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Some erroneous radiocarbon dates of lacustrine sediments

PER BLYSTAD & LOTTE SELSING

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In some cases radiocarbon datings of both the NaOH soluble fraction and the insoluble fraction of lacustrine sediments give different ages as a result of dating errors: (1) the insoluble fraction is too old, due probably to contamination by old inactive carbon, either bedrock-derived graphite or carbonate; (2) the soluble part is also too old, due probably to hard-water effect or contamination by redeposited interstadial organic carbon.

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Based mainly on ^{14}C-datings and pollen analysis we (Blystad & Selsing 1988) established a deglaciation chronology for the mountain area between Suldal and Setesdal, southwestern Norway (Fig. 1). We concluded that several of the radiocarbon ages obtained in this study are too old, and in this

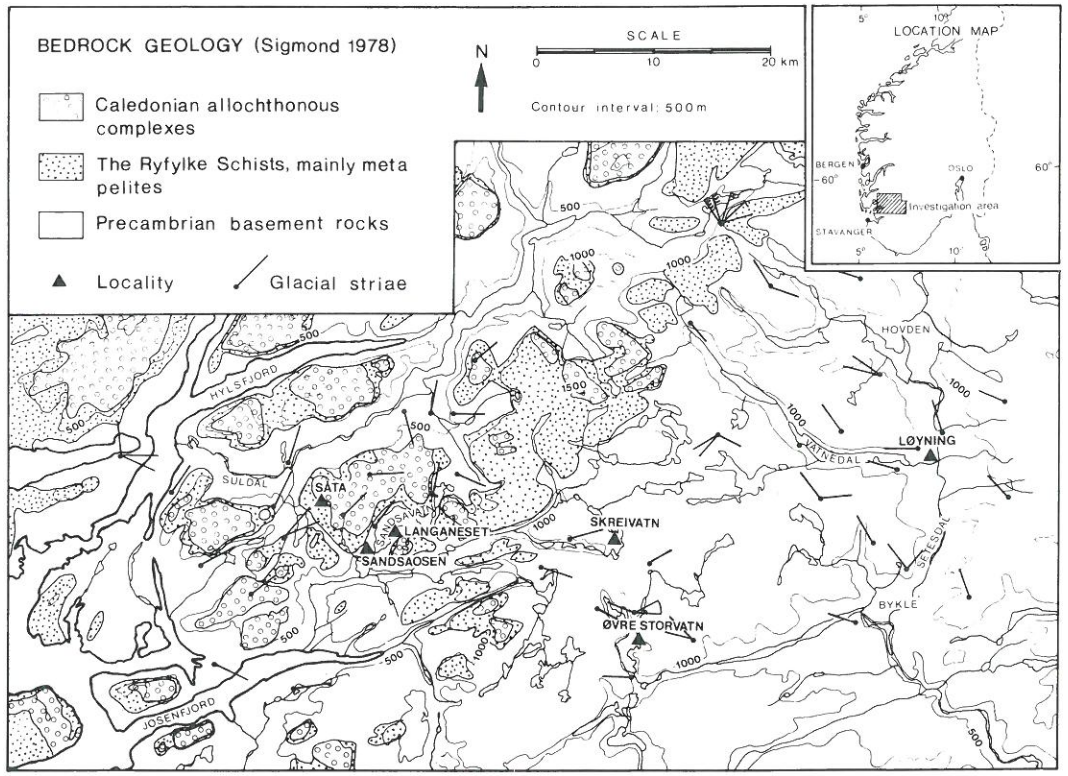

Fig. 1. Map showing the location of the six investigated localities, the bedrock geology (Sigmond 1978) and selected glacial striae (Anundsen (1972) for the western part and Blystad (1978) for the eastern part).

Table 1. Radiocarbon dates from the six investigated basins

Locality (m a.s.l.) Greenwich coor. morphostratigraphy	Sample: sediment (loss on ignition), and event dated	Depth below sediment surface, cm	Weight of sample dated, g	Radiocarbon date reference	Age T½ 5570 years BP	$\delta^{13}C$ ‰ PDB	Expected age
SÅTA (710) 59°25′50″N 6°27′10″E between YD and Trollgaren ter. mor.	Sand with organic matter (3.6%), deglaciation	207.5–210.0	2.1 68.4	T–3488A T–3488B	10,100 ± 280 11,210 ± 150	−26.4 −26.4	10,000 years BP
	Detritus gyttja with sand (20%), Trollgaren stage	205.5–207.5	1.3 35.1	T–3846A T–3846B	9,610 ± 210 10,090 ± 100	−27.7 −24.5	PB
	Detritus gyttja with sand (10–20%), and ½ cm of sand with organic matter (6%), maximum age of Blåfjell stage	203.5–205.0	3.8 18.4	T–3847A T–3847B	9,510 ± 150 9,700 ± 140	−26.6 −25.2	PB
	Detritus gyttja (58%), *Alnus* rise	189.5–191.5	14.02	T–5687A	8,370 ± 100	−26.4	late B
SANDSAOSEN (630) 59°23′30″N 6°31′50″E between Trollgaren and Blåfjell ter. mor.	Detritus gyttja with sand (22–24%), deglaciation	220.5–222.0	6.4	T–3141A	9,650 ± 90		PB
	Detritus gyttja with sand (24%), Blåfjell stage	219.0–221.0	8.7 12.9	T–3489A T–3489B	9,280 ± 80 9,340 ± 140	−29.5 −28.0	late PB
LANGANESET (610) 59°25′0″N 6°34′20″E just inside Blåfjell ter. mor.	Macroscopic plant remains from silt, deglaciation	372.0–384.0	0.9	T–3486	8,940 ± 200	−26.1	late PB
	Algae gyttja (12%), deglaciation	371.0–372.0	12.7	T–3140A	10,210 ± 180		late PB/early B
	Algae gyttja (45%), *Alnus* immigration on locality	321.0–323.0	5.42	T–5689B	7,170 ± 140	−28.1	late B/early A
ØVRE STORVT. (980) 59°20′10″N 6°57′20″E inside Blåfjell ter. mor.	Detritus gyttja (6%), deglaciation	139.5–141.0	3.5	T–3224A	8,640 ± 120	early B	
	Eriophorum peat (38–42%), *Alnus* rise	128.0–130.0	30.17	T–5686	6,720 ± 90	−25.8	late B/early A
SKREIVT. (1030) 59°24′20″N 6°55′0″E inside Blåfjell ter. mor.	Silty detritus gyttja (3%), deglaciation	112.0–113.5	1.5 70.8	T–3487A T–3487B	8,600 ± 250 9,020 ± 210	−26.4 −24.3	early B
	Detritus gyttja (28%), *Alnus* rise	94.0–96.0	27.45	T–5690A	8,280 ± 100	−27.1	late B
LØYNING (720) 59°2′30″N 7°23′50″E inside Preboreal ter. mor.	Silty gyttja and algae gyttja (6–24%), deglaciation	476.0–478.5	3.7	T–3139A	9,270 ± 180	early B	
	Plant remains of *Pinus* from algae gyttja, and algae gyttja (24–32%)	470.0–476.0	0.5 30.7	T–4313 T–4314A	8,470 ± 210 9,000 ± 100	−29.8 −29.4	B
	Algae gyttja (38%), *Alnus* rise	461.5–463.5	8.15	T–5688B	7,900 ± 90	−29.4	late B/early A

A NaOH soluble fraction, B insoluble fraction, YD Younger Dryas chronozone, PB Preboreal chronozone, B Boreal chronozone, A Atlantic chronozone, ter. mor. terminal moraines.

paper we will examine these erroneous dates more thoroughly.

The radiocarbon dates are listed in Table 1. A graphic presentation of the ages of the dates compared with expected age is given in Fig. 2. Some of the dates are erroneous as they: (1) deviate by more than one standard deviation, and (2) differ from the expected age. To solve these problems, we have dated different fractions of the sediment, i.e. the NaOH soluble fraction, the insoluble fraction, the total fraction, and macroscopic plant remains.

Discussion

Insoluble fraction too old

At Såta (Fig. 3), the ages of the soluble fractions (T–3488A, T–3846A, T–3847A and T–5687A) fit well with the pollen record in the basin and the general glacial chronology in the area. They are therefore regarded as correct.

The age differences between the soluble and insoluble fractions of the three pairs of datings from Såta are 1100, 500 and 200 radiocarbon years on the oldest, younger and youngest samples, respectively (T–3488B, T–3846B and T–3847B); all exceed one standard deviation. The corresponding losses on ignition are 3–6%, 18% and 6–18%, respectively. Såta is situated in the Ryfylke Schists zone, which consists of metapelites, so graphite from the metapelites is probably present to various degrees in the basal

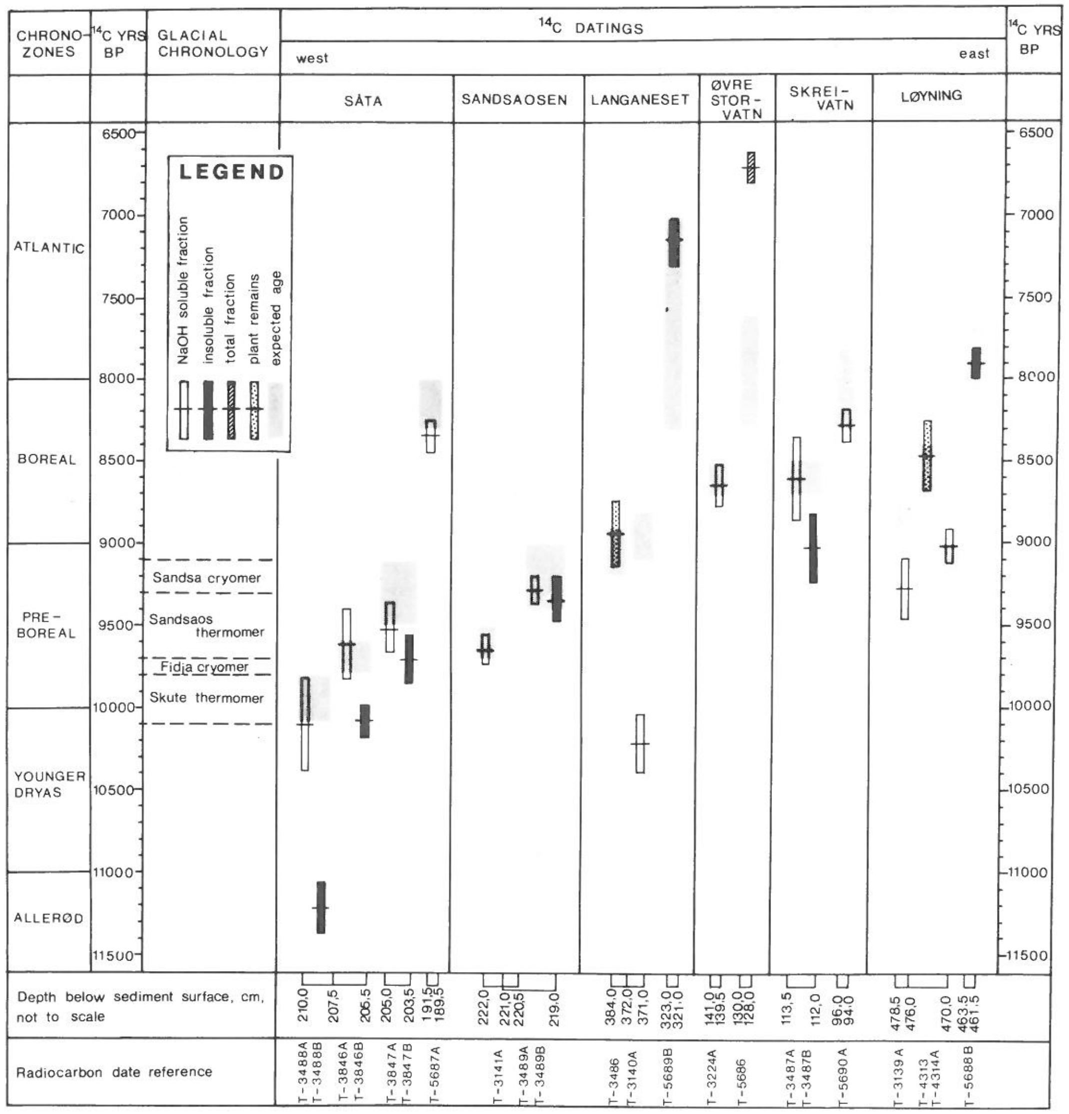

Fig. 2. Graphic representation of the radiocarbon dates with one standard deviation. The westernmost locality is presented to the left and the easternmost to the right. The radiocarbon dates at one locality are presented in stratigraphic order with the result of the lowest dated level to the left and the highest dated level to the right. The position is indicated on the horizontal scale. The expected age for each dating is shaded.

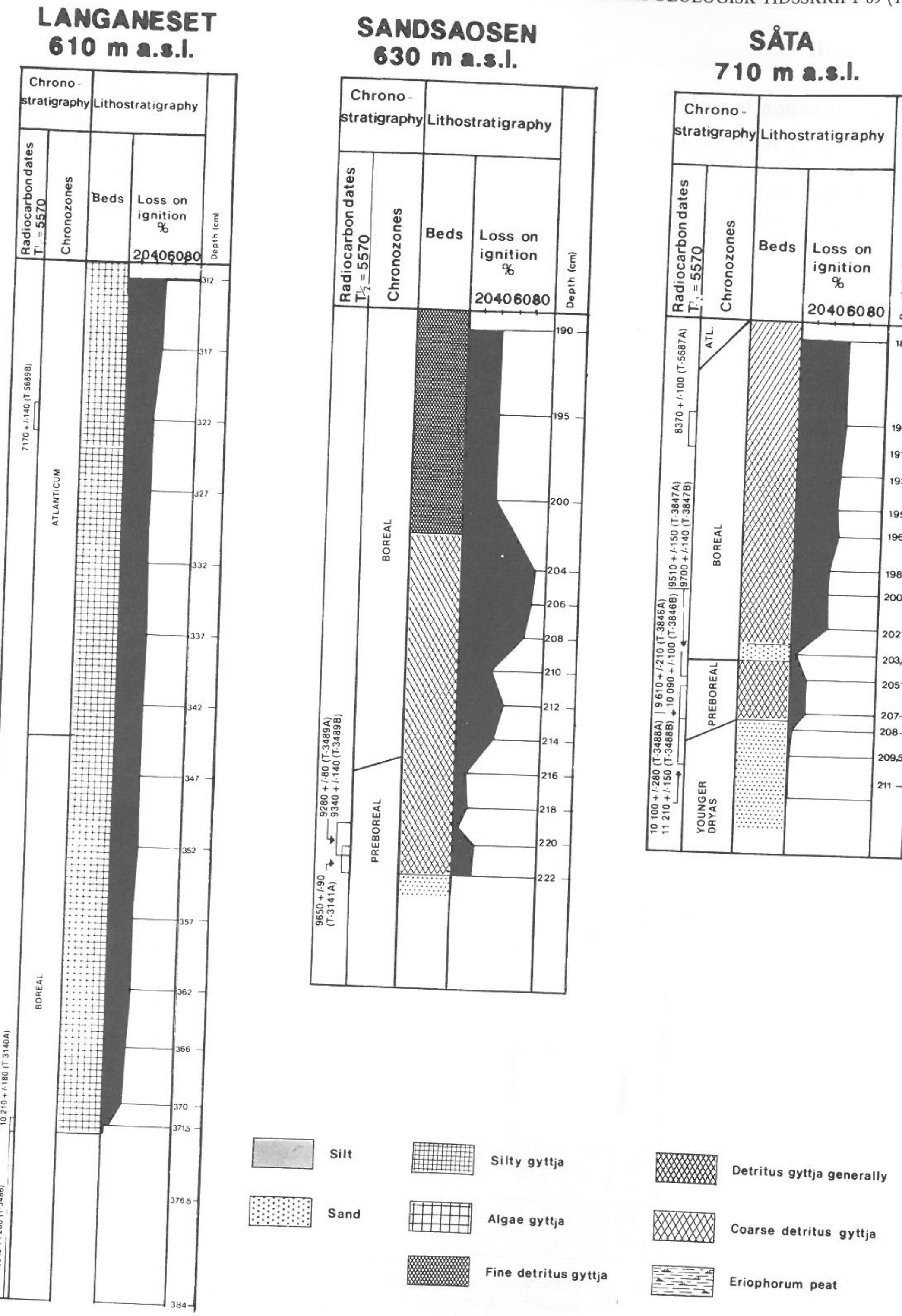

Fig. 3. Chrono- and lithostratigraphy at the localities of Langaneset, Sandsaosen and Såta.

sediments. Loss on ignition of this sediment is low, hence graphite may be a major contaminating factor when dating the insoluble fraction. The effect should become more important the less the organic content. Using the graphs of Olsson (1974:312), this contamination corresponds to a content of 13%, 6% and 3% graphite of the total carbon content of the samples.

At Skreivatn (Fig. 4) the datings of the soluble fractions concur with the pollen record and are thus assumed to be correct. The two datings of the basal sediment (T–3487A and T–3487B) are not significantly different within one standard deviation. However, the high *Corylus* content (26%) at the bottom of the pollen diagram from Skreivatn (Blystad & Selsing 1988, Fig. 12, p. 82) indicates that the correct age of this sediment is 8600 years BP rather than 9000 years BP.

Skreivatn is situated in an area with granitic gneiss, and the sediment cover is thin or absent. Granitic and higher grade metamorphic rocks have a very low carbon content composed mostly of carbonate. In basal sediments with a very low organic content, this may be an important allochthonous constituent (Sutherland 1980). At Skreivatn loss on ignition is 3% in the basal part. It is uncertain whether this carbon survives the acid treatment at the radiocarbon laboratory and whether it gives old carbon in the insoluble fraction. If carbon in the form of carbonate is present in the bedrock at Skreivatnet, this possible dating error might be present in the insoluble fraction in the basal sediment, and this effect is presumed to be the most probable explanation for this recorded dating error.

NaOH soluble fraction too old

At Langaneset (Fig. 3), the radiocarbon dating of the plant remains from the basal silt (T–3486) fits both the pollen record and the glacial chronology and is considered correct.

To get enough dating matter five cores of the basal part of the sediment were collected. Small macroscopic plant remains (leaves, seeds and tiny twigs) were collected from an approximately 10 cm thick basal layer of laminated silt and fine sand.

As it could not be excluded that some of the plant remains were derived from aquatic plants, $\delta^{13}C$ analysis was carried out in connection with the datings. The sample of small twigs and other macroscopic plant remains has a $\delta^{13}C$ value of −26.1‰, which corresponds to the interval of terrestial plants (−24 to −34‰) recorded by Stuiver (1975:256). The $\delta^{13}C$ value of aquatic plants is higher (−8 to −20‰) (Smith & Walker 1980:235). Consequently, the radiocarbon-dated plant remains are derived from terrestial plants, as assumed from the determination of some of the macrofossils (Asbjørn Simonsen pers. comm.). Incorporation of old carbon from hard-water into aquatic plants can thus be ruled out. As the dated plants probably grew in the vicinity of the basin during deposition of the basal silt, the dating gives the deglaciation at Langaneset.

The first date from Langaneset of the stratigraphically younger basal algae gyttja (T–3140A, soluble fraction) is more than 1000 years older than indicated by the *Corylus* rise (Blystad & Selsing 1988:70). The dated sediment is characterized by a high content of *Pediastrum* (77%), which is favoured by high trophic conditions (Nilsson 1961:33). In the initial stage of the development of the basin, high trophic conditions existed probably as a function of leaching of glaciated rock surfaces and the glacial deposits in the drainage area of basin. As the locality is situated in the Precambrian zone, but receives drainage water from the Ryfylke Schist zone, a hard-water effect is probable. Presumably $CaCO_3$ was leached out from the bedrock and/or the sediments and supplied to the water in the basin. The CO_2 and HCO_3^- containing inactive carbon could have been dissolved in the water and incorporated in the photosynthetic activity in the *Pediastrum* algaes, thus causing a hard-water effect (Deevey et al. 1954). This would give too old radiocarbon ages on both the soluble and insoluble fractions. Carbonates are not mapped from the area around Langaneset (Sigmond 1975, 1978). Contamination by the hard-water effect may, however, have occurred as carbonate is associated with the Ryfylke Schist. Thus, at the locality, the contamination by old, inactive carbon of the basal organic sediments is calculated to approximately 15%, based on the graphs constructed by Olsson (1974).

At Løyning (Fig. 4), the dating of the soluble fraction of the basal silty gyttja (T–3139A) was considerably older than expected based on the pollen record and from the adopted deglaciation model. In order to check this dating, a parallel dating of bark remains from *Pinus* (T–4313) and the corresponding soluble fraction of gyttja (T–4314A), both sampled from the same sediment

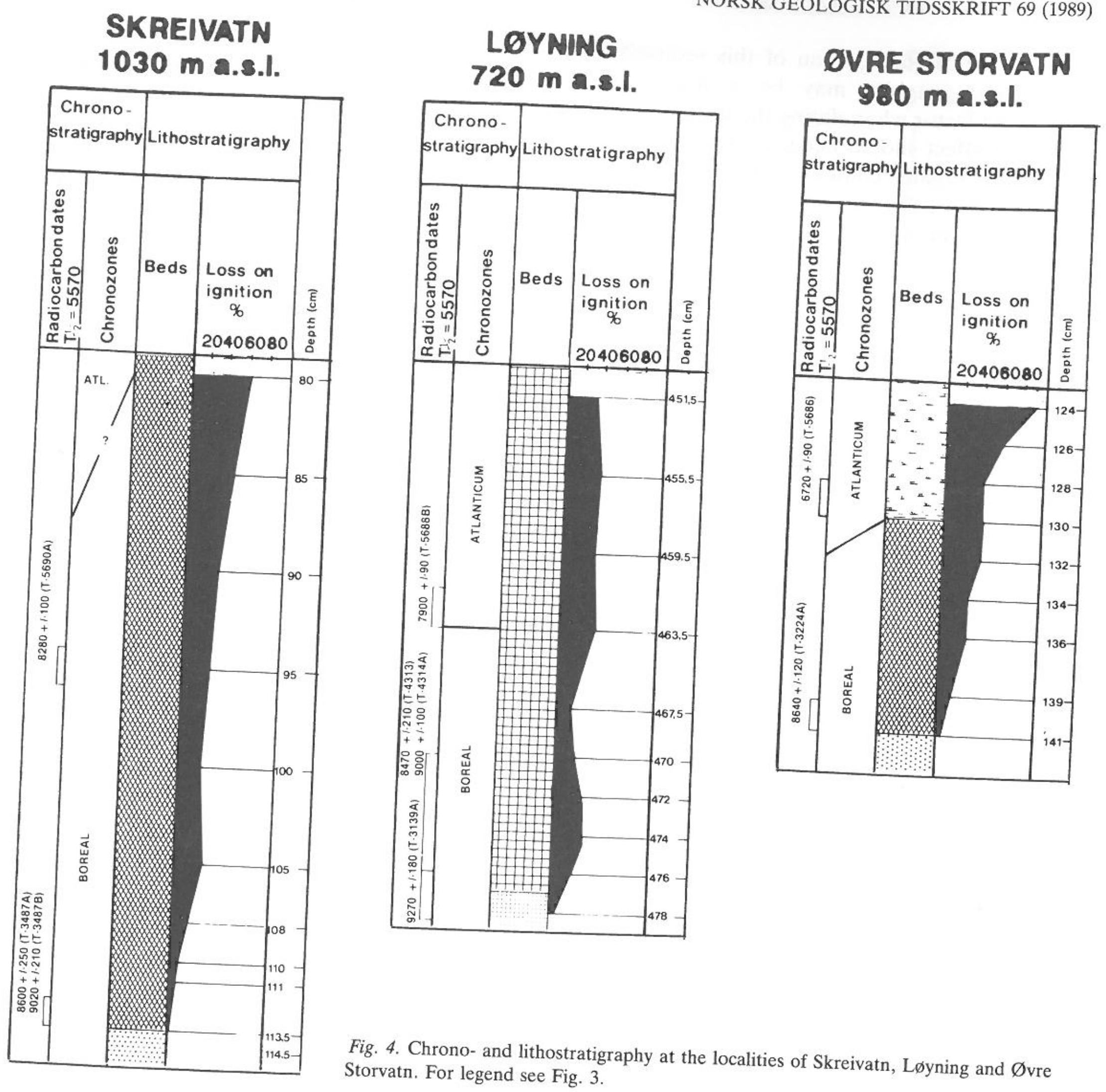

Fig. 4. Chrono- and lithostratigraphy at the localities of Skreivatn, Løyning and Øvre Storvatn. For legend see Fig. 3.

stratigraphically above the first dating, was carried out. The bark fragments are supposed to be derived from trees living close to the basin and should give a correct age for the sediment. These datings demonstrated that the gyttja is approximately 500 years older than the bark, indicating a dating error of the gyttja at this level in the order of 500 years.

The pollen record shows no aquatic plants in the dated sediment, while the algaes *Pediastrum* and *Botryococcus* occur with maximum values of 3% and 9%, respectively. As these are the only aquatic organisms which could cause a hard-water effect, the low values of algaes confirm our assumption that the hard-water effect and the reservoir effect are not the cause of the reported dating error.

An old organic inter-till sediment of Early or Middle Weichselian age is reported from a locality 1 km south of Løyning (Blystad 1981). Characteristic of this sediment is a local pollen/spore assemblage with a high content of *Selaginella selaginoides* spores and *Polygonum viviparum* pollen. These species are not observed in the pollen record in the lower part of the sediment at Løyning. The recorded interstadial pollen/spore flora might, however, have been locally distributed and other types of vegetation might have

been common in the area at that time. It is therefore suggested that the basal sediments at Løyning are contaminated by organic carbon originating from an interstadial sediment which had a pollen content similar to the pollen content in the basal sediment at Løyning. Ignatius et al. (1980) report a similar model from Finland.

Additional effect complicating interpretation of the chronology

At Såta the result of the date 9510 ± 150 years BP (T–3847A, soluble fraction) is too old compared with the *Corylus* rise. As the other dates at Såta on the soluble fractions are probably not subject to any serious hard-water effect, it is unlikely that the uppermost date should be subject to a high hard-water effect. The too high age compared with the *Corylus* rise is most likely due to a hiatus in the sediment at level 204 cm caused by erosion during deglaciation of the late Preboreal Blåfjell ice. At this level a 1 cm thick sand layer is seen in the dark brown coarse detritus gyttja (Blystad & Selsing 1988:74, Fig. 4). The greater amount of organic material in the lower part of the radiocarbon dated sample than in the upper part has given an age older than the geometric middle of the sample. Presumably both these reasons have caused the too high age of the sample compared with the *Corylus* rise.

At Øvre Storvatn (Fig. 4) the date of the total fraction (T–5686) is too young compared with the *Alnus* rise. This is most likely due to a hiatus at 130 cm depth between the basal gyttja and the upper peat, probably caused by erosion during overgrowth of this tiny tarn (Blystad & Selsing 1988:80, Fig. 10).

Conclusions

The radiocarbon dates of the insoluble fraction yield old and presumed wrong dates at two localities. At both localities contamination by old inactive carbon is suggested as the reason for this dating error. At Såta contamination by graphite from the bedrock is most probably the cause of the dating error, while at Skreivatn contamination from the bedrock by carbonate carbon is the most probable cause of the dating error.

The radiocarbon dates of the soluble fraction yield old and presumed wrong dates at two localities. At Langaneset a hard-water effect probably caused this dating error. At Løyning redeposition of an interstadial organic sediment may have caused the observed dating error.

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