Distribution of Lateglacial Tephra in Scandinavia

Útbreiðsla av seinglasialari tefru í Norðurlondum

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Úrtak

Útbreiðslan av tefrahorisontum í syðra parti av Norðurlondum, sum er dagfest at vera tað seinasta glasiala/-interglasiala skiftið, verður kannað. Uppi í hesum eru Vedde-øskan (um 10.400-10.300 ^{14}C ár BP) og saksunarvatnsøskan (um 9000 ^{14}C ár BP), sum eru av íslendskum uppruna, og tann miðevropeiska Laachervatnstefran (um 11.200 ^{14}C ár BP). Tað, at fleiri nýggj støð við Vedde-øsku eru funnin í Suðursvøríki, hevur økt ta kendu útbreiðsluna av hesum týðandi markingarhorisontinum munandi. Eitt øki í Suðurbaltalondum verður møguliga valt til framhaldandi rannsóknir, av tí at útbreiðslan av øllum hesum trimum tefrunum tykist at koma fyri samstundis.

Abstract

The distribution of tephra horizons in south Scandinavia dated to the Last Glacial-Interglacial Transition is reviewed. These include the Vedde Ash (*c.* 10,400 – 10,300 ^{14}C years BP) and the Saksunarvatn Ash (*c.* 9000 ^{14}C years BP), which are of Icelandic origin and the Central European Laacher See Tephra (*c.* 11,200 ^{14}C years BP). The identification of several new sites with the Vedde Ash in south Sweden has increased the known distribution of this important marker horizon significantly. An area in the southern Baltic region may be chosen for further research, as the distribution of all these three tephras seem to coincide in this area.

Introduction

The Last Glacial-Interglacial Transition (LGIT) in the North Atlantic region (*c.* 14,000 - 9000 ^{14}C years BP) was characterised by a number of rapid climate shifts between cold and warm conditions. These are well established in ice cores from Greenland (*e.g.* the GISP2 and GRIP cores; *e.g.* Grootes *et al.*, 1993; Kapsner *et al.*, 1995) as well as in marine and terrestrial records (e.g. Lowe *et al.*, 1994; Hafliðason *et al.*, 1995). A widespread warming at *c.* 13,000 ^{14}C years BP started the Lateglacial Interstadial or the Bølling-Allerød complex. Two or three short-lived cold events have been described during this interstadial which ended with the onset of the cold Younger Dryas stadial, which lasted between *c.* 11,000 and 10,000 ^{14}C years BP (*e.g.* Lowe *et al.*, 1994). A rapid warming at *c.* 10,000 ^{14}C years BP ended the Younger Dryas, but full interglacial conditions were not established until the middle of the Preboreal (*c.* 9600 BP; Björck *et al.*, 1996; Knudsen *et al.*, 1996).

Different records from marine and terrestrial sources often show similar patterns of climate variation during the LGIT, suggesting that the different systems responded more or less simultaneously to the climate forcing processes. This is, however, complicated to prove by using radiocarbon dating. Comparisons of marine and terrestrial records are hampered by different reservoir ages and by the fact that the marine reservoir age was not constant and seems to have increased during the Younger Dryas (*e.g.* Bard *et al.*, 1994). Furthermore, the time period in question is characterised by a number of radiocarbon plateaux with near-constant radiocarbon ages, *e.g.* at 10,400 - 10,300 ^{14}C years BP and 10,000 ^{14}C years BP (*e.g.* Wohlfarth, 1996; Hughen *et al.*, 1998).

The use of tephra layers as time-synchronous marker horizons in Late Quaternary deposits has increased considerably during the last decades. Tephra horizons enable high-precision comparisons between sequences and sediments/deposits of different origin. The volcanic activity during the Lateglacial period was extremely high, possibly due to increased crustal stresses that occur with changing volumes of continental ice sheets (Zielinski *et al.*, 1997). This infers that many time-equivalent tephra horizons may occur in sediments deposited during this time period.

Volcanic eruptions on Iceland has frequently dispersed tephra over north-west Europe in the Late Quaternary. Recent identification of tephra in the ice cores from Greenland have increased the value of these tephra horizons as dating tools, as these often can be dated with high precision. Several significant sulphate peaks in the ice cores also suggest that many tephra horizons remain to be discovered.

The first tephrochronological investigations in Scandinavia were made by Persson, who studied Holocene tephra in peat deposits in Sweden, Norway and on the Faroe Islands (*e.g.* Persson, 1971). Persson described many distinct tephra horizons which he correlated with well-known eruptions, such as the Hekla 4, Hekla 3 and the Öræfajökull eruption at 1362 AD. There are also well-known records of tephra fallout in Scandinavia and Finland from historical eruptions on Iceland Askja 1875 AD and Hekla 1947 AD; see *e.g.* Einarsson, 1986).

Distribution of Lateglacial tephra in Scandinavia

So far, three tephra horizons from the LGIT have been discovered in Scandinavia. Of these, two are of Icelandic origin, the Vedde Ash (*c.* 10,300 ^{14}C years BP) and the Saksunarvatn Ash (*c.* 9000 ^{14}C years BP) and one of Central European origin, the Laacher See Tephra (LST, *c.* 11,200 ^{14}C years BP). The recent discovery of the previously unreported Borrobol Tephra (*c.* 12,400 ^{14}C years BP) in Scotland (Turney *et al.*, 1997), implies that other Lateglacial tephra horizons of Icelandic origin also may be searched for in Scandinavia.

The distribution of these three tephra horizons is shown in Fig. 1. The dispersal fans are drawn according to known terrestrial sites with geochemically confirmed occurrence of tephra.

The Laacher See Tephra is a widespread tephra horizon which was the result of the first and only eruption of the Laacher See volcano in the Eifel area in western Germany (Fig. 1). The distribution of this phonolitic tephra is mostly confined to

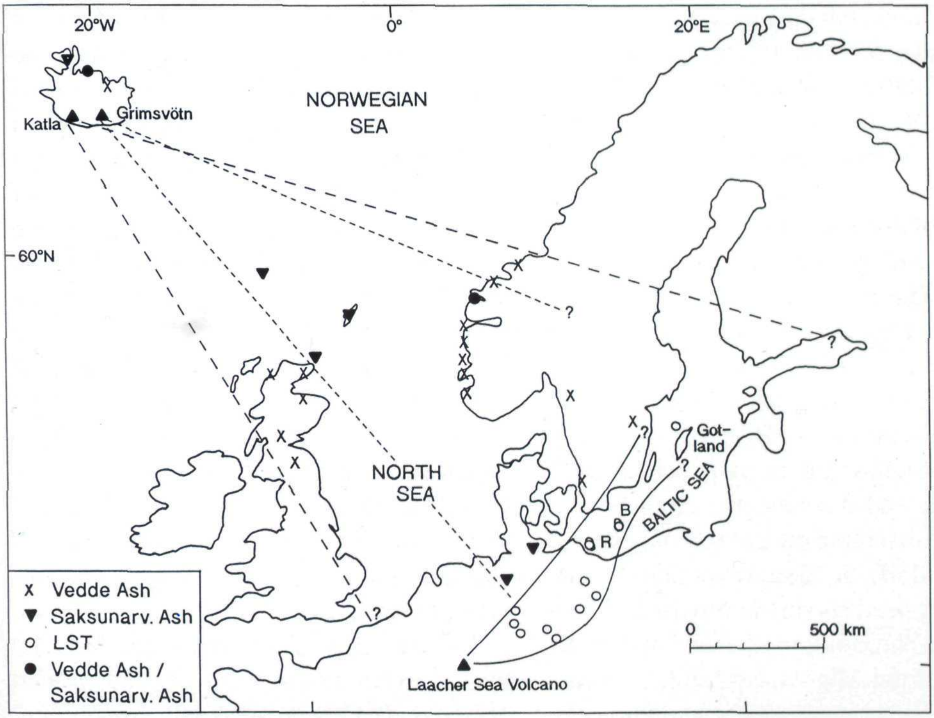

Fig. 1. Map of north-west Europe showing the distribution of terrestrial sites around the North Atlantic with confirmed occurrences of the Vedde Ash, the Saksunarvatn Ash and the Laacher See Tephra (LST). Islands in the Baltic Sea: B = Bornholm; R = Rügen. Sites are taken from Mangerud et al (1984, 1986), van den Bogaard and Schmincke (1985), Bennett et al. (1992), Björck et al. (1992), Norðdahl and Hafliðason (1992), Merkt et al. (1993), Bard et al. (1994), Bunting (1994), Juvigné et al. (1995), Birks et al. (1996), Roberts (1997), Turney et al. (1997), Wastegård et al. (1998) and in preparation. The dispersal fans are drawn according to these sites, but the northern distribution of the Vedde Ash (long dashes) and Saksunarvatn Ash (short dashes) can probably be extended towards north, since many marine cores from the Norwegian Sea have recorded these. The north-eastern fan of the LST (solid lines) is drawn according to van den Bogaard and Schmincke (1985) and Juvigné et al. (1995). Note that the LST in the northernmost site, north-west of Gotland in the Baltic Sea has not been geochemically confirmed. This site is often erroneously placed north-east of Gotland in maps showing the distribution of the areal distribution of LST (e.g. van den Bogaard and Schmincke, 1985).

Mynd 1. Kort, sum vísir útbreiðsluna av støðum á landi kring Norðuratlantshavið, har ið Vedde-øska, saksunarvatnsøska og Laachervatns-tefra (LST) eru staðfest. Oyggjar í Eystarasalti: B = Bornholm; R = Rügen. Støð eru tikin úr Mangerud et al. (1984, 1986), van den Bogaard and Schmincke (1985), Bennett et al. (1992), Björck et al. (1992), Norðdahl and Hafliðason (1992), Merkt et al. (1993), Bard et al. (1994), Bunting (1994), Juvigné et al. (1995), Birks et al. (1996), Roberts (1997), Turney et al. (1997), Wastegård et al. (1998) og í umbúna. Útbreiðsluviftan er teknað í samsvari við hesi støð, men tann norðara útbreiðslan av Vedde-øsku (langar strikur) og saksunarvatnsøsku (stuttar strikur) kann møguliga leingjast norðureftir, av tí at hesar eru skrásettar í nógvum havborikjarnum úr Norska havinum.Landnyrðingsviftan av LST (óbrotnar strikur) er teknað sambært van den Bogaard and Schmincke (1985) og Juvigné et al. (1995). Gev gætur, at LST í tí norðasta staðnum, í ein útnyrðing úr Gotlandi, er ikki jarðevnafrøðiliga staðfest. Hetta staðið er mangan av órøttum sett at vera í ein landnyrðing úr Gotlandi á kortum, sum vísa útbreiðslu av LST-økisútbreiðsluni (t.d. van den Bogaard and Schmincke, 1985).

Central Europe, but the north-eastern fan of ash dispersal reached at least as far as the southern Baltic area, including the Bornholm and Rügen islands (Fig. 1; Usinger, 1977; van den Bogaard and Schmincke, 1985; Juvigné *et al.*, 1995). It is possible that at least the south-eastern part of Sweden also may have received tephra from this eruption. The northernmost record of LST was made in a core with laminated clay from the Baltic, north-west of Gotland, and was dated by pollen analysis to the late Allerød (Påhlsson and Bergh Alm, 1985). This record has not been geochemically confirmed, and it would therefore be important to re-sample the Lateglacial clays in the Central Baltic Sea, especially as the LST can be used as a marker in the Swedish clay-varve chronology. LST is dated to the later part of the Allerød, *c.* 11,200 ^{14}C years BP (*e.g.* Hajdas *et al.*, 1995), and it may be used as an important marker horizon for the Killarney/Gerzensee oscillation, which is the last cold event during the Lateglacial Interstadial. LST has not yet been identified in the ice-core records, but some sulphate peaks around 13,000 ice-core years BP may be possible candidates (cf. Zielinski *et al.*, 1996; 1997).

The Vedde Ash is the most important Lateglacial ash horizon in the North Atlantic region and is also the main component of the so called North Atlantic Ash Zone 1 (*e.g.* Kvamme *et al.*, 1989; Lacasse *et al.*, 1995). It has been found in a large area around in the North Atlantic and consists of two geochemically distinct populations: one rhyolitic and one basaltic (e.g. Mangerud *et al.*, 1984). A new technique for extracting the rhyolitic part of this bimodal tephra from minerogenic deposits (Turney, 1998) has extended the area of detection to the British mainland and south Sweden (Fig. 1). The technique relies upon a difference between the specific gravity of the rhyolitic shards (2.4 – 2.5 g/cm^3 for the Vedde Ash) and that of the host sediment, and uses sodium polytungstate as the flotation medium (Turney, 1998). This has led to the identification of the rhyolitic part of the Vedde Ash in several sites in Scotland and south Sweden (*e.g.* Roberts, 1997; Turney *et al.*, 1997; Wastegård *et al.*, 1998; J. Björck and Wastegård, submitted), even at sites where the peak concentration of shards is extremely low (<100 shards/cm^3 sediment).

The Vedde Ash is radiocarbon dated by the AMS technique to a plateau around 10,400 - 10,300 ^{14}C years BP (Birks *et al.*, 1996; Wastegård *et al.*, 1998), and is present in the GRIP core where it is dated to 11,980 ± 80 ice-core years (Grönvold *et al.*, 1995). The source of the Vedde Ash is probably the Katla volcano on south-west Iceland (Lacasse *et al.*, 1995).

The Saksunarvatn Ash was first found on the Faroe Islands where it can be found as a several cm thick horizon in many places (Mangerud *et al.*, 1986; Edwards and Craigie 1998). Its terrestrial distribution also includes northern Germany (Merkt *et al.*, 1993) and western Norway (the Kråkenes site; Birks *et al.*, 1996). It is possible that this ash has a much wider distribution, especially in Scandinavia, and further investigations are needed to investigate its distribution. The source of the Saksunarvatn Ash is probably the Grímsvötn volcano on south-eastern Iceland and this major basaltic eruption has been dated to *c.* 9000 ^{14}C years BP (*e.g.* Birks *et al.*, 1996) or to *c.* 10,400 – 10,200 ice-core years BP in the GRIP and GISP2 ice cores (Grönvold *et al.*, 1995; Zielinski *et al.*, 1997).

Conclusions

The possibility for establishing a tephrochronological framework for the Last Glacial-Interglacial Transition in south Scandinavia has been improved greatly by the discovery of several new sites with the Vedde Ash in south Sweden and by the application of the new technique for extracting tephra shards from minerogenic deposits. The dispersal fans of the Laacher See Tephra and the Icelandic tephras may in some areas coincide, so that sites with more than one tephra horizon can be found. This would be a great step forward as it would enable many sediment sequences to be tied directly to the ice-core records, and it would also provide a link between the tephrochronological frameworks of North and Central Europe. The most suitable areas for further research include the southern Baltic Sea area and adjacent land areas, *e.g.* northern Germany, Denmark and south Sweden (cf. Fig. 1).

The Swedish clay-varve chronology (the "Swedish Time Scale") is presently regarded as floating with an offset of 600-800 years to other calendar-year based time-scales (*e.g.* Wohlfarth, 1996). If time-synchronous tephra horizons can be detected within the Swedish Time Scale, then the possible errors and the precision of this calendar-based time-scale can be determined independently.

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