HINGE MOVEMENTS INFLUENCING DEPOSITION DURING THE UPPER DEVONIAN IN THE ESLA AREA OF THE CANTABRIAN MOUNTAINS, SPAIN

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SUMMARY

In the Upper Devonian succession the presence of allochthonous lithological elements and replaced fossils, a regular vertical alternation of layers of coral rubble and biostromes, and abundant indications of erosion and subareal exposure can be explained by application of a regional epeirogenetic model.

Epeirogenetic movements governed sedimentation and led to a regressive and a transgressive depositional phase. The Portilla Limestone Formation and the Nocedo Formation have been mainly deposited during the regressive phase; the deposits of the Ermita Formation reflect the transgressive phase.

INTRODUCTION

The rocks which constitute the Cantabrian Mountains of northwest Spain are well exposed and readily accessible. Their geological history is summarised as follows.

On an earlier folded Precambrian basement Lower Paleozoic sediments (mainly siliciclastic) reflect a variety of depositional environments.

The succeeding Devonian rocks comprise an alternating sequence of carbonates and terrigenous siliciclastics which show textures and structures indicative of deposition in environments grading from below the wave base to intertidal and occasionally supratidal. The first significant tectonic movement in the southern area of the present mountain chain was tilting of the northern part of the Leonides, an EW running longitudinal structural unit which is separated from the northerly Asturides by the León line (see d e S i t t e r, 1962). This tilting was followed by extensive erosion which cut progressively into the sequence in a northerly direction just prior to the time that Famennian-Frasnian siliciclastics completed the Devonian succession.

The Carboniferous sediments form a complex of carbonates and siliciclastics mainly deposited in shallow water. During the Sudetic phase (Westphalian) a second important tectonic movement occurred. Large-scale folding and faulting took place and several structural units were formed. Those in the Esla area are described by R u p k e (1965). Subsequently the Asturide phase was responsible for the refolding of many of the structures.

Throughout the Mesozoic and Cainozoic non-deposition occurred in the area. In the Miocene the Alpine phase finally formed the mountain chain and placed the sediments in their present position.

In this paper the Devonian succession in the area northwest of Cistierna in the province of León (figs. 1, 2, 3) is described from the Middle Givetian onwards and analysed in some detail. The area is part of the Peña Corada unit (R u p k e, 1965) which is bounded to the north by the fundamental Sabero-Gordón fault zone (d e S i t t e r, 1966) which was active from Middle-Upper Devonian times up to at least the Tertiary (R u p k e, 1965; E v e r s, 1967; S t a a l d u i n e n, 1973). Along this fault zone Devonian sediments of the Peña Corada unit are thrust against Carboniferous sediments of the Sabero basin (figs. 2 and 3). To the south the Peña Corada unit is unconformably overlain by marine Turonian and Cainozoic sediments.

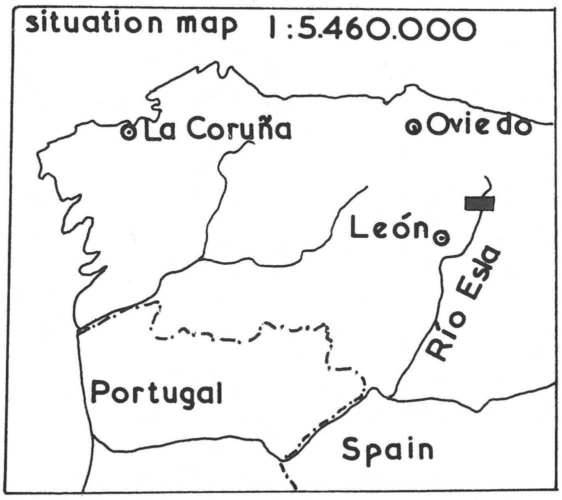

Fig. 1
Locality map of study area.

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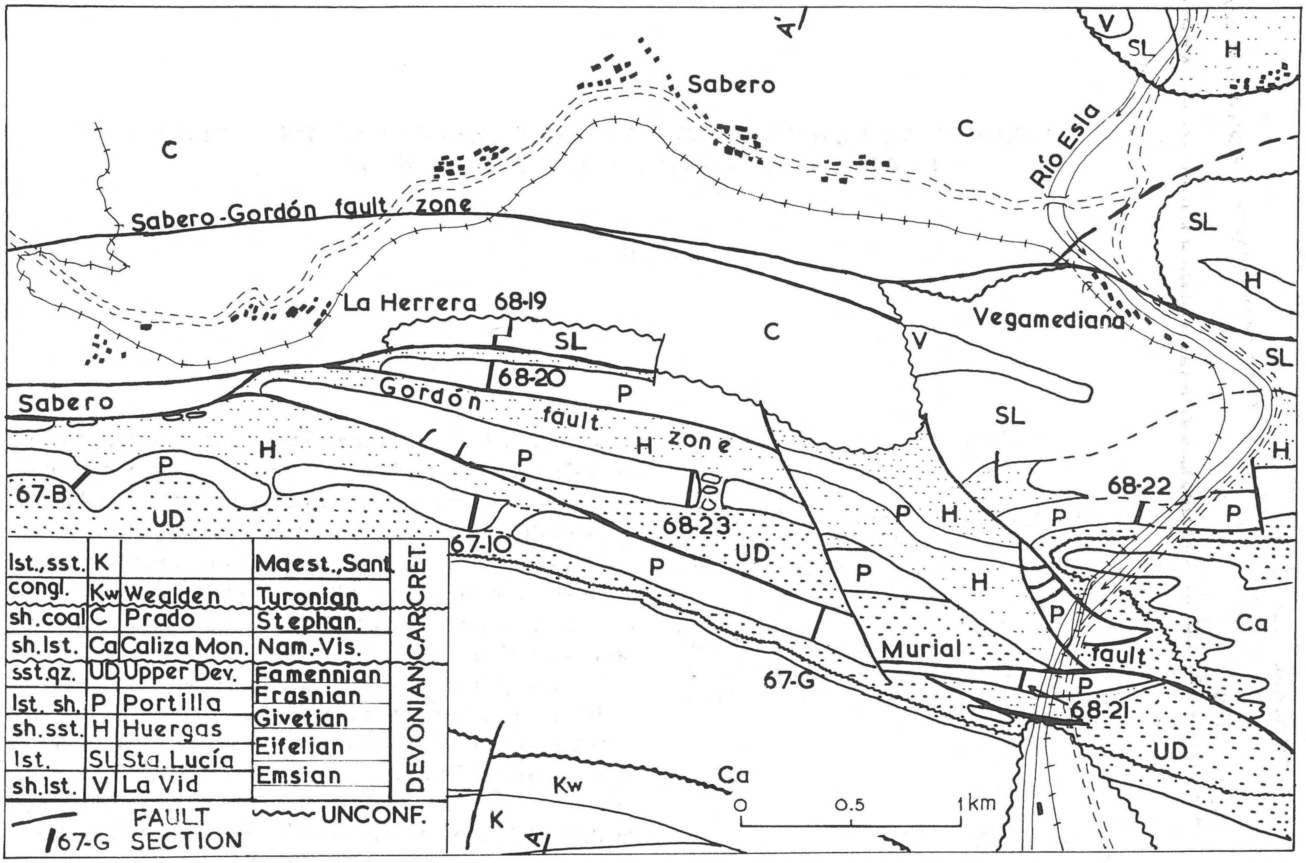


Fig. 2
Geological map of the Peña Corada unit north of Cistierna (just off the map) in the province León, NW Spain. Map drawned after Rupke (1965) with modifications after Reijers (1969).

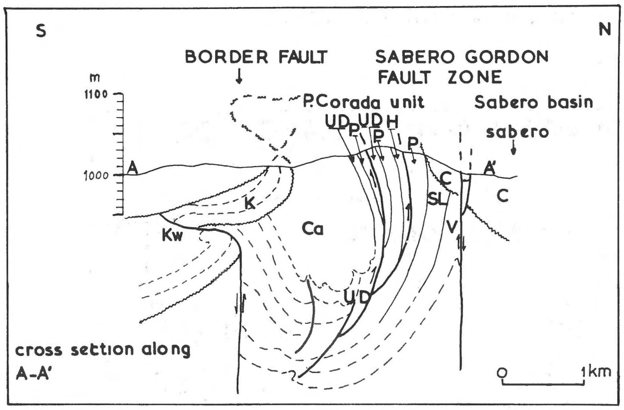


Fig. 3
Structural cross-section of the area pictured in fig. 2. Section constructed along the line A-Ai on fig. 2. Slightly modified after Rupke (1965).

This paper describes the effects of activity along the Sabero-Gordón fault zone from Middle Givetian to Famennian times in terms of sedimentary, palaeontological and facies characteristics, and interprets these in terms of a regional epeirogenetic model.

DEVONIAN LITHOSTRATIGRAPHY OF THE ESLA AREA

A striking feature of the Devonian succession in the southern slope of the Cantabrian Mountains is the regular vertical variation in lithology (R e i j e r s, in prep.). The succession consists of three main carbonate units separated by intervals of shale, sand and marl in varying proportions. Before concentrating on the Upper Devonian, the main subject of this paper, a summary of the lithologies and the environmental interpretation for the Lower and Middle Devonian succession is given. A more detailed treatment of the whole Devonian sequence by the author is in preparation.

Uppermost Silurian to Middle Givetian

In Uppermost Silurian to Lowermost Devonian times the San Pedro Formation was widely deposited. Lithologically it consists of ferruginous argillaceous sandstones which contain glass pellets presumably of volcanic origin. The sand stones are partly cross-bedded and are considered to have deposited in a shallow to very shallow coastal shelf environment.

The lowermost unit of the La Vid Formation consists of foetid limestones and sandy dolostones deposited in relatively deep marine, partly euxinic basin conditions. Higher up in the sequence an abundance of crinoidal limestone intercalations in shales and marls seems to point to an shallow open marine carbonate platform environment where aerobic conditions prevailed.

This is succeeded by the Sta. Lucía Limestone Formation, the lowermost units of which display a shallowing towards a depositional environment above the wave base. Local patch reefs occur. The higher units were deposited in deeper water. They consist of alternating thick and thin bedded limestones and are succeeded by griotte-like limestones, probably representing an environment in which turbulence was low and water circulation at depth restricted. The formation is completed by a unit in which tidal bars of bioclastic material were formed. The environment was well oxygenated but inhospitable to marine life because of the shifting substrate.

The Huergas Formation comprises immature argillaceous sands, silts and shales deposited in the shelf which was subject to high energy conditions. In certain places (especially seen in the younger horizons) conditions of deposition were restricted and quiet.

Middle Givetian to Middle Frasnian

The Portilla Limestone Formation was deposited during this period. This Formation comprises four members (R e i j e r s, 1972) in which several lithofacies have been recognised. Figure 4 summarises lateral facies changes in the study area.

Veneros Member. – 1. Description. This member contains 10- 50 cm thick, regularly bedded, detrital packstones and grainstones (carbonate classification of D u n h a m, 1962). Bryozoan and crinoidal fragments are well sorted, well rounded and moderately recrystallised. A significant ostracod-conodont association in the bottom part of this Member is discussed later. An oölite bed, 0,5-1 m thick, defines the lowermost part of the Veneros Member and is traceable throughout the whole Peña Corada unit and beyond, extending over the whole southern slope of the Cantabrian Mountains.

2. Interpretation. The oölite bed marks the gradual transition from the underlying Huergas Formation, the topmost part of which was essentially laid down below wave base. It reflects increase in energy and shallowing of the depositional environment. Sedimentological, paleontological and paleogeographical considerations (R e i j e r s 1972) suggest that sediments of the Veneros Member were deposited on a shallow marine shelf under influence of ware activity. Moderately high hydrodynamic conditions prevailed. The shelf was inhabited by numerous crinoids and bryozoans.

Member B. – 1. Description. Packstones and boundstones in a biostromal setting alternate with detrital intervals. A nodular appearance is due to the presence of ramose tabulate and massive rugose corals with massive stromatoporoids. Layers in which these fossils are in growth position alternate with layers consisting predominantly of coral rubble. Brachiopods, crinoids and bryozoans are also common. Interstitial material varies from calcirudite to calcilutite. Locally, black slightly bituminous shaly interstitial material is present. Cross-bedding, pinch-outs, slumps and interfingering layers are common in the detrital intervals. The depositional structures and textures are to some extent obscured by recrystallisation.

2. Interpretation. By analogy with recent reefal provinces (e.g. M a x w e l l, 1968) the ramose, platy and massive corals (with a low surface to volume ratio) may indicate a reef-front environment. Slumps point to appreciable depositional slopes (up to 5%) while cross-bedding and channels indicate moderate to high hydrodynamic energy. In contrast, however, black splintery bituminous shale indicates the former presence of low energy reducing environments in shallow pools on reef tops and in sheltered interreefal areas. Alternations of layers with corals in growth position and with coral rubble indicate significant changes in hydrodynamic energy. This was presumably a result of alternating phases of emergence and submergence.

Member C. – 1. Description. Due north of Cistierna (fig. 4) there are well exposed calcareous sediments among which biostromal lenses (50 m long, 2 m high) are common. These consist of considerable amounts of branching tabulate corals. Elsewhere in the Peña Corada unit member C is soft and poorly exposed. Such exposures that one knows of are unsorted, greyish, argillaceous sand and silt. One or two exposures of pure quartz sand, essentially outside the Esla area, show parallel lamination and concentrations of heavy minerals in certain laminae.

2. Interpretation. The immature and unsorted argillaceous sands and silts suggest that burial occurred rapidly and that little or no winnowing could take place. This, together with the lateral transition into shallow carbonates, points to a shallow coastal depositional environment. The pure sands with parallel laminations and heavy mineral streaks may then be regarded as an indication that beaches could develop. The source of the material was presumably to the northwest, because towards the southeast the siliciclastic layer gives way to biostromes, suggesting the presence of a somewhat shallower area in which reef-building organisms thrived.

Member D. – 1. Description. Bioherms, biostromes and micritic deposits characterise this member. The bioherms in

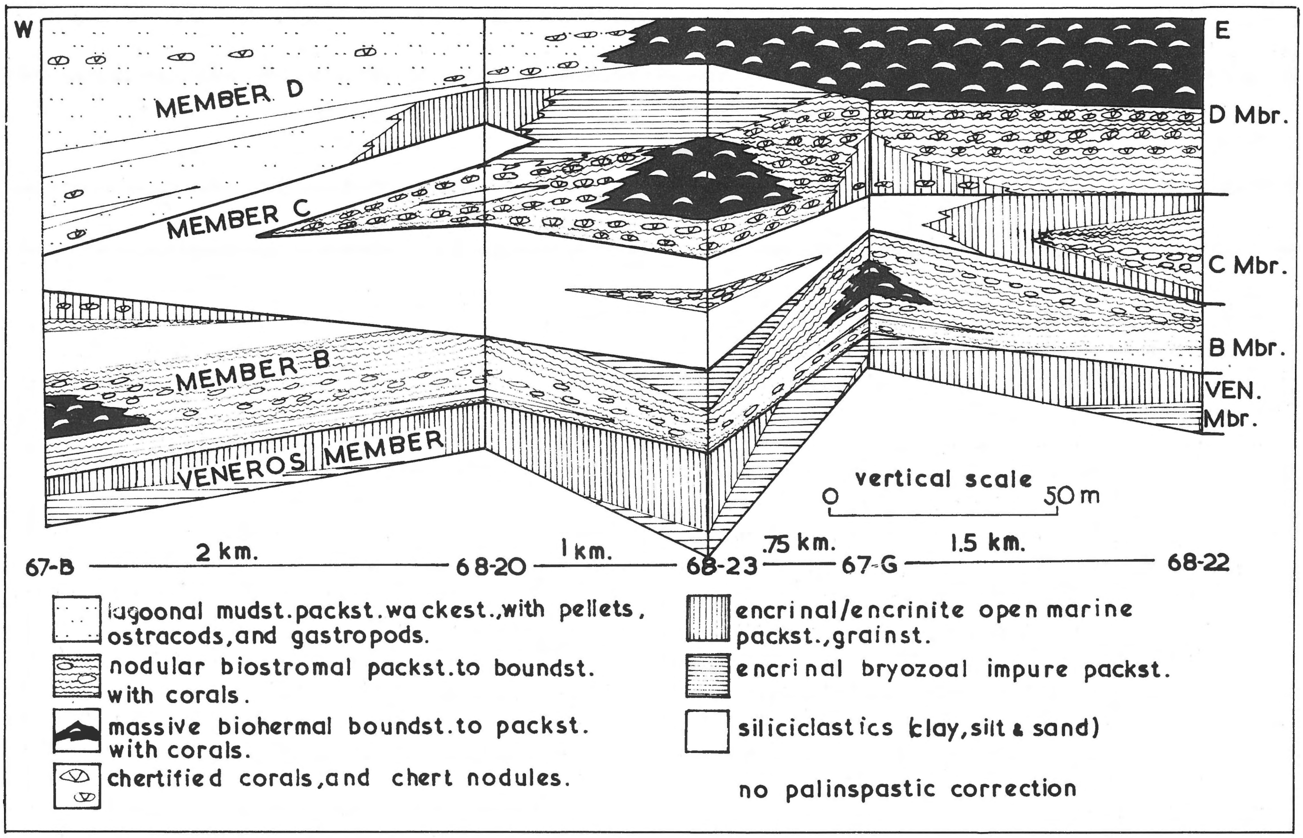


Fig. 4
Lateral correlation of the lithofacies in the study area. No palinspastic corrections are made.

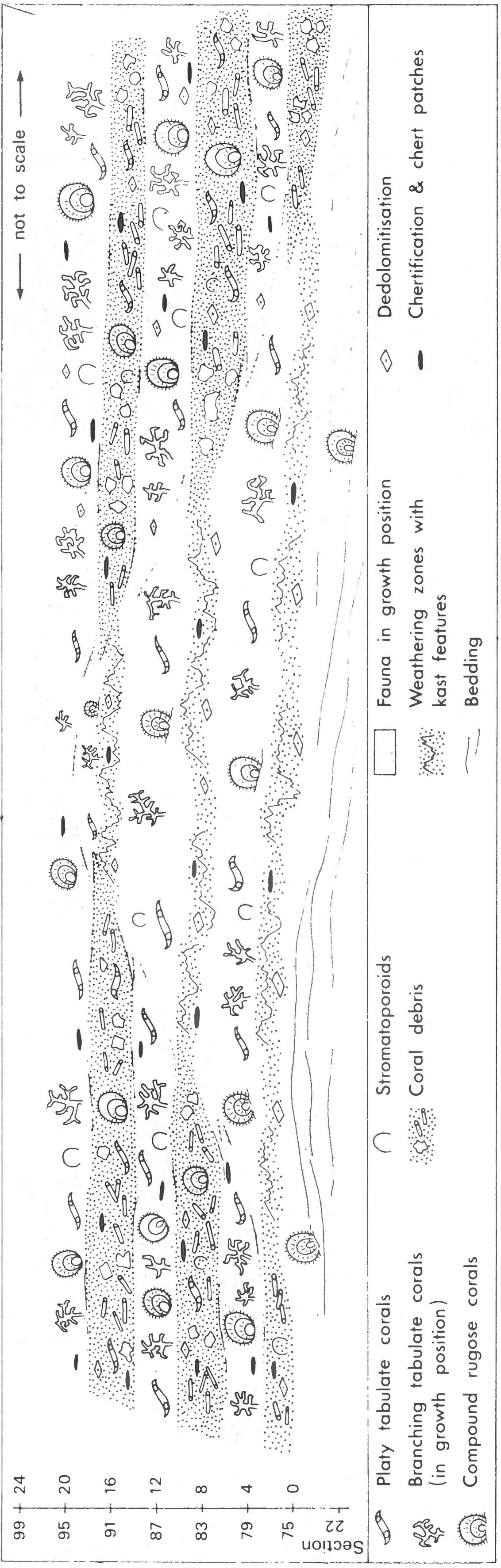
sections 68-22, 67-G and 68-23 and those in member B in sections 67-B and 67-G (fig. 4) are described as follows.

Bedding is 1-5 m thick and often indistinguishable as a result of recrystallisation. Depositional dips have been measured up to 5° The boundstones and packstones form mound-like structure which protrude, owing to selective weathering of less resistant surrounding layers. The individual dimensions are laterally up to 200 m and vertically up to 24 m (fig. 5). The dome-like mounds interconnect and form thus larger reef complexes which are clearly visible from a distance (figs. 6a, b; 7a, b and 8a, b). In a decreasing order of importance platy, massive and ramose tabulate corals, platy stromatoporoids, ramose and "fan" shaped bryozoans, crinoids and ostracods characterise the bioherms. Many faunal elements are present in growth position. Silicification of corals and stromatoporoids is common (cf. R e i j e r s, in press). The rock varies in colour from very light grey to white. On certain levels stylolites, pale yellowish dots, streaks and pale reddish brown erosional surfaces are present. Erosion planes sometimes truncate fossils. Microscopic examination of these erosion surfaces reveals partly dedolomitised rhombohedral crystals with a yellowish brown ferruginous coating.

The description of the biostromes given for member B applies equally well to these biostromes and needs no repetition. The thickness of the biostromes is inversely proportial to that of the bioherms. Erosion zones in the bioherms correlate with zones of abundant silicification in the biostromes (R e i j e r s, in press).

The laterally equivalent mudstones, wackestones and packstones show a regular, slightly nodular bedding. Channels, pinch-outs and gradings are common. Nodular chert-layers characterise this facies and correlate with zones of silicified corals in biostromes and with erosion zones in bioherms. The colour grades from grey to yellowish grey and reddish pink. Dolomitisation locally affects 10% of the sediment.

2. *Interpretation.* Bioherms formed in shallow water and were surrounded by biostromes. The bioherms were at times emergent and eroded by surf action. The resultant bioclastic material was spread over the surrounding biostromes. On resubmergence the corals re-established themselves and build out over the coarse rubble. Lime muds were deposited on the leeward side of the reefs under low energy conditions. Dedolomitised erosion zones in these sediments indicate local



and occasional periods of emergence. The erosion zones were selectively silicified in all facies (R e i j e r s, 1972, and in press).

Middle Frasnian and Famennian

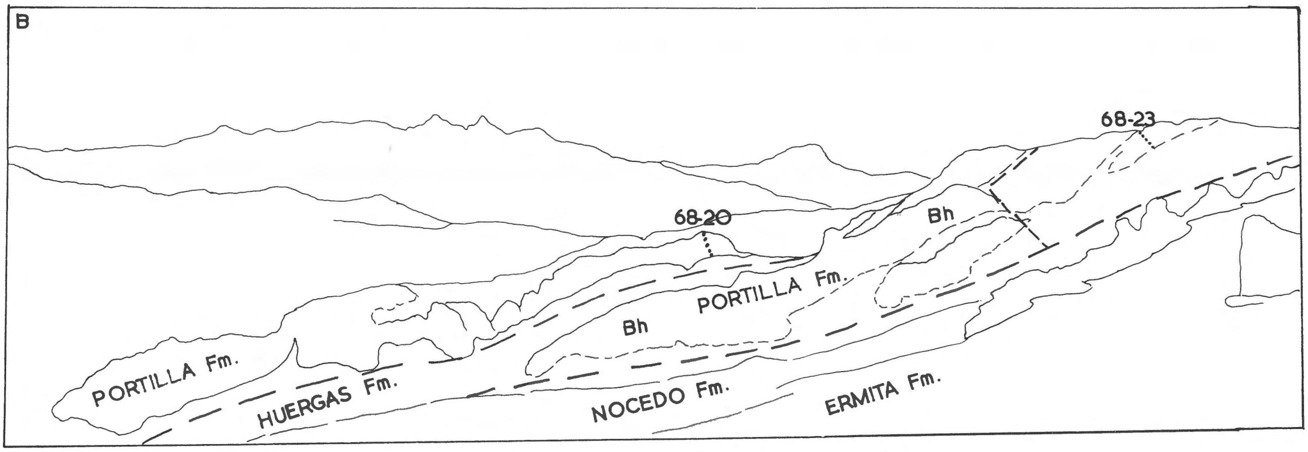
The Portilla Limestone Formation is everywhere conformably overlain by the Frasnian siliciclastic Nocedo Formation. An angular unconformity (fig. 2) separates the latter from the overlying Famennian Ermita Formation. A general feature of these formations is grading of the sediments towards the unconformity; i.e. coarsening upwards in the Nocedo Formation, and fining upwards in the Ermita Formation. R u p k e (1965), E v e r s (1967) and R e i j e r s (1972, 1973) report conglomerates of Lower Devonian San Pedro pebbles in the Upper Devonian siliciclastic succession on both sides of the Sabero-Gordón fault zone. In the study area these pebbles must have a northerly provenance since no San Pedro sediments are exposed south of the Sabero-Gordén fault zone in the Esla area.

Nocedo Formation. – 1. Description. The Nocedo Formation everywhere conformably overlies the Portilla Limestone Formation. At the base there is a white to yellow calcareous cemented cross-bedded quartz sandstone which locally gives way to a quartzite. In places decalcification was responsible for some porosity. Crinoids and brachiopods are the only recognisable fossils in this unit. In an overlying unit pebbles of ferruginous sandstone occur with volcanic glass spheres which resemble those in the San Pedro Formation. Certain intervals in this unit are strongly stained with ferruginous matter. High angle trough crossbedding and low angle inclined bedding with scour and fill structures are common. The uppermost part of the Nocedo Formation consists of yellow shales and sands which contain crinoids and brachiopods.

2. Interpretation. The sedimentary structures and the bottom-dwelling crinoids are regarded as evidence for a shallow marine, well aerated depositional environment above wave base. The environment became more shallow when the upper beds of the formation were deposited, indicated by the increasing proportion of clay and silt, proving a rapid deposition before winnowing could take place. The uppermost unit of the Nocedo Formation may have been deposited in a tidal flat area.

Ermita Formation. – 1. Description. This Formation unconformally overlies the Nocedo Formation. The basal unit is usually a white to pink orthoquartzite, locally changing into a ferruginous and/or calcareous sandstone. Decalcification is

Fig. 5
Diagrammatic representation of a bioherm in section 68-23. Scale in metres. Compare with figs. 6 a, b; 7a, b and 8a, b.



Figs. 6a, b
View over study area. Photo-station is approximately locality 67-B (Fig. 2).

indicated by the presence of moulds of fossils. Major trough cross-bedding is common in places. The coarse grained sand is often well sorted. Local conglomerates of pebbles from the San Pedro Formation are present.

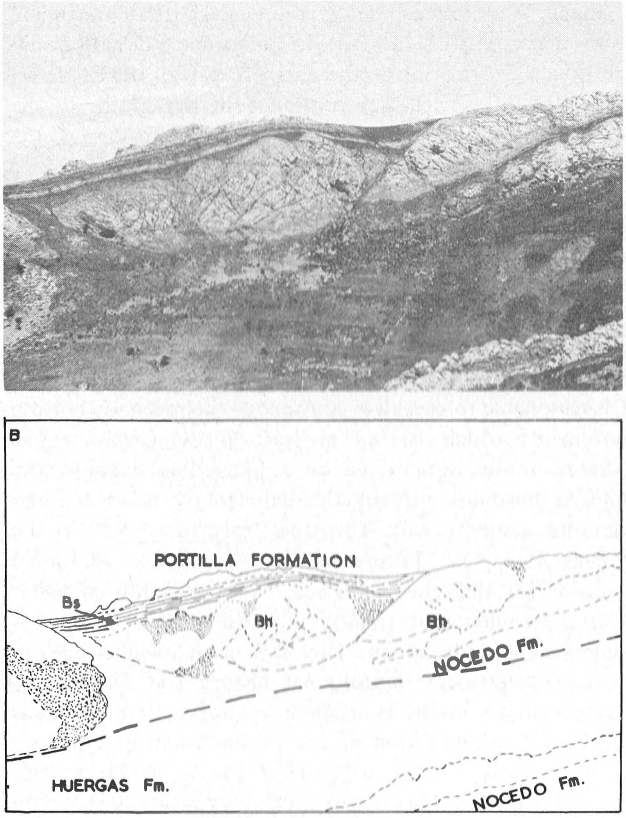
2. Interpretation. The good sorting and the major cross-bedding suggest a moderate to high energy littoral environment in which the sediments were to some extend reworked. Parallel beaches spread continuous over coastal plains as a response to transgression.

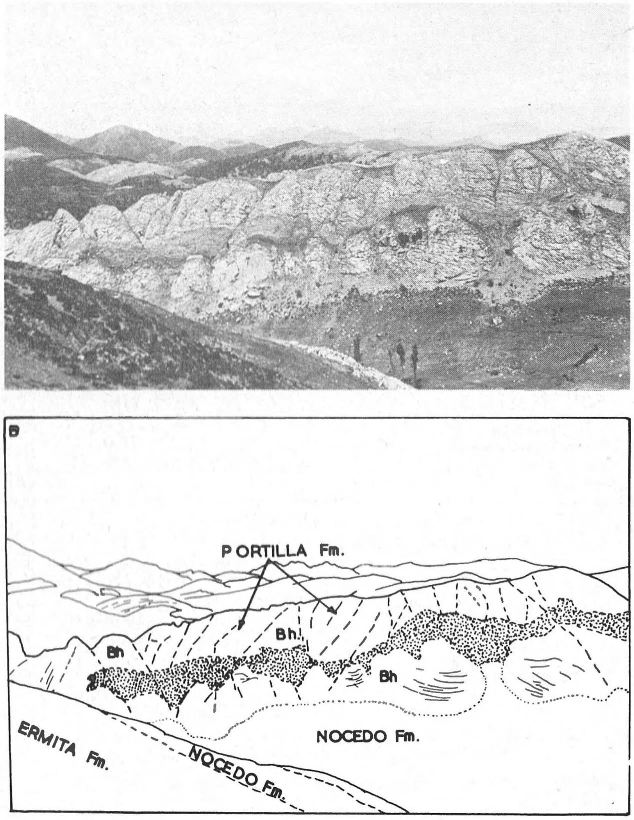
SOME BIOSTRATIGRAPHIC REMARKS

The lowermost beds of the Veneros Member of section 68-22 (fig. 4) contain ostracods of the Primiopsidae Family. These strongly suggest an Emsian age (Dr. M. Michel, Leiden University, personal communication, 1971). From the same sample the following conodont association has also been identified: *Icriodus eslaensis, Polygnathus linguiformis linguiformis, Polygnathus linguiformis mucronatas, and Polygnathus varca.* This conodont fauna indicates a Givetian-Eifelian age (Dr. K.Th. Boersma, Leiden University, personal communication, 1971).

In member B some 30 metres higher in the same section, the following fauna of conodonts and of spiriferid brachiopods has been identified: *Icriodus expansus, Spatognadotus* sp.indet., and *Cyrtina* sp., *Spinocyrtia* sp., *Tingilla* sp. This association suggests a Givetian age (Dr. K.Th. Boersma and Dr. Th. Krans, Leiden University, personal communication, 1971).

The difference in age between the ostracods and the rest of the fauna and the fact that these ostracods are present in a detrital lithological unit, indicate that they are an allochthonous assemblage. The Portilla Limestone Formation in this area is of Givetian-Frasnian age (cf. Adrichem Boogaert, 1967, Reijers, 1972). Therefore, the ostracods rather than the conodonts or brachiopods are regarded as transported elements. They were presumably derived by erosion from the top of the La Vid Formation or the base of the Sta. Lucía Formation north of the Sabero-





Figs. 7a, b
View to the north from locality 67-10 (fig. 2). Note the joint pattern which indicates the presence of the more rigid bioherms (Bh). The biostromes (Bs) drape over the bioherms. Dotted areas are covered with loose debris.

Figs. 8a, b
View to the north from a locality in the middle between 67-10 and 67-B (fig. 2). Note the joints which stress the presence of the rigid bioherms (Bh).

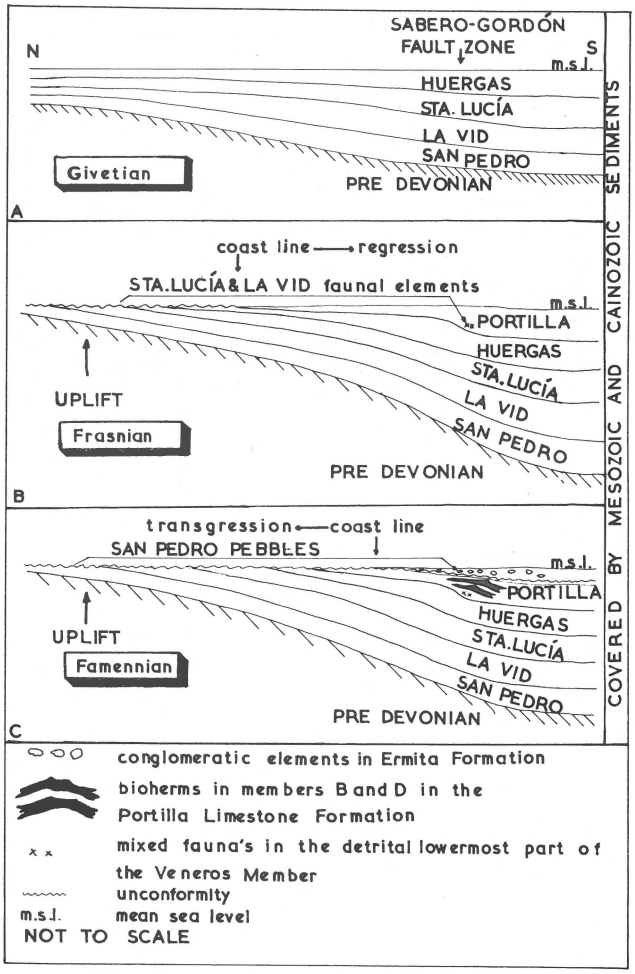
Gordón fault zone because no eroded La Vid or Sta Lucía exposures are known south of this zone (cf. R u p k e, 1965; R e i j e r s, 1969, 1972).

DISCUSSION AND CONCLUSIONS

Foreign faunal elements in the Veneros Member have been reported only from section 68-22 (fig. 4) and from the section north of Huergas de Gordón in the valley of the river Bernesga (cf. R e i j e r s, 1972, 1973). However, a detailed biostratigraphic examination of the Portilla Limestone Formation has never been attempted. Transported faunal elements may be much more common but have yet to be recognised in the detrital Veneros Member of the Portilla Limestone Formation. The ostracods appear to be undamaged but their small size could account for this (low mass to area ratio).

The correlation between dedolomitised erosion surfaces in bioherms, detrital coarse bioclastic intervals in biostromes and intervals with erosion features in lagoonal sediments leads one to believe that periodic emergence of, or extreme shallowness over vast areas occurred during deposition of the Portilla Limestone Formation. This opinion is supported by the presence of large compound coral fragments which in certain layers are upside down while in other layers they occur in life position (S l e u m e r 1969, p. 14). An idea of the regional extend of the emergence is obtained by carefully correlating these features (fig. 4).

The presence of pebbles of San Pedro sandstones of Gedinnian age in Frasnian-Famennian siliciclastics can be explained only by postulating erosion of Lower Devonian sediments in the hinterland north of the Sabero-Gordón fault zone. The erosion products were transported towards the sedimentary basin south of the Sabero-Gordón fault zone and in Upper Devonian times were deposited in shallow water near the coast, together with siliciclastics. If progressive erosion which begins in the Givetian as a response to continuous uplift north of the Sabero-Gordón zone is postulated, then the points which have been raised previously



Figs. 9a, b and c
Diagrammatic cross-section through the Upper Devonian sedimentary basin in the Cantabrian Mountains, picturing the relation between erosion in the north as a response to uplift and accumulation of sediments in the south in a subsiding part of the basin. The Sabero-Gordón zone acted as a hinge line.

can be explained satisfactoraly in terms of a regional epeirogenetic model as presented in figure 9.

Figure 9a pictures the sedimentary basin during the Givetian when siliciclastic sediments characterising an open marine environment were deposited.

Figure 9b shows progressive emergence of the northernmost part of the basin during the Frasnian which accounts for erosion of Sta. Lucía and La Vid sediments. Eroded material includes the ostracods which were brought towards the area of deposition south of the Sabero-Gordón zone. The emergence also accounts for shallowing of the basin towards the north which caused the belt of optimal conditions for carbonate deposition to move gradually to the south. As a result, the base of the Portilla Limestone Formation is time transgressive in a north-south direction (cf. Reijers, 1972).

Figure 9 c pictures the situation late in the Famennian. After deposition of the Portilla Limestone Formation and the Nocedo Formation in the northern part of the Esla area, deposition of siliciclastics continued in the south. In the north the continuous uplift caused deep erosion of the Devonian strata, resulting in a big hiatus and a time break of 12 to 37 million years. Gedinnian ferruginous sandstones from the San Pedro Formation were cut into and fragments of this material were transported into the sedimentary basin to the south.

If one considers that Emsiam elements (ostracods) are present in Giventian strata and Gedinnian elements (San Pedro pebbles) in Famennian layers in the Peña Corada unit, it is reasonable to postulate continuous epeirogenetic bottom movements which started at least in the Givetian. The Sabero-Gordón zone acted as a hinge line between the uplifted northern part of the sedimentary basin and the subsiding southern part. The gross "layered aspect" of the Portilla Limestone Formation (fig. 4) provides additional evidence for this concept. Each "layer" roughly coincides with a member and reflects a phase in the continuous epeirogenetic movements. Therefore each member has an almost independent depositional history (fig. 4). The individual phases in the continuous epeirogenetic movements which lead to deposition of one of the sediment types are discussed in an earlier paper (Reijers, 1972). A sedimentation model is postulated which is an idealized representation at a given time of the most likely spatial relations between the depositional facies in an essentially shallow sea where predominantly carbonates were deposited. Nowhere the complete lateral succession has been found however, which is a result of general depositional conditions being fairly constant over vast areas and lengths of time. The model is a direct consequence of the application of Walther's Law of Facies (1893-1894).

The Veneros Member was deposited mainly on an open marine, shallow, subtidal platform. A slight positive movement of the sea bottom lead to a regressive phase and triggered incipient reef growth in member B on favourable, possibly structurally controlled, areas. At the end of deposition of member B sedimentation conditions suddenly changed and incipient reef growth was abruptly cut off because the hinterland started supplying siliciclastic material. By dilution with clay, silt and sand, carbonate sedimentation was obscured in most places in member C. During deposition of member D, however, conditions like those prevailing during deposition of member B returned, indicating a minor transgression. In favourable places close to the Sabero-Gordón fault zone, bioherms and biostromes developed and locally formed huge reef complexes. Sedimentation conditions changed suddenly at the end of member D and the hinterland again supplied siliciclastic sediments which were deposited in a well aerated infra-littoral depositional environment which later possibly graded into a tidal flat area. This indicates setting in of a major regressive phase which culminated in widespread erosion and peneplanation of the

Esla area. Subsequently, the Ermita sediments represent a transgressive phase. These regressive and transgressive phases are thought to be reflections of the epeirogenetic movements in the Upper Devonian sedimentary basin.

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REFERENCES

Adrichem Boogaert, H.A. van (1967) – Devonian and Lower Carboniferous conodonts of the Cantabrian Mountains (Spain) and their stratigraphic application. Leidse Geol. Med., 39, p. 130-189.

Comte. P. (1959) – Recherches sur les terrains anciens de la Cordillère Cantabrique. Mem. Inst. Geol. Minero de Esp., 60, 440 p.

Dunham, R.J. (1962) – Classification of carbonate rocks, according to depositional texture. In (Ham W.E., Editor) Classification of carbonate rocks. Am. Assoc. Petr. Geol. Mem. I, p. 108-122.

Evers, H.J. (1967) – Geology of the Leonides between the Bernesga and Porma rivers, Cantabrian Mountains, NW Spain. Leidse Geol. Med., 41, p. 83-151.

Maxwell, W.H.G. (1968) – Atlas of the Great Barrier Reef. Elsevier, Amsterdam, 258 p.

Reijers, T.J.A. (1969) – De stratigrafie van de Portilla Formatie tussen de río en Esla en de río Porma in de provincie León (Spanje), en de tectonische problemen in het Peñolagebied. Leiden University, Depts. of Stratigraphy and Structural Geology. Internal Report, 80 p.

(1972) – Facies and diagenesis of the Devonian Portilla Limestone Formation between the river Esla and the Embalse de la Luna, Cantabrian Mountains, Spain. Leidse Geol. Med., 47, p. 163-249.

(1973) – Stratigraphy, sedimentology and paleogeography of Eifelian, Givetian and Frasnian strata between the river Porma and the Embalse de la Luna, Cantabrian Mountains, Spain. Geol. en Mijnbouw, 53, p. 115-124.

(in press) – Diagenesis in reefal facies in the Devonian Portilla Limestone Formation, NW Spain.

Reijers, T.J.A.; D. v.d. Baan, J.C.M. Coo and Th.F. Krans (in prep.) – The Devonian System in the Asturo-Leonese Facies Belt in the Provinces León and Oviedo (N.W. Spain).

Rupke, J. (1965) – The Esla Nappe, Cantabrian Mountains (Spain). Leidse Geol. Med., 32, p.1-74.

Sitter, L.U. de (1962) – The structure of the southern slope of the Cantabrian Mountains: explanation of a geological map with sections scale (1:100,000): Leidse Geol. Med., 26, p. 255-264.

(1966) – De relatie tussen orogenese en epeirogenese in het Cantabrische Gebergte (voordracht). Verslag Kon. Ned. Acad. Wet., 75 (7), p. 114-120.

Sleumer, B.H.G. (1969) – Devonian stromatoporoids of the Cantabrian Mountains, Spain. Leidse Geol. Med., 44, p. 1-136.

Staalduinen, C.J. van (1973) – Geology of the area between the Luna and Torío rivers, southern Cantabrian Mountains, NW Spain. Leidse Geol. Med., 49, p. 167-205.

Walther, J. (1893-1894) – Einleitung in die Geologie als historische Wissenschaft. Beobachtungen über die Bildung der Gesteine und ihrer organischen Einschlüsse. bd. I. Fischer, Jena.