Calpionellid biostratigraphy across the Jurassic/Cretaceous boundary in San José de Iturbide, Nuevo León, northeastern Mexico

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Detailed bed-by-bed sampling on an outcrop of the La Casita and Taraises formations in northeastern Mexico (San José de Iturbide, Nuevo León State) allows the delimitation of the Jurassic/Cretaceous boundary. The Late Tithonian was determined by the presence of the Crassicollaria Zone (Colomi Subzone). Underlying subzones (Remanei and Brevis) were not identified due to the scarcity and poor preservation of calpionellids. The Jurassic/Cretaceous boundary was defined by the acme of the small and spherical form of the species *Calpionella alpina* Lorenz in sample IT-120. The Berriasian was divided into two zones and five subzones: the Calpionella Zone (Alpina, Ferasini and Elliptica subzones) and the Calpionellopsis Zone (Simplex and Oblonga subzones). The facies studied indicate that deposition during the Tithonian occurred in a toe of slope environment with occasional deep shelf incursions. Near the Jurassic/Cretaceous boundary, a sea level drop is recorded and the facies indicate a slope environment with the occurrence of a breccia level. A general deepening of the environments recorded within the frame of the Elliptica Subzone where the deposits pass into basinal facies.

Key words: Calpionellids, Jurassic/Cretaceous boundary, Mexico, biostratigraphy.

INTRODUCTION

The Jurassic/Cretaceous boundary in northern Mexico has been discussed by several authors (López-Oliva, 1991; Adatte et al., 1994, 1996a; Eguiluz et al., 2012). Nonetheless, the use of calpionellids for its determination is still under discussion due to the preservation and abundance of these microfossils, mainly in Tithonian deposits. At this point, some authors claim the low utility of calpionellids for the determination of this boundary in Mexico (Adatte et al., 1994, 1996a) because the Crassicolaria Zone and the base of the Calpionella Zone (Alpina Subzone) cannot be determined with certainty.

In the present work a detail sampling was carried out in order to increase the precision of calpionellid biostratigraphy towards the delimitation of the Jurassic/Cretaceous boundary in a section in the state of Nuevo León in northern Mexico.

PREVIOUS MICROPALAEONTOLOGICAL STUDIES

Some micropalaeontological studies regarding the Upper Jurassic and Lower Cretaceous have been carried out in Mexico, starting with the classical works of Bonet (1956) and Trejo (1975, 1980), who established the first descriptions and biostratigraphic distributions of calpionellids and other incertae sedis from oil cores and surface sections.

Cantú-Chapa (1967, 1982, 1989, 1992, 1999) studied some sections and established the Jurassic/Cretaceous boundary, based on ammonites and geophysics data. Calpionellids were not taken into account, and this author claims that they are not of biostratigraphical importance in Mexico. Due to the high endemism of the reported ammonites, correlations with the whole Tethys are difficult. Lugo (1975) reported that chitinoidellids form the Upper Jurassic in oil cores and demonstrated the influence of Mediterranean Tethys in Mexico during this interval.

Other authors (Adatte et al., 1993, 1994, 1996a, b; Stinnesbeck et al., 1993) defined the Jurassic/Cretaceous boundary by means of calpionellids and ammonites, and confirmed that calpionellid biozones used in Eastern Tethys can be used with some minor variations in Mexico. The problem is concentrated around the Crassicollaria Zone due to the scarcity of specimens in this zone, induced by palaeogeographic and tectonic conditions during Tithonian times in Mexico. The other problem is related with the separation of the Elliptica Subzone, also due to the scarcity of specimens.

In contrast, Pessagno et al. (2009) argued for the diachronous appearance of calpionellids between Europe and North America and, in consequence, the impossibility to use them for the delimitation of the Jurassic/Cretaceous boundary.

Eguiluz et al. (2012) confirmed a sea level change associated with the Jurassic/Cretaceous boundary recorded in the Huizachal section, in concordance with a global sea level fall. López-Martínez et al. (2013) found no significant differences between the calpionellid biozones of Europe and Mexico.

While diverse opinions are published, the problem of the Jurassic/Cretaceous boundary in Mexico remains controversial.

LOCATION AND GEOLOGICAL SETTING

The section studied is located at 24°43'33.68" N and 99°53'46.31" W, near the town of San José de Iturbide in Nuevo León State, northern Mexico (Fig. 1), and is part of the Sierra Madre Oriental fold-thrust belt. The sedimentary cover of the area studied is mainly composed of Jurassic and Cretaceous rocks. The present study focuses on the Upper Jurassic and Lower Cretaceous rocks, especially on those of the contact between the La Casita and Taraises formations.
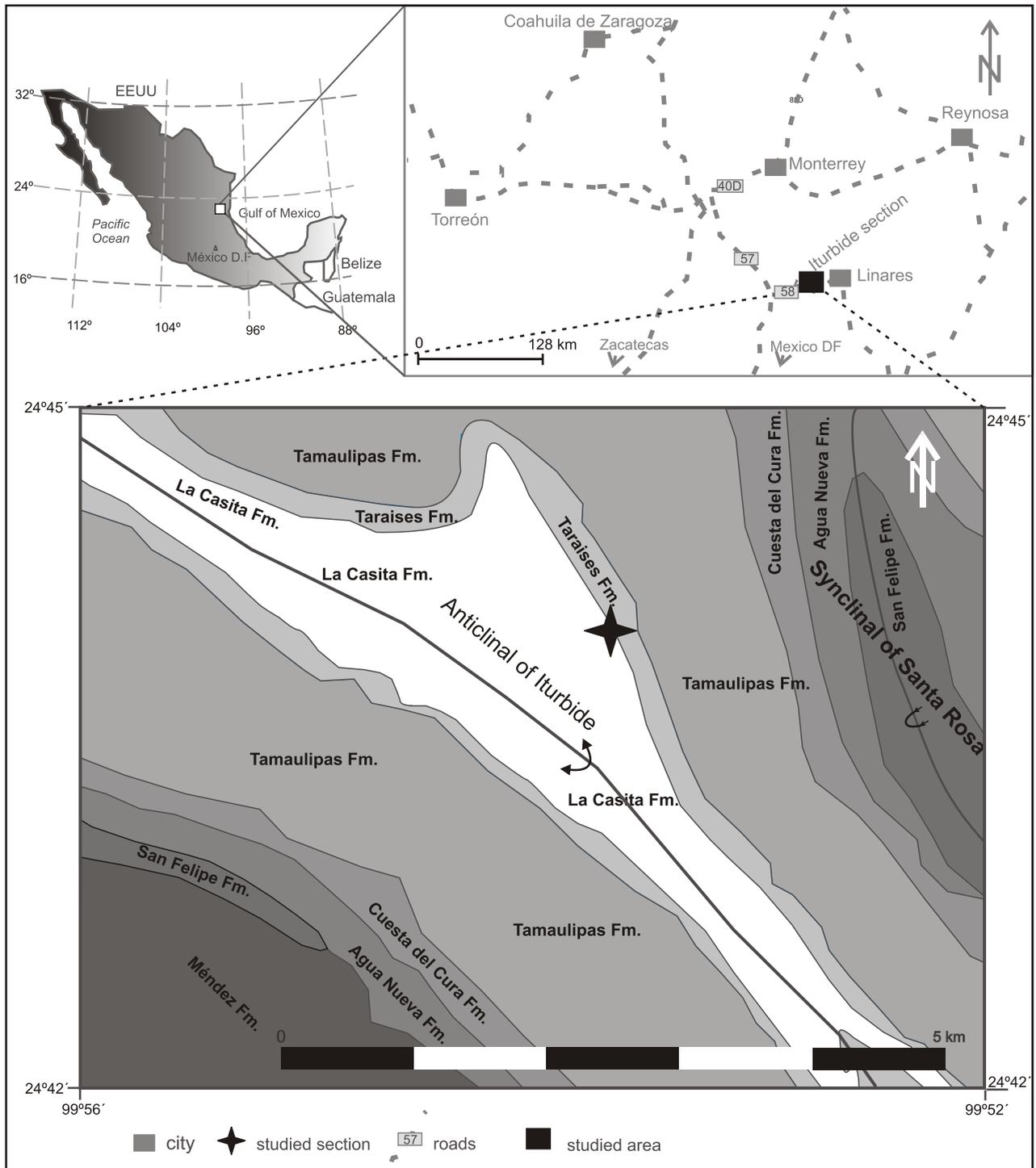

Fig. 1. Location of the section studied on a simplified geological map

The section studied is composed of sedimentary rocks of the upper part of the La Casita Formation and the lower part of the Taraises Formation (Fig. 2).

The La Casita Formation was first described by Imlay (1936), and comprises a large variety of rocks, such as polymictic conglomerates, sandstones, calcareous sandstones, shales and limestones. Fossils are abundant, represented by prevailing ammonites, belemnites, pelecypods, gastropods, wood fragments, and others. Microfossils are represented by radiolarians and some calpionellids. Due to its importance as a source rock, many works about its palaeontological composition, regional distribution, and stratigraphy can be found in the literature (Kellum, 1932; Imlay, 1936, 1937, 1938, 1953; Heim, 1940; Humphrey, 1949; Pantoja-Alor, 1962; Pérez-Rul, 1967; Aranda-García et al., 1987; Contreras-Montero et al., 1988; Cantú-Chapa, 1999; Olmstead, 1999; Pessagno and Martin, 2003). The thicknesses of the unit in outcrops are variable, with an average thickness of 400 m. However, in subsurface, a thickness of 1300 m was reported by the Mexican Petroleum Company PEMEX (1988). In the section studied, a sequence of the La Casita Formation spans approximately 75 m in thickness.

Locally, this unit is composed of an alternation of thin, well-stratified shale-limestone successions (Fig. 3A). Levels with abundant ellipsoidal calcareous concretions (Fig. 3B), containing well-preserved ammonites inside are frequent (Fig. 3C). These concretion levels decrease in abundance upwards in the section. Bioturbation (Fig. 3D) and oxidation (Fig. 3E) are related with concretions and are frequent too. In the interval studied, ammonites and other macrofossils are very scarce and badly preserved, which prevents a real correlation between this useful index fossil group and calpionellids. The La Casita Formation gradually passes to a more calcareous facies, corresponding to the Taraises Formation.

The Taraises Formation was originally described by Imlay (1936), who divided the unit into two main members. The lower member was described as a grey limestone, resistant to erosion; whereas the upper member was identified as a fossiliferous and clayey limestone.

Locally, this unit is represented by thick well-stratified grey limestone (Fig. 3F). Ammonites and other macrofossils are very scarce.

MATERIAL AND METHODS

Careful bed-by-bed samplings, including thin shale intercalations, were carried out. A total of 150 samples were used for thin-section preparations. Microfacies and calcareous microfossils were observed under an *Olympus BX 60* petrographic microscope.

Calpionellid biozonation was built taking into consideration previous studies (Fig. 4), and adapted to the vertical succession of index forms in the section studied. The microfacies analysis of thin sections was based on the standard methodology outlined by Flügel (2004).

Rock samples and thin sections are stored in the collections of the Instituto de Geología, Universidad Nacional Autónoma de México (UNAM).

RESULTS

The succession of calpionellids in the samples studied yielded three standard zones and six subzones as follows:

LATE TITHONIAN CRASSICOLARIA ZONE, COLOMI SUBZONE (SAMPLES IT-100–119)

The Crassicolaria Zone is characterized by abundant radiolaria and scarce calpionellids. The calpionellidas sociation comprises the species *Crassicollaria intermedia* Durand-Delga (Fig. 5A), *Crassicollaria parvula* Remane (Fig. 5B–D), *Crassicollaria colomi* Doben (Fig. 5E), *Crassicollaria brevis* Remane (Fig. 5F), *Tintinnopsella remanei* Borza (Fig. 5G), *Calpionella grandalpina* Nagy (Fig. 5H), *Calpionella alpina* Lorenz (Fig. 5I), and *Tintinnopsella carpathica* (Murgeanu and Filipescu). Calcareous dinoflagellate cysts are scarce, being represented by *Cadosina semiradiata semiradiata* (Wanner) (Fig. 5J). The unusual vertical distribution of the species *Crassicollaria intermedia* Durand-Delga and *Tintinnopsella remanei* (Borza) – species which never appear so high in the stratigraphic sequence – is assumed to be a result of reworking even when the specimens do not exhibit the physical taphonomic features of this process. This assumption can be justified due to the vigorous hydrodynamic conditions suggested by microfacies analysis.

The microfacies of the Colomi Subzone can be divided into three types:

Microfacies A: radiolarian wackestone-packstone (Fig. 6A, B), primarily composed of radiolaria and less abundant calpionellids, sponge spicules, and calcareous dinocysts. The matrix is dark with abundant silt and organic matter. Evidence of resedimentation is common. This facies is similar to the Standard Microfacies SMF 3 and could have been deposited in a near toe of slope. Sediments were deposited in a dysoxic environment with a large amount of organic matter input, perhaps attributable to upwelling currents that contributed to the nutrient supply indicated by the abundant radiolaria.

Microfacies B: composed of wackestone-packstone of filaments, sponge spicules, echinoderms, and poorly-determined organic fragments (Fig. 6C) displaying horizontal lamination.

Period	Epoch	Age	Formations
		Albian	Upper Tamaulipas
		Aptian	La Peña
		Barremian	Tamaulipas
Cretaceous	Early	Hauterivian	
		Valanginian	Taraises
		Berriasian	
Jurassic	Late	Tihonian	La Casita

Fig. 2. Stratigraphy of the area studied

Grey area indicates the interval studied at the Iturbide section
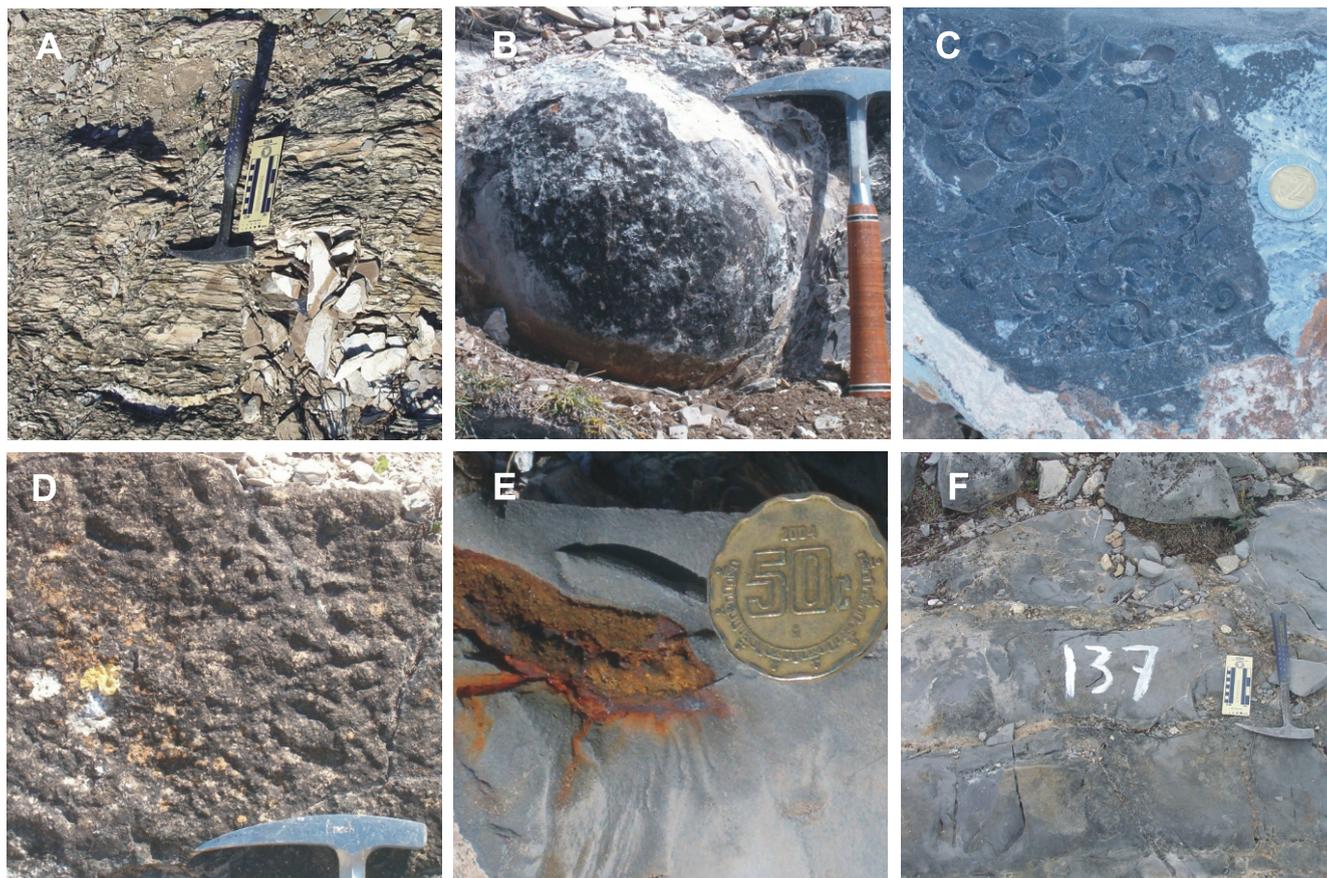
Fig. 3. Some lithological aspects of the La Casita and Taraises formations as observed in outcrop

A – intercalation of thin laminated shale-limestone in La Casita Formation; **B** – ellipsoidal calcareous concretions of the La Casita Formation; **C** – some well-preserved ammonites inside the concretions of the La Casita Formation; **D** – ichnofossils preserved in the upper part of the La Casita Formation; **E** – oxidation of some bioturbation structures in the La Casita Formation; **F** – general aspect of facies of the Taraises Formation in the Iturbide section; generally rocks belonging to this formation display numerous fractures and calcite veins displaying a secondary brecciated texture

Standard microfacies SMF 1, characteristic of a deep shelf environment, was recognized. The record of this microfacies represents a short-term deepening.

Microfacies C: characterized by a microbrecciated fabric (Fig. 6D) with angular to rounded clasts that contain some radiolarians inside. Contacts between clasts display dissolution seams impregnated by Fe-minerals. The microbreccia horizons situated close to the Jurassic/Cretaceous boundary were previously documented by different authors (Olóriz et al., 1995; Grabowski et al., 2010; Michalík and Reháková, 2011; Reháková et al., 2011; Eguiluz et al., 2012). This microfacies is similar to SMF 4 and is related to a slope environment.

EARLY BERRIASIAN, CALPIONELLA ZONE,
ALPINA SUBZONE (SAMPLES IT-120–123)

The Early Berriasian Calpionella Zone represents a change in both microfossils and facies composition. This change occurs from sample IT-119 to IT-120 (Fig. 7A, B), where the radiolarian association is replaced by a near-monospecific association of *Calpionella alpina* Lorenz with small and spherical forms of their loricas. This shift on the facies marks the beginning of the Alpina Subzone within the Calpionella Zone. The onset of the Alpina Subzone was considered and discussed by the Berriasian Working Group of the International Commission on Stratigraphy as one of the potential events useful to locate the J/K boundary (Wimbledon et al., 2011, 2013).

The calpionellid association is composed of the species *Calpionella alpina* Lorenz (Fig. 7C, D), *Tintinnopsella carpathica* (Murgeanu and Filipescu) (Fig. 7E) and *Lorenziella* sp. (Fig. 7F).

Radiolarian packstone abruptly changes to calpionellid-radiolarian wackestone to packstone. The matrix is more calcareous and the silt practically disappears. The preservation of the calpionellid loricas increases upwards within the zone. Two main microfacies were determined in this interval.

Microfacies D: calpionella-radiolarian wackestone (Fig. 7B). This microfacies is characterized by an increase of calpionellids compared with microfacies A of the previous subzone. It is similar to SMF 3, where sediments are assumed to have been deposited in the toe of a slope, as well as in deeper basinal environments. The previous assertion is supported by the influx of shallow water derived clasts and the presence of clay and land-derived material in microfacies D. Nonetheless, this facies settled in a deeper environment compared to microfacies A.

Microfacies E: slightly bioturbated calpionellid-spicule wackestone-packstone (Fig. 7G). This facies displays similar

System	Stage		Remane (1971)		Pop (1994)	Olóriz et al. (1995)	Reháková and Michalík (1997)	Andreini et al. (2007)	López-Martínez et al. (2013)	Present work
Cretaceous	Valanginian	Late	Tintinnopsella		carpathica		Tintinnopsella	Tintinnopsella		
					cadischiana					
		Early	Ct.	E	major		Ct. major	Ct. major		
					darderi		darderi	darderi		
	Berriasian	Late	Calpionellopsis	D 3	murgeanui		Calpionellopsis murgeanui	Calpionellopsis oblonga	Calpionellopsis	oblonga
				D 2	oblonga		oblonga		oblonga	
				D 1	simplex		simplex	simplex		simplex
		Mid		C	longa	elliptica	Calpionella elliptica	Calpionella cadisch.	Calpionella elliptica	elliptica
		Early	Calpionella	B	elliptica	Calpionella remaniella		elliptica		
					ferasini		ferasini	remaniella	ferasini	ferasini
					alpina	alpina	alpina	alpina	alpina	alpina
Jurassic	Tithonian	Late	Crassicollaria	A 3	colomi	Crassicollaria intermedia	Crassicollaria colomi	Crassicollaria intermedia	Crassicollaria colomi	colomi
				A 2	intermedia		brevis			
				A 1	remanei	remanei	remanei	remanei		
		Middle			Praetintinnop.		Praetintinnop.		boneti	
						Chitinoidella	boneti	Chitinoidella		
					Chitinoidella	Chitinoidella	dobeni	dobeni		
		Early								

Fig. 4. Selected calpionellid biozonations considered for correlation purposes including the biozonation constructed in this study for the Iturbide section

features to those previously described, but frequent bioturbation and heterolithic textures make it distinct. Sediments were deposited in the toe of a slope as for microfacies D.

CALPIONELLA ZONE, FERASINI SUBZONE
(SAMPLES IT-124–127)

The base of this subzone is characterized by the First Occurrence (FO) of the genus *Remaniella* with its species *Remaniella ferasini* Catalano (Fig. 7H). *Remaniella ferasini* Catalano is scarce at the base of the subzone and becomes more abundant upwards.

Microfacies D1: calpionellid-radiolarian wackestone with abundant organic matter and pyrite. Some calpionellid loricas and radiolarian tests are pyritized (Fig. 7J–L). Locally, phosphatized bone fragments were also identified (Fig. 7I). This microfacies is a variation of microfacies D, but reflects more anoxic conditions.

CALPIONELLA ZONE, ELLIPTICA SUBZONE
(SAMPLES IT-128A–132)

The onset of the subzone is defined on the base of the FO of the species *Calpionella elliptica* Cadish (Fig. 7N). The calpionellid association is composed of the species *Calpionella alpina*

Lorenz, *Calpionella elliptica* Cadish, *Remaniella ferasini* Catalano, and *Tintinnopsella carpathica* (Murgeanu and Filipescu).

The microfacies of this subzone is similar to those previously described, but some aspects allow its separation.

Microfacies F: calpionella-globochaetae wackestone with few ostracods (Fig. 8A) and ammonite aptychi (Fig. 8B). Representatives of the foraminifera genus *Lenticulina* sp. and some gastropods are common (Fig. 8C). Resedimentation is less frequent than in previous microfacies, but is still present and can be seen in geopetal structures in ostracods (Fig. 8A black arrows). This microfacies is similar to SMF 3-calp (*sensu* Flügel, 2004) and corresponds to sediments deposited in a basinal environment.

LATE BERRIASIAN, CALPIONELLOPSIS ZONE,
SIMPLEX SUBZONE (SAMPLES IT-133–136)

The Calpionellopsis Zone is defined at the base by the FO of the genus *Calpionellopsis* and can be divided into two main subzones, Simplex and Oblonga, in reference to the FO of the two species of the genus, *Calpionellopsis simplex* (Colom) and *Calpionellopsis oblonga* (Cadish), respectively.

The Simplex Subzone is characterized by a calpionellid wackestone with small portions of ostracods, foraminifera, bivalves, crinoid fragments, and loricas of calpionellids, from
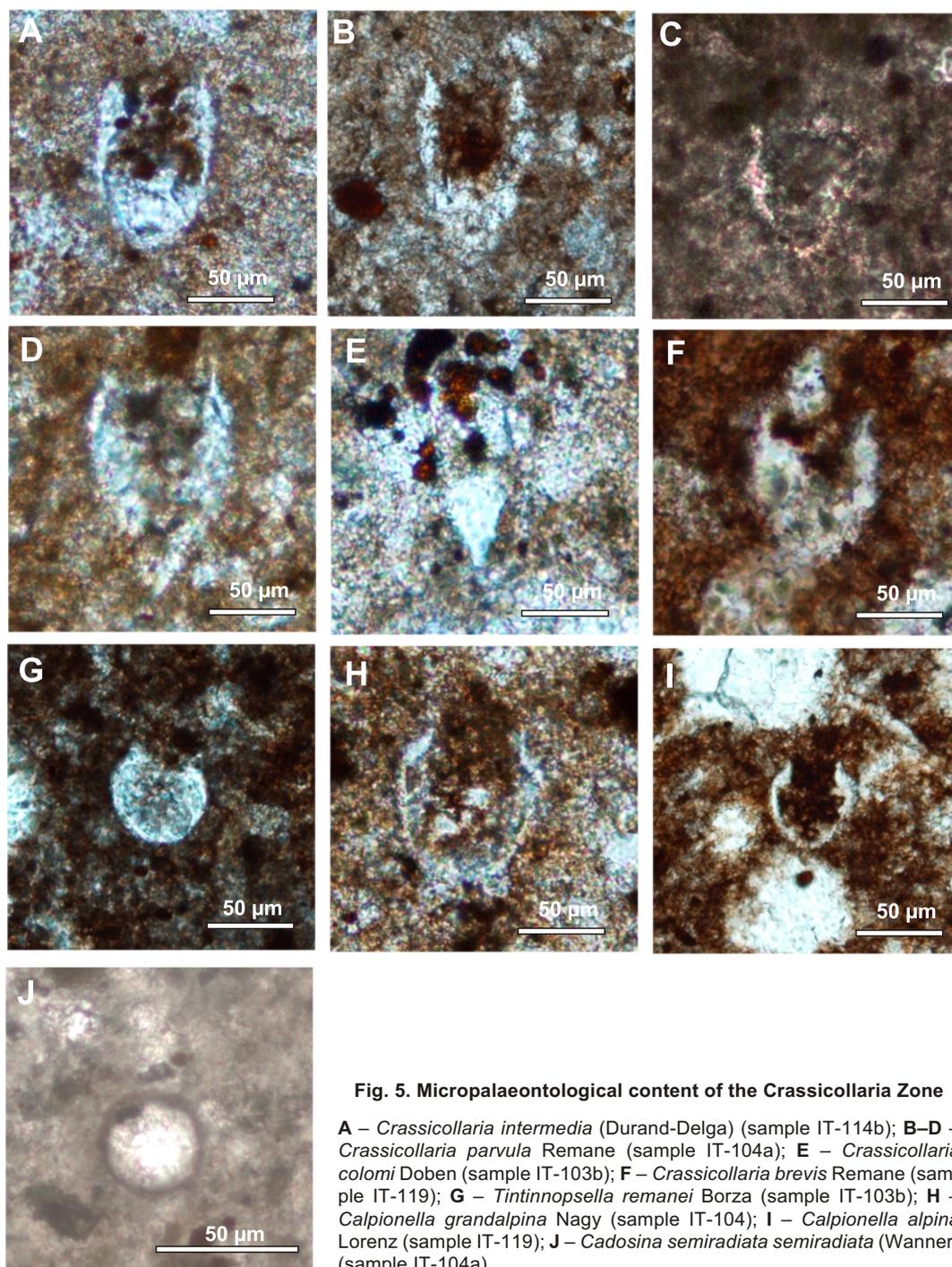
Fig. 5. Micropalaeontological content of the Crassicollaria Zone

A – *Crassicollaria intermedia* (Durand-Delga) (sample IT-114b); **B–D** – *Crassicollaria parvula* Remane (sample IT-104a); **E** – *Crassicollaria colomi* Doben (sample IT-103b); **F** – *Crassicollaria brevis* Remane (sample IT-119); **G** – *Tintinnopsella remanei* Borza (sample IT-103b); **H** – *Calpionella grandalpina* Nagy (sample IT-104); **I** – *Calpionella alpina* Lorenz (sample IT-119); **J** – *Cadosina semiradiata semiradiata* (Wanner) (sample IT-104a)

which stand out those of *Calpionellopsis simplex* (Colom) (Fig. 8D). The calpionellid association comprises the species *Calpionellopsis simplex* (Colom), *Calpionella alpina* Lorenz, *Calpionella elliptica* Cadish, *Remaniella ferasini* Catalano and *Tintinnopsella carpathica* (Murgeanu and Filipescu).

CALPIONELLOPSIS ZONE, OBLONGA SUBZONE
(SAMPLES IT-137–145)

The base of the Oblonga Subzone is defined by the FO of *Calpionellopsis oblonga* (Cadish) (Fig. 8E).

The maximum abundance of calpionellids in the Iturbide section is recorded within this subzone. The assemblage is rep-resented by the species *Tintinnopsella longa* (Colom) (Fig. 8F), *Tintinnopsella carpathica* (Murgeanu and Filipescu), *Remaniella colomi* Pop (Fig. 8G), *Remaniella filipescui* Pop (Fig. 8H), *Remaniella duranddelgai* Pop (Fig. 8I), and *Tintinnopsella sub-acuta* (Colom) (Fig. 8J).

Among calpionellid loricas, many of them have suddenly thinner and damaged walls, and display deformed and "aberrant" forms (Fig. 8K, L). The same observations were documented by Borza (unpublished data) and Reháková (2000). On the basis of observations made in several sections, Reháková (2000) stated that events of "aberrant" loricas were coincident with the calpionellid crisis. The first one recorded at the J/K boundary (crassicollarian decimation), and the second one at
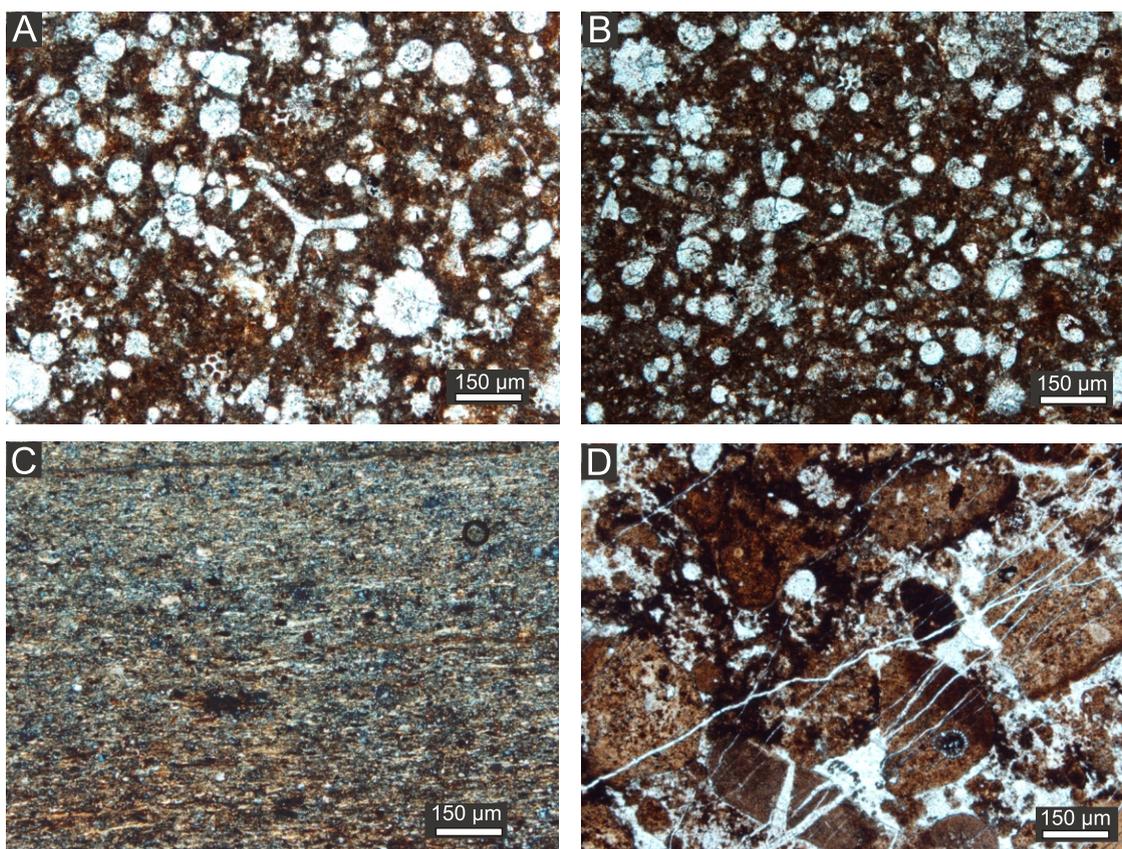
Fig. 6. Typical microfacies of the Colomi Subzone

A, B – microfacies A, radiolarian wackestone-packstone; **C** – microfacies B, filaments, spicules and poorly
determined organic fragments with fine horizontal lamination; **D** – microfacies C, microbreciated limestone

the end of Calpionellopsis Zone (diversified calpionellid associations decreased in diversity and abundance, later leading to calpionellid extinction).

The sediments of this subzone are similar to the previously described microfacies F, and they are assumed to be deposited in a similar environment.

DISCUSSION

The vertical distribution of calpionellids in the Iturbide section is slightly different from those described elsewhere for the rest of the Tethys (Figs. 4 and 9).

In the Late Tithonian uppermost part of the La Casita Formation, only the Colomi Subzone of the standard Crassicollaria Zone was determined. The predominance of radiolarians in the underlying facies prevented the recognition of older crasicollarian subzones. Nonetheless, the calpionellid association of the Colomi Subzone contains older forms such as *Tintinnopsella remanei* Borza and *Crassicollaria intermedia* (Durand-Delga), index markers of the Taxon Range Remanei and Intermedia subzones.

At the end of the Colomi Subzone, beds of breccias appear suddenly. Marks of erosion, accompanied by siliciclastic input and/or breccia accumulations, have been identified from coeval Late Tithonian intervals in many other Tethyan sections (Reháková, 2000; Grabowski et al., 2010; Michalík and Reháková,

2011; Wimbledon et al., 2013). Reháková (2000) described huge, several metres thick breccia bodies visible across the West Carpathians area as evidence of the Zliechov Event (Reháková, 1998), which was influenced by a third-order sea level fall, and which is coincident with the "Purbeckian regression". Similar breccias accumulated during a coeval sea level fall were reported from the Huizachal section in northeastern Mexico by Eguiluz et al. (2012).

The Jurassic/Cretaceous boundary in the Iturbide section was determined at the base of the onset of the Alpina Subzone of the standard Calpionella Zone (the bloom or acme of spherical forms of the species *Calpionella alpina* Lorenz), and was locally placed in sample IT-120 in the upper part of the La Casita Formation (Fig. 9). This boundary marks a change in the depositional conditions. Calpionellids become abundant and replace the radiolarian-rich facies, indicating slightly deeper and more stable conditions. This transition was gradual, and facies began to change from the toe of the slope into the deeper parts of the basin. Perhaps the palaeobathymetric conditions did not change dramatically, but the records of the deposits are clearly different. This phenomenon could be explained by an environmental change, perhaps induced by the acceleration of subsidence, however, additional studies are necessary.

Batten (1984), based on palynological records, and afterwards Adatte et al. (1996a), on the basis of changes in clay minerals and stable isotopes, proposed a palaeoclimate change close to the Jurassic/Cretaceous boundary. According to these authors, the palaeoclimate changed from a warm humid Juras-
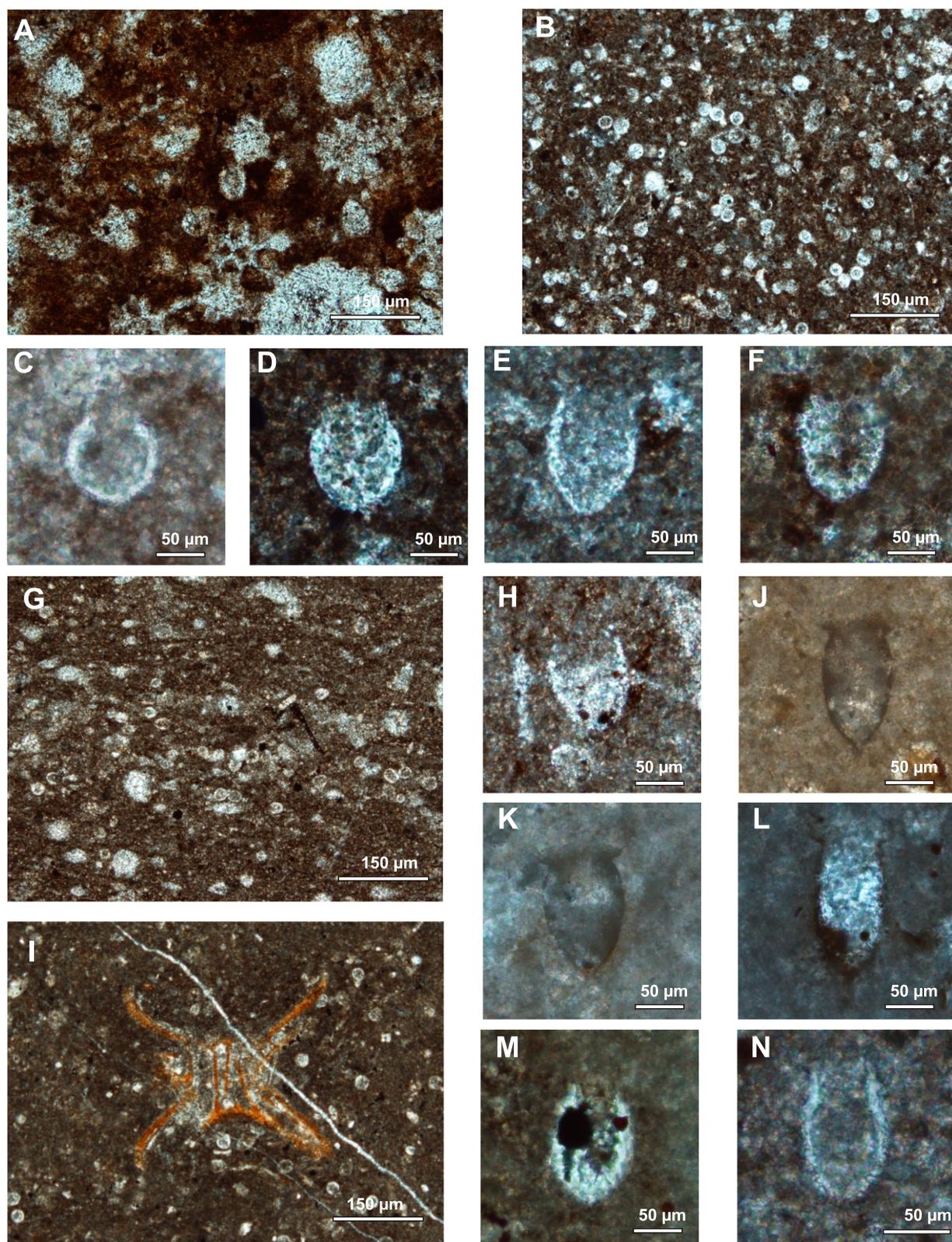
Fig. 7. Facies and calpionellids of the Jurassic/Cretaceous boundary and the Berriasian part of the section

A – radiolarian wackestone to packstone with rare calpionellids (sample IT-119 which represents the latest Tithonian facies); **B** – Calpionella microfacies (wackestone to packstone with acme of *Calpionella alpina* Lorenz) (sample IT-120; Early Berriasian); **C**, **D** – *Calpionella alpina* Lorenz (sample IT-121); **E** – *Tintinnopsella carpathica* (Murgeanu and Filipescu) (sample IT-125); **F** – *Lorenziella* sp. (sample IT-127); **G** – microfacies E, slightly bioturbated calpionellid-radiolarian wackestone (sample IT-122); **H** – *Remaniella ferasini* Catalano (sample IT-125); **I** – phosphatized bone fragment in calpionellid wackestone (sample IT-127); **J, K** – *Tintinnopsella carpathica* (Murgeanu and Filipescu) (sample IT-127, pyritized calpionellids); **L** – *Tintinnopsella longa* (Colom) (sample IT-129, pyritized or biomineralised loricas); **M** – ellipsoidal form of *Calpionella alpina* Lorenz (sample IT-129); **N** – *Calpionella elliptica* Cadish (sample IT-130)
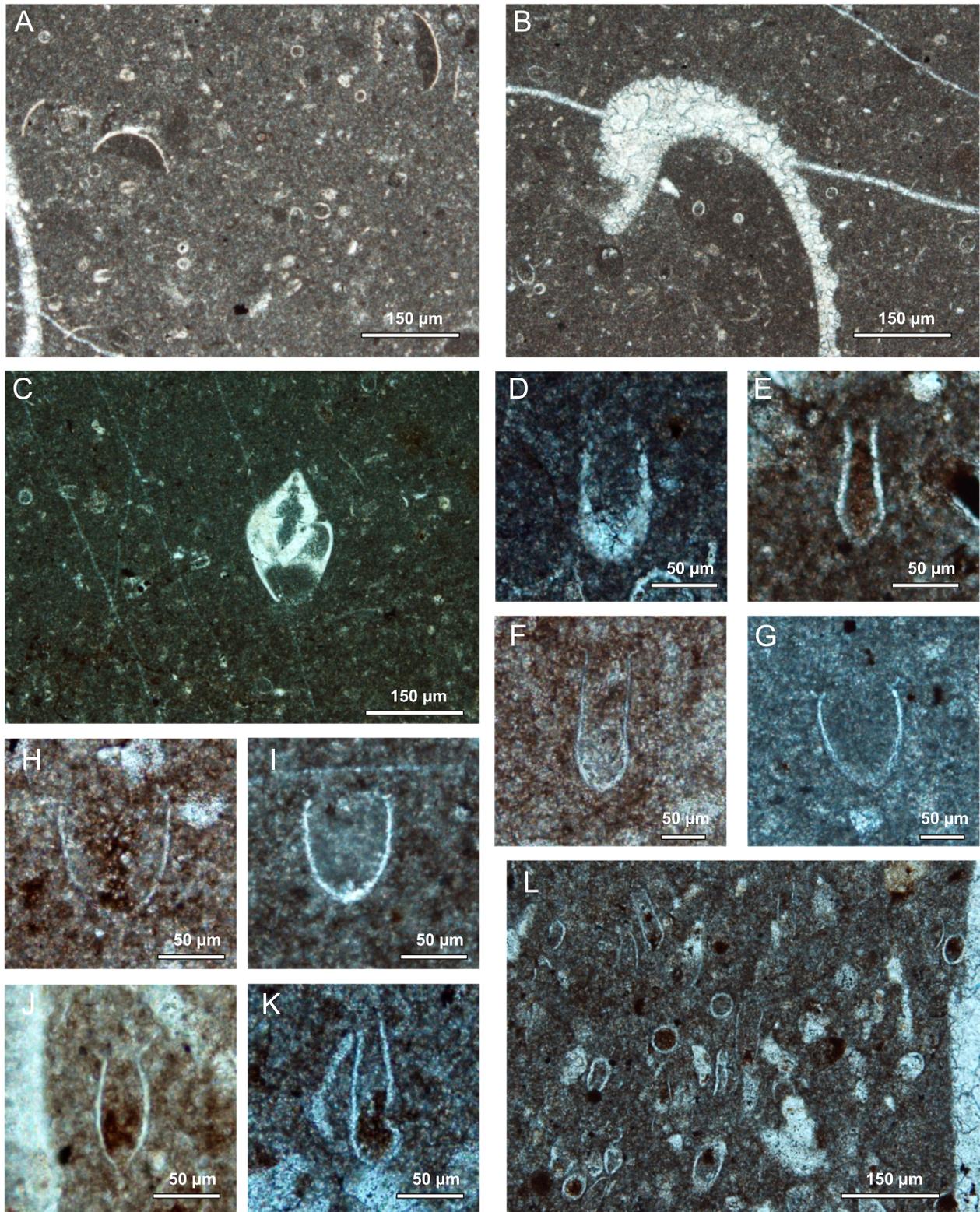
Fig. 8. Facies and calpionellids of the Berriasian part of the section

A, B, C – microfacies F: *Calpionella-globochaete* wackestone with rare ostracods, gastropods, *Lenticulina* sp. and aptychus; black arrows show geopetal structures, evidence that they are not in their original position; **D** – *Calpionellopsis simplex* (Colom) (sample IT-135); **E** – *Calpionellopsis oblonga* (Cadish) (sample IT-140); **F** – *Tintinnopsella longa* (Colom) (sample IT-141); **G** – *Remaniella colomi* Pop (sample IT-142); **H** – *Remaniella filipescui* Pop (sample IT-142); I – *Remaniella duranddelgai* Pop (sample IT-142); **J** – *Tintinnopsella subacuta* (Colom) (sample IT-143); **K, L** – aberrant (thin-walled) and deformed calpionellid loricas in upper part of the Oblonga Subzone (sample IT-143)
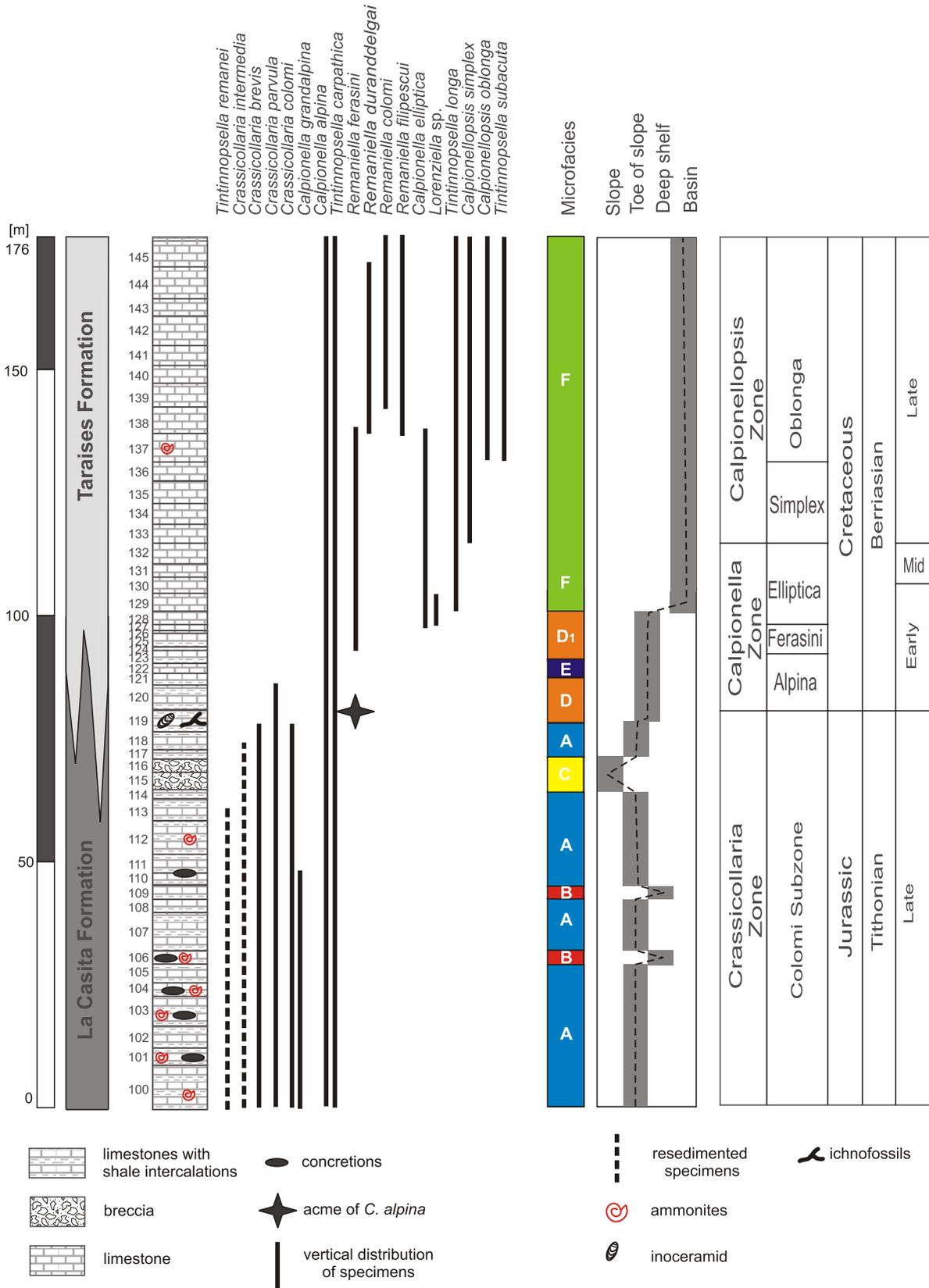
Fig. 9. Lithological log with calpionellid occurrences and proposed calpionellid biostratigraphy in the Iturbide section

sic to a more contrasted (warm to dry) climate in the Cretaceous. This palaeoclimate change and the installation of a clear open marine connection between the Gulf of Mexico and the Tethys (*sensu* Adatte et al., 1996a) is also visible in the section studied herein (facies changes recorded between samples IT-119 and IT-120) just at the Jurassic/Cretaceous boundary.

Upwards in the section, calpionellids increase in abundance and their diversification allows the recognition of all successive calpionellid subzones. The Ferasini and the Elliptica subzones of the standard Calpionella Zone were easily determined by the FO´s of their zonal markers: *Remaniella ferasini* Catalano and *Calpionella elliptica* Cadish, respectively. A short-term sea level change is recorded within the Elliptica Subzone (calpionellid diversification) and can be correlated with LBZ-1, 1.5 from Haq et al. (1988), and is also in agreement with the results of Adatte et al. (1996a) and Reháková (1998). Afterwards, until the end of the section, the palaeobathymetry stayed without distinctive changes.

The Iturbide section can be correlated with the Apulco section (López-Martínez et al., 2013). In both sections Crassicollaria Zone is represented only by the Colomi Subzone. The Jurassic/Cretaceous boundary in both sections occurs in the transition of two coeval geological formations; La Casita-Taraises in northern Mexico, and Pimienta-Tamaulipas in central Mexico. The only difference between both sections is the appearance of the Simplex Subzone in the Iturbide section while it was not possible to define in the Apulco section possibly due to resedimentation processes.

Calpionellid biozones can be correlated in northern and central Mexico without significant differences and with European biozonations. This observation is counter to the conclusions of the previous work of Pessagno et al. (2009). We have no evidence from the sections studied that show a diachronous appearance of calpionellids between the Mediterranean Tethys and Mexico (at least in the sections studied). It is worth noting a difference in the definition of diachronism between formations and the Jurassic/Cretaceous boundary. In Mexico, due to active tectonics, geological formations are mainly diachronous, even between nearby areas. This, though, does not prove diachroneity in the appearance of calpionellids or of the Jurassic/Cretaceous boundary, which is a time plane and so cannot be diachronous. On the other hand, the presence of one or another formation in this interval only reflects the sedimentary conditions that can change from one basin to another at different times. The main problem about the use of calpionellids for biostratigraphical purposes in Mexico are focused on the determination of two main species: *Calpionella alpina* Lorenz and *Calpionella elliptica* Cadish. The determination of *Calpionella alpina* is very easy, but the correct differentiation between elliptical forms of *Calpionella alpina* and real *Calpionella elliptica* is difficult in some intervals due to the similarity of both forms (see Fig. 7M, N).

CONCLUSIONS

The vertical distribution of calpionellids in the Iturbide section is slightly different from those described elsewhere for the rest of the Tethyan region. The section was divided on the basis of calpionellid bioevents into three major biozones and their corresponding subzones. The calpionellid record spans from the Crassicollaria Zone (Colomi Subzone) at the top of the La Casita Formation to the Calpionellopsis Zone (Oblonga Subzone) at the end of the stratigraphic section within the Taraises Formation. Microfacies of the Crassicollaria Zone rich in siliceous microplankton (radiolarians), and spicules were replaced by calcareous oozes in which nannofossils and calpionellids dominated in the Oblonga Subzone.

The Jurassic/Cretaceous boundary was determined by the acme of *Calpionella alpina* Lorenz, and was placed near the transitional contact between the La Casita and Taraises formations. A sea level fall, associated with the deposition of breccias in the upper part of the Crassicolaria Zone, marks a horizon that can be correlated with coeval sections of the eastern Tethys and with the Huizachal section of northeastern Mexico. This sea level fall fits within the global eustatic curve. A sea level rise was interpreted within the Elliptica Subzone and remains throughout the rest of the section.

Future works will clarify some aspects, such as the diachroneity in the transition between the La Casita and Taraises formations.

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