Stratigraphy and facies of the Nocedo, Fueyo and Ermita formations (Upper Devonian to lowermost Carboniferous) in León, N Spain

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Loevezijn, G.B.S. van, Stratigraphy and facies of the Nocedo, Fueyo and Ermita formations (Upper Devonian to lowermost Carboniferous) in León, N Spain. — Scripta Geol. 81 : 1-116, 74 figs., Leiden, June 1986.

The Asturo-Leonese Basin is one of the three large palaeogeographical units of the Cantabrian Zone. In the north the basin is bounded by the Asturian Geanticline and the Palencian Basin. In the south the Palaeozoic succession is covered by Mesozoic and Tertiairy deposits. The Upper Devonian to lowermost Carboniferous succession of the Asturo-Leonese Basin includes the Nocedo Formation with the Gordón and Millar members, the Fueyo and the Ermita Formation. In these units, eight facies and ten subfacies are distinguished. The sediments of facies **a, b, c2, c3,** and **cr** are grouped in an inner shelf cluster, whereas facies **c1, e, f,** and **g** are grouped in an outer shelf cluster. With the aid of facies maps and conodont data the palaeogeographic development of the southern part of the Asturo-Leonese Basin during the Frasnian-Famennian and earliest Tournaisian is described. Synsedimentary block movements caused very rapid lateral changes in facies and thickness. The Sabero-Gordón Fault Zone, which is closely related to the Intra-Asturo-Leonese Facies Line, divided the Asturo-Leonese shelf into an outer area, which corresponds with the External Zone, and an inner area, which is subdivided into an Intermediate and an Internal Zone. Each zone has a characteristic Upper Devonian succession. The Pardomino High was an important palaeogeographic feature during the Frasnian. It divided the Asturo-Leonese Basin into an eastern Peña Corada Subbasin and a western Alba Subbasin. Due to upheaval and erosion of the Asturian Geanticline and of the Internal Zone, and subsidence and deposition in the External Zone and, though less so, in the Intermediate Zone, two cycles were deposited during the Frasnian. Each cycle consists of a regressive siliciclastic unit and a transgressive carbonate unit. The lower cycle is included in the Gordón Member, the upper in the Millar Member. In the distal parts of the Alba Subbasin an outer shelf environment existed, whereas in the Peña Corada Subbasin the sediments were deposited in a shallow marine inner shelf environment. When the siliciclastic supply decreased a reef belt advanced in the Peña Corada Subbasin (Crémenes Limestone). Block movements about the Frasnian-Famennian boundary caused the extension of the outer shelf environment at the cost of the inner shelf environment and the Pardomino High virtually vanished as well as the last Devonian reefs of the Asturo-Leonese Basin. The Fueyo Formation was subsequently deposited in the narrow area of the External Zone on the edge of the Asturo-Leonese Basin. During the late Famennian the sea transgressed over the northern part of the Asturo-Leonese Basin and over large parts of the Asturian Geanticline and a thin succession of mainly littoral sands and crinoidal shoals was deposited. Locally these deposits preserve a karst topography with a very remarkable relief. Only in the southernmost part of the Asturo-Leonese Basin a quiet subtidal environment existed where silts, sulphuric black muds and lime muds were deposited.

Het Asturo-Leonese Bekken is een van de drie grote paleogeografische eenheden van de Cantabrische Zone. In het noorden grenst het bekken aan de Asturische Geanticlinaal en aan het Palentijnse Bekken. In het zuiden worden de Paleozoische sedimenten bedekt door Mesozoische en Tertiaire afzettingen. In de Bovendevonische en onderste Karbonische opeenvolging worden de Nocedo Formatie met de Gordón en Millar members, de Fueyo Formatie en de Ermita Formatie onderscheiden. De sedimenten zijn gegroepeerd in acht facies en tien subfacies. De sedimenten van facies **a, b, c2, c3, d** en **cr** zijn gegroepeerd in een binnen-shelf cluster, terwijl de facies **c1, e, f** en **g** zijn gegroepeerd in een buiten-shelf cluster. Met behulp van facies-kaarten en conodont-gegevens wordt de paleogeografische ontwikkeling van het zuidelijk gedeelte van het Asturo-Leonese Bekken beschreven gedurende het Frasnien, Famennien en onderste Tournaisien. Synsedimentaire blokbewegingen veroorzaakten snelle laterale facies- en dikte-veranderingen. De Sabero-Gordón Zone, welke direct gerelateerd is aan de Intra-Asturo-Leonese Facieslijn, verdeelt het Asturo-Leonese shelf-gebied in een binnen en een buiten gebied. Het buiten gebied omvat de Intermediaire en de Interne zones. Elke zone bezit een karakteristieke Bovendevonische opeenvolging. Het Pardomino Hoog was een belangrijk paleogeografisch fenomeen gedurende het Frasnien. Het verdeelde het Asturo-Leonese Bekken in een oostelijke Peña Corada Subbekken en een westelijk Alba Subbekken. Door opheffing en erosie van de Asturische Geanticlinaal en de aangrenzende Interne Zone werden gedurende het Frasnien twee sedimentaire cycli afgezet. Elke cyclus bestaat uit een regressieve siliciklastische eenheid en een transgressieve carbonaat eenheid, de onderste cyclus omvat de Gordón Member terwijl de bovenste cyclus overeenkomt met de Millar Member. In de distale gedeelten van het Alba Subbekken bestond een buiten-shelf gebied, terwijl in het Peña Corada Subbekken de sedimenten zijn afgezet in een ondiep marien binnen-shelf gebied, waar zich, toen de siliciklastische aanvoer afnam, een rifgordel kon vormen (Crémenes Kalk). De blokbewegingen omstreeks de Frasnien-Famennien grens veroorzaakten uitbreiding van het diepere milieu van de buitenshelf ten koste van het binnenshelf gebied van het Peña Corada Subbekken. Als gevolg hiervan verloor het Pardomino Hoog zijn importantie en verdwenen de laatste Devonische riffen uit het Asturo-Leonese Bekken. In het late Famennien transgredeerde de zee over het noordelijke gedeelte van het Asturo-Leonese Bekken en over grote delen van de Asturische Geanticlinaal en een dunne opeenvolging van hoofdzakelijk littorale zanden en crinoïden-banken werd afgezet. Alleen in het zuidelijkste gedeelte van het Asturo-Leonese Bekken werden silten, donkere pyriet modder en kalkmodder afgezet in een rustig milieu buiten de littorale zone.

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Introduction

This paper is part of a detailed geological investigation which the University of Leiden Department of Geology and Geophysics has carried out in the southern part of the Cantabrian Mountains in the provinces Palencia and León, from the early fifties onwards. It deals with the Upper Devonian and lowermost Carboniferous deposits in León: the Nocedo, Fueyo and Ermita formations. The scope of this study is to give an environmental interpretation of their sediments and to reconstruct the palaeogeographic development during the late Devonian and early Carboniferous of the southern part of the Cantabrian Mountains. The conodont biostratigraphy and the outlines of the Middle Devonian to early Carboniferous depositional history were recently published by Raven (1983), whose work had a more general scope. In the present work earlier publications of the author are incorporated (van Loevezijn, 1983; van Loevezijn & Raven, 1983, 1984). Supplementary fieldwork in the summers of 1983 and 1984 resulted in many new data which necessitated several reinterpretations.

The region is subdivided into three major areas (Fig. 1). The Esla area in the east is separated by the Porma Fault from the adjacent Bernesga area. In the west another area with important Upper Devonian outcrops occurs: the Somiedo area. The Caldas area, where little Upper Devonian is present, will only be discussed briefly. The separate treatment of each of the three areas is not only for convenience of description. The sedimentary successions vary slightly from area to area probably owing to their different positions with respect to the fundamental fault lines and palaeogeographical elements.

Fieldwork was carried out between 1979 and 1984. Fifty sections were studied. They were logged at scales varying from 1:10 to 1:500, depending on the degree of variation in the interval studied. Approximately 250 thin sections were used for checking and to supplement the macroscopic descriptions and field observations. Limestones were sampled for conodont investigations.

In this thesis the limestones are classified according to the system of Dunham (1962), and the sandstones follow that of Williams et al. (1954) in modified form as proposed by Dott (1966) as well as the sand-silt-clay triangle of Travis (1970). Grain sizes were classified according to the Udden-Wentworth scale.

The extensive lithological collection as well as the conodont samples of the measured sections are stored at the Rijksmuseum van Geologie en Mineralogie (National Museum of Geology and Mineralogy), Leiden.

Acknowledgements

I wish to express my gratitude to the Subfaculty of Biology of the University of Leiden and the Rijksmuseum van Geologie en Mineralogie for the facilities kindly provided. I am also indepted to the Molengraaff-Fonds for the financial support of the field trips in

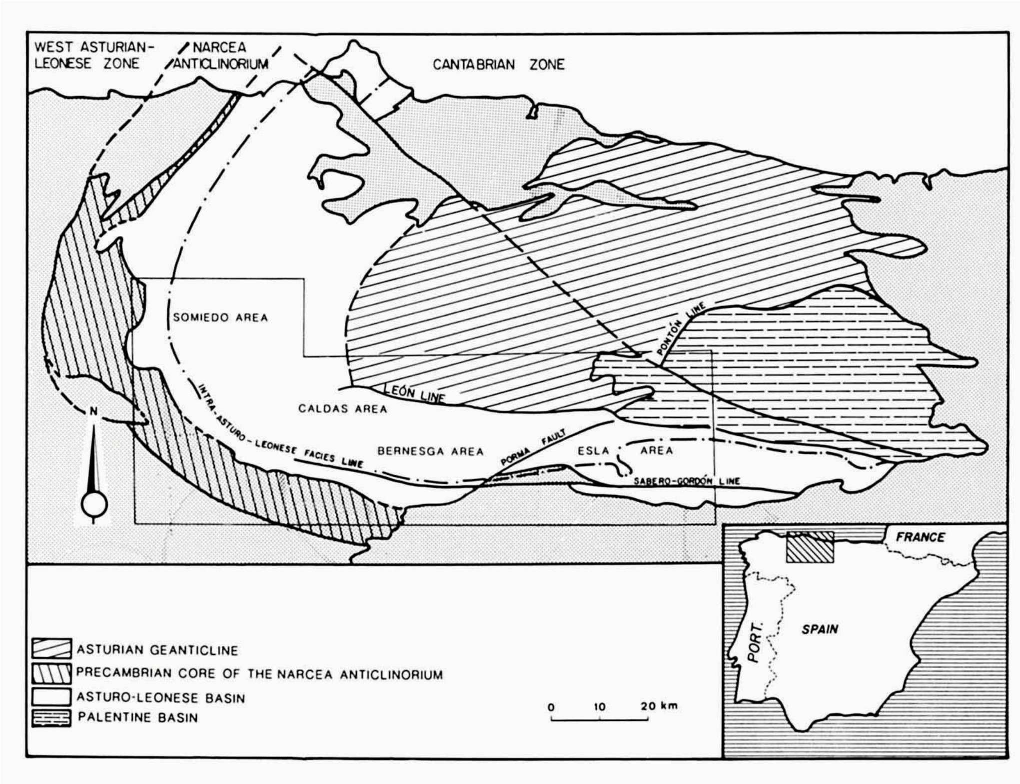


Fig. 1. Map of the major Devonian and early Carboniferous palaeogeographic units.

1983 and 1984. I am grateful to several students for having generously provided information from their unpublished reports. Drs M. van den Boogaard (Leiden) and J.G.M. Raven (Leidschendam) identified the conodonts and Drs J.F. Savage (Utrecht) and J.G.M. Raven gave some usefull criticism on an earlier draft of the work. To them I express my sincere thanks.

GEOLOGICAL SETTING

The Cantabrian and West Asturian-Leonese Zones

Lotze (1945) divided the Iberian Variscan Orogene into a number of structural zones. This paper only deals with the virtually unmetamorphic Cantabrian Zone. Its western boundary is formed by the Narcea Anticlinorium, a narrow structure with Praecambrian in its core. Apart from differences in metamorphism and tectonic style, the differences of sedimentary successions in these zones add to the distinction between them. In the West Asturian-Leonese Zone the enormous thickness of the Lower Palaeozoic sediment pile (10 000 m) contrasts with the sediment pile in the Cantabrian Zone (2000 m). Devonian limestone deposits of the Cantabrian Zone (Santa Lucía, Portilla Formation) are absent in the West Asturian-Leonese Zone, where mainly siliciclastics were deposited (Carls, 1982). De Coo (1974) and many others interpreted the Cantabrian Zone as a miogeosynclinal area and the Western Asturian-Leonese Zone as a eugeosynclinal area. However,

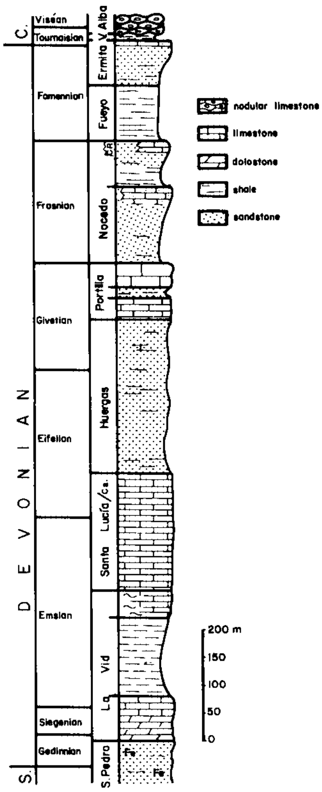


Fig. 2. Simplified Devonian sequence of the southern part of the Asturo-Leonese Basin. Ca = Caldas Fm., Cr = Crémenes Lst., V = Vegamián Fm.

apart from a temporary deepening in the West Asturian-Leonese Zone during part of the Ordovician, most of the Palaeozoic deposits are considered to be of a shallow-water type, and laterally the succession shows a remarkable persistency over hundreds of kilometres. This implies stable conditions for over a long period of time, suggesting a cratonised crust from the beginning of the era. There is no evidence of a continental margin or a near by oceanic realm (Savage, 1981; Brouwer, 1982). Kuyper (1979) and den Tex et al. (1980) developed an intracratonic model for the geological evolution of the Hesperian Massif. According to these writers the Palaeozoic history of the massif can be understood in terms of a mantle-plume which reached the base of the lithosphere in Praecambrian times, resulting in the formation of a broad intracontinental rift-zone (aulacogen or failed arm).

Palaeogeographical units

The Cantabrian Zone can be subdivided into three Palaeogeographical units, mainly based on the Devonian succession. The Asturian Geanticline in the north is characterised by the absence of Devonian pre-Ermita deposits. The region acted as a positive area during most of the Devonian, supplying clastics to the adjacent sedimentary basins. To the west and south the Asturo-Leonese Basin is situated, to the east the Palencian Basin. Most of the erosion products of the Asturian Geanticline were deposited in the Asturo-Leonese Basin, whereas the Palencian Basin shows a relatively thin succession of shales and nodular limestones. The studied areas are situated in the Asturo-Leonese Basin. A simplified Devonian succession of that basin is pictured in Fig. 2.

Fundamental lines

The Cantabrian Zone is intersected by deep-seated fundamental faults, which divide the area into a number of individual blocks. The blocks were subjected to limited relative movements both vertical and horizontal. As these movements influenced the Palaeozoic deposition on each block, the fundamental faults also are facies boundaries. For this study four faults appear to be of importance: the León Line (de Sitter, 1962), the Sabero-Gordón Line (Rupke, 1965), the Intra-Asturo-Leonese Facies Line (Raven, 1983), and the Porma Fault (Rupke, 1965). The León Line acted as a boundary between the Asturo-Leonese Basin in the south and the Asturian Geanticline in the north. The Asturo-Leonese shelf was divided into two platforms, separated by a sharp break in the slope related to the Sabero-Gordón Line and the Intra-Asturo-Leonese Facies Line. The southwest-northeast running Porma Fault divided the Asturo-Leonese Basin into an eastern and a western subbasin. The fault borders the Pardomino High to the west, a positive area during the Devonian (Rupke, 1965; Reijers, 1972).

Nappes

In the Cantabrian Mountains, the Variscan orogenic structure shows a number of superimposed thrust sheets. These supra-structural elements were formed by décollement at several stratigraphic levels and were transported by gravity (Savage, 1979). Transport components in the order of tens of kilometres must be assumed (Savage, 1979). Palinspastic reconstructions are difficult because we often do not know the exact direction and magnitude of the thrusting. In this paper only a few palinspastic reconstructions are made in order to avoid uncertain base maps. For instance, the Esla Nappe was shifted to its original position south of the Sabero-Gordón Line.

PALINSPASTIC RECONSTRUCTIONS

In order to avoid deformation structures dominating the palaeogeographic picture of the Esla area, palinspastic corrections had to be made. Bastida et al. (1976) deduced a sinistral displacement along the Sabero-Gordón Fault Zone of about 15-20 km, which divided a once continuous structure into two structures: the Felechas Syncline and the Peña Corada Syncline (Fig. 6c). The continuity of these two units, both with regard to stratigraphic succession and tectonic structures, is obtained by the necessary palinspastic dextral displacement. However, using dip measurements on large-scale cross-bedding in littoral sands of the Upper Devonian deposits, a more accurate estimate of the wrench fault displacement may be obtained from the resulting configuration of palaeocurrent directions. In the eastern part of the Bernesga area the seaward dip directions of cross-bedding point between south and west. In the Esla area in section A (Fig. 3) this direction is N225° and in section LA the main direction is N265°. In the eastern part of the Peña Corada unit a mean of N115° (section CI) and of N130° (section RO) is found. Thus in the eastern part of the Bernesga area as well as in the western part of the Peña Corada unit southwestward dominating palaeocurrent patterns occur. In the eastern part of the Peña Corada unit southeastward dominating palaeocurrent patterns occur. So the overall pattern is roughly a fan shape with directions from W through S to E. This fan shape may indicate a southward bulge of the coastline, which in our opinion is an expression of the southern extension of the Pardomino High. Consequently the sinistral strike-slip displacement along the Sabero-Gordón Fault Zone must have been about 20 km. After the

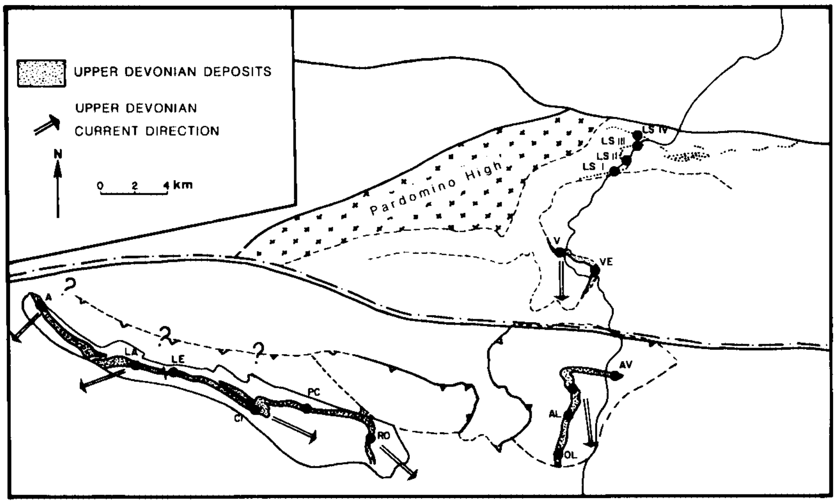


Fig. 3. Palaeogeographic base map for the Esla area containing a few palinspastic corrections: the Peña Corada unit is shifted towards the west, the Felechas Syncline and the Aguasalio Syncline are connected with the Peña Corada unit, and then the reconstructed Esla Nappe is shifted towards the south (compare Fig. 6C). For an explanation of the locality symbols see also Fig. 6C and Table 1.

palinspastic strike-slip reconstruction the Esla Nappe forms an extensive structure about 40 km wide including the Peña Corada unit in the west. The nappe must have been situated south of the Sabero-Gordón Fault Zone (Bastida et al., 1976; Amboleya, 1981; Raven, 1983). This is moreover confirmed by the striking similarity between the Upper Devonian deposits south of the Sabero-Gordón Fault Zone in the Bernesga area and those of the Esla Nappe. In Fig. 3 palinspastic reconstructions were made for the strike-slip displacement along the Sabero-Gordón Fault Zone and the northward transport of the nappe. The Upper Devonian facies trends of the Asturo-Leonese Basin warrant this palinspastic reconstruction and Fig. 3 wil be used as a base map. However, the author realizes that this reconstruction causes structural implications which are not yet fully resolved.

Lithostratigraphy

INTRODUCTION

The Upper Devonian deposits of the Bernesga area occur in the Alba Syncline, the Pedroso Syncline and in the thrust sheets in the northern part of the area (Fig. 6b). South of the Intra-Asturo-Leonese Facies Line three stratigraphic units can be distinguished as proposed by Comte (1959): the Nocedo, Fueyo and Ermita formations.

The Nocedo Formation in the type section contains two coarsening-upwards sequences. Each sequence begins with shale or siltstone and passes upwards into sandstone. The lower sequence is capped by a coarse-grained limestone unit. The sequences were designated as informal units by van Loevezijn & Raven (1983) and Raven (1983): units A and B. Van Loevezijn (1983) proposed formal names for these units: the Gordón Member for the lower and the Millar Member for the upper unit.

The Fueyo sediments are included by many authors in the Nocedo Formation as the uppermost part because of the supposed local occurrence (Evers, 1967; van de Bosch, 1969; van Staalduinen, 1973). However, from recent investigations it appeared that the Fueyo Shales Formation is not restricted to a small outcrop area in the Bernesga Valley (van Loevezijn & Raven, 1983). The shales occur in the whole area south of the Intra-Asturo-Leonese Facies Line. Therefore I prefer a separate lithostratigraphic unit for the Fueyo Shales as initially proposed by Comte (1959).

In the uppermost part of the Ermita Formation a thin limestone unit occurs, which is nowhere thicker than 10 m. Wagner et al. (1974) introduced the Baleas Formation as a limestone unit of late Tournaisian and early Visean age. They also noticed that the late Famennian limestones of the Ermita Formation have a similar lithological aspect. Because Raven (1983) discovered that the hiatus between both limestones is less important than Wagner et al. supposed, I prefer to include the Baleas Limestones in the Ermita Formation sensu Raven (1983).

Between Barrios de Luna and Mirantes (3 km west of Sagüera) the Portilla Limestone Formation consists of max. 246 m of biostromal and biohermal limestones (Mohanti, 1972), but towards the east in the southern limb of the Alba Syncline, it thins rapidly, and at Sagüera this limestone succession is absent. The underlying Huergas Formation, consisting of shales and siltstones, also disappears towards the east. Van Staalduinen (1973) explained this by the interfingering of the Huergas, Portilla, Nocedo, Fueyo, and Ermita formations with the newly introduced Piedrasecha Formation (Fig. 4a). However, a detailed study of the sections proves that in the southern limb of the Alba Syncline the Nocedo Formation, the Fueyo Formation and, in most of the sections, also the Ermita Formation has developed in a thick succession with a very low sandstone/shale ratio. The new correlations make the Piedrasecha Formation superfluous (Fig. 4b).

The Upper Devonian deposits of the Esla area are found in the Peña Corada Unit, in the Aguasalio Syncline, in the parautochthonous of Valdoré, and in the Las Salas unit (Fig. 6c). There, all the Upper Devonian lithostratigraphic units of the Bernesga area are recognized. Moreover in the top of the Millar Member one more limestone unit is distinguished: the Crémenes Limestone. This limestone unit should not be confused with the limestone unit of the Gordón Member as is done by Herbig and Buggisch (1984).

Comte (1959, pp. 212-214) described the Upper Devonian deposits near Valdoré (herein section V) and introduced the Calcaire de Valdoré, a calcareous lateral development of the Nocedo Formation. The name caused much confusion. Evers (1967) and García Alcalde et al. (1979) even used the name as synonimous for the Crémenes Limestone. Van Adrichem Boogaert (1967), however, clearly proved a late Famennian-Tournaisian age for the approximately 2 m thick unit. This limestone forms obviously part of the often calcareous Ermita Formation. In the Esla area Brouwer (1962) introduced the 'Formation d'Aguasalio' for the Upper Devonian deposits. Since the lithostratigraphic units originally described from the Bernesga Valley are also recognized in the Esla area, there is no need to continue the use of this name.

The Upper Devonian of the Somiedo area crops out in three synclines: from southwest to northeast the Palomas, Quejo and Saliencia synclines (Fig. 6a). Previous workers in the Somiedo area often did not subdivide the Upper Devonian deposits. Julivert et al. (1968) referred to these deposits as 'Areniscas del Devonico superior'. In the same year van den Bosch published a geological map of the Luna-Sil region (herein referred to as the Somiedo area). He recognized the Nocedo Formation with the Fueyo Shales and the Ermita Formation. The detailed sections which have recently been measured in this area prove that the Nocedo Formation can be subdivided into a lower

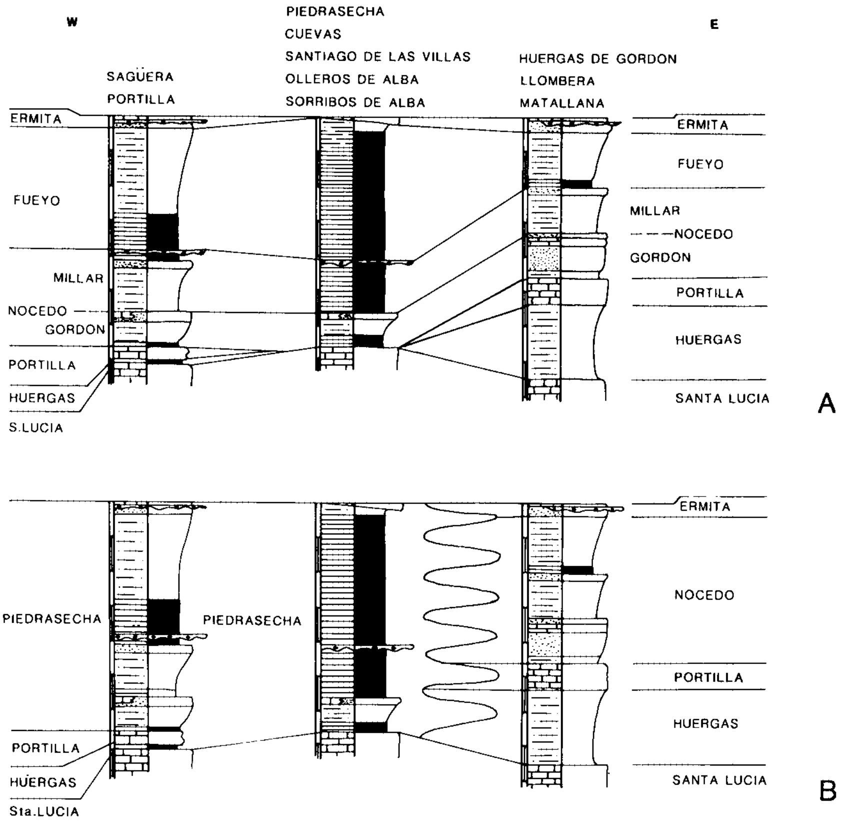


Fig. 4. Subdivision of the Middle and Upper Devonian deposits in the Alba Syncline, (A) as proposed by van Staalduinen (1973), and (B) the subdivision as proposed in this paper. The scale bars indicate units of 100 m.

Gordón, and an upper Millar Member (van Loevezijn & Raven, 1984), conformably to the subdivision in the Bernesga and Esla areas. Fig. 5 shows the Upper Devonian and lowermost Carboniferous succession of the Bernesga Valley and the different interpretations.

DESCRIPTION OF THE SECTIONS

Forty-five sections were measured of the Nocedo, Fueyo and Ermita formations. Eight sections of the Crémenes Limestone were measured in detail. They are depicted in the appendix with the exception of the sections VA, CIG and MI. Section VA is from Frankenfeld's publication (1981), section CIG is from van Loevezijn & Raven (1983, fig. 4), and the poorly exposed section MI yielded only few data. In Figs. 6 and 7 the outcrop maps of the Upper Devonian deposits of the three areas are pictured with the positions of the sections. The general lithology is shown in the columnar sections of Fig. 8. For the purpose of a general description sections situated in the same outcrop area and showing only minor variations were grouped together.

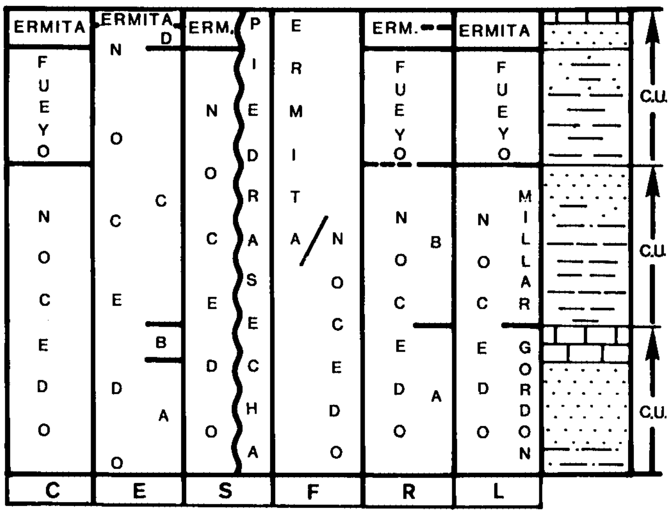


Fig. 5. Subdivisions of the Upper Devonian in the Bernesga area by various authors (c.u. stands for coarsening upwards).
C = Comte, 1959; E = Evers, 1967; S = van Staalduinen, 1973; F = Frankenveld, 1981; R = Raven, 1983; L = this paper.

Bernesga area

Southern limb of the Alba Syncline (Fig. 6b: sections S, PO, PIE, CU, SV, O, SA, R) — In the southern limb of the Alba Syncline the thickest and probably most complete Upper Devonian succession of the Asturo-Leonese Basin is found.

Overlying formation: Vegamián or Alba Formation
Ermita Formation (0-96 m):
  sandy grain-supported limestone
  cross-bedded sandstone
  bioturbated siltstone
Fueyo Formation (142-325 m):
  shale-sandstone
  shale
Nocedo Formation, Millar Member (114-152 m):
  polymict conglomerate
  shale
  cross-bedded sandstone
  sandstone-shale
  shale
Nocedo Formation, Gordón Member (98-181 m):
  sandy grain-supported limestone
  cross-bedded sandstone
  bioturbated siltstone
  shale
Underlying formation: Portilla, Huergas, or Santa Lucía Formation

Only in the three western sections the Gordón Member is well exposed (sections S, PO, PIE). In the basal shales slump-folded limestone boulders and channels with a channel-fill of pebbly mudstone occur. The sandy limestone interval is not a continuous unit, but consists of lenticular-shaped bodies. These lenticles are also exposed in the sectons SV

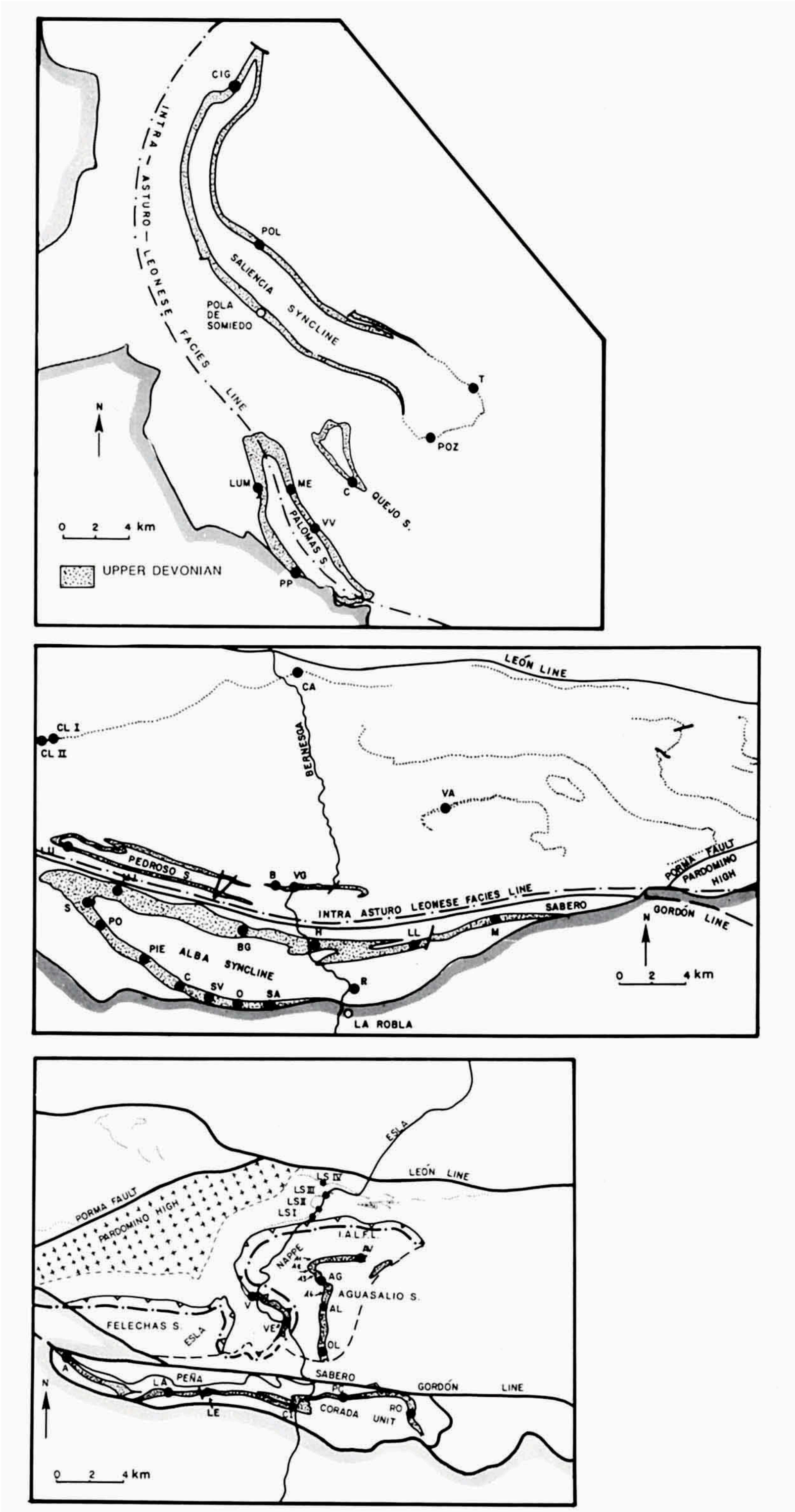


Fig. 6. Outcrop map of the Upper Devonian deposits with the position of the sections: (A) Somiedo area, (B) Bernesga area, (C) Esla area. For an explication of the locality indications see Table 1.

and O where the lower part of the member is covered by Stephanian deposits. To the east the Nocedo Formation and the lower part of the Fueyo Formation are covered by Cretaceous deposits.

In the sections PIE, SV and O the coarsening-upward sequence of the Millar Member is incomplete because of the absence of the sandstone-shale and the cross-bedded sandstone interval. In this area shales with abundant laminated silt nodules are overlain by the polymict conglomerate interval. The silt nodules also occur in the shale interval of the Fueyo Formation. C. 50 m above the base of the Fueyo Formation in section PIE a septaria horizon is found. In the shale-sandstone interval channel-fill deposits occur frequently. The boundary between the Fueyo and the Ermita Formation is arbitrary: sand-bed thickness and sandstone/shale ratio increase upward and the sediments merge into the sandy siltstones of the Ermita Formation. The boundary is defined at the base of the first sandstone bed, which surpasses 0.5 m above which the sandstone/shale ratio surpasses the 4:1 ratio.

In the siltstone interval and the lower part of the cross-bedded sandstone interval of the Ermita Formation a haematite-ooid layer occurs. In the upper part of the cross-bedded sandstone interval micro-conglomerate intercalations are found. The uppermost centimetres of the Ermita Formation in the sections S and R contain black mud clasts, probably resedimented Vegamián deposits. East of section PIE the Ermita Formation is very thin (sections CU, O), or even absent (sections SV, A). The shale-sandstone interval of the Fueyo Formation is also absent and dark shales with argillaceous limestone lenticles are overlain by the black shales of the Vegamián Formation.

Northern limb of the Alba Syncline (Fig. 6b: sections MI, BG, H, LL, M) — The Upper Devonian deposits of the northern limb of the Alba Syncline show a considerable variation in thickness from 300 m to c. 600 m. But even in the relatively thin sections all the lithostratigraphic units of the southern limb of the Alba Syncline are present, in spite of the absence of some intervals.

The Gordón Member (89-306 m) is locally incomplete. In section H the basal shale interval is absent and in the sections LL and M also the bioturbated siltstone interval is absent. In section H, above the red, coarse-grained limestone interval an alternation of sandy siltstones and wackestones is present, whereas elsewhere a few metres of crumbly sandstone with haematite horizons occur.

The Millar Member (72-229 m) mainly consists of a basal shale interval, a shale-sandstone interval with channel-fill deposits and a cross-bedded sandstone interval. Only in the uppermost part of the western sections (MI and BG) the polymict conglomerate deposits are present.

Like in the succession in the southern limb, the Fueyo Formation (97-152 m) can be subdivided into a lower shale interval and an upper shale-sandstone interval.

For the Ermita Formation (32-71 m) the same subdivision as described for the southern limb of the Alba Syncline is applicable. Chamosite and haematite ooids occur in the bioturbated siltstones of section H, microconglomerates occur in the cross-bedded sandstones of section LL and locally in the top part of the formation a thin limestone bed is present (sections N and M). In the uppermost centimetres of the formation reworked Vegamián shales occur (section H).

Pedroso Syncline (Fig. 6b: sections LU, B, VG) — In this area a thin incomplete Upper Devonian succession (80-90 m) is present. The Millar Member and the Fueyo Formation are absent.

Overlying formation: Alba Formation
Ermita Formation (27-29 m):
sandy grain-supported limestone
cross-bedded sandstone
Nocedo Formation, Gordón Member (52-63 m):
mottled ferruginous sandstone
sandy grain-supported limestone
bioturbated calcareous silty sandstone
Underlying formation: Portilla Formation.

In section B channels are observed cutting in the top of the Portilla Formation (up to 12 m deep and c. 30 m wide), which cause an erosive undulating contact between the Portilla and the Nocedo Formation. In section VG a local limestone bed occurs in the uppermost part of the Gordón Member. Everywhere a sharp paraconformable contact is observed between the mottled sandstone interval of the Nocedo Formation and the cliff-forming, cross-bedded sandstone interval with channel conglomerates of the Ermita Formation. In the limestone interval Raven (1983) observed several hardgrounds.

Northern part; Caldas area (Fig. 7: sections CA CLI, CLII, LL, E) — In this group of sections only the Ermita Formation is present.

Overlying formation: Vegamián or Alba Formation
Ermita Formation (0-86 m):
sandy grain-supported limestone
ferruginous sandstone
Underlying formation: Oville, Barrios, San Pedro, La Vid, Santa Lucía, Caldas, or Huergas Formation.

The Ermita deposits have an irregular distribution pattern. A karst topography is well exposed in the Caldas area, where depressions up to 50 m deep in the Caldas Limestones have been filled up with clastic deposits of the Ermita. The deposits vary considerably in character. Due to a collapse of cavities a mixture of brecciated Caldas limestone and purple-coloured Ermita sandstone occur in section CLI. Penecotemporaneous deformed, clean, white, well-sorted quartzarenites and quartzites occur, which were partly lithified before they slided into the depressions of the collapsed cavities (section U); some beds have lost their coherence and have fallen apart into folded portions. Other depressions are filled with a mixture of red- and green-coloured poorly sorted sandstones with grains up to 4 mm, fossil debris and shale clasts (section CLI). Fissures are found which penetrate from the unconformity surface tens of metres into the Caldas Formation. They are filled with a mixture of dark-red haematite sandstones of the Ermita Formation and limestone pebbles of the Caldas Formation. Where the unconformity is less pronounced, cross-bedded haematite sandstones are found with overturned foreset laminae, indicating deposition by strong sediment-laden currents, which dragged the upper part of the foresets into folds.

Esla area

Western part of the Peña Corada Unit (Fig. 6c: sections A, LA, LE, CI) — In this area the Upper Devonian succession as described for the Alba Syncline is applicable, although some units are locally absent in the 147-263 m thick succession.

In the Gordón Member (35-50 m) the shale interval, and locally the bioturbated siltstone interval, is absent. The cross-bedded sandstones are overlain by the limestone

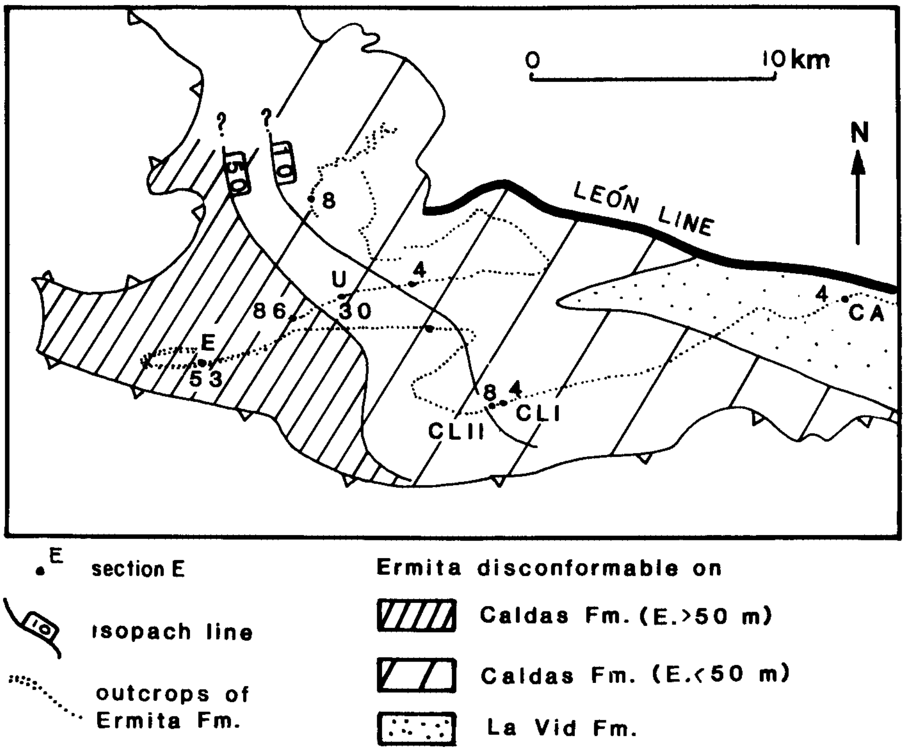


Fig. 7. The isopach pattern of the Ermita Formation with the unconformity surface of the Caldas area. Well-developed ferruginous soils are found in the Ermita deposits where the thickness of the formation surpasses 50 m. An irregular karst landscape is levelled off in the area where the Ermita Formation does not surpass the 50 m and is lying upon the Caldas Limestone Formation. In the east, where the Ermita Formation overlies the shales and siltstones of the La Vid Formation, it is distributed in broad, lenticular-shaped bodies. Based on sections of Frankenfeld (1981) (section numbers without a character), and sections measured by the present author (sections marked with a character).

interval. The lower part of the limestone is mud-supported and only the upper part is grain-supported.

The Millar Member (70 m) only occurs in section LA, where it consists of cross-bedded sandstones.

In the Fueyo Formation (30-61 m) the lower shale interval is absent, and the formation only consists of the shale-sandstone interval.

In the Ermita Formation (60-87 m) the siltstone interval and the limestone interval are absent, and the formation is composed of cross-bedded sandstones with in the uppermost part shallow channels filled by microconglomerates.

Eastern part of the Peña Corada Unit and Aguasalio Syncline (Fig. 6c: PC, RO, OL, AL, AG, AV, 1, 2, 3, 4) — In this area the 27 to 319 m thick Upper Devonian succession is almost complete and the same subdivision as in the Alba Syncline can be recognised.

The Gordón Member (34-125 m) consists, from base to top, of bioturbated siltstone, a cross-bedded sandstone and an interval with mud supported and grain-supported limestones.

In the Millar Member (75-110 m) the basal shale and the shale-sandstone interval are absent, and the base of the member consists of bioturbated siltstones. Only in this group of sections a c. 15 m thick coral-stromatoporoid limestone occurs above the cross-bedded sandstone interval (Crémenes Limestone), with the exception of the thin westernmost section (PC), where ferruginous soils occur in the uppermost part of the member.

The Fueyo Formation (10-42 m) only consists of the shale-sandstone interval: the basal shales are absent.

In the Ermita Formation (60-100 m) the siltstone interval is absent and almost the entire formation consists of cross-bedded sandstones. Only in the uppermost part of sections AG and RO the limestone interval is present. In the uppermost part of section OL greensands occur.

Parautochthonous of Valdoré (Fig. 6c: sections V, VE) — This area shows a rather thin and incomplete Upper Devonian succession (15-62 m), resembling the succession of the Pedroso Syncline in which the Millar Member and the Fueyo Formation are absent.

The Gordón Member (13-52 m) consists of a bioturbated silty shale interval which is overlain by a sandstone interval. The limestone interval is absent.

In the Ermita Formation (2-10 m) only the limestone interval is present, which rests with a basal conglomerate on the purple sandstones of the Nocedo Formation.

Northern part (Fig. 6c: sections LSI, LSII, LSIII, LSIV) — In this area only a thin, patchy distributed, Ermita Formation (0-20 m) occurs, which is very similar to the Ermita Formation in the northern part of the Bernesga area with a lower ferruginous sandstone interval and an upper grain-supported limestone interval.

Somiedo Area

Western limb of the Palomas Syncline (Fig. 6a: sections LUM, PP) — The Upper Devonian succession of this area (c. 430 m thick) contains all the lithological units and is very similar to the succession of the Alba Syncline.

The Gordón and Millar members have identical coarsening-upward sequences as described for the Alba Syncline. In the cross-bedded sandstone interval of the Millar Member a monomict quartzite breccia (probably a fault breccia) occurs.

The basal shale interval of the Fueyo Formation (53 m) is absent and the shale-sandstone deposits are overlain by the cross-bedded sandstones of the Ermita Formation (190 m), with in the upper part abundant cross-bedded channel conglomerate intercalations. At the top of the formation the limestone interval is present.

Eastern limb of the Palomas Syncline, the Quejo Syncline and the northwestern part of the Saliencia Syncline (Fig. 6a: sections ME, VV, C, POL, CIG) — The Upper Devonian succession (134-291 m) of this group of sections lacks the Millar Member and the Fueyo Formation, and the succession is very similar to the succession in the Pedroso Syncline.

The Gordón Member (36-76 m) consists, from base to top, of a bioturbated siltstone, a grain-supported limestone and a ferruginous sandstone.

The Ermita Formation (81-255 m) is divided into a lower cross-bedded sandstone interval with channel-conglomerate intercalations and a thin upper limestone interval. In section POL a microconglomerate horizon marks the paraconformable contact between the red fine-grained sandstones of the Nocedo Formation and the white conglomeratic sandstones of the Ermita Formation.

Southeastern part Saliencia Syncline (Fig. 6a: sections POZ, T) — In these sections only a thin, discontinuously distributed Ermita Formation (0-50 m) is present, very similar to the Ermita in the northern parts of the Esla, Bernesga and Caldas areas. The formation only consists of ferruginous sandstones, the limestone interval being absent.

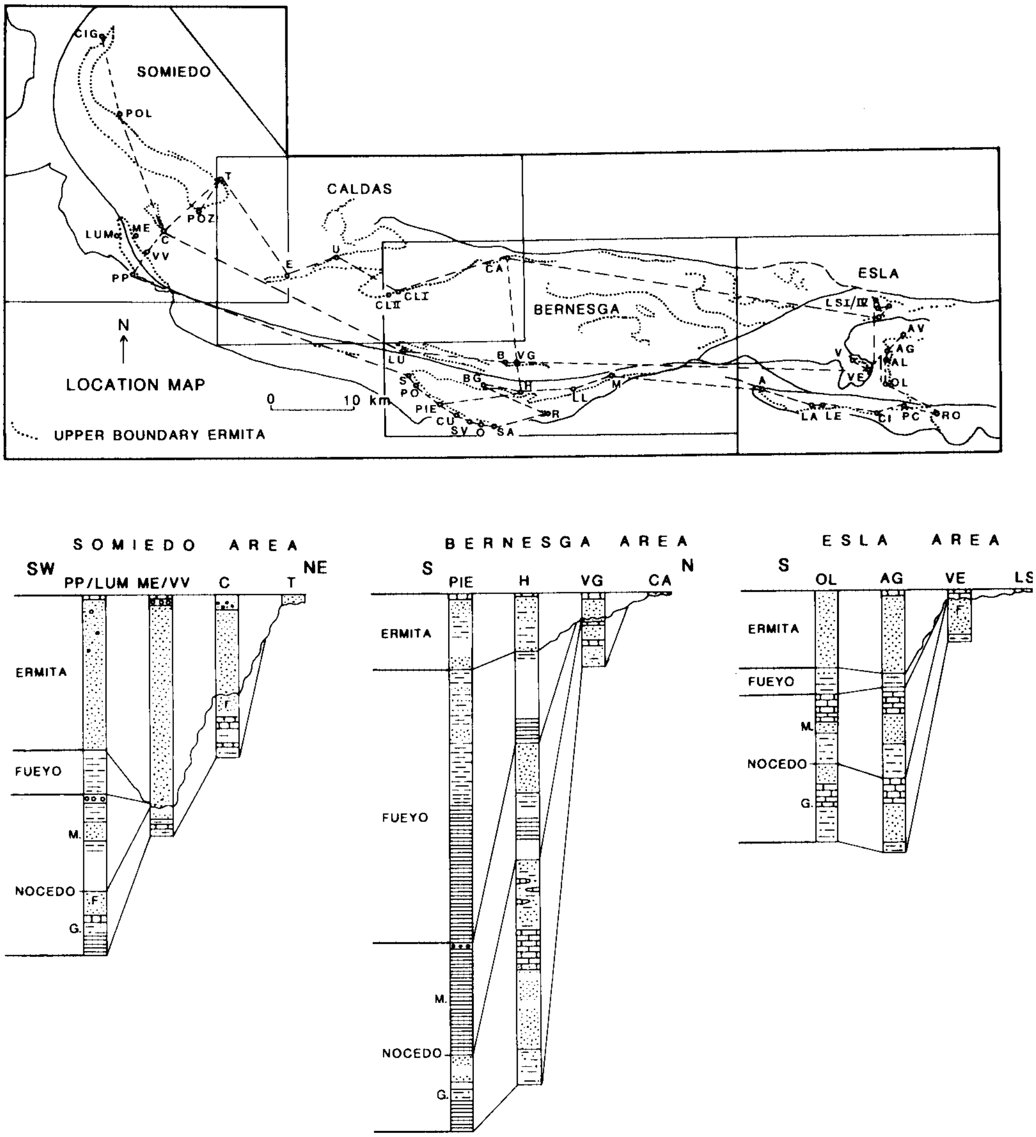
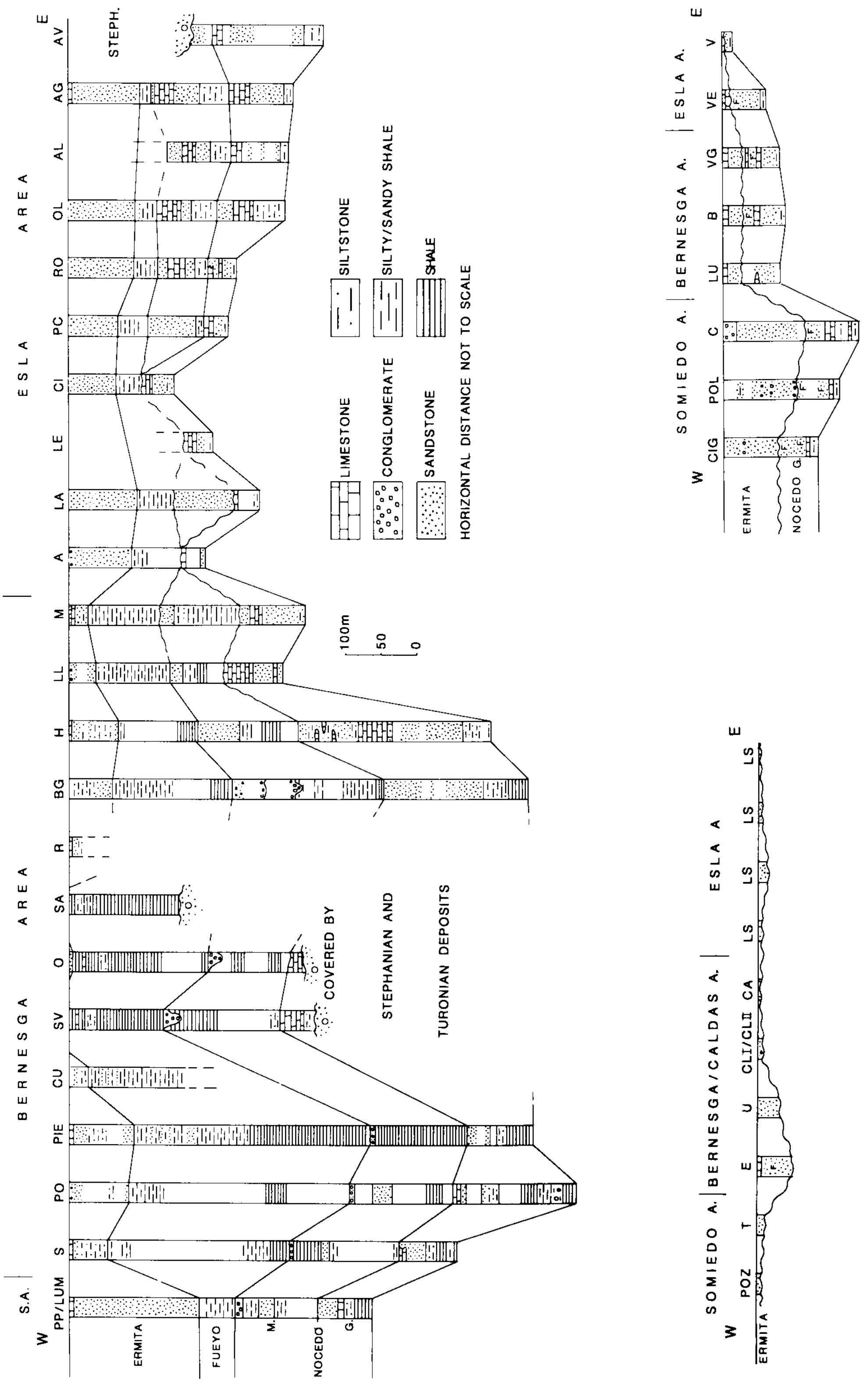


Fig. 8. Columnar sections of the Upper Devonian deposits of the Asturo-Leonese Basin arranged according to differently orientated section lines (parallel and perpendicular to main structures). Horizontal distances not to scale. For an explanation of the locality symbols see Table 1.


W
S.A.
B E R N E S G A   A R E A
E S L A   A R E A
E
PP/LUM
S
PO
PIE
CU
SV
O
SA
R
BG
H
LL
M
A
LA
LE
CI
PC
RO
OL
AL
AG
AV
STEPH.
ERMITA
FUEYO
M.
NOCEDO
G.
COVERED BY
STEPHANIAN AND
TURONIAN DEPOSITS
100m
50
0
LIMESTONE
CONGLOMERATE
SANDSTONE
SILTSTONE
SILTY/SANDY SHALE
SHALE
HORIZONTAL DISTANCE NOT TO SCALE
S O M I E D O   A.
B E R N E S G A   A.
E S L A   A.
CIG
POL
C
LU
B
VG
VE
V
NOCEDO G.
S O M I E D O   A.
B E R N E S G A / C A L D A S   A.
E S L A   A
POZ
T
E
U
CLI/CLII
CA
LS

REGIONAL LITHOLOGICAL VARIATIONS OF THE UNITS

In order to get a better idea of the composition of and differences between the various formations and members in the different areas, field estimations on quantities of lithological components for each lithostratigraphic unit in every section were made. The thicknesses of the sandstone and conglomerate units, the shale and siltstone units and the carbonate units of each section were measured. For mixed lithologies the percentages of the three lithlogical components were estimated. For each group of sections the values were calculated and the results are presented in circular diagrams (Figs. 9-12). The sections in the Peña Corada Unit and in the Aguasalio Syncline are grouped together in the Esla Nappe group.

Nocedo Formation

Gordón Member — Figure 9 shows the average composition of the Gordón Member in the various areas. In the southernmost Upper Devonian exposures of the Somiedo and Bernesga areas the high percentage shales and siltstones in the member is striking (almost 50%). In the northern limb of the Alba Syncline and in the Esla Nappe more sandstones and limestones are present, and the shale + siltstone percentage decreases to about 10-17%. Towards the north, in the Pedroso Syncline and the parautochthonous of Valdoré the decrease of the percentage fines (shales + siltstones) in the Gordón Member continues (from 10-17% to 6-12%). Also in the Somiedo area the percentage of fines decreases in a north(east)ward direction (from 47% tot 20%), but 20% is still a high value in comparison with the percentages in the Bernesga and Esla areas. The absence of limestone in the Gordón Member of the parautochthonous of Valdoré is striking, whereas in the Pedroso and Quejo synclines up to 15% of the member consists of limestone.

Millar Member — No diagram could be constructed for the Millar Member in the Somiedo area because of the poor exposure of the sections. In comparison with the Gordón Member, the Millar Member contains much more fine-grained sediment (Fig. 10). The highest value is found in the southern limb of the Alba Syncline (65%). The percentage of fines in the Esla Nappe is of the same order of magnitude as in the northern limb of the Alba Syncline (37-38%). The Crémenes Limestone, which occurs only in the eastern part of the Esla Nappe, is clearly indicated by the segment of limestone in the diagram.

Fueyo Formation

From all the Upper Devonian lithostratigraphic units the Fueyo Formation contains the highest percentage of fines (Fig. 11). In the southern limb of the Alba Syncline, 78% of the Fueyo sediments are shales and siltstones. This percentage decreases to 66% for the sediments in the northern limb of the Palomas Syncline and in the Esla Nappe the percentage of fines decreases to 39-45%.

Ermita Formation

In the southern exposures of the Bernesga area an important part of the Ermita Formation consists of siltstones (11-24%), whereas in the southernmost parts of the

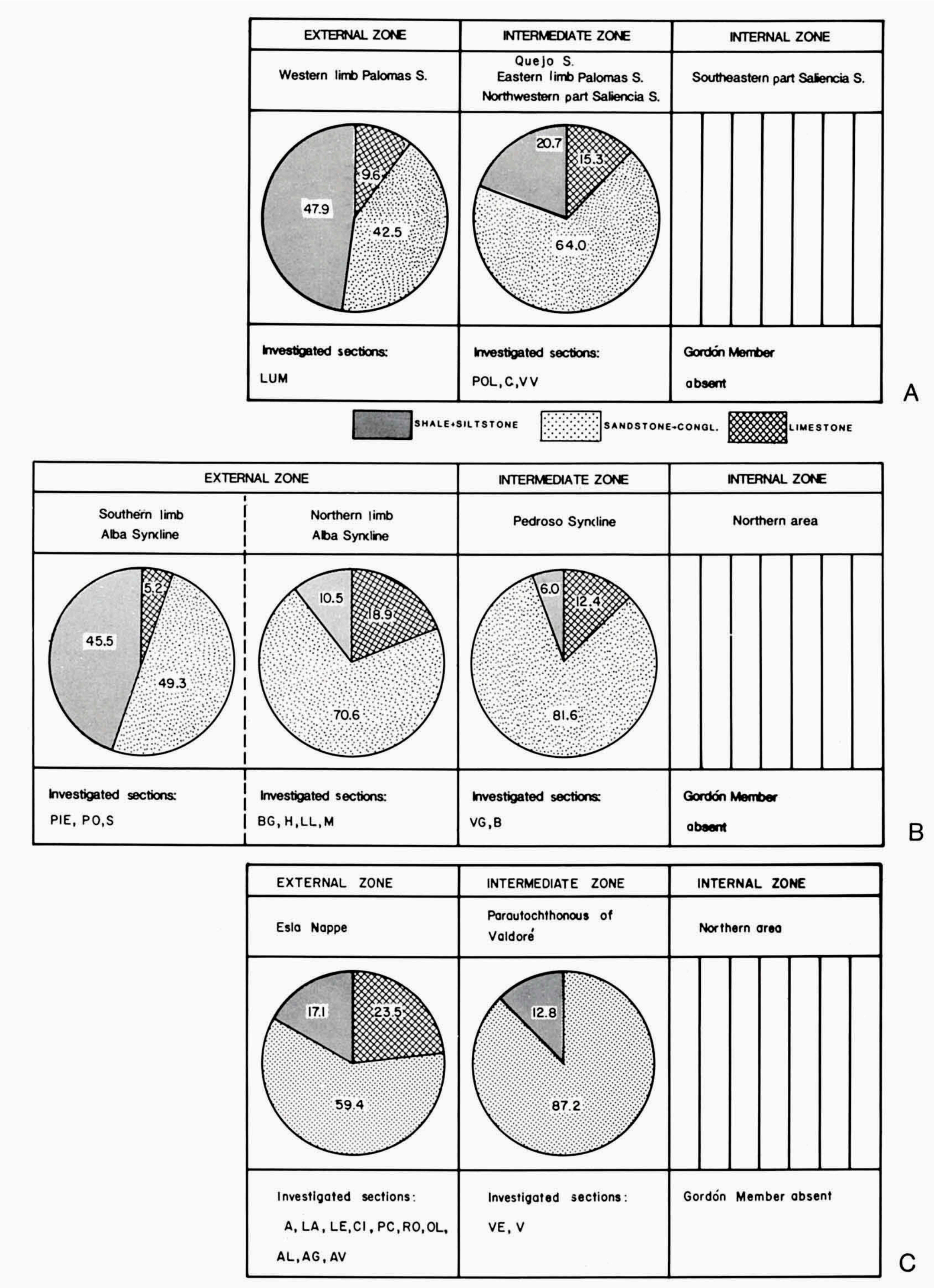


Fig. 9. Average lithological composition of the Gordón Member for the different groups of sections in the various areas; (A) Somiedo area, (B) Bernesga area, (C) Esla area. For an explanation of the locality symbols see Fig. 6 and Table 1.

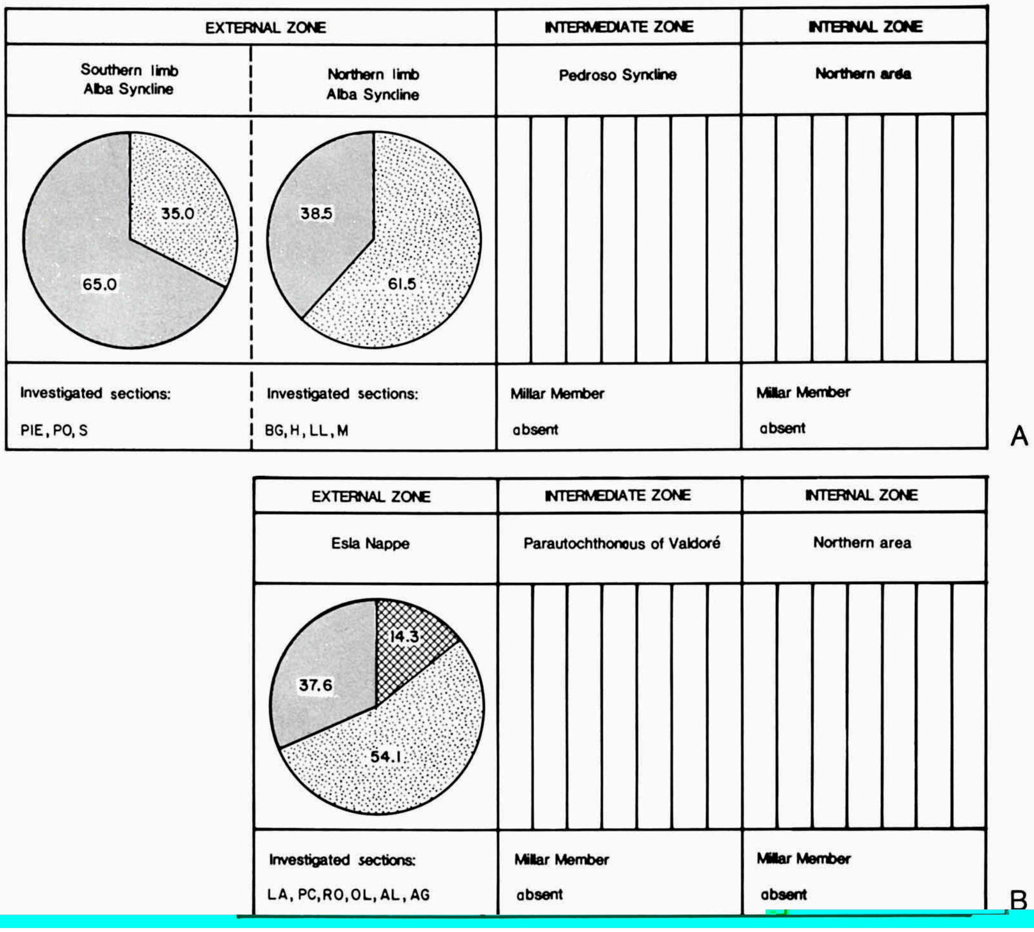


Fig. 10. Average lithological composition of the Millar Member for the different groups of sections in the various areas: (A) Bernesga area, (B) Esla area. For the legend see Fig. 9.

adjacent Somiedo and Esla areas the fines are replaced by sandstones. Northward, in the Pedroso Syncline and in the parautochthonous of Valdoré, an important part of the formation consists of limestones (42-76%). In the northern areas mainly sandstones, with locally a limestone and/or siltstone intercalation, occur.

CONCLUSIONS

Based on lithological characteristics, the sections can be arranged in three main groups: that of the External Zone, of the Intermediate Zone and of the Internal Zone. The External Zone comprises the Upper Devonian successions of the Alba Syncline, the Esla Nappe and the western limb of the Palomas Syncline. In the south the zone is bounded by the Praecambrian deposits of the Narcea Anticlinorium. In the north the zone is limited by the Intermediate Zone along the Intra-Asturo-Leonese Facies Line.

In the External Zone a thick (c. 200-700 m) and fairly complete succession occurs, with a high shale percentage. In most sections all lithostratigraphic units are present and each unit consists of a coarsening-upward sequence:

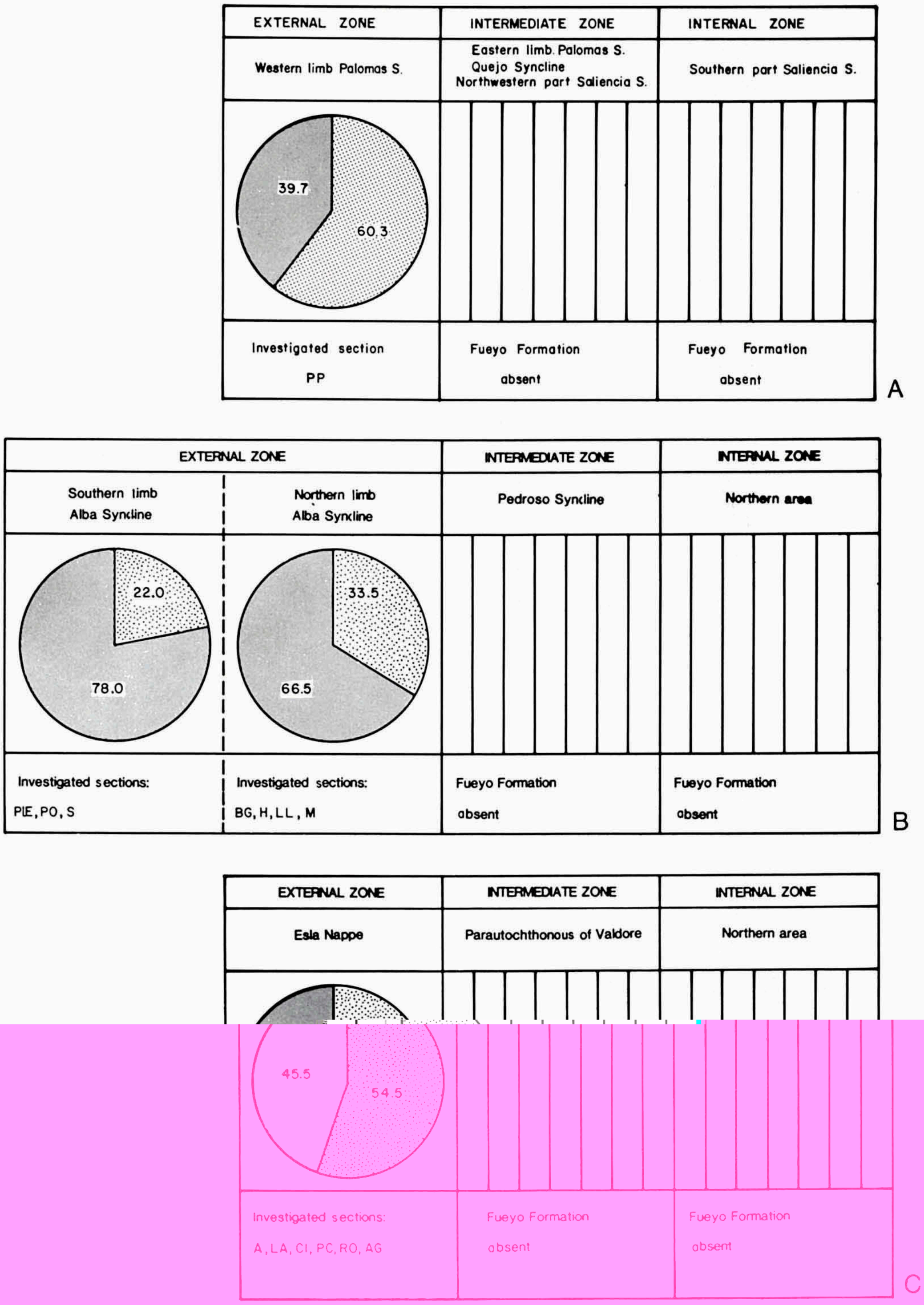


Fig. 11. Average lithological composition of the Fueyo Formation for the different groups of sections in the various areas: (A) Somiedo area, (B) Bernesga area, (C) Esla area. For the legend see Fig. 9.

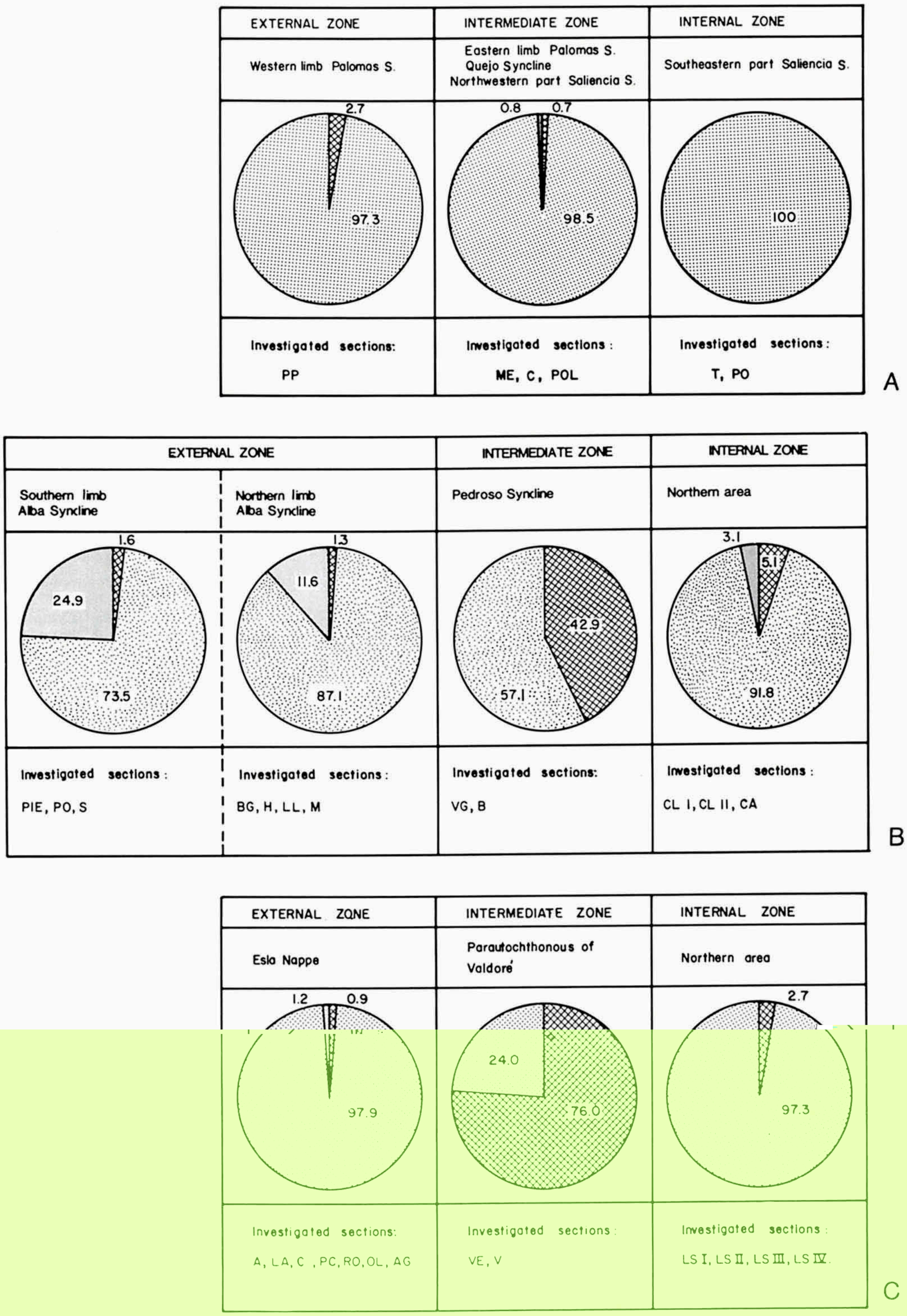


Fig. 12. Average lithological composition of the Ermita Formation for the different groups of sections in the various areas: (A) Somiedo area, (B) Bernesga area, (C) Esla area. For the legend see Fig. 9.

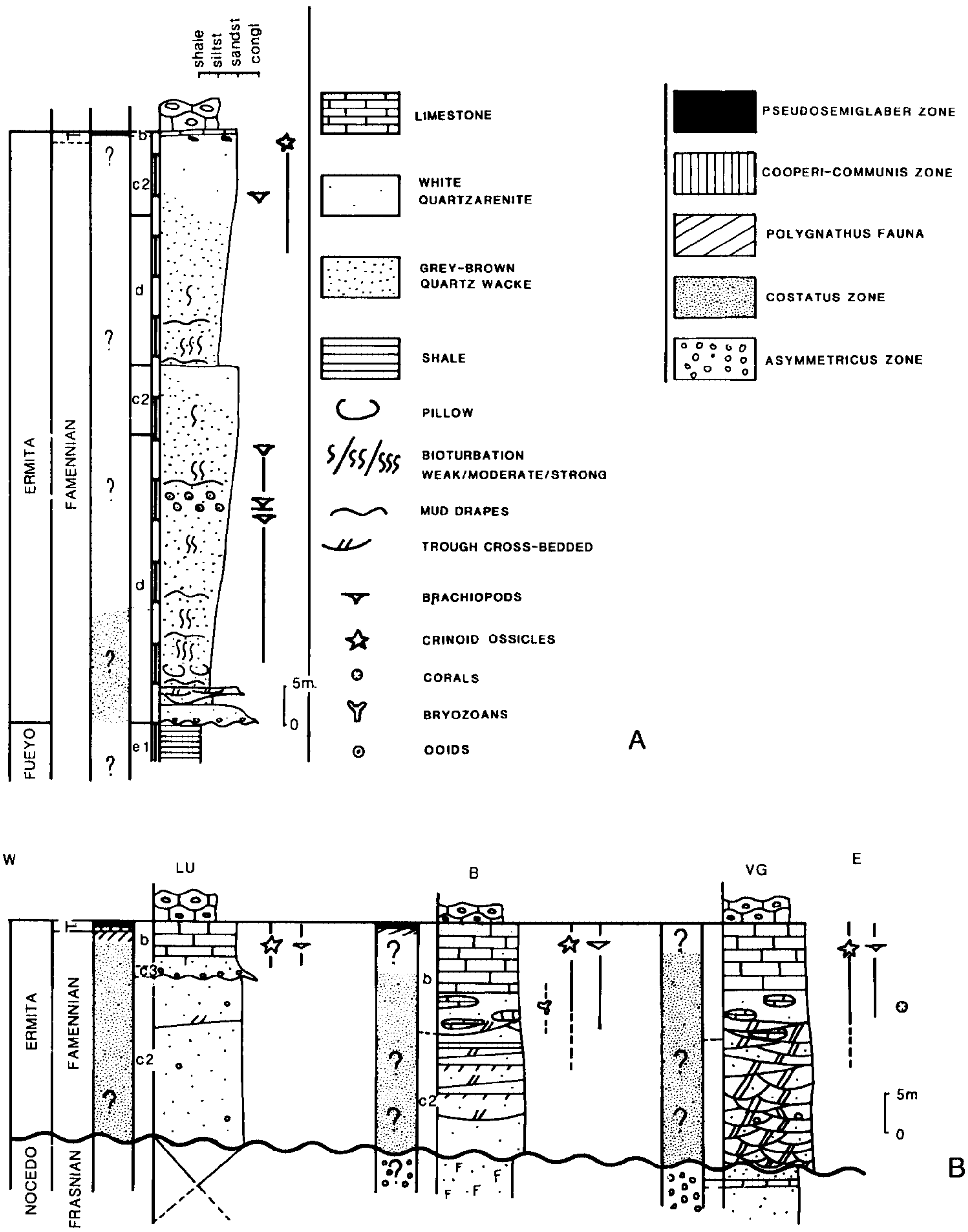


Fig. 13. The Ermita Formation in the Bernesga area.
(A) The Ermita Formation of section H is characteristic for the development in the Alba Syncline. The shales of the Fueyo Formation are overlain by bioturbated siltstones and quartz wackes, which grade upward into quartzarenites. In the uppermost part of the section black shale clasts occur (probably reworked sediment of the Vegamián Formation), which are overlain by a thin bioclastic limestone bed.
(B) The Ermita Formation in the Pedroso Syncline consists of cross-bedded quartzarenites and microconglomerates (lower unit), and bioclastic limestones (upper unit).
Conodont zonation after Raven (1983).

ZONATION	SECTION	THICKNESS (m)
EXT. Z.	PP/LUM, PUENTE DE LAS PALOMAS/LUMAJO	430
INTERMEDIATE ZONE	ME/VV, MEROY/VEGA DE LOS VIEJOS	291
	C, LA CUETA	195
	POL, POLA DE SOMIEDO	164
	CIG, CIGUEDRES*	134
INTERNAL ZONE	POZ, PEÑA ORNIZ	8
	T, TORRISTIO	11

* VAN LOEVEZIJN & RAVEN, 1984

A

ZONATION	SECTION	THICKNESS (m)
EXTERNAL ZONE	M, MATALLANA	333
	LL, LLOMBERA	301
	H, HUERGAS DE GORDÓN	593
	BG, BARRIOS DE GORDÓN	647
	MI, MIRANTES	?
	S, SAGÜERA	542
	PO, PORTILLA DE LUNA	730
	PIE, PIEDRASECHA	649
	CU, CUEVAS	?
	SV, SANTIAGO DE LAS VILLAS	?
	O, OLLEROS DE ALBA	420
	SA, SORRIBOS DE ALBA	?
	R, LA ROBLA	?
INTERM. ZONE	VG, VEGA DE GORDÓN	81
	B, BEBERINO	90
	LU, LUNA	82
INTERNAL ZONE	CLI, CALDAS DE LUNA I	4
	CLII, CALDAS DE LUNA II	8
	CA, CAMPLONGO	4
	E, SAN EMILIANO	53
	U, UBIÑA	30
	VA, VALPORQUERO*	18

*FRANKENFELD, 1981

B

ZONATION	SECTION	THICKNESS (m)
EXTERNAL ZONE	A, SAN ADRIAN	183
	LA, SOBREPEÑA	263
	LE, LA ERCINA	?
	CI, CISTIERNA	147
	PC, PEÑA CORADA	227
	RO, ROBLEDO	232
	OL, SANTA OLAJA	302
	AL, ALEJE	?
	AG, AGUASALIO	319
	AV, ARGOVEJO	?
INTERM. ZONE	VE, VERDIAGO	62.5
	V, VALDORÉ	15
INTERNAL ZONE	LSI, LAS SALAS I	7
	LSII, LAS SALAS II	15
	LSIII, LAS SALAS III	6
	LSIV, LAS SALAS IV	1

C

Table 1. Thickness of Upper Devonian deposits in the sections of (A) the Somiedo area, (B) the Bernesga area, (C) the Esla area.

Ermita : siltstone-sandstone-limestone
Fueyo : shale-sandy shale
Nocedo, Millar : shale-sandy shale-sandstone-conglomerate or limestone
Nocedo, Gordón : shale-siltstone-sandstone-limestone.

The boundaries between the lithological units are sharp but only locally a clearly erosional contact is observed. The stratotypes of the lithological units occur in section H on the east side of the Bernesga Valley, which section is representative for the External Zone.

The Intermediate Zone comprises the sections of the Pedroso Syncline, the parautochthonous of Valdoré, the Quejo Syncline, and the northeastern part of the Saliencia Syncline. In the south the zone is separated from the External Zone by the Intra-Asturo-Leonese Facies Line. The northern boundary in the Somiedo area is situated in the nose of the Saliencia Syncline. In the Bernesga area the boundary is situated between the Pedroso Syncline and the Correcilla Syncline at the Aralla Fault Zone. It seems to be the expression of the same deep-rooted zone of crustal weakness as the parallel-running Sabero-Gordón Fault Zone. In the Esla area the northern boundary of the Intermediate Zone is situated somewhere between the sections V and LSI. In this zone a relatively thin, incomplete Upper Devonian succession (c. 50-300 m) of mainly sandstones and limestones occurs. The principal subdivision is:

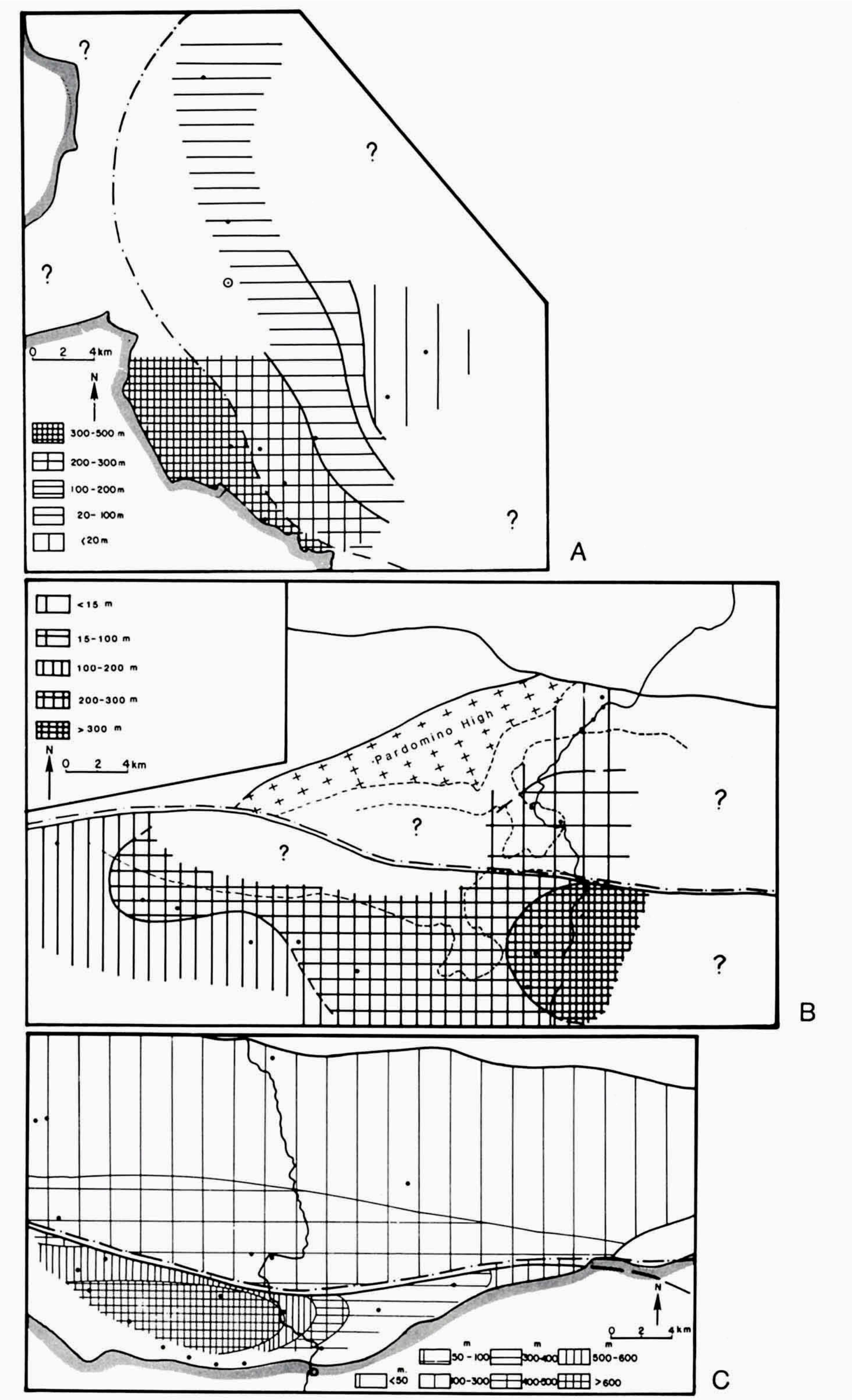


Fig. 14. Isopach patterns of the Upper Devonian deposits of: (A) the Somiedo area, (B) the Bernesga area, (C) the Esla area.

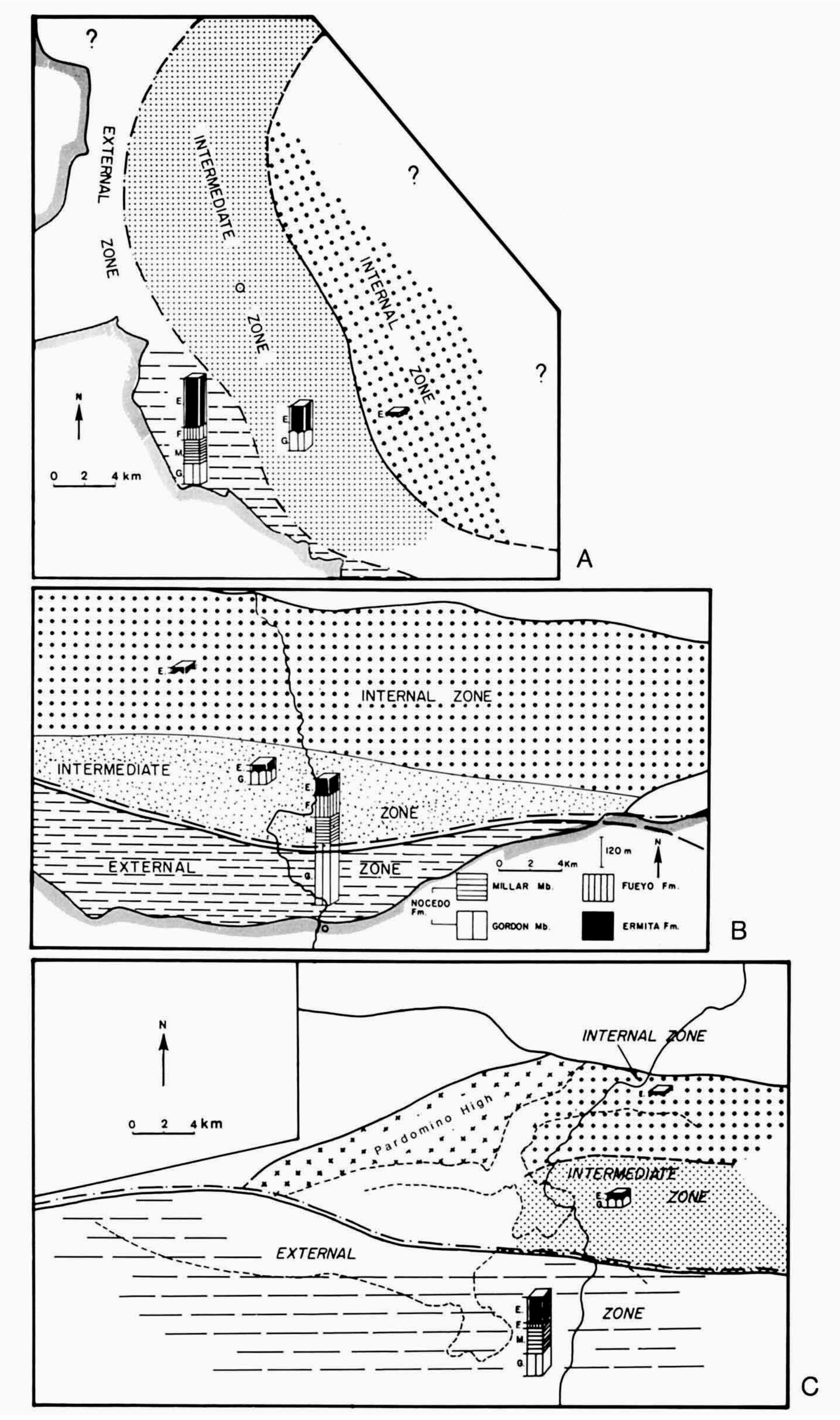


Fig. 15. Extension of the three facies zones: (A) Somiedo area, (B) Bernesga area, (C) Esla area.

Ermita : sandstone-limestone
Nocedo, Gordón : silty sandstone-limestone-ferruginous sandstone.

A sharp paraconformable boundary separates the Nocedo Formation from the Ermita Formation, the Fueyo Formation being absent. Section C in the Somiedo area has been chosen as the hypostratotype for the Upper Devonian succession of the Intermediate Zone (van Loevezijn, 1983).

The principal group of the Internal Zone comprises the sections in the northern part of the Somiedo, Bernesga and Esla areas. The zone is situated north of the Intermediate Zone. The León Line separates the Asturo-Leonese Basin in the south from the Asturian Geanticline in the north. This implies that the line is the northern boundary of the Internal Zone as a facies zone of the Asturo-Leonese Basin. However, it should be kept in mind that the Upper Devonian to lowermost Carboniferous succession of the Asturian Geanticline is very similar to that of the Internal Zone, where a thin, patchy distributed succession occurs (0-50 m), mainly consisting of sandstones, which rests with an irregular disconformable contact on older Palaeozoic deposits. The Nocedo and Fueyo formations are absent:

Ermita: ferruginous sandstone-limestone

The section 2.25 km south of San Emiliano along the east side of the road is chosen as a hypostratotype for the succession of the Internal Zone (van Loevezijn, 1983). In Fig. 16 a summary of the characteristics of the three zones is given.

PROPERTIES	EXTERNAL ZONE	INTERMEDIATE ZONE	INTERNAL ZONE
THICKNESS	150-730 m	15-291 m	0-53 m
LITHOSTRATIGRAPHIC UNITS	Ermita Formation Fueyo Formation Nocedo Formation: -Millar Member -Gordón Member	Ermita Formation Nocedo Formation: -Gordón Member	Ermita Formation
SEDIMENTS	shales, turbidites, siltstones, sandstones, conglomerates, limestones, very few ferruginous soils	siltstones, sandstones, conglomerates, limestones, few ferruginous soils	sandstones, congl., limestones abundant ferruginous soils
CONTACTS	base of the Ermita Formation paraconformable or conformable	base of the Ermita Formation paraconformable	base of the Ermita Formation disconformable
REFERENCE SECTION	section H	section C	section E

Fig. 16. Characteristics of the main facies zones.

Biostratigraphy

The biostratigraphic correlations were made with the aid of new identifications of conodonts (Raven, 1980), brachiopods (van der Pol, 1985; Krans, in van Loevezijn, 1982) as well as the most important faunal identifications of earlier publications. The conodont samples are marked in the sections (see Appendix).

CORRELATIONS

Nocedo Formation

Gordón Member — In the top of the Portilla Formation conodont assemblages were found of the Upper *hermanni cristatus* Zone to lowermost *asymmetricus* Zone (Fig. 17). The basal siltstones of the overlying Gordón Member contained large quantities of bryozoans, crinoid ossicles, solitary corals, and brachiopods (*Apousiella bouchardi, Apousiella* sp., *Cariniferella dumontiana*). In the basal siltstones of section LA, Becker et al. (1979) found an early Frasnian ostracode fauna. The base of the member in the Llombera section (section LL) contains a conodont assemblage of the Lower *asymmetricus* Zone. Eastward, at Matallana (section M), the age of the base of the member is in the Middle *asymmetricus* Zone. Exposure of the area near Mantallana during the Lowermost to Lower *asymmetricus* Zone may be due to the influence of the Pardomino High in the east. The limestones of the upper part of the member in the Esla area contain a Devonian brachiopod fauna (*Apousiella bouchardi*, *Athyris* sp., *Atrypa* sp., *Cariniferella dumontiana, Cyrtina* sp., *Cyrtospirifer* sp., *Gypidula* sp., *Chonetes* sp., *Productella subacculeata*, Productidina, Rhychonellida, Spiriferida). A similar fauna is mentioned by García Alcalde et al. (1979) for the limestone unit of section H in the Bernesga Valley. One sample from the middle of the limestone at Portilla de Luna (section PO) contained the trilobite *Bradocryphaeus sexspiriferus* (Smeenk, 1983) which until now is only found in the Middle *asymmetricus* Zone. Moreover tentaculitids (*Tentaculites* sp., *Homoctenus ultimus*), gastropods (*Platyceras* sp.), bryozoans, crinoids, and stromatoporoids are found. *Homoctenus ultimus* indicates a Frasnian age. More detailed information on the age of the limestone unit was obtained from conodonts. The base of the limestone in most sections is in the Lowermost to Lower *asymmetricus* Zone. Only in the eastermost sections of the Bernesga area (LL, M) younger faunas were found at the base (Middle to Upper *asymmetricus* Zone). The carbonate sedimentation continued into the *Ancyrognathus triangularis* Zone or may be even into the *gigas* Zone as was proved in the sections H and LA.

In the southern limb of the Alba Syncline the Huergas and Portilla formations are very thin or absent (Fig. 18). There, in the basal shales of the Gordón Member, numerous goniatites were found. Buggisch et al. (1982) found the same goniatites in the Huergas Formation. According to these authors they indicate a late Eilelian to Givetian age. From a slumped limestone boulder in the basal part of the Gordón Member a conodont fauna very similar to the conodont faunas of the top of the Portilla Formation was found (sample SC2: Lowermost *asymmetricus* Zone). At Piedrasecha a 1 m thick shale layer with an abundant bryozoan fauna overlies the Santa Lucía Formation. The shales are probably the equivalent of the goniatite shales at Portilla de Luna and Sigüera. The shales are overlain by 5 m of sandy packstones, which belong to the lower part of the

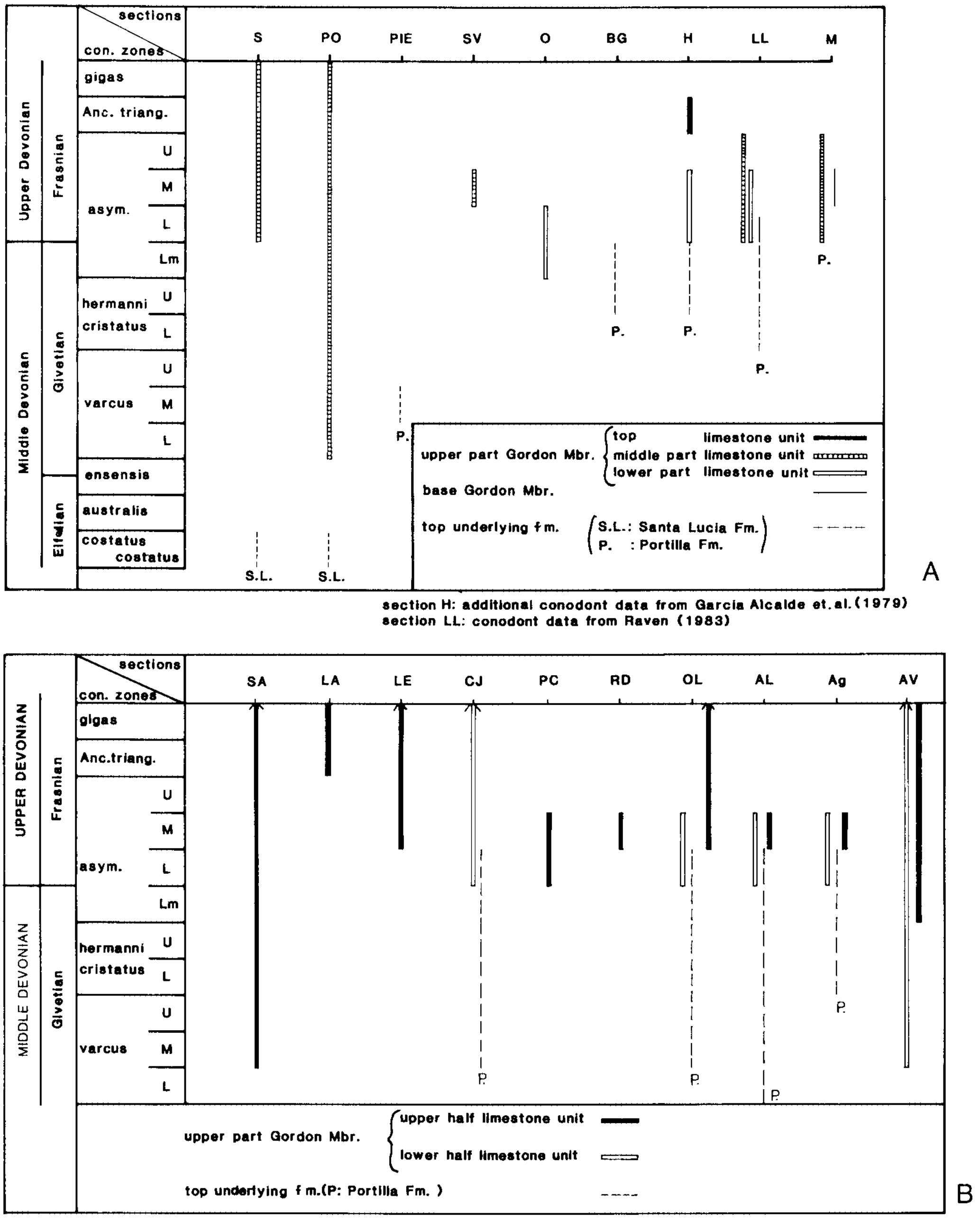


Fig. 17. Ranges of the conodont faunas from the samples of the Gordón Member and the underlying Portilla Formation: (A) Bernesga area, (B) Esla area. For an explanation of the locality symbols see Fig. 6 and Table 1.

Portilla Formation as is suggested by the conodont fauna of the Middle *varcus* Zone of sample PIEC6 (Fig. 18). The limestone is overlain by the shales of the Gordón Member which contain the tentaculite *Striatostiliolina striata*, indicating a late Givetian to Frasnian age, and the bivalve *Buchiola*.

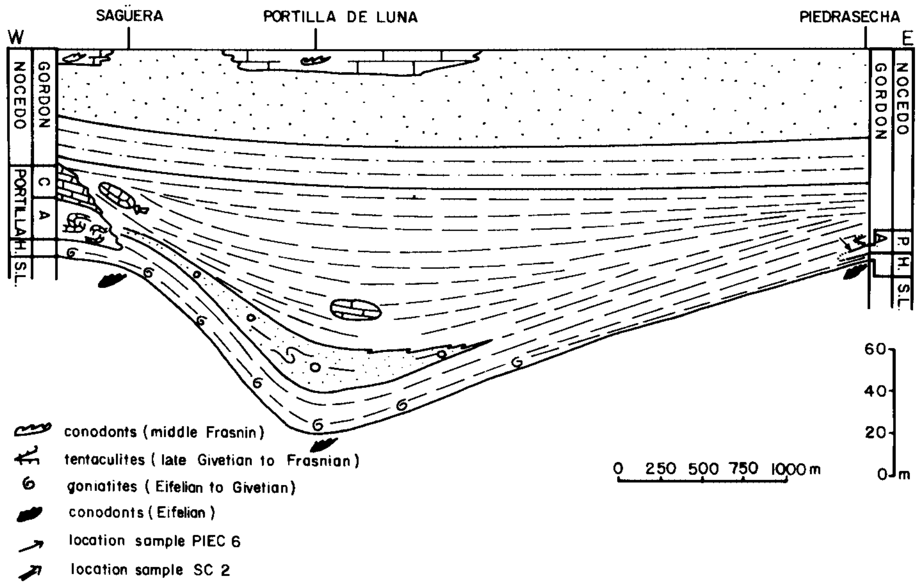


Fig. 18. Detailed west-east correlation of the Gordón Member in the southern limb of the Alba Syncline, with the distribution of the goniatites, conodonts, and with the location of the samples PIEC6 and SC2 (modified after van Loevezijn & Raven, 1983).
H = Huergas Fm., S.L. = Santa Lucía Fm., P = Portilla Fm.

Millar Member — In the basal siltstones, the brachiopod *Apousiella bouchardi* occurs. A very interesting fauna was collected from the lower part of the Crémenes Limestone: tentaculitids (*Homoctenus ultimus ultimus*), corals (*Medusaephyllum* sp., *Tabulophyllum* sp., *Amplexocarinia* sp., *Hexagonaria* sp., *Thamnophyllum* sp., *Papiliophyllum* sp., *Pterorrhiza* sp., *Thamnophora* sp., *Alveolites suborbicularis, Alveolitella schladensis, Aulopora* sp.), stromatoporoids (*Stromatoporella granulata, Stromatoporella* sp., *Actinostroma* sp.), algae (*Sphaerocodium* sp.), ostracodes (*Polyzygia neodevonica, Jenningsina* sp., *Microcheilinella* sp.), bryozoans (*Fistulipora* sp., *Fenestella* sp., *Rhombopora* sp., *Stereotoechus* sp., *Anomalotoechus* sp., *Amplexoporalla* sp.,) receptaculids *(Receptaculites neptuni)*, brachiopods *(Guerichella pseudomultifida, Cyrtiopsis* cf. *senceliae, Cyrtospirifer verneuili, C. verneuili,* C. aff. *lonsdalii, C. stolbovi, C. syringothyriformis, Thomasaria gibbosa, Athyris concentrica, Atrypa* sp., *Desquamatia* sp., *Spinatrypa* sp., *Spinatrypina* sp., *Douvillina* sp., *Productella subaculeata, Schizophoria antiqua*, Rhynchonellida gen. et sp. indet.), trilobites, gastropods, and a few conodonts. The most interesting fossils are listed in Fig. 19 together with the conodont zones and the Upper Devonian subdivision of the Ardennes (Ourthe Valley). The occurrence of four species of Atrypinae and the species *Athyris concentrica, Schizophoria antiqua, Thomasaria gibbosa*, and *Douvillina* sp. indicates and age older than Famennian, because these fossils became extinct at the Frasnian-Famennian boundary. The abundant occurrence of trilobites and stromatoporoids supports this age identification; most of these species became extinct at the end of the Frasnian (McLaren, 1970). The conodonts *Icriodus subterminus, Polygnathus webbi, Polygnathus xylus xylus*, and the ostracode *Polyzygia neodevonica* are hardly known from deposits younger than Frasnian. The most precise information is obtained from the tentaculite *Homoctenus ultimus ultimus* (identified by J.P.S. Goeijenbier) and

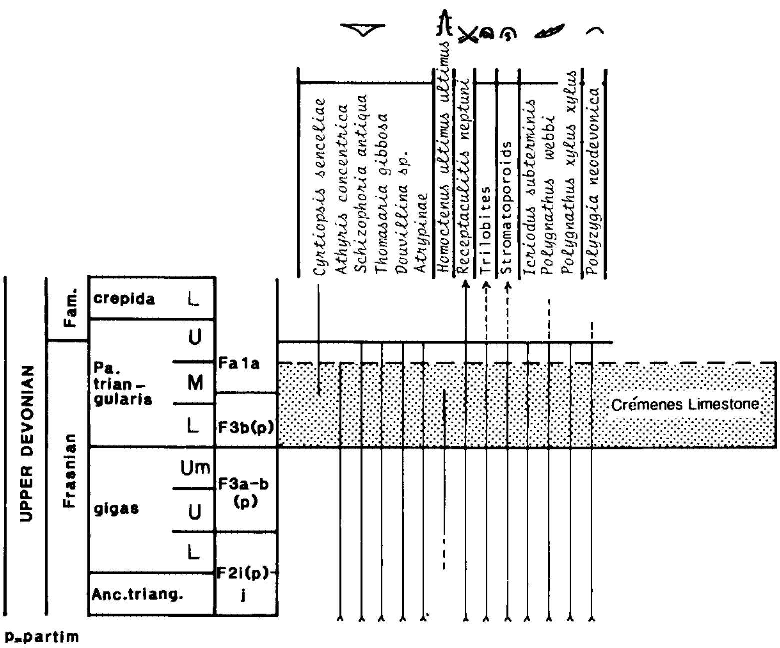


Fig. 19. Vertical distribution of some of the fossils collected from the Crémenes Limestone.

the brachiopod *Cyrtiopsis* cf. *senceliae*. The tentaculite is also found in the Kellwasserkalk, which was deposited during the *gigas* Zone - *Palmatolepis triangularis* Zone transition. The brachiopod *Cyrtiopsis senceliae* is known from the Upper Devonian of the Ardennes. Sartenaer (1956) restricted the range to Fa1a which corresponds with the *Pa. triangularis* Zone - *crepida* Zone transition. Westbroek (1964) suggested that the limestone was deposited during the earliest part of the Famennian. He based his conclusion on the determinations of Rhynchonellidae: specimens of *Camarotoechia boloniensis* and *Cupularostrum cantabricum*, which suggest a Frasnian age, as well as *Ptychomaletoechia* cf. *gonthieri*, suggesting a Famennian age. The preliminary conclusion that might be drawn is that either the diagnosis of these fossils has to be revised or *Ptychomaletoechia gonthieri* occurs earlier than assumed. Raven (1983) suggests that the limestone was deposited near the *gigas-Pa. triangularis* Zone transition, a conclusion based mainly on the occurrence of the tentaculite *Homoctenus ultimus ultimus*. With the identification of *Cyrtiopsis senceliae* the age of the lower part of the limestone is now restricted to the lower part of the *Palmatolepis triangularis* Zone. The upper part of the limestone was still being deposited during the Frasnian, but there the poorly preserved fossils prevent a more accurate conclusion.

Fueyo Formation

The scarce fauna of the Fueyo Formation in the Esla and Somiedo areas does not permit any accurate conclusion about the age of the formation, but data from the underlying Nocedo Formation suggest that deposition of the Fueyo Formation started after the Frasnian. Probably most of the sediments of the Fueyo Formation were deposited during the early Famennian, as is indicated by the rather few conodont data on the age of the

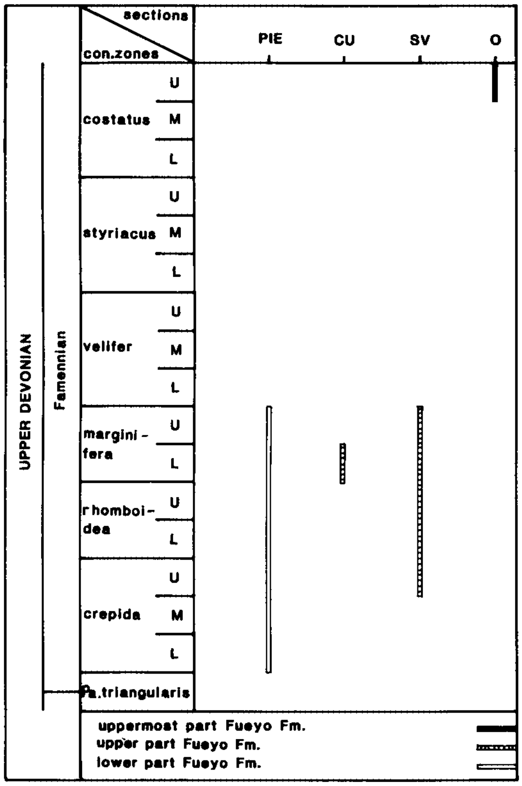


Fig. 20. Ranges of the conodont faunas of the samples of the Fueyo Formation. For an explanation of the locality symbols see Fig. 6 and Table 1.

Fueyo Formation in the Bernesga area (Fig. 20). Limestone intercalations are only found in the southern limb of the Alba Syncline. Therefore no data are available about the Fueyo Formation in the northern limb of the syncline. At Piedrasecha, in the lower part of the Fueyo Formation about 50 m above the base, conodont-bearing septaria nodules are found. The nodules contain a conodont fauna of the *crepida* to *marginifera* zones, indicating that these sediments were deposited during th early Famennian. At Cuevas erosive cross-bedded channel-fill deposits occur in the upper part of the Fueyo Formation. The channel-lag consists of reddish mud pebbles, shale flakes and bioclasts (fragments of brachiopods, crinoids and goniatites) with an abundant conodont fauna (650 conodonts/kg). The conodonts *Palmatolepis glabra glabra* and *Polygnathus fallax* indicate the Lower *marginifera* Zone. At Santiago de las Villas a sample from one of the burrowed calcareous bioturbated horizons in the upper part of the formation (Fig. 21) contains the conodonts *Polygnathus semicostatus*, *Pandorinellina insita* and *Palmatolepis pectinata*. The first two species have a long vertical range, but the last one is only known from the Upper *crepida* Zone to Upper *marginifera* Zone. At Olleros de Alba a conodont sample from the uppermost part of a bioturbated unit at approximately the same stratigraphic level as the burrowed horizons at Santiago de las Villas contains a conodont fauna of the Upper *costatus* Zone. The burrowed calcareous horizons are interpreted as submarine hardgrounds, which explains the concentration of conodont elements of different zones in a thin unit. Samples from the uppermost part of the underlying Millar Member in the Esla area contain a fauna of the Lower *Palmatolepis triangularis* Zone. Thus the sedimentation of the Fueyo Formation probably started

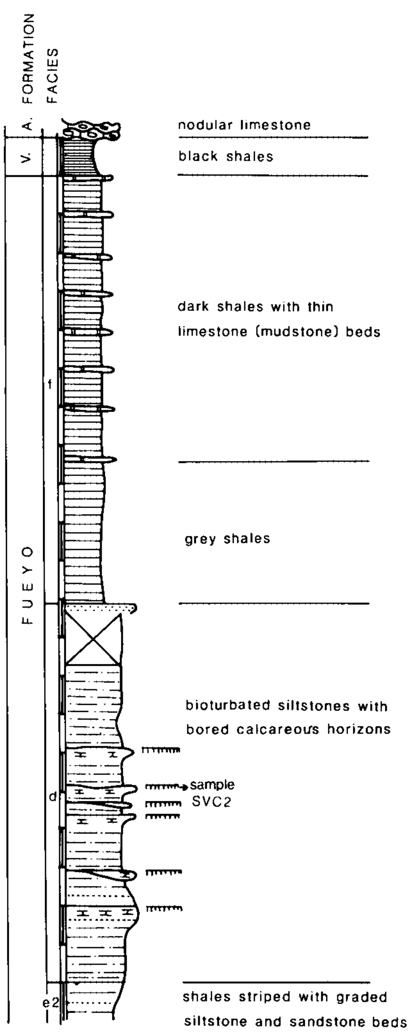


Fig. 21. A detailed section of the uppermost part of the Fueyo Formation at Santiago de las Villas. The hardgrounds are indicated, as well as the position of the conodont sample. The Fueyo Formation is overlain by the black shales of the Vegamián Formation (V.). In the southermost part of the Bernesga area the Ermita Formation is absent. The scale bars indicate units of 2 m.

during the early Famennian, before or during the *marginifera* Zone. Just above the hardgrounds dark shales with limestone (mudstone) intercalations occur with a conodont fauna of the *costatus* Zone. The *velifer* Zone and the *styriacus* Zone are not recognised. Thus instead of a hiatus of almost the entire Famennian, advocated by Raven (1983), I conclude to a continuous Upper Devonian sedimentation at least up to the *velifer* Zone in the southern part of the Asturo-Leonese Basin. However, the absence of the *velifer* Zone and the *styriacus* Zone in the Famennian deposits is not certain: only four out of seven Fueyo samples contained a conodont fauna. More research is necessary.

Palaeoecological remarks on the conodont faunas — Recently two biofacies models of Upper Devonian deposits have been proposed: one by Sandberg (1976) based upon deposits of the *styriacus* Zone in the U.S.A. and one by Dreesen and Thorez (1980) based upon Famennian deposits of Belgium. The interpretation of the Famennian conodont biofacies of the Fueyo Formation is essentially based on their models. From three samples histograms have been made (Fig. 22). It was too much time-consuming to

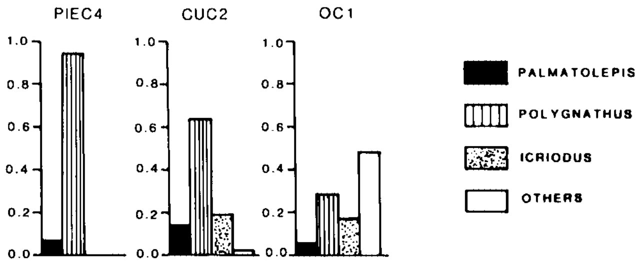


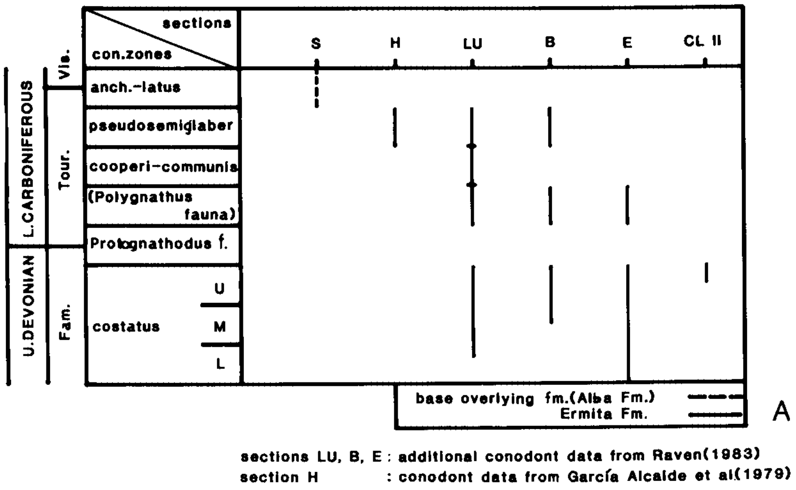
Fig. 22. Histograms of the conodont samples of the Fueyo Formation. For an explanation of the locality symbols see Fig. 6B and Table 1.

count the conodonts from sample SVC2 because of the high pyrite content. In all three samples *Polygnathus* and *Palmatolepis* species occur. Similar faunas occur according to the conodont biofacies model of Sandberg only in moderately deep water on the continental shelf. According to the model of Dreesen and Thorez, sediments with *Polygnathus* and *Palmatolepis* species are deposited in subtidal and offshore areas. Indeed the laminated shales and siltstones suggest an open marine offshore environment. Samples CUC2 and OC1 contain up to 19% *Icriodus*. These conodonts are generally interpreted as indicative for a shallow marine tidal environment. Probably some of these conodonts were transported into deeper water: sample CUC2 is from the base of a channel fill sequence. The facies belts were very narrow: the conodont faunas are found only 5 km south of the Intra-Asturo-Leonese Facies Line, which was probably the border of the outer shelf area. Probably (storm)wave action and tidal currents picked up shallow-water elements and transported them into the infratidal environment. According to Raven (1983) it is also possible that some species of *Icriodus* lived in the surface layer of the water with *Palmatolepis* in the deeper zone below. The remaining conodonts ('others') mainly consist of '*Spathognathodus*' (69%), which occurs in environments ranging from deep to shallow water, and are not indicative for any particular environment. The sample with exclusively *Palmatolepis* and *Polygnathus* is from the lower part of the Fueyo Formation, whereas the samples with *Icriodus* are from the upper part, which indicates that the sediments of the lower part of the Fueyo Formation were deposited in a slightly deeper and/or more distal environment than the sediments from the upper part of the formation, what is confirmed by the sediments and sedimentary structures.

Ermita Formation

In the Ermita Formation of section H an abundant late Famennian brachiopod fauna occurs (García Alcalde et al., 1979). The occurrence of *Araratella* in the upper part of the formation might even indicate the latest Famennian. In the Esla area the brachiopods *Cyrtospirifer almadenensis*, *Leptaena* sp. and *Camarotoechia letiensis* are found, which also indicate a late Famennian age. In the cross-bedded sandstones of the Ermita Formation of sections B and UG Frasnian coral clasts occur (Sanchez de la Torre, 1977). Probably these purple-coloured *Hexagonaria* clasts are erosion products originated from other formations.

More detailed information on the age of the sediments is obtained from conodonts (Fig. 23). The lower part of the Ermita Formation in the Intermediate and Internal zones contain conodonts of the late Famennian *costatus* Zone, e.g. in the basal part of the



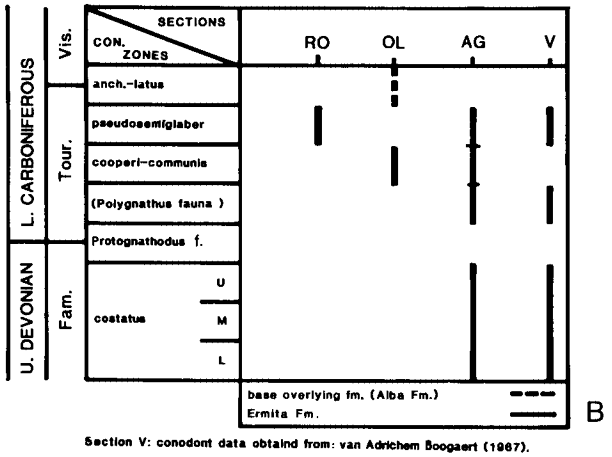


Fig. 23. Conodont faunas obtained from samples of the Ermita Formation: (A) Bernesga area, (B) Esla area; zonation after Raven (1983). For an explanation of the locality symbols see Fig. 6 and Table 1.

limestones of sections LU and B (Fig. 13b), and in the sections E and CLII. In the External Zone almost the entire Ermita Formation consists of siliciclasts, and consequently no condont data are available. Because no dates older than the late Famennian *costatus* Zone are available from the Ermita Formation only the uppermost part of the Fueyo Formation was deposited contemporaneously with the Ermita Formation. There is no reason to postulate a synchronous deposition of the entire Fueyo Formation and Ermita Formation as supposed by Raven (1983). Beyond the area of the Vegamián Black Shales a conodont fauna of the *cooperi-communis* and *pseudosemiglaber* zones occurs in the limestones of the uppermost part of the Ermita Formation. The Vegamián Formation overlies the Ermita Formation on the Asturian Geanticline and in parts of the Asturo-Leonese Basin (southernmost part of the External Zone and in the Internal Zone). Sedimentation of that formation started in the *cooperi-communis* Zone and continued into the *pseudosemiglaber* Zone - *anchoralis-latus* Zone (Raven, 1983). Thus the upper-

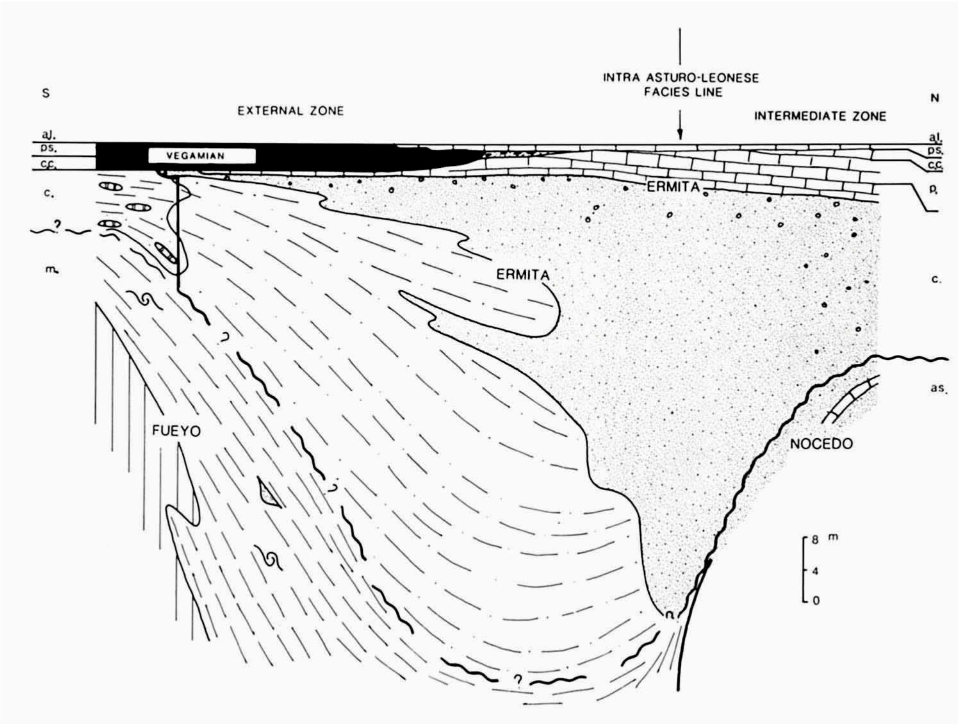


Fig. 24. Generalized north-south cross-section through the southern part of the Bernesga area showing the relations between the Fueyo, Ermita and Vegamián formations (m. = *marginifera* Zone, as. = *asymmetricus* Zone, c. = *costatus* Zone, p. = *Polygnathus* fauna, c.c. = *cooperi-communis* Zone, ps. = *pseudosemiglaber* Zone, a.l. = *anchoralis-latus* Zone). (Heavy lines are formation boundaries).

most part of the Ermita Formation was deposited contemporaneously with the Vegamián Formation. In Fig. 24 the relation between the Fueyo, Ermita and Vegamián formations is illustrated.

CONCLUSIONS

In Fig. 25 a biostratigraphic correlation chart of the Upper Devonian to lower Carboniferous deposits of the studied areas is given. There are noteworthy differences between the chart and the recently published correlation chart of Raven (1983). In the present work the Givetian-Frasnian boundary is drawn between the Lowermost and Lower *asymmetricus* Zone according to the proposal of the Subcommission on Devonian Stratigraphy (Ziegler & Klapper, 1982).

In the External Zone of the Esla area the Millar Member is locally absent (sections A, CI) and northward, in the Intermediate Zone, the upper limestone unit of the Gordón Member is absent (sections V, VE). Obviously erosion removed a much larger part of the Nocedo Formation in the Esla area than in the Bernesga and Somiedo areas, which is not apparent from the correlation chart of Raven (1983).

The upper boundary of the Nocedo Formation is not situated in the *gigas* Zone, as supposed by Raven (1983), but in the *Palmatolepis triangularis* Zone as proved by the Crémenes fauna. The deposition of the Fueyo Formation, which was restricted to the

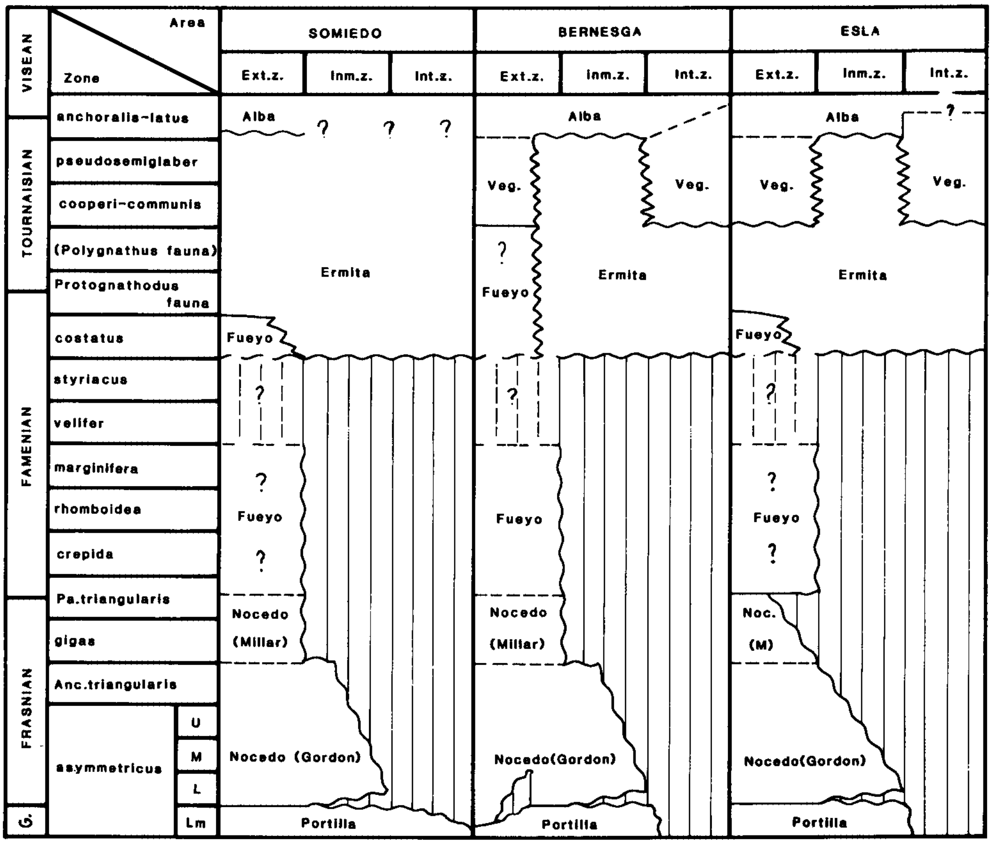


Fig. 25. Biostratigraphic correlation chart for the Upper Devonian to lower Carboniferous deposits in the southern part of the Asturo-Leonese Basin.

costatus Zone by Raven (1983), is here proved to start earlier in the Famennian already in or before the *crepida* Zone. In the southermost part of the Bernesga area, the Ermita Formation is absent and there the Fueyo Formation is overlain by the Vegamián Formation. No erosional contact is observed and a continuation of the Fueyo Formation into the Early Tournaissian is supposed.

Facies

DESCRIPTIONS AND INTERPRETATIONS

In the Upper Devonian deposits eight facies and ten subfacies are distinguished on the basis of lithological and palaeontological characteristics. The facies and subfacies types are, as far as possible, differentiated in natural units which should be recognisable in the field by subsequent workers. Nevertheless, many arbitrary boundaries had to be defined, especially where the facies types have gradational contacts, or where they have many characteristics in common.

Facies **a**

Lithology — This facies mainly consists of grey and brown bioturbated calcareous sandy siltstones and silty sandstones, locally with red and pink mottled horizons. Ripple marks and parallell lamination have been observed. In the Esla area siltstones are often absent and there facies **a** mainly consists of thin-bedded argillaceous limestones of wackestone and mudstone composition.

Fossils — In the bioturbate siltstones and limestones abundant disarticulated but almost undisturbed stem and crown crinoid ossicles occur. Brachiopods and ostracodes are frequently observed. Moreover branching and solitary corals, trilobites, gastropods, bryozoans, tentaculites, and stromatoporoids are present.

Interpretation — Sediments of facies **a** are very similar to the silty to sandy argillaceous limestones which Habermehl (1970) recognised in the Lower Devonian Basibé Formation in the Central Pyrenees. A slight increase in the supply of terrigenous material to the carbonate depositional environment could give rise to calcareous siltstones and sandstones and to silty to sandy argillaceous limestones. The clastics may have been supplied by rivers or derived from littoral sources. As the deposits of facies **a** occur directly below or above quartzarenites or crinoidal grainstones which are interpreted as littoral sandstones and crinoidal shoal deposits, the sediments of facies **a** are considered as leeside deposits of barrier islands or offshore bars, which areas are similar to lagoonal environments or small depression zones between ridges on the shallow sea floor, protected areas with quiet water conditions. These open-marine, though relatively sheltered, back-bar environments permitted the sedimentation of mud-supported limestones and argillaceous material while water agitation may have brought in the silty and sandy material. The differences in the amount of terrigenous material in the Somiedo and Bernesga areas (calcareous siltstones and sandstones) and in the Esla area (silty argillaceous limestones) were caused by differences in the supply from the hinterland, in water agitation, in current or wave conditions, and/or differences in submarine topography. The completely bioturbated nodular sediments suggest an abundant benthos. The large quantities of undisturbed disarticulated crinoidal ossicles suggest a low rate of sedimentation, allowing time for fragments binding the ossicles together to decay. The close proximity of the ossicles suggest weak currents (Lane, 1971). Because of the low sedimentation rate there was time for benthonic organisms to rework the sediment. The mottled horizons suggest local subaerial exposure of the shallow-water environment.

Facies **b**

Lithology — Facies **b** consists of cross-bedded grey and red bioclastic packstones and grainstones with an admixture of rounded to well-rounded quartz grains of up to 10%. At several locations leached horizons are found forming dark-red haematite sandstone crusts.

Fossils — Although ichnofossils are rare in this facies, some burrowing activity is observed. Thin, red- and green-coloured, completely burrowed mud drapes are locally found between the cross-bedded packstone and grainstone beds. Also some beds with deep vertical burrows are observed in sediments of facies **b** with a high sandstone percentage. Apart from large quantities of crinoid ossicles, considerable quantities of clasts of branching and solitary corals, stromatoporoids, bryozoans, gastropods, trilobites, conodonts, echinoderms, tentaculitids, and brachiopods occur.

Interpretation — Large quantities of bioclastic material must have been produced in fairly shallow water, where strong wave actions caused the fragmentation and transport of the crinoidal ossicles and resistant parts of other fossils. This is evidenced by the occurrence of rounded and fairly well sorted quartz grains. In addition the occurrence of large-scale cross-stratification, produced by migrating large-scale ripples, indicates a highly turbulent environment in which the bioclasts were reworked and transported by strong currents, which resulted in well-oxygented, unstable bottom conditions. The occurrence of deep vertical burrows is typical of a littoral environment where rapid sedimentation and erosion are critical factors (Seilacher, 1964). The herringbone cross-stratification is a typical feature of a tidal environment (Reineck & Singh, 1975). Convolute lamination, which also occurs in a tidal environment (Wunderlich, 1967), is also present. Facies **b** is very similar to facies belt 6 of the standard facies scheme of Wilson (1975). This facies represents a crinoidal shoal environment in agitated water. Wilson assumes a depth of deposition ranging from 10 m to well above sea level. The shoal could develop on the littoral sands when the siliciclastic supply decreased. On the lee side the shoal created the protected environment of facies **a**. The palaeorelief of a shoal is to be seen at Olleros de Alba at the west side of the road to La Magdalena.

Facies **c**

General remarks — Facies **c** consists of coarse siliciclastic deposits (sandstones and conglomerates). A subdivision into three subfacies can be made. Subfacies **c1** consists of pebbly sandstones and conglomerate beds without cross-bedded structures. Subfacies **c2** consists of well-sorted and well-rounded very fine to fine-grained, cross-stratified sandstones. Subfacies **c3** consists of coarse-grained, cross-stratified pebbly sandstones.

Subfacies **c1**

Lithology — The pebbly sandstones and conglomerates of subfacies **c1** are classified according to Davies and Walker (1974). The granule-sandstone group consists of medium and coarse sandstones with granules up to 4 mm, in the fine-pebble conglomerate group most of the clasts belong to the smaller pebble sizes (4-15 mm), and in the coarse-pebble conglomerate group most of the clasts belong to the larger pebble sizes (15-65 mm). Almost all the granules and pebbles consist of quartz (95%). Some quartzite pebbles have a dark-green or even black colour due to the occurrence of abundant fine-grained light-brown and green poikiloblastic tourmalines. Flat haematitic sandstone pebbles make up the remaining 5%. The matrix of the conglomerate consists of white, fine- to medium-grained quartzarenite. Parallel lamination, imbrication and normal-graded structures occur frequently in the fine-pebble beds and granule-sandstone beds. The coarse-pebble beds have sharp, commonly scouring bases and sharp tops and tend to be laterally discontinuous. In these beds normal as well as inverse grading occurs. Flat haematitic sandstone pebbles developed an excellent upcurrent imbrication fabric. Cross-bedding is almost completely absent in subfacies **c1** (Fig. 26).

Fossils — Fossils are rare in subfacies **c1**, but moulds of gastropods and bivalves are observed in cobbles at Barrios de Gordón (section BG).

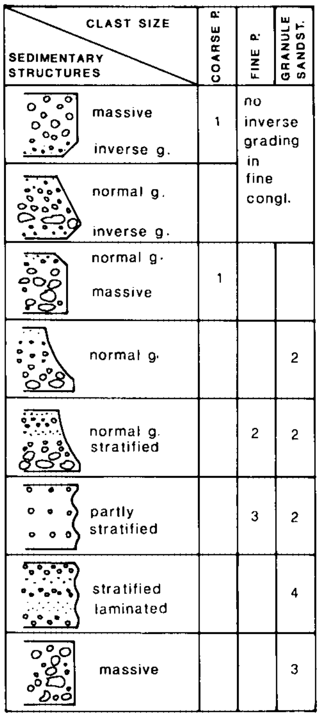


Fig. 26. Internal features of 20 conglomerate beds of subfacies **c1** at Barrios de Gordón, classified according to clast size (classification modified after Davies & Walker, 1974). Note that inverse grading does not occur in the fine pebble fraction.

Interpretation — One of the most striking features is the almost complete absence of cross-stratified structures. Moreover the imbricated clasts have a preferred orientation of their longest axis parallel to the current direction, whereas imbricated fabrics resulting from rolling transport have their orientation of the longest axis statistically transverse to the flow direction (Davies & Walker, 1974). Obviously traction currents are of minor importance. If we eliminate rolling bed transport, we are left with sediment gravity flow as the transport mechanism. Middleton and Hampton (1973) made a classification of the sediment gravity flows (turbidity current, fluidized sediment flow, grain flow, debris flow). Basal loadcasts and fluid escape structures, which are characteristic for sediments transported by fluidized sediment flow, were not found. A debris flow mechanism with a sluggish downslope movement of mixtures of granular solids, clay and water as a response to pull gravity can also be eliminated because of the graded structures, the stratification, the preferred clast fabric, and because of the absence of a muddy matrix. A mechanism with clasts supported above the bed by a highly turbulent flow (turbidity flow mechanism) in combination with dispersive pressure, generated by grain-to-grain interaction (grain-flow mechanism) is a possibility. Turbulence would help support the solid grains in addition to the support provided by dispersive pressure. The dynamics of a turbulent grain-flow is discussed by Davies and Walker (1974). They distinguished essentially two types of conglomerates, which are also found in subfacies **c1**: the inverse and normal graded coarse conglomerate type and the graded-laminated fine conglomerate type. Moreover, sandstones with sparcely distributed granules, often massive and structureless, sometimes containing a weak lamination, can be distinguished. These deposits are very similar to the so-called massive sandstones described by Walker (1978), who interpreted them as proximal turbidites. The inverse to normally graded conglomerates, the graded-stratified conglomerates and the massive granule-sandstones are succes-

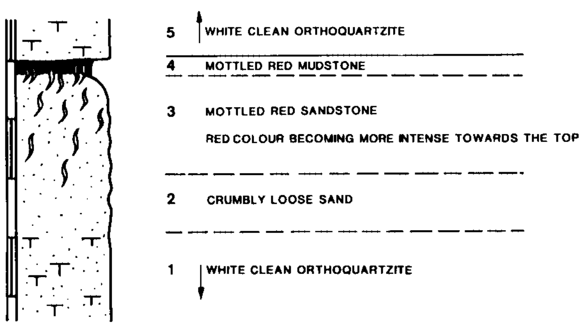


Fig. 27. A completely developed palaeosoil in the quartzites of subfacies **c2**. Each bar indicates one metre.

sively deposited in a more downcurrent position, according to Walker (1978). The discontinuous conglomerate bodies always cut into shales of facies **e**. The conglomenrates represent probably submarine channel fills, which were deposited in the transition area between the littoral platform and the adjacent deeper area.

Subfacies **c2**

Lithology — Most of the sediments of subfacies **c2** consist of light-grey and white, medium-grained quartzarenites with parallel and low-angle cross-laminations. Large-scale tabular and trough cross-bedding are also found. Wave ripples are often observed. Sometimes haematitic horizons also occur (Fig. 27). Criteria to consider them as fossil soils are:
the limited thickness (generally 0.5-2.5 m) and the vast horizontal extension;
the red and violet colours becoming more intense from base to top;
the occurrence of haematite-bearing mottled shale crusts;
the gradual transition of the lower boundary in contrast to the sharp upper boundary.
The sediments are often cemented by calcite or quartz during diagenesis to form calcareous sandstones and (ortho)quartzites. Locally the sandstones contain a considerable matrix percentage of up to 20% consisting of a finely dispersed mixture of haematite-limonite carbonate or quartz wacke composition.

Interpretation. — The stratigraphic affinities to the siltstones of facies **d** (which, as will be shown below, are considered to be transition and lower shore face deposits) and the back-bar and shoal deposits of facies **a** and **b**, respectively, indicates a littoral environment. The pure very fine- to fine-grained sandstones, with parallel lamination and low-angle cross-lamination are interpreted as beach deposits. These laminations are formed by swash and backwash activity in the fore-shore zone (Reineck & Singh, 1975). Palaeosoils were locally formed where the shallow marine sands were subaerially exposed. The red sandstone beds are interpreted as winnowed reworked soils. The mineralogically as well as the texturally mature sediments indicate a constant turbulent environment in which almost no fines could settle down. The high energy of the environment is also indicated by the large-scale cross-bedded structures which were formed by migrating bars and tidal channels.

Subfacies **c3**

Lithology — Subfacies **c3** consists of medium- to coarse-grained white pure quartz sandstone with irregularly distributed well-rounded fine gravel. In the Somiedo area however, quartz pebbles, quartz cobbles and even quartz boulders occur in these sediments, but in the Bernesga and Esla areas the size does not surpass the gravel fraction. Shale, siltstone and fine-grained sandstone do not occur in these quartz-cemented pebbly sandstones. The subfacies **c3** sediments form discontinuous channel bodies. Near the base of the bodies gravel is often concentrated forming a channel lag. Tabular as well as through-shaped large-scale cross-stratification occurs frequently. Sometimes the channel fill is structureless.

Fossils — Fossils were not found in subfacies **c3**.

Interpretation — The roundness of grains, pebbles, cobbles, and boulders, the coarse sizes of the clasts and the absence of fine-grained sediments indicate highly turbulent conditions. Van den Bosch (1969) supposes that these deposits were formed in the zone of the breaking waves near a cliff shore. Where few pebbles occur in finer grained sediment the grain-size distribution often is bimodal. According to Krumbein and Sloss (1963, p. 162) this feature is found mainly in river deposits. The fact that the sediments of subfacies **c3** always cut into littoral deposits of subfacies **c2** and the absence of a marine fauna support this view. It may be concluded that subfacies **c3** was deposited near a high-energetic shore – partly fluvial environment.

Facies **d**

Lithology — Facies **d** consists of nodular bioturbated brown argillaceous sandstones, silty sandstones and sandy siltsones. They are all of quartz wacke composition. The matrix percentage ranges between 20% and 70% and consists of clay minerals, dispersed iron-oxyde and quartz. Locally concretionary haematitic beds with haematite ooids occur near the quartz wackes of facies **d** and the quartzarenites of subfacies **c2**. In section H the concretionary haematite beds are underlain by a chamosite-ooid-bearing sandstone horizon. The sediments were often thixotropically or plastically deformed, as a result of the high water-content of the intensely reworked sediment surface during deposition (Rhoads, 1970). Due to these deformations, mud drapes were often broken up into flakes. Parallel lamination and low-angle cross-lamination are sporadically observed, horizons of sand layers, broken up into pillow-shaped ellipsoidal masses floating in the muddy sediment, occur frequently. Some trough cross-bedded channeling sandstone beds are found. Locally several metres thick sandstone units, consisting of flat, up to 0.1 m thick beds, are intercalated in the nodular silty sandstones. The upper and lower surfaces of the beds are planar or gently wavy and always sharp. The beds are parallel-laminated or wavy-laminated. Small-scale cross-lamination is observed. The beds are sometimes separated by thin mud drapes. Amalgamation of the sandstone beds is common.

Fossils — The sediments of facies **d** contain large quantities of brachiopods and bryozoans. Moreover bivalves and crinoid ossicles occur and locally a few trilobites and solitary corals are found. The brachiopods and bivalves are often found in life position. The sediments are intensively burrowed by deposit-feeders.

Interpretation — Facies **d** sediments are interpreted as low-energy deposits, as is to be concluded from the considerable amount of siltstone and shale and the scarcity of large-scale cross-bedded structures. Facies **d** deposits often intercalate between facies **e** and subfacies **c2**. The deposits are finer grained than the littoral sands of subfacies **c2** but coarser grained than the shelf-mud sediments of facies **e**. It may be concluded that the sediments were mainly deposited just below wave base where both sand and mud were available. Biologically this area is characterized by a very high rate of bioturbation. Similar deposits are described by Reineck & Singh (1975) from the Gulf of Gaeta, where these sediments are included in the transition-zone and lower shore face. The thin-bedded sandstone units were probably the product of storm episodes after which sand settled out from suspension. The association with channel-sandstones suggests deposition seaward or lateral of the feeder channels.

Facies **e**

General remarks — Sediments belonging to facies **e** consist of an alternation of sandstone and shale. A subdivision is made into two subfacies. Subfacies **e1** is formed of shales and siltstones alternating with persistent flat sandstone beds, up to 0.5 m thick, and discontinuous channeling sandstone deposits. The sandstone/shale ratio is up to 0.9. In subfacies **e2** only sporadically sandstone occurs, and there the ratio seldom surpasses 0.2, the coarser influxes are less frequent and the discontinuous channelling deposits are absent.

Subfacies **e1**

Lithology — The sediments consist of grey- and brown-coloured fine-grained sandstone beds alternating with grey and brown shales and siltstones. The sandstones contain some shale fragments. The sandstone/shale ratio ranges between 0.1 and 0.9. The shales are often laminated although bioturbation has locally destroyed these structures. The intercalated sandstone beds may be up to 0.5 m thick, but usually they are not thicker than 0.2 m. The basal parts of the beds are structureless followed by a parallel-laminated unit. The top of the bed is sometimes characterised by small-scale cross-lamination. Grading is occasionally present, usually only in the upper part of the beds. The above-mentioned structures are not always present in a single layer. Some sandstone beds have a burrowed upper part. Occasionally the beds are completely reworked by burrowing organisms. In the thickest beds (between 0.2 and 0.5 m) tabular cross-bedding, low-angle cross-bedding and parallel-lamination is observed. The lower boundary of the beds is often planar or gently wavy, occasionally irregular and clearly erosional. The upper boundary of the beds is sometimes sharp but often, however, a merging from sandstone into mudstone is present. The transitional zone is never more than a few centimetres thick. Sole features, e.g. scour marks and tool marks, occur frequently. Locally the mud intervals are very thin or even absent and the sandstone beds are amalgamating at erosional surfaces. Slightly erosive shallow channels and strongly erosive deep channels are found. Structureless massive channel-fill deposits, as well as cross-bedded channel-fill deposits, sometimes with parallel-laminated structures near the top, occur. Almost 40% of the channel-fills possesses a channel lag. Most of the channel-lag deposits consist of quartz grains with grain-sizes ranging between a few millimetres and two centimetres. In some channel-lag deposits shale flakes, red mud pebbles and bioclasts are found. Penecontemporaneous deformation structures are frequently found. Loading of the sandstone layers into the underlying shales and siltstones is a common feature. Ball-and-pillow structures ranging in size from 0.2 to 1 m are found. The underlying mud layers are often involved in the deformation. The more or less ellipsoidal-shaped masses themselves may be structureless or show lamination. In the latter case the laminae are curved. Slumped sandstone beds are frequently found.

Fossils — Fossils are rare in this facies. Gastropod and brachiopod fragments are found in the basal part of some sandstone beds and in a channel-fill deposit as channel lag. The fauna was obviously transported. Occasionally the sediment can be fairly bioturbated. The trace fossil assemblage belongs to Seilachers (1963, 1964) *Cruziana* association.

Interpretation — The lithology and sedimentary structures indicate sharply contrasting energy levels. The laminated shale is deposited from suspension indicating an overall low-energy environment. The intercalated sandstone beds represent much higher energy levels of deposition. Each sandstone bed represents a single catastrophic event, probably a storm, or if there is evidence of amalgamation, two or more such events. Each storm event resulted in a three-stage succession. The initial stage entrained sediment and placed it in suspension. The depositional stage occurred when the storm decreased in intensity. The structureless basal sandstone represents rapid deposition. The overlying parallel-laminated sandstone unit was deposited under high shear-stress conditions at the sediment-water interface, sweeping the sands out as flat sheets (Johnson, 1978). Waning current conditions are demonstrated by grading and by the frequent occurrence of ripple-cross-lamination on top of the parallel-laminated division. The third stage, the post-storm stage, is indicated by wave ripples and bioturbation, which modified the storm layers. Channel deposits are cutting frequently into these layers. They are often found very close to the overlying littoral sandstone deposits of subfacies **c2** and are interpreted as the feeders of the next set of storm layers. The occurrence of sliding and slumping, which appears from the penecontemporaneous deformation structures, is indicative for deposition on unstable slopes.

Subfacies **e2**

Lithology — This facies mainly consists of grey shales and siltstones. Sandstones are not, however, completely absent; they form layers ranging in thickness from 1 mm to 3 cm. The sandstones are very fine or fine grained. These layers are separated by shale and siltstone units. The sandstone percentage of subfacies **e2** seldom surpasses the 20%. The flat sandstone layers are laminated, weakly graded, graded-laminated, or structureless. The undulating layers and the isolated lenticles consist of ripple-cross-laminated sandstone. They were obviously deposited by traction currents, the first with moderate sand supply, the latter with deficient sand supply. Penecontemporaneous deformation structures are present as irregulary knobby bodies on the lower side of the sand layers, interpreted as load structures. In the shales argillaceous siltstone nodules with a diameter of up to 10 cm are found in large quantities. They have a laminated core with siltstone and very fine sandstone streaks and a limonite crust. The laminae can be traced into the surrounding sediment. In the shales of the Fueyo Formation at Piedrasecha also a horizon with septaria nodules occurs.

Fossils — Only fossils of small, thin-shelled animals are found in subfacies **e2**; goniatites with a maximum diameter of 1 cm, tentaculites and small bivalves and brachiopods. Locally plant fragments are observed. Occasionally horizontal burrows belonging to sediment-feeding animals are observed. The sediment is only little bioturbated.

Interpretation — The laminated shales were deposited from suspension and indicate a low energy environment with occasional brief intervals when fine sand was introduced. Vertical change in sand-bed thickness or in sand/shale ratio values is often used as an indication of proximality (Crimes, 1970). Taking this into account, with respect to the more sandy deposits of subfacies **e1** and facies **d**, which often overlie subfacies **e2** with a gradual contact, I assume that the latter was deposited seaward of the siltstones of facies **d** and the sand layers of subfacies **e1**. The coastal sediments of subfacies **e1** were kept in suspension and were transported seawards by offshore bottom currents and storm-enhanced wave-generated currents to a depth where the fair-whether accumulate is mud. When the storm was waning, the coastal sediments were deposited as sharp-based graded layers. However, we can imagine that if the bed sloped sufficiently and the density of the sediment-current mixture was large enough, the density current could flow under its own weight into deeper waters, thus forming turbidity currents. This resulted in deposits without wave-action structures, closely resembling classical turbidites of the thin-bedded variety, as described by Allen (1982). In this way a continuum developed between storm sand layers and turbidites. The thin sandstone layers of subfacies **e2** are interpreted as such storm-generated turbidity deposits.

Facies **f**

Lithology — Facies **f** consists of dark-grey, parallel laminated shales with dark-grey limestone beds and lenticles. The beds have and average thickness of 8 cm. The lenticles vary in length between 0.5 and 2 m. No internal structures are observed in the limestones, which are pyrite-bearing mudstones.

Fossils — The limestones contain few conodonts. Bioturbation is almost absent. Only one trail, belonging to Seilacher's *Zoophycus* facies is observed.

Interpretation — The sediments of facies **f** have been slowly deposited in the quiet parts of the outer shelf below wave base, entirely out of suspension. No evidence of traction currents is found. The influx of silt was minimal. The scarcity of benthonic fauna, the dark, occasionally black, bituminous sediments and the occurrence of pyrite suggest an oxygen-depleted environment.

Facies **g**

Lithology — This facies consists of a chaotic group of sediments. The dominant lithology is mudstone with scarcely and irregularly distributed quartz pebbles up to 4 cm in diameter. Conglomerates with a muddy sandstone matrix are intercalated in these deposits. These conglomerates contain 70-90% subangular to subrounded white quartz pebbles and 30-10% flat red-coloured mudstone pebbles. Also isolated sandstone lenticles and thin sandstone beds (average thickness 5 cm) are observed.

Fossils — No fossils are found in facies **g**.

Sedimentary structures and interpretation — This facies consists of a number of individual debris-flow units, between 0.5 and 6 m thick. Pebbly muddy sandstone units without a preferred orientation of the pebbles, as well as those with imbricated flat pebbles occur. An intra-formational folded slab of well-bedded sandstone-shale alternation occurs, which represents a slumpfolded turbidite unit. Exotic limestone boulders were observed at Sagüera by the author, and de Coo (1970) found some limestone boulders at Portilla de Luna. They have a diameter ranging from 5 to 10 m. Conodonts suggest that they were derived from the Portilla Limestone Formation situated in the north(west). These boulders represent olistoliths. During the waning of the transport the boulders moved individually under their own weight causing deformation of the sediment in front of them. The folded toes of some boulders demonstrate that the limestone olistoliths were not, or only partly, lithified at the time of their transport. Another type of deformation, which is caused by independent olistolith transport, is the flattening of the olistolith by pull apart along normal faults (Maas & van Ginkel, 1983), observed in an olistolith near Sagüera.

Facies **cr**

General remarks — Sediments of this facies occur only in the Crémenes Limestone. A subdivision is made into five subfacies:
cr1: sandy crinoidal grainstone;
cr2: coral-stromatoporoid boundstone;
cr3: argillaceous packestone-wackestone-boundstone;
cr4: packestone-wackestone-mudstone with brachiopods and bryozoans;
cr5: grainstone with bryozoans.
The subdivision has been compared with Lecompte's (1970) bathymetrical subdivision of the Devonian reef deposits of Belgium, and with Wallace's (1972) Lower and Middle Devonian faunal associations of the Cantabrian Mountains.

Subfacies **cr1**

Stratigaphical relationships — This subfacies is always underlain by the littoral sandstone deposits of subfacies **c2** and overlain by the coral-stromatoporoid boundstones of subfacies **cr2**. The lower boundary is always transitional: an upward decrease of the sandstone percentage in the limestones of this subfacies is common. The boundary between subfacies **cr1** and the overlying subfacies **cr2** is always sharply delineated.

Lithology and fossils — This subfacies consists of coarse-grained red-coloured crinoidal grainstones with a sand content of up to 50%. Locally ooids and small haematite pebbles are observed. Most of the pores and veins of the bioclasts are impregnated with ferruginous material. Bed thickness ranges from 0.1 to 0.3 m. Cross-bedding occurs frequently. Most of the fossil fragments are crinoid ossicles; fragments of brachiopods, bryozoans and conodonts also occur.

Interpretation — This subfacies is very similar to facies **b**. However, subfacies **cr1** is associated with reef deposits, whereas facies **b** is intercalated in littoral sand deposits. The abundant large-scale current ripples, the occurrence of ooids and haematite pebbles and the well-rounded quartz grains indicate deposition in agitated water. No fine sediments are known in this facies. Probably this fraction was washed out by powerful currents.

Subfacies **cr2**

Stratigraphic relationships — This subfacies is intercalated between the sandy grainstones of subfacies **cr1** and the marly boundstones of subfacies **cr3**. The lower boundary is always sharp. The upper boundary is usually not very distinct.

Lithology and fossils — The sediments of this subfacies are laminar stromatoporoid-coral boundstones with a biostromal aspect. The shale content is low. The bedding is very thick to indistinguishable. The colour is light-grey. Mainly encrusting laminar stromatoporoids and platy corals occur. In the lower half of the sequences the stromatoporoids are dominating, but in the upper half more corals are found. Encrusting blue-green algae, tentaculites, ostracodes, bryozoans, trilobites, brachiopods, crinoids, and conodonts are occasionally found in this subfacies.

Interpretation — The massive boundstones are very similar to the '*Favosites*/Massive Stromatoporoid Association' of Wallace (1972) and the 'Zone turbulente' of Lecompte (1970). However, Wallace's associations are based on Lower and Middle Devonian faunas. In the Upper Devonian coral-stromatoporoid association of the Millar Member *Favosites* is replaced by *Alveolites*. The well-washed nature of the massive boundstones suggests deposition within the zone of breaking waves.

Subfacies **cr3**

Stratigraphic relationships — This subfacies is underlain by the boundstones of subfacies **cr2** and overlain by the platy limestones of subfacies **cr4**. The boundaries are indistinct.

Lithology and fossils — In the nodular argillaceous limestones of this subfacies the matrix is volumetrically important. Lamellar stromatoporoids encrust large amounts of red- and green-coloured shales and siltstones. Locally branching corals (mainly *Disphyllum* and *Thamnopora*) bind the matrix. In section OL a specimen of the compound coral *Hexagonaria* with a diameter of 1.5 m was found. Brachiopods occur in large quantities in this subfacies. Moreover bryozoans, crinoid ossicles, ostracodes, trilobites, bivalves, gastropods, and receptaculitids occur.

Interpretation — This subfacies is very similar to Wallace's 'Lamellar Stromatoporoid Association' and the analogies with Lecompte's 'Zone sousturbulente' and 'Zone subturbulente' are obvious. They suggest that these sediments were deposited in slightly deeper and less turbulent water than the stromatoporoid-coral boundstones described for subfacies **cr2**.

Subfacies **cr4**

Stratigraphic relationships — Subfacies **cr4** is underlain by the nodular argillaceous limestones of subfacies **cr3** and is overlain by the grainstones of subfacies **cr5**. The upper and lower boundaries are not very distinct.

Lithology and fossils — This subfacies mainly consists of thin-bedded (5-10 cm), yellow- and grey-coloured fine-grained bioclastic platy limestones. Thick beds (up to 0.5 m) are exceptional. The limestones contain hardly any siliciclastic admixture. Locally some thin, red-coloured shale lenticles occur. In the lower part of the sequences mud-supported limestones dominate. In the upper part packstones occur frequently. Occasionally cross-bedding and bioturbation are present. The identification of the fine-grained bioclasts is often difficult. Brachiopod, crinoid, trilobite, gastropod, and ostracode fragments are recognized. In the mudstones some stromatoporoid and coral fragments are found.

Interpretation — This subfacies mainly contains lime mud as interstitial matter, which indicates that the conditions were quiet enough for the finest fraction to be deposited.

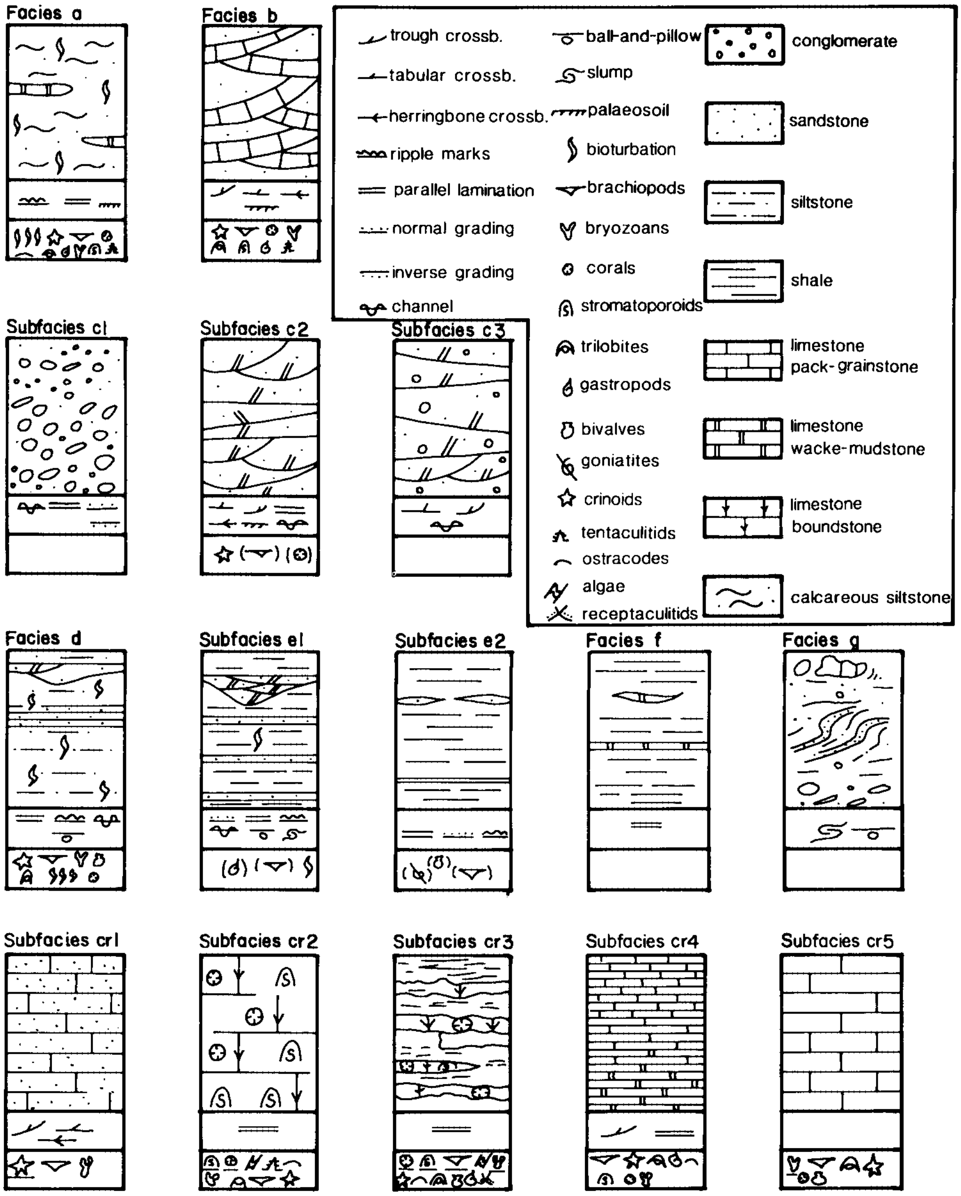


Fig. 28. Diagrammatic representation of the (sub)facies of the Upper Devonian deposits in the studied areas. Upper two-thirds of columns show type of sediment, the next part shows the sedimentary structures and the lowermost part the fossil content.

The bioturbation in the sediments shows that biological activity must have been considerable at the time of deposition. The low terrigenous admixture suggests a deposition seawards of the argillaceous boundstones of subfacies **cr3**, where most of the siliciclastic matter was bound and encrusted.

Subfacies **cr5**

Stratigraphic relationships — This subfacies is underlain by the platy limestones of subfacies **cr4** and is overlain by the cross-bedded calcareous sandstones of subfacies **cr2**. The boundaries are not very distinct.

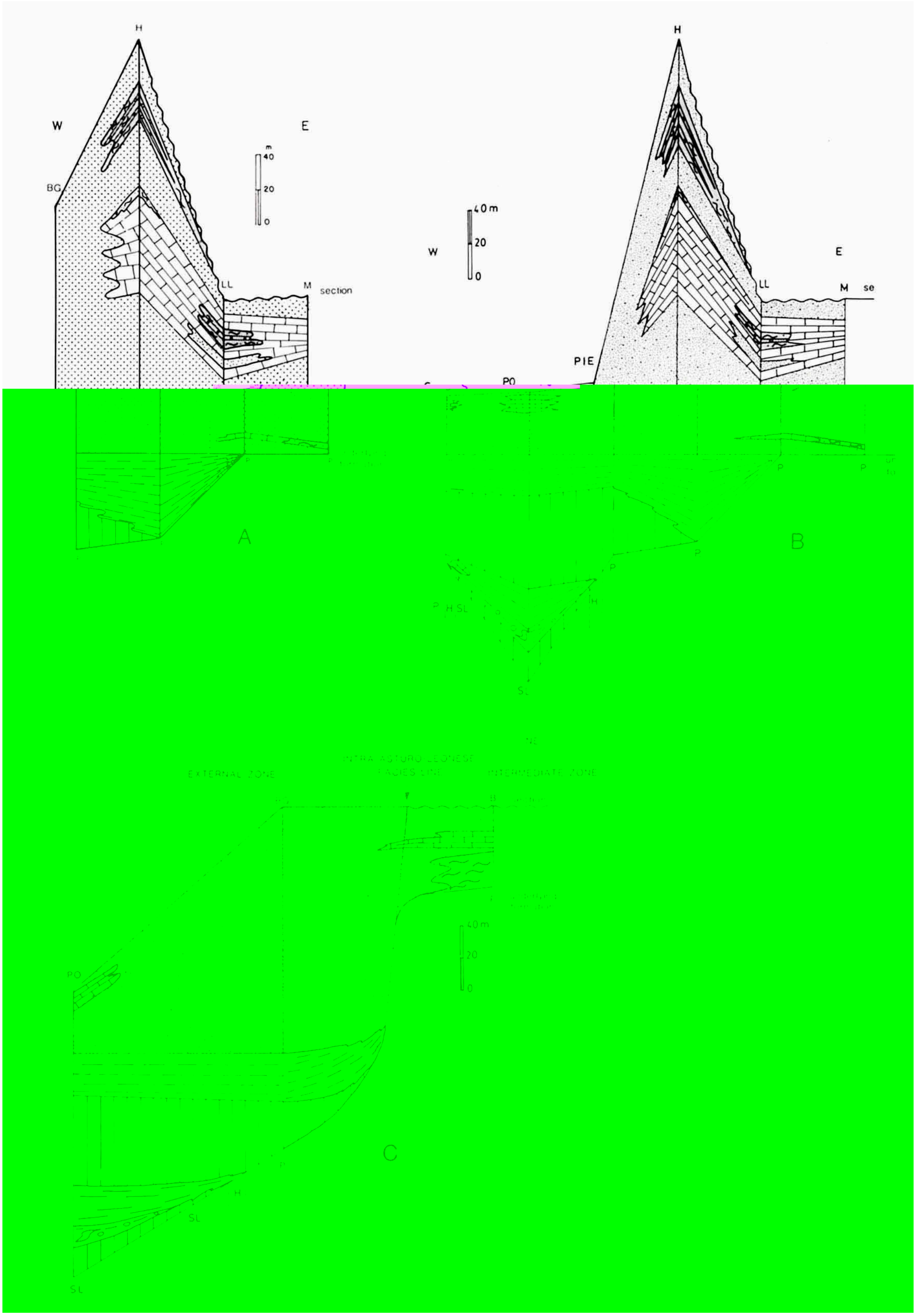
Lithology and fossils — The sediments consist of fine-grained, grey- and yellow-coloured well-bedded bioclastic grainstones (bed thickness between 0.3 and 5 cm). Sand grains are scarce. Locally stylolites and recrystalisation have destroyed much of the original features of the grainstones. The fossil debris mainly consists of fragments of bryozoans, brachiopods, trilobites, and crinoids; fragments of corals, bivalves and echinoids are locally found.

Interpretation — The absence of matrix in the sediments of subfacies **cr5** can be explained by the lack of fine-grained sediments at the time of deposition, or by the turbulence of the environment causing the mud to be winnowed away from the coarse fraction. The grainstone texture gives no definite information on the depositional environment (de Coo, 1974). Folk (1962) suggested that the rounding of the grains could inform us on the 'energy' of the environment. According to de Coo (1974) this is a doubtful criterion since in a carbonate environment most carbonate grains originate in the basin itself, unlike siliciclastic grains, which usually have a more complex transport history. The sedimentary structures and the biota are more reliable criteria concerning the depositional environment of the grainstones. The bedding planes are slightly undulating, cross-bedding and erosional structures like gullies and channels are absent. Bioclasts of bryozoans occur in large quantities. In Devonian times bryozoans lived mainly in the quiet zones of the pre-reef area, where they occur in large quantities together with brachiopods (Lecompte, 1970; Krebs, 1974, fig. 14). The absence of terrigenous siliciclasts suggests deposition beyond the siliciclastic supply, probably in a quiet distal environment seawards of subfacies **cr4**.

CORRELATIONS

Nocedo Formation

Gordón Member — In the Bernesga area the sections south of the Intra-Asturo-Leonese Facies Line are characterized by a relatively thick succession (89-306 m) with a fairly persistent east-west facies pattern: the facies may be traced over tens of kilometres. A pattern in the (sub)facies succession can be recognized: **e2-d-a-b** (Fig. 29a, b). The succession can be divided into a lower siliciclastic unit with a regressive character, consisting of (sub)facies **e2-d-c2**, and an upper limestone unit with a transgressive character comprising the (sub)facies **c2-b-a**. In section H the offshore shale deposits of subfacies **e2** are absent, and more to the east the littoral sandstone deposits of subfacies **c2** increase at the cost of the transitional siltstone deposits of facies **d**. Also the member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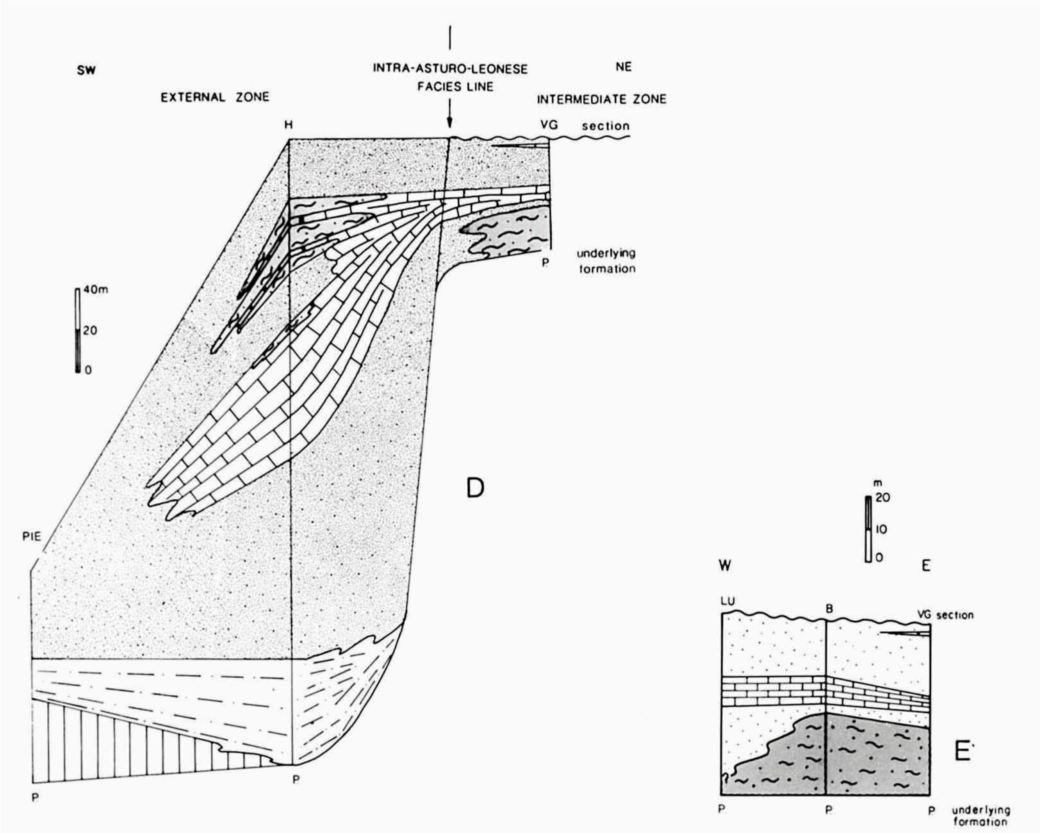


Fig. 29. Facies correlations of the Gordón Member in the Bernesga area: (A) east-west facies distribution through the northern limb of the Alba Syncline, (B) east-west facies distribution through the northern and southern limb of the Alba Syncline, (C) northeast-southwest distribution, (D) northeast-southwest facies distribution east of the area of Fig. 29C, (E) east-west facies distribution through the Pedroso Syncline. Horizontal distances not to scale; for locality indications see Fig. 6B and for the legend see Fig. 36; SL = Santa Lucía Fm., H = Huergas Fm., P = Portilla Fm.

decreases rapidly in thickness in that direction, and haematitic sandstones and ferruginous soils were found at the top of the member, indicating a marginal-marine, or even non-marine, environment (Heckel, 1972), with non-depositional and erosional phases (sections LL and M). An important change in facies is found between the sections south of the Intra-Asturo-Leonese Facies Line and those north of that line: south of the line the basal shales and siltstones ((sub)facies **e2** and **d**) wedge out and north of it only the transgressive limestone unit is present (Fig. 29c, d). Note that also in the Intermediate Zone the east-west facies correlations are persistent and lithosomes may be traced over many kilometres (Fig. 29e).

The facies succession of the Gordón Member in the Esla area is very similar to the succession in the Bernesga area. In Fig. 30 the regressive siliciclastic wedge is clearly shown. Note the absence of offshore shales (subfacies **e2**) from the basal part of the member. The siliciclastic wedge is overlain by transgressive mud-supported limestones (facies **a**) and grain-supported limestones (facies **b**). In the Intermediate Zone erosion probably removed the limestone unit.

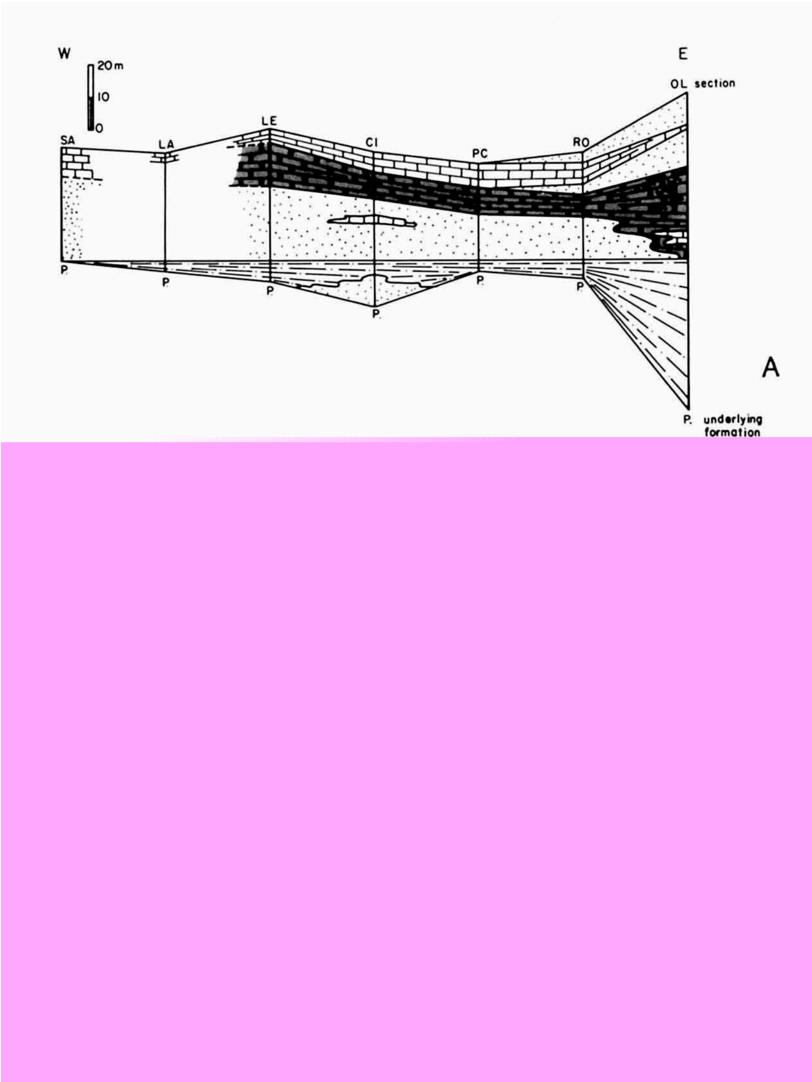


Fig. 30. Facies distributions of the Gordón Member in the Esla area: (A) east-west facies distribution of the Esla Nappe, (B) north-south facies distribution. Horizontal distances not to scale; for locality indications see Fig. 6C and for the legend see Fig. 36; P = Portilla Fm.

In Fig. 31 the facies diagram of the Gordón Member in the Somiedo area is given. South of the Intra-Asturo-Leonese Facies Line a regressive sequence is found consisting of the offshore shales of subfacies **e2**, which are overlain by the transitional bioturbated siltstones of facies **d**. The same facies succession is found in the Gordón Member of the Bernesga area. These deposits are overlain by bioclastic grainstones of facies **b** and bioturbate wackestones, siltstones and shales of facies **a**, forming the calcareous transgressive upper unit of the member. The limestones grade upward into the littoral ferruginous sandstone deposits of subfacies **c2**.

Millar Member — In the Bernesga area the Millar Member shows a regressive facies succession, from base to top: **e2-e1-(d)-c2**. This unit differs from the siliciclastic unit of the Gordón Member by the intercalation of the shale-sandstone deposits of subfacies **e1**

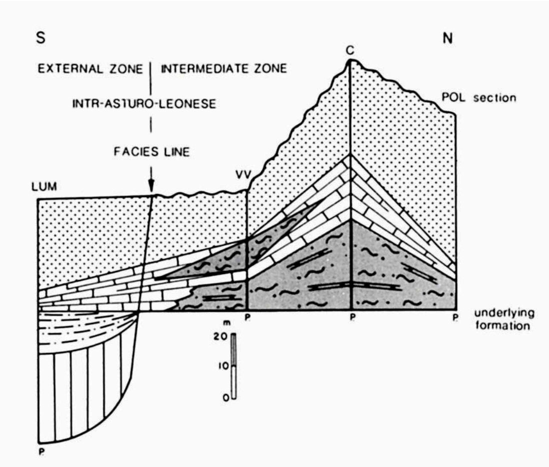
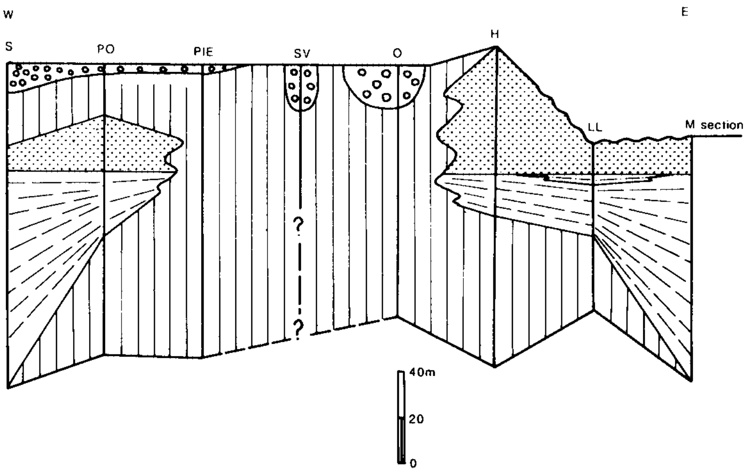


Fig. 31. North-south facies distribution of the Gordón Member in the Somiedo area. Horizontal distances not to scale; for locality indications see Fig. 6A and for the legend see Fig. 36; P = Portilla Fm.



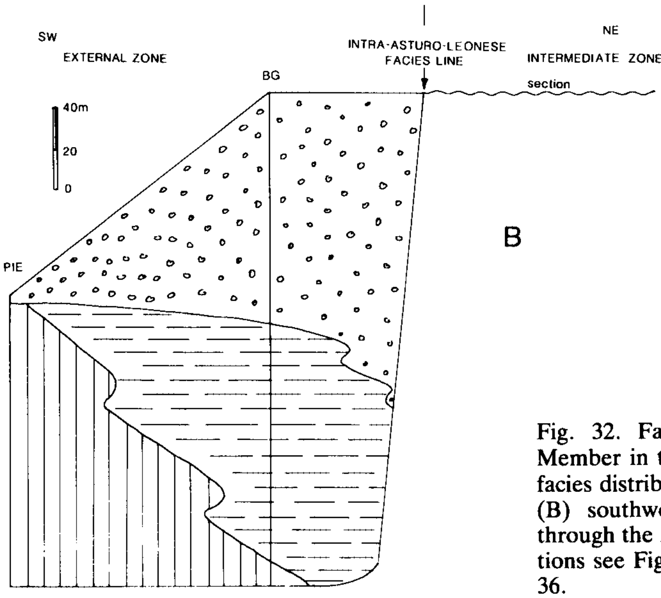


Fig. 32. Facies distribution of the Millar Member in the Bernesga area: (A) east-west facies distribution through the Alba Syncline, (B) southwest-northeast facies distribution through the Alba Syncline; for locality indications see Fig. 6B and for the legend see Fig. 36.

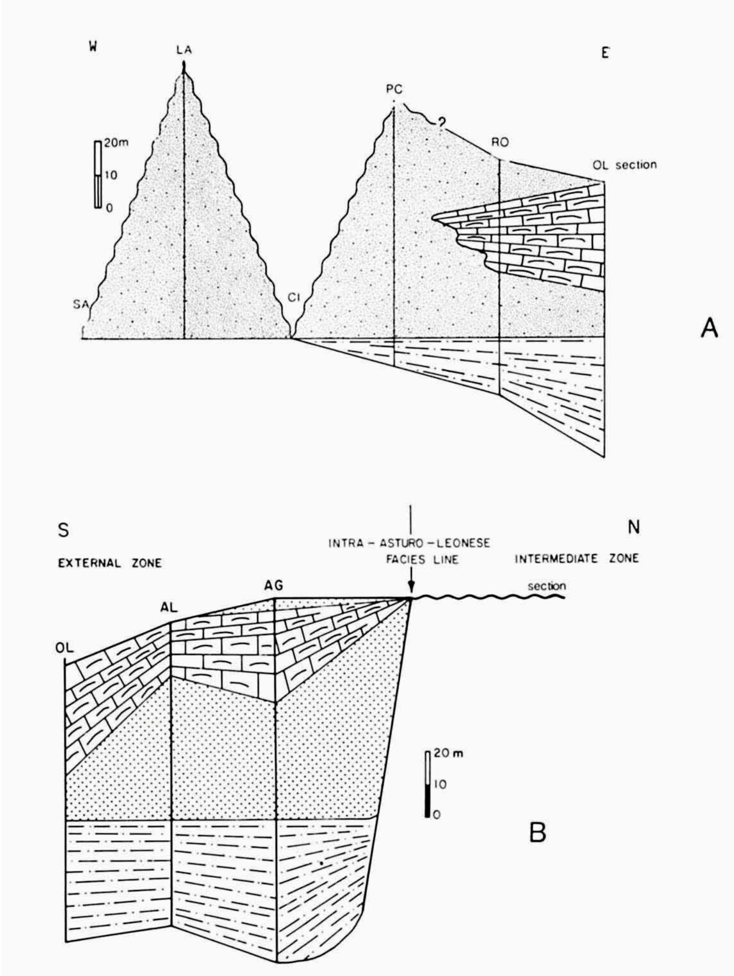


Fig. 33. Facies distributions of the Millar Member in the Esla area: (A) east-west facies distribution through the Esla Nappe, (B) north-south facies distribution. Horizontal distances not to scale; for locality indications see Fig. 6C and for the legend see Fig. 36.

and the scarcity of the siltstones of facies **d**. Only in the eastern- and westernmost sections (S, P, H, LL, M) a littoral sandstone wedge is present showing a regressive facies succession (Fig. 32a), whereas in the sections PIE, SV, and O the member consists of offshore shales and channel-fill conglomerates (subfacies **e2** and **c1**). The erosive conglomerates can be traced towards the west (sections PO, S), where these deposits occur above the shallowing upward sequence, with c. 25 m of shales in between. East of the sections O and BG these conglomerates are absent. At the top of the shallowing upward sequence, in the easternmost part of the Bernesga area, erosional truncation occurs, but in the western sections the sequence is buried under the offshore deposits of subfacies **e2** and no erosional surface marks the upper boundary of the sequence. It seems as if there the subsidence of the area or the rising sealevel outpaces clastic accumulation resulting in a 'drowning of the sequence'. In the north the facies mosaic is cut off by the Intra-Asturo-Leonese Facies Line (Fig. 32b).

In the Esla area facies **e** is absent from the Millar Member and the regressive siliciclastic wedge consists of transitional siltstone deposits (facies **d**) and littoral sand-

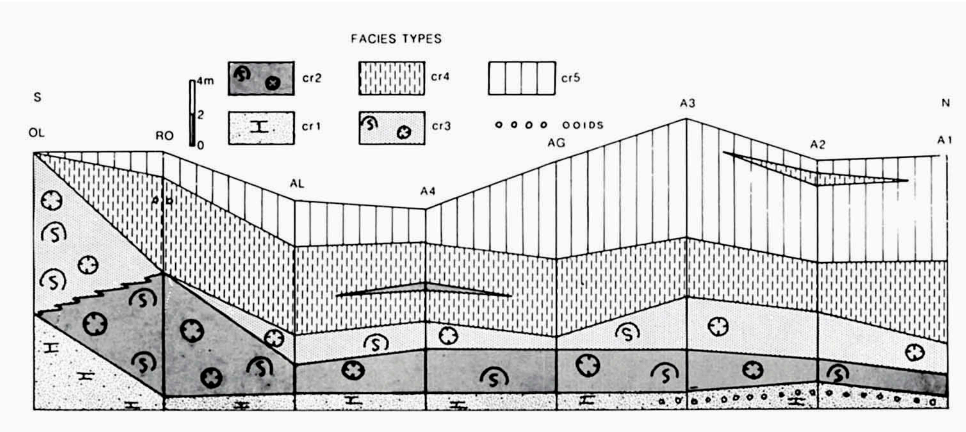


Fig. 34. North-south facies distribution of the Crémenes Limestone in the Esla area. Horizontal distance not to scale; for locality indications see Fig. 6C.

stone deposits (subfacies **c2**) (Fig. 33). The upper part of the member comprises limestones of facies **cr** (Crémenes Limestone). West of section RO the limestone interfingers with sandstones, and there the irregulary distributed Millar Member is cut off by an erosive surface. The section LA suggests that a much thicker pile of **c2** sandstones was originally deposited further to the west, but subsequent ersosion has removed much of it.

In Fig. 34 the Crémenes Limestone is pictured in detail. It is laterally monotonous: almost everywhere the transgressive facies succession **crl-cr2-cr3-cr4-cr5** is found. Only in the southernmost sections some important facies changes occur. In section RO the argillaceous boundstones of subfacies **cr3** are replaced by the massive boundstones of subfacies **cr2**, and in the southernmost section (OL) the fore-reef deposits of subfacies **cr4** and **cr5** are wedging out.

In the Millar Member of the Somiedo area a regressive siliciclastic wedge occurs consisting of shale-sandstone deposits of subfacies **el** and littoral sandstones of subfacies **c2** (Fig. 35). At the top of the member channel-fill conglomerates of subfacies **cl** occur. A similar succession is observed in the Bernesga area.

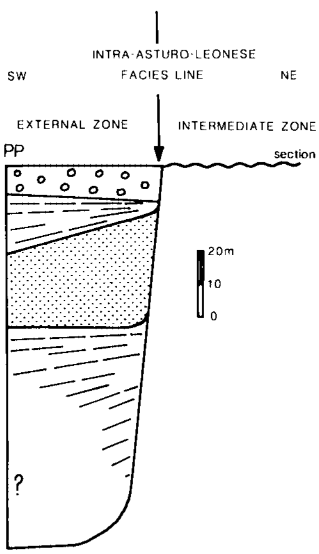


Fig. 35. Northeast-southwest facies distribution of the Millar Member in the Somiedo area. Horizontal distance not to scale; for locality indications see Fig. 6A and for the legend see Fig. 36.

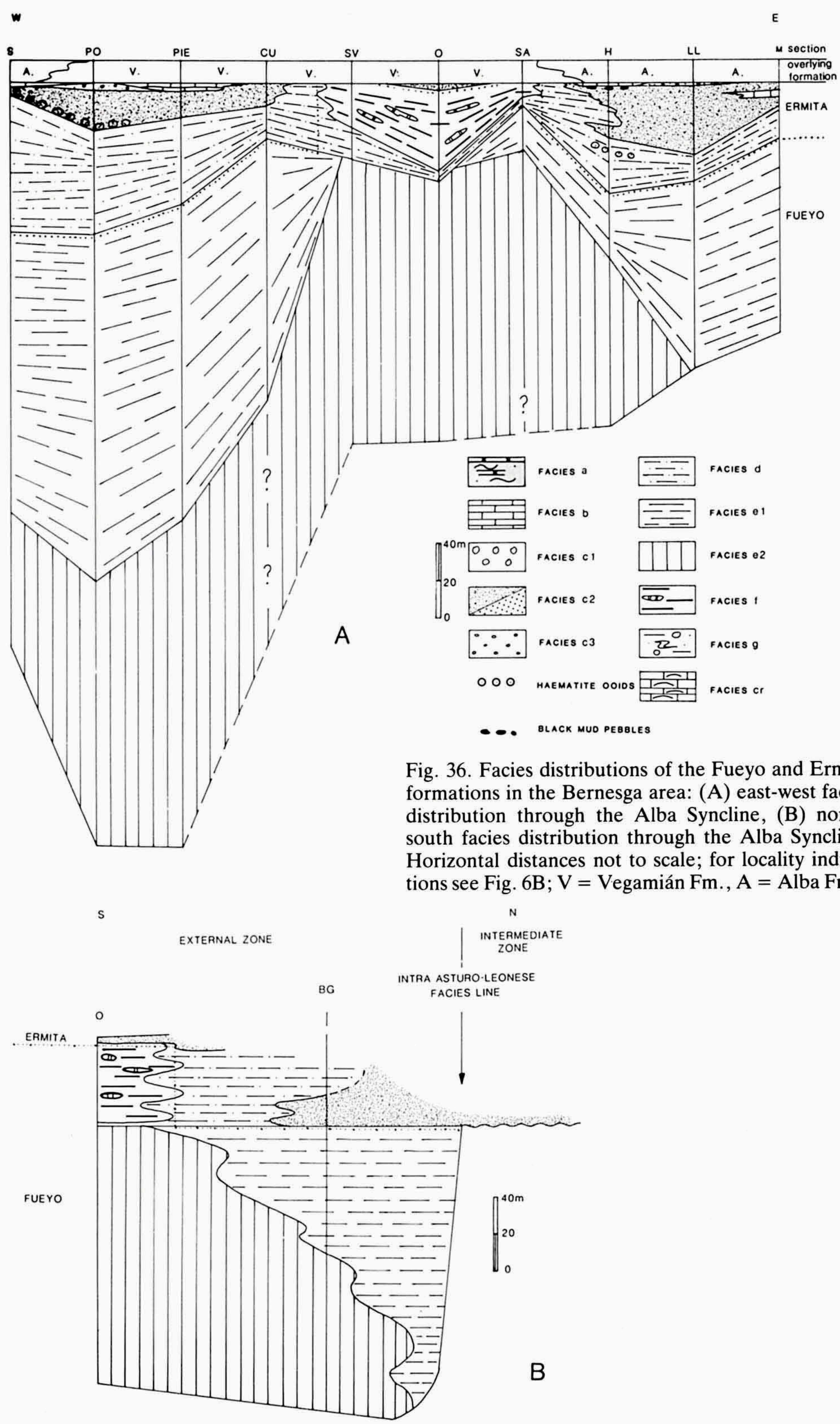


Fig. 36. Facies distributions of the Fueyo and Ermita formations in the Bernesga area: (A) east-west facies distribution through the Alba Syncline, (B) north-south facies distribution through the Alba Syncline. Horizontal distances not to scale; for locality indications see Fig. 6B; V = Vegamián Fm., A = Alba Fm.

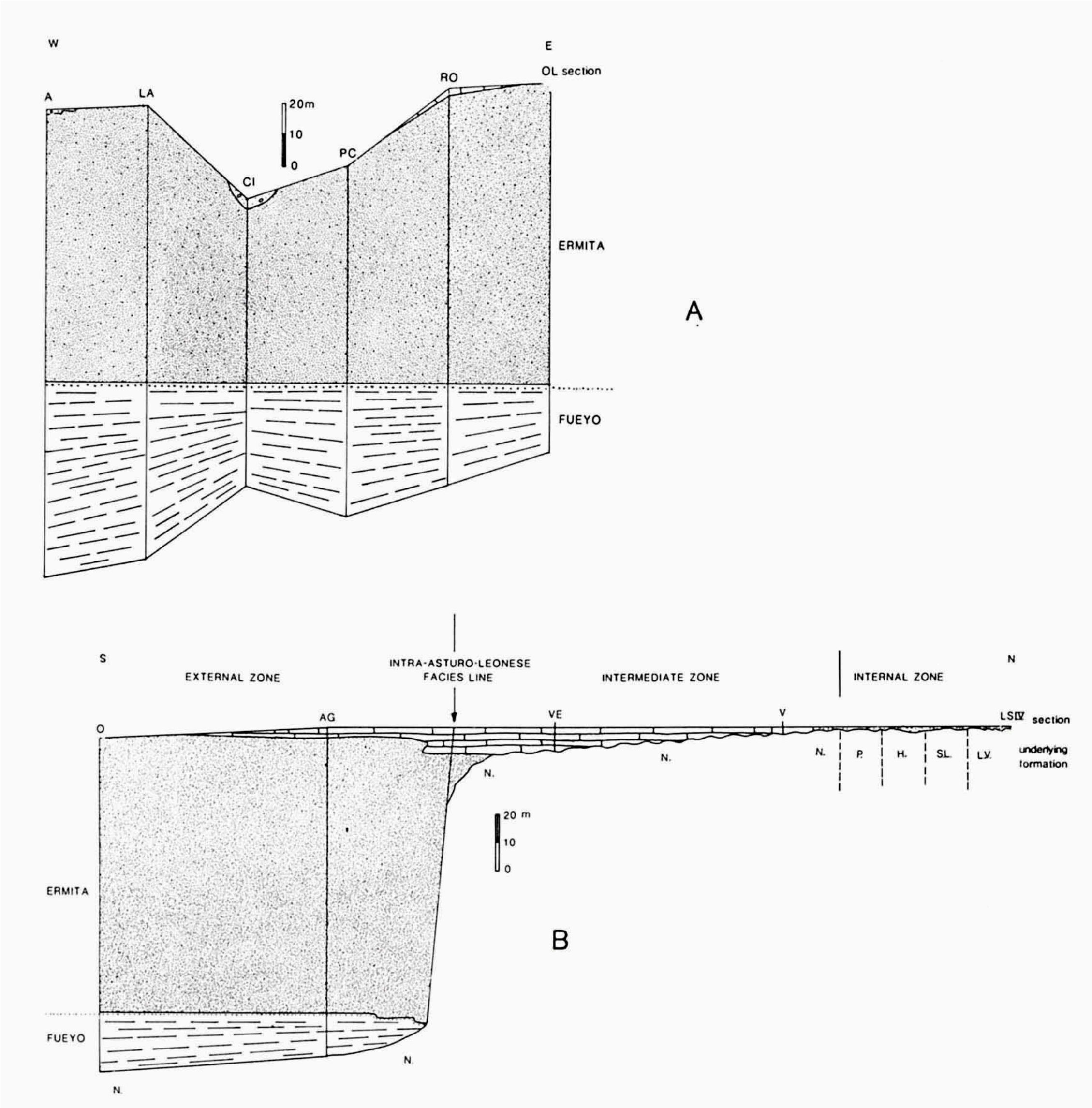


Fig. 37. Facies distributions of the Fueyo and Ermita formations in the Esla area: (A) east-west facies distribution through the Esla Nappe, (B) north-south facies distribution. Horizontal distances not to scale; for the locality indications see Fig. 6C and for the legend see Fig. 36; L.V. = La Vid Fm., S.L. = Santa Lucía Fm., H = Huergas Fm., P = Portilla Fm., N = Nocedo Fm.

Fueyo Formation

The Fueyo Formation only occurs in the External Zone. For the Bernesga area an east-west and a north-south correlation diagram have been made to illustrate the facies geometry (Fig. 36a, b). A thick (up to 332 m) regressive succession can be recognized, consisting from base to top of subfacies **e2** and **e1**. In Fig. 36a the offlap relationship of the shales (**e2**) to the sandy shales (**e1**) is clearly demonstrated. The eastern- and westernmost sections have a similar facies succession, thus resulting in a symmetrical facies mosaic

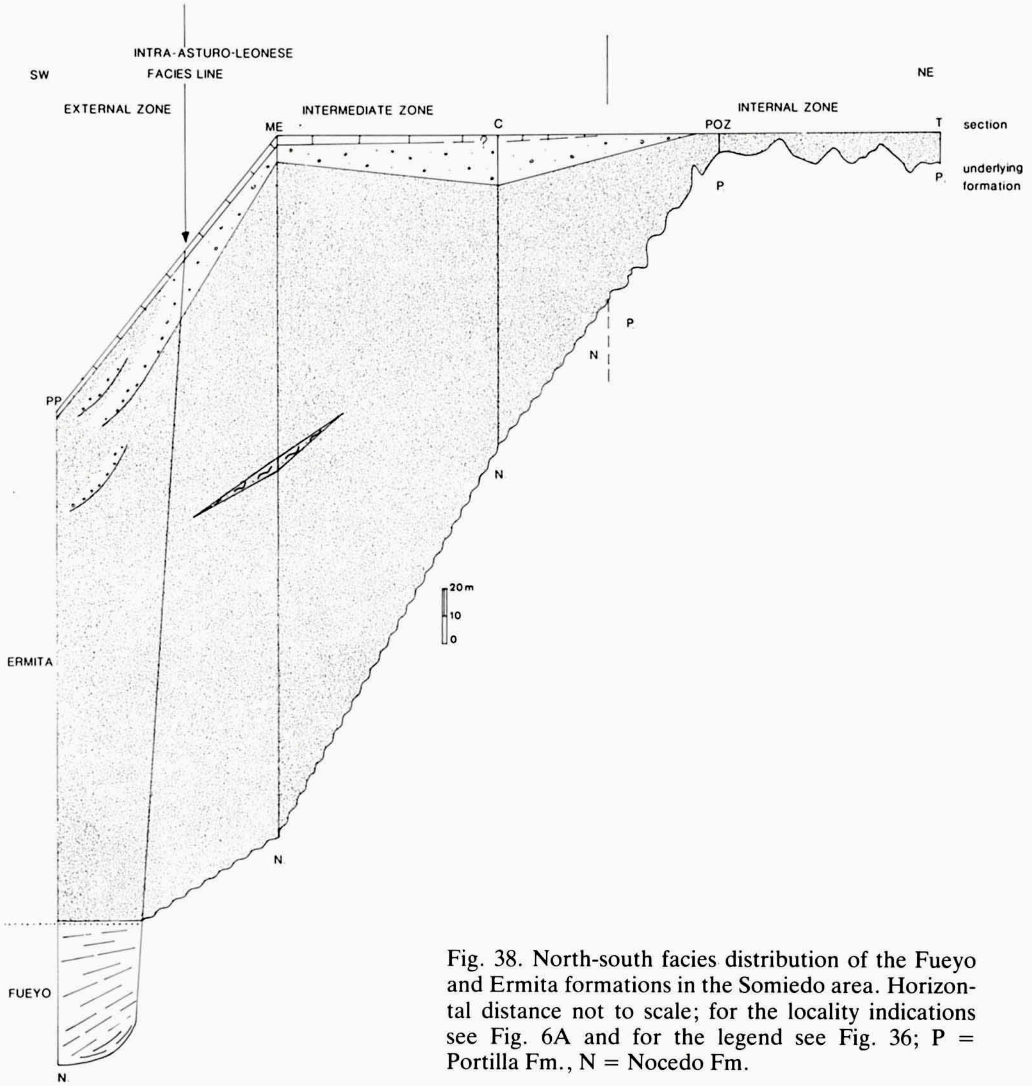


Fig. 38. North-south facies distribution of the Fueyo and Ermita formations in the Somiedo area. Horizontal distance not to scale; for the locality indications see Fig. 6A and for the legend see Fig. 36; P = Portilla Fm., N = Nocedo Fm.

(Fig. 36a), very similar to the facies succession of the Millar Member (Fig. 32a). Between the sections CU and SA subfacies **e1** wedges out, and the **e2** shales are overlain by the dark calcareous shales of facies **f**. In Fig. 36b the interfingering of the dark shales (Fueyo Formation) with the silty sandstones of facies **d** (Ermita Formation) is clearly shown.

In both the Esla and the Somiedo area a relatively thin Fueyo Formation occurs, exclusively consisting of subfacies **e1** (Figs. 37, 38). The gradual decrease in thickness of the formation from 332 m in the western part of the Bernesga area (section PO) to c. 20 m in the eastern part of the Esla area (sections OL, AG) is remarkable.

Ermita Formation

The Ermita Formation in the Bernesga area forms a clastic wedge (Fig. 39). In the northern areas the Ermita Formation is thin and irregularly distributed. It consists of

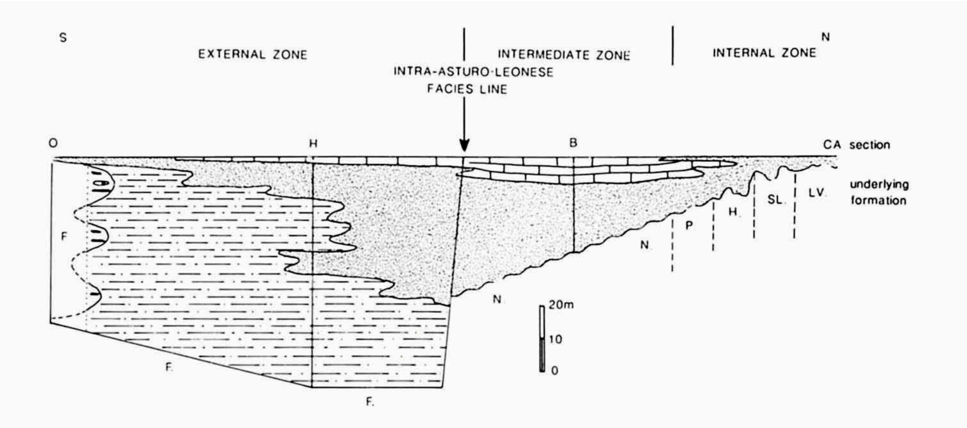


Fig. 39. North-south facies distribution through the Ermita Formation in the Bernesga area, with the arbitrary cut-off between the Ermita Formation and the Fueyo Formation in the southernmost part of the External Zone. Horizontal distance not to scale; for locality indications see Fig. 6B and for the legend see Fig. 36; LV = La Vid Fm., SL = Santa Lucía Fm., H = Huergas Fm., P = Portilla Fm., N = Nocedo Fm., F = Fueyo Fm.

quartzites, quartzarenites and microconglomerates of subfacies **c2** with thin bioclastic intercalations of facies **b**. Southwards the formation increases in thickness, and a relatively thick bioclastic grainstone unit occurs above the clean-washed sandstones. South of the Intra-Asturo-Leonese Facies Line subfacies **c2** interfingers with the bioturbated siltstones of facies **d**. In the southernmost area facies **d** interfingers with the dark shales of facies **f**. There an arbitrary cut-off separates the Ermita Formation from the Fueyo Formation. In Fig. 36 the east-west facies distribution in the External Zone is presented. West of section CU and east of section H the siltstones and sandstones of (sub)facies **c2** and **d** are the most important sediments. In the southernmost sections (SV, O, SA) the dark shales of facies **f** dominate. Again, like the east-west facies patterns of the Millar Member and the Fueyo Formation, a symmetrical east-west facies-distribution pattern occurs. In the facies mosaic the easternmost and westernmost sections contain an rather similar facies succession. Note that the haematite ooids were mainly deposited in the facies **d**-subfacies **c2** transition. Black mud clasts, probably reworked sediment from the Vegamián Formation, are to be found in the uppermost part of the Ermita Formation of the sections S, H, and R, just beyond the distribution of the black shales of the Vegamián Formation.

In Fig. 37 the distribution of facies recognized in the Ermita Formation in the Esla area are pictured. In the Internal Zone the Ermita Formation consists of a thin irregular succession of quartzarenites and quartzites of subfacies **c2** with local grainstone intercalations of facies **b**. The sections in the Intermediate Zone entirely consist of grainstones of facies **b**. These limestones interfinger south of the Intra-Asturo-Leonese Facies Line with quartzarenites and greensands of subfacies **c2**. In the uppermost part of the formation discontinuous pebbly sandstones of subfacies **c3** occur locally.

In the Somiedo area the lower part of the Ermita Formation consists almost exclusively of sediments of subfacies **c2** (Fig. 38). In section ME a local lenticle of facies **a** is present. In the upper half micro-conglomerates and true conglomerates of subfacies **c3** occur. A thin limestone bed of facies **b** covers the siliciclastic deposits in the southern part of the Somiedo area.

REGIONAL INTERPRETATION OF THE FACIES RELATIONS

Nocedo Formation

Gordón Member — With the aid of a facies ratio map, an isopach map and a palaeocurrent analysis an attempt has been made to reconstruct the depositional history of the Gordón Member in the Bernesga area. Three groups of sediments are distinguished for the member.
The first group comprises the back-bar sediments of facies **a**, the carbonate shoals of facies **b** and the littoral sandstones of subfacies **c2**.
The second includes the transitional bioturbate siltstones of facies **d**, deposited seawards of the first group of sediments.
The third consists of the shales of subfacies **e2**, which were deposited seawards of the sediments of the second group.

Sediments of (sub)facies **c1, c3, e1, f, g,** and **cr** do not occur in the Gordón Member. The three groups were used as end members in a facies triangle (Krummbein & Sloss, 1963). For each section the ratios between the groups were plotted in order to observe the distribution of points in terms of changing composition of the Gordón Member (Fig. 40). Four facies blocks were selected to block out clusters of points in the triangle, and a facies ratio map was constructed (Fig. 41a). The picture of the map is mainly defined by the influence of three palaeogeographic elements: the Asturian Geanticline in the north, the Pardomino High in the east and the Sabero-Gordón Fault

ZONATION	SECTION	THICKNESS (m)	% FACIES a+b+c2	% FACIES d	% FACIES e2
EXTERNAL ZONE	M, MATALLANA	90	100	0	0
	LL, LLOMBERA	89	100	0	0
	H, HUERGAS DE GORDÓN	306	83	17	0
	BG, BARRIOS DE GORDÓN	198	71	15	14
	MI, MIRANTES	197	?	?	?
	S, SAGÜERA	96	45	26	28
	PO, PORTILLA DE LUNA	181	18	26	56
	PIE, PIEDRASECHA	98	49	13	38
	CU, CUEVAS	?	?	?	?
	SV, SANTIAGO DE LAS VILLAS	?	?	?	?
	O, OLLEROS DE ALBA	?	?	?	?
	SA, SORRIBOS DE ALBA	?	?	?	?
	R, LA ROBLA	?	?	?	?
INTERM. ZONE	VG, VEGA DE GORDÓN	52	100	0	0
	B, BEBERINO	63	100	0	0
	LU, LUNA	56	100	0	0
INTERNAL ZONE	CLI, CALDAS DE LUNA I	0	—	—	—
	CLII, CALDAS DE LUNA II	0	—	—	—
	CA, CAMPLONGO	0	—	—	—
	E, SAN EMILIANO	0	—	—	—
	U, UBIÑA	0	—	—	—
	VA, VALPORQUERO*	0	—	—	—

* FRANKENFELD, 1981

Table. 2. Thickness and facies percentages of the Gordón Member in the Bernesga area.

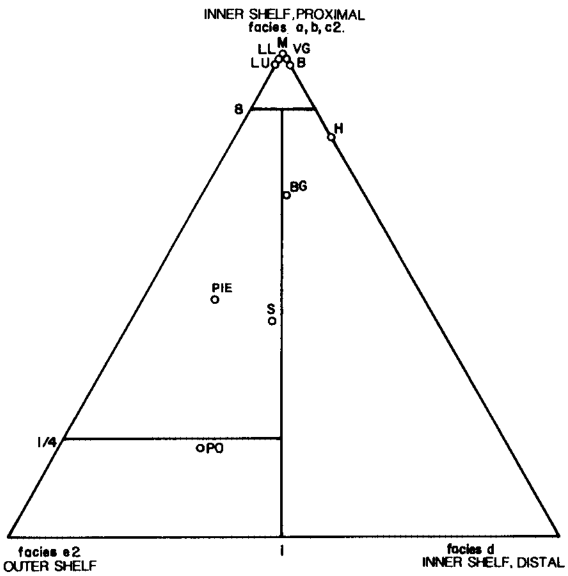


Fig. 40. Facies ratio triangle based on Table 2.

Zone with the connected Intra-Asturo-Leonese Facies Line. The Asturian Geanticline and the Pardomino High were active source areas of detrital material. The Sabero-Gordón Fault Zone mainly controlled the distribution of the sediment. No net sedimentation is known in the Internal Zone. The northern area of the Asturo-Leonese Basin was probably also part of the dedritus source area. In the southwestern part of the Bernesga area offshore deposits make up the thickest part of the sediment pile. Eastwards gradually deposits appear which indicate a shallower water environment. In the easternmost parts of the External Zone and in the Intermediate Zone a shallow marine platform was present which bordered the Pardomino High in the east and the area of the Internal Zone and the Asturian Geanticline in the north. The thickest deposits occur in an area just south of the Intra-Asturo-Leones Facies Line in the northern limb of the Alba Syncline (see Fig. 41b). This is mainly due to the variation in thickness of the lower siliciclastic unit of the member. The unit shows the same characteristics as the regressive barrier unit in the model proposed by David et al. (1971) (Fig. 42). The offshore shales of subfacies **e2** are overlain by the transitional and lower shoreface sediments of facies **d** (bioturbated siltstones and sandstones). The upper part of the unit is made up of littoral sandstone deposits of subfacies **c2**. The sandstone body is lenticular and thins towards the north(east) (landwards) and to the south(west) (seaward). The body is elongated parallel with the palaeocoast in an approximately east-west strike as is indicated by the two

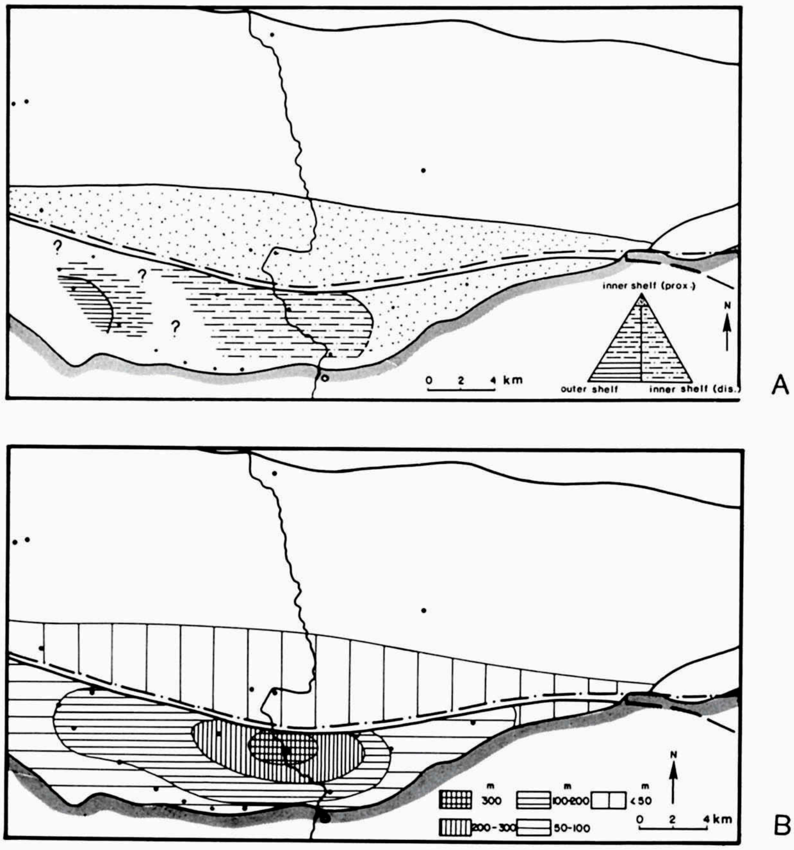


Fig. 41. Facies maps of the Gordón Member in the Bernesga area: (A) facies ratio map based on the facies ratio triangle of Fig. 40, which is shown in reduced size in this figure, (B) isopach pattern based on values of Table 2.

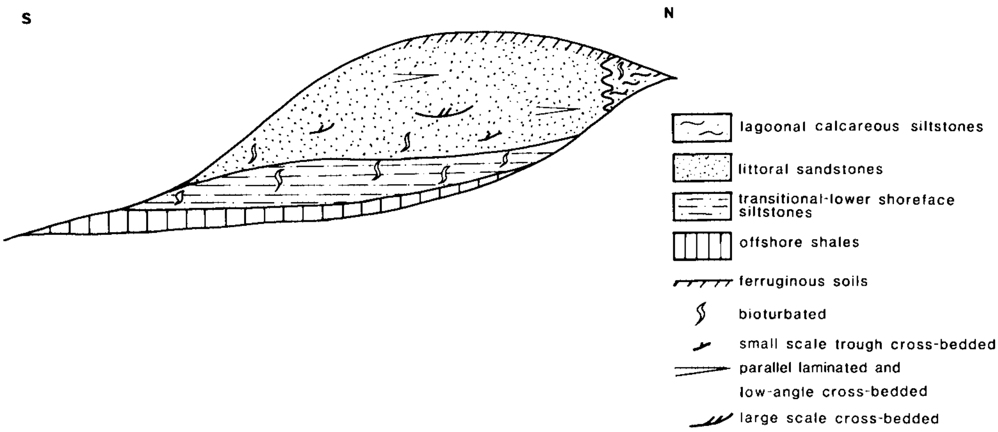


Fig. 42. Barrier model for the lower siliciclastic unit of the Gordón Member (after David et al., 1971).

north(east)-south(west) facies distribution diagrams which are almost identical (Fig. 29c, d). The littoral sandstones are flanked on their landward side (north) by lagoonal sediments of facies **a**. The vertical sequence represents an upward transition of offshore deposits to shallower marine deposits in a coarsening upward sequence. The ferruginous beds in the uppermost part of the littoral sandstones (section H) may indicate subaerial exposure (van Houten, 1961). In the External Zone the thickness of the regressive unit ranges from 35 to 100 m. The thickest deposits occur in the area near Barrios de Gordón and Huergas de Gordón (sections BG, H). In the Intermediate Zone the thickness is c. 25 m. These values are rather high in comparison with the barrier sequences described by David et al. (1971) with values ranging from 16 to 50 m. Thickness depends upon the complex interrelation of the rate of subsidence and the sediment supply. A delicate balance between the (high) production of clastic material in the hinterland and the downwarping of the area of deposition must have caused the thick pile of littoral sediments. Marine currents were strong enough to redistribute the land-derived sediment, preventing the formation of a delta. Seaward of the depositional centre, in the southwestern part of the Bernesga area, a thin sequence, consisting mainly of siltstones and shales, was deposited in a transitional and offshore environment. Northwards and eastwards of the depositional center a thin succession of red beds was deposited on the shallow marine platform. Upheaval of the Asturian Genaticline and adjacent areas in the north in combination with block movements and downwarping of the area south of the Intra-Asturo-Leonese Facies Line was followed by an interval of predominant siliciclastic sedimentation. Barrier sands prograded seaward in a southwestward direction. Erosion peneplained gradually the hinterland, the supply decreased and carbonate deposits of the upper unit covered the area of the External and Intermediate Zones. The thickness of the unit is of the same order of magnitude on both sides of the Intra-Asturo-Leonese Facies Line. In the External Zone its thickness ranges from 10 to 40 m. At Huergas de Gordón (section H) the unit has an exceptional thickness of 158 m. In the Intermediate Zone it is approximately 30 m thick. There dark-red and purple haematite sandstones are intercalated in the limestones. Van Loevezijn (1983) and Raven (1983) pointed out the transgressive character of these deposits and Raven (1983) supported this conclusion with biostratigraphic information obtained from conodonts; the base of the calcareous unit appears to be younger in a northeastward (landward) direction.

Palaeocurrent directions have been measured in the calcareous upper unit of the

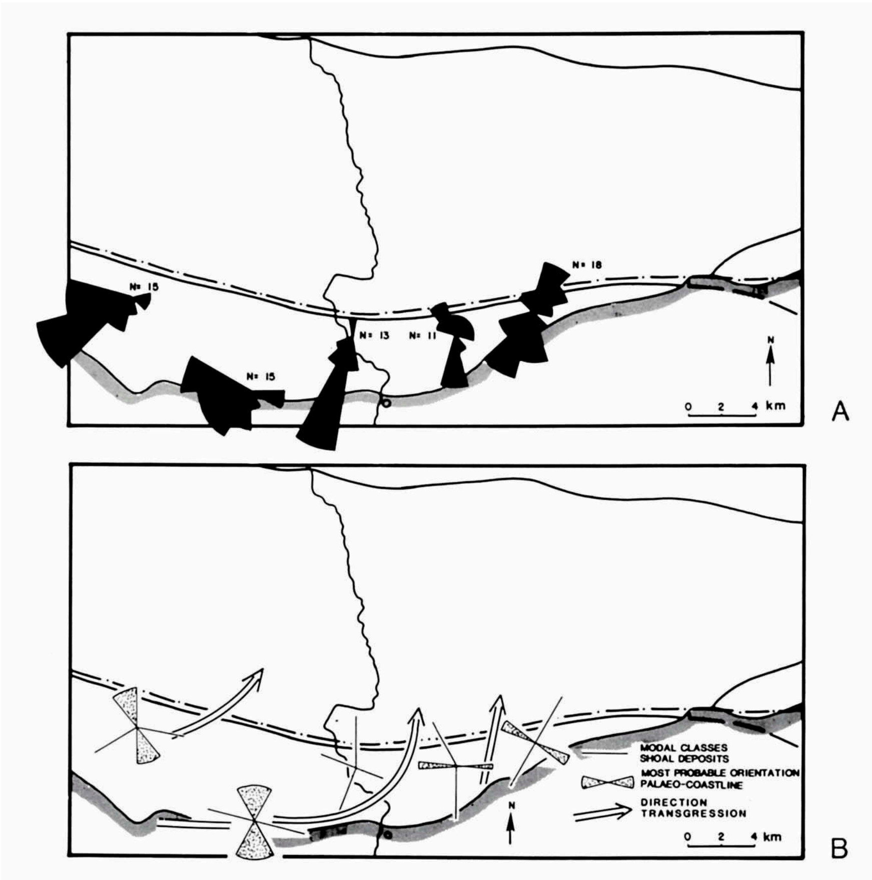


Fig. 43. Rose diagrams and transgression directions: (A) rose diagrams constructed from measurements on large-scale cross-stratificaction in the bioclastic shoal deposits of facies **b** in the top of the Gordón Member, (B) direction of the transgression with the aid of the most probable position of the palaeo-coastline, obtained from the rose diagrams of Fig. 43a, and with the aid of the conodont faunas of Fig. 17.

Gordón Member, but only the large-scale cross-stratification in the winnowed bioclastic shoal deposits of facies **b** supplied sufficient measurements to allow conclusions. De Vries Klein (1967) studied the dispersal patterns in recent coastal environments. Reversal of current directions are common in these environments because of the existence of tidal currents and wave swash. The reversal of these currents is clearly demonstrated in the rose diagrams of Fig. 43a. One of the two opposite classes always strongly dominates the other. The direction containing the largest modal class represents the ebb direction. From an evaluation of the rose diagrams a source area in the north(east) must be assumed. With the aid of the above an attempt has been made to find the direction of the coastline of each section (Fig. 43b). From the westernmost measurements which are available an approximately north-south running coastline has been constructed. Northeastward the coastline had a more northwest-southeast direction. Because the northeastern deposits are slightly younger, the direction of transgression can be reconstructed, assuming that the vector of transgression made a normal angle with the direction of the coastline. The transgression direction fits very well with the facies ratio

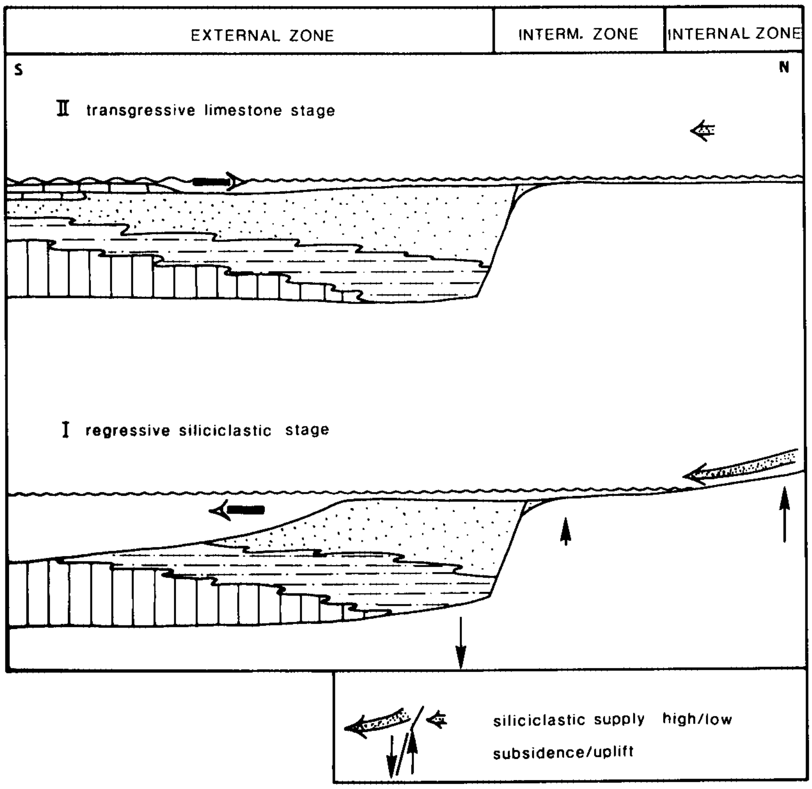


Fig. 44. Due to the uplift and erosion of the northern part of the Asturo-Leonese Basin and the Asturian Geanticline, and subsequent downwarping and deposition in the southern part of the basin, a regressive coarsening-upward sequence developed in the External Zone (regressive siliciclastic stage). When the relief was low the siliciclastic supply decreased, and a carbonate platform developed in a landward direction (transgressive limestone stage).

ZONATION	SECTION	THICKNESS (m)	% FACIES a-b-c2	% FACIES d
EXTERNAL ZONE	A. SAN ADRIAN	35	100	0
	LA. SOBREPEÑA	50	91	9
	LE. LA ERCINA	49	87	13
	CI. CISTIERNA	45	93	7
	PC. PEÑA CORADA	34	92	8
	RO. ROBLEDO	38	85	15
	OL. SANTA OLAJA	92	57	43
	AL. ALEJE	64	81	19
	AG. AGUASALIO	93	86	14
	AV. ARGOVEJO	125	79	21
INTERM. ZONE	VE. VERDIAGO	52	81	19
	V. VALDORÉ	13	81	19
INTERNAL ZONE	LSI. LAS SALAS I	0	–	–
	LSII. LAS SALAS II	0	–	–
	LSIII. LAS SALAS III	0	–	–
	LSIV. LAS SALAS IV	0	–	–

Table 3. Thickness and facies percentages of the deposits of the Gordón Member in the Esla area.

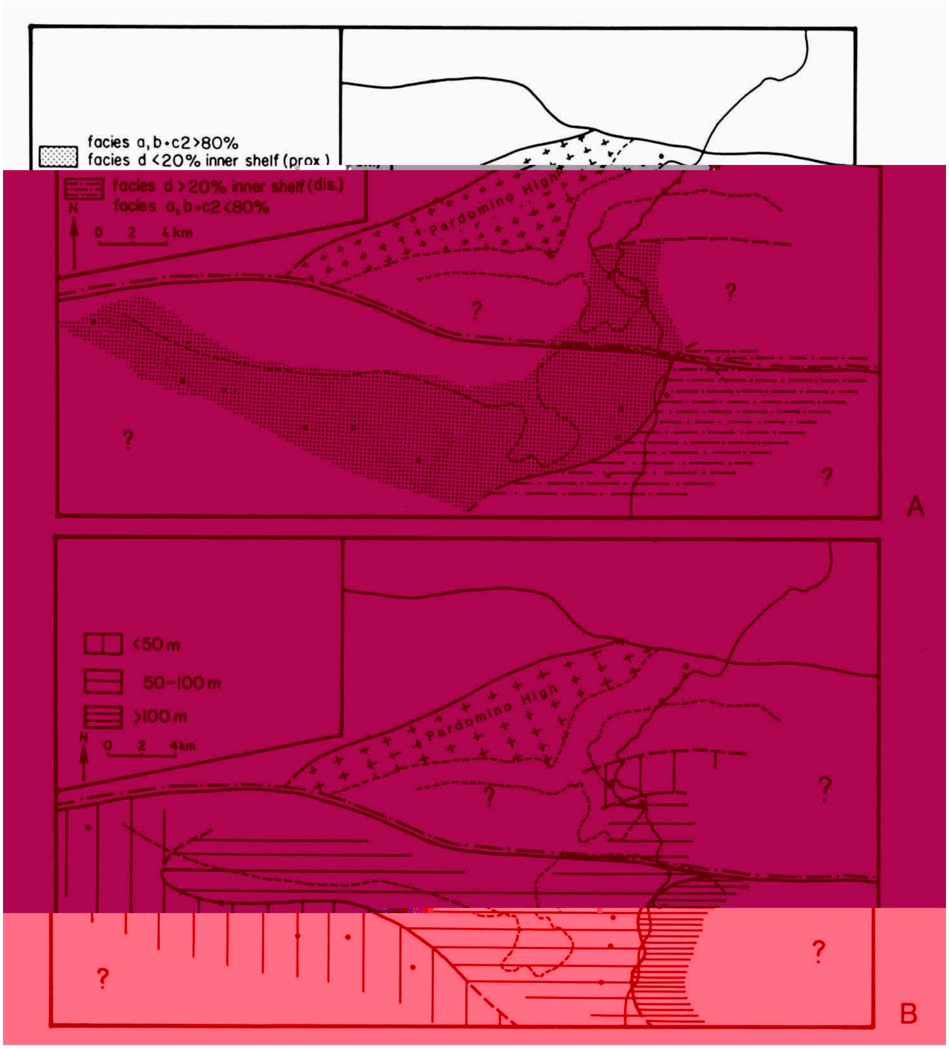


Fig. 45. Facies maps of the Gordón Member in the Esla area based on the values of Table 3: (A) facies ratio map, (B) isopach map.

map of the Gordón Member (Fig. 41a). The first shoal deposits were developed in the southwest. There, limited supply of detrital material could not prevent the build-up of a carbonate shoal. With decreasing clastic supply the carbonates shifted landwards in a northeastward direction (Fig. 44).

The same groups of sediments, which are distinguished in the Gordón Member of the Bernesga area, are distinguished in the Esla area, with the exception however of one group of sediments – the offshore shales of subfacies **e2** – which are absent. So basically there are only two groups of sediments.

The first group comprises the back-bar deposits of facies **a**, the carbonate-shoal deposits of facies **b**, and the littoral sandstone deposits of subfacies **c2**.

The second group includes the transitional bioturbate siltstone deposits of facies **d**, deposited seaward of the first group of sediments.

Sediments of (sub)facies **c1, c3, e, f, g,** and **cr** do not occur in the Gordón Member of the Esla area. The values **(d/a+b+c2+d)**. 100 are calculated, and to designate the

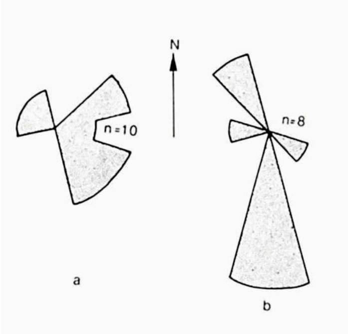


Fig. 46. Current directions measured on large-scale cross-bedding in the deposits of facies **b** in the upper part of the Gordón Member: (A) section CI, (B) section AG.

general palaeogeographic trend the 20% line is constructed (Fig. 45a). The picture obtained from the facies ratio map is that of a shallow marine shelf, where most of the sediments of the second group were deposited in the southeastern part of the area. The sediments of the first group were mainly deposited in the northwest near the Pardomino High.

The thickest succession occurs in the southeastern area, where deeper water deposits are met with; there the thickness surpasses 100 m. Northward and westward the member is thinning and north of the Intra-Asturo-Leonese Facies Line mainly a thin sequence with ferruginous soils, red beds and erosion surfaces is present. The source area of the clastics was most probably situated in the north and northwest as is indicated by the cross-bedded structures in the upper part of the Gordón Member (Fig. 46), and by the wedging out towards the southeast of the sandstones (Fig. 30). The characteristics of the siliciclastic lower unit compare well with the barrier model of Fig. 42. These are:
a non-erosive base of the sand body (the sands are underlain by burrowed silts and very fine sands of the transitional zone and lower shoreface);
a northeast-southwest elongation of the sand body;
a wedging of the sand body in a southeastward direction;
a sequence of structureless and laminated sediments in the lower half of the unit and cross-bedded sediments in the upper half;
indications of subaerial exposure near the top of the sandbody;
the typical regressive situation with an increase in grain-size from lower shoreface deposits to beach deposits.

These characteristics support the interpretation of the sandstone belt as a barrier coastline. However, true barrier sands will be flanked on their landward side by lagoonal sediments (David et al., 1971). These sediments are not found in the siliciclastic unit of the Esla area; but we have to bear in mind that in the Intermediate Zone only two sections have been studied (V, VE), of which one is poorly exposed (section V). Upheaval of the Pardomino High and the Asturian Geanticline was probably the cause of the supply of the siliciclastic material. The barrier sands prograded seawards in a southeastward direction over the subtidal fine-grained sediments of facies **d**. Meanwhile erosion peneplained the hinterland and, after a period of time, the siliciclastic supply decreased. A carbonate platform was able to develop in the southeasternmost part of the Esla area beyond the reach of the siliciclastic supply (section OL). When the relief was low and the supply of siliciclastic material decreased, this platform developed in a landward (northwestward) direction. Both a low-energy lagoonal facies (**a**) and a high-energy carbonate shoal facies (**b**) occur, and locally some siliciclastic deposits of subfacies **c2** (Fig. 44).

All facies types of the Gordón Member in the Bernesga area also occur in the Somiedo area. However, in the Bernesga area three groups of sediments are distinguish-

ZONATION		SECTION	THICKNESS (m)	% FACIES a+b+c2	% FACIES d+e2
EXT.	Z.	PP/LUM,PUENTE DE LAS PALOMAS/LUMAJO	73	45	55
INTERMEDIATE	ZONE	ME/VV,MEROY/VEGA DE LOS VIEJOS	36	100	0
		C. LA CUETA	76	100	0
		POL,POLA DE SOMIEDO	60	100	0
		CIG,CIGUEDRES*	53	100	0
INTERNAL	ZONE	POZ,PEÑA ORNIZ	0	–	–
		T. TORRISTIO	0	–	–

* VAN LOEVEZIJN & RAVEN, 1984

Table 4. Thickness and facies percentages of the deposits of the Gordón Member in the Somiedo area.

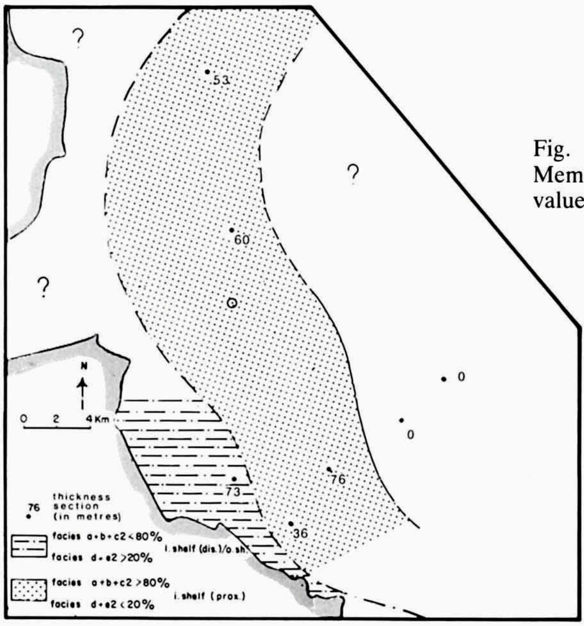


Fig. 47. Facies ratio map of the Gordón Member in the Somiedo area based on the values of Table 4.

ed for the construction of the facies ratio map, whereas in the Somiedo area two groups are distinguished. This is due to the few control points in the Somiedo area (only one section southwest of the Intra-Asturo-Leonese Facies Line). The second and third group of sediments of the facies ratio map of the Bernesga area, which in the Somiedo area only occur southwestward of the facies line, have been lumped.

The first group includes the back-bar deposits of facies **a**, the carbonate shoal deposits of facies **b** and the littoral sandstone deposits of subfacies **c2**.

The second group comprises the offshore shales of subfacies **e2** and the transitional and lower shoreface siltstones of facies **d**.

The palaeogeographical picture of Fig. 47 is very similar to that of the Gordón Member of the adjacent Bernesga area (Fig. 41a), with mainly offshore and transitional deposits in the External Zone, and littoral, shoal and back-bar deposits in the Intermediate Zone. The sedimentation area borders the Internal Zone and the Asturian Geanticline in the northeast, which probably was the source area of terriginous material.

ZONATION	SECTION	THICKNESS (m)	% FACIES c2+d	% FACIES c1+e1	% FACIES e2
EXTERNAL ZONE	M, MATALLANA	113	16	72	12
	LL, LLOMBERA	72	25	16	59
	H, HUERGAS DE GORDÓN	119	40	14	46
	BG, BARRIOS DE GORDÓN	221	5	92	3
	MI, MIRANTES	?	?	?	?
	S, SAGÜERA	152	8	74	18
	PO, PORTILLA DE LUNA	146	25	30	46
	PIE, PIEDRASECHA	145	0	3	97
	CU, CUEVAS	?	?	?	?
	SV, SANTIAGO DE LAS VILLAS	?	6	16	78
	O, OLLEROS DE ALBA	114	0	20	80
	SA, SORRIBOS DE ALBA	?	?	?	?
	R, LA ROBLA	?	?	?	?
INTERNAL ZONE	VG, VEGA DE GORDÓN	0	–	–	–
	B, BEBERINO	0	–	–	–
	LU, LUNA	0	–	–	–
INTERNAL ZONE	CLI, CALDAS DE LUNA I	0	–	–	–
	CLII, CALDAS DE LUNA II	0	–	–	–
	CA, CAMPLONGO	0	–	–	–
	E, SAN EMILIANO	0	–	–	–
	U, UBIÑA	0	–	–	–
	VA, VALPORQUERO*	0	–	–	–

*FRANKENFELD, 1981

Table 5. Thickness and facies percentages of the Millar Member in the Bernesga area.

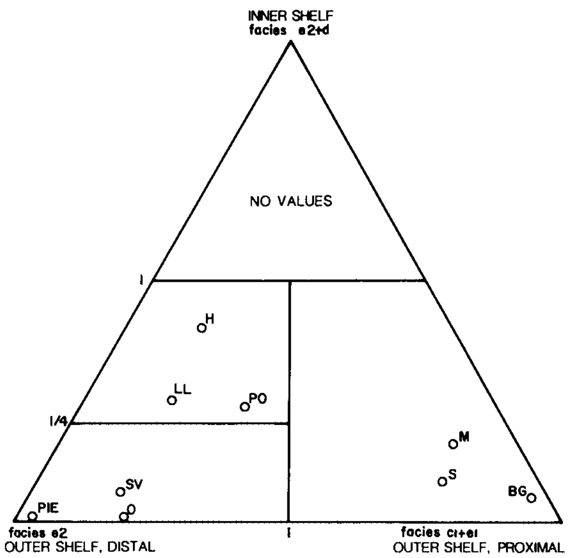


Fig. 48. Facies ratio triangle based on Table 5.

Millar Member — The facies and subfacies of the Millar Member in the Bernesga area are arranged into three groups:

The first includes the littoral sandstone deposits of subfacies **c2** and the transitional bioturbate siltstone deposits of facies **d**.

The second comprises the sediments of subfacies **c1** (conglomerate deposits) and **e1** (heterolithic shale-sandstone deposits). The sediments were deposited on the proximal part of the outer shelf on an unstable slope as is suggested by the slump structures and grainflow deposits.

The third consists of the laminated shales of subfacies **e2**, which were deposited seaward of the second group of sediments in a plain and quiet environment.

Sediments of (sub)facies **a**, **b**, **c3**, **f**, **g**, and **cr** do not occur in the Millar Member of the Bernesga area. From the facies ratio map (Fig. 49a) and the isopach map (Fig. 49b) it can be concluded that the influence of the Asturian Geanticline in the north, the Pardomino High in the east and the Intra-Asturo-Leonese Facies Line is very obvious. The latter marked a depositional slope which divided the Asturo-Leonese shelf into a southern area with a clastic succession, up to 229 m thick and a northern area with no net sedimentation. On the unstable slope a thick succession consisting mainly of conglomerates of subfacies **c1** and slumped sandstone-shale alternations of subfacies **e1** was laid down. Davies and Walker (1974) describe a conglomerate from the Ordovician of Quebec, very similar to the deposits of subfacies **c1**. For the origin of these deposits they envisage a slope of transport of c. 10°. Southward of the section near Barrios de Gordón

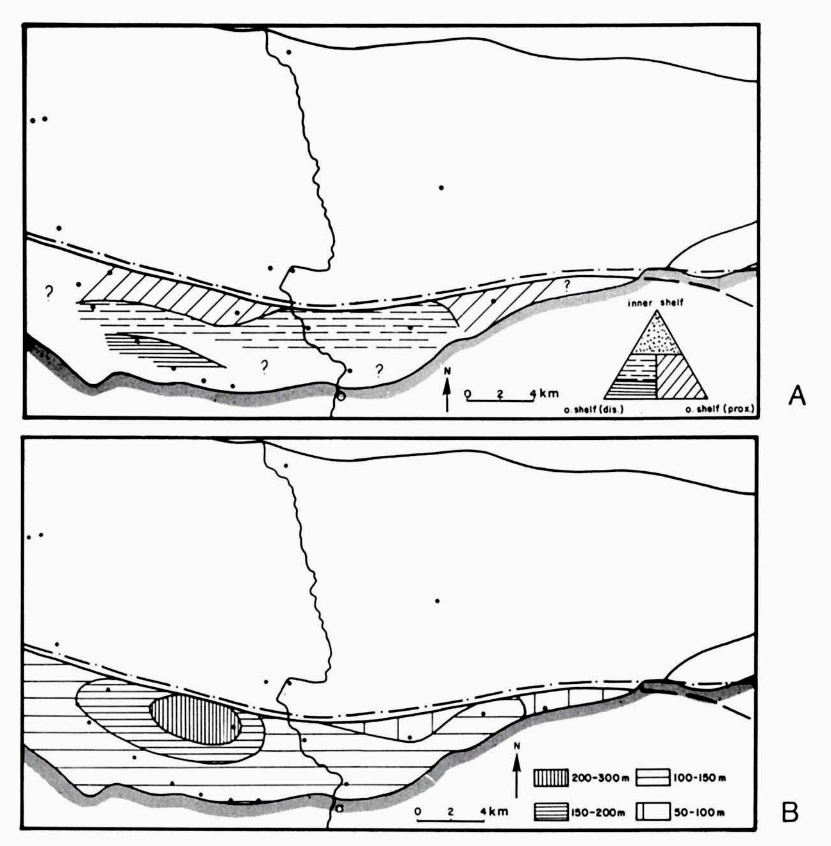


Fig. 49. Facies maps of the Millar Member in the Bernesga area: (A) facies ratio map based on the facies ratio triangle of Fig. 48, (B) isopach pattern based on the values of Table 5.

(BG) the thickness decreases and the slope deposits interfinger with shales and thin-bedded distal turbidites of the outer shelf. A gradual decrease in thickness of the Millar Member in an eastward direction in combination with a decrease in importance of subfacies **e2** underline the influence of the Pardomino High on the sedimentation pattern. Northward, in the Intermediate Zone, we may expect a thin, shallow marine succession, but probably due to erosion the Millar deposits are absent. In Fig. 50 the maximum clast size and thickness of the conglomerate unit of subfacies **c1** is depicted. In the north the distribution pattern is bounded by the Sabero-Gordón Fault Zone and the connected Intra-Asturo-Leonese Facies Line. The thickest deposits occur just south of this line near Barrios de Gordón (109 m). Southward and eastward the thickness and the maximum clast size decrease rapidly and the conglomerate passes into pebbly sandstone and fine-grained sandstone. Laterally the sediments of subfacies **c1** interfinger with shales and sandstones of facies **e**. From Fig. 50 it becomes plausible that these sediments originated from a northern source area and that the main distribution channel was situated near Barrios de Gordón. The conglomerate wedge was probably the result of a sudden tectonic activity along the Intra-Asturo-Leonese Facies Line: uplift and erosion of the area north of the facies line combined with downwarping and sedimentation in the External Zone south of the facies line.

The excellent exposure of the Millar Member in the river Torío near Matallana offers the possibility of a detailed investigation. There the member consists mainly of a

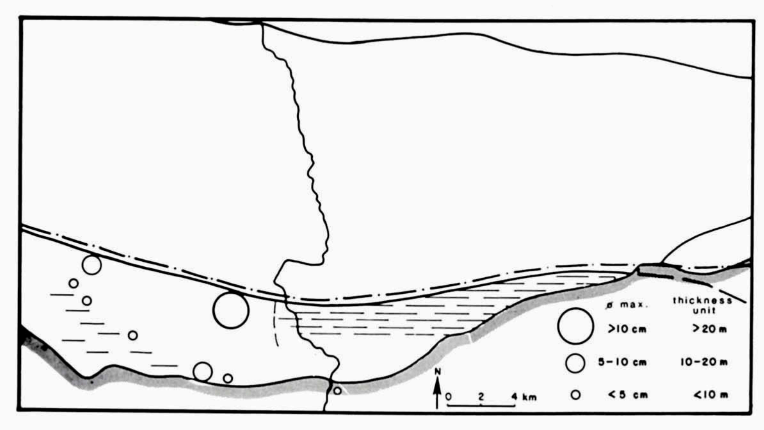


Fig. 50. Maximum clast size and thickness of the conglomerate unit of subfacies **cl** in the uppermost part of the Millar Member.

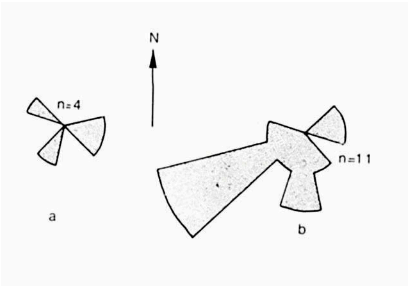


Fig. 51. Current directions measured on large-scale cross-bedding in the upper part of the Millar Member: (A) section S, (B) section PO.

shale-sandstone unit (subfacies **el**). Modern continental shelves display a definite seaward decrease in sediment grain size (Emery, 1960; Reineck & Singh, 1975; and many others). Vertical change in sand bed thickness and sand-mud ratio can therefore be used as an indication of proximality (Crimes, 1970; Bose, 1983). The palaeocurrent directions from the Matallana locality seem to indicate a northeastern source area (Fig. 51). The relative position of the sequence with respect to the source area was probably constant. The sand-bed thickness and the sand-mud ratio for successive five-metre intervals of the Millar Member is pictured in Fig. 52. The succession has been divided into two parts. The base of part I consists mainly of shales and siltstones. The sandstone/shale ratio (tr) and the sand bed thickness (tm) increase upward. The top of part I is taken where the ratio falls and the bed thickness decreases. Part II consists of a similar sequence, but there the coarsening upward continues and at the top clean cross-bedded quartzarenites occur. The upward decreasing proportion of mud in part I may be interpreted as the result of a decrease in basin depth. This interpretation is supported by the observed succession of sedimentological structures. The base of part I consists of planar persistent thin beds, but in the upper part channeling and amalgamation of sand beds are common. An increase in basin depth is demonstrated by the abrupt fall of the bed thickness and the sandstone/shale ratio from part I to part II at 40 m, from 55 m upward the thin planar beds grade into a shallow channel sequence and a cross-bedded sandstone unit, again indicating a shallowing of the basin. Thus, although the overall picture of the Millar Member is a shallowing upward sequence, minor cycles can be recognized within the member. The

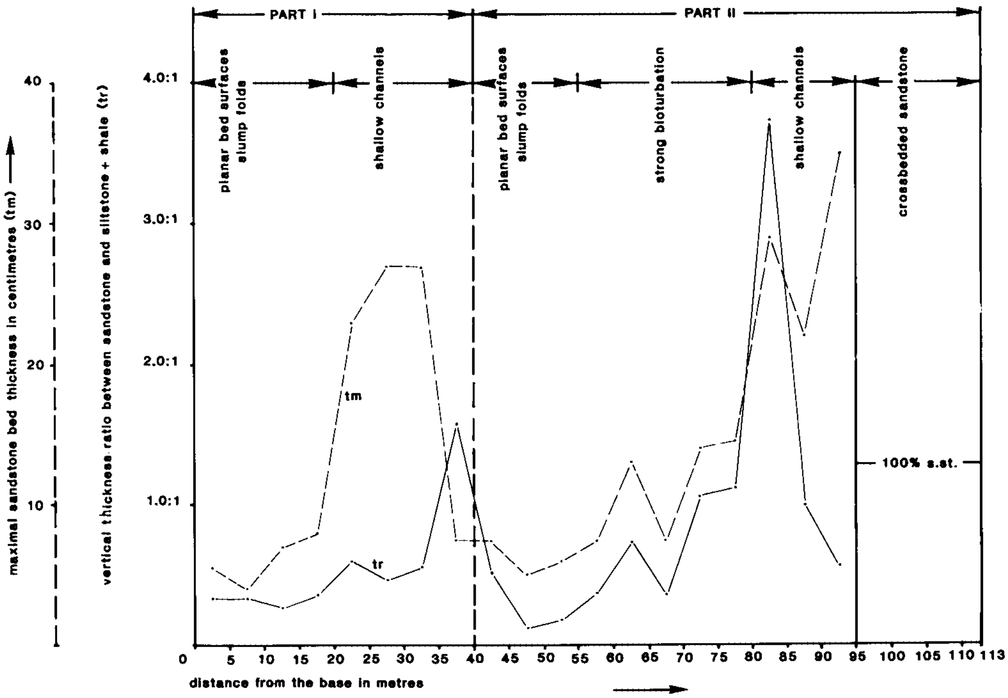


Fig. 52. The maximal sandstone bed thickness (tm), and the sandstone/shale+siltstone ratio (tr) of five metre intervals of the Millar Member in section M.

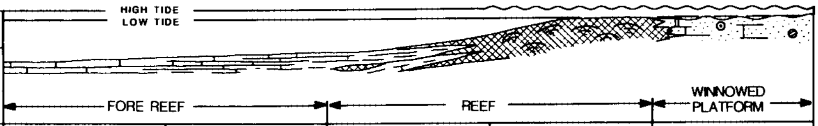
fluctuation of depth during the deposition of the Millar Member must have been due either to basin subsidence or eustatic sea level changes. The conglomerate wedge of subfacies **c1** near Barrios de Gordón, and the appearance of slump folds associated with an apparent increase in supply of fine-grained sediment at the base of part I and part II suggest that basin subsidence was a major reason for deepening. Block movements along the Sabero-Gordón Fault Zone may have caused the fluctuations in depth (van Loevezijn, 1983).

In the Esla area the facies and subfacies of the Millar Member can be arranged into two groups:

The first group comprises the littoral sandstone deposits of subfacies **c2** and the coral-stromatoporoid limestones of facies **cr**.

The second group includes the transitional bioturbated siltstone deposits of facies **d**.

Sediments of subfacies **c1** and facies **e**, which are present in the Millar Member in the Bernesga area, are not found in the Esla area, nor are sediments of (sub)facies **a, b, c3, f,** and **g**. Sediments or structures related to mass-gravity transport are not present in the Millar Member in the Esla area. The subtidal siltstones of facies **d**, which grade upward into the littoral sandstones of subfacies **c2**, and the north-south facies mosaic with the pinch-out of littoral sands in a south(east)ward direction, suggest a depositional model for the lower siliciclastic unit with a smooth palaeorelief without a significant break in the slope of the shelf, very similar to the regressive barrier model of the underlying Gordón Member. The regressive siliciclastic unit is overlain by the Crémenes Limestone. An attempt has been made to incorporate the five subfacies of the limestone



SEDIMENTATION MODEL CRÉMENES LIMESTONE	FORE REEF		REEF		WINNOWED PLATFORM
FACIES CODE	CR5	CR4	CR3	CR2	CR1
LITHOLOGY	fine grained bioclastic grainstone	fine grained bioclastic packstone, wackestone, mudstone	argillaceous nodular boundstone	massive boundstone	coarse grained sandy grainestone, ooids, haematite pebbles
BEDDING	medium, well bedded	thin, well bedded	irregular and wavy	thick, sometimes indistinguishable	medium, cross - bedded
COLOUR	grey, yellow, pink	grey, yellow	grey, red, green	light grey	red
TERRIGENOUS CLASTICS ADMIXED OR INTERBEDDED	none	few shale - silt lenticles interbedded	abundant silt - shale material interbedded	few siliciclastic material	abundant well - rounded quartz grains admixed
BIOTA	fine grained bioclastic detritus: bryozoans, brachiopods, trilobites crinoids, bivalves, echinoderms	fine grained bioclastic detritus: brachiopods, bryozoans, corals, stromatoporoids, trilobites, gastropods, crinoids, ostracods	coral - stromatoporoid boundstone with abundant complete fossils: brachiopods, bryozoans, echinoids, trilobites, ostracods, crinoids, bivalves, gastropods, receptaculitids	coral - stromatoporoid boundstone with a few blue - green algae, trilobites, tentaculitids, brachiopods, bryozoans, crinoids, ostracods	coarse grained bioclastic detritus of crinoids, brachiopods, bryozoans

Fig. 53. Sedimentation model of the Crémenes Limestone.

in a model showing the sedimentary environments. In Fig. 53 an idealized cross-section is sketched through the carbonate shelf.

Three main depositional environments are recognized: a high energetic sandy platform environment (sandy coarse-grained limestones of subfacies **crl**); a reef environment, mainly subtidally formed on the margin of a winnowed platform (boundstones of subfacies **cr2** and **cr3**); and a fore-reef environment (fine-grained bioclastic limestones of subfacies **cr4** and **cr5**). The values **(d/c2+crd)**.100 were calculated and in the palaeogeographical map of Fig. 54a the 20% line has been constructed. The southeastern area, already recognized in the palaeogeographical map of the Gordón Member, where mainly

ZONATION	SECTION	THICKNESS (m)	% FACIES c2+cr	% FACIES d
EXTERNAL ZONE	A. SAN ADRIAN	0	–	–
	LA. SOBREPEÑA	70	100	0
	LE. LA ERCINA	?	?	?
	CI. CISTIERNA	0	–	–
	PC. PEÑA CORADA	82	88	12
	RO. ROBLEDO	70	75	25
	OL. SANTA OLAJA	85	55	45
	AL. ALEJE	90	64	36
	AG. AGUASALIO	110	58	42
	AV. ARGOVEJO	>60	?	?
INTERM. ZONE	VE. VERDIAGO	0	–	–
	V. VALDORÉ	0	–	–
INTERNAL ZONE	LSI. LAS SALAS I	0	–	–
	LSII. LAS SALAS II	0	–	–
	LSIII. LAS SALAS III	0	–	–
	LSIV. LAS SALAS IV	0	–	–

Table 6. Thickness and facies percentages of the deposits of the Millar Member in the Esla area.

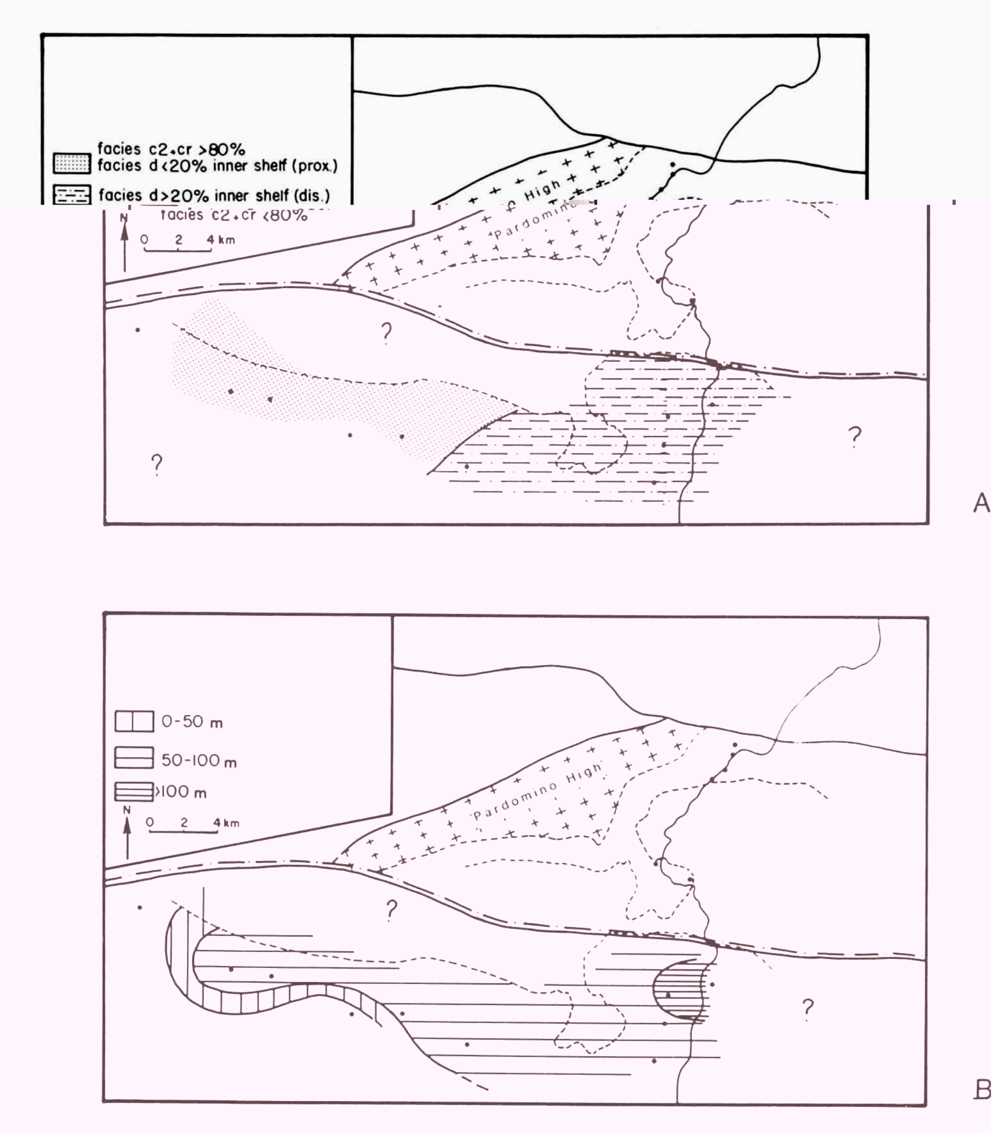


Fig. 54. Facies maps of the Millar Member in the Esla area based on the values of Table 6, (A) facies ratio map, (B) isopach map.

subtidal sediments were deposited, again acted as the deepest (subtidal) part of the shallow marine shelf. There also the thickest succession occurs (Fig. 54b). In the western part of the area a mainly littoral sandstone succession is found. From the isopach map and the facies ratio map a small elongated basin parallel to the Intra-Asturo-Leonese Facies Line may be deduced with a facies and thickness distribution very similar to the underlying Gordón Member. However, the Millar Member is absent in the area north of the Intra-Asturo-Leonese Facies Line. The palaeocurrent directions measured on large-scale cross-bedding in the upper part of the member suggest a northern source area, probably the Pardomino High and the Asturian Geanticline (Fig. 55). When the relief was low and the supply of siliciclastics decreased, a sandy crinoidal platform developed,

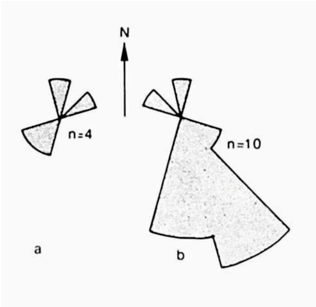


Fig. 55. Current directions measured on large-scale cross-bedding of subfacies **c2** and **cr1** in the upper part of the Millar Member: (A) section LA, (B) section AG.

characterized by high-energy conditions with haematite pebbles, microconglomerates and ooids. On the platform a coral-stromatoporoid reef belt could develop. The 'reef' deposits clearly show a biostromal aspect; they consist of a coral-stromatoporoid boundstone, only a few metres thick, which can be traced over several kilometres without any significant change in thickness. Fine-grained bioclastic sediments were deposited seaward of the reefs. A transgressive succession can be clearly recognized in the sequence of the Crémenes Limestone (Fig. 34), where the reef deposits of subfacies **cr2** and **cr3** are overlain by the fore-reef deposits of subfacies **cr4** and **cr5**. Probably the carbonate producing organisms, restricted to certain optimum water depths, could not keep up with an increasse in water depth and shifted towards shallower water (towards the Pardomino High and the Asturian Geanticline in a northern direction). In the uppermost part of the Millar Member sedimentation conditions suddenly changed. Siliciclastic sediments obscured, or became intensively admixed with, the carbonates. Obviously, the hinterland again supplied terrigenous material, killing off the last Devonian reefs of the Cantabrian Mountains.

In the Somiedo area little can be said about the regional distribution of the facies since only one exposure of the Millar Member is known in the External Zone (section PP). In the two other zones this member is absent. The occurrence of subfacies **c1** suggests a depositional slope, related to the Intra-Asturo-Leonese Facies Line. The same palaeogeographic reconstruction is made for the environment of deposition of the Millar Member in the adjacent Beresga area.

Fueyo Formation

In the Bernesga area the three groups which are distinguished as end members for the facies triangle of the Fueyo Formation of Fig. 56 are very similar to the three facies groups of the Millar Member (Fig. 48):
The first group consists of the transitional bioturbated siltstones of facies **d**.
The sandstone-shale deposits of subfacies **e1** form the second group.
The third group comprises the laminated shales of subfacies **e2** and the laminated dark shales with limestone intercalations of facies **f**, deposited seawards of the second group of sediments, almost beyond the reach of the silt and sand supply.

Sediments of facies **a, b, c, g**, and **cr** have not been found in the Fueyo Formation. The facies ratio map does not differ much form the facies ratio map of the underlying Millar Member. The Intra-Asturo-Leonese Facies Line divides the Bernesga area into a southern area with a succession of up to 332 m and a northern area with no net sedimentation (Fig. 57). In the southernmost part of the Bernesga area the distal outer shelf shales dominate. Beyond this area, near the Intra-Asturo-Leonese Facies Line and

ZONATION	SECTION	THICKNESS (m)	% FACIES d	% FACIES e2-f	% FACIES e1
EXTERNAL ZONE	M, MATALLANA	99	0	100	0
	LL, LLOMBERA	100	3.5	96	0
	H, HUERGAS DE GORDÓN	97	0	60	40
	BG, BARRIOS DE GORDÓN	152	0	47	53
	MI, MIRANTES	?	?	?	?
	S, SAGÜERA	247	0	72	28
	PO, PORTILLA DE LUNA	307	0	45	55
	PIE, PIEDRASECHA	325	0	44	50
	CU, CUEVAS	?	?	?	?
	SV, SANTIAGO DE LAS VILLAS	142	12	0	88
	O, OLLEROS DE ALBA	190	3	0	97
	SA, SORRIBOS DE ALBA	?	?	?	?
	R, LA ROBLA	?	?	?	?
INTERM. ZONE	VG, VEGA DE GORDÓN	0	–	–	–
	B, BEBERINO	0	–	–	–
	LU, LUNA	0	–	–	–
INTERNAL ZONE	CLI, CALDAS DE LUNA I	0	–	–	–
	CLII, CALDAS DE LUNA II	0	–	–	–
	CA, CAMPLONGO	0	–	–	–
	E, SAN EMILIANO	0	–	–	–
	U, UBIÑA	0	–	–	–
	VA, VALPORQUERO*	0	–	–	–

*FRANKENFELD, 1981

Table 7. Thickness and facies percentages of the Fueyo Formation in the Bernesga area.

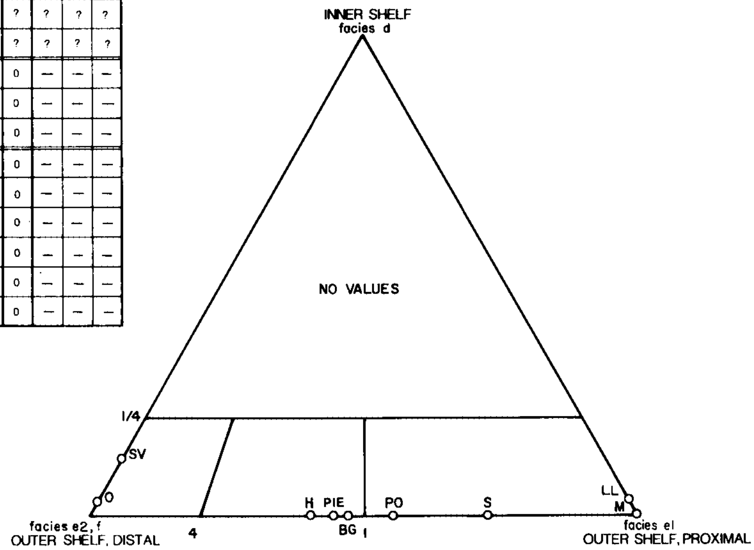


Fig. 56. Facies ratio map triangle based on Table 7.

the Pardomino High, graded sandstone beds occur frequently, sometimes deformed by slumping. The Fueyo Formation is excellently exposed in the section near Matallana in the river bed of the Torio (section M). The shales, with at the base a 40 m thick unit consisting of slump-folded fine sediment with siltstone and sandstone intraclasts, suggest that the major reason for increasing depth at the transition Nocedo Formation – Fueyo Formation resulted from subsidence rather than an eustatic rise of sealevel (Fig. 58). Upwards the sandstone ratio increases which may indicate basin infill during regression. A depositional slope, related to the Sabero Gordón Fault Zone and the Intra-Asturo-Leonese Facies Line, bordered probably a shallow marine platform in the north but due to erosion no sediments of the Fueyo Formation are left in the northern areas. Of the Fueyo Formation palaeocurrent directions are only available from Piedrasecha and Cuevas (Fig 59). Sole marks on the lower surface of a sandstone bed offer the dispersal pattern of Fig. 59a, and from cross-bedded channel-fill deposits the rose diagrams of Fig. 59b and c are constructed. Although measurements are few, they support the theory of a clastic source area in the north.

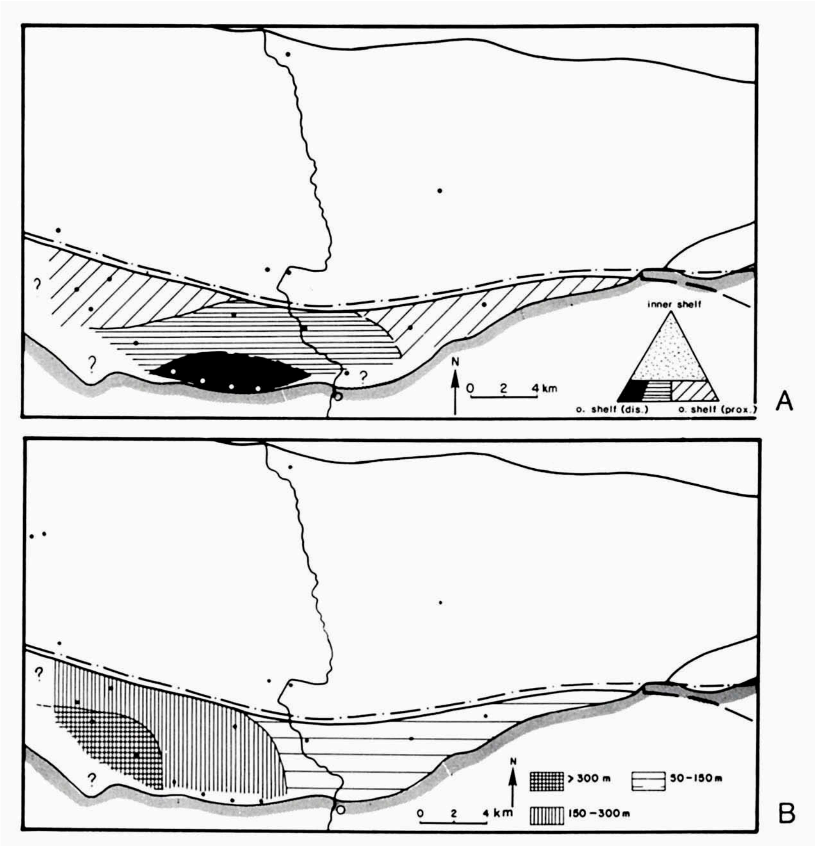


Fig. 57. Facies maps of the Fueyo Formation in the Bernesga area: (A) facies ratio map based on the triangle of Fig. 56, (B) isopach map based on the values of Table 7.

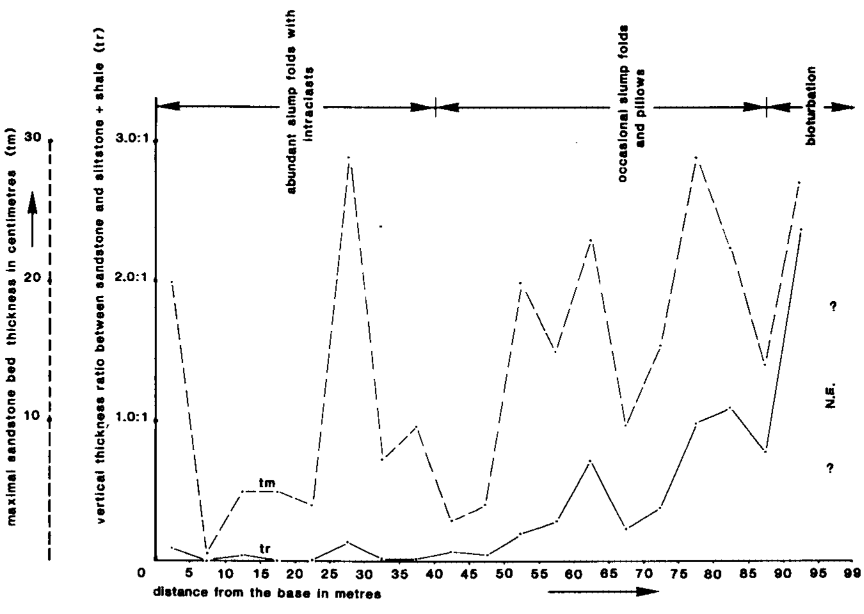


Fig. 58. The maximal sandstone bed thickness (tm) and the sandstone/shale+siltstone ratio (tr) of five-metre intervals of the Fueyo Formation in section M.

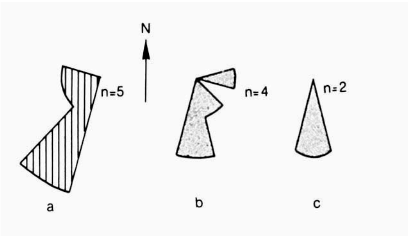


Fig. 59. Current directions measured in the Fueyo Formation: (A) section PIE (sole marks), (B) section PIE (cross-bedded channel-fill deposits), (C) section CU (cross-bedded channel-fill deposits).

The palaeogegraphical picture, which can be obtained form the facies map and the isopach pattern of the Fueyo Formation in the Esla area matches very well with that of the adjacent Bernesga area. In the Esla area the formation also wedges in an eastern direction, the thinnest deposits are found in the eastern sections (Fig. 60). The Intra-Asturo-Leonese Facies Line divides also the Esla area into a southern area (External Zone), with a succession of up to 61 m (section A) consisting of outer shelf deposits, and a northern area with no net sedimentation. There are, however, some differences between the Fueyo deposits in the Bernesga area and in the Esla area. The absence of the outer shelf shales of subfacies **e2** and facies **f** in the Esla area, their presence in the southwestern part of the Bernesga area, and the high sanstone/shale ratio of the Fueyo sediments in the Esla area with respect to the deposits of the Bernesga area are notable (Fig. 11). In the area north of the Intra-Asturo-Leonese Facies Line probably a thin succession of inner shelf sediments was laid down, but since erosion removed most of the Frasnian and Famennian deposits there, this can not be proved.

The development of the Fueyo Formation in the Somiedo area is very similar to its development in the Esla areas as is indicated by the absence of subfacies **e2** and by the high sandstone/shale ratio (Fig. 11). The slump horizon suggests deposition on an unstable slope which was probably related to the Intra-Asturo-Leonese Facies Line. No net sedimentation is known in the Intermediate and Internal zones (Fig. 61).

ZONATION	SECTION	THICKNESS (m)	% FACIES e1
EXTERNAL ZONE	A. SAN ADRIAN	61	100
	LA. SOBREPEÑA	56	100
	LE. LA ERCINA	?	?
	CI. CISTIERNA	30	100
	PC. PEÑA CORADA	42	100
	RO. ROBLEDO	33	100
	OL. SANTA OLAJA	21	100
	AL. ALEJE	?	?
	AG. AGUASALIO	16	100
	AV. ARGOVEJO	?	?
INTERM. ZONE	VE. VERDIAGO	0	–
	V. VALDORÉ	0	–
INTERNAL ZONE	LSI. LAS SALAS I	0	–
	LSII. LAS SALAS II	0	–
	LSIII. LAS SALAS III	0	–
	LSIV. LAS SALAS IV	0	–

Table 8. Thickness and facies percentages of the deposits of the Fueyo Formation in the Esla area.

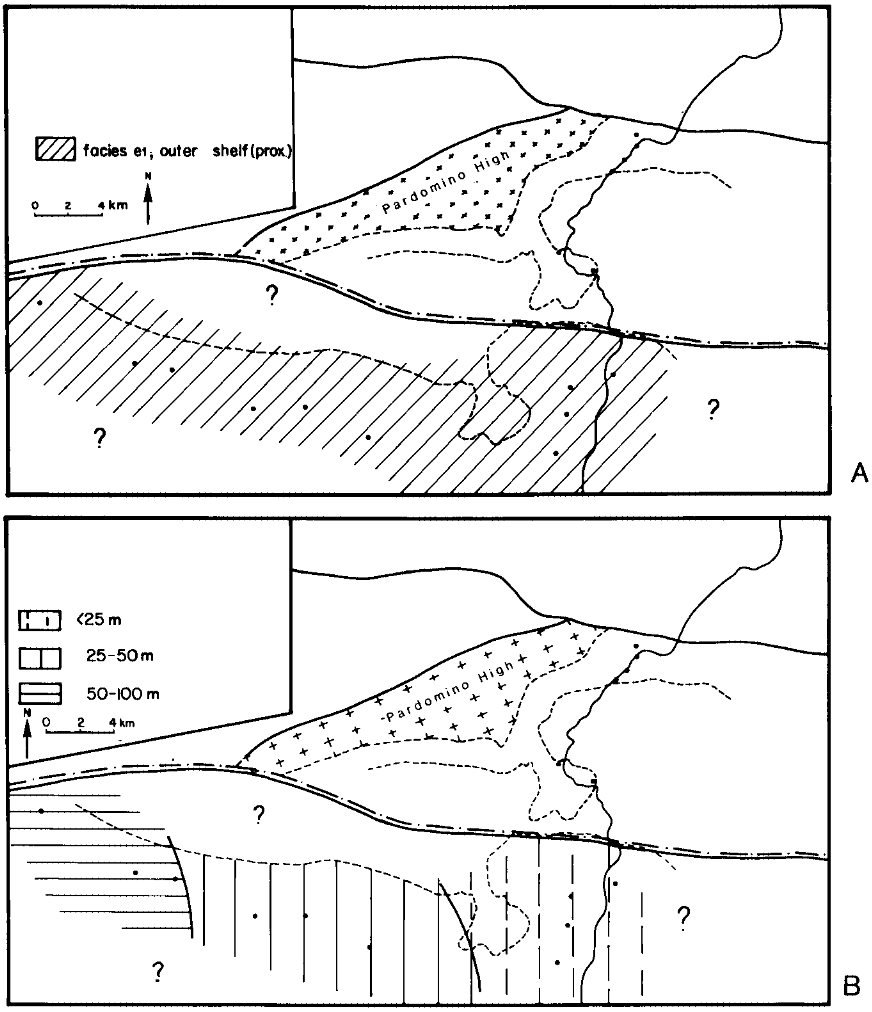


Fig. 60. Facies maps of the Fueyo Formation in the Esla area based on the values of Table 8: (A) facies ratio map, (B) isopach map.

Ermita Formation

In the Ermita Formation in the Bernesga area the following three groups of sediments are distinguished:

The first group mainly consists of cross-bedded quartzites and quartzarenites of subfacies **c2**. Locally some microconglomerate intercalations of subfacies **c3** occur. This group of sediments was deposited in a littoral environment with some fluvial influences.

The second group includes the bioclastic limestones of facies **b**, deposited mainly seaward of the sediments of the first group in a subtidal to intertidal environment forming crinoidal shoals on the sand substrate.

The third group consists of bioturbated siltstones of facies **d**, deposited seaward of the turbulent littoral environment.

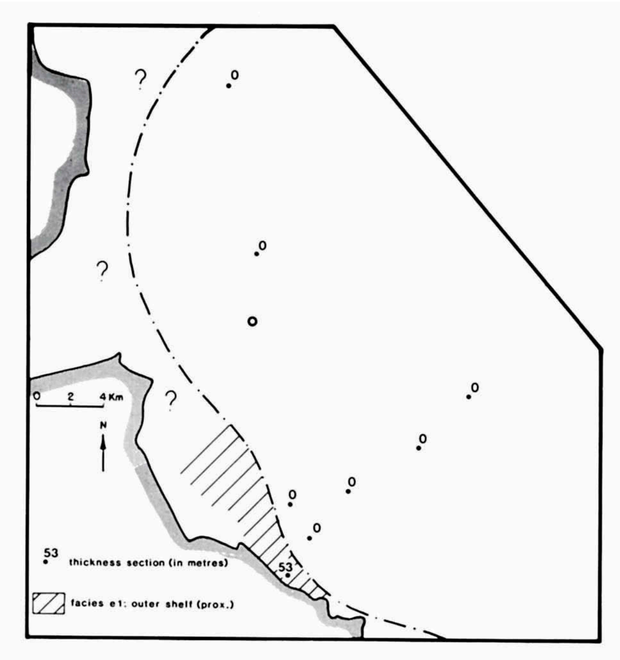


Fig. 61. Facies map of the Fueyo Formation in the Somiedo area.

ZONATION	SECTION	THICKNESS (m)	% FACIES b	% FACIES c2+c3	% FACIES d
EXTERNAL ZONE	M, MATALLANA	32	9	35	56
	LL, LLOMBERA	45	0	93	7
	H, HUERGAS DE GORDÓN	71	1	30	69
	BG, BARRIOS DE GORDÓN	62	0	27	73
	MI, MIRANTES	?	?	?	?
	S, SAGÜERA	47	1	9	90
	PO, PORTILLA DE LUNA	96	0	29	71
	PIE, PIEDRASECHA	81	5	25	70
	CU, CUEVAS	18	0	11	89
	SV, SANTIAGO DE LAS VILLAS	0	—	—	—
	O, OLLEROS DE ALBA	3	0	100	0
	SA, SORRIBOS DE ALBA	0	—	—	—
	R, LA ROBLA	20	10	30	60
INTERM. ZONE	VG, VEGA DE GORDÓN	29	47	53	0
	B, BEBERINO	27	57	43	0
	LU, LUNA	27	30	70	0
INTERNAL ZONE	CLI, CALDAS DE LUNA I	4	0	100	0
	CLII, CALDAS DE LUNA II	8	4	96	0
	CA, CAMPLONGO	4	0	100	0
	E, SAN EMILIANO	53	17	83	0
	U, UBIÑA	30	0	100	0
	VA, VALPORQUERO*	18	6	94	0

* FRANKENFELD, 1981

Table 9. Thickness and facies percentages of the Ermita Formation.

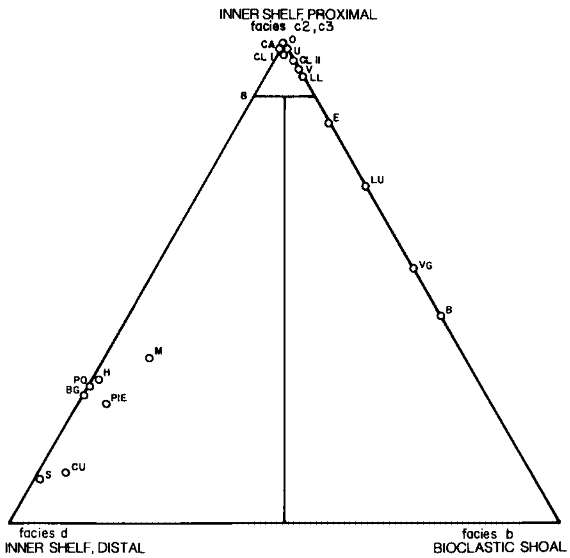


Fig. 62. Facies ratio triangle based on Table 9.

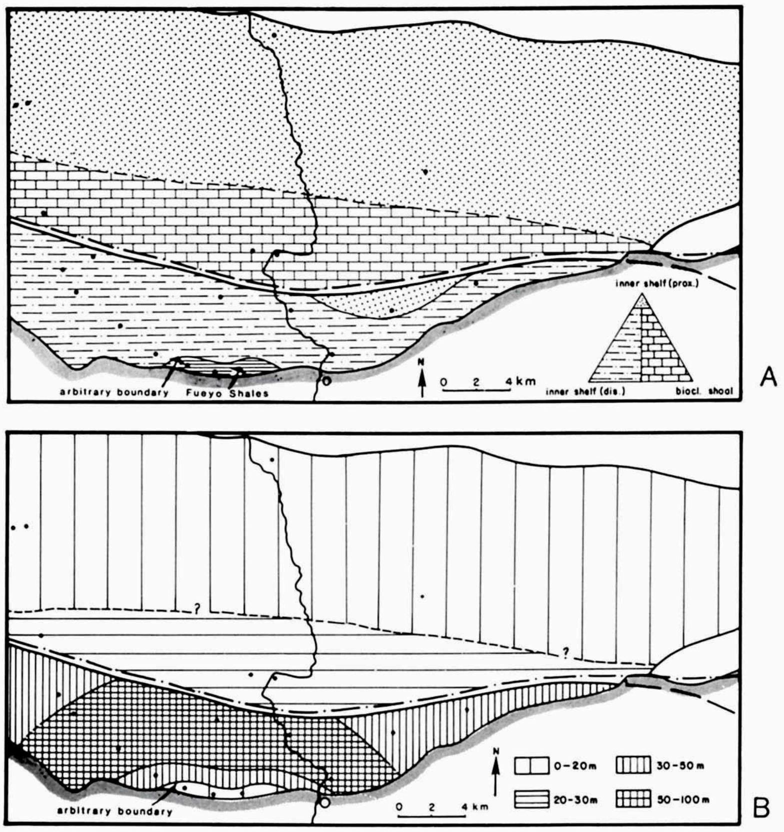


Fig. 63. Facies maps of the Ermita Formation in the Bernesga area: (A) facies ratio map based on the triangle of Fig. 62, (B) isopach pattern based on the values of Table 9.

The Ermita Formation was deposited during an important transgression. The formation is extended over the entire Asturo-Leonese Basin as well as part of the Asturian Geanticline (van Adrichem Boogaert, 1967) During the Late Famennian the Cantabrian area must have been a flat peneplained area because no conglomerate is found in the basal part of the Ermita Formation. Only a few sandstone beds with some irregularly distributed quartz pebbles are known and the angle between the Ermita Formation and the underlying formations is hardly visible in the field. The sea transgressed rapidly over the northern part of the Asturo-Leonese area and over the Asturian Geanticline, and a karst topography was levelled off where the Ermita Formation was deposited on the limestones of the Caldas, Santa Lucía and Portilla formations. Sediments were reworked constantly by strong currents, giving rise to a thin succession of mature polycyclic sandstones, which originated from older formations. Because the clastic supply was low, carbonate build-ups could develop locally. The thickness increases southward and in a small belt on the edge of the sandy platform (Intermediate Zone) a 30 m thick succession of mainly sandy crinoidal shoal deposits was laid down (Fig. 63). The limestone area separates the shallow littoral area in the Internal Zone with mainly a thin sandstone succession up to 20 m thick from the transitional and offshore areas in the External Zone with mainly a siltstone succession of up to 100 m. The isopach pattern has an arc shape, surrounding an embayment with mainly offshore shales (Fueyo Formation).

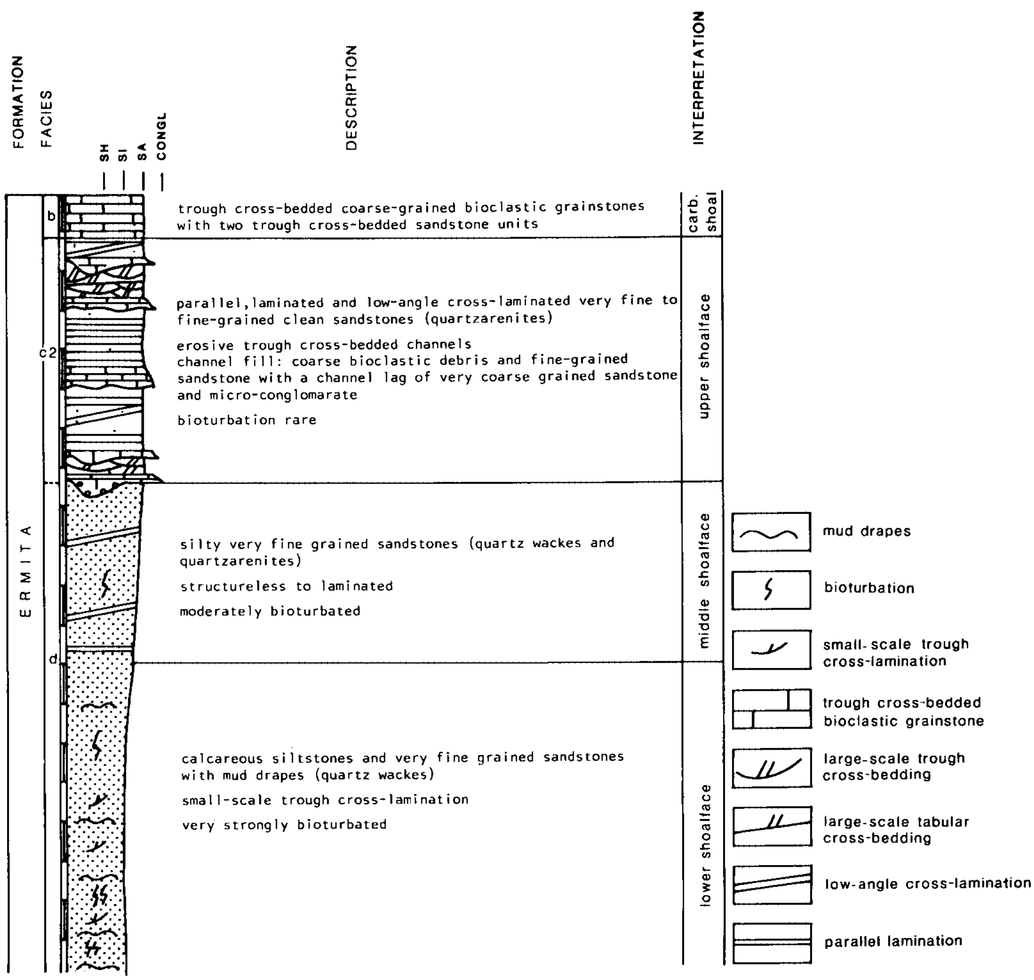


Fig. 64. Lithology, sedimentary structures and environmental interpretation of the Ermita Formation exposed 1 km north of La Robla along the old road to Oviedo. The scale bar indicates units of 1 m.

In this bay the rate of sedimentation was very low, which is evidenced by the thin Upper Famennian-Lower Tournaisian sequence (generally not surpassing 25 m). A shifting of facies belts in a mainly southern direction resulted in a shallowing upward sequence successively consisting of shales, transitional siltstones and littoral deposits including crinoidal shoal deposits. The siltstones form the major part of the sediment pile (Fig. 64)

From the large-scale cross-bedded structures in the littoral sandstones of subfacies **c2** the rose diagrams of Fig. 65 have been constructed. The ebb-current in the west (section S) had approximately a southeastward direction, and the ebb-current in the east (section R) had roughly a southwestward direction. In section PIE, situated in between the sections S and R, the ebb-current direction is south to southwest with longshore current directions to the east. Obviously the coast prograded from different sides into the embayment.

In the Ermita Formation in the Esla area two groups of sediments are distinguished:

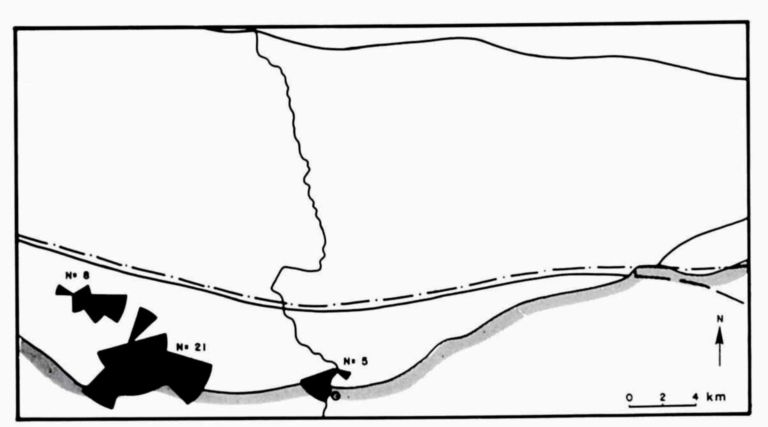


Fig. 65. Current directions measured on large-scale cross-bedding of the littoral sandstones of subfacies **c2** in the Ermita Formation.

The first group contains cross-bedded quartzarenites and quartzites of subfacies **c2**, with locally pebbly sandstone intercalations of subfacies **c3**. The sediments were deposited in a littoral and partly fluvial environment.
The second group consists of coarse-grained bioclastic limestones of facies **b**, deposited in a shallow-marine shoal environment.

Neither the siltstones of facies **d**, which are present in the Ermita Formation in the Bernesga area, are found in the Esla area, nor the sediments of (sub)facies **a, cl, e, f, g,**

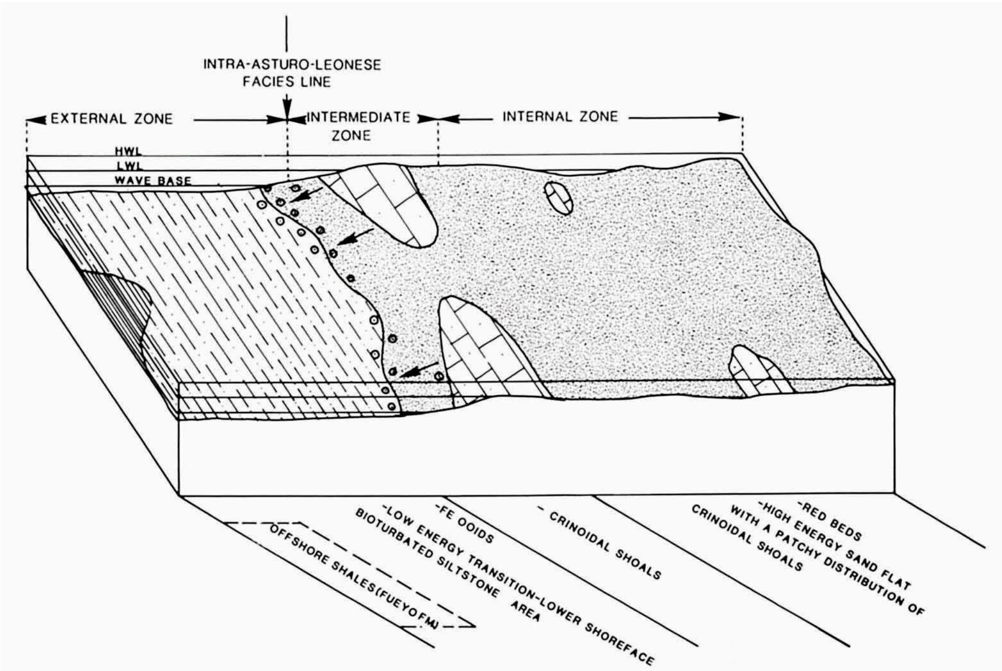


Fig. 66. Sedimentation model for the Ermita Formation in the Bernesga area.

and **cr**. In the northern part of the Asturo-Leonese Basin (Internal Zone) the Ermita shows an irregular distribution pattern of subfacies **c2** and facies **b**. There a sandflat with a patchy distribution of crinoidal shoal deposits occurs. The irregularly distributed succession never surpasses a thickness of 20 m, locally it preserves landforms with a karst topography (Fig. 67). In the Intermediate Zone mainly crinoidal shoal deposits occur. So far the palaeogeographical picture resembles the depositional model of the Ermita Formation in the adjacent Bernesga area (Fig. 66). South of the Intra-Asturo-Leonese Facies Line, in the External Zone, a thick Ermita succession (up to 100 m) occurs, mainly consisting of littoral sandstone deposits. The External Zone was probably a slowly downwarping area where the rate of sedimentation equalled or slightly surpassed the subsidence, causing a thick pile of shallow marine sandstone deposits with in the uppermost part of the succession local fluvio-marine pebbly sandstone lenticles. The few measurements on large-scale cross-bedding support the hypothesis of a clastic scource area in the north (Fig. 68).

The Ermita Formation in the Somiedo area almost completely consists of sediments of subfacies **c2**. From Fig. 69 we see that most of the sediments were deposited in the southwestern part of the area; there the thickest Ermita successions of the Asturo-Leonese Basin with a thickness of up to 250 m occur. On both sides of the Intra-Asturo-Leonese Facies Line, however, we find a similar thickness. Large quantities of detrital material, which were derived from the Asturian Geanticline as is indicated by the rose diagram of Fig. 70, were transported towards the Somiedo area. The area was gradually tilted with a maximum subsidence in the southwest. The rate of sedimentation almost kept pace with the rate of subsidence, causing a thick, continuous succession of littoral deposits. In the northern part of the Intermediate Zone however, ferruginous soils occur within these deposits, indicating subaerial exposure. Obviously sedimentation slightly surpassed the rate of subsidence. The regression continued: near the top of the Ermita Formation fluvio-marine pebbly sandstones occur, but when the supply of siliciclastics decreased marine crinoidal grainstones formed a carbonate platform covering most of the area (van Loevezijn & van Raven, 1984). The thick pile of quartzarenites and

ZONATION	SECTION	THICKNESS (m)	% FACIES c2+c3	% FACIES b
EXTERNAL ZONE	SA. SAN ADRIAN	86	100	0
	LA. SOBREPEÑA	87	100	0
	LE. LA ERCINA	?	?	?
	CI. CISTIERNA	60	100	0
	PC. PEÑA CORADA	70	100	0
	RO. ROBLEDO	92	99	1
	OL. SANTA OLAJA	95	100	0
	AL. ALEJE	?	?	?
	AG. AGUASALIO	100	16	4
	AV. ARGOVEJO	?	?	?
INTERM. ZONE	VE. VERDIAGO	10	0	100
	V. VALDORÉ	2	0	100
INTERNAL ZONE	LSI. LAS SALAS I	7	100	0
	LSII. LAS SALAS II	15	100	0
	LSIII. LAS SALAS III	7	100	0
	LSIV. LAS SALAS IV	0.3	0	100

Table 10. Thickness and facies percentages of the deposits of the Ermita Formation in the Esla area.

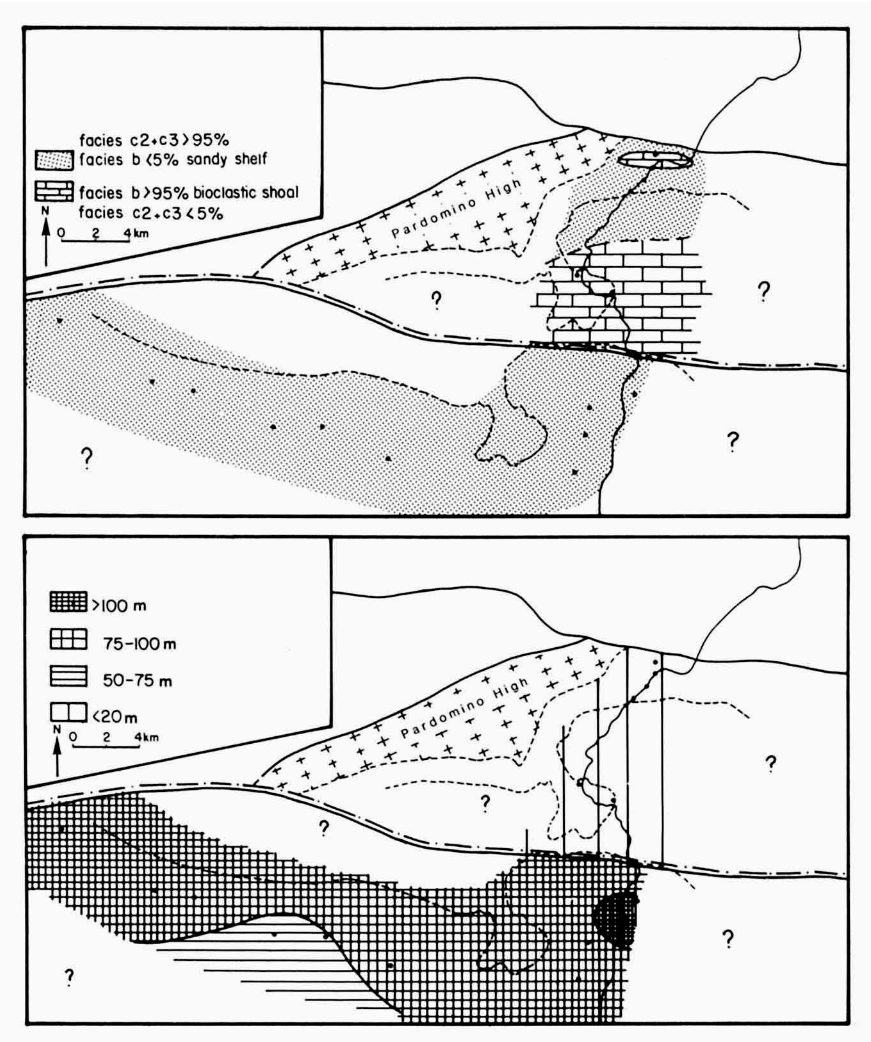


Fig. 67. Facies maps of the Ermita Formation in the Esla area based on the values of Table 10: (A) facies ratio map, (B) isopach map.

quartzites in the Somiedo area resembles the Ermita Formation in the Esla area. There also a quartzarenite succession of at least 100 m is found. In the Bernesga area the thickness does not surpass the 95 m and there most of the sediments are siltstones of facies **d**. Obviously the Bernesga area was the deepest part of the Asturo-Leonese Basin during the deposition of the Ermita Formation, while the adjacent Esla and Somiedo areas acted as stable platforms.

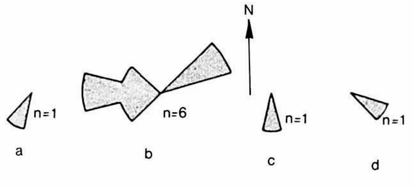


Fig. 68. Current directions measured on the large-scale cross-bedding of facies **b** and subfacies **c2** in the Ermita Formation: (A) section A, (B) section LA, (C) section V, (D) section RO.

ZONATION	SECTION	THICKNESS (m)
EXT. Z.	PP/LUM.PUENTE DE LAS PALOMAS/LUMAJO	188
INTERMEDIATE ZONE	ME/VV.MEROY/VEGA DE LOS VIEJOS	255
	C. LA CUETA	119
	POL.POLA DE SOMIEDO	104
	CIG.CIGUEDRES*	81
INTERNAL ZONE	POZ.PEÑA ORNIZ	8
	T. TORRISTIO	11

*VAN LOEVEZIJN & RAVEN, 1984

Table 11. Thickness of the deposits of the Ermita Formation in the Somiedo area.

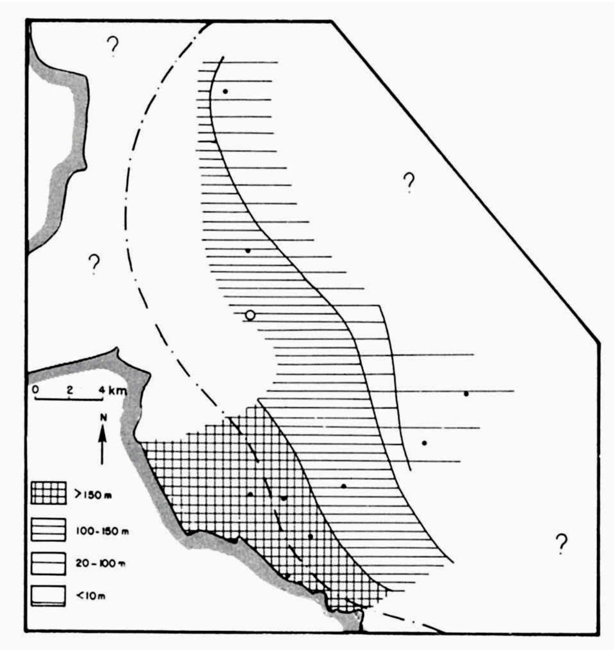


Fig. 69. Isopach pattern of the Ermita Formation in the Somiedo area.

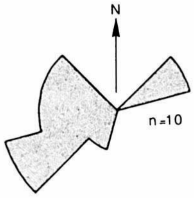


Fig. 70. Curent directions measured on the large-scale cross-bedding of subfacies **c2** in the Ermita Formation of section ME.

Synthesis

GEOLOGICAL HISTORY

About the time of the Givetian-Frasnian transition the Asturian Geanticline and probably also the adjacent Internal Zone and the Pardomino High emerged and their erosion products were deposited in the subsiding marginal seas (Nocedo Formation; Gordón Member). In the Intermediate Zone back-bar and littoral deposits occur (Fig. 71). Most of the latter deposits are coloured by ferric-oxyde pigment. As chemical analyses by van Houten (1961) pointed out, haematite is the predominant ferric oxyde in the red beds. The prevailing view holds that haematite pigment, developed in upland soils in warm moist climates with seasonally distributed rainfall, was deposited as a detrital sediment in an oxidizing environment. Thus most of the ferric oxide probably originated from soils developed on the Asturian Geanticline and adjacent positive areas and was subsequently transported into the marine environment where it accumulated in the back-bar environment and shallowest parts of the littoral environment. South of the Intra-Asturo-Leonese Facies Line near the Pardomino High a littoral environment existed where sediments were influenced by the agitation of strong currents as is demonstrated by the clean

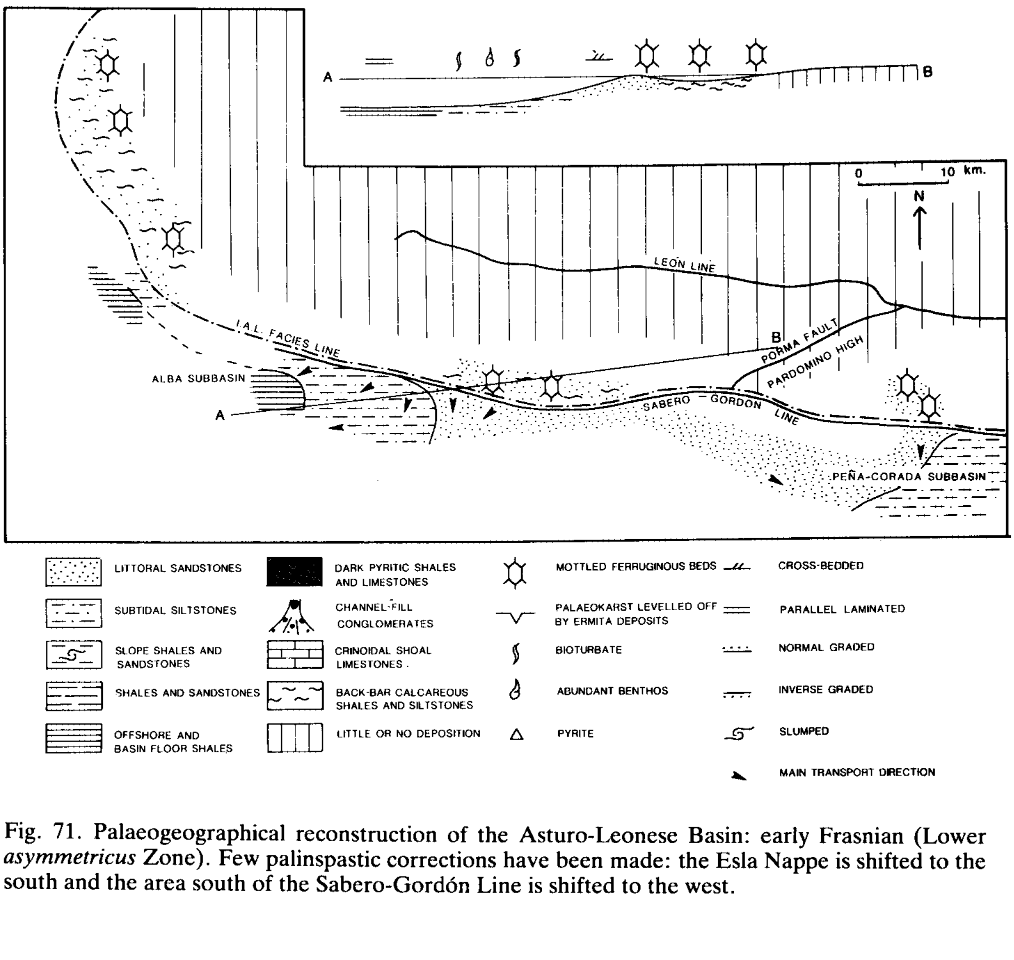


Fig. 71. Palaeogeographical reconstruction of the Asturo-Leonese Basin: early Frasnian (Lower *asymmetricus* Zone). Few palinspastic corrections have been made: the Esla Nappe is shifted to the south and the area south of the Sabero-Gordón Line is shifted to the west.

cross-bedded sandstone succession in this area. The Pardomino High divided the basin into two subbasins: an eastern Peña Corada Subbasin and a western Alba Subbasin (Evers, 1967). On both sides of the Pardomino High the depth gradually increased and the littoral environment interfingered with a subtidal one where mainly silts and silty very fine grained sands were deposited. These sediments have been intensively bioturbated and contain a rich brachiopod fauna. Only in the Alba Subbasin an offshore environment existed as is demonstrated by the laminated shales which are found in the southern parts of the Bernesga and Somiedo areas. Southeastward of the studied sediments of the Peña Corada Subbasin also an offshore environment might have existed but there no Upper Devonian outcrops are available. Because the supply of detrital material surpassed the subsidence, the coast gradually prograded southward causing a regressive sequence from offshore deposits to littoral and back-bar deposits (Alba Subbasin) or from subtidal to littoral deposits (Peña Corada Subbasin). When the detrital supply decreased, crinoidal shoals developed in the littoral environment with back-bar deposits (lime mud and calcareous shales and silts) on the lee-side of these constructional features. First these shoals developed in the outermost parts of the subbasins and with decreasing detrital supply they gradually extended towards the Pardomino High and the Asturian Geanticline.

A sudden mobilization of the blocks and subsequent supply of detrital material during the late Frasnian caused the end of the crinoidal limestone platform. The Asturian Geanticline and large parts of the Asturo-Leonese Basin emerged. Due to downwarping of the External Zone and upheaval of the Intermediate and Internal zones a pronounced topographic differentiation between these two areas developed. Sedimentation was mainly restricted to the External Zone (Nocedo Formation; Millar Member). In the Alba Subbasin a slope related to the Intra-Asturo-Leonese Facies Line existed (Fig. 72). Along this slope sediments were transported to the deeper parts of the basin by mass-gravity transport: sliding and slumping occurred on the unstable slope and large quantities of conglomerates were transported by turbulent grainflows. These sediments

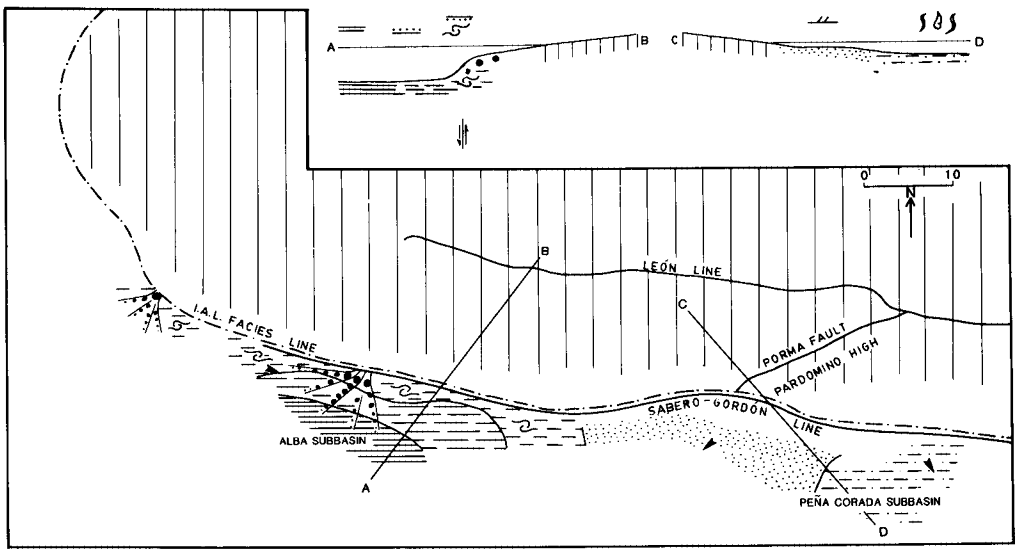


Fig. 72. Palaeogeographical reconstruction of the Asturo-Leonese Basin: late Frasnian (*gigas* to *Pa. triangularis* Zone).

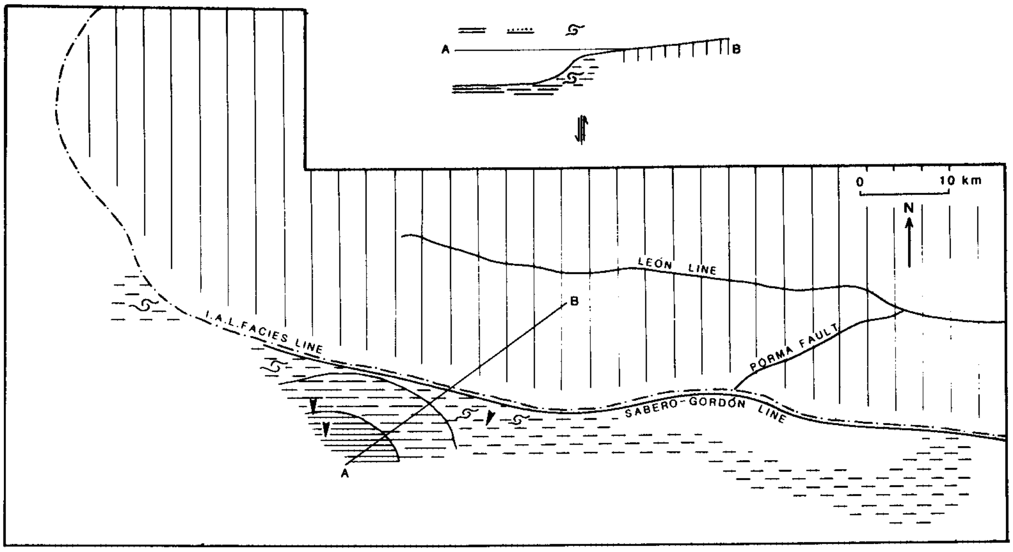


Fig. 73. Palaeogeographical reconstruction of the Asturo-Leonese Basin: early Famennian (*crepida* Zone to *marginifera* Zone).

interfinger in a southern direction with laminated shales of the outer shelf. Eastward, in the Alba Subbasin around the Pardomino High, a shallow marine littoral platform existed. In comparison with the littoral platform of the previous sequence its extension was reduced remarkably. In the Peña Corada Subbasin the sedimentation was still strongly affected by the Pardomino High, and there the sediments were deposited in a shallow marine subtidal environment with a low relief; outer shelf sediments are absent. Because of the high production of clastics in the source area the coast gradually shifted over the subtidal area of the Peña Corada Subbasin and over the proximal part of the Alba Subbasin, whereas in the distal parts of the latter subbasin the sedimentation of outer-shelf clays continued. When the siliciclastic supply decreased crinoidal shoals transgressed gradually over the shallow marine area of the Peña Corada Subbasin towards the Pardomino High, and reef organisms (stromatoporoids and corals) settled on top of these shoals or offshore bars.

With the downwarping of the External Zone during the Frasnian-Famennian transition a new sedimentary sequence started. Siliciclastic erosion products were transported to the External Zone where a depositional slope, related to the Intra-Asturo-Leonese Facies Line, caused the deposition of slumped deposits: shales with intraclasts and turbulent grain-flow deposits (Fueyo Formation; Fig. 73). The reef-building organisms disappeared completely. The Pardomino High, which was until then an important feature in the Devonian palaeogeography, vanished and the Alba and Peña Corada subbasins were united into a single basin. The bathymetrical center of the basin again was situated in the southernmost part of the Bernesga area.

In the late Famennian the sea transgressed over the largely peneplained northern part of the Asturo-Leonese Basin and the Asturian Geanticline, resulting in the deposition of the Ermita Formation. In the southernmost part of the Bernesga area a thin succession of dark shales and mudstones of the Fueyo Formation was deposited in an oxygen-depleted environment (Fig. 74). Elsewhere in the External Zone of the Bernesga area silts and very fine grained sands were deposited in a subtidal environment, whereas

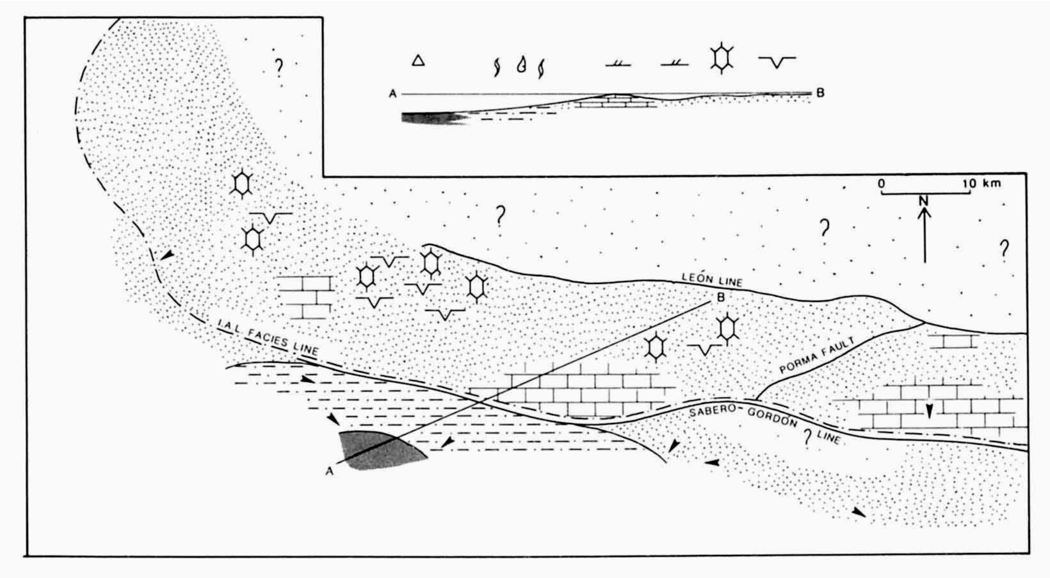


Fig. 74. Palaeogeographical reconstruction of the Asturo-Leonese Basin: late Famennian (*costatus* Zone).

in the External Zones of the adjacent Somiedo and Esla areas cross-bedded sandstones formed in a littoral environment. In the northern part of the Asturo-Leonese Basin and probably also on the Asturian Geanticline sands were deposited under the constant agitation of sorting and winnowing currents. Locally crinoidal shoals were formed in the shallow agitated water. Karst landscapes with a marked relief were levelled off by the transgressive Ermita sediments. These deposits are often red-coloured by ferric oxides. Sedimentation slightly surpassed the rate of subsidence and the littoral environment gradually shifted to the south. The regression continued and at the top of the formation fluvio-marine channel deposits cut into the littoral deposits. Especially in the Somiedo area these deposits occur frequently. When the supply of siliciclastics decreased once again a carbonate platform was formed in the Asturo-Leonese Basin.

The following conclusions may be drawn for the late Devonian to earliest Carboniferous history of sedimentation in the southern part of the Cantabrian Mountains:

Sedimentation was strongly influenced by synsedimentary block movements which caused very rapid lateral changes in facies as well as in thickness of the deposits.

The most important zone of crustal weakness was the Sabero-Gordón Fault Zone which caused the important facies differences at the Intra-Asturo-Leonese Facies Line. They divided the Asturo-Leonese shelf area into an inner area with only a thin, partly protected marine succession, which generally did not surpass a 150 m, and an outer area where an up to 730 m thick open-marine succession was deposited.

The Pardomino High, already a topographical high during the Early Devonian (Rupke, 1965; Evers, 1967), still strongly influenced the Frasnian sedimentation pattern, when it divided the Asturo-Leonese Basin into an eastern Peña Corada Subbasin and a western Alba Subbasin. In the beginning of Fammenian times it dissappeared.

During the late Devonian to earliest Carboniferous the bathymetrical center of the Asturo-Leonese Basin was always situated in the southernmost part of the Bernesga area.

Three major cycles can be recognized in the Upper Devonian to lowermost Carboniferous succession of the Asturo-Leonese Basin. Each cycle is made up of a regressive siliciclastic coarsening-upward sequence of shale, siltstone and sandstone and a transgressive limestone sequence. Raven (1983) and van Loevezijn & Raven (1983) explained the cyclicity as follows. Uplift of the Asturian Geanticline and adjacent areas led to an increase of the siliciclastic supply and progradation of the coast in the marginal seas, causing a regressive coarsening upwards sequence. Gradually the erosion peneplained the hinterland, the extension of the marginal sea increased at the cost of the source area, the clastic supply decreased and the carbonate sedimentation could commence. Each new uplift started a new cycle. The cycles are beautifully demonstrated in the northern part of the External Zone. North of the Intra-Asturo-Leonese Facies Line, where uplift persisted, erosion surfaces are prominent and the cycles are incomplete (Intermediate Zone) or absent (Internal Zone) due to non-deposition and erosion. On the outer edges of the External Zone, where subsidence continued, the water was sometimes too deep for the effect of epeirogenetic block movements and/or eustatic sea-level fluctuations to be reflected in the sedimentary record.

EPEIROGENETIC MOVEMENTS AND THE FRASNIAN BOUNDARIES

During the Early Devonian, marine carbonates developed mainly over extensive shallow stable platforms (La Vid and Santa Lucía limestones). These deposits have a biostromal aspect; no large build-ups are known. During late Eifelian and early Givetian times shallow siliciclastic sedimentation dominated the Asturo-Leonese Basin but as soon as the clastic supply decreased carbonates extended again over the shelf area. At that time epeirogenetic movements had become an important factor; large coral-stromatoporoid bioherms developed in a narrow zone of fault activity close to the Sabero-Gordón line (Reijers, 1980). Minor pulses of clastic supply interrupted the carbonate sedimentation several times (van Loevezijn & Raven, 1984), but the reef-building organisms re-established themselves rapidly. An important break in the carbonate sedimentation coincides with the Givetian-Frasnian boundary when block movements increased. At this time large quantities of detrital material caused the death of most reef organisms. When the supply of siliciclastics decreased, reef growth could commence again in the shallow marine area of the Asturo-Leonese Basin albeit that the area of carbonate deposition was smaller than during the late Givetian: locally stromatoporoids occurred and only in a small area at Perlora and Playa de Carranques (Asturias) a compound coral biostrome occurred. Increased block movements in the late Frasnian created a small unstable basin with a southward sloping bottom on the margin of an extensive land area in the north. Only in the Esla area a large platform still existed until sudden mobilization of the blocks near the transition of Frasnian to Famennian times caused the extension of the basin over the Esla area. Most of the animals living on the subtidal sand or mud bottom or on the reefs disappeared. They were probably more sensitive to sudden changes in sea level and/or siliciclastic supply. From the above the following conclusions may be drawn for the Devonian development in the southern Cantabrian Mountains:

In the course of the Devonian an increase in crust instabillity can be demonstrated which culminated during the late Frasnian and earliest Famennian (compare Reijers, 1985; Fig. 2).

Due to the increase of epeirogenetic movements the extensive shallow marine shelf gradually decreased in area in the course of the Devonian up to the late Famennian transgression (compare Julivert, 1981; Fig. 5b).

The Givetian-Frasnian boundary and even more so the Frasnian-Famennian boundary coincide with sudden mobilisations of the crust which caused drastic environmental changes.

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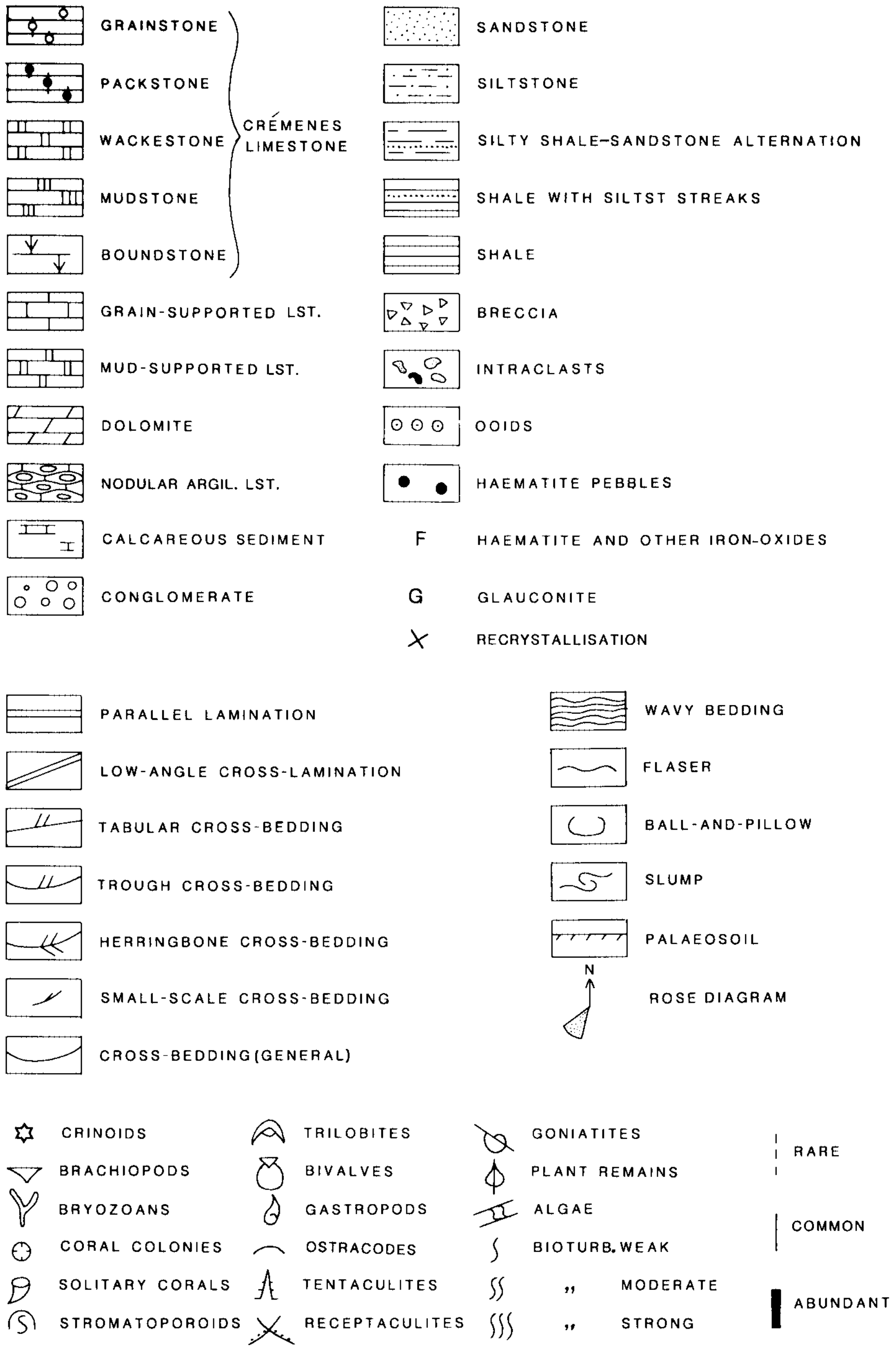
Revised manuscript received 25 November 1985.

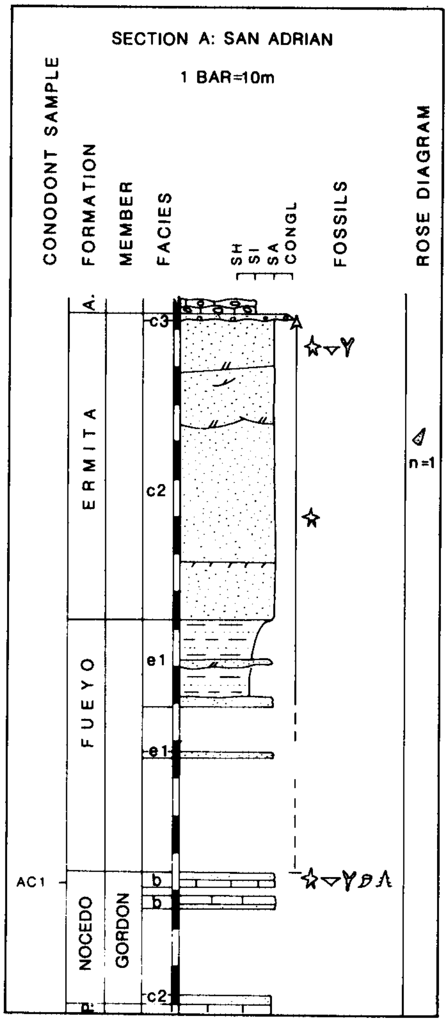
Appendix: stratigraphic sections and conodont distribution charts

The sections are given in alphabetic order, according to the abbreviations used in the text (see Fig. 6 and Table 1); the Crémenes Limestone sections are all given under the C of Crémenes.

Other abbreviations used are: formations: S.L. = Santa Lucía, H. = Huergas, P. Portilla, N. = Nocedo, FU. = Fueyo, E(RM). = Ermita, V. = Vegamián, A. = Alba, C.M. = Caliza de Montaña; member: G. = Gordón; SH = shale, SI = siltstone, SA = sandstone, CONGL = conglomerate; C.U. = coarsening upwards.

LEGEND


GRAINSTONE
PACKSTONE
WACKESTONE
MUDSTONE
BOUNDSTONE
CRÉMENES LIMESTONE
GRAIN-SUPPORTED LST.
MUD-SUPPORTED LST.
DOLOMITE
NODULAR ARGIL. LST.
CALCAREOUS SEDIMENT
CONGLOMERATE
SANDSTONE
SILTSTONE
SILTY SHALE–SANDSTONE ALTERNATION
SHALE WITH SILTST STREAKS
SHALE
BRECCIA
INTRACLASTS
OOIDS
HAEMATITE PEBBLES
F HAEMATITE AND OTHER IRON-OXIDES
G GLAUCONITE
RECRYSTALLISATION
PARALLEL LAMINATION
LOW-ANGLE CROSS-LAMINATION
TABULAR CROSS-BEDDING
TROUGH CROSS-BEDDING
HERRINGBONE CROSS-BEDDING
SMALL-SCALE CROSS-BEDDING
CROSS-BEDDING (GENERAL)
WAVY BEDDING
FLASER
BALL-AND-PILLOW
SLUMP
PALAEOSOIL
N
ROSE DIAGRAM
CRINOIDS
BRACHIOPODS
BRYOZOANS
CORAL COLONIES
SOLITARY CORALS
STROMATOPOROIDS
TRILOBITES
BIVALVES
GASTROPODS
OSTRACODES
TENTACULITES
RECEPTACULITES
GONIATITES
PLANT REMAINS
ALGAE
BIOTURB. WEAK
" MODERATE
" STRONG
RARE
COMMON
ABUNDANT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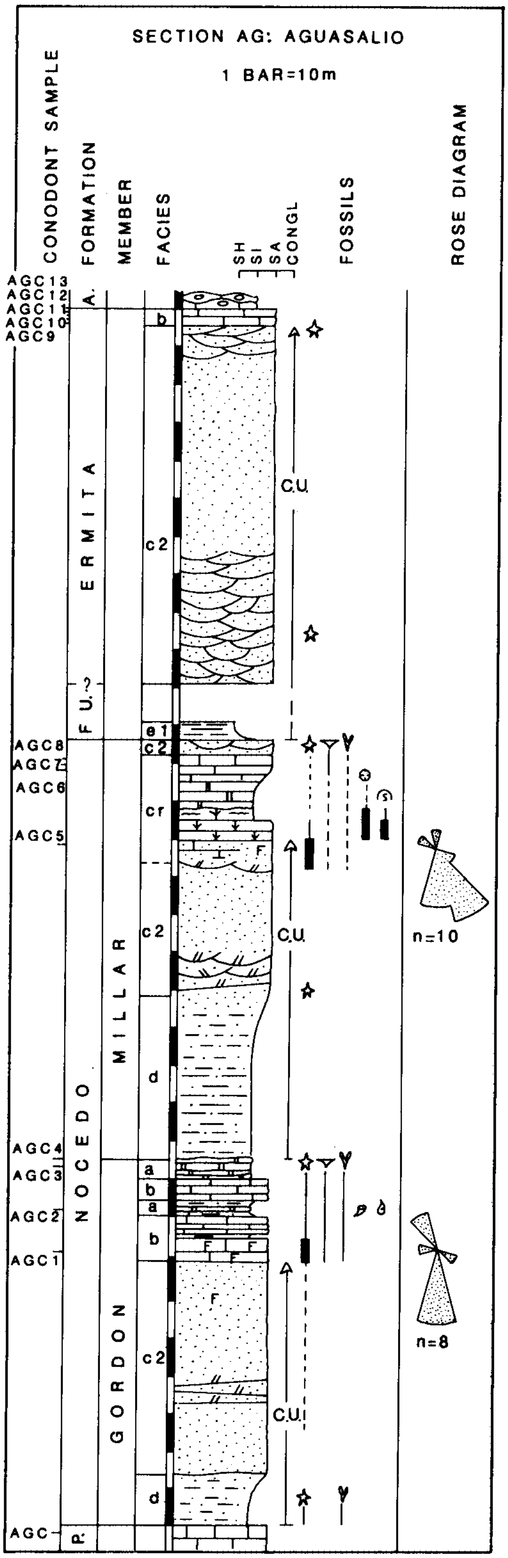
1 BAR=10m
CONODONT SAMPLE
FORMATION
MEMBER
FACIES
SH SI SA CONGL
FOSSILS
ROSE DIAGRAM
A.
ERMITA
FUEYO
NOCEDO
GORDON
c3
c2
e1
e1
b
b
c2
AC1
n=1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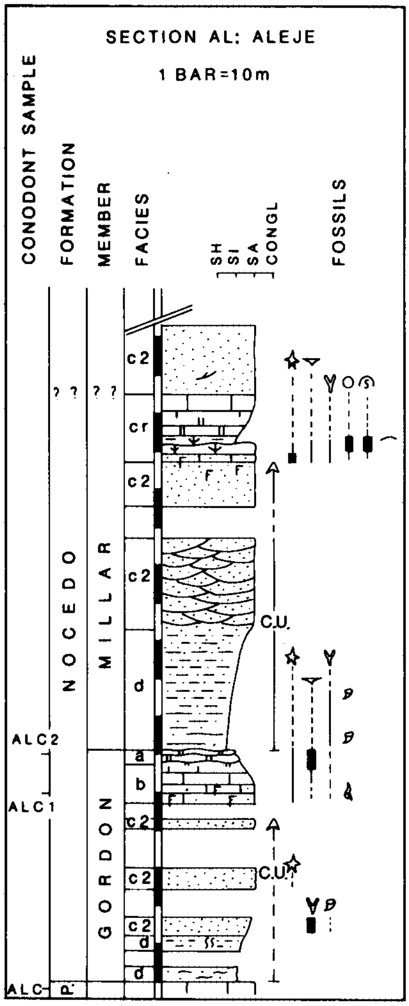
1 BAR=10m
CONODONT SAMPLE
FORMATION
MEMBER
FACIES
SH SI SA CONGL
FOSSILS
ROSE DIAGRAM
AGC13
AGC12
AGC11
AGC10
AGC9
AGC8
AGC7
AGC6
AGC5
AGC4
AGC3
AGC2
AGC1
AGC
A.
ERMITA
FU.?
NOCEDO
MILLAR
GORDON
b
c2
e1
c2
cr
c2
d
a
b
a
b
c2
d
C.U.
C.U.
C.U.
n=10
n=8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1 BAR=10m
CONODONT SAMPLE
FORMATION
MEMBER
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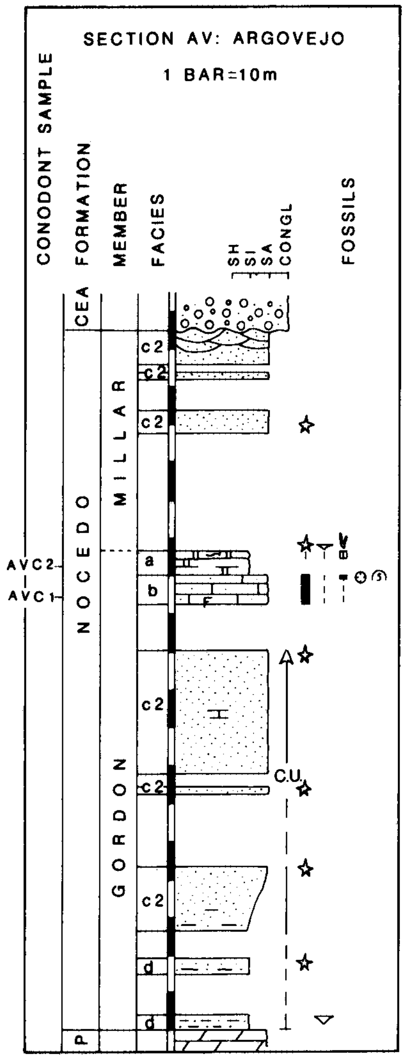
CONGL
FOSSILS
NOCEDO
MILLAR
GORDON
ALC2
ALC1
ALC
C.U.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CONODONT SAMPLE
FORMATION
MEMBER
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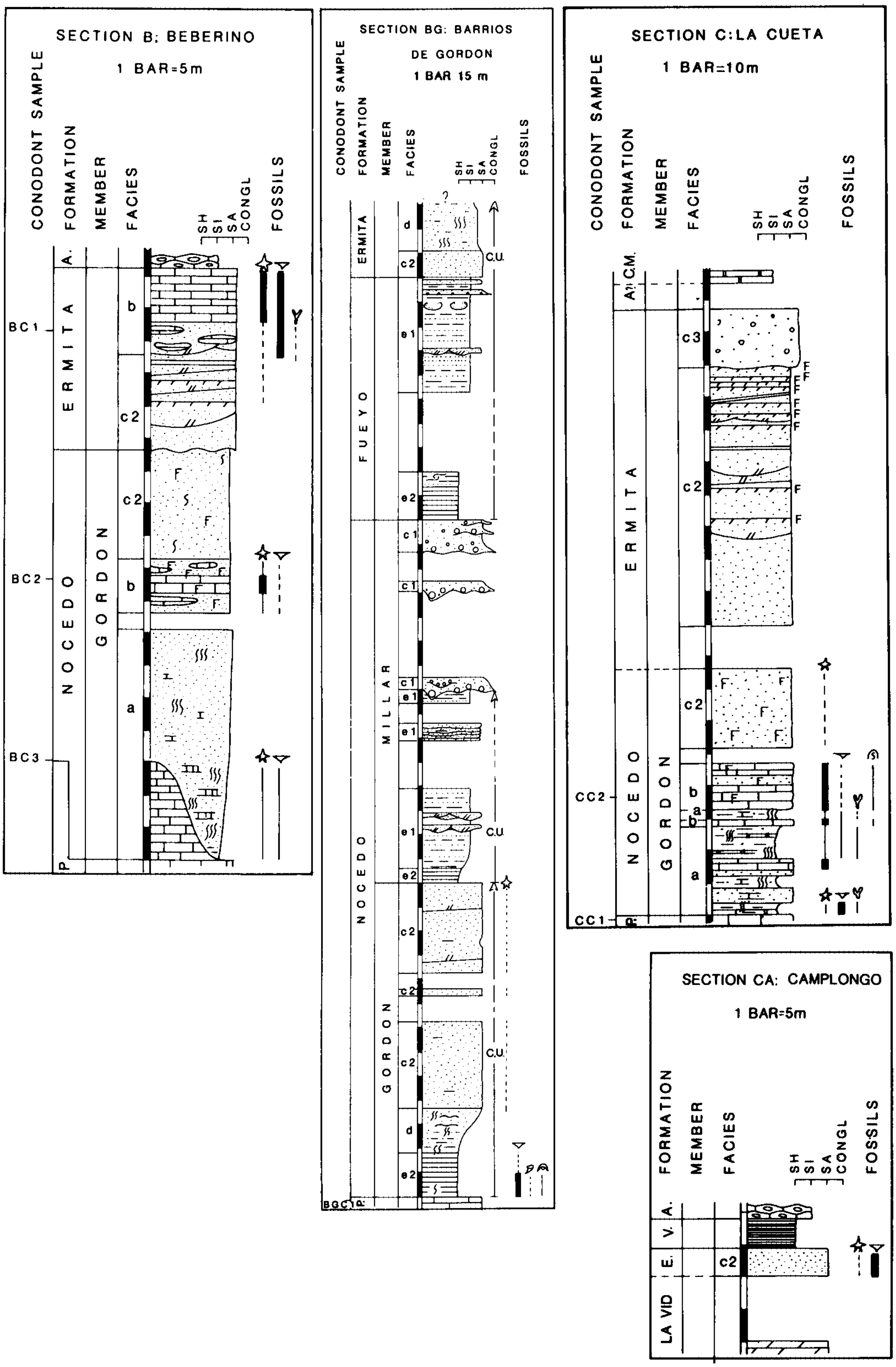
NOCEDO
MILLAR
GORDON
AVC2
AVC1
C.U.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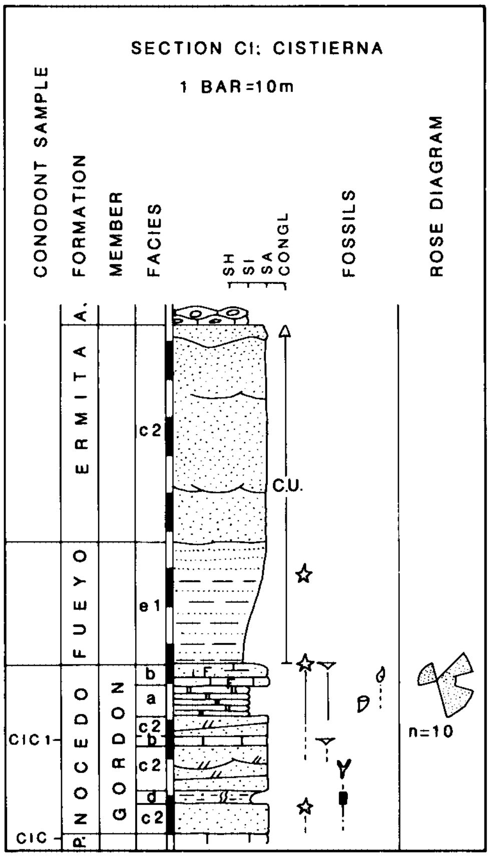
CONODONT SAMPLE
FORMATION
MEMBER
FACIES
SH SI SA CONGL
FOSSILS
ERMITA
NOCEDO
GORDON
BC1
BC2
BC3
SECTION BG: BARRIOS DE GORDON
1 BAR 15 m
ERMITA
FUEYO
MILLAR
NOCEDO
GORDON
C.U.
SECTION C: LA CUETA
1 BAR=10m
ERMITA
NOCEDO
GORDON
CC1
CC2
SECTION CA: CAMPLONGO
1 BAR=5m
LA VID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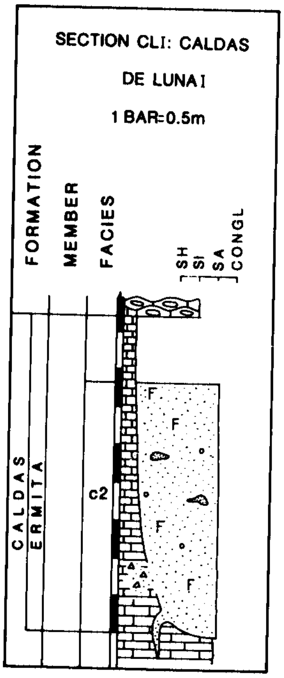
FORMATION
MEMBER
FACIES
SH
SI
SA
CONGL
FOSSILS
ROSE DIAGRAM
ERMITA
A.
FUEYO
NOCEDO
GORDON
c2
e1
b
a
c2
b
c2
d
c2
C.U.
CIC 1
CIC
n=10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DE LUNA I
1 BAR=0.5m
FORMATION
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SI
SA
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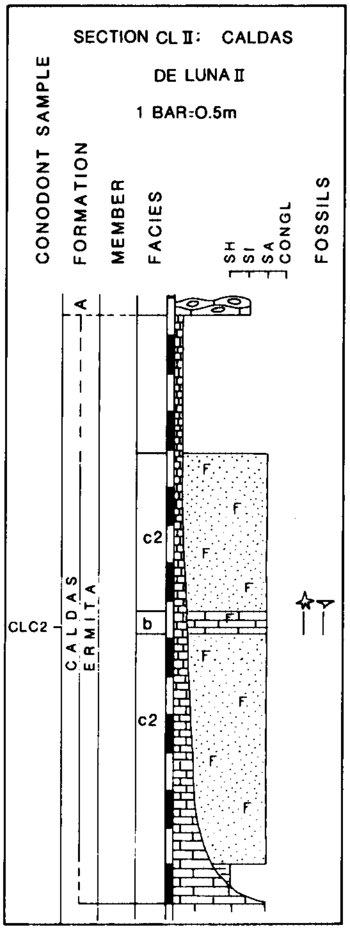
CALDAS
ERMITA
c2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DE LUNA II
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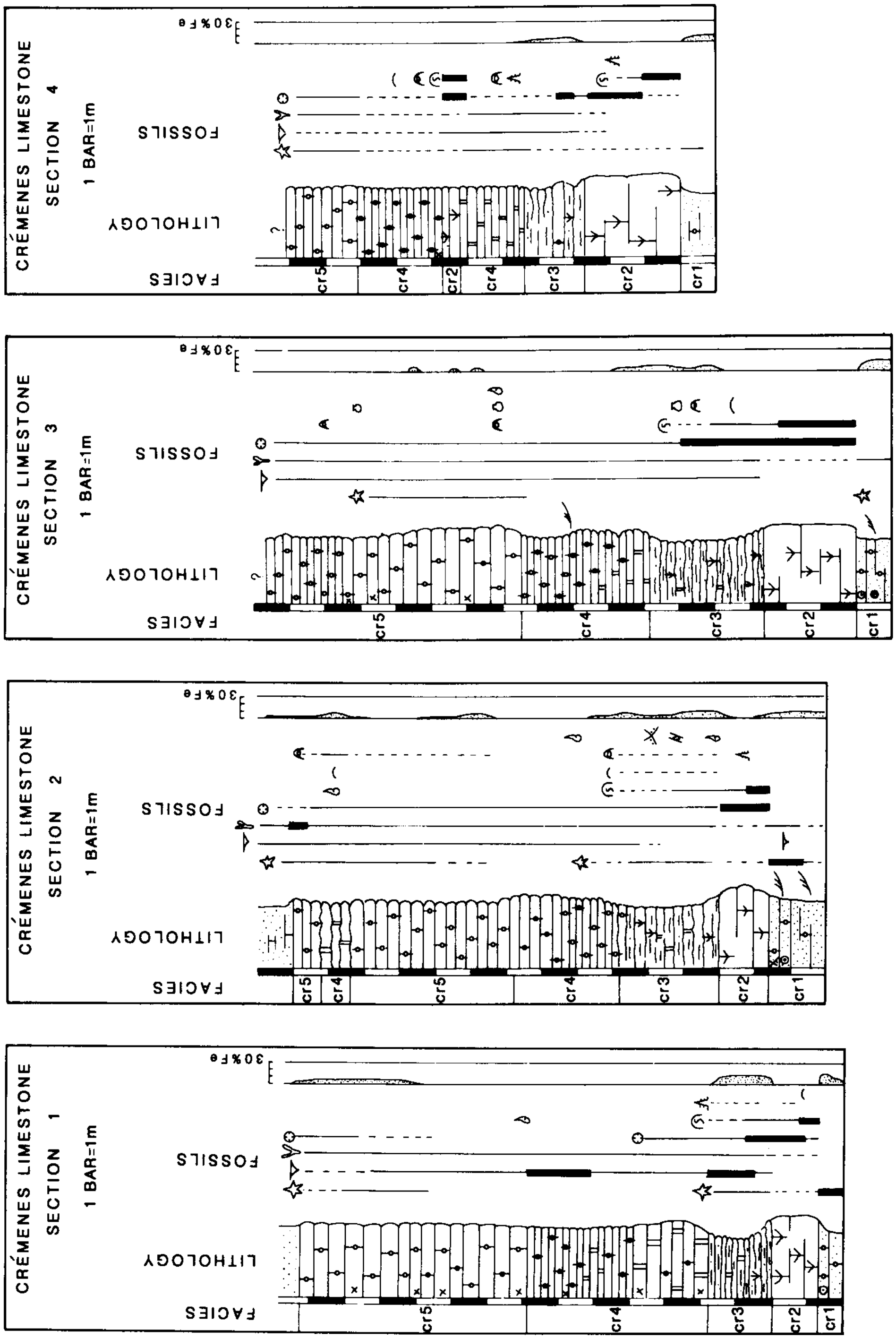
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SECTION 4
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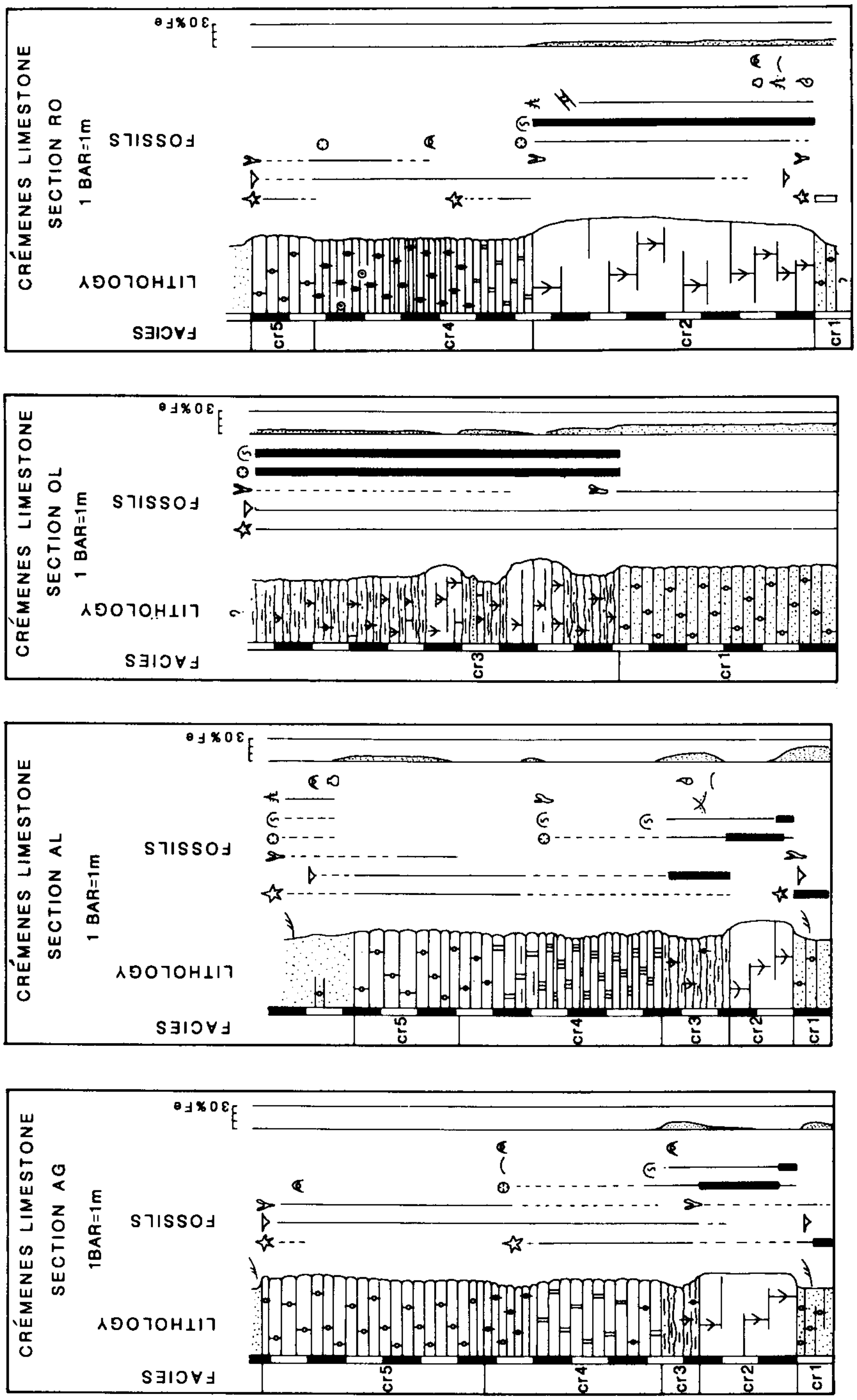
CRÉMENES LIMESTONE
SECTION 3
1 BAR=1m
CRÉMENES LIMESTONE
SECTION 2
1 BAR=1m
CRÉMENES LIMESTONE
SECTION 1
1 BAR=1m
30%Fe
FOSSILS
LITHOLOGY
FACIES
cr1
cr2
cr3
cr4
cr5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30%Fe
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SECTION OL
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30%Fe
FOSSILS
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cr3
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CRÉMENES LIMESTONE
SECTION AL
1 BAR=1m
30%Fe
FOSSILS
LITHOLOGY
FACIES
cr5
cr4
cr3
cr2
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CRÉMENES LIMESTONE
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FACIES
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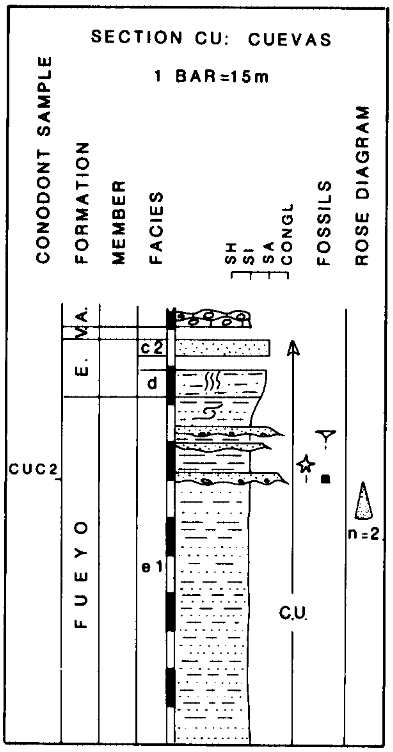
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CUC2
C.U.
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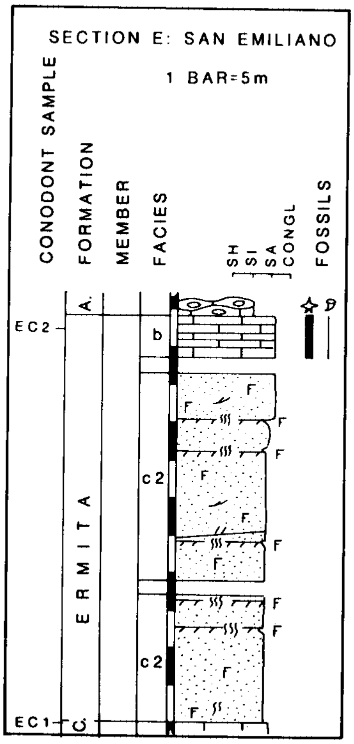
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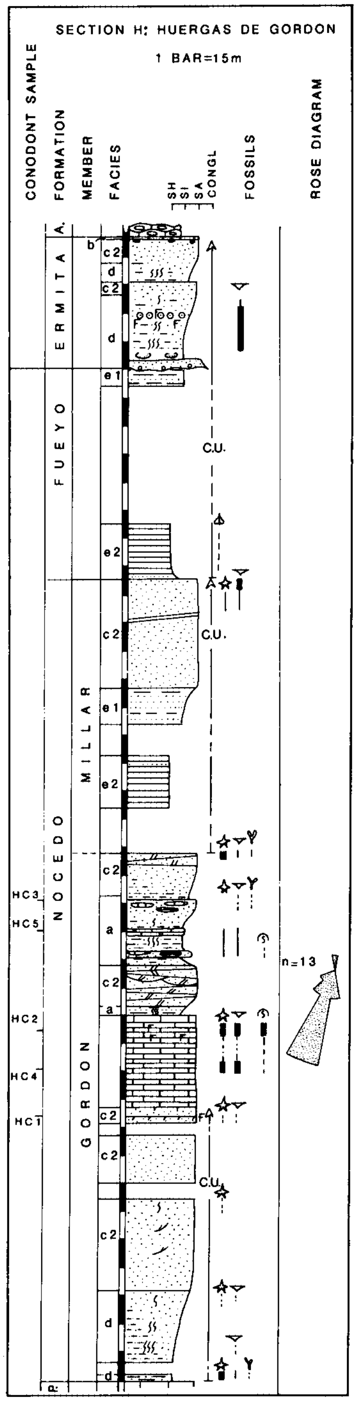
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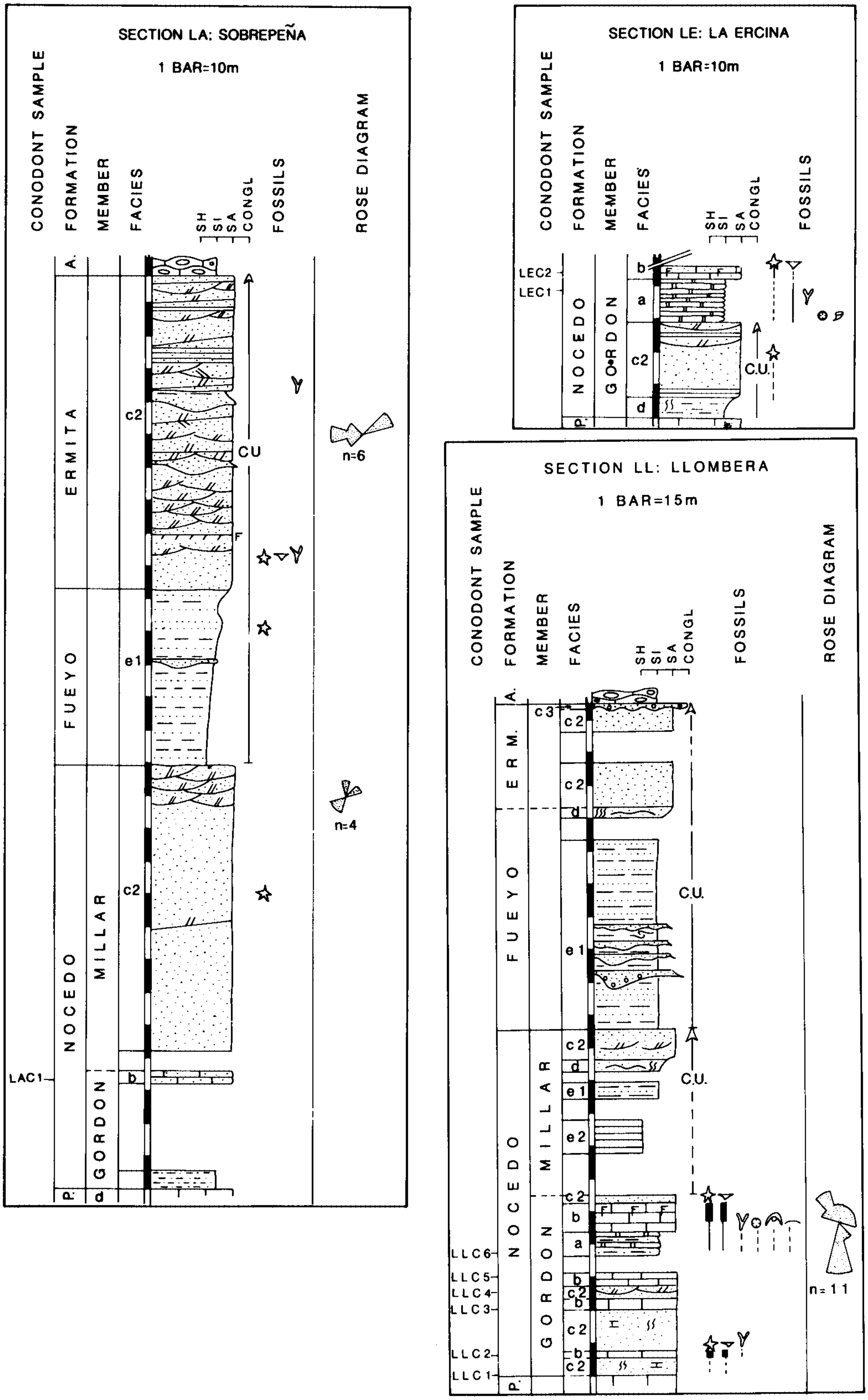
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FUEYO
NOCEDO
MILLAR
GORDON
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SECTION LE: LA ERCINA
1 BAR=10m
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SECTION LL: LLOMBERA
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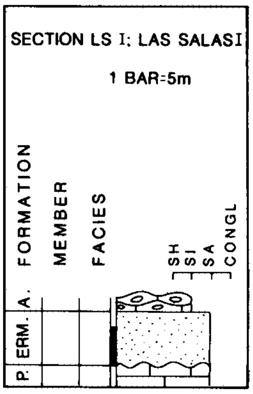
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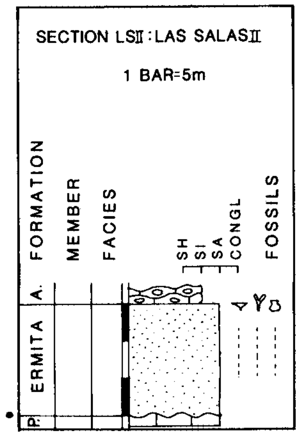
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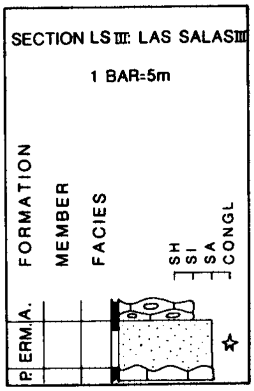
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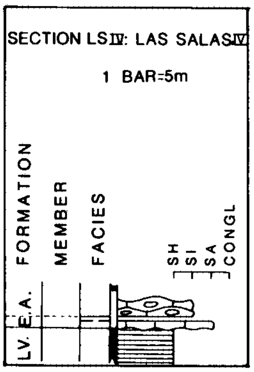
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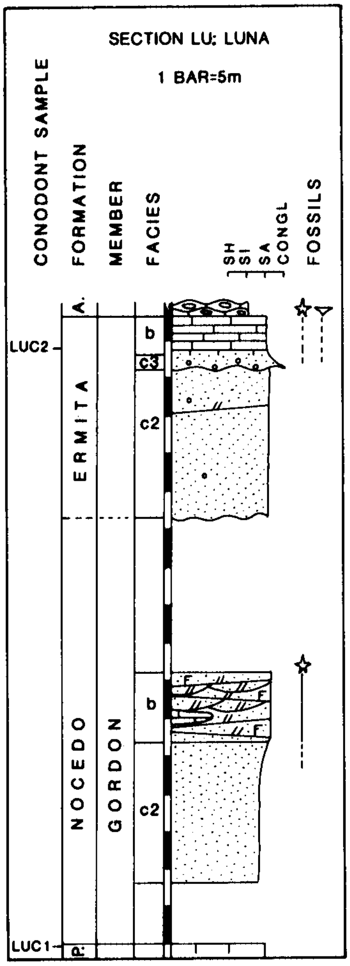
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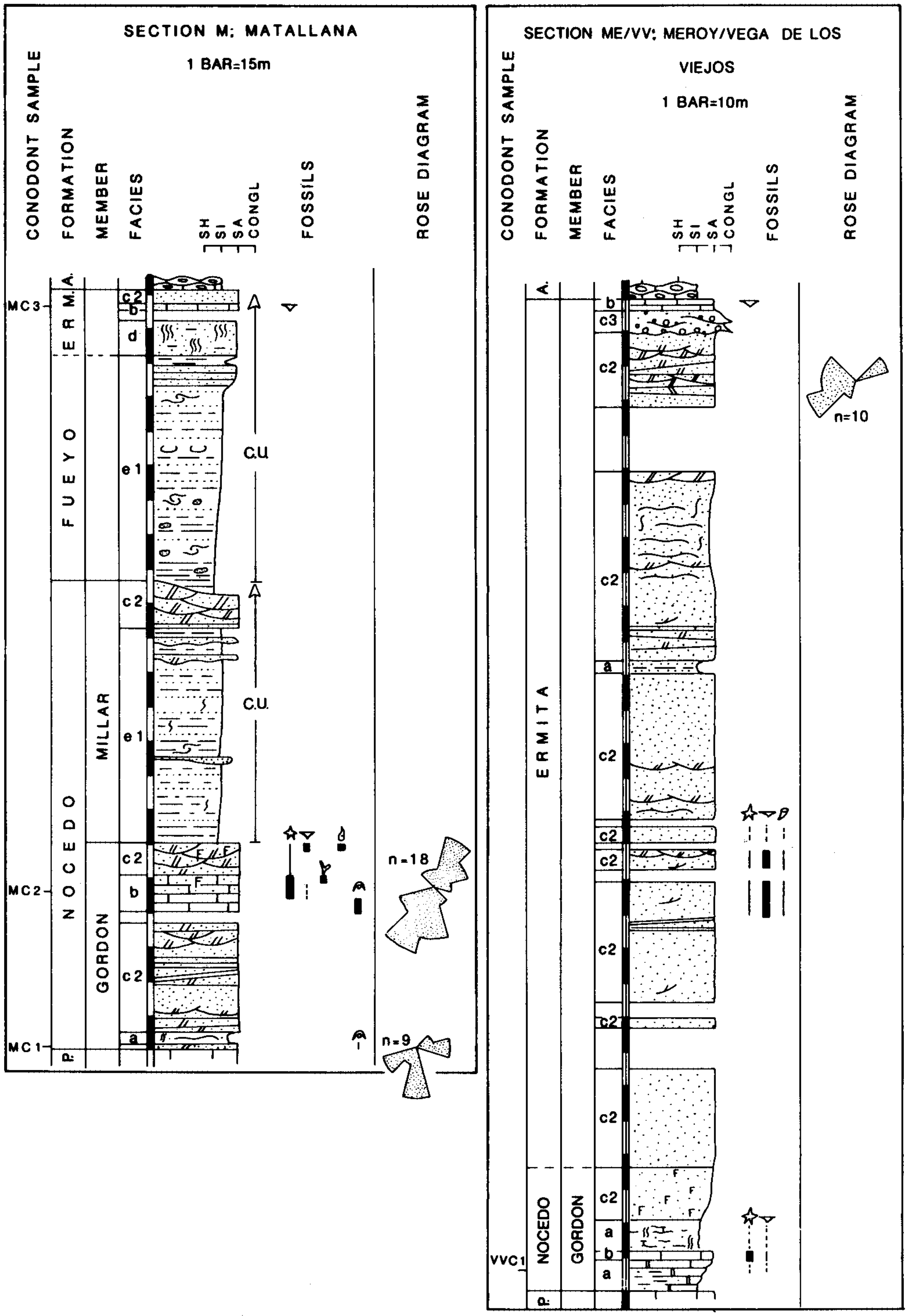
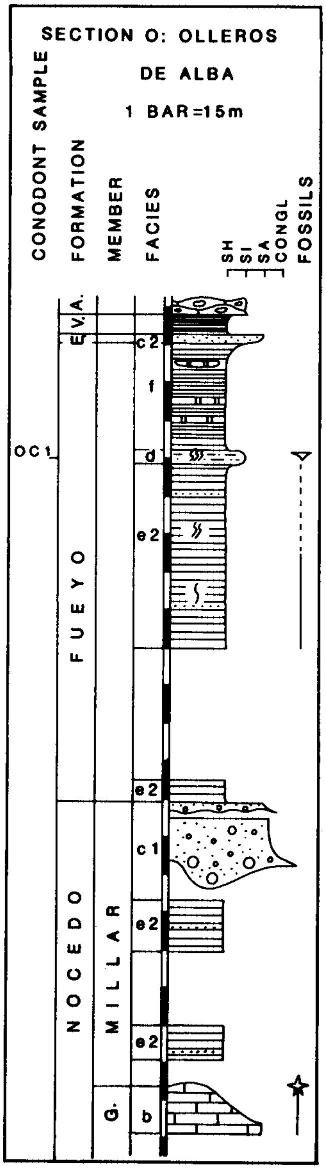
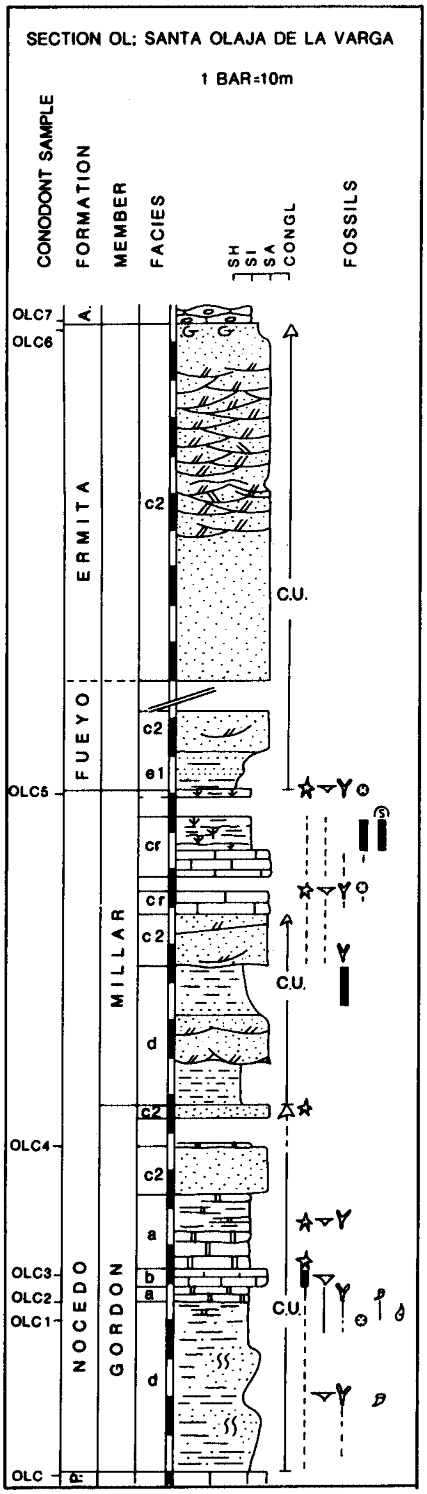
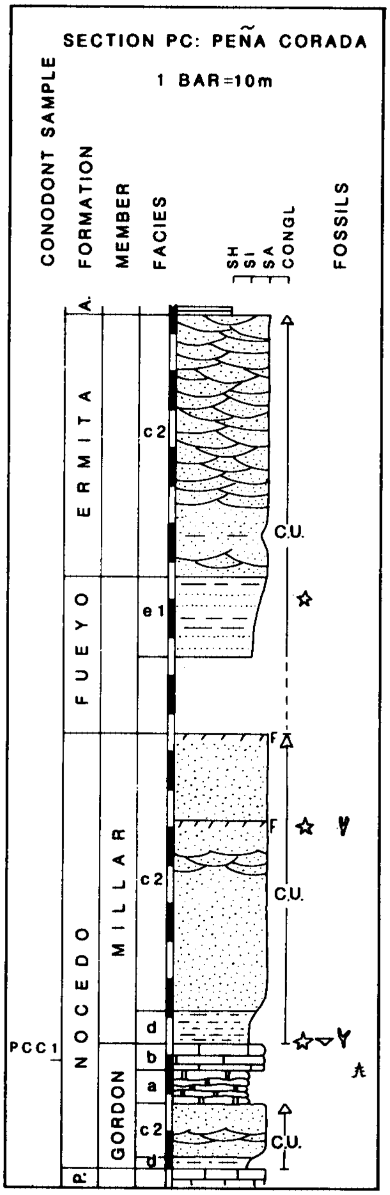
FOSSILS
A.
LUC2
b
c3
c2
ERMITA
b
c2
NOCEDO
GORDON
LUC1
P.

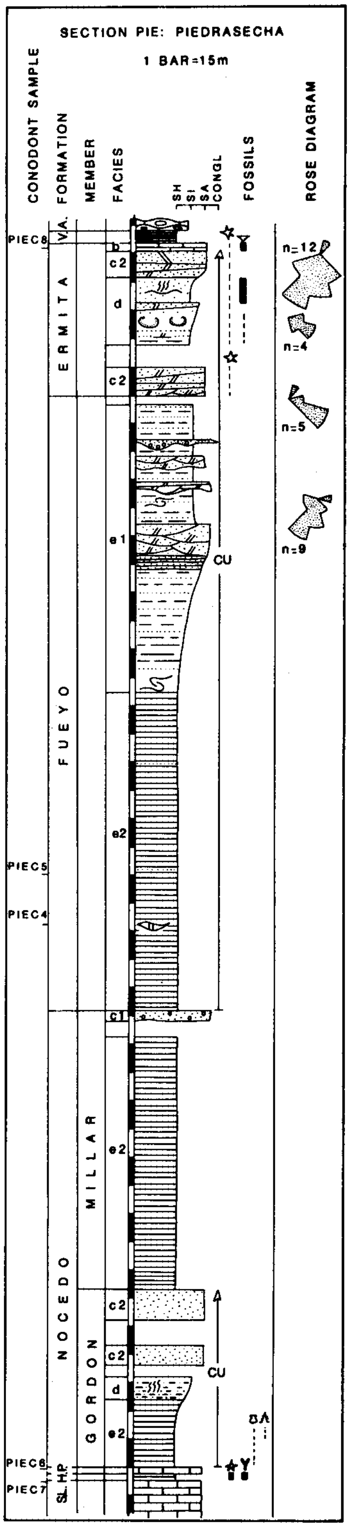

SECTION M: MATALLANA
1 BAR=15m
CONODONT SAMPLE
FORMATION
MEMBER
FACIES
SH
SI
SA
CONGL
FOSSILS
ROSE DIAGRAM
MC3
MC2
MC1
E R M.A.
F U E Y O
N O C E D O
P.
MILLAR
GORDON
C.U.
n=18
n=9
SECTION ME/VV: MEROY/VEGA DE LOS VIEJOS
1 BAR=10m
CONODONT SAMPLE
FORMATION
MEMBER
FACIES
SH
SI
SA
CONGL
FOSSILS
ROSE DIAGRAM
VVC1
A.
E R M I T A
NOCEDO
GORDON
P.
n=10


SECTION O: OLLEROS DE ALBA
1 BAR=15m
CONODONT SAMPLE
FORMATION
MEMBER
FACIES
SH SI SA CONGL
FOSSILS
OC1
FUEYO
NOCEDO
MILLAR
E.V.A.
G.
c2
f
d
e2
c1
b

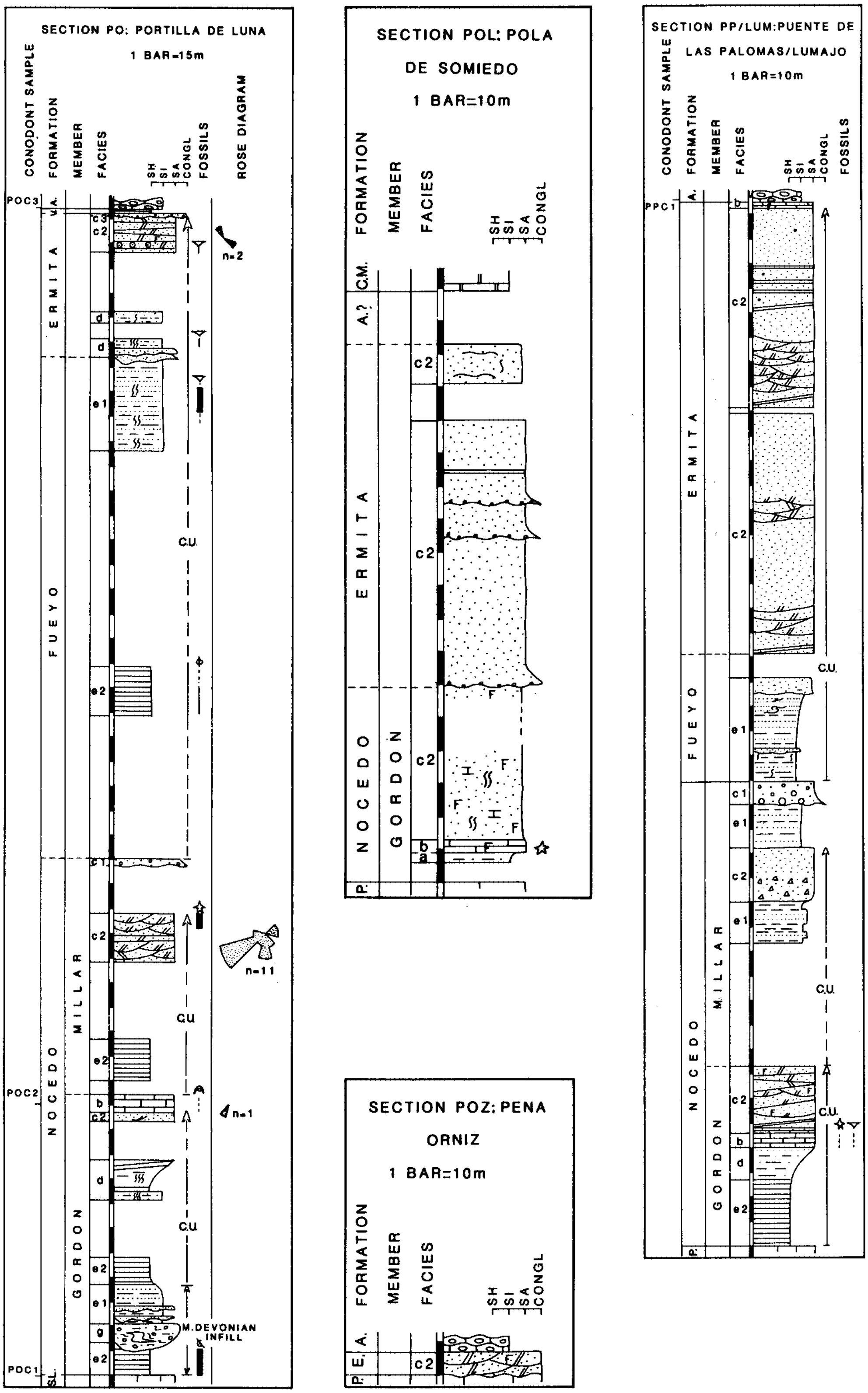

SECTION OL: SANTA OLAJA DE LA VARGA
1 BAR=10m
CONODONT SAMPLE
FORMATION
MEMBER
FACIES
SH SI SA CONGL
FOSSILS
OLC7
OLC6
OLC5
OLC4
OLC3
OLC2
OLC1
OLC
ERMITA
FUEYO
NOCEDO
MILLAR
GORDON
A.
c2
e1
cr
d
a
b
C.U.

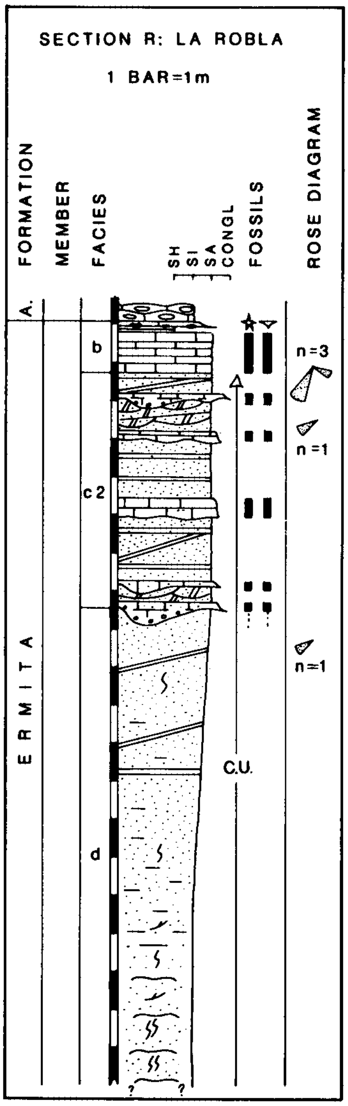


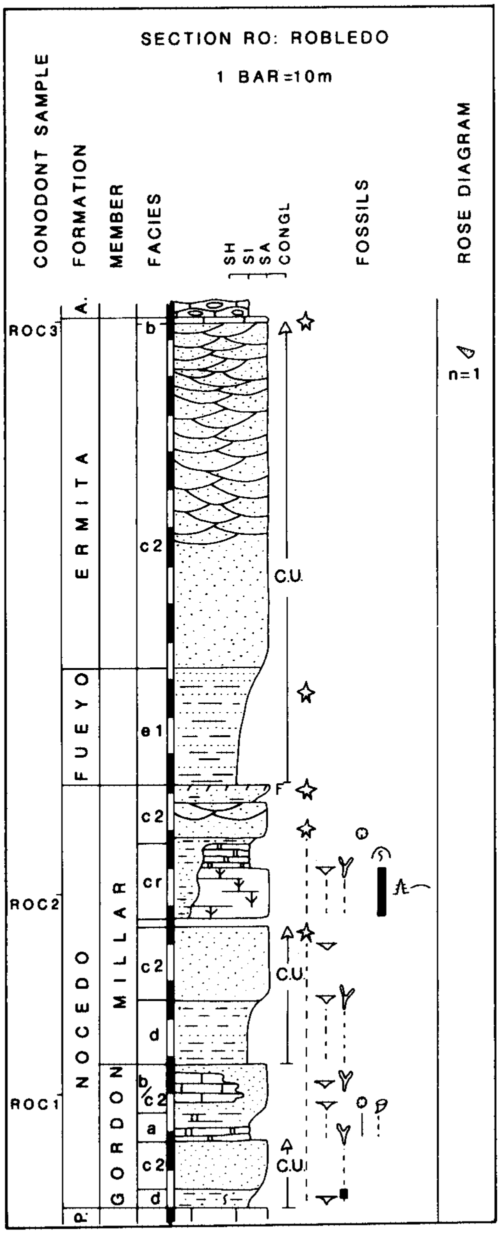
SECTION PC: PEÑA CORADA
1 BAR=10m
CONODONT SAMPLE
FORMATION
MEMBER
FACIES
SH
SI
SA
CONGL
FOSSILS
C.U.
PCC1

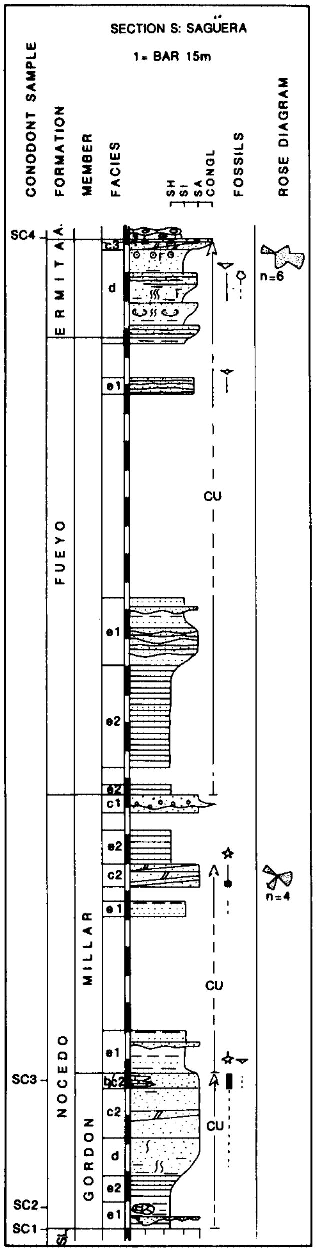


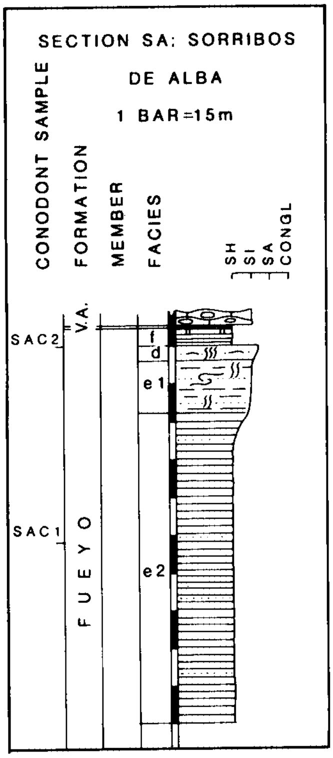
SECTION PIE: PIEDRASECHA
1 BAR=15m
CONODONT SAMPLE
FORMATION
MEMBER
FACIES
SH
SI
SA
CONGL
FOSSILS
ROSE DIAGRAM
CU
n=12
n=4
n=5
n=9

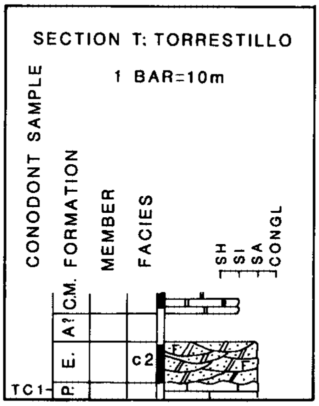

SECTION PO: PORTILLA DE LUNA
1 BAR=15m
CONODONT SAMPLE
FORMATION
MEMBER
FACIES
SH SI SA CONGL
FOSSILS
ROSE DIAGRAM
POC3
POC2
POC1
ERMITA
FUEYO
MILLAR
NOCEDO
GORDON
n=2
n=11
n=1
C.U.
M.DEVONIAN INFILL
SECTION POL: POLA DE SOMIEDO
1 BAR=10m
C.M.
A.?
ERMITA
NOCEDO
GORDON
SECTION PP/LUM: PUENTE DE LAS PALOMAS/LUMAJO
1 BAR=10m
PPC1
SECTION POZ: PENA ORNIZ
1 BAR=10m
P.
E. A.

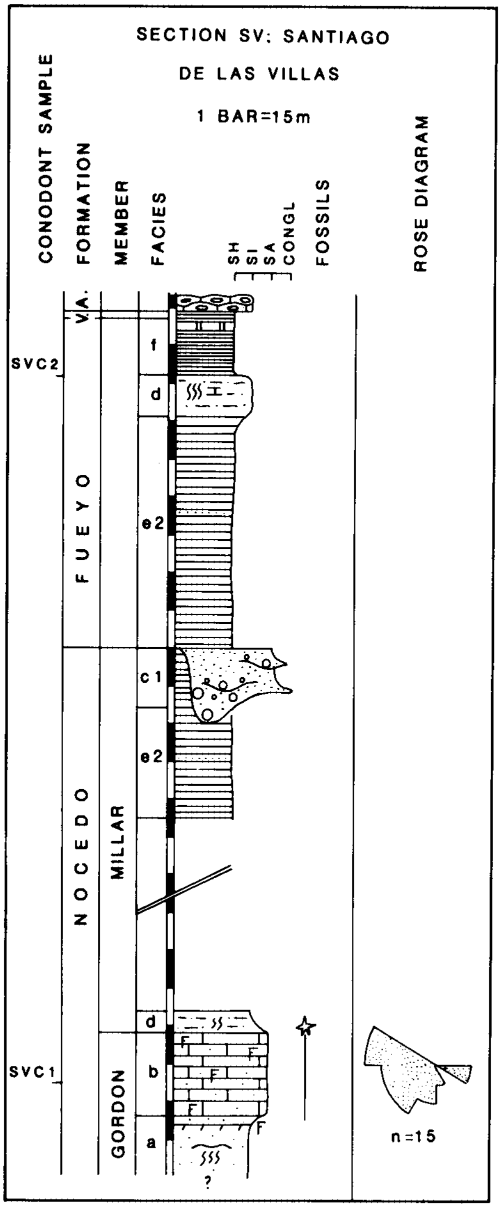

SECTION R: LA ROBLA
1 BAR=1m
FORMATION
MEMBER
FACIES
SH
SI
SA
CONGL
FOSSILS
ROSE DIAGRAM
A.
ERMITA
b
c2
d
n=3
n=1
n=1
C.U.

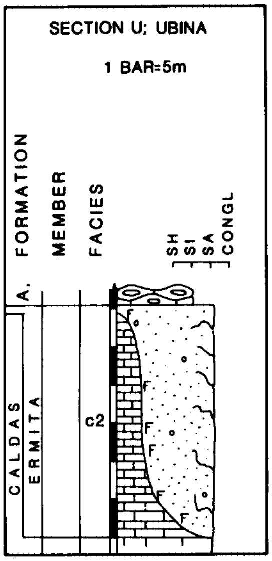

SECTION RO: ROBLEDO
1 BAR=10m
CONODONT SAMPLE
FORMATION
MEMBER
FACIES
SH
SI
SA
CONGL
FOSSILS
ROSE DIAGRAM
ROC3
ROC2
ROC1
A.
ERMITA
FUEYO
NOCEDO
MILLAR
GORDON
P.
b
c2
e1
c2
cr
c2
d
b
c2
a
c2
d
C.U.
F
C.U.
C.U.
n=1

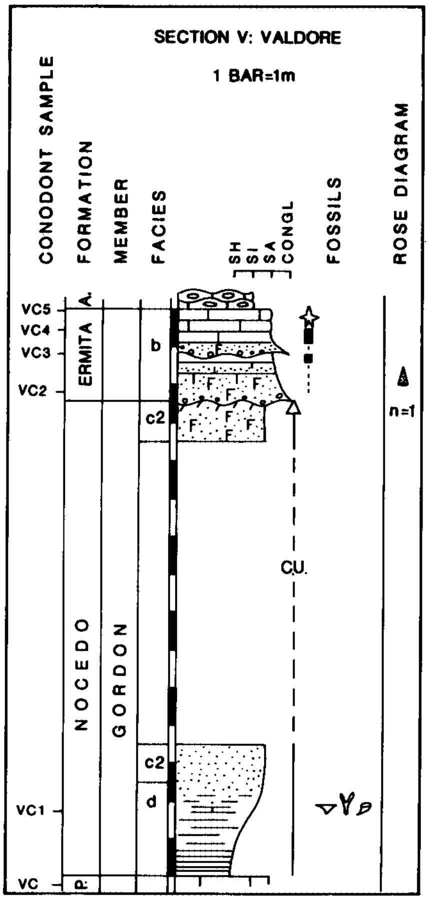

SECTION S: SAGÜERA
1 = BAR 15m
CONODONT SAMPLE
FORMATION
MEMBER
FACIES
SH
SI
SA
CONGL
FOSSILS
ROSE DIAGRAM
SC4
SC3
SC2
SC1
E R M I T A
A.
F U E Y O
N O C E D O
M I L L A R
G O R D O N
c3
d
e1
e2
c1
c2
bc2
CU
n=6
n=4

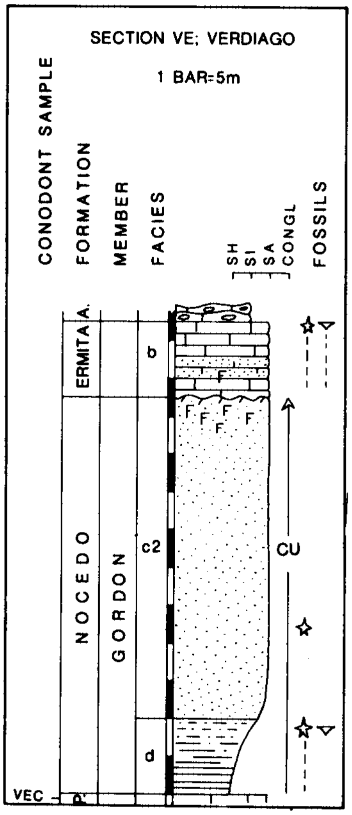

SECTION SA: SORRIBOS DE ALBA
1 BAR=15m
CONODONT SAMPLE
FORMATION
MEMBER
FACIES
SH
SI
SA
CONGL
SAC2
SAC1
V.A.
F U E Y O
f
d
e1
e2

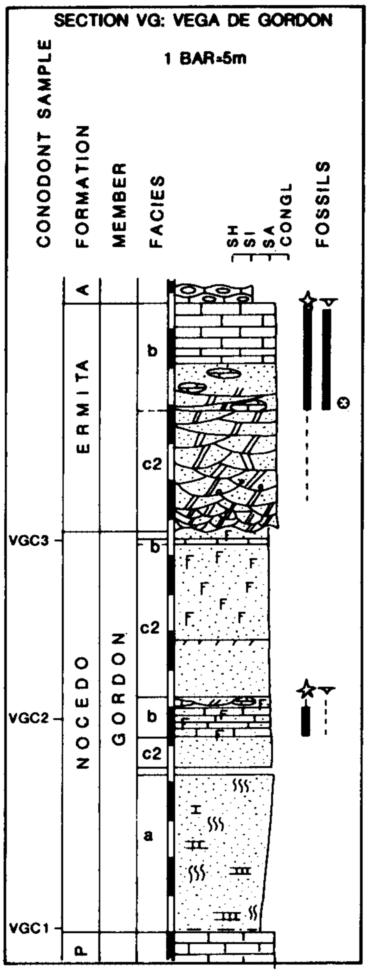

SECTION T: TORRESTILLO
1 BAR=10m
CONODONT SAMPLE
FORMATION
MEMBER
FACIES
SH
SI
SA
CONGL
C.M.
A?
E.
P.
c2
TC1


SECTION SV: SANTIAGO DE LAS VILLAS
1 BAR=15m
CONODONT SAMPLE
FORMATION
MEMBER
FACIES
SH
SI
SA
CONGL
FOSSILS
ROSE DIAGRAM
SVC2
SVC1
V.A.
FUEYO
NOCEDO
MILLAR
GORDON
f
d
e2
c1
e2
d
b
a
n=15


SECTION U: UBINA
1 BAR=5m
FORMATION
MEMBER
FACIES
SH
SI
SA
CONGL
A.
CALDAS
ERMITA
c2


SECTION V: VALDORE
1 BAR=1m
CONODONT SAMPLE
FORMATION
MEMBER
FACIES
SH
SI
SA
CONGL
FOSSILS
ROSE DIAGRAM
VC5
VC4
VC3
VC2
VC1
VC
A.
ERMITA
NOCEDO
GORDON
b
c2
c2
d
n=1
C.U.


SECTION VE; VERDIAGO
1 BAR=5m
CONODONT SAMPLE
FORMATION
MEMBER
FACIES
SH
SI
SA
CONGL
FOSSILS
ERMITA A.
NOCEDO
GORDON
b
c2
d
CU
VEC
P


SECTION VG: VEGA DE GORDON
1 BAR=5m
CONODONT SAMPLE
FORMATION
MEMBER
FACIES
SH
SI
SA
CONGL
FOSSILS
A
ERMITA
NOCEDO
GORDON
b
c2
b
c2
b
c2
a
VGC3
VGC2
VGC1
P

SPECIES / SAMPLE	*Gnathodus* sp.	,, *typicus*	,, *pseudosemiglaber*	,, *symmutatus*	,, *semiglaber*	,, *homopunctatus*	*Pseudopolygnathus* sp.	,, *pinnatus*	,, *primus*	*Polygnathus* sp.	,, *webbi*	,, *xylus xylus*	,, *decorosus*	,, *ordinatus*	,, *costatus costatus*	,, *brevilaminus*	,, *linguiformis linguiformis* (delta)	,, *linguiformis linguiformis* (gamma)	,, *dubius*	,, *semicostatus*	,, *communis communis*	,, *nodocostatus*	,, *fallax*	,, *delicatus*	,, *symmetricus*	,, *inornatus*	,, *varcus*	,, *timorensis*	*Latericriodus l. latericrescens*	*Pelekysgnathus* sp.	*Belodella* sp.	*Bispathodus* sp.	,, *stabilis*	,, *aculeatus*
SC4	●	●	●	●			●	●		●																							●	
SC3											●	●																						
SC2											cf.		●	●																				
SC1															●																			
POC3	●	●	●	●	●	●																												
POC2												●																						
POC1																																		
PIEC8																																		
PIEC5																																		
PIEC4																●																		
PIEC3																	●	●									cf.	●	●					
PIEC6																	●	●	●															
PIEC7																																		
SVC2																				●														
SVC1										●	●	●	●						●															
SVC3																																		
OC1										●											●													
CUC2										●						●				●	●	●	●							●				
SAC2																																		
SAC1																																		
BGC1													●						●												●			
HC3																																		
HC5											●																							
HC2													●						●															
HC4										●	●	●							●															
HC1													●																					
LLC6											●	●																						
LLC5											●																							
LLC4											●																							
LLC3											●	●	●						●															
LLC2											●	●	●																					
LLC1																																		
MC3																																		
MC2																			cf.															
MC1											●	●	●						●															
VGC3											●	●																						
VGC2												●																						
VGC1																																		
BC1									●	●											●			●	●							●	●	●
BC2																																		
BC3																																		
LUC2																								●										
LUC1																																		
EC2									cf.												●			●		●								
EC1																																		
CLC2										●											●			●										

SPECIES / SAMPLE	*Bispathodus costatus*	,, *aculeatus aculeatus*	,, *spinulicostatus*	*Spathognathodus* sp.	,, *bohlenanus*	*Icriodus* sp.	,, *symmetricus*	,, *difficilis*	,, *corniger*	,, *corniger leptus*	,, *struvei*	,, *corniger corniger*	,, *eslaensis*	,, *obliquimarginatus*	,, *subterminis*	,, *cornutus*	*Schmidtognathus wittekindti*	,, *peracutus*	,, *hermanni*	*Palmatolepis* sp.	,, *pectinata*	,, *gracilis*	,, *minuta minuta*	,, *glabra pectinata*	,, *glabra glabra*	,, *schindewolfi*	*Pandorinellina insita*	,, *plumulus*	*Mesotaxis asymmetricus asymmetricus*	*Ancyrodella gigas*	,, *rotundiloba rotundiloba*	,, *rotundiloba*	,, *rotundiloba binodosa*	*Hindeodella segaformis*
SC4				●																														●
SC3						●																												
SC2							●	●									cf.	●																
SC1									●		●																							
POC3																																		
POC2																																		
POC1										●	●																							
PIEC8																																		
PIEC5																																		
PIEC4																				●														
PIEC3																																		
PIEC6								●						●																				
PIEC7												●																						
SVC2																					●						●							
SVC1						●	●								cf.														●	●	cf.			
SVC3										●		●																						
OC1				●												●						●						●						
CUC2																●				●			●	●	●	●								
SAC2																																		
SAC1																																		
BGC1								●					●																					
HC3															aff.																			
HC5															aff.																			
HC2							●																								cf.			
HC4							●								aff.																			
HC1							●																									●		
LLC6							●																											
LLC5							●																											
LLC4							●																									●		
LLC3							●																											
LLC2																																cf.	●	
LLC1																			●															
MC3																																		
MC2															aff.																			
MC1															aff.															●				
VGC3															aff.																			
VGC2																																		
VGC1																																		
BC1	●																																	
BC2																																		
BC3																																		
LUC2	●	●	●		●																													
LUC1																																		
EC2	●				●																													
EC1																																		
CLC2		●		●																								●						

SAMPLE \ SPECIES	*Icriodus eslaensis*	,, *subterminis*	,, *expansus*	*Palmatolepis subrecta*	*Ancyrodella* sp.	,, *gigas*	,, *rotundiloba rotundiloba*	,, *lobata*	*Belodella* sp.	*Siphonodella* sp.	,, *obsoleta*	,, *cooperi*	*Doliognathus latus*	*Scaliognathus anchoralis*	*Protognathodus praedelicatus*	,, *collinsoni*	*Coelocerodontus* sp.	*Clydagnathus gilwernensis*
AC1																		
LAC				●														
LEC2		aff.																
LEC1		aff.				●												
CIC1					●													
CIC	aff.		●															
PCC1							●											
ROC3										●	cf.							
ROC2																		
ROC1						●	●											
OLC7													●	●	●			
OLC6											cf.	●						
OLC5																		
OLC4								●										
OLC3		aff.			●													
OLC2																		
OLC1		aff.					●											
OLC	●																	
ALC2						cf.			●									
ALC1						●	●											
ALC	●																	
AGC13											cf.							
AGC12										●						cf.		
AGC11																		
AGC10																		
AGC9																		
AGC8		aff.																
AGC7									●								●	
AGC6		aff.																
AGC5																		
AGC4						cf.												
AGC3					●													
AGC2					●													
AGC1																		
AGC	●																	
AVC2		aff.																
AVC1		aff.																
VC5																		
VC4																		●
VC3																		
VC2																		
VC1																		
PPC1																		
MEC1																		
VVC1		aff.																
CC1																		
CC2																		
TC1																		

SPECIES / SAMPLE	*Gnathodus* sp.	,, *typicus*	,, *pseudosemiglaber*	,, *symmutatus*	,, *semiglaber*	,, *delicatus*	,, *cuneiformis*	*Pseudopolygnathus* sp.	,, *pinnatus*	,, *primus*	,, *oxypageus*	,, *multistriatus*	,, *marginatus*	,, *nodomarginatus*	*Polygnathus* sp.	,, *webbi*	,, *xylus xylus*	,, *decorosus*	,, *dubius*	,, *communis communis*	,, *delicatus*	,, *inornatus*	,, *longiposticus*	,, *purus*	,, *purus subplanus*	,, *decorosus*	*Bispathodus* sp.	,, *stabilis*	,, *aculeatus*	,, *costatus*	,, *aculeatus aculeatus*	,, *spinulicostatus*	*Icriodus* sp.	,, *symmetricus*
AC1																	●																	
LAC																●		●															●	
LEC2																●	●																	●
LEC1																●	●																	
CIC1																	●																	
CIC																	cf.																	
PCC1																		●															●	
ROC3			●		●	●	●				cf.	●	●							●		●		●			●				●	●		
ROC2																	cf.																	cf.
ROC1															●		●		●															
OLC7			●			cf.		●	●											●								●						
OLC6						●	●													●												●		
OLC5																	●																	
OLC4																		●																
OLC3															●																			
OLC2																																	●	
OLC1																	cf.	cf.	cf.															●
OLC																	●																	
ALC2															●		●																●	
ALC1															●																			
ALC																																		
AGC13	●		●		●	●	●		●	●										●		●		●								cf.		
AGC12		●				cf.														●		●			●									
AGC11										●				●						●		●	●					●						
AGC10										●										●		●								●	●			
AGC9										●					●					●														
AGC8																●	●																	
AGC7																●																		
AGC6																●	●																	
AGC5															●																		●	
AGC4															●																			
AGC3																●	●		●															●
AGC2																																		cf.
AGC1																																	●	
AGC																																		
AVC2															●		●																●	●
AVC1																	●																	
VC5	●	cf.			●					●										●	●	●			●						●			
VC4										●										●									cf.					
VC3										●										●								●	cf.					
VC2										●					●					●		●	●					●		●	●			
VC1																		●																
PPC1	●		●	●																														
MEC1																																		
VVC1																										●								
CC1																																		
CC2																																		
TC1																	cf.																●	

Errata Scripta Geol. 81

p. 9, Fig. 4: A and B should be interchanged.
p. 11, Fig. 6: upper figure = A, middle figure = B, lower figure = C.
p. 24, line 10 from below: northeastern should read northwestern.
p. 34, line 6 from below: section UG should read section VG.
p. 41, line 13 from below should read: 'limonite carbonate and clay-minerals. These sandstones are of quartzarenite or quartz-wacke composition.'
p. 70, line 5 from above: 'from the Matallana locality' should be left out.
p. 72, line 3 from below: the formula 'd/c2 + crd' should read 'd/c2 + cr +d'.
p. 75, Table 7: the headings of the last two columns should be interchanged.