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2020.010

Age and location of late Bølling–early Allerød ice-marginal substages in Mid-Norway – Outer Coast and Tingvoll, based on mapping and a compilation of 14C dates

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14 kyr old Outer Coast – Older Dryas ice marginal moraines at Osen in Trøndelag county: two moraine ridges (1 and 2) in the central part of the photograph; from www.norgei3D.no, a third moraine ridge of almost the same age is located just a few km in proximal direction (to the right of the photograph).

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Age and location of late Bølling–early Allerød ice-marginal substages in Mid-Norway – Outer Coast and Tingvoll, based on mapping and a compilation of 14C dates.

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Summary:

Abstract (short version)

The Outer Coast (OC)–Tingvoll ice margins in Mid Norway do not show continuous lines of ice marginal deposits (moraines, ice contact deltas, etc.)(Fig. 1), they appear rather as discontinuous lines of correlated deposits from fjord to fjord and valley to valley, with variable distances between distinct deposits along the 300 km long distance from Djupvika in northernmost part of Trøndelag to Tingvoll in Nordmøre. The correlation lines are all based on Quaternary maps, relationship and distance to the more continuous Younger Dryas (YD) maximum (Tautra) ice marginal position (Sveian 1997, Olsen et al. 2015), and considerations of reasonable ice dynamics and ice surface gradients based on comparison to known present or reconstructed old glaciers.

The ages of the OC–Tingvoll ice marginal substages are dated to the interval 14.3–13.6 cal kyr BP based on ^{14}C dates of 109 samples spread from Djupvika in the north to Tingvoll in the south (Figs. 1, 2, 3 and 10, and Table 1). The age range is narrowed to c. 14.1–13.8 cal kyr BP if these data, after quality screening (leaving a total of 49 remaining representative datings), is divided in two groups older than (n=26) and younger or equal to (n=23) the associated ice marginal moraines. The ages of the diachronous OC–Tingvoll substages are therefore slightly older than Older Dryas (OD) or approximately of OD age.

Till-like diamictons overlying glaciomarine sediments with shells dated to YD–Allerød and Bølling presented from five sites distally both to the YD and the OC–OD ice margin positions, indicate that grounded icebergs or shelf ice may have produced these deposits rather than the inland ice itself. If activity from thick sea ice in the shore zone during Holocene could produce till-like diamictons, including clast fabrics with strong preferred dominating orientation, parallel to the last ice movement direction in the area, then this may explain formation of some of these diamictons as well.

Keywords: Late-glacial history	Ice marginal moraines	^{14}C dating
Ice margin re-advances	Outer Coast moraines	Older Dryas
Whalebone finds	Ice shelf, iceberg or sea-ice	Till-like diamictons

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Age and location of late Bølling–early Allerød ice-marginal substages in Mid-Norway ─ Outer Coast and Tingvoll, based on mapping and a compilation of ^{14}C-dates

Extended abstract

The ice-marginal Outer Coast (OC) and Tingvoll substages in the Trøndelag–Nordmøre area, Mid-Norway, have for a long time been considered to be as old as or slightly older than Older Dryas (OD), an interval referring to a cold phase – inferred from palaeobothanical data – that separates the lateglacial Bølling and Allerød interstadials. Here we show that the diachronous OC substage, represented by the Lauvsnes, Uran, Osen, and Ørland ice marginal moraines in Trøndelag, and the Tingvoll substage moraines at Nordmøre further south, are all represented with re-advances, locally of considerable size, and in places ending with multiple moraine ridges in the coastal areas after major early to mid Bølling age ice retreat from the shelf to the fjord areas. The age of these ice marginal moraines is therefore corresponding to either late Bølling or to OD, just before Allerød interstadial. The basis for this is the regional distribution and morphological correlations of the associated moraines and a number of ^{14}*C- datings, mainly of marine shells, previously presented in different papers and map-sheets. Almost all of the sample sites referred to here are located distally to the maximum Younger Dryas (YD) ice marginal position, the Tautra substage, in this area, and most of these are located close to the OC ice marginal positions. In this overview report we present a collection of 109* ^{14}*C-dates associated (more or less accurately) with the mentioned substages. Using all these dates for a first approximation constrain the OC–Tingvoll substages in the Trøndelag–Nordmøre area with maximum age interval 14.3–13.8 cal kyr BP, and 14318 (n=39) – 13314 (n=70) cal yr BP between average ages of dates older than and younger than the OC–Tingvoll substages. Improved accuracy of the age intervals can be obtained by further weighing of geology and stratigraphical positions of the dates. Omitting of dates considered to be slightly too old or too young to be strictly representative, have reduced the number of representative dates to 59. The corresponding age interval for the OC–Tingvoll substages is unchanged, but the age interval between the average ages of dates older than and younger than OC–Tingvoll substages is narrowed to 14269 (n=36) – 13613 (n=23) cal yr BP.*

A bone of Greenland whale from sediments in sub-till (or sub till like diamicton) position a few km distally to the Lauvsnes–Uran ice marginal moraines in Trøndelag is dated by 20 different international ^{14}*C AMS dating laboratories with the outcome of a mean age of c. 14.3 cal kyr BP. This is, after final quality screening of data, close to the mean age, c. 14.1 cal kyr BP, of all remaining 26 late-glacial dates, mainly of marine shells, which are older than or equal to the OC–Tingvoll substages.*

Till-like diamictons overlying glaciomarine sediments with shells dated to YD–Allerød and Bølling presented from five sites distally both to the YD and the OC–OD ice margin positions, indicate that grounded icebergs or shelf ice, or in some cases even activity from grounded thick sea ice during the postglacial period, may have produced these deposits rather than the inland ice itself.

Background

The first ^{14}C-dates referring to the late-glacial late Bølling–Older Dryas (OD) ice-marginal zones – Outer Coast (OC), Lauvsnes, Uran, Osen, Ørland, and Tingvoll – in Mid-Norway (Fig. 1), were carried out during the 1980s and 1990s. However, we have here also included a few references for the deglaciation period between the OC and Younger Dryas (YD) substages, with among the oldest south of Trondheimsfjorden being Lasca (1969) with dates from the Hemne area. Løfaldli et al. (1981), Sveian (1981a, 1981b), Reite et al. (1982), and Sollid and Reite (1983) are included as our oldest sources from the northern side of outer Trondheimsfjorden. Most of the dates originate from the 1980–1990s, whereas the most recent dates included here are from various publications from the last two decades.

The major part of the dates presented here has been published earlier, albeit on map sheets in reports and publications which may be difficult to obtain. In this report we compile and present relevant ^{14}C dates in relation to the major OC and Tingvoll substages from Mid-Norway (Table 1; Figs. 1–7). The data is a collection of dates with various accuracy (relevance to the actual substages), obtained from a long period of Quaternary geological mapping.

The regional distribution and location of the mapped and correlated outer coast late-glacial ice margins in the Trondheimsfjord area (Sveian 1997, Olsen et al. 2013, Olsen et al. 2014), with aerial photographs of the Lauvsnes moraines and the multiple Osen moraines as examples of the OC substage are shown in Figs. 2, 5 and 6, respectively. However, a variety of ice-marginal features occur along the OC ice marginal zones, such as glaciofluvial deltas and moraine ridges, deposited both sub-aerially and sub-aquatically.

Late-glacial marine reservoir age

^{14}C-dates of marine shells from Norway have since the 1970s been corrected for a marine reservoir age expected to be c. 400 (±) yrs along the coast of Norway (Mangerud and Gulliksen 1975), and a standard marine reservoir age of 440 yrs has generally been used both for late-glacial and younger shells. However, more recent studies have shown that the marine surface water reservoir age in the North Sea – Norwegian Sea area has changed over time, from less than 400 yrs in late Allerød to 700 yrs in mid-YD, and back to around 400 yrs at the YD–Preboreal boundary (Bondevik et al. 1999, Bondevik et al. 2006). Today the marine ^{14}C reservoir age in the North Atlantic area seems to be slightly less than 400 yrs (Mangerud et al. 2006).

Since most of the dates referred to in this paper is of mid Allerød age or older, and since the marine ^{14}C reservoir age has not been shown properly in Norway to differentiate much from the previous used general value for pre mid Allerød ages, we maintain the general reservoir age used since the 1970s for all the dates in Table 1. However, in the column with ages calibrated to cal yr BP varying general (not specific for the area) marine reservoir ages have been accounted for (Reimer et al. 2013).

Fig. 1. Overview map with location of the Outer Coast (OC), Tingvoll and Tautra ice-marginal substages in Mid-Norway, as part of the regional Older Dryas (OD) and major Younger Dryas (YD) ice-marginal zones in Fennoscandia (red and grey continuous and stippled lines). The area dealt with in this paper (Trøndelag and Nordmøre areas) and covered by figures 2 and 3 is framed. The OC–OD ice margin is reaching beyond the maximum YD ice sheet extension along c. 50% of the Norwegian mainland, from north to south (red lines). Notice also that the YD maximum ice extension, which is indicated as the most continuous ice marginal line around Fennoscandia, is a diachronous event, as the OC–OD maximum ice extension is also thought to be.

Fig. 2. Mapped and correlated OC and Tingvoll ice margins in the Trøndelag–Nordmøre region (frame in figure 1), with locations of 95 ^{14}C-dated samples of a total of 109 dates used to constrain the ages of the OC and Tingvoll ice marginal substages, both inferred to represent the OC–OD oscillation. The locations and results of the remaining background dates (dating nos. 96–103 and 106–111) are shown in map figures 4 and 7. Moraines and inferred ice-front positions are indicated with red continuous and stippled lines. YD ice margin, indicated with grey continuous and broken lines, is in most of the area, except for an area in the north, at Djupvika north of Kolvereid, located several km east of the OC–OD ice margin.

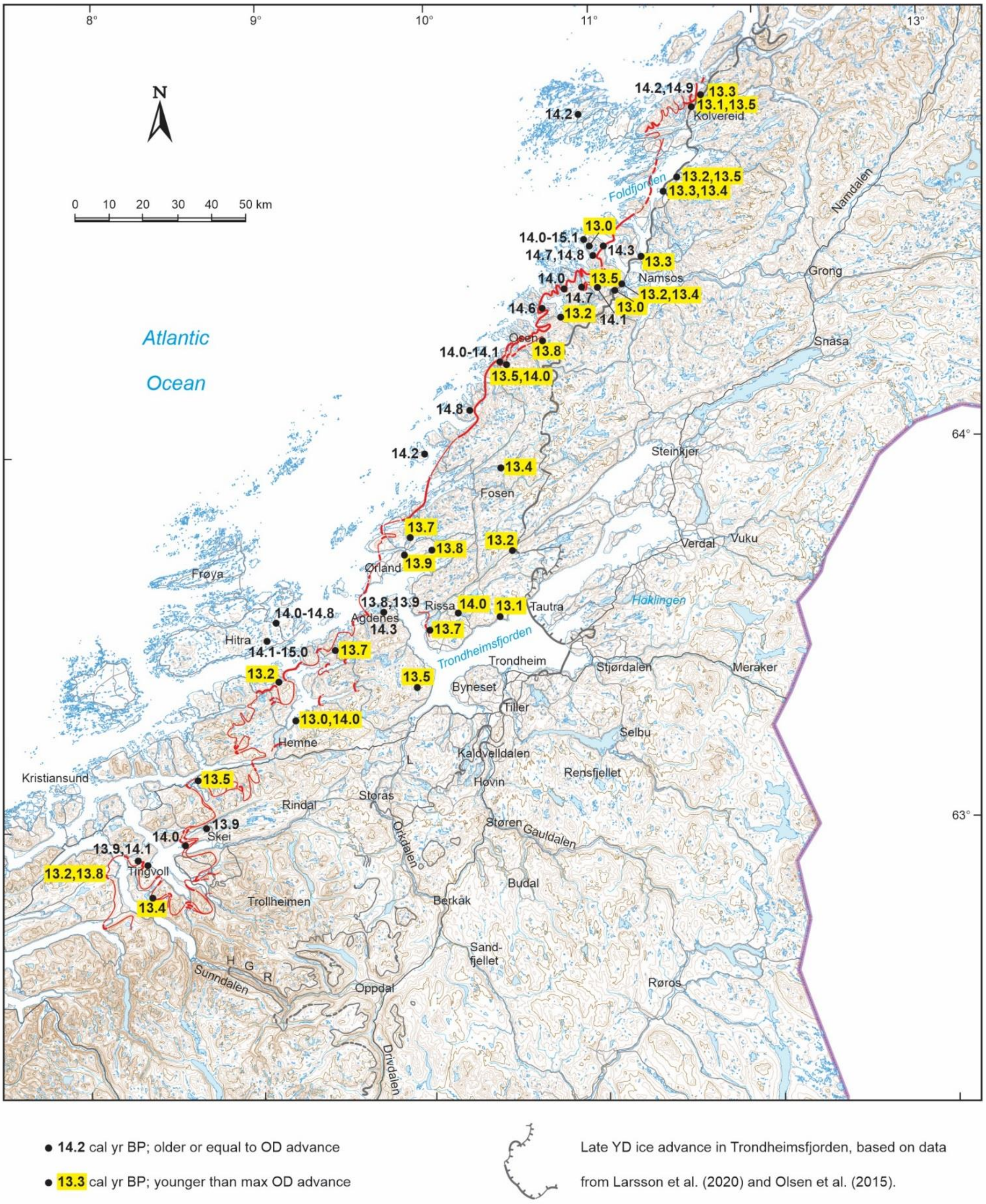

Fig. 3. Ice margins and localities as in figure 2, with dating results indicated in cal kyr BP added. Dates with yellow background-colour indicate ages younger than ice-advance towards OC–OD ice margin, whereas the other dates indicate ages equal to or older than ice-advance.

Results

New field data combined with air photo interpretations and previous mapping has led to a new reconstruction of the assumed OC substage ice margin in the Agdenes area at the mouth of Trondheimsfjorden (Fig. 4). Recently, a big whale bone (from a Greenland whale, J. Rosvold, oral communication 2017) was found in a deformed shell-bearing glaciomarine diamicton below a glacial diamicton, inferred as a lodgement till, about 5–6 km proximal to the OC ice-marginal substage there. Results from four shell dates and one date of whalebone from sub-till sediments at this site, all with age c. 14 kyr BP indicate an age older than the OD re-advance and that the OC–OD substage represented by the deformation of sediments and the overlying till, had a considerable advance (at least 6 km) in this area. This site and the Agdenes whalebone find will be dealt with in a separate paper.

Fig.4. OC–OD ice margin in the Ørland–Agdenes area, surrounding the outer part of Trondheimsfjorden, with glacial striae and dating results (cal kyr BP) from dating nos. 96, 97, 99, 100, and 101 are indicated. Colour code for dates as in figure 3.

The locations of all the dated regional samples compiled in this report are spread out from north to south in the Trøndelag–Nordmøre region, with a clear dominance (c. 1/2) of the OC substage dates located in the northernmost part of the area. However, dates are spread along the whole length from north to south, which gives a fair basis for constraining the age of the correlated ice advances to an interval around 14,000 cal yr BP (Figs. 1–3). The distribution of mollusk shell dates is, naturally, closely related to ice-marginal features which were deposited in contact with a marine environment, i.e. where one could collect shells for radiocarbon dating.

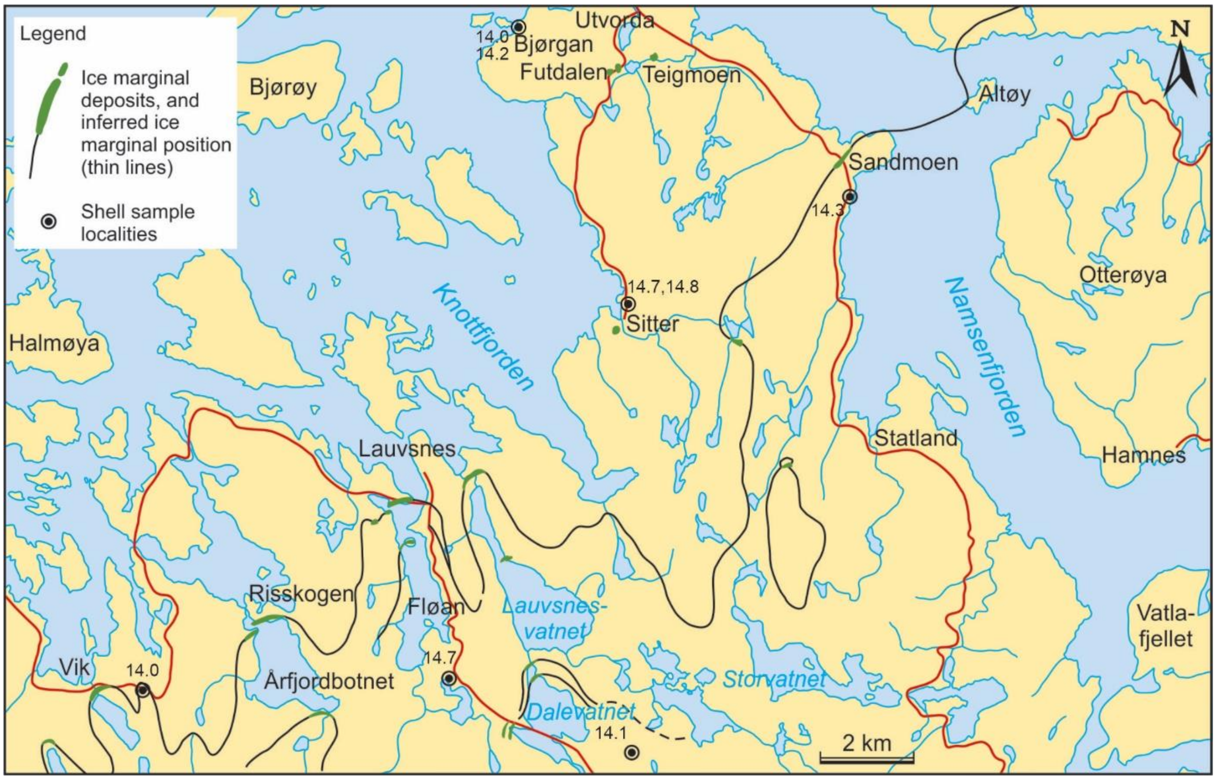

Fig. 5. OC–OD ice margins in the area west of Namsenfjorden, along the zone Vik–Risskogen–Lauvsnes–Sandmoen–Altøy. Locations and dating results (cal kyr BP) from dating nos. 13, 16, 21, 22, 23, 24, 29, and 31 are indicated. All ages are older than the OC–OD ice margin substages. Locations of sites with diamictons which are supposed to have been deposited during grounded iceberg-/ice shelf activity or sea-ice activity are also indicated (green small dots).

Marine mollusk shells of the sediment feeder *Macoma calcarea* is represented in three of the dated samples referring to older than the OC substage, and in eight of the dating samples younger than this substage. This may have given a slightly too old age (old carbon contamination) for these dates (e.g., Mangerud et al. 2006). However, only five of these eleven dating samples were dominated by Macoma, in all the other shell dating samples, including all where Macoma is not recorded, suspension feeders like *Mya truncata*, *Hiatella arctica*, and *Balanus balanus*, are known or inferred to dominate. These are generally expected to give more reliable ^{14}C-ages. The “Macoma” dates have been found seemingly reliable (100–300 yrs too old) and the average OC substage age will hence be little affected. However, the uncertainty of the degree of old carbon contamination, have occasionally been found to be quite large, e.g., with ages as much as 1000–2000 yr too old for late-glacial Macoma-samples in other parts of Norway (NGU, unpublished dates from Troms county). This suggests that the five pure “Macoma” dates should be excluded from the age range and average estimates, which is done accordingly (Table 1).

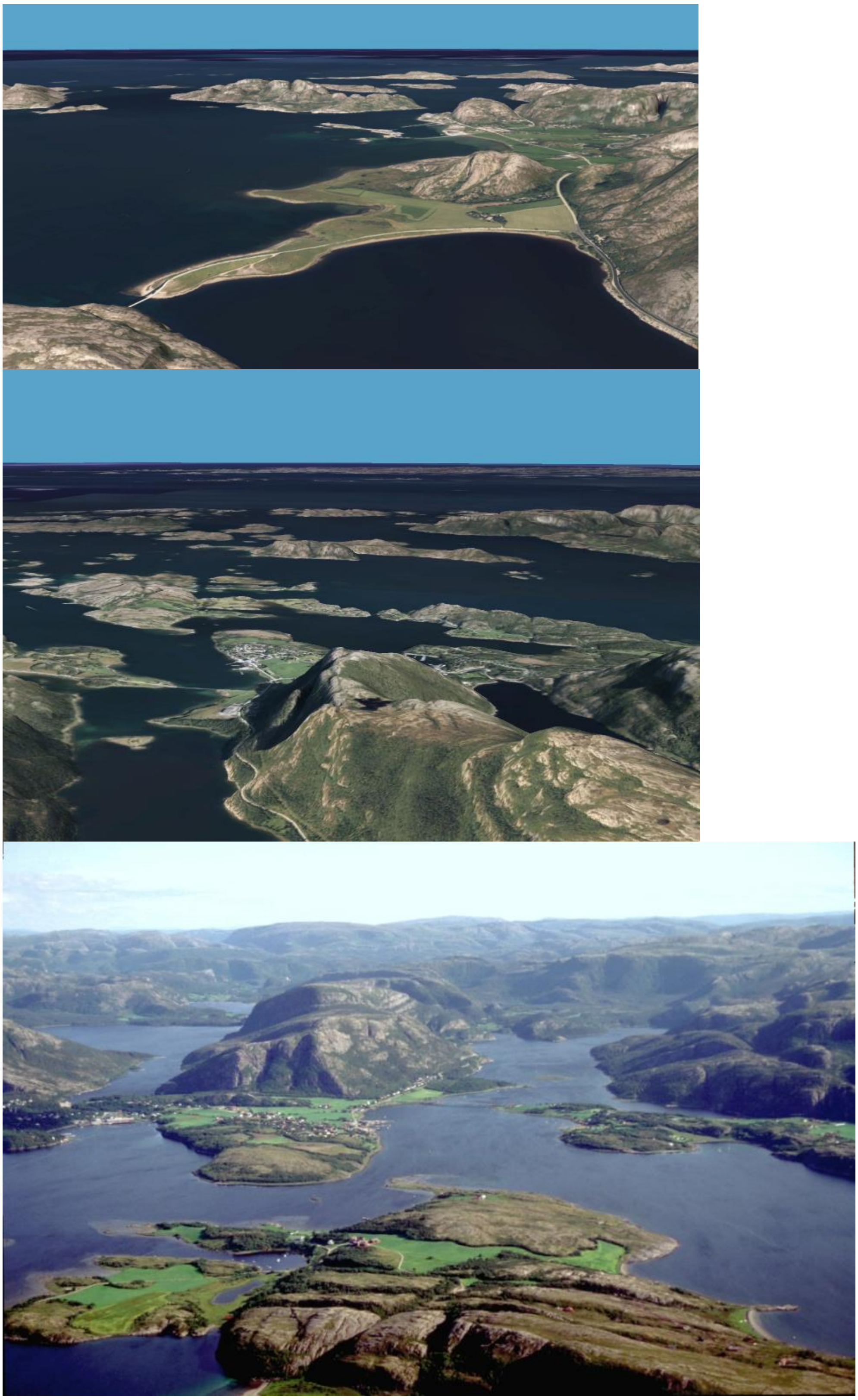

Fig. 6. Outer Coast ice marginal moraines at Osen and Lauvsnes, Nord Flatanger, Trøndelag. A - Upper photo: Osen outer moraines, view towards NW (www.norgei3D.no). B - Middle photo: Lauvsnes moraines, view towards NW (from www.norgei3D.no). C - Lower photo: Lauvsnes moraines, view towards SE (H. Sveian, 1996).

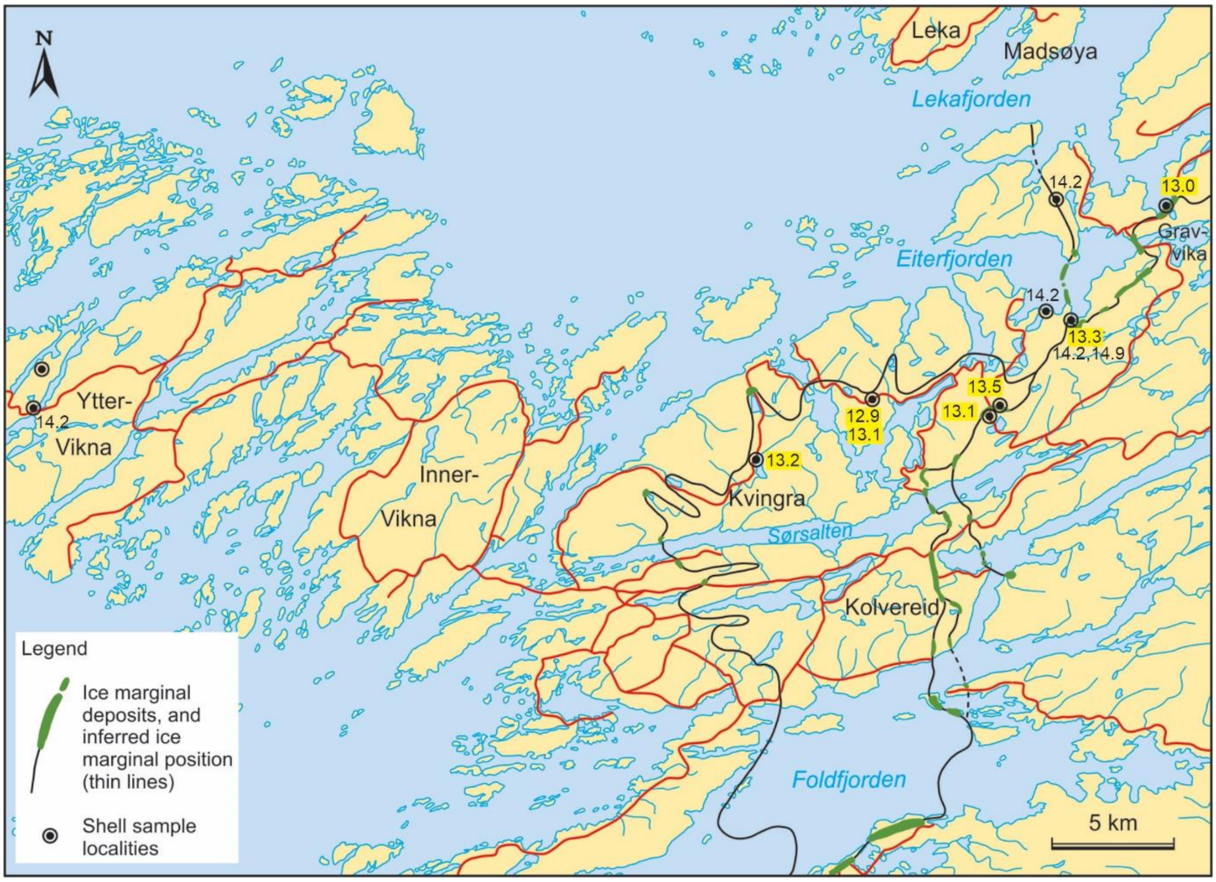

Fig. 7. OC–OD ice margin in the Ytter-Vikna–Kolvereid area, from Foldfjorden in the south to Lekafjorden in the north. Locations and results in cal kyr BP from dating nos. 2–7, 102, 103, 106, 107, 109, 110, and 111 are indicated with the same colour code as in figure 3.

Age intervals and average ages

The age interval obtained, for the 39 late-glacial pre-OC substage ^{14}C-dates, is 12635–11870 ^{14}C-yr BP (with a standard marine reservoir age of 440 years subtracted) (Table 1). The age interval for the 69-70 pre-YD and post-OC substage ^{14}C-dates is 12090–11000 ^{14}C-yr BP.

Using IntCal13 and Marine13 data (Reimer et al. 2013) for calibrating the ^{14}C ages (without subtraction of reservoir age, which is already accounted for on a general basis in the calibration tables), the resulting age interval for the youngest late-glacial pre-OC substage period (n=39) is 15110–13785 cal yr BP (mean ±1σ = 14318 ± 382 cal yr BP) (Fig. 8), and 14020–12920 cal yr BP (mean ±1σ = 13292 ± 288 cal yr BP) for the pre-YD and post-OC substage dates (n=69), respectively.

Improvement by weighing of data

We know from the mapped geology and the stratigraphical location of the dating samples that some dates used to constrain the OC substage phases are from sediments and events assumed to be 100–200 yrs younger or older than the substages' actual ages. More accurate substage age-intervals can therefore be obtained if the dates to some degree are weighed. For example,

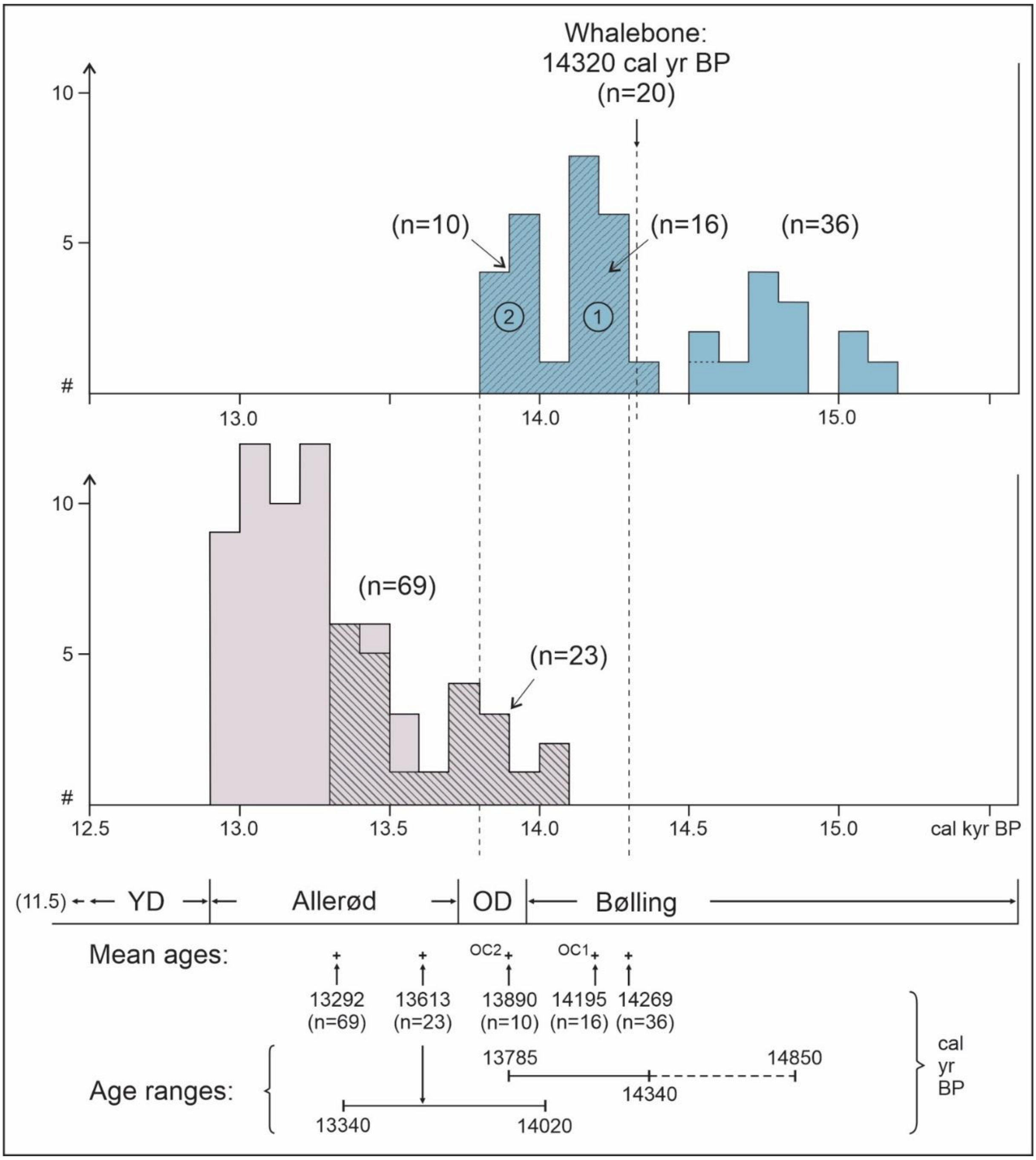

Fig. 8. Histogram of ^{14}C-dates. The distribution of 108 dates is shown, 39 older than the OC–OD ice substages and 69 younger or equal to these substages. It is also indicated the distribution after quality screening of data, first with 36 remaining dates older than OC–OD (ages older than 15 cal kyr BP omitted), and then with just 26 remaining dates older than OC–OD, and 23 remaining dates younger or equal to OC–OD. The group of dates (1 and 2) representing the outer (older) and inner (younger) OC–OD ice margins (OC1 and OC2) are also indicated.

omitting all the dates representing events that are considered to be too old or too young in Table 1, including those located at longest distance from the ice-marginal deposits (Figs. 2

and 3), reduces the number of relevant dates (to 59) and narrows the age range for the OC substage considerably. The dates omitted, in addition to “Macoma” shell dates, are indicated with grey-pink (too old) and green colours in Table 1 (too young). The associated weighed age intervals (Figs. 8 and 9) would then be 14850–13785 cal yr BP (mean ±1σ = 14269 ± 348 cal yr BP) and 13840–13386 cal yr BP (mean ±1σ = 13613 ± 227 cal yr BP), for the pre late-glacial OC substage interval (n=36) and post-OC–pre-YD interval (n=23), respectively.

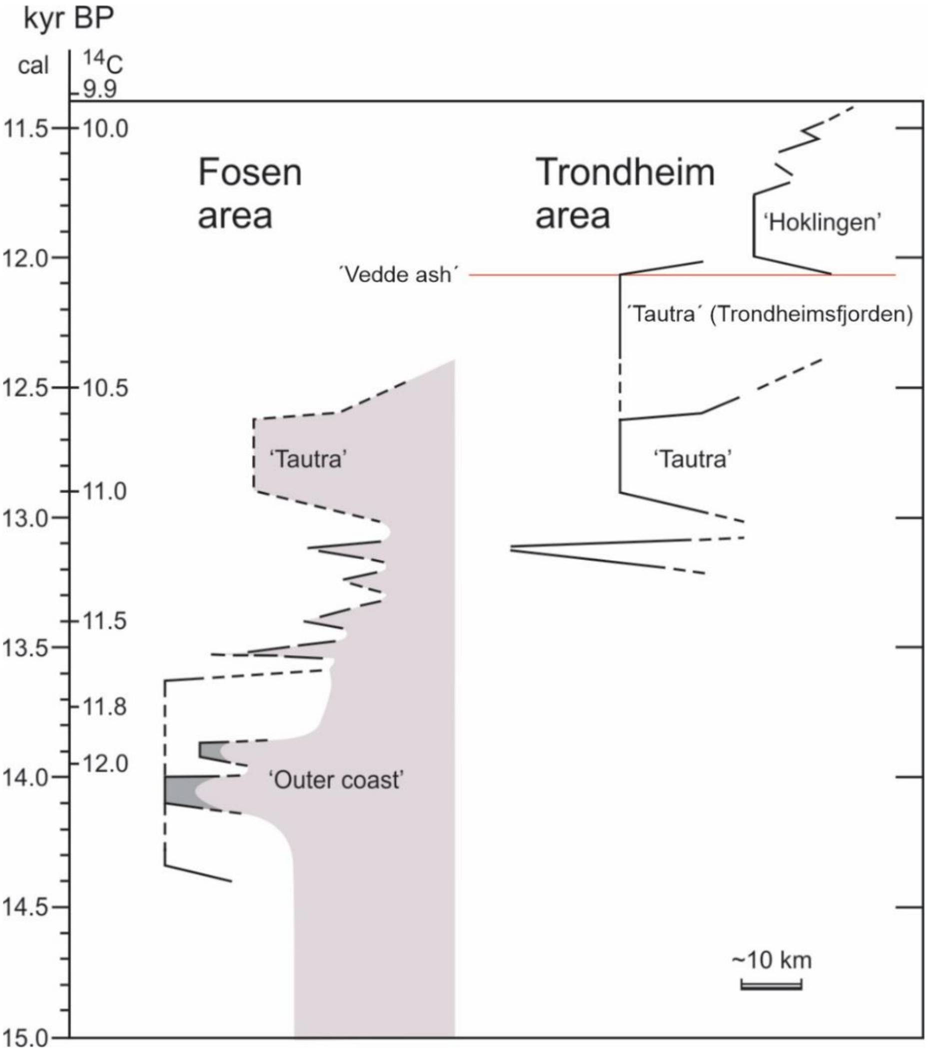

Fig. 9. Time–distance (glaciation) curves for the OC–OD and Tingvoll ice-marginal substages in Mid-Norway, focusing on the Fosen area in the middle (shaded area), between significant lateglacial ice-marginal oscillations (ice-retreat phases) from Bølling and Allerød time. It is indicated two ice marginal phases during the OC–OD substage interval, occurring in some areas (e.g., Tingvoll, Osen, and Lauvsnes) as two distinct zones separated up to 6–9 km apart, and both with ages close to 14 cal kyr BP. Location of the complex YD Tautra ice-marginal substage (age: early to mid-YD in the Trondheim area and to the south, and north-northwest of Trondheimsfjorden, and late YD in Trondheimsfjorden approximately crossing Tautra island) is also indicated (grey line). The Hoklingen ice advance, as well as a late YD* ice advance in Trondheimsfjorden (Fig. 3, grey line with barbs), coexisting with the Vedde ash outburst event, reaching the same position as previously mapped as the early to mid-YD ‘Tautra’ ice margin in central (Tautra island) and western side of the fjord at Leksvik (Olsen et al. 2015, *Larsson et al. 2020) are also indicated.*

With a further screening of dates which excludes samples dominated by Macoma, and those with the deepest stratigraphic position in the sub-till sediments and also longest geographical distance to the OC ice marginal moraines, then samples nos. 4, 15, 18, 21, 22, 29, 33, 40, 71 and 72 are omitted. This leaves the remaining 26 dates as old or older than the OC–Tingvoll substage moraines in two groups (1 and 2 in figure 8), equal to or younger than: (1) 14340–14032 cal yr BP (mean ±1σ = 14195 ± 75 cal yr BP) (n=16) and (2) 13980–13785 cal yr BP (mean ±1σ = 13891 ± 68 cal yr BP) (n=10). Group 1 is supposed to represent the outer (older) moraines, where multiple moraines occur, and group 2 the inner (younger) moraines, for example in the Osen, Hemne and Stangvik–Tingvoll areas. This constrains apparently the outer moraines to the interval between c. 14.1 and 14.0 cal kyr BP, whereas the inner moraines are just slightly younger.

However, a screening of dates like this may imply a loss in regional data representation. Thus, before using 'improved' age assignments like this the gain in age accuracy should be considered against possible reduced regional validity. In this report we choose to show both the regional data representation for the entire Trøndelag–Nordmøre region (Figs. 8 and 9) and a glaciation curve focusing on the Fosen area (Fig. 1), with age ranges based on the screened dates we consider most accurate for the OC substages in Mid-Norway (Fig. 9).

Bølling to early Allerød sea levels compared to YD maximum sea level

Shoreline displacement curves, based on dating of isolation contacts in lakes previously inundated by the sea in the Bjugn area, and based on shell dates, and altitude of shorelines, beach ridges and delta surfaces in the Verdal area, have been reconstructed for the interval from late Bølling transition to early Allerød–late YD to present (Kjemperud 1982, 1986, Sveian and Olsen 1984). Shorelines or other features representing sea level during the Bølling to early Allerød period, including the OD cold phase have been recorded as marine limit (ML) observations in the coastal areas during general quaternary geological mapping (e.g., Follestad 1984, 1989, Reite 1988, 2002). It follows that the marine limit features, or traces of Bølling to early Allerød relative sea levels are generally located a few meters higher than middle to late Allerød sea levels and similar features from the YD interval in the same area. The height difference between the sea level from late Bølling–early Allerød, or OD interval, and maximum YD sea level is recorded to more than 15 m in the Bjugn–Ørland area (Kjemperud 1982, 1986, Reite 1988), and c. 15 m in the Osen–Jøssund area (Olsen and Riiber 2006, Sveian et al. 2016). Similar data is reported from Hitra island (Kjemperud 1986) and areas south of Trondheimsfjorden (Follestad and Ottesen 1996). A shoreline gradient of 1.6 m km^{-1} is previously estimated for the middle to late Allerød in the Trondheim area (Olsen et al. 2015). The shoreline gradient for late Bølling and early Allerød in the coastal zone is considered from general reasoning to be higher, and Kjemperud (1986) speculates that it may be at least up to 1.7 m km^{-1} there. With a gradient of 1.8 m km^{-1} of a theoretical shoreline from ML at 98–100 m a.s.l. at the eastern side of Hitra in the west, just a few km distally to the OC substage moraines, to Holla northeast of Kyrksæterøra in the Hemne area in the east, this shoreline would have reached c. 15 m higher than the marine limit at 130 m a.s.l. from the YD interval at Holla. With an isobase direction at 40°, as used by, e.g., Sørensen et al. (1987)

and Svendsen and Mangerud (1987) for YD, and probably valid for the whole Bølling–Allerød–YD period in this region, the 150-m a.s.l. isobase that is crossing the just mentioned theoretical shoreline just a few km east of Holla is also touching the top surface at 150 m a.s.l. of the Ålvund ice-contact delta from Tingvoll substage mapped by Follestad (1984) in the Stangvik area in the southwest. This supports the steepness of the suggested gradient of the late Bølling–early Allerød theoretical shoreline. It is therefore very likely that the shore displacement between late Bølling and YD sea levels is generally at least 15 m in the Trøndelag–Nordmøre outer coastal region.

The Older Dryas (OD) re-advance in Norway

The ice margin c. 14 cal kyr BP, i.e. the time for the beginning of the short-lived OD cold phase, is considered to be represented with the Repparfjord Substage in Finnmark (Fig. 1) (Marthinussen 1960, 1961, 1962, 1974, Sollid et al. 1973), the Skarpnes Substage in Troms (Marthinussen 1962, Andersen 1968, Vorren and Plassen 2002, Sveian et al. 2005), the Substage A in Nordland in general (Andersen et al. 1981), the Vassdal Event in the area west of Svartisen, Nordland (Rasmussen 1981, Olsen 2002), the OC Substage in Trøndelag (Reite 1995), the Tingvoll Substage in Nordmøre (Follestad 1984, 1989), and also correlative moraines at the mouth of Hardangerfjorden in Hordaland (Mangerud et al. 2016), in the outer part of the YD ice-marginal zone at Sørlandet, Vest Agder (Fredin et al. 2015), and the Tjøme–Hvaler Moraines in the outer Oslofjord area (Sørensen 1983, Olsen and Sørensen 1998, Bergstrøm 1999). All of these ice marginal locations are resulting from halts during overall late-glacial ice retreat or re-advances of the ice margin from positions of varying length proximal to these locations. The age estimates for the Repparfjord Substage were originally based mainly on association to shorelines of estimated c. OD age (Marthinussen op.cit., Sollid et al. op cit.), but are later supported by mapping of lateral moraines up to 600 m a.s.l. at the northern side of Repparfjord (Follestad and Hamborg 1985), which indicates that a correlation with the Outer Porsanger Substage in the Porsanger fjord area is the obvious and most likely candidate to the east. A correlation to a younger ice marginal zone some 25–30 km south of the Outer Porsanger Substage in the Porsanger fjord area, as suggested by Sollid et al. (1973), is simply not feasible due to general consideration of ice-surface levels and possible glacier configuration. An age of c. 14 cal kyr BP for the Outer Porsanger Substage is proposed by Romundset (2010), based on ^{14}C dates of shells in till or deglaciation sediments (in isolation basins) at the coast of Finnmark, distally to the Outer Porsanger Substage Moraines. Terrestrial cosmic nuclear ^{10}Be isotope dates of erratic boulders on moraines in the Vardø and Kongsfjord areas at the Varanger peninsula in the northeast (Romundset et al., 2017), indicates a possible even more extensive ice sheet also in this area at c. 14 cal kyr BP than previously thought (Sollid et al. 1973, Andersen 1979, Olsen et al. 1996). In Troms (e.g., Andersen 1968, Sveian et al. 2005, NGU unpublised data), as well as in Nordland, Trøndelag–Nordmøre, Western Norway and the Oslofjord area the chronology of the substages c. 14 cal kyr BP is based mainly on shell dates in sub-till, sub-moraine or associated deglaciation marine sediments. At Sunnmøre in southern Møre & Romsdal the deglaciation occurred with ice-free areas at the outer coast c. 15 cal kyr BP, inferred from studies and dating of (isolation) basin sediments (Kristiansen et al. 1988, Svendsen and

Mangerud 1990). There are a number of sites at the outer coast with shells in till-like diamictons or sub-diamicton sediments, where the shells are dated to c. 14–15 cal kyr BP (e.g., Larsen et al. 1988). These locations indicate a possible extensive ice sheet in this area during this time and possibly also a considerable re-advance of the ice towards the west. An alternative explanation of locations of till-like diamictons covering sediments of age approximately the same as during ice phases with ice margin well inside (proximal or landward from) these locations may be a series of small glacial re-advances during general and fast ice-retreat, as suggested by Larsen et al. (1988) for Bølling–Allerød in the Storfjord area, and Olsen et al. (2007) for Allerød–YD in the Trondheimsfjord area. However, most of or all of these sites in the Storfjord area are located at elevations below the Bølling–Allerød maximum sea level and may be explained by an environment with icebergs or even ice-shelf development during OD time, or younger seasonally thick grounded sea ice, and may not necessarily require ice advance of the main ice sheet. This is in that case similar to what is the current interpretation of the diamicton overlying the Blomvåg Beds northwest of Bergen (Mangerud et al. 2016), where grounded thick sea-ice origin is inferred, and also similar as suggested here (described later) for many similar sites distally to the OC substage ice margin in the northern part of Trøndelag, and also for similar sites of YD age distally to the YD maximum ice margin in Troms, Nordland and Trøndelag (Olsen 2002, Olsen et al. 2014, Olsen et al. 2015, and unpublished material). A reconstruction of ice marginal positions and distribution of De Geer moraines in Møre & Romsdal is published by Larsen et al. (1991). According to their reconstruction the ice margin after the c. 14 cal kyr BP advance was located close to the YD ice margin at the end of Romsdalsfjorden in the southern part of this region. Deglaciation in Storfjorden further south seems to have been delayed compared to Romsdalsfjorden (Larsen et al. 1991), which indicates that the 14 cal kyr BP ice margin may have been located further out (west) in this area and further south, in concordance with the previous reconstruction made by Andersen and Karlsen (1986).

Fredin et al. (2015) have mapped two moraine ridges, one outer and one inner moraine, in the YD ice marginal zone in some areas in Vest Agder, southern Norway. Erratic boulders have been dated from terrestrial cosmic nuclear ^{10}Be isotopes from both ridges. The dates from the outer ridge have come out with OD age, whereas those from the inner ridge have given YD age. From the map in Fig.1 it seems that a situation where the YD ice re-advance has reached at least as far out on the coast as the OD ice margin was located is represented in alternating intervals along about half of the coastline from north to south in Norway. In most areas between the areas with overlapping OD–YD ice margins c. 14 cal kyr old marginal moraines are located in varying distance distally to the YD moraines, the longest distances between these ice margins are in Finnmark and in Mid-Norway. Based on the long zones characterized by re-advances at c. 14 cal kyr BP of the ice margin it is not surprising that most authors (e.g., Marthinussen 1962, Andersen 1968, 1979, Mangerud 1977, Anundsen 1977, Vorren and Elvsborg 1979, Mangerud et al. 1979, Mangerud 1980, Andersen et al. 1981, 1982, Sørensen 1983, Follestad 1985, Sørensen 1992, Reite 1994, Bergstrøm 1999), tended to think that this was linked to a period of climatic deterioration and that the re-advances are mainly a response from the ice-sheet to a climatic oscillation. However, very few of these re-advances are found to be represented with lateral moraines at high elevations, e.g. up to 600 m a.s.l. at Repparfjord in Finnmark (Follestad and Hamborg 1985), up to just above 300 m a.s.l. west of

Svartisen in Nordland (Rasmussen 1981, Olsen 2002), and possibly up to 400–500 m a.s.l. in the Stangvik–Vinjeøra area in mid Norway, not far from the ice front (Follestad 1984, Reite 2002).

Implications for deglaciation history and climatic variations around Older Dryas

The elevation of the lateglacial pre YD ice-marginal moraines reaching at least 1500 m a.s.l. south of Oppdal (Follestad 2005, Olsen et al. 2014), 100–200 m higher than the YD moraines in the same area show that the mountain areas in the inland to the south and east of Oppdal must have been more or less ice covered during OD, with the ice surface situated at least some 1600–1700 m a.s.l. in the Dombås–Lordalen area further south (Follestad 2006, 2008).

Considerable ice-retreat by calving on the shelf and in the outer Trondheimsfjord area, at least to a position east of Ørland, and in adjacent fjords during Bølling was succeded by an OC re-advance from the east to the Lauvsnes–Uran–Osen–Ørland ice marginal position north of Trondheimsfjorden (Holtedahl 1929, Kjenstad and Sollid 1982, Reite 1988, Sveian 1997, Olsen and Riiber 2006, Sveian et al. 2016), and also re-advance in the Hemne–Bøverfjord–Stangvik–Tingvoll area in the south (Follestad 1984, 1985, 1989, 1992, Follestad and Ottesen 1996, Reite 2002). The presence of Bølling marine clay overlain by OC–Tingvoll till locally in these areas suggests a considerable re-advance, locally of at least 6–9 km length (Figs. 2 and 3). However, a considerable OC re-advance is not recorded everywhere from north to south. In northernmost part of Trøndelag, close to the boundary to Nordland county, the OC substage is in contrast to the neighbouring area a few km further south seemingly represented more by a halt/stillstand in the ice-margin, an interruption in the ice retreat, rather than a major ice re-advance, as inferred by less frequent push-moraines and more of other frontal melt-out features, such as ice-marginal deltas. For example, at ***Djupvika locality*** (Figs. 7 and 10) in the north, the OC ice-marginal delta, which is overlying Bølling marine sediments, is itself overlain by Allerød marine sediments and YD ice marginal deposits (B. Bergstrøm in Bargel et al. 1994), with holocene sub-littoral and littoral sediments on top. In general, no significant OC ice re-advance is yet recorded in the northernmost part of Trøndelag, which is different from the subsequent YD re-advance which must have had considerable length based on the huge end moraines and lateral moraines of YD age, also occurring in this area (e.g., Riiber and Bergstrøm 2001). However, new datings of shell from till or sub-till sediments several km distally to the YD ice margin just a few km to the north of the Djupvika locality (Fig. 7) may indicate a significant ice re-advance during the OC substage further north than hitherto recognized.

The ice margin in outer Trondheimsfjord before the OC re-advance to Ørland is supposed to have been just a few km to the east, which led to a re-advance of just small to moderate size (Kjenstad and Sollid 1982, Reite 1988). Another clear difference in ice-sheet dynamics between OC and YD is, as mentioned above, that YD ice-marginal moraines are often distinct and of considerable size also on higher ground in most areas, such as in the Foldfjorden area

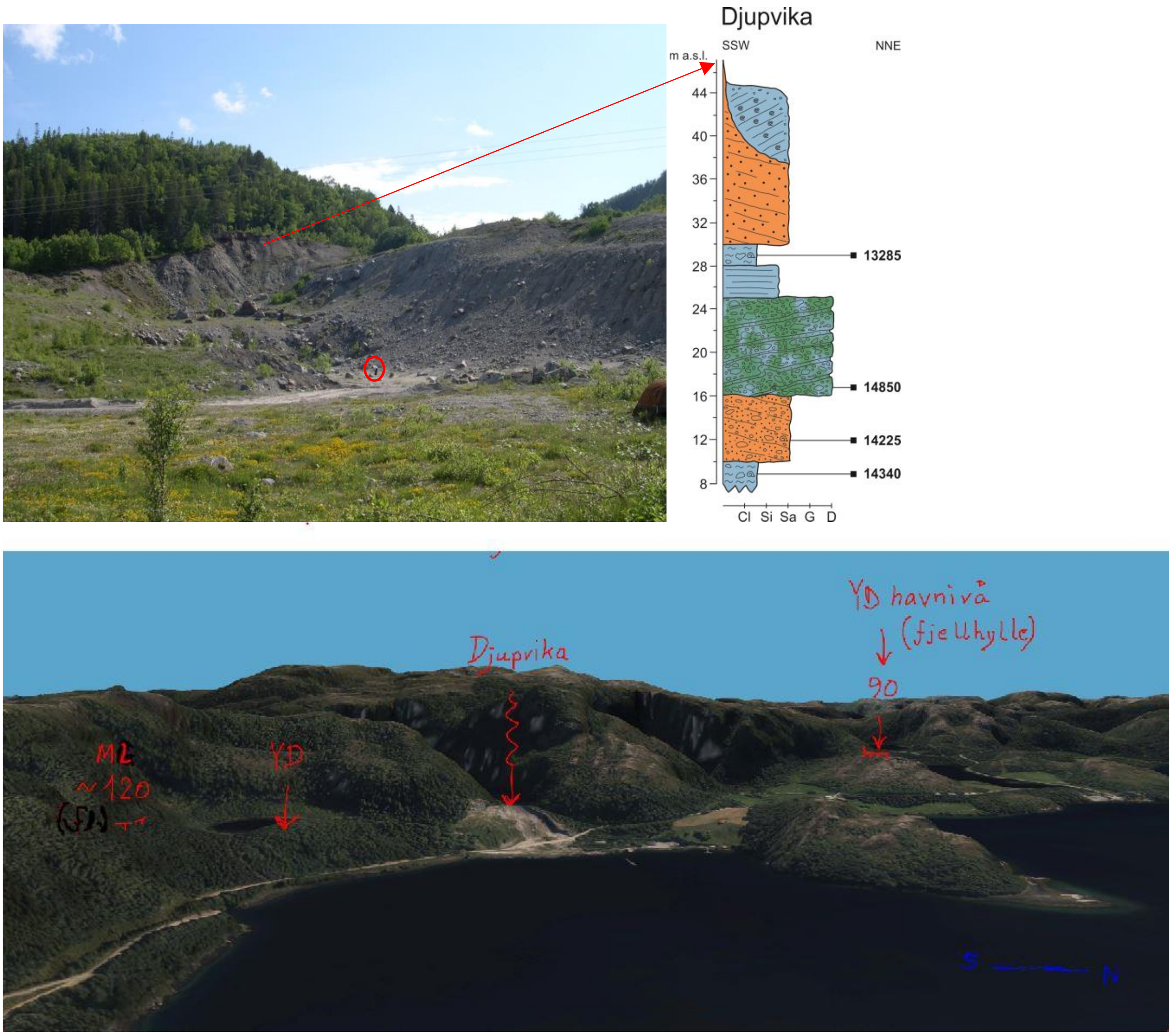

Fig.10. Djupvika, complex stratigraphy with lateglacial ice marginal deposits (OD and YD) overlying Bølling and Allerød marine sediments, respectively, and subsequently reworked by the sea during Holocene (Tapes transgression). A - Upper photo: Abandoned gravel pit in the complex deposit, person for scale (red circle), photograph by H. Sveian, 2011. Simplified stratigraphic log of sediments to the right, with marine silty clay, overlain by shallow marine and glaciofluvial sand, followed by ice marginal sediments deposited from the fjord area in the NNE towards onshore position in the SSW, overlain by another silt and clay succession, followed by glaciofluvial outwash sediments deposited towards the fjord, and finally on top, shallow marine gravelly sand, with abundance of marine shells. Some shell datings in cal yr BP is also indicated. B - Lower photo: Overview of the site, with YD ice marginal deposit in adjacent valley, and shore terraces (with irregular surfaces, assumed just slightly abraded late glacially by the sea) in bedrock representing marine limit (120 m a.s.l.) and YD sea level (90 m a.s.l.) also marked. Photo from: www.norgei3D.no. Both photos, view towards the west.

in the north and in the Fosen mountains where YD lateral moraines are located up to more than 600 m a.s.l. (Sveian 1997, Olsen et al. 2015), while ice-marginal moraines from the OC substage are almost always constrained to lower ground (Reite 1994). Just a few exceptions to this are recorded in the south, e.g. at Stangvik were such moraines occur up to c. 400 m a.s.l., and at Vinjeøra were these occur up to c. 500 m a.s.l. (Follestad 1984, Reite 2002). This may indicate that while the YD maximum ice re-advance included most of the ice sheet in the Trøndelag–Nordmøre area, the OC re-advance may have been dynamically constrained mainly to the lower ground and fjord areas, and therefore possibly with a much lower glaciations limit than during YD.

The distance parallel to ice flow direction between the positions of outer and inner ice marginal moraines representing the OC substage varies significantly from one area to the other, with maximum of 3 km at Osen, 4 km at Lauvsnes and Hemne, and 7 km at Stangvik (Figs. 2, 3 and 5), with an average regional distance of maximum 4–5 km. The difference in ice-surface elevation varied accordingly, with an assumed vertical difference of several hundred meters in areas near the ice margins, and a few meters to tens of meters further inland. The ice volume that have melted during deglaciation between the outer and inner moraines of the OC–Tingvoll substages, along a 300 km transect from north to south in Trøndelag and Nordmøre, must therefore have been larger than 300 x 4 x 0.2 km^3 (c. 240 km^3). This represents a considerable body of melted ice, although it may still indicate mainly or only adjustments of ice retreat and re-distribution due to topographical variations. In comparison, the preceding Bølling ice-marginal retreat from the continental shelf to the outer coastal areas and the subsequent Allerød ice-marginal retreat and reduction of ice volume were of a quite different scale, indicating significant climatic ameliorations, with ice retreat and volume reduction of several 1000 km^3 of ice before the OC re-advance occurred in the outer coastal areas, and subsequently also before the YD re-advance occurred.

A possible climatic deterioration with colder climate during late Bølling and transition to Allerød, the short interval known as the Older Dryas (e.g., Fægri 1953), may explain the halt in reduction and subsequent increase of area extension and volume of ice associated with the initial part of the OC substage in Trøndelag and Nordmøre areas. An indication of climatic deterioration during or just after late Bølling in various parts of Norway, as seen from the Bølling–Allerød glacier-response history as described above, is also to some extent recognized in the palaeovegetation history. A small reduction in pollen from thermophilous trees and increased content of none-tree pollen during late Bølling transition to early Allerød, or OD, is recorded in some basins along the coast of western Norway (Paus 1988, 1989, 1990, Birks et al. 1994), although Thomsen (1981) could not confirm properly from northern Jæren the distinct short-lived OD event that Fægri (1953) and Chanda (1965) reported from pollen analyses from Jæren further south. Pollen and plant macro fossils of OD age in central Norway indicate small variations, but no significant climatic deterioration during this interval is reported so far (Kjemperud 1982, 1986), in contrast to the late-glacial ice front oscillation history during this interval.

A small and short-lived climatic deterioration during late Bølling transition to Allerød is however more distinctly recognized from the palaeovegetation record in other parts of Norway. For example, at Andøya in northern Norway such data have been recorded for a short period around c. 14 cal kyr BP, with a mean July temperature c. 2–3 °C (up to 4 °C) colder during a short interval just before 14 cal kyr BP compared to Bølling–Allerød in general (Vorren and Alm 2009, Vorren et al. 2009). The OD climatic fluctuations at c. 14 cal kyr BP are also documented in marine records from the North Sea and Norwegian Sea areas (e.g., Koc Karpuz and Jansen 1992, Koc and Jansen 1994), and may also be reflected farther north in a significant ice advance of approximately the same age at the western margin of the Svalbard–Barents Sea ice sheet (e.g., Svendsen et al. 1996).

Lateglacial diamictons, possibly formed by grounded icebergs, shelf ice or thick sea ice

Bjørgan. – Bones that later were concluded to be remains of a Greenland whale (by Rolf Lie, Geological Museum, University of Bergen) were found in diamict clayey material 1 m below beach gravel in 1990 during excavation of a garage site c. 10 m a.s.l. at Bjørgan farm, Nord Flatanger, Trøndelag (owner of farm: Einar Hågensen), 64.583°N and 10.9°E (Figs.11 and 12). The site where then excavated and the Geological Survey initiated a study of the sediments and stratigraphy represented, both from excavations in 1990–1991 and from several drillings in the vicinity. All units below the beach deposits were shell-bearing and 6 shell samples and 1 bone sample from these were dated.

The overall stratigraphy of the c. 3 m thick sediment overburden on bedrock at the garage site was as shown in Fig. 12A, with beach deposits (unit A) on top overlying a unit B mapped as till during fieldwork at the site, but may be better considered scientifically as just a till-like diamicton. It was subdivided in three subunits B1, B2 and B3, with the uppermost part, subunit B1 as the most homogenous, massive "till-like" type of deposit. Subunits B2 and B3 were also very compact, consolidated deposits, but appeared to be different from B1 by the clear original glaciomarine character of the material, B2 appearing as a deformed and "tillised" glaciomarine sediment and B3 with less deformation structures and including the many whale bones from a Greenland whale skeleton. Some of the bones penetrate the boundary between B2 and B3, reaching with their end just a little into the overlying B2 subunit. The lowermost sediment unit at the site, unit C is also subdivided in subunits (e.g., gravel C1, sand C2, and gravel C3) and is resting on bedrock of granitic gneiss. Glacial striae from bedrock surfaces at and close to the site, and in the vicinity show all directions towards the northwest, approximately normal to the local coastline here (Sveian and Olsen 2014). All clast fabrics and deformation structures, except in the uppermost part of B1 where the direction is considered indefinite, show also a preferred direction approximately towards the northwest (Fig. 12A). Consequently, our first hypothesis was that unit B (at least subunits B2 and even more so subunit B1) represents an ice advance of the inland ice sheet, crossing the coastline and moving towards the shelf area. Regional quaternary mapping in the surrounding areas that was carried out around 1990 and the following years led us to conclude that this ice advance must have happened before c. 14 cal kyr BP, because the Bjørgan site is located c. 8

Fig. 11. Bjørgan, Nord Flatanger, site with whale bones found 1990 in and below a till-like diamicton, c. 10 m a.s.l. Lateglacial marine limit in the area is c. 120 m a.s.l. Upper and lower photo, H. Sveian, 1991. Middle photo from www.norgei3D.no, with site location (red arrow) and postglacial shore terraces (40, 60, 100 and 120 m a.s.l.) in bedrock indicated.

km distally to the approximately 14 cal kyr old OC or OD ice-margin position between Lauvsnes and Namsenfjorden in the east (Fig. 5).

Results from 7 radiocarbon dates of shells and a whale bone from Bjørgan have a range of 14.0–15.1 cal kyr BP, with the oldest ages from the lowermost unit. The whale bone from unit B3 was additionally dated by 20 different international ^{14}C laboratories, which resulted in a mean age of c. 14.3 cal kyr BP (12348 ± 30 ^{14}C yr BP). Therefore, it should be reasonable to conclude that diamicton B, comprising subunits B2 and B1, is produced after this age. If the origin of the diamicton was the inland ice, then several hundred meters of ice must have melted between this and c. 14 cal kyr BP, i.e. the time the ice margin was located 8 km further southeast along the OC–OD ice margin from Lauvsnes to Namsenfjorden (Fig. 5). This is possible, but an alternative that has to be considered is that the Bjørgan diamicton may have been produced by grounded icebergs or shelf ice during OD (or YD?), when the water depth at the site was more than 100 m (marine limit at least 115–120 m a.s.l. here; Sveian and Olsen 2014). Deformation structures and preferred clast fabric directions in diamictons produced by such processes in this area would most likely be similar to, and not possible to distinguish from, those in glacial diamictons produced by the inland ice sheet.

Sitter. – This site is represented by the sections of four machine-excavated trenches in 1995 of 1.5 m with, 2.5–3.5 m depth and 5–10 m length, with location at c. 64°31'N and 10°50'E, map ref. 1624 II, UTM 947572 (Fig. 5) (Olsen et al. 2001). The sections, reaching up to c. 50 m a.s.l., comprise a combined stratigraphy which includes six thin tills or diamictons with reworked and/or intercalated and underlying waterlain sediments. The surface is covered with beach gravels. The three lower tills are all very compact, but different in composition. The lowermost till is a c. 0.3 m-thick, mainly compacted and glaciotectonised sandy silt, with a more diamictic character including clasts in its upper part. An AMS radiocarbon dating of bulk organics from this unit, which contains only terrestrial organic material, yielded an age of c. 34 cal kyr BP (Fig. 12B). The organic content in the overlying till seems to be close to zero, whereas the subsequent thin till is mainly reworked and ‘tillised’ marine sediments with microfossils such as dinoflagellates and foraminifera (Olsen and Grøsfjeld 1999). A dating of bulk marine organics from these sediments gave an age of c. 25 cal kyr BP, indicating that the reworking and compaction probably occurred during the LGM 2 ice advance and that the underlying till belongs to LGM 1 (Olsen et al. 2001). All units which overlie the lower three tills represent late-glacial depositional events, c. 14.7–14.8 cal kyr BP or younger. This is based on a dating of bulk organics in sandy silt underlying the three upper diamictons and a dating of shell from reworked marine sediments in the lowermost of the three upper diamictons. Based on the location of this site several km distally to the ice margin at c. 14 cal kyr BP it is assumed that at least the uppermost diamicton at this site may represent a unit formed by grounded, tide-influenced icebergs or ice shelf formation and activity, similar as a hypothesis for the origin of the Bjørgan diamicton mentioned before. The water depth at this period was up to 70 m over the site, but if the uppermost diamicton was formed much later and during a much lower sea level, which cannot be excluded, then thick grounded sea ice should not be disregarded as a possible source of formation.

Teigmoen. – Excavation of trenches c. 8 m from a small bedrock knob that penetrates the shore deposits at the little farm Teigmoen in Nord Flatanger (Figs. 5 and 12C) revealed the

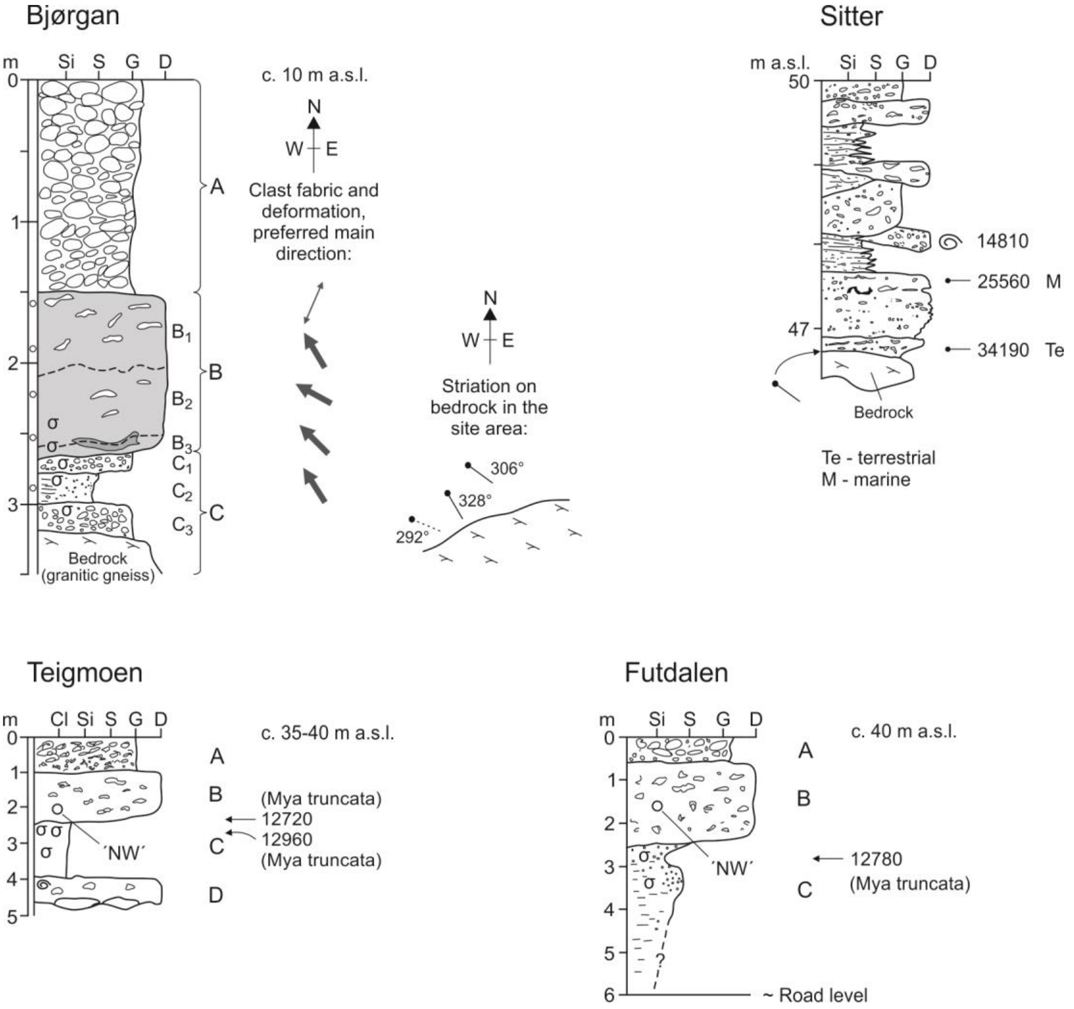

Fig. 12. Stratigraphies from sites supposed to include diamictons which originate from grounded iceberg-/ice shelf activity during OD (A, B; see also Fig. 11) and YD (C, D), or from mid to late Holocene thick sea-ice activity. A – Bjørgan; B – Sitter; C – Teigmoen; D – Futdalen. Ages are indicated in cal yr BP. See figure 7 for location.

stratigraphy of a 4.7 m thick sediment sequence from c. 35.3 m a.s.l. to the surface at c. 40 m a.s.l. Below 1 m of beach deposits (unit A), a c. 1.5 m thick diamicton (unit B) originally mapped as a till follows, and is overlying a c. 1.5 m thick glaciomarine unit (C), and then follows a diamicton, with small shell species in the upper part and with stones and bigger boulders at the base, which is also the base of the trenches. Clast fabrics in unit B indicate preferred direction towards the northwest, as also indicated from striation on bedrock in the vicinity (Sveian and Olsen 2014). Two ^{14}C dates, one conventional and one AMS from shells in unit C yield ages of 12.7 and 13.0 cal kyr BP, which indicate that the diamicton unit B is formed during YD or later. Considering these ages, and the location of the site, c. 20 km distally to the YD maximum ice margin (Fig. 5), it is very unlikely that diamicton B is a till produced by the inland ice. The sea level during YD reached about 100 m a.s.l. in this area, and the water depth at Teigmoen was therefore about 60 m, which rejects a hypothesis of sea-ice activity as the origin of the diamicton if it has a YD age. In addition, neither the clast fabrics and parallel striation on nearby bedrock surfaces, nor the till-like appearance of unit B support a sea-ice activity origin of this diamicton. It is therefore most likely that the diamicton is produced by grounded, tide-influenced icebergs or has a grounded ice-shelf origin, and if so then it most likely happened during YD which was a time when ice-shelf formation and iceberg activity are supposed to have been widespread along the coast of Norway (e.g. Olsen 2002). Regional quaternary mapping in Norway – 1990 to present – by the Geological Survey supports this view since several localities of similar diamictons, most likely produced during the YD, and located distally to maximum YD ice margins are mapped for example in northern Troms, in Nordland west of Svartisen, and in Trøndelag.

Futdalen. – Sections along the road in Futdalen, Nord Flatanger (Fig. 5), c. 40 m a.s.l. revealed a stratigraphy with shore-washed diamicton mapped originally as till, overlying glaciomarine sediments at two sites just 150–200 m separated from each other. Clast fabrics in the diamicton at both sites and dating of shell from the glaciomarine sediments at one of the sites (Fig. 12D) indicate production of the diamicton during movement towards northwest, as striation on bedrock also shows on nearby locations (Sveian and Olsen 2014), and age of formation after 12.8 cal kyr BP, which means YD or younger. This age and the location more than 20 km distally to the maximum YD ice-marginal position, make an origin of the diamicton connected to the inland ice sheet as very unlikely, and sea ice may also be disregarded if the production happened during YD. The water depth of about 50 m would be much too deep to allow this to happen. However, grounded icebergs and/or a shelf-ice origin of these diamictons are alternatives that seem to explain these formations well, as for the diamictons at Teigmoen, Bjørgan and Sitter.

Ytter-Vikna. – A section through the sediment overburden along a road in Ytter-Vikna (Figs. 7 and 13; map ref.: Bergstrøm and Riiber 2001), c. 8 m a.s.l., includes a stratigraphy with till (unit C) directly overlying bedrock, and overlain by sublittoral glaciomarine sediments (unit B) and shore material (unit A), with slope slide material on top. The lowermost part of the till (subunit C2) includes some lenses of gravelly sand, and less stones and boulders than in the upper part (subunit C1). Clast fabrics in the till (2, 3 in Fig.13) have preferred orientation indicating ice movement towards c. 290–300º, whereas a clast fabric (1 in Fig.13) in a diamict part (subunit B2) of the overlying glaciomarine sediments indicates a more westerly depositional direction (c. 270º). Resedimented shells of at least Middle Weichselian age are recorded from the diamict part (subunit B2, Fig.13) of the glaciomarine unit. However, the location more than 25 km west of (distally to) the OC ice margin (Fig.7), supported by a shell date from the contact zone between units B and C, indicate a deglaciation here during late Bølling. The due west orientation of clasts may indicate that the diamict part of unit B (subunit B2) was deposited from ice directly in contact with the marine ground surface, i.e. the fjord bottom, rather than randomly deposited as ice-rafted material from icebergs. The origin of the diamict part of unit B is uncertain, because a strong glacial till indicator as clast fabric preferred orientation cannot in this area discriminate properly between deposition from the inland ice sheet, grounded shelf ice, tide-influenced grounded icebergs or even thick sea-ice. The stratigraphy at Ytter-Vikna may therefore include evidence of a small oscillation of the inland ice during general ice retreat shortly before the OC–OD substage. Alternatively, the younger part of the stratigraphy may equally well, or more likely, similar as for the localities at Bjørgan, Sitter, Futdalen, and Teigmoen, include evidence of ice-shelf, ice-berg, or thick sea-ice activity during deglaciation, here some 25 km distally from the OC–OD ice margin.

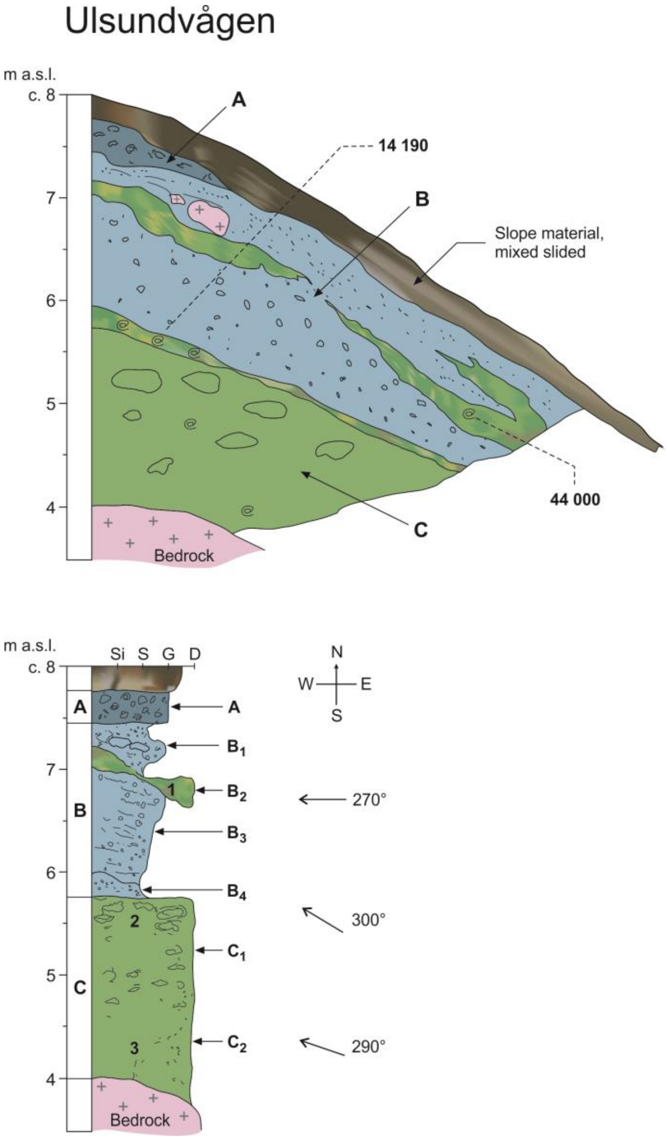

Fig. 13. Section and stratigraphic column from Ytter-Vikna (Fig. 7, and Bergstrøm and Riiber 2001). Preferred clast fabric orientations and dating results in cal yr BP are indicated. The youngest diamict sediments here may have a similar origin as described for Bjørgan, Sitter, Teigmoen or Futdalen (Fig. 12).

Summary and conclusions

The ages of the Outer Coast (OC)–Tingvoll ice marginal substages in Mid-Norway are dated to the interval 14.3–13.6 cal kyr BP based on ^{14}C dates of 108 samples spread from Djupvika in the north to Tingvoll in the south (Figs. 1, 2, 3 and 10, and Table 1). The age range is narrowed to c. 14.1–13.8 cal kyr BP if these data, after quality screening (leaving a total of 49 remaining representative datings), is divided in two groups older than (n=26) and younger or equal to (n=23) the associated ice marginal moraines. The ages of the diachronous OC–Tingvoll substages are therefore slightly older than Older Dryas (OD) or approximately of OD age (Figs. 8 and 9).

The OC–Tingvoll ice margins do not show continuous lines of ice marginal deposits (moraines, ice contact deltas, etc.), they appear rather as discontinuous lines of correlated deposits from fjord to fjord and valley to valley, with variable distances between distinct deposits along the 300 km long distance from Djupvika to Tingvoll. The correlation lines are all based on Quaternary maps, relationship and distance to the more continuous YD maximum (Tautra) ice marginal position (Sveian 1997, Olsen et al. 2015), and considerations of reasonable ice dynamics and ice surface gradients based on comparison to known present or reconstructed old glaciers.

The ice margin dynamics are apparently also variable from area to area. In some areas, as at Osen, Hemne and Stangvik, the OC–Tingvoll substages are including two parallel ice marginal zones which are separated up to several km apart. At Djupvika (1-4 in Fig. 2; Fig. 10) in the north there is no indication of significant ice advance connected to the OC ice margin there, just deposition of an ice-contact delta after a minor ice advance which followed a halt in ice retreat during Bølling time. In the Jøssund–Osen area further south there are indications of several km ice advance towards the maximum OC ice margin, and in the Vinjeøra–Stangvik–Tingvoll area in the south there are ^{14}C dated shells in tills and some lateral moraines from the Tingvoll substage reaching up to 300–500 m a.s.l. (Follestad 1984, Reite 2002), which indicate that ice advance of several km, locally up to 6–9 km occurred during this substage.

Till-like diamictons overlying glaciomarine sediments with shells dated to YD–Allerød and Bølling presented from five sites (Figs. 5, 12 and 13) distally both to the YD and the OC–OD ice margin positions, indicate that grounded icebergs or shelf ice may have produced these deposits rather than the inland ice itself. If activity from thick sea ice in the shore zone during Holocene could produce till-like diamictons, including clast fabrics with strong preferred dominating orientation, parallel to the last ice movement direction in the area, then this may explain formation of some of these diamictons as well.

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Most of the ^{14}C-dates referred to in this report have been carried out as a part of the general Quaternary geological mapping made by the Geological Survey of Norway during the last decades. Data from these activities and from other sources is referred to in Table 1. Irene Lundqvist has drawn the figures. This report is a contribution to NGU-project 378700: “Regional quaternary geological mapping in Norway-II”, with focus on mapping in various regional map scales, as well as on glacial and deglacial history in Norway.

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Table 1

(^{14}C dates constraining the Outer Coast (OC) – Tingvoll substages)

^{14}C dates from lateglacial pre YD sediments, including dates constraining the OD Outer Coast - Uran Substage, Trøndelag, and OD Tingvoll Substage, Nordmøre, mid Norway. The original data for marine shells is given without subtraction of reservoir age (J and O).

No.	A Locality	B Lab. Ref.	C Geographical latitude	D position longitude	E Elevation m a.s.l.	F Site type	G Dated material	H Stratigraphical context	I Dating method 14C Ams, conv.	J[d] C14-age yr BP (older)	K Uncertainty +/- 1 std dev	L **Calibrated age IntCal13**	M[e] Uncertainty +/- yr	N[a] Age J adjusted for reservoir age	O[d] C14-age yr BP (younger or equal)	P Uncertainty +/- 1 std dev	Q **Calibrated age IntCal13**	R[e] Uncertainty +/- yr	S[a] Age O adjusted for reservoir age	T References
1	Djupvika	T-9809	64.953°	11.718°	45	OD ice margin	Mya truncata	Subtill glacim.sed.	Conv	12795	135	14340	40	12355						Bargel et al. 1994
2	Djupvika	T-9188	64.953°	11.718°	45	OD ice margin	Mya truncata	Subtill glacim.sed.	Conv	12735	135	14225	45	12295						Bargel et al. 1994
3	Djupvika	T-9810	64.953°	11.718°	55	Tautra ice margin	Mya truncata	Subtill glacim.sed.	Conv						11810	125	13285	54	11370	Bargel et al. 1994
4	Djupvika	UtC 1804	64.953°	11.718°	45	OD ice margin	Hiatella arctica	Subtill sed.	Ams	12940	90	14850	45	12500						Bargel et al. 1995
5	Rød, Kolvereid	T-9808	64.93°	11.65°	65	Tautra ice margin	Mya truncata	Subtill sed.	Conv						11570	80	13080	38	11130	Bargel et al. 1994
6	Rød, Kolvereid	T-9187	64.93°	11.65°	65	Tautra ice margin	Mya truncata	Subtill sed.	Conv						12095	90	13515	54	11655	Bargel et al. 1994
7	Ytre Vikna	UtC 2100	64.9°	10.8°	7	Pre OD substage	Mya truncata	Subtill sed.	Ams	12710	130	14190	49	12270						Bargel et al. 1994
8	Sørbekkmoen	Ua-1585	64.72°	11.50°	12	pre Tautra substage	Hiatella arctica	Subtill glacim.sed.	Ams						11725	145	13215	48	11285	Bargel et al. 1994
9	Sørbekkmoen	UtC 1237	64.72°	11.50°	10m b.s.l.	Pre YD substage	shell	Subtill sed.	Ams						12070	80	13490	56	11630	Olsen, Sveian, unpubl.
10	Moelva	UtC 1238	64.694°	11.44°	6	Tautra ice margin	shell	Subtill mar. sed.	Ams						11880	70	13340	54	11440	Olsen, Sveian, unpubl.
11	Moelva	UtC 1239	64.694°	11.44°	6	Tautra ice margin	shell	Subtill mar. sed.	Ams						11900	130	13355	54	11460	Olsen, Sveian, unpubl.
12	Otterøya I	Ua-430	64.533°	11.283°	50	Pre YD substage	Portlandia arctica	Subtill mar. sed.	Ams						11820	170	13295	55	11380	Olsen, Sveian, unpubl.
13	Bjørgan	T-9265	64.583°	10.9°	11	Pre OD substage	shells	Subtill mar. sed.	Conv	12495	125	13980	53	12055						Olsen, Sveian, unpubl.
14	Bjørgan	T-9266	64.583°	10.9°	10	Pre OD substage	Macoma, a.o.	Subtill mar. sed.	Conv	13075	125	15110	53	12635						Olsen, Sveian, unpubl.
15	Bjørgan	UtC 1806	64.583°	10.9°	10	Pre OD substage	shell	Subtill mar. sed.	Ams	12830	100	14510	38	12390						Olsen, Sveian, unpubl.
16	Bjørgan	UtC 1807	64.583°	10.9°	10	Pre OD substage	shell	Subtill mar. sed.	Ams	12730	140	14220	45	12290						Olsen, Sveian, unpubl.
17	Bjørgan	UtC 1805	64.583°	10.9°	10	Pre OD substage	shell	Subtill mar. sed.	Ams	12740	150	14235	44	12300						Olsen, Sveian, unpubl.
18	Bjørgan	T-92001	64.583°	10.9°	9	Pre OD substage	whalebone	Subtill sed.	Conv	12895	100	14735	44	12455						$\bar{X}$= 12348 ± 30 c14-yr (N=20)
19	Bjørgan	TUa-396	64.583°	10.9°	10	Pre OD substage	shell	Subtill mar. sed.	Ams	13015	185	15050	49	12575						Olsen, Sveian, unpubl.
20	Teigmoen	UtC 1808	64.58°	10.98°	31	pre Tautra substage	Mya truncata	Subtill glacim.sed.	Ams						11500	90	12965	42	11060	Bargel et al. 1994
21	Sitter	UtC 4726	64.256°	10.972°	48.5	pre Tautra substage	shell	Subtill glacim.sed.	Ams	12930	70	14810	47	12490						Bargel et al. 1994
22	Sitter	UtC 4799	64.256°	10.972°	48	pre Tautra substage	Bulk org., INS frac.	Subtill sed.	Ams	12480 (P)	70	14720	47	12480 (P)						Olsen, Sveian, unpubl.
23	Hylla	UtC 2075	64.554°	11.075°	18	OD ice margin	Portlandia arctica	Subtill sed.	Ams	12770	90	14280	44	12330						Olsen, Sveian, unpubl.
24	Vik, Sørflatang.	UtC 1381	64.421°	10.783°	80	Pre OD substage	Mya truncata	Shell in till	Ams	12480	90	13965	53	12040						Olsen, Sveian, unpubl.
25	Oksdøl	T-11780	64.405°	11.163°	90	pre Tautra substage	Mya truncata	Deformed glacim.	Conv						11900	95	13355	54	11460	Olsen, Sveian, unpubl.
26	Tøttdal I	T-11781	64.425°	11.15°	20	pre Tautra substage	Mya truncata	Deformed glacim.	Conv						11690	165	13180	46	11250	Olsen, Sveian, unpubl.
27	Tøttdal II	T-11782	64.433°	11.17°	70	pre Tautra substage	Mya truncata	Deformed glacim.	Conv						11775	150	13260	52	11335	Olsen, Sveian, unpubl.
28	Skjellåa, Jøss.	UtC 1382	64.378°	11.78°	10	OD ice margin	Nuculana, Mytilus	Shell in till	Ams						12270	80	13745	48	11830	Olsen, Sveian, unpubl.
29	Fløaunet, Flat.	UtC 1388	64.495°	10.913°	60	Pre OD substage	shell	Shell in till	Ams	12860	110	14670	39	12420						Olsen, Sveian, unpubl.
30	Myrvang, Flat.	UtC 1389	64.444°	11.011°	100	pre Tautra substage	Macoma calcarea	Shell in till	Ams						12090	100	13510	54	11650	Olsen, Sveian, unpubl.
31	Myrvang, Flat.	UtC 5414	64.444°	11.003°	100	Pre OD substage	shell	Subtill sed.	Ams	12610	60	14100	54	12170						Olsen, Sveian, unpubl.
32	Engesdalen	UtC 1386	64.43°	11.09°	110	Tautra ice margin	shell	Delta sed.	Ams						11510	110	12980	40	11070	Bargel et al. 1994
33	Uran	UtC 1384	64.416°	10.644°	85	OD ice margin	Macoma calcarea	Shell in moraine	Ams	12840	120	14580	37	12400						Olsen & Riiber 2006
34	Svartholet	UtC 1387	64.325°	10.63°	80	post OD maximum	shell	Deformed glacim.	Ams						12300	110	13775	53	11860	Olsen & Riiber 2006
35	Seterbekken	T-11961	64.307°	10.374°	65	post OD maximum	Macoma, a.o.	Deformed glacim.	Conv						12055	95	13480	56	11615	Olsen & Riiber 2006
36	Reveggheia	T-11960	64.313°	10.533°	55	post OD maximum	Macoma, Myt., Bal.	Deformed glacim.	Conv						12475	230	13960	53	12035	Olsen & Riiber 2006
37	Setranvatna	T-11963	64.269°	10.46°	98	pre OD maximum	Macoma, a.o.	Shell in till	Conv	12440	125	13915	53	12000						Olsen & Riiber 2006
38	Jevika	T-11962	64.262°	10.425°	5	Pre OD substage	Macoma, Hiatella	Subtill sed.	Conv	12765	215	14270	44	12325						Olsen & Riiber 2006
39	Skaudalen	T-6549	63.73°	10.40°	130	pre Tautra substage	shell	Subdelta sed.	Conv						11670	120	13160	44	11230	Reite & Olsen 2002
40	Krogfjord, Roan	T-10549	64.131°	10.215°	40	Pre OD substage	whalebone	Subtill sed.	Conv	12930	135	14810	47	12490						R.W.Lie, pers. comm. 1993
41	Stokkøya, Åfj.	T-10550	64.061°	10.02°	15	Pre OD substage	whalebone	Subtill sed.	Conv	12695	135	14175	52	12255						R.W.Lie, pers. comm. 1993
42	Frigård II	T-11783	63.4°	10.9°	180	Proxim. Tautra subst.	Mya truncata, a.o.	Sed., le of rock	Conv						11810	350	13285	54	11370	Posibly overrun by YD max.
43	Sveberg	TUa-5486	63.42°	10.75°	165	Tautra ice margin	Mya truncata	Till	Ams						11630	55	13125	43	11190	Sveian, unpubl.
44	Tranggeilen	T-13127	63.58°	10.36°	135	pre Tautra substage	Mya truncata	Till	Conv						11580	140	13085	38	11140	Feragen 1997
45	N. Lomtjern	T-3858A	63.66°	10.53°	209	Tautra ice margin	gyttja clay, SOL	Postgl first org.	Conv						11190 (P)	200	13070	47	11190 (P)	Reite et al. 1982
46	Trondheimsfj	AAR-5736	63.54°	10.34°	b.s.l.	pre Tautra substage	shell	Glacimarine sed.	Ams						11590	70	13095	40	11150	Rise et al. 2006
47	Engan[b]	TUa-822	63.42°	10.68°	120	Tautra ice margin	Macoma calcarea	Glacimarine sed.	Ams						11640	85	13135	43	11200	Sveian, unpubl.
48	Vikåsen	T-11100	63.42°	10.53°	150	Tautra ice margin	Whalebone	Subtill glacim.sed.	Conv						11510	145	12980	40	11070	Reite 1994
49	Voll	TUa-1750	63.41°	10.45°	125	pre Tautra substage	Portlandia arctica	Till	Ams						11620	85	13120	43	11180	Rokoengen et al. 1997
50	Dragvoll	TUa-895	63.40°	10.47°	160	pre Tautra substage	shell	Till	Conv						11615	75	13110	43	11175	Rokoengen et al. 1997
51	Steinan	T-3296	63.40°	10.45°	162	pre Tautra substage	Hiatell, Balanus	Deformed glacim.	Conv						11460	90	12920	51	11020	Reite et al. 1982
52	Tiller Plateau	T-	63.36°	10.38°	155	Tautra ice margin	shell	Deformed glacim.	Conv						11540		13040	34	11100	K. Rokoengen, unpubl., 2007
53	Buvika	TUa-4572	63.31°	10.16°	37	pre Tautra substage	Spirorbis sp.	Deformed glacim.	Ams						11460	60	12920	51	11020	Solberg et al. 2008
54	Buvika	TUa-4571	63.31°	10.16°	37	pre Tautra substage	Portlandia arctica	Deformed glacim.	Ams						11540	60	13040	34	11100	Solberg et al. 2008
55	Heimdal	UtC 14734	63.35°	10.35°	145	pre Tautra substage	Nuculana pernule	Subtill glacim.sed.	Ams						11450	80	12910	53	11010	Olsen et al. 2007, 2014
56	Ånøya (lake)	UtC 15248	63.25°	10.17°	125	pre Tautra substage	Mya truncata	Deformed glacim.	Ams						11520	50	12990	39	11080	Olsen et al. 2014
57	Ånøya (lake)	UtC 15249	63.25°	10.17°	125	pre Tautra substage	Hiatella arctica	Deformed glacim.	Ams						11600	60	13100	42	11060	Olen et al. 2014
58	Viggja	T-14609	63.32°	09.98°	137	pre Tautra substage	Mya truncata	Subdelta sed.	Conv						11710	115	13200	47	11270	Olsen et al. 2007, 2014
59	Byneset, Berg	T-14608	63.38°	10.18°	140	pre Tautra substage	Balanus sp.	Till	Ams						11570	90	13080	38	11130	Olsen et al. 2007, 2014
60	Nordmyra	Tua-2526	63.36°	10.33°	160	pre Tautra substage	Macoma calcarea	Deformed glacim.	Ams						11740	85	13230	49	11300	Olsen et al. 2007, 2014
61	Lundv.1,Heimd.	UtC 14599	63.35°	10.33°	170	pre Tautra substage	shell	Subtill sed.	Ams						11950	80	13395	54	11510	Olsen, unpubl.
62	Lundv.9,Heimd.	UtC 14600	63.349°	10.33°	175	pre Tautra substage	shell	Deformed glacim.	Ams						12060	80	13485	56	11620	Olsen, unpubl.
63	Havstein	UtC 14598	63.401°	10.37°	140	pre Tautra substage	Mya truncata	Till	Ams						11650	100	13140	43	11210	Olsen et al. 2007, 2014
64	Sagfossen	T-14607	63.385°	9.867°	155	pre Tautra substage	Mya truncata	Degl. marine sed.	Conv						12205	80	13440	57	11765	Olsen et al. 2007, 2015
65	Kvåle	UtC 10104	63.24°	09.77°	45	pre Tautra substage	Portlandia arctica	Ice marginal sed.	Ams						11720	60	13210	47	11280	Olsen et al. 2007, 2014
66	Løftmoen	TUa-7540	63.19°	09.80°	145	pre Tautra substage	Mya truncata	Delta slope sed.	Ams						11480	50	12940	46	11040	Olsen et al. 2014
67	Holland gård	UtC 10106	63.2°	09.76°	150	pre Tautra substage	Macoma calcarea	Delta slope sed.	Ams						11980	70	13420	56	11540	Olsen et al. 2014
68	Liavatnet, Bju.	T-3428	63.729°	09.833°	40	Degl. marine sed.	shell	Glacimarine sed.	Conv						12240	210	13715	46	11800	Reite 1990; Bjugn
69	Stallvika	T-4282	63.67°	09.906°	80	Degl. marine sed.	shell	Glacimarine sed.	Conv						12360	290	13830	54	11920	Reite 1990; Bjugn
70	Moberg	T-6298	63.735°	09.783°	75	Degl. marine sed.	Macoma, Nuculana	Glacimarine sed.	Conv						12390	150	13860	53	11950	Reite 1990; Bjugn
71	Hitra, Innerdbk	T- …	63.572°	09.027°	64	Pre OD substage	shell	Subtill sed.	Conv	12920	120	14785	48	12480						I.Aarseth, unpubl. 1990
72	Hitra, Innerdbk	T- …	63.572°	09.027°	65	Pre OD substage	shell	Subtill sed.	Conv	12540	110	14032	52	12100						I.Aarseth, unpubl. 1990
73	Rissa, loc. A	T-3034	63.55°	09.94°	27	post OD substage	Balanus, Mya, a.o.	Subtill sed.	Conv						12220	90	13690	47	11780	Løfaldli et al. 1981
74	Belsvik,Hemne	T-554	63.411°	09.0°	15	post OD substage	Mya, Mytilus, a.o.	Glacimarine sed.	Conv						11690	180	13180	46	11250	Lasca 1969
75	Nesavatnet	T-14606	63.485°	09.386°	80	Degl. marine sed.	Chlamys islandica	Glacimarine sed.	Conv						12245	85	13720	47	11805	Olsen, unpubl. 2000
76	Hollaelva	T-14605	63.301°	09.15°	85	Degl. marine sed.	Mya truncata	Glacimarine sed.	Conv						11445	85	12905	55	11005	Olsen, unpubl. 2001
77	Hollaelva	UtC 10105	63.31°	09.15°	15	post OD substage	Portlandia arctica	Subtill sed.	Ams						12530	70	14020	52	12090	Olsen, unpubl. 2000
78	Hollaelva	T-551	63.311°	09.15°	21	post OD substage	Pecten, Astarte, a.o.	Delta slope sed.	Conv						11750	140	13240	50	11310	Lasca 1969

79	Hollaelva	T-552	63.311°	09.15°	20	post OD substage	shells	Delta slope sed.	Conv						11740	150	13230	49	11300	Lasca 1969
80	Kjergroneset	T-5057	62.974°	08.496°	100	Tingvoll substage	shell	shell in till	Conv	12490	160	13975	53	12050						Follestad 1989; Tingvoll
81	Bøverfjord	UtC 10107	63.021°	08.62°	40	Tingvoll substage	shell	Subtill sed.	Ams	12410	60	13880	53	11970						Olsen, unpubl. 1999
82	Leirvik, Halsa	T-8212	63.152°	08.57°	70	post Tingvoll subst.	shell, growth pos.	Degl. marine sed.	Conv						12080	100	13500	55	11640	Follestad 1992: Halsa
83	Holtavatnet	T-5696	62.9°	08.253°	70	Distal Tingvoll subst.	shell	Degl. marine sed.	Conv	12650	160	14135	55	12210						Follestad 1989: Tingvoll
84	Holtavatnet	T-4517	62.9°	08.253°	70	post Tingvoll subst.	shell	Degl. marine sed.	Conv						11750	130	13240	50	11310	Follestad 1989: Tingvoll
85	Sollia	T-5396	62.926°	08.2°	130	post Tingvoll subst.	shell	Degl. marine sed.	Conv						12340	160	13815	55	11900	Follestad 1989: Tingvoll
86	Sollia	T-5395	62.92°	08.2°	120	Tingvoll subst.	shell	Till	Conv	12430	220	13905	52	11990						Follestad 1989: Tingvoll
87	Skar	T-3783	62.83°	08.23°	80	post Tingvoll subst.	shell	Degl. marine sed.	Conv						11960	140	13400	54	11520	Follestad 1989: Tingvoll
88	Bjørndal	T-6548	63.588°	10.1°	120	post OD substage	shell	Degl. marine sed.	Conv						12520	150	14010	52	12080	Reite 1988; Ørlandet
89	Ugedalstjernet	T- ...	63.91°	10.4°	50	post OD substage	shell	Degl. marine sed.	Conv						11920	160	13370	53	11480	Selnes 1982, Reite 1993
90	Vikåsen	T-4242	63.42°	10.53°	150	pre YD substage	shell?, whalebone?	Till	Conv						11880	110	13340	54	11440	Reite & Olsen, H. 2002
91	Øvre Heilfj.tj.	T-4323A	63.53°	08.97°	96	pre OD substage	bulk org., SOL fraction	lake sed., lowest org.	Conv	12600	170	15030	49	12600						Kjemperud 1982, 1986
92	Svartdalstjernet	T-4321A	63.53°	08.97°	95	pre OD substage	bulk org., SOL fraction	lake sed., lowest org.	Conv	12210	160	14100	49	12210						Kjemperud 1982, 1986
93	Vollan, Agdenes	Poz-91920	63.585°	09.66°	25	pre OD substage	Mya truncata	Till	Ams	12410	60	13880	53	11970						Olsen & Høgaas, unpubl.2018
94	Vollan, Agdenes	Poz-91921	63.585°	09.66°	23	pre OD substage	Chlamys isl.	Subtill glacim. sed.	Ams	12350	60	13820	54	11910						Olsen & Høgaas, unpubl.2018
95	Vollan, Agdenes	Poz-91922	63.585°	09.66°	21	pre OD substage	Hiatella arctica	Subtill glacim. sed.	Ams	12310	60	13785	53	11870						Olsen & Høgaas, unpubl.2018
96	Vollan, Agdenes	Poz-101619	63.585°	09.66°	18	pre OD substage	Whalebone	Subtill glacim. sed.	Ams	12370	70	13840		11930						Olsen & Høgaas, unpubl.2018
97	Vollan, Agdenes	Poz-103460	63.585°	09.66°	16	pre OD substage	Chlamys isl.	Subtill glacim. sed.	Ams	12750	70	14260		12310						Olsen & Høgaas, unpubl.2018
98	Vollan, Agdenes	Poz-103461	63.585°	09.66°	30	post OD substage	Mytilus edulis	Glacimarine sed.	Ams						11880	60	13280		11440	Olsen & Høgaas, unpubl.2018
99	Stordalen, Agd.	Poz-103464	63.59°	09.66°	88	post OD substage	Mya truncata	Glacimarine sed.	Ams						11590	60	12990		11150	Olsen & Høgaas, unpubl.2018
100	Smidalen, Agd.	Poz-103465	63.585°	09.68°	85	pre OD substage	Mytilus edulis	Glacimarine sed.	Ams	13010	70	14780		12570						Olsen & Høgaas, unpubl.2018
101	Verrafjorden	Poz-103487	63.568°	09.5°	15	post OD substage	Mya truncata	Glacimarine sed.	Ams						11580	60	12980		11140	Olsen & Høgaas, unpubl.2018
102	Sørvatnet, Kolv.	Poz-103488	64.9°	11.447°	50	post OD substage	Mya truncata	Glacim. diamicton	Ams						11710	60	13120		11270	Olsen & Høgaas, unpubl.2018
103	Sørvatnet, Kolv.	Poz-103489	64.9°	11.447°	40	post OD substage	Mya truncata	Glacimarine sed.	Ams						11810	60	13220		11370	Olsen & Høgaas, unpubl.2018
104	Kolvereid V	Poz-103531	64.86°	11.468°	15	post OD substage	Chlamys isl.	Glacimarine sed.	Ams						11550	50	12950		11110	Olsen & Høgaas, unpubl.2018
105	Kolvereid V	Poz-103532	64.86°	11.468°	15	post OD substage	Hiatella actica	Glacimarine sed.	Ams						10880	50	12290		10440	Olsen & Høgaas, unpubl.2018
106	Nubbdal, Kolvereid	Poz-98451	64.92°	11.55°	92	post OD substage	Hiatella arctica	Till	Ams						11410	60	12870	55	10970	Olsen & Høgaas, unpubl.2018
107	Nubbdal, Kolvereid	Poz-98698	64.92°	11.55°	92	post OD substage	Shell fragment	Till	Ams						11620	50	13120	43	11180	Olsen & Høgaas, unpubl.2018
108	Tennfjord, Kolvereid	Poz-98452	65.00°	11.69°	57	pre OD substage	Shell fragment	Till- subtill sediment	Ams	12700	70	14180	50	12260						Olsen & Høgaas, unpubl.2018
109	Tennfjord, Kolvereid	Poz-98453	65.00°	11.69°	57	pre OD substage	Shell fragment	Till- subtill sediment	Ams	12700	60	14180	50	12260						Olsen & Høgaas, unpubl.2018
110	1 km W of Djupvika	Poz-98454	64.95°	11.69°	18	Distal OD substage	Shell fragment	Glacimarine sed.	Ams	12710	60	14190	49	12270						Olsen & Høgaas, unpubl.2018
111	Gravvikvågen	T-3520	64.98°	11.80°	30	YD ice margin	Mya truncata	End moraine	Conv.						11520	140	12990	50	11080	Andersen et al. 1981
	Average age (X̄) =:									(N= 39)		**14269** (N= 36)	348	(N= 39)	(N= 71)		**13613** (N= 23)	227	(N= 71)	

[a] *Correction: Reservoir age is generally set at 440 yr according to Mangerud and Gulliksen (1975).*

[b] *Shell type: Macoma calcarea dominating in sample, indicated with grey shading.*

[c] *AMS* ^{14} *Samples omitted in the age estimates due to screening based on stratigraphy (older or younger units) indicated with pink or green shading.*

[d] *Dating of samples from older units, meaning from units that are either reworked in sediments in the moraine zone or from sediments older than the Outer Coastal-Tingvoll substages.*

[e] *Dating of samples from units younger or equal to the OC substage, meaning from proglacial sediments, or deglaciation sediments from the moraine zone or younger sediments proximal to the substage.*

[f] *The uncertainties in column M and R are simply copied from the calibration tables of Reimer et al. (2013), and are therefore not "real" uncertainties, except for the uncertainties for the mean values which are achieved by using an ordinary scientific calculator.*

(P) indicates dating of plant remains in sediments.

Orange colour: NaOH soluble fraction of bulk plant remains in lowermost layers with organic content in isolation basin lake sediments from Hitra island (Kjemperud 1982, 1986),.

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