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THE GEOLOGY OF THE SOUTHERN PART OF THE PISUERGA BASIN AND THE ADJACENT AREA OF SANTIBANEZ DE RESOBA PALENCIA, SPAIN

BY

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I. INTRODUCTION

The "Cordillera Cantabrica", which borders the Old-Castilian meseta in the north, is mainly a Hercynian mountain chain. The area with which this study is concerned is part of the southern border of this mountain belt and lies in the northeast in part of the province of Palencia.

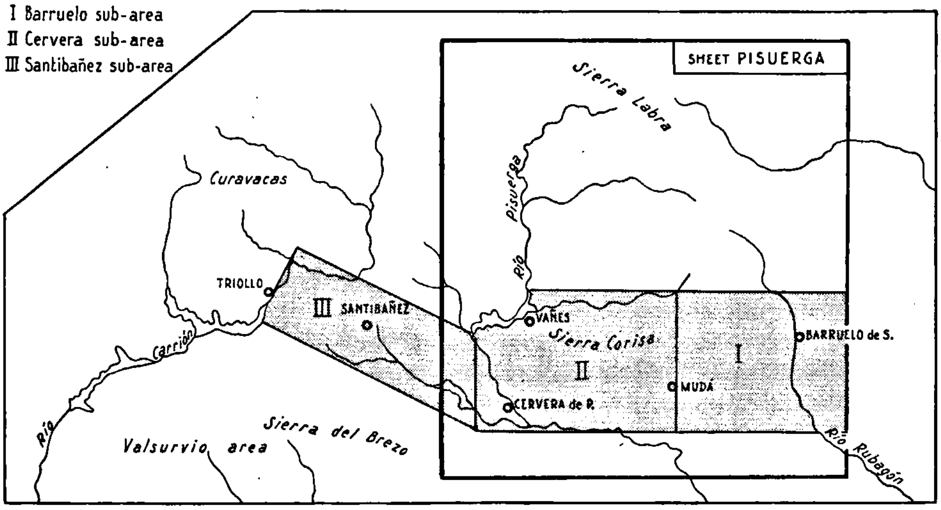

Fig. 1. Location of the investigated area.

The topographic elevation varies from approximately 1000 m at the southeastern border to 2000 m in the northeastern and western parts. The central part of the mountain range has a true mountain climate, but towards the south this rapidly becomes semi-arid continental. The Pisuerga River, flowing south, is the main river; its drainage-area borders towards the northeast on that of the Ebro River and towards the west — near Santibañez — on that of the Carrión River. For more information about the topography, morphology, and Quaternary history of this territory, the reader is referred to the publications of Hernandez Pacheco (1944) and Nossin (1959).

In 1951 the Department of Geology of the University of Leiden began a surface mapping project in the Pisuerga basin and in later years continued mapping progressively in a western direction. This work resulted in the publication of several papers concerning the geology of the area by the Department of Geology (Leiden) under the guidance of Prof. Dr. L. U. de Sitter.

After some years, however, it appeared both necessary and worthwhile to make a renewed survey of the Pisuerga basin because many tectonic and stratigraphic problems remained unsolved. This time the work could benefit from the fact that the structures of the adjacent areas towards the west were known. The mapping described in this paper is part of this later survey.

This same volume of the Leidse Geologische Mededelingen contains the first map of the southern part of the Cantabrian mountains (sheet 1: the Pisuerga basin) published by Prof. de Sitter, which includes the central and eastern part of my surveyed territory between the Pisuerga and the Rubagón Rivers and the Castillería River in the north. The geology of the western part (Santibañez area) is shown on a separate map included in this publication.

Use has been made of the topographic maps of the Mapa de España, sheet 106: Camporredondo de Alba and sheet 107: Barruelo de Santullán.

I. STRATIGRAPHY

1. *Devonian*

The Pisuerga basin lies enclosed between two Devonian blocks: the Polentinos block in the west and the San Julian block in the east. The stratigraphy of the latter will be discussed in this chapter.

The maps of Casiano de Prado (1861) and Dupuy de Lôme & De Novo (1924) already show the outlines of these blocks. Quiring (1939) gives the first stratigraphic section of these Devonian rocks, although very incorrectly because his interpretation of the structure was wrong. In a critical review of Quiring's paper Alvarado & Sampelayo (1945) made some corrections to it. In recent years Wagner (1955) has worked out the stratigraphy of these older Paleozoic rocks in more detail.

The Carazo formation. — This formation is exposed north of Verbios on the southern slope of the San Julian massive. The lowest part of the formation can not be observed because of tectonic disturbance (a fault) and consequently the total thickness remains unknown. For lithologic reasons the formation is subdivided here into two members: an older shale/mudstone member and a younger quartzite member.

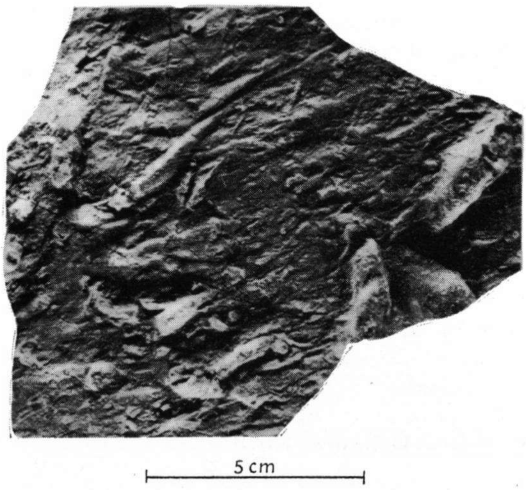

Fig. 2. Groove casts, striations, and worm burrows in the lower part of the Carazo formation.

The older part consists of an alternation of brown-green, strongly micaceous shales and brown, thinly laminated, quartzitic mudstones with a thickness of 5 to 10 cm. Sedimentary structures such as load casts, groove casts, flute casts, and worm burrows and tracks are abundant. This seems to indicate a quiet sedimentary environment, interrupted occasionally by turbidity currents. Near the top of this member the casts of a few brachiopods were found in a more arenaceous part with grey-yellow sandstone beds. They are, however, badly preserved. Dahmer & Quiring (1953) mention the determination of a brachiopod *Trigeria robustella*, probably from the same beds north of Verbios. North of Nava de Santullán lies an exposure of strongly recrystallized limestones containing a few corals, crinoids, nautiloids, and brachiopods. It is not clear whether they also belong to this formation, but Wagner assumes so. Recent studies by Cramer (1964) of the microplankton contents of the stratigraphically equivalent beds of the Polentinos block indicate that at any rate the lowest part of this formation belongs to the Upper Silurian.

The younger quartzite member comprises thick-bedded, white, coarse-grained and well-cemented quartzites, and has a thickness of 110 m. The thickness of the individual beds varies from 50 cm to 100 cm. Locally, they are strongly ferruginous and contain many small clay pebbles, in which case the cement is a true iron cement.

The Lebanza formation. — The Carazo formation is followed concordantly by the Lebanza formation, which crops out in the central part of the San Julian massive. In addition, two small exposures of the same limestones are found, one near Revilla and the other near Orbó.

The formation is built up of well-bedded, fossiliferous limestones that can be classified as recrystallized biosparites (Folk, 1959), and contain a fauna of brachiopods, corals, crinoid-fragments, bryozoans, and a few tribolites. The transition from the Carazo formation to the Lebanza formation is developed in a shaly facies, whose thickness varies from 0 to 5 m. These black and dark-green shales contain a fauna of tentaculites and nautiloids (Orthoceras). A beautiful section of the basal part is exposed 300 m southeast of Valle de Santullán.

Dr. J. G. Binnekamp (Leiden) has determined several specimens of brachiopods, samples of which were collected by the present author in the following localities:

1. The northwestern part of the San Julian,

Hebetoechia cantabrica Binnekamp, 1965
Podolella rensselaeroides Kozlowski, 1929
Schellwienella septirecta Wolf, 1930
Dalmanella fascicularis (d'Orbigny, 1850)
Stropheodonta gigas (Mc. Coy, 1852)
Brachyspirifer rousseaui (Rouault, 1846)
Schizophoria cf. provulvaria (Maurer, 1886)
Chonetes sarcinulata (Schlotheim, 1820)
Cryptonella inornata (d'Orbigny, 1850)
Athyris undata (Defrance, 1828)

This association indicates a Lower and Middle Siegenian age.

2. Near Revilla de Santullán,

Hebetoechia cantabrica Binnekamp, 1965
Athyris undata (Defrance, 1828)
Cryptonella inornata (d'Orbigny, 1850)
Hysterolites hystericus Schlotheim, 1820
Camarotoechia cypris (d'Orbigny, 1850)

This association also indicates a Lower and Middle Siegenian age.

3. Near Orbó,

Brachyspirifer rousseaui (Rouault, 1846)
Schizophoria provulvaria (Maurer, 1886)
Athyris undata (Defrance, 1828)
Trigonirhynchia fallaciosa (Bayle, 1878)

This association points to a Middle Siegenian age.

Therefore, the Lebanza limestones in this area are most probably of a Lower to Middle Siegenian age. Quiring (1939) and Alvarado & Sampelayo (1945) also mention determinations of fossils (mainly brachiopods) from the same limestones of the San Julian massive. Among the fossils mentioned by Quiring is one species of a trilobite: *Phacops latifrons*. However, an exact age is not stated.

The Abadia formation. — This formation overlies the Lebanza formation and comprises thinly-bedded, strongly recrystallized marls and limestones. These rocks crop out only in limited, isolated exposures scattered all over the area (for instance, near Mudá, Vallespinoso, Villabellaco, and Cervera). Consequently, the total thickness of the formation can not be measured. The fauna contains brachiopods, goniatites, corals, and a few trilobites.

1. The exposure 600 m east of Mudá. Mallada (1892) already published an extensive list of determinations of fossils from the "mancha pequenita de San Cebrián de Mudá", which in the present author's opinion must be the same exposure. He mentions determinations of several species of brachiopods as well as three determinations of trilobites, and attributes them to the Eifelian.

Mr. J. A. van Hoeflaken (Leiden) identified the following species of brachiopods from the same locality:

Stropheodonta murchisoni (De Vern. & d'Arch.)
Athyris avirostris (Krantz)
Spirifer rousseaui (Rouault)
Camarotoechia cf. daleidensis (Roemer)

He considers them to belong to the Emsian.

Recently Kullmann (1960) determined a goniatite *Mimagoniatites* sp. A, which is also an indication for the Emsian.

2. The exposure 500 m west of Mudá. From this exposure Van Hoeflaken (Leiden) determined the following brachiopods:

Chonetes plebeja (Schnur.)
Meganteris inomaia (d'Orbigny)
Athyris avirostris (Krantz)
Spirifer rousseaui (Rouault)
Rhynchonella sp.

This association is indicative for the Lower Emsian.

3. Another exposure of the same limestones is found 1000 m north of Vallespinoso. Alvarado & Sampelayo (1945) mention many determinations of brachiopods and attribute them to the Coblencian/Eifelian.

4. The age of the limestones 100 m north of Cervera (Peña Barrio) is still problematic. The few fossils they have yielded are impossible to determine. Mallada (1892) mentions the determination of the following brachiopods: *Spirifer hystericus* Schloth. and *Spirifer rogasi* Vern. and attributes them to the Coblencian/ Givetian.

5. Lastly, Wagner (1960) describes an exposure of Devonian rocks 100 m southeast of Villabellaco, comprising a series of thinly-bedded limestones, which contain brachiopods, conodonts, and a few trilobites. An exact age has not yet been demonstrated.

The Upper Devonian. — The development of the Upper Devonian north and south of the León ridge is quite different. The southern facies comprises mainly quartzites of Frasnian/Famennian age: the Camporredondo formation (Koopmans, 1962). These are directly overlain by the Lower Carboniferous Alba-griottes.

In addition to a series of quartzites, the Murcia formation (Van Veen, in press), the northern facies also comprises horizons of nodular limestones. The rocks of the northern facies are rather well exposed north and northwest of Santibañez de Resoba, and small exposures of the same quartzites are encountered all over the area of Cervera and Barruelo. They are greyish white, coarse-grained, and occasionally micro-conglomeratic quartzites. Sometimes they are slightly ferruginous. The thickness of the individual layers varies from 30 cm to 150 cm. Between the quartzite beds, thin horizons of green, sandy shales are intercalated. The rocks are completely barren.

The age of the series of quartzites north of Villabellaco and west of Nava de Santullán is still problematic. For many years a Lower Carboniferous age was assumed on the basis of the interpretation of the structure, but recently Wagner & Wagner-Gentis (1963) determined a goniatite *Aulatornoceras bicostatum* Hall collected by them in shales at the base of the quartzites, which should point to a Frasnian age. The present author also attributes them to the Upper Devonian on the basis of this determination and the strong resemblance of the Villabellaco quartzites to the Upper Devonian Camporredondo and Murcia quartzites.

Wagner & Wagner-Gentis's theory (1963), that the Villabellaco series wedges out in a southeastern direction, is not supported by field evidence.

The thickness of the quartzites mentioned measures approximately 300 m. According to Koopmans (1962), the Camporredondo formation has a thickness of 300—500 m in the Valsurvio area, but on the León ridge itself it rapidly decreases to 10—20 m. The thickness of the Murcia quartzites is still unknown.

The Upper Devonian nodular marls and limestones are exposed north of Santibañez de Resoba, near Mudá and north of Verbios. They are thinly-bedded, grey or red, clay-containing nodular limestones. A fragment of a goniatite is often found in the core of the nodules. The thickness of the individual horizons measures about 7—10 m. They contain a rich fauna of goniatites and conodonts. From an exposure 400 m west of Mudá Kullmann (1960) collected and identified the following goniatites: *Sporadoceras biferum biferum* (Phill.), *Sporadoceras biferum sulciferum* L G E, *Prionoceras* (*Imitoceras*) cf. *substriatum* (Mstr.), *Kosmoclymenia undulata* (Mstr.) and *Biloclymenia* sp. He attributes them to the Famennian.

Conodonts, collected by the present author in several localities, were studied by Mr. H. A. van Adrichem Boogaert (Leiden):

1. The limestone exposure 700 m north of Verbios,

Palmatolepis deflectens deflectens Müller
Pseudopolygnathus dentilineata E. R. Branson
Spathognathodus costatus spinulicostatus (E. R. Branson)
Spathognathodus aculeatus (Branson & Mehl)
Spathognathodus stabilis (Branson & Mehl)
Spathognathodus inornatus (Branson & Mehl)

He attributes this association to the Upper Famennian.

2. Also the nodular limestones north of Triollo at the eastern border of the Carrión River appear to have an Upper Famennian age.

3. Four localities of nodular limestones just north of the village of Santabañez de Resoba,

(loc. 3) *Palmatolepis glabra glabra* Ulrich & Bassler
Palmatolepis deflectens deflectens Müller
Palmatolepis perlobata schindewolfi Müller
Polygnathus nodocostata Branson & Mehl s.l.
Spathognathodus strigosus (Branson & Mehl)
Spathognathodus amplus (Branson & Mehl)
Icriodus sp.

This association points to a Middle Famennian age.

(loc. 11) *Palmatolepis* cf. P. *perlobata schindewolfi* Müller

It has a very poor fauna, but it probably also belongs to the Middle Famennian.

(loc. 9) *Spathognathodus aculeatus* (Branson & Mehl)
Spathognathodus costatus costatus (E. R. Branson)
Spathognathodus costatus spinulicostatus (E. R. Branson)
Spathognathodus stabilis (Branson & Mehl)
Spathognathodus inornatus (Branson & Mehl)
Palmatolepis deflectens deflectens Müller
Polygnathus communis Branson & Mehl

(loc. 5) *Polygnathus communis* Branson & Mehl
Spathognathodus aculeatus (Branson & Mehl)
Spathognathodus costatus costatus (E. R. Branson)
Spathognathodus costatus spinulicostatus (E. R. Branson)
Spathognathodus supremus Ziegler
Spathognathodus inornatus (Branson & Mehl)

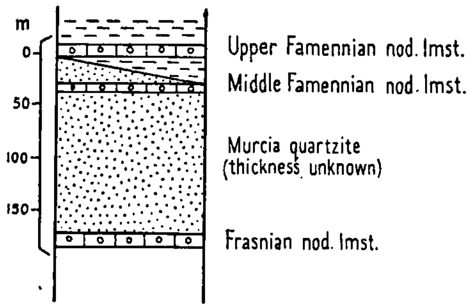

Fig. 3. The development of the Upper Devonian near Santibañez de Resoba.

The fauna of both loc. 9 and loc. 5 belong to the Upper Famennian.

On the basis of these data, the stratigraphic column of fig. 3 has been composed for the Upper Devonian of the northern facies near Santibañez de Resoba.

Regional correlations. — There appears to be a certain resemblance between the Devonian stratigraphic sections of the Valsurvio region (Koopmans, 1962), the region near Ventanilla-San Martin de los Herreros (Kanis, 1956) and, further to the west, the Esla-Bernesga region (Comte, 1959). Lithostratigraphic correlation of these sections with those of the Polentinos and San Julian area of the northern facies appears to be impossible. The Carazo formation and the Lebanza formation can

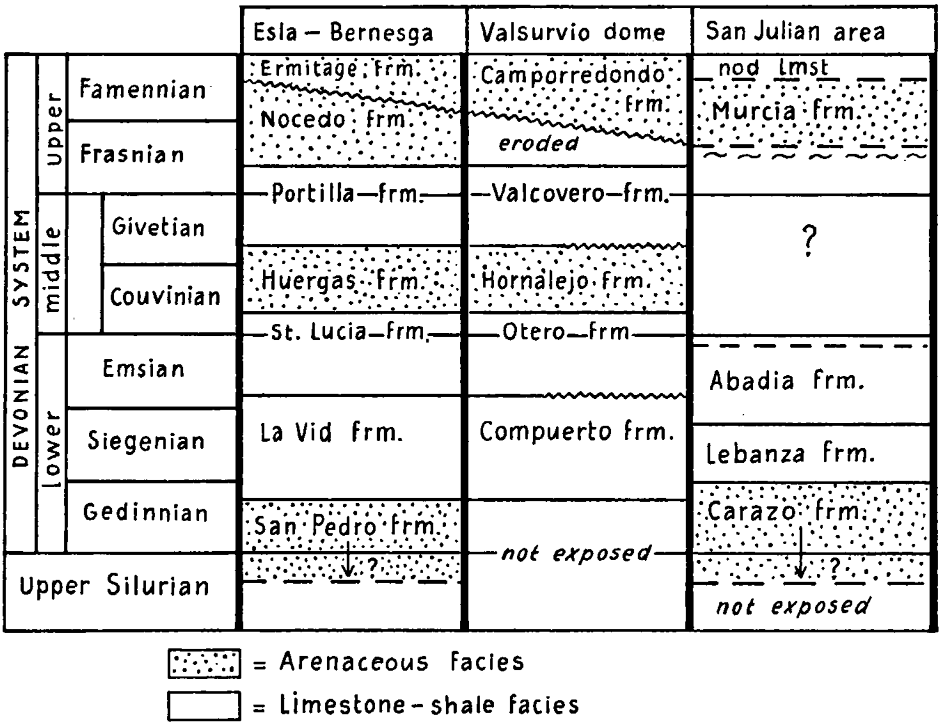

Fig. 4. The correlation of three stratigraphic sections of the Devonian from different areas in the Cantabrian Mts.

still be compared with the San Pedro and the La Vid formations respectively (Fig. 4). The development of the Middle and Upper Devonian, however, is quite different. Consequently, we speak of a northern, Asturian facies and a southern, Leonide facies. The narrow, roughly WNW-ESE trending zone which separates those two facies areas has been called the León Line by de Sitter (1962). As appears from the thickness and facies distributions, the León Line had the character of a ridge during the Paleozoic, and we shall therefore speak of the León ridge in the following chapters.

On the ridge itself we find a very incomplete development of the Devonian caused by occasional periods of non-sedimentation combined with erosion of the underlying rocks. Koopmans (1962) mentions two important breaks in the sedimentation: the first between the Lower and the Middle Devonian and the second at the base of the Camporredondo formation. As a consequence of these factors, southeast of Triollo the Lower Devonian limestones are directly overlain by a very thin series of Camporredondo quartzites: the whole Devonian has been reduced to approximately 30 m. The Camporredondo formation is probably to be correlated with the Upper Devonian Murcia quartzites of the northern facies, which are exposed northwest of Santibañez de Resoba and north of Villabellaco. In the author's opinion the hiatus between the Lower-Middle Devonian and the Upper Devonian quartzites is also present in the Cervera and Barruelo areas.

It is possible that these quartzites are stratigraphically equivalent to the transgressive Ermitage quartzites known from regions more towards the west in the province of León (Comte, 1959).

Besides the lithofacies differences, clear biofacies differences can also be observed between the Devonian of both facies areas. The southern facies is characterized by a fauna of brachiopods, corals, and bryozoans, while the Middle and the Upper Devonian of the northern facies is characterized by a fauna of trilobites, goniatites, and conodonts. Tentaculites, which occur frequently in the Lower Devonian of the Asturian facies, are completely lacking in the Leonide facies (Brouwer, 1962).

The lithology (the occurrence of reef-like limestones) and the fauna of the Leonian facies, indicate a sedimentation in a shallower, near-shore environment as compared with the Asturian facies.

A conspicuous fact is the rapid transition of the Leonian facies into the Asturian facies over a very short distance. Consequently, the two facies seem to have been brought nearer to each other by tectonic forces. This is quite possible, for it is a well-known fact that generally the Sudetic folding movements were directed towards the León ridge, both in the northern and the southern areas.

2. *Carboniferous*

It is very difficult to draw a stratigraphic column for the Carboniferous, and especially for the Lower Carboniferous, of the Pisuerga basin. This is due to the extremely variable lithofacies, the rather poor exposure, and the lack of determinable fossils in the clastic Lower Carboniferous.

The biostratigraphy is based mainly on fusulinids and plants. However, the correlation of both biostratigraphic subdivisions still raises difficulties. The fusulinids are found only in marine and sub-marine deposits, while the plants are restricted to terrestrial deposits. Only for cases in which rapid vertical facies changes occur between the sub-marine and sub-terrestrial deposits, can correlations be made.

Because of the economic importance of the coal-groups of the Pisuerga basin and the Barruelo area, the Carboniferous has been studied by several geologists, including Dupuy de Lôme & de Novo (1924), Quiring (1939), Alvarado & Sampelayo (1945) and Wagner (several papers).

2a. *The Ruesga group*

The Sella formation. — This formation includes the Alba griotte member and the Vegamián black shales and bedded cherts. It contains the oldest Carboniferous sediments known in the Cantabrian Mountains. The griotte horizon has a very large regional extension and it has about the same age almost throughout the Cantabrian Mountains. This makes it an ideal marker horizon for the field geologist occupied with mapping th e structure.

The true Alba griottes, comprising red nodular limestones, red shales, and occasionally radiolarites, are well developed south of the León ridge. Good exposures are found in the Santibañez area, south of the road from Ventanilla to Santibañez de Resoba. A complete description of the griottes of the Sierra del Brezo and the Valsurvio area can be found in the publications of Kanis (1956) and Koopmans (1962).

For many years the radiolarites and the griottes were thought to represent sediments in a bathyal or abyssal environment, but investigators such as Davis (1918), Shackleton Campbell (in Moore, 1954) and de Sitter (1949) are of opinion that they represent depositions in shallow water or water of moderate depth. The typical brecciated griotte texture has been discussed by several authors. Kanis (1956) and Koopmans (1962) consider it the consequence of squeezing of the shales between the angular limestone fragments under tectonic pressure. Recent investigations by Nagtegaal (Leiden) revealed that at any rate a synsedimentary solution of the limestone, due to variations of the pH and Eh in the bottom sediment of the basin must have played an important part in the genesis of the griotte texture.

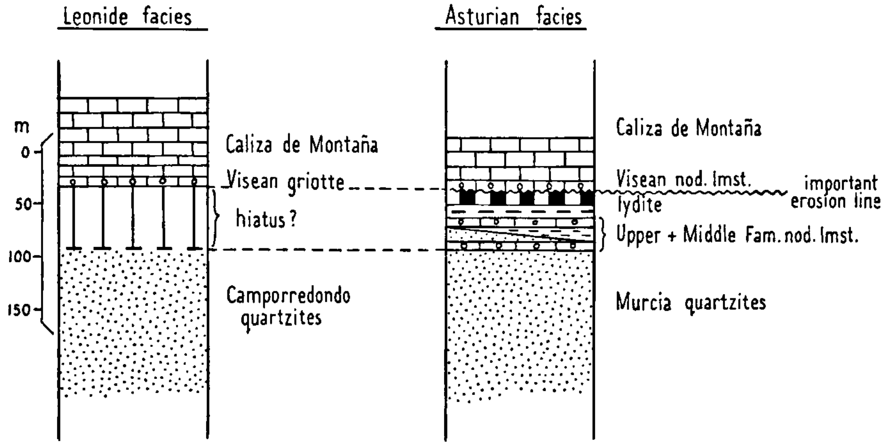

Fig. 5. Possible correlations between the Upper Devonian/Lower Carboniferous rocks of both facies areas, near Santibañez de Resoba.

In the northern facies the Visean nodular limestones are only locally developed as a very thin horizon. Here the Famennian nodular limestones are generally followed by a series of dark-green to black shales with a thickness of 5 to 10 m. They contain many phosphate nodules. Near Santibañez a goniatite was found in these shales by the author. Locally, a series of bedded cherts lies on top of the shales. Good exposures of this type of rock are found north of Santibañez de Resoba and east of Mudá. Higgins et al. (1963) have shown that the equivalent lydites in the province of León still belong to the Lower Carboniferous and that they have an Upper Tournaisian age.

Before the deposition of the Visean nodular limestones, an erosion of the underlying rocks took place. At present, part of the sequence between the Murcia quartzites and the Visean griottes is locally missing: for instance, near Mudá bedded cherts are exposed, which directly overlie the Upper Devonian quartzites. In the present author's opinion this erosion horizon of the northern facies corresponds to a sedimentary break between the Camporredondo quartzites and the Alba griottes in the area south of the León ridge.

The Visean nodular limestones contain a rich fauna of goniatites and conodonts. Kullmann (1961) gives the following combined lithostratigraphic and biostratigraphic section of the northern part of the Villabellaco limestone:

3. Limestone breccias and limestones (1—2 m)
2. Massive limestone and thin marl beds, containing,
   b. *Goniatites (Gon.) granosus gran.*
      Procelanites sp.
   Zone Go. γ: i.e. Upper Visean
   a. *Goniatites (Gon.)* sp. II, *ex gr. striatus*
      Goniatites (Gon.) stenumbilicatus globiformis sbsp.
      Goniatites (Gyrtyoceras)
   Zone Go. β: i.e. Upper Visean
1. Thinly-bedded marls and limestones.

Wagner-Gentis (1960, 1963) published a comprehensive list of determinations of goniatites from the Barruelo area and mentions that the southern part of the Villabellaco limestone (= St. Maria formation, Wagner, 1963) must be younger, i.e. Upper Visean/Namurian A, than the northern part, whose age is Lower Visean/ Upper Visean. In addition to the above mentioned authors, Higgins (1962) studied several samples of conodonts from the same limestone.

The following goniatites, collected by the present author, were identified by Dr. J. Kullmann (Tübingen):

1. From the limestone west of Villanueva,

   Ammonellipsites (Pericycles) aff. asiaticus Librovitch, 1940
   Prionoceras (Imitoceras) sp., *cf. P. (I.) subbilobatum*
   Goniatites (Gon.) sp.

They belong to the zone Pe. α—β/Go., which corresponds to the Lower Visean/ Upper Visean.

2. From the small limestone exposure 500 m west of Revilla,

   Pronorites cyclolobus (Philipps)
   Goniatites sp.

They belong to the zone Go. β, which indicates an Upper Visean age.

3. From a limestone exposure WNW of Santibañez de Resoba,

   Stenophronorites uralensis (Karp.)
   Goniatites s. str. (striatus-granosus gr.)
   Prionoceras (Imitoceras) cf. globosum Schelw.

This association indicates an Upper Visean/Namurian age.

From the following two localities samples of conodonts, collected by the author, were studied by Mr. H. A. van Adrichem Boogaert (Leiden):

1. The limestone exposure west of Villanueva,

   Gnathodus bilineatus (Roundy)
   Gnathodus commutatus commutatus (Branson & Mehl)
   Gnathodus semiglaber (Bischoff)
   Gnathodus texanus Roundy
   Gnathodus cf. Gn. delicatus Branson & Mehl

This association points to a Middle Visean age.

2. The northern part of the Villabellaco limestone,

Gnathodus bilineatus (Roundy)
Gnathodus commutatus commutatus (Branson & Mehl)
Gnathodus commutatus nodosus Bischoff
Gnathodus commutatus homopunctatus Bischoff

This association indicates an Upper Visean to Lower Namurian age.

In conclusion, it can be said that the age of the griottes in this area varies from Lower to Upper Visean. Prolonged, nearly continuous sedimentation, in contrast to the marked slight thickness of the griotte series, is the main characteristic of these rocks; it is a typically condensed sequence.

According to Kullmann (1963) the age of the Visean griottes varies regionally from Lower Visean in the southern part of the Cantabrian Mountains, to Upper Visean in the northern part. With regard to the above mentioned, he assumes a transgression of the Lower Carboniferous sea from south to north. This is in direct contradiction to the opinion of Wagner (1955), who assumes a transgression from northwest to southeast on the basis of the thickness distribution of the Caliza de Montaña over the Cantabrian Mountains.

The Caliza de Montaña formation. — (= Escapa formation: Brouwer & Van Ginkel 1964). This is a thick, massive limestone known in the Spanish literature as Caliza de Montaña and in French literature as Calcaire de Cañons (Barrois, 1882). Extensive exposures of this limestone are found both north and south of the León ridge; for instance, in the Sierra del Brezo and in the mountains northwest of Santibañez de Resoba. The influence of the ridge is reflected again in the thickness distribution of the limestones. In the Sierra del Brezo the thickness of the Caliza de Montaña measures approximately 300 m (Kanis, 1956), but on the ridge itself it decreases to only 20 to 30 m (zone of Ventanilla—Triollo). North of the León ridge the thickness again increases to 150 to 200 m, e.g. northwest of Santibañez de Resoba.

The Caliza de Montaña is a micro-crystalline, massive limestone with a grey-bluish colour. According to the classification of Folk (1959), it is a true micrite. The top of the Caliza de Montaña is often oolitic and contains fragments of crinoids, brachiopods, and algae. In addition, the limestone at the top of the Caliza has a dark colour and is well-bedded. This type of limestone forms the transition of the limestone facies to the overlying clastic Cervera formation. Except for the few fragments of crinoids, foraminifers, and algae, fossils are very scarce.

Mr. A. C. van Ginkel (Leiden) determined the following species of foraminifers from a limestone exposure north of San Martin de los Herreros:

Millerella sp.
Profusulinella ex gr. staffeloides Manukalova

They belong to the Fusulinella zone (sub-zone A), which agrees with the Bashkirian.

Dr. L. Rácz (Leiden) determined some species of algae from an exposure of the Caliza 100 m north of Santibañez de Resoba:

Archaeolithophyllum johnsoni Rácz
Donezella lunaensis Rácz

They belong to the zone II of the calcareous algae, which corresponds with the top of the Bashkirian. Rácz (1964).

Northeast of the line Santibañez de Resoba—Cervera de Pisuerga, the limestone facies has a different character: here it is an oolitic-intraclastic, fossiliferous limestone with a high content of foraminifers, algae, bryozoans, corals, crinoids, a few brachiopods and ostracods. Exposures of this type of limestone are found near Arbejal, Rabanál de los Caballeros, Mudá, and Villabellaco. The present author attributes the southern part of the Villabellaco limestone (= St. Maria formation, Wagner & Wagner-Gentis, 1963) too, to the Caliza de Montaña formation because of the Namurian age of this limestone. Locally, these limestones wedge out into shales.

Kanis (1956) mentions a few determinations of brachiopods collected in a limestone exposure just north of the village of Resoba. De Groot (1963) gives a comprehensive list of determinations of corals from the Rabanál limestone and she makes the following remarks about the coral fauna: "Cerioid colonial corals, flourishing in the reefs near Perapertú, are unknown at Rabanál. The fauna of Rabanál consists mainly of *Lithostrotion reticulatum* and *Pseudozaphrentoides rabanaliensis*, which are poorly represented near Perapertú. The contrast between the

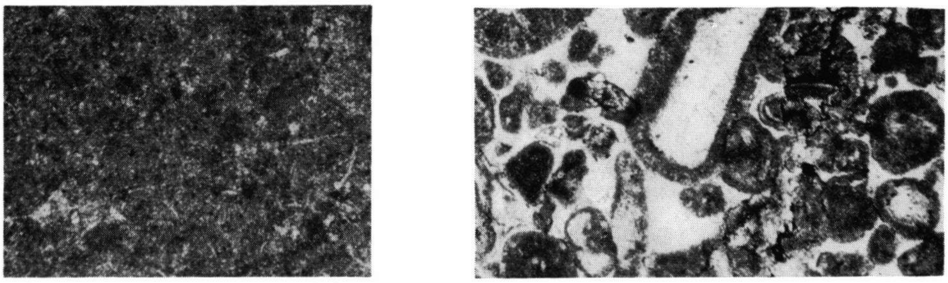

Fig. 6. The micritic and oolitic facies of the Caliza de Montaña.

uniform fauna of Rabanál and the diversified fauna of Perapertú is striking". Breimer (1963), in a study on the Paleozoic Spanish crinoids, mentions the following determinations from the Rabanál limestone: *Pimlicocrinus latus* Wright, 1943, *Aorocrinus* sp., and *Platycrinus* sp. *ex. gr. bollandensis*. With respect to age, he concludes the Namurian.

Mr. A. C. van Ginkel (Leiden) identified the following species of foraminifers from:

1. The southern part of the Villabellaco limestone (= St. Maria limestone),

Parastaffella ex gr. mathildae (Dutkevitch)
Millerella cf. parastruvei (Rauser Chernoussova)
Millerella cf. mosquensis var. acuta (Rauser Chernoussova)
Millerella cf. pseudostruvei (Rauser Chernoussova & Beljaev)
Millerella ex gr. acuta et mutabilis (Rauser Chernoussova)
Millerella breviscula (Ganelina)
Millerella sp.
Pseudostaffella cf. antiqua var. grandis Shlykova
Profusulinella sp.

This association belongs to the Profusulinella zone (sub-zone A), which indicates a Bashkirian age.

2. The limestone exposure east of Mudá,

Parastaffella sp.
Millerella cf. breviscula (Ganelina)
Millerella cf. varvariensis (Brazhnikova)
Millerella ex gr. protvae (Rauser Chernoussova)
Millerella ex gr. acuta et mutabilis (Rauser Chernoussova)
Pseudostaffella antiqua (Dutkevitch)
Pseudostaffella ex gr. antiqua (Dutkevitch)
Pseudostaffella sp.

This association belongs either to the Millerella zone or to the Profusulinella zone (sub-zone A), pointing to a Lower Bashkirian age.

3. The limestone exposure near Rabanál de los Caballeros,

Staffella sp. nov.
Parastaffella sp. nov.
Profusulinella sp.

These belong to the Profusulinella zone (sub-zone A), but are slightly younger than those of the Mudá limestone, which points to an Upper Bashkirian age.

In addition to these determinations, the following species of algae were identified by Dr. L. Rácz (Leiden) from the Rabanál limestone:

Amorfia jalinki Rácz
Dvinella comata Chvorova
Epimastopora bodoniensis Rácz
Beresella hermineae Rácz

This association contains species of both zone II and zone III and must consequently lie on the boundary between these zones; this agrees with a Lower Vereyan age. The rather young age of the Rabanál limestones as compared with the other limestones of the Caliza de Montaña, makes their assignment to this formation problematic. It is possible that they must be attributed to the Perapertú formation.

From these determinations it follows that the age of the base of the Caliza de Montaña is Upper Visean and that the top of the Caliza locally reaches into the upper part of the Namurian B.

The Perapertu formation. — This formation is found only in the Barruelo area and is beautifully exposed in the valley between San Martin de Perapertú and Monasterio. It comprises small reef-limestones in addition to shales, sandstones, and limestone breccias. Because of the highly irregular lithofacies, no lithologic section can be given.

East of San Martin de Perapertú, beautiful exposures of small reefs can be observed, consisting of a massive, structureless reef-core and a coarse-grained, fragmental, outward-dipping reef flank. The debris zones consist of angular and rounded limestone fragments embedded in shales. They contain many classes of fossils such as corals, brachiopods, and crinoids. From the occurrence of the debris zones with respect to the location of the reefs, it can be concluded that often extensive slumping of the debris material must have occurred. In the surroundings of the reefs many well-rounded quartzite pebbles are also observed; these pebbles have a different origin than the limestone fragments and must be correlated with the basal conglomerates of the Cervera formation on top of the Mudá limestones. For more information about the reefs the reader is referred to the detailed description given by Wagner & Wagner-Gentis (1952).

According to Wagner, the maximum thickness of the big reef-limestone east of Perapertú measures approximately 250 m. The outer reef consists of an organo-clastic, oolitic limestone. The fauna consists mainly of foraminifers, algae, crinoids, and corals. De Groot (1963) studied the coral fauna of the reefs near Perapertú and Orbó. According to her, they contain a highly diversified fauna of corals: an indication that the environment (salinity, slight depth, and clear water) was very

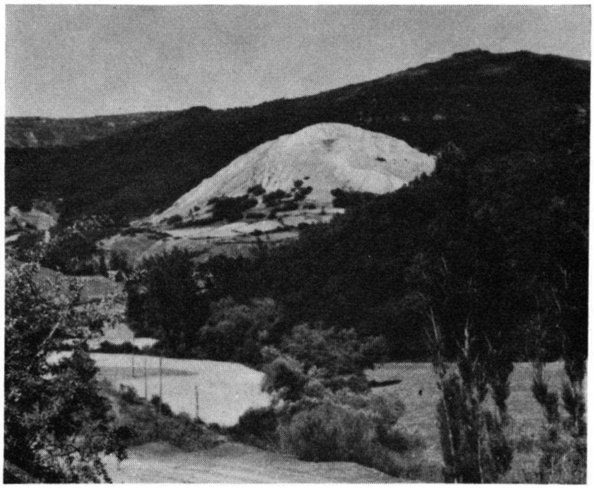

Fig. 7. The big Perapertú reef east of the village of Perapertú.

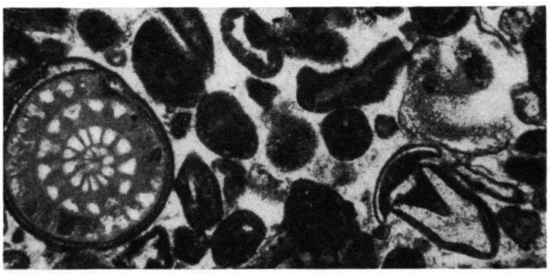

Fig. 8. The organo-clastic facies of the reef-limestones of the Perapertú formation.

favourable for the growth of these organisms. Wagner (1955) mentions several determinations of brachiopods, indicating a Namurian age. Higgins (in Wagner & Wagner-Gentis, 1963) studied the fauna of conodonts, which after determination appeared to indicate an age between Upper Namurian and Westphalian A.

Mr. A. C. van Ginkel (Leiden) identified several species of foraminifers from the following two localities:

1. The reef-limestones west of the San Julian massive,

Staffella cf. pseudosphaeroidea Dutkevitch
Staffella sp.
Parastaffella cf. bradyi Moeller
Millerella cf. compressa (Brazhnikova)
Millerella ex gr. acuta et mutabilis (Rauser Chernoussova)
Profusulinella ex gr. pararhomboides Rauser Chernoussova
Profusulinella cf. parva (Lee & Chen)
Profusulinella? sp.

This association belongs to the Profusulinella zone (sub-zone B), which agrees with a Lower Moscovian (Vereyan) age.

2. The reef-limestone east of Orbó,

Fusulinella sp.
Beedeina sp.

The fauna of the Orbó limestone already belongs to the Fusulinella zone, which indicates an Upper Moscovian age (possibly the uppermost part of the Lower Moscovian).

Dr. L. Rácz (Leiden) studied the calcareous algae from the same limestones:

1. The reef-limestones west of the San Julian massive,

Anthracoporella spectabilis Pia
Archaeolithophyllum johnsoni Rácz
Beresella hermineae Rácz
Donezella lunaensis Rácz
Donezella lutuginii Maslov
Epimastopora bodoniensis Rácz
Girvanella sp.
Ivanovia? sp.
Meleporella anthracoporellaformis Rácz
Osagia sp.
Parachaetetes sp.
Ungdarella uralica? Maslov

This association must be attributed to zone II, which corresponds to the uppermost part of the Baskkirian and the lowermost part of the Vereyan. Rácz (1964).

2. The reef-limestone east of Orbó,

Dvinella comata Chvorova
Ivanovia tenuissima Chvorova
Parachaetetes sp.

The occurrence of *Dvinella comata* is limited to zone III, which indicates a Lower Moscovian (Vereyan) age. There is a striking contrast between the uniform fauna of the Orbó limestone and the highly diversified fauna of the Perapertú limestones, with respect to both the foraminifers and the calcareous algae.

On the basis of these determinations, it can be concluded that the age of the reefs of the Perapertú formation varies from Upper Namurian to Westphalian A. Consequently they are younger in age than the Caliza de Montaña (Mudá limestones). The rather young age of the Orbó limestone in relation to the other Perapertú reefs is curious. With regard to that, it can be compared to the Upper Carboniferous Curavacas formation.

The presence of the reefs points to the proximity of the coast in this area during that period. The present author assumes that they grew in situ along the border of the San Julian massive, which formed a positive area during that period. According to Folk (1959), the occurrence of the limestone breccias and the intraclastic and oolitic character of the limestones indicate a high-energy depositional environment; in this case probably near-shore.

The Cervera formation. — (= Culm facies, Koopmans, 1962) This formation is exposed mainly in the area between Rabanâl de los Caballeros, Mudá, and Cervera, but other exposures are found in the zone between Cervera and Triollo exactly on the León ridge. The stratigraphic relations are still problematic because of the lack of determinable fossils. The Cervera sandstones are overlain by the Curavacas formation, which has a Westphalian A/B age. They partially overlie the Caliza de Montaña formation, whose age reaches into the Namurian B. From this it follows

Fig. 9. Conglomerate horizon near Santibañez de Resoba; characteristic for the Cervera formation.

that at any rate the upper part of the Cervera formation must have an age between the Namurian B and the Westphalian A/B. The age of the Perapertú reefs also reaches into the Westphalian A; consequently, the Cervera formation must in part be the lateral equivalent of the Perapertú formation.

Locally, slight unconformable contacts are known between the Caliza de Montaña and the overlying Cervera formation. For instance, east of Mudá the base of the Cervera formation — here developed as quartzite conglomerates — overlies unconformably the Mudá limestones. North of Santibañez de Resoba a series of limestone breccias and quartzite conglomerates overlies the Caliza de Montaña. In addition, west of San Martin de los Herreros Koopmans (1962) describes a horizon of quartzite conglomerates following immediately upon the thinly-developed Caliza de Montaña. From this it is clear that at any rate north of the León Line the contact between the Caliza de Montaña and the overlying, clastic Lower Carboniferous represents an important erosion horizon. The unconformity near Mudá indicates that a slight folding movement took place prior to the erosion.

The Cervera formation is a sequence of shales, mudstones, sub-graywackes, and conglomerates; a sequence with a very monotonous character. The sediments are generally badly sorted and show rapid lateral lithofacies changes. Structures are difficult to recognize, because the beds are very uniform in texture and consequently the amount of deformation is not exactly known. The thickness remains unknown, but is certainly less than the 1200 m supposed by Kanis (1956).

Koopmans (1962) gives an interesting description of the Cervera formation as exposed east of Triollo. On the basis of the sedimentological properties of the rocks he concludes that these deposits do not represent turbidites, although in his opinion slumping and coastal gliding played an important part in the genesis of the polymict conglomerates. The main characteristic of these conglomerates is that the individual quartzite pebbles often do not touch each other (Fig. 9).

Along the brook 500 m northeast of Mudá, a rather good section of the lower part of the Cervera formation is exposed. The basal part comprises breccias and conglomerates with fragments of limestones, graywackes, lydites and quartzites.

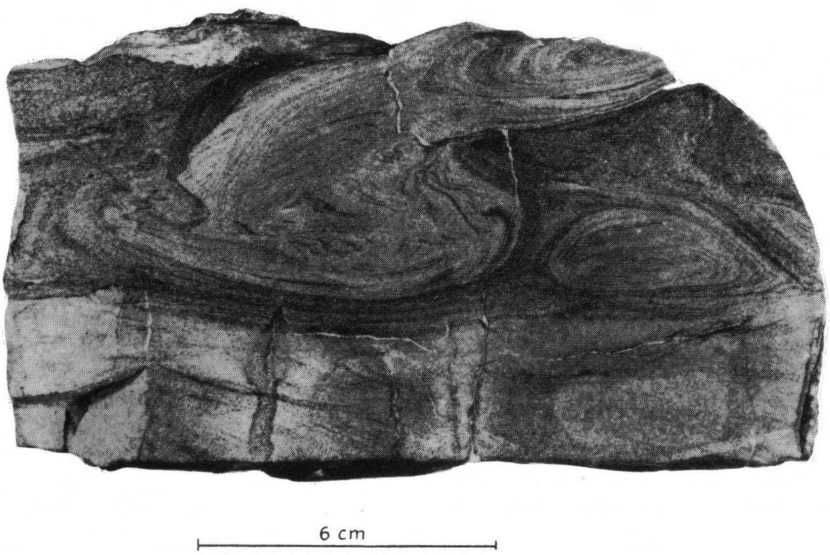

Fig. 10. Slumped graywacke beds near Mudá.

These are followed by a series of graywackes showing a clear grading; groove casts and flute casts are found on the bottom of the strata. Evidently, turbidity currents occurred here during the sedimentation of the clastic Lower Carboniferous. In addition to turbidity currents, indications of slumping are sometimes found.

In the syncline north of Santibañez de Resoba we encounter the following series lying upon the Caliza de Montaña: first a horizon of limestone breccias, then a horizon of quartzite conglomerates, and lastly a 100 m thick series of massive graywackes. The graywackes show indications of slumping.

The irregular character of the sedimentation is indicative of deposition on a shallow, unstable shelf-area. Fossils are very scarce throughout the whole sequence. Kanis (1956) mentions the determination of a plant fragment, *Mesocalamites haneri* Stur., found near Valsadornín. Another plant fragment, *Sphenopteris* sp., was collected by him in shales along the road from Cervera to Vañes. These fragments may provide an indication for the Namurian. Kanis also collected a specimen of *Pterinopecten rhytmicus* Jackson, in a locality 1000 m west of Valsadornín; this species is common in the Namurian B. In 1962 a goniatite was found in a locality 1500 m north of Cervera de Pisuerga, along the road from Cervera to Vañes:

Reticuloceras sp. (det. Dr. J. Kullmann)

This species belongs to the lower part of the R. zone (R_1), which points to an Upper Namurian age.

Conclusions. — In the foregoing we have seen that during the Lower Carboniferous the León ridge still exerted an influence upon both the thickness distribution and the facies distribution, although the pronounced division between a Leonide and a Asturian facies has faded away. During the Lower Carboniferous on the other hand, the León Line forms a division between the massive, micritic Caliza de Montaña facies in the south and the oolitic, intraclastic Caliza de Montaña facies in the northeast. The latter represents a high-energy, probably near-shore sedimentary environment with respect to the southern facies. The area of the northern facies is limited in the northwest by the positive area of the Polentinos block and in the east by that of the San Julian block.

The several erosion horizons in the Lower Carboniferous of the northern facies — at the base of the Visean griottes and at the top of the Caliza de Montaña — in addition to the lithologic character of the Lower Carboniferous, are also indications for the proximity of the coast during that period. This author can not agree with Koopmans' view that near Santibañez the León ridge must have formed a zone of subsidence with respect to the neighbouring areas during the sedimentation of the Cervera sandstones. The present author is inclined to think that the León zone maintained a higher position with respect to the neighbouring ares, but was less pronounced than during the sedimentation of the Devonian sediments. The slumping and the coastal gliding phenomena are due to the presence of the positive area of the Polentinos block in the north.

The stratigraphic relations between the several formations of the Lower Carboniferous have been a source of much discussion during recent years. Mainly on the basis of Van Ginkel's investigations of the Carboniferous fusulinids, we are able now to make the following schematic correlations of the Lower Carboniferous formations:

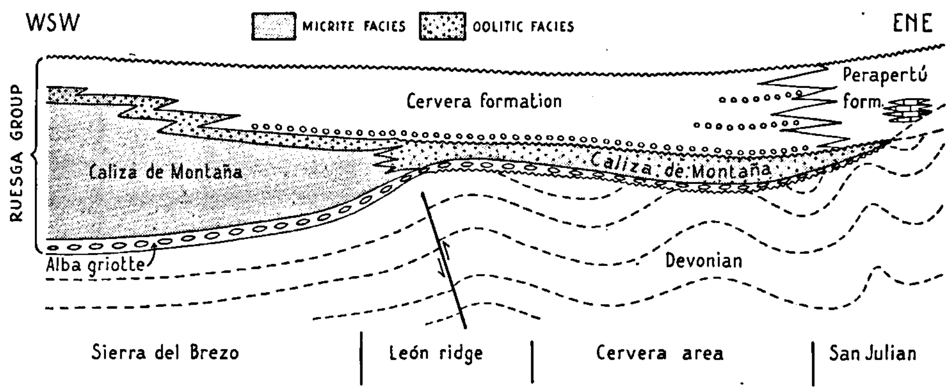

Fig. 11. Schematic correlations in the Lower Carboniferous.

2b. *The Yuso group*

The Curavacas formation. — This formation forms the basal, conglomeratic part of the Yuso group. The latter comprises the sediments which are younger than the Curavacas unconformity, but older than the Asturian folding. Oriol (1876) was the first author to mention the thick conglomerates of the Peña Curavacas, which is situated north of the Pantano de Camporredondo. In this area these rocks are exposed north of Santibañez de Resoba and north of Resoba. They are oligomict conglomerates, with quartzite pebbles ranging in diameter from 2 to 50 cm. They show a poor sorting and a sandy matrix. North of Santibañez the thickness measures almost 500 m, but towards the east this rapidly decreases to 100 m or less. The conglomerates lie with an angular unconformity upon older formations of the Ruesga group and of the Devonian.

Around the Pantano de Camporredondo the base of the Yuso group was formed by pelitic sediments and subordinate amounts of conglomerates, e.g. south of La Lastra. The sediments strongly resemble the Cervera formation of the Ruesga group in lithological outlines. Between Triollo and Santibañez they both occur and it is impossible to draw an accurate boundary between them.

Occasionally, floral remains are found in the shale intercalations. Wagner (1960) gives a summary of the plant determinations made by him and mentions that among them *Neuropteris linguaefolia* P. Bertrand is a common element. He fixes the age as Upper Westphalian B, but Stockmans (in Brouwer & Van Ginkel, 1964) collected a flora which is still older and indicates a Westphalian A age.

On the basis of the sedimentological characteristics the conglomerates are considered to represent fluviatile-paralic deposits (Kanis, 1956). Towards the south, the occurrence of the Curavacas conglomerates is limited by the León ridge, while towards the east the thickness of the formation rapidly decreases. In the Pisuerga basin they are even completely missing.

After the Lower Westphalian, Sudetic movements the true Pisuerga basin became visible as a result of the uplift of the western Polentinos block along a fault. Examination of the map shows that in spite of the subsequent strong folding in the Upper Carboniferous, the basin structure can still be clearly observed.

The most complete stratigraphic section of the Upper Carboniferous is exposed between the villages of Perapertú, Herreruela, and San Felices. The Upper Carboniferous contains several highly productive coal seams. The most important mines, where the coal is exploited, lie near San Cebrián and Barruelo de Santullán. Originally, the whole section from San Cebrián to San Felices was called the "paquete de San Cebrián" by Wagner (1955). In a later publication Nederlof & de Sitter (1957) proposed to split up the section into a lower Vañes sandstone series, a higher Sierra Coriza series, including the San Cebrián coal-group at the base, and the Barruelo series, including the San Felices coal-group. The distinction between a Sierra Coriza series and a Barruelo series is accentuated by an unconformable contact between the two formations at the top of the San Cristóbal, as mapped and described by Wagner & Breimer (1958). In this paper we will use the following subdivision of the Upper Carboniferous in the Sierra Coriza basin:

Cea group	The San Cristóbal formation (Wagner & Wagner-Gentis, 1963) (= Barruelo series)
Yuso group	The Sierra Coriza formation The Vañes formation The Molino formation

The Molino formation. — This formation is rather well exposed along the road from San Cebrián to Perapertú. Towards the south, the formation is cut off by the northern branch of the Mudá fault. The thickness of the complete section measures 400 m. The formation comprises sub-graywackes, graywackes, and brown/green, sandy shales which are often micaceous. The thickness of the individual sandstone beds varies between 5 cm and 30 cm. Small fragments of plants occur frequently, and although locally they form dirty, black intercalations of shales, they could not be determined until now.

The base of the formation is developed as a 1 m to 2 m thick, polymict breccia with angular fragments of shale, graywacke, and limestone. The breccia is followed by 50 m of thick-bedded, locally conglomeratic graywackes which pass laterally into a sequence of true conglomerates north of the village of Perapertú. It is characteristic for these conglomerates that the pebbles are generally not contiguous; this indicates that they originated in an environment different from that of the surrounding shales. These rocks represent the first deposits after the Sudetic folding in this area.

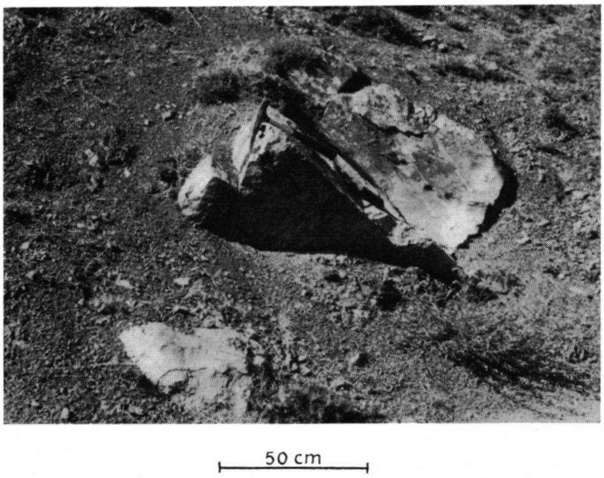

Fig. 12. Angular boulders of graywacke and limestone in the "wildflysch" horizon south of Perapertú.

The base is overlain by a sequence of sub-graywackes and sandy shales with a thickness of almost 300 m. Sole marks such as groove casts and flute casts occur frequently, and graded bedding has also been observed. Turbidity currents evidently played an important part during the sedimentation. The sole marks indicate a NW-SE paleocurrent direction.

On top of the formation, two horizons of a 'wildflysch facies' are encountered. The thickness measures 10 to 20 m. They consist of angular limestone and graywacke fragments ranging in size from 5 to 50 cm and lying embedded in brown/green shales. Characteristically, the angular fragments do not touch each other, indicating a reworking of older rock-material and resedimentation of the fragments from the coastal area into deeper parts of the basin without much current transport, but probably with concommitant slumping. It is assumed that the San Julian massif still formed part of the basin margin during this period.

Due to lack of determinable fossils the age cannot be fixed exactly, but must be pre-Westphalian D (the age of the San Cebrián coal seams) and post-Westphalian A (the base of the Curavacas formation). De Sitter (1957), Wagner (1955) and Wagner & Wagner-Gentis (1963) gave a Namurian age to this formation and correlated it with the Cervera formation. For a long time the contact between the Molino formation and the Vañes formation has been a point of discussion between de Sitter and Wagner. De Sitter considered the contact to be unconformable, while Wagner views it as a fault contact. In the latter case the Curavacas formation would have been cut out by the fault. However, the present author mapped a conformable contact between both formations and assigns the Molino formation to the Yuso group.

A similar sequence of graywackes has been found between the villages of Villabellaco and St. Maria in the Barruelo area. It consists of thick-bedded graywackes, breccias, and dark, sandy shales. They overlie the Villabellaco limestones with a slight unconformity. An exact age has not yet been fixed, and consequently this remains questionable. Wagner & Wagner-Gentis (1963) calls this the Carmen formation and attributes it to the Westphalian on the basis of the determination of a *Lonopteris* sp.

The Vañes formation. — This formation conformably overlies the Molino sandstones. The upper boundary of the formation has not yet been accurately fixed. Wagner & Wagner-Gentis (1963) considers the Socavón limestone to be the top member

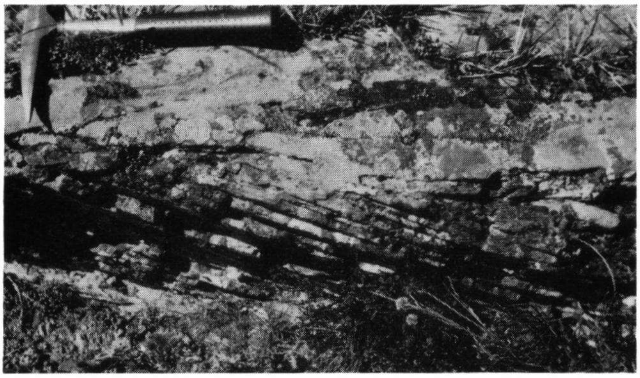

Fig. 13. Characteristic macro cross-bedding in the Vañes formation.

of the Vañes series, while Brouwer & Van Ginkel (1964) attribute it to the overlying Sierra Coriza formation. For practical reasons the present author prefers to define the boundary at the base of the San Cebrián coal-group. The formation is well exposed west of San Cebrián, where the thickness measures almost 700 m.

The stratigraphic section comprises a sequence of shale and sandstone members, each consisting of an alternation of thinly-bedded, quartzitic sandstones and shales, but in the sandstone member the sandstones dominate and in the shale member the shales. A few badly-preserved floral remains were found. In the lower part, some indications for turbidites are present, but the dominant feature of these rocks is macro-current bedding, which indicates a different environment of sedimentation.

West of San Cebrián two small limestone banks are exposed, which belong to the upper part of this formation. Wagner & Wagner-Gentis (1963) called the upper one the Socavón limestone (Socavón Sp. = tunnel). If we use Folk's classification (1959), we could call them biopelsparites, the fossils being predominantly foraminifers, bryozoans, corals, and a few brachiopods. Quiring (1939) mentions the determination of a new coral species *Amygdalophyllum quirini* Weissermehl 1935, while

Wagner (1955) determined a brachiopod species *Spirifer mosquensis* Fich, which is indicative for the Westphalian. De Groot (1963) collected and indentified several species of corals from the Socavón limestone and attributes them to the Upper Moscovian. This age has been confirmed by the determination of the foraminifers by Mr. A. C. van Ginkel (Leiden),

Millerella cf. acutissima (Kireeva)
Beedeina ex gr. rauserae (Chernova)

This association belongs to the Fusulinella zone (sub-zone B), which is consistent with the Upper Moscovian (Podolskian).

In conclusion, it can be said that the various determinations of foraminifers and corals point to a Westphalian C/D age for the upper part of the Vañes formation.

The Sierra Coriza formation. — The formation overlies the Vañes formation in a conformable way. The upper boundary lies at the top of the Sierra Coriza limestone member. The formation is built up of a lower sandstone/shale member and an upper limestone member. East of Herreruela the thickness measures 800 m, but towards the west it rapidly decreases to almost 350 m.

At the base lies the San Cebrián coal-group, which can be followed from a point east of Herreruela to Vergaño. The coal is mainly mined in the 'Minas de San Cebrián', where three or four productive coal seams are found with a thickness respectively of 0.7 m, 1 m, and 2.5 to 3 m. The total thickness of the productive group is about 50 m. Quiring (1939) mentions a few determinations of plants and concludes the age to be Westphalian B/C on the basis of the determination of a *Lonchopteris rugosa.* More recently, Wagner (1955) determined several floral elements from the same coal beds and according to him the occurrence of *Neuropteris ovata, Alethopteris grandini* and *Linopteris obliqua* points to a Lower Westphalian D age.

In the north the coal-group is followed by a massive limestone bank — the Cotarazo limestone — which has a maximum thickness of 50 m. Towards the south this limestone rapidly wedges out into a sandstone/shale facies. It is a biosparite, with foraminifers, algae, brachiopods, corals, and crinoids. Sieverts-Doreck (1953) determined two species of crinoids: *Iberocrinus multibrachiatus* Sieverts-Doreck and *Archaeocidaris cf. urii* Fleming, while Breimer (1962) identified two other species: *Cromyocrinus* sp. cf. C. *simplex* Trautschold 1867 and *Paradelocrinus* sp. These indicate a Moscovian age. De Groot (1963) studied the fauna of corals, but an exact age could be fixed by the determination of foraminifers from the Cotarazo limestone by Van Ginkel (Leiden),

(Loc. P40) *Staffella?* sp.
Pseudostaffella cf. sphaeroidea (Ehrenberg)
Fusulina sp. nov.
Fusulinella sp.
(Loc. P58) *Fusulinella ex gr. bocki* Moeller

This association belongs to the Fusulinella zone (sub-zone B2), which indicates the Upper Moscovian (Podolskian/Myachkovian).

Between the Cotarazo limestone and the Sierra Coriza limestones lies a clastic series, built up of shales, andstones, and conglomerate beds. Fossils are occasionally found in this sequence: Wagner (1955) mentions two species of brachiopods, *Spirifer fasciger* Keys and *Spirifer* sp. Nederlof (1959) attributes the series to the paralic association. He determined the paleocurrent direction from the observed sole marks and concludes that the supply of clastic material must have been from the east during that period.

The higher, limestone member comprises three massive limestone beds, separated from each other by thin shale intercalations. Towards the northwest the limestones wedge out into a sandstone/shale facies. They are well exposed north of Vergaño. In the intercalated shales a few brachiopods, corals, and ammonites are found. The limestones yield algae, bryozoans, corals, foraminifers, and crinoids. Nederlof (1959) attributes this series to the orthoquartzite-carbonate association. The most common environment of sedimentation connected with that association is shallow marine or neritic. He also describes a beautiful example of filled-in crevices, observable in the highest limestone bed, on the southern slope of the Cabra Mocha north of Gramedo. This represents a short period of local uplift, erosion, and non-sedimentation: a diastem.

Originally, the Sierra Coriza limestones were thought to be of the same age as the Lower Carboniferous Caliza de Montaña. However, Quiring (1939) proposed a younger, Upper Carboniferous age for the limestones. This opinion was confirmed by the determination of a few foraminifers by Alvarado & Sampelayo (1945). Wagner (1955) mentions the determination of the following brachiopods: *Echinoconchus punctatus* (Mart.), *Spirifer strangwaysi* De Vern., *Spirifer fasciger* Keys, and *Spirifer cf. tegulatus* Trb. De Groot (1963) has identified many species of solitary corals from the same limestones. Mr. A. C. van Ginkel (Leiden) studied the foraminifers and gives the following determinations:

(Loc. P57) *Fusulinella ex gr. colaniae* Lee & Chen
(Loc. P98) *Beedeina* sp. nov.
(Loc. P22) *Ozawainella cf. sphaeroidea var. cuboides* Rauser-Chernoussova
Pseudostaffella soligalichi sb. sp. *archedensis* Semikhatova & Melnikova
Schubertella ex gr. kingi Dunbar & Skinner
Fusulinella cf. schwagerinoides (Deprat)
Fusulinella ex gr. mosquensis Rauser-Chernoussova

This association belongs to the Fusulinella zone (sub-zone B2, B3), which points to an Upper Moscovian (Myachkovian) age. This has been confirmed by the determination of the following algae by Dr. L. Rácz (Leiden):

Eugonophyllum mulderi Rácz
Zaporella cantabriensis Rácz
Komia sp.
Osagia sp.
Anchicodium sp.
Donezella lutugini Maslov

They belong to the zone IV of the calcareous algae, which agrees with the Upper Moscovian.

From these determinations it follows that the Sierra Coriza limestone member belongs to the upper part of the Westphalian D.

2c. *The Cea group*

The San Cristóbal formation. — Outside the Pisuerga basin, all the Lower Stephanian basins (for instance the Guardo basin, the Cea basin, and the Sabero basin, etc.) lie unconformably over the older Carboniferous rocks, which were folded by the Asturian folding. However, in the Pisuerga basin the folding occurred later: after the Stephanian A. Therefore on the basis of age, the San Cristóbal formation must be attributed to the Cea group, although the formation itself was folded during the Asturian phase. Nevertheless, Wagner & Breimer (1958) describe an unconformity between the San Cristóbal formation and the Sierra Coriza and Vañes formations, exposed at the "monte de San Cristóbal" northwest of Rabanál de los Caballeros. This unconformity probably represents a reflection of the folding that took place at the end of the Westphalian D in regions south of the León Line. Towards the east the unconformity passes into a stratigraphical hiatus.

The formation has a minimum thickness of 750 m. At the base lies a grey, quartzitic sandstone, which forms a fairly constant horizon over a long distance. Above this is 20 m of sandy brown/dark shales which locally contain a few coal seams. In former years the coal was mined on a small scale at the San Cristóbal and east of Herreruela. Wagner & Breimer (1958) mention several determinations of plants collected at the San Cristóbal and conclude a Lower Stephanian A age, on the basis of the presence of *Linopteris gangamopteroides* (De Stefani), *Alethopteris bohemica* Franke and *Pecopteris viannae* Teixeira.

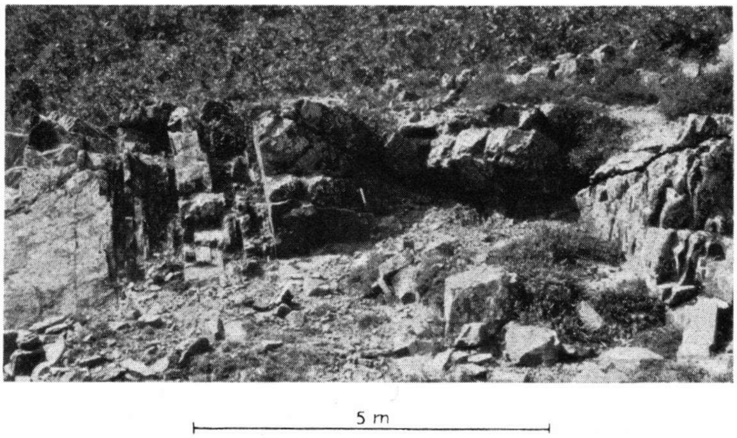

Fig. 14. The San Cristóbal unconformity.

These shales are followed by 20 m of thick-bedded sandstone in which macrocurrent bedding is a dominant feature. They are overlain by 30 m of brown shales and limestones: the "Estalaya beds". They contain a fauna of gasteropods, foraminifera, and algae. The following species of gastropods, from a locality near the village of Estalaya, were identified by Mme. Butusava (Leningrad):

Bellerophon munsteri d'Orbigny
Baylea volgensis Stuck.
Anomphalus rotulus (Meek & Worthen)
Trachydomia wheeleri Swallow
Murchisonia paronai Gortani
Murchisonia fischeri Stuck.
Pseudozygopleura semicostata (Meek)

They belong to the lower part of the Gzhelian (Kasimovian), which indicates a Lower Stephanian age.

After a thick series (100 m) of massive, thick-bedded, locally conglomeratic, grey quartzitic sandstones, follows a sequence of shales and reef-like limestones. The latter contain foraminifers, algae, crinoids, and a few brachiopods. Mr. A. C. van Ginkel (Leiden) has determined the following foraminifers from the Vañes limestone:

(Loc. P36) *Beedeina? ex gr. conspecta* (Rauser-Chernoussova)
Fusiella cf. lancetiformis Putrya
Obsoletes? sp. (aff. *Obsoletes mirabilis* Kireeva)
(Loc. P99) *Staffella* sp. nov.
Staffella cf. moelleri Ozawa
Staffella sp.

This association belongs to the Fusulinella zone (sub-zone B3)/Protriticites zone, which points to a lowermost Kasimovian age. The following algae from the same limestone were identified by Dr. L. Rácz (Leiden):

Eugonophyllum sp.
Gyroporella nipponica? Endo
Ortriosiphon sp.
Clavaphysoporella sp.
Girvanella sp.

They belong to the highest zone, zone VI, of the Carboniferous algae and thus confirm the age fixed by the determination of the foraminifers (Lower Kasimovian).

Near the top of the formation lies the San Felices coal group, which according to the flora has a Stephanian A age (Wagner, 1962b). Nederlof (1959) attributes this formation to the paralic association.

East of the San Julian lies another Upper Carboniferous basin which shows a different lithostratigraphy. The section is well exposed in the valley of the Rio Rubagón between Barruelo and Brañosera. The complete section is divided into two formations: the lower, nonproductive, Brañosera formation and the upper, productive Barruelo formation.

The Brañosera formation. — (= Rubagón formation, Wagner & Wagner-Gentis, 1963). The lower part of the formation is covered by the Triassic red beds. The first exposed member is the Brañosera limestone. The top of the formation lies at the base of the Peña Corba coal-group. The thickness of the exposed section measures about 750 m.

The Brañosera limestone is well-bedded, often bituminous limestone with a few thin, dark shale intercalations. It yields the following fossils: foraminifera, algae, gasteropods (*Bellerophon*, *Murchisonia* etc.), nautiloids (*Orthoceras*), and a few brachiopods. This is the type-locality of the new fusulinid species Fusulinella branoserae, as described by Van Ginkel (1957). In addition, the following other species were determined:

(Loc. P38) *Millerella cf. acuta forma nana* (Kireeva)
Schubertella ex gr. kingi Dunbar & Skinner
Schubertella sp.
(*ex gr. obscura* Lee & Chen
cf. toriyamai Ishii
cf. pauciseptata var. diversa Kireeva
cf. paraobscura Putrya & Leontovich,
elongata Kireeva or *inominensis* Toriyama)
Profusulinella ex gr. librovitchi (Dutkevitch)
Beedeina ex gr. elegans (Rauser-Chernoussova & Beljaev)
Fusiella cf. pulchella Safonova
Fusulinella brañoserae Van Ginkel

This association belongs to the Fusulinella zone (sub-zone B3), which points to a Myachkovian age. Of the two species of algae determined by Dr. L. Rácz, the presence of the first indicates an age comparable to that of the Sierra Coriza limestones:

Eugonophyllum mulderi? Rácz
Girvanella sp.

The limestone is overlain first of all by a few metres of sandy shales with a few floral remains and then by a massive, grey quartzitic sandstone, 25 m thick. Next follows a shale/limestone series, comprising three limestone banks with a fauna of foraminifera, algae, and gasteropods. A few brachiopods are occasionally found in the shales (Spirifer). The thickness of the series is almost 260 m. It is overlain by a more arenaceous part, which is built up of thick-bedded, grey, quartzitic sandstones and sandy shales. The thickness of the individual sandstone beds varies from 20 cm to 75 cm. A great variety of sole marks is found. Nederlof (1959) describes them as load casts, current ripple marks, flute casts, groove casts, impact casts, and flow casts. In addition convolute lamination and graded bedding has been observed. On the basis of these characteristics, Nederlof attributes the rocks to the turbidite association, which is connected with an infraneritic environment of sedimentation. He measured a SSW paleocurrent direction, indicating a supply of clastic material from the NNE.

The top of the formation comprises a sequence of shales, sandstones, and thin, clay-containing limestones with a fauna of gasteropods, algae (*Petschoria elegans* Korde and *Eugonophyllum* sp.), and a few brachiopods. From the upper limestone Wagner & Wagner-Gentis (1952) collected: *Schizophoria plicata* Delep., *Spirifer strangwaysi* De Vern., *Camerophoria alpina* Schellw. and *Reticularia lineata* Mart., indicating a Westphalian age.

The stratigraphic position of these rocks has been discussed by Wagner (1952, 1955), Wagner & Breimer (1958), and Van Ginkel (1959).

The Barruelo formation. — Towards the northwest and the southeast this formation is covered by the Triassic. The formation rests conformably upon the Brañosera formation. The total thickness measures 800 m. The lowest part is formed by the Peña Corba coal-group, which comprises three or four coal seams and is exploited in the mine Peña Corba. The age of the flora has been discussed by Wagner (1955), who concludes it to be Stephanian A and correlated with the flora of the San Felices coal-group of the San Cristóbal formation in the Pisuerga basin. The marine horizons contain many ostracods.

The Peña Corba coal-group is overlain by a 350 m thick, monotonous sandstone/shale series. The sandstones are grey/green sub-graywackes, alternating with brown/green sandy shales. The whole sequence is strongly micaceous. Fragments of plants and gasteropods are occasionally found.

Next follows an intermediate, thin coal horizon, which is exploited north of Mercedes, southeast of Barruelo, and near Orbó. Above this coal horizon there is a second, unproductive sandstone/shale series with a thickness of 150 m. Then follows the important Calero coal-group, which is exploited near Mercedes, Helechar, Barruelo, and Vallejo. It comprises ten or twelve productive coal seams with a thickness varying from 50 cm to 1.5 m. Dupuy de Lôme & de Novo (1924) and Wagner & Wagner-Gentis (1952) give detailed stratigraphic sections from the mines near Barruelo and Orbó. Mallada (1892) mentions some floral determinations; samples which were collected in the mines near Barruelo and Orbó. On the basis of these determinations Quiring (1939) attributes the Calero group to the Westphalian B/C.

However, recent studies of Wagner (1955, 1962b) indicate a younger, Stephanian A age. This author also mentions a horizon between coal seams four and five that is characterized by the occurrence of *Leaia baentschiana* Beyr, a phyllopod species common in the Stephanian A.

The top of the formation is formed by two massive, quartzite conglomerate layers with a thickness of 40 m. These probably form the reflection of the first Asturian movements in this area, which took place at the end of the Stephanian A.

The Peña Cilda formation. — This formation rests unconformably upon the older, Asturian folded, Carboniferous rocks. The upper part is partly eroded and covered by the Triassic. The total thickness measures about 500 m. The conglomerates are exposed at the Peña Cilda north of Valle de Santullán. The unconformity at the base was first mapped by Wagner & Wagner-Gentis (1952), who attributed it to the Asturian phase.

At the base we find 20 m of sandy, coal-containing, dark shales. They are exposed exactly east of the village of Valle de Santullán. The shales are overlain by a conglomerate/shale series, which is built up by five massive conglomerate banks, separated from each other by sandy, brown shales. The thickness of the individual conglomerate beds varies from 30 m to 50 m. They contain rather angular and poorly sorted quartzite pebbles in a sandy matrix. The lower conglomerate bed also contains angular limestone fragments. These yielded a few foraminifera, indicating — according to Van Ginkel — a Lower Moscovian age. This suggests that the limestone fragments were directly eroded from the underlying Perapertú formation. Between the third and the fourth conglomerate bank a thin coal horizon is present; this was exploited in former years, but the mines are now abandoned. The flora has been studied by Wagner (1955, 1958); according to him it points to a Stephanian B/C age.

The conglomerates represent typically fluviatile-paralic, orogenic deposits.

Conclusions. — Table I gives a summary of the Carboniferous biostratigraphy based on fusulinids, goniatites and algae, and the probable correlation between the Russian and West-European sub-division of the Carboniferous.

We have already seen that during the Lower Carboniferous the León ridge still exerted an influence upon the facies distribution, although the effect was less pronounced than during the Middle and Upper Devonian. Eastwards, the sedimentation was limited by the San Julian ridge. After the Curavacas folding and during the sedimentation of the Curavacas conglomerates, the present Pisuerga basin and the San Julian massive formed positive areas. After the Westphalian A/B, the Upper

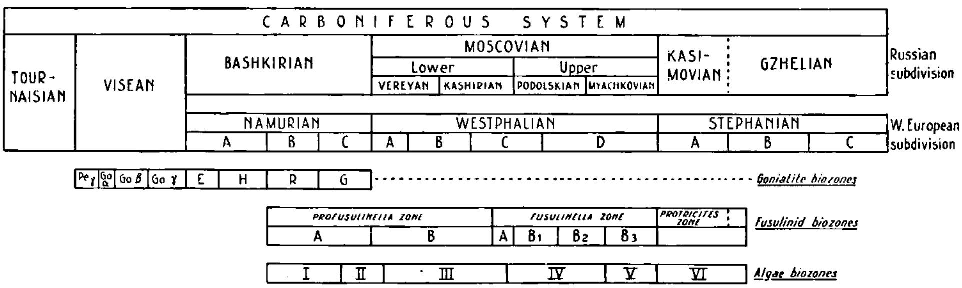

TABLE I Biostratigraphic correlations in the Carboniferous according to Van Ginkel (1965), Kullmann (1964) and Rácz (in press).

Carboniferous Pisuerga basin began to develop between the higher Polentinos and San Julian blocks, and limited towards the south by the Rabanál ridge which formed the backbone for the southern Sierra Coriza basin.

It is striking that south of the León ridge the Asturian folding (= le phase léonniene, Wagner, 1962a) took place earlier, namely at the end of the Westphalian, than north of the ridge, namely after the Stephanian A. While Middle and Upper Westphalian deposits are completely lacking south of the ridge, we see a normal continuation of the sedimentation in the Pisuerga basin during that period. The slight unconformity between the Sierra Coriza formation and the San Cristóbal formation is probably a reflection of the folding which occurred in the southern areas.

After the Asturian folding, small, discordant, intramontane Stephanian basins developed south of the León ridge, e.g. the Guardo basin. This basin shows a gradual transgression from west to east (Helmig, 1965). In the Pisuerga basin the Stephanian sediments have a paralic character and lie slightly transgressively from north to south over the Westphalian rocks. Eastwards, the San Julian massive continued to form a ridge — although a less dominant one — between the Pisuerga and the Rubagón basins.

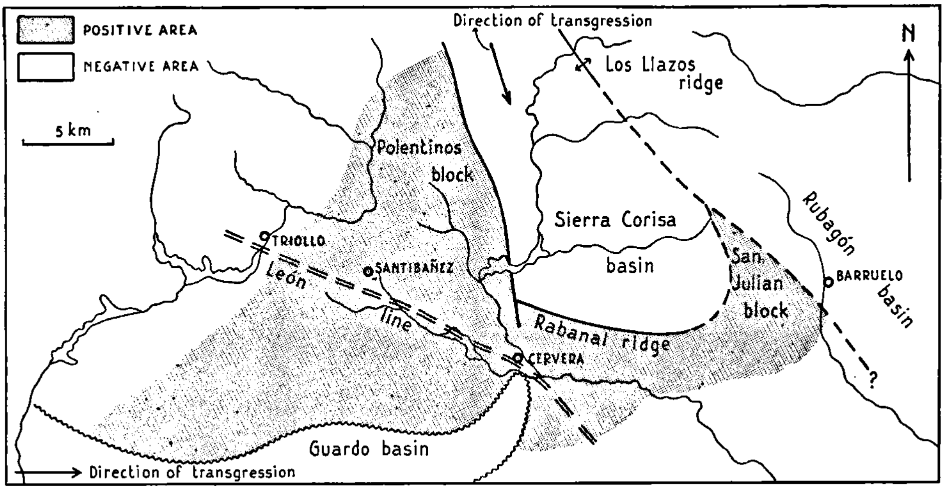

Fig. 15. The Stephanian basins in this region.

3. *Triassic*

The Triassic rocks rest unconformably upon the Paleozoic. They are exposed along the southern and eastern border of the territory mapped, from Cervera de Pisuerga to Brañosera. Towards the east, the Paleozoic is definitively covered by the Mesozoic rocks. Near Bustillo the thickness measures 500 m, but it decreases to 200 m near Rueda, which is situated more to the west.

At the base lies a conglomerate series with a red/brown colour and a thickness of about 50 m. The individual conglomerate beds have a thickness of 10 m. The quartzite pebbles are rather well rounded and sorted. Comparison of the different stratigraphic columns of the Triassic shows that the conglomerate member wedges out in an eastern direction. Considering the large extension of the exposed Carboniferous limestones, it is striking that hardly any limestone fragments are found in the conglomerates. They are overlain by a series (150 m) of red, coarse-grained, micaceous and strongly calcareous sandstones with cross-bedding and ripple marks. Next follows an sandstone/shale series with the same thickness and the same characteristics, e.g. cross-bedding, ripple marks, and load casts.

Lastly, on top lies a shale series varying in colour from red to green depending on oxydation or reduction of the Fe contents. The shales contain some evaporites such as gympsum, barite, and halite. Formerly, the halite was mined on a small scale near Salinas de Pisuerga (Salinas = Sal minas Sp. = salt mines). In a thin horizon of strongly calcareous shales just underneath the Jurassic limestones, many idiomorphic quartz crystals varying in size from 5 mm to 15 mm are found. Karrenberg (1934) and Ciry (1939) attribute this series of shales to the Keuper.

Papa (Leiden, int. report) studied the Triassic rocks and concludes a supply of clastic material from the west to northwest on the basis of the orientation of the

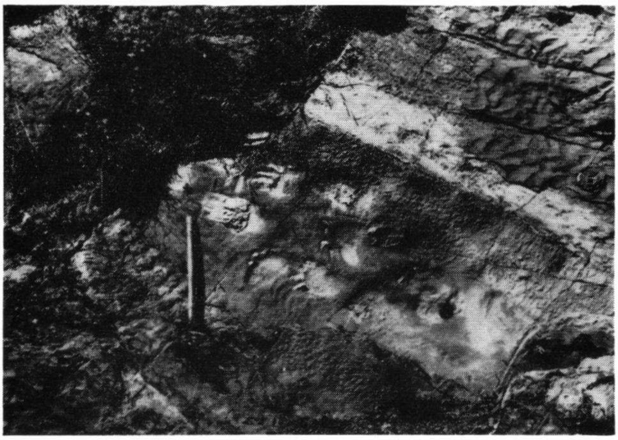

Fig. 16. Footprints of a reptile-like animal near Rueda.

ripple marks, the cross-bedding, and the decrease in pebble size towards the southeast. He assumes that they represent fluviatile deposits in a restricted, terrestric basin under conditions of a rather warm climate. Near Rueda, the footprint of a reptile-like animal were found: several prints of a foot with five toes. Probably they were made by a reptile allied to Cheirotherium. Except for this and a few indeterminable floral remains, the rocks are completely barren.

Karrenberg (1934) gives two stratigraphic sections: the first near Rueda and the second near Matabuena. The present author assumes — as does Karrenberg — that the border of the Triassic basin must have been near Cervera de Pisuerga. This opinion is based upon the decrease in the thickness of the red beds, the increase in the thickness of the conglomerate member, and the increase in the pebble size of the conglomerates in a westerly direction. Near Vado de Cervera the Paleozoic rocks are unconformably overlain by the Cretaceous.

4. *Jurassic*

The Jurassic limestones lie conformably and slightly transgressively over the clastic Triassic rocks. They are exposed along the southern border of the mapped area between Cervera de Pisuerga and Cillamayor. The thickness measures approximately 300 m. The whole Jurassic is built of limestones and marls.

At the base lies a series of massive, grey, and slightly breccious limestones in which the bedding plane can hardly be observed. Next follows a sequence of well-bedded, grey marls and limestones. The thickness of the individual limestone beds varies from 20 cm to 40 cm. They contain many ammonites and brachiopods. A beautiful exposure of these rocks is found 500 m south of Cillamayor in an old, now abandoned limestone quarry. From this locality Ciry (1939) mentions the following determinations of fossils:

Hammatoceras sp.
Catulloceras sp.
Dumorteiria levesquei d'Orbigny
Cotteswoldia sp.
Pleydellia aalensis
Lioceras opalinum Reinecke
Rhynchonella sp.
Terebratula sp.

This association indicates a Lower Aalenian age.

Wagner (1955) and de Sitter (1955, 1957) mapped the Villanueva limestone as a Jurassic rock, but recent determinations of conodonts and goniatites (page 15) collected by the present author indicate a Lower Carboniferous age.

Although the Jurassic limestones overlie the Triassic slightly transgressively, the extension of the Jurassic basin was also limited by the León ridge near Cervera de Pisuerga.

5. *Cretaceous*

The Cretaceous rocks lie conformably upon the Jurassic limestones and near Vado de Cervera unconformably upon the Paleozoic rocks. A beautiful section, comprising nearly the entire Cretaceous, is exposed along the road from Cervera de Pisuerga to Vado de Cervera. Along the same road the unconformity between the Cretaceous and the underlying Stephanian rocks can be observed. The total thickness measures about 800 m.

A short summary of the Cretaceous stratigraphy will be given. For more detail the reader is referred to Ciry (1939).

W e a l d e n: this facies is built up of grey/white conglomerates and coarse-grained sandstones with a high kaolinite content. These clastic, continental-lagunal deposits form an indication for the renewed uplift of the central Cantabrian massif. The thickness measures 200 m. Although the conglomerates northeast of Liguérzana have been attributed by several investigators to the Triassic, the present author attributes them to the Wealden facies because of the thickness of the series and the lithologic characteristics of the conglomerates.

C e n o m a n i a n: these are white, glauconite-containing sandstones with some thin lignite/clay intercalations. The upper part of the series contains an arenaceous limestone which yielded the following fossils (Ciry, 1939): *Exogyra flabellata*, *Ostrea* sp., and *Plicatula auressensis*. The thickness is almost 30 m.

T u r o n i a n: this is built up of well-bedded marls and limestones, which grade upwards in massive limestones. At the beginning of the Turonian a transgression of the Cretaceous sea sets in.

C o n i a c i a n: these are white and blue, massive limestones. In a locality west of Liguérzana, Ciry (1939) collected *Exogyra spinosa* and *Tissotia haplophylla*.

S a n t o n i a n: this comprises yellow, marly limestones, which grade upwards in white, massive limestones. After the Santonian a regression of the Cretaceous sea sets in.

C a m p a n i a n and M a a s t r i c h t i a n: these are arenaceous, detritic limestones.

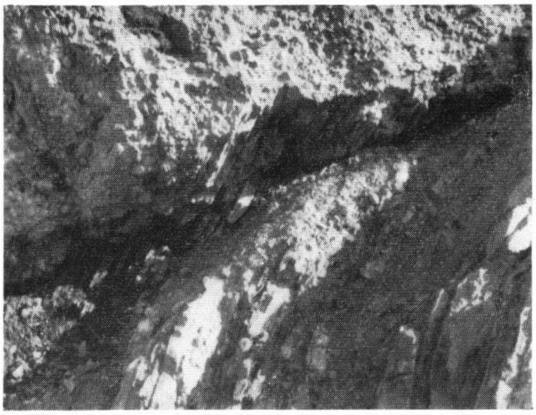

Fig. 17. The unconformity between the Paleozoic and the Cretaceous near Vado de Cervera.

The age of the Wealden facies is not known exactly in this area because the rocks are completely barren. Karrenberg (1934) assumes that the lower boundary of the Wealden deposits still belongs to the Malm and that the upper boundary reaches into the Barremian/Aptian.

Note

After the Hercynian folding the Triassic basin developed as a post-tectonic, marginal basin of the central Cantabrian massif. The extension of the basin was limited westwards by the León ridge. During the Triassic the relief of the central orogene gradually decreased and during the Jurassic it became so low that a limestone facies could develop; the limestones lie transgressively over the Triassic rocks. The clastic facies of the Lower Cretaceous indicates a renewed uplift of the Cantabrian massif. However, after the Cenomanian the Cretaceous sea invaded an important part of the land area and, for the first time during the Mesozoic, overflowed the León ridge towards the west. We see that this ridge, a prominent geanticline during the Paleozoic, still exerted an important influence upon the sedimentation during the Mesozoic.

For a detailed description of the Tertiary and Quaternary history of this territory the reader is referred to Mabesoone (1959) and Nossin (1959).

6. *Igneous rocks*

Igneous rocks occur in this area as discordant intrusive bodies, concordant sheets, and discordant dykes. The rocks are mostly completely altered and as a consequence it is often difficult to distinguish between concordant sheets of igneous origin and of sedimentary origin, even by microscopic investigation. The intrusives have a hypidiomorphic, porphyritic texture. A thermal aureole of contact metamorphism is almost always absent.

1. The intrusives on the Rabanál ridge:

Along the whole length of the Rabanál ridge from Vañes to Mudá several intrusives are found. In addition, a few other instrusives are found near Resoba, Arbejal, and Verbios. Concordant sills are encountered north of Arbejal and at the Sierra Coriza (Cabra Mocha). Casiano de Prado (1856) already mapped some granite near Gramedo, while Quiring (1939) describes the occurrence of hornblende granite and porphyry near Valsadornín, Rabanál de los Caballeros, and Arbejal, and a diabase rock near Verbios. Kanis (1956) gives a more detailed petrographic description of the intrusives near Resoba and Arbejal.

They are light-green and dark-green porphyritic rocks. Phenocrysts of quartz, plagioclase (mostly andesine), biotite, and garnet are present. Potash feldspar and pale-green pyroxene are found in subordinate quantities. The plagioclase shows albite and Carlsbad twins, and is often almost wholly altered into sericite, carbonate, and chlorite. The brown coloured, euhedral biotite is often chloritized and limonitized. Apatite occurs as accessory mineral. The groundmass consists of plagioclase (lath-shaped), quartz, and some biotite. The mineralogical composition varies from granodiorite to diorite.

In the central part of the Pisuerga basin the rocks are intruded in sediments of Stephanian age and consequently they must have a late-Carboniferous origin (post-Stephanian A).

2. The intrusives along the southern border of this territory: porphyritic rocks with a white and grey colour are found northwest of Rueda, east of Mudá, and south of Revilla. The rocks contain phenocrysts of quartz, plagioclase, and brown biotite as well as potash feldspar in only minor amounts. The plagioclase is almost wholly altered into sericite, kaolinite, and carbonate. The biotite is chloritized and limonitized. The groundmass consists of plagioclase (lath-shaped), quartz, and some biotite. The intrusives have the mineralogical composition of a quartz porphyry.

It is a curious fact that these intrusives are restricted to the southern, Triassic border of this area.

3. The igneous rocks in the Ruesga zone:

These are light-green, fine-grained rocks, which occur mainly as concordant sills and thin, discordant dykes. The limestones at the northwestern border of the Pantano de Ruesga, for instance, are cut by several such discordant dykes. Because of the high degree of alteration no petrographic description of the intrusives can be given. According to Koopmans (1962), the dyke north-northwest of San Martin de los Herreros appears to represent a rock with a spilitic composition.

The restriction of these intrusives to the Ruesga fault-zone makes a causal relations between the two quite plausible.

III. STRUCTURE

In order to obtain a clear insight into the structural problems, the area shall be divided into three sub-areas for separate discussion:

1. The Barruelo sub-area, bordering towards the west to the valley of San Cebrián—Perapertú.
2. The Cervera sub-area, forming the southern part of the Pisuerga basin and extending towards the north as far as the Rio Castilleria.
3. The Santibañez sub-area,bordering towards the west to the Pantano de Camporredondo.

The reader is referred to the following publications, which include a geological map with an interpretation of the structures of these areas: Dupuy de Lôme & de Novo (1924), Quiring (1939), Alvarado & Sampelayo (1945), Wagner (1955, 1960), and De Sitter (1955, 1957).

1. *The Barruelo sub-area*

a. *The structure of the San Julian unit*

The San Julian unit consists of one large synclinorium which is cut by several transversal faults. This can be subdivided into a northern and a southern part, separated by an E-W trending longitudinal fault. The northern part consists of three strongly compressed folds, which towards the east are cut off by a transverse normal fault. At the other side of the fault, however, the central anticline can still vaguely be discerned in the nearly vertical, massive quartzite beds. The southern part consists of one flat syncline with a somewhat more steeply dipping northern flank which still forms the hinge of the next anticline just beside the northern E-W fault. The synclinal and anticlinal axes in the limestones of the south-western part of the San Julian have been shifted southwards in relation to the main fold axes by movement along a transverse wrench-fault.

The folds are E-W trending and the axial plane dips steeply northwards, while the fold axes generally plunge towards the west at a small angle. In the northwestern and southeastern part of the San Julian, however, the fold axes curve into a WNW-ESE direction. Possibly this is due to the influence of a later Carboniferous folding.

As has already been said, the synclinorium is intersected by a number of transverse faults. Alongside them, movements took place such that the same synclinorium was stretched out into an E-W direction. Consequently, the present author believes that most of the faults are related to the same N-S compression that caused the E-W trending folds of the San Julian, but they must be slightly younger because the fold axes themselves have been disturbed by them.

In some exposures of Lower Devonian shales of the Carazo formation a cleavage is observed, which is always parallel to the axial planes of the E-W folds, pointing to a close genetic relation with the main folding of the San Julian. In connection with the cleavage, small parasitic microfolds have often been developed.

The contact of the San Julian unit with the surrounding Carboniferous shales is as follows: on the southern border the Lower Devonian clearly overlies the Lower

Carboniferous in a parallel manner. Due to bad exposure, however, the contact plane can not be observed. At the northern border the Carboniferous shales, characterized by floral remains and conglomerates, lies nearly vertically compressed against the Devonian quartzites and limestones; in some localities concordantly, in other localities in a slightly discordant manner. At the western border the Carboniferous has a N-S strike and dips steeply towards the west. From the map it can be seen that the E-W trending Devonian folds meet the Carboniferous nearly at a right angle. Here we note two quite different structural trends.

Casiano de Prado (1861) and Dupuy de Lôme & de Novo (1924) both located the Lower Paleozoic San Julian massif on their maps, but they do not discuss the structural problems. Quiring (1939) interpreted the structure of the San Julian and the surrounding Carboniferous as one large anticline (the Cervera anticline), the quartzites east of Verbios forming the Cambro-Silurian anticlinal core. He thinks the Mudá limestones to be of the same age as the Lebanza limestones, and maps them as the western flank of the NW-SE trending anticline. From recent exact datings of the rocks mentioned above, this interpretation appears to be incorrect. Alvarado & Sampelayo (1945) give a N-S structural section across the San Julian. They criticize the mapping and interpretation of Quiring. However, they remain of the opinion that the San Julian unit is part of an anticlinal structure, limited at the southern border by an E-W trending, vertical normal fault. In any case, their mapping of the Devonian was more accurate than Quiring's.

Since Wagner (1955, 1960) correctly mapped the Devonian of the San Julian as a synclinal structure, his interpretation is quite contrary to those of the former authors. In various localities he observes an inverted, concordant contact between the Lower Devonian and the Lower Carboniferous. On this basis he concludes that the San Julian must be the remains of a large overthrust-sheet of unknown dimensions and origin. This hypothesis implies that the Devonian strata and the surrounding Carboniferous must have been deformed in one folding phase: the Asturian.

Although at the first glance this solution seems to be quite acceptable, various objections can be raised. First, a minor objection: it seems rather improbable that within a distance of 800 m a thrust-fault would cut three times through a massive quartzite sequence at the northern border of the San Julian, thus causing the variable contact between the Carboniferous shales and the Devonian quartzites and limestones. The main objection, however, consists of the following observations: it is true that at the southern border the Carboniferous is overlain by the Lower Devonian, but at the northern border this is much less evident, and at the western border a structural concordance is even nowhere to be found. According to Wagner, the overthrust and the folding of it must have taken place simultaneously with the folding of the surrounding Lower Carboniferous. This is in direct contradiction to the general structural picture, especially at the western border of the San Julian (Fig. 18); there we observe two quite different folding directions which cannot have originated in one and the same folding phase. In addition, the folding of the Devonian strata is more intense than that of the surrounding Carboniferous. This is also quite obvious if — standing near St. Maria — we regard the landscape in a northern direction: we see before us the nearly horizontal Carboniferous graywackes and, in the background, the strongly-compressed, vertical Devonian quartzites of the northeastern part of the San Julian. From a regional point of view too, a nappe structure seems very doubtful. The structures of the Devonian block west of the Pisuerga basin have the same E-W trending folds with axial planes dipping towards the north. A few northwards-dipping upthrust-faults occur, but they can not be compared in any way to the nappe structure proposed by Wagner for the San Julian unit. Further, in several localities round the San Julian unit outcrops of Devonian rocks can be observed projecting through the surrounding Carboniferous shales. This occurs, for instance, near Mudá, Revilla, and Orbó, and in several other localities. It is illogical to regard the San Julian unit as a nappe structure and the other small Devonian outcrops as unconformably covered by the Carboniferous, as Wagner does. North of Verbios an exposure of an Upper Devonian limestone is found about 100 m below the overthrust fault at the base of the San Julian unit. It is difficult to imagine a complete Lower Carboniferous sequence to be present between the overthrusted San Julian massive and the underlying, authochtonous Upper Devonian limestone.

Taking these observations into account, the present author considers the San Julian to be the remnant of an old erosion cliff of Paleozoic age, around which the Carboniferous shales and sandstones were compressed in an apparently concordant manner due to mutiple subsequent folding movements. The E-W folds of the San Julian itself, however, are older than the folding of the surrounding Perapertú

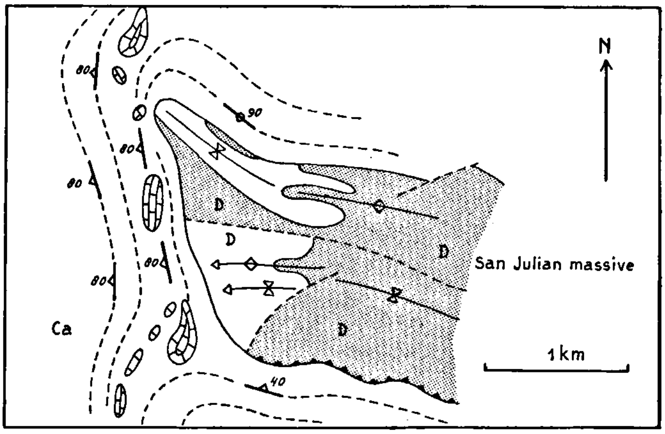

Fig. 18. Structural picture of the western part of the San Julian.

formation, i.e. Bretonic folding. It is possible that the subsequent folding of the Carboniferous intensified the earlier San Julian structures. At any rate, the thrust-fault at the southern border must be of a younger, Carboniferous origin.

Koopmans (1962) mentions that on the León ridge the development of the Devonian is greatly reduced. For instance, near Triollo and Santibañez Lower Devonian limestones are directly overlain by a thin sequence of Upper Devonian quartzites. On the Rabanál ridge and perhaps in the San Julian area also, we encounter the same reduced sequence of the Devonian: the Lebanza limestones and the Abadia marls are overlain transgressively by Upper Devonian sandstones and quartzites as, for instance, exposed near Mudá. Wagner himself in 1962 described an unconformable contact between Lower Carboniferous limestones and underlying Devonian limestones, as exposed 350 m southeast of the village of Villabellaco. In the Cervera area, west of the San Julian, we see the same unconformity between the Cervera sandstones and the Devonian marls and limestones as in the Barruelo area between the Perapertú formation and the Devonian. The present author does not believe that the folding occurred as one, clearly-marked folding phase, but rather that is occurred as a sequence of less important local movements, resulting in several local unconformities.

This theory is also in better agreement with the geologic data provided by the stratigraphic sequence. The type of the sediments of the Perapertú formation and the Cervera formation indicates the proximity of the coast during the Lower Carboniferous. The development of the Upper Carboniferous of the Pisuerga basin (coal seams, reef-like limestones) and the difference in lithology of the Upper Carboniferous of the Pisuerga and Rubagón basins, indicate the presence of a positive ridge near the present San Julian unit during that period. Consequently both the facies development and the thickness distribution of the Carboniferous seems to be in accordance to this theory.

b. *The structure of the Carboniferous*

Structures in the Lower Carboniferous are difficult to map because of the rapidly varying lithofacies in a lateral sense and the frequency of local discordances caused by the multiple tectonic movements during the Carboniferous.

The local stress fields of the Carboniferous folding phases (Sudetic, Asturian, Saalic) were probably strongly influenced by the direction of the older San Julian folds and the earlier irregular shape of the basement caused by folding, erosion and subsequent basin forming. The N-S strike west of the San Julian massive, for instance, seems to have its origin in the influence of the ancient relief of the San Julian upon the stress field. The N-S trend of the ancient shoreline is still marked by the occurrence of the Perapertú reefs along a N-S line: Perapertú-Monasterio.

The Villabellaco limestone, west of Revilla, forms a flat anticline with a WNW-ESE trending axis and an axial plane dipping towards the northeast. The exposed minor folds and microfolds generally show the same folding trend and type. Towards the east, near the Barruelo fault, the dip of the Lower Carboniferous shales and sandstones gradually increases to 80°—90°. Apparently, we see here the influence of the Asturian folding, which caused the inverted position of the Barruelo beds, upon the Lower Carboniferous rocks.

For many years the coal beds near Barruelo were thought to constitute the western flank of a normal syncline and to overlie the Lower Carboniferous conformably. Such was the interpretation of Dupuy de Lôme & De Novo (1924) with regard to the suspected prolongation of the coal seams underneath the Triassic cover. Cueto & Ruiz Diaz (1926) already suspected an inverted position of the Rubagón series, on the basis of the stratigraphic position of the stigmaria banks and conglomerate beds. However, later investigators such as Quiring (1939) and Alvarado & Sampelayo (1945), still remained of the opinion that the series formed a normal syncline. With more exact determinations and a better insight into the stratigraphic relations, Wagner & Wagner-Gentis (1952) and Wagner (1955) interpreted the structure of the Barruelo beds as part of an overturned anticline, separated by a normal fault from the Lower Carboniferous to the west. The inverted position is implied by the following evidence:

1. The position of a variety of sole marks at the bottom of the sandstone layers of the Brañosera formation.
2. The younger age of the Barruelo formation in relation to the Brañosera formation, as indicated by plants and foraminifers.
3. The fact that even the flora of the Calero coal-group appears to have a younger character than the flora of the Peña Corba coal-group, as Wagner (1955) mentions.
4. The occurrence and position of the Stigmaria beds and conglomerate beds in relation to the coal seams.

North of Mercedes the Barruelo fault is covered unconformably by the Peña Cilda conglomerates. This makes an exact dating of the fault movement possible, namely post-Stephanian A and pre-Stephanian B. The folding is correlated by Wagner & Wagner-Gentis (1952) with the Asturian folding phase. Due to bad exposure the dip of the fault-plane can not be observed, but it must be rather steep. The Barruelo fault forms part of a regionally important fault-zone with a NW-SE trend, which can be followed from Orbó in the southeast to Piedrasluëngas in the northwestern part of the Pisuerga basin. The amount of movement along the fault decreases from south to north and is very slight in the core of the strongly-compressed Los Llazos anticline near Piedrasluëngas. The whole series east of the fault-zone is characterized by an inverted position. In the Barruelo area, the San Julian unit acted as a block against which the Upper Carboniferous beds were overturned.

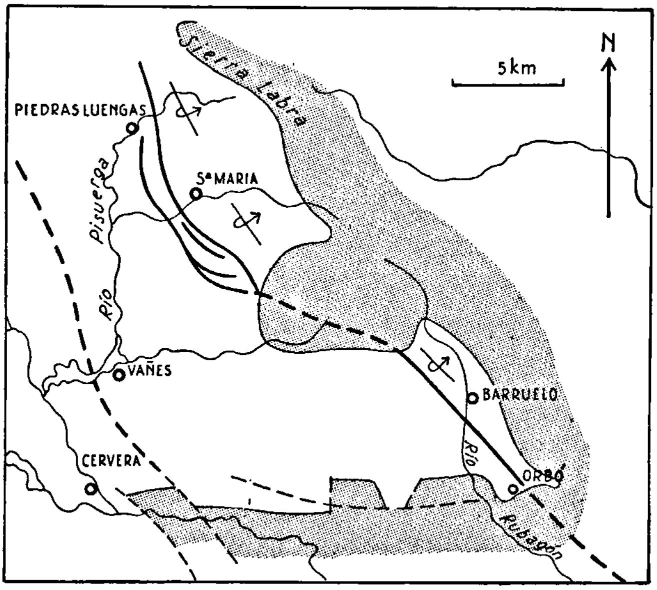

Fig. 19. The extension of the Barruelo fault towards the northwest.

As can be deduced from the difference in strike between the Perapertú reefs and the Molino sandstones formation — close to the village of Perapertú — the Curavacas folding did not cause a very strong deformation in this area. The main folding is due to the late-Carboniferous folding, which produced the major structures. The Barruelo structure is unconformably overlain by the Peña Cilda conglomerates, which in turn are folded in a few flat synclines and anticlines with a NW-SE trend and a slight axial plunge towards the northwest. These folds are cut off by the Triassic conglomerates, which dates them as post-Stephanian B/C and pre-Triassic. The latter deformation is generally attributed to the Saalic folding phase.

c. The structure of the Mesozoic

The Mesozoic beds are folded in a large E-W trending asymmetric anticline, with a flat northern flank and a rather steeply dipping southern flank (50°—60°). The folding is mainly a flexure folding of the southern border due to the uplift of the central Cantabrian massive. Generally, this deformation is attributed to a late-Eocene, Pyrenean folding phase (Ciry, 1939).

The structure of the southern border of the Barruelo area is rather complicated because of the presence of several longitudinal and transversal faults. Wagner (1955) and de Sitter (1958) mapped the Villanueva limestone as a Jurassic rock and interpreted the structure as a normal syncline, but determinations of conodonts and goniatites indicated a Lower Carboniferous age for this limestone. Consequently, the structure had to be re-examined. The latest mapping showed four E-W trending folds with north dipping axial planes. The Villanueva limestone is bordered towards the south by a normal fault which can be traced towards the east along two other small Carboniferous exposures. Towards the west, near Monasterio, it is cut off by a transversal fault: the offset of the beds along the fault-line indicates that the fault movement must have had an important horizontal component. However, the main fault runs from Mudá along the northern border of the Villanueva limestone to Matabuena, where it passes into a NW-SE trending fault. This one causes a repetition of the stratigraphic sequence in a N-S direction, due to the uplift of the southern part in relation to the northern part.

The axis of the Barruelo anticline shows the same change of the strike from E-W to NW-SE as the Mudá fault. Evidently, here we observe the transition of the fundamental Cantabrian structures into the fundamental NW-SE Celtiberian structures.

2. *The Cervera sub-area*

The folding of the southern part of this sub-area (Cervera formation and Mudá limestones) is due mainly to the Sudetic folding which took place in the Upper Namurian and Lower Westphalian. Structures are almost impossible to map in the Cervera sandstones because of the rapid lithofacies changes, both in the horizontal and the vertical sense. In addition, the exposure is rather bad. In the major part of the area the strike of the strata is E-W, but near Mudá this gradually shifts to a WNW and NW direction. The macrofolds and the microfolds in the Mudá limestones all show a NW-SE folding trend. The dip of the beds is nearly always to the south and varies from 20° to 70°. Occasionally, an overturned position of a sequence can be concluded from top and bottom indications such as groove casts and cross-bedding. Further, a few macro-structures could be mapped along the road from Rueda to Mudá and the road from Cervera to Vañes. More information about the type of folding can be obtained from the few exposures of minor folds, as exposed, for instance, 1 km south of the village of Valsadornín. The type of folding is clearly dependent on the lithology: sandstones and conglomerates are less deformed and more regularly than the shale-rich parts. The Rabanál ridge, characterized in the field by the occurrence of several outcrops of Lower Devonian rocks, shows the same trend as the structures in the Cervera formation.

North of Cervera de Pisuerga, the NW-SE trending, isoclinal Devonian folds of the Peñas Negras meet the E-W trending, Lower Carboniferous folds. Originally, this was supposed to be a fault contact, but neither to the west nor to the east can the influence of such a fault be observed. Another possibility is that this discontinuity represents an unconformable contact. The Cervera formation is the stratigraphic equivalent of the Perapertú formation and consequently it is quite logical to compare this discontinuity with the unconformity known from the San Julian area. The present author therefore supposes that part of the folding of the Peñas Negras is older than the overlying, clastic Lower Carboniferous (Namurian).

In the opinion of Dupuy de Lôme & De Novo (1924), Quiring (1939), and Alvarado & Sampelayo (1945), the Cervera formation is conformably overlain by the Vañes formation north of the Rabanál ridge. However, more exact mapping has revealed that this is completely out of the question for both stratigraphic and tectonic reasons. Wagner (1955, 1960) traces a low-angle thrust-fault at the base of the Vañes formation and assumes that part of the stratigraphic sequence (Curavacas formation) has been cut out by the fault. De Sitter (1955, 1957), as distinct from Wagner, found an unconformable contact between the two formations: an unconformity which he related to the Curavacas folding. The present author, however, puts the Molino formation in the Upper Carboniferous and, as a consequence, draws the Curavacas unconformity at the base of this formation. The normal fault which now has been drawn at the base of the Vañes series, cuts off the Molino formation near San Cebrián and separates the Mudá limestones with NW-SE trending structures from a northern part with E-W trending folds. Towards the east this fault can be traced in the Triassic rocks, which indicates that the last movements alongside it were of Tertiary age. Towards the west the fault can be linked up with the N-S trending normal fault which separates the Polentinos block from the younger Pisuerga basin.

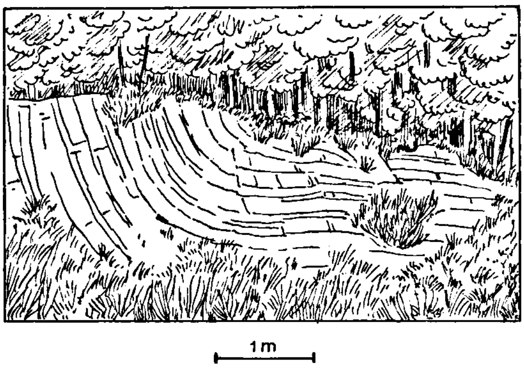

Fig. 20. The core of a synclinal fold, as exposed in shales south of Valsadornín.

The rocks of the Sierra Coriza are folded in a horseshoe-shaped structure which can be followed from Vañes, over San Cebrián, to Herreruela. Near Rabanál the dip of the southern flank measures 45° or less, but towards the northeast this rapidly increases to 90° or is even slightly overturned. The axis of this synclinal structure has a NW-SE trend, while the axial plane dips to the northeast. The folding is due to the Asturian folding, which took place at the end of the Stephanian A. The same folding trend we observed in the Upper Carboniferous of the Barruelo sub-area. From the map we see that the northeastern flank of the Sierra Coriza structure has been pushed towards the west with regard to the southern flank along an E-W fault which can be followed from Vergaño to San Cebrián. Due to lack of space in the synclinal core, part of the Sierra Coriza limestones were squeezed in a wedge towards the northwest. In the hinge of the structure, near San Cebrián, several secondary minor folds and faults occur. They cause a doubling of the San Cebrián coal-group over a short distance and it is just here that the most important mine of San Cebrián is located.

The quiet type of folding of the Upper Carboniferous in the Sierra Coriza basin is in strong contrast to the highly compressed and overturned structures which can be observed in the northeastern part of the Pisuerga basin. In the author's opinion this is a consequence of:

1. The situation of the Sierra Coriza basin west of the San Julian block. Probably this Devonian block received the greater part of the orogenic forces. Due to a slight westward movement of this block the northeastern part of the Sierra Coriza basin was tilted steeply.
2. The fact that the Rabanál ridge formed a rigid backbone for the Upper Carboniferous basin and thus prevented strong folding of the overlying rocks.

Ciry (1939) made a very detailed map of the Mesozoic structures east of Cervera de Pisuerga. Only between Cervera and Liguërzana have a few modifications been introduced. Exactly as in the Barruelo area, the Triassic strata dip steeply southwards

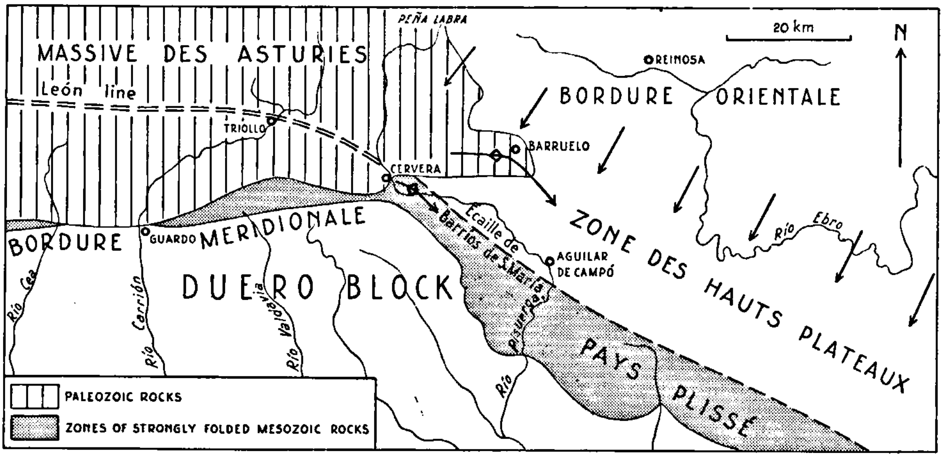

Fig. 21. The relation between the Cantabrian and the Celtiberian structures, partly after Ciry (1939).

along the southern border of this area, due to the uplift and marginal folding of the Cantabrian massive in Tertiary period. Between Cervera and Liguërzana the structures are more complicated, due to the presence of several longitudinal normal faults. The fold axis of the Cadaramo anticline shows a gradual change of the strike from E-W towards NW-SE. The same fact can be observed in nearly all the other Mesozoic structures. The rather complicated area around Cervera de Pisuerga forms the northern part of the highly-disturbed zone with a NW-SE trend, the "Pays Plissé" which has been described by Ciry (1939). This represents a narrow zone of strongly deformed and folded Mesozoic strata, produced by the compression of these rocks against the rigid Duero block (Fig. 21).

The Barrios de St. Maria fault, separating the Cadaramo anticline from the Barruelo anticline, is the continuation of the León Line, a fundamental fault, and can be followed towards the southeast over a long distance. From the foregoing it is clear that the Cantabrian structures must be linked to the NW-SE trending Celtiberian fold-belt and that they cannot be connected with the E-W trending structures of the Pyrenean mountain chain as supposed by Bertrand & Mengaud (1912).

3. *The Santibañez sub-area*

(see Map and inserts)

This sub-area forms an interesting region because two important structural lines come together near Santibañez de Resoba. The first is the León Line, which runs from Cardaño de Abajo, over Triollo, to Cervera de Pisuerga and exerted an important influence on the lithostratigraphy. The second is an important fault-zone, which has a NW-SE trend and can be traced from Santibañez, over Cardaño de Arriba, to Barrios de la Reina and even further to Asturias (the Cardaño zone).

In chapter II reference is made to the influence exerted by the León ridge on the sedimentation: the two different facies areas, the erosion horizons and sedimentation breaks and, as a consequence, the limited thickness of the deposits on the ridge. In the area around San Martin de los Herreros the large, recumbent folds of the Sierra del Brezo pass into several refolded overthrust structures, the griotte horizon nearly always forming the detachment plane. This is an immediate consequence of the decrease in the thickness of the Upper Devonian quartzites and the Caliza de Montaña on the León ridge. These competent, massive rocks mainly determined the amplitude of the folds. The movement of the overthrusts was from south to north, a characteristic of all the folding movements south of the León Line. However, the subsequent E-W refolding, attended by movements along the fundamental León fault, folded the overthrusts into an intricate pattern of E-W folds with an axial plane dipping towards the north. The village of La Lastra is built upon limestones which form the utmost northern of those overthrusts.

The straight fault-line, which runs from a point south of Triollo to Cervera de Pisuerga and separates the zone of the refolded overthrusts from the structures north of Santabañez and La Lastra, probably represents the upper part of the fundamental León fault. The latter has its origin in the core of the León ridge. On a small scale the influence of this fault can be observed in the highly faulted sequence of limestones associated with igneous dykes at the northwestern border of the Pantano de Ruesga.

Koopmans (1962) assumes that the forming of the overthrusts and the E-W refolding took place separately, during the Curavacas phase and the Asturian phase respectively. However, the present author is inclined to think that the forming of the overthrusts gradually proceded during the Westphalian into a steepening of the overthrusts and a further subsequent refolding into northwards-dipping folds due to the upthrust southwards of the León zone along the fundamental León fault.

For more information about these refolded overthrusts the reader is referred to a discussion by Koopmans (1962).

North and northwest of Santibañez de Resoba we observe several WNW-ESE trending, recumbent folds, whose axial plane dips towards the north at a small angle. The synclinal folds are separated from each other by several longitudinal upthrust-faults, which generally cause a pushing up of the northern part in relation to the southern part. The most striking element of these structures is formed by the large, recumbent synclinal fold which forms the top of the Peña de St. Lucia, and which is cut off to the west by the unconformably covering Curavacas conglomerates.

It is a curious fact that the E-W refolding observed in the area around San Martin de los Herreros is completely lacking in these structures north of Santibañez. A reflection, however, of the refolding is still found in the minor folds and microfolds of the less competent Cervera sandstones and shales which crop out east and west of Santibañez de Resoba. Towards the east, the limestones of the Caliza de Montaña wedge out and as a consequence we observe a decrease of the amplitude of the folds and an increase of the number of faults in that direction. Originally, the southern ridge of the Santibañez limestones were interpreted as an anticlinal structure, but the present author recently mapped several outcrops of Upper Devonian nodular limestones at their southern border. Consequently, the structure had to be re-examined. It is now interpreted as a recumbent synclinal fold, cut off by an E-W trending upthrust-fault from the Cervera sandstones and shales. North of La Lastra, the same fault causes the contact of the Upper Devonian quartzites with the Cervera formation. The unconformable cover of Curavacas conglomerates exactly upon the fault-line dates the movement as pre-Curavacas. In this area the influence of the regionally important Cardaño fault-zone finds expression in the several WNW-ESE trending upthrust-faults.

In the rocks of the Cervera formation, exposed in the central part of this sub-area, only a few macro-structures could be mapped. The same WNW-ESE trending, overturned folds with a northwards-dipping axial plane are observed. The minor folds and microfolds, however, are mainly developed as E-W trending knick folds with an axial plane which dips rather steeply towards the north. Parallel to the axial plane a cleavage has been developed. These folds probably represent a faint reflection

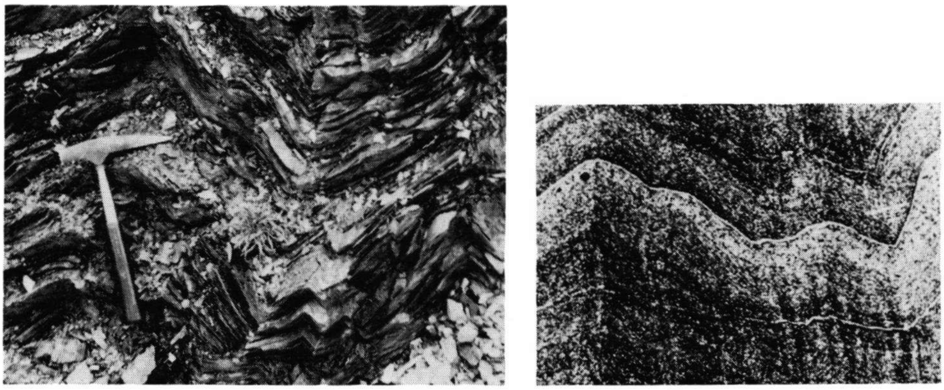

Fig. 22. Typical E-W knick-fold with well-developed cleavage near Santibañez de Resoba.

of the strong E-W refolding which occurred in the area south of the León Line. Near La Lastra, another type of minor folds is found. Here we observe N-S trending, asymmetric folds, which plunge to the north and have an eastwards-dipping axial plane. According to Koopmans (1962), the N-S folding is contemporaneous with or slightly later than the E-W refolding of the overthrusts. This is confirmed by Kanis (1956), who mentions a N-S refolding of the earlier large recumbent E-W folds in the area around Ventanilla.

Lastly these structures are coverd unconformably by the Curavacas formation, which in turn is folded in E-W to WNW-ESE trending flat synclines and anticlines.

4. *Summary*

According to the present observations, it may thus be said that the region under study shows the following succession of tectonic and epeirogenetic movements:

During the Lower Devonian this region formed part of the central Devonian sedimentation basin; the sedimentation is rather uniform and the formations of this period can be correlated over great distances. In the Middle Devonian, however, a differentiation began to develop in a northern and a southern facies as a result of the upward movement of a narrow zone with a WNW-ESE trend, the León ridge. In the Upper Devonian we see an uplift of the region followed by erosion and, possibly, the beginning of folding in the San Julian area. This erosion was more severe upon the León ridge than in the other parts of the basin. The next period was marked by the sedimentation of the transgressive Upper Devonian quartzites during the Frasnian/Famennian. The Upper Devonian folding movements, known from the San Julian, probably also find expression in the erosion horizon at the transition from the Devonian to the Carboniferous, as observed in the Santibañez area. This erosion horizon corresponds to a break in the sedimentation between the Camporredondo quartzites and the Alba griottes to the south of the León Line. A similar break and/or erosion horizon is also known from other regions of the Cantabrian Mountains, as reported by Ziegler (1959), Higgins et al. (1963), Radig (1964) and Budinger & Kullmann (1964). These movements can be correlated with the Bretonic folding phase of Stille.

After this active period, which continued into the Upper Tournaisian, the deposition of the transgressive griottes occurred in the Visean. This initiated a period of quiet limestone sedimentation throughout the Visean and into part of the Namurian. The end of the Middle Namurian, however, saw the commencement of the first Carboniferous folding movements, as can be observed in the unconformity near Mudá and the subsequent deposition of the thick sequence of the Cervera sandstones and conglomerates; this led in the Westphalian to the main folding of the mountain chain, i.e. the Sudetic folding. The erosion horizon on top of the Caliza de Montaña is only known from the region north of the León Line; some authors, such as Comte (1959), Koopmans (1962), and Rácz (1964), report a normal concordant succession of the Caliza de Montaña and the Cervera formation above it in regions south of the León Line. The main folding, which thus took place in the Lower and Middle Westphalian, resulted in the important cross-folding structures in the region of Ventanilla—San Martin de los Herreros and the structures north of Santibañez de Resoba and north of Cervera de Pisuerga. While in the regions south of the León ridge the folding continued into the Upper Westphalian, north of this Line the thick sequence of Curavacas conglomerates was deposited on the western border of the Polentinos block. East of this block the true Pisuerga basin began to develop. Here, during the Westphalian and the Stephanian A a steady, uninterrupted, paralic sedimentation took place, only the local unconformity at the San Cristóbal indicating that there were continual fault movements with, possibly, accompanied folding. Ultimately, after the Stephanian A, the folding of this Upper Carboniferous basin took place, resulting in the large overturned and faulted structures in the Pisuerga basin and the Barruelo area.

The unconformable cover of the Peña Cilda conglomerates over the Barruelo fault dates the last movement in this zone as Stephanian A/B. This unconformity can be attributed to the Asturian folding. The exact age of the Asturian phase has been a point of considerable disagreement during recent years. Wagner & Wagner-Gentis (1952) and Wagner (1955), who mapped the Peña Cilda unconformity, located the Asturian phase between the Stephanian A and B, but de Sitter (1961), on the basis of data from the province of León, placed it at the end of the Westphalian. Wagner (1959b), however, mapped another unconformity along the border of the Sabero basin, supposing it to date pre-Westphalian D and called this the Leonesian folding phase.

At present, however, we know that not every unconformity can be termed a phase. We have seen in this region that in a given area folding can occur in one place and contemporaneously sedimentation in another. One particular unconformity need not be important over the entire mountain chain. Thus, we must see the unconformities discussed above as the reflection of local movements that in combination led to the folding of the entire region and, in combination, must be assigned to the Asturian folding phase.

After the Asturian folding we observe in the Pisuerga basin still another slight folding before the sedimentation of the Triassic, that must be attributed to the Saalic phase.

All these folding phases, which formed the true Cantabrian orogene, must be assigned to the Hercynian folding period. There after, the morphogenetic phase began in which the central orogene was slowly uplifted and post-orogenic Mesozoic basins were formed along its border. In the Tertiary this upwards movement was accompanied by the development of a marginal fault-zone along the southern border, as indicated by the flexure folding of the Triassic strata in this zone (Pyrenean phase).

The León Line, as defined by de Sitter (1962), appears to have had an important influence as a ridge on the sedimentation from the Middle Devonian to the end of the Mesozoic. In addition, it was an important fault-zone during the main folding of the mountain chain and thus exerted an considerable influence on the type of the structures in the area of Ventanilla—San Martin de los Herreros. This fault-zone seems to be traceable in the Mesozoic fault-zone on the northeastern border of the Duero block, the "Pays Plissé" (Ciry, 1939). This transition from the WNW-ESE oriented Cantabrian structures into the NW-SE oriented Celtiberian structures is found in both the Paleozoic and Mesozoic folds and faults. It follows from this that the Cantabrian structures have in any case no direct connection with the Paleozoic Pyrenean structures.

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