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DATA ON THE GEOCHEMISTRY OF SURFACE SEDIMENTS OF THE EBRO SHELF AND SLOPE, NORTHEASTERN SPAIN

BY

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INTRODUCTION

The U.S. Geological Survey and the Institut d'Investigacions Geologiques "Jaime Almera", Universitat de Barcelona collected a series of cores on the continental shelf and slope of the Ebro margin (Fig. 1) as part of an international interdisciplinary study of the processes and deposits of the Spanish continental margins. Surface sediments were collected from these cores for analyses for inorganic geochemistry and organic carbon. Our objectives were to determine the influence of the Rio Ebro on the general distribution of surface sediment on the shelf and to identify any local influences, from such as the Columbretes volcanics or the Catalonides, that may have contributed sediment.

Twenty three gravity cores were collected on a grid (Fig. 2) and surface samples from these cores were analyzed for inorganic geochemistry and organic carbon. Our data provide a complimentary data set to that presented by Alonso (1981). Alonso's study includes inorganic geochemistry on 47 surface samples immediately north of our study area but the only parameters in common in the two data sets are Pb, Cr, Mn, Zn, Ni, and calcium carbonate.

METHODS

The samples for geochemical analyses were collected aboard ship prior to splitting the cores. Samples were collected by removing approximately 2 cm (about 20 g) of surface sediment from the top of each core. The samples were air dried and ground in a ceramic mill to pass a 100-mesh (149 µm) sieve. Concentrations of 29 major, minor, and trace elements (Al, Fe, Mg, Ca, Na, K, Ti, P, Mn, As, Ba, Be, Ce, Co, Cr, Cu, Ga, La, Li, Nd, Ni, Pb, Sc, Sr, Th, V, Y, Yb, and Zn) were determined in all samples by inductively coupled, argon-plasma emission spectrometry (ICP). In addition, concentrations of 10 major elements (Si, Al, Fe, Mg, Ca, Na, K, Ti, P, and Mn) were determined by X-ray Fluorescence (XRF) with excellent agreement between XRF and ICP results. Concentrations of total sulfur and total carbon were determined using LECO combustion-infrared instrumentation. Carbonate carbon was determined by coulometric titration of acidevolved CO_2, and organic carbon was calculated as the difference between total carbon and carbonate carbon. All of the methods listed above are described by Baedecker (1987).

RESULTS

Results of analyses for major, minor, and trace elements are listed in Table 1. A few observations are apparent from the table. First, the calcium carbonate and organic-carbon contents of all samples are relatively high with an average of 32% $CaCO_3$ and 0.8% organic carbon. Because of the relatively high content of organic carbon, all of the sediment samples are chemically reduced and green. We were surprised, therefore, to find that samples from the continental slope in the southeastern part of the study area (Fig. 2) have relatively high concentrations of MnO (>0.1%). Reduced muds typically have concentrations of MnO of <0.05%. The amount of detrital clastic material, as indicated by the content of Al_2O_3, appears to be highly variable. Some variation be due to dilution with carbonate (e.g. core 4, Table 1). However, some samples with similar carbonate contents have very different Al_2O_3 contents (e.g. cores 1 and 2). The SiO_2:Al_2O_3 ratio is generally low but ranges from 2.7 to 10 with a mean of 3.8. It would appear, therefore, that aluminosilicates are diluted by quartz as well as by carbonate.

To objectively examine relationships among numerous geochemical variables, and to determine groupings of samples based on their chemistry, we ran a Q-mode factor analysis using the CABFAC program of Klovan and Imbrie (1971). Prior to the analysis, concentrations of all elements and oxides were transformed to proportions of the total range for each element or oxide. A five-factor varimax solution accounts for 99.4% of the variance in the original data. Basically, the 5-factor Q-mode model reduced 31 measured variables (element concentrations) to five "composite" geochemical variables. The intensities of these composite geochemical variables are the factor loadings.

The factor loadings describe the relative importance of each composite chemical variable (factor) for each sample but give no indication of what elements have the most influence in determining each of the five factors. To determine what elements have the most influence on each factor, the factor loadings were treated as composite chemical variables, and correlation coefficients were computed between the loadings and the 31 observed compositional variables. Results of the correlation analysis are given in Table 2.

Table 2 shows that most of the elements we analyzed for are associated with aluminosilicate minerals. Factor 1 is the most important in the data set, explaining 84% of the variance in the data and has high loading values in the aluminosilicate-forming elements. The concentrations of SiO_2 and $CaCO_3$ are negatively correlated with Factor 1 loadings. Organic carbon is positively correlated with loadings for both Factor 1 and Factor 4. These correlations suggest that organic carbon has some association with the aluminosilicate fraction, probably because of adsorption onto clay minerals. However organic carbon is also somewhat independent of the aluminosilicate fraction and forms its own factor (Factor 4). Organic carbon is relatively minor and explains only about 16% of the variance in the data.

Factor 2 is dominated by the distribution of SiO_2. This "silica factor" accounts for 44% of the variance in the data. $CaCO_3$ shows a weak association with Factor 1, but most of the variance in $CaCO_3$ is explained by Factor 3. Most of the variances in Sr and total sulfur (T-S) also are explained by this "carbonate factor", which suggests that these two elements are associated with the carbonate fraction. Factor 3 accounts for 22% of the variance in the data. Factor 5 is very weak and explains only 11% of the variance but is strongly correlated with Yb, and, to a lesser extent, with MnO and with several trace elements commonly associated with manganese oxides and hydroxides (Co, Cu, Ni, and As; Table 2).

REFERENCES CITED

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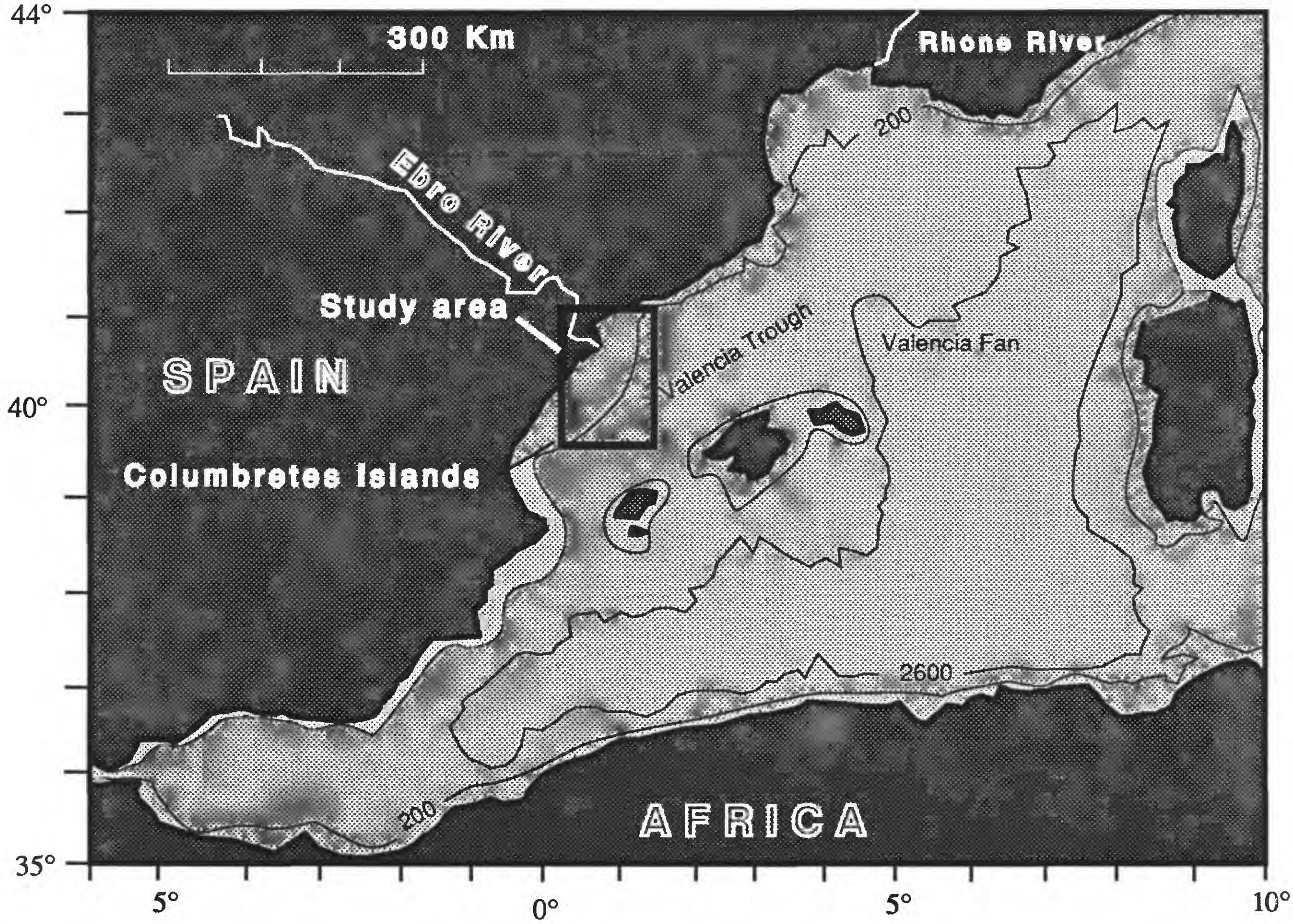
FIGURE CAPTIONS

Figure 1. Generalized map of the western Mediterranean with the study area outlined by black rectangle. Bathymetric contours in meters.

Figure 2. Core locations. Dark area in northwest corner is coastal Spain. Bathymetric contours in meters.



44°
40°
35°
5°
0°
5°
10°
300 Km
Rhone River
Ebro River
200
Study area
Valencia Trough
Valencia Fan
SPAIN
Columbretes Islands
2600
200
AFRICA

Figure 1

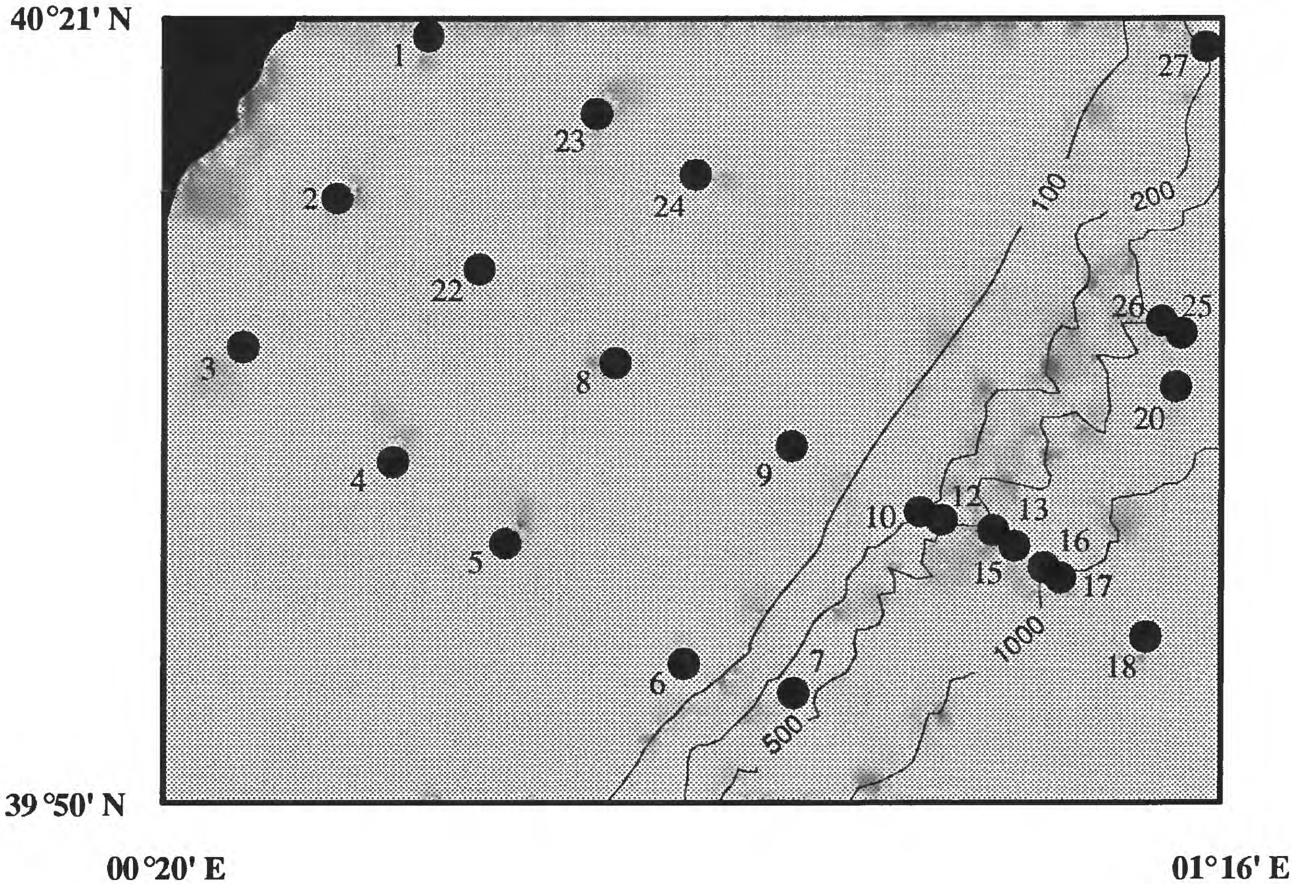

40°21' N
39°50' N
00°20' E
01°16' E
1
2
3
4
5
6
7
8
9
10
12
13
15
16
17
18
20
22
23
24
25
26
27
100
200
500
1000

Figure 2

Table 1. Geochemical data for Rio Ebro continental margin samples.

Core No.	Lat (N)	Long (E)	% SiO_2	% Al_2O_3	% Fe_2O_3	% MgO	% CaO
1	40°20.13'	00°34.48'	36.1	12.50	4.52	2.55	18.3
2	40°13.26'	00°29.06'	42.6	6.65	2.88	1.94	22.1
3	40°06.54'	00°23.24'	34.8	12.10	4.31	2.40	19.3
4	40°03.43'	00°32.53'	29.6	4.66	1.77	1.78	31.5
5	40°00.36'	00°39.36'	46.9	6.53	2.65	1.65	20.1
6	39°56.06'	00°48.25'	50.2	4.98	1.72	1.26	20.8
7	39°54.29'	00°55.23'	38.4	10.80	3.99	2.55	19.1
8	40°08.02'	00°44.17'	35.5	12.30	4.47	2.54	18.7
9	40°03.58'	00°48.25'	43.7	5.24	2.19	1.62	23.6
10	40°01.19'	01°00.40'	39.5	10.60	3.85	2.36	18.8
12	40°01.12'	01°01.23'	37.5	12.10	4.49	2.61	17.2
13	40°00.54'	01°03.29'	38.2	13.90	5.09	2.73	15.3
15	40°00.04'	01°05.06'	37.9	14.00	5.20	2.82	14.7
16	39°59.20'	01°07.26'	38.1	14.10	5.17	2.76	14.3
17	39°59.13'	01°07.41'	38.0	13.90	5.08	2.82	14.6
18	39°56.35'	01°12.11'	36.4	13.50	4.93	2.73	15.6
20	40°05.24'	01°18.14'	–	14.55	4.43	2.65	14.0
22	40°10.55'	00°36.58'	41.1	8.45	3.25	1.93	20.5
23	40°17.13'	00°43.12'	–	13.60	4.43	2.65	16.8
24	40°15.18'	00°49.05'	48.6	6.14	2.66	1.60	19.6
25	40°09.00'	01°17.46'	37.7	13.90	5.10	2.84	14.3
26	40°09.00'	01°17.46'	–	14.36	5.18	2.65	14.0
27	40°09.52'	01°20.56'	37.7	14.00	5.18	2.83	14.1

Table 1 (cont.). Geochemical data for Rio Ebro continental margin samples.

Core No.	% $CaCO_3$	% Na_2O	% K_2O	% TiO_2	% P_2O_5	% MnO	ppm Ba	ppm As	ppm Be
1	33.2	1.33	1.56	.51	.12	.05	300	20	2
2	33.4	.85	1.02	.32	.09	.03	180	20	1
3	35.3	1.18	1.63	.48	.12	.04	280	30	2
4	57.5	.74	.53	.17	.06	<.02	140	20	<1
5	35.9	.85	.96	.27	.08	.02	190	10	1
6	37.2	.75	.73	.18	.06	<.02	160	<10	<1
7	34.9	1.41	1.69	.46	.11	.04	290	20	2
8	40.5	1.60	1.75	.50	.12	.05	390	30	2
9	42.7	.81	.88	.22	.07	<.02	160	<10	<1
10	34.7	1.30	1.32	.46	.10	.04	280	<10	2
12	31.2	1.90	1.60	.50	.12	.06	290	20	2
13	27.6	1.58	1.73	.55	.13	.10	360	20	2
15	26.6	1.78	1.77	.55	.13	.38	380	40	2
16	25.3	1.69	1.54	.55	.13	.85	390	30	2
17	26.3	1.75	1.47	.55	.13	.59	390	30	2
18	27.4	2.24	1.38	.53	.13	.20	360	30	2
20	25.8	2.56	1.47	.53	.13	.40	380	20	2
22	36.9	1.10	.87	.33	.10	.03	210	20	1
23	30.3	2.56	1.38	.51	.13	.06	310	20	2
24	34.9	.93	1.00	.25	.08	.03	190	20	1
25	25.7	1.84	1.35	.56	.13	.54	410	30	2
26	25.9	2.43	1.35	.55	.13	.39	400	20	2
27	25.4	2.03	1.28	.56	.14	.16	380	30	2

Table 1 (cont.). Geochemical data for Rio Ebro continental margin samples.

Core No.	ppm Co	ppm Cr	ppm Cu	ppm Ni	ppm Pb	ppm Sc	ppm Sr
1	12	76	18	40	32	12	380
2	8	39	10	24	22	6	490
3	11	73	15	38	28	11	430
4	5	33	11	19	9	4	1,400
5	8	42	9	25	21	6	500
6	5	26	5	16	15	4	510
7	11	64	18	37	28	10	430
8	18	87	29	59	42	13	370
9	7	30	7	17	18	4	580
10	11	62	17	37	27	10	440
12	11	76	17	39	35	11	400
13	15	81	26	54	29	13	380
15	16	84	28	54	43	13	360
16	19	88	30	62	40	13	370
17	18	85	30	58	40	13	370
18	17	87	34	61	39	12	430
20	17	88	33	64	40	13	390
22	9	53	13	28	25	8	470
23	13	78	17	41	38	12	380
24	8	37	9	23	22	5	490
25	18	91	32	62	51	13	370
26	17	89	31	61	45	13	380
27	15	85	36	55	36	13	350

Table 1 (cont.). Geochemical data for Rio Ebro continental margin samples.

Core No.	ppm V	ppm Zn	ppm La	ppm Ce	ppm Y	ppm Yb	ppm Ga
1	110	82	26	49	13	1	17
2	56	45	21	41	9	<1	9
3	110	78	26	47	13	2	16
4	37	26	11	23	6	<1	6
5	51	47	19	35	9	<1	8
6	33	30	14	28	7	<1	6
7	88	71	28	50	12	1	14
8	100	96	30	52	14	2	21
9	39	39	17	32	8	<1	7
10	80	70	26	47	12	1	14
12	110	82	27	47	13	2	16
13	110	85	29	51	14	1	18
15	110	97	30	52	14	1	20
16	110	97	31	54	14	2	23
17	100	96	29	55	14	2	21
18	110	96	29	52	13	2	20
20	110	98	30	54	14	2	21
22	73	57	20	36	10	<1	11
23	110	86	27	48	13	1	17
24	54	42	22	42	8	<1	7
25	110	110	30	54	14	2	22
26	110	100	30	54	14	2	21
27	110	93	30	56	14	2	19

Table 1 (cont.). Geochemical data for Rio Ebro continental margin samples.

Core No.	ppm Li	ppm Th	ppm Nd	% Total S	% Total C	% Org. C	% Carb. C
1	76	8	20	.08	5.01	1.03	3.98
2	37	4	17	.10	5.03	1.02	4.01
3	74	9	21	.09	5.20	.96	4.24
4	28	<4	6	.23	7.59	.69	6.90
5	39	5	14	.04	4.98	.67	4.31
6	26	<4	8	.04	4.96	.50	4.46
7	63	8	21	.06	4.95	.76	4.19
8	77	10	23	.02	5.56	.70	4.86
9	28	<4	13	.03	5.77	.65	5.12
10	61	8	19	.05	4.91	.75	4.16
12	76	8	22	.08	4.61	.87	3.74
13	79	8	23	.07	4.07	.76	3.31
15	79	9	23	.08	4.09	.90	3.19
16	78	11	23	.08	3.88	.84	3.04
17	77	11	24	.09	3.94	.79	3.15
18	75	9	22	.11	4.10	.81	3.29
20	79	10	25	.09	3.91	.82	3.09
22	50	5	16	.04	5.24	.81	4.43
23	79	6	20	.12	4.34	.70	3.64
24	35	<4	16	.02	4.89	.70	4.19
25	78	9	22	.09	3.89	.81	3.08
26	77	10	27	.09	4.04	.93	3.11
27	79	9	22	.11	3.83	.78	3.05

Table 2 Correlation matrix of factor loadings and geochemical variables.

VARIABLE	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
SiO2	-.435	.893	-.416	.092	-.003
Al2O3	.910	-.831	-.486	-.147	.063
Fe2O3	.931	-.816	-.507	-.063	.088
MgO	.895	-.899	-.338	-.075	.020
CaCO3	-.752	.383	.780	-.022	-.131
K2O	.640	-.548	-.391	-.085	-.065
TiO2	.858	-.740	-.468	-.049	.044
P2O5	.868	-.763	-.468	-.037	.061
MnO	.435	-.431	-.247	-.171	.497
Ba	.858	-.780	-.487	-.223	.219
As	.542	-.648	-.099	.076	.379
Be	.858	-.837	-.416	-.263	-.080
Co	.833	-.738	-.470	-.163	.313
Cr	.908	-.857	-.437	-.154	.147
Cu	.757	-.776	-.323	-.220	.356
Ni	.825	-.785	-.421	-.209	.309
Pb	.838	-.675	-.536	-.086	.255
Sc	.921	-.843	-.480	-.140	.051
Sr	-.723	.127	.972	-.088	.035
V	.928	-.842	-.469	-.054	.013
Zn	.910	-.796	-.508	-.140	.168
La	.948	-.723	-.627	-.017	.071
Ce	.930	-.714	-.618	.001	.099
Y	.944	-.793	-.555	-.104	.039
Yb	.561	-.576	-.251	-.293	.693
Ga	.874	-.819	-.448	-.180	.220
Li	.926	-.851	-.470	-.128	.013
Th	.828	-.789	-.419	-.283	.244
Nd	.944	-.699	-.618	.073	.097
Corg	.544	-.510	-.101	.596	-.060
T-S	-.110	-.528	.721	-.107	.166