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Facies distribution patterns and environment interpretation of the Upper Láncara Formation in the Esla Nappe (Cantabrian zone, NW Spain) by quantitative microfacies analysis

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with 6 figures, 3 appendices and 1 plate

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Abstract

The microfauna of the carbonatic Upper Láncara Formation in the Esla Nappe (Cantabrian zone, NW-Spain) is described in detail and discussed in respect to biofacies and palaeoecology for the first time. For it, thin-sections were undergone bio- and lithofacial investigations. The here represented data on point-counting exhibit the first quantitative biofacies values for the vertical succession of the Upper Láncara Formation. The curves of faunal distribution show clear trends in the development of the biofacies. The microfauna reveal three biofacies associations which allow a palaeoecological interpretation.

The deposition of the Lower Láncara Formation took place on a southwest-tilted, carbonate-dominated homoclinal ramp, influenced by siliciclastic input from the northeast. Oolitic-bioclastic packstones indicate the existence of an oolitic shoal in the northeast. This shoal supplied oolites to the distal environment, and protected the distal areas from siliciclastic input. Due to a rising sea-level during the Upper Láncara time, the sedimentation belts shifted to proximal areas of the shelf and the oolitic shoal were drowned. Subsequently, the drowned shoal was invaded by echinoderms. The high abundance of echinoderm ossicles created the so-called Beleño facies. Toward the top of the Upper Láncara Formation, a gradual change from the echinoderm-dominated fauna to a trilobite and brachiopod dominated fauna can be observed. The here occurring lithotypes are typic for the so-called Barrios facies. The constant thickness of that facies over the whole working area and the same faunal succession in the investigated sections suggest a deposition under similar bathymetric conditions. An increase of siliciclastic material leads to the development of a mixed carbonate-siliciclastic ramp. This sedimentary turnover mirrors the general drowning process of the depositional environment.

Zusammenfassung

Die Mikrofauna der karbonatisch ausgebildeten Oberen Láncara Formation innerhalb der Esla Decke (Kantabrische Zone, NW-Spanien) wird erstmals hinsichtlich ihres biofaziellen und paläoökologischen Charakters detailliert beschrieben und diskutiert. Hierfür wurden Dünnschliffe bio- und lithofaziell analysiert. Die hier präsentierten Pointcounting-Daten stellen die ersten qualitativen Biofazieswerte für den Sedimentations-verlauf der Oberen Láncara Formation dar. Die erstellten Faunenverteilungskurven zeigen deutliche Trends in der vertikalen Entwicklung. Die Mikrofauna ist durch drei Faunenvergesellschaftungen charakterisiert, anhand derer paläoökologische Interpretationen möglich sind.
Der Ablagerung der Unteren Láncara Formation erfolgte auf einer nach SW-einfallenden, karbonatisch dominierten homoklinalen Rampe, welche durch von NE eintretende siliciklastische Schüttungen beeinflusst wurde. Oolithic-bioclastic packstones deuten auf die Existenz einer Ooid-Barre im NE hin, welche Ooide in distale Gebiete schüttete und die distalen Bereiche von siliciklastischem Eintrag abschirmte. Während eines kontinuierlichen Meeresspiegelanstiegs zur Zeit der Oberen Láncara Formation kam es zur Verlagerung der Sedimentationsgürtel in proximale Schelfbereiche. Dies führte zu einer Deaktivierung und Absenkung der Ooid-Barre, welche nun von Echinodermen besiedelt wurde. Echinodermenschüttungen führten zur Ausbildung der so genannten Beleño Fazies. Zum Top der Láncara Formation werden die Echinodermen zunehmend durch Trilobiten und Brachiopoden verdrängt. Die damit assoziierten Lithotypen sind charakteristisch für die so genannte Barrios Fazies. Gleiche Mächtigkeiten über das gesamte Arbeitsgebiet und gleiche Faunenzusammensetzung innerhalb der untersuchten Profile deuten auf eine Ablagerung unter gleichen bathymetrischen Bedingungen hin. Der Anstieg des siliciklastischen Eintrags führte zur Anlage einer gemischt karbonatisch-siliciklastischen Rampe. Diese sedimentäre Umstellung spiegelt das generelle Absinken des Sedimentationsraumes wider.

1 Introduction

On the Iberian Peninsula, Cambrian rocks are mostly distributed in the Iberian Massif, but they also occur in the cores of several Alpidic domains (Iberian Chains, Catalonian Coastal Ranges and Pyrenees). Because of sedimentological and structural peculiarities of some sub-regions, the Iberian Massif was formally separated by LOTZE (1945) into six zones (Fig. 1a):

(1) Cantabrian zone,
(2) West Asturian-Leonese zone,
(3) Galician-Castilian zone,
(4) East Lusitanian-Alcudian zone,
(5) Ossa Morena zone and
(6) South Portuguese zone.

Only the last mentioned zone is characterised by the absence of Cambrian outcrops.

The first biostratigraphic classification of the Spanish Cambrian was done by LOTZE and SDZUY (in LOTZE, 1961). During the following years, increased knowledge led to numerous modifications (mainly based on studies by SDZUY). Today, the Lower Cambrian of Spain is subdivided into four regional stages (Cordubian, Ovetian, Marianian, Bilbilian, Fig. 2) based on trilobites, archaeocyaths, and trace fossils as well as, locally, on acritarchs (PALACIOS & VIDAL, 1992; LIÑÁN et al., 1993; PEREJÓN, 1994). Based on trilobites, the Middle Cambrian is divided into three stages (Leonian, Caesaraugustian, Languedocian, Fig. 2; LIÑÁN et al., 1993; PEREJÓN, 1994; ÁLVARO & VIZCAÏNO, 1998).
A biostratigraphic classification of the Láncara Formation as well as the fixation of their boundaries in general is difficult. Archaeocyaths described from the lower part of the Láncara Formation by DEBRENNE & ZAMARREÑO (1970) and PEREJÓN (1994) represent an uppermost Lower Cambrian age. According to ZAMARREÑO (1972) the Beleño facies is located beneath the *Acadolenus* zone (middle and upper Leonian), SDZUY & LIÑÁN (1993) postulated that the upper part of the Láncara Formation represents the *Acadolenus* zone, which overlays the zone of *Eoparadoxides mureroensis* (Fig. 2).
The Cambrian of the Cantabrian zone (in which the Esla Nappe is situated, Fig. 1b) consists of a carbonate succession (Láncara Formation) sandwiched between siliciclastic deposits below (Herrería Formation) and above (Oville Formation, Fig. 3). As identified by SDZUY (1974) the boundaries between these units are diachronic. The Herrería Formation (Neoproterozoic? - Lower Cambrian) consists of a succession of 500 m to 1700 m of

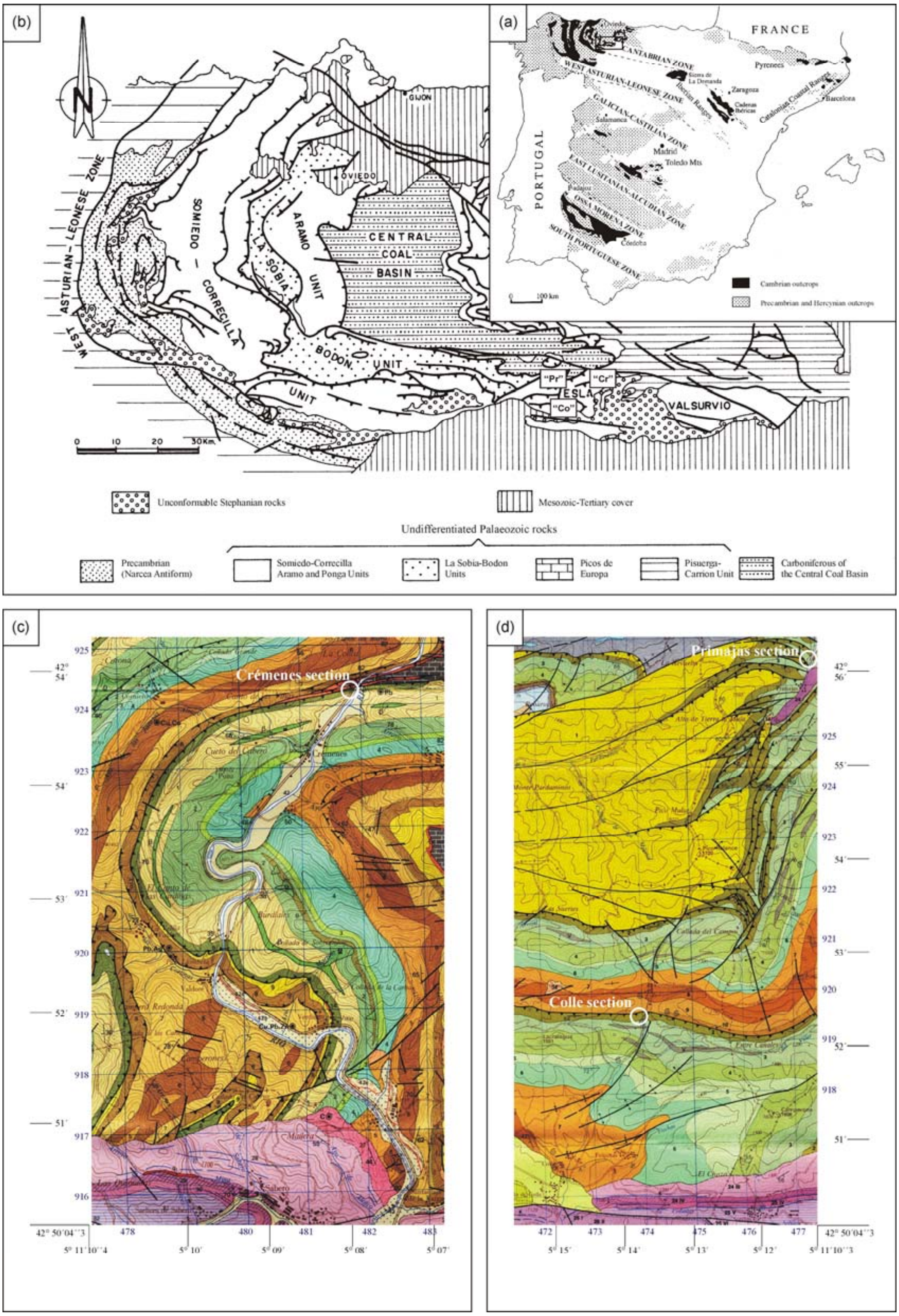

Fig. 1: (a) Simplified geological map of the Iberian Peninsula (modified after LIÑÁN et al., 2002); marked is the area of interest. (b) Generalised geological map of the Cantabrian zone (modified after PÉREZ-ESTAÚN et al., 1988); "Co" = Colle section; "Cr" = Crémenes section; "Pr" = Primajas section. (c) Detail of the geological map Riaño (modified after ALONSO et al., 1991); marked is the Crémenes section. (d) Detail of the geological map Boñar (modified after ALVAREZ et al., 1984); marked are the Colle section and the Primajas section.

claystone, sandstone and conglomerate. Sometimes, intercalations of carbonates were detected. The depositional environment of this lithosome is interpreted by different authors as a shallow-marine platform, on which deltaic environments were punctuated by intertidal and fluvial episodes (RUPKE, 1965; VAN DEN BOSCH, 1969; VAN STAALDUINEN, 1973; CRIMES et al., 1977; VAN DER MEER MOHR, 1983; TRUYOLS et al., 1990; RODRÍGUEZ FERNÁNDEZ et al., 1991; ARAMBURU et al., 1992). The Láncara Formation overlies the Herrería Formation conformably and consists of two members, different in fossil content and lithological characteristics. The Lower Láncara Formation (100-220 m) is represented by yellow dolomites and grey (dolomitic) limestones, partly rich in algal mats, fenestral fabrics and oolites. The Upper Láncara Formation (up to 40 m thick) is subdivided into two facies-types. The basal Beleño facies consists of sparry (dolomitic) limestone, including a high content of disarticulated echinoderms and glauconite. This facies is overlain by reddish to purple nodular limestone of the Barrios facies, which is characterised by a diverse fauna and a high fossil content. The following Oville Formation consists of claystone and sandstone without any carbonate content.

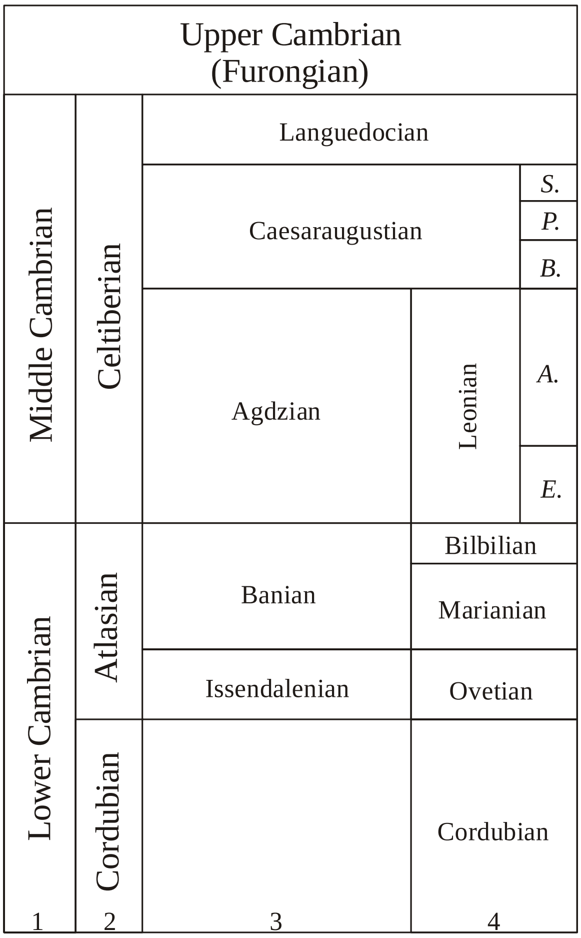

Fig. 2: Biostratigraphic scheme of the Iberian Cambrian. (1) epochs. (2, 3) Western Gondwana composite scale. (4) Iberian regional scale. (E.) *Eoparadoxides mureroensis* zone. (A.) *Acadolenus* zone. (B.) *Badulesia* zone. (P.) *Pardailhania* zone. (S. *Solenopleuropsis* zone. Modified after GEYER & LANDING (2004) and LIÑÁN et al. (1996); for discussion of the problematic correlation of the Lower-Middle Cambrian boundary see GEYER & LANDING (2004).

The Esla Nappe, the working area to which this paper is referred, is located on the southern margin of the Cantabrian zone (Fig. 1b). According to COMTE (1959) and DE SITTER (1959) the complete Palaeozoic succession is represented in this area. Following these authors, the sedimentation took place on a platform, resulting in a Cambrian to Carboniferous sequence of a thickness of 3-5 km. As a result of a low-angle Upper Devonian unconformity these strata thin towards northeast (ALONSO, 1982; 1987). According to RUPKE (1965) and ALONSO (1987) the Esla Nappe is characterised by a development of three major thrust sheets and three duplexes, which led to a distinct shortening and displacement of about 90 km as well as to a replication of parts of the stratigraphic sequence up to three times.
A peculiarity of the Cambrian succession within the Esla Nappe area is an exceptional development of the Lower Láncara Formation. Only here this portion contains archaeocyathan buildups. They were found in the uppermost part and yield the archaeocyathan species *Pycnoidocyathus erbiensis* and *Archaeocyathus laqueus* (DEBRENNE & ZAMARREÑO, 1970; PEREJÓN & MORENO-EIRIS, 2003) as well as diverse calcimicrobes.
Investigation of the Cambrian of the Cantabrian zone has been limited. ZAMARREÑO (1972) studied 56 sections in the whole Cantabrian Mountains, focussed exclusively on the lithological evolution, while biofacies aspects were not considered. Until present time, only stratigraphic relevant taxa (mainly archaeocyaths and trilobites) were documented, whereas the knowledge on the microfauna is still relatively low.

In this report, details on microfacies of the carbonate succession of the Láncara Formation are presented for the first time. The paper is focussed on the microfauna of the Upper Láncara Formation from the Esla Nappe. Appearance and palaeobiology of its microfaunal content are researched. On the basis of this information, sedimentary environments are reconstructed. A more detailed view on the lithotypes of the Lower Láncara Formation and Oville Formation are not in the scope of this paper.

2 Lithological characteristics of the Upper Láncara Formation in the Esla Nappe area

Three sections of the Upper Láncara Formation were intensively sampled. Their lithological successions are described here. Some reference-samples were taken from the Lower Láncara Formation, too.

The ***Crémenes section*** is located about 500 m north of Valdoré village on the road between the localities Cistierna and Riaño (Fig. 1c). This locality was described by ÁLVARO et al. (2000) in respect to the sedimentary facies. The ***Colle section*** (Fig. 1d) is situated along the road from Vozmediano to Colle, 200 m south of Vozmediano village. Both sections are already mentioned by ZAMARREÑO (1972). The ***Primajas section*** is situated north of the previews section, near the Primajas village (Fig. 1d). This locality is characterised by the so called Primajas duplex and was also described by ZAMARREÑO (1972).

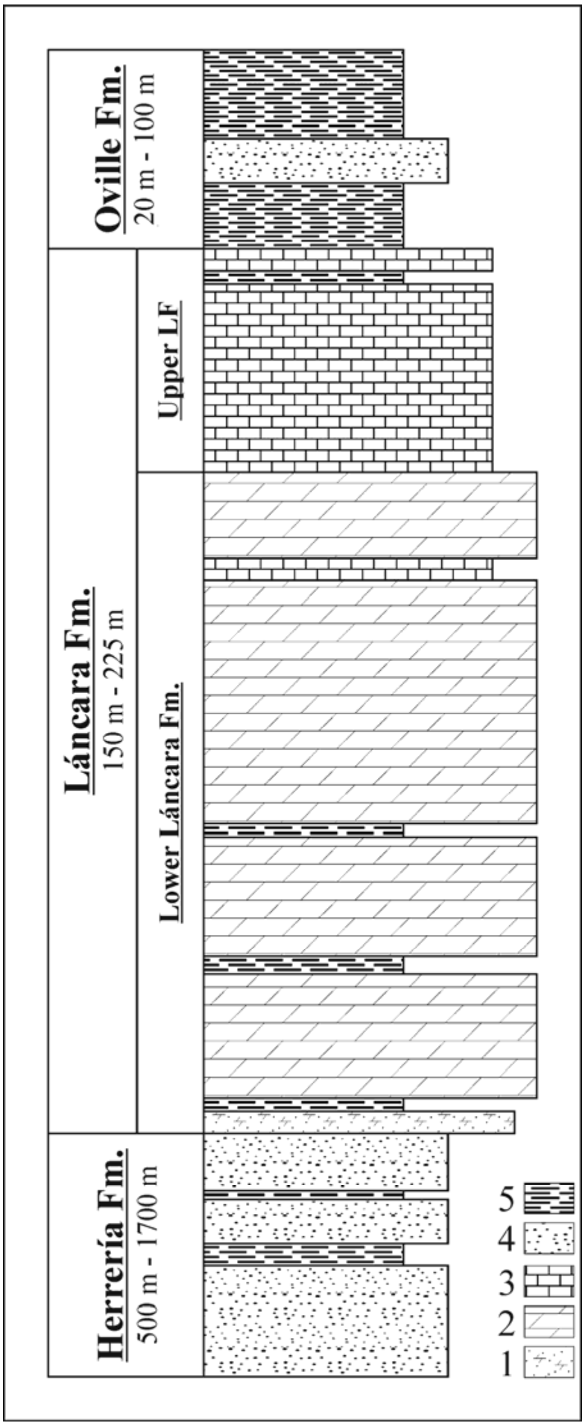

Fig. 3: Simplified stratigraphic column of the Cambrian in the Cantabrian Mountains. Legend: (1) dolomitic sandstone, (2) dolomite, (3) limestone, (4) sandstone, (5) claystone.

In all mentioned sections the transition from the Lower to Upper Láncara Formation is exposured. The boundaries to the siliciclastics of the underlying Herrería Formation and the overlaying Oville Formation are not exposed. But, the latter transition is mostly recognisable by typic changes of the vegetation (Pl. 1/1).

The lithological succession of the Upper Láncara Formation is well comparable in all of the researched sections. Differences, however, exist in the development characteristics of the Lower Láncara Formation. At the Crémenes section the Lower Láncara Formation starts with grey massive dolomites which are overlain by laminated, fine-crystalline dolomites. The lamination of this lithotype is interpreted as due to algal mats. Fenestral fabric is typical for this part of the section. Above, 12 m of oolitic-bioclastic packstone follows, which is characterised by a distinct cross-stratification as well as by an extensive pseudosparitic recrystallisation. The diameter of the ooids ranges between 0.1 mm and 1 mm, whereas the latter is quite common. The fossil content consists of trilobites, brachiopods, echinoderms, chancellorids, and hyoliths. The three latter faunal groups are sometimes preserved as glauconite pseudomorphs. After 11 m, a intercalation of 1.60 m of claystone is observable. This portion is characterised by the absence of any fossil content and sedimentary structures.

A similar lithological succession occurs in the Primajas section, where only a small part of the Lower Láncara Formation crops out. The lowermost exposed portion is represented by an alternation of laminated dolomites and claystones. The claystone intercalations range from 0.5 m to 2 m in thickness. Toward the top of the dolomites, an increased content of reworked lithoclasts, bioclasts and pellets is recognised (Pl. 1/3). The components are overgrown by calcimicrobes. The oolitic part of this section has a thickness of about 2.50 m. Its lithological development is similar to the Crémenes section and characterised by an increase of the faunal content to the top.

The lowermost exposed stratum of the Lower Láncara Formation of the Colle section is a fine-crystalline, laminated dolostone, which is characterised by fenestral fabric. Following that, 3.70 m of grey-weathering, cross-bedded, oolitic-bioclastic packstone occurs. In contrast to the former localities, here, siliciclastic intercalations are absent.
Above the oolitic interval, all the studied sections show an abrupt onset of granular-crystalline, glauconitic, grey to roan bioclastic wackestones and bioclastic packstones of the Beleño facies of the Upper Láncara Formation (Figs. 4-6). The fossil content of this facies is distinctly dominated by echinoderm debris which results in a typical sparry feature of this lithotype (Pl. 1/4, 5). The Beleño facies passes continuously into the Barrios facies. The transition is characterised by a change in the fossil content (see above), and by an increase in siliciclastic material, which is accumulated now in mm- to cm- bands of insoluble material originated by pressure solution processes. This increase in siliciclastics is accompanied by a colour change from roan to red and violet-brown. The thickness of the Upper Láncara Formation is nearly equal in all the studied sections. At Crémenes and Colle, the carbonate portion reaches about 33 m, whereas the Primajas section is characterised by more than 36 m of Upper Láncara limestones.
Generally, the limestones of the Upper Láncara Formation are rich in matrix, which was primary micritic, but diagenetically recrystallised into microsparite. Only few abiogenous components are observed. These are mainly represented by clay minerals and pyrite, showing dispersion or a nest-like enrichment. Small, subangular quartz-grains were also found. Clay minerals are diffuse and dispersed or accumulated in residual-layers, caused by pressure solution. In contrast to the carbonates of the Barrios facies, the Beleño facies shows a lesser amount of clay minerals, so that diagenetic pressure solution structures are less common and limestone nodules did not formed.

3 Quantitative microfacies analysis

The biofacies of the Upper Láncara Formation were investigated by point-counting analysis on thin-sections. According to FLÜGEL (1978, 2004), to provide an accurate measurement, the number of counts per thin-section should be ranged between 300 and 500. Therefore a regular orthogonal grid with a raster width of 0.3 mm and 368 grid points was laid on each thin-section. The following fossil groups were counted:

- echinoderms,
- trilobites,
- brachiopods,
- chancellorids,
- hyoliths, poriferids, and
- spheroid problematics (App. 1-3).

Every component corresponding to a grid point was counted. The results of this analysis were compared with the chart of VAN DER PLAS & TOBI (1965). By plotting the total number of counted points and those of each faunal group into this chart, an average standard derivation of 2 s = 4 % up to 5 % was determined. Measurements with raster widths of 0.2 mm and 0.25 mm led to similar results. Thus, documentation using the raster of 0.3 mm can be considered as sufficiently exact.
Based on the counted thin-sections (Crémenes = 26, Colle = 30, Primajas = 46), a distinct variation pattern of the vertical faunal succession is observable (Figs. 4-6, App. 1-3): so, the Beleño facies is characterised by a predominance of echinoderms, which decrease from the bottom to the top. The base of the Beleño facies shows a relatively constant amount of echinoderms. The portion of this remains ranges between 30 % (Colle section) to 47 % (Primajas section). The amount on trilobites and brachiopods is much lower (each group between 9 % and 24 %), but increasingly upward. The different thicknesses of the mentioned portion of the successions are interesting: whereas in the Colle section the echinoderm-rich part is only about 1 m thick, an increase in thickness to the northeastern localities is observable (about 2.5 m in the Primajas section and 5.5 m in Crémenes).
Toward the top of the Upper Láncara Formation a gradual decrease in echinoderms can be observed. In the Crémenes section (Fig. 4) the decrease in echinoderms runs continuously, whereas in the other sections (Figs. 5 & 6) an occasional rise is observable (peaks up to 34 % are not unusual). In contrast to the decreasing echinoderm content, the trilobites and brachiopods show an increase: the Colle section is characterised by an increase of both fossil groups in destination to the top from 14 % to 37 % (trilobites), and respectively from 14 % to 21 % (brachiopods; both values were measured on sample Co 5 and on Co 29). In the Crémenes and Primajas sections, the increase of trilobites and brachiopods is not constant, but shows strong fluctuations in both

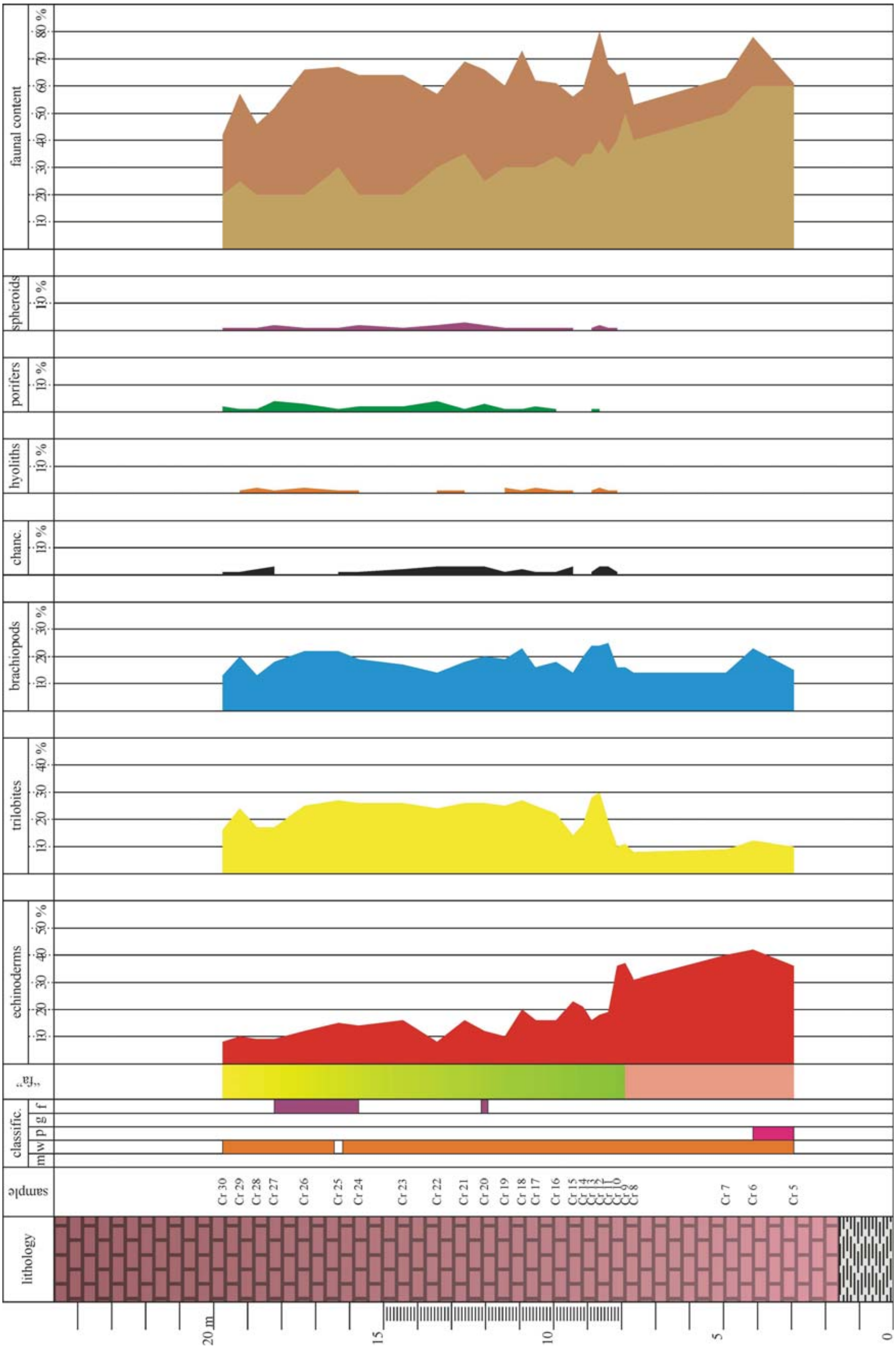

Figure 4: Faunal distribution patterns in the Upper Láncara Formation of the Crémenes section; for legend see (Fig. 5).

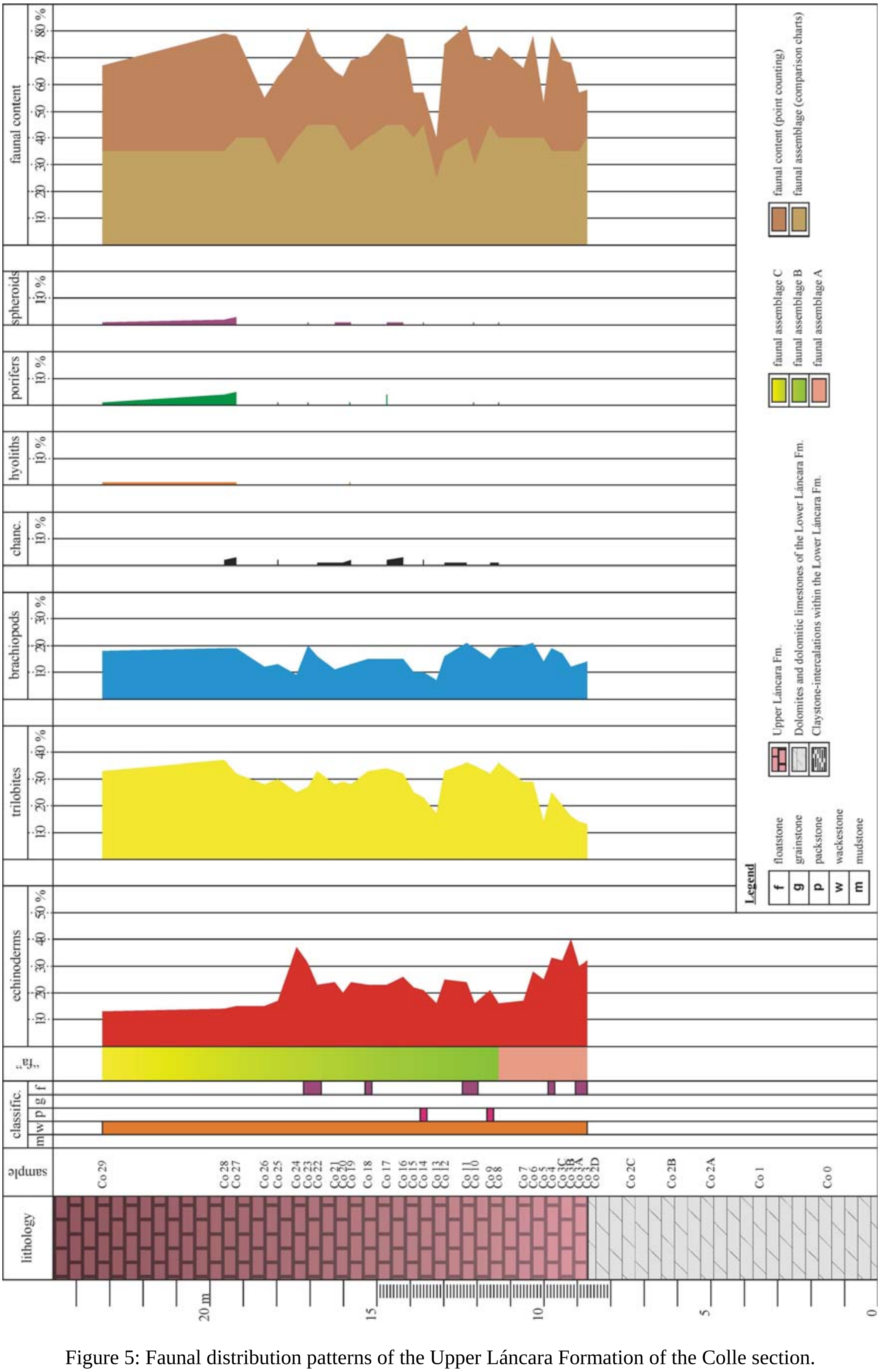

Figure 5: Faunal distribution patterns of the Upper Láncara Formation of the Colle section.

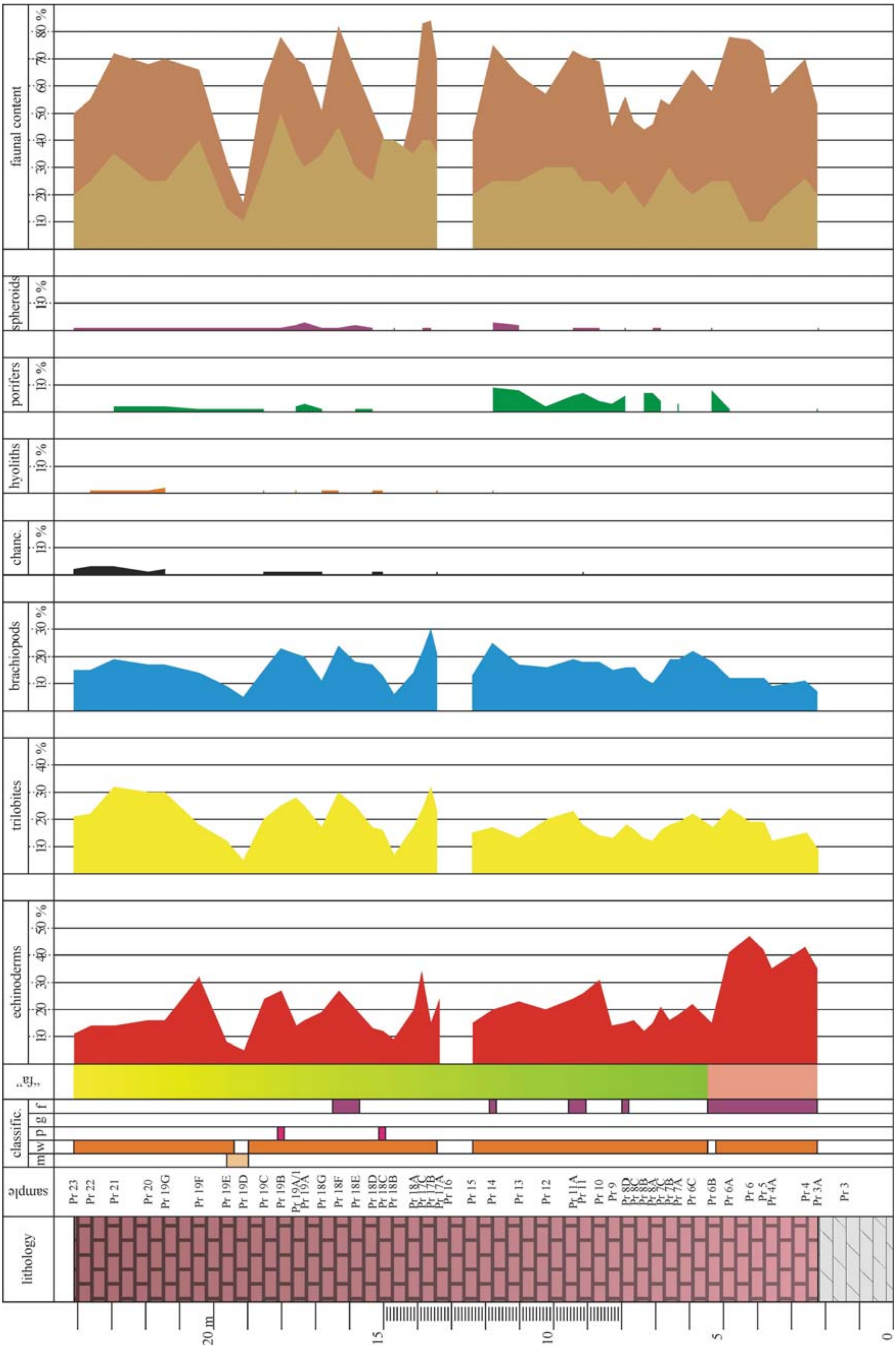

Figure 6: Faunal distribution patterns of the Upper Láncara Formation of the Primajas section; for legend see (Fig. 5).

groups. These changes are mostly similar: an increase or decrease in the content of trilobites results in an equally directed change in the brachiopod content. The first fluctuates between 5 % and 35 % in the Primajas section, and between 14 % and 30 % in the Crémenes section. The content in brachiopods varies between 13 % and 25 % (Crémenes) and between 5 % and 30 % (Primajas). In all mentioned sections chancellorids, molluscs and poriferids are clearly minor constituents. Whereas these groups are present in the whole Crémenes section and in parts of the Primajas section, they were rarely found at Colle.

4 Biofacies successions

The faunal content can be subdivided into several faunal assemblages (Figs. 4-6). The lower part of the Upper Láncara Formation is represented by sparitic, glauconite-rich, reddish to crimson echinoderm-trilobite-brachiopod packstones and echinoderm-trilobite-brachiopod wackestones. These lithotypes characterise the "faunal assemblage A". The beginning of "faunal assemblage B" is marked by the abrupt decline in echinoderms, while the content of trilobites and brachiopods increases. This faunal turnover is accompanied by a lithological change to trilobite-echinoderm-brachiopod wackestones. "Faunal assemblage B" continues upward into "faunal assemblage C", where the fossil groups are dominated by brachiopods and especially by trilobites. This faunal association continues until the onset of the siliciclastic Oville Formation.

Lithotypes represented by the last two faunal assemblages are characterised by a chaotic orientation of the fossils, suggesting an intensive bioturbation. This bioturbation is observable on deposit surfaces as well as within thin-sections (Pl. 1/6). The uppermost part of the Upper Láncara Formation shows a high percentage of broken fossils but also of complete large brachiopod valves and trilobites. The predominating lithotype of the faunal assemblages "B" and "C" are (i) trilobite-echinoderm-brachiopod wackestons to trilobite-echinoderm-brachiopod floatstones and (ii) trilobite-brachiopod-echinoderm wackestones to trilobite-brachiopod-echinoderm floatstones, or (iii) floatstones, with lesser amounts on broken fossil remains. Near the transition to the Oville Formation the lithotypes show a high amount on siliciclastic material or they alternate with crimson to greenish claystones.

Fluctuations in the content of trilobites and brachiopods, as described above, are possibly caused by moderate water currents. Indices for certain currents are given by the often observable curved-up-position of brachiopods as well as by cone-in-cone-stacking of some hyoliths (Pl. 1/8).

5 Reconstruction of the environment and discussion

Interpreting the data presented herein, important new arguments result for the reconstruction of the depositional environment of the Esla Nappe Cambrian.

The siliciclastic intercalations within the Lower Láncara Formation decline in thickness from the northeastern situated Crémenes section to the westward located Primajas section and disappear totally to the southwestern Colle section. Assuming that the stratigraphic succession was shortened for about 90 km and displaced by tectonic processes as postulated by RUPKE (1965) and ALONSO (1987) (see above), clear distal *versus* proximal positions within the Lower Láncara Formation can be distinguished: the Crémenes section represents a proximal position whereas the Colle section reflects distal conditions. Thus, the source area of the siliciclastic material must be located northeast of the Crémenes section. The oolitic-bioclastic packstones, in which the siliciclastics were intercalated, indicate the existence of an oolitic shoal. This shoal supplied oolites to the distal environment and protected also the distal areas from siliciclastic input. A similar interpretation of the environment of the Lower Láncara Formation was suggested by ÁLVARO et al. (2000). These authors postulated a southwest-tilting carbonate ramp with shoals in the northeast. Within the protected back-shoal environment archaeocyathan-calcimicrobial mounds developed. These buildups disappear to the southwestern of the Esla Nappe area (ÁLVARO et al., 2000).

In all the studied sections, the oolitic limestones are overlain by echinoderm-rich carbonates of the Beleño facies. In consideration to a continuous increase of the sea-level, the sedimentation belts shifted to the proximal areas of the shelf and the oolitic shoal was drowned leading to a stop of ooid production. Subsequently, the drowned shoal was settled by echinoderms, so that we interpret the echinoderm-rich facies as a facies-changed continuation of the former oolitic shoal - now as a swell - within a deeper environment. This interpretation is further supported by the different thicknesses of the Beleño facies within the investigated sections. As described above, the Crémenes section is characterised by a 5.5 m-thick layer of the echinoderm-rich limestone, whereas at Primajas locality only about 2.5 m of this lithotype are represented. Within the Colle section the thickness of this layer decreases to only about 1 m. This horizon indicates a distal position of the Colle section and a proximal position of Crémenes on a more or less homoclinal ramp.

Toward the top of the Upper Láncara Formation, the continuous transition from an echinoderm-dominated fauna (Beleño facies) to a trilobite and brachiopod dominated one (Barrios facies) is indicated. The latter facies is associated with a successive increase in the siliciclastic content. The thickness of the Barrios facies at Colle is 32 m, at Primajas about 33.5 m and at Crémenes about 27.5 m. The faunal succession and the nearly constant thickness suggest that the Barrios facies was deposited at these localities under same bathymetric conditions. ÁLVARO et al. (2000) interpreted the Barrios facies of the Láncara Formation as "a mixed deposition on tectonically induced highs and lows". This interpretation is based on the lithologic succession of several sections of the Crémenes area. The detailed microfacies analysis presented here as well as the investigation of additional sections elsewhere in the Esla Nappe area allow for the first time for that region the interpretation of the Lower-/Middle Cambrian biofacies evolution given above. Because of the similarity of the biofacies successions and of the lithofacies characteristics in each of the investigated sections, a transition of the ramp into a carbonate platform environment with significant morphology (ARAMBURU et al., 1992) can not be confirmed. The nearly same thickness as well as the equal biofacies distribution patterns within the researched sections, point to a more or less constant progress of the sea-level rise. Therefore, the sedimentation belts shifted further proximal, resulting in some same thickness of the Barrios facies. According to this, the sediments of the Láncara Formation represent a diachrone succession as described by SDZUY (1974). The increase of siliciclastic material leads to a development from a carbonatic homoclinale ramp to a mixed carbonate-siliciclastic ramp environment. Furthermore, the large siliciclastic content of the Barrios facies (higher Upper Láncara Formation) and the greenish clay- and siltstone layers at the transition to the Oville Formation point to a successive drowning of the ramp.

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References

ALONSO, J.L. (1982): Una nueva discordancia pre-"leónica" fosilizando el manto del Esla (Cordillera Cantábrica). - Trabajos de Geología, Universidad de Oviedo, 12: 83-92.

ALONSO, J.L. (1987): Sequence of thrusts and displacement transfer in the superposed duplexes of the Esla Nappe Region (Cantabrian Zone, NW Spain). - Journal of Structural Geology, 9 (8): 969-983.

ALONSO, J.L.; ALONSO HERRERO, E.; ALVAREZ VÁZQUEZ, C.; BARBA, P.; CUESTA, A.; GALÁN, L.; GALLASTEGUI, G.; FERNÁNDEZ, L.P.; HEREDIA, N.; HORVATH, V.; MATAS, J.; MONTESINOS, R.; PANIAGUA, A.; PEVIDA, L.; RODRÍGUES FERNÁNDEZ, L.R.; Suárez Rodríguez, A. & VILLA, E. (1991): Mapa Geológico de España, E. 1/50.000, 2a serie, no. 105 (Riaño). - ITGE Press., Madrid: 1-182.

ALVAREZ, J.; ARBIZU, M.A.; GARCÍA-ALCALDE, J.L.; GARCÍA-LÓPEZ, S.; LOBATO, L.; MARTÍNEZ-CHACÓN, M.L.; MÉNDEZ BEDIA, I.; MÉNDEZ-FERNÁNDEZ, C.A.; MENÉNDEZ, J.R.; RODRÍGUES FERNÁNDEZ, L.R.; SÁNCHEZ DE POSADA, L. & SOTO, F. (1984): Mapa Geológico de España, E. 1/50.000, 2a serie, no. 104 (Boñar). - ITGE Press., Madrid: 1-77.

ÁLVARO, J.J. & VIZCAÏNO, D. (1998): Révision biostratigraphique de Cambrien moyen de versant méridional de la Montagne Noire (Languedoc, France). - Bull. Soc. Geol. France, 169 (2): 233-242.

ÁLVARO, J.J.; VENNIN, E.; MORENO-EIRIS; E.; PEREJÓN; A. & BECHSTÄDT, T. (2000): Sedimentary patterns across the Lower-Middle Cambrian transition in the Esla nappe (Cantabrian Mountains, northern Spain). - Sedimentary Geology, 137: 43-61.

ARAMBURU, C. & GARCÍA-RAMOS, J.C. (1993): La sedimentación cambro-ordovícica en la Zona Cantábrica (NO de España). - Trabajos de Geología, Universidad de Oviedo, 19: 45-73.

ARAMBURU, C; TRUYOLS, J.; ARBIZU, M.; MÉNDEZ-BEDIA, I.; ZAMARREÑO, I.; GARCÍA-RAMOS, J.C.; SUAREZ DE CENTI, C. & VALENZUELA (1992): El Paleozoico Inferior de la Zona Cantábrica. In: GUTIÉRREZ MARCO, J.C.; SAAVEDRA, J. & RÁBANO, I. (eds.), Paleozoico Inferior de Ibero-América. Universidad de Extemadura: 397-421.

BACCELLE, L. & BOSELLINI, A. (1965): Diagrammi per la stima visiva della composizione percentuale nelle rocce sedimentary. . Ann. Univ. Ferrara, N.S., Sez. IX, Sci. Geol. Paleont, 1 (3): 59-62.

COMTE, P. (1959): Recherches sur les terrains anciens de la Cordillere Cantabrique. - Mems. Inst. geol. min. Esp., 60: 1-440.

CRIMES, T.P.; LEGG, I.; MARCOS, A. & ARBOLEYA, M.L. (1977): Late Precambrian - low Lower Cambrian trace fossils from Spain. In: CRIMES, T.P. & HARPER, J.E. (eds.), Trace Fossils. - Geol. J., Spec. Issue, 9: 91-138.

DEBRENNE, F. & ZAMARREÑO, I. (1970): Sur la découverte d'Archáocyathes dans le Cambrien du NW de l'Espagne. Breviora. - Geol. Asturica, 14: 1-11.

DE SITTER, L.U. (1959): The Rio Esla nappe in the zone of León of the Asturian Cantabric mountain chain. - Notas Comun. Inst. geol. Min. Esp., 56: 3-24.

FLÜGEL, E. (1978): Mikrofazielle Untersuchungsmethoden von Kalken.- Springer Verlag: 454 pp.

FLÜGEL, E. (2004): Microfacies of Carbonate Rocks - Analysis, interpretation and application.- Springer Verlag: 976 pp.

GEYER, G & LANDING, E. (2004): A unified Lower-Middle Cambrian chronostratigraphy for West Gondwana.- Acta Geologica Polonica, 54/2: 179-218.

LIÑÁN, E.; GÁMEZ-VINTANED, J.A. & GOZALO, R. (1996): The Lower and Middle Cambrian series of the Iberian peninsula.- II. Field Conference of the Cambrian Stage Subdivision Working Group.- Spain, 13-21 September.- field trip guide and abstracts: 7-18.

LIÑÁN, E.; PEREJÓN, A. & SDZUY, K. (1993): The Lower-Middle Cambrian stages and stratotypes from the Iberian Peninsula: a revision. - Geol. Mag., 130 (6): 817-833.

LIÑÁN, E.; GOZALO, R.; PALACIOS, T.; GÁMEZ VINTANED, J.A.; UGIDOS, J.M. & MAYORAL, E. (2002): Cambrian. In: GIBBSON, W. & MORENO, T. (eds.), The Geology of Spain, Geological Society, London: 17-31.

LOTZE, F. (1945): Zur Gliederung der Varisciden der Iberischen Meseta. - Geotekt. Forsch., 6: 63-81.

LOTZE, F. (1961): Das Kambrium Spaniens. Teil I: Stratigraphie. - Akademie der Wissenschaften und der Literatur, Abhandlungen der mathematisch-naturwissenschaftlichen Klasse, 1961 (6): 1-216.

PALACIOS, T. & VIDAL, G. (1992): Lower Cambrian acritarchs from northern Spain: the Precambrian-Cambrian boundary and biostratigraphic implications. - Geol. Mag., 192: 421-436.

PEREJÓN, A. (1994): Palaeogeographic and biostratigraphic distribution of Archaeocyatha in Spain. - Courier Forsch.-Inst. Senckenberg, 172: 341-354.

PEREJÓN, A. & MORENO-EIRIS, E. (2003): Arqueociatos del Bilbiliense (Cámbrico Inferior) del manto del Esla, Cordillera Cantábrica, Norte de España.- Bol. R. Soc Esp. Hist. Nat. Sec. Geol., 98 (1-4): 51-71.

PÉREZ-ESTAÚN, A.; BASTIDA, F.; ALONSO, J.L.; MARQUÍNEZ, J.; ALLER, J.; ALVAREZ-MARRÓN, J.; MARCOS, A. & PULGAR, J.A. (1988): A thin-skinned tectonics model for an arcuate fold and thrust belt: the Cantabrian Zone (Variscan Ibero-Armorican Arc). - Tectonics, 7 (3): 517-537.

RUPKE, J. (1965): The Esla nappe, Cantabrian Mountains (Spain). - Leidse Geologische Mededelingen, 32: 1-74.

RODRÍGUEZ FERNÁNDEZ, L.R.; BARBA, P.; BARDAJÍ, T.; BRAVO FERNÁNDEZ, I.; FERNÁNDEZ, L.P.; GALÁN, L.; GALLASTEGUI, G.; GUTIÉRREZ CLAVEROL, M.; HEREDIA, N.; LÓPEZ DÁZ, F.; MARTINEZ ALVAREZ, J.A.; PANIAGUA, A.; SALVADOR GONZÁLEZ, C.; SILVA, P.G.; SUÁREZ RODRÍGUEZ, P.I.; TORRES ALONSO, M.; TOYOS, J.M. & VILLA, E. (1991): Mapa Geológico de España, E. 1/50.000, 2a serie, no. 102 (Los Barrios de Luna). - ITGE Press., Madrid: 1-130.

SDZUY, K. (1974): Mittelkambrische Graptolithen aus NW-Spanien. Paläontologische Zeitschrift, 48 (1/2): 110-139.

SDZUY, K. & LIÑÁN, E. (1993): Rasgos paleogeográficos del Cámbrico Inferior y Medio del norte de España. - Cuad. Lab. Xeol. Laxe, 18: 189-215.

TRUYOLS, J.; ARBIZU, M.A.; GARCÍA ALCALDE, J.L.; GARCÍA LÓPEZ, S.; MÉNDEZ BEDIA, I.; SOTO, F. & TRUYOLS MASSONI, M. (1990): Cantabrian and Palentian Zones; Stratigraphy: The Asturian-Leonese Domain (Cantabrian Zone). In: DALLMEYER, R.D. & MARTÍNEZ GARCÍA, E. (eds.) Pre-Mesozoic Geology of Iberia. - Springer Verlag, Berlin: 10-19.

VAN DEN BOSCH, W.J. (1969): Geology of the Luna-Sill region, Cantabrian Mountains (NW Spain). - Leidse Geologische Mededelingen, 44: 137-225.

VAN DER MEER MOHR, C.G. (1983): The Lower Palaeozoic of the Leonides and Pisuerga-Carrión Province in the Cantabrian zone of northwest Spain. - ITC J., 3: 205-213.

VAN DER PLAS, L. & TOBI, A.C. (1965): A chart for judging the reliability of point counting results. - Amer. J. Sci., 263: 87-90.

VAN STAALDUINEN, C.J. (1973): Geology of the area between the Luna and Torío rivers, southern Cantabrian Mountains, NW Spain. - Leidse Geologische Mededelingen, 49: 167-205.

ZAMARREÑO, I. (1972): Las litofacies carbonatadas del Cámbrico de la Zona Cantábrica (NW de España) y su distribución paleogeográfica. - Trabajos de Geología, Universidad de Oviedo, 5: 1-118.

	points	echinoderms		trilobites		brachiopods		chancellorids		hyoliths		poriferids		problematics		faunal content		
	count.	count.	%	count.	%	count.	%	count.	%	count.	%.	count.	%	count.	%	count.	%	comparison charts [%]
Cr 30	366	29	8	60	16	47	13	4	1	1	0	8	2	4	1	153	42	20
Cr 29	355	35	10	84	24	72	20	2	1	3	1	3	1	2	1	201	57	25
Cr 28	351	30	9	61	17	46	13	8	2	6	2	5	1	4	1	160	46	20
Cr 27	368	32	9	64	17	65	18	10	3	3	1	13	4	6	2	193	52	20
Cr 26	299	36	12	75	25	65	22	1	0	6	2	10	3	3	1	196	66	20
Cr 25	368	54	15	101	27	80	22	3	1	2	1	2	1	3	1	245	67	30
Cr 24	368	50	14	97	26	69	19	3	1	3	1	8	2	7	2	237	64	20
Cr 23	358	57	16	92	26	61	17	8	2	1	0	6	2	5	1	230	64	20
Cr 22	368	30	8	89	24	52	14	11	3	5	1	14	4	8	2	209	57	30
Cr 21	353	56	16	93	26	65	18	11	3	5	1	3	1	12	3	245	69	35
Cr 20	339	42	12	89	26	68	20	10	3	1	0	9	3	6	2	225	66	25
Cr 19	368	38	10	91	25	71	19	4	1	6	2	4	1	5	1	219	60	30
Cr 18	368	73	20	99	27	83	23	7	2	2	1	3	1	3	1	270	73	30
Cr 17	368	58	16	91	25	58	16	4	1	6	2	6	2	4	1	227	62	30
Cr 16	352	57	16	79	22	63	18	5	1	4	1	2	1	4	1	214	61	35
Cr 15	356	81	23	50	14	51	14	11	3	3	1	0	0	2	1	198	56	30
Cr 14	368	76	21	67	18	72	20	1	0	1	0	0	0	1	0	218	59	35
Cr 13	368	59	16	99	27	88	24	5	1	3	1	3	1	2	1	259	70	35
Cr 12	363	66	18	109	30	87	24	10	3	8	2	3	1	7	2	290	80	40
Cr 11	365	69	19	70	19	91	25	10	3	4	1	1	0	3	1	248	68	35
Cr 10	366	130	36	36	10	58	16	5	1	2	1	0	0	5	1	236	64	40
Cr 9	368	136	37	42	11	59	16	1	0	1	0	0	0	1	0	240	65	50
Cr 8	266	82	31	20	8	37	14	1	0	0	0	0	0	0	0	140	53	40
Cr 7	368	147	40	34	9	50	14	1	0	0	0	0	0	1	0	233	63	50
Cr 6	363	154	42	45	12	83	23	0	0	0	0	0	0	0	0	282	78	60
Cr 5	366	130	36	37	10	55	15	0	0	0	0	0	0	0	0	222	61	60

Appendix 1

	points	echinoderms		trilobites		brachiopods		chancellorids		hyoliths		poriferids		problematics		faunal content		
	count.	count.	%	count.	%	count.	%	count.	%	count.	%.	count.	%	count.	%	count.	%	comparison charts [%]
Co 29	343	46	13	112	33	62	18	1	0	2	1	4	1	2	1	229	67	35
Co 28	349	48	14	130	37	65	19	7	2	3	1	14	4	10	3	277	79	35
Co 27	356	55	15	113	32	66	19	10	3	5	1	17	5	13	4	279	78	40
Co 26	348	51	15	97	28	41	12	1	0	0	0	0	0	0	0	190	55	40
Co 25	368	64	17	109	30	48	13	6	2	1	0	5	1	0	0	233	63	30

Co 24	296	110	37	74	25	26	9	0	0	0	0	0	0	0	0	210	71	40
Co 23	367	115	31	100	27	75	20	1	0	1	0	2	1	5	1	299	81	45
Co 22	368	84	23	121	33	58	16	2	1	0	0	0	0	1	0	266	72	45
Co 21	368	90	24	104	28	42	11	2	1	0	0	0	0	2	1	240	65	45
Co 20	346	70	20	102	29	40	12	2	1	1	0	1	0	2	1	218	63	40
Co 19	356	84	24	100	28	48	13	6	2	3	1	2	1	3	1	246	69	35
Co 18	312	71	23	104	33	46	15	1	0	0	0	0	0	1	0	223	71	40
Co 17	310	71	23	104	34	48	15	5	2	1	0	12	4	3	1	244	79	45
Co 16	287	75	26	92	32	42	15	9	3	1	0	0	0	2	1	221	77	45
Co 15	322	71	22	80	25	33	10	0	0	0	0	0	0	0	0	184	57	40
Co 14	324	68	21	76	23	32	10	7	2	0	0	0	0	2	1	185	57	45
Co 13	353	55	16	61	17	24	7	1	0	0	0	0	0	0	0	141	40	25
Co 12	359	90	25	118	33	59	16	3	1	0	0	0	0	0	0	270	75	35
Co 11	308	75	24	110	36	64	21	3	1	0	0	1	0	0	0	253	82	40
Co 10	336	53	16	116	35	64	19	0	0	0	0	2	1	4	1	239	71	30
Co 9	332	71	21	107	32	50	15	2	1	0	0	0	0	0	0	230	69	45
Co 8A	343	56	16	124	36	65	19	2	1	1	0	4	1	2	1	254	74	40
Co 7	368	61	17	107	29	73	20	1	0	1	0	0	0	0	0	243	66	40
Co 6	367	103	28	107	29	76	21	0	0	0	0	0	0	0	0	286	78	40
Co 5	344	87	25	49	14	48	14	0	0	0	0	0	0	0	0	184	53	40
Co 4	344	115	33	85	25	67	19	0	0	0	0	0	0	0	0	267	78	35
Co 3C	358	113	32	72	20	61	17	0	0	0	0	0	0	0	0	246	69	35
Co 3B	339	135	40	53	16	42	12	0	0	0	0	0	0	0	0	230	68	35
Co 3A	368	112	30	50	14	46	13	0	0	0	0	0	0	0	0	208	57	35
Co 3	368	116	32	49	13	50	14	0	0	0	0	0	0	0	0	215	58	40

Appendix 2

	points	echinoderms		trilobites		brachiopods		chancellorids		hyoliths		poriferids		problematics		faunal content		
	count.	count.	%	count.	%	count.	%	count.	%	count.	%.	count.	%	count.	%	count.	%	comparison charts [%]
Pr 23	365	41	11	76	21	54	15	8	2	1	0	1	0	3	1	184	50	20
Pr 22	344	49	14	75	22	50	15	9	3	2	1	1	0	2	1	188	55	25
Pr 21	316	45	14	101	32	60	19	8	3	4	1	5	2	4	1	227	72	35
Pr 20	343	54	16	102	30	58	17	5	1	3	1	6	2	4	1	232	68	25
Pr 19G	305	48	16	91	30	51	17	5	2	7	2	7	2	4	1	213	70	25
Pr 19F	313	101	32	57	18	44	14	1	0	1	0	2	1	2	1	208	66	40
Pr 19E	364	30	8	45	12	32	9	0	0	1	0	3	1	5	1	116	32	15
Pr 19D	332	18	5	17	5	16	5	0	0	1	0	3	1	2	1	57	17	10
Pr 19C	333	76	23	65	20	49	15	4	1	2	1	4	1	3	1	203	61	30

Pr 19B	325	89	27	82	25	76	23	3	1	1	0	1	0	2	1	254	78	50
Pr 19A/1	202	28	14	57	28	43	21	3	1	2	1	5	2	4	2	142	70	35
Pr 19A	318	50	16	78	25	64	20	3	1	1	0	10	3	9	3	215	68	30
Pr 18G	323	60	19	55	17	37	11	3	1	3	1	4	1	4	1	166	51	35
Pr 18F	321	87	27	95	30	76	24	1	0	2	1	1	0	2	1	264	82	45
Pr 18E	315	62	20	78	25	58	18	0	0	1	0	3	1	6	2	208	66	30
Pr 18D	283	37	13	48	17	47	17	2	1	2	1	4	1	3	1	143	51	25
Pr 18C	352	42	12	55	16	46	13	3	1	2	1	0	0	1	0	149	42	40
Pr 18B	287	26	9	21	7	16	6	1	0	1	0	1	0	2	1	68	24	40
Pr 18A	250	51	20	42	17	36	14	1	0	1	0	0	0	0	0	131	52	35
Pr 17C	186	63	34	47	25	43	23	0	0	0	0	0	0	1	1	154	83	40
Pr 17B	201	31	15	71	35	61	30	1	0	1	0	1	0	2	1	168	84	40
Pr 17A	311	75	24	72	23	64	21	2	1	2	1	0	0	0	0	215	69	35
Pr 16																		
Pr 15	315	46	15	47	15	42	13	0	0	0	0	0	0	0	0	135	43	20
Pr 14	340	69	20	57	17	86	25	1	0	2	1	32	9	9	3	256	75	25
Pr 13	270	62	23	36	13	46	17	1	0	0	0	22	8	5	2	172	64	25
Pr 12	332	65	20	65	20	53	16	0	0	0	0	5	2	0	0	188	57	30
Pr 11A	312	76	24	71	23	58	19	0	0	0	0	18	6	4	1	227	73	30
Pr 11	347	91	26	61	18	63	18	2	1	1	0	25	7	5	1	248	71	25
Pr 10	256	80	31	37	14	45	18	1	0	1	0	9	4	3	1	176	69	25
Pr 9	341	49	14	43	13	50	15	0	0	0	0	10	3	0	0	152	45	20
Pr 8D	267	40	15	49	18	42	16	0	0	1	0	15	6	2	1	149	56	25
Pr 8C	243	39	16	38	16	38	16	0	0	0	0	0	0	0	0	115	47	20
Pr 8B	347	43	12	46	13	40	12	0	0	0	0	25	7	0	0	154	44	15
Pr 8A	318	47	15	39	12	33	10	1	0	1	0	23	7	2	1	146	46	20
Pr 7C	282	58	21	46	16	39	14	0	0	0	0	11	4	2	1	156	55	25
Pr 7B	366	58	16	66	18	69	19	0	0	1	0	0	0	0	0	194	53	30
Pr 7A	356	64	18	67	19	67	19	0	0	0	0	9	3	0	0	207	58	25
Pr 6C	358	79	22	79	22	79	22	0	0	0	0	0	0	0	0	237	66	20
Pr 6B	354	52	15	59	17	62	18	0	0	0	0	28	8	5	1	206	58	25
Pr 6A	310	126	41	73	24	38	12	1	0	0	0	4	1	0	0	242	78	25
Pr 6	339	159	47	63	19	39	12	0	0	0	0	0	0	0	0	261	77	10
Pr 5	342	143	42	66	19	42	12	0	0	0	0	0	0	0	0	251	73	10
Pr 4A	341	120	35	42	12	30	9	1	0	0	0	0	0	0	0	193	57	15
Pr 4	343	149	43	51	15	39	11	0	0	0	0	0	0	0	0	239	70	25
Pr 3A	353	125	35	32	9	24	7	0	0	0	0	2	1	2	1	185	52	20

Appendix 3

Plate 1

Fig. 1: Colle section; LF_L: massive dolomites and dolomitic limestones of the Lower Láncara Formation, LF_U: nodular limestones of the Upper Láncara Formation (more overgrown by grass than the former), OF: siliciclastic sediments of the Oville Formation. Colle section. Car for scale.

Fig. 2: Typical outcrop-conditions of the Barrios facies. Crémenes section. Hammer for scale.

Fig. 3: Thin-section of the oolitic portion of the Lower Láncara Formation. Lower Láncara Formation. Primajas section (Pr 2B). Scale bar: 2 mm.

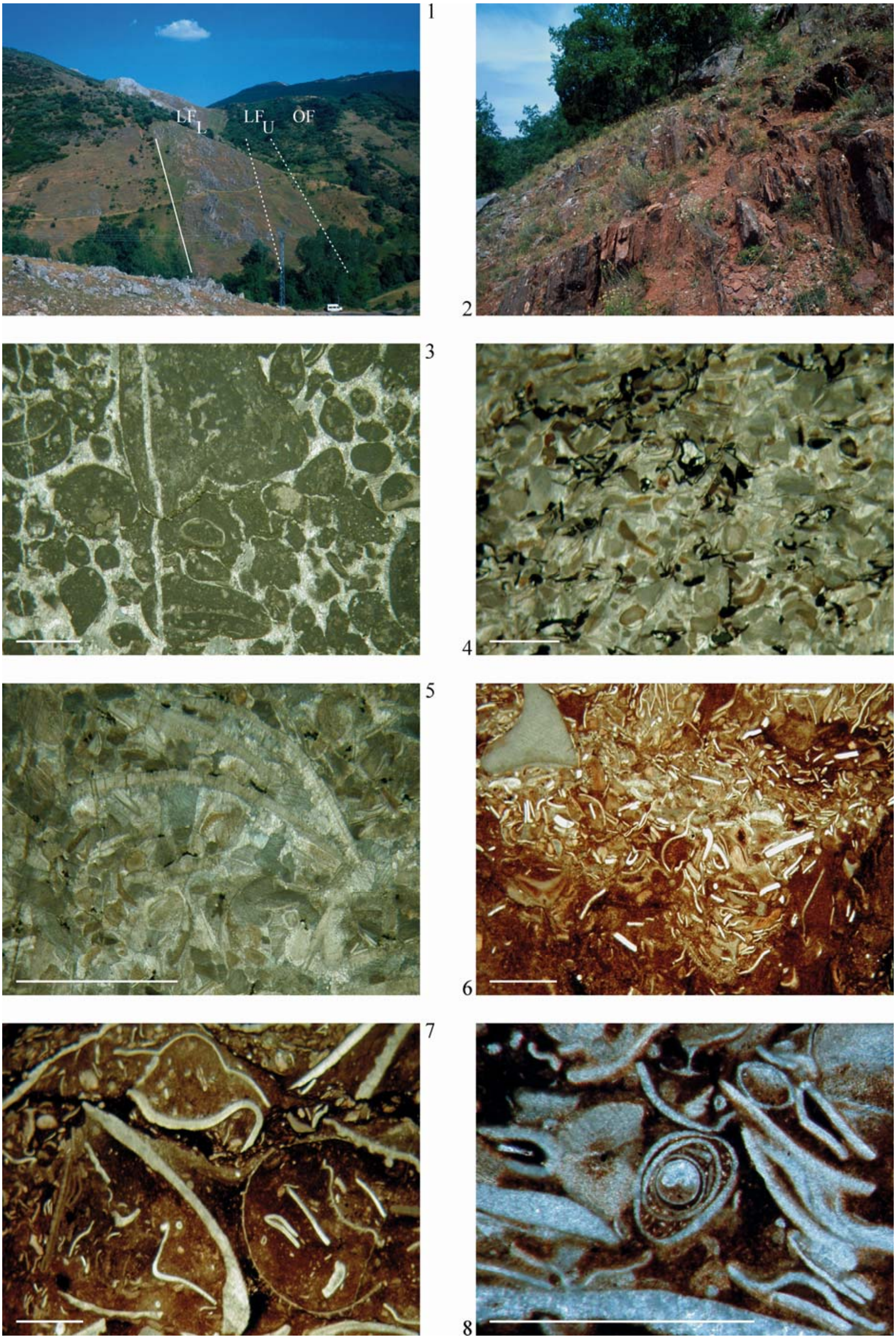
Fig. 4: Thin-section of the Beleño facies. Note the high amount of echinoderms and glauconite. Upper Láncara Formation. Colle section (Co 6). Scale bar: 2 mm.

Fig. 5: Thin-section of the Beleño facies. Well visible: large complete shells of brachiopods. Upper Láncara Formation. Colle section (Cr 6). Scale bar: 5 mm.

Fig. 6: Thin-section of the Barrios facies. The fossils show different orientation caused by bioturbation. Upper Láncara Formation. Barrios facies. Crémenes section (Cr 24). Scale bar: 2 mm.

Fig. 7: Transversal section of a trilobite. Well observable are also unbroken shells of brachiopods. Upper Láncara Formation. Barrios facies. Crémenes section (Cr 26). Scale bar: 2 mm.

Fig. 8: Cone-in-cone stacking indicates some moderate water current. Upper Láncara Formation. Barrios facies. Crémenes section (Cr 12). Scale bar: 2 mm.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Paläontologie, Stratigraphie, Fazies

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