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EXPLANATION GEOLOGICAL MAP OF THE PALAEOZOIC OF THE SOUTHERN CANTABRIAN MOUNTAINS 1 : 50.000 SHEET 1 PISUERGA

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(with coloured map, coloured sections and stratigraphical columns)

ABSTRACT

The Carboniferous Pisuerga basin developed north of the León line and as such is the most eastern one of the Asturide basins. The Carboniferous sequence is subdivided into Ruesga Group (roughly Lower Carboniferous + Namurian), Yuso Group (roughly Westphalian) and Cea Group (roughly Stephanian).

Since the beginning of the Yuso Group the Pisuerga basin became subdivided into a western and eastern basin and since the beginning of the Cea Group the western basin became subdivided into two separate basins. The main folding started during the Stephanian.

A remarkable interaction of epeirogenic and orogenic movements leads to the analysis of a close relation between sedimentological and structural features. Several pronounced structural lineaments can be traced to have been active since the Middle Devonian into the Tertiary.

SUMARIO

La cuenca Carbonifera de Pisuerga se ha desarollado al norte de la linea tectonica de León, y es la que se encuentra mas al este de las cuencas Asturianas. La sucesion Carbonifera se ha subdividido en los siguientes grupos: Ruesga (aproximadamente Carbonifero inferior y Namuriense); Yuso (aproximadamente Westfaliense) y Cea (aproximadamente Estefaniense)

Desde el comienzo de la deposición del grupo Yuso la cuenca comenzó a subdividirse en dos, una parte al este y una parte al oeste. A su vez desde el comienzo de la deposición del grupo Cea la parte oeste comenzó a subdividirse en dos cuencas separadas.

El plegamiento principal empezó durante el Estefaniense. Una marcada relación de los movimientos epirogenicos y orogenicos ha permitido observar una estrecha relación entre los fenómenos sedimentologicos y estructurales.

Algunos bien marcados lineamientos estructurales han podido ser trazados cuya actividad se ha establicido desde el Devonico Medio hasta el Terciario.

CONTENTS

INTRODUCTION

Since 1950 the Geological Institute of the Leiden University has been studying the geology of the Palaeozoic portion of the southern Cantabrian Mountains in the northern parts of the provinces of Palencia and León and a portion of the province of Santander in northern Spain.

Many papers and a few theses of this group have been published, starting in 1952 with the first paper by Wagner and Wagner-Gentis, and summarized by de Sitter in 1962 (de Sitter, 1962b) with a provisional 1 : 100.000 map and finally a set of theses in 1964 and 1965. Much of the work is still unpublished in the form of reports of different kinds in the files of the above mentioned Institute. It has always been our purport to assemble all the material in a set of 1 : 50.000 maps of which the sheets Pisuerga and Esla (Rupke, 1965; Helmig, 1965) are the first ones to be published. We hope that we will be able to publish many more of these maps in the near future. It has taken us a relatively long time to come to this first result because the study of the stratigraphy of the Devonian but more especially of the Carboniferous has taken considerable effort.

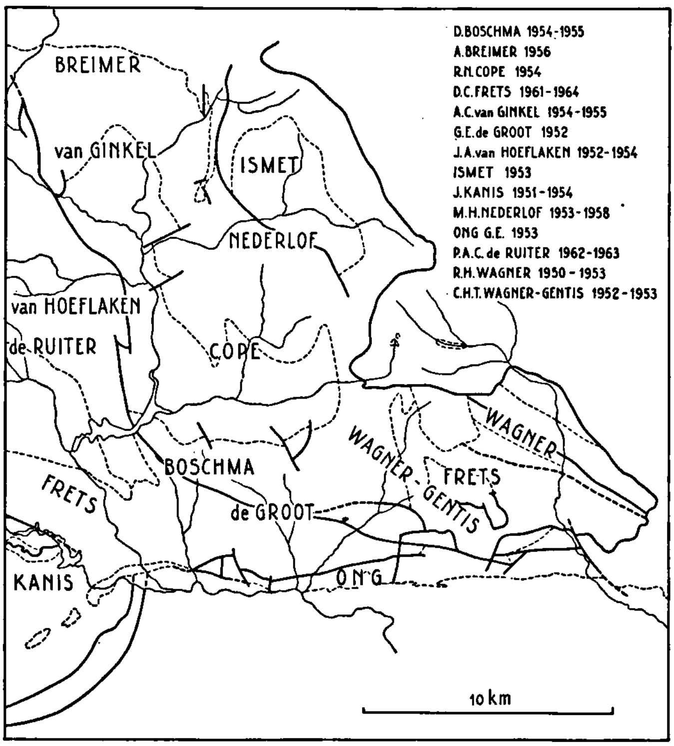


Fig. 1. Field work regions of the Pisuerga basin and surroundings

Eventually the Carboniferous of the Cantabro-Asturian mountains will give us a very complete and unique section for Western Europe, because the faunal assemblages of marine character reach from the bottom of the Lower Carboniferous to the top of the Upper Carboniferous and the floral assemblage from the Mid-Carboniferous to the top of the Upper Carboniferous. The correlation of these faunas and floras has proven to be of great interest (van Ginkel, 1965). Another interesting point is the lateral variation of facies both in the Devonian and in the Carboniferous. Especially during the Carboniferous great differences arise between the Leonide and Asturian facies (de Sitter, 1962a). The Pisuerga basin certainly belongs to the Asturide marginal basin facies.

On the small map of fig. 1 the fieldwork regions of the contributing geologists have been marked. We want to thank those who have not published for their permission to use their work.

We have had the assistance of many paleontologists for fossil determinations. Those which have not published their contributions are Prof. H. K. Erben, Bonn and Mrs I. A. Butusova, Leningrad; we thank them most heartily for their important contribution and their permission to publish their results. Dr. Kullmann has also assisted us at many occasions, and we are grateful for his contributions, which he had occasion to publish himself.

In our own department many people helped us, students, technicians and staff members. We hope they are satisfied that their work has finally come to publication and we want to thank them for their assistance.

SHORT HISTORY OF GEOLOGICAL RESEARCH

The first time the geology of the Pisuerga basin was mentioned in literature was probably in connection with the 1 : 400.000 map of the province of Palencia, published by Casiano de Prado in 1856. A few years later in 1861 a 1 : 100.000 map of the northern part of this province was published by Prado showing the Pisuerga basin with roughly its Devonian and Carboniferous regions without further subdivisions. The Barruelo and the San Cebrian coal seams appear on this map.

The Devonian of a "mancha pequeñita de San Cebrian de Muda" with Middle Devonian brachiopods (probably the small outcrop east of Mudá) is mentioned by Mallada (1875—1881). In the same work plant fragments from the coal seam of Barruelo and Orbó are described, without conclusions as to their age.

The coal mining industry attracted attention early as shown by publications such as Arce (1850), Cantalapiedra (1855), Donayre (1857), Navarro (1876), Oriol (1876) and Bentabol (1879). In the first years of the twentieth century a borehole was drilled southeast of Cervera starting in the Cretaceous and penetrating into the Stephanian with coal seams, reaching a depth of 396 m. The stratigraphic section of the 396 m penetrated by this borehole has been given by Sanchez Lozano (1912).

A new geological map, scale 1 : 100.000, was published in 1924 by Dupuy de Lome and Pedro de Novo, which was not a great improvement on the older map. All the Carboniferous limestones were considered to be of Lower Carboniferous age. The authors discuss the possible extension of the Barruelo basin which they considered as a simple syncline, postulating the recurrence in its east flank of the known coal seams of the west flank, with the consequence of a borehole drilled east of Barruelo in the Westphalian which obviously did not find the postulated coal seams.

In the work of Cueto y Ruy-Diaz (1926) on the tectonics of the Cantabrian

Mountains, the tectonic structure of the coal-bearing series of Barruelo and Redondo are considered, a problem which is again taken up by the same author in 1934 in relation to the coal seams near Vergaño, Celada and Redondo.

In 1931 Sheet 12 of the official geological map 1 : 400.000, including the Pisuerga region was published, on which appear two Devonian outcrops, a few intrusives and a subdivision of the Carboniferous in Lower and Upper Carboniferous.

In 1934, Patac describes from a technical point of view all the ten coal mines in production at that time. He still considered the Sierra Corisa limestones to be correlable with the Caliza de Montaña. By then Quiring had started his work in the Pisuerga basin. In a short paper of 1935 he established the Westphalian B–C age of the San Cebrian coal seams, and in 1939 his maps of the Pisuerga basin and the Carrion region appeared, a great step forward. The structure and stratigraphy are established in a much better way, although many errors are still apparent. The Sierra Corisa limestone is finally recognized as being of Westphalian age, but Quiring does not yet recognize the Stephanian age of the overlying sequence in the cores of the synclines.

In the meantime Karrenberg (1934) had made the first study of the Mesozoic surroundings, south and east of the Pisuerga basin, a study which was taken up again by Ciry, in 1939. The detailed maps of Ciry are still the basis of the Cretaceous stratigraphy and structure on the southern border of the Cantabrian Mountains.

In a short paper Dahmer (1936) mentions three brachiopods, collected from one of the Upper Devonian quartzite outcrops southeast of Cervera.

Alvarado and Sampelayo (1945) gave a critical review of the work of Quiring on the Pisuerga basin. They still thought that the San Cristóbal coal seams should be correlated with those of Vergaño, and as they found a Triticites fusulinid in the limestones of Cabra Mocha the Stephanian was recognized for the first time. Their structural interpretation is an improvement on that of Quiring. In 1949 de Sitter published a paper summarizing the results of the stratigraphic work on the Palaeozoic of these regions.

In 1951 Jongmans reviewed the previous work on the flora (Mallada and Quiring) and made some corrections. Since that time an intensive study of the southern zone of the Palaeozoic of the Cantabrian Mountains has developed directed by the Geological Institute of the Leiden University in the Netherlands. The first published papers were by Wagner and Wagner-Gentis (1952) and Wagner (1955), who were interested in the first place in the flora and goniatite fauna of the Carboniferous of the Barruelo basin. Since then this study has given rise to numerous papers by Wagner on the flora of the Cantabrian Mountains in general. Starting in 1955 de Sitter has published a series of papers on the general geology of our region. Nederlof (1959) made a special study of the sedimentology of the Carboniferous of the northern part of the basin and together with de Sitter (1957) studied the coal reserves of the whole basin. Kanis (1956) wrote a thesis on the Ruesga region, Nossin (1959) studied the geomorphology and van Ginkel (1959) gave the first results of his studies on the Fusulinid faunas of the Carboniferous completed in 1965 by his thesis. Breimer (1962) mentions several Crinoidea from the Pisuerga region in his treatise on the Spanish Palaeozoic Crinoidea.

Since 1955 the Leiden Institute has accumulated numerous unpublished reports on the Pisuerga region in particular and the stratigraphy of the Palaeozoic of the southern Cantabrian Mountains in general, which will be used extensively in this map description.

Besides these unpublished reports a series of papers appeared in the Leidse Geologische Mededelingen.

Recently Frets (1965) gave an account of his study of the southern border of the Pisuerga region.

The thesis of van Veen (1965) gives a detailed description of the region west of the Pisuerga basin including the Devonian of the Lebanza anticline and the Devonian structures north of it. We will refer the reader to these studies and those by Kanis (1956) and Nederlof (1959) for more detail on the regions they treat.

In broad outlines our stratigraphical interpretation of the Carboniferous is based on the studies of Wagner of the flora and van Ginkel on the fusulinids and Kullmann on the goniatites. The Devonian stratigraphy in the region was started by van Hoeflaken (unpublished) and was continued by Binnekamp (1965) and others, who have greatly profited from the work of Comte (1959) further to the west in the Porma-Bernesga region.

Finally in this same volume of the Leidse Geologische Mededelingen appears an article of Rácz (1966) about the algae which he studied in van Ginkels samples of the Pisuerga area.

GEOMORPHOLOGY

The geomorphology of the Pisuerga-Rubagon basin has been studied in detail by Nossin (1959). There is a very strong contrast between the steep valleys north of the water divide, north of Piedrasluengas and the gentle topography to the south of it. The northern streams have their base-level in the Atlantic ocean, very close by, the southern ones have as their erosional base-level the Castillian Meseta at about 900 m altitude.

The Cantabrian mountains are the result first of Tertiary uplifts, starting in the late Eocene and renewed in the late Miocene, which stopped at the end of the Pontian, but none of the erosional features of that time have been preserved in the Pisuerga basin. A renewed uplift of the whole Meseta region and Cantabrian Mountains in the Rhodanic phase reactivated the erosion and planation started again. In Villafranchian time the pediment in front of the Cantabrian mountains was formed, and considerable remnants of this Villafranchian planation surface are preserved in the Pisuerga region. Nossin has called them the Redondo Surface in the higher reaches of the Pisuerga river and the Mudá-Barruelo Surface along the southern border (fig. 2). High terraces consisting of coarse boulders are preserved on these surfaces the largest one between the Ruesga and Pisuerga rivers. At that time the Pisuerga river still flowed southwards from Cervera de Pisuerga on through the so called Brezo gap. These terraces are also still very well preserved on the northern slope of the Castilleria river. North of the village of Herreruela the Villafranchian slope even reaches up to 1600 m alt., starting at the 1200 m terrace level, and leading up to the Cueto mountain (summit 2088 m alt.). The top of this slope is at the base of the scree below the outcrop of the flat lying Triassic and the slope is covered with blocks of Triassic rocks often of very large dimensions. A curious, old millstone workshop is still discernable on this slope, where enormous blocks of these Triassic pebblebeds were sculptured into the shape of millstones of 1 to 2 meters diameter and half a meter thickness. Those that broke during manufacture are still lying around.

The steeply sloping small valleys on either side of this old scree covered slope were eroded in a later period and as in one of them a moraine is preserved the slope is obviously of preglacial age, as are the terraces with which it is connected.

The high terraces of the Pisuerga river are found at levels from 1140 to 1200 meters altitude. Their sediments reach a thickness of 10 to 12 meters and

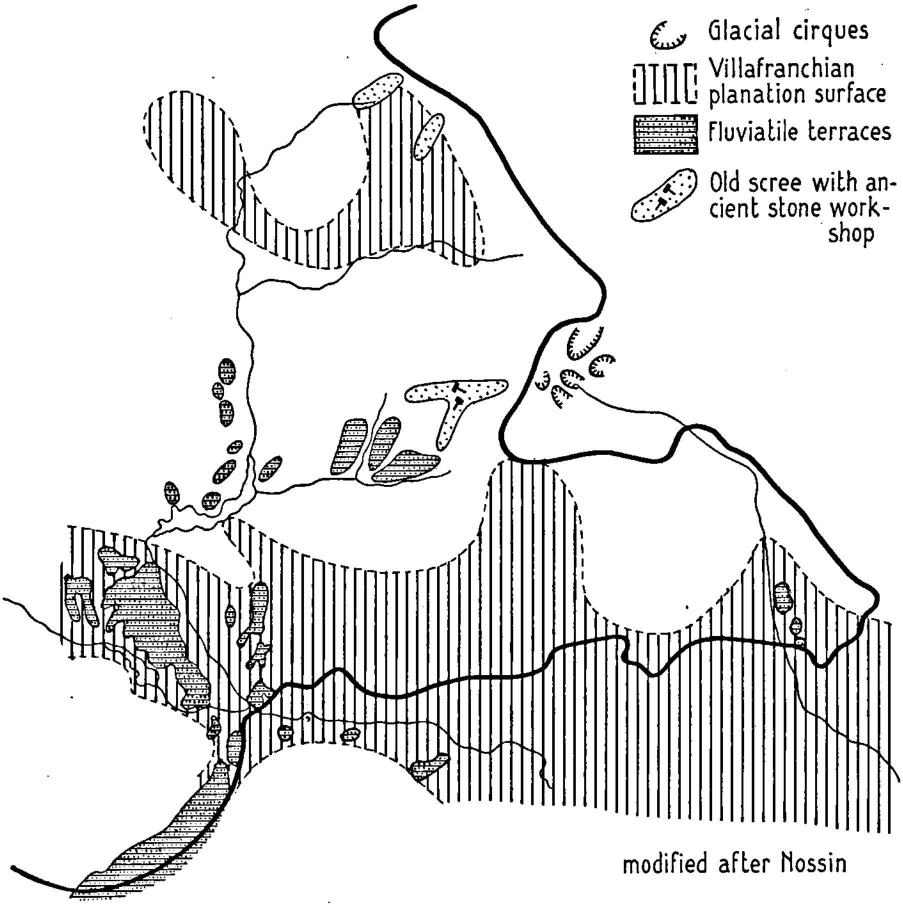


Fig. 2. Geomorphological features of the Pisuerga area

consist mostly of well-rounded pebbles derived from the Curavacas Conglomerate of the Los Cintos syncline, and reach from the village of Vañes downstream. The Castilleria terraces have a high content of Triassic rocks.

As mentioned above, glaciation took place on the highest mountains, the Valdecebolla and Cueto, where some shallow cirques are preserved, most of them facing east and southeast, one north and one west. Some moraines are preserved in the Upper Pisuerga and Upper Castilleria rivers.

Along the Pisuerga river, downstream of Cervera de Pisuerga younger alluvial terraces have developed.

STRATIGRAPHY

Of the stratigraphical units which appear on the Pisuerga sheet the oldest one, the Carazo Formation, belongs probably to the Silurian and its top certainly to the Lower Devonian, extending upward with the Lebanza and Abadia Formations into the Middle Devonian. The higher part of the Middle Devonian is not very well represented on this sheet, and the Upper Devonian, only in more or less isolated outcrops. The Carboniferous sequence is complete reaching from the base of the Lower Carboniferous to the top of the Upper Carboniferous, most of it well dated. The Permian is probably missing, the Triassic is complete together with the base of the Jurassic. The Cretaceous starts with a Wealden facies transgression and continues through the Cenomanian and Turonian into the upper Cretaceous. Tertiary is almost missing except in the form of Upper Tertiary conglomerates and some terraces (table 1).

For fossil lists of the described formations we refer the reader in general to the original publications: Binnekamp (1965), Devonian brachiopods; Wagner (1955 to 1963), Carboniferous flora; de Groot (1963), corals; Rácz (1964, 1966), algae and Kullmann (1960, 1961, 1962, 1963), goniatites.

TABLE I *General Stratigraphy*

Tertiary	some, probably Miocene, conglomerates and Upper Tertiary terraces		
	Maastrichtian-Campanian:	limestones and marls	
	Santonian-Cenomanian:	limestone, sandstone, glauconite sandstone, marls	
Cretaceous	Wealden:	conglomerates, sandstones, white-red clay lenses	
Jurassic		marls, limestones	
Triassic		red conglomerate, sandstone and shale beds, almost undated, but probably reaching from Lower Triassic into Rhaetic.	
	Stephanian B/C Stephanian A	Cea Group	Peña Cilda Formation Barruelo Formation
Carboniferous	Westphalien A/B (?)	Yuso Group	Corisa Formation Vañes Formation Molino Formation Curavacas Conglomerate Formation
	Visean/Namurian	Ruesga Group	Cervera Formation Caliza de Montaña Formation
	Visean Tournaisian		Alba Griotte Formation Vegamian Formation
	Frasnian/Famennian	quartzites	Upper Devonian quartzite lenses and members
	Givetian	Gustalapiedra Formation	
	Eifelian	Abadia Formation	Polentinos Limestone Member
Devonian	Emsian		Requejada Limestone Member
	Siegenian Gedinian (part)	Lebanza Formation	Lebanza limestone
Silurian	Lower Gedinian Upper Silurian (?)	Carazo Formation	sandstone, shale, limestone ferruginous quartzites ferruginous shales and limestones.

SILURIAN

As the top of the Carazo Formation yields lower Gedinian brachiopods, it is probable that the lower part of the formation is of Silurian age. The general lithological aspect is not unlike that of the San Pedro Formation in the Rio Luna area of which also the lower part is considered to be Silurian (Comte, 1959; Cramer, 1964).

The principal outcrops of the Carazo Formation occur in the core of the Polentinos anticline and in the overthrusted sheet north of this structure.

A rough subdivision gives (also fig. 3):

TABLE II *Carazo Formation*

Lower Devonian	80 m	finegrained slightly micaceous sandstone alternating with slightly sandy shales, becoming calcareous towards the top. Brachipod fauna — Gedinian.
Silurian?	180 m	quartzites; upper band of 90 m, lower one of 60 m, ferruginous, with 30 m shale and sandstone in between.
	60 m	strongly micaceous ferruginous shales alternating with fine grained micaceous sandstone, strongly ferruginous. Some badly preserved brachiopods and graptolites, probably Silurian.

In the San Julian hills (fig. 4) the Carazo Formation consists of an upper quartzitic sequence and a lower shale-mudstone sequence, together some 400 m thick. The shales of the lower sequence are micaceous and alternate with thinly laminated mudstones and sandstones, with frequent loadcasts and groove casts. They often contain brachiopod fragments. The white quartzites are thickly bedded and well cemented and highly ferruginous in places.

DEVONIAN

The main exposures of Devonian rocks occur on the western border of the Pisuerga sheet in a continuous sequence in the Lebanza anticline, including parts of the Carazo and Abadia Formations. The Carazo Formation and the Lebanza limestone also crop out in the San Julian hills in the southeastern corner of the map, and there are some isolated outcrops of the Abadia Formation and younger Devonian round the village of Mudá. The Upper Devonian quartzites and graywackes are found at the base of the Carboniferous east and west of Cervera de Pisuerga and most probably also around San Julian (Moradillo sandstone).

Carazo Formation

The brachiopod fauna from the calcareous uppermost layer of the Carazo Formation has been described by Binnekamp (1965) and points to a Lower Gedinian age for these sediments.

In the San Julian hills the Carazo Formation (fig. 4) consists of micaceous shales with quartzites, the latter of some 100 m thickness. Northeast of Nava de Santullan several small quartzite exposures stick through the blanket of Namurian rocks.

Lebanza Formation (fig. 3)

In the top of the Carazo Formation the shales become calcareous and thus form the transition to the rather massive Lebanza limestone, which carries a very well preserved brachiopod fauna, particularly well exposed in the deserted quarry on the southern shore of the Vañes lake and in a small quarry on the northern flank of the anticline near the village of Lebanza. This last mentioned Lebanza quarry has been known since 1885, when Mallada gave the determination of the fauna collected by de Prado. It is also mentioned in the work of Alvaredo and Sampelayo (1945).

In general one can distinguish well-layered limestones at the top and bottom, both rich in fossils, and a central part of massive limestone, poor in fossils, but this subdivision is not developed everywhere. The total thickness is about 100 m. The fauna consists of brachiopods, bryozoans, corals, tentaculites, trilobites, gastropods and lamellibranchs.

From the basal well-stratified limestone a characteristic brachiopod fauna has been collected indicating a Lower Siegenian or Upper Gedinian age (Binnekamp, 1965).

From the middle and top part of the limestone the brachipod fauna indicates a Middle Siegenian age (Binnekamp, 1965).

The trilobites collected from the Lebanza limestone near the village of Lebanza have been determined by Prof. H. K. Erben from Bonn, who lists the following species (personal communication): *Asteropyge* n. sp. (aff. *wallacci*) = ex parte "*sublacianata*" (de Verneuil) *Comura* (*Delocara*) n. sp. (aff. *boopis*).

According to Alvarado y Sampelayo (1945) the Lebanza limestone contains the following corals:

Favosites polymorpha (Gold.)
Favosites cervicornis (Blam.)
Heliolites porosa (Gold.)
Zaphrentis sp.

In the San Julian hills limestones follow immediately upon the quartzites of the Carazo Formation. They are well bedded, partly recrystallized. The basal part is locally developed as a shaly limestone with Tentaculites and Nautiloidea. The limestone is full of brachiopods, trilobites, corals and bryozoans.

Similar limestones of the same age crop out near Revilla and Orbo de Santullan, piercing through the cover of Namurian rock. Their brachiopod fauna indicates a Lower to Middle Siegenian age (Frets, 1965, Binnekamp, 1965). Quiring (1939) mentions one trilobite species: *Phacops latifrons*.

Abadia Formation (fig. 3)

On top of the Lebanza limestone follows a series of shales, with occasional sandstones, marls and limestones, the Requejada Limestone Member and the Polentinos Limestone Member.

The tectonic structure in this part of the Abadia Formation is rather complicated with the result so that the true stratigraphic sequence is frequently difficult to determine. On the map sandstone and shale members are discerned, but no distinction has been made between the different limestone members.

The total thickness of the formation in the present area is some 250 m. At the base of this formation and on top of the Lebanza limestone we find slightly sandy, dark coloured shales which become marly further upwards. From these shales and marls a collection of trilobites has been collected including the following (after Prof. H. K. Erben, personal communication):

Asteropyge aff. *munieri*
Comura (*Delocare*) spec.
Phacops spec. indet.
Homalonotus spec.

The next limestone, the Requejada limestone member, consists of two or three beds, total thickness up to 30 m, well bedded. In this limestone trilobites have been found.

Phacops cf. *potieri* (Bayle) and in particular
Homalonotus spec.

Locally this limestone is followed again by some dark, coarse ferruginous sandstone and shales, on top of which follow two or three beds of limestone. These limestones have been called the Polentinos Limestone Member, together 40 m thick, and contain many trilobites, principally *Phacops* together with goniatites and brachiopods.

Trilobites:	*Phacops* spec. ex gr. *latifrons*
(Erben, pers. comm.)	*Phacops* (*Reedops*) *broussi* (Barrande)
Goniatites:	*Anarcestas*
Brachiopods:	*Chonetes plebeja* (Schnur)
	Dalmanella opercularis
	Schellwienella hipponyx (Schnur)
	Spirifer pellicoi (de Verneuil)
	Athyris sp.
	Uncinulus sp.

Large orthoceras shells are also quite often found, and corals are frequent. The age of the Abadia Formation in the present area seems to be Emsian-Couvenian.

East of Mudá occurs a small outcrop of reddish shales, which according to their age, may be equivalent to the Abadia Formation. From the trilobite fauna Prof. H. K. Erben (pers. comm.) determined:

Phacops (*Phacops*) aff. *batracheus* (Whitborne)
Proetus (*Proetus*) sp.
Cheirurus (*Crobalocephalus*) sp. (*myops*, Roemer?)

which are typical of the Givetian, but a goniatite found in the same outcrop:

Mimagoniatites sp.

indicates on the contrary an Emsian age.

Upper Devonian

No attempt has been made to try and correlate the smaller Upper Devonian outcrops with formations elsewhere. The age of several of these outcrops has been succesfully determined from their fossil content.

In the east round the village of Muda occur isolated outcrops of Devonian

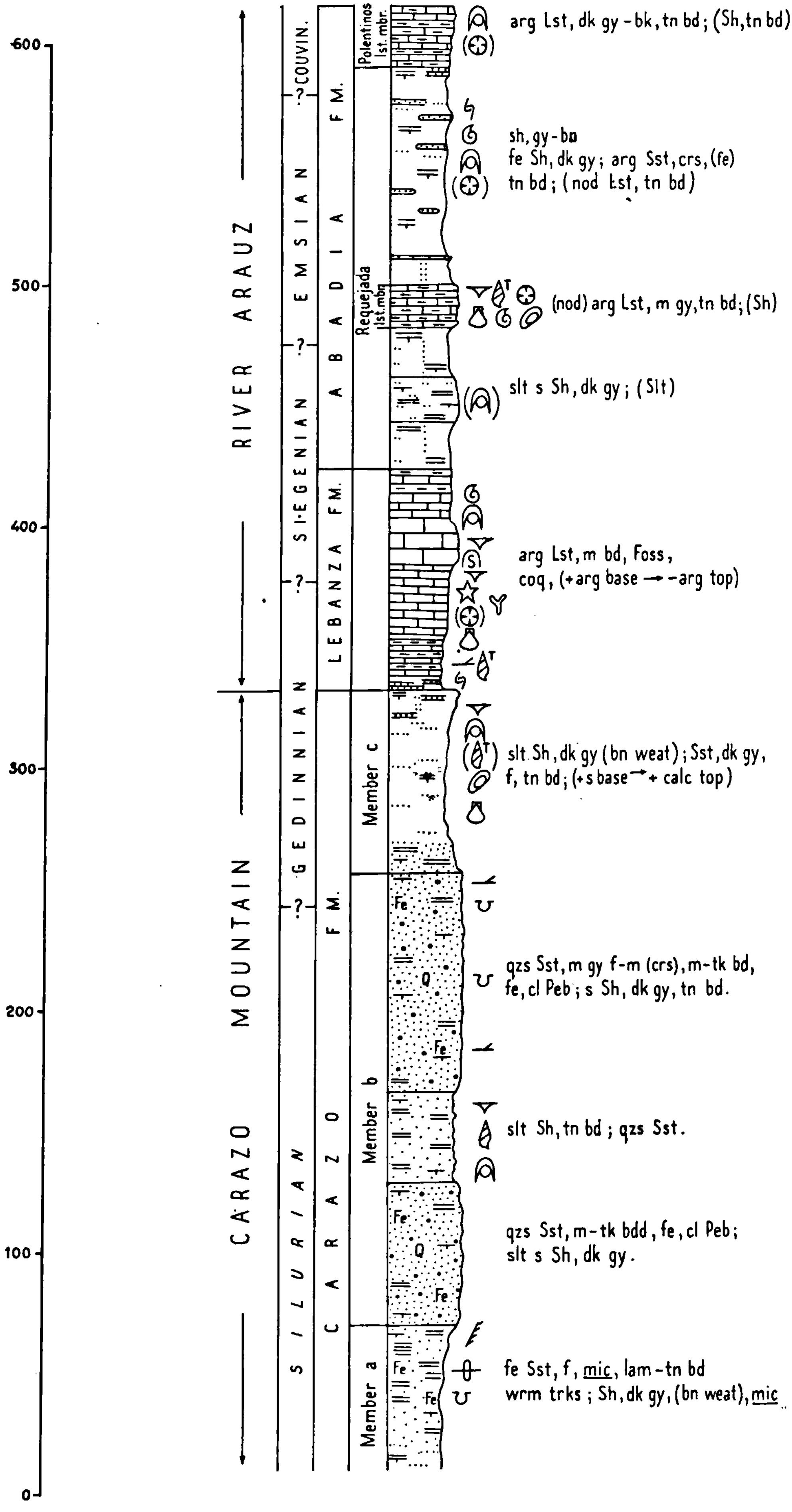


Fig. 3. Stratigraphical column of Silurian and Devonian (after v. Veen)

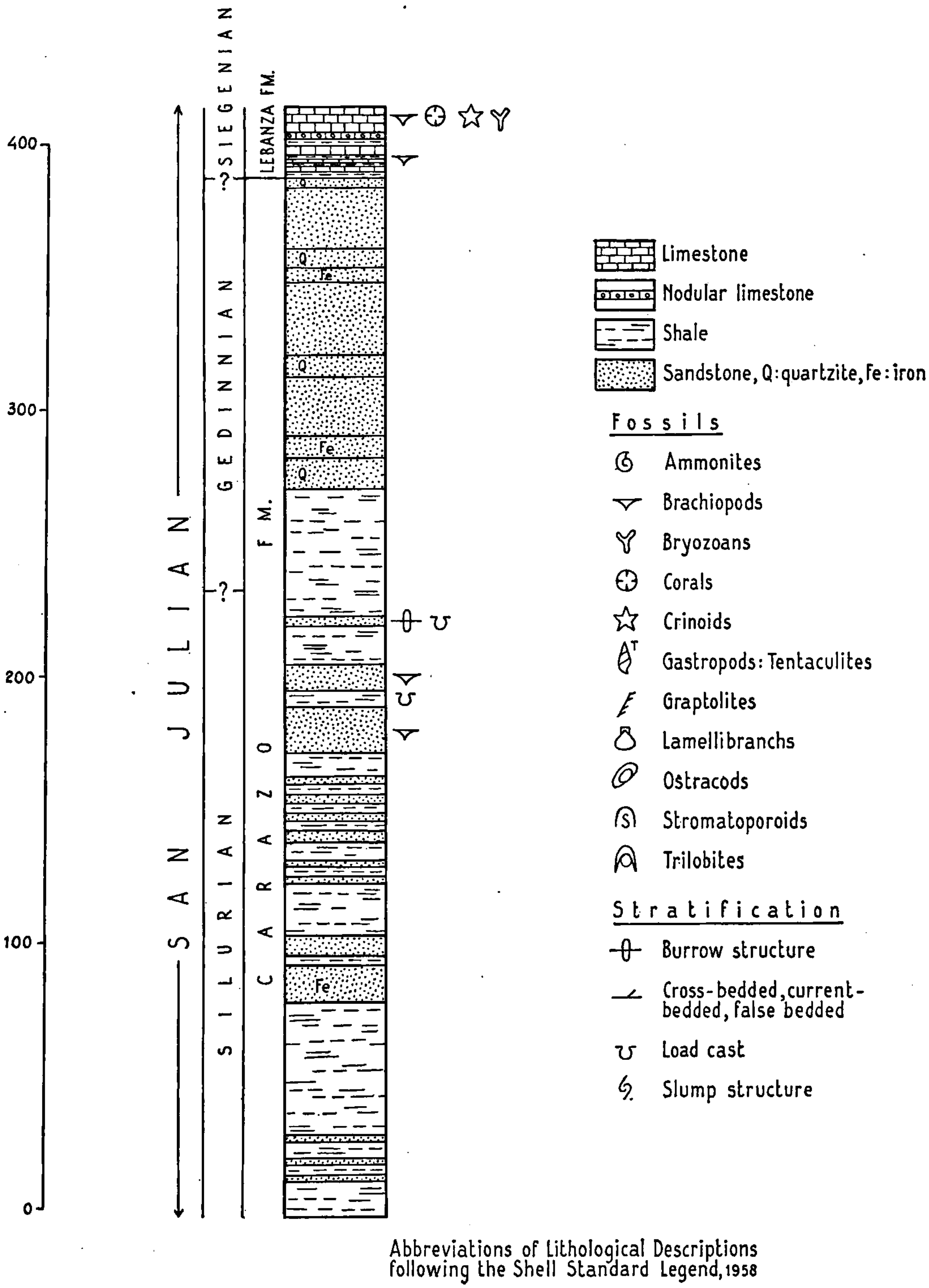


Fig. 4. Stratigraphical column of the San Julian structure

in which goniatites and brachiopods have been found. Most of them consist of quartzitic sandstone which probably belongs to the Upper Devonian quartzites, but west of Mudá a red nodular marly limestone crops out.

Kullmann, (1960) found its age to be Famennian with the following goniatites:

Sporadoceras biferum biferum (Phil.)
Sporadoceras biferum sulciferum (Lge.)
Prionoceras (Imitoceras) cf. *substriatum* (Mstr.)
Kosmoclymenia undulata (Mstr.)
Biloclymenia sp.

It is probable that this isolated outcrop can be correlated with the nodular limestone at the top of the Devonian in the Cardaño area, called Vidrieros Formation by van Veen (1965).

Another outcrop north of Verbios also contains a limestone with goniatite fragments and a conodont fauna of Upper Famennian age (Frets, 1965).

Besides these scattered dated limestone outcrops there occur some very small and some larger outcrops of quartzites. The much larger outcrop of the Moradillo sandstone west of the village of Barruelo from the eastern slope of the Peña Cilda to the Rio Rubagón, and a similar larger outcrop east of Bustillo de Santullán, are believed to belong to the Upper Devonian. Only one goniatite specimen has been found in shales, presumably connected to the Moradillo quartzite (Wagner & Wagner-Gentis, 1963) an

Aulatornoceras bicostatum (Hall)

which would indicate a Frasnian age. These sandstones probably represent the development of the Murcia quartzite of the Cardaño ridge (v. Veen, 1965) in this eastern area.

Upper Devonian quartzites occur in their normal sequence below the Lower Carboniferous in the Cervera-Ruesga region (Kanis, 1956). (The church of Cervera de Pisuerga is built on this quartzite). Some fossil fragments have been found in it, always badly preserved, but its position between the Lower Carboniferous and shales of Frasnian age leaves little doubt that it must be correlated with the Famennian Ermitage quartzites of Comte in the Esla-Bernesga region.

CARBONIFEROUS

Lithostratigraphic subdivisions of the Carboniferous on the Pisuerga sheet have been named as follows:

TABLE III *Carboniferous*

CEA Group (roughly equal to Stephanian)	Peña Cilda Formation Barruelo Formation with Caldero Turbidite Member	
YUSO Group (roughly equal to Westphalian)	Corisa Formation Vañes Formation Molino Formation Curavacas Conglomerate Formation	several limestone members clastic clastic north of Resoba only

RUESGA Group (roughly equal to Tournasian + Visean + Namurian)	Cervera Formation (Culm facies)	Piedrasluengas Limestone Member Perapertu Limestone Member Mudá Limestone Member Rabanal Limestone Member and limestone beds and lenses in Barruelo area
	Caliza de Montaña Formation	
	Alba Griotte Formation	
	Vegamián Formation	

This lithostratigraphic subdivision has its base in the three principal unconformities which can be recognized and have been well dated in several instances. The highest one is that of the Triassic on anything older. The next one at the base of the Cea Group is situated at the base of many intramontane basins along the southern border of the Cantabrian Mountains. Most of this Cea Group has been dated as Stephanian, but in the Pisuerga basin proper this unconformity has only developed very locally so we had to choose between other lithostratigraphic and biostratigraphic arguments to establish here this base of the Cea Group. As the base of the Yuso Group functions the unconformity at the base of the enormous Curavacas conglomerate north of the Camporedondo lake. Again this unconformity and the conglomerates are often lacking or badly developed in the Pisuerga basin. The Yuso Group is roughly equivalent to the Westphalian. The Ruesga Group starts on top of the Devonian which is often characterized by a stratigraphic hiatus at the base of the Carboniferous.

The three groups have been distinguished on the map in three colours: blue, brown and yellow-brown, from bottom to top. With the division into these groups we follow Koopmans (1962). Within each of these groups mapable lithostratigraphic units are distinguished as formations, and on the map prominent conglomerates, sandstones, limestones and coalbeds are distinguished by special signatures.

Ruesga Group (fig. 5)

The Ruesga Group is best exposed on a southern strip of our map, where it forms part of the Cardaño-Rabanal ridge and in the south west corner where it belongs to the Leonides. In this Rabanal strip the strong limestone development of the Sierra del Brezo (Leonides) is replaced by the psammitic facies of the Cervera Formation deposited unconformably on isolated reefs. In the north we find limestones (Piedrasluengas limestones) outcropping, forming part of a large region extending northwards which has not been mapped in detail yet, but is similar to the Cervera Formation in the south. The Vegamian Formation at the base occurs only in isolated spots at the bottom of the Ruesga Group on the Rabanal ridge.

Vegamián Formation. — The type section is situated 1 km SSW of Vegamián in the Bernesga valley (León), and in general it shows some 15 m of black and greenish shales, sometimes with phosphate nodules often with thin chert beds. The name Vegamián has first been used for these sediments by Comte (1959).

On the present map the Vegamián Formation is only represented in the Mudá area. Here a bedded chert has been found between limestone outcrops, resting upon Upper Devonian. According to its position on top of the Devonian and to its lithology there is no doubt, that the rock in question belongs to the Vegamián Formation.

In this exposure the chert is not accompanied by the overlying Alba Griotte Formation, as is usual in the western Leonides in the Cantabrian Mountains.

Outside of the Pisuerga sheet, west of Resoba, where the Vegamián Formation is well developed (Frets, 1965) and from whereon it continues in the Cardaño area for a long way, it always lies at the bottom of the Alba Griotte (de Sitter 1962a, v. Veen 1965). In the Cardaño area the formation reaches about 30 m thickness. It has also been found in many sections in the Bernesga-Porma area, where near Olleros de Alba (León) Higgins found conodonts in a limestone in the Vegamián Formation, indicating its upper Tournaisian age (Higgins et al. 1964).

The Tournaisian age is the more interesting because of the analogy with the cherts at the base of the Carboniferous in the Pyrenees which are of the same age (de Sitter, 1962a).

Apart from the outcrop of well bedded black chert SE of Mudá, chert fragments occur in limestone breccias in other outcrops in the Cervera Formation mostly at or near its base. In the Resoba region just west of the map, the cherts occur as thin bands in black shale beneath the calcarenites of the Caliza de Montaña (Frets, 1965).

Alba Griotte Formation. — The type locality of the Alba Formation is near Puente de Alba in the Bernesga valley (León). The name Alba for the griotte limestone is first been used by Comte (1959). The griotte has been described by de Sitter (1962b), Koopmans (1962) and Kanis (1956).

The presence of the Alba Formation at the base of the Carboniferous or on top of the Vegamián Formation in the greater part of the Cantabrian Mountains indicates a uniform facies over a large area.

The formation contains red and grey nodular limestone, (Marbre griotte and Marbre campan), red nodular marl, red claystone, red shales often with silica, red chert or radiolarite. The total thickness amounts to some 30 metres.

Goniatites have been described from the formation by Kullmann (1961, 1962, 1963) and Wagner-Gentis (1963). Conodonts by Higgins (1962) and v. Adrichem Boogaert (in Frets, 1965).

The age of the Alba Formation ranges from Lower Visean into the Namurian. According to Kullmann (1963) Middle Visean goniatites are generally absent (Go α). In the Bernesga area, however, this part is present too.

The griotte is considered to have been developed under special physical conditions in shallow water. As with the 30 m of Alba Formation and the maximum of 30 m of Vegamián Formation a time span is represented from Upper Tournaisian into Lower (?) Namurian, it is obviously a condensed sequence, which gives rise to re-mixing of conodont faunas within each formation.

In the present area, the Alba Formation is extremely well developed both in the Sierra del Brezo and just north of the León line on the north side of the Ruesga valley, either at the base of the massive Caliza de Montaña or of thin calcarenites. It is lacking at the base of the Mudá limestone reefs.

Caliza de Montaña Formation. — The name has been used by many authors, Oriol (1876) and Julivert (1960) for instance, and has also been in use by the Leiden group in the Cantabrian Mountains. Lately it has been replaced by Escapa Formation (Brouwer & van Ginkel 1964, Rácz 1964, van Ginkel, 1965), called after the Sierra de Escapa (Barrois 1882, Delepine 1943), but we see little reason to introduce the name of Escapa Formation in the present area.

The Caliza de Montaña Formation succeeds the Alba Formation, either as a massive limestone or as a calcarenite. It can be replaced laterally by a Culm facies, which also occurs on top of it and has been called the Cervera Formation.

In the present area we have the Caliza de Montaña Formation in the Leonides of the Ruesga area, with clastic intercalations between the limestones, and the Cervera Formation in the Cervera — Muda — Barruelo area.

The Caliza de Montaña is charecterized by limestone, marble and dolomite, massive or bedded, and often very dark in colour. At the base dark bituminous calcarenites are frequent. Koopmans mentions bipyramidal quartz crystals enclosed in the recrystallized limestone (Koopmans, 1962). Sandstone and shale members occur within the formation.

Thicknesses are reported to be very variable from zero to 800 m, see van Ginkel (1965) and van Veen (1965). Kanis (1956) reports 300 m from the Sierra del Brezo, the area west of Ruesga.

According to van Ginkel, who collected samples at three locations in the Sierra del Brezo area, these limestones of the Caliza de Montaña Formation contain fusulinids of the Zone of Profusulinella, Subzone A, which is to be correlated with the Bashkirian (v. Ginkel 1965).

Kanis (1956) mentions a *Goniatitus Falcatus* Roemer, limited to the Upper Visean and also an Upper Visean coral, *Carcinophyllum.* A list of forams, identified by van Ginkel, however, indicates Westphalian A and/or Upper Namurian (Kanis 1956).

Frets (1965) mentions the determination of two calcareous algea *Archaeolithophyllum johnsoni* Racz and *Donezella lunaensis* Racz, which belong to the Algae Zone II corresponding to the top of the Bashkirian.

According to Brouwer and van Ginkel (1964) the chronostratigraphical position of the Escapa Formation (= Caliza de Montaña Formation) is Lower to Middle Bashkirian.

Cervera Formation. — The name of Cervera Formation has been proposed by Brouwer and van Ginkel (1964) indicating the rocks which form the southern border of the Pisuerga basin between Mudá and Cervera de Pisuerga. The formation actually extends as far as the Barruelo area to the east, and to the west it has been found as far as Triollo (Frets, 1965). Further west it occurs generally on top of the Caliza de Montaña in the Leonides. The limestone shale formation in the north is here included in this formation.

Our Cervera Formation includes Wagner's Mudá Formation, Wagner and Wagner-Gentis (1963) and the Perapertú Formation, Wagner and Wagner-Gentis (1952).

The Cervera Formation is characterized by the occurrence of alternating shales and greywackes, with sandstones and conglomerates in a generally well bedded sequence. In this formation reef limestone knolls and lenses are found, often associated with their debris zones. Locally unconformities occur, as near Mudá, with some "wildflysch" masses. The reef lenses are especially distinguished in the zone Rabanal — Mudá — Perapertu, but also occur in the Barruelo area.

According to van Ginkel the Mudá Limestone yields an older fauna, Profusulinella A — Millerella, than the Perapertu and Rabanal Limestones: Profusulinella A. The few samples, however, are not very representative.

The base of the limestones in the Mudá—Barruelo region is seldom exposed,

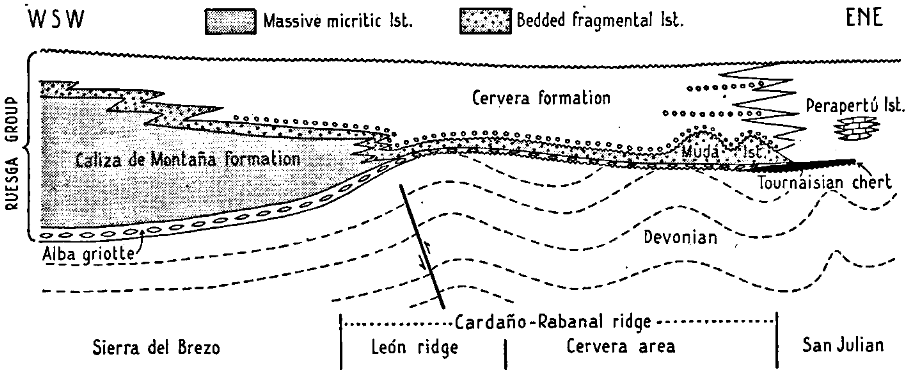


Fig. 5. Schematic correlation of the Ruesga Group

but one outcrop near the village of Villabellaco gave a rather complete section of Visean unconformable upon Devonian (Wagner, 1962). There are several small outcrops of such limestones in the near surroundings, all unconformably covered by sandstones typical of the Cervera Formation. They are referred to as the Revilla de Santullan and Santa Maria de Nava outcrops and contain a fauna reaching from the Lower Visean into the Namurian. At Villabellaco occurs a *Pericyclus* fauna in the lowest two meters of the nodular limestone above the Devonian with *Pericyclus virgatus* (Holzappel) and *Pericyclus* c.f. *hauchecornei* (Holzappel) indicating a Lower Visean age. In the next 1,5 meters a goniatite fauna with *Merocanites lenslowi* (Sowerby) and *Orthoceras* sp, represents the Middle Visean and the following 15 meters contain an Upper Visean fauna with *Goniatites striatus* and *Goniatites granosus* (Wagner-Gentis, 1963; Wagner, 1962).

The Santa Maria limestone rests on this Visean limestone and contains a rich coral fauna with principally *Lithostrotionella*, but all new species (de Groot, 1963). The fusulinids of this limestone serie gave a Bashkirian age with *Pseudostaffela* sp., *Parastaffella* sp., *Profusulinella* sp. and many species of the *Millerella* genus, zone Profusulinella A (van Ginkel, 1965). The Perapertu reefs have also a coral fauna of *Lithostrotion* and *Lithostrotionella* and solitary corals of mostly new species (Frets, 1965).

Several other outcrops of reef lenses occur in a narrow band running from Mudá to Rabanal. The most western one has been called the Rabanal limestone. It has delivered a blastoid species, *Pentablastus supracarbonicus* (see Sieverts-Doreck, 1951) which has been described in detail by Joysey and Breimer (1963).

The Piedrasluengas Formation has been designated by Brouwer and van Ginkel, including the rocks exposed to the north of the watershed of the Duero in the north of Palencia and the SW of Santander, and called after the village of that name.

On the present map, part of the Piedrasluengas limestones are shown at the northern boundary of the Pisuerga basin. More to the north, beyond these limestones lies the Liebana basin. The mapping of that area is in progress. From the preliminary investigations in that area it is clear, that the Piedrasluengas limestones are beds and lenses in a Culm facies. Van Ginkel considers them to belong to his Profusulinella B zone. The zone, in which the limestone beds occur can be followed for about 20 km to the west. Only these uppermost limestone lenses and beds have been described up to now, but it seems clear that they will most logically be classified as a member or members of a larger formation.

Yuso Group

The stratigraphy of the Yuso Group is well exposed in two complete sections, one of the Casavegas syncline and one on the south and east flank of the Castilleria syncline. See columns appendix III. In the Redondo section the basal part is covered by the Trias. The Barruelo section is also incomplete, due to the Triassic cover, and the unconformable Curavacas conglomerate in the Ruesga region contains probably only the base of the Yuso. The type locality of the Yuso Group is in the region of the Yuso river and further east, where the Curavacas conglomerate with its base dated as Westphalian A (van Veen, 1965), is conformable overlain and laterally replaced by a sequence continuing high into the Westphalian D. In that region the conglomerate development has been mapped as the Curavacas Conglomerate Formation, at the base of the Yuso Group, and its continuation upwards as the Lechada Formation.

In the actual Pisuerga basin the Yuso Group is represented by three formations (table IV); the Molino Formation at the base, followed by the Vañes Formation and the Corisa Formation at the top.

In the north Curavacas Conglomerate Beds and Lenses occur at the base of the Yuso Group unconformable upon the Piedrasluengas limestone, and also in the south at the base of the Molino Formation in the Castilleria syncline. As these conglomerates can not be traced into the actual Curavacas Formation, they have been classified as beds and lenses.

North of Camporredondo a Westphalian A flora has been collected from a shale at the base of the Curavacas Conglomerate (van Veen, 1965). The outcrops of the conglomerates on the Pisuerga sheet in the Los Cintos basin have yielded a Westphalian B flora (Wagner, 1960).

In the Yuso Group, the Curavacas Conglomerate Beds and Lenses, and the Molino conglomerates are considered of the same Westphalian A—B age as the Curavacas Formation. The shale and sandstone of the Vañes Formation have never yielded a good flora or fauna. The coal beds of the San Cebrian de Mudá mines have a Westphalian D age (Wagner, 1955; Wagner & Wagner-Gentis, 1963). The top part of the Yuso Group carries many limestones in the whole Pisuerga basin, and has been called the Corisa Formation. Its individual limestones are regarded as members. According to van Ginkel (1965) the fusulinids in the limestone members belong to assemblages of the Upper Moscovian.

TABLE IV *Yuso Group*

North of Resoba	Pisuerga basin
	Corisa Formation with many limestone members
	Vañes Formation
Curavacas Formation	Molino Formation

Curavacas Conglomerate Formation. — West of the Pisuerga river a thick series of conglomerates and graywackes covers unconformably structures in the Devonian, Visean and Namurian forming the Los Cintos basin.

It has been folded to some extent, forming an asymetric syncline with an E—W axis, but much gentler than the underlying older structures. Its age has been determined by plants collected from four shale and sandy shale intercalations between the coarse conglomerates. A flora of the Westphalian B age has been determined by Wagner (1960). The conglomerate reaches a total thickness of some 500 m and consists mainly of thick beds of badly sorted quartzitic pebbles and boulders ranging in size from 0,5 cm to 50 cm alternating with shale and sandstone beds. The matrix of the boulder beds is sandy. The terrestrial facies is proven by the bad sorting, the plant fossil content and the fact that often the boulders are not touching each other. Although its age has been established as Westphalian B in this region, a similar conglomerate further west, upstream of the village of Cardaño, has at its base a shale with a Westphalian A flora (van Veen, 1965). The folding phase preceding the Curavacas Conglomerate must be of pre-Westphalian A age, and probably post Namurian.

Curavacas Conglomerate Beds. — The same unconformity as that of the Los Cintos basin can be established in the north, west of the Piedrasluengas pass, where a conglomerate of a few tens of meters thickness unconformably cuts of a limestone, the Piedrasluengas Limestone Member, which belongs to the *Profusulinella* B zone.

East of Rabanal the division between the Yuso Group and the Cervera Formation is accentuated by a different folding pattern and the divergent strike south and north of this line. This represents most probably the Curavacas unconformity. The line itself, however, has been interpreted as a fault.

Molino Formation. — The Molino Formation has been described by Frets (1965). It covers the Perapertu Member with a pronounced angular unconformity. At its base a 1 to 2 metres thick "wildflysch" horizon with quarzite boulders drifting in shales has developed, followed by 50 metres thickbedded greywackes, laterally passing into conglomerates. Next a sequence of about 300 meters of subgraywackes and sandy shales with graded bedding and erosional bottom casts is developed with again „wildflysch", with big angular rock fragments drifting in shale at the top.

The Molino Formation is restricted to the Perapertu area and is there conformably overlain by the Vañes Formation, which continues much further westward. In the Castelleria subbasin the Yuso has been subdivided into a lower Vañes Formation, containing mainly sandstones, graywackes and shales, with the San Cebrian coal and an occasional conglomerate, and an upper Corisa Formation in which thick bedded limestones alternate with sandy shales.

In the Casavegas syncline the Curavacas Conglomerate beds at the base of the Yuso are considered to be the lateral equivalent of the conglomerates in the Molino Formation.

In the Casavegas and Redondo synclines the Yuso Group is also subdivided into a clastic Vañes Formation and a Corisa Formation which contains most of the limestones.

Vañes Formation. — A section through the south flank of the Castilleria syncline over Vergaño roughly shows the following development: the sequence starts with thick sandstone layers with coarse cross bedding, alternating with graywacke-shale intervals. The graywackes are turbidites with typical bottom casts and graded bedding. The thickness of the graywackes varies in the order of tens of centimetres, that of the sandstones in the order of tens of metres.

The coal seam of the San Cebrian mines has developed in a sandstone environment. The shales on top of the psammitic sequence contain a few sandstone layers, and one thick conglomerate bed has been mapped.

The transition into the Sierra Corisa limestones starts NE of Vergaño with the appearance of several limestone debris beds, many of which clearly have been slumped. West of Vergaño the boundary is sharp, possibly with a small hiatus. The type section mentioned by van Ginkel (1965) runs north of Rabanál de los Caballeros, and is comparable with the Vergaño section. Only the coal bearing standstone intercalation is missing.

In the San Cebrian section the turbidites are less predominant and restricted to the lower part of the sequence (Frets, 1965).

The lower part of the Yuso Group in the Casavegas syncline contains a greywacke-shale alternation with several thick sandstone beds not unlike the San Cebrian section. Several of the greywacke beds are turbidites.

Between the Coterraso limestone and the thick limestones of the Sierra Corisa Formation lies a succession of sandstones and shales and thin conglomerates.

The lower 600 m of the Celada section consist of a monotonous sequence of shales, sandy shales and sandstones.

Corisa Formation. — The Corisa Formation at the top of the Yuso Group and characterized by its limestones, occurs in the whole Pisuerga basin, but the individual limestone beds often wedge out and are replaced by others and therefore can not be followed over long distances. In the Sierra Corisa west of Vergaño occurs a beautifully developed diasthem on top of one of the limestone beds with crevices up to 5 m deep in the limestone (fig. 6), filled with sandstone and sandy conglomerates of the overlying bed (Nederlof, 1959).

In the Redondo syncline the Corisa Formation starts with the Agujas Limestone Member, to be followed by a regular alternation of calcareous fine grained clayey sandstones and darkgrey mudstones, followed by a hard darkgrey to black micaceous shales with intercalations of sandy shales and quartzites. Next we find the Abismo Limestone Member in the north, while in the east layers of black nodular limestone occur. In the north, the Abismo Limestone Member is followed by shales and sandy shales.

In the Corisa part of the Celada sections several limestones occur, separated by sandstones and shales.

In the Barruelo area several outcrops show limestone lenses interbedded in a sequence with graded sandstones. The thickness of the very persistent sandstone beds is about the same as in the Redondo area, as is the composition of the layers (Part of the graded succession is synchroneous with the Caldero Member of the Cea Formation).

The Casavegas section displays a great thickness of Upper Westphalian sediments. Limestones in the lower part, associated with quartzites, sandy shales

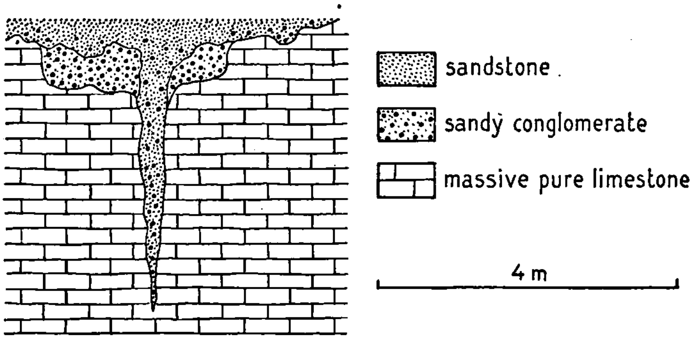


Fig. 6. Diasthem in Sierre Corisa limestone (after Nederlof)

and shales. Coal seams occur at the top of the Corisa Formation. Graded bedding is absent in the entire sequence, but large scale cross bedded sandstones are common.

Comparing the two northern, more or less complete sections (app. III), we find that there are two important limestone horizons in the upper part of the Yuso Group, near the base the Ajugas Limestone Member and the Camasobres Limestone Member and near the top the Abismo Limestone Member and the Maldrigo Limestone Member. The Agujas and Camasobres Limestone Members belong to the lower Fusulinella B Zone, containing *Pseudostafella ozawai* and *Fusulinella bocki* as typical forams. The Abismo and Maldrigo Limestone Members belong to the high Fusulinella B Zone typified by *Fusulinella pseudobecki* and *Fusulinella bocki* (van Ginkel, 1965). Both these limestones zones wedge out in a southward direction, and can not be connected on the map with the limestones of the Verdeña-Celada region between the upper Pisuerga river and the Castilleria river. The Sierra Corisa Limestone Member appears to belong to the uppermost Fusulinella B Zone with *Fusulinella branoserae* and *Fusulinella pseudobecki* as typical forams. The limestone can be correlated with the Lores Limestone Member in the Casavegas section and the Brañosera Limestone Member of the Barruelo section. The Coterraso Limestone Member of the Sierra Corisa section can be correlated with the Maldrigo Limestone Member and the still lower San Cebrian Limestone Beds with the Camasobres Limestone Beds (table V).

TABLE V *Limestones of tbe Yuso Group*

Fusulinella Zones	Casavegas section	Redondo section	S. Corisa section	Barruelo section
B_3	(Lores limestone)	—	S. Corisa limestone	Brañosera lst.
B_2	Maldrigo limestone	Abismo limestone	Coterraso, S. Corisa lst.	
B_1	Camasobres limestone	Agujas limestone	Socavón limestone	
A	In this area not represented by limestones			

The Coterraso limestone also wedges out westwards and the Socavón limestone is only a lense shaped body.

Coal seams in the Yuso Group occur in the sections 3, 5 and 6 (appendix III).

(Casavegas Coal)			
Maldrigo limestone	Verdegosa limestone	Sosa limestone	Sierra Corisa limestone
	Por Si Acaso coal		
		Perniana coal	San Cebrian coal
			Socavón limestone

The Casavegas coal seams have a flora indicating an Upper Westphalian D to Stephanian A age (Wagner & Wagner-Gentis, 1963; van Amerom in van Ginkel, 1965).

The San Cebrian coal measures contain a flora indicating a Lower Westphalian D age (Wagner, 1955; Wagner & Wagner-Gentis, 1963).

The limestones of the Yuso Group contain a rich coral fauna, which has been the subject of an extensive study by Miss G. E. de Groot (1963). The corals do not give us a good medium for a bio-stratigraphic correlation because most of the species are new. To a large extent the coral fauna can be compared to the Russian ones of the Moscovian from the Donetz and Moscow basins.

The correlation of the floral and faunal biostratigraphic sections results then in:

Lores, Brañosera and Sierra Corisa Limestone Members	Fusulinella B_3 Zone
Casavegas coal measures	Upper Westphalian D flora
Maldrigo, Coterraso, Abismo and Sierra Corisa Limestone Members	Fusulinella B_2 Zone
San Cebrian coal measures	Lower Westphalian D flora
Camasobres, Agujas and Socavón Limestone Members	Fusulinella B_1 Zone
Curavacas Conglomerate Formation	Westphalian B flora
Base of Curavacas Formation more to the west	Westphalian A flora

Cea Group

The Cea Group is present in each of the four different structural units of the Pisuerga basin, the Casavegas and Redondo synclines, the Castilleria basin and in the Barruelo area. The biostratigraphic correlation is mainly based on the flora associated with the coal beds as determined by Wagner (1955) and Wagner & Wagner-Gentis (1963). Those limestones which have been investigated by van Ginkel range between his Fusulinella Subzone B_3 and the Protriticites Zone.

The following subdivisions can be distinguished:

TABLE VI *Cea Group*

	Peña Cilda Formation	Conglomerate members and one coal seam
	unconformity	
		Several coal and conglomerate members
Cea Group	Barruelo Formation	Several limestone members
		Caldero turbidite member

Barruelo Formation. — The Barruelo Formation, the name proposed by de Sitter (1957), is developed in the Barruelo area and in the other basins of the Pisuerga basin. The formation in the Barruelo basin consists of a continental and paralic sequence of sandstone and shale with coal seams and limestone beds and lenses. The equivalent beds in the Castilleria section may have a few more marine intercalations, but is also regarded as Barruelo Formation. Due to lack of exposure no good type section is available from this area, in order to distinguish it as a separate Cristóbal Formation as proposed by Wagner and Wagner-Gentis (1963).

The Barruelo Formation rests in general conformably upon the Yuso Formation, except on the San Cristóbal hill, where the only angular unconformity at its base has been mapped.

In the Castilleria syncline, the top of the Sierra Coriza Limestone has been regarded as the proper boundary, and the succeeding quartzites are correlated with those at the base of the Cea at the Cristóbal hill unconformity (fig. 7). In the

Redondo subbasin the base of the Cea Group is marked by "wildflysch" deposits. In the Casavegas syncline no distinct boundary between Yuso and Cea can be distinguished, as all deposition was parallel. The boundary on the map roughly represents the top of the Sierra Corisa limestones and the base of the following quartzites.

In the Castilleria section the Cea Group starts at the unconformity of San Cristóbal near the western boundary of the Pisuerga basin (Wagner and Breimer, 1958). The unconformity is at this location an almost 90° angular unconformity

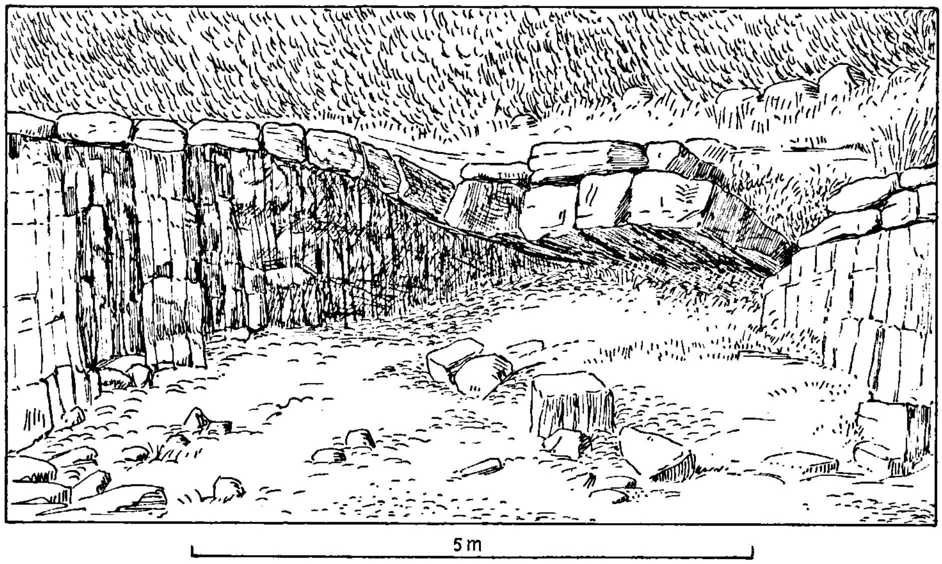


Fig. 7. The Yuso — Cea unconformity at San Cristobal hill

(fig. 7) without any basal conglomerate or pebble bed, but following it eastwards its angular property diminishes rapidly and above the northward bend of the Sierra Corisa limestones it has diappeared altogether. In none of the other three units such an angular unconformity is present.

At San Cristóbal a coal bed occurs just above the unconformity with a flora of undoubtedly Stephanian A age (Wagner & Breimer, 1958).

The approximately 1000 m thick succession between this San Cristóbal coalseam and that of San Felices [1], consists of shales, sandy shales, quartzites, very few limestones and some conglomerates. There occurs one very impersistent limestone horizon with a *Protriticites* fauna, and at a slightly higher level a 4 m thick black shaly limestone, the Estalaya Bed, rich in fossils with a Stephanian fauna of gastropods, brachiopods and lamellibranchs. The gastropods were determined by Mrs I. A. Butusova from Leningrad.

[1] The San Felices coalbed is marked on the map only by an abandoned mine signature, west of the village.

Bellerophon muensteri (d'Orb.)
Baylea volgensis (Stuck)
Anomphalus rotulus (Meek & Worthen)
Trachydomia wheeleri (Swallow)
Murchisonia paronai (Gortani), *M. fischeri* (Stuck)
Pseudozygopleura semi costata (Meek)
Soleniscus sp. indet.

The San Felices coal bed contains a flora which according to Wagner & Wagner-Gentis (1963) also indicates a Stephanian A age.

In the Casavegas section of some 2000 m thickness occur three coalgroups, the lower are the Casavegas coalbeds, the next the Areños coalgroup and the highest the Rosa Maria group (de Sitter & Nederlof, 1957).

The Lores limestone is situated between the Casavegas and Areños coals and has a fusulinid fauna belonging to van Ginkel's Fusulinella B_3 Zone (van Ginkel, 1965).

The Areños coal group has a flora of Stephanian A or possibly Westphalian D age (Wagner & Wagner-Gentis, 1963). At about the same level van Ginkel (1965) collected fusulinids from his locality P_2 (fig. 8) having a Fusulinella B_3 age.

The Urbaneja limestone just above the Rosa Maria coal seam has an algae fauna comparable with some of the Castilleria section and belonging to Rácz's Zone VI (Rácz in van Ginkel, 1965).

In the Redondo syncline the base of the Cea Group has been drawn rather arbitrary at the base of a turbidite sequence and above a shale on top of the Abismo limestone. A limestone lens in this sequence, the Corros limestone has a *Protriticites* fauna. This remarkable sequence of graded beds described in detail by Nederlof (1959), called the Caldero Turbidite Member, is a typical turbidite sedimentation. It also contains many lenses of muddy limestone breccia's and pebbly mudstones, illustrating its slumped character.

The lower part, with maximal thickness of a 1000 m is more shaly, the upper part consists mostly of sandstones and reaches some 500 m thickness. The whole series wedges out completely both to the north and south against the Celada ridge.

The Caldero Member is followed by a sequence of mostly continental character with a few marine intercalations of some 1000 m maximum thickness. It contains three coalseam groups, the Lomba group, The Redondo group and the Reboyal coalseam. The flora of the Lomba group contains a flora collected from the Mina Santa Maria with a Westphalian D to Stephanian A age (Wagner, 1955). This top member also wedges out in the north and south against the Celada ridge. The eastern fault line boundary of this ridge certainly was active as a normal fault during the deposition of the whole Cea Group in the Redondo syncline basin.

In the Barruelo section the Cea Group starts with the coal bearing Barruelo Formation with two coal seam groups: the Peñacorba Member at the bottom and the Calero Member at the top.

The Peñacorba Member contains a Stephanian A flora (Wagner & Wagner-Gentis, 1963). It can be correlated with the San Felice coal of the Castillera basin.

A few hundred meters higher appears the Calero Member with a rich flora of slightly younger aspect. The Barruelo Formation ends with a set of conglomerate beds.

Between the coal seam of the Calero Member occur two layers of dark grey shales with an abundant phyllopod fauna with *Leaia baentschi* (Beyrich) as the most common fossil (Wagner and Wagner-Gentis, 1952), which are very useful as a key bed in the coal mines.

Peña Cilda Formation. — The Peña Cilda conglomerates rest with a strong angular unconformity, described by Wagner (1955) on the overturned Barruelo Formation. They contain one coal bed with a Stephanian B flora (Wagner, 1955). This Stephanian B formation can not be correlated to any of the top beds of the other synclines of the Pisuerga region, but does find its equivalents in many small basins situated along the León line further to the west.

Correlation of Carboniferous limestones

From the limestones of the Cantabrian Mountains van Ginkel (1959, 1965) studied the fusulinids in a great number of samples. Based upon the fusulinid association in the Carboniferous limestones van Ginkel established four biozones, of which the second and third have been subdivided into subzones. See table VII.

Recently van Ginkels samples have been studied by Rácz (1966) who established a biozoning based upon algae from the Cantabrian Mountains (Rácz, 1965). In general Rácz' division of the Pisuerga area limestones is in agreement with that of van Ginkel. See table VIII. Rácz' (1966) paper on the Pisuerga algae appears in this same volume of the Leidse Geologische Mededelingen.

Apart from the stratigraphic correlations which have been mentioned before in the part about the Carboniferous, some striking facts appear from both the works of van Ginkel and Rácz.

In the southern part of the Pisuerga area, where the Ruesga Group sediments prevail, exposures are poor and structures difficult to unravel. In this area the fusulinid and algae correlation shows that the Mudá limestone is the oldest, to be followed by the Perapertu and Rabanal limestones. It is obvious that the reef limestone facies continued throughout the deposition of the Cervera Formation, together with the shales and greywackes. The unconformity on top of the Mudá limestones is not accompanied by a distinct hiatus in the biostratigraphic sequence. This lack of biostratigraphic hiatus is even more striking in the case of the unconformity of the Curavacas conglomerate on the Piedrasluengas limestones in the north of the Pisuerga area. Here the Piedrasluengas limestone and the Albas limestone are divided by the unconformable Curavacas conglomerates in between, but the time gap was not sufficiently large to show a distinction in the fusulinid and algae contents of either limestone.

Rácz (1966) distinguishes possible Permian algae mixed with Stephanian ones in the samples van Ginkel collected from the Vañes limestones of the Cea Formation (p. 99). Accordingly Rácz considers the possibility of a continuation of the Cea deposits into the Permian, where van Ginkel considers these limestones still Stephanian. The Estalaya Bed above it and the San Felices coal seam still higher up are also considered to be of Stephanian age (p. 000). Moreover the unconformity at the base of the Peña Cilda beds, which according to Wagner (1955) contain Stephanian B plants, would have to be absent in the Castilleria section.

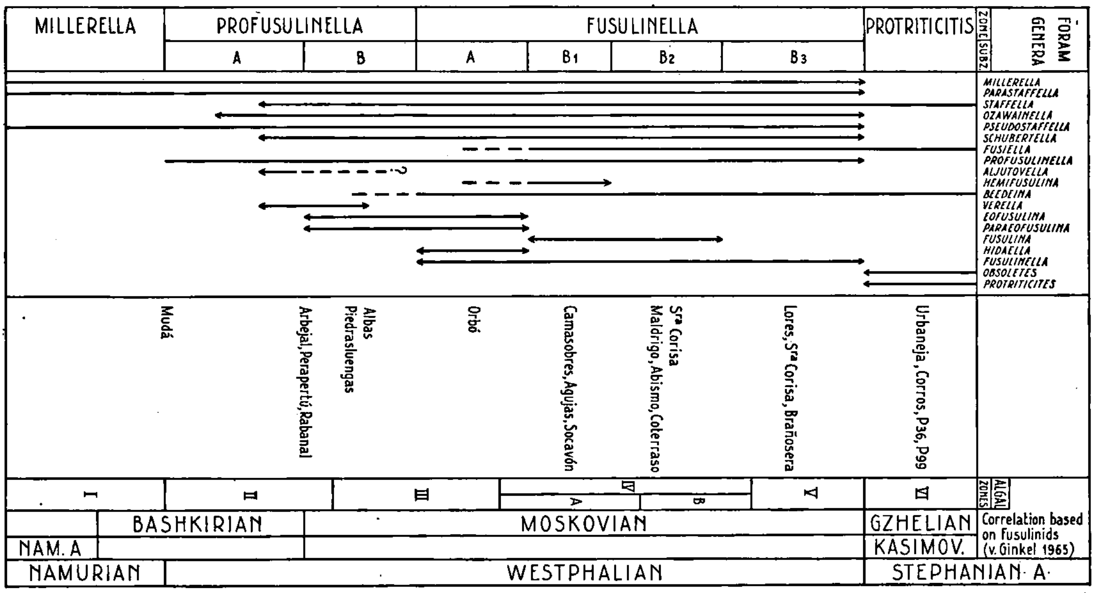
MESOZOIC

As we have never studied the Mesozoic in any detail the following description has been taken mostly from the extensive work of Ciry, (1939).

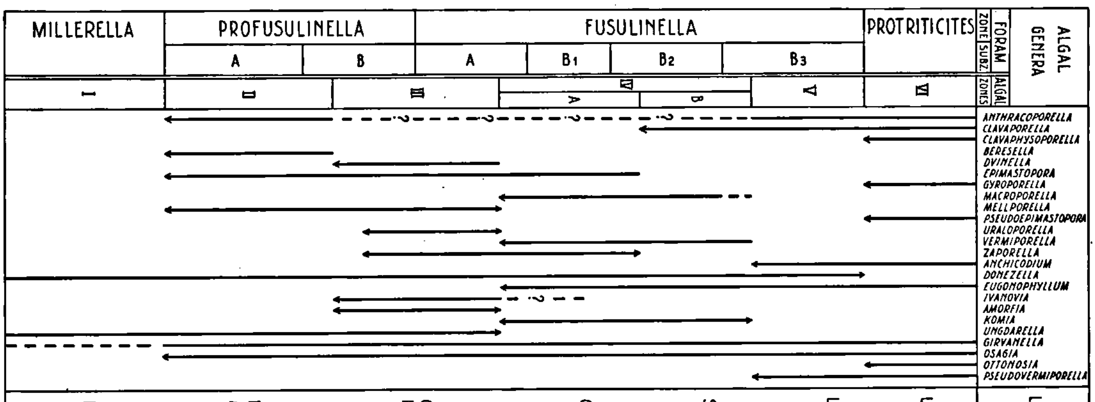
Triassic and Jurassic

The folded Palaeozoic of the Cantabrian orogene is covered unconformably by red continental deposits, which are supposed to be of Triassic or Permo-Triassic

TABEL VII



TABEL VIII



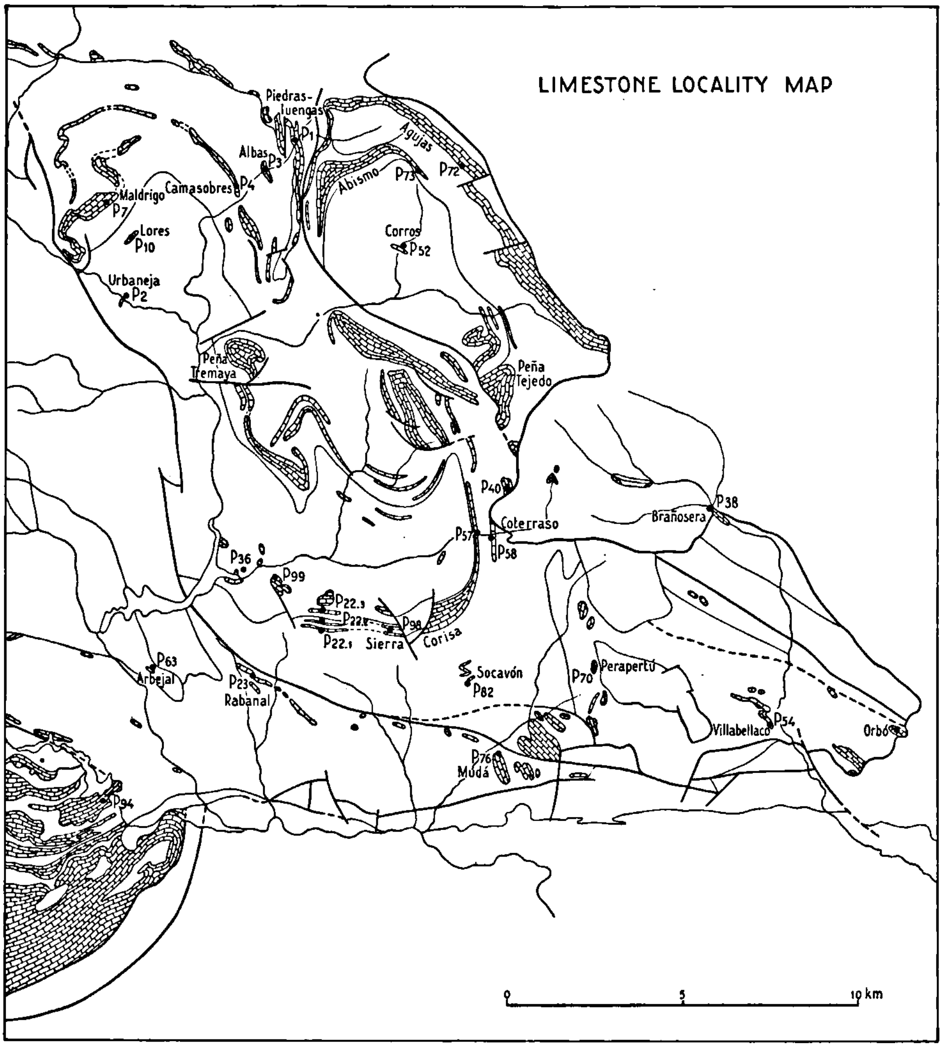


Fig. 8. Limestone locality map

age. Along the southern border of the Hercynian mountains the Triassic forms a narrow band from Cillamayor to Ligüérzana, then it disappears, because from south of Cervera the Cretaceous in Wealden facies reposes directly on the Palaeozoic rocks. Near Rueda the Triassic rocks still have a thickness of some 200 meters and the outcrop near Ligüérzana is of roughly the same thickness.

The Triassic is represented in its germanic red-bed facies, with pebble beds, crossbedded sandstones and sandy shales.

On the eastern border of our map sheet these red-beds reach a considerably greater thickness, but their character does not change.

Towards the top the red mudstones may contain cavernous dolomites and gypsiferous marls, which are supposed to belong to the Keuper. Even salt has been encountered (Salinas de Pisuerga) in lenses formerly exploited for local consumption. The Triassic is conformably overlain by the *Jurassic* of which a good section is exposed between Cillamayor and Salinas. It starts with dolomitic or well bedded limestones of the Infraliassic and ends with the Bathonian, which is overlain by the Wealden facies of the Lower Cretaceous (fig. 3, p. 41, Ciry).

Cretaceous

The Cretaceous starts on the Pisuerga sheet with the Wealden of continental facies, covered by Cenomanian limestones. The *Wealden* rests unconformably on the Stephanian south of Cervera and its unconformable position on the Jurassic is known from elsewhere. West of Rueda it consists exclusively of pebble beds and sandstone and kaolin clay. Further to the east the formation becomes more complete with sandstones at the top. In the lower part we sometimes find fresh water limestones with fragments of brachiopod shells. Sometimes the limestones are intercalated with thin lignite or clay lenses.

Van Amerom collected samples from the Wealden in León along the southern border of the Cantabrian Mountains in the areas of the rivers Cea, Porma and Curueño. Pollen from these samples indicate a "possibly Cenomanian-Turonian" age for this so called "Wealden" (van Amerom, 1965).

Ciry distinguished the Santonian immediately overlying the "Wealden" in León, but in Palencia Cenomanian sandstones and limestones are found on top of the Wealden. Thus it seems that the Wealden facies continued in León and the marine Upper Cretaceous transgressed from east to west.

The Wealden is followed by the *Cenomanian* which consists near Vado (south of Cervera) and Ligüérzana of black clay, glauconitic sandstone with oysters and sandy limestone with some lignite intercalations of some 15—20 m thickness. Further Ciry (1939) distinguished in the present area limestones and marls from Turonian up to Maastrichtian.

The *Turonian* consists of marls at its base and of white rudiste limestones at the top.

The *Coniacian* consists again of marls with at the base a glauconite sandy marl.

The *Santonian* is formed by limestone, white massive limestone at its base becoming sandy and detrital towards the top.

The *Campanian* and *Maastrichtian* are formed by arenaceous, detrital limestones.

IGNEOUS ROCKS, ORES AND COAL

The León Line is accompanied on its north side in a large part of the Cantabrian mountains by small intrusions of variable nature. They intrude all the rocks of Palaeozoic age up to the Cea Formation, but have never been observed in the Triassic and therefore must be of late Hercynian age. On our map the largest one is the Gramedo intrusion. A cluster of small intrusions is found round the village of Estalaya and from Rabanal they run out in a narrow stretch to Mudá and further to the Rubagon river. They are in general very weathered and no detailed study has ever been undertaken. Their composition varies from diorite to granite and their texture is in general porphyritic with quartz and andesine phenocrysts, sometimes even garnet. Dykes and sills occur also frequently. A long sill occurs in the Corisa Formation east of the San Cristóbal hill. The larger bodies have a thermal metamorphic aureole, but the smaller ones generally not. The instrusions on both banks of the Pisuerga river, just north of the Vañes lake have well developed metamorphic aureoles, in which the limestones have been marmorized. Except for the fact that their emplacement is certainly related to the León line no distinctive pattern in their distribution can be discerned.

ORE DEPOSITS

In the same zone occupied by the intrusive rocks occur small and insignificant ore bodies of low temperature character, which have occasionally been exploited on a small scale. On the left bank of the Pisuerga river, near the northern point of the Vañes lake is a deserted copper mine, which exploited chalcopyrite. A little higher up the river on its right bank occurs a small mine that produced arsenic and copper from arseno-pyrite and chalcopyrite veins. In the Ruesga region there are small chalcopyrite veins in the limestones.

COAL

The principal mining activity is concentrated on the coal measures of the Yuso and Cea Formations. Nederlof and de Sitter (1957) gave a description of the coal occurrences in the Pisuerga basin. In general the coal is very dirty with an ash content running up to 20 % and sometimes higher. They vary in constitution from semi-anthracite to low volatile bituminous coals. The following table shows that there is no relation between their volatile content and their age or thickness of the sedimentary sequence. Neither is there any connection between the structure and the volatiles. One can speculate about hidden intrusions of course.

Total reserves of the Pisuerga basin are small, not more than 12 million tons to a depth of 500 m below surface.

In the Barruelo basin the coal exploitation is better. The coal seams are cleaner, ash content about 6,5 %. They are thicker and more continuous. Their volatile content varies from 17—28 %, and the total reserves to 500 m depth are perhaps some 30 million tons.

TABLE IX

	Coal seams	Volatile content in %
	Barruelo basin	17—28
	Guardo basin, Mina Constancia	2,5—8
Cea Formation	San Felices	23—30
	Redondo	8—12
	Areños	3—10
	Verdeña	8—9
	Casavegas	5—10
Vañes Formation	Celada	32
	San Cebrian	24

STRUCTURAL GEOLOGY OF THE PISUERGA BASIN

As has been mentioned before our map contains many structural units of quite different character (fig. 9). On the western side of the map, in the Devonian, we can distinguish the *Polentinos anticline* with the complicated and thrusted structures of the Carrion region on its northern flank and its southern flank continuing in the Peñas Negras ridge. South of this unit we find the simple *Los Cintos syncline* developed in Curavacas conglomerates. Then follows the *Resoba region* of the Ruesga Formation, mostly covered with Tertiary terraces and continuing eastward in the *Cervera-Muda region.* Still further south appears the structure of the *Sierra del Brezo* with prominent Caliza de Montaña development.

In the Pisuerga basin proper we distinguish in the north the *Casavegas syncline,*

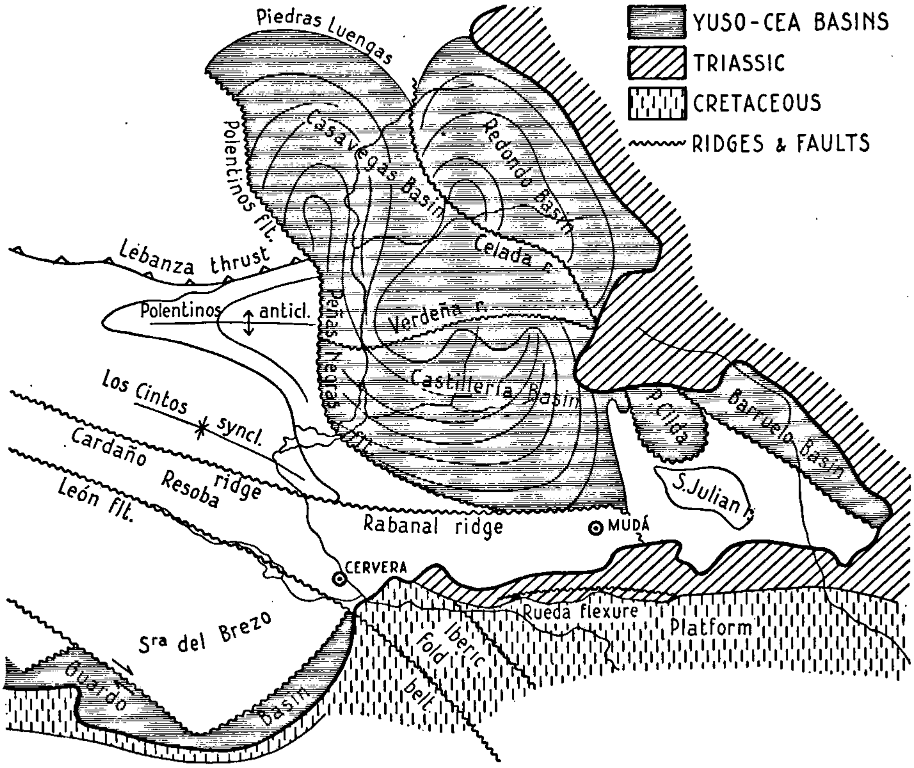


Fig. 9. Index map of the Pisuerga area

the *Piedrasluengas ridge* and the *Redondo syncline*. In the centre a succession of folds has developed between the Pisuerga river and the Peña Tejedo, which we might call the *Verdeña ridge folds*. They are followed southwards by the *Castilleria syncline*. East of the south flank of this syncline we enter into the region of the *Peña Cilda syncline* and the *San Julian Devonian structures*, and still further to the east the *Barruelo syncline*. On the southern border of the map we find the *Rueda flexure* exposed in the Triassic rocks. On fig. 10 the structural features with their names have been plotted.

The E–W striking *Polentinos anticline* is a rather simple anticlinal structure (section A–B), plunging westward and cut by many small cross faults, which have the character of perianticlinal faults. Its southern flank is bent in a SSE direction and continues in the Peñas Negras ridge. Together with this bending there develops a larger fault running through the Polentinos village, which brings the Abadia Formation in direct contact with the Carazo Formation, cutting out the Lebanza Limestone Formation. In the Peñas Negras ridge itself we observe the development of a secondary syncline and anticline, steep but simple structures with a NNW–SSE strike. The throw of this *Vañes fault* diminishes southwards and its function is taken over by these Peñas Negras folds. The fact that these structural features of the Peñas Negras have quite a different strike than the Polentinos anticline suggests that they are of a later origin, probably related to the development of the Rabanal ridge and the Polentinos fault. Such secondary folds occur also 2 km west of Polentinos in the limestone members of the Abadia Formation, and further west across the

Carrion river in the Upper Devonian (van Veen, 1965). Here they are parallel to the main fold axis, but they also give the impression of representing a refolding phase.

In the north flank of the Polentinos anticline, beyond the outcrop of the Lebanza Limestone, an important thrustfault has developed, the *Lebanza thrust* (section A–A). Further to the west this thrust becomes a very flat overthrust (section A of van Veen, 1965) and conceals completely the adjoining syncline of the Polentinos anticline.

The next anticline, thrusted over this syncline has been named the *Carazo anticline* and the next syncline the *Cortes syncline*, or rather anticlinorium and synclinorium because their fold structure is very complicated by secondary folds (van

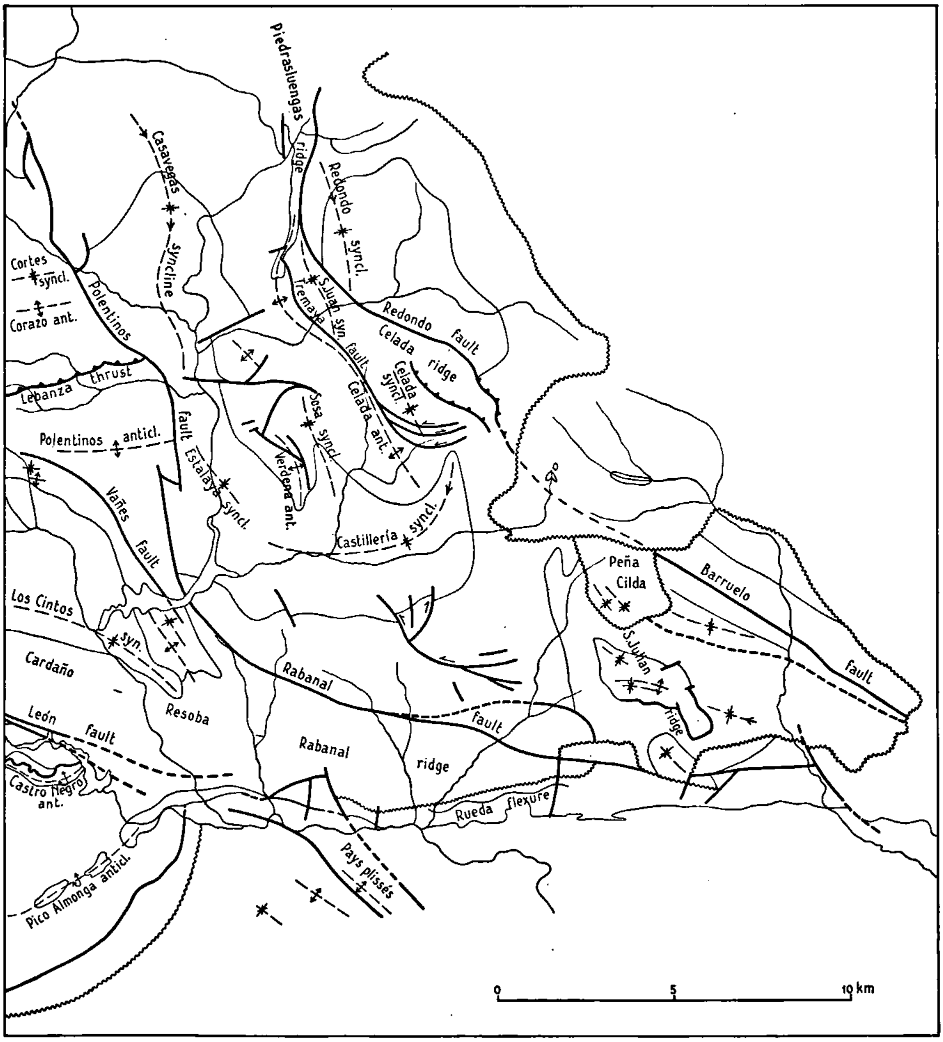


Fig. 10. Structural map of the Pisuerga asea

Veen, 1965). Om our map all these structures are cut off by the N–S running Polentinos fault of much later date.

The *Los Cintos syncline*, consisting of the Lower Yuso Curavacas Conglomerate Formation, which covers unconformably the southern flank of the Polentinos anticline, is a relatively gentle structure with a broad northern flank and a steep southern flank. It is strongly asymmetric, the south flank being very narrow and pressed up against the Resoba ridge.

This *Resoba ridge* is almost completely covered by a Tertiary terrace conglomerate and its structure as drawn on section A–B is derived from outcrops further west in the Santibañez region and east in the Cervera-Mudá zone (Frets, 1965). There seem to be many small folds, all with their axial plane dipping northwards, but the poor exposure here and further eastward in the region between Arbejal and Mudá does not allow any accurate mapping. Some of these small structures are exposed along the road Cervera-Vañes, detectable mainly by an analysis of top and bottom features (fig. 11). Towards the east the pronounced northern dip

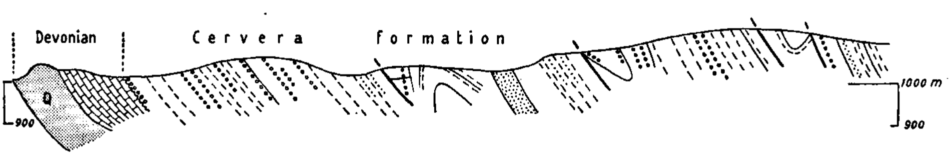


Fig. 11. Section through the Cervera Formation N. of Cervera de Pisuerga

becomes steeper and in the Mudá region the axial planes stand vertically or have a southern dip in almost isoclinal folds.

A further step to the south on the western side of our map brings us in the *Sierra del Brezo region*, which has been described by Kanis (1956). The fold structures of this region are exposed in the Caliza de Montaña formation with Devonian in the core of the anticlines (section A–B). The fold structures are isoclinal, overturned and dipping northwards. There are two principal anticlines, the southern one of the Pico Almonga and the northern one of the Castro Negro, but many smaller folds and thrusts occur in the synclinal zone between these anticlines. The boundary with the Resoba region is an important fault line, the continuation of the León line, which in the Esla-Bernesga region further to the west separates the Leonides from Asturides. Here it has been joined by the Cardaño ridge and together they form here the dividing ridge between these two great structural units. Its function as a fault is clearly demonstrated by the different strikes south and north of the fault line, and its older function as facies boundary by the differences in the development of the Lower Ruesga Formation in its Caliza de Montaña facies south, and its Culm facies north of the fault line.

The Pico Almonga anticline with Devonian in its core crosses the Pisuerga river in the town of Cervera de Pisuerga, and is bent from its NE strike to an E–W strike east of this village. The Upper Devonian is here covered by conglomerates belonging to the Cervera Formation suggesting that some of this folding or uplift took place already in pre-Namurian time.

When we turn our attention now to the Pisuerga basin proper one is struck by the fact that their structures are completely different from those discussed before. Their strike is different, their shape and intensity of folding or faulting is different and even their dimensions are different.

The *Casavegas syncline* in the north is one large synclinal basin, with the curious feature that the south directed plunge of the synclinal axis in the north is steeper than the dip of its west flank, the east flank being also steep up to some 80°. There are no particular complications except in the west flank against the Polentinos fault line. The whole shape of this western flank has been adapted to the curved trace of this fault line, illustrating that the fault line formed a butress against which the synclinal structure developed, and therefore is older than the synclinal fold. The fault existed already during the basin subsidence which developed along this fault line, a fact which is also demonstrated by the development of conglomerate beds near the fault line and wedging out away from it.

The plunge of its axis flattens out southwards and it looks probable that part of the strong plunge in the north is due to the gradual subsidence of the central part of the basin and only partly to later folding.

The *Redondo syncline* on the eastern side of the Piedrasluengas-Celada ridge has a similar character as the Casavegas syncline, only its asymmetry is much more pronounced. It shows the same steep plunge of the axis in the Peña Abismo, but further north it flattens again. Towards the south the syncline closes also with its axis plunging northwards. Its eastern flank is overturned, the overturning increasing southwards to a 15° dip to the east in the overthrusted Peña Tejedo. Its western flank is only present in the north, where it is steep and locally overturned, but is gradually cut off towards the south by the Redondo fault.

The Redondo fault has the same function for the Redondo basin as the Polentinos fault for the Casavegas basin, the basin subsiding along the fault during its filling up and in the later folding phase it was presed against it.

The two synclinal basins discussed above are separated by the continuation of the *Piedrasluengas ridge.* It contains a strongly folded and upthrusted syncline, the San Juan syncline, flanked in the east by the upthrust of the Redondo fault, and in the west by another upthrust, the Tremaya fault, both representing anticlinal structures (section G–H). The Tremaya fault runs into the Los Llazos anticline

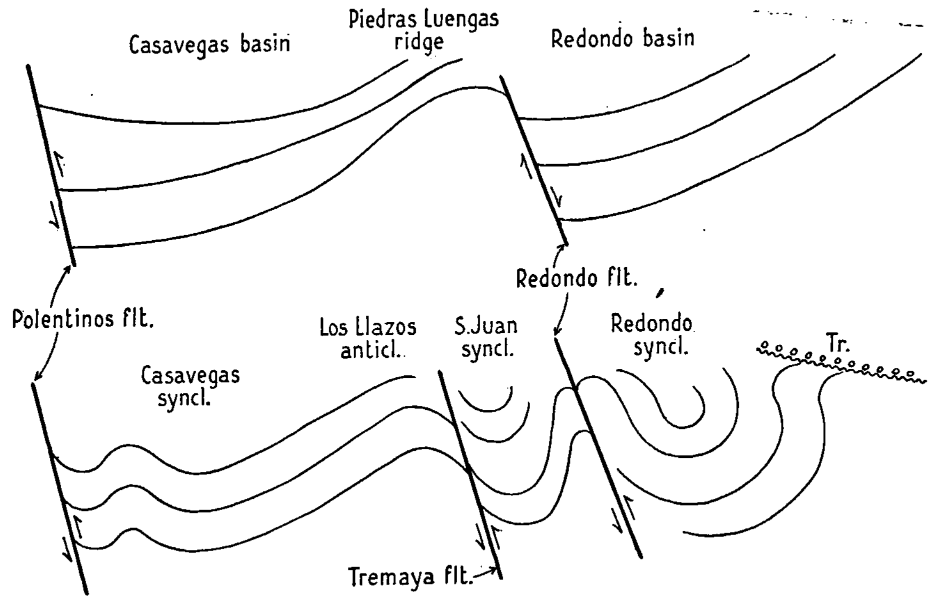


Fig. 12. The development of the northern basins and the Piedrasluengas ridge

in the north and in the Celada anticline in the south. The development of this structure is sketched in fig. 12. It is possible that some strike-slip movement took place along these faults also (Nederlof, 1959), but this can not be ascertained.

The two basins in the north are bounded in the south by an E–W striking ridge, the *Verdeña ridge* which has been strongly folded and broken up by thrustfaults. It separates the two northern synclinal structures from the Castilleria synclinal basin in the south. An E–W section along this ridge is given by fig. 13 (after Nederlof,

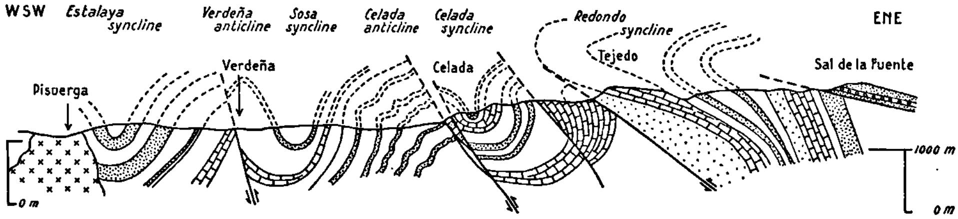


Fig. 13. Section through the Verdeña ridge (after Nederlof)

1959) and the eastern part also in the section C–Ḋ. It contains from west to east the simple Estalaya syncline, the faulted Verdeña anticline, the steep Sosa syncline, the Celada anticline, the Celada syncline (fig. 15) and then some faulted structure, (fig. 14) and finally the overturned Peña Tejedo limestone. It is made obvious by the fact that the longitudinal Verdeña and Celada faults die out in the fold-structures that these faults form part of the folding process. The same is true for

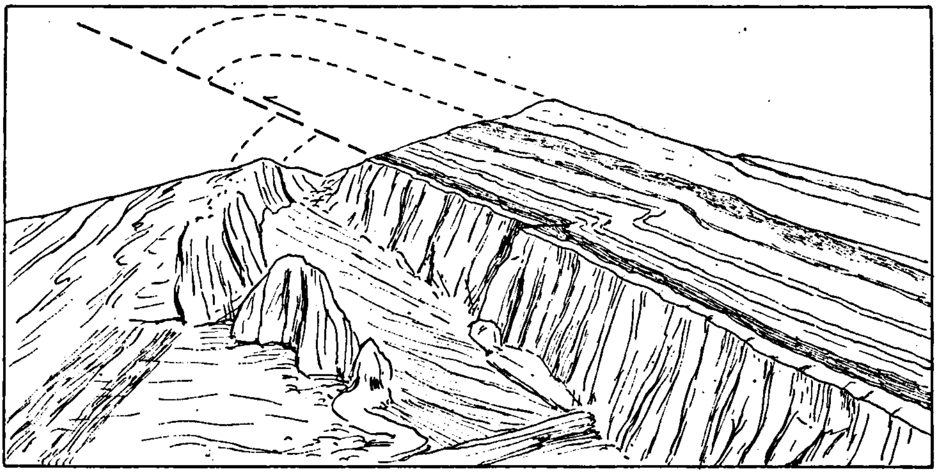


Fig. 14. The overthrust east of the Celada syncline (after photograph)

the cross folds on both sides, north and south, of the Peña Tremaya. This limestone block of Peña Tremaya represents probably an anticline, the continuation of the Verdeña anticline. The Celada syncline (fig. 15) with on its east flank an overthrusted anticline (fig. 14) are spectacular phenomena by the beautiful and complete exposure of their limestones.

Because the Cea formation of the Casavegas basin continues uninterruptedly

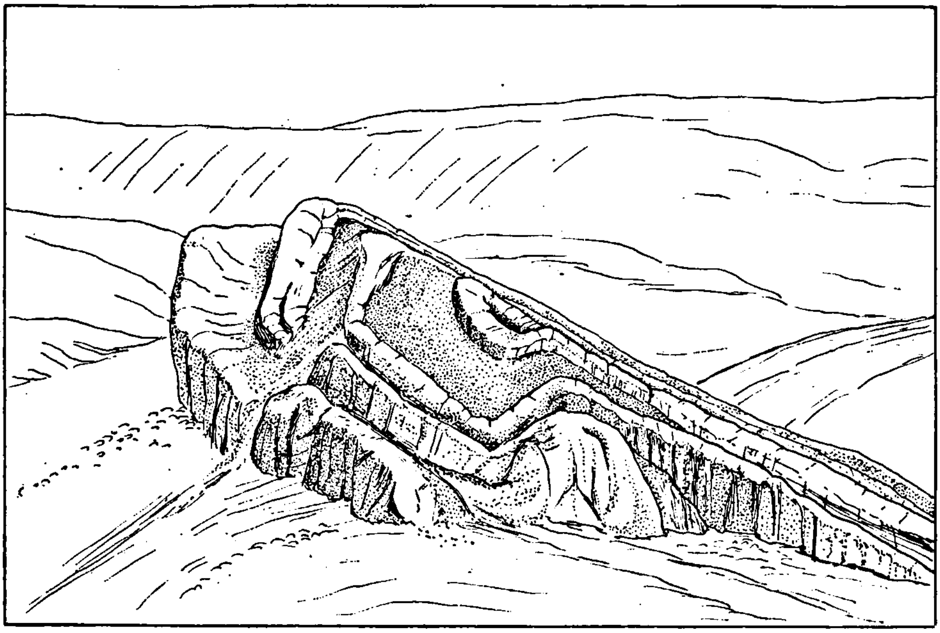


Fig. 15. The Celada syncline (after photograph)

southward into the Castilleria basin, and the Redondo basin probably finds its continuation in the Barruelo basin, the Verdeña ridge originally formed only a shallow interruption in the western basin. It lies in the direct continuation eastward of the Polentinos anticline and therefore probably reflects this structure during the basin subsidence.

The *Castilleria syncline* represents also a rather simple structure but in contrast with the two above mentioned synclines it has an east-west running synclinal axis. Its northern flank is formed by the southward plunging axes of the Verdeña-Celada folds, which flatten out in this direction with the result that they have disappeared when they reach the E–W axis of the Castilleria syncline. The south flank of this syncline is gentle, dipping some 30°—50° north. The eastern side of this syncline turns sharply to the north, the south flank steepening and turning into a north-south striking vertical, locally overturned, flank. The synclinal axis itself runs then into the Celada folds. The bend in this flank shows a set of small wrench faults and some secondary folds. It is obvious that this bending of the whole synclinal structure occurs against the pre-existing Piedrasluengas-Celada-San Julian-ridge. The structure of this syncline is again largely due to the local basin subsidence north of the Rabanal ridge and west of the San Julian ridge. The steepening of the east flank to its vertical position is more a tectogenic feature but the slope of the south flank is largely of an epeirogenic character, and the east-west trend of the synclinal axis is due to the rise of the Verdeña and Rabanal ridges and not a folding phenomenon. With the decreasing influence of the NW–SE folding southward, the original E–W direction of the basin development predominates in the south.

The structure of the *San Julian region* is rather problematic because the Devonian structures are largely concealed by a thin Upper Ruesga unconformable blanket. The structure of the Devonian of the San Julian hill proper has been described in detail by Frets (1965). It consists of a complicated synclinal structure exposed in Lower Devonian rocks with an east-west trend, plunging westward and with north dipping axial planes (section E–F). The southern border of this devonian structure seems to be thrusted on the Carboniferous, the northern border is a steep dipping unconformable contact. The western border is also a steep unconformable contact, probably originally a cliff of the San Julian island bordering the Carboniferous sea (see fig. 18), with the Perapertu reefs growing in front of it (fig. 16 after Frets) during Upper-Ruesga time.

Numerous small outcrops of mostly Upper Devonian occur in the whole region between the Barruelo fault in the east, the Triassic in the south and the east flank of the Castilleria structure. Their structural relation to the San Julian hill syncline remains unknown. Two large outcrops of the so-called Moradillo sandstone are supposed to be of Devonian age because of the find of one Frasnian goniatite in the northern outcrop. Because both have a synclinal structure these outcrops were originally thought to belong to the Vañes Formation, in normal position on top of the surrounding Ruesga Formation, but the east-west strike of Moradillo hill syncline is in better agreement with a Devonian structure.

The *Peña Cilda syncline* with its northwest-southeast trend is again a rather simple structure with some secondary folds as indicated on the map. Its westflank is steep and partly thrusted over the underlying Perapertu Member. Its unconformable position is very clearly expressed on the map.

The *Barruelo basin* (section E–F) consists only of the overturned northeast flank of a syncline, bordered on its south-western side by the Barruelo fault. Its structure is in a certain way an exageration of the Redondo syncline and it looks very probable that the Barruelo fault is the direct continuation of the Redondo fault. The Barruelo basin is still more asymmetric than its northern continuation and the conglomerates at the top of the Barruelo Formation lying against the Barruelo fault plane are of a synorogenic character. No particular complications arise in the overturned flank. A large portion of the structure is covered by Triassic rocks so that the structure of the northwest and southeast plunges remains unknown.

The *Triassic blanket* on the east side of the Pisuerga basin is largely the south flank of a very large synclinal structure of which the axis is very near the Peña Labra on the northern border of our map. It dips with some 20° to the northeast.

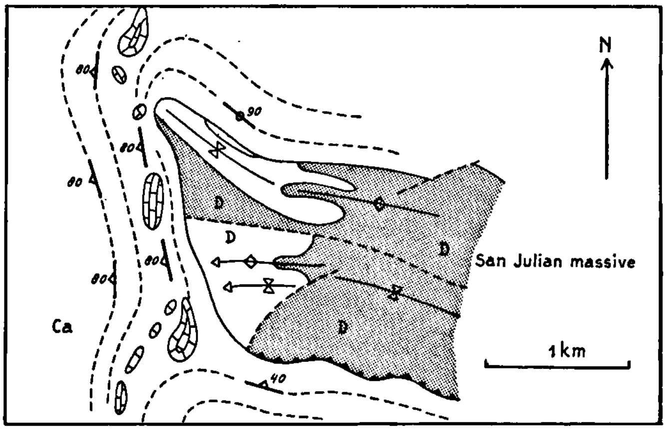


Fig. 16. Structural map of the western part of the San Julian area (after Frets)

The westward bulge in its outcrop towards the Castilleria valley is a flat secondary synclinal structure, of which the axis is roughly the continuation of the Castilleria syncline. This flat east-west striking Triassic synclinal structure is certainly related to the steep east-west flexure at the southern border of the Palaeozoic reaching from Cillamayor to Cervera de Pisuerga, called the *Rueda flexure*. The steepness of this flexure varies from 90° west of Rueda to some 60° near the Rubagon river. The structure is accompanied by many faults (section E–F) and flattens out very quickly southward, where it is unconformably overlain by the Cretaceous. This Rueda flexure is certainly due to a cratonic block uplift of the Cantabrian Mountains along a deep seated faultline which started to move even during the Upper Carboniferous in the west where the Cea intramontane basins of Guardo, Sabero, Matallana and Magdalena are also related to such cratonic uplift movements.

In the Rubagon area the structure of the southern border shows the effect of the interference of the east-west strike of the Rueda flexure and the north-east strike of the large syncline of Peña Labra. In the west this southern boundary line is interrupted by an alpine fold belt, striking northeast, called the "Pays Plissés" by Ciry (1939), butting against the uplifted area near Cervera and causing there first of all the wedging out of the Triassicand Jurassic and in the second place a set of faults in this border zone between Ligüérzana and Cervera. Moreover this fold belt also offsets the flexure itself, displacing it horizontally for some 5 km southwards west of the belt. The alpine deformation consists of two major structures, the east-west running Rueda flexure and the north-east running Iberic fold belt, crossing near the town of Cervera de Pisuerga.

THE DEVELOPMENT OF THE PISUERGA BASIN

On the map the Pisuerga basin of Upper Carboniferous age is flanked to the west by the Devonian of the Polentinos region and in the east by the Triassic unconformable blanket. In the north we find the Carboniferous of the Piedrasluengas region, and in south the basin is limited by the Rabanal ridge, running from Rabanal to Mudá, consisting of Namurian with small Devonian outcrops. In the southeast corner the Devonian of the San Julian hills separates the Pisuerga basin from the Upper Carboniferous of the Barruelo basin. There is good evidence that this structural high of San Julian extends toward the northwest along the Celada ridge to the Piedrasluengas anticlinorium. This Celada-Piedrasluengas ridge divides the northern part of the Pisuerga basin in two synclines, the Casavegas syncline in the west and the Redondo syncline in the east. The strongly folded E–W striking central region (the Verdeña ridge) reaching from the Peña Tejedo over Verdeña to the Pisuerga river forms the southern limit of these two synclinal basins and the northern boundary of the Castilleria basin (fig. 9, p. 219).

In the southwest corner of the map the Visean and Namurian of the Ruesga region enters our map and continues eastward with the Cervera Formation to the San Julian region. South of this Ruesga-Rabanal zone we find the unconformable cover of Triassic and Cretaceous, the Triassic wedging out between the Cretaceous and Carboniferous in the neighbourhood of Cervera de Pisuerga. South of this Ruesga region in the SW corner of the maps we find the strong development of the Caliza de Montaña formation of the Sierra del Brezo in the south in contrast with the predominating Cervera formation north of the Ruesga lake continuing eastward to Mudá. The dividing line, along the Ruesga lake, is the continuation of the León line (de Sitter, 1962b).

The Rabanal ridge can be linked up westward with the Cardaño ridge (van

Veen, 1965), but this connection is partly masked by the thick cover of Curavacas conglomerate of the Los Cintos syncline.

Recapitulating this short outline of the Pisuerga basin and its surroundings, the major structural units in this map area are four Upper Carboniferous basins, the Casavegas, the Redondo, the Castilleria and the Barruela basins limited and separated by ridges or anticlinoria: the León line, the Rabanal ridge, the San Julian- Celada-Piedrasluengas ridge (the Celada ridge), the Polentinos block with the Polentinos fault and the Verdeña ridge. These ridges are important structural features.

The León line separates the Leonides from the Asturides in the southern Cantabrian Mts. (de Sitter, 1962). The Leonides are devoid of Yuso sedimentation, and in front of this line in the Asturides deep Yuso basins developed. The Pisuerga basin is one of these Yuso basin developments with continuing subsidence during the Cea Formation, which is lacking in the other Asturide Yuso basins. A comparison of the Devonian of the Polentinos region with that of the Esla-Bernesga region shows that this León line was already active as early as during Siegenian time (Brouwer, 1962; Kullmann, 1965). The fact that the Triassic-Jurassic deposits

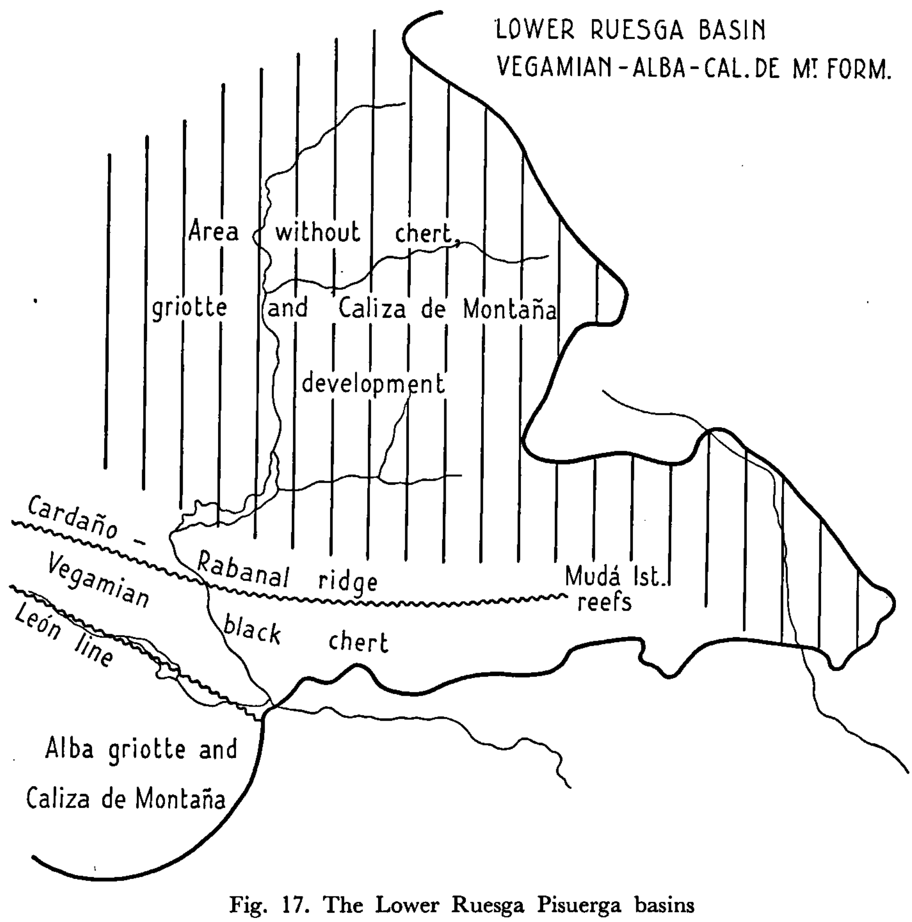


Fig. 17. The Lower Ruesga Pisuerga basins

wedge out near Cervera proves that its activity continued into the Mesozoic. At this point we find that the northern extension of the Iberic foldbelt south of the Ebro block, called the "Pays Plissé" (= fold belt) by Ciry (1939), butts against the Paleozoic of the Cantabrian Mts. Such recurring movements along the same line can also be established for other of the above mentioned ridges, but the starting point in time of their function need not be the same.

From our information of the central and western part of the Cantabrian Mountains we know that an important epeirogenic uplift occurred near the end of the Devonian, continuing into the Lower Carboniferous, the Famennian or the Visean being transgressive on an eroded surface cutting down into the Lower Palaeozoic (Comte, 1939; de Sitter 1962b; Rupke, 1965). This uplift was not restricted to the Leonides, but affected the Asturides as well. Nevertheless both, the León and the Cardaño lines, were active during this Bretonnic epeirogenic phase. In our region this phase is clearly expressed by the fact that the Vegamian Formation (Tournaisian) with black chert, is only developed in a narrow zone north of the León line reaching from Resoba to Mudá (fig. 17). It is absent in the Sierra del Brezo where the Alba griotte (Visean) rests on the Famenian. The

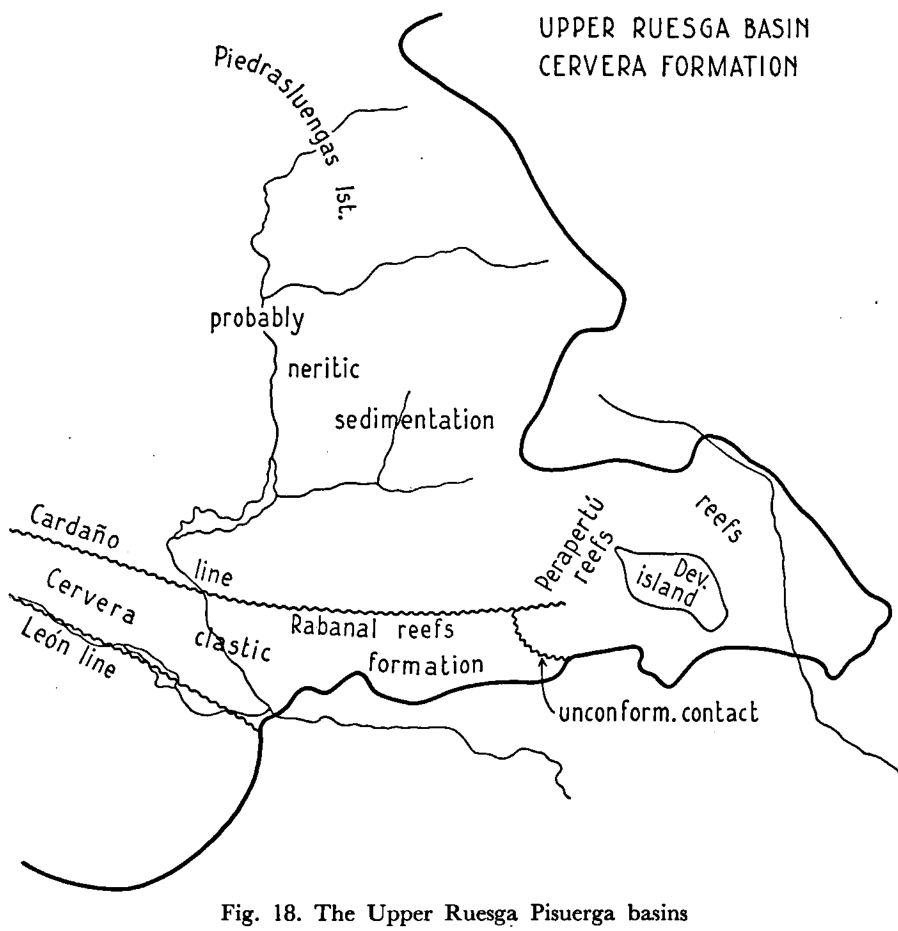


Fig. 18. The Upper Ruesga Pisuerga basins

Caliza de Montaña development of the Sierra del Brezo disappears also against this line and is replaced north of it by the clastic Cervera Formation with often a chert containing breccia at its base when the Vegamian chert beds are missing. In some places the Alba griotte is overlain by graded calcarenites. In the Mudá region reef limestones represent this Caliza de Montaña Formation. It is probable that north of the Cardaño-Rabanal ridge the Ruesga Formation also does not contain any Caliza de Montaña development (fig. 17). The activity of this Bretonnic phase continued during the Ruesga Formation and is expressed by the clearly unconformable position of the basal conglomerates and "wildflysch" of the Cervera Formation on the reef limestones of Mudá. The San Julian hills probably formed an island during this time and the Upper Ruesga Perapertu reefs grew along its western coast line (fig. 18).

It is difficult to ascertain the age of the strong folding of the Devonian in the Polentinos area and in the San Julian hills. The Polentinos structure is covered unconformably by the Curavacas conglomerates of the Lower Yuso, and in the San Julian region an unconformable contact between the Villabellaco limestone of the Lower Ruesga and the Devonian was established by Wagner (1962). There

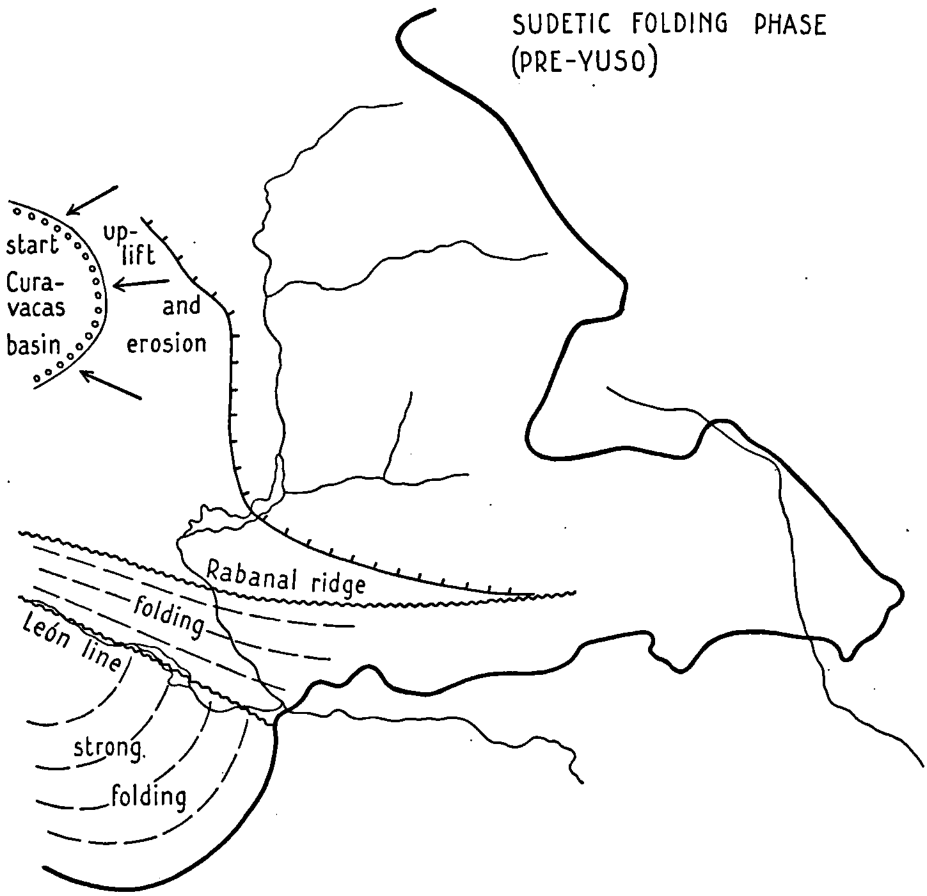


Fig. 19. Sudetic folding of the Pisuerga area

are several small Devonian outcrops sticking through their Carboniferous cover in this region.

The reef limestones of Perapertu continue in the Rabanal ridge and in the Barruelo region always more or less connected with outcrops of Upper Devonian. These folds in the Devonian could be of Bretonnic age; if this is true the epeirogenic Bretonnic phase of the Central Cantabrian Mountains developed into an orogenic phase in the eastern part of these mountains. It looks more probable that they are due to an early Sudetic phase.

The effect of the continuation of the Bretonnic phase into the Upper Ruesga is also expressed by the facies development of the Cervera Formation, which contains shales and silty shales, with occasional thin bands of turbidite origin. Associated we find a few conglomerate beds of some metres thickness which sometimes can be traced into sandstone beds of equal thickness, with coarse cross bedding. The conglomerates have boulders of various size mixed together and which often do not touch each other. Near Cervera quartzite boulders have been found, widely scattered in pure shale. For the deposition of such boulder beds the mechanism of sliding or slumping seems the most probable means of transport.

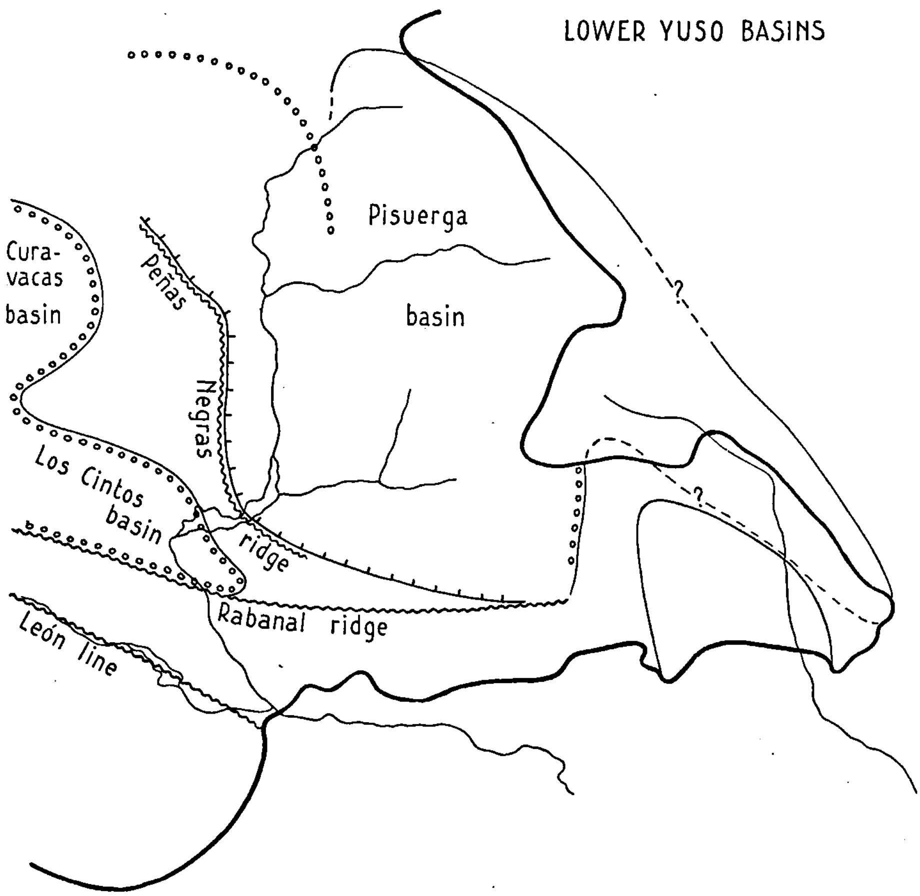


Fig. 20. The Lower Yuso Pisuerga basins

The Sudetic phase has been established as a strong folding phase in the Leonides of the Esla-Bernesga region further to the west. From some regions in the Asturides we have information that the Sudetic phase was also active there, but in other regions it is apparently absent. It was followed and accompanied by the development of the Yuso basins in the Asturides of which the Pisuerga basin is the most eastern one. The Rabanal ridge formed the southern limit of this basin (figs. 19, 20). The strong isoclinal folding of the Sierra del Brezo is of Sudetic age proven by the unconformable contact with the Yuso Formation in the Camporredondo region.

The western boundary of the Pisuerga basin is formed at present by the Polentinos fault which certainly was active as the boundary area during the deposition of the Yuso. As such it forms the direct continuation of the Iberic fold belt. Here we are confronted with the puzzling phenomenon of two positive ridges crossing one another, a NW and an E–W striking one. The Polentinos ridge bends and merges with the Rabanal ridge and the Iberic fold belt bends and continues as the León line, at least since the beginning of the Carboniferous (fig. 21). Between the Peñas Negras ridge and the Cardaño ridge the Curavacas basin of Los Cintos developed, filled with thick and coarse conglomerates alternating with sandstones.

The base of the Yuso Group in the Pisuerga basin contains less conglomerates than in the Los Cintos basin, but both in the north and in the southeast it reposes

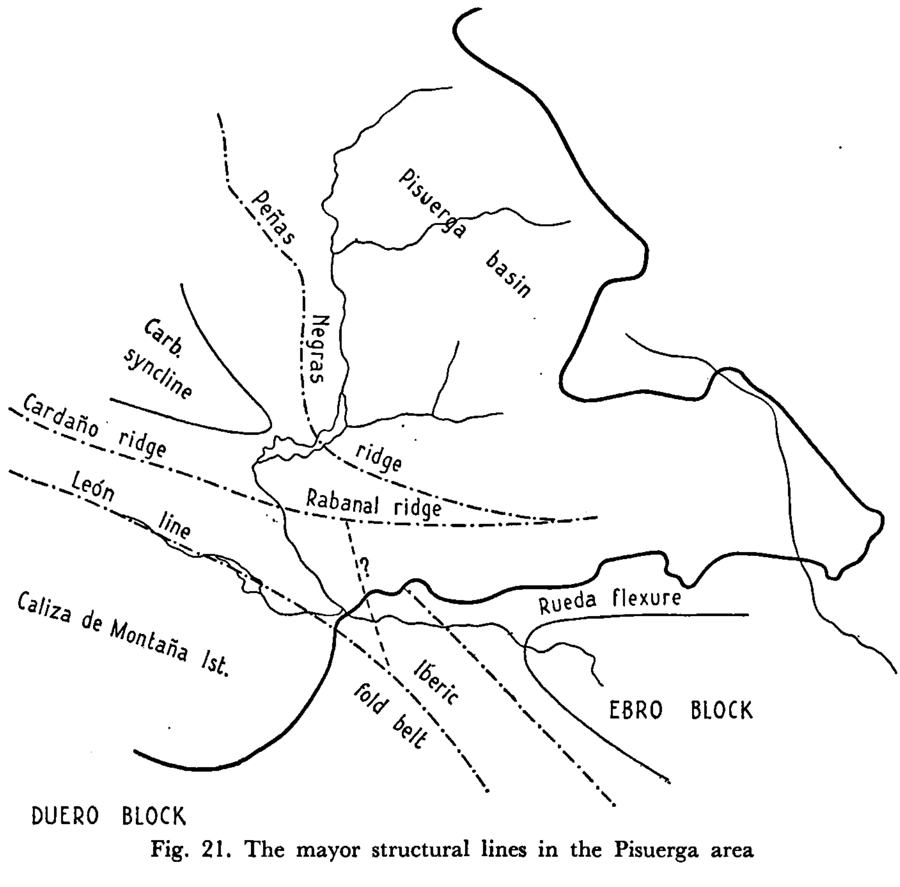


Fig. 21. The mayor structural lines in the Pisuerga area

with a clear unconformity on the Ruesga Group. Upwards, in the Vañes Formation, it becomes a sandstone shale alternation with occasional coal beds and at the top it shows characteristics of a much quieter environment with the Corisa Formation, containing numerous limestones.

During deposition of the Upper Yuso the Celada ridge started to develop (fig. 22) separating the Redondo-Barruelo northeastern part of the Casavegas-Castilleria southwestern part.

This ridge is even more pronounced in the Cea sediments (fig. 23). The facies became paralic with frequent coal beds in each of the basins (Nederlof and de Sitter, 1957). It is probably only during sedimentation of this Lower Cea that the Verdeña ridge developed, partly separating the Casavegas basin in the north from the Castilleria basin in the south (fig. 23).

On the western border a quick uplift of the Polentinos block occurred, causing a pronounced unconformity between the Cea and Yuso Groups, in the San Cristóbal region, east of the Vañes lake, demonstrating the tilting of the block with erosion on its uplifted edge and continuous or interrupted deposition on the down dropped side. This unconformity dies out very quickly in an eastern direction.

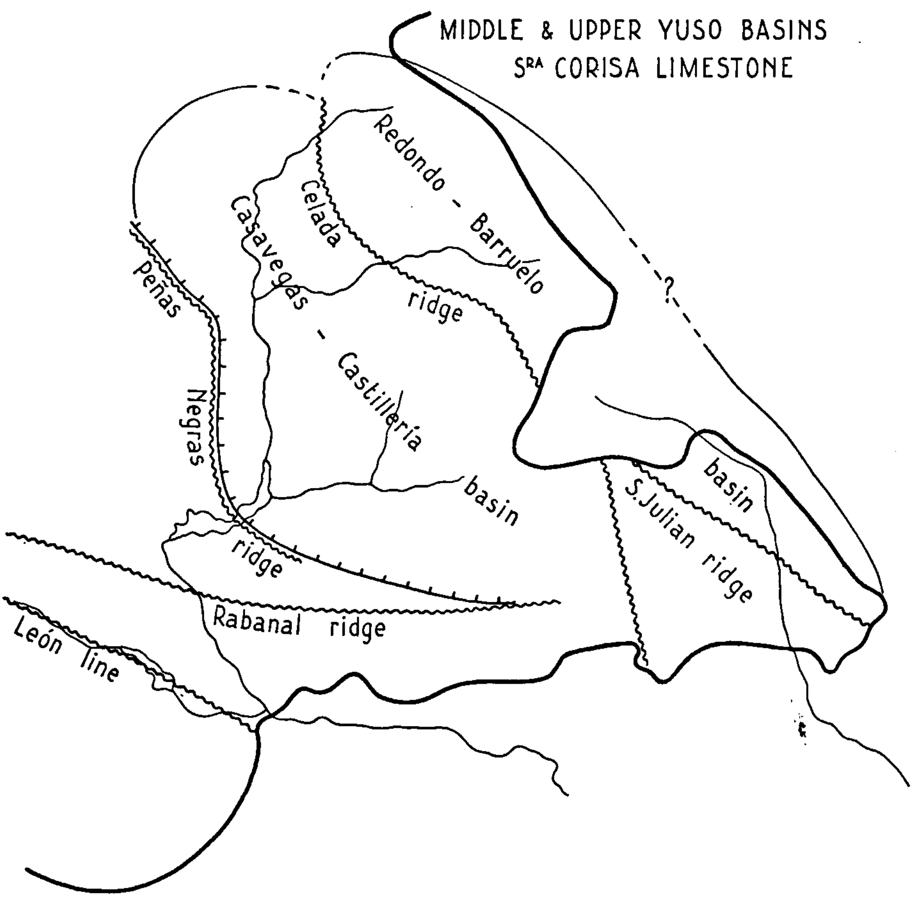


Fig. 22. The Middle and Upper Yuso Pisuerga basins

The Redondo basin subsided quickly and there the base of the Cea Group is formed by the turbidites of the Caldero Member described by Nederlof (1959). At the same time separate Cea basins developed on the southern slope of the Leonides of which the eastern extension of the Guardo basin enters our map area in its southwest corner.

These Cea basin developments have the character of tilted blocks. On the northeastern borders of the Polentinos and the Celada ridges normal faults developed and the Casavegas-Castilleria basin in the west and the Redondo-Barruelo basin in the east represent blocks subsiding on their western side along these fault lines. The Guardo basin is certainly also bound to a subsidence along a fault line on the southern border of the Leonides.

The subsidence of the Pisuerga basin stopped at the end of the Barruelo Formation and the Asturian folding started here at a very late stage between the Lower and Upper Stephanian as is proven by the completely unconformable deposition of the Peña Cilda conglomerates on the folded and overthrusted Barruelo Formation (fig. 24). It is possible of course that this Peña Cilda unconformity is

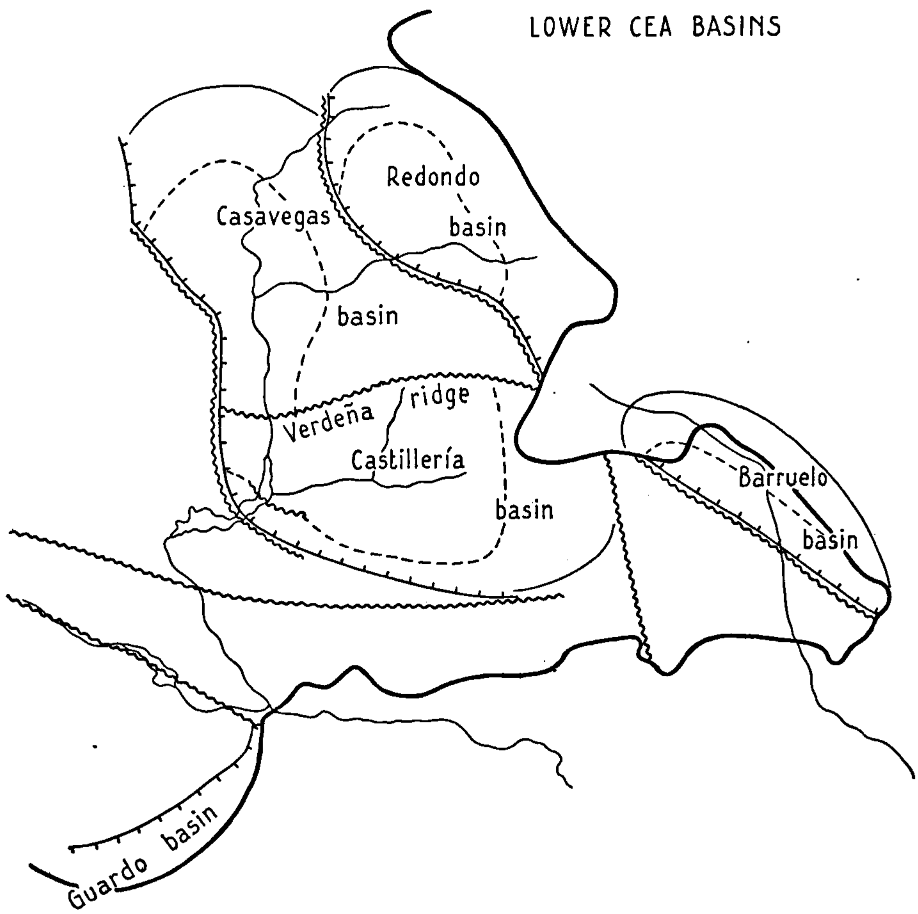


Fig. 23. The Lower Cea Pisuerga Basins

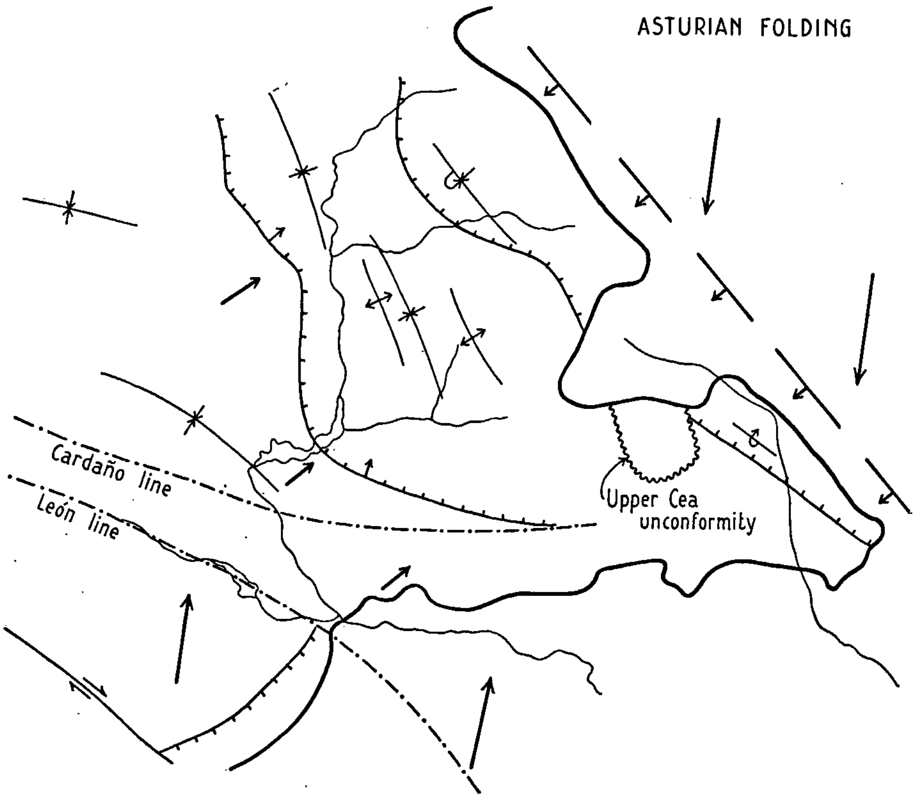


Fig. 24. Asturian folding of the Pisuerga area

only a local affair, the Peña Cilda Conglomerate Formation being a syntectonic deposit related to the upthrust along the Barruelo fault. The folding continued certainly because this formation itself is folded and unconformably overlain by the Triassic.

We have seen then that the development of the Pisuerga basin, including the Casavegas, Redondo, Castilleria and Barruelo synclines, started at the base of the Yuso Group between the Cardaño-Rabanal ridge in the south, the Polentinos ridge in the west, and the Piedrasluengas region in the north.

The filling up of the basin started with epeirogenic active movements with characteristic conglomerate and "wildflysch" deposits grading upwards into greywackes, shales and sandstones with a few coal beds. (Vañes Formation). Then the sinking became less accentuated, and the limestones of the Corisa Formation (Upper Yuso) were deposited. With the start of the Cea Group activity increased again and the basin became subdivided into the four above mentioned synclinal units by block tilting along the NW–SE striking Polentinos ridge and the Redondo-San Julian ridge and the E–W striking Verdeña ridge, each of these subbasins having its own distinctive sedimentation of the Cea Group. These subbasins reacted also differently to the tectonic stress, with stronger compression east of the Celada-San Julian ridge. Of the Castilleria subbasin only the eastern border zone became folded, the basin itself maintained its original E–W strike. Thus the major structural features have outlined distinct basins which prove to have been distinctly differentiated during the deposition of the Upper Carboniferous sediments and whose distinctive characters have been accentuated by their individual reactions to the tectonic stress.

The structural and stratigraphic evidence for the epeirogenic and orogenic activity, assembled in the foregoing pages, has shown us that since the Middle Devonian a continuous development of the Pisuerga basin and its surroundings has taken place. Nevertheless there are certain maxima of intensity which can be correlated with the Hercynian Stille phases:

old	Bretonnic phase	active from Upper Devonian to Lower Visean
	Sudetic phase	active from the Namurian into the base of the Westphalian
	Asturian phase	active from the Upper Westphalian into the Stephanian
young	Saalic phase	pre Triassic.

It is often difficult to decide to which of these phases a certain unconformity belongs, for instance the unconformable position of basal Cervera Formation on the Mudá reef limestones, Namurian on Lower Bashkirian or Visean. Is this a late Bretonnic or an early Sudetic subphase? In different structural units the maximum of movement also occurs at different times. On the southern slope of the Cantabrian Mts. the pre-Cea uplift occurred before the end of the Westphalian, but in the Pisuerga basin there is only locally on its western border an unconformity between the Stephanian and the Westphalian, the main movement taking place between the Upper- and Lower Stephanian, or even later.

One could also attempt to subdivide the Stille phases in subphases and give each of them a name as Wagner (1962) has done.

Bretonnic phase	subphase between Upper and Lower Famennian
	subphase between Alba Formation and Famennian
Sudetic phase	subphase between Cervera Formation and Caliza de Montaña Formation
	subphase between Curavacas Formation and Cervera Formation
Asturian phase	subphase between Yuso and Cea Group
	subphase between Stephanian A and Stephanian B

but we do not think this would be practical, the movement was more or less continuous with paroxysmal maxima at slightly different moments in different parts of the orogene. Moreover with six well established unconformities found at present and in such an irregular sedimentation environment future work will probably reveal more of them.

An interesting feature reveals itself when we compare the start in time of the activity of the ridges.

The León line has been active since the Emsian and continued ever since as an active zone. The Cardaño line has been active since the Visean and continued its activity till the end of the Carboniferous. The Peñas Negras ridge started its activity probably at the base of the Yuso and continued during the whole of the Carboniferous. The Celada ridge seems to be of somewhat younger origin, top of Westphalian. Apparently the activity progresses from southwest to northeast, from the Leonides into the Asturides.

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