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VARIABLE ISOSTATIC UPLIFT PATTERNS DURING THE HOLOCENE IN SOUTHEAST SWEDEN, BASED ON HIGH-RESOLUTION AMS RADIOCARBON DATING OF LAKE ISOLATIONS – A PRELIMINARY INTERPRETATION

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Abstract. To describe changes in shoreline configuration in northern Uppland, south-east Sweden, the isolations of 17 present and overgrown lakes have been interpreted from diatom analysis and AMS radiocarbon dates on terrestrial macrofossils. The sites studied are spread c. 60 km in east-west and c. 70 km in north-south direction. The oldest isobase direction, representing the "Neolithic Sea", extends in more or less north-south direction. The present day isobase system shows a clear east-west trend. The results indicate a complicated pattern of isostatic uplift during the late Holocene. We have defined five different shore displacement curves denoted A–E. It is obvious that the present day east-western isobase system is not valid for the investigated sites. Instead, the north-south isobases for the "Neolithic Sea" should to a relatively high degree explain the geographic distribution of sites. It is suggested that a re-direction of the isostatic uplift pattern has occurred sometime during the last c. 5000 years. This shift could have taken place as a slow deformation of the bedrock and/or as neotectonic movements along existing fault lines.

Key words: isostatic uplift, AMS radiocarbon dating, Holocene, southeastern Sweden.

INTRODUCTION

The construction of a new highway between Uppsala and Mehedeby in northern Uppland, southeastern Sweden, has motivated extensive archaeological excavations. To describe changes in shoreline configuration over time in the area, the isolations of 17 present and overgrown lakes have been interpreted from diatom analysis and AMS radiocarbon dates on terrestrial macrofossils (Fig. 1). The purpose was to increase the accuracy of previous models in a consistent way.

The previous shore displacement curve for the area was based on bulk sediment dating of five sites, marked with triangles in Figure 1. This model indicated a consistent regressive shore displacement between 6300 and 3800 ^{14}C yrs BP (Robertsson, Persson, 1989; Risberg, 1999; Bergström, 2001; Hedenström, Risberg, 2003). The corresponding palaeo-shorelines defined in the above mentioned investigation can today be found at c. 57 and 27 m a.s.l., respectively.

INVESTIGATION AREA

The bedrock topography in the main part of investigated area is relatively smoothly undulating (Lidmar-Bergström, 1995, 1996; Johansson *et al*., 2001). The accumulation of Quaternary deposits is in places relatively thick consisting of till, glacifluvium, clay and peat. Ordovician limestone is common in the area being transported from the north by the Weichselian glacier (Axberg, 1980). The investigated basins are small and shallow. At all sites, the lithostratigraphy indicates a regressive shore displacement with minerogenic strata (clay, gyttja clay) in the lower part and organic strata (clay gyttja, gyttja) towards the surface. The sites studied are spread c. 60 km in east-west and c. 70 km in north-south direction.

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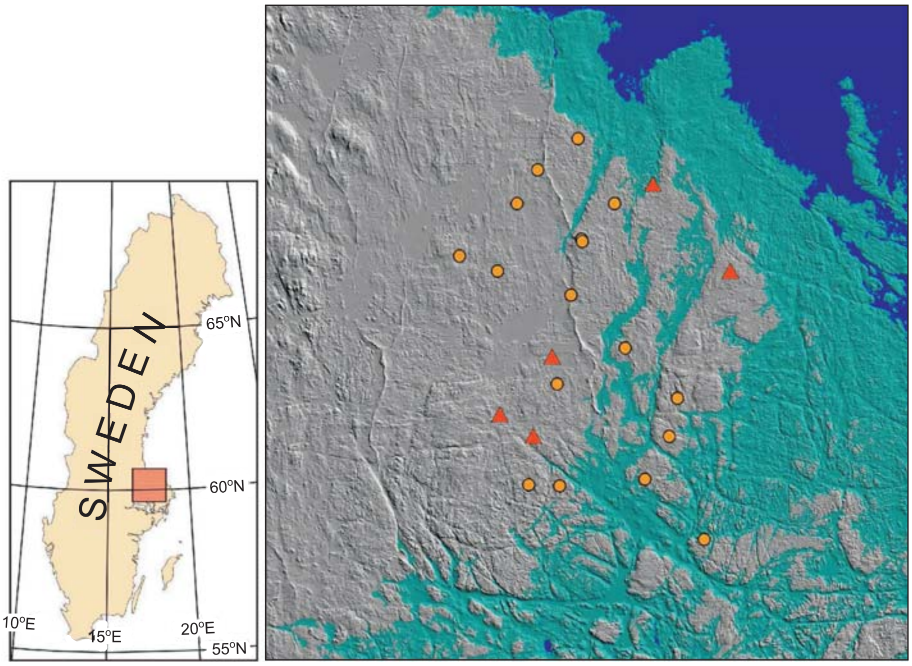

Fig. 1. Location of the investigated area in central Sweden

Circles indicate the positions of the 17 newly investigated sites. Triangles indicate the position of sites used for the construction of a shore displacement curve based on bulk sediment dating between 6300 and 3800 ^{14}C yrs BP (Robertsson, Persson, 1989; Risberg, 1999; Bergström, 2001; Hedenström, Risberg, 2003). Grey colour indicates ground surfaces above 30 m above present day sea level, corresponding to c. 3200 cal. years BP. Green areas indicate the present exposed land surfaces. Blue area is the present day Baltic Sea

A major fault line is visible in north-north-east – south-south--west, separating the four south-eastern sites from the remaining ones (Fig. 1). Several minor fault lines are visible further to the north-west. Two sets of isobase directions have been published for the area. The oldest, representing the "Neolithic Sea" (De Geer, 1925), extend in more or less north-south direction. The present day isobase system shows a clear east--west trend (Ekman, 1996).

METHODS

The field work consisted of two parts, i.e. levelling of the isolation thresholds and collection of sediment for diatom analysis and extraction of terrestrial macrofossils. The topography of the isolation thresholds were described by a levelling instrument and a lath. A temporary bench mark was established in the vicinity, which in turn was levelled with a ground based RTK GPS instrument. The latter technique allowed an accuracy of ±4 cm. The geologic accuracy, however, is estimated to be in the order of ±0.5 or ±1.0 m. About 20 parallel sediment cores were collected in each basin to allow sufficient amount of terrestrial macrofossils, mainly seeds from *Betula* and *Alnus*. The cores were correlated in the laboratory using sampling depths and visible lithostratigraphic boundaries.

The sediment was wet-sieved through 250 μm where after the terrestrial macrofossil was picked under a microscope (Björck, Wohlfarth, 2001). The seeds were dried in 105°C and sent to the Radiocarbon Laboratory in Poznan, Poland, for dating. The dates were calibrated in OxCal 3.5 and the V-Sequence was applied in order to delimit the possible age intervals. After this procedure, the statistical errors varied between ±30 years and ±120 years, with an average of ±70 years.

Diatoms were extracted from one of the cores. Preparation techniques followed the compilation in Battarbee (1986). In order to interpret the stratigraphic position of the isolation from the Baltic, the diatoms were grouped into three different classes. Typical brackish-marine taxa indicate deposition in the Litorina Sea, while freshwater taxa indicate accumulation in the isolated lake. Lagoonal, halophilous and indifferent taxa were grouped together as representing accumulation during the transition phase (e.g. Mölder, Tynni, 1967–1973; Tynni, 1975–1980; Krammer, Lange-Bertalot, 1986, 1988, 1991a, b). The diagrams were constructed using the Tilia program, including the application of stratigraphically constrained cluster analysis (Grimm, 1987, 1992).

RESULTS

The isolation ages and the corresponding altitudes indicate a complicated pattern of isostatic uplift during the late Holocene (Fig. 2). From the scattered distribution of sites in Figure 2, we have defined five different shore displacement curves denoted A–E. It is obvious that the present day east-western isobase system is not valid for the investigated sites. For example, the southernmost four sites should in this case fall on the same shore displacement curve. It is also striking that the lines D and E represent the most elevated sites. These lines cannot easily be combined with the remaining lines A–C. The reason for this is at the moment not known but a tentative suggestion involves effects from a transgressive sea level, which is recorded further south (cf. Miller, Hedin, 1988). If the interpretation in Figure 2 is correct, the north-south isobases for the "Neolithic Sea" should to a relatively high degree explain the geographic distribution of sites shown in Figure 3. It is therefore suggested that a re-direction of the isostatic uplift pattern has occurred sometime during the last c. 5000 years. This shift could have taken place as a slow deformation of the bedrock and/or as neotectonic movements along existing fault lines (Lenngren, 2003; Risberg *et al.*, 2005). Three sites stand out as anomalies; the easternmost site in area C and the two sites in area D. The first site may be explained by its position in a pronounced fissure-valley landscape east of a major fault line resulting in a fast uplift in relation to the surroundings. This seems also to be the case with area D.

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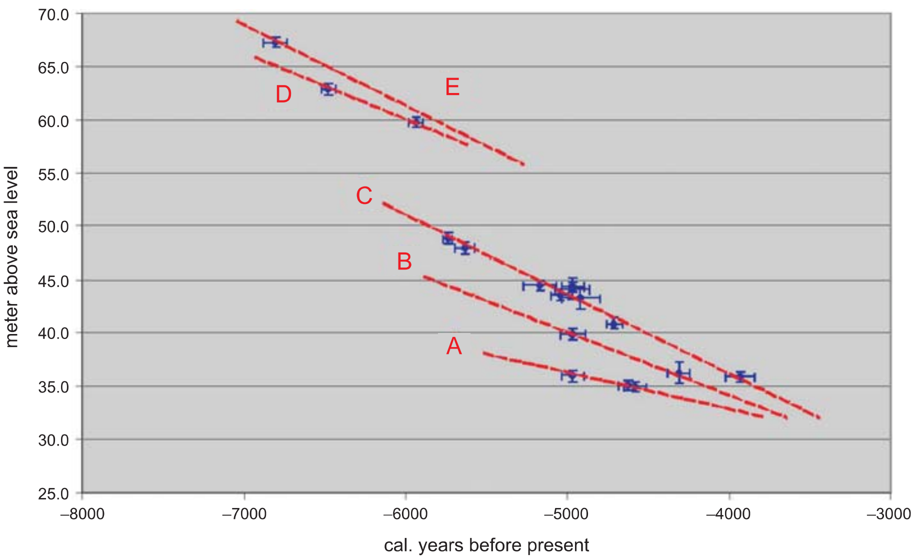

Fig. 2. Isolation thresholds in Northern Uppland

Plot of the 17 newly investigated sites regarding their isolation thresholds and calibrated isolation ages. Estimated error bars for altitudes and ages are shown. The straight lines A–E indicate tentative interpretations of shore displacement in different geographic areas

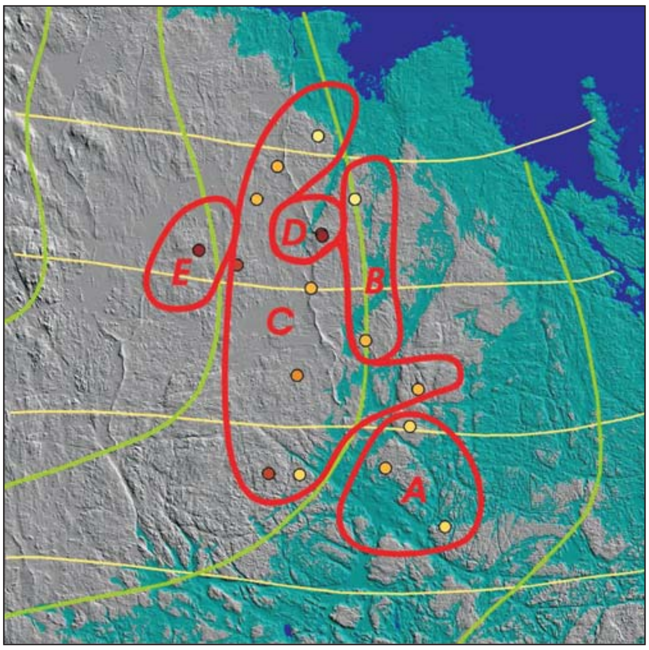

Fig. 3. Delimitation of geographic areas A–E for five shore displacement curves indicated in Figure 2

Green lines indicate the north-south configuration of isobases for the "Neolithic Sea" (redrawn from De Geer, 1925). The values vary from 60 m a.s.l. in the southeast to 130 m a.s.l. in the northwest. Yellow lines indicate present day isobases (redrawn from Ekman, 1996). Uplift rates vary from 4.5 mm/year in the south to 6.0 mm/year in the north. The colouring of the sites indicates relative ages (dark colour represent older sites and light colour young sites). It is obvious that uplift patterns in general have followed the isobase system suggested by De Geer (1925). Area D and the easternmost site in area C constitute anomalies from this rule

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