

Microbiostratigraphy of Pelagic Berriasian and Valanginian Sediments in the Western Carpathians in Relation to the Western Mediterranean Region (Tunisia, France)

VLADIMÍR BORZA¹ – JOZEF SALAJ² – ANNA ONDREJČKOVÁ¹

¹Dionýz Štúr Institute of Geology, Mlynská dolina 1, 817 04 Bratislava

²Geological Institute of the Slovak Academy of Sciences, Dúbravská cesta 9, 842 26 Bratislava

Abstract: The authors of the paper present microbiostratigraphic data from Berriasian and Valanginian sediments of some key profiles in the Western Carpathians, northern Tunisia and southern France. Increased attention has been given to calpionellids, which, due to their paleogeographic spreading, rapid evolution as well as continuous paleontologic record, are important index fossils for detailed microbiostratigraphic zoning of pelagic Berriasian-Valanginian sediments. On the basis of composition and preservation of foraminifer associations the authors characterised bathymetric conditions in the regions studied.

Key words: Lithology, biostratigraphy, calpionellids, radiolarians, calcareous dinoflagellate cysts, foraminifers, Berriasian, Valanginian, Western Carpathians, Tunisia, France

Introduction

In view of the fact that occurrences of ammonites - representatives of the orthostratigraphic scale - are in Berriasian sediments of the Western Carpathians a great rarity and their more abundant occurrence is dated only from the upper part of the Lower Valanginian (cf. VAŠÍČEK, 1991), stratigraphic studies are based on calpionellid microfauna. Detailed calpionellid zoning (ALLEMANN et al. 1971, REMANE et al. 1986) became the starting point for parabiostatigraphic correlations with other fossil groups - aptychi (VAŠÍČEK, 1991, BORZA – VAŠÍČEK, 1993, VAŠÍČEK et al., 1994), calcareous dinoflagellates (BORZA, 1969, 1984, ŘEHÁNEK, 1992), calcareous nannoplankton (BORZA et al., 1980, HALÁSOVÁ – BORZA, 1992). The least elaborated was the correlation of calpionellids with radiolarians, which we shall treat with increased attention.

To the contrary, biostratigraphy of Berriasian and Valanginian sediments of northern Tunisia and southern France is based, besides on calpionellids, mainly on ammonite and foraminifer classification

(cf. BUSNARDO et al. 1979, MAAMOURI – SALAJ et al. 1994). Especially the ammonite group allows to make detailed conclusions on the character of sedimentation environment.

Western Carpathians

a) Lithofacial evolution

The character of Berriasian sediments is determined by changes on the boundary of the Jurassic-Cretaceous period. Rapid development of calcareous nannoplankton (especially nannocons), the skeleton remnants of which form 60 and more per cent of the rock, caused rapid fall of the calcite compensation zone level (GARRISON – FISCHER, 1969) and influenced the type of sediments in the whole Tethyan area.

Limestone formations of the biancone facies, locally described also as "Oberalm Beds", "Venetian Biancone Formation", "Calcare Rupestre", "Svaljavska svita" etc.(cf. WIECZOREK, 1988) formed in eupelagic environment, and deposited at the rate from 5 to 30 mm for one thousand years. They contain rich associations of calpionellids and calcareous nannoplankton. Representatives of benthic organisms are practically missing here, remnants of nektonic organism are relatively rare.

Calpionellid-nannocon biomicrites described in older literature as "limestones with *Calpionella alpina*" (KOUTEK – ANDRUSOV, 1927) "limestones of biancone type" (e.g. ANDRUSOV, 1959, K. BORZA, 1969) are also a characteristic Lower Cretaceous facies of the Central Western Carpathians and the Klippen Belt (Ladce Formation of the Manín Unit, Padlá voda Formation of the Vysoká Unit, Osnica Formation of the Zliechov Unit, Lučivná Formation of the Tatricum, lower part of the Pieniny limestone formation of the Kysuce and Pieniny Unit of the Klippen Belt).

This sedimentation of pelagic carbonates of the monotonous "Neocomian" facies continued uninterrupted also during the Valanginian period. The limestones are of micrite or biomicrite character. They differ from Berriasian sediments by their higher proportion of the marly admixture and more frequent occurrence of cherts and marly intercalations. A spotty structure is characteristic for some developments (Mrázňica Formation of the Zliechov Unit, upper part of the Pieniny Limestone Formation). Spotty structure is characteristic also of micrite limestones of the Kostolec (Manín Belt) and Rohatá Skala (=Choč) Unit of the Strážov belt (SALAJ, 1995).

Tectonic activity of the finishing Late Kimmerian movements is documented by beds of the Nozdovice breccia. In the Outer Carpathians, the Oliveta and Kopřivnice limestones deposited on shallow marine elevations (Bašský development). On the other hand, characteristic for basin parts of the Godul development is sedimentation of the Tešín limestones of turbiditic character.

b) Distribution of microorganic remnants

Calpionellids (*Calpionellidae* BONET, 1956) were a component of the planktonic ecosystem of the first depth level in the Tethys ocean, on the boundary of the Jurassic-Cretaceous period. The evolution of the branches of this family, according to present knowledge, covered a period of 15 million years (HOUSÁ, 1990).

These planktonic microorganisms were rapidly spread by sea currents, which explains the identical composition of associations in the whole area of their occurrence. Their geographic explosion within the Tethyd province includes an area from eastern Mexico, Texas, Venezuela and Cuba in west, to Iran, Oman and Kogar nappes of Tibet in east.

For this reason, calpionellids, as generally known, are of great stratigraphic importance and they are besides ammonites a key group for fine biostratigraphic zoning of the Middle-Upper Tithonian, Berriasian and Lower Valanginian. The last occurrences of representatives of *Calpionellidae* BONET are associated with the Hauterivian (BORZA, 1984).

The systematic position of calpionellids is determined by the character and structure of their test - lorica. Their lorica is formed by spiral-like arranged calcite prisms, oriented perpendicularly to the surface (AUBRY et al. 1976). In spite of the generally accepted opinion COLOM (1948), BONET (1956), TAPPAN-LOEBLICH, (1968), BORZA (1969), REMANE

(1969a, 1978) stated that calpionellids are not fossil tintinnids, since their test consists primarily of calcite. Recent tintinnids represent a substantially more significant morphological group than calpionellids and especially the chemistry of tests is in both groups different. REMANE (1969a) supported his statement of primary calcite character of calpionellid tests by the following arguments:

Findings of sandy foraminifers, which had not been calcified in calpionellid limestones, with different crystallographic orientation of the collar and test, of the genus *Calpionellopsis* COLOM, 1948, which excludes calcification post mortem. On the other hand, tintinnids have organic lorica and at some species the surface is agglutinated. According to REMANE (1978), taxonomic position of *Calpionellidae* BONET, 1956 remains unclear and this author suggests to classify them with protozoans, with unsure systematic position.

The importance of calpionellids for the zoning of the uppermost Jurassic and Lower Cretaceous is determined by their abundant occurrence, rapid evolution, relatively easy identification of taxons, advanced elaboration of biostratigraphic zoning and continuous paleontologic record of the development of individual branches, allowing so-called phylogenetic control of biostratigraphically important changes in associations.

Although evolutionary changes in this group were not as important as in ammonites, they provide useful boundaries for stratigraphic correlations.

The foundations for calpionella scales have been laid down in the works of REMANE (1969b), LE HÉGARAT - REMANE (1968), K.BORZA (1969), ALLEMANN (1970), CATALANO - LIGUORI (1971), FARÉS - LASNIER (1971). Standard calpionellid biozoning for the Mediterranean province has been elaborated by ALLEMANN - CATALANO - FARÉS - LASNIER (1971).

On a colloquium in Lyon and Neuchâtel in the year 1973, one of three variants was proposed, to shift the boundary of the Berriasian to the base of the ammonite zone *Berriasella jacobí*, which would result in the boundary Jurassic-Cretaceous running between the calpionellid zones *Crassicollaria* and *Calpionella* (cf. MEMMI-SALAJ, 1975). This variant was generally accepted only in the year 1984 in Sumeg (REMANE et al. 1986). The latest modification of this scale was presented by POP (1994), based on standard zones (*Crassicollaria*, *Calpionella*, *Calpionellopsis* and *Calpionellites*), complementing them by the late Valanginian-Hauterivian zone *Tintinnopsella* and dividing further more in detail the above zones into sub-zones.

The applicability of the standard calpionellid zoning for the Western Carpathian region has been demonstrated by BORZA (1969). On the basis of a further detailed study, BORZA (1984) complemented this study by the distribution of microplanktonic remnants of the families *Cadosinidae* WANNER, 1940, *Stomiosphaeridae* WANNER, 1940 and *Calcisphaerulidae* BONET, 1956. A summary description of calpionellid fauna in the Western Carpathians, as well as of reference profiles, was presented by BORZA (1969, 1980). Correlation study of Upper Jurassic - Lower Cretaceous profiles was presented by BORZA - MICHALÍK (1986), REHÁKOVÁ - MICHALÍK (1992).

A continuous fossil record of standard calpionellid zones (*Calpionella*, *Calpionellopsis*, *Calpionelites*) in Berriasian and Lower Valanginian pelagic sediments is represented in the profiles Strážovce (BORZA et al. 1980, MICHALÍK et al. 1990 a, BORZA - PETERČÁKOVÁ, 1994), Hlboč (BORZA - MICHALÍK 1987) and Brodno (BORZA, 1969, MICHALÍK et al. 1990 b). In the profiles Brodno and Štramberk (HOUSA et al. 1993), the distribution of calpionellids was checked by magnetostratigraphic study. For example, the boundary between the calpionellid zones A (*Crassicollaria*) and B (*Calpionella*), corresponding to the boundary Tithonian-Berriasian, is located approximately in the middle of the magnetozone M-19n. The above result may be well correlated with results from profiles in the area of northern and central Italy (cf. HOUSA et al. 1994).

Radiolarians

Similarly as calpionellids, radiolarians provide to a certain extent the possibility for a wide paleogeographic and stratigraphic correlation. For the Tethyd realm in the greatest detail elaborated is the biozoning of BAUMGARTNER (1984, 1987), which divides the Middle Jurassic - Lower Cretaceous (Bathonian-Hauterivian) on the basis of unit associations (UA) into nine zones.

In spite of the fact that towards the end of the Jurassic period paleoceanographic conditions changed and radiolarians gradually lost their rock-forming importance (DE WEVER, 1989), changes in their associations on the boundary between the Tithonian and Berriasian may be well correlated with calpionellid events.

The Jurassic-Cretaceous boundary is indicated by a significant change on the base of the zone D, where UA 11 appears (Table 1).

The unit association 11 has a wide paleogeographic extension, but its onset is not every-

where quite synchronous. For example, in the profile Fiumo Bosso (Umbria, Italy), UA 11 is found several meters below the boundary of the calpionellid zones A/B (*Crassicollaria/Calpionella*) in the uppermost Tithonian. In the Atlantic region (Blake Bahama Basin) UA 11 is found directly above a sample of the zone *Calpionella*, which corresponds already to the Upper Berriasian. In the profile Svinita (Romania), the onset of UA 11 was dated on the basis of ammonites in the Upper Berriasian (BAUMGARTNER, 1984, 1987).

From the above mentioned facts it follows that the onset of this unit association may be confined by the range Upper Tithonian-Upper Berriasian. For this reason, the onset of UA 11 has been tested in the Western Carpathian region in the profile Hrušové (ONDREJČKOVÁ et al. 1993), controlled by common occurrence and distribution of calpionellids and calcareous nannoplankton. In the profile Hrušové, similarly as in the profile Fiumo Bosso in Italian Umbria, UA 11 appears in the uppermost Tithonian, below the boundary of calpionellid zones A/B. The onset of UA 11 may be well correlated with the occurrence of calcareous nannoplankton association of the zone CC1 (*Nannoconus steinmanni*). In Lower Berriasian horizons (zone *Calpionella*) of the Hrušové profile, besides typical representatives of UA 11 - *Parvicingula cosmoconica* (FOREMAN), *Obescapsula rusconensis* BAUMGARTNER, *Archeodityomitra excellens* (TAN-SIN-HOK), *Alievum helenae* (SCHAAF), *Xitus spicularius* (ALIEV), *Pseudodityomitra depressa* BAUMGARTNER - there are found also species described in younger stages than the Berriasian. Here belong *Pseudodityomitra lilyae* (TAN-SIN-HOK) and *Archeodityomitra nuda* SCHAAF belong.

The Upper Berriasian has not been studied so well from the viewpoint of radiolarian zoning to distinguish it separately. Valanginian radiolarian fauna has not been mentioned yet to occur in the Western Carpathian region.

Calcareous dinoflagellates

Calcareous microfossils (cadosinas, stomiosphaeras, calcispherulas) are an important component of the Upper Jurassic - Lower Cretaceous ecosystem. Their suitability for zoning of pelagic sediments of the Western Carpathians was verified in the works of BORZA (1969, 1984), NOWAK (1968), ŘEHÁNEK (1985), having been classified by the authors with a group with unsure systematic position.

Table 1 Correlation scheme of radiolarian and calcareous nannoplankton distribution in relation to calpionellid zones (ONDREJČKOVÁ et al. 1993)

														RADIOLARIA

According to KEUPP (1987), KEUPP et al. (1989), they are at present classified with the group of calcareous dinoflagellate family *Calciodinellaceae* DEFLADRE 1947 emend. BUJAK et DAVIES 1983). In spite of the wider stratigraphic range of some taxa, their distribution may be well correlated with calpionellids. ŘEHÁNEK (1992) distinguished for the Berriasian – Early Valanginian interval the zones *Colomisphaera proxima* and *Cadosina minuta*. The

most important profiles for the elaboration of zoning based on calcareous dinoflagellates have been presented in the works by BORZA (1969, 1980).

Foraminifers

Sporadic presence of benthic foraminifers in pelagic sediments of the Berriasian-Valanginian in the Western Carpathians did not allow so far to

elaborate a zoning and its correlation with the above mentioned groups of fossils. In thin sections from Berriasian and Valanginian sequences of the "Neocomian facies" from different tectonic units, the so far unique presence of the genera *Spirillina* EHRENBURG 1843, *Patellina* WILLIAMSON 1858, *Ammodiscus* REUSS 1963, *Lenticulina* LAMARCK 1804, *Nodosaria* LAMARCK 1812 and *Textularia* DEFRANCE 1824 has been recorded. The occurrence of planktonic foraminifers is dated already as Late Hauterivian, by the zone *Globuligerina hoterivica* (SALAJ – SAMUEL 1966). The character of the tests (predominant are thin-walled benthic calcareous and agglutinated forms) as well as of preservation (frequent corrosion) indicates sedimentation in deep-water environment, near to the CCD level with oxygen and light deficiency. Therefore it may be well understood that in the Western Carpathians, in the Berriasian-Valanginian range, planktonic foraminifers are missing.

A poor Valanginian foraminifer microfauna was mentioned by SALAJ – SAMUEL (1966) in the Western Carpathian region from the profile Podskalie (Kostelec unit of the Manín belt). It is sporadically represented by representatives of the genus *Lenticulina* LAMARCK 1804, from which the species *Lenticulina (Lenticulina) guttata* (TEN-DAM) and *L. (L.) muensteri* (ROEMER) could be determined.

Tunisia

a) Lithology and biostratigraphy

The best and in fauna richest regions for establishing Lower Cretaceous stratigraphy are Zaghouan and Djebel Oust, situated 60-70 km from Tunis.

Biostratigraphic studies of these sediments are based mainly on ammonites (SOLIGNAC, 1927, CASTANY, 1951, BUROLLET et al. 1983), calpionellids (COLOM et al. 1953, MEMMI – SALAJ, 1975) and foraminifers (STRÁNIK et al. 1972, MAAMOURI and SALAJ, 1974, 1978, SALAJ, 1980, 1984, 1989, MAAMOURI et al. 1994). Radiolarians and calcareous dinoflagellates have not been studied so far in sediments from these areas.

Due to its quality and abundance in fauna, the Djebel Oust area has been proposed as type region for the Lower Cretaceous (CASTANY, 1951), or parahypostratotype of the individual stages (SALAJ, 1980, MAAMOURI, et al. 1994).

The Berriasian is represented by a sequence of dark sub-lithographic (intrabiopelmicrites and mic-

rites) calpionellid limestones, with layers of dark-grey to black marls.

The Berriasian stage in Tunisia is defined from the microfaunistic viewpoint by the zone *Tintinnopsella carpathica*/*Globospirillina neocomiana* (MEMMI and SALAJ, 1975).

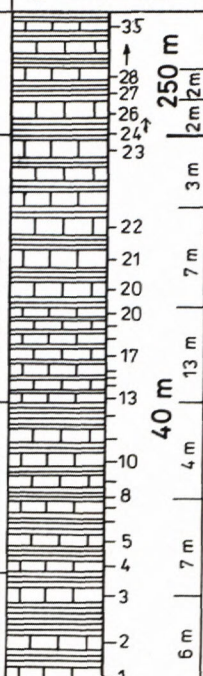
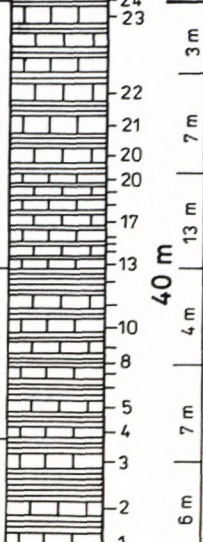
Index species appear on the base of the *Grandis* zone. It is the first appearance of large forms of *Tintinnopsella carpathica* (MURGEANU et FILIPESCU), determining unambiguously the base of the Berriasian. We note that small - primitive *Tintinnopsella carpathica* (MURGEANU et FILIPESCU) specimens appear in the Jacobi zone. This fact has been pointed out by MEMMI – SALAJ (1975), SALAJ (1980) and REMANE (1985). In any case, these small specimens should be described as a new sub-species within the species *Tintinnopsella carpathica* (MURGEANU et FILIPESCU).

The upper boundary of this zone, and thus also the boundary Berriasian-Valanginian, is determined by the appearance of foraminifer species *Epistomina (Brotzenia) ornata* (Roemer) and *Epistomina (Hoeglundia) caracolla* (ROEMER). Biostratigraphic classification of Berriasian and Valanginian sediments from the area of Djebel Oust is represented in Tab. 2.

Marly layers in the Berriasian, from the base of the ammonite *Grandis* zone, are rich in microfauna. It is represented by the following species: *Spirillina minima* (SCHACKO), *Globospirillina neocomiana* (MOULLADE), *Trocholina molesta* GROBATCHIK, *Trocholina vasserodi* GUILLAUME and *Trocholina burlini* GROBATCHIK. From planktonic foraminifers, the presence of the species *Globuligerina gulekhensis* GROBATCHIK et POROSCHINA has been proved and it occurs in the whole Valanginian. From radiolarians there is *Sethocapsa cetia* FOREMAN, passing from the Upper Jurassic into the Berriasian and occurring still in the whole Valanginian. (MAAMOURI et al. 1994).

From benthic foraminifers, besides the above mentioned species, the following ones are found practically in the whole Berriasian: *Rhizammina indivisa* BRADY, *Ammodiscus cretaceous* REUSS, *Dorothia* sp., *Ramulina spinata* ANTONOVA, *Dentalina linearis* ROEMER, *Dentalina* aff. *hilsicana* REUSS, *Dentalina deflexa* REUSS, *Nodosaria nuda* REUSS, *Dentalina deflexa* REUSS, *Dentalina gracilis* D'ORBIGNY, *Dentalina nana* REUSS, *Dentalina siliqua* REUSS, *Lenticulina (Saracenaria) parallela* (REUSS), *Vaginulina* aff. *denudata* REUSS, *Lenticulina (Saracenaria) planiscula* (REUSS), *Lenticulina (Lenticulina) aff. turgidula* (REUSS), *Lenticulina (L.)*

Table 2 Microbiostratigraphic classification of the Berriasian in the Djebel Oust region (MAAMOURI et al. 1994)

STAGES		S U B D I V I S I O N				ASSEMBLAGES				
		LITHOLOGIE & SAMPLES	ZONES AND SUBZONES				OF			
VALAN- GINIAN		250 m	<i>Calpionellites darderi</i>	E	<i>E. (Br.) ornata</i> <i>E. (H.) caracolla</i>	<i>Globuligerina gulekensis</i> GORBATCHIK & POROSCHINA	<i>Sethocapsa cetia</i> FOREMAN	<i>Ostracoda div. sp.</i>	<i>Nodosariidae</i> EHRENBURG, 1838	
			<i>Praecalpionellites murgearui</i>							
		3 m	<i>Lorenziella hungarica</i>	D						
		7 m	<i>Calpionellopsis oblonga</i>							
		13 m	<i>Calpionellopsis simplex</i>							
		4 m	<i>Calpionella elliptica</i>	C						
		7 m	<i>Remaniella cadischiana</i>	B						
		6 m	<i>Calpionella alpina</i>							
		B E R R I A S I A N		40 m						
					<i>Globospirillina neocomiana</i>					

subangulata (REUSS) and *Lenticulina* (*Lenticulina*) *macrodisca* (REUSS).

Besides the above mentioned species, the species *Lenticulina* (*Lenticulina*) *nodosa* (REUSS) and *Epistomina* (*Hoglundina*) *caracolla* anterior BARTENSTEIN et BRAND occur for the first time in the upper Berriasian with *Favriella boissieri*.

Further species occur in the Upper Berriasian in the area of Zaghoun (Temple des Eaux), where the second standard profile for the Berriasian is found (SALAJ, 1980, 1984): *Verneulinoides neocomiensis* (MJATLIUK), *Dorothia kummi* ZEDLER, *Conorboides valendiscesis* BARTENSTEIN et BRAND, *Conorboides hofkeri* BARTENSTEIN et BRAND, *Lenticulina* (*Lenticulina*) *guttata* BARTENSTEIN et BRAND, *Trocholina infragranulata* NOTH, *Lenticulina* (*Planularia*) *crepidularis* (ROEMER), *Lenticulina* (*Planularia*) *tricarinelia* (REUSS), *Gaudryina chettabaensis* SIGAL and *Heterostomella chettabaensis* SIGAL.

The base of the Valanginian is determined by the ammonite zone with *Kilianella roubaudiana* with *Thurmanniceras pertransiens* (SAYN) in the wider sense (the index species with *Thurmanniceras otopeta* of basal Valanginian has not been proved to occur yet, BUROLLET et al. 1983).

From planktonic foraminifers, the species *Globuligerina gulekensis* GORBATCHIK et Poroshina passes from the Berriasian into Valanginian, from benthic foraminifers determining the base of the Valanginian we have to mention *Epistomina* (*Brotzenia*) *ornata* (ROEMER) and *Epistomina* (*Hoeglundina*) *caracolla* (ROEMER). The base of the Valanginian is determined from calpionellids by the appearance of *Praecalpionellites murgeanui* (POP). From the lithofacial viewpoint, the Lower Valanginian is built of a marly limestone and marl series (200 to 250 m), defined from the viewpoint of microfauna by the foraminifer association of the zone *Epistomina* (*Brotzenia*) *ornata* - *Epistomina* (*Hoeglundina*) *caracolla*, defined by SALAJ (1975). Its base is defined by the appearance of these leading species, while the upper boundary is determined by the species *Epistomina* (*Brotzenia*) *djaffaensis* SIGAL and *Lenticulina* (*Lenticulina*) *ouachensis* (SIGAL).

We would like to add that the base of the flysch formation, as pointed out by A. - L. MAAMOURI, SALAJ, M. MAAMOURI, MATMATI et ZARGOUNI (1994), corresponds to the uppermost part of the lower Valanginian, i.e. it still belongs to the zone with *Epistomina* (*Brotzenia*) *ornata*, *Epistomina* (*Hoeglundina*) *caracolla*.

The Upper Valanginian is represented by a flyschoid formation (up to 300 m) formed by greenish aleuritic claystones with abundant beds of dark-grey micaceous quartzites, with traces of plant fragments and hieroglyphs. In the middle to upper part of this sequence (200-250 m), decrease in the quantity of quartzites and appearance of rare intercalation of grey marls and grey sometimes even dark-grey to black clayey limestones may be observed, which are relatively abundant and form several horizons in the uppermost part of the Valanginian.

In the immediate underlier of dark bituminous Hauterivian limestones, in a 5 m thick dark marlstone complex, there are rarely present specimens of *Marginulina reticulosa* TEN DAM (A. - L. MAAMOURI, SALAJ, M. MAAMOURI, MATMATI et ZARGOUNI, 1994). Comparing this horizon with the same horizon in the stratigraphic region of Kef el Blidah, dated by ammonites (STRÁNIK et al. 1972, SALAJ, 1980), this horizon was classified with the lowermost part of the Hauterivian (MAAMOURI et al. 1994).

b) *Biostratigraphic correlation of sediments from the area of Djebel Oust with the hypostratal profile of Angles*

The profile of Angles lying in the road-cut at the foot of Baussayes hill in the French province Alpes de Haute, has been proposed as hypostratotype of the Valanginian by BUSSNARDO - THIEULOUY - MOULLADE et al. (1979). The Vocontian Lower Cretaceous bed succession is represented by a sequence of marly limestones and marlstones. The Valanginian part of the profile attains a thickness of 240 m. An overview of biostratigraphic classification based on ammonites is presented in Table 3, 4. The calpionellid microfauna has been studied in the profile by ALLEMANN et al. (1971).

Foraminifer zones of the Valanginian in the Vocontian trough were defined in detail by MOULLADE (1966, 1974) and redefined again on the Valanginian hypostratotype in relation to ammonite zones (BOUSNARDO et al. 1979).

In view of the importance of the Berriasian and Valanginian on the Djebel Oust profile as well as in the Vocontian trough, one of the authors (Salaj) dealt with a revision of the Berriasian-Valanginian profile of the Vocontian trough (profile Angles - type profile of the Valanginian hypostratotype). This necessity resulted above all from the fact that the presence of eipistominas, important not only for Lower Cretaceous but also Jurassic stratigraphy, has not been reported from this profile.

From the comparison material (profile Angles) it is evident that the most abundant component in the microfauna are representatives of the family *Nodosariidae* EHRENBURG, 1838. Even though in the stratigraphic horizons they are synchronous in age, they have been predominantly redeposited by turbidite wash from the external platform and slope into the basin. This is supported by the taphonomic analysis of these foraminifer associations, which have been damaged by mechanical transport due to turbidites, while their tests are clearly sorted according to size. Juvenile and developing stages of tests are missing in the foraminifer associations. From the above mentioned facts it follows that there are present thanatocenoses from various paleoecologic nests of various depth horizons.

From species important for the Berriasian and Valanginian not described from the Angles profile, we present the following:

In the Berriasian there occur: *Globospirillina neocomiana* (MOULLADE), *Trocholina molesta* GORBATCHIK, *Trocholina burlini* GORBATCHIK, *Conorboides valendisensis* BARTENSTEIN et BRAND, *Conorboides hofkeri* BARTENSTEIN et BRAND, *Lenticulina* (*Lenticulina*) *nodosa* (REUSS), *Falsogaudryinella tealbyensis* (BARTENSTEIN) and *Globuligerina gulkensis* GORBATCHIK et POROSHINA.

In the Valanginian, from which not more than 40 species have been described, there occur practically about 100 well identifiable species. We shall present only the more important and so far in publications about the Vocontian trough not mentioned ones.

Otopeta zone (6 m)

In this zone, besides the already mentioned index species *Lenticulina* (*Lenticulina*) *nodosa* (REUSS), passing into this zone already in the Berriasian, there occur also *Haplophragmoides* sp., *Valvulina fusca* WILLIAMSON, *Dentalina linearis* REUSS, *Bythoceratina* sp. and *Ophthalmidium* div. sp.

Petransiensis zone (53 m)

The following species occur in this zone: *Conicospirillina reussi* ANTONOVA, *Lamarckina reussi* ANTONOVA, *Lamarckina membranaacea* ANTONOVA, *Epistomina* (*Hoeglundina*) *caracolla* (ROEMER), *Globuligerina gulekhensis* GORBATCHIK et POROSHINA and *Globuligerina* sp.

Campylotoxum zone (45m)

Besides by Moullade (In BOUSNARDO et al. 1979) described species, the following ones occur in this

Table 3 An overview of the biostratigraphic classification of the Vocontian trough based on ammonites (BUSNARDO et al., 1979)

		Lory, 1898	Paquier, 1990	Killian, 1906-13	Mazenot, 1939	Colloque Cretace Inf., 1965	Moullade et Thieuloy, 1967
HAUTERIVIEN (pars)			<i>Hoplites radiatus</i> <i>H. castellanensis</i>	<i>Acanthodiscus radiatus</i> et <i>L. castellanensis</i>		<i>Acanthodiscus radiatus</i>	<i>Radiatus</i>
VALANGINIEN	SUPERIEUR	<i>Hoplites</i> cf. <i>longinodus</i>	<i>Duvalia emerci</i> et	<i>Duvalia emerci</i> et	<i>Neocomites neocomiensis</i>	" <i>Lyticoceras</i> "	<i>Neocomites</i> aff. <i>sciptychus</i>
		<i>Seynocras verrucosum</i>	<i>Seynocras verrucosum</i>	<i>Seynocras verrucosum</i>		<i>Verrucosum</i>	<i>Himantoceras trinodosum</i> <i>Verrucosum</i>
	INFERIEUR	<i>Duvalia lata</i> et <i>Hoplites pexiptychus</i>	<i>Duvalia conica</i> et <i>Hoplites pexiptychus</i>	<i>Duvalia conica</i> et <i>Kilianella roubaudiana</i>		<i>Roubaudiana</i>	<i>Roubaudiana</i>
BERRIASIEN (pars)		<i>Hoplites boissieri</i> (pars)	<i>Hoplites boissieri</i> (pars)	<i>Hoplites boissieri</i> (pars)	<i>Kilianella</i> aff. <i>pexiptycha</i> et <i>Thurmannites</i> aff. <i>pertransiens</i>		

Tab. 4 An overview of the biostratigraphic classification of the Vocontian trough based on ammonites (BUSNARDO et al., 1979)

		Le Hégarat, 1968	Thieuloy, 1973	zonation proposée 1978	Espagne Wiedmann, 1975	Bulgarie Nikolov, 1960	Crimée-Caucase Drushchits, 1960
HAUTERIVIEN (p. p.)			<i>Radiatus</i>	<i>Radiatus</i>			
VALANGINIEN	SUPERIEUR		<i>Teschenites callidiscus</i>	<i>Callidiscus</i>	<i>Saynocras verrucosum</i>	<i>Neocomites neocomiensis</i>	<i>Olcostephanus astieri</i> <i>Neocomites neocomiensis</i>
			<i>Trinodosum</i>	<i>Trinodosum</i>			
			<i>Verrucosum</i>	<i>Verrucosum</i>			
	INFERIEUR		<i>Neocomites campylotoxus</i>	<i>Campylotoxum</i>	<i>Kilianella roubaudiana</i>	<i>Kilianella roubaudiana</i>	<i>Kilianella roubaudiana</i>
			<i>Roubaudiana</i>	<i>Pertransiens</i>	<i>Thurmanniceras thurmanni</i>		
		<i>Thurmanniceras pertransiens</i>	<i>Pertransiens</i>	<i>Otopeta</i>			<i>Thurmanniceras thurmanni</i>
BERRIASIEN (p. p.)		<i>Boissieri</i>	<i>Boissieri</i>	<i>Boissieri</i>	<i>Berriasella callisto</i> (p. p.)		

zone: *Lenticulina* (*Lenticulina*) *subalata* (REUSS), *Lenticulina* (*Lenticulina*) *gibba* (REUSS), *Lenticulina* (*Lenticulina*) *turgidula* (REUSS), *Lenticulina* (*Lenticulina*) *saxonica* BARTENSTEIN et BRAND, *Lenticulina* (*Lenticulina*) *multicella* MOULLADE, *Lenticulina* (*Lenticulina*) *catascopium* MITJANICA, *Fronicularia* *mirodisca* REUSS, *Tristix* *excavatum* REUSS and *Bolivina* *textilaroides* REUSS.

Finally, in the zones *Verrucosum*, *Trinodosum* and *Callidiscus* (120 m), from further important species the following have been determined: *Globospirillina* *condensa* ANTONOVA, *Globospirillina* *clara* ANTONOVA, *Globuligerina* *gulekhensis* GROBATCHIK et POROSHINA, *Globuligerina* sp. and *Epistomina* (*Brotzenia*) *djaffaensis* SIGAL. The species *Fronicularia* cf. *bidentata* CUSHMAN corresponds in fact to the species *Fronicularia* *angusta glabra* (PERNER).

Besides this, attention has been given on the Angles profile to the boundary of Valanginian-Hauterivian boundary. The basal part of the Hauterivian was determined by the ammonite zone *Radiatus* (approx. 5 m). Besides the index species *Haplophragmoides* *vocontianus* MOULLADE for the Lower Hauterivian zone of the same name, determined by MOULLADE (1966) further important species are found in the basal part of the Hauterivian: *Bigennerina* *gracilis* ANTONOVA, *Marginulinopsis* *breyeri* (ZENDLER) and *Marginulina* *reticulosa* TEN DAM, known better under the name *Marginulopsis* *djaffaensis* (SIGAL). The latter, due to later description, became the synonym for the species *Lenticulina* (*Marginulinopsis*) *reticulosa* (TEN DAM, 1948).

For this reason, the Lower Hauterivian zone *Lenticulina* (*Marginulinopsis*) *djaffaensis* defined by A.-L. MAAMOURI – SALAJ (1978) was renamed by A.-L. MAAMOURI – SALAJ – M. MAAMOURI – MATMATI – ZARGOUNI (1994) as *Lenticulina* (*Marginulopsis*) *reticulata* zone.

From the above revision it is evident that microbiostratigraphic classification of the Valanginian on the French hypostratotype and in Tunisia is basically identical. The lack of epistomins on the hypostratotype profile of Angles is a result of the fact that their aragonite tests have been dissolved due to greater depth and thus in the majority of cases only their pyritised or limonitised cast have been preserved, sporadically with remnants of the aragonite tests.

Conclusions

From the comparison of the presented biostratigraphic data, especially the composition and

preservation of foraminifer associations, conclusions may be made on the character of sedimentation environment in the areas studied.

The sedimentation environment of the monotonous "Neocomian" facies of the Western Carpathians during the Berriasian and Valanginian stage may be characterised as the hemipelagic part of a sea basin, with oxygen and light deficiency, the bottom of which was situated above CCD level, but significantly below ACD level. This is supported by the sporadic presence of thin-walled agglutinated foraminifers of the genus *Ammodiscus* REUSS, as well as rare occurrence of calcareous benthos with corroded tests, represented above all by the genera *Lenticulina* LAMARCK and *Nodosaria* LAMARCK.

The relatively deep-water conditions of sedimentation predominated during the Berriasian and Valanginian stage in the Vocontian trough. Besides thin-walled agglutinated, relatively rare foraminifers, there occur foraminifer associations redeposited by turbidite wash (BUSNARDO et al. 1979), from the external platform and slope towards the basin. This is supported by the taphonomic analysis of these associations, which have been damaged by mechanical transport due to turbidites and the tests are evidently sorted according to size. The lack of epistomins on the hypostratotype profile of Angles is a result of the fact that their aragonite tests have been dissolved due to greater depth, and thus in the majority of cases only their pyritised or limonitised cast have been preserved, sporadically with remnants of the aragonite tests.

The most optimal conditions for parabiostratigraphic studies based on the distribution of foraminifers are provided by the Lower Cretaceous sediments of Djebel Oust in northern Tunisia. In Berriasian sequences a rich occurrence of benthic foraminifers has been determined, especially the family *Nodosaridae* EHRENBERG. The presence of the genera *Lenticulina* LAMARCK and *Epistomina* TERQUEM is important for the biostratigraphic classification of the Valanginian. The occurrence of epistomins in Tunisia, with frequently preserved aragonite tests, indicates a relatively shallower sedimentation environment. On the basis of a detailed microfacial analysis, calcimetry and abundance relation of planktonic and benthic foraminifers, MAAMOURI – SALAJ et al. (1994, Tab. 1 a, b, c) stated that Lower Cretaceous sediments of this region deposited in the depth range of 200–500 m (maximally up to 700 m), above ACD level.

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