Discussion and conclusions

Objekttyp: Chapter

Zeitschrift: Eclogae Geologicae Helvetiae

Band (Jahr): 87 (1994)

Heft 1

PDF erstellt am: **17.05.2024**

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sic black shales. This geochemical anomaly is also detected, although less strongly, down to the underlying VD-382 level.

In view of the mineralogical and geochemical data, we may conclude that the anoxic facies in the Valdorbia section begins within 391,8-369 s.i. (sample VD-382) and includes the interval up to the top of 369-359,2 s.i. (at least up to the sample VD-361,8). The degree of anoxia was not uniform, reaching maximum values in levels VD-364,15 and VD-362,8, where the organic contribution (carbonate content) is lowest. Therefore, since analysis in the field is not always sufficient, the geochemical anomalies described above are a valid chemical-stratigraphic criterion by which to delimit the anoxic levels in the Toarcian of the Apennines (central Italy). Similar anomalies have been described by Ortega-Huertas et al. (1993) for correlatable stratigraphic levels in the Pozzale and Pale Vallone sections.

The mineralogical and geochemical data indicate that these facies were deposited (Fig. 21) in a pelagic environment, in which restricted palaeogeographical subenvironments developed. It seems likely possible that the presence of physiographically subdivided environment encouraged the existence of calm subenvironments in which confined conditions formed with restricted water circulation. This agrees with the positive anomaly in B (Tab. 4), detected in the black shale samples in comparison with the other levels at Valdorbia. According to this model maximum restriction of circulation would have occurred in levels VD-364,15 and VD-362,8. Maximum anoxia conditions also occurred in these levels, according to other mineralogical and geochemical criteria mentioned above. This model also agrees with the values found for the La/Lu ratio (9.90 to 12), which are typical of pelagic environments, as indicated by Ronov et al. (1967). The ternary diagram of V-Cr-Ni, which are elements usually associated with a detrital origin, can be used to study the possible variations in input from the source area. Comparison of the V/Cr ratio in the Valdorbia (1.70), Pozzale (1.69), Monte Serrone (1.51) and Pale Vallone (1.49) sections indicates that the MS Formation as a whole was deposited under the influence of a homogeneous source area.

9. Discussion and conclusions

9.1 The Lower Toarcian anoxic event

The occurrence of black shales in the Valdorbia Section has been discussed by Baudin et al. (1990), Nocchi et al. (1991) and by Bartolini et al. (1992). These authors consider the laminated, pyrite-rich black sediments as evidence of the extension of the Early Toarcian anoxic event, widespread in the North European Jurassic shelves to the Umbria-Marche basin.

Geochemical, Total Organic Carbon content, micropaleontological data (see Fig. 9 and 5 in Bartolini et al. 1992) and trace fossils show that anoxia reaches the maximum in the upper part of the Tenuicostatum Zone, between 369 m and 360 m, with a peak around 364 m. However, the positive geochemical anomalies have revealed that the sea-floor was poorly oxygenated in the older part of the Tenuicostatum Zone as well, at least from the 382 m level (Tab. 4). These data confirm that the abundance of small Eoguttulina's is indicative of a restricted and poorly ventilated environment but these forms become slightly less able to tolerate adverse bottom conditions than Paralingulina gr. tenera when the anoxia increases.

SAMPLES	Lithology	SiO ₂	Al ₂ O ₃	CaO	MgO	Na ₂ O	К,О	$\operatorname{Fe}_{2}\operatorname{O}_{3}$	MnO	TiO ₂	P_2O_5	LOI
VD-161	CP	19,00	4,11	38,60	1,27	60,0	1,12	1,84	0,04	0,20	60'0	33,80
VD-177	RAUM	29,10	8,44	27,20	1,65	0,18	3,15	4,71	0,02	0,49	0,14	25,20
VD-180	RAUM	11,70	3,28	44,40	1,21	0,08	1,00	1,27	0,03	0,17	0,06	37,20
VD-184	RAUM	14,80	4,47	40,70	1,11	0,12	1,47	2,56	0,03	0,22	0,07	34,80
VD-184,5	RAUM	13,50	3,91	43,00	1,00	0,09	1,37	1,85	0,03	0,20	0,08	35,40
VD-185,3	RAUM	26,00	7,70	29,50	1,57	0,22	2,69	4,68	0,02	0,42	0,10	27,20
VD-186,3	RAUM	27,00	8,06	30,20	1,61	0,25	2,63	2,76	0,03	0,42	0,10	27,30
VD-186,5	RAUM	34,30	10,10	23,40	2,07	0,28	3,37	3,74	0,04	0,60	0,13	22,70
VD-189,1	RAUM	22,80	6,87	34,00	1,47	0,20	2,10	2,24	0,03	0,35	0,07	30,30
VD-194	MS	25,80	7,25	30,80	1,59	0,20	2,38	3,47	0,03	0,38	0,07	28,50
VD-198,9	MS	22,80	5,99	34,70	1,40	0,23	1,88	2,34	0,04	0,32	0,07	30,70
VD-203,3	MS	30,10	7,91	27,00	1,71	0,24	2,66	3,19	0,03	0,43	0,08	26,80
VD-361,8	MS	54,20	13,80	5,37	2,26	0,29	4,64	5,75	0,11	0,86	0,11	12,70
VD-362,8	MS	51,10	12,90	6,83	2,11	0,29	4,49	5,11	0,04	0,76	60'0	16,50
VD-364,15	MS	48,50	12,30	7,44	2,05	0,28	4,79	5,13	0,06	0,76	0,11	17,60
VD-368,5	MS	41,70	10,50	14,90	1,97	0,28	3,99	5,10	0,15	0,61	0,19	18,60
VD-371	MS	29,10	7,19	29,10	1,41	0,17	2,74	2,98	0,25	0,41	0,07	25,20
VD-375,8	MS	39,20	10,30	19,50	2,30	0,25	3,36	3,81	0,19	0,63	0,08	20,60
VD-380,5	MS	25,40	6,47	33,50	1,71	0,22	2,14	2,39	0,06	0,34	0,08	27,20
VD-382	MS	24,90	5,37	34,80	1,61	0,24	1,79	2,07	0,05	0£0	0,10	29,10
VD-384	MS	17,30	4,05	40,50	1,35	0,11	1,30	1,85	0,04	0,20	0,05	33,40
VD-391	MS	20,00	5,39	37,00	1,34	0,11	1,68	2,09	0,03	0,29	0,06	32,30
VD-396,5	MS	13,60	3,10	43,70	66'0	0,05	0,73	1,21	0,02	0,15	0,06	36,90
VD-490,2	COR	7,81	2,09	48,00	1,09	0,06	0,78	1,12	0,02	0,10	0,06	39,10
VD-496,18	COR	15,80	4,39	39,80	1,43	0,10	1,35	2,31	0,02	0,25	60'0	34,40

SAMPLES	Lithology	Ba	V	Cr	Ni	Cs	Hf	Ta	W	Pb	Th	Ge	Br	Mo	Ag	Cd
VD-161	СР	100	62	25	36	3	1,20	<1	<3	<2	2,90	20	4	<5	<0,5	<1
VD-177	RAUM	120	76	61	60	4	2,70	<1	<3	<2	6,20	<10	5	<5	<0,5	<1
VD-180	RAUM	100	38	26	21	2	1,00	<1	<3	<2	2,20	<10	6	<5	<0,5	<1
VD-184	RAUM	50	35	21	28	2	1,30	<1	<3	<2	2,90	<10	3	<5	<0,5	<1
VD-184,5	RAUM	60	29	27	22	2	0,90	<1	<3	7	2,80	<10	3	<5	<0,5	<1
VD-185,3	RAUM	127	78	46	30	4	2,20	<1	<3	<2	5,60	<10	2	<5	<0,5	<1
VD-186,3	RAUM	129	55	42	28	4	2,30	<1	<3	3	5,80	<10	3	<5	<0,5	<1
VD-186,5	RAUM	104	75	61	37	4	3,50	<1	<3	<2	8,00	15	3	<5	<0,5	<1
VD-189,1	RAUM	139	45	37	26	3	2,00	<1	<3	6	4,70	23	3	<5	<0,5	<1
VD-194	MS	137	47	35	26	3	2,00	1	<3	7	5,30	11	4	<5	<0.5	<1
VD-198,9	MS	117	40	30	27	2	1,80	<1	<3	5	4,50	<10	2	<5	<0,5	<1
VD-203,3	MS	162	76	46	19	3	2,50	<1	<3	4	5,70	<10	3	<5	<0,5	<1
VD-361,8	MS	314	112	74	54	5	4,20	1	<3	13	9,70	<10	4	<5	<0,5	<1
VD-362,8	MS	752	140	83	53	6	4,50	1	<3	8	10,00	<10	4	<5	<0,5	1
VD-364,15	MS	989	160	85	44	5	4,20	1	<3	8	9,30	<10	3	<5	<0,5	1
VD-368,5	MS	166	100	68	49	5	3,60	1	<3	4	1,80	<10	4	<5	<0,5	<1
VD-371	MS	157	76	42	22	3	2,60	1	<3	2	5,20	<10	3	<5	<0,5	<1
VD-375,8	MS	69	66	58	40	4	3,40	1	3	8	7,20	<10	3	<5	<0,5	<1
VD-380,5	MS	103	46	33	33	4	1,90	<1	<3	8	4,30	11	3	<5	<0,5	<1
VD-382	MS	119	43	29	24	3	1,90	<1	<3	<2	4,00	<10	2	<5	<0,5	1
VD-384	MS	42	32	21	22	2	1,10	<1	<3	<2	2,60	11	3	<5	<0,5	<1
VD-391	MS	85	38	30	23	3	1,50	<1	<3	<2	3,40	<10	3	<5	<0,5	<1
VD-396,5	MS	57	31	17	18	2	0,50	<1	<3	<2	1,80	16	3	<5	<0,5	<1
VD-490,2	COR	28	17	11	18	1	0,50	<1	<3	<2	1,40	10	2	<5	<0,5	<1
VD-496,18	COR	100	50	26	26	2	1,50	<1	<3	<2	3,20	<10	2	<5	<0,5	<1
SAMPLES	Lithology	Co	Cu	Zn	As	Se	Sb	В	U	Pb	Rb	Sr	Y	Zr	Nb	
SAMPLES VD-161	Lithology CP	Co	Cu 16	Zn 32.00	As <2	Se <3	Sb 0.5	B 50	U 0.60	Pb <2	Rb 40	Sr 407	Y 12	Zr 26	Nb 13	
SAMPLES VD-161 VD-177	Lithology CP RAUM	Co 11 12	Cu 16 20	Zn 32,00 69,00	As <2 2	Se <3 <3	Sb 0,5 0,7	B 50 60	U 0,60 1,00	Pb <2 <2	Rb 40 80	Sr 407 204	Y 12 40	Zr 26 89	Nb 13 15	
SAMPLES VD-161 VD-177 VD-180	Lithology CP RAUM RAUM	Co 11 12 9	Cu 16 20 12	Zn 32,00 69,00 33,00	As <2 2 <2	Se <3 <3 <3	Sb 0,5 0,7 0,5	B 50 60 20	U 0,60 1,00 0,60	Pb <2 <2 <2	Rb 40 80 30	Sr 407 204 252	Y 12 40 <10	Zr 26 89 25	Nb 13 15 <10	
SAMPLES VD-161 VD-177 VD-180 VD-184	Lithology CP RAUM RAUM RAUM	Co 11 12 9 4	Cu 16 20 12 11	Zn 32,00 69,00 33,00 47,70	As <2 2 <2 <10	Se 3 3 3 3	Sb 0,5 0,7 0,5 0,3	B 50 60 20 39	U 0,60 1,00 0,60 0,80	Pb <2 <2 <2 <2 <2	Rb 40 80 30 40	Sr 407 204 252 270	Y 12 40 <10 <10	Zr 26 89 25 40	Nb 13 15 <10 39	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184,5	Lithology CP RAUM RAUM RAUM RAUM	Co 11 12 9 4 5	Cu 16 20 12 11	Zn 32,00 69,00 33,00 47,70 31,70	As <2 2 <2 <10 <10	Se 3 3 3 3 3 3 3	Sb 0,5 0,7 0,5 0,3 0,5	B 50 60 20 39 44	U 0,60 1,00 0,60 0,80 0,90	Pb <2 <2 <2 <2 <2 <2 7	Rb 40 80 30 40 33	Sr 407 204 252 270 243	Y 12 40 <10 <10 <10	Zr 26 89 25 40 31	Nb 13 15 <10 39 39	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184,5 VD-185,3	Lithology CP RAUM RAUM RAUM RAUM RAUM	Co 11 12 9 4 5 7	Cu 16 20 12 11 10 9	Zn 32,00 69,00 33,00 47,70 31,70 45,00	As <2 2 <2 <10 <10 3	Se 3 3 3 3 3 3 3 3 3	Sb 0,5 0,7 0,5 0,3 0,5 0,9	B 50 60 20 39 44 70	U 0,60 1,00 0,60 0,80 0,90 1,00	Pb <2 <2 <2 <2 <2 <2 7 <2	Rb 40 80 30 40 33 62	Sr 407 204 252 270 243 201	Y 12 40 <10 <10 <10 <10	Zr 26 89 25 40 31 72	Nb 13 15 <10 39 39 17	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184.5 VD-185,3 VD-186,3	Lithology CP RAUM RAUM RAUM RAUM RAUM	Co 11 12 9 4 5 7 6	Cu 16 20 12 11 10 9 104	Zn 32,00 69,00 33,00 47,70 31,70 45,00 39,80	As <2 2 <2 <10 <10 3 <10	Se 3 3 3 3 3 3 3 3 3 3 3	Sb 0,5 0,7 0,5 0,3 0,5 0,9 0,4	B 50 60 20 39 44 70 60	U 0,60 1,00 0,60 0,80 0,90 1,00 1,70	Pb <2 <2 <2 <2 <2 <2 7 <2 7 <2 3	Rb 40 80 30 40 33 62 58	Sr 407 204 252 270 243 201 187	Y 12 40 <10 <10 <10 <10 20	Zr 26 89 25 40 31 72 82	Nb 13 15 <10 39 39 17 31	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184,5 VD-185,3 VD-186,3 VD-186,5	Lithology CP RAUM RAUM RAUM RAUM RAUM RAUM RAUM	Co 11 12 9 4 5 7 6 8	Cu 16 20 12 11 10 9 104 30	Zn 32,00 69,00 33,00 47,70 31,70 45,00 39,80 68,70	As <2 2 <10 <10 3 <10 15	Se 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3	Sb 0,5 0,7 0,5 0,3 0,5 0,9 0,4 0,5	B 50 60 20 39 44 70 60 102	U 0,60 1,00 0,60 0,80 0,90 1,00 1,70 1,70	Pb <2	Rb 40 80 30 40 33 62 58 85	Sr 407 204 252 270 243 201 187 194	Y 12 40 <10 <10 <10 <10 20 23	Zr 26 89 25 40 31 72 82 106	Nb 13 15 <10 39 39 17 31 31	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184,5 VD-185,3 VD-186,3 VD-186,5 VD-189,1	Lithology CP RAUM RAUM RAUM RAUM RAUM RAUM RAUM RAUM	Co 11 12 9 4 5 7 6 8 7	Cu 16 20 12 11 10 9 104 30 26	Zn 32,00 69,00 33,00 47,70 31,70 45,00 39,80 68,70 112,00	As <2 <2 <10 <10 3 <10 15 23	Se 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3	Sb 0,5 0,7 0,5 0,3 0,5 0,9 0,4 0,5 0,4	B 50 60 20 39 44 70 60 102 56	U 0,60 1,00 0,60 0,80 0,90 1,00 1,70 1,70 1,60	Pb <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <3 <2 <3 <2 <3 <2 <5 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2	Rb 40 80 30 40 33 62 58 85 47	Sr 407 204 252 270 243 201 187 194 229	Y 12 40 <10 <10 <10 <10 20 23 16	Zr 26 89 25 40 31 72 82 106 55	Nb 13 15 <10 39 39 17 31 37 27	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184,5 VD-184,5 VD-185,3 VD-186,3 VD-186,5 VD-189,1 VD-194	Lithology CP RAUM RAUM RAUM RAUM RAUM RAUM RAUM RAUM	Co 11 12 9 4 5 7 6 8 8 7 6	Cu 16 20 12 11 10 9 104 30 26 16	Zn 32,00 69,00 33,00 47,70 31,70 45,00 39,80 68,70 112,00 46,70	As <2 <2 <10 <10 3 <10 15 23 11	Se 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3	Sb 0,5 0,7 0,5 0,3 0,5 0,9 0,4 0,5 0,4 0,4	B 50 60 20 39 44 70 60 102 56 74	U 0,60 1,00 0,60 0,80 0,90 1,00 1,70 1,70 1,60 1,10	Pb <2 <2 <2 <2 <2 7 <2 3 <2 3 <2 6 7	Rb 40 80 30 40 33 62 58 85 47 56	Sr 407 204 252 270 243 201 187 194 229 268	Y 12 40 <10 <10 <10 <10 20 23 16 <10	Zr 26 89 25 40 31 72 82 106 55 68	Nb 13 15 <10 39 39 17 31 31 37 27 25	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184,5 VD-184,5 VD-185,3 VD-186,3 VD-186,5 VD-189,1 VD-194 VD-198,9	Lithology CP RAUM RAUM RAUM RAUM RAUM RAUM RAUM RAUM	Co 11 12 9 4 5 7 6 8 8 7 6 8 8 7 6 8	Cu 16 20 12 11 10 9 104 30 26 16	Zn 32,00 69,00 33,00 47,70 31,70 45,00 39,80 68,70 112,00 46,70 42,20	As <2 <2 <10 <10 3 <10 15 23 11 <10	Se 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3	Sb 0,5 0,7 0,5 0,3 0,5 0,9 0,4 0,5 0,4 0,4 0,4	B 50 60 20 39 44 70 60 102 56 74 43	U 0,60 1,00 0,60 0,90 1,00 1,70 1,70 1,60 1,10 1,10	Pb <2 <2 <2 <2 <2 7 <2 3 <2 6 7 5	Rb 40 80 30 40 33 62 58 85 47 56 43	Sr 407 204 252 270 243 201 187 194 229 268 321	Y 12 40 <10 <10 <10 20 23 16 <10 <10	Zr 26 89 25 40 31 72 82 106 55 68 67	Nb 13 15 <10 39 39 17 31 37 27 25 33	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184.5 VD-184.5 VD-185.3 VD-186.3 VD-186.5 VD-186,5 VD-189,1 VD-194 VD-198,9 VD-203,3	Lithology CP RAUM RAUM RAUM RAUM RAUM RAUM RAUM MS MS MS	Co 11 12 9 4 5 7 6 8 7 6 8 7 6 8 7	Cu 16 20 12 11 10 9 9 104 30 26 16 16	Zn 32,00 69,00 33,00 47,70 31,70 45,00 39,80 68,70 112,00 46,70 42,20 37,00	As <2 2 <10 <10 15 23 11 <10 <2	Se 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3	Sb 0,5 0,7 0,5 0,3 0,5 0,9 0,4 0,5 0,4 0,4 0,3 0,4	B 50 60 20 39 44 70 60 102 56 74 43 60	U 0,60 1,00 0,60 0,80 1,00 1,70 1,70 1,60 1,10 1,10 1,00	Pb <2	Rb 40 80 30 40 33 62 58 85 47 56 43 72	Sr 407 204 252 270 243 201 187 194 229 268 321 294	Y 12 40 <10 <10 20 23 16 <10 <10 15	Zr 26 89 25 40 31 72 82 106 55 68 67 861	Nb 13 15 <10 39 39 17 31 37 27 25 33 26	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184,5 VD-185,3 VD-186,3 VD-186,5 VD-186,5 VD-189,1 VD-194 VD-198,9 VD-203,3 VD-361,8	Lithology CP RAUM RAUM RAUM RAUM RAUM RAUM RAUM MS MS MS MS	Co 11 12 9 4 5 7 6 8 7 6 8 7 6 8 7 19	Cu 16 20 12 11 10 9 9 104 30 26 16 16 16 56	Zn 32,00 69,00 33,00 47,70 31,70 45,00 39,80 68,70 112,00 46,70 42,20 37,00 58,90	As <2 2 <10 <10 3 <10 15 23 11 <10 <2 <10	Se Se So So	Sb 0,5 0,7 0,5 0,3 0,5 0,9 0,4 0,5 0,4 0,4 0,4 0,3 0,4 1,4	B 50 60 20 39 44 70 60 102 56 74 43 60 96	U 0,60 1,00 0,60 0,80 1,00 1,70 1,70 1,60 1,10 1,10 1,00 2,30	Pb <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <3 <2 6 6 7 5 5 4 4 13	Rb 40 80 30 40 33 62 58 85 47 56 43 72 109	Sr 407 204 252 270 243 201 187 194 229 268 321 294 151	Y 12 40 <10 <10 <10 20 23 16 <10 <10 <10 15 32	Zr 26 89 25 40 31 72 82 106 55 68 67 861 67	Nb 13 15 <10 39 39 17 31 37 27 25 33 26 42	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184,5 VD-185,3 VD-186,3 VD-186,5 VD-186,5 VD-189,1 VD-194 VD-194 VD-198,9 VD-203,3 VD-361,8 VD-362,8	Lithology CP RAUM RAUM RAUM RAUM RAUM RAUM RAUM MS MS MS MS MS	Co 11 12 9 4 5 7 6 8 7 6 8 7 6 8 7 7 19 18	Cu 16 20 12 11 10 9 104 30 26 16 16 16 16 56 47	Zn 32,00 69,00 33,00 47,70 31,70 45,00 39,80 68,70 112,00 46,70 42,20 37,00 58,90 92,00	As <2 2 <10 <10 3 <10 15 23 11 <10 <2 <10 (11	Se 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3	Sb 0,5 0,7 0,5 0,3 0,5 0,9 0,4 0,5 0,4 0,4 0,4 0,3 0,4 1,4 1,7	B 50 60 20 39 44 70 60 102 56 74 43 60 96 100	U 0,60 1,00 0,60 0,80 1,00 1,70 1,70 1,60 1,10 1,10 1,00 2,30 2,50	Pb <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2	Rb 40 80 30 40 33 62 58 85 47 56 43 72 109 95	Sr 407 204 252 270 243 201 187 194 229 268 321 294 151 233	Y 12 40 <10 <10 <10 20 23 16 <10 <10 (10 15 32 12	Zr 26 89 25 40 31 72 82 106 55 68 67 861 67 162	Nb 13 15 <10 39 39 17 31 37 27 25 33 26 42 24	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184,5 VD-185,3 VD-186,3 VD-186,3 VD-186,5 VD-189,1 VD-194 VD-194 VD-198,9 VD-203,3 VD-361,8 VD-364,15	Lithology CP RAUM RAUM RAUM RAUM RAUM RAUM RAUM MS MS MS MS MS MS MS	Co 11 12 9 4 5 7 6 8 8 7 6 8 7 6 8 7 19 18 19	Cu 16 20 12 11 10 9 104 30 26 16 16 16 16 56 47 46	Zn 32,00 69,00 33,00 47,70 31,70 45,00 39,80 68,70 112,00 46,70 42,20 37,00 58,90 92,00 69,00	As <2 2 <10 <10 3 <10 15 23 11 <10 <2 <10 (11 12	Se Se So So	Sb 0,5 0,7 0,5 0,3 0,5 0,9 0,4 0,5 0,4 0,4 0,4 0,3 0,4 1,4 1,7 1,8	B 50 60 20 39 44 70 60 102 56 74 43 60 96 100 110	U 0,60 1,00 0,60 0,90 1,00 1,70 1,70 1,60 1,10 1,10 1,10 2,30 2,50 2,50	Pb <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2	Rb 40 80 30 40 33 62 58 85 47 56 43 72 109 95 100	Sr 407 204 252 270 243 201 187 194 229 268 321 294 151 233 180	Y 12 40 <10 <10 <10 20 23 16 <10 <10 15 32 12 26	Zr 26 89 25 40 31 72 82 106 55 68 67 861 67 162 142	Nb 13 15 <10 39 39 17 31 37 27 25 33 26 42 24 16	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184,5 VD-185,3 VD-186,3 VD-186,3 VD-186,5 VD-189,1 VD-194 VD-194 VD-198,9 VD-203,3 VD-361,8 VD-362,8 VD-364,15 VD-368,5	Lithology CP RAUM RAUM RAUM RAUM RAUM RAUM RAUM MS MS MS MS MS MS MS MS MS	Co 11 12 9 4 5 7 6 8 8 7 6 8 7 6 8 7 19 18 19	Cu 16 20 12 11 10 9 104 30 26 16 16 16 16 56 47 46 46	Zn 32,00 69,00 33,00 47,70 31,70 45,00 39,80 68,70 112,00 46,70 42,20 37,00 58,90 92,00 69,00 71,00	As <2 2 <10 <10 3 <10 15 23 11 <10 <2 <10 (11 12 11	Se 3 3 3 3	Sb 0,5 0,7 0,5 0,3 0,5 0,9 0,4 0,5 0,4 0,4 0,4 0,3 0,4 1,4 1,7 1,8 1,3	B 50 60 20 39 44 70 60 102 56 74 43 60 96 100 110 80	U 0,60 1,00 0,60 0,90 1,00 1,70 1,70 1,60 1,10 1,10 1,10 2,30 2,50 2,50 1,80	Pb <2	Rb 40 80 30 40 33 62 58 85 47 56 43 72 109 95 100 74	Sr 407 204 252 270 243 201 187 194 229 268 321 294 151 233 180 241	Y 12 40 <10 <10 <10 20 23 16 <10 <10 15 32 12 26 <10	Zr 26 89 25 40 31 72 82 106 55 68 67 861 67 162 142 121	Nb 13 15 <10 39 39 17 31 37 27 25 33 26 42 24 24 16 <10	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184,5 VD-185,3 VD-186,3 VD-186,3 VD-186,5 VD-189,1 VD-194 VD-194 VD-198,9 VD-203,3 VD-361,8 VD-362,8 VD-364,15 VD-368,5 VD-371	Lithology CP RAUM RAUM RAUM RAUM RAUM RAUM RAUM MS MS MS MS MS MS MS MS MS MS MS	Co 11 12 9 4 5 7 6 8 8 7 6 8 8 7 6 8 8 7 19 19 18 19 19	Cu 16 20 12 11 10 9 104 30 26 16 16 16 16 56 47 46 46 22	Zn 32,00 69,00 33,00 47,70 31,70 45,00 39,80 68,70 112,00 46,70 42,20 37,00 58,90 92,00 69,00 71,00 37,00	As <2 2 <10 <10 3 <10 15 23 11 <10 <2 <10 (11 12 11 4	Se Se So So	Sb 0,5 0,7 0,5 0,3 0,5 0,9 0,4 0,5 0,4 0,4 0,4 0,3 0,4 1,4 1,7 1,8 1,3 0,8	B 50 60 20 39 44 70 60 102 56 74 43 60 96 100 110 80 60	U 0,60 1,00 0,60 0,90 1,00 1,70 1,70 1,60 1,10 1,10 1,00 2,30 2,50 2,50 1,80 1,10	Pb <2	Rb 40 80 30 40 33 62 58 85 47 56 43 72 109 95 100 74	Sr 407 204 252 270 243 201 187 194 229 268 321 294 151 233 180 241 353	Y 12 40 <10 <10 <10 20 23 16 <10 <10 15 32 12 26 <10 26	Zr 26 89 25 40 31 72 82 106 55 68 67 861 67 162 142 121 70	Nb 13 15 <10 39 39 17 31 37 27 25 33 26 42 24 24 16 <10 15	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184,5 VD-185,3 VD-186,3 VD-186,3 VD-186,3 VD-186,5 VD-189,1 VD-194 VD-194 VD-198,9 VD-203,3 VD-361,8 VD-361,8 VD-362,8 VD-364,15 VD-368,5 VD-371 VD-375,8	Lithology CP RAUM RAUM RAUM RAUM RAUM RAUM RAUM MS MS MS MS MS MS MS MS MS MS MS MS MS	Co 11 12 9 4 5 7 6 8 7 6 8 7 6 8 7 6 8 7 7 9 19 18 19 19 10 14	Cu 16 20 12 11 10 9 104 30 26 16 16 16 16 56 47 46 46 22 32	Zn 32,00 69,00 33,00 47,70 31,70 45,00 39,80 68,70 112,00 46,70 42,20 37,00 58,90 92,00 69,00 71,00 37,00 32,00	As <2 2 <10 <10 3 <10 15 23 11 <10 <2 <10 11 12 11 4 <10	Se Se So So	Sb 0,5 0,7 0,5 0,3 0,5 0,9 0,4 0,5 0,4 0,4 0,3 0,4 1,4 1,7 1,8 1,3 0,8 0,6	B 50 60 20 39 44 70 60 102 56 74 43 60 96 100 110 80 60 79	U 0,60 1,00 0,60 0,90 1,00 1,70 1,70 1,60 1,10 1,10 1,00 2,30 2,50 2,50 1,80 1,10 1,90	Pb <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <3 <2 6 6 7 7 5 4 4 13 8 8 8 8 4 4 2 8	Rb 40 80 30 40 33 62 58 85 47 56 43 72 109 95 100 74 52 81	Sr 407 204 252 270 243 201 187 194 229 268 321 294 151 233 180 241 353 295	Y 12 40 <10 <10 20 23 16 <10 <10 15 32 12 26 <10 26 24	Zr 26 89 25 40 31 72 82 106 55 68 67 861 67 162 142 121 70 131	Nb 13 15 <10 39 39 17 31 37 27 25 33 26 42 24 16 <10 15 31	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184,5 VD-185,3 VD-186,3 VD-186,3 VD-186,5 VD-188,3 VD-186,5 VD-194 VD-194 VD-194 VD-198,9 VD-203,3 VD-361,8 VD-361,8 VD-362,8 VD-364,15 VD-368,5 VD-371 VD-375,8 VD-380,5	Lithology CP RAUM RAUM RAUM RAUM RAUM RAUM RAUM MS MS MS MS MS MS MS MS MS MS MS MS MS	Co 11 12 9 4 5 7 6 8 7 6 8 7 6 8 7 6 8 7 7 9 19 18 19 19 10 14 7	Cu 16 20 12 11 10 9 104 30 26 16 16 16 16 56 47 46 46 22 32 24	Zn 32,00 69,00 33,00 47,70 31,70 45,00 39,80 68,70 112,00 46,70 42,20 37,00 58,90 92,00 69,00 71,00 37,00 32,00 125,00	As <2 2 <10 <10 3 <10 15 23 11 <10 <2 <10 11 12 11 4 <10 11	Se Se So So	Sb 0,5 0,7 0,5 0,3 0,5 0,4 0,5 0,4 0,4 0,3 0,4 1,4 1,7 1,8 1,3 0,8 0,6 0,7	B 50 60 20 39 44 70 60 102 56 74 43 60 96 100 110 80 60 79 69	U 0,60 1,00 0,60 0,90 1,00 1,70 1,70 1,60 1,10 1,10 1,00 2,30 2,50 2,50 1,80 1,10 1,90 1,40	Pb <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2	Rb 40 80 30 40 33 62 58 85 47 56 43 72 109 95 100 74 52 81 54	Sr 407 204 252 270 243 201 187 194 229 268 321 294 151 233 180 241 353 295 331	Y 12 40 <10 <10 20 23 16 <10 <10 15 32 12 26 <10 26 24 <10	Zr 26 89 25 40 31 72 82 106 55 68 67 861 67 162 142 121 70 131 53	Nb 13 15 <10 39 39 17 31 37 27 25 33 26 42 24 16 <10 15 31 32	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184,5 VD-185,3 VD-186,3 VD-186,3 VD-186,5 VD-186,5 VD-189,1 VD-194 VD-194 VD-194 VD-198,9 VD-203,3 VD-361,8 VD-361,8 VD-362,8 VD-364,15 VD-368,5 VD-371 VD-375,8 VD-380,5 VD-382	Lithology CP RAUM RAUM RAUM RAUM RAUM RAUM RAUM MS MS MS MS MS MS MS MS MS MS MS MS MS	Co 11 12 9 4 5 7 6 8 7 6 8 7 6 8 7 6 8 7 7 9 19 19 19 10 14 7 7	Cu 16 20 12 11 10 9 104 30 26 16 16 16 16 56 47 46 46 22 32 24 21	Zn 32,00 69,00 33,00 47,70 31,70 45,00 39,80 68,70 112,00 46,70 42,20 37,00 58,90 92,00 69,00 71,00 37,00 32,00 125,00 37,10	As <2 2 <10 <10 3 <10 15 23 11 <10 <2 <10 11 12 11 4 <10 11 <10	Se Se So So So <	Sb 0,5 0,7 0,5 0,3 0,5 0,9 0,4 0,5 0,4 0,4 0,3 0,4 1,4 1,7 1,8 1,3 0,8 0,6 0,7 0,5	B 50 60 20 39 44 70 60 102 56 74 43 60 96 100 110 80 60 79 69 78	U 0,60 1,00 0,60 0,80 1,00 1,70 1,70 1,60 1,10 1,10 1,10 2,30 2,50 2,50 1,80 1,10 1,90 1,40	Pb <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <2 <3 <2 6 6 7 7 5 4 4 13 8 8 8 8 4 2 8 8 8 8 8 2	Rb 40 80 30 40 33 62 58 85 47 56 43 72 109 95 100 74 52 81 54	Sr 407 204 252 270 243 201 187 194 229 268 321 294 151 233 180 241 353 295 331 314	Y 12 40 <10 <10 20 23 16 <10 <10 15 32 12 26 <10 26 24 <10 26 24	Zr 26 89 25 40 31 72 82 106 55 68 67 861 67 162 142 121 70 131 53 62	Nb 13 15 <10 39 39 17 31 37 27 25 33 26 42 24 16 <10 15 31 32 30	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184,5 VD-186,3 VD-186,3 VD-186,5 VD-189,1 VD-194 VD-198,9 VD-203,3 VD-361,8 VD-362,8 VD-364,15 VD-364,5 VD-368,5 VD-371 VD-375,8 VD-380,5 VD-382 VD-384	Lithology CP RAUM RAUM RAUM RAUM RAUM RAUM RAUM MS MS MS MS MS MS MS MS MS MS MS MS MS	Co 11 12 9 4 5 7 6 8 7 6 8 7 6 8 7 19 18 19 19 10 14 7 6 8 7 6 8 7 7 7 6 8 7 7 7 6 8 7 7 7 6 8 7 7 7 7 7 8 8 7 7 7 7 7 7 8 8 7 7 7 7 7 8 8 7 7 7 7 7 8 7 7 7 7 7 7 7 7 7 7 7 7 7	Cu 16 20 12 11 10 9 104 30 26 16 16 16 16 56 47 46 46 22 32 24 21 14	Zn 32,00 69,00 33,00 47,70 31,70 45,00 39,80 68,70 112,00 46,70 42,20 37,00 58,90 92,00 69,00 71,00 37,00 32,00 125,00 37,10 22,80	As <2 2 <10 <10 3 <10 15 23 11 <10 <2 <10 11 12 11 4 <10 11 <10 11	Se 3	Sb 0,5 0,7 0,5 0,3 0,5 0,4 0,5 0,4 0,4 0,3 0,4 0,3 0,4 1,7 1,8 1,3 0,8 0,7 0,5 0,3	B 50 60 20 39 44 70 60 102 56 74 43 60 96 100 110 80 60 79 69 78 81	U 0,60 1,00 0,60 0,80 1,00 1,70 1,70 1,70 1,60 1,10 1,10 2,30 2,50 2,50 1,80 1,10 1,90 1,40 1,40 0,70	Pb <2	Rb 40 80 30 40 33 62 58 85 47 56 43 72 109 95 100 74 52 81 54 42 26	Sr 407 204 252 270 243 201 187 194 229 268 321 294 151 233 180 241 353 295 331 314 349	Y 12 40 <10 <10 <10 20 23 16 <10 <10 <10 15 32 12 26 <10 26 <4 <10 <10 <10 <10 <10 <10 <10 <10	Zr 26 89 25 40 31 72 82 106 55 68 67 861 67 162 142 121 70 131 53 62 32	Nb 13 15 <10 39 39 17 31 37 27 25 33 26 42 24 16 <10 15 31 32 30 11	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184,5 VD-186,3 VD-186,3 VD-186,5 VD-189,1 VD-194 VD-198,9 VD-203,3 VD-361,8 VD-362,8 VD-364,15 VD-364,5 VD-368,5 VD-371 VD-375,8 VD-380,5 VD-382 VD-384 VD-391	Lithology CP RAUM RAUM RAUM RAUM RAUM RAUM RAUM MS MS MS MS MS MS MS MS MS MS MS MS MS	Co 11 12 9 4 5 7 6 8 7 6 8 7 6 8 7 6 8 7 19 19 19 19 10 14 7 7 6 7	Cu 16 20 12 11 10 9 104 30 26 16 16 16 16 56 47 46 46 22 32 24 21 14 23	Zn 32,00 69,00 33,00 47,70 31,70 45,00 39,80 68,70 112,00 46,70 42,20 37,00 58,90 92,00 69,00 71,00 37,00 32,00 125,00 37,10 22,80 31,70	As <2 2 <10 <10 3 <10 15 23 11 <10 <2 <10 11 12 11 4 <10 11 <10 11 <10	Se 3	Sb 0,5 0,7 0,5 0,3 0,5 0,9 0,4 0,5 0,4 0,4 0,3 0,4 1,7 1,8 1,3 0,8 0,7 0,5 0,3	B 50 60 20 39 44 70 60 102 56 74 43 60 96 100 110 80 60 79 69 78 81 64	U 0,60 1,00 0,80 0,90 1,00 1,70 1,70 1,60 1,10 1,10 1,00 2,30 2,50 2,50 1,80 1,10 1,90 1,40 1,40 0,70 1,20	Pb <2	Rb 40 80 30 40 33 62 58 85 47 56 43 72 109 95 100 74 52 81 54 42 26 39	Sr 407 204 252 270 243 201 187 194 229 268 321 294 151 233 180 241 353 295 331 314 349 311	Y 12 40 <10 <10 <10 20 23 16 <10 <10 <10 15 32 12 26 <10 26 24 <10 <10 <10 <10 <10 <10 <10 <10	Zr 26 89 25 40 31 72 82 106 55 68 67 861 67 162 142 121 70 131 53 62 32 40	Nb 13 15 <10 39 39 17 31 37 27 25 33 26 42 24 16 <10 15 31 32 30 11 24	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184,5 VD-186,3 VD-186,3 VD-186,5 VD-198,9 VD-203,3 VD-361,8 VD-362,8 VD-364,15 VD-364,15 VD-368,5 VD-371 VD-375,8 VD-380,5 VD-382 VD-384 VD-391 VD-396,5	Lithology CP RAUM RAUM RAUM RAUM RAUM RAUM RAUM MS MS MS MS MS MS MS MS MS MS MS MS MS	Co 11 12 9 4 5 7 6 8 7 6 8 7 6 8 7 6 8 7 19 19 19 19 10 14 7 7 6 7	Cu 16 20 12 11 10 9 104 30 26 16 16 16 16 56 47 46 46 22 32 24 21 14 23	Zn 32,00 69,00 33,00 47,70 31,70 45,00 39,80 68,70 112,00 46,70 42,20 37,00 58,90 92,00 69,00 71,00 37,00 32,00 125,00 37,10 22,80 31,70	As <2 2 <10 <10 3 <10 15 23 11 <10 <2 <10 11 12 11 4 <10 11 <10 11 <10	Se 3 3 3	Sb 0,5 0,7 0,5 0,3 0,5 0,9 0,4 0,5 0,4 0,4 0,3 0,4 1,7 1,8 1,3 0,8 0,7 0,5 0,3	B 50 60 20 39 44 70 60 102 56 74 43 60 96 100 110 80 60 79 69 78 81 64	U 0,60 1,00 0,80 0,90 1,00 1,70 1,70 1,60 1,10 1,10 1,10 2,30 2,50 2,50 1,80 1,10 1,90 1,40 1,40 0,70 1,20 0,90	Pb <2	Rb 40 80 30 40 33 62 58 85 47 56 43 72 109 95 100 74 52 81 54 42 26 39 19	Sr 407 204 252 270 243 201 187 194 229 268 321 294 151 233 180 241 353 295 331 314 349 311 315	Y 12 40 <10 <10 <10 20 23 16 <10 <10 <10 <10 25 32 12 26 <10 26 24 <10 <10 <10 15 32 12 12 26 <10 <10 <10 15 32 11 20 21 15 32 10 21 10 20 21 21 21 21 21 21 21 21 21 21	Zr 26 89 25 40 31 72 82 106 55 68 67 861 67 162 142 121 70 131 53 62 32 40 21	Nb 13 15 <10 39 39 17 31 37 27 25 33 26 42 24 16 <10 15 31 32 30 11 24 30	
SAMPLES VD-161 VD-177 VD-180 VD-184 VD-184,5 VD-185,3 VD-186,3 VD-186,3 VD-186,5 VD-189,1 VD-194 VD-194 VD-198,9 VD-203,3 VD-361,8 VD-361,8 VD-362,8 VD-364,15 VD-368,5 VD-371 VD-375,8 VD-380,5 VD-384 VD-384 VD-391 VD-396,5 VD-490,2	Lithology CP RAUM RAUM RAUM RAUM RAUM RAUM RAUM MS MS MS MS MS MS MS MS MS MS MS MS MS	Co 11 12 9 4 5 7 6 8 7 6 8 7 6 8 7 6 8 7 19 19 19 10 14 7 7 6 7 7 3	Cu 16 20 12 11 10 9 104 30 26 16 16 16 16 56 47 46 46 22 32 24 21 14 23 18	Zn 32,00 69,00 33,00 47,70 31,70 45,00 39,80 68,70 112,00 46,70 42,20 37,00 58,90 92,00 69,00 71,00 37,00 32,00 125,00 37,10 22,80 31,70 41,70	As <2 2 <10 <10 3 <10 15 23 11 <10 <2 <10 11 12 11 4 <10 11 <10 11 <10 11	Se 3	Sb 0,5 0,7 0,5 0,3 0,5 0,9 0,4 0,5 0,4 0,4 0,3 0,4 0,4 0,4 0,4 0,3 0,4 0,7 0,5 0,3 0,3	B 50 60 20 39 44 70 60 102 56 74 43 60 96 100 110 80 60 79 69 78 81 64 34	U 0,60 1,00 0,80 0,90 1,00 1,70 1,70 1,60 1,10 1,10 1,00 2,30 2,50 2,50 1,80 1,10 1,90 1,40 1,40 0,70 1,20 0,90 <<0,5	Pb <2	Rb 40 80 30 40 33 62 58 85 47 56 43 72 109 95 100 74 52 81 54 42 26 39 19 18	Sr 407 204 252 270 243 201 187 194 229 268 321 294 151 233 180 241 353 295 331 314 349 311 315 222	Y 12 40 <10 <10 <10 20 23 16 <10 <10 <10 <10 <10 <10 <10 <10	Zr 26 89 25 40 31 72 82 106 55 68 67 861 67 162 142 121 70 131 53 62 32 40 21	Nb 13 15 <10 39 39 17 31 37 27 25 33 26 42 24 16 <10 15 31 32 30 11 24 30 21	

Tab. 4. Chemical analyses of the whole samples (ppm).

ACIES	ALS ALS ALS ALS ALS ALS ALS ALS		absent	rare Plantinvoluta, Vemeutinidae. Paralingulina gr. tenera. Corruspriacea. fecal	the lower part	absent	Kiliolina, Corruspiracca, Agerina martana, Dphthalmidium, Doities and coated grains, coal pellets, green algae	crinoid fragments and peloids	absent	large calcareous sponge spicules, ennoid articles, scattered peloids	
BIOF	Rosinesto Rosinesto Rosinesto	filaments (bivalves) and radiolarians	Bivalves with shelter porosity; microgastropoda and brachiopoda, ammonites, echinoderms <i>Lenticulino</i> , radiolarians	echinoderns, filaments (bivalves) from m 189 ooine unwards.	Globochaete, Lagenina, Haptophragmoides	radiolarians; rare echinoderms and Lagenina	only radiolarians at m 378,8 and 375.5; rare Lagenina, Prodentatino, G Marginulina, large vaginulinids, Lenticulino	rare organisms: calcispherulids, radiolar., Lagenina (<i>Paralingulina</i>), echinoderns, ostracods, belemnites (rare)	decrease in the organic content. Ammodiscus, Lagenina, gastropods, ostracods, ammonites, radiolarians, echinoderns	Lagenina, Paralingulina, Marginulina gr. prima, Miliolina, gastropods, large echinoid spines, radiolarians, ostracods	
n d	taopter total	Contract Condition of the Contract of the Contract of the Condition of the Condition of the Contract of the Condition of the			absent	Strong positive anomalic in Ba, V. Cr. Ni, Co, Cu, Za, As, Sb and Pb.	Weak positive anomalie in Ba, V. Cr. Ni, Co, Cu. Zn, As, Sb and Pb at the top of this interval	abscrit	absent	without data	
8	ANT ST			Cal - II Cal - II - Cal - II - Cal - II - Cal - II - (Sm Cal - II - (Sm Fieldspar)		III - Sm - Qz - K feldspar - (Cal - Kln)	Cal - 11 - Sm - Qz - (Kln)	Cal - III - (Sm - Qz)	Cal - II	without data	
I E S	15501 DRIT			Thalassinoides, Ophiomorpha, Chondrites, Paleo- phycus, Planolites. Vertical tr. abundant	Chondrites. Prevailing horizontal traces on the bottom of turbidites	Very rare or absent	Chondrites. Ornate horiz. forms (Protopaleodicryon) on the bottom of turbidites	Chondrites. Omate boriz. forms (Protopaleodictyon) on the bottom of turbidites	Prevailing Chondrites and Planolites	rare Chondrites	
F A C	A A A A A A A A A A A A A A A A A A A			thin WB (3 - 8 cm thick)	absent	absent	abscrit	absent	absent	absent	
H O I	dap woll	absent	sharp-based HCS (20 - 40 cm thick); oscillatory ripples	sharp-based HCS (20 - 40 cm thick); oscillatory ripples	absent	absent	absent	HCS in the upper part of some high-density turbiditic beds	absent	absent	
LIT	SIL SIL	pebbly mud-flows prevailing	absent	absent	absent	absent	mud flow deposits (rare)	debris flows, pebbly mud flows & slumps	thin debris flows (20 cm thick)	absent	
(4)	SIISII SUSI	fine-grained turbidites very rare	absent	absent	low-density turbidites (calcisiltites)	low-density turbidites (calcilutites)	low to high-density turbidites (calcarenite/ rudites)	low to high-density turbidites (calcisilitie arcuite)	absent	low-density turbidites very rare	
\$	·1.3141. iBI	well-bedded mudstones & sporadic floatstones	well-bedded mudstones with nodular horizons	nodular bioturbated mudstones; fine-grained packstones	fine grained packstones interbedded with shales	black shales	fine- to coarse-grained packstones interbodded with shales	homoge- neous, fine-grained packstones	nodular bioturbated mudstones	well bedded wackestones packstones with chert	
11	ALL DELLE	159 174,5	174,5 179	179 190	190 204,6	359,2 369	369 391,8	391,8 488,9	488,9 500	510 530	
\swarrow	· elan	6	%	7	9	S	4	3	7	-	
	-135. (14)	CP RAUM	RAUM	RAUM	WS	WS	WS	MS-OR	COR	COR	
	-6	AA1	AA 1 TO 5	TO 5 - TO 3	TO 3	TOI	TO 1	T01 - D03	D01	CAR IX.	

Fig. 20. Comparative scheme between lithofacies and biofacies, including selected mineralogical and geochemical data.

Therefore the reduced oxygenation conditions are more extensive in time than is indicated by the extent of the black shales facies. Calm, confined environments with restricted circulation are therefore represented also by sediments other than those containing black shales.

9.2 Reworking

The Valdorbia area, during the Early Jurassic, was a depressed area where detrital material accumulated by means of different types of transport. Thus the study of the micropaleontological and sedimentological features provides useful information concerning the reworking mechanisms that occurred, throughout the time, and the original environment of the microfossils (Fig. 20). By comparing of the organic content of the microfacies with that of the incoherent sediments, it can be seen that porcellaneous foraminifers, occurring within the detrital limestones, are absent in the marks and hence are allochthonous.

- a Carixian Early Domerian. Episodic muddy turbidites occur and microfaunal content could be autochthonous or from surrounding elevated areas or both. During the Middle Domerian nodular bioturbated facies testify to a normal pelagic deposition with low sedimentation rates and autochthonous faunas.
- b Middle/Late Domerian. An abrupt increase in detrital supply due to mass flow deposits and slumping occurs at this time. These deposits contain intrabasinal microfossils indicating that reworking was local and isochronous. These features are probably linked to local sea-floor instability in the Valdorbia area.
- c Early Toarcian (Tenuicostatum Zone). An increase in the thickness of detrital beds, and in the grain fraction of calcarenites/rudites occur. Moreover these beds contain oolites, coated grains and calcareous algae fragments. They are reworked from a (old-er?) carbonate platform, mixed with other fossils characteristic of shallow-water areas such as Miliolina (Fig. 20). The porcellaneous microforaminifers occurring within the detrital limestones are not present in the soft sediments such as marls. Ophthalmidi-um, Agerina martana and other Cornuspiracea are allochthonous within the Toarcian interval of time, and probably derive from the Pliensbachian assemblage A, characteristic of the relatively shallow water sediments, deposited after the drowning of the "Calcare Massicio" carbonate platform. Agerina martana, in fact, is considered a Pliensbachian microfossil. In the upper part of the Tenuicostatum Zone the detrital supply decreases considerably, corresponding to the black shale deposition. The arenitic fraction consists mainly of radiolarians.
- d Early/Middle Toarcian (Serpentinus Bifrons Zones). Low-density, fine-grained calcarenites still contain reworked microfossils and rare, small oolites. Reworked material decreases in the upper part of this interval.
- e Middle/Late Toarcian (Bifrons and Erbaense Zones). HCS calcarenites are characterized by crinoidal fragments, peloids and porcellaneous foraminifers, such as Planiinvoluta. The depositional environment of Planiinvoluta (Leischner 1961) is rather uncertain. This sessile foraminifer was cited as Glomospira by Radoicic (1966) in the shallow-water carbonate platform of the external Dinarids, middle-upper Early Jurassic in age. Wernli (1971) on the other hand, does not exclude a deeper distribution of

this form in his discussion on the paleoecology of Planiinvoluta. In the Valdorbia Section, it has been found associated with Ophthalmididae and Agerina both in the Carixian and in the reworked microfauna within Lower-Middle Toarcian sediments. The source of this material could be either an open platform or structural highs in the

surrounding area, although Planiinvoluta and Miliolina have never been found in the Toarcian of the Umbria-Marche area.

- f Late Toarcian-Early Aalenian (Meneghinii-base of Opalinum Zones). Nodular and autochthonous bioturbated facies containing abundant bivalve concentrations with shelter porosity. Winnowed beds, and large trace fossils are common and abraded Lenticulina's seem to indicate a high energy or well oxygenated sea-bottom, due to proximity to a major storm wave base, lacking in extrabasinal detrital input.
- g Early Aalenian (Opalinum Zone). Reworking phenomena are confined to the local area and pebbly mudstone deposits seem to be connected with local sea-floor instability. Turbidites are very rare.

9.3 Depositional trends

In the Valdorbia Section different trends are recognized in the sedimentological, microfaunal and geochemical studies (Fig. 21).

- a The microfaunal assemblages indicate a deepening trend from Carixian Early Domerian to the early part of the Toarcian (base of Tenuicostatum Zone), where the microfaunal assemblage and the presence of the illite-smectite association give indications of the maximum depth (and reworking) reached by the basin at the beginning of the Toarcian (Fig. 21). The absence of kaolinite supports the hypothesis of a relative-ly deep marine environment.
- b The major factor affecting the microfauna within the Tenuicostatum Zone is a lack of oxygen which prevents recognition of any depositional trend. A fining-upward trend is recognizable, by means of sedimentological analysis, from the Tenuicostatum to the Serpentinus Zones. Coarse-grained, high-density calcarenitic turbidites were overlain by thin, fine-grained planar-bedded calcisilitic turbidites during the maximum black shale deposition (see Fig. 14, 20 and 21). The persistent, relative deep conditions during the black shale deposition is indicated by the greater abundance of smectite and the continuing scarcity of kaolinite and by the ornate burrow-systems. As mentioned in 9.1, it is clear that, together with the continuity of a deep depositional environment, confined areas of restricted water circulation also existed in which the black shales were deposited.
- c After the period of poorly ventilated sea-bottom conditions (Serpentinus Zone), the microfaunal assemblages indicate a slow improvement in the oxygenation level. A relative shallowing began from the lower part of the Bifrons Zone and reached a maximum at the end of the Toarcian (Meneghinii Zone) (Fig. 21), as shown by the continuous reduction in smectite content. An abrupt change in the environmental conditions is evident at the Bifrons/Erbaense zonal boundary. From the sedimentological point of view a shallowing-upward trend from the Serpentinus Zone to the the upper part of the Toarcian (Meneghinii Zone) is observed. Planar-bedded calcisiltitic turbidites are overlain by sharp-based HCS calcarenites and, finally, by winnowed beds



Fig. 21. Valdorbia Section related to the Hallam (1988) eustatic curve. Tectonic and eustacy interpretations have been reported on the right side, according to despositional trends, mineralogy and geochemistry.

(Fig. 14, 20 and 21). The sharp-based HCS calcarenites were probably formed under very rare, unusually stormy conditions that caused a strong oscillatory flow regime near the bottom during the Middle and Upper Toarcian. Characteristic abrasion surfaces on some benthic foraminiferal tests seem to be due to oscillatory conditions at the sediment/water interface during the deposition of the winnowed beds (Fig. 13). The minimum depth and sedimentation rate of the depositional environment was reached in the upper part of the Toarcian and corresponds roughly to an outer/middle shelf environment, near the major storm wave base (Fig. 21). Moreover in the Erbaense-Meneghinii Zones the succession is strongly condensed – testified by repeated hardgrounds – and represented by sediments only 7.5 m thick, in comparison with the Tenuicostatum-Bifrons Zones where deposits 60 m thick occur.

9.4 Tectonics and eustacy

The microforaminiferal assemblage BC present at the boundary between Corniola and Marne del M. Serrone is lacking in the Valdorbia area where Glomospirella disappears in the Upper Domerian, earlier than in the other areas. At the Domerian/Toarcian boundary slumps, mass-flow and calcareous turbidites occur. These sedimentary features can be interpreted as indicative of regional synsedimentary tectonics rather than a eustatic lowstand phase because this sedimentological character seems to be relatively local. Hence, the Domerian regressive stage expressed in the eustatic curve of Hallam (1988) is not evident in this area, probably because of local tectonic activity of M.Catria-Valdorbia area (Fig. 21).

The deepening found in the Tenuicostatum Zone can be connected to sea-level rise (Hallam 1967), according to the Jurassic eustatic curve of Hallam (1988), and/or to an increase in the rate of the subsidence (Fig. 21). In fact the degree of reworking reaches its maximum intensity in the Lower Toarcian.

The shallowing trend suggested for the Middle/Late Toarcian fits better into a geological context clearly affected by a regressive phase (Hallam 1988), than into one affected by tectonic activity (Fig. 21). In fact a regressive-shallowing can be considered to be widespread in the central Apennines, as in the Umbria-Marche basin and the Lazio-Abruzzi carbonate platform area (Giannini et al. 1970; Colacicchi & Bigozzi 1992). Massflow deposits which occurred in the Lower Aalenian are widely scattered in the Umbria-Marche area (M. Cucco, M. Serrone, Narni-Amelia ridge, M. Martani) and seem to reflect regional sea-floor instability. The cause of these features is still uncertain, although the Aalenian regression is probably the result of Western Tethys tectonics (Hallam 1988).

Acknowledgements

Our best thanks to Prof. F. Venturi who has provided us with his data on ammonite horizons. We are very grateful to Dr. R. Rettori, University of Perugia, for help in microfacies description and to Dr. C. Arias, University of Madrid, for the ostracod classification. We would like also to express our thanks to A. Bartolucci and G. Vinti, University of Perugia, for their technical assistance and to G. Tosti for his help with the photography. Work published with the financial support of M.U.R.S.T. (40%, Prof. R. Colacicchi) and by the Project PB-92-0960 (D.G.I.C.Y.T.- Spain).