# A HIGH-RESOLUTION CARBONATE RECORD FROM HOLOCENE IMAGES CORE MD99-2286, SKAGERRAK

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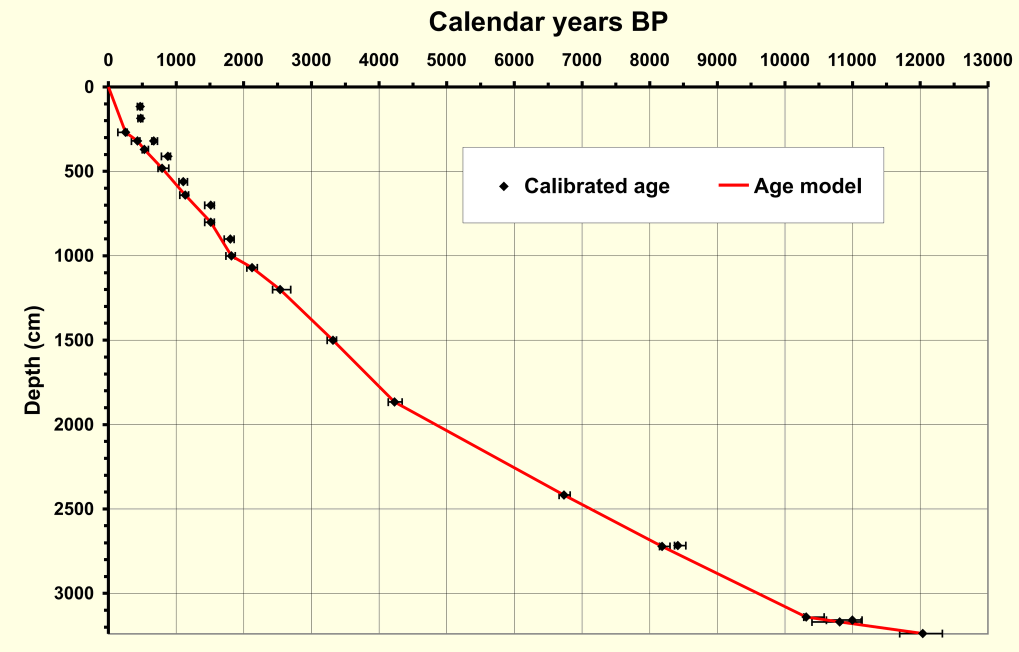
## Introduction

Skagerrak is the deepest part and the major sediment trap of the North Sea. The investigated area is characterised by intense water mass mixing and high sedimentation rates, up to 1 cm/year (Bøe et al., 1996), as a branch of the North Atlantic Current turns anti-clockwise, slows down and becomes mixed with other waters to form the Norwegian Coastal Current (figure 1). Present-day SSTs in Skagerrak are strongly linked to the NAO-index. Coring was performed in 1999 within the International Marine Past Global Changes Study program (IMAGES). Marine sediments in the 32.4 m long piston core MD99-2286, provides a continuous and detailed palaeoceanographic and palaeoenvironmenatal record of the last 12 000 years in the Skagerrak.

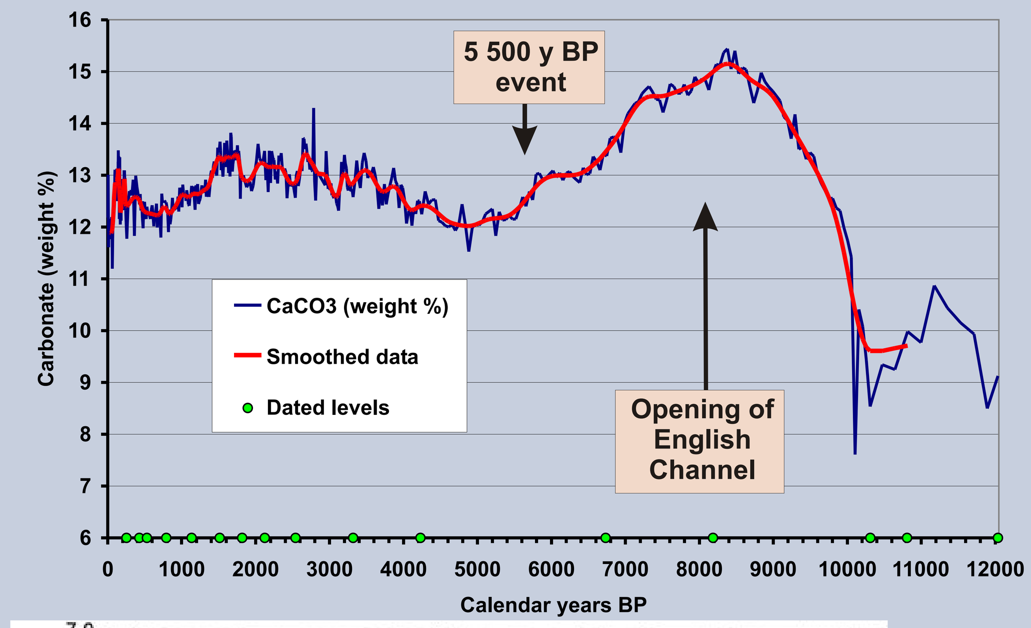
Figure 2 **Age model**

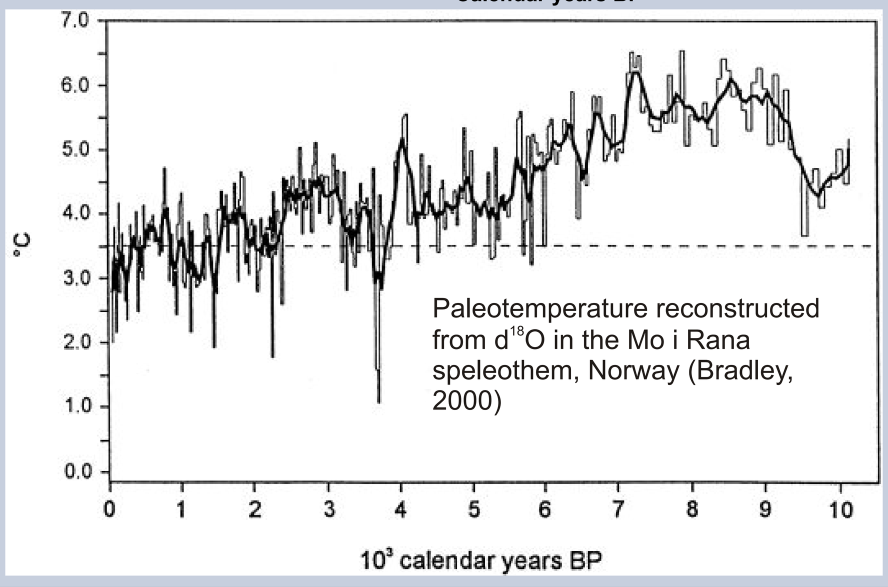



The chronostratigraphic control of core MD99-2286 relies on twenty-five AMS C-14 dates performed by the Institute of Particle Physics, ETH, Zürich, Switzerland. The radiocarbon dates were calibrated using the CALIB (rev 4.3) software (Stuiver and Reimer, 1993) and the MARINE98 calibration data set (Stuiver et al., 1998a) with a delta R-value of -40 ± 25 $^{14}C$-years (Stuiver and Braziunas, 1993), assuming 100 % marine carbon.


Major currents in the North Sea area. The location of core MD99-2286 is indicated with an arrow. (Map by Geological survey of Norway)

Figure 3 **$CaCO_3$ vs Age**




## Data and Methods

### Dating

The chronostratigraphic control of core MD99-2286 relies on twenty-five AMS C-14 dates performed by the Institute of Particle Physics, ETH, Zürich, Switzerland. The calibrated ages shows that core MD992286 spans 12000 calendar years, thus encompassing the entire Holocene. Nine of the twenty-five dates were omitted from the age model because of supposed reworking (figure2).

### Carbonate content

Carbonate content in core MD99-2286 was measured using coulometry, with a sampling resolution of 5 cm in the interval 0 -15 m, 10 cm in the 15 - 32.4 m interval, and 2 cm in the interval 1 - 2.5 m (figure 3).

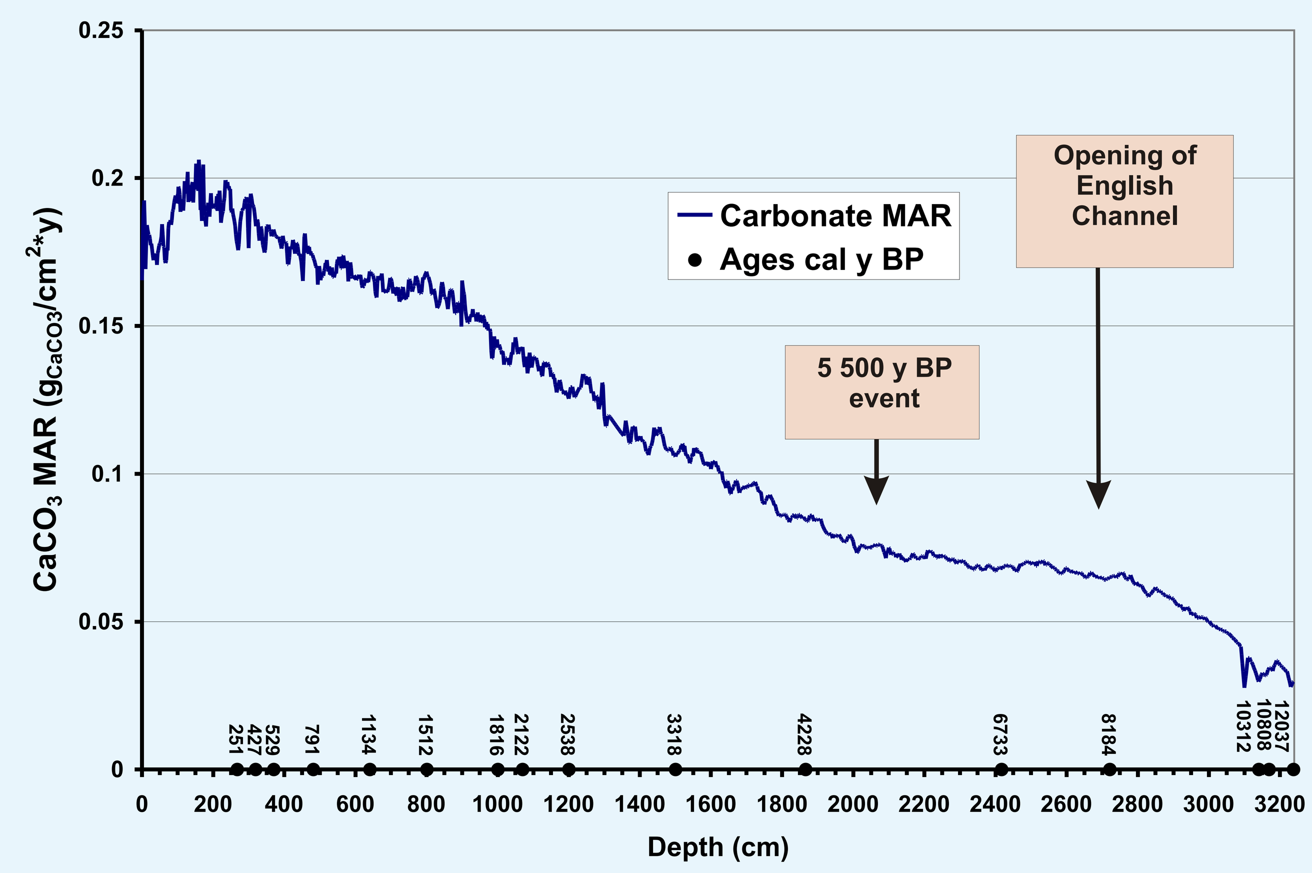
### Carbonate Mass Accumulation Rates

The conversion of $\%CaCO_3$ to $CaCO_3$ Mass Accumulation Rate (MAR) corrects for the effects of dilution by siliciclastic material in the sediments (figure 4). $CaCO_3$ MAR was calculated as

$$CaCO_3\ MAR\ (g/cm^2y) = \text{weight fraction } CaCO_3 * \text{dry bulk density } (g/cm^3) * \text{linear sedimentation rate } (cm/y) \quad (1)$$

Dry bulk density was estimated from Gamma Ray Attenuation (GRA) density data from MST measurements with 2-cm resolution, which were calibrated using true dry bulk density measured using gas pycnometry with 100-cm sample resolution.

Figure 4 **$CaCO_3$ Mass Accumulation Rates**

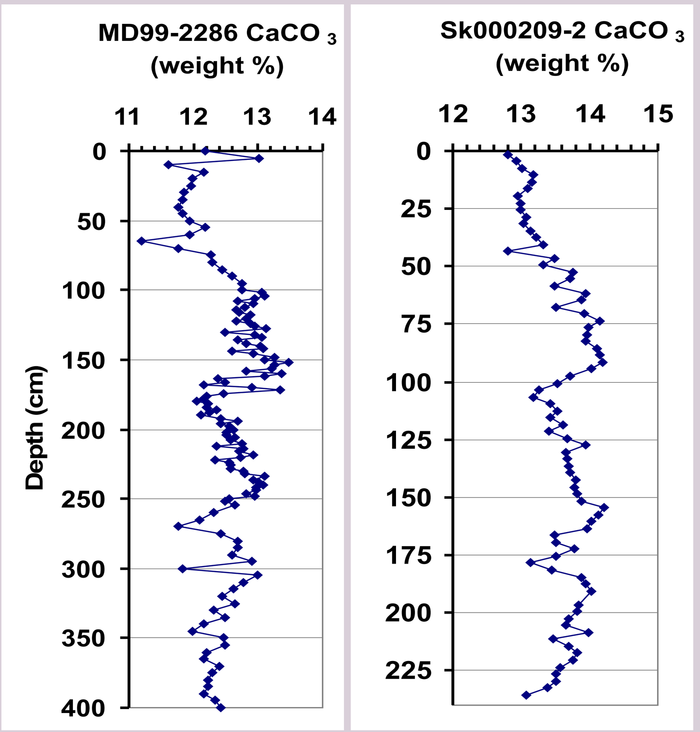



The linear sedimentation rate was interpolated between C-14 dated levels in the core, which gives the $CaCO_3$ MAR vs Age plot distinct steps at the inflection points of the age model. In order to obtain a non incremental sedimentation rate, a 3:rd grade polynomial function

$$y = (0.0000002\, x^3) + (0.00007\, x^2) + (1.662\, x) \quad (2)$$

where y = Age (cal y BP) and x = Depth (cm), was fitted to the age model ($R^2$= 0.997). The sedimentation rate at a certain depth is then given by the gradient of the polynomial curve, i.e. the derivative of (2). For computing reasons, the carbonate content was resampled to the same sample resolution as the GRA-density data (2 cm), using linear interpolation.

## Carbonate content as a correlation tool




A 2.5 m long gravity core, Sk000209-2, was retrieved from the same area as MD99-2286 in order to get full recovery of the surface sediments. An age model, based on 7 Pb-210 dates and 2 AMS C-14 dates, shows that Core Sk000209-2 comprises 0 - 900 calendar years (Senneset, 2002). Correlation using carbonate contents indicate that the core top in MD99-2286 is of modern (zero) age, and that the sediment in the CALYPSO core MD99-2286 is expanded by a factor 1.6 relative to the gravity core Sk000209-2.

## Results and Discussion

The probable processes controlling carbonate content in the Skagerrak sediments are primary productivity, redeposition of older carbonate particles (mainly controlled by the Jutland Current) and dilution by siliciclastic material. Observations:

- $CaCO_3$ MAR increase from 12 000 to 8 000 cal y BP
- $CaCO_3$ MAR is nearly constant and siliciclastic sedimentation increase from 8 000 to 5 500 cal y BP
- $CaCO_3$ MAR steadily increase after 5 500 cal y BP
- During the last 200 years, $CaCO_3$ MAR decrease rapidly.

The shift in $CaCO_3$ MAR at 8 000 cal y BP coincides with the opening of the English Channel (Lambeck, 1995; Conradsen and Heier-Nielsen, 1995), which was a prerequisite for the formation of the Jutland Current and subsequently the modern Norwegian Current.

High calcium carbonate contents during the Holocene reflects a stronger inflow of North Atlantic surface water in the Norwegian Sea, leading to formation of the Norwegian current; a major source of heat for the Scandinavian landmass (Kellogg, 1977; Heinrich et al., 1989). The carbonate record from MD99-2286 correlates with a palaeotemperature reconstruction based on oxygen isotopes (Bradley, 2000) from a coast-near speleothem in northern Norway (figure 5). The correlation is positive from 10 000 to 5 500 cal y BP, and negative from 5 500 cal y BP to present. The timing of the shift in this correlation, and the onset of steady increase in $CaCO_3$ MAR, coincides with a hydrographic change in the Skagerrak at 5 500 cal y BP, interpreted from grain size and biostratigraphical data (Jiang et al., 1997). This change is manifested by an increase in the Jutland Current and stronger inflow of saline North Sea water to Skagerrak and Kattegat, and marks the establishment of the modern circulation pattern.

## Conclusions

1. Core MD99-2286 spans 0 - 12 000 calendar years
2. Siliciclastic deposition in northeastern Skagerrak increase after the Opening of the English Channel
3. Calcium carbonate mass accumulation rates starts to increase at 5 500 cal y BP, when the Jutland Current intensified and the modern circulation pattern was established.
4. Regardless of the carbonate source (primary productivity or redeposition), the carbonate content in north eastern Skagerrak sediments reflects major oceanographic changes during the Holocene.

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