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Cenozoic microfossils in northern Finland: Local reworking or distant wind transport?

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ABSTRACT

Allochthonous Cenozoic microfossils have been reported from Late Pleistocene lake and mire host sediments across an area of >30,000 km^2 in northern Finland. Two main groups of microfossils are recognised: Palaeogene marine diatoms, silicoflagellates and ebridians that include taxa from around the time of the Palaeocene–Eocene Thermal Maximum and Pliocene to early Pleistocene freshwater diatoms. The presence of these microfossils has been regarded as evidence that Eocene marine and late Neogene freshwater sediments formerly existed on the shield surface. Both groups have been referred to frequently in reconstructions of the sea level, tectonic and erosion history of the northern Fennoscandian shield. The questions raised by the presence of allochthonous Cenozoic microfossils in northern Finland are, however, strongly resonant of the debate over the biota, origin and age of the Pliocene Sirius Group in Antarctica where competing hypotheses have been put forward of local deposition and reworking versus distant wind transport of marine diatoms from the continental shelf.

This review explores alternative origins for the allochthonous Cenozoic microfossils in northern Finland. Local reworking of Palaeogene marine sediments during Pleistocene glaciation is unlikely, as no source rocks of Palaeogene age are known from the shield surface or from surrounding sedimentary basins in the Baltic and White Sea. Moreover, at all sites except Akanvaara, the marine diatom taxa cover wide age ranges and occur only as minor components in diatom assemblages that are dominated by Quaternary freshwater taxa. Local reworking of Pliocene–Pleistocene freshwater diatoms is, however, compatible with the widespread survival of pre-Pleistocene deep weathering although no *in situ* or unmixed, ice-rafted Pliocene–Pleistocene lacustrine sediment has yet been found. An alternative origin for the marine Palaeogene microfossils by distant wind transport is proposed. In this hypothesis, Palaeogene diatomites on the Barents Sea shelf were exposed to deep glacial and fluvioglacial erosion during the Pliocene and Early Pleistocene and in low sea level stages of the Middle and Late Pleistocene. Intense wind action acting on comminuted mudstones on outwash plains carried dust including microfossils into northern Fennoscandia to be deposited by rain-out in lakes and wetlands. This material may have been later further recycled by glacial and meltwater transport and more localised wind action, processes that also may help to account for the distribution of Eemian marine diatoms well beyond Eemian shorelines. The distant wind transport hypothesis implies that the presence of marine Palaeogene diatoms on the shield surface in northern Finland cannot be regarded as vestiges of former marine sediments and so do not constrain the tectonic and geomorphic history of the northern Fennoscandian shield in the Cenozoic.

1. Introduction

Cenozoic microfossils have been recovered widely from Pleistocene host deposits on the Fennoscandian shield in northern Finland (Fig. 1). Two microfossil groups have been identified: (i) Palaeogene marine diatoms, found together with other siliceous microfossils, and (ii) Pliocene–Pleistocene freshwater diatoms. These finds are confined partly to the ice divide beneath the former Fennoscandian Ice Sheet (FIS), a zone of limited glacial erosion in which pre-glacial deep weathering is widely preserved (Hirvas, 1991). Both groups of microfossils have been assumed to be *in situ* or to have been reworked by glacial erosion from pre-existing source deposits on the shield surface (Hirvas and Tynni, 1976; Grönlund, 1977; Tynni, 1982; Fenner, 1988; Grönlund, 2005). This interpretation is here named the Local Reworking hypothesis (LRW).

Based on acceptance of the LRW hypothesis, the former or continuing presence of Palaeogene marine sediments in northern Finland has become widely accepted (Huuse, 2002; Rohrman et al., 2002; Rasmussen et al., 2008; Knox et al., 2010). The distribution of diatoms has been used to reconstruct the extent of Eocene marine transgression in northern Finland (Tynni, 1982) and to infer the pattern and magnitude of Late Cenozoic uplift for this part of the shield (Riis, 1996). Overlying Palaeogene marine microfossils have also

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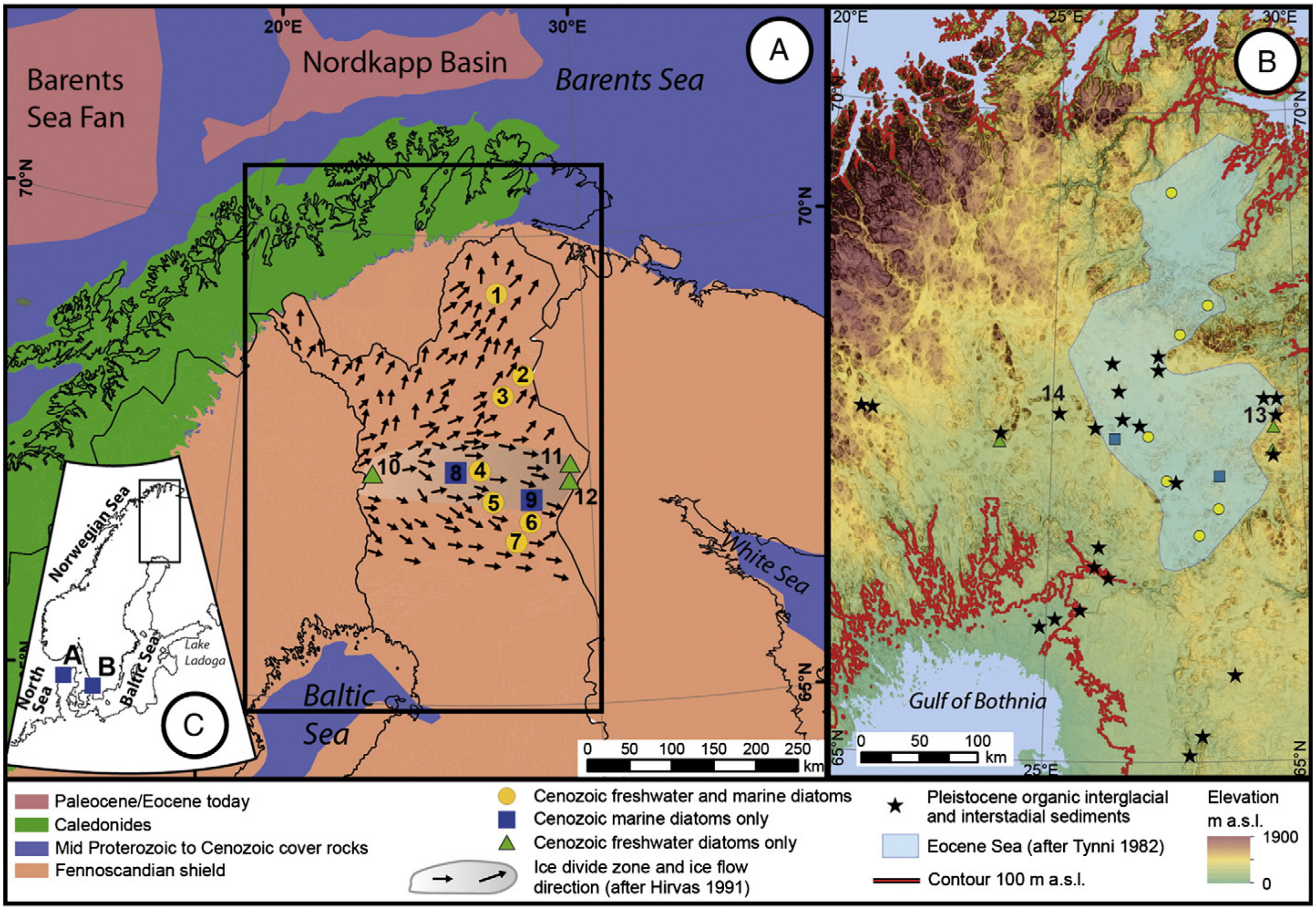

Fig. 1. Location. A. Microfossil localities. 1. Unnamed site, Inari.; 2. Riukuselkä, Inari.; 3. Kopsusjärvi, Inari.; 4. Siurunmaa, Sodankylä.; 5. Kelloääpa, Pelkosenniemi.; 6. Kulväkkopalo, Salla.; 7. Kankaanlampi, Kemijärvi.; 8. Vaalajärvi, Sodankylä.; 9. Akanvaara, Savukoski.; 10. Sivakkapalo, Kolari.; 11. Värriöjoki, Salla.; 12. Naruskajärvi, Salla. B. Geomorphology. 13. Sokli, Salla.; 14. Tepsankumpu, Kittilä. C. Location. A. Fur Formation, Denmark. B. Glacially-transported Eocene diatoms, Alnarp valley, Skåne.

been assumed to constrain the minimum age of deep kaolinitic weathering profiles found beneath the shield surface at Siurunmaa, Sodankylä (Tynni, 1982) and elsewhere (Riis, 1996). More widely, the presence of Eocene diatoms has been interpreted as critical evidence for the survival of topography from the Palaeogene in northern Fennoscandia (Söderman, 1985; Lidmar-Bergström, 1995, 1996). According to the LRW hypothesis, reworking of Palaeogene diatoms into Pleistocene host deposits also implies that Palaeogene sediments persisted on the shield surface until at least the onset of ice sheet glaciation at 2.7 Ma. Hence the Palaeogene marine microfossils are key markers for the Cenozoic tectonic and erosion history of the northern Fennoscandian shield (Kohonen and Rämö, 2005; Paulamäki and Kuivamäki, 2006; Fjellanger and Nystuen, 2007; Rasmussen et al., 2008; Lidmar-Bergström et al., 2012).

The Pliocene–Pleistocene freshwater diatoms have received less attention, perhaps because the apparent survival of Eocene marine microfossils renders the presence of younger forms unremarkable. Here again the Pliocene to Early Pleistocene freshwater diatoms are hosted in Late Pleistocene sediments. Although the Naruskajärvi diatomite has been referred to as an *in situ* Pliocene deposit (Williams et al., 2002), all of these freshwater diatoms have been presumed previously to have been eroded from Pliocene–Pleistocene source sediments that formerly or still exist on the shield surface.

Despite its far reaching implications, the taphonomy implicit in the LRW hypothesis has not been scrutinised closely. One obvious difficulty is that no Cenozoic source sediments have been reported from the shield surface in northern Fennoscandia in the 40 years since the first discoveries of Cenozoic microfossils were made (Hirvas and Tynni, 1976). Palaeogene to Early Pleistocene sediments are also absent from the surrounding basins of the Gulf of Bothnia and White Sea (Fig. 1). This absence is especially puzzling given the widespread distribution of finds covering an area of >30,000 km^2 (Fig. 1) and the intensive drilling and pitting programmes made in northern Finland in the search for economic minerals by the Geological Survey of Finland (GTK). There is also a widespread lack of recognition in the literature that the Cenozoic microfossils occur as part of mixed assemblages, with taxa of both freshwater and marine environments and of different ages. The key Akanvaara and Naruskajärvi deposits, in particular, have been routinely dated by their oldest faunal elements, rather than the youngest, as should be the case. Mixed assemblages imply a complex taphonomy and either multiple sources or multiple reworking.

The Cenozoic microfossils are clearly allochthonous, hosted typically in clays and silts that represent either *in situ* or ice-rafted Pleistocene lacustrine or paludal deposits (Fig. 2). In many other contexts, allochthonous diatoms have been recognised as products of long distance reworking. In particular, allochthonous diatoms have been linked to wind transport (Gasse et al., 1989; Abelmann, 1992). Long distance aeolian transport of marine and freshwater microfossils is recognised widely from ice core (Burckle et al., 1996; Stroeven et al., 1996), deep ocean (Scherer and Koç, 1996; Rea et al., 1998) and terrestrial records (Polyakova, 2001; Cremer et al., 2004). This raises the possibility that the Cenozoic microfossils reported from northern Finland were also transported by wind from distant sources. Allochthonous microfossils are, however, usually penecontemporaneous with the enclosing