STRATIGRAPHY AND GEOCHEMICA ANOMALIES OF THE EARLY TOARCIA OXYGEN-POOR INTERVAL IN TH UMBRIA-MARCHE APENNINES (ITAL

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ABSTRACT - A multidisciplinary approach is used to demonstrate the occurrence of oxygen-poor sediments in t Tenuicostatum Zone (Early Toarcian) within the clayey-marly pelagic sediments of Marne del Monte Serrone Formati (Umbria-Marche basin). This approach involves examination of some geochemical anomalies (trace elements), meas rement of Total Organic Carbon and observation of benthic foraminifera and trace fossils. A distinction between **"bla shale facies"** (BSF1) and **"black shale-like sediments"** (BSF2) allows better identification of the variable ano conditions present within the same basin. A high degree of organic matter preservation and major anoxia extensic occur in the middle-upper part of the Tenuicostatum Zone (Early Toarcian) probably related to maximum flooding - hi stand of the global Early Toarcian sea-level rise. Several subenvironments showing pelagic conditions and high prin ry productivity of planktonic organisms (mainly radiolarians and calcareous nannofossils), have been defined on t basis of organic matter content and positive geochemical anomalies. The diversified physiography of the Umbria-Marc basin, related to synsedimentary tectonic activity and circulation patterns, probably determined different intensities ventilation conditions on the sea-floor.

KEYWORDS : OXYGEN-POOR SEDIMENTS, STRATIGRAPHY, GEOCHEMICAL ANOMALIES, UMBRIA-MARCI BEGIN, EARLY TOARCIAN.

RÉSUMÉ - Une étude pluridisciplinaire est utilisée pour démontrer la présence de sédiments pauvres en oxygène da la Zone à Tenuicostatum (Toarcien inférieur) inclus dans des sédiments argilo-marneux de la Formation des Marnes Monte Serrone (Bassin de Umbria-Marche). Cette étude implique l'examen de certaines anomalies géochimiques (é ments traces), la mesure du Carbone Organique Total et l'observation de foraminifères et de traces fossiles. La disti tion entre **"facies des black shales"** (BSF1) et **"sédiments semblables à des black shales"** (BSF2) permet u meilleure identification des conditions anoxiques variables dans le même bassin. Dans la partie moyenne et supérieu de la Zone à Tenuicostatum (Toarcien inférieur) il y a une importante préservation de la matière organique et des exte sions anoxiques, probablement en relation avec la montée la plus forte du niveau de la mer durant le Toarcien inférie Nous avons identifié, à partir de la teneur en matière organique et des anomalies géochimiques, plusieurs environnemе pélagiques avec une grande productivité d'organismes planctoniques (principalement radiolaires et nannofossiles c caires). La physiographie diversifiée du bassin de Umbria-Marche, mise en relation avec des processus d'activité tec nique synsédimentaire et avec les modèles de circulation, a probablement déterminé des intensités différentes des con tions de ventilation sur le fond océanique.

MOTS-CLÉS : SÉDIMENT PAUVRES EN OXYGÈNE, STRATIGRAPHIE, ANOMALIES GÉOCHIMIQUES, BASSIN UMBRIA-MARCHE, TOARCIEN INFÉRIEUR.

INTRODUCTION AND PREVIOUS STUDIES

Early Jurassic marly-clayey sediments were deposited in the Umbria-Marche basin (UMB, Central Italy) with variable thickness (from several decimeters to 60 m) depending on the palaeomorphology of the basin area inherited from the break-up and fl ding of the Early Jurassic carbonate platfo (Channell *et al.* 1979 ; Colacicchi *et al.* 1988). La Domerian/Middle Toarcian sedimentation is rep sented by the marly and marly-clayey "Marne c Monte Serrone" (MS) Formation (Pialli 1969a Pialli 1969b). This formationis interposed betwe a calcareous unit (Corniola = COR) and a reddish nodular calcareous marly one (Rosso Ammonitico Umbro-Marchigiano = RAUM) (Colacicchi *et al.* 1988 ; Cresta *et al.* 1988). Organic-rich black shale intervals formed during the Early Toarcian in the MS formation. Jenkyns & Clayton (1986) and Jenkyns (1988) found this organic-rich interval in the Umbria-Marche area (Valdorbia section) and in other parts of the Mediterranean Tethys. These authors defined the interval as the "Oceanic Anoxic Event " (OAE) dating it as Early Toarcian (early Falciferum or Serpentinus Zones). Baudin *et al.* (1990a, 1990b) studied the OAE in the Mediterranean area including northern and central Italy. These authors suggested that the OAE is located between the Tenuicostatum/Falciferum Zones in northern Italy (Lombardia and Belluno area, see also Claps *et al.* 1995), and in the upper part of the Tenuicostatum Zone in central Italy (Valdorbia section). Bassoullet & Baudin (1994) believe that the Toarcian anoxic event was caused in the Tethys by several periods of biological crises that could span from the Domerian/ Toarcian boundary to the top of the Serpentinus Zone. According to these authors, the preservation of organic matter can be explained by the concurrence of several factors, depending on the palaeogeography: variation of sea-level, organic productivity, anoxia of the water, tectonization of margins and degree of clay sedimentation.

Recently, other authors have investigated black shale facies in several areas of the Umbria-Marche basin using calcareous nannofossils, ammonite biostratigraphy, palynology and organic-matter geochemistry (Bucefalo-Palliani & Cirilli 1993 ; Cresta *et al.*1989 ; Mattioli 1993 ; Nocchi 1992 ; Reale *et al.* 1991 ; Bartolini *et al.* 1992).

Oxygen-poor deposits often occur during deposition of the MS formation (see also Nini *et al.* 1995), although the black shale facies were not found in all the examined portions of the UMB, as proposed by Bartolini *et al.* (1992).

Furthermore, during a preliminary study on clay minerals from Late Domerian to Early Aalenian, positive geochemical anomalies were detected in black shale episodes during the Early Toarcian (Tenuicostatum Zone) (Ortega-Huertas *et al.* 1993 ; Monaco *et al.* 1994).

The aim of this paper consists in determining and constraining relationships among some trace elements geochemical anomalies, Total Organic Carbon (TOC), benthic foraminifera, trace fossils and sediment types, during MS deposition.

Data presented in this paper intend to contribute to the understanding of factors causing deposition of oxygen-poor sediments and organic-rich ones in the Umbria-Marche area.

LITHOLOGY OF THE STUDIED SECTIONS

Many Jurassic stratigraphic sections have bee[n stu]died in the central part of the Umbria-M[arche] Apennines, but only five have been examined [using] geochemistry (Fig. 1). These sections consi[st of] various lithologies represented mainly by li[mes]tones, marly-limestone, shales and clay dep[osits] that are sometimes bioturbated, vary wide[ly in] thickness (Fig. 2, 6) and correspond to a differe[ntia]ted palaeodepositional setting in Jurassic tim[e] "condensed", "intermediate" and "extended [se]quences Colacicchi *et al.* 1988 ; Cresta *et al.* 1... Monaco 1992).

This paper considers the Early Toarcian porti[on of] Valdorbia (VD), Colle d'Orlando (CO), Pale Va... (PLV), Monte Serrone (MS) and Pozzale (PO...) [sec]tions. The stratigraphic intervals concerned ... the study belong to the Tenuicostatum ... Serpentinus Zones ; age is determined by a[mmo]nites and calcareous nannofossils (Baldan... Mattioli 1992a ; Cresta *et al.* 1989 ; Reale ... 1991; Benedetti *et al.* in press).

The lower boundary of the Tenuicostatum Zon[e has] been identified with *Dactylioceras* FO (first o[ccur]rence) and *Calyculus* FO, while the upper boun[dary] is marked by *Hildaites* FO indicating the ba[se of] the Serpentinus Zone. This last event occurs s[light]ly above the *Discorhabdus ignotus* FO (Baldan... Mattioli 1992a). The FO of *Lotharingius cruc[iforme-cen]tralis* represents an important event for ox[ygen-]poor deposit correlations from different sec[tions] and falls approximately in the middle part o[f the] Tenuicostatum Zone. On the basis of macros[copic] and microscopic observations, two groups of ... have been recognized: a) oxygenized deposits ... and OF2) ; b) poorly-oxygenized deposits (BSF... BSF2).

OXYGENIZED DEPOSITS

Facies 1 (OF1) is made up of white mudston[es to] wackestones, generally well stratified and mo[dera]tely bioturbated with cherty lenses (COR unit... by nodular, highly bioturbated mudstones to [wac]kestones of reddish colour (RAUM unit). The a[bun]dant macrofauna of this last unit contains a[mmo]nites, echinoderm remains, and thin-sh[elled] bivalves. Foraminifera associations belong t[o] assemblage units BC, F, G and H recordin[g] occurrence of oxygen on the sea-floor (Nocchi 1... Assemblage BC is characterized by the occur[rence] of both *Glomospira-Glomospirella* and high s[truc]tured large Lagenina with a Pliensbachian af[finity]. In the F assemblage the characteristic bent[hic] foraminifers of BC assemblage are disapp[earing] while *Eoguttulina* and *Prodentalina* (mediu...

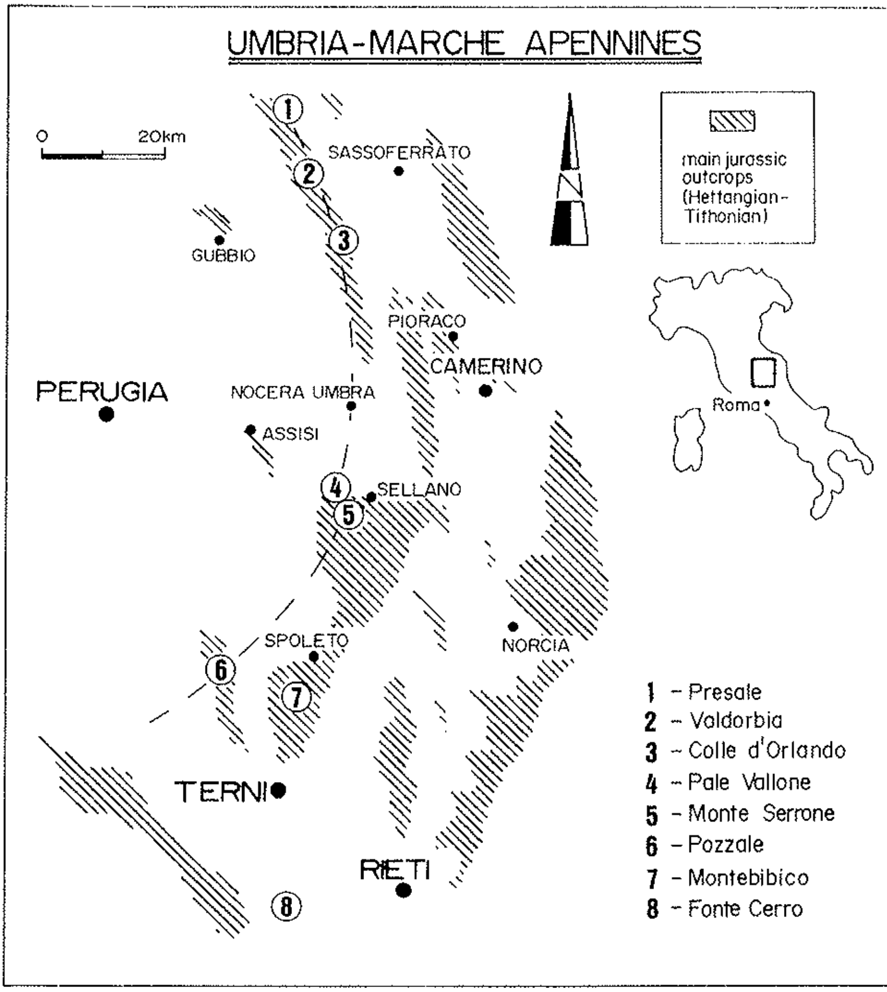


FIGURE 1 - Geological map and location of the studied sections. Geochemical anomalies were only analyzed in sections 2, 3, 4, 5 and 6. A discontinuous line links the selected sequences showed in Figure 7. *Carte géologique et localisation des coupes étudiées. Les anomalies géochimiques ont été analysées dans les coupes 2, 3, 4, 5, et 6 seulement. La ligne en tirets réunit les coupes sélectionnées en Figure 7.*

size) prevail. G and H asemblages are characterized by the abundance of large Vaginulinidae and by the occurrence of small gastropods, brachiopods, ammonite nuclei and bivalve lumachellas. Bioturbation is abundant and pervasive (both horizontal and vertical trace fossils are noted) throughout RAUM, displaying a diversified trace fossil association: *Chondrites, Planolites, Zoophycos, Thalassinoides, Ophiomorpha, Skolithos, Paleophycus, Helminthopsis* and *Trypanites* (Monaco 1995 ; Monaco *et al.* 1994). Penetration depths, burrow diameters, trace fossils density and species diversity emphasize well oxygenated conditions both on the sea-bottom and in the sediment column (Monaco 1995 ; Monaco *et al.* 1994).

Facies 2 (OF2) is characterized by wackestones, mudstones and packstones varying in colour from violet to reddish and from green to light grey. These sediments are generally not laminated and show scattered nodules. The scarce macrofaunal content consists of thin-shelled bivalves and few amm nites; the foraminifera belong to the assembla unit D (characterized by small and tiny *Eoguttuli* and *Prodentalina*) which is indicative of modera oxygenation on the sea-floor (Nocchi 1992). Tra fossils are scattered and not pervasive : *Chondrit* and *Planolites* are prevalent, while *Zoophycos* rare (see assemblages of Savrda & Bottjer 198 1989).

In the sediments of OF1 and OF2 the Total Orga Carbon (TOC) is very low (0 to 0.05 %) (Figs. 2- Pyrite is absent or scattered ; moreover, geoche cal anomalies are lacking indicating the absence organic matter deposition.

POORLY-OXYGENIZED DEPOSITS

Oxygen-poor sediments can be characterized positive geochemical anomalies, by colour, by t presence of laminated sediments, as regards und lying and overlying sediments (lower MS form tion). Oxygen-poor deposits can basically be subdivided into two different groups characterized as follows : III) **"black shale facies"** (BSF1) already well known in the literature, and IV) **"black shale-like sediments"** (BSF2). The TOC values generally range from 0.5 to 2.7 % in both facies and maximum values are recorded in BSF1.

BSF1 consists of dark gray to black very fine (mm) laminated shales, containing pyrite crystals, sulphate-rich horizons (mainly secondary gypsum microcrystals probably due to pyrite alteration), carbon fragments and bituminous sapropels with fish remains. Macrofaunal content is absent or very rare (thin-shelled bivalves and rare ammonites in the Colle d'Orlando and Pozzale sections). Trace fossils are rare and poorly diversified. Only sporadic *Chondrites* are present at Valdorbia, Colle d'Orlando and Pozzale sections. Microfauna is characterized by the dominance of *Paralingulina* gr. *tenera* (Bartolini *et al.* 1992), which is an oligotypical and r-selected form. This taxon flourishes in organic-rich sediments since the greatest abundance coincides with the highest TOC values. The occurrence of *Paralingulina* gr. *tenera* indicates dysaerobic to anaerobic conditions with low availability of $CaCO_3$; such conditions are still bearable by benthic assemblages. *P. tenera* is associated to small (<500 µm) pyritized bivalve prodissoconchs, juvenile or dwarf gastropods, ornated ostracods and tiny, transparent echinoderm spines. In this facies (dysaerobic to anaerobic conditions with low availability of $CaCO_3$) other Lagenina, such as tiny Eoguttulina (*E. metensis*) and Prodentalina (*P. gracilis*) can be found, but often *P.* gr. *tenera* is almost the only surviving foraminifer species. In fact, when TOC values are highest the other foraminifers are very rare (few tiny *Eoguttulina,* e.g. sample CO 204.20 with TOC=2.69). The microfauna is attributable to the E assemblage unit, characterized by the abundance of *Paralingulina* gr. *tenera* (Nocchi 1992).

BSF2 consists of grey, green to dark-brown, yellowish or ochre mm- to cm-laminated, locally stratified silty levels. Pyrite always occurs abundantly. Ammonites are rare, trace fossils are scarce, very small and represented by *Chondrites* 0.3-0.5 mm in diameter; very rare *Planolites* 3-6 mm in diameter are present only at the BSF2/OF2 transition. When benthic microfauna is poor, pyrite is not always present and geochemical data show fluctuation in the anomalies, sediments are interpreted as transitional between BSF2 and OF2 facies. The microfauna is characterized by the occurrence of *Paralingulina* gr. *tenera,* but this form is not dominant, being associated to *Prodentalina, Eoguttulina, Astacolus* and *Lenticulina* representing the transition between assemblage unit D and assemblage unit E (Nocchi 1992). Other invertebrate remains are rare and there are no pyritized organisms.

DESCRIPTION OF THE OXYGEN-POOR INTERVAL IN THE STUDIED SECTIONS

LITHOLOGICAL CHARACTERISTICS

Figures 2 to 6 represent the five studied sec Pyrite abundance, trace fossil content, TOC v positive geochemical anomalies and *Paraling tenera* occurrences are all plotted together v lithological characteristics. Diagrams allow a parison between the most significant param and vertical trends, representative of oxygen conditions.

Valdorbia. The oxygen-poor interval in Valdorbia section is about 23 m thick. BSF BSF1 are easily recognizable in the field (F The former occurs throughout all the Ten tatum Zone, except for the base, while the represents the only poorly-oxygenated facies i upper part of the Tenuicostatum Zone. More small intervals of BSF2 although uncertain ar sent at the base of the Serpentinus Zone an intercalated with oxygenated facies (Fig. 2).

During the Early Toarcian low-density, fine-gr (muddy to silty) calcareous turbidites show fining-upward trend are interbedded with ox poor sediments. These calciturbidites are asso with gravity-flow deposits at the Dome Toarcian transition (Monaco 1992 ; Monaco 1994).

Colle d'Orlando. In the Colle d'Orlando se (Benedetti *et al.* in press) the oxygen-poor in is 16 m thick, but the lower part does not ou and no data are available below sample CO-20 Fig. 3). From samples CO-200 to CO-204 the gen-poor interval shows a rhythmic alternat couplets of mm-laminated BSF1 sediments cm thick and brownish-yellowish BSF2 silty- deposits of the same thickness (Fig. 3). This r mic alternation begins above the *L. crucicen* FO and corresponds to the middle part o Tenuicostatum Zone. On the other hand, the part of the Tenuicostatum Zone is represented by BSF1. Intercalated within poorly-oxyge deposits are 20-40 cm thick calcarenitic beds c ting of planar-bedded, densely packed echino and peloidal fine-grained packstones, or s based hummocky cross-stratified (HCS) ca nites. A short BSF2? interval occurs at the top Tenuicostatum Zone where oxygenated sedi are present.

Pale Vallone. This section is a condensed s sion and the MS Formation is very thin (1 m t The oxygen-poor interval is 0.90 m thick (The lower part of the Pale Vallone section is

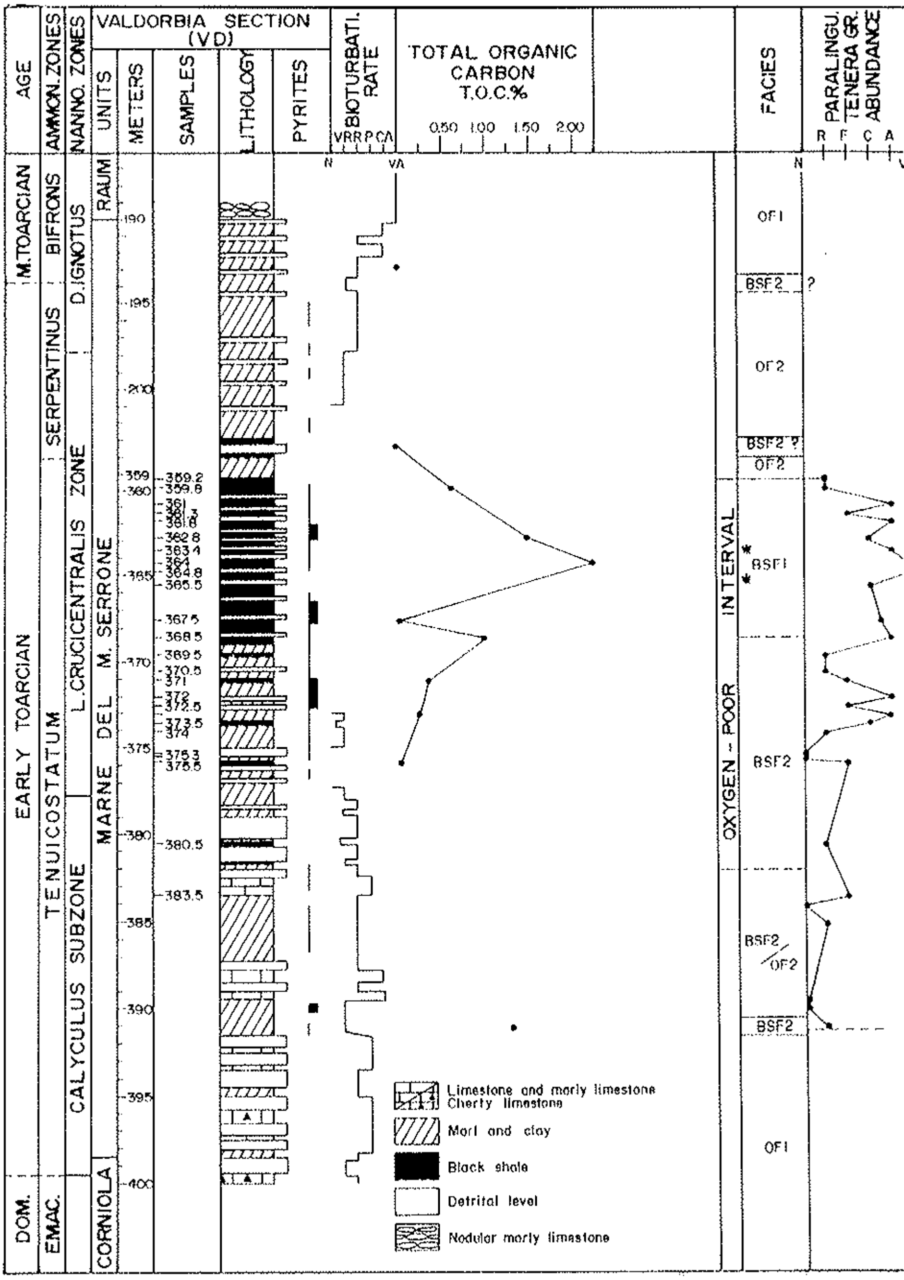
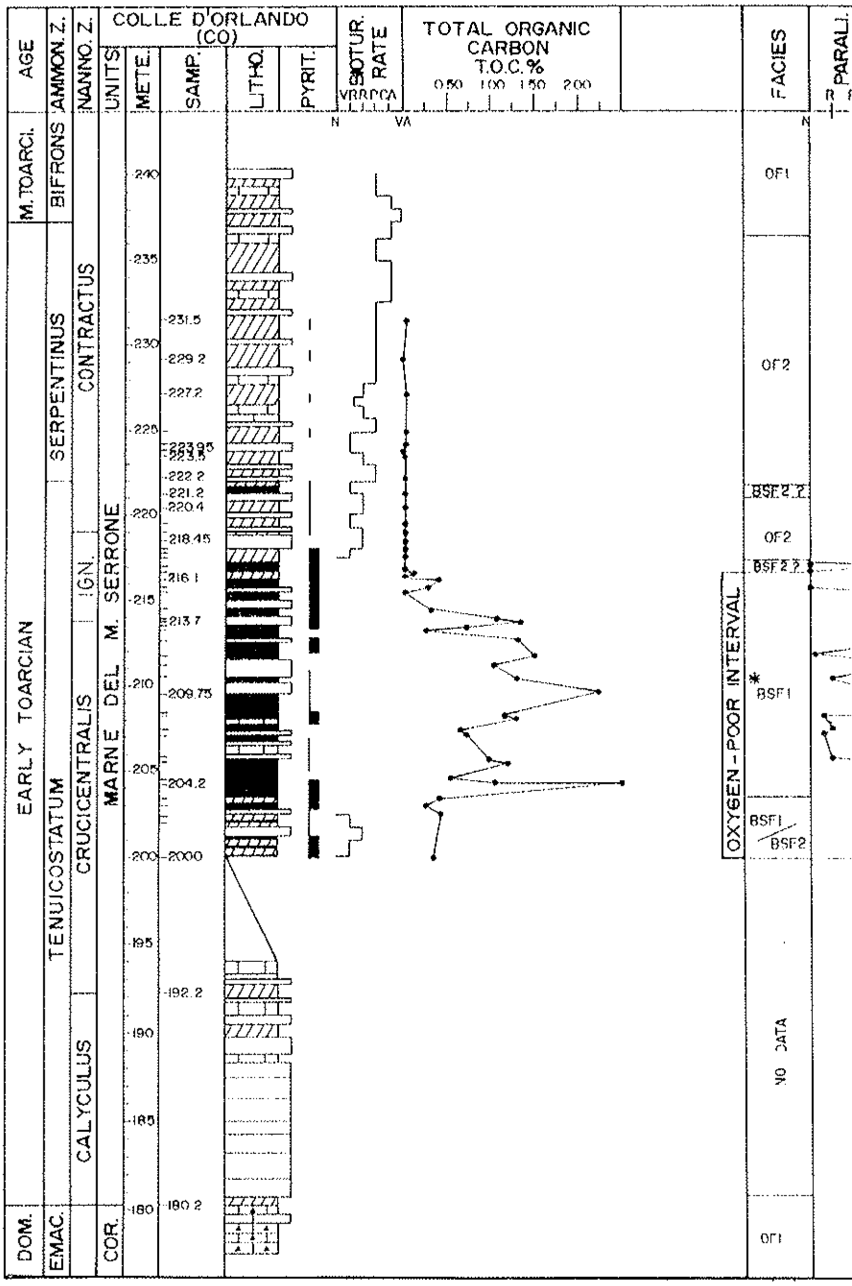


FIGURE 2 - Valdorbia stratigraphic section (VD). Abbreviations : N = none ; VR = very-rare ; R = rare ; F = few ; P=present ; C = common ; A = abundant ; VA = very abundant. Asterisks indicate levels with maximum anoxic conditions. Pyrites : thinline=present ; thickline = abundant. *Coupe stratigraphique de Valdorbia (VD). N = nul ; VR = très rare ; R = rare ; F = quelques spécimens ; P = présents ; C = communs ; A = abondants. VA = très abondant. Les astérisques indiquent les niveaux avec le maximum de conditions anoxiques. Pyrite : ligne mince = présente ; ligne épaisse abondante.*

up of limestones of COR unit spanning the lower part of the Tenuicostatum Zone (Bartolini *et al.* in press). Clay levels appear suddenly within MS formation (middle-upper part of the Tenuicostatum Zone, immediately below the *L. crucicentralis* FO) and are represented by BSF2-type sediment 0.70 m thick. However, BSF1-type sediment is 0.20 m thick. The transition from BSF1 and BSF2 falls around the *L. crucicentralis* FO.

Monte Serrone. Previous authors dealing with black shale deposits in the Umbria-Marche basin did not mention the occurrence of oxygen-poor deposits in the Monte Serrone section (Baudin *et a* 1990b ; Bartolini *et al.* 1992). The Early Toarcia part of this succession is 50 m thick with a high ra of clay sedimentation. Further research has indic ted the predominance of oxygenized sedimen within the Tenuicostatum Zone (OF2-type), but al rare and thin (2-3 cm) intercalations of BSF2-ty sediments ; only one horizon showing BSF1-ty lenses (5-10 cm thick) was observed in the middl upper part of the Tenuicostatum Zone, above the *crucicentralis* FO. The oxygen-poor interval has n been plotted in Figure 5 because the poorly-oxyg

FIGURE 3 - Colle d'Orlando stratigraphic section (CO). Asterisk indicates level with maximum anoxic conditions. Lithology and abbreviations as Figure 2. *Coupe stratigraphique de Colle d'Orlando (CO). Lithologie et abréviations les mêmes que pour la Figure 2. L'astérisque indique le niveau avec le maximum de conditions anoxiques.*



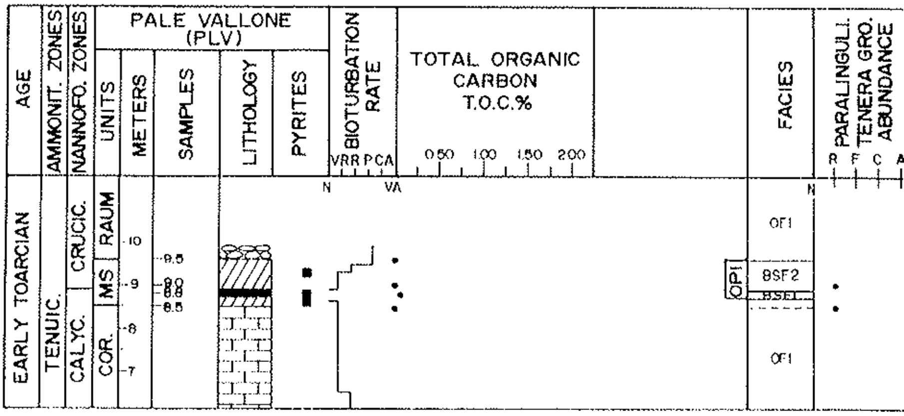
nized facies are rare, discontinuous and mixed with reworked Domerian/Toarcian microfauna (BC foraminifer assemblages).

Pozzale. The oxygen-poor interval in the Pozzale section is 5.5 m thick (Fig. 6) and belongs to the middle-upper part of Tenuicostatum Zone. In the lower part of the MS formation, a 10 cm thick level with BSF2 characteristics occurs within oxygenized sediments (OF2). A thin-shelled bivalve-bearing bed (30 cm thick), overlying 1,70 m of bioturbated, polychrome marls, occurs immediately below the poorly-oxygenized interval. BSF2 prevails lower part of the oxygen-poor interval, above *crucicentralis* FO (Mattioli 1993) and occurs between 7.45 and 8.50 m. BSF1 prevails bet and 7.45 m. From 8.50 m upwards sedimer oxygenized, progressively bioturbated and tl dish colour becomes more defined (OF1 of unit).

GEOCHEMICAL DATA

X-ray fluorescence, neutron activation, indu coupled plasma and atomic absorption spec

FIGURE 4 - Pale Vallone stratigraphic section (PLV). Lithology and abbreviations as Figure 2. *Coupe stratigraphique de Pale Vallone (PLV). Lithologie et abréviations, voir Figure 2.*



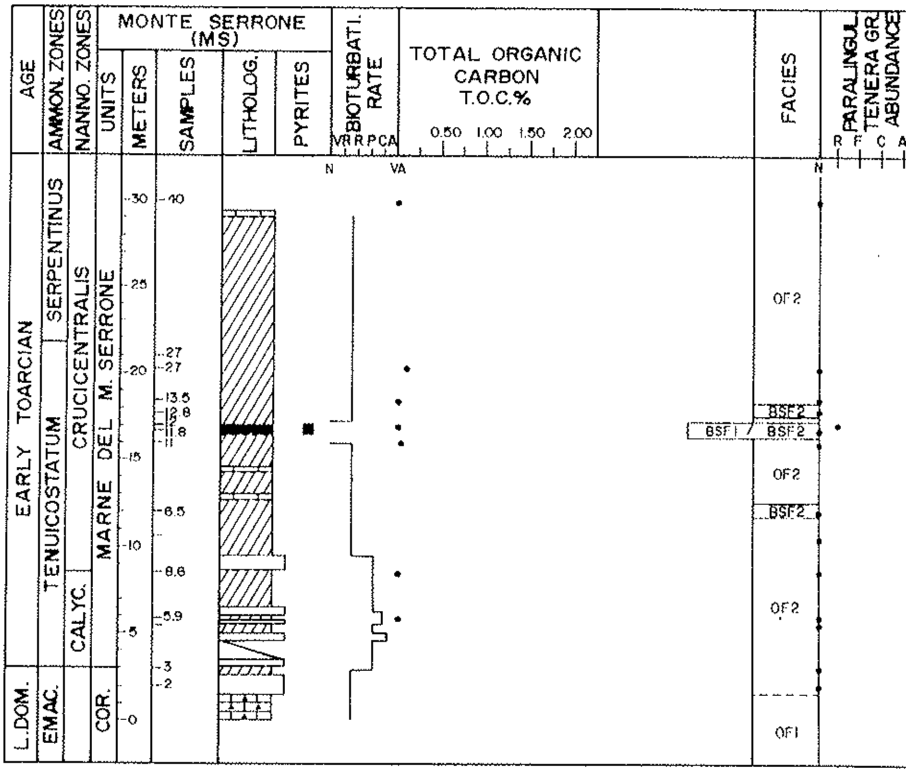


FIGURE 5 - Monte Serrone stratigraphic section (MS). Lithology and abbreviations as Figure 2. *Coupe stratigraphique de Monte Serrone (MS). Lithologie et abréviations, voir Figure 2.*

try techniques were used for the geochemical studies. Table 1 summarises the most significant results obtained in the studied sections, and includes a border indicating samples with geochemical anomalies by which they can be classified as BSF1 or BSF2 facies. An asterisk indicates layers corresponding geochemically to maximum anoxia conditions.

MINERALOGY, GEOCHEMISTRY AND MAXIMUM OXYGEN-POOR CONDITIONS

The whole mineralogy of the BSF1 and BSF2 facies consists of calcite, feldspars, quartz and clay minerals; gypsum, dolomite, celestite and barite wer detected exceptionally in some sections. The cla minerals found were illite, smectites and kaolinit In percentage terms the illite contents vary fro 70%-76% in the VD sequence, 52%-69% in CO, 65% 90% in PO, 80%-90% in PLV and 65%-75% in M Smectite proportions vary from 17%-25% in V 26%-46% in CO, 10%-30% in PO, 0%-10% in PL and 20%-30% in MS. Kaolinite, which is not alway present, reaches a maximum of 10% in PLV, with most frequent value of 5%. To summarize, the BSF and BSF2 facies are characterized by an illite-smec tite-quartz association as predominant mineral with lower contents of feldspars, kaolinite and ca

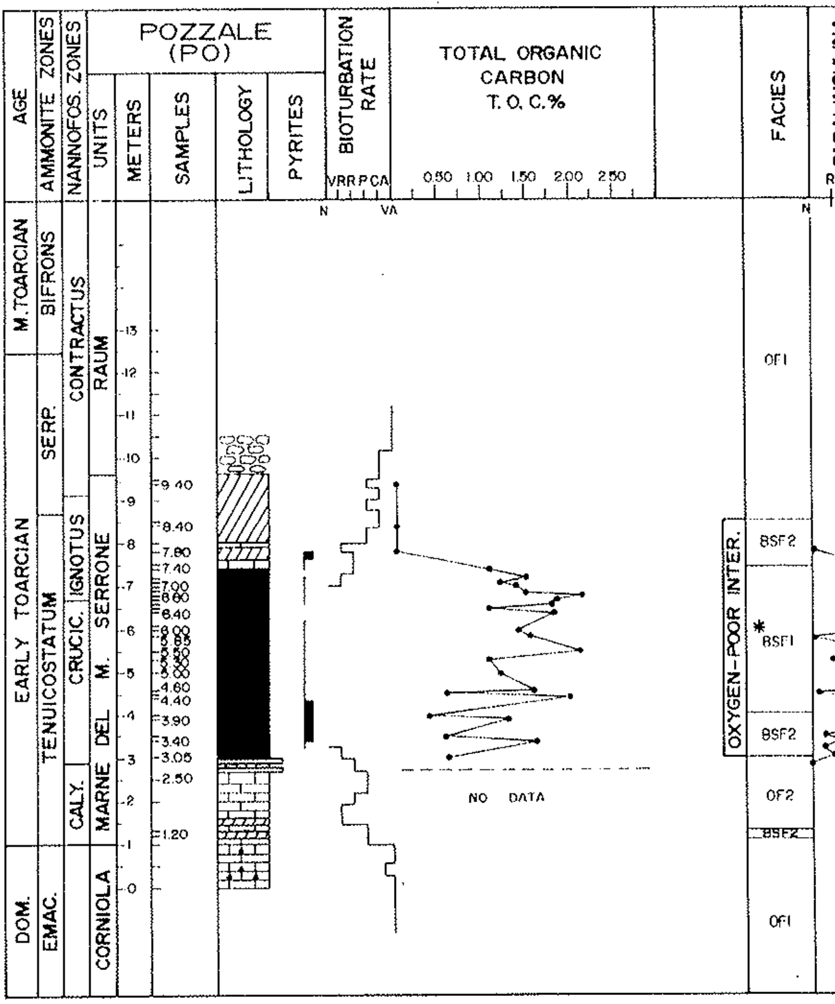


FIGURE 6 - Pozzale stratigraphic section (PO). Lithology and abbreviations as Figure 2. Asterisk indicates level with maximum anoxic conditions. *Coupe stratigraphique de Pozzale (PO). Lithologie et abréviations voir Figure 2. L'astérisque indique le niveau avec le maximum de conditions anoxiques.*

cite. This mineral association coincides both quantitatively and qualitatively with that proposed by Weissert (1981) for Cretaceous black shale and similar facies in the region of the Western Tethys, deposited in rhythmic alternation with limestones, marls and silts. The lithological differences visible in the field between typical "black shale facies" (BSF1) and "black shale-like sediments" (BSF2) do not correspond to different mineralogical compositions. Similar conclusions were reached by Palomo (1987) and Ortega-Huertas *et al.* (1991) for Early Jurassic pelagic sediments in the Betic Cordilleras (S Spain).

The maximum oxygen-poor levels can also be distinguished mineralogically, as they are characterized by an important increase in smectite content (50%-60%) in comparison to the other BSF1 and BSF2 levels, where the proportions of this mineral are no higher than 35%, which agrees with the data of Ortega-Huertas *et al.* (1993). Another distinguishing feature of these black shale levels is the low $CaCO_3$ content. X-ray diffraction data and th percentages included in Table 1 show the contents to be as follows : 12% (VD-364.15 a 362.8 layers), 16% (CO-209.75 and PO-6.40 29% (PLV-8.80 layer). These proportions of are very different to those presented by th BSF1 levels, where the contents vary as follo (12%-27%), CO (21%-39%), PO (19%-35%).

The geochemical studies differentiate the tw types from other Early Toarcian sediments. because the black shale facies present im geochemical variations as they are mainly m of fine particles with a high adsorption c such as oxy-hydroxide, clays and organic m (Murdmaa *et al.* 1977). The horizons richest i nic material correspond to a reductive enviro in which the relation between the organic m and an enrichment in certain trace elements fically, those included in Table 1) has been established by several authors (e.g. Tardy Klinkhammer & Palmer 1991 ; Hatch & Le

SAMPLE	%			ppm													FACIES
	SiO_2	CaO	Fe_2O_3	Ba	V	Cr	Ni	Co	Cu	Zn	As	Sb	Pb	U	REE		
VD-194	25.80	30.80	3.47	137	47	35	26	6	16	47	9	0.4	7	1.1	79.98		BSF2?
VD-203.3	30.10	27.00	3.19	162	76	46	19	7	16	37	<2	0.4	4	1	91.24		BSF2?
VD-361.8	54.20	5.37	5.75	314	112	74	54	19	56	59	10	1.4	13	2.3	133.8		BFS1
VD-362.8*	51.10	6.83	5.11	752	140	83	53	18	47	92	11	1.7	8	2.5	146.9		BSF1
VD-364.15*	48.50	6.83	5.11	989	160	85	44	19	46	69	12	1.8	8	2.5	140.58		BSF1
VD-368.50	41.70	14.90	5.10	166	100	68	49	19	46	71	11	1.3	4	1.8	167.95		BSF1
VD-371	29.10	29.10	2.98	157	76	42	22	10	22	37	4	0.8	2	1.1	103.45		BSF2
VD-375.8	39.20	19.50	3.81	69	66	58	40	14	32	32	10	0.6	8	1.9	119.78		BSF2
VD-380.5	25.40	33.50	2.39	103	46	53	33	7	24	125	11	0.7	8	1.4	62.67		BSF2
VD-382	24.90	34.80	2.07	119	43	29	24	7	21	37	10	0.5	<2	1.4	64.67		BSF2
VD-384	17.30	40.50	1.85	42	32	21	22	6	14	23	11	0.3	<2	0.7	43.93		BSF2/OF2
VD-391	20.00	37.00	2.09	85	38	30	23	7	23	32	10	0.3	<2	1.2	58.96		BSF2
CO-227.20	14.00	42.60	1.87	114	26	20	17	6	11	18	3	0.3	2	1.3	49.64		OF2
CO-221.20	18.40	38.40	1.92	64	25	24	18	5	15	30	2	0.3	6	1.0	55.01		BSF2?
CO-216.10	37.70	20.70	1.87	194	62	49	35	13	21	41	3	0.4	9	1.6	97.61		BSF1
CO-213.70	44.40	13.70	5.61	819	85	59	67	18	37	63	9	1.0	9	1.8	117.36		BSF1
CO-209.75*	49.90	9.25	5.10	390	115	60	47	15	53	74	11	1.3	11	2.8	123.09		BSF1
CO-204.20*	46.90	11.80	5.15	171	107	66	67	19	50	106	10	1.3	14	2.1	125.48		BSF1
CO-200	37.60	21.80	3.44	64	68	50	33	11	27	46	4	0.5	8	2.0	125.70		BSF1
PLV-9.50	25.70	31.40	2.59	153	72	51	43	21	18	130	6	1	4	1	101.54		BSF2
PLV-8.80*	40.10	16.70	4.88	114	96	75	83	50	25	64	7	1.3	16	1.1	144.24		BSF1
PO-8.40	32.00	25.80	2.63	109	68	41	39	13	28	46	<2	0.3	5	1.2	88.24		BSF2
PO-7.40	42.30	14.30	4.33	145	140	76	49	18	41	88	11	1.5	6	1.9	160.85		BSF1
PO-7	46.40	10.80	4.35	194	150	79	40	15	45	72	14	2	10	2.6	166.87		BSF1
PO-6.40*	49.00	9.05	5.13	314	113	67	52	13	47	82	9	1.4	9	2	131.01		BSF1
PO-4	36.60	19.40	3.33	450	100	60	29	14	37	69	5	0.7	2	1.6	127.33		BSF1
PO-1.20	34.40	21.30	4.74	173	67	52	77	15	28	89	<2	0.8	8	1.4	82.94		BSF2

[dotted box] Samples with geochemical anomalies.

* level with maximum anoxic conditions.
BSF1, BSF2 and OF2: see text.

TABLE 1 - Selected chemical analyses of the whole samples. *Analyses géochimiques sélectionnées pour l'ensemble des échantillons.*

1992). In particular, the BSF1 and BSF2 facies are characterized by an important positive geochemical anomaly in certain trace elements, such as Ba, V, Cr, Ni, Co, Cu, Zn, As, Sb, Pb, U and rare-earth elements (REE) (Table 1). Similarly, the percentages of SiO_2 and Fe_2O_3 are quite different to those in the oxygenized Toarcian sediments (OF2).

Detailed study of the geochemical contents (Tabl also permits differentiation of the BSF1 and BS facies separately and, therefore, geochemical di rences can be established between them which co plement the macroscopic criteria in the field. Th the samples with a lower CaO content, higher S and Fe_2O_3 contents, and the highest trace elem values (Table 1) correspond to the BSF1 facies. T levels presenting a less intense geochemical anomaly in trace elements correspond to the BSF2 facies (Table 1). In the broad anoxic layer (Table 1 and Figs. 2-6), the maximum anoxic conditions invariably correspond to BSF1 layers (see samples marked by asterisks in Table 1).

The relative richness in MgO is often taken as characteristic of black shale facies. In the case studied here, the BSF1 facies present mean values ranging from 2.10% to 2.34%, with the exception of the PLV sequence, where the content of the BSF1 level is 2.80%. This facies is clearly richer in MgO than the BSF2 facies, whose mean values range from 1.30% to 2.07%, which also indicates the more anoxic nature of the BSF1 facies. In fact, as these percentages are similar to those detected by Brosse (1982), the maximum values coincide with the most anoxic levels in all the sequences (VD-362.8 = 2.11%, CO-209.75 = 2.10%, PO-6.40 = 2.40%, PLV = 2.80%).

The Monte Serrone section is a case apart, as some of its levels can be geochemically characterized as similar to BSF2 facies. Specifically, the samples in question are MS-6.50, MS-12.80 and MS-43, belonging to the Early Toarcian.

The geochemical results obtained in these Toarcian black shale facies are very similar to those of Gavshin (1991) for Jurassic black shales and the geochemical anomalies shown in Table 1 present a trend similar to that of the Cretaceous black shale facies studied by other authors (Debrabant *et al.* 1979 ; Chamley *et al.* 1979 ; Brosse 1982). Likewise, the studies by Turekian & Wedepohl (1961) and Lyons & Gaudette (1979), in which a connection is established between trace elements and clayey facies, coincide with our results.

Finally, we should point out that the absence of important diagenetic effects is common to all the sections. This is confirmed by the abundance of smectite, which X-ray diffraction shows to contain illite layers in all cases. The illite proportions are lower than 15%, as quantified by the methods of Reynolds & Hower (1970) and Srodon (1984), i.e. it is R=0, following the terminology of Reynolds (1980).

DISCUSSION

PALAEOENVIRONMENTAL INFERENCES

Authors that have studied Jurassic sedimentation in the Mediterranean domain (García Hernández *et al.* 1980 ; Vera 1981 ; Jenkyns & Clayton 1986 ; Palomo 1987 ; Ortega-Huertas *et al.* 1991, 1993 ; Hallam 1988 ; Baudin *et al.* 1990a ; Baudin *et al.* 1990b) agree that the Early Toarcian was a period of important transgression, characterized by the input of a marly-argillaceous deposition, as i
UMB area, where the marly-argillaceous sedi
abruptly replace the predominant calcareous
mentation typical of the Domerian (Farinacci
1981 ; Bartolini *et al.* 1992 ; Baudin *et al.* 19
Monaco *et al.* 1994 ; Bucefalo-Palliani &
1993). These facies were deposited in a clearly
gic environment and are similar to those
Betic Cordilleras (SE Spain), given by rhy
alternations of marls and marly limestones (P
1987 ; Ortega-Huertas *et al.* 1991 ; Palomo
1994).

Reductive conditions of different intensity, to
the BSF1 and BSF2 facies are related, cou
referred to different subsidence conditions le
to the individualization of subenvironments
basin (troughs and swells). The Early Toarcia
mineral association in the VD, CO, MS and P
tions consists of illite-smectite-(kaolinite) (F
and is characteristic of a pelagic environmen
low influence from emerged reliefs. On the
hand, the BSF1 and BSF2 facies in the PLV s
must have been deposited under the influe
nearby emerged areas (perhaps islands), as s
by the greater abundance of kaolinite and the
derable decrease in smectite (Fig. 7). The
values of the Ce/Ce^* ratio (0.80-1, Fig. 7) (Co
responds to the concentration obtained by ex
lation between La and Nd, as described by Co
& Hoffert 1977), which is a parameter indica
the degree of detrital influence in a basin (Co
& Hoffert 1977), indicate considerable de
influence in all the studied sequences. These c
sions agree with the high values (0.65-0.90) f
detrital index (D = Al/Al+Fe+Mn, Boström
1969) found by Ortega-Huertas *et al.* (1993
Monaco *et al.* (1994) in some of these sequence
also with the high concentration of REE, pa
larly in the BSF1 facies (Table 1). Similar val
the D parameter (0.65-0.81) were foun
Cretaceous black shale facies by Brosse (1982
detrital influence is important as it may hav
sed some resedimented layers. In this sens
TiO_2 values (0.42%-0.86%) are in accordance
those indicated for the D parameter and the C
ratio, and are also similar to those given by V
Tourtelot (1970), Chamley et al. (1979) and I
(1982) for black shale facies. On the other ha
oceanic influence was detected in the sequenc
died here, as indicated by the low MnO co
(0.05%-0.19%).

Several authors (e.g. Ronov *et al.* 1967 ; Cul
al. 1975) established that the La/Lu ratio no
zed to chondrites presents values of 21.8, 14
9.4 as respectively characteristic of sediments
sited in continental, nearshore marine and p
environments. In the sections studied her
values obtained correspond to sediments dep

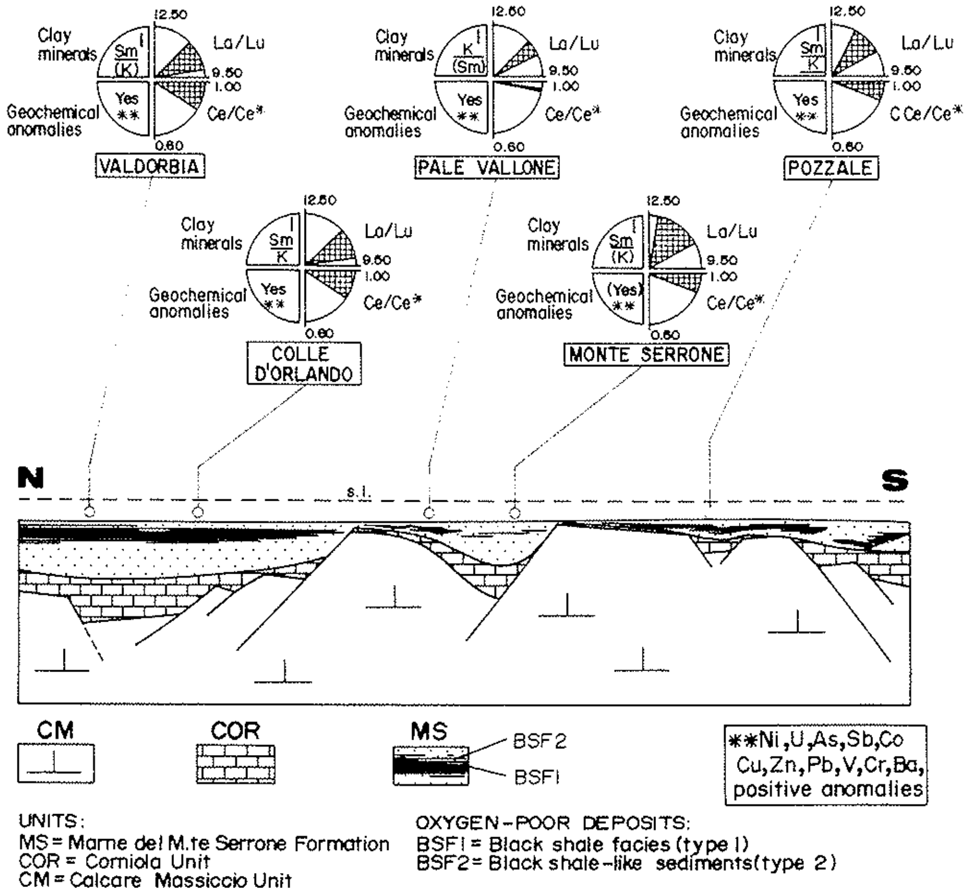


FIGURE 7 - Mineralogical and geochemical data and schematic palaeoenvironmental interpretation of the oxygen-poor deposits da as Tenuicostatum Zone (Early Toarcian) (not in scale). Clay minerals : I=illite ; Sm=smectites ; K=kaolinite. *Données minéralogique géochimiques et interprétation des dépôts pauvres en oxygène datés de la Zone à Tenuicostatum (Toarcien inférieur).*

in a clearly pelagic environment, although some levels present values more representative of environments intermediate between pelagic and near-shore marine characteristics. This geochemical parameter shows that there are no differences between the BSF1 and BSF2 facies as regards their pelagic conditions. Thus, the variation ranges of the La/Lu ratio are similar in all the studied sections : VD (BSF1 : 9.90-11 ; BSF2 : 9.70-11.20), CO (BSF1: 10.45-11.96; BSF2: not present), PO (BSF1: 10.52-11.51 ; BSF2 : 9.83-10.97), PLV (BSF1 and BSF2 : 10.97). Consequently, the geochemical differences between both facies are due to their different degrees of anoxia. To be more specific, we can say that the levels with maximum oxygen-poor conditions present the lowest values of the La/Lu ratio (VD = 9.90, CO = 10.45, PO = 10.67, PLV = 10.97).

Together with the greater intensity of the geochemical anomaly (Table 1) and the greater abundance of smectites in these levels, this suggests that we should interpret these levels as having been depo ted in more pelagic and perhaps even deeper ma ne conditions. According to this criterion, the de sitional conditions of the most oxygen-poor le evolved towards less pelagic and/or shallower con tions as follows: VD-CO-PO-PLV. Since even t most anoxic levels contain calcite in the proportic indicated above (see also the CaO values in Ta 1), we can say that they were deposited above t calcite compensation depth (CCD).

The BSF1 deposits are generally preceded by BSI which indicates that the anoxic conditions beca gradually established in the depositional bas Similarly, after the anoxic maximum, the n conditions in which oxygenized sediments we deposited also became established gradually. Th features can be clearly observed in the Valdor and Pozzale sections (Figs. 2, 6), where the BS facies correspond to levels VD-368.50 to VD-36 and PO-4 to PO-7.40. In the case of the Co d'Orlando section, the samples taken correspond

BSF1 facies (CO-200 to CO-216.10), although level CO-221.20 presents geochemical characteristics intermediate between the BSF2 facies and the overlying, Early Toarcian oxygenized sediments (OF2).

According to the hypothesis of Hatch & Leventhal (1992), the V/(V+Ni) ratio (0.63-0.79) indicates that the BSF1 facies were deposited in a less strongly stratified water column, whereas the low V/(V+Ni) values in the BSF2 facies (0.46-0.62) suggest that these were deposited in a weakly stratified, primarily dysoxic water column.

On the basis of geochemical analyses both BSF1 and BSF2 represent poorly-oxygenized sediments which are differentiated by different degrees of anoxic intensity. Therefore, sediments can also be attributed to BSF2 that do not have features characteristic of black shales, but which are grey-green or yellowish in color, not completely laminated, slightly bioturbated, with a low TOC value and microfaunal assemblage D (*Eoguttulina, Prodentalina*, flat vaginulids and more or less abundant *Paralingulina* gr. *tenera*). It has thus been possible to recognize in the field poorly-oxygenized sediments that were not identified. This in turn has led to the extension in both time and space of the development of environments characterised by oxygen deficiency even for a short interval of time. In fact, in the Pale Vallone and Monte Serrone sections and in the lower part of MS formation in the VD and PO sections signals of poor oxygenation were not recorded before the geochemical analyses were carried out.

Consequently a multidisciplinary approach to the study of more or less organic-rich levels in the Early Toarcian can be useful to detect subenvironments with different degrees of anoxic intensity in the UMB. Information can be obtained on both the causes of deposition and preservation of a variable amount of organic matter and on its post-depositional oxydation.

The presence of BSF2 and very rare BSF1 facies in the MS section should be interpreted as a consequence of a less restricted depositional environment (Bartolini et al., 1992). However, as in the other sections studied here, the depositional conditions of the BSF2 facies corresponded to an environment intermediate between pelagic and nearshore marine characteristics (La/Lu range = 9.80-11.17).

The recognition of two types of poorly-oxygenized sediments and the scarcity of benthic life leads us to consider that the poorly ventilated conditions on the sea-floor and the consequent biological crisis started as early as the lower part of the Tenuicostatum Zone and lasted till the upper part of this Zone. Only rare BSF2 levels have been found in the Serpentinus Zone, indicating the possible occurrence of scarce oxygenation episodes in the areas where the MS deposition persists. However, dif trends in deposition and accumulation of or matter, together with development of rest environments during the Tenuicostatum Zone been detected also considering TOC value microfaunal assemblages from other se (Bartolini *et al.* 1992 ; Nini et al. in press) (Fi

Presale, M. Bibico and F. Cerro sections hav been investigated by geochemical analyses an refore, the detailed logs are not shown. Mor detailed study of M. Bibico and F. Cerro sectio reported *in* Nini *et al.* (1995), and in Sto Baldanza (in prep.).

On the basis of the preservation of organic r preservation, the present state of research ha ched the following environmental distinctions
a) Depressed areas with long lasting black (Valdorbia, Colle d'Orlando, Pozzale and Cerro) or troughs : such areas may or ma contain calcareous detrital discharges ; rare levels appear in the lower part of the Ten tatum Zone below the *Lotharingius crucicen* FO. The maximum development of poorly-ox zed sediments occurs above the FO of *Lothar crucicentralis*, within the middle-upper part Tenuicostatum Zone. Parameters indicative o oxygen conditions and rich-organic sediment sition, show a trend that coincides in sectior CO and PO ; curves representative of these se show an acme of maximum anoxia in the uppe of the Tenuicostum Zone (Fig. 2, Fig. 3, Fig. 6
b) Depressed areas with discontinuous anc poorly-oxygenized sediments (Monte Se Section); here the MS formation is very thick characterized by rare, brief episodes of oxyge sedimentation above the *L. crucicentrali* (Bartolini *et al.* 1992) (Fig. 5).
c) Depressed areas with short lasting black (Monte Bibico, Nini *et al.* in press): these area black shales at the base of the Tenuicostatum while oxygen-rich sediments occur above the *cicentralis* FO. In each depressed area the ning of clay discharge coincides approximatel the Domerian/Toarcian boundary .
d) Swell areas : Presale (Monte Nerone are Pale Vallone. These correspond to areas repre by very condensed sections ; here BSF1 and display different TOC high values ; the h values are found in the Presale section (Bart *al.* 1992). Oxygen-poor deposits are found just the FO of *L. crucicentralis* in the Pale area, ar above it in the Presale section. In these are thickness of MS formation is less than 1 m, a lower boundary with the Corniola unit falls the lower part of the Tenuicostatum Zone. Th TOC values that occur in different suber ments such as Colle d'Orlando, Pozzale and F are unrelated to sea-floor depth.

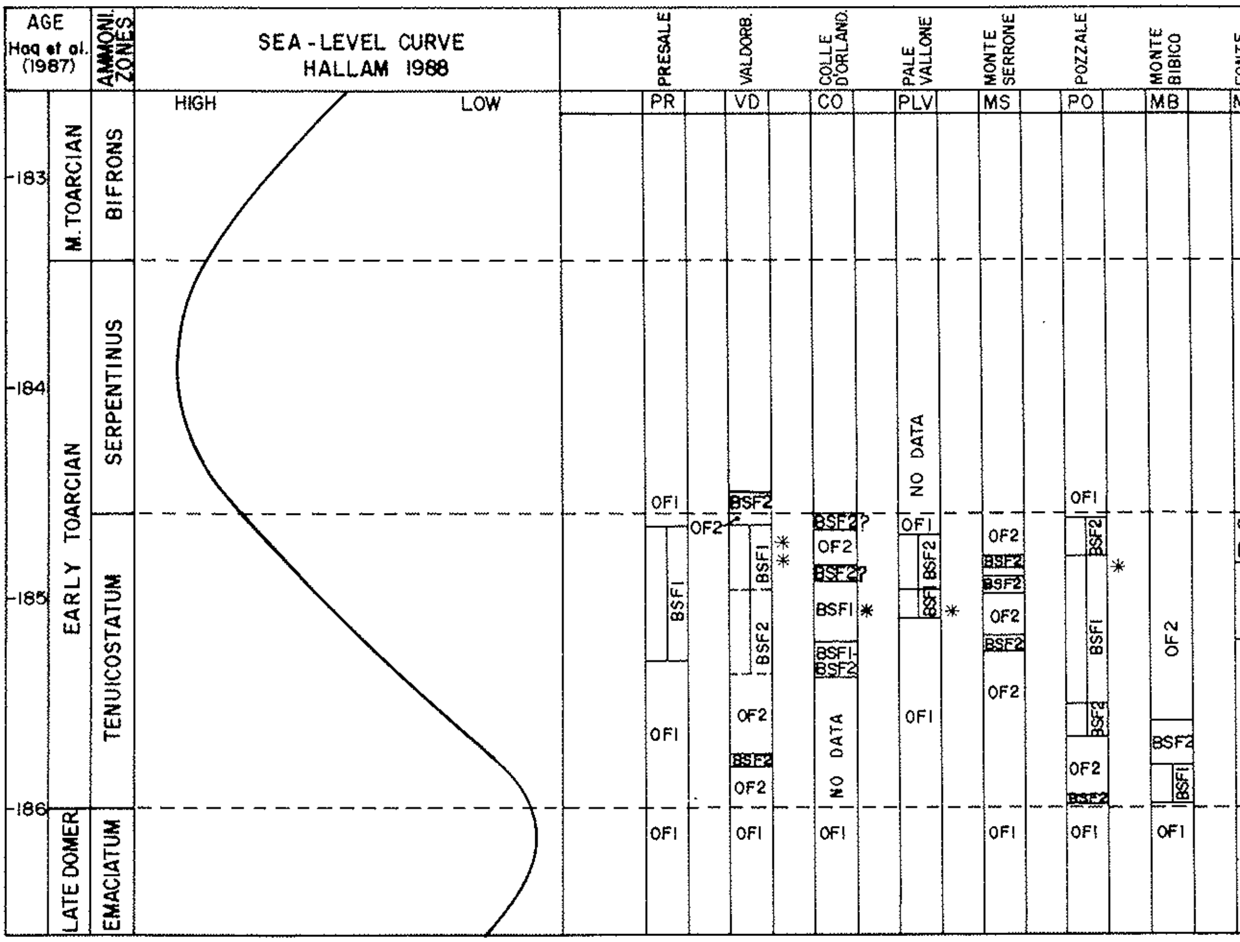


FIGURE 8 - Correlation of the oxygen-poor deposits to the sea-level curve (Hallam 1988). Asterisks indicate levels with maximum an conditions. *Corrélation entre les dépôts pauvres en oxygène et la courbe du niveau de la mer. Les astérisques indiquent les niveaux m mum de conditions anoxiques.*

Discussion on factors affecting the degree of anoxia and organic matter preservation in the different subenvironments as now defined must take into account the possibility of post-depositional oxidation or a thermal maturation effect on the organic matter. However, mineralogy reveals that the analyzed succession seems to lack diagenetic overprinting ; the occurrence of abundant *Paralingulina* gr. *tenera* and positive geochemical anomalies, related to the TOC value, show that organic matter was both accumulated and preserved here. The concurrence of the two parameters can not be verified when organic matter is not preserved (low TOC values).

The identification of different types of subenvironments shows that the evolution of anoxic conditions and organic matter preservation occurred differe ly in the UMB and has varied through time Bibico area). Parameters such as clay input planktonic productivity do not account for the d rentiation of these subenvironments during Early Toarcian. Clay sedimentation, necessary organic matter preservation, was in fact spread and not specifically localized, in the UMB (Orte Huertas *et al.* 1993) ; at the same time, the wi pread abundance of planktonic organisms (radi rians and nannoplankton, Bartolini *et al.* 19 through the entire Tenuicostatum Zone, indic an equally high primary productivity of sur water. Factors that must instead be taken account are : **a)** persistence in some areas of tricted environments with sea-floor stagnant w that allowed maximum anoxia development in the middle-upper part of the Tenuicostatum zone ; **b)** oxygenation of the sea bottom in other less restricted areas (M. Serrone) ; **c)** at M. Bibico anoxic conditions began to develop at the base of the Tenuicostatum Zone, and the environment only became oxygenized later, when other areas display maximum anoxia (Fig. 8).

Circulation patterns were therefore slightly different in the various subenvironments, thus causing differentiated distribution of poorly-oxygenized sediments. Anoxic conditions seem independent from sea-floor depth. Restricted conditions and organic-rich sediments might occur in any situation, and their vertical distribution is probably affected by the physiography of the UMB, inherited from an earlier phase of extensional tectonics and modified by a synsedimentary one. The existence of physical barriers probably determined differentiated current circulation and differentiated oxygen supply reaching the various subenvironments. These last factors can be of fundamental importance in controlling anoxic facies development, since primary productivity is not locally affected because of the pelagic nature of the UMB.

RELATIONSHIPS WITH SEA-LEVEL FLUCTUATIONS

The Early Toarcian global transgression modified the sedimentary regime of the Tethyan realm into differentiated types of environment.

The sea-level rise determined an increase both in clay input and in primary productivity, thereby establishing conditions favorable for development of anoxia and preservation of organic matter (Bassoullet & Baudin 1994). This global trangression and more or less extended anoxia are associated with a biological crisis and faunal changes (Hallam 1988 ; Bassoullet & Baudin 1994). In the UMB this biological crisis is recorded by scarcity of ammonites, reduced sizes and low generic and specific diversity of benthic microfauna. Such parameters occur within the Tenuicostatum Zone even in oxygenized subenvironments, while microfauna abundance, size and species diversity are observed to increase from the base of the Serpentinus Zone on.

Maximum anoxia occurs in the middle-upper part of the Tenuicostatum Zone, above the FO of *L. crucicenralis*, when suitable organic matter preservation conditions occurred in the different UMB subenvironments. The development of anoxic conditions has also been observed in structural highs or swells, when clay sedimentation reached the most elevated areas of the UMB.

In this paper, clayey sedimentation including poorly-oxygenized levels is related to the Hallam curve (1988), corresponding to the Early Toarcian level rise. The anoxia maximum, identified multidisciplinary approach for the different su sions reported here, falls slightly above the i tion point of the eustatic curve (Fig. 8). Recen dies on the composition and preservation of or matter in the Pozzale section (Bucefalo-Pallia Cirilli 1993) distinguished differently oxyge organic intervals within the Tenuicostatum related to the Early Toarcian eustatic rise. Th oxygenated interval (anaerobic condition) is re to the maximum flooding event and the over intervals, showing conditions ranging from dys bic to aerobic, have been assigned to the high phase. Consequently, the anoxia maximum rec zed here coincides with the maximum flo event-high stand phase inferred by Buc Palliani & Cirilli (1993).

However, interferences with regional tectonics ve during the Early Jurassic probably led to ir lar expansion of the anoxia maximum in the rent subenvironments developed after floodi an Early Jurassic platform. The depth of these ronments was such that eustatic variations have affected sea-floor sedimentation.

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REFERENCES

BALDANZA A. & MATTIOLI E. 1992 - Biozonazione nofossili calcarei del Giurassico Inferiore-Medic Provincia Mediterranea (Dominio Tetideo) : rev ed ampliamento. *Paleopelagos*, **2** : 69-78.

BARTOLINI A., BALDANZA A. & GALDENZI S. (in p Il Giurassico dell'area di Pale (Appennino U Marchigiano, Italia Centrale) : biostratigrafia, lit tigrafia e ricostruzione paleoambientale. *Memo Scienze Geologiche, Padova.*

BARTOLINI A., NOCCHI M., BALDANZA A.. & PAR 1992 - Benthic life during the early Toarcian event in the southwestern Tethyan Umbria-M basin, Central Italy. *Studies in benthic foramin Benthos'90, Sendai, Japan, Tokai University* 323-338.

BAUDIN F., HERBIN J.-P., VANDENBROUCKE M. 1 Mapping and geochemical characterization Toarcian organic matter in the Mediterranean and Middle East., **16**, (4-6) : 677-687.

BAUDIN F., HERBIN J.-P., BASSOULLET J.-P., DERC J., LACHKAR G., MANIVIT H. & RENARD M. 1 Distribution of organic matter during the Toarc the Mediterranean Tethys and Middle East. *In* HUC A. Y. (eds.) : Deposition of Organic facies. *AAPG, Studies in Geology, Tulsa* : 73-91.

BASSOULLET J. P. & BAUDIN F. 1994 - Le Toarcien inférieur : une période de crise dans les bassins et les plates-formes carbonatées de l'Europe du Nord-Ouest et de la Téthys. *In* E. CARIOU & P. HANTZPERGUE (eds.) : 3ème Symposium International de Stratigraphie du Jurassique. *Geobios,* **M.S. 17** : 645-654.

BENEDETTI L., PARISI G., BALDANZA A., MATTIOLI E., CRESTA S. & VENTURI F. in press - Toarcian stratigraphy in the Colle d'Orlando section (Umbria, Central Italy). *Bollettino della Società Paleontologica Italiana*, (1996).

BOSTRÖM K., PETERSON N.M., JOENSUU O. & FISHER D. 1969 - The origin of the aluminum-poor ferromanganoan sediments in areas of hight heat flow in the East Pacific Rise. *Marine Geology*, **7** : 427-447.

BROSSE E. 1982 - Contribution à la minéralogie et à la géochimie des sédiments pélagiques profonds. Ph. thesis, Université Paris, France.

BUCEFALO-PALLIANI R. & CIRILLI S. 1993 - Palaeoenvironmental influences on the composition and preservation of the organic matter : preliminary results from the Pozzale section (Early Toarcian, Central Apennines, Italy). *Paleopelagos*, **3** : 129-144.

CHAMLEY H., DEBRABANT P., FOULON J., GIROUD D'ARGOUD G., LATOUCHE C., MAILLET N., MAILLOT H. & SOMMER F. 1979 - Mineralogy and geochemistry of Cretaceous and Cenozoic Atlantic sediments off the Iberian Peninsula (Site 398, DSDP Leg 47 B). *In* Sibuet J.C. & Ryan W.B.F. (eds) : *Initial Reprint Deep Sea Drilling Project*, **47,** B : 429-449.

CHANNELL J.E.T., D'ARGENIO B. & HORVATH F. 1979 - Adria, the African Promotory, in Mesozoic Mediterranean paleogeography. *Earth Science Review*, **15** : 213-292.

CLAPS M., ERBA E., MASETTI D. & MELCHIORRI F. 1995 - Milaukovitch-type cycles recorded in Toarcian black shales from the Belluno Trough (Southern Alps, Italy). *Memorie di Scienze Geologiche, Padova*, **47** : 179-188.

COLACICCHI R., NOCCHI M., PARISI G., MONACO P., BALDANZA A., CRESTA S. & PALLINI G. 1988 - Paleoenvironmental analysis from Lias to Malm (Corniola to Maiolica Formations) in the Umbria-Marche basin, Central Italy (preliminary report). *In* ROCHA R.B. &. SOARES A.F. (eds.) : *2nd International Symposium on Jurassic Stratigraphy*, Lisboa, Sept. 1987 : 717-728

COURTOIS CH. & HOFFERT M. 1977 - Distribution des Terres Rares dans les sédiments superficiels du Pacifique sud-est. *Bulletin de la Société géologique de France*, **19** : 1245-1251.

CRESTA S., CECCA F., SANTANTONIO M., PALLINI G., BRÖNNIMANN P., BALDANZA A., COLACICCHI R., MONACO P., NOCCHI M., PARISI G., & VENTURI F. 1988 - Stratigraphic correlations in the Jurassic of the Umbria-Marche Apennines (Central Italy). *In* ROCHA R.B. &. SOARES A.F. (eds.) : *2nd International Symposium on Jurassic Stratigraphy,* Lisboa, Sept. 1987 : 729-744.

CRESTA S., MONECHI S. & PARISI G. 1989 - Stratigra del Mesozoico e Cenozoico nell'area Umbro-Marc giana (itinerari geologici sull'Appennino Umb Marchigiano (Italia). *Memorie Descrittive Ca Geologica d'Italia, Servizio Geologico d'Italia*, **39**: 18

CULLERS RL., CHAUDHURI S., ARNOLD B., LEE M WOLF CW. 1975 - Rare earth distribution in clay mi rals and in the clay-sized fraction of the lower Perm Havensville and Eskridge shales of Kansas a Oklahoma. *Geochimica Cosmochimica Acta*, **39** : 16 1703.

DEBRABANT P., CHAMLEY H., FOULON J. & MAILLOT 1979 - Mineralogy and geochemistry of Up Cretaceous and Cenozoic sediments from North Bis Bay and Rockall Plateau (Eastern North Atlant DSDP Leg 48. *In* Montadert L. & Roberts DG (eds *Initial Reprints Deep Sea Drilling Project*, **48** : 703-7

FARINACCI A., MARIOTTI N., NICOSIA U., PALLINI G SCHIAVINOTTO F. 1981 - Jurassic sediments in Umbro-Marche Apennines : an alternative model. A. Farinacci (ed) : *Rosso Ammonitico Symposi Proceedings*. Ed. Tecnoscienza, Roma : 335-398.

GARCÍA HERNÁNDEZ M., LÓPEZ GARRIDO A.C., RIV P., SANZ DE GALDEANO C. & VERA J.A. 198 Mesozoic palaeogeographic evolution of the Exter Zones of the Betic Cordillera. *Geologie in Mijnbo* **59**: 155-168.

GAVSHIN V.M. 1991- Sea water as a source of metals black shales. *Proceeding of the Society for Geol Applied to Mineral Deposits Meeting : source, transp and deposition of metals*. Nancy : 519-522.

HALLAM A. 1988 - A reevaluation of Jurassic eustasy the light of new data and the revised Exxon curve. Sea-level changes - An integrated Approach. *Societ Economic and Paleontologists and Mineralogi Special Publication,* **42** : 261-273.

HAQ B.U., HARDENBOL J. & VAIL P.R. 1987 - Chronol of fluctuating sea levels since the Triassic. *Scie* **235**: 1156-1167.

HATCH J.R. & LEVENTHAL J.S. 1991 - Relationship b ween inferred redox potential of the depositional en ronment and geochemistry of the Upper Penns vanian (Missourian) Stark Shale Member of Dennis Limestone, Wabaunsee County, Kansas, U.S *Chemical Geology*, **99** : 65-82.

JENKYNS H.C. 1988 - The early Toarcian (Juras anoxic event : stratigraphic, sedimentary and geoc mical evidence. *American Journal of Science*, **288** : 1 151.

JENKYNS H.C. & Clayton C. 1986 - Black shale and c bon isotope in pelagic sediments from the Tethy lower Jurassic. *Sedimentology,* **33** : 87-106.

KLINKHAMMER G.P. & PALMER M.R. 1992 - Uranium the oceans : Where it goes and why. *Geochimica Cosmochimica Acta*, **55** : 1799-1806.

LYONS B.W. & GAUDETTE H.E. 1979 - Sediment geoc mistry of Jeffreys Basin, Gulf of Maine : inferred tra port of trace metals. *Oceanology Acta*, **2/4** : 447-481

MATTIOLI E. 1993 - Quantitative analysis of calcare nannofossils in the Liassic portion of Pozzale sect (Martani mts., Central Italy) : preliminary repo *Paleopelagos,* **3** : 261-278.

MONACO P. 1992 - Hummocky cross-stratified deposits and turbidites in some sequences of the Umbria-Marche area (central Italy) during the Toarcian. *Sedimentary Geology*, **77** : 123-142.

MONACO P. 1995 - Relationships between trace-fossil communities and substrate characteristics in some Jurassic pelagic deposits in the Umbria-Marche basin, central Italy. *In* M. GAYET & B. COURTINAT (eds) : First European Palaeontological Congress, Lyon 1993. *Geobios,* **M.S. 18** : 299-311.

MONACO P., NOCCHI M., ORTEGA-HUERTAS M., PALOMO I., MARTINEZ F. & CHIAVINI G. 1994 - Depositional trends in the Valdorbia section (Central Italy) during the Early Jurassic, as revealed by micropaleontology, sedimentology and geochemistry. *Eclogae geologicae Helvetiae*, **87** (1) : 157-223.

MURDMAA J.O., DEMIDENKO Y.L., KURNOSOV V.B. & FAUSTOV S.S. 1977 - Composition and rates of accumulation of clayey sediments in the Philippine Sea. *Oceanology,* **17** : 318-321.

NINI C., BALDANZA A. & NOCCHI M. 1995 - Late Domerian-Toarcian calcareous nannofossils biostratigraphy, benthic foraminiferal assemblages and their paleoenvironmental implications. *Revue de Paléobiologie*, (1994), **14** (2) : 271-319.

NOCCHI M. 1992 - Associazioni a foraminiferi bentonici del Bacino Umbro-Marchigiano (Appennino centrale) durante il Lias. *Paleopelagos,* **2** : 37-53.

ORTEGA-HUERTAS M., PALOMO I., MORESI M. & ODDONE M. 1991 - A mineralogical and geochemical approach to establishing a sedimentary model in a passive continental margin (Subbetic Zone, Betic Cordilleras, SE Spain). *Clay Minerals*, **26** : 389-407.

ORTEGA-HUERTAS M., MONACO P. & PALOMO I. 1993 - First data on clay mineral assemblages and geochemical characteristics of Toarcian sedimentation in the Umbria-Marche basin (central Italy). *Clay Minerals,* **28,** 297-310.

PALOMO I. 1987 - Mineralogía y geoquímica de sedimentos pelágicos del Jurásico inferior de las Cordilleras Béticas (SE España). Ph thesis, Univ. Granada, Spai: 344 p.

PALOMO I., ORTEGA-HUERTAS M., MONACO P., MARTÍNEZ RUÍZ F., NOCCHI M. & PARISI G. 1994 - Geochemical characteristics of Toarcian sedimentation in Alpine geological domains. *Mineralogical Magazine,* **58A** : 684-685.

PIALLI G. P. 1969a - Un episodio marnoso del Lias superiore nel bacino umbro-marchigiano : le Marne del M. Serrone. *Bollettino Società Naturalistica, Napoli,* **78** : 3-23.

PIALLI G. P. 1969b - Geologia delle Formazioni Giuresi dei Monti ad est di Foligno (Appennino Umbro). *Geologica Romana,* **9** : 1-30.

REALE V., BALDANZA A., MONECHI S. & MATTIOLI E. 1991 - Calcareous nannofossil biostratigraphic events from the Early-Middle Jurassic sequences of the Umbria-Marche area (central Italy). *Memorie Scienze Geologiche Università di Padova*, **43** : 41-75.

REYNOLDS R.C. 1980 - Interstratified clay minera BRINDLEY G.W. & BROWN G. (eds.) : *Crystal s tures of clay minerals and their X-ray identific* Mineralogy Society, London : 249-303.

REYNOLDS R.C. & HOWER J. 1970 - The nature of layering in mixed-layer illite-montmorillonites *Clays & Clay Minerals*, **18** : 25-36.

RONOV A.B., BALASHOV Y.A. & MIGDISOV A.A. 1 Geochemistry of the rare earths in the sedime cycle. *Geochemistry International*, **4** : 1-17.

SAVRDA C.E. & BOTTJER D.J. 1987 - The exaerobic a new oxygen-deficient marine biofacies. *Nature* 6117 : 54-56.

SAVRDA C. E. & BOTTJER D. J. 1989 - Trace-fossil r for reconstructing oxygenation histories of an marine bottom waters : application to U Cretaceous Niobrara Formation, Colorado. *Pa geography, Palaeoclimatology, Palaeoecology*, **74** 74.

SRODON J. 1984 - X-ray powder diffraction identific of illitic materials. *Clays & Clay Minerals*, **32** 349.

TARDY Y. 1975 - Element partition ratios in some mentary environments. I. Statistical treatmen Studies on North-American black shales. *Sci Geological Bulletin*, **28,** 1 : 59-85.

TUREKIAN K.K. & WEDEPOHL K.H. 1961 - Distrib of the elements in some major units of the E crust. *Geological Society of America Bulletin*, 175-191.

VERA J.A. 1981 - Correlación entre las Cordi Béticas y otras Cordilleras Alpinas duran Mesozoico. PIGC *Real Academia of Ciencias Ex Físicas y Naturales, Madrid*, **2** : 125-160.

VINE J.D. & TOURTELOT E.B. 1970 - Geochemis black shales deposits. A summary report. *Eco Geology*, **65** : 253-272.

WEISSERT H. 1981 - The environment of deposit black shales in the Early Cretaceous: An on controversy. *Society of Economic and Paleontol and Mineralogists, Special Publication*, **32** : 54

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