C-14 dating of the 32.4 m long Holocene CALYPSO Core MD99-2286 from the Skagerrak

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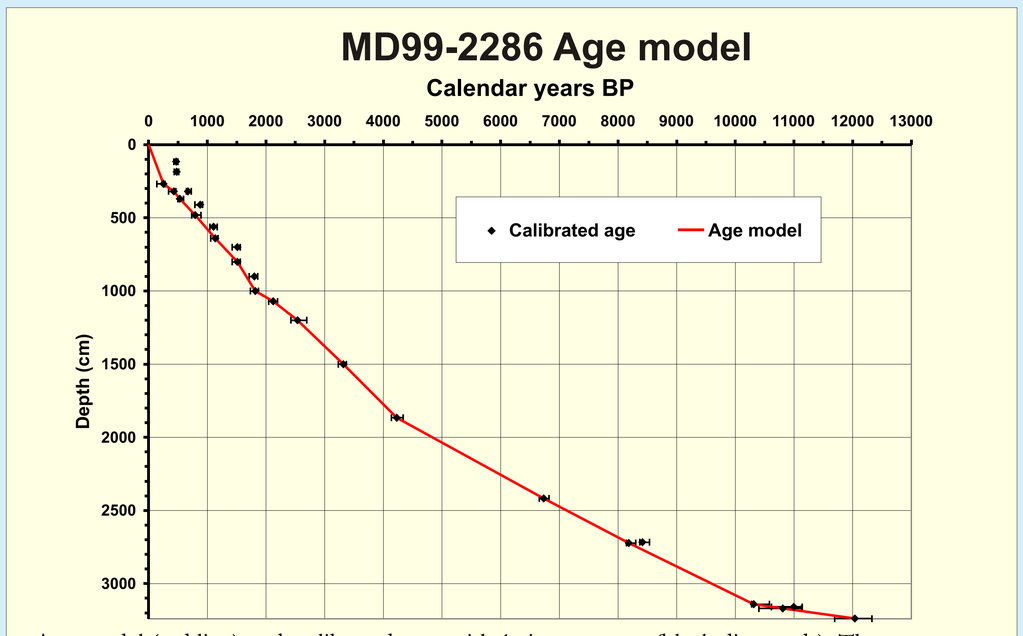
Major currents in the North Sea area. The location of core MD99-2286 is indicated with an arrow. (Map by Geological survey of Norway)

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). The focus of this research is Holocene climate variability in the Skagerrak, by multi-proxy analysis of the 32.4 m long piston core MD99-2286, which provides a continuous and detailed palaeoceanographic and palaeoenvironmenatal record of the last 12 000 years in the Skagerrak. This high-resolution climate archive has chronostratigraphical control based on 25 radiocarbon dates from shells and forams. Some samples show evidence of reworking, especially in the top 10 m of the core (last 2000 calendar years), an interval crucial to any comparison of proxy data to instrumental records.



Age model (red line) and calibrated ages with 1 sigma ranges (black diamonds). 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.

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 (marked with grey below).

Table 1. AMS C-14 dating for core MD99-2286

No.	Laboratory reference	Depth (cm)	d^{13}C ‰	1s +/-	14C age (y BP)	1s +/-	Age range (Cal y BP) obtained from intercepts Max (2 s)	Max (1 s)	Cal age	Min (1 s)	Min (2 s)	Species	Weight (mg)	Type
1	ETH-24953	115.5	-3.8	1.2	785	50	529	501	467	426	329	Scaphander *sp.*	27.78	g,w
2	ETH-25546	185.5	2.0	1.2	800	55	542	509	477	434	358	*Yoldiella lucida*	8.85	m,w
3	ETH-24001	268	1.7	1.2	535	50	307	277	251	136	0	*Ennucula tenuis*	26.1	m,w
4	ETH-24397	319.5	1.8	1.2	730	45	498	466	427	339	296	*Thyasira Equalis*	49.67	m,b
5	ETH-26937	319.5	0.5	1.2	1095	55	785	725	670	643	608	Foraminifera (mixed fauna)	11.86	f
6	ETH-25547	370.5	0.7	1.2	900	60	641	591	529	497	457	*Nucula tumidula*	9.55	m,b
7	ETH-26388	410.5	0.1	1.2	1270	50	954	916	879	783	726	Foraminifera (mixed fauna)	13.07	f
8	ETH-26938	481.5	2.7	1.2	1225	55	927	892	791	731	673	Foraminifera (mixed fauna)	16.77	f
9	ETH-26939	561	-0.1	1.2	1510	50	1232	1168	1104	1043	964	Foraminifera (mixed fauna)	18.57	f
10	ETH-26940	640.5	0.8	1.2	1530	50	1251	1182	1134	1055	983	Foraminifera (mixed fauna)	16.23	f
11	ETH-25955	700.5	2.3	1.2	1915	55	1659	1563	1512	1422	1359	Foraminifera (mixed fauna)	16.42	f
12	ETH-25956	801	-0.2	1.2	1915	55	1659	1563	1512	1422	1359	Foraminifera (mixed fauna)	18.04	f
13	ETH-26389	901	0.5	1.2	2155	50	1915	1858	1801	1713	1666	Foraminifera (mixed fauna)	19.29	f
14	ETH-26390	1001	-0.5	1.2	2175	50	1934	1873	1816	1737	1687	Foraminifera (mixed fauna)	15.51	f
15	ETH-26941	1070.5	3.0	1.2	2440	55	2301	2201	2122	2048	1974	Foraminifera (mixed fauna)	11.62	f
16	ETH-26418	1200.5	1.4	1.2	2765	60	2725	2691	2538	2428	2339	Foraminifera (mixed fauna)	12.56	f
17	ETH-26419	1500.5	1.3	1.2	3390	60	3445	3369	3318	3232	3147	Foraminifera (mixed fauna)	14.05	f
18	ETH-26137	1866	1.0	1.2	4120	60	4407	4340	4228	4136	4058	*Polinices montagui*	16.73	g,w
19	ETH-24003	2417	1.3	1.2	6255	65	6904	6824	6733	6661	6598	*Portlandia intermedia*	42.6	m,b
20	ETH-25548	2716.5	3.4	1.2	7955	70	8605	8534	8417	8369	8320	*Pseudamusium septemradiatum*	62.37	m,b
21	ETH-25549	2721.5	2.9	1.2	7710	60	8347	8297	8184	8146	8035	*Pseudamusium septemradiatum*	100.02	m,b
22	ETH-25550	3140.5	-0.6	1.2	9620	70	11117	10582	10312	10276	10104	*Pseudamusium septemradiatum*	44.68	m,b
23	ETH-24004	3159	1.1	1.2	9955	85	11591	11138	10997	10613	10340	*Bathyarca glacialis*	25.5	m,b
24	ETH-25551	3169.5	-2.0	1.2	9910	70	11290	11126	10808	10400	10332	*Cryptonautica affinis*	25.77	g,b
25	ETH-24005	3238	1.4	1.2	10715	80	12806	12325	12037	11695	11414	*Portlandia intermedia*	134.5	m,b

Type abbreviations: g = gastropod, m = mollusc, f = foraminifera, w = whole, b = broken

Results and Discussion

The chronostratigraphic control of core MD99-2286 relies on twenty-five AMS C-14 dates, performed on mixed foraminifera and seven mollusc shell samples of known species. The radiocarbon dates were calibrated using the CALIB (rev 4.3) software (Stuiver and Reimer, 1993), with a delta R-value of -40 +/- 25 ^{14}C-years (Stuiver and Braziunas, 1993). The samples were assumed to consist of 100 % marine carbon, and the calibration data set MARINE98 (Stuiver et al., 1998a) was used.

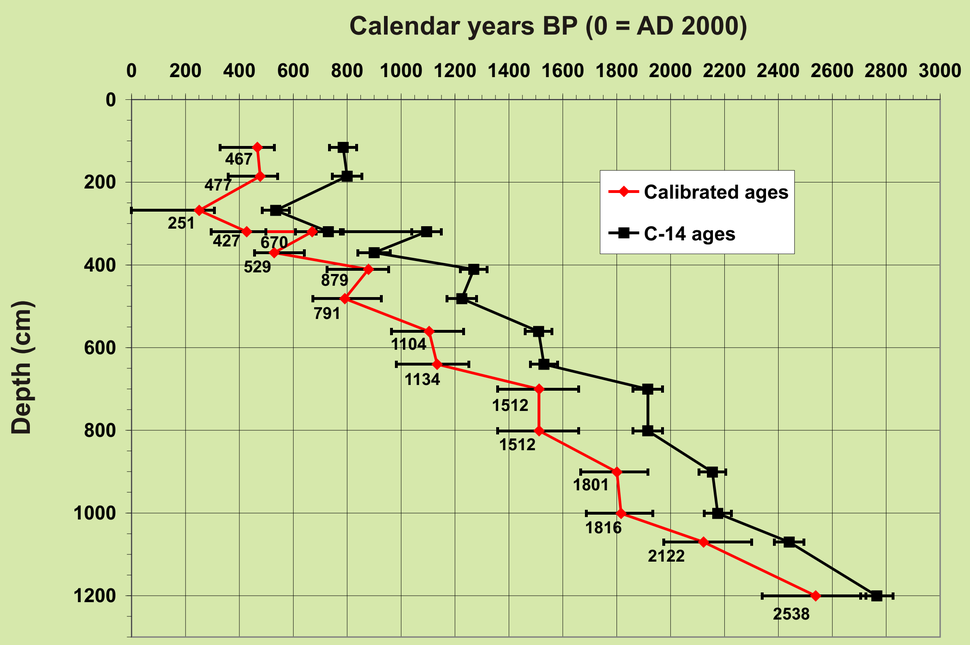
The calibrated ages show that core MD992286 spans 12000 calendar years, covering the entire Holocene and the latest Pleistocene. The inferred sedimentation rate gradually increases with time (with minor exceptions), from 0.05 cm/y at 12000 cal y BP to about 1 cm/y in the recent sediments. The latter is consistent with the measured modern sedimentation rate of >0.6 cm/y (Bøe et al. 1996).

The twelve dates in the top ten metres of the core are somewhat problematic, as the ages in every other sample is older or of identical age as the closest underlying sample. This consistent pattern cannot be explained by the order of analyses, as samples from different depths were analysed in random order. Too old ages can be explained by reworking, whereas too young ages can be explained by contamination with modern carbon or by deep burrowing of the dated species. Modern carbon contamination is generally only likely in foraminifer samples, as the mollusc samples are etched, and foraminifer samples are not. Errors from deep burrowing is less likely as all of the dated mollusc-species are known not to burrow more than ca 10 cm into the substratum (pers. comm., Anders Warén, Museum of Swedish Natural History, 2002). Assuming that all samples yielding older or identical ages as the closest underlying samples are reworked, it follows that the older ages should be excluded from the age model.

Reservoir correction

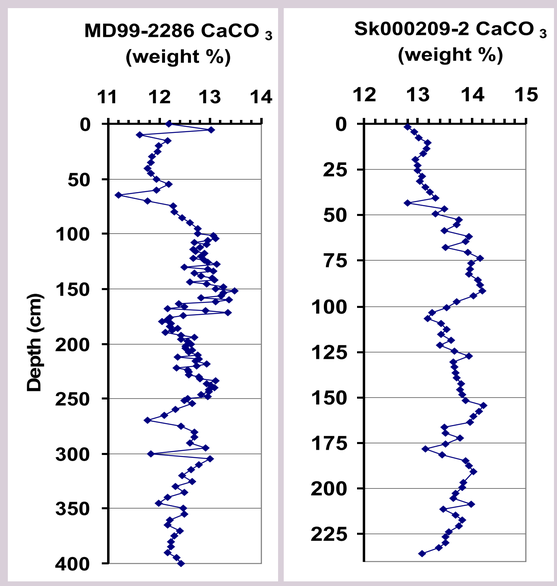
In the present age model, a delta R-value of -40 +/- 25 ^{14}C-years (Stuiver and Braziunas, 1993) was used. However, the regional mean for the southeastern Norway, western Sweden and eastern Denmark region is delta R = -13 ± 16, based on the Marine Reservoir Correction Database (Reimer, 2000). Samples from depths greater than 75 m were not included in the database, because the marine model ages in the marine calibration dataset are only valid for the surface mixed layer (Reimer, 2000). Because the regional difference from the global reservoir correction in the Skagerrak is relatively low but varied within the region, and the core is collected from 225 m water depth, the use of a normal global reservoir correction, with no difference (delta R = 0) could be argued.

Radiocarbon- and calibrated ages, top 12 m detail



C-14 ages (black) with 1 sigma ranges and Calendar ages(red) with 2 sigma ranges in the top 12 metres of core MD99-2286. Numbers in black denote calendar ages (cal y BP, 0 = AD 2000).

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.

Conclusions

- Core MD99-2286 spans 0 -12 000 calendar years
- Top ten metres (possibly more) are likely affected by reworking
- Carbonate content is a useful core correlation tool

Questions:

- How can reworking and bioturbation be estimated (esp. for the northeastern Skagerrak)?
- Can paleomagnetic data be used to improve the age model in this environment?
- How should an age model be constructed (interpolation, spline fit, break points etc)?

References

Bøe, R., Rise L., Thorsnes, T. H., de Haas, H., Saether, O. M. and Kunzendorf, H.1996. Sea-bed sediments and sediment accumulation rates in the Norwegian part of Skagerrak. *Nor. geol. unders. Bull.* 430, 75-84.

Senneset, L. 2002. A record of high resolution ocean variability from Skagerrak over the past 900 years. *Cand. Scient. Thesis, Department of Geology, University of Bergen, Norway*, 81 pp.

Stuiver, M. and Braziunas T. F. 1993. Modelling atmospheric ^{14}C influences and ^{14}C ages of marine samples to 10,000 BC. *Radiocarbon* 35 (1),137-189.

Stuiver, M. and Reimer, P. J. 1993. Extended ^{14}C data base and revised CALIB 3.0 14C age calibration program. *Radiocarbon* 35 (1), 215-230.

Stuiver, M., Reimer, P.J., Bard, E., Beck, J.W., Burr, G.S., Hughen, K.A., Kromer, B., McCormac, F.G., v.d. Plicht, J., and Spurk, M. 1998a. INTCAL98 Radiocarbon age calibration, 24,000-0 cal BP, *Radiocarbon* 40 (3), 1041-1083.

Reimer, P. 2000. Marine Reservoir Correction Database, http://radiocarbon.pa.qub.ac.uk/marine, 16-04-2003.

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