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Radiocarbon geochronology of the sediments of the São Paulo Bight (southern Brazilian upper margin)

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ABSTRACT

The aim of this work was to generate an inventory of the data on radiocarbon datings obtained from sediments of the São Paulo Bight (southern Brazilian upper margin) and to analyze the data in terms of Late Quaternary sedimentary processes and sedimentation rates. A total of 238 radiocarbon datings from materials collected using different sampling procedures was considered for this work. The sedimentation rates varied from less than 2 to 68 cm.kyr^{-1}. The highest sedimentation rate values were found in a low-energy (ría type) coastal system as well as in the upwelling zones of Santa Catarina and Cabo Frio. The lowest rates were found on the outer shelf and upper slopes. Our results confirm the strong dependency of the shelf currents, with an emphasis to the terrigenous input from the Río de La Plata outflow which is transported via the Brazilian Coastal Current, as well as of the coupled Brazil Current – Intermediate Western Boundary Current (BC-IWBC) dynamics on the sedimentary processes. At least three indicators of the paleo sea level were found at 12200 yr BP (conventional radiocarbon age) (103 meters below sea level – mbsl), 8300-8800 cal yr BP (13 mbsl) and 7700-8100 cal yr BP (6 mbsl).

Key words: continental margin, quaternary, radiocarbon, sea-level, sedimentation.

INTRODUCTION

The northernmost part of the southern Brazilian margin is known as the São Paulo Bight, an arc-shaped embayment extending from 23°S to 28°S (Zembruscki 1979). Due to the absence of important adjacent fluvial sources, Late Quaternary depositional processes on the São Paulo Bight have been considered for decades to be a result of the reworking of sediments that had been previously deposited at sea level lowstands during the Late Pleistocene. More recently, a series of papers has reevaluated the sedimentary processes on the continental shelf and upper slope in terms of hydrodynamic factors and the input of terrigenous sediments. The latter is especially related to the transport of the Río de La Plata sediments to the Brazilian margin (Mahiques et al. 2004, 2008, Campos et al. 2008).

The hydrodynamic control, together with the relative tectonic stability and the absence of post-glacial rebound, makes the area a favorable site for investigations of the Late Quaternary climatic changes of the southwestern Atlantic. The area has a big potential for studying changes related to the Last Climatic Cycle, sub-Milankovitch variations such as latitudinal shifts of the Intertropical Convergence Zone (ITCZ) (Haug et al. 2001), and variations in the El Niño Southern Oscillation (ENSO) (Woodroffe et al. 2003).

On the other hand, due to flourishing oil and gas exploration activities and related engineering and environmental aspects such as the installation of pipelines and platforms, studies on sedimentary processes are of great importance.

In the last decade, a set of more than two hundred radiocarbon datings have been obtained by the authors using sediment samples from the São Paulo Bight. Most

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of these datings has never been published, although some are available in the scientific literature (Mahiques et al. 2002, 2005, 2007, 2009, Nagai et al. 2009).

Here we present an inventory of the data and analyze the radiocarbon datings in terms of Late Quaternary sedimentary processes and sedimentation rates. In addition, these data provide indications of sea level stabilization periods that occurred prior to the Holocene Climatic Optimum, a subject that is not well understood in this area of study.

Different aspects have been described by other authors that could make it difficult or even impossible to utilize radiocarbon datings in studies of sedimentary and stratigraphical processes in the São Paulo Bight. In particular, inconsistencies between radiocarbon datings and other geological or geochronological indicators may affect the usefulness of this method for examining such processes.

Carroll et al. (2003) analyzed the radiocarbon ages of brachiopod shells found in the first 10 cm of sediment in cores collected from the inner shelf (between 5 and 23 meters). The authors identified a wide range of ages among these samples, varying from 540-410 to 2420-2240 cal yr BP. In another study comparing radiocarbon datings with ^{210}Pb and ^{137}Cs data, Figueira et al. (2007) identified a difference of one order of magnitude in estimates of the sedimentation rates in sediment samples from the continental shelf of the area. Finally, Angulo et al. (2008) observed the occurrence of radiocarbon age inversions in the coastal plain adjacent to the study area. The authors therefore defined two sets of radiocarbon ages, e.g., those representing *in situ* or poorly transported samples, and those indicating allochthonous, highly transported materials.

STUDY AREA

Figure 1 presents the study area. The ocean floor of the São Paulo Bight shows a rather complex morphology involving channels, canyons, and considerable variations in slope morphology (Furtado et al. 1996). The shelf break is located at a water depth of approximately 140 meters, with the upper slope showing an average gradient of approximately 1:55.

The distribution of surface sediments on the southeastern Brazilian margin was extensively studied in the decade of 1970 and is described in the papers of Rocha et al. (1975) and Kowsmann and Costa (1979). In general, the present sea floor is covered by very fine siliciclastic sands and silts with variable amounts of clay and calcium carbonate. Coarser terrigenous sediments, carbonate gravel and boulder facies found on the outer shelf represent less than 5% of the present bottom and are generally related to relict sediments that are deposited under lower sea level conditions.

Sedimentary processes in the area have been reevaluated in recent papers in terms of the controlling hydrodynamic processes. On the inner shelf, the sedimentation is mainly determined by the displacement of the Brazilian Coastal Current (Souza and Robinson 2004), which carries sediments from the Río de La Plata and, to a lesser extent, from the southern Brazilian coastal lagoons (Campos et al. 2008, Möller Jr. et al. 2008, Mahiques et al. 2008). On the middle and outer shelves, as well as on the upper slope, the sedimentary processes are mainly influenced by the southward flow of the Brazil Current (BC) along the western Atlantic continental margin (Mahiques et al. 2002, 2004).

METHODS

In this study, we organized all of the information obtained by the authors on radiocarbon datings performed on sediment samples collected along the São Paulo Bight (Fig. 1). A total of 238 radiocarbon datings obtained from materials collected with different sampling procedures (scuba diving, box cores, piston cores, vibracores) (see Tables I to IV for details) were considered for this work.

With few exceptions, the content of suitable carbonate materials in the collected cores was insufficient for radiocarbon dating, and at several sampling sites the bulk organic fraction was used for dating. Almost all of the samples were AMS dated at Beta Analytic Inc. (Miami, USA). Calibrated ages of marine samples (preserved bivalve shells, corals, specimens of the planktonic foraminifer *Globigerinoides ruber* on core 7485 and the benthic foraminifer *Elphydium* sp on core SSB01) were calculated using Calib software, version 5.0.2html, available at http://calib.qub.ac.uk/calib/. We employed the standard marine correction of 408 years and a regional reservoir effect of $\Delta R = 12 \pm 60$,

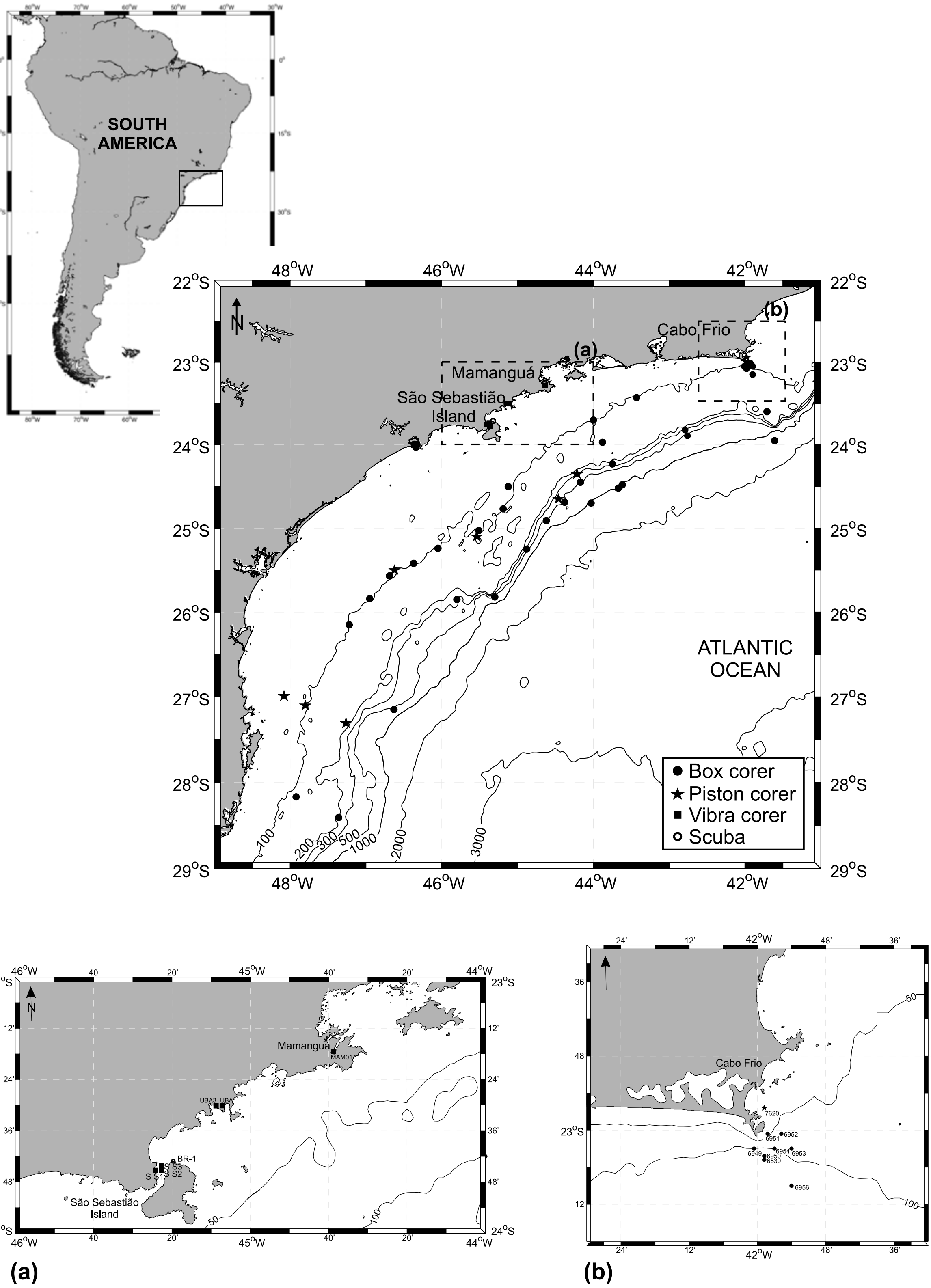

Fig. 1 – Location of the study area and samples considered in this study.

corresponding to the average value of eleven samples reported for the SE Brazilian coast between the latitudes 23°S and 28°S (Nadal de Masi 1999, Eastoe et al. 2002, Angulo et al. 2005) and the Marine04 Calibration Dataset (Hughen et al. 2004). For terrestrial material, the Southern Hemisphere Calibration Curve (McCormac et al. 2004) was used. Finally, for organic matter samples, the Mixed-Marine calibration curve was used. Estimates of marine *versus* terrestrial percentages are based on $\delta^{13}C$ end-members for the São Paulo Bight (–19.00‰ PDB for marine and –26.00‰ PDB) (Mahiques et al. 1999).

Average sedimentation rates were obtained by linear interpolation of calibrated ages only for those samples that presented at least three datings with Holocene ages, assuming that the surface sediment was modern (0 kyr). For each of these average rates, the significance level was determined as shown in Tables I to III.

RESULTS

Tables I to III present the results of the radiocarbon datings. In order to develop a better comprehension of the sedimentary processes in the context of these data, the samples were divided into three different geomorphological sectors, i.e., "Coast", comprising the submerged coastal environments up to the 20-meter isobath; "Inner and Middle Shelf", comprising the samples located from the 20-meter to the 100-meter isobath; and "Outer Shelf/Upper Slope", beyond the 100-meter isobath.

The samples from the Coast sector comprise 69 datings that were performed on seven vibracores, five box cores and four beach rock samples collected by scuba diving (Table I). In this sector, most of the datings showed Mid- to Late Holocene ages with the exception of the base of one core (SS1), which showed a coherent sequence of datings (foraminifers and organic matter) with conventional radiocarbon ages ranging from ca. 39,300 yr BP to 10,240 yr BP. Age inversions are not rare in core samples from this sector, and incoherencies between carbonate-based (mollusk) and organic matter-based radiocarbon ages were also observed. Due to these complications, the estimates of sedimentation rates were performed at only three vibracore and two box core stations, providing a range varying from 12 ± 2 $cm.kyr^{-1}$ to 68 ± 2 $cm.kyr^{-1}$. The highest sedimentation rate value was obtained from a vibracore sampled in the Mamanguá inlet (23°17.40′S-044°38.88′W), a coastal system with geomorphological and sedimentological characteristics that are very similar to those present in the northwestern Iberian Rías (Méndez and Vilas 2005). The lowest sedimentation rate values were observed in cores collected in the São Sebastião Channel (23°45.12′S-045°22.62′W) and in Santos Bay (24°00.00′S-046°20.58′W), two coastal systems in which the wave action is more effective.

Samples from the Inner and Middle Shelf sector (Table II) correspond to 98 datings from 17 box cores and 5 piston cores. Most of these show a rather coherent pattern of radiocarbon dating, with only a few age inversions at the base of some cores and a prevalence of Mid- to Late-Holocene calibrated ages. One of the piston core samples (7616, 25°05.88′S-045°38.64′W) presented an erosional contact at its lowermost levels. Corresponding radiocarbon hiatuses detected at these levels showed indications of the transition from Late Pleistocene sandy beach facies, with conventional radiocarbon ages ranging from 13370 ± 70 to 12170 ± 70 yr BP, to a Mid-Holocene muddy shelf sediment.

Sedimentation rate estimates were calculated based on 11 box cores and 5 piston cores; the highest values (40 ± 9 and 62 ± 10 $cm.kyr^{-1}$) were found in samples from the Cabo Frio and the Santa Catarina upwelling zones. Lower sedimentation rate values (lower than 15 $cm.kyr^{-1}$) were found in two samples located close to the 100-meter isobath (samples 6561 and 7605).

Samples from the Outer Shelf/Upper Slope sector (Table III) comprise 71 datings from 21 box cores and 3 piston cores. This sector is characterized by very low sedimentation rate values that were present in several samples. These values indicate the presence of relict terms such as those found in samples 6573, 6626, 6652 and 6680, in which Pleistocene ages were reached at a thickness of few centimeters of sediment (see Table III for location). Also, a 4.5-meter long core (7607, 27°22.14′S-47°08.40′W), which was collected at 287 meters below sea level (mbsl) and was composed exclusively of massive mud, exhibited a sedimentary column with a completely fuzzy pattern and ages ranging between 30000 and 40000 yr BP These features lead us to consider this latter core as an evidence of a relict

TABLE I

Location, type of sample, conventional radiocarbon age (yr BP), 2σ radiocarbon calibrated age (yr BP), and estimated sedimentation rate (cm.kyr^{-1}), of samples collected in the Coast Sector.

Sample	Latitude (S)	Longitude (W)	Water Depth (m)	Level (cm)	Device	Lab Number	Material	Measured Radiocarbon Age (BP)	$\delta^{13}C$ (‰ PDB)	Conventional Radiocarbon Age (BP)	2σ range (cal BP)	Sedimentation Rate (cm.kyr^{-1})
FLT01	-23,501	-45,119	3	190	Vibra corer	n.a.	Bivalve	n.a.	n.a.	5850 ± 60	6029-6435	
				220		n.a.	Bivalve	n.a.	n.a.	6230 ± 50	6467-6859	
				340		n.a.	Bivalve	n.a.	n.a.	7470 ± 60	7734-8116	
				420		n.a.	Bivalve	n.a.	n.a.	8260 ± 60	8547-8999	
				460		n.a.	Bivalve	n.a.	n.a.	7680 ± 100	7915-8367	
UBA3	-23,500	-45,138	3	036-038	Vibra corer	191274	Bivalve	4110 ± 40	1,6	4550 ± 40	4516-4901	
				088		189506	Bivalve	4410 ± 40	1,0	4840 ± 40	4892-5298	
				202-204		191275	Bivalve	4890 ± 40	1,0	5320 ± 40	5546-5871	
				306		189507	Bivalve	6890 ± 40	0,5	7310 ± 40	7620-7917	
				312		189508	Bivalve	7130 ± 40	-0,4	7530 ± 40	7835-8147	
UBA1	-23,502	-45,122	3	015	Vibra corer	189502	Wood	160 ± 40	-27,9	110 ± 40	0?-146 (0.82), 222-263 (0.78)	0.21 ± 0.03 (0.12)
				028		180825	Bivalve	660 ± 40	1,0	1090 ± 40	519-766	
				066		189503	Bivalve	4030 ± 40	1,6	4470 ± 40	4441-4814	
				068-070		191272	Bivalve	3170 ± 40	1,7	3610 ± 40	3336-3676	
				130		180826	Bivalve	2440 ± 40	-0,2	2850 ± 40	2365-2735	
				143		189504	Wood	5070 ± 40	-26,8	5040 ± 40	5604-5766 (0.78), 5806-5890 (0.22)	
				166-168		191273	Bivalve	6090 ± 40	1,6	6530 ± 40	6845-7209	
				232		189505	Bivalve	6870 ± 40	0,5	7290 ± 40	7603-7904	
SS1	-23,755	-45,406	3	065-068	Vibra corer	166942	Organic matter	1810 ± 40	-22,6	1850 ± 40	1415-1687	
				066		180819	Bivalve	30 ± 40	0,2	440 ± 40	0?-229	
				130-133		166943	Organic matter	5830 ± 40	-22,2	5880 ± 40	6302-6561	
				131		180820	Bivalve	2170 ± 40	1,9	2610 ± 40	2077-2476	
				136-139		166944	Organic matter	10210 ± 40	-23,4	10240 ± 40	11320-11818	
				177-180		170284	Organic matter	23950 ± 180	-23,8	23970 ± 180	O.R.	
				233-236		170285	Organic matter	24950 ± 200	-23,9	24970 ± 200	O.R.	
				249-251		179055	Foraminifera	36890 ± 550	-1,0	37280 ± 550	O.R.	
				265-269		179056	Foraminifera	39140 ± 750	-3,0	39500 ± 750	O.R.	
				265-269		166945	Organic matter	39240 ± 1100	-22,9	39270 ± 1100	O.R.	
SS3	-23,735	-45,377	4	025	Vibra corer	180822	Bivalve	480 ± 40	2,3	930 ± 40	420-647	
				028-030		170289	Organic matter	4920 ± 40	-24,3	4930 ± 40	5332-5373 (0.04), 5448-5610 (0.96)	
				030-032		166950	Organic matter	1350 ± 40	-23,0	1380 ± 40	980-1235	
				077		170290	Bivalve	4140 ± 40	-0,8	4540 ± 40	4508-4882	
				104-106		170288	Organic matter	1660 ± 40	-24,9	1660 ± 40	1352-1535	
				128-130		170291	Organic matter	5900 ± 40	-24,3	5910 ± 40	6446-6677	
				226-229		166951	Organic matter	5000 ± 40	-23,3	5030 ± 40	5467-5665 (0.99), 5673-5682 (0.01)	
				227		180823	Bivalve	4350 ± 40	1,6	4790 ± 40	4854-5258	
				242-245		166952	Organic matter	5510 ± 40	-23,2	5540 ± 40	5999-6269	
				244		180824	Bivalve	4630 ± 40	1,5	5060 ± 40	5265-5570	
				397-400		166953	Organic matter	10690 ± 50	-24,5	10700 ± 50	O.R.	

TABLE I (continuation)

Sample	Latitude (S)	Longitude (W)	Water Depth (m)	Level (cm)	Device	Lab Number	Material	Measured Radiocarbon Age (BP)	$\delta^{13}C$ (‰ PDB)	Conventional Radiocarbon Age (BP)	2σ range (cal BP)	Sedimentation Rate ($cm.kyr^{-1}$)
SS2	-23,752	-45,377	5	014-017	Vibra corer	166946	Organic matter	1170 ± 40	-21,9	1220 ± 40	753-984	0.12 ± 0.02 (0.13)
				028-030		170286	Organic matter	3250 ± 40	-23,6	3270 ± 40	3217-3441	
				050-052		170287	Organic matter	3170 ± 40	-23,5	3190 ± 40	3080-3093 (0.02), 3104-3361 (0.98)	
				087-090		166947	Organic matter	6750 ± 50	-21,9	6800 ± 50	7322-7560	
				088		180821	Bivalve	5690 ± 40	0,9	6110 ± 40	6356-6702	
				093-096		166948	Organic matter	7220 ± 40	-23,1	7250 ± 40	7785-7991	
				148-150		166949	Organic matter	10600 ± 50	-24,5	10610 ± 50	O.R.	
MAM-01	-23,290	-44,648	4	0-2	Vibra corer	259334	Organic matter	240 ± 40	-22,7	280 ± 40	0?-153 (0.85), 169-182 (0.02), 186-193 (0.01), 207-258 (0.12)	0.68 ± 0.02 (<0.05)
				50-52		259335	Organic matter	930 ± 40	-22,1	980 ± 40	565-602 (0.07), 615-769 (0.93)	
				100-102		259336	Organic matter	1800 ± 40	-22,9	1830 ± 40	1411-1636 (0.93), 1646-1687 (0.07)	
				150-152		259337	Organic matter	2340 ± 40	-21,8	2390 ± 40	2005-2307	
				170-172		259338	Organic matter	2570 ± 40	-22,7	2610 ± 40	2343-2618 (0.89), 2631-2683 (0.11)	
6947	-23,995	-46,362	9	010-012	Box corer	165993	Organic matter	1160 ± 40	-23,0	1190 ± 40	788-1001 (0.99), 1034-1043 (0.01)	
				018-020		165994	Organic matter	1420 ± 40	-22,4	1460 ± 40	1055-1278	
SAN2	-24,001	-46,328	10	038-040	Box corer	180817	Bivalve	60 ± 40	-1,0	450 ± 40	0?-233	
				050-052		180818	Bivalve	2180 ± 40	-0,9	2580 ± 40	2040-2421	
6945	-24,007	-46,352	10	010-012	Box corer	165988	Organic matter	990 ± 40	-23,2	1020 ± 40	670-841 (0.94), 866-897 (0.06)	0.24 ± 0.03 (0.08)
				024-026		165989	Organic matter	1220 ± 40	-23,9	1240 ± 40	920-1093 (0.99), 1107-1121 (0.01)	
				038-040		165990	Organic matter	1690 ± 40	-24,0	1710 ± 40	1352-1548	
6948	-24,000	-46,343	11	008-010	Box corer	166977	Organic matter	1290 ± 40	-23,4	1320 ± 40	958-1175	0.18 ± 0.02 (<0.05)
				012-014		165995	Organic matter	1260 ± 40	-23,5	1280 ± 40	929-1138	
				020-022		170283	Organic matter	1330 ± 40	-23,9	1350 ± 40	997-1035 (0.07), 1045-1255 (0.93)	
				022-024		165996	Organic matter	1250 ± 40	-23,6	1270 ± 40	928-1134	
				034-036		165997	Organic matter	1890 ± 40	-23,4	1920 ± 40	1553-1807	
BR-1	-23,726	-45,362	13	000	Scuba	191270	Bivalve	7580 ± 40	0,0	7990 ± 40	8303-8594	
BR-2				000		191271	Faecal pellets	8000 ± 40	-19,4	8090 ± 40	8377-8755	
BR-4				000		CENA201	Total rock	n.a.	n.a.	7870 ± 80	8108-8539	
BR-20				000		CENA202	Total rock	n.a.	n.a.	8050 ± 80	8299-8801	
6946	-24,028	-46,341	14	010-012	Box corer	165991	Organic matter	910 ± 40	-23,1	940 ± 40	572-588 (0.02), 630-770 (0.92)	
6946	-24,028	-46,341	14	024-026		165992	Organic matter	1960 ± 40	-22,3	2000 ± 40	1565-1838	

TABLE II

Location, type of sample, conventional radiocarbon age (yr BP), 2σ radiocarbon calibrated age (yr BP), and estimated sedimentation rate (cm.kyr^{-1}), of samples collected in the Inner and Middle Shelf Sector.

Sample	Latitude (S)	Longitude (W)	Water Depth (m)	Level (cm)	Device	Lab Number	Material	Measured Radiocarbon Age (BP)	$\delta^{13}C$ (‰ PDB)	% Marine carbon	Conventional Radiocarbon Age (BP)	2σ range (cal BP)	Sedimentation Rate (cm.kyr^{-1})
7620	-22,94	-41,98	44	000-002	Piston corer	217363	Organic matter	800 ± 40	-21,7	61	850 ± 40	507-651	0.40 ±0.09 (0.05)
				002-004		217364	Organic matter	1060 ± 40	-21,4	66	1120 ± 40	673-897	
				050-052		217365	Organic matter	1650 ± 50	-21,5	64	1710 ± 50	1263-1510	
				100-102		217366	Organic matter	2200 ± 50	-21,3	67	2260 ± 50	1818-2132	
				150-152		217367	Organic matter	3060 ± 40	-21,5	64	3120 ± 40	2862-3200	
				200-202		217368	Organic matter	3720 ± 40	-21,5	64	3780 ± 40	3673-3986	
				250-252		217369	Organic matter	4320 ± 40	-21,4	66	4380 ± 40	4503-4824	
				300-302		217370	Organic matter	5850 ± 40	-21,5	64	5910 ± 40	6296-6568	
				350-352		217371	Organic matter	8390 ± 40	-21,9	59	8440 ± 40	9016-9327 (0.98), 9345-9370 (0.02)	
				400-402		217372	Organic matter	8690 ± 60	-22,2	54	8740 ± 60	9403-9682	
				414-416		217373	Organic matter	8410 ± 50	-22,8	46	8450 ± 50	9036-9047 (0.01), 9075-9424 (0.99)	
6952	-23,01	-41,93	58	004-006	Box corer	166007	Organic matter	520 ± 40	-20,8	74	590 ± 40	150-214 (0.06), 240-466 (0.94)	0.30 ± 0.05 (<0.05)
				008-010		179049	Organic matter	740 ± 40	-21,0	71	810 ± 40	444-630	
				012-014		166008	Organic matter	560 ± 40	-20,8	74	630 ± 40	270-484	
				022-024		179050	Organic matter	1120 ± 50	-21,1	70	1180 ± 50	683-928	
				028-029		166009	Organic matter	960 ± 40	-21,2	69	1020 ± 40	561-769	
6951	-23,01	-41,97	60	004-006	Box corer	166004	Organic matter	480 ± 40	-20,8	74	550 ± 40	119-444	0.25 ± 0.02 (<0.05)
				006-008		166978	Organic matter	500 ± 40	-20,9	73	570 ± 40	145-450	
				012-014		179047	Organic matter	980 ± 40	-21,0	71	1050 ± 40	566-602(0.04), 607-798 (0.96)	
				020-022		179048	Organic matter	1150 ± 40	-20,8	74	1220 ± 40	716-953	
				022-025		166006	Organic matter	1080 ± 40	-20,7	76	1150 ± 40	666-898	
7606	-26,99	-48,08	60	000-002	Piston corer	209911	Organic matter	1320 ± 40	-19,6	91	1410 ± 40	817-1387	0.62 ± 0.10 (<0.05)
				050-052		209912	Organic matter	1590 ± 40	-19,8	89	1680 ± 40	1105-1387	
				098-100		209913	Organic matter	1990 ± 50	-19,8	89	2080 ± 50	1512-1862	
				148-150		209914	Organic matter	2480 ± 50	-20,3	81	2560 ± 50	2093-2475	
				198-200		209915	Organic matter	2680 ± 40	-20,9	73	2750 ± 40	2367-2713	
				248-250		209916	Organic matter	3020 ± 50	-20,6	77	3090 ± 50	2764-3130	
				298-300		209917	Organic matter	3150 ± 50	-20,2	83	3230 ± 50	2897-3306	
				352-354		209918	Organic matter	3680 ± 40	-19,6	91	3770 ± 40	3546-3909	
				398-400		209919	Organic matter	4410 ± 40	-19,9	87	4490 ± 40	4520-4848	
				448-450		209920	Organic matter	5260 ± 40	-20,3	81	5340 ± 40	5617-5898	
				504-506		209921	Organic matter	7210 ± 40	-20,4	80	7290 ± 40	7674-7933	
6953	-23,05	-41,90	73	004-006	Box corer	166979	Organic matter	630 ± 40	-21,1	70	690 ± 40	309-511	0.30 ± 0.06 (0.12)
				012-014		166980	Organic matter	690 ± 40	-20,9	73	760 ± 40	329-554	
				026-027		166010	Organic matter	1060 ± 40	-20,9	73	1130 ± 40	662-893	

TABLE II (continuation)

Sample	Latitude (S)	Longitude (W)	Water Depth (m)	Level (cm)	Device	Lab Number	Material	Measured Radiocarbon Age (BP)	$\delta^{13}C$ (‰ PDB)	% Marine carbon	Conventional Radiocarbon Age (BP)	2σ range (cal BP)	Sedimentation Rate (cm.kyr^{-1})
6954	-23,05	-41,95	78	004-006	Box corer	166981	Organic matter	610 ± 40	-21,1	70	670 ± 40	302-501	0.31 ± 0.07 (0.15)
				012-014		166982	Organic matter	720 ± 40	-21,0	71	790 ± 40	416-628	
				028-030		166011	Organic matter	1030 ± 40	-20,7	76	1100 ± 40	631-857 (0.99), 862-877 (0.01)	
7610	-25,51	-46,64	89	000-002	Piston corer	248113	Organic matter	1140 ± 40	-20,3	81	1220 ± 40	686-928	0.28 ± 0.05 (0.10)
				050-052		248114	Organic matter	2390 ± 40	-19,9	87	2470 ± 40	1989-2317	
				100-102		248115	Organic matter	3210 ± 40	-20,3	81	3290 ± 40	2999-3350	
				150-152		248116	Organic matter	4550 ± 40	-20,5	79	4620 ± 40	4719-4752 (0.01), 4780-5089 (0.98), 5093-5124 (0.01)	
				198-200		248117	Organic matter	5650 ± 40	-20,8	74	5720 ± 40	6016-6323	
				238-240		248118	Organic matter	7030 ± 40	-21,4	66	7090 ± 40	7564-7784	
				308-310		248119	Organic matter	8880 ± 50	-21,6	63	8940 ± 40	9543-9897	
6949	-23,05	-42,01	92	004-006	Box corer	165998	Organic matter	560 ± 40	-21,0	71	630 ± 40	280-484	0.27 ± 0.05 (0.11)
				012-014		165999	Organic matter	820 ± 40	-21,2	69	880 ± 40	503-654	
				024-026		166000	Organic matter	1060 ± 40	-20,9	73	1130 ± 40	662-893	
6696	-25,57	-46,69	92	002-004	Box corer	142541	Organic matter	1400 ± 40	-19,9	87	1480 ± 40	926-1217	
				042-044		142542	Organic matter	1740 ± 40	-20,1	84	1820 ± 40	1282-1538	
7605	-27,10	-47,80	93	000-002	Piston corer	257051	Organic matter	1530 ± 40	-20,4	80	1610 ± 40	1068-1326	0.13 ± 0.02 (0.08)
				050-052		257052	Organic matter	2910 ± 40	-23,0	43	2940 ± 40	2755-2980	
				098-100		257053	Organic matter	6940 ± 40	-21,9	59	6990 ± 40	7471-7696	
				108-110		259339	Organic matter	7860 ± 50	-20,7	76	7930 ± 50	8331-8589	
				234-236		257056	Organic matter	N/A	N/A	50?	8060 ± 40	8470-8874 (0.98), 8876-8899 (0.01), 8916-8930 (0.01)	
6704	-25,24	-46,05	97	002-004	Box corer	142545	Organic matter	1180 ± 40	-20,2	83	1260 ± 40	707-967	0.23 ± 0.05 (<0.05)
				006-008		166972	Organic matter	1110 ± 40	-20,2	83	1190 ± 40	669-907	
				022-024		166973	Organic matter	1330 ± 40	-20,4	80	1410 ± 40	898-1170	
				028-030		142546	Organic matter	1610 ± 30	-20,5	79	1690 ± 30	1177-1400	
				046-048		166974	Organic matter	1630 ± 40	-20,4	80	1710 ± 40	1175-1444	
6539	-23,08	-41,98	98	010-012	Box corer	137008	Organic matter	930 ± 40	-21,5	64	990 ± 40	556-751	
				020-022		137009	Organic matter	1410 ± 40	-21,4	66	1470 ± 40	988-1257	
6740	-23,43	-43,43	99	014-016	Box corer	166975	Organic matter	1120 ± 40	-21,1	70	1180 ± 40	694-922	
				026-028		166976	Organic matter	1230 ± 40	-21,5	64	1290 ± 40	801-1059	
6561	-23,70	-44,00	99	004-006	Box corer	135530	Organic matter	1290 ± 60	-21,3	67	1350 ± 60	828-1254	0.09 ± 0.02 (0.14)
				010-012		135531	Organic matter	1370 ± 50	-21,8	60	1420 ± 60	952-1254	
				014-016		139015	Organic matter	1510 ± 40	-21,9	59	1560 ± 40	1116-1336	

TABLE II (continuation)

Sample	Latitude (S)	Longitude (W)	Water Depth (m)	Level (cm)	Device	Lab Number	Material	Measured Radiocarbon Age (BP)	$\delta^{13}C$ (‰ PDB)	% Marine carbon	Conventional Radiocarbon Age (BP)	2σ range (cal BP)	Sedimentation Rate ($cm.kyr^{-1}$)
6678	-24,77	-45,19	100	010-012	Box corer	139018	Organic matter	2060 ± 40	-21,9	59	2110 ± 40	1689-1952	
				020-022		139019	Organic matter	2190 ± 40	-22,7	47	2230 ± 40	1878-2127	
6683	-25,06	-45,54	100	040-042	Box corer	142538	Organic matter	2040 ± 40	-20,8	74	2100 ± 40	1594-1898	
7616	-25,10	-45,64	100	000-002	Piston corer	224532	Organic matter	1400 ± 40	-21,1	70	1460 ± 40	965-1238	0.33 ± 0.06 (<0.05)
				050-052		224533	Organic matter	2360 ± 40	-21,2	69	2420 ± 40	2004-2311	
				100-102		224534	Organic matter	3240 ± 40	-21,4	66	3300 ± 40	3079-3384	
				150-152		224535	Organic matter	3420 ± 40	-21,7	61	3470 ± 40	3347-3594 (0.99), 3598-3606 (0.01)	
				200-202		224536	Organic matter	4450 ± 40	-21,3	67	4510 ± 40	4621-4954	
				250-252		224537	Organic matter	5260 ± 50	-21,6	63	5320 ± 50	5648-5926	
				300-302		224538	Organic matter	6550 ± 60	-21,4	66	6610 ± 60	7078-7416	
				350-352		224539	Organic matter	12140 ± 70	-23,3	39	12170 ± 70	O.R.	
				400-402		224540	Organic matter	13270 ± 80	-22,9	44	13300 ± 80	O.R.	
				450-452		224541	Organic matter	13310 ± 70	-23,1	41	13340 ± 70	O.R.	
6700	-25,42	-46,37	100	002-004	Box corer	142543	Organic matter	1120 ± 40	-20,4	80	1200 ± 40	680-917	0.23 ± 0.06 (0.17)
				030-032		166971	Organic matter	1510 ± 40	-20,4	80	1590 ± 40	1055-1307	
				032-034		142544	Organic matter	1550 ± 40	-20,0	86	1630 ± 40	1065-1333	
6692	-25,84	-46,95	100	002-004	Box corer	142539	Organic matter	1230 ± 40	-19,7	90	1310 ± 40	722-1021	0.26 ± 0.05 (<0.05)
				010-012		166967	Organic matter	1220 ± 50	-19,8	89	1310 ± 50	723-1039	
				020-022		166968	Organic matter	1400 ± 40	-19,7	90	1490 ± 40	924-1219	
				030-032		166969	Organic matter	1440 ± 40	-19,8	89	1530 ± 40	961-1253	
				044-046		142540	Organic matter	1600 ± 40	-20,1	84	1680 ± 40	1134-1399	
				046-048		166970	Organic matter	1550 ± 40	-20,2	83	1630 ± 40	1075-1341	
6688	-26,15	-47,22	100	010-012	Box corer	170276	Organic matter	1430 ± 40	-20,7	76	1500 ± 40	979-1257	0.25 ± 0.05 (<0.05)
				020-022		170277	Organic matter	1440 ± 40	-20,6	77	1510 ± 40	984-1262	
				040-042		170279	Organic matter	1700 ± 40	-20,7	76	1770 ± 40	1278-1515	
				050-052		170280	Organic matter	1860 ± 40	-20,7	76	1930 ± 40	1394-1700	
6950	-23,07	-41,98	101	004-006	Box corer	166001	Organic matter	510 ± 40	-21,0	71	580 ± 40	151-172 (0.02), 177-213 (0.03), 242-467 (0.95)	0.39 ± 0.10 (0.15)
				012-014		166002	Organic matter	590 ± 40	-21,2	69	650 ± 40	297-464	
				024-028		166003	Organic matter	700 ± 40	-21,3	67	760 ± 40	337-356 (0.01), 390-571 (0.96), 589-620 (0.03)	
6669	-24,13	-44,71	102	010-012	Box corer	139016	Organic matter	1410 ± 40	-21,8	60	1460 ± 40	1002-1263	
				026-028		139017	Organic matter	2340 ± 40	-22,3	53	2380 ± 40	2012-2021 (0.01), 2033-2317 (0.99)	

TABLE III

Location, type of sample, conventional radiocarbon age (yr BP), 2σ radiocarbon calibrated age (yr BP), and estimated sedimentation rate (cm.kyr^{-1}), of samples collected in the Outer Shelf/Upper Slope Sector.

Sample	Latitude (S)	Longitude (W)	Water Depth (m)	Level (cm)	Device	Lab Number	Material	Measured Radiocarbon Age (BP)	$\delta^{13}C$ (‰ PDB)	% Marine carbon	Conventional Radiocarbon Age (BP)	2σ range (cal BP)	Sedimentation Rate (cm.kyr^{-1})
6613	-28,17	-47,92	111	010-022	Box corer	166957	Organic matter	1480 ± 40	-19,5	93	1570 ± 40	979-1271	0.27 ± 0.05 (<0.05)
				020-022		166958	Organic matter	1490 ± 40	-19,6	91	1580 ± 40	996-1283	
				030-032		166959	Organic matter	1500 ± 40	-19,7	90	1590 ± 40	1008-1291	
				040-042		166960	Organic matter	1560 ± 40	-19,9	87	1640 ± 40	1068-1341	
				050-052		166961	Organic matter	1530 ± 40	-19,8	89	1620 ± 40	1048-1321	
6956	-23,15	-41,90	118	004-006	Box corer	166983	Organic matter	720 ± 40	-21,0	71	790 ± 40	416-628	0.18 ± 0.04 (0.14)
				012-014		166984	Organic matter	1290 ± 40	-21,2	69	1350 ± 40	851-863 (0.01), 881-1145 (0.99)	
				026-028		166012	Organic matter	1450 ± 40	-21,2	69	1510 ± 40	1011-1030 (0.02), 1040-1280 (0.98)	
6627	-23,97	-43,88	133	008-010	Box corer	135535	Organic matter	1300 ± 60	-21,4	66	1360 ± 60	841-873 (0.02), 876-1179 (0.98)	
				026-028		135536	Organic matter	2750 ± 60	-21,6	63	2810 ± 60	2436-2838	
6541	-23,60	-41,71	143	010-012	Box corer	139011	Organic matter	2170 ± 40	-23,9	30	2190 ± 40	1894-2127	
				018-020		139012	Organic matter	3220 ± 40	-23,1	41	3250 ± 40	3147-3397	
6611	-28,41	-47,36	197	006-008	Box corer	166954	Organic matter	1800 ± 40	-20,6	77	1870 ± 40	1328-1621	0.08 ± 0.01 (0.08)
				022-024		166955	Organic matter	2510 ± 40	-20,9	73	2580 ± 40	2144-2513	
				028-030		170275	Organic matter	3710 ± 40	-20,5	79	3780 ± 40	3615-3956	
				034-036		166956	Organic matter	12670 ± 50	-21,6	63	12730 ± 50	O.R.	
6573	-24,91	-44,62	201	010-012	Box corer	135532	Organic matter	9850 ± 80	-20,6	77	9920 ± 80	10666-11175	
				024-026		135533	Organic matter	13900 ± 100	-21,2	69	13960 ± 100	O.R.	
7374	-24,25	-44,00	203	000	Box corer	179053	Coral	780 ± 40	-3,7		1130 ± 40	537-820	
6626	-24,23	-43,75	205	012-014	Box corer	135554	Organic matter	3820 ± 60	-21,4	66	3880 ± 60	3729-3753 (0.01), 3755-4155 (0.99)	
				032-034		133643	Organic matter	12800 ± 80	-25,3	10	12800 ± 60	O.R.	
6652	-25,85	-45,80	206	028-030	Box corer	166966	Organic matter	3630 ± 40	-20,6	77	3700 ± 40	3512-3853	
6553	-23,82	-42,79	227	004-006	Box corer	137010	Organic matter	9210 ± 40	-22,0	57	9260 ± 40	10111-10389	
				014-016		137011	Organic matter	14740 ± 50	-20,5	79	14820 ± 50	O.R.	
7486	-24,40	-44,33	233	000-002	Piston corer	215807	Organic matter	2790 ± 50	-21,7	61	2840 ± 50	2507-2854	
				020-022		215808	Organic matter	19060 ± 90	-21,9	59	19110 ± 90	O.R.	
				040-042		215809	Organic matter	22840 ± 140	-22,1	56	22890 ± 140	O.R.	
				070-072		215810	Organic matter	25990 ± 190	-22,5	50	26030 ± 190	O.R.	
				094-096		215811	Organic matter	25690 ± 180	-18,7	100	25790 ± 180	O.R.	
7369	-24,35	-44,22	237	000	Box corer	179052	Coral	1750 ± 40	-6,2		2060 ± 40	1435-1806	
6680	-25,25	-44,88	258	010-012	Box corer	139020	Organic matter	9150 ± 50	-21,6	63	9210 ± 50	9911-10247	
				020-022		139021	Organic matter	13860 ± 60	-21,2	69	13920 ± 60	O.R.	

TABLE III (continuation)

Sample	Latitude (S)	Longitude (W)	Water Depth (m)	Level (cm)	Device	Lab Number	Material	Measured Radiocarbon Age (BP)	$\delta^{13}C$ (‰ PDB)	% Marine carbon	Conventional Radiocarbon Age (BP)	2σ range (cal BP)	Sedimentation Rate ($cm.kyr^{-1}$)
7607	-27,37	-47,14	287	000-002	Piston corer	249571	Organic matter	32420 ± 260	-20,8	74	32490 ± 260	O.R.	
				100-102		249572	Organic matter	30190 ± 230	-22,7	47	30230 ± 230	O.R.	
				150-152		249573	Organic matter	37750 ± 450	-22,6	49	37790 ± 450	O.R.	
				200-202		249574	Organic matter	38870 ± 510	-22,2	54	38920 ± 510	O.R.	
				250-252		249575	Organic matter	37430 ± 450	-23,0	43	37460 ± 450	O.R.	
				300-302		249576	Organic matter	39590 ± 530	-20,9	73	39660 ± 530	O.R.	
				350-352		249577	Organic matter	39630 ± 540	-22,4	51	39670 ± 540	O.R.	
				400-402		249578	Organic matter	37540 ± 460	-21,0	71	37610 ± 460	O.R.	
				446-448		249579	Organic matter	33530 ± 310	-22,9	44	33560 ± 310	O.R.	
7485	-24,65	-44,46	374	000-002	Piston corer	189509	Foraminifera	2600 ± 40	0,9		3020 ± 40	2613-2627 (0.01), 2647-2980 (0.99)	0.01 (0.05)
				010-012		189510	Foraminifera	6970 ± 40	2,2		7420 ± 40	7701-8006	
				020-022		189511	Foraminifera	13820 ± 90	-0,1		14230 ± 90	16033-16901	
				030-032		185176	Foraminifera	16840 ± 90	-0,6		17240 ± 90	19602-19666 (0.03),	
												19792-20245 (0.97)	
				050-052		185177	Foraminifera	17670 ± 160	-0,6		18070 ± 160	20402-21360	
				076-078		185178	Foraminifera	18150 ± 140	0,3		18560 ± 140	21007-22074	
				126-128 150-152		185179 185180	Foraminifera Foraminifera	19330 ± 250 21340 ± 160	-2,5 -0,2		19700 ± 250 21750 ± 160	22349-23702 25409-26000?	
				170-172		185181	Foraminifera	24450 ± 270	0,0		24860 ± 270	O.R.	
				202-204		185182	Foraminifera	34390 ± 400	0,1		34800 ± 400	O.R.	
6664	-24,45	-44,17	472	010-012	Box corer	142061	Organic matter	2250 ± 40	-20,9	73	2310 ± 40	1854-2155	
				030-032		142062	Organic matter	3280 ± 40	-21,4	66	3340 ± 40	3156-3441	
6630	-25,82	-45,30	485	010-012	Box corer	166962	Organic matter	1410 ± 40	-20,8	74	1480 ± 40	968-1245	0.21 ± 0.03 (<0.05)
				022-024		166963	Organic matter	1490 ± 40	-20,5	79	1560 ± 40	1038-1294	
				030-032		166964	Organic matter	1590 ± 40	-20,4	80	1670 ± 40	1142-1397	
				040-042		166965	Organic matter	1870 ± 40	-20,8	74	1940 ± 40	1406-1712	
6554	-23,89	-42,76	496	010-012	Box corer	137012	Organic matter	2470 ± 50	-20,6	77	2540 ± 50	2091-2457	
				020-022		137013	Organic matter	3530 ± 30	-22,5	50	3570 ± 30	3583-3782 (0.89), 3786-3823 (0.11)	
6670	-24,69	-44,38	503	006-008	Box corer	137014	Organic matter	2200 ± 50	-21,7	61	2260 ± 50	1835-2143	
				024-026		137015	Organic matter	5330 ± 50	-20,9	73	5390 ± 50	5668-5983	
6689	-27,15	-46,63	532	020-022	Box corer	170281	Organic matter	2390 ± 40	-21,0	71	2460 ± 40	2049-2334	
				034-036		170282	Organic matter	2540 ± 50	-21,5	64	2600 ± 50	2200-2240 (0.02), 2277-2622 (0.93), 2627-2678 (0.05)	
6625	-24,48	-43,62	980	008-010	Box corer	122076	Organic matter	3550 ± 50	-19,0	100	3650 ± 50	3355-3748	
				034-036		122077	Organic matter	11650 ± 80	-18,9	100	11750 ± 80	13021-13398	
7366	-24,70	-44,03	983	042	Box corer	179051	Coral	10470 ± 50	-0,2		10880 ± 50	12092-12702	
7376	-24,52	-43,67	1000	038-040	Box corer	179054	Coral	10620 ± 40	0,8		11040 ± 40	12378-12532 (0.22), 12551-12821 (0.78)	
6542	-23,95	-41,61	1226	010-012	Box corer	142555	Bivalve	920 ± 40	1,9		1360 ± 40	728-1048	0.07 ± 0.01 (<0.05)
				010-012		139013	Organic matter	2160 ± 40	-23,5	36	2180 ± 40	1873-2112	
				018-020		139014	Organic matter	2830 ± 40	-22,7	47	2870 ± 40	2714-2888 (0.99), 2909-2916 (0.01)	
				022-024		142556	Bivalve	1740 ± 40	2,1		2190 ± 40	1581-1944	

slump. The highest sedimentation rates were found in the shallowest samples of the sector, as well as in one sample located in the 485-meter isobath (Sample 6630, 25°49.20′S-45°17.88′W).

DISCUSSION

Sedimentary Processes

As a rule, the Southwestern Atlantic upper margin is marked by low sedimentation rates. Nevertheless, when compared with its SE counterpart, the South African margin, marked by intense upwelling and terrigenous input (Herbert and Compton 2007), the pattern observed in our study area shows important similarities, such as the presence of a starving surface on the outer shelf (Compton and Wiltshire 2009, Compton et al. 2010). In the Holocene mudbelt of the western margin of South Africa, Herbert and Compton (2007) estimated sedimentation rate values ranging from 25 to 240 $cm.kyr^{-1}$, whereas on the slope, the values varied from 4 to 22 $cm.kyr^{-1}$.

The sedimentation rates calculated here never exceeded the limit of 70 $cm.kyr^{-1}$, and estimates from the Coast sector have the same order of magnitude than those from the Inner and Middle Shelf sector (Fig. 2). Outer Shelf/Upper Slope sector sediments present sedimentation rate values that are negligible, indicating the relict character of part of this sector.

Cores from the Coast sector also exhibit several age inversions, which may represent both sediment reworking due to hydrodynamic factors or biological activity. This aspect has been previously analyzed in the scientific literature (Kinoshita et al. 2002, Wood et al. 2006).

The highest sedimentation rates on the shelf were found on the Cabo Frio (around 23°S) and Santa Catarina (around 27°S) upwelling zones, which may be an indication that the marine productivity matter may represent a significant process on the sedimentary processes. On the other hand, these two areas are located closer to the main potential allochthonous sources of terrigenous sediments in the area, e.g., the Paraíba do Sul and La Plata rivers.

Figure 2 also shows a marked latitudinal break at 25°S, with an abrupt decrease in sedimentation rates northward to São Sebastião Island. In fact, this break marks the limit of influence of the sediments originating from the Río de La Plata as stated by Campos et al. (2008) and Mahiques et al. (2008).

There is a significant difference in terms of sedimentation rates when comparing the Middle Shelf sector with the Outer Shelf/Upper Slope sector sediments. Figure 3 shows a cross-shelf shallow seismic (chirp) profile in which it is possible to recognize a marked break in the sedimentary processes. The sea bottom below the 140-meter isobaths is marked by a strong roughness that, in conjunction with the low sedimentation rates obtained, indicates the effectiveness of the Brazil Current (BC) moving over the outer shelf and upper slope in reworking sediments (Silveira et al. 2001). This aspect has been locally pointed out in previous papers (Macario et al. 2004, Mahiques et al. 2007) but, considering our data, it acquires a regional importance that extends all along the outer shelf and upper slope, between 23°S and 27°S.

A representative cross-margin transect of current speeds is shown in Figure 4. The strong correlation between both speed and sedimentation rate can be seen. In this sense, the slight increase in sedimentation rate at the 450- and 500-meter isobaths is coincident with the transition between the southward flow of the Brazil Current (BC) and the northward flow of the Intermediate Western Boundary Current.

Evidence of Sea Level Stabilizations Prior to the Mid-Holocene Maximum

The scarcity of datings and reliable sea level indicators is the main characteristic of the sea level curves of the southern Brazilian shelf prior to 7,000 cal yr BP. Most of the papers published on the subject is restricted to correlations of the morphosedimentary features such as submerged terraces with global sea level curves. The study by Correa (1996) is one of the exceptions and, according to this report, stabilization periods occurred at 9,000 cal yr BP (between 32 and 45 meters below sea level) (mbsl) and 8,000 cal yr BP (between 20 and 25 mbsl). We found some indication of these paleo-sea levels. A core collected on the coast off São Sebastião (SS1, see Table I) represents a sequence of sediments varying from a mixohalyne environment, dated at 39000 cal yr BP (organic matter and benthic foraminifers) at

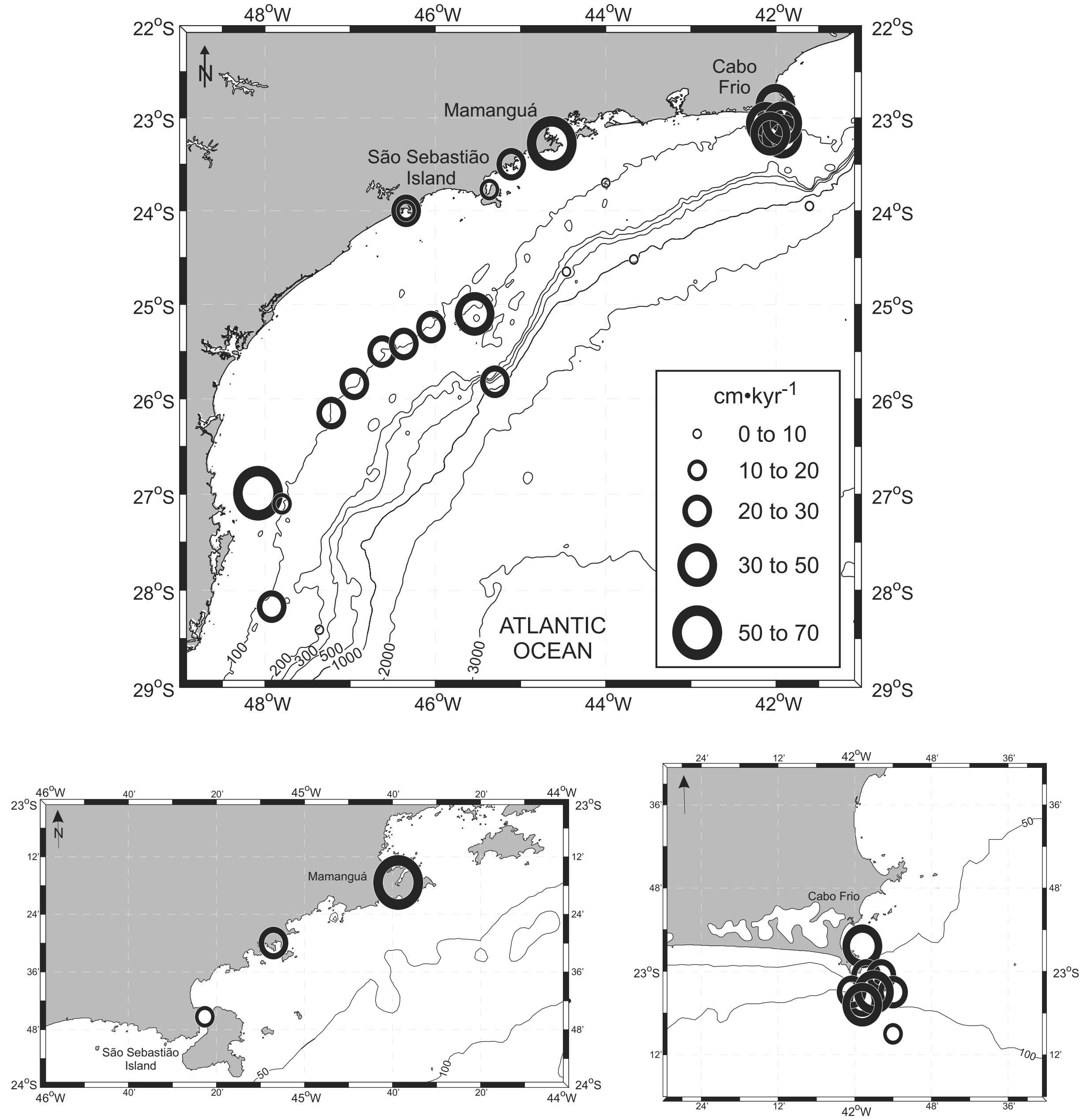

Fig. 2 – Average sedimentation rate values (in cm.kyr^{-1}) of selected samples. See the Methods section for the criteria for the choice of the samples used to determine sedimentation rates.

300 cm (6 meters bmsl) to freshwater sediments at 136 cm dated at 10240 ± 40 yr BP. This depth also marks an erosional contact, and sediments located above it exhibit properties of the Mid- to Late-Holocene ages. Due to the location of the core at the present water depth of 3 mbsl, this evidence of a coastal environment in such shallow waters during the Isotope Stage 3 represents a paradox when the worldwide sea level curves are considered. In this sense, one hypothesis to explain these anomalous ages would be a general contamination of organic matter originally deposited during the Isotope Stage 5e by young carbon (Hanebuth et al. 2006). On the other hand, the coherency of the data along the core is noteworthy. These data do not represent the

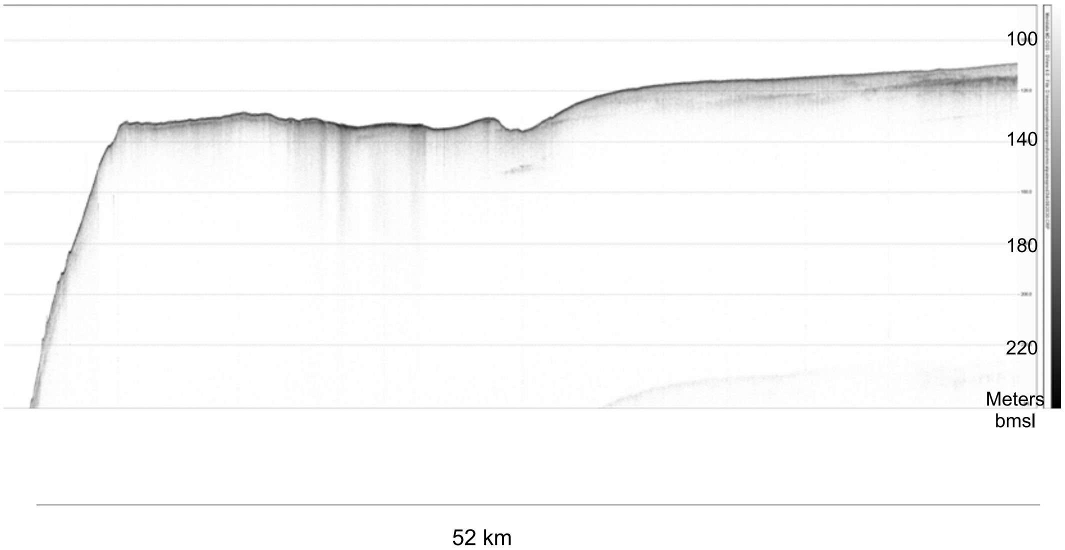

Fig. 3 – Cross-shelf shallow seismic (2-8 kHz chirp) profile showing a marked break in the bottom morphology and echo character at 130 mbsl.

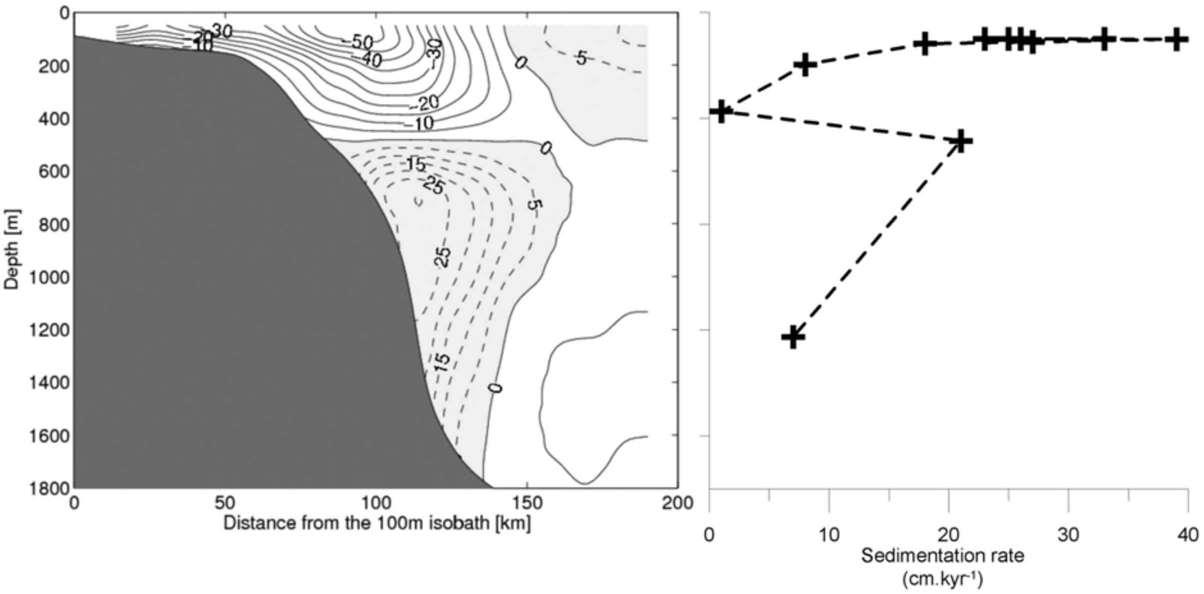

Fig. 4 – (Left) Vertical section of a typical absolute geostrophic velocity pattern (in cm/s) off the São Sebastião Island (~24.5-25.5°S). Measurements were taken in September 2003. (b) Bathymetrical variation of the average sedimentation rates (in cm.kyr^{-1}).

first evidence of high sea level during the Isotope Stage 3; in fact, other indications of sea level highstands of the same age have been found worldwide (Mausz and Hassler 2000, Rodriguez et al. 2000, Hanebuth et al. 2006, Angulo et al. 2008, among others). Nevertheless, further work is needed to improve our understanding of the significance of these data.

Sedimentological evidence of past sea levels was also found in cores FLT01 (Fig. 5) and 7616 (see Tables I and II for further information). Both cores exhibit a passage from sandy beach sediments, attributed to intense bioturbation from *Callichirus major* (Crustacea, Thalassinidea), to sandy mud sediments. In core 7616, located at 100 mbsl, the top of the sandy facies was dated at 12170 ± 70 yr BP (beyond the limit of calibration). In core FLT01, collected at a water depth of 3 mbsl, the top of the facies was dated at 7470 ± 60 yr BP (7734-8116 cal yr BP), as previously reported by Mahiques and Souza (1999).

Finally, a beach rock located at 13 mbsl presented

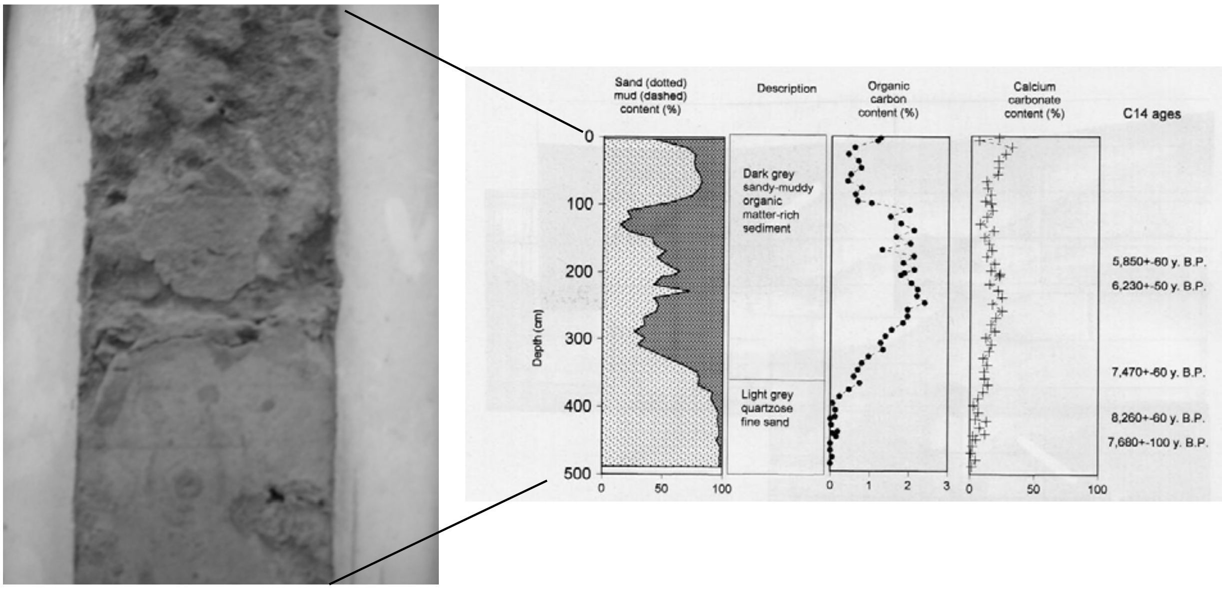

Fig. 5 – Transition between intertidal (below) to infralitoral sediments in a sediment core from the northern coast of the São Paulo Bight. See Mahiques and Souza (1999) for details.

a consistent set of four datings obtained from different materials (total rock, bivalve and fecal pellets), presenting an average age of 8470 ± 110 cal yr BP (Fig. 6).

Although the assumption that beach rocks represent the sea level during the time of their formation may not be valid (Kelletat 2006), these data may indicate the minimum depth of a sea level stabilization that occurred immediately before the Melt Water Pulse I-C, as reported in the scientific literature (Clark et al. 2001).

CONCLUSIONS

In this paper we summarize all of the information on radiocarbon datings compiled by the authors in the São Paulo Bight (southern Brazilian upper margin). Our results confirm the strong dependency of the dynamics of the shelf current system, as well as those of the Brazil Current-Intermediate Western Boundary Current (BC-IWBC) system, in the sedimentary processes of the area.

The sediments from the Coast sector exhibit sedimentation rates that may vary from 12 to 68 $cm.kyr^{-1}$. Several cores from this data set exhibit characteristics of reworking and/or bioturbation, as has been previously observed by other authors.

The sediments from the Inner and Middle Shelf sector present rates that are equivalent to those of the Coast. The highest values of sedimentation rates were found in the zones that are more favorable for upwelling processes, suggesting that organic production may act as an important source for particulate sediments. Nevertheless, the proximity of these areas to the main source of terrigenous input must not be neglected.

The sediments from the Outer Shelf/Upper Slope sector are those that are directly affected by the BC-IWBC system. As a rule, there is a clear relationship between current speeds and sedimentation rates. A Transition Zone between the cores of these two main flows is also recognizable in the sedimentation rate values.

At least three indicators of the paleo sea level at 12200 yr BP (conventional radiocarbon age) (103 mbsl), 8300-8800 cal yr BP (13 mbsl) and 7700-8100 cal yr BP (6 mbsl) were found. A Marine Isotope Stage 3 highstand at 6 mbsl found in the coast off the São Paulo State will require further study for confirmation.

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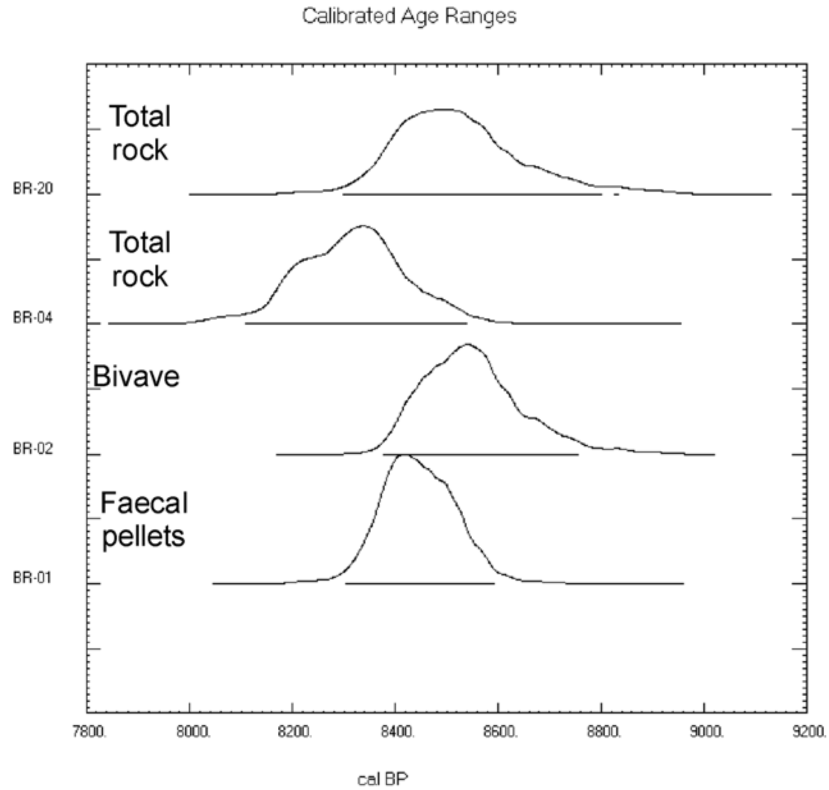

Fig. 6 – Calibrated age ranges of four samples from a beach rock located at 13 mbsl on the northern coast of São Paulo Bight. The average age of 8470±110 cal BP is consistent with a phase of sea level stabilization occurring prior to the Melt Water Pulse I-C (Clark et al. 2001).

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RESUMO

O objetivo deste trabalho foi a geração de um inventário dos dados de datação de radiocarbono obtidos de sedimentos do Embaiamento de São Paulo (Margem Continental Superior do Sul do Brasil) e analisar os dados em termos de processos sedimentares quaternários e taxas de sedimentação. Um total de 238 datações ao radiocarbono de materiais coletados com a utilização de procedimentos amostrais diferentes foi considerado neste trabalho. As taxas de sedimentação variaram de menor que 2 a 68 cm.kyr^{-1}. As taxas de sedimentação mais altas foram encontradas em um sistema costeiro de baixa energia (tipo ría), bem como nas zonas de ressurgência de Santa Catarina e Cabo Frio. As taxas mais baixas foram encontradas na plataforma externa e talude superior. Nossos resultados confirmam a forte dependência do sistema de correntes de plataforma, com ênfase no aporte terrígeno oriundo do Rio da Prata, transportado através da Corrente Costeira do Brasil, e da dinâmica da Corrente do Brasil – Corrente de Contorno Intermediária (CB-CCI) nos processos sedimentares. Pelo menos três indicadores de paleo-níveis marinhos foram encontrados a 12200 anos AP (idade radiocarbônica convencional) (103 metros abaixo do nível do mar atual – manm), 8300-8800 cal anos AP (13 manm) e 7700-8100 cal anos BP (6 manm).

Palavras-chave: margem continental, quaternário, radiocarbono, nível do mar, sedimentação.

REFERENCES

ANGULO RJ, SOUZA MC, ASSINE ML, PESSENDA LCR AND DISARÓ ST. 2008. Chronostratigraphy and radiocarbon age inversion in the Holocene regressive barrier of Paraná, southern Brazil. Mar Geol 252: 111–119.

ANGULO RJ, SOUZA MC, REIMER PJ AND SASAOKA SK. 2005. Reservoir effect of the southern and souheastern Brazilian coast. Radiocarbon 47: 67–73.

Campos EJD, Mulkherjee S, Piola AR and Carvalho FMS. 2008. A note on a mineralogical analysis of the sediments associated with the Plata River and Patos Lagoon outflows. Cont Shelf Res 28: 1687–1691.

Carroll M, Kowalewski M, Simoes MG and Goodfriend GA. 2003. Quantitative estimates of time-averaging in terebratulid brachiopod shell accumulations from a modern tropical shelf. Paleobiology 29: 381–402.

Clark PU, Marshall SJ, Clarke GKC, Hostetler SW, Licciardi JM and Teller JT. 2001. Freshwater forcing of abrupt climate change during the last Glaciation. Science 293: 283–287.

Compton JS and Herbert CT, Hoffman MT, Schneider RR and Stuut JB. 2010. A tenfold increase in the Orange River mean Holocene mud flux: implications for soil erosion in South Africa. The Holocene 20: 115–122. doi: 10.1177/0959683609348860.

Compton JS and Wiltshire JG. 2009. Terrigenous sediment export from the western margin of South Africa on glacial to interglacial cycles. Mar Geol 266: 212–222.

Correa ICS. 1996. Les variations du niveau de la mer durant les derniers 17.500 ans BP: l'exemple de la plateforme continentale du Rio Grande do Sul – Brésil. Mar Geol 130: 163–178.

Eastoe CJ, Fish S, Fish P, Gaspar MD and Long A. 2002. Reservoir corrections for marine samples from the South Atlantic coast, Santa Catarina state, Brazil. Radiocarbon 44: 145–148.

Figueira RCL, Tessler MG and Mahiques MM. 2007. Is there a technique for the determination of sedimentation rates based on calcium carbonate content? A comparative study on the southeastern Brazilian shelf. Soils Found 47: 649–656.

Furtado VV, Bonetti Filho J and Conti LA. 1996. Paleo river morphology and sea level changes at southeastern Brazilian continental shelf. An Acad Bras Cienc 68: 163–169.

Hanebuth TJJ, Saito Y, Tanabe S, Vu QL and Ngo QT. 2006. Sea levels during late marine isotope stage 3 (or older?) reported from the Red River delta (northern Vietnam) and adjacent regions. Quat Int 145-146: 119–134.

Haug G, Hughen KA, Sigman D, Peterson L and Rohl U. 2001. Southward migration of the Intertropical Convergence Zone through the Holocene. Science 293: 1304–1308.

Herbert CT and Compton J. 2007. Geochronology of Holocene sediments on the western margin of South Africa. South Afr Jour Geol 110: 327–338.

Hughen KA et al. 2004. Marine04 Marine radiocarbon age calibration, 26-0 ka BP. Radiocarbon 46: 1059–1086.

Kelletat D. 2006. Beachrock as sea-level indicator? Remarks from a geomorphological point of view. Jour Coast Res 22: 1558–1564.

Kinoshita A, Brunetti A, Avelar WEP, Mantelatto FLM, Simões MG, Fransozo A and Baffa O. 2002. ESR dating of a subfossil Shell from Couve Island, Ubatuba, Brazil. Appl Rad Isot 57: 497–500.

Kowsmann RO and Costa MOA. 1979. Sedimentação quaternária da margem continental brasileira e das áreas oceânicas adjacentes. In: REMAC Project (Final Report). Rio de Janeiro, Petrobras, p. 1–55.

Macario KD, Anjos RM, Gomes PRS, ueiredo Jr AG, Lacerda de Souza C, Barbosa CF, Coimbra MM and Elmore D. 2004. AMS radiocarbon dating on Campos basin, southeast Brazilian continental slope. Nucl Instr Meth Phys Res B 223–224: 535–539.

Mahiques MM, Bícego MC, Silveira ICA, Sousa SHM, Lourenço RA and Fukumoto MM. 2005. Modern sedimentation in the Cabo Frio upwelling system, Southeastern Brazilian shelf. An Acad Bras Cienc 77: 535–548.

Mahiques MM, Fukumoto MM, Silveira ICA, Figueira RCL, Bícego MC, Lourenço RA and Sousa SHM. 2007. Sedimentary changes on the Southeastern Brazilian upper slope during the last 35,000 years. An Acad Bras Cienc 79: 171–181.

Mahiques MM, Mishima Y and Rodrigues M. 1999. Characteristics of the sedimentary organic matter on the inner and middle continental shelf between Guanabara Bay and São Francisco do Sul, southeastern Brazilian margin. Cont Shelf Res 19: 775–798.

Mahiques MM, Silveira ICA, Sousa SHM and Rodrigues M. 2002. Post-LGM sedimentation on the outer shelf – upper slope of the northernmost part of the São Paulo Bight, southeastern Brazil. Mar Geol 181: 387–400.

Mahiques MM and Souza LAP. 1999. Shallow seismic reflectors and upper Quaternary sea level changes in the Ubatuba region, São Paulo State, Southeastern Brazil. Rev Bras Oceanogr 47: 1–10.

Mahiques MM, Tassinari CCG, Marcolini S, Violante RA, Figueira RCL, Silveira ICA, Burone L and Sousa SHM. 2008. Nd and Pb isotope signatures on the southeastern South American Upper Margin: Implications for sediment transport and source rocks. Mar Geol 250: 51–63.

MAHIQUES MM, TESSLER MG, CIOTTI AM, SILVEIRA ICA, SOUSA SHM, FIGUEIRA RCL, TASSINARI CCG, FURTADO VV AND PASSOS RF. 2004. Hydrodynamically driven patterns of recent sedimentation in the shelf and upper slope off Southeast Brazil. Cont Shelf Res 24: 1685–1697.

MAHIQUES MM, WAINER ICK, BURONE L, NAGAI R, SOUSA SHM, FIGUEIRA RCL, SILVEIRA ICA, BÍCEGO MC, ALVES DPV AND HAMMER O. 2009. A high-resolution Holocene record on the Southern Brazilian shelf: Paleoenvironmental implications. Quat Int 206: 52–61.

MAUSZ B AND HASSLER U. 2000. Luminescence chronology of Late Pleistocene raised beaches in southern Italy: new data of relative sea-level changes. Mar Geol 170: 187–203.

MCCORMAC FG, HOGG AG, BLACKWELL PG, BUCK CE, HIGHAM TFG AND REIMER PJ. 2004. SHCal04 Southern Hemisphere calibration, 0-11.0 cal kyr BP. Radiocarbon 46: 1087–1092.

MÉNDEZ G AND VILAS F. 2005. Geological antecedents of the Rias Baixas (Galicia, northwest Iberian Peninsula). J Marine Syst 54: 195–207.

MÖLLER JR OO, PIOLA AR, FREITAS AC AND CAMPOS EJD. 2008. The effects of river discharge and seasonal winds on the shelf off southeastern South America. Cont Shelf Res 28: 1607–1624.

NADAL DE MASI MA. 1999. Prehistoric hunter-gatherer mobility on the Southern Brazilian coast: Santa Catarina island. Unpublished PhD Dissertation. Stanford University, 186 p.

NAGAI RH, SOUSA SHM, BURONE L AND MAHIQUES MM. 2009. Paleoproductivity changes during the Holocene in the inner shelf of Cabo Frio, southeastern Brazilian continental margin: Benthic foraminifera and sedimentological proxies. Quat Int 206: 62–71.

ROCHA J, MILLIMAN JD, SANTANA CI AND VICALVI MA. 1975. Southern Brazil. Upper continental margin sedimentation off Brazil. Contr Sedimentol 4: 117–150.

RODRIGUEZ AB, ANDERSON JB, BANFIELD LA, TAVIANI M, ABDULAH K AND SNOW JN. 2000. Identification of a –15m middle Wisconsin shoreline on the Texas inner continental shelf. Palaeogeogr Palaeoclimatol Palaeoecol 158: 25–43.

SILVEIRA ICA, SCHMIDT ACK, CAMPOS EJD, GODOI SS AND IKEDA Y. 2001. A Corrente do Brasil ao Largo do Sudeste Brasileiro. Rev Bras Oceanogr 48: 171–183.

SOUZA RB AND ROBINSON IS. 2004. Lagrangian and satellite observations of the Brazilian Coastal Current. Cont Shelf Res 24: 241–262.

WOOD SLB, KRAUSE JR RA, KOWALEWSKI M, WEHMILLER J AND SIMÕES MG. 2006. Aspartic acid racemization dating of Holocene brachiopods and bivalves from the Southern Brazilian shelf, South Atlantic. Quat Res 66: 323–331.

WOODROFFE CD, BEECH MR AND GAGAN MK. 2003. Mid-Late Holocene El Niño variability in the equatorial Pacific from coral microatolls. Geophys Res Lett 30: 1358–1361. doi: 10.1029/2002GL015868, 2003.

ZEMBRUSCKI SG. 1979. Geomorfologia da margem continental sul brasileira e das bacias oceânicas adjacentes. In: CHAVES HAF (Ed), Geomorfologia da margem continental brasileira e áreas oceânicas adjacentes. REMAC Project Series, Rio de Janeiro, Petrobras 7: 129–177.