Discussion and conclusions

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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 seafloor 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_2O_3	CaO	MgO	Na_2O	K_2O	Fe_2O_3	MnO	TiO_2	P_2O_5	LOI
VD-161	CP	19,00	4,11	38,60	1,27	0,09	1,12	1,84	0,04	0,20	0,09	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	0,09	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	0,30	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	0,99	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	0,09	34,40

Tab. 3. Chemical analyses of the whole samples (%). LOI = Loss on ignition.

SAMPLES	Lithology	Ba	V	Cr	Ni	Cs	Hf	Ta	W	Pb	Th	Ge	Br	Mo	Ag	Cd
VD-161	CP	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	B	U	Pb	Rb	Sr	Y	Zr	Nb
VD-161	CP	11	16	32,00	<2	<3	0,5	50	0,60	<2	40	407	12	26	13
VD-177	RAUM	12	20	69,00	2	<3	0,7	60	1,00	<2	80	204	40	89	15
VD-180	RAUM	9	12	33,00	<2	<3	0,5	20	0,60	<2	30	252	<10	25	<10
VD-184	RAUM	4	11	47,70	<10	<3	0,3	39	0,80	<2	40	270	<10	40	39
VD-184,5	RAUM	5	10	31,70	<10	<3	0,5	44	0,90	7	33	243	<10	31	39
VD-185,3	RAUM	7	9	45,00	3	<3	0,9	70	1,00	<2	62	201	<10	72	17
VD-186,3	RAUM	6	104	39,80	<10	<3	0,4	60	1,70	3	58	187	20	82	31
VD-186,5	RAUM	8	30	68,70	15	<3	0,5	102	1,70	<2	85	194	23	106	37
VD-189,1	RAUM	7	26	112,00	23	<3	0,4	56	1,60	6	47	229	16	55	27
VD-194	MS	6	16	46,70	11	<3	0,4	74	1,10	7	56	268	<10	68	25
VD-198,9	MS	8	16	42,20	<10	<3	0,3	43	1,10	5	43	321	<10	67	33
VD-203,3	MS	7	16	37,00	<2	<3	0,4	60	1,00	4	72	294	15	861	26
VD-361,8	MS	19	56	58,90	<10	<3	1,4	96	2,30	13	109	151	32	67	42
VD-362,8	MS	18	47	92,00	11	<3	1,7	100	2,50	8	95	233	12	162	24
VD-364,15	MS	19	46	69,00	12	<3	1,8	110	2,50	8	100	180	26	142	16
VD-368,5	MS	19	46	71,00	11	<3	1,3	80	1,80	4	74	241	<10	121	<10
VD-371	MS	10	22	37,00	4	<3	0,8	60	1,10	2	52	353	26	70	15
VD-375,8	MS	14	32	32,00	<10	<3	0,6	79	1,90	8	81	295	24	131	31
VD-380,5	MS	7	24	125,00	11	<3	0,7	69	1,40	8	54	331	<10	53	32
VD-382	MS	7	21	37,10	<10	<3	0,5	78	1,40	<2	42	314	<10	62	30
VD-384	MS	6	14	22,80	11	<3	0,3	81	0,70	<2	26	349	<10	32	11
VD-391	MS	7	23	31,70	<10	<3	0,3	64	1,20	<2	39	311	<10	40	24
VD-396,5	MS								0,90	<2	19	315	11	21	30
VD-490,2	COR	3	18	41,70	10	<3	0,3	34	<0,5	<2	18	222	<10	19	21
VD-496,18	COR	6	11	36,00	<2	<3	0,4	50	0,60	<2	40	213	<10	47	15

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

AGE	Stratigraphic units	microfacies	Stratigr. interv. (m)	Characteristics	Turbidites	Gravity flow dep.	HCS beds	Winnowed beds	Trace fossils	Mineralogy	Geochemical anomalies	Autochthonous organisms	Allochthonous organisms
				LITHOFACIES and BIOFACIES									
AA1	CP – RAUM	9	159 – 174,5	well-bedded mudstones & sporadic floatstones	fine-grained turbidites very rare	pebbly mud-flows prevailing	absent	absent	rare *Chondrites*	Cal - Ill	absent	filaments (bivalves) and radiolarians	intraclasts with ammonites, microgastropods and brachiopods, large ostracods & *Lenticulina*; radiolarians
AA 1 – TO 5	RAUM	8	174,5 – 179	well-bedded mudstones with nodular horizons	absent	absent	sharp-based HCS (20 - 40 cm thick); oscillatory ripples	thin WB (3 - 8 cm thick) in the lower part	*Thalassinoides, Ophiomorpha, Chondrites, Paleophycus, Planolites.* Vertical tr. abundant.	Cal - Ill - (Sm - Kln - Qz - K feldspar)	absent	Bivalves with shelter porosity; microgastropods and brachiopods, ammonites, echinoderms, *Lenticulina*, radiolarians	absent
TO 5 – TO 3	RAUM	7	179 – 190	nodular bioturbated mudstones; fine-grained packstones	absent	absent	sharp-based HCS (20 - 40 cm thick); oscillatory ripples	thin WB (3 - 8 cm thick)	*Thalassinoides, Ophiomorpha, Chondrites, Paleophycus, Planolites.* Vertical tr. abundant.			echinoderms, filaments (bivalves) from m 189 going upwards. Globochaete, Lagenina, *Haplophragmoides*	rare *Planiinvoluta*, Verneulinidae. *Paralingulina* gr. *tenera*, Cornuspiracea, fecal pellets, small oolites in the lower part
TO 3 – TO 2	MS	6	190 – 204,6	fine-grained packstones interbedded with shales	low-density turbidites (calcisiltites)	absent	absent	absent	*Chondrites.* Prevailing horizontal traces on the bottom of turbidites	Cal - Ill - (Sm - Qz)	absent		
TO 1	MS	5	359,2 – 369	black shales	low-density turbidites (calcilutites)	absent	absent	absent	Very rare or absent	Ill - Sm - Qz - K feldspar - (Cal - Kln)	Strong positive anomalie in Ba, V, Cr, Ni, Co, Cu, Zn, As, Sb and Pb.	radiolarians; rare echinoderms and Lagenina	absent
TO 1	MS	4	369 – 391,8	fine- to coarse-grained packstones interbedded with shales	low- to high-density turbidites (calcarenite/ rudites)	mud flow deposits (rare)	absent	absent	*Chondrites.* Ornate horiz. forms (*Protopaleodictyon*) on the bottom of turbidites	Cal - Ill - Sm - Qz - (Kln)	Weak positive anomalie in Ba, V, Cr, Ni, Co, Cu, Zn, As, Sb and Pb at the top of this interval	only radiolarians at m 378,8 and 375,5; rare Lagenina, *Prodentalina*, *Marginulina*, large vaginulinids, *Lenticulina*	Miliolina, Cornuspiracea, *Agerina martana*, *Ophthalmidium*, *Planiinvoluta*, Verneulinidae; oolites and coated grains, fecal pellets, green algae
TO 1 – DO 3	MS – COR	3	391,8 – 488,9	homogeneous, fine-grained packstones	low to high-density turbidites (calcisiltite/ arenite)	debris flows, pebbly mud flows & slumps	HCS in the upper part of some high-density turbiditic beds	absent	*Chondrites.* Ornate horiz. forms (*Protopaleodictyon*) on the bottom of turbidites	Cal - Ill - (Sm - Qz)	absent	rare organisms: calcispherulids, radiolar., Lagenina (*Paralingulina*), echinoderms, ostracods, belemnites (rare)	crinoid fragments and peloids
DO 2 – DO 1	COR	2	488,9 – 500	nodular bioturbated mudstones	absent	thin debris flows (20 cm thick)	absent	absent	Prevailing *Chondrites* and *Planolites*	Cal - Ill	absent	decrease in the organic content, *Ammodiscus*, Lagenina, gastropods, ostracods, ammonites, radiolarians, echinoderms	absent
CAR IX.	COR	1	510 – 530	well bedded wackestones / packstones with chert	low-density turbidites very rare	absent	absent	absent	rare *Chondrites*	without data	without data	Lagenina, *Paralingulina*, *Marginulina* gr. *prima*, Miliolina, gastropods, large echinoid spines, radiolarians, ostracods	large calcareous sponge spicules, crinoid articles, scattered peloids

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 marls 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 (older?) 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. Ophthalmidium, 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 Ophthalmidiidae 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 relatively 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 calcisiltitic 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

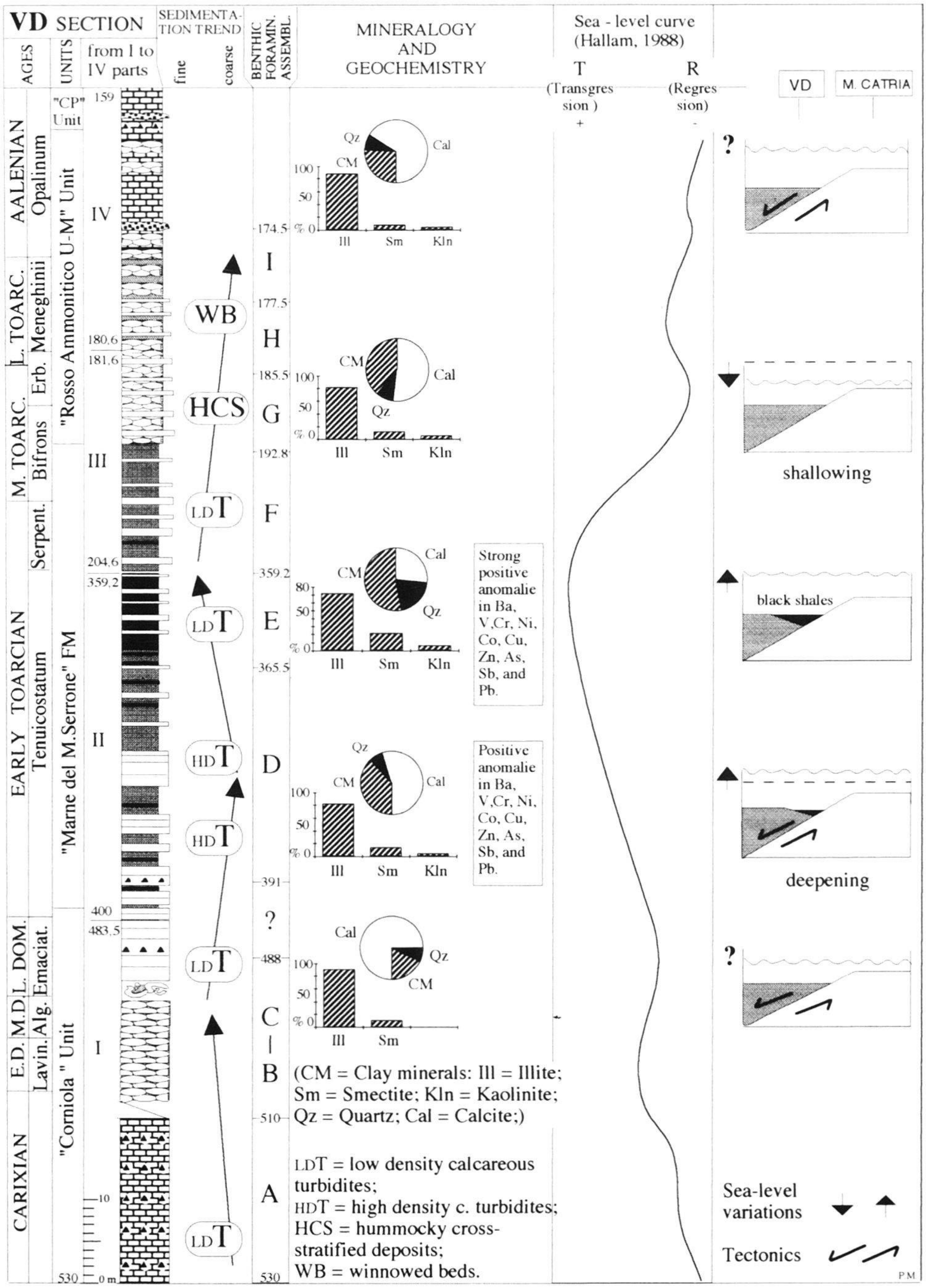

Fig. 21. Valdorbia Section related to the Hallam (1988) eustatic curve. Tectonic and eustacy interpretations have been reported on the right side, according to despositional trends, mineralogy and geochemistry.

(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). Mass-flow 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).

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