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Research paper

Sandwaves and sand transport on the Barents Sea continental slope offshore northern Norway

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ABSTRACT

We integrate morphological, geological and geophysical observations with oceanographic measurements and modelling results to interpret the processes behind the origin and evolution of sandwaves on the upper continental slope of the southwestern Barents Sea. Seven sandwave fields covering c. 130 km^2 and with a volume of c. 72 × 10^6 m^3 occur in water depths of c. 475–800 m. Individual sandwaves reach heights up to 6 m. The sandwaves are sinusoidal with asymmetric stoss–lee side relationships, and time lapse multibeam bathymetry analysis indicates that some sandwaves have migrated up to 10 m towards the NNW over a 4-year time period. This contour current parallel migration is counteracted by currents in several other directions, and the sand unit is thus not a simple contourite. Measurements show prominent diurnal period oscillations and clear spring-neap variations of current direction and speed with along-slope and cross-slope current velocities up to 75 cm s^{-1} and 65 cm s^{-1}, respectively. Numerical ocean modelling results produce eddies travelling along the slope, positionally stable, daily recurring vortices and bottom current velocity up to 100 cm s^{-1} in the sandwave fields. Sandwave migration towards the SE is also observed, and the cross-slope currents are capable of transporting sand up and down the slope, as evidenced by ripples migrating normal to the sandwaves. Eroded sand accumulates in the sandwave fields along the boundary between North Atlantic Water and Norwegian Sea Arctic Intermediate Water. This is a consequence of the combined effect of the NNW directed along-slope Norwegian Atlantic Current and tidally induced topographic waves. The sandwave fields started to form 11 000–13 000 ^{14}C yrs BP or possibly later by current erosion of glacial sediments on the continental shelf and slope.

1. Introduction

Sandwaves have been widely documented on continental shelves around the world (e.g., Flemming, 1980; Viana et al., 1998). Their formation requires the operation of bottom currents to erode, transport and deposit sands. Local variations in topography, sediment availability, hydrodynamic regime and global variations in climate and sea-level influence their formation, distribution and evolution. The dynamic nature of sandwaves can present a navigation hazard in shallow areas and pose a risk to seabed infrastructure such as pipelines.

Mud-dominated sediment waves in deepwater environments have been described from many areas and attributed to downslope-flowing turbidity currents and alongslope-flowing bottom (contour) currents (e.g., Wynn and Stow, 2002). Detailed studies of sandwaves in deepwater environments are more limited (Faugéres et al., 1999), but with increasing availability of high resolution marine geophysical and oceanographic datasets, supplemented by modelling, we now have the potential to gain a better understanding of how sandwaves form and evolve. Known occurrences of sandwaves on the continental slope include those in the

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South China Sea (Reeder et al., 2011), the Strait of Gibraltar (Heezen and Hollister, 1971), Gulf of Cadiz (Kenyon and Belderson, 1973; Baraza et al., 1999; Habgood et al., 2003; Hanquiez et al., 2007), and the Faeroe-Shetland Channel (Kenyon, 1986; Masson, 2001).

The sandwaves on the southwestern Barents Sea continental margin were first noted from sidescan investigations by Kenyon (1986). The sandwaves occur at c. 475–800 m water depth, and are most prolific in two areas (Fig. 1). Video data acquired under the MAREANO programme (www.mareano.no) indicated that they are mainly composed of well-sorted sand transported by the Norwegian Atlantic Current (NAC) towards the NNW. However, sediment transport directions suggested by the orientation of sandwaves and superimposed sand ripples indicated a more complex hydrologic regime than a simple continuous northward contour current which drives the bedforms. Thus, a project under the Norwegian Deepwater Programme (NDP, 2014) was initiated to study the sandwaves. The present paper is the last in a series of three, where the first, by King et al. (2014), presented a detailed description and statistical analyses of the sandwaves based on existing MAREANO data, and the second, by Skarðhamar et al. (in press), oceanographic measurements and modelling results. Here, we integrate geological and morphological observations, including time lapse multibeam bathymetry, with the oceanographic results to interpret the processes behind the origin and evolution of the sandwave fields.

2. Physical setting

2.1. Geological setting

The continental shelf offshore northern Norway has been glaciated multiple times during the Quaternary (Sættem et al., 1992; Vorren et al., 1998), and during the last glaciation it was located at the confluence of the Fennoscandian and Barents Sea ice sheets (Vorren and Kristoffersen, 1986; Landvik et al., 1998; Winsborrow et al., 2010). During maximum glaciation, the ice sheets covered the entire continental shelf, reaching the shelf edge. Major ice streams operated at this time in cross-shelf troughs, including the Bear Island Trough and Håkjerringdjupet (Fig. 1) and discharged large volumes of sediment and meltwater (Vorren and Laberg, 1996; Ottesen et al., 2008; Winsborrow et al., 2010). The glacigenic sequence of the SW Barents Sea has been described as a succession of prograding units with glacial debris flows (e.g., Vorren et al., 1991; Sættem et al., 1992, 1994; Rafaelsen et al., 2002; Andreassen et al., 2004). Stratified units were deposited predominantly in glacial marine environments when the ice margin retreated from the outermost shelf (Rise et al., 2012), and fine-grained sediments accumulated very slowly on the shelf and slope during interglacial periods. Chronological control is limited, however the few available dates suggest that initial ice retreat from the shelf edge occurred prior to c. 14 500 ^{14}C yrs BP (Rüther et al., 2011).

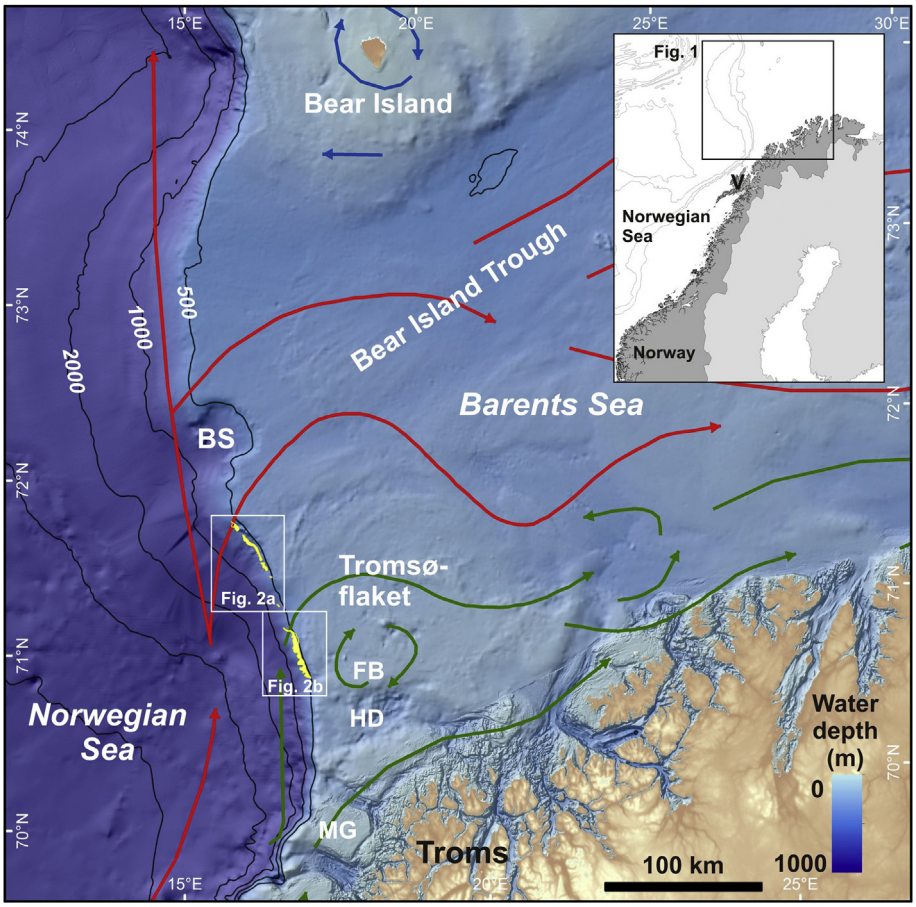

Figure 1. Bathymetric map of the southwestern Barents Sea and continental slope showing the location of the main southern and northern sandwave areas (yellow polygons), surface ocean currents and place names mentioned in the text. Red arrows: Norwegian Atlantic Current; green arrows: Norwegian Coastal Current; blue arrows: arctic water; HD: Håkjerringdjupet; FB: Fugløybanken; BS: Bear Island Slide; V: Vesterålen. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)