

15. ORGANIC MATTER IN PLEISTOCENE TO QUATERNARY TURBIDITES FROM SITES 897, 898, 899, AND 900, IBERIA ABYSSAL PLAIN¹

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ABSTRACT

Shipboard determinations of total organic carbon by difference between total carbon and carbonate carbon contents were compared to direct measurements of organic carbon in Carbonate-free sediments and found to be in generally good agreement. The direct measurement procedure tends to give slightly higher organic carbon concentrations and slightly lower organic C/N ratios. Organic C/N ratios and organic $\delta^{13}\text{C}$ values indicate that the organic matter contained in Pleistocene to Pliocene turbidites encountered at Sites 897, 898, 899, and 900 is predominantly marine in origin. Depressed C/N ratios and results of Rock-Eval pyrolysis indicate that the marine organic matter in these sequences has been extensively degraded, presumably by microbial reworking. Organic matter at Site 897 has been less degraded than at the other three sites.

INTRODUCTION

The organic matter contents of marine sediments are influenced by a variety of processes. Concentrations of organic matter reflect delivery rates from marine and continental sources, sediment accumulation rates, and post-depositional degradation rates. The character of sedimentary organic matter is controlled by its biotic sources, transport routes, and degree of preservation. Because the amount and type of organic matter are affected by these various oceanographic processes, much information about oceanic conditions of the past can be inferred from the organic matter contents of sediment cores. Reliable determination of the concentration of sedimentary organic matter is therefore a fundamental prerequisite for many paleoceanographic studies.

Different analytical procedures, however, potentially lead to different values for measurements of organic carbon concentration (Arthur et al., 1987). It is therefore not wise to use results from different procedures uncritically when comparing organic matter characterizations from various settings. The method used onboard the *JOIDES Resolution* during Leg 149 estimates organic carbon concentrations indirectly as the difference between total and carbonate carbon concentrations. Small errors in either the total or the carbonate carbon measurement can become magnified in the organic carbon estimate, particularly where organic matter levels are low. We have investigated how important this potential source of analytical error might be in estimating the concentrations of organic matter by comparing shipboard results with those of direct measurements of organic carbon in the same samples. In addition, we have employed organic $\delta^{13}\text{C}$ determinations to confirm preliminary identifications of organic matter sources based on organic C/N ratios. The results, from a Pliocene-Pleistocene turbiditic unit, are discussed in their paleoceanographic context.

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SAMPLING AND ANALYSIS

Samples and Setting

Seismic surveys performed in preparation for Leg 149 drilling identified a series of seaward-dipping sedimentary reflectors on the landward edge of the Iberia Abyssal Plain (Fig. 1). A transect of four sites drilled during Leg 149 revealed that these seismic reflectors represent a succession of Neogene-to-Quaternary turbidite layers (Table 1).

Sediment samples from the Unit I turbiditic sequences at Sites 897, 898, 899, and 900 were employed to compare the results of the shipboard and shorebased analytical schemes. Samples were selected to represent the variety of lithologies present in the turbidites. They were freeze-dried and ground prior to analysis. The two procedures for organic carbon concentrations and organic C/N ratios were performed on subsamples of the same samples. Organic carbon isotope and Rock-Eval pyrolysis analyses were done on subsets of these samples.

Organic Carbon Concentrations

Two procedures were used to determine the total organic carbon contents (TOC) of Leg 149 samples. Shipboard TOC analyses employed the difference between total carbon concentrations as measured by a Carlo Erba NA 1500 NCS analyzer and the carbonate carbon concentrations as measured by a Coulometrics 5011 inorganic carbon analyzer (Engleman et al., 1985). Shorebased TOC analyses involved first removing carbonate carbon from samples by treatment with 3N HCl, washing and drying the Carbonate-free residue, and then measuring the carbon content of the residue with a Carlo Erba 1108 CHNS analyzer. In both procedures, freeze-dried samples were combusted at 1000°C in an oxygen atmosphere in the Carlo Erba elemental analyzer, and the resulting combustion products were chromatographically separated and quantified to yield the concentrations of carbon and nitrogen (Verardo et al., 1990). These values were also used to calculate atomic C/N ratios of sediment organic matter.

C/N ratios help to distinguish between algal and land-plant origins of sedimentary organic matter. Algae typically have atomic C/N ratios between 4 and 10, whereas vascular land plants have C/N ratios of 20 and greater (Premuzic et al., 1982; Jasper and Gagosian, 1990; Meyers, 1994; Prah et al., 1994). This distinction arises from the absence of cellulose in algae and its abundance in vascular plants and is largely preserved in sedimentary organic matter.

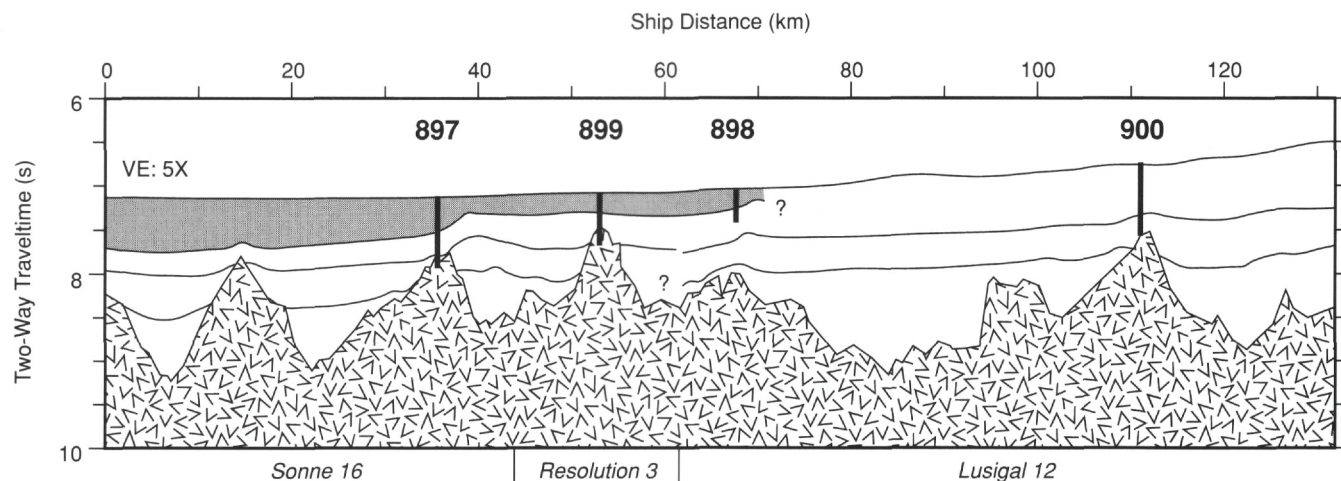


Figure 1. A composite seismic profile of the turbidite layers encountered by drilling during Leg 149. The layer of Pleistocene to Pliocene terrigenous sediments that is the focus of this study is shown in stippling. Vertical exaggeration (VE) is fivefold.

TOC concentrations are reported on a whole-sediment basis. As observed by Arthur et al. (1987), reliable and consistent CaCO_3 measurements are critical to using the whole-sediment basis. The coulometric carbonate carbon analysis procedure used by ODP is well-tested (Engleman et al., 1985). In addition, we have tested the coulometric procedure against the DSDP-standard carbonate bomb procedure of Müller and Gastner (1971) and found the results to agree very well (Meyers, unpubl. data). Finally, the TOC concentrations determined by the two procedures are converted to whole-sediment percentages using the same CaCO_3 values for each sample, thereby eliminating this source of possible variability.

Organic Carbon Isotope Ratios

Organic carbon isotope measurements of Leg 149 samples were done in the Stable Isotope Laboratory at The University of Michigan. Organic carbon $^{13}\text{C}/^{12}\text{C}$ ratios of the Carbonate-free residues used for shorebased TOC analyses were measured after reacting the samples with CuO in evacuated and sealed quartz tubes for 3 hours at 800°C . The CO_2 produced by oxidation of the organic matter was analyzed with a Finnigan Delta S mass spectrometer. National Bureau of Standards carbon isotope standards were routinely used to calibrate the instruments. Results are reported relative to the PDB standard.

Organic carbon isotopic ratios are useful to distinguish between marine and continental plant sources of sedimentary organic matter. Most photosynthetic plants incorporate carbon into organic matter using the C_3 Calvin pathway which biochemically discriminates against ^{13}C to produce a $\delta^{13}\text{C}$ shift of about -20‰ from the isotope ratio of the inorganic carbon source. Organic matter produced from atmospheric CO_2 ($\delta^{13}\text{C} \approx -7\text{‰}$) by land plants using the C_3 pathway consequently has an average $\delta^{13}\text{C}$ (PDB) value of $\sim -27\text{‰}$ (cf. O'Leary, 1988). The source of inorganic carbon for marine algae is dissolved bicarbonate, which has a $\delta^{13}\text{C}$ value of $\sim 0\text{‰}$. Marine organic matter consequently typically has $\delta^{13}\text{C}$ values between -20‰ and -22‰ . The $\approx 7\text{‰}$ difference between organic matter produced by C_3 land plants and marine algae has been used to trace the delivery and distribution of organic matter to sediments of ocean margins (Newman et al., 1973; Prahl et al., 1994). Carbon isotope ratios can be affected, however, by photosynthetic dynamics and by post-depositional diagenesis (Dean et al., 1986; McArthur et al., 1992) and consequently must be interpreted cautiously. Prominent among these are the availability of CO_2 during photosynthesis and the possibility of selective diagenesis of organic matter fractions that are isotopically

heavy or light. Any diagenetic isotope shift appears to be small, less than 2‰ (Hayes et al., 1989; Fontugne and Calvert, 1992; McArthur et al., 1992; Meyers, 1994). Increased availability of dissolved CO_2 to algae, however, would enhance their isotopic discrimination and produce marine organic matter that is isotopically light (Hayes et al., 1989), as would increased delivery of isotopically light fluvial dissolved inorganic carbon (Fontugne and Calvert, 1992).

Rock-Eval Pyrolysis

Rock-Eval analyses were done onboard the JOIDES Resolution using a Girdel II instrument. Rock-Eval pyrolysis of organic matter consists of heating samples at a rate of $25^\circ\text{C}/\text{min}$ between 300°C to 600°C to yield the amount of volatile hydrocarbons (S_1), the amount of thermogenic hydrocarbons (S_2), and the amount of CO_2 released during pyrolysis to 390°C (S_3). These values are combined with TOC values to provide the information necessary to calculate the hydrogen index ($\text{HI} = 100 \times \text{S}_2/\text{TOC}$, or mg hydrocarbons/g organic carbon) and the oxygen index ($\text{OI} = 100 \times \text{S}_3/\text{TOC}$, or mg CO_2/g organic carbon). The temperature of peak hydrocarbon release during pyrolysis (T_{max}) is also obtained and provides a measure of organic matter thermal maturity (Espitalié et al., 1977).

Rock-Eval pyrolysis was originally developed to characterize the organic matter present in oil source rocks, which typically contain more thermally mature organic matter that is at higher concentrations than commonly found during scientific ocean drilling. Rock-Eval analyses have nonetheless proved valuable in helping to determine organic matter sources in DSDP and ODP samples. Land-plant organic matter is usually rich in woody components and consequently has lower hydrogen indices and higher oxygen indices than found in lipid-rich and cellulose-poor algal organic matter. This distinction between organic matter from continental and marine sources becomes blurred by diagenesis as marine matter oxidizes and gradually takes on HI and OI values similar to those of land-plant material.

RESULTS AND DISCUSSION

Calcium Carbonate Concentrations

Concentrations of CaCO_3 are quite variable in the Unit I sediments (Table 2). The ranges of concentrations are: Site 897, 2% to 78%; Site 898, 2% to 61%; Site 899, 3% to 48%; Site 900, 2% to 67%. This variability reflects the intermix of pelagic and hemipelagic

Table 1. Summary of the turbidite units found by drilling at Sites 897, 898, 899, and 900 on the Iberia Abyssal Plain.

	Site 897	Site 899	Site 898	Site 900
Water depth (m):	5320	5291	5279	5037
Lithologic unit (mbsf):				
Pleistocene to Pliocene terrigenous turbidites (silty clay, silt, fine sand)	0–292	81–132	0–162	—
Pleistocene to Pliocene hemipelagic turbidites (nanofossil clays and oozes)	—	—	—	0–67
Pliocene to Miocene hemipelagic sediments (silty clay with nanofossil clay and chalk)	—	132–207	162–172	—
Late Pliocene to late Miocene hemipelagic turbidites (nanofossil claystone and chalk)	292–301	—	—	67–96
Late Miocene to early Miocene hemipelagic turbidites (nanofossil claystone and chalk with fine sandstone)	301–360	—	—	96–181

Note: The variations in the thickness and compositions between the units at the four sites, which are separated by only 75 km, are noteworthy.

sediment types in these turbidites, which ranges from nanofossil ooze to fine sand (Shipboard Scientific Party, 1994a-d).

Organic Carbon Concentrations

The results of the shipboard and shorebased organic carbon analyses of individual samples are compared in Table 2. About one-third of the comparisons agree within 0.1%, which is excellent for sediments with relatively low TOC concentrations (<0.5%). The post-cruise concentrations determined by analysis of Carbonate-free samples tend to be systematically higher than concentrations determined onboard ship by difference between total carbon and carbonate carbon concentrations (Fig. 2). The difference between the two procedures is not related to CaCO₃ content. This comparison shows that (1) the difference method slightly underestimates TOC concentrations in sediments having low amounts of organic matter and (2) washing Pleistocene and older sediment samples with 3N HCl and water does not mobilize and remove significant amounts of organic matter. These results agree with a similar comparison of the shipboard TOC by-difference procedure with a shorebased direct analysis in the sense that little difference was found, but they disagree in that the shorebased procedure gave slightly lower values (Katz, 1992). Two factors are important to the differences between the results of our comparison and those of Katz (1992). The primary factor is probably that he used a LECO CS analyzer instead of a Carlo Erba CHNS analyzer, and the secondary one is that the sediments he studied contained between 1% and 8% TOC. The two comparisons nonetheless show that little error is introduced into TOC determinations over a wide range of concentrations by the shipboard by-difference procedure.

Averaged shorebased organic carbon concentrations of the Unit I samples are: Site 897, 0.78%; Site 898, 0.68%; Site 899, 0.44%; Site 900, 0.36%. These values are slightly higher than the average organic carbon content of 0.2% of deep-sea sediments and rocks from DSDP Legs 1 through 33 compiled by McIver (1975). Many of the samples, however, are poor in organic carbon, and their low concentrations are not related to their CaCO₃ concentrations (Table 2). Of particular note, the uppermost lithologic units drilled at Sites 897, 898, and 899 seem to be parts of a single, continuous turbidite unit (Fig. 1; Table 1), yet the TOC concentrations at Sites 897 and 898 are significantly higher than those at Site 899, which is located between the other two. In addition, TOC concentrations are variable with depth in Unit I as it is expressed at each of the four drill sites. The accumulation of organic matter at the landward edge of the Iberia Abyssal Plain evidently has varied both spatially and temporally during the Pliocene and Pleistocene. Part of this variability may result from the turbidites originating from different locations on the Iberia Margin, and part

may be caused by the greater thicknesses of the turbidites at Sites 897 and 898 relative to Sites 899 and 900, which affects the degree of postdepositional preservation of organic matter (Shaw and Meyers, this volume).

Organic Matter C/N Ratios

Atomic C/N ratios calculated from the shipboard and shore-based TOC analyses are compared in Table 2. Nearly half the comparisons agree within ± 1 , and only one sample (149-898A-13H-6, 95-96 cm) has widely divergent ratios. In general, the two procedures give comparable results, particularly when considering that C/N ratios should not be over-interpreted. The ratios based on shorebased TOC measurements tend to be systematically higher than those based on the shipboard TOCs (Fig. 3). This difference cannot be caused by differences in TOC concentrations, which are higher in the shorebased results (Fig. 2). Instead, it is likely that errors in quantifying the nitrogen concentrations are larger in the shipboard procedure, inasmuch as these concentrations are determined by NCS elemental analysis of whole sediment samples in which the total carbon peak is much larger than the nitrogen peak. A likely consequence of this procedural difference is that the variability of the shorebased C/N ratios is less than that of the shipboard ratios (Table 2). For this reason, the results of the shorebased analyses will be the basis for discussing the significance of the C/N ratios.

The averaged shorebased atomic C/N ratios of the Unit I samples are: Site 897, 4.6 ± 1.6 ; Site 898, 3.8 ± 3.9 ; Site 899, 3.7 ± 1.8 ; Site 900, 2.9 ± 2.1 . These ratios indicate that marine contributions dominate the organic matter in these turbidite layers and that the organic matter has been at least partially degraded within its host sediment. Fresh algal organic matter typically has C/N ratios between 4 and 10 (Meyers, 1994). Degradation of organic matter in marine sediments tends to lower C/N ratios as nitrogenous compounds break down to produce ammonia, which is retained by clay minerals, and the CO₂ released by oxidation of organic carbon escapes (Müller, 1977). Some of the samples have C/N ratios of 1 or 2; these are too low to represent undegraded organic matter. A few samples have C/N ratios between 10 and 20; these samples probably contain elevated proportions of land-derived organic matter. Furthermore, the higher average C/N ratio of 4.6 in the Site 897 Unit I samples suggests that the marine organic matter at this location has experienced less degradation than at the other sites. This is consistent with the greater average thickness of the turbidite units at this site (Shipboard Scientific Party, 1994a).

Carbon Isotope Ratios

Organic $\delta^{13}\text{C}$ values of Unit I sediment samples from the four sites average $\sim 23\text{‰}$, which indicates that most of the organic matter originated from marine production (Meyers, 1994). The range of these values, from -19.0‰ to -26.8‰ (Table 2), suggests, moreover, that the origins have not been identical and that the proportion of land-derived material may become important in some turbidite layers. For example, Sample 149-898A-7H-6, 63-64 cm, has a $\delta^{13}\text{C}$ value of -25.1‰ and a shorebased C/N value of 13.3. The organic carbon in this sample appears to be as much as 50% terrigenous. The $\delta^{13}\text{C}$ values of other samples, in contrast, are significantly heavier than the average. Sample 149-897C-19R-3, 61-62 cm, for example, has a value of -19.0‰ , which is somewhat heavier than typical marine organic matter (-20‰ to -22‰ ; Meyers, 1994). Isotopically heavy organic matter can be produced by marine algae during times of diminished availability of dissolved CO₂, such as accompany spring blooms or upwellings. The organic matter in the isotopically heavy samples may have originated from coastal areas of high productivity 200 km to the east of the abyssal plain and was delivered to the deep-sea by turbidity flows of continental shelf sediment.

Rock-Eval Analyses

A Van Krevelen-type plot of the HI and OI values suggests that the Leg 149 turbiditic sediments contain type III (land-derived) organic matter (Fig. 4). This source assignment for the organic matter conflicts, however, with the low C/N ratios and the $\delta^{13}\text{C}$ values for these samples (Table 2), which suggest that the organic matter is predominantly marine. The contradiction between the Rock-Eval source characterization and the elemental and isotopic source characterizations indicates that the marine organic matter has been heavily oxidized, probably by microbial reworking. The microbial reworking of the organic matter in the turbiditic units at Sites 899 and 900 evidently happened prior to redeposition of these sediments on the Iberia Abyssal Plain, inasmuch as little sulfate reduction has occurred at these locations (Shipboard Scientific Party, 1994c, 1994d). In contrast, in situ microbial reprocessing of organic matter is indicated at Sites 897 and 898 by the disappearance of interstitial sulfate and accompanying appearance of pore-water methane with increasing sediment depth at these locations (Shipboard Scientific Party, 1994a, 1994b). The HI values of samples from Sites 897 and 898 are in general higher than those of samples from Sites 899 and 900 (Fig. 4), indicating that the marine organic matter at Sites 897 and 898 has in fact not been as severely microbially reworked.

Paleoceanographic Significance

The amounts and types of organic matter present in Pliocene-Pleistocene Unit I sediments at Sites 897, 898, 899, and 900 differ. Both Site 897 and Site 898 have sediments that contain higher amounts of organic matter that has experienced less microbial reworking than present at Sites 899 and 900. The lithologic contents of Sites 897, 898, and 900 seem to be the same, although Unit I sediments at Site 900 are clearly different from sediments obtained at the other three sites (Table 1). The four sites are in close proximity to each other, and it is unlikely that they experienced significantly different paleoceanographic conditions since the sediments were emplaced. Instead, it is likely that two factors associated with the turbidity flows that created the turbidite sequence on the Iberia Abyssal Plain influenced accumulation of organic matter in the sediments at these sites.

The first possibility is that the turbidity flows may have obtained their entrained organic matter from different environments during the Pliocene-Pleistocene. A variety of possible initial settings exists on the Iberia Margin. The locations of the Leg 149 drill sites are surrounded by topographic highs to the south and the north and are not very far from the continental margin of Iberia (Fig. 5). Turbidites could have originated from all of these locations, and they would carry their entrained organic matter to the Iberian Abyssal Plain locations where the sediments would only partially intermix. Considerable geographic heterogeneity would remain, as would the downcore differences in the various turbidity layers (Shipboard Scientific Party, 1994a-d).

The second possibility is that differences in the thicknesses of turbidite layers present at the four sites affected post-depositional degradation of the entrained organic matter. Turbidite sequences are thicker at Sites 897 and 898 (Shipboard Scientific Party, 1994a, b) and probably protected organic matter from oxic early degradation. In contrast, turbidites at Sites 899 and 900 are thinner (Shipboard Scientific Party, 1994c, d) and organic matter could be oxidized soon after deposition. An analogous relationship between rates of turbidite accumulation and degree of organic matter preservation has been described in Quaternary sediments on the Cape Verde Abyssal Plain (Thomson et al., 1993). The more distal Iberia Abyssal Plain sites in particular, have thicknesses (up to 1 m) that approximate those studied on the Cape Verde Abyssal Plain. Nonetheless, both differences in delivery of organic matter and in its subsequent preservation could be involved at the Leg 149 sites.

SUMMARY

Shipboard determinations of total organic carbon by difference between total carbon and carbonate carbon contents and direct measurements of organic carbon in Carbonate-free sediments are in generally good agreement. The direct measurement procedure tends to give slightly higher organic carbon concentrations and slightly lower organic C/N ratios. Organic C/N ratios and organic $\delta^{13}\text{C}$ values indicate that the organic matter contained in Pleistocene to Pliocene turbidites encountered at Sites 897, 898, 899, and 900 is predominantly marine in origin. Depressed C/N ratios and results of Rock-Eval pyrolysis indicate that the marine organic matter in these sequences has been extensively degraded, presumably by microbial reworking. Organic matter in sediments from Sites 897 and 898 is at higher concentrations and has been less degraded than that from Sites 899 and 900. Variability in the amounts and types of organic matter at these four locations indicates that (1) their turbidity layers originated from different shallow-water locations that changed through time, even though their sediment lithologies are generally the same, and (2) differences in thicknesses of the turbidity layers at the four sites have contributed to the differing degrees of organic matter preservation.

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Table 2. Concentrations of calcium carbonate and organic carbon, organic matter atomic C/N ratios, and organic $\delta^{13}\text{C}$ values from Quaternary and Neogene turbiditic sediments at Sites 897, 898, 899, and 900 on the Iberia Abyssal Plain.

Core, section, interval (cm)	Depth (mbsf)	CaCO ₃ (%)	Org. C (%)		Atomic C/N		$\delta^{13}\text{C}_{\text{org}}$ (‰)
			ship	shore	ship	shore	
Site 897							
Unit I: Pleistocene to Pliocene silty clay, silt, and fine sand							
149-897A-							
3R-CC, 1-2	17.21	20	0.58	0.95	7.2	6.8	-23.3
4R-1, 58-60	26.88	22	0.73	0.97	10.0	6.9	-23.5
4R-1, 121-122	27.51	32	0.34	0.52	5.6	4.5	-23.3
4R-2, 60-62	28.40	65	0.40	0.74	6.6	4.8	-23.0
5R-2, 21-22	37.71	55	0.53	0.84	8.8	6.0	-22.6
5R-2, 45-46	37.95	64	0.50	1.09	8.3	6.3	-22.8
5R-2, 122-123	38.72	37	0.47	0.60	7.8	5.1	-23.0
149-897C-							
1R-1, 30-31	50.20	37	0.49	0.76	3.2	5.8	-22.8
149-897A-							
6R-5, 2-3	51.62	41	0.25	0.47	—	4.0	-24.0
6R-5, 36-37	51.96	18	0.56	0.56	5.6	4.5	-24.0
149-897C-							
2R-1, 58-59	60.48	3	0.43	0.45	3.9	4.1	-23.8
3R-1, 12-13	69.72	22	0.19	0.17	3.1	4.5	-22.9
4R-1, 17-18	79.37	42	0.57	0.92	5.7	6.2	-23.3
4R-1, 54-55	79.74	14	0.50	0.59	4.5	4.5	-23.9
5R-1, 59-60	89.49	28	0.74	0.81	6.7	6.0	-23.1
5R-2, 61-62	91.01	28	0.33	0.36	4.1	3.5	-23.1
6R-1, 53-54	99.03	34	0.64	0.75	7.1	5.2	-22.7
7R-1, 34-35	108.54	16	0.60	0.68	6.0	4.7	-23.3
7R-1, 113-114	109.33	17	0.82	0.83	7.4	6.1	-23.5
8R-2, 19-20	119.59	17	0.52	0.59	6.5	5.9	-21.6
8R-2, 113-114	120.53	38	0.37	0.51	4.6	4.0	-22.9
8R-3, 57-58	121.47	71	0.17	0.47	3.4	3.2	-22.7
9R-1, 1-2	128.51	12	0.34	0.33	3.4	2.9	-23.0
10R-1, 56-57	137.76	22	0.79	0.93	7.9	6.7	-23.1
11R-2, 65-66	147.74	28	0.39	0.44	4.3	3.6	-23.1
11R-2, 71-72	147.80	14	0.47	0.47	4.7	3.6	-23.4
11R-4, 29-30	150.09	2	0.25	0.34	2.5	2.6	-23.1
11R-4, 92-93	150.72	49	0.38	0.30	4.7	2.4	-23.2
12R-5, 138-139	163.98	78	0.16	0.59	4.0	4.3	-22.6
12R-6, 13-14	164.23	65	0.11	0.50	2.2	4.0	-23.0
12R-6, 34-35	164.44	12	0.63	0.64	7.0	5.9	-23.5
14R-2, 84-85	178.14	58	0.08	0.39	1.0	3.2	-22.9
14R-3, 30-31	179.10	10	0.07	0.39	1.0	2.8	-23.6
14R-3, 36-37	179.16	12	0.62	0.82	10.0	6.9	-22.4
14R-4, 64-65	180.94	20	1.21	1.47	10.1	7.3	-22.7
15R-1, 23-24	185.63	16	0.79	0.97	7.9	5.9	-22.0
15R-1, 37-38	185.77	15	0.57	0.58	9.5	6.7	-22.2
15R-2, 119-120	188.09	52	0.32	0.59	5.3	4.0	-23.3
16R-1, 69-70	195.79	31	0.45	0.50	5.6	3.4	-23.0
16R-1, 107-108	196.17	34	0.13	0.38	2.1	3.1	-23.1
17R-1, 39-40	205.09	34	0.34	0.46	5.6	2.9	-23.4
17R-1, 125-126	205.95	78	0.20	0.96	5.0	0.5	-22.5
19R-1, 10-11	224.20	15	0.77	0.98	8.5	6.2	-22.4
19R-3, 61-62	227.71	13	0.77	3.13	9.6	3.4	-18.9, -19.1
20R-1, 10-11	233.90	9	0.80	0.90	8.0	6.0	-23.2
20R-1, 134-135	235.14	55	0.36	0.44	7.2	3.4	-23.9
21R-1, 107-108	244.47	8	0.85	0.44	12.0	3.1	-23.6

Table 2 (continued)

Core, section, interval (cm)	Depth (mbsf)	CaCO ₃ (%)	Org. C (%)		Atomic C/N		$\delta^{13}\text{C}_{\text{org}}$ (‰)
			ship	shore	ship	shore	
21R-1, 134-135	244.74	6	0.57	0.68	11.0	7.9	-21.6
22R-2, 73-74	255.23	27	0.31	1.43	3.9	2.2	-23.7
22R-2, 99-100	255.49	31	0.90	1.95	9.0	4.2	-19.1
23R-1, 140-141	264.10	16	1.03	1.56	14.7	6.4	-21.7
25R-1, 11-12	282.11	10	0.51	1.64	7.3	3.1	-19.8
25R-1, 128-129	283.28	11	0.48	1.70	6.8	2.2	-23.5
Unit II: Upper Pliocene to Miocene nannofossil claystone and chalk							
26R-2, 60-61	293.60	53	0.13	0.17	6.5	1.5	-23.5
26R-2, 134-135	294.34	30	0.11	0.17	2.7	1.2	-23.6
28R-5, 30-31	317.20	47	2.53	0.13	—	1.3	-23.1
29R-5, 21-22	326.71	34	0.17	0.55	2.8	0.6	-23.1
31R-1, 129-130	341.19	37	0.66	2.81	8.2	2.6	-20.8
Site 898							
Unit I: Pleistocene to Pliocene silty clay, silt, and fine sand							
149-898A-							
7H-4, 79-80	61.99	14	1.08	1.07	12.0	8.5	-23.3
7H-6, 63-64	64.83	22	1.20	0.74	15.0	13.3	-25.1
7H-6, 79-80	64.99	18	0.43	0.36	21.0	7.3	-21.6
8H-1, 103-104	67.23	26	0.39	0.67	3.9	5.8	-22.8
8H-5, 106-107	73.32	4	0.33	0.40	3.6	3.8	-23.4
8H-7, 60-61	75.86	8	0.35	0.06	11.0	1.2	-22.5
9H-4, 24-25	80.56	19	1.77	1.95	22.1	18.7	—
10H-3, 85-86	89.05	25	0.42	0.54	6.0	4.2	-21.7
10H-5, 81-82	92.01	16	0.85	1.04	—	7.4	-23.9
11H-1, 106-107	95.76	18	0.53	0.59	7.6	5.0	-23.3
11H-2, 73-74	96.95	2	0.16	0.39	—	4.1	-23.7
12H-3, 105-106	108.27	15	0.49	0.69	6.1	5.6	-22.9
13H-6, 95-96	122.15	12	3.33	0.36	83.2	3.1	-22.9
14H-5, 74-75	130.00	31	0.30	0.54	2.5	4.6	-23.7
14H-5, 77-78	130.03	10	0.38	0.49	5.4	3.6	-23.9
15X-1, 45-46	133.15	16	0.39	0.59	6.5	5.0	-23.3
15X-2, 43-44	134.63	12	0.53	0.69	13.0	8.3	-24.0
17X-1, 70-71	149.20	15	0.60	0.71	10.0	7.3	-22.1
17X-2, 100-101	151.00	29	0.76	1.25	8.4	6.3	-21.9
17X-2, 134-135	151.34	61	0.10	0.53	0.8	4.2	-22.9
Unit II: Pliocene to Miocene silty clay with nannofossil clay and ooze							
23X-1, 78-79	207.18	28	0.16	0.15	1.1	1.8	-23.4
26X-1, 101-102	236.21	21	0.38	0.46	2.4	4.7	-22.6
Site 899							
Unit I: Pleistocene to Pliocene silty clay, silt, and fine sand							
149-899A-							
1R-1, 48-49	81.98	20	1.07	1.49	13.4	8.6	-20.8
1R-1, 73-74	82.23	3	0.04	0.11	2.0	3.8	-19.0
2R-1, 48-49	91.58	24	0.24	0.39	4.8	3.5	-24.6
2R-1, 69-70	91.79	15	0.30	0.59	5.0	3.3	-24.1
2R-2, 16-17	92.76	39	0.03	0.33	1.0	3.7	-23.3
3R-1, 33-34	101.13	6	0.00	0.25	—	2.6	-25.2
3R-2, 146-147	103.76	20	0.14	0.42	4.6	3.5	-24.0
4R-1, 107-108	111.47	9	nd	0.20	nd	2.3	-24.1
4R-2, 48-49	112.38	8	0.24	0.36	4.8	2.5	-23.2
5R-2, 101-102	122.61	48	0.18	0.31	6.0	3.0	-23.1
Site 900							
Unit IA: Pleistocene to Pliocene nannofossil clays and oozes							
149-900A-							
4R-1, 54-55	21.34	28	0.00	0.28	—	2.5	-22.8
6R-1, 29-30	40.29	56	0.53	0.32	10.0	2.6	-22.9
7R-3, 119-120	53.79	68	nd	0.39	nd	3.7	-23.5
9R-2, 25-26	66.25	67	nd	0.32	nd	3.2	-23.5
Unit IB: Upper Pliocene to upper Miocene nannofossil claystone and chalk							
10R-4, 52-53	79.12	37	0.04	0.19	1.0	1.8	-23.2
11R-3, 90-91	87.60	38	nd	0.16	nd	1.5	-23.3
12R-2, 48-49	95.38	20	nd	0.08	nd	0.9	-23.4
Unit IC: Upper Miocene to lower Miocene nannofossil claystone, chalk, and sandstone							
14R-1, 49-50	113.20	2	0.00	0.13	—	1.5	-21.1
14R-5, 143-144	120.10	45	nd	0.17	nd	2.0	-24.3
16R-2, 73-74	134.20	47	0.08	0.30	2.0	3.0	-26.8
17R-2, 15-16	143.30	29	nd	0.76	nd	6.0	-21.3
18R-1, 49-50	151.80	28	nd	0.21	nd	2.3	-23.6
18R-4, 34-35	156.10	48	nd	1.78	nd	9.2	-21.6
20R-1, 25-26	170.90	50	nd	0.23	nd	2.5	-23.5
21R-1, 58-59	180.90	3	nd	0.14	nd	1.5	-23.7
Unit IIA: Lower Miocene nannofossil claystone, siltstone, and sandstone							
22R-1, 86-87	190.80	68	nd	0.20	nd	2.0	-23.7
23R-2, 101-102	202.00	38	nd	0.03	nd	0.4	-23.9
24R-4, 59-60	214.30	23	nd	0.08	nd	1.2	-23.3
26R-2, 119-120	231.10	24	nd	0.48	nd	6.4	-22.9

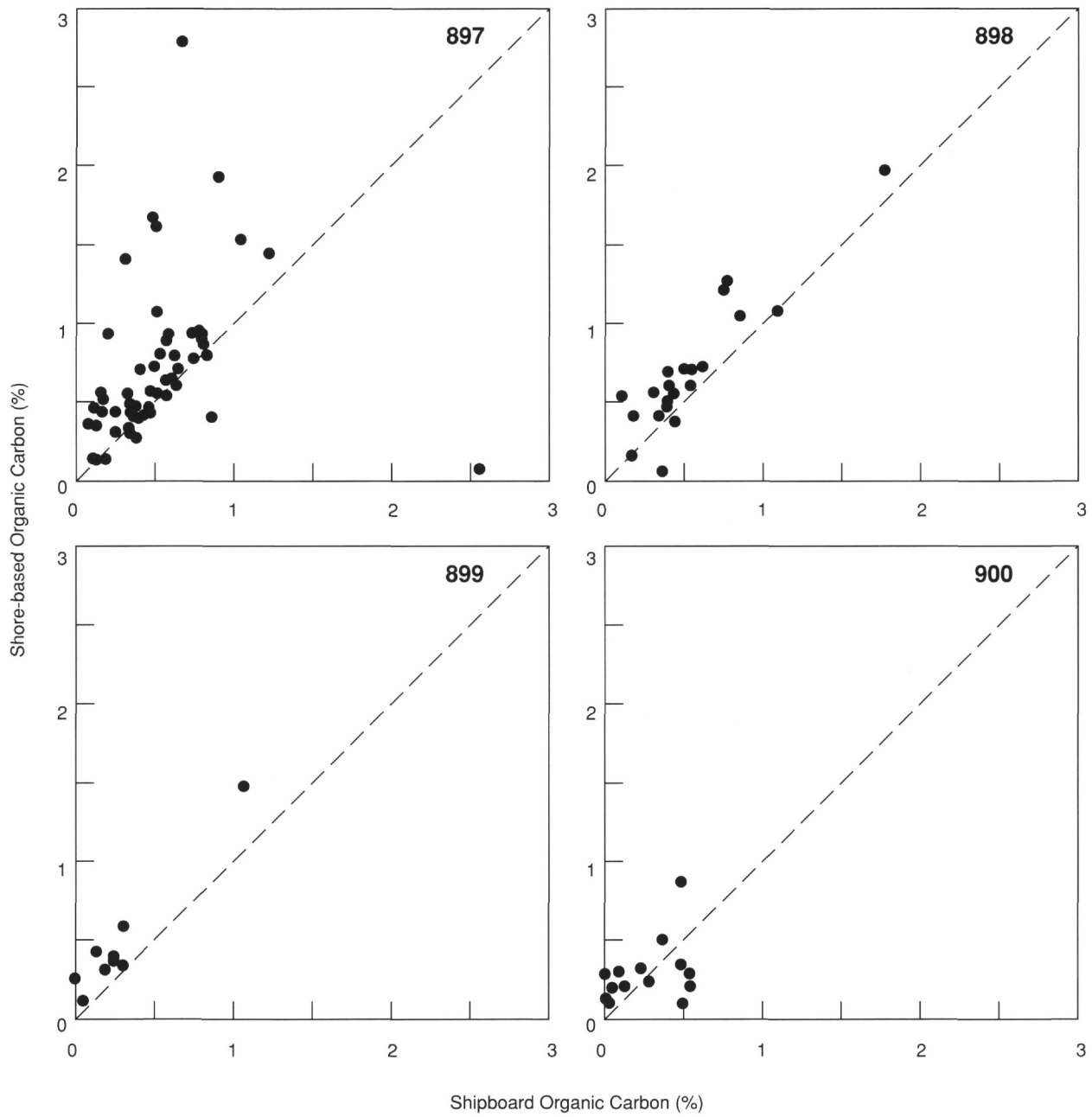


Figure 2. Comparison of organic carbon measurements for Sites 897-900. Measurements done on board ship were by difference between total and carbonate carbon contents, and those in the shore-based laboratory were by direct analysis of Carbonate-free samples. Dashed lines indicate one-to-one correspondence of two procedures.

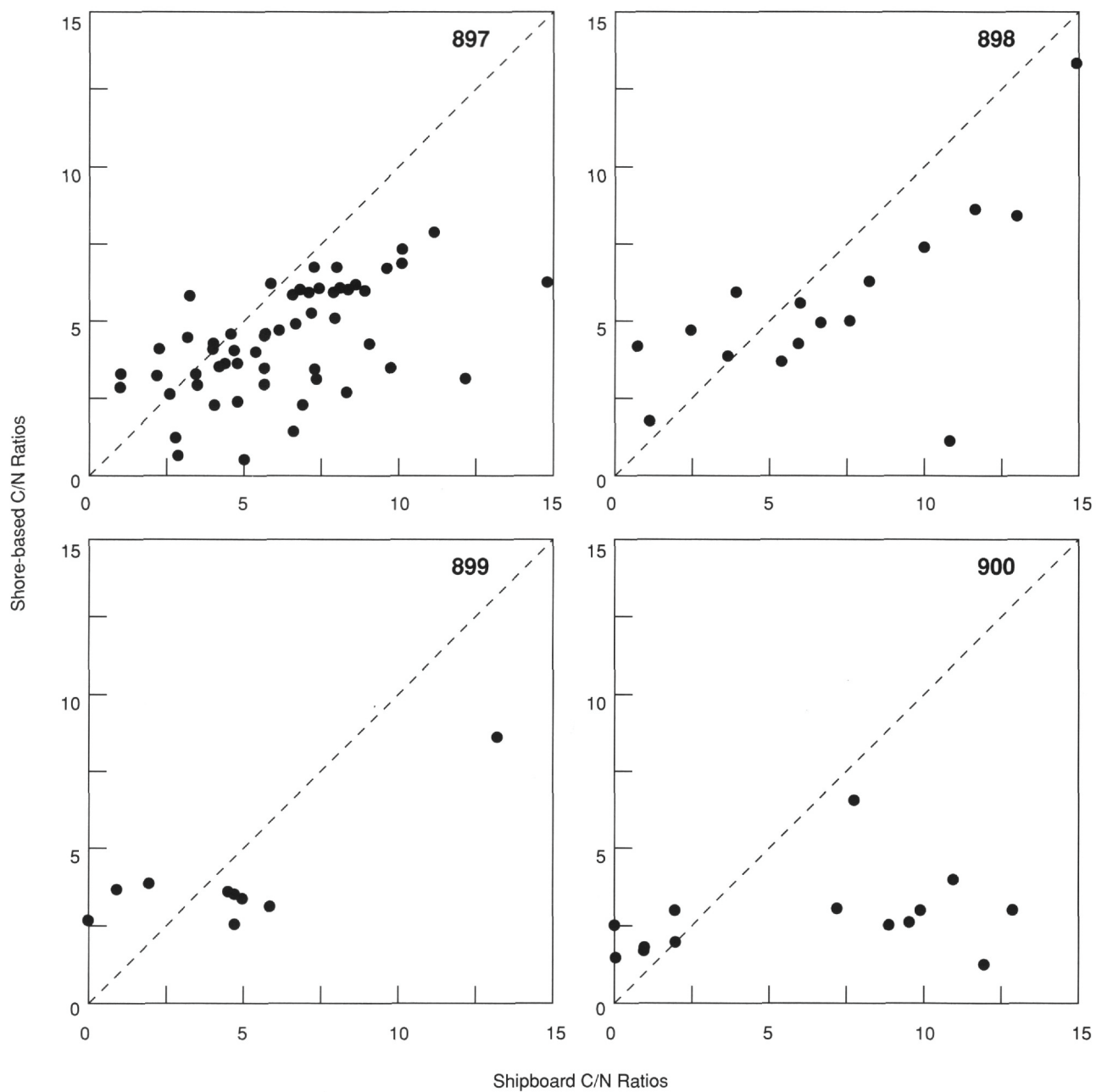


Figure 3. Comparison of organic C/N ratios for Sites 897-900. Those determined from shipboard organic carbon measurements were based on difference between total and carbonate carbon contents. Those determined from shore-based measurements were based on direct analysis of Carbonate-free samples. Dashed lines indicate one-to-one correspondence of two procedures.

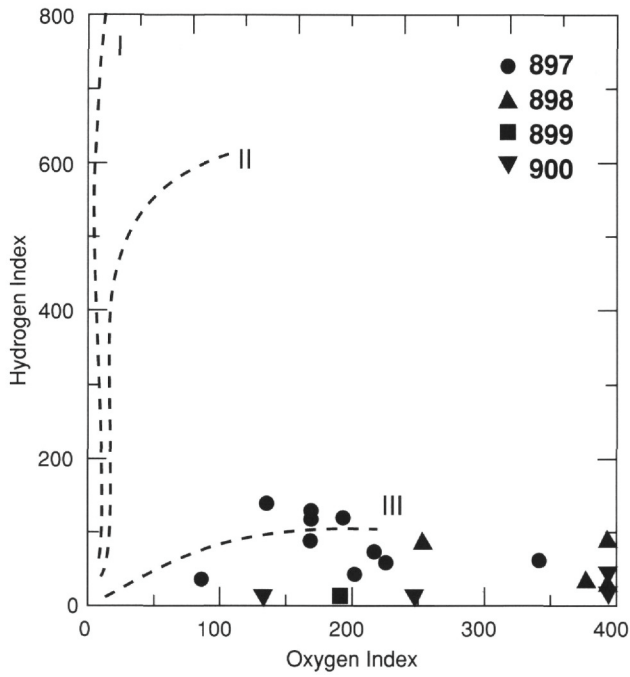


Figure 4. Rock-Eval analyses of Pleistocene to Pliocene turbidite samples from Sites 897-900. Units for Hydrogen Index are mg hydrocarbons/g TOC and for Oxygen Index are mg CO₂/g TOC.

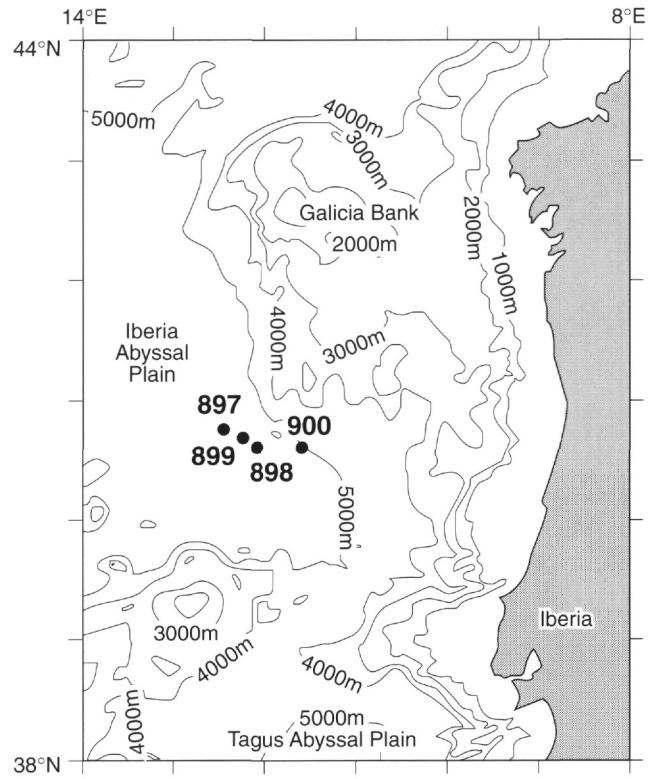


Figure 5. Relationship of Leg 149 sites on the Iberia Abyssal Plain to topographically elevated parts of the eastern North Atlantic Ocean seafloor and to the Iberia Margin. Depth contours given in meters.