NGU-rapport nr. 86.035

INQUA-IGCP excursion and symposium
in Norway, June 16-23, 1985

SEA-LEVEL CHANGES ON THE WEST-NORWEGIAN COAST

Trondheimsfjorden area,
June 22-23, 1985

Excursion guide

Norges geologiske undersøkelse

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Rapport nr. 86.035	ISSN 0800–3416	Åpen/~~Fortrolig til~~

Tittel:	INQUA-IGCP excursion and symposium in Norway, June 16-23, 1985, SEA-LEVEL CHANGES ON THE WEST-NORWEGIAN COAST. Trondheimsfjorden area, june 22-23, 1985. Excursion guide.
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Fylke:	Kommune: Stjørdal Levanger Verdal Steinkjer
Kartbladnavn (M. 1:250 000) Trondheim	Kartbladnr. og -navn (M. 1:50 000)
Forekomstens navn og koordinater:	Sidetall: 34 Pris: 50.00 Kartbilag:
Feltarbeid utført: Rapportdato: 29.01.1986	Prosjektnr.: Prosjektleder:

Sammendrag:

Ekskursjonsguide for Trøndelagsdelen av INQUA-IGCP ekskursjonen:
SEA-LEVEL CHANGES ON THE WEST-NORWEGIAN COAST.
22.-23. juni 1985.

Komplett program for hele ekskursjonen, omfattende Bergen-, Ålesund- og Trondheimsområdet.

Emneord		
	Kvartærgeologi	
		Ekskursjonsguide

Hydrogeologiske rapporter kan lånes eller kjøpes fra Oslokontoret, mens de øvrige rapportene kan lånes eller kjøpes fra NGU, Trondheim.

INQUA Subcommision on Shorelines
of Northwestern Europe.

IGCP Project 200: Sea-level changes
and applications.

SEA-LEVEL CHANGES ON THE WEST-NORWEGIAN COAST.
EXCURSION AND SYMPOSIUM IN NORWAY 16 JUNE - 23 JUNE 1985.

Innledning

Rapporten omfatter Trøndelagsdelen av ekskursjonen, 22.-23. juni 1985.

Til orientering gjengis nedenfor programmet for hele ekskursjonen.

Guide for Bergensområdet, 17.-19. juni 1985, ble skrevet av Peter Emil Kaland, Jan Mangerud og Bjørg Stabell.

Guide for Ålesundområdet, 20.-21. juni 1985, ble skrevet av J. Mangerud, S. Greve, T. Henningsen, Ø. Hovden, I. L. Kristiansen, J. Landvik, E. Larsen, S. E. Lie, L. Lømo og J. I. Svendsen.

Ulf Hafsten　　Arne J. Reite　　Harald Sveian

PROGRAMME

Sunday 16 June.

17.00	Departure from the Realfagbygg (Science building) by bus and ferry to Westland hotell, Lindås.
19.00	Dinner.

Accomodation: Westland hotell (Tel. 05 - 36 01 00).

Monday 17 June.

8.30 - 13.00	Excursion in the Lindås/Austrheim area. - 1.1 Jervågen. Demonstration of a marine basin with a well defined threshold. - 1.2 Fonnes. Younger Dryas endmoraine. - 1.3 Longevatn, Fosnøy. Lake with threshold 10.9 m above present mean sea level.
13.00 - 14.30	Lunch
14.30 - 18.00	Symposium.
19.00	Dinner

Accomodation: Westland hotel.

Tuesday 18 June.

8.00 - 12.00	Excursion in the Lindås/Austrheim area. - 2.1 Fonnastraumen. A shore-bound late mesolithic/early neolithic dwelling place. - 2.2 Lomtjørn, Fonnes. Lake with threshold 7.2 m above present mean sea level. - 2.3 Altersvatn, Fonnes. Lake with threshold 3.9 m above present mean sea level
12.00 - 12.45	Lunch at Westland hotel.
13.00 - 19.00	Excursion Lindås - Masfjord - Bergen - Sotra - 2.5 Matre, Masfjorden. Glacifluvial delta. - 2.6 Haugsdal, Masfjorden. Fluvial terraces. - 2.7 Romarheim, Osterfjorden. Marine terraces. - 2.8 Eikemo, Osterfjorden. Marine terraces. - 2.9 Eikangervåg, Osterfjorden. Till with shells (Allerød). - 2.10 Fjøsanger. Eemian sediments.
19.30	Dinner.

If weather is favourable a fishing tour by boat in the archipelago outside the island of Sotra will be arranged.

Accomodation: Havtun turistsenter (Tel. 05 - 32 82 50)

Wednesday 19 June.

8.00 - 12.00 Excursion on Sotra.
- 3.1 Klæsvatn,Tofterøy. Lake with Late Weichselian transgression. Threshold 30,5 m above present mean sea level.
- 3.2 Storetjønn, Tofterøy. Lake with threshold 35,8 m above present mean sea level.
- 3.3 Hamravatn, Sotra. Lake with threshold 29,0 m above present mean sea level.

12.00 - 12.45 Lunch at the industrial centre of Ågotnes.

12.45 - 15.30 Excursion at Øygarden north of Sotra
- 3.4 Dale,Blomøy. Late Weichselian pollen daigram.
- 3.5 Blomvåg, Blomøy. Classical locality with Late Weichselian sediments.
- 3.6 Sture. Shore-bound early and late mesolithic sediments.
- 3.7 Trolltjønn; Sture. A small lake with late Weichselian sediments. Pollen diagram.

15.45 - 16.30 Return to the city of Bergen by speed boat.
No prepared dinner. Possibility for sightseeing.

Accomodation: Fantoft Studentby og Sommerhotell (Tel. 05 - 28 29 10)

Thursday 20 June.

6.45 Departure hotel by ordinary airport bus to Flesland airport.

7.35 - 8.10 Airplane Flesland airport(Bergen) - Vigra airport (Ålesund)

8.30 - 12.00 Excursion on the islands Vigra and Valderøy west of Ålesund.
- 4.1 Molnes. Tapes beach ridge.
- 4.2 Blindheim church. Marine limit.
- 4.4 Brattrima. Section in beach sediments.

12.00 - 12.45 Packed lunch.
- 4.5 Valderhaug. Marine limit
- 4.6 Skjonghelleren. Cave.

15.20 Ferry from Valderøy to Godøya.

15.45 - 17.45 Excursion on the island Godøya west of Ålesund.
- 4.7 Myrane. Marine limit.
- 4.8 Strandkleiv. Middle Weichselian sandur.
- 4.9 Dyp. Middle Weichselian sandur.
- 4.10 Støbakkvika. Tapes shoreline.

17.55 Ferry from Godøya to Ålesund.

19.00 Dinner.

Accomodation: Parken hotell (Tel. 071-22 22 1).

Friday 21 June.

8.30 - 12.00 Excursion in the Ålesund area.
- 5.1 Aksla. View of cirque moraines.
- 5.2 Borgund. Peat below sea level (not visible).
- 5.3 Lerstadvatn. Coring. Marine/lacustrine sediments.

12.00 - 13.00 Packed lunch.
- 5.4 Slettbakktjørn. Coring. Marine/lacustrine sediments.
- 5.5 Eidsvik. Shelly till.
- 5.6 Skodjevåg. Marine sediments.
- 5.7 Sjøholt. Glacifluvial delta.

19.00 Dinner.

Accomodation: Parken hotell.

Saturday 22 June.

7.15 Departure hotel. Ferry and airport bus to Vigra airport.

8.30 - 10.10 Airplane Vigra airport - Vernes airport (Trondheim).

10.30 - 13.00 Excursion Vernes - Levanger.
- 1. Frigården. Delta.
- 2. Alstad. Marine shore deposits.

13.00 - 14.00 Lunch Backlund hotell, Levanger.

14.00 - 18.00 Excursion Levanger - Steinkjær.
- 3. Vinne. Marine terrace.
- 4. Sundby. Quick clay slide.
- 5. Helgådalen. Sediments exposed by river erosion.
- 6. Mo. Marine terrace.

19.00 Dinner.

Accomodation: Grand hotell, Steinkjær. (Tel. 077 - 64700)

Sunday 23 June.

8.30 - 12.30 Excursion Steinkjær area.
- 7. Helge at Byafossen. Burial mound and stone monuments from Roman Iron Age.
- 8. Bardal. Rock carvings of both Arctic and Bronze Age type.
- 9. Hammer. Arctic rock carving site at 42 m above sea level.

12.30 - 13.30 Lunch Backlund hotell, Levanger.

13.30 - 14.00 Bus Levanger - Vernes airport.

14.00 - 15.00 Bus Vernes airport - Trondheim. Radiocarbon conference.

Individual accomodation or arranged through the Radiocarbon conference.

INQUA - IGCP EXCURSION AND SYMPOSIUM IN NORWAY

JUNE 16 - 23, 1985

SEA-LEVEL CHANGES ON THE WEST-NORWEGIAN COAST

TRONDHEIMSFJORDEN AREA

JUNE 22 - 23, 1985

ULF HAFSTEN
ARNE J. REITE
HARALD SVEIAN

- DEGLACIATION
- SHORE DISPLACEMENT
- ARCHAEOLOGY AND SHORE LEVEL
- VEGETATIONAL HISTORY
- LOCALITIES TO BE VISITED

DEGLACIATION

Radiocarbon datings related to the deglaciation of the Trondheimsfjord area suggest that the coastal areas and outer part of the fjord were deglaciated before 11,000 B.P. (see Fig. 1). During early Younger Dryas the inland ice advanced to the Tautra moraines (10,800 - 10,500 B.P.). Further inland the Hoklingen moraines (10,300 - 10,100 B.P.) and the Vuku moraines (9,900 - 9,800 B.P.) were deposited during marked glacial advances (Figs. 1, 2 and 11). Other ice-marginal deposits in the area are mostly dependent on the local topography (Fig. 3).

During the deglaciation this part of the country was deeply submerged. The marine limit lies at an altitude of about 100 m in the coastal areas and at 180 - 185 m along the eastern part of the Trondheimsfjord (Fig. 4).

Large areas to the east of the fjord are covered by glaciomarine silt and clay deposits which in the main valleys reach a thickness of 100 m and in the fjord up to 300 - 400 m.

SHORE DISPLACEMENT

The shore displacement has been described by Kjemperud (1982) and Hafsten (1983), who based their studies on the 'isolation contact' method and radiocarbon datings of gyttja (Figs. 5 - 8), whereas the curve for Verdalsøra, worked out by Sveian & Olsen (1984), was based on radiocarbon datings of marine shore deposits (Figs. 10 and 11). The direction of the isobases in the Trondheimsfjord area is shown in Figs. 9 and 11 and an equidistant shore-line diagram in Fig. 8. Isobases for the present land uplift are set out in Fig. 14.

The curves from Frosta and Verdalsøra are compared in Fig. 13. They show both that as much as 2/3 of the total post-glacial shore displacement took place already during the Preboreal and Boreal (10,000 to 8,000 yrs B.P.). In Preboreal the displacement was close to 6 m per century (60 mm per year in average). Today it is only between 0.3 and 0.4 m per century (3 to 4 mm per year, see Fig. 14).

During Holocene an extensive fluvial erosion took place, which reduced the stability of the remaining sediments and lead to numerous slides. River terraces and deltas were built up at successive levels. Sveian & Olsen (1984) pointed out large terraces in Verdalen at altitudes of 65 - 70 m, ca. 40 m and 20 - 25 m and beach ridges at 10 - 12 m.

ARCHAEOLOGY

The area at and around Trondheimsfjorden is rich in remains of ancient human activity, referring particularly to Neolithic time, Bronze Age and early Iron Age. Of special interest to scientists are the many burial mounds and rock-carvings occurring in the area. The burial mounds are mostly located to the plateau or upper part of moraine ridges or other exposed heights where they were easily seen. The rock-carvings are often located at or closely above the former shore level and are in some cases partly covered by beach deposits consisting of worn and rounded stones and pebbles (see Fig. 22).

The carvings refer both to the Arctic and the Bronze age type of rock-carvings and show both naturalistic and abstract figures and patterns. The range of motifs is rather comprehensive including animals such as elk, reindeer, bear, whale, birds (ducks) and fish; boats; human beings; sexual and fertility symbols, as well as various abstract patterns such as zigzag bands and chevrons, placed both separately and inside the bodies (Fig. 23). Some of the animals also show a median line, leading from the head or mouth to the heart or the tail, often called the 'life-line', after ethnographic parallels. Among primitive people in recent time such features have a magical significance as well as a special name (see Fig. 23).

Dating of rock-carvings by means of the shore displacement has been tried at various sites on the coast of S. Norway (e.g. Bakka 1973), and so also at Hammer (loc. 9) where basal peat resting on minerogenous beach deposits at Kirknesmyr situated only a few hundred metres N of Hammer and at the same altitude (about 36 m) provided a calibrated age of 2400$\pm$210 B.C. (Hafsten unpubl).

VEGETATIONAL DEVELOPMENT

The main trends of the vegetational development in the area may be seen from the two pollen diagrams enclosed from the lakes Vassaunvatnet (Fig. 24) and Lomtjern (Fig. 25), situated in the area vest of Steinkjer, at heights of 117 and 170 m, respectively.

In the Lomtjern diagram the development may be traced back to the end of Younger Dryas, if the basal radiocarbon date of 10,590 B.P. is correct. However, the fact that the Fosen stage or main Younger Dryas end moraine is situated about 30 km vest of the site, indicates that the ^{14}C-date is too high.

The pollen diagrams reveal a development which is typical for the Mid-Norwegian region: 1) an early Holocene development with a *Preboreal birch maximum* succeeded by a *Boreal pine maximum* (lacking the Boreal hazel maximum occurring in South Norway), 2) a megathermal or hypsithermal development characterized by a pronounced *Atlantic alder maximum*, commencing very abruptly around 8000 B.P. and coinciding in the later stage with moderate or low *maxima of hazel and elm*, and the *Subboreal pine and birch stadium and decreasing hazel and elm*, and 3) *a Subatlantic birch, pine and eventual spruce dominans*. Spruce (*Picea abies*), the dominating tree species today, reached the borderland between Norway and Sweden in late pre-Christian time, after a more than 3000 years long migration through Finland and Sweden. but the more extensive spread of this tree species did not take place until after the Roman Iron Age (AD 400). Oak and elm, which were dominating in many areas in S. Norway during the megathermal period, are lacking in Mid-Norwegian pollen diagrams and so also extreme thermophilous indicators such as Mistletoe, Ivy and Holly.

LOCALITIES TO BE VISITED ON SATURDAY

Locality 1 - Frigården

Ice-contact delta, with topset and foreset beds, deposited at a sea-level of ca. 185 m above the present one. Beds of till in the proximal slope indicate minor glacial oscillations.

The delta is underlain by bottomset beds consisting of marine silt and clay. This is indicated also by a slide depression just to the north of the delta.

The fine-grained marine sediments in this valley are strongly influenced by fluvial erosion and slides. - Several of these slides have taken place during the last centuries, causing great damage and loss of lives.

Locality 2 - Alstad

Marine shore deposits situated at an altitude of 65 - 70 m. Note the molluscan shells in the sandy beds and the horizontal coarse-grained tidal sediments, with well rounded stones and gravel. This locality has been strongly exposed to westerly wind directions. Generally the shore sediments are less than 2 m in thickness in this region.

Locality 3 - Vinne

The Vinne terrace, at ca. 40 m altitude, is one of the most dominating terraces in Verdal. 10 - 15 m of sand with foreset and topset beds is overlying silt and clay of great thickness. Vinne is interpreted as a raised delta dating at ca. 5,500 B.P according to Fig. 12.

Locality 4 - Sundby

Locality provides a view to the lower part of Verdalen, particularly the area of a quick clay slide, 'Verdalsraset', where 112 persons were lost the night 18-19 May 1893. About 30 mill. m^3 sand, silt and clay dammed the river, destroyed farms and covered several square kilometres of land (Figs. 15, 16, 19, and 20). Terraces at different levels can be seen in the valley.

Between stops at locality 4 and 5 one can see ice-marginal glaciofluvial deposits and levels of marine limit at 180 - 185 m altitude.

Locality 5 - Helgådalen

River erosion changing the course of the river Helgåa. The sketch in Fig. 17 shows the situation at the Hærfossen waterfall (29 m high) before (A) and after (B) September 12, 1893, when the river cut through the marine sediments at a bend many km upstreams (at 3) and left the old course over the bedrock threshold at 1. The change of the river course caused great damage. Many sections are still open.

A glaciofluvial terrace at the marine limit here at 180 m altitude may be seen from the bus 2 - 3 km further up the valley.

Locality 6 - Mo

A short trip along the Verdalen slide depression from 1893 (Fig. 15) and up to the 65 - 70 m terrace at Mo. This terrace was cut by the slide in 1893, but is still a dominating deposit in the valley. Borings carried out at the Mo farms reveal about 20 m of sand and coarse silt overlying silt and clay. Many beach ridges are present on the surface. The stratigraphy is shown in Fig. 18. Dating No. 10 in the Verdalsøra shore displacement curve (Fig. 12) was carried out on molluscs being found in the foreset beds in one of the sand pits at Mo. Sveian & Olsen (1984) concluded from the great thickness of the sand, the beach ridges on the surface, the stratigraphy, and the age of the molluscs that Mo is a raised delta formed about 7,500 yrs B.P. during a period of very slow shore displacement.

LOCALITIES TO BE VISITED ON SUNDAY

Locality 7 - Helge at Byafossen

Burial mounds ('Ormshaugen' and 'Helgeshaugen') and stone monuments at a cult place from early Roman Iron Age, situated at about 10 m altitude, at a strategic point along the water course between the fjord and the lake series Reinsvatn - Fossemvatn - Snåsavatn. The local name 'Helge' derives assumably from 'Helg-eid', meaning the holy isthmus, viz. cult place.

On the top of the conspicuous Egge ridge ('Eggehvammen') lies the greatest concentration in Norway of graves and burial mounds from pre-Christian time, viz. Roman Iron Age and also Viking Age. 27 monuments are still visible, containing burned bones, chair coal, veapens, bronze vessels, gold rings etc.

Locality 8 - Bardal

One of the most conspicuous rock-carving sites in Trøndelag, containing numerous figures and forms of both Arctic and Bronze age type of carvings. The Arctic carvings show both animals (elk, reindeer, porpoise, bear, birds) and human bodies, and the Bronze Age carvings: manned ships, horses, human bodies, foot prints, sun symbols, geometric patterns, etc. The foot of the rock face at Bardal is described to be situated at ca. 42 m altitude, indicating that the rock-carvings at Bardal cannot be older than ca. 5000 years.

Locality 9 - Hammer

The Arctic rock-carvings at Hammer are among those which had been partly covered by old beach material, presumably deposited by wave action at the time when sea-level was at the foot of the rock face, viz. about 36 m (see Figs. 22 and 23, and chapter on Archaeology).

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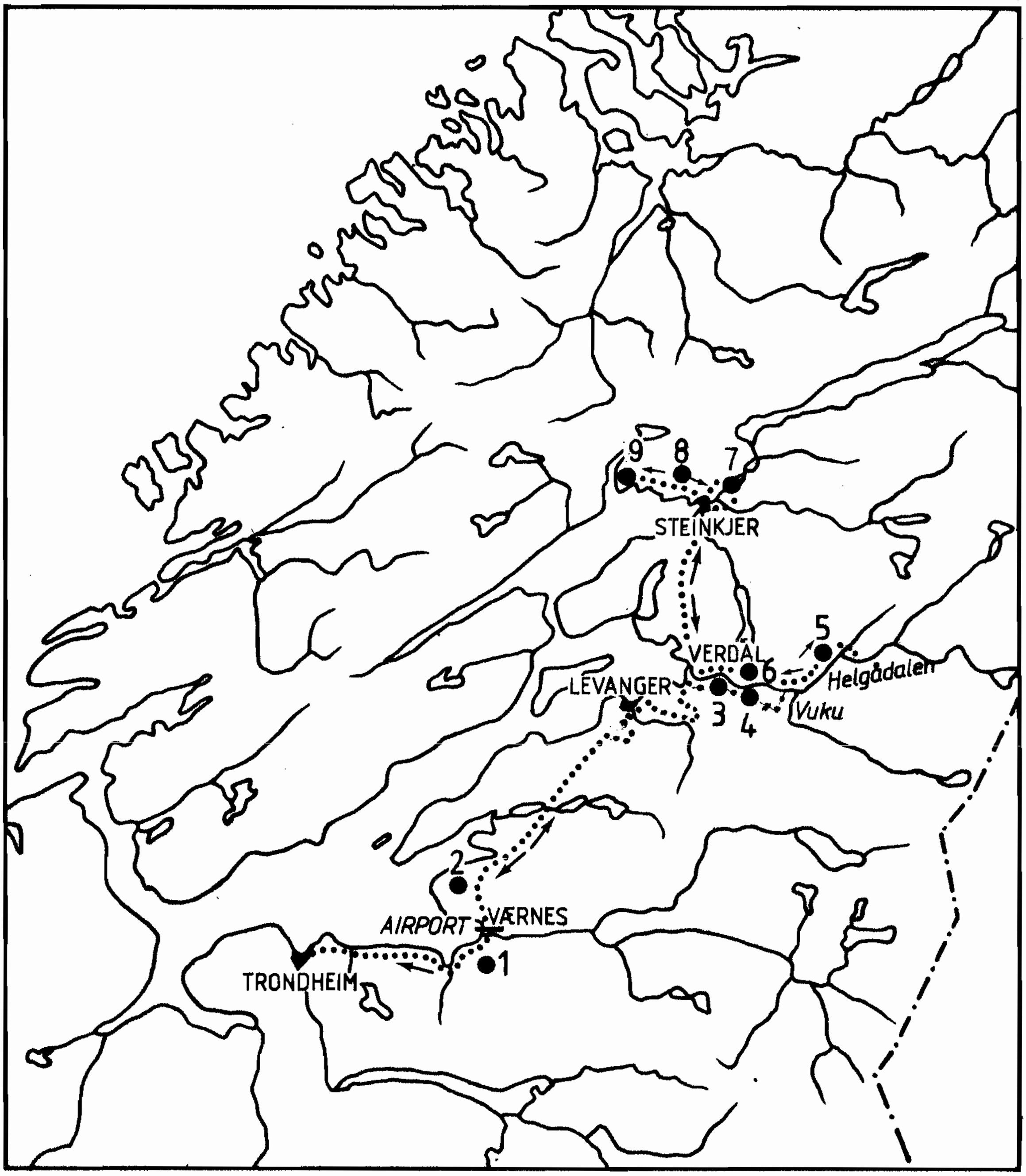
Sveian, H. & Olsen, L. 1984: A shoreline displacement curve from Verdalsøra, Nord-Trøndelag, Central Norway. Nor. geol. Tidsskrift 64, 27-38.



LOCATION MAP

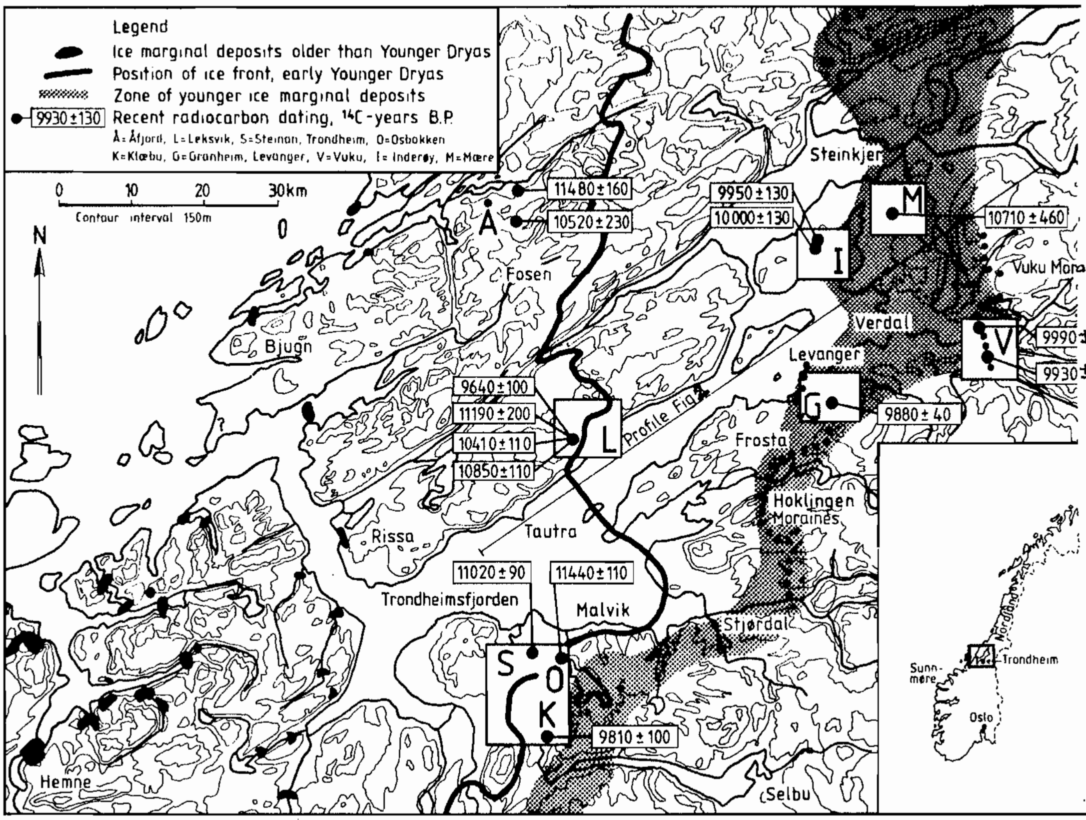


Fig. 1. Map of the Trondheimsfjord area showing ice-marginal features and recent radiocarbon datings. Frames mark the location of the more detailed maps shown in Figs. 3

Fig. 1

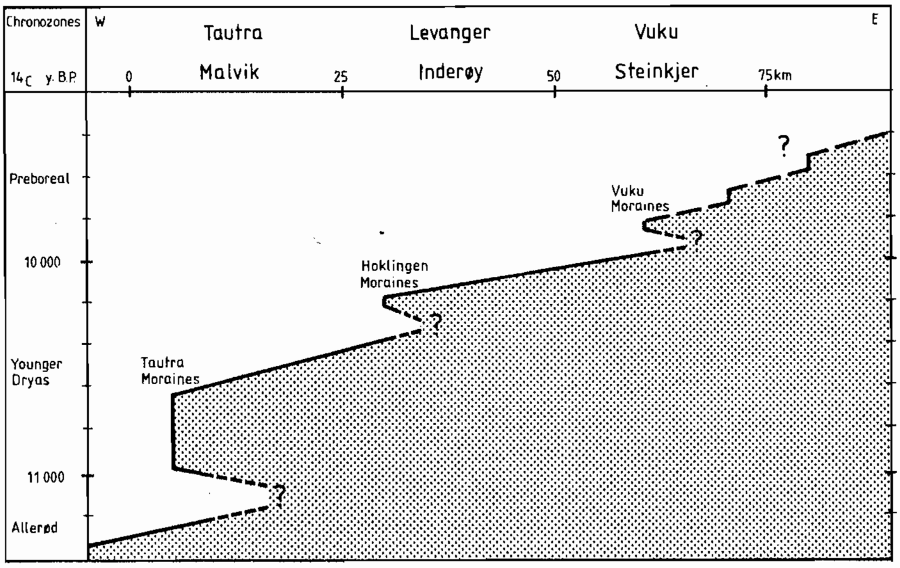


Fig.2. Time-distance diagram of the ice recession in central and eastern parts of the Trondheimsfjord area.

Fig. 2

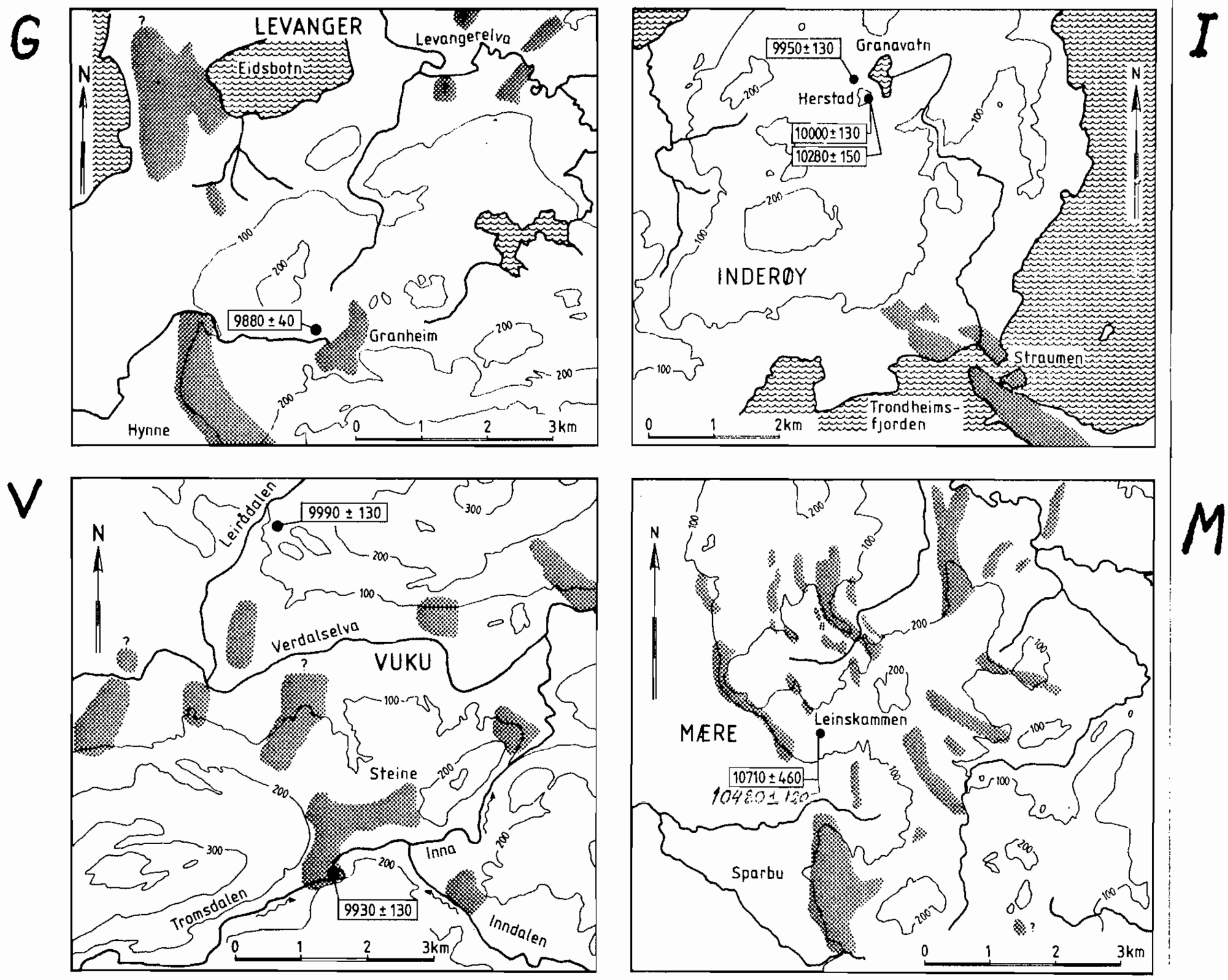
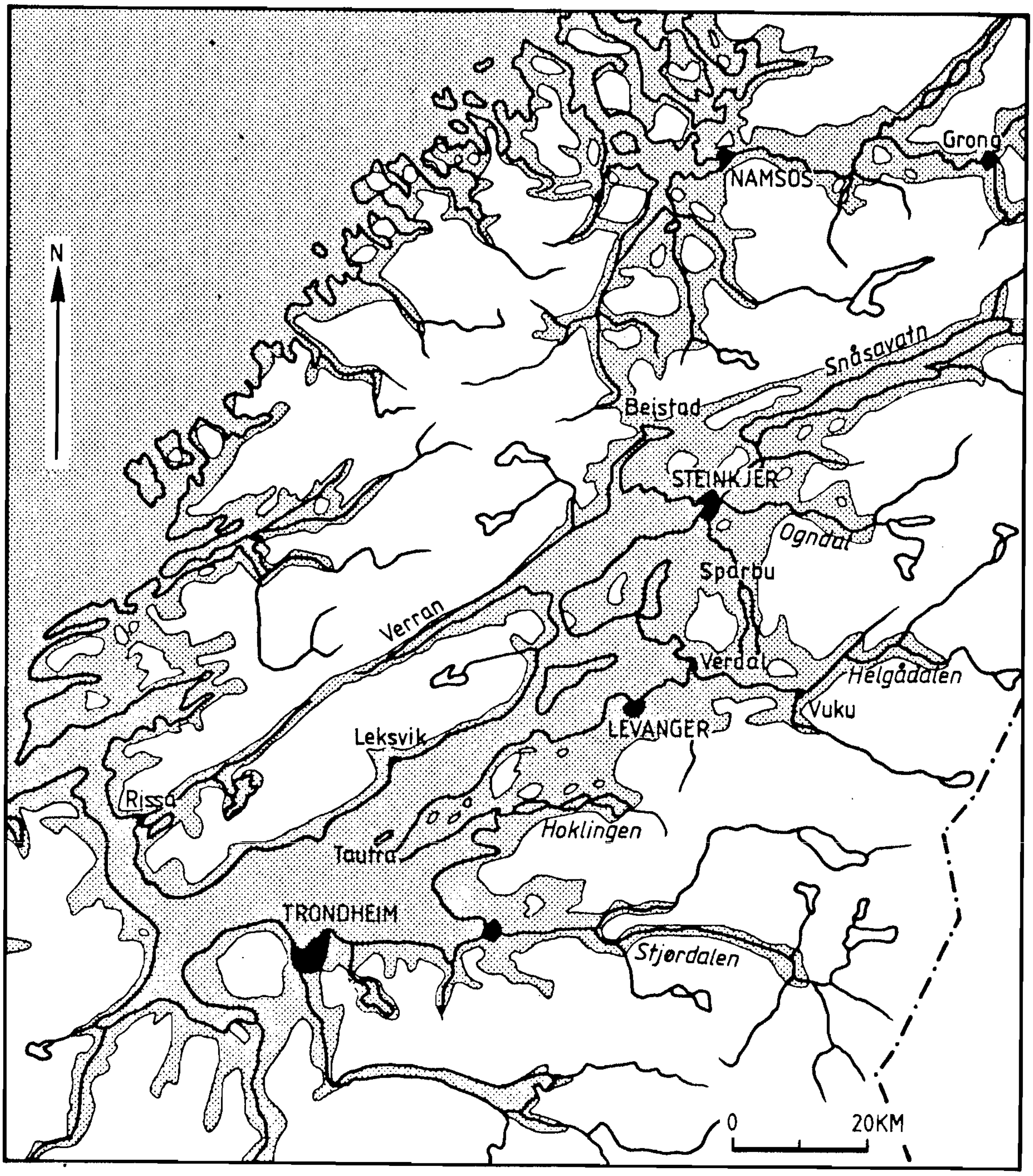


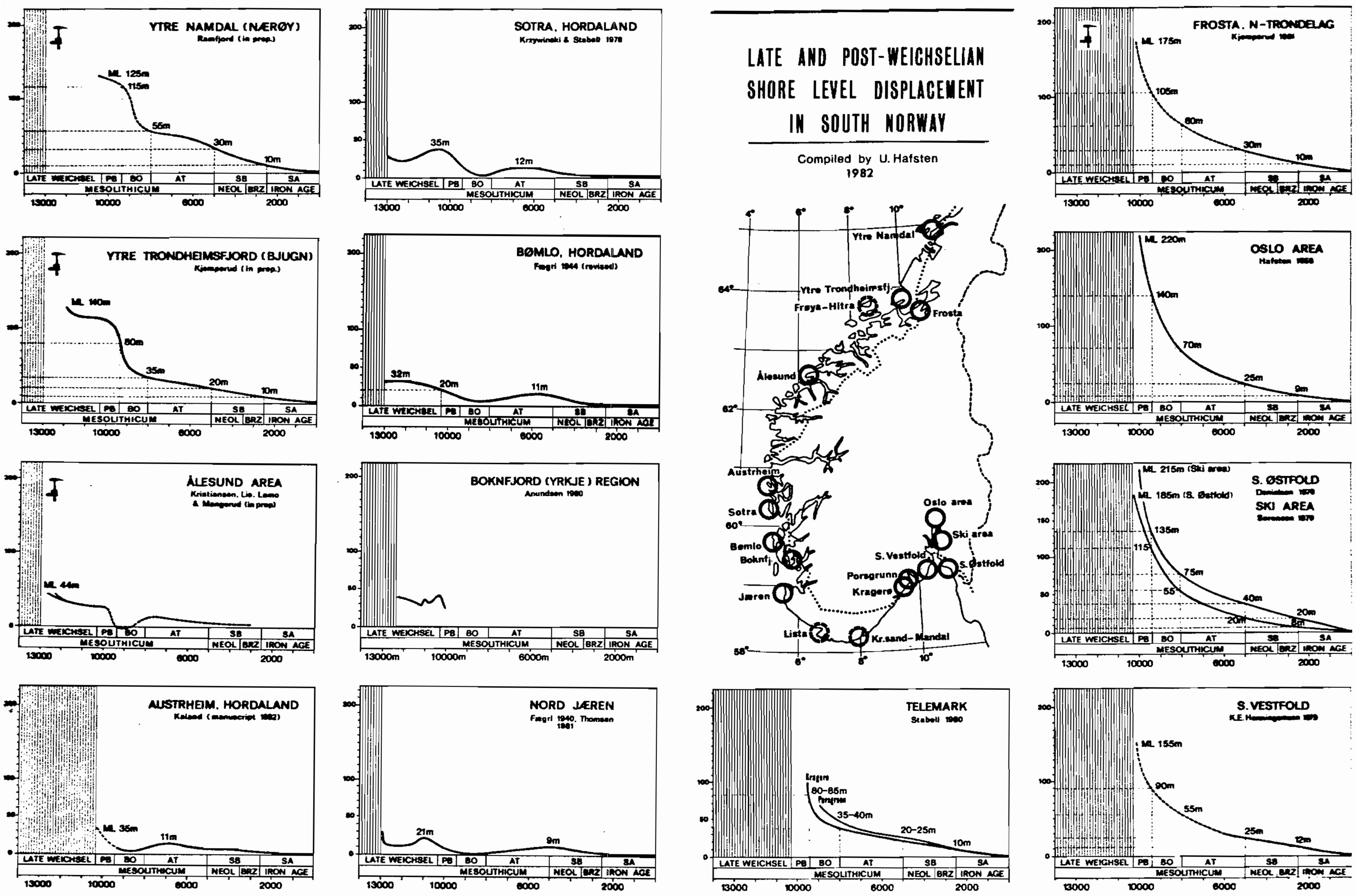
Fig. **3.** Maps showing ice-marginal deposits (shaded areas) and radiocarbon datings.

Fig. 3



Reconstruction of the fjords (shaded) shortly after the deglaciation (c. 10,000 y. B.P.). The contours of the present fjords are given by full, heavy lines. Major rivers and lakes are also shown.

Fig. 4 From Sveian in prep.



<u>Fig. 5</u> From Hafsten 1983, showing the great variance in shore displacement in S. Norway.

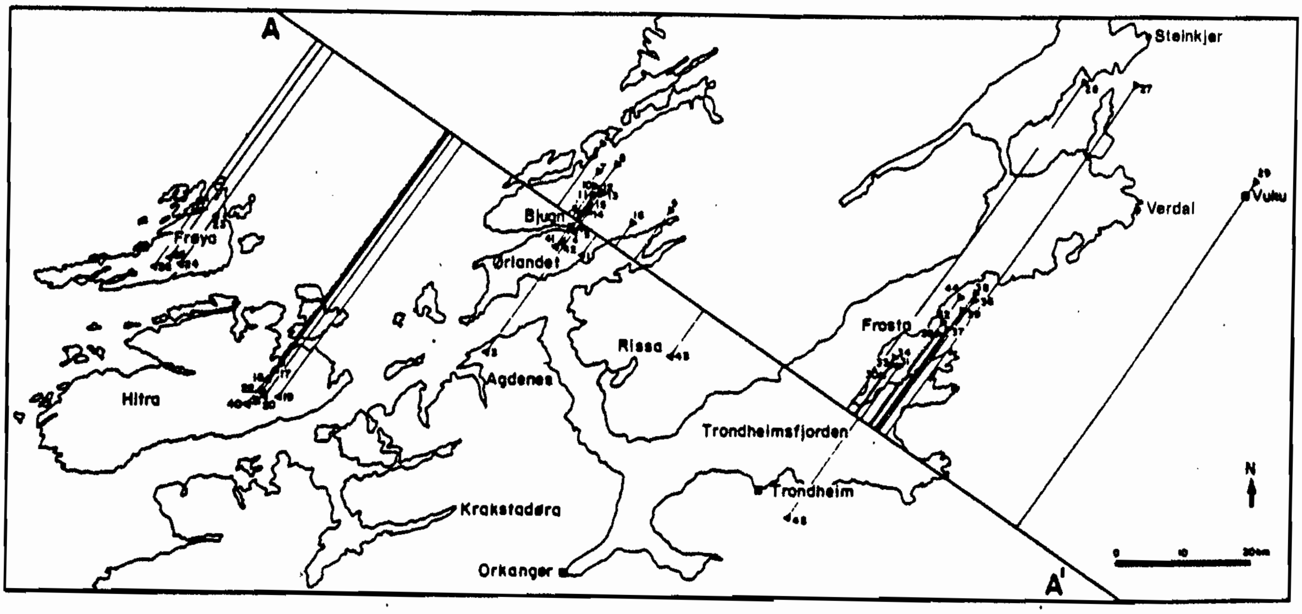


Fig.6. : The investigated area with all localities.
The numbers refere to Fig.8.
After Kjemperud (1982).

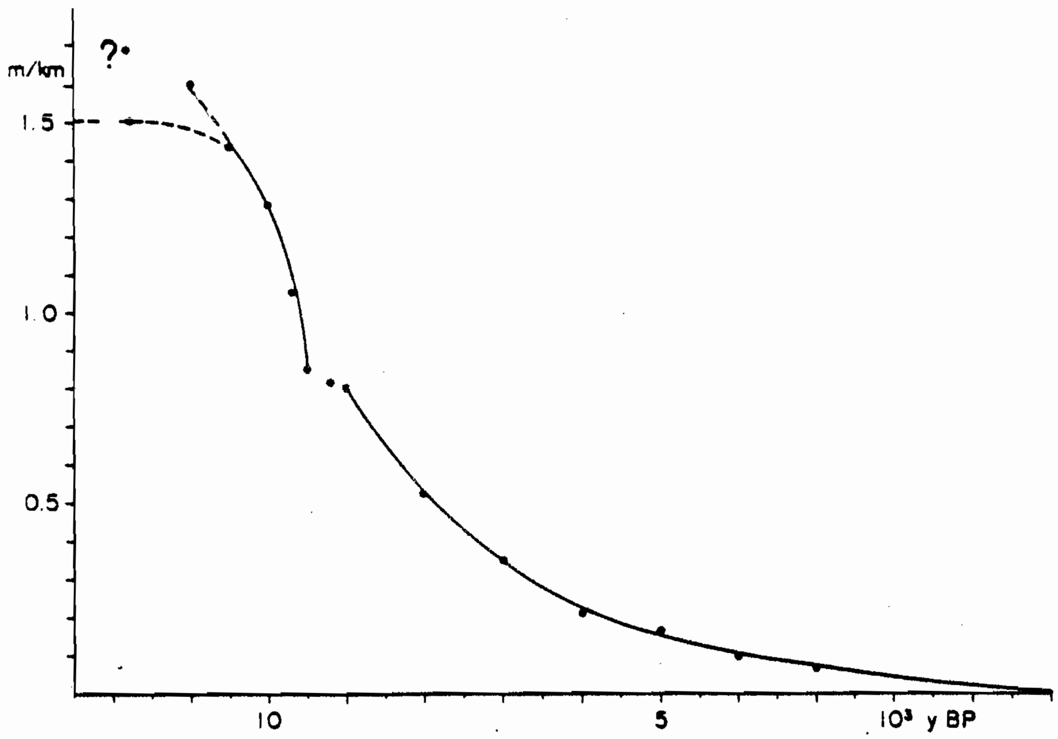


Fig. 7: Shoreline gradients in the Trøndelag area. The break in the curve between 9 500 and 9 000 y BP is probably a result of an irregular shoreline displacement during this period of time. The course of the curve in the Late Weichselian is a result of the same phenomena. From Kjemperud 1982.

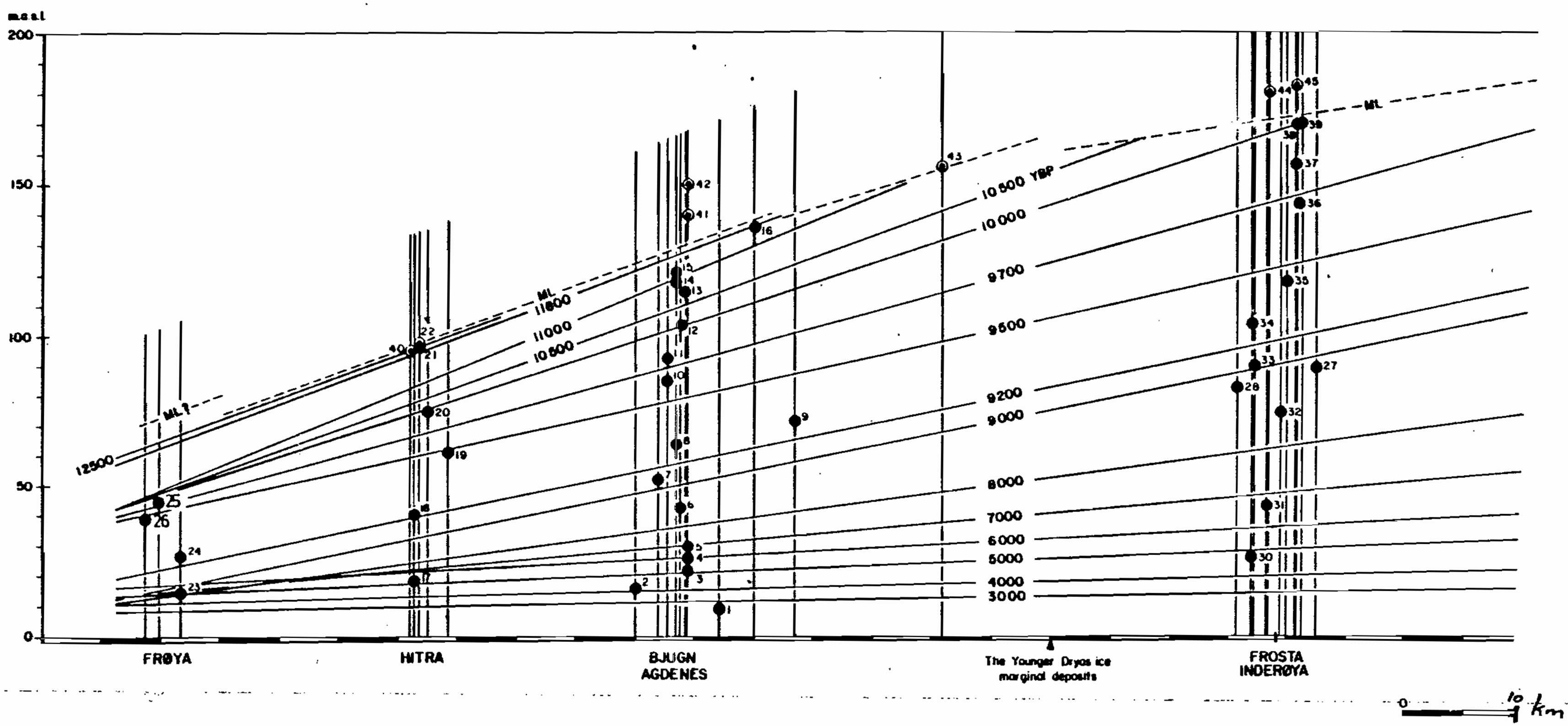


Fig.8 Equidistant shoreline diagram based exclusively on dated sediments from isolated basins. The projection plane is shown in Fig.6 .

After Kjemperud (1982).

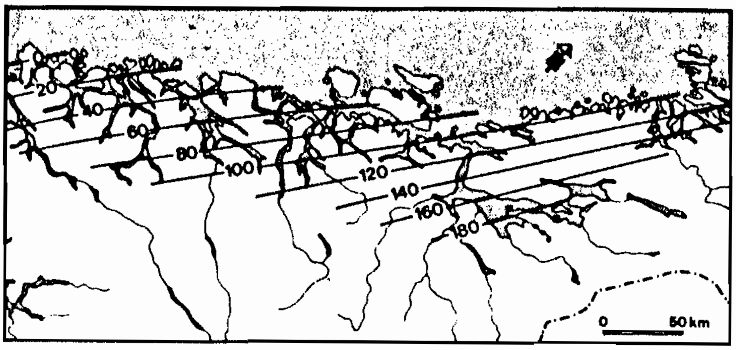
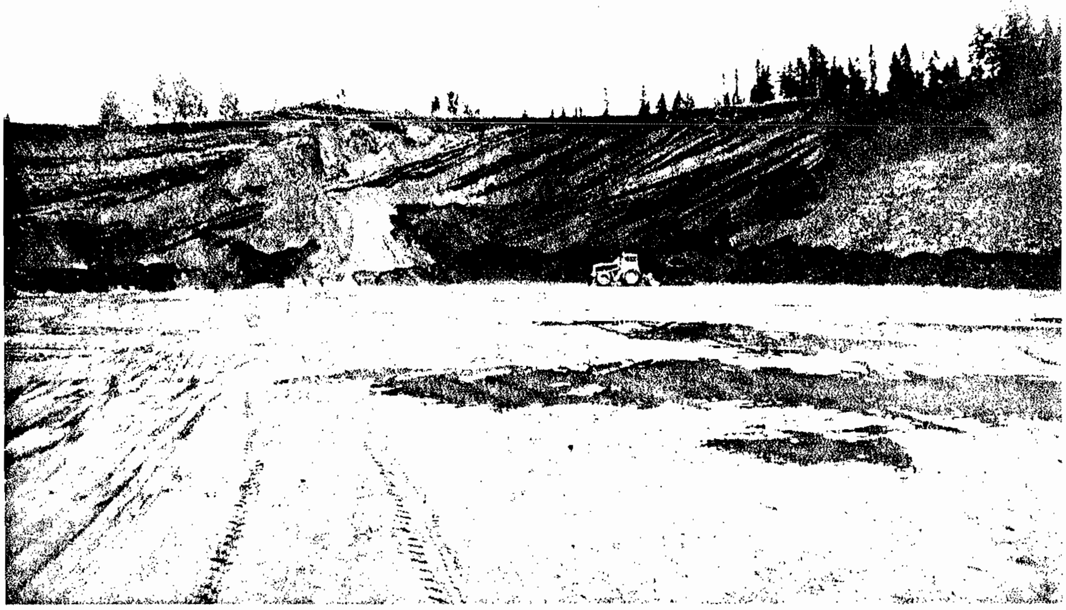


Figure 9. Isobases of the Younger Dryas sea level in Central Norway, heights in metres. After Sollid & Kjenstad (1980).

Fig. 9

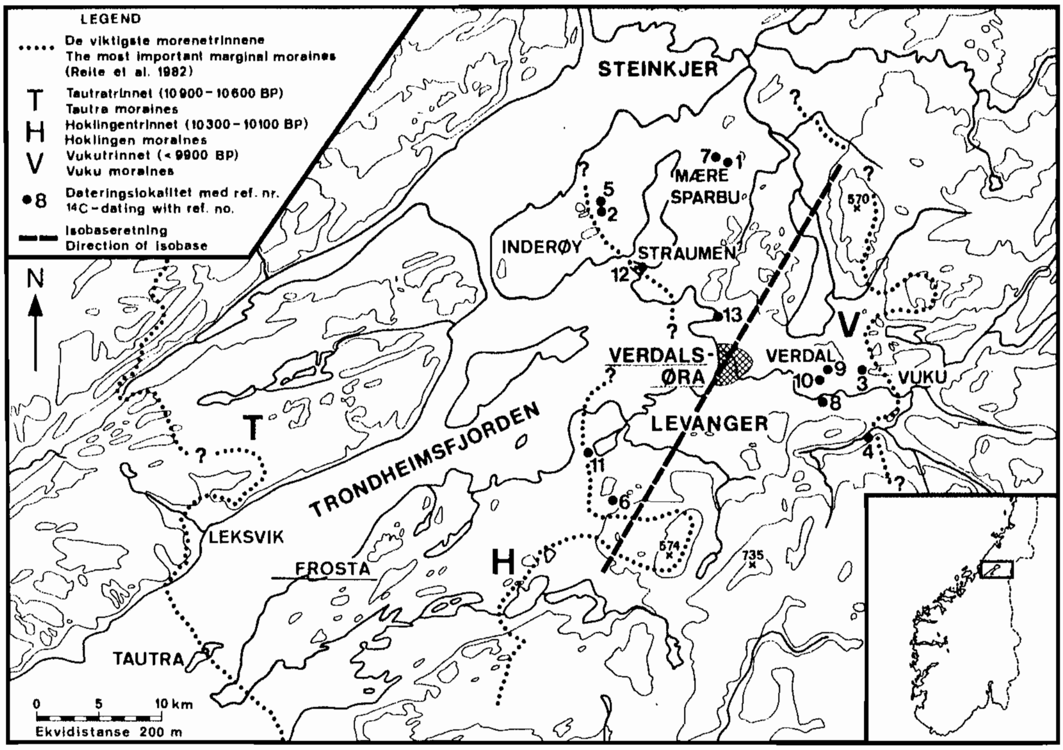


Snitt i israndddeltaet ved Granheim i nærheten av lok. 6. Topset-laget er 1–2 m mektig. Foresetlagene faller ca. 20° mot vest. Dette er en av de beste lokalitetene for bestemmelse av MG. (181 m o.h.).

Section in the ice-marginal delta at Granheim, close to loc. 6. The topset bed is 1–2 m thick. The foreset layers are dipping c. 20° towards the west. This is one of the best localities for determining the marine limit. (181 m a.s.l.).

Fig.10. After Sveian & Olsen (1984).

28 *H. Sveian & L. Olsen* NORSK GEOLOGISK TIDSSKRIFT 1 (1984)



Oversiktskart over indre deler av Trondheimsfjorden med dateringslokaliteter. De viktigste morenetrinnene og isobaseretningen er også antydet.

Topographical map of the inner part of Trondheimsfjorden with dating localities. The most important moraines and the direction of the isobases are shown. Contour interval 200 m.

Fig. 11.

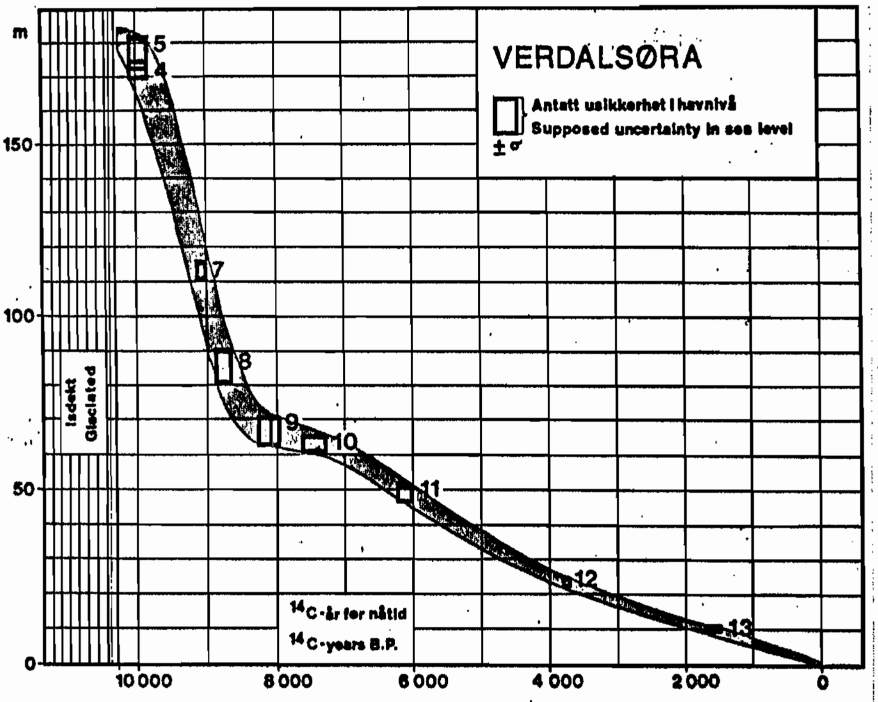
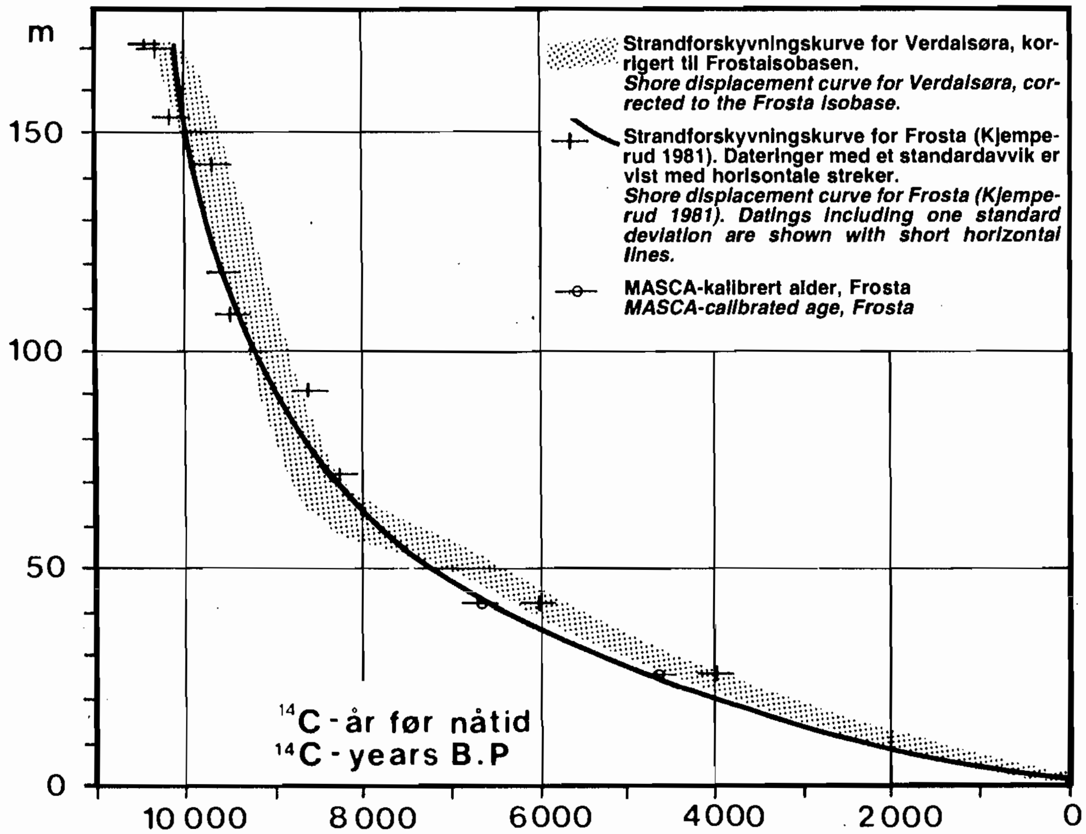


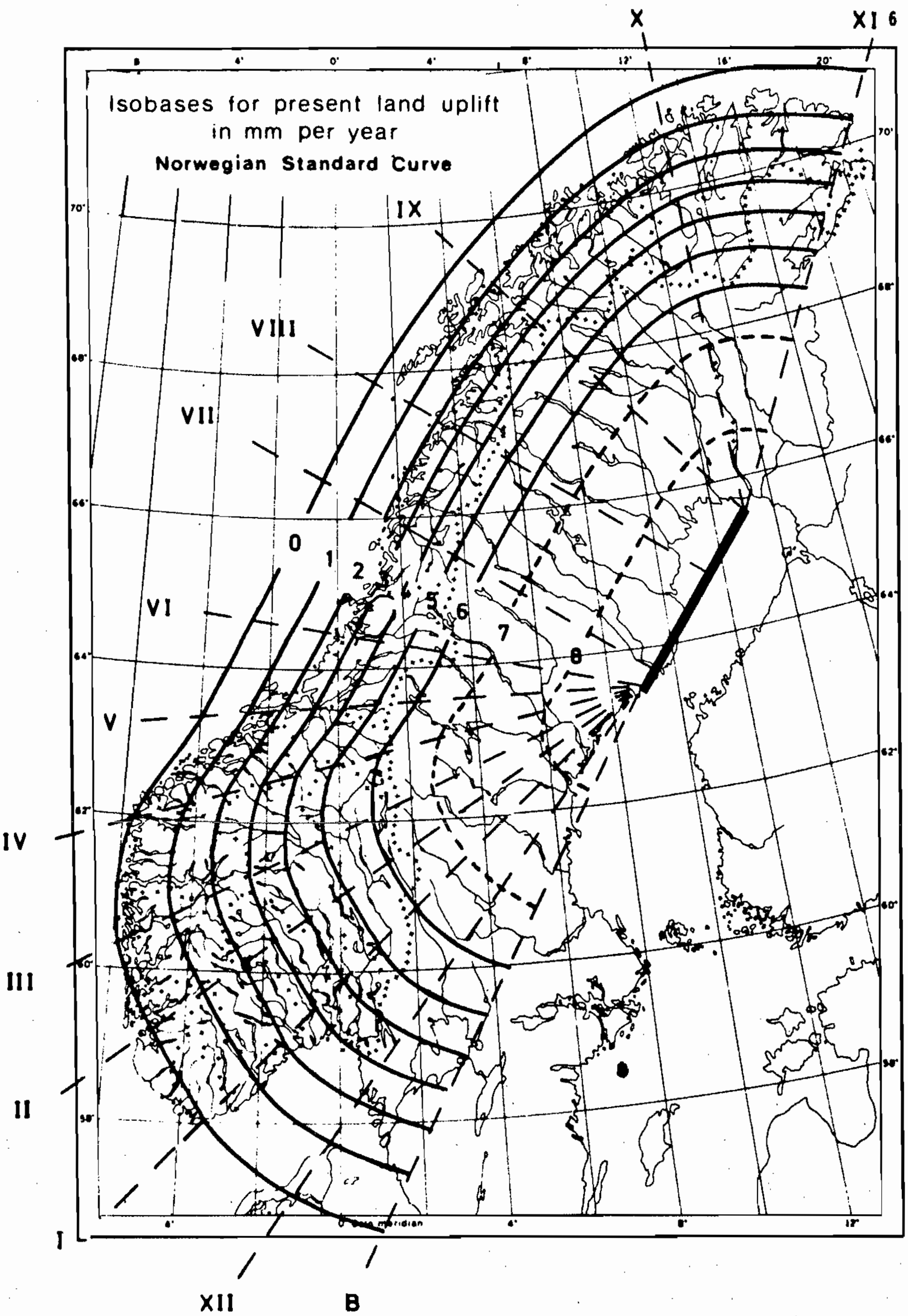
Fig. 12. Shore displacement curve from Verdalsøra. After Sveian & Olsen (1984).



Sammenligning av strandforskyvningskurver fra Frosta (Kjemperud 1981) og Verdalsøra.

Comparison of shoreline displacement curves from Frosta (Kjemperud 1981) and Verdalsøra (shaded). The Verdalsøra curve is corrected for this comparison, as in reality there is a distance of c. 15 km between the isobases.

Fig. 13 From Sveian & Olsen 1984



Isobases for the present land uplift in West Scandinavia, in mm per year. Norwegian standard curve after S. Bakkelid at the Geographical Survey of Norway.

Fig. 14 From Hafsten 1983.

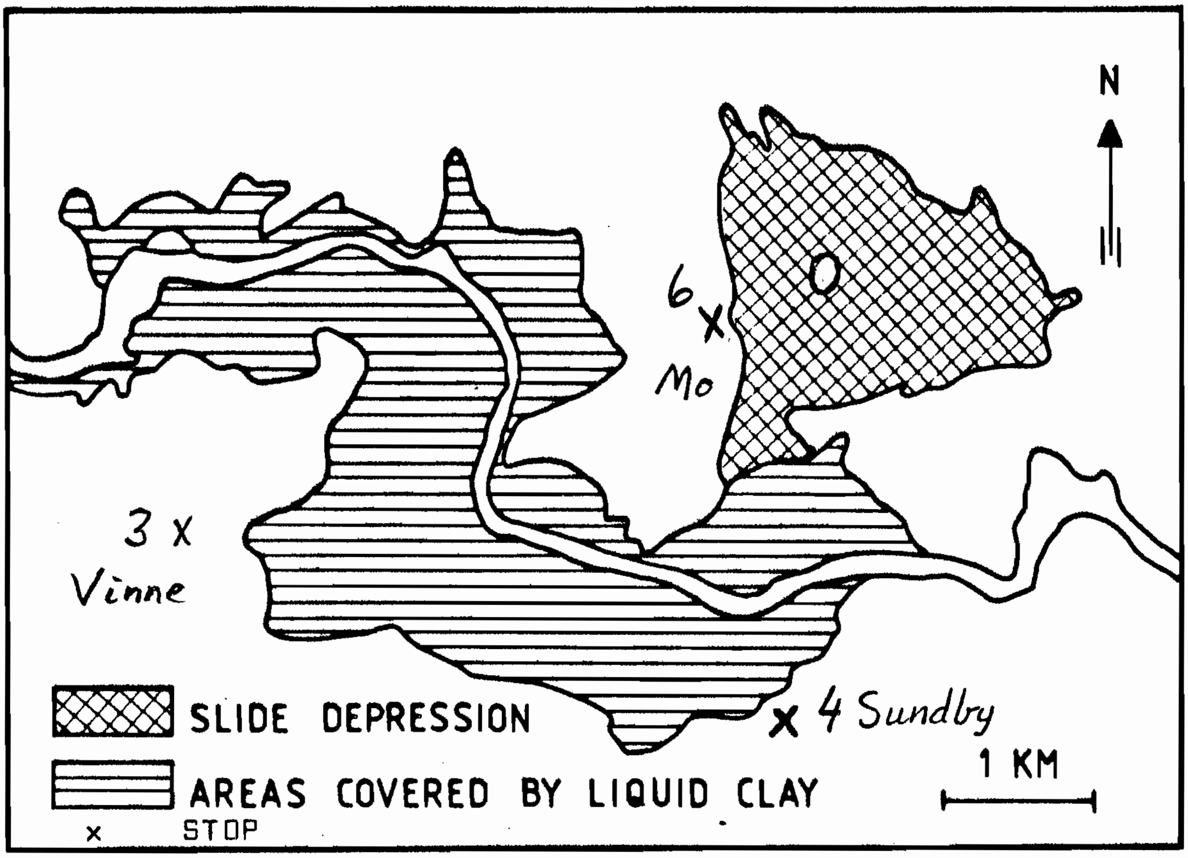


Fig. 15. The quick clay slide "Værdalsraset" 1893.
After Sollid & Reite (1983).

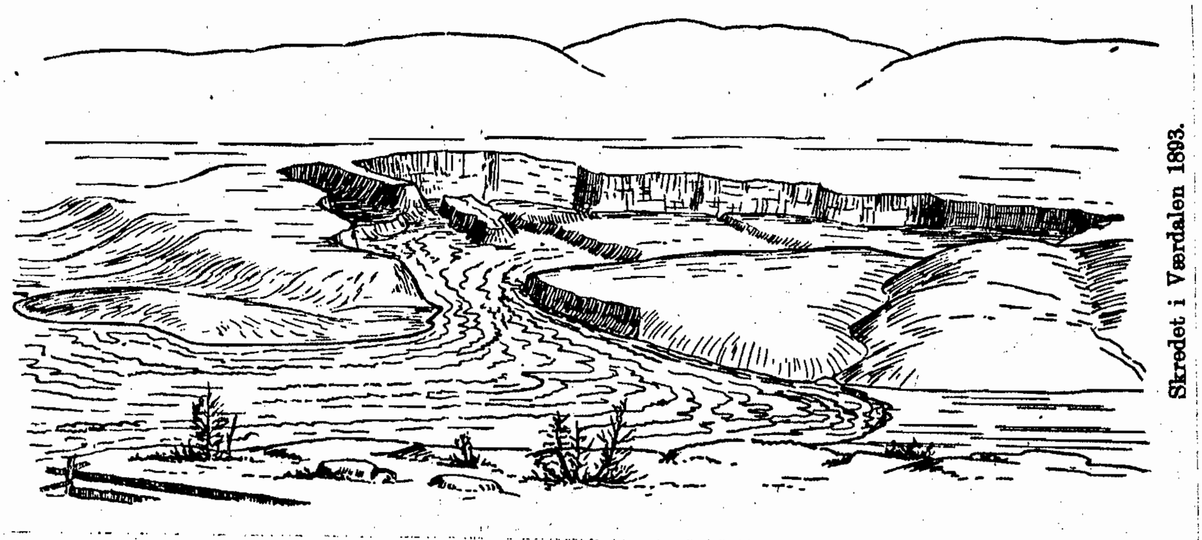
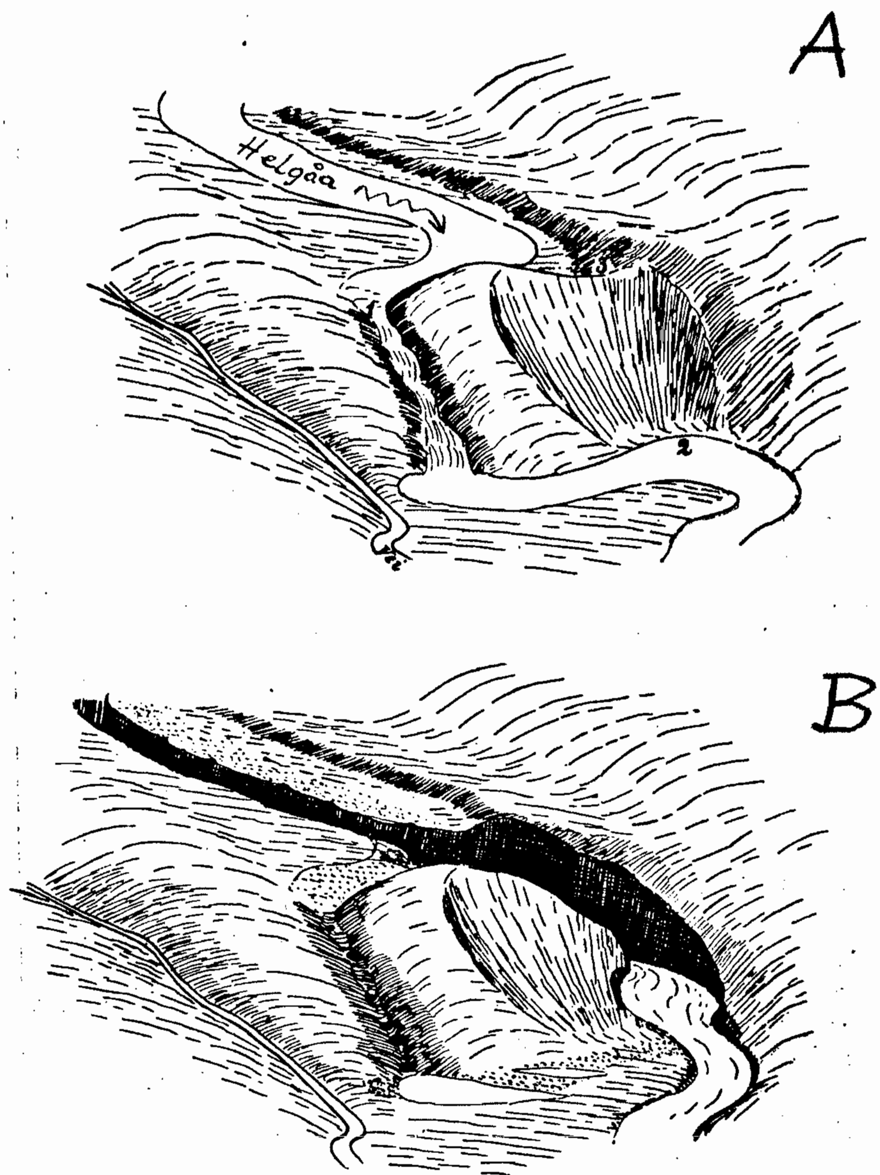


Fig. 16. Sketch of the quick clay slide "Værdalsraset", seen from approx. stop 4.
After Reusch (1901).



Strøget ved Hærfossen før og efter den 12te september 1893.
Skematiseret.

Fig.17. Helgådalen, near stop 5. For explanation, see the text. After Reusch (1901).

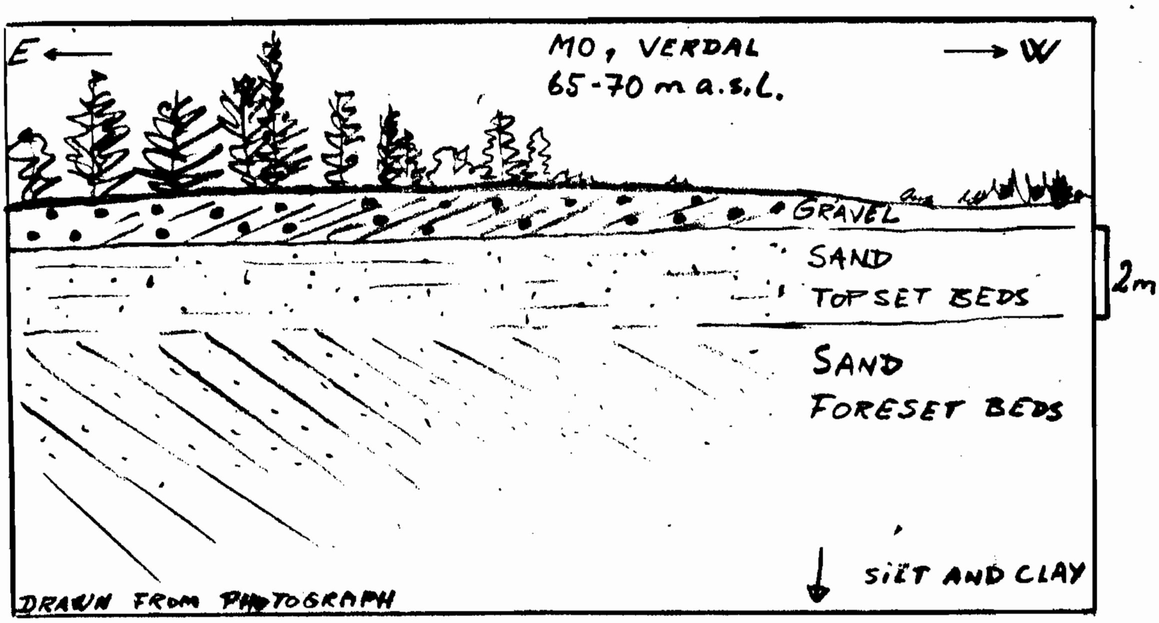


Fig. 18. Section at Mo, stop 6. After Sveian & Olsen (1984).

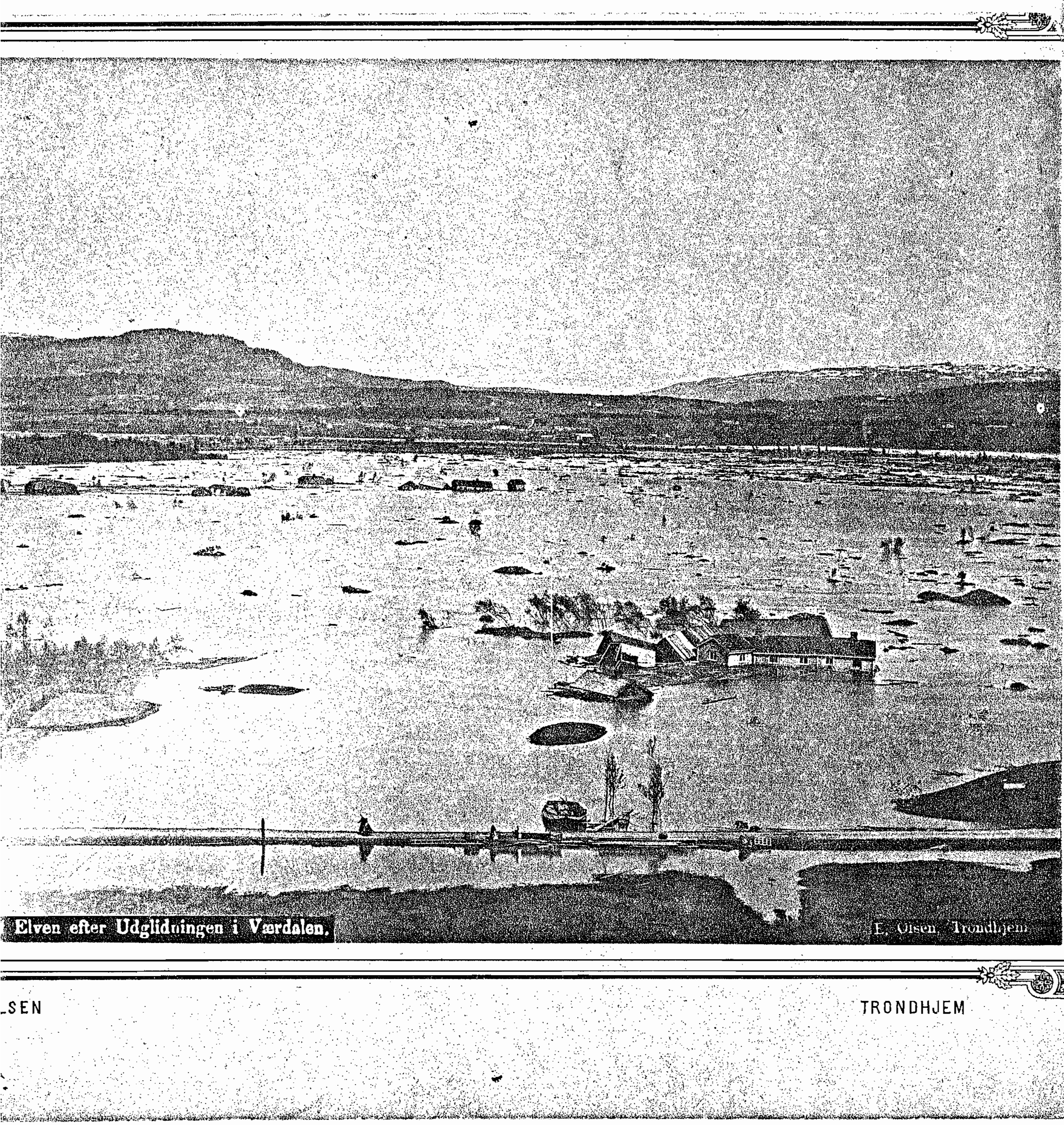
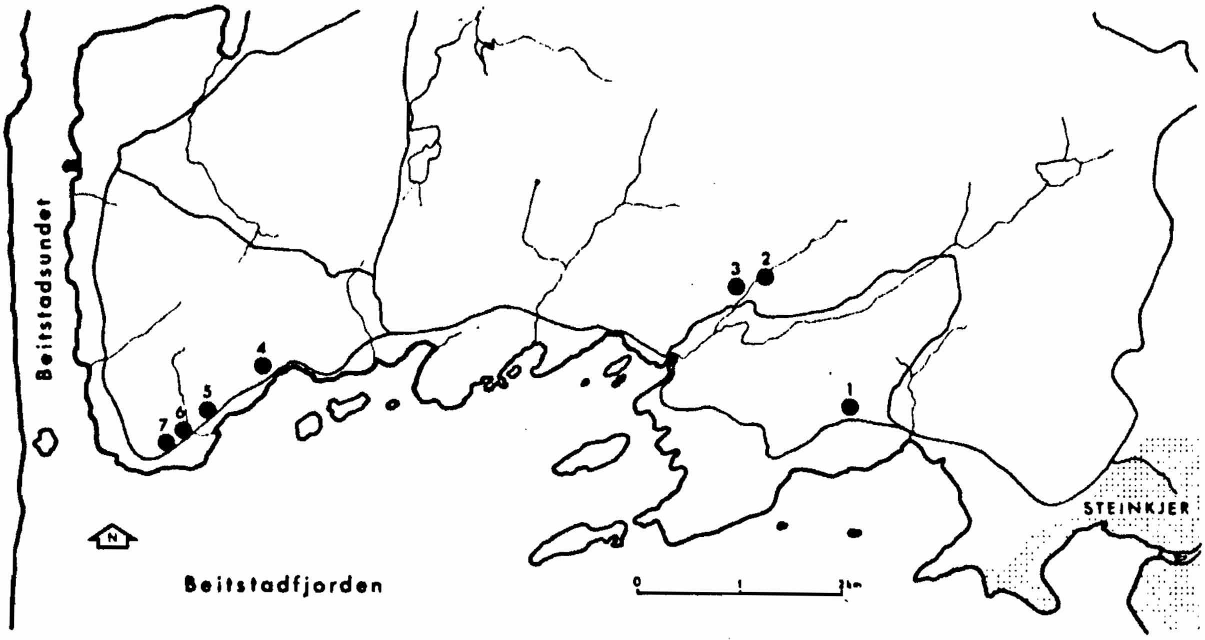


Fig. 19. Photograph from Værdalsraset 1893, looking north.

Fig.20. Photograph from Værdalsraset 1893, looking NW.



Location of Arctic rock carvings in Beitstad, to the west of Steinkjer, Nord-Trøndelag. 1. Skotrøa. 2. Lamtrøa. 3. Bardal. 4. Buavika. 5-7. Hammer I, IV-VII, VIII.

Fig. 21. From Bakka 1975

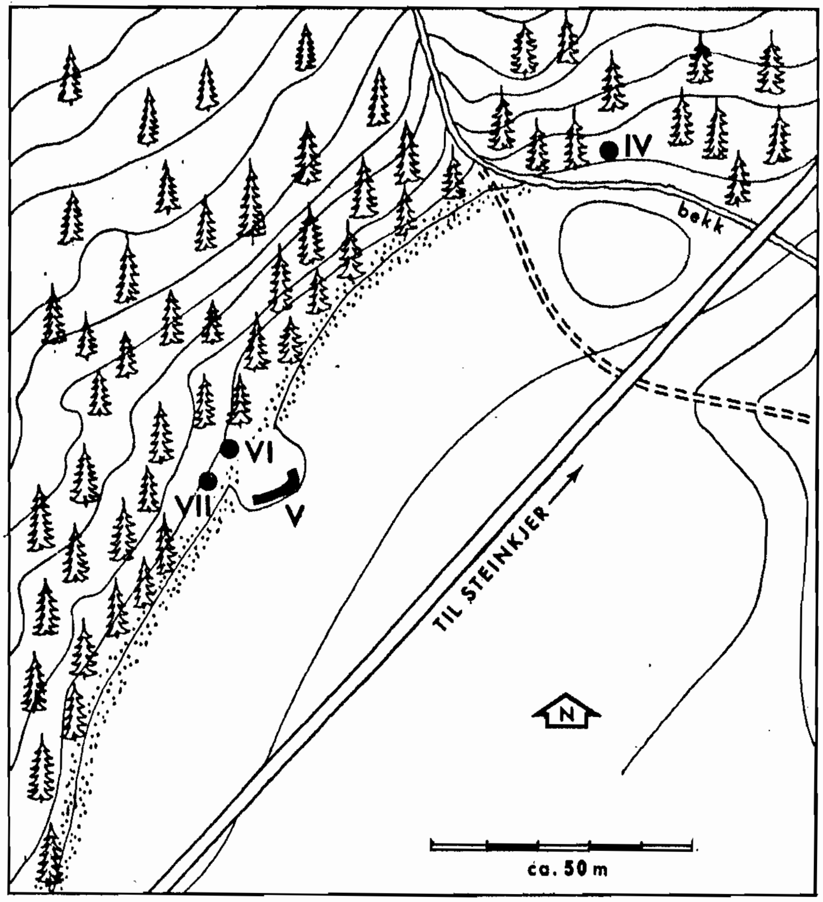
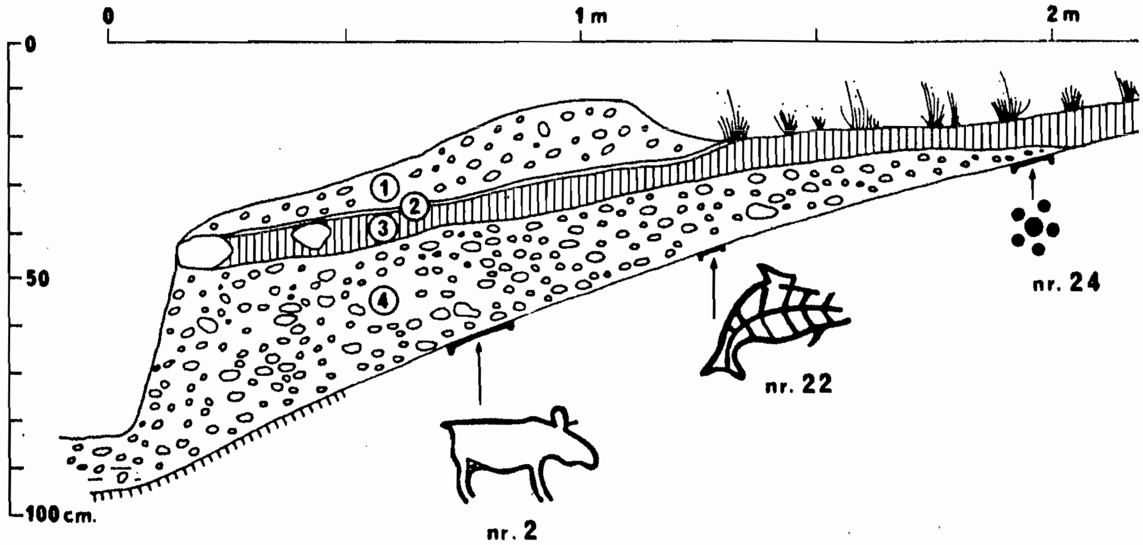


Fig. 1. Sketch map of the rock carving localities Hammer IV-VII.



①: *Gravel from trench 1963.*

②: *Vegetation zone from 1963.*

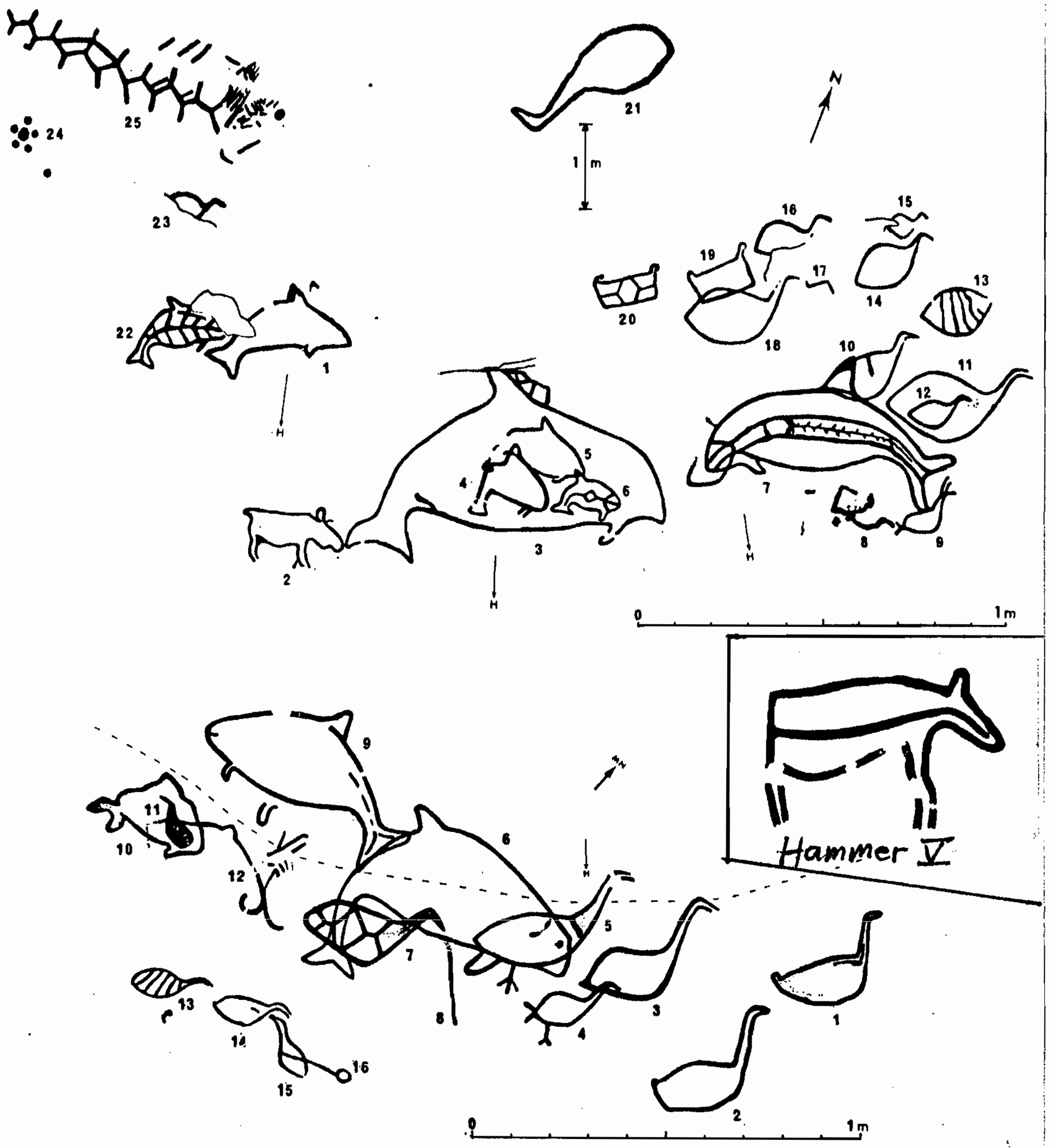
③: *Humus.*

④: *Coarse gravel and pebbles, old beach formation.*

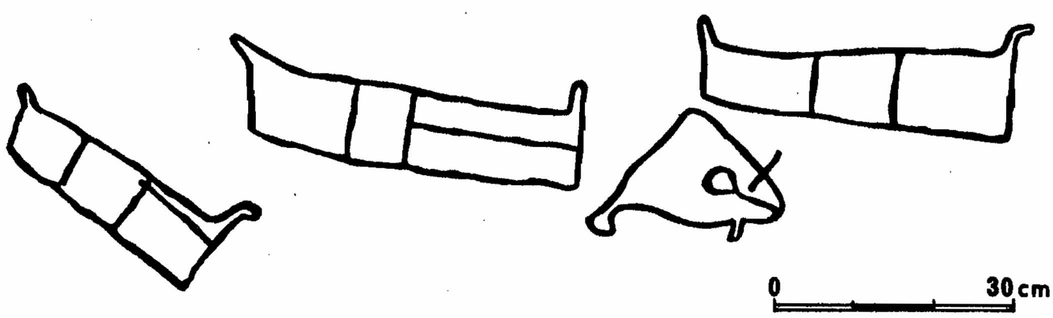
Rock face with glacial striae.

Section at the SW of Hammer VI.

Fig. 22. From Bakka 1975



Rock carvings Hammer VI and VII.
Author's tracing 1974.



Rock carving Hammer VIII. Author's tracing 1974.

Fig. 23. From Bakka 1975

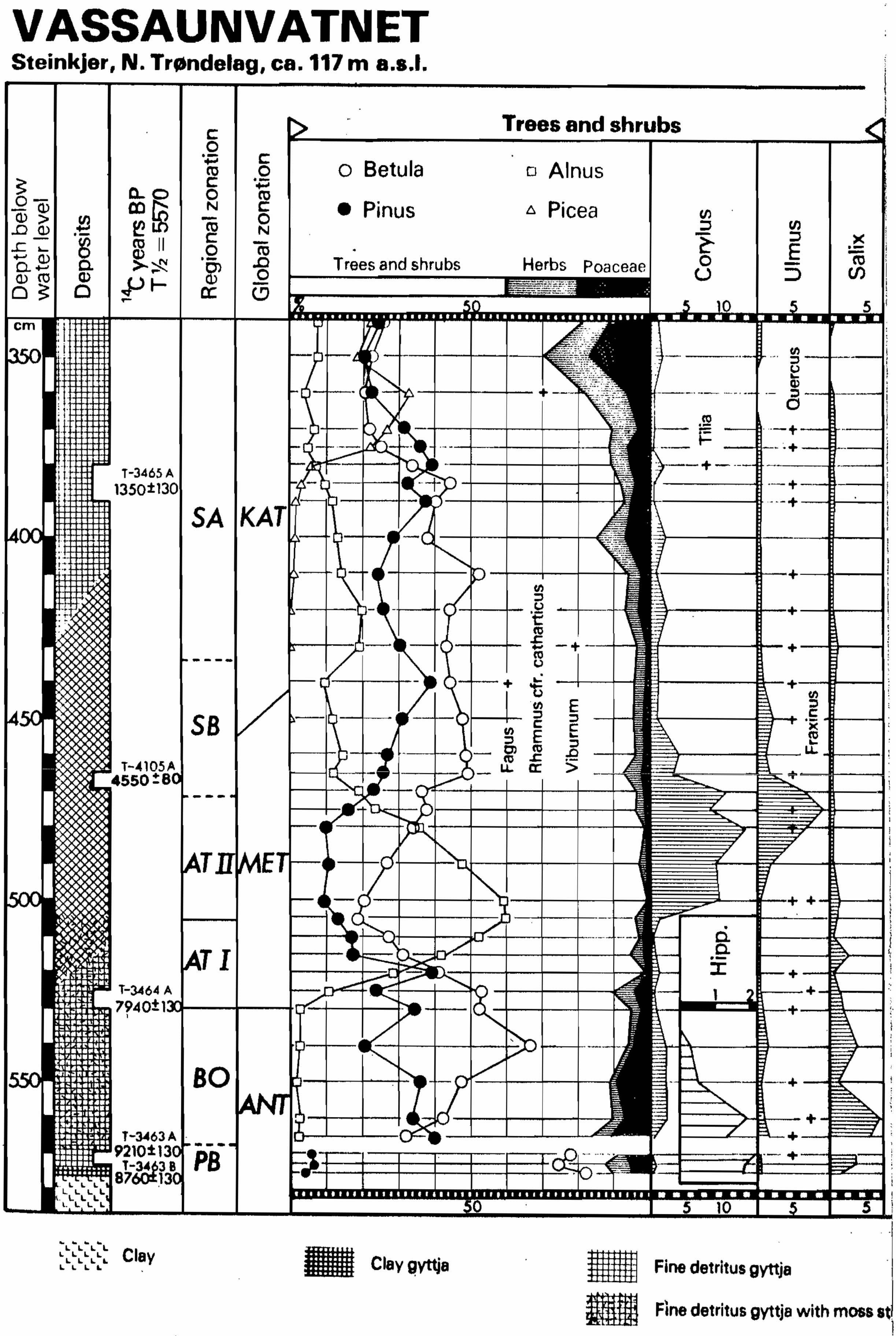


Fig. 24 Vegetational development in the Steinkjer region, after Jevne 1982. Non-arboreal part of pollen diagram deleted.

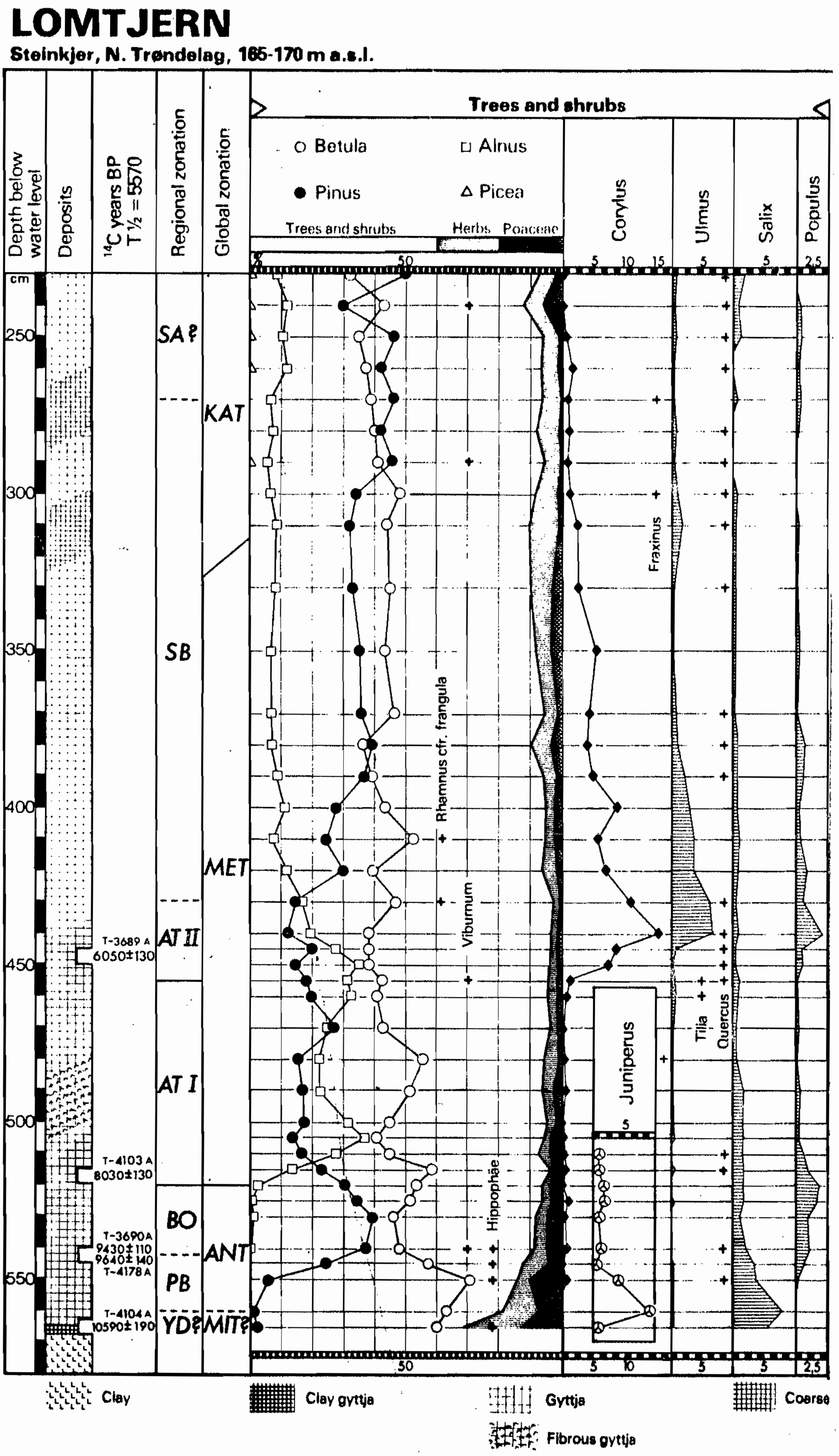


Fig. 25 Vegetational development in the Steinkjer region, after Jevne 1982. Non-arboreal part of pollen diagram deleted.