Annals of Glaciology 5 1984

MEAN SUMMER TEMPERATURES AND CIRCULATION IN A SOUTH-WEST NORWEGIAN MOUNTAIN AREA DURING THE ATLANTIC PERIOD, BASED UPON CHANGES OF THE ALPINE PINE-FOREST LIMIT

by

L. Selsing and E. Wishman

(Arkeologisk museum i Stavanger, Boks 478, N-4001 Stavanger, Norway)

ABSTRACT

Radiocarbon dates on 16 pine stumps and trunks revealed the position of the alpine pine-forest limit for the biostratigraphic (i.e. pollen)-defined Atlantic period (8.2 to 5.0 ka BP) in the coastal mountains of south-west Norway. Based on the present topographic mean summer temperature gradients (mean temperature from June to September), and the difference in elevation between the alpine pine-forest limits of the present and the Atlantic periods, mean summer temperature differences between these periods in the forest limit zone are calculated as 0.7°C to the west and 1.0°C in the inner valley districts to the east of the watershed. On the eastern side the mean summer temperature difference becomes greater towards lower altitudes. The alpine pine-forest limits of both the present and the Atlantic periods are characterized by a marked west-to-east inclination. This indicates pronounced westerly winds during the Atlantic period, similar to those today, characterized by more cloudy weather, higher precipitation and less sunshine to the west than to the east of the watershed.

LIST OF SYMBOLS

APFL	Climatic alpine pine-forest limit, Atlantic period
PPFL	Climatic alpine pine-forest limit, present
g_A	Topographic gradient of mean summer temperature in atmosphere of Atlantic period
g_{AE}	Topographic gradient of mean summer temperature in atmosphere of Atlantic period, east side
g_{AW}	Topographic gradient of mean summer temperature in atmosphere of Atlantic period, west side
g_P	Topographic gradient of mean summer temperature in present atmosphere
g_{PE}	Topographic gradient of mean summer temperature in present atmosphere, east side
g_{PW}	Topographic gradient of mean summer temperature in present atmosphere, west side
h_A	Height of climatic alpine pine-forest limit during the Atlantic period
h_{AE}	Height of climatic alpine pine-forest limit during the Atlantic period, east side
h_{AW}	Height of climatic alpine pine-forest limit during the Atlantic period, west side
h_P	Mean height of present climatic alpine pine-forest limit
h_{PE}	Mean height of present climatic alpine pine-forest limit, east side
h_{PW}	Mean height of present climatic alpine pine-forest limit, west side
h_S	Height of watershed
h_E	Height, east side
h_W	Height, west side
P_{AE}	Point on mean summer temperature curve for Atlantic period, east side (Fig.6)
P_{AW}	Point on mean summer temperature curve for Atlantic period, west side (Fig.6)
Δh	$= h_A - h_P$, difference between Atlantic period and present climatic alpine pine-forest elevation
Δh_E	$= h_{AE} - h_{PE}$, difference between Atlantic period and present climatic alpine pine-forest elevation, east side
Δh_W	$= h_{AW} - h_{PW}$, difference between Atlantic period and present climatic alpine pine-forest elevation, west side
τ	Mean summer temperature, i.e. the mean temperature for June, July, August and September ("tetraterm" in Norwegian)
τ_S	Mean summer temperature at the watershed
τ_P	Mean summer temperature at optimal climatic alpine pine-forest limit
τ_{PE}	Mean summer temperature at optimal climatic alpine pine-forest limit, east side
τ_{PW}	Mean summer temperature at optimal climatic alpine pine-forest limit, west side
$\Delta\tau_A$	Difference in mean summer temperature of east and west sides, Atlantic period
$\Delta\tau_P$	Difference in mean summer temperature of east and west sides, present
$\Delta\tau_E$	Difference between mean summer temperature of the Atlantic period and present, east side
$\Delta\tau_W$	Difference between mean summer temperatureof the Atlantic period and present, west side
$\Delta\tau_S$	Difference between mean summer temperature of the Atlantic period and present, at watershed
τ_E	Mean summer temperature, east side
τ_W	Mean summer temperature, west side

https://doi.org/10.3189/1984AoG5-1-127-132 Published online by Cambridge University Press

1. INTRODUCTION

The post-glacial climatic optimum is well-documented in Scandinavia. Evidence of this warm period in western Norway is based mainly upon studies of vegetation history by pollen analysis (Fægri 1940, Moe 1977). Climatic interpretation in terms of mean temperatures of the Atlantic period usually refer to lowland areas, and yearly and summer mean temperatures of 1 to 2°C above those of the present are frequently mentioned (see, for example, Lamb 1977).

In our study we present some quantitative estimates of mean summer temperatures in the mountain area between Suldal and Setesdal in south-west Norway (Fig.1). These estimates are based upon the interpretation of the presence of old pine stumps and trunks

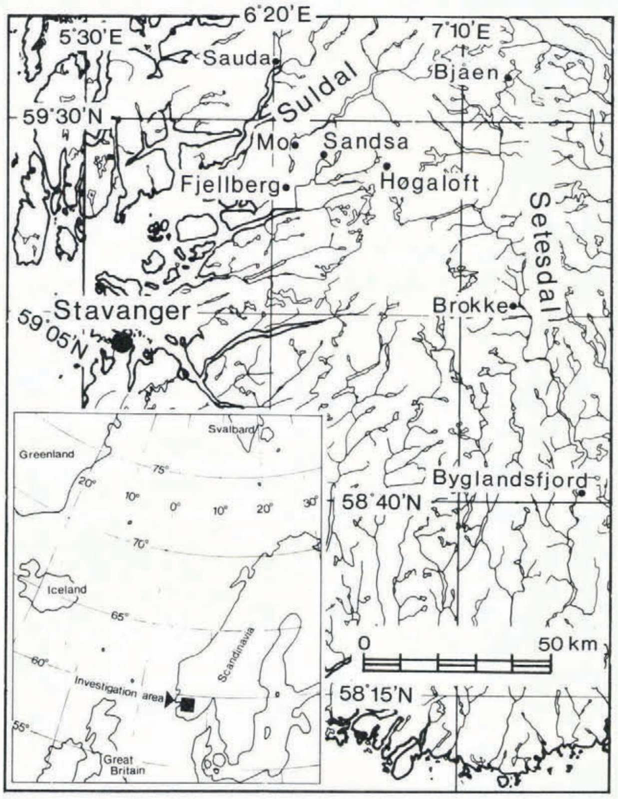

Fig.1. Map showing locations of meteorological stations.

above the present pine-forest limit, which, we believe, represents a higher pine-forest limit. We assume that moisture has always been sufficient in this area and that possible moisture variations have not affected the pine-forest limit. Therefore the alpine pine-forest limit is mainly determined by the mean amount of heat available during the summer season. As an indicator for the summer heat, we use the mean summer temperature (τ), i.e. the mean temperature for June, July, August and September (or "tetraterm" in Norwegian).

The area investigated (Fig.1) lies between Suldal to the west and the north-south oriented valley of Setesdal to the east. The lowland in Suldal is at sea-level, while the valley floor of Setesdal is at 500 to 900 m a.s.l. The mountainous area lies between 1 000 and 1 200 m a.s.l., although in the northern part some summits reach 1 600 m a.s.l. The mountainous area is above the tree line belonging to the low and middle alpine zone. It forms a topographic and climatological divide between the districts to the east and the west of it.

2. THE PRESENT OPTIMAL CLIMATIC ALPINE PINE-FOREST LIMIT

Mork and Heiberg (1937) define the alpine forest limit as the zone between the forested and the non-forested areas, where the distance between the trees, which are at least 3 m high, is greater than 30 m; we have adopted this definition in the present work. By means of detailed field studies (Fig.2), we have determined the alpine pine-forest limit close to systematically collected subfossil trunks and stumps.

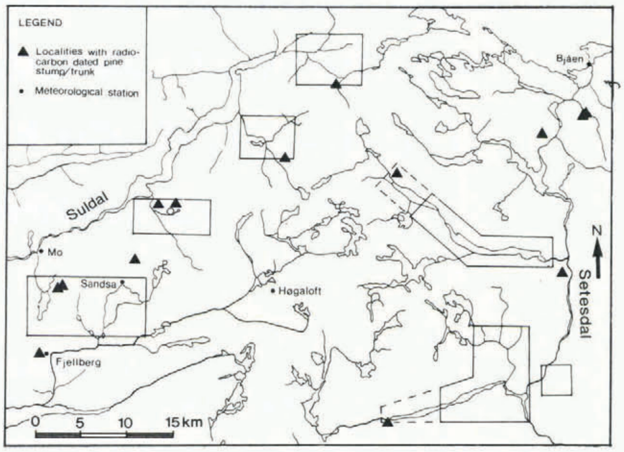

Fig.2. Locations of radiocarbon-dated pine stumps and trunks found above PPFL. PPFL was determined in the enclosed areas.

The highest alpine forest limit was found on south-west exposed slopes, confirming the findings of Aas (1969), and the optimal climatic present pine-forest limit (PPFL) is defined by a line drawn through these points (Fig.3). This line is unambiguous and allows chronological and geographical correlations to be made. The PPFL generally rises eastwards (Fig.3) and is lowest at the westernmost localities at 630 m a.s.l. It rises to 750 m a.s.l. west of the watershed, and reaches 930 m a.s.l. east of the watershed. The mean elevations were estimated to be h_{PW} = 700 m a.s.l. and h_{PE} = 930 m a.s.l. on the Suldal and Setesdal sides, respectively.

3. PRESENT SUMMER CLIMATE

The mean summer temperatures for the "normal" 1931-60 period change with elevation on the west and east sides of the watershed (Fig.4). The mean summer temperature curves are linear regression curves based on temperature records from meteorological stations (Fig.1) for seven years reduced to a 1931-60 standard. Stations to the west of the watershed are Mo, Fjellberg, Sandsa and Høgaloft, at 58, 381, 630, and 1 095 m a.s.l., respectively, and stations to the east of the watershed are Byglandsfjord, Brokke and Bjåen, at 212, 443 and 920 m a.s.l., respectively.

The linear regression curves for the areas west and east of the watershed are given by the equations

$$h_W = 2\,400 - 173\tau_W$$

and

$$h_E = 2\,250 - 148\tau_E$$

respectively, h and τ being corresponding elevation/mean summer temperature values. Each area is characterized by a specific temperature gradient, which is 0.58°C per 100 m (g_{PW}) for the western area, and 0.68°C per 100 m (g_{PE}) for the eastern area.

The mean summer temperature curves are considered as mean curves for the Suldal and Setesdal areas. The curves intersect at a point h_S = 1 350 m a.s.l. and τ_S = 6.1°C. Below the intersection point, the mean summer temperature difference between the

https://doi.org/10.3189/1984AoG5-1-127-132 Published online by Cambridge University Press

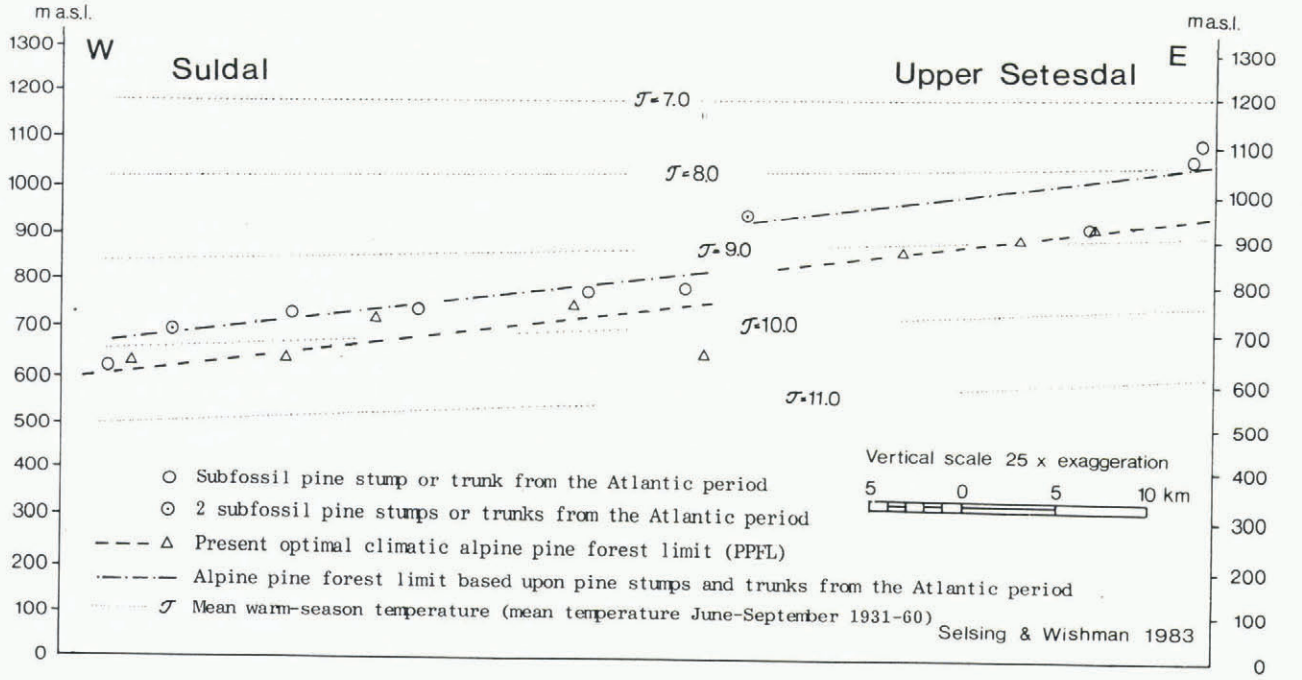

Fig.3. Field of present mean summer temperatures (1931-60), distribution of pine stumps and trunks, and alpine pine-forest limits between Suldal (west) and Setesdal (east).

TABLE I. PRESENT ($\Delta\tau_p$) AND ATLANTIC PERIOD ($\Delta\tau_A$) MEAN SUMMER TEMPERATURE DIFFERENCE BETWEEN EAST (SETESDAL) AND WEST (SULDAL)

	Elevation (m a.s.l.)									
	500	600	700	800	900	1 000	1 100	1 200	1 300	1 350
$\Delta\tau_p$	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0.0	0.0
$\Delta\tau_A$	1.6	1.4	1.2	1.0	0.8	0.7	0.5	0.3	0.1	0.0
$\Delta\tau_A-\Delta\tau_p$	0.8	0.7	0.5	0.5	0.4	0.4	0.3	0.2	0.1	0.0

west and the east increases towards lower elevations. The observed mean summer temperature differences between east and west indicate a different response of the Setesdal and Suldal areas to the general circulation (Table I). Westerly winds are frequent in western Norway. The mean temperatures observed in the east of the area depend largely upon the heat content of air masses arriving from the west. They often carry moist air masses from the Atlantic Ocean, forming clouds, and, frequently, precipitation to the west of the watershed. To the east, the amount of cloud is less and sunshine is more frequent (Table II). These situations favour higher day temperatures to the east.

The observed mean summer temperature differences may also be due to the different locations of the two areas in relation to the sea. In clear weather, proximity to the sea will lessen the maximum air temperatures, and, hence, lower the mean day temperatures. This effect decreases rather rapidly with height, and may contribute to the previously mentioned greater mean summer temperature differences between east and west observed at lower elevations in Setesdal and Suldal.

TABLE II. MEAN NUMBER OF OVERCAST DAYS JUNE TO SEPTEMBER 1931-60

	June	July	Aug	Sept	Mean (June-Sept)
Sauda (west)	14.1	15.8	15.2	16.1	15.3
Byglandsfjord (east)	8.5	10.1	10.9	12.1	10.4

4. ON THE RELATIONSHIP BETWEEN PPFL AND SUMMER CLIMATE

The calculated mean summer temperature curves have positive gradients from west to east, and so has the PPFL (Figs. 3 and 4). This result confirms that the PPFL is correlated with the temperature distribution. Thus, the general circulation which determines the mean summer temperature curve will also to a certain degree determine the position of the PPFL, and both the mean summer temperature curves and the PPFL may be considered as indicators for the mean general atmospheric circulation.

The inclination from west to east of the PPFL and the curves of the mean summer temperature are different (Fig.3). The mean summer temperature at the PPFL to the west (h_{P_W} = 700 m a.s.l.) is 9.8°C and to the east (h_{P_E} = 930 m a.s.l.) is 8.9°C (Fig.4). This implies that the mean summer temperature at the pine forest limit decreases with increasing distance from the coast. This has already been pointed out by, for example, Dahl (1967). We take these mean summer temperature values to be characteristic of the mean PPFL to the west and east sides respectively. Further we assume that they were the same values for the mean alpine pine-forest limit of the Atlantic period (APFL).

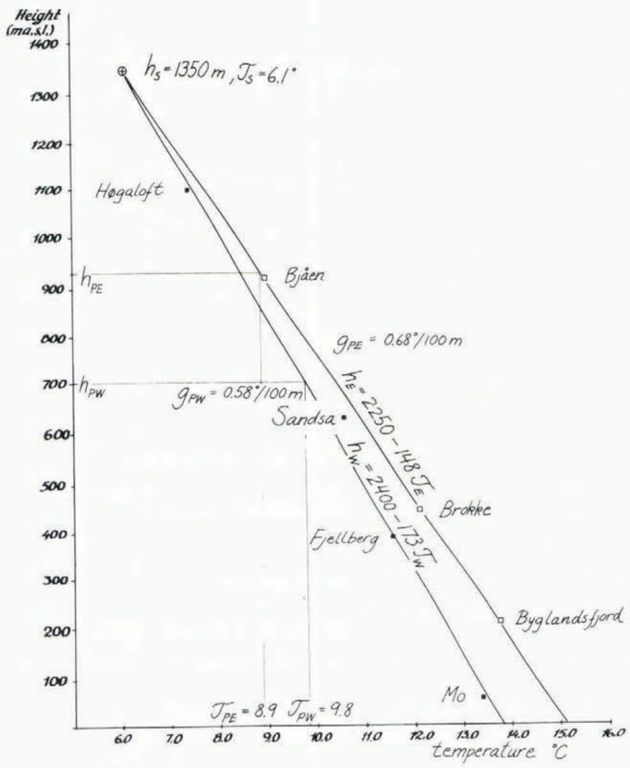

Fig.4. Present mean summer temperatures (1931-60) and mean elevations of PPFL in Suldal (west) and Setesdal (east). (Symbols: see list of symbols.)

5. THE HEIGHT DIFFERENCE BETWEEN THE OPTIMAL CLIMATIC APFL AND THE CORRESPONDING PPFL

By systematic fieldwork we have located the stumps and trunks at the greatest altitude along a west-east line across the area lying above the PPFL. Sixteen stumps and trunks have been radiocarbon-dated at the Radiological Dating Laboratory in Trondheim (Table III), and 12 of these gave an age between 8.2 and 5.0 ^{14}C ka BP, i.e. within a biostratigraphic (i.e. pollen)-defined Atlantic period (Fig.3).

The mean elevations of the stumps and trunks lying to the west and east of the watershed were 765 and 1 045 m a.s.l., respectively. The levels of the stumps and trunks give a minimum height for the APFL elevation. The differences between this minimum value for the APFL and the PPFL are 65 m to the west and 115 m to the east of the watershed. These differences in elevation must, however, be corrected for land upheaval after 8.2 ka BP. The influence of the general soil development and cultural impact has been assumed to be insignificant in this context. Quantitative values for the upheaval are uncertain, but by scrutinizing the literature (Hafsten 1979, Mørner 1980, Anundsen in preparation) we estimate them to be 30 m to the east and 10 m to the west of the watershed. All trunks and stumps were found in peat in bogs. We observed that the pine-forest limit is lower on bogs than on surrounding "dry" land. The difference has been estimated as 60 m. Adding these corrections to the mean level of the stumps, we arrive at a mean elevation for the optimal climatic APFL of 815 m a.s.l. (h_{AW}) to the west and 1 075 m a.s.l. (h_{AE}) to the east of the watershed.

The corrected difference between APFL and PPFL becomes

$$\Delta h_W = h_{AW} - h_{PW} = 115 \text{ m a.s.l.}$$

$$\Delta h_E = h_{AE} - h_{PE} = 145 \text{ m a.s.l.}$$

This result implies that the APFL was characterized by a west-to-east mean inclination that was slightly steeper than the PPFL.

6. CLIMATIC INTERPRETATION

In section 3 we pointed out that the west-to-east inclination of the PPFL is a result of maritime impact, caused by the general westerly circulation. Applying this to the position of the APFL, we conclude that similar conditions must have prevailed during the Atlantic period. If the steeper inclination of the APFL is significant, this may indicate that the general east-west mean summer temperature difference was greater during the Atlantic period than at present.

We have established the alpine pine-forest limits for the Atlantic period and the present in the area of investigation and the results infer a displacement of the limit from the earlier period to the present. We will now present some quantitative estimates of the mean summer temperature differences between the Atlantic period and the present in the areas west and east of the watershed. The estimates show a greater mean summer temperature difference for the eastern than for the western side. Today the lowest part of the troposphere is characterized by a mean decrease of mean summer temperature with height, given by a mean topographic gradient gp (Fig.5).

TABLE III. RADIOCARBON DATES OF WOOD MATERIAL FROM ALPINE SUBFOSSIL STUMPS AND TRUNKS (Reference year in the BP system is AD 1950. $T_{1/2}$ = 5.57 ka)

Test no.	Stump/trunk site	Year of collection	Latitude	Longitude	Elevation (m a.s.l.)	^{14}C ka BP
T-2711	Rennedalen	1977	59°33'21"N	6°52'17"E	780	8.15±0.13
T-2558	Venehei(east)	1976	59°22'04"N	6°25'16"E	620	8.06±0.90
T-2712	Olavstogtjønn	1976	59°35'53"N	7°27'52"E	1 080	7.84±0.10
T-3134	Vallarmyr	1977	59°37'20"N	6°58'21"E	790	7.12±0.60
T-2407	Ormsa I	1976	59°32'50"N	7°04'25"E	950	7.01±0.90
T-2710	Ormsa II	1977	59°32'50"N	7°04'31"E	950	6.74±0.13
T-3138	Olavstogtjønn (east)	1978	59°35'44"N	7°28'37"E	1 110	6.64±0.90
T-2031	Stavastøl I	1973	59°25'44"N	6°28'54"E	690	6.63±0.10
T-3135	Seten(east)	1978	59°25'59"N	7°21'01"E	1 000	6.28±0.80
T-3136	Vidmyr(south)	1978	59°35'20"N	7°21'58"E	930	5.80±0.60
T-2408	Steinstøl(west)	1976	59°30'23"N	6°42'52"E	740	5.69±0.11
T-2709	Stavastøl II	1977	59°25'47"N	6°28'54"E	690	5.24±0.60
T-2409	Væting(west)	1976	59°28'09"N	6°36'13"E	730	4.74±0.90
T-3137	Stavastølsdalen	1978	59°26'13"N	6°29'06"E	710	3.91±0.80
T-2557	Røyneskårheia	1976	59°30'36"N	6°40'16"E	650	3.21±0.50
T-2559	Flatstøl	1976	59°18'42"N	7°03'37"E	540	1.71±0.60

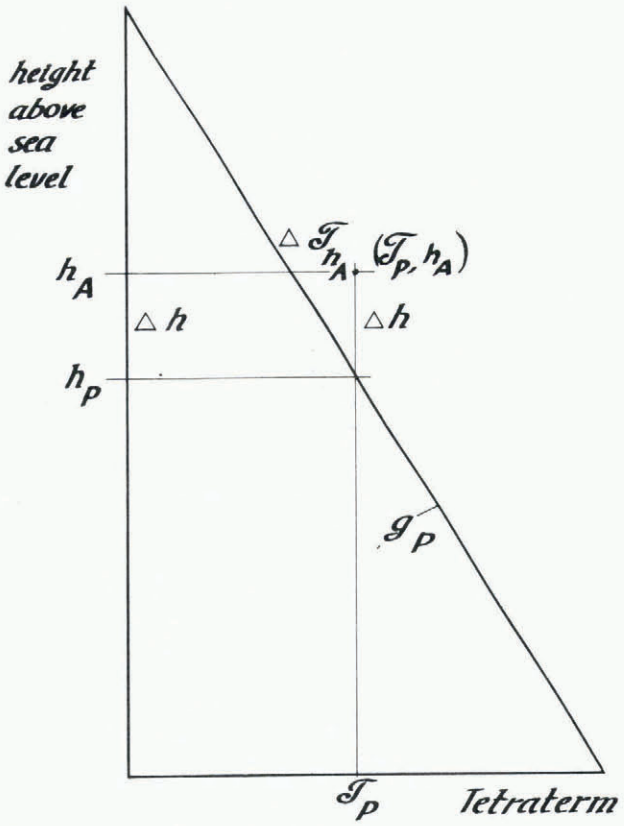

Fig.5. Relation between difference in alpine pine-forest limits and mean summer temperatures. (Symbols: see list of symbols.)

The PPFL is situated at an elevation h_P, characterized by $\tau = \tau_P$. We assume this value to be valid also for the APFL at the elevation h_A. Thus, at h_A the τ-difference between the Atlantic period and the present time is given by

$$\Delta\tau_{hA} = g_P \times \Delta h.$$

We have made two assumptions here: firstly, that the characteristic mean summer temperature of the alpine pine-forest limit was the same during the Atlantic period as it is today in the investigated area, and, secondly, that the topographic gradient of the mean summer temperature curve of the Atlantic period was the same as it is today. This implies that the mean summer temperature differences between the Atlantic period and the present are equal at all elevations.

For the PPFL to the west, and h_{PW} = 700 m a.s.l., we found that the characteristic mean summer temperature was τ_{PW} = 9.8°C (section 4). This value is also taken to be characteristic for the APFL at a height h_{AW} = 815 m a.s.l. Thus we arrive at the point P_{AW} (Fig.6), which represents a point on the mean summer temperature curve for the Atlantic period west of the watershed. At this height (h_{AW} = 815 m a.s.l.), the mean summer temperature during the Atlantic period was 9.8°C, which is $\Delta\tau_W$ = 0.58 x 115 m = 0.7°C higher than at present at the same elevation.

Similarly, we find for the east side, at the point P_{AE} at the height h_{AE} = 1 075 m, that the mean summer temperature during the Atlantic period was 8.9°C, which is $\Delta\tau_E$ = 0.68 x 145 m = 1.0°C higher than present. The mean summer temperature difference is greater to the east than to the west, partly because g_{PE} is greater than g_{PW}, and partly because Δh_E is greater than Δh_W. If we had used the minimum alternative for displacement of the alpine pine-forest limit, i.e. Δh_W = 55 m and Δh_E = 85 m, we would have arrived at the smaller values of $\Delta\tau_W$ = 0.3°C and $\Delta\tau_E$ = 0.6°C.

The complete mean summer temperature structure from the valley bottom to the watershed for the west and the east areas has been constructed tentatively (Fig.6) by choosing, for the mean summer temperature

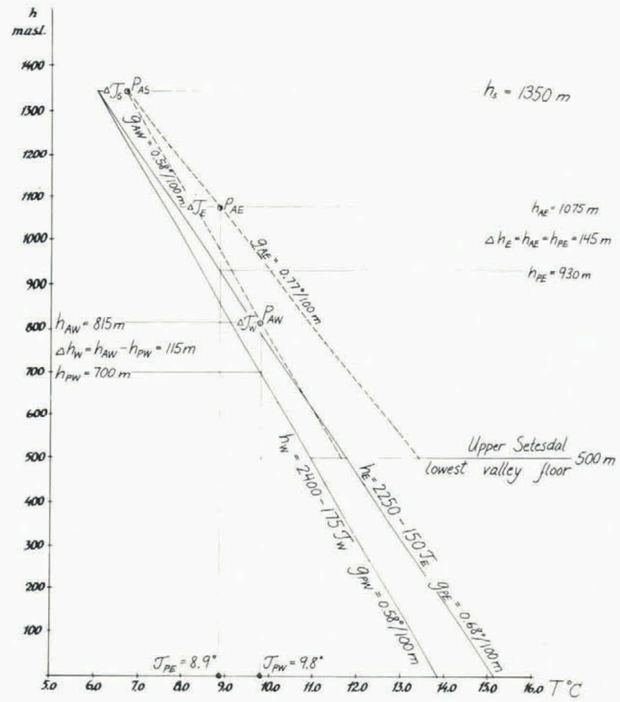

Fig.6. Present mean summer temperature curves and suggested mean summer temperature curves during the Atlantic period for Suldal (west) and Setesdal (east). Present: ——— and Atlantic period: ----- (Symbols: see list of symbols.)

difference at the watershed, the same value as found for the west side, that is $\Delta\tau_S = \Delta\tau_W$ = 0.7°C. The basis for this choice is the observed inclination of the APFL. We take this as an indicator of a pronounced maritime influence with frequent westerly winds during the Atlantic period. The mean summer temperature difference at the watershed should, therefore, be more in accordance with the difference found at the alpine pine-forest limit to the west than to the east.

A linear mean summer temperature structure in

TABLE IV. SUGGESTED DIFFERENCES IN MEAN SUMMER TEMPERATURE ($\Delta\tau_E$) BETWEEN THE ATLANTIC PERIOD AND THE PRESENT, EAST OF THE WATERSHED AT ELEVATIONS ABOVE 500 m

	Elevation (m a.s.l.)									
	500	600	700	800	900	1 000	1 100	1 200	1 300	1 350
$\Delta\tau_E$	1.5	1.4	1.3	1.2	1.2	1.1	1.0	0.9	0.8	0.7

the Atlantic atmosphere is assumed. For the eastern area, the gradient becomes g_{AE} = 0.77°C per 100 m, which is steeper than the present (g_{PE} = 0.68°C per 100 m). Thus, we suggest that the reconstructed fall in temperature from the Atlantic period to the present for the west side is 0.7°C at all elevations. For the eastern area the difference decreases with elevation as shown in Table IV, being 1.5°C at 500 m a.s.l.

Table I shows the difference in mean summer temperature between the east (Setesdal) and the west (Suldal) during the Atlantic period compared to the present for elevations above 500 m. We see that the difference in mean summer temperature between Setesdal and Suldal was greater during the Atlantic period than at present.

CONCLUDING REMARKS

Our study indicates that the decrease of the mean summer temperature from the Atlantic period to the present time was less at the coast than in the inner valley districts of south-west Norway. This implies that the horizontal temperature difference between east and west was greater during the Atlantic period than it is at present. We also suggest that the decrease of summer temperature from the Atlantic period to the present was less in the upper mountain areas than in the lower valley floors to the east.

The mean summer temperatures suggested for the Atlantic period, and their gradients to the west and east of the watershed, must be in accordance with a certain mean general circulation, typical for the Atlantic period. The circulation seems to have had fundamental similarities with that of the present, a conclusion which arises from the result that the mean summer temperatures during the Atlantic period were higher to the east of the watershed than to the west. This points to more clouds and precipitation, and less sunshine on the west side than on the east side during the Atlantic period, which suggests mean westerly winds like those at present.

The steeper topographic temperature gradient on the east side compared to the west side during the Atlantic period may indicate more pronounced subsidence of the air on the lee side of the mountains to the east than at present. This can be explained by more frequent anticyclonic circulation over south-west Norway during the Atlantic period arising from more frequent movement of the Azoric High towards the north-east.

From time to time, this situation has been altered by the movement of migratory cyclones from west to east along the north-western flank of the high mountain ridge, transporting air from the Atlantic Ocean across the coastal mountains of south-west Norway. These air masses were warmer and moister than at present, and resulted in the liberation of greater amounts of heat during the Atlantic period than today to the leeward side of the mountains. This is in accordance with Fægri (1940), who stated that the Atlantic period was characterized by more windy conditions than the Sub-Boreal period.

Extrapolation of the mean summer temperature curve of the Atlantic period on the east side to sea-level, leads to very high mean summer temperature differences between the Atlantic period and the present in the lowlands. The calculation indicates that the suggested topographic temperature gradient on the east side is too great. More realistic temperature curves for both sides may be obtained by thorough research on the distributions of thermophile plant species dating from the Atlantic period in the lowland areas.

Numerical experiments, such as those carried out by Manabe and Wetherald (1975, 1980), may give a firmer basis for understanding the general circulation in different geographical areas during periods with higher temperatures. Such models must be in accordance with observed evidence of past warmer climates in different parts of the world. We hope that our study may form a contribution to such models.

ACKNOWLEDGEMENTS

K Blystad and P Blystad participated in the field work. Our colleagues at the Archaeological Museum in Stavanger, the Botanical Institute in Bergen and the Norwegian Meteorological Institute have contributed with fruitful discussions and technical help. The manuscript was read and commented upon by P Blystad, R Mook and A Simonsen. All ^{14}C dates were carried out by R Nydal and S Gulliksen at the Trondheim Radiological Dating Laboratory. Financial support was given by the Archaeological Museum in Stavanger, the Norwegian Research Council for Science and Humanities (NAVF) and Borregaard A S Research Council. To all these persons and institutions we proffer our sincere thanks.

REFERENCES

Aas B 1969 Climatically raised birch lines in south-eastern Norway 1918-1968. *Norsk Geografisk Tidsskrift* 23(3): 119-130

Dahl E 1967 *Forelesninger i økologi ved Norges Landbrukshøgskole*. Oslo, Universitetsforlaget

Fægri Knut 1940 Quartärgeologische Untersuchungen im westlichen Norwegen. II. Zur spätquartären Geschichte Jærens. *Bergens Museums Årbok. Naturvitenskapelig rekke* 1939-40(7)

Hafsten U 1979 Late and post-Weichselian shore level changes in south Norway. *Acta Universitatis Upsaliensis. Symposia Universitatis Upsaliensis Annum Quingentesimum. Celebrantis* 2: 45-49

Lamb H H 1977 *Climate: present, past and future. 2. Climatic history and the future*. London, Methuen; New York, Barnes & Noble Books

Manabe S, Wetherald R T 1975 The effects of doubling the CO_2 concentration on climate of a general circulation model. *Journal of the Atmospheric Sciences* 32(1): 3-15

Manabe S, Wetherald R T 1980 On the distribution of climate change resulting from an increase in CO_2 content of the atmosphere. *Journal of the Atmospheric Sciences* 37(1): 99-118

Moe D 1977 *Studies in the Holocene vegetation development on Hardangervidda. II. General development and tree-line variations*. Bergen, Botanisk Museum

Mork E, Heiberg H H H 1937 Om vegetasjonen i Hirkjølen forsøksområde. *Norsk Skogforsøksvesen. Meddelelser* 5: 617-684

Mörner N-A 1980 The Fennoscandian uplift: geological data and their geodynamical implication. *In* Mörner N-A (*ed*) *Earth rheology, isostasy and eustasy*. Chichester etc, John Wiley and Sons: 251-284