Salix polaris leaves dated at 14.3 ka BP from northern Jylland, Denmark

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Leaves of the tiny willow *Salix polaris* Wahlenberg from a lake deposit in northern Jylland have been dated to *c.* 14,300 cal. years BP. These are some of the oldest dated plant remains after the last deglaciation from an on-shore deposit in Denmark. *Salix polaris* was probably one of the first woody plants that immigrated to Denmark, where it played an important role on the raw, carbonate rich but unstable soils.

Key words: Late-glacial, Denmark, macrofossils, *Salix polaris,* palaeoenvironments.

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Little is known about the nature and chronology of the first vegetation that became established on the ice-free land in Denmark following the last deglaciation. Dates of shells of marine bivalves show that the deglaciation of northernmost Jylland was slightly before 17,500 cal. years BP (Fig. 1; Table 1; Knudsen 1978; Richardt 1996). After deglaciation, major parts of Vendsyssel was inundated by a glacio-marine environment. A dated bone from a ringed seal (*Pusa hispida*) from Nivå in northern Sjælland show that this region was deglaciated and characterised by glacio-marine conditions slightly before 16,900 cal. years BP (Lagerlund & Houmark-Nielsen 1993).

With respect to terrestrial biotas in Denmark, the oldest dated reindeer (*Rangifer tarandus*) find from Jylland is 14,700 cal. years BP (Holm 1991), and the oldest one from Sjælland is 14,100 cal. years BP (Petersen & Johansen 1991). The oldest dated plant remains from Denmark that post-date the last deglaciation come from Fakse Bugt in eastern Denmark (Bennike & Jensen 1995), from where two samples of *Salix polaris* leaves were dated to 14,400 and 14,300 cal. years BP. The terrestrial floras are dominated by *Salix polaris*, but it also includes rare remains of the following land plants: *Empetrum nigrum*, *Saxifraga oppositifolia*, *Potentilla* sp., *Minuartia* sp., *Sagina* sp., *Armeria* sp., Poaceae indet. and *Carex* sp. Slightly younger un-identified wood fragments dated to 14,180 cal. years BP were reported by Noe-Nygaard & Heiberg (2001) from Tøvelde in south-east Denmark (Table 1). Un-identified plant remains from Lodbjerg yielded an age of 14,100 cal. years BP, and a bulk-sediment sample of gyttja from Bovbjerg gave an age of 14,200 cal. years BP (Table 1; Houmark-Nielsen 2003).

From the Baltic Sea of north-eastern Germany, but only a few kilometers from the border to Denmark, plant remains from a submarine core yielded an age of 15,300 cal. years BP (Jensen *et al*. 1997). The flora herefrom comprises a larger diversity of dwarf shrubs, with rare remains of *Salix polaris*, *Salix herbacea*, *Betula nana* and *Dryas octopetala*.

From two lake basins on the Kullen peninsula in southern Sweden, macrofossil analyses indicate that *Salix polaris* was the first woody plant to immigrate to this region, and at two coring sites leaves of this tiny willow was found to be abundant over a short interval. The chronology of this interval is rather poorly known, being based on conventional radiocarbon dating of bulk sediment samples, but an age of more than 15,300 cal. years BP was suggested by Lidberg Jönsson (1988). The deglaciation of the Kullen Peninsula took place slightly before 17,000 cal. years BP (Sandgren & Snowball 2001). Other woody plants, such as *Dryas octopetala*, *Betula nana* and *Betula alba* arrived somewhat later. From southern Sweden, the Locarp mammoth has given a radiocabon date of *c.* 15,900 cal. years BP (Berglund *et al*. 1976).

As it appears from these notes, our knowledge

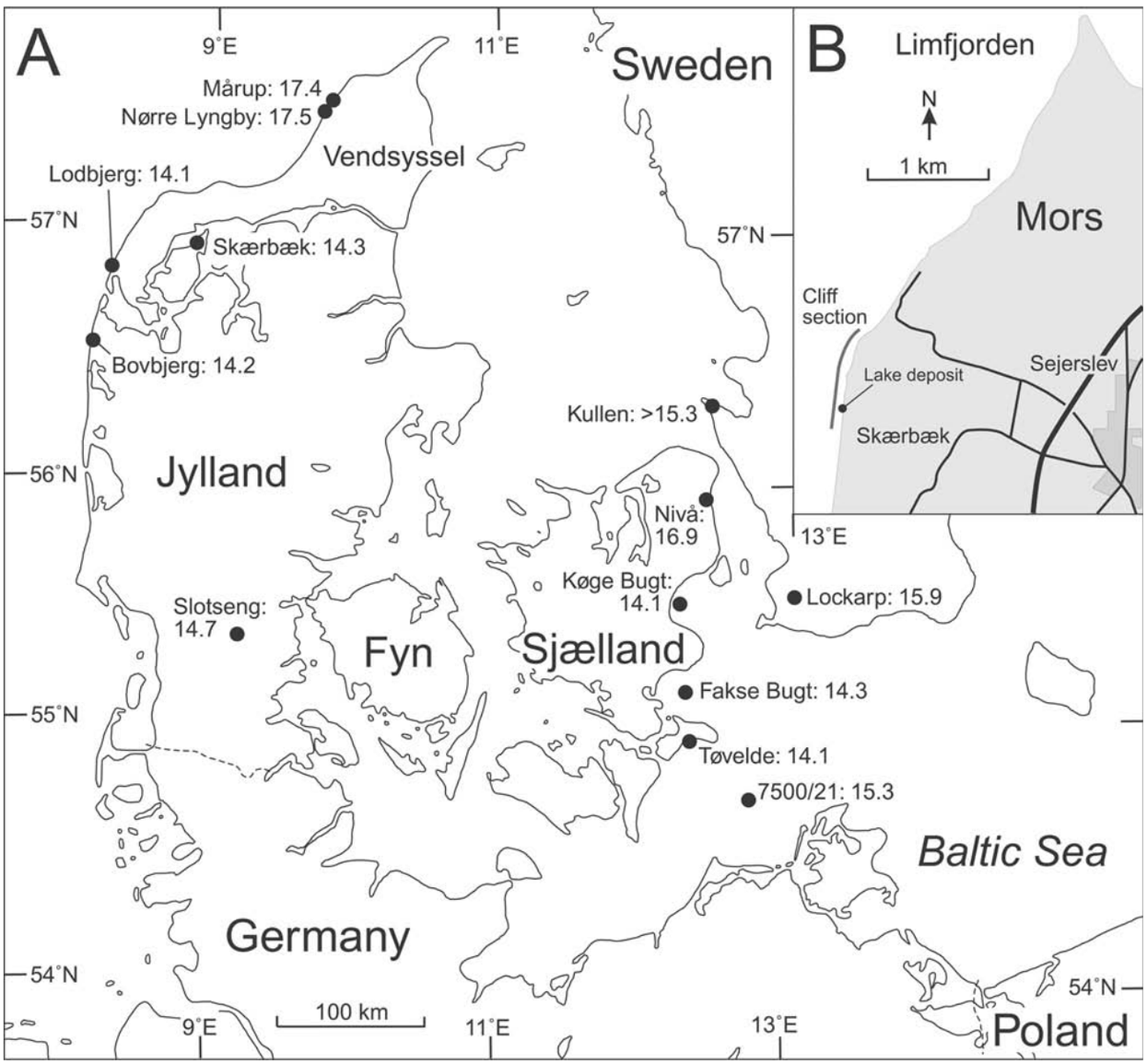

Fig.1A. Map of Denmark and the surrounding region showing the location of Skærbæk on Mors in northern Jylland and the location of different sites mentioned in the text. Dates in cal. ka BP. B. Map of the north-western part of the island of Mors and the location of the lake deposit described in this paper.

about the flora and fauna that invaded the newly deglaciated terrain in Denmark and the surrounding region after the last deglaciation is scanty. This note reports on a new deposit with late-glacial finds of *Salix polaris* at Skærbæk in northern Jylland.

The site

The Skærbæk locality (Fig. 1) is a coastal cliff section that was first described by Gry (1940, 1979) and Korsager (2002) provided detailed stratigraphical and structural investigations. Palaeogene and Quaternary sediments show pronounced glaciotectonic deformations caused by ice pressure from north-east. The late-glacial deposits are found in the southern part of the cliff section. They were discovered in 2000 as a 1×4 m large exposure, but they are not exposed at present.

Ground water seepage takes place above glaciotectonically dislocated Oligocene marine clay, which is found in the lower part of the cliff at the site of the late-glacial deposits. The overlying beds are strongly disturbed, and display elongated recumbent folds produced by gravity gliding. The different sediments

Table 1. Oldest radiocarbon dates from Denmark and the surrounding region after the last deglaciation

Age/ cal. yr BP	Age/ ^{14}C yr BP	Lab. no	Material	Locality	Reference
17,500	14,650±190	K-2670	Marine shells	Nørre Lyngby	Knudsen 1978
17,400	14,540±210[1]	AAR-2133	Marine shell	Mårup	Richardt 1996
16,900	14,110±250	Ua-1023	Ringed seal bone	Nivå	Lagerlund & Houmark 1993
14,700	12,500±190	AAR-906	Reindeer	Slotseng	Holm 1991
14,100	12,140±110	AAR-1036	Reindeer	Køge Bugt	Petersen & Johansen 1991
14,400	12,440±150	AAR-1313	*Salix polaris*	Fakse Bugt	Bennike & Jensen 1995
14,300	12,260±160	AAR-1314	*Salix polaris*	Fakse Bugt	Bennike & Jensen 1995
14,180	12,110±90	AAR-4094	Wood, bark, twigs	Tøvelde	Noe-Nygaard & Heiberg 2001
14,100	11,800±100	AAR-3724	Plant remains	Lodbjerg	Houmark-Nielsen in press
14,200	11,900±30	Lu-3806	Gyttja	Bovbjerg	Houmark-Nielsen in press
15,300	12,700±110	AAR-2637	Plant remains	7500/21	Jensen *et al.* 1997
c. 15,300			Bulk sediment	Kullen	Lidberg Jönsson 1988
15,900	13,260±110	Lu-796:2	Mammoth	Lockarp	Berglund et al. 1976
14,300	12,420±120[2]	Ua-16600	*Salix polaris*	Skærbæk	This study

[1]Reservoir corrected by subtracting 400 years. [2]d^{13}C = –23.8‰†on the PDB scale

of the lake deposit are mixed so intensely that the original stratigraphy cannot be recognised.

The sediment assemblage of the lake deposit comprises a clay-gyttja (unit i) and a bluish-black sand rich in plant macrofossils (unit ii) (Fig. 2). Inter-fingering with these sediments are stringers of rust-coloured coarse sand, which is most likely of fluvial origin (unit iii). This sand also forms a *c.* 10–15 cm thick layer above the gyttja. Overlying the sand is an approximately 1 m thick layer of massive clayey diamicton (unit iv), which is either a solifluction deposit or it is a till body from a deeper stratigraphical level which has been repositioned *en bloc* by gravity from further uphill.

Methods

Five samples taken from unit ii were analysed for macrofossils. One of the samples, S128, weighed around 2 kg, whereas the other samples were somewhat smaller. The samples were wet sieved on 0.4, 0.2 sieves, and a small fraction of each sample was wet sieved on a 0.1 mm sieve. The residue left on the sieves was analysed using a dissecting microscope. One sample of *Salix polaris* leaves was dried and submitted for AMS dating at the Ångström Laboratory, Uppsala University, Sweden.

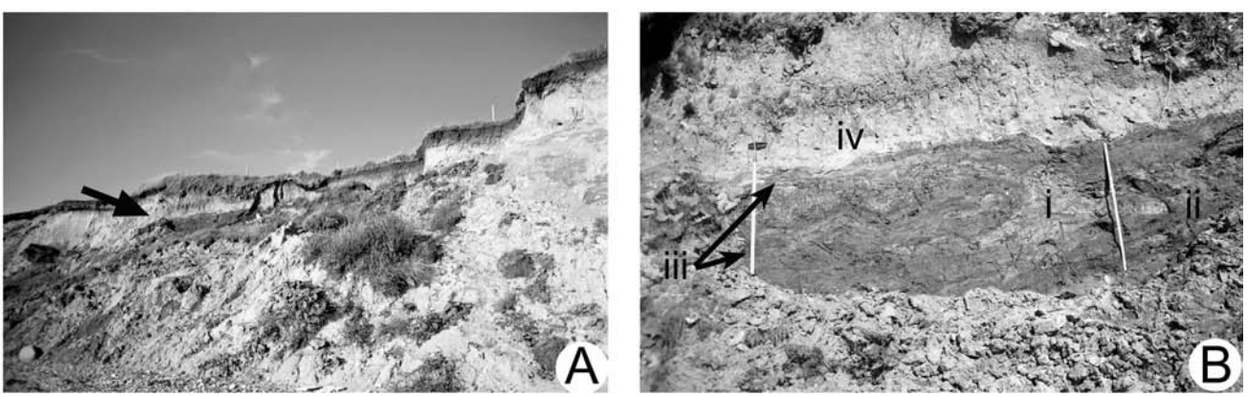

Fig. 2A. Coastal cliff section with the position of the deposit (indicated by arrow), as it appeared in 2001. View towards the northeast. B. The lake deposit at 56°55.5' N 8°50' E consists of i) a clay-gyttja and ii) bluish-black sand rich in plant macrofossils. It is overlain and interfingered by iii) rust-coloured coarse sand, which is capped by iv) a massive clayey diamicton. The sticks are 1 m long.

Table 2. Macrofossils from Skærbæk

Sample no.	S124	S125	S126	S127	S128
Amblystegiaceae indet.[1]	–	c[8]	r	–	c
Carex sp.[2]	–	3	–	–	1
Poaceae indet.[2]	–	1	–	–	1
Minuartia sp.[2]	–	–	–	1	–
Potentilla sp.[2]	–	–	2	–	–
Salix polaris[1]	–	50	6	r	30
Candona candida[3]	–	–	–	r	–
Coleoptera indet.[4]	–	1	1	–	r
Brachycera indet.[5]	–	–	1	–	–
Chironomidae indet.[6]	–	r	–	–	–
Gastropoda[7]	–	–	–	r	–
Pyrite	r	c	a	a	c

[1]stems, leaves, [2]seeds, fruits, [3]shells, [4]skeletal fragments, [5]puparia, [6]larval head capsules, [7]shell fragments, [8]r: rare, c: common, a: abundant

Results and discussion

The results of the macrofossil analyses appear from Table 2. The first thing to note is the extremely low diversity of macrofossils. This is not a consequence of preservation, since the preservation of the macrofossils was excellent. It is also not a consequence of taphonomic factors, since both leaves, fruits and other types of macrofossils are found. Although the deposit contains allochtonous remains of plants and animals, hydrodynamic sorting only played a minor role. Both aquatic taxa (the freshwater ostracod *Candona candina* and freshwater snails), wet ground taxa (Amblystegiaceae and *Carex*) and more dry ground taxa (*Minuartia*, *Potentilla* and *Salix polaris*) are represented, and although the plant remains undoubtedly come from a small area, different plant communities are probably represented. Therefore we suggest that the low diversity of the samples reflect a low diversity flora.

The plant remains are dominated by leaves of the willow *Salix polaris*. This plant is a small creeping shrub with short, ascending branches. It is better adapted to lower summer temperatures than any other woody plant in Europe. At the same time, this plant can grow in unstable soil characterised by frequent solifluction events, and in raw soils with little humus but rich in carbonates. It can endure long lasting snow cover and often grows in moist soils in snow beds, but it is also found in areas where the snow disappears early. The seeds are small and light with hairs and adapted to dispersal by wind. Since *Salix polaris* is a deciduous plant, many leaves are produced per plant. Also the leaves are tough and coriaceous and preserve well. Therefore it could be argued that *Salix polaris* is overrepresented, but many other dwarf shrubs have similar characteristics. It appears that *Salix polaris* was one of the first woody plants to colonise Denmark and southern Sweden after the last deglaciation. It may be speculated that the plant spread after the drastic warming that is recorded in the Greenland ice sheet cores around 14,700 cal. years BP (Björck *et al*. 1998). Although *Salix polaris* continued to grow in Denmark during the late-glacial, it appears that competition with larger woody plants reduced its role during this time period. Only a few remains of herbaceous plants were found in the Skærbæk deposit, and none of them could be identied at the species level. The four recorded taxa are common in late-glacial assemblages from Denmark; they can all be characterised as heliophytes. Bryophyte remains were present in three samples, but these remains have not been identified beyond the family level. Amblystegiacaea are also common in late-glacial deposits in Denmark, most members of the family are wet-land species or aquatic plants. Animals are mostly represented by rare remains of insects, of which the larval head capsules of Chironomidae most likely represent aquatic animals. However, chironomids can live in small ponds and in wet soil.

One sample of *Salix* leaves gave an age of 12,420 ± 120 radiocarbon years BP, corresponding to *c.* 14,300 cal. years BP (Table 1). This is among the oldest dated plant remains post-dating the last deglaciation from an on-shore deposit in Denmark (Table 1). This early age, in combination with the low diversity and the dominance of *Salix polaris*, sheds new light on the vegetation that became established on the deglaciated terrain. However, the presence of reindeer remains at Slotseng in southern Jylland (Fig. 1), dated to 14,700 cal. years BP shows that some vegetation was present here somewhat earlier (Holm 1991).

In Svalbard, where reindeer and *Salix polaris* coexist at the present, *S. polaris* is a major food source for reindeer, especially during early summer (Van der

Wal *et al.* 2000a, b). Reindeer was by far the most common large herbivore in the late glacial environment of Denmark (Degerbøl & Krog 1959; Aaris-Sørensen 1988), and *S. polaris* which was apparently common and widespread, may have been a main component of the reindeer diet.

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