TURONIAN-CONIACION OCEANIC RED BEDS IN THE RÍO FARDES SECTION, MIDDLE SUBBETIC, SOUTHERN SPAIN

西班牙南部 Subbetic 中带 Río Fardes 剖面 Turonian-Coniacian 大洋红层

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HU Xiu-mian, LILIAN Š, MASSIMO S. Turonian-Coniacian oceanic red beds in the Río Fardes section, Middle Subbetic, southern Spain. *Earth Science Frontiers*, 2005, 12(2):038-044

Abstract: The Río Fardes section NE of Granada, belongs to the deep basinal Middle Subbetic domain. This section is composed mainly of Cretaceous(hemi) pelagic sediments which appear together with turbidites and olistostromes together forming the Fardes Formation. Two types of red beds are present within the turbidite succession of the Fardes Formation. Nannofossil assemblages show that the age of the red beds is the uppermost part of Lower Turonian (Zone UC 7) to Middle-Upper Coniacian boundary (Zone UC10/?UC11). The red beds sequence consists of mm-thick reddish clays alternating with gray, variegated, locally black clays and calcareous clays. It is concluded that the newly discovered Turonian-Coniacian pelagic red clays were deposited in the deepest basin below the carbonate compensation depth(CCD), where turbiditic and debris flow sediments are diluted and strongly affect the background pelagic/hemipelagic facies. This results in the termination of sedimentation of the red clay facies.

Key words: oceanic red beds; Río Fardes section; Fardes Formation; Upper Cretaceous; Subbetic; southern Spain
CLC number: P588; P595 **Document code**: A **Article ID**: 1005-2321(2005)02-0038-07

摘 要: Río Fardes 剖面位于西班牙南部 Granada 东北,构造上属于深水环境的 Subbetic 中带。该剖面主要由白垩纪 Fardes 组第Ⅱ段和第Ⅲ段(半)远洋沉积构成,并出现浊流沉积和混杂沉积。本次研究在 Fardes 组浊流层序内首次发现两段红色沉积。钙质超微化石表明红层的时间从 Turonian 早期 (UC7 带)到 Coniacian 中期—晚期界线 (UC10/?UC11 带)。红层由 mm 级红色泥岩夹灰色、杂色、偶尔黑色泥岩和钙质泥岩组成。沉积学研究表明新发现的 Turonian-Coniacian 远洋红色泥岩沉积形成于 CCD 面之下深水盆地环境,浊流和碎屑流沉积强烈地影响着(半)远洋环境的背景泥岩相,并成为红色沉积结束的原因。

关键词: 大洋红层; Río Fardes 剖面; Fardes 组; 晚白垩世; Subbetic; 西班牙南部

0 Introduction

Cretaceous oceanic red beds (CORB) is recently becoming an new window into Cretaceous palaeoceanography and palaeoclimate[1], with the development of the ongoing IGCP Project 463 and Project 494.

收稿日期: 2004-10-20; **修回日期**: 2004-12-27
基金项目: 国家自然科学基金重点资助项目(40332020); 科学技术部重大基础研究前期专项资助项目(2001CCA01800); 联合国教育科学文化组织地球科学项目 IGCP 494/463
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In southern Spain, the CORB, locally so-called Capas Rojas (red beds in Spanish) Formation is extensively outcropped in the Betic Cordillera. There is not much data available from the CORB in southern Spain except the work by Vera and Molina[2]. The latter authors made an analysis of this Capas Rojas Formation including characteristics such as lithofacies, biofacies, age, thickness, vertical and lateral relationships, and concluded that the Capas Rojas red beds was deposited in a hemipelagic marine environment[2].

During the 2003 Spain-expedition, the Upper Cretaceous deep-water facies in the Río Fardes section was visited. Besides the post-Campanian hemipelagic Capas Rojas red limestones and marlstones, the Turonian-Coniacian red shales and marls were firstly found within the turbiditic sequences, which is stratigraphically underlying the Capas Rojas Formation. This paper will date those red beds within tubiditic sequences, and will examine its lithology, sedimentology and sedimentary environments.

1 Geological setting

In the Betic Cordillera, southern Spain, two great geological realms can be recognized: the External Zone and the Internal Zone. Between them the Campo de Gibraltar Complex crops out at the westernmost point (Fig. 1). The External Zone is made up of Triassic to Early Miocene rocks which were deposited along the Southern Iberian Palaeomargin. Two major tectonic and paleogeographical domains have been recognized in the External Zone: the Prebetic and Subbetic[3] (Fig. 1).

During Cretaceous the Prebetic formed a pericontinental carbonate platform bordering the southwest of the old Iberian continent, where shallow-water environments prevailed. Basinwards, between the Prebetic and Subbetic, there existed a smaller, individual, palaeogeographical domain, which has been called the Intermediate Domain (Fig. 1). In the innermost area of the basin was the Subbetic, where throughout the Cretaceous was a pelagic zone with mainly marly and marly-calcareous sedimentation, punctuated locally by calciturbidites[5]. The Subbetic Zone is further subdivided into three structural units, the External Subbetic (intra-basinal swell) to the North, the Median Subbetic (deepest basin) in the central part of the basin and the Internal Subbetic (basinal high) to the South[3] (Fig. 1).

In spite of the different facies and sediments related to each Subbetic Zone, four main formations can be differentiated in the Cretaceous. These are, from bottom to top[6]: (1) the Carretero Formation, consisting of limestones and marls rhythmite; (2) Fardes Formation, characterized by predominant marly constituents; (3) Capas Blancas Formation, composed of white marls and marly limestones; and (4) Capas Rojas Formation, consisting of interbedded reddish marls and marly limestones.

Our studies were mainly concerned with the Cretaceous Median Subbetic Zones, where the Río Fardes section outcropped. In the Median Subbetic, the Early Cretaceous Carretero Formation consists of limestones, marls and marly limestones with an average thickness about 200～300 m[7]. The

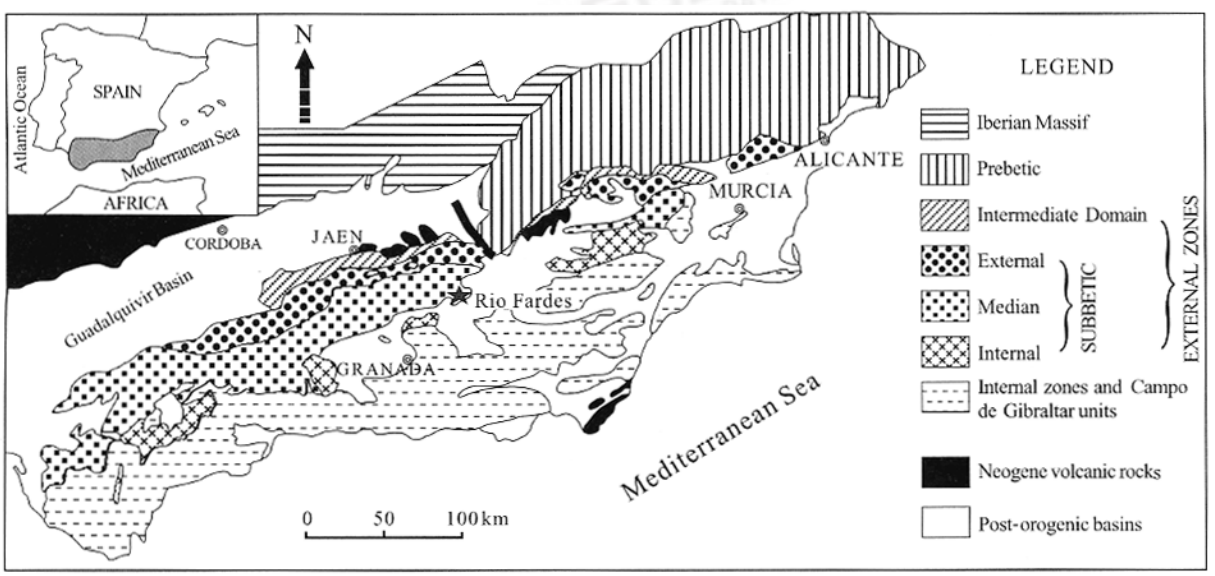

Fig. 1 Simplified geological map showing the distribution of units of the Betic Cordillera[4]

underlying Fardes Formation reaches a maximal thickness of 580 m and has been divided into three members, according to the relative proportion of detritic and pelagic materials[7]. Member I is mostly made up of green clays with sporadic turbidite insertions; Member Ⅱ is characterized by clastic lithologies predominating over the thin hemipelagic beds; Member Ⅲ is containing alternating layers of calcarenites, calcilutites and clay lithologies.

The Capas Biancas Formation is mostly absent in the Median Subbetic, and the Capas Rojas Formation directly overlies the Fardes and the Carretero Formations. The Capas Rojas Formation, characterized by its reddish color, is the most uniform and extensively outcrops in the External Zone of the Betic Cordillera[2], which spans from latest Cenomanian to Early Eocene[2,8]. It consists of rhythmically alternating micritic limestones, marly limestones and marls, pink to light reddish colour, locally intercalated with carbonate turbidites. Palaeoecological and sedimentological data led Vera and Molina[2] to suggest that deposition of the Capas Rojas occurred at continental margin in water depth between 200～1 000 m, similar to the Scaglia Rossa in Apennines. In the Median Subbetic, this formation is restricted to the Maastrichtian and has a thickness of 300～350 m.

2 Samples and method

The Río Fardes section is located along the road leading from Huélago to Villanueva de las Torres, NE Granada. Paleogeographically, this section belongs to the deep basinal Middle Subbetic domain (Fig. 1), and contains (hemi)pelagic sediments which appear together with turbidites and olistostromes[5],①. Thirty samples were collected along the section, especially near the two bands of the red beds within the Fardes Formation (see below).

Twenty four samples were analyzed for nannofossil study. Smear slides were prepared using standard method of decantation, samples were inspected under light microscope Nikon at 1 000 magnification. For biostratigraphic dating nannoplankton UC zones by Burnett[9] were applied.

3 Results

3.1 Lithostratigraphy

In the Río Fardes section, the Cretaceous sequences comprise of the Member Ⅱ and Ⅲ of the Fardes Formation (Fig. 2). Member Ⅱ consists of breccia and conglomerate layers, predominated over thin hemipelagic beds of dark green and red clays (Fig. 2). Member Ⅲ makes up of clear alternations of fine-grained turbidite levels, consisting of calcarenites, calcilutites and gray, purple, red clays (Fig. 2). Several dark-black clay horizons occur.

Two brands of red beds were found in the Fardes Formation (Fig. 2). The first one is within the Member Ⅱ, the second within the Member Ⅲ. Red beds sequence consists of mm-thick reddish clays alternating with gray, variegated, sometimes black, clays and calcareous clays. Turbiditic beds with normal grading also occur within the red beds. The occurrence and disappearance of red beds was bounded by turbiditic conglomerates.

3.2 Biostratigraphy

Calcareous nannofossil specimens are poorly preserved, since overgrowth and etching is extensive. Nannofossil assemblages are characterized by lower species diversity (Table 1, Fig. 3). Qualitative and quantitative data of nannofossil spectra are surely secondarily modified by dissolution. Conclusive proof of this hypothesis is a high number of *Watznaueria barnesae* that is resistant to dissolution[10] and relative abundance of Polycyclolithaceae that also survive poor preservational conditions better than placoliths[11].

Red beds in Member Ⅱ of the Fardes Formation provided nannofossils with relatively common polycycloliths of *Eprolithus moratus* and *Quadrum gartneri* and rare morphotypes of *Quadrumgartneri-gothicum*, zone UC7[9] that is correlated with the uppermost part of Lower Turonian (Table 1). Red beds in Member Ⅲ contained assemblage with *Marthasterites furcatus*, *Micula staurophora* (very rare), *M. adumbrata*, *M. swastica*, *Lithastrinus septenarius*, *Lithastrinus grillii* (one controversial specimen), *Neocrepidolithus cohenii*, and *Micrantholithus quasihoschulzii* complemented by *Quadrum gartneri* and other species. Nannofossils document zones UC10 and ?UC11 (lower part) that are compared with stratigraphic interval from the Middle up to lower part of Upper Coniacian[9] (Table 1).

Abundance of nannofossil species: A = abundant (>5 specimens/1 field of microscope), C = common (5～1 specimens/1 field of view of microscope), F = few (9～1 specimens/10 fields of view of microscope), R = rare (9～1 specimens/20 fields of view of microscope),

① HERNANDEZ-MOLINA F J. La sedimentacion cretacica en el sector del Río Fardes (Surco meridional Subbetico, paleomargen sudiberico). PhD Thesis. University of Granada, 1992:197.

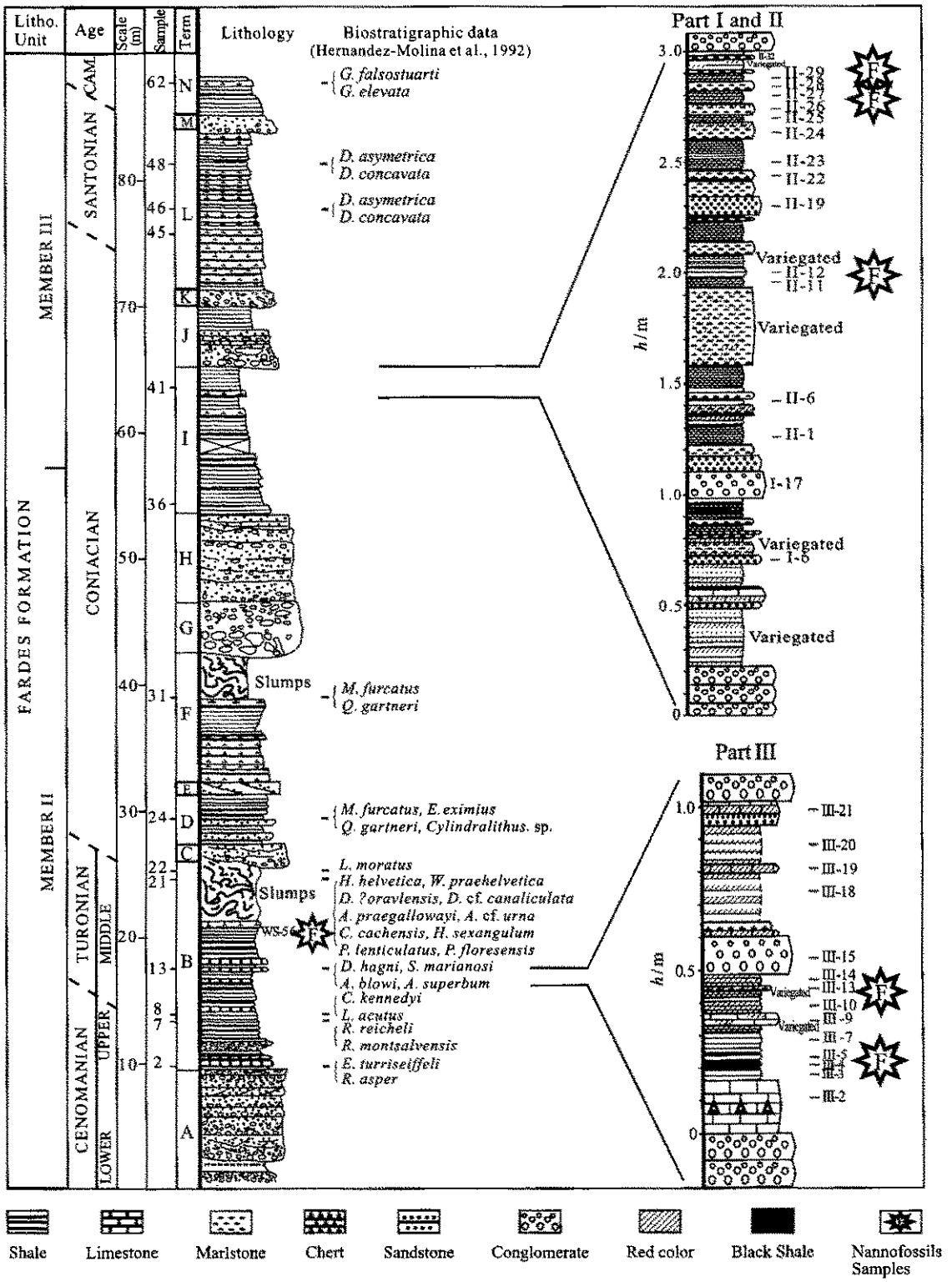

Fig. 2 Stratigraphic log of the Río Fardes Section, showing the samples' position and the red facies

VR = very rare (scarce presence), r = reworked species from the Lower Cretaceous strata, f = fragments, ? = questionable specimen, segm. = segments. Sample abundance: M = moderate (> 20 specimens/field of microscope), L = low (< 20 specimens they can be identified/1 field of view they can be identified/1 field of the microscope).

3.3 Sedimentary characters

In the Río Fardes section, pelagic and hemipelagic facies typically coexisted with turbidites. They

Table 1 Río Fardes Section-distribution table of calcareous nannofossils

Río Fardes Section	Turonian			Coniacian		
	Lower		Middle	Middle		?Upper
Nannofossil zones (Burnett 1998)	UC7		UC9a	UC10		UC10/?11
Sample No.	Ⅲ/5	Ⅲ/13	WS/56	Ⅱ/12	Ⅱ/27	Ⅱ/28
Sample abundance	L	L	L	M	M	M
Broinsonia enormis	R			R		
Broinsonia signata	R					
Cretarhabdus striatus	r					
Eiffellithus turriseiffelii	R	R	F	C	F	F
Eiffelithus turriseiffelii-eximius	R	f				
Eprolithus floralis	F	F	C	R	R	R
Eprolithus moratus	C	C	R			
Gartnerago obliquum	R		R	R	R	R
Haqius circumradiatus	R			R	R	
Manivitella pemmatoidea	f	f	f	F	F	R
Nannoconus elongatus	R					
Prediscosphaera columnata	R	R		R		R
Prediscosphaera cretacea	F	f	R	C	F	R
Prediscosphaera ponticula	R		R	R	R	R
Quadrum gartneri	F	R	F	F	F	R
Quadrum gartneri-gothicum	R					VR
Quadrum intermedium(5~7 segm.)	R	R	R			
Retacapsa angustiforata	R		R	C	C	F
Retacapsa crenulata	R		R	F	R	R
Tegumentum stradneri	R		R	F	R	
Tranolithus gabalus	R					
Watznaueria barnesae	C	C	C	A	A	A
Watznaueria biporta	R		R		R	
Zeugrhabdothus bicrescenticus	R					R
Zeugrhabdotus embergerii	R	R	R	R	R	
Cretarhabdus conicus		f	R	C	R	R
Eprolithus-Rucinolithus(7 segm.)		R	R	F	F	F
Zeugrhabdotus diplogrammus		R	R	R	R	
Braarudosphaera bigelowii			R			

Río Fardes Section	Turonian			Coniacian		
	Lower		Middle	Middle		?Upper
Nannofossil zones (Burnett 1998)	UC7		UC9a	UC10		UC10/?11
Sample No.	Ⅲ/5	Ⅲ/13	WS/56	Ⅱ/12	Ⅱ/27	Ⅱ/28
Chiastozygus litterarius			R	F	R	R
Cribrosphaerela ehrenbergii			R	F	R	R
Cyclagelosphaera sp.			R			
Eiffellithus eximius			f	F	F	F
Eprolithus octopetalus			R			
Lithastrinus septenarius			R	R	R	R
Lithraphidites carniolensis			R	C	F	R
Lucianorhabdus cf. *maleformis*			f	R		
Marthasterites furcatus			F	F	F	R
Micrantholithus hoschulzii			r			
Placozygus cf. *fibuliformis*			R			
Tranolithus orionatus			R			
Watznaueria britannica			R			
Zeugrhabdothus noeliae			R			
Helicolithus trabeculatus				R	R	R
Lucianorhabdus cf. *inflatus*				R		
Microrhabdulus attenuatus				R	R	R
Micula adumbrata				R		
Micula staurophora				VR	R	R
Quadrum svabenickae				R	R	
Rotelapillus crenulatus				F		
Zeugrhabdothus biperforatus				R		
Ahmuellerella octoradiata					R	
Cylindralithus biarcus					R	R
Micrantholithus quasihoschulzii					VR	
Micula swastica					R	R
Neocrepidolithus cohenli					R	R
Amphizygus brooksii						R
Lithastrinus grillii						?
Prediscosphaera cf. *grandis*						*R*

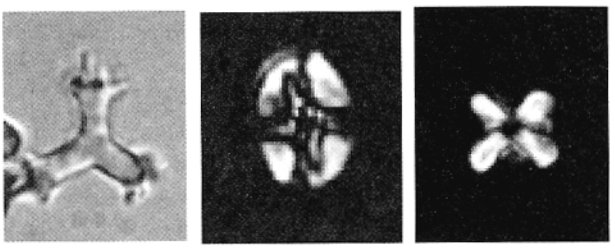

Fig. 3 Photos of three stratigraphically most important nannofossil taxa: *Micula staurophora*, *Marthasterites furcatus*, *Eiffellithus eximius*

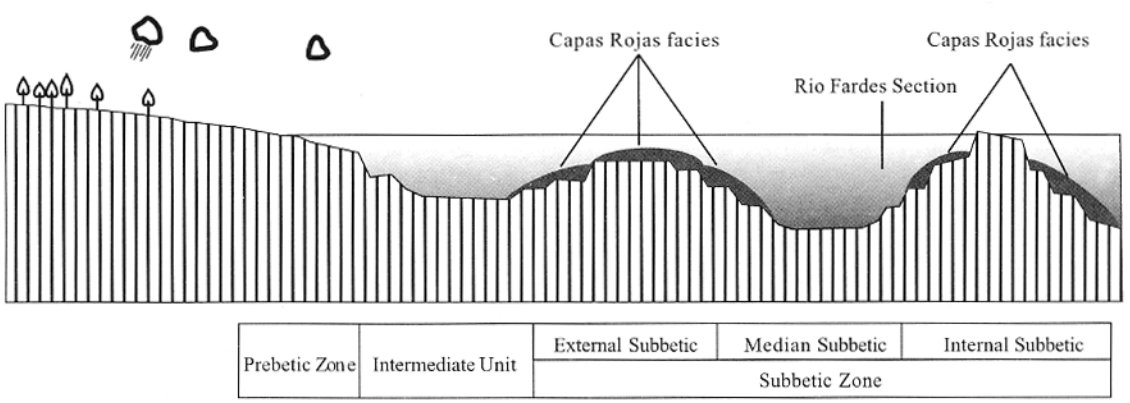

Fig. 4 Palaeogeographic reconstruction of the southern continental margin of the Iberian plate showing the differentiation into swells and troughs and the distribution of the Capas Rojas facies[4]. The studied section is indicated

disappear at the top of the Campanian when truly pelagic sedimentation (Capas Rojas facies) is reestablished①. The existing pelagic and hemipelagic sediment layers are dark green, black, and occasionally red in color, rich in clay minerals and poor in carbonates, indicating the depositional environments are below CCD.

Turbiditic and debris flow deposits diluted the pelagic and hemipelagic facies and dominated in most of the section. Normal grading beds of gravity deposits are widely outcropped. The sedimentation of the Fardes Formation is dominated by pelagic and hemipelagic facies as background with usually affection by gravity currents deposited in a slope environments. In the Member Ⅱ of the Fardes Formation, there are two beds of syn-sedimentary slumps(Fig. 2) which further evidence an unstable environment of lower slope.

4 Discussions

In the Median Subbetic, the main pelagic sediments of the Fardes Formation are dark green, black shales. The mineralogical, geochemical and sedimentological features of the dark facies suggest that anoxic-dysoxic sedimentation prevailed in the Median Subbetic domain[12]. This dysoxic conditions would further be interpreted as a result of restricted basin. The occasionally occurrences of the red clays demonstrated that oxic conditions do also occur at the certain time during Turonian-Coniacian in Median Subbetic. This oxic conditions become more dominated when the post-Campanian pelagic Capas Rojas red facies established. It is interesting to note that in the External Subbetic, Capas Rojas red beds facies extensively developed in more shallower pelagic (200～1 000 m) environments, spanning from latest Cenomanian to Early Eocene [2,8] (Fig. 4).

As discussed above, the newly discovered Turonian-Coniacian pelagic red clays were deposited in the deepest basin below CCD in the Median Subbetic. The turbiditic debris flow sediments diluted and strongly affected the background pelagic/

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hemipelagic facies resulted in the termination of sedimentation of the reddish facies.

This study was supported in part by the Post-Docs Fellowships at Ancona University, Italy, to Xiumian HU, and by the NSFC Project (40332020) *and the MOST-Pre* 973 *project* (2001CCA01800), *and by a grant to Massimo Sarti from the Ministry of Foreign Affairs, Italy. This is a contribution to IGCP* 463 *and* 494.

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