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THE ESLA NAPPE, CANTABRIAN MOUNTAINS (SPAIN)

BY

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CONTENTS

ABSTRACT

In the southern slopes of the Cantabrian mountains (prov. León NW Spain) a miogeosynclinal and non-metamorphic series, 2—3 km thick, of Precambrian to Carboniferous age has been studied. Four main stratigraphic and tectonic units have been recognized:

1. Northern fracture zone of Las Salas,
2. Autochthone of Valdoré,
3. Esla nappe,
4. Western-Bernesga thrust structures.

Expression of the Caledonian orogeny is very vague. The rocks have been subjected to tectonic forces during the Hercynian and Alpine orogenies.

Epeirogenic movements during the Devonian (Bretonic phase of Stille) preceded large scale folding and thrusting during the early Westphalian (Sudetic phase). During this time the rocks of the Esla nappe have travelled a distance of 15—20 km to the north and northeast.

It is suggested, that folding and thrusting happened simultaneously in different parts of the area. Further it is shown that basement configuration as expressed in facies boundaries played an important role putting limits to the rather thin thrust sheet during its movement. Fundamental weakness zones border the thrusted area.

The Asturian phase of Stille may be held responsible for a great amount of refolding of the previously- formed thrust structures.

To the north of the thrusting boundary i.e. fracture zone of Las Salas otherwise León line of de Sitter (1962 b), Westphalian deposits are found resting unconformably on rocks, that are represented in the nappe. So in the north and in front of the thrusts deposition went on during „middle" and upper Carboniferous times.

Stephanian coal bearing rocks in the northern fracture zone are unconformably resting on both the Westphalian and the Older Palaeozoic thrusted series. Likewise Stephanian rocks of the Sabero basin in the south fill a depression in the nappe. This depression also occurs on a fundamental zone of weakness, the Sabero-Gordon line.

From several locations it is inferred, that the tectonic forces, which folded the Stephanian rocks severely, left the older Palaeozoic,Sudetic and Asturian folded,rocks practically unaltered.

The southern border zone is seen as an Alpine flexure zone; in places the Cretaceous steeply covers the previously mentioned series.

Morphogenetic uplift of the chain most probably is accounted for by the Pyrenean phase. The Tertiary conglomerates of the Duero basin are to be derived from this uplift.

It is held, that none of the mentioned unconformable rocks have covered the older Palaeozoic thrust series as full and uninterrupted blankets.

The basin configuration of the Cambrian as described by Lotze 1961 is supported by stratigraphic and tectonic observations in the area. Thus Lotze's Cambro-Ordovician geosyncline may have been tectonised as late as the Devonian—Lower Carboniferous. De Sitter's view, that the thrustsheets contained in the Leonides moved from south (center of preceding basin) to north is confirmed by stratigraphic and tectonic evidence. In the east-west striking part of the Asturian—Cantabrian chain only the miogeosynclinal part of the greater subsidence is disclosed to our inquiry, the orthogeosynclinal development was not uplifted.

Fig. 1. View of the Esla nappe, in background, and autochthone of Valdoré, in foreground; photostation on Pico Riondo W of the village Corniero and looking E (photo by van Adrichem Boogaert).

INTRODUCTION

Since the early fifties the Department of Structural Geology of the Geological Institute of Leiden University has been carrying out a systematic program of mapping the southern slopes of the Palaeozoic core of the Cantabro—Asturian mountain chain. This area now covers the northern part of the provinces of Palencia and León and the SW corner of the province of Santander, all situated in NW Spain.

Mountains on and south of the E-W running watershed seldom rise to altitudes of more than 2500 m above sealevel. Distances from the divide to the coast, going north, range from 50 to 80 km, whereas going south this is at least 300 km, both following river courses.

To the north the present E-W trending mountain chain follows the coast of the Bay of Biscay. In the south the Mesozoic and Tertiary underlying the highland plateau of Old Castile puts an end to our investigation of Paleozoic structures. The level of this plateau is from 1000 to 700 m above sealevel.

The Hercynian orogene is known to change its E-W trend in a N-S and NE-SW direction west of the river Luna (see Lotze 1961, de Sitter 1962). Before doing so it covers the provinces mentioned, with a NE-SW trend it is truncated by the coast roughly between Ribadeo and Gijon in the western half of the province of Oviedo.

In the east the headwater-region of the Rio Pisuerga mainly consists of complicated structures in Carboniferous series (see Quiring 1943, de Sitter 1957, 1962b, Kanis 1956 and Wagner 1958).

In the adjoining area to the west Koopmans (1962) worked. My colleague H. M. Helmig (1965) studied the Stephanian basin west of the area described by Koopmans. In fact the herewith presented map sheet was prepared in close coöperation with Mr. Helmig.

The present paper discusses the rocks and structures in the headwater regions of the Esla and Porma rivers south of the towns Riaño and Camposollilo. To the east the Stephanian cover, to the south the Mesozoic and Tertiary cover, form natural boundaries to the area. In the north the area is limited by the Carande—Huelde basin and the Lois—Cigera basin both with rocks of Westphalian (Moscovian) age and forming part of the great Asturian basin. In the western part covered by the map we fing a great expanse of Cambrian rocks; west of the river Porma we run into several thrustfold structures of the Bernesga basin, that are analogous to our Esla nappe (see also Comte 1959, de Sitter 1962b, Wagner 1963).

The economic backbone of the area is cattle raising supplemented with coal mining in the Stephanian depressions of Sabero and Huelde—Carande.

A dam project in the river Porma south of Vegamian is under construction; a similar project in the Esla river north of Las Salas is being discussed. Important center are Cistierna, pop. 6000, Riaño, pop. 2000 and Boñar, pop. 2500.

Use was made of 1 : 50.000 scale topographic maps of the Instituto Topografico y Catastral at Madrid e.g. the sheets 104, 105, 106 and 130, 131 and 132. Mapping was carried out on a 1 : 25.000 scale.

The aerial photographs were put at our disposal through the courtesy of the Instituto Geologico y Minero de España. The runs: 430 no 43739—43751, 428 no. 43527—43536, 427 no. 43313—43306, 426 no. 43190—43200 and 204 no. 20340—20327 have an approximate scale of 1 : 37.500 and have been of great help in certain zones of the area.

CHAPTER I

STRATIGRAPHY

Introduction

Rocks of various ages are exposed in the discussed area. The series ranges from Lower Cambrian to Lower and Middle Carboniferous, deposited without major tectonic interruptions. The Caledonian orogeny finds no expression except for volcanic activity.

The Palaeozoic rocks older than the Upper Carboniferous compose the structural backbone of the area.

For the Cambrian to Lower Carboniferous sequence usé was made of the excellent lithostratigraphic subdivision Comte (1959) proposed. The majority of his type sections occur in the Bernesga river valley and surroundings, approximately 50 km to the west. Thanks to the uniform cratonic development of rock units his subdivision proved correct in the Esla region (on strike with the Bernesga type region) and needed only minor corrections. Upper Devonian strata of the autochthone of Valdoré do for instance cut time horizons.

Cambro-Ordovician and Silurian rocks predominantly consist of clastic material, the Devonian and Lower Carboniferous series boast many thick limestone formations.

Various parts of the region show great differences in the Devonian stratigraphic section due to epeirogenic movements during the Famennian; similar movements on a smaller vertical scale are recorded in the condensed Lower Carboniferous sequence. Nowhere in the field the Devonian movements appear as visible angular unconformities.

The configuration of the pre-Westphalian rocks of the Esla region leads to a separate description of mainly three subareas with different stratigraphic development especially during the Devonian and a different tectonic style.

These subareas are: *

The Esla nappe including the syncline of Agua Salio, the syncline of Felechas and the Peña Corada zone; here the most complete succession is found. Only Lower Famennian rocks, besides the Tournaisian-Lower Visean sequence, seem to be absent. This „nappe" development may reflect a more southern and central basin (within cratonic terms) type of development.

Total thickness: 2000—2100 m.

Thickness of the Upper Devonian clastic rock sequence: 280 m.

The Autochthone of Valdoré with a thinner 1800—1900 m total rock sequence, that contains the same kind of sediments as the nappe series.

In this area the Upper Famennian hiatus reaches down from Upper Famennian into Middle Givetian rocks.

* For limits of these areas see Chapter on Structure.

I wish to express my sincere thanks to Mr. H. A. van Adrichem Boogaert for determining the conodonts and for his great amount of stratigraphic help in general and to Mr. A. C. van Ginkel for determining the foraminifera and to Dr. L. Rácz for determining the algae.

Plant fossils were worked on by Mr. H. A. van Amerom in collaboration with Prof. Stockmans of Brussels University.

Field data were put at my disposal by Mr. J. J. Bos, Mr. H. Rijckborst and Mr. J. F. Savage.

The close collaboration and resulting discussion with Mr. H. M. Helmig, Mr. H. A. van Adrichem Boogaert and Mr. J. F. Savage was of great help.

Technically I was aided by Miss C. P. J. Roest and Mr. H. Scheuer in the preparation of the map and illustrations, by Mr. J. Hogendoorn photographer and by Mr. J. Schipper and Mr. M. Deyn who prepared the thin sections.

Professor Dr. L. U. de Sitter head of the Department lent us and the surveying in general a great deal of impetus by his inspired supervision.

The following publications have a more direct bearing on the subject:

1900 Mallada published reports on the Stephanian coal basins of Sabero and Valderueda.

1939 Ciry investigated the Mesozoic of the southern border zone.

1949 Almela gave a review on coal reserves in the province of León.

1959 de Sitter published a short note on the Esla nappe.

1958—1963 Wagner published on the Sabero-Matallana coal basins and their basement.

1959 Comte analyzed the stratigraphy of the Paleozoic series. Although he chose his type localities more to the west, his nomenclarure of formations could be applied to the Esla area, few alterations have been made. Comte's work stemmed from before the Spanish Civil war and was published only in 1959. Through the courtesy of the University of Lille we were acquainted with Comte's results before publication.

1961 Kullmann published an account on Cephalopoda collected from NW. Spain, recently reviewed by Gomez de Llarena (1964).

1961 Lotze and Sdzuy mentioned Cambrian rocks in the Porma and Esla valleys in the description of the Spanish Cambrian.

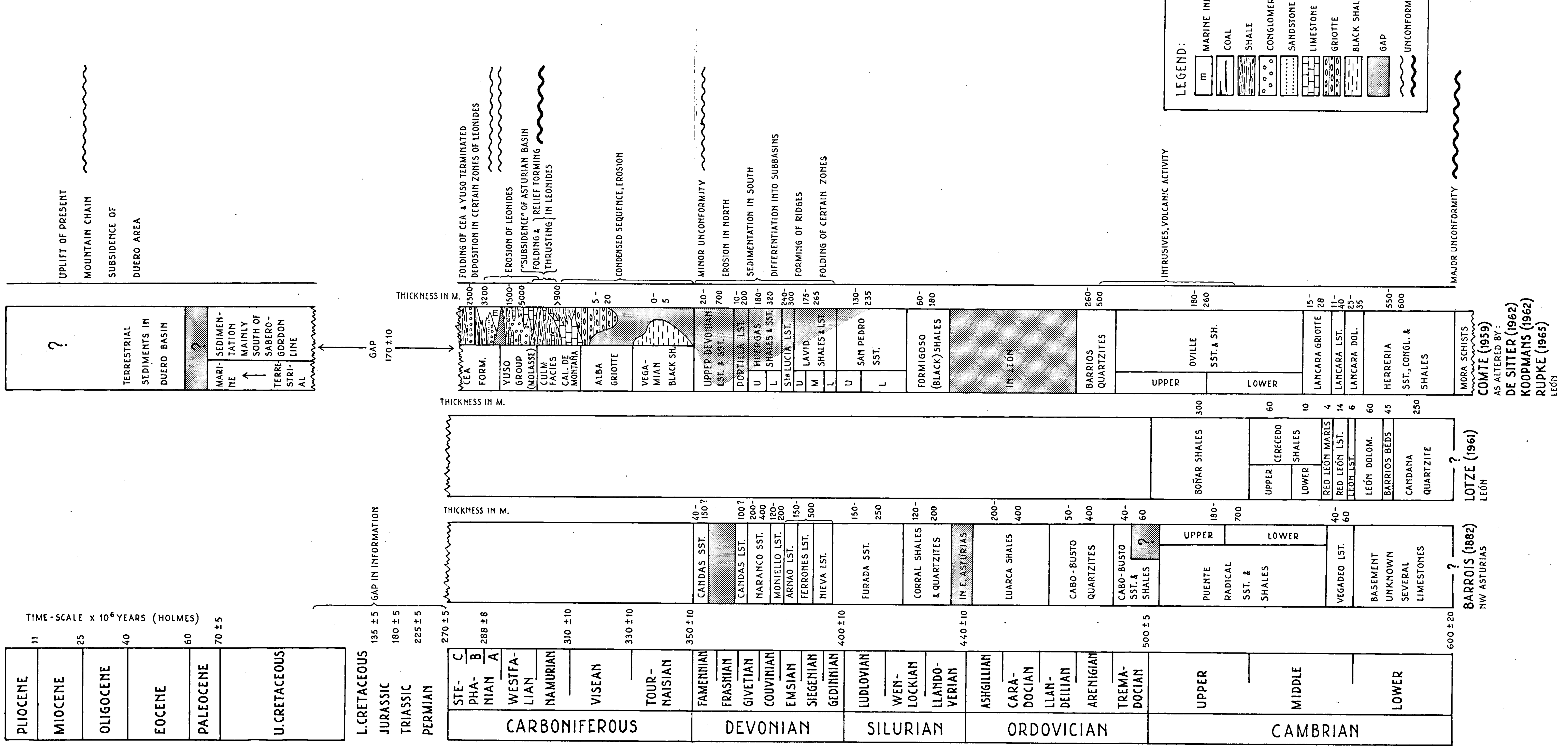
1962 De Sitter published a reconnaissance map (scale 1 : 100.000) giving the preliminary results obtained by Leiden in the area from Pisuerga basis in the east, to the river Luna in the west.

1964 Higgins, Wagner—Gentis and Wagner gave a sound description of the black Tournaisian shales, that occur in the area west of the Porma river.

1964 Oele described the Cambro-Ordovician part of the series that build the area. His paper was on a sedimentological basis.

For complete references see list in back.

Fig. 2. Table showing Cantabrian lithostratigraphy as subdivided by different authors, compared on the basis of the absolute Time scale. (Holmes 1959).



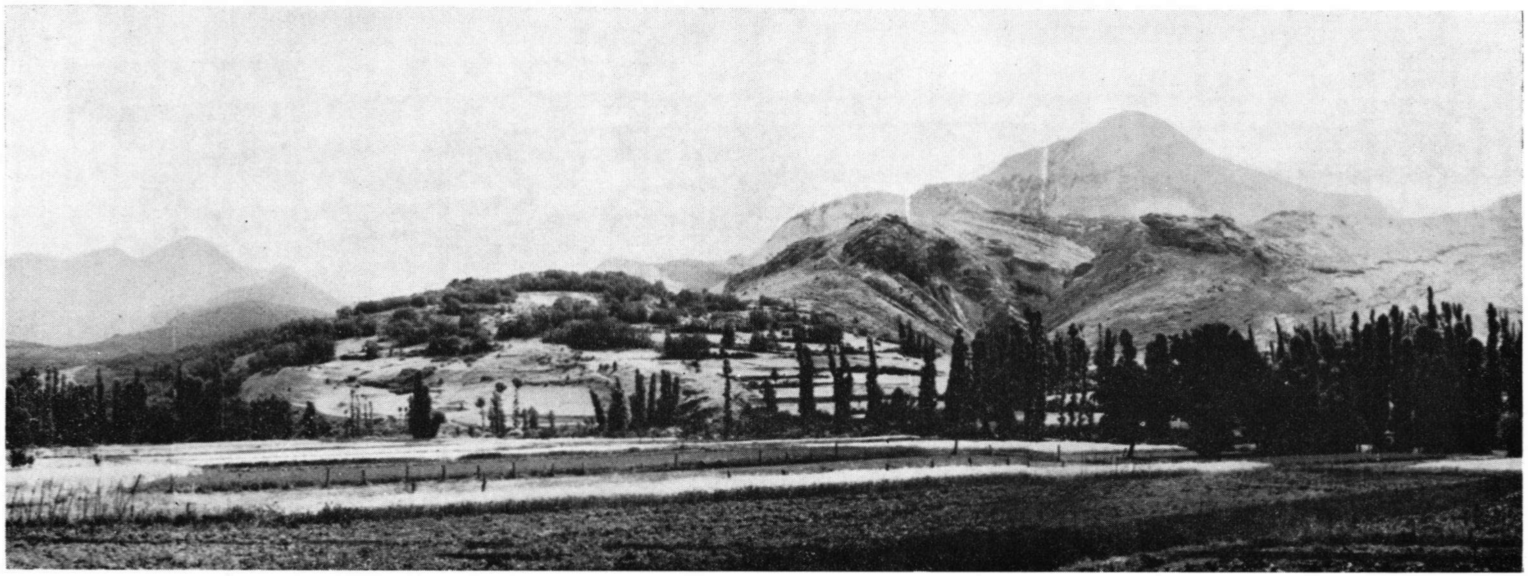


Fig. 3. The centre of the Agua Salio syncline; where the most complete stratigraphic succession is found.

The Las Salas zone: here Famennian and Visean rocks rest disconformably on Siegenian limestones or even Gedinnian to Ludlovian ferruginous sandstones.

This zone represents the most northerly facies of the area and contains the strongest development of the Upper Famennian hiatus.

Apart from these three areas the pre-Westphalian sequence is exposed in the west and east of the map sheet area. In the west we see the extreme noses of the Gayo, Bodon and Forcada thrusted structures together with the Armada unit.

The stratigraphy here can easily be compared with that in the areas east of Pardomino. The rôle of the Upper Devonian hiatus increases from Gayo to Forcada and Armada structure. When compared to the autochthone of Valdoré the latter shows a more complete lithostratigraphic record than either of the four western structures.

The Tournaisian is found only in the Gayo to Armada units.

In the east Middle Devonian to Lower Carboniferous rocks build the Valsurvio dome. Here quite a different lithostratigraphic character developed in Devonian times. The Valsurvio area has been described by Koopmans (1962).

The Upper Carboniferous rocks belong to two different facies of the Westphalian, that we find to the north of the Las Salas fault zone.

Two depressions in the pre-Stephanian rocks, i.e. in the south, the Valderueda—Sabero basin and in the north the elongate depression of Rucayo-Viego-Salamon along the Leon line (de Sitter 1962b) contain coal-bearing rocks. The Valderueda basin ranges from Westphalian D to Stephanian B in age, the northern depressions contain Stephanian B rocks. The Westphalian D — Stephanian B rocks are exhaustively described by my colleague H. M. Helmig (Helmig 1965).

The southern border zone of the mountain chain contains Cretaceous rocks unconformable on the folded Paleozoic of the area; they have been described in full detail by Ciry (1939).

In their turn the Cretaceous limestones are covered with angular unconformity by Tertiary conglomerates, that reach great thicknesses in the Duero basin.

Description of the stratigraphy is to be considered as a brief outline of rocks. Only where a difference in opinion with previous authors, mainly Comte (1939), exists more stratigraphic detail will be given. First follows a concise diagram of the rock units recognized in the field and drawn in on the map. The diagram shows the system Comte proposed as changed and extended by us to include all the rock types of the area (fig. 2).

Outline of Palaeozoic rock groups

The Palaeozoic is divided into five groups:

Cea formation containing a paralic to limnic sequence of conglomerates, sandstones, shales and coal beds generally ranging from Upper Westphalian D (at its base in the east) to Stephanian B (at its top in the west) in age.

Thickness: 1500—2000 m (see Helmig 1965).

Yuso Group containing a sequence of either: conglomerates, sandstones, shales and very few limestones and few floral or faunal evidence or: in a different facies thick limestones, shales and sandstones with an abundant fauna of micro-organisms. In fact these rocks represent the whole Westphalian rock sequence, that in the province of Oviedo builds the Asturian coal basin. There thicknesses grow over

5000 m, here nearer to the edge of the basin thickness totals from 1000—2500 m. Especially in the conglomerate sequence many hiatuses are suspected. The conglomerate facies has been described as Curavacas formation (Kanis 1957, de Sitter 1962). These rocks lie with marked unconformity on folded Upper Devonian and in fewer places on folded Lower Carboniferous rocks.

Ruesga Group composed of:

a. Black shales, griotte limestone and radiolarites. Cherts, black, green and red also occur.
Conodonts and Goniatites of Tournaisian to Lower Visean age connect the group to bio-stratigraphy. Thickness totals from 2 to 50 m.
The black shales and the griotte limestone form fine marker beds and have been exaggerated on the map.

b. Bituminous limestones, shales and sandstones each differing considerably in thickness from one section to the other. The complex is known under the name Caliza de Montaña.
The character of quick lateral facies changes has been described by Koopmans, it dominates the upper part of the formation.
The role of the Caliza deposits may be taken over completely by the following,

c. Culm series. These are defined (Koopmans 1962) as generally devoid of limestones mostly developed in conglomerates, sandstones, shales with very few, brecciated, limestones. Plant remains, few goniatites and Foraminifera have been found in rocks of type *b* and *c.*
The Ruesga group represents the Tournaisian, Upper Visean and Namurian, not counting the interruptions in sedimentation. On fusulinid determinations van Ginkel correlates this group as of Bashkirian age (fig. 30).
Thickness ranges from 400—800 m in the area. Rocks of the Ruesga Group type c are exposed in the region around the Monte Viejo Pass — Prioro. Here the boundary had to be chosen largely on tectonic arguments; the Culm beds resemble the Yuso beds very closely.

Bernesga Group: this group (de Sitter 1962b) comprises the total of formations building the Devonian of the region south of the León line. There is predominance of limestones over clastic rocks; connection between lithostratigraphy and biostratigraphy is well established due to the abundance of Spiriferid faunas throughout this part of the column. The so-called Fueyo hiatus below the Famennian sandstones and limestones may bring these sediments in paraconformable contact with from S to N progrssively older Devonian and Silurian rocks.

Luna group: this name (de Sitter 1962b) has been proposed for the whole of clastic rock types and few limestones building the Cambrian through Silurian sequence. In the presently discussed area the bottom part of the group is not outcropping. In sections along the Luna river and to the west of that river the base of the Herreria formation — base of the group — is unconformable upon folded, tilted and eroded schists of Precambrian age (de Sitter 1962a, Pastor Gomez 1962).

In sharp contrast with the Bernesga group, rocks of the Luna group yield fossils at few levels. Only the Acadian and Upper Llandoverian are relatively well dated with trilobites and graptolites.

By correlation with the lithostratigraphy proposed by Barrois for Asturias, in the northern slopes of the chain, Comte concludes to a hiatus of Upper Llandoverian to Llandeilo below the graptolite beds. This cannot be demonstrated in the field.

Deseription of formations and other rock units

This paper serves as a description of the greater part of the sheet Porma-Esla-Cea as published by the Geological Institute of the University of Leiden. Hence the briefest as possible and necessarily incomplete description of the outcropping formations is given below.

As far as the Devonian formations goes, special emphasis is put on differences between stratigraphic development in the different parts of the basin.

The Esla region belongs to those cratonic parts, that show a very intricate connection between structure and lithostratigraphy.

For further details concerning stratigraphy and sedimentology the reader should consult:

R. Ciry 1939	—	Cretaceous
J. M. Mabesoone 1959	—	Tertiary
P. Comte 1959	—	Cambrian to Carboniferous
R. H. Wagner 1955—1963	—	Stephanian
H. M. Helmig 1965	—	Stephanian
E. Oele 1964	—	Cambrian-Ordovician
L. Rácz 1964	—	Carboniferous

Papers dealing with Devonian and Carboniferous rocks are being prepared in the Geological Institute, Leiden.

Herreria Sandstone conglomerate formation

The Herreria formation is the oldest rock unit in the Esla-Porma area. It is exposed in the western part of the map sheet area, called Montes Pardominos and in the Bodon and Armada structures.

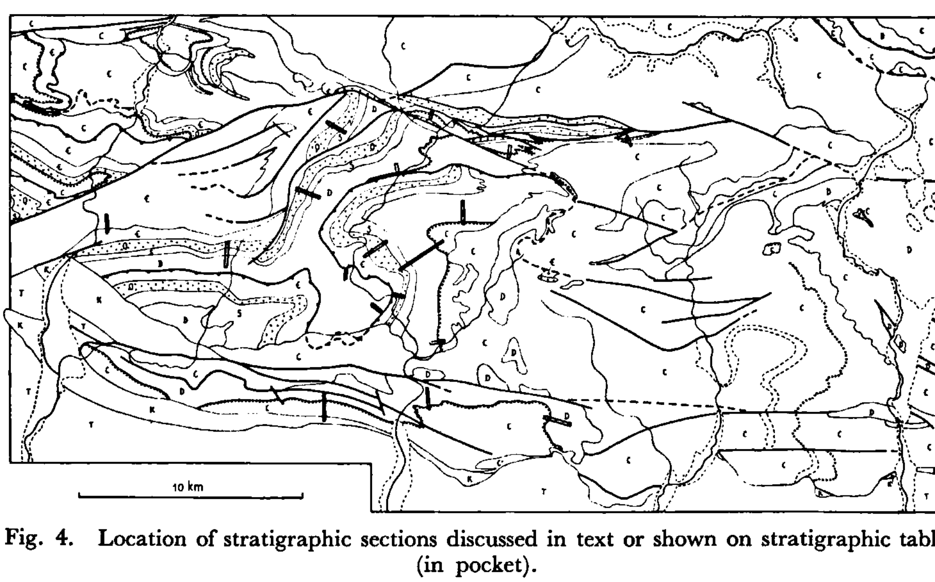


Fig. 4. Location of stratigraphic sections discussed in text or shown on stratigraphic table (in pocket).

The Montes Pardominos forms the autochtone to the Esla thrust sheet.

In the Esla nappe the Herreria formation does not crop out.

The Herreria rocks are made up of a very coarse shale-sandstone-conglomerate alternation more predominant near the base, to a mixture of fine layered micaceous shales and quartzites higher in the sequence.

Pebbles consist mostly of white to pink quartz. Very few metamorphic rock types have been observed among the pebbles. Matrix is felspar-rich sandy material. Rounding is moderate to quite good, sizes are from a few mm to 5 cm. cementation neither in the conglomeratic beds nor in the pure sandstone members is strong. Consequently the topography of the Pardomino area is quite rounded and exposure is poor except in stream cuts.

Bedding is irregular and ranges in thickness from 3 cm in the sandstones and shales to several meters in the coarser deposits. Shaly intercalations, that are more frequent near the top are finely (2-4 mm) laminated.

Crossbedding, ripple marks, sole markings and worm tracks on the greyish mica covered surfaces of the sandstones are frequent near the top.

In the Luna river section fossils of Lower Cambrian age have been collected by Lotze and Sdzuy from the top 50 m of Herreria beds. Below this section de Sitter 1962a) proved Precambrian rocks unconformably overlain by Herreria deposits.

In our area the only fossil evidence in this part of the column are trilobites from the overlying Lancara griotte beds. Herreria rocks range from Cambrian to Middle Cambrian in age.

Attempts to subdivide and determine real thickness for the Herreria formation were unsuccessful due to lack of exposures, absence of fossils and the tectonic complications in which the Herreria rocks of Pardomino area are involved.

Comte (1939) mentions 1400 m as total thickness of the Herreria rocks, Lotze (1961) gives no data on this subject. As is clearly shown on the map the exposure of Herreria rocks in the Montes Pardominos has its only normal boundary in the south where this clastic series in 10—15 meters quietly grades upward into the dolomites of the younger Lancara formation. This is easily verified near the village of Cerecedo on the left bank of the Rio Porma 4 km north of Boñar (see also Lotze 1961). West of Boñar the Herreria rocks make contact with the Cretaceous (fault) and Tertiary (unconformity) of the southern border zone.

In all other directions the great Pardomino expanse of Herreria sandstones is limited by faults.

In the east of the area between Pico Relance and Primajas several thrust faults clearly multiply stratigraphic thickness by at least a factor of 4. Not all these faults can be followed to the Rio Porma, but faulting certainly exaggerates the Herreria type section along the left bank of the river between Valdecastillo and Cerecedo, where Comte unluckily chose it.

Consequently I put the figure 600 m to the stratigraphic thickness instead of 1400 m as Comte does. About the same figure is derived from the section north of Valdecastillo in which the dam is being constructed. In this independent Bodon structure the Herreria is 550—710 m thick, although a thrust fault limits its base. A detailed sedimentological description of part of this section at La Braña in the Curueño valley can be found in Oele 1964.

Along the river Luna 50 km to the west in the previously mentioned sections not only the top, but also the base of the Herreria unconformable on previously folded Precambrian rocks, is known (de Sitter 1962a, Pastor Gomez 1963). There the thickness of Herreria beds certainly does not reach 1400 m.

Lotze (1961) reports that Cambrian (Cadaña) series rest unconformably on Assyntian folded rocks in the Sierra de la Demanda to the east of Burgos. The same is the case in the area around Palacios del Sil in northwestern León and Belmonte in Asturias. Both these areas, however, contain a more eugeosynclinal series than the presently discussed one.

The lithostratigraphic continuity of the bedding and the rock characteristics such as crossbedding, ripple marks and all sorts of flute and groove-like casts in the poorly sorted sediments of the Herreria lead to the opinion of near-shore deposition (deltaic?) in the aftermath of the tectonic movements, which produced the unconfirmity of the Herreria on the folded Precambrian schists known to the west.

Observations on crossbedding and sole markings in the Herreria beds of Pardomino point to a generally N-S transport direction.

The transition of the Herreria sandstones into the overlying Lancara dolomites has been studied in exposures along the road from Remellan to Oville and in the fresh exposure south of the damsite in the Porma river. There are no indications of a hiatus in deposition between the clastic and the carbonate series.

Lancara dolomite griotte formation

The Lancara formation is present throughout the area in autochthone and in the thrust sheet. In the nappe it acted as gliding horizon during the thrusting, hence it cannot be trusted to be complete everywhere; its sandy base partner, the Herreria, is never represented in the nappe, so part of the dolomites may be missing too. Elsewhere the Herreria takes part in the thrust plate as in the Bodon structure. The difference in competency between the clastic Herreria and the calcareous Lancara formations often favored detachment along this plane. A comparison between the nappe and autochthonous series does not show fundamental lithologic differences. The Lancara formation may be subdivided as follows:

C. Red, sometimes greenish, ferruginous shales and nodular griotte limestones containing trilobites, orthids and a concentration of broken trilobite shells, 15—28 m. thick.

B. Massive thickbedded (0,5—2,5 m) bluish-grey limestones. Glauconitic in part. Oolites frequent, also shoal breccias but no fossils. Dolomitization may also occur, 11—40 m. thick.

A. Yellow-weathering dolomites with fine crystalline texture; dolomitization seems connected to this level.

Sedimentary dolostone. Black shales intercalated and important near the base, 25—35 m. thick.

Level A probably represents a very condensed sequence.

In his study: „Das Kambrium Spaniens" 1961 F. Lotze discusses (p. 355) two sections through the Cambrian series of the region. The first, near Cerecedo, is situated in our autochthone, the second, near Verdiago, cuts the base of the Esla nappe. He then compared these sections using the faulty official 1 : 400.000 Spanish Geological map and concluded to a change in lithofacies from W to E. This change in facies should be read roughly N-S, due to the thrusting in which the Verdiago section, belonging to the Esla nappe, took part. This picture of N-S facies change suits even better Lotze's theory of the Cambrian geosyncline whose central depression ran from the Sierra de la Demanda through León (now covered by Tertiary) over the upper Sil valley into Asturias. Observations of Oele 1964 and the author rather well agree with Lotze's theory.

In the Esla area the rock unit succession finds its lowermost connection to biostratigraphy in the Lancara griotte. Trilobites are frequent and indicate a lower Middle-Cambrian age (Comte 1959, Lotze and Sdzuy 1961).

In the previously mentioned section at Barrios de Luna Lotze collected a Lower Cambrian fauna from what he calls the Ubergangsschichte. In the nomenclature of Comte these should be included in the upper part of the Herreria formation. As noted before the Luna section shows a fully exposed deposition from unfossiliferous Precambrian Mora schists to the Lower Palaeozoic Luna group.

It has been suggested, that the Lancara carbonate series may be seen as an increase in waterdepth after more active sedimentation shown by the Herreria sediments, but the shoal breccias in level B of the Lancara formation correlate better to shallow conditions together with an important decrease in production of clastic material. In fact the rocks demonstrate a striking similarity between this part of the geologic record and the Tournaisian-Visean column. Both have the combination black shales-nodular limestone.

In the Cambrian the black shales are intercalated with continuous dolomite layers, in the Lower Carboniferous the black shales are closer to the griotte beds (see Stratigraphic table at back). Higgins (Higgins et al. 1964) shows the Carboniferous black shales - griotte series to bear proof of slow sedimentation and erosion i.e. in the Bernesga region. In analogy to the Carboniferous, the Cambrian black shale - griotte limestone are an extremely condensed sequence (though not interrupted) is seen. Fossil evidence, however, is lacking (see also Lindström 1960).

Oville shale-sandstone formation

The vertical transition of the Lancara rocks into the overlying Oville shale sandstone forms a depositional sequence with slow but increasing sedimentation velocity.

On top of the red Lancara shales and griotte limestone we find a 180—260 m thick series of grey-greenish and brown shales alternating with sometimes calcareous yellow sandstones. The lower part contains most shales and some nodular marls, the top carries more sandy and quartzitic beds. Pyrite in the green shales, glauconite and haematite in the decalcified sandstones are common. Flecks of mica are abundant near the top of the quartzitic sandstones.

For mapping convenience the limit with the overlying Barrios quartzites is chosen where a thick quartzite layer stands out with appreciable relief in nappe and autochthone.

In the layers directly over the Lancara griotte a horizon with brown weathering glauconite admixture is very characteristic and useful as marker bed. These lower beds have also yielded trilobites of Acadian age.

In the Middle and Upper Oville formation we find no reliable connection with biostratigraphy. Only *Scolithus linearis;* remains of animal borings, has been encountered. Bedding surfaces may literally be covered by animal tracks. Still the Upper Oville is held to represent the Potsdamian and Tremadocian.

In general the Oville is found in the valleys, cementation is strong only in the upper quartzite layers. An interesting example of slumping is to be seen 1½ km to the north of Valdoré where the road crosses the river Esla. On the eastern bank the river has cut a fresh exposure in a sandstone - silty shale alternated series.

Vertical distance to the massive Barrios quartzites is 50 m. Here a 5 m thick sequence shows two horizons of slumping. The slumped „balls" are 20—120 cm big, rounded and rolled at southern, and sharp nosed at their northern ends. Also the movement shown by the silt fraction around the slumps is best explained by assuming a slumping direction from north to south (see also Oele 1964, p. 68—71).

The upper part of the Oville formation often bears igneous masses of a generally subaqueous extrusive character. The dimensions of the doleritic sill-like bodies are up to 800 m in length and from 5 to 150 m in width. Flow structures, ejecta of the surrounding sandstones and gas bubbles in lapilli have been observed. Contact margins are absent. The mineral composition is described by Comte (1959 p. 74), but the division between a first and second generation of crystals was, however, not observed. The same type of sills occurs in the Oville, Barrios and Formigoso formations.

A map connection between this Ordovician—Silurian igneous complex and the more acid intrusive complex in the Westphalian rocks of the zone Riaño - Cervera cannot be established. Mineral composition is also different in these two complexes. The conclusion of Comte's, that the dolerite bodies of the Oville formation are of pre-Stephanian age is inexact, they belong to Ordovician-Silurian times and may signify a vague expression of the Caledonian orogeny. Mineral composition and way of emplacement of the dolerite sills and pipes is the same in the thrust sheet and in the autochthose. These rocks weather quickly, and often form locally important aquifers.

After the Herreria-Lancara cycle the Oville sediments seem to mark a quickening of sedimentation in a offshore but epicontinental environment.

Barrios-quartzite formation

The Barrios quartzite formation does not have a well defined lower boundary. Sandstone beds grow thicker and gradually more quartzitic when ascending the succession from Upper Oville level to the basal parts of the Barrios formation. The white and flesh-coloured quartzites grow very thick (single beds 20 m) near the top of the Barrios formation. Thickness totals from 260—500 m.

The Lower Barrios quartzites have a high content of white micaflakes covering the bedding planes of the quartzites and forming many shaly intercalations 1—200 cm thick. These mica flakes have been determined as phengite by Oele (1964), who considers this mineral characteristic for the Barrios quartzite formation.

Cementation in the quartzites is strong, grain boundaries are obscured by secondary growth of silica.

All through the Barrios rocks dots of fresh and decomposed pyrite crystals form a conspicuous component of the white orthoquartzites.

Crossbedding is very frequent in the Barrios rocks of nappe and autochthone. In the Esla thrust sheet no coarse beds are found in the Barrios formation; of the Esla autochthone the top layers are conglomeratic with pebbles up to 2,5 cm in size near Boñar and Corniero. This sedimentological tendency would confirm a transport direction from north to south.

The igneous rocks mentioned above under the heading of Oville formation also occur in the midst of the Barrios quartzite outcrops but here seem slightly more acid in composition (Comte 1959).

The age of the Barrios sediments should be Llanvirnian to Arenigian but this could nowhere be positively ascertained. The animal track *Cruziana furcifera* is widely used to determine the Ordovician of Spain. The only species of *Cruziana?* found in the Esla area stems from much higher beds.

As a depositional environment of the Barrios quartzites I accept shallow water very near to shore conditions with rapid sedimentation.

A correlation of Barrios quartzites-with Grès Armoricains I reject; no transgressive character of the former is found. A second cycle in erosion and sedimentation comes to a close with the top Barrios beds. A hiatus between these and the overlying graptolite shales as table fig. 2 shows, becomes very likely (see also Comte 1959).

Formigoso shale-sandstone formation

A change in lithology from the thick top layer (15—20 m) of white orthoquartzite to thin splintery often black graptolite shales forms the boundary between Barrios formation and Formigoso formation. The higher part of the Formigoso formation demonstrates a growing amount of thin (1—20 cm) sandstone intercalations. Total thickness 60—180 m. Because of tectonic thickening a wide range in thickness is measured in the incompetent Formigoso beds. In the nappe the black shales are not very typical and did not yield graptolites. In the autochthone the equivalent section near Valbuena de Roblo yielded many monograptids and rhynchonellids which led Comte to date this formation as of Llandoverian to Lower Wenlockian age. In the nappe section the Upper Formigoso contains a ferruginous sandstone of 40 cm thickness. In this as in other younger iron sandstones white weathering pellets of volcanic material are observed.

Limonite and haematite occur frequently on markings especially in the top part of the section.

The sudden change in lithology from quartzites to black shales, correlation to Asturias and lack of fossil zones, that are recognized in Asturias brought Comte to suppose a stratigraphic break comprising the Upper Llanvirnian to the Lower Llandoverian. Like the Upper Famennian hiatus, the hiatus at the base of the Formigoso formation never shows as an angular unconformity. This applies to the whole region from Esla to Luna river (see table in pocket). As known now, the black shales facies correlates rather to a lack of oxygen than to depth of sedimentation. The noted difference in black shale content between the nappe and the autochthone might be interpreted as proof for this tendency.

San Pedro sandstone formation

The San Pedro formation clearly splits into a lower and upper part. The basal layers consist of thick bedded (0,5—4 m) ferruginous sandstones with a medium grain size. In these an abundance of volcanic pellets and in places clay slivers can be found. Iron content is near 40 % in the autochthone of the area around Corniero. Chemical alteration of calcareous sandstone into haematite-rich sandstone like Comte 1959 assumes on authority of. A Cailleux may have been active on a small scale. Proof for this process is seen in partly altered crinoid stems. Nevertheless we find no solution holes; the sandstone is crossbedded and in some places sharply bounded by pure green shales without a trace of carbonate content. Consequently a primary transport of the iron sandstone is preferred. Perhaps the origin may be connected with the volcanic activity, that produced the glass pellets enclosed in the ferruginous beds. The Lower San Pedro is 20—45 m thick. On top of the iron

Fig. 5. San Pedro formation: crossbedding and ripplemarks in autochthone. (Photo by V. Adr. Boogaert).

Fig. 6. San Pedro formation: print of Crustacean (Photo by V. Adr. Boogaert).

beds a sequence of dark-brown, sometimes green sandstones and shales is found. In these beds a great many tracks of crawling and burrowing animals have been conserved. The top of the San Pedro formation has been dated by Comte as of Upper Ludlow and Lower Gedinnian age. Hence the boundary between the Silurian and Devonian lies in the upper half of the San Pedro section. In the Esla region only one fossil locality is found near Adrados. A doubtful specimen of *Cruziana* stems from the Lower San Pedro beds NE of Corniero. Thickness of the Upper San Pedro formation is 110—190 m in the nappe and autochthone respectively.

After the very low sedimentation rate, recorded by the black shale facies of the Formigoso formation the San Pedro rocks again represent rapid sedimentation in a near shore environment.

La Vid limestone-shale formation

The La Vid formation is a complex of four lithologic units:

a. yellow weathering thinly bedded S dolostones (in the sense of Dunbar and Rodgers) with a fine crystalline texture and few fossils (brachiopods, trilobites). Thickness ranges from 25—80 m. The dolomites form the most resistant part of the La Vid formation. In the autochthone the dolostones are thicker than in the nappe.

b. grey-bluish thinly bedded fetid limestones at the base intercalated with and wedging out into black shales. These beds contain many trilobites, brachiopods, tabulates and conodonts. In the autochthone they are replaced by less bituminous limestones and brown shales with few fossils. Thickness: 25 m in the autochthone and 40 m in the nappe.

In the Esla nappe the bituminous complex is overlain by 20 m of massive and thick bedded grey-blue limestones, that have not been encountered in the autochthone of Valdoré.

c. a succession of brown shales and marls. Often the marls show a pink (manganese?) surface. These beds carry a great quantity of fossil debris and form a source of brachiopods, solitary corals, crinoids and conodonts, that give determinations of Lower Emsian.

Thickness: 15—35 m.

This sequence is ended with a horizon of 1—2 m, consisting of small bioherms, that are especially well developed in the autochthone near Velilla.

d. a sequence of brown-greenish splintery shales and marls, topped by 2 levels consisting of red limestone built of a concentrate of crinoid stems. The limestones are separated by 10 m of brown-purplish shales. Many brachiopods, crinoids have been sampled here. Total thickness member d: 70—90 m.

In the autochthone the red top of the La Vid formation is thicker and to the SW tends to be developed in limestone exclusively.

The equivalent La Vid sections of autochthone and nappe show no fundamental differences.

In the tectonically complicated Las Salas fracture zone elements of members *a*, *b* and *c* could be recognized in a reduced sequence. At the extreme E near Peña Teja and in sections S of the arroyo de Remolina even the red debris limestone is conserved. Elsewhere the transgressive Ermitage rocks overlie member c of the La Vid formation. Total thickness of La Vid formation in the Las Salas zone: 15-20 m W of Las Salas village, 20—60 m E of Las Salas village.

This evidence demonstrates, that already during the Lower Devonian this zone shows activity of uplift. The autochthonous La Vid rocks have a comparable thickness everywhere around the Pardomino region. As will be shown in the case of other formations, thickness suddenly drops to about 30 m when crossing the arroyo Riochiu, imaginary boundary between the Las Salas zone and the autochthone of Valdoré.

The La Vid sediments seem to have been deposited in quiet water, with relatively small inflow of terrigenous material.

Santa Lucia limestone formation

The Santa Lucia limestone formation consists almost exclusively of limestones and dolomites with very few shales. Four members above the La Vid red debris limestone have been recognized in the field:

a. a sequence of grey layered almost sterile limestones	15—20 m
a sequence of massive blue thickbedded limestones	50—70 m
a sequence of homogeneous pink dolostone	10—15 m

The dolostone seems restricted to this horizon and is considered as of sedimentary origin.

b. Biostromal and biohermal limestones going over in medium grained crystalline detrital limestones.

Fossils: Tabulates, solitary Rugose and Stromatoporoids. Dolomitization occurs at various places. Thickness: 25—45 m.

c. Fine crystalline thick to thin bedded limestones; in which concretions are frequent The limestones often thin out and are intercalated with yellow greenish shales. In the autochthone this member shows desiccation cracks in the limestone in exposures just north of the road Las Salas — Salomon. (fig. 7). This member may grow very thickbedded near the top. Fossil content is poor and the fossils, that are present are heavily silicified. Total thickness: 95—130 m.

d. At various places a medium grained often griotte-like detrital limestone is developed at the top of the Santa Lucia formation. This red top has intermittantly been observed in the autochthone of Valdoré and the Esla nappe and has yielded *Spirifer cultrijugatus* in great quantities. This horizon is correlated with the Lower Eifelian by Comte. Thickness: 5—10 m.

Quite independently from the mentioned dolomite horizons the thickbedded massive Santa Lucia limestones often turn into equally massive T. dolostone. This tectonic dolomitization is complete in the area SW of Las Salas near the mouth of the Riochiu. Mineralizations accompany this process.

The development of the Santa Lucia rocks in the nappe closely resembles that in the autochthone of Valdoré, the latter area shows a tendency to have a slightly more argillaceous facies in member c.

In the Las Salas zone we encounter Santa Lucia rocks twice in a concordant position on top of the La Vid shales (see description of La Vid formation). Whether the tendency of reduced thickness that the La Vid here demonstrates also applies to the Santa Lucia formation cannot be verified for lack of fossil zones in the Santa Lucia rocks. In the Las Salas fracture zone pockets of Fe-sandstone and Upper Devonian limestone rest unconformably on 40—5 m of thick bedded St. Lucia limestone.

Fig. 7. Synsedimentary cracks in Santa Lucia limestone; in autochthone of Valdoré (Photo by V. Adr. Boogaert).

Chemical deposition is supposed to have been very active during Upper Emsian and Lower Eifelian times. Water depths are shown to have been very shallow in parts of the autochthone.

Thickness figures for the Santa Lucia limestone as measured in nappe match those taken from the autochthone quite well. Total thickness: 240—300 m.

Huergas sandstone-shale formation

The Huergas formation consists of three separate members:

a. dark brown powdery shales and sandstones, limonitic and haematitic, bearing a horizon of trilobite-, brachiopod- and rugose casts. Thickness: 10—50 m.

These shales and sandstones overly the top of the Santa Lucia formation with a remarkably sharp contact. No traces of erosion on this contact have been observed.

b. Medium to thick bedded brown weathering sandstones and quartzitic sandstones. On a fresh surface Fe containing rock shows the green Fe_3O_4 colour.

Decalcification is very active. Crossbedding is frequently observed. Beds are thinner higher in the sequence. Thickness: 20—50 m.

c. The uppermost part of the Huergas formation is composed of soft brown decalcified sandstones at the top intercalated with shales. At a level app. 45 m below the overlying Portilla limestone a 30 cm thick sandstone occurs. This layer consists of a concentrate of brachiopods, that give a Lower Givetian age.

Thickness: 160—260 m. The wide variation in thickness occurs in the shaly part and is due to tectonic deformation.

Total thickness is: 220—320 m in the autochthone
180—240 m in the nappe.

In the Las Salas zone it does not occur.

Differences in development between the two units; nappe and autochthone exist: shaly facies of member c in the nappe as against predominant calcareous sandstones in the autochthone. Again the Huergas formation represents epicontinental conditions with slightly higher input of terrigenous material. At other places in the mountain chain the Upper Eifelian and Lower Givetian are developed in a mixed clastic carbonate rock facies.

Portilla limestone formation

The Portilla limestone formation is split into 5 members. All can be recognized in the nappe and the southern part of the autochthone of Valdoré. In the northern half of the area the Portilla is incomplete due to the Upper Devonian hiatus. In the Las Salas zone no Portilla rocks are present.

Fig. 8. Crossbedded Portilla limestone.

a. yellow-weathering thin layered arenaceous limestones, that are coarse grained, detrital and rich in brachiopods and corals. An Upper Givetian age is derived from this horizon by Comte (confirmed on conodonts by van Adrichem Boogaert). Shale lenses are frequent. Crossbedding is observed in the bottom-, oölites in the top layers.

Thickness: 40—45 m in the nappe
15—25 m in the autochthone.

b. This member consists of massive fine to medium grained limestone, that is thick bedded and forms prominant scarps in the landscape.

In the nappe the top part of this member contains reef deposits, that are poorly developed in the autochthone.

Thickness: 50—55 m in the nappe
30—35 m in the autochthone.

c. Well layered detrital limestones; in the nappe many shale lenses are intercalated in the sequence. Traces of reef building activity are abundant in the top beds of this member.

Thickness: 25—35 m in the nappe
5—15 m in the autochthone.

d. Massive white often chert-bearing fine-crystalline limestone often developed as one thick band, that is relief forming. At the top silicified reef building organisms occur.

Thickness: 25 m in the nappe
15—20 m in the autochthone.

Total thickness of Portilla formation ranges from 180—200 m in the Agua Salio syncline to 110—135 m in the Peña Corada syncline. Both these belong to the nappe. In the southern part of the autochthone of Valdoré — i.e. south of Valdoré — the Portilla is 105—125 m thick. In general this tendency of greater thicknesses of the nappe section correlates with a higher content of clastic material (shale lenses) in the nappe Portilla section.

The Upper Devonian sandstone sequence

The Upper Devonian rocks vary considerably in composition and total thickness in nappe and autochthone and within these units. Before discussing the separate formations we give a separate introduction for this part of the rock sequence.

After defining the Devonian succession of the region around the Bernesga valley, P. Comte (1959) compares the most complete rock sequence, which occurs near Pola de Gordon with Devonian outcrops in the adjoining parts.

For a better understanding of the Devonian sequence in the presently discussed area we should start with a discussion of Comte's results. For reasons of comparison the Pola de Gordon section is given together with results of the Esla area (see table in back of this paper).

There is a discrepancy between Comte's and our observations. On p. 212—214 Comte (1959) describes the Valdoré Upper Devonian section, on top of Frasnian limestones Comte mentions:

6. calcareous sandstones and arenaceous shales decalcified	10 m
7. white to reddish limestone with crinoids	2 m
8. greyish blue clear thin bedded limestone	0- 2 m

On top of these, Cambrian beds, that form the base of the Esla nappe, are thrusted.

Comte places no. 6, 7 and 8 in the Calcaire de Valdoré — a calcareous lateral development of the Nocedo formation — a name for which he finds no justification in other sections.

The beds no. 6 we place in the Nocedo formation. On macrofossil evidence Comte places no 7 and 8 in the Frasnian, from 7 and 8, which we handle as one unit, Mr. van Adrichem Boogaert collected conodonts of Upper Famennian age. Further it must be noted, that palaeontologists and stratigraphers still have a very wide range in opinion as regards correlation of spirifer information from Belgium to Spain (Krantz, Vander Camme pers. comm.) Consequently we place the Upper Devonian (Fueyo) hiatus below unit no. 7.

On the one hand the arenaceous beds below no 7 can be followed to the southeast till they reach a thickness of 50 m at Verdiago.

The crossbedded arenaceous limestone (Comte's no 7 and 8) can be followed to the north beneath the Esla thrust till we reach the Las Salas zone. These beds are shown on our map with the same lightgreen colour as the Nocedo formation is indicated with, but a wavy black line indicates the base of the transgressive Ermitage formation.

The outcrop of Upper Devonian sandstones near the village of Valdecastillo in the Porma valley has drawn our special attention. Here Comte (1959) describes a 1000 m thick shale-sandstone-quartzite sequence, thus building an exceptionally thick Ermitage formation. Mapping now shows clearly that only the uppermost 20 meters represent the Upper Devonian; the rest of the sandstone-quartzite complex belongs to the Ordovician and Upper Cambrian. It is the Upper Devonian hiatus, that is responsible here for a deceptive paraconformable contact between formations of almost identical lithology. Only the last 10 m of sandstone directly beneath Lower Carboniferous shale and griotte limestone have yielded a Famennian fauna both to Comte and the author (see Comte 1959, p. 204, p. 315, p. 326).

The resulting picture now is, that the Bernesga profile of Pola de Gordon besides containing the most complete Devonian section of the region also bears the thickest post-hiatus development; the Ermitage formation there is appoximately 140 m thick not counting the 100 m shales of Comte's Fueyo formation. The latter are now (personal communication van Dillewijn) demoted to a member of the Nocedo formation (see Comte 1959, p. 192, p. 193).

A comparable development of the Upper Devonian section is extensively developed in the Esla nappe, there 100 m of sandstones and quartzites form the Ermitage formation. Outside the Esla nappe and the Bregon structure (de Sitter 1962) or Alba syncline, the Ermitage formation never attains a thickness of more than app. 20 m (see also table with strat. columns in back).

Nocedo sandstone-limestone formation

The Nocedo formation is present in the Esla nappe; the basal part of the Nocedo crops out in the southern part of the autochthone i.e. south of Velilla and Valdoré. In the Las Salas zone it is lacking.

In the nappe the formation consists of app. 250 m clastic beds, the base is formed by soft coarse grained yellow decalcified sandstones. These may become marly and grade upwards in reddish very coarse detrital arenaceous limestones; these are topped by medium grained white limestones. The limestone member is called Crèmenes limestone after the village, where it attains its most complete and pure development. On top of this complex follows again a porous decalcified sandstone series with a thickness of 40—50 m.

The detrital beds may become conglomeratic with pebbles up to 3,5 cm, consisting of ferruginous sandstone. The iron-oxide pebbles are especially frequent in the lower limestone beds.

Dating of the Crèmenes limestone was done by Mr. Th. Krans who concluded to a probable Frasnian age on a excellent spirifer fauna collected east of Crèmenes.

It should be mentioned here that determinations by Comte and correlation of the Spanish Upper Devonian spirifer faunas to those of the type area are still being scrutinized: revision by Krans is in preparation.

Correlation of the Upper Devonian nappe section to its autochthonous counterpart was attempted by Mr. v. Adrichem Boogaert, but as the Crèmenes limestone was barren of conodonts he was unsuccessful.

Here comparison of the nappe section with that of the Las Salas zone on a lithological basis provided help. In the northern slope above the Arroyo de Remolina situated in the Las Salas zone the following sequence was found below the Caliza de Montaña:

20 m	red cherts and griotte limestone	goniatites
10 m	quartzites	no fossils
10—15 m	quartzites and sandstones decalcified	*Spirifer verneuilli*
30—75 m	ferruginous sandstones	pebble-beach beds at top.

The ferruginous sandstones belong to the San Pedro formation, at several places graptolite shales of the Formigoso formation do outcrop.

At various places north of the Arroyo ferruginous pebble beds mark the contact between the San Pedro rocks and the overlying Upper Devonian. The pebble beds have been interpretated as a possible source for the similar Fe pebble conglomerate interbedded in and below the Crèmenes limestone of the nappe. Our conclusion is, that the erosion products of the Las Salas uplift, here in situ, are to the south included in the Nocedo sediments, that have been thrusted 15 to 20 km from the south to a position next to the former sediment-producing ridge.

The hiatus that Comte defined below the Fueyo shales in the Pola de Gordon section here explains the absence of La Vid to Nocedo formations. This situation is considered typical for the northern part of the region (see also Comte 1959, de Sitter 1962 and the description of Ermitage formation).

In the autochthone of Valdoré the lowermost 50 m of the Nodeco is represented by yellow decalcified sandstones with crinoid debris grading upwards into purple more massive ironstained sandstones and yellowish brown fine shales with brachiopod fragments (cemetery of Valdoré). The 50 m of Nocedo sandstones present at Verdiago are reduced to 10 m at Valdoré and 0 m at Velilla, the same crossbedded Ermitage limestone overlying it everywhere. This Nocedo section shows no differences of major importance when compared to the basal 50 m of the Nocedo rocks present in the nappe.

The Ermitage sandstone-limestone formation

The Ermitage formation varies considerably in composition and thickness. It is encountered in all major stratigraphic and tectonic units of the Esla-Porma area.

As is shown in the lithostratigraphic table in the back of this paper, the development of the Ermitage formation, as found in the Agua Salio and Peña Corada synclines, resembles that of the equivalent Bernesga section of Comte quite closely. Here, as in the Bernesga section, it is very difficult to locate the horizon of the Upper Devonian hiatus at the base of the transgressive Ermitage formation.

In the Peña Corada unit the upper 40—50 meters of white-reddish, often calcareous, quartzitic sandstones immediately below the Alba griotte yield specimens of

Camarotoechia letiensis indicating the Upper Famennian (Comte p. 216). These rocks represent the Ermitage formation.

In the Agua Salio syncline the Ermitage formation is represented by app. 80 m of thick bedded white quartzites. No conclusive fossil evidence has been found, nevertheless our conclusion must be: Upper Famennian. Probably the Lower Famennian is the maximum range for the Fueyo hiatus in the Esla nappe.

In the autochthone of Valdoré s.l. the Ermitage formation is a 5—10 m thick limestone dated with conodonts at several places in the Esla and Porma region (see description Valdoré section). In mapping the Ermitage beds here, the crossbedded nature (admixture of ferruginous sand and the presence of small Fe sand pockets at the base, are very useful (see fig. 9).

Where the transgressive Ermitage beds are in contact with equally calcareous beds of the Portilla formation, as is the case in the area between Valdoré and the Arroyo Riochiu, mapping is extremely difficult.

Summing up the evidence in the autochthone of Valdoré we see, that at Verdiago the Fueyo lacuna encompasses the Lower Famennian and Upper Frasnian; going north in the same tectonic unit also the Lower Frasnian and Upper Givetian limestone below the Ermitage crossbedded limestone are missing.

In the Las Salas zone the Ermitage formation is even more variable in composition. One kilometer west of the Las Salas village the crossbedded Ermitage limestone (4 m thick) rests on what seems to be a lens of reworked shales (15—20 m) of the La Vid formation, a limestone dated with conodonts as Siegenian follows underneath (0—10 m).

In the already mentioned sections halfway along the Arroyo de Remolina the crossbedded Ermitage limestone is substituted by a decalcified ferruginous sand-

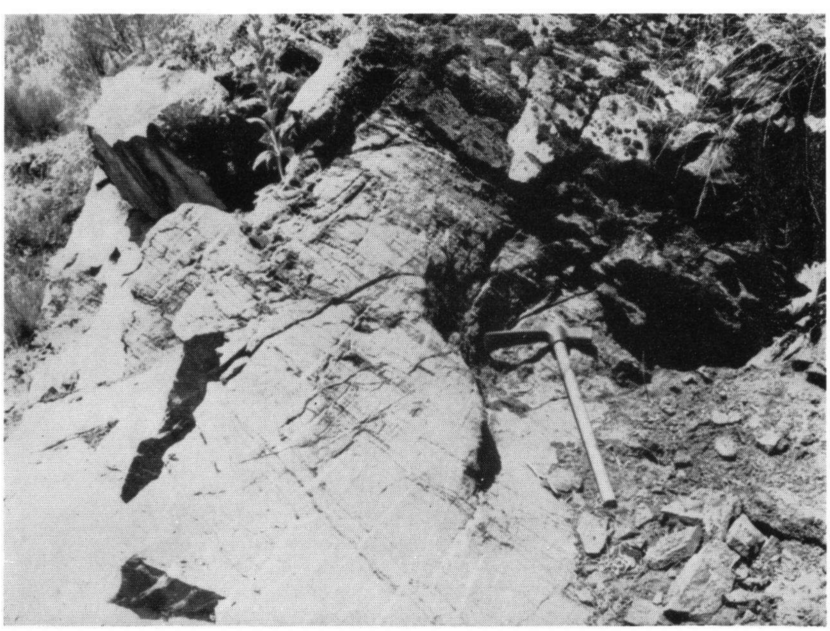


Fig. 9. Coarse, sandy Ermitage limestone, shows crossbedding and grades into pebbly ferruginous sandstone (in autochthone).

stone resting on a pebble bed of reworked San Pedro rocks, most often this section is topped by 10 m of white quartzitic sandstone directly underneath the Alba griotte. This complex ranges in thickness from 20—50 m, the decalcified sandstone yields *Spirifer verneuilli* together with crinoid fragments. Here because of its position in the Las Salas zone these fossils point to deposition posterior to the Fueyo hiatus for the sandstones. Further to the east near Peña Teja the crossbedded limestone reappears and paraconformably overlies the La Vid shales.

In the western and northwestern part of the map area the Gayo, Bodon and Armada structures show a stratigraphic development of the Devonian ranging from that of the autochthone of Valdoré to that of the Las Salas zone.

The transgressive Upper Devonian sandstones (approximately 20 m) paraconformably overly the La Vid formation in the Gayo unit in the south, whilst in the Bodon and Armada structures the Ordovician Barrios quartzites are overlain by an equally developed Ermitage formation (see also de Sitter 1962b, Comte 1959). Conodonts indicate a Strunian limestone layer (1 m) in this part of the sequence e.g. in the Gayo unit E of the Rio Porma. In these western thrust units the Upper Devonian hiatus again reaches progressively deeper in the Devonian and Silurian sequence as we go from the south to the north.

Ruesga group

In this group the following rock types are assembled:

Vegamian black shales

Black cherty shales 0—2 m thick (Comte's Vegamian Beds). This marker bed is not found in the Esla area, neither in nappe nor autochthone.

To the east in the Valsurvio dome it is not reported by Koopmans (1962). In the Pisuerga basin black cherts do occur, but have as yet not been dated.

To the west of the Esla area black cherts and shales occur intermittantly in the Bodon and Gayo units etc. (see Higgins etc. 1964). In the Bernesga region Higgins extracted conodonts of Tournaisian age from beds at the base and top of the black shales.

To the north in the Asturides (de Sitter 1962b, van Adrichem Boogaert 1963) equivalent black shale deposits seem to be present in the region around Isidro, Tarna and Ponton passes.

Before continuing we must make a historical note:

For the Esla area two possibilities exist:

1⁰ The Pardomino and Las Salas areas acted as barriers between a black shale facies to the west and north and a different one in the Esla area or:

2⁰ The area bounded by Pardomino and Las Salas zone has been uplifted during post-Tournaisian and pre-Upper Visean times so as to erode previously deposited black shales. Higgins reports similar movements in the Bernesga area, that may have been restricted to a few meters. Considering his results and the extreme thin dimension of the black shale section the second explanation is more likely. Finally there is a remarkable correlation between these Tournaisian shales and similar deposits in the Pyrenees as Ziegler (1959) and de Sitter (1957, 1962b) have pointed out. The black shales have been called „Schistes de Vegamian" by Comte (1959).

Alba griotte limestone.

In a section of variable thickness we find the Alba griotte on top of the Ermitage quartzites or the black shales; east and west of Pardomino respectively. As the previously described black shales it is an extremely condensed series.

The Alba griotte is a red, sometimes greenish grey, nodular limestone. The nodules may float in the shale surrounding it, in other exposures the griotte formation is reduced to 2 meters of pink-coloured limestone at the base of the Upper Visean — Namurian fetid limestone sequence.

At those places, where the overlying member of the Ruesga group is developed in shales, the Alba griotte is often substituted by 5—10 m of fine dark-red purplish shales (Peña Corada zone); at other places the shales precede the nodular limestone horizon (Agua Salio syncline near Santa Olaja in which the griotte varies in thickness from 2 to 20 meters.

In the autochthone of Valdoré the Alba formation is confined to a layer of 3 m of pink limestone near Verdiago and at Velilla. In other places the Esla nappe rests on older strata of the Devonian.

In the Las Salas zone the Alba griotte is developed as in the Esla nappe, varying from 1 m pink limestone to 20 m of red nodular limestone and chert.

Kullmann (1961) has dated the Alba griotte in the Esla area on its Cephalopoda as uppermost Lower Visean to Upper Visean. This dating is confirmed by van Adrichem Boogaert on conodonts collected from autochthone and nappe (Boogaert pers. comm.).

In the Esla area the griotte rests directly on upper Devonian quartzites or limestone; the whole of the Tournaisian and part of the Lower Visean are absent in the Esla area.

C. H. T. Wagner-Gentis has carefully investigated the griotte section at the base of the Caliza de Montaña section E of Santa Olaja. This section is continuous in the Esla nappe.

Further to the east the Sierra del Brezo and Valsurvio areas do not bear black shales. From the area around Cardaño to the north of the Leon line now being worked by van Veen et al, the Tournaisian is reported (see also map in de Sitter 1962b).

Total thickness of the Alba griotte ranges:

0—20 m in the nappe
2— ? m in the autochthone of Valdoré
5—20 m in the Las Salas zone

The picture, that we get from the distribution of datings of griotte faunas (Wagner-Gentis 1963, Kullmann 1961, and van Adrichem Boogaert personal communication) does fit our deductions as regards the role of Pardomino and Las Salas uplifts during these times. The above mentioned authors agree on an upper Visean to lower Namurian age for the griotte limestone. In the area of dated Visean griottes of the Esla region no black shales occur.

Theories for understanding the depositional environment of griotte type rocks have varied greatly. In our case a slow rate of sedimentation with occasional solution under shallow but quiet water conditions during a period of small epeirogenic movements stretching from Upper Devonian into Lower Carboniferous times seems adequate to explain the situation.

Caliza de Montaña limestone-shale formation

The Alba griotte is folowed by the Caliza de Montaña formation. It consists of very fine grained, dark grey-blue bituminous limestones, thinly laminated and practically barren of recognizable organic material. Probably the limestone was deposited chemically in an euxinic environment. Sometimes the base is developed in a shaly facies directly overlying the Alba griotte as happens in the southern Peña Corada unit. Generally though, shales and greywackes occur higher in the sequence on top of the euxinic complex. The upper part of the formation is less bituminous. Light grey and medium-grained rather clear limestones carry gastropods and in adjacent areas Algae and Foraminifera, that place the complex in the Bashkirian (fig. no 30) have been found. In the chain the Bashkirian must be correlated with our Viseo-Namurian, Caliza de Montaña limestone complex according to van Ginkel (1963) and Racz (1964).

Thickness of the Caliza de Montaña formation:

in the nappe (Agua Salio syncline)	700—800 m
in the autochthone (P. Jano syncline)	> 500 m
in the Las Salas zone (complicated structure)	> 200? m
in the area of Peñas Pintas to Pico Gilbo	600—800 m

The contact Alba griotte — Caliza de Montaña limestone has been observed closely throughout the area but no signs of interruption in sedimentation have been found.

When comparing the different outcrops of and sections through the Lower Carboniferous limestone and shale complex it appears very clear, that from north to south the composition of the Caliza de Montaña formation s.l. changes from 80 % limestone 20 % shale-sandstone ratio in the north to a 50—50 limestone — shale-sandstone ratio in the Peña Corada zone in the south.

Thus the source of Viseo-Namurian sediments situated to the south of the area becomes likely. The recent study of Tournaisian rocks to the west by Higgins, Wagner etc. (1964) point to the same tendency in the area west of the Pardomino uplift.

Culm facies

The Culm-type rocks in the area consist of shales, sandstones, graywackes with occasional microconglomerates and limestone conglomerates passing laterally in limestones. It is a hard to typify sequence, that must be regarded as a lateral facies of the previously described Caliza de Montaña limestones.

Fossils are extremely scarce, a marine character is founded on rare Foraminifera occurring in the limestones. Indeterminable plant remains have been found occasionally. The Culm rocks occur mainly in two areas, that are shown on the map in a light blue colour.

In the extension of Peña Corada unit between Cistierna and La Acisa de Arrimadas the Caliza de Montaña is almost wholly replaced by the Culm (see also strat. table, section Yugueros). The Alba formation is represented by 5—60 m of wine-red shales and radiolarites. In the Culm beds of this zone a small amount of coarse pebbly sandstones have been found.

The section north of Yugueros constituted the tectonically least complicated profile through the Lower Carboniferous sequence in the area. Near Yugueros the Lower Carboniferous is thicker — up to 800 m — than at all other places in the Esla region.

Culm rocks are also found to represent all of the Lower Carboniferous in the region of Prioro, Puerto Monte Viejo and Mina Alègre on the Pando road. Here we are on top and just south of one of the most active and complicated structures of the chain. The León line, boundary between Lower Carboniferous plus older rocks to the south and Westphalian beds roughly belonging to the Asturian basin demonstrates itself clearly. The thickness of the Ruesga rocks on the Leon line is very much less than on the southern flank of the Tejerina suncline to the south.

The Westphalian — Yuso group — is developed here in a facies very much resembling that of the Culm rocks, hence limits are founded on tectonic reasoning in several places.

At three places north of the Monte Viejo road and north of the pass, flatlying patches of Yuso conglomerates cut off the underlying Ruesga rocks i.e. limestone conglomerates and shales. Another site, where the unconformity of Yuso conglomerates on Ruesga limestone is exposed, occurs in the Salio valley just west of the Pando road near the Alègre mine. In the vicinity, but now 500 m south of the Alegre mine, they form an extension of the fractured Las Salas anticline and mark the course of the León line. Limestone and limestone conglomerates, that apparently are draped over a core of the Barrios quartzites can be followed to the east. Between the Pando and Monte Viejo roads this layer has yielded Foraminifera of Profusulinella subzone B (datings and system van Ginkel). The limestone should thus be compared to the Piedras Luengas limestone occurring in one of van Ginkel's best known type sections, the Casavegas profile in the Pisuerga basin.

In the Monte Viejo area the limestone conglomerates have some tens of meters of black shales underneath, but generally form the base of the Ruesga, which is relatively thin on the León line.

A schematic lithostratigraphic column taken from the southern limb of Tejerina shows the more complete thickness of Ruesga rocks there (fig. 10). Finally the reader should consult Koopmans (1962) for a detailed description of Ruesga sediments of the type area to the east.

Yuso group

In this group, rocks of widely diverging facies are comprised. In fact the Yuso beds should be regarded only as a lateral facies of the Westphalian rock sequence underlying the Asturian basin situated in the province of Oviedo.

Rocks belonging in the Yuso group almost exclusively occur in the area north of the Leon line. In the Cea-Esla-Porma sheet two exceptions to this general rule are demonstrated.

In the western half of the sheet the area between Viego and Rucayo is covered by Westphalian —rather Moscovian— shales, sandstones, few carbonaceous shales and limestones. Several limestones have yielded Foraminifera of Upper Moscovian age (Fusulinella subzone B, van Ginkel). Similar developments with shales and limestones spread in the same order of quantitative importance have been found in the area west of the Porma river. The name Ferreras — Lodares facies will be used for these rocks.

The León line fracture-zone runs north of the Armada structures consisting of Cambrian, Ordovician and Lower Carboniferous rocks. The León line is marked by a narrow band of unconformable conglomerates of Stephanian B age.

The Ferreras — Lodares facies —higher Moscovian or Westphalian— seems to truncate the previously formed structures in the Lower Palaeozoic South of Campillo and Vegamian, that belong to the western thrusts.

In the Tejerina syncline we find Yuso beds for a second time south of the León line. Here the Westphalian is represented by shales, sandstones, quartzite conglomerates and several limestones together forming the Mesao limestone. We call this the Tejerina facies. The rocks are of Upper Moscovian age. Van Ginkel correlates the Mesao limestone to a level slightly below the Panda limestones of Coriscao mountain near the Puerto San Glorio. There a connection of floral and faunal standards is made, for the Panda limestone overlies shales and sandstones, that according to Prof. Stockmans yielded a Westphalian D — Stephanian A plant association. Hence our Mesao sequence should represent the Westphalian C/D.

Figure 10 shows the lithostratigraphy of the lower part of the Tejerina syncline; the centre of the syncline is filled by Cea rocks. In few places the contact of Cea rocks-lowermost Stephanian A possibly Upper Westphalian D— on the Mesao sequence is seen as an angular unconformity (see Helmig 1965). The contact between the Yuso and the Ruesga beds cannot be studied in exposures in this part. On the most active part of the León line Yuso beds transect the Ruesga limestone conglomerates and shales (see also under Ruesga).

The bulk of Moscovian/Westphalian rocks is situated to the north of the León line. Roughly two different facies must be discerned here in the Yuso Group.

In the area around Ciguera — Anciles — Lois and west of the Esla river the Yuso group is developed in limestones, shales and sandstones in that order of importance. These may represent almost the whole of the Moscovian. The stratigraphy and faunal zoning of this area will be treated extensively in a paper by J. J. de Meyer (see also Brouwer and van Ginkel (1963). They call this the Lois — Ciguera formation.

East of the Esla river the Yuso beds are in order of importance: shales, sandstones, greywacke, conglomerates and limestones, with occasional coal deposits of local extent. The coal of these deposits consists of drifted plant remains, that never yield satisfactory paleobotanical material. To the north and

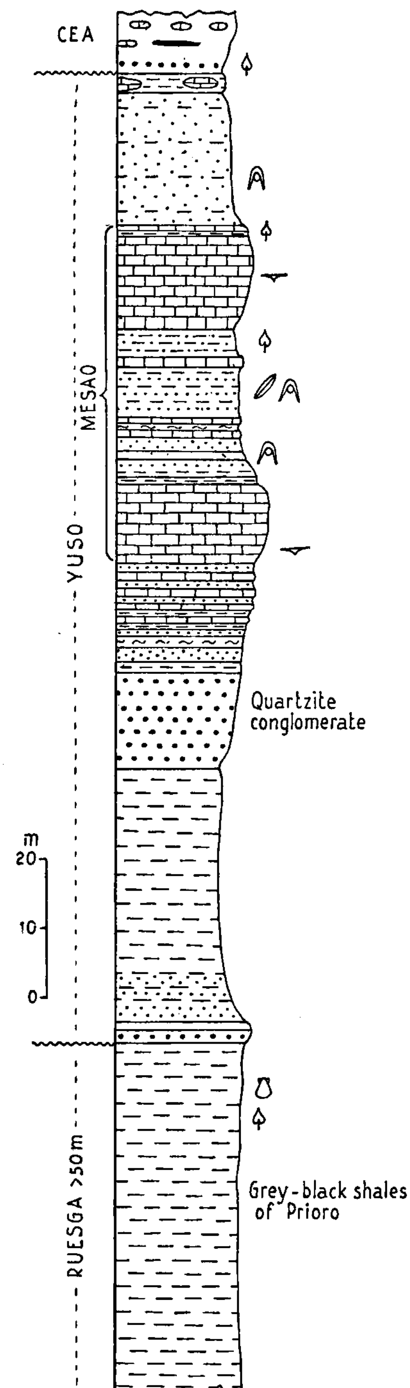


Fig. 10. Stratigraphic section through S flank of Tejerina syncline, N of Prioro.

east this facies of Huelde gradually grades laterally in an almost pure conglomeratic facies; the Curavacas conglomerate facies. In the east van Veen (in press), Koopmans (1962) and Kanis (1957) report these conglomerates, whose base is dated as Westphalian A (de Sitter 1962b), unconformably overlying folded and eroded Upper Devonian and in few places overlying folded Ruesga sediments.

Limestones in the Huelde — Horcadas — Salio area give datings of uppermost Lower Moscovian to uppermost Moscovian.

The limestone-sandstone series of the Huelde type lie unconformable on the lowermost limestones of the Lois — Ciguera complex i.e. to the south of Peñas Pintas and Pico Gilbo. The contact of the Gilbo — Huelde limestone and shales, that exists very clearly north of Huelde and to the west of Riaño is at several places accompanied by the development of a limestone conglomerate of varying extent. At two places the limestones underneath the conglomerates belonged in the Profusulinella B zone, whereas those over it gave Fusulinella A—B associations. The lower limestones have a tendency to grow bituminous and void of organic material. The upper limestones of the Huelde basin are lightgrey to white and of a coarse recrystallized type.

There is quite a sharp NNE-SSW line roughly coinciding with the course of the Esla river between Pico Gilbo and Las Salas, that divides the predominant calcareous Lois — Ciguera facies west of the Esla from the Huelde facies of the Yuso in which the limestones play a very subordinate role. It seems, that this line also marks as boundary between faunal associations (van Ginkel personal communication).

Cea formation

The sediments comprised in the Cea formation are in order of quantitative importance, shales, sandstones or greywackes, conglomerates and coal seams. In four places in the Valderrueda basin marine fossils were found in shale or sandstone beds of 0,5—2 m thick.

By definition the Cea formation should actually be called a paralic sequence, but the bulk of the Cea rocks is of purely limmic origin. More to the east, in the Guardo — Cervera basin the Cea deposits clearly demonstrate an increase of marine intercalations towards the east (Kanis 1956, Koopmans 1962). This tendency culminates in the Pisuerga basin still further east where limmic beds alternate with marine limestones (van Ginkel 1960, 1963).

In the presently discussed area Helmig (1965) finds only in the Valderrueda basin marine fossils; towards the west in the Ocejo and Sabero basins no such influence exists. A lateral transition from a paralic to a limmic facies is concluded for the Cea.

In relatively few places the unconformable contact between Cea and its basement in the form of folded Westphalian limestones can be observed. On the map though, it shows clearly, that Cea beds overlie folded and eroded Cambrian to Westphalian rocks with marked discordance.

In the Valderrueda basin, that contains the most complete stratigraphic section, three productive zones are recognized in analogy to Quiring's observations to the east in the Guardo — Cervera basin. These zones differ in lithology, age and coal composition.

This threefold subdivision may be logical from a mining point of view, but Helmig rightly describes Cea rocks in terms of a twofold subdivision, which usefully can be applied in the field. In his system the lowermost limestone conglomerates of the upper Cea member are indicated on the map as Villacorta beds. The separate indication of these beds facilitates map reading and became necessary as marker beds in the monotonous shale-sandstone Cea series are absent.

Subdivision of the Cea group then appears as follows:

2b Prado member characterized by floras of Stephanian A and possibly Stephanian B age, the frequent occurrence of limestone conglomerates and the lack of quartzite conglomerates. In this formation dry to fat coal occurs.

2a The section between the two lowest limestone conglomerates is named the Villacorta beds, and serves as an arbitrary marker horizon at the base of the Prado member.
The Villacorta beds consist mostly of limestone conglomerates, shales, sandstones and coals with a plant association indicating a lower Stephanian age.

1 Carrion member of Westphalian D age with quartzite conglomerates and absence of limestone conglomerates. Anthracitic coal is mined from these beds.

In the basin of Valderrueda the Carrion member along the Carrion river attains a thickness up to 1200 m, whereas in the Tejerina, Ocejo and Sabero basins in the west the lower Cea is either represented by less than 50 m of shales, sandstones, coal and quartzite conglomerates, or absent.

Separate outcrops of Stephanian rocks we find in the north of the area along the León line (de Sitter 1962b). Here the Stephanian is represented by conglomerates, shales and sandstones with few coal intercalations. The rocks are dated as Stephanian B on plant associations near Rucayo (Wagner 1963) and near Viego. The Viego plants have been worked by Mr. van Amerom (in press) in coöperation with Prof. Stockmans.

East of the Esla river, two depressions in the Huelde and Salio area are encountered. These are considered to belong with the Lower Cea rocks to the south exposed in the Tejerina syncline and have yielded associations of Westphalian D to Stephanian A age accordingly.

A full description of the Cea rocks can be found in Helmig (1965).

Cretaceous and Tertiary

Along the southern edge of the Cantabrian mountain chain rocks of Upper Cretaceous age are found. Permo-Triassic conglomerates as known from the area east of the Pisuerga basin do not crop out west of the Pisuerga river. The Cretaceous of the present area is included in the extensive treatise of Ciry (1938) on this subject. The Cretaceous rocks crop out in a continuous band of 1 km width from Cervera de Pisuerga in the east to Guardo. In the discussed area and still further to the west this strip is discontinuous, tongues of conglomeratic beds underlying the Tertiary Duero basin cause these interruptions. On the map the Cretaceous is split into two main units.

The oldest rocks of this zone in our area are developed in a Wealden facies; white-reddish sands mixed with gravels and red clay lenses build a 70—250 m thick

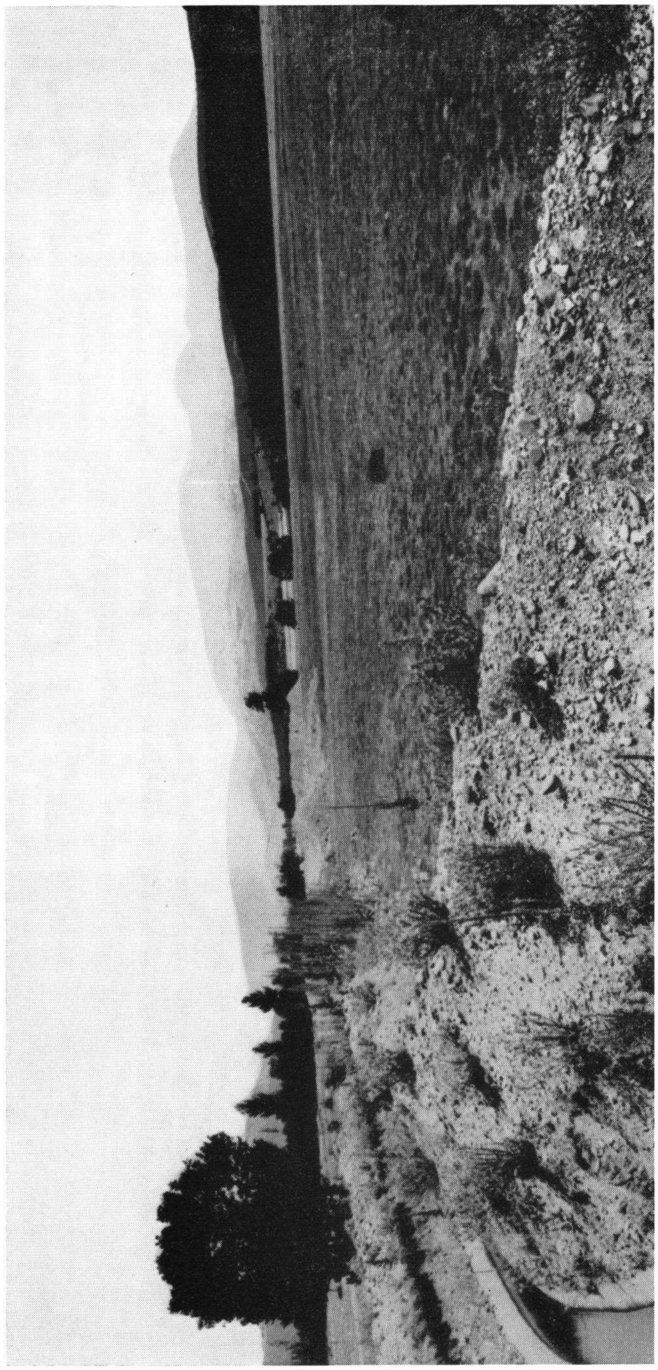


Fig. 11. Contrast in topography; foreground: the Tertiary of the Paramo, background: the mountainfront, at right the Palaeozoic of Peña Corada.

Fig. 12. Eocene conglomerates (TL in map) dipping 25—30 degrees to the south. Photo near Candanedo.

formation. On top of these beds we find a white limestone — marl — clay succession (thickness 200—300 m) from which macrofossils of Santonian to Maestrichtian age have been collected by Ciry. Generally the Cretaceous rocks are dipping steeply to the south (W of La Ercina) or even demonstrate an overturned position dipping steeply to the north. Palaeozoic rocks (of the Stephanian and Namurian successions) then cover the Mesozoic; this last feature is predominant in the areas E of La Ercina and around Prado de la Guzpeña.

In the surroundings of Boñar the rocks of the above mentioned complex are anticlinally draped over a core of Palaeozoic rocks. Here thicknesses reach maxima. Probably this is an exception, no indications have been found that elsewhere a roof of Mesozoic rocks has been present over the Palaeozoic complex described. Moreover, Ciry has proved, that the Cretaceous rocks, as the Permo-Triassic, thin out from E to W. In the east near the junction of the Celtiberic chain and the Cantabrian chain, Wealden rocks should represent the Albian. There a proven Cenomanian—Turonian sequence follows.

In the Esla area the Wealden facies rocks precede Santonian limestones. Small lignite intercalations, that yielded pollen of Turonian age to van Amerom (1965) solved the problem of the age of these mostly unfossiliferous beds.

Comparison with the Pisuerga area now shows all the more clearly, that the Cretaceous transgressive seas reached the Esla area later.

In the Tertiary, cropping out to the south of the described rocks, a two-fold division is made. The lower series consists of steep dipping mostly well lithified conglomerates with sandstone-shale lenses, these lenses are often more weathered. Pebbles consist of Cretaceous and Palaeozoic material. Current bedding in the sandstone lenses occasionally shows an overturned position. These rocks are found near the railroad cutting at Prado, around Cistierna and in the area west of Yugueros to Boñar, where Ciry names these deposits Grès de las Bodas. The same author dates these lower conglomerates as upper Eocene.

The unconformity between the Cretaceous sediments and the Eocene conglomerates is very slight and only comes out on map scale. With clear unconformity the latter conglomerates are overlain by massive conglomerates of almost identical composition except that boulders of the Eocene conglomerate are included. The younger conglomerates are dipping very gently (5—10 degrees) to the south. It is held that these younger conglomerates were deposited in Miocene times (Bataller y Sampelayo 1944). For a detailed sedimentpetrological description the reader should consult Mabesoone (1959), who describes the two above mentioned conglomerates as rocks of the Cuevas facies.

CHAPTER II

STRATIGRAPHIC SUMMARY; REMARKS ON PALAEOGEOGRAPHY

The rocks of the Esla area, allochthone and autochthone all testify cratonic conditions Lotze (1961), however, has made likely the presence of a more geosynclinal development of the Cambro-Ordovician situated to the south and presently covered by the Tertiary. In fact he has proved such for the region west of the Asturian Knee i.e. around Belmonte. In this light the Esla region could take a position of marginal shelf area to the north of that geosyncline.

For the different subareas, the Las Salas zone, the authochthone of Valdoré, the Esla nappe and the western Bernesga structures, no differences of importance could be found in the development of the Cambro-Ordovician and Silurian part of the column. The facies distribution of Lancara, Oville, Barrios, Formigoso and San Pedro formations shows no traces of tectonic activity splitting the basin into „sub-basins" as is true for the Devonian and Carboniferous deposits.

The Herreria sandstones, quartzites, conglomerates and shales of late Precambrian or early Cambrian age constitute the most terrestrial of any of the forma-

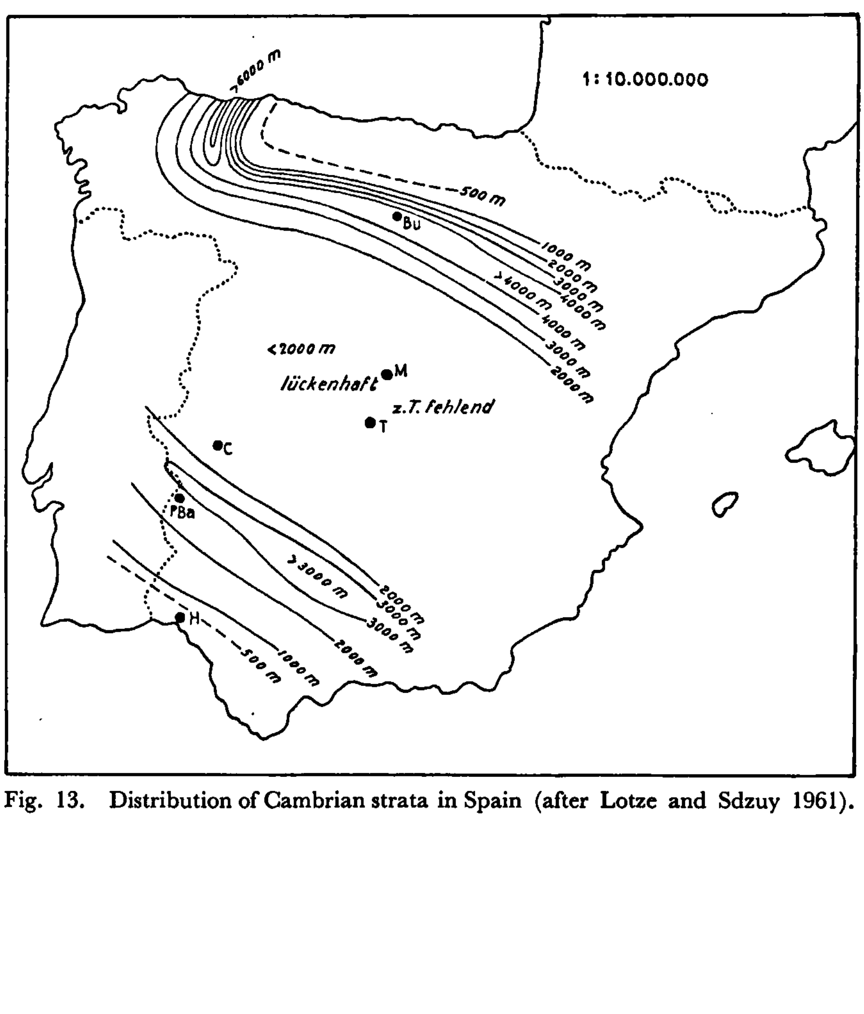


Fig. 13. Distribution of Cambrian strata in Spain (after Lotze and Sdzuy 1961).

tions. The Herreria material probably was derived from a Precambrian massif to the north.

With the Lancara dolomites, limestones and griotte the rate of sedimentation slowed down during the Middle Cambrian and the sea encroached on the land probably from south to north. The Cambro-Ordovician shows again an increase in sediment production in the form of the Oville sandstones and shales and especially in the Barrios quartzites. In these deposits sedimentary structures still seem to favour a current direction generally N-S (see also Oele 1964). With the thick Barrios quartzites sedimentation came to a halt and an extensive hiatus without detectable angle of unconformity is present between the quartzites and the overlying graptolite facies of the Silurian Formigoso formation.

At the close of the Silurian the San Pedro sedimentary ferruginous sandstone represents rapid sedimentation in close to shore surroundings.

All the sediments summed up above are equally present throughout the area in nappe, autochthone and Las Salas zone as well as in the western Bernesga structures.

During deposition of the La Vid dolomite, limestones and shales differentiation of the basin sets in. In sections of the Las Salas zone all elements of the La Vid formation, as known in the south, have been encountered, though in a very reduced thickness. Such a section of the La Vid often is completed by the red basal part of the overlying Santa Lucia limestones. The latter then form the youngest preserved Devonian, that has been found below the, post- Fueyo hiatus, transgressive Ermitage sandstones in the Las Salas zone.

Due to a. the fact, that all the lithotopes of the La Vid formation are present in the Las Salas, zone, carrying the normal fossil zones,

b. the reduced thickness in which it is developed, it must be concluded that the Las Salas zone existed already during the Lower Devonian as a tectonically active area.

The prevailing opinion on the character of the break in the Devonian lithostratigraphic record has been, that all of the Devonian series, that are present in the south and lacking in the north, have been removed there by a Famennian period of erosion from an originally equally developed column.

This theory is not supported by

a. the early Devonian movements of the Las Salas ridge

b. the conglomeratic remnants of the San Pedro ironstone, that we found enclosed in and just below the Crèmenes limestone (Frasnian) of the Agua Salio section. The Agua Salio sediments were laid down app. 20 km to the south.

The early rising of the Las Salas zone gives an explanation, that accounts for both. These movements were epeirogenetic in character and probably continued through the Devonian to reach a climax during the Upper Famennian.

Towards the east Koopmans (1962) described similar early Devonian movements in the area, that forms the continuation of the León line. In the west no such detailed results are available yet.

During the Carboniferous the Las Salas ridge acted as southern boundary for the Westphalian Yuso sediments outcropping north of it. The León line still is a narrow zone. Fundamental faults are expected to accompany the contact between Barrios quartzites and the Yuso beds in the northern limits of the Las Salas zone.

A second fundamental line also running roughly E-W has been acting as facies boundary. It runs mainly south of the Sabero basin, over Vegamediana, forms the northern limit of the Peña Corada massif and is found in the Valderrueda basin as a fractured zone in the Cea sediments. In the extreme east the quartzites of the Sextil

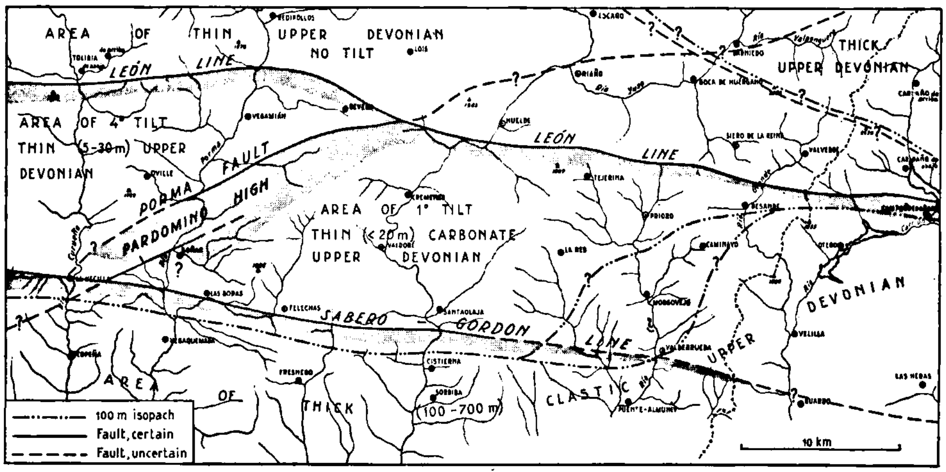


Fig. 14. Palaeogeographic map of the Esla region during the Upper Devonian showing differentiation of the basin.

are situated next to this line. West of La Herrera the line can be followed as a fracture zone, 200 m wide, through the galleries of the Sabero mines (Helmig 1965).

South of Colle and near Las Bodas even the Cretaceous and Tertiary are displaced along this fault zone. Still further to the west in the Bernesga region (see maps of de Sitter 1962 and Comte 1959) the continuation of the Sabero line persists as the fault zone bordering the asymmetric Matallana basin to the south. Near Pola de Gordón it clearly forms the boundary between the thick and probably in a chronostratigraphic sence complete Upper Devonian (700 m thick in Alba syncline) and a development of rather thin (150 m) Upper Devonian north of it. Hence a name Sabero-Gordón line seems appropriate. It has the following stratigraphic characteristics:

1a. complete and thick Upper Devonian deposits outcropping to the south and comparatively thin Upper Devonian deposits to the north of it.

b. in the east it divides the autochthone of Valdoré with thin (5—10 m) transgressive Ermitage, developed in crossbedded limestone, from a relatively thick section (> 100 m) of clastic Upper Devonian deposited to the south of it.

2. the zone was active from at least Upper Devonian through Tertiary times.

3. it forms the southern margin or it is situated generally in the southern edge of the Matallana and Sabero basins, in the Valderrueda basin it is expressed as a fractured zone at the surface, which is supposed to derive from a step in the pre-Cea basement (Helmig 1965).

A third fundamental line in the sedimentation pattern of the region is the Porma fault, that borders the Monte Pardominos to the northwest. Near Viego this fault joins with the Las Salas fracture zone; from this junction it stretches southwestwards to La Vecilla de Curueño, that falls just outside our map sheet. The Porma fault forms a sharp boundary to the great expanse of Cambrian and Precambrian rocks of Pardomino area.

The following characteristics of the areas west and east of Pardomino may be gathered on the Porma fault to show, that it acted as a facies boundary:

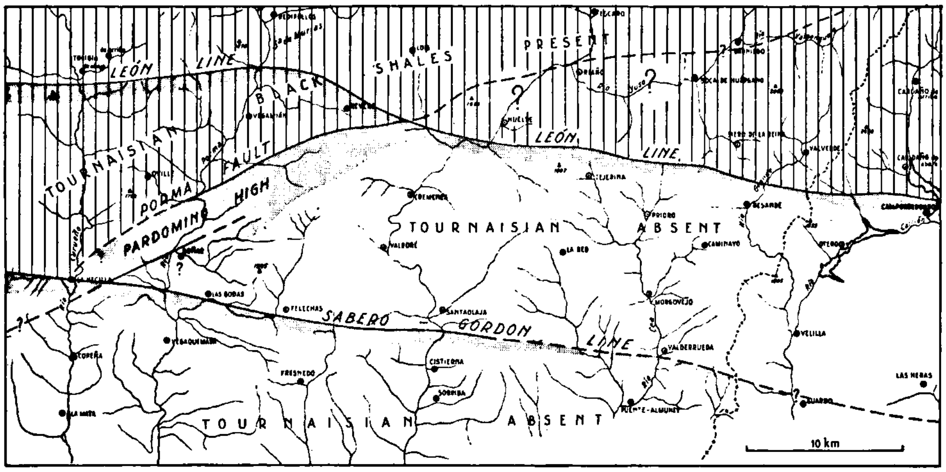


Fig. 15. Palaeogeographic map of the Esla region, distribution of the Tournaisian.

1. In the area west of Pardomino the Bernesga — Torio thrust structures of the Bernesga „sub-basin" display a trend of very rapid downcutting of the Fueyo hiatus from south to north; within a distance of 18 km we find the Ermitage shifting from a position of transgressive formation on Frasnian (Correcillas) to one in which it transgresses on Ordovician shales and quartzites (Bodon and Forcada). In the autochthone of Valdoré the Ermitage rocks are resting on the Upper Frasnian (base of Nocedo formation) in the south, whereas app. 10 km to the north they are transgressive only on the Portilla formation (Frasnian) (compare map in de Sitter 1962).

We consider the Fueyo hiatus to be caused by the tilting of a block (de Sitter 1962). In this warping, the northern part moving up and the southern down, the Pardomino area clearly separates a western and an eastern part. Hence the results are;

a. a Bernesga block with an important angle of Upper Devonian tilt = about 8° (for method of calculation see fig. 26) to the west of Pardomino and

b. a block now forming the Esla autochthome to the east of Pardomino. In this the Devonian hardly changes from south to north and the Devonian movements caused less tilt = about 1° (see fig. 26).

The angle of tilt causing the Devonian hiatus in the Esla basin (autochthonous part) is far less than that in the Bernesga basin.

2. The Porma fault is a facies boundary for the black shales (schistes de Vegamian, Comte 1959), that have been dated recently by Higgins et al. (1964) as Tournaisian. These shales occur in the Bernesga structures to the west and right up to the Porma fault. In the region east and south of Pardomino they do not crop out. Koopmans (1962) did not find black shales of the Tournaisian in the Valsurvio dome. — The black shales and chert occur again near Resoba i.e. north of the Leon-line sensu stricto.

3. When we extend the line of the Pardomino crest across the León line it forms a facies boundary during the Moscovian (Westphalian). The Lois — Cigueira calcareous facies is to the west and the Huelde — Salio facies —mostly clastic— is

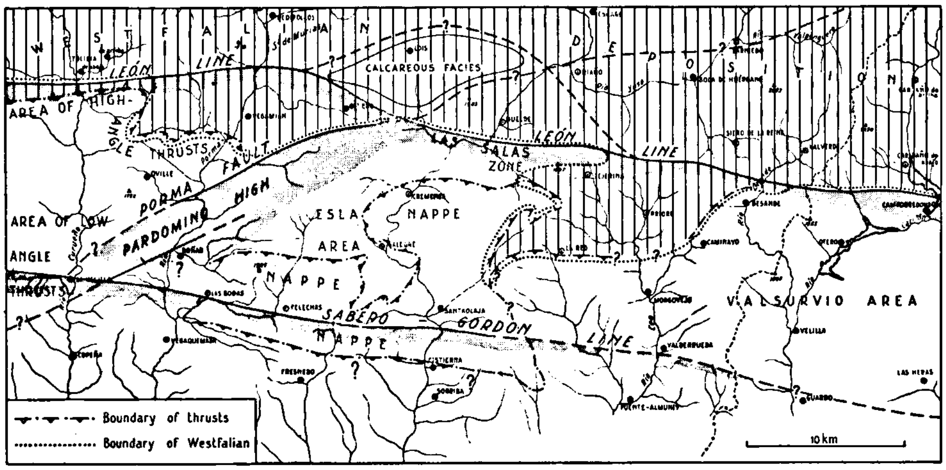


Fig. 16. Palaeogeographic map of the Esla region; the relation between the thrusted area of the Leonides and the Westphalian deposits to the north.

to the east of this continuation. The Foraminifera associations of these two facies are equivalent in time, but contain remarkably different species (van Ginkel personal communication).

The Las Salas zone (León line), the Sabero — Gordón line and the Pardomino ridge all form fundamental steps in the basin influencing the facies distribution from the Siegenian to the Westphalian in the tectonic frame of the area.

The sedimentation pattern of the younger Cea rocks is very much related to the Sabero-Gordón line as well as to the León line (de Sitter 1962b). When drawn to scale (see sections in back) the seeming importance of the Cea deposits is reduced through comparison with the great amount of folded pre-Cea rocks. The unconformable Cea is no more than a skin feature present in fundamental fault zones, that influenced the underlying Palaeozoic in sedimentation as well as structure and which Palaeozoic also has the skin nature of shelf sedimentation.

The Cretaceous rocks are with varying but mostly clear discordance deposited over the former beds. The uplift of the Cantabrian — Asturian chain produced large masses of Eocene-Oligocene conglomerates making up the marginal facies of the Tertiary Duero basin underlying the Meseta of Castile.

CHAPTER III

STRUCTURES

Introduction

The main problem, that we have to cope with in the Esla-Porma region is the setting of the Esla nappe in its proper relationship to its autochthonous surroundings. In order to do so we shall first discuss the separate subareas, that can be recognized. These subareas have a special character in the structural pattern, which pattern coincides to a high degree with the facies distribution.

These subareas are:

1. Las Salas fracture zone directly south of the León line.
2. Autochthone of Valdoré or Esla autochthone.
3. Esla nappe.
4. Western Bernesga-Torio structures.

Further the attention is called to structures as developed in the Yuso group sediments occurring mainly just north of the León line.

Finally special features encountered in different subareas will then be seen in juxtaposition and a tentative synthesis of the stratigraphic and tectonic history will be given.

All sediments, that occur in the area are folded in concentric fashion. No cleavage occurs in the Esla area.

In describing the tectonics of the area it is understood, that the reader consults the sections (in pocket) continuously while he progresses with the reading.

It is attempted to discuss the effects of deformation in their successive chronological order. Several subareas will thus enter in our discussion repeatedly as they have undergone more episodes of deformation.

The Las Salas zone

This zone forms the northernmost representative of the Leonides as the León line separates the Barrios quartzites of the zone from the higher Yuso shales, sandstones and limestones of Upper Moscovian age to the north of it.

East of the Rio Esla to a point north of Pico de la Teja the Las Salas zone forms a fairly simple isoclinally folded anticline (section: 9). This anticline is asymmetric, the southern limb, containing a normal section of Lancara griotte, Oville shales and Barrios quartzites, is somewhat raised over the northern limb of which only the quartzites appear at the surface. In places the northern limb is even overturned to the north.

To the north the quartzites of the northern limb are in contact with Yuso shales and limestones of Upper Moscovian age (Fusulinella B zone). In the chapter on special features the nature of the contact will be discussed.

The southern flank of the Salas structure is more complicated, here normal faults develop in an isoclinally folded pattern, that takes advantage of the incompetent rock character, that the Alba griotte has.

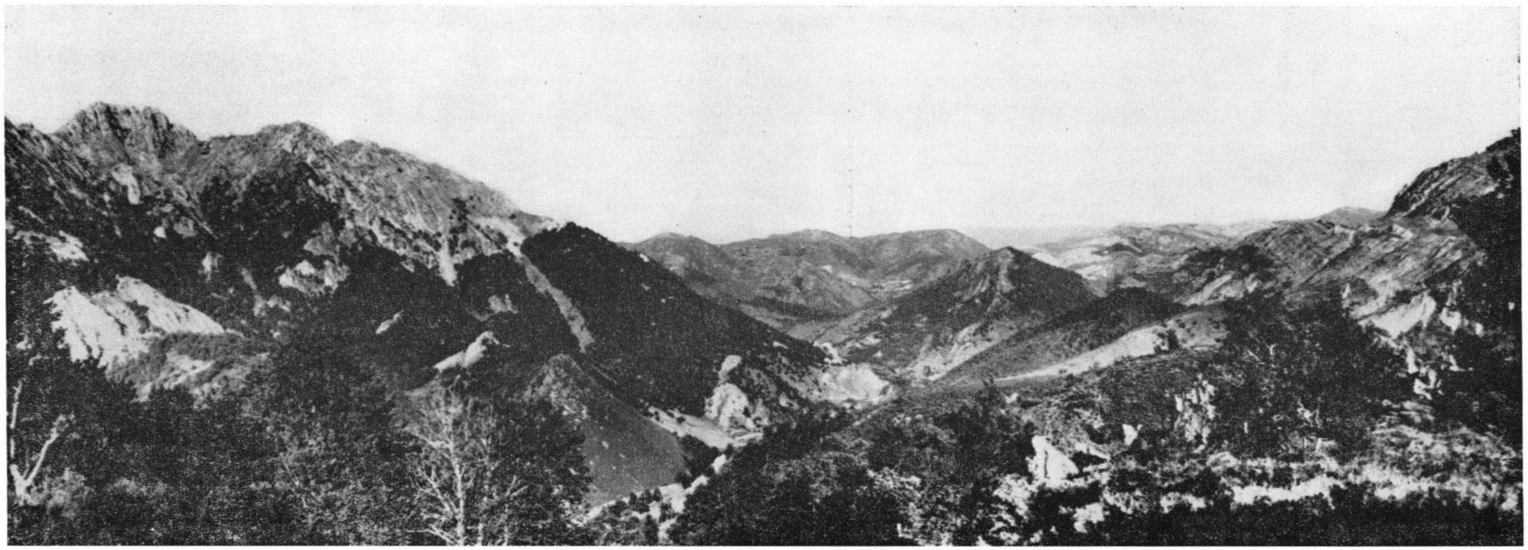


Fig. 17. Presently the Las Salas zone stretches as a narrow zone with low relief between the Carboniferous limestones of Pico Jano (left) and Peñas Pintas (right). Photostation 2 km S of Huelde looking W.

Apart from these ruptures, the blanket of Upper Devonian sandstones and Lower Carboniferous limestones can be traced to the south across the Arroyo de Remolina into the Pico Jano massif, thus building a connection between the Las Salas zone and the autochthone of Valdoré. Only one important fault with mainly vertical movement, the northern side being downthrown, is encountered.

To the East this Remolina fault is joined by the front of the Esla thrust, towards the west the Remolina fault line finds its extension in the Porma fault near Viego.

East of the nose of the Las Salas anticline one finds again the Barrios quartzite in the extension of the Las Salas structure. Next to the León line i.e. master fault, the quartzites with a thin cover of limestone breccia and shales of the Ruesga group, are exposed. Thanks to careful mapping by Mr. J. F. Savage, the main fault could be traced into the St. Eugenia fault (Koopmans 1962), that limits the quartzites of the Valsurvio dome to the north. Between the Monte Viejo road and the Rio Grande, the Ruesga shales and limestone breccia's that form the base and northern flank of the Tejerina syncline north of the fault are downthrown. Here there occurs thrusting from the north, that reaches across the León line to the south. This is in contrast with the rest of the area further west, where the León line separates structures with southdipping axial planes and northdipping axial planes respectively south and north of the line.

Besides it is clear, that the Ruesga section on the eastern extension of the Las Salas ridge is much thinner than its equivalent as exposed in the southern flank of the Tejerina syncline near Prioro. The Tejerina syncline contains rocks of the Ruesga, Yuso and Cea groups. All have been folded in a similar synclinal form with axes that roughly coincide with each other. In a few places, however, angular unconformities between each of the rock groups, that take part in the syncline are exposed. Several branches of the León line — St. Eugenia fault run in a NW direction. The area of Riaño is marked by intrusions of the rather acid Arbejal — Riaño type. These have been described by Henkes (internal report Leiden University) as trachy-andesites.

Mineralizations occurring along the main faults between Puerto Pando and Mt. Viejo roads have been mined for arsenic, antimony and mercury.

In section 10 a profile through the Salio valley is shown. Thanks to the presence of well developed Yuso limestones, that could be correlated on Foraminifera with the limestones of Cueto Mesao (in the Tejerina syncline) a good insight in the style of folding on and just north of the León line could be gained.

During the Westphalian (Moscovian) the ridge was also active. East of Monte Viejo road and northeast of the main fault flatlying patches of Yuso quartzite conglomerates truncate the structure of the Ruesga limestone breccias; further to the norththe same quartzite conglomerates are normally interbedded in the clastic Yuso series.

Let us return to the parts west of the Esla river. From Salamon to the west the León line as fracture zone is accentuated in later times by the presence of a small band of unconformable Cea conglomerates of Stephanian B age (for datings the readeris referred to a separate paper by H. A. van Amerom). The Cea conglomerates form an interrupted band running EW from the river Esla to the river Torio. West of Viego the León line is the boundary south of the calcareous facies dominating in the Lois Ciguera basin. To the south of the line a completely different facies of the Yuso beds is found. Still further west near Rucayo the Stephanian conglomerates join the front of the Bernesga-Torio thrust structures.

A special meaning is attached to two synclinal depressions filled with Cea rocks near Huelde and south of Salio respectively. Flora's from the Huelde and Salio mines (see also Helmig 1965) give an age of Westphalian D-Stepanian A. Hence we compare these coalbearing deposits with the coalbearing basal shale-sandstone beds underneath the Villacorta beds in the Tejerina syncline. Near Ocejo these basal beds produced a flora of Westphalian D age (Wagner 1958 and Helmig 1965).

Near Viego-Salomon we see a convergence of the faults, that border the Las Salas fracture zone to the east. In a small stretch north of the Rio Dueñas between Las Salas and Salomon we find all formations from Lancara to La Vid and Ermitage to Caliza de Montaña squeezed and faulted together in an extramely narrow zone.

The Remolina fault brings the Lower Palaeozoic of the Las Salas zone in contact with all lithostratigraphic elements of the Esla autochthone to the south.

The Las Salas zone sensu stricto does not exist west of the pass Viego — Salomon. The León line, that limits the quartzites of the zone to the north is drowned by the Stephanian B conglomerates and shales, that are mentioned before.

The rocks contained in the Las Salas zone all demonstrate a subvertical, vertical or overturned position. The folds in the zone are small in number, very sharp and have all vertical axial planes with axes plunging gently to the east along the Arroyo de Remolina and rather steeply plunging to the west in the vicinity of Las Salas village. They are of minor importance as the tectonics of the Las Salas zone are governed by steep dipping or vertical, probably far reaching fundamental, fault-set. The majority of these faults run E-W, a course dictated by the León line, they can be traced over long distances.

In and just north of the village Las Salas a set of steeply north and northwest plunging axes of „drag" folds developed in the Lancara dolomites. They are demonstrative of the horizontal movement, that certainly occurred on the E-W trending fault system north of Pico Jano described above. The amplitudes of these „drag" folds is 5—20 m. The amount of wrench movement horizontal sense cannot be estimated but is expected to be small.

The fault plane stands vertical, the movement is in the left-lateral sense. The asymmetry of the „drag" folds supports this movement.

The autochthone of Valdoré

In contrast to the Las Salas zone this unit has a fairly simple structure. It is built of the complete series ranging from the Cambrian Herreria formation to the Caliza Montaña formation of Namurian age. This latter formation is only present in the Pico Jano massif north of the Esla nappe; the Esla thrust has sheared the Caliza de Montaña off the autochthone of Valdoré in the southern part of the area. On its top the Esla autochthone carries the Esla nappe, its outer limits are more complicated.

In the west the Herreria formation forms the slightly thrusted base of the autochthone, the Porma fault, a first-order fundamental fault forms the boundary from Viego to la Vecilla de Curueño, that lies west of Boñar and west of our map sheet. The Porma fault has been shown to have acted as a facies boundary during the Upper Devonian and Lower Carboniferous.

In the north the autochthone of Valdoré is connected to the Las Salas zone disregarding the disturbances along the Remolina fault. The Pico Jano massif forms part of both these units.

In the east little patches of Caliza de Montaña and Lower Palaeozoic griotte and quartzites, that stick up through the Stephanian cover near Los Castros and Ferreras have made it possible to trace the course of the thrustfault between autochthone and allochthone but north of La Red no more evidence is seen through the unconformable Cea rocks.

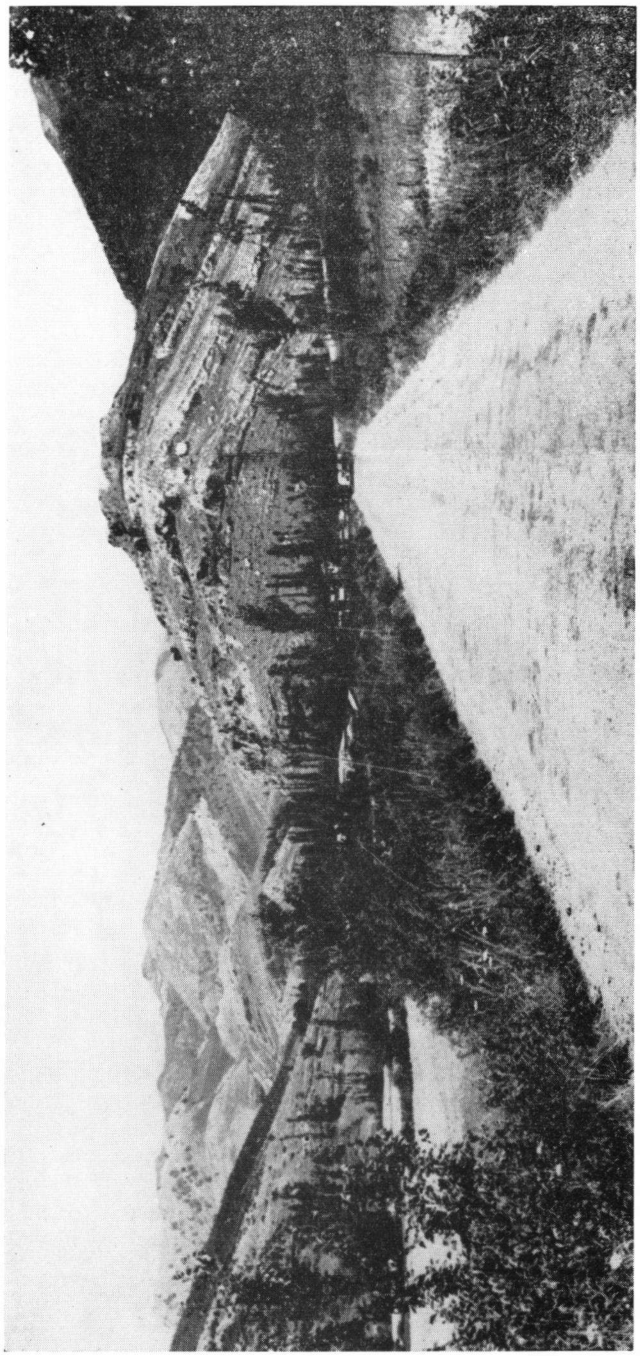


Fig. 18. Looking northward to Valdoré; at left the autochthone, at right the nappe.

In the rest of the area no Esla autochthone crops out except north of Sabero in the fenster of Valdoré. Here the Middle and Upper Devonian belonging with the Esla autochthone is unconformably overlain by the Cea conglomerates and shales, that lie at the base of the Sabero basin.

The use of the term autochthone of Valdoré is not strictly correct for parts of it i.e. west of the village Corniero and Valbuena del Roblo have been thrusted. A fault runs from near Vozmediano through Pico Sobrandio, west of Corniero until it merges with the Remolina fault east of Valbuena del Roblo. This „Roblo" fault is primarily a thrustfault. The attitude of the faultplane is now subvertical. The syncline west of the Roblo fault is developed in Cambrian to Lower Devonian and has a vertically plunging axis. The basal layers of the Valbuena syncline take part in complicated faulting especially on the northern flank. The Valbuena syncline is beneath the Roblo fault, the continuous expanse of the Esla autochthone outcropping east and south of it is thrusted upon the necessarily prexisting Valbuena syncline. The Valbuena syncline is seen as the western extension of the Pico Jano — Tejerina syncline; an old EW direction, just south of the EW trending Las Salas high.

A whole set of similar thrustfaults is developed in the area west of the Roblo thrust and east of the Porma fault. These thrustfaults multiply the apparent thickness of the Herreria rocks greatly.

The thrusting clearly took advantage of the great difference in rock-character between the competent Herreria sandstones and quartzites and the incompetent Lancara griotte limestone. The direction is parallel to the Roblo fault: SSW-NNE to SW-NE.

From the relation of the Roblo fault to the Valbuena syncline it seems reasonable to conclude, that the order of development of these thrusts, that border the base of the Valbuena structure, has been from west to east. The Esla thrust then forms the latest and most „successful throughgoing" thrust bordering a real nappe sheet, the deformation being a pure overthrusting process.

As shown in the map and sections 4, 5 and II-V there is a tendency of increased overturning in this particular area going from southeast to northwest.

Along the Roblo fault itself a special characteristic is displayed. The Lancara griotte and dolomite horizon next to the Roblo fault shows a series of small (amplitude 0,5 m to 10 m) folds with axes plunging steeply in varying directions. Here the situation is analogous to that near Las Salas.

Going southeast in the direction of Pico Sobandrio the Lancara griotte south of Valbuena is substituted by a red silicified fault breccia. After tracing this horizon for about 2 kms one finds the normal Lancara griotte and dolomites regaining its position. The drag-like folds and the later silicification of the Lancara are best explained by reactivation of the Roblo fault as a wrench fault, the „autochthone" east of the fault moving to the northeast. Hence the Roblo fault is seen as an early thrust with subsequent wrench movement. The movement on the Roblo faulting surface has been small, the thrust dies out after 3—4 kms, the lateral movement need not have been great and cannot be estimated.

The small thrusts in the Corniero, Primajas area are now in overturned position. Originally they cut up to the surface under a steep angle because of the nearby presence of the Pardomino buffer, hence: later refolding need not account for all of their present attitude.

To conclude: It is my view, that the interference of the Pardomino ridge, as delineated in the chapter on stratigraphy, with the oncoming thrustforces is the best explanation for the structural pattern of the Valbuena—Corniero—Primajas area.

The tectonic composition, strike and dip of the beds are a direct result of the trend of the old Pardomino ridge in relation to the north-south acting compressive forces.

The part of the autochthone situated south of Valdoré —also called fenster of Valdoré— boasts several well preserved anticlines and synclines. The axes of these structures run in a NNE-SSW direction parallel to the trend in the E part of the buffer zone of Pardomino.

The Esla thrustfault as the limit of the fenster of Valdoré is essentially folded in the same direction. It must be concluded, that this western edge of the nappe is folded subsequent to the thrusting. However, this refolding need not be an independent feature. North-south compression —of the same primary stressfield, that produced the thrusts— and acting upon older (Pardomino trend) SW-NE basinal directions explain the form of „refolding" in the Esla nappe as well, without applying a younger, differently oriented (Asturian) stressfield.

The Esla nappe

The Esla nappe forms the most important structural element of the area. It contains rocks of Middle Cambrian (Lancara formation) to Lower Carboniferous (Caliza de Montaña formation) age. With exception of the Herreria sandstones of Precambrian and Cambrian age all stratigraphic elements building the autochthone of Valdoré are represented in the nappe.

In European literature there has been considerable confusion regarding the meaning of the term: nappe. W. Zeil (1959) has summed up a list of specifications, that a thrusted mass of rocks should fullfil in order to qualify as a nappe.

The more important factors are:

1. A difference in facies between the allochthonous and autochthonous rocks.
2. A fundamental divisionline between the „regio sedimentationis" of the autochthonous and the thrusted part of the original basin.
3. A difference in tectonic style between the two elements.
4. A thrust horizon, that originally was flatlying.
5. The dimension of the nappe should be of importance.
6. The „travel" distance of the nappe rocks should be important.

In general I agree with these requirements, it must be noted, that the qualifications 5 and 6 are always seen in relation to the true stratigraphic thickness of the rocks taking part in the nappe movement.

Furthermore it seems characteristic of large thrusts to leave no signs of disturbance on and next to the plane, that was used as gliding surface.

Traces of fault breccias are very rare in the case of the Esla nappe; approximately I km north of Saelices de Sabero the Lancara formation contains a layer of breccia of doubted tectonic origin.

The Esla nappe is split in three seperate parts:

1. the syncline of Felechas
2. the syncline of Agua Salio,
3. the Peña Corada unit.

East of Boñar and north of Voznuevo the Esla thrust brings Lancara griotte, at the base of the Cambrian to Devonian series of the Esla nappe forming the Felechas

Fig. 19. Relation between nappe and autochthone near Verdiago. From left (nappe) to right (autochthone): Barrios quartzites, Oville shales and sandstones, Lancara limestones, Nocedo sandstones, Portilla limestone and Huergas shales.

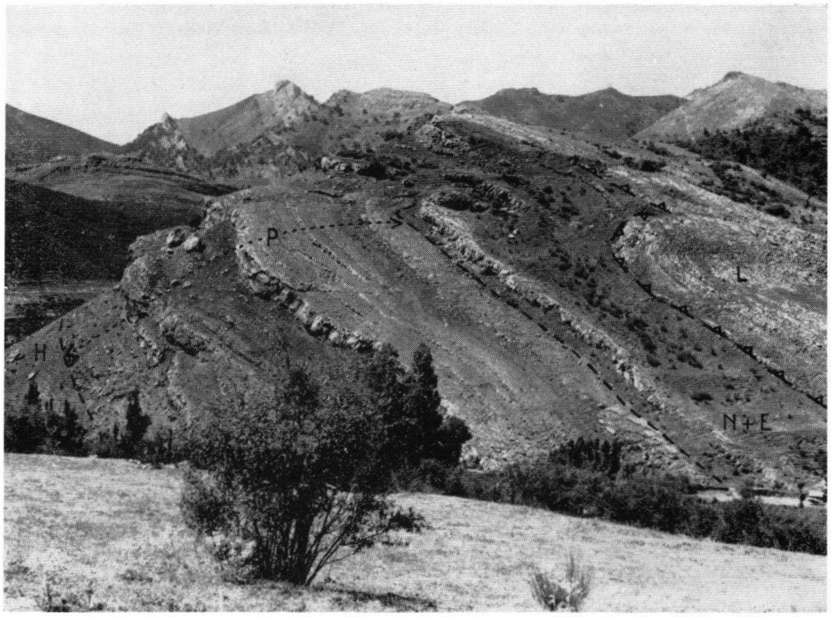


Fig. 20. Contact between nappe and autochthone: section at Valdoré. From left to right: Portilla, Nocedo and Ermitage formations (autochthone) Esla thrust, Lancara formation (nappe). Photographer looking west.

syncline, into contact with the Huergas and Portilla rocks belonging to the autochthone north of it. From this point till the Camperona mountain this part of the thrustplane is in vertical position; at a spot northeast of the Camperona the faultplane sharply swerves round from its E-W direction with vertical dip to a SSW-NNE strike and dips of 40—50 degrees to the west.

North of Sotillos the Esla thrust is covered by Cea sediment at the base of the Sabero basin. About 2 kms east of this point the basal series of the nappe presents itself again; in a SSW-NNE trending syncline belonging to the fenster of Valdoré the Lancara griotte is exposed on top of the Upper Devonian both just north of the Cea unconformity. Still 2 kms further to the east the same section as lost under the Stephanian south of the Camperona, crops out again, but now the section youngs to the east. The Esla thrustfault surface is in vertical position now, and again the base of the nappe consists of Lancara griotte and limestone. The section now is continuous into the centre of the Agua Salio syncline, that holds rocks as young as the Namurian Caliza de Montaña formation. The Esla thrustfault can be traced all around the Agua Salio syncline to north of the village La Red.

Between the edge of the Sabero basin and the village Verdiago it curves round to continue with a shallow NE (20—30 degrees) dip over Valdoré to Velilla de Valdoré opposite and to the northeast of the Camperona. Here again the fault changes abruptly to a vertical position; runs from here with a S-N and later on with a SW-NE strike in a large curve round Crèmenes to cross the river Esla for the third time 1 km to the north of Crèmenes. Here a subsidiary thrust fault underneath the main fault surface made it difficult to recognize the meaning of this section (see figs. 19, 20, 21).

Fig. 21. Contact between nappe and autochthone. Esla thrust (in center) separating Lancara limestone from faulted mass of Caliza de Montaña limestone (at right). Photo 2 km NNE of Crèmenes and looking SW.

Fig. 22. Contact between nappe and autochthone. In center of photo: Esla thrust separating Pico Jano massif (left) from Barrios quartzites belonging to nappe. Photostation: 2 km NNE of Crèmenes and looking east.

This difficulty was overcome when the existence of the crossbedded Ermitage limestone in this section on top of a practically completely eroded Portilla limestone was proved by van Adrichem Boogaert (pers. comm.).

From its upsurge south of Verdiago the thrust followed the same stratigraphic horizon, having the Lancara limestone and griotte on top and the crossbedded Ermitage limestones underneath. Near Verdiago and Velilla de Valdoré small slivers of Alba griotte in normal order over the Ermitage beds have been preserved (see map).

South of Pico Jano this parallel trend is rapidly changed. The Esla thrust cuts upward in the lithostratigraphy of the autochthone as well as the nappe. The highest position regarding the stratigraphic levels is reached between Remolina and the mountain Los Castros; in this stretch the Middle Devonian Santa Lucia and Huergas formations of the nappe make contact with the Caliza de Montaña of the autochthone.

Hence the frontal zone of the Esla nappe lies here and a direction of movement from SW to NE is the preliminary result. From Los Castros the Esla nappe grows more complete again in a southern and eastern direction. North of La Red the Cea conglomerates and shales cover the Esla nappe and autochthone. The nappe section near La Red is complicated by WNW-ESE trending normal faults.

Careful analysis of the structures in the Valderueda basin by my colleague H. M. Helmig shows, that the extension to the east of the faulted nappe contact of the Ferreras-La Red high leads us into an anticlinal structure of the Stephanian. This anticline can be traced esat of the Cea river almost to the Caliza de Montaña belonging to the Valsurvio dome. Here Peña Lampa shows a „breakthrough" of

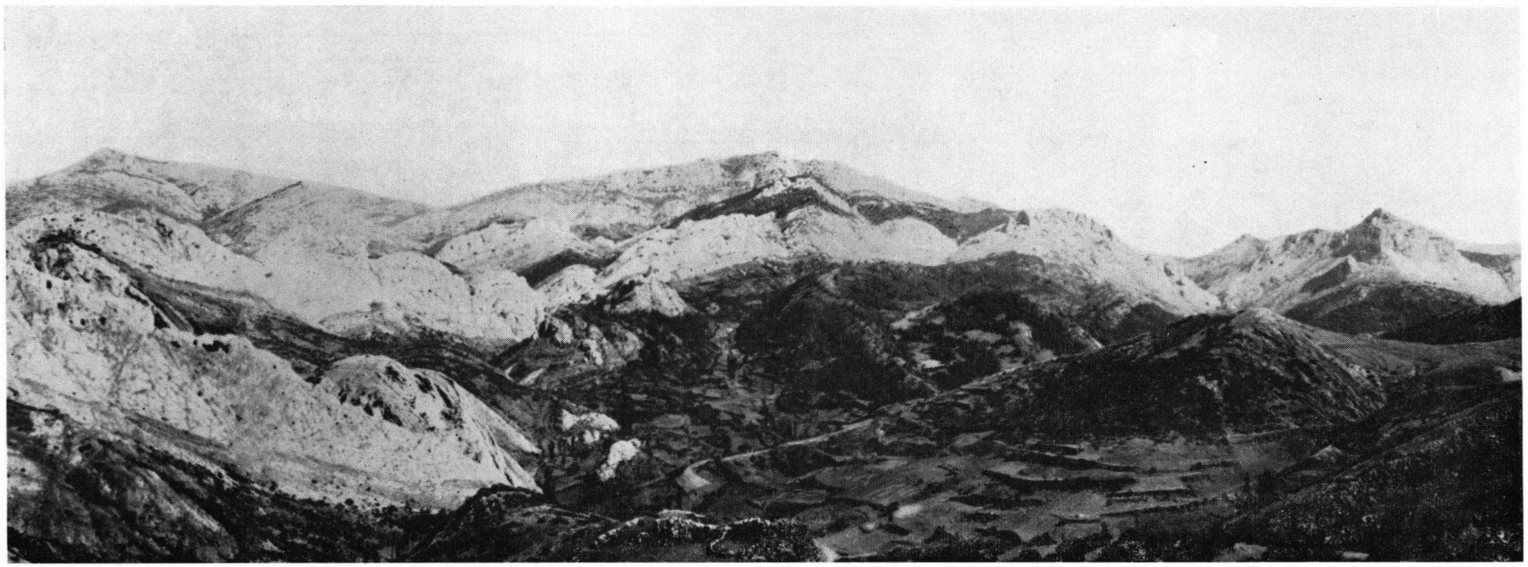


Fig. 23. The E side of the Esla nappe between Ocejo and Remolina. Photostation on La Solana, mountain Los Castros at right. From top to bottom: cover of Cea conglomerates, Portilla limestones, Huergas shales and sandstones, Santa Lucia limestones; a syncline of Cea conglomerates, with a patch of Caliza de Montaña (autochthone), covers the Esla thrust.

the Devonian quartzites. This anticline is the only major anticline in the Stephanian basin. In this way a tentative map connection between the Esla thrust and the thrustzone of San Martin situated east of the Valsurvio dome would be established. The movement on the Esla thrust would decrease from west to east.

The third component of the Esla nappe is formed by the Peña Corada unit, stretching from Robledo in the east to Las Bodas in the west.

As the Peña Corada unit is not eroded to the level used by the Esla thrust (the Lancara formation), no direct argument to connect this zone with the Agua Salio or Felechas syncline is provided.

However, the facies of the Upper Devonian enclosed in the Peña Corada unit correlates quantitatively as well as qualitatively with the equivalent in the Agua Salio section as opposed to the Upper Devonian section of the autochthone of Valdoré.

Secondly it can easily be maintained, that after „removal" of the unconformable Cretaceous and Stephanian sediments, a map connection between the Santa Lucia section northwest and the Huergas-Portilla section south of Colle would appear. Likewise the Santa Lucia limestones of Santa Olaja could be connected with those of Vegamediana.

In the third place it can hardly be imagined, that the Esla nappe as represented by the two northern synclines could have been thrusted from S to N over the top of the Peña Corada massif thus placing the Peña Corada unit with the autochthone. In addition it would mean a larger transport distance for the Agua Salio and Felechas synclines.

It has been shown, that the Esla nappe was essentially a flat cake gliding over the Ermitage crossbedded limestone. Posterior to the thrusting the Esla rocks, nappe and autochthone, have been folded. This folding is best demonstrated by the fenster of Valdoré. Here the Lancara of the nappe is folded with the autochthonous Portilla and Huergas formations. Both display axes trending SSW-NNE.

In the discussion of the Valbuena structure it became clear, that the early (anterior to the Roblo and Esla thrust faults) Valbuena syncline was cut by faults striking in the same direction.

A similar cause, the presence of the older Pardomino high, trending roughly parallel to both the Valbuena and Valdoré strikes, is supposedly expressing itself before and after the Esla thrustsheet had reached the respective areas.

The reader's attention is further directed to the set of folds inside the nappe between Argovejo and Remolina. The folds occur most clearly in the La Vid and Santa Lucia formations; the E-W striking axes plunge about 40 degrees to the east.

The Esla thrustfault is not folded together with these. In this particular area the thrustplane is cutting up as it meets the masses of the prexisting Las Salas anticline and Pico Jano syncline. The folds can only be related to this upcutting activity in the frontal zone of the Esla thrust, they are prior to and simultaneous with the Esla thrust.

East of Ocejo de la Peña the Santa Lucia limestones of the Solana mountain form a N-S trending anticline with La Vid shales cropping out in the centre of the structure. The axial plane is dipping steeply to the west. The Solana is also crossfolded E-W, an extra lobe of the limestones reaches far out towards the west.

The N-S structure of the Solana mountain is repeated in the complicated Los Castros mountain north of Ocejo. East of Fuentes de Peña Corada N-S striking Santa Lucia limestones form the southern extension of Solana mountain.

In the Peña Corada synclinorium the prevailing strike of the beds is E-W, dips are vertical mostly and there is a tendency to overturning to the south.

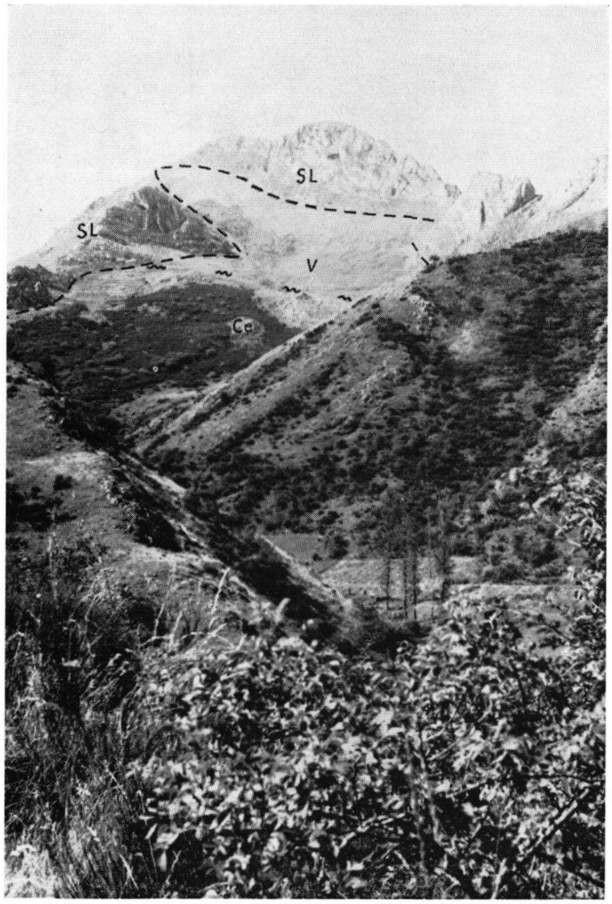


Fig. 24. Looking southwards to Peña Solana, frontal anticline of the Esla nappe in its last stage of movement. Core developed in La Vid shales, axial plane dipping to the west. Photostation: 2 km NE of Ocejo de la Peña.

East of Peña Corada summit the consistent E-W strike rapidly changes to a N-S strike. This trend is cut off by the unconformity beneath the Cea rocks near the village Robledo. The change from E-W to N-S strike happens without disturbances.

The following conclusions are drawn:

a. The Solana NS anticline repeats itself in the Robledo area of Peña Corada unit.
b. The NS direction is an inherent feature of the eastern zone of the Esla nappe.

The Peña Corada unit is limited to the north by a fundamental fault zone i.e. the Sabero-Gordón line. In the Peña Corada unit itself and especially to the west of the river Esla many E-W striking faults occur. East of the Esla river one important fault (faultplane dipping 70°—80° to the north) runs over the Murrial of Cistierna and splits the Peña Corada synclinorium into a simple southern syncline and a complicated northern syncline. The Murrial fault takes the place of the missing anticline.

Fig. 25. Folding and faulting on the Sabero-Gordon line; at left: „churchwindows" are isoclinal folds of Peña Corada unit; at right: fault face between Santa Lucia limestones and Cea deposits south of Sabero.

Almela (1949) has explained the doubling (even tripling occurs) of the upper Devonian in the section south of Sabero by assuming a series of folds trending E-W. The N-S sections, however, are asymmetric in composition and strike-faults running E-W, bordering the formations, are the only answer. The nature of these strike-faults can only be that of thrusts as they follow the formation boundaries closely over many kilometers. In addition they develop in a logical place between the two halves of the Peña Corada synclinorium: they run out in the Murrial fault.

The rock character at the level of the Alba griotte is very incompetent versus that at the lower level of the Upper Devonian sandstones and quartzites underneath the griotte. Consequently the structural style west of the Esla is projected below the Peña Corada syncline (sect. 6 and 7).

At several places we find folding complications like those of the Peñola and of Vegamediana on the Sabero—Gordón line. Like the thrustfaults of the Murrial set, they express the difficulties, that arose for the Peña Corada — „tail" — part of the nappe as it started to be pushed onto its northern counterpart across the Sabero —Gordón step.

The facies of the Upper Devonian in autochthone versus that in the nappe is the main qualitative stratigraphic difference between the two elements.

The Sabero—Gordón line acted as facies boundary thus creating different conditions during the Devonian in the northern and relative southern Esla basin.

As regards the relationship between Esla allochthone and autochthone two lines of thought can be followed (see fig. 26): a stratigraphic and a tectonic line.

Relationship Esla autochthone and allochthone

The stratigraphy of the Esla autochthone shows a remarkable development of the Upper Devonian hiatus as shown in the description of the Portilla, Nocedo and Ermitage formations.

Near Verdiago the Nocedo sandstones underneath the Ermitage limestone of Upper Famennian age (conodont information van A. Boogaert) and Visean griotte measures about 60 m; 3 km to the north between Valdoré and Velilla de Valdoré the Ermitage beds rest directly on the Portilla limestones, there 100—110 m thick.

On the western bank of the river Esla 1½ km to the north of the village Crèmenes the Ermitage—Alba griotte section is on top of only 10 m of limestone, that belongs to the basal layers of the Frasnian Portilla formation. The top 100 m of the Portilla formation still present at Valdoré added to the 60 m of Nocedo sandstones in the Verdiago section as compared to the situation north of Crèmenes represent an erosion angle between the Famennian erosion surface and the boundary between the Portilla and Ermitage formations.

$$\text{Erosion angle} = \text{sine } \frac{160 \text{ m}}{8 \text{ km}} = \text{sine } 0.02 = \text{about } 1°$$

In the Esla nappe the Agua Salio section contains a 200 m thick section of the Nocedo formation. When we assume, that the boundary Portilla limestone — Nocedo sandstones has stayed in the same stratigraphic position and, that the angle of unconformity does not show sharp inflexions, the Esla nappe must stem from a place sufficiently to the south for angle a to contain 200 m of sediments present in the Agua Salio section. This results in an area of deposition about 10 km to the south of Valdoré (fig. 26). Consequently the Esla nappe rocks must have travelled a distance of 10 km + 6 km (6 km is the distance Valdoré—Crèmenes) = 16 km to their present position.

The — originally — flat sheet of the (subsequently folded) Esla nappe, that can be seen resting on the autochthone of Valdoré has a N-S dimension of 16 km (measured along curve).

Thus, the continuity of these units and the evidence of movement allow of no less movement than 16 km.

The Esla nappe forming the greater part of the mountains between the León line in the north and the southern border zone near Cistierna has been thrusted from a place south of the Sabero—Gordón line to its present position.

Thus original area of sedimentation of the Esla nappe rocks is now partly covered by hundreds of metres of Tertiary conglomerates and Cretaceous limestones (see also borehole evidence Sorriba in Almela 1949).

The two figures derived for the distance of movement on the Esla thrust fit each other well and bring the frontal zone rocks in the vicinity of the Sabero—Gordón line.

The dimensions of the Esla nappe are:

area covered by nappe	app.	200 sq kms
thickness of moving sheet	app.	2 kms
cubic mass, that moved	app.	400 kms^3
mean travel distance		10 km from S-N
product kms		4000 prod. kms

These figures are minima as the Esla nappe probably stretched further south than its present exposures in the Peña Corada zone.

Rodgers, J. (1963) has made this calculation for several thrust plates in the Appalachian foreland:

Sequatchie-Walden ridge	5000 prod. miles
Cumberland Plateau	600 prod. miles
Pine mountain	30000 prod. miles

Summing up it is seen, that the Esla thrust sheet qualifies as a nappe except for the fact, that a difference in tectonic style is not observed in the case of the Esla nappe versus the autochthone.

This exception to condition 3 of Zeil's may be due merely to the lack of sufficient exposures of the autochthone of Valdoré.

Bernesga—Torio structures

In the western part of our map sheet the continuation to the east of the Bernesga —Torio thrust structures is shown. For a complete description of this part of the Leonides the reader should see Comte's 1959 and de Sitter's 1962 papers and maps.

The area is limited to the north by the León line, whilst the Porma fault in the east produces the contact with the autochthone of Valdoré.

The tilt of the Leonide blocks during the Middle and Upper Devonian has been more important in the area west of the Pardomino ridge. On comparison it appears, that the sections in this area grow rapidly incomplete from S to N.

From south to north five elements can be recognized on the map:

a. The Gayo syncline,
b. The Bodon syncline,
c. The Forcada syncline,
d. The Westphalian zone of Ferreras-Lodares,
e. The Armada, Pallide synclines and the Reyero, Viego antiforms.

North of these subunits the León line marked by its accompanying Stephnian conglomerates, connects the Las Salas fracture zone in the east with the thrust front of the Leonides in the west.

All the beds in the Older Palaeozoic series are in subvertical or vertical positions. A small part of the units, a, b and c is shown on the present map.

Three thrust faults mappable over long distances to the west bring the Gayo, Bodon and Forcada synclines in contact with each other and in the case of the Forcada unit probably in contact with the Lower Westphalian. This contact, forming the frontal zone of the thrusts in the Leonides, will be commented on later.

The thrusts in the Bernesga structures usually also follow the Lancara, but sometimes part of the Herreria formation is thrusted. The northern thrusts cut deeper in lithostratigraphy, but here the entire Devonian is missing.

The synclines are by no means complete structures; over long distances only the northern flanks and occasionally parts of the southern flanks (Bodon sheet near Carmenes) are present. Small subsidiary anticlines may be preserved against the thrust, that has cut out the southern limbs of the synclines.

The rocks in the thrust structures show dips ranging from 80° to the north to 80° dipping to the south. In the vicinity of the Porma fault all three synclines are structurally complete again, the axes of these complete synclinal noses of the Forcada and Bodon structures locally plunge vertically (see fig. 27).

To the west of the village Valdehuesa the Forcada thrust is involved in a rather small and complicated anticline. Beyond this anticline the course of the Forcada

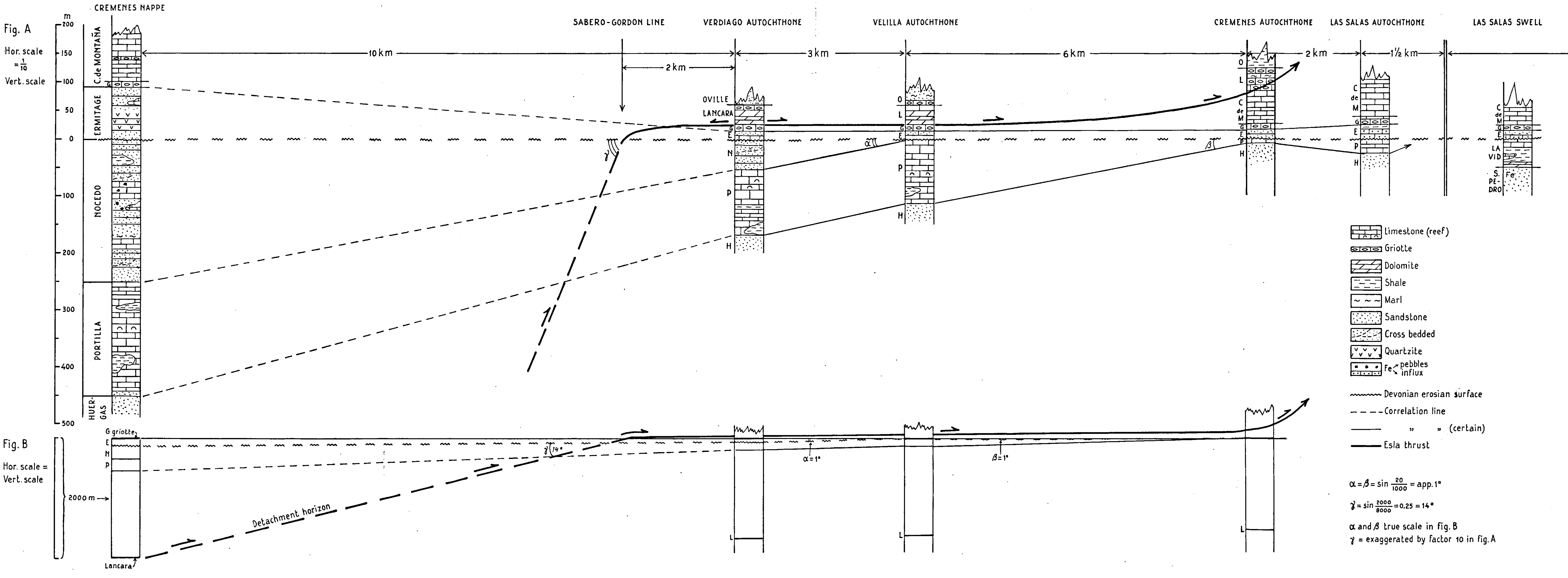


Fig. 26. Relationship upper Devonian of Nappe and autochthone with angle of tilt and min. dip of thrust.

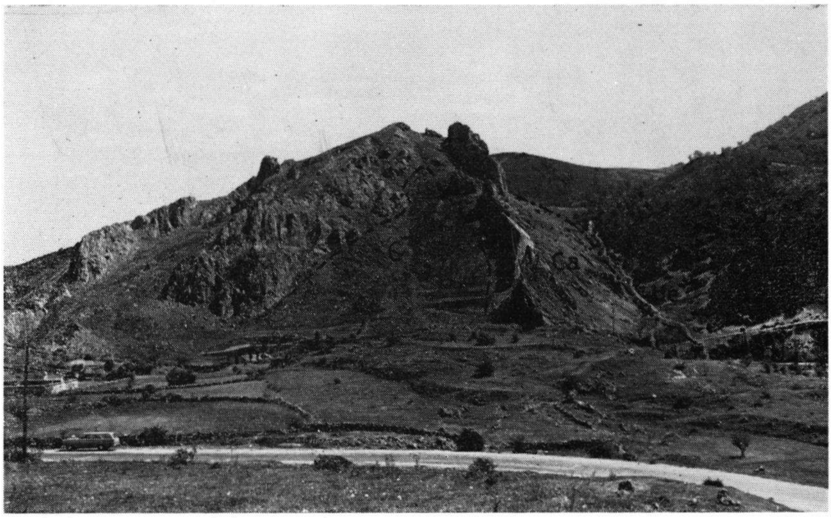


Fig. 27. The Bodon structure is cut off by the Porma fault east of Valdecastillo. From left to right: synclinal „nose" of Bodon structure with vertical axis, developed in Caliza de Montaña, Porma fault and Herreria sandstones.

sheet is changed to a N-S trend only to change after 8 kms again to the regular E-W strike. The León line coincides with the front of the thrusts from this turning point westwards. Along most of the S-shaped curve of the Forcada fault the fault plane is dipping from 40° to 80° to the west.

Subunit d, the zone of Ferreras—Lodares is underlain by shales, few sandstones and very rare limestones. The limestones, that occur near Rucayo, Lodares and Orones have yielded Foraminifera of the Upper Moscovian (translated in palaeobotanical terms: Upper Westphalian).

The Yuso beds of this zone are unconformable on the Forcada unit as demonstrated by the structures in this thrust unit south of Campillo, that are truncated by the Yuso beds of subunit d. The syncline of Pallide clearly is drowned and infilled by the Yuso beds.

It must be remenbered, that there is a sudden facies change of the Yuso as we cross the León line north of Pallide and Reyero. Clearly the line acted during the Westphalian. Both the Campillo and the Pallide structures are proof, that in this zone of the Leonides considerable folding took place both before and after deposition of the Upper Westphalian.

The demonstration of this Upper Westphalian unconformity on the scale of one exposure has been much looked for, but would be of no regional value. Subsequent disturbance at the contact of the younger Yuso rocks of the Ferreras—Lodàres zone with the pre-Namurian rocks blur the picture we get (figs. 28, 29).

The Older Palaeozoic and Visean—Namurian rocks of the Armada—Viego area are folded into four main synclines. These synclines have axes, that are equal in length, with vertical axial planes.

The Armada syncline attains full closure, but of the Pallide syncline only three-quarters is exposed. The Reyero and Viego structures are only half complete. There is increasing overturning from west-Armada to east-Viego.

The Viego antiform structure finds its extension to the southeast in the base of

Fig. 28 and 29. Two photos of exposed contact between Lancara limestone and coaly shales belonging to the Yuso group. Later movements have made it impossible to find unconformable or faulting-relationship between rocks contained in the thrusts and the Yuso beds i.e. on the scale of exposure. Photos near Lodares.

the autochthone of Valdoré. The Lancara griotte, that runs east of Primajas joins with the Lancara griotte in the Viego antiform.

Similar connections exist between the two eastern and the two western synclines. Extra faulting between the Pallide and Armada units complicates the core of the N-S trending anticline between them.

The consequence of this connection across the Porma fault is that the whole set of „onion-like" structures is autochthonous. This conclusion is further supported by the stratigraphic development of the Upper Devonian hiatus in this particular area betwee the León line and the Porma fault. It is the same in all four synclines.

A detailed structural analysis of the Bernesga area is being worked on in the Leiden Geological Institute and this will include the area of the wertern part of the present map sheet.

CHAPTER IV

GEOLOGICAL HISTORY AND SPECIAL FEATURES

During the late Precambrian and Cambrian the Herreria, Lancara and Oville formations were developed as shelf deposits at the margin—miogeosyncline— of a presumed geosyncline (Lotze 1961), that occupied the nortwestern part of Spain. The palaeogeographical pattern worked out by Lotze and Sdzuy (1961) is given in fig. 13.

The earliest differentiation of the greater basin, that was noted in the Older Palaeozoic sequence of the Cantabrian—Asturian mountains occurred during later Ordovician and early Silurian times. Comte (1959) observed, that 200—400 m of the Lower Palaeozoic section known in Galicia and northwestern Asturias was not represented in the Leonides (fig. 2). In the Leonides then, we find proof of further sedimentation in a shelf facies continuing through the Upper Silurian, Devonian and Lower Carboniferous.

It is important to observe, that the trends of younger Palaeozoic series run closely parallel to the pattern, that Lotze proposed for the Cambrian basin. The previously described Palaeozoic miogeosynclinal series now forming the Leonides curves round the Asturian knee according to the Cambrian facies pattern. The ultimate tectogenesis of the basin occurred in post-Namurian times as the Caliza de Montaña formation is the youngest rock unit taking part in the thrusting and folding of the Leonides.

When we come to the Esla region in particular we have proof of many earlier movements; folding, block faulting and tilting occurred during the Devonian. None of these early movements fall outside the scope of epeirogenesis. They did, however, influence the facies distribution, that is shown to have had primary influence on the ultimate tectonic configuration of the Esla area and surroundings.

The Las Salas zone was activated as early as the Gedinnian. The rising of the Las Salas anticline may have continued until the Upper Devonian, here too epeirogenesis reached a climax during the Famennian. It is reasonable to interpret the northern parts of the Bernesga—Torio structures, and the Forcada, Armada, Viego zone in particular, in the same sense. The Devonian tilt acted ont his northern part of the Leonides from Middle and Lower Devonian onwards.

The Pardomino ridge trending SW-NE separated a west rn block from an eastern block during the Devonian tilt of the Leonides. Most ofethe differential tilt movement was concentrated on the Porma fault. The angle of tilt was about 1° east of the fault and 3°—4° west of the Porma fault.

A little later the Sabero—Gordón line manifests itself. There is no evidence for Devonian erosion south of the Sabero—Gordón line. The Upper Devonian sections of the Esla nappe and of the Alba syncline carry a probably complete and continuous chronostratigraphic sequence.

During the Tournaisian the Porma fault and the León line again show activity as facies boundaries. No black shales are found in the area east and south of the two fault lines.

In the Esla area sedimentation was resumed very slowly with deposition of the Alba griotte.

The youngest formation in the Esla nappe and conformable with the Lower Carboniferous is the Caliza de Montaña limestone formation. At the end of, or after the Namurian the compressive phase, that produced the thrusts in the Leonides must be placed. The exact dating of the thrusts is a problem on which comments will follow in a separate discussion.

We consider the thrusting to represent the tectogenetic phase of the mountain chain in the sense of Haarman (1930).

The rock blanket, that was subjected to compression was far from homogeneous due to the described effects of earlier epeirogenesis.

In the west no important thrusts have carried material from south to north across the Sabero—Gordón line. The Rozo, Bregon, Gayo or Forcada thrusts originated north of this line.

In the east —east of the Pardomino ridge— the Esla nappe with its „southern" complete Upper Devonian section was carried across the Sabero—Gordón line. As shown in fig. 26 the angle of detachment need not have been larger than appoximately 14°.

The mode and result of thrusting also differs east and west of the Pardomino ridge. In the Esla area the pre-Westphalian Paleozoic series thins only gradually from south to north as the Devonian tilt in this zone was very gentle (in fig. 26 shown as 1°).

In the Bernesga basin the rock sheet thins more rapidly due to the greater slope of the Devonian erosion surface. This difference in nature and form of the primary pre-thrusting rock blanket —as defined between top of the Mora schists and the top of the Caliza de Montaña— is seen as the cause for the different tectonic styles. In the sharply northward thinning „wedge-like" blanket west of the Porma fault, the thrusts cut up and reached the surface rapidly whereas in the Esla basin compression acted on a rock „cake", that is almost parallelsided and more homogeneous. In the case of the Esla basin the mechanical properties of the given rock sheet change more gradually than in the Bernesga basin both going from south to north.

Detachment and movements of the Esla nappe

The front of the Esla nappe, now next to Pico Jano, rooted just south of the Sabero-Gordón line. On the Sabero-Gordón line the Upper Devonian shows an abrupt jump in lithostratigraphic thickness. The Sabero—Gordón line is a very logical hinge to detach the Esla nappe sheet from its neighbouring rock sheet the autochthone of Valdoré.

During the first episode in compression the Las Salas anticline already existed. South of this E-W trending high the Pico Jano syncline with extension to the east in the Tejerina syncline follows in a natural way. Part of the isoclinal character of these old structures stems from this early compressive phase. Pico Jano syncline extended itself to the west also, the Valbuena syncline is part of it. The old synclinal zone just south of the León line and Las Salas hogh extended even further in the Pallide Armada synclines.

In the south the Esla nappe departed and crossed the Sabero—Gordón line in this episode.

In a second episode, between the birth of the Valbuena syncline and the arrival of the Esla thrust sheet in the northern zone, the set of small thrusts in the Corniero—Primajas area developed. As we have seen before, the most probable order of development is from N-W to S-E. In other words the deepest thrust is earliest. The

Roblo fault terminates this process of subsidiary thrusting as it is far enough out from the Pardomino high.

After tearing loose and crossing the Sabero—Gordón line the Esla thrust sheet met two old buffer zones on its way from south to north.

The western part, now Felechas syncline, of the moving thrust sheet was the first to run into the southern edge of the Pardomino buffer. On its way to the north the Esla nappe could only swerve to the east as the SW-NE trending Pardomino high blocked the way directly to the north.

In this second stage of affairs the Corniero—Primajas set of faults originated. N-S compression made the nappe now move in a SSW-NNE direction, a direction parallel to the eastern edge of the Pardomino high. The Roblo thrust fault was reactivated probably at the end of this movement as a wrench fault.

During the third episode the thrust fault underneath the nappe met with the complicated zone of Las Salas as a second E-W running buffer. It cut up, thus forming the frontal zone south of Pico Jano syncline. This syncline is truncated by the Esla thrust fault, here a straight E-W running line. The Remolina-Argovejo folds were formed during the third episode just before the Esla thrust reached the surface.

The eastern zone of the Esla nappe is characterized by a large N-S trending anticline (Solana anticline), that is overturned to the east. Two theories can be forwarded:

a. The N-S directions in this zone are due to later refolding and are independent of the thrusting phase.

b. The N-S trending Solana anticline is the expression in a frontal anticline of the eastward moving nappe, derived after it reached full compression in the west against Pardomino high and in the north against the Las Salas high.

The N-S trend of Solana anticline is restricted to the nappe, north of Los Castros and outside the nappe this trend is not found. Hence the second theory is preferred.

An E-W course for the Esla thrust near La Red as a first theory has been described. As a second hypothesis it might be fancied, that the Solana anticline runs parallel to the thrust. The Esla thrust would be east of the Solana anticline and covered by the later Stephanian deposits.

A fourth and latest episode in thrusting is recorded in the Peña Corada unit. It was shown, that the E-W trending set of Murrial faults are subsidiary thrust faults with steep attitudes occurring just south of the Sabero—Gordón line.

In the nappe sheet further folding complications arose e.g. in the Peñola mountain south of Colle, in the Vegamediana area and south of Fuentes de Peña Corada. Both these folds and the Murrial faults have a cause in common; a step in the basement expressing itself as the Sabero—Gordón fault line.

In this picture the folds of the Peña Corada Synclinorium and the Murrial faults belong together in the same process of deformation. The Murrial thrust faults have not been folded, there is no evidence for later —post thrusting stage— refolding in the Peña Corada unit.

The folding of the Esla thrust around the fenster of Valdoré and the western edge of the Agua Salio syncline certainly reflects the trend of the Pardomino high, the time at which this refolding took place cannot be ascertained exactly. There are two possibilities:

a. The nappe sheet was folded at the end of the thrusting phase.

b. The nappe sheet was folded after an interval of time.

During this time the Lois-Ciguera basin was filled. Structures in this basin trend parallel to the axis of refolding in the fenster of Valdoré (compare de Sitter 1957). In both cases the general SW-NE trend might be inhereted from the Pardomino high.

Refolding also brought the subsidiary thrustplanes of the Corniero-Primajas area to their present overturned position.

In the Bernesga—Torio basin to the west of the Pardomino high thrusting from south over north also took place.

In contrast to the Esla area the thrusting in the Bernesga basin is limited to the area north of the Sabero—Gordon line. The Alba syncline south of that line holds a continuous section from Caliza de Montaña to the Mora schists of the Precambrian (de Sitter 1962). The Mora schists do not take part in the thrusting.

Conditions were quite different in this area. The Devonian erosion reduced the thickness of the post-Mora sedimentary rock blanket sharply, cutting more deeply in the north. I hold this to be the reason, that the mechanic conditions in the Bernesga rocks change rapidly from south to north. Hence a different type of thrusting resulted.

The Pardomino high also played a role as buffer zone in the eastern part of the Bernesga basin.

A diamond-shaped area between the León line in the north and the Porma fault in the south stayed „protected" during the period of deformation, that originated the thrusts.

The area north of the Pardomino ridge and south of the León line found itself in a „pressure shadow", no thrust sheets are stacked one on top of the other in this area.

The influence of the Pardomino ridge diminishes to the west as it plunges in that direction; east and near the Curueño river the thrust sheets could be pushed further to the north. This applies to the Forcada and Bodon thrusts in particular. The movement of the Bodon and Gayo thrust-sheets is read as from S-W to N-E.

In this theory the abrupt change in strike, demonstrated by the Forcada „nappe" between Valdehuesa and Rucayo is related to the basin configuration in the first place. In the Valdehuesa-Rucayo stretch the movement is expected to grow from S to N till the Forcada unit meets the E-W running León line structure as a final obstacle; no refolding chronologically separated from the thrusting phase is needed to explain this „S" curve in the „nappe" front.

Following this line of though the Vegamian embayment of the great Asturian basin formed in a logical place, where no previous heightening of relief of the Leonides had taken place.

Relation in time and space of the thrusts in the Leonides to the Asturian basin

As a general rule it has been stated, that the León line fracture zone forms the southern boundary of the Westphalian Asturian basin. Two exceptions, however, exist. The Tejerina syncline east of the Esla frontal zone and the Vegamian basin in the upper reaches of the Porma river; both contain rocks of the Yuso group and are situated to the south of the León line. The area between these two southern lobes of the Westphalian basin is the early rising Las Salas high.

In the west i.e. west of the „S"-curve in the Forcada thrust (compare map de Sitter 1962b), the thrusts have reached the León line. East of Valdehuesa the southern boundary of the Vegamian basin is dictated by the front of the thrust. Here the best examples of unconformable relationship of the Yuso beds on the pre-Westphalian series, thrusted (near Campillo and Rucayo) or autochthonous (Pallide) occur.

East of Ocejo the situation is less clear, but the Yuso beds in the southern

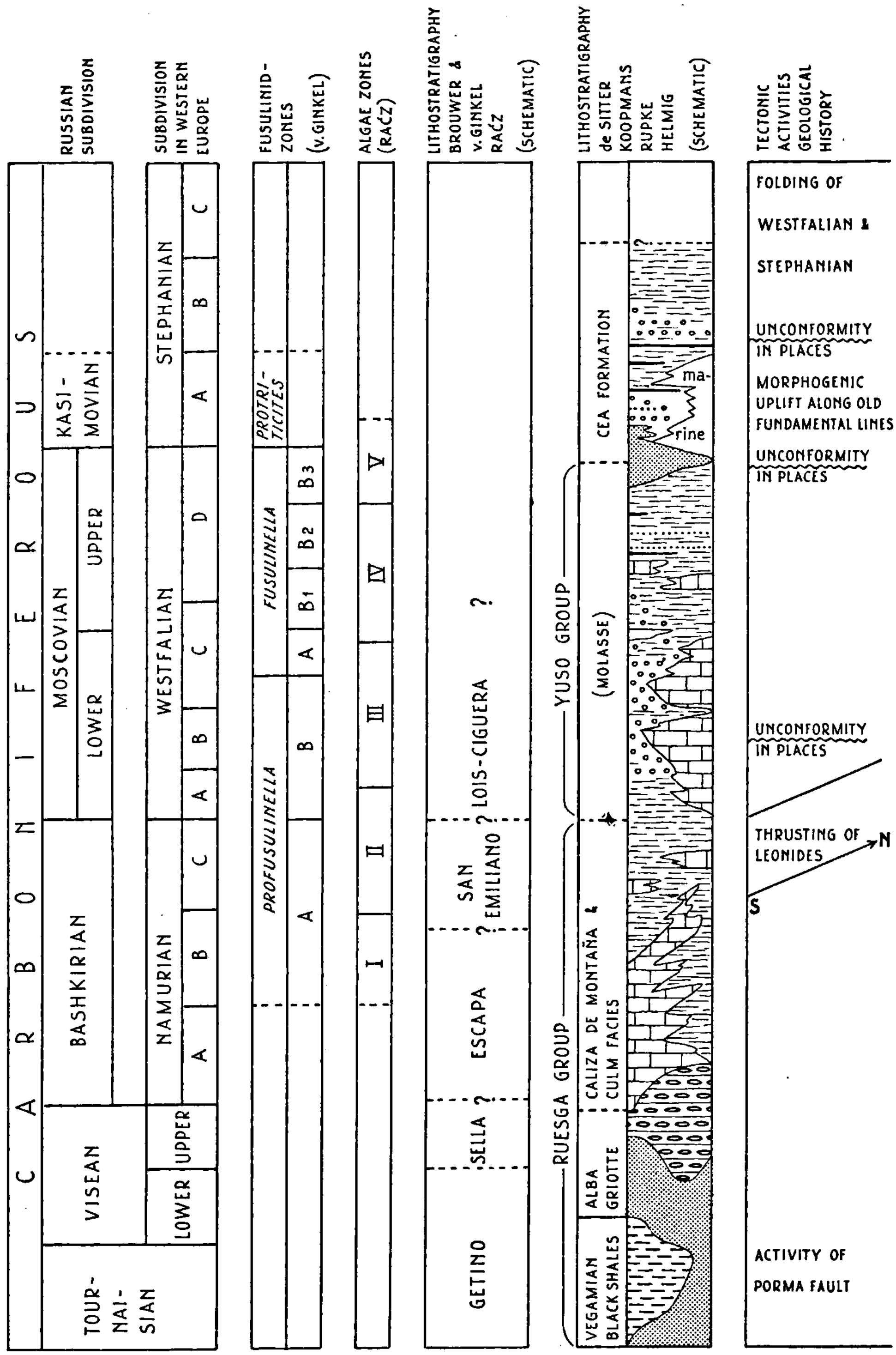


Fig. 30. Table showing Carboniferous stratigraphy as used in Cantabrian mountains (modified after Brouwer and van Ginkel 1963).

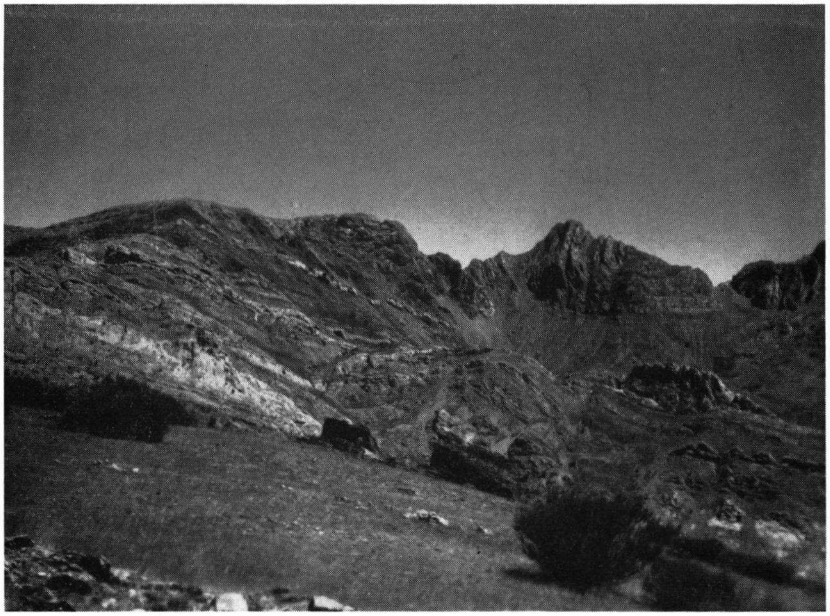


Fig. 31. Example of detachment occurring at the base of the Stephanian series. Isoclinally folded limestone conglomerates of Villacorta beds are unconformable on gently dipping Devonian strata of Esla nappe. Photographer looking NE toward Peña Rionda.

flank of the Tejerina syncline reach the probable front of the Esla nappe near La Red. The distribution of the micropalaeontological evidence gathered by Mr. A. C. van Ginkel and Dr. L. Racz in the Ruesga and Yuso group rocks be summarized as follows: (see also fig. 30).

1. The thrusts contain rocks belonging in the Profusulinella zone subzone A and the Algae zone II as youngest formation. This includes the lower-most part of the Moscovian.

2. The same zones are represented in anticlinal structures further north in the Yuso beds of the Asturian basin.

3. The rocks nearest to the front of the thrusts produced only a „young" microfauna: Fusulinella zone subzone B_1, B_2 and B_3 belonging in the Upper Moscovian.

4. The two southern lobes of the Asturian basin, the Vegamian basin and the Tejerina syncline only contain Upper Moscovian sediments.

It must be deduced that:

1. The thrusting in the Leonides took place during the Lower Moscovian (Lower Westphalian) after sedimentation in the Asturian basin had started.

2. The thrusting formed the palaeogeographical limits during the Westphalian at the southern edge of the Asturian basin, the thrusted area forming relative highs due to stacking up of the thrusted series.

3. The parts south of the León line, that were not thrusted or did not exist as old highs (Las Salas zone) formed „embayments" at the southern coast of the Asturian basin. As the Westphalian spread southward the younger Yuso beds „onlapped" over the Leonides.

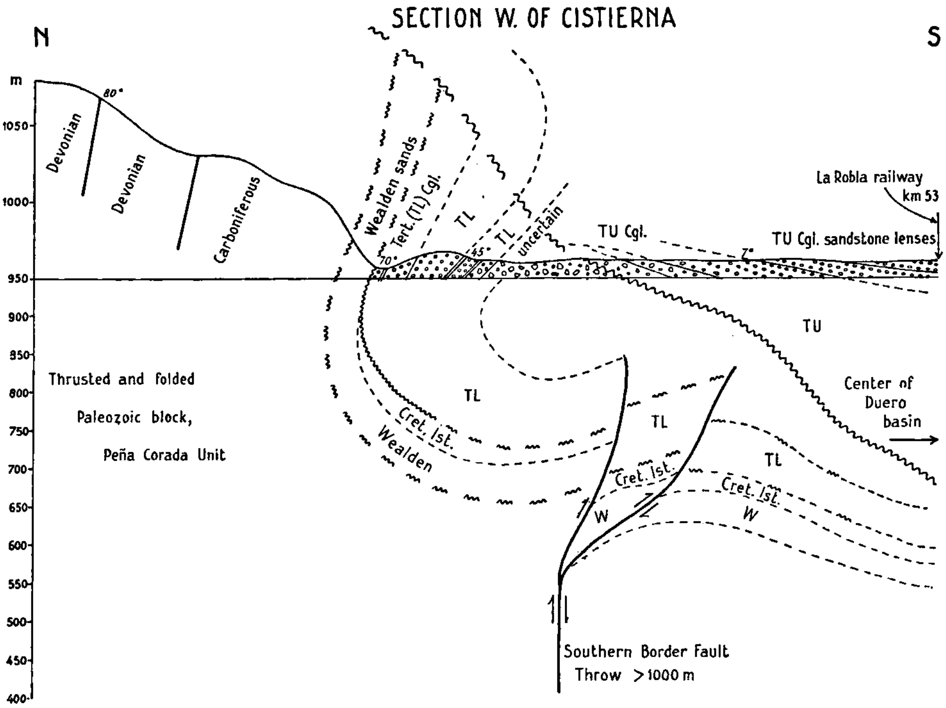


Fig. 32. Section showing relation between (from N to S) the Paleozoic of Peña Corada unit, the Cretaceous, the Eocene-Oligocene conglomerates and the miocene conglomerates.

The subsequent Stephanian deposits of the area are described in great detail by my colleague H. M. Helmig (1965).

It may suffice to state in short the Stephanian history of the area.

The high relief of the Esla nappe probably lasted until the end of the Stephanian; a consequent topography in the Ocejo and Remolina area is deduced. Moreover a transgression from east to west from Westphalian D to Stephanian A and B coincides with a change in environment from one with marine influence to a pure limnic environment.

The occurrence of the Stephanian deposits is, especially in the case of the limnic intramontane basins like the Sabero and Huelde — Salio basins, closely related to fundamental fault lines, that border tectonic blocks, which have been active during the Devonian and earlier Carboniferous history. These basins occur on and near to the Sabero-Gordón and León lines.

The folding style of the Stephanian sediments also is governed to a great extent by its position on previously folded and uplifted pre-Stephanian series, that had been eroded to considerable relief during late Westphalian and early Stephanian times.

Due to this situation the Esla nappe and autochthone play the role of „basement" to the unconformable Cea sediments. Detachment occurred frequently in the lower Cea beds, folding of the Stephanian did not result in shortening of the „basement" series (see fig. 31).

In the presently discussed area we find no record of Permian through Lower Cretaceous history. Upper Cretaceous sands and limestone-shale sequences are exposed in a steep dipping and narrow zone in the south between the Palaeozoic and Tertiary.

There is a slight unconformity of the Wealden sands on the Palaeozoic (see fig. 32).

Eocene-Oligocene conglomerate deposits in their turn demonstrate a slightly unconformable position as regards the Cretaceous sediments.

Miocene conglomerates containing large blocks of all the older sediments overly with sharp unconformity the previously mentioned beds.

The Eocene-Oligocene beds dip almost vertical to 40° to the south whereas the Miocene series show dips of 10 to 5 degrees to the south. By this evidence the southern border fault is dated as post-Eocene-Oligocene and pre-Miocene. The total throw of this fault is estimated as from 400 to more than 1000 m. (see also sections 6, 7 and 8 and Almela 1949).

Thoughts on tectonic evolution of the Esla region

Finally it seens appropriate to scan the effects of tectonic activities as recorded before in the light of the absolute time scale (Holmes 1959).

In the wake of Stille's (1922) theories concerning mountain building several authors on the geology of the Cantabrian mountains have proposed different names

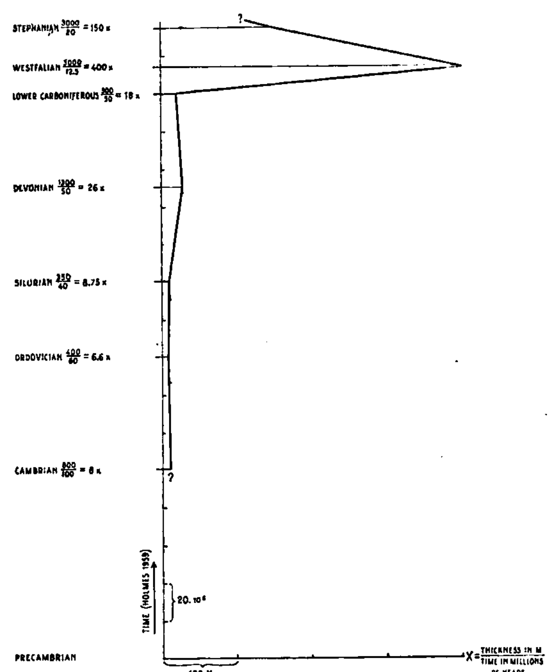


Fig. 33. Rate of sedimentation in Leonides and Asturides. Peak is extrapolated to thrusting of Leonides and subsidence of Asturian basin.

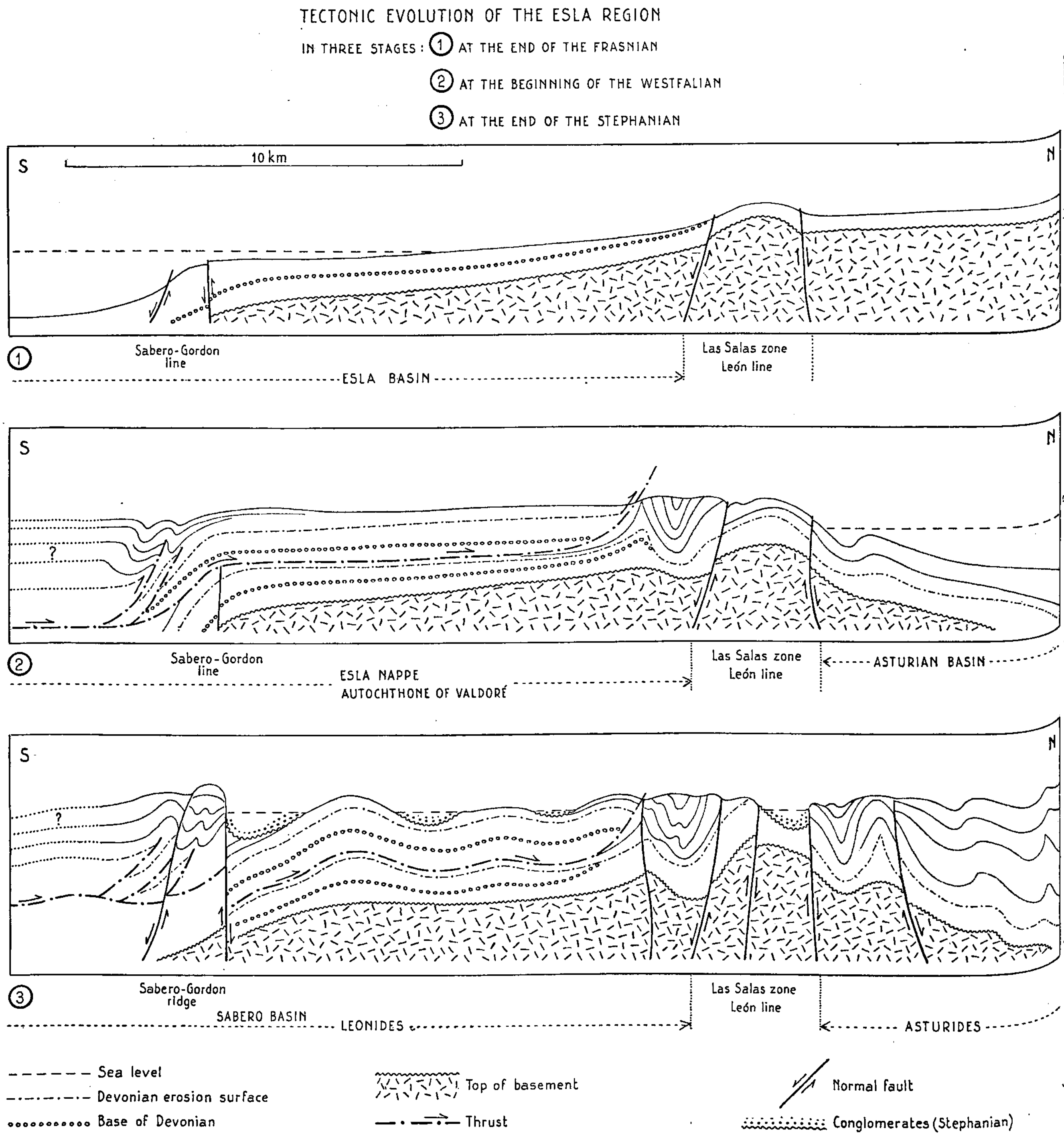


Fig. 34 Three diagrams showing tectonic evolution of the Esla region.

for tectonic phases. These phases were founded on unconformities of varying, but mostly small, horizontal extent. This especially is so for the Westphalian and Stephanian part of the geologic record.

In fig. 33 the rate of deposition: x as recorded by maxima of thicknesses in various parts of the Leonides and Asturides has been plotted against time. As shown in the graph the rate of deposition did not change appreciably during Cambrian, Ordocivian and Silurian times.

A small increase in sedimentation is demonstrated by the Devonian. This change is correlated to the Devonian movements of which we discussed the early rise of the León line, the birth of the Pardomino high and the Sabero-Gordón line and the general uplift and tilt of the Asturides and the Leonides.

The name Bretonic phase has been used for these movements, but it should be emphasised, that none of its activities falls outside the scope of epeirogenesis.

The Lower Carboniferous also is a relatively „quiet period" but the Westphalian and Stephanian show as an enormous peak in our graph. This peak in sediment production is directly correlated to real tectogenesis (Haarman 1930). During a far smaller time span far more sediment is laid down.

The thrusting of the Leonides, the subsidence of the Asturian basin (see fig. 34) took place during the end of the Namurian and the beginning of the Westphalian.

The Westphalian deposits were folded before deposition of Stephanian B accumulations on the southern border, i.e. on the León line, of the Asturian basin took place.

Finally the major morphogenetic uplift (Haarman 1930) of the present mountain chain had to wait until the Alpine orogeny.

In the author's opinion it will be an evermore frustrating experience to try and analyse the period taken up by what was real tectogenesis in order to determine „mountain building" tectonic phases of Cantabrian extent.

It seems far more relevant to the problem of orogenesis to map those unconformities in detail and in the meantime try to arrive at a tectonic synthesis.

LITERATURE

ALMELA, A., 1949. Estudio geológico de la reserva carbonifera de León. Bol. Inst. Geol. y Min. Esp. t. 62, p. 403—486.

AMEROM, H. W. J. VAN, 1965. Upper-Cretaceous pollen and spore assemblages from the so-called „Wealden" of the province of León (N. Spain). Spores et Pollen.

AMERON, H. W. J. VAN, and J. VAN DILLEWIJN, 1963. Note sur le bassin houiller de Ciñera-Matallana. Leidse Geol. Med., deel 29, p. 303—312.

BARROIS, CH., 1882. Recherches sur les terrains anciens des Asturies et de la Galice. Mém. Soc. géol. Nord, II, i, p. 1—630.

BATALLER, J. R. y P. H. SAMPELAYO, 1944. Contribucion al estudio del Mioceno de la cuenca hullera en la zona leonesa. Not. y Comm. Inst. Geol. y Min. Esp., 13, p. 21—36.

BELOUSSOV, V. V., 1962. Basic problems in geotectonics. New York, Mc Graw-Hill, 816 p.

BERTRAND, L. y L. MENGAUD, 1912. Sur l'existence de plusiers nappes superposées dans la Cordillère Cantabrique entre Santander et Llanes. Com. Rend. Ac. Sc., 155, Sr. 737, et Sc. 984.

BROUWER, A. & A. C. VAN GINKEL, 1964. La succession Carbonifère dans la partie méridionale des montagnes Cantabriques (Espagne du Nord-Ouest). C.R. 5e Congr. de Strat. et de Géol. du Carbonifère, v. 1, p. 307—319.

BOOGAERT, H. A. v. ADRICHEM et al, 1963. A new stratigraphic interpretation of Paleozoic sections in the region between San Isidro pass and Tarna pass (province of León, Spain). Not. y Comm. Inst. Geol. y Min. Esp. t. 70, p. 131—135.

CIRY, R., 1939. Etude géologique d'une partie des provinces de Burgos, Palencia, León et Santander. Bull. Soc. Hist. Nat. Toulouse, vol. 74, 4° trim. p. 1—528.

COMTE, P., 1938. Les faciès du Dévonien supérieur dans la Cordillère Cantabrique. C. R. Acad. Sci. Paris, t. 206, p. 1496—1498.

—— 1938. La transgression du Famennien supérieur dans la Cordillère Cantabrique. C. R. Acad. Sci. Paris, t. 206, p. 1741—1743.

—— 1959. Recherches sur les terrains anciens de la Cordillère Cantabrique. Mem. Inst. Geol. y Min. Esp. t. 60, p. 1—440.

DELEPINE, G., 1938. Correlations entre le Carbonifère moyen de la Russie et celui de l'Europe Occidental. Bull. Soc. Géol. Fr., 5 me ser., t. 8, p. 593—598.

—— 1943. Les faunes marines du Carbonifère des Asturies (Espagne). Mém. Akad. Sci. Inst. France, 66, p. 1—122, pls. I—VI. (Trad. extr. P. H. Sampelayo, 1946: Faunas marinas del Carbonifero de Asturias. Bol. Inst. Geol. Min. Esp., 59, p. 21—127, láms. I—VI).

GILLULY, J., 1960. A folded thrust in Nevada — Inferences as to time relations between folding and faulting. Am. Jour. of Sc. v. 285A, Bradley vol., New Haven, Conn.

—— 1962. The tectonic evolution of the Western United States. Quart. Jour. Geol. Soc. Londen, vol. 119, no. 474, part 2, p. 134—169.

GINKEL, A. C. VAN, 1960. The Casavegas section and its fusulinid fauna. Leidse Geol. Med. 24/2, p. 705—720.

—— 1965. Carboniferous fusulinids from the Cantabrian mountains (Spain). Leidse Geol. Med. Deel 31.

GOMEZ, VICENTE PASTOR, 1962. Probable area precambriana al N.O. de León. Not. y Comm. Inst. Geol. y Min. Esp. no. 67 tercer trium, p. 71.

HAARMANN, E., 1930. Die Oszillationstheorie. Ferd. Enke Verlag. Stuttgart.

HELMIG, H. M., 1965. The geology of the Valderrueda, Tejerina, Ocejo and Sabero Coal basins. (Cantabrian Mountains Spain) Leidse Geol. Med. deel 32.

HENKES, H., 1961. Note sur le bassin Houiller de Sabero, España. Leidse Geol. Med. deel 26, p. 50—58.

HIGGINS, A. C., 1962. Conodonts from the „Griotte" limestone of Northwest Spain. Not. y Comm. Inst. Geol. y Min. Esp., 65, p. 5—22.

HIGGINS, A. C. et al., 1964. Basal Carboniferous strata in part of northern León, NW Spain. Stratigraphy of conodont and goniatite fauna. Bull. Soc. belge. Geol., Pal., Hydrol., t. 72, fasc. 2, p. 205—248.

HOLMES, A., 1959. A revised geological time scale. Trans. Edinburgh Geol. Soc. p. 183—216.

HUME, G. S., 1941. A folded fault in the Pekisko area foothills of Alberta. Roy. Soc. Canada Trans. 3d ser. vol. 35, sec. 4, p. 87—92.

JULIVERT, M., 1957. Sintesis del estudio geologico de la cuenca de Beleño. Breviora Geol. Astur. vol. 1, p. 9—12.

KANIS, J., 1956. Geology of the eastern zone of the Sierra del Brezo (Pal.-Spain). Leidse Geol. Med. 21, p. 377—445.

KARRENBERG, H., 1934. Die postvariscische Entwicklung des Kantabro-Asturischen Gebirges N.W. Spaniens. Abh. Ges. Wiss. Göttingen Math. Phys. Kl. 3, H. 12.

KAY, M., 1955. Sediments and subsidence through time. Crust of the Earth (a symposium). Geol. Soc. Am. Special Paper no. 62, p. 665—684.

KEITH, A., 1925. Outlines of Appalachian strucure. Geol. Soc. Am. Bull. vol. 34, p. 309—380.

—— 1960, The anatomy of low angle thrust-faults. Am. Jour. of Sc., Bradley Volume, vol. 258A, p. 115—125.

KOOPMANS, B. N., 1962. The sedimentary and structural history of the Valsurvio dome, Cantabrian Mountains, Spain. Leidse Geol. Med. deel 26, p. 121—232.

KULLMANN, J., 1960. Die Ammonoidea des Devons im Kantabrischen Gebirge (Nordspanien). Akad. Wiss. u. Lit. Abh. nr. 7, p. 1—101.

—— 1961. Die Goniatiten des Unterkarbons im Kantabrischen Gebirge (Nordspanien). N. Jahrb.. Geol. Paläont. Abh. 113, no. 3, p. 219—326.

LLOPIS LLADO, N., 1954a. Estudio geológico del reborde meridional de la cuenca carbonifera de Asturias. Rev. Pirineos, núm. 31—32, p. 3—117.

—— 1954b. Sobre la tectónica de la cuenca carbonifera de Asturias. Estud. Geológicos, núm. 21, p. 79—101.

LINDSTRÖM, M., 1960. On some sedimentary and tectonic structures in the Ludlovian Colonus shale of Scania. Geol. Fören. i Stockholm Förh. no. 502, Bd. 82, H. 3, p. 319—341.

LOTZE, F. & K. SDZUY, 1961. Das Kambrium Spaniens. T. 1 Stratigraphie. Abh. Akad. Wiss. Math. Naturw. nr. 6.

MABESOONE, J. M., 1959. Tertiary and Quaternary sedimentation in a part of the Duero basin (Pal. Spain). Leidse Geol. Med. deel 24/1, p. 36—179.

MALLADA, L., 1900. Descripción de la cuenca carbonifera de Sabero (León). Bol. Com. Map. Geol. Esp., t. 27, p. 1—66.

MARTINEZ, J. A., 1962. Estudio geológico del reborde oriental de la cuenca carbonifera central de Asturias. Inst. Estudios Ast.

MENGAUD, L., 1920. Recherches géologiques dans la région Cantabrique, 370 p.

MENGAUD, L., 1932. Sur la structure de la chaîne cantabrique. Com. Rend. Ac. Sc. Paris, t. 195, p. 1092—1094.

MILICI, R. C., 1963. Low angle overthrust faulting as illustrated by the Cumberland Plateau-Sequatchie valley fault system. Am. Jour. of Sc. vol. 261, no. 9, p. 815—825.

OELE, E., 1964. Sedimentological aspects of four Lower-Paleozoic formations in the Northern part of the province of León (Spain). Thesis, Leiden, 99 p.

OELE, E. and J. M. MABESOONE, 1963. Origin of the Stephanian red beds in the Ocejo basin (prov. León, Spain). Leidse Geol. Med. deel 28, p. 377—388.

PRADO, C. DE, 1850. Sur les terrains de Sabero et de ses environs (León). Bull. Soc. Géol. Fr. 2ème ser. t. 7, p. 137—155.

QUIRING, H., 1939. Die ostasturischen Steinkohlenbecken. Arch. f. Lagerstättenforsch., nr. 69.

RACZ, L., 1965. Leidse Geol. Med. deel 31.

RADIG, F., 1963. Ordoviciense-Siluriano y la cuestion de los plegamientos prevariscos en España septentrional. Not. y Comm. Inst. Geol. y Min. Esp. t. 72/4.

RODGERS, J., 1963. Mechanics of Appalachian foreland folding in Pennsylvania and West Virginia. Bull. Am. Ass. Petr. Geol. vol. 47, no. 8, p. 1527—1536.

RUBEY, W. W. and M. K. HUBBERT, 1959. Role of fluid pressure in mechanics of overthrust faulting ect. Geol.Soc. America Bull. vol. 70, no. 2, p. 115—206.

SCHINDEWOLF, O. & J. KULLMAN, 1958. Cephalopoden-führendes Devon und Karbon im Kantabrischen Gebirge (Nordspanien). Neue Sr. Geol. Paläontol. Abh., núm. 1, p. 12—20.

SITTER, L. U. DE, 1956. Structural Geology, London-New York, McGraw Hill, 552 p.

—— 1957. Structural history of the SE corner of the Paleozoic core of the Asturian Mountains. N. Jahrb. f. Geol. u. Paläont. Abh., p. 272—284.

—— 1959. The Rio Esla nappe in the zone of León of the Asturian Cantabric mountain chain. Not. y Comm. Inst. Geol. y Min. Esp. no. 56, p. 3—23.

—— 1960. Crossfolding in non-metamorphic of the Cantabrian Mountains and in the Pyrenees. Geol. & Mijnb. 39e jrg., p. 189—194.

—— 1962a. El Precambriano de la cadena cantabrica. Not. y Comm. Inst. Geol. y Min. Esp., no. 67, tercer trim. p. 145.

—— 1962b. The structure of the Southern slope of the Cantabrian Mountains; explanation of a geological map with sections. Scale 1 : 100.000. Leidse Geol. Med. deel 26, p. 255—264.

—— 1965. Explanation of a geological map of the Cantabrian Mountains, sheet Pisuerga. Scale 1 : 50.000. Leidse Geol. Med. deel 31.

STILLE, H., 1924. Grundfragen der vergleichende Tektonik. Berlin, Gebr. Borntraeger, 443 p.

VERNEUIL, E. DE, 1850. Note sur les fossiles dévoniens de Sabero. Bull. Soc. Geol. France, 2ème sér., t. 7, p. 155—186.

WAGNER, R. H., 1958a. Stratigraphy and floral succession in the Carboniferous of NW Spain. 4. Cong. Strat. & Geol. Carbón Summary, num. 31, Heerlen.

—— 1958b. Nota sobre la estratigrafia del terreno hullero de Sabero (León). Est. Geologicos vol. 14, num. 35—36 p. 229—240.

—— 1960a. Presencia de una nueva fase tectonica Leoniense de edad Westfaliense D en el Nor-Oeste de España. Not. y Comm. Inst. Geol. y Min. Esp. no. 60, p. 221—226.

—— 1960b. Middle Westphalian floras from northern Palencia (Spain). Est. Geol. vol. 16, no. 2, p. 55—93.

—— 1963. A general account of the Paleozoic rocks between the rivers Porma and Bernésga (León, NW Spain) Bol. Inst. Geol. Min. España, t. 74, 163 p.

ZALONA, M. y A. H. SAMPELAYO, 1943. Investigaciones carboniferas Sondeo num. 1 de Boñar (León). Bol. Inst. Geol. y Min. de Esp. t. 56, p. 645—649.

ZEIL, W., 1959. Zur Deutung der Tektonik in den deutschen Alpen zwischen Iller und Traun. Zeitschr. Deutsch. Geol. Ges., Hannover, B. 111, p. 74—100.

ZIEGLER, W., 1959. Conodonten aus Devon und Karbon Südwest Europas und Bemerkungen zur Bretonischen Faltung. (Mont. Noire, Massiv v. Mouthomet, Span. Pyrenäen). N. Jahrb. Geol. Paläont. Abh. 7, p. 289—309.