HOLOCENE STRATIGRAPHY OF THE SHALLOW OFFSHORE ZONES OF THE SHETLAND ISLANDS: INSIGHTS INTO PALEOTSUNAMI AND PALEOENVIRONMENT RECONSTRUCTIONS

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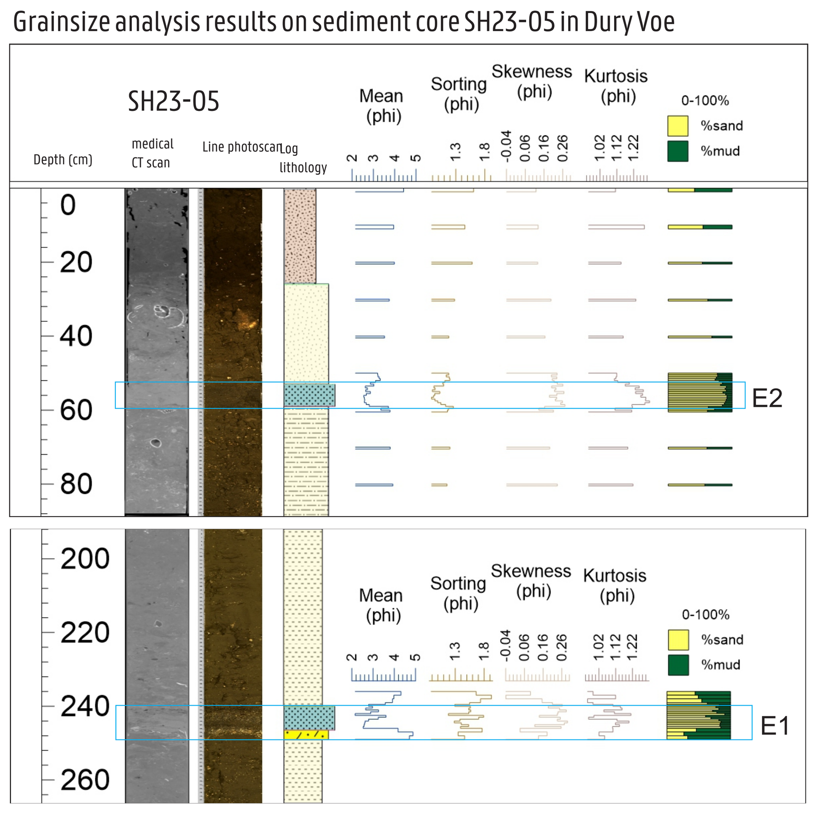
Introduction

Understanding the evolution of coastal environments requires integrating evidence from both onshore coastal regions and shallow marine environments. The Shetland Islands offer a unique natural laboratory to investigate episodic impacts on the coastal environment through abundant well-preserved tsunami deposits. While numerous studies have identified tsunami deposits onshore in the Shetland Islands, offshore tsunami deposits remain underexplored. This study aims to reconstruct the stratigraphic history of these offshore environments by utilizing shallow seismic surveys, geomorphological analyses, and sediment core investigations.

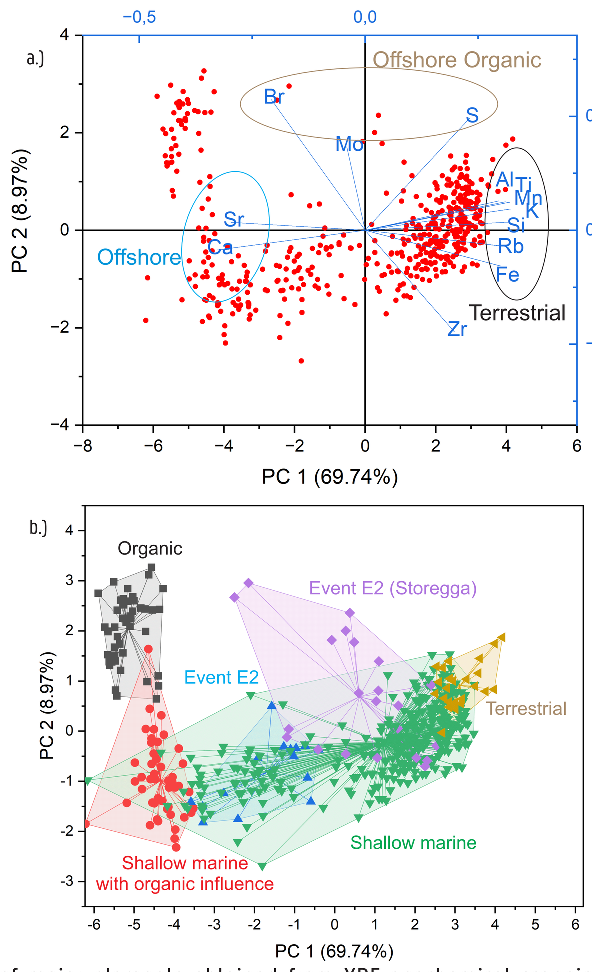
Preliminary Results

The high-resolution seismic data from the Dury Voe area, located on the eastern side of the Shetland archipelago, reveal the sedimentation history and dynamics in the shallow marine environment. Seismic stratigraphic interpretation, combined with the sediment core data, has allowed for the identification of several facies units. In many of the cores, we observe coarse-grained graded beds sandwiched between finer-grained shell hash deposits. These coarser layers, often with sharp basal contacts are normally graded, and suggest temporary interruptions of the steady-state sedimentary regime and are interpreted as possible event deposits based on their contrasting textural and lithological characteristics.

Grainsize analysis results on sediment core SH23-05 in Dury Voe

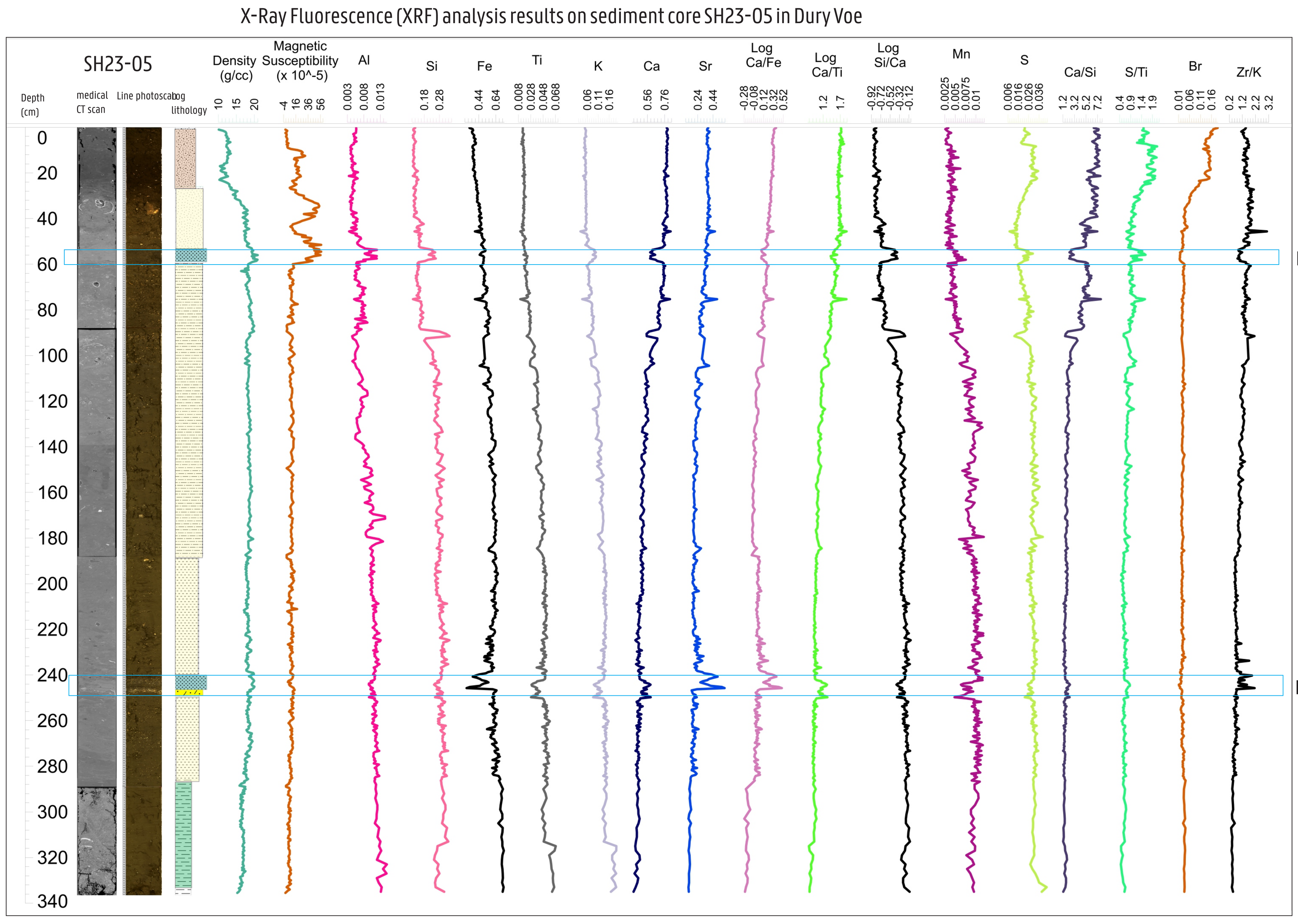


The E1 and E2 layers, which were identified as potential tsunami deposits, are composed of sediments that are slightly coarser than the surrounding layers. The mean grain size ranges from 2.15Φ to 4.18Φ with sorting values between 1.18Φ and 1.92Φ. The sediments primarily consist of very coarse to medium silt, exhibiting a unimodal to trimodal distribution pattern. The grain size distribution comprises 54.9–91.1% sand and



a.) The biplot of major elements obtained from XRF geochemical scanning, analyzed using Principal Component Analysis (PCA), represents the statistical distribution of elemental components that indicate the source of the sediment.
b.) Clustering analysis, based on confidence levels from PCA results, provides a more detailed classification of sediment origins.

X-Ray Fluorescence (XRF) analysis results on sediment core SH23-05 in Dury Voe



MSCL core logging and XRF scanning analysis shows that the E1 layer is characterized by slightly higher gamma density, lower magnetic susceptibility, and lower Fe and Ti values. In contrast, Si, Ca, and Sr values are elevated, indicating a marine environment rich in quartz particles and calcium carbonate from marine shells. On the other hand, the E2 layer shows lower Ca values compared to Al, Si, and Fe, alongside an increase in magnetic susceptibility intensity. This suggests that the E2 layer is more influenced by detrital input and fine-grained sediments, indicating a greater terrestrial influence in the depositional environment.

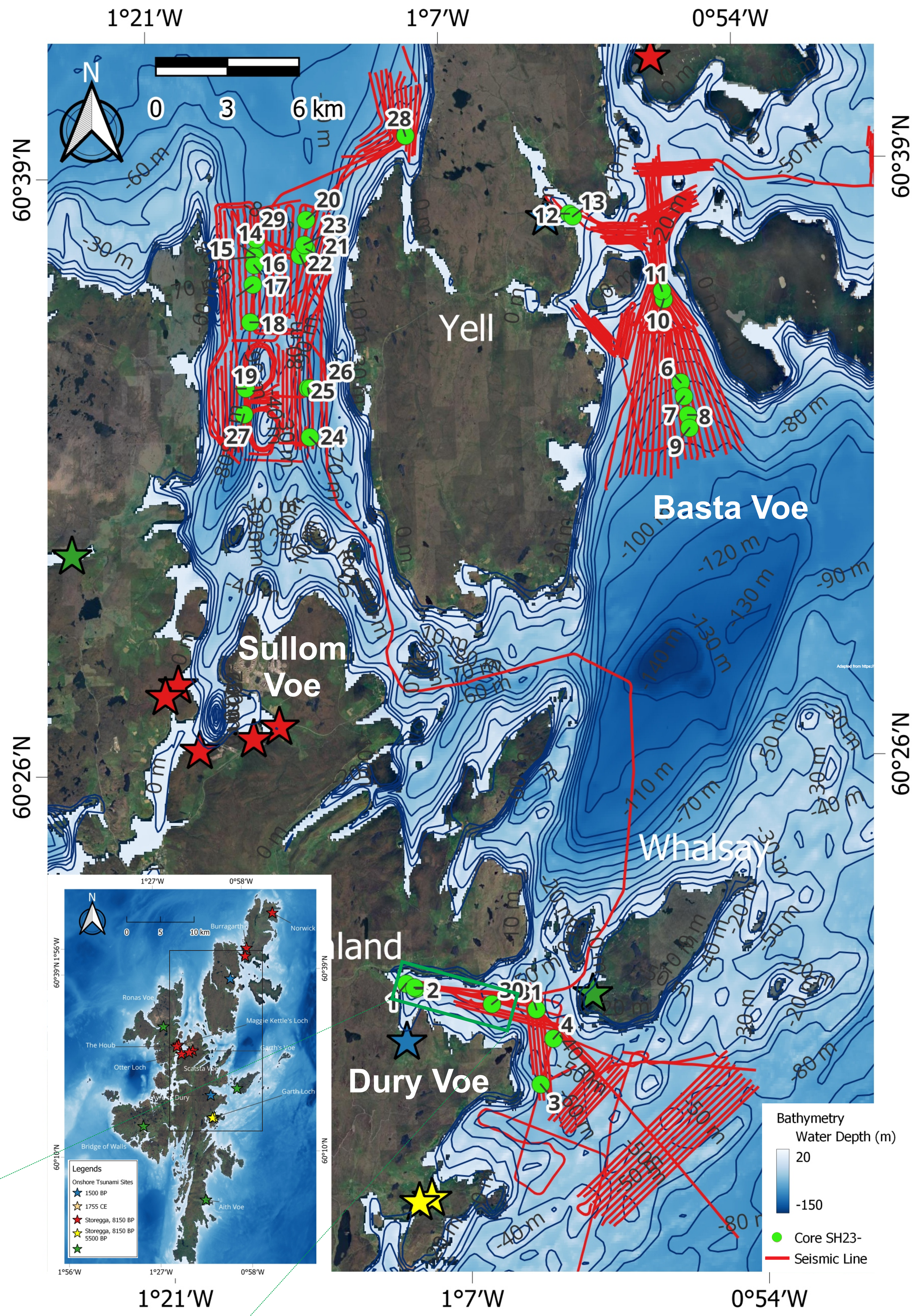
Discussion

Based on the results of a multi-proxy analysis, at least five stratigraphic units and two event layers can be identified, each representing distinct sedimentary environments and depositional conditions. The sequence begins with glacial deposits, followed by potential lake deposits, as indicated by the presence of consistent laminations and relatively uniform fine sand grain size. These are overlain by shallow marine sediments, suggesting a transgressive phase. Within this marine phase, a potential tsunami event deposited a distinct layer of poorly sorted, coarser materials with noticeable color gradation and significant changes in geochemical element composition, distinguishing it from the surrounding sediments. Subsequent marine sedimentation occurred, followed by another, younger potential tsunami deposit. The uppermost layer consists of organic-rich sediments, suggesting deposition in a nearshore environment.

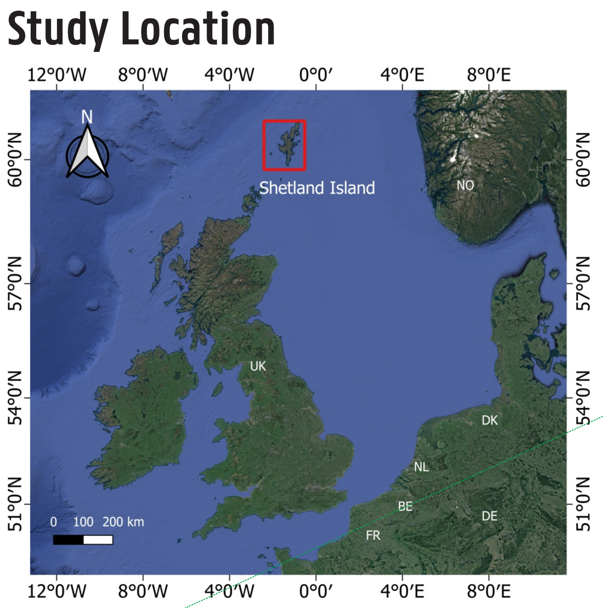
Preliminary luminescence dating indicates that some of the potential layer deposits date to approximately 8150 yr BP, which allows attributing it to the Storegga tsunami, and around 1400 yr BP, associated with another younger tsunami event. Radioisotope dating further supports these findings: the lower layer of E1 dates to 7.615 ± 160 cal yr BP, aligning it with the Storegga event, and the sediment above E2 layer dates to 1.262 ± 84 cal yr BP, consistent with a tsunami event in the 1400s. While these chronological findings align well, further calibration with age models at specific depths is needed for more precise dating.

Methods

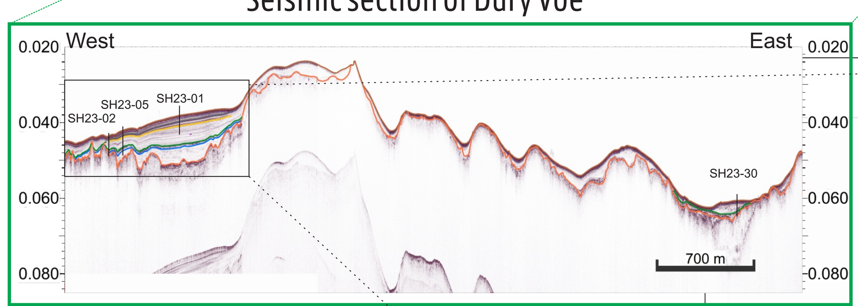
Two surveys with RV Belgica have been conducted in 2022 and 2023, during which high-resolution geophysical data (multibeam bathymetry, subbottom data) was collected, along with vibrocores from 31 sites, spread over three embayment areas around the Shetland Islands. The sediment cores were cut and split for description based on macroscopic observations. Subsequently, the cores were scanned for petrophysical and geochemical properties (i.e. Geotek Core Logging (MSCL), computer tomography (CT) scanning, X-ray fluorescence (XRF) spectroscopy) and subsampled for grain size analysis using laser particle diffraction, and geochronology using OSL and C14 radioisotope dating.



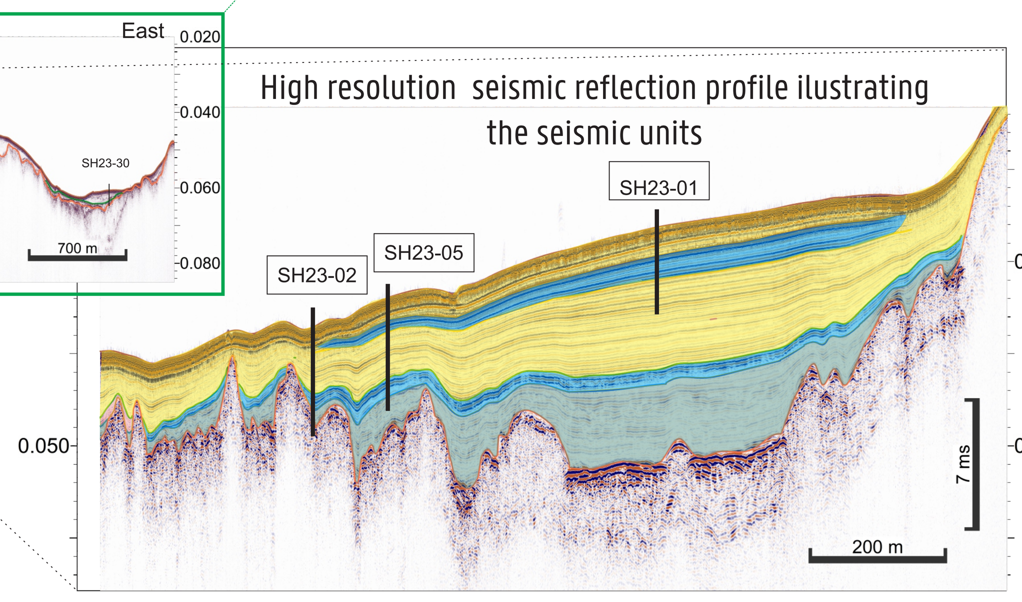
Study Location



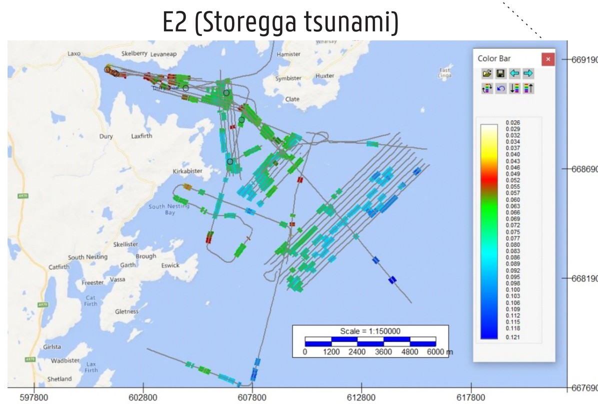
Seismic section of Dury Voe



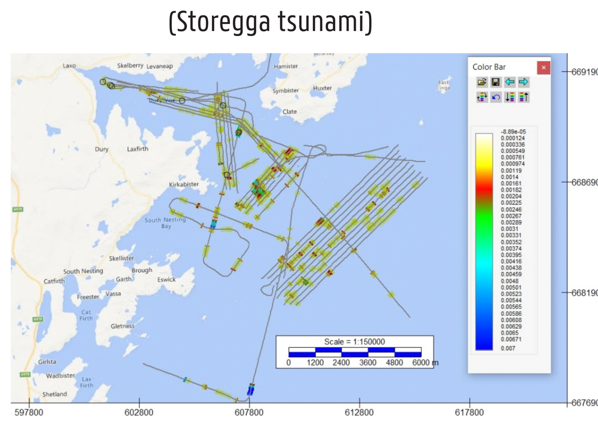
High resolution seismic reflection profile illustrating the seismic units



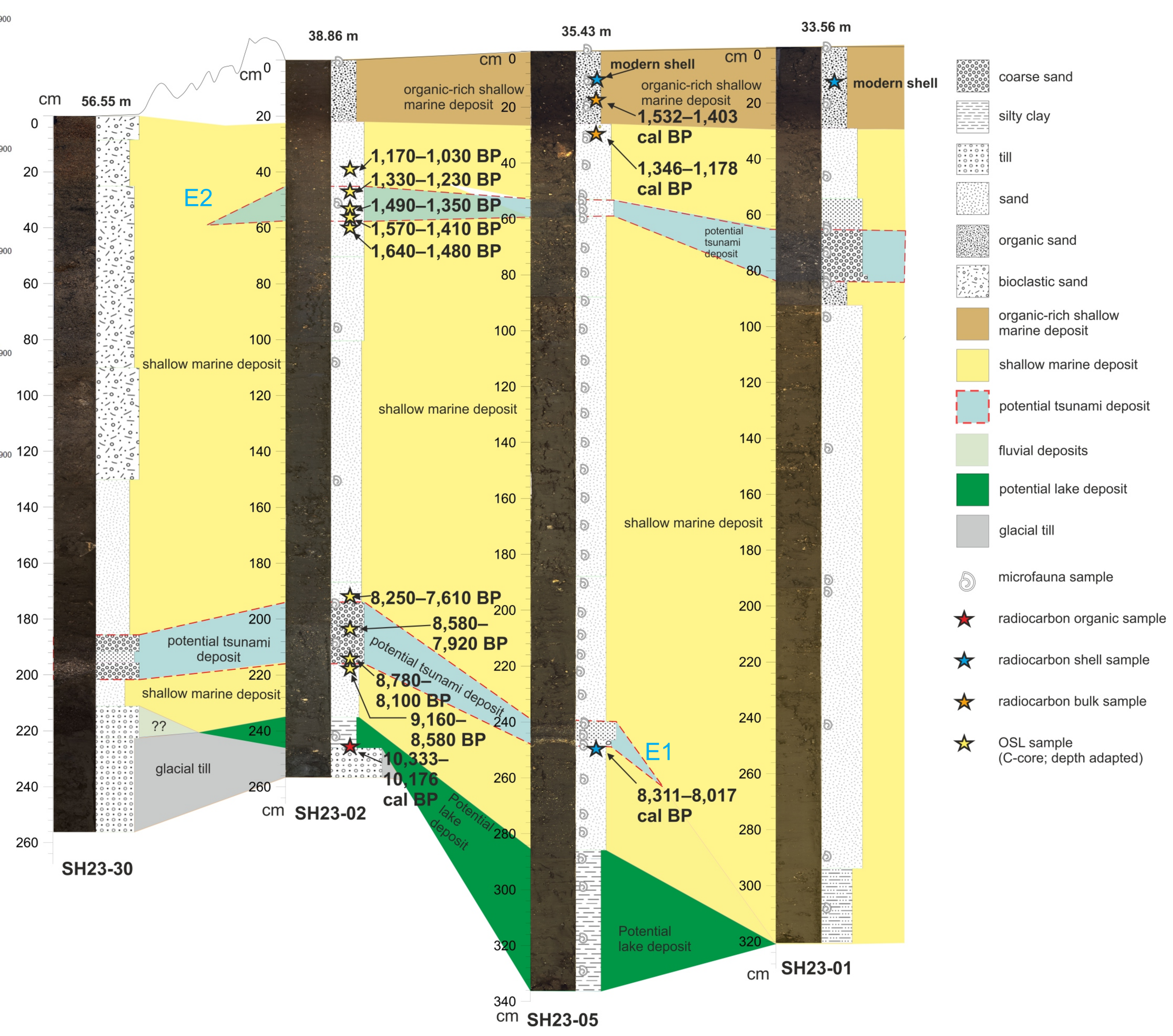
Map of depth from surface tsunami deposit layer E2 (Storegga tsunami)



Map of thickness on tsunami deposit E2 (Storegga tsunami)



Core to core correlation of sedimentary units in Dury Voe.



In the western part of Dury Voe, near the river mouth at 15-30 m water depth, two layers of potential tsunami deposits have been identified on the seismic data, and confirmed by vibrocoring. Optically Stimulated Luminescence (OSL) dating and Radiocarbon dating (C-14) results help confirm if these deposits can be attributed to the Storrega tsunami and 1500 yr BP tsunami.

Future work

Determining the precise ages and depositional patterns of these layers through radiocarbon dating, more grain-size analysis, geochemical analysis, microtextural analysis, heavy mineral distribution patterns, and microfossil distribution within the sediment cores. These aim to establish a robust tsunami event stratigraphy for the region. Combined with planned relative sea-level reconstructions, this stratigraphy will enable us to improve the paleotsunami run-up height assessment by correlating onshore and offshore deposits.

Acknowledgement

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