ARBEID 3

WASTAGE FEATURES OF THE INLAND ICE SHEET IN CENTRAL SOUTH NORWAY

Kari Garnes and Ole Fr. Bergersen

Detailed field mapping of different lateral phenomena, striae, texture and till fabric are the basis of a reconstruction of five deglaciation phases in the east Jotunheimen- Gudbrandsdalen area, a landscape with moderate relief in the vicinity of the ice divide. During the wastage, the inland ice sheet was separated into several ice lobes situated in valleys encircled by large ice-free uplands. The slope of the ice surface varied with local changes in the ice-movement pattern as well as due to breaking of ice-dams giving reversal of drainage from ice-dammed lakes. Non-climatic, large marginal moraines are thought to have been formed as a result of locally increased steepness of the ice surface. By tracing the deglaciation phases through two different valley-systems which converge in the lake Mjøsa area, deglaciation events in the ice divide zone are correlated with marginal deposits at the front of the ice lobes.

Kari Garnes, University Library of Bergen, Allégt.41, N-5014 Bergen-University, Norway; Ole Fr. Bergersen, Geological Institute, Dept.B, Allégt.41, N-5014 Bergen- University, Norway.

The last years' investigation in the east Jotunheimen and Gudbrandsdalen area have brought to light a detailed view of the deglaciation events in an area around the last ice-divides of the inland ice. The area mentioned is classical ground for studies of deglaciation phenomena. Numerous papers have been published. Many of these were written already at the middle of the nineteenth century. The main topics discussed in older days were former ice-dammed lakes and the position of the ice-divide of the last inland ice (among others, Sars & Kjerulf 1860, Schiøtz 1895, Hansen 1886, 1890, 1891, 1895, Øyen 1896, 1898, 1899, Reusch 1894, 1910, Rekstad 1895, 1896, 1898, Holmsen, G. 1918). In the last decades, however, papers have been dealing very much with the problems of vertical wastage (Reusch 1901, Mannerfelt 1940, Ramsli 1947, Strøm 1956, Gjessing 1960, 1965, Samuelsen 1953, Mangerud 1963, Jørgensen 1964, Tollan 1963, Bergersen 1964. See also Vorren 1977).

Reading the literature, it is striking that many scientists have tried to interpret the deglaciation on the basis of simple models, often making conclusions for large areas based on insufficient field-work.

Based on data collected during the years 1968 - 1978, this paper presents a picture of the deglaciation separated into five phases. The phases represent situations during a continuous downmelting of the inland ice. The separation of the different phases has been enabled by the reconstruction of some drastic changes in the catchment area of the ice. The changes locally gave large

differences in the direction of flow and in the gradient of
the ice surface as well.

After the period when the highest mountain area became ice-free,
the inland ice seems to have melted down almost continuously with-
out any marked stagnations or oscillations. At a relatively early
stage, the inland ice was divided into different branches confined
mainly to valleys and depressions without supply from any accumu-
lation areas. This division makes it possible to relate events
and phenomena in the nunatak area with (sub-)synchronous phenomena
at the ice-front in the lower areas. The authors have earlier
discussed parts of the deglaciation in the actual area, but no
full presentation has been published yet (Bergersen & Garnes 1972,
Garnes 1978). Up till now, the last ice age in the
Gudbrandsdal area has been divided into four stadia (Fig. 1).
The figure shows that the last culmination zones of the inland
ice were situated close to the district of the river Vinstra
(stage C and D). Stage D represents the deglaciation period
after the highest mountains became ice-free. This stage is in
the following divided into five sub-stages or phases.

Today the river Vinstra has its uppermost sources in the higher
areas of Jotunheimen, about 2,000 m a.s.l., where also a few
small, recent glaciers are situated. The drainage from these
mountain areas, is gathered in several big valleys. Some of
these have long lakes situated at about 1,000 m a.s.l. The lakes
are located at the boundary between glacially sculptured mountains
in the west and a wide, mainly pre-glacial landscape further east.
The latter widespread smooth-formed palaeic surface is in
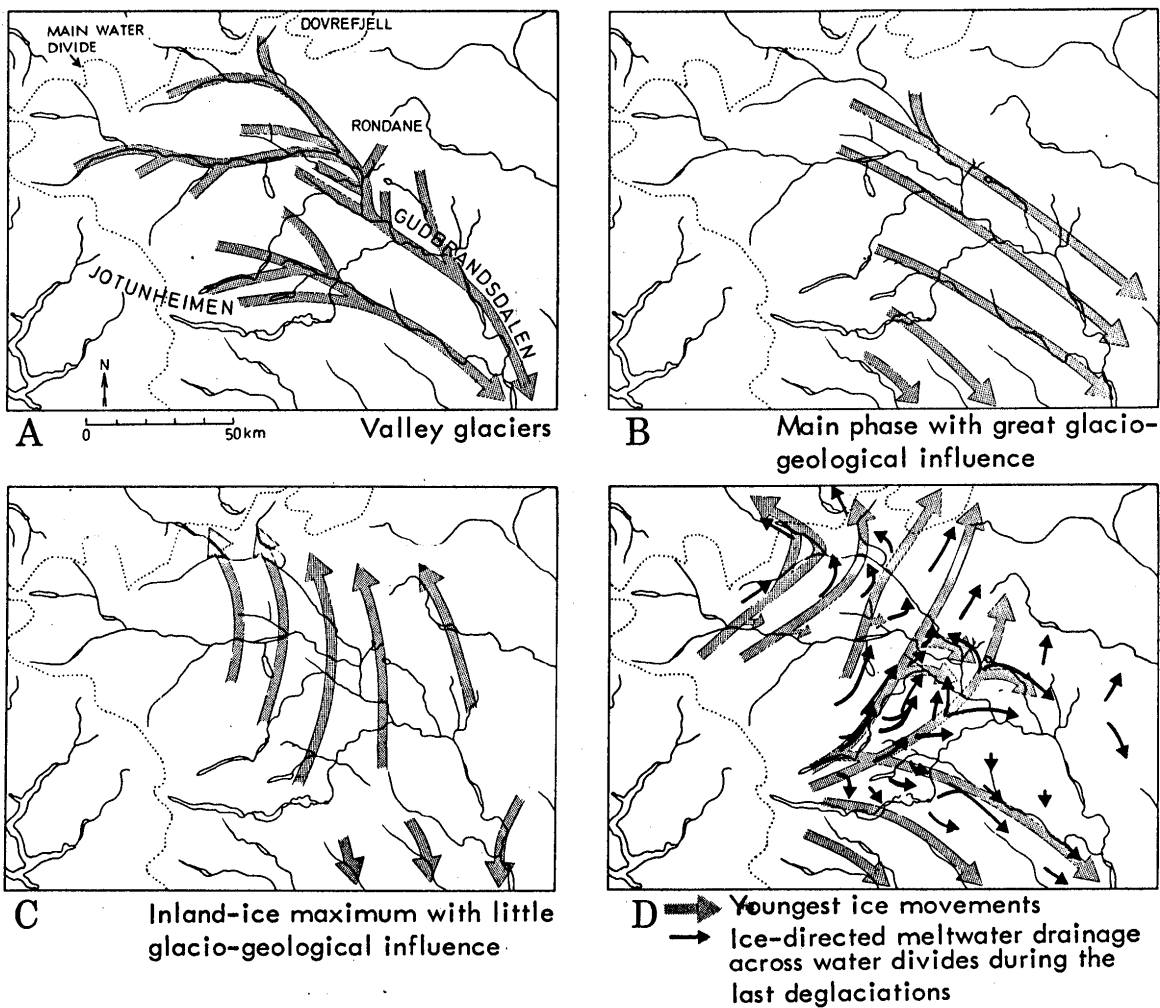Norwegian termed vidde. Well-marked valleys are almost missing

Fig. 1. A reconstruction of four stadia of the last ice age in the investigated area (Garnes 1978).

in the vidde-landscape. Most of the drainage from east Jotun-
heimen converges on Skåbu, and follows the deep, meandering
valley of Vinstra towards the northeast to the Gudbrandsdal
(220 m a.s.l.) (Fig. 2). From Skåbu there is also a well-
developed valley-system towards the southeast, through the
Espedal and the Vestre Gausdal to the lake Mjøsa. This valley-
system has a low watershed between the Espedal and the Vestre
Gausdal at 728 m a.s.l. During deglaciation, considerable parts
of east Jotunheimen were drained through this valley-system for
a period of time, thus creating important possibilities for
correlation of deglaciation phenomena in the lowlying country.

The drainage through the Espedal to the Gausdal valleys has been
briefly described by Rekstad (1898), Ramsli (1948), and Berger-
sen (1964, 1971). However, the history of the drainage is more
complicated than earlier believed. In this paper the drainage
history is separated in five phases, approximately equivalent
to the phases that the deglaciation of the whole region is
divided into. In order to facilitate understanding of the
regional reconstruction, three of the phases have been simpli-
fied on Fig. 2., which shows the whole area of study.

The reconstruction of the deglaciation phases is based on
an evaluation of a great variety of available data. These
data have been gathered by mapping, and by the study of forms,
as well as of glacial sediments. The most important information
has been revealed by:
a) Mapping and investigation of all types of lateral phenomena,
    frontal deposits and overflow-channels.
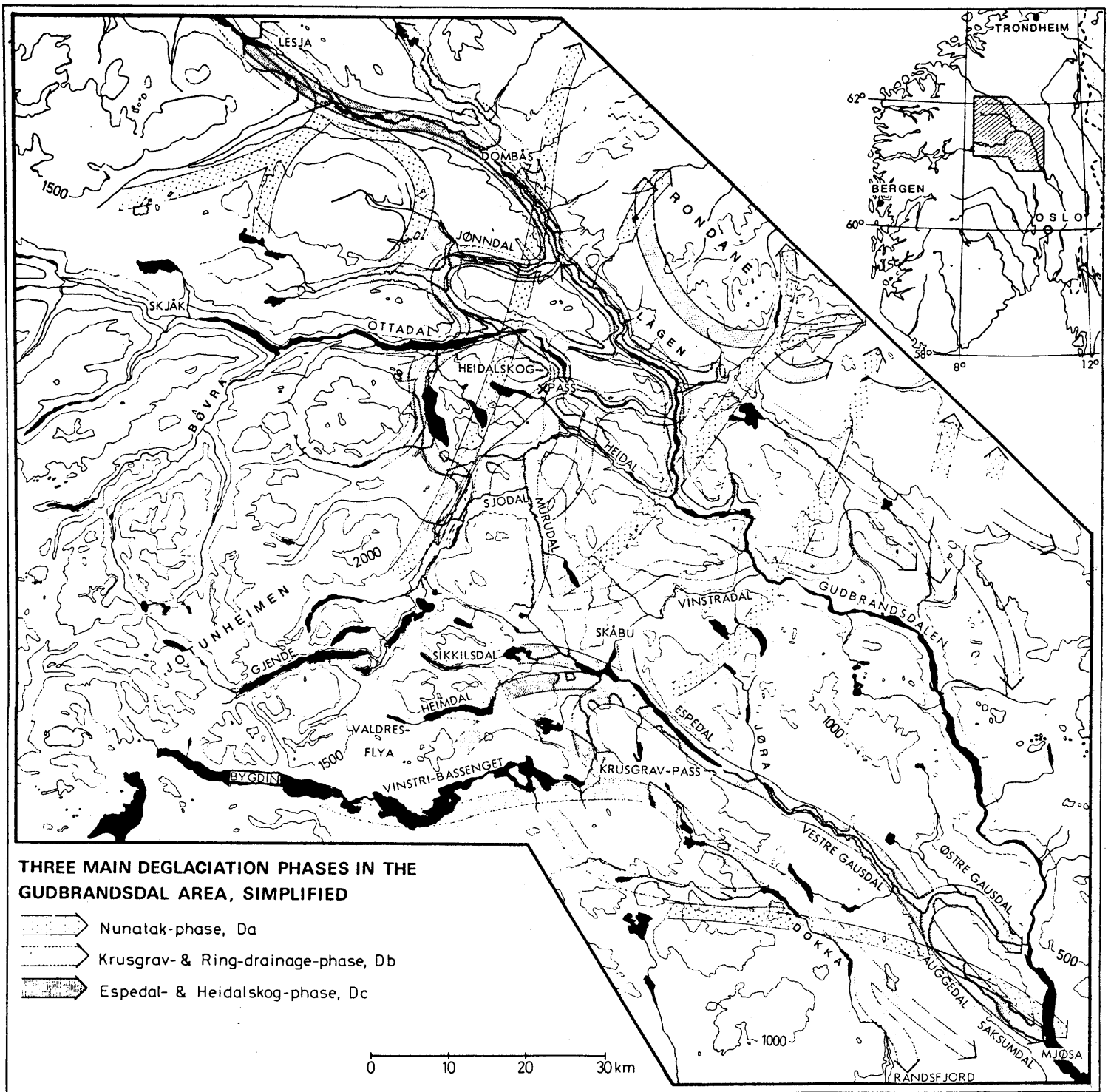b) Mapping and interpretation of striae and other indicators

Fig. 2. The investigated area, showing the most important melt-water routes during the three oldest drainage phases. As can be seen, the drainage during the oldest phase, Da, is almost independent of the topography. Later, the ice movements, as well as the melt-water routes became more and more topographically controlled. During the youngest phase drawn, the thickest remnant of the ice sheet was situated in Mid-Gudbrandsdalen. It directed all drainage in areas north of Vinstradalen up the main valley slope. The contour interval is 500 m.

of direction (drumlins, fluted surface).

c) Studies of sediments, especially different types of ablation till. However, glacio-fluvial material and basal tills have also been studied.

d) Establishing a till stratigraphy.

A certain danger of placing phenomena in the wrong phase, or correlating non-synchronous phenomena, applies for all these criteria. Therefore, it is necessary to use as many different criteria as possible. This is specially important in the investigated area, as its stratigraphy is thought to be more varied than is common elsewhere in Norway (Garnes 1978). In other areas, similar problems are discussed by e.g. Lundqvist (1973), Fulton (1967).
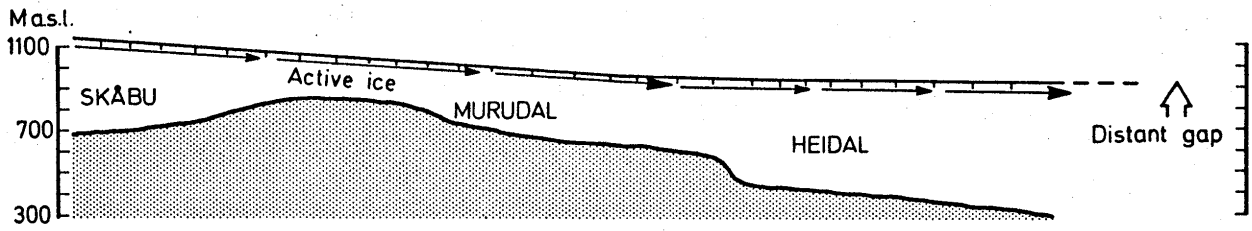
THE NUNATAK-PHASE, Da.

It has been found that, at the beginning of phase D (Fig. 1), there was an ice-culmination zone across the Vinstra and the Gudbrandsdal valleys, in a $60^{\circ}-240^{\circ}$ direction. The ice-divide zone sloped towards the northeast. This may be a result of the fact that the ice melted down more rapidly in the eastern part than in the western part. At the same time, however, the inland ice in the east of South Norway sloped towards the north-west. This is shown by the deglaciation course in north Øster-dalen and in Rondane (e.g. G. Holmsen 1915, Mannerfelt 1940, Gjessing 1960). The convergence area between the north-east and the northwest-sloping ice moved during deglaciation. However, a great amount of ice and water drained towards Dovre-fjell and Drivdalen at the time when the ice-surface had sunk
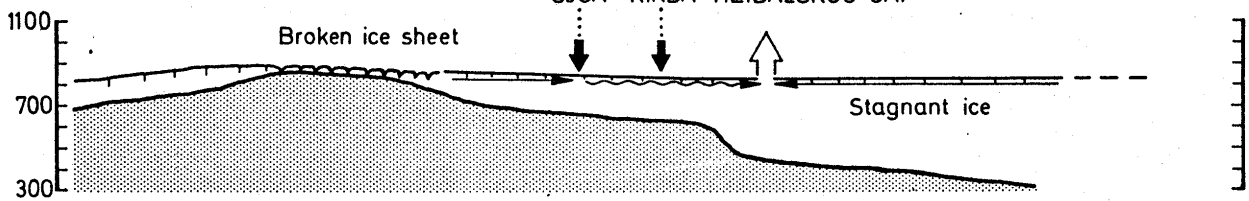
to c. 1100 m a.s.l. at Dovrefjell (P. Holmsen 1964, Sollid
1964).

From the investigated area, ice and water drained nearly
radially away from a culmination zone in the southwest, as
shown on Fig. 2. At the same time, ice flowed from another
culmination center in the northwest. The drainage of ice and
water away from the investigated area through numerous passes
north and east to Gudbrandsdalen, is therefore the most charac-
teristic trait of phase Da, see Fig. 2. During this phase,
only the highest mountain areas were free of ice. As the ice
surface melted down to the same levels as the northeastern
and eastern gaps, i.e. about 1100 m a.s.l., the ice surface
60 - 70 km to the west-southwest reached up to about 1400 m a.s.l.
The gradients of the inland ice were therefore small. Between
the mountain sides and the ice margin the melt-water drainage
caused numerous lateral channels. Some of these can be traced
continuously for several kilometers as erosion channels in the
till deposits. Sometimes they are even seen as canyons in the
bedrock. When followed over long distances the phenomena are
considered to be almost strictly laterally eroded. It is
therefore assumed that the channels show an almost correct
picture of the position of the ice surface. Such channels
have been found to have a gradient of less than 0,5% proximally.
The gradients are even less distally, and the lateral channels
indicate an asymtotic approach towards zero at the draining
gaps. Fig. 3 illustrates examples of general wastage phenomena
which are found in the area between the ice divide crossing
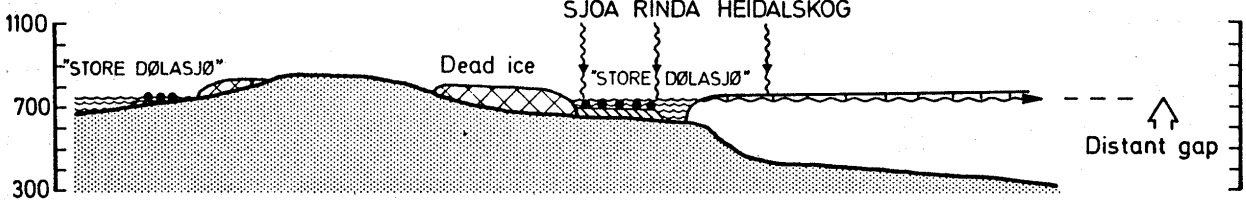Gudbrandsdalen and the main watershed in the north.

Phase Db

Ma.s.l.

SKÅBU
Active ice
MURUDAL
HEIDAL
Distant gap

Phase Dc

SJOA RINDA HEIDALSKOG GAP
Broken ice sheet
Stagnant ice

Phase Dd

SJOA RINDA HEIDALSKOG
"STORE DØLASJØ"
Dead ice
"STORE DØLASJØ"
Distant gap

0   5   10 km

⇧⇡   Overflow channel
→   Melt-water route
⬇   Tributary valleys with remnants of ice
↯   Tributary valleys ice-free
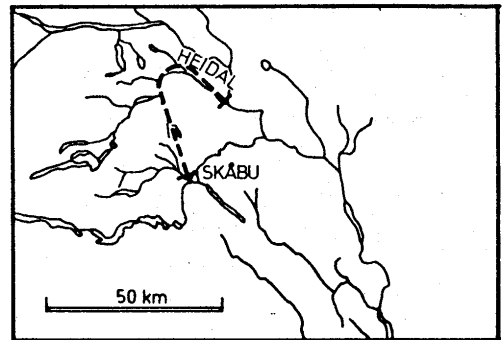〰   Lateral lake
≪≪   Delta

50 km

Fig. 3. Longitudinal profile showing some characteristic
phenomena during the wastage of the northern branch of the
ice sheet, approximately in the direction of flow. In phase
Db (or Da) the gradient of the ice surface close to overflow
passes approached zero. Phase Dc shows the situation around
a pass when the ice surface had melted down further. The
drainage now converged on the Heidalskog gap and flowed
down the valley, as well as up the valley slope. The height
of the different lateral deposits shows very small differences
in value, lateral lakes therefore probably also existed. When
the ice sheet broke up over a pass or a watershed the surface
of the ice adjusted to the slope of the terrain (to the left,
phase Dc). Phase Dd, following shortly after phase Dc, shows
the situatin in large tributary valleys, namely the Vinstra
valley (Skåbu) to the left and the Sjoa valley (Heidal) to
the right, during the "Store Dølasjø" phase. Ice several
hundred meters thick was still lying in Gudbrandsdalen while
uplands and upper parts of tributary valleys were free of
ice, or covered with remnants of dead ice.

Typical of the nunatak phase is that some zones along the mountain sides became washed completely clean. The zones are usually only 10 - 30 m wide. They may completely lack till, even though there may be several meters of till-layers on both sides. The zones may often have a well-defined boundary to the thick till below, while the border above may be more diffuse. Accumulation terraces are common where the mountain sides curve inward, as well as close to drainage passes. The outlet areas themselves are somewhat differently formed, due to the magnitude of the drainage and to what time the next, lowerlying gap was opened. If the drainage continued untill the gap was free of ice and a subaerial drainage occurred, the outlet area became washed. Typical for these are distinct kame terraces leading into the pass. If the drainage stopped, - or turned, - while there was still ice in the gap, both till and glacio-fluvial deposits can be found in the pass area, often as eskers. If the drainage stopped at a very early stage, it may be difficult to find any traces of the drainage through the gap at all. In these cases it is therefore difficult to evaluate the importance of the pass. When ice and water no longer could pass through one gap, and a lowerlying outlet was opened, the ice surface gradient adjusted itself to the new one. This often changed the drainage pattern for ice and water to a great extent, depending on the position, the size and the elevation of the new pass. The consequences of this will be discussed further in connection with the next phase.

THE KRUSGRAV-PHASE, Db.

When all the gaps east of the Gudbrandsdal were closed (the lowest at 1080 m a.s.l.) because the ice surface had melted

down to a lower level, there occurred an important drainage
divide over the middle part of the valley. This divide caused
a bifurcation of ice and water in east Jotunheimen (Fig. 2
and 4). The ice was still flowing away from the former
culmination center, but the flow diminished when the ice sur-
face was c. 1200 m a.s.l. From the beginning of phase Db
deglaciation proceeded differently on the northern side of
the ice divide from the southern side. In the northern area,
as far north as the Ottadal, the slope of the ice surface changed
slightly towards the east. This was followed by considerable
lateral drainage that curved along the eastern boundary of
the inland ice, to the east of the Gudbrandsdal. The northern
branch of phase Db is therefore named "Ring-drainage-phase"
(see Fig. 2). The drainage pattern during the continued degla-
ciation of this phase, was determined by a complicated inter-
action between the ice surface (which continued to flatten out)
and a number of transfluent valleys. During this phase the
runoff increased considerably along the lower Gudbrandsdal
because of sudden supply from the mid-Gudbrandsdal area, cf.
Fig. 2. The deflection of ice and melt-water along the lower
part of the Gudbrandsdal are thought to have given increased
frontal accumulations. A presumed gradient of the ice surface
of c. 1%, indicates that the front of the ice sheet during
this phase was situated may be 20 - 30 km south of Lillehammer.
It has not been proved, but it is postulated that the increased
runoff along Gudbrandsdalen may have caused the deposition
of a large, subaquatic end-moraine crossing lake Mjøsa at
Moelv. This ridge, wellknown from soundings and drillings,
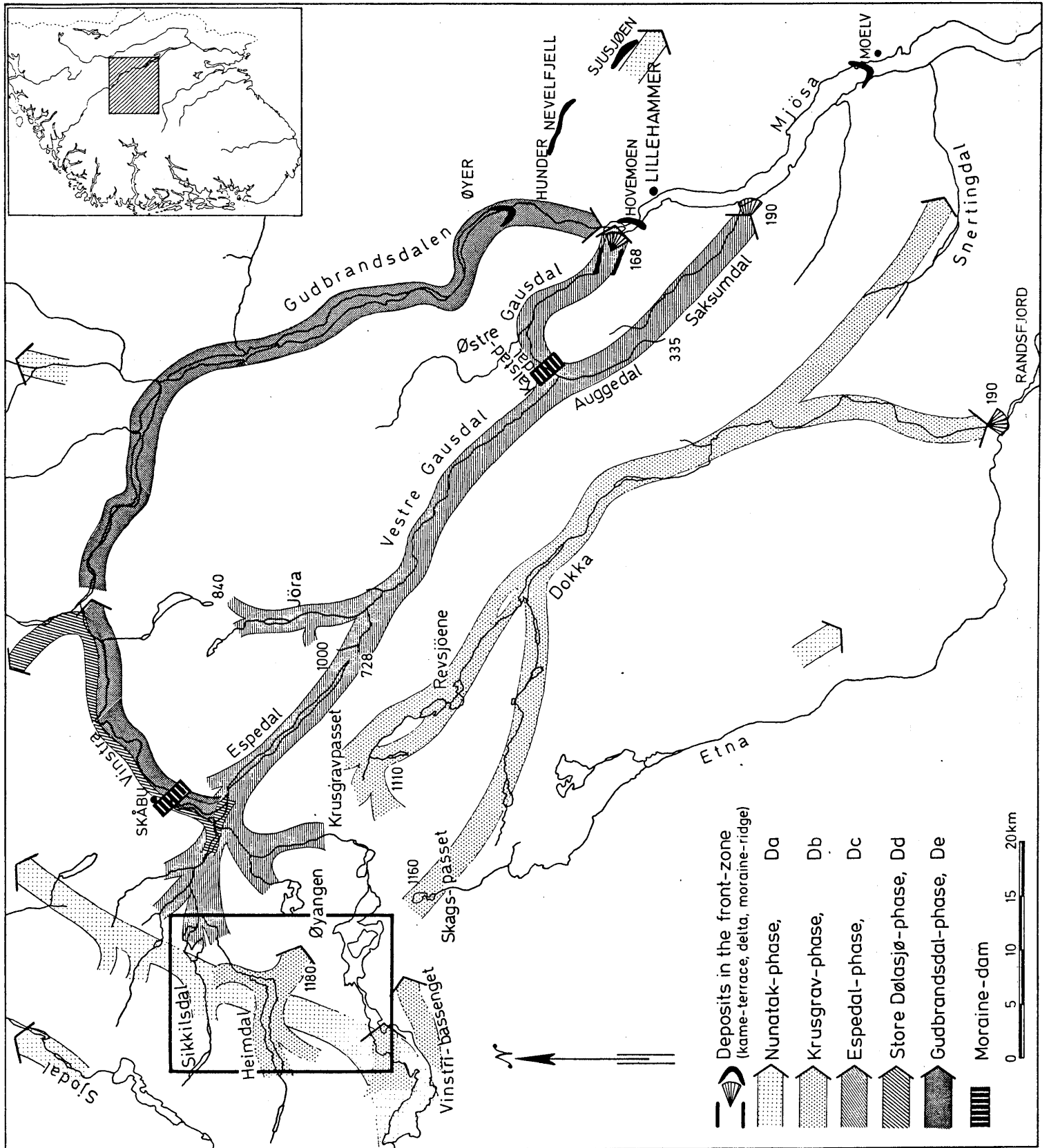is tentatively named the Moelv moraine.

Fig. 4. The history of the river Vinstra during deglaciation, separated into five phases. Framed area is location map for Fig. 8.

Labels on map:

Gudbrandsdalen
ØYER
HUNDER NEVELFJELL
SJUSJØEN
Østre Gausdal
HOVEMOEN
LILLEHAMMER
MOELV
168
Mjösa
190
Saksumdal
335
Auggedal
Vestre Gausdal
Snertingdal
RANDSFJORD
190
Dokka
Jöra
840
1000
Espedal
728
Krusgravpasset
Revsjöene
1110
Etna
1160
Skags-passet
Vinstra
SKÅBU
Øyangen
1180
Heimdal
Sikkilsdal
Vinstri-bassenget
Jepol

Legend:

Deposits in the front-zone
(kame-terrace, delta, moraine-ridge)

Nunatak-phase, Da
Krusgrav-phase, Db
Espedal-phase, Dc
Store Dølasjø-phase, Dd
Gudbrandsdal-phase, De
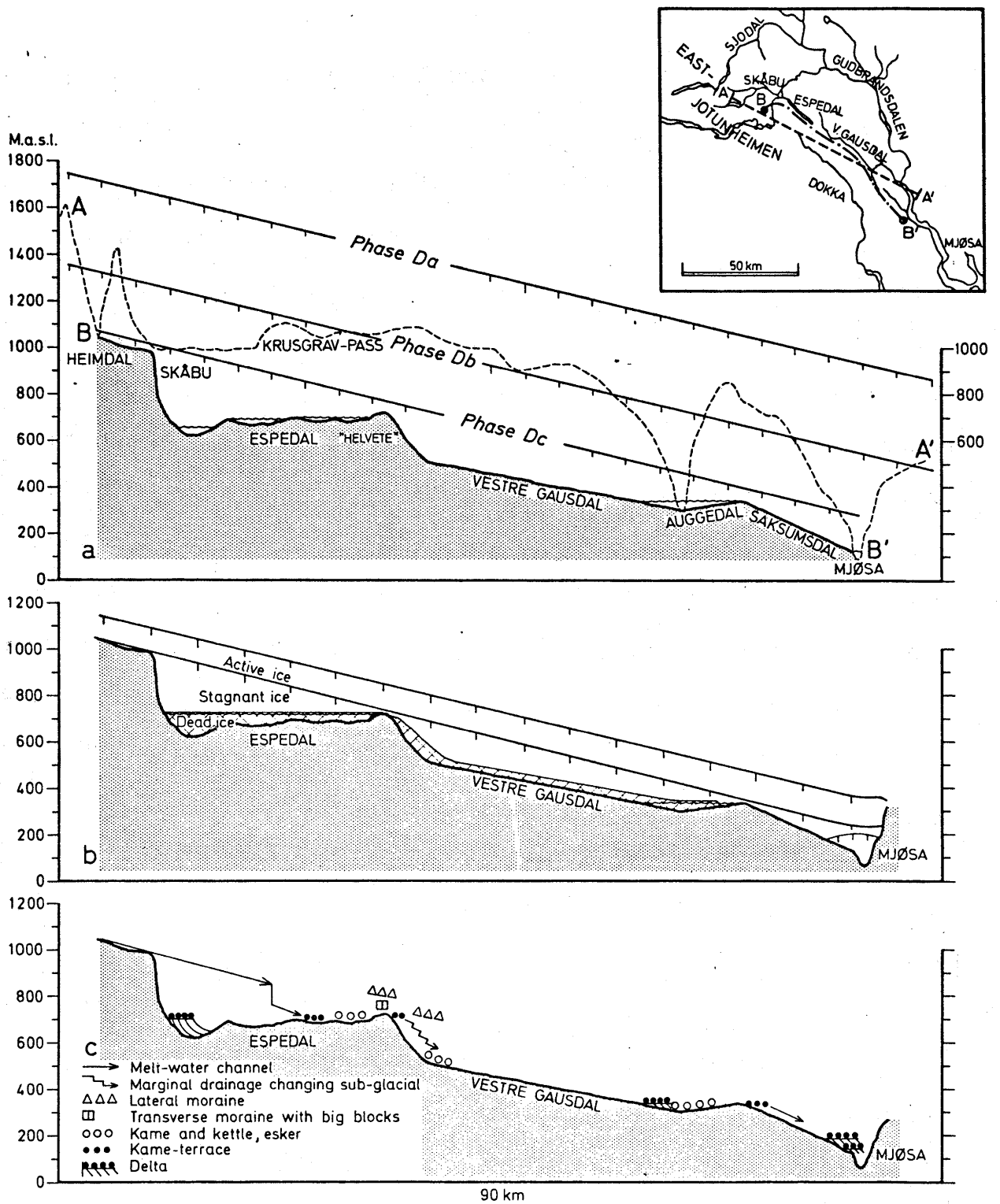
Moraine-dam

0   5   10   15   20 km

Fig. 5. Two longitudinal profiles from east Jotunheimen to lake Mjøsa, straight (A-A') and along the valleys (B-B') showing three phases of down-wastage (b). The surface of the ice sheet is presumed to have had a gradient during phases Da, Db, and the first part of Dc of about 1% in the direction of ice flow. After being separated into several ice bodies during phase Dc, the ice gradually sank in conformity with the valley bottom slope (b). At the same time, the ice bodies in the valleys became stagnant, and at last dynamically dead. The lowermost valley profile (c) shows the most characteristic deposits from the Espedal-phase Dc.

The ice surface of the inland ice south of the ice divide
is found to be practically conformal to the general slope of
the land surface . However, the details of the course of de-
glaciation were to large extent controlled by local topography
(Fig. 5). The "vidde" area around the upper part of the river
Dokka is particularly interesting. This area was the recipient
of large amounts of meltwater during this phase, notably from
extensive mountain and "vidde" areas to the west through the
Krusgrav gap, 1110 m a.s.l. This drainage was especially heavy
when the ice surface was at about 1150-1200 m a.s.l. in the Vinsrti
basin when the outlets to the south, towards the Etna valley,
became closed to drainage. The ice surface in the Vinstri basin
was then almost horizontal. Large flows of water were led laterally
and supraglacially through different gaps towards the east, and
further towards the southeast along the Dokka valley. It is
important to note that the drainage, which at the end went sub-
aerially through the Krusgrav gap, encountered thicker ice in
the east, and there again took an essentially lateral, supra-
glacial course (Figs. 6 and 7). East of the pass, the ice sur-
face dipped towards the east-southeast, and the drainage was
therefore led to Snertingdal and to Mjøsa lake, and later out
through the Dokka valley into Randsfjord lake. On the basis of
erosion marks and accumulations in Snertingdal, one can assume
that the ice surface here, and at Mjøsa, lay at 400 m a.s.l. in
an early stage of the phase. However, a large delta at Rands-
fjord indicates a Randsfjord level at approximately 190 m a.s.l.
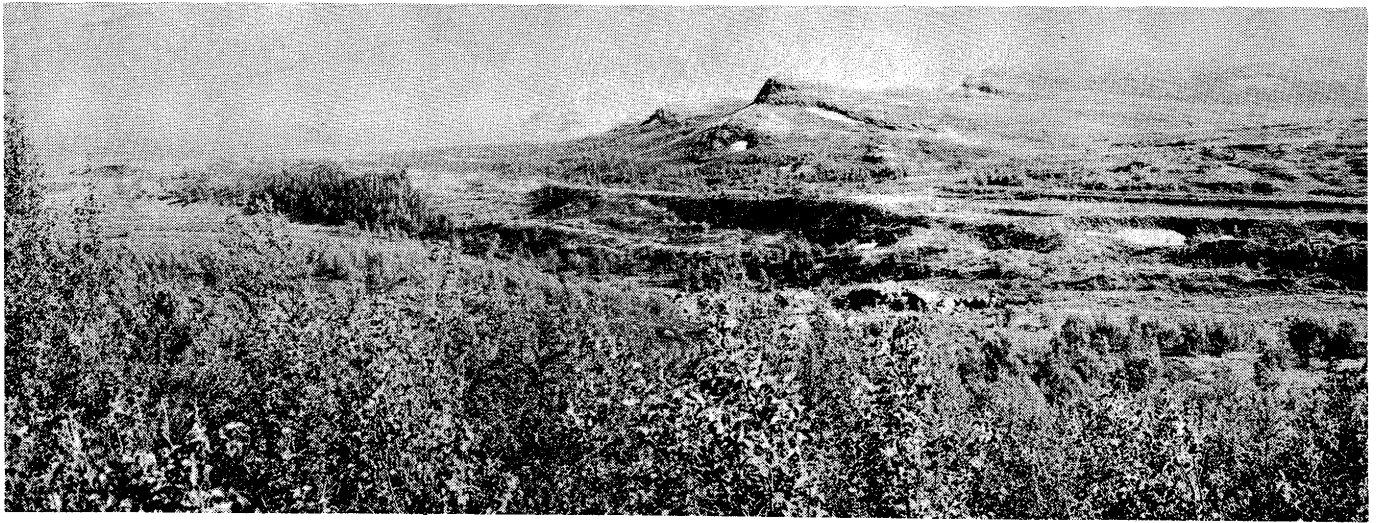at the end of phase Db (see Fig. 4).

Fig.6. Glacio-fluvial deposits on the distal side of the Krusgrav-pass, viewed towards the southeast. The kame-terraces seen to the right are built up to approximately the same height as the pass (outside the picture to the right). The deposits continue several kilometers to the left and were evidently deposited in a lateral position as the drainage gradually encountered thicker ice. The surface of the deposits shows fine examples of dead ice topography.

Fig.7. Traces of two sub-phases of strong lateral, sublateral drainage at Revsjøen in the upper catch-ment area of Dokka river, viewed to the northwest. The light zone in the background along the valley side became washed completely clean by lateral drainage coming through the arrowed pass. The esker in the center of the photo was deposited when the melt-water later found its way along the valley, from the right to the left.

Observations of lateral marks, and the mapping of deposits
assumed to correlate with these, indicate that the gradient of
the ice surface in the area between east Jotunheimen and Mjøsa
was approximately 1% during most of the deglaciation period.
As seen on Fig. 5, most of the upland (vidde) became ice-free
simultaneously. Thus very large areas became ice-free in a short
period of time. The inland ice was comparatively rapidly divided
into different ice-bodies, which were connected in vallyes and
depressions.

In the wide "vidde" basins isolated remnants of the ice sheet
remained over large areas. These melted away as dead-ice, often
preserving older deposits and forms as well. In certain areas
nearly all older deposits were removed by glacio-fluvial erosion
along the routes of the melt-water. Large accumulations of abla-
tion till and glaciofluvial material somtimes line these routes.
In other places older deposits were covered by glacio-fluvial
material. The Vinstri basin shows good examples of all these
types of phenomena. It is evident that the widespread, dead-ice
sheets in the "vidde" basins yielded enormous amounts of melt-
water which, from this stage onwards, mainly followed the valleys.
While the ice sheet in the upland areas gradually became dynamically
dead, there was several hundred metres thickness of ice in the
valleys. When the upland areas (approximately 900 m a.s.l.)
around the Gudbrandsdal were almost ice-free the ice was still
c. 700 m thick in the main valley. Even if there was practically
no supply of ice to the valleys, the masses there were still
dynamically active. Striae and lateral moraines indicate
this particularly clearly.

LATERAL MORAINES

In east Jotunheimen there are strikingly many large lateral
moraines at the altitude where the surface of the inland-ice
was situated during phase Db, i.e. 1500 - 1200 m a.s.l. They
have been known for a long time. Reusch (1894) for example
mentioned two of them, one in the Heimdal and one in the
Sikkilsdal valleys. Reusch (op.cit.) suggested that both
examples might be shorelines formed in local ice-dammed lakes.
However, further studies have shown that the ridges consist
mostly of till and that they, without doubt, often are true
lateral moraines. On the other hand, many examples show that
such lateral moraine ridges can be followed into kame-terraces
consisting of sorted material. Other ridges continue as melt-
water channels or washed zones. The slope of the most typical
lateral moraines varies considerably, but it is usually 0 - 2 %.
Many of the morphologically clear examples can be found on only
one of the valley sides. They may occur on a north- as well
as on a south-facing slope, seemingly independent of aspect.
The ridges have been found to be more than ten meters thick,
and there are evidently several types with different origins.
Garnes (1978) has given examples of lateral moraines in the
area that she considers to have been deposited at the beginning
of the last ice age, as well as of moraines from the deglacia-
tion formed independent of climatic conditions.

In the following, examples will be given from a smaller area
at the mouths of the Heimdal and the Sikkilsdal valleys. These
examples will show the genesis of the ridges as well as give

important information about the course of deglaciation itself.
In the eastern parts of Sikkilsdalen and Heimdalen, there
are distinct lateral moraines and other lateral phenomena at
several levels. By studying these, one has been able to recon-
struct the ice-flow pattern, e.g. during the two phases drawn on
the maps (Fig. 8). On the north side of Heimdalen, as well as
on the west side of Dørådalen, distinct moraine ridges are
situated at 1300 m a.s.l. They are found only on one side of
the valley, and both slope at about 2 %. The moraine in
Dørådalen indicates that the ice masses in the Vinstri basin
flowed out to Heimdalen at this stage (Fig. 8, map a). At
the same time, ice moved from Sikkilsdalen to Heimdalen as
well. This can be concluded from the direction and aspect of
different lateral erosion and accumulation forms in the
eastern part of Heimdalen, situated between c. 1250 m and
1180 m a.s.l. As there is clear evidence of synchronous
northerly movements in the Sikkilsdal area, ice flowed
both northwards and southwards from Sikkilsdalen at this stage.
While the Vinstri basin and Sikkilsdalen were supplied with
ice each from their own large basin (the fingerlakes Bygdin
and Gjende), the supply to Heimdalen was gradually reduced.
Leirungsdalen, a much smaller valley than Bygdin and Gjende, is
the continuation of Heimdalen westwards. After having con-
verged from the Vinstri basin and the Sikkilsdal, the ice flowed
from Heimdalen over Flatstranda towards the outer part of the
Vinstri basin (see Fig. 8, map a). The gap is situated at the
continuation of Heimdalen. The ice surface probably sloped
further towards the south-east, with large runoff through the
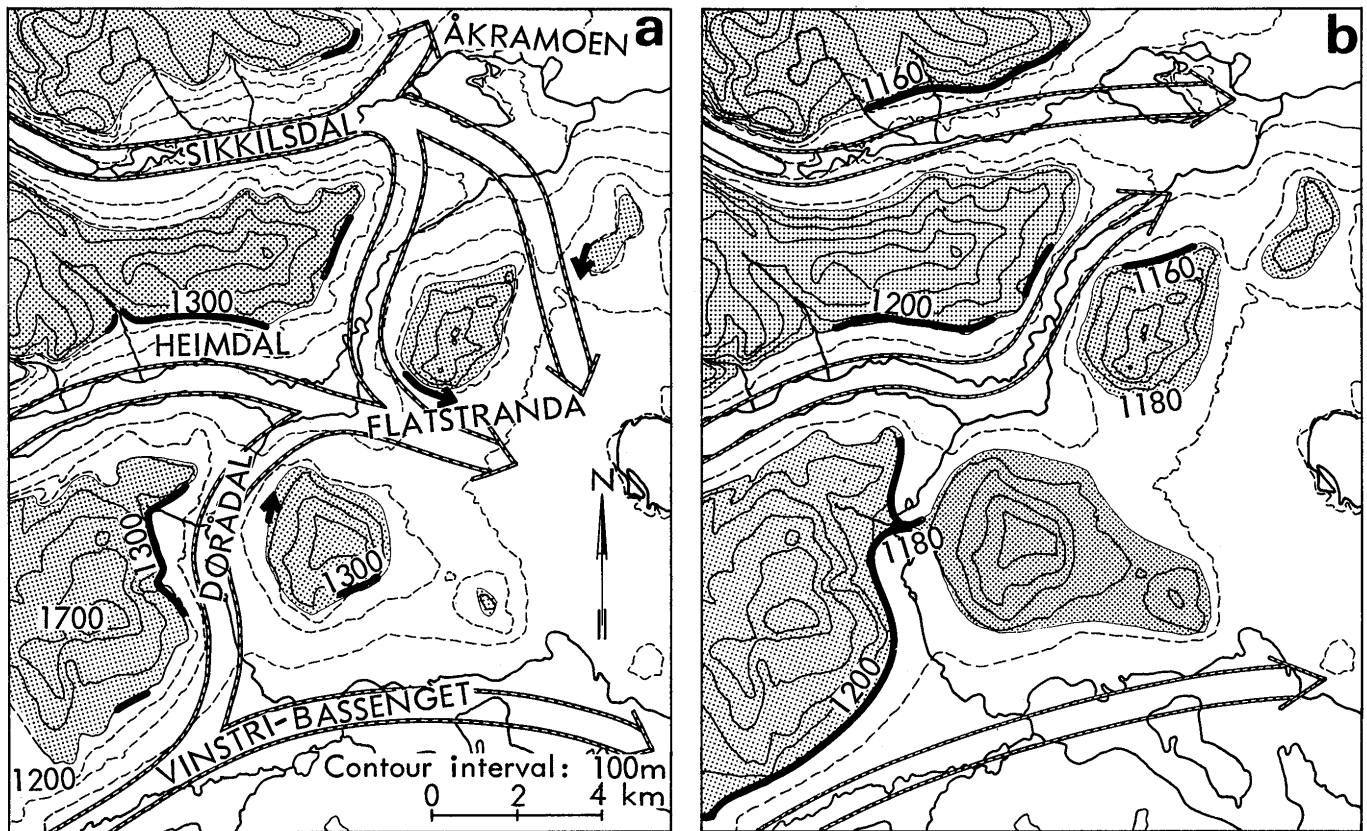Krusgrav-pass.

Fig. 8. Sketch-maps showing two phases with different ice movements patterns in a small area of east Jotunheimen. For location, see Fig. 4. The situation shown on Maps a) and b) corresponds to phase Db and Dc respectively. Large moraine ridges (heavy line) and important cannels (arrow) are pointed out. The ice surface in the situation shown on Map a) is about 1300 m a.s.l. with a gradient near 2%. The ice surface on map b) is close to horizontal and it lies at about 1200 m a.s.l. The lateral moraines marked on Map b) are presumed to have been formed when the ice movements shifted from the situation seen on Map a) to that on Map b).

The ice movements through the Dørådal valley ceased when
the ice surface had melted down close to the level of the
outlet, 1180 m a.s.l. Small lateral moraines were formed at
this level on both sides of the pass. Lateral phenomena
(both erosion and accumulation forms) can be traced along the
1200 m contour line in the Vinstri basin westwards to Bygdin,
presumably controlled by the level mentioned. These forms
show that the ice surface had now levelled out, with a gradient
in the basin approaching zero. At the same time, the ice move-
ment from Sikkilsdalen to Heimdalen was also decreasing (cf.
Fig. 8, map b). After this stage, the melt-water drainage
lined the valleys. For the area studied the drainage was
confined to the Espedal valley. Ice masses from Sikkilsdalen,
Heimdalen and the Vinstri basin as well, converged therefore
on Espedalen (cf. the Espedal-phase, Dc). The ice surface
adjusted in general to the valley profile, giving steeper
gradients again (see Fig. 5).

On the southern valley side of Heimdalen, there are large
moraine ridges situated between 1280 and 1160 m a.s.l. The
highest situated ridges have no well defined dip. They are,
however, found to slope up the valley westwards. The largest
ridges lie at about 1160 m a.s.l. The western part of these
is also found to slope westwards. The eastern part, however,
clearly slopes eastwards (Fig. 9). These ridges, mainly con-
sisting of till, are partly eroded by melt-water. As their
altitude correlates well with the changes of the ice movements
mentioned above, the authors' interpretation is that the moraines
were formed due to these changes. Such moraines are often
situated close to the same level as that of important overflow

passes or transfluent valleys. In a few cases, however, ridges of this type seem to have no relation to distinct passes at all.

As shown, distinct marks indicate that the ice surface was adjusting to the slope of the terrain during this late stage of the deglaciation. As a result of locally increased steepness of the ice surface, lateral moraines could be formed independently of climate. Several examples of such non-climatic moraines are presented on Table 1 (i.e. the Hovemoen, and the Øyer- and Moelv-moraines).

THE ESPEDAL PHASE, Dc.

As already emphasized, enormous quantities of melt-water were concentrated in the larger valleys when the ice surface had melted down below the 1200 m contour line. Melt-water channels show that the drainage from the Vinstri basin and Øyangen flowed mainly to the Espedal valley when the Krusgrav gap (1110 m a.s.l.) became too high. During this phase, therefore, Espedalen drained the whole area that today is the catchment area of the river Vinstra. As shown on Fig. 4, the Gausdal valleys also received supplies from the north, i.e. from the lower part of the Vinstra valley, to the river Jøra. Thus the Gausdal valleys were the recipients of drainage from an area almost 2.5 times larger than the catchment area of the river Gausa today. Because the Espedal drainage can be followed to and correlated with different levels in the Mjøsa lake, it is important to reconstruct the main events of this phase. As shown on Fig. 5, the ice surface is found to have had a mean gradient of about 1 % during this phase. The topography exercised an increasing

Fig. 9. The eastern part of a lateral moraine at 1.160 m a.s.l.
on the southside of the valley in the outer part of Heimdalen.
The irregularity of the surface which is easily seen, is due
mainly to melt-water erosion and in a lesser degree to the
burying of dead ice. The moraine is thought to have been formed
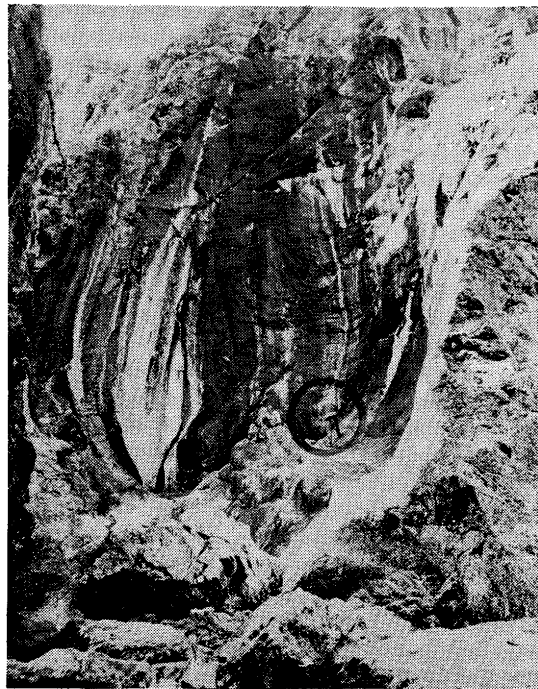as a result of a sudden shift in ice movement pattern (see text).

Fig. 10. Large pot-holes near the pass
between the Espedal and Vestre Gausdal
valleys. The scale is indicated by a
person. The pot-holes, eroded in homo-
genous anorthosite, are thought to have
been excavated sub-glacially during an
early stage of deglaciation.

control over the movements of the ice. The gradienst, therefore, varied somewhat down through the valley. The pass area between Espedalen and Vestre Gausdal shows evidence of this. In the distal part of the pass well developed lateral moraines indicate a local dip of 2 - 4 %. Lateral moraines are seldom found elsewhere in the vicinity.

The reconstruction of the drainage history of the Espedal phase can bes be based on two criteria, i.e. morphology and the texture of the glacial sediments. The most important morphological traces in Espedalen are erosion channels. In Vestre Gausdal and Auggedal accumulation forms dominate. From the lower part of the valley system some of these deglaciation phenomena have already been described by Rekstad (1898), Bergersen (1964, 1971), Enger (1973).

In the accumulations deposited from the Espedal drainage, there occur high percentages of rocks with a characteristic origin. West of a north-south line, approximately along the river Jøra, the so-called Jotun rocks (anorthosite, gabbro, and other crystallines) dominate the bedrock. East of this line the bedrock consists of different sedimentary rocks only. The percentage of Jotun rocks in glacio-fluvial deposits is higher than 30 in the pebble fraction (usually quite a bit higher) as far down the valley as 60 km east of the bedrock border, In other glaciofluvial deposits along the valley such rocks form a far smaller share, normally 2 - 5 % (Bergersen 1964, 1971). The stones deposited by the Espedal drainage also have a considerably higher degree of round-ness than other glacial sediments in the area (Bergersen 1973).

When the Espedal drainage started, the ice sheet was probably

near the breaking point above the passes at Espedal -
Vestre Gausdal and Auggedal - Saksumdal (cf. Fig. 5).
Therefore the drainage through these passes evidently encountered
thicker ice. On the distal part of the two watersheds there
occur characteristic kame terraces at the same height as the
passes. The accumulations that at first appear as terraces
along the valley sides, continue as ridges several hundred
meters distally to the watershed-gaps. Eventually, the accumu-
lations, consisting of coarse glacio-fluvial material, assume
a small gradient down the valley, but this is less than the
slope of the valley floor. It is not possible to follow the
deposits continuously any further than about one kilometer.
A blanket of ablation material with characteristic elements
of Jotun rocks and with a sharp upper boundary, however,
can be followed along the whole valley system to the Mjøsa lake.

The connecting valley from Espedalen to Vestre Gausdal declines
200 m from the watershed (728 m a.s.l.) to the confluence with
the river Jøra (Gausa), a distance of 5 km. In the confluence
area large glacio-fluvial masses showing magnificent dead-ice
topography have been accumulated on the southwest side of the
valley up to 80 m above its floor. Further down the valley
glacio-fluvial accumulations are only found along the valley
floor and up to 20 - 30 m above it. The areas around the
Mjøsa lake, where the base level at that time was up to 70 m
higher than today, are exceptions. In these areas deltas were
formed at different levels to above 190 m a.s.l.

The pass areas between Espedal - Vestre Gausdal and Auggedal -
Saksumdal both have distinct signs of lateral, as well as

subaerial melt-water drainage. In the former pass there
are 10 - 12 exceptionally well developed potholes, up to 40 m
deep, in the strongly washed valley floor. These are named
Helvete (Hell) (Fig. 10). The connecting valley from Espedalen
is clearly polycyclical, having obviously been eroded during
many periods. The potholes, evidently belonging to the youngest
generation, are situated in a superimposed canyon on the side
of the "Talweg". As there existed an extensive, lateral, melt-
water drainage through the valley during most of the Espedal
phase, the potholes were probably due to sub-glacial erosion
before the ice broke up over the pass. The potholes are
therefore thought to be from the very beginning of this phase,
or they may originate from an older phase.

As already shown, there are different erosion forms, as well as
different types of depositional forms, that originated from
the Espedal phase. Well developed melt-water channels and
kame-terraces dominate the northwestern part of the Espedal
valley. Otherwise few traces can be found, except in the
watershed area where several eskers occur proximally and
distinct kame-terraces distally . . Evidence of
sub-glacial drainage cannot be found until the melt-water
drainage reached Vestre Gausdal where it encountered thinner
ice. From Fig. 5 c it can be seen how accumulations of presumed
sub-glacial origin are to be found mainly in areas proximal to
the watersheds. Here the melt-water was ice-directed under
hydrostatic pressure against the slope of the valley bottom.
Distally, however, where the melt-water was confronted with
gradually thicker ice, lateral terraces dominate. Accumulations
can also be found elsewhere, especially where the drainage

managed to take a sub-glacial course and at the ice front.

The Espedal phase has two succesive sub-phases. First the drainage can be followed, as described, across the watershed (335 m a.s.l.) between Auggedal and Saksumdal and to lake Mjøsa. A delta was built up at Mjøsa, somewhat higher than 190 m a.s.l. The extent of the delta towards the south indicates an accumulation in a lateral lake, probably due to an ice lobe in Mjøsa. The melt-water drainage also continued for some time after the watershed was free of ice. At that time, a lateral lake dammed against the watershed (335 m a.s.l.), existed in Auggedal. The lake grew to a length of 13 km, but the depth was never more than 30 m. The whole lake was probably filled with fine-grained sediments and dead-ice remnants when the break-through to Kalstaddalen and Østre Gausdal occurred (Fig. 4).

The second sub-phase of the Espedal drainage started as the water made its way through the transverse Kalstaddal valley to Østre Gausdal . Distinct lateral channels at an altitude of 270 - 200 m a.s.l. in Østre Gausdal show that ice still remained in this valley (Bergersen 1964, Enger 1973). At the beginning of this sub-phase, kame-terraces were built up in Østre Gausdal to a height of 168 m a.s.l. - the level of Mjøsa at that time.

In the northern part of Mjøsa, outside the mouth of Gausdalen there exists a large transverse ridge, called Hovemoen. The deposit is thought to be of importance to the understanding of the sequence of deglaciation in this area (Vogt 1943,

Bergersen 1975, Østmo 1972). Hovemoen, which is situated east of the delta area, has a concave form towards Østre Gausdal. . Both its surface and outline are formed by glacio-fluvial erosion. Characteristic dead-ice topography has nevertheless been preserved, and it covers almost the whole surface. The accumulation, which lies at 181 m a.s.l. consists of a 10 - 30 m thick cover of coarse, glacio-fluvial material with an assembly of rocks that cannot have arrived from Vestre Gausdal. . The feature is probably derived from older deposits (mostly basal till) in the delta area. The till seems to originate mostly from Gudbrandsdalen. This coarse accumulation rest upon thick layers of lacustrine sediments, maybe 100 meter thick (Østmo 1972).

A general survey of available information shows that the Hovemoen was probably built up in the vicinity of the ice margin, at a base level in the Mjøsa close to 170 m a.s.l. as the result of a catastrophic flood. The lake level correlates well with the altitude of the kame-terraces in Østre Gausdal. that correspond to a base level of 168 m a.s.l. It is therefore possible that Hovemoen was formed by a flood wave caused by the tapping of the ice-dammed lake in Auggedalen (Østmo 1972). However, a study of the rock content suggests that the drainage came from Gudbrandsdalen (Bergersen 1964, 1975). This apparent contradiction in views may be explained in the following way. When huge amounts of melt-water, resulting from tapping of the lake, reached the outer part of Østre Gausdal. ., the water eroded old basal tills derived from Gudbrandsdalen in earlier phases of glaciation. It can be concluded from this description that the transition between

the first and second Espedal sub-phases occurred when Mjøsa
had subsided to 170 - 168 m a.s.l.

At the mouth of Østre Gausdal   there is also a large delta
built up to about 140 m a.s.l. (Jørstadmoen). Between the
168 m terraces and this delta, no distinct level of deposi-
tion has been found. The delta is so extensive that it most
probably originated during the Espedal phase, when the whole
Vinstra river-catchment area drained into Østre Gausdal.
Since no ice-contact phenomena have been found on the delta,
the area was probably ice-free during deposition. Hence, the
Espedal phase lasted at least until Mjøsa had subsided to
140 m a.s.l. Between the 140 m delta, and today's delta at
122 m a.s.l., no distinct levels have been established.

Towards the end of the Espedal phase, a big lake was dammed up
between the ice remnants in Espedal - Vinstradal and the
watershed between Espedal and Vestre Gausdal. When this
watershed had become ice-free, the ice lobe in Espedalen lost
its gradient, at the same time as the ice probably was gradually
broken up (Fig. 5b). This lake eventually became 26 km long,
and Ramsli (1948) called it "Storsjøen" (The great lake).
Normal deltas were built in this lake at the mouth of the
tributary valleys. This fact indicates that it at least
partly was an ice-free lake. During the Espedal phase "Storsjøen"
was drained to the southeast through Vestre Gausdal. . Later,
during the phases Dc and Dd, it drained along the Vinstra
valley. ^{14}C-dating of the bottom layers of a c. 0.7 m deep bog
at the watershed Espedal-Vestre Gausdal gave the result 6050 $\pm$
90 years B.P. (T-855). Another two datings from the bottom

layers of a bog at Skåbu at 695 m a.s.l., i.e. 33 m below the level of "Storsjøen", gave the results $8787\overset{+}{-}210$ years B.P. (T-2525) and $9080\overset{+}{-}140$ years B.P. (T-2875) (Alstadsæter 1979). The latter bog lies on bedrock of calcarious micashists. Therefore, the dates may be somewhat too old due to the so-called hard-water effect. However, if the dates are approximately correct, the "Storsjøen" must have existed for only a very short time, and the Espedal phase must have ended more than 9.000 years ago.

THE STORE DØLASJØ PHASE, Dd.

The authors have previously shown that large remnants of the inland ice lay in the central parts of Gudbrandsdalen after the upland areas were almost ice-free. The ice masses comprised a gigantic dam to consequent drainage down the main valley (e.g. Garnes 1978). By follwoing different types of lateral phenomena (so-called "seter" or "parallel roads") a marginal lake has been reconstructed. This lake is called "Store Dølasjø", and, at its latest stage, it stretched from Skåbu to the main watershed between East and West Norway, at Lesja (612 m a.s.l.), a distance of 140 km. In addition, the lake had up to 80 km long branches in the tributary valleys. Many scientists have discussed the northern part of this north-flowing lake (older works reviewed by Øyen 1896, also G. Holmsen 1918, Gjessing 1960). In all the earlier works, the lake dam was thought to have been located at Selsrosten, a narrow part of Gudbrandsdalen just south of the mouth of Jønndalen (Fig. 2). Continuation of the synchronous "seter" also far to the south of this area, shows that this assumption was incorrect (Garnes 1978, Lie 1974, Hole 1979, Skjerven 1978). Because of isostatic down-warping, probably caused by the remaining ice-bodies, the reconstructed level of the lake is found at c. 670 m a.s.l. in the Vinstra valley. Traces of the lake are scarce as

far south as the Vinstra area, but even here the level is marked
by small lateral deltas and erosion terraces. Several small
moraine ridges are of interest in this context. They are thought
to have been formed as the ice-dam broke and the lake drained
southwards. The sudden reversal of the drainage direction is
thought to have been followed by a locally increased gradient of
ice lobes left in the tributary valleys. This phenomenon can be
observed in the upper part of the Vinstra valley, for example.
The formation of several moraine ridges in east Jotunheimen can
be explained in the same way (see p. 10-13).

The authors believe that, when the ice surface in Gudbrandsdalen
had been sufficiently lowered, "Storsjøen" drained northwards,
up Gudbrandsdalen for a short period of time before draining
northeastwards through the Vinstra valley. This happened during
a period when the "Storsjøen" surface sank from 728 m to about
670 m a.s.l. and resulted in a drastic reduction of the extention
and volume of the lake. Already in 1898, Rekstad mentioned three
levels, thereby indicating that "Storsjøen" was drained at diffe-
rent stages. Ramsli (1948) found by levelling that the two hig-
hest surfaces of two deltas at the western part of the former
lake lay at 728 m and 695 m a.s.l. He also mentioned a surface
at about 680 m a.s.l.

At Skåbu, the Vinstra valley has probably been filled with water-
laid sediments and overlaid till up to a level of at least 720 m
a.s.l. This assumtion is based on erosion terraces found at
different levels in the thick deposits still remaining on both
valley sides. It has previously been suggested that these
deposits were the real dam of "Storsjøen, or part of it (Rekstad
1898, Mangerud 1963, Bergersen 1971). The reconstruction of the
large ice dam in mid-Gudbrandsdalen, the ^{14}C-datings already
mentioned, and the step by step-drainage,

are all strong evidence against such an interpretation.
Furthermore, the lower part of these deposits, consisting
of coarse glacio-fluvial material, is very permeable. The
deposits, therefore, are thought to have a low damming effect.

THE GUDBRANDSDAL PHASE, De.

Phase De represents the last phase in the deglaciation of
the Gudbrandsdal valley system. The phase started as the
ice lobe in the main valley allowed the "Store Dølasjø" to
be drained southwards. From then on, the drainage followed
the valley as it does today. However, the ice remnants,
still almost 500 m thick in the main valley, controlled to
a large extent the routes of the melt-water. The authors
have not so far compiled all the details concerning this last
reconstructed phase of deglaciation. In this paper, therefore,
only a few events important to the correlations between
deglaciation phenomena in mid-Gudbrandsdalen with those at
the ice front will be dealt with. The reversal of melt-water
drainage represents an important event in the deglaciation
history. As long as the drainage was directed to the north,
the lower Gudbrandsdal received drainage from areas south of
the Vinstra valley only. The catchment area then was less
than 1700 km^2. When the drainage reversed southwards the
catchment area suddenly became six times larger than it had
been before (c. 11,000 km^2), i.e. almost the present size.
In addition the water stored in the ice-dammed lake, "Store
Dølasjø", had to be drained along the same route. Extensive
washed zones on some exposed valley sides north of the
former ice-dam are thought to be the result of the reversed

drainage (Fig. 11). In the southern area, only a few phenomena
have been identified that could have been formed in connection
with the catastrophic flood. Some of these (canyons and
eskers, all transverse to the valley sides) indicate that the
drainage very soon became   sub-glacial or englacial.

The reversal of drainage is correlated with large frontal
deposits consisting of coarse glacio-fluvial material, called
the Øyer moraines. These moraines are situated about ten
kilometers north of Mjøsa, showing that the front of the ice
lobe had melted back to this position when the "Store Dølasjø"
ceased to exist. Both the frontal deposits and a sheet of
ablation material also correlated with the reversal of drainage
towards the south, contain a characteristically large amount
of rocks transported over long distances, especially gabbroid
rocks of the Jotun type from the Vinstra and the Sjoa areas.
The reconstruction shows that the ice surface, also in the
lower parts of Gudbrandsdalen, had a gradient of about 1 %
during this phase.

Important features of phase De, was that the ice remnants in
the main valley still dammed the drainage from the tributary
valleys. Therefore, local ice-dammed lakes occurred in some
of the tributary valleys. The accumulations there were exposed
to heavy erosion when the lakes drained, as well as during
intensive postglacial slope development on the steep valley
sides. Slope processes have buried many signs of deglaciation
on the floor of the main valley as well.

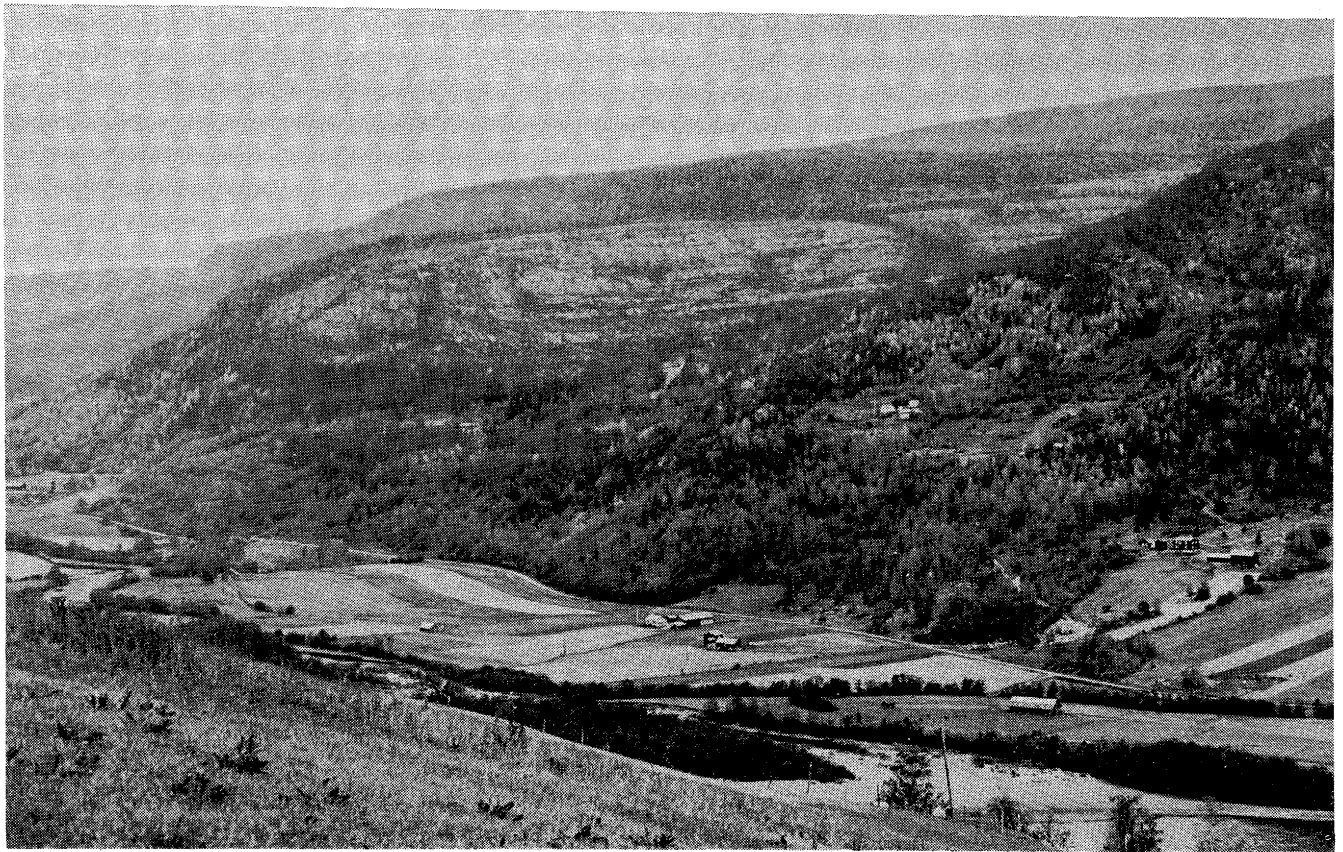A large deposit of sorted material is located at the mouth of

Fig.11. Example of washed zone in the valley side presumed
being stripped by the melt-water after the reversion of the
drainage in Gudbrandsdalen. The actual zone, situated about
600 m a.s.l. just north of the mouth of the Vinstra valley,
is completely free of deposits. (Viewed to the southwest).

the Vinstra valley in Gudbrandsdalen. Mangerud (1963) inter-
preted this as a fan deposited by water from "Storesjøen"
pouring through the Vinstra valley when the postulated dam
at Skåbu was broken. Sections in this deposit show normal
delta formations (Fig. 12). The boundary between the foreset
and topset layers is at 250 m a.s.l. All observations indi-
cate that the delta was built by the river Vinstra during
post-glacial time, when all the ice had disappeared. Similar
young deltas or fans are situated in front of all larger
tributary valleys in Gudbrandsdalen. The authors believe
therefore that the delta has no connection with "Storsjøen".

CORRELATION

To outline the most important events and phenomena that can
be correlated at the present stage, the main features are
shown in tableform. The drainage through east Jotunheimen
has been traced, both through the Espedal - Gausdal valleys
and through the Vinstra - Gudbrandsdal valleys. It converges
at the northern end of Mjøsa. The most important correlations
and relative dating can be found on   Table 1. Some main
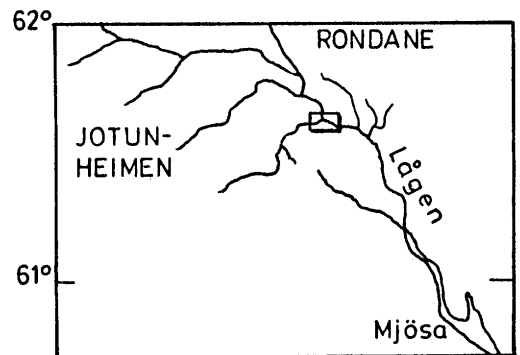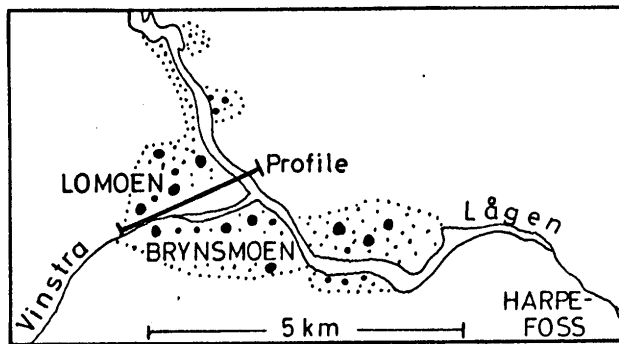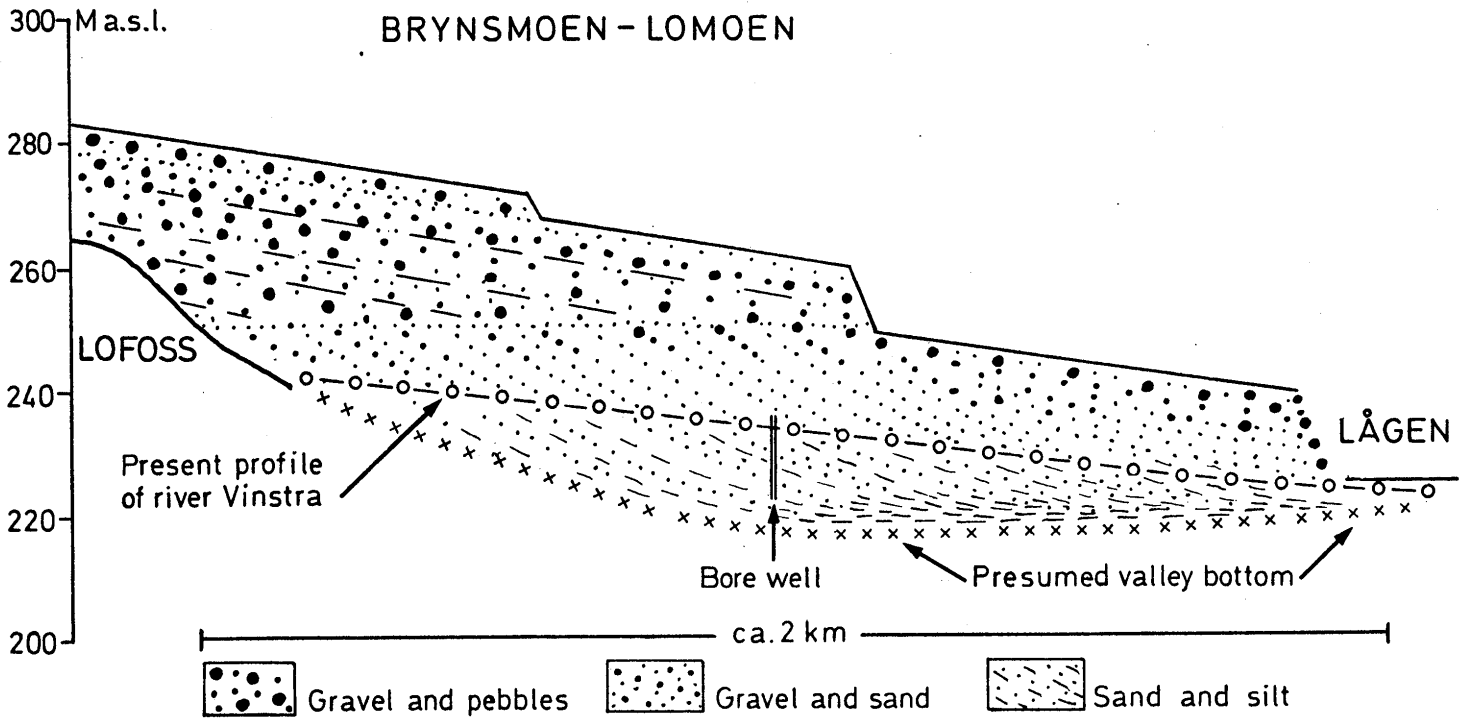features will be commented upon.

BRYNSMOEN – LOMOEN

Fig. 12. *Longitudinal section through the delta at the mouth of the Vinstra valley in Gudbrandsdalen. The deposition shows normal delta formations.*

Da. During the Nunatak-phase, the inland ice in the Mjøsa
area was increasingly affected by the fjord-lake, Mjøsa,
which is about 500 m deep in its southern part. Very
rapid retreat probably occurred here due to calving. This
is comparable to the retreat of the ice lobes in the large
fjords in West-Norway (among others,H.Holtedahl 1975). The
rapid retreat presumably led to a steeper gradient, at least
on the outer parts of the inland ice. This may have resulted
in the formation of the distinct lateral moraines east of
Lillehammer. Here considerable moraines can be traced more
or less continuously from Nevelfjell to Sjusjøen c. 13 km to
the southeast (Fig. 4) e.g. O.Holtedahl 1953 p.782-786). The
position of the moraines agrees very well with the change in
the ice-flow pattern that had to occur as the inland ice was
deflected towards Mjøsa due to calving. Therefore, these
lateral moraines were probably not determined by climatic
conditions.

Db. The Krusgrav-phase to the south and the Ring-drainage-
phase to the north of the ice divide are not entirely
synchronous. The heavy drainage of melt-water along Gudbrands-
dalen during this phase may have contributed to the formation
of the sub-aquatic, front deposit across Mjøsa at Moelv
mentioned on page . The break-up of the ice as it floated
in Mjøsa probably happened rather quickly up as far as Moelv.
This is indicated by soundings in Mjøsa. However, further
north, things may have happened more slowly. The ice front
could have lingered at Moelv during a greater part of phase
Db, when the Mjøsa level was approximately 190 m a.s.l.

Dc.   During the Espedal phase, the last remnants of the inland ice melted in the Mjøsa area. The level of Mjøsa sank very rapidly from 190 m to about 140 m a.s.l. This may be attributed to the rapid breaching of the large frontal deposits at the southern end of the lake (Minnesund) due to quick regression of the sea in the Oslofjord area during Preboreal time   (e.g. Hafsten 1960).

Dd and De. Considerable ice masses still remained in Gudbrands-dalen. However, the large amounts of water coming from icefree areas caused rapid deglaciation here too, especially during the phase De.

Until detailed investigations are carried out along Mjøsa itself, the exact age of the phases and of the most important events cannot be determined accurately enough. The hitherto ^{14}C-datings are few and far between, and they are associated with a certain degree of inaccuracy. At least two important questions concerning the Mjøsa area must be resolved in the future:

1. Correlation of synchronous levels, and correlations of these with marine levels south of the lake.

To accomplish this we must also:

2. Determine the isobase directions and the rate of up-heaval in the Mjøsa area during this period.

SUMMARY

1. The history of the wastage of the last ice sheet in a land scape with a relief up to 1000m, shows that downmelting of the ice was of a greater importance than frontal retreat. The ice surface is found to have melted down with very small gradients

in the area between the ice divide zone across Gudbrandsdalen

and the main watershed in the north. This was specially the

case when the ice sheet was no longer supplied by ice from the

former culmination areas. This happened when the ice surface

was situated about 1200 m a.s.l. in east Jotunheimen. During

the further deglaciation, until the last ice masses in central

Gudbrandsdalen no longer dammed the drainage and the drainage

reversed, the slope of the ice surface was very close to zero.

The reversion took place when the ice lobe was lowered to a

level adjusted to the lowermost pass in the north (612 m a.s.l.).

In the area south of the ice divide zone it is found that the

gradient of the ice surface during most of the deglaciation

was c. 1 %. However, during the very last phases the ice

lobes probably were in close conformity with the relief.

The descending angle of 1 % is of the same value as the inclina-

tion of the general land slope. Therefore, very large areas

became free of ice almost simultaneously. While the ice

movement to a high degree was independent of the relief at an

early stage of the deglaciation, the movements and the drainage

as well, became more and more topographically controlled. The

interaction between the ice movements and the topographical

conditions caused large differences in local gradients. Small

gradients (0 - 2 %), caused erosion of terraces as well as

their accumulation by melt-water, gradients exceeding c. 2 %

locally caused the formation of lateral moraines. When the

supply of ice from the former culmination centers in the Jotun-

heimen ended, the ice sheet was already separated into several

lobes, situated in the valleys. The partition of the ice sheet

into different bodies gave the result that the front areas of the ice existed as retreating lobes in the valleys with large ice-free areas between the valleys. This picture of the last ice sheet differs from older views where the last remnants of the inland ice are drawn as a plateau-like glacier with a straight-lined boundary.

2. Due to the down-wasting there existed simultaneously active ice in the valleys, stagnant ice in upper areas, and dead ice in many high-level basins. The last remnants of the ice sheet in central South Norway seems to have existed in the Gudbrandsdal.

3. In attempting to reconstruct the level of the ice surface, different phenomena presumed to have formed laterally or sub-laterally, should be used very carefully. Nevertheless, by following and correlating terraces step for step over a large region, combined with other methods, it is concluded that the study of lateral phenomena often gives important and adequate information about the ice sheet's gradients.

4. During the downmelting, the inland ice sheet is believed to have been climatically dead from the time of the Nunatak-phase or at least from the later part of it. In mountain areas as well as in lowlands in the investigated region there occur distinct and surprisingly large marginal moraines. These moraines are believed to have been formed by sudden changes in the ice-flow pattern, causing increased steepnes of the ice surface and faster ice movements. There are different reasons for drastic changes like this. Many moraines are found at the same height as

important overflow passes, deflection of the ice streams is

probably the reason for their existence. The lobes often

dammed the melt-water drainage, large quantities of water

being stored in lateral lakes. When dams broke, large

frontal deposits were built up as a consequence of renewed acti-

vity in the ice lobe as well as of the greater runoff with a

heavy sediment load.

5. The melt-water drainage have been traced through two

different valley-systems which converge at the northern

end of Mjøsa, namely the Espedal - Gausdal valleys and the

Vinstra - Gudbrandsdal valleys. When linked together, it is

possible to correlate different deglaciation phenomena in the

ice divide zone with those at the ice front in the Mjøsa area.

A relative correlation table showing the preliminary results,

is presented in Table 1. Absolute age dates are few in the

investigated area. However, all available information suggests

that the four oldest phases reconstructed all belong to the

Preboreal chronozone, the youngest one probably being of

Boreal age.

ACKNOWLEDGEMENTS

Phase	Ice surface at Skåbu, m a.s.l.	Frontal deposition	Level in the northern part of Mjøsa, m a.s.l.	Remarks
Da Nunatak-phase	1900 - 1300	Nevelfjell-Sjusjøen-moraine		Starting of the break-up of the ice along Mjøsa?
Db Krusgrav-phase Ring-drainage-phase	1300 - 1000	Moelv-moraine	c. 190	Calving along Mjøsa.
Dc Espedal-phase	1000 - 800	Saksumdal-delta Hovemoen-moraine Kame-terraces in Gausdal Jørstadmoen-delta	c. 190 c. 170 c. 168 c. 140	Calving decreased and ended. Down-wasting of all ice lobes.
Dd Store Dølasjø-phase	Ice-free	Øyer-moraine	< 140	C. 9000 years B.P. Down-wasting continued.
De Gudbrandsdal-phase	Ice-free	Smaller glaciofluvial deposits in Gudbrandsdalen	< 140	Reversed drainage along Gudbrandsdalen. Ice left in the main valley only.

Table 1.

REFERENCES

Alstadsæter, I. 1979: Kvartær stratigrafi og sedimentologi i Vinstra-dalen, Oppland. University thesis, Bergen (unpubl.)

Bergersen, O.F. 1964: Løsmateriale og isavsmeltning i nedre Gud-brandsdalen og Gausdal. Nor. geol. Unders. 228, 12-83.

Bergersen, O.F. 1971: Kvartærgeologien i Sør-Gudbrandsdalsregionen. Report, Geological institute, University Bergen, 68 pp. 5 maps.

Bergersen, O.F. 1973: The roundness analysis of stones. A neglected aid in till studies. Bull. Geol. Inst. Univ. Upps. 5, 69-79.

Bergersen, O.F. 1975: Lågen-Gausa deltaet. Beskrivelse og vurdering av de kvartærgeologiske forhold. Report. Geological institute, University Bergen, 30. pp.

Bergersen, O.F. & Garnes, K. 1972: Ice movements and till strati-graphy in the Gudbrandsdal area. Preliminary results. Nor. geogr. Tidsskr. 26, 1-16.

Enger, K.A. 1973: Vestre Gausdal i kvartærtiden og spesielt under isavsmeltningen. 89 pp. Dølaringen Boklag. Lillehammer.

Fulton, R.J. 1967: Deglaciation studies in Kamloops region, an area of moderate relief, British Columbia. Geol. Surv. Canada, Bull. 154, 36 pp.

Garnes, K. 1978: Zur Stratigraphie der Weichseleiszeit im zentralen Südnorwegen. In H. Nagel (ed.): Beiträge zur Quartär-und Landschafts-forschung. Festschrift zum 60. Geburtstag von Julius Fink, 195-220. Hirt. Wien.

Gjessing, J. 1960: Isavsmeltningstidens drenering. Dens forløp og formdannende virkning i Nordre Atnedalen. Med sammenlignende studier fra Nordre Gudbrandsdalen og Nordre Østerdalen. Ad Novas 3, 492 pp.

Gjessing, J. 1965: Deglaciation of southeast and east-central South Norway. Nor. geogr. Tidsskr. 20, 133-149.

Hafsten, U. 1960: Pollen-analytic investigations in South Norway. In O. Holtedahl (ed.): Geology of Norway. Nor. geol. Unders 208. 540 pp.

Hansen, A.M. 1886: Om seter eller strandlinjer i store høider over havet. Arch. Math. Naturv. 10, 1-25.

Hansen, A.M. 1890: Strandlinjestudier. Arch. Math. Naturv. 14, 254-343.

Hansen, A.M. 1891: Strandlinjestudier. Arch. Math. Naturv. 15, 1-96.

Hansen, A.M. 1895: Om beliggenheden av bræskillet og forskjellene mellom kyst- og kontinentalsiden hos den skandinaviske storbræ. Nyt Mag. Naturvid. 34, 112-214.

Hole, J. 1979: Kvartærgeologiske granskingar i Skjåk-området. University thesis, Bergen (unpubl.).

Holmsen, G. 1915: Brædæmte sjøer i Nordre Østerdalen Nor. geol. Unders. 73, 211 pp.

Holmsen, G. 1918: Gudbrandsdalens bræsjø. Nor. geol. Unders. 83, 1-25.

Holmsen, G. 1964: Om glasiasjonssentra i Sør-Norge under slutten av istiden. Nor. geol. Unders. 228, 151-161.

Holtedahl, H. 1975: The Geology of the Hardangerfjord, West Norway. Nor. geol. Unders. 323, 1-87.

Holtedahl, O. 1953: Norges geologi. Nor. geol. Unders. 164: II, 587-1118.

Holtedahl, O. 1960: Geology of Norway. Nor. geol. Unders. 208, 540 pp.

Jørgensen, P. 1964: Kvartærgeologiske undersøkelser i Randsverk-området, Jotuneheimen. Nor. geol. Unders. 228, 162-179.

Lie, E. D. 1974: Kvartærgeologiske undersøkelser i Otta-området. University thesis, Bergen (unpubl.).

Lundqvist, J. 1973: Isavsmältningens förlopp i Jämtlands län.
Sver. geol. Unders. Ser. C 681, 187 pp.

Mangerud, J. 1963: Isavsmeltingen i og omkring midtre Gudbrandsdal.
Nor.geol.Unders. 223, 223-274.

Mannerfelt, C.M. 1940: Glacialmorfologiska studier i Norska høg-
fjäll. Nor.geogr.Tidsskr. 8, 9-47.

Østmo, S.R. 1972: Geologiske og hydrogeologiske undersøkelser i
Korgen-Hovemoen området. Forslag til klausulområder for Lillehammer
vannverk. Nordisk Hydrologisk Konferanse Sandefjord 6.-8. Sept. 1972:I,
49-65. Oslo.

Øyen, P.A. 1896: Strandlinjer i Gudbrandsdalen. Arch. Mat. Naturv. 18:6,
22 pp.

Øyen, P.A. 1898: Bidrag til Jotunfjeldenes glacialgeologi. Nyt Mag.
Naturvid. 36, 73-65.

Øyen, P.A. 1899: Kontinentalglaciation og lokalnedisning.
Arch. Mat. Naturv. 21: 7, 66 pp.

Ramsli, G. 1947: Siste istid i Gudbrandsdalen. Nor. geogr.
Tidsskr. 11, 253-259.

Ramsli, G. 1948: Kvartærgeologiske undersøkelser i Skåbu og Espe-
dalen. University thesis, Oslo (unpubl.).

Rekstad, J. 1895: Bræbevægelsen i Gudbrandsdalen mod slutningen
af Istiden. Arch. Math. Naturv. 17, 15 pp.

Rekstad, J. Mærker efter istiden i det nordlige af Gudbrandsdalen.
Arch. Math. Naturv. 18, 22 pp.

Rekstad, J. 1898: Mærker efter istiden i Gudbrandsdalen.
Arch. Mat. Naturv. 20, 18 pp.

Reusch, H. 1894: Har der existeret store, isdæmmede indsjøer paa
østsiden af Langfjeldene? Nor. geol. Unders. 14, 51-59.

Reusch, H. 1901: Høifjeldet mellem Vangsmjøsen og Tisleia (Valdres).
Nor. geol. Unders. 32, 45-88.

Reusch, H. 1910: De formodede strandlinjer i Øvre Gudbrandsdalen.
Nor. geol. Unders. 57: IV, 24 pp.

Samuelsen, A. 1953: Innlandsisens avsmelting mellom Gudbrandsdalen
og Østerdalen. Nor. geogr. Tidsskr. 14, 229-235.

Sars, M. & Kjerulf, Th. 1860: Den postpliocene eller glaciale
formation. Universitets-program for første halvaar 1860, ved Det
kgl. norske åredriks Universitet. Christiania.

Schiøtz, O.E. 1895: Om isskillets bevægelse under avsmeltning af
en indlandsis. Nyt Mag. Naturvid. 34, 102-111.

Skjerven, J. 1978: Kvartærgeologiske undersøkelser i Vågå-området.
University thesis, Bergen (unpubl.).

Sollid, J.L. 1964: Isavsmeltningsforløpet langs hovedvass-skillet
mellom Hjerkinn og Kvikneskogen. Nor. geogr. Tidsskr. 19, 51-76.

Strøm, K. 1956: The disappearance of the last ice sheet from central
Norway. J. Glaciology 2, 747-755.

Tollan, A. 1963: Trekk av isbevegelsen og isavsmeltningen i
Nordre Gudbrandsdalens fjelltrakter. Nor. geol. Unders. 223,
328 - 345.

Vogt. J. 1943: De terrasseformede morener ved Lillehammer.
University thesis, Oslo (unpubl.).

Vorren, T.O. 1977: Weichselian ice movement in South Norway and
adjacent areas. Boreas 6, 247-257.