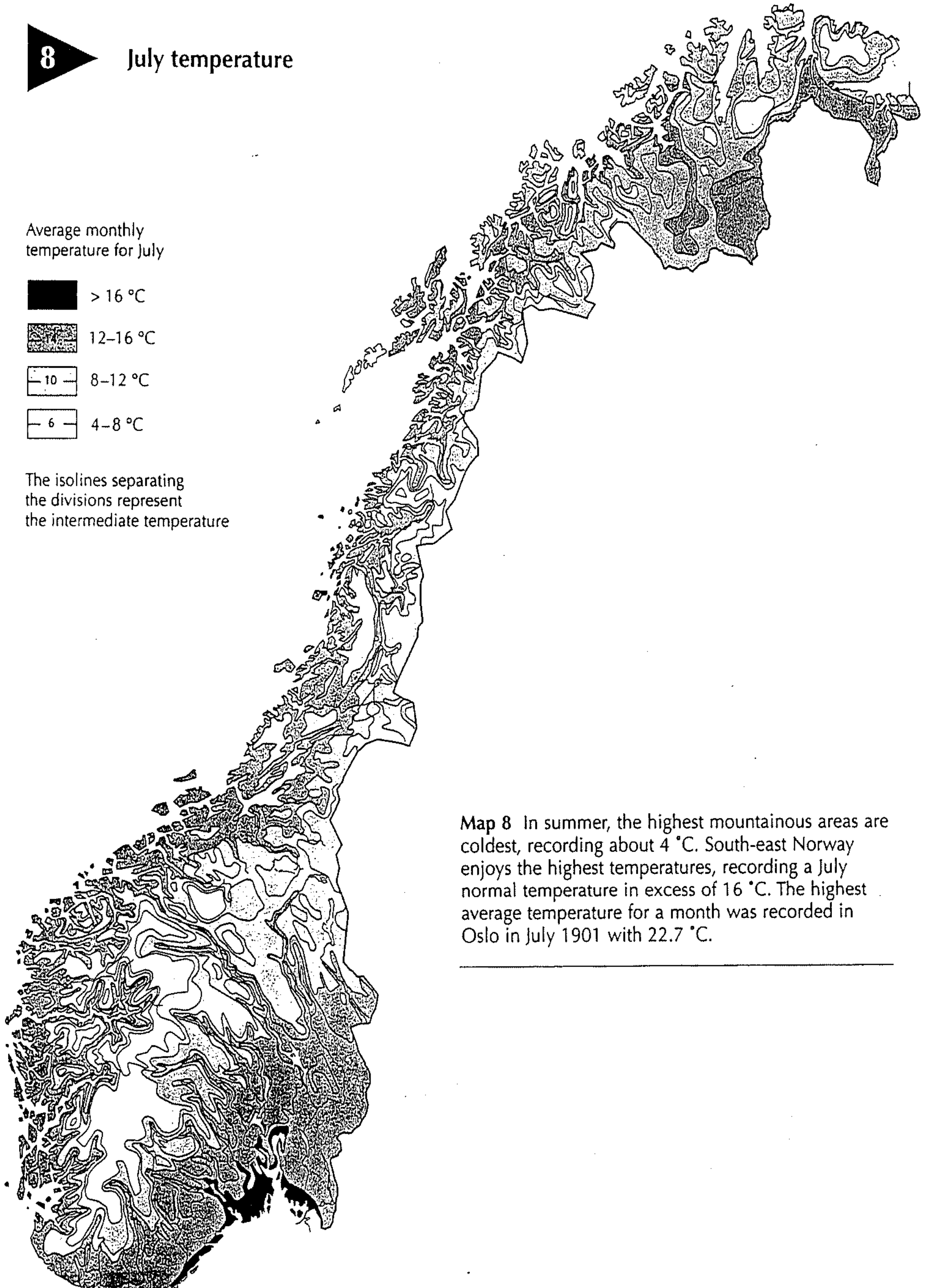
The marine limit, which is the highest level reached by the sea measured by its present-day elevation in the terrain, is shown as lines on the map. It is highest north of Oslofjord, where it stands 221 m above present-day sea level at Aker. In the Jæren district in the extreme south-west, it is 20 m a.s.l., at Stad in the extreme west it is a mere 5 m a.s.l., at Trondheim it is about 180 m a.s.l., at Tromsø about 50 m a.s.l. and at Kirkenes about 75 m a s.l.



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 in such areas. The map is grossly simplified and is largely based on 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.

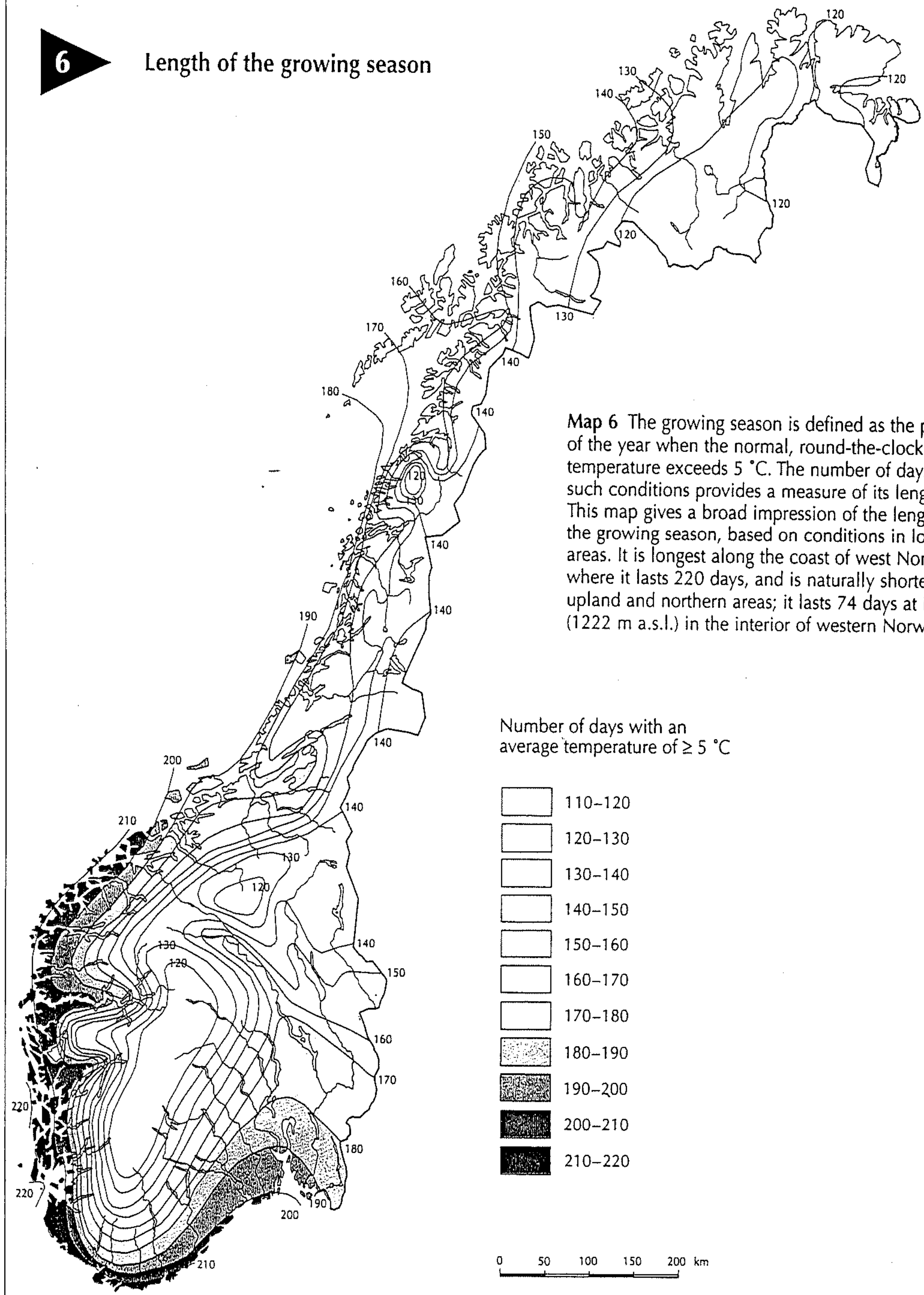
Orography and geologi

8 July temperature



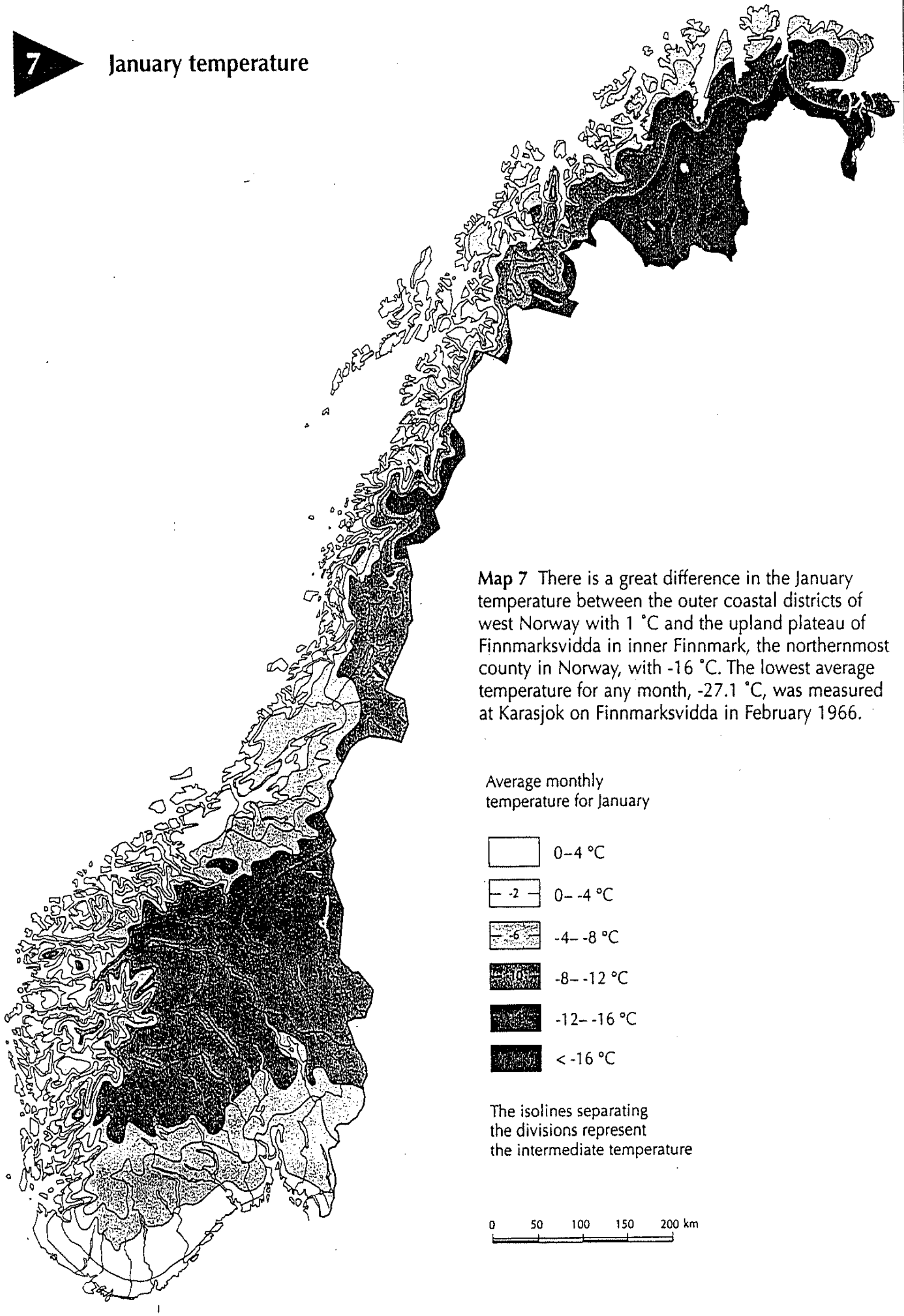
Map 8 In summer, the highest mountainous areas are coldest, recording about 4 °C. South-east Norway enjoys the highest temperatures, recording a July normal temperature in excess of 16 °C. The highest average temperature for a month was recorded in Oslo in July 1901 with 22.7 °C.

6 Length of the growing season



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 lasts 74 days at Finse (1222 m a.s.l.) in the interior of western Norway.

7 January temperature



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 county in Norway, with -16 °C. The lowest average temperature for any month, -27.1 °C, was measured at Karasjok on Finnmarksvidda in February 1966.

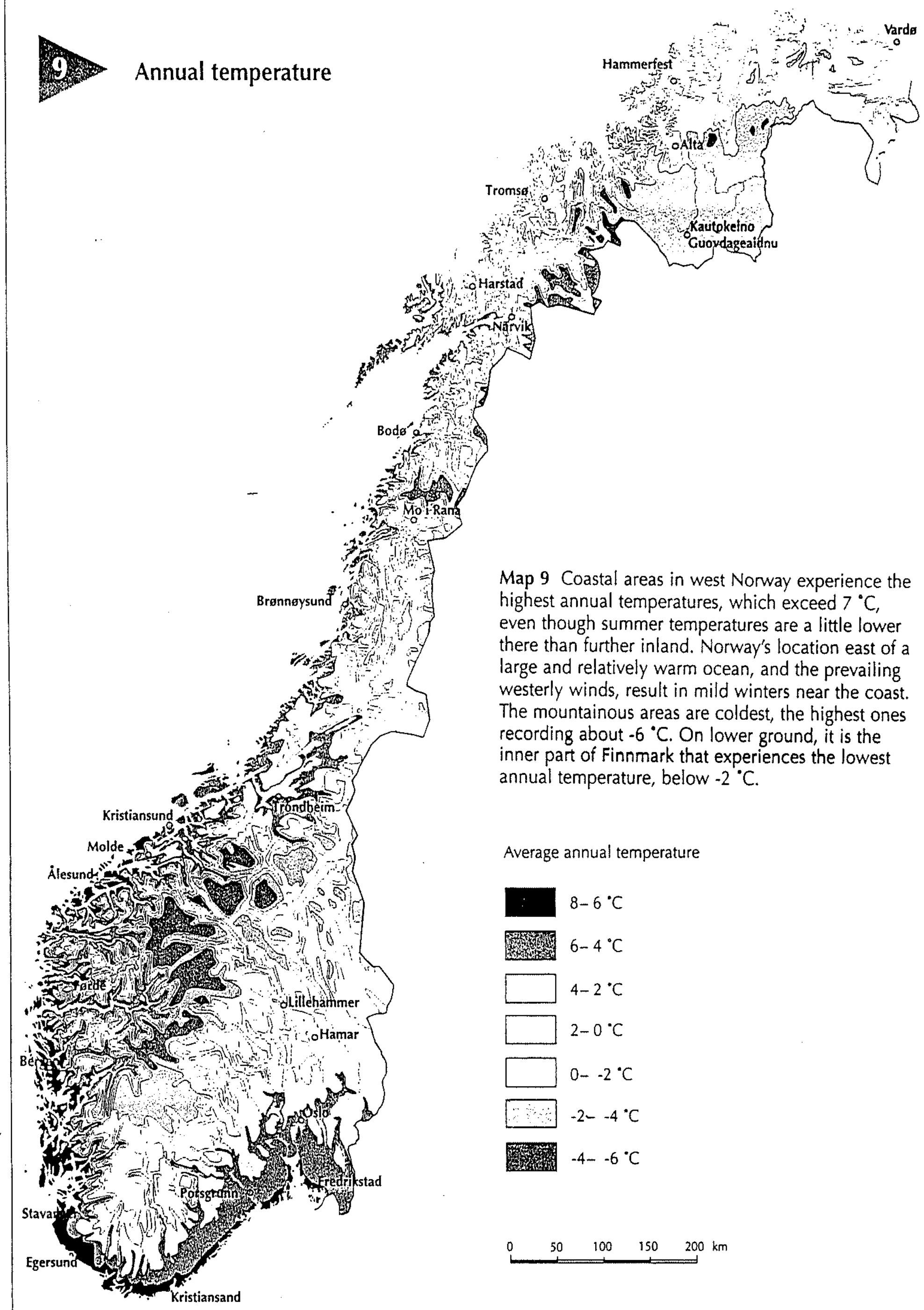
Average monthly temperature for January

- 0–4 °C
- 0– -4 °C (-2)
- -4– -8 °C (-6)
- -8– -12 °C (-10)
- -12– -16 °C
- < -16 °C

The isolines separating the divisions represent the intermediate temperature

0 50 100 150 200 km

9 Annual temperature

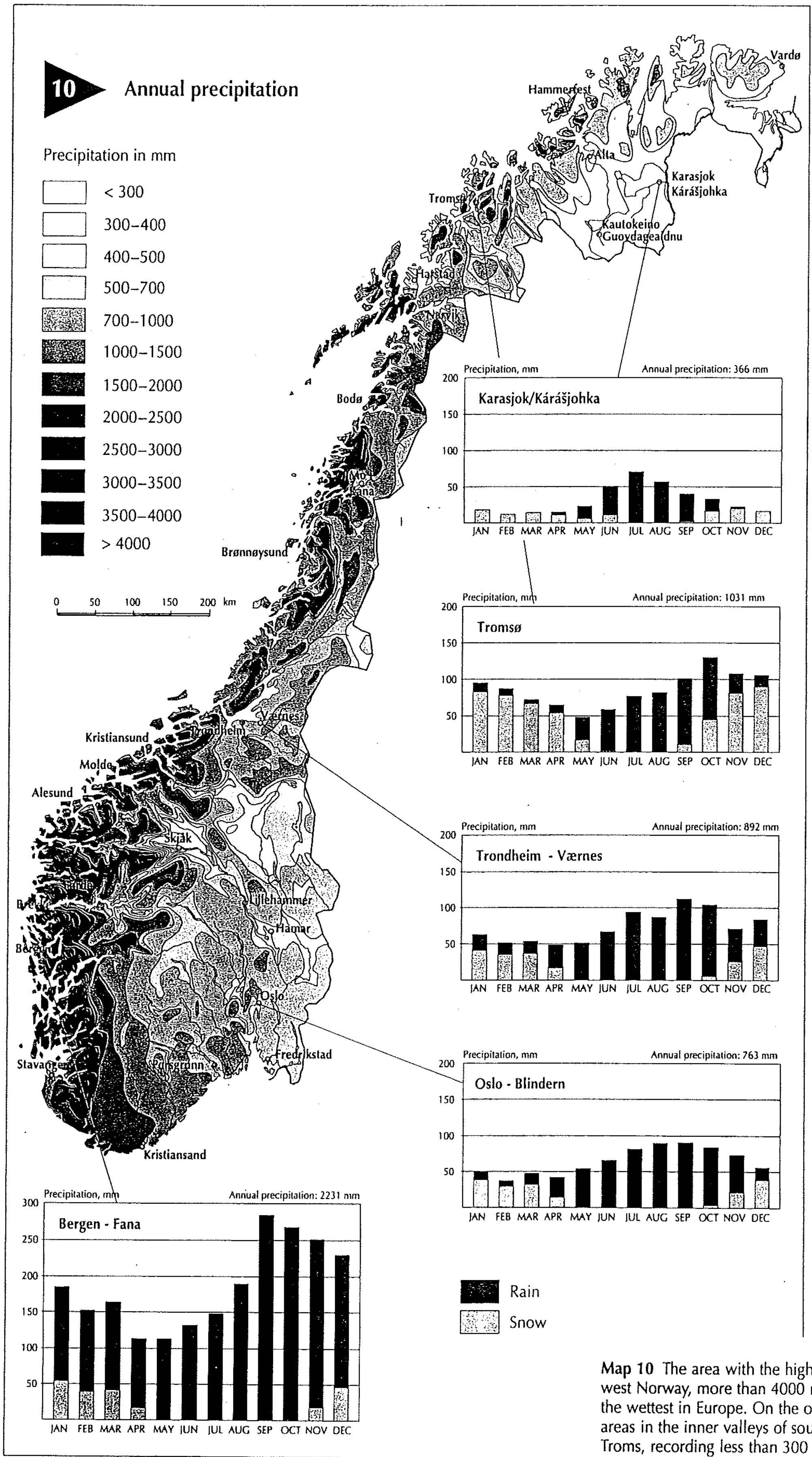


Map 9 Coastal areas in west Norway experience the highest annual temperatures, which exceed 7 °C, even though summer temperatures are a little lower there than further inland. Norway's location east of a large and relatively warm ocean, and the prevailing westerly winds, result in mild winters near the 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.

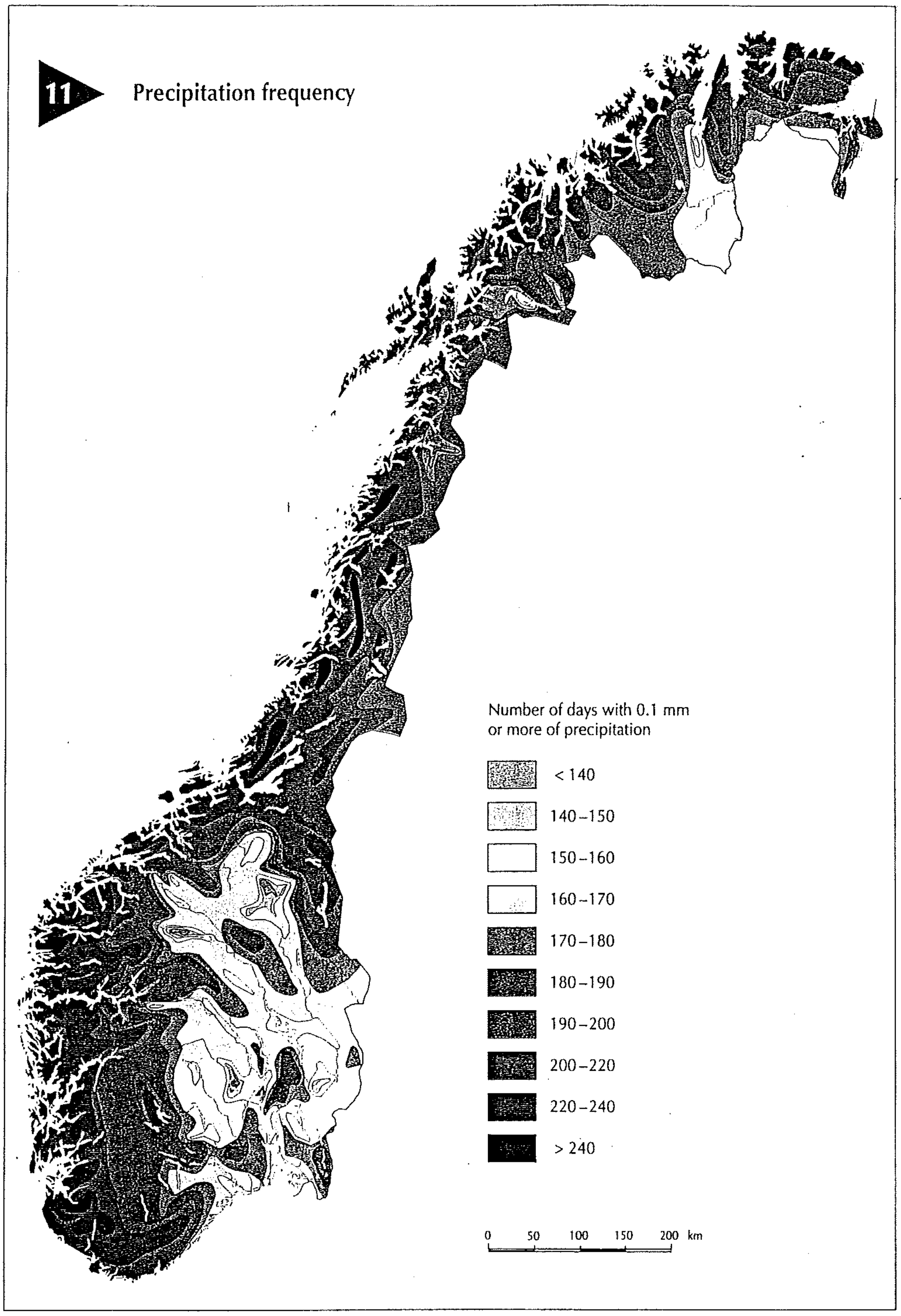
Average annual temperature

- 8– 6 °C
- 6– 4 °C
- 4– 2 °C
- 2– 0 °C
- 0– -2 °C
- -2– -4 °C
- -4– -6 °C

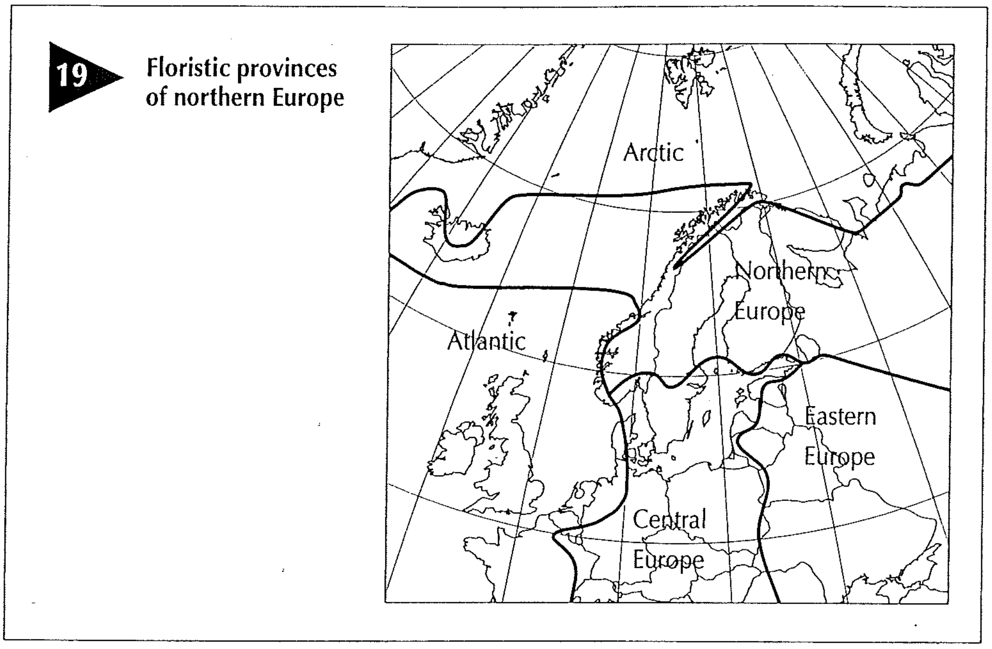
0 50 100 150 200 km



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, are among the driest in western Europe. 1 mm of precipitation means that 1 litre of water has fallen per m². The precipitation graphs show how the precipitation varies through the year and the proportion that falls as snow.



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.



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

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.

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

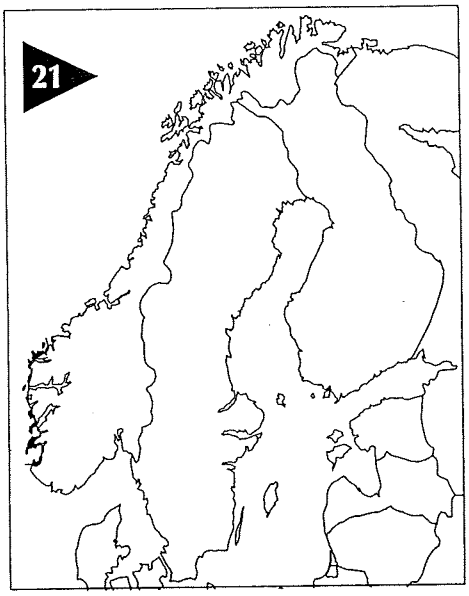
Western species
- strongly western species
- distinctly western species
- weakly western species
- species with a western tendency

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

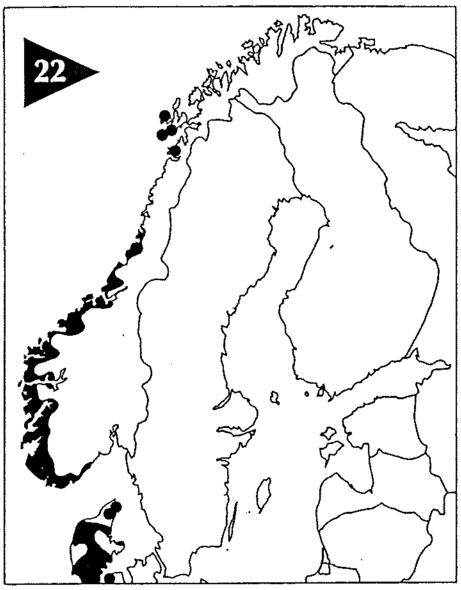
South-eastern species
- strongly south-eastern species
- distinctly south-eastern species
- weakly south-eastern species
- species with a south-eastern tendency

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

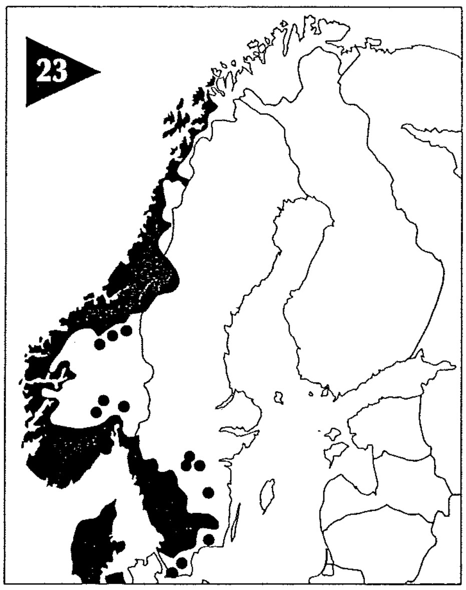
Alpine and northern boreal species
- strongly alpine species
- distinctly alpine species
- weakly alpine and northern boreal species
- species with an alpine and a northern boreal tendency



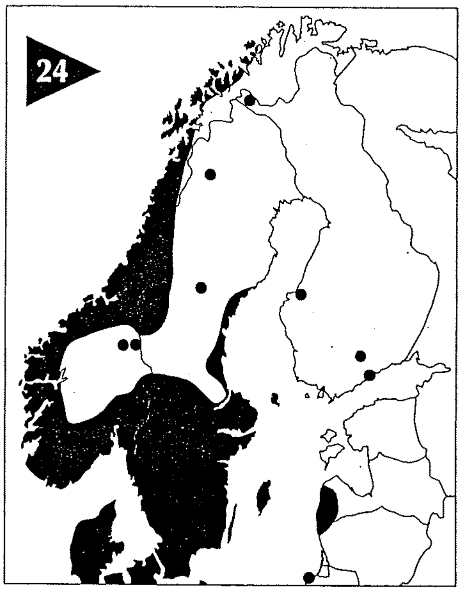
Bell heather (*Erica cinerea*) :



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

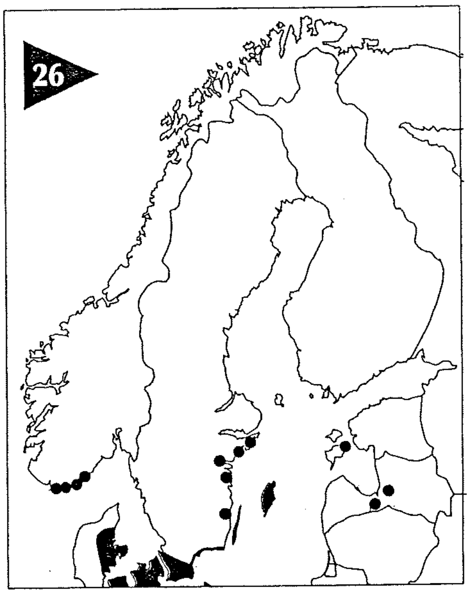


Map 23 Bog asphodel (*Narthecium ossifragum*), a weakly western species.

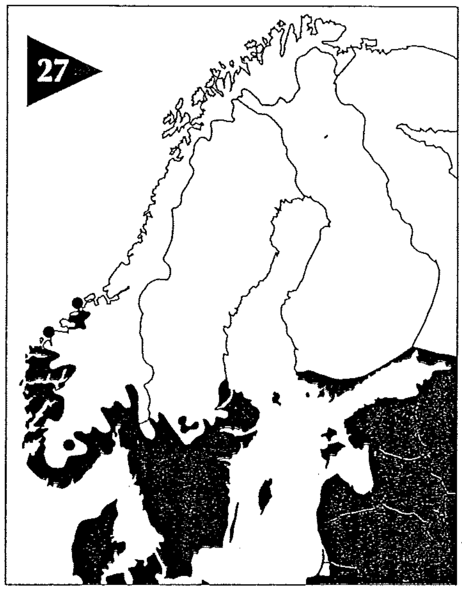


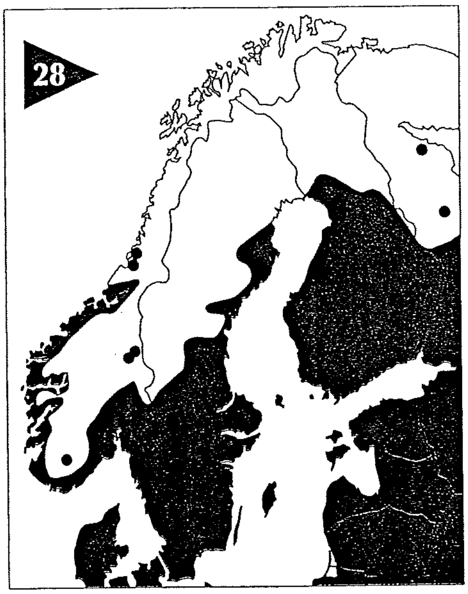
Map 24 Hard-fern (*Blechnum spicant*), a species with a western tendency.

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

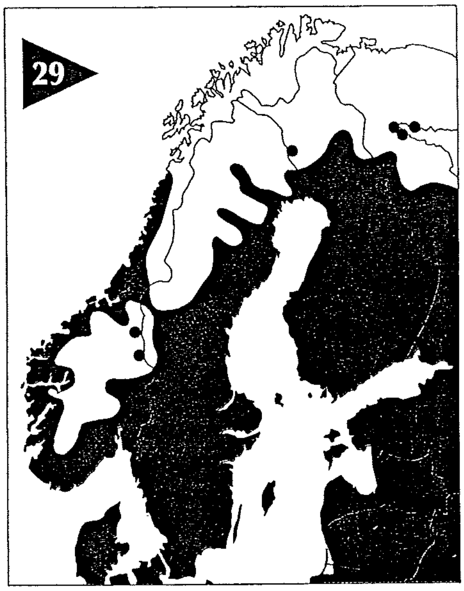


Map 26 Grey sedge (*Carex divulsa*), a strongly southern species.



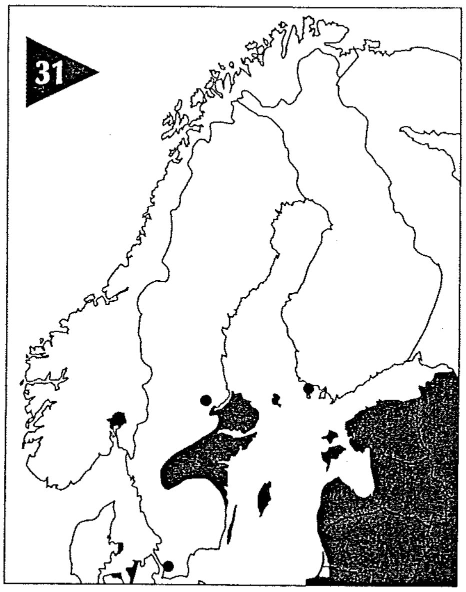


Map 28 Alder (*Alnus glutinosa*), a weakly southern species.

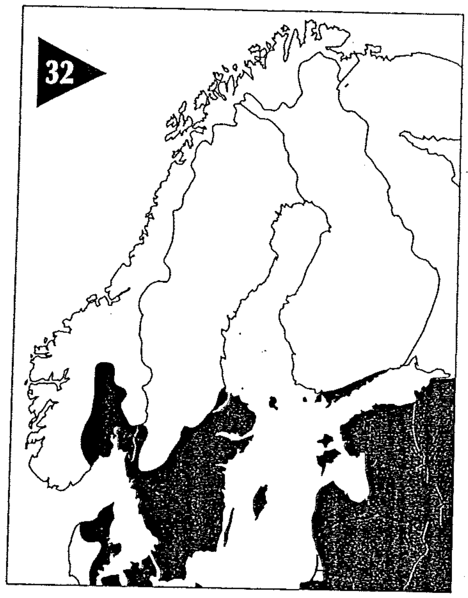


Map 29 Eared willow (*Salix aurita*), a species with a southern tendency.

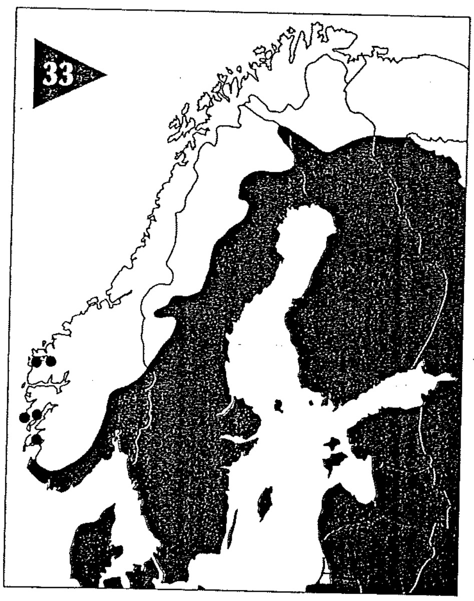
South-eastern species



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

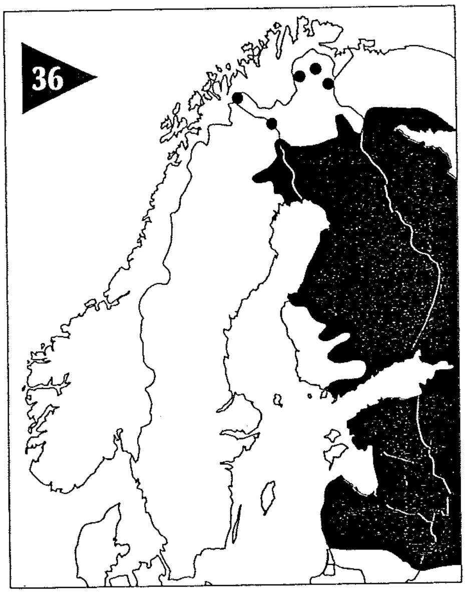


Map 32 Green strawberry (*Fragaria viridis*), a distinctly south-eastern species.

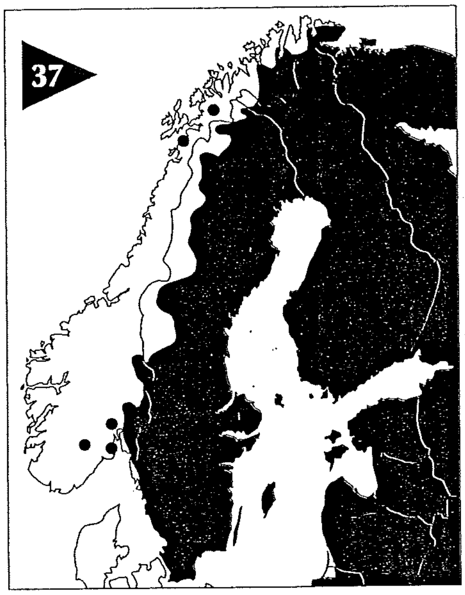


Map 33 Milk-parsley (*Peucedanum palustre*), a weakly south-eastern species.

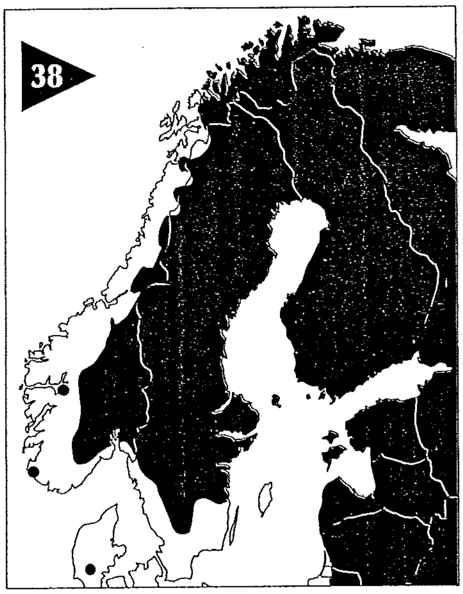
Map 34 Tufted loosestrife (*Lysimachia thyrsiflora*), a species with a south-eastern tendency.



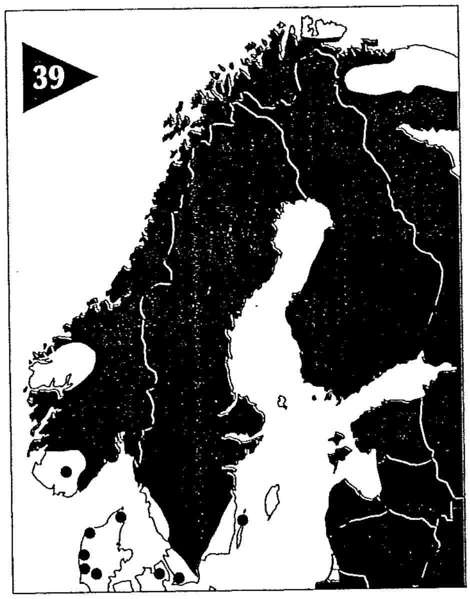
Map 36 Leatherleaf (*Chamaedaphne calyculata*), a strongly eastern species.



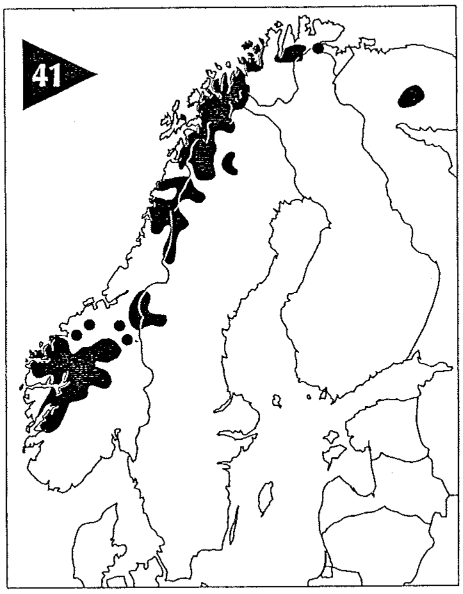
Map 37 Labrador-tea (*Ledum palustre*), a distinctly eastern species.



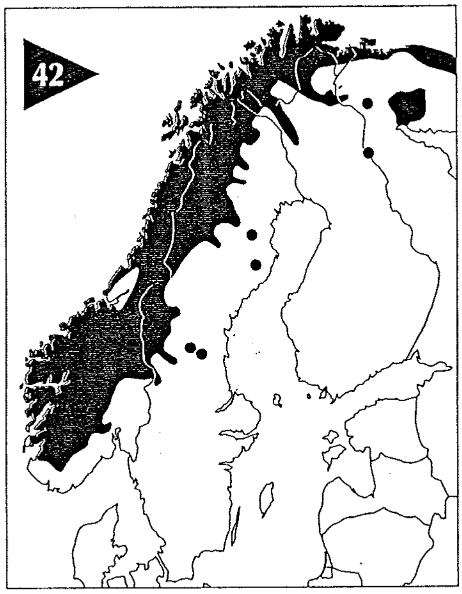
Map 38 Sceptred lousewort (*Pedicularis sceptrum-carolinum*), a weakly eastern species.



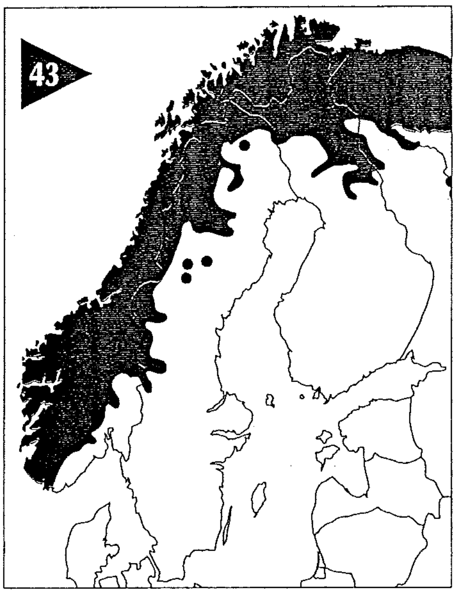
Map 39 String sedge (*Carex chordorrhiza*), a species with an eastern tendency.



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



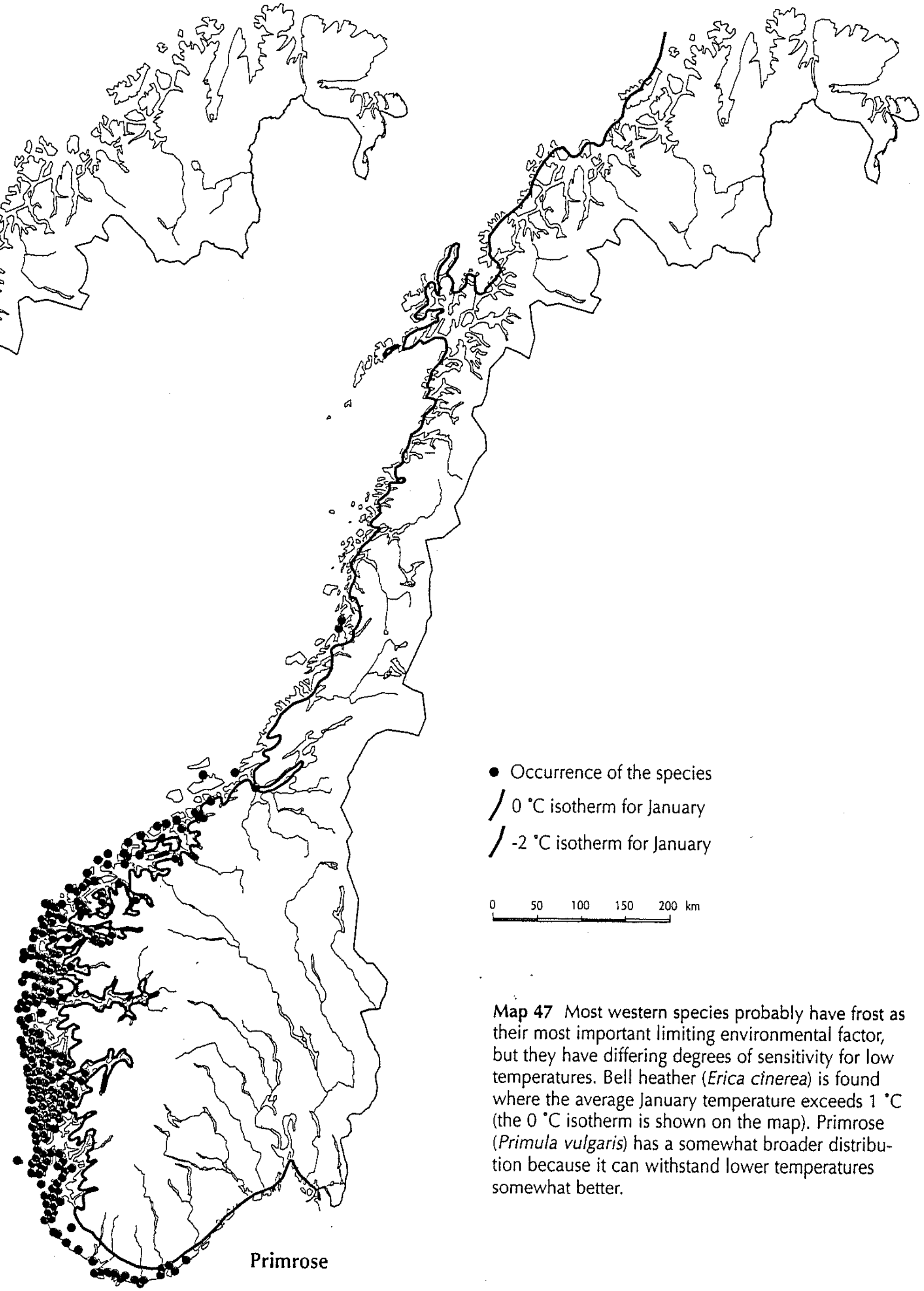
Map 42 Dwarf willow (*Salix herbacea*), a distinctly alpine species.



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

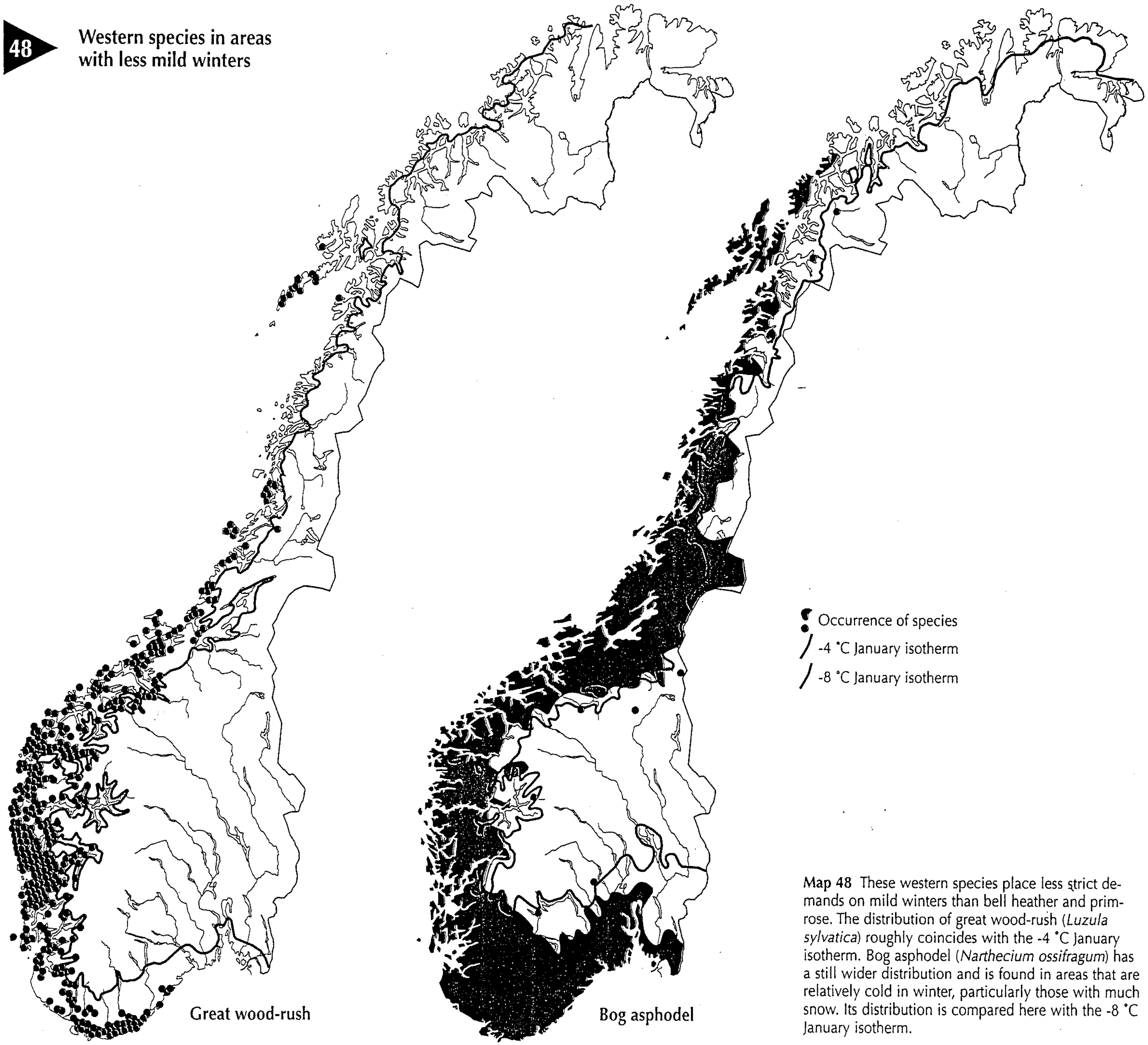
Map 44 Dwarf birch (*Betula nana*), a species with an alpine tendency.

47 Western species in areas with mild winters

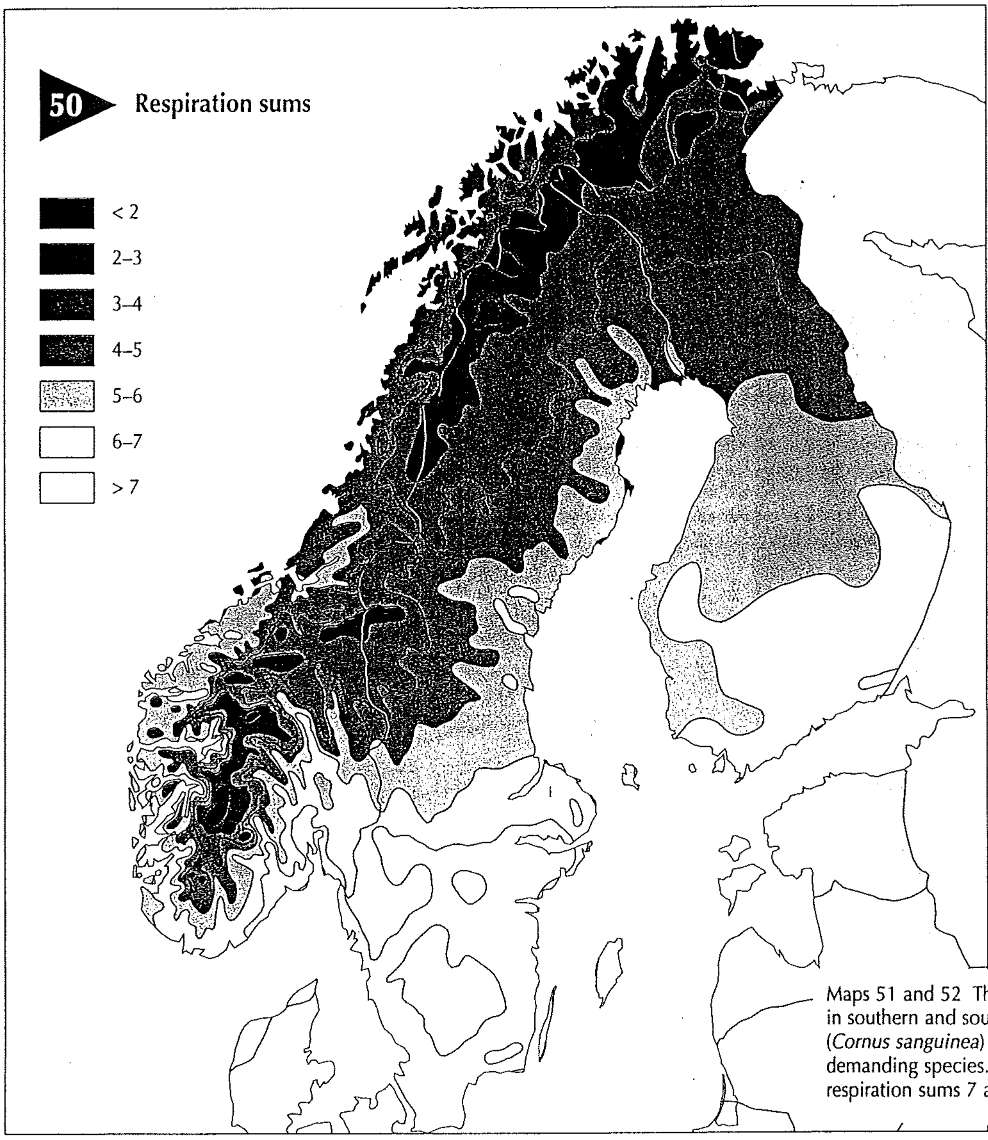


Map 47 Most western species probably have frost as their most important limiting environmental factor, but they have differing degrees of sensitivity for low temperatures. Bell heather (*Erica cinerea*) is found where the average January temperature exceeds 1 °C (the 0 °C isotherm is shown on the map).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

48 Western species in areas with less mild winters

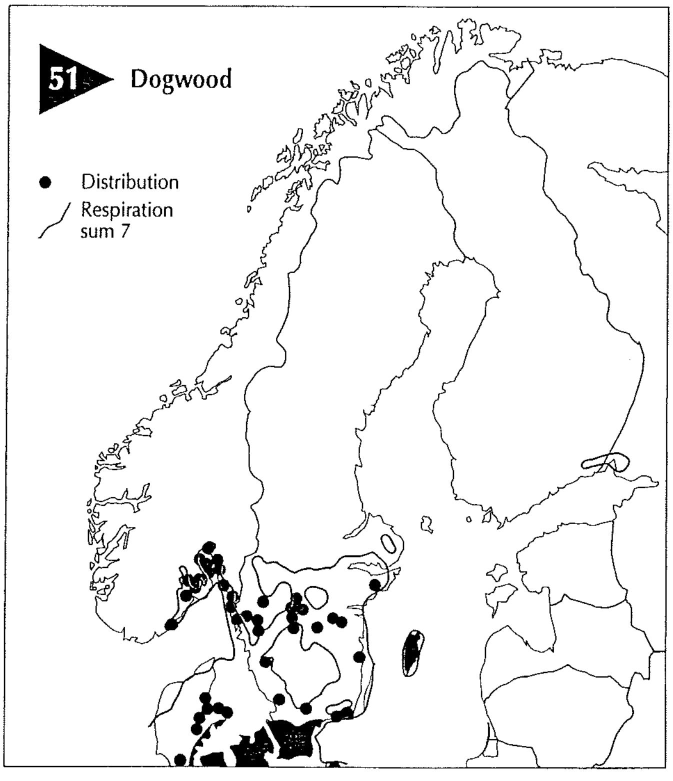


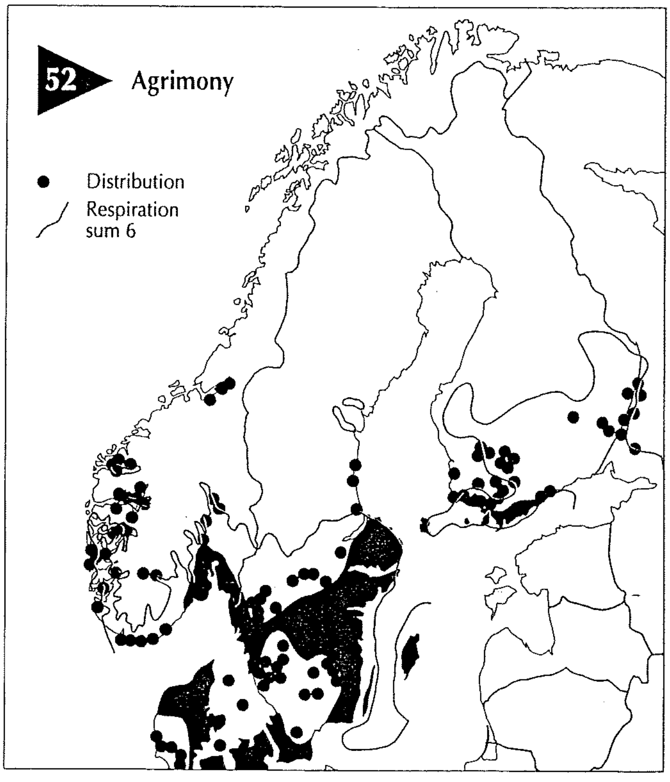
Map 48 These western species place less strict demands on mild winters than bell heather and primrose. The distribution of great wood-rush (*Luzula sylvatica*) roughly coincides with the -4 °C January isotherm. Bog asphodel (*Narthecium ossifragum*) has a still wider distribution and is found in areas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



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.

Map 50 The possibility for the 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.

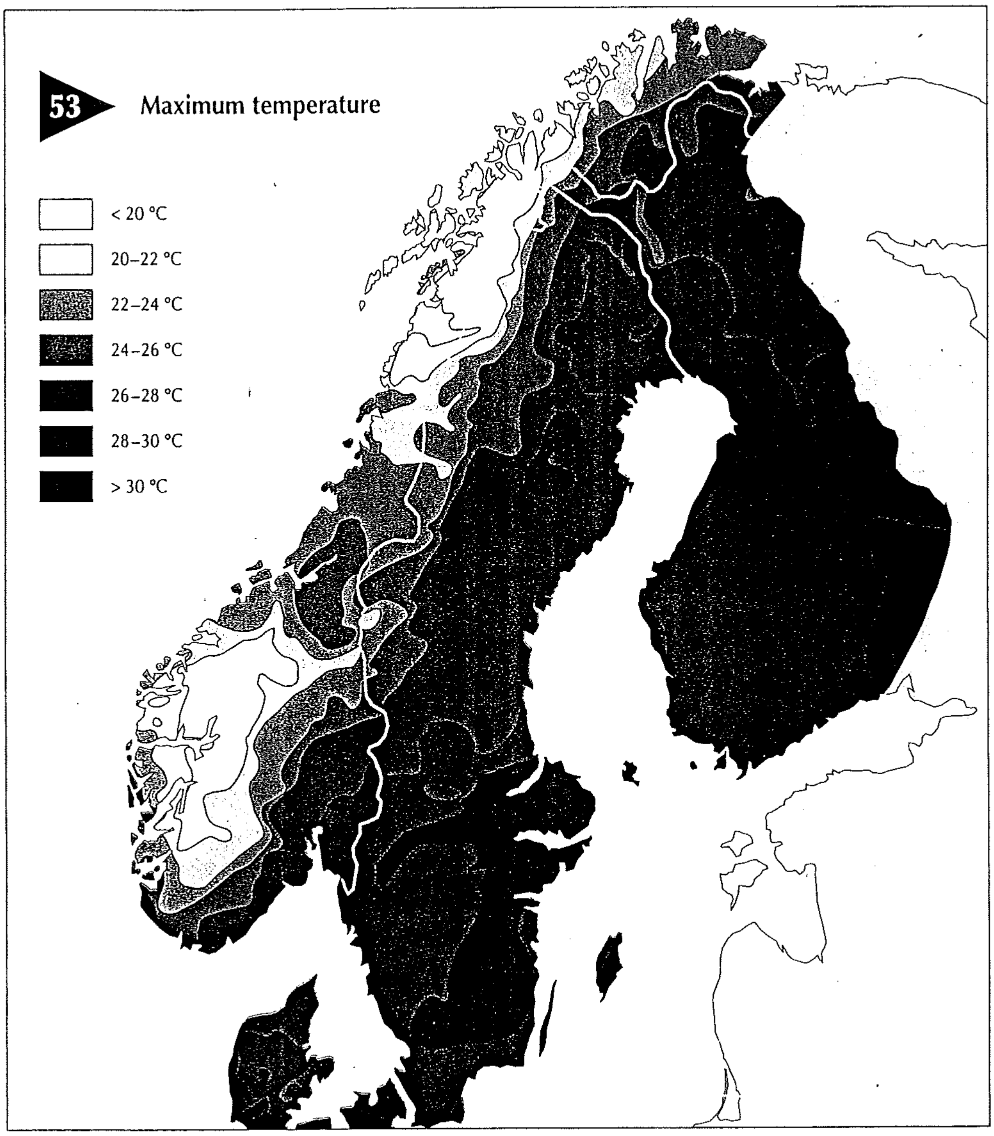




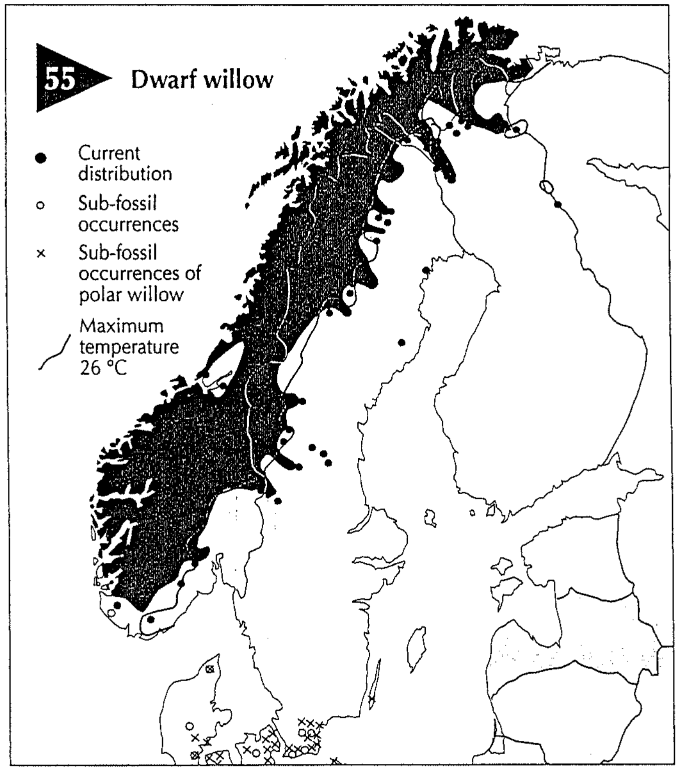
Eastern distribution

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.

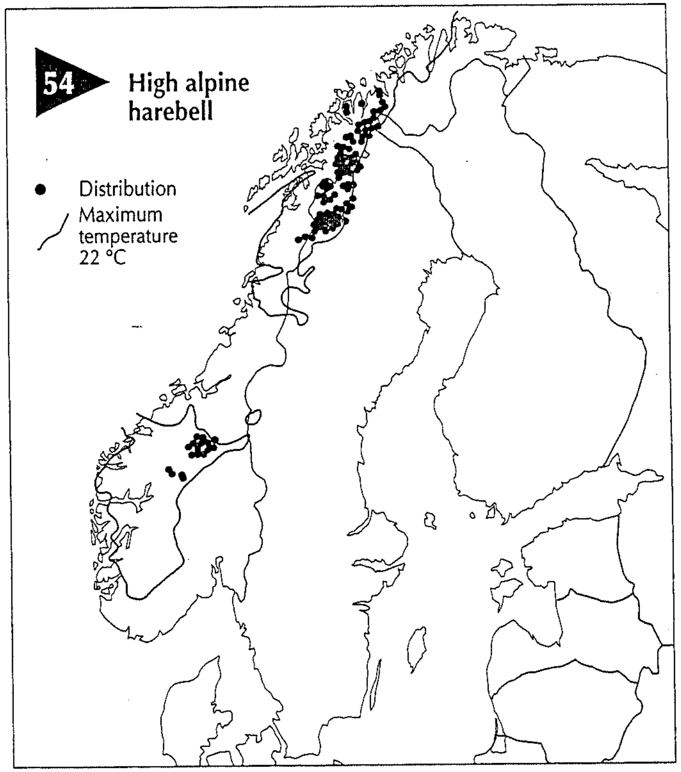
The latter hypothesis is based on there being two main ways in which the dormancy is induced and broken, through threshold values for day length or for temperature. The winter temperature in oceanic areas is less predictable than in more continental regions, and Eilif Dahl's hypothesis was that it is 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.



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.



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 (rings) or the related polar willow (*Salix polaris*, crosses) from the end of the last Ice Age, when these parts of southern Scandinavia had a significantly cooler climate.



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.

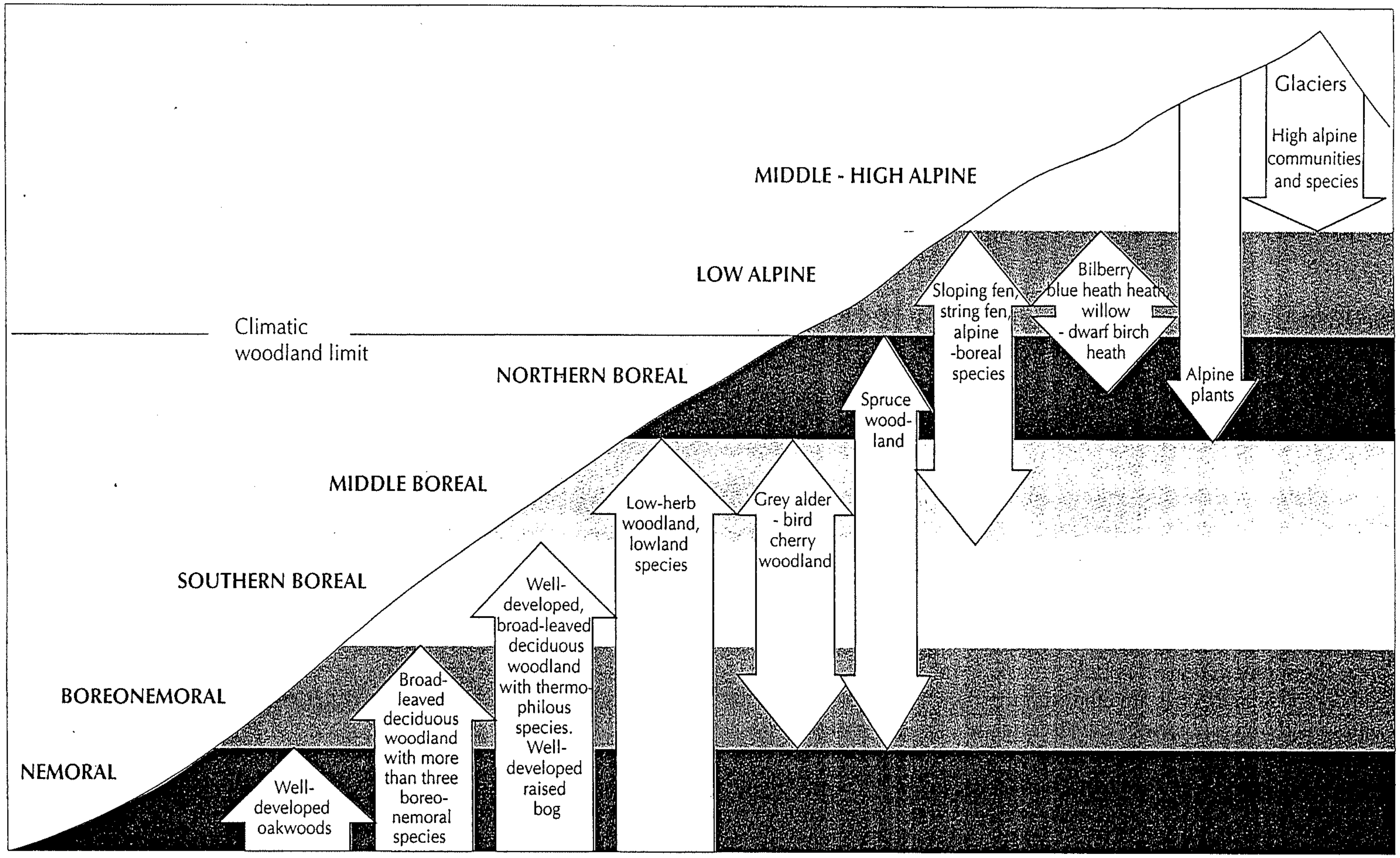
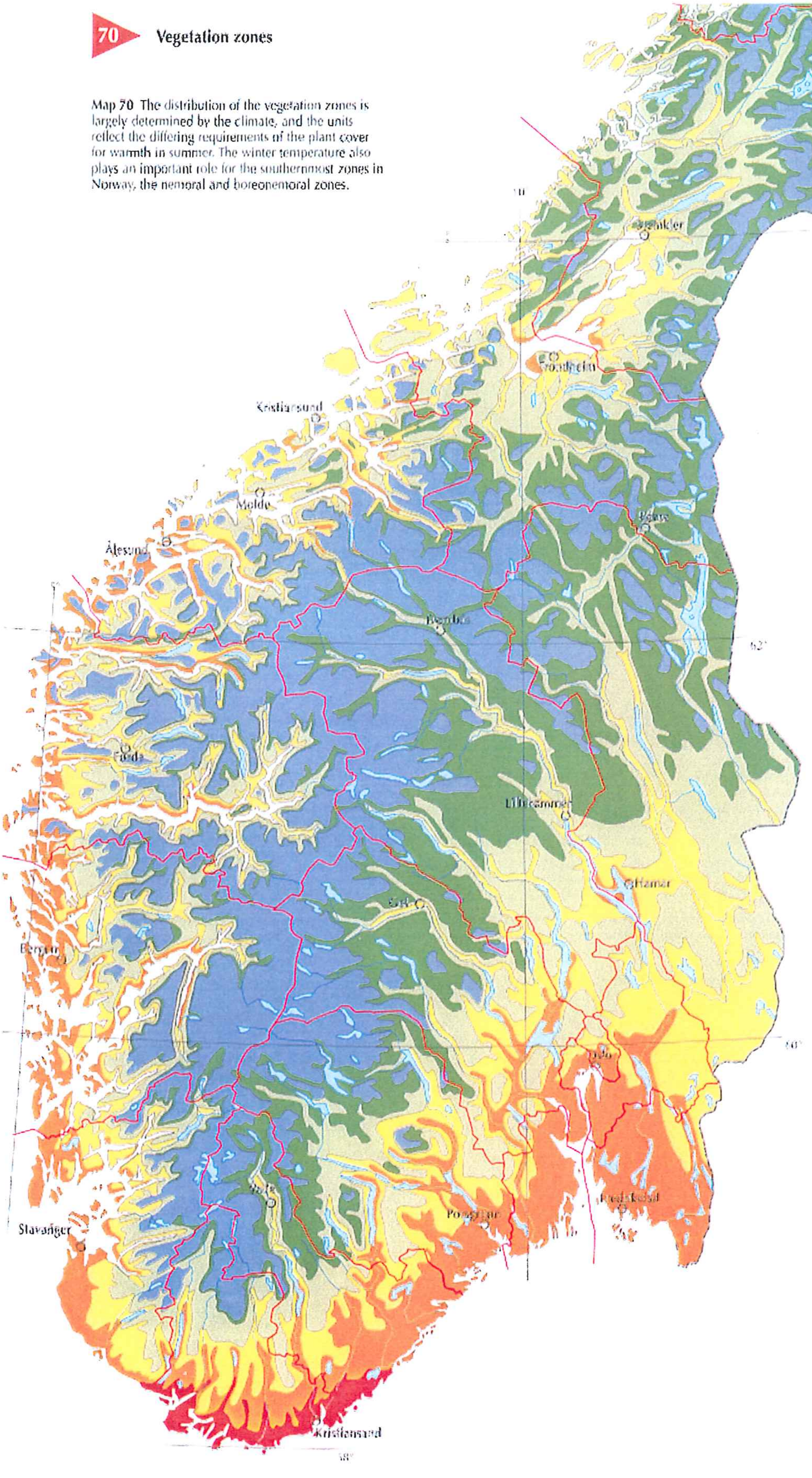


Figure 17 The main criteria for distinguishing the vegetation zones shown schematically. Lists of species that are limited to the zones (e.g. nemoral species, boreonemoral species, etc.) are given under the description of each zone.

70 Vegetation zones

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.



Low, middle and high alpine zones; southern arctic zone
The alpine zones occupy the area above the climatic woodland limit. The southern arctic zone (demarcated by a blue line), which is situated north of the arctic woodland limit, occurs in the far north of Finnmark, where it grades into the low alpine zone. The low alpine and southern arctic zones are characterised by bilberry heath, juniper - dwarf birch scrub and willow communities. The vegetation in the middle alpine zone is dominated by grass heaths and snow patches. The high alpine zone lacks a continuous cover of vascular plants, bryophyte carpets dominating in the depressions, and umbilicate and crustose lichens in localities exposed to the weather.

Northern boreal zone (northern coniferous and birch woodland zone)
This zone is dominated by birch woodland (often called sub-alpine birchwood) and some coniferous woodland with sparse, low trees. Minerotrophic mires cover large areas. The upper boundary is placed at the climatic woodland limit. The zone has traditionally been an important area for summer dairy farming.

Middle boreal zone (middle coniferous woodland zone)
Coniferous woodland and forest dominate and typical low-herb spruce woodland has its altitudinal boundary in this zone. The same applies to well-developed grey alder - bird cherry woodland and a number of thermophilous communities and species. Mires cover large areas, and typical sloping fens occur from this zone up to the low alpine zone.

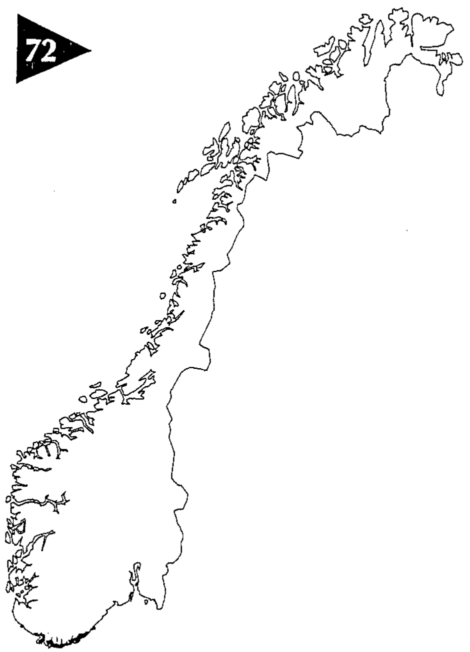
Southern boreal zone (southern coniferous woodland zone)
Coniferous woodland and forest dominate, but there are also large areas of alder woodland and raised bogs, as well as some broad-leaved deciduous woodland and dry grassland vegetation. The zone is typified by a large number of species which require high summer temperatures.

Boreonemoral zone (coniferous and broad-leaved deciduous woodland zone)
This zone forms a transition between the nemoral zone and typical coniferous woodland and forest areas. Broad-leaved thermophilous woodlands with oak, ash, elm, lime, hazel and other species requiring warmth dominate on sun-facing slopes with good soils. Birch, grey alder or coniferous woodlands dominate the rest of the wooded landscape.

Nemoral zone (temperate deciduous woodland zone)
This zone is characterised by broad-leaved deciduous woodlands and large numbers of frost-sensitive and thermophilous species. The narrow strip in southernmost Norway is the northerly outlier of a zone that covers Denmark and large parts of central Europe.

Nemoral zone (temperate deciduous woodland zone)

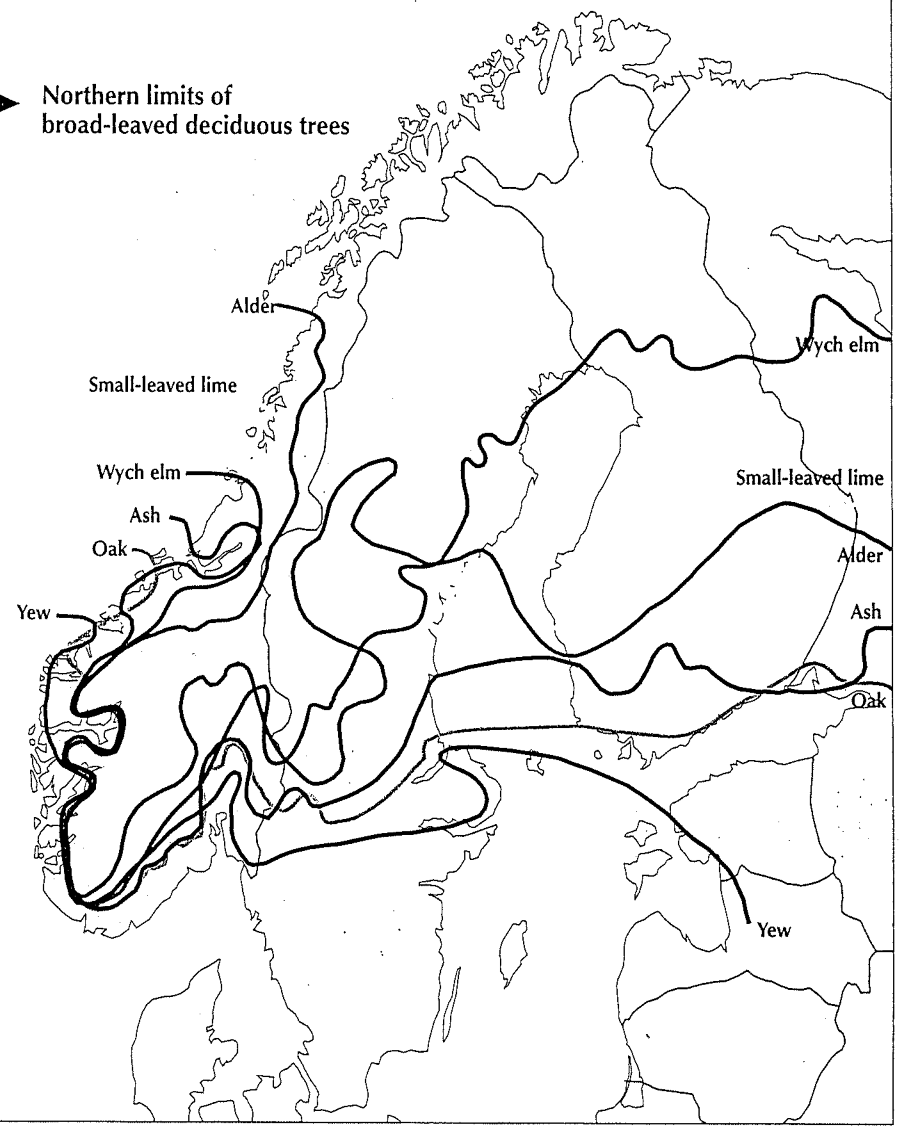
72



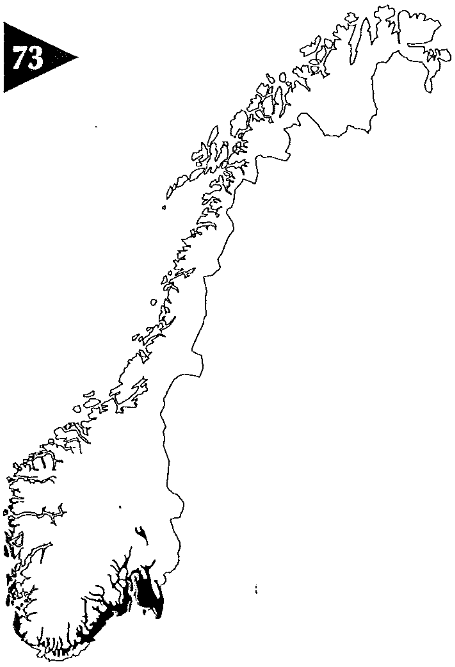
Map 72 The nemoral zone is only found in the lowlands on the southern fringe of south Norway.

58

Northern limits of broad-leaved deciduous trees



Map 58 The northern limits in Scandinavia and Finland for alder, ash, oak, yew, small-leaved lime and wych elm (*Alnus glutinosa, Fraxinus excelsior, Quercus* spp., *Taxus baccata, Tilia cordata, 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.



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

Boreonemoral zone (coniferous and broad-leaved deciduous woodland zone)

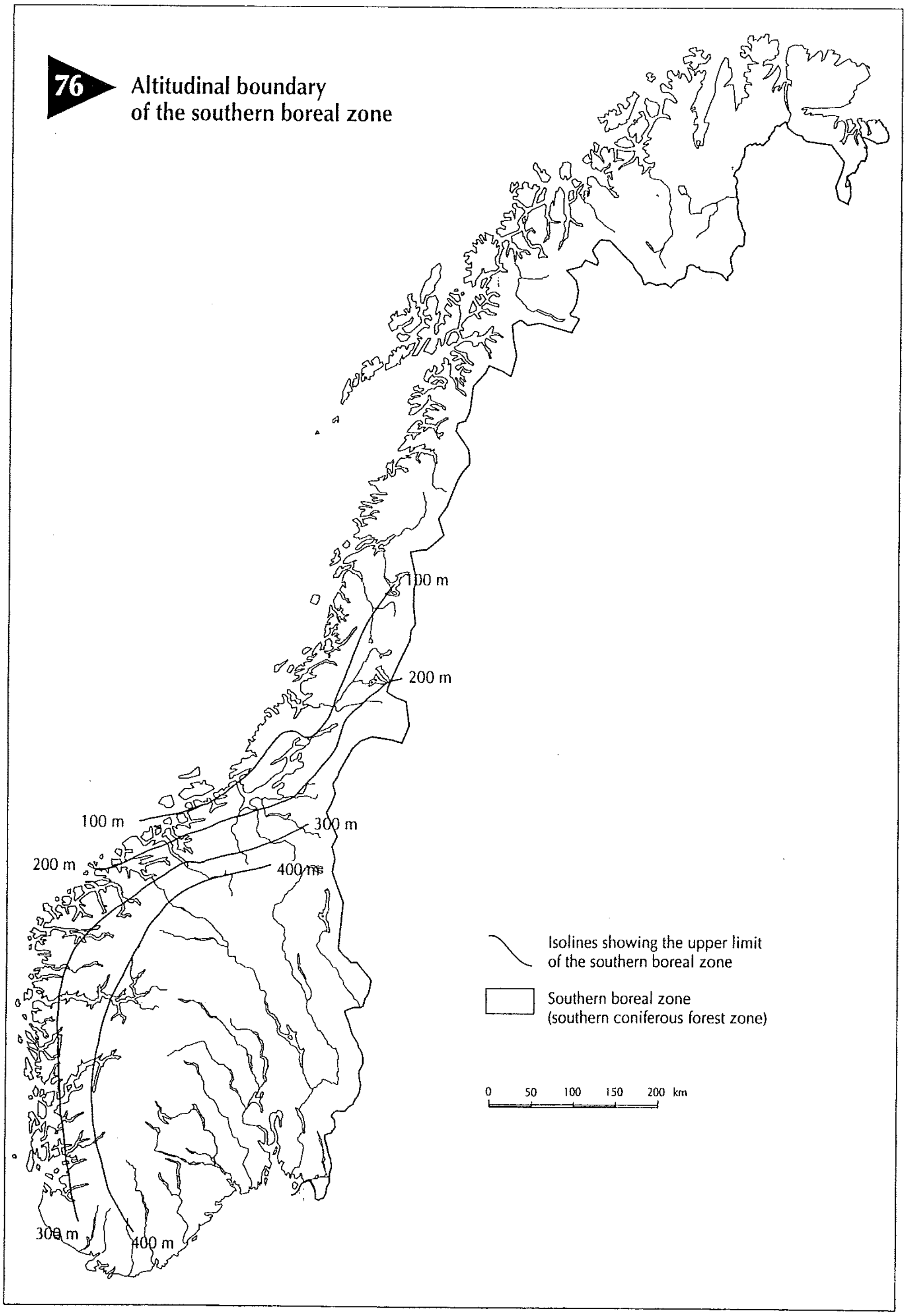
Boreonemoral species

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 (the floristic elements mentioned below are dealt with in more detail on page 41):

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

The boreonemoral species which are found north of the continuous distribution of the boreonemoral zone are listed in the framed text on page 102.

Southern boreal zone (southern coniferous woodland zone)



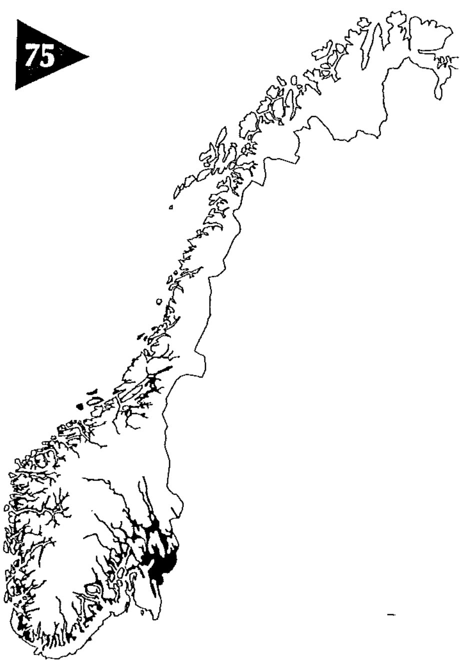
Map 76 The upper limit of the southern boreal zone in south-east Norway and inner fjord districts of west Norway is situated above 400 m a.s.l. It drops eastwards and northwards, passing below 100 m north and west of Trondheimsfjord.

Southern boreal zone species lacking in the middle boreal zone

Species that have their upper or northern limits in th southern boreal zone belong to several floristic elem (page 41). The most important ones are the "weakly southern species". Otherwise, the "distinctly south-eastern species" and most of the "weakly south-east species" have their limit in the southern boreal zone Examples of common species which only occur in tl lower or southern parts of the southern boreal zone, which are found north of Dovre are wild liquorice, shining crane's-bill, soft-grasses, fly honeysuckle, rue leaved saxifrage and reflexed stonecrop (*Astragalus glycyphyllos, Geranium lucidum, Holcus* spp., *Loni xylosteum, Saxifraga tridactylites, Sedum rupestre*).

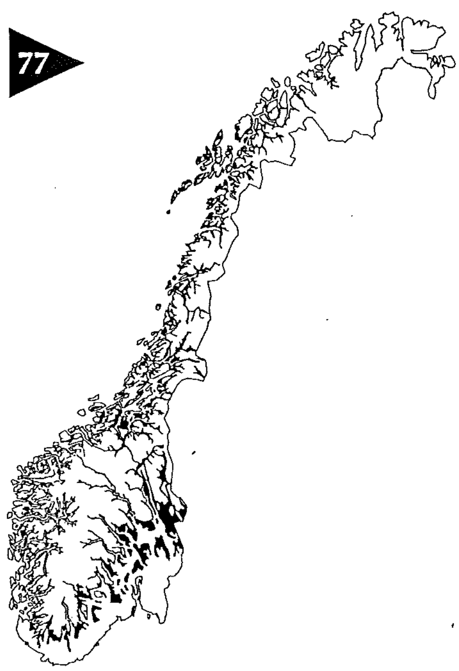
Common species which are found almost to the boundary to the middle boreal zone are important fc demarcating the southern boreal zone. They include:

Basil thyme	*Acinos arvensis*
Alder	*Alnus glutinosa*
Lesser burdock	*Arctium minus*
Throat-wort	*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*

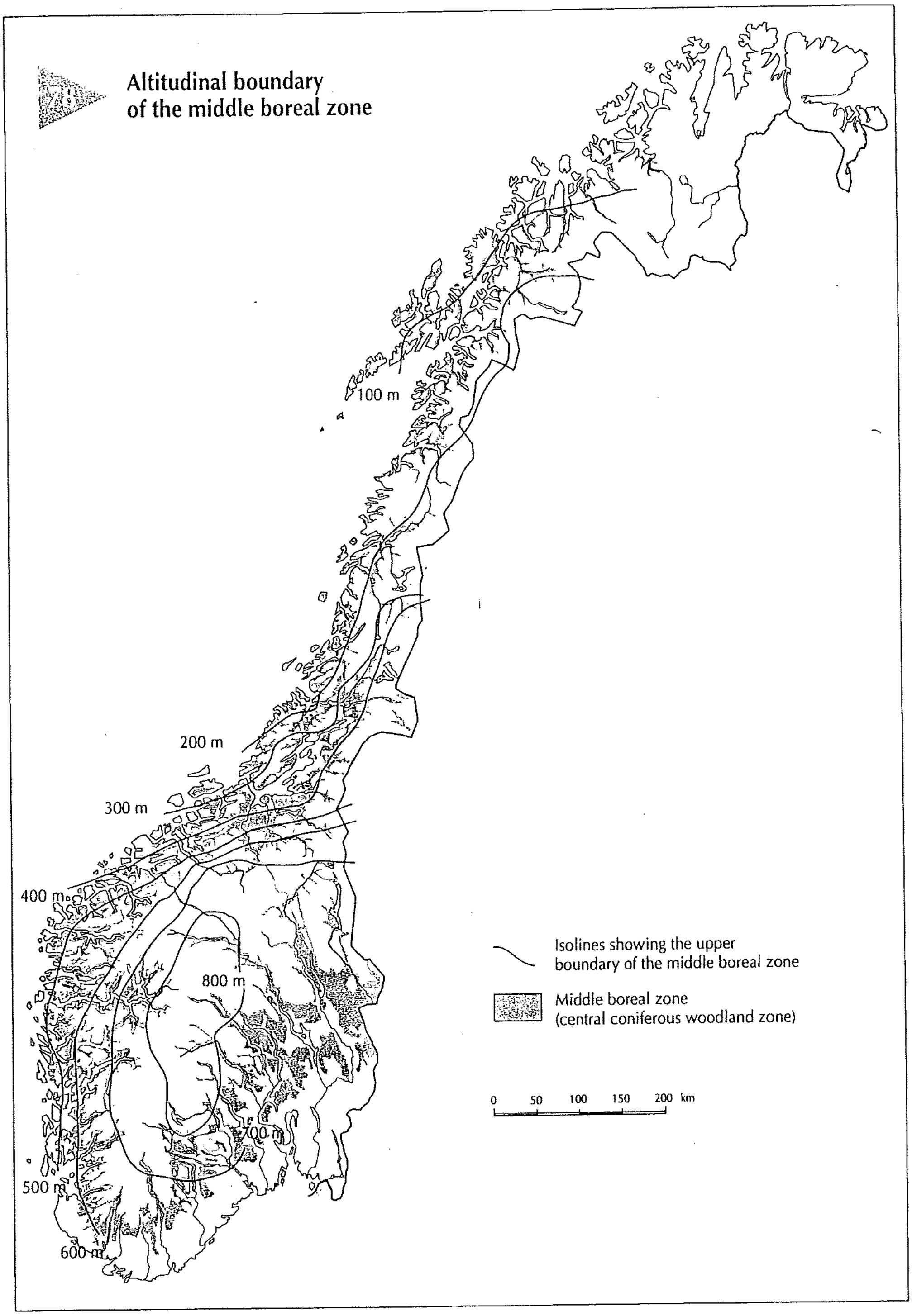


Map 75 The southern boreal zone occurs continuously in southern Norway as far north as Helgeland (southern Nordland); further north it is found in favourable localities as far as Bodø.

Middle boreal zone (middle coniferous woodland zone)



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



Map 78 The upper boundary 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 in north Norway.

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 44), 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 effusus*
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

Northern boreal zone (northern coniferous and birch woodland zone)

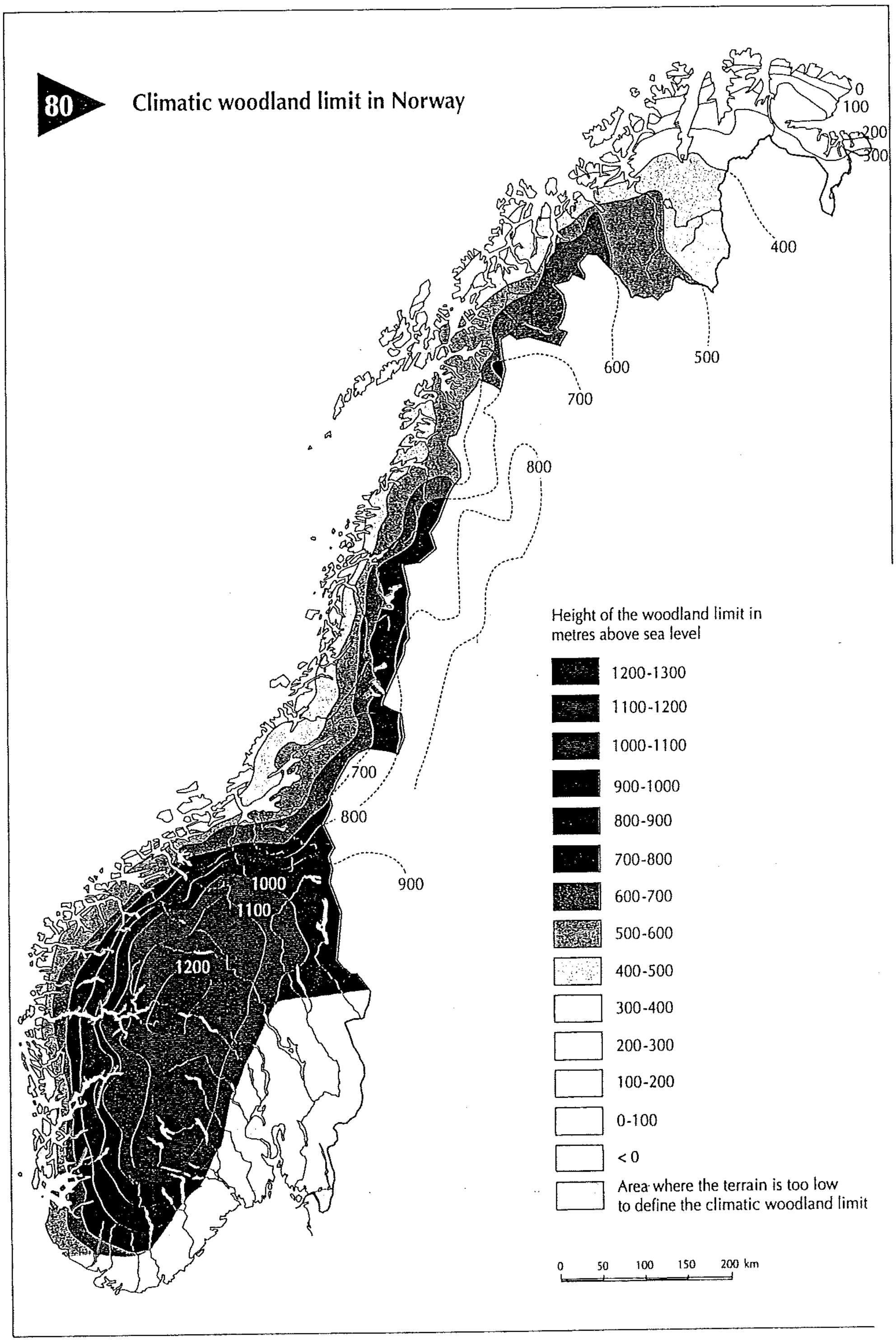
Map 79 The northern boreal zone is found continuously in upland and montane areas from Agder to northern Finnmark.

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, bird cherry, dark-leaved willow and bay willow (*Alnus incana, Prunus padus, Salix myrsinifolia, 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*
+ a meadow-grass	*Poa remota*
Whorled Solomon's-seal	*Polygonatum verticillatum*
+ Broad-leaved pondweed	*Potamogeton natans*
+ Bird cherry	*Prunus padus*
+ Raspberry	*Rubus idaeus*
	Sphagnum subnitens
Clovers	*Trifolium* spp.
+ Germander speedwell	*Veronica chamaedrys*
Heath speedwell	*Veronica officinalis*
Tufted vetch	*Vicia cracca*
+ Bush vetch	*Vicia sepium*
+ Common dog-violet	*Viola riviniana*

80 Climatic woodland limit in Norway



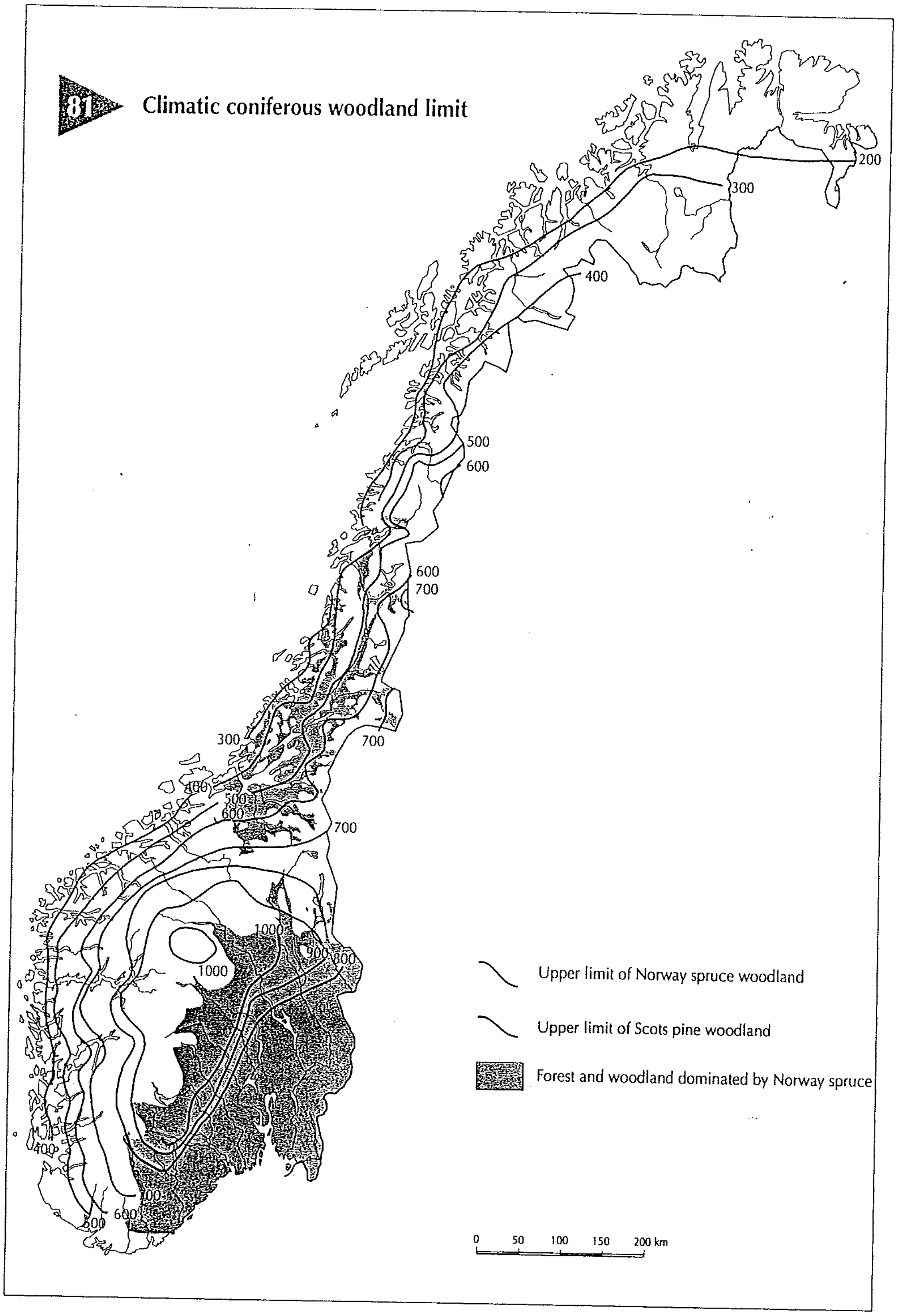
Map 80 This map shows isolines for the climatic woodland limit in Norway and neighbouring countries. This limit corresponds with the boundary between the boreal and alpine/arctic zones. Over most of the country, this is the upper boundary of the northern boreal zone, and upland birch woodland forms the 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 part of Finnmark is situated north of the climatic woodland limit, and the 0 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 woodland, this is the *climatic woodland limit*. Otherwise the *actual woodland limit* may be determined by topographical factors, soil factors, or the impact of Man, and is often situated considerably lower than the climatic woodland limit.

The climatic woodland limit extends significantly higher on south-facing than on north-facing slopes. For instance, on one particularly favourable south-facing slope in the Jotunheimen, birch woodland continues right 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. 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, newly published 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, altitudinal 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 a.s.l. in coastal districts from central Norway northwards, particularly in large parts of north Norway.

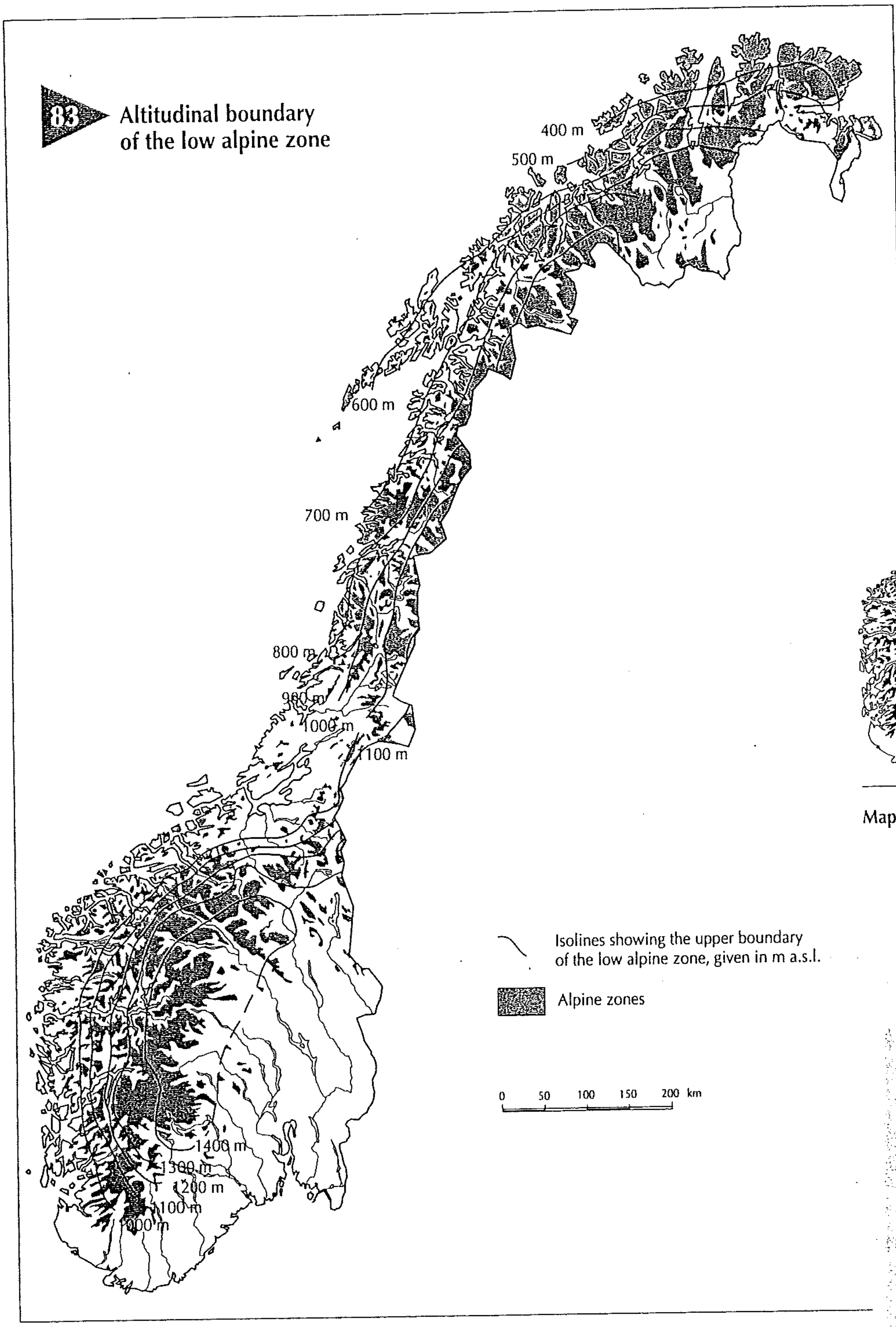


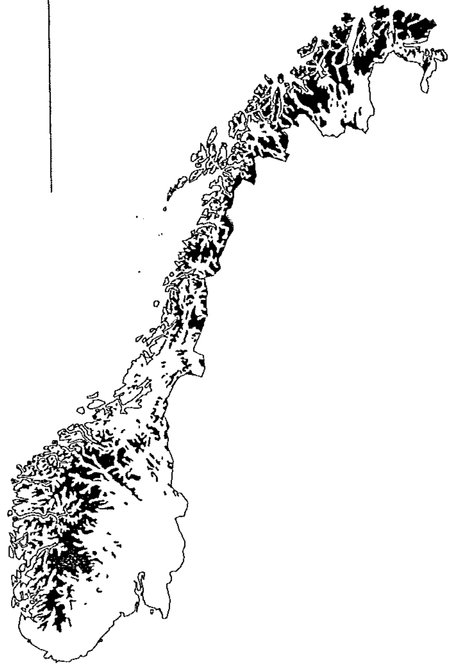
Map 81 The upper limits of Scots pine and Norway spruce woodlands and forests are shown on the map by isolines. The main areas of spruce forest and woodland are also shown, and within these areas the upper limit for Scots pine is not shown since it was difficult to determine a representative limit owing to the predominance of spruce.

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 the Jotunheimen The coniferous woodland limit drops in all directions from these central mountainous regions. The northernmost pinewoods are found in Porsanger, in eastern Finnmark.

This map has been prepared by Børre Aas and is based on research in the early 1960's.

Low alpine zone (low mountainous areas)





Map 82 Areas above the woodland limit.

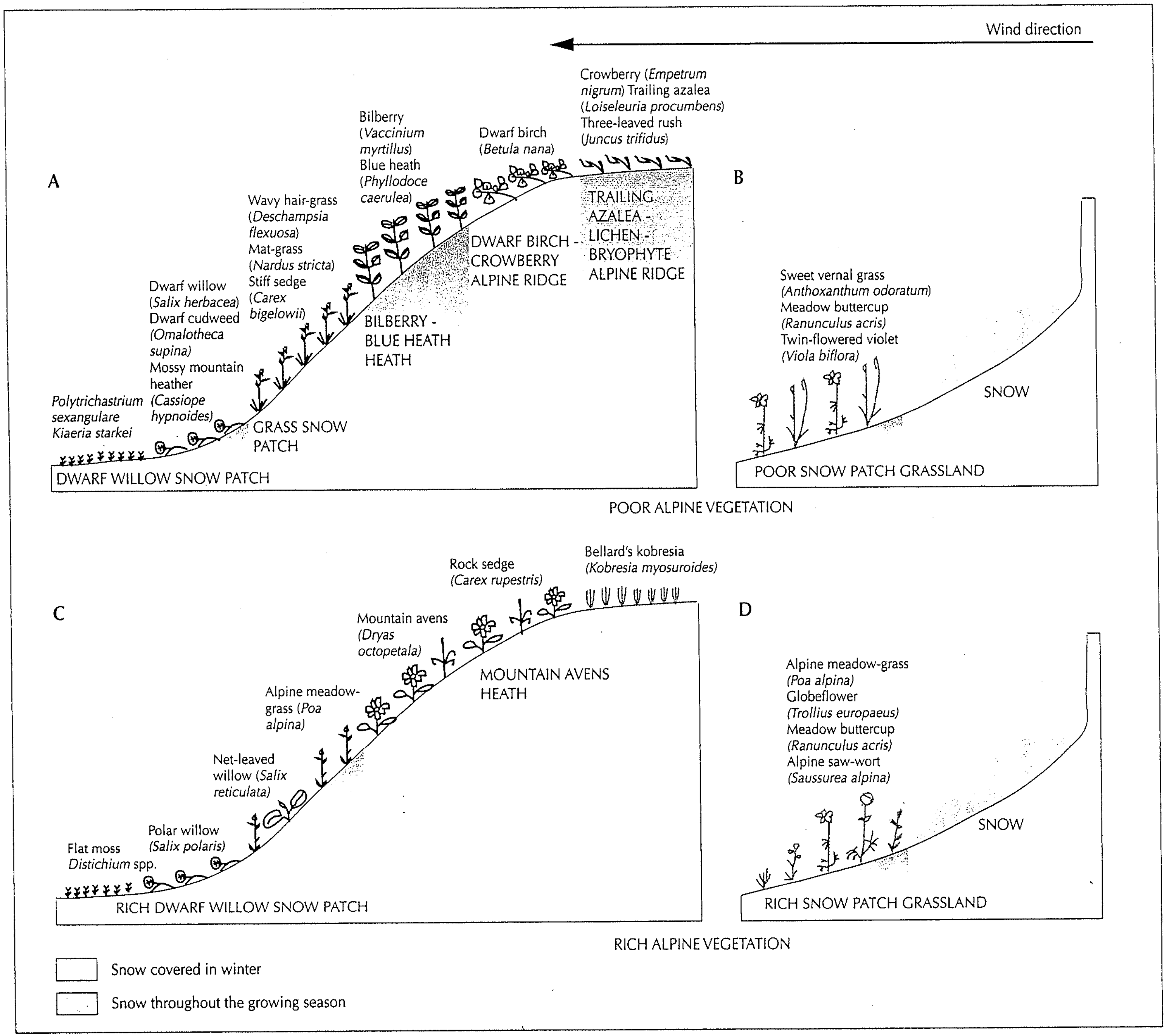
Map 83 The alpine areas are coloured. The upper boundary of the low alpine zone is located above 1400 m in the central mountainous region, but drops towards the south, west and north, and is below 400 m furthest north.

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, northern stitchwort and mountain hair-grass (*Gentiana purpurea, Stellaria borealis, Vahlodea atropurpurea*).

The upper limit of many mire species is in the low alpine zone, including large yellow-sedge and deergrass (*Carex flava, 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*


Wind direction
A
Crowberry (Empetrum nigrum) Trailing azalea (Loiseleuria procumbens) Three-leaved rush (Juncus trifidus)
Dwarf birch (Betula nana)
Bilberry (Vaccinium myrtillus) Blue heath (Phyllodoce caerulea)
Wavy hair-grass (Deschampsia flexuosa) Mat-grass (Nardus stricta) Stiff sedge (Carex bigelowii)
Dwarf willow (Salix herbacea) Dwarf cudweed (Omalotheca supina) Mossy mountain heather (Cassiope hypnoides)
Polytrichastrium sexangulare Kiaeria starkei
TRAILING AZALEA - LICHEN - BRYOPHYTE ALPINE RIDGE
DWARF BIRCH - CROWBERRY ALPINE RIDGE
BILBERRY - BLUE HEATH HEATH
GRASS SNOW PATCH
DWARF WILLOW SNOW PATCH
B
Sweet vernal grass (Anthoxanthum odoratum) Meadow buttercup (Ranunculus acris) Twin-flowered violet (Viola biflora)
SNOW
POOR SNOW PATCH GRASSLAND
POOR ALPINE VEGETATION
C
Bellard's kobresia (Kobresia myosuroides)
Rock sedge (Carex rupestris)
Mountain avens (Dryas octopetala)
Alpine meadow-grass (Poa alpina)
Net-leaved willow (Salix reticulata)
Polar willow (Salix polaris)
Flat moss Distichium spp.
MOUNTAIN AVENS HEATH
RICH DWARF WILLOW SNOW PATCH
D
Alpine meadow-grass (Poa alpina) Globeflower (Trollius europaeus) Meadow buttercup (Ranunculus acris) Alpine saw-wort (Saussurea alpina)
SNOW
RICH SNOW PATCH GRASSLAND
RICH ALPINE VEGETATION
Snow covered in winter
Snow throughout the growing season

Middle alpine zone (fairly high mountainous terrain)

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*

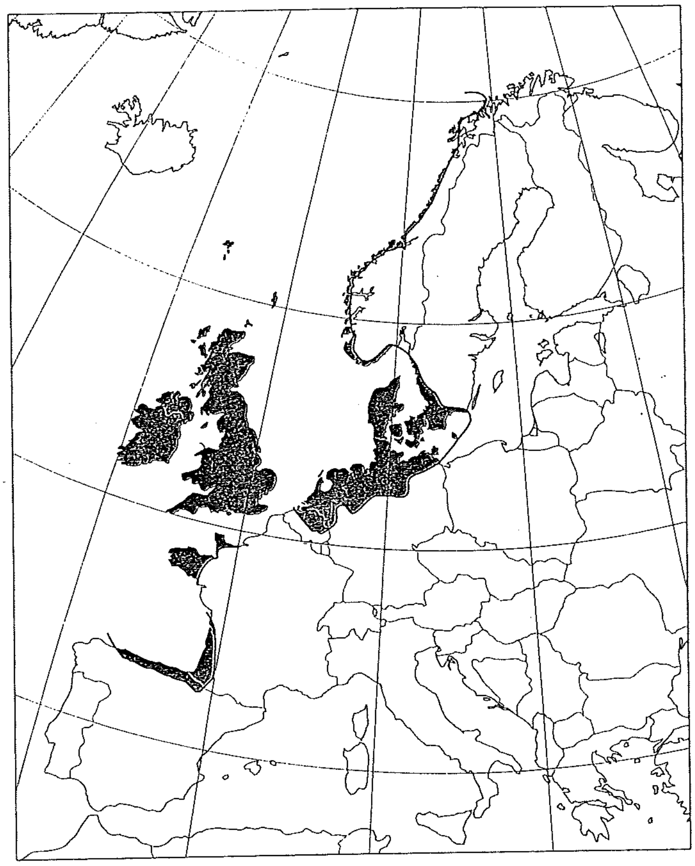
High alpine zone (high mountains)

Middle and high alpine species

Some species mainly occur above the low alpine zone:

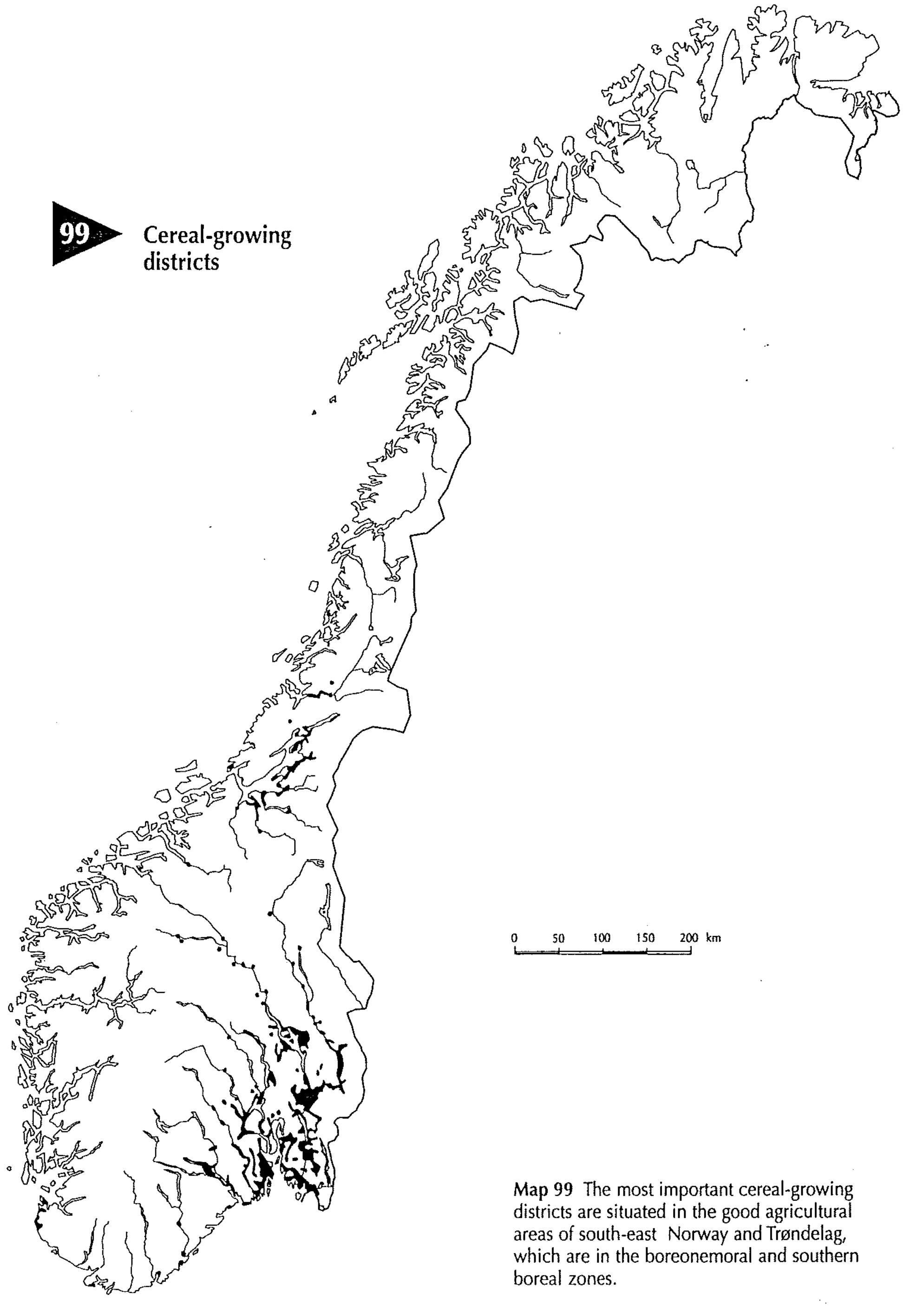
High alpine harebell	*Campanula uniflora*
High alpine cress	*Cardamine bellidifolia*
Nodding sedge	*Carex fuliginosa* ssp. *misandra*
Arctic wood-rush	*Luzula arctica*
Curved wood-rush	*Luzula arcuata* ssp. *arcuata*
Curved wood-rush	*Luzula arcuata* coll.
Spiked snow-grass	*Phippsia algida*
Outspread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

101 Coastal heathland in Europe



Map 101 Coastal heathland is a treeless type of environment created by Man during the last few thousand years. It was common on the Atlantic coasts from Spain to northern Norway, mainly within the highly oceanic section. The great majority of European coastal heathlands are in the nemoral zone, but those in Norway are mostly in the boreonemoral and southern boreal zones. After Gimingham (1972) and Skogen (1974).

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.

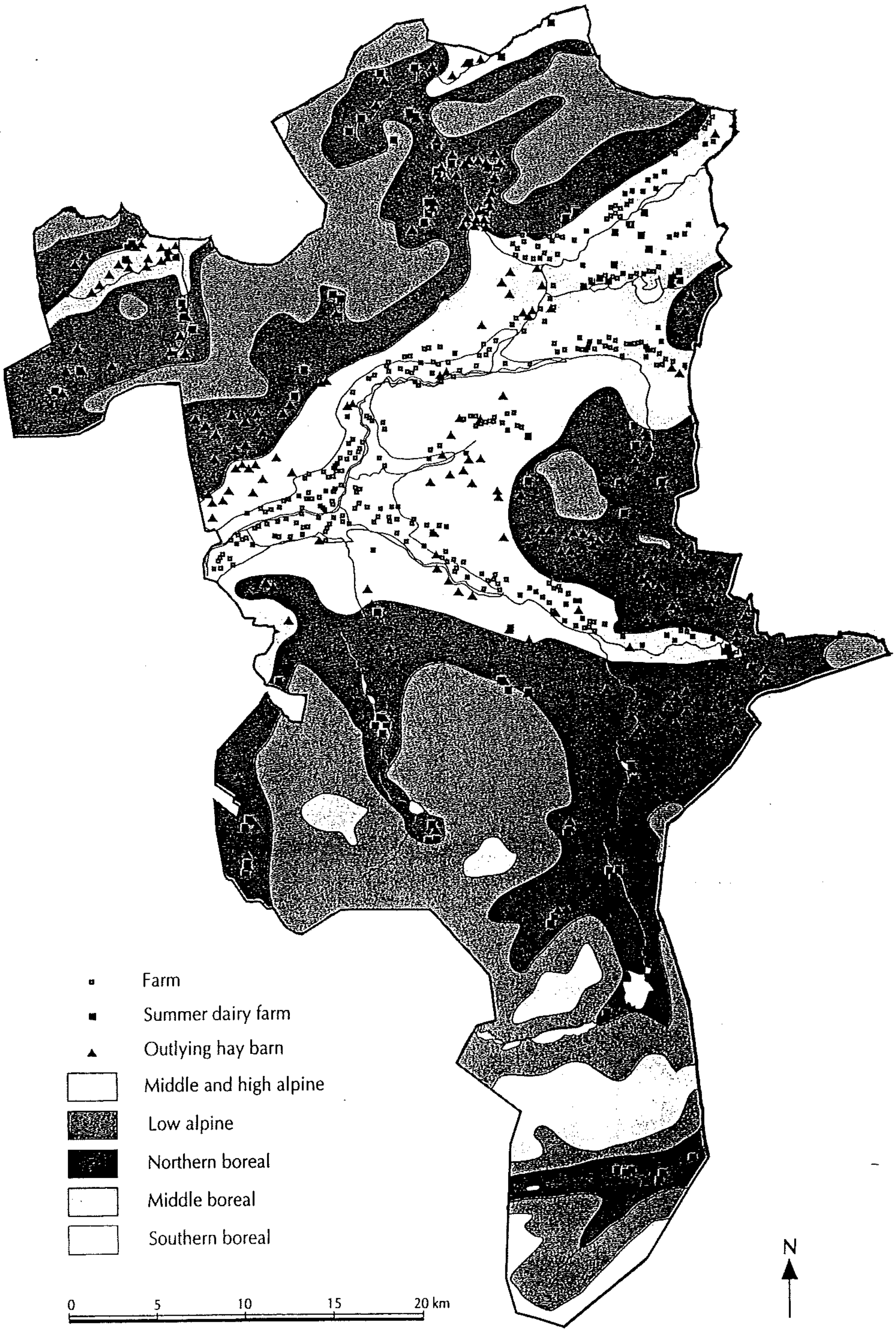
98 Fruit-growing districts

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.

	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			

Figure 22 Distribution of vegetation zones, farms, summer dairy farms and outlying hay barns in Rindal, Nordmøre. Dark red depicts main occurrence, lighter colours depict more seldom occurrence. Based on information in the framed text on the left.

100 Vegetation zones, farms, summer dairy farms and outlying hay barns in Rindal



Farms, summer dairy farms and outlying hay barns relative to altitude

Rindal is typical for the inland districts of central Norway where summer dairy farming and haymaking on outlying land continued until the late 1950's.The borough covers 592 km², situated between 55 and 1596 m a.s.l. The lowlands in the central-western part are in the southern boreal zone up to about 180 m, slightly higher on south-facing slopes. The middle boreal zone extends to around 450 m in central parts, somewhat lower in the north, and up to 600 m in the south. In central parts, the northern boreal zone extends to about 700 m and the low alpine zone to about 1000 m. Both zones are around 100 m lower in the north and 200 m higher in the south, which is situated in the central part of the Trollheimen range.

The 318 farms in the borough are located in the southern and middle boreal zones, mostly between 60 and 300 m a.s.l. Several in the south-east are somewhat higher, even as high as 463 m. The average altitude of all the farms is less than 200 m. Above the southern boreal zone, virtually all the farms are located on the north side of the rivers, i.e. on south-facing slopes. This is most obvious in the upper parts of the middle boreal zone, and is explained by the greater warmth on south-facing compared with north-facing slopes.

The mapping of houses and foundation walls of ruins on outlying land has shown that all but five of the 100 summer dairy farms are located between 300 and 730 m a.s.l., in the upper part of the middle boreal zone and in the northern boreal zone. The 51 summer dairy farms north of the main valley are, on average, located at 410 m a.s.l. and those on the south side at 560 m a.s.l. Most of the 233 outlying hay barns that have been mapped, which were in use in the first half of this century, also stood in the middle and northern boreal zones. A few were located in the lowlands, close to the flood limit of the river and elsewhere where cultivation was impossible. The average altitude of the outlying hay barns is 410 m.

Why live in Norway?
Compelling reasons include...

- Eleventh in urban quality of life of its major city, Oslo.
- Stable, with 11th lowest rate of inflation.
- Scenic, with four of the world's ten highest waterfalls.
- Spacious, with 30th lowest population density.
- High in health care: third in number of hospital beds per 1,000 population.
- Safe: 44th in traffic injuries.
- Second in the human development index.
- Second in the environmental sustainability index.
- Visitable: As many tourist arrivals per year as residents in the country.

Source: The Economist Pocket World in Figures 2002 Edition

What are Norwegians like?

- Healthy: sixth lowest infant mortality, 20th in death due to heart attack
- Hard working: 9th greatest percentage of population in the work force
- Gender equality: 46.4% women in the workforce
- Slim: Lowest percentage obesity of industrialised countries
- Long-lived: 11th in life expectancy
- Young: 24th in median average age
- First in book and newspaper sales and second in music sales per head
- Slowly growing: with 37th lowest birth rate
- Environmentalists: Fifth in glass recycling and 13th in paper recycling percentages

Source: The Economist Pocket World in Figures 2002 Edition

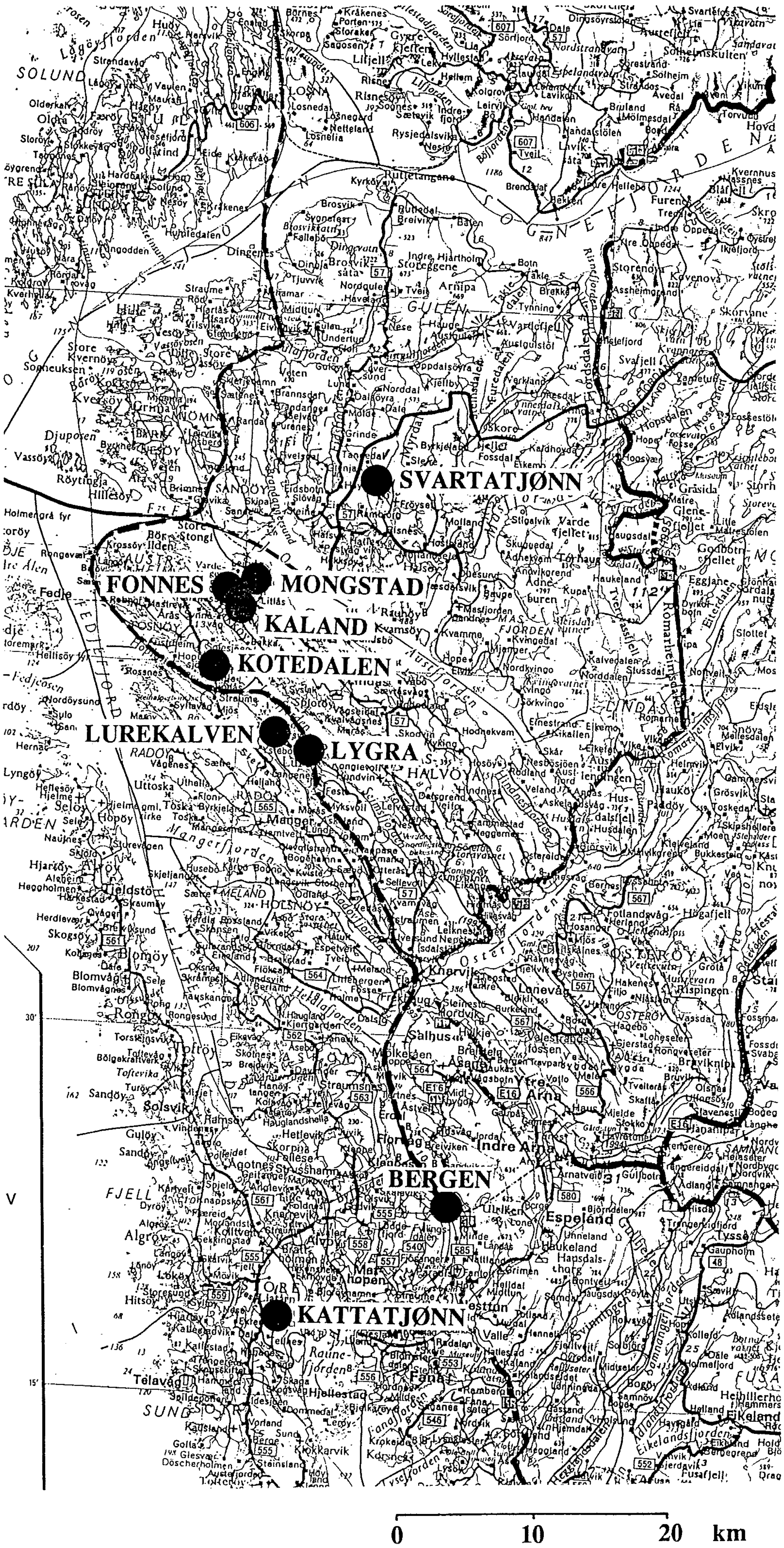
10.15 h bei
→ Shed 8 "Skur 8" (Statsråd Lemkuhl)
Bryggen
Steam Boat "Granvin" at 11.00 h

Sunday, 18 August 2002

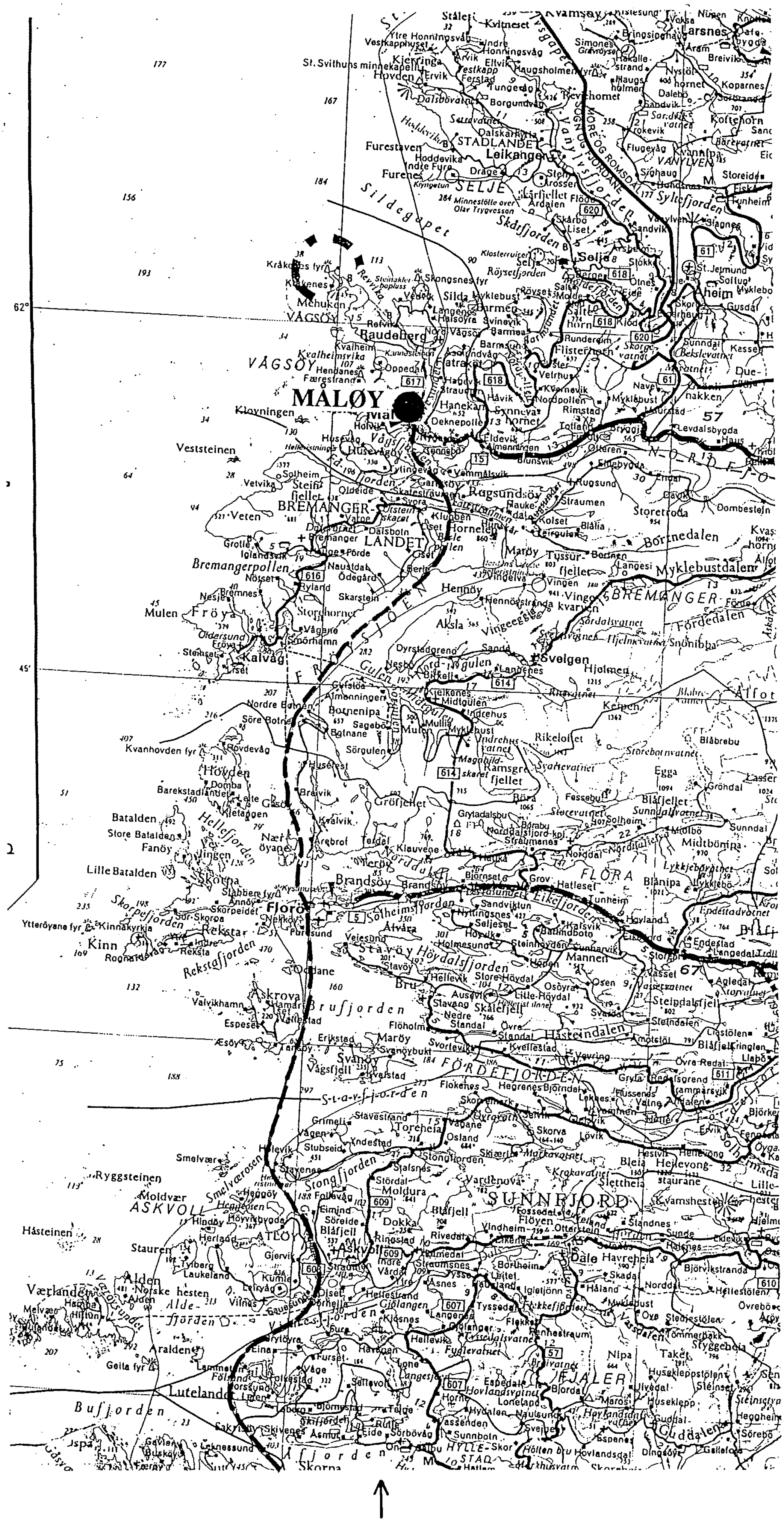
Lygra Heath Centre, Kotedalen, Mongstad

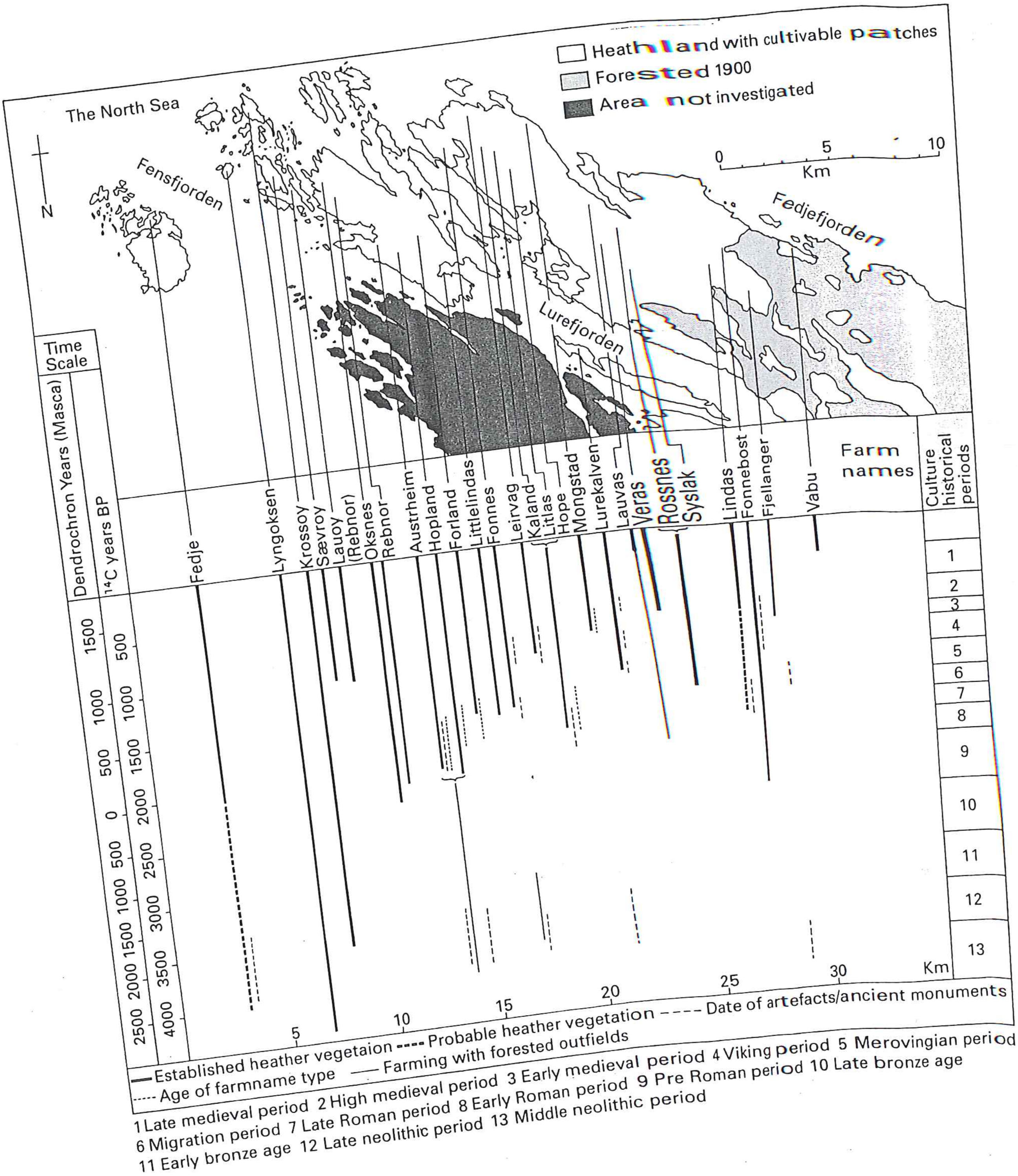
(cont.)

DAY 1. Sunday, 18th. August

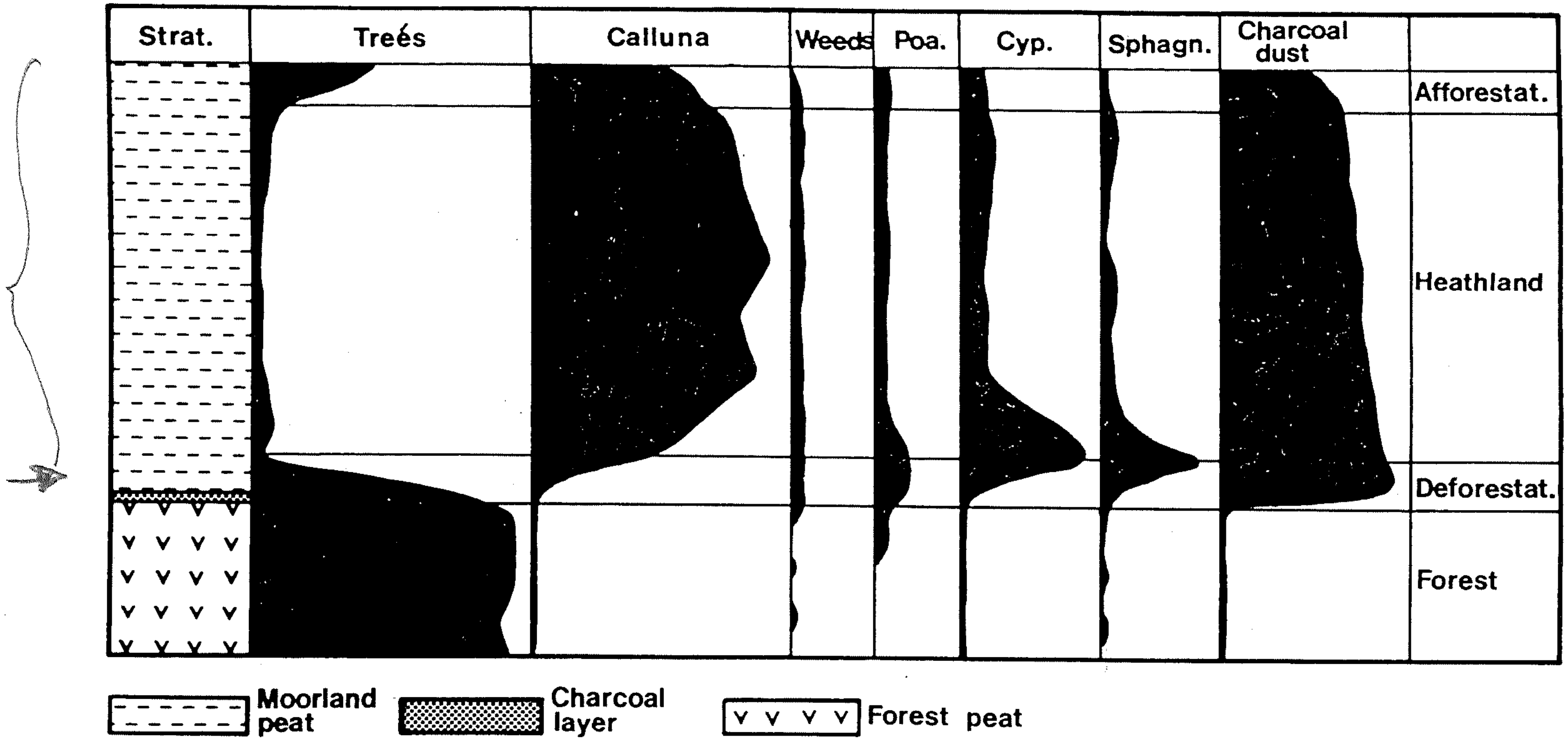


DAY 1. Sunday, 18th. August (cont.)

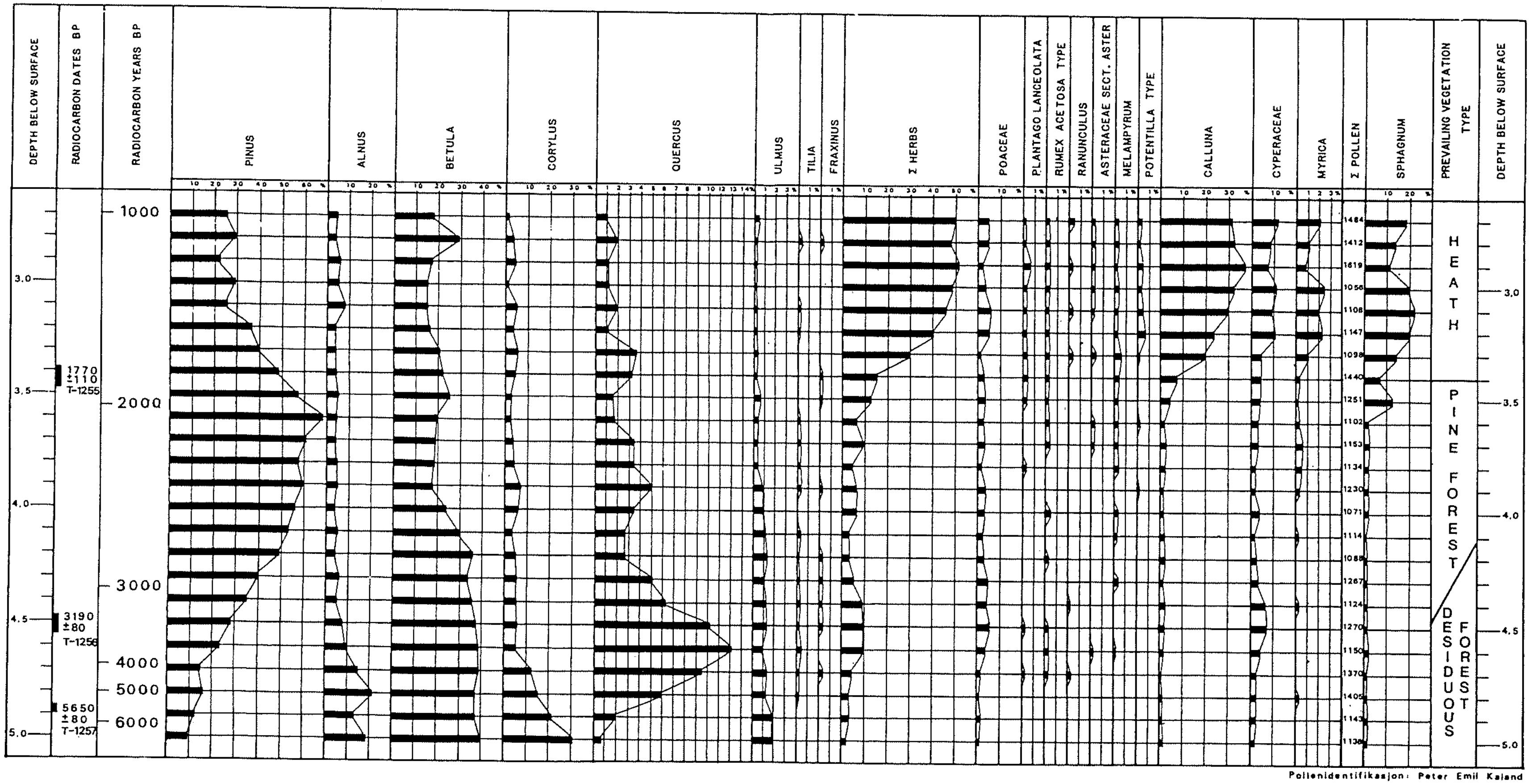




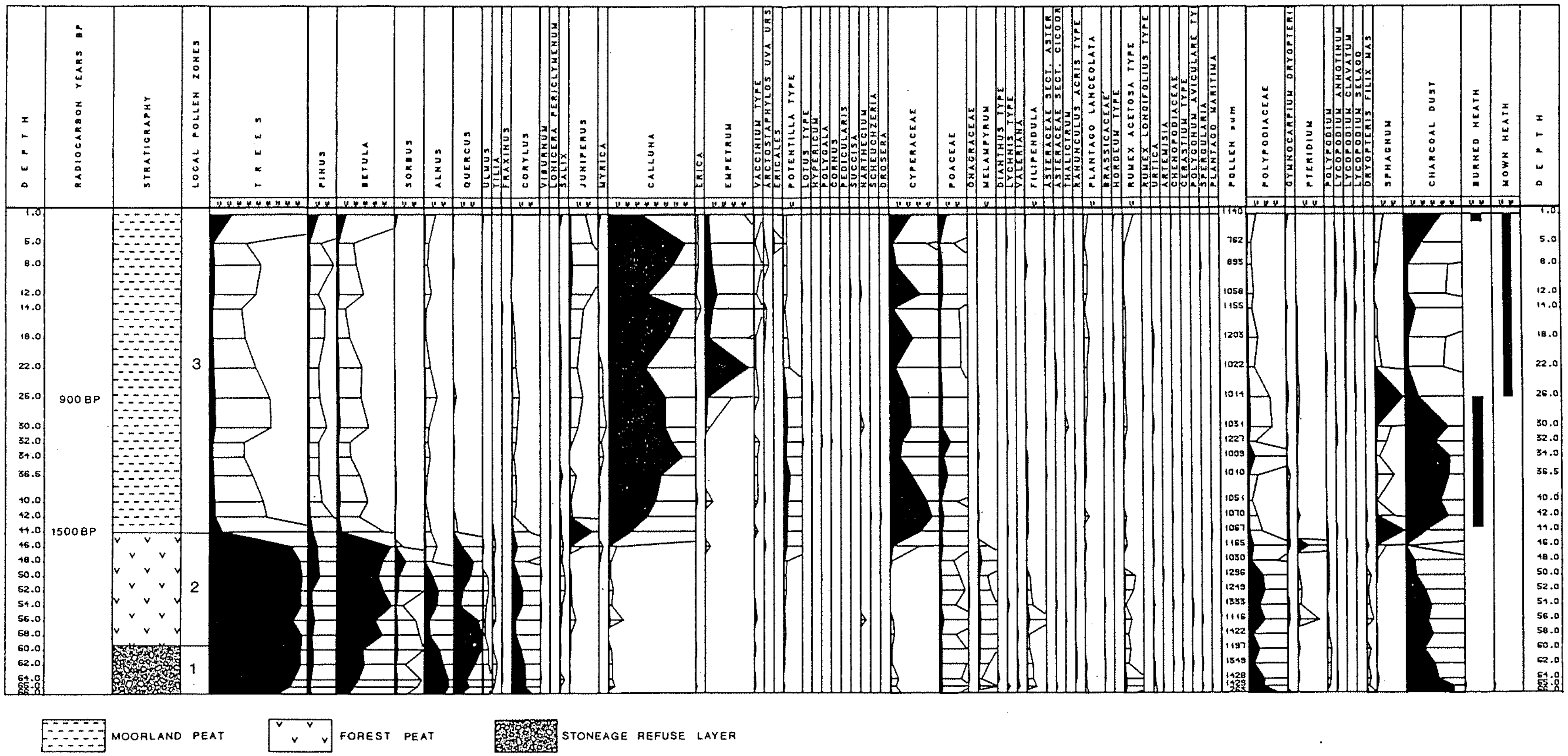
The dates of heathland formation along a west-east transect in Nordhordland, Norway (after Kaland, 1986) (Bell & Walker, 1992).



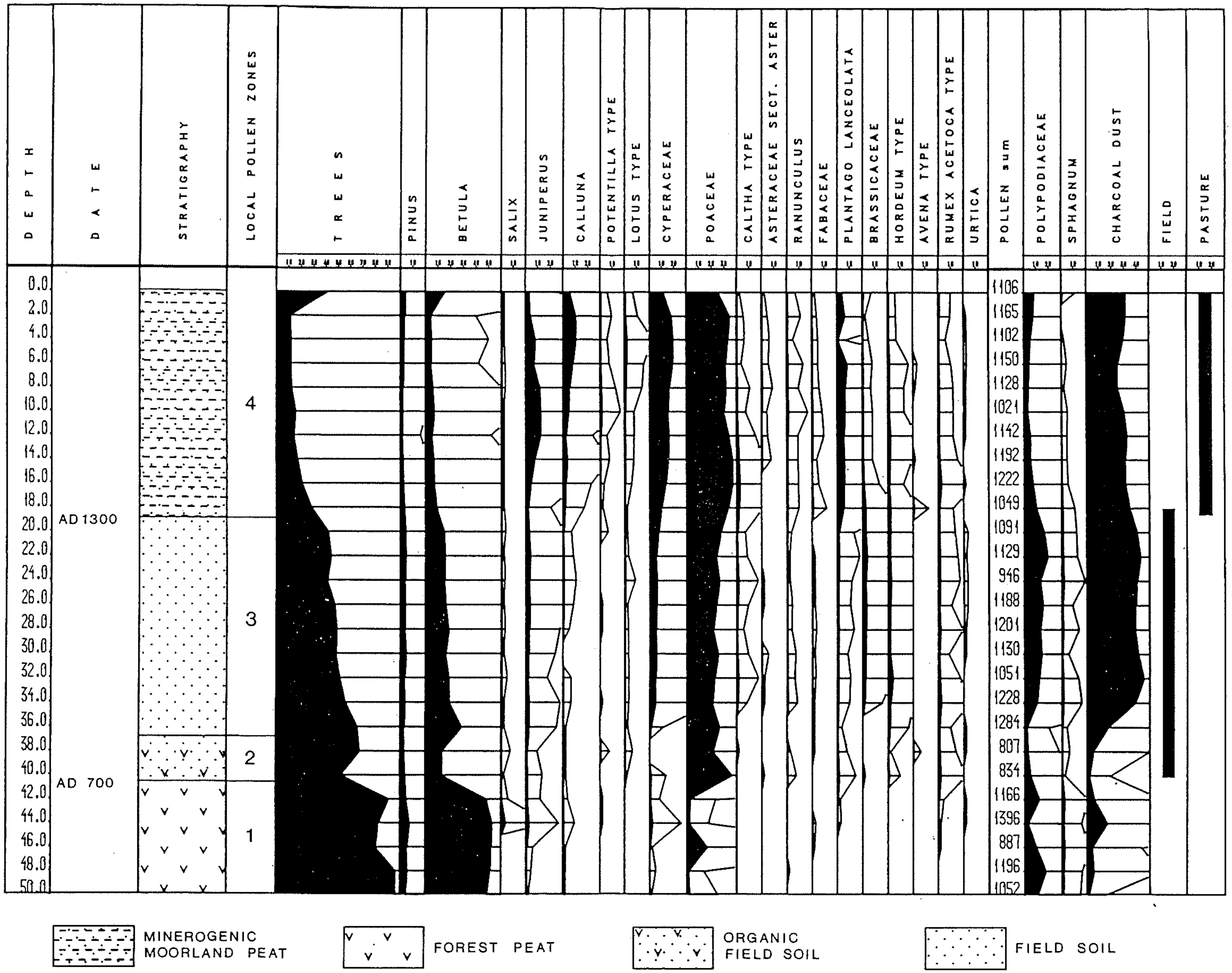
Simplified pollen diagram showing the heath development in bogs (Kaland, 1986).



Pollen diagram from the lake Longstjørn, Kaland, Nordhordland, western Norway (Kaland, 1986).



Pollen diagram from the bog Fonnastrumen, Fonnes, Nordhordland, western Norway (Kaland, 1986).



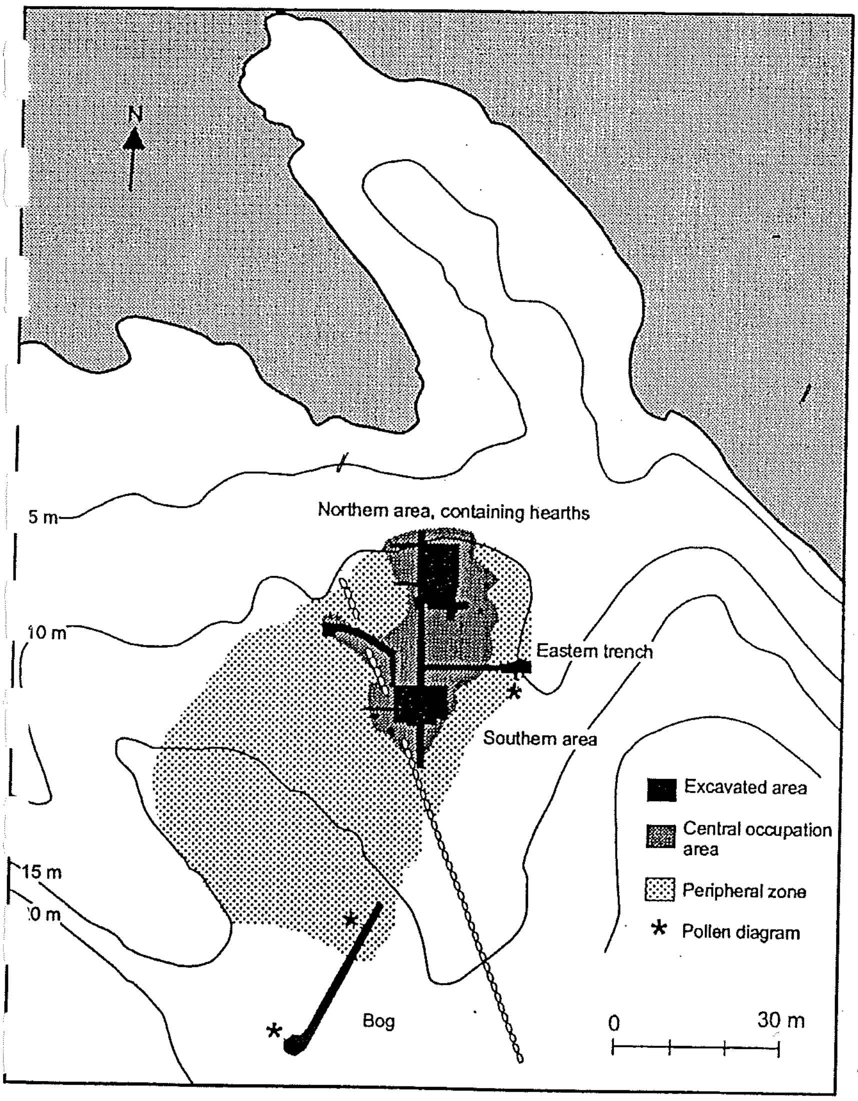
Pollen diagram through a field at Lurekalven, Nordhordland, western Norway. Simplified after Kvamme (1982) (Kaland, 1986).

KOTEDALEN, WESTERN NORWAY – AN OCCUPATION SITE FROM THE MESOLITHIC AND NEOLITHIC

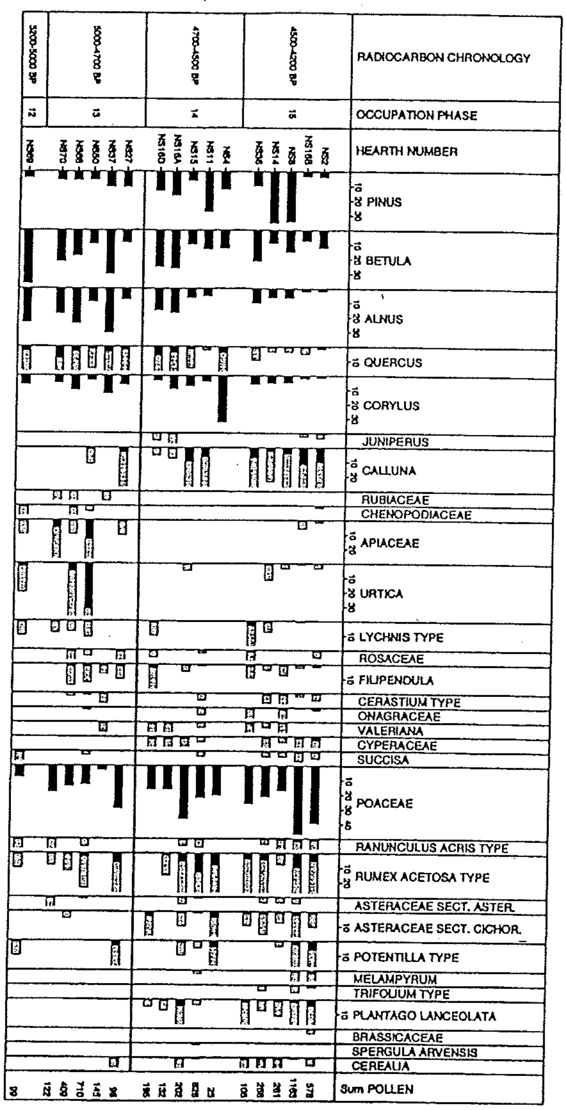
The site Kotedalen is situated on Radøy in Hordaland. It is one of several occupation sites along the Fosnstraumen tidal currant channel, where the opportunities for fishing and hunting were optimal. Intensive use of the Kotedalen site through a long time period, 9000-4200 BP (uncalibrated 14C-years), resulted in accumulation of thick cultural layers.

Archaeological excavations including osteological and palaeobotanical (pollen and macrofossils) investigations have been carried out. Pollen diagrams were made from a bog close to the site and from deposits within the occupation site. Pollen samples from hearths show the presence of cereals in the two youngest occupation phases (4700-4200 BP). Together with the bog diagrams this indicate that agriculture was known or introduced to the people at this traditional hunter-fisher site.

References:
Hjelle, K.L. 1998. The use of on-site pollen analysis, local pollen diagrams and moderen pollen samples in investigations of cultural activity. Archaeologia Baltica 3, 87-101.
Hjelle, K.L., Hufthammer, A.K., Kaland, P.E., Olsen, A.B., Soltvedt, E.C. 1992. Kotedalen – en boplass gjennom 5000 år. Bind 2. Naturvitenskapelige undersøkelser. Universitetet i Bergen. 150 pp.



KOTEDALEN, HEARTHS
Radøy, Hordaland, Norway



Myr, Kotedalen, Straume, Radøy Hd., Hordaland, Norway.

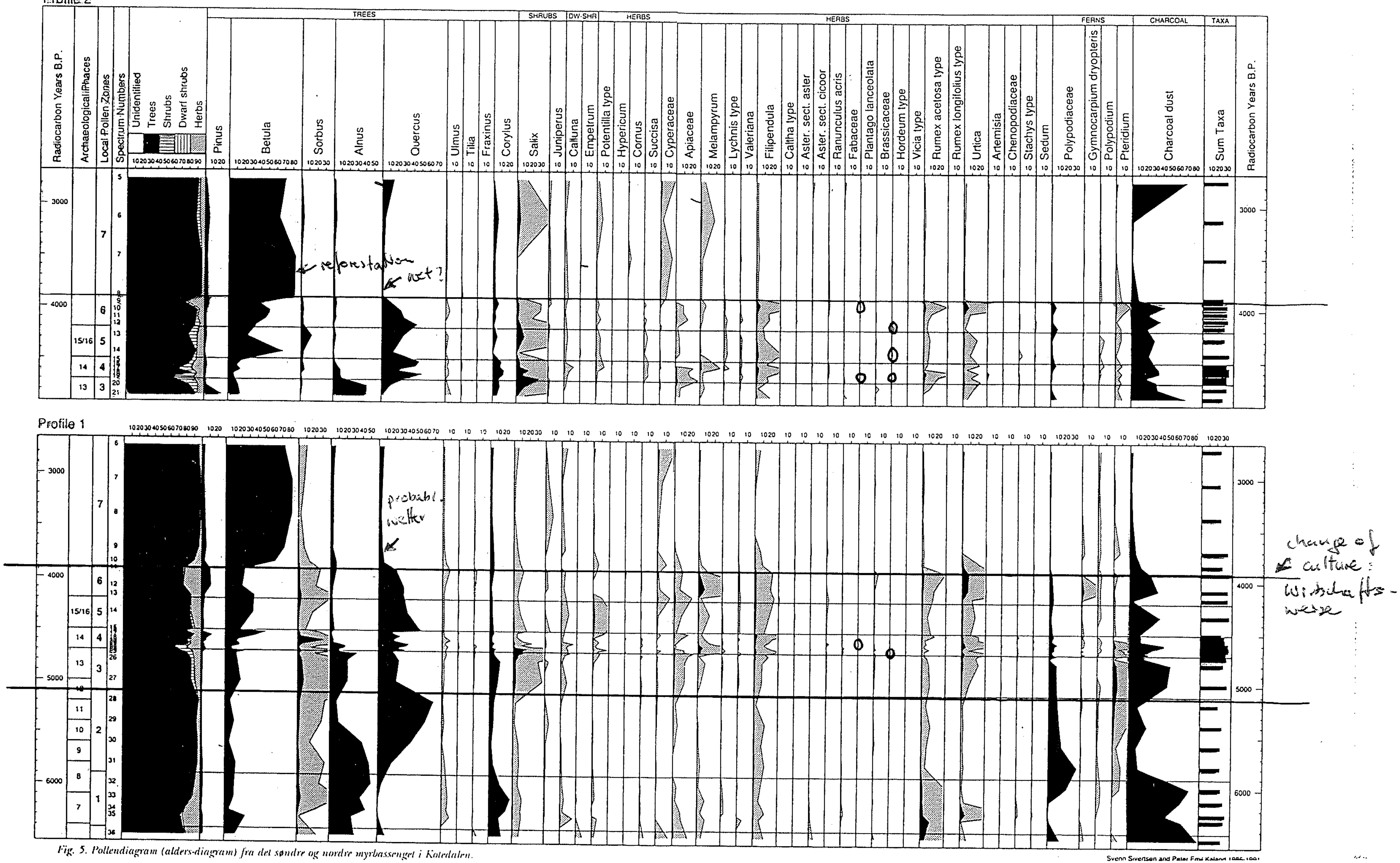
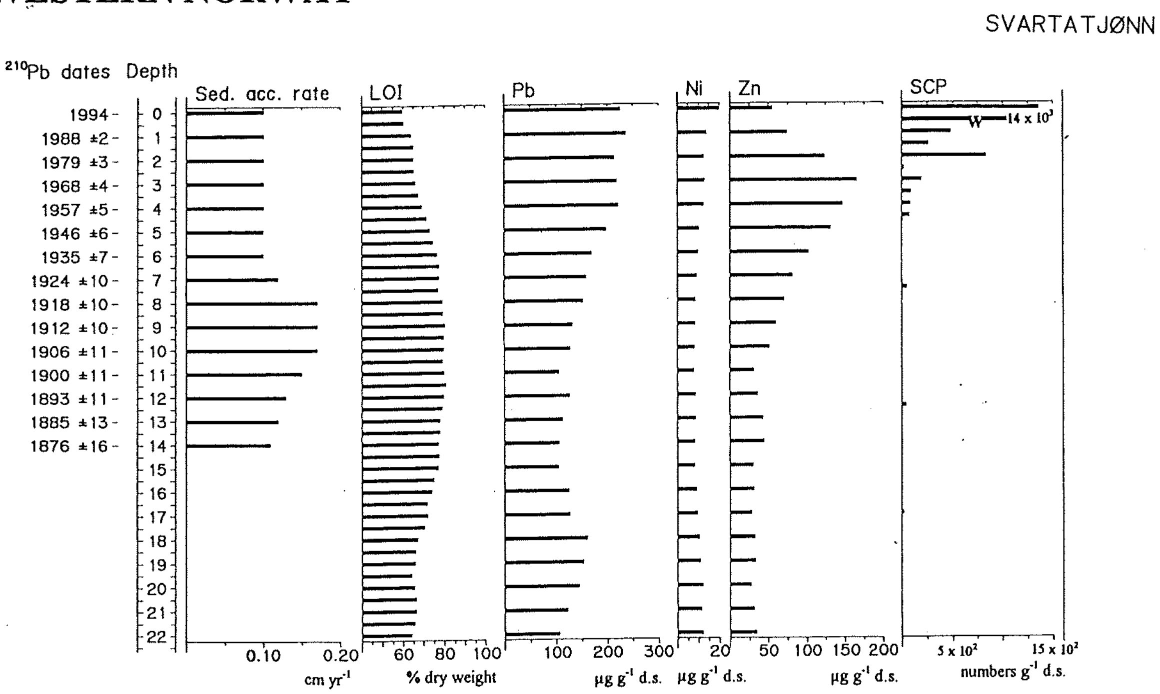
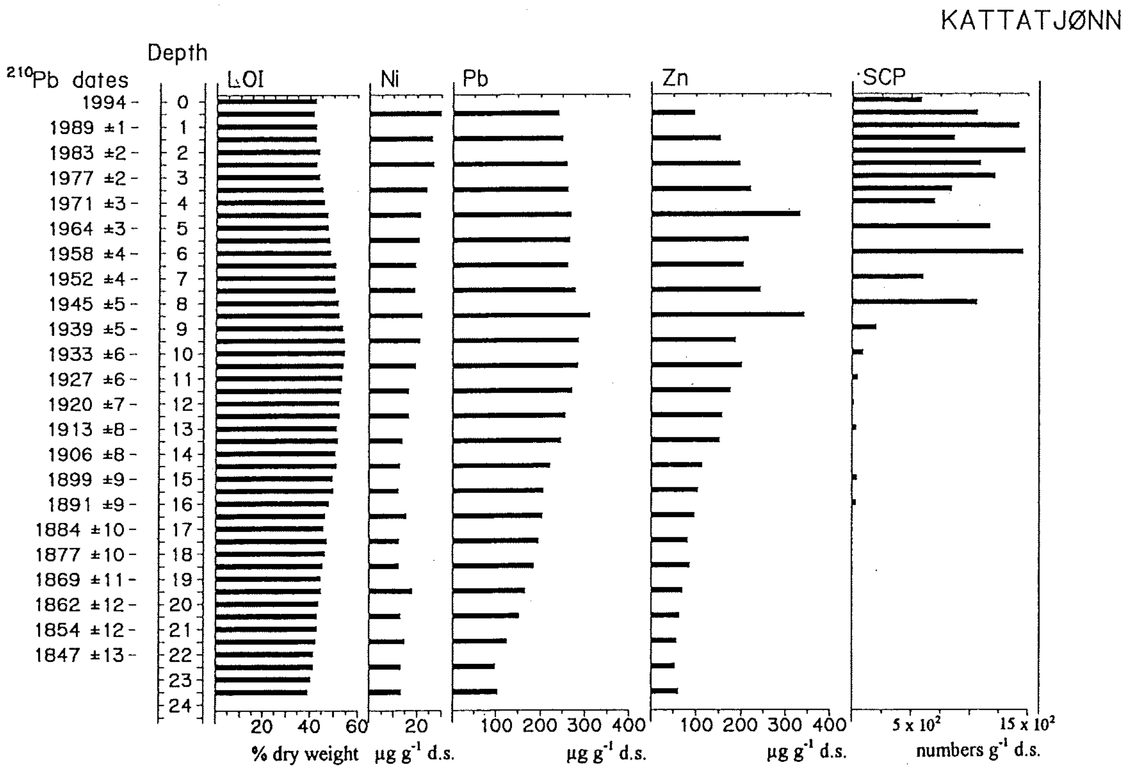


Fig. 5. Pollendiagram (alders-diagram) fra det søndre og nordre myrbassenget i Kotedalen.

INVESTIGATION OF LOCAL IMPACT OF ATMOSPHERIC POLLUTION FROM AN OIL REFINERY ON A SMALL LAKE IN WESTERN NORWAY

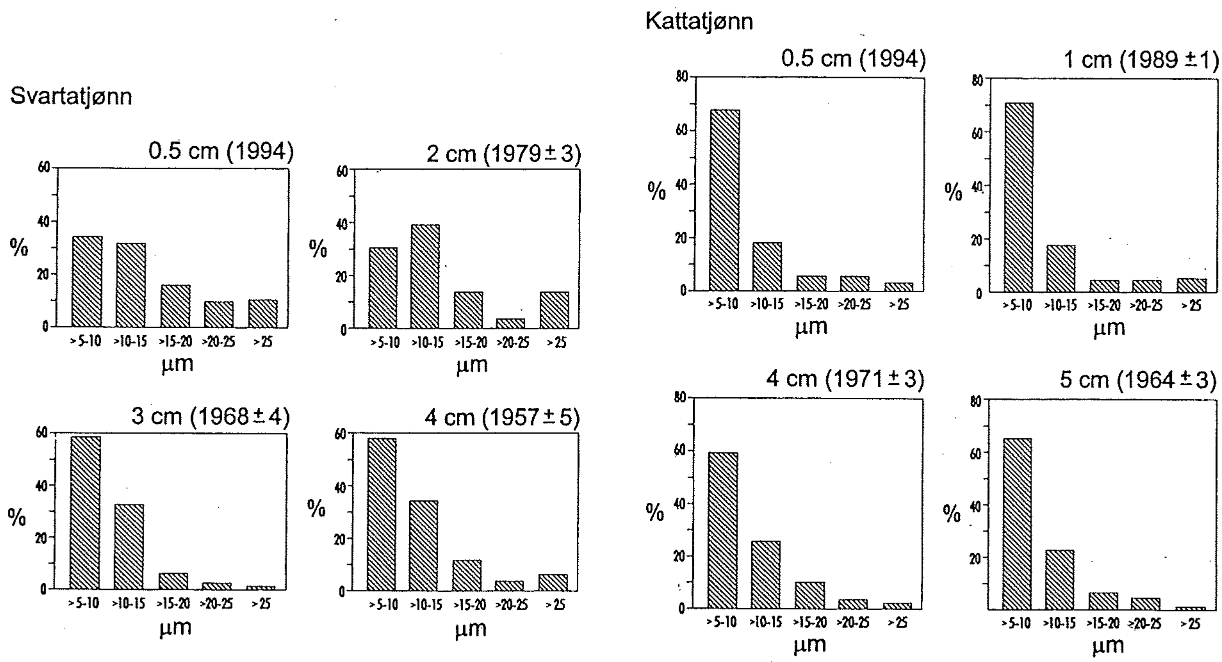




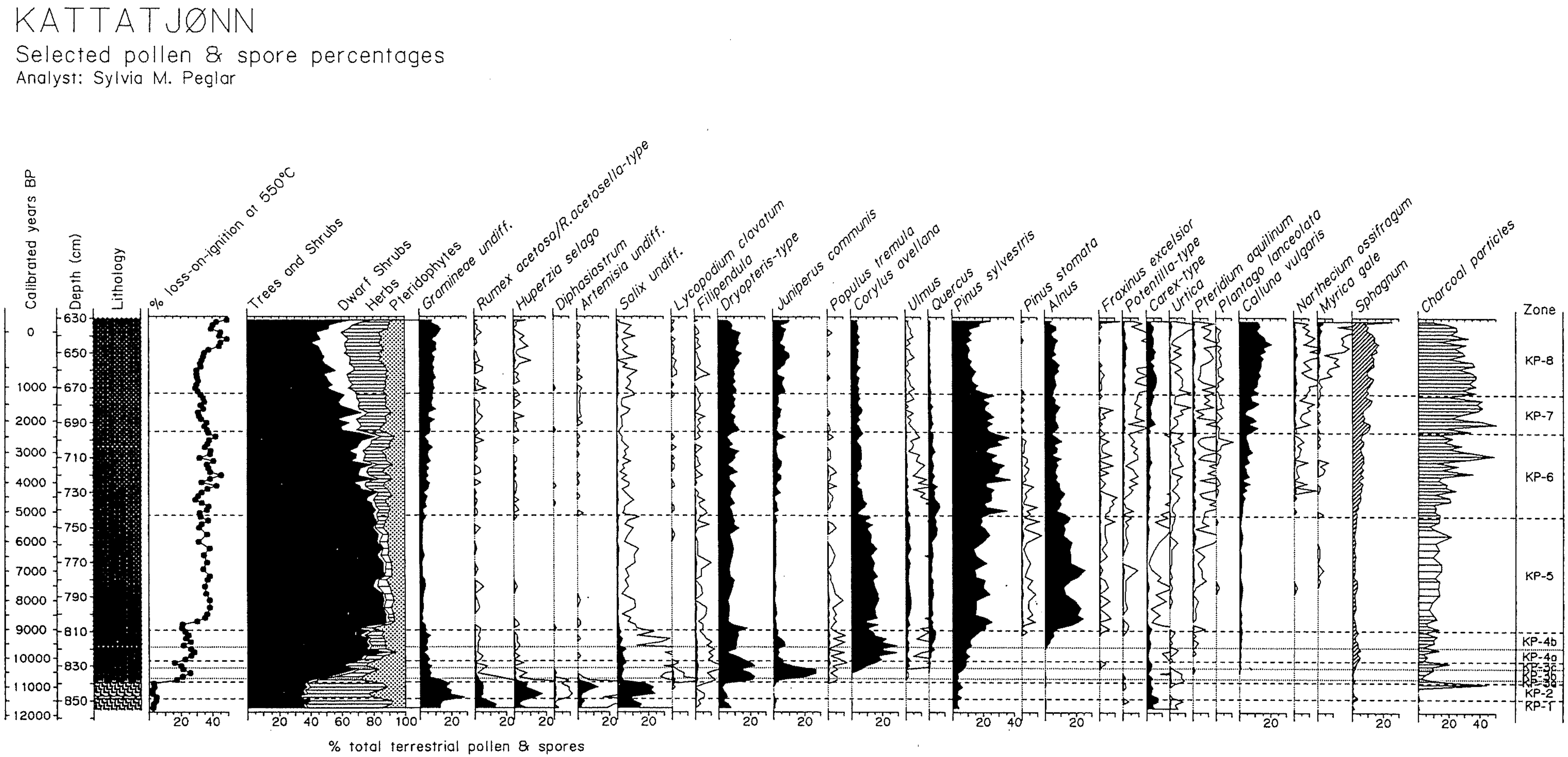
Results of the analyses of the sediments of Svartatjønn and Kattatjønn showing the sediment accumulation rate (in Svartatjønn) (cm yr^{-1}), loss-on-ignition (% of dry weight), Pb, Ni, and Zn expressed as concentrations of dry weight (µg g^{-1} dry sediment (d.s.)), and spheroidal carbonaceous particles (SCPs) expressed as numbers per gram dry sediment (numbers g^{-1} d.s.). Abbreviations: Sed. acc. = Sediment accumulation, LOI = loss-on-ignition.

Kattatjønn was selected as a reference lake that only receives long-distance transported air pollution mainly from the south-west. Svartatjønn is the lake with the potential local impact from the Mongstad oil refinery but also receives long-distance transported air pollution mainly from the south-west. The refinery started production in 1975 and expanded in 1987. The diagrams and results of the investigation are published in Larsen (2000).

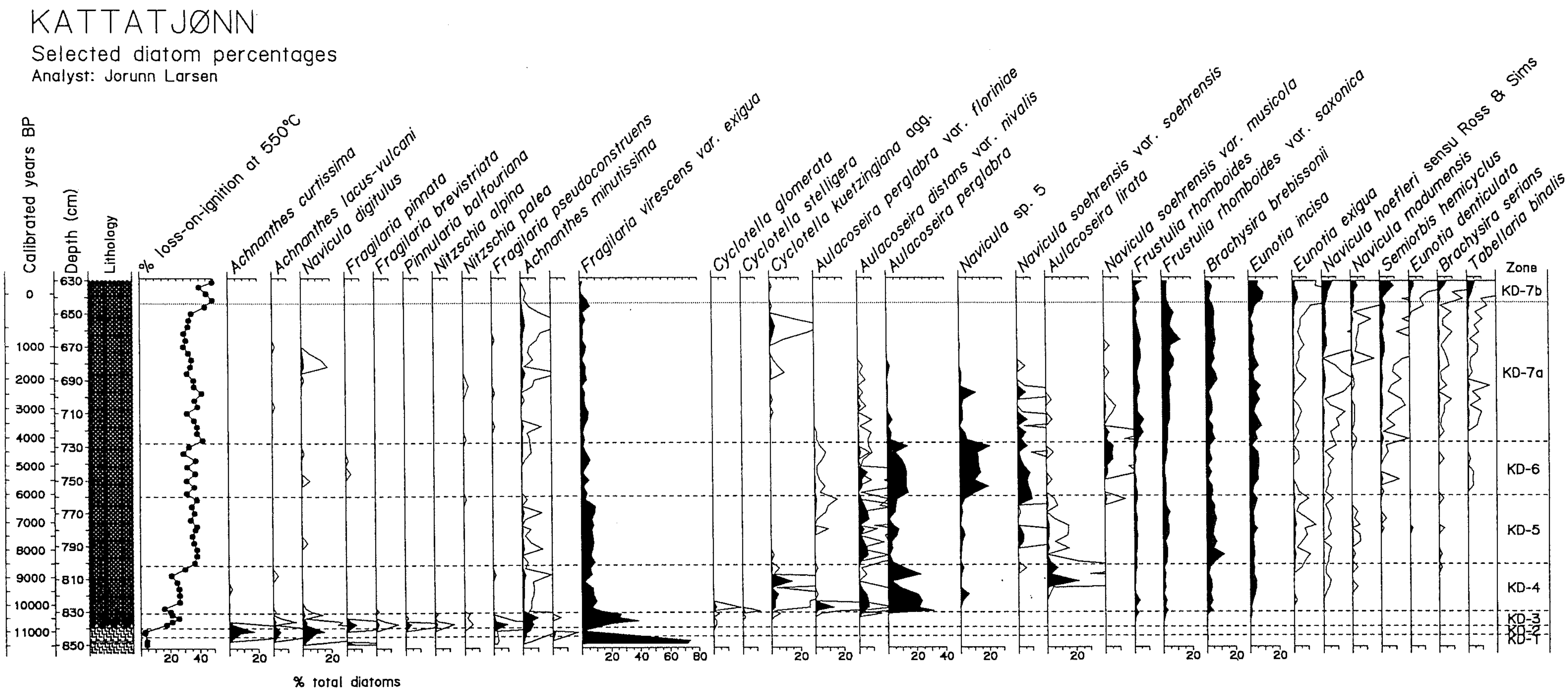
Reference:
Larsen J. (2000). Recent changes in diatom-inferred lake pH, heavy metals, and spheroidal carbonaceous particles in lake sediments near an oil refinery at Mongstad, western Norway. *Journal of Paleolimnology,* **23:** 343-363.



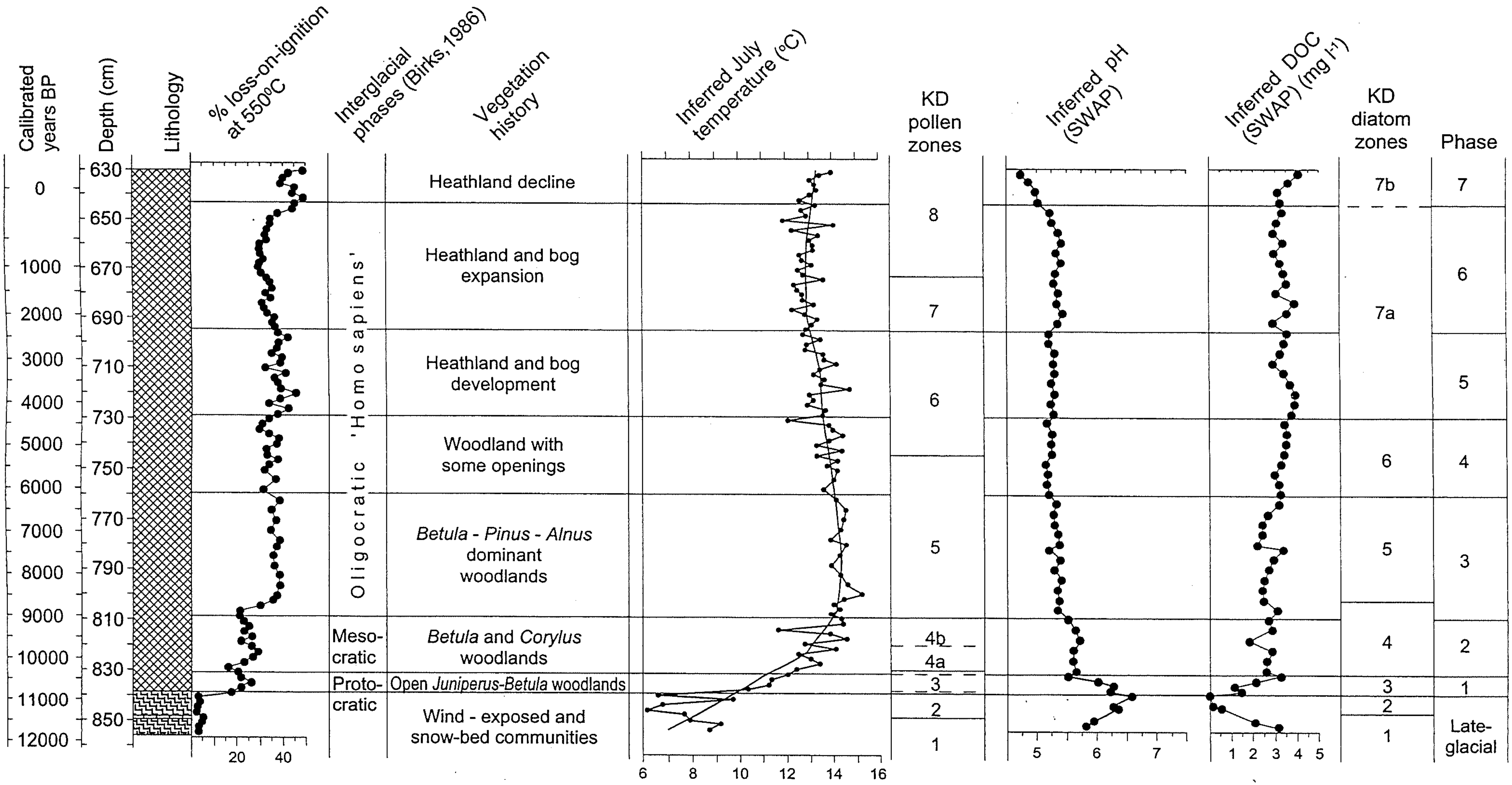
The diameter distribution of spheroidal carbonaceous particles in sediment levels in Kattatjønn and Svartatjønn before and after the oil refinery started.



Summary pollen diagram from Kattatjønn, Sotra, western Norway.



Summary diagram of selected diatom taxa from Kattatjønn.

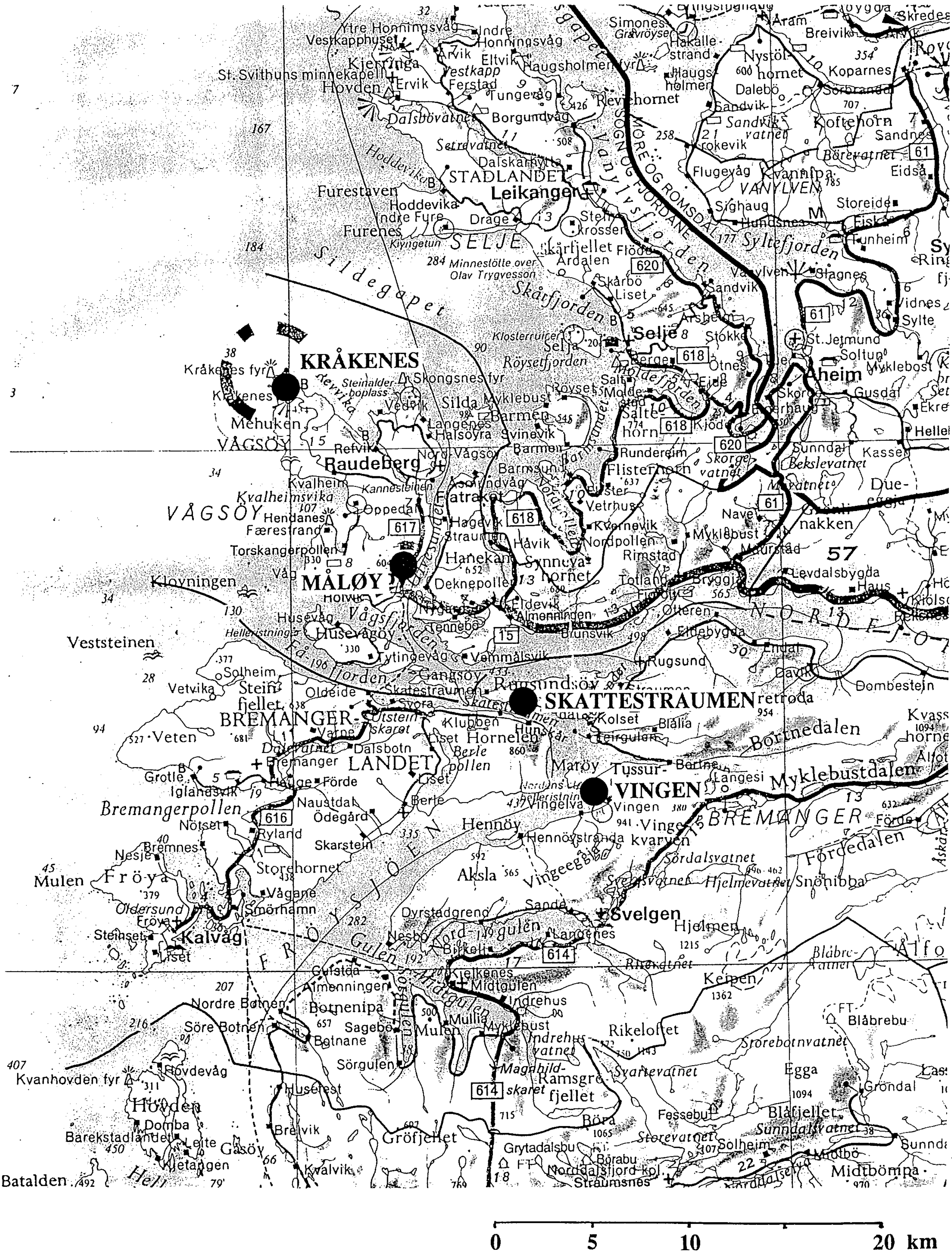


Summary of results from Kattatjønn.

Monday, 19 August 2002

Kråkenes, Skattestraumen, Vingen

DAY 2. Monday, 19th. August



The KRÅKENES PROJECT

COLLABORATORS

Plant macrofossils	Hilary Birks (UiB, Bergen)
Pollen	Sylvia Peglar (UiB)
Mosses	Birgitte Jonsgard (UiB)
Diatoms	Emily Bradshaw, Viv Jones, Rick Battarbee (UCL, London)
Oribatid Mites	Ingrid and Torstein Solhøy (UiB)
Chironomids	Steve Brooks (Nat. Hist. Museum, London)
Cladocera	Catherine Duigan (CCW, Wales)
Coleoptera	Geoffrey Lemdahl (Växjö, Sweden)
Trichoptera	John O. Solem (NTNU, Norway)
^{14}C dating	Steinar Gulliksen (NTNU), Göran Possnert (Uppsala, Sweden)
Tephras	Haflidi Haflidason (UiB)
Stomata/CO_2	David Beerling (Sheffield, UK)
Geology/glaciology	Jan Mangerud, Reidar Løvlie (UiB), Eiliv Larsen, Martha Stalsberg (NGU, Norway), Eivind Sønstegaard (Sogndal, Norway)
Numerical analyses	John Birks (UiB)
General	Herb Wright (Minnesota), Rick Battarbee (UCL), John Smol (Kingston, Canada)

LATE-GLACIAL & EARLY-HOLOCENE ECOSYSTEM RECONSTRUCTIONS AT KRÅKENES

Consider the ecosystem

CLIMATE ↙ ↘

LAKE ← CATCHMENT

Multi-disciplinary study -

- chronology (AMS dating)
- palaeo-environmental reconstructions
  - Terrestrial organisms
  - Aquatic organisms
- Climate reconstructions

Numerical analyses -

- DCA
- rate of change
- climate reconstruction

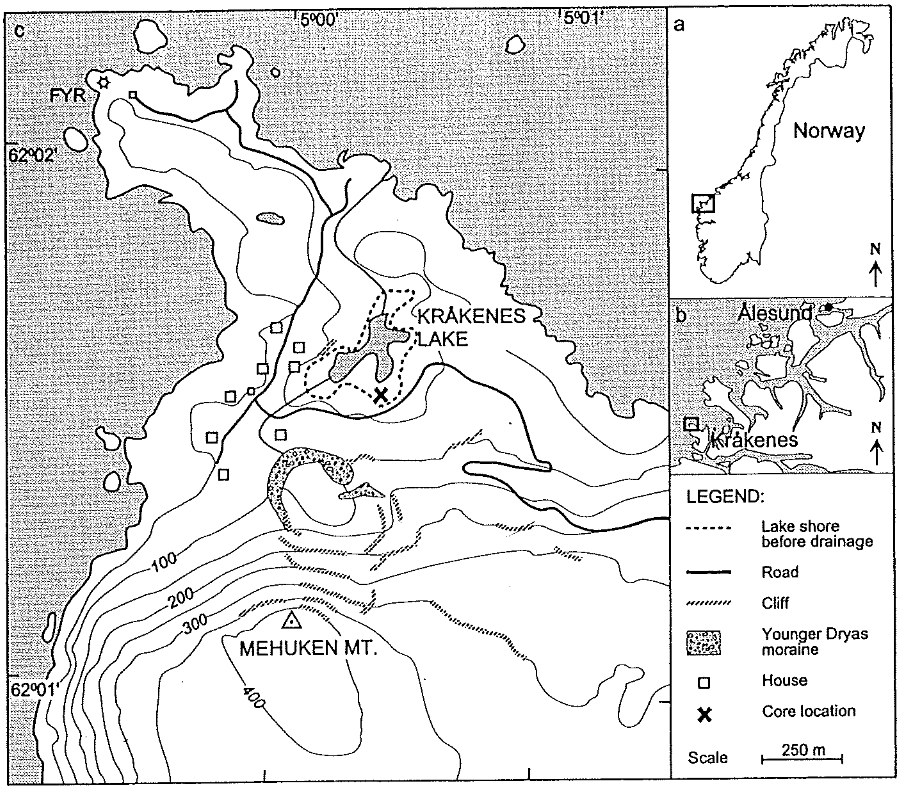
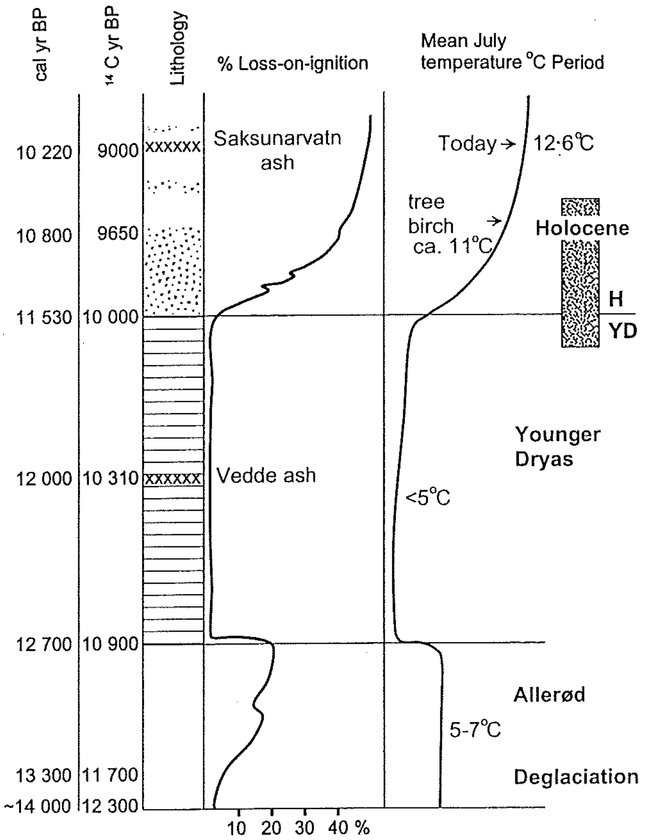


Figure 1. Maps showing the location of Kråkenes (a, b), and the surroundings of the lake (c). The core site is marked by x.

Figure 2. Photograph of Kråkenes Lake from the top of Mehuken Mountain, showing the Younger Dryas cirque moraine in the middle ground below the cliff, the lake and the drained marshy areas, and the Kråkenes peninsula. (Photo – H. H. Birks).

THE LATE-GLACIAL AT KRÅKENES



RADIOCARBON DATING

Salix herbacea

RECONSTRUCTION OF THE ECOSYSTEMS AT KRÅKENES

Time Period:

Late-glacial and early Holocene 12,300 - 8800 ^{14}C BP
14,200 - 9000 cal BP

Climatic Changes:

Allerød interstadial ~12,000 - 10,900 ^{14}C BP
(GI-1) ~14,000 - 12,700 cal BP
~1300 yr ~0.45 mm yr^{-1}

Younger Dryas Stadial
(GS-1) ~10,900 - ~10,000 ^{14}C BP
12,700 - 11,530 cal BP
~1200 yr ~1.5 mm yr^{-1}

YD/Holocene Transition
~10,000 ^{14}C BP
11,530 - 11,200 cal BP
~300 yr

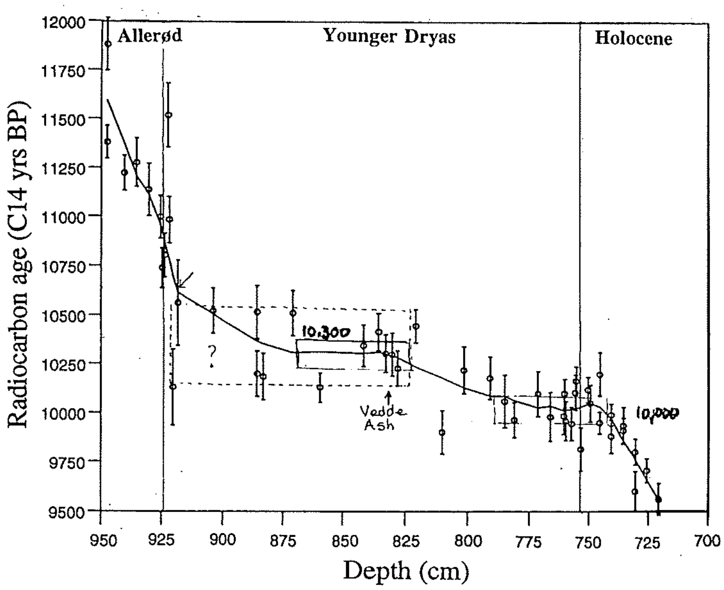
Early Holocene
~10,000 - 8800 ^{14}C BP
11,200 - 9000 cal BP
~2350 yr ~0.7 mm yr^{-1}

The main external driving force is TEMPERATURE

Temperature affects the catchment and the lake directly
Organisms respond directly or indirectly to temperature
Changes in the catchment affect the lake

Radiocarbon Dates

Kråkenes 725.5 - 947.5 cm (>0.6 mgC)



Kråkenes Radiocarbon Calibration

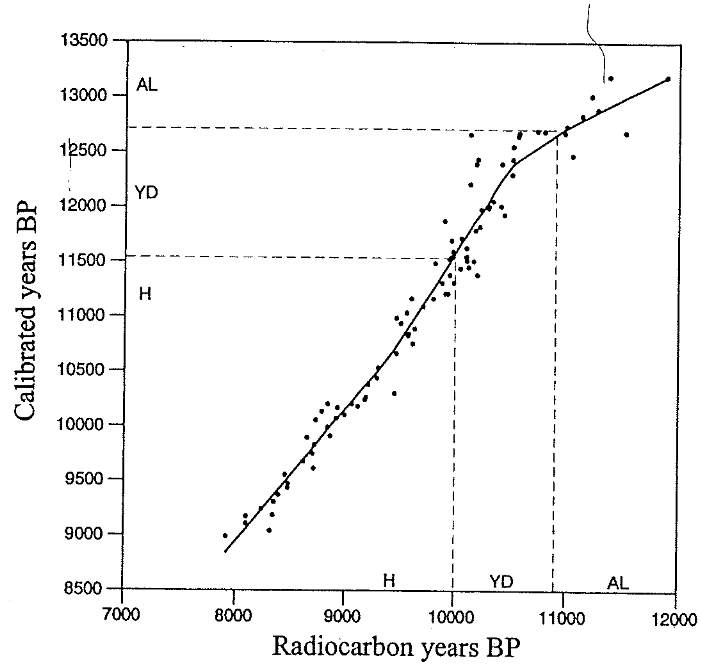
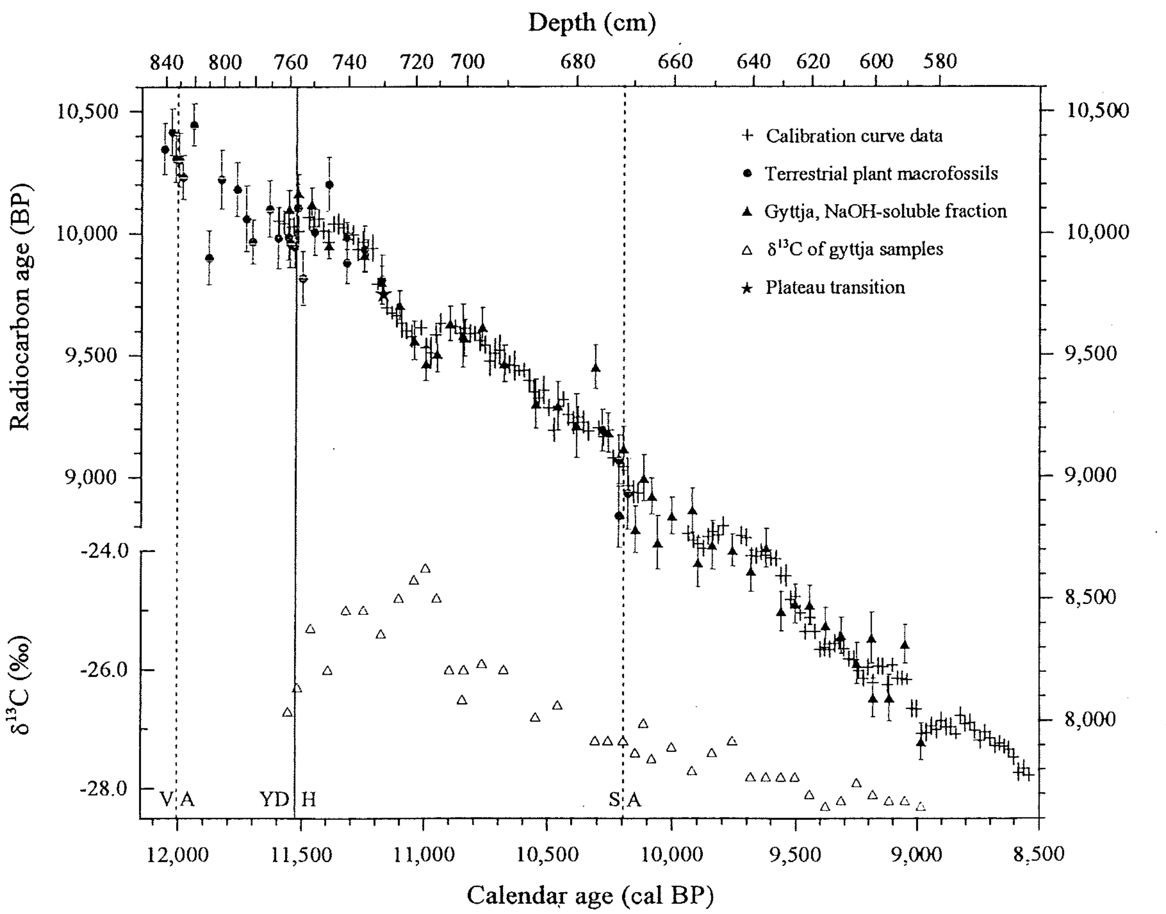


Figure 2. The relationship between radiocarbon yrs and calibrated ^{14}C yrs for the Kråkenes master core. Dates from the Holocene to the mid-Younger Dryas were calibrated by wiggle matching against the Hohenheim dendrochronology (Gulliksen et al., 1998). Below that, a smoother was put through the radiocarbon dates, and the most likely radiocarbon age was estimated for each level and calibrated against the Lake Suigetsu chrononlogy (Kitagawa & van der Plicht, 1998). The boundaries of the lithological units AL (Allerød), YD (Younger Dryas), and H (Holocene) are marked. The line is a LOESS scatter plot smoother, span 0.35.

Younger Dryas - Holocene calibration



Dating of Vedde and Saksunarvatn Tephras

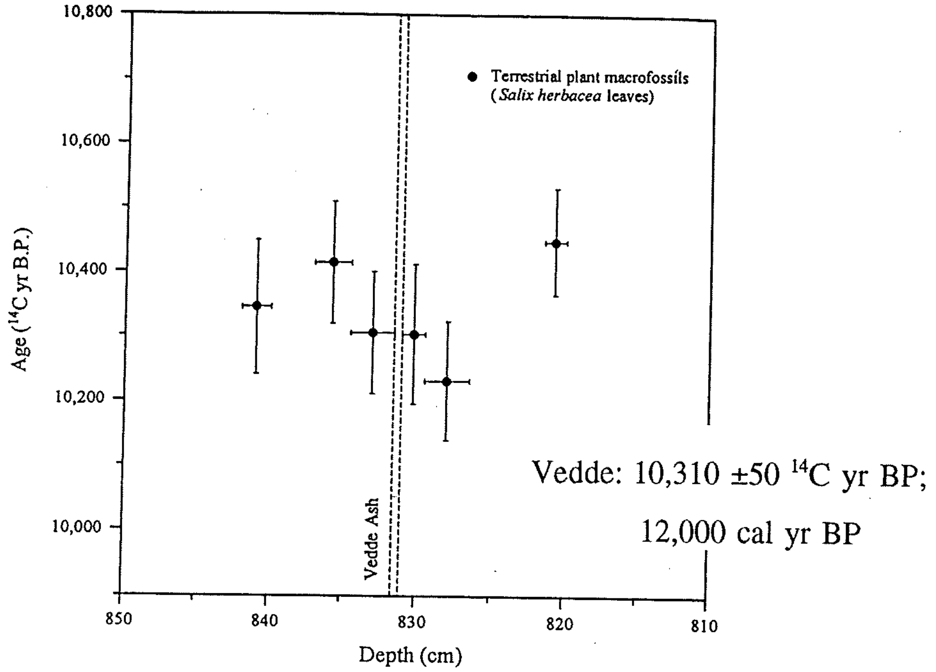


FIG. 4. Radiocarbon dates vs depth across the Vedde Ash layer at Kråkenes (indicated at 831–831.5 cm), all on *Salix herbacea* leaves. Horizontal bars are the depth span of the sample, vertical bars are 1 standard deviation of measurement.

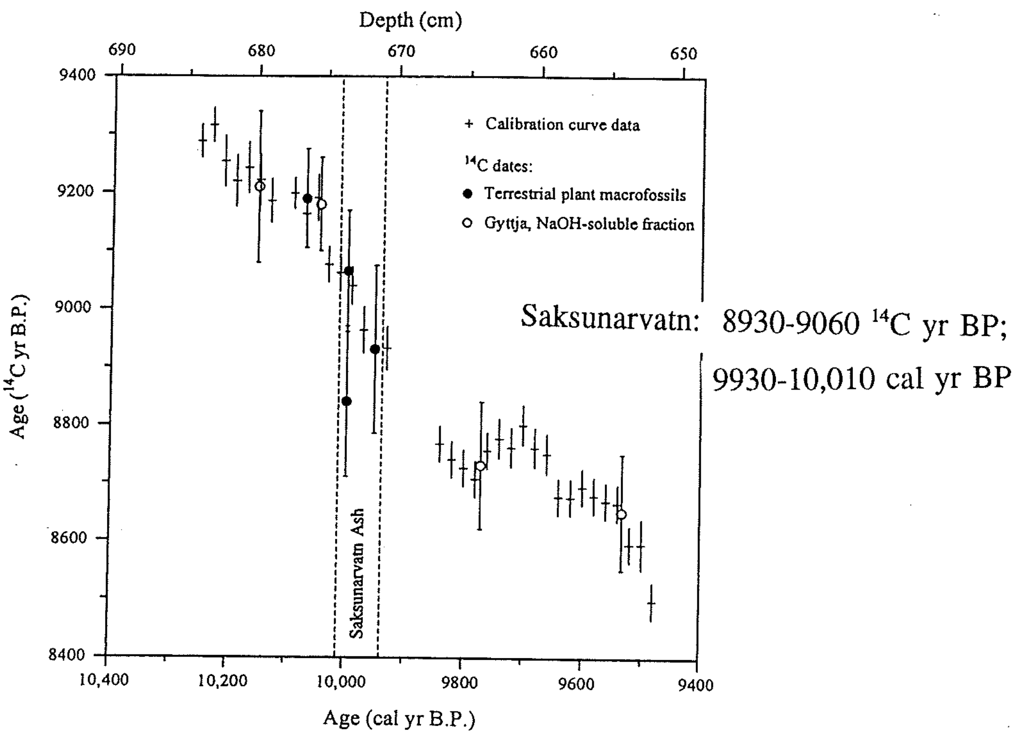
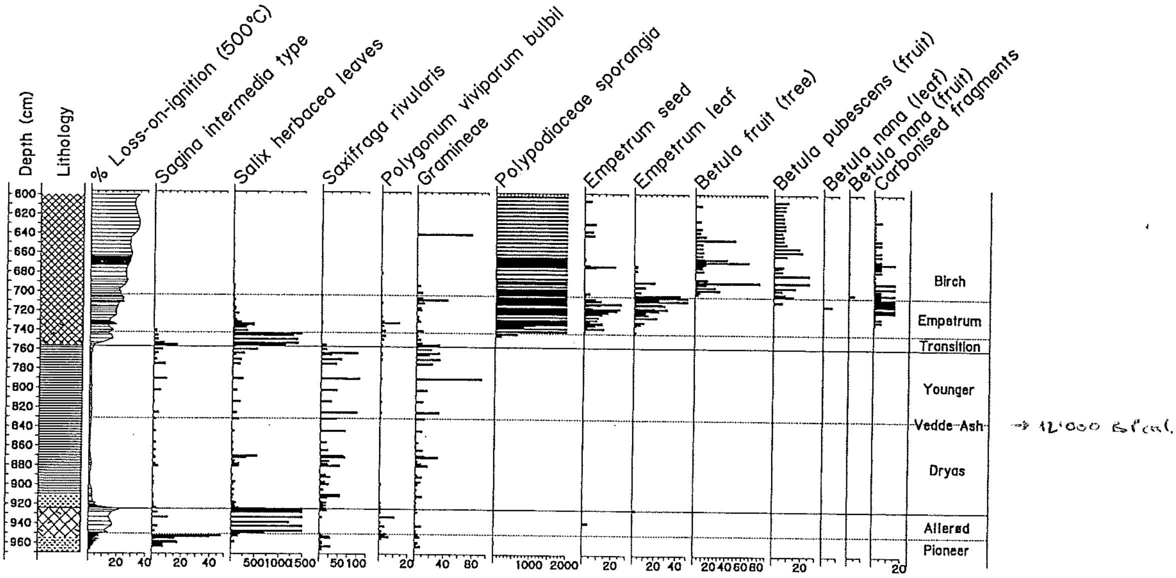


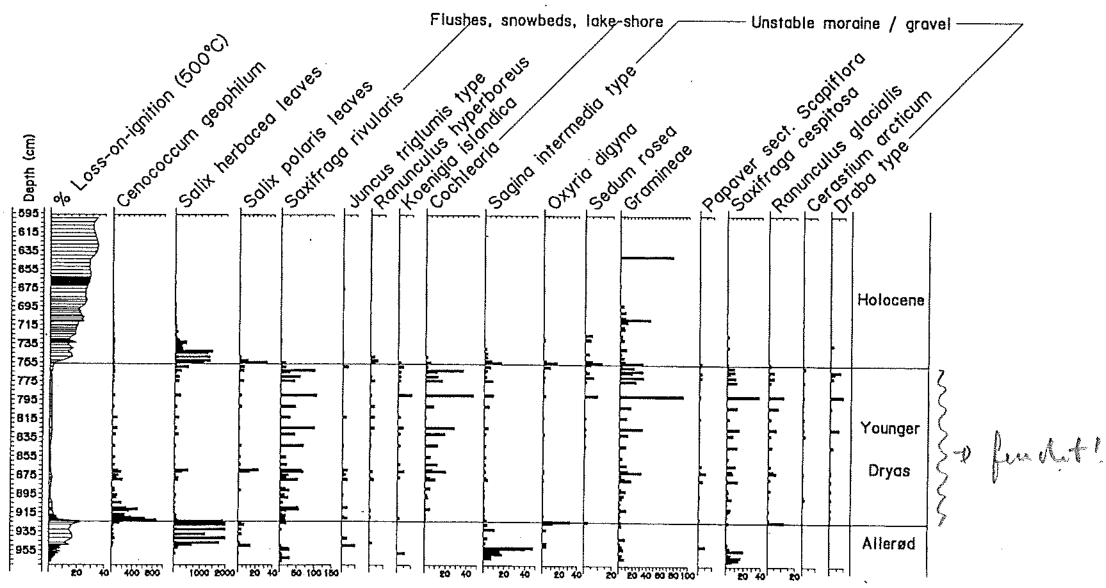
FIG. 5. Radiocarbon dates (circles) vs depth (upper scale) across the Saksunarvatn Ash layer at Kråkenes (indicated between 671–674 cm). Samples all span 1 cm depth. Vertical bars are 1 standard deviation of measurement. Radiocarbon ages versus calibrated age (lower scale) from the dendrochronological calibration curve (Stuiver and Reimer, 1993) are shown with crosses. The Kråkenes dates are matched to the calibration curve data by varying the scale and the chronological position of the depth (upper) axis (see text).

TERRESTRIAL ECOSYSTEM

Kråkenes Terrestrial Macrofossils
Summary Diagram



Kråkenes macrofossils, Allerød and Younger Dryas



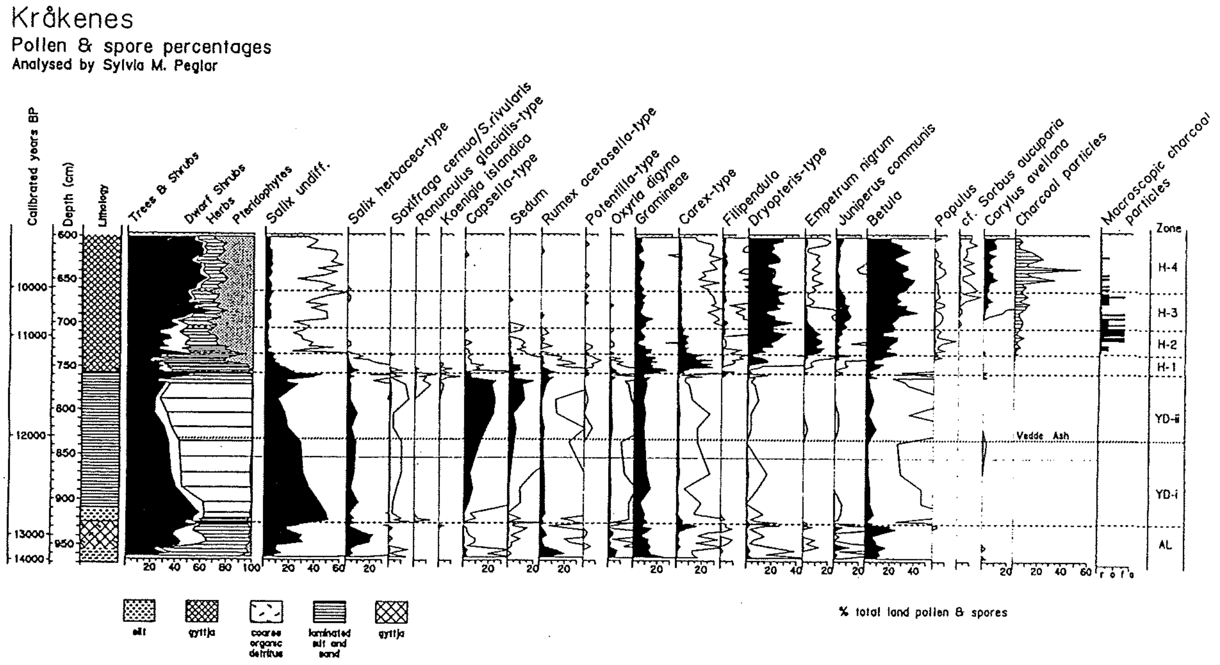


Figure 3. Pollen percentage and influx diagrams from the Kråkenes core for major pollen and spore taxa. (a) Pollen and spore percentages of the main terrestrial taxa, along with microscopic charcoal particles. Macroscopic charcoal particles are plotted on an ordinal scale; r o f a = rare, occasional, frequent, abundant;

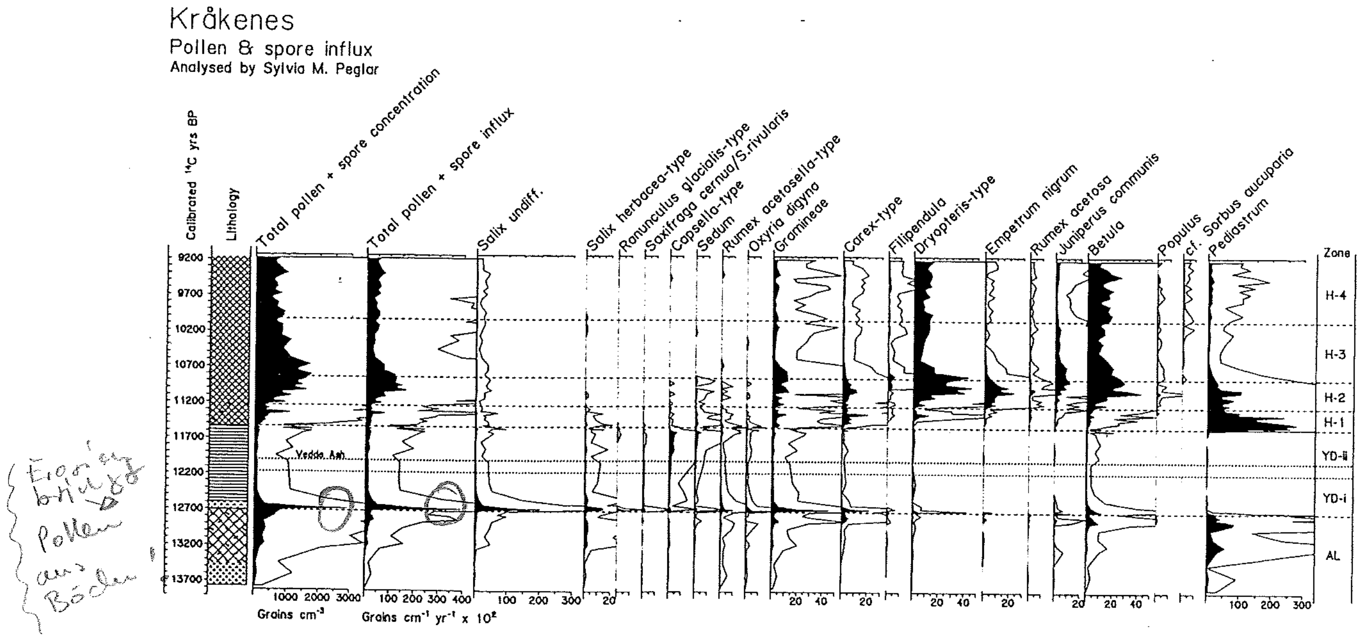


Figure 3. Continued.

Pollen and spore influx of the main terrestrial taxa and of *Pediastrum*. The total concentration and influx values for all terrestrial pollen and spores are also shown. This diagram is plotted on a calibrated ^{14}C age-scale. Note the different horizontal scales.

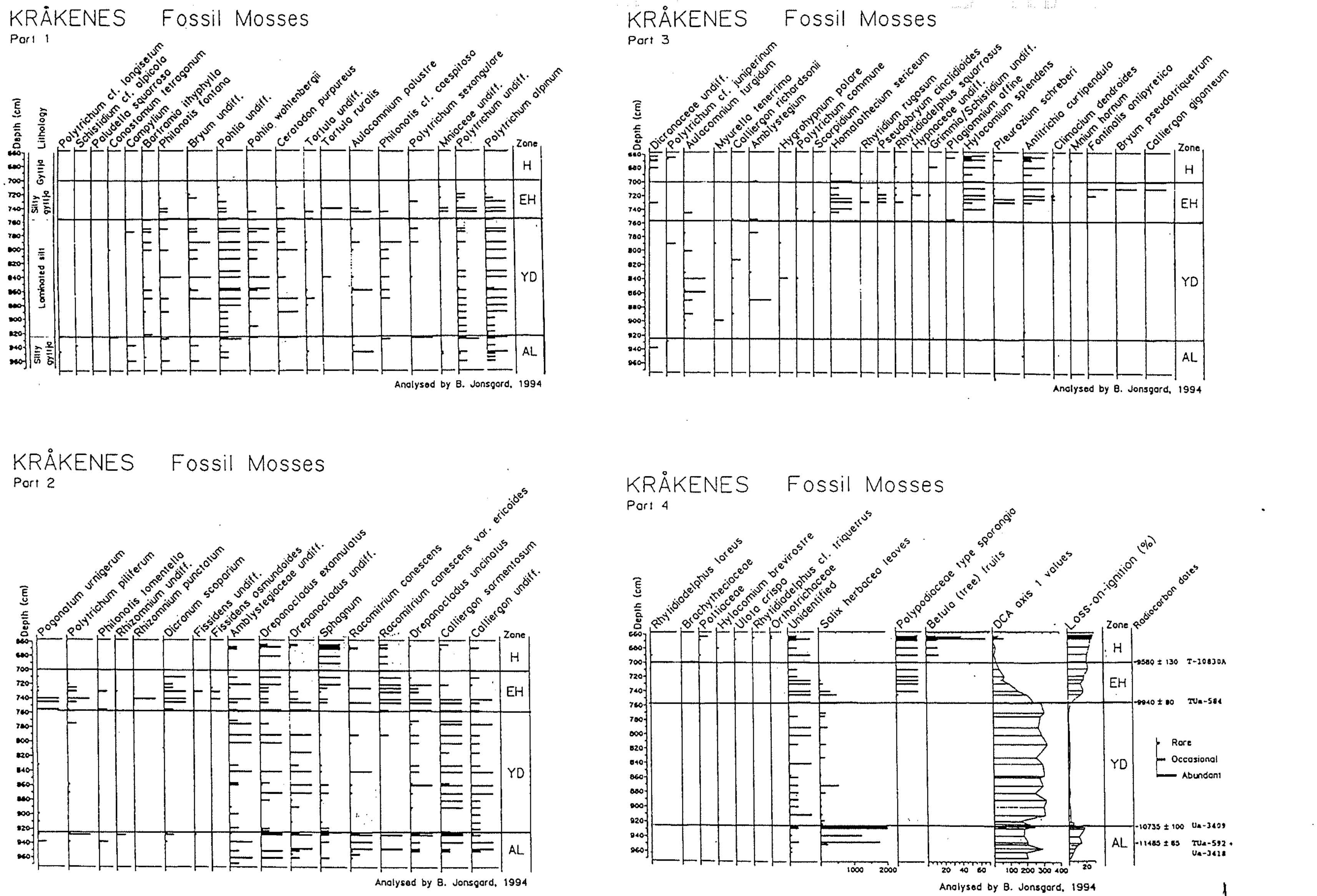


Fig. 2. Stratigraphic diagram of the relative abundance of each taxon in the samples. Taxa are arranged according to their time of appearance. AL = Allerød, YD = Younger Dryas, EH = Earliest Holocene, H = Holocene. The AL/YD and YD/EH boundaries are defined lithostratigraphically. The EH/H boundary is placed at the start of the record of *Betula* (tree) fruits. The relative abundance of the mosses and Polypodiaceae-type sporangia in 3 classes (rare, occasional, abundant) are indicated. *Salix herbacea* leaves and *Betula* (tree) fruits are numbers in 100 cm^3 sediment. Loss-on-ignition was measured after heating dried (100°C) sediment to 550°C for 6 hours. The radiocarbon dates are all AMS dates on *Salix herbacea* leaves from the sequence. Undiff. = undifferentiated.

Jonsgard & Birks (1995)
Lindbergia 20: 64-82.

Milben

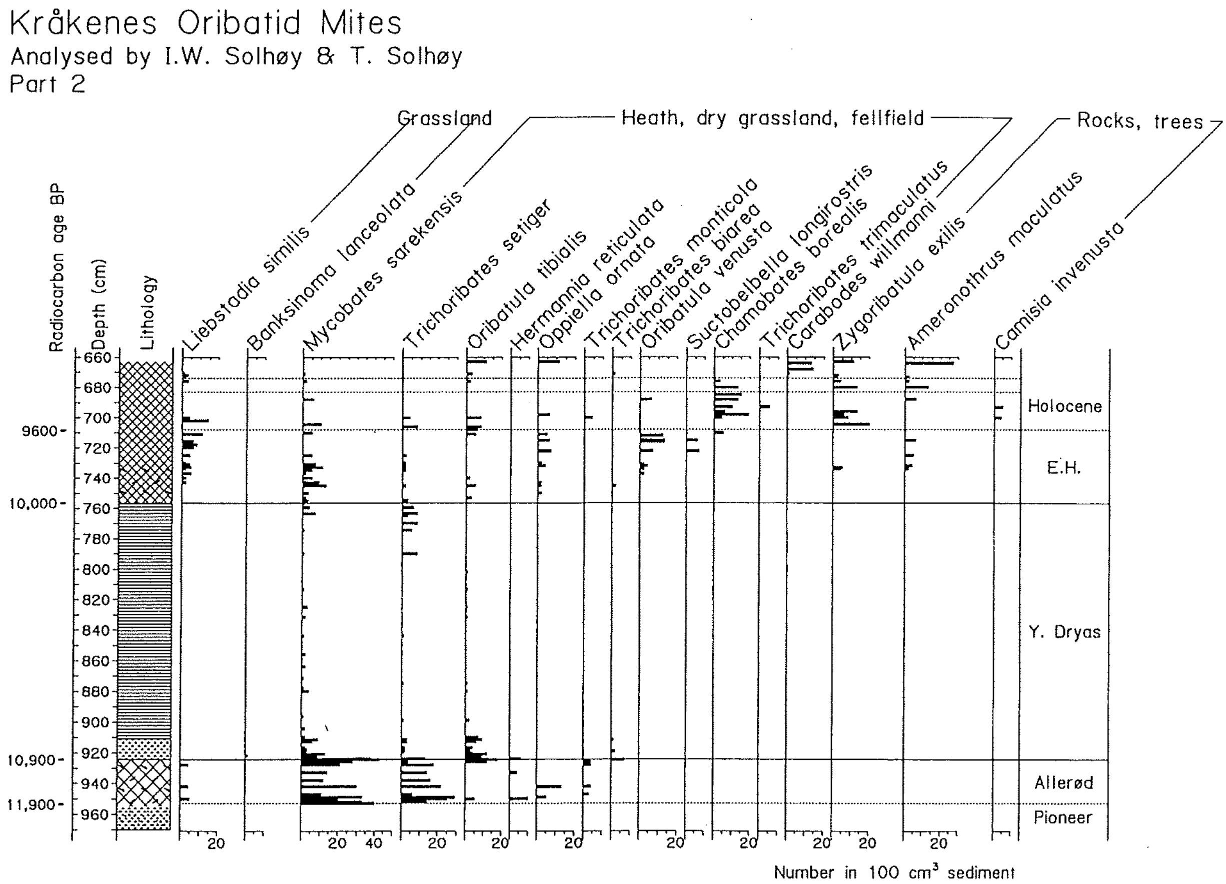
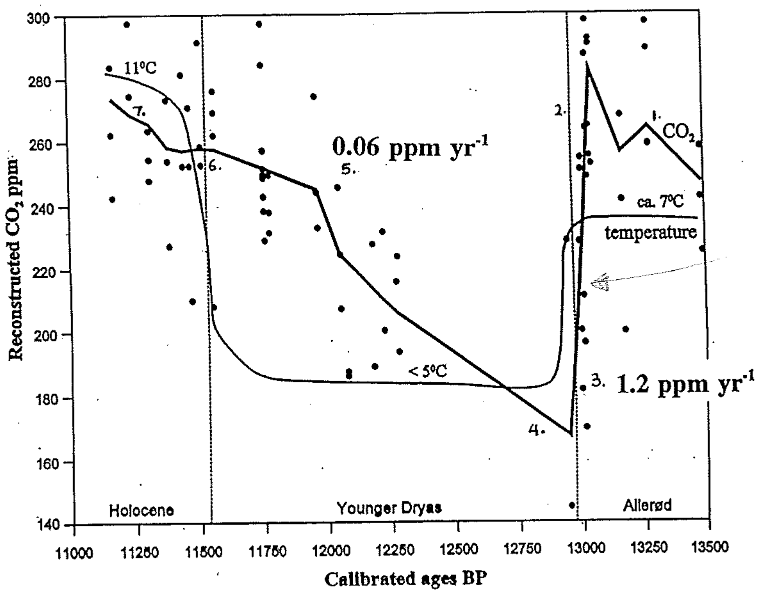


Figure 3. Stratigraphic diagram of the Oribatid species shown as number of mites in 100 cc sediment. Note changing concentration scales. Part 2: Species living in dry to extremely dry habitats as grassland, heath and lichens on rocks and trees. Pioneer = Pioneer period, Y. Dryas = Younger Dryas, E.H. = Earliest Holocene. The E.H./Holocene boundary is placed at the first record of *Betula* (tree) fruits, while the other zone boundaries mark lithostratigraphical changes. The lithology is described by Birks & Wright (2000).

RATES OF CO_2 AND TEMPERATURE CHANGES

Late-glacial CO_2 reconstructions at Kråkenes, western Norway (38 m a.s.l.)



Allerød - Younger Dryas

- The rate of CO_2 decrease is ca. 1.2 ppm yr^{-1}
- The temperatures falls at least 2°C over the same time period
- The rate of biotic response is similar

Younger Dryas - Holocene

- CO_2 increases through the Younger Dryas at 0.06 ppm yr^{-1}
- CO_2 increases during the early Holocene at 0.08 ppm yr^{-1}
- Temperature increases ca. 6°C during ca. 500 yr of the early Holocene
- Biotic response to the temperature rise is immediate (5-10 yr)

Modern

- The present rate of CO_2 rise is 1.25 ppm yr^{-1} (Mauna Loa data)
- Temperature has increased by ca. 0.5 - 1.0°C over the last century

Comparison

- The rate of decline in the late Allerød was similar to the rate of present CO_2 increase; ie. large, rapid changes can occur naturally
- The Younger Dryas - Holocene rate of CO_2 increase was about 6% of that at present
- The temperature increase over the YD / Holocene boundary at Kråkenes was perhaps only a littl faster than the present rate of global warming. The CO_2 increase could not have been fully responsible for the rapid Holocene temperature increase

RESPONSE OF ECOSYSTEMS TO THE

YOUNGER DRYAS / HOLOCENE TEMPERATURE RISE AT KRÅKENES

Questions:

The Greenland ice cores record a large temperature rise over 20-50 yr. Is this so at Kråkenes ?

How fast did plants and animals respond to a rapid temperature rise ?

What were the ecological responses ?

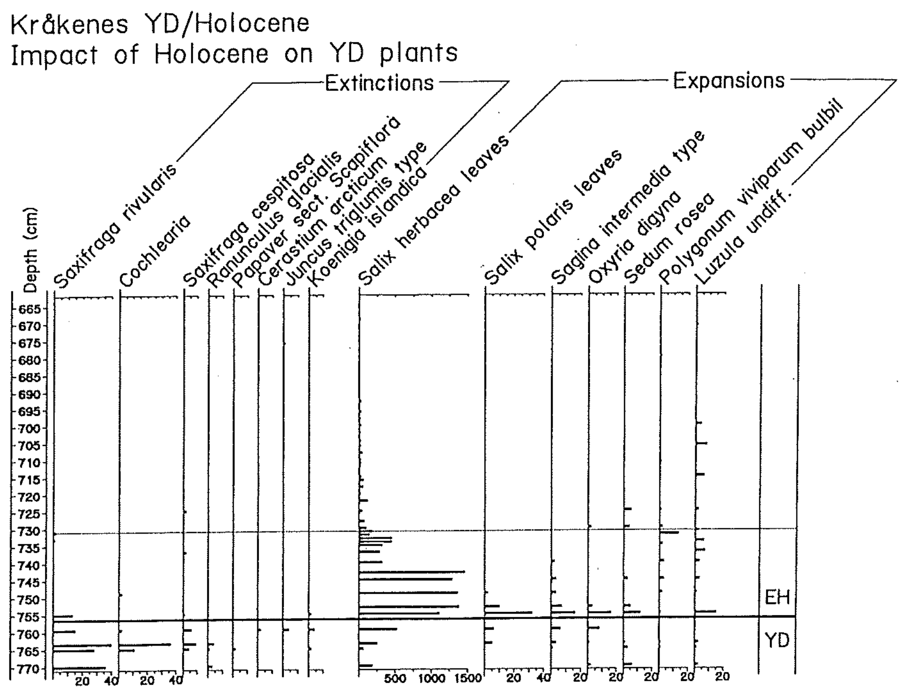
What happened next ?
on land?
in the lake?

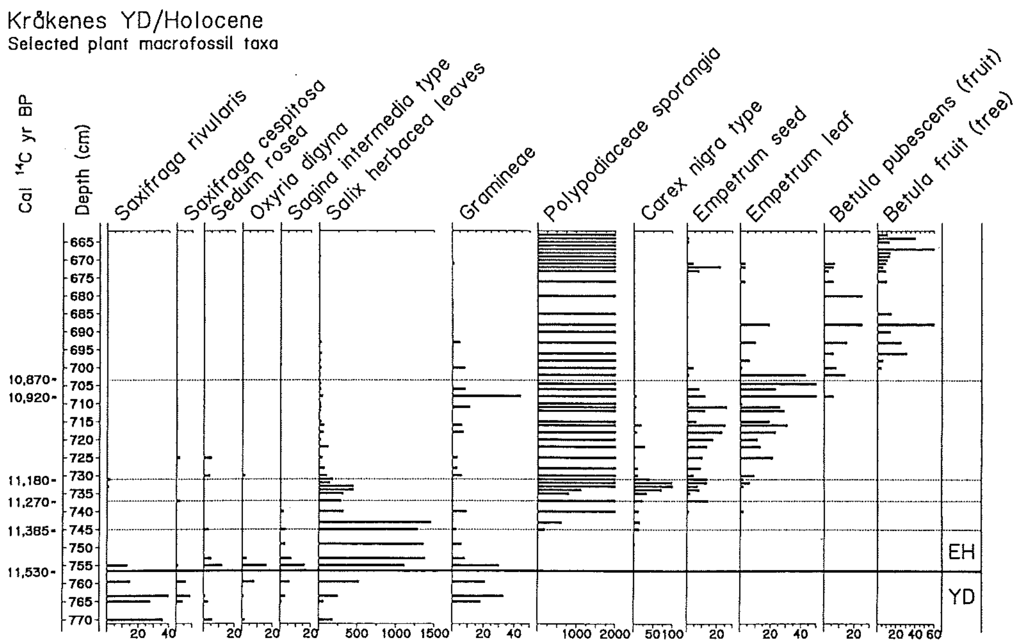
How does the Kråkenes succession compare to those at the present day ?

What controlled the succession ?

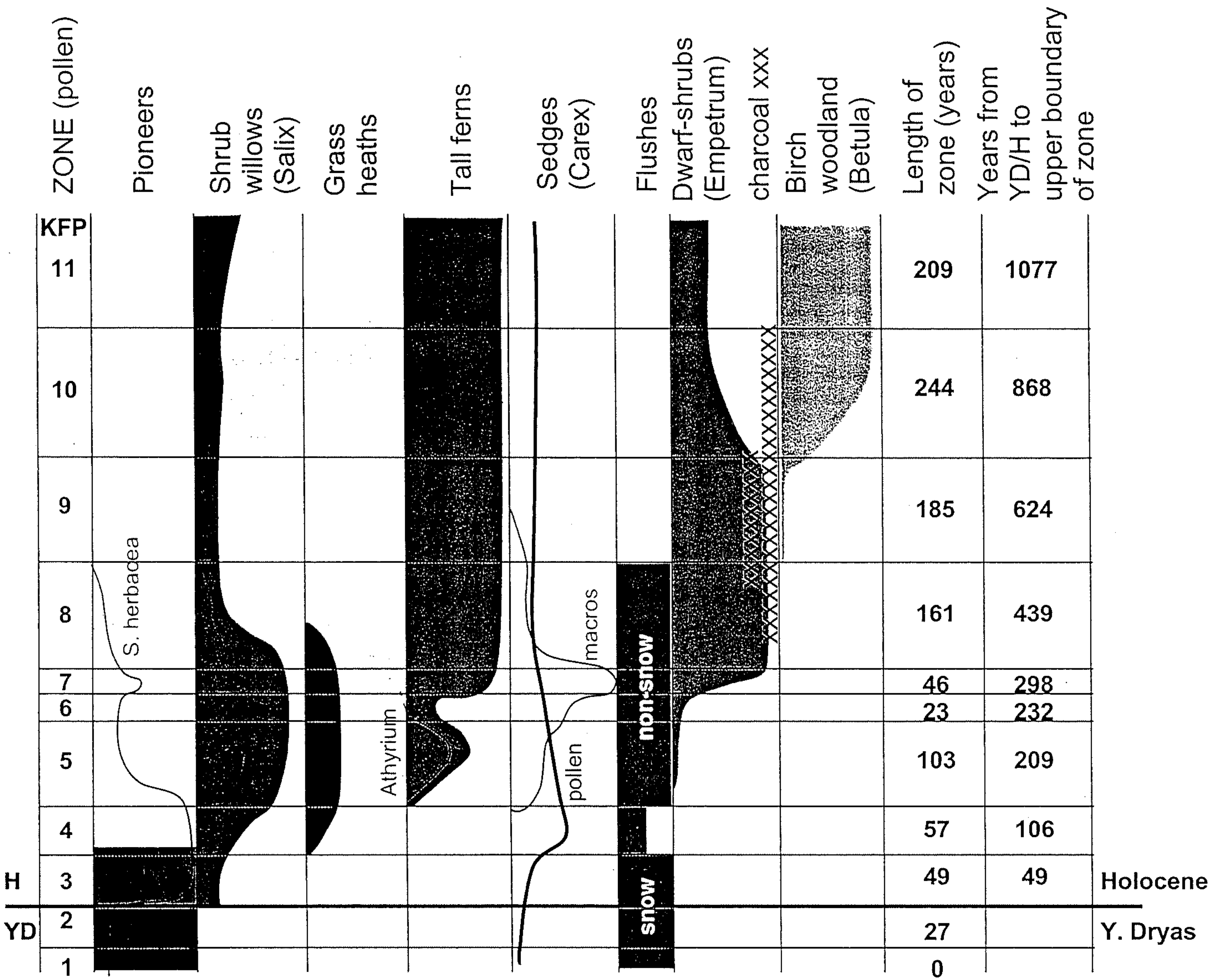
What was the *rate* of change ?

How does a palaeoecological study contribute to the understanding of modern ecological processes ?


Kråkenes YD/Holocene
Impact of Holocene on YD plants
Extinctions
Expansions
Depth (cm)
Saxifraga rivularis
Cochlearia
Saxifraga cespitosa
Ranunculus glacialis
Papaver sect. Scapiflora
Cerastium arcticum
Juncus triglumis type
Koenigia islandica
Salix herbacea leaves
Salix polaris leaves
Sagina intermedia type
Oxyria digyna
Sedum rosea
Polygonum viviparum bulbil
Luzula undiff.
EH
YD

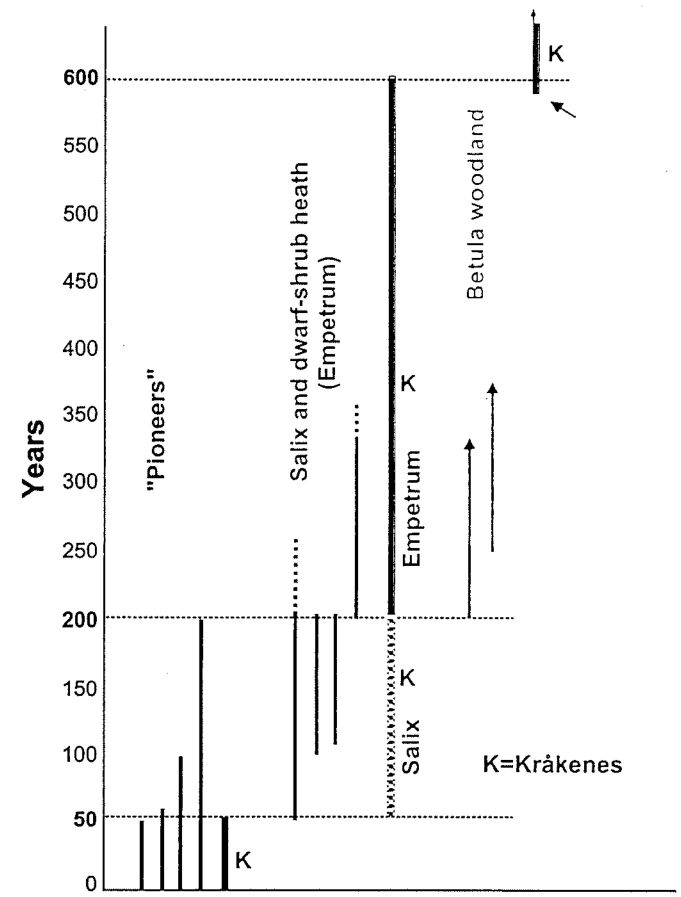

Kråkenes YD/Holocene
Selected plant macrofossil taxa
Cal 14C yr BP
Depth (cm)
Saxifraga rivularis
Saxifraga cespitosa
Sedum rosea
Oxyria digyna
Sagina intermedia type
Salix herbacea leaves
Gramineae
Polypodiaceae sporangia
Carex nigra type
Empetrum seed
Empetrum leaf
Betula pubescens (fruit)
Betula fruit (tree)
10,870
10,920
11,180
11,270
11,365
11,530
EH
YD

Holocene terrestrial succession at Kråkenes



ZONE (pollen)	Length of zone (years)	Years from YD/H to upper boundary of zone
11	209	1077
10	244	868
9	185	624
8	161	439
7	46	298
6	23	232
5	103	209
4	57	106
3	49	49
2	27	
1	0	

Modern successions
Timing depends on altitude /°N



d.h. im Vgl. zu heutigen Sukzessionen war Betula einige 100e Jahre verspätet (>200 Jr auf z.B. Gletschervorfeldern). D.h. s.w. Einwanderungsverzögerung

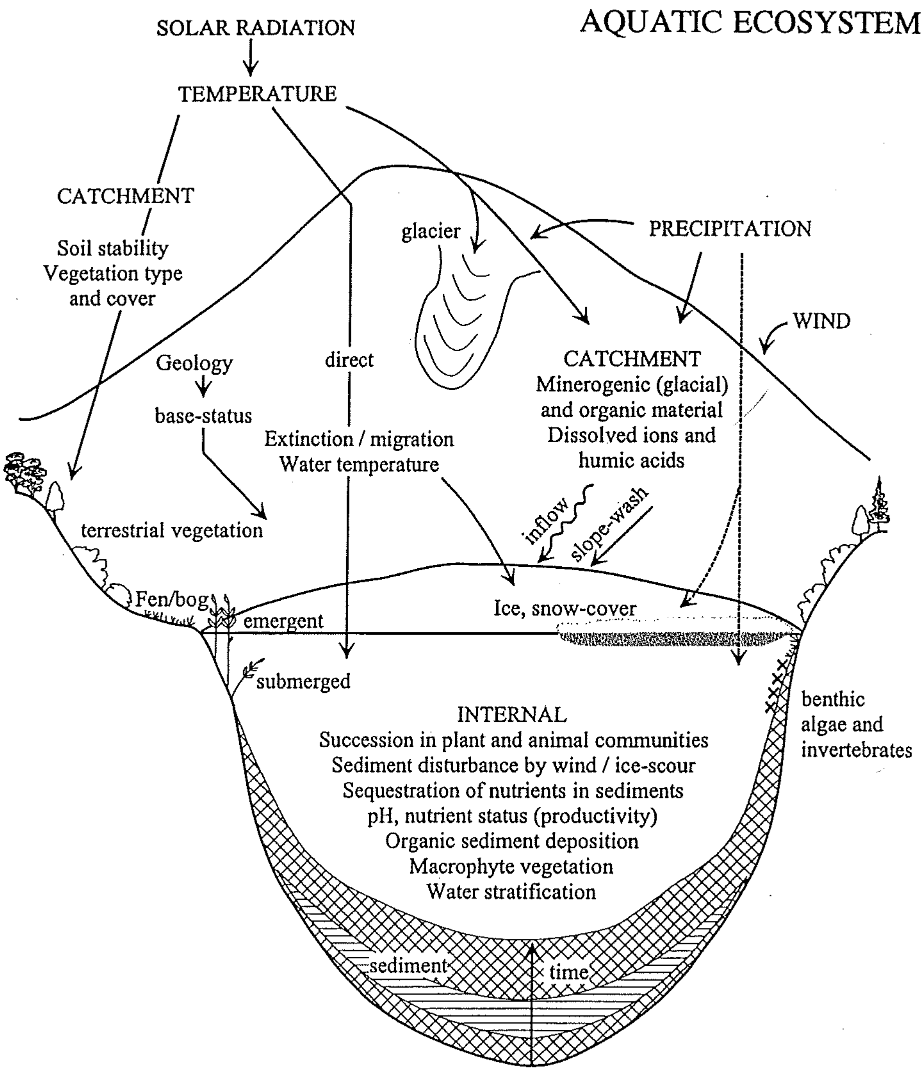
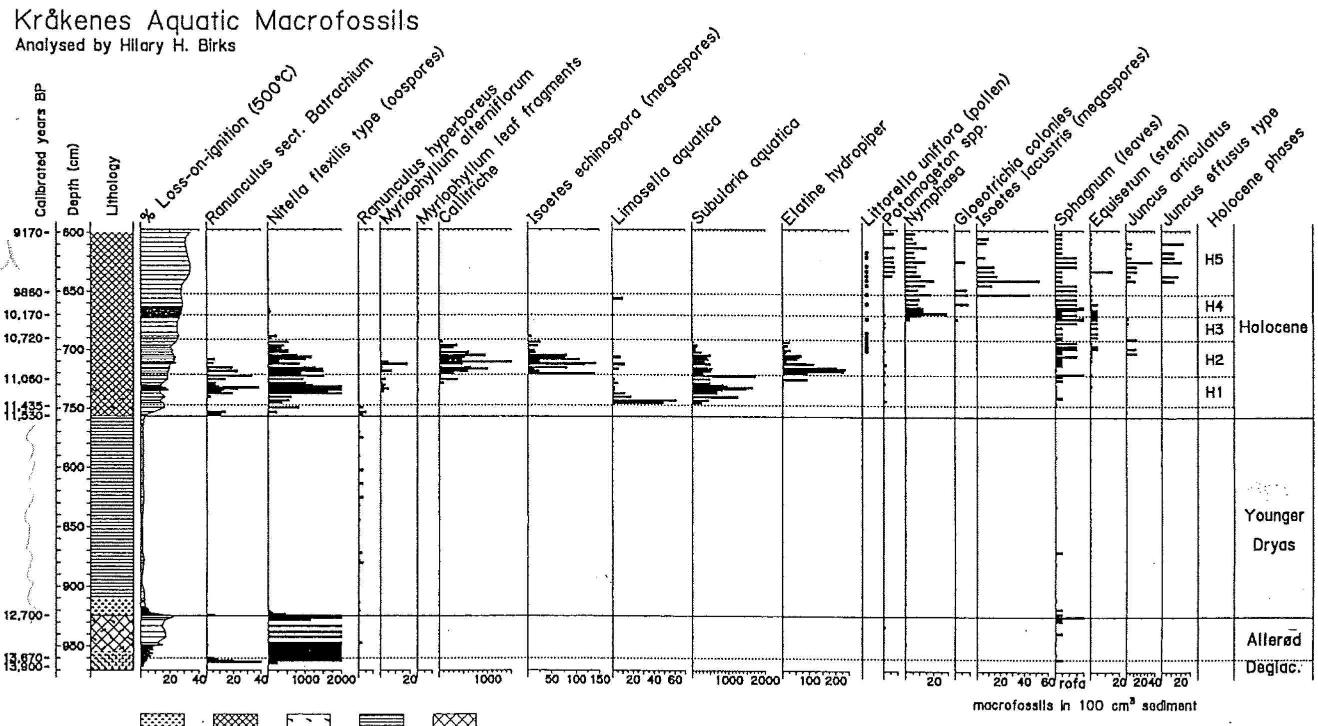


Figure 1. Diagrammatic representation of the major processes affecting a lake ecosystem such as that at Kråkenes during the late glacial and early Holocene.



Birks, H.H. (2000) J. Paleolimnology 23: 7-19.

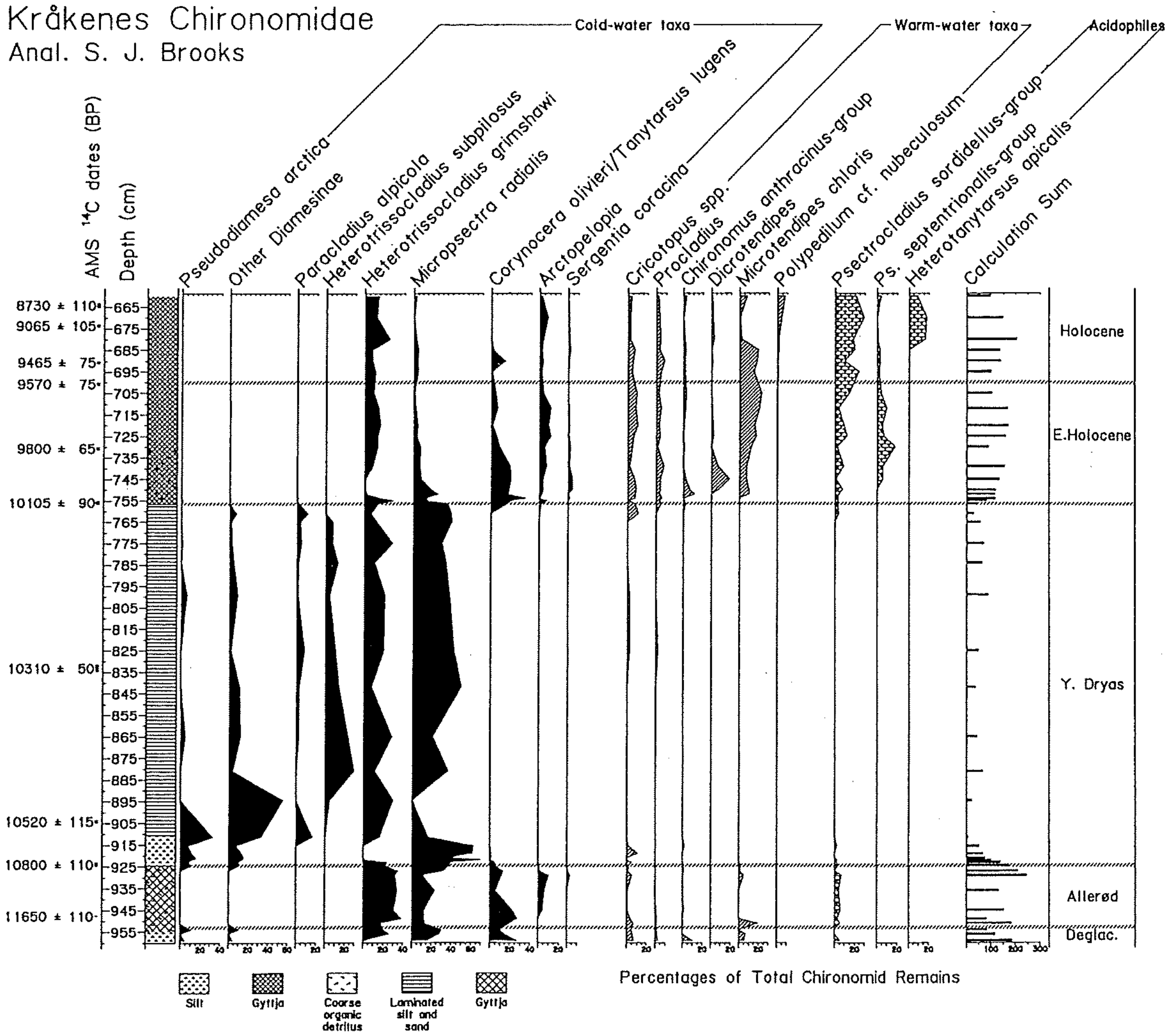


Figure 3. Changes in the percentage abundances of the major chironomid taxa during the-late-glacial and early Holocene at Kråkenes Lake, western Norway. Deglac. = deglaciation phase, Y. Dryas = Younger Dryas, E. Holocene = earliest Holocene.

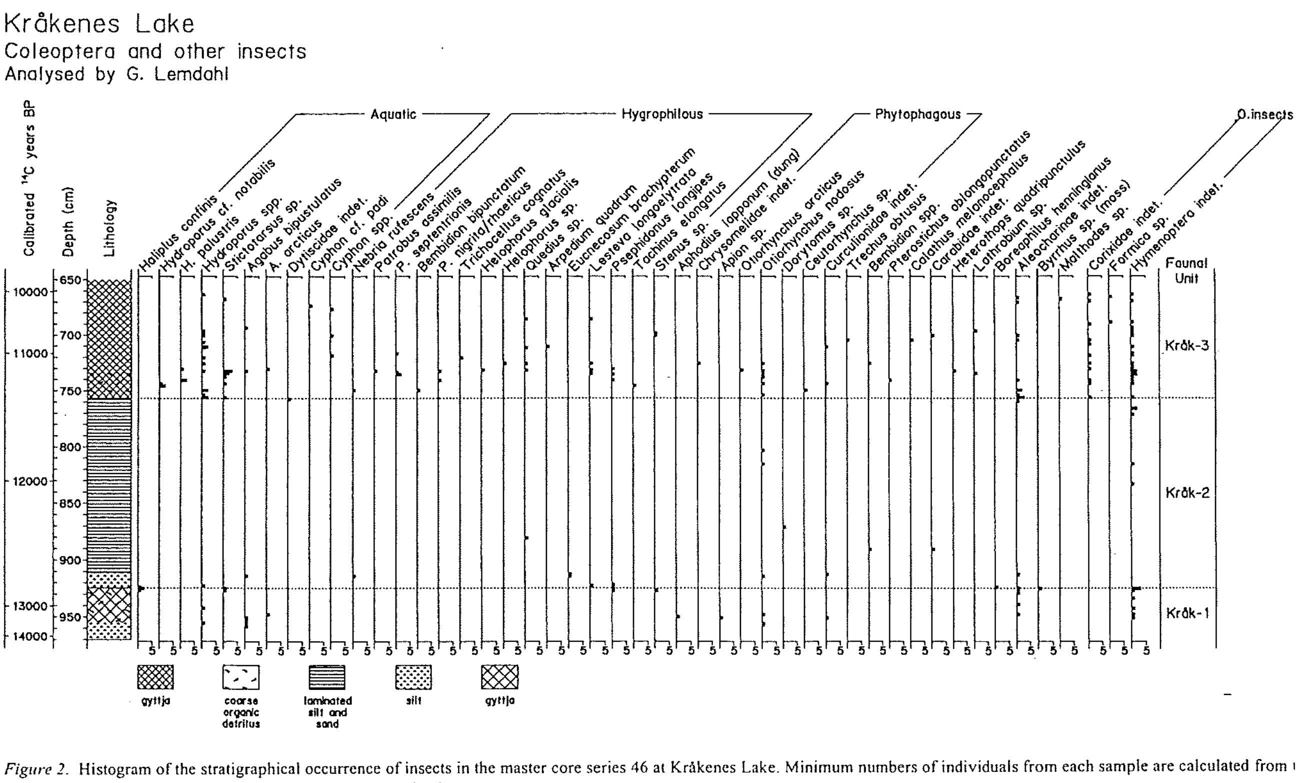


Figure 2. Histogram of the stratigraphical occurrence of insects in the master core series 46 at Kråkenes Lake. Minimum numbers of individuals from each sample are calculated from most abundant skeletal part, but not adjusted for a standard volume.

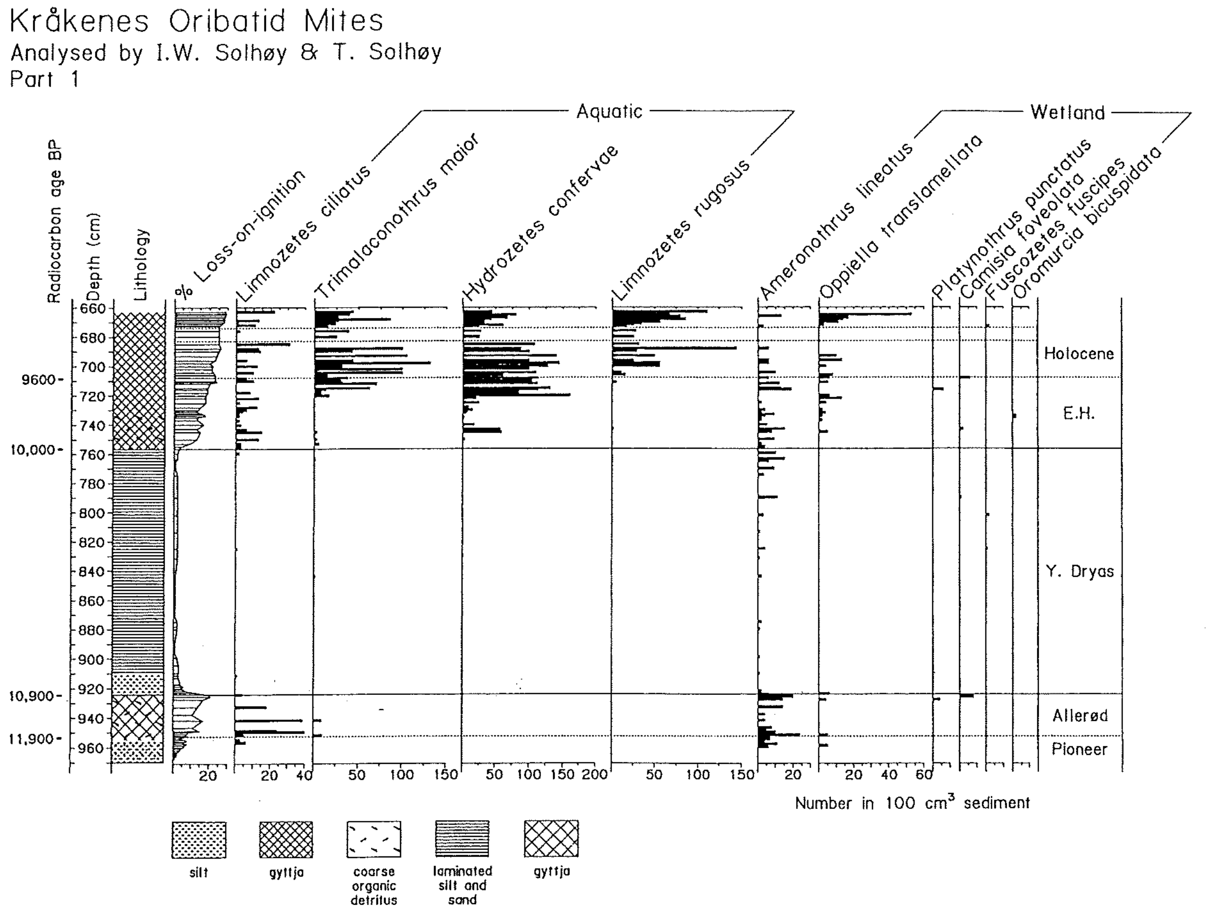


Figure 2. Stratigraphic diagram of the Oribatid species shown as number of mites in 100 cc sediment. Note changing concentration scales. Part 1: Aquatic species and wetland dwellers. Pioneer = Pioneer period, Y. Dryas = Younger Dryas, E.H. = Earliest Holocene. The E.H./ Holocene boundary is placed at the first record of *Betula* (tree) fruits, while the other zone boundaries mark lithostratigraphical changes. The lithology is described by Birks & Wright (2000).

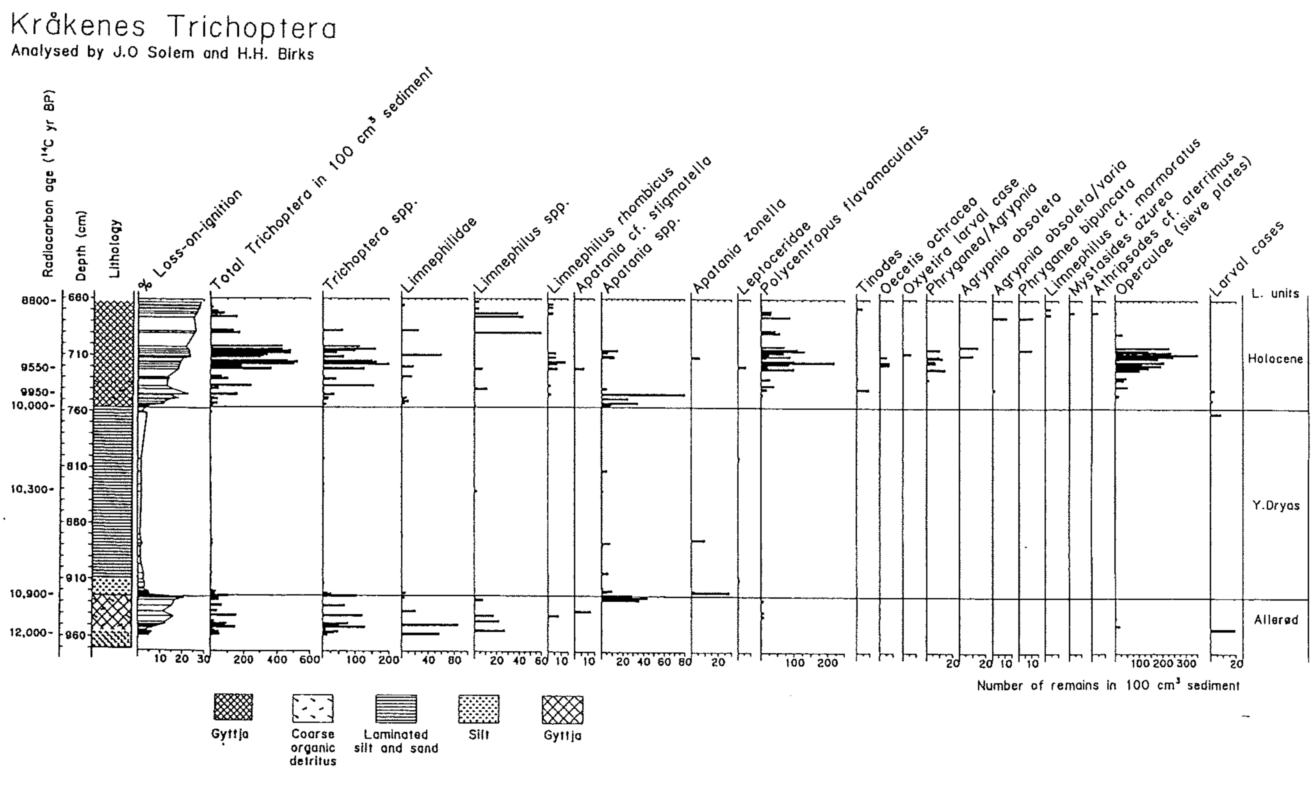


Figure 2. A stratigraphic concentration diagram of the Kråkenes late-glacial and early-Holocene Trichoptera (see text for further explanation). Concentrations are numbers of remains in 100 cm^{-3} sediments. Note changes of scale on the x-axes. The sediment lithology is represented diagrammatically and the % loss-on-ignition at 500 °C (LOI) is also shown. The stratigraphic divisions (L. units) are based on the lithology of the core.

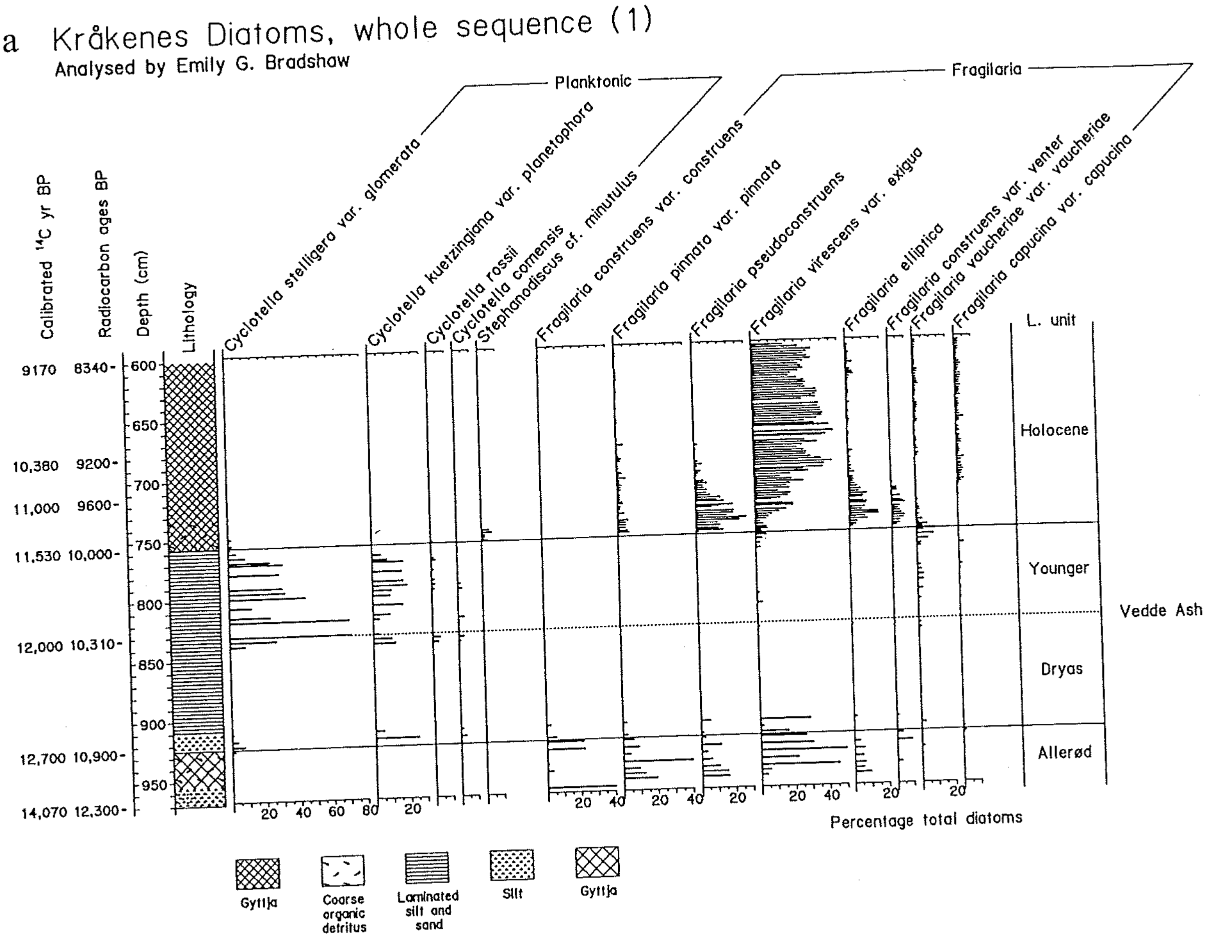


Figure 1. Summary diatom percentage diagram for the whole sequence examined at Kråkenes Lake. All taxa that occur at, or over, 2% in two or more of the samples counted are shown. The Allerød/Younger Dryas lithostratigraphic boundary (924.5 cm; 10,900 ^{14}C yrs BP) and the Younger Dryas/Holocene boundary (756.5 cm; 10,000 ^{14}C yrs BP) are drawn. The concentration of diatom valves was very low throughout the Younger Dryas. Samples analysed between 912 cm and 839 cm contained too few diatom valves to obtain reliable counts. Abbreviations: Y = Younger; BP = Before Present (1950); L. = Lithological.

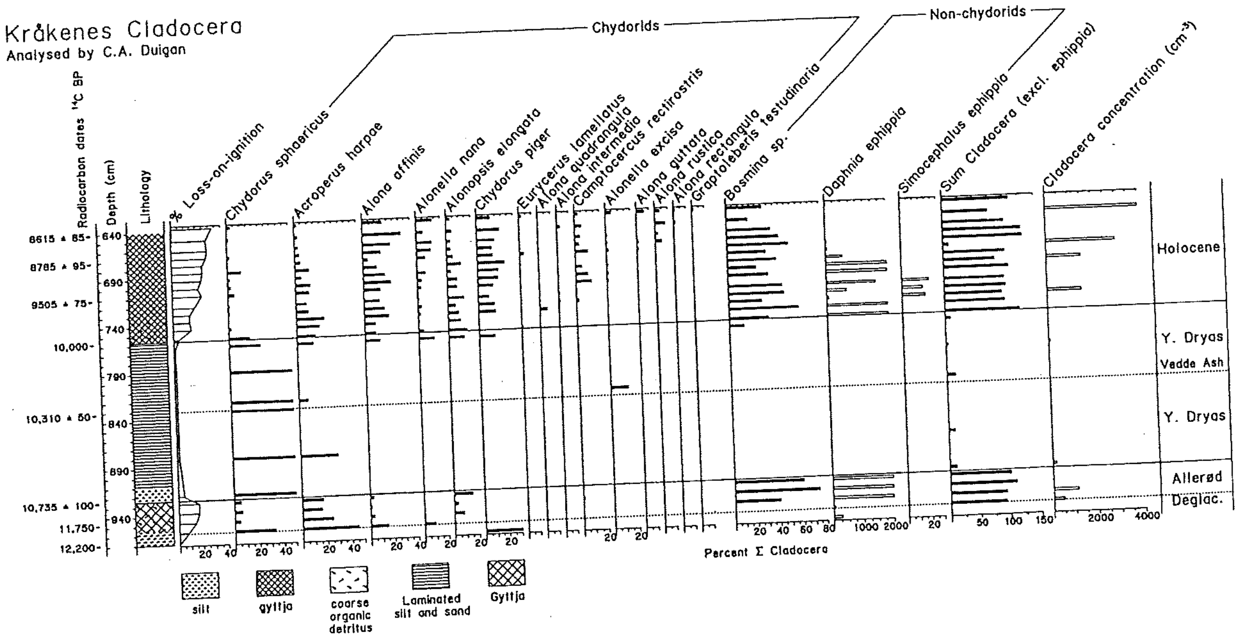


Figure 1. Stratigraphic diagram of the relative abundance of the major cladoceran taxa from Kråkenes. The x-axes for *Chydorus sphaericus* and *C. piger* are truncated at 50 and 30% respectively. Where the histogram bars reach this value, the taxa are calculated at 100%, but there are so few fossils in these samples (see text) that percentages are relatively meaningless. The taxa are arranged approximately on the basis of their persistence and appearance throughout the study sequence. The black bars indicate data collected during the cladoceran analysis of the sediments; unshaded bars are derived from ephippia counts made from the macrofossil samples for the same levels (see text for details). *Daphnia* and *Simocephalus* ephippia values are number in 100 cm^3 sediment. Values of 2000 indicate 'a very large number, too many to count'. Loss-on-ignition data and radiocarbon dates for selected levels are shown. Actual dates are given with standard deviations; the basal two are estimates from the date series (S. Gulliksen & H. H. Birks, unpublished), and the Younger Dryas/Holocene boundary falls within the 10,000 BP plateau (Gulliksen et al., 1998). Cladocera concentration values are shown for selected samples on the right side of the diagram.

Stratigraphic plots of Detrended Correspondence Analyses scores on DCA Axis 1

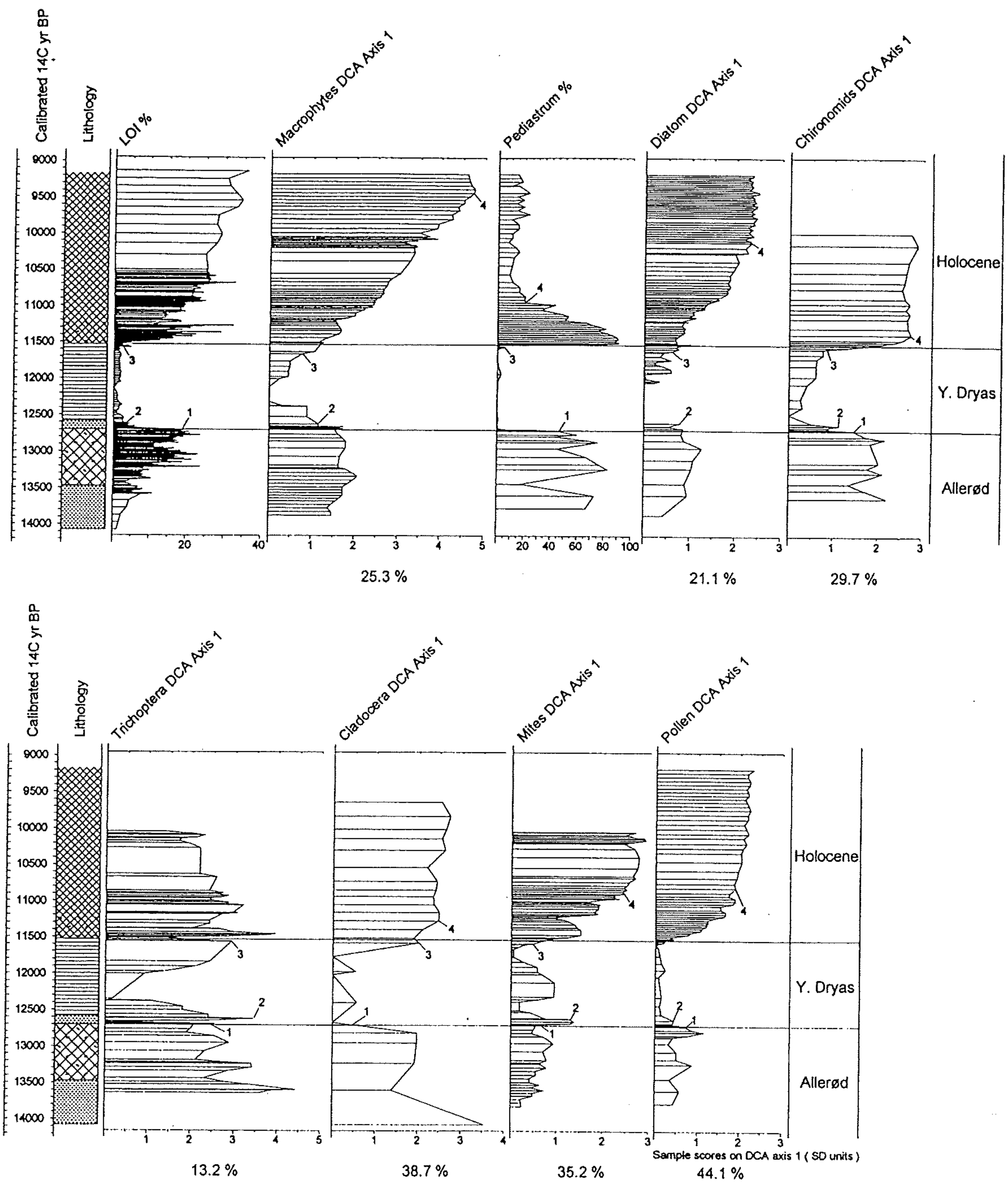


Figure 6. Plots of the sample scores on DCA axis 1 for the fossil groups, the % loss-on-ignition curve, and the % *Pediastrum* curve. The vertical axis is in calibrated ^{14}C yrs BP; the horizontal axes for the fossil groups are DCA standard deviation (SD) (= compositional turnover) units, and are all at the same scale. The curves for macrophytes, Trichoptera, and mites have been smoothed with a running mean of 3 samples. The % of the total inertia for each group represented by DCA axis 1 is also shown (see Table 1). The points 1–4 on these plots refer to discussion points in the text.

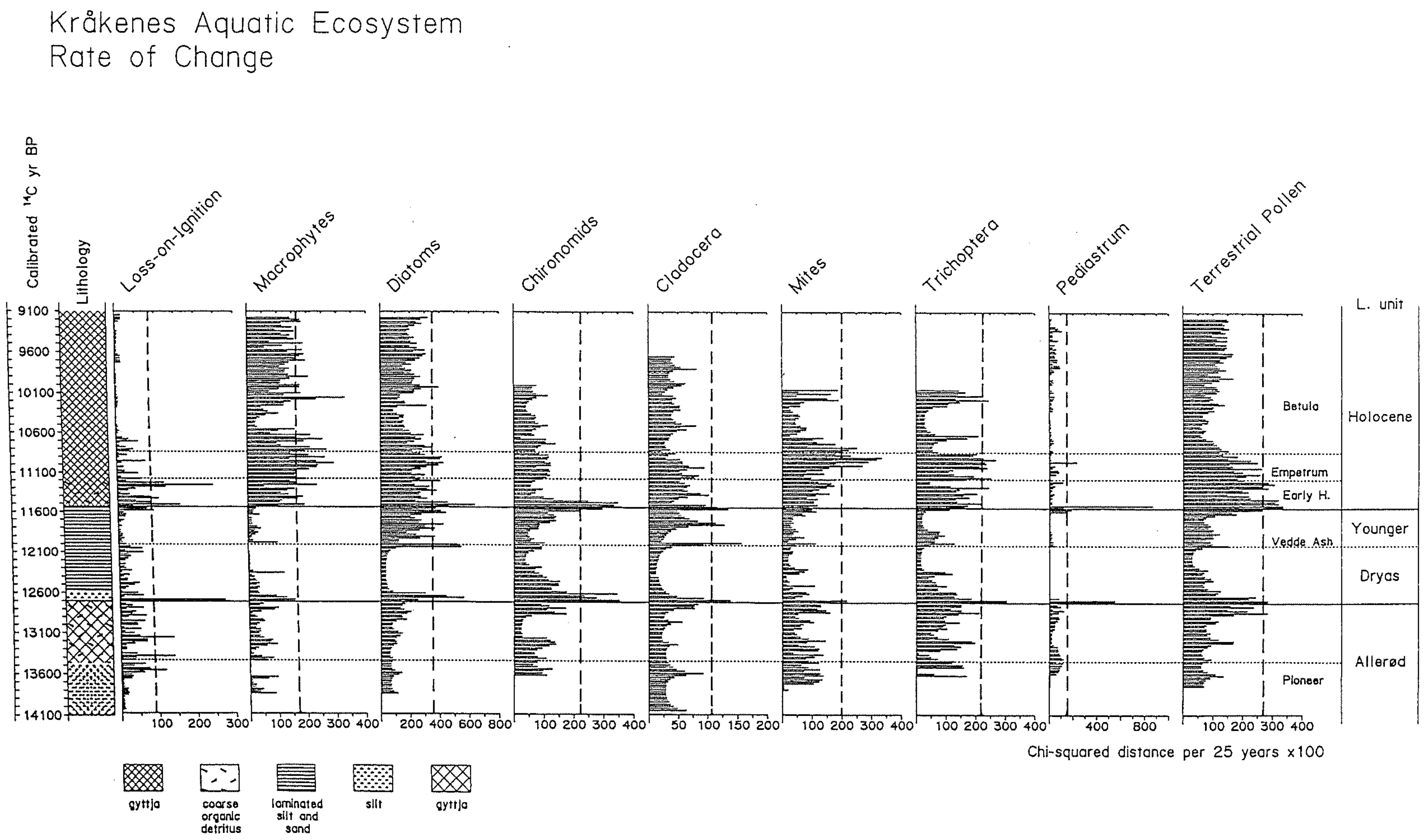
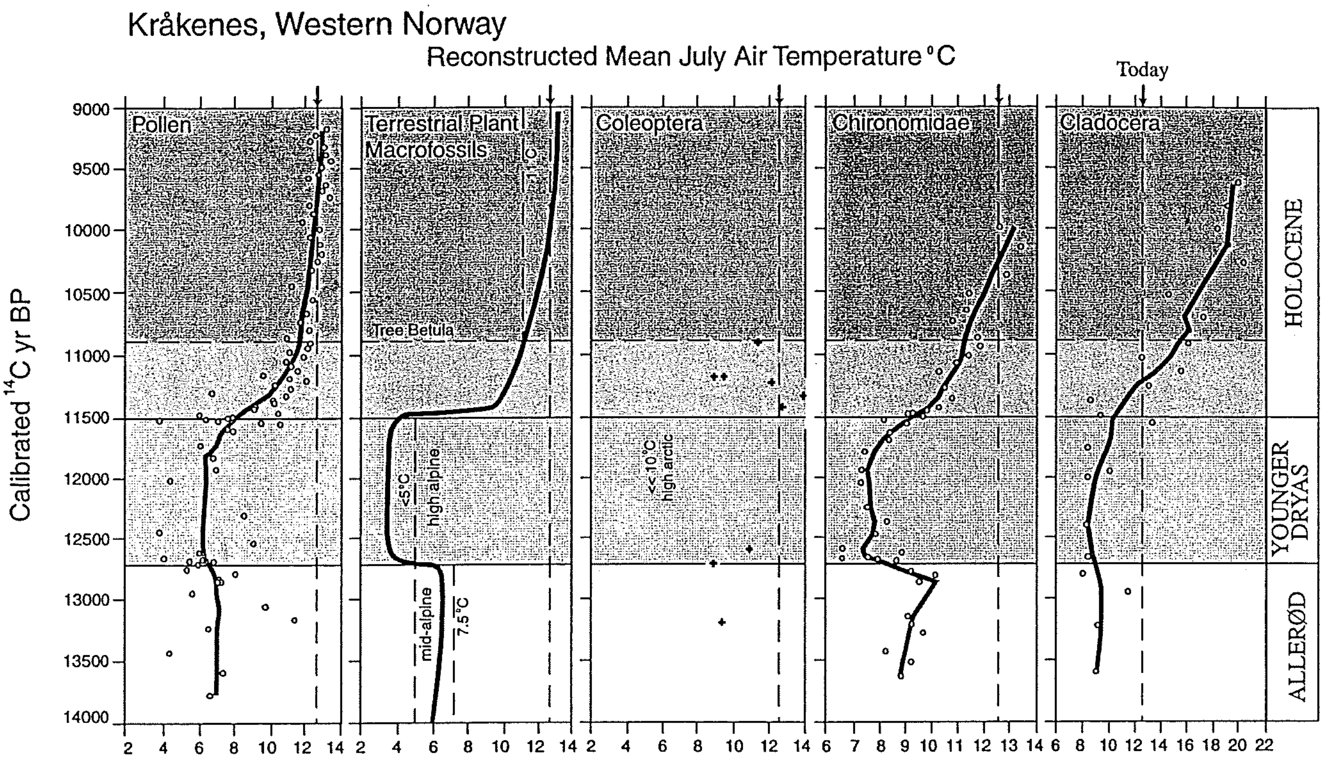


Figure 7. Rates of change for the fossil groups, % LOI, and % *Pediastrum*, plotted against calibrated 14C yrs BP. The approximate 95% significance levels for the rate of change estimates based on permutation tests are shown by the vertical lines. Rate of change values lying beyond these significance levels are unlikely to have arisen by chance given the inherent variability and sampling density of the group or variable concerned (see text for further details).

TEMPERATURES AND RATES OF CHANGE



	mean AL °C	AL -> YD drop	Rate per 25 yr	mean YD °C	increase Hol 500yr	Rate per 25 yr
Pollen	7	1°C	0.7°C	6	6°C	0.25°C
Chironomids	9-10	1.5-2.5°C	0.7°C	7.5	3.5°C	0.2°C
Cladocera	9	1°C		8	6°C	0.3°C
Macrofossils	~6	>1°C	~1°C	<5	6°C	
Coleoptera	9.6	~2°C		<<10	~5°C	

KEY ISSUES IN THE KRÅKENES ECOSYSTEM RECONSTRUCTIONS

1. The plots of the first DCA axis scores and rates of change are very useful summaries of the magnitudes and rates of change of the various organisms.

They demonstrated synchronous changes in response to temperature changes and the presence of the glacier, and individual successional stages.

2. Lake processes depend on events in the catchment.
The catchment is a source of nutrients, minerogenic, and organic material.

Allerød: - immature ecosystem was maintained by silt input from unstable soils and cool temperatures

Y. Dryas: Glacial silt nearly exterminated biota

Holocene: Inwash of nutrients from mineralisation of organic matter and leaching of soil
- inwash of humic acids from paludified and podsolised soils
- retention of nutrients in biomass and soil (peat)

3. pH of lake and catchment fell as organisms used the nutrients in a nutrient- and base-poor system.

4. The rates of change in response to large temperature changes are very rapid: terrestrial and aquatic organisms are good reflectors of climate change (as good as ice cores).

5. Further work is needed on how environmental factors affect the organisms in the ecosystem, e.g. temperature, nutrient status, pH, ice-cover, snow-cover, competition etc. Quantitative transfer functions need to be refined and new ones developed.

6. Kråkenes is special because it had a Younger Dryas glacier in the catchment. Another lake without a glacier should now be investigated for comparison.

7. A multi-disciplinary study is essential to reconstruct environment and climate using as many independent sources of evidence as possible.

8. This attempt at ecosystem and environmental reconstructions has demonstrated the value of a multi-disciplinary study at Kråkenes. Thank you to all the participants.

CONCLUSIONS

The essential components of a project to reconstruct past climates are:

1. A multi-disciplinary approach. Because organisms are variable, and factors other than climate may be important to their occurrence, we need to make reconstructions from several independent sources of evidence

2. Expertise of analysts. The fossil analyses must be made to the same standard as the modern calibration data-set

3. Time. Detailed fossil analyses take much time and patience

4. A detailed chronology. AMS dating needs (a) expertise to pick out terrestrial plant material for dating; (b) time for picking out material; (c) time and expertise for the dating process. A great advantage is an interested and motivated radiocarbon analyst(s)

5. Several sites.
   (a) geographical coverage of climate gradients
   (b) checks between different types of sites.

Two more sites will be analysed in NORPAST for plant macrofossils and pollen. These will be supplemented in NORPEC with chironomids, diatoms, and mites.

KRÅKENES PROJECT CONTRIBUTIONS (22.7.2002)

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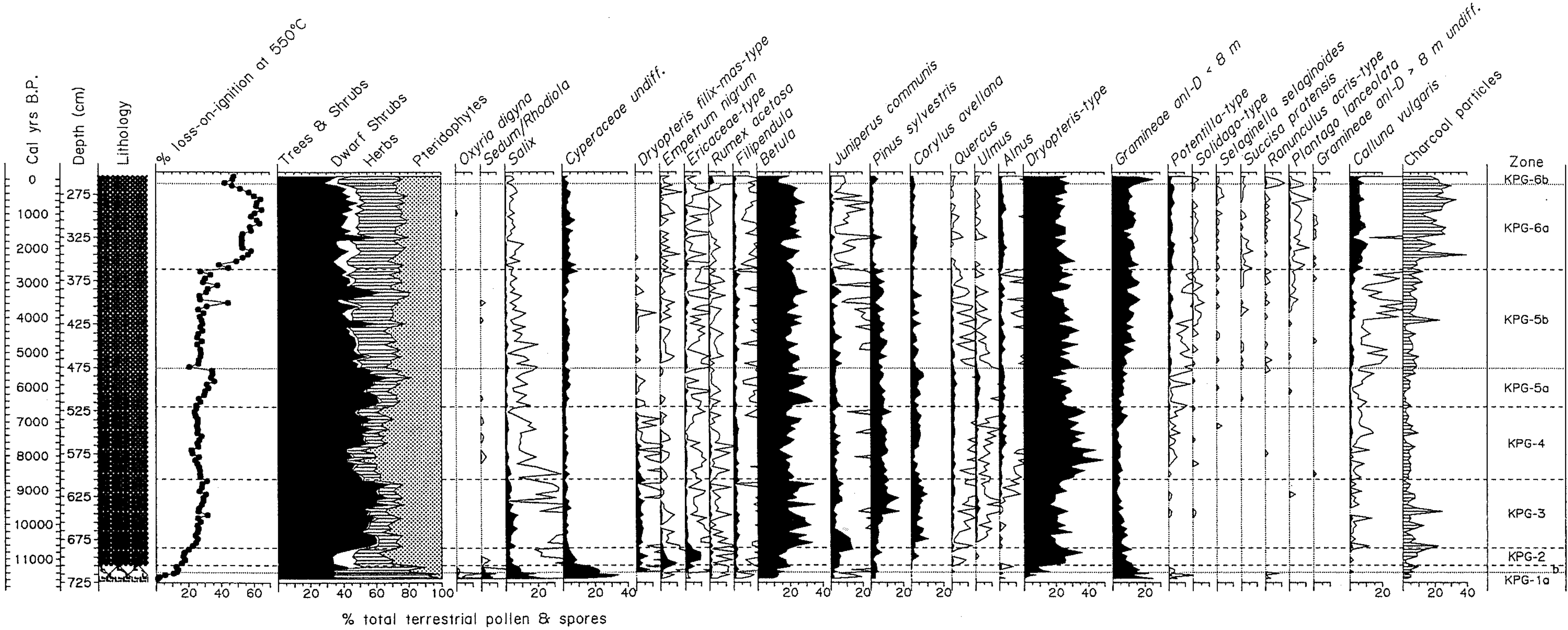
KRÅKENES POST-GLACIAL

Selected pollen & spore percentages

Anal: Sylvia M. Peglar & Aukje Hof, 2000



SKATESTRAUMEN, WESTERN NORWAY – OCCUPATION SITES FROM THE MESOLITHIC AND NEOLITHIC

Along Skatestraumen in Bremanger, Sogn og Fjordane, several occupation sites dated to the Mesolithic and Neolithic are found. The area along the tidal currant channel was important for occupation, especially through the Late Mesolithic and Early/Middle Neolithic when people were sedentary hunter-fishers.

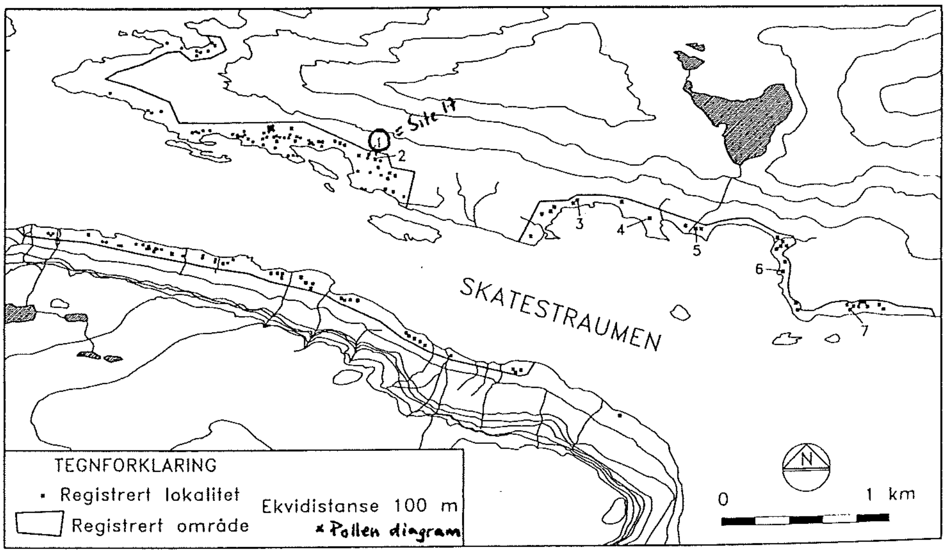
Archaeological excavations as well as paleobotanical and osteological investigations have been carried out from several of the sites.

References:

Bergsvik, K.A. 2001. Strømmer og steder i vestnorsk steinalder. [Channels and places in Stone Age western Norway]. Viking, 11-34. (In Norwegian with English summary).

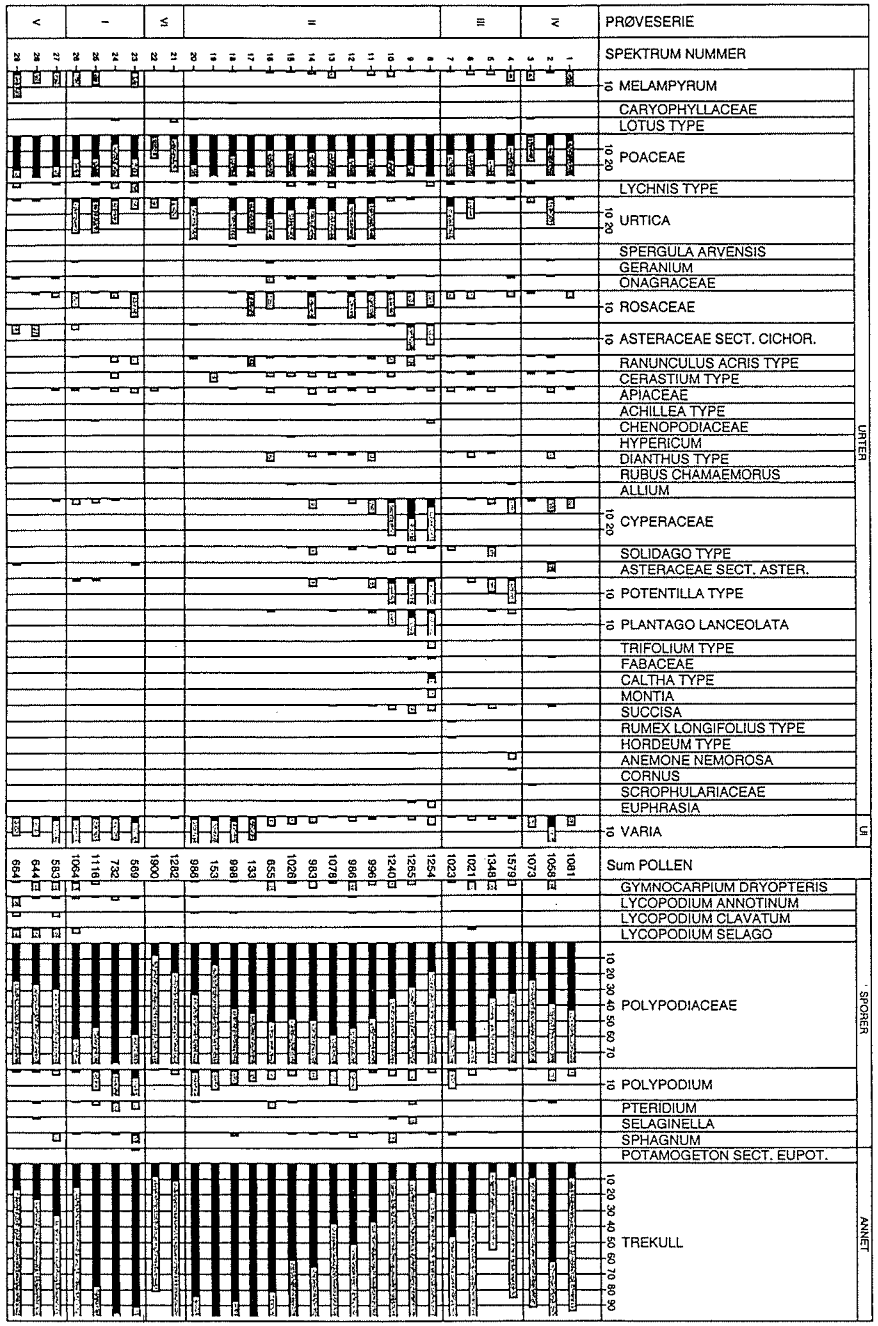
Hjelle, K.L. 1998. The use of on-site pollen analysis, local pollen diagrams and moderen pollen samples in investigations of cultural activity. Archaeologia Baltica 3, 87-101.

Hjelle, K.L. 2002. Pollenanalytiske undersøkelser fra lok. 17 Havnen og lok. 1 Haukedal, Skatestraumen. Appendix 2 in: Bergsvik, K.A. (ed.). Arkeololgiske undersøkelser i Skatestraumen. Bind I. Arkeologiske avhandlinger og rapporter fra Universitetet i Bergen, 7.

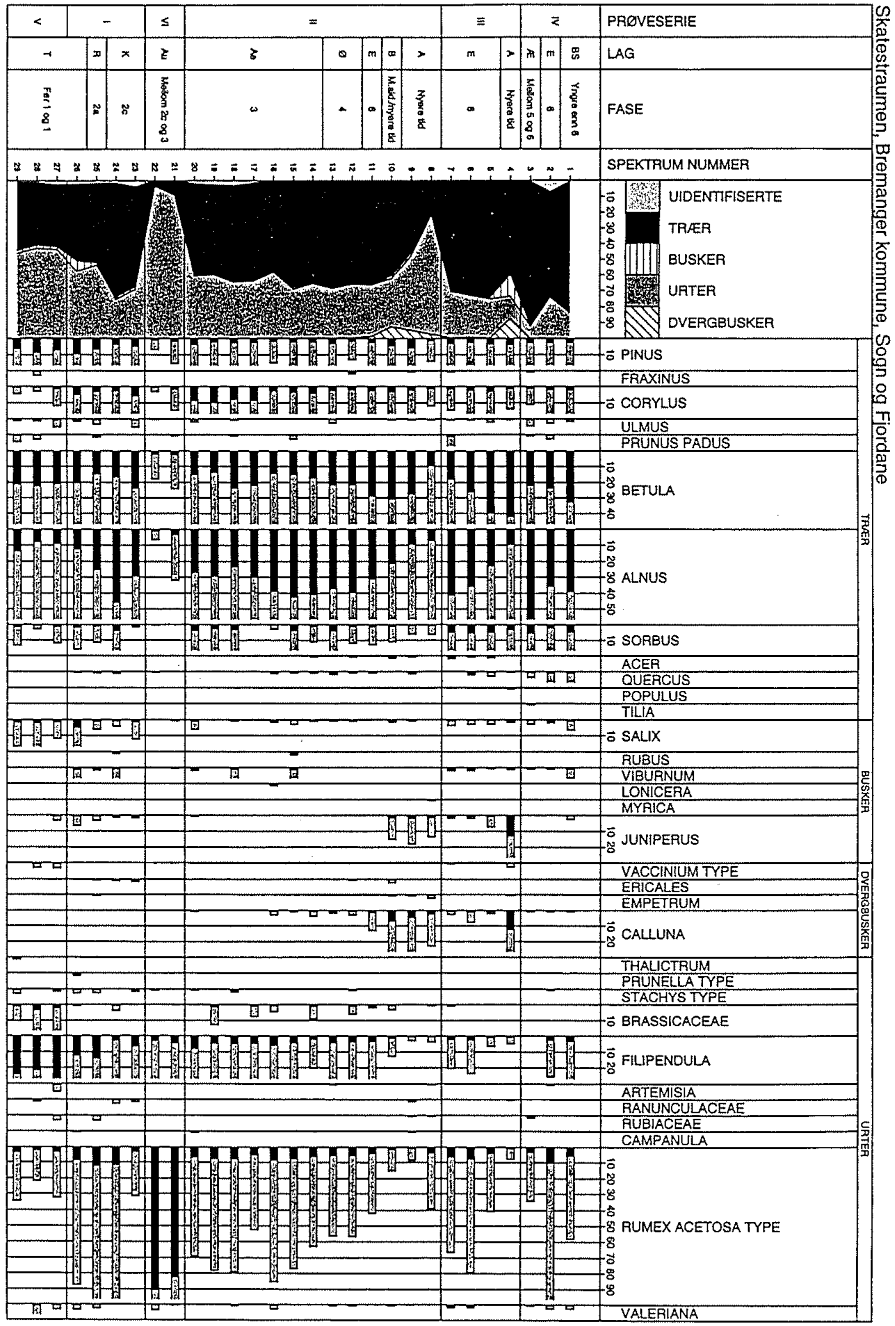


Lokalitet 17 Havnen

Skatestraumen, Bremanger kommune, Sogn og Fjordane

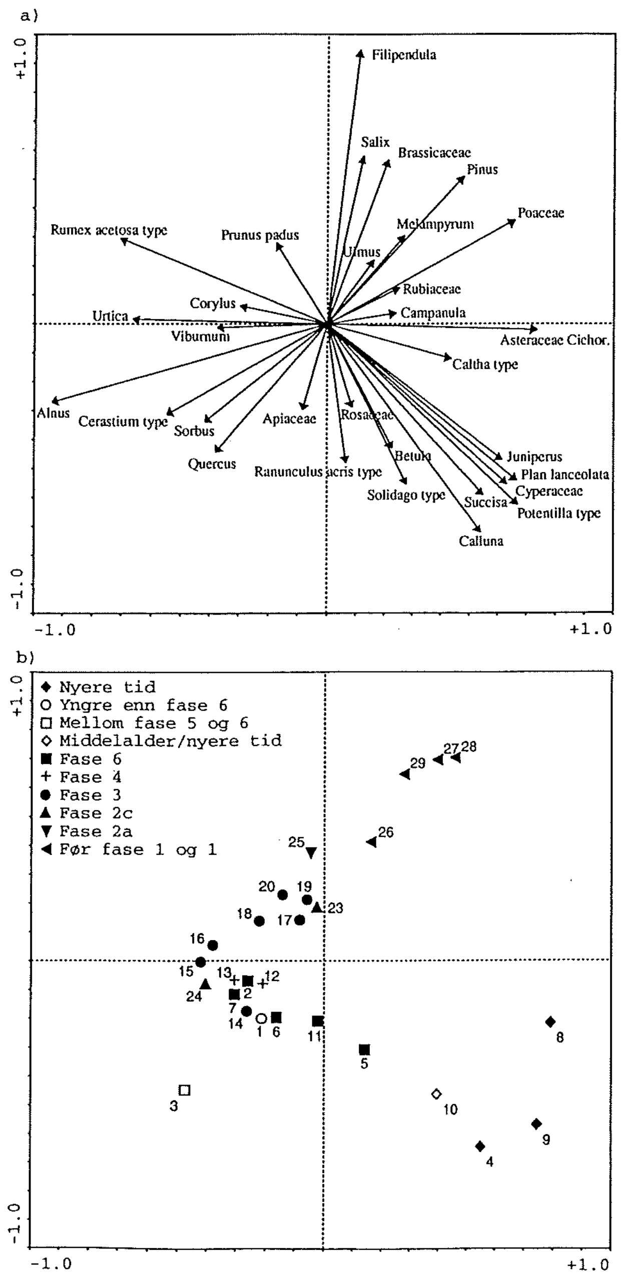


Analyse:N.Torske,J.Berge,K.Hjelle,S.Hjelmtveit,A.Kaland

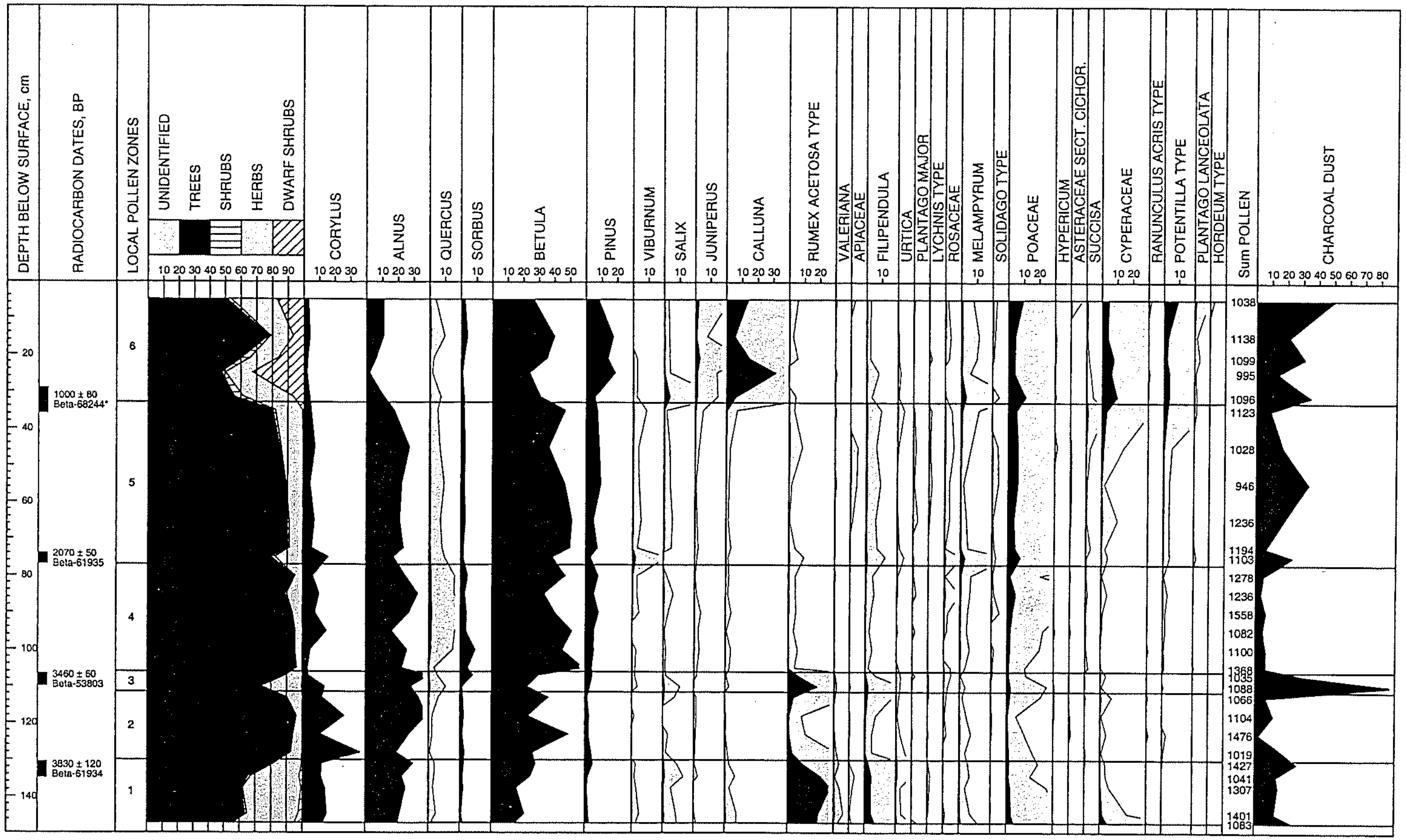


Principal Component Analysis (PCA) of pollen samples from different cultural layers of occupation site 17. The correlation biplot shows the characteristics of the vegetation development through six occupation phases to modern time.

Phase 6 (2500-2000 BP)
Phase 4 (4500-4000 BP)
Phase 3 (4900-4500 BP)
Phase 2c (6200-6000 BP)
Phase 2a (6500-6300 BP)
Phase 1 (7150-7000 BP)



SKATESTRAUMEN
Bremanger, Sogn og Fjordane, Norway



Analysis: K.L.Hjelle

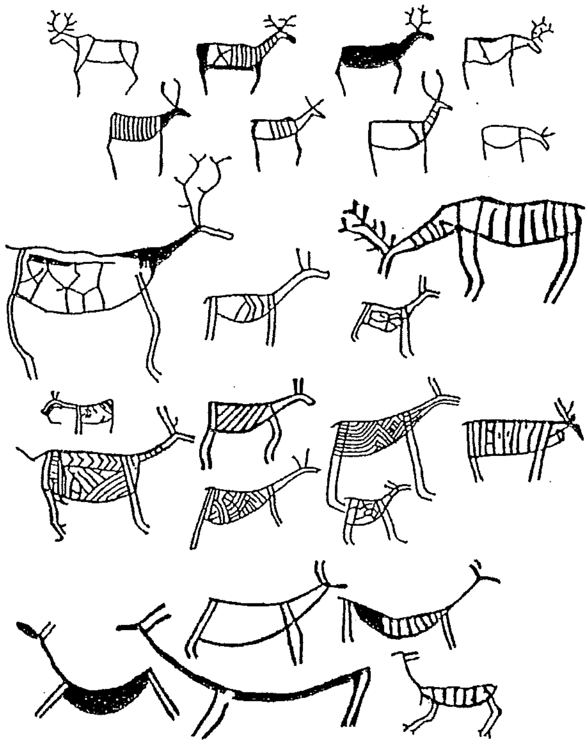
VINGEN– FAMOUS ROCK CARVINGS FROM WESTERN NORWAY

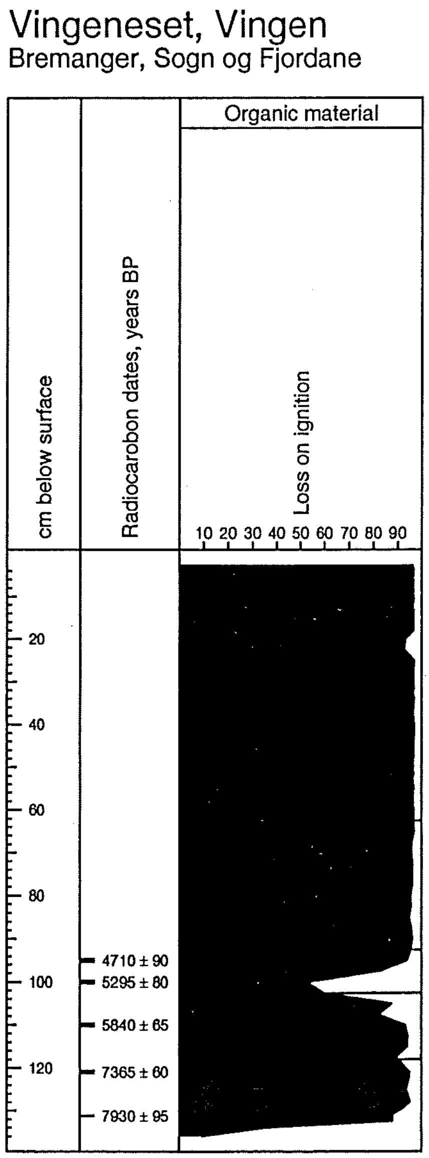
The Vingen area in Bremanger, Sogn og Fjordane, contain more than 2000 rock carvings. Deer is the dominating figure, but also other animals and abstract-geometric figures occur. The dates of the carvings have been discussed and the time period Late Mesolithic/Early Neolithic until the end of the Middle Neolithic has been suggested. Recent archaeological excavations have provided material from the Late Mesolithic. This is supported by radiocarbon dates, indicating the time period 6200-5500 BP (uncalibrated 14C-years).

At Vingeneset two small Neolithic sites have been found. From this area a pollen diagram from a bog is in preparation. The aim of this investigation is to provide information about the vegetation history and the date of the production period of the rock carvings in Vingen.

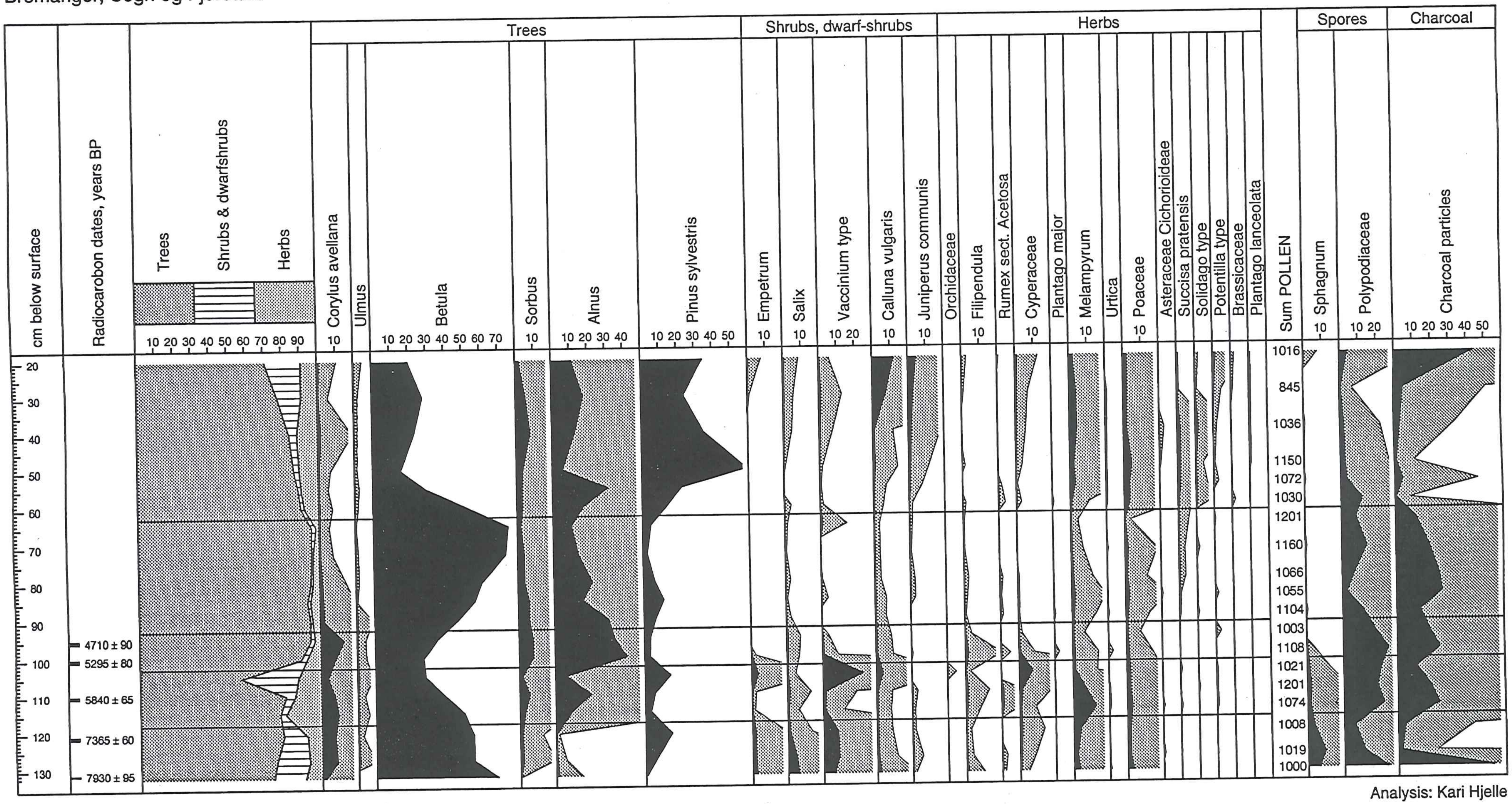
Reference:

Lødøen, T.K. 2001. Contextualizing rock art in order to investigate Stone Age ideology. Results from an ongoing project. In: Helskog, K. (ed.). Theoretical perspectives in rock art research. Novus, Oslo, pp. 211-223.





Vingeneset, Vingen
Bremanger, Sogn og Fjordane



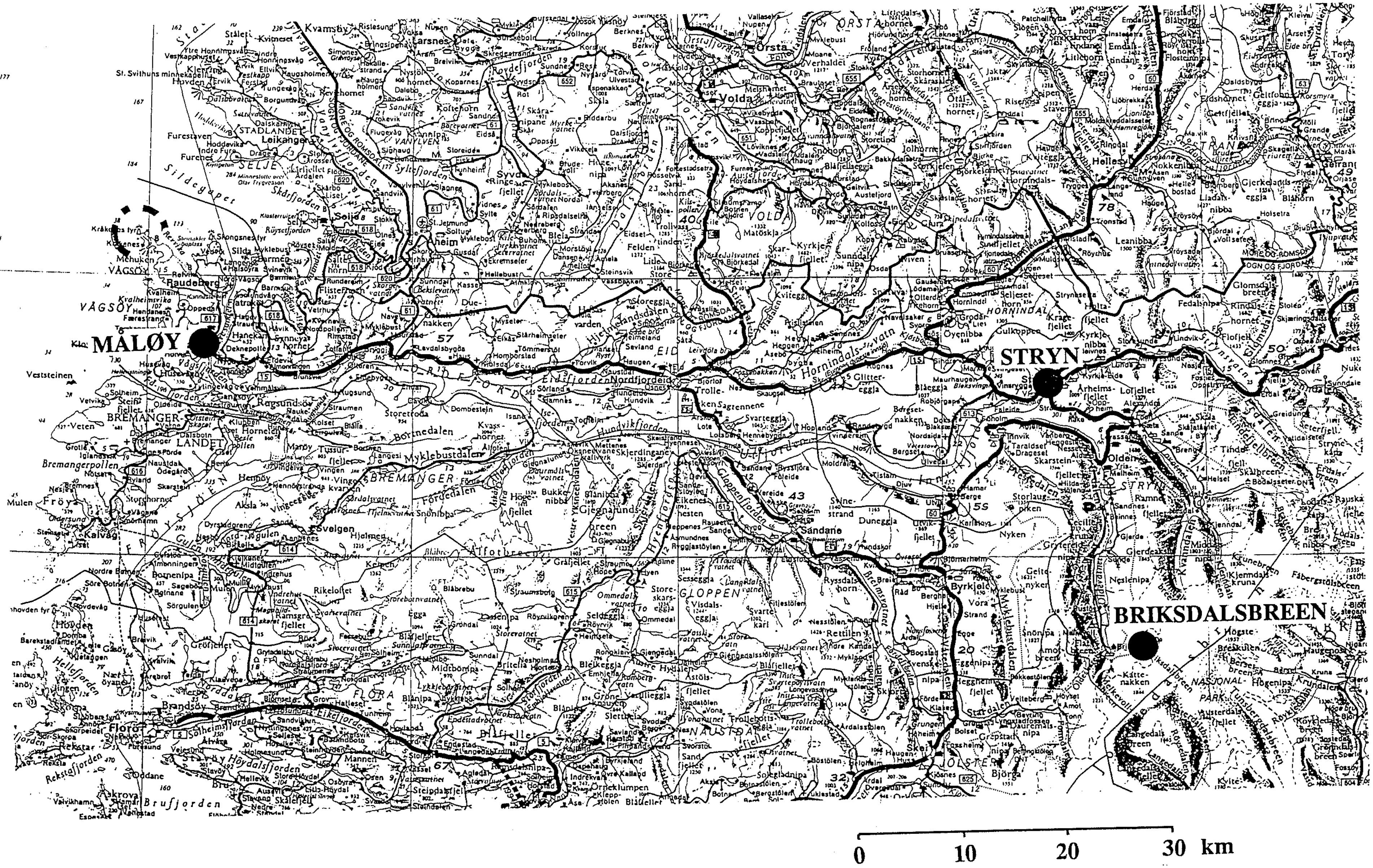
Analysis: Kari Hjelle

5500 - 6200 BP uncal. → datierte, archäolog. Periode von Vingen

Tuesday, 20 August 2002

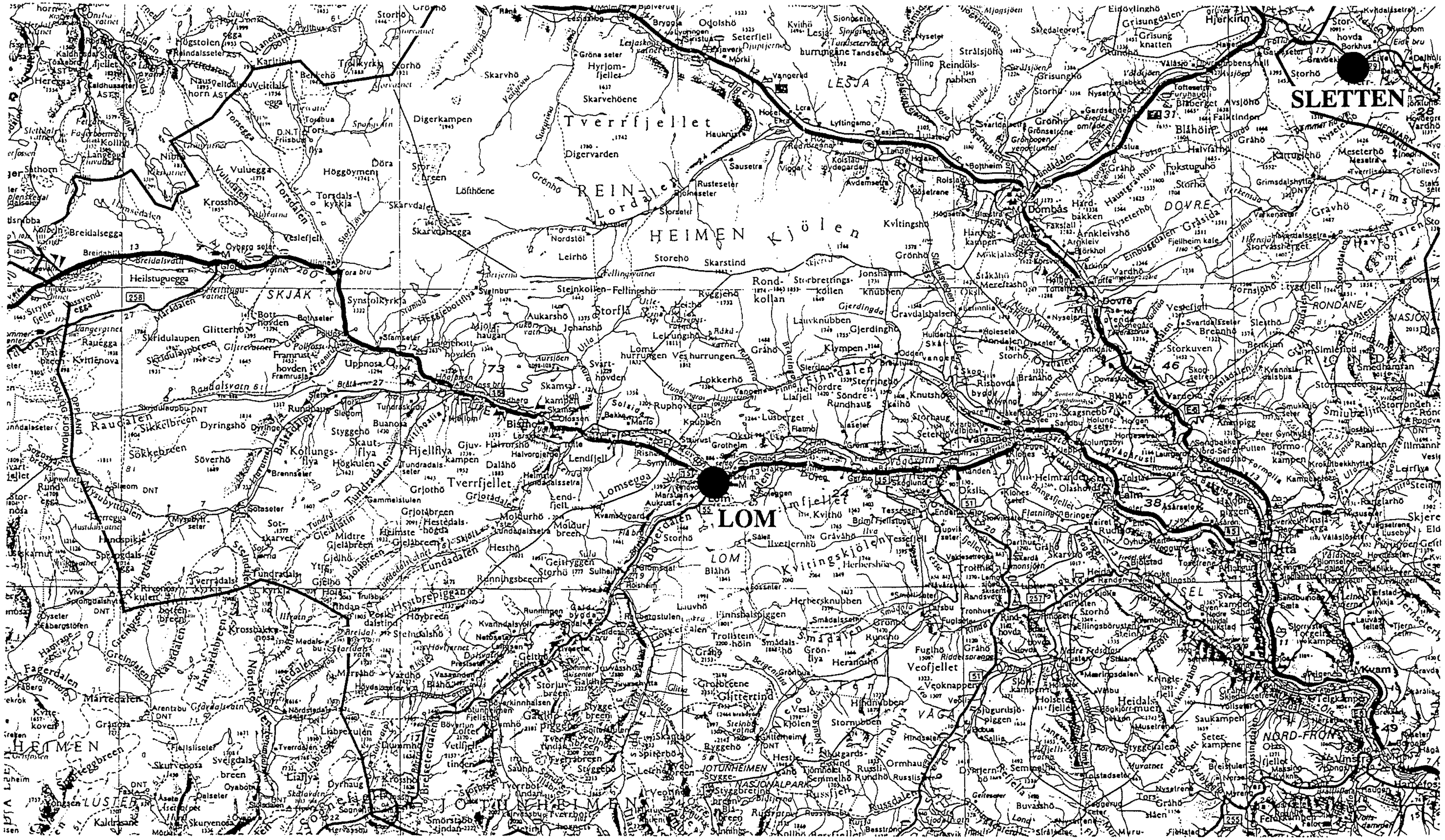
Briksdalsbreen, Stryn Glacier Museum, Lom

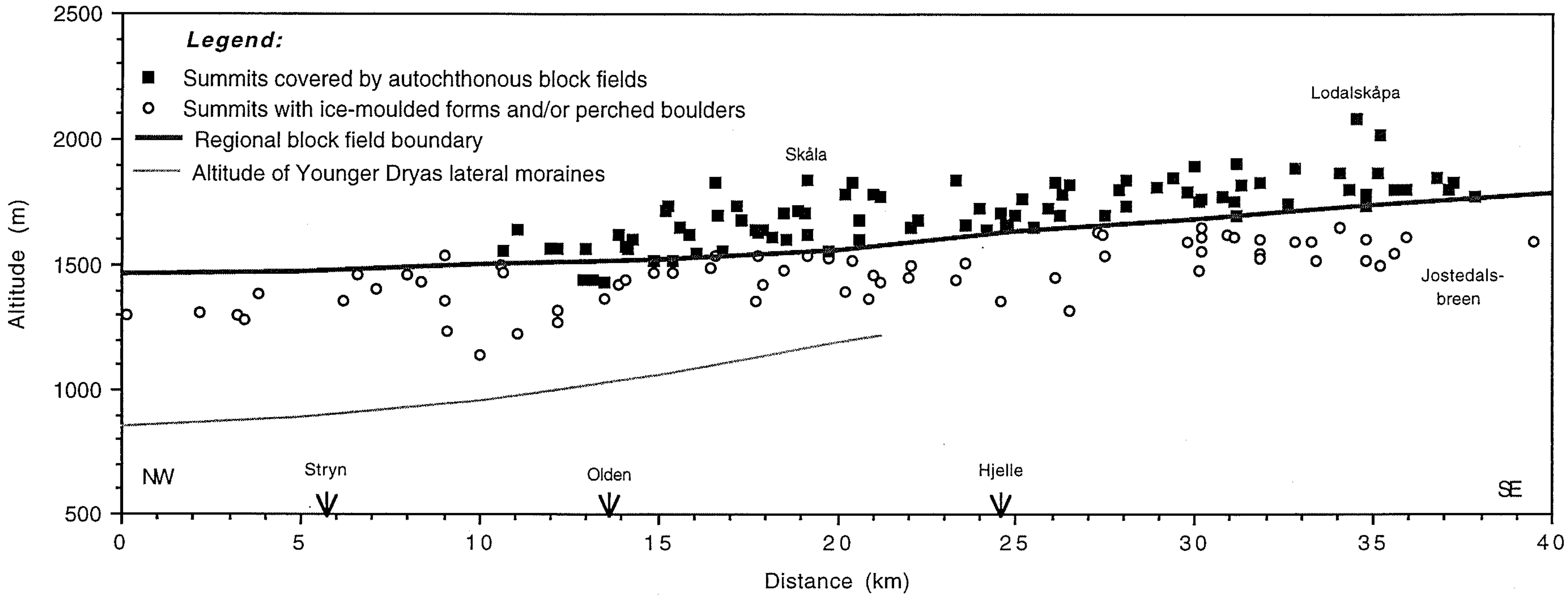
DAY 3. Tuesday, 20th. August



→ (cont.)

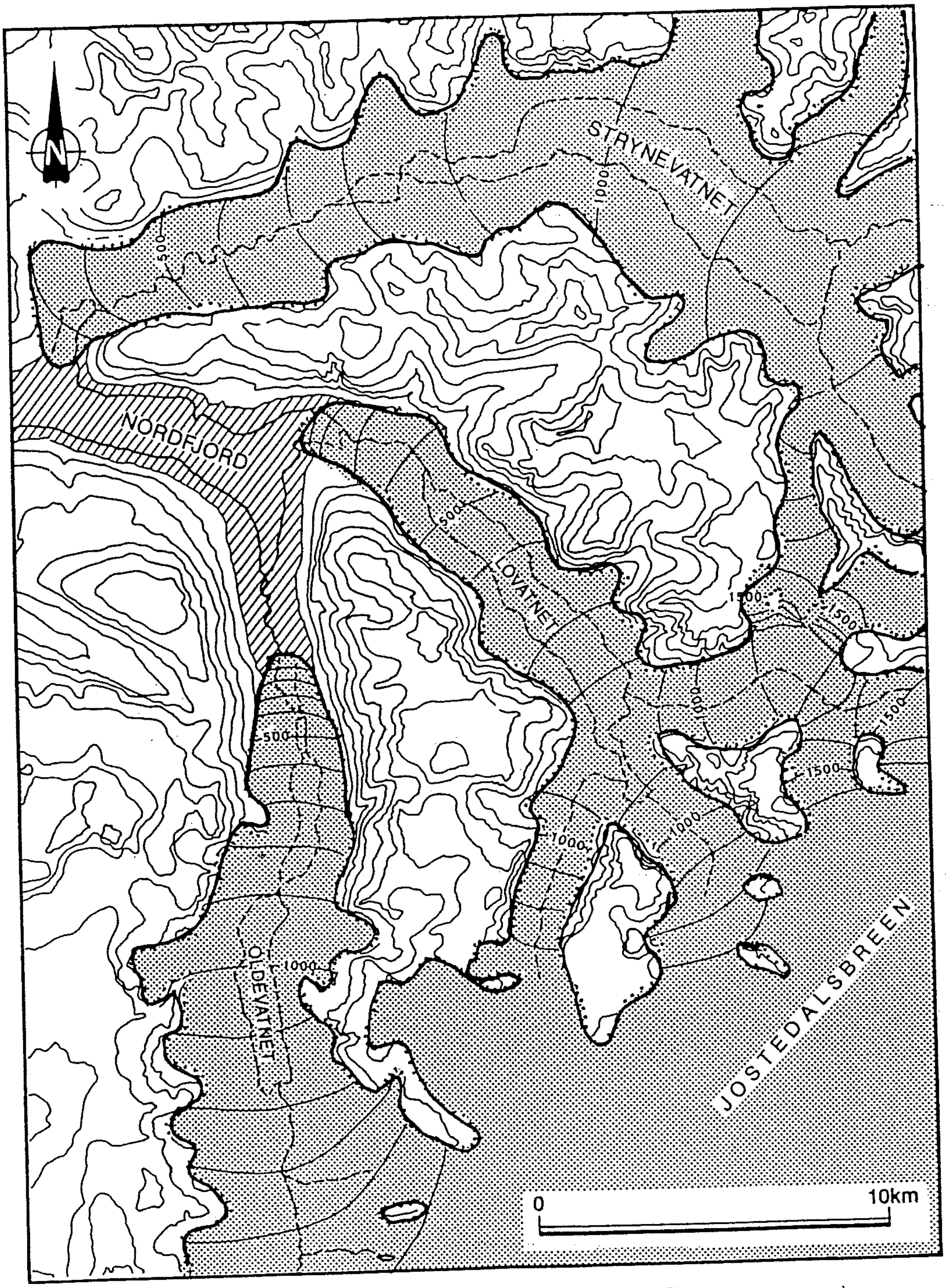
DAY 3. Tuesday, 20th. August (cont.)



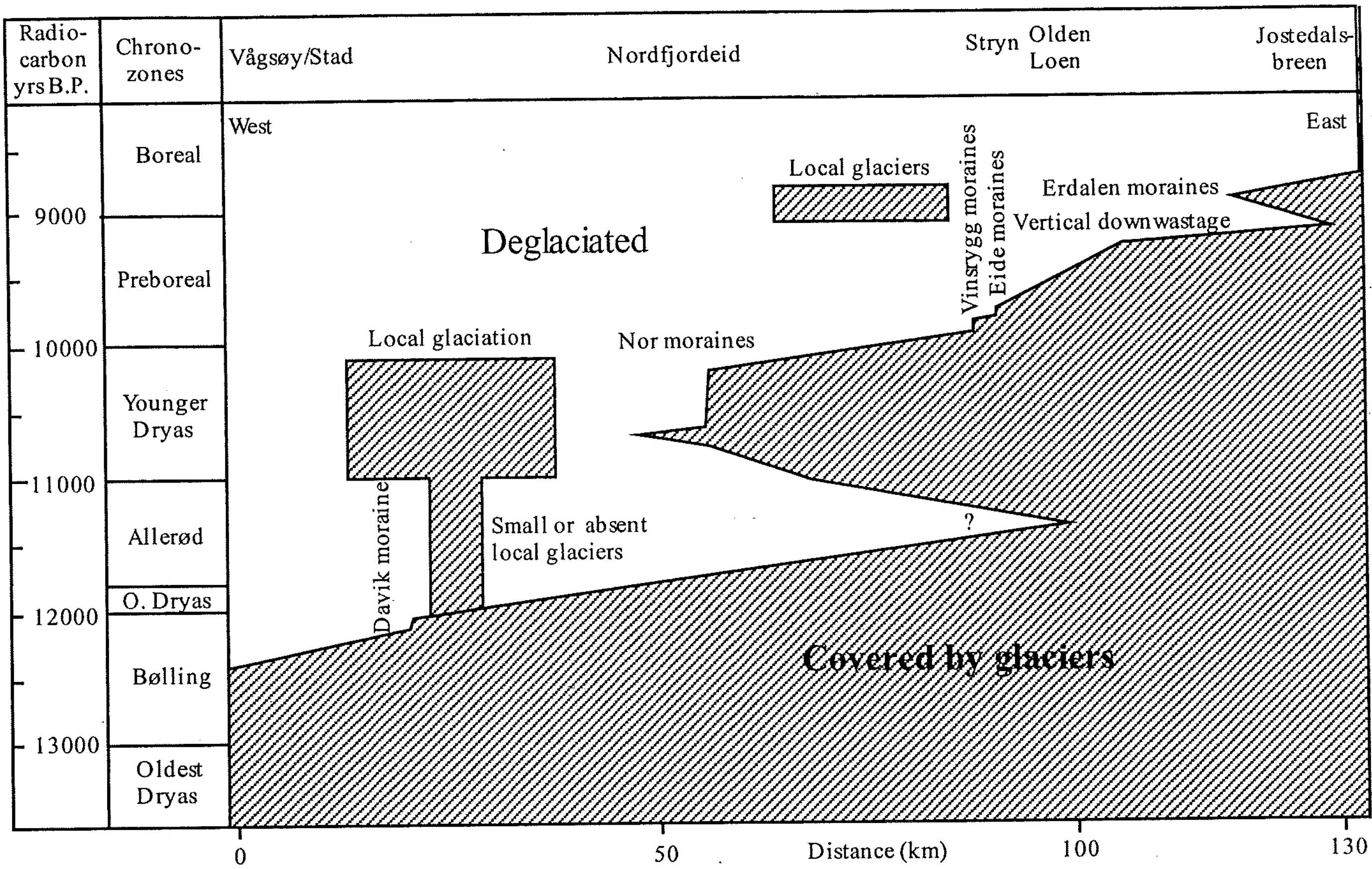


2500
2000
1500
1000
500
Altitude (m)
Legend:
Summits covered by autochthonous block fields
Summits with ice-moulded forms and/or perched boulders
Regional block field boundary
Altitude of Younger Dryas lateral moraines
Skåla
Lodalskåpa
Jostedals-
breen
NW
Stryn
Olden
Hjelle
SE
0
5
10
15
20
25
30
35
40
Distance (km)

AUSTEFJORDEN
SUNNYLVSFJORDEN
GEIRANGERFJORDEN
HORNINDALSVATNET
STRYNSVATNET
Stryn
INNVIKSFJORDEN
Loen
Olden
UTFJORDEN
GLOPPENFJORDEN
Sandane
BREIMSVATNET
JOSTEDALSBREEN
Skei
JØLSTRAVATNET
GROVE
BREEN
N



Tidleg Preboreal
Early Preboreal



Eisfrei bis ca 6000 BP

1740-1760 max. Stand Kl. Eiszeit

Seit 1400 AD: Start des Gletschers

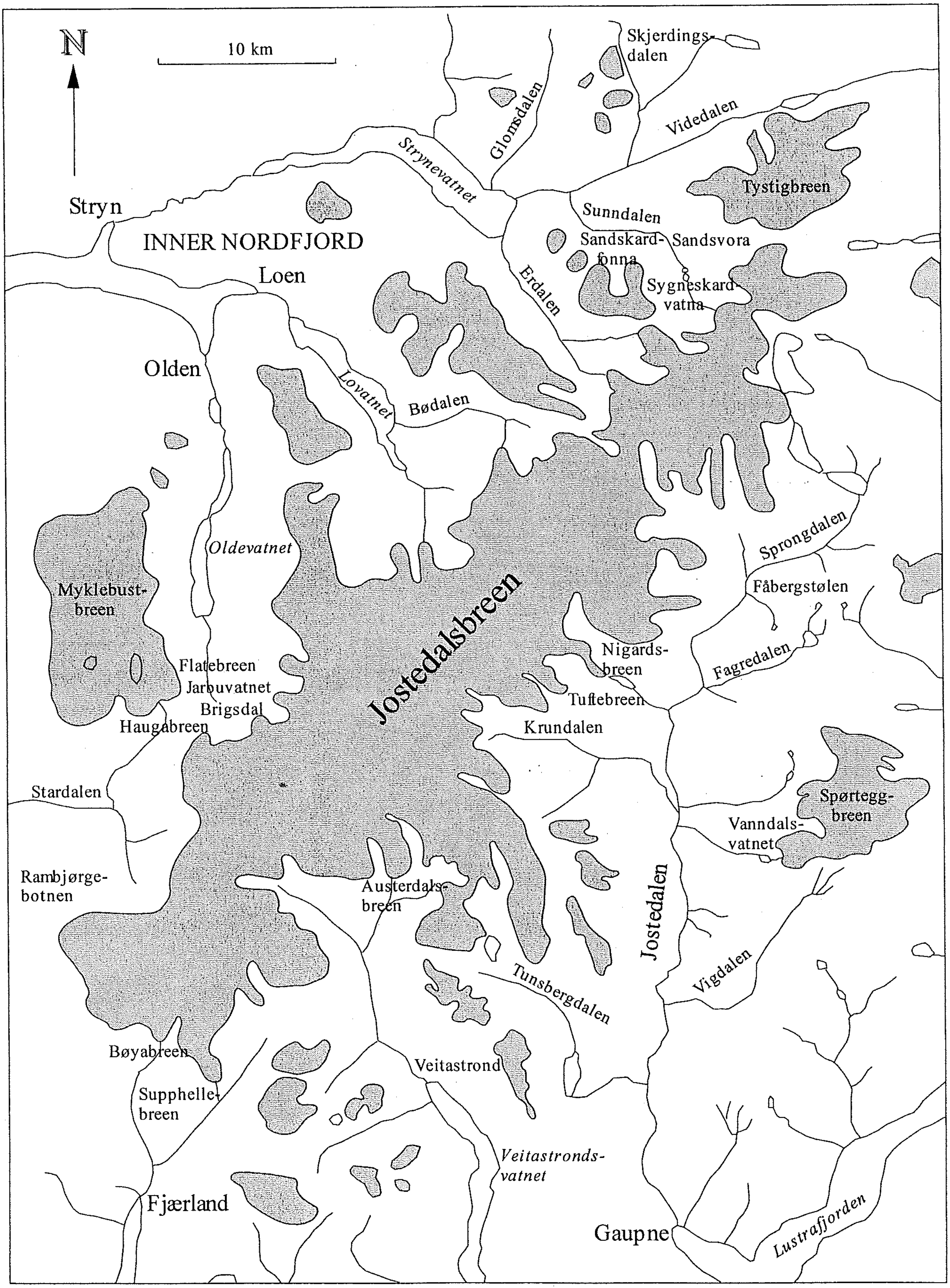
1710-1735 2,8 km Vorstoss

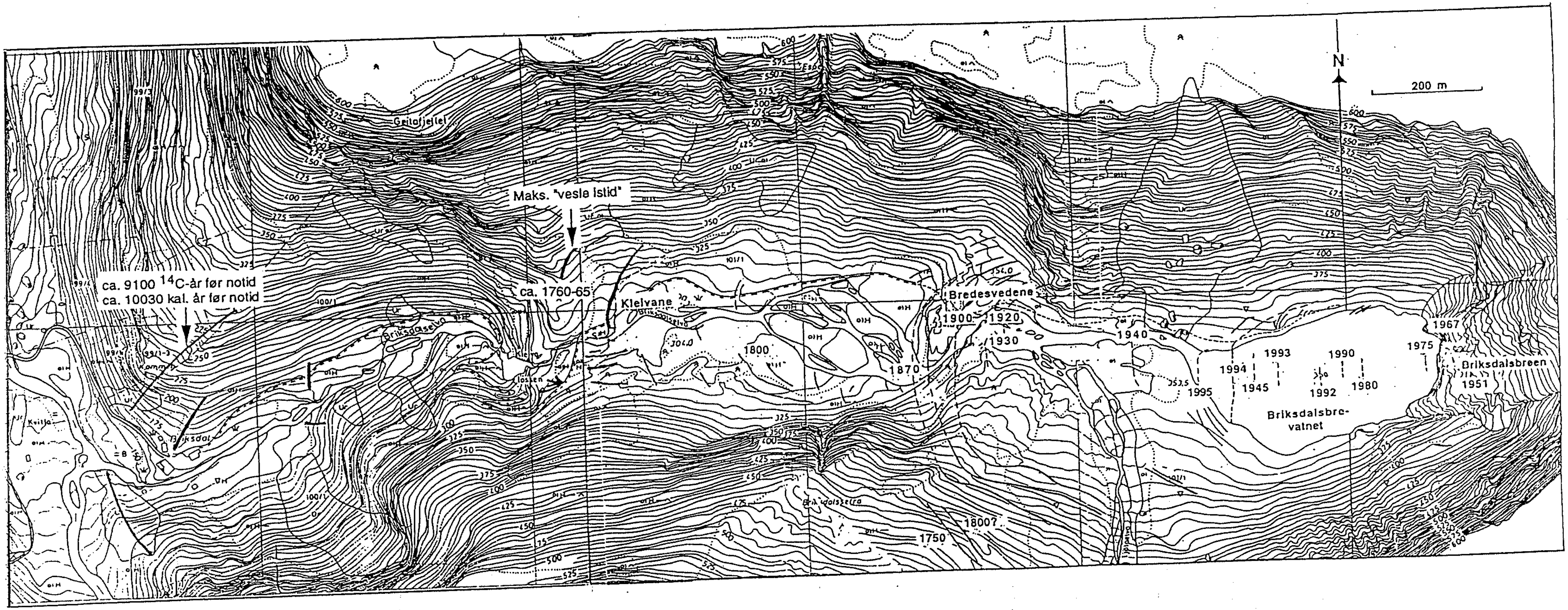
1994: in 1 Juli 80 m

1997: Hochststand des Gletschers: hohe Winterniederschläge

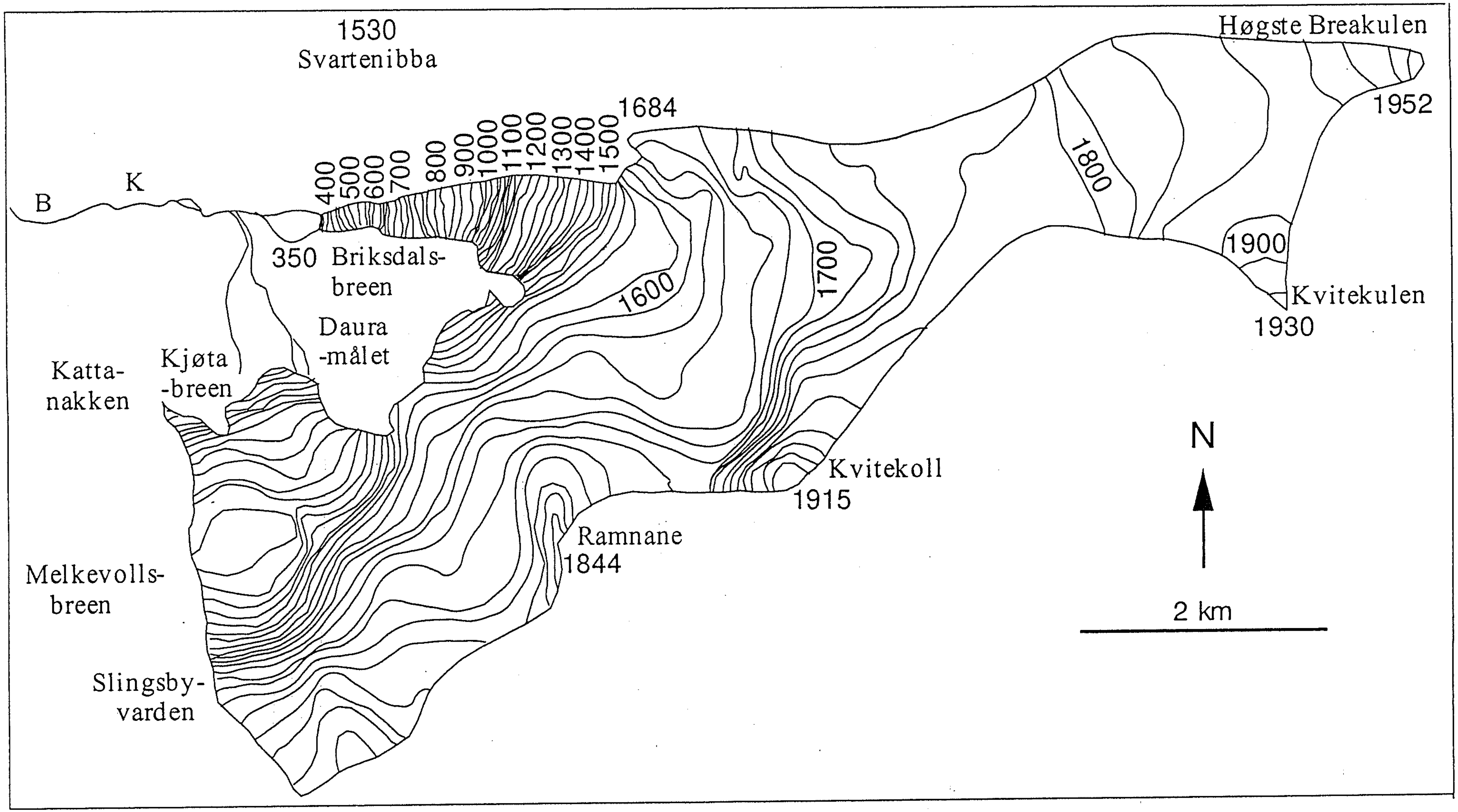
d.h. Winterniederschläge (neben Sotemp) wichtig

4 years lag in response to climatic change

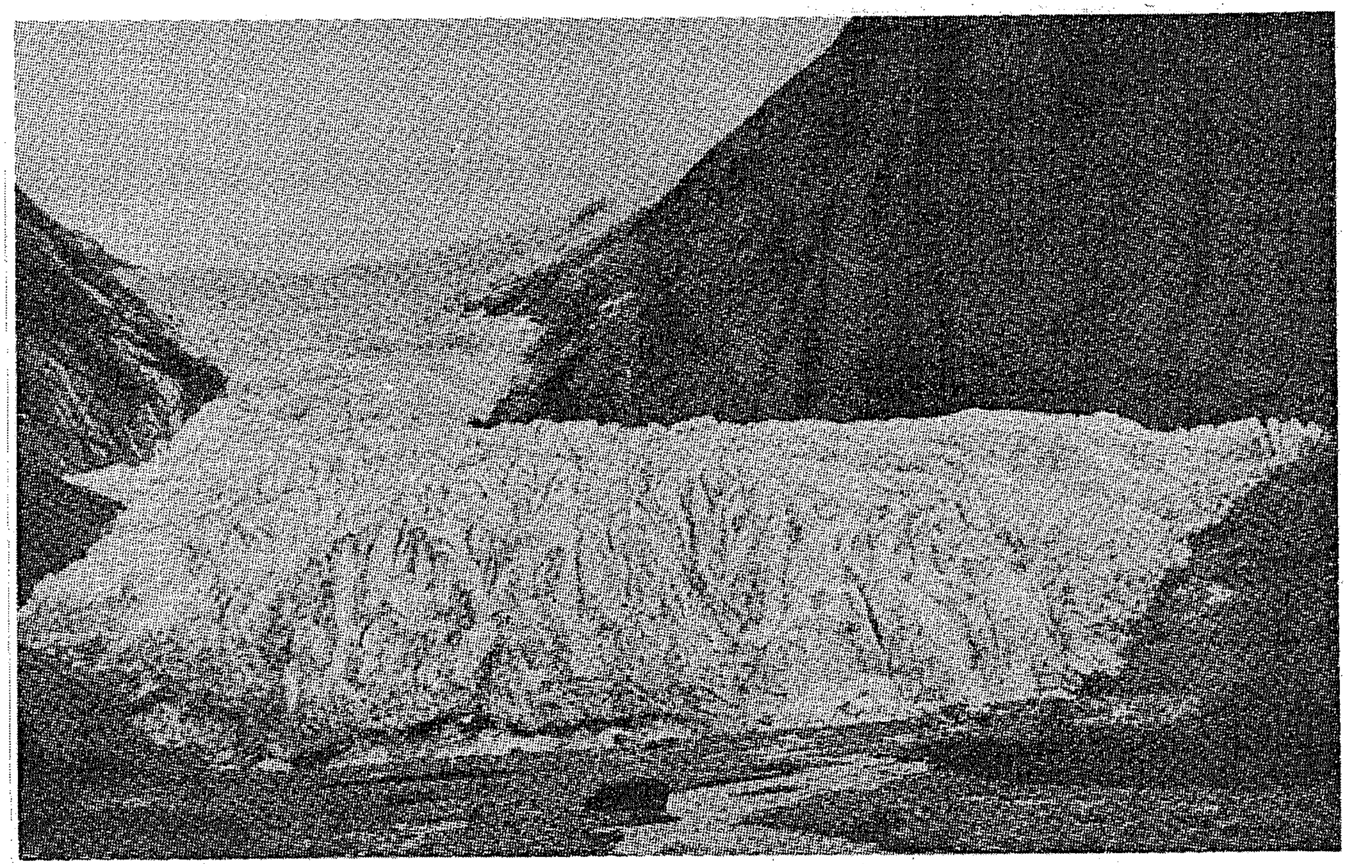

N
10 km
Stryn
INNER NORDFJORD
Loen
Olden
Strynevatnet
Glomsdalen
Skjerdings-
dalen
Videdalen
Tystigbreen
Sunndalen
Sandskard-
fonna
Sandsvora
Sygneskard-
vatna
Erdalen
Lovatnet
Bødalen
Oldevatnet
Myklebust-
breen
Flatebreen
Jarbuvatnet
Brigsdal
Haugabreen
Jostedalsbreen
Sprongdalen
Fåbergstølen
Nigards-
breen
Fagredalen
Tuftebreen
Krundalen
Stardalen
Spørtegg-
breen
Vanndals-
vatnet
Rambjørge-
botnen
Austerdals-
breen
Jostedalen
Vigdalen
Tunsbergdalen
Bøyabreen
Veitastrond
Supphelle-
breen
Veitastronds-
vatnet
Fjærland
Gaupne
Lustrafjorden



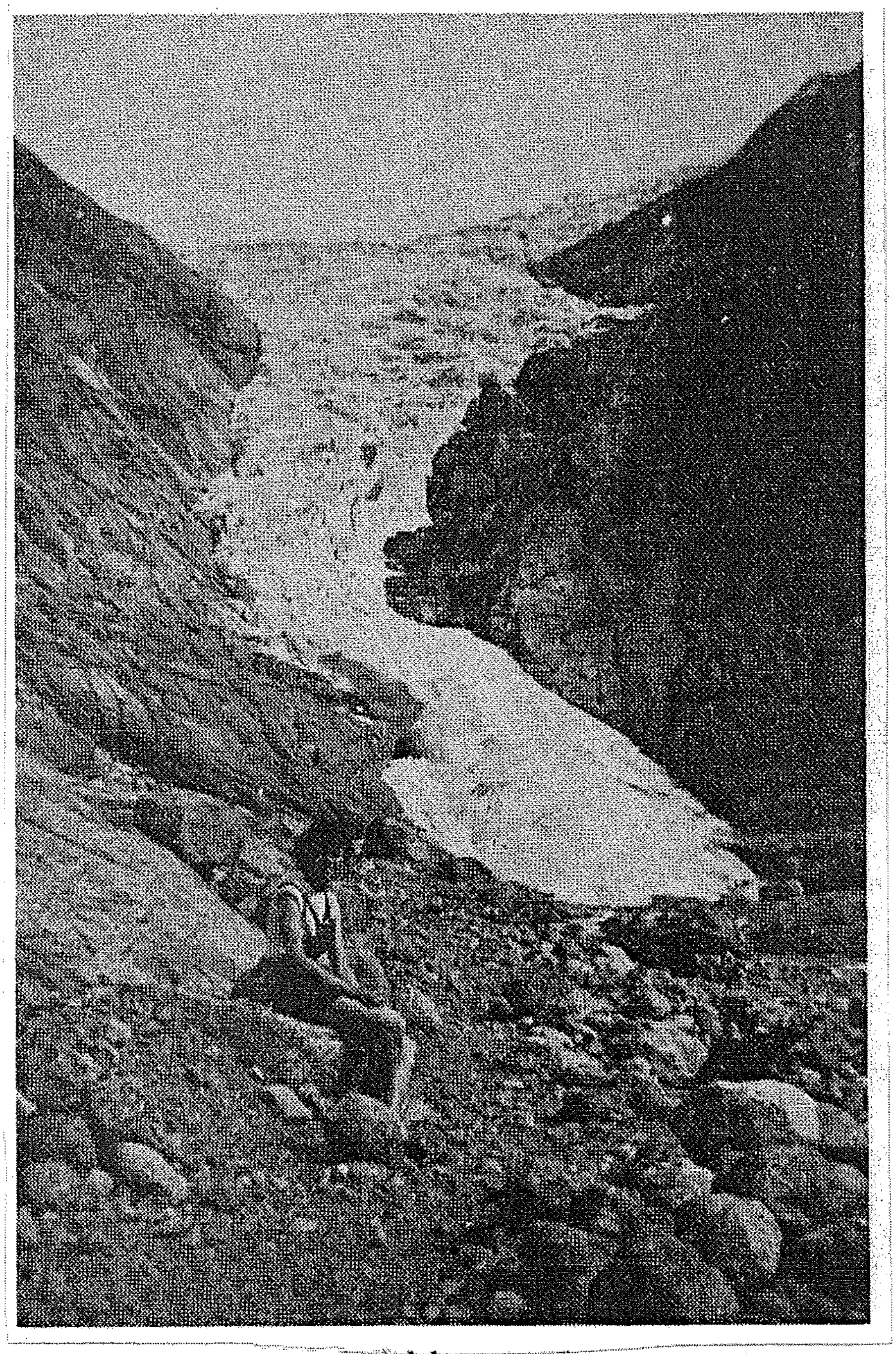
1400 AD : Start
1680 AD : historische Berichte über Schäden, 1750 Max.
hier LIA gut ausgebildet



1530
Svartenibba
Høgste Breakulen
1952
1684
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
B
K
350
Briksdals-
breen
Daura
-målet
1600
1700
1800
1900
Kvitekulen
1930
Katta-
nakken
Kjøta
-breen
N
Kvitekoll
1915
Ramnane
1844
Melkevolls-
breen
2 km
Slingsby-
varden

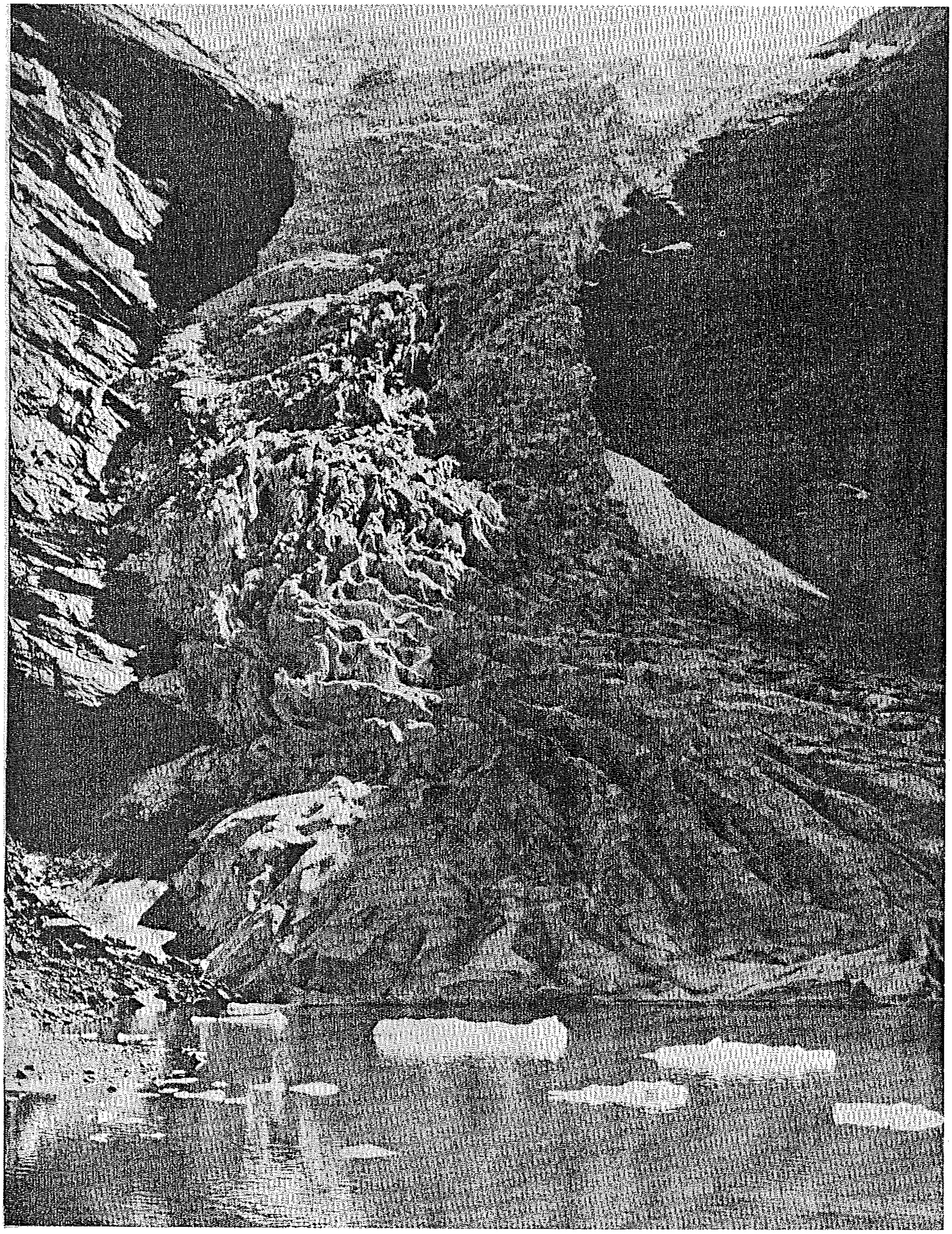


AD1870

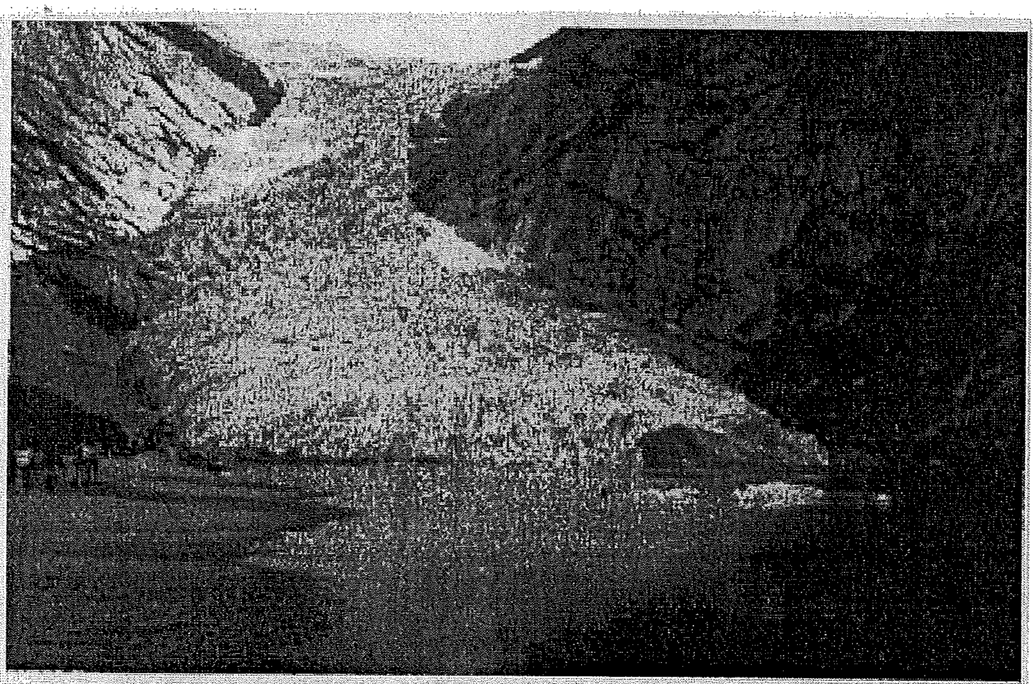


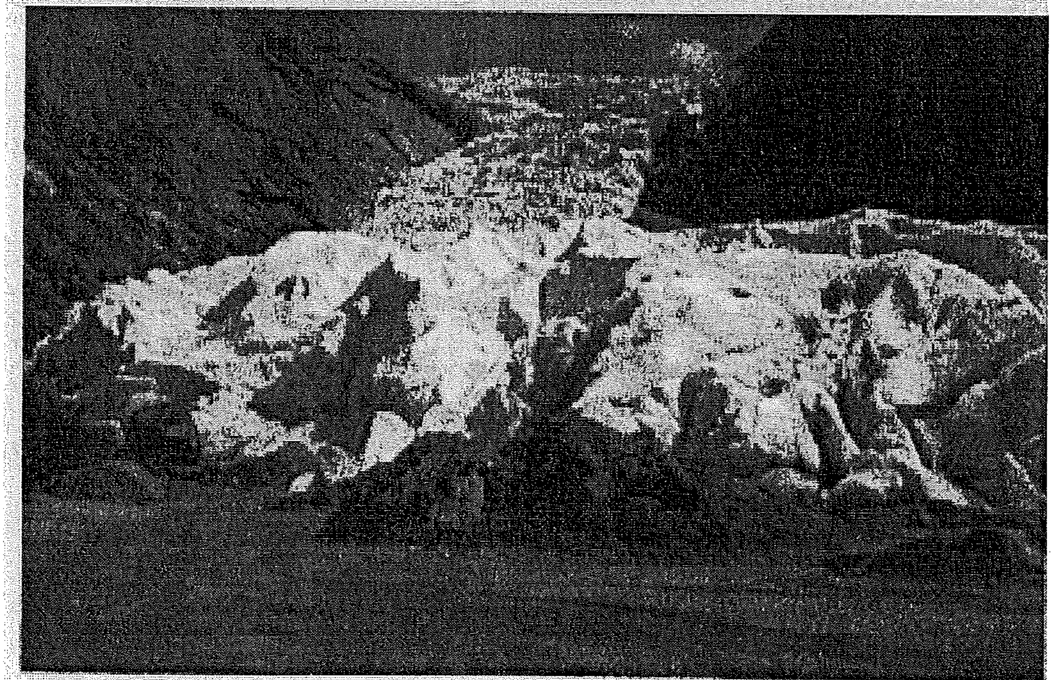
AD 1952

AD 1960

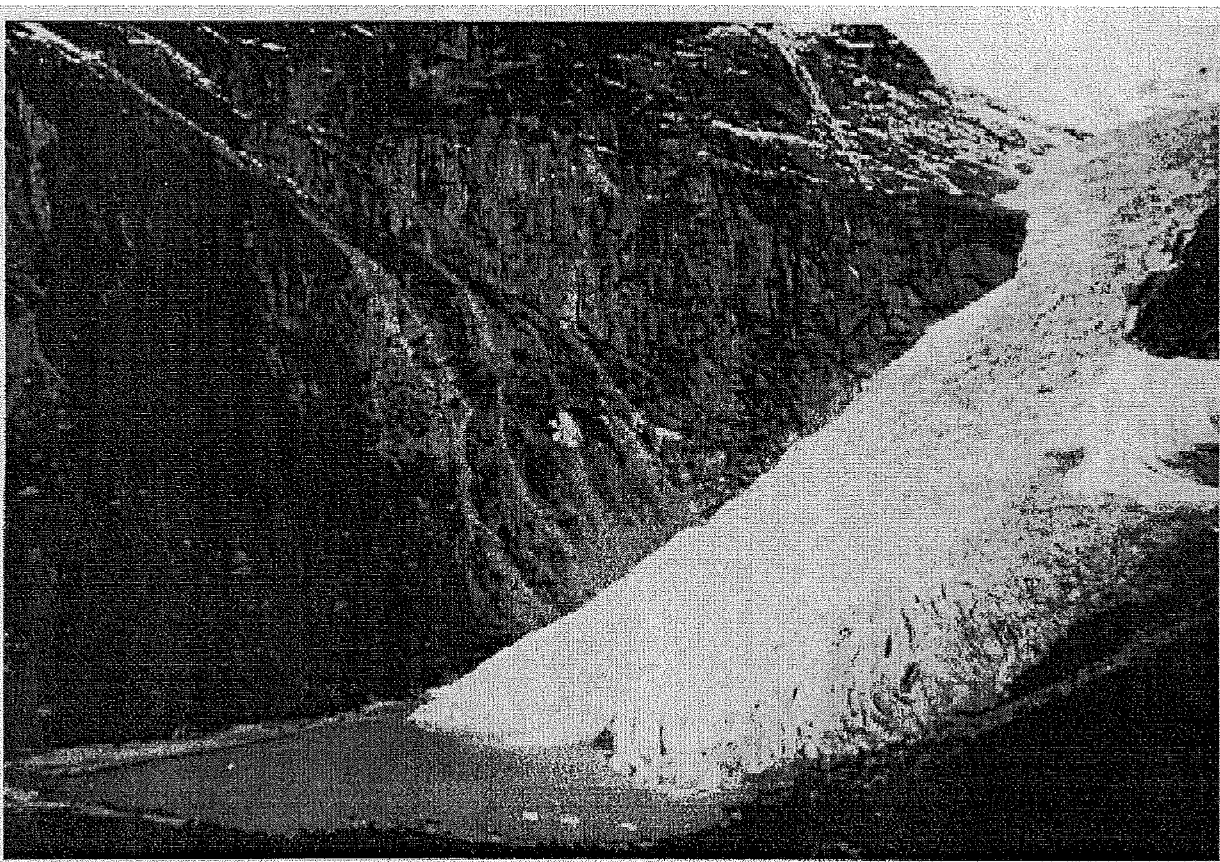


AD 1989

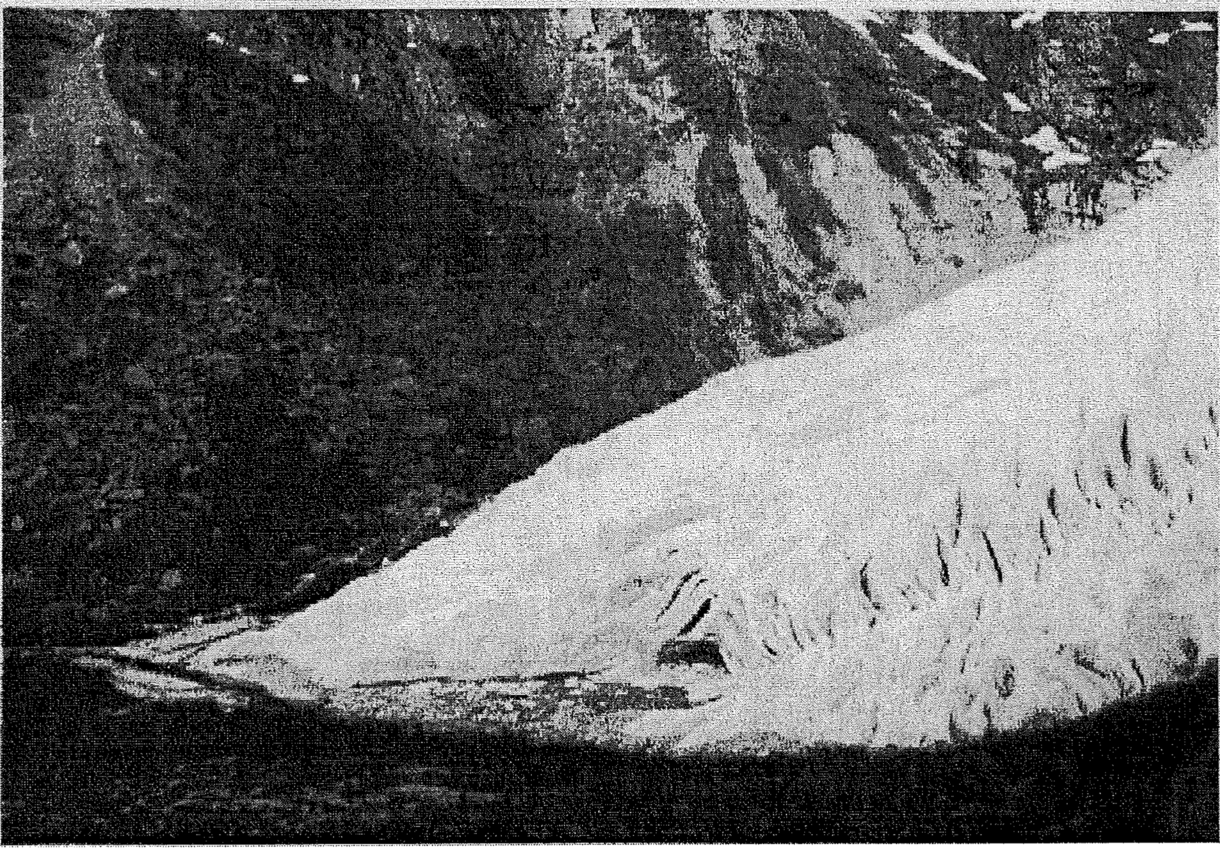




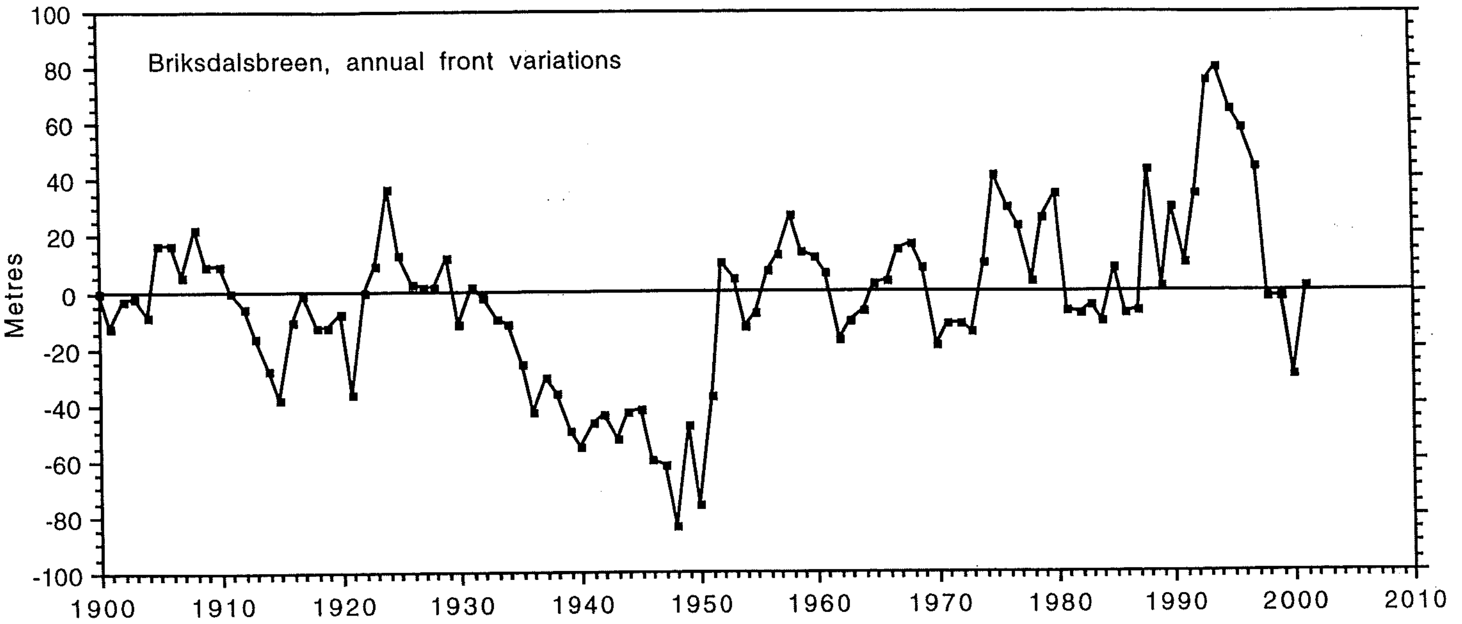
AD 1996

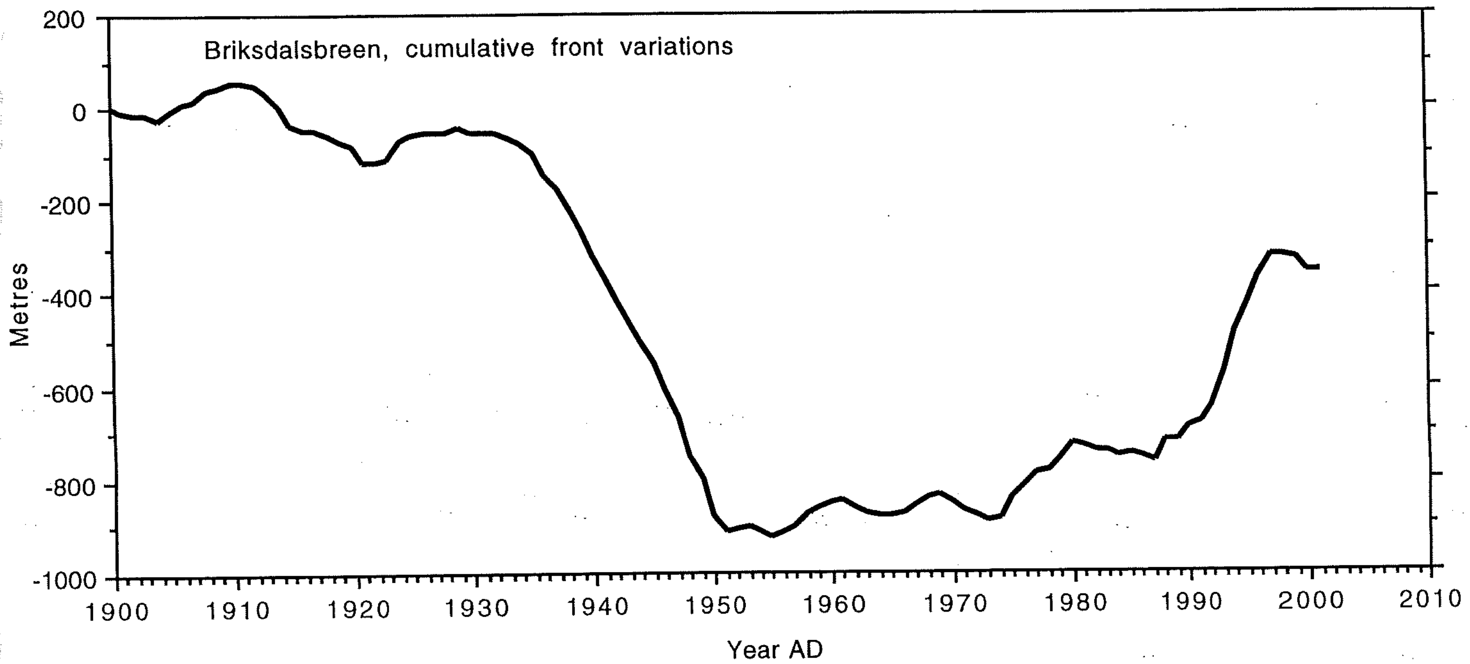


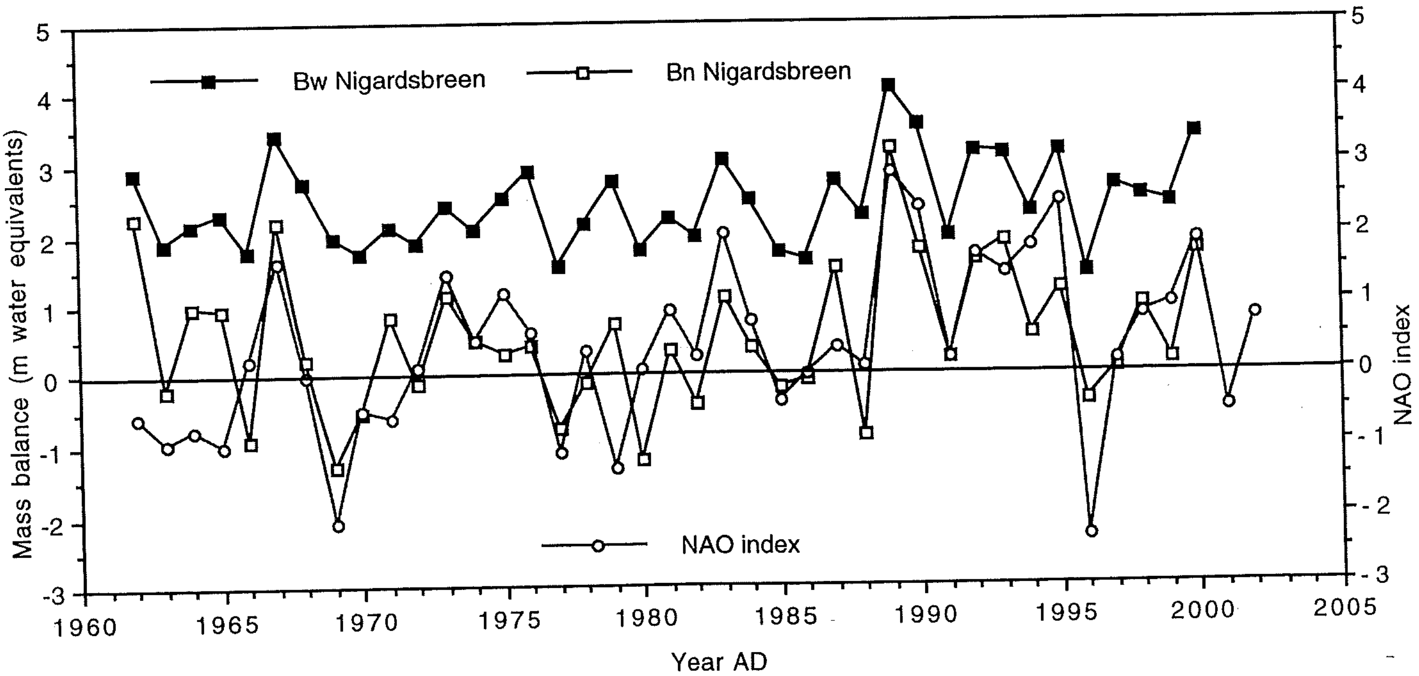
1993

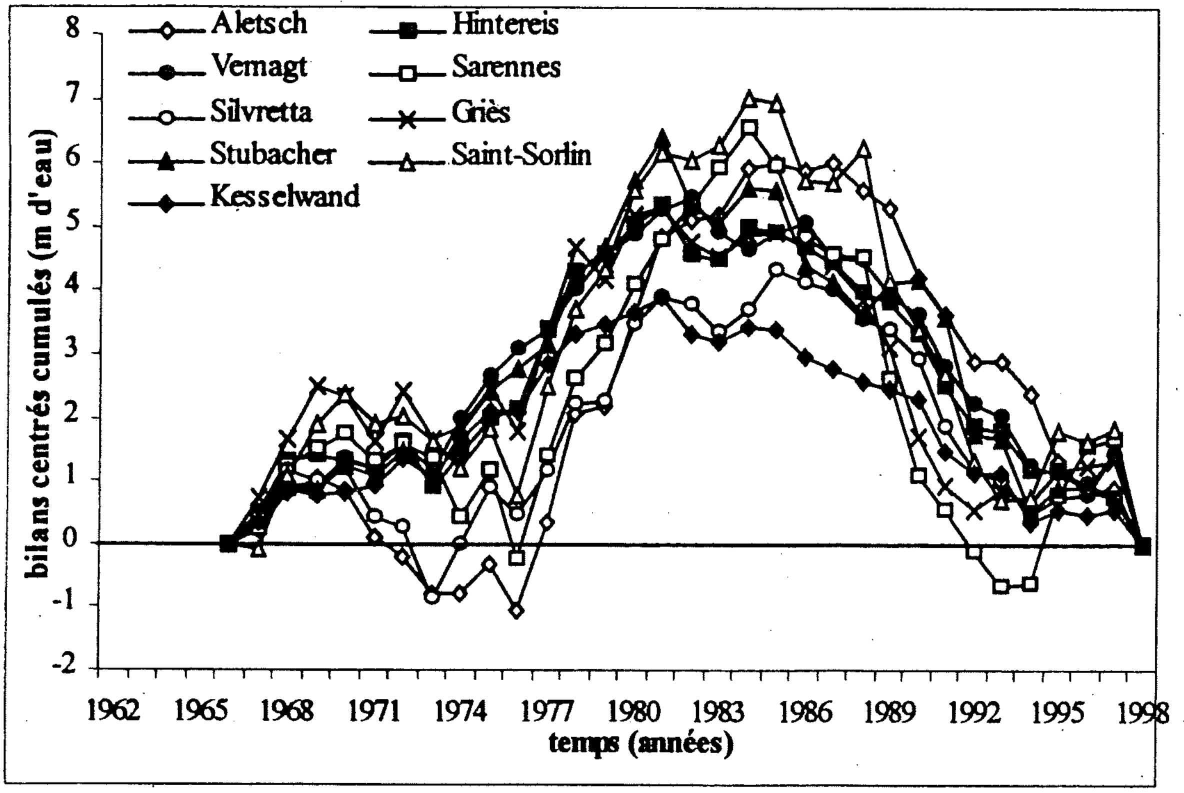


1997

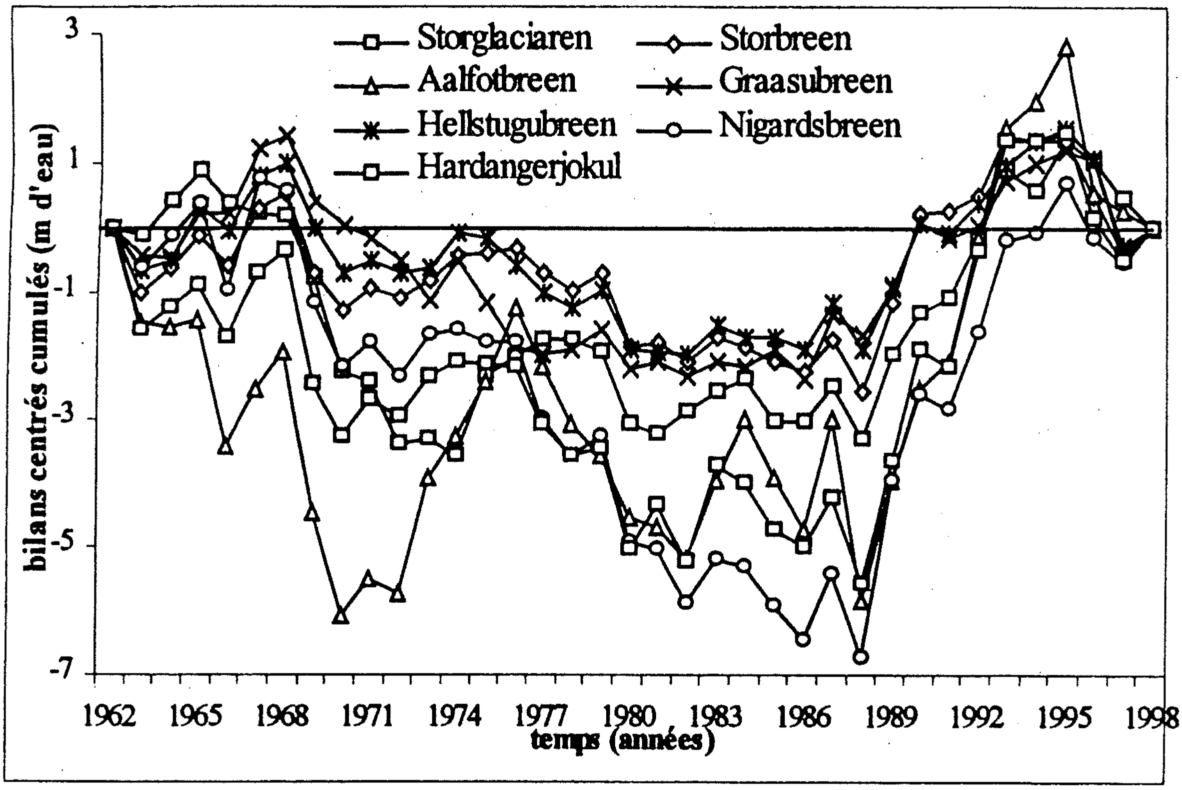

Briksdalsbreen, annual front variations
Metres
100
80
60
40
20
0
-20
-40
-60
-80
-100
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010


Briksdalsbreen, cumulative front variations
Metres
200
0
-200
-400
-600
-800
-1000
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year AD


Bw Nigardsbreen
Bn Nigardsbreen
NAO index
Mass balance (m water equivalents)
NAO index
5
4
3
2
1
0
-1
-2
-3
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year AD

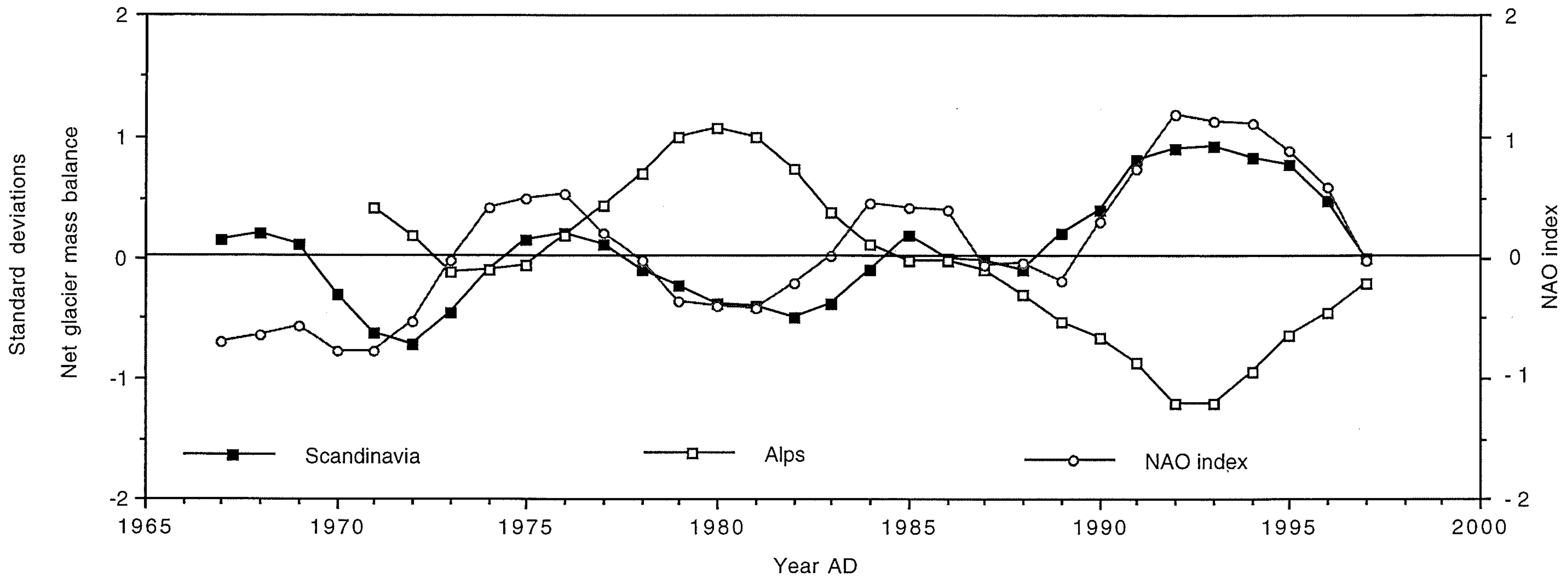


(a)



(b)

Figure 1. Cumulative deviations from the means for mass balance series of nine Alpine glaciers (**a**) (1966–1998 period) and seven Scandinavian glaciers (**b**) (1962–1998) (in metres water equivalent).

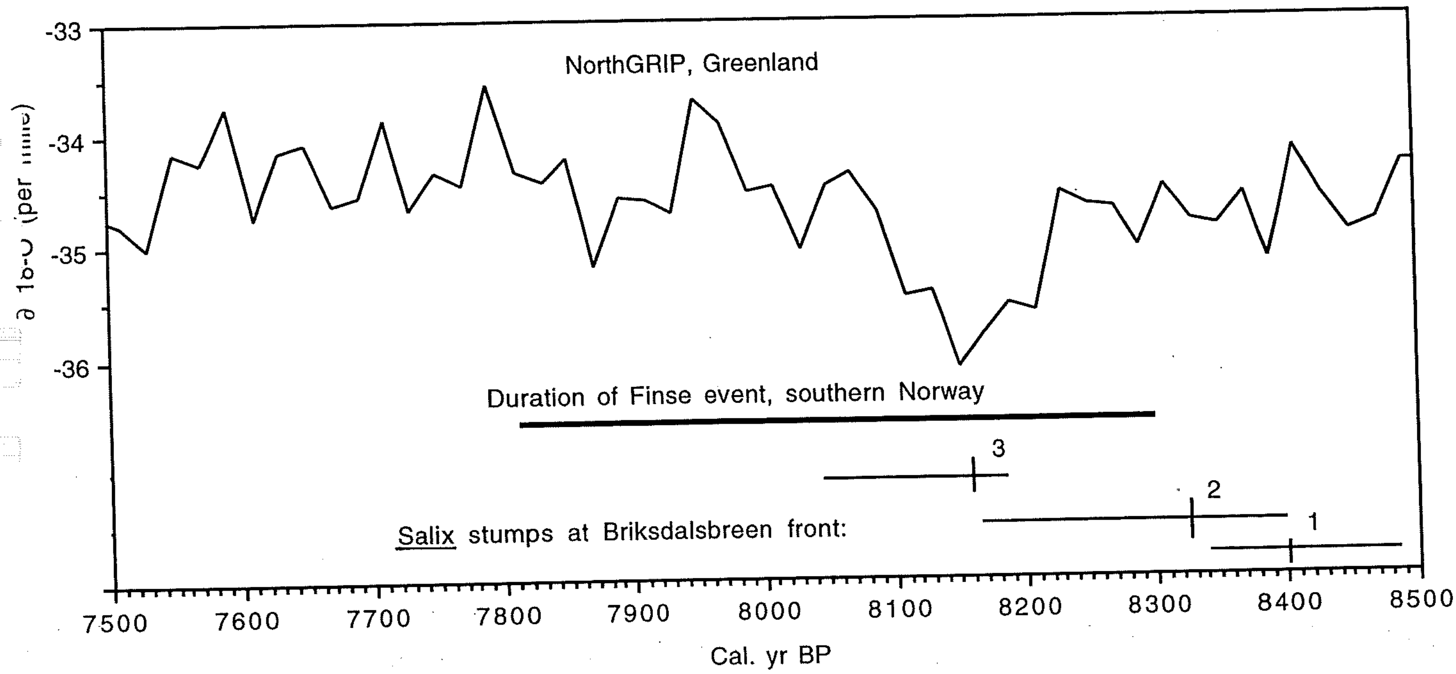


Mean mass balance of nine glaciers in the Alps and seven Scaninavian glaciers in the period 1967-1997, compared to the North Atlantic Oscillation (NAO) index.
The series are centred, divided by standard deviations, and filtered on five years.

Adapted from Six et al. (2001)

Radiocarbon dates of <u>Salix</u> stumps at Briksdalsbreen

Radiocarbon age:	Cal yr BP:
7650 ± 85	8405 (8485 - 8340)
7530 ± 100	8324 (8400 - 8165)
7340 ± 60	8160 (8190 - 8050)



- 7000 - 4000 BP cal wärmste Holozänperiode im Norden
- Im Zentrum: Frühholozän
- Süden: Finse event! 8200

Im Norden: Temperaturgipfel von Briks festgestellt → leider kein Signal in Proxi-temperaturrekonstruktion, Temperatur zeigt wegen heutiger [illegible] sogar einen leichten qualitativen Gipfel der Temperatur.

Klimamodell: so lange Eisschild vorhanden → grosse Schwankungen möglich. Evt 8.2 doch Kollaps der Eisschildes

Chronologieprobleme.

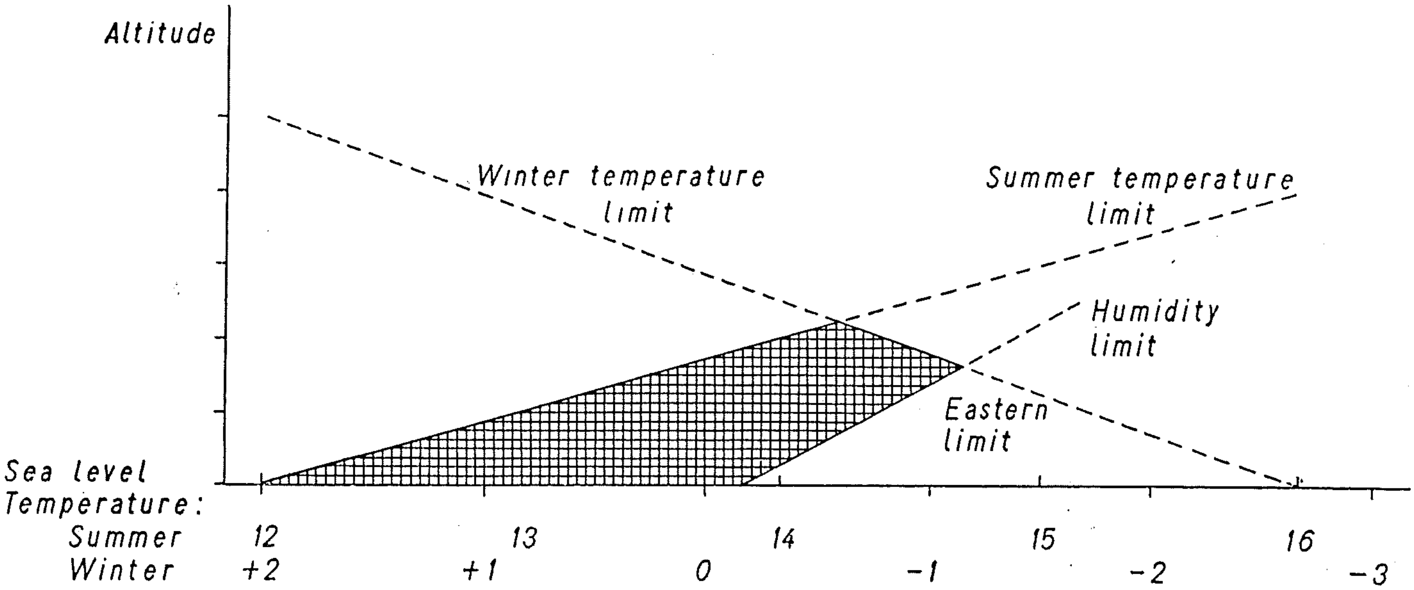
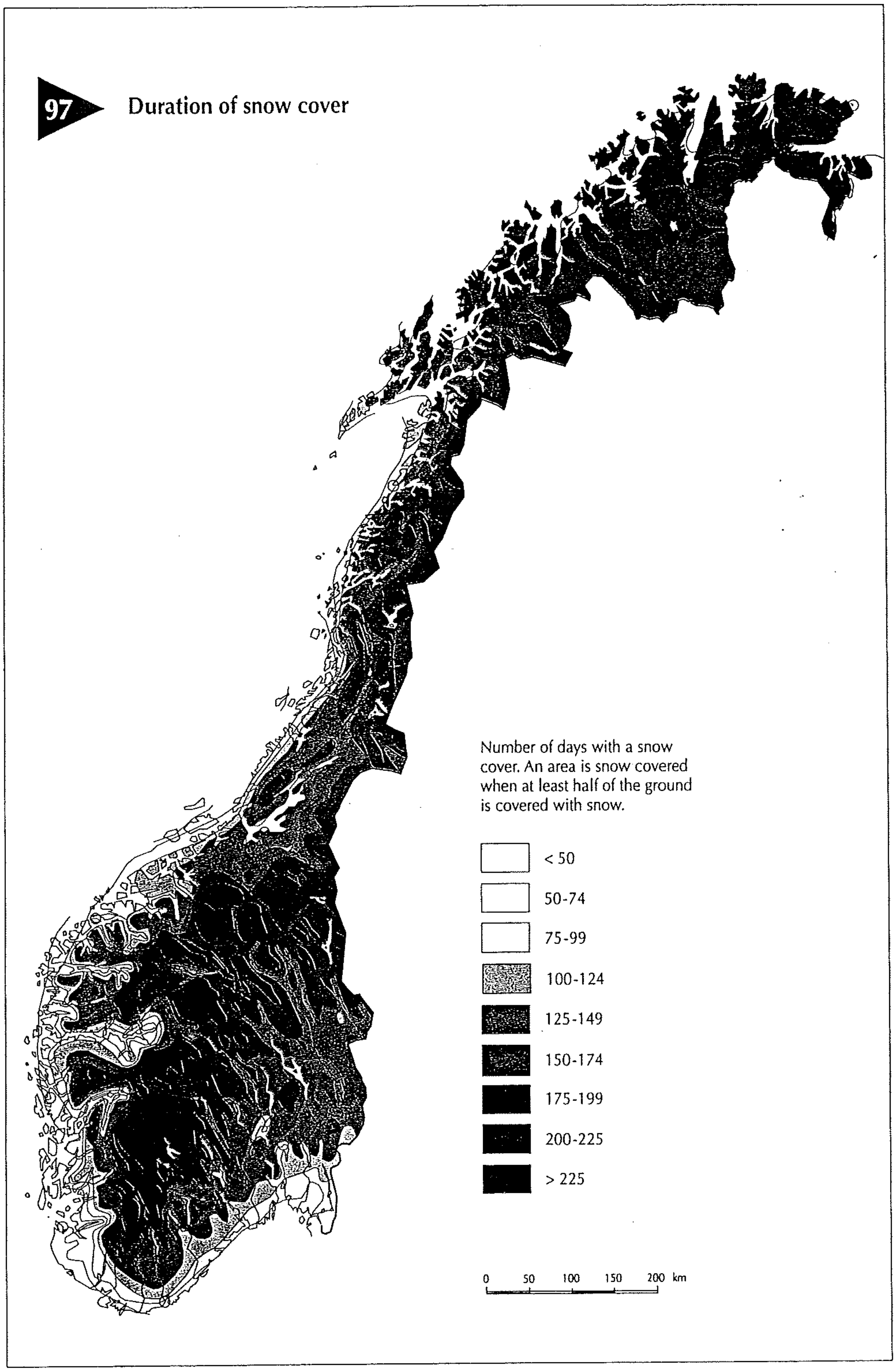


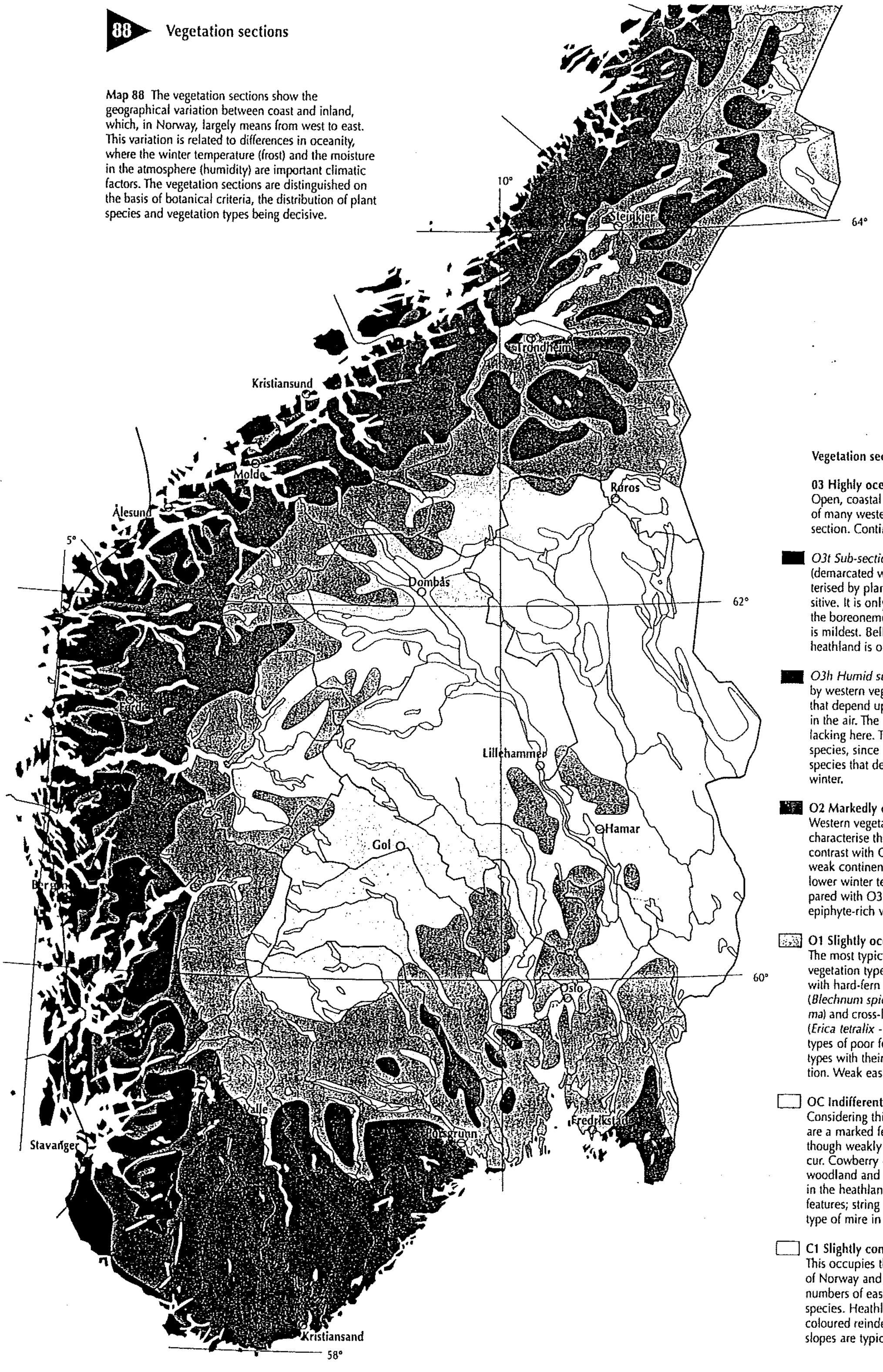
Fig. 3. Schematic representation of the interaction of temperatures and humidity in a W.—E. section in Western Norway.



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. Other important climatic factors are presented on maps in the chapter on the environment of the plants (see page 15). 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.

88 Vegetation sections

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 oceanity, 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.



Vegetation sections

03 Highly oceanic section
Open, coastal heathland and the presence of many western species characterise this section. Continental features are lacking.

O3t Sub-section with mild winters (demarcated with a green line) is characterised by plants that are highly frost sensitive. It is only found in lowland areas (in the boreonemoral zone) where the winter is mildest. Bell heather (*Erica cinerea*) heathland is only found in O3t.

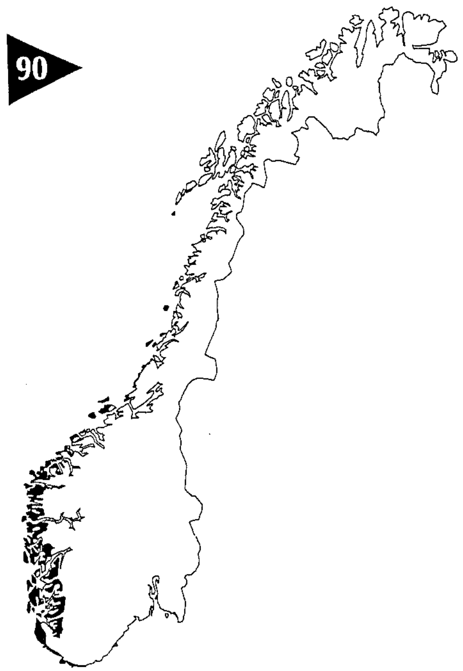
O3h Humid sub-section is characterised by western vegetation types and species that depend upon a high moisture level in the air. The northern boreal zone is lacking here. The alpine zones have few species, since they lack many alpine species that demand stable conditions in winter.

O2 Markedly oceanic section
Western vegetation types and species also characterise this section. However, in contrast with O3, there are also some weak continental traits, partly because of lower winter temperatures in O2 compared with O3. Steeply sloping fens and epiphyte-rich woodlands are typical.

O1 Slightly oceanic section
The most typical western species and vegetation types are lacking. Woodlands with hard-fern and lemon-scented fern (*Blechnum spicant, Oreopteris limbosperma*) and cross-leaved heath - bog asphodel (*Erica tetralix - Narthecium ossifragum*) types of poor fen are western vegetation types with their inner boundary in this section. Weak eastern traits are also present.

OC Indifferent section
Considering this is Norway, eastern traits are a marked feature of the plant life, although weakly western species also occur. Cowberry - bilberry (*Vaccinium* spp.) woodland and large quantities of lichen in the heathland vegetation are typical features; string fen is the most common type of mire in the OC and C1 sections.

C1 Slightly continental section
This occupies the most continental parts of Norway and is characterised by large numbers of eastern vegetation types and species. Heathland vegetation with light-coloured reindeer lichen and dry grassy slopes are typical.

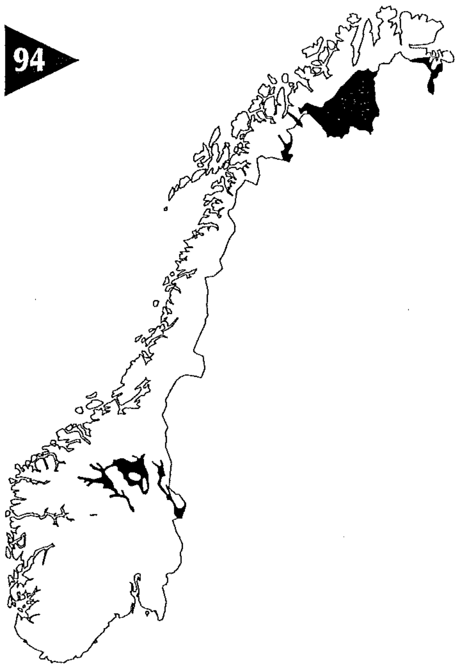


Map 90 The highly oceanic section is found along the coast from Mandal in the south to the southernmost part of Lofoten in the north.

Map 91 The markedly oceanic section is found in Østfold, and occupies the greater part of southernmost Norway and large tracts in the fjord districts northwards as far as Troms.

Map 92 The slightly oceanic section covers large areas in south-east Norway and inner parts of west Norway, Trøndelag and Nordland, as well as outer parts of Troms and Finnmark as far north-east as Nordkapp.

Map 93 The indifferent section occupies large areas in the interior of south-east Norway, central Troms and west Finnmark, and much of the area from the coast to the interior in east Finnmark.



Map 94 The slightly continental section occupies some of the interior valleys in south-east Norway and the greater part of the Finnmarksvidda plateau in north-east Norway.

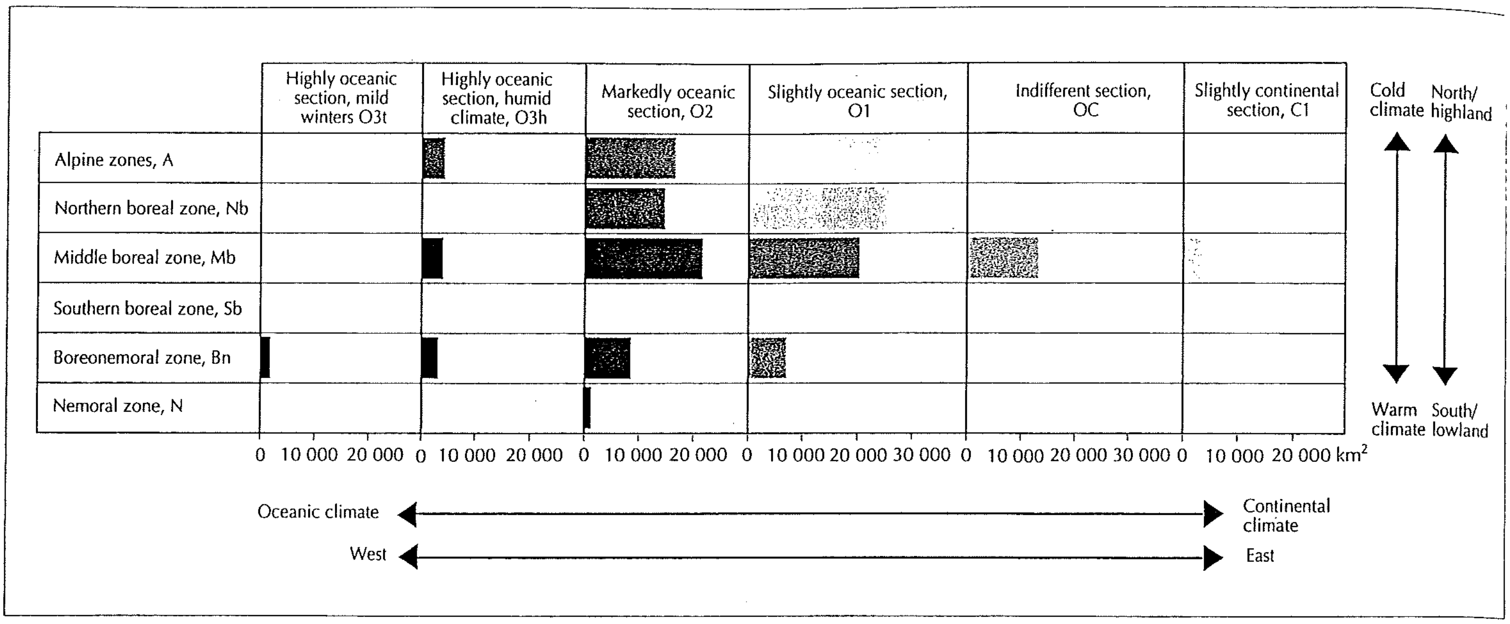


Figure 19 The area occupied by the various vegetation ecological regions. The 26 regions have the same colour as on the map and the bars show the area covered by each region.

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

Table 5 Main aspects in the relationship between vegetation zones, sections, climatic factors and climatic maps.

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

Table 6 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 (see Map 50). 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

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

Table 7 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 months of the year.

* values for lowland localities near Sognefjord

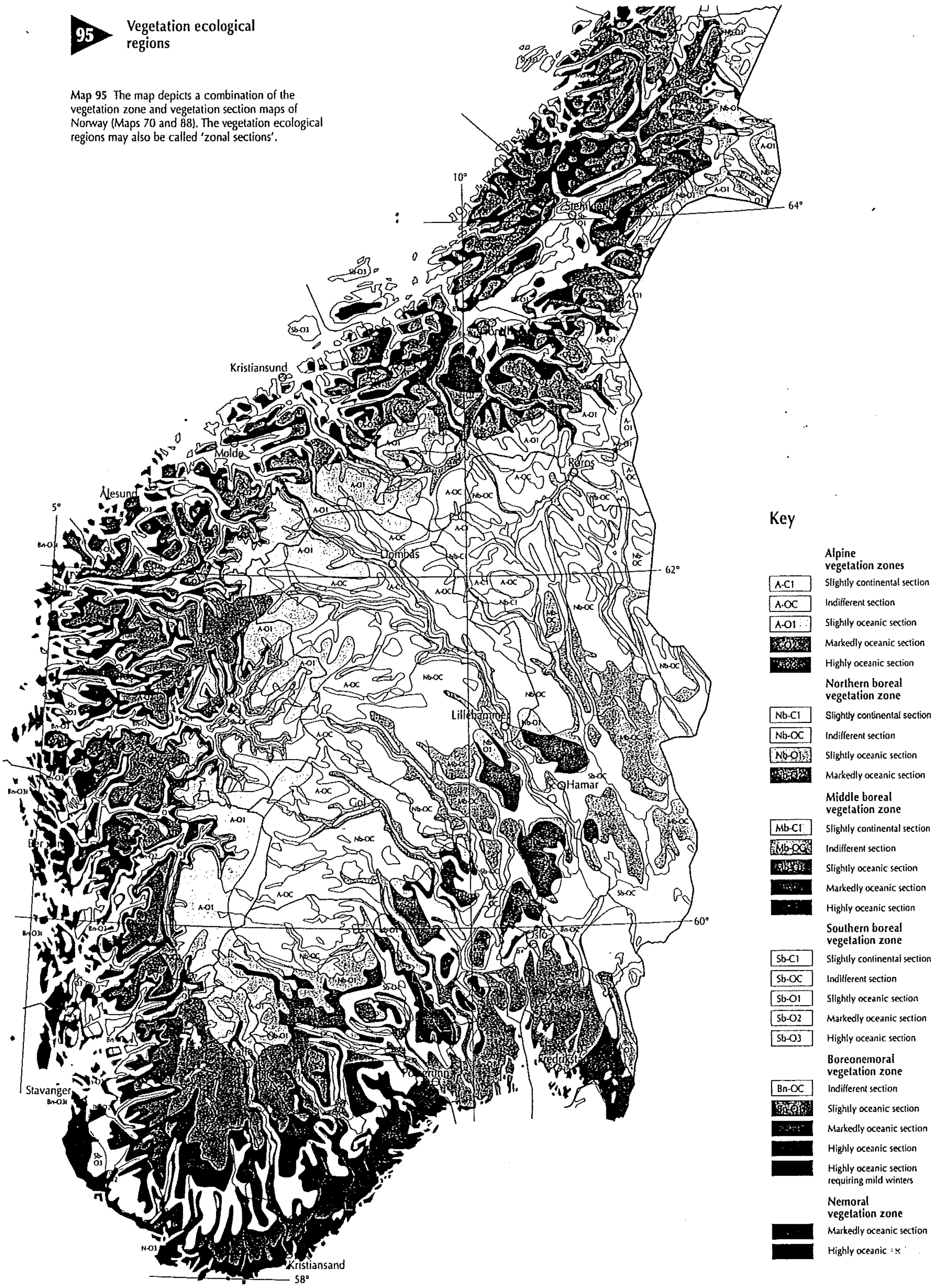
** many more days with precipitation on the coast of Finnmark

Zones \ Sections	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			

Table 8 Frost sums in the various vegetation ecological regions. The values represent rounded off averages for at least 10 localities in each region.

95 Vegetation ecological regions

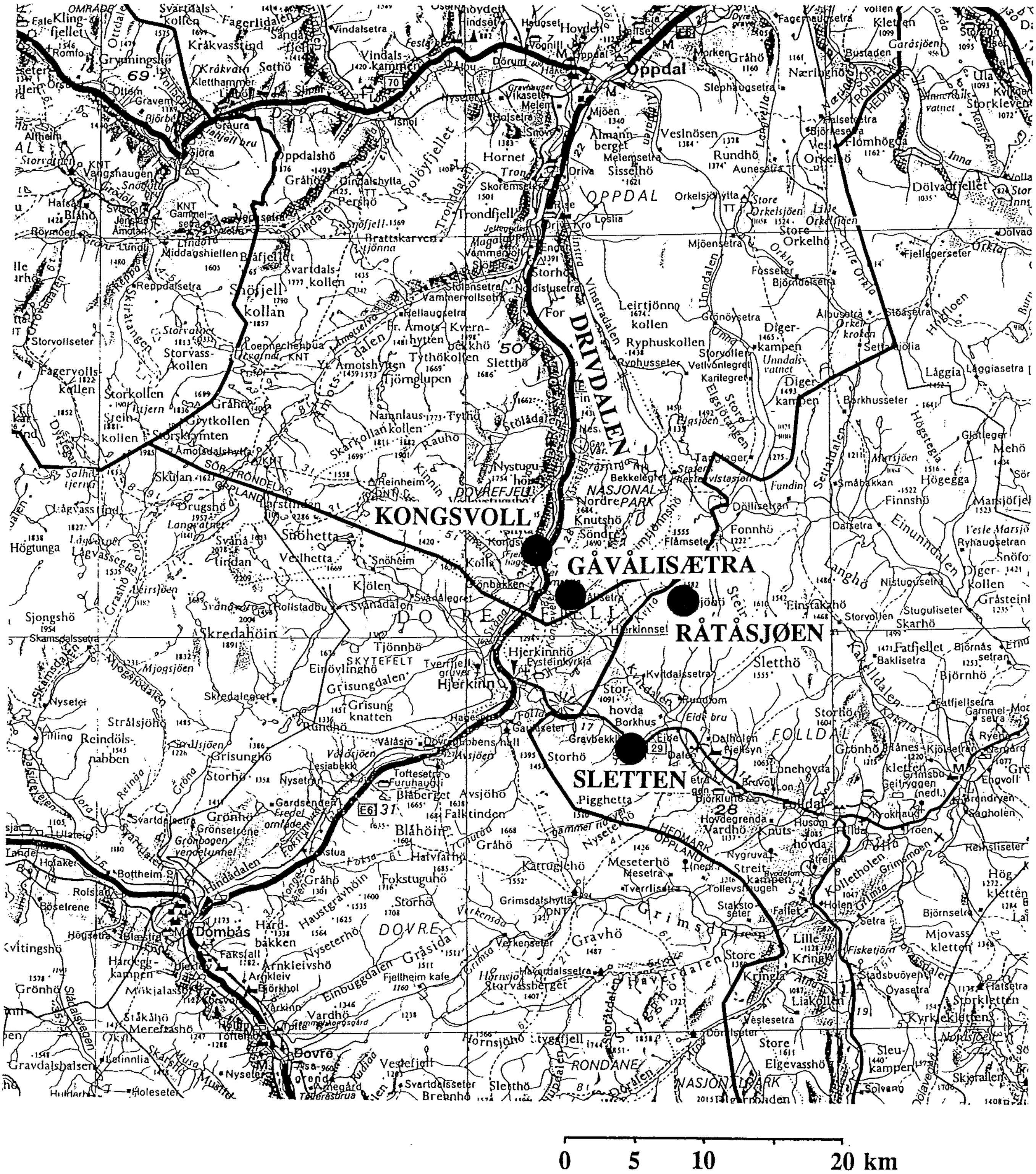
Map 95 The map depicts a combination of the vegetation zone and vegetation section maps of Norway (Maps 70 and 88). The vegetation ecological regions may also be called 'zonal sections'.



Wednesday, 21 August 2002

Råtåsjøen, Gåvålisætra, Kongsvoll, Drivdalen

DAY 4. Wednesday, 21st.August

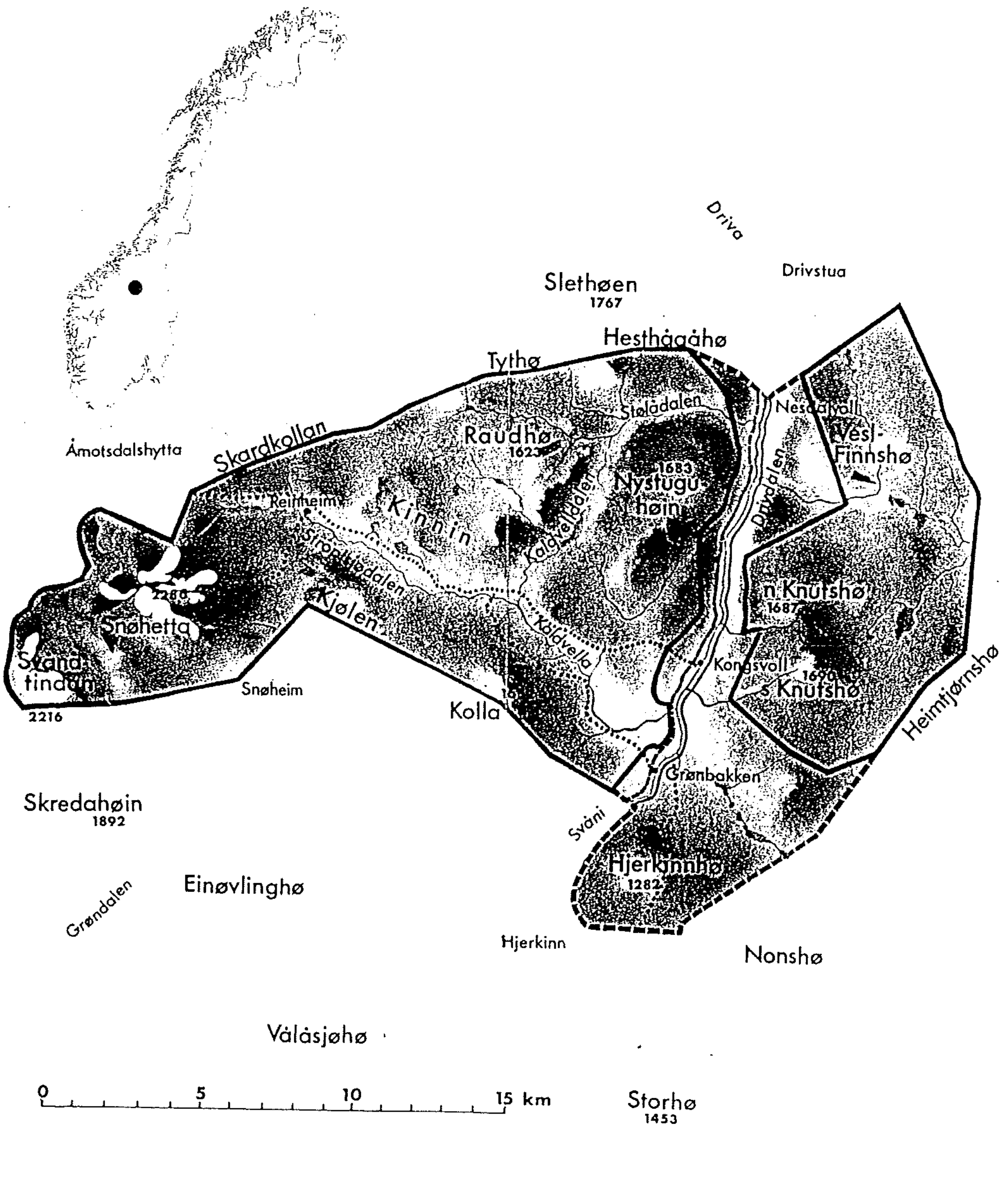


DOVRE

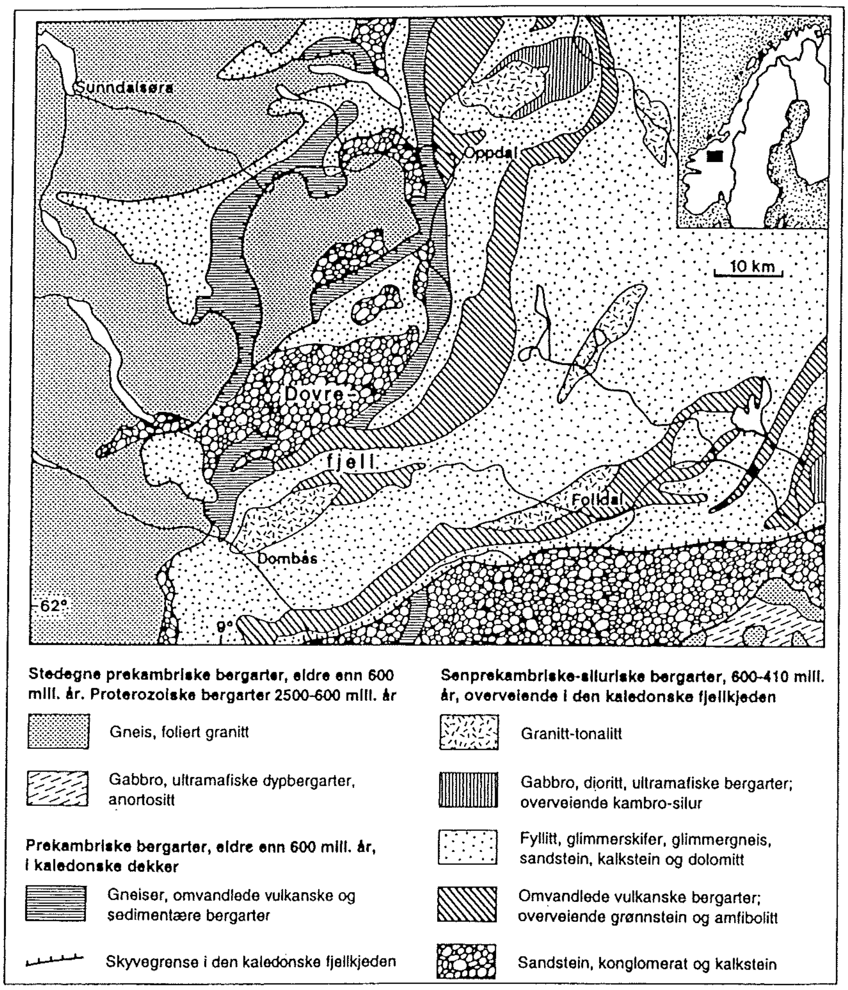
Background

Dovre (also called Dovrefjell) is considered as the national symbol of Norway. This is where the wise men of Eidsvoll met in 1814 and promised to be "united and faithful until the fall of Dovre".

Dovrefjell became a national park in 1974. The area is 265 km^2 and the altitude ranges between 900-2278 m asl. With dry and cold winters (average temperature of January-February is -10^0C) and wet and warm (average temperature of June-August is $+10^0$C) summers, the climate is considered to be continental. The mean annual precipitation measured at Kongsvoll is 473 mm. However, the western parts around Snøhetta receive more, being closer to the coast.



The bedrock belongs to two different bedrock-complexes. The western part contains old (more than 600 mill years) Precambrian bedrock. Gneiss dominates together with feldspar-rich sandstone, all acid hard rocks. The eastern part belongs to Trondheimsfeltet, a part of the Caledonian mountain range, formed 400-600 mill years ago. Most of the bedrock is sedimentary and metamorphic, such as phyllite and mica schist, and they dominate the area between Snøhetta and Drivdalen. During the Caledonian mountain range folding, bedrock was transported from north and east, covering the old bedrock. Today the borderline between young and old rock follows more or less Drivdalen. These younger bedrocks weather easily and are rich in minerals, providing good, fertile soils. This is the reason for the very species-rich eastern Dovre, such as the Knutshø-area.



Findings of human-made ditches to catch large mammals (such as reindeer) and arrowheads show that man, in the period 300-1700 AD, used the area. In addition, one Viking grave has been found south of Kongsvoll, suggesting more or less permanent settlement.

Flora

The birch-forest lies between 800 and 1000 m a.s.l. In mesic and calcareous habitats the tall-herb vegetation dominates, mainly represented by:

Aconitum septentrionale
Angelica archangelica
Athyrium filix-femina
Calamagrostis purpurea
Cicerbita alpina
Circium helenioides
Dryopteris expansa
Elymus caninus
Geranium sylvaticum
Milium effusum
Myosotis decumbens
Poa remota
Polemonium caerulum
Polygonatum odoratum
Ranunculus platanifolius
Valeriana sambucifolia

Where the bedrock is more acidic, but in mesic habitats, *Vaccinium myrtillus* dominates the field-layer, whereas *Empetrum nigrum* takes over in more dry habitats, together with *Solidago virgaurea* and *Trientalis europaea.*

Springs are often bordered by *Epilobium alsinifolium*, *E. hornemanni* and *Cystopteris montana*. With good availability of water the willows (*Salix glauca*, *S. lapponum*, *S. myrsinifolia*, *S. phylicifolia*) make up an almost impenetrable belt. On the slopes up to Knutshø and along Kaldvella the rich bedrock promotes the growth of *Salix myrsinites* and *S. reticulata*.

The low-alpine vegetation zone is dominated by *Betula nana*, heath (*Arctostaphylos uva-ursi*, *A. alpinus*, *Empetrum nigrum*, *Loiseleuria procumbens*, *Vaccinium uliginosum*), and willows. At about 1450 m elevation, the vegetation cover is no longer continuous, and the soil is unstable. This is where the mid-alpine vegetation zone takes over, with a dominance of grasses (*Festuca ovina*) and sedges (*Carex bigelowii*, *Juncus trifidus*, *Luzula arcuata*, *L. spicata*, *L. muliflora*).

Where the bedrock is somewhat calcareous, some of the highlights in these two vegetation zones are:

Artemisia norvegica
Carex rupestris
Campanula unifloria
Dryas octopetala
Kobresia myosourides
Leucorchis albida ssp. *albida*
L. albida ssp. *straminea*
Phippsia concinna
Potentilla nivea
Primula scandinavica
Silene acaulis
S. uralensis ssp. *apetala*

Between the more dry habitats with herbs and heath and the snow-beds, there is a transition zone dominated by grasses and some sedges. Typical species in these areas are:

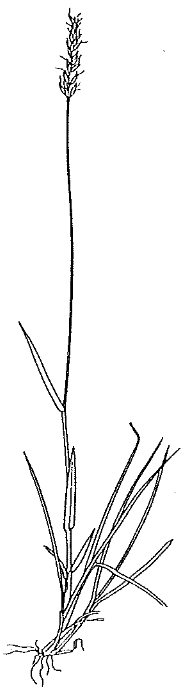
Agrostis mertensii
Anthoxanthum odoratum ssp. *alpinum*
Carex bigelowii
C. brunnescens
Deschampsia flexuosa
Diphasium alpinum
Hieracium alpinum
Nardus stricta
Omalotheca norvegica
Pyrola minor
Rumex acetosa ssp. *lapponicus*

The species composition in snow-beds differs a lot, depending on duration of snow-cover, exposition, and bedrock. Some of the characteristic species occurring in calcareous snow-beds are:

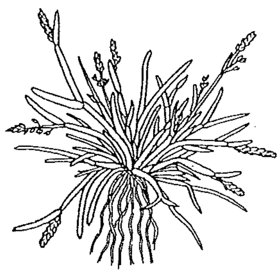
Draba alpina
Equisetum variegatum
Juncus biglumis
Koenigia islandica
Phippsia algida
P. concinna
Poa arctica
P. alpina
Salix polaris
S. reticulata
Saxifraga cernua
S. oppositifolia
S. rivularis
S. tenuis
Selaginella selaginoides

Where the bedrock is more acidic, common species are:

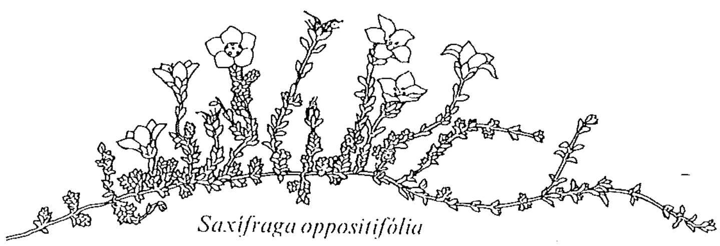
Carex lachenalii
C. rufina
Cerastium cerastoides
Deschampsia alpina
Eriophorum scheuchzeri
Oxyria digyna
Salix herbacea
Saxifraga stellaris
Sagina saginoides
Sibbaldia procumbens



Anthoxánthum odorátum ssp. alpínum



Phíppsia álgida

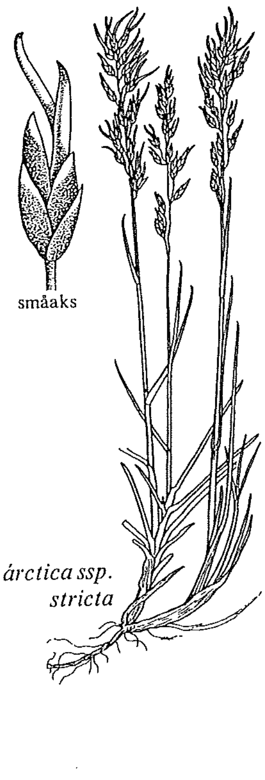


Saxífraga oppositifólia

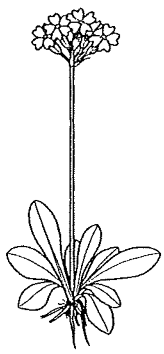
At 1800 m the high-alpine vegetation zone begins. In general the vegetation is sparse, with singular occurrences of herbs, sedges and grasses from the two lower zones. However one species, *Ranunculus glacialis*, thrives in this harsh environment, sometimes making up a scattered white carpet between the boulders. The last ones to disappear are the Bryophytes, and *Polytrichum norvegicum* is known to be one of the last plants to hold the fort. At the highest and most exposed habitats only lichens appear on the rocks.

Endemic and rare species

There are two endemic species at Dovre, *Taraxacum dovrense* and *Poa arctica* ssp. *stricta*, whereas *Primula scandinavica* is endemic for Scandinavia. In addition there are two forms (sometimes considered as subspecies) of *Papaver radicatum* in the area, *P. radicatum* ssp. *ovatilobum* and *P. radicatum* spp. *groevudalen*. The closest relatives are found on the Faeroe Islands, Iceland, Greenland and arctic areas of North America.



Poa árctica ssp. stricta

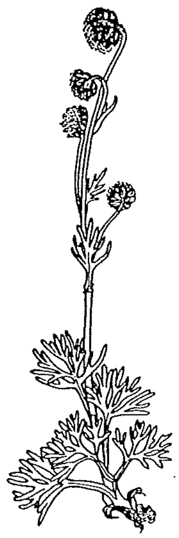


Prímula scandinávica

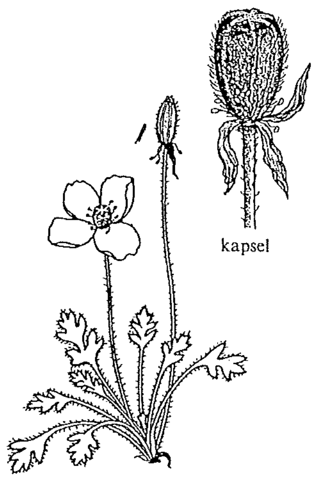
Taráxacum dovrénse (Árctica)

In addition, there are some species with a very special distribution. *Artemisia norvegica* has its main occurrence at Dovre and Trollheimen (mountain area just north of Dovre), in additions to some occurrences further south in Norway, in Scotland, and the Ural mountains. It can grow both high up in the mountains as well as on sandy hills by the road. The amphi-atlantic *Campanula uniflora* is one of the bicentric species, and prefers the mid-to high-alpine vegetation zone. Other rare species, both in Norway and for the Dovre area, include *Draba cacuminum*, *D. nivalis* and *Stellaria longipes*.

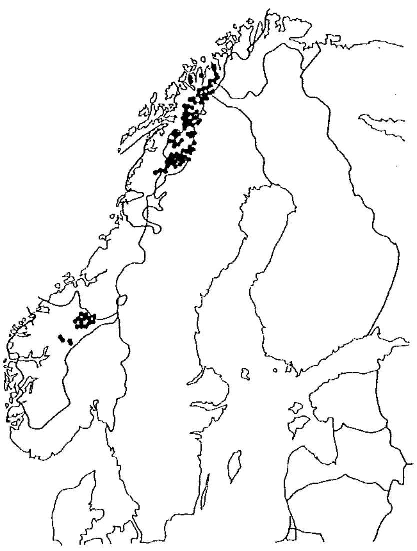
Campánula uniflóra



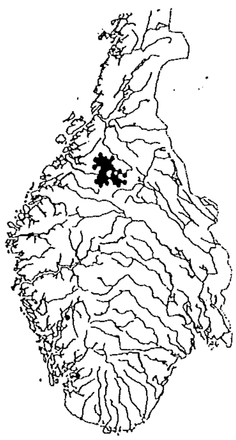
Artemísia norvégica

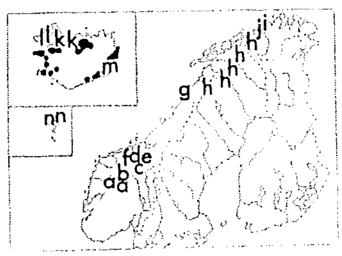


Papáver radicátum ssp. ovatilóbum

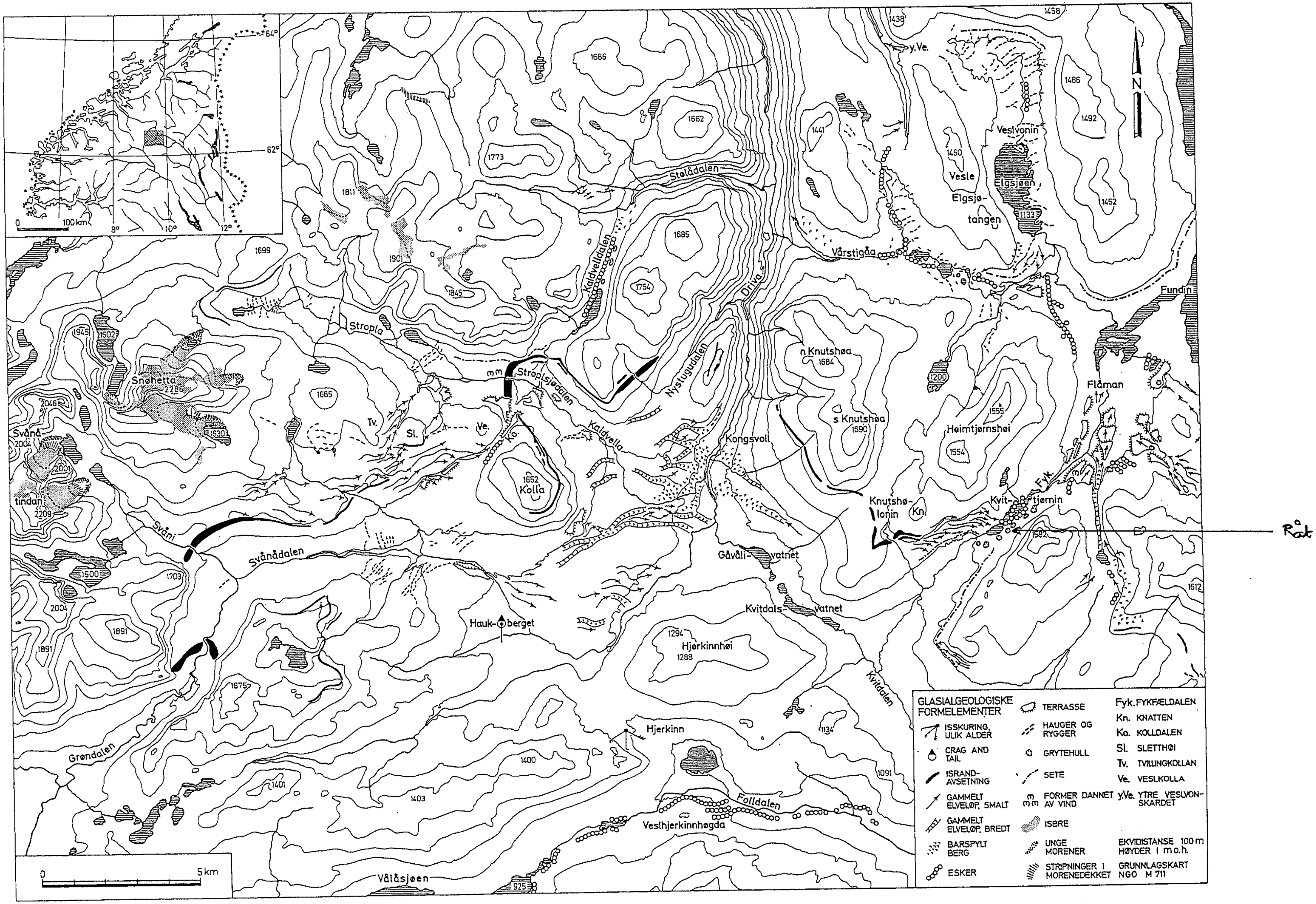


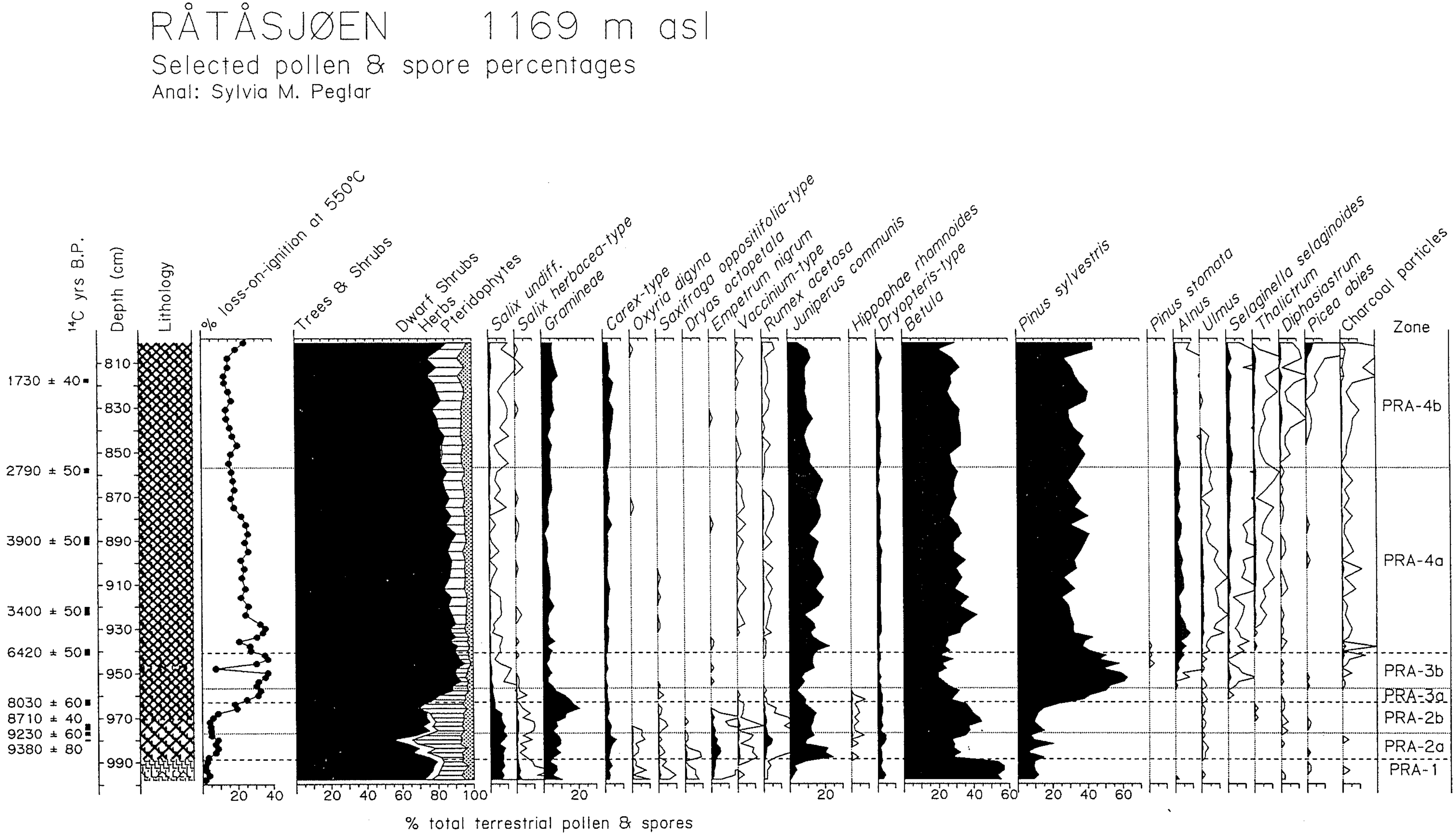
Maximum temperature 22°C





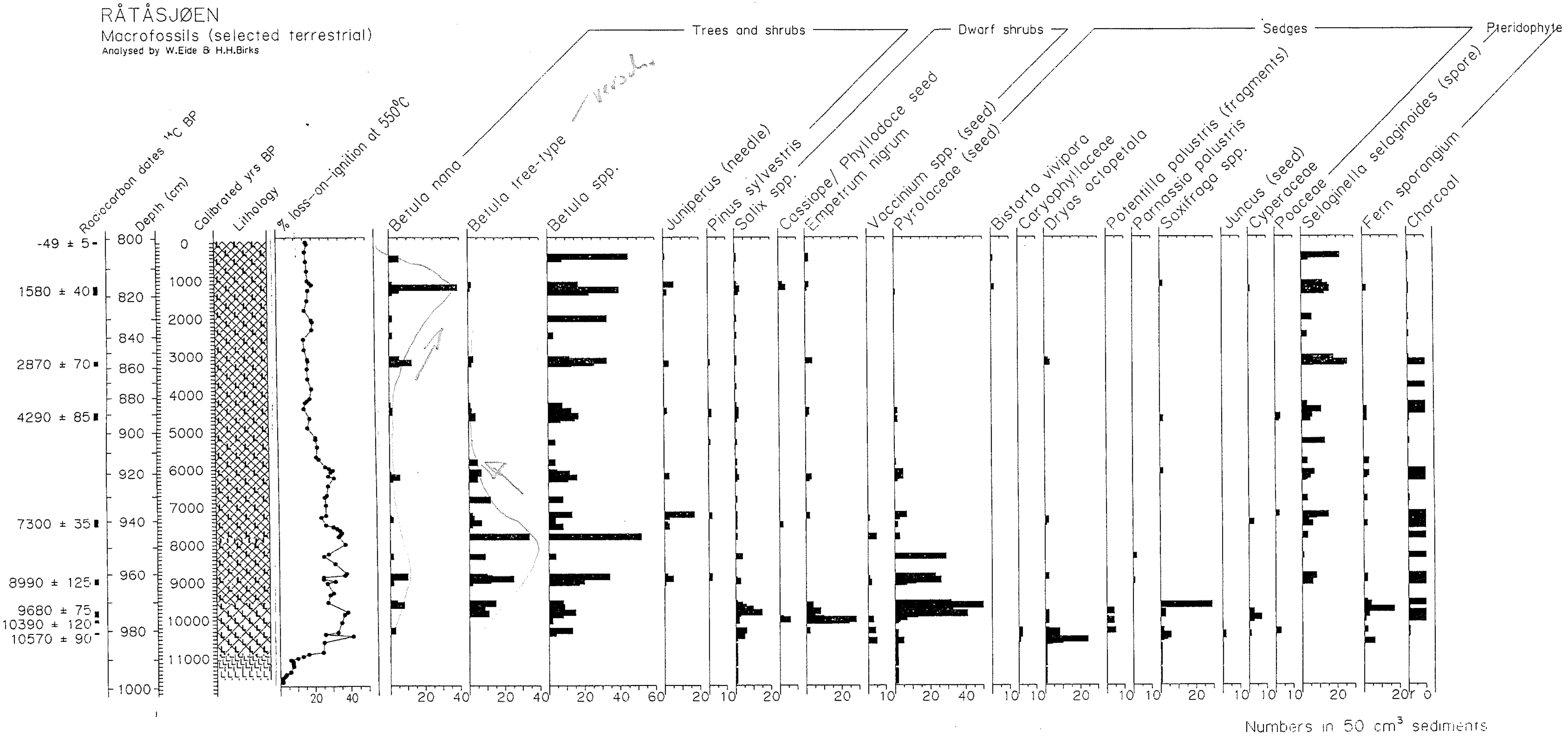
Distribution of all *P. radicatum* species
c: *P. radicatum* ssp. *ovatilobum*
d: *P. radicatum* ssp. *groevudalen*


GLASIALGEOLOGISKE FORMELEMENTER
ISSKURING, ULIK ALDER
CRAG AND TAIL
ISRAND-AVSETNING
GAMMELT ELVELØP, SMALT
GAMMELT ELVELØP, BREDT
BARSPYLT BERG
ESKER
TERRASSE
HAUGER OG RYGGER
GRYTEHULL
SETE
FORMER DANNET AV VIND
ISBRE
UNGE MORENER
STRIPNINGER I MORENEDEKKET
Fyk. FYKFÆLDALEN
Kn. KNATTEN
Ko. KOLLDALEN
Sl. SLETTHØI
Tv. TVILLINGKOLLAN
Ve. VESLKOLLA
y.Ve. YTRE VESLVON-SKARDET
EKVIDISTANSE 100 m
HØYDER I m o.h.
GRUNNLAGSKART NGO M 711
N
0 5 km
0 100 km
Snøhetta
Svånå-tindan
Sváni
Svånådalen
Grøndalen
Stropla
Stroplsjødalen
Kaldvelldalen
Kaldvella
Støládalen
Nystugudalen
Driva
Kongsvoll
n Knutshøa
s Knutshøa
Knutshø-lonin
Kolla
Hauk-berget
Gåvåli-vatnet
Kvitdals-vatnet
Hjerkinnhøi
Hjerkinn
Folldalen
Veslhjerkinnhøgda
Vålåsjøen
Kvitdalen
Vesle Elgsjø-tangen
Elgsjøen
Veslvonin
Vårstigåa
Fundin
Flåman
Heimtjørnshøi
Kvit-tjørnin
Råt



Summary pollen diagram from Råtåsjøen, in the low-alpine region today.

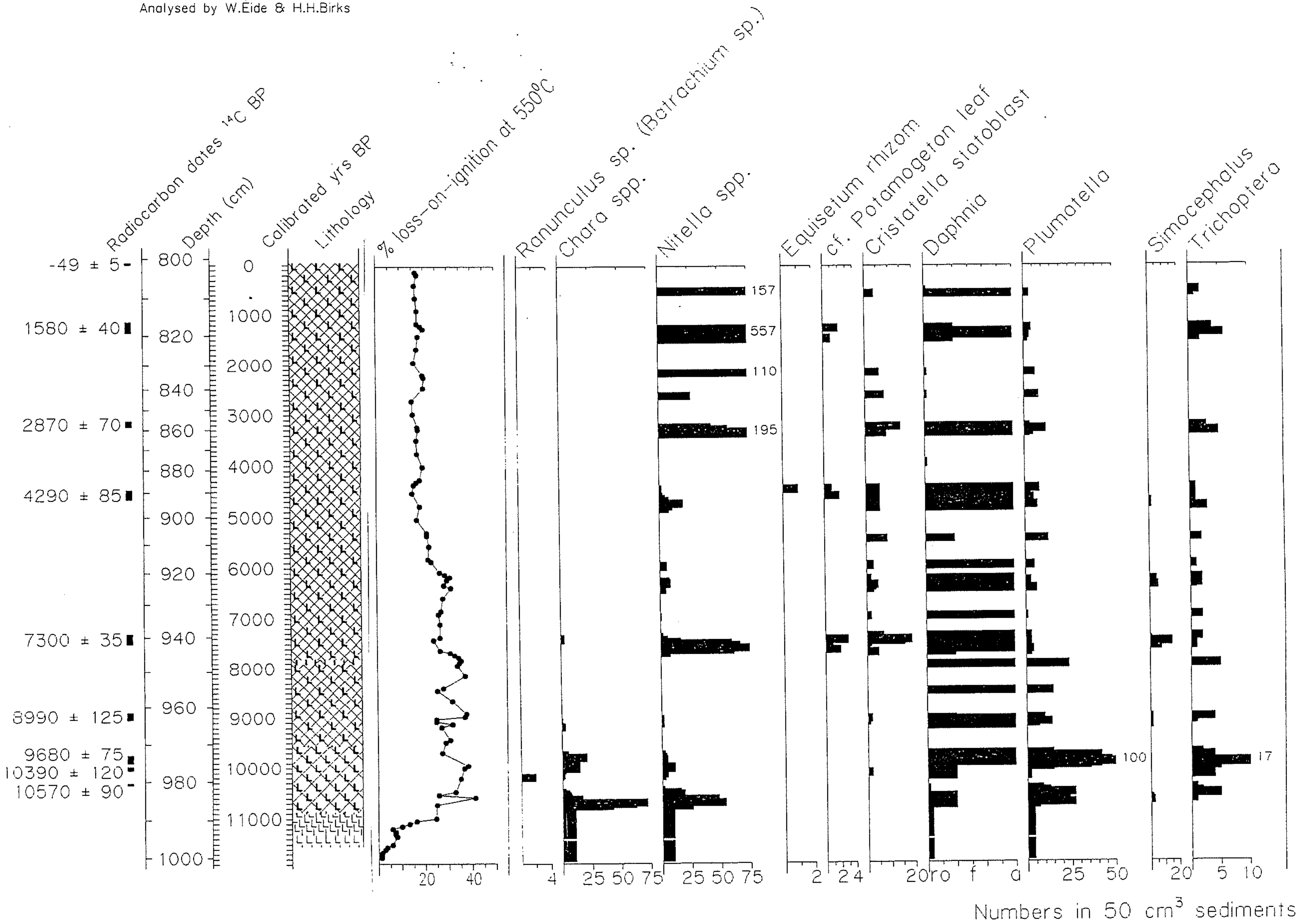
Kontroverse: Bulk-Datierung hat Alleröd-Datum, was zeigt sich mit Sicherheit zu alt.

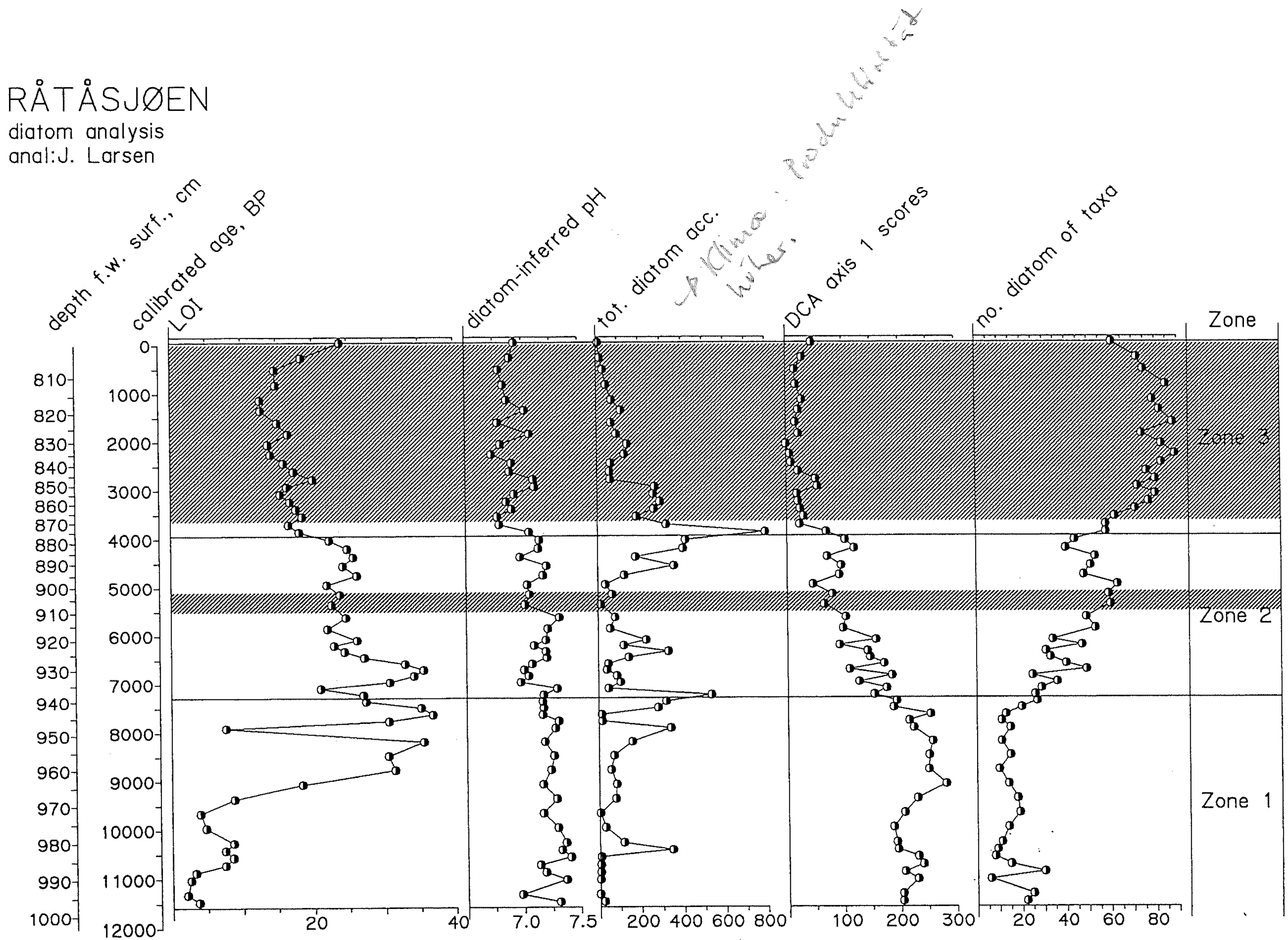


RÅTÅSJØEN - 1169 m asl

Macrofossils (aquatic and wetland fauna and flora)

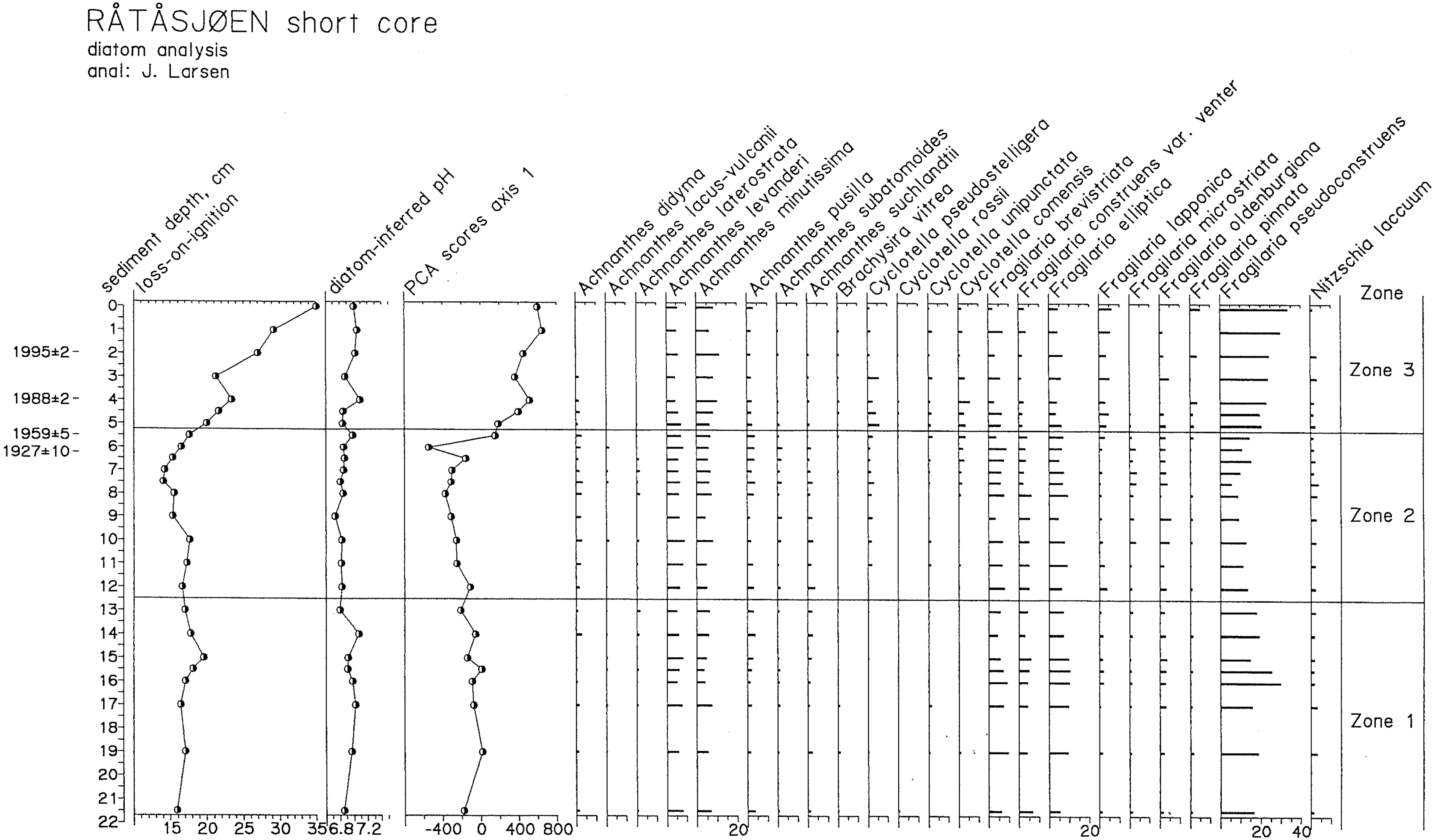
Analysed by W.Eide & H.H.Birks





Summary diagram of the diatom analysis from Råtåsjøen covering the Holocene.

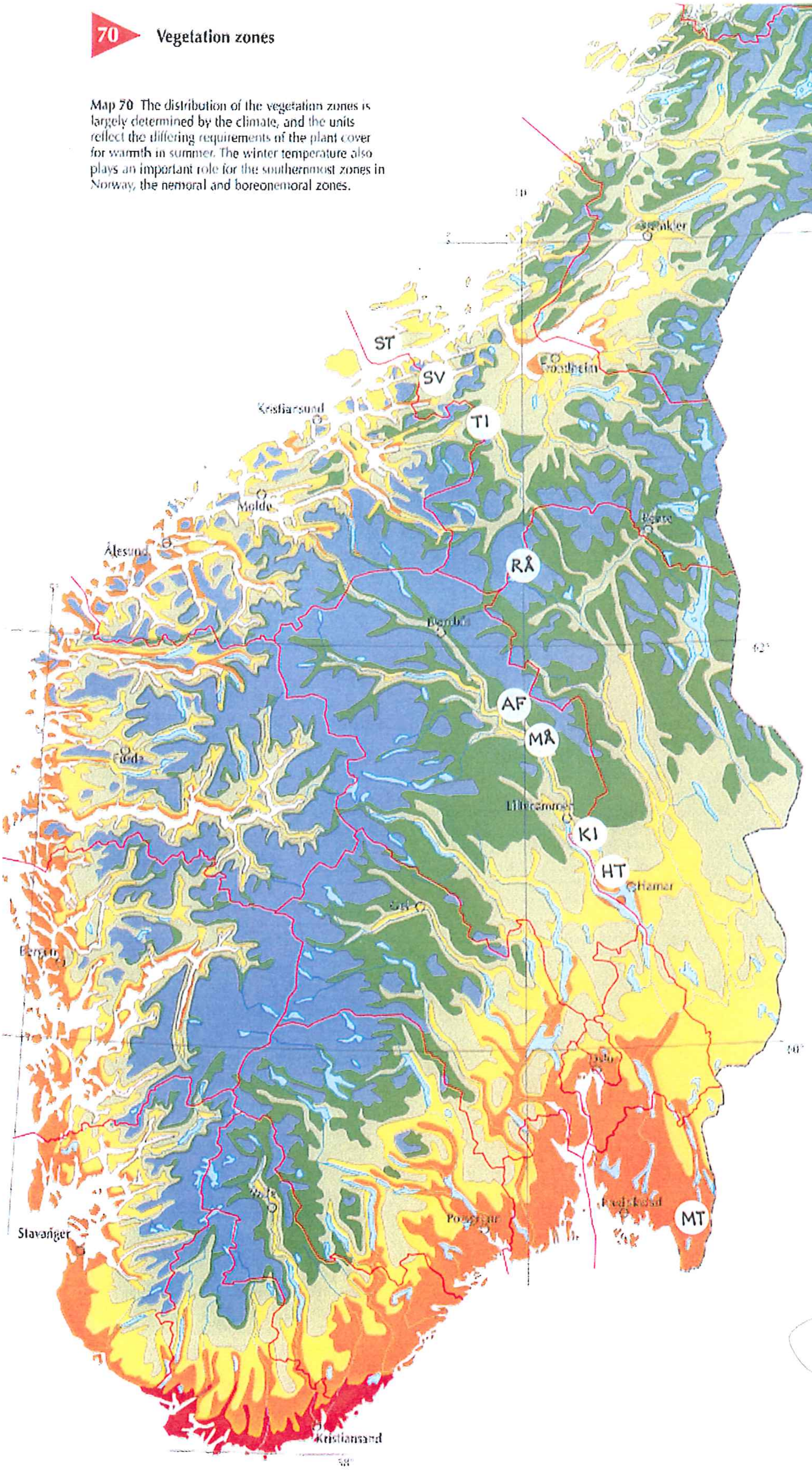
Waldweg → Produktivität sinkt → Erosion steigt (Schneeschmelze)
→ mineral. Anteil steigt.



Summary diagram of the diatom analysis from the short core of Råtåsjøen.

70 Vegetation zones

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.



Low, middle and high alpine zones; southern arctic zone
The alpine zones occupy the area above the climatic woodland limit. The southern arctic zone (demarcated by a blue line), which is situated north of the arctic woodland limit, occurs in the far north of Finnmark, where it grades into the low alpine zone. The low alpine and southern arctic zones are characterised by bilberry heath, juniper - dwarf birch scrub and willow communities. The vegetation in the middle alpine zone is dominated by grass heaths and snow patches. The high alpine zone lacks a continuous cover of vascular plants, bryophyte carpets dominating in the depressions, and umbilicate and crustose lichens in localities exposed to the weather.

Northern boreal zone (northern coniferous and birch woodland zone)
This zone is dominated by birch woodland (often called sub-alpine birchwood) and some coniferous woodland with sparse, low trees. Minerotrophic mires cover large areas. The upper boundary is placed at the climatic woodland limit. The zone has traditionally been an important area for summer dairy farming.

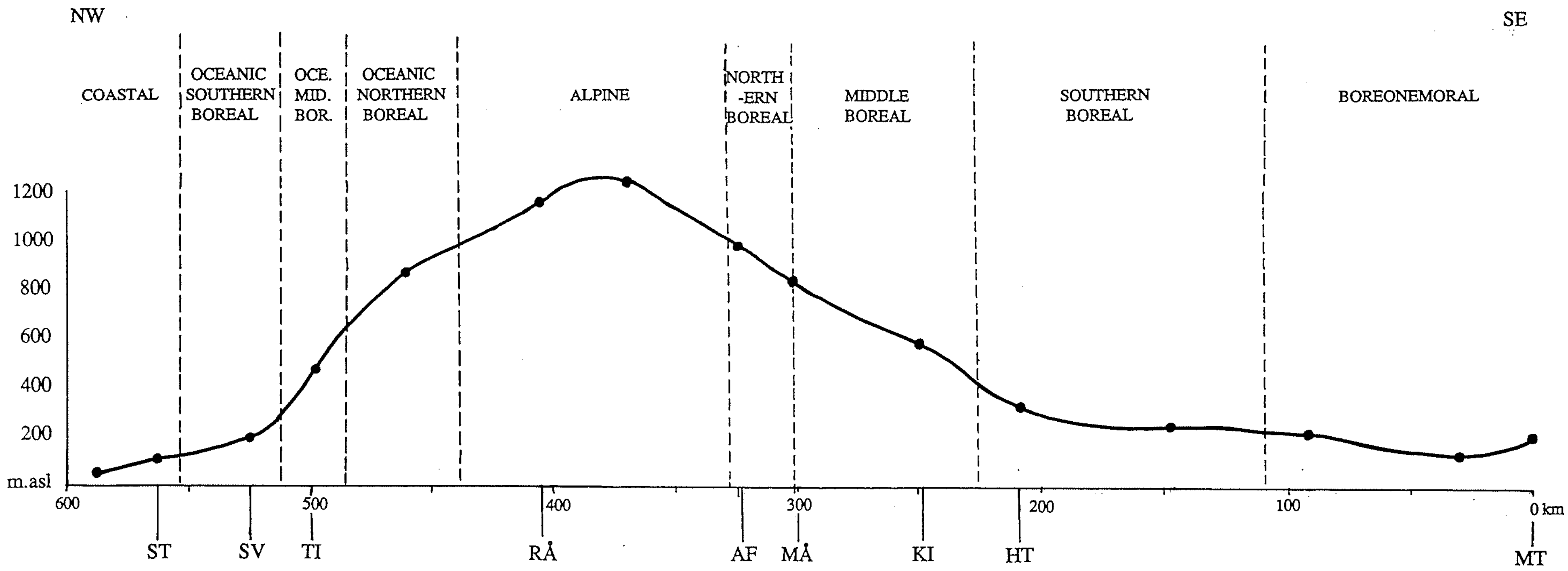
Middle boreal zone (middle coniferous woodland zone)
Coniferous woodland and forest dominate and typical low-herb spruce woodland has its altitudinal boundary in this zone. The same applies to well developed grey alder - bird cherry woodland and a number of thermophilous communities and species. Mires cover large areas, and typical sloping fens occur from this zone up to the low alpine zone.

Southern boreal zone (southern coniferous woodland zone)
Coniferous woodland and forest dominate, but there are also large areas of alder woodland and raised bogs, as well as some broad-leaved deciduous woodland and dry grassland vegetation. The zone is typified by a large number of species which require high summer temperatures.

Boreonemoral zone (coniferous and broad-leaved deciduous woodland zone)
This zone forms a transition between the nemoral zone and typical coniferous woodland and forest areas. Broad-leaved (thermophilous) woodlands with oak, ash, elm, lime, hazel and other species requiring warmth dominate on sun-facing slopes with good soils. Birch, grey alder or coniferous woodlands dominate the rest of the wooded landscape.

Nemoral zone (temperate deciduous woodland zone)
This zone is characterised by broad-leaved deciduous woodlands and large numbers of frost-sensitive and thermophilous species. The narrow strip in southernmost Norway is the northerly outlier of a zone that covers Denmark and large parts of central Europe.

OSLO-TO-TRONDHEIM TRANSECT



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

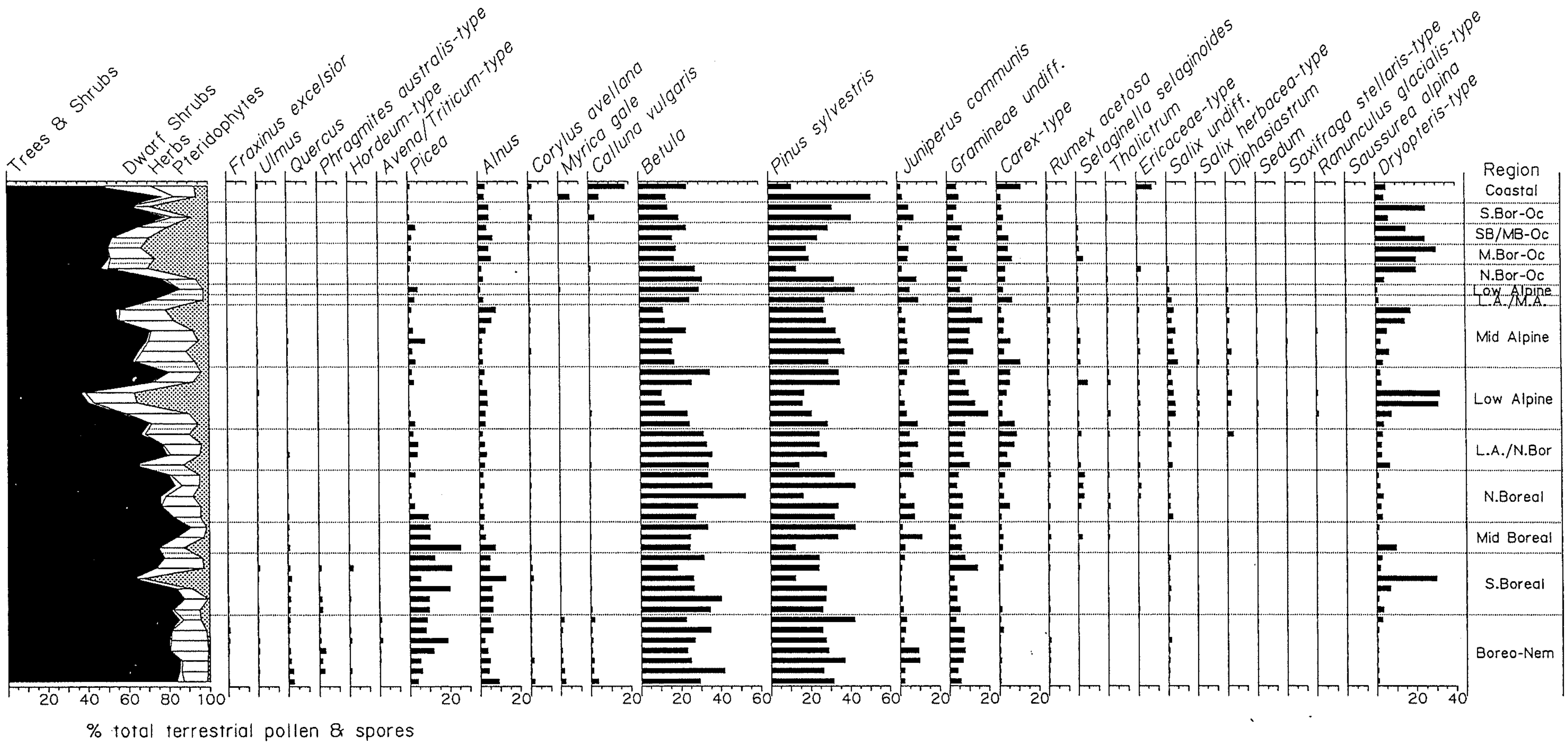
	Altitude	Sediment thickness	Site abbreviation on Transect diagram	Mean July temp. °C	Mean Jan temp. °C	Annual pptn. (mm)
Boreo-nemoral region						
Morttjenn	227 m	520 cm	MT	15.2	- 4.7	880
Southern-boreal region						
Haugtjern	338 m	242 cm	HT	14.4	- 9.1	570
Middle-boreal region						
Kinnshaugen	591 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).

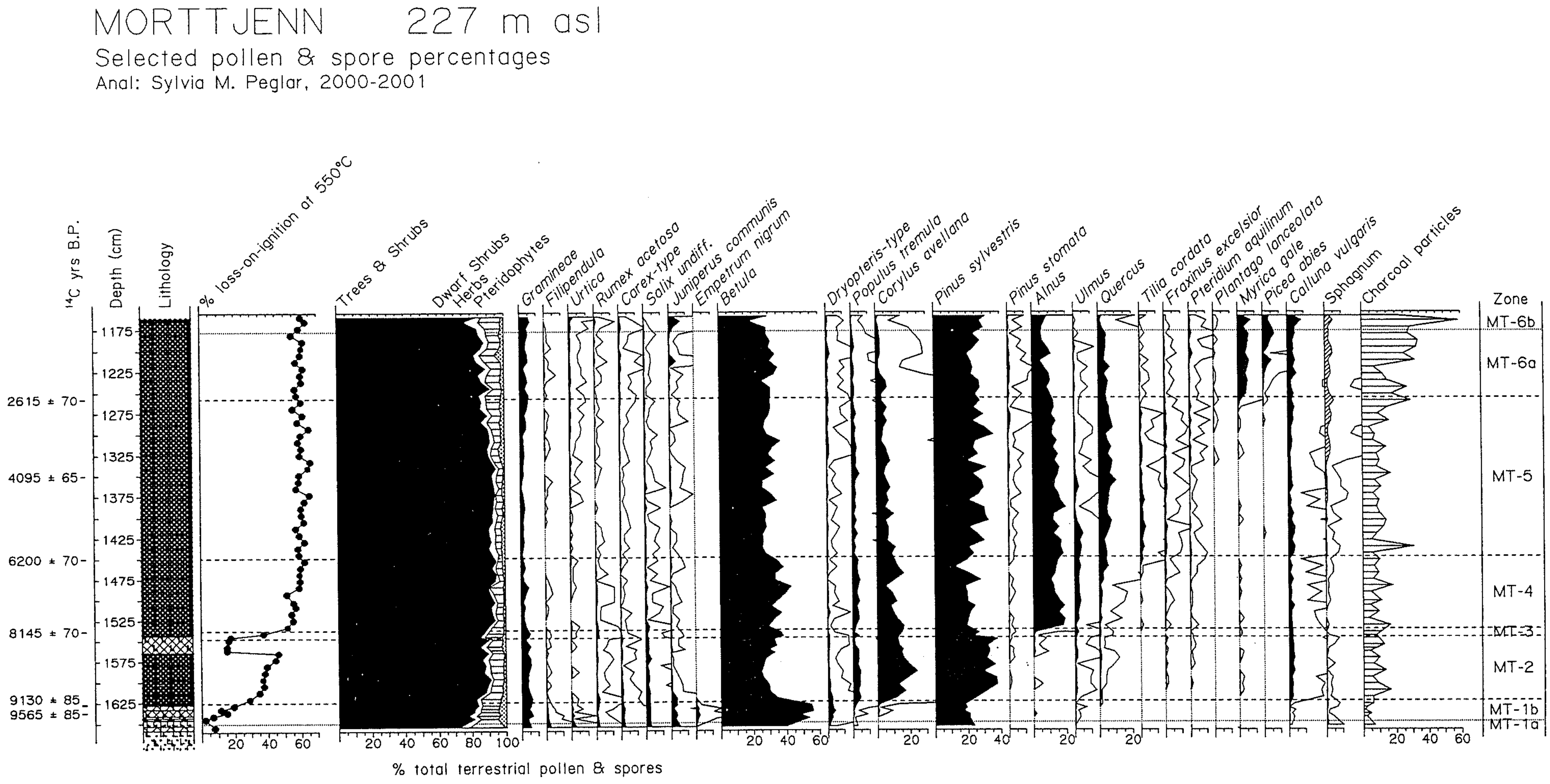
OSLO-TO-TRONDHEIM TRANSECT SURFACE SAMPLES

Selected pollen & spore percentages

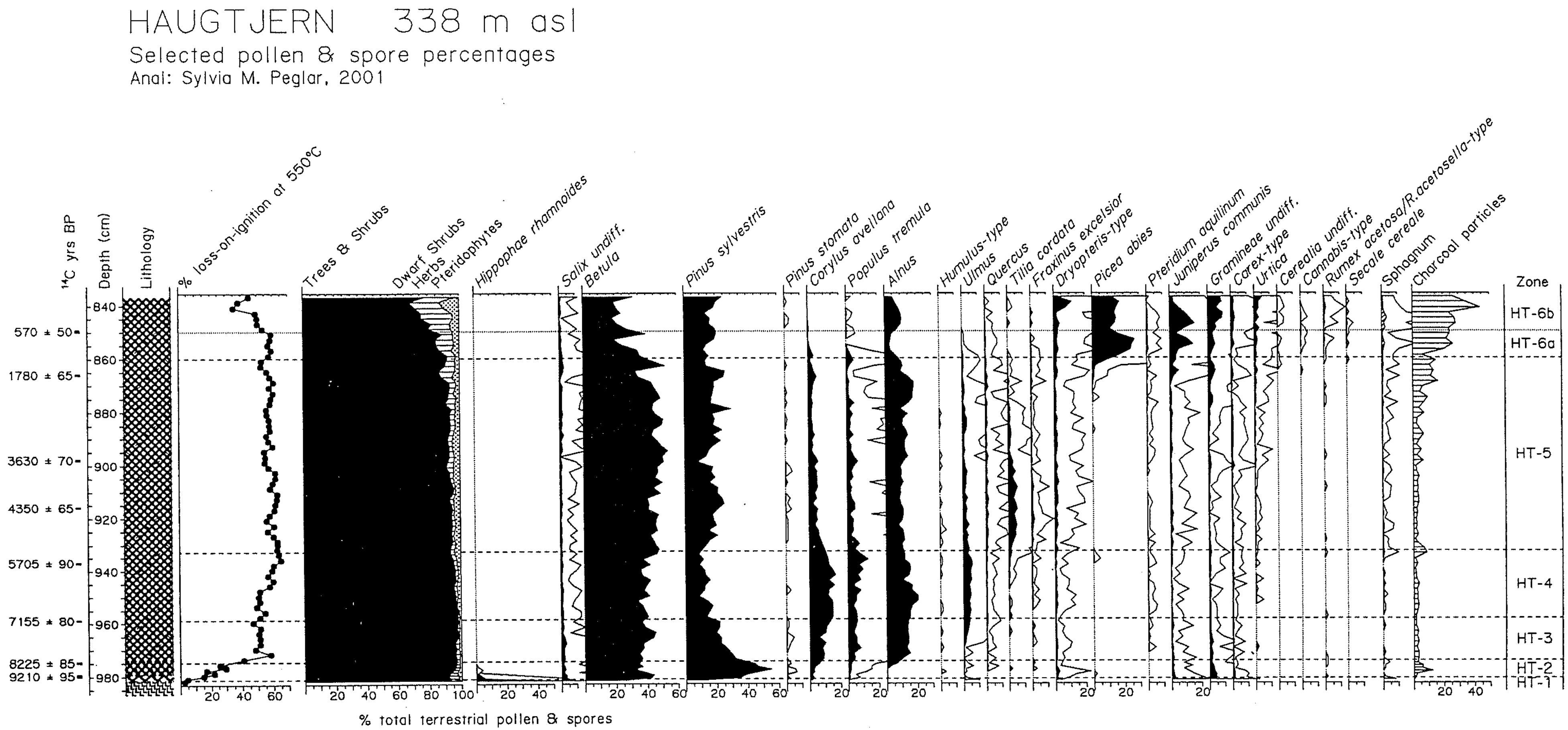
Anal: Sylvia M. Peglar, 2000-2002



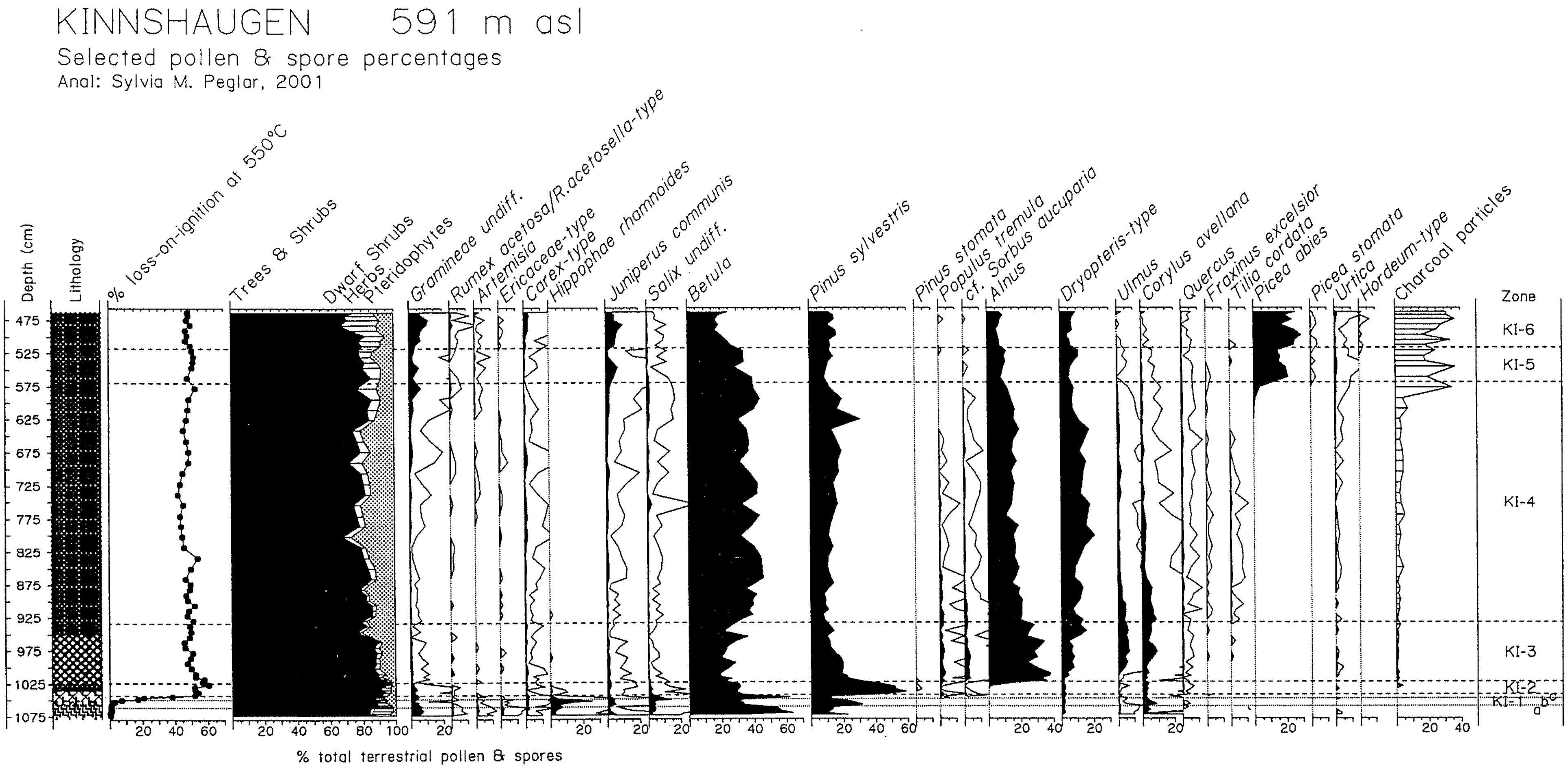
Summary pollen diagram for modern surface-samples (0-1 cm) from 49 lakes along the Oslo-to-Trondheim transect arranged on south-east to north-west transect in relation to the modern vegetation region. Within each vegetation region, the sites are arranged latitudinally from south (bottom) to north (top).



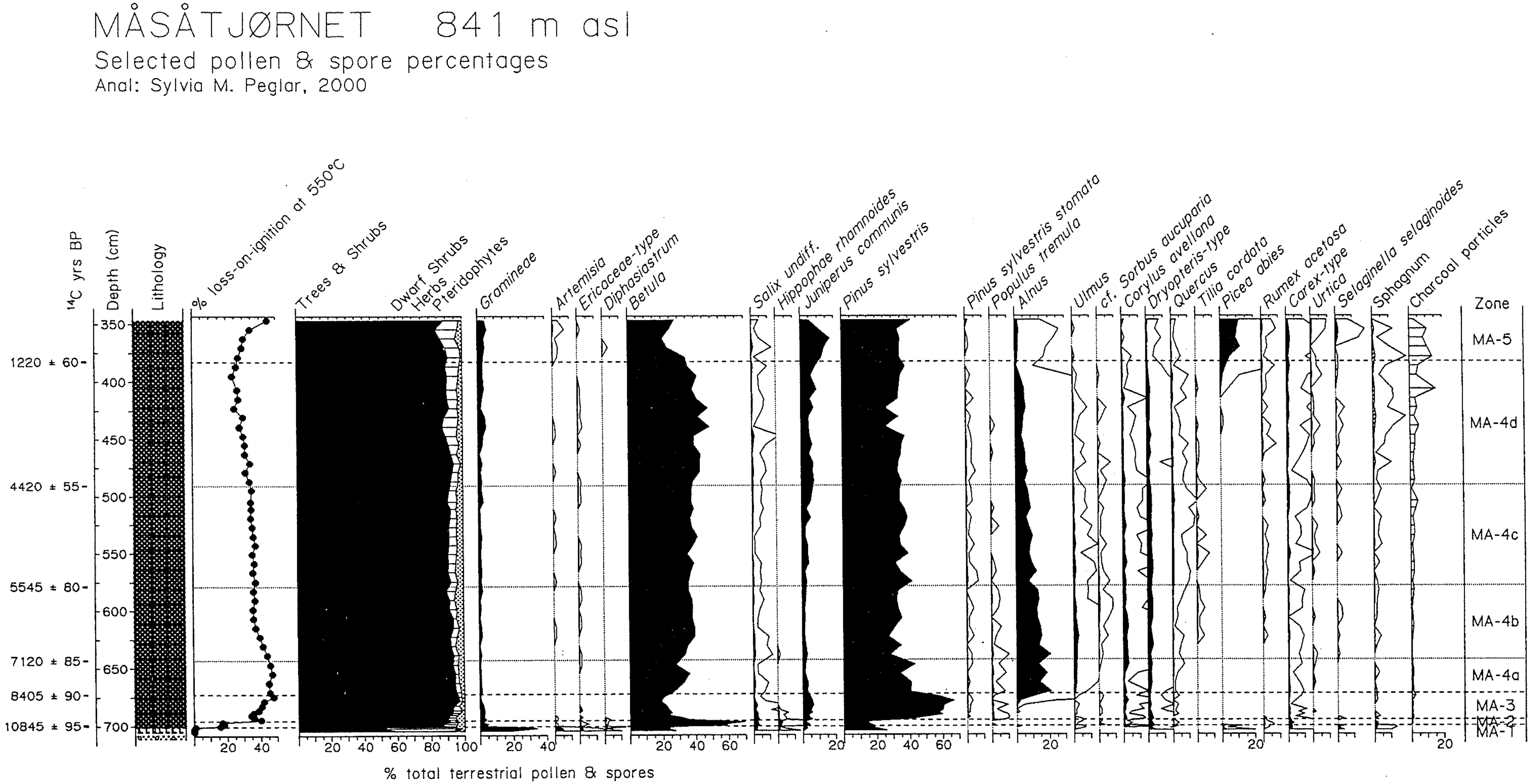
Summary pollen diagram from Morttjenn, in the boreo-nemoral region today.



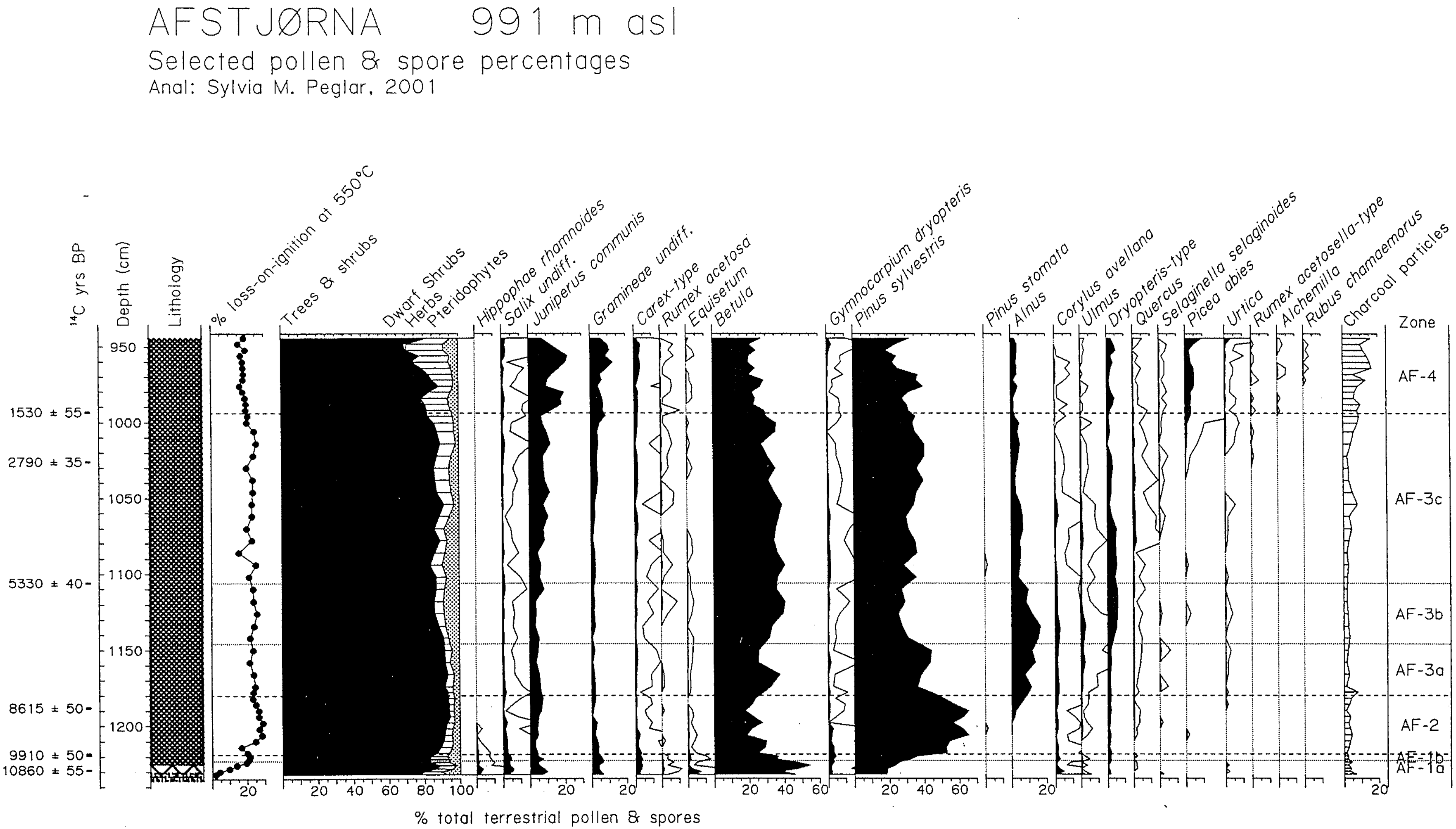
Summary pollen diagram from Haugtjern, in the southern-boreal region today.



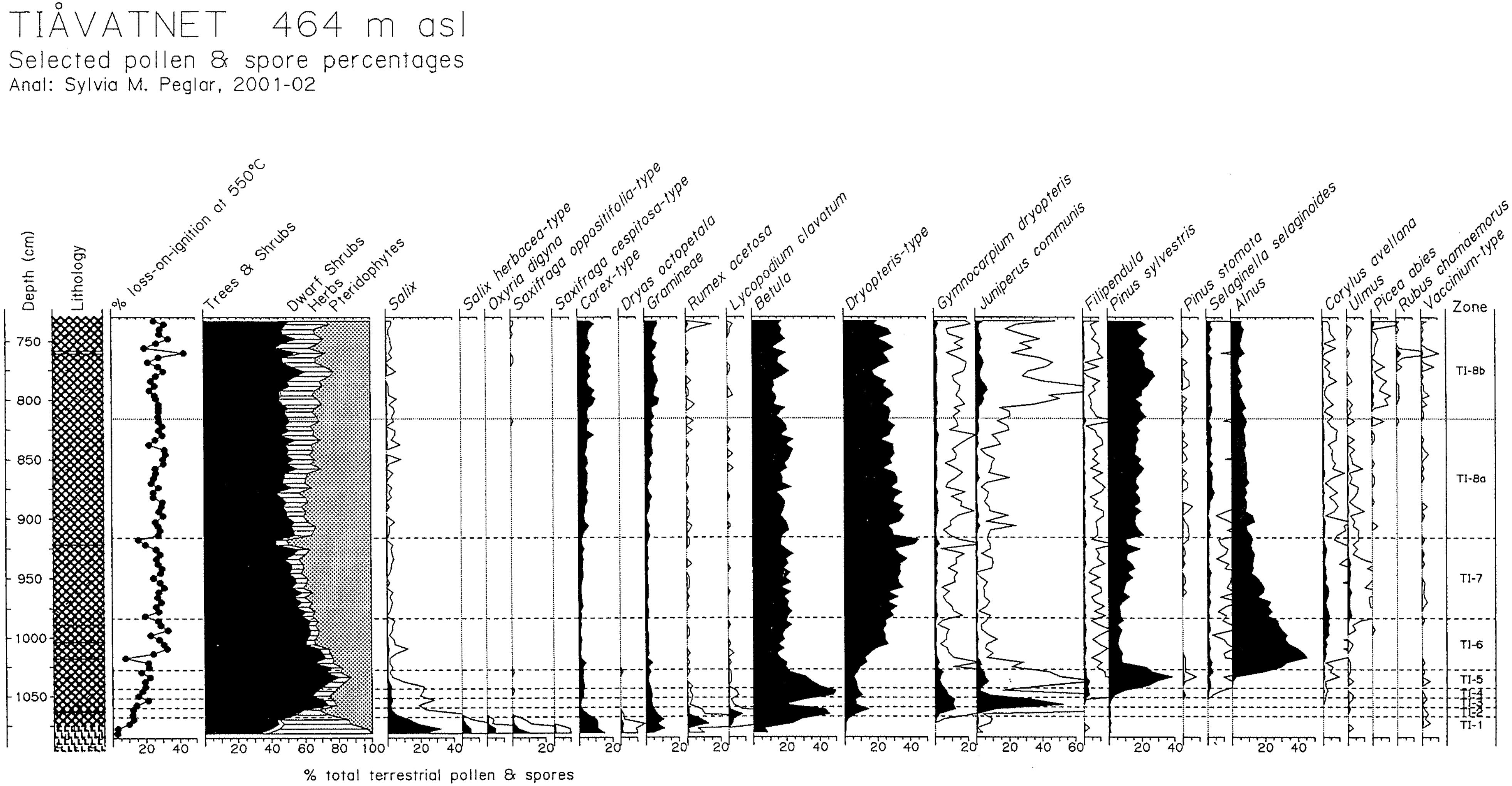
Summary pollen diagram from Kinnshaugen, in the middle-boreal region today.



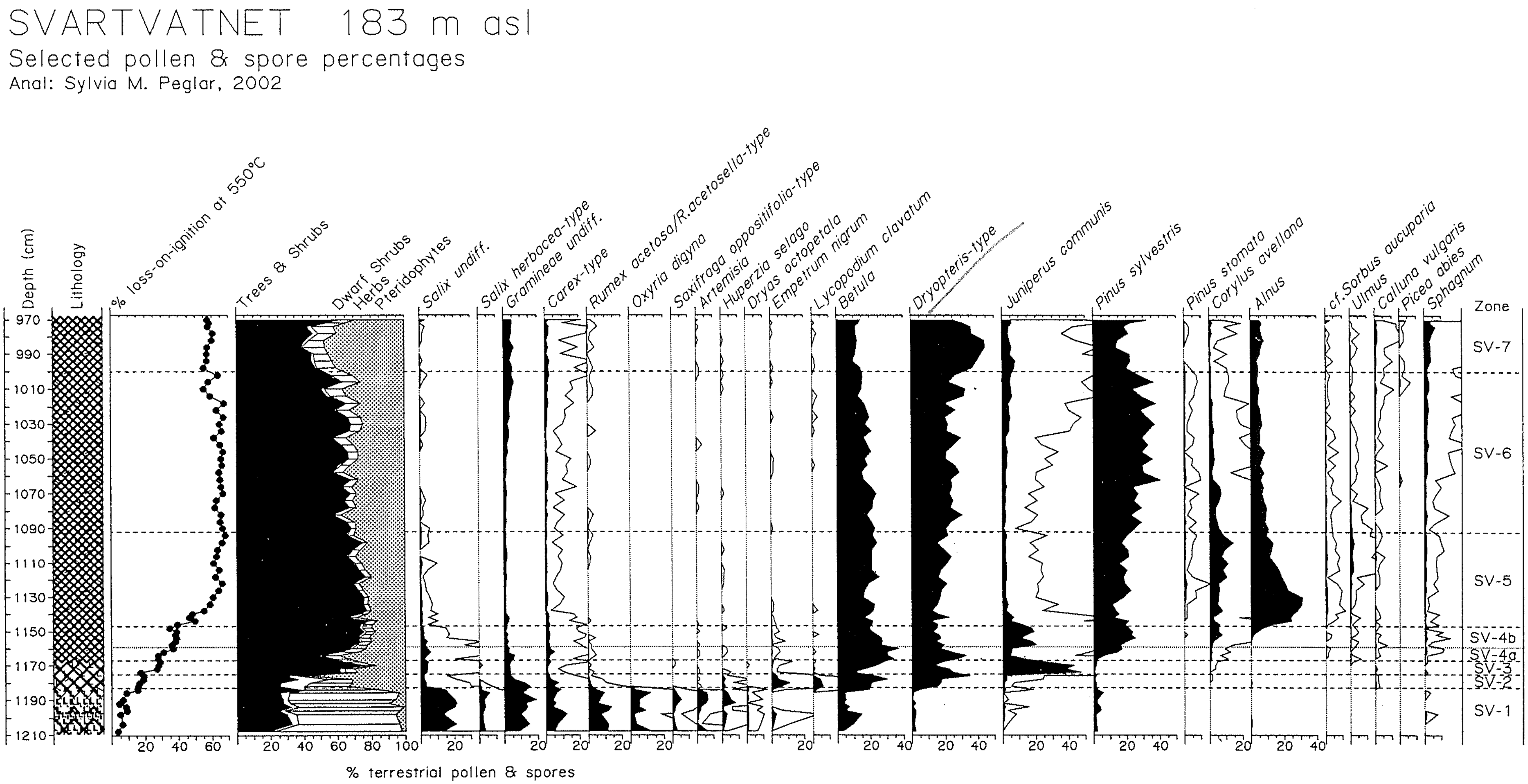
Summary pollen diagram from Måsåtjørnet, in the upper middle-boreal region today.



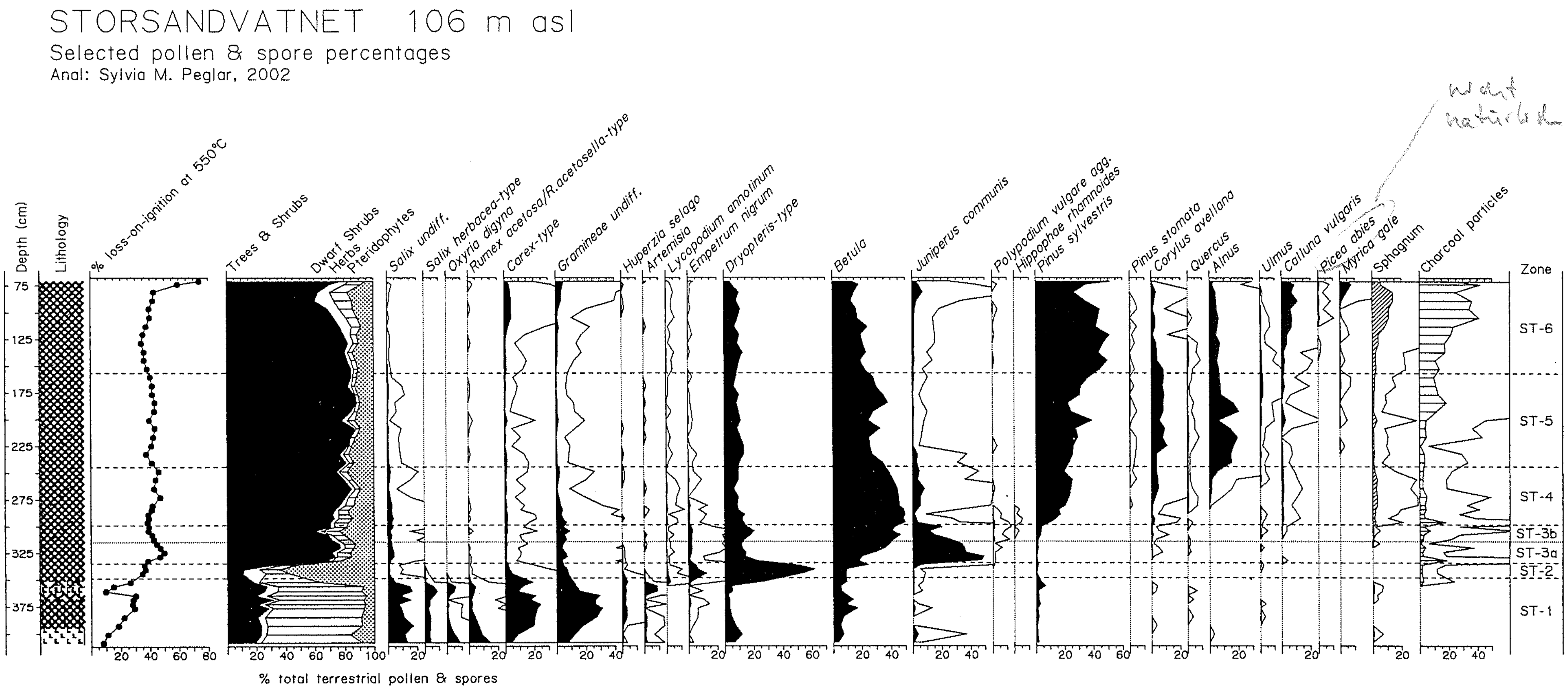
Summary pollen diagram from Afstjørna, in the northern-boreal region today.



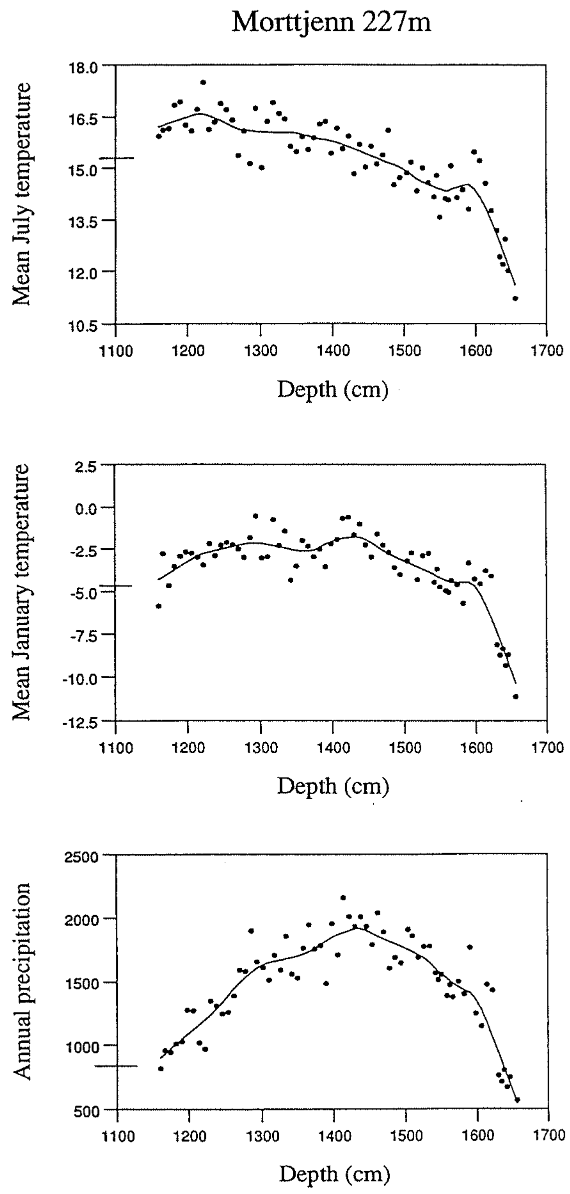
Summary pollen diagram from Tiåvatnet, in the middle-boreal (oceanic) region today.



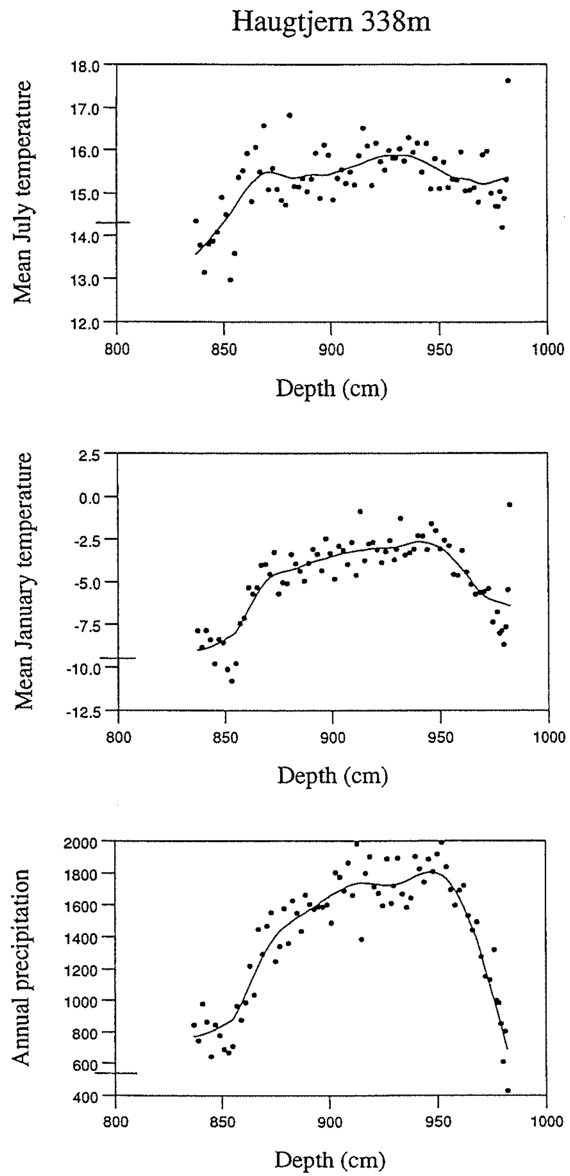
Summary pollen diagram from Svartvatnet, in the southern-boreal (oceanic) region today.



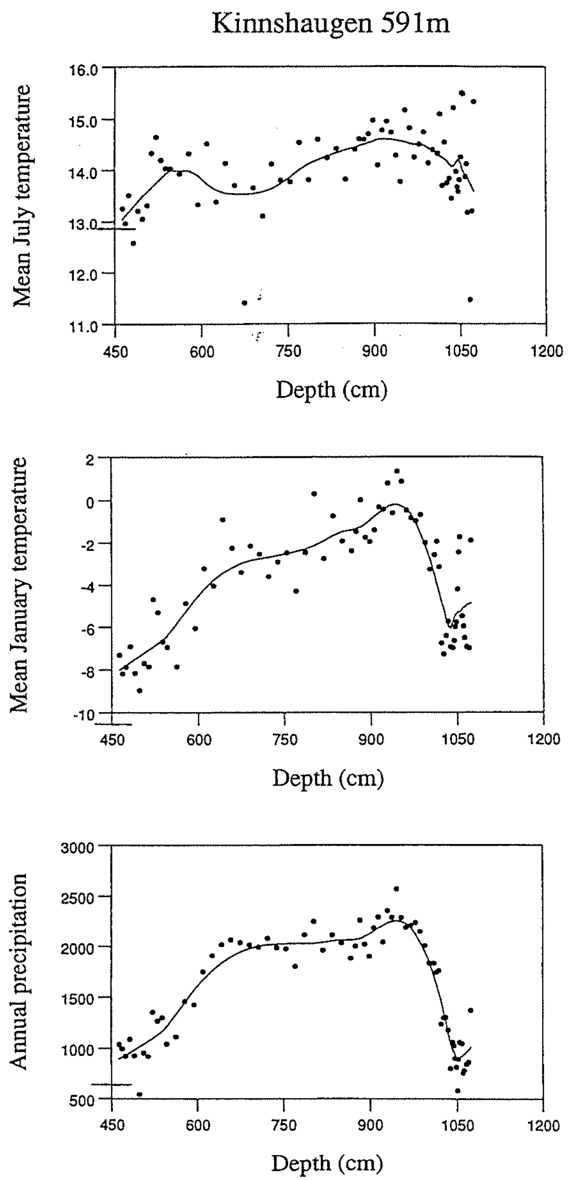
Summary pollen diagram from Storsandvatnet, Hitra, in the coastal region today.



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.

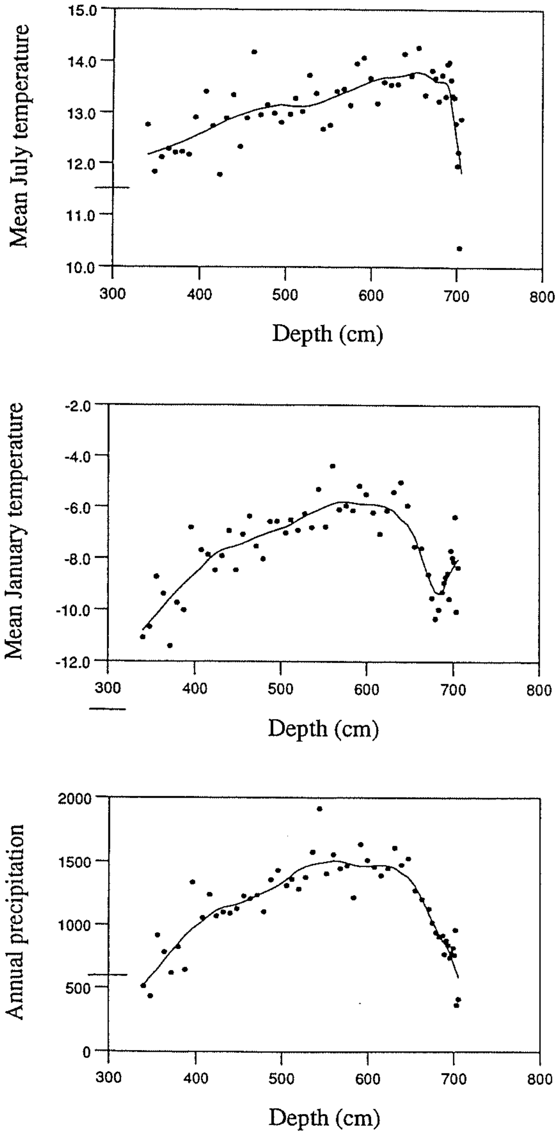


Preliminary reconstructions of mean July and January temperatures (°C) and annual precipitation at Haugtjern, in the southern-boreal region today, with a LOESS smoother (span = 0.25) fitted.



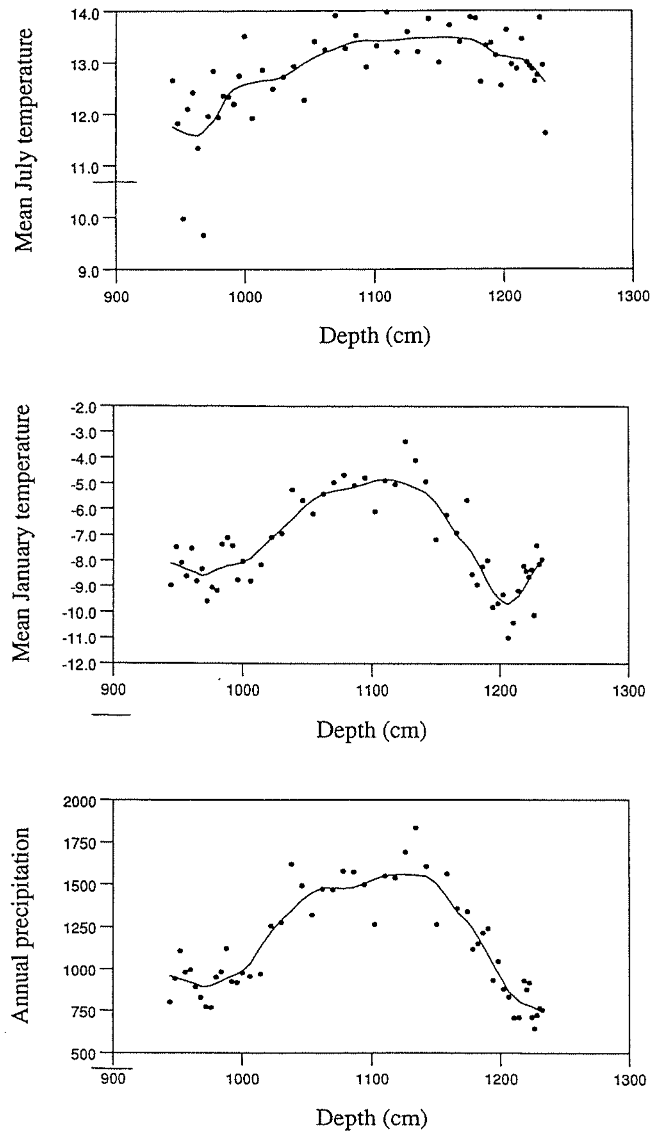
Preliminary reconstructions of mean July and January temperatures (°C) and annual precipitation at Kinnshaugen, in the middle-boreal region today, with a LOESS smoother (span = 0.25) fitted.

Masatjornet 841m



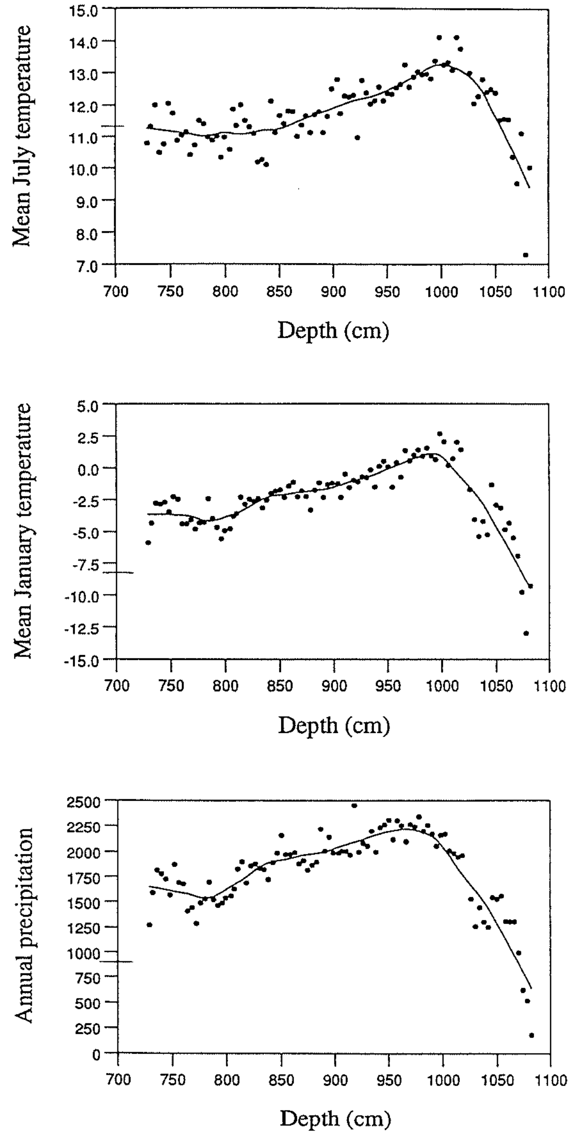
Preliminary reconstructions of mean July and January temperatures (°C) and annual precipitation at Måsåtjørnet, in the upper middle-boreal region today, with a LOESS smoother (span = 0.25) fitted.

Afstjorna 991m



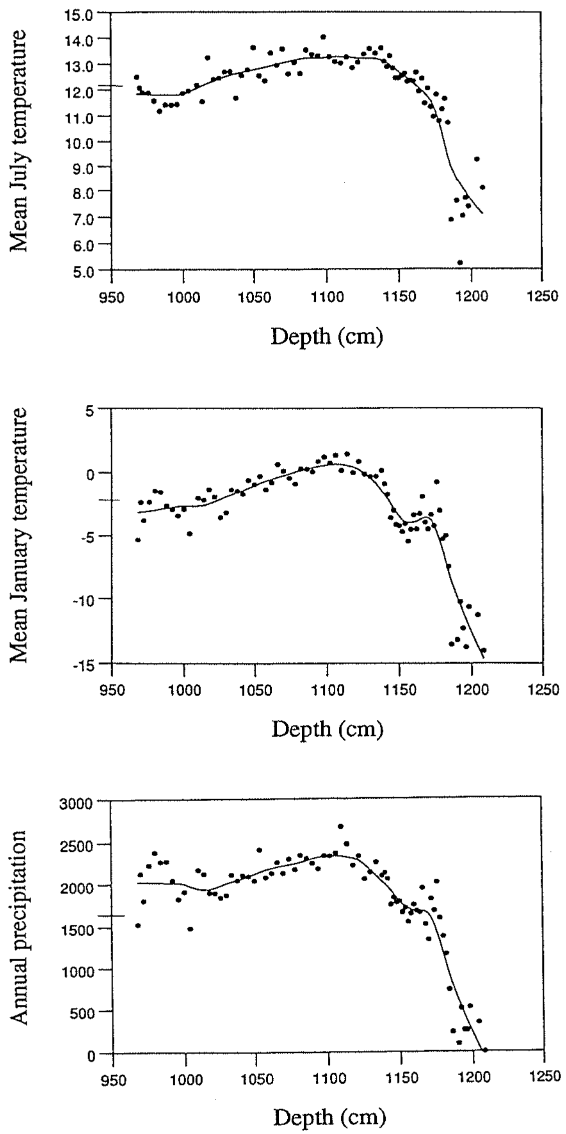
Preliminary reconstructions of mean July and January temperatures (°C) and annual precipitation at Afstjørna, in the northern-boreal region today, with a LOESS smoother (span = 0.25) fitted.

Tiavatnet 464m



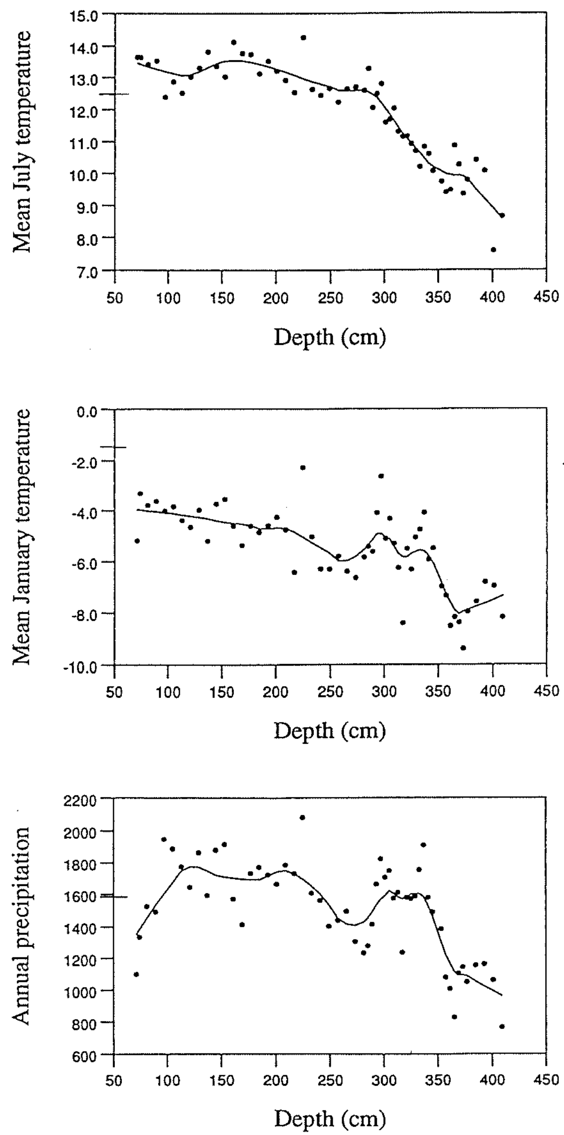
Preliminary reconstructions of mean July and January temperatures (°C) and annual precipitation at Tiavatnet in the middle-boreal (oceanic) region today, with a LOESS smoother (span = 0.25) fitted.

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

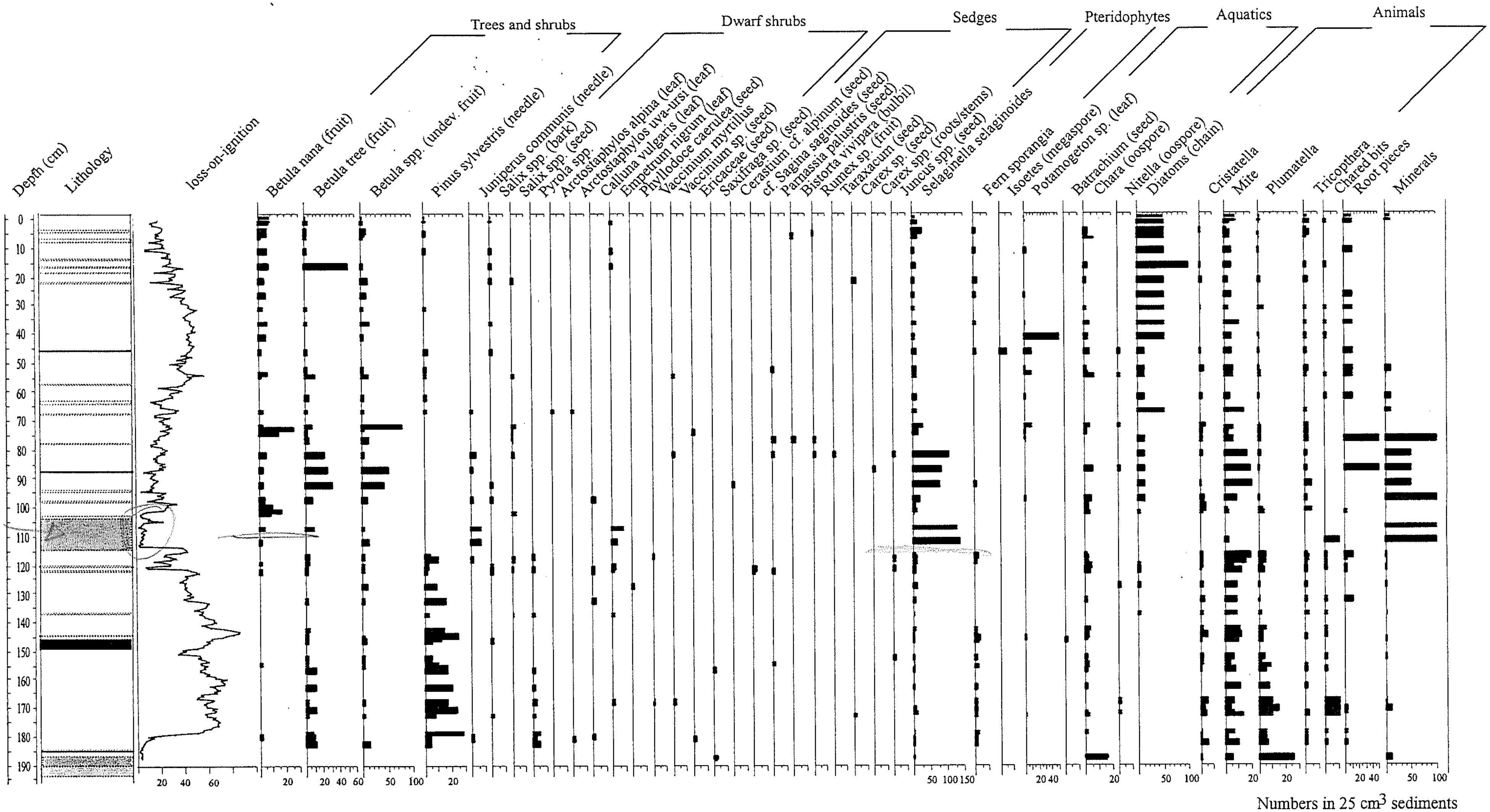


Preliminary reconstructions of mean July and January temperatures (°C) and annual precipitation at Storsandvatnet, in the coastal region today, with a LOESS smoother (span = 0.25) fitted.

GÅVÅLIVATNET - 939 m asl
Selected macrofossils
Analysed by W. Eide

innerhalb Wg

18m Wassertiefe

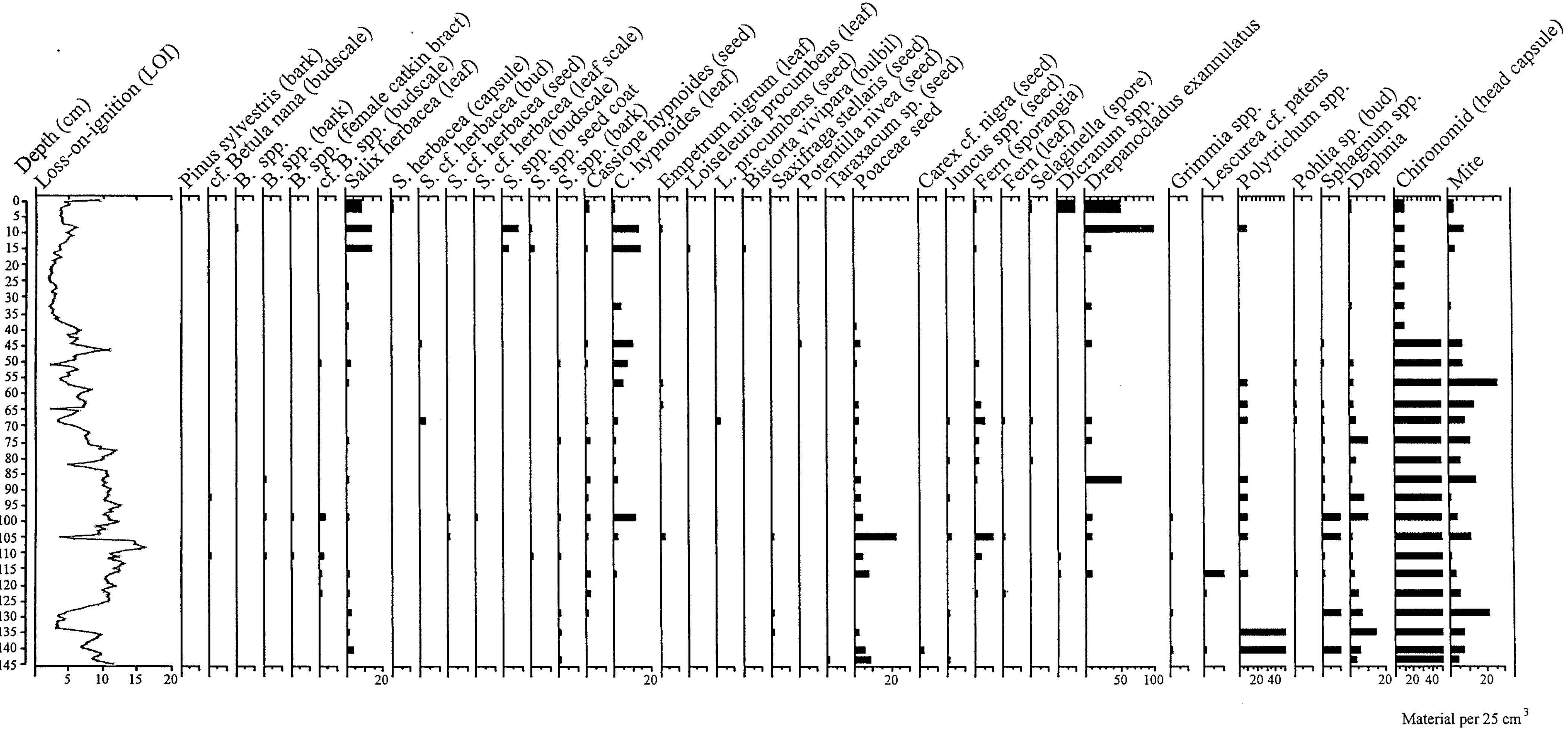


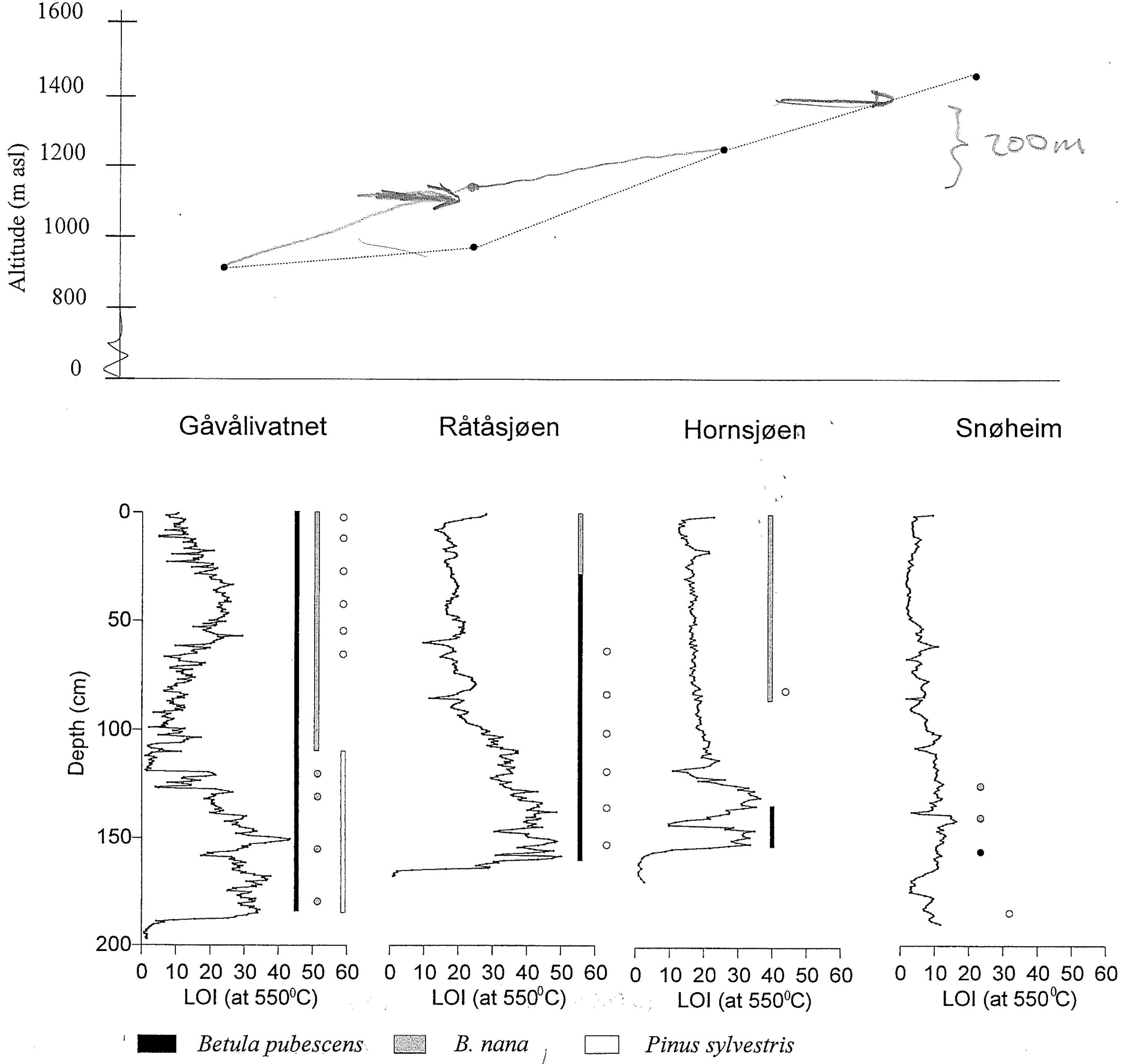
Clay and silt
Silt and clay
Black layer
Brown layer

SNØHEIM-3 1474 m asl

Macrofossils

Analysed by W. Eide



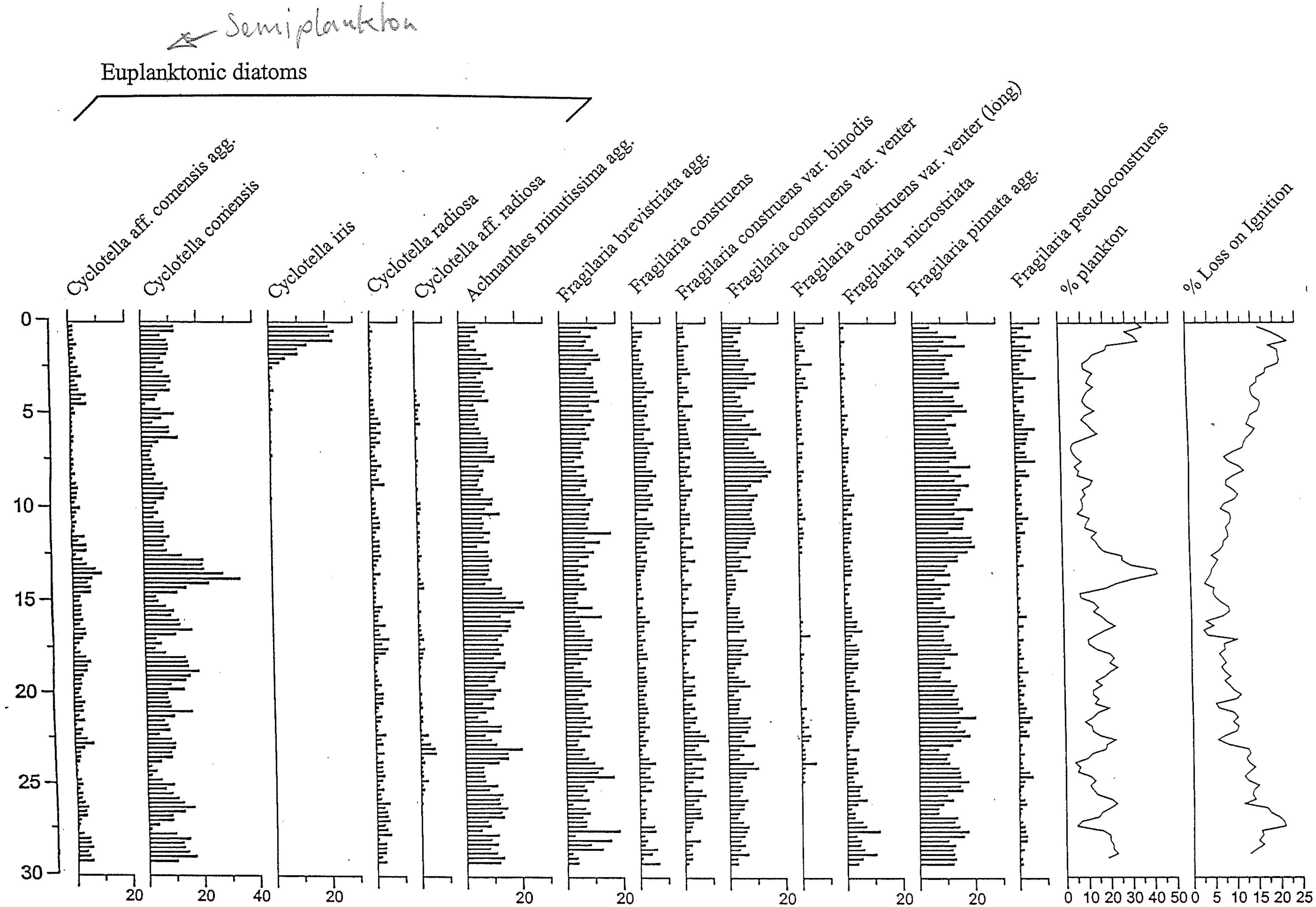


Preliminary results of tree-line fluctuations at Dovre, during the Holocene.

Note that the Y-axis is based on sediment depth.

Circles indicate very small fragments, reflecting long-distance transport or/and only solitary trees growing around the lake.

Summary diatom diagram for Gåvålivatnet, with % diatom plankton and LOI curves



Til John Birks
med hilsen og takk for hjelp.
fra
[illegible]

Ecological Bulletins 38: 77–94. Copenhagen 1987

The nunatak theory reconsidered

Eilif Dahl

Dahl, E. 1987. The nunatak theory reconsidered. – Ecol. Bull. (Copenhagen) 38: 77–94.

The nunatak theory proposes that unglaciated areas existed along the shores of the North Atlantic ocean where plants and animals survived the last or previous glacial ages. This theory is examined in light of recent research.
Reconstructions of summer temperature conditions 18,000 years ago suggest that the lowland flora of Scandinavia could not survive in icefree refuges but immigrated from the south or east when the ice melted. However, numerous species of the alpine flora could not survive in the lowlands south and east of the north European ice sheet 18,000 years ago and must have survived in ice-free refugia. This is confirmed by an analysis of the phytogeographic affinities of the lowland and the alpine floras.
A relatively high amount of endemism, presence of numerous amphiatlantic species lacking in the Alps and similarity between the alpine-subalpine floras of Iceland, the British Isles and Scandinavia indicate that these floras survived in refuges since early Pleistocene times. Recent geological evidence suggest that a land area once connected Scandinavia, Scotland and Iceland up to Late Pliocene – Early Pleistocene. With present topography several areas around the North Atlantic could not be covered by an inland ice because of the plasticity of ice.
New dating methods (amino acid analysis, thermoluminescence) show that some areas in Spitsbergen have remained ice-free during most of the Pleistocene.
Presence of gibbsite and other clay minerals suggest that the mountain top detritus is a remnant of the Tertiary weathering crust which has survived the Pleistocene glacial ages.

Journal of Biogeography (1987) **14**, 377–388

Tabula rasa after all?
Botanical evidence for ice-free refugia in Scandinavia reviewed

I. NORDAL University of Oslo, Botanical Garden and Museum, Trondheimsvn. 23b, N-0562 Oslo 5, Norway

ABSTRACT. The three botanical main components of the earlier arguments for ice-free refugia in Scandinavia – the endemic alpine element, the 'West Arctic element', and the special disjunctions – are reconsidered. New knowledge about evolutionary rates and geological conditions are brought in. The method proposed by Haldane, introducing the unit *darwin*, is applied to the *Papaver radicatum* complex. The conclusion is that the rates of evolution may have been underestimated in earlier literature on the subject. Isolation of small populations during a period of 10–15,000 years might be sufficient to explain the endemisms. Postglacial immigration by long-distance dispersal is regarded as the most probable explanation for the West Arctic element, with drifting ice, icebergs or migratory birds as probable dispersal vectors. The alternative hypothesis of preglacial immigration via a North Atlantic landbridge with subsequent survival in ice-free refugia, carries with it an unlikely evolutionary rigidity in Scandinavian alpine plants, and is therefore regarded as not very probable.

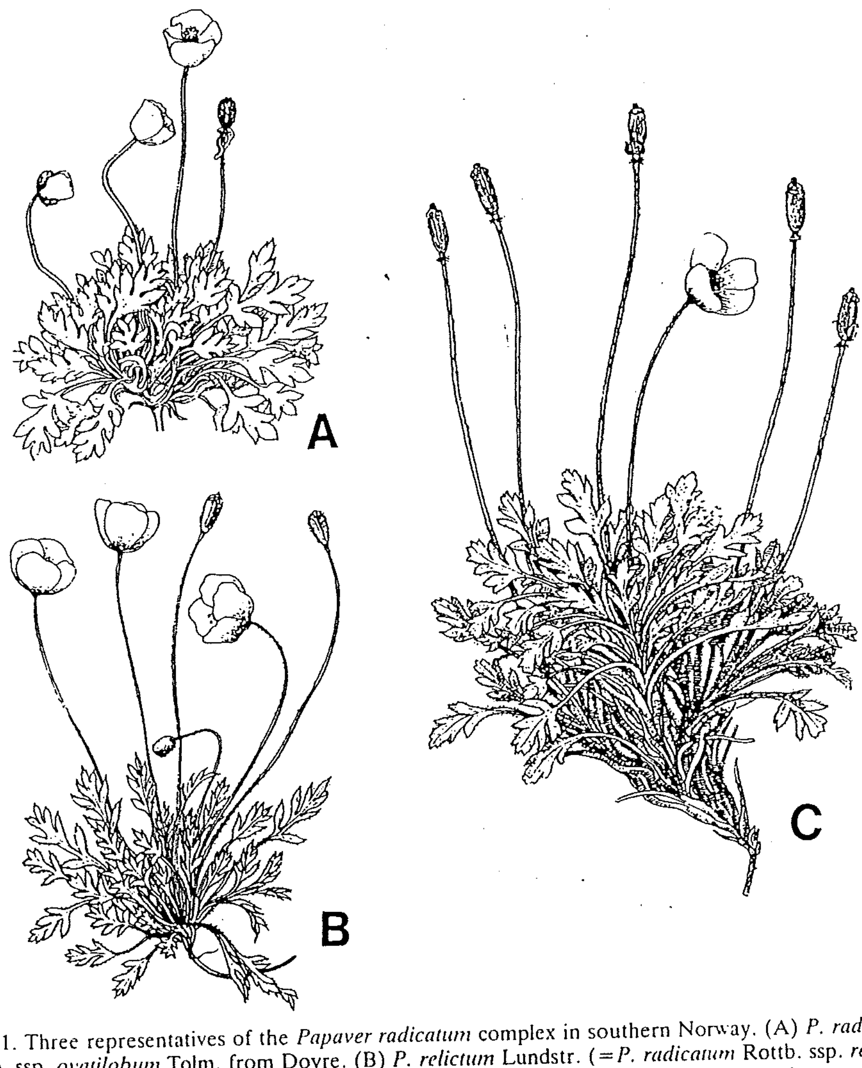
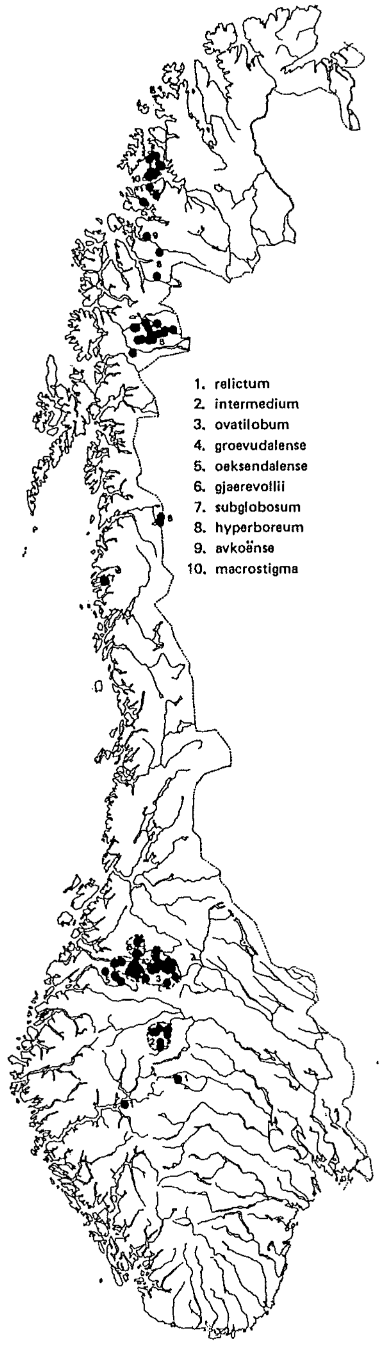
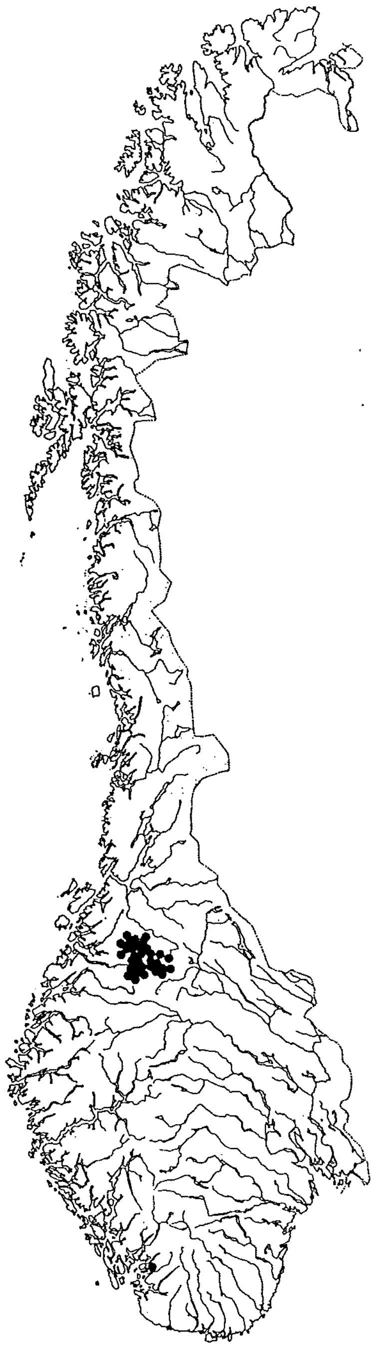


FIG. 1. Three representatives of the *Papaver radicatum* complex in southern Norway. (A) *P. radicatum* Rottb. ssp. *ovatilobum* Tolm. from Dovre. (B) *P. relictum* Lundstr. (=*P. radicatum* Rottb. ssp. *relictum* (Lundstr.) Tolm.) from Sogn–Valdres. (C) *P. angusticarpum* Nordh. (=*P. radicatum* Rottb. ssp. *oeksendalense* G. Knaben) from Øksendal. (After Miranda Bødtker, in Nordhagen, 1970.)

Papaver radicatum Rottb.



Artemisia norvegica Fr.



Phytocoenologia	23	399 - 426	Berlin-Stuttgart, December 15, 1993

Is the hypothesis of survival on glacial nunataks necessary to explain the present-day distributions of Norwegian mountain plants?

by H.J.B. BIRKS, Bergen and London

with 2 figures, 10 tables, and 1 appendix

Abstract. The occurrence and relative frequency of 109 species of mountain plant in Norway in 75 grid squares were related statistically to 11 explanatory variables representing modern geography, topography, bedrock geology, and climate and, as a historical variable, the relative abundance of unglaciated areas. The numerical analyses involved (partial) constrained ordinations and associated Monte Carlo permutation tests. They were designed to answer the following questions: (1) Are any of the 11 explanatory variables statistically significant in explaining the distribution patterns of different species groups?, (2) How much of the variance in the species data is explained by geography and topography, climate, geology, and unglaciated areas?, (3) Do unglaciated areas make a unique statistically significant contribution to explaining the species group distributions?, and (4) Are unglaciated areas a statistically significant variable in explaining the observed distribution and relative frequency of any of the 109 individual species? The numerical results all suggest that there is no statistically significant contribution from unglaciated areas in explaining the present-day distribution patterns when the effects of modern topography, climate, and geology are considered first. There is thus no need to invoke the nunatak hypothesis of glacial survival to explain contemporary distributions of Norwegian mountain plants. The nunatak hypothesis appears, in light of these statistical results and recent palaeobotanical, biosystematical, and evolutionary studies, to be superfluous.

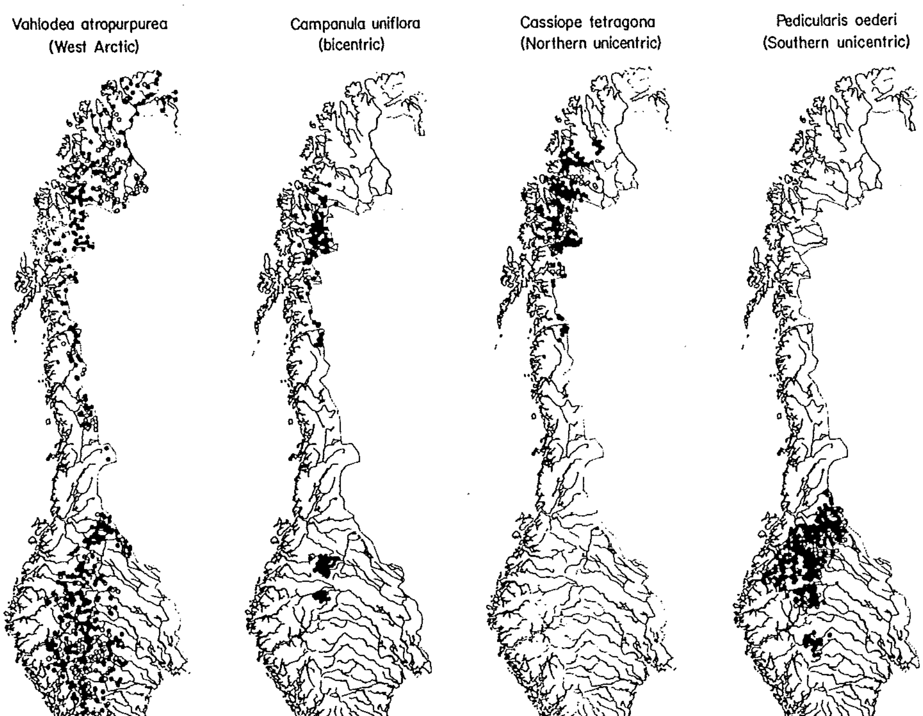


Fig. 1. Present-day distribution patterns in Norway of four species that are important in the nunatak hypothesis of glacial survival in Norway. The species distributions shown are of *Vahlodea atropurpurea*, a West Arctic species, of *Campanula uniflora*, a Bicentric species, of *Cassiope tetragona*, a Northern Unicentric species, and of *Pedicularis oederi*, a Southern Unicentric species. • = herbarium records, ○ = literature records, · = rejected records (modified from GJÆREVOLL 1990).

FÆGRI (1963) emphasised that 'the two main problems of centricity and West-Arctic distribution exist, and they demand an explanation'. He added, however, 'it must be admitted that biologists should take up the problems for some fresh thinking. Is centricity anything more than one might expect from actual ecologic conditions? Nobody has tried to give an objective answer to this, but it is a fact that very few, if any, other areas in Scandinavia offer the same combination of favorable bed-rock, climate, and topography. If this is enough to explain the distribution without recourse to other factors, centricity loses much of its argumentative value'.

Table 1. The eight species groups used in the statistical analysis, the number of species in each group, the gradient lengths in standard deviation (SD) units (HILL & GAUCH 1980), and the basis for the species classification. The composition of each group is listed in the Appendix.

Group	Number of species	Gradient length (SD units)	Basis for classification
Alpine	109	2.97	All species mapped by GJÆREVOLL (1990)
Refugial	72	3.40	All centric, West Arctic, and other species proposed as 'glacial survivors'
West Arctic	28	2.91	All West Arctic species sensu NORDAL (1987)
Centric	61	2.57	All bicentric and unicentric species sensu GJÆREVOLL (1990)
Bicentric	42	2.84	All bicentric species including "weakly bicentric species" sensu GJÆREVOLL (1990)
Southern Unicentric	3	0.93	All southern unicentric species sensu GJÆREVOLL (1990)
Northern Unicentric	16	4.26	All northern unicentric species sensu GJÆREVOLL (1990)
Unicentric	19	4.48	All southern and northern unicentric species sensu GJÆREVOLL (1990)

Table 2. Explanatory ('predictor') variables recorded for each grid square and used in the statistical analyses.

Geography and topography	Type of variable
Latitude	Continuous
Longitude	Continuous
Maximum elevation	5 500 m classes
Land area in grid square	Proportions
Geology	
Abundance of schist and/or limestone	4 abundance classes (0–3)
Climate	
Maximum summer temperature	Continuous 1 °C classes
Accumulated respiration	Continuous
Total annual precipitation	4 1000 mm classes
Mean January temperature	Continuous 1 °C classes
Mean July temperature	Continuous 1°C classes
History	
Unglaciated areas	3 abundance classes (0–2)

Question 1: Are any of the explanatory variables statistically significant predictors of the distributional patterns of the species groups?

Table 3. Results of forward selection of explanatory variables in constrained ordinations. CCA was used for all species groups except for the southern Unicentric group where RDA was used. The order of selection of each variable is given, along with the amount of variance (= inertia) explained by each variable. Only variables with $p \leqslant 0.05$ in Monte Carlo permutation tests were selected.

	Alpine		Refugial		West Arctic		Centric		Bicentric		S. Unicentric		N. Unicentric		Unicentric	
	Var.	Order	Var.	Order	Var.	Order	Var.	Order	Var.	Order	Var.	Order	Var.	Order	Var.	Order
Latitude	0.17	1	0.22	1	0.29	1	0.19	1	0.09	2	ns	-	ns	-	0.89	1
Longitude	0.06	3	0.11	2	0.19	2	0.11	2	0.09	1	ns	-	0.31	1	0.27	2
Elevation	0.08	2	0.04	4	0.02	7	0.06	3	0.05	3	ns	-	ns	-	0.07	5
Land area	0.02	6	0.05	5	0.04	5	0.03	5	0.02	6	ns	-	0.09	2	0.08	4
Schist/lst.	0.03	5	0.02	7	0.04	4	0.02	7	0.02	7	ns	-	0.06	3	ns	-
Max summer t.	0.02	7	ns	-	0.02	8	ns	-	ns	-	ns	-	ns	-	ns	-
Acc. respn.	ns	-	ns	-	ns	-	ns	-	ns	-	ns	-	ns	-	ns	-
Total pptn.	0.04	4	0.07	3	0.08	3	0.04	4	0.03	4	ns	-	ns	-	ns	-
Mean Jan.t.	0.02	10	ns	-	ms	-	ns	-	ns	-	ns	-	ns	-	0.09	3
Mean July t.	0.02	8	ns	-	ns	-	ns	-	ns	-	0.43	1	ns	-	ns	-
Unglac. areas	0.02	9	0.03	6	0.03	6	0.03	6	0.02	5	ns	-	ns	-	ns	-
Total spp. var.	1.07		1.32		1.38		1.30		1.02		1.00		1.15		2.57	
Total var. expl.	0.47		0.53		0.71		0.48		0.33		0.43		0.47		1.40	

Abbreviations: Var. = variance explained, lst. = limestone, Max. = maximum, t. = temperature, Acc. = Accumulated, respn. = respiration, pptn. = precipitation, Jan. = January, Unglac. = unglaciated, ns = not significant ($p > 0.05$), expl. = explained, spp. = species

Question 2: How much of the variance in the distributional patterns of the species groups is explained by geography and topography, geology, climate, and history?

Table 4. Cumulative percentages of variance (= inertia) in the species-group distributional data explained by groups of predictor variables in constrained ordinations in the 'Ecology First Analysis'. CCA was used for all species groups except for the Southern Unicentric group where RDA was used.

Species group	Geography and topography	+ Geology	+ Climate	+ History
Alpine	26.2	27.0	28.1	28.1
Refugial	27.2	27.6	28.2	28.2
West Arctic	37.8	38.4	39.3	39.4
Centric	25.0	25.3	25.8	25.8
Bicentric	19.5	19.7	21.3	22.0
Northern Unicentric	35.8	36.3	38.2	38.3
Southern Unicentric	54.3	58.8	74.5	75.2
Unicentric	45.6	45.9	49.0	49.2

Table 5. Cumulative percentages of variance (= inertia) in the species-group distributional data explained by groups of predictor variables in constrained ordinations in the 'History First Analysis'. CCA was used for all species groups except for the Southern Unicentric group where RDA was used.

Species group	History	+ Geology	+ Climate	+ Topography	+ Latitude and longitude
Alpine	4.6	10.6	25.2	26.1	28.1
Refugial	5.7	11.6	23.7	24.6	28.2
West Arctic	5.5	15.7	32.0	33.0	39.4
Centric	5.9	11.7	21.5	22.3	25.8
Bicentric	3.4	8.8	18.1	19.2	22.0
Northern Unicentric	4.3	19.3	33.1	35.3	38.3
Southern Unicentric	13.1	19.7	62.8	71.0	75.2
Unicentric	14.1	21.4	41.5	44.0	49.2

Table 6. Cumulative percentages of residual variance (= inertia) in the species-group distributional data explained by groups of predictor variables after the effects of latitude, longitude, and land area in the grid squares have been partialled out in partial constrained ordinations in the 'partial Ecology First Analysis'. CCA was used for all species groups except for the Southern Unicentric group where RDA was used.

Species group	Elevation	+ Geology	+ Climate	+ History
Alpine	6.6	10.5	13.7	14.2
Refugial	4.2	7.4	11.2	12.2
West Arctic	4.9	9.7	14.4	16.0
Centric	4.0	7.0	10.0	11.1
Bicentric	4.5	7.6	11.2	12.1
Northern Unicentric	7.3	13.4	17.0	17.6
Southern Unicentric	12.1	23.8	50.6	51.8
Unicentric	4.3	7.0	14.5	15.9

Table 7. Cumulative percentages of residual variance (= inertia) in the species-group distributional data explained by groups of predictor variables after the effects of latitude, longitude, and land area in the grid squares have been partialled out in partial constrained ordinations in the 'partial History First Analysis'. CCA was used for all species groups except for the Southern Unicentric group where RDA was used.

Species group	History	+ Geology	+ Climate	+ Elevation
Alpine	3.8	9.3	13.5	14.2
Refugial	3.7	7.8	11.9	12.2
West Arctic	5.1	10.8	15.3	16.0
Centric	3.5	7.2	10.7	11.1
Bicentric	3.4	7.3	11.3	12.1
Northern Unicentric	2.7	10.7	16.6	17.6
Southern Unicentric	7.4	15.3	43.1	51.8
Unicentric	4.5	7.6	14.9	15.9

Question 3: Does the history variable (unglaciated areas) make a statistically significant unique contribution to the explanation of the distributional patterns of the species groups?

Table 8. Variance partitioning into (1) total variance explained by all 11 explanatory variables and a cubic trend-surface of the latitude and longitude variables, (2) the variance explained by the history variable, and (3) the total unexplained variance in the species-group distributional data. The statistical significance (p) of the history variable was assessed by spatially restricted Monte Carlo permutation tests. Note that History is included in the Total explained component, thus the column sums exceed 100 %.

	Alpine	Refugial	West Arctic	Centric	Bi-centric	N. Uni-centric	S. Uni-centric	Uni-centric
Total explained variance (%)	54.1	52.8	62.1	50.6	46.1	70.6	96.5	61.3
Unexplained variance (%)	45.9	47.2	37.9	49.4	53.9	29.4	3.5	38.7
History (%)	4.7	5.7	5.5	5.9	3.5	4.3	13.1	14.0
Significance level (p)	0.01	0.01	0.01	0.01	0.01	0.43	0.10	0.01

Abbrevation: p = probability

Table 9. Variance partitioning into (1) the total variance explained by the climate, geology, geography and topography variables independent of the history variable, (2) the variance explained by the history variable independent of geography and topography, climate, and geology ('ecology') (3) the variance explained by the history variable that is itself influenced by climate, geology, geography and topography ('ecology'), and (4) the total unexplained variance in the species-group distributional data. A cubic trend-surface of the latitude and longitude variables was included in the geographical variables. The statistical significance (p) of the history-variable variance component independent of ecology was assessed by spatially restricted Monte Carlo permutation tests.

	Alpine	Refugial	West Arctic	Centric	Bi-centric	N. Uni-centric	S. Uni-centric	Uni-centric
'Ecology' independent of history (%)	50.0	47.2	56.5	44.7	42.6	66.3	83.4	53.4
Ecologically structured history (%)	3.8	4.4	4.3	4.6	2.1	1.4	8.8	11.6
History independent of 'ecology' (%)	0.9	1.3	1.2	1.3	1.4	3.0	4.3	2.4
Significance level (p)	0.07	0.12	0.06	0.12	0.17	0.70	0.07	0.08
Unexplained variance (%)	45.3	47.2	37.9	49.4	53.9	29.4	3.5	32.5

Abbrevation: p = probability

Table 10. Variance partitioning into (1) the variance explained by area, elevation, climate, and geology independent of the history variable, (2) the variance explained by the history variable independent of area, elevation, climate, and geology ('ecology'), (3) the variance explained by the history variable that is itself influenced by climate, geology, area and elevation, ('ecology'), and (4) the total unexplained variance in the species-group distributional data. The statistical significance (p) of the history-variable component independent of ecology was assessed by Monte Carlo permutation tests.

	Alpine	Refugial	West Arctic	Centric	Bi-centric	N. Uni-centric	S. Uni-centric	Uni-centric
'Ecology' independent of history (%)	35.7	32.9	40.6	30.0	28.5	33.8	64.1	40.0
Ecologically structured history (%)	3.1	4.2	3.8	4.8	2.0	1.9	12.1	12.5
History independent of 'ecology' (%)	1.6	1.5	1.7	1.6	1.5	1.6	1.0	1.5
Significance level (p)	0.10	0.09	0.06	0.12	0.26	0.66	0.85	0.38
Unexplained variance (%)	59.7	61.4	53.9	64.1	68.1	49.9	22.8	45.9

Abbrevation: p = probability

Question 4: Is the history variable (unglaciated areas) a statistically significant predictor variable in explaining the observed distribution and relative frequency of any of the 109 individual alpine species?

The distribution and relative frequency data of each of the 109 species mapped by GJÆREVOLL (1990) were subjected to multiple regression analysis with a forward-selection procedure and associated Monte Carlo permutation tests to find, from the 11 predictor variables (Table 2), any statistically significant ($p \leqslant 0.05$) explanatory variables. No regression model was possible for *Arenaria pseudofrigida, Braya purpurescens, Carex scirpoidea, Papaver læstadianum*, or *P. lapponicum* because these species are so rare in Norway today and only occur in 1 or 2 grid squares. Of the remaining 104 species, 56 produced statistically significant ($p \leqslant 0.05$) multiple regression models. Many (30) of these significant models only involved one explanatory variable (e.g. limestone/schist – *Carex microglochin* (27 % of its variance explained by the regression model), *Juncus castaneus* (17 %); maximum elevation – *Cardaminopsis petraea* (53 %), *Poa flexuosa* (28 %), *Potentilla nivea* (14 %), *Sagina caespitosa* (59 %), *Pedicularis hirsuta* (54 %), *Kobresia myosuroides* (18 %), *Draba cacuminum* (40 %), *Carex rufina* (23 %); maximum summer temperature – *Oxyria digyna* (12 %), *Silene acaulis* (17 %); mean July temperature – *Dryas octopetala* (23 %), *Epilobium davuricum* (18 %), *Lychnis alpina* (32 %), *Pedicularis oederi* (58 %) (cf. NORDHAGEN 1963), *Saxifraga cernua* (17 %); mean January temperature – *Campanula uniflora* (53 %), *Silene wahlbergella* (25 %)). Twenty-two of the significant models involve two predictor variables (e.g. limestone/schist and maximum summer temperature – *Astragalus frigidus* (38 %); limestone/schist and maximum elevation – *Carex atrofusca* (43 %), *Oxytropis lapponica* (36 %); limestone/schist and mean July temperature – *Carex rupestris* (37 %); limestone/schist and mean January temperature – *Cystopteris montana* (37 %), *Equisetum variegatum* (32 %), *Petasites frigidus* (23 %)). Only 4 species have significant regression models involving more than two predictor variables (*Draba crassifolia* (93 %) – maximum summer temperature, area, and limestone/schist; *Erigeron politus* (28 %) – mean January temperature, maximum summer temperature, and area; *Luzula wahlenbergii* (47 %) – latitude, mean July temperature, maximum summer temperature; *Saxifraga hieracifolia* (98 %) unglaciated areas, area, limestone/schist). The 48 species for whom a regression model could be fitted but that was not statistically significant ($p > 0.05$) are marked with an asterisk in the Appendix.

Of the 87 statistically significant predictor variables selected in the 56 different statistically significant regression models, the unglaciated areas variable was selected for 4 species (*Antennaria porsildii* (51 %), *Botrychium boreale* (31 %) in the order mean July temperature + unglaciated areas, *Equisetum scirpoides* (34 %) mean July temperature + unglaciated areas, *Saxifraga hieracifolia*). It was selected as the first significant predictor variable for 2 species only, *Antennaria porsildii* and *Saxifraga hieracifolia*. In deciding if unglaciated area is a statistically significant explanatory variable, it is strictly necessary to perform a global test of significance as several simultaneous tests (v) are involved here. The global test asks if the variance explained by the unglaciated areas variable is significant at the $\alpha^1 = \alpha/v$ level (where $\alpha = 0.05$) according to the Bonferroni method of correcting for multiple tests (COOPER 1968, LEGENDRE & FORTIN 1989). Unglaciated area is not globally significant (Bonferroni-corrected test) at an overall 5 % significance level.

The most frequently statistically significant explanatory variables are maximum elevation (17 models), mean July temperature (16), limestone/schist (13), and mean January temperature (11). DAHL'S (1951) maximum summer temperature was a statistically significant predictor for only 9 species (selected as the first predictor for *Athyrium distentifolium* (23 %) followed by maximum elevation, *Draba crassifolia* (+ area + limestone/schist), *Oxyria digyna*, *Roegneria borealis* (45 %) (+ maximum elevation), *Silene acaulis*). It is a second predictor for *Astragalus frigidus, Erigeron politus*, and *Sedum villosum* (41 %) after area, and a third predictor variable for *Luzula wahlenbergii*.

ECOGRAPHY 19: 332–340. Copenhagen 1996

Statistical approaches to interpreting diversity patterns in the Norwegian mountain flora

H. J. B. Birks

Birks, H. J. B. 1996. Statistical approaches to interpreting diversity patterns in the Norwegian mountain flora. – Ecography 19: 332–340.

The richness of Norwegian mountain plants in 75 grid squares is mapped from published distributional data for 109 species. Eleven explanatory variables representing bedrock geology, geography and topography, climate, and history (relative abundance of unglaciated areas) for each square are used in multiple regression analysis with associated Monte Carlo permutation tests to find statistically significant predictor variables for species richness. The variance in richness explained by the four major groups of explanatory variables is established by (partial) multiple regression analysis in which the groups of predictors are entered in different orders. The variance in species richness explained by the predictor variables is partitioned into four independent components. A predictive model for species richness using partial least squares regression and all explanatory variables has a coefficient of determination (R^2) of 0.79. The statistical results consistently show that species-richness patterns are well explained by modern-day factors such as climate, geology, elevation, and geography without recourse to historical variables. The nunatak hypothesis of plant survival on unglaciated areas within Norway does not explain the observed richness patterns when modern ecological factors are considered first. The nunatak hypothesis thus appears to be redundant, a view supported by recent palaeobotanical, biosystematical, and evolutionary studies.

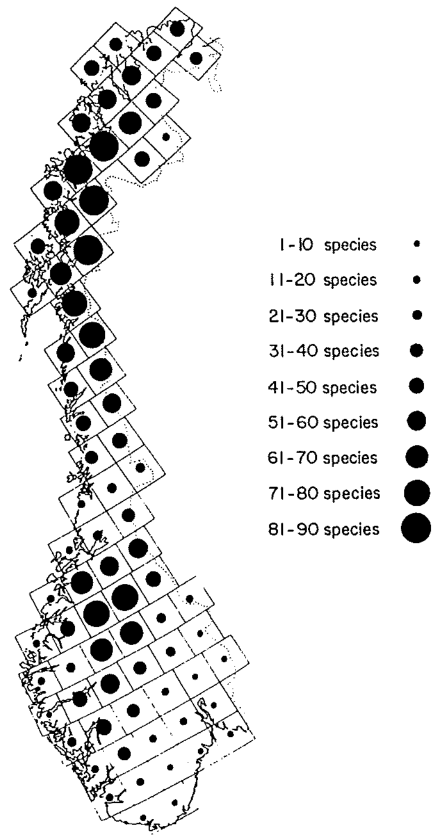


Fig. 1. The number of mountain plant species, as mapped by Gjærevoll (1990) in 75 grid squares in Norway.

Table 2. Results of forward selection in multiple regression analysis to find a minimal set of statistically significant explanatory predictor variables among the eleven variables (Table 1) for the observed patterns of species richness. Only significant variables are shown ($p \leq 0.05$ with Bonferroni corrections for multiple tests) in order of selection.

Explanatory variable	Percentage variance explained ($R^2 \times 100$)*	p	r	Regression coefficient†
Mean July temperature	61	0.001	−0.78	−0.26
Mean January temperature	4	0.007	−0.49	−0.36
Abundance of schist and/or limestone	5	0.002	0.52	+0.27
Maximum summer temperature	4	0.003	−0.65	−0.35
Total model	75	0.001	0.87	–

p = Exact Monte Carlo significance level (ter Braak 1990a)
r = Correlation coefficient
† = Regression coefficients of the regression of the response variable on standardised explanatory variables
* = Additional explained variance at each step in the regression

Table 4. Variance decomposition into 1) total variance explained by all explanatory variables including statistically significant terms of a cubic trend-surface of latitude and longitude 2) variance explained by history alone, and 3) the total unexplained variance in species richness. The statistical significance (p) of the explained components was assessed by Monte Carlo permutation tests (999 unrestricted permutations). Note that as History is included in the Total explained component of variance, the column sum exceeds 100%.

	%	p
Total explained variance	85	0.001
Unexplained variance	15	–
History	7.6	0.072

Table 5. Variance decomposition into 1) total variance explained by the climate, geology, geography, and topography variables after taking account of the history variable, 2) variance explained by the history variable after taking account of geography, topography, climate, and geology ("ecology"), 3) variance explained by the history variable that is itself influenced by and covaries with climate, geology, geography, and topography ("ecology"), and 4) total unexplained variance in species richness. Statistically significant terms of a cubic trend-surface of latitude and longitude were included in the geography variables. In a second analysis the effects of land area within each grid square were partialled out by entering area into the regression model first. The statistical significance (p) of component 2 (history after taking account of other explanatory variables) was assessed by Monte Carlo permutation tests (999 unrestricted permutations).

Component	Percentage variance	p	Effects of area allowed for statistically	p
"Ecology" after taking account of history	77.4	–	75.1	–
History after taking account of "ecology"	0.1	0.532	0.2	0.381
"Ecology" covarying with history	7.5	–	7.3	–
Unexplained	15.0	–	17.4	–

Festschrift Gerhard Lang
A.F. Lotter & B. Ammann (eds.), 1994
Dissertationes Botanicæ 234, 129-143

PLANT MACROFOSSILS AND THE NUNATAK THEORY OF PER-GLACIAL SURVIVAL

Hilary H. BIRKS[1]

Abstract

The so-called nunatak theory of ice-age survival proposes the per-glacial survival of certain Norwegian mountain plants in ice-free refugia at the coast or on nunataks on coastal and inland mountains. The main support for the theory is drawn from the modern distributions of the species concerned.

The presence of plant macrofossils (seeds, fruits, leaves, *etc.*) is good evidence for the former local occurrence of their parent taxa. This paper collates fossil records of taxa of importance to the nunatak theory. *Papaver* sect. *Scapiflora* is the most frequently recorded taxon, and the significance of the fossil finds to the nunatak theory, including the differentiation of the subspecies of *Papaver radicatum*, is discussed.

Although there is no fossil evidence from the areas of supposed glacial refugia to support or deny the nunatak theory directly, there is an increasing number of fossil records of taxa important to the nunatak theory from beyond the margins of the last ice-sheet. Seeds of pleniglacial age have been found beyond the ice-sheet maximum, and of Weichselian late-glacial age (14,000-10,000 B.P.) inside this limit but outside the Younger Dryas glacial readvance. This shows that these taxa, important to the nunatak theory because of their present distributions, together with many other more widespread mountain plants, grew beyond the ice sheet during the Weichselian glaciation, and migrated and colonised open habitats as rapidly as they were made available by ice-melting. Presumably their distributions were subsequently restricted by climatic warming and forest development during the Holocene. Although there is no fossil evidence directly for or against the nunatak theory, the available fossil evidence indicates that it is not necessary to propose per-glacial survival on nunataks or other ice-free refugia as an explanation of present mountain-plant distributions in Norway.

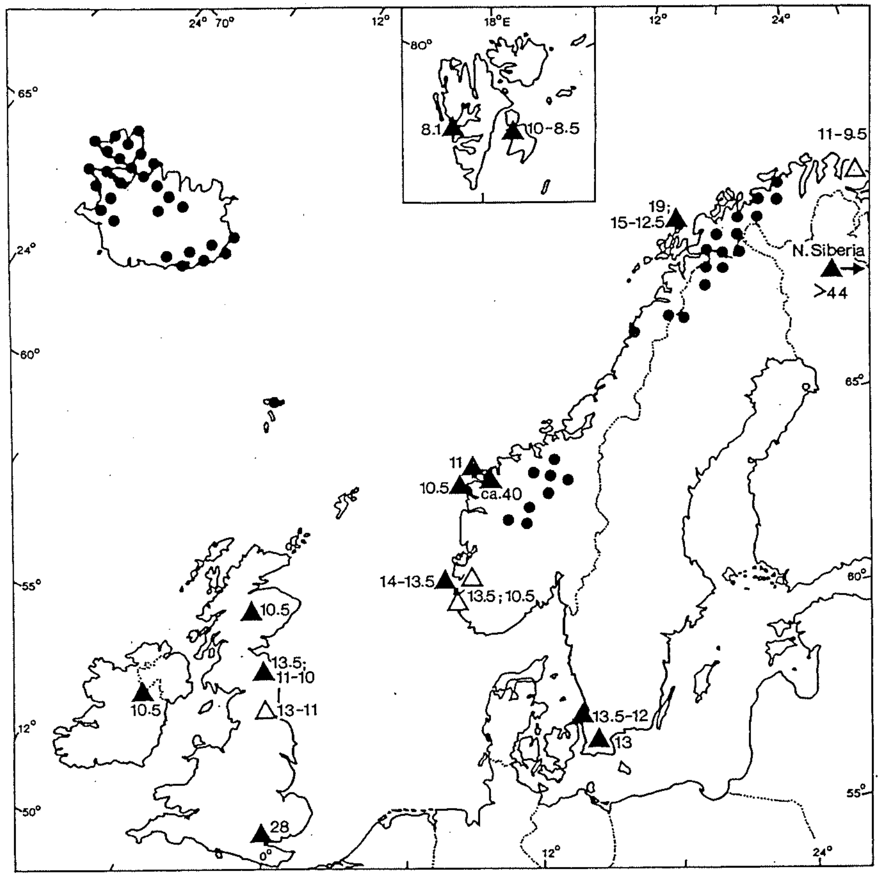


Figure 1. The modern European distribution of *Papaver radicatum* (●) from JALAS & SUOMINEN (1991). Fossil seed records (▲) and pollen only records (△) are shown, together with their ages in thousands of years B.P. The details of these localities are given in Table 1. *P. dahlianum* is widely recorded from Spitsbergen but these records are not shown on this figure.

Seed dispersal and molecular phylogeography: glacial survival, *tabula rasa*, or does it really matter?

Christian Brochmann, Tove M. Gabrielsen, Aslaug Hagen & Mari Mette Tollefsrud
Botanical Garden and Museum
Department of Biology
University of Oslo

Brochmann, C., Gabrielsen, T. M., Hagen, A. & Tollefsrud, M. M. 1996. Seed dispersal and molecular phylogeography: glacial survival, *tabula rasa*, or does it really matter? - Det Norske Videnskaps-Akademi. I. Mat.Nat.Kl. Avh. Ny Serie 18: 54-68. In this paper, we review our published and ongoing molecular studies (RAPDs, SCARs, and isozymes) on intraspecific phylogeography in the Nordic area. The studies include hardy pioneer species with wide arctic-alpine distributions, addressing the level and type of geographic structuring of their genetic variation, the allogamous, mainly diploid *Saxifraga oppositifolia*, and the more or less autogamous polyploids *Draba alpina*, *Saxifraga cespitosa*, and *Cerastium arcticum*. Although all of these species contain considerable amounts of molecular genetic variation, a surprisingly high proportion of this variation is poorly structured geographically. The outcrossing *Saxifraga oppositifolia* shows the highest level of intrapopulational variation ant the poorest geographic structures of aal species. *Cerastium arcticum* contains two genetically very divergent lineages, one southern (Norway and Iceland) and one northwestern (Svalbard and Greenland), but there is poor geographic structuring within each lineage. There is some regional differentiation within *Draba alpina* and *Saxifraga cespitosa*, in particular between two groups of populations: 1) the south Norwegian populations and 2) the populations from northern Norway and Svalbard, but there are several striking exceptions to this overall trend that may result from long-distance dispersal.

The conspicuous poverty of distinct local geographic races within these widespread species most likely reflects a past and/or present dynamic scenario with much higher migration rates than previously envisioned. The data can nevertheless not be used to discriminate between 'glacial survival' and '*tabula rasa*' with certainty. Potential effects of long-term isolation and evolution in putative 'intraglacial' survivor populations have most likely been wiped out by waves of new immigrants from periglacially surviving populations. Thus, our molecular analyses agree with recent phytogeographic and palaeobotanic analyses in suggesting that the hypothesis of 'glacial survival' is superfluous - we do not need it to explain present-day geographic distributions and variation in the Nordic arctic-alpine flora.

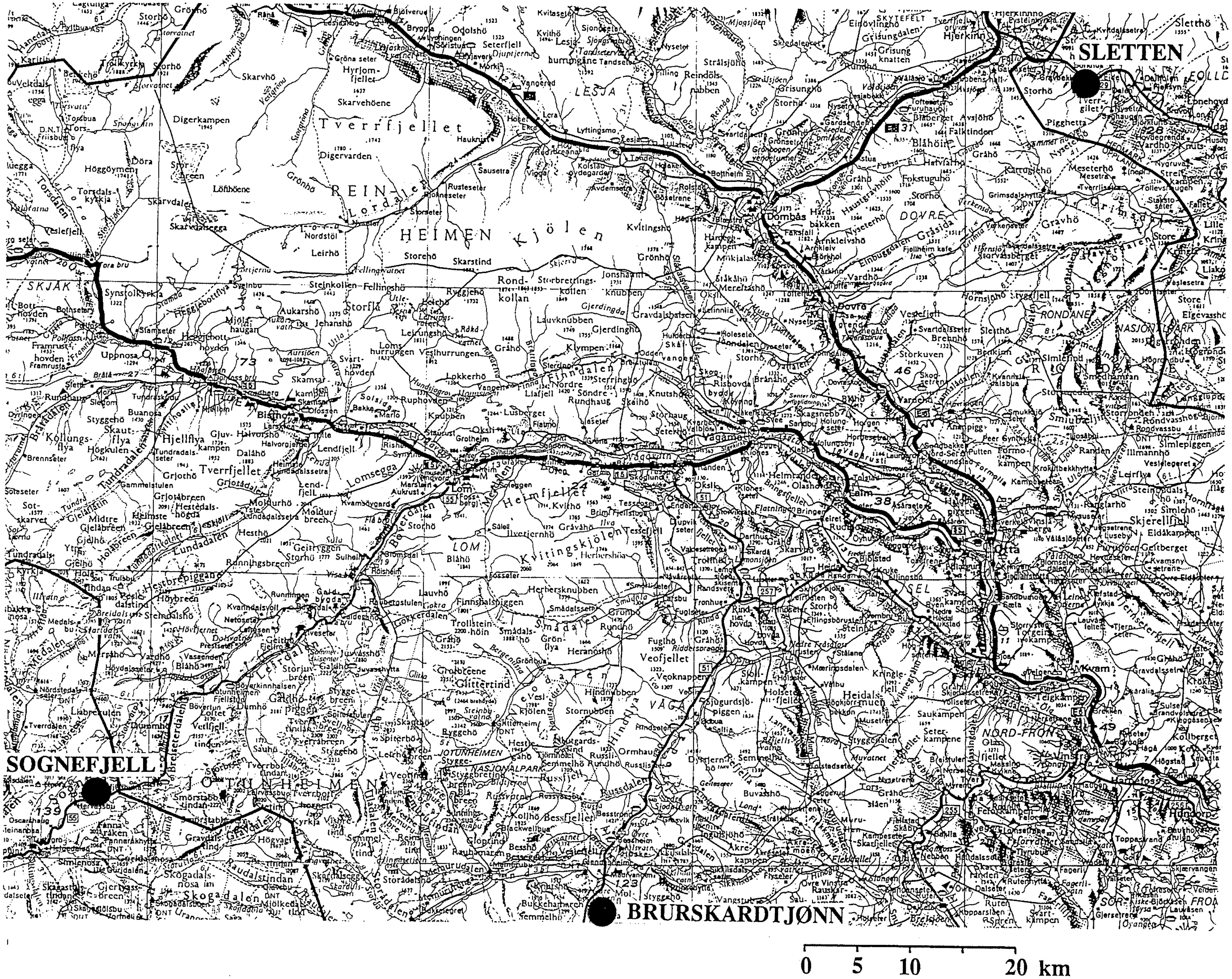
> *"Generalized and chance dispersal act as an ever-present background 'noise', which supplements and modifies the effects of specialized dispersal, as illustrated by the arrival of* Stellaria media *and* Carex nigra *to Surtsey, and by the spread of short-distance dispersers throughout the world"*
>
> R. Y. Berg (1983)

> *"However, most Scandinavian biogeographers explain the arctic-alpine disjunctions in terms of glacial survival.....It is my opinion that no single explanation can account for all the arctic-alpine disjunctions in Scandinavia. A great deal of argumentation has resulted from a futile search for the one universal cause. Each species area should be regarded a problem* per se. *For future advance to be made in this field, more exact descriptive and experimental data .....must be accumulated, species by species"*
>
> R. Y. Berg (1963)

Thursday, 22 August 2002

Brurskardstjønn, Bøvertun, Sognefjell

DAY 5. Thursday, 22nd. August



BRURSKARDTJØRN, EASTERN JOTUNHEIMEN

The lake, Brurskardtjørn, is situated 1309 m asl in the low alpine vegetation zone, about 150-200 m above the present day tree-line. The area consists mainly of gabbroic bedrock.
The site has been selected as one of the multi-proxy sites within the norpec project. Analysis of mites, chironomids, diatoms, pollen, macrofossils, and the sediments have been performed for reconstructions of the Holocene climate and environment.

The present day climate is characterised by a mean January temperature of −11.5°C, a mean July temperature of 8.7°C, and annual precipitation of 540 mm.

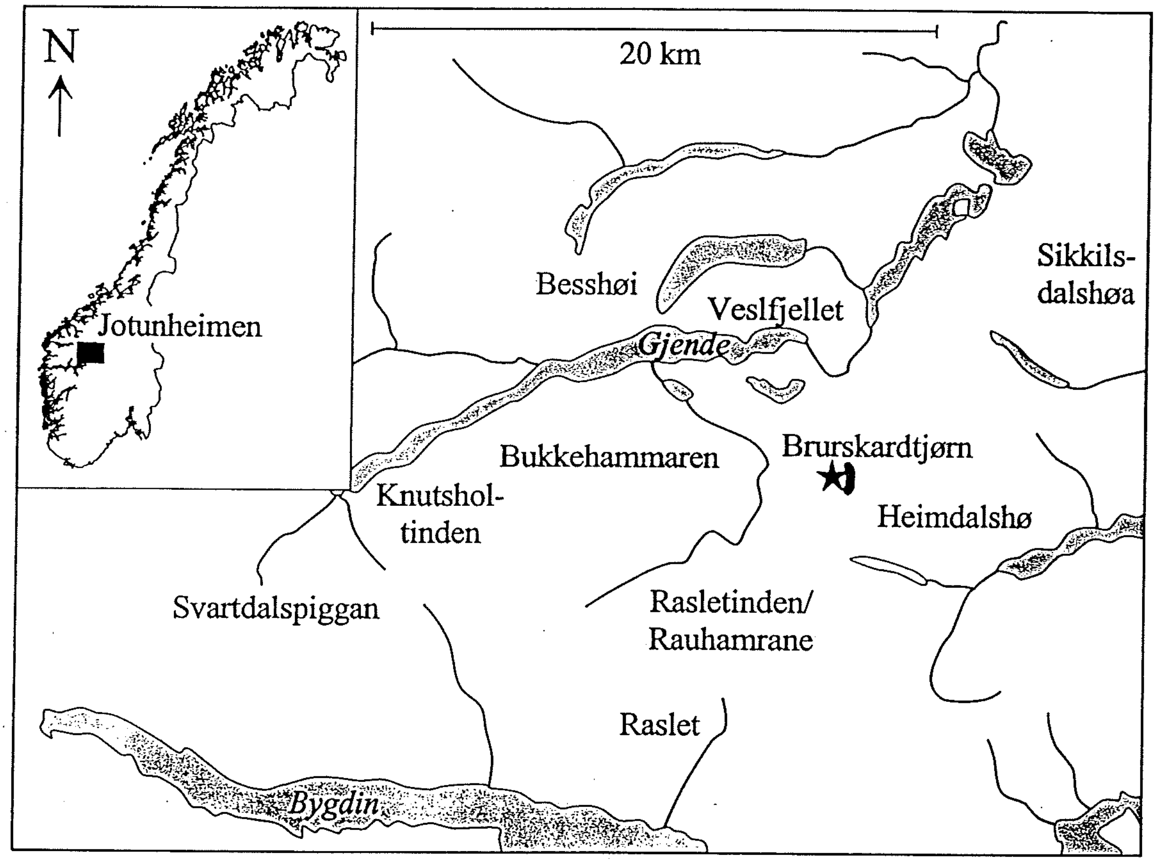
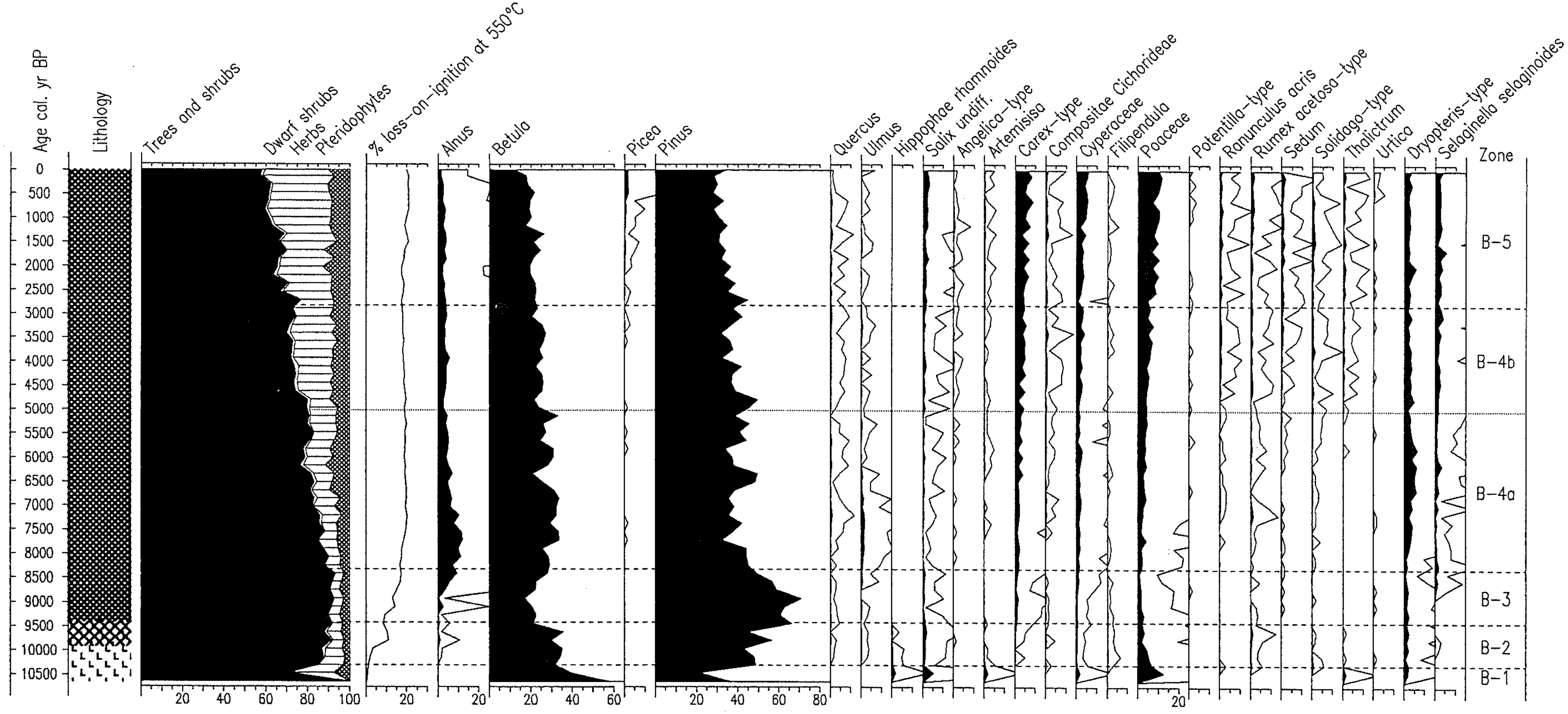


Figure: Map showing the location of the lake Brurskardtjørn, eastern Jotunheimen.

Brurskardtjonn, Jotunheimen, 1309 m asl

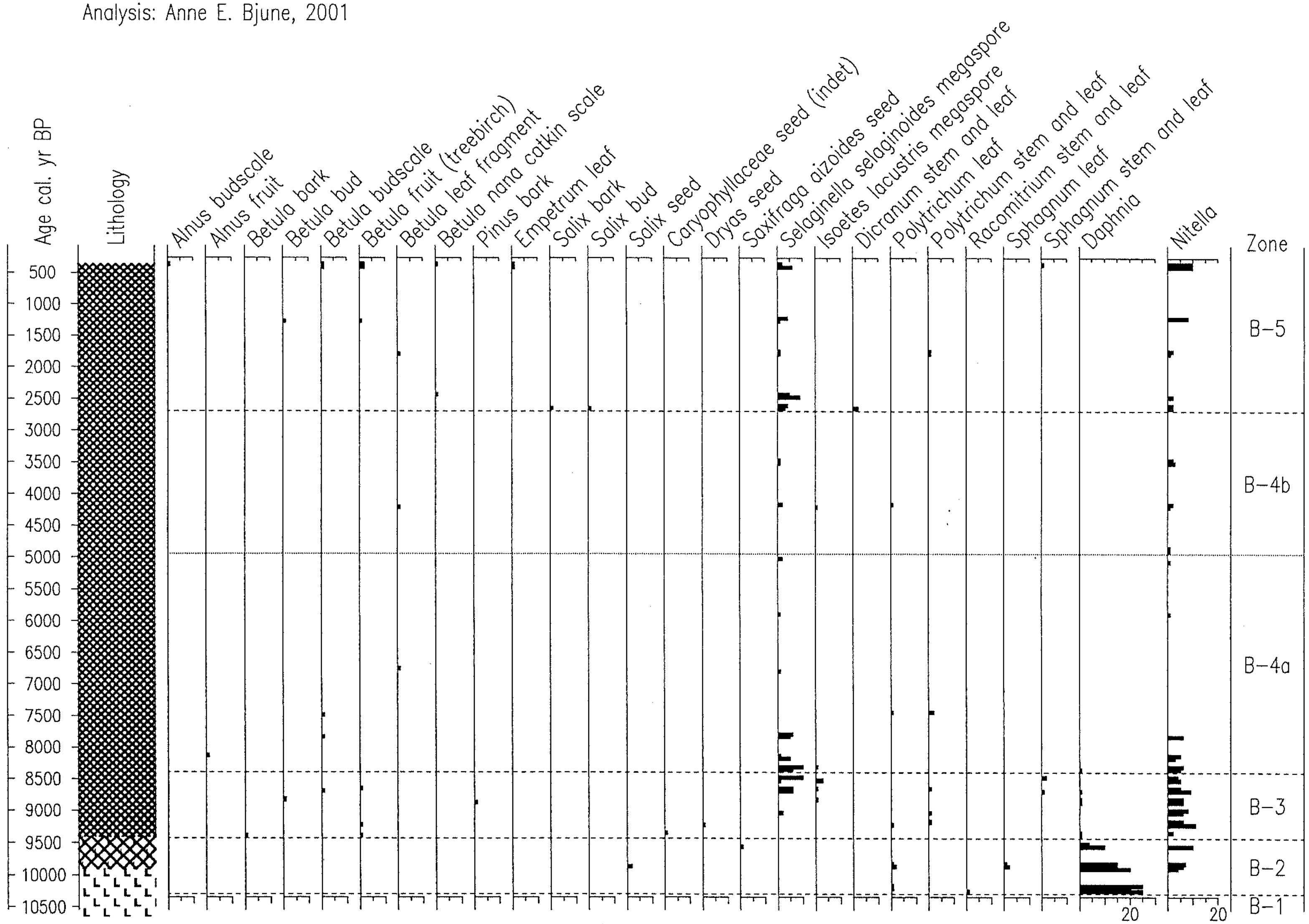
Pollen and spore percentages of selected taxa

Analysis: Anne E. Bjune, 2000/2001

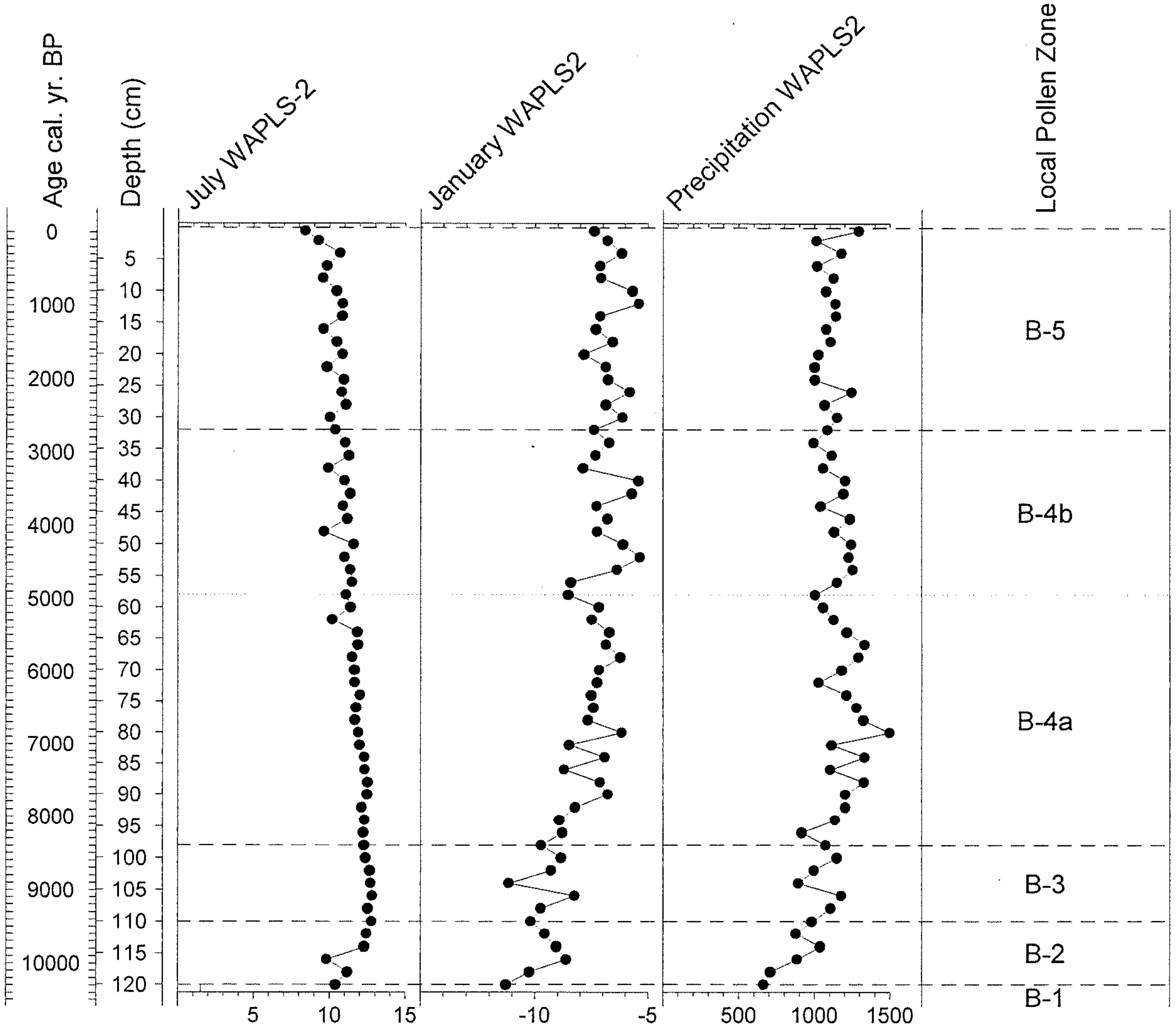


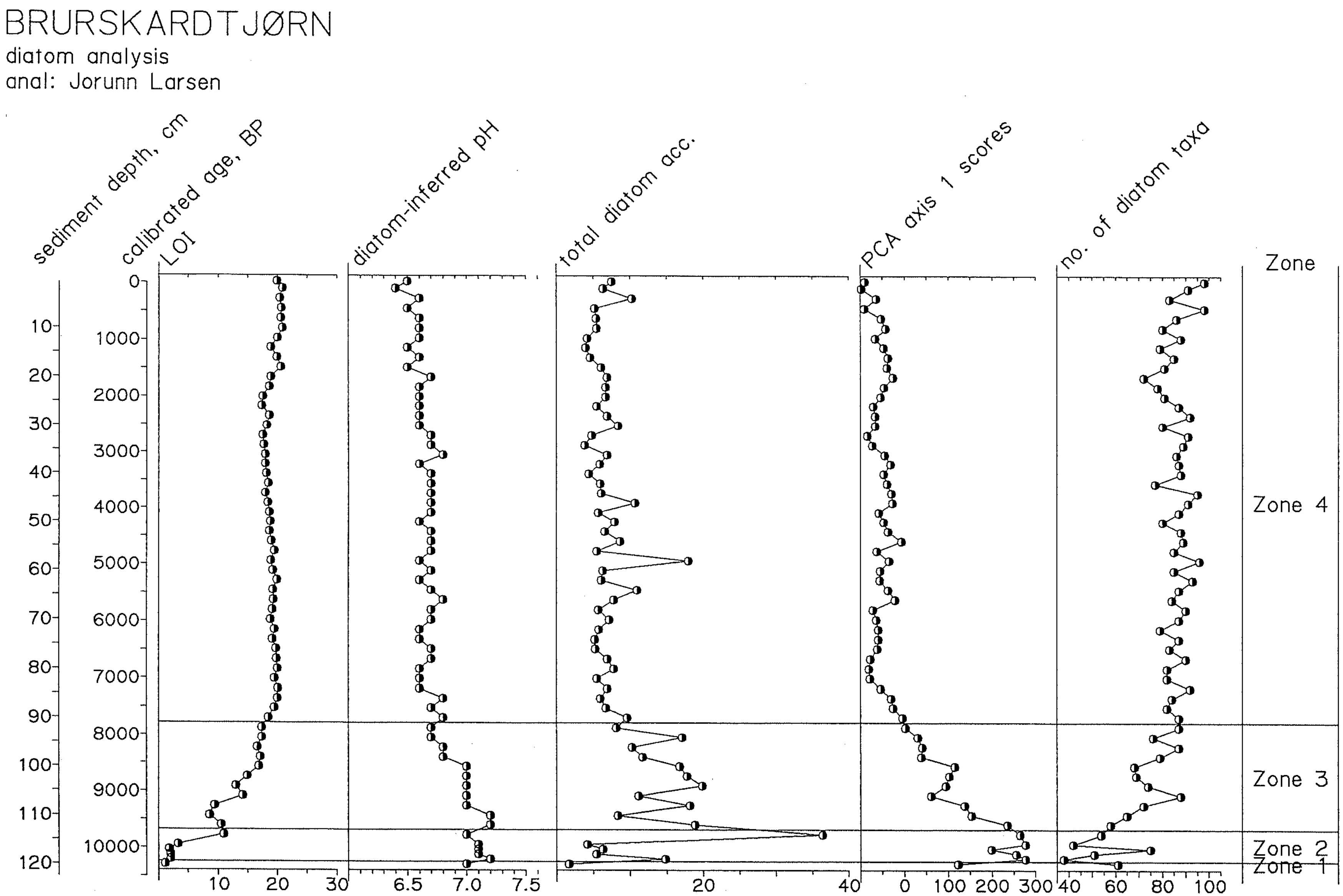
Brurskardtjonn, Jotunheimen, 1309 m asl

Macrofossils (selected taxa)
Analysis: Anne E. Bjune, 2001



Reconstructed January and July temperature, annual precipitation
Brurskardtjorn, Jotunheimen, 1309 m asl





Summary diagram of the diatom analysis from Brurskardtjørn covering the Holocene.

Holocene fluctuations of a polythermal glacier in high-alpine eastern Jotunheimen, central-southern Norway: a multi-site, multi-parameter approach on lacustrine sediments

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Abstract: Bukkehåmmårbreen is a polythermal cirque glacier lying in the permafrost zone of eastern Jotunheimen, central southern Norway. In the proglacial lake Bukkehåmmårtjørna, sediment analyses of loss-on-ignition (LOI), magnetic susceptibility and analyses of grain-size distribution have been used to reconstruct Holocene variations in glacier activity and other catchment processes. The glacier has low sediment production, hence a low signal-to-noise ratio of minerogenic sediment flux is found. Grain-size analyses are therefore used to enhance the glaciogenic signal and to detect glacier variations and other changes in sediment input. The sedimentological record from Bukkehåmmårtjørn is compared with three other lake records from the same region in order to separate the glacial signal from variations in organic production and episodes of enhanced paraglacial activity. Subsequent to the deglaciation after the Younger Dryas, a Preboreal glacial advance culminated before 10,100 cal. BP. This was followed by a prolonged period with no glaciers in the catchment until 7500 cal. BP, after which there is evidence of limited glacier activity lasting until 6800 cal. BP. Between 6700 and 6000 cal. BP the catchment was deglaciated. After 6000 cal. BP Bukkehåmmårbreen reformed, increasing in size towards ~3800 cal. BP, with evidence for reduced glacier activity around 5200 cal. BP. A glacier with approximately similar size as at present has existed after ~3800 cal. BP. The investigation has demonstrated the usefulness of multi-site and multi-parameter lacustrine investigations in reconstructing glacier fluctuations and for testing and validating the results. The investigations have shown that grain-size variations in sediment cores located at increasing distance from the meltwater inlet of a lake may provide an indicator of paraglacial activity in the catchment during the Holocene. The results also suggest that the lower altitudinal limit of permafrost in eastern Jotunheimen remained below about 1800 m during the Holocene.

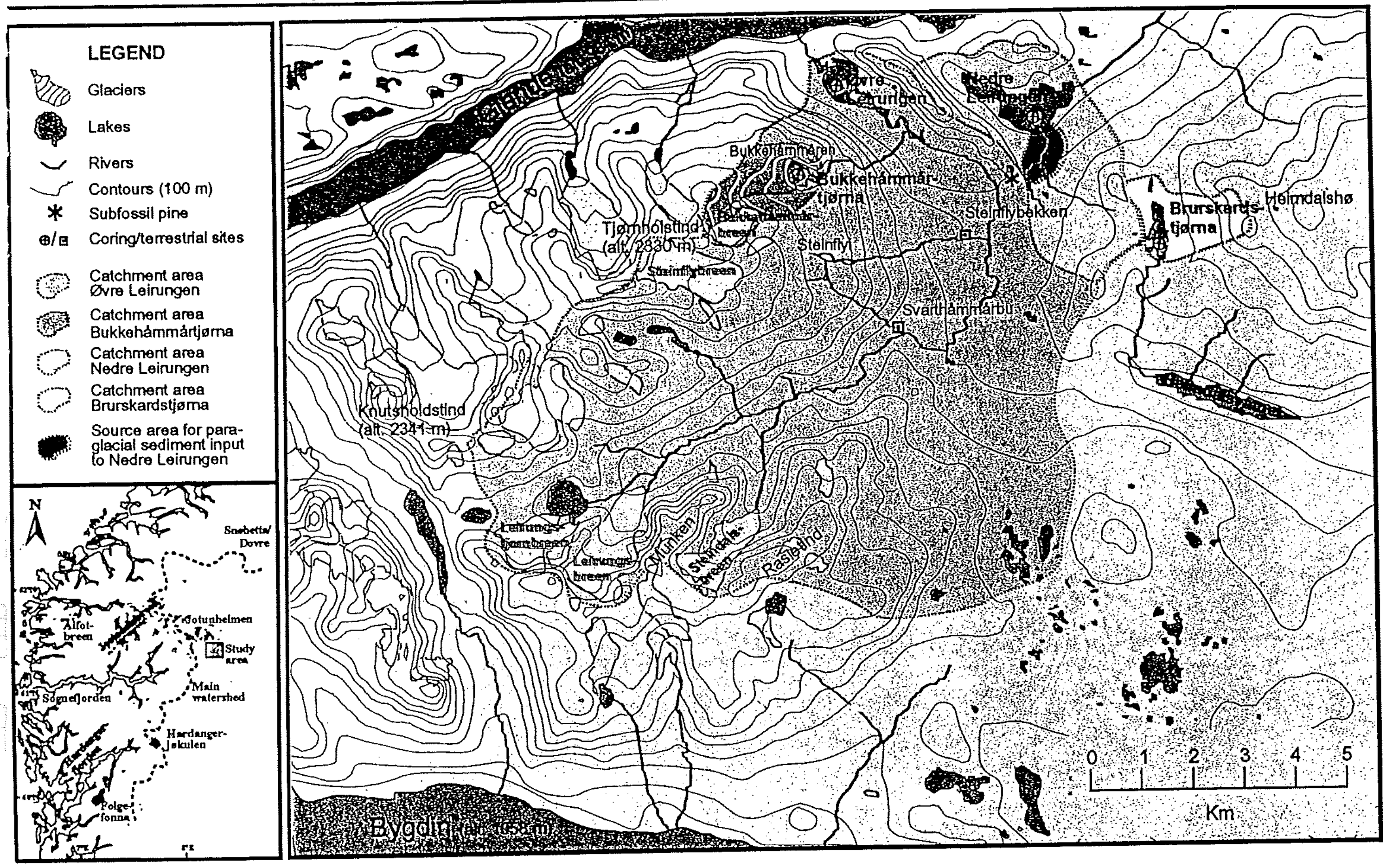


Figure 1. Location map of the study area. The catchments of the cored lakes are indicated.

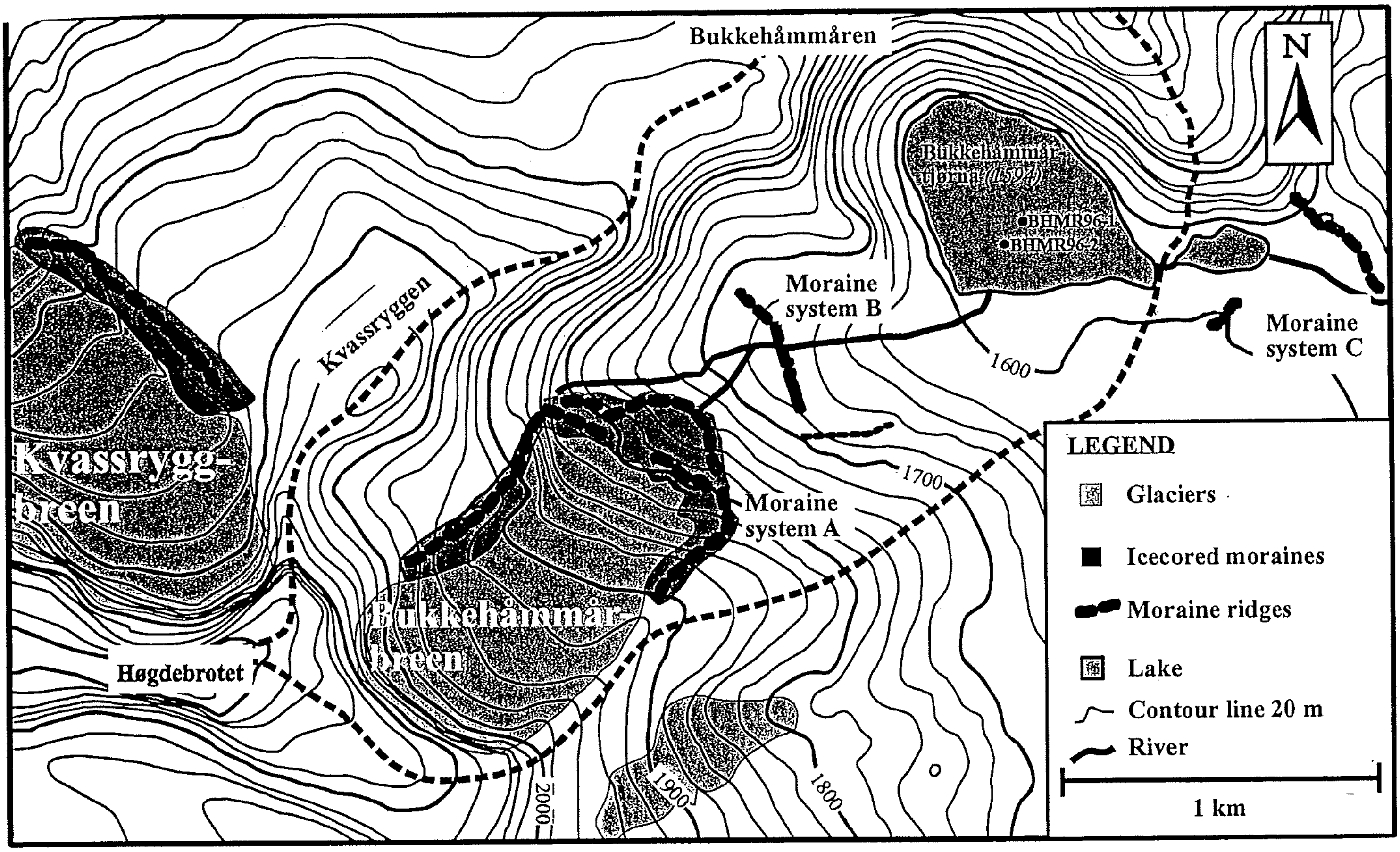


Figure 2: Map showing Bukkehåmmårtjørna and its catchment, Bukkehåmmårbreen and three moraine systems (A, B and C). The coring sites for BHMR96-1 and BHMR96-2 are marked.

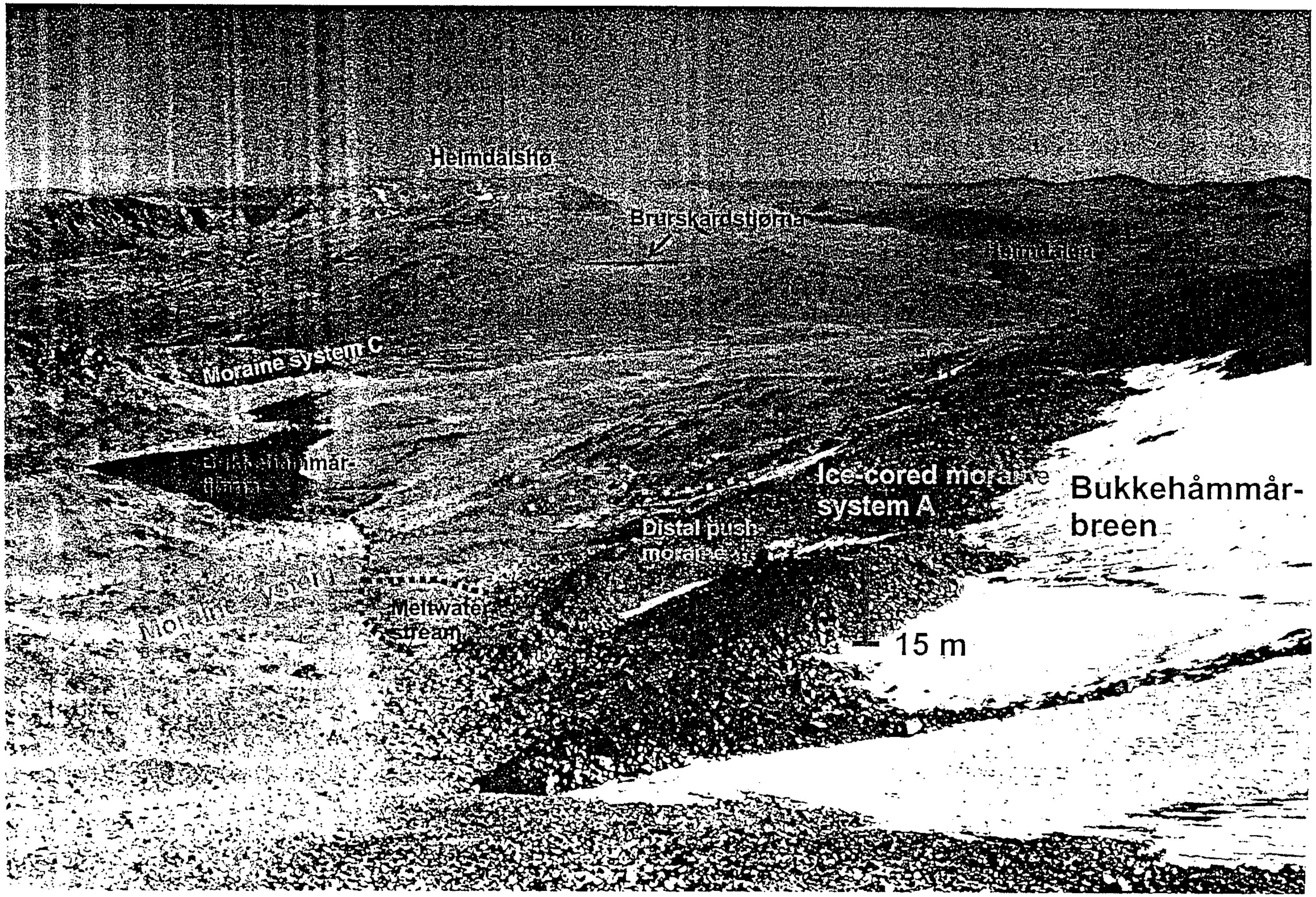


Figure 3: The front and foreland of Bukkehåmmårbreen, with moraine complexes A, B and C indicated. Lake Bukkehåmmårtjørn can be seen, and Lake Brurskardstjørn is indicated in the distance. View towards E/SE

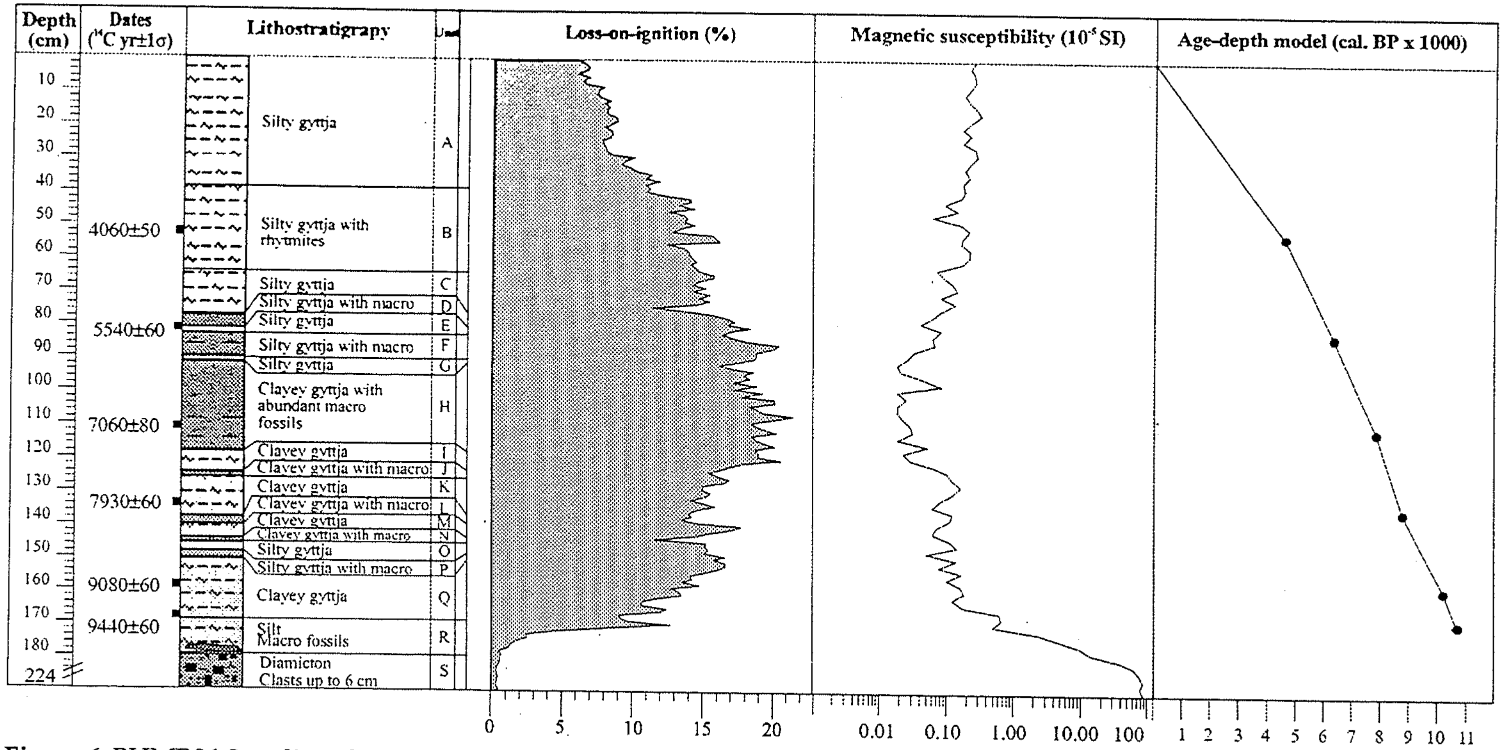


Figure 6: BHMR96-2: radiocarbon dates, lithostratigraphy, loss-on-ignition, magnetic susceptibility and calendar age-depth model in calendar years.

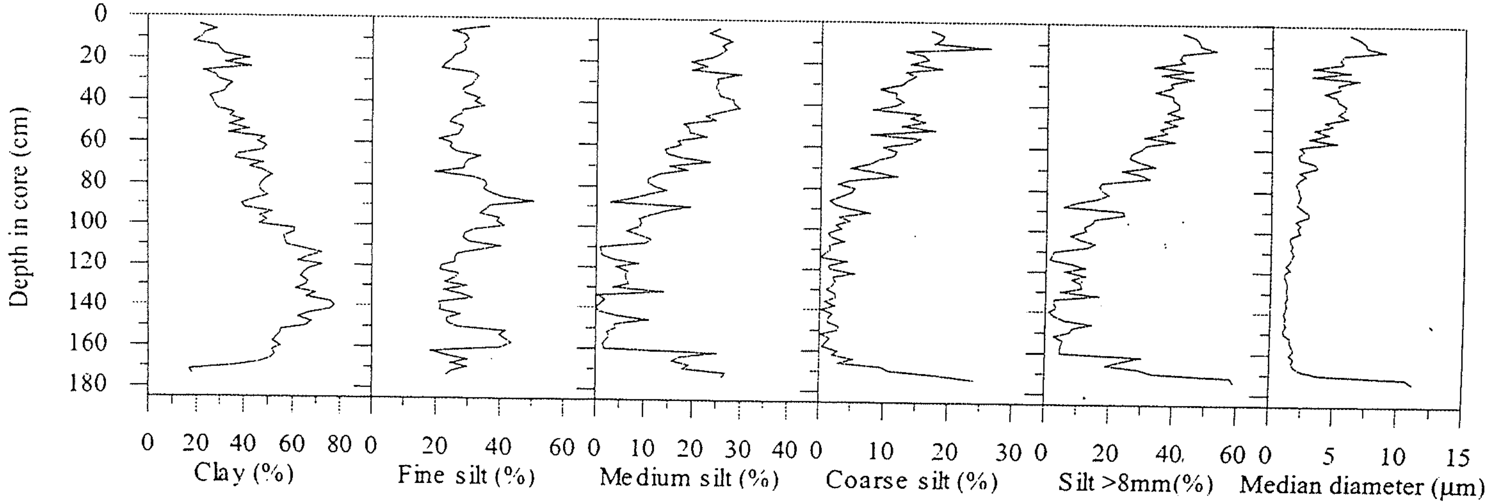


Figure 7: BHMR96-2: grain-size analyses: clay (< 2 μm), fine silt (2-8 μm), medium silt (8-20 μm) coarse silt (20-63 μm), silt > 8 μm and median diameter (μm).

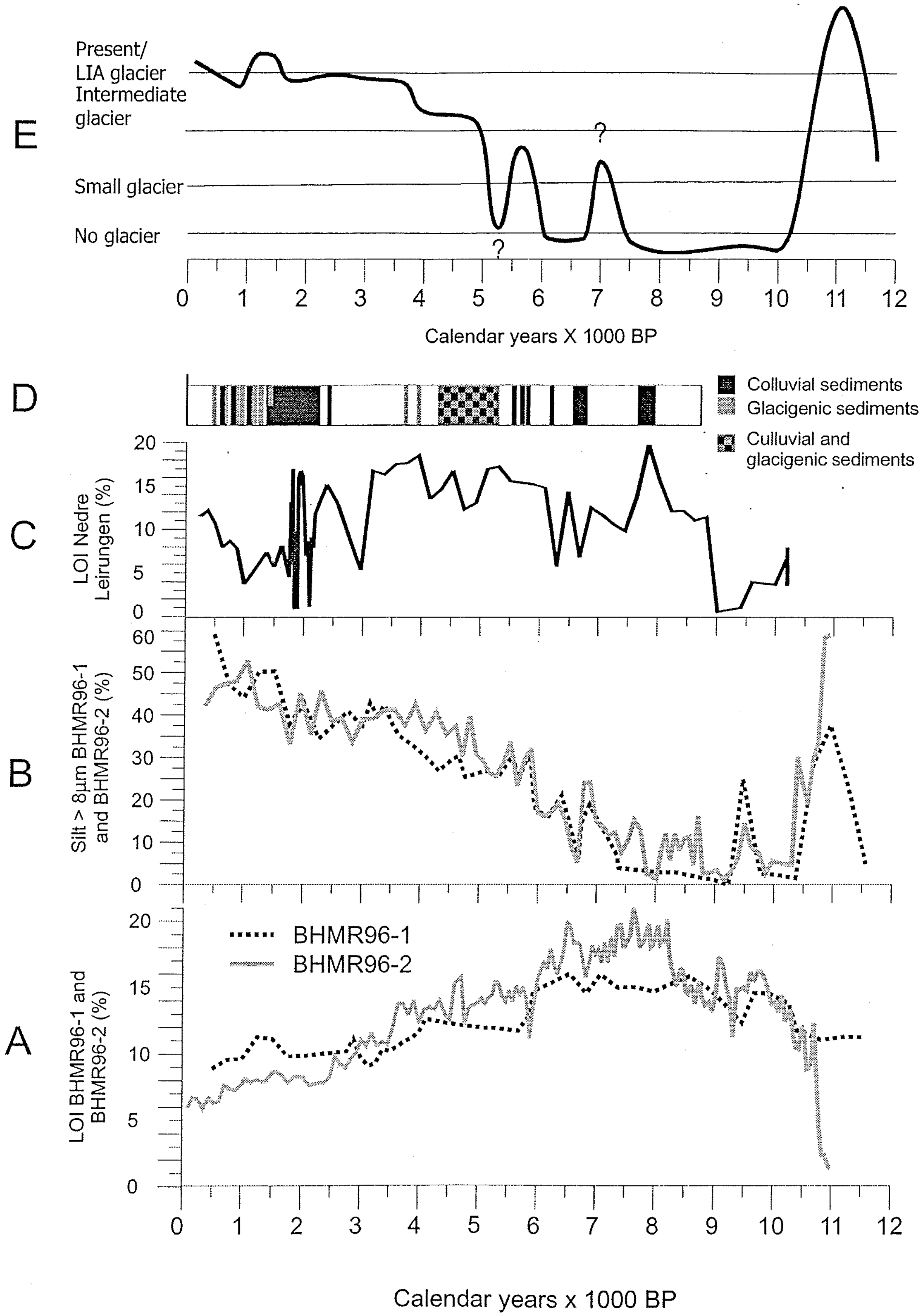
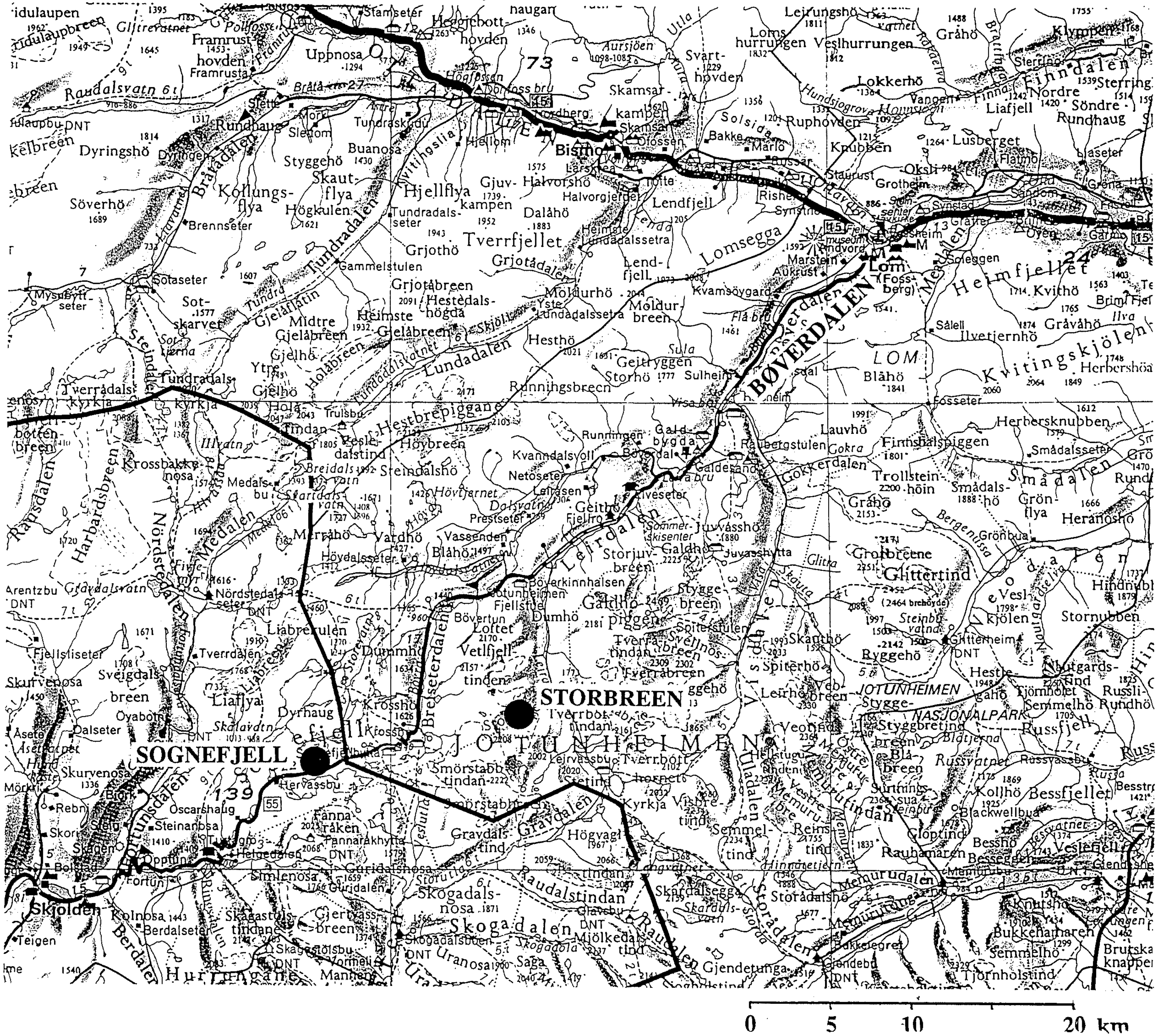


Figure 11: A) Loss-on-ignition curves for BHMR96-1 (broken line) and BHMR96-2 (grey line) plotted on a wiggle-matched calendar year time scale. B) Silt > 8 µm in BHMR96-1 (broken line) and BHMR96-2 (grey line). C) Loss-on-ignition from Nedre Leirungen. D) Periods of clastic sedimentation in two river gullies, Steinflybekken and Svarthammarbu (Sandvold *et al.*, 2001). E) Interpreted glacier activity and size variations of Bukkehåmmårbreen.

Friday, 23 August 2002

Leirdalen, Storbreen, Kyrkja

DAY 6. Friday, 23rd. August



PERGAMON

Quaternary Science Reviews 19 (2000) 1625–1647

QSR

Holocene glacier variations in central Jotunheimen, southern Norway based on distal glaciolacustrine sediment cores☆

John A. Matthews[a,*], Svein Olaf Dahl[b], Atle Nesje[c], Mark S. Berrisford[a], Carin Andersson[c]

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Abstract

Sediment cores from two glacier-fed lakes are used to reconstruct a continuous record of glacier variations since about 10,000 cal. BP in the Smørstabbtinden massif of central Jotunheimen, southern Norway. Particular attention is paid to the century- to millennial-scale, pre-Little Ice Age glacial signal based on an estimated temporal resolution of $\leqslant 55$ and $\leqslant 25\ \mathrm{yr\,cm^{-1}}$ for Bøvertunsvatnet and Dalsvatnet, respectively. Visible lithostratigraphic variations, organic content/loss-on-ignition, calcium carbonate content, magnetic susceptibility and grain-size fractions (especially the fine silt) are used as proxy indicators of glacier presence and extent in the lake catchments.

Following deglaciation, the early Holocene was characterized by generally small glaciers until a major advance (the Finse Event) peaking at approximately 8200 cal. BP. From 7900 to at least 5300 cal. BP glaciers appear to have been absent from central Jotunheimen. There is evidence of glacier expansion between about 2400 and 1600 cal. BP (the Bøvertun I Event) and between about 1400 and 800 cal. BP (the Bøvertun II Event) before reduced glacier extent during the Mediaeval Warm Period. Finally, the most extensive Neoglacial maximum occurred during the Little Ice Age after 500 cal. BP. In addition to providing a record of the broad pattern of climatically forced Holocene glacier variations, periodicities at 110–140, 200–285 and about 500 yr have been identified. Uncertainties remain concerning the precise timing of events, glacierization and deglacierization detection thresholds, a possible mid- to late-Holocene (5300–2500 cal. BP) Neoglacial build-up of small glaciers, and shorter-term, decadal- to century-scale variations in glacier size, for which more proximal sites are required.

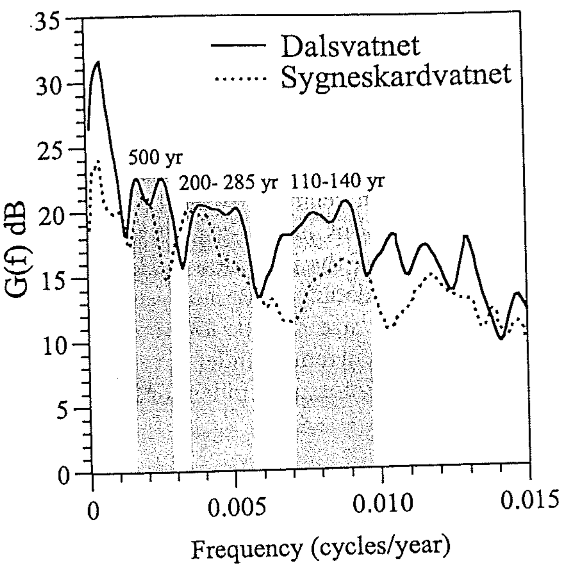


Fig. 12. Spectral estimates of loss-on-ignition data from Dalsvatnet core 2 compared with the corresponding data from Sygneskardvatnet (Nesje et al., 2000). Autospectra were calculated using SPECTRUM software (Schultz and Stattegger, 1997) (OFAC = 6; HIFAC = 1; $N_{seg} = 6$; Hanning-window). Dominant frequencies are indicated.

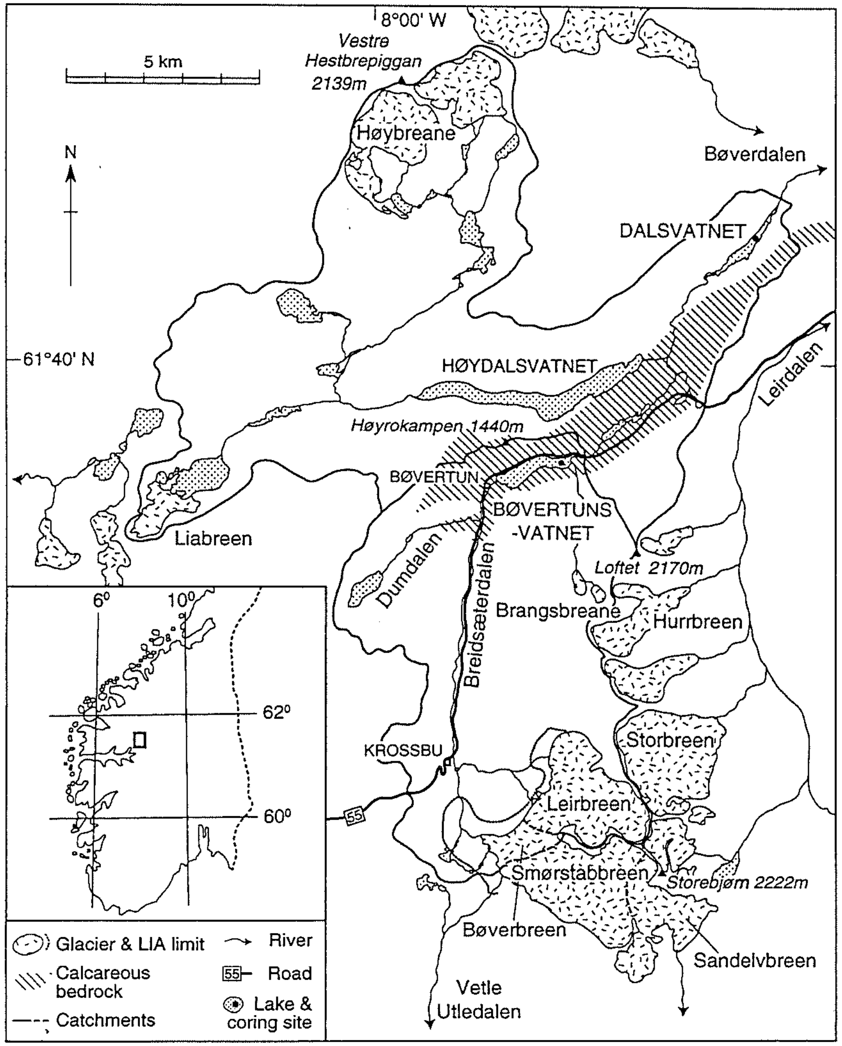


Fig. 1. Bøvertunsvatnet and Dalsvatnet: lake catchments, glaciers and approximate location of calcareous bedrock in central Jotunheimen and the area to the north.

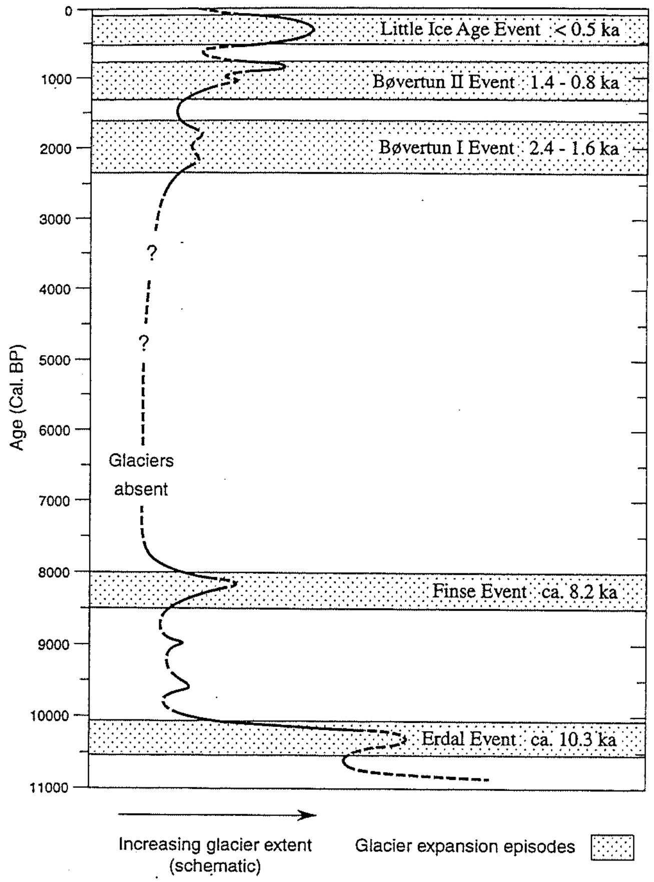


Fig. 10. Summary of the pattern of Holocene glacier variations in central Jotunheimen.

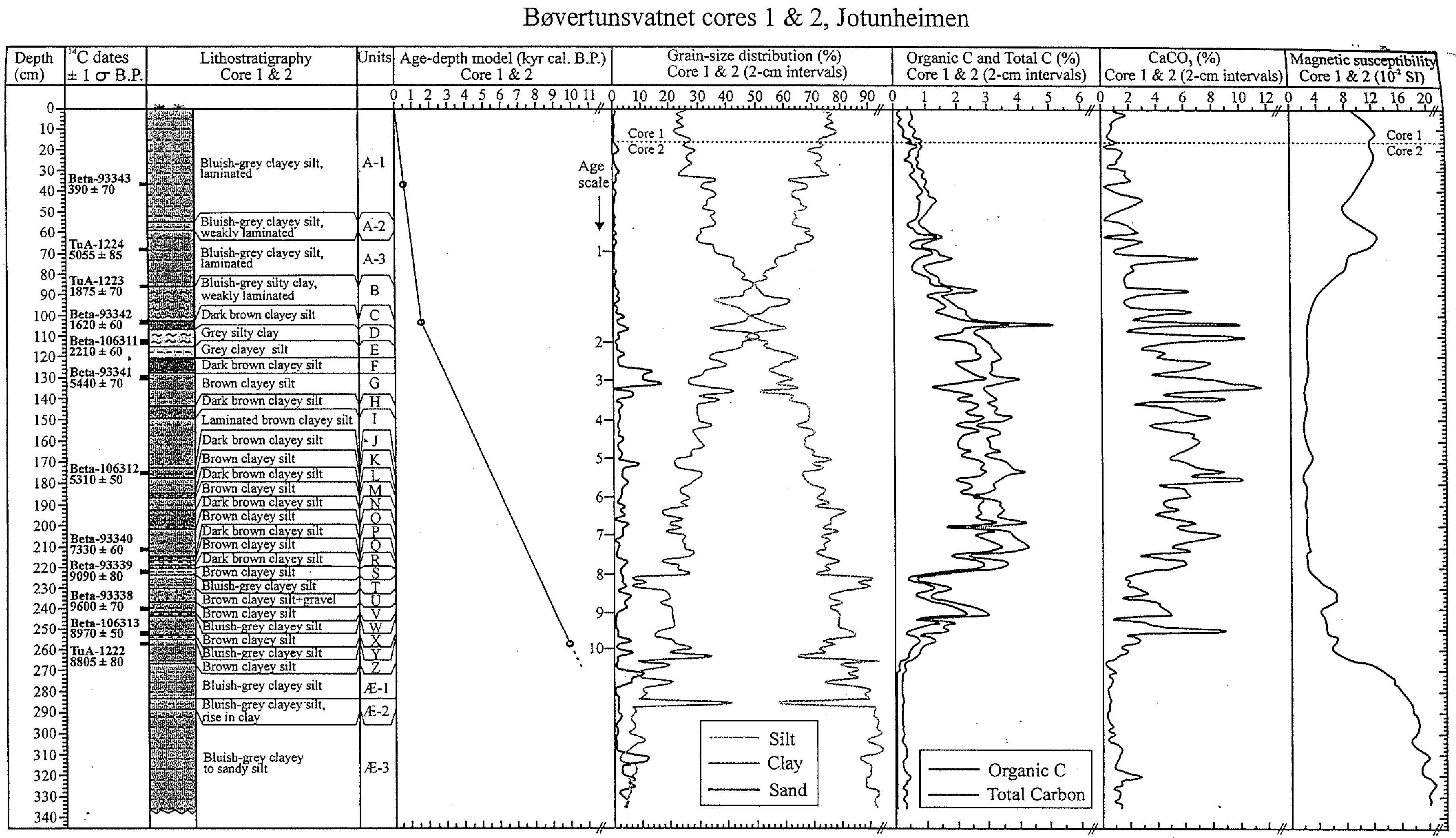


Fig. 5. Bøvertunsvatnet cores 1 and 2: radiocarbon dates; lithostratigraphy; calibrated age/depth model; sand, silt and clay content; organic and total carbon content; calcium carbonate content; and magnetic susceptibility curve. These data relate primarily to core 2 with core 1 used for the uppermost 18 cm.

THE FLORA OF BØVERDALEN

The flora in this valley is characterised by the distinct transition between poor soil and acid bedrock in the west and a calcareous rich bedrock and soil in the east giving the rich flora in Bøverdalen. The valley lies in climatic dry area with not more than a 1000 mm of precipitation each year. Sheep graze the slopes in summer and in winter avalanches keep the snow cover light, also preventing trees to recolonise.

On the slopes on northern side of the lake Bøvertunvatnet from ca. 950 – 1100 m asl, there is a rich alpine flora with species like *Dryas octopetala*, *Saxifraga oppositifolia*, *Cypripedium calceolus*, *Astragalus alpinus*, *Oxytropis lapponica*, *Gymnadenia conopsea*, *Braya linearis*, *Chamorchis alpina*, *Euphrasia salisburgensis, Rhododendron lapponicum, Sedum villosum, and Gentianella tenella.*

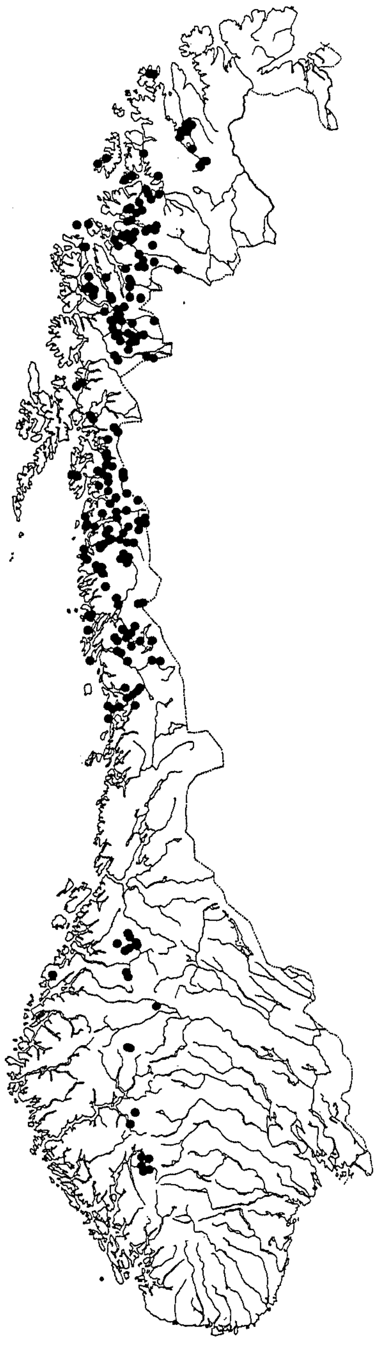
Together with these alpine species other more heat demanding species are found, such as *Epipactis atrorubens, Cotoneaster scandinavicus* and *Carex ornithopoda. C. ornithopoda* has as many species its altitudinal limit here.

Species with a bicentric distribution have their south-western limit in Bøverdalen; *Braya linearis*, *Chamorchis alpina*, *Euphrasia salisburgensis, and Rhododendron lapponicum.*

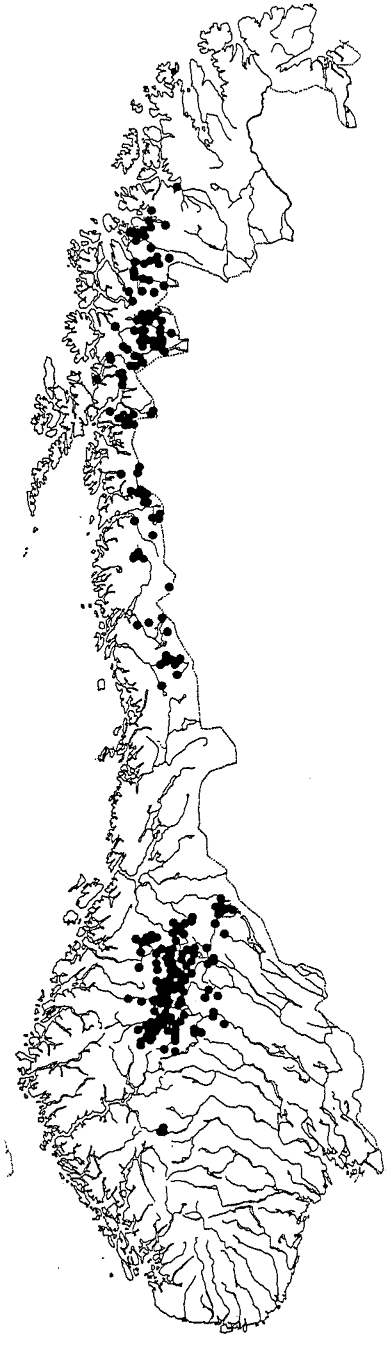
Towards the top of the slope towards the top Høyrokampen you find a relict occurence of *Hippophaë rhamnoides*. Pollen analysis (e.g. Fægri 1940, Hafsten 1956, 1966, S.M. Peglar unpub., etc…) has shown that it did grow widely in southern Norway during the Preboreal following the ice margin growing on inorganic, unstable soils. Today *Hippophaë rhamnoides* is found only at Høyrokampen in southern Norway and also on several localities north of Trondheimsfjorden (see map).

Rhododendron lapponicum (L.) Wahlenb. Bi

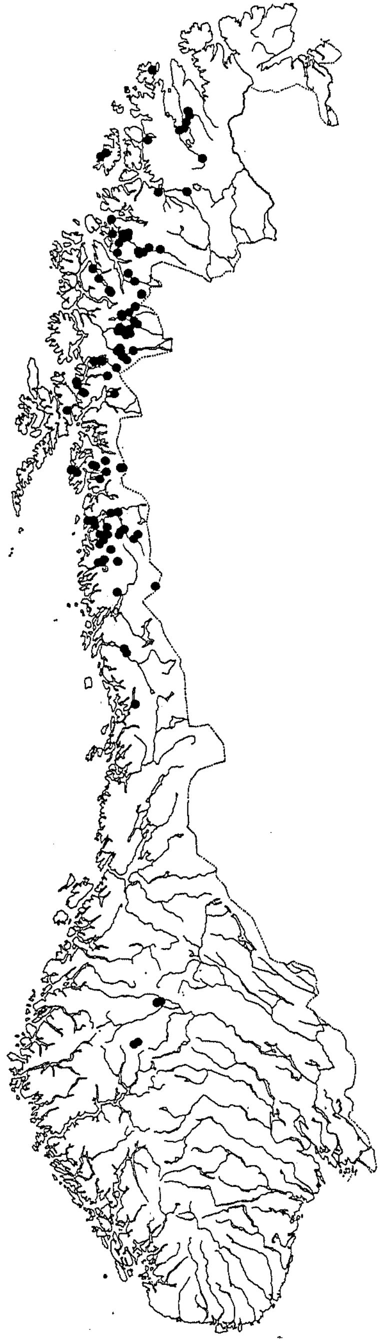
Euphrasia salisburgensis Funck Bi



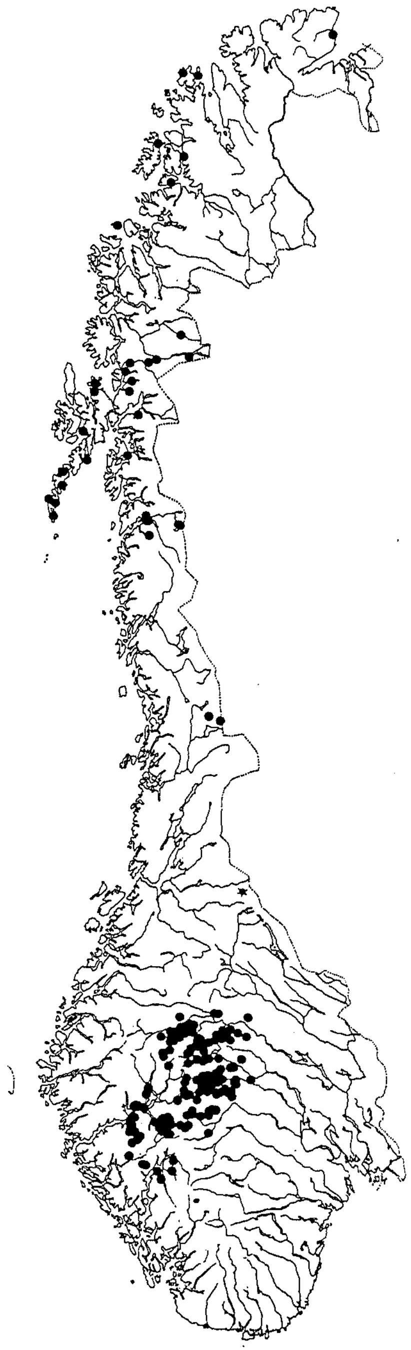
Gentianella tenella (Rottb.) Börner Bi



Braya linearis Rouy Bi



Sedum villosum L. Bi



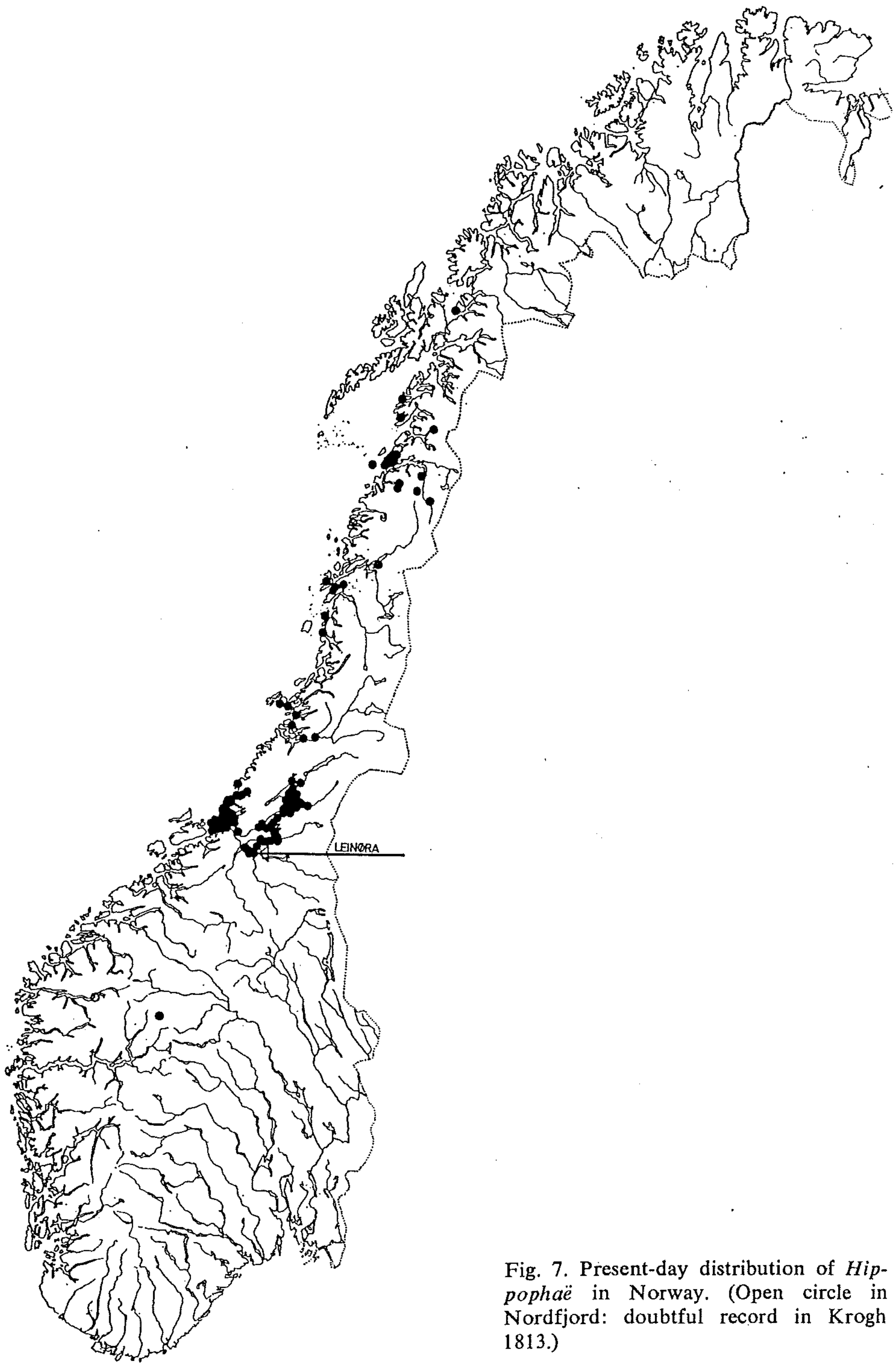


Fig. 7. Present-day distribution of *Hippophaë* in Norway. (Open circle in Nordfjord: doubtful record in Krogh 1813.)

Arctic and Alpine Research, Vol. 19, No. 4, 1987, pp. 385-395

VEGETATION SUCCESSION ON THE STORBREEN GLACIER FORELAND, JOTUNHEIMEN, NORWAY: A REVIEW

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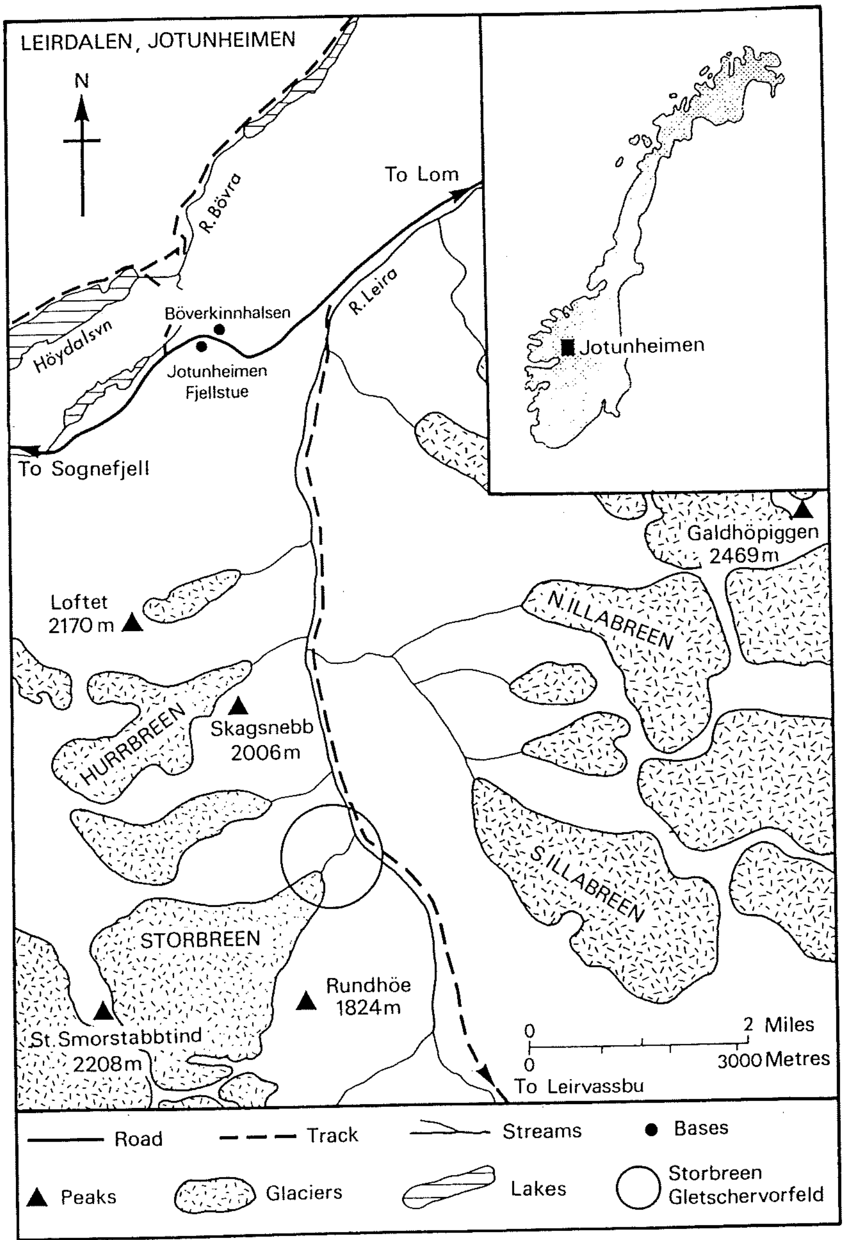

FIG. 1. Location of Storbreen and the Storbreen gletschervorfeld.

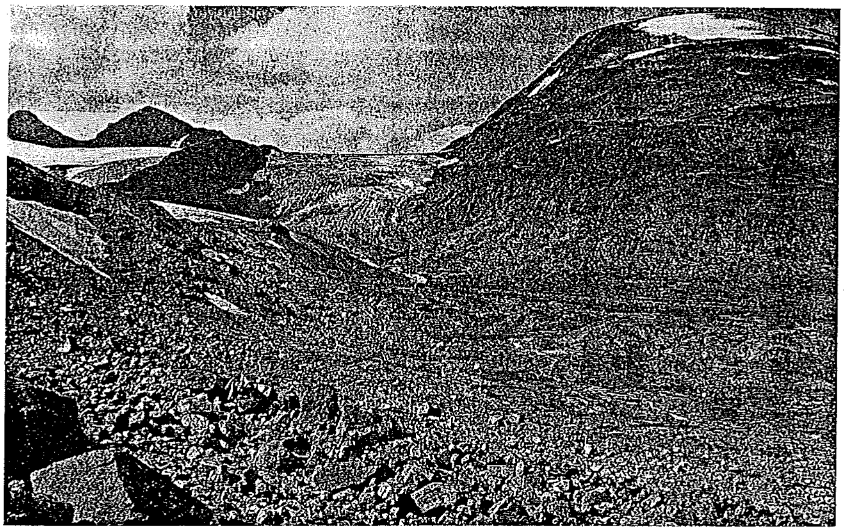

Fig. 1.1. Recently-deglaciated terrain, Storbreen glacier foreland, Jotunheimen, photographed in 1985. Bouldery terrain in the foreground (with moraine ridges) was deglaciated about 140 years ago.

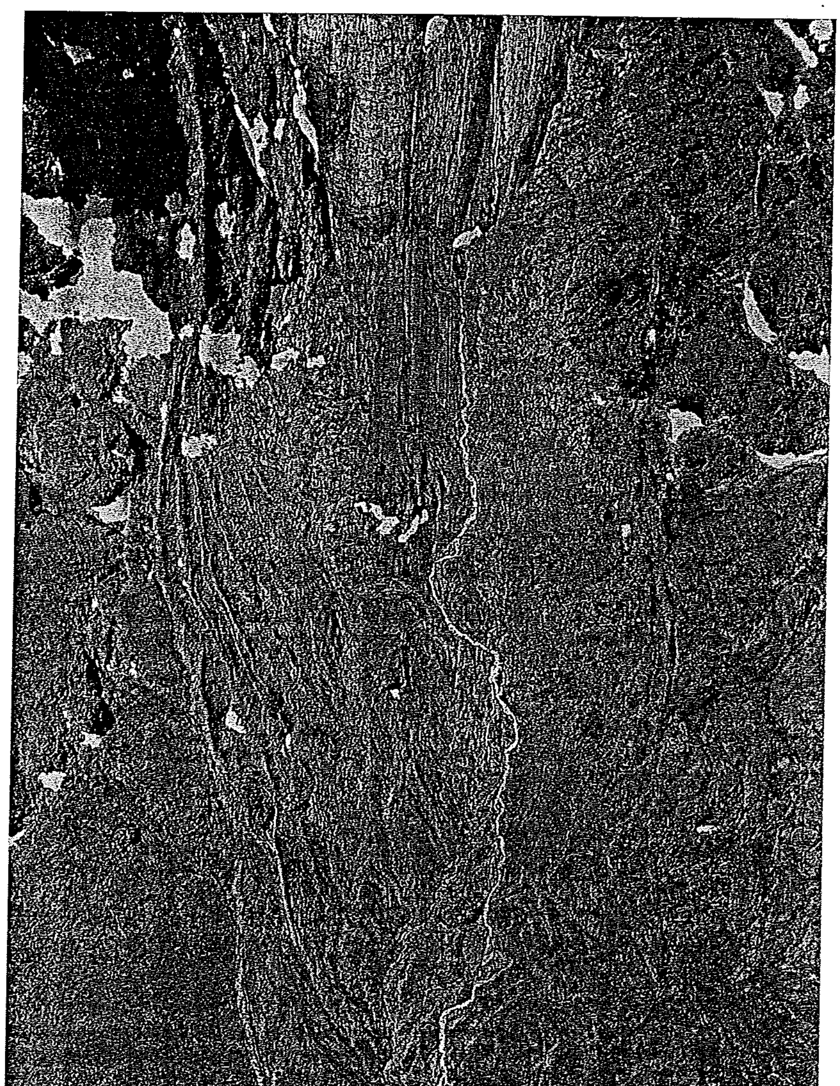

Fig. 1.2. Vertical aerial photograph of the Storbreen glacier foreland, Jotunheimen, southern Norway (Widerøe's Flyveselskap A.S., 1968). The outermost of the prominent sequence of end-moraine ridges, which extends about 1.5 km from the glacier snout, defines the glacier foreland boundary and indicates the position of the glacier about A.D. 1750. See also Fig. 2.4.

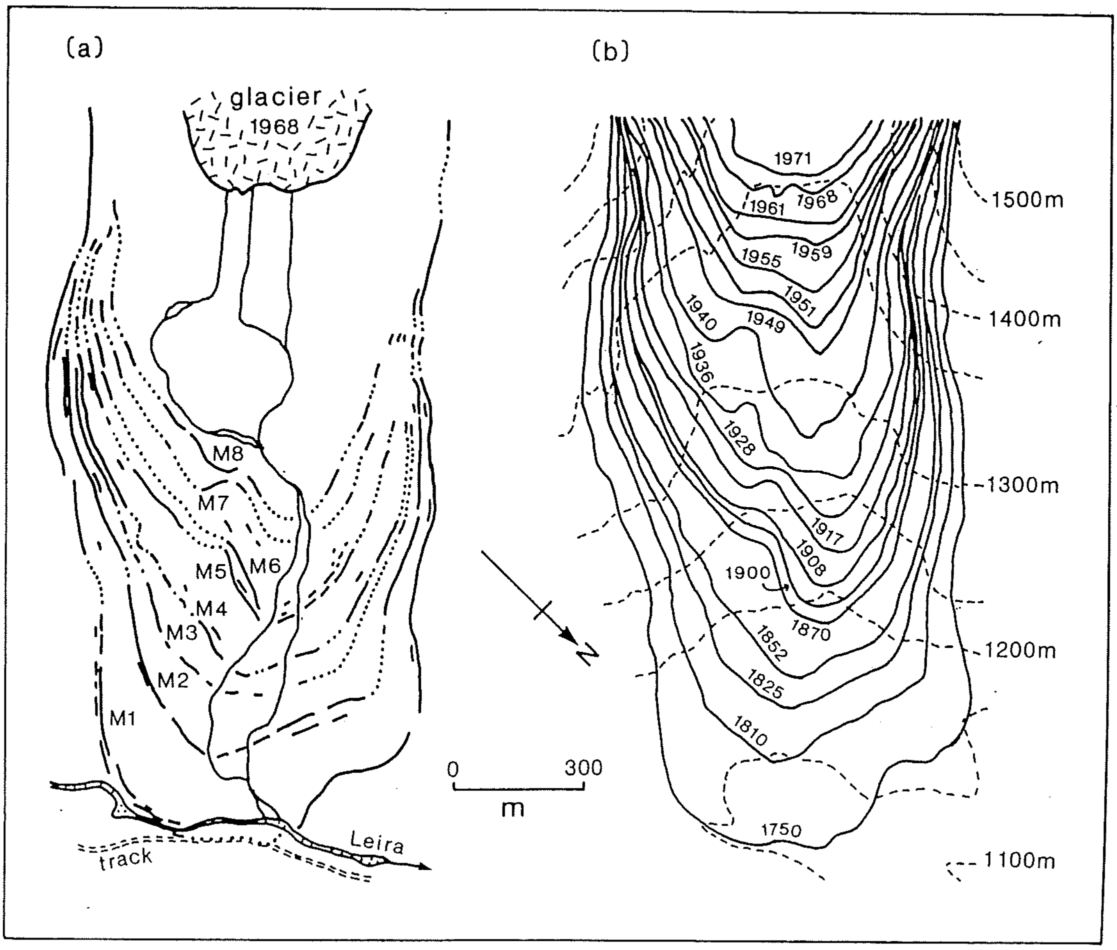

Fig. 2.4. Storbreen glacier foreland, Jotunheimen, southern Norway: (a) the end moraine sequence (M1–M8) (from Matthews, 1974); (b) the areal chronology depicted by isochrones (dated). Contours are also shown in (b) (from Matthews, 1978a).

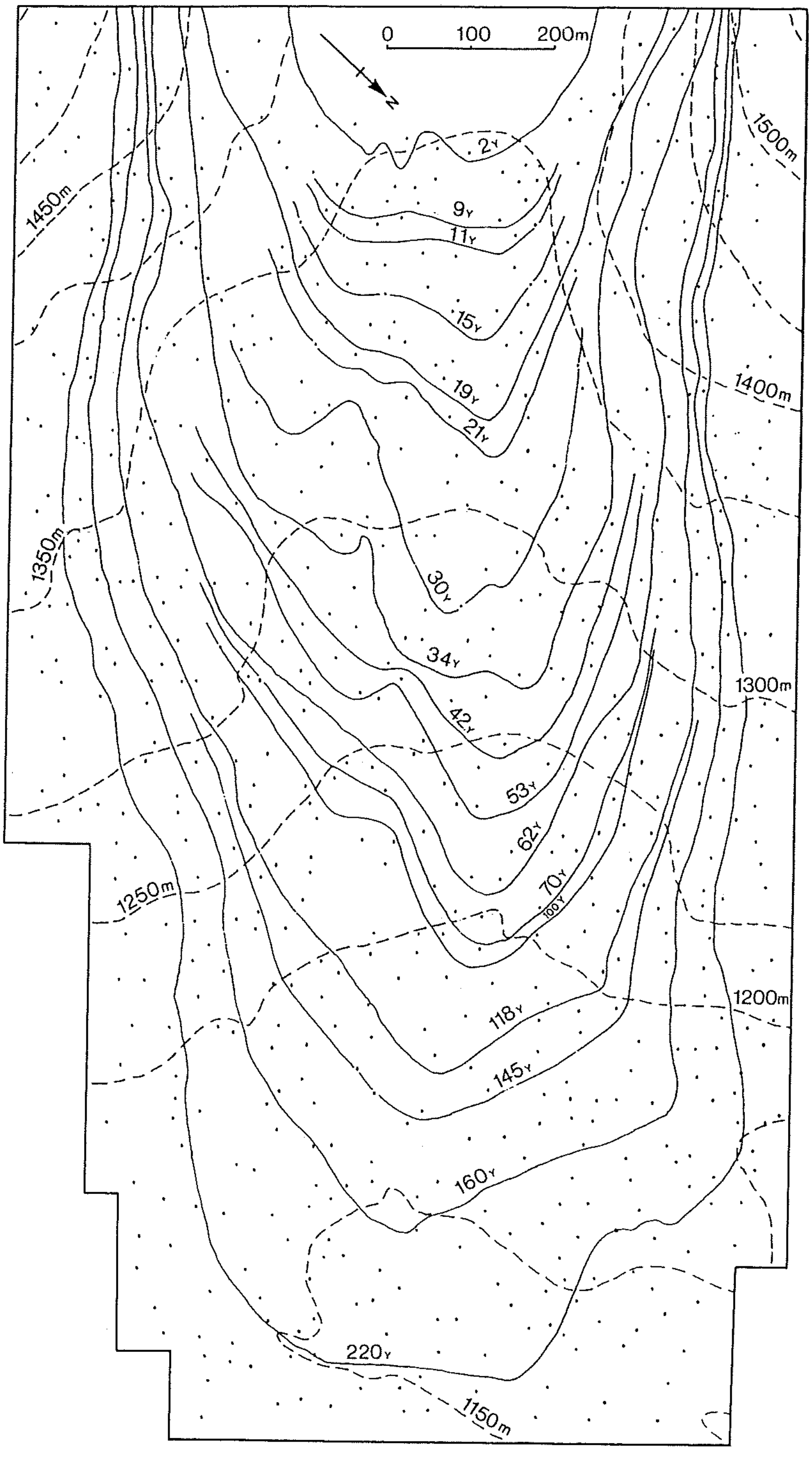

FIG. 3. Map of Storbreen gletschervorfeld showing the areal chronology: ——, isochrone; – – –, contour; •, study site.

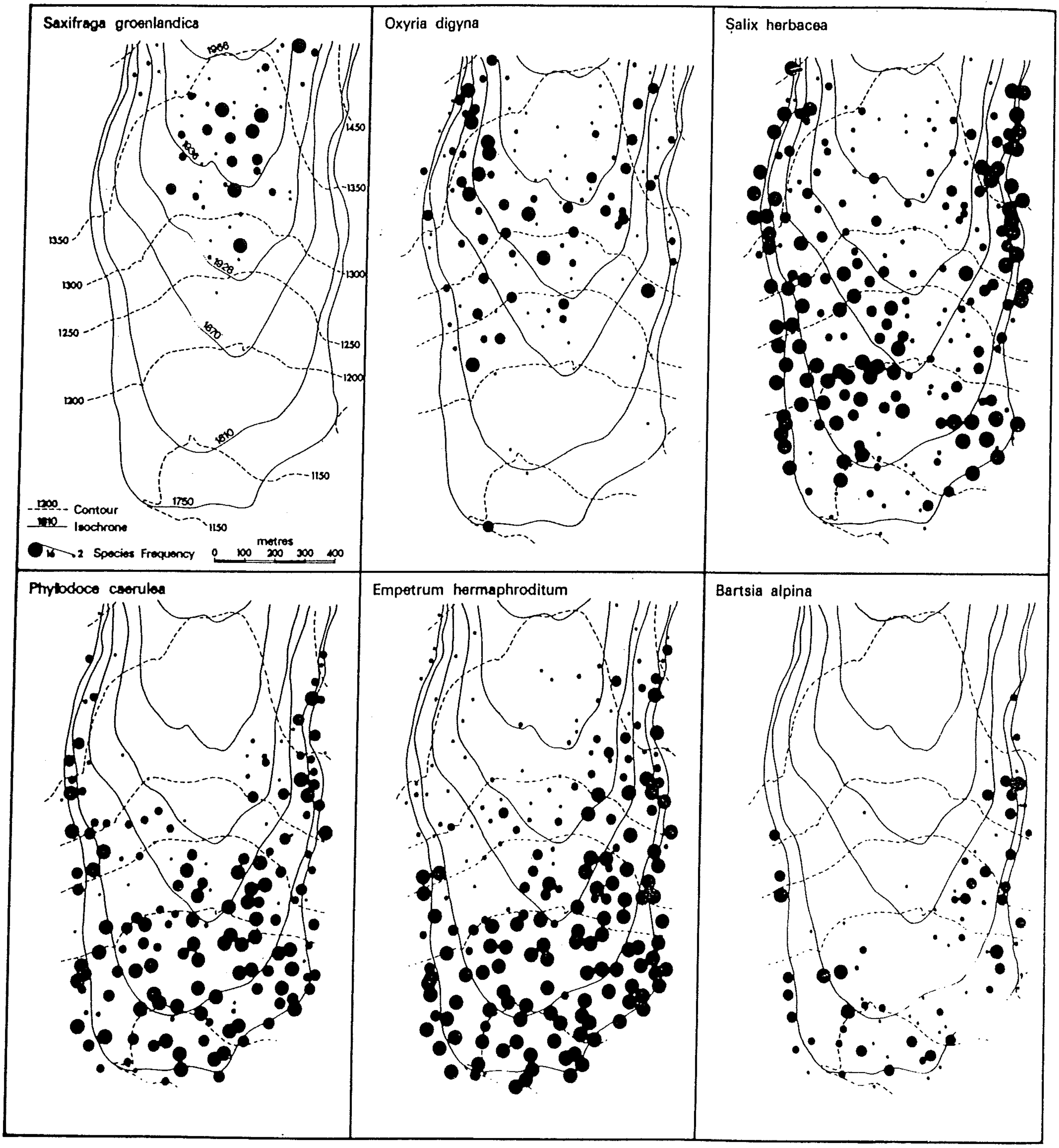

FIGURE 3. Distribution maps of selected species in relation to terrain age and topographic variation. Each circle represents the number of quadrats per site at which the species occurs. For clarity, only those sites recorded in 1970 are included.

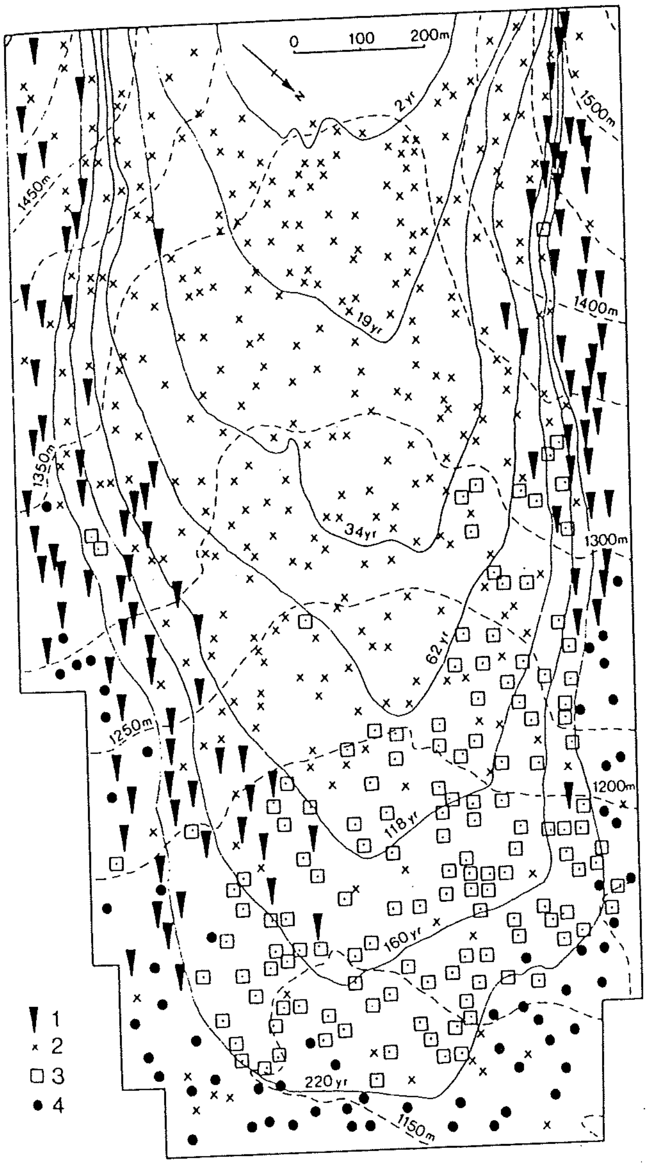

FIGURE 4. Distribution maps of four vegetation types in relation to terrain age and topography: 1, *Salix herbacea-Polygonum viviparum* snowbed community; 2, *Poa alpina-Cerastium* spp. pioneer community; 3, *Phyllodoce caerulea-Salix* spp. species-poor heath community; 4, *Betula nana-Vaccinium* spp. heath community. The assemblage-types were defined using the numerical classification technique of minimum variance agglomeration, combined with a reallocation procedure to check for misclassifications.

Recent increases in species richness and shifts in altitudinal distributions of Norwegian mountain plants

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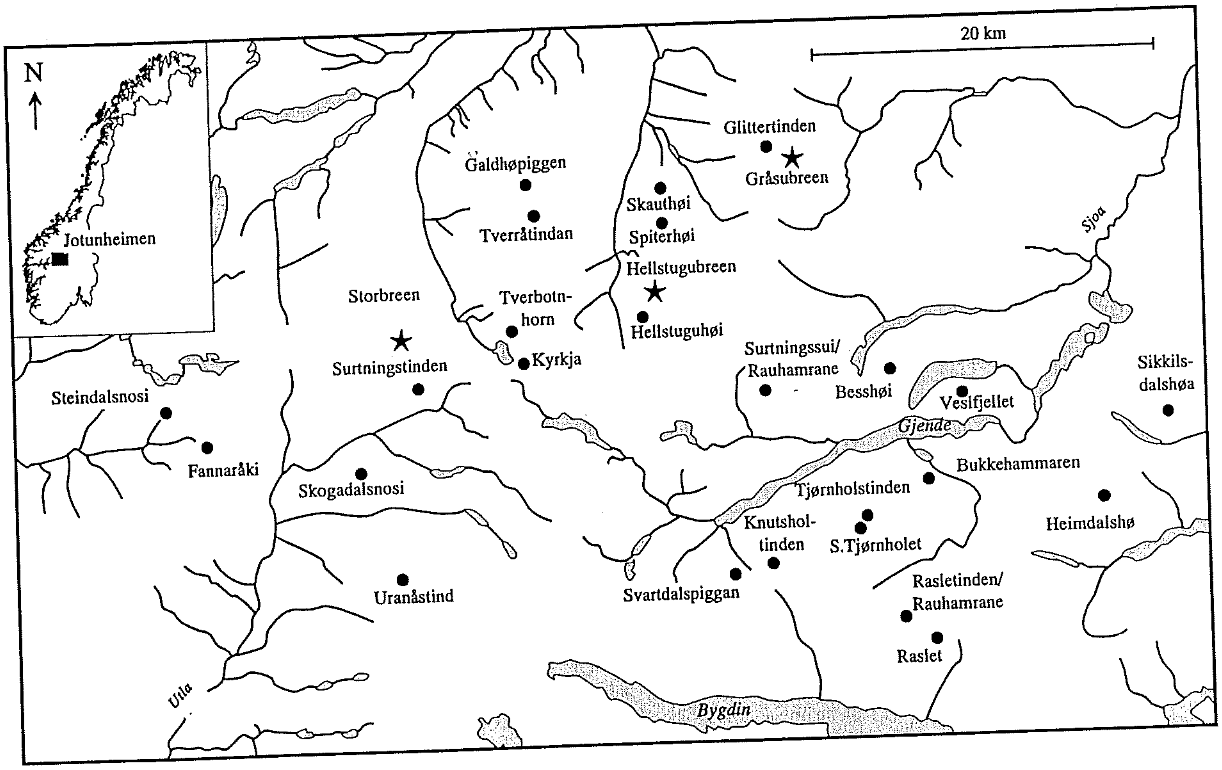


Figure 1 Map of Jotunheimen, central south Norway, showing the 25 mountains studied by Jørgensen (1933) and this study. Three local glaciers are given by •.

om enkelte arters høidegrenser vil også være av mindre betydning. Du Rietz bemerker meget treffende i sin avhandlig »Studien über die Höhengrenzen der Hochalpinen Gefäßpflanzen im nördlichen Lappland« s. 68: »Was wir aber vor allem brauchen, das sind nicht Angaben über derartige extreme Maximalgrenzen der Arten, sondern vergleichende Studien über die Höhengrenzen jeder Art auf verschiedenen Bergen und in verschiedenen Gebieten, ferner vergleichende Studien über die Reihenfolge der Artengrenzen auf demselben Berg.«

3. Undersøkelsen av de enkelte fjelltopper.

Beskrivelsen av ruten på de enkelte fjelltopper i forbindelse med lokalitetsfortegnelsen vil gi et inntrykk av terrengforholdene, og den tilhørende planteliste vil gi et begrep om vegetasjonen og artsrikdommen på de forskjellige topper.

På hver fjelltopp undersøkte jeg en rekke lokaliteter nogenlunde jevnt fordelt opover, idet jeg fortrinsvis valgte de beste lokaliteter. Som oftest tok jeg 2—3 observasjoner for hver 100 m jeg gikk opover. De fleste undersøkelser blev utført på veien op til toppen.

Tjernhulstind 2329 m.

24. og 26. juli 1930.

Fra Svarthammerhytta fulgte jeg stien opover Leirungsdalen ca. 3 km. Derifra drog jeg rett op lien som ligger mot syd. Den er meget frodig, en mengde små og store bekker gir den tilstrekkelig fuktighet. På hellingen ned mot Tjernhulsbekken er der mange meget gode lokaliteter. Terrenget er småkupert, hauger og knauser gir mange lune bakkehell.

Lien er temmelig bratt op til ca. 1700 m. Da blir den slakkere og går over til den store steinslette som strekker sig helt henimot opstigningen til selve tinden.

Sletten består for det meste av middelstor stein, så noen sammenhengende vegetasjon finnes ikke. Heller ikke ved opstigningen til den egentlige topp er der sammenhengende vegetasjon. Steinuren her består av veldige steinkolosser som ligger

Fig. 2. Tjernhulstind sett fra Høgdebrottet. Leirungstind i bakgrunnen. Fot. R. J. 23. juli 1930.

hulter til bulter. Det blir vanskelig å komme frem, og jeg stanser på 2130 m. Mellem steinblokkene er der enkelte steder små vegetasjonsflekker som vesentlig består av *Ranunculus glacialis*, *Luzula confusa*, *Poa laxa* og *Salix herbacea*.

På Tjernhulstind fant jeg 48 arter, derav 5 over 2000 m.

I det hele undersøkte jeg 15 lokaliteter som her er numererte fra 1 til 15:

1	1520 m	Frodig gress-skråning mot S.
2	1600	Bratt gressbakke mot S. Små bekker.
3	1660	Bekkefar mot S.
4	1700	Myret slette.
5	1710	Steinet slette mot S.
6	1750	Sneleie nedenunder en snefonn mot S.
7	1800	Sneleie mot S mellem to snefonner.
8	1850	Mager steinslette mot S.
9	1880	Ved opstigning til Tjernhulstind. Fuktig, steinet helling.
10	1950	Steil, storsteinet ur mot S. Tørt.
11	2000	Steil, storsteinet ur mot S. Tørt.
12	2050	Flat, værhård rygg med meget stein.
13	2080	Mellem store steiner mot SV.
14	2090	Mellem store steiner mot SV.
15	2130	Steil, storsteinet ur mot S. Tørt.

Planteliste for Tjernhulstind.

Meter	1520	1600	1660	1700	1710	1750	1800	1850	1880	1950	2000	2050	2080	2090	2130
Lokalitet	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ranunculus glacialis	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Poa laxa	-	+	-	+	+	+	+	+	+	+	+	-	+	+	+
Luzula confusa	+	-	+	+	+	+	+	+	+	+	+	-	-	+	-
Salix herbacea	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-
Silene acaulis	+	+	+	+	+	-	+	+	-	+	+	+	-	-	-
Erigeron uniflorus	+	+	+	+	+	+	-	+	+	+	-	-	-	-	-
Cerastium alpinum	+	+	+	+	+	-	-	-	+	-	-	-	-	-	-
Saxifraga groenlandica	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Sibbaldia procumbens	-	-	+	+	+	+	+	+	-	-	-	-	-	-	-
Trisetum spicatum	-	+	-	-	-	+	+	+	-	-	-	-	-	-	-
Carex rupestris	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Sedum roseum	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-
Polygonum viviparum	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-
Deschampsia alpina	-	+	+	+	+	+	-	-	-	-	-	-	-	-	-
Carex rigida	+	+	-	+	+	+	-	-	-	-	-	-	-	-	-
Festuca ovina	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
Antennaria alpina	+	+	+	-	+	-	-	-	-	-	-	-	-	-	-
Potentilla alpestris	+	+	+	-	+	-	-	-	-	-	-	-	-	-	-
Taraxacum croceum	+	+	+	-	+	-	-	-	-	-	-	-	-	-	-
Juncus trifidus	+	-	+	-	+	-	-	-	-	-	-	-	-	-	-
Thalictrum alpinum	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Saussurea alpina	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Pedicularis Oederi	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-
Veronica fruticans	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-
Phleum alpinum	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Hieracium alpinum	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Anemone vernalis	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Anthoxanthum odoratum	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Viscaria alpina	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Lycopodium selago	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Campanula rotundifolia	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Bartschia alpina	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxyria digyna	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Luzula frigida	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Angelica archangelica	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salix lapponum	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ranunculus acer	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rumex acetosa	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vaccinium vitis idæa	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Solidago virgaurea	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Veronica alpina	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euphrasia minima	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chamænerium angustifolium	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Minuartia biflora	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juniperus communis	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arctostaphylos alpina	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Empetrum nigrum	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Geranium silvaticum	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-

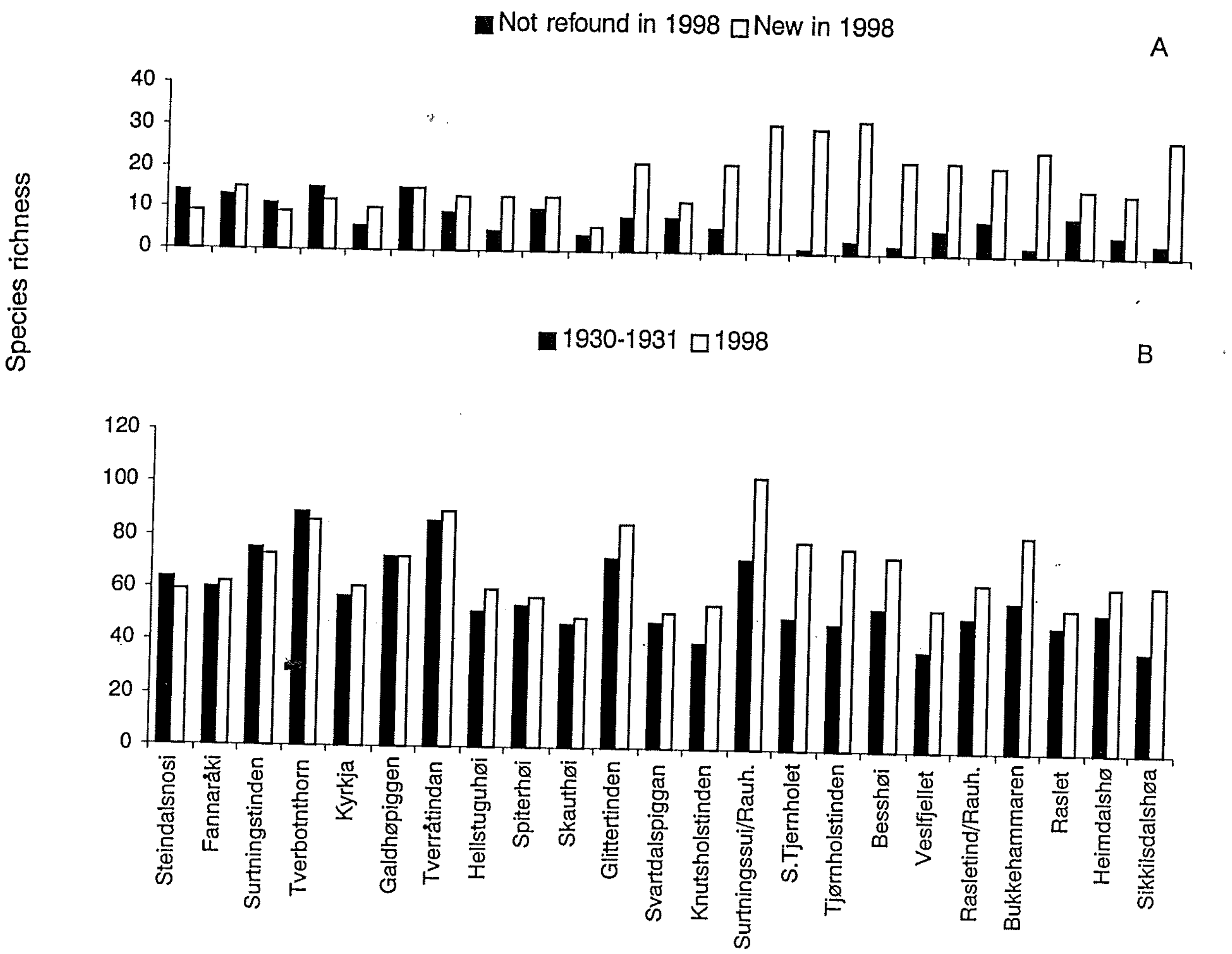
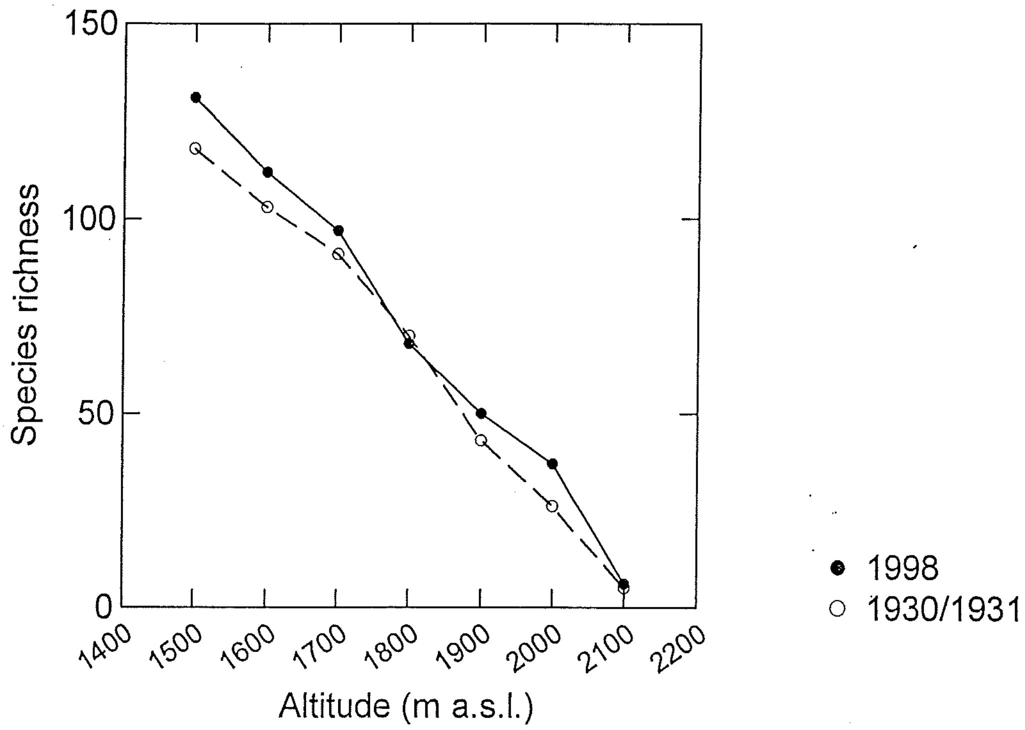
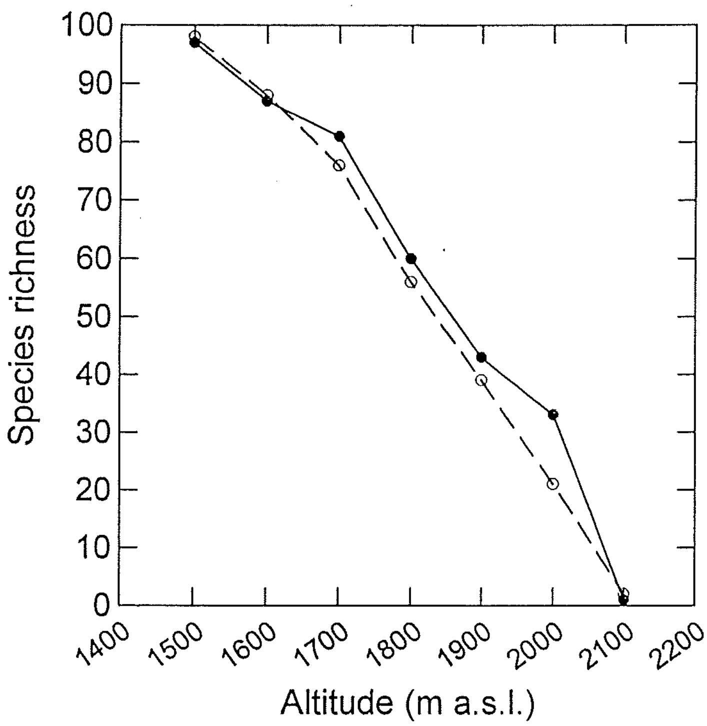


Figure 2 The species richness on the 23 mountains studied arranged from west (left) to east (right), showing **(A)** the number of species not refound in 1998 and of new species found in 1998 only, and **(B)** the total species richness per mountain in 1930-1931 and 1998.

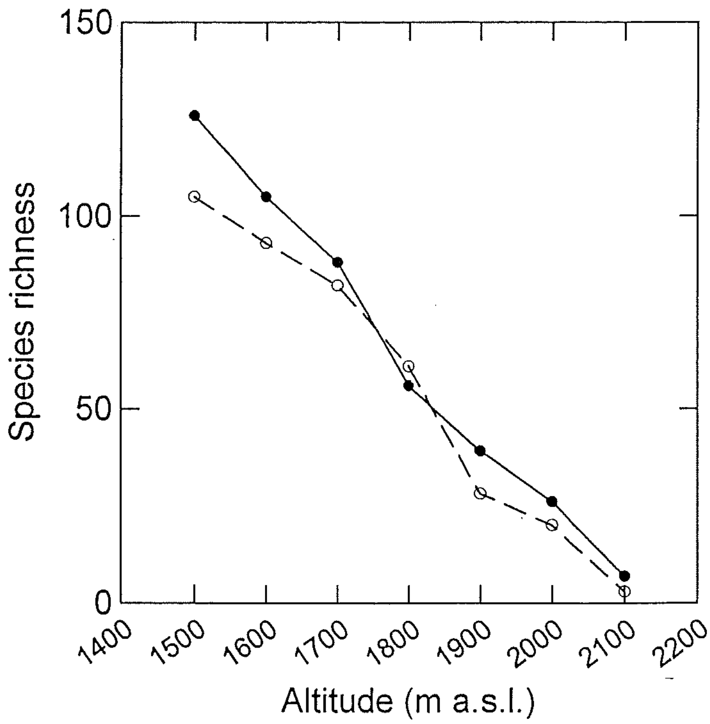
All mountains



West 1931/1998



East 1930/1998



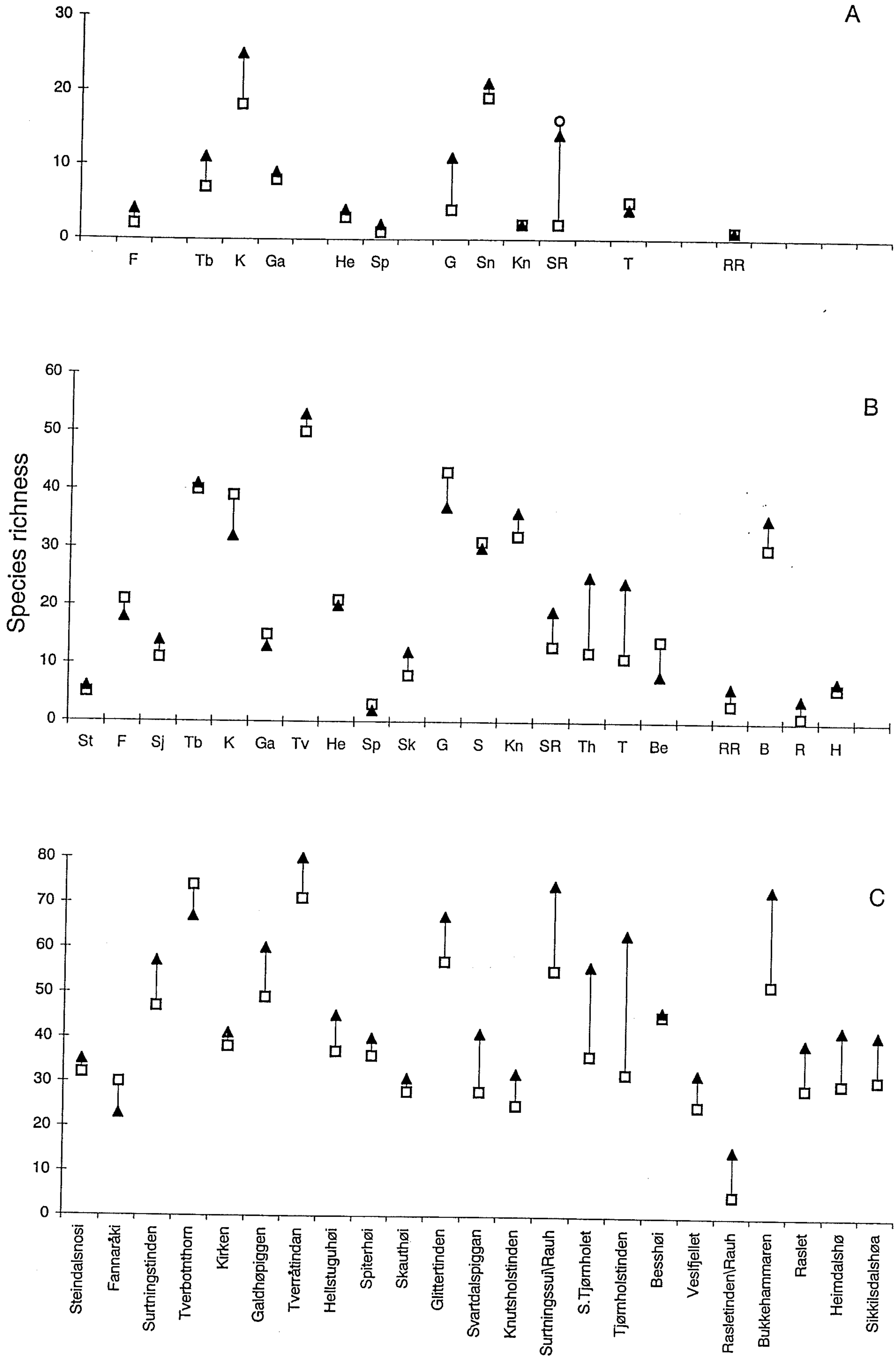
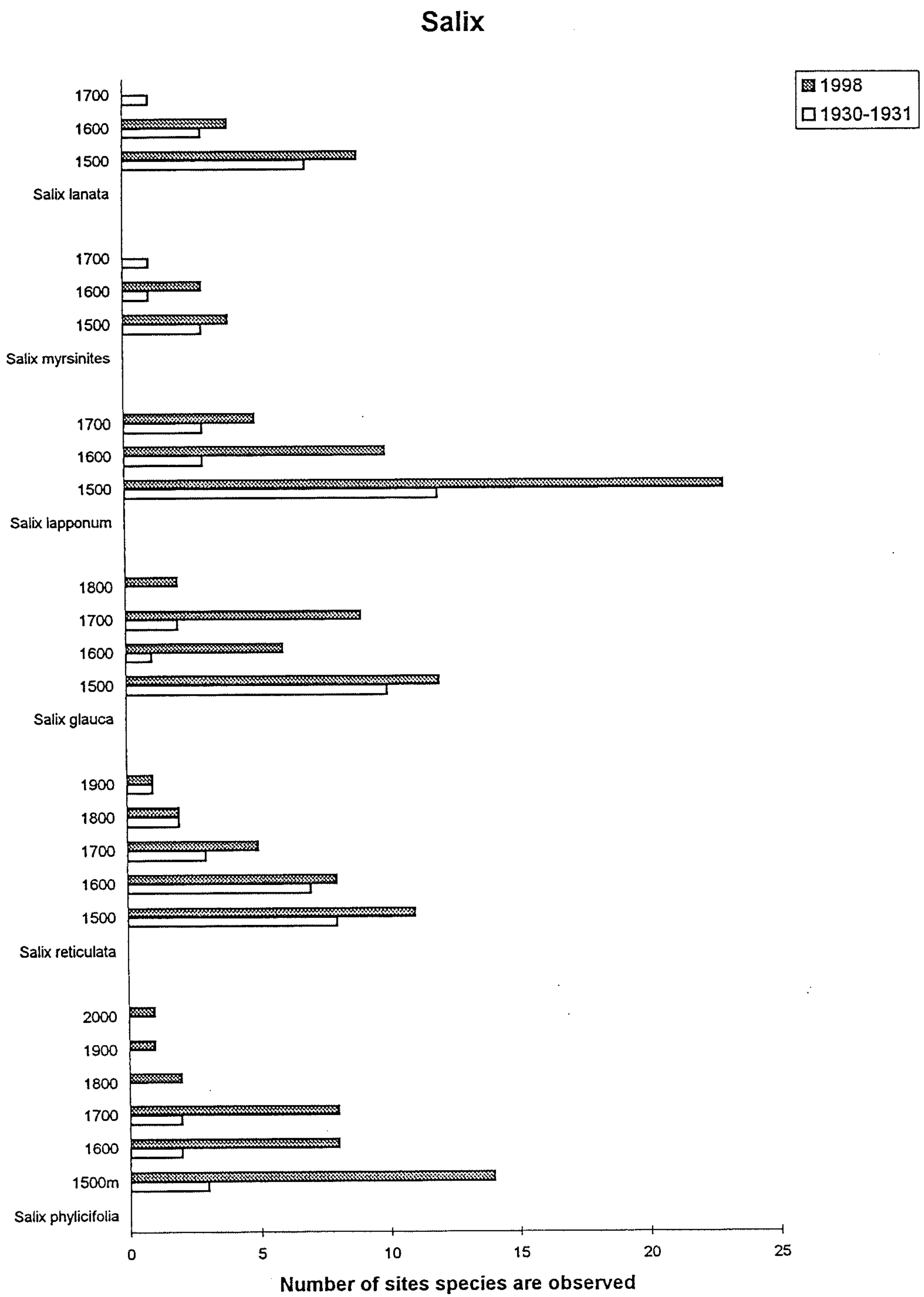
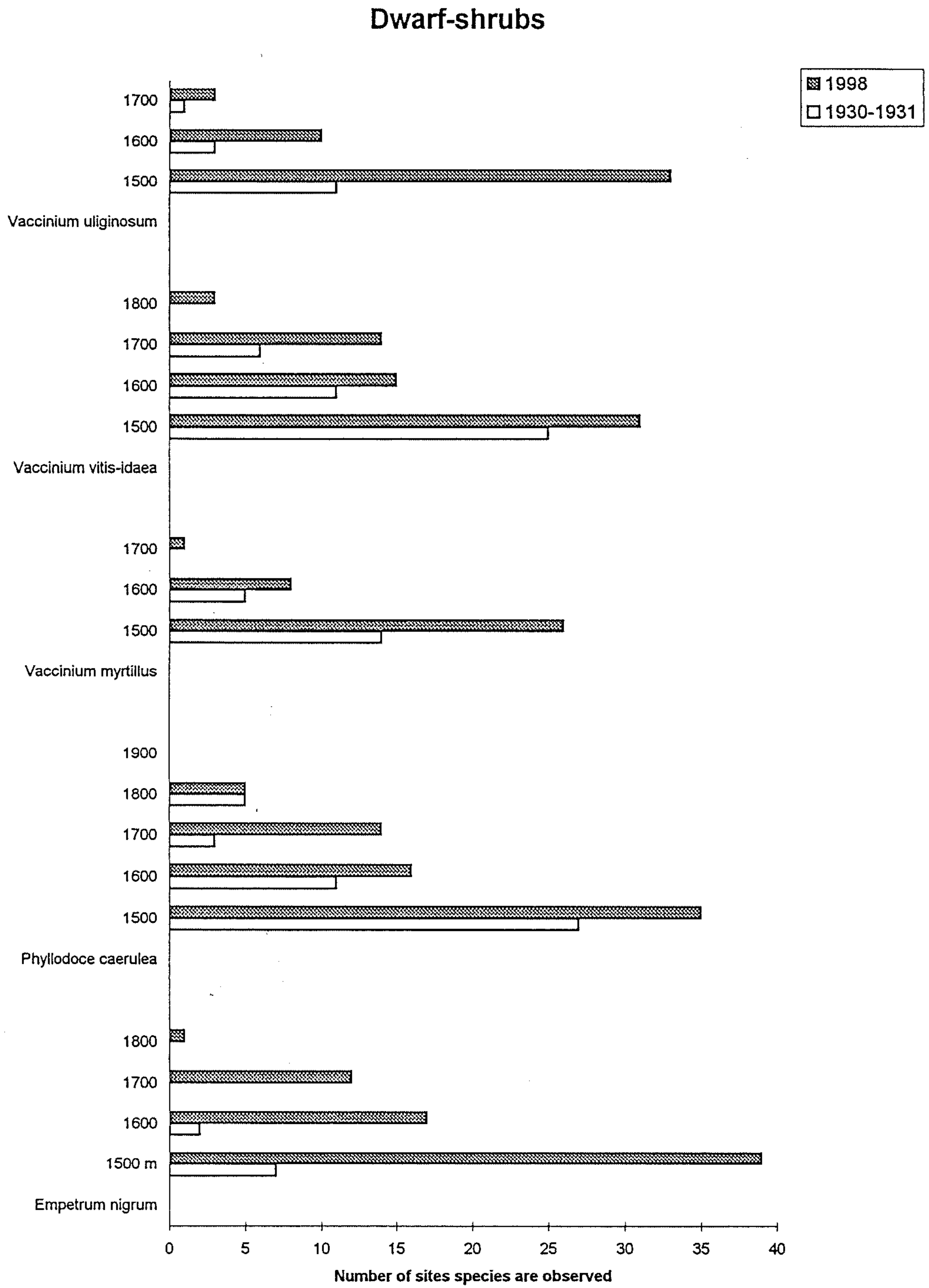


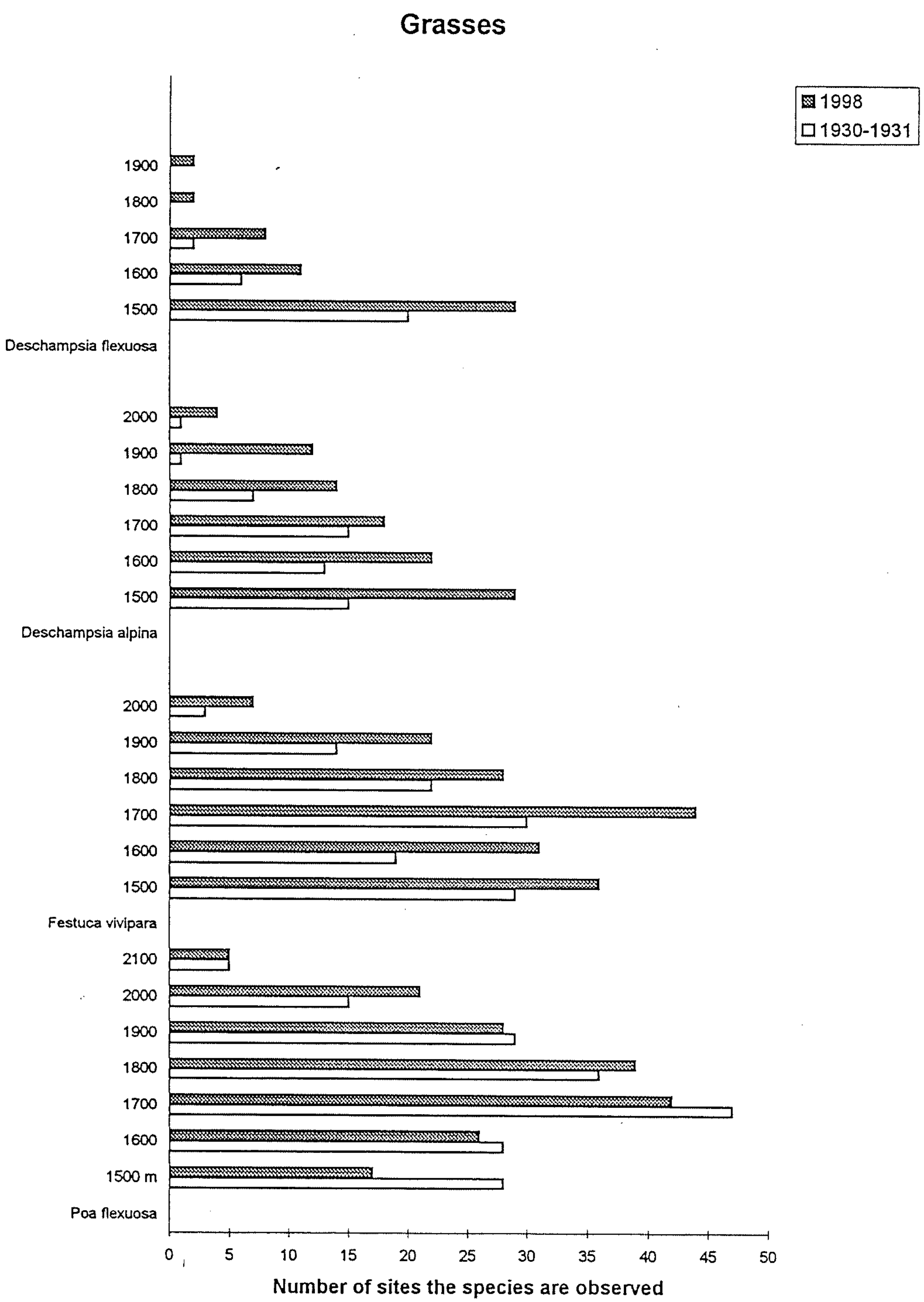
Figure 4 Change in total species richness within different altitudinal bands **(A)** > 2000 m, **(B)** 1800-2000 m, and **(C)** 1600-1800 m. □ = 1930-1931 records, ▲ = 1998 records, o = 1951 records (Dahl and Hygen, 1951). The mountains are arranged from west (left) to east (right), as in Fig. 2.



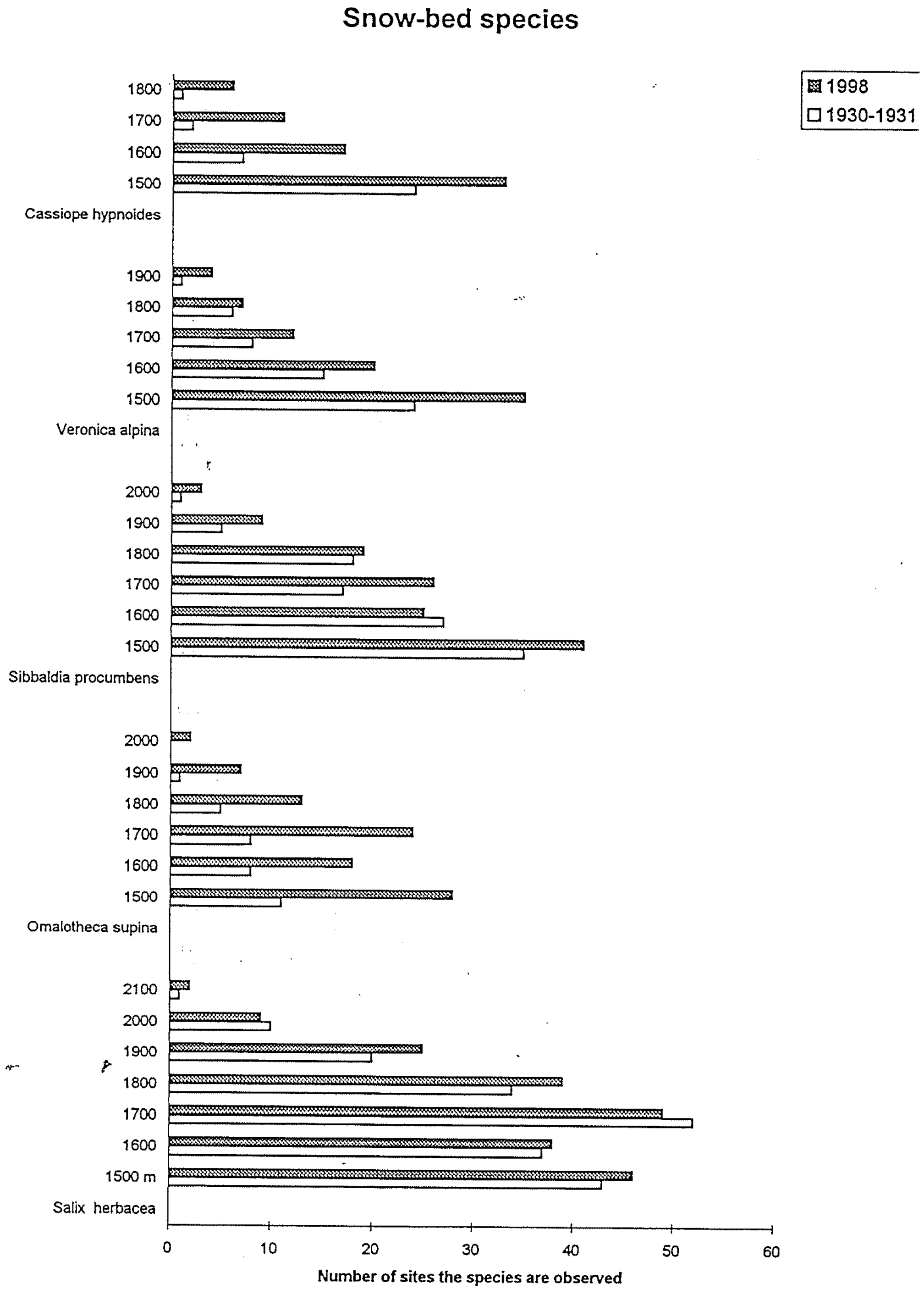
Salix
1998
1930-1931
1700
1600
1500
Salix lanata
1700
1600
1500
Salix myrsinites
1700
1600
1500
Salix lapponum
1800
1700
1600
1500
Salix glauca
1900
1800
1700
1600
1500
Salix reticulata
2000
1900
1800
1700
1600
1500m
Salix phylicifolia
0
5
10
15
20
25
Number of sites species are observed



Dwarf-shrubs
1998
1930-1931
1700
1600
1500
Vaccinium uliginosum
1800
1700
1600
1500
Vaccinium vitis-idaea
1700
1600
1500
Vaccinium myrtillus
1900
1800
1700
1600
1500
Phyllodoce caerulea
1800
1700
1600
1500 m
Empetrum nigrum
0
5
10
15
20
25
30
35
40
Number of sites species are observed



Grasses
1998
1930-1931
Deschampsia flexuosa
Deschampsia alpina
Festuca vivipara
Poa flexuosa
1500 m
1600
1700
1800
1900
2000
2100
0
5
10
15
20
25
30
35
40
45
50
Number of sites the species are observed



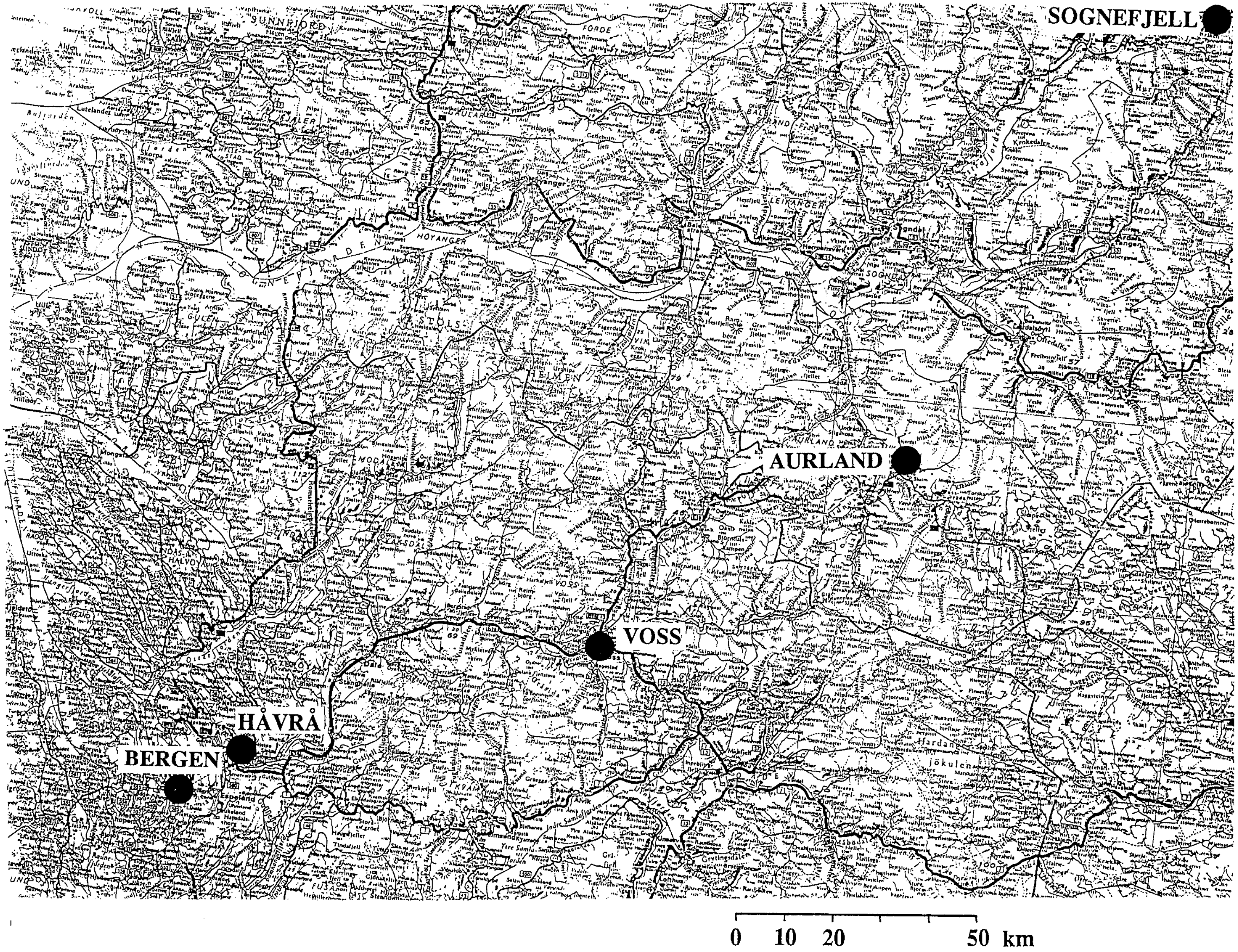
Snow-bed species
1998
1930-1931
Cassiope hypnoides
Veronica alpina
Sibbaldia procumbens
Omalotheca supina
Salix herbacea
1500 m
1600
1700
1800
1900
2000
2100
0
10
20
30
40
50
60
Number of sites the species are observed

	Number of observations 1930-1931	1998	Difference
Luzula spicata	91	161	70
Empetrum nigrum	9	69	60
Omalotheca supina	34	93	59
Festuca vivipara	123	174	51
Deschampsia alpina	55	101	46
Carex rupestris	14	52	38
Carex vaginata	21	59	38
Taraxacum spp.	59	95	36
Cassiope hypnoides	35	70	35
Juncus trifidus	61	92	31
Vaccinium uliginosum	16	46	30
Salix phylicifolia	7	35	28
Saussurea alpina	122	150	28
Thalictrum alpinum	37	64	27
Minuartia biflora	34	59	25
Saxifraga oppositifolia	35	60	25
Phyllodoce caerulea	48	73	25
Carex bigelowii	69	93	24
Veronica alpina	56	79	23
Deschampsia flexuosa	29	49	20
Huperzia selago	45	65	20
Salix lapponum	19	38	19
Sibbaldia procumbens	105	124	19
Vaccinium vitis-idaea	45	63	18
Pedicularis oederi	67	84	17
Bistorta vivipara	116	133	17
Salix glauca	15	30	15
Vaccinium myrtillus	20	35	15
Silene acaulis	128	143	15
Luzula confusa	164	179	15
Pyrola minor	7	21	14
Poa alpina	28	42	14
Solidago virgaurea	34	48	14
Omalotheca norvegica	19	32	13
Festuca ovina	52	65	13
Euphrasia frigida	11	23	12
Salix herbacea	201	213	12
Bartsia alpina	44	55	11
Athyrium distentifolium	3	13	10
Viola palustris	7	17	10
Antennaria dioica	16	26	10
Cardamine bellidifolia	80	90	10
Saxifraga cernua	33	21	-12
Cerastium alpinum	118	104	-14
Saxifraga cespitosa	62	47	-15
Oxyria digyna	111	92	-19
Trisetum spicatum	138	114	-24
Erigeron uniflorus	123	85	-38

Saturday, 24 August 2002

Aurland, Voss, Håvrå, Bergen

DAY 7. Saturday, 24th. August



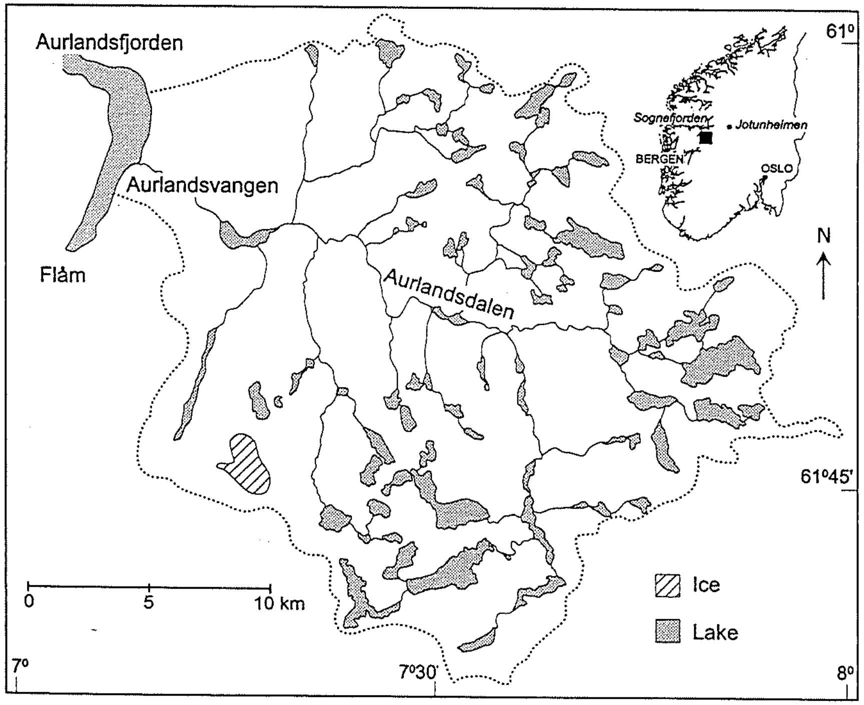


Fig. 1. The Aurland study area and (insert) its position in southern Norway (from Faugli 1994b).

Table 1. Vascular plant species statistics, percentage area, and climatic parameters along the Aurland altitudinal gradient.

Altitudinal band (m)	Mean temperature[a]		Mean annual precipitation (mm)	Percentage area of band	Species with distribution limits		Total species turnover (Upper+Lower)	Total number of species
	July °C	January °C			Upper	Lower		
0–100	15.0	−2.0	695[b]	1.9	18	–	–	236
100–200	14.4	−2.4	718	0.5	14	31	45	256
200–300	13.9	−2.9	747	0.4	12	7	19	248
300–400	13.3	−3.3	783	0.6	13	10	23	241
400–500	12.7	−3.8	825	0.6	11	11	22	238
500–600	12.2	−4.2	875	0.8	7	15	22	242
600–700	11.6	−4.6	931[b]	1.0	30	28	58	263
700–800	11.0	−5.1	994	2.9	29	24	53	253
800–900	10.4	−5.5	1064[b]	2.4	23	27	50	249
900–1000	9.9	−6.0	1140	5.2	23	2	25	227
1000–1100	9.3	−6.4	1224	17.0	30	12	42	217
1100–1200	8.7	−6.8	1314	16.4	26	14	40	198
1200–1300	8.2	−7.3	1411	10.0	17	1	18	168
1300–1400	7.6	−7.7	1515	11.3	32	4	36	155
1400–1500	7.0	−8.2	1625	24.6	60	0	60	124
1500–1600	6.5	−8.6	1743	2.4	33	1	34	67
1600–1700	5.9	−9.0	1867	1.9	25	0	25	34
1700–1764	5.3	−9.5	1998	0.1	(10)	0	–	10

[a] based on interpolations from neighbouring stations, [b]values measured, others are estimated by regression.

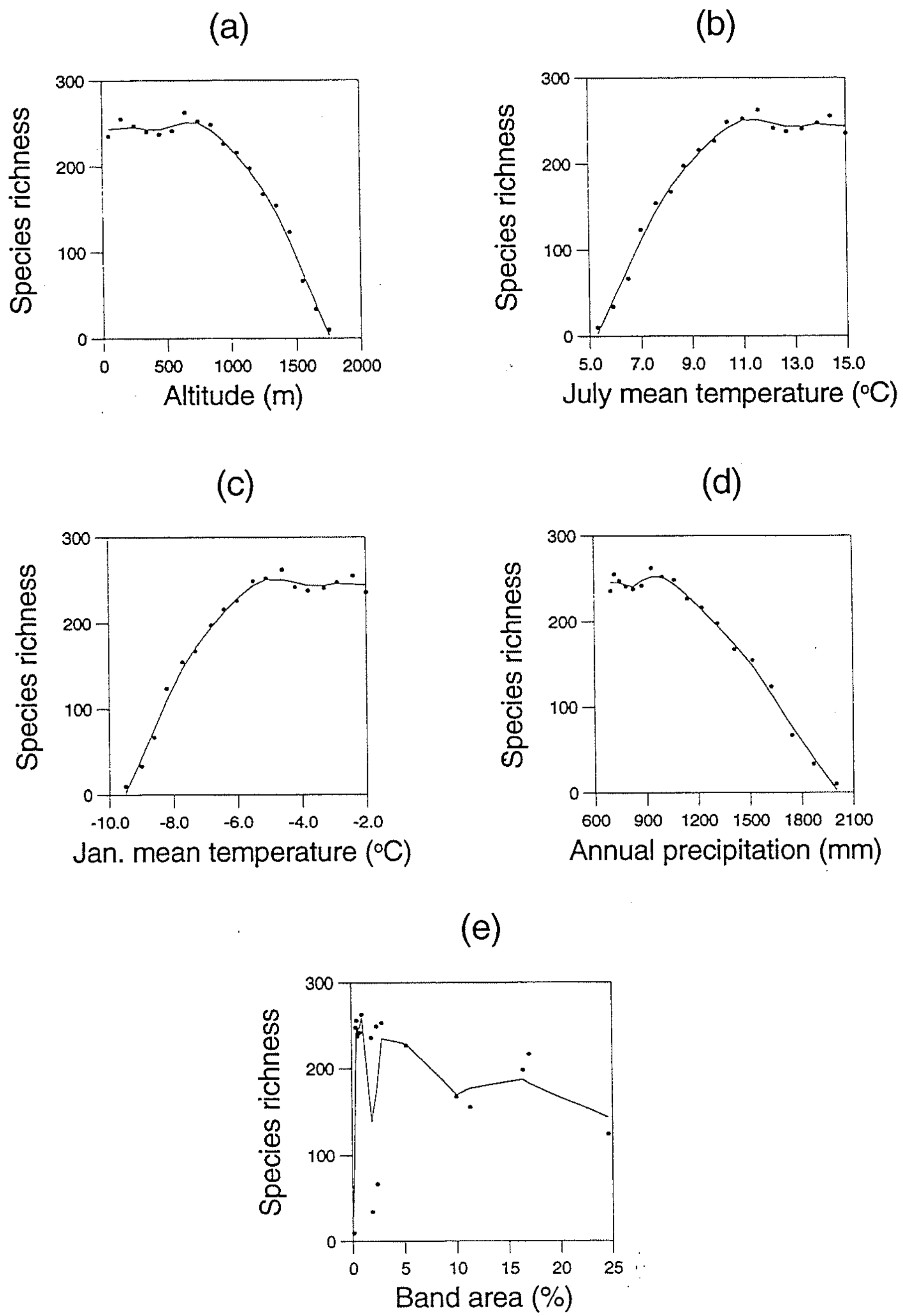
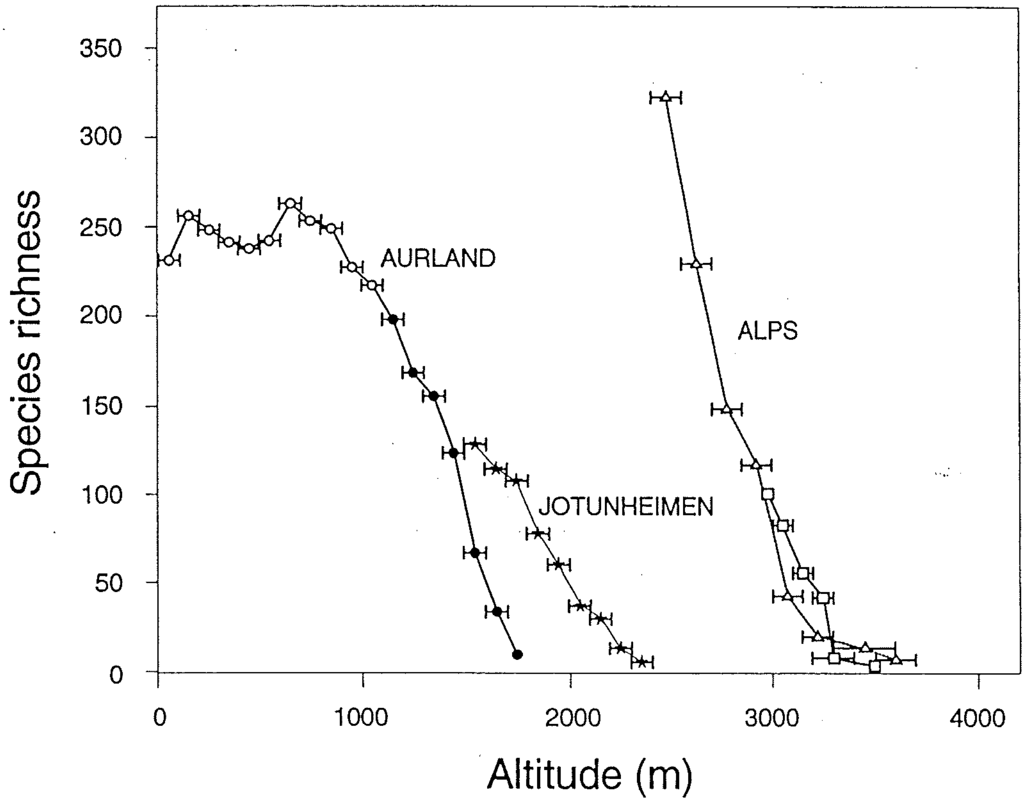


Fig. 2. Number of vascular plant species within 100 m altitudinal bands plotted against a) altitude, b) mean July temperature, c) mean January temperature, d) annual precipitation, and (e) percentage area of altitudinal band. The fitted lines are LOESS smoothers (span = 0.35).

Fig. 3. Number of vascular plant species within 100 m altitudinal bands plotted against altitude. Circles are the results from Aurland. Solid circles denote bands above the birch forest limit. Data from the Jotunheimen mountains in southern Norway are shown as asterisks (data from Jørgensen 1932). To the right, the number of species in relation to altitude in similar investigations in the Alps. Squares give the results from Rübel (1911) and triangles the results from Raunkiær (1908).



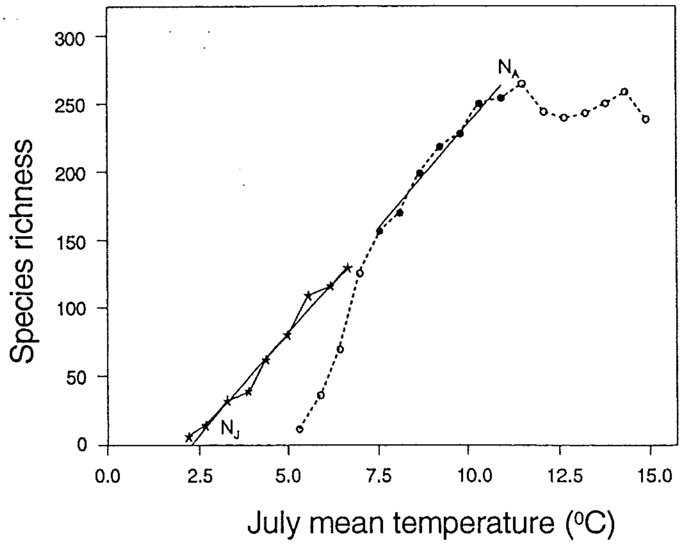


Fig. 6. Number of vascular plant species in relation to mean July temperature along two altitudinal gradients. The regression lines for Aurland (N_A), based on the altitudinal bands between 700 and 1500 m a.s.l. (solid circles) are compared to the relationship found by regression analysis of data from the Jotunheimen mountains (N_J) (asterisks) (Jørgensen 1932). The open circles represent Aurland data not included in the N_A regression model.

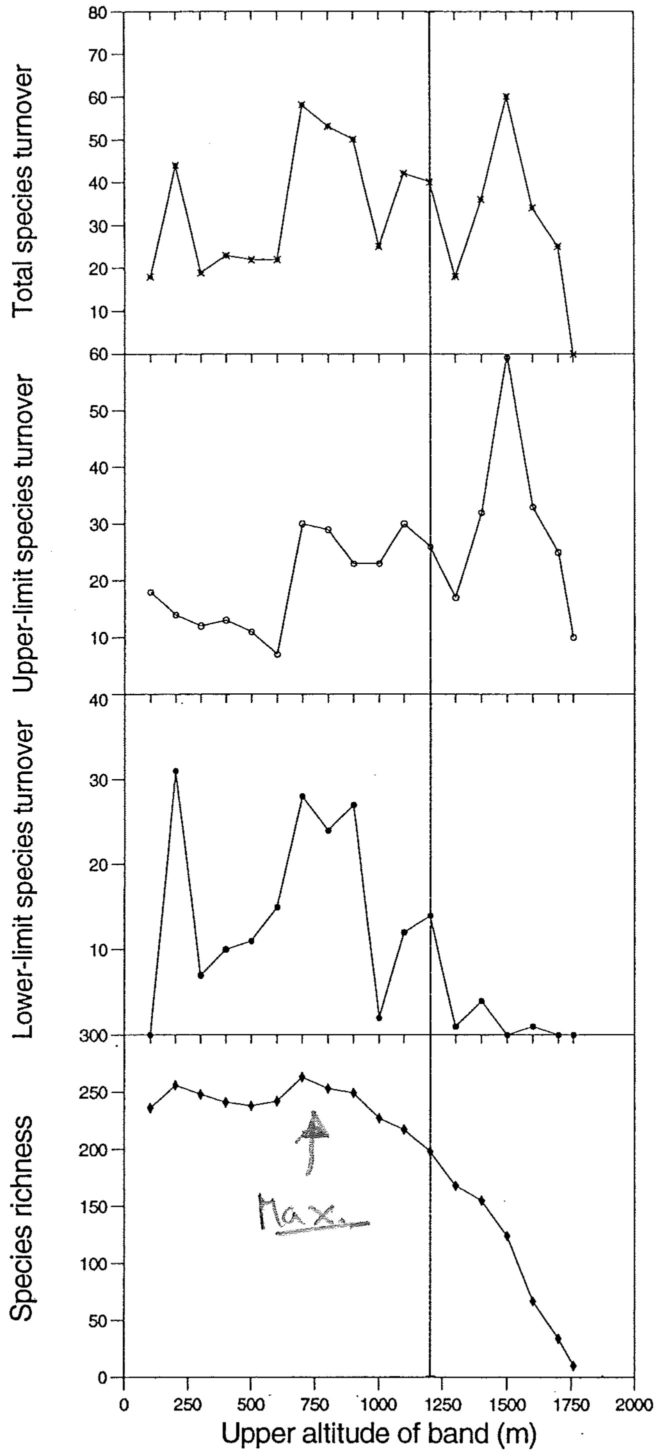


Fig. 4. Variation in vascular plant species richness and species turnover along the Aurland altitudinal gradient. The turnover of upper- and lower-limits of species, total turnover, and total species richness are plotted against the upper altitude of the altitudinal bands. The vertical line shows the position of the forest-limit ecotone.

Weshalb Max. vor WG? Bäume sind entscheidend! Oberhalb fehlen sie, unterhalb sind Kräuter in Nischen sowieso vorhanden.

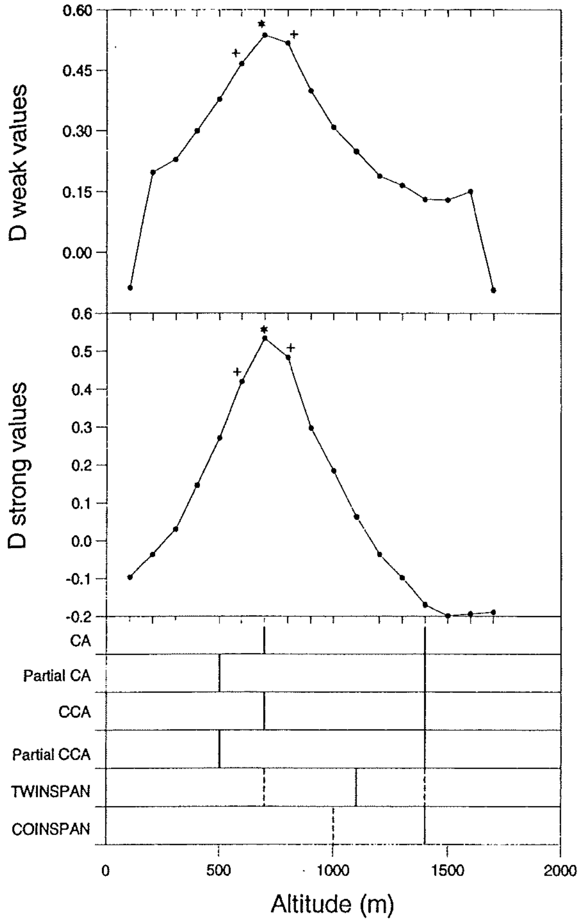


Fig. 7. Plots of D_{strong} and D_{weak} values for the Aurland floristic data. The asterisks indicate the positions of the strongest strong and weak boundaries, the plus signs indicate the other statistically significant ($p < 0.05$) values. The positions of marked changes in CA, partial CA, CCA, and partial CCA axis 1 scores for the different altitudinal bands (see Fig. 8) and the positions of the major divisions in TWINSPAN and COINSPAN analyses of the floristic data are shown for comparison. In the TWINSPAN and COINSPAN results, the first dichotomy is drawn as a solid line, the second-level divisions by a broken line.

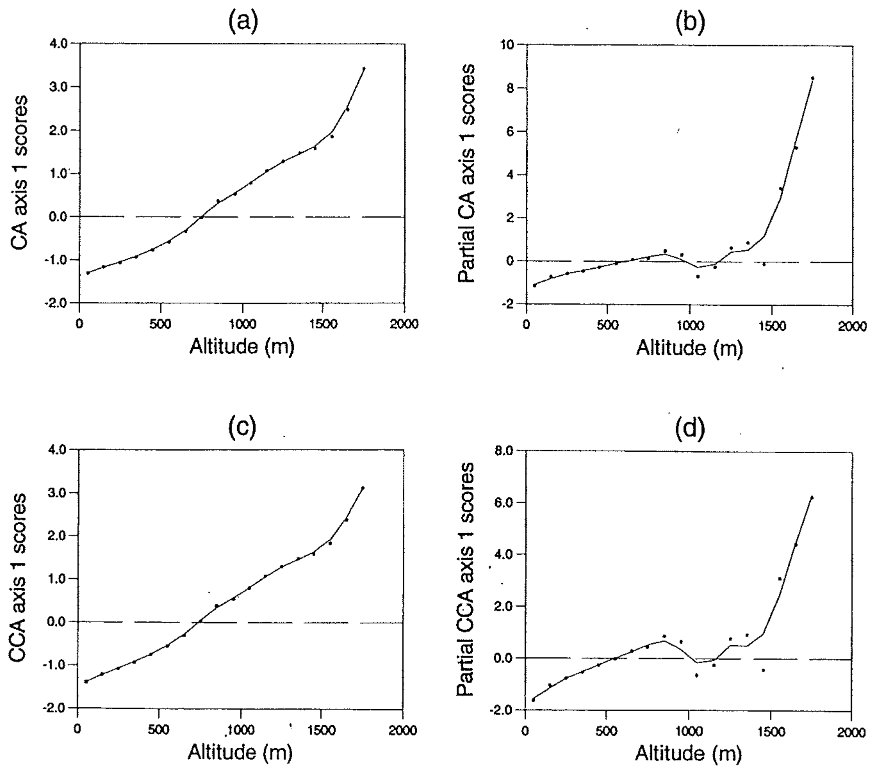


Fig. 8. a) Correspondence analysis (CA) axis 1 scores, b) partial CA axis 1 scores, c) canonical correspondence analysis (CCA) axis 1 scores, and d) partial CCA axis 1 scores for the 18 altitudinal bands plotted against altitude (mid-altitude of each bands). The fitted lines are LOESS smoothers (span = 0.35). The dashed lines distinguish between positive (above the line) and negative (below) scores.

Floristic changes between 600-800 m in Aurland (111 species)

Upper limits (59)

Betula pendula
Ulmus glabra
Salix caprea

Geum urbanum
Epilobium montanum
Vicia sylvatica
Pteridium aquilinum

Asplenium septentrionale
Woodsia ilvensis
Lychnis viscaria

Galium aparine
G. verum
Linaria vulgaris
Dactylis glomerata

Drosera rotundifolia
Cirsium palustre
Caltha palustris
Phalaris arundinacea

Lower limits (52)

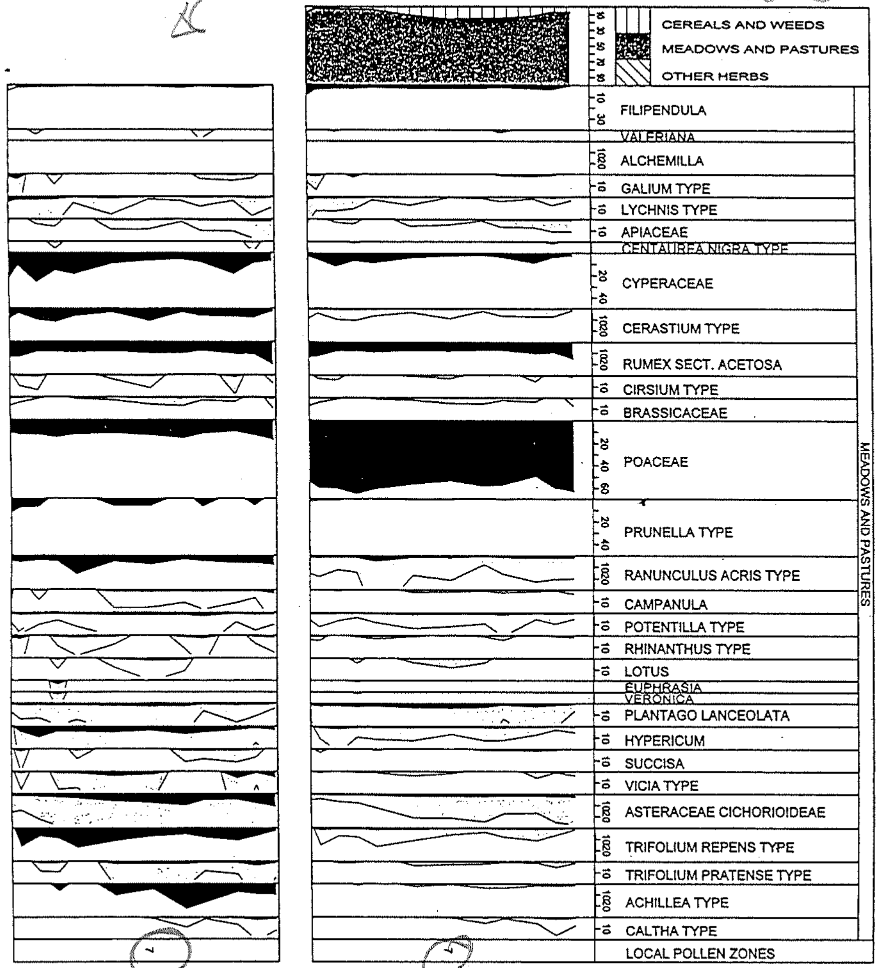
Silene acaulis
Oxyria digyna
Potentilla crantzii
Bartsia alpina
Draba norvegica
Saxifraga cernua
Saussurea alpina
Salix reticulata
Gentiana nivalis
Pyrola norvegica
Astragalus alpinus

Cornus suecica
Listera cordata
Orthilia secunda
Betula nana
Phyllodoce caerulea

Carex pauciflora
Ranunculus reptans
Andromeda polifolia
Vaccinium oxycoccus
ssp. microcarpum

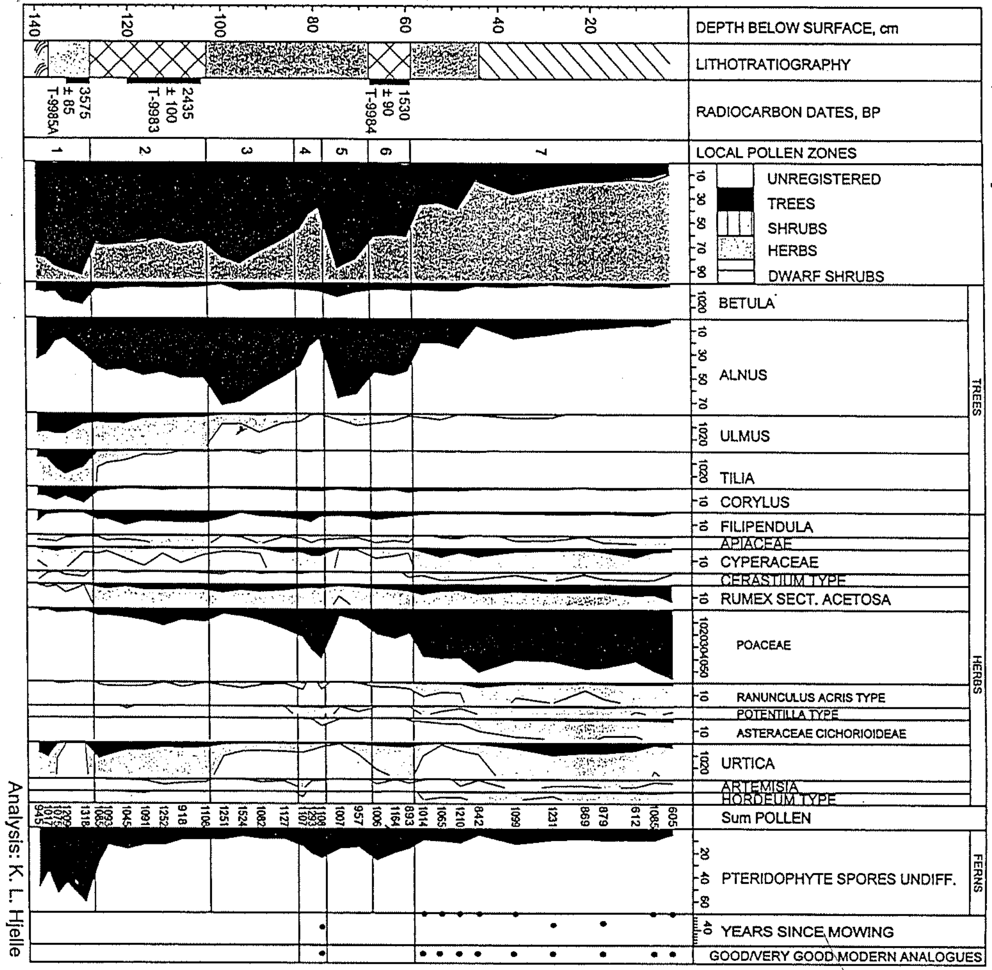
Korrektur über Beobachtung der Oberflächenproben-Pollenhäufigkeiten + der tatsächlichen Vegetation

Herb pollen diagram (top) and transformed herb pollen diagram (bottom)



kalibriert % [?]   ursprüngliche %

Havrå, Osterøy, Hordaland



Analysis: K. L. Hjelle

0 = Heu[?]
40 = Weide[?]