GEOLOGY OF THE EASTERN ZONE OF THE SIERRA DEL BREZO (PALENCIA-SPAIN)

BY

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CONTENTS

PREFACE

The basis for this thesis is a field investigation in the northwestern part of the province Palencia (Spain) in the summers 1951—1954.

The thesis is a summary of my Spanish paper, which will be published in about a year by the "Lucas Mallada" Institute (Madrid) under the auspices of the Consejo Superior de Investigaciónes Científicas.

In the thesis one will find a few figures, as well the appendices with Spanish text, which were already prepared for the Spanish edition.

First of all I want to acknowledge the help of Prof. Dr. L. U. DE SITTER, who showed his interest in all the problems which arose during the investigation and whose stimulating advice was a great aid to me.

I am very grateful for the help and co-operation I had from the Consejo Superior de Investigaciónes Científicas and from the President, Prof. Dr. SAN MIGUEL DE LA CÁMARA and the Secretary, Prof. Dr. BERMUDO MELÉNDEZ of the Instituto de Investigaciónes Geológicas "Lucas Mallada".

I should like to express my gratitude to the N.V. Handels- en Transportmaatschappij "Vulcaan" (Rotterdam) for their assistance during the fieldwork.

My deeply felt thanks go to Dr. J. SHIRLEY (Newcastle upon Tyne), whose kind assistance in the field and in the determination of the Devonian fauna contributed much to this thesis.

I am indebted to Dr. C. L. FORBES (Cambridge) for identifying some of the Foraminifera, as well to my colleagues Mr. R. H. WAGNER, Mr. J. A. VAN HOEFLAKEN and Mr. A. C. VAN GINKEL, who identified respectively the Carboniferous plants, the Devonian brachiopods and the Lower Carboniferous Foraminifera, and to Mr. A. H. VAN DER VEEN for the many constructive discussions during the optical investigation of the dikes. I also appreciate the co-operation of the students A. BRANTS and B. N. KOOPMANS, during one summer fieldwork.

I want to express my gratitude to Dr. JOHN R. GEALY (Dallas, Texas) and Dr. R. VAN VLOTEN (Mexico), who assisted me in correcting the English text.

The illustrations and appendices were made by Miss C. ROEST. Mr. J. HOOGENDOORN handled the photograph material. Messrs. M. DEYN Sr. and Jr. made the thin sections. Mr. A. VERHOORN prepared some X-ray powder diagrams. Miss S. A. M. VERMEULEN and Mrs. J. A. A. ZWAAN—VAN WERKHOVEN typed the manuscript.

I am grateful to all for their co-operation.

CHAPTER I

INTRODUCTION

The man for whom a rock is something valuable,
will be surrounded by riches wherever he goes.
PÄR LAGERKVIST "Dvärgen"

In 1920 E. HERNÁNDEZ-PACHECO wrote a preface in a paper by PATAC, beginning: "La geología de la región asturiana es de lo más intrincadas e interesantes de la Peninínsula Ibérica".

Northwestern Palencia ,which I studied, is a part of this intricate and interesting "region asturiana".

Much detailed investigation during the summers 1951—1954 was necessary to come to a geological synthesis of the Devonian and Carboniferous sediments underlying this district of the province Palencia.

Only by concientious study and by mapping on a scale of at least 1:25,000 can one get a better insight into the geological structure and history of the Asturian-Cantabric mountains. In recent years this type of investigation has been done by the "Servicio Geológico del Instituto de Estudios Asturianos" (cf. LLOPIS LLADÓ 1954a) and by some geologists of the Geological and Mineralogical Institute at Leiden, directed by Prof. Dr. L. U. DE SITTER and under the auspices of the Consejo Superior de Investigaciónes Científicas at Madrid.

That detailed study yields valuable results is shown by the fact that WAGNER (1955) could fix accurately the Asturian phase in the Barruelo de Santullán district, proving it to be younger than previously accepted (p. 175): "La discordancia Astúrica de Barruelo es, sobre todo, notable por la oportunidad que ofrece para datar con gran precisión la fase orogénica aludida, ya que por el contacto inmediato entre el Estefaniense B—C discordante (paquete de la Peña Cilda) y las capas anteriormente plegadas del Estefaniense A (paquete de Barruelo) debe situarse al final del Estefaniense inferior".

In the Sierra del Brezo region, discussed here, a very important post-Westphalian A phase, the Curavacas phase could be identified. Here the Curavacas formation, a conglomerate of Westphalian B—C age, lies with angular unconformity on Westphalian A or older rocks. This newly recognized orogenic phase is an important factor in the Paleozoic history of Palencia and no doubt it asserted its influence in Leon and Asturias also.

The recognition of the Asturian and the Curavacas orogenic phases opens new vistas for a structural interpretation of the Paleozoic of the Asturian-Cantabric mountains.

As the Devonian between Ventanilla and San Martin de los Herreros (on the geological map indicated only as San Martin) is very rich in fossils, a rather complete subdivision of the almost 600-metres-thick Devonian section (cf. Appendix III) could be made. The beds range from Emsian to Famenian in age.

In this section an economically valuable haematite-bearing sandstone was found; it is now being exploitated. In addition, the investigation contributes to a better understanding of the coal-containing Carrión basin (Stephanian A) which lies south of Cervera de Pisuerga and extends many tens of kilometres to the west.

A. Nomenclature

In describing the stratigraphy of an area misunderstandings can arise unless stratigraphic terms and concepts are clearly defined. In this paper I have used the terminology introduced by the American authors KRUMBEIN and SLOSS (1951) and PETTIJOHN (1949). Among those are the terms and concepts of subgraywacke, orthoquartzite, epi- and infraneritic, shelf area, biohermal and biostromal limestone; their definitions of stratigraphic units has also been followed.

The system of P. NIGLLI (1931, 1935) was used in the discussion of the intrusive rocks.

CHAPTER II

GEOGRAPHY AND MORPHOLOGY

A. La Sierra del Brezo

The central part of Spain, the Meseta Ibérica, is bordered in the north by the Cordillera Contábrica. The Paleozoic part of the Asturian-Cantabric mountains is a Hercynian region, which is difficult to subdivide in physiographic units because of its involved geology and tectonics.

One of the physiographic units is formed by the Sierra del Brezo, situated on the southern margin of the Asturian-Cantabric mountain belt, and therefore bordering on the Meseta. The eastern part of the Sierra del

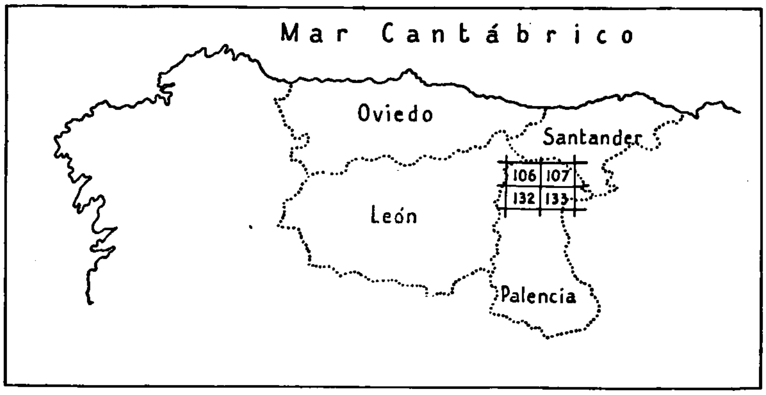


Fig. 1. Index map of the area mapped. The numbers are those of the sheets of the topographic map (1: 50,000) which were used in part.

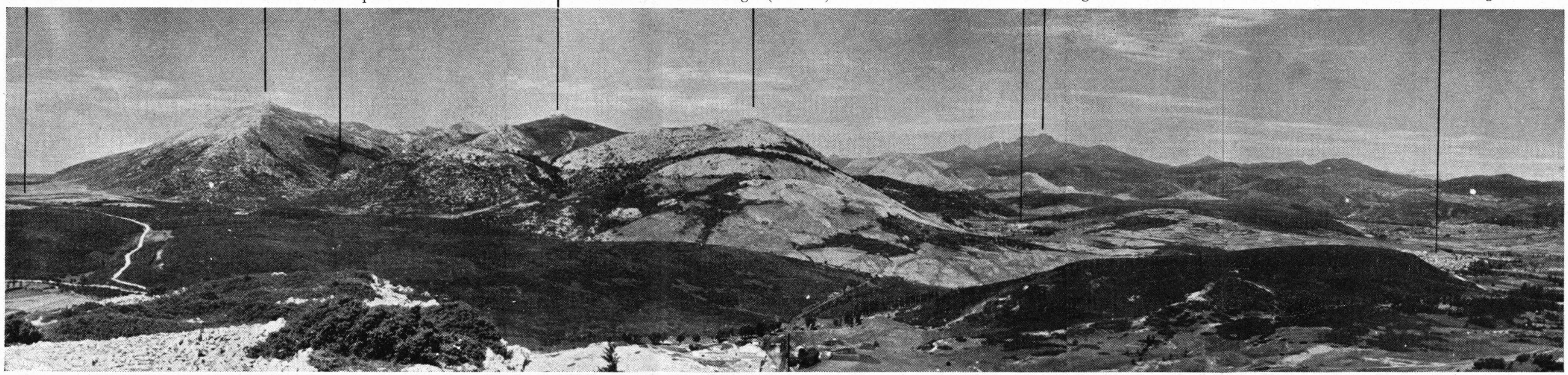
Brezo, which ends in the Pico Almonga (1511 m) and which includes Peña Redonda, is pictured on the geological map (Appendix 1). As this is the main part of the mapped area, the name: "zona oriental de la Sierra del Brezo" was chosen for this sheet.

B. Maps and aerial photographs

Topographic maps of the region exist in the scale of 1:50,000. Fig. 1 indicates the situation of the area mapped and which sheets of the topographical map have served as partial base for the geological map (Appendix 1).

The fieldwork during the last two seasons was facilitated because aerial photographs on a scale of 1:37,500 were placed at the author's disposal through the courtesy of the "Lucas Mallada" Institute of Madrid.

a. The eastern part of the Sierra del Brezo looking north from Traspeña. In the foreground the Stephanien A basin, containing coal seams.



b. View from the Mariserrana top (east of the Vado de Cervera station) towards the west, showing among other things the eastern end of the Sierra del Brezo.

C. Morphology

There is a remarkable contrast in topography between the flat, Tertiary Duero basin and the steep mountains of the Sierra del Brezo, which rise about 700 metres above the plains. This contrast is well illustrated in plate 1a. On the north side of the Sierra del Brezo lies a broad valley which runs more or less east—west. From Cervera de Pisuerga, via Triollo to Guardo, a highway has been constructed in this valley, which thus forms the northern limit of the Sierra del Brezo. West of Santibañez de Resoba this road reaches its highest point between Kilometres 15 and 16, where the divide is between the Carrión and Pisuerga Rivers.

The artificial lake of Camporredondo gathers the waters of the Carrión River while east of the divide the headwaters of the Rivera River form the artificial lake of Ruesga (fig. 2). This river forms further downstreams the link with the Pisuerga River.

The broad basin of the Pisuerga River north of Cervera is locally called La Pernía. Three kilometres north of Arbejal a dam was built across this river forming a lake, "La Requejada" also known as Pantano de Vañes. The rivers that drain the mapped region, have developed a mature landscape.

The relict mountain about 1200 m east of Arbejal, in the wide valley of the Pisuerga, is one of the indications of the shifting meanders of this stream, between the dam site and the town of Cervera. At both sites the narrowing of the riverbed is due to structural reasons; to the north the heavy Curavacas conglomerate crosses the river, at Cervera a hard Devonian orthoquartzite.

1. Alluvial terraces.

Another phenomenon which should be discussed here, are the terraces which occur in the eastern and southern parts of the area, as illustrated on the geological map and in fig. 3.

These terraces were deposited by rivers in the basins of the Pisuerga River itself and its tributaries the Resoba River, the Rivera River, and a river that followed the outcrop of the Stephanian A basin entering the Rivera River to the west of Vado.

QUIRING (1939, p. 59) is of the opinion that in this group of terraces four steps can be distinguished, but I have serious objections to this subdivision. With QUIRING I can distinguish an upper terrace about 160 metres above the level of the Pisuerga valley and a lower river terrace, but the two intervening stages are extremely doubtful. The upper terraces cover the flat tops of the surrounding hills and have a slightly undulating character.

There is no reason at all to accept QUIRING's hypothesis that the upper two terraces, as regards their age, can be correlated with the two "Stufen des Rheinischen Hauptterrasse", formed roughly between the Pliocene and the Pleistocene, neither can the third and fourth terrace be correlated with respectively the older Middle and the younger Middle Terrace of the Rhine. The climatic and geomorphotectonic circumstances in both regions are so different that such a far fetched correlation is certainly not warranted.

ALVARADO and SAMPELAYO (1945) are of the opinion that the age of these terraces is post-Eocene ,probably even Quaternary, and that the highest and oldest terrace has been deposited in the torrential epoch of the Pisuerga.

An investigation of the components of these deposits will probably have

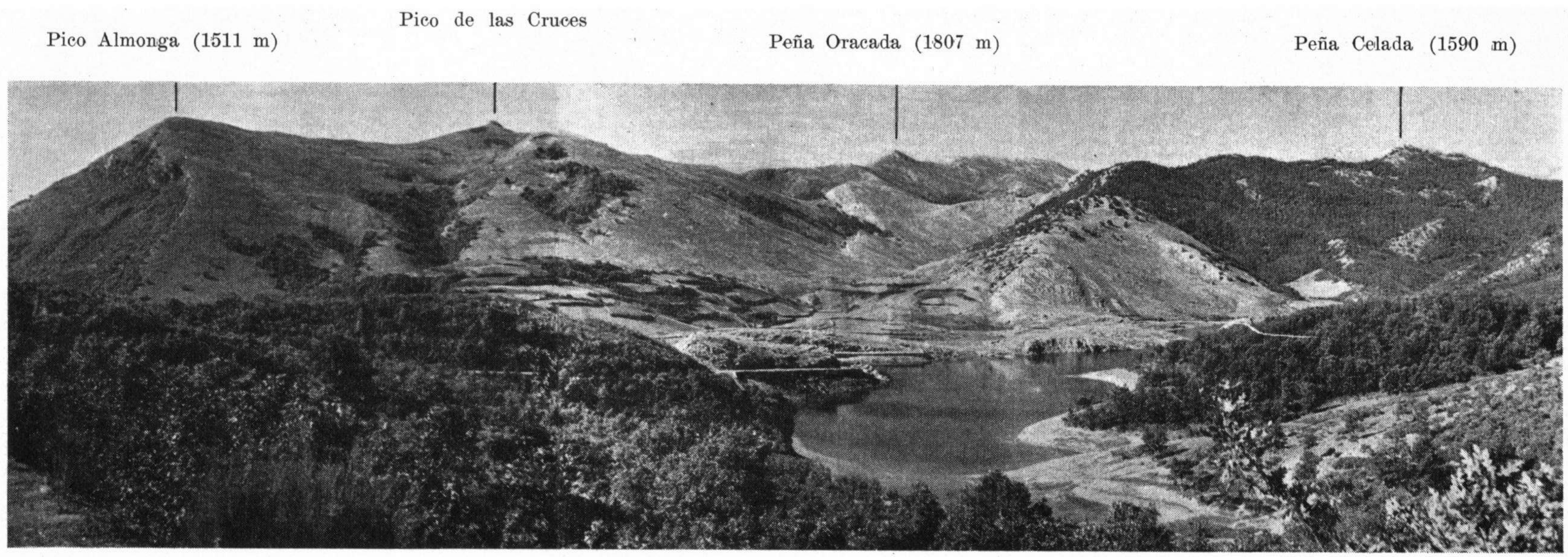


Fig. 2. The northern slopes of the eastern part of the Sierra del Brezo. In the foreground the artificial lake of Ruesga.

little succes; they consist mainly of Paleozoic orthoquartzite boulders, often of large diameter. In my opinion it will not be possible to assign an exact age to the terraces until archeological or palynological material has been collected.

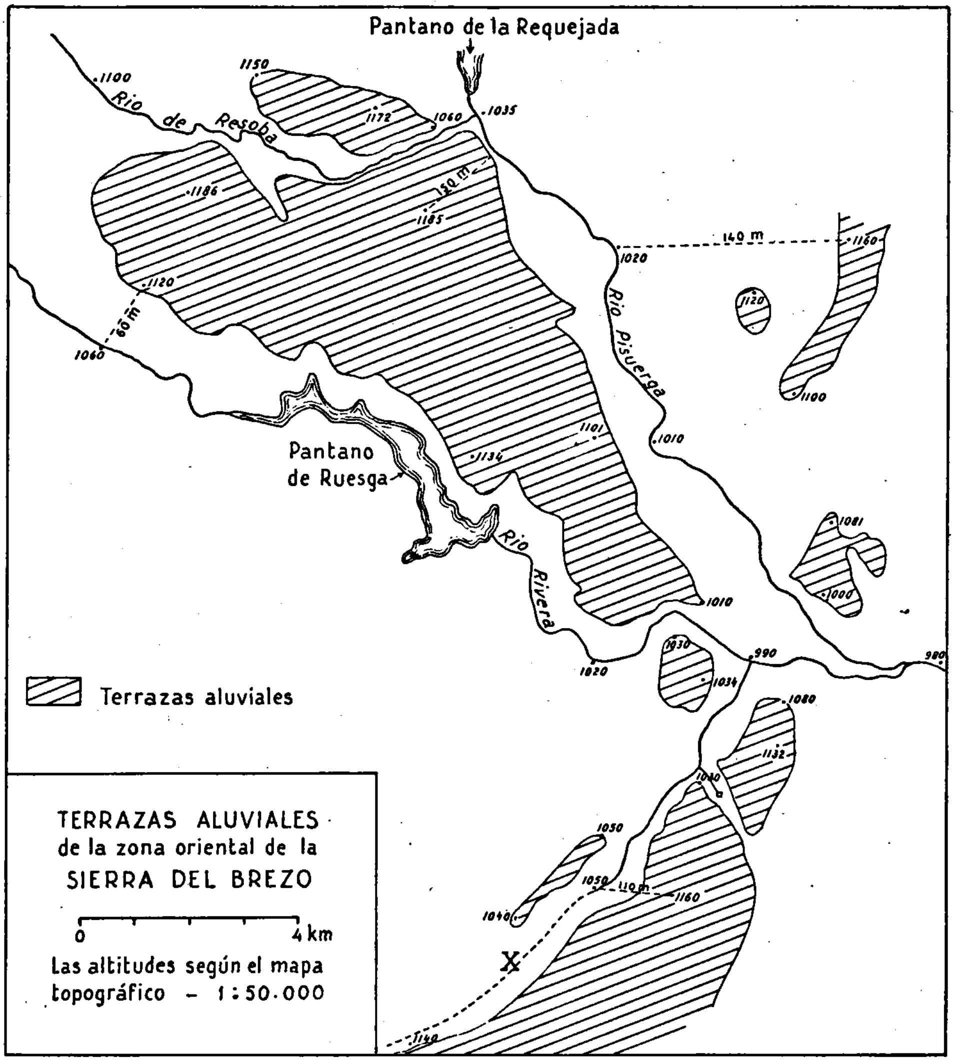


Fig. 3. General view of the alluvial terraces around Cervera de Pisuerga.

2. Piedmont alluvial plain.

At the foot of the southern slopes of the Sierra del Brezo large extensions of the Stefanian A basin are covered by talus fans which consist of boulders of limestone, derived from the adjoining "Caliza de Montaña". Where these fans have been cemented a plain was formed, the piedmont alluvial plain. Under these circumstances the alluvial material can reach a considerable thicknes; to the north of Traspeña a thickness of ten metres was recorded.

Here again, it is impossible to gain any detailed knowledge on the age of these fans, other than that they are post-Eocene and that at present the small rivers descending from the Sierra del Brezo have cut deep gorges into them.

CHAPTER III

PREVIOUS AUTHORS

Much has been published already on the geology of the Asturian-Cantabric mountains and according to the bibliography in the study of RUIZ FALCÓ and MADARIAGA (1941), a paper was published on the geology of the Asturias as early as 1831.

As regards the northwestern part of the province of Palencia, the first published work dates from 1856. In that year CASIANO DE PRADO published his geological map of this province on the scale of 1:400,000. The northern part of this map is shown in fig. 4.

In 1861 a revised map on the scale of 1:100,000 was published, of the northern part of the province. The main correction by ORIOL in this map is the Devonian boundary between Guardo and Cervera de Pisuerga; this is marked in fig. 4 by a dotted line.

In 1876 ORIOL (1876a) published two studies on northern Palencia in which he mentioned already the unconformity between the Devonian quartzites and the Lower Carboniferous "Caliza de Montaña".

Several years later, in 1894, ORIOL wrote a synthesis on the Castilian coal basins, in which one chapter deals with the Carrión basin (Guardo-Cervera).

In 1898 MALLADA published a paper on the Geological Map of Spain in which he gave a synthesis of the Devonian and Carboniferous Systems. According to this author the age of the Carrión basin is from Middle Carboniferous to the base of the Upper Carboniferous.

From 1906 dates a paper by SÁNCHEZ LOZANO on the Carboniferous basin of Guardo, accompanied by a geologic map on the scale 1:50,000. In this publication the southern contact of the Paleozoic with the Cretaceous rocks is still conceived as a fault. In 1912 SÁNCHEZ LOZANO must have changed his views, however, when he described a drillhole made to the southeast of the station Vado de Cervera. After drilling through 263.52 metres of Cretaceous sediments the Carboniferous was encountered with several coal seams.

PATAC (1920) correctly gives the age as Uralian for the Guardo-Cervera basin, but concludes less correctly that this basin was formed after the Asturian folding phase. PATAC too was of the classical opinion that this phase in the Asturian-Cantabric mountains occurred at the end of the Westphalian. As will be shown later on WAGNER and WAGNER-GENTIS (1952) have been able to prove that the Asturian phase occurred at least in the northern part of Palencia not until after the Stephanian A had reached its greatest development, and therefore also after the formation of the Carrión basin.

In 1922 appeared Sheet 11 (Oviedo-Léon-Palencia) of the "Mapa Geológico de España" on the scale 1:400,000.

Fig. 4. Geological map of the northern part of the province Palencia by CASIANO DE PRADO (1856).

Dupuy de Lôme and de Novo (1924) add a geological map (1:100,000) to their publication, showing the Paleozoic to the northeast of Palencia.

Not only these two authors noted the continuation of the Carboniferous below the Cretaceous, but also Cueto and Rui-Díaz in 1926 (p. 67) wrote on this subject.

The adjacent sheet to the east of Sheet 11 of the Mapa Geológico de España appeared in 1931 as Sheet 12 (Burgos-Santander-Vizcaya).

Karrenberg published a general summary in 1934: "Die postvariscische Entwicklung des Kantabro-Asturischen Gebirges". Two years later, in 1936, Ciry published a short, preliminary report on the same subject limited to the southern border of the Asturian Massif. In 1939 his thesis, a classical

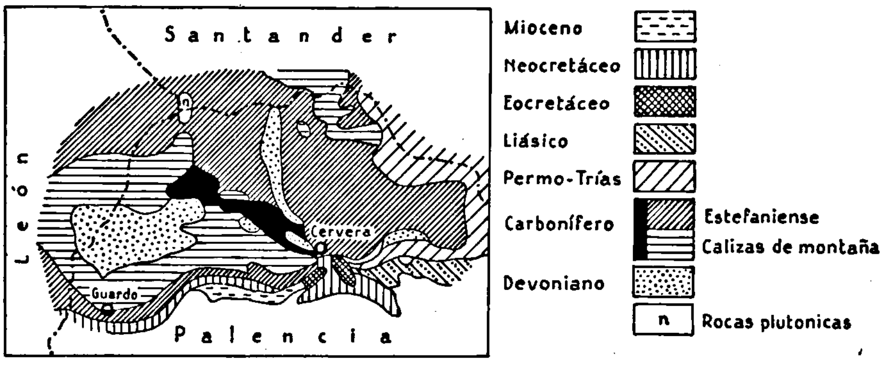


Fig. 5. The Paleozoic of Palencia according to the "Mapa Geológico de España y Portugal" (1952), (Scale 1: 1,000,000).

work, is published: "Étude géologique d'une partie des provinces de Burgos, Palencia, Léon et Santander". These studies by Karrenberg and Ciry, together with the publications of Schriel and Clementz Saénz are reviewed and supplemented in the article of Rios, Almela and Garrido (1945).

One of the more recent investigators of the Paleozoic in Palencia is the German author Quiring, who published papers in 1935, 1939, 1953 and 1955. His work published in 1935 treats mainly of the Guardo-Cervera coal-basin. The compilation of his geological studies in north Palencia was published in 1939 as: "Die ostaturischen Steinkohlenbecken", of which a Spanish translation appeared in 1943.

In the following chapters this publication will be quoted several times, but it may be noted here that Alvarado and Sampelayo (1945) in a critical review of Quiring's work correctly remark (p. 4): ... and other syntheses seem to be based on doubtful or mistaken grounds". This latter paper supplements the Quiring paper.

In 1952 the Mapa Geológico de España y Portugal (1:1,000,000) was published. Fig. 5 illustrate the part dealing with the geology of north Palencia.

In the near future more papers on geology of this region by the geologists of the team headed by Prof. Dr L. U. de Sitter can be expected and then will be possible to revise this part of the Mapa Geológico de España y Portugal.

Preliminary notes on the geology of an area in the northeastern part of the province of Palencia, the region of Barruelo, was published by WAGNER and WAGNER-GENTIS (1952) and WAGNER (1955). DE SITTER himself gave his general views of the geology of the whole Pisuerga basin (1955).

Finally I want to mention the short publication of DAHMER and QUIRING (1953) in which DAHMER gives a description of Devonian fossils collected by QUIRING between Ventanilla and San Martín.

CHAPTER IV

STRATIGRAPHY

A. Introduction

The geology of the northwestern part of Palencia has been studied by many authors, but untill now none has made a detailed stratigraphic study. The stratigraphy of the area is complex and is moreover tectonically highly disturbed.

Fortunately the ages of the Devonian and Carboniferous sediments are indicated by guide fossils, which are found at many places. In particular, the Devonian between Ventanilla and San Martin de los Herreros is very rich in well preserved specimens (When my colleague VAN HOEFLAKEN publishes his monograph on the Devonian brachiopods of northern Palencia he will also describe my collection and make a very interesting comparison with the results of BARROIS in Asturias and COMTE in Leon.)

The greatest part of the area under discussion here is underlain by Carboniferous sediments from late Visean to Stephanian A in age. The Upper Visean lies unconformably on the Devonian.

The basal unit of the Carboniferous of Upper Visean age is a dominantly radiolarian rock. This is overlain by griotte containing a few chert nodules and in turn is overlain by a thick limestone, the Caliza de Montaña, with intercalated shale.

The Namurian is probably 1200 m thick and consists of shales, conglomerates and subgraywackes and contains lenses of biostromal limestone. It passes upwards into the Westphalian A without a distinct contact, but instead changes gradually, the conglomerates and subgraywackes becoming less abundant and the biostromal limestone becoming biohermal.

A peculiar feature higher in the stratigraphic column is the unconformity separating the Westphalian A from the Curavacas formation, a conglomerate at least 500 metres thick of Westphalian B—C age. This previously unknown unconformity is an important addition to the stratigraphic knowledge of the Carboniferous of Palencia. It is possibly also represented in Leon and Asturias, where very little is known about the Westphalian B—C.

The youngest Carboniferous sediments in northern Palencia are Stephanian A in age. They are exposed along the southern border of the mapped area.

Unconformably overlying the Stephanian A are Mesozoic sediments. They have been studied especially by CIRY (1939) and his conclusions about the Permo-Triassic, Jurassic and Cretaceous, in contact with the Paleozoic of the mapped area are included at the end of this chapter.

	Lower Siegenian	Upper Siegenian	Lower Emsian	Upper Emsian	Lower Couvinian	Upper Couvinian
Stropheodonta sedgwicki d'Archiac et de Verneuil (Plate 3, I)	—	+	+	+	—	—
Spirifer (Costispirifer) trigeri de Verneuil (Plate 3, H)	—	+	+	—	—	—
Spirifer (Acrospirifer) arduennensis Schnur (Plate 3, J)	—	+	+	+	—	—
Spirifer (Hysterolites) hystericus Schlotheim	+	+	+	—	—	—
Spirifer (Acrospirifer) pellico d'Archiac et de Verneuil	—	+	+	+	—	—
Eodevonaria dilatata Roemer	—	+	+	+	+	—
Uncinulus pila Schnur (Plate 3, K)	—	—	+	+	—	—
Nucleospira marginata Mauer	—	—	+	+	—	—
Athyris ferronesensis de Verneuil et d'Archiac	+	+	+	+	—	—
Athyris campomanesi de Verneuil et d'Archiac	—	—	—	+	+	—
Stropheodonta gigas MacCoy	—	+	+	+	—	—
Leptaena rhomboidalis Wahlenberg	+	+	+	+	+	+
Stropheodonta murchisoni de Verneuil et d'Archiac	+	+	+	+	+	—
Schizophoria vulvaria Schlotheim (Plate 3, M)	—	+	+	+	?	—
Trigeria oliviana de Verneuil et d'Archiac (Plate 3, L)	+	+	+	+	—	—
Meganteris archiaci de Verneuil						
Atrypa sp.	—	+	+	+	+	—
Anaplotheca lepida Goldfuss						
Pleurodictyum problematicum Goldfuss						
Pleurodictyum sp.						
"*Rhynchonella*" sp.						
Cryphaeus sp.						
Dalmanites sp.						
Homalonotus sp.						
Bryozoa						
Crinoidea						
Single corals						

Appendix 3 gives three stratigraphic columns of the Devonian between Ventanilla and San Martin de los Herreros. Among other features the lateral variation in lithology of these neritic sediments becomes apparent in these columns. The other stratigraphic profiles in this appendix are from the Stephanian A basin.

At the end of this chapter is a stratigraphic table of this region.

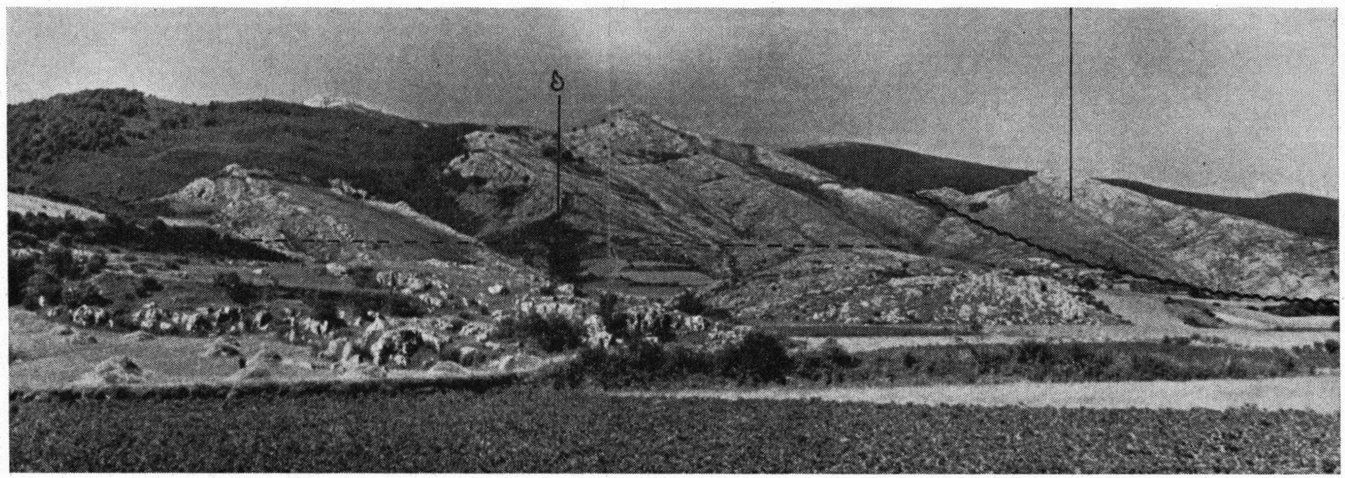


Fig. 6. Devonian between Ventanilla and San Martin. The stratigraphic section of appendix 3: II was taken along the horizontal dotted line.

B. Devonian

1. Emsian

The core of the overturned Devonian fold between Ventanilla and San Martin is of Emsian age (or older?) and is the oldest deposit known in this area.

The stratigraphic section (cf. column II, Appendix 3) has at the base an irregular bedded coralline limestone about 90 metres thick (fig. 6). Though no fossils have been identified from the limestone, an Emsian age is indicated by fossils (fig. 6) just overlying the limestone in beds which are part of the same sequence of deposition. Its age can probably be ascertained correctly from the coral content, but unfortunately the results of the investigation of the Devonian corals of the Ventanilla—San Martin area are not yet complete and can not be inserted in this paper.

All the limestones in the Devonian are biohermal and rich in corals and Bryozoa.

The Emsian limestone grades upward gradually into a shale (Appendix 3, column II) which is very rich in fossils (fig. 10).

The following fossils have previously been identified from the locality (see pag. 390):

The thickness of the Emsian shales is approximately 90 metres. If, in the future, the corals prove that the underlying limestone belongs to the Emsian also, then the total thickness of this stage is almost 200 metres.

2. Couvinian.

Overlying the Emsian is about 225 metres of Couvinian beds (fig. 6). The Emsian shales grade upward into the Couvinian through a crinoidal limestone about 20 metres thick, which grades into a bedded limestone, massive in its upper part. This latter limestone, 110 metres thick, is a biohermal limestone and is very rich in silicified corals. Field identification indicated that the limestone probably contains species of the following genera: *Acervularia, Favosites, Cystiphyllum, Heliolites* and *Prismatophyllum.* In addition, there are numerous *Stromatoporoidea* and *Bryozoa.*

It is interesting to compare column II (Appendix 3) with column III, measured south of San Martin. About 30 metres above the base of column III is a sandstone 10 metres thick and rich in fossils. This deposit is laterally constant in contrast to the great lateral variation in lithology which is typical of the Devonian here. Field examination indicated that the sandstone is equivalent in age to the upper part of the massive limestone, mentioned above.

The following fossils are found in the sandstone of San Martin (see pag. 393).

This association of fossils is Couvinian in age.

Between San Martin and Ventanilla and overlying the Couvinian limestone is a sandstone 70 metres thick (column II). At Ventanilla this unit has the same thickness (column I), but it increases in thickness toward San Martin, reaching there a thickness of 120 metres. In some localities this sandstone is very ferruginous and contains the ore "rubio" (cf p. 438), but in the upper part of the unit a more valuable ore is found.

The following fauna was identified from the upper ore body (see pag. 393).

(Sandstone of San Martin)	Lower Emsian	Upper Emsian	Lower Couvinian	Upper Couvinian	Lower Frasnian	Upper Frasnian
Conchidium oehlerti BARROIS (Plate 3, F)	—	—	+	—	—	—
Stropheodonta piligera SANDBERGER (Plate 3, G)	—	—	+	—	—	—
Spirifer (Acrospirifer) paradoxus SCHLOTHEIM	+	+	+	—	—	—
Productella subaculeata MURCHISON	—	—	+	+	+	+
Atrypa sp.						
Pleurodictyum cf. *problematicum* GOLDFUSS						
Bryozoa						
Single corals						

(Upper ore body)	Upper Emsian	Lower Couvinian	Upper Couvinian	Lower Frasnian	Upper Frasnian
Schellwienella umbraculum SCHLOTHEIM (Plate 3, E)	—	+	+	+	+
Schizophoria striatula SCHLOTHEIM	—	+	+	+	+
Pleurodictyum problematicum GOLDFUSS					
"*Rhynchonella*" sp.					
Cryphaeus sp.					
Fenestella sp.					

About 2 kilometres southwest of Ventanilla ("Coral Vieja") and a few metres above the ferruginous sandstone is a bioherm with a rich coral fauna. In addition, there are crinoidcolumnals, especially of *Cupressocrinus crassus* GOLDF., a guide fossil of the Middle Devonian.

3. Frasnian.

The base of the Frasnian lies a few tens of metres above the ferruginous Couvinian sandstone. The interesting stage varies greatly laterally, the shales of 75 metres thickness near Ventanilla being completely developed as a coralline limestone near San Martin.

The Frasnian shales (column I) are extremely rich in fossils. The following species could be identified:

	Lower Couvinian	Upper Couvinian	Lower Frasnian	Upper Frasnian
Leptaena rhomboidalis Wahlenberg	+	+	+	+
Schellwienella umbraculum Schlotheim	+	+	+	+
Schizophoria striatula Schlotheim	+	+	+	—
Spirifer (Cyrtospirifer) verneuili Murchison, var. *lonsdalii* Murchison (Plate 3, D)	—	—	+	+
Spirifer bouchardi Murchison	—	—	+	+
Atrypa aspera Schlotheim (Plate 3, C)	+	+	+	+
Atrypa sp.				
Cyrtina intermedia Oehlert				
"*Rhynchonella*" sp.				
"*Orthis*" *devonica* d'Orbigny				
Phacops (Reedops) sp.				
Dalmanites sp.				
Homalonotus sp.				
Cryphaeus sp.				
Lamellibranchiata				
Bryozoa				
Crinoidea				

Spirifer bouchardi and *Spirifer verneuili* especially show the Couvinian age of this fauna.

Overlying, and in sharp contact with the Frasnian shales is a sandstone and orthoquartzite. The lowest part of this sandstone and orthoquartzite is also abundantly fossiliferous. Most common is *Spirifer bouchardi* Murch.

In the Frasnian sediments (column II) there are some limestone intercalations. High in the sequence some Bryozoa and Spirifer beds have a wide lateral extention; similar faunas were collected from these beds in two different places (col. I, col. II).

Identified species are:

	Upper Couvinian	Lower Frasnian	Upper Frasnian
Douvillina ferquensis Rigaux (Plate 3, A)	—	+	+
Spirifer verneuili Murchison, var.	—	+	+
Douvillina dutertrii Murchison	—	+	+
Spirifer bouchardi Murchison (Plate 3, B)	—	+	+

The section of column III was taken along the path south-southwest of San Martin where the Frasnian is a coral-bearing limestone, species of the genera *Acervularia, Favosites, Cystiphyllum* being most abundant. *Stromatoporoidea* are also very abundant.

At the top of the Frasnian is an orthoquartzite 2.20 metres thick, overlying this is the radiolarian rock of the Lower Carboniferous.

4. Other Devonian exposures.

The Devonian is not only exposed between Ventanilla and San Martin, but also at other places, as indicated on the geological map. One occurrence is the Frasnian orthoquartzite exposed between Ventanilla and Ruesga (cf. Appendix 2, profile B—B′). All the other Devonian orthoquartzites in the eastern zone of the Sierra del Brezo are identical to this one.

DAHMER (1936) described some fossils from one of these, the "cuarcita de Cervera", between "Pico Almonga" and the Rivera River. I also found fossils there, but their preservation was very poor and one can hardly say more than there occur rests of crinoids, a "*Rhynchonella*" type and indistinct Spirifer impressions; it seems to me almost impossible that DAHMER found suitable specimens on which to base his new species, *Spirifer wakoniggi*. His conclusion was that this orthoquartzite belongs to the Middle Devonian, but he added by way of precaution: "si es que de los incompletos hallazgos se puede sacar alguna conclusión acerca de la edad de las cuarcitas de Cervera".

I think it will be more correct to call the Cervera orthoquartzite Upper Devonian (Frasnian), because of its similarity to the Ruesga-Ventanilla orthoquartzite of this age. The same can be said for the following orthoquartzite occurrences in the mapped area:

a. between Pico Almonga and Pico de las Cruces,
b. in the Tosande valley *), where the orthoquartzite is in the core of one of the isoclinal folds,
c. more to the west in this valley,
d. in the cut crest of the isoclinal fold southwest of Peña Oracada.

Further northeast of Santibañez de Resoba, one can see steep orthoquartzite ridges surrounded by the Westphalian A sediments; on the north part the orthoquartzite is in contact with the Westphalian B—C conglomerates of the Curavacas formation (fig. 7).

Much of Cervera de Pisuerga is built on Devonian sediments and it is almost certain that the orthoquartzite of the adjacent Peña de Castillo and Peña de Barrio belong to the Frasnian, as does the already mentioned "curacita de Cervera".

On the north side of both Peñas near Cervera is Devonian limestone and shales. But too few fossils were found to give a correct age determination so these exposures are mapped as Devonian undifferentiated. The same is true for the Devonian west of San Martin, near the Peña Negra peak, as well as for the Peña Negras area, which will be described by my colleague VAN HOEFLAKEN.

Another Devonian exposure, the limestone ridge about 1500 metres east of Cervera de Pisuerga, is also not yet subdivided.

*) The Tosande valley lies between Pico de las Cruces and Peña Oracada.

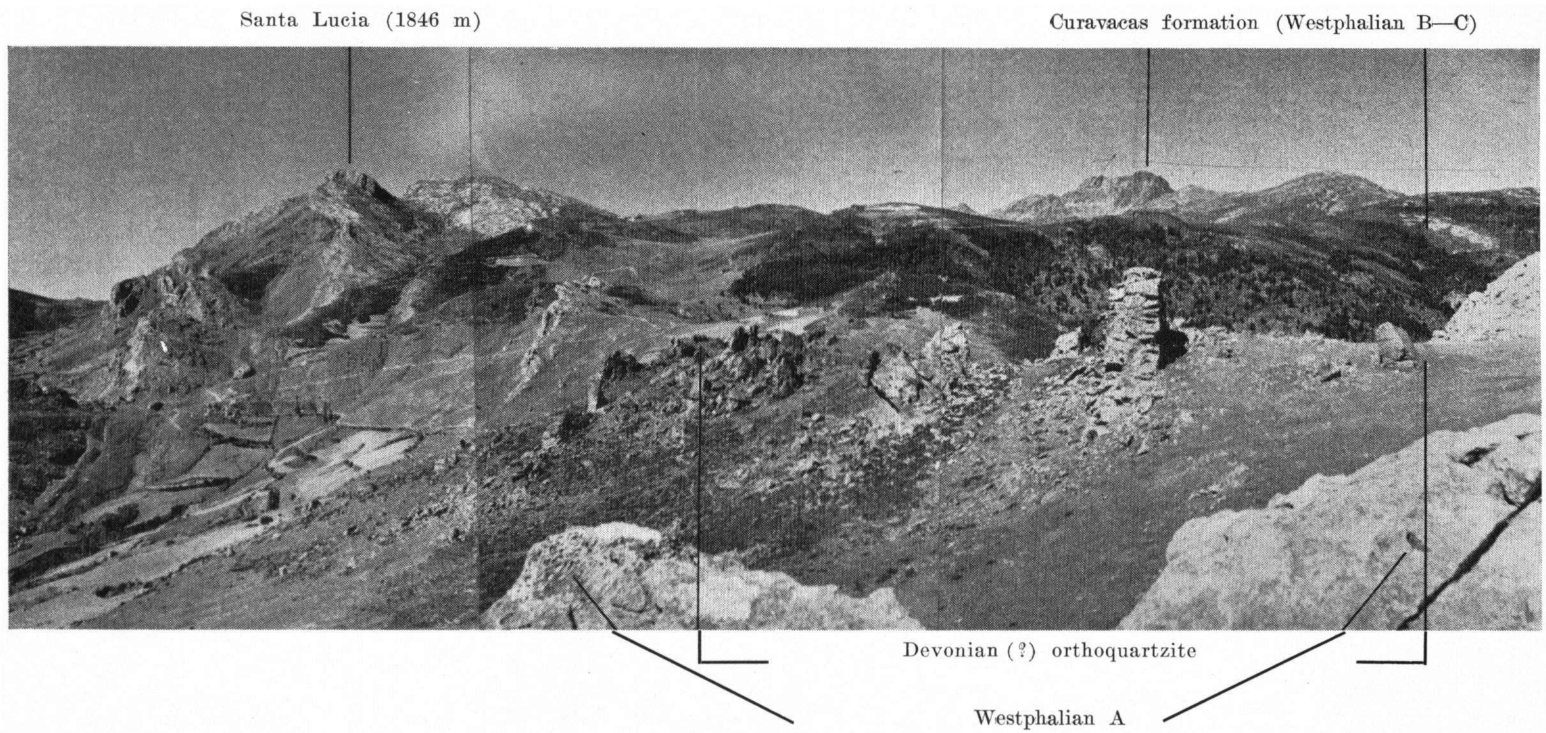


Fig. 7. Devonian (?) orthoquartzite surrounded by Carboniferous rocks, northeast of Santibañez de Rebosa.

5. Final remarks.

In general it can be said that the lithological association of the Emsian, the Couvinian and part of the Frasnian was formed in an epineritic environment, a stable shelf area. This inference is in good accordance with the paleogeographic map published by MELÉNDEZ (1953), on the division between land and sea in Spain during the Middle Devonian (fig. 8). MELÉNDEZ indicated that the area of Cervera—San Martin was situated, during the Devonian, near the shore line.

Corals are very abundant in the Devonian, a feature typical of a neritic shelf area in which the transport of detrital material is very small.

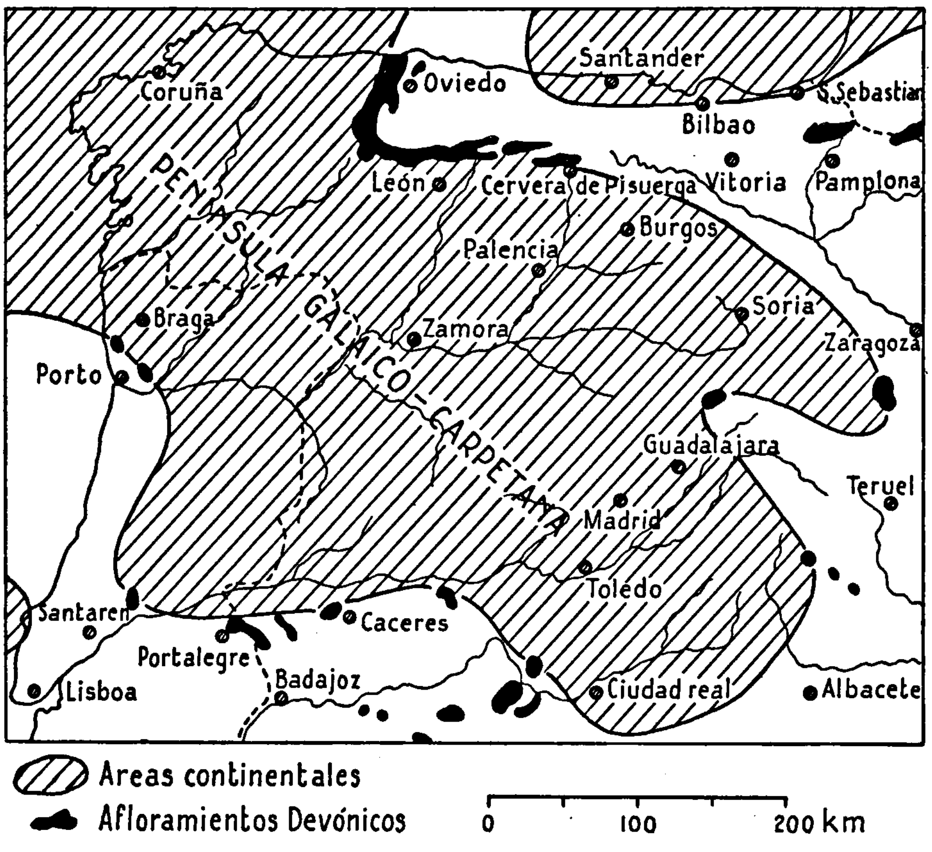


Fig. 8. The division between land and sea in Spain during the Middle Devonian (MELÉNDEZ, 1953).

Famenion deposits were not observed in the mapped area, although it is not impossible that the highest part of the Frasnian orthoquartzite which is poor in fossils belongs to the Famenian.

The Frasnian sediments have a transgressive character in Palencia as well as in Leon and Asturias (Candas sandstone), but there appeared at the end of the Devonian a regression which MELÉNDEZ (1953) described as follows:

"The Upper Devonian is ind general characterized by a regression with gradual diminution of the sea. At the end of the Famenian, however, emersion movements become general in a so extensive area that they can be considered as epirogenetic movements of the Bretonic phase of the Hercynian orogeny."

There is no doubt that the disconformity between Frasnian and Upper Visean in northwestern Palencia was caused by the first Hercynian phase.

C. Carboniferous

Stephanian A: *paralic coal-basin (Carrión basin)*
Westphalian B—C: *conglomerates of the Curavacas formation*
Namurian and Westphalian A: *Culm facies*
Upper Visean—Lower Namurian: *Caliza de Montaña (limestone) and shales*
Upper Visean: *Griotte*
Radiolarian rock

1. Upper Visean and Lower Namurian.

a. *Radiolarian rock*

On the geological map radiolarian rock is indicated with the general term "roca de radiolarios", for the mineralogical composition of this rock varies very much.

It is a known fact there are many gradations between a hard compact chert and a muddy shale in radiolarian-bearing rocks. The typical laminated structure of the radiolarian rock can be observed in thin sections (fig. 9).

Although Radiolaria occur in this rock, the age is not apparent. The overlying griotte, however, is of Upper Visean age, and because the two units are transitional the radiolarian rock is considered to be Upper Visean in age also.

DELÉPINE (1935, p. 155) has given a very interesting explanation of the Visean transgression:

"Il est possible que la transgression se soit faite là soudainement couvrant toute l'étendue d'un compartiment de l'écorce en voie d'affaisement rapide. Un processus de ce genre rendrait compte de la couleur rouge des schistes et griottes des Asturies, la mer englobant dans ces premiers sediments, les terres latéritiques couvrant la surface du continent inondé. Il expliquerait également la présence de radiolaires si communs dans toutes ces formations.

Car la transgression se fait, non point par simple déplacement et avance d'une tranche de mer néritique avec toute sa faune, mais par l'irruption d'une masse d'eau venant d'un grand bassin à caractères pélagiques."

SUJOWSKI (1933, p. 675) gives a map of the geographical distribution of the Devonian-Carboniferous radiolarian-bearing beds, demonstrating their enormous horizontal distribution over hundreds of square kilometres and their importance in the Lower Carboniferous sediments.

It has been proved for many areas (TROMP, 1948 et. al.) that radiolarian rocks are not only bathyal or abyssal sediments, but can be neritic also. Such was the environment of deposition of the radiolarian-bearing rocks of northwest Palencia ,the sea being a transgressive one. Justly writes DE SITTER (1949) — about griotte in the Pyrenees — "The base of a transgressive facies can hardly have an abyssal facies", a statement which holds true for the radiolarian rock of northwest Palencia.

And SHACKLETON CAMPBELL (MOORE 1954, p. 18) has said: "Most radiolarian-bearing cherts are thought to be of shallow-water origin."

The radiolarian rock of Palencia was deposited in an oxidizing environment as indicated by the presence of hematite which was identified by X-ray analysis.

Briefly we can say the following about the radiolarian rock:

1. the lithology varies from a red shale to a hard chert,
2. this rock was formed in a transgressive sea in a neritic environment and under oxidizing conditions,

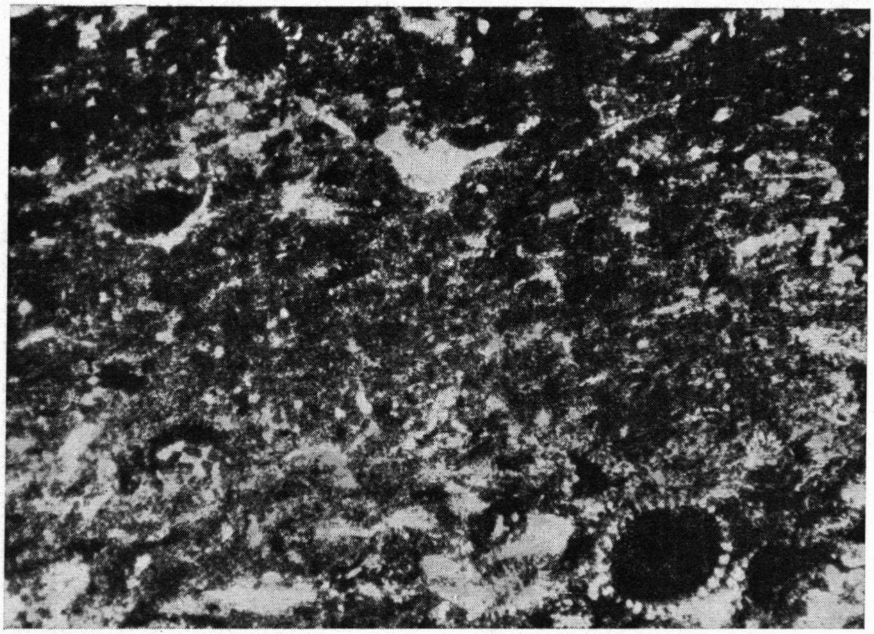


Fig. 9. Thin section of radiolarian-bearing rock from northwestern Palencia, × 150.

3. it is not a local sediment, but belongs to the "roca de radiolarios" of the Pyrenees, Montagne-Noir, Harz and the St. Croix massive of Poland,
4. Radiolaria of the genus *Cenellipsis* are most abundant here. Description on page 412.

b. *Griotte*

The griotte is a spotted limestone, especially known from the Upper Devonian of the French Pyrenees.

Where the griotte occurs together with the "roca de radiolarios", or contains chert nodules or forms distinctly the base of the Caliza de Montaña, it is called "mármol grioto", as indicated on the geological map. This is an important guide horizon in the Upper Visean of Palencia, Leon and Asturias.

Interesting is the question of the genesis of the griotte. Opinions have been rather different and for a long time it was supposed that the griotte was a deep sea facies, for it contains often nothing else but goniatites, thought to indicate an abyssal facies.

By investigating griotte in thin sections and in the field, I came to the following conclusion: when a muddy rock grades gradualy into a limestone, or vice versa, the possibility exists that the rock has formed in a transition zone between the mud and limestone domains, but:

1. both types of rocks must be deposited alternately, forming a series of relatively competent and incompetent thin layers,
2. during sedimentation, oscillation ripple marks could be caused by the orbital motion of water waves, being a to-and-fro motion along the bottom Such markings can also be an indication of the rocks neritic character.
3. one may suppose that an irregular surface form between the muddy and the more calcareous sediments, but that this typical structure of griotte is accentuated by internal tectonic action.

Fig. 10 a, b shows, how the griotte structure was formed by compression

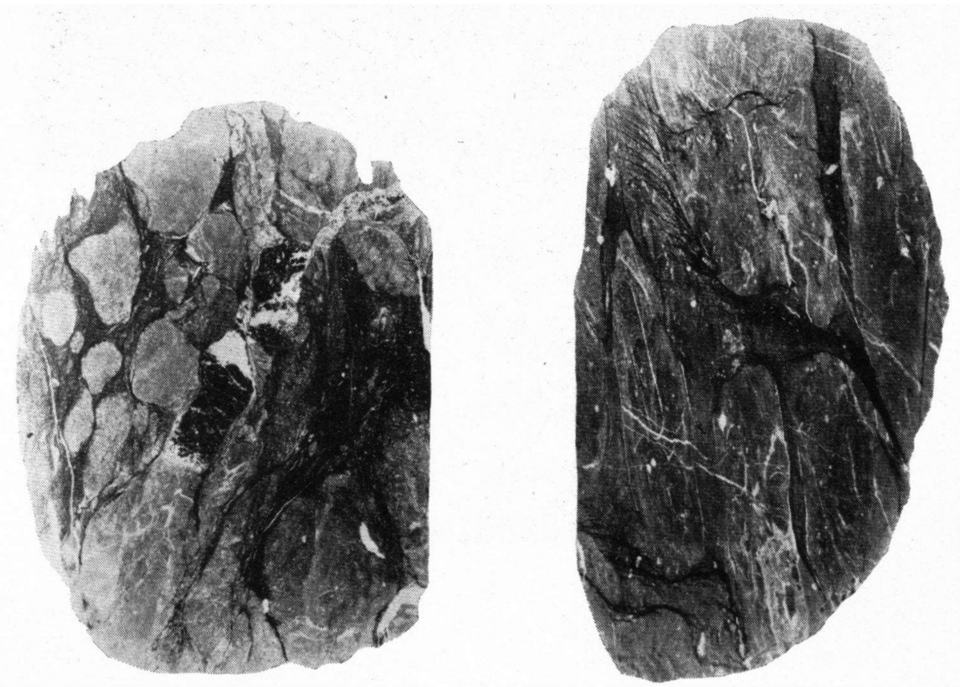


Fig. 10. a. Thin section of Upper Viscan griotte from northwestern Palencia, × 3.
b. Thin section of Upper Devonian griotte from Montferrier (French Pyrenees), × 3.

(boudinage), whereby the softer parts (black on the photograph) were squeezed around the harder parts. By this process the more angular pieces can be rounded off and even become amygdaloidal in form.

Because the rock appears to be easily internally deformed, it is not surprising that ALMELA and RIOS (1953) wrote: "estas calizas griotas tienen la peculiaridad de replegarse extraordinarimente, con una complicación accesoria mucho mayor que la de la tectónica general en que se incluyen".

The griotte with chert nodules and thin chert layers, as found near the dam of Ruesga, is represented in fig. 11. These chert intercalations are also found south-southwest of San Martin; COMTE and DELÉPINE have previously described chert nodules from griotte in the provinces Leon and Asturias.

Nodules in the griotte are of the same composition as the underlying "roca de radiolarios" and contain — at least in northwest Palencia — the same Radiolaria.

Lastly a few notes about the age of the griotte. Unfortunately I could not find fossils in this rock, except some crinoid remains, probably of *Poteriocrinus* sp. However, data of BARROIS (1882) and DELÉPINE (1935) fill this gap. DELÉPINE (p. 147) writes, concerning Asturias: "Les schistes rouges *) et griotte de la base renferment des espèces nombreuses de goniatites: *G. Crenestria, Pronorites cyclolobus* PHILL, *Prolecanites henslowi* SOW., *Münsteroceras malladae* BARROIS. Ces goniatites indiquent certainement que la formation appartient à un niveau élevée du Viseén".

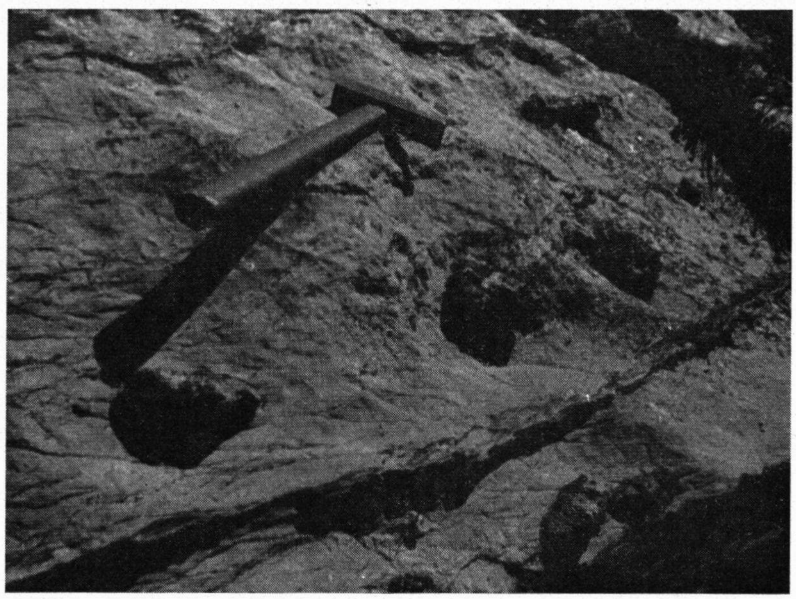


Fig. 11. Upper Visean griotte with chert nodules near the Ruesga dam.

His conclusion of an Upper-Visian age for the griotte of northwest Palencia is accepted here.

c. *Caliza de Montaña*

In 1876 ORIOL noted: "Caliza de Montaña que constituye los picos de Almonga y de Cantoral."

Indeed, the mapped area of the Sierra del Brezo, which is limited on the south by a thrust fault and on the north by the fault zone of Ruesga consists almost entirely of Caliza de Montaña, occurring in isoclinal folds the cores of which generally contain Devonian.

The thickness of this series is about 300 metres. It is composed mainly of a light grey, compact limestone with intercalations of shales and beds of

*) This author means probably with this rock the "roca de radiolarios" of this report.

subgraywacke. Remarkably, the unit is chiefly limestone in the southern part of the Sierra del Brezo sensu stricto and shales in the northern part.

In general the Caliza de Montaña is a rather massive limestone, but at some places it is developed as a crinoidal limestone. Examination of thin sections indicates that the unit is locally an oölitic limestone. KRUMBEIN and SLOSS (1951, p. 139) wrote about this type of rock: "Oölitic limestone is a common example of a primary chemical limestone of calcite about nuclei in strongly agitated, shallow waters." The occurrence of crinoidal limestone in the Caliza de Montaña also points to a neritic environment and in reference to this type of rock KRUMBEIN and SLOSS (p. 138) said: "Local movement on shallow bottoms under wave or current action is apparently sufficient to rearrange and sort the fossil fragments."

The fossil content of the Caliza de Montaña is small, only the following forms being found: Foraminifera, corals, fragments of crinoids and brachiopods and one single goniatite by which it became possible to determine the age of this series.

The goniatite belongs to the species *Goniatites falcatus* ROEMER, limited to the Upper Visian or the P 2 zone of the English subdivision. WAGNER (1955, p. 153) also found this goniatite together with other species in the Perapertú series.

Another indication of the Upper Visian age of the limestone is the coral of the genus *Carcinophyllum,* a typical Visean genus. The Foraminifera studies of FORBES and VAN GINKEL, however, are somewhat contradictory with this conclusion.

The following genera and species were identified from thin sections from three localities of the Caliza de Montaña by VAN GINKEL:

1. near Peña Redonda, (loc. 201) *)
   Bradyina cribrostomata RAUSER-CERNOUSSOVA
   Fusiella (Profusulinella) sp.
   Fusiella (Profusulinella) aljutovica
2. 250 metres west of Ruesga (loc. Pr)
   Bradyina cf. *cribrostomata* RAUSER-CERNOUSSOVA (fig. 15, C)
   Bradyina nautiliformis MÖLLER
   Ozawainella aff. *angulata?* THOMPSON (fig. 15, B)
   Pseudostaffella spheroidea? (LAMARK 1836) (fig. 15, D)
   Fusiella (Profusulinella) sp.
   Fusiella (Profusulinella) aljutovica?
3. 750 metres southwest of Ruesga (loc. Ls)
   Plectogyra sp. (*phrissa?*)

This Foraminifera association is thought to be a Westphalian A and/or Upper Namurian fauna. The occurrence of *Profusulinella* makes a Visian age especially improbable. This age determination is founded, however, on correlation with Pennsylvania in the U. S. A. and the Russian and Chinese fauna.

The great distance makes the age determination by Foraminifera perhaps less trustworthy.

At the present time the age of the Caliza de Montaña given by the goniatite and corals, Upper Visian—Lower Namurian, seems to me better

*) The numbers of the localities are indicated in respect to a future paper about these and other Foraminifera from Palencia by VAN GINKEL.

founded than the age given by the Foraminifera, Westphalian A and/or Upper Namurien.

Further, because of faunal and facies similarities, I believe that the Caliza de Montaña series is the equivalent of the Perapertú series, which has an Upper Visian—Lower Namurian age (WAGNER 1955).

2. Namurian

(excluding the oldest part, belonging to the Caliza de Montaña series)

In the Namurian paleontological remains are very scarce. It is probable that the Namurian Culm facies and the Westphalian A make a continuous sequence; repetitions could not be detected.

The Namurian is an alternation of shales, subgraywacke beds and conglomerates, the latter varying in thickness from 1 to 50 metres. These conglomerates pinch out to the west, where biostromal limestone is developed.

The Namurian is most complete from Cervera de Pisuerga northwards to the rather arbitrarily fixed contact with the Westphalian A. In this continuous sequence, the Namurian reaches a thickness of about 1200 metres.

The lithological association indicates an unstable shelf occurrence of a moderate rate of subsidence ,probably with some oscillations. This explains the thickness of the series.

In these sediments fossils are always very scarce. The subgraywacke beds contain a few plant remains, among others cf. *Mesocalamites haneri* STUR., found near Valsadornin. About 500 metres northwest of Cervera de Pisuerga a *Sphenopteris* sp. was found in the shales along the road. This specimen could be correlated with *Sphenopteris* sp., represented by STOCKMANS and WILLIÈRE (1952, Pl. LVII, fig. 4) from the Namurian of Belgium, Assise d'Andenne.

From the shale about 700 metres west of Valsadornin came a specimen of *Pterinopecten rhytmicus* JACKSON, which is common in the Namurian B (cf. p. 413).

Foraminifera were identified from the limestone 200 metres north of the road Ventanilla—San Martin namely:

Ozawainella sp.

Bradyina cribrostomata RAUSER-CERNOUSSOVA (fig. 15, E).

The new fossil identifications all indicate a Namurian age for this series.

3. Westphalian A.

The contact between Namurian and Westphalian A is not known exactly because of poor fossil content and is therefore not indicated on the geological map. Were known, however, these units are marked by symbols.

The lithological composition of the Westphalian A differs from the Namurian, conglomerate being absent and limestones, as bioherms, being more important in particular, to the west near Santibañez de Resoba. In fig. 12 one can see the increase of dimension of these bioherms to the west (from right to left). In the background is Los Cintos underlain by a part of the enormous conglomerate of the Curavacas formation.

East of Resoba are some small limestone occurrences containing the same brachiopods as the bioherm northeast of Santibañez de Resoba. The fossils

Fig. 12. In the foreground the valley of San Martin, in the middle the biohermal limestone of the Westphalian A, and in the background the conglomerate of the Curavacas formation.

I found near Resoba are not yet cocpletely identified, but Miss G. E. DE GROOT (Leiden) was so kind as to give a preliminary determination:

from the *Schizophoriidae*
Schizophoria sp.
from the *Productidae*
Striatifera sp.
Dictyoclostus div. sp.
Linoproductus sp.
Echinoconchus div. sp.
Marginifera sp.
from the *Rhynchonellidae*
Pugnax sp
from the *Spiriferidae*
Neospirifer fasciger KEYSERLING
Choristites sp.

In addition there are some horn corals and many crinoid remains. Also, Foraminifera were found:
from the limestone near Resoba (loc. 71):

Ozawainella sp.
Plectogyra sp. (phrissa?) and probably
Bradyina cribrostomata RAUSER-CERNOUSSOVA

and in small limestone occurrences about 800 metres north of Arbejal (loc. 121):

Bradyina cribrostomata RAUSER-CERNOUSSOVA
Plectogyra sp. (*phrissa?*)
Ozawainella sp.
Pseudostaffella? (staffella) mölleri? (fig. 15, G)
Fusiella (Profusinella) sp. (fig. 15, F)
Fusiella (Profusinella) cf. *aljutovica* RAUSER-CERNOUSSOVA (fig. 15, A).

The problem of correlation by foraminiferal content is the same as that of the Caliza de Montaña series but for the limestones near Resoba, an age of Westphalian A and/or Upper Namurian fits better.

4 .Westphalian B—C.

ORIOL (1876) was the first author to mention "la immensa capa de conglomerado que constituye la llmada Peña de Curavacas". This conglomerate of the Curavacas formation has an enormous thickness, more than 500 metres near the peak of Los Cintos. A detail-photograph of this conglomerate is given in fig. 13, in which one can observe:

1. poor sorting,
2. size distribution varying from fine-grained to boulders of 50 cm in diameter, but a diameter of 5—15 cm being most common,
3. incomplete rounding of the orthoquartzite boulders,
4. a sand matrix, through which the boulders do not touch each other.

Considering these characteristics, we must consider this a fluviatile, orogenic conglomerate (cf. PETTIJOHN 1949, p. 209). The presence of shales with plant remains intercalated in the conglomerate also proves the terrestrial character of this formation. The plant finds are described in the chapter on paleobotany; they belong incontestably to the Westphalian B—C.

The determination of Westphalian B—C age of the Curavacas formation by the plants was very surprising. Especially, because it was first correlated on lithological analogy with the Peña Cildá series (Upper Stephanian) from the Barruelo de Santullán district.

The Curavacas formation is interesting and very important, for it lies with angular unconformity on older Carboniferous and Devonian rocks. Little is known about the Westphalian B—C in Asturias, Leon and Palencia, but it seems to me that many stratigraphic and structural problems can be solved by this newly recognized Curavacas orogeny, for considering its dimensions, it cannot be a local feature.

Fig. 13. Detail of the conglomerate of the Curavacas formation, Westphalian B—C.

5. Stephanian A.

The southern strip of the Paleozoic of northwestern Palencia is formed by a Stephanian A basin ,named the Carrión basin by Oriol (1876).

This Upper Carboniferous basin is limited on the north by a thrust fault and plunges unconformably under the Cretaceous in the south. It is understandable that these sediments are greatly disturbed in the north below the thrust; to the south the interesting question about the continuation of the basin under the Mesozoic arises, because the Stephanian A is coal-bearing.

In 1912 a hole was drilled near the Vado de Cervera station, through the Mesozoic into the Carboniferous; the boring was described by Sánchez Lozano (1912). He recorded good coal seams at depths of:

275	metres,	thickness	of	the	seam	1.35	metres
281,8	„	„	„	„	„	0.53	„
331	„	„	„	„	„	0.82	„
350	„	„	„	„	„	0.60	„

Two stratigraphic profiles (Appendix 3) have been drawn to get a better insight into the lithology of this basin. We find in the "Constancia" profile (Appendix 3: IV) a group of 4 coal seams, all of which are being exploited at present. At the top of this profile, near the Mesozoic, one seam of a group of three seams is exposed at the surface; all three were exploited in the early days of the mine. This last group is named group I and the other, with 4 seams, group II.

QUIRING (1939) named these groups of the Carrión basin, respectively, Aviñante-group and Santibañez-group. In the Traspeña profile (Appendix 3: V) coal measures occur belonging to group III, named by QUIRING the Requejada-group; but here any exploitation is out of question.

According to the literature the coal of group III is much better developed to the west of Traspeña and is workable in Villaverde de la Peña.

Near Traspeña 3 of the 4 coal seams of group II are in exploitation; the shaft is indicated on plate 1a. Seams of the Aviñante-group (group I) are not exposed along profile V because they are covered by terrace deposits. The poorly exposed coal seem about 800 metres north of Castrejon de la Peña is probably an indication of this group and it is advisable to explore the Aviñante-group between Cubillo and Villanueva de la Peña by mans of small drills, especially because these seams are of a workable thickness in the nearby "Constancia" area.

Almost all the fossils found in the Stephanian A are of a marine character and the Pterinopecten bed indicated by P in profile IV probably has value as a guide horizon in this basin. QUIRING (1939) considered this basin as a limnic one, but it is here considered to be paralic. WAGNER and WAGNER-GENTIS (1952, p. 322) have already pointed out that the arguments of QUIRING for making a separation between the Rubagón and the Carrión basin "nach Bildungszeit und Bildungsweise" are not quite valid.

The partly marine fauna found by HERNÁNDEZ-SAMPELAYO (1944) near Santibañez de la Peña and Guardo is in accordance with the above mentioned finds in the eastern part of the Carrión basin.

D. Mesozoic

The Paleozoic of the eastern zone of the Sierra del Brezo is bordered on the south by Mesozoic rocks, as one can see on the geological map. Although a special investigation of the Mesozoic was beyond my mapping scheme, nevertheless the Triassic and Cretaceous rocks of the adjoining area are indicated on the geological map. The geology of CIRY's map (1939) has been copied, almost without alteration on my map; in particular the complicated structures of the Cretaceous southeast of Cervera de Pisuerga.

My investigation of the Paleozoic and CIRY's of the Mesozoic complement each other entirely. It was especially desirable to copy this part of CIRY's detailed map (1:50,000) of the Liguërzana area in order to bring out the complications in structure around Cervera de Pisuerga in a more complete form than the Paleozoic map alone could show.

CIRY has entered into the details of this Mesozoic area more than any

Stratigrafic column of the Devonian and Carboniferous of the eastern zone of the Sierra del Brezo

Formation	Stage	Thickness	Lithology	Fossils
Carboniferous	Stephanian A	(near Castrejon de la Peña) ± 900 metres	Shales to sandy shales with coal-seams, subgraywacke and conglomerate beds	*Brachiopoda* and *Lamellibranchiata* Plants: *N. scheuchzeri*, *N. ovata*, *C. gigas*, *M. nervosa*, *A. stellata*
	Westphalian D	absent	——	——
	Westphalian B—C	500 metres	Conglomerate with intercalations of shales and sandstone (Curavacas formation)	Plants: *P. volkmanni*, *L. rugosa*, *N.* cf. linguaefolia, A. radiata
			—— Unconformity ——	
	Westphalian A	± 600 metres	Shales with biohermal limestone intercalations	*Foraminifera*, *Brachiopoda*, *Crinoidea*, corals
	Namurian	± 1200(?) metres	Shales, conglomerate and subgraywacke beds, intercalations of biostromal limestone	*Pterinopecten rytmicus* Jacks., *Mesocalamites*
	Lower Namurian / Upper Visean	± 300 metres	Caliza de Montaña with intercalations of shales and subgraywacke beds	*Foraminifera*, *G. falcatus*, corals, plant remains
	Upper Visean	1—7 metres 1—5 metres	Griotte, locally with chert nodules Radiolarion-bearing rock	*Crinoidea* *Cenellipsis* sp., *Crinoidea*
	Tournesian	absent	——	——
			—— Unconformity ——	
Devonian	Frasnian	absent (?)	——	——
	Famenian	150 metres	Orthoquartzite, fossiliferous shales, biohermal limestone	*Brachiopoda* (*Spirifer bouchardi*), *Crinoidea*, *Bryozoa*, *Trilobita*, corals
	Givetian / Eifelian } Couvinian	± 220 metres	Biohermal limestone, iron-bearing sandstone, shales, sandstone	*Brachiopoda* (*Conchidium oehlerti*) *Trilobita*, *Bryozoa*, *Crinoidea* (*Cupressocrinus crassus*), corals
	Coblencian { Emsian / Siegenian Gedinnian	± 200 metres absent (?) absent	Fossiliferous shales, biohermal limestone	*Brachiopoda* (*Uncinulus pila*), *Trilobita*, *Bryozoa*, *Crinoidea*, corals

N = Neuropteris; C = Callipteridium; M = Mariopteris; A = Annularia; P = Pecopteris; L = Lonchopteris.

other, first in his preliminary note (1935) and then in his extensive and valuable work of 1939. A few other authors have written on the Mesozoic, namely KARRENBERG (1934) and RIOS, ALMELA and GARRIDO (1945), but the latter authors have been most interested Mesozoic rocks further east.

The angular unconformity between the Carboniferous and the Cretaceous is well exposed along the road to Vado de Cervera. Here the Cretaceous, varying from a breccia to a conglomerate, lies unconformably on the Carboniferous shales (fig. 14).

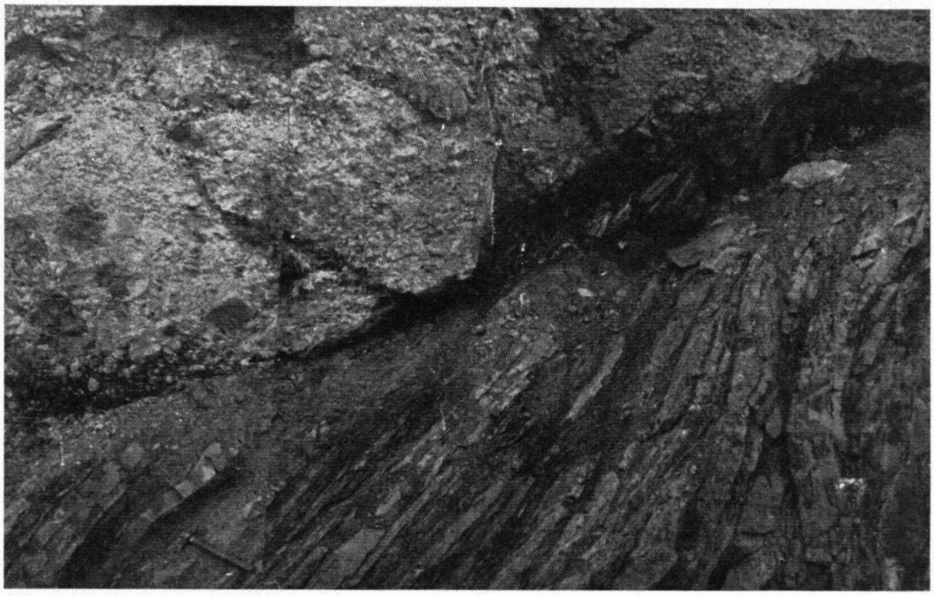


Fig. 14. Angular unconformity between the Wealden and the Carboniferous shales along the road from Cervera de Pisuerga to Vado de Cervera.

The Cretaceous between Cubillo and Villanueva de la Peña lies also with an angular unconformity on the Stephanian A basin; it has not been subdivided on our geological map. It probably represents here the WEALDEN because, CIRY (1939) writes:

"Les graviers kaoliniques de base correspondent à la phase de démantèlement du Massif asturien et se sont formés au cours de la période d'émersion qui a précédé la transgression. Ils sont d'origine torrentielle ou lacustre et représentent un équivalent partiel des dépôts a faciès dit "Wealdien" qui se développent si largement vers l'Est."

CHAPTER V

PALEONTOLOGY

A. Introduction

In the chapter about the stratigraphy it is evident how rich the Devonian fauna is especially between Ventanilla and San Martin.

Faunal lists and ages are inserted in chapter IV, so we do not go into this subject here. As already mentioned, VAN HOEFLAKEN shall describe this Devonian fauna completely in his dissertation. A number of the Devonian brachiopods is represented in plate 3.

It is the intention that Dr. SHIRLEY (Newcastle upon Tyne) will publish about the interesting collection of Devonian corals which I collected with him in this region, but there will be some delay for the fauna is a large and rich one.

B. Some paleontological notes

We will give here some notes about *Foraminifera, Radiolaria, Crinoidea, Pterinopecten* and *Palaeoxyris* cf. *appendiculata* LESQ., all found in the investigated area.

1. Foraminifera.

The Foraminifera collected by me were studied first by Dr. C. L. FORBES (Cambridge); later VAN GINKEL (Leiden) investigated this collection together with other Foraminifera from northern Palencia.

The best specimens from the area are represented in fig .15.

The determination of *Bradyina cribrostomata* is tentative, because the

Figure 15.
A. *Fusiella (Profusulinella)* cf. *aljutovica* RAUSER-ČERNOUSSOVA
Loc. 121, × 36, slide central oblique.
C. *Ozawainella* aff. *angulata* THOMPSON
Loc. Pr., × 77, slide central oblique.
C. *Bradyina* cf. *cribrostomata* RAUSER-ČERNOUSSOVA
Loc. Pr., × 26, slide axial.
D. *Pseudostaffella spaeroidea* (LAMARCK 1836)
Loc. Pr., × 16, slide central oblique.
E. *Bradyina cribrostomata* RAUSER-ČERNOUSSOVA
Loc. 144, × 107, slide sagital.
F. *Fusiella (Profusulinella)* sp.
Loc. 121, × 100, slide central oblique, almost axial.
G. *Pseudostaffella? (Staffella) mölleri?*
Loc. 121, × 81, slide axial.

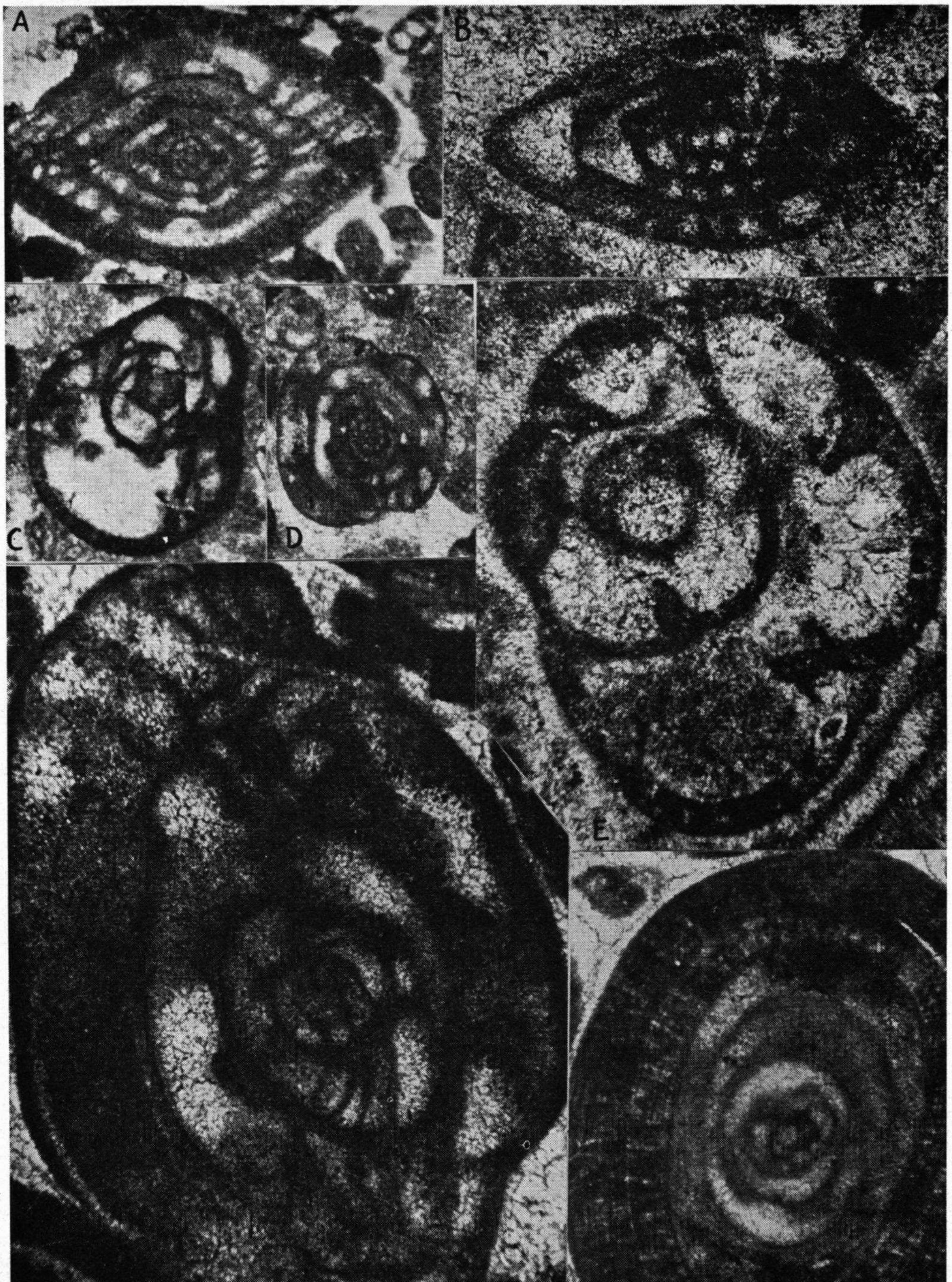


Fig. 15.

specimens are similar in form as well as in dimensions to *Bradyina potanini.*

I mentioned the problem of age determination by correlation already on page 402 the problem of age determination by correlation. The investigation of Foraminifera from the Carboniferous of northern Palencia by VAN GINKEL forms, however, a good basis for a more extensive study of specimens of the Carboniferous of northwestern Spain.

2. Radiolaria.

The interesting radiolarian rock is important in the stratigraphy of northwestern Spain, because of its extensive horizontal distribution. I did not find in the literature, however, information about any study of the Radiolaria of these rocks. Therefore I could not correlate the Radiolaria of my area with others from northwestern Spain.

These fossils have undoubtedly a stratigraphic value and SHACKLETON CAMPBELL (MOORE 1954) writes: "Radiolaria seem to be as useful as Foraminifera if they are abundant."

The study of Radiolaria is not simple and after PIVETEAU: "N'est pas plus ardue que celles des autres Protistes."

At present there are more than 400 known genera of fossil Radiolaria and this number may indicate how difficult it is to determine a species name.

Another difficulty is the fact that the determination is based principally on details, which makes a three-dimensional study necessary. A thin section, as represented in fig. 9, gives little information; it is better to enclose the whole specimen. The method of SCHWARZ (1928, p. 196) for this gave me good results. SHACKLETON CAMPBELL (MOORE 1954, p. 21, 22) also gives methods of study.

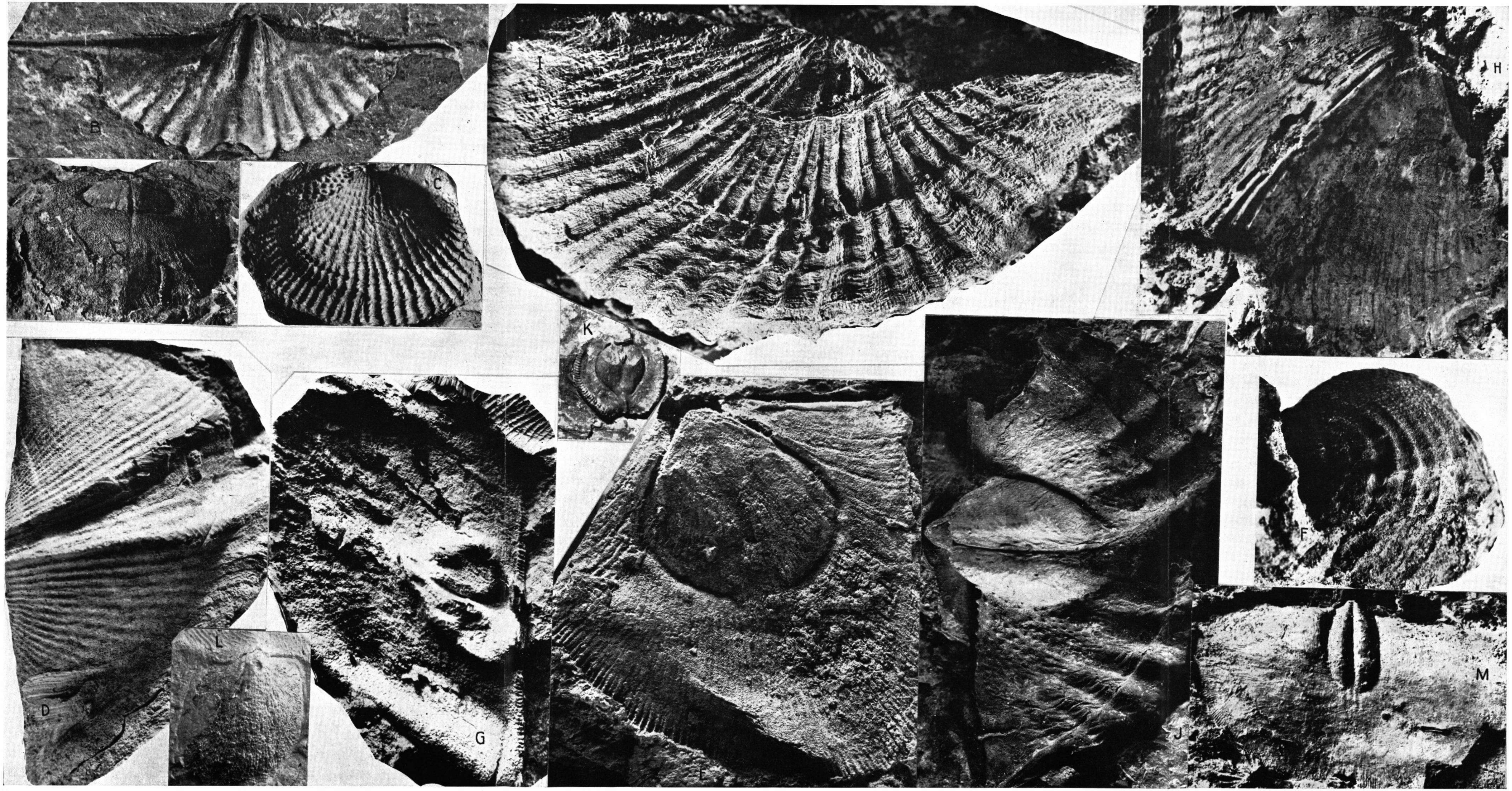
The result of preparing the Radiolaria out of the radiolarian rock is shown in fig. 16.

The radiolarian rock near Mudá, as well as from the area mapped, contain the figured species. They are of the genus Cenellipsis, with an oval shaped skeleton, simple pores and without radial spines. The long axis is 0.093 mm and the short axis 0.071 mm, the pores have a diameter of 0.0055 mm. RÜST (1892) mentioned 4 species of this genus, known from Carboniferous rocks. It was impossible, however, to determine the species name for the specimen in fig. 16.

Plate 3

A. *Douvillina ferquensis* RIGAUX, dorsal valve, × 2,3.
B. *Spirifer bouchardi* MURCHISON, ventral valve, × 3,5.
C. *Atrypa aspera* SCHLOTHEIM, plasticine impression, × 2,5.
D. *Spirifer (Cyrtospirifer) verneuili* MURCHISON, var. *lonsdalii* MURCHISON, plasticine impression, ventral valve, × 2,5.
E. *Schellwienella umbraculum* SCHLOTHEIM, ventral valve, × 2,5.
F. *Conchidium oehlerti* BARROIS, profile ventral valve, × 2.
G. *Stropheodonta piligera* SANDBERGER, dorsal valve, × 2,3.
H. *Spirifer (Costispirifer) trigeri* DE VERNEUIL, dorsal valve, × 2,5.
I. *Stropheodonta sedgwicki* D'ARCHIAC et DE VERNEUIL, ventral valve, × 2,5.
J. *Spirifer (Acrospirifer) arduennensis* SCHNUR, ventral valve, × 4.
K. *Uncinulus pila* SCHNUR, cast, ventral valve, × 1,5.
L. *Trigeria oliviani* DE VERNEUIL et D'ARCHIAC, plasticine impression, ventral valve, × 1,8.
M. *Schizophoria vulvaria* SCHLOTHEIM cast, ventral valve, × 1,6.

(Photograph HOOGENDOORN and VAN HOEFLAKEN).


B
A
C
I
H
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M

3. Crinoidea.

Stems of crinoids are very abundant here in Devonian and Carboniferous sediments. Between Ventanilla and San Martin stems of *Cupressocrinus crassus* GOLDF. were found in Couvinian limestone. According to MELÉNDEZ (1947, p. 296) this is characteristic of the Eifelian and is abundant in Asturias. ZITTEL also considered this fossil Middle Devonian.

The griotte and the Caliza de Montaña contain many Crinoid stems, most of which belong to the genera *Poteriocrinus* and *Actinocrinus*. Crinoid remains were also found in the radiolarian rock. The Westphalian A biohermal limestone is locally rich in Crinoid stems.

4. Pterinopecten rhytmicus JACKSON.

A specimen of Pterinopecten was found 1 kilometre west of Valsadornin, in Namurian shales.

The group of *Pterinopecten papyraceus* Sow. was divided by JACKSON (1927) into 5 species, namely:

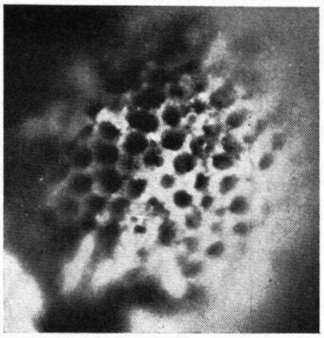


Fig. 16. Radiolaria of the genus Cenellipsis.

Pterinopecten papyraceus Sow.
Pterinopecten elegans JACKSON
Pterinopecten speciosus JACKSON
Pterinopecten rhytmicus JACKSON
Pterinopecten persimilis JACKSON

Considering the descriptions by JACKSON, the Valsadornin specimen belongs to species *Pteridopecten rhytmicus* JACKSON.

The occurrences of *Pteridopecten rhytmicus* beds is indicated in the table (fig. 17) by dots. One sees that *Pt. rhytmicus* is limited to the Middle Namurian in 4 of the 5 countries. DORSMAN (1945) mentioned, however, the occurrence of *Pt. rhytmicus* from the marine Petit-Buisson horizon (Westphalian C) in Limburg, Holland. If one compares his description of this species with those of DEMANET (1935, 1941) or WIRTH (1935), it becomes evident that DORSMAN's specimen probably belongs to another species. DORSMAN describes the anterior ear with five radiating ribs, while DEMANET and WIRTH speak of six strongly developed ribs, the same as the Valsadornin species.

These authors also do not agree on the number of radial ribs on the valve. This number is 47 for *Pterinopecten rhytmicus.*

Considering the great distribution of *Pteridopecten rhytmicus* and its similarity of age everywhere, we may accept that the shales in which the Valsadornin specimen was found are also of (Middle) Namurian age.

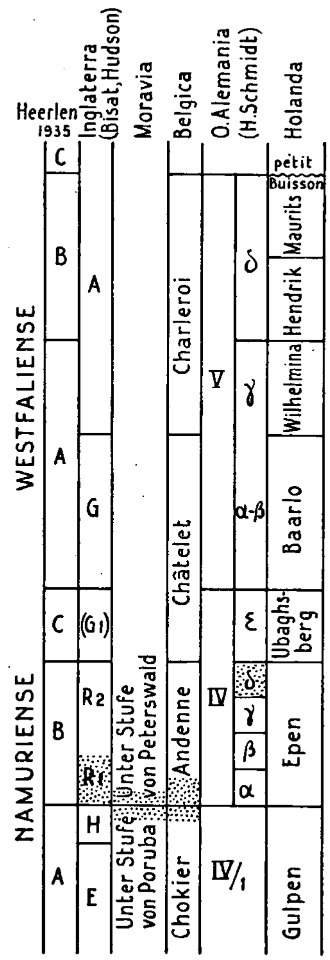


Fig. 17. The occurrences of *Pterinopecten rhytmicus* are indicated by dots.

5. Palaeoxyris cf. appendiculata Lesq.

This is not first mention of the occurrence of a species of the genus Palaeoxyris Brogniart in Spain.

Hernández-Sampelayo (1946) described a find from the Turón mines, namely *Palaeoxyris marini* nov. sp. and gave a synopsis of the different descriptions of fossils of the genus *Palaeoxyris,* given by Brogniart (1828), Schenk (1867) and Pruvost (1919).

A specimen of this genus was found in the Carrión basin ROMEIN *) has kindly identified it as *Palaeoxyris* cf. *appendiculata* LESQ. (fig. 18).

The description is as follows:

Part and counterpart both incomplete. Only part of pedicle, beak not at all preserved. Even the body is incomplete. Length of body (estim.) 20 mm width (estim.) 12 mm. Broadly fusiform. Expansion from pedicle to body gradual. Segments ± equally broad (1.5 mm), minimum 11 in number. The

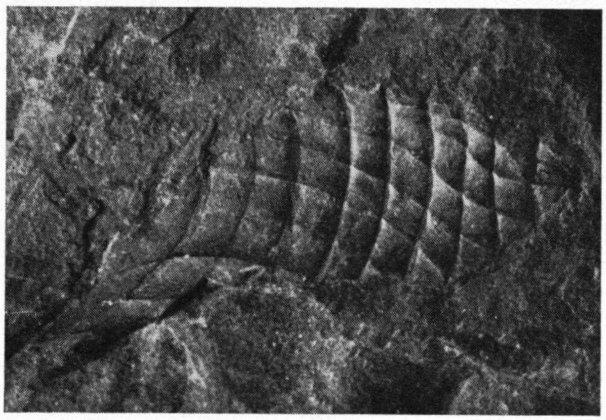


Fig. 18. Palaeoxyris cf. appendiculata LESQ. found near Traspeña, Carrión basin. × 3.

rather strongly curved ribs arise at very variable angles (0—45°). All these features are characteristic for *P. appendiculata,* with exception of the number of segments and the very low angles of rise of some ribs, which are resp. too high and too low for *P. appendiculata.* Both point to *P. pringlei,* but this species has even more and narrower segments. Since the angle of ribs is one of the chief diagnostic features in determining the species in *Palaeoxyris* the name *appendiculata* is not fully justifiable.

*) Mr. B. J. ROMEIN, geologist of the Geologisch Bureau, Heerlen (Holland).

CHAPTER VI.

PALEOBOTANY.

A. Introduction.

In the area mapped there are two stages that furnish interesting fossil localities from the Carboniferous, the Westphalian (B—C) and the Stephanian (A).

Especially from the Stephanian A, to which belongs the Carrión basin, much paleobotanical material was collected. The most surprising results were obtained with the carboniferous plants from the conglomerate of the Curavacas formation which occur in the lenses of a shaly rock intercalated in the conglomerate. In the chapter on stratigraphy the importance of this flora was pointed out already. It was possible to prove a discordance between the lower Westphalian A and the Westphalian B—C.

All the plant rests were studied by WAGNER (Heerlen) and his determinations will be included in this chapter without further descriptions. It is the intention of the writer to publish the complete descriptions by WAGNER in the more extensive Spanish publication, of which the present thesis is a synopsis.

At the end of this chapter a list of plants will be given that I collected near Guardo (Palencia) from beds 2 and 3 of the southern group. This division is according to the "capataz" used in the mines.

B. Westphalian B—C.

Several lenses of sandstones and shales occur in the conglomerate of the Curavacas formation, in which often occur plant fragments and also some better preserved specimens.

One relatively large lens of sandstone with shales in the conglomerate is indicated on the geological map and here the following plants were encountered:

Mariopteris sp.
Cordaicarpus sp.
Calamites sp.
Pecopteris acuta-dentata BGT.
Lepidodendron cf. *ophiurus* BGT.
Samaropsis sp.
Lepidodendron sp. (cf. *aculeatum* STERNB.)
Lonchopteris cf. *rugosa* BGT.
Annularia radiata BGT.
Pecopteris volkmanni SAUVEUR.
Neuropteris linguaefolia BERTR.
Neuropteris tenuifolia (v. SCHL.)

VAN HOEFLAKEN who is mapping a region on the north side of the Curavacas conglomerate, has also found plant remains in the conglomerate, but more in the vicinity of the Pantano de la Requejada. For the sake of completeness I give here the list of plants from this locality:

Lepidodendron cf. *aculeatum* STERNB.
Sphenopteris cf. *spinosa* (GOEPPERT)
Mariopteris sp.
Sphenophyllum cf. *cuneifolium* STERNB.
Pecopteris dentata BGT-*plumosa* (ARTIS)
Pecopteris fruct.
Neuropteris linguaefolia BERTR.

When studying both lists it turns out that the following species are characteristic for the Westphalian B—C age of the Curavacas conglomerate:

Pecopteris volkmanni SAUVEUR
Lonchopteris cf. *rugosa* BGT.
Neuropteris tenuifolia (v. SCHL.)
Neuropteris linguaefolia BERTR.

These four species are illustrated in plate 2 (A, B, C, D, × 3).

This collection of plants is not sufficiently large to make it possible to define more exactly the age of the Curavacas conglomerate. Without doubt it will be possible to augment our knowledge in the future by new finds, enabling us to define more clearly the age during which occurred the new phase that led to the discordance of the Curavacas conglomerate on the older series.

C. Stephanian A.

The eastern part of the Carrión basin, which is included in the mapped area has an abundance of carboniferous plants. I collected plants in 17 localities, indicated by numbers on the geological map. It was attempted only in a few localities to collect a complete flora, because the material is generally sufficient to prove a Stephanian A age. Here follows a list of these 17 localities with the names of the plants encountered:

1. Along the path to the "Constancia" mine a large dump is found, originating from the exploitation of the beds of group II. Here I found:

Neuropteris ovata HOFFM.
Neuropteris scheuchzeri HOFFM.
Neuropteris cordata BGT.
cf. *Callipteridium regina* ROEMER (non ZEILLER)
Alethopteris sp.
Pecopteris polymorpha BGT.
Pecopteris fruct.
Sphenophyllum emarginatum BGT.
Annularia stellata v. SCHL.
Annularia radiata BGT.
Calamites carinatus STERNB.
Sigillaria cf. *tessellata* BGT.
Lepidodendron sp.
Stigmaria ficoides BGT.

To group II belong 4 exploitable coal seams which are mined by the "Constancia" mine to the southeast of Cervera de Pisuerga. Formerly this company mined tow coal seams of group I, which are indicated on the geological map to the south of group II and which are younger stratigraphically.

2. The following plants were collected in a locality about 200 metres north of the buildings of the "Constancia" mine and to the north of group II, therefore from a shale which is stratigraphically older.

Neuropteris ovata HOFFM.
Alethopteris sp.
Pecopteris unita BGT.
Phenophyllum sp.
cf. *Macrostachya* sp.
Cordaites sp.

3. From the second seam of group II came the following plants:

Neuropteris cf. *ovata* HOFFM.
Neuropteris scheuchzeri HOFFM.
Sphenopteris sp.
Mariopteris nervosa BGT.
Pecopteris unita BGT.
Pecopteris cf. *koenigi* CORSIN
Sphenophyllum sp.
Annularia stellata v. SCHL.

4. From the third seam of group II come:

Odontopteris obtusa BGT.
Mariopteris nervosa (BGT)
Pecopteris sp.
Annularia stellata v. SCHL.

5. From the fourth seam of group II come

Neuropteris ovata HOFFM.
? Sphenopteris? sp.
Pecopteris cf. *lamurensis* HEER
Pphenophyllum cf. *emarginatum* BGT.

6. A few metres below the last seam (to the northwest on the geological map) occurs a shale with the following plants:

Neuropteris ovata HOFFM. (Plate 2, H, × 3)
Cyclopteris fimbriata (LESQ.)
Linopteris brongniarti (v. GUTB.) (Plate 2, G, × 3)
Pecopteris unita BGT.
Pecopteris cf. *pluckeneti* (v. SCHL.)
Lepidophyllum majus BGT
Seed

7. On the same stratigraphical level, but to the southwest, where the stratigraphical section was measured, the same shale is found with plants as

in locality 6, with the exception that here one species was found which does not occur in the collection made at locality 6:

Neuropteris cordata Bgt.

8. One of the most interesting fossil localities on the claim of the "Constancia" mine lies at the entrance of the shaft, built some years ago for the exploitation of the seams of group I.

The plants occur in a grey subgraywacke and the following species were determined from this locality which belongs to group I:

cf. *Callipteridium pteridium* (v. Schl.)
cf. *Callipteridium gigas* (v. Gutb.)
Alethopteris missouriensis (d. White)
Alethopteris sp.
Pecopteris "alloiopteroides" ? nov. sp.?
Sphenophyllum emarginatum Bgt.
Annularia sphenophylloides Zenker (Plate 2, K)
Calamostachys tuberculata Weiss. (= *Annularia stellata* v. Schl.)
Cordaites palmaeformis (Goeppert)

A new species was found here, *Pecopteris "alloiopteroides"* ? nov. sp.?, of which Wagner will give the full description in the Spanish work.

9. The coal seams from the region of "Constancia" cannot be traced in outcrops in the basin towards the West and could not be related with the seams that are known to the north of Castrejon de la Peña.

The few and pour outcrops near Cantoral did not furnish enough information to make it possible for me to decide to which group of coal seams these localities belong. The few plant remains that were encountered in locality 9 belong to the species:

Neuropteris scheuchzeri Hoffm.
Sphenophyllum emarginatum Bgt.
Calamites sp.

10. About 50 metres to the north I found still in a shale:

Alethopteris friedeli Bertr.

It is clear that these species at 9 and 10 are not determinative for either group of coal seams.

11. About 650 metres to the southeast of Traspeña an outcrop is found of a coal seam which probably can be classified as belonging to group I. The plant species

Neuropteris ovata Hoffm.

was found here.

12. The open pit mine situated about 500 metres to the northeast of Traspeña, shown in Plate 1a, works the beds of group II. The dump which was formed here, furnished the following, pretty complete collection of plants:

Neuropteris ovata HOFFM.
Cyclopteris fimbriata (LESQ.)
Linopteris brongniarti (v. GUTB.)
cf. *Potoniéa* sp.
Callipteridium cf. *pteridium* (v. SCHL.)
Callipteridium armasi (ZEILLER)
Sphenopteris sp.
Mariopteris nervosa BGT. (Plate 2, I)
Alethopteris sp.
Pecopteris densifolia (GOEPPERT)
Pecopteris aff. *oreopteridia* (v. SCHL.)
Pecopteris (3 species)
Pecopteris bucklandi BGT.
Pecopteris pluckeneti (v. SCHL.)
Pecopteris cf. *leptophylla* ZEILLER (non BUNBURY)
Pecopteris fruct.
Sphenophyllum oblongifolium GERMAR & KAULFUSS
Sphenophyllum emarginatum BGT.
Annularia sphenophylloides ZENKER
Asterophyllites equisetiformis v. SCHL.

13. To the northeast of Traspeña, close by the thrust fault against the caliza de montaña a few coal seamlets occur which are never thicker than 30 cm and usually not more than a few centimetres.

These rather unpromising seams belong to group III, which is altogether unknown in the region of Constancia. Probably the coal seams are not developed here as such, but become more valuable westward.

In this group were found at locality 13:

Mariopteris nervosa BGT.
Alethopteris friedeli BERTR.
Pecopteris unita BGT.

14. About 200 metres north of locality 13 near a thin coal seam of a few centimetres was found:

Alethopteris friedeli BERTR.

15. Further west was found the important species:

Callipteridium gigas (v. GUTB.) (Plate 2, E, × 3)

which belongs to a seam between those of localities 12 and 14.

16. About 380 metres east of Villanueva de la Peña an old dump is found which belongs to the first seam of group II. I found there:

Neuropteris scheuchzeri HOFFM.
Ninopteris brongniarti (v. GUTB.)
Alethopteris friedeli BERTR. (Plate 2, F, × 3)
Alloiopteris cf. *similis* STERNB.
Pecopteris unita BGT.
Pecopteris sp. (2 species)

17. The last fossil locality of the Stephanian A basin is found about 1000 metres to the north of Villanueva de la Peña and consists of shales

and a coal seam of a few decimetres thickness, that should probably be classified as group III. This would then form the thickest seam of this group as far as I know. I found here:

Linopteris brongniarti (v. GUTB.)
Sphenopteris sp. (2 species)
Pecopteris pluckeneti (v. SCHL.)
Sphenophyllum cf. *verticillatum* (v. SCHL.)
Annularia stellata (v. SCHL.)

I add here a list of fossil plants that I collected near Guardo and of which it was already said in the introduction to this chapter that they were found in the second and third seam of the southern group. The following species were determined by WAGNER:

Neuropteris ovata HOFFM.
Neuropteris scheuchzeri HOFFM. (Plate 2, J, × 3)
Alethopteris friedeli BERTR.
Alethopteris bohemica FRANKE
Pecopteris unita BGT.
Sphenophyllum cuneifolium STERNB.
Sphenophyllum cf. *emarginatum* BGT.
Annularia stellata v. SCHL.
Asterophyllites equisetiformis v. SCHL.
? *Lepidodendron* sp.
Cordaites palmaeformis (GOEPPERT)

Between these plants a small snail was found, *Spirorbis pusillus* MARTIN.

We will shortly recapitulate here a few conclusions that can be drawn from these collections.

In general we can say that this flora is an association of species that can occur both in the upper Westphalian D and in the lower Stephanian, for instance the species:

Alethopteris friedeli BERTR.	— Westphalian D — Stephanian
Neuropteris ovata HOFFM.	— Westphalian D — Stephanian
Neuropteris scheuchzeri HOFFM.	— Westphalian C—D — Stephanian A
Annularia stellata v. SCHL.	— high Westphalian D — Stephanian
Pecopteris unita BGT.	— high Westphalian D — Stephanian
Pecopteris pluckeneti (v. SCHL.)	— high Westphalian D — Stephanian.

Then we find rather frequently *Maropteris nervosa* (BGT.) (localities 3-4-12-13), which as a rule does not occur later than Westphalian D.

On the other hand we find several species of the genus *Callipteridium,* which roughly is characteristic for the Stephanian. Especially the occurrence of *Callipteridium gigus* (v. GUTB.) among others in the lower part of the series (group III, locality 15) would suggest that the whole series belongs to the Stephanian A. This species reaches its greatest extension in middle and upper Stephanian, is less abundant in the lower Stephanian and generally is not considered to occur in the Westphalian D. Accepting this criterium one is forced to conclude that *Mariopteris nervosa* (BGT.) occurs in this basin stratigraphically higher than is generally accepted for this species. The simultaneous occurrence of *Callipteridium gigas* (v. GUTB.) and *Mariopteris nervosa* (BGT.) would thus indicate Stephanian A age.

In agreement with this supposition is the presence of the species: *Sphenophyllum oblongifolium* GERMAR & KAULFUSS (loc. 12) and *Alethopteris bohemica* FRANKE (Guardo).

The conclusions of Stephanian A furnishes a somewhat more exact definition as to the age of the Cervera-Guardo group than was given by QUIRING (1939, p. 46—47), who concluded on a Westphalian D and Stephanian age on the basis of determinations by GOTHAN and lists of fossils by MALLADA (1898).

In principle these two conclusions are not very different as this group belongs almost entirely to the lower Stephanian A, bordering on the Westphalian D.

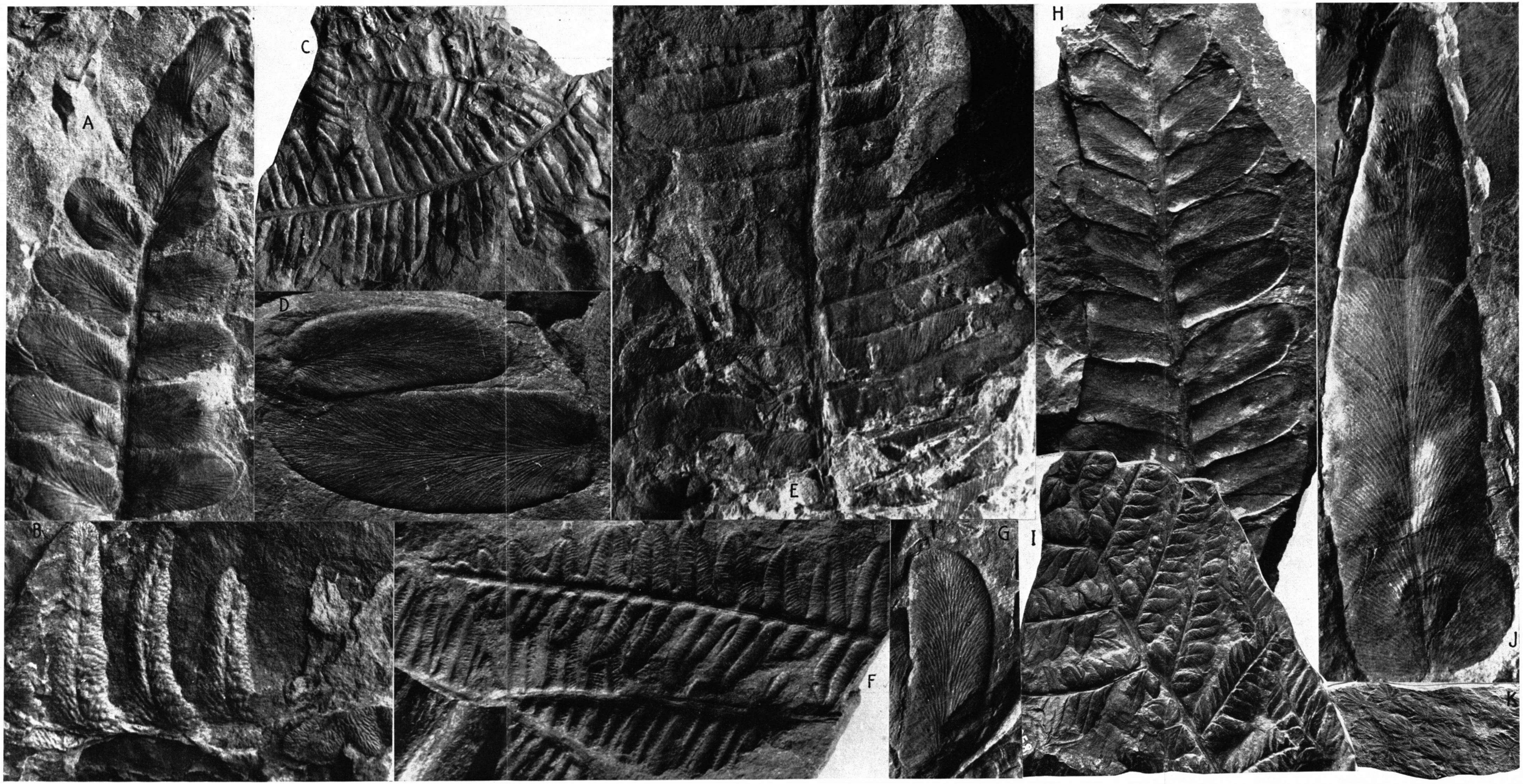
Plate 2

Plants from the Westphalian B—C:

A. *Neuropteris tenuifolia* (v. SCHL.) × 3 (10944) *)
B. *Lonchopteris* cf. *rugosa* BGT. × 3 (10952).
C. *Pecopteris volkmanni* SAUVEUR × 3 (10949).
D. *Neuropteris linguaefolia* BERTR. × 3 (10948).

	Plants from the Stephanian A (Carrión basin):	Locality:
E.	*Callipteridium gigas* (v. GUTB.) × 3 (10961).	15
F.	*Alethopteris friedeli* BERTR. × 3 (10960).	16
G.	*Linopteris brogniarti* (v. GUTB.) × 3 (10962).	6
H.	*Neuropteris ovata* HOFFM. × 3 (10963).	
I.	*Mariopteris nervosa* BGT. (10958).	12
J.	*Neuropteris scheuchzeri* HOFFM. × 3 (10957).	Guardo
K.	*Annularia sphenophylloides* ZENKER (10964).	8

*) Numbering of the collection at the Geologisch Bureau (Heerlen, Holland).



(Photograph van Voskuylen).

CHAPTER VII

STRUCTURE

A. Introduction

The complexity of the structures has already been indicated in the discussion on stratigraphy.

If one looks at the geological map, it is evident that the structure can be treated in units from south to north as follows:

1. the Mesozoic rocks,
2. the Stephanian A basin (Carrión basin),
3. the area between the thrust fault in the south and the fault zone of Ruesga (from Cervera de Pisuerga to Santibañez de Resoba) in the north. We will call this the eastern zone of the Sierra del Brezo s.s.,
4. a unit between the fault zone of Ruesga and the angular unconformity with the Curavacas formation,
5. the Curavacas formation.

These five structural units we will describe in their stratigraphical order, namely 3-4-5-2-1.

B. Structural units

1. Eastern zone of the Sierra del Brezo, sensu stricto.

This region is limited on the south by a thrust fault and on the north by the fault zone of Ruesga and can be subdivided again in:

a. structure of the Devonian between Ruesga and San Martin,
b. structure of the Lower Carboniferous Caliza de Montaña (south of a).

a. *Structure of the Devonian.*

In the Devonian between Ruesga and San Martin the structure around and between the villages of Ventanilla and San Martin is especially complicated. Therefore the geology in the vicinity of San Martin is reproduced at a scale 1:10,000.

Broadly outlined, one has to consider the Devonian between Ventanilla and San Martin as a great overturned anticlinal fold with a core of at least Emsian age. This isoclinal fold in the Devonian, overturned towards the south, lies on Lower Carboniferous rocks and is covered by them. The prevailing opinion is that this anormal Devonian-Carboniferous contact in the Asturian-Cantabric mountains represents an unconformity caused by the Bretonic phase (cf. MELÉNDEZ, p. 397).

The literature about the Paleozoic of northwestern Spain gives little information about this orogenic phase and there is still much fieldwork to be done before the relative importance of this phase in northwestern Spain is fully known.

In Palencia it is known, however, that the Devonian had a considerable relief before sedimentation of the Lower Carboniferous rocks of the transgressive Visean sea.

Evidence is the irregular "pricked" structure of the Devonian through Carboniferous rocks further east (cf. WAGNER 1955). The folding of the overturned fold of Ventanilla—San Martin occurred, however, in post-Visean time, probably during the Curavacas orogeny.

The axial plane of the major Devonian fold between Ventanilla and San Martin is folded again, the result of still later compression. This axial plane folding is indicated not only in the topography, but if one could imagine the area planed by erosion, one should still observe the slight folding in the axial plane, directed perpendiculary to the older axis. This Devonian area

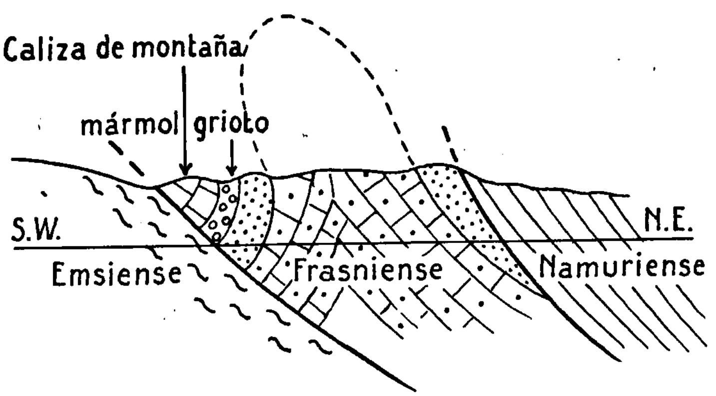


Fig. 19. Section through the small Devonian anticline exposed near the river east of San Martin.

has, therefore, been influenced at least by two deformations, one having a northeastern direction and a second, later one, causing the folded axial plane.

The small anticline, inside the big recumbent fold, is separated by faults from the Namurian on the northeast side and from the Emsian on the southwest side (profile A—A′, appendix 2).

The last mentioned fault is indicated by a dashed line on the map for it can not be observed in the field; its presence was recognized, however, because Frasnian and Emsian rocks are in contact with each other. Although the structure will be in principle as in fig. 19 (near the border of the river east of San Martin) is it difficult to reconstruct where the profile A—A′ cuts this small anticline, because the Caliza de Montaña limestone (Lower Carboniferous) is found here among the Emsian shales.

South of San Martin, where the valley is perpendicular to the strike, one can observe internal complications in the major overturned fold, but the many secondary folds and faults on both sides of the valley make the structure difficult to understand. The projection of the geology on the map shows a few of the internal complications here.

The major Devonian fold plunges under the Carboniferous near the road to Rebanal de las Llantas (fig. 20).

One problem remains more or less unsolved due to insufficient exposures near San Martin: namely, the nature of the connection between the small overturned Devonian anticline west of San Martin (which plunges under the Carboniferous near Peña Negra) and the small Devonian anticline east of this village (fig. 19).

These two small anticlinal structures west and east of San Martin, apparently part of one unit are separated from the major Devonian fold by a fault (dashed line ending with a query east of San Martin).

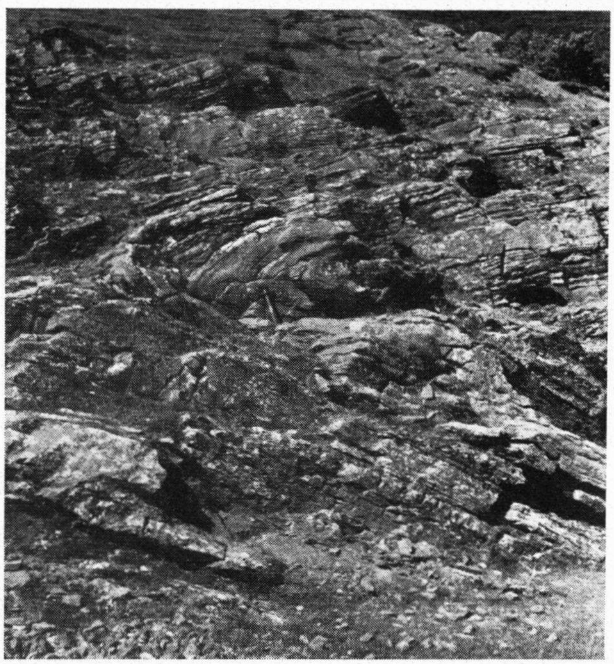


Fig. 20. The Devonian recumbent anticline along the road to Rebanal de las Llantas. The axis plunges under the Carboniferous, (place of the photograph is marked on the map by x).

The structure near Ventanilla is also complicated. Here the most important features are folds in the axial plane of the overturned anticline, caused by compression (alpine?) from east—southeast. This compression is represented schematically in fig. 21, along with the fold axes of the first compression (major overturned fold) and the second compression (folded axial plane). Near Ventanilla an important synclinal cross-fold, plunging to the northeast and a smaller anticlinal cross-structure, plunging in the same direction are developed.

The soft shale and limestone deposits near Ventanilla were compressed and partly cut out by a "massif" of folded orthoquartzite coming from an eastern direction.

b. *Structure of the Caliza de Montaña series.*

This structural unit between the great thrust fault and the fault zone of Ruesga contains, besides limestones and shales with subgraywacke beds, griotte and radiolarian rock.

From the structural profiles of this region (A—A′, B—B′ and C—C′, appendix 2), one can detect the following:

1. great, almost isoclinal folds form the principal structure,
2. these folds are overturned towards the southwest in the profiles A—A′ and B—B′ and are overturned towards the southeast in profile C—C′,
3. this change in direction of the axial plane gives rise to structural complications around Peña Celada, caused by compression,

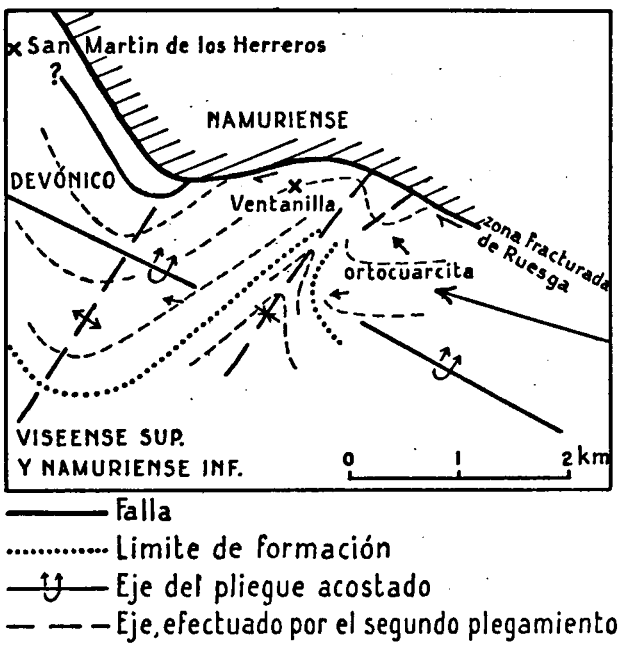


Fig. 21. Sketch of the tectonic movements around Ventanilla.

4. it is probable that this change of direction is connected with the compressed structure in the Devonian between Ventanilla and San Martin,
5. the thrust fault bordering the Carrión basin bends to the west southeast of Peña Redonda but another fault continues in a northwesterly direction along the projected extension of the thrust.

The recumbent fold near the dam of the "Pantano de Ruesga" is one of the interesting details in the structure of this region and is represented in fig. 22. The griotte with chert nodules in the core of the anticline is exposed near the road (cf. fig. 11). A similar structure can be observed about a 1000 metres towards the west; although not so obvious, griotte also occurs in the core of this recumbent anticline.

Another important feature is observable in the field in the Peña Redonda mountain. In the middle of the south face of the mountain is a horizontal line, the plane of contact of two isoclinal folds. This contact is slightly more metamorphosed than the bulk of the limestone (cf. also this feature on plate 1a).

2. Namurian and Westphalian A structures.

The Namurian and the Westphalian A sediments are bordered by the fault zone of Ruesga in the south and the angular unconformity with the Curavacas formation in the north.

About half these sediments in the mapped area are covered by an extensive alluvial terrace.

Fig. 22. Recumbent fold in the Caliza de Montaña near the dam of the Pantano de Ruesga.

It is most probable that the Namurian and Westphalian A sediments occur as a contineous sequence; their thickness here is not in discordance with known thicknesses in Asturias and Leon.

The southern part of Cervera de Pisuerga is built on Devonian and the rest on Carboniferous rocks. The contact, an unconformity, is indicated on the map. There has probably been displacement along this unconformity but it cannot be proved. The same can be said for the contact between the Devonian of the Peñas Negras area and the Westphalian northeast of Arbejal. These unconformities show very few field criteria from which can be said something definitive about later tectonic movement.

It is most probable that the fault zone of Ruesga cuts out a part of the

Namurian near San Martin, causing the Caliza de Montaña series to come almost in contact with the Westphalian A sediments northeast of this village. The fault zone of Ruesga is well exposed as a fault near kilometerstone 6, on the Cervera-Ventanilla road.

An orthoquartzite ridge comes through the Westphalian A shales and biohermal limestone northeast of Santibañez de Resoba, showing a strong resemblance to the Peñas Negras ridges northeast of Arbejal. It is regrettable that fossils have not been found in the orthoquartzite rock, but the lithological resemblance leads to the supposition that it is the same age as the Peñas Negras ridges, Devonian.

3. Structure of the Curavacas formation.

The conglomerate of the Curavacas formation extends from the Los Cintos peak 2 kilometres towards the north, ends near the La Loma peak in the east (northeast of Arbejal) and seems to continue many tens of kilometres to the west.

The Curavacas formation forms a great synclinal depression in the area mapped. In the northern part, for example near Polentinos, as well as in the southern area, one can observe a plunge toward the synclinal axis in the centre. This axis extends in a northwesterly direction from La Loma towards Los Cintos.

Thus the Curavacas conglomerate has a dish like shape and lies with angular unconformity on the older Carboniferous and Devonian rocks.

It will be very interesting to investigate the great conglomerate deposits in Leon as well as Asturias for their paleobotanical content. It is possible that some of these conglomerates, untill now considered to be post-Asturian are of Westphalian B—C age.

4. Structures of the Carrión basin.

The Stephanian A strip, several kilometres long, is bordered by a thrust fault in the north and by an angular unconformity with the Mesozoic in the south.

The fault on the northern side of the coal-basin has always been called a thrust fault, but it must be noted that this could not be proved anywhere in the area; the dip of the fault could not be observed. Nevertheless the general structure of the Sierra del Brezo, an area with great overturned isoclinal folds, strongly suggests that its contact with the Carrión basin is a thrust fault with about the same dip as the dip of the axial planes of its folds.

The Carrión basin is a synclinorium as indicated among other things, by a boring (cf. p. 406) and by the position of the Stigmaria beds and fossil remains. The exposed northern limb, partly covered by the Caliza de Montaña, dips towards the north and the syncline is covered in the south by the Cretaceous.

The dips in the exposed part of the basin vary greatly, a feature which is not surprising taking into consideration the compression from the north, by which the Caliza de Montaña moved against and onto the Stephanian A. The northern limb became almost entirely inverted.

The sediments of the Carrión basin have always been considered as post-Asturian. Among others, Comte (1939, p. 1661) wrote:

"Presque toute la bordure sud de la Cordillère est occupée par du

Houiller stéphanien assez fortement plissé qui repose en discordance sur les formations précédentes. La discordance est bien asturienne."

WAGNER (1952, 1955) proved, however, by paleobotanical investigation that the conglomerate (Peña Cildá series) near Barruelo de Santullán is of Stephanian B—C age. The age of the Asturian phase is therefore younger and the Carrión basin is pre-Asturian in age.

The major structure is an inverted north limb of a synclinorium in which many small cross-folds are developed. One of these complications can be seen near Villaneuva de la Peña, where a vertical S-form structure occurs; this structure is also present in the Mesozoic rock here and is, therefore, of Tertiary age.

SÁNCHEZ LOZANO (1906) wrote about the eastern part of the Carrión basin: "en el extremo de la faja cerca de Cervera se manifiestan las capas plegadas y retorcidas de mil maneras diferentes."

The structure is very disturbed here indeed because it was subjected at the least to both the Asturian and the Alpine phases.

5. Structure of the Mesozoic.

CIRY's schematic reproduction of the Mesozoic structure is very interesting in connection with the structures south of Cervera de Pisuerga (fig. 23).

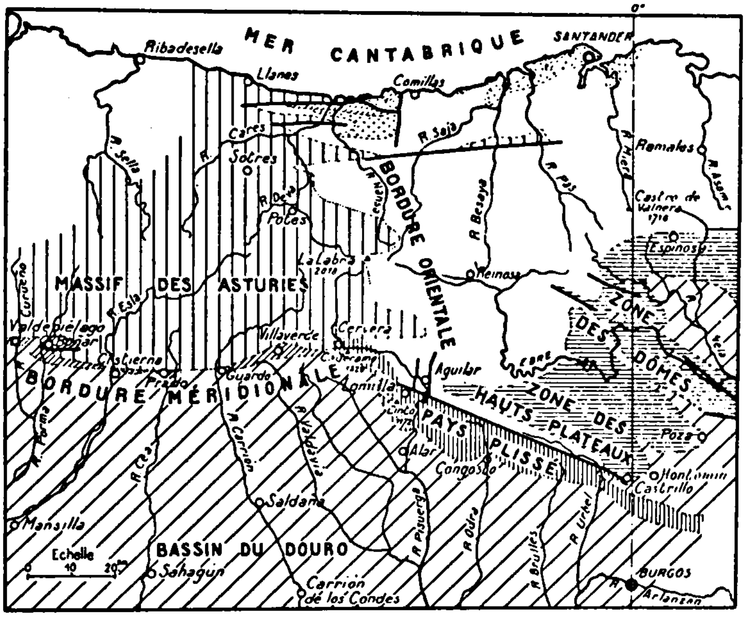


Fig. 23. Sketch of the main structural units (CIRY, 1939).

It shows the "pays plissé" and the "bordure meridionale", which come together near Cervera.

DE SITTER remarks about the complicated structures near Cervera: "Asi pues, encontramos dos direcciones tectónicas en el Secundario: una E—O a lo largo del borde meridionale del macizo Primario de Asturias; otra N.O.—S.E. a lo largo del borde de la cubeta continental neógena de la Alta Castilla, dos direcciones que tienen su punto de interseccion cerca de Cervera de Pisuerga. Estas dos direcciones se encuentran igualmente en las estructuras primarias de nuestro terreno."

C. Tectonic synthesis

The scheme of the geological history of the area mapped is given in fig. 24.

The Devoinan rocks are a rather stable shelf occurrence of a neritic environment. It is most probable that Famenian sediments are almost entirely absent.

The stratigraphical gap of Famenian and Tournesian rocks is caused by the Bretonic phase. It is not very probable that there was an orogenic movement in addition to the epeirogenic one. It seems more likely that the Upper Devonian landscape was deeply eroded before Carboniferous deposition. Partial uncovering of this erosion surface discloses Devonian hills surrounded by Carboniferous sediments.

A transgression took place after the Bretonic phase, in which shallow marine sediments were formed during Upper Visean and Lower Namurian.

The Namurian and part of the Westphalian A were deposited in an unstable shelf area, subsiding at a moderate rate with some oscillations.

After the Westphalian A came the important Curavacas orogenic phase, probably Westphalian B in age. This phase is recorded by the angular unconformity between the enormous post-orogenic Curavacas conglomerate and the older rocks. It can not be called a local feature, in view of the immense dimensions of this conglomerate.

Rocks of Westphalian C and D do not occur in the area, but it is known from the neighbouring regions (cf. WAGNER 1952, 1955; DE SITTER 1955) that there was not any tectonic influence at this time which was of any importance to the structure of the area mapped.

The Carrión basin contains the youngest Paleozoic beds in the area, namely Stephanian A. Carboniferous strata younger than the Asturian folding phase do not occur here. We can accept, however, that the Asturian phase had a great influence on the structure in accordance with the work of many authors in other parts of the Asturian-Cantabric mountains.

The Triassic, a thick sediment near Bustillo de Santullán, thins westward, so does the Jurassic. Both these systems are completely absent about two kilometres east of Cervera de Pisuerga.

Also, more to the west, the Cretaceous lies with angular unconformity on the Stephanian A sediments.

CIRY (1939) gives an extensive synopsis about the tectonic activity which occurred in these regions during the Mesozoic and Tertiary.

LLOPIS LLADÓ's investigations are important; he writes (1951 b):
"C'est a la fin du Miocène que d'importantes failles orientées W—E, ont coupé ce massif en deux parties: le bloc asturien qui est resté émergé et le bloc cantabrique qui a constitué le basin atlantique. Des failles satellites à cette dislocation principale ont morcelé le bloc asturien en multiples compartiments dont les plus importants sont orientés W—E comme la faille cantabrique."

Altogether we know of the following more or less pronounced epeirogenic and orogenic phases, all of which had their influence on the Paleozoic structure of the area mapped:

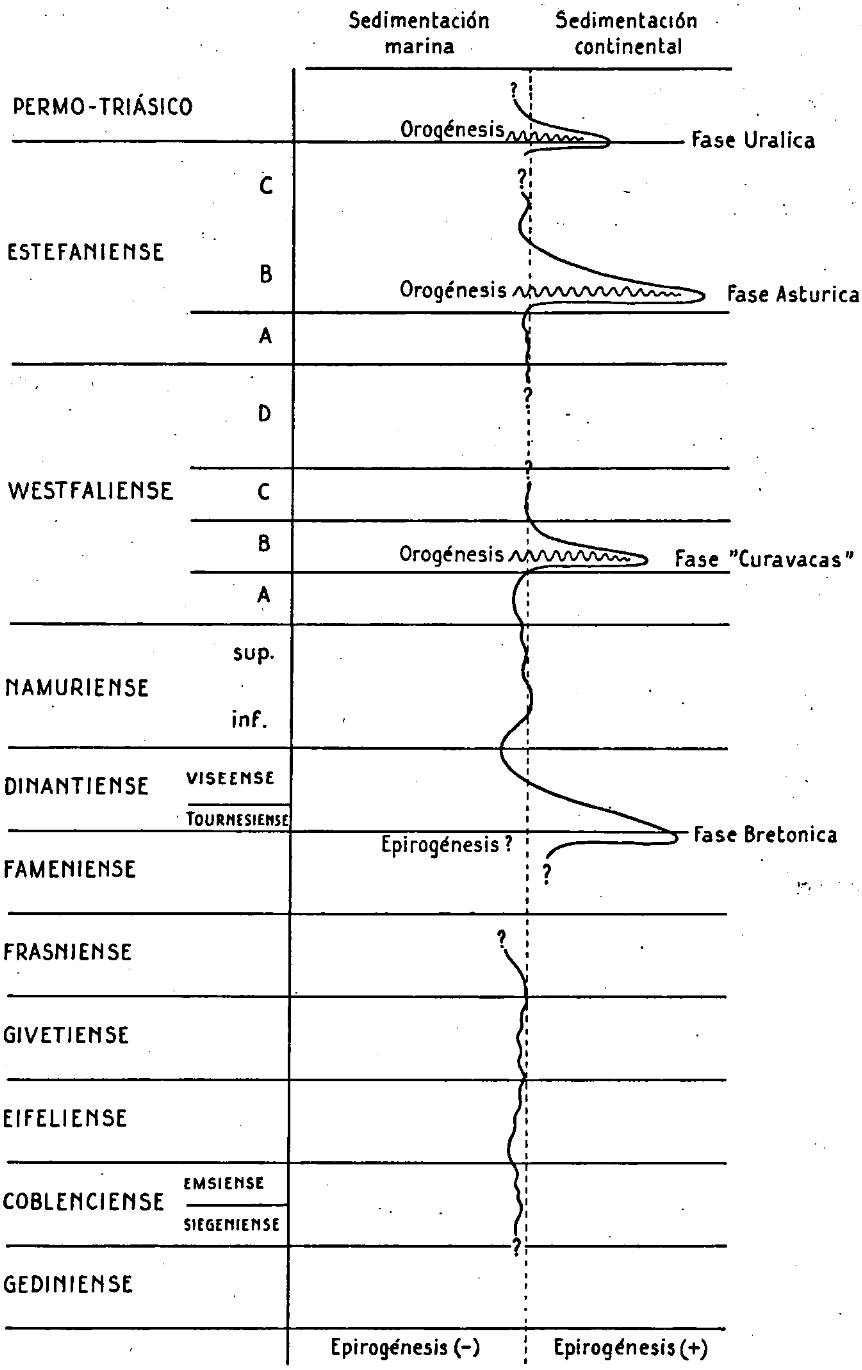


Fig. 24. Schematic reproduction of the geological history of the Paleozoic of the eastern Sierra del Brezo region.

1. Bretonic phase (Upper Devonian) — epeirogenic (?)
2. Cuarvacas phase (post Westphalian A) — orogenic
3. Asturian phase (Middle Stephanian) — orogenic
4. Uralic phase (between Triassic (Permian?) and Stephanian B—C) — orogenic
5. Alpine phases — orogenic.

It is therefore not astonishing that the structure of this Paleozoic marginal region is very complicated.

D. The tectonic profiles

Four tectonic profiles of the area are represented in appendix 2. Except for a few notes, they do not need further comments.

The profile B—B′ from Castrejon de la Peña to the Pantano de la Requejada has been published by QUIRING (1939). Differences in tectonic interpretation have arisen probably because I had more stratigraphic details for the profile construction.

ALVARADO and SAMPELAYO (1945) published a profile from Pico Almonga to Rabanal de los Caballeros. It is, however, almost impossible to construct a profile in this way parallel to the general strike. One can not do any more than to mark out the surface observations on the topographic profile, as is done in the profile D—D′, appendix 2.

CHAPTER VIII

PETROGRAPHY

A. Introduction

Only a few papers have been written about intrusives in the Asturian-Cantabric mountains. An extensive publication about this subject is that of BARROIS (1882), who, besies a description, also gave a classification of the igneous rocks investigated by him in northwestern Spain. Intrusives in northern Palencia were earlier known, for CASIANO DE PRADO (1856) had mapped some granite, see fig. 4.

Further, COMTE (1937) mentioned in a note the occurrence of dikes in Leon having a mineralogical composition between diorites and gabbros.

QUIRING (1939) has described hornblende granite and porphyry near Valsadornin, Rabanal de los Caballeros, Arbejal and Ventanilla and remarked that these rocks are only associated with sediments from Dinantian, Namurian and Westphalian A age and do not occur in the Upper Carboniferous. In the near future colleague's papers about neighbouring regions will indicate that these dikes do occur in younger Carboniferous sediments as well.

B. Intrusives of the investigated area

At the following 10 localities intrusive rocks crop out; alle are plotted on the geological map.

1. 500 metres northwest of the peak of Peña Redonda
2. 900 metres north-northwest of San Martin de los Herreros
3. some boulders of an earlier existing dike 300 metres southwest of San Martin de los Herreros
4. near the village Arbejal
5. 1000 metres south of Peñas Negras
6. 500 metres north of Arbejal
7. near the village Arbejal
8. beside the road Cervera—Rabanal de los Caballeros
9. along the road Cervera—Ventanilla, 500 metres west of kilometre-stone 4
10. along the road Cervera—Ventanilla, 200 metres west of kilometre-stone 5.

The nomenclature used in this report is according to the system of P. NIGGLI (1931, 1935).

The dikes have a holocrystalline, hypidiomorphic, more or less porphyritic, massive structure.

In this paper only the most important minerals in the dikes will be mentioned, but in the complete Spanish text further details will be included. Almost all the dikes belong to the family of the diorites or else vary slightly for this composition.

1. A few metres wide and ten metres long; about 500 metres northwest of the Peak of Peña Redonda in the Caliza de Montaña. Regarding the mineralogical composition the dike has to be called a mela quartz diorite.
   The important minerals are: plagioclase feldspar (andesine), common hornblende, quartz, carbonate.
2. A few metres wide in Lower Carboniferous limestone, about 900 metres north-northwest of San Martin de los Herreros. It may be noted that this mela- to mafic rock has a distinct heterogeneous composition, but it falls in the syeno-diorite family.
   The most important minerals are: plagioclase feldspar (andesine), quartz, common hornblende.
3. About 300 metres southwest of San Martin de los Herreros; some big boulders, undoubtedly dike fragments. Considering the mineralogical composition we have to call it quartz-bearing mela hornblende diorite. Important minerals are: brown-green coloured hornblende, quartz, feldspar, predominantly oligoclase.
4. A long dike with a length of about 500 metres, on which is built the western part of the village Resoba. This porphyritic rock has a very heterogeneous composition, being between quartz-bearing plagisyenite and quartz poor diorite.
   The following important minerals could be detected: plagioclase feldspar (andesine), orthoclase feldspar, quartz, brown coloured biotite, pale green pyroxene and garnet.
5. A small dike occurring in the Westphalian A, about 1000 metres south of Peñas Negras is a garnet-bearing biotite porphyrite.
   Plagioclase feldspar (andesine), quartz, brown coloured biotite, some orthoclase feldspar (among others microcline), and garnet are the most important minerals.
6. On the left bank of the Pisuerga River 500 metres north of Arbejal there occurs a small porphyritic dike in shales. The dike is a quartz-bearing biotite diorite porphyrite.
   Important minerals observed: plagioclase feldspar (andesine), biotite, quartz, carbonate.
7. The porphyritic rock occurring on both borders of the Pisuerga River at Arbejal is very heterogeneous in composition. The observed composition therefore varies from gabbroïtic to grano-gabbroïtic.
   The important minerals are: plagioclase feldspar (labradorite), quartz, some orthoclase feldspar, green brown biotite, garnet, carbonate and muscovite.
8. Along the road between Cervera and Rabanal de los Caballeros a very heterogeneous porphyritic rock is exposed. The average composition of this rock is between quartz-bearing monzonite and adamellite. These transition-families are intermediate between syenites and diorites.
   Important minerals are: plagioclase feldspar, hornblende, brown coloured biotite, quartz, orthoclase feldspar, garnet.
9. A rock varying in composition from granodiorite to quartz diorite occurs along the road from Cervera to Ventanilla about 500 metres west of kilometrestone 4.

The important rock building minerals are: quartz, plagioclase feldspar (albite-oligoclase), biotite and muscovite. It turned out from X-ray analysis that the plagioclase feldspar has an albite-oligoclase composition.

10. Along the same road as the last mentioned rock and 200 metres west of kilometrestone 5 can be seen a dike, a few metres wide, in the limestone. The dike has a quartz dioritic composition.
Important minerals are: brown coloured hornblende, quartz, plagioclase feldspar.

C. Conclusions

Investigation of these 10 dikes indicates that they have mainly a diorite to granodiorite composition. This classification has been given in fig. 25.

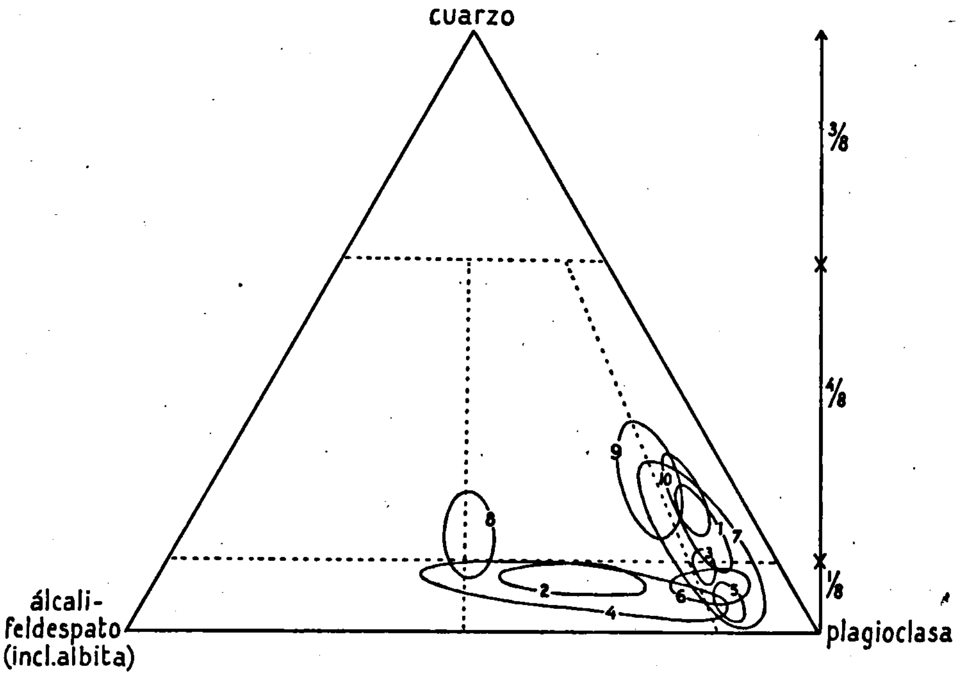


Fig. 25. Composition of the 10 investigated dike rocks, plotted in the quartz-orthoclase-plagioclase-field.

The dark components of these dikes are generally biotite and hornblende. Pyroxenes were observed only in a few cases and in small quantities. It may be noted that prehnite and garnet are rather abundant minerals. Microscopic investigation was very difficult because all these dikes are highly altered.

The following opinion of Barrois (1882, p. 116) about Asturias and Galicia does not wholy agree with the results from northwestern Palencia.

Barrois says: "Les diorites ne présentent pas un grand développement dans les monts Cantabriques, j'en ai rencontré que quelques filons isolés dans les Asturies et de la Galice."

On the other hand, BARROIS mentioned a wide distribution of the "kersantites quarzifère récentes" in Asturias. The dikes of northwestern Palencia do not have these properties, but are more similar to the diorites, mentioned by BARROIS.

It will be necessary, however, to examine these petrologically interesting dikes over a more extensive area, before making conclusions about their mutual connections and their age.

CHAPTER IX

MINING

A. History of mining exploitation

In Chapter III, the synopsis of geological publications and maps of the northwestern part of Palencia, many authors are named in reference to the Carrión coal-basin.

The publication of ORIOL (1876 a) is one of the oldest on this coal-basin; another paper by the same author (1876 b) deals with the copper and iron ores near Ruesga and Ventanilla respectively.

These three deposits: coal, copper and iron are still the only workable deposits in the oriental zone of the Sierra del Brezo.

B. The coal seams

In chapter IV is the stratigraphic information given about the Carrión coal-basin; the following remarks concern the coal mining in this basin.

The quality of the antracite is excellent, as shown by analyses of the average composition from the mine "Constancia" and from exploited coal near Traspeña.

	"Constancia"	Traspeña
volatile matter	2.5—8 %	6 %
ash	2.5—3 %	10 %

1. The reserves.

It is very difficult, if not impossible to calculate the coal reserve because:

1. great part of the coal-basin are covered by alluvial terrace sediments and by the piedmont alluvial plain,
2. the area is disturbed by tectonical influence,
3. the coal measures are in "forma rosaria" and locally wedge out,
4. information from trill holes is lacking except for the boring near the station of Vado de Cervera, described by SÁNCHEZ LOZANO (1912).

The thickness of the coal seams that occur in the exposed parts of the basin and that are known from the drilling are not so promising that it is economically justified to make exploitation shafts of a few hundreds of metres depth. QUIRING (1939, p. 55), though he recognized the difficulty of the task, calculated a reserve of 70.6 millions of tons of workable coal between Guardo and Cervera de Pisuerga. As I studied only the eastern part of the basin, it is impossible for me to evaluate this estimate, but it is probably too large.

C. The iron-bearing sandstone between Ventanilla and San Martin de los Herreros

According to tradition, San Martin de los Herreros *) owes its name to the fact that the Romans made their swords here.

The iron-containing deposit between Ventanilla and San Martin de los Herreros has been exploited on a small scale since 1953 by the Sociedad Minera Metalúrgica Palentína.

1. Origin and composition of the ferruginous sandstone.

This type of iron-containing sediment is known from the Devonian in many places in the Asturian-Cantabric mountains. (ADARO and JUNQUERA, 1916).

As is already known, the areas of shallow water such as marine lagoons or large narrow continental seas are in particular suitable for sedimentation of such iron containing deposits. It was in such an environment that the iron-bearing sandstones of northern Spain formed during the Devonian. It is interesting to compare this interpretation with the survey map of MELÉNDEZ (1953), showing the division between land and water during the Middle Devonian in Spain (fig. 8).

The iron-bearing sandstone between Ventanilla and San Martin de los Herreros is a layer about 12 metres thick with a variable iron content. In this layer is a horizon about 2 metres thick which yields a workable ore. This ore contains a minimum of 47 % pure iron.

The following two analyses are from samples taken near San Martin; one analyse is given from a deposit in Leon (San Pedro) for purposes of comparison.

	San Martin de los Herreros		San Pedro (COMTE, 1937)
Fe_2O_3	57.98	67.26	54.3 %
FeO	9.25	5.91	0.7
SiO_2	14.13	13.12	20.3
Al_2O_3	1.84	1.73	6.4
MgO	0.40	0.15	0.3
CaO	5.35	2.60	8.8
Mn_3O_4	0.72	0.66	MnO tr.
P_2O_5	1.01	1.40	H_3PO_4 4.9
H_2SO_4	0.01	0.02	0.07
lost by calcining (+ 110° C)	9.26	7.10	—
	99.95	99.95	95.77

The remaining non-workable 10 metres of this deposit are poorer in pure iron, the content ranging from 20 to 42 %. Fig. 26 is a photomicrograph (× 60) of this sediment, showing the fairly angular quartz grains in hematite.

A porous iron-containing sandstone, locally called "rubio", lies a few metres below the main ore-bearing sandstone. This layer has a thickness of about 1 metre and is irregular in its occurrence. The pure iron content is good, namely 56 %.

According to the tables of DE SITTER (1949, pp. 325 and 327) compiled

*) Sp. herrero = smith.

from publications by BARROIS, COMTE and DELÉPINE, the deposit of San Pedro should belong to the Siegenian. From these tables it is obvious that the iron deposits in the northern part of Leon are of Famenian age.

GARCIA-FUENTE (1952, p. 85) places the "arenisca ferruginosa" near Teverga (Asturias) in the Lower Devonian.

From the above the conclusion can be drawn that the different iron occurrences in Palencia, Leon and Asturias are identical in facies and mineralogical composition, but difficult to compare in age.

QUIRING (1955) compares, in a short note, the ore of Ventanilla with ore of the Lahn-Dill type of Germany.

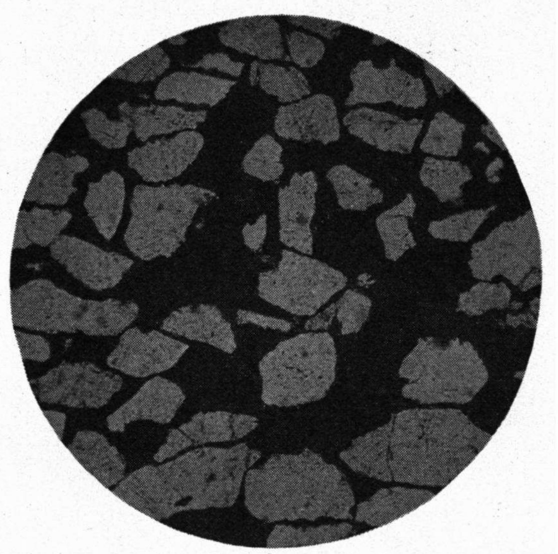


Fig. 26. Thin section of iron-bearing sandstone of Couvinian age between Ventanilla and San Martin. The photograph shows the intergrowth of hematite and quartz. × 60 (the opaque mineral is hematite).

2. The reserves.

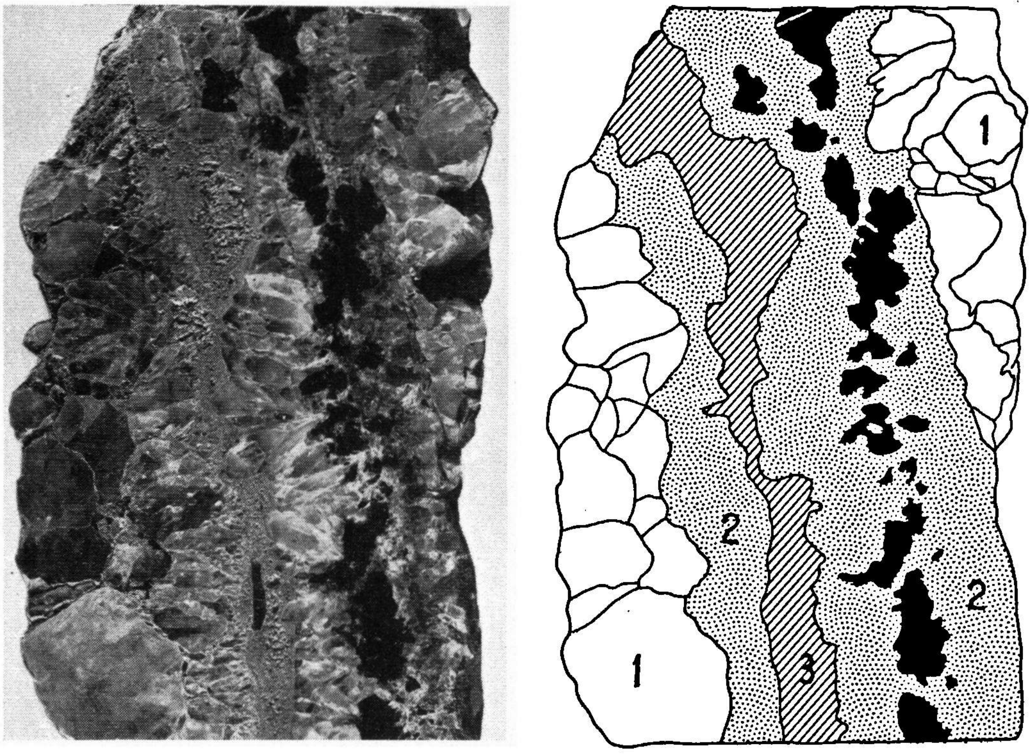
The iron-bearing sandstone belongs to the major overturned fold between Ventanilla and San Martin de los Herreros, but is missing in the northern limb of the fold due to faulting.

The iron ore has in longitudinal profile a surface of about 2.000.000 m^2 above water level. The total reserve will be 2.000.000 × 3.8 × 2 = 15.960.000 tons, the ore calculated as being 2 metres thick and with a S.G. of 3.8. Further the "rubio" will yield as workable ore perhaps another 1.000.000 tons in open workings.

D. The copper veins

This chapter can not be closed without mentioning the copper minerals from the studied area.

Some chalcopyrite was exploited not only near Ruesga, but also at some other places on a very small scale. During fieldwork I found at more places indications of the occurrence of copper, but there were mostly no more than



a. b.

Fig. 27. Picture (a) with diagram (b) shows quartz crystals formed in two sequences, with chalcopyrite (in the figure as opaque mineral) in a second sequence. The vug (3) was filled with material from above.

a few traces of malachite and azurite. None of these small occurrences are very promising.

1. Origin.

The copper deposits I have seen are found in the Devonian and Carboniferous limestones. In these limestones some of the openings have been filled by hydrothermal processes; the very small fissures being filled completely and the wider fissures partially by crystallization.

In many places I found big quartz and calcite crystals in the copper containing deposits, further evidence that many deposits belong to cavity-filling deposits. This is obvious in fig. 27, where a fissure was filled by a first sequence, when big quartz crystals were formed and by a second sequence when smaller crystals with chalcopyrite were formed (chalcopyrite at the hanging wall). Finally the remaining vugs were filled with material from above. Part of the chalcopyrite has changed in the zone of oxidation into malachite and azurite and also into limonite, under the influence of carbonaceous water. BATEMAN (1947, pp. 251 and 252) has described this process.

Röntgenographic methods ascertained that the limonite occurs as goethite.

As the oxidized zone is very poor and there is nowhere a zone of supergene enrichment, the occurrence of a somewhat sizeable accumulation of ore is very unlikely.

I did not put the places of copper indications on the geological map.

SAMENVATTING

In het noordwestelijk deel van de provincie Palencia vormt de Sierra del Brezo een onderdeel van de Cordillera Cantábrica. Het resultaat van een geologische kaartering van het oostelijk gedeelte der Sierra del Brezo met zijn aangrenzend gebied is weergegeven in de hier bijgevoegde geologische kaart (schaal 1:25.000).

Zowel een onderzoek der stratigrafie, als van de tektoniek leidde tot nieuwe gezichtspunten omtrent dit Palaeozoïsch gebied. Verder wordt in dit werk de petrografie van tien waargenomen gangen besproken en werd aandacht besteed aan het voorkomen van ertsen, t. w. ijzer en koper, en van steenkolen.

Dit gebied, dat bijna geheel uit Devonische en Carbonische afzettingen bestaat, is zeer rijk aan fossielen. Vooral het Devoon tussen Ventanilla en San Martin heeft een rijke fauna, in het bijzonder van brachiopoden en koralen. Door middel van fossielen kon worden aangetoond, dat hier een ononderbroken afzetting voorkomt vanaf Emsien (of ouder?) tot Frasnien, met mogelijk een gedeelte van het Famenien.

Als bewijs voor de invloed van de Bretonse fase kan het stratigrafisch hiaat gelden (van een gedeelte?) van het Famenien, Tournesien en het Onder-Viséen. Waarnemingen in het veld maakten waarschijnlijk, dat het hier meer een epirogenetische beweging betreft.

Howel de fauna van het Carboon hier armer is dan die van het Devoon, kan de stratigrafie door plantenvondsten worden aangevuld. Hierdoor bleek het mogelijk te zijn het Carboon in zijn diverse etages onder te verdelen.

Interessant is de oudste Carbonische afzetting, een roodbruin radiolaria-houdend gesteente, dat een grote laterale verspreiding heeft. Dit gesteente gaat over in griotte, die plaatselijk knollen van het radiolaria-houdend gesteente bevat. Stratigrafisch volgt de Caliza de Montaña-serie, een neritische kalkafzetting met inschakelingen van schalies. Deze serie heeft een dikte van ongeveer 300 m en komt samen met het Devoon voor in grote, isoclinale plooien, die in zuidelijke richting overhellen.

De jongere Namurien en Westfalien A afzettingen, ontwikkeld als een Culm-facies, bevatten geen steenkolenlagen en zijn bovendien arm aan fossielen.

Belangrijk bleken de plantenvondsten in het Curavacas-conglomeraat te zijn, die duidelijk een Westfalien B of C ouderdom te zien gaven. Dit enige honderden meters dikke conglomeraat rust met een hoek-discordantie op oudere afzettingen. Hiermee werd een nieuwe orognetische fase, de Curavacas-fase, aangetoond, die ongetwijfeld in deze gebieden een sterke tektonische invloed moet hebben uitgeoefend, gezien de honderden vierkante kilometers grote uitgestrektheid van dit post-orogene conglomeraat.

Afzettingen van Westfalien D ouderdom werden in het gebied niet waargenomen.

Aan de voet van de zuidelijke hellingen van de Sierra del Brezo bevindt zich — hiervan gescheiden door een overschuivingsbreuk — het steenkolenvoerende Carrión-bekken. De gevonden planten wezen uit, dat dit paralisch bekken een Stefanien ouderdom heeft. Dit zijn de jongste Carbonische gesteenten, die in het bestudeerde gebied voorkomen.

De orogenetische Asturische fase, die aangetoond kon worden in een aangrenzend gebied, blijkt tijdens het Boven-Stefanien een sterke tektonische invloed te hebben uitgeoefend. Hieraan zal ook ongetwijfeld het gebied van de Sierra del Brezo onderhevig geweest zijn.

Het gekaarteerde Palaeozoicum vindt zijn zuidelijke begrenzing in een discordante bedekking van Mesozoïsche afzettingen, die bijna geheel tot het Krijt behoren, maar ten zuidoosten van Cervera de Pisuerga nog gedeeltelijk tot de Trias en Jura gerekend moeten worden. Mesozoïsche structuren tonen aan, dat Alpine fasen hun invloed in dit gebied hebben doen gelden.

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