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STRATIGRAPHY, SEDIMENTOLOGY AND PALAEOGEOGRAPHY OF EIFELIAN, GIVETIAN AND FRASNIAN STRATA BETWEEN THE RIVER PORMA AND THE EMBALSE DE LA LUNA, CANTABRIAN MOUNTAINS, SPAIN

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SUMMARY

The chronostratigraphy of the Middle-Upper Devonian Portilla Limestone Formation is discussed in three stratigraphic sections. Deposition of limestones occurred in a diachronous way. A discussion in four sections, of the sedimentology of the Huergas Formation, the Portilla Limestone Formation and the Nocedo Formation leads to a palaeogeographic picture of two shallow platforms in the west and in the east, resp., on which open marine subtidal to intertidal limestone sediments were deposited. The platforms were separated by a slightly deeper depositional environment into which a delta protruded, eventually filling up the basin. This delta was covered with limestones, similar to those present on the platforms but patchy, irregularly distributed and in smaller thicknesses. The limestone deposition ended with a new, strong pulse of siliciclastic sediments, presumably coming from the NE and spreading out gradually over the whole area. In these sediments, Lower Devonian ferrugenous San Pedro pebbles are present, indicating a deep erosion in the Northern Leonides.

INTRODUCTION

On the southern slope of the Cantabrian Mountains in NW Spain the Middle-Upper Devonian Portilla Limestone Formation (fig. 1) is exposed and has recently been studied (Reijers, 1969, 1972; van der Baan, 1969; Mohanti, 1972) in the frame of a broader investigation of the Devonian by members of the stratigraphic department of Leiden University. The investigated outcrops are situated on the strongly folded longitudinal southern structural unit of the Cantabrian Mountains, the Leonides, which is separated from the northern Asturides by the León line (de Sitter, 1959, 1962).

The northeast-southwest running Porma fault (Evers, 1967) divides the Leonides into two parts with different structural histories (Rupke, 1965; Evers, 1967). In the present paper attention will be focussed on the part west of the Porma fault. The major east-west running Sabero-Gordón fault divides the Leonides into an area of progressively higher uplift and subsequently deeper erosion to the north, and an area of continued subsidence and rapid sedimentation to the south (Evers, 1967; Reijers, 1972). This paper concentrates mainly on outcrops to the south of this line.

Detailed studies of facies in the Portilla Limestone Formation (Reijers, 1972; Mohanti, 1972) revealed that the sediments had been deposited on shallow subtidal to intertidal flats on which bio-accumulated banks, biostromes and occasionally bioherms could develop. An analysis of the lateral relations and the geometry of facies leads to a paleogeographic picture in which highs (possibly land areas) are presumed north of the León line and near the Porma fault (van Adrichem Boogaert, 1967; Reijers, 1972). Dating of the sequence (van Adrichem Boogaert, 1967; Reijers, 1972; Struve and Mohanti, 1971; and Mohanti, 1972) revealed that sedimentation was not synchronous. It is the intention of this paper to review this diachronism in relation to the overlying and underlying formations, and to evaluate it in terms of a more detailed paleogeography of the area considered.

LITHOSTRATIGRAPHY AND SEDIMENTOLOGY

The Portilla Limestone Formation (35-95 m as an average thickness, and 246 m in the nose of the Alba syncline, cf. Mohanti, 1972) is sandwiched between the underlying sandy, silty and shaly Huergas Formation (cf. Comte, 1959; Evers, 1967 and van der Bosch, 1969), and the overlying siltstones, fine to coarse grained sandstones and locally, the quartzites of the Nocedo Formation (Comte, 1959; Rupke, 1965 and Evers, 1967). Only the upper part of the Huergas Formation, the entire Portilla Limestone Formation and the lower part of the Nocedo Formation will be discussed.

The Huergas Formation

Almost everywhere in the area of consideration the Huergas Formation underlies the Portilla Limestone Formation. An exception must be made, for the southern limb of the Alba syncline near Sagüera, where the Portilla Limestone Formation wedges out, so that the Huergas Formation underlies the Nocedo Formation (Mohanti, 1972). Transition

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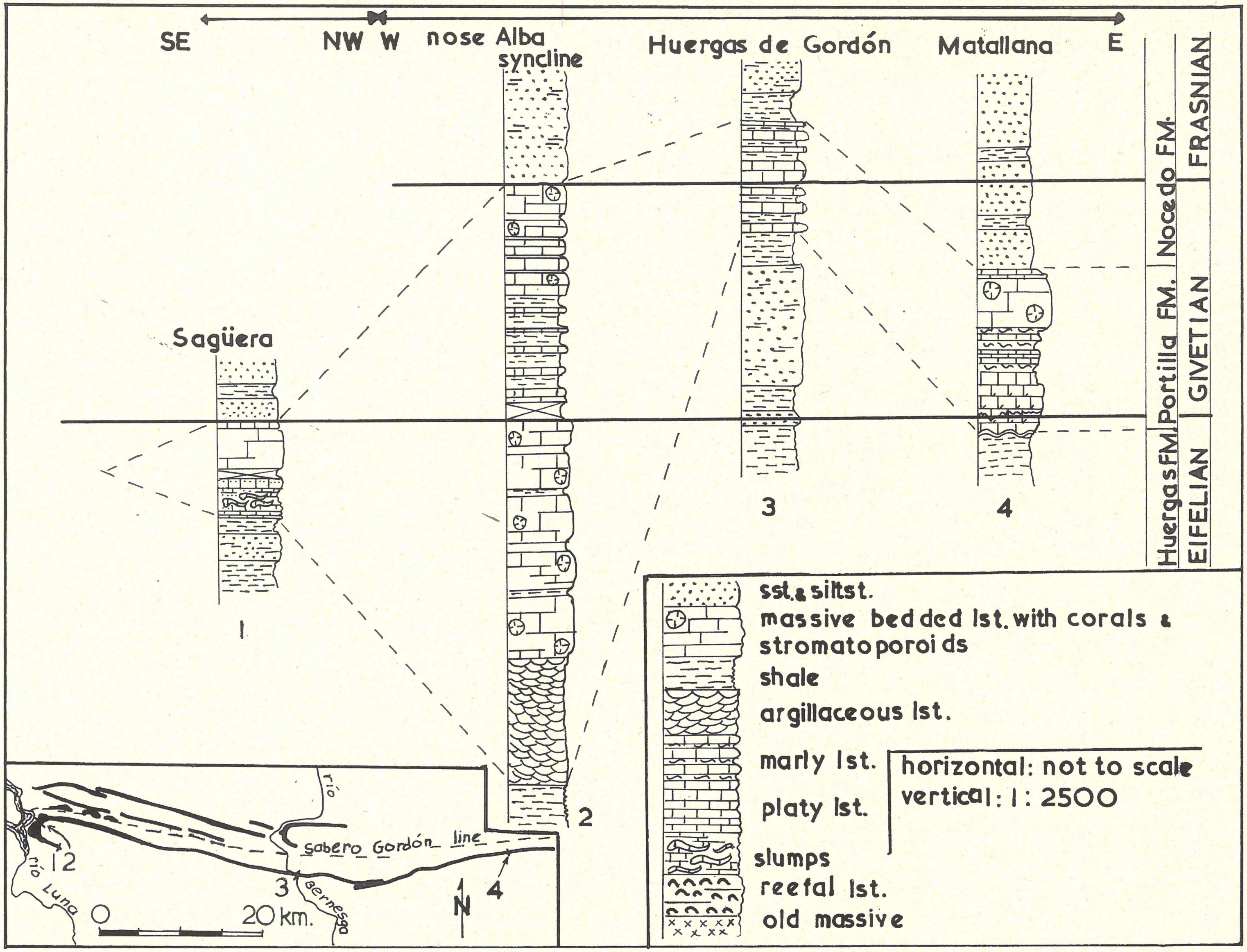


Fig. 1
Lithostratigraphic correlation of Huergas Formation, Portilla Limestone Formation and Nocedo Formation, against a horizontal time axis. Indication of the localities of the studied sections. Legend serves both, fig. 1 and fig. 3

from the Huergas Formation into the Portilla Limestone Formation is generally gradual. This is especially the case when going from Huergas de Gordón (type locality; cf. C o m t e, 1959) in an easterly direction where limestone lenticles (packstones and wackestones) are found in the uppermost part of the Huergas Formation. Elsewhere the uppermost part consists of fine sandstones, shales and siltstones.

The Huergas Formation contains a marine fauna. The fauna of the packstone and wackestone lenticles in the vicinity of Hergas de Gordón is extremely variable and contains for example solitary zaphrentoid and colonial heliolites-like rugose corals, platy *Coenites* sp. and *Alveolites* sp., massive *Chaetetes* sp., and rod-like *Thamnopora* sp. tabulate corals, cistoids, blastoids, bryozoans and ossicles of crinoids. Locally there are indications that land was nearby (plant remains, coaly inclusions). Especially in the top part of the formation, coquinoid levels rich in hematite have been observed. In places bioturbation frequently occurs.

1. Sedimentary characteristics. The siliciclastic sediments are mainly parallel bedded in layers varying in thickness from a few mm to 1 m. Sandstone beds are often separated by shaly intervals, sometimes not more than a few mm thick. The sandstone shale ratio shows a tendency to increase towards the top of the formation. About 50 m from the top this ratio is visually estimated at 1 : 3 whereas near the top it is locally 1 : 1 or sometimes even 2 : 1. A high degree of bioturbation, a poorly preserved stratification and a moderately to strongly mottled aspectaspect are characteristics for the more shaly intervals. Towards the top of the Huergas Formation the number of wave and current ripples increases and a few gullies are visible in which planar and trough stratification with angles ranging up to 15°, are common. Some pseudo-parallel beds are present. Occasionally loadcasts and slumps are found. In the uppermost part of the Huergas Formation near Huergas de Gordón, cross stratifications and current lineations are frequent in the detrital bioclastic limestone lenticles.

2.Interpretation. The bioturbated, mottled, siliciclastic sediments are indicative of a pro-delta environment (S c r u t o n, 1960). Wave ripples and parallel bedding overlaid by sediments with current ripples, current lineations, slumps, loadcasting, pseudo-parallel bedding and gullies, point towards a delta slope (cf. S c r u t o n, 1960; v a n S t r a a t e n, 1969). This sequence is gradually influenced by wave and current activity, and is finally overlaid by (partly carbonate) sediments, deposited on open marine shallow medium/high energetic) platforms (R e i j e r s, 1972). Hereafter the supply of siliciclastic material decreases and (detrital) limestones are continuously accumulated.

The Portilla Limestone Formation

The Portilla Limestone Formation has been subdivided into four members by the present author (cf. R e i j e r s, 1972, p. 173, and table 1). M o h a n t i (1972) recognised a three-fold lithostratigraphic division of the Portilla Limestone Formation in the nose of the Alba syncline. His member A correlates with Reijers' Veneros Member and member B combined.

The Veneros Member (lowermost unit) predominantly consists of crinoidal and bryozoan fragments. Minor amounts of medium to coarse grained coral fragments are present in a moderately to strongly argillaceous, irregularly bedded limestone.

West from the section near Matallana (type section, cf. C o m t e, 1959, revised by R e i j e r s, 1972 and by M o h a n t i, 1972), member B contains coral biostromes. Member B and C often form an intricate complex of sediments.

Member C can be recognised by its locally high content of intercalated shale and sand in the limestones. This member correlates with M o h a n t i's member B (1972).

From east to west member D is mainly composed of detrital bioclastic calcarenites, coral biostromes and some coral bioherms. The biostromes near Huergas de Gordón are very sandy and silty. Towards the top of member D siltstones and shale layers may alternate with limestone lenticles. Consequently the transition into the overlying Nocedo Formation is gradual. Only between the nose of the Alba syncline and Huergas de Gordón it is sharp in places. Here the sequence is not always completely present, presumably due to the influence of the parallel running Sabero-Gordón fault. Member D correlates with M o h a n t i's member C (1972).

The Veneros Member and Member B. – 1. Sedimentary characteristics. In the nose of the Alba syncline, irregular (largely thin bedded) to massive (medium to thick bedded) parallel to pseudo-parallel detrital limestone layers are common. The beds thicken and thin over relatively short distances. No bottom structures or cross-beddings are reported by M o h a n t i (1972). The present author however, noticed some cross-beddings and gullies during short visits in the summers of 1969 and 1970. In Huergas de Gordón packstones and wackestones are present, which are more lenticular and irregular and which display some slumps, gullies, cross stratification and graded sequences (mainly fining upwards). These lenticles alternate with siliciclastic intervals. The fauna is extremely rich, both in number of species and of individuals within a species. In the section near Matallana the sediments belonging to these members are partly covered. Dedolomitisation related to erosion planes and gullies, wedging-out of sedimentary layers and 'fining upwards' structures are common.

2. Interpretation The deposits described are open shallow platform sediments, essentially laid down below low tide. Locally (e.g. near Matallana) intertidal sediments are found. The intertidal origin is proved by erosion planes, dedolomitisation and (tidal) gullies. Sediments in the Veneros Member and in member B are distinguished as 'facies c' (coral, bryozoan, packstone-boundstone biostromes with argillaceous interstitial material), 'facies e' (encrinal/encrinite, bryozoan grainstone), 'facies f' (encrinal, bryozoan, coral, brachiopodal packstone and wackestone with marly intercalations) and 'facies g' (bioclastic packstones admixed with important amounts of siliciclastics), (cf. R e i j e r s, 1972). From, both Matallana and the nose of the Alba syncline towards Huergas de Gordón, the sediments tend to become more open marine.

Member C. – 1. Sedimentary characteristics. Sandy, silty, shaly and marly intercalations, red brown and greenish yellow in colour, occur in wavy, irregular, very thin (mm) to medium (dm) bedded packstones and boundstones. These intercalations characterise member C in the nose of the Alba syncline and in the section near Matallana. The red colour of the sediments is mainly caused by hematite. Locally, green intervals (due to reduction of hematite) are present. Gullies, wedges of sedimentary layers, graded bedding, current lineations and geopetal features are common, especially near Matallana. In the nose of the Alba syncline prominent 'large scale cross-bedding' slopes down towards NW (M o h a n t i, 1972). A similar major cross-bedding was observed by the author in Mallo on the other side of the reservoir on the River Luna. The main rock-building faunal elements are corals and stromatoporoids, especially *Thamnopora* sp., *Coenites* sp. and *Alveolites* sp. In the section near Huergas de Gordón member C contains dolomitic packstone, essentially poorly bedded to unbedded (due to recrystallisation). Burrows, pellets and some geopetal structures are discernable. Dedolomitisation is fairly common.

2. Interpretation. Approaching Huergas de Gordón from both, the nose of the Alba syncline and the section near Matallana one goes again towards more open marine sediments. Coming from Matallana one passes 'facies c' (bioaccumulated banks and coral biostromes) then, 'facies e' and 'facies g', both essentially subtidal open, shallow platform sediments.

Member D. – 1. Sedimentary characteristics. Regular, medium to thick-bedded limestones, occasionally slightly dolomitised, are characteristic for member D in the nose of the Alba syncline. Stylolitic indentations follow closely the bedding. Massive tabulate and rugose corals, stromatoporoids and thamnoporoid corals are the dominant faunal elements. In the section near Matallana partly dedolomitised, massive bedded packstone-boundstone layers show vague wedging-out and gullies. Near Huergas de Gordón a nodular packstone-boundstone sequence with shaly and sandy intervals is found. Bedding is wavy and irregular (10-20 cm). 'Fining upwards', slumps and burrowing are common. In this section the main faunal elements are corals, brachiopods, cronoids and bryozoans. Towards the top of the Portilla Limestone Formation the content of shale, silt and sand increases. Between the nose of the Alba syncline and the section near Huergas de Gordón, M o h a n t i (1972) records an incomplete top part of the Portilla Limestone Formation. He relates this to non-deposition of sediments.

2. Interpretation. In the three sections discussed, member D consist of coral biostromes and bioaccumulated banks, belonging to 'facies c'. In Huergas de Gordón the influence of the 'facies e' (shallow open marine subtidal grainstones) indicates that the sediments were presumably deposited somewhat further into the open marine environment. The author is of the opinion that the local incompleteness of the top part of the Portilla Limestone Formation is related with faulting along the Sabero-Gordón line. This opinion is supported by descriptions by S m i t (1972). The Sabero-Gordón line runs parallel to the exposures at only a few hundred metres distance. Along this line, lenticles of the Portilla Limestone are present (cf. R e i j e r s, 1969; S m i t, 1972).

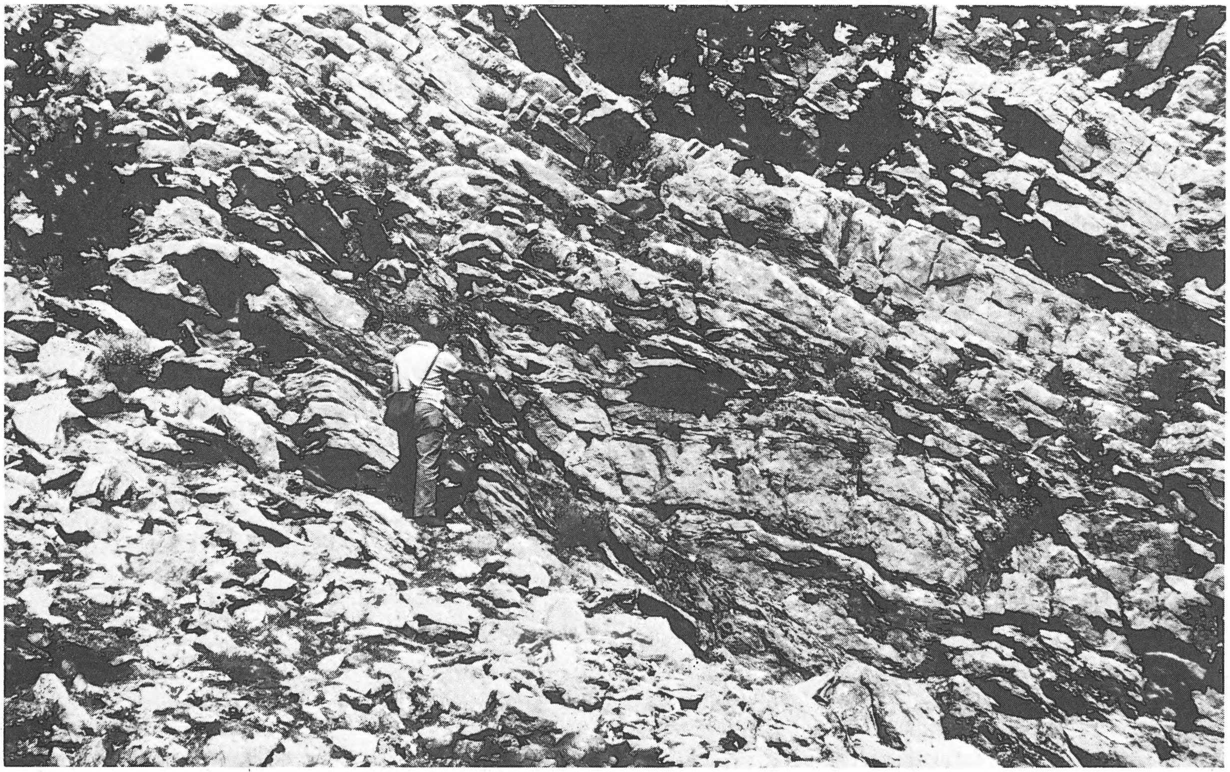
The Portilla Limestone Formation near Sagüera

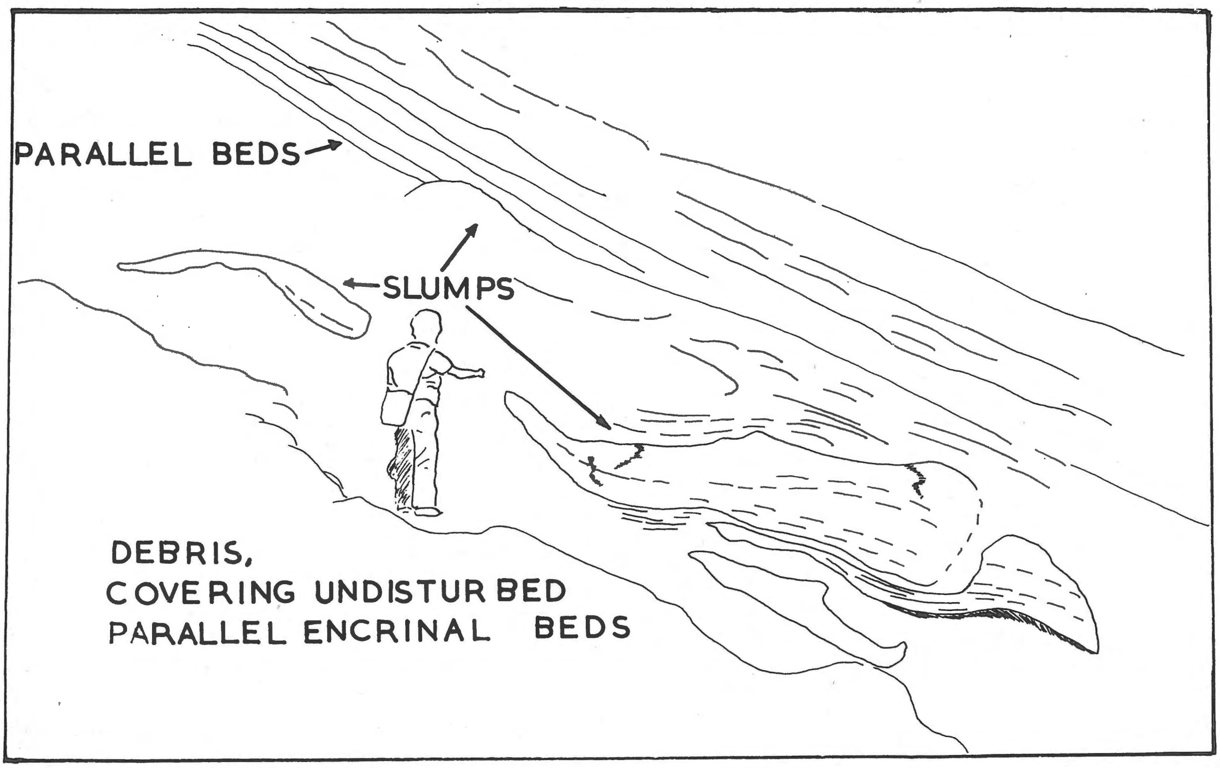
A dark brown to black bioturbated shale with some 10-30 cm thick, regular siltstone and mudstone layers underlies the 4 m thick yellow grey weathered grainstone which is the lowermost unit of the Portilla Limestone Formation. This grainstone contains coarse crinoidal and bryozoan debris. Bedding is parallel to pseudo-parallel and fairly regular. Part of this interval is covered with debris from higher units. (fig. 2).

A 6 m thick unit follows, composed of yellow brown grainstonema in places strongly hematitic. In this unit slightly wavy distorted lenticular slumps are present, consisting of coarse unsorted detrital crinoidal material. Sometimes parts of stems of crinoids are present among the bioclasts. The slumps reach lengths of 15 m and have wave amplitudes of 3-5 m. Between these slumps irregularly dragged layers are present, adapting themselves to the shape of the main slumped bodies. Current bedding and wedging-out over short distances are common structures in the dragged layers. The material is basically the same as that of the main slumped bodies, though somewhat finer. Entire crinoidal stems are lacking (fig. 2).

This unit is overlaid by a 6 m thick, poorly exposed interval with partly parallel layered partly unlayered grainstones. Hereafter follows a marly packstone-interval. In places the packstones change into sandstones with a calcitic cement. Cross-stratification is common.

On top of this interval a 15 m thick recrystallised packstone-grainstone unit is present in which stylolitic indentations roughly follow the bedding direction. After close study, a few slumps of 2-10 m length and 0.5-2 m height became visible. Stylolitic seams show gracitational 'knicks' nearby the point where the whole Portilla Limestone Formation wedges out. Curvatures are visible in the layers, suggesting that the whole unit has been transported by gravitational forces.





'ig. 2
'he section near Sagüera. The layer with internal contortions and slumps is clearly visible between two intervals with parallel but tilted layers.

The uppermost unit in the Portilla Limestone Formation near Sagüera is a platy grainstone with crinoidal debris. The parallel bedded layers are 20-60 cm thick. No gravitational phenomena are present in this unit. Transition from the locally siliciclastic uppermost limestones of the Portilla Limestone Formation into the pale yellow to yellow brown shales and mudstones of the Nocedo Formation is gradual. Laterally, in a southeasterly direction from the point where the Portilla Limestone Formation wedges out, some small (5-10 m) lenticles of limestones are still present. But in general the dark brown bioturbated shale underlying the Portilla Limestone Formation passes fairly suddenly into the pale yellow shales, overlying the Portilla. It becomes extremely difficult to distinguish between the two, and therefore it is better to follow (v a n S t a a l d u i n e n (in prep.), and to distinguish the whole interval as the Piedrasecha Formation.

The Nocedo Formation

1. Sedimentary characteristics. The Nocedo Formation overlies the Portilla Limestone Formation everywhere except in the area around Sagüera. In the Alba syncline the contact is generally unconformable; further to the east we find a gradual transition. The sediments are mainly sandstones and quartzites; lacally important amounts of siltstones and shales are present. Going from the west towards the section near Huergas de Gordón, one can state that the shaliness of the Nocedo Formation slightly increases.

In general the sediments directly overlying the Portilla Limestone Formation display an increase in grain size towards the top of the sequence. In a few places breccia-like ferrugenous pebbles are apparent. Limestone lenses containing coated quartz grains and bioclasts are present mainly near the River Bernesga. In a few places (e.g. near Sagüera and Huergas de Gordón) we noticed sequences with convolute, parallel and graded bedding or with laminations. The beds are 10-15 cm thick and alternate with silty and shaly intervals of 10-20 cm thickness. The greater part of the Nocedo Formation however, (especially near the top) shows a parallel to pseudo-parallel lamination, locally accentuated by concentrations of dark, heavy minerals. Primary current lineations occur. Large-scale low angle planar cross-stratification is common. In the 'coarsening upwards' sequence loadcasting of coarser material into the underlying finer material has been seen.

The sand is roughly subangular, moderately sorted medium to fine grained and becomes coarser towards the top of the formation. It has as an average 15-25% matrix containing plagioclase, microcline, biotite and calcite as main components, and quartz and various iron minerals (e.g. limonite, hematite, goethite and magnetite) as minor minerals.

2. Interpretation. The convolute, parallel and graded bedding point towards turbiditic sequences. The parallel laminated quartzites with current lineation, and the large-scale low-angle planar cross-stratification are characteristic for beach sediments. The 'coarsening upwards' in the entire Nocedo Formation is thought to be connected with epeirogenetic uplift of the northern Leonides (R u p k e, 1965; E v e r s, 1967). Then the breccia-like ferrugenous pebbles may be derived from the Lower Devonian San Pedro Formation. The composition of the siliciclastic material is immature, and strongly suggests a relatively nearby place of origin. The cross stratification suggests a source somewhere to the N or NE.

CHRONOSTRATIGRAPHY

The lower and middle parts of the Portilla Limestone Formation in the nose of the Alba syncline have been dated as Eifelian by S t r u v e and M o h a n t i (1970) on the basis of Atrypid Brachiopoda. *Spinatrypa (spinatripa)* and *Spinatrypa (isospinatrypa)* sp. cf. *wotanica* in the upper part are definitely Givetian species. The authors find it '...highly improbable that beds of Frasnian age are represented in the Portilla Formation of the Alba syncline...' (p. 164). M o h a n t i (1972) reports from the basal part of member B, an Eifelian assemblage of Rhynchonellid Brachiopoda, viz. *Kransia* aff. *parallelepipeda, Nalivkinaria* aff. *lacunata* forma *tenuinostata*, and some 'Pugnax' specimens. *Kransia subcordiformus, Beckmannia minor beckmanni* and *Cupularostrum sartenaeri* are mainly present higher up in member B and point towards a Givetian age. In the basal part of member B a 'mixed fauna' is often found. Mohanti calls this mixed aspect a boundary phenomenon (p. 180-181), implying transition from Eifelian to Givetian.

These datings are fairly well in accordance with those of the section near Matallana. Here, in the lowermost beds of the sequence the spiriferid Brachiopoda *Euryspirifer supraspeciosa* is of Eifelian age. The uppermost part of this section (members B, C and D) contain *Spinatrypa (isospinatrypa)* cf. *wotanica* and a few comparable atrypid species (M o h a n t i, pers. comm.). These point towards (Lower) Givetian age. East of the Proma fault the succession has been dated as Givetian-Frasnian (v a n A d r i c h e m B o o g a e r t, 1967; R e i j e r s, 1972). This area, however, will not further be considered in the present paper.

Problems arise with the section in the valley of the River Bernesga near Huergas de Gordón. There, in the shaly and sandy intervals between the limestones of the Veneros Member the conodonts *Polygnathus varca, Polygnathus linguiformis linguiformis* and *Icriodus eslaensis* are present. These point towards an (Upper) Givetian age for this part of the section. This dating is confirmed by the presence in this section of the spiriferid Brachiopoda *Mucrospirifer* cf. *bouchardi*, and of the atrypid Brachiopoda *Spinatrypa (isospinatrypa)* cf. *wotanica* which has been found in a section 5500 m towards the east. In the Veneros Member, however, the conodont *Polygnathus foveolatus* is also present in red-brown marly/silty sediment intercalations. This species is only known from (Upper) Emsian strata (B o e r s m a, pers. comm.). In the shaly part of member B of the section near Huergas de Gordón, the conodonts *Icriodus latericresens latericresens* and *Belodus triangularis* indicate a Givetian age. In the basal part of the slightly dolomitic and massive bedded member C the trilobite *Neocalmonia (heliopyge) iberia*, H a a s, 1970 indicates a (Lower) Frasnian age (S m e e n k, pers. comm.). Until the top of the section near Huergas de Gordón we remain in the (Lower) Frasnian, as is confirmed by an association of the trilobites *Phacops (phacops)* sp.; *Scutellum* sp.; *Proetus (proetus)* sp. (cf. S m e e n k in prep.).

The three sections discusses in a chronostratigraphic way are shown on fig. 1. An attempt has been made to picture the lithologies against time, in order to visualise the Portilla Limestone Formation as a diachronous unit in the discussed area.

DEPOSITIONAL HISTORY

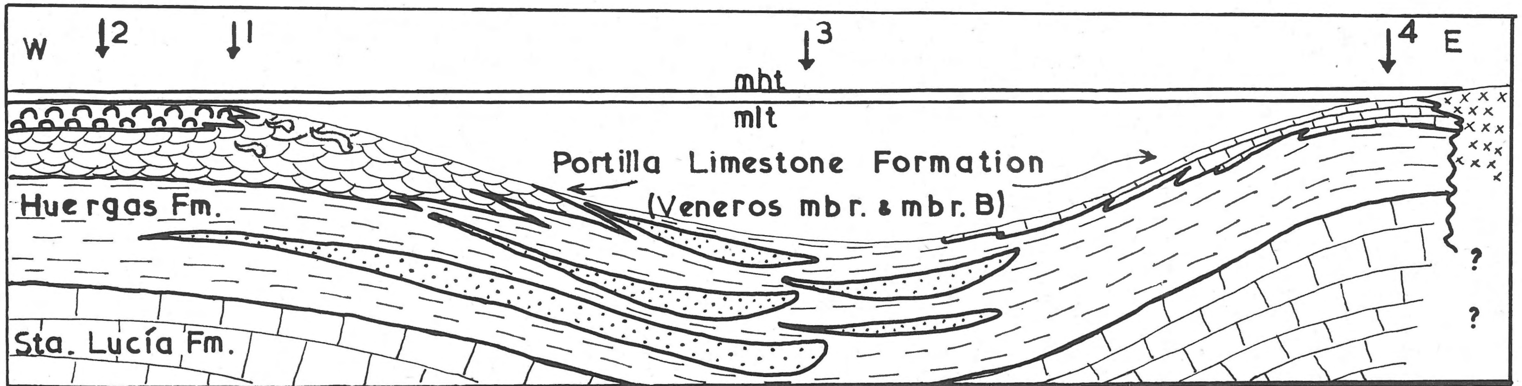
During the Eifelian, in the west and in the east, deposition occurred on shallow platforms (fig. 3). These were presumably related with adjacent heighs and/or land areas (R e i j e r s, 1972) which occasionally supplied siliciclastic sediments. In the shallow seas a favourable environment prevailed for the flourishing of a rich variety of benthic life so that we find the remainder of prolific crinoid-bryozoan growth mixed with considerable amounts of coralline elements. The desintegrated skeletal fragments swept together by current and wave activity form the detral well-washed cross-bedded lower part of the Portilla Limestone Formation. In places, however, muddy sediments and intervals with calcareous shales and argillaceous limestone indicate rather quiet conditions.

In the nose of the Alba syncline coralline elements became prominent, and more uniform conditions of deposition prevailed towards the end of deposition of member A (*sensu* M o h a n t i, 1972). Extreme shallow, turbulent conditions may be deduced from erosion surfaces and from the prominence of stromatoporoids (L e c o m t e, 1958, 1961, 1970; E d i e, 1961). Generally carbonate sedimentation kept pace with subsidence of the sea bottom. A few times influxes of siliciclastics interrupted the accumulation of carbonates and platy and branching tabulate corals started flourishing in argillaceous sediments. Near Sagüera subsidence presumably was too quick for the carbonate sediments to keep pace with, resulting in wedging-out and gravitational gliding and slumping of the partly lithified carbonate sediment, as can be deduced from the 'knicks' in beddings in the interval, and from the internal contortions in certain beds. The slumping direction, after correction for the structural dip, is towards SE, suggesting the presence of a slope in that direction.

The central area shows characteristics of a basin with a somewhat deeper and quieter depositional environment. Real slopes are present along the edges of the basin as is illustrated by the gravitational features near Sagüera. The limestone deposition stops where the basin is unfavourable for limestone deposition, or it is 'drowned' where the supply of siliciclastic material predominates. The siliciclastic material is supplied by the northern Leonides, as a response to erosion, due to positive epeirogenetic movements (cf. d e S i t t e r, 1966; E v e r s, 1967). The deposits strongly resemble a protruding delta which gradually filled up the basin (Fig. 3).

In the Givetian period the supply of siliciclastic material increased – possibly due to increased positive epeirogenetic movements north of the Sabero-Gordón line – and transported siliciclastic material was spread out more evenly over the whole area. The area in which in previous times predominantly limestone was deposited, now show red-brown marly and silty intercalations and shaly intervals. The siliciclastic sediments are finer grained than those previously deposited. Together with this material the conodont *Polygnathus foveolatus* was transported towards the base of the Portilla Limestone Formation in the section near Huergas de Gordón indicating that erosion in the northern Leonides had already cut into the Emsian . (The Emsian coincides with the top La Vid and the base Sta. Lucía Formation). The mixed Brachiopoda fauna on the transition Eifelian-Givetian in the Portilla Limestone Formation, described by M o h a n t i (1972), might partly be considered as transported from the eroded northern area. In the area of deposition of the siliciclastics locally extremely rich coral faunas developed. The corals formed small scattered biostromes which are present as limestone lenses in a predominantly siliciclastic deposit. Bioherms are not present. The sedimentary features suggest a shallow, open marine depositional environment, strongly resembling 'facies g' of the sedimentation model for the Portilla Limestone Formation (R e i j e r s, 1972). Further towards the east these sediments change into dolomitised and dedolomitised (dedolomitisation points towards temporary subareal exposure; cf. d e G r o o t, 1967) bio-accumulated banks and protected shallow-platform sediments.

In the west the situation was entirely different. M o h a n t i (1972) recognised a 'barrier reef' pattern emerging at the beginning of the Givetian. It is characterised by prolific stromatoporoid-coral growth, which established on areas with slightly higher relief. Behind the reef (to the east) a sheltered, back reef facies is characterised by '...calcareous silty shales and argillaceous wackestones and packstones containing platy tabulates, few compound rugose corals and localised concentrations of brachiopod shells...' (p. 155), followed by argillaceous packstone-wackestone in which platy and branching tabulates abounded. Mohanti reasons (p. 154) '...this backreef area was separated from the area of siliciclastic deposition farther southeast of section PSF (near Sagüera village) by an extremely shallow marine or shoal area which might have been emergent...'. The present author favours the opinion that in said direction a gradual transition occurred into the basinal (siliciclastic) environment. This explains quite satisfactorily the oscillatory influx of siliciclastics and the simultaneous development of Thamnopora carbonates, which latter are supposed to be result of prolific growth of *Thamnopora* sp. in biostromes on the edge of the siliciclastic basin. The 'large-scale cross-bedding' aspect and



SHALLOW PLATFORM		BASIN WITH DELTA & TURBIDITE SEDIMENTS	SHALLOW PLATFORM
ALBA	SAGÜERA	HUERGAS DE GORDÓN	MATALLANA
massive beds	platy, regular beds	predominantly parallel bedded, some pseudo-parallel beds	wavy bedded
structureless reefal lst. cross bedding some arg.lst.	15 m long, 3-5 m. high slump. graded beds	planar and trough stratification. angles ranging to 15°. occasional load casts & slumps. poorly preserved stratification in bioturbated intervals	erosion planes gullies & wedges fining upwards
reefal lst, arg. lst. & shale (Pst/Wst to Bdst)	(reefal lst.) arg. lst., encrinal lst. (Gst)	sandstone, siltstone & shale, locally Wst/Pst lenticles. sst/sh ratio increases towards top	Pst/Wst lst. dolomite, dolomitic lst., dedolomite
massive, platy & "rod"-like corals, stromatoporoids, bryozoans	crinoids, bryozoans (platy corals)	zaphrentoid corals, heliolites-like corals, cistoids, blastoids, plant remains, coquinoid levels	"rod"-like & platy corals, stromatoporoids, crinoids

PORMA HIGH (cf. REIJERS, 1972)

HYPOTHETICAL CROSS SECTION THROUGH BASIN IN LUNA-PORMA AREA AT TRANSITION EIFELIAN-GIVETIAN

mht= mean high tide

NOT TO SCALE

Fig. 3
Hypothetical cross section through the basin in the Luna-Porma area at the transition Eifelian-Givetian, and some of the sedimentological, stratigraphical and palaeontological characteristics. For legend see fig. 1. The lithological description is according to D u n h a m, 1962.

the gentle depositional slope in roughly NW direction are then explained as a prograding of the reef (talud?) towards a slightly deeper environment. The 'barrier reef' pattern persisted throughout the deposition of member B, due to favourable ecological and epeirogenetic conditions. Probably due to changes in relative subsidence during deposition of member C the 'barrier reef' growth terminated. A strong supply of siliciclastics covered the carbonate sediments in the area near Matallana, towards the end of the Givetian period, and brought somewhat later an end to the Portilla carbonate sedimentation in the Alba syncline. Only in the area near Huergas de Gordón the carbonate sedimentation persisted. The sands are medium grained. The transport direction of the sand suggests a provenance from the NW corner of the northern Leonides, between the Porma fault and the León line, which corner is most deeply eroded (cf. van den Bosch, 1969, p. 174 Fig. 43).

In the Frasnian period deposition of fine-grained sands sometimes was interrupted by deposition of minor amounts of shale and of some limestone lenses. In the central part of the considered area a reversal in topography in comparison with the Eifelian period may now be assumed from the increasing amount of limestone. The previous basin has successively been filled up with delta sediments and with sediments resembling 'facies g' (Reijers, 1972). Biostromes developed. Erosion surfaces and dedolomitisation point to the extremely shallow character of the area of deposition. Transition into overlying shaly sediments is very gradual. The sediments contain coaly inclusions and plant remains, proving that land was relatively nearby. Shale is gradually replaced by silt and sand. In the western and central parts of the area, immediately overlying the Portilla Limestone Formation, we see turbidites. Since no turbidites have been seen near Matallana, but beach-like deposits instead, we may presume that the Porma fault area acted as a high, along which beaches formed. From this high onwards, towards the west, turbidites developed. Breccious, ferruginous sandstone fragments higher up in the sequence prove that the erosion of the Upper Devonian in the northern Leonides has reached the Lower Devonian San Pedro Formation.

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