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LONGSHORE SUBSURFACE ANOMALIES CONSISTENT WITH MID-HOLOCENE CHANNELIZED STORM EROSION: TIHU STRANDPLAIN, HIIUMAA ISLAND, ESTONIA

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Introduction: In recent decades, field surveys and geophysical imaging using ground-penetrating radar (GPR) surveys have revolutionized coastal paleoenvironmental research, including the coasts of Estonia [1-7] (Fig. 1A; inset). Most surveys are designed to traverse multiple morphostratigraphic elements of coastal strandplains, such as beach/dune-ridge sets (Fig. 1), in order to capture the most complete temporal range represented by wave and wind deposition in swash aligned (concave-seaward) ridges (white lines in Fig. 1B; red survey line in Fig. 1C).

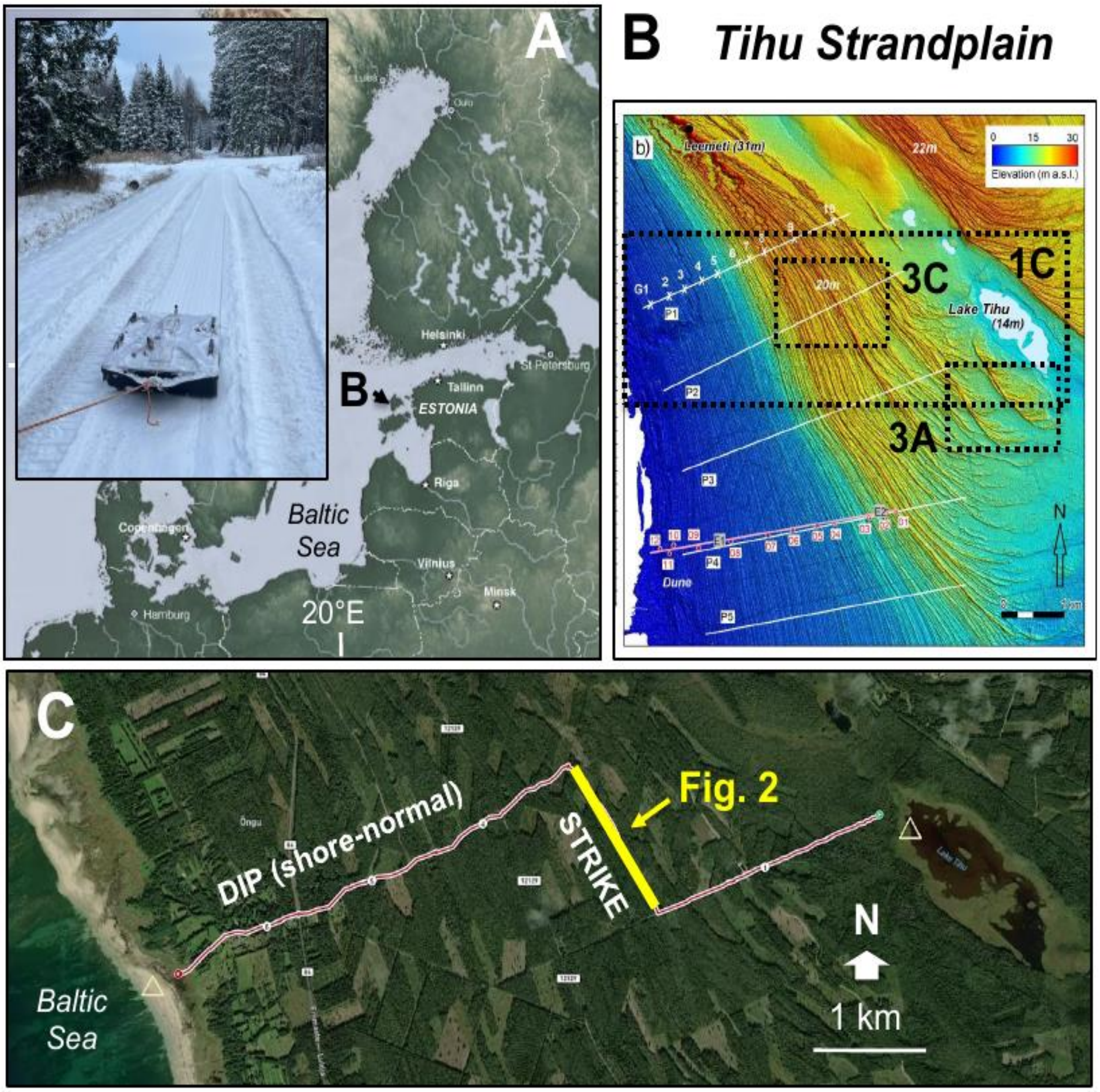

Figure 1. A) Location map of the study area on Hiiumaa Island, Estonia. B) Topography of the Tihu ridgeplain segment [5]. C) Georadar database (Nov. 2022) includes a shore-parallel segment, which reveled shallow subsurface anomalies (see Fig. 2). Image source: GoogleMaps^{TM}.

These shore-perpendicular (dip) orientation is sometimes accompanied by shore-parallel (strike) surveys, typically as connecting profiles.

One such survey at Tihu strandplain provided an opportunity to image a section of a large ridge (Fig. 1C), part of the Ridge Set 9 situated at ~20 m above mean sea level [5].

The aim of this paper is to provide a preliminary interpretation of subsurface features visualized by georadar and to propose scenarios that may explain near surface paleo-depressions.

Methodology:

Geophysical survey (length: ~ 7 km) collected in November 2022 over snow employed a digital Impulse Radar 70/300 MHz system (Fig. 1A; inset). This study focuses on a 1.2-km-long shore-parallel (SE-NW) connecting segment (Fig. 1C). Geolocation was provided by built-n GPS unit and there was minimal topographic variation. Signal velocities of 14 and 6 cm/ns were used for unsaturated and saturated sections, respectively. Radar facies interpretation (Fig. 2) is based on a recently published research of strandplain development [5].

Results and Summary:

Shore-parallel GPR segment shows at least two depressions, ranging between 270 and ~400 m in width. The paleo-topographic lows are 1.5-2.5 m deep, with cut-and-fill sections suggesting 3-4 m of total erosion, or ~1:100 depth:width ratio (Fig. 2). Some scenarios that may explain alongshore heterogeneity are summarized in Figure 3, with storm-surge erosion and partial infilling as the most likely explanation for the subsurface expression (Fig. 3C):

A) A traverse across buried recurve spits would show a pattern similar to a shore-normal (dip) expression of the ridge plain (Fig. 3A). However, drift-aligned relict recurves are still exposed along the Tihu strandplain to the southeast of the study site (Fig. 1B), with Ridge Set 9 segment shown here being part of the swash-aligned barrier section (Figs. 3B, C).

B) Shore-parallel antecedent topographic heterogeneity may result from NW-SE-oriented glacial deposits (e.g., moraines), which may control the overlying topography (Fig. 3B). Although there are paleo-topographic lows in glacial facies at the bottom of the image (Fig. 2B), no evidence of such linear Pleistocene structures have been reported. Furthermore, sand tends to fill the antecedent relief, in contrast to mud that drapes it.

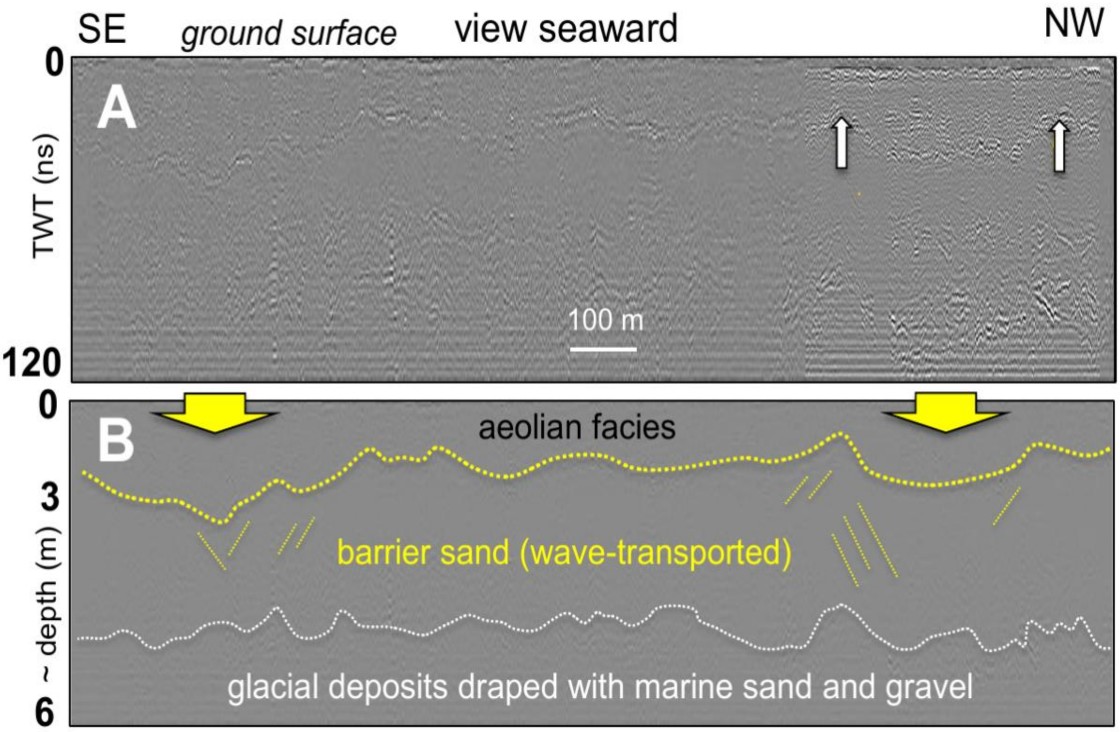

Figure 2. Raw (A) and interpreted (B) 300 MHz GPR images along a paleo-ridge (looking seaward; see Fig. 1 C for segment location). A) Note the highly irregular shallow subsurface reflection (beach/dune facies), including levee-like structures at right (white arrows). B) Clinoforms (dipping layers) suggest channel cut-and-fill structures, corresponding to possible storm channels (large arrows). GPR signal velocity decreases from 14 to 6 cm/ns in saturated segment; TWT – two-way travel time.

C) The simplest explanation is storm-generated channelized erosion of swash-aligned barriers (Fig. 3C).

This is supported by longshore and inward-dipping cut-and-fill structures (Fig. 2B).

The overall dimensions are similar to some larger non-tidal breaches along the Black Sea coast [8, 9].

This interpretation is consistent with a stormy period during the mid-Holocene formation of these ridge sets, as reported in a recent study [5].

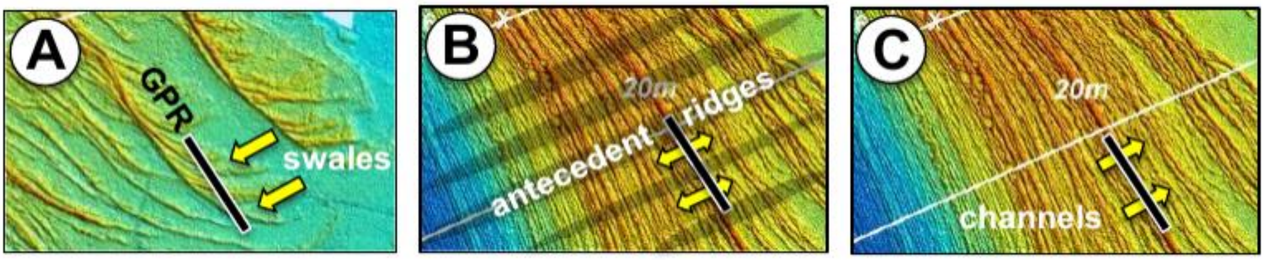

Figure 3. Schematic representation of the three scenarios described above, which show the appearance of depressions (yellow arrows) in shore-parallel GPR surveys (black boxes): A) inter-ridge swales in drift-aligned recurve sections; B) antecedent lows between shore-normally oriented moraines or other glacial deposits; 3) erosional paleo-channels (arrows).

Our study supports recent paleo-environmental interpretation of this section of Tihu strandplain and shows a high preservation potential for storm breach channels within barrier lithosomes, which can be mapped using shore-parallel surveys. Because subsequent aeolian reworking and deposition often masks paleo-channels, GPR serves as a vital tool for identifying and mapping these relict structures [9,10].

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