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FACIES DISTRIBUTION AND BASIN CONFIGURATION IN THE PISUERGA AREA BEFORE THE LEONIAN PHASE

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ABSTRACT

A sedimentary facies description is given of a thick sequence of Westphalian D strata developed below the Leonian disconformity in the Pisuerga area of northern Palencia. This succession was formed in a series of deltas, and including limestones as the open sea equivalent of siliciclastic delta top deposits. Submarine fans were apparently associated with the deltas. The supply of siliciclastic material came from the south-west, and the facies zonation in the deltas shows an approximate NW-SE strike.

RESUMEN

Se describen sedimentos de edad Westfaliense D en la cuenca hidrográfica del alto río Pisuerga (Palencia), estudiándose la secuencia desarrollada antes de la fase tectónica leónica que aquí se presenta como una disconformidad. Estos sedimentos se formaron en una serie de deltas, hallándose además calizas que son consideradas como el equivalente totalmente marino de las capas superiores, siliciclásticas, del delta. Los deltas están asociados con turbiditas que se interpretan como coluviones submarinos. El material siliciclástico muestra una procedencia suroeste y los deltas tienen las líneas isópicas orientadas de NW a SE. El desarrollo de estos deltas se asemeja al del delta actual del Ródano, si bien existe una diferencia en la escasez de calizas en este último.

INTRODUCTION

The Pisuerga area forms the easternmost part of the Palaeozoic core of the Cantabrian Mountains. Predominantly Carboniferous strata are exposed here in a number of steeply dipping fold structures, controlling the outcrop of strata which form only part of the originally much more extensive depositional basin. The general aspects of the area were described by DE SITTER & BOSCHMA (1966) who published a useful 1 : 50,000 map, and by WAGNER & WAGNER-GENTIS (1963), among others. Palaeontological data used for correlations were furnished by VAN GINKEL (fusulinids, 1965), RÁCZ (calcareous algae, 1965), and WAGNER (continental floras, 1960, 1962).

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The sedimentary facies and their depositional history have, thus far, been studied only by NEDERLOF (1959) who presented a statistical treatment of turbidites and some broad facies interpretations. READING (1970) gave more detailed facies interpretations but, owing to the nature of his work, did not present a regional interpretation of their distribution.

This preliminary report will be followed by a more fully documented paper in the *Leidse Geologische Mededelingen* (1971).

DELIMITATION OF THE SEDIMENTARY INTERVAL STUDIED

The lower limit has been taken within the upper part of the Vañes Formation (*sensu* BROUWER & VAN GINKEL 1964), at about the level where a change occurs from relatively deep water sediments, i.e. turbidites, to shallow-water sediments, as indicated by large-scale cross-stratification. As the level of this transition is not very far below the Socavón Limestone, which is the lowest well dated horizon, there is a sufficiently accurate palaeontological control for correlation.

The upper limit lies at a major disconformity which has been first described as a local diastem by NEDERLOF (1959) at Cabra Mocha in the Sierra Corisa/Alto Sierra but which was not generally recognized until WAGNER & WINKLER PRINS (1970) and WAGNER & VARKER (1971) showed its areal extent and stratigraphic significance in northern Palencia. This disconformity is marked by clear signs of erosion and often shows the presence of a well washed, well sorted quartz arenite following upon a limestone in the upper part of the sedimentary sequence formed before the uplift. The tectonic movements associated with this disconformity are ascribed to the Leonian phase (*op. cit.*). The disconformity truncates the Westphalian D succession described here, with a new basin development taking place after a stratigraphic gap of variable magnitude (WAGNER & VARKER 1971).

The sedimentary interval as defined above comprises the upper part of the Vañes Formation and most of the Sierra Corisa Formation (base of the latter arbitrarily taken at the base of the Socavón, Agujas and Camasobres Limestones).

It should be noted that the stratigraphic nomenclature in this area is in urgent need of revision as the different authors have used generally ill-defined names in a rather haphazard way.

The age of the studied interval is Westphalian D (continental floras, WAGNER, pers. comm., and 1962, 1963) or Upper Moscovian (fusulinids, VAN GINKEL 1965).

DESCRIPTION OF SECTIONS

Three sections have been selected for description. They give a fair representation of the sedimentary facies types present in this area and their location permits a reconstruction of the way in which the original depositional basin was filled. The location of these sections is given in text-fig. 1.

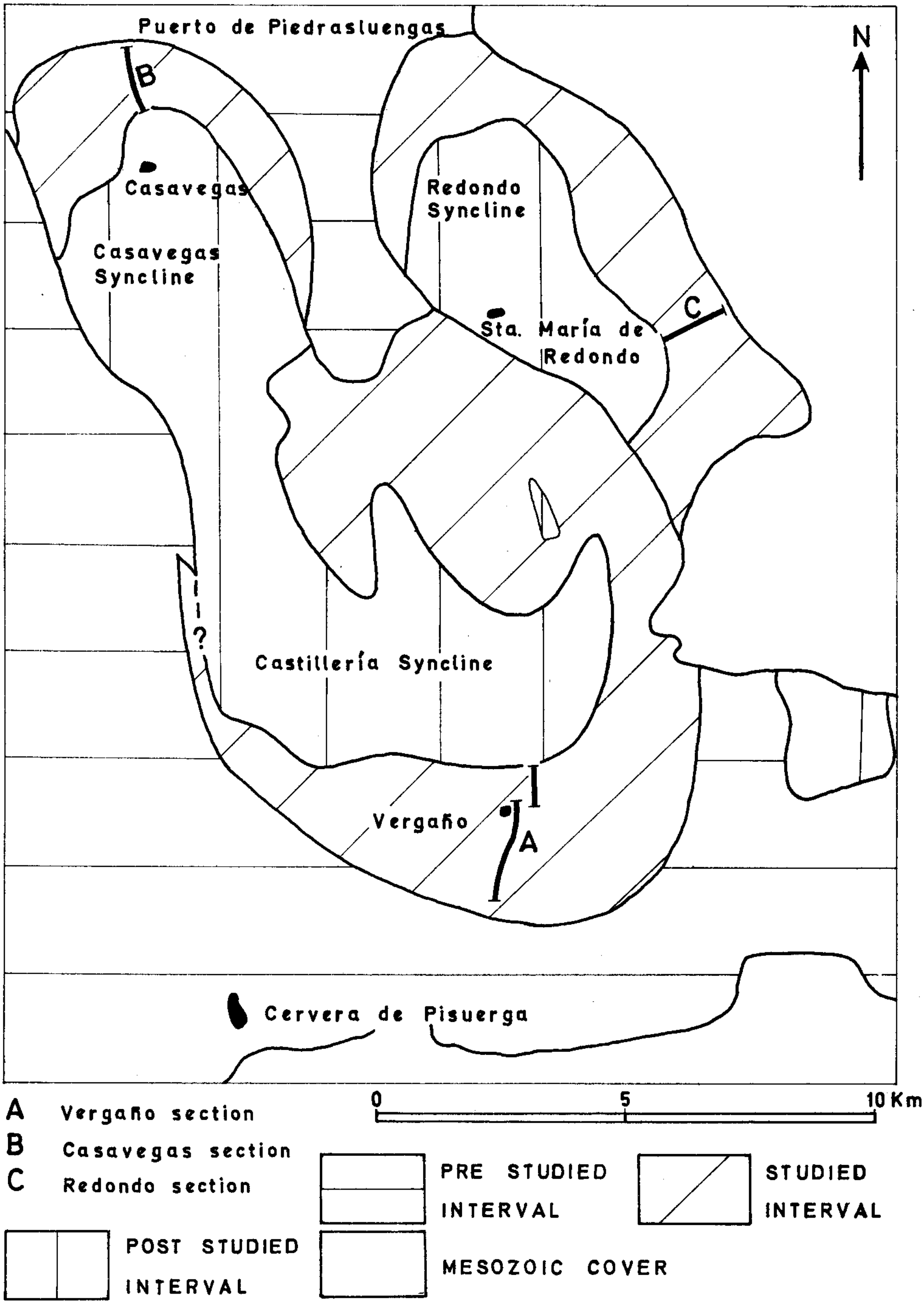


Fig. 1.—Situation map of Pisuerga area (modified after DE SITTER & BOSCHMA 1966).

Vergaño section.

This section was measured along the road to Vergaño and, from the San Cebrián coals upwards, in the valley NE of Vergaño. The base was taken at the top of a thick unit of black shales. Below these shales occur at least 350-450 metres of fairly well exposed, nearly undisturbed strata, which are not considered here. In the highest part of the black shales, which are about 60 m thick in this locality, gastropods, lamellibranchs, trilobites, ostracods and cephalopods were found. They are followed by a sandstone-shale alternation, approximately 200 m thick. The sandstones are lithic arenites to lithic wackes which are characterized by good lateral continuity, sharp bases, frequent grading and sporadic sole marks. The thicker beds tend to have sharp tops, but on the whole gradational tops are more common. Where a sequence can be distinguished within a bed, it is as follows: massive - laminated - rippled - laminated. This sequence is not always complete but the order remains the same. Especially the thicker beds occurring mainly in the first 50 m, tend to be massive and structureless. Spheroidal weathering can mask the characteristics mentioned.

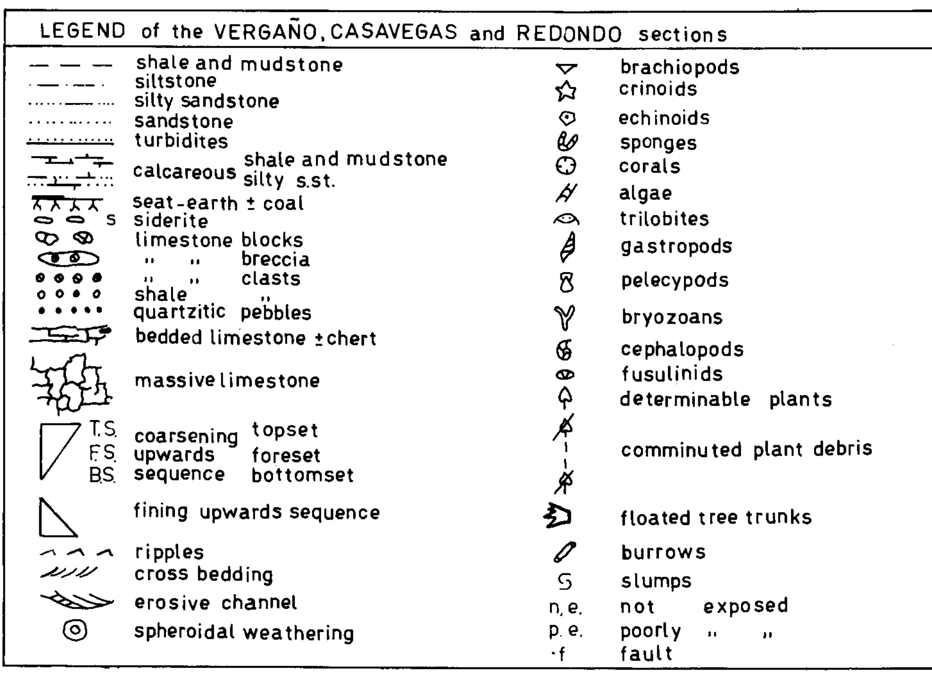


Fig. 2.—Legend of stratigraphic sections.

At about 170 - 200 m a pronounced facies change occurs. True shales disappear and the contacts between the beds become gradational. The following sequence shows clearly an upward increase in mean grain size. Whether the maximum grain size also increases has not yet been ascertained. At 235 m channel-fill sandstones with large trough cross-stratification appear for the first time. These channelled, cross-bedded sandstones dominate the sequence in the next 40 m. They often show an upward decrease in mean and maximum grain size, and a concomitant decrease in the size of the cross-stratification. READING (1970) has observed indications of autochthonous plant growth at about this horizon.

Rippled and laminated shales, siltstones and sandstones with some channel sandstones constitute the next 50 m.

A subsequent unexposed interval contains shales and siltstones, as could be ascertained by tracing this unit laterally. A discontinuous, micritic limestone, up to 0.5 m thick, is present at 405 m. It yielded algae, crinoids, brachiopods and solitary corals.

In the next 100 m several units show the upward increase in mean and maximum grain size as mentioned before. These sequences are mostly terminated by large-scale cross-bedded or, less commonly, channelled sandstones with either a gradational or a sharp top.

At 525 m another discontinuous, micritic limestone is found. It contains solitary corals, algae and crinoids. Poorly exposed sandstones on top of this limestone contain a fairly rich fauna consisting of brachiopods, gastropods and lamellibranchs.

Shales and siltstones with some sideritic concretions, overlying this horizon, are followed by another sandstone-shale alternation as observed in the lower part of the section. The sandstone beds are again characterized by a marked lateral continuity, sharp bases, and mainly gradational tops. The sequence of internal structures is massive-laminated-rippled-laminated, always in this order though it may be incomplete. In comparison with the lower part of the section fewer thick sandstones are present. Spheroidal weathering is a characteristic feature of the thick, often rather massive beds.

A gradational change to shales, siltstones and sandstones takes place at 640 m. This unit is characterized by mainly gradational contacts between the beds. There follows another sequence with an overall increase of mean and maximum grain sizes in upward direction. In the upper part channelled, large-scale cross-bedded sandstones are common.

Between 830 and 877 m similar channel-fill sandstones are present. These, however, show clearly an upward decrease in mean and maximum grain size, concomitant with a decrease in the size of the cross-stratification. Three seat-earth horizons with associated coals are present in this interval. Strongly erosive channel-fill sandstones cut through two of these coal horizons.

At 850 m exposures along the road become too poor to permit the measuring of a detailed section. The measuring was continued at the eastern side of the valley, along the path from Vergaño to San Cebrián de Mudá. Either a minor overlap or a gap in the measuring may have occurred at this level.

The uppermost coal is cut by an over 12 m thick channel-fill sandstone. Its lower part is of a lithic arenitic composition and contains numerous floated tree trunks. Up to this horizon all the sandstones, except the one overlying the upper Socavón Limestone, can be classified as lithic arenites to lithic wackes, i. e. all are

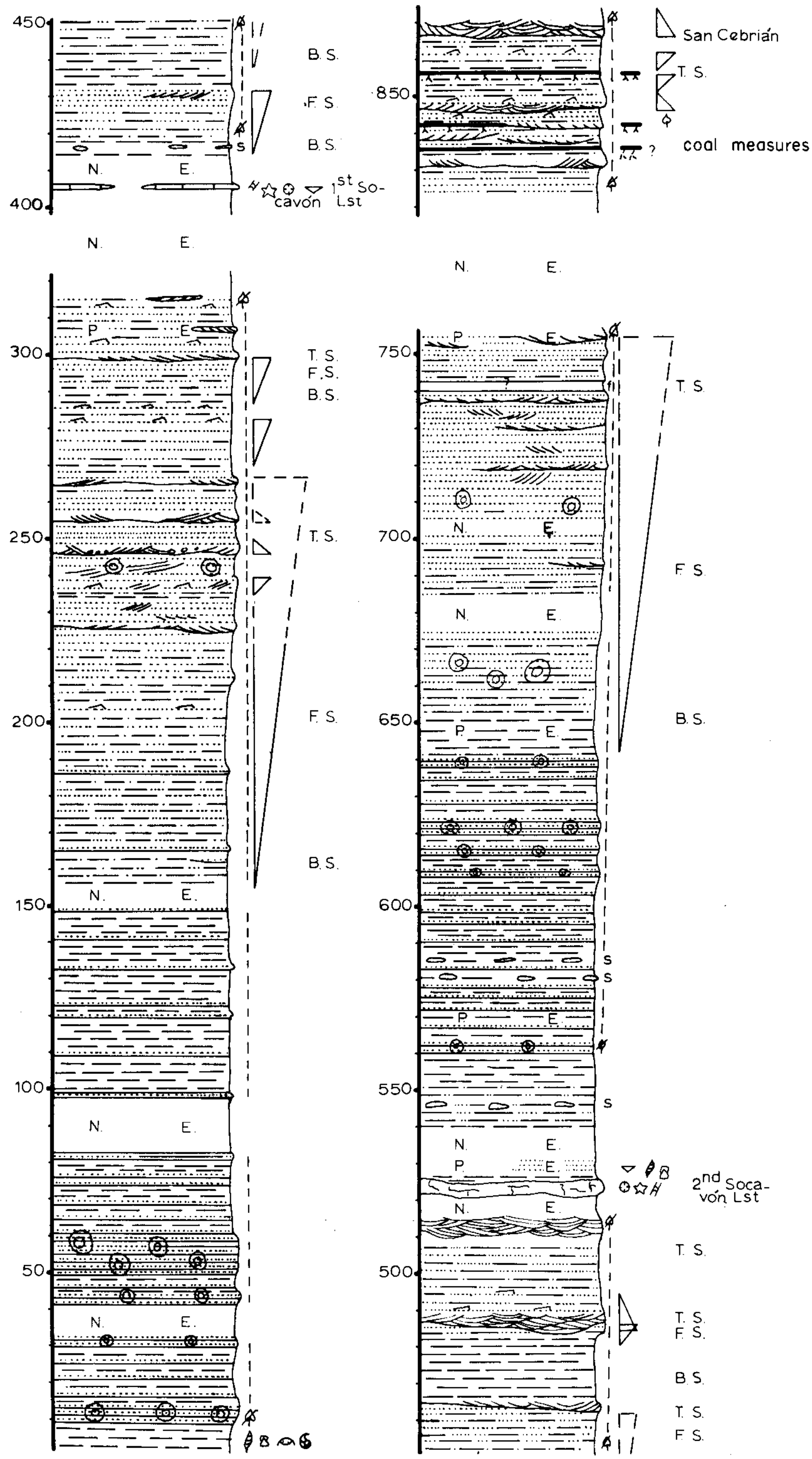
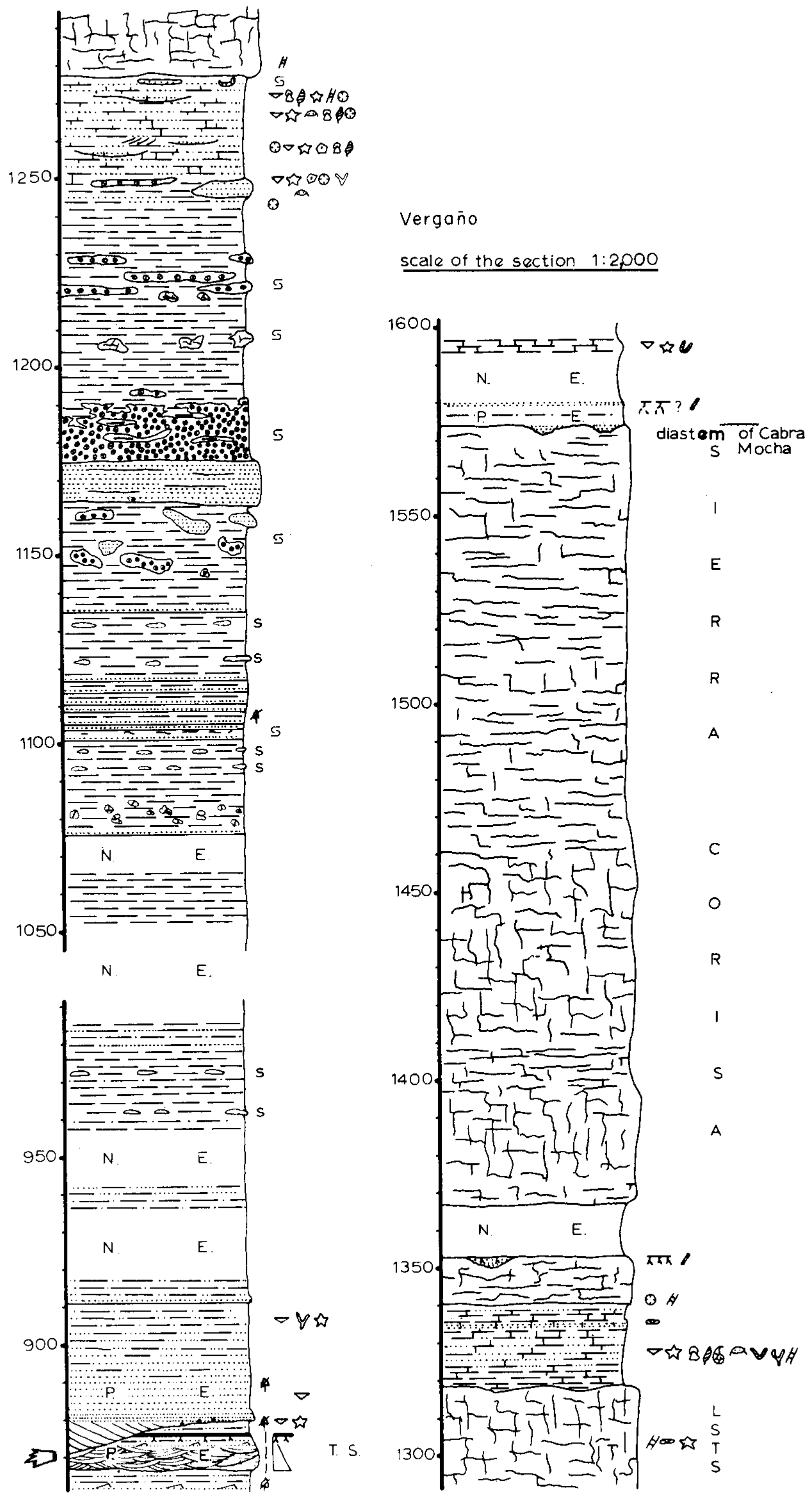


Fig. 3.—Section measured along the road and in the valley NE. of Vergaño (Palencia). Scale 1: 2,000.


Vergaño
scale of the section 1:2000
1250
1200
1150
1100
1050
950
900
N. E.
P. E.
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1300
diastem of Cabra Mocha
SIERRA CORISA
LSTS

texturally and compositionally immature. Furthermore, most of these sandstones are fairly rich in comminuted plant material. This can clearly be seen on the bedding and lamination planes.

The upper part of the channel-fill is a slightly calcareous quartz arenite containing some quartzite pebbles as well as some brachiopods and crinoids. It seems to grade into some 10 metres of poorly exposed sandstones which are characterized by mostly gradational contacts between the different beds. There is an upward decrease in maximum and mean grain sizes and at 905 m the sandstones have changed into decalcified sandy siltstones with numerous brachiopods, crinoids and bryozoans.

From 910 to 1070 m there is a predominantly shaly interval with some silty intercalations. Sideritic concretions occur at several levels.

Between 1070 and 1240 m sandstones and shale-rich limestone breccias form important intercalations in a shale sequence. Sandstones at 1076, 1110, and 1135 m show the following characteristics: good lateral continuity, sharp bases, grading, sole marks, gradational tops. The sequence of internal structures of a bed is massive-laminated-rippled-laminated, always in the same order even though the sequence may be incomplete. The thick sandstone at 1170 m has a sharp erosive base and a sharp top. A few irregular bedding planes could be seen in the sandstone itself. The limestone breccias have a shale to siltstone matrix. The limestone clasts often «float» in this matrix but they may also form a grain-supported framework. Some large, contorted sandstone fragments (over 1 m in diameter) are present at 1155 m. These breccias have mostly a lensing or irregularly bedded appearance. The maximum diameter of the limestone clasts is about 5 metres (at 1208 m). In or near these breccia horizons, there are frequent indications of intensive contortion.

From 1245 to 1278 m calcareous shales, siltstones, sandstones and impure calcarenites to calcirudites form a transition from the rather pure siliciclastic sequence below to massive limestones above. These calcareous strata show vague channelling in places, but contorted and brecciated layers also occur. Some contorted sandstone lenses are present a few decimetres below the very sharp and irregular contact with the overlying limestone.

The limestone is a rather massive, micritic limestone containing numerous stromatactis-like structures in the basal part. Its top is irregular and sharp. It is partly greyish yellow because of diagenetic dolomite.

Above the limestone lies a shale which is locally of a reddish brown colour. The remainder of this siliciclastic interval may locally grade into impure limestones. Small-scale unconformities occur in the lower part. At about 1330 m the sediment is richly fossiliferous containing, among others, prolific sphinctozoan sponges (VAN DE GRAAFF 1969).

This siliciclastic interval has a sharp junction with overlying limestone. On top of this limestone, which is largely micritic, a few erosion pockets occur, which are filled with quartz arenites. Rootlets and burrows are present in the upper part of the sandstone. This is followed by over a hundred metres of limestone, which is a massive to irregularly bedded wackestone to packstone. The upper 115 m of this limestone interfinger with siliciclastic sediments. On top of this thick limestone there is another horizon with erosion pockets filled by quartz arenites.

Interpretation.—The fossil contents of the black shales at the base of the section prove their marine origin, and the succeeding sandstone-shale alternation is interpreted as a turbidite sequence. Whilst the turbidites of the basal part are immature and amalgamated, those of the upper part are mainly mature.

The increase in grain size, which begins at about 160-200 m, with a concomitant change in sedimentary structures from scarcely rippled sandstone to channels with large-scale cross-stratification, indicate an increase in water energy. Such a coarsening upwards sequence is characteristic of deltaic environments (e. g. OOMKENS 1967). A differentiation into bottomset, foreset and topset has been indicated in the drawn section. The topset, with its fining upwards sequences characteristic of channel-fills, can be interpreted as a fluviatile delta top. However, the lack of rootlets and coal indicates that subaerial exposure was unimportant in this part of the delta. Several minor coarsening upwards sequences were recognized between 250 and 300 m. These probably represent minor distributaries which discharged into fairly shallow water.

The limestones at 405 and 525 m indicate that fully marine conditions alternated with the fluviatile deltaic phases. Between these two limestones, which correlate with the Socavón Limestones, there is no evidence in the form of rootlets that the coarsening and fining upwards sequences ever produced a really sub-aerial sedimentary surface. The occasional occurrence of such conditions cannot be excluded, however. The presence of limestones indicates that, locally, the supply of siliciclastic material was sometimes negligible. The most favourable conditions for this absence could be realized in isolated lagoons on the delta top. In addition after a major delta switching there is little siliciclastic sediment available on the delta top. Combined with continued subsidence a transgression would be produced, during which limestones could be deposited. The limestone at 525 m may represent the early stage of such a transgression.

From 560 to 640 m there is another turbidite sequence followed by yet another major coarsening upwards sequence. This one may culminate in subaerially deposited sediments, but the paucity of exposure does not permit an unequivocal conclusion in this respect. However, the lateral equivalent of this interval indicates that it consists of delta top deposits. The coal-bearing delta topset sediments around 850 m constitute the San Cebrián coal measures, which are mined approximately three kilometres to the east. The autochthonous coals prove that this part of the section represents the subaerial part of the delta top. The large sandstone filled channel which cuts through the uppermost coal is probably of fluviatile origin. This is indicated by the lithic arenitic composition of the sandstone which is the same as that of the deltaic sandstones below. The upper part of the channel fill has a quartz arenitic composition and contains marine fossils. This means that the upper part was deposited after a drastic change in environment.

A gradual increase in the volumetric importance of the finer grain sizes in the next 15 - 25 m indicates a marked decrease in the supply of coarse clastics with an associated deepening of the environment.

Instability of the depositional slope is indicated by mudflow and/or slump deposits interbedded with turbidites between 1070 and 1250 m. The limestone rich sequence between 1250 and 1277 m represents a shallower environment than the underlying strata. Nevertheless, the instability of the sea bed continued since some slumping occurred. A shallow water origin is indicated by the rich flora and fauna.

The very sharp and irregular contact of the lowermost Sierra Corisa Limestone with the underlying strata may be due to some minor syn-sedimentary movements of the limestone. That these movements were indeed syn-sedimentary is proved by the small unconformities which occur in the siliciclastic interval above the *ca* 45 m thick limestone. The stromatactis-like structures occurring at the base indicate that the limestone itself is at least partly a boundstone, whereas the entire unit is considered to be a biogenetic bank deposit. The very shallow water origin of these limestones and the associated siliciclastics is indicated by the numerous algae. The seat-earth horizon at 1352 m furnishes additional proof of the very shallow water origin. The poor lateral continuity of this diastem indicates that it is only of minor importance.

The overlying limestone is another biogenetic bank deposit, which interfingers with a seat-earth containing siliciclastic delta top deposit, about 200 - 500 m west of the line of the section.

The diastem above this limestone is of more than local importance as it can be traced around the Castillería Syncline. This diastem is best developed SE of the Cabra Mocha hill, a few kilometres to the west.

Casavegas section.

This section was measured along the path from Caloca to Casavegas. Exposure below the Camasobres Limestone is poor in this part of the Casavegas Syncline.

The Camasobres Limestone, which shows rapid thickness variations in this area, consists mainly of massive to irregularly bedded, micritic limestone. It is followed by *ca*. 60 m of shale/mudstone.

At 155 m a few sandstone beds occur. These are characterized by good lateral continuity, sharp bases, gradational tops, grading and sole marks. The sequence of internal structures is laminated-rippled-laminated.

At about 170 m the character of the sediment changes from shale to siltstone and/or sandstone with some ripples and gradational bases and tops. An overall increase in mean and maximum grain sizes towards the top is apparent. At 183 m channel-fill sandstones, of a quartz arenitic composition, with large-scale cross-bedding, are present. These cross-bedded sandstones grade into rippled and laminated sandstones and siltstones.

Between 220 and 250 m a sandstone-shale alternation is present. These lithic arenitic sandstones have the following characteristics: sharp bases, gradational tops, grading, indistinct sole marks and good lateral continuity. The sequence of internal structures is laminated-rippled-laminated.

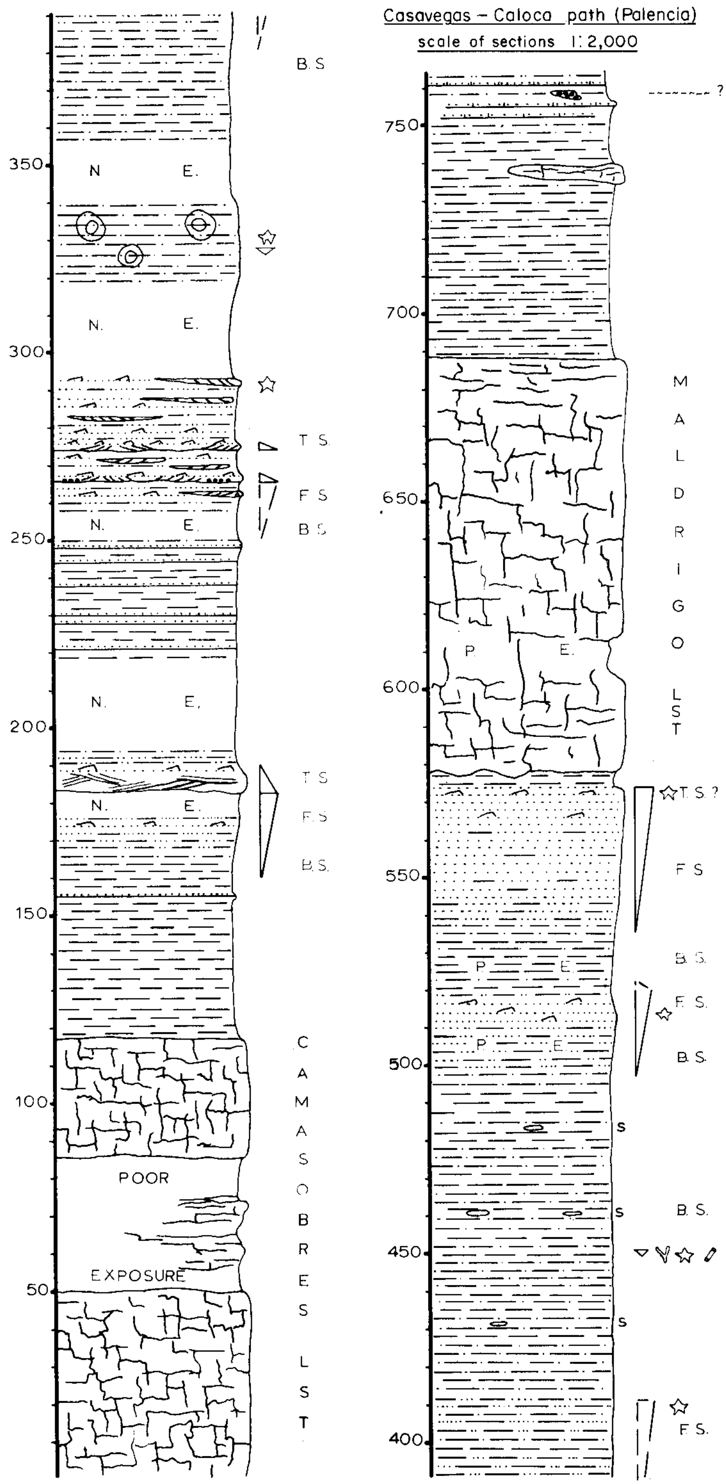

Fig. 4.—Section measured along the path from Casavegas to Caloca (Palencia). Scale 1 : 2,000

Between 260 and 295 m quartz arenitic sandstones and siltstones are exposed. The basal part shows a clear increase in mean and maximum grain sizes. The remainder of this part of the section contains numerous channel-fill sandstones, with erosive bases and large-scale cross-bedding. One of these channel-fills can be traced laterally for several hundreds of metres. It is characterized by lydite and quartzite pebbles, up to five centimetres in diameter. In the upper part of this sequence a few crinoid columnals were found.

Then follows a monotonous sequence of sometimes slightly calcareous shales, siltstones and some sandstones. Distinct bedding planes are few and only gradational contacts have been observed. Marine fossils occur at several horizons. At about 400 m there is a slight increase in the mean and maximum grain sizes of the sediment, without becoming a true sandstone. From 320 to 500 m bioturbation is obvious in polished surfaces.

At 510 m another example of this upwards increase in mean and maximum grain sizes occurs. This time the uppermost part is a rippled quartz arenitic sandstone which grades into shale. Between 540 and 575 m yet another such sequence with an upwards increase in mean and maximum grain sizes is exposed. Its upper part consists of a quartz arenite, sometimes rippled, with some crinoid debris. This sandstone has a sharp top and is covered by shale.

The Maldrigo Limestone was not studied in any detail at this point. Nevertheless it is clear that very rapid thickness changes occur. The lower part has an irregular, possibly erosive contact with the underlying shale. In the first few metres it has a brecciated appearance. The middle part is mainly a massive micritic limestone. The upper part is again a calcirudite to calcarenite.

After a sharp contact a shale - siltstone sequence follows, which has not been surveyed accurately. At about 740 m a massive, micritic limestone lens is present. Its contacts with the surrounding shales were poorly exposed.

Above 750 m a few thin (4 - 8 cm) calcareous to calcarenitic sandstones occur. They seem to have the following characteristics: good lateral continuity, sharp bases, gradational tops and grading. A small lens of limestone breccia with clasts of over a centimetre in diameter, occurs at about this level. This lens probably correlates with a much larger one, down in the valley to the west of the path. From this larger lens WAGNER & VARKER (1971) record transported coal fragments. They refer this to the base of the post - Leonian succession. From here on the section is described in the paper by WAGNER & VARKER.

I n t e r p r e t a t i o n.—The Camasobres Limestone seems to consist mainly of biogenetic bank deposits. The shales with the turbidites at 155 m are considered to have been deposited in slightly deeper water than the limestones. The turbidites are overlain by a coarsening upwards sequence, the upper part of which consists of channel-fill sandstones. This is typically a shoaling or regressive sequence as presently found in deltaic areas. Compared with the Vergaño section the sandstones are relatively clean and mature. It has not been possible to ascertain whether these are fluviatile or marine deltaic deposits.

The sandstone-shale alternation between 220 and 250 m is interpreted as a turbidite sequence, and this indicates a return to slightly deeper water, as compared to the delta topset deposits below.

The next coarsening upwards sequence has a poorly exposed lower part. The topset is very well developed as compared to the foreset. The marine influence on the delta topset is clearly shown by the presence of crinoidal debris.

The next 200 m are good examples of off-delta to pro-delta deposits, intensively bioturbated and quite fossiliferous.

The indistinct coarsening upwards sequences as preserved at 400 and 510 m are considered to be incipient beach barriers, which never fully developed. Only in the uppermost one did the beach barrier develop fully, as is indicated by its sharp top.

The Maldrigo Limestone is also considered to have originated as a biogenetic bank deposit. The overlying shales and siltstones indicate a slight deepening and/or a greater supply of siliciclastic material.

Redondo section.

This section was measured in the valley of the Pisuerga river in the eastern flank of the Redondo Syncline. Its base was taken at the base of the Agujas Limestone, *ca.* 1 km north of the Cueva Cobre. The top was taken at the top of the lateral equivalent of the Abismo Limestone, due east of the Pozo del Diablo.

The Agujas Limestone consists, at this point, of a well bedded lower part and a more massive upper part. Both parts are largely micritic.

It has a sharp contact with the overlying, monotonous sandstone-shale alternation which has a thickness of several hundreds of metres. The sandstones are characterized by sharp bases, good lateral continuity, sole marks, grading, gradational tops and an internal sequence of structures as follows: massive - laminated - rippled-laminated. Although this sequence may be incomplete its order does not vary. Most of the sandstones are quartz arenites to quartz wackes but a few lithic arenites to lithic wackes do occur. At a few horizons sideritic concretions are present.

From 554 to 722 m a number of thicker sandstones are intercalated in this sequence. These thicker sandstones have sharp bases with rare sole marks. They sometimes show a vague sequence in their upper part, from massive to laminated and rippled, and then a sharp top. Their thickness ranges from a few decimetres to over two metres. A 3 m thick, pebbly mudstone with some limestone clasts is intercalated in this part of the sequence.

Above this interval with thick sandstones follows a monotonous sequence of black shales with sporadic sharply based and graded calcareous sandstone beds. Horizons with sideritic concretions are numerous in this part of the section. At a few horizons, lenses or layers with limestone breccias occur. The graded calcareous sandstones become rarer towards the top.

At 1012 m there is a poorly exposed quartz arenitic sandstone with probably a sharp top and bottom. Above this sandstone lie about 12 m of richly fossiliferous calcareous shales. Gastropods, brachiopods, poorly preserved cephalopods, solitary corals, calcareous algae and sphinctozoan sponges were collected from this interval.

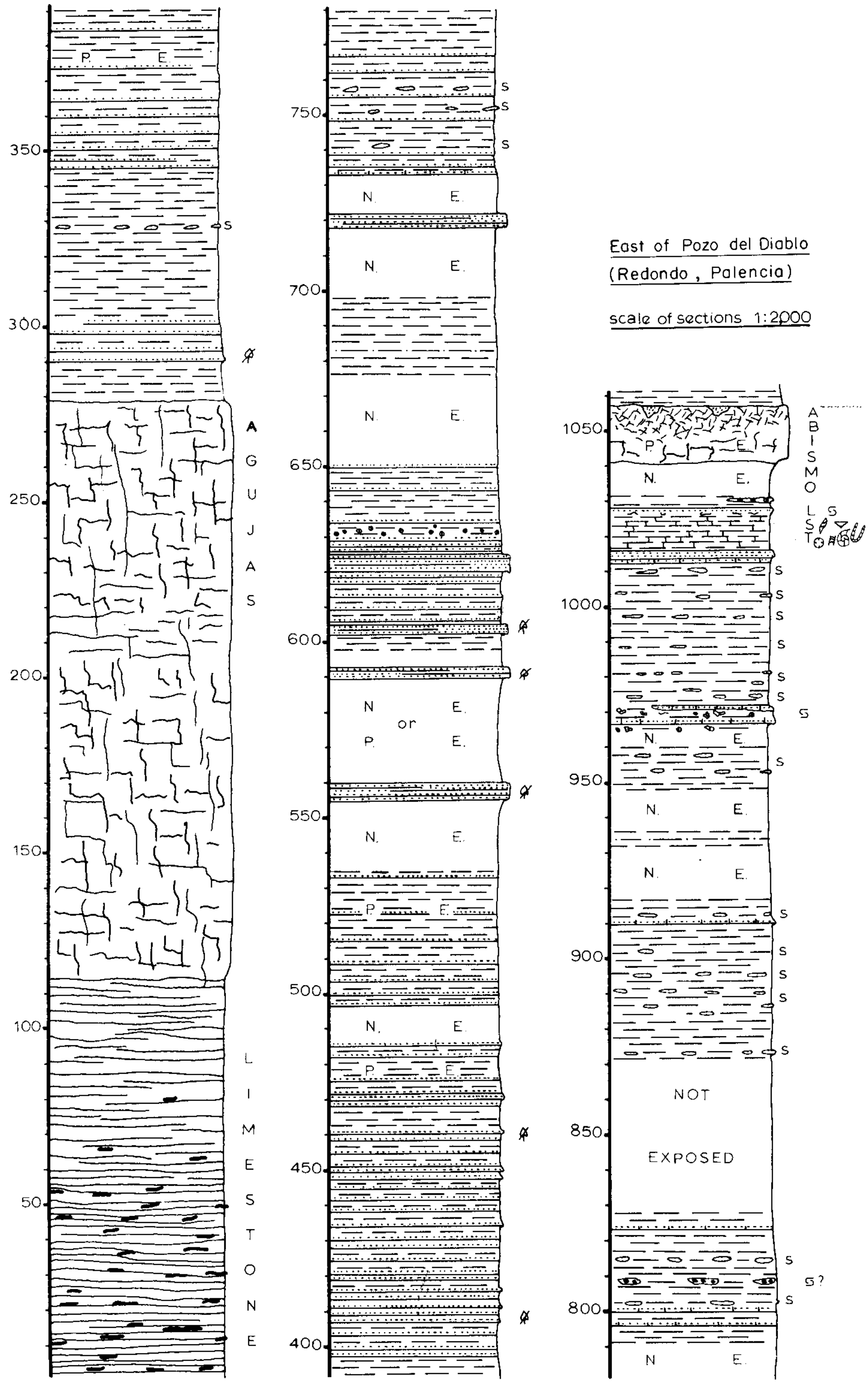

Fig. 5.—Section measured along the Pisuerga river, east of the Pozo del Diablo, Redondo Valley (Palencia). Scale 1 : 2,000

The next few metres are not exposed, and then follows a massive, micritic limestone with numerous algae. The base of the limestone is unexposed. Towards the top it seems to be progressively brecciated and the upper surface presents an over two and a half metres deep, sub-circular erosion pocket filled with a well sorted quartz arenite. This erosion level is ascribed to the Leonian uplift by WAGNER & VARKER (1971) who describe this locality.

Interpretation.—The lower part of the Agujas Limestone is interpreted as a lagoonal deposit, and the upper part as a biogenetic bank (see VAN DE GRAAFF, this volume). The sandstone - shale alternation is interpreted as a turbidite sequence. The lower part contains predominantly mature turbidites, but the 554 - 722 m interval also contains many immature turbidites.

The next part of the sequence still contains a few turbidites of mainly calcareous composition, but is mainly characterized by the presence of sideritic concretions.

The abundant fauna at 1020 m indicates a fairly shallow, open marine environment. The following limestone is the lateral equivalent of the upper (?) part of the Abismo Limestone. It is also considered to be a biogenetic bank deposit.

The erosion pocket in the top part of the limestone can be interpreted as a karst pothole and is indicative of sub-aerial erosion. The sub-aerial erosion probably caused also the brecciation of the limestone.

REGIONAL RELATIONSHIPS AND INTERPRETATION

The three sections described differ quite profoundly, as is obvious from the foregoing. The differences are due to their relative positions in the original depositional basin.

The Vergaño and Casavegas sections both show a cyclicity, although of a different kind. An alternation of relatively deep and shallow water deposits (turbidites and undisturbed shales *versus* sandstones with large-scale cross-stratification and limestones) is present in both sections. A cyclicity of a different scale may also have been produced by the channel-fill sequences. However, this type of cyclicity will not be discussed here.

The cycles are explained by changes in supply of clastic material at a certain point, combined with (irregular?) subsidence. The changes in supply are probably due to periodic changes in the course of delta distributaries.

In the Redondo section such a cyclicity has not been recognized. The Agujas and the Abismo Limestones are the only shallow water deposits in the whole sequence. As such they may form one very thick cycle.

Before the original relationships of these sections can be reconstructed the palaeontological data must be considered. The only palaeontological data available for a limestone correlation in this area are the foraminiferal and algal assemblages described by VAN GINKEL (1965) and RÁCZ (1965), respectively. The algal zonations closely conform to those provided by fusulinid foraminifera and this may be due in part to the fact that RÁCZ used VAN GINKEL's samples.

On the basis of their results the following correlations were established.

Castillería Syncline		Casavegas Syncline		Redondo Syncline.
Sierra Corisa Lst.	=	Maldrigo Lst.	=	Abismo Lst.
Socavón Lst.	=	Camasobres Lst.	=	Agujas Lst.

With these correlations it is now possible to interpret the regional facies distribution, as deduced from the described sections. It should be noted that these interpretations are partly based on additional data not discussed in the present paper.

The Vergaño section represents the most proximal part present of the deltas. Northwards, these deltas were fringed by a beach barrier rim. Beyond this rim no true delta topsets were formed, and the only shallow water deposits are limestones (Casavegas and Redondo sections). The two most important requisites for the deposition of the limestones are: 1) little or no supply of siliciclastics, and 2) sufficiently shallow water. These conditions are most likely fulfilled laterally off the deltas and on the delta top when a major shift in delta distributaries has occurred. This means that the limestones are in general the open sea equivalent of the delta topset deposits, or occur in close association with them. The former applies to the Agujas and Abismo Limestones and the latter to the Sierra Corisa Limestone which interfingers with delta topset deposits.

These deltaic deposits interfinger with turbidite - shale alternations, which are interpreted as submarine fan deposits. The sediment for these fans was provided by the deltas themselves. In these fan deposits, sandstones which were winnowed and sorted in the beach barrier rim before being resedimented, and sandstones which were directly resedimented, are easily distinguishable.

Two major delta «pulses» occurred and these are recognizable over the whole area. The first one culminated in the Socavón, Camasobres and Agujas Limestones. The second one culminated in the Sierra Corisa, Maldrigo and Abismo Limestones. The one which ended with the San Cebrián coal-measures is of minor importance. Numerous minor, more local deltaic sequences are present, as is shown on the sections.

The facies patterns indicate a sediment source in the southern to southwestern part of the area, with the deltas spreading to the northeast.

Compared with recent deltas, these deltas are rather exceptional in that they are associated with important carbonate deposits. A recent delta which is associated with a submarine fan, like these are, is the recent Rhône delta, and it is suggested that the general tectonic and sedimentary setting of these Carboniferous deltas is rather similar to that of the Rhône delta. Their size, however, is more like that of the recent Ebro delta.

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