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# Reconstructing a continuous Holocene composite sedimentary record for the eastern Gotland Deep, Baltic Sea

Aarno T. Kotilainen*, Jyrki M.S. Hämäläinen and Boris Winterhalter

*Geological Survey of Finland, Betonimiehenkuja 4, FIN-02150 Espoo, Finland (*e-mail: aarno.kotilainen@gsf.fi)*

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It has been generally assumed that sediments in the deepest parts of the Gotland Basin have accumulated in a relatively calm depositional environment during the entire Holocene, thus representing a continuous sedimentary record. As part of the Baltic Sea System Study (BASYS) we have had access to several long cores from the Gotland Deep, which we have investigated in detail. The study, utilising sediment physical properties (e.g., magnetic susceptibility) and lithostratigraphic (core descriptions, photographs, stereo X-ray radiographs) data, has shown that even over very short horizontal distances the sedimentary records reflect considerable variations in sediment accumulation. Definable sedimentary units show marked variation in thickness, including clear hiatuses. These indicate that environmental conditions have been far more dynamic than has been previously assumed, and that the patchy nature of sediment deposition in the Baltic Sea is characteristic also to the Gotland Deep. This is true especially of the Litorina Sea, Post-Litorina Sea and Recent Baltic Sea stages of the Baltic Sea (~ past 7500–8000 cal years BP). Due to the fact that sediment stratigraphy can change a lot even over very short distances in this deep basin, correlation between different cores should be done with great care. To produce a stratigraphically continuous sequence for the Gotland Deep, we have spliced data together from several different cores.

## Introduction

Several studies have shown that sediments from Baltic Sea basins contain detailed information on changes in the Holocene palaeo-environment and palaeo-climate (e.g. Salonen *et al.* 1995, Sohlenius *et al.* 1996, Sternbeck and Sohlenius 1997, Andrén *et al.* 1999, Andrén *et al.* 2000a, 2000b, Emeis *et al.* 2000, Sohlenius *et al*. 2001). This is also one of the main reasons why one of the sub-projects in the multi-disciplinary Baltic Sea System Study (BASYS), addressing the

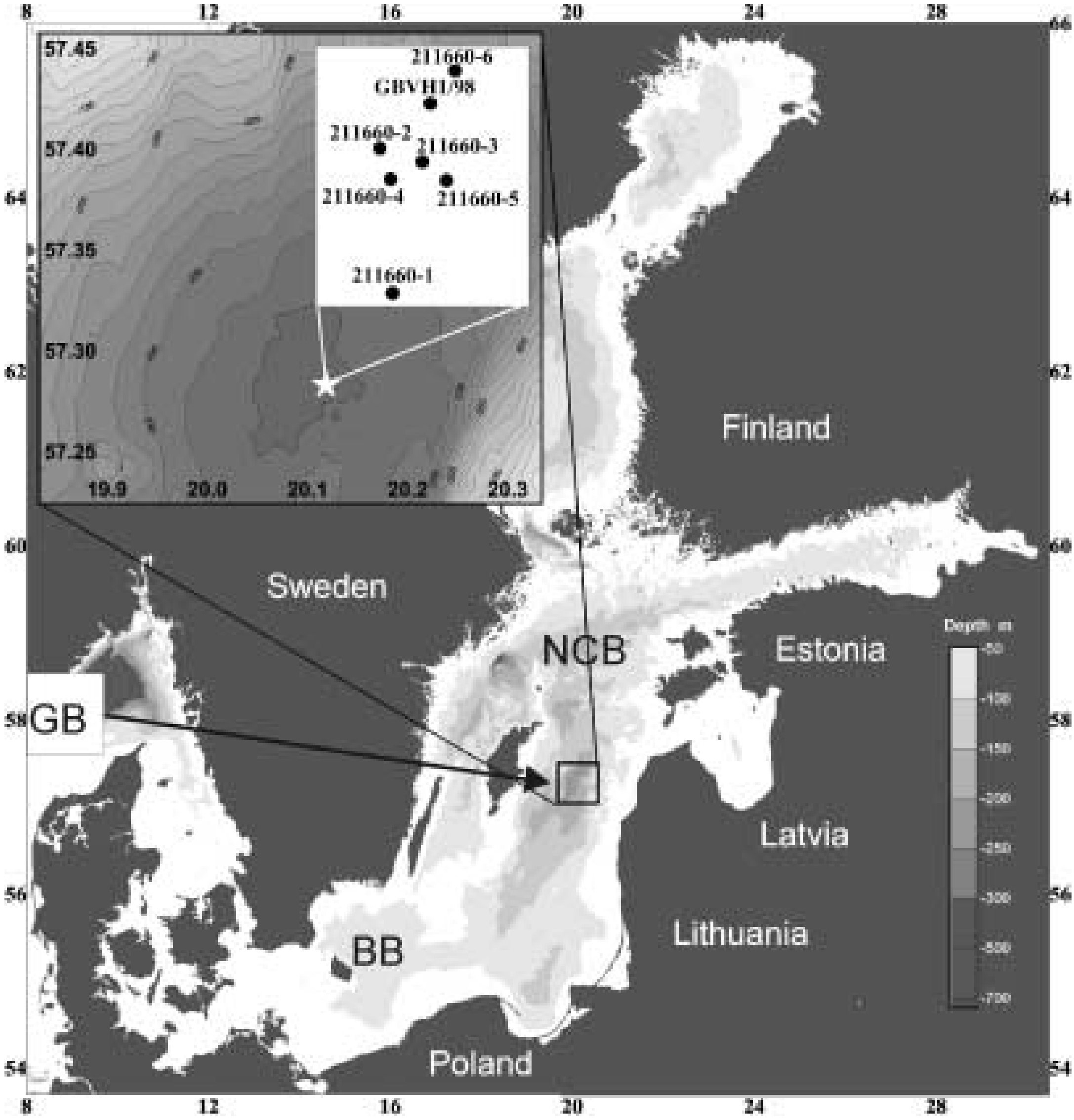


**Fig. 1**. Index map of the Baltic Sea and surrounding countries. The general bathymetry is based on data from Seifert and Kayser (1995). BB, GB and NCB indicate Bornholm Basin, Gotland Deep and North Central Basin, respectively. The black square in the central Baltic Sea indicates the location of the study area. Small inset in the upper left corner of the map shows the location of the Gotland Deep cores.

present and past environmental issues, is especially directed towards the detailed sedimentary study of three carefully chosen basins: Bornholm Basin, Gotland Deep and North Central Basin.

The relatively high linear sedimentation rate in these basins, average of 1 mm/year during the Litorina phase for the central Gotland Basin (e.g. Ignatius 1958, Ignatius and Niemistö 1971), provides a good temporal resolution for detailed palaeo-environmental studies. For the most recent sediments from the Gotland Deep even higher average linear sedimentation rates (> 2 mm/year) have been observed (e.g. Kunzendorf and Christiansen 1997, Emeis *et al.* 1998).

The main purpose of the present study is to reconstruct a continuous sedimentary record for the Gotland Deep. These continuous records are essential e.g. for the high-resolution palaeoclimate, palaeo-environment, and dating studies (Kotilainen *et al.* 2000). However, the patchy nature of sediment deposition even in the deepest basins of the Baltic Sea (Winterhalter 1992) makes it very difficult to acquire a sediment core exhibiting a continuous sedimentary record. In addition to variations in sedimentation rates, sediment cores may exhibit errors and disturbances caused, e.g. during coring, recovery, cutting, splitting and sampling procedures (Ruddiman *et al.* 1987, Rea *et al.* 1993). Thus, a reliable continuous sedimentary record from a specific study area should be based on several cores using "composite depth" method. In the "composite depth" method data from different records are spliced (or joined) together so that the gaps in the records could be avoided. If the gap occurs in the one record, the construction of continuous record continues to the other core where the record is undisturbed etc. This splicing is based on the careful and detailed correlation between the cores, e.g. by using high-resolution magnetic susceptibility measurements. Using the "composite depth" method, at least some of the disturbed intervals can be avoided. This "composite depth" method has been used successfully already for a long time by the Ocean Drilling Program (ODP) and its predecessor the Deep Sea Drilling Project (DSDP) in the deep-sea environment (e.g. Ruddiman *et al.* 1987), but it is applicable also to smaller basins like the Baltic Sea and lakes.

## Study area

The Gotland Deep is one of the deepest basins (maximum depth of ~249 m; Fig. 1) in the Baltic Sea and one of the largest brackish water bodies on Earth. After the last glaciation the Baltic Sea has been connected continuously with the Atlantic Ocean over the past ~8000 years (e.g. Sohlenius *et al.* 1996, Andrén *et a*l. 2000a, Sohlenius *et al*. 2001), via the Danish straits. The low average salinity of the Baltic Sea is due to restricted exchange with the North Sea and the relatively high runoff of fresh water. The average inflow of saline deep-water into the Baltic Proper has been estimated to 475 $km^3 yr^{-1}$ and the outflow of surface-water to 950 $km^3 yr^{-1}$ (HELCOM 1993). The fresh water input to the Baltic Sea generates a brackish surface layer of ~7‰ salinity in the study area while the incoming subsurface flow from the North Sea increases the salinity of the bottom waters to ~14‰ (Kullenberg 1981). Well-mixed surface water is separated from dense bottom waters by haloclines. This density stratification, which is characteristic for most of the deep basins, including the Gotland Deep, leads to occasional anoxia in bottom-near waters. These periods of stagnation are mainly the result of the depletion of dissolved $O_2$ levels in the dense bottom waters caused by oxidation and bacterial decomposition of organic material. The oxygen in the deep water is occasionally replenished by pulses of highly saline and oxygenated North Sea water. Major inflows in more recent times occurred e.g. in 1976 and 1993 (Matthäus and Lass 1995).

## Methods

The location of the four long sediment cores taken in the Gotland Deep and used in the present study are shown in Fig. 1 and listed in Table 1. Cores 211660-1, 211660-5 and 211660-6 were recovered during the *r/v Petr Kottsov* BASYS

**Table 1**. Location, depth, type and recovery of the long cores.

| Core | Latitude | Longitude | Depth (m) | Gear* | Recovery (m) |
|---|---|---|---|---|---|
| 211660-1 | 57°16.9772 N | 20°07.1122 E | 240.3 | PC | 8.79 |
| 211660-5 | 57°17.0030 N | 20°07.1347 E | 241.3 | SL | 8.29 |
| 211660-6 | 57°17.0283 N | 20°07.1386 E | 240.3 | KAL | 7.35 |
| GBVH1/98 | 57°17.0208 N | 20°07.1280 E | 241.0 | VH | 4.58 |

* PC = piston corer, SL = gravity corer, KAL = Kastenlot (box corer, long), VH = vibro-hammer corer.

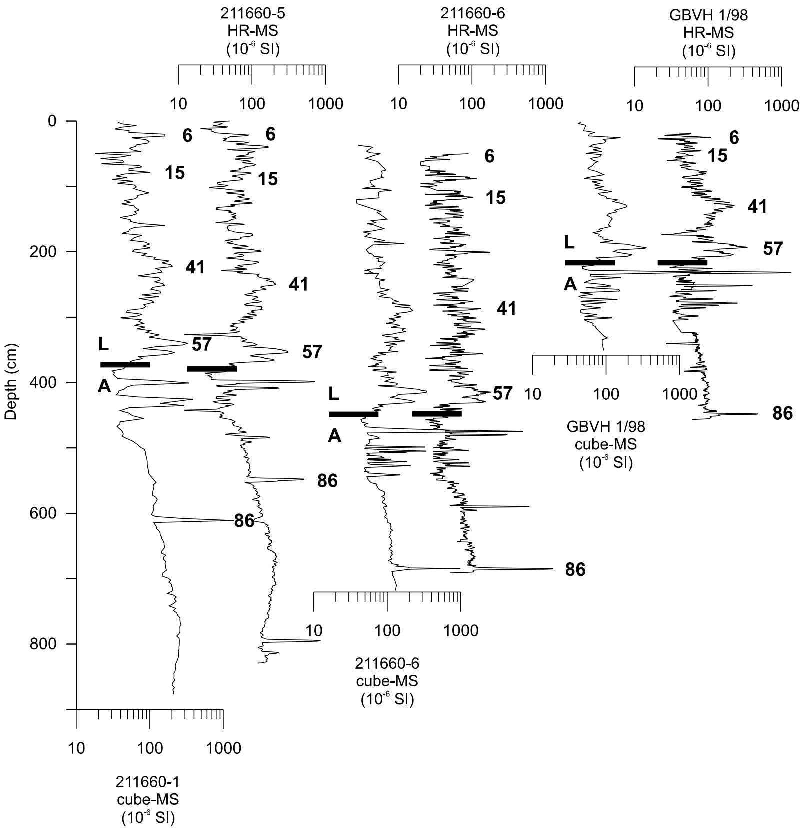


**Fig. 2**. Bulk susceptibility records for Gotland Deep long cores. High-resolution (at every 5 mm) measurements (HR-MS) were made from cores 211660-5, 211660-6, and GBVH 1/98. Cube-MS measurements were run from cores 211660-1, 211660-6, and GBVH 1/98, at every 2.5–3 cm. L/A indicates the Litorina/Ancylus lithostratigraphical boundary. Also shown are a few correlation tie points (numbers in boldface).

Cruise in July–August 1997. The vibro-hammer core GBVH 1/98 was acquired during the *r/v Aranda* cruise in April 1998.

The Kastenlot core 211660-6 was opened, described, photographed and subsampled onboard the *r/v Petr Kottsov*. The other cores were opened at the shore-based laboratories (at GSF, Espoo; IOW, Warnemünde; and SU, Stockholm) and described, photographed and subsampled (by the authors) there. Cores 211660-1, 211660-6 and GBVH 1/98 were subsampled for mineral magnetic and palaeomagnetic studies almost continuously (~ at every 2.5 cm), using polystyrene sample boxes, "cubes" (size of approximately $2 \times 2 \times 2$ cm). Continuous subsamples for X-ray radiographs (and for high-resolution magnetic susceptibility measurements) from cores 211660-5, 211660-6 and GBVH 1/98 were collected using 50 cm long plastic electrical installation liners 1.5 cm by 5 cm in cross section.

Magnetic susceptibility measurements were applied to core correlation. The magnetic susceptibility is a function of the concentrations (i.e. mass, mineralogy and grain size) of magnetizable material that the sample contains (Thompson and Oldfield 1986). Downcore variations in the magnetic susceptibility values of marine sediments reflect changes in lithology, which reflects fluctuations in the ratio of biogenic to lithogenic components in the sediment (Robinson 1990) and variations in mineralogical constituents. It has been shown that magnetic susceptibility measurements are a useful tool for (high-resolution) core correlations in lakes (e.g. Thompson 1973, Thompson *et al.* 1975, Oldfield *et al.* 1978, Bloemendahl *et al.* 1979, Thompson and Oldfield 1986) as well as in the deep-sea (e.g. Robinson 1982, 1986, Thompson and Oldfield 1986).

In the present study, the bulk susceptibility (K) was measured from the subsamples using a KLY-2 susceptibility meter (Jelinek 1973), and the high-resolution magnetic susceptibility

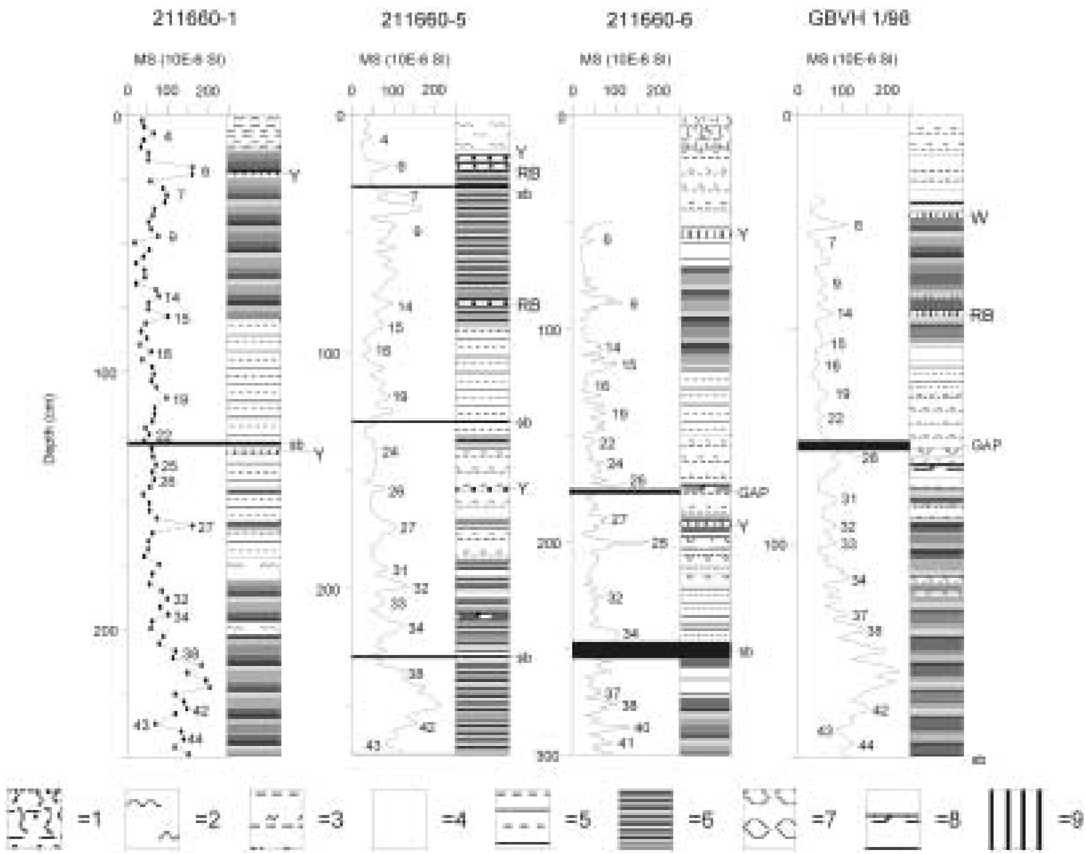

**Fig. 3**. Lithostratigraphy and susceptibility record for the upper part of the Gotland Deep long cores. Susceptibility events are shown by numbers. Y, RB and W indicate yellow, reddish brown and whitish horizons in sediment column, respectively. A short gap found in the cores GBVH 1/98 and 211660-6 is indicated in the figure, as well as section and core breaks (sb). The symbols for sediment lithostratigraphy are (1) Bioturbated slightly banded mud with black spots, (2) Disturbed sediment, (3) Mud with slightly mottled colour banding, (4) Homogenous mud, (5) Mud with colour banding, (6) Finely laminated mud, (7) Shells, (8) Erosional structures, and (9) Coloured horizons (e.g. yellow laminae).

measurements (at every 5 mm) were made from the 50 cm long rectangular plastic liners before taking X-ray radiographs, using a Barlington MS2E1 Surface Scanning Sensor. Core images were either scanned from photographs or directly produced from the split core by digital techniques (scanner or digital camera).

The Gotland Deep cores used in the present study were correlated visually, using magnetic susceptibility data and digital as well as X-ray core photographs. For the correlation procedure, both a 5-point running mean of the high-resolution susceptibility data, and the raw ”cube” susceptibility records were used.

## Results

Sediment core descriptions and photographs were used as a starting point in the core-to-core correlation work. For intervals, which needed a closer examination, X-ray radiographs were a great help. Unfortunately, X-ray radiographs were not available for core 211660-1. Main lithostratigraphical events (e.g. Litorina/Ancylus boundary; Andrén *et al.* 2000a, several finely laminated intervals and some colourful horizons) can be recognised and correlated between each core (Figs. 2 and 3).

A closer look at our data revealed considerable variations in rate of deposition from core to core including several gaps and larger hiatuses. The hiatuses we found were mainly short (in duration), but some significant gaps were found too. The most significant sedimentary gap was observed in the core GBVH 1/98 at the depth of around 77 cm. Sediments from this core were eroded from susceptibility event 26 down, close to event 28. In the lithostratigraphy this interval showed definite signs of disturbance. Shell fragments of the bivalve *Macoma calcaria* are associated with the hiatus. This erosional surface can probably also be seen in cores 211660-1, 211660-5 and 211660-6 at the depths of 141.7, 157.5 and 179 cm, respectively. According to the X-ray radiographs approximately 7–8 cm of sediment is missing (below the magnetic susceptibility event 26) from the core GHVH 1/98 and a few cm from the core 211660-6. These gaps, based on a correlation with core 211660-1, correspond approximately to time intervals of 400 and 20–30 years, respectively (Kotilainen *et al.* 2000).

The correlation procedures between the different Gotland Deep long cores 211660-1, 211660-5, 211660-6 and GBVH 1/98 were relatively easy, and the correlations between these cores seem to be very good. Totally, 130 different susceptibility "events" were used to tie different cores together (Table 2).

Although our detailed study of the cores has revealed erosional features and marked variations in thicknesses between identifiable laminae or layers, the sedimentation seems to have been relatively continuous in the Gotland Deep throughout the Holocene (dating of these cores is shown elsewhere, Andrén and Andrén 1999, Andrén *et al.* 2000a, Kotilainen *et al.* 2000). However, the observed hiatuses and variations especially in the sedimentation rates between different cores, even over very short distances, are factors to be considered when evaluating the palaeo-environment on the basis of sediment cores. It should be noted that the greatest variations are restricted to the middle and latter part of the marine Litorina phase. The late-glacial and early post-glacial (Baltic Ice Lake to Ancylus Lake) sediments seem to represent a more uniform rate of deposition.

In order to produce a continuous high-resolution sedimentary record for the Gotland Deep we have constructed, on the basis of our core correlation, the following composite depth scale. The greatest difficulty was to avoid section and core breaks in the different records (in this case bulk susceptibility records). In almost every 50 cm sample liner, the susceptibility data were slightly disturbed (lower values) in the first bottom and top centimetres. To produce a continuous and relatively undisturbed proxy record from this susceptibility data we spliced data together from offsets (e.g. liner breaks) using data from cores 211660-5 and 211660-6. Composite depth sections can be seen in Table 3. Fig. 4 shows bulk susceptibility record for the Gotland Deep composite depth record.

In the case when two records, like 211660-5 and 211660-6, were overlapping, the composite proxy record (in this case bulk susceptibility) was easy to construct by simply jumping from one record to another thus avoiding section breaks or other disturbances. This core-to-core or more exactly liner-to-liner correlation (Table 3) was based on bulk susceptibility events (Table 2). In the few cases with no possibilities to use data from other cores to replace gaps (e.g. section breaks or other disturbances) seen in the record, disturbed intervals were deleted from the studied records (i.e. no susceptibility data was used from these intervals).

## Discussion and Summary

The cores investigated in the present study could be relatively well cross-correlated throughout the Holocene. However, the study also showed that on a finer scale, considerable variations in e.g. sedimentation rates could be observed even between cores taken within close proximity of each other, (within one hundred metres or less). Features found in one core could not always be observed in an adjacent one. A major gap was observed at approximately 2200 varve years BP (Kotilainen *et al.* 2000), lasting approximately for 400 and 20–30 years in cores GBVH 1/98 and 211660-6, respectively.

The observed variations in sediment accumulation in cores close together in the Gotland Deep may be explained by the nature of bottom

**Table 2**. Correlation between the different Gotland Deep long cores used in this BASYS study. The correlation is based mainly on the susceptibility events (4–130) shown here.

| Core | Mag. susc. event | Depth (cm) | Core | Mag. susc. event | Depth (cm) |
|---|---|---|---|---|---|
| 211660-1 | 4 | 7.0 | 211660-1 | 84a | 578.6 |
| 211660-1 | 6 | 23.0 | 211660-1 | 85 | 601.9 |
| 211660-1 | 7 | 31.2 | 211660-1 | 86 | 610.9 |
| 211660-1 | 9 | 47.0 | 211660-1 | 87 | 614.1 |
| 211660-1 | 13 | 63.0 | 211660-1 | 88 | 651.5 |
| 211660-1 | 14 | 70.4 | 211660-1 | 89 | 660.9 |
| 211660-1 | 15 | 78.4 | 211660-1 | 90 | 664.1 |
| 211660-1 | 16 | 92.0 | 211660-1 | 91 | 670.4 |
| 211660-1 | 17 | 100.8 | 211660-1 | 92 | 673.5 |
| 211660-1 | 19 | 110.0 | 211660-1 | 93 | 676.8 |
| 211660-1 | 22 | 124.2 | 211660-1 | 96 | 687.1 |
| 211660-1 | 25 | 136.0 | 211660-1 | 97 | 695.8 |
| 211660-1 | 26 | 141.7 | 211660-1 | 98 | 702.2 |
| 211660-1 | 27 | 159.7 | 211660-1 | 99 | 705.3 |
| 211660-1 | 32 | 188.1 | 211660-1 | 100 | 715.1 |
| 211660-1 | 34 | 194.3 | 211660-1 | 101 | 722.4 |
| 211660-1 | 37 | 202.8 | 211660-1 | 102 | 734.7 |
| 211660-1 | 38 | 208.5 | 211660-1 | 103 | 741.8 |
| 211660-1 | 39 | 214.0 | 211660-1 | 104 | 759.8 |
| 211660-1 | 41 | 222.6 | 211660-1 | 105 | 763.1 |
| 211660-1 | 42 | 231.0 | 211660-1 | 106 | 770.3 |
| 211660-1 | 43 | 236.9 | 211660-1 | 107 | 777.2 |
| 211660-1 | 44 | 242.8 | 211660-1 | 108 | 787.7 |
| 211660-1 | 45 | 251.5 | 211660-1 | 109 | 794.7 |
| 211660-1 | 46 | 257.3 | 211660-1 | 110 | 807.7 |
| 211660-1 | 47 | 262.9 | 211660-1 | 111 | 811.1 |
| 211660-1 | 48 | 271.5 | 211660-1 | 112 | 817.4 |
| 211660-1 | 49a | 277.1 | 211660-1 | 113 | 830.5 |
| 211660-1 | 49b | 280.9 | 211660-1 | 114 | 834.5 |
| 211660-1 | 49c | 283.8 | 211660-1 | 115 | 844.8 |
| 211660-1 | 50 | 292.5 | 211660-1 | 116 | 855.2 |
| 211660-1 | 51 | 295.5 | 211660-1 | 117 | 862.8 |
| 211660-1 | 52 | 301.1 | 211660-1 | 118 | 866.4 |
| 211660-1 | 53 | 309.5 | 211660-1 | 119 | 870.0 |
| 211660-1 | 54 | 312.3 | 211660-1 | 120 | 873.5 |
| 211660-1 | 55 | 327.2 | 211660-5 | 4 | 3.5 |
| 211660-1 | 56 | 330.4 | 211660-5 | 6 | 22.0 |
| 211660-1 | 57 | 339.7 | 211660-5 | 7 | 32.5 |
| 211660-1 | 58 | 348.2 | 211660-5 | 9 | 50.5 |
| 211660-1 | 59 | 354.2 | 211660-5 | 13 | 65.5 |
| 211660-1 | 60 | 360.5 | 211660-5 | 14 | 79.5 |
| 211660-1 | 61 | 363.4 | 211660-5 | 15 | 89.5 |
| 211660-1 | 64 | 382.0 | 211660-5 | 16 | 99.5 |
| 211660-1 | 65 | 385.0 | 211660-5 | 17 | 107.5 |
| 211660-1 | 66 | 400.6 | 211660-5 | 18 | 117.5 |
| 211660-1 | 67 | 418.8 | 211660-5 | 19 | 120.0 |
| 211660-1 | 68 | 425.4 | 211660-5 | 20 | 125.0 |
| 211660-1 | 69b | 443.0 | 211660-5 | 21 | 130.0 |
| 211660-1 | 70 | 455.0 | 211660-5 | 22 | 133.5 |
| 211660-1 | 71 | 466.9 | 211660-5 | 23 | 137.5 |
| 211660-1 | 72 | 482.2 | 211660-5 | 24 | 141.0 |
| 211660-1 | 81 | 552.8 | | | |
| 211660-1 | 83 | 572.0 | | | |

*Continued*

**Table 2**. Continued.

| Core | Mag. susc. event | Depth (cm) | Core | Mag. susc. event | Depth (cm) |
|---|---|---|---|---|---|
| 211660-5 | 25 | 148.5 | 211660-5 | 77 | 476.0 |
| 211660-5 | 26 | 157.5 | 211660-5 | 78 | 479.0 |
| 211660-5 | 27 | 173.5 | 211660-5 | 79 | 484.0 |
| 211660-5 | 28 | 180.0 | 211660-5 | 80 | 486.0 |
| 211660-5 | 30 | 184.5 | 211660-5 | 81 | 490.5 |
| 211660-5 | 31 | 192.0 | 211660-5 | 82 | 499.0 |
| 211660-5 | 32 | 200.0 | 211660-5 | 83 | 512.5 |
| 211660-5 | 33 | 205.5 | 211660-5 | 84a | 515.0 |
| 211660-5 | 34 | 215.0 | 211660-5 | 84b | 521.0 |
| 211660-5 | 35 | 223.0 | 211660-5 | 84c | 536.0 |
| 211660-5 | 36 | 226.5 | 211660-5 | 85 | 544.0 |
| 211660-5 | 37 | 230.0 | 211660-5 | 86 | 548.0 |
| 211660-5 | 38 | 234.0 | 211660-5 | 87 | 552.0 |
| 211660-5 | 39 | 241.5 | 211660-5 | 88 | 574.0 |
| 211660-5 | 40 | 248.5 | 211660-5 | 89 | 579.0 |
| 211660-5 | 41 | 250.0 | 211660-5 | 90 | 580.5 |
| 211660-5 | 42 | 256.0 | 211660-5 | 91 | 584.0 |
| 211660-5 | 43 | 265.0 | 211660-5 | 92 | 587.5 |
| 211660-5 | 44 | 269.0 | 211660-5 | 93 | 589.0 |
| 211660-5 | 45 | 275.0 | 211660-5 | 94 | 594.5 |
| 211660-5 | 46 | 281.0 | 211660-5 | 95 | 599.5 |
| 211660-5 | 47 | 288.0 | 211660-5 | 96 | 601.0 |
| 211660-5 | 48 | 294.5 | 211660-5 | 97 | 611.5 |
| 211660-5 | 49a | 296.0 | 211660-5 | 98 | 618.0 |
| 211660-5 | 49b | 300.0 | 211660-5 | 99 | 620.0 |
| 211660-5 | 49c | 301.0 | 211660-5 | 100 | 629.5 |
| 211660-5 | 50 | 311.0 | 211660-5 | 101 | 632.5 |
| 211660-5 | 51 | 322.0 | 211660-5 | 102 | 641.5 |
| 211660-5 | 52 | 327.0 | 211660-5 | 103 | 654.0 |
| 211660-5 | 53 | 333.5 | 211660-5 | 104 | 662.5 |
| 211660-5 | 54 | 336.5 | 211660-5 | 105 | 672.5 |
| 211660-5 | 55 | 342.5 | 211660-5 | 106 | 675.5 |
| 211660-5 | 56 | 345.0 | 211660-5 | 107 | 679.5 |
| 211660-5 | 57 | 353.0 | 211660-5 | 108 | 682.0 |
| 211660-5 | 58 | 359.0 | 211660-5 | 109 | 684.0 |
| 211660-5 | 59 | 365.0 | 211660-5 | 110 | 691.5 |
| 211660-5 | 60 | 372.0 | 211660-5 | 111 | 697.5 |
| 211660-5 | 61 | 373.5 | 211660-5 | 112 | 709.0 |
| 211660-5 | 62 | 379.0 | 211660-5 | 113 | 715.0 |
| 211660-5 | 63 | 383.5 | 211660-5 | 114 | 717.5 |
| 211660-5 | 64 | 385.0 | 211660-5 | 115 | 726.5 |
| 211660-5 | 65 | 387.0 | 211660-5 | 116 | 733.0 |
| 211660-5 | 66 | 398.5 | 211660-5 | 117 | 738.0 |
| 211660-5 | 67 | 404.5 | 211660-5 | 118 | 739.5 |
| 211660-5 | 68 | 408.5 | 211660-5 | 119 | 742.0 |
| 211660-5 | 69a | 426.5 | 211660-5 | 120 | 744.0 |
| 211660-5 | 69b | 428.0 | 211660-5 | 121 | 752.5 |
| 211660-5 | 70 | 433.5 | 211660-5 | 122 | 756.5 |
| 211660-5 | 71 | 441.5 | 211660-5 | 123 | 781.5 |
| 211660-5 | 72 | 453.0 | 211660-5 | 124 | 786.5 |
| 211660-5 | 73 | 460.0 | 211660-5 | 125 | 789.0 |
| 211660-5 | 74 | 462.0 | 211660-5 | 126 | 795.0 |
| 211660-5 | 75 | 468.5 | | | |
| 211660-5 | 76 | 473.0 | | | |

*Continued*

**Table 2**. Continued.

| Core | Mag. susc. event | Depth (cm) |
|---|---|---|
| 211660-5 | 127 | 805.0 |
| 211660-5 | 128 | 813.0 |
| 211660-5 | 129 | 817.5 |
| 211660-5 | 130 | 822.0 |
| 211660-6 | 6 | 53.0 |
| 211660-6 | 7 | 62.5 |
| 211660-6 | 9 | 88.5 |
| 211660-6 | 13 | 100.0 |
| 211660-6 | 14 | 111.0 |
| 211660-6 | 15 | 116.0 |
| 211660-6 | 16 | 126.5 |
| 211660-6 | 17 | 131.5 |
| 211660-6 | 18 | 136.0 |
| 211660-6 | 19 | 140.0 |
| 211660-6 | 20 | 144.5 |
| 211660-6 | 21 | 147.5 |
| 211660-6 | 22 | 156.0 |
| 211660-6 | 23 | 158.5 |
| 211660-6 | 24 | 161.5 |
| 211660-6 | 25 | 170.0 |
| 211660-6 | 26 | 179.0 |
| 211660-6 | 27 | 196.0 |
| 211660-6 | 28 | 200.0 |
| 211660-6 | 30 | 206.5 |
| 211660-6 | 31 | 221.5 |
| 211660-6 | 32 | 229.5 |
| 211660-6 | 33 | 237.0 |
| 211660-6 | 34 | 242.0 |
| 211660-6 | 35 | 256.0 |
| 211660-6 | 36 | 260.5 |
| 211660-6 | 37 | 269.5 |
| 211660-6 | 38 | 276.5 |
| 211660-6 | 40 | 287.0 |
| 211660-6 | 41 | 294.5 |
| 211660-6 | 42 | 308.0 |
| 211660-6 | 43 | 310.5 |
| 211660-6 | 44 | 314.5 |
| 211660-6 | 45 | 318.5 |
| 211660-6 | 46 | 324.0 |
| 211660-6 | 47 | 330.0 |
| 211660-6 | 48 | 343.0 |
| 211660-6 | 49a | 350.0 |
| 211660-6 | 49b | 353.0 |
| 211660-6 | 49c | 356.5 |
| 211660-6 | 50 | 363.0 |
| 211660-6 | 51 | 367.5 |
| 211660-6 | 52 | 374.0 |
| 211660-6 | 53 | 382.5 |
| 211660-6 | 54 | 397.0 |
| 211660-6 | 55 | 403.0 |
| 211660-6 | 56 | 405.5 |
| 211660-6 | 57 | 414.5 |
| 211660-6 | 58 | 422.5 |
| 211660-6 | 59 | 430.5 |
| 211660-6 | 60 | 437.5 |
| 211660-6 | 61 | 440.5 |
| 211660-6 | 62 | 446.5 |
| 211660-6 | 63 | 453.0 |
| 211660-6 | 64 | 456.5 |
| 211660-6 | 65 | 459.5 |
| 211660-6 | 66 | 475.0 |
| 211660-6 | 67 | 476.5 |
| 211660-6 | 68 | 480.0 |
| 211660-6 | 69a | 517.5 |
| 211660-6 | 69b | 521.0 |
| 211660-6 | 70 | 522.5 |
| 211660-6 | 71 | 539.0 |
| 211660-6 | 72 | 548.0 |
| 211660-6 | 73 | 554.0 |
| 211660-6 | 74 | 561.5 |
| 211660-6 | 75 | 570.5 |
| 211660-6 | 76 | 575.0 |
| 211660-6 | 77 | 582.0 |
| 211660-6 | 78 | 587.5 |
| 211660-6 | 79 | 589.5 |
| 211660-6 | 80 | 592.5 |
| 211660-6 | 81 | 595.0 |
| 211660-6 | 82 | 614.5 |
| 211660-6 | 83 | 643.0 |
| 211660-6 | 84a | 644.5 |
| 211660-6 | 84b | 656.5 |
| 211660-6 | 84c | 668.5 |
| 211660-6 | 85 | 679.5 |
| 211660-6 | 86 | 685.0 |
| 211660-6 | 87 | 690.5 |
| GHVH 1/98 | 6 | 26.0 |
| GHVH 1/98 | 7 | 29.5 |
| GHVH 1/98 | 9 | 39.5 |
| GHVH 1/98 | 13 | 43.0 |
| GHVH 1/98 | 14 | 46.0 |
| GHVH 1/98 | 15 | 53.5 |
| GHVH 1/98 | 16 | 58.0 |
| GHVH 1/98 | 19 | 65.0 |
| GHVH 1/98 | 22 | 69.0 |
| GHVH 1/98 | 23 | 70.0 |
| GHVH 1/98 | 24 | 71.5 |
| GHVH 1/98 | 25 | 75.0 |
| GHVH 1/98 | 26 | 76.8 |
| GHVH 1/98 | 27 | GAP |
| GHVH 1/98 | 28 | 79.0 |
| GHVH 1/98 | 30 | 83.0 |
| GHVH 1/98 | 31 | 89.5 |
| GHVH 1/98 | 32 | 96.0 |
| GHVH 1/98 | 33 | 100.0 |
| GHVH 1/98 | 34 | 108.0 |
| GHVH 1/98 | 35 | 111.0 |

*Continued*

**Table 2**. Continued.

| Core | Mag. susc. event | Depth (cm) | Core | Mag. susc. event | Depth (cm) |
|---|---|---|---|---|---|
| GHVH 1/98 | 36 | 113.5 | GHVH 1/98 | 62 | 217.5 |
| GHVH 1/98 | 37 | 116.5 | GHVH 1/98 | 64 | 224.5 |
| GHVH 1/98 | 38 | 120.0 | GHVH 1/98 | 65 | 226.0 |
| GHVH 1/98 | 39 | 125.0 | GHVH 1/98 | 66 | 232.5 |
| GHVH 1/98 | 40 | 130.0 | GHVH 1/98 | 67 | 237.5 |
| GHVH 1/98 | 41 | 132.5 | GHVH 1/98 | 68 | 252.0 |
| GHVH 1/98 | 42 | 139.0 | GHVH 1/98 | 69a | 286.5 |
| GHVH 1/98 | 43 | 144.0 | GHVH 1/98 | 69b | 292.5 |
| GHVH 1/98 | 44 | 147.0 | GHVH 1/98 | 70 | 299.0 |
| GHVH 1/98 | 45 | 150.5 | GHVH 1/98 | 73 | 335.5 |
| GHVH 1/98 | 49a | 157.0 | GHVH 1/98 | 75 | 346.5 |
| GHVH 1/98 | 49b | 158.5 | GHVH 1/98 | 76 | 353.0 |
| GHVH 1/98 | 49c | 160.5 | GHVH 1/98 | 77 | 358.0 |
| GHVH 1/98 | 50 | 168.0 | GHVH 1/98 | 78 | 361.5 |
| GHVH 1/98 | 51 | 169.5 | GHVH 1/98 | 79 | 369.0 |
| GHVH 1/98 | 52 | 174.5 | GHVH 1/98 | 80 | 371.5 |
| GHVH 1/98 | 53 | 178.5 | GHVH 1/98 | 81 | 375.5 |
| GHVH 1/98 | 54 | 180.5 | GHVH 1/98 | 82 | 397.0 |
| GHVH 1/98 | 55 | 184.0 | GHVH 1/98 | 83 | 412.0 |
| GHVH 1/98 | 56 | 185.5 | GHVH 1/98 | 84a | 417.0 |
| GHVH 1/98 | 57 | 193.5 | GHVH 1/98 | 84b | 419.5 |
| GHVH 1/98 | 58 | 199.0 | GHVH 1/98 | 84c | 437.5 |
| GHVH 1/98 | 59 | 204.0 | GHVH 1/98 | 85 | 447.0 |
| GHVH 1/98 | 60 | 210.0 | GHVH 1/98 | 86 | 448.5 |
| GHVH 1/98 | 61 | 211.0 | | | |

**Table 3**. Composite depth sections for the Gotland Deep on the basis of correlation between the BASYS Gotland Deep long cores.

| Core | From (cm) | To (cm) | Cumulative composite depth (cm) |
|---|---|---|---|
| 211660-5 | 0 | 125 | 125 |
| 211660-6 | 144.5 | 147.5 | 128 |
| 211660-5 | 130 | 275 | 273 |
| 211660-6 | 318.5 | 330 | 284.5 |
| 211660-5 | 288 | 311 | 307.5 |
| 211660-6 | 363 | 382.5 | 327 |
| 211660-5 | 333.5 | 373.5 | 367 |
| 211660-6 | 440.5 | 453 | 380 |
| 211660-5 | 383.5 | 426.5 | 423 |
| 211660-6 | 517.5 | 522.5 | 428 |
| 211660-5 | 433.5 | 476 | 470.5 |
| 211660-6 | 582 | 589.5 | 478 |
| 211660-5 | 484 | 515 | 509 |
| 211660-6 | 644.5 | 668.5 | 533 |
| 211660-5 | 536 | 829 | 826 |

water, e.g. changes in its motion and transport mechanisms. It should be noted that irregularities in the sediment accumulation are typically found in the top part of studied sediments. Due to the rather high content of detrital organic matter these sediments have most likely been transported as a fair-sized flocculated particles. In other words, even very weak bottom currents may have moved sediment around leading to resuspension and uneven deposition. The occurrence of undulating and meandering bottom near currents capable of producing the observed features could be related to occasional inflow of more dense, saline waters from the North Sea through the Danish Straits flowing through the deeper parts of the southern Baltic Sea and finally reaching the Gotland Basin.

It is possible that at least some of the observed variations in sediment accumulation could have been caused by the coring procedure itself. The cores used in the present study were recovered

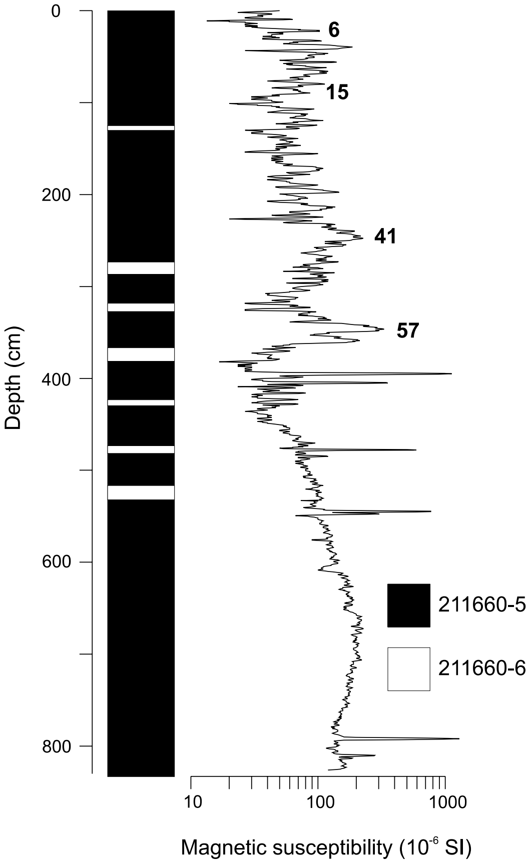


**Fig. 4**. Bulk susceptibility data for the Gotland Deep Composite Depth Record. The composite depth record has been spliced together from cores 211660-5 (black square) and 211660-6 (white square) as seen in Table 2 and in this figure.

using different coring techniques, ranging from various gravity corers to a vibro-hammer corer (cf. Table 1). Sediment structures in the vibro-hammer core (GBVH 1/98) seemed to be more disturbed (at least in the upper 125 cm), and sedimentation rates in the upper part of that core were just a half compared to the piston and gravity cores (211660-1 and 211660-5) (Kotilainen *et al.* 2000). The box (Kastenlot) core (211660-6) had the highest apparent sedimentation rates (Kotilainen *et al.* 2000), but this is, at least in part, due to the fact that the corer penetrated into the bottom at an angle of about 20° off the vertical. Sediments from cores 211660-1 and 211660-5 were less disturbed and records from these cores exhibit similar sedimentation rates.

Nevertheless, the features observed in the sedimentary records of the four different cores, suggest that locally changing sedimentation, non-deposition and erosion is natural and characteristic for the Gotland Deep sediments. To achieve high spatial and temporal resolution in the study of sediment records, it is important to acquire several closely spaced cores and to construct composite depth sections for the study area.

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