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DEVONIAN AND LOWER CARBONIFEROUS CONODONT BIOSTRATIGRAPHY, SPANISH CENTRAL PYRENEES

BY

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ABSTRACT

Conodont faunas were collected from the Devonian and Lower Carboniferous in an area ranging from the Rio Esera (prov. of Huesca) in the west to the Rio Llobregat (prov. of Barcelona) in the east.

Most conodont zones and -Faunas recognized in Germany and Spain could be distinguished.

The ages of the formations distinguished in the Compte-, Sierra Negra s.l.- and Renanué sub-facies of the Southern facies (Mey, 1968a) could be indicated quite accurately. The formations in the various sub-facies are lithostratigraphically and chronostratigraphically correlated.

There is very strong evidence of a Tournaisian hiatus of changing extent, while the existence of a small Lower Frasnian hiatus is probable and the existence of a Siegenian hiatus in the Compte subfacies might be suggested.

Lithostratigraphic correlation of the formations of the Southern facies area with formations to the east, north and west, furnished stratigraphic cross sections, which were used for a reconstruction of the Pyrenean Basin. The picture arises of a basin in which during the Upper Givetian or lowermost Frasnian a central geanticline emerged, the Pyrenean Geanticline. Until the end of the Viséan the Pyrenean Geanticline remained an area of non-deposition. During the Namurian an intermontane basin possibly developed.

A lithostratigraphic correlation is presented between the Central Pyrenees and the Palentine facies of the Cantabrian Mountains, which suggests that both areas belonged to the same basin during the Devonian and Lower Carboniferous.

SAMENVATTING

Uit een gebied van de Rio Esera (prov. Huesca) in het westen tot de Rio Llobregat (prov. Barcelona) in het oosten zijn Devonische en Onder Karbonische conodontenfaunas verzameld.

De meeste conodontenzones en -Faunas die in Duitsland en in Spanje onderscheiden zijn, konden herkend worden.

De ouderdommen van de formaties van de Compte-, Sierra Negra s.l.- en Renanué sub-faciës van de Zuidelijke faciës (Mey, 1968a) konden tamelijk nauwkeurig worden aangegeven. De formaties van de verschillende sub-faciës werden lithostratigrafisch en chronostratigrafisch met elkaar gekorreleerd.

De aanwijzingen voor een Tournaisien hiaat van wisselende omvang zijn zeer sterk, terwijl het bestaan van een klein Onder Frasnien hiaat waarschijnlijk lijkt, en het bestaan van een Siegenien hiaat in de Compte sub-faciës wordt gesuggereerd.

De stratigrafische dwarsdoorsneden, samengesteld door lithostratigrafische korrelatie van de formaties van de Zuidelijke faciës met de formaties ten oosten, noorden en westen daarvan, werden gebruikt voor een rekonstruktie van het Pyreneese bekken. Men krijgt een beeld van een bekken waarin gedurende het Boven Givetien of onderste Frasnien een centrale geanticline opdook, de Pyreneese Geanticline. Tot aan het eind van het Viséen bleef de Pyreneese Geanticline een gebied van nondepositie. Tijdens het Namurien ontwikkelde zich mogelijk een intermontaan bekken.

Een lithostratigrafische korrelatie van de Centrale Pyreneeën en de Palentijnse faciës van het Cantabrisch Gebergte suggereert dat beide gebieden tijdens het Devoon en Onder Karboon deel uitmaakten van het zelfde bekken.

CONTENTS

CHAPTER 1

INTRODUCTION

Since 1948 the structure and the stratigraphy of the Pyrenees have been the subject of investigations by the Department of Structural Geology of the Geological Mineralogical Institute of Leiden. Palaeontological data, however, were scarce and often hard to compare. Until recently most palaeontological data in the Spanish Central Pyrenees came from Dalloni (1910, 1913, 1930) and Schmidt (1931). Ziegler (1959) described conodont faunas from several localities in the Spanish Central Pyrenees: Compte (Rio Noguera Pallaresa), Isobol (Rio Segre) and Canfranc (Rio Aragón).

Since the study of conodonts seemed very useful in dating the Devonian and Lower Carboniferous formations, the author in 1965 began collecting conodont samples at La Guardia de Arés and Castells (Nogueras Zone), with the special purpose of establishing the Devonian/Carboniferous boundary. In 1968 this project resulted in an internal report of the Department of Stratigraphy and Palaeontology (Boersma, 1968b). Additional field work was carried out during the summers of 1967–1969. Samples were collected from Devonian and Lower Carboniferous limestone formations, from the Rio Esera (prov. of Huesca) in the west to the Rio Llobregat (prov. of Barcelona) in the east (Fig. 1).

Use was made of the geological maps by Wennekers (1968), Mey (1967, 1968b) and Hartevelt (1970), and of the geological maps in internal reports of the Geological Mineralogical Institute of Leiden, prepared by Rijnsburger (1967), Boersma (1968a), Brouwer (1968) and Bloemraad (1969).

Previous conodont research, with the exception of the above-mentioned work by Ziegler (1959), was carried out in the Pyrenees by Marks & Wensink (1970), in the Lower Carboniferous of the Rio Aragón Valley. Krylatov & Stoppel (1968, 1969, 1971) described a number of Frasnian and Famennian faunas from the central and western part of the Central Pyrenees. A Gedinnian fauna was mentioned by Walliser (1962) from the Rio Noguera Pallaresa; a Tournaisian fauna was mentioned from the Rio Cinca area by van Lith (1965). Boersma described a number of morphological elements of some species of *Siphonodella* from Castells and La Guardia de Arés (1973a), and some Lower Devonian conodonts from the Nogueras Zone (1973b).

Acknowledgements

I am greatly indebted to Dr. H. A. van Adrichem Boogaert who introduced me to the field of conodont studies.

Highly stimulating for the progression of my conodont research was my visit to the Symposium on Conodont Taxonomy (Marburg/Lahn, September, 1971) and the discussions with Prof. Dr. K. J. Müller (Bonn).

I am furthermore indebted to Prof. Dr. H. J. Zwart, Dr. J. J. A. Hartevelt, Mr. K. J. Roberti and Mr. J. L. Liezenberg for the useful discussions on stratigraphical problems relating to the Spanish Pyrenees, and to Mr. Th. N. Brouwer and Mr. J. Bloemraad for their guidance in the field. Dr. M. A. Habermehl kindly provided some additional samples.

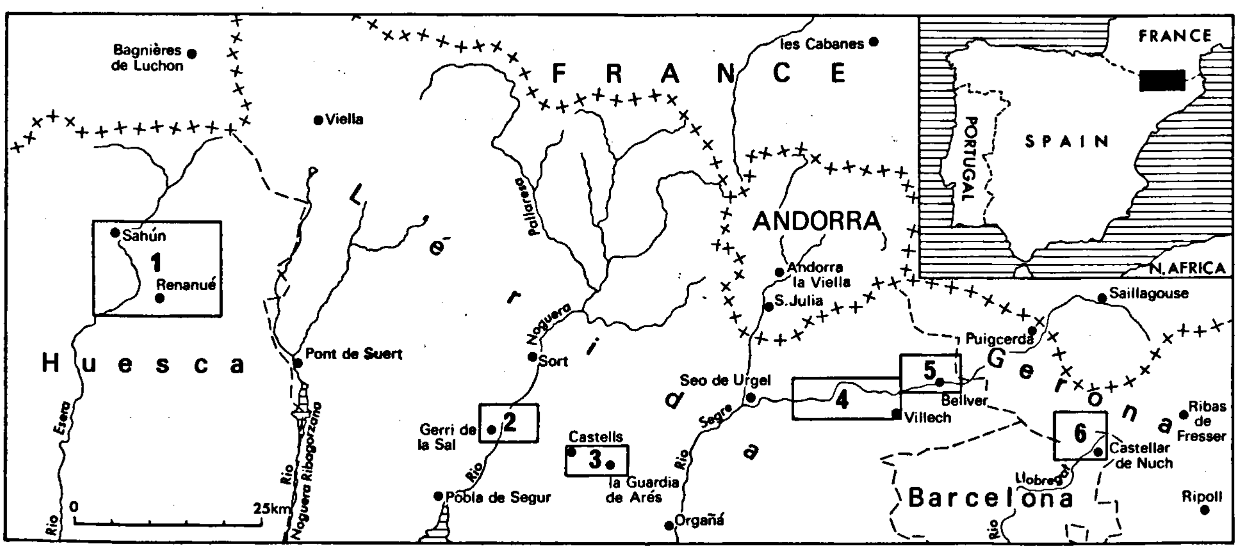


Fig. 1. Map (1 : 1,000,000) showing the location of the areas investigated. 1: Sahún – Renanué area (Fig. 20); 2: Gerri de la Sal area (Fig. 4); 3: Castells – La Guardia de Arés area (Fig. 7); 4: Torres – Villech area (Fig. 9); 5: Bellver area (Fig. 13); 6: Castellar de Nuch area (Fig. 15).

Finally I am grateful to Mr. M. L. Brittijn, Mr. J. Bult, Mr. K. A. Hakkert and Mr. B. G. Henning for preparing the drawings, to Mr. A. V. Zimmermann, who corrected the English text, and to Mrs. J. M. M. Knotter-van der Wijdeven, who typed the manuscript.

OUTLINE OF STRATIGRAPHY

The lithostratigraphic framework of the Devonian and Carboniferous of the Spanish Central Pyrenees was established by P. H. W. Mey, K. J. Roberti and J. J. A. Hartevelt.

Mey (1968a) distinguished four facies areas in the Devonian and pre-Hercynian Carboniferous of the Pyrenees. Only the southern facies area has been the subject of the present investigations. In the southern facies area Mey distinguished four sub-facies areas*:

1) Sierra Negra sub-facies area (Mey, 1967, 1968b; Hartevelt, 1970),
2) Baliera sub-facies area (Mey, 1967, 1968b; Habermehl, 1970),
3) Renanué sub-facies area (Mey, 1968b),
4) Compte sub-facies area (Hartevelt, 1970).

Only in the Renanué sub-facies area were no formal formation names recognized. The successsion of the strata in the Devonian of the Renanué sub-facies area was incorrectly interpreted by Mey (1968b). Two sections were sampled at Renanué (location map: Fig. 20; sections: Fig. 21), corresponding with the upper part of Mey's section. According to Mey these limestones should have an Upper Devonian and Lower Carboniferous age. Conodonts, however, indicate quite a different age (see Chapter 4.C). No complete section of the Devonian could be compiled.

In the opinion of K. J. Roberti, J. J. A. Hartevelt, J. L. Liezenberg (pers. comm.) and the present author the differences between the Sierra Negra- and Baliera sub-facies are only of minor importance. The only differences are the rather subjective subdivision of the Rueda Formation in Aneto Formation and Gelada Formation in the Baliera sub-facies, and the presence of the San Silvestre Quartzite-Dolomite Member (Habermehl, 1970) in the Baliera sub-facies. The differences in thickness in the Sierra Negra area and the Baliera area are caused partly by differences in tectonic deformation (K. J. Roberti, pers. comm.). It is consequently preferable to combine the Sierra Negra sub-facies and Baliera sub-facies, to the Sierra Negra sub-facies s.l.

Groos-Uffenorde et al. (1972) concluded that the clastic 'série de Vilaller' (= Civis Formation, Hartevelt, 1970), which they recognized in the Llavorsi Syncline, Torre de Capdella – Aguiró area, Vilaller area and Benasque area, should not be placed in the Carboniferous but somewhere between the Emsian and Frasnian. The conclusion is based on datings of ostracods and undetermined tentaculids in the Torre de Capdella – Aguiró area. If the exact location is considered (Roberti, 1973), it seems highly probable that the fossils were not collected from the Civis Formation, but from the Rueda Formation or Fonchanina Formation (J. L. Liezenberg, pers. comm.). Furthermore, the occurrence of tentaculids is established in the Rueda and Fonchanina Formation, but not in the Civis Formation. The suggestion by Groos-Uffenorde et al., that the Civis Formation should be placed in the Devonian, is therefore here rejected.

One change is made in the lithostratigraphic framework. In this paper the upper boundary of the Compte Formation is not placed below the first bedded cherts (Hartevelt, 1970), but at the limestone – clastic boundary. The Bellver Formation consequently begins with sandstones, conglomerates or shales. The bedded cherts are considered as marker beds in the C-Member of the Compte Formation. This change has hardly any consequences for the map published by Hartevelt (1970), since seldom more than a few metres of limestone occur above the bedded cherts.

The Sierra Negra sub-facies s.l. and Compte sub-facies can be defined by their succession of formations. The Renanué sub-facies which is still fragmentarily known, is defined here as the Devonian/Lower Carboniferous succession in which a thick sequence of massive limestones is overlain by a thin sequence of sandy shales intercalated by sandy marly limestones, which in turn are overlain by, in the lower part nodular, massive limestones. The limestones are overlain by the rather coarse clastic sequence of the higher Carboniferous. The formations and members recognized in the Sierra Negra sub-facies s.l. and the Compte sub-facies are indicated in Fig. 2.

No signs of erosion during the Devonian are observed, only locally are parts of the Compte Formation eroded, before the deposition of the Bellver Formation (Rijnsburger, 1967; Brouwer, 1968; Hartevelt, 1970). West of the Rio Fresser the A-Member of the Compte Formation is probably absent (Trouw, 1969).

The Devonian almost everywhere conformably overlies the black 'Silurian' shales, in which in the uppermost part the so-called *Orthoceras* limestones occur. Only in the eastern part of the Compte sub-facies area does Devonian conformably overlie the Camprodon Formation, which consists of dirty sandstones, which are badly layered (Trouw, 1969).

There is an angular unconformity between the Devonian and pre-Hercynian Carboniferous, and the locally present overlying Aguiró Formation (Mey et al., 1968), which has a Westphalian age.

Mey (1968a) correlated his four sub-facies with each other, but for want of sufficient palaeontological data the correlations are partly erroneous. Hartevelt (1970) could correlate the Compte sub-facies more precisely with the Sierra Negra sub-facies, since he was able to

* It is debatable whether the terms 'facies' and 'sub-facies' are used by Mey in a proper way and possibly it is preferable to use the term 'group' in this case. However, since the term 'group' implies some lithologic unity, which is certainly not the case in all (sub-)facies, and to avoid confusion the terms 'facies' and 'sub-facies' are maintained.

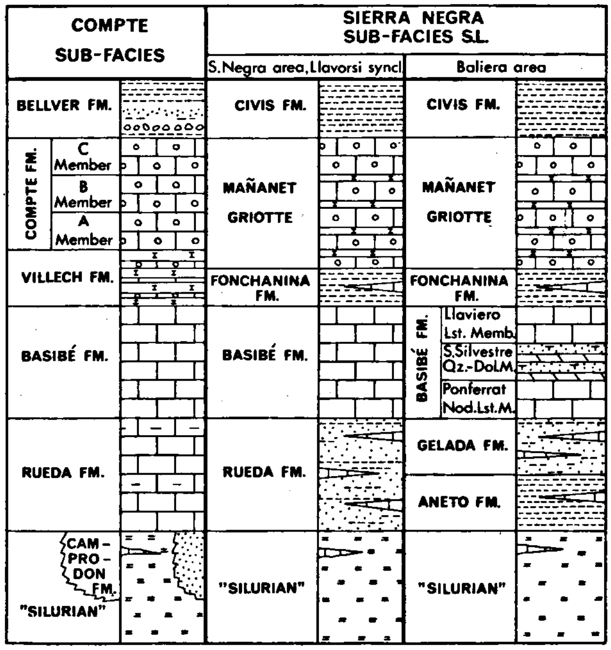


Fig. 2. Lithostratigraphic framework of the Compte sub-facies and Sierra Negra sub-facies s.l. Not to scale.

publish some preliminary age determinations presented in this paper. As will be demonstrated in Chapter 5.A, an even more precise correlation is possible.

Areal distribution of the sub-facies (Fig. 3)
The areal distribution of the sub-facies was indicated by Mey (1968a). However, several corrections have to be made.

The Compte sub-facies occurs from south of the Andorra – Mont Louis Granodiorite, south also of the Cambro-Ordovician Puigmal Dome (Hartevelt, 1970; Brouwer, 1968; Bloemraad, 1969, Trouw, 1969), and in the Feixa block (Rijnsburger, 1967; Boersma, 1968a; Roberti, 1974) of the Nogueras Zone. The Compte sub-facies probably also occurs in the Erdo block (Mey, 1968b) of the Nogueras Zone. The Compte sub-facies is not present in the Montsech de Tost as was suggested by Hartevelt; here the Devonian, as in the Castells block, belongs to the Sierra Negra sub-facies s.l.

A complete Devonian section in the Compte sub-facies area could not be sampled. Nearly complete, however, is the section at La Guardia de Arés.

At Farga de Moles, just south of Andorra, the Compte sub-facies, in a narrow badly exposed zone, grades into the Sierra Negra sub-facies s.l. of the Llavorsi syncline. Only the Rueda Formation is recognized in this transition zone (Hartevelt, 1970).

The Sierra Negra sub-facies s.l. occurs south of the Maladeta Granodiorite, from the Rio Esera in the west to the Rio Noguera Pallaresa in the east (Wennekers, 1968; Mey, 1967, 1968b; Frijlinck, 1963; Roberti, 1965, 1974), in the Llavorsi Syncline (van Wees, 1970; Zandvliet, 1960; Hartevelt, 1970) and in parts of the Nogueras zone, viz., from west to east, in the Gotorta – Malpas block, Las Inglesias block and Sta. Coloma block (Mey, 1968b), in the Castells block (Rijnsburger, 1967; Boersma, 1968a; Roberti, 1974) and in the Montsech de Tost (Hartevelt, 1970).

In the west and south-west the Sierra Negra sub-facies is separated by faults from the Renanué sub-facies.

The possibility of sampling undisturbed sections was very limited. Only at Castells could a section of the complete Devonian be sampled. The possibilities of sampling were further limited by the increasing degree of tectonization towards the north. It is probably for this reason that a section of the Mañanet Griotte in the eastern part of the Llavorsi Syncline did not yield any conodonts at all.

According to Wennekers (1968), a section in the Rio Esera (location map: Fig. 20; section: Fig. 22) consists of the upper part of the Basibé Formation, Fonchanina Formation and Mañanet Griotte. Conodont data are, however, so different to data from the same formations in more eastern areas that the assignment of the section to the Renanué sub-facies appears justified (see Chapter 4.C). The Renanué sub-facies was recognized by Mey (1968a) in the Las Paules block, the most western part of the Nogueras zone.

We may therefore conclude that the Renanué sub-facies is separated from the Sierra Negra sub-facies s.l., in the Rio Esera Valley, by the Eriste – Sahún Thrust, a western continuation of the Cerler Thrust (Wennekers, 1968). It is unknown whether the Renanué sub-facies also occurs west of the Rio Esera, between the Erices Thrust and the Eriste – Sahún Thrust, but it might be expected.

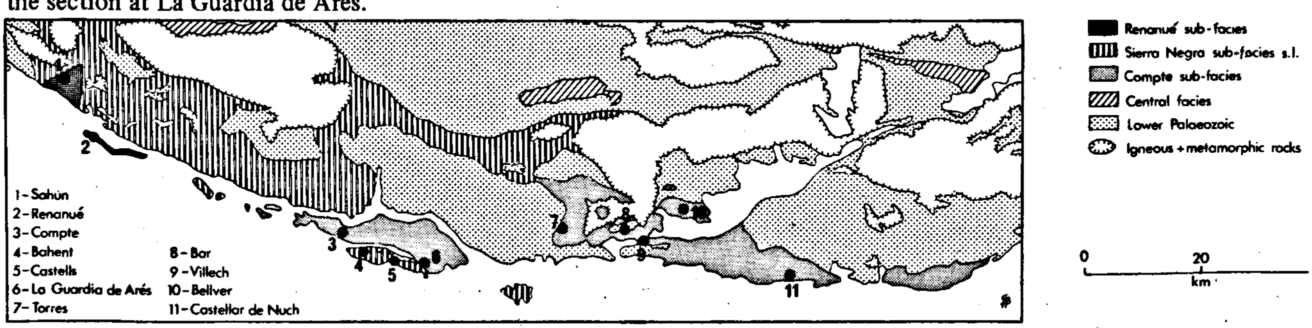


Fig. 3. Areal distribution of the sub-facies in the Southern facies area.

CHAPTER 2

STRATIGRAPHIC AND PALAEONTOLOGIC OBSERVATIONS

2.A. COMPTE SUB-FACIES

Compte (03)

At Compte the type section of the Compte Formation was sampled (location map: Fig. 4; section: Fig. 6). Two bedded chert layers are present, but above the second bedded chert the section is tectonically disturbed, so that the few metres of greyish nodular limestone recorded elsewhere above the bedded cherts are absent. The thickness of the Compte Formation is about 105 m.

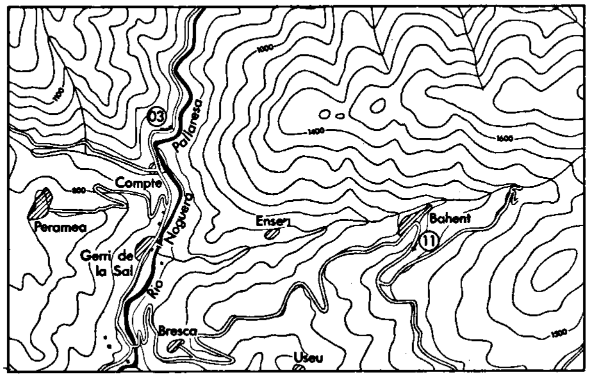


Fig. 4. Location map (1 : 100,000) of the Gerri de la Sal area, showing the location of the sections at Compte (03) and Bahent (11). The arrows point towards the youngest parts of the sections.

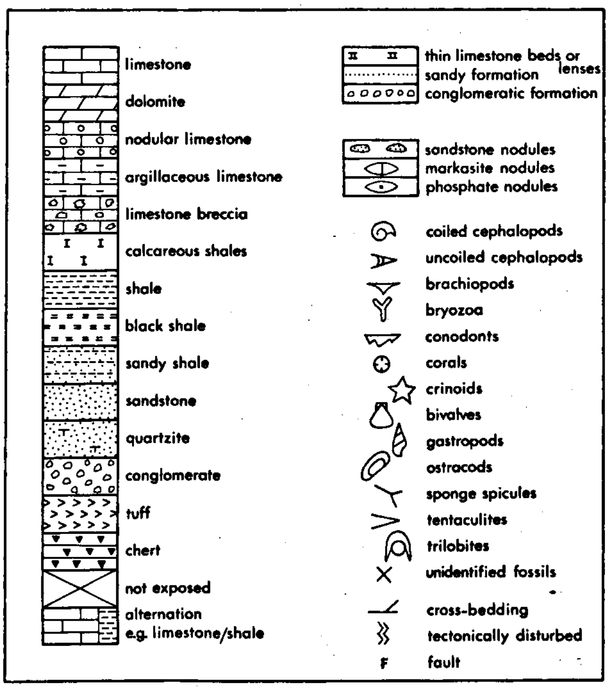


Fig. 5. Legend to the stratigraphic sections.

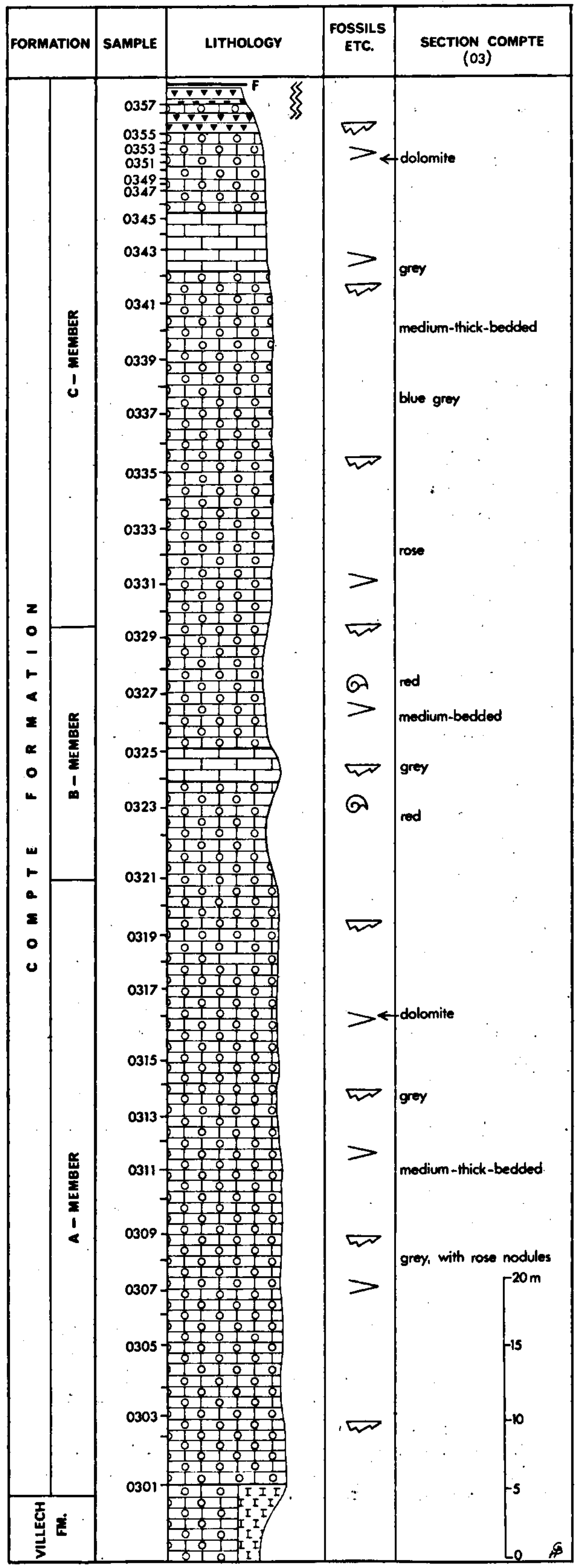


Fig. 6. Section 03.

In the upper part of the C-Member a 20 cm thick dolomite layer is observed. In the middle part of the B-Member a blue grey limestone occurs.

The conodonts recovered from the Compte section are listed in Table 1.

La Guardia de Arés (01)

At La Guardia de Arés the uppermost parts of the Basibé Formation, Villech Formation and Compte Formation are sampled (location map: Fig. 7; section: Fig. 8).

The upper part of the Basibé Formation consists of grey nodular limestone, alternating with more marly parts. The lowermost part of the Villech Formation consists of an alternation of grey calcareous shales and grey nodular limestones, while its middle and upper part consists mainly of rose nodular limestones and reddish calcareous shales. The thickness of the Villech Formation is here about 80 m. The uppermost metres of the A-Member of the Compte Formation consist of intraformational breccias. As at Compte, a blue grey limestone occurs in the middle part of the B-Member. In the upper part of the C-Member two bedded chert layers are recognized, the lower of which is accompanied by some phosphate nodules. The thickness of the Compte Formation at La Guardia de Arés is about 120 m.

The conodonts recovered from samples of the section at La Guardia de Arés are listed in Table 2.

Torres (09)

At Torres the Rueda Formation, Basibé Formation and the lowermost part of the Villech Formation were sampled (location map: Fig. 9; section: Fig. 10).

The boundary of the Rueda Formation and the 'Silurian' is not well exposed. The Rueda and Basibé Formation both consist of dark to light grey limestones, which are somewhat more impure in the lower part of the Rueda Formation and somewhat more nodular in the Basibé Formation. A distinction between both formations can hardly be made. In both formations brecciated limestones occur. The thickness of the Rueda Formation at Torres is 22 m, of the Basibé Formation 16 m. The transition to the Villech Formation is rather gradual.

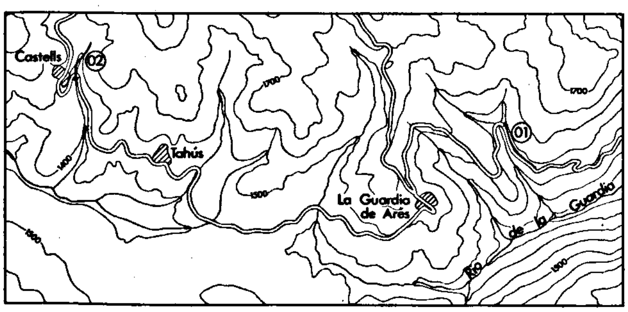


Fig. 7. Location map (1 : 100,000) of the Castells – La Guardia de Arés area, showing the location of the sections at Castells (02) and La Guardia de Arés (01). The arrows point towards the youngest parts of the sections.

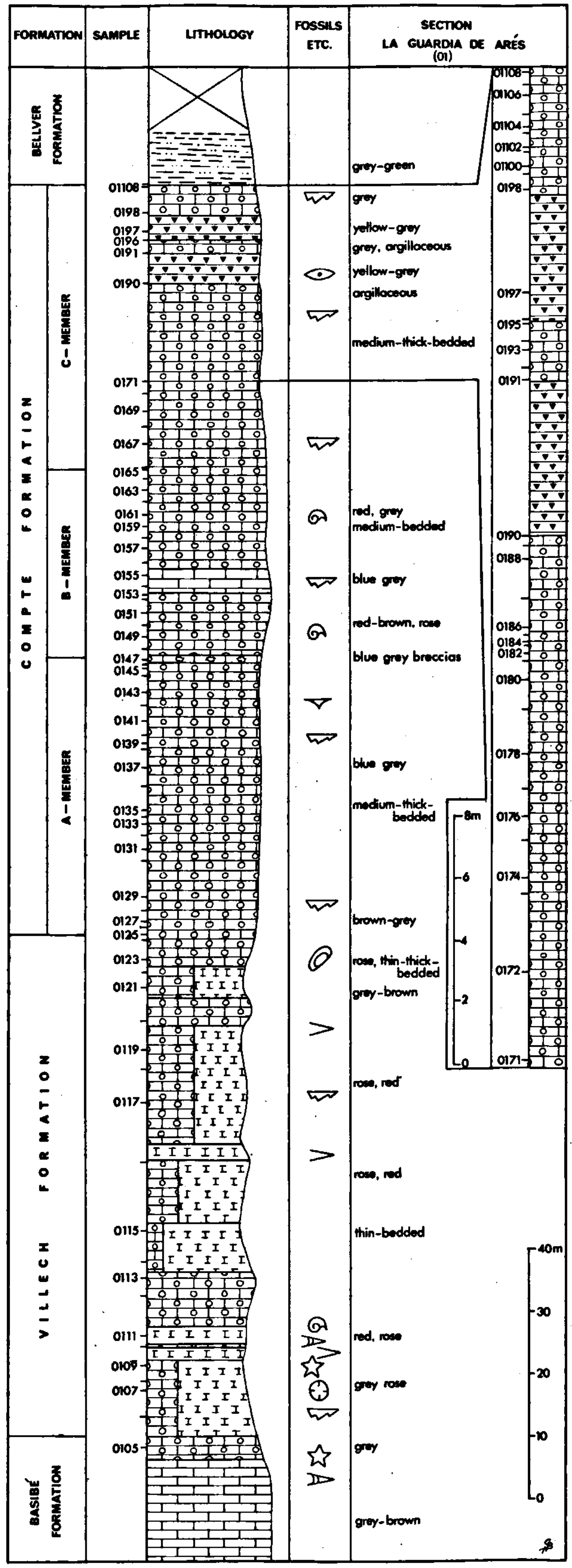


Fig. 8. Section 01.

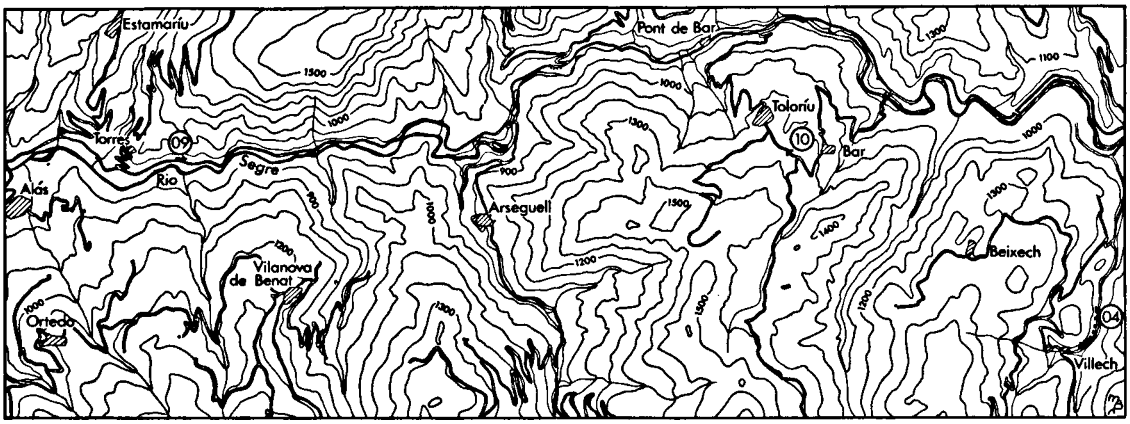


Fig. 9. Location map (1 : 100,000) of the Torres – Villech area, showing the location of the sections at Torres (09), Bar (10) and Villech (04). The arrows point towards the youngest parts of the sections.

The conodonts recovered from the Torres section are listed in Table 3.

Bar (10)
About 10 m of greyish black nodular limestone, intercalated by some black shale beds, were sampled at Bar: the Toloríu Limestone (location map: Fig. 9; section: Fig. 11) (Hartevelt, 1970, section 39). The limestones are about 75 m below the boundary of the 'Silurian' and the Rueda Formation. Orthocerids are not recorded in the limestones.

The conodonts recovered from the Toloríu Limestone are listed in Table 4.

Villech (04)
The uppermost part of the Basibé Formation, Villech Formation (type section) and Compte Formation up to the lower part of the C-Member were sampled at Villech (location map: Fig. 9; section: Fig. 12).

The type section of the Villech Formation is not well chosen, since the section is tectonically severely disturbed. It was consequently only relevant to sample the

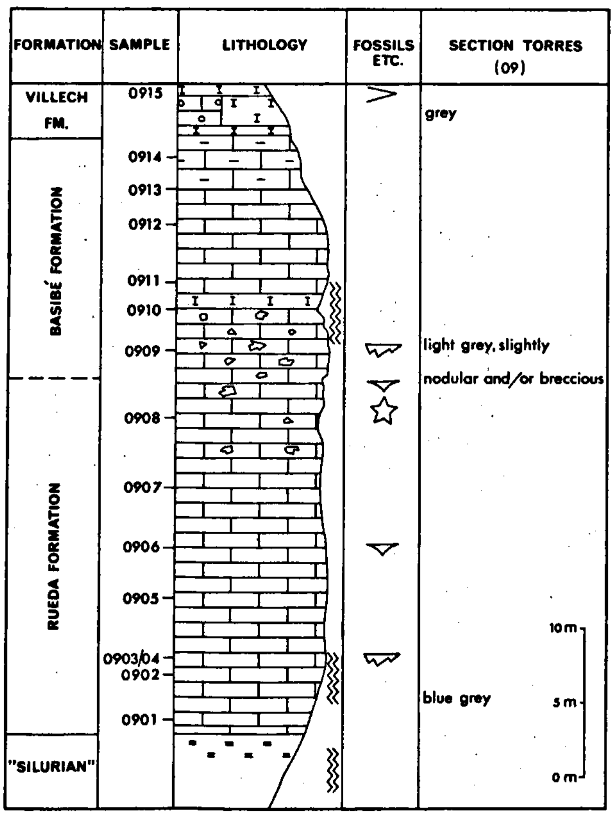


Fig. 10. Section 09.

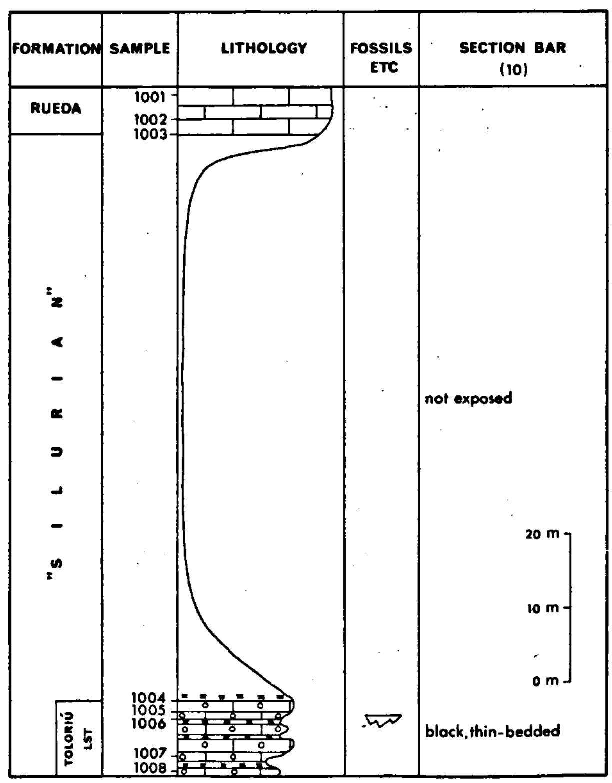


Fig. 11. Section 10.

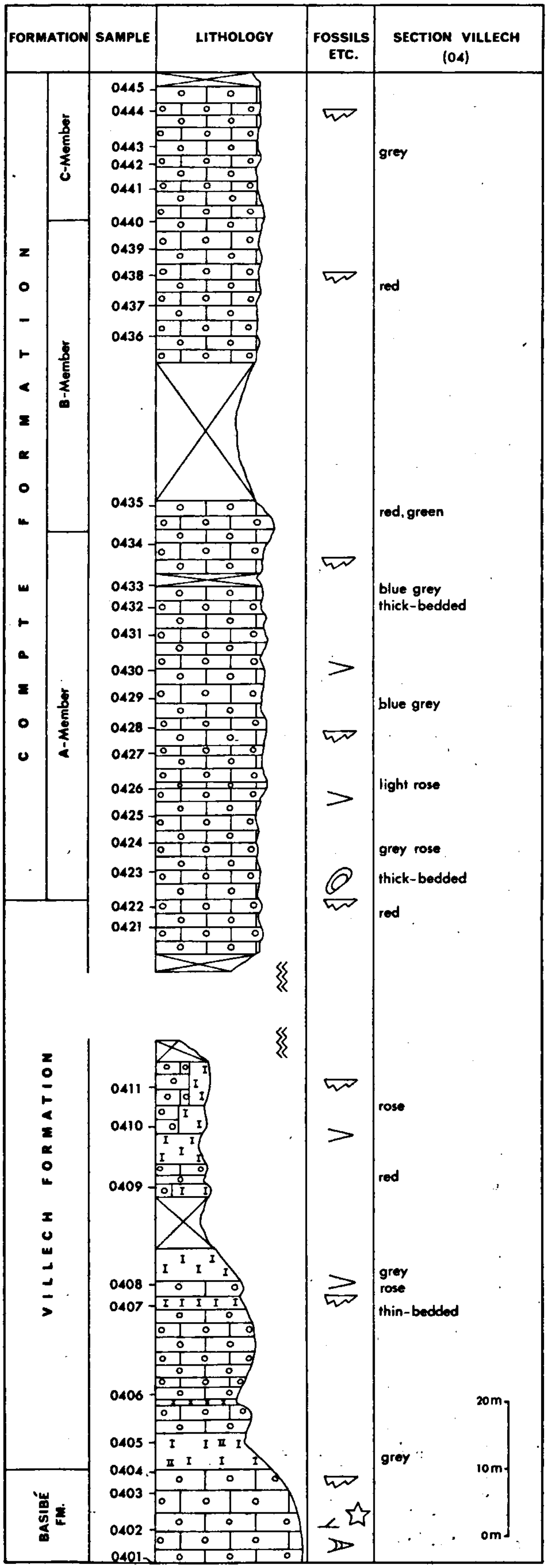


Fig. 12. Section 04.

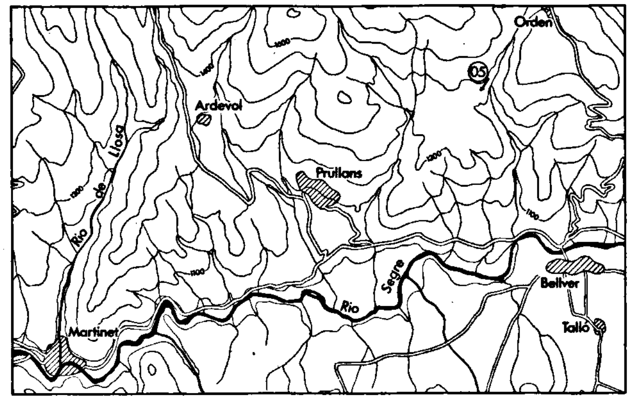


Fig. 13. Location map (1 : 100,000) of the Bellver area, showing the location of the section at Bellver (05). The arrow points towards the youngest part of the section.

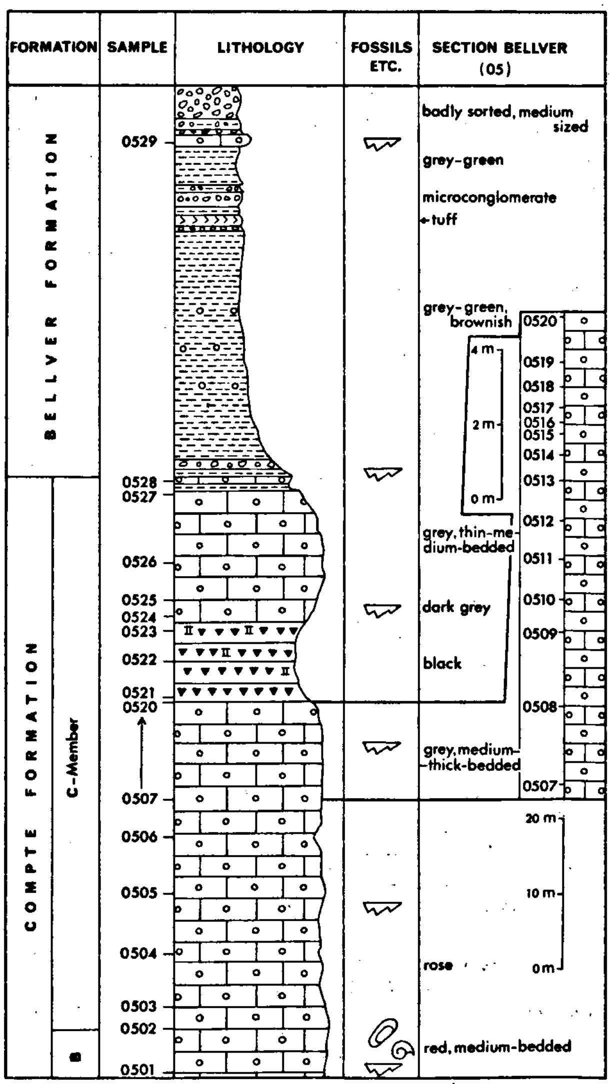


Fig. 14. Section 05.

lowermost and uppermost parts of the formation. The lowermost part of the Villech Formation consists here, too, of greyish calcareous shales and nodular limestones.

The conodonts recovered from the Villech section are listed in Table 5.

Bellver (05)

At Bellver (location map: Fig. 13; section: Fig. 14) the upper parts of the B-Member and C-Member of the Bellver Formation were sampled, and a limestone from the Bellver Formation.

Here only one bedded chert layer occurs, which contains several limestone nodules.

In the lower part of the Bellver Formation a 2 m thick layer of green tuffs is observed.

The conodonts recovered from the section at Bellver are listed in Table 6.

Castellar de Nuch (06)

In the Castellar de Nuch area (location map: Fig. 15) the Rueda Formation, Basibé Formation and lower part of the Villech Formation were sampled in one locality (section 06-A, Fig. 16). Since it was not possible to sample a complete section of the Compte Formation in this area, the Villech Formation/Compte Formation (section 06-B) and B-Member/C-Member (section 06-C) boundaries, as well as the uppermost part of the C-Member (section 06-D) were sampled in various localities (sections: Fig. 17).

Here, too, brecciated and nodular parts occur in the Rueda and Basibé Formations. A distinction between both formations is hardly possible. The thickness of the Rueda Formation is here about 19 m, of the Basibé Formation also about 19 m. In the Castellar de Nuch area the Villech Formation consists almost entirely of nodular limestones, so that the transition into the Compte Formation is here more gradual than elsewhere. The uppermost part of the B-Member is only slightly reddish. In the uppermost part of the C-Member two bedded chert layers are recognized, separated by shales and nodular limestones. The lower chert layer is accompanied by phosphate nodules. The second bedded cherts are here not overlain by nodular limestones, but directly by the shales of the Bellver Formation, in which some limestone nodules occur in the lower part.

The conodonts recovered from section 06-A are listed in Table 8, while those from sections 06-BCD are listed in Table 7.

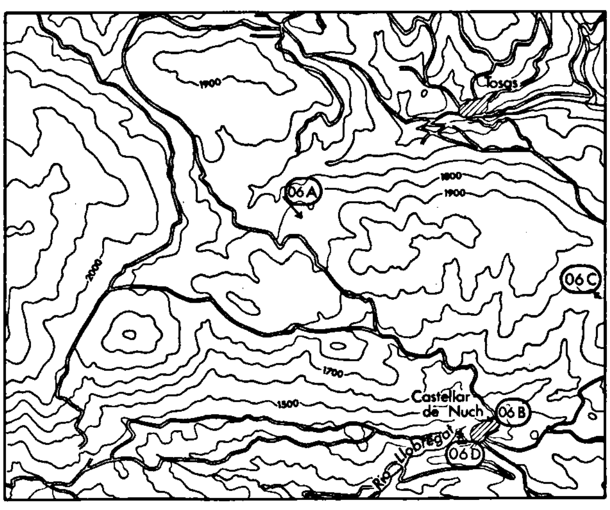


Fig. 15. Location map of the Castellar de Nuch area, showing the location of sections 06-ABCD. The arrows point towards the youngest parts of the sections.

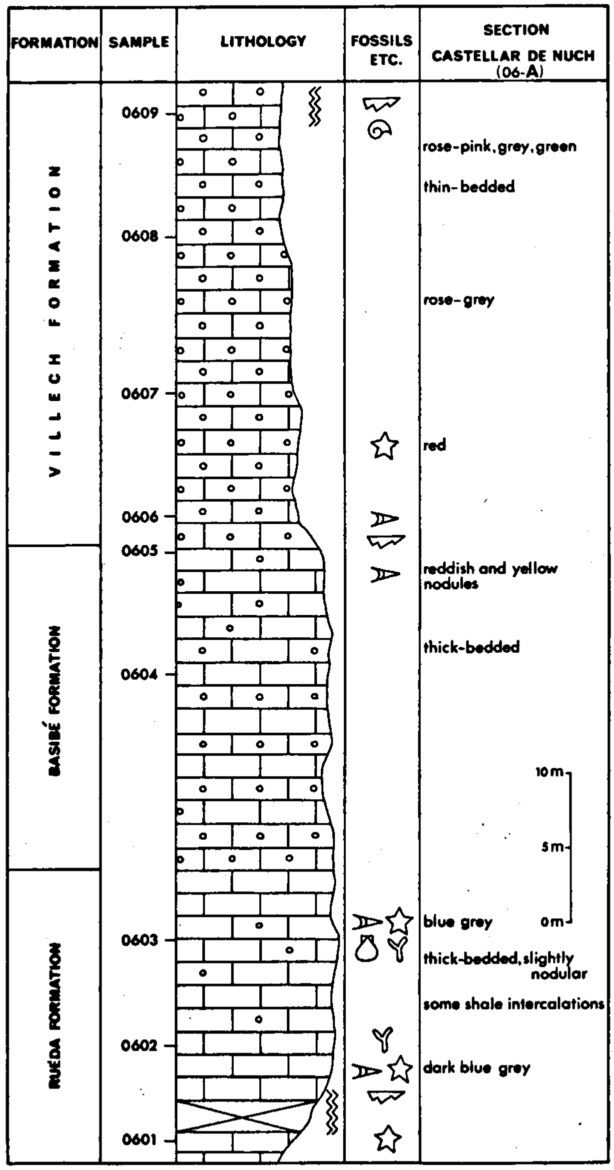


Fig. 16. Section 06-A.

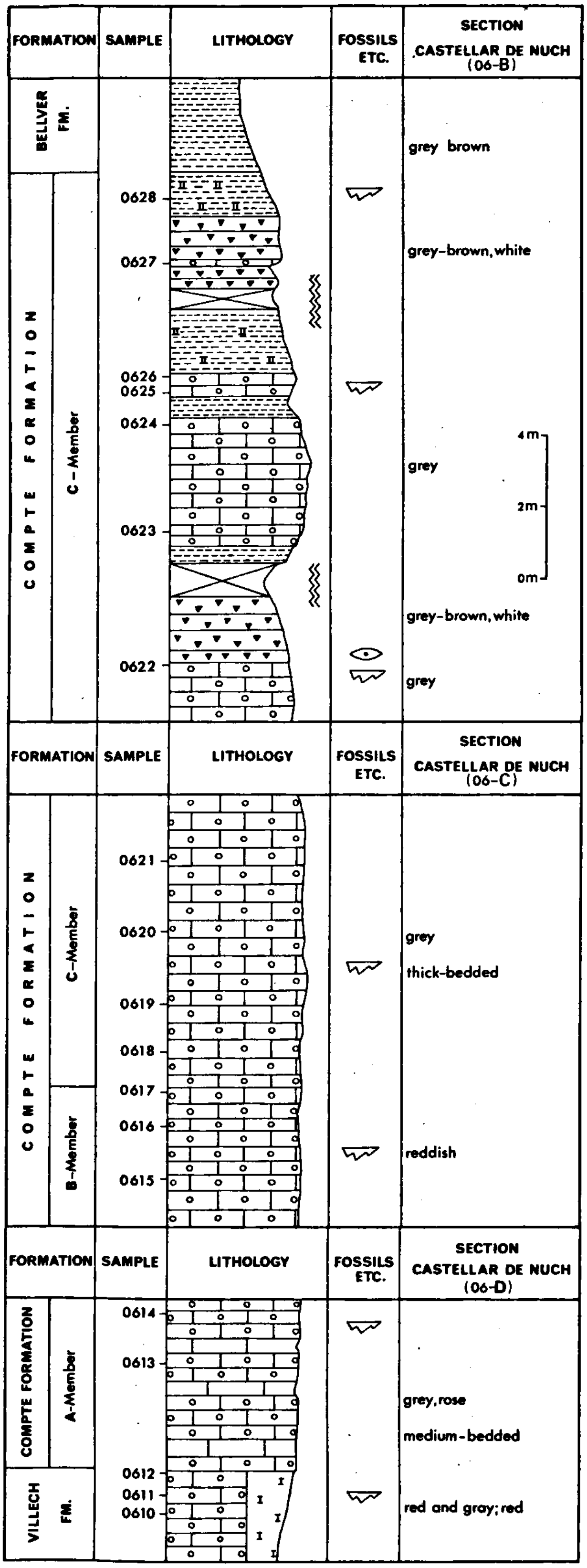


Fig. 17. Sections 06-BCD.

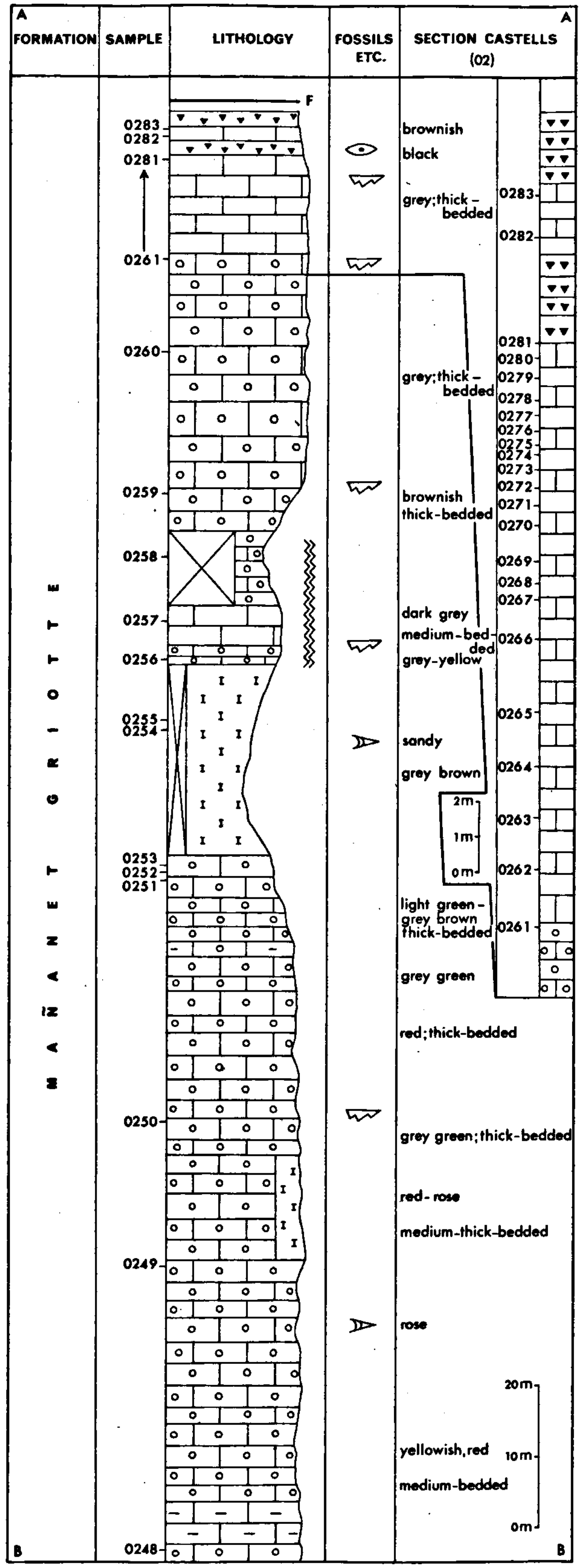
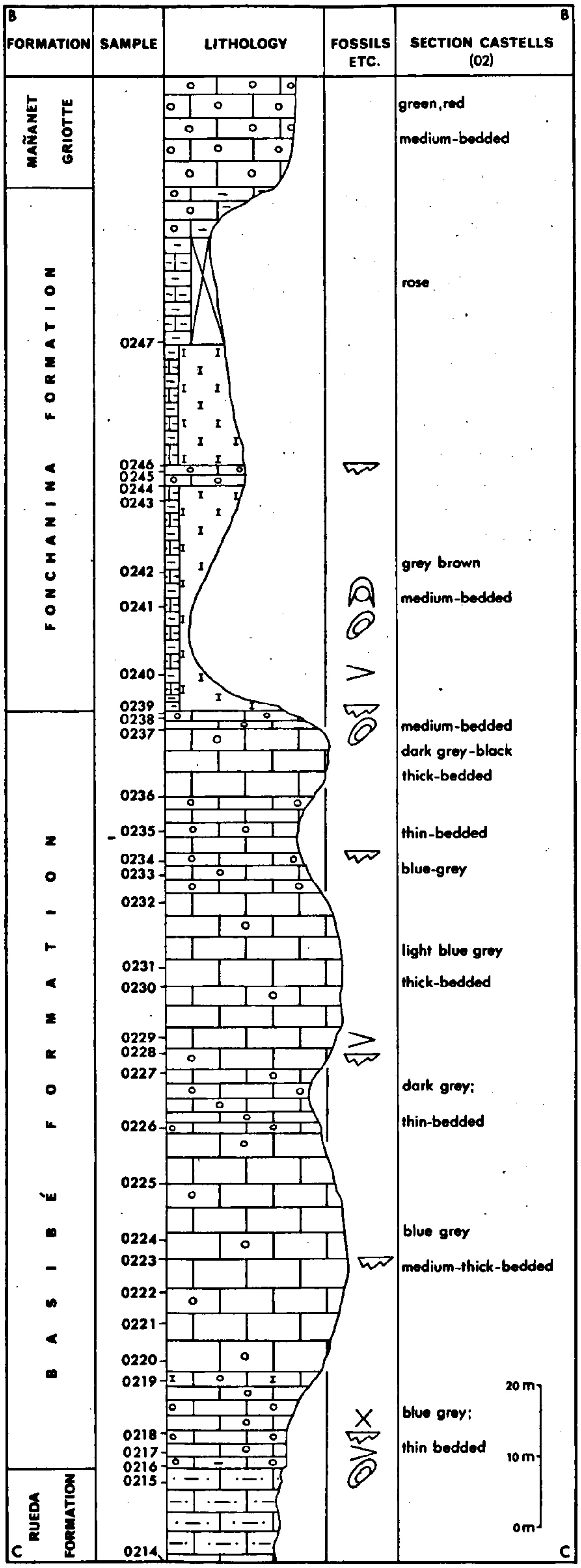


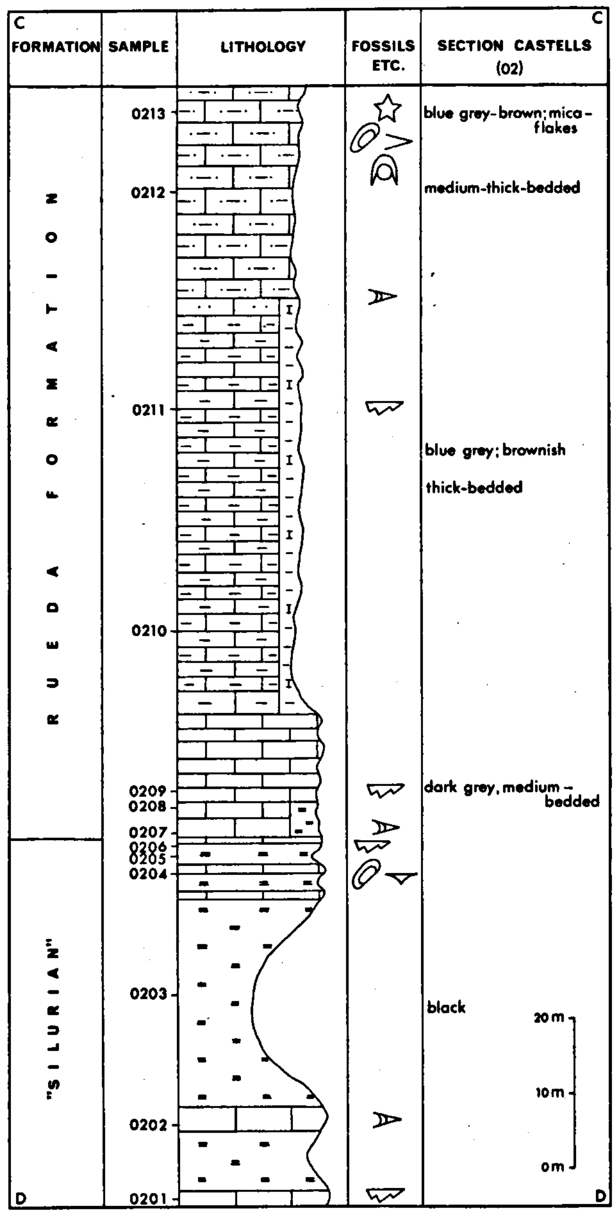
Fig. 18. Section 02.



2.B. SIERRA NEGRA SUB-FACIES S.L.

Castells (02)
At Castells (location map: Fig. 7; section: Fig. 18) the *Orthoceras* limestones, Rueda Formation, Basibé Formation, Fonchanina Formation and Mañanet Griotte were sampled.

In the black shales intercalating the *Orthoceras* limestones markasite nodules were observed. In the Rueda Formation two members may be recognized, the lower of which consists of siltstones and marly limestones, the upper member of sandy limestones and sandy marly limestones. The base of the lower member consists of



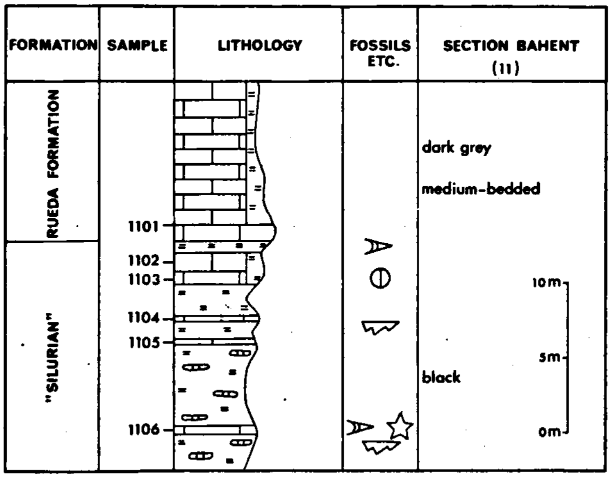


Fig. 19. Section 11.

dark grey limestones. The thickness of the Rueda Formation at Castells is about 114 m.

The Basibé Formation consists at Castells of three massive limestones, separated from each other by five thinly layered slightly nodular and marly limestones. The thickness is 107 m.

In the Mañanet Griotte two parts may be recognized, a lower part consisting mainly of reddish and greenish nodular limestones, and an upper part which is richer in calcareous shales and greyish limestones and with a massive grey limestone in the uppermost part. Although the transition into the Civis Formation is not exposed, in the uppermost part of the massive grey limestones two bedded chert layers occur the lower of which is accompanied by phosphate nodules. Layered cherts do not occur elsewhere in the uppermost part of the Mañanet Griotte. At Castells the thickness of the Mañanet Griotte is about 230 m.

The conodonts recorded from the Castells section are listed in Table 9.

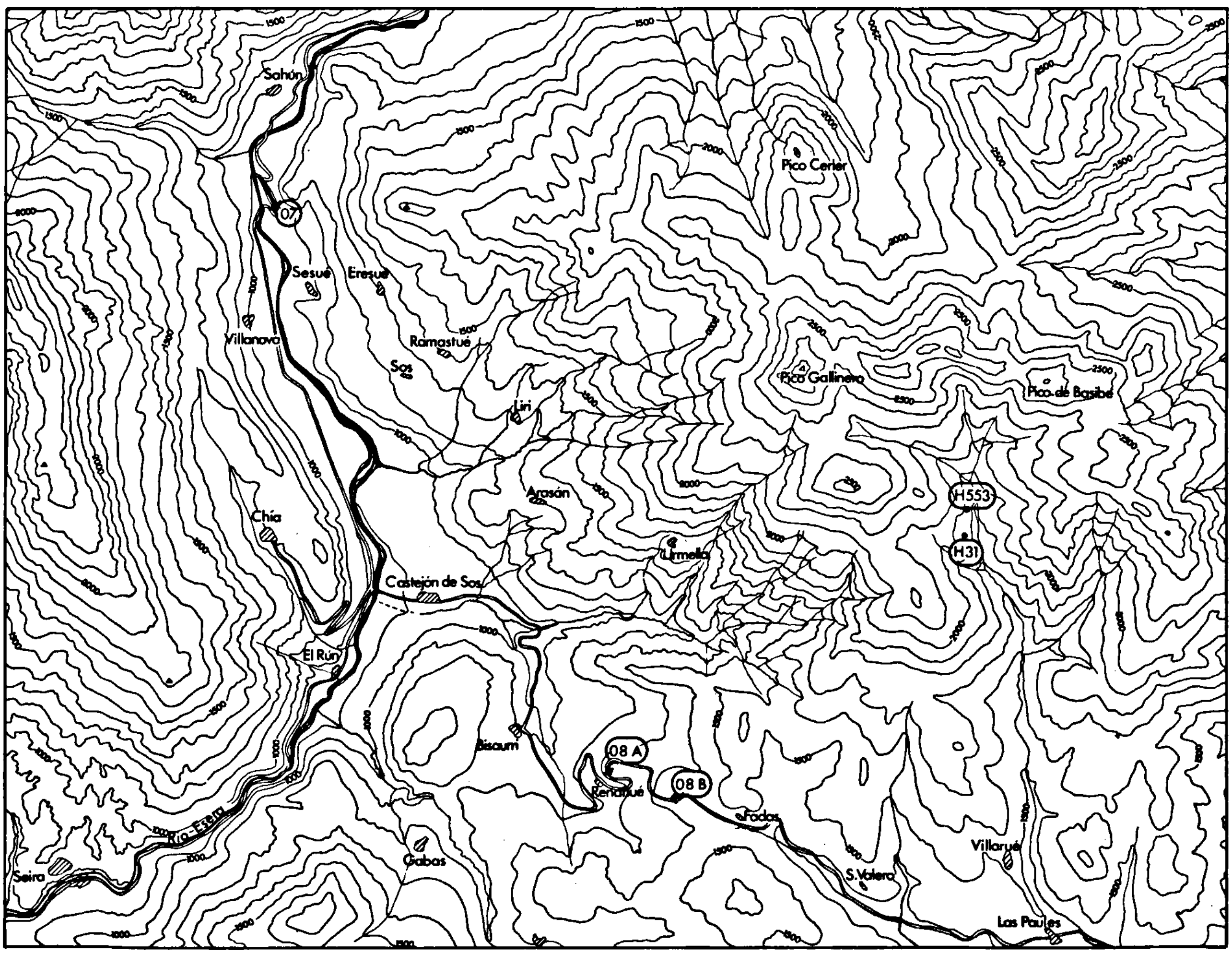


Fig. 20. Location map (1 : 100,000) of the Sahún – Renanué area, showing the location of the sections at Sahún (07) and Renanué (08-AB) and of samples H 553 and H 31. The arrows point towards the youngest parts of the sections.

Bahent (11)
At Bahent (location map: Fig. 4; section: Fig. 19) some black *Orthoceras* limestones were sampled.

The conodonts recovered from the section at Bahent are listed in Table 10.

Upper Rio Isabena Valley
Two samples were provided by Dr. M. A. Habermehl from the Basibé Formation in the Upper Rio Isabena Valley (location map: Fig. 20). Sample H 553 comes from section 7 (Habermehl, 1969), 15 m above the uppermost quartzite bed, sample H 31 comes from section 8 (Habermehl, 1969), 10 m above the uppermost quartzite bed.

The conodonts recovered from the two samples are listed in Table 11.

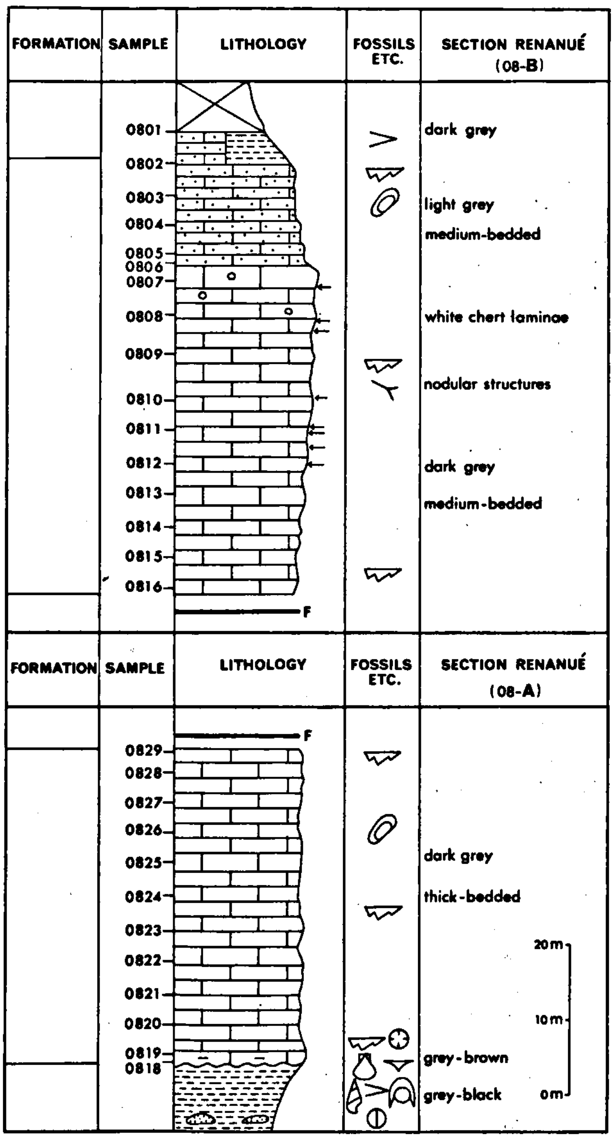


Fig. 21. Sections 08-AB.

2.C. RENANUE SUB-FACIES

Renanué (08)
The base of the first section (08-A) at Renanué (location map: Fig. 20; section: Fig. 21) consists of 2 m of marly limestones with nodular bedding planes. They are overlain by about 40 m of dark grey often bituminous and slightly nodular limestones. The limestones lie conformably on dark shales which contain detrital mica, markasite and sandstone concretions.

A second limestone section (08-B) at Renanué (section: Fig. 21) consists of 42 m of dark grey, often bituminous limestones with nodular sedimentary structures probably partly of algal origin. In the uppermost part of the limestones thin intercalations of white cherts

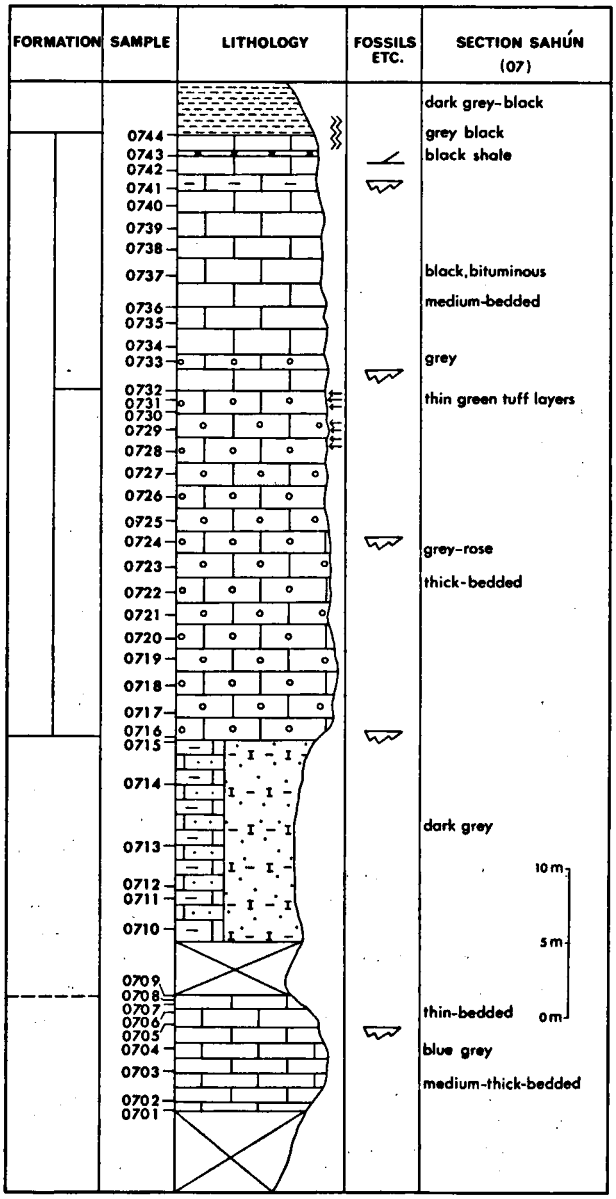


Fig. 22. Section 07.

occur. The dark grey limestones are overlain by 13 m of platy sandy pink weathering limestones, which in their turn are overlain by a sequence of dark shales intercalated by dark thinly bedded sandy limestones.

The total thickness of the limestone sequence at Renanué is not known, but is certainly much more than the 45 m indicated by Mey (1968b) and also much more than the 95 m measured.

The conodonts recovered from the limestone sections at Renanué are listed in Table 12.

Sahún (07)

The limestone sequence at Sahún (location map: Fig. 20; section: Fig. 22) consists of 15 m of thickly bedded blue grey limestones, overlain by about 33 m of dark grey calcareous and sandy shales, intercalated by some marly and sandy limestones. The shales are overlain by massive limestones, which were interpreted by Wennekers (1968) as Mañanet Griotte. In the massive limestones two members may be recognized. The lower member consists of 45 m of grey and sometimes greenish and reddish nodular limestones, which are intercalated in the uppermost part by 2–10 cm thick green tuff beds. The upper member consists of 33 m of dark grey and grey-black, slightly bituminous limestones, which in the lower part still contain some nodular limestones and which are in the upper part intercalated by some grey-black marly limestones with cross-bedding, and some blackish calcareous shales.

The limestones are overlain by greywackes, sandstones, conglomerates and black shales. The limestones are slightly overthrust over the clastic sequence.

The conodonts recovered from the section at Sahún are listed in Table 13.

CHAPTER 3

CONODONT ZONAL SUCCESSION

3.A. INTRODUCTION

The Middle and Upper Devonian conodont zones established in Germany by Ziegler (1962, 1965) and Wittekindt (1965), and partly revised by Ziegler (1971), could be quite well distinguished in the faunas studied. Ziegler (1971) indicated index species for the Upper Devonian conodont zones. Although a complete Lower Devonian succession of conodont zones is not yet available, the Lower Devonian faunal succession presented by Ziegler (1971), largely based on the work carried out by Carls & Gandl (1968) and Carls (1969) in the Celtiberian Mountains, proved to be a valuable basis for dating Lower Devonian conodont faunas of the Spanish Pyrenees. The succession of Faunas is certainly not complete.*

Silurian conodont zones were established by Walliser (1964).

Ziegler (1969) and Koch et al. (1970) described a *Protognathodus* Fauna from the gap between the Upper Devonian zones (Ziegler, 1962) and the Lower Carboniferous zones (Voges, 1959), corresponding with the uppermost Devonian Hangenbergschiefer.

The succession of Lower Carboniferous zones of Voges (1959) could be applied well to the faunas present. However, for the Viséan and Lower Namurian neither the zonal succession of Voges, nor that of van Adrichem Boogaert (1967) has been accepted. For practical reasons the zonal succession of Marks & Wensink (1970) is used. The present author, however, considers *Gnathodus commutatus* and *G. nodosus* as different species as suggested by Rhodes et al. (1969), and not as two sub-species belonging to one species. The names of the zones have been changed accordingly into *Gnathodus commutatus* and *Gnathodus nodosus* zone.

For the relation of the Devonian and Carboniferous conodont zonal successions to the stages, the reader is referred to Table 14.

The extent of the various sections sampled in the conodont zonal succession is indicated in Table 15.

The conodont species occurring in each zone or Fauna will be mentioned, and, if necessary, discussed.

3.B. FAUNAL CONTENT OF ZONES AND FAUNAS

The oldest conodont zone recognized in the present material is the *eosteinhornensis* zone (Walliser, 1964). The zone was recognized in the Toloríu Limestone at Bar (Table 4) and contains *Spathognathodus eosteinhornensis* Walliser and *S. inclinatus inclinatus* (Rhodes).

The *Icriodus woschmidti woschmidti* Fauna (Ziegler, 1971) was not recognized.

In the *Icriodus woschmidti postwoschmidti* Fauna (Ziegler, 1971), recorded at Castells (Table 9), Bahent (Table 10), Torres (Table 3) and Castellar de Nuch (Table 8), the following species were recognized: *Spathognathodus inclinatus inclinatus* (Rhodes), *S. steinhornensis repetitor* Carls & Gandl, *S. remscheidensis* Ziegler, *S. carlsi* Boersma, *Icriodus woschmidti postwoschmidti* Mashkova, *I. angustoides bidentatus* Carls & Gandl, *I. rectangularis* Carls & Gandl s.l. and *I.* cf. *I. angustoides* Carls & Gandl (transitional to *Pelekysgnathus*. Samples placed in the Fauna from the sections

* Ziegler (1968, 1971) introduced informal biostratigraphic units into the conodont zonal succession, faunas, because of the lack of detailed information on the exact vertical ranges of many species. To avoid confusion with 'fauna' in the normal sense, the fauna as biostratigraphic unit will be written in this paper as 'Fauna'.

at Torres and Castellar de Nuch contain only *Icriodus woschmidti* Ziegler ssp. indet. and *Spathognathodus steinhornensis repetitor* Carls & Gandl. Although the exact Fauna cannot be determined from these species alone, it seems justified, comparing the faunas with the conodont record at Castells and Bahent, to place the faunas in the *I. woschmidti postwoschmidti* Fauna.

The *Ancyrodelloides – Icriodus pesavis* Fauna (Ziegler, 1971) was recorded at Castells (Table 9), Torres (Table 3) and in sample H 553 (Table 11). In the Fauna the following species were found: *Pelekysgnathus serrata* n. ssp. A Carls, *Polygnathus pireneae* Boersma, *Spathognathodus inclinatus wurmi* Bischoff, *S. steinhornensis* n. ssp. A Carls, and N. gen. n. sp. Boersma. The complete absence of *Icriodus* and *Ancyrodelloides* in the Fauna is remarkable. Samples 0216 and 0218, containing *P. pireneae* and N. gen. n. sp. may represent an interval which did not as yet yield any conodonts.

In the *Icriodus huddlei curvicauda – I. rectangularis* s.l. – *I. angustoides angustoides* Fauna (Ziegler, 1971), only recorded at Castells (Table 9), the following species were observed: *Icriodus rectangularis* Carls & Gandl s.l., *Spathognathodus inclinatus inclinatus* (Rhodes), *S. inclinatus wurmi* Bischoff and *S. steinhornensis* ssp. indet. In the poor faunas *I. huddlei curvicauda* Carls & Gandl and *I. angustoides angustoides* Carls & Gandl were not found.

In the *Icriodus huddlei curvicauda – I. huddlei huddlei* Fauna (Ziegler, 1971), also only recorded at Castells (Table 9), the following species were observed: *Icriodus huddlei curvicauda* Carls & Gandl, *Spathognathodus inclinatus wurmi* Bischoff and *S. steinhornensis* cf. *S. steinhornensis steinhornensis* Ziegler. *I. huddlei huddlei* Klapper & Ziegler was not demonstrated in this Fauna.

The *Icriodus bilatericrescens bilatericrescens – Spathognathodus steinhornensis steinhornensis – Polygnathus* Fauna (Ziegler, 1971) was recorded at La Guardia de Arés (Table 2), Castells (Table 9), Torres (Table 3), Villech (Table 5) and Castellar de Nuch (Table 8). The following species were recognized in the Fauna: *Polygnathus foveolatus* Philip & Jackson, *P. lenzi* Klapper, *Icriodus bilatericrescens bilatericrescens* Ziegler, *I. fusiformis* Carls & Gandl, *I. huddlei huddlei* Klapper & Ziegler, *I. sigmoidalis* Carls & Gandl, *I.* cf. *I. corniger* Wittekindt and *Spathognathodus steinhornensis* Ziegler. The presence of *P. lenzi* indicates the lower part of the Fauna, the presence of *P. foveolatus* indicates the upper part (Boersma, 1973b). Only at Castells are the two species recorded in the same section. *I. bilatericrescens bilatericrescens* was only observed in the upper part of the Fauna.

The nonlatericrescid – *Icriodus – Polygnathus* Fauna (Ziegler, 1971) was recorded at La Guardia de Arés (Table 2) and Castellar de Nuch (Table 8). The following species were recorded: *Icriodus angustus* Stewart & Sweet, *I. corniger* Wittekindt and *I.* cf. *I. corniger* Wittekindt. A specimen classified as *I.* cf. *I. bilatericrescens bilatericrescens* Ziegler (in sample 0116) was also found in the Fauna. *Polygnathus linguiformis linguiformis* Hinde was not demonstrated in the Fauna, only a number of specimens transitional from *P. foveolatus* Philip & Jackson to *P. linguiformis linguiformis*, and some specimens transitional from *P. lenzi* Klapper to *P. costatus* Klapper were recorded. They are classified as *P.* cf. *P. foveolatus* and *P.* cf. *P. lenzi* (see Boersma, 1973b).

The boundary with the overlying *Icriodus corniger* zone (Wittekindt, 1965) is placed below the first occurrence of *P. linguiformis linguiformis* Hinde and *P. costatus* Klapper, together with *Icriodus corniger* Wittekindt.

In the *Icriodus corniger* zone (Wittekindt, 1965), recorded at Castellar de Nuch (Table 7) and La Guardia de Arés (Table 2), the following species were observed: *Icriodus corniger* Wittekindt, *I.* cf. *I. latericrescens* n. ssp. A Klapper & Ziegler, *Polygnathus costatus* Klapper and *P. linguiformis linguiformis* Hinde.

The *Spathognathodus bidentatus* zone was recognized at Renanué (Table 12), where the following species were observed: *Icriodus curvatus* Branson & Mehl, *I. nodosus* (Huddle), *I. regularicrescens* Bultynck, *I. symmetricus* Branson & Mehl, *Polygnathus costatus* Klapper, *P. eiflius* Bischoff & Ziegler, *P. linguiformis linguiformis* Hinde, *P. pseudofoliatus* Wittekindt, *P. robusticostatus* Bischoff & Ziegler, *P. xylus* Stauffer and *Spathognathodus obliquus* Wittekindt. At La Guardia de Arés (Table 2) two samples (0118 and 0119) were, on negative evidence, placed in the *S. bidentatus* zone, since they fall between the observed ranges of *I. corniger* and *Polygnathus kockelianus* Bischoff & Ziegler.

The *Polygnathus kockelianus* zone (Wittekindt, 1965) was observed at La Guardia de Arés (Table 2) and Villech (Table 5), and questionable at Castellar de Nuch (Table 10). Except for *Polygnathus kockelianus* Bischoff & Ziegler, the following species were observed in the zone: *Icriodus nodosus* (Huddle), *I. symmetricus* Branson & Mehl, *Polygnathus linguiformis linguiformis* Hinde, *P. costatus* Klapper, *P. eiflius* Bischoff & Ziegler, *P. angustipennatus* Bischoff & Ziegler, *P. xylus* Stauffer, *P. pseudofoliatus* Wittekindt, *P. robusticostatus* Bischoff & *P. trigonicus* Bischoff & Ziegler, *Spathognathodus bidentatus* Bischoff & Ziegler, *S. intermedius* Bultynck and questionably *P. angusticostatus* Wittekindt. At Castells (Table 9) no distinction could be made between the *Spathognathodus bidentatus* zone and the *Polygnathus kockelianus* zone, since no species characteristic of either of the zones was recognized. At Renanué (Table 12) the samples above the last occurrence of *Spathognathodus obliquus* Wittekindt were placed in the *P. kockelianus* zone.

In the *Icriodus obliquimarginatus* zone (Ziegler, 1971), recorded at Compte (Table 1), La Guardia de Arés (Table 2) and Villech (Table 5), the following species were recognized: *Polygnathus linguiformis linguiformis* Hinde, *P. xylus* Stauffer, *P. latus* Wittekindt, *P. kluepfeli* Wittekindt, *P. eiflius* Bischoff & Ziegler, *P. robusticostatus* Bischoff & Ziegler, *P? variabilis* Bischoff & Ziegler, *Spathognathodus planus* Bischoff & Ziegler, *Icriodus obliquimarginatus* Bischoff & Ziegler and, again, *I.* cf. *I. latericrescens* ssp. A Klapper & Ziegler. *P. latus* was only recorded at La Guardia de Arés, so that only here a distinction could be made between the upper and lower parts of the zone (see Ziegler, 1971).

The *Polygnathus varcus* zone (Wittekindt, 1965) was recognized at Compte (Table 1), La Guardia de Arés (Table 2), Villech (Table 5) and Castells (Table 9). The following species were recorded: *Polygnathus linguiformis linguiformis* Hinde, *P. linguiformis mucronatus* Wittekindt, *P. varcus* Stauffer, *Schmidtognathus hermanni* Ziegler, *Spathognathodus planus* Bischoff & Ziegler and *Icriodus eslaensis* van Adrichem Boogaert. Since neither *Icriodus latericrescens lateriscrescens* Branson & Mehl nor *Ancyrolepis walliseri* (Wittekindt) were recorded, the *Icriodus latericrescens* horizon could not be recognized.

The *hermanni – cristatus* zone (Ziegler, 1965) could not be identified. *Schmidtognathus hermanni* Ziegler was only identified at La Guardia de Arés in sample 0132, which, however, undoubtedly has to be placed in the *Polygnathus varcus* zone. *Polygnathus cristatus* Hinde occurs at Villech, together with *P. asymmetricus ovalis* Ziegler & Klapper, and at Compte together with *P. dengleri* Bischoff & Ziegler. Both additional species are only known from the overlying *Polygnathus asymmetricus* zone. At Sahún (Table 13) samples 0702-0705 could neither be placed with certainty in the *hermanni – cristatus* zone, nor in the *P. varcus* zone, since no conodonts typical of either were recognized.

The *Polygnathus asymmetricus* zone (Ziegler, 1962) was recognized at Compte (Table 1), La Guardia de Arés (Table 2), Villech (Table 5), Renanué (Table 12) and Sahún (Table 13). The following index species were recorded: *Polygnathus varcus* Stauffer, *P. decorosus* Stauffer s.l., *P. asymmetricus asymmetricus* Bischoff & Ziegler, *P. dengleri* Bischoff & Ziegler, *P.* cf. *P. ancyrognathoideus* Ziegler, *Palmatolepis transitans* Müller, *Pa? disparalvea* Orr & Klapper, *Ancyrodella rotundiloba rotundiloba* (Bryant) and *A. rotundiloba alata* Glenister & Klapper. *P. linguiformis linguiformis* was no longer recorded in this zone. Although a subdivision into subzones could generally not be made, it is remarkable that in the Compte sub-facies species first occurring in the middle and upper *P. asymmetricus* zones (Ziegler, 1962), were either not recorded at all (*Ancyrodella gigas* Youngquist and *A. lobata* Branson & Mehl), or only recorded together with *Ancyrognathus triangularis* Youngquist (*A. curvata* (Branson & Mehl)), so that it may be concluded that the faunas belong to the lowermost and lower *P. asymmetricus* zone. Only at Renanué was *A. curvata* recorded before the occurrence of *An. triangularis*, also indicating the upper *P. asymmetricus* zone.

The *Ancyrognathus triangularis* zone (Ziegler, 1962) was recognized at Compte (Table 1), La Guardia de Arés (Table 2), Villech (Table 5) and Renanué (Table 12). In the zone the following species were observed: *Palmatolepis foliacea* Youngquist, *Pa. hassi* Müller, *Pa.* cf. *Pa. proversa* Ziegler, *Pa. punctata* (Hinde), *Pa. subrecta* Miller & Youngquist, *Pa. transitans* Müller, *Polygnathus decorosus* Stauffer s.l., *Ancyrodella curvata* (Branson & Mehl), *A. ioides* Ziegler, *A. nodosa* Ulrich & Bassler and *Ancyrognathus triangularis* Youngquist.

The *Palmatolepis gigas* zone (Ziegler, 1962) was recorded at Compte (Table 1), La Guardia de Arés (Table 2) and Castells (Table 9). Only the following species were recorded in the zone: *Palmatolepis foliacea* Youngquist, *Pa. punctata* (Hinde), *Pa. subrecta* Miller & Youngquist, *Pa. unicornis* Miller & Youngquist, *Ancyrodella curvata* (Branson & Mehl) and *Ancyrognathus asymmetricus* Ulrich & Bassler. The presence of *An. asymmetricus* indicates the upper or uppermost part of the zone at Compte and Castells, while the presence of *Pa. foliacea* indicates the lower part of the zone at La Guardia de Arés. The absence of *Pa. gigas* Miller & Miller & Youngquist is remarkable.

The *Palmatolepis triangularis* zone (Ziegler, 1962) was recorded at Compte (Table 1) and La Guardia de Arés (Table 2). The following index species were demonstrated: *Palmatolepis delicatula clarki* Ziegler, *Pa. delicatula delicatula* Branson & Mehl, *Pa. subperlobata* Branson & Mehl, *Pa. tenuipunctata* Sannemann, *Pa. triangularis* Sannemann, *Ancyrodella curvata* (Branson & Mehl) and *Polygnathus decorosus* Stauffer s.l. The absence of *Pa. delicatula clarki* and *Pa. delicatula delicatula* indicates the lower *Pa. triangularis* zone at La Guardia de Arés, while the presence of these two subspecies together with *Pa. tenuipunctata* at Compte indicates the upper *Pa. triangularis* zone.

The *Palmatolepis crepida* zone (Ziegler, 1962) was recognized at Compte (Table 1), La Guardia de Arés (Table 2), Villech (Table 5) and Castells (Table 9). In the zone the following index species were recorded: *Polygnathus decorosus* Stauffer s.l., *P. glaber glaber* Ulrich & Bassler, *P. nodocostatus* Branson & Mehl s.s., *Palmatolepis crepida* Sannemann, *Pa. glabra prima* Ziegler & Huddle, *Pa. minuta minuta* Branson & Mehl, *Pa. perlobata perlobata* Ulrich & Bassler, *Pa. quadrantinodosalobata* Sannemann, *Pa.* cf. *Pa. regularis* Bond, *Pa. subperlobata* Branson & Mehl, *Pa. tenuipunctata* Sannemann, *Pa. termini* Sannemann, *Pa. triangularis* Sannemann and *Ancyrolepis cruciformis* Ziegler. At Compte the three faunas can respectively be placed in the Lower, Middle and Upper *Pa. crepida* zone. At La Guardia de Arés the fauna (sample 0160/0161) has to be placed in the Lower *Pa. crepida* zone on account of the absence of *Pa. termini* and the presence of *Pa. triangularis*, while at Villech (sample 0435) and Castells (sample 0256) the faunas contain *Pa. glabra prima* and consequently have to be placed in the Upper *Pa. crepida* zone.

In the *Palmatolepis rhomboidea* zone (Ziegler, 1962), recorded at Compte (Table 1), La Guardia de Arés (Table 2), Villech (Table 5), Bellver (Table 6) and Castellar de Nuch (Table 7), the following index species were recognized: *Polygnathus glaber glaber* Ulrich & Bassler, *P. nodocostatus* Branson & Mehl s.s., *P. rhomboideus* Ulrich & Bassler, *P. triphyllatus* (Ziegler), *Palmatolepis distorta* Branson & Mehl, *Pa. glabra acuta* Helms, *Pa. glabra pectinata* Ziegler, *Pa. glabra prima* Ziegler &

Huddle, *Pa. gracilis gracilis* Branson & Mehl, *Pa. minuta minuta* Branson & Mehl, *Pa. minuta schleizia* Helms, *Pa. perlobata schindewolfi* Müller, *Pa. quadrantinodosa inflexa* Müller, *Pa. quadrantinodosa inflexoidea* Ziegler, *Pa. quadrantinodosa marginifera* Ziegler, *Pa. quadrantinodosa quadrantinodosa* Branson & Mehl, *Pa. rhomboidea* Sannemann, *Icriodus cornutus* Sannemann and *Spathognathodus stabilis* (Branson & Mehl).

The *Palmatolepis quadrantinodosa* zone (Ziegler, 1962) was recorded at Compte (Table 1), La Guardia de Arés (Table 2), Villech (Table 5), Bellver (Table 6), Castellar de Nuch (Table 7) and Castells (Table 9). The following index species were recognized: *Palmatolepis distorta* Branson & Mehl, *Pa. glabra acuta* Helms, *Pa. glabra lepta* Ziegler & Huddle, *Pa. glabra pectinata* Ziegler, *Pa. glabra prima* Ziegler & Huddle, *Pa. gracilis gracilis* Branson & Mehl, *Pa. minuta minuta* Branson & Mehl, *Pa. minuta schleizia* Helms, *Pa. perlobata schindewolfi* Müller, *Pa. quadrantinodosa inflexa* Müller, *Pa. quadrantinodosa inflexoidea* Ziegler, *Pa. quadrantinodosa marginifera* Ziegler, *Pa. quadrantinodosa quadrantinodosa* Branson & Mehl, *Pa. rugosa ampla* Ziegler, *Pa. rugosa grossi* Ziegler, *Polygnathus diversus* Helms, *P. glaber bilobatus* Ziegler, *P. glaber glaber* Ulrich & Bassler, *P. glaber medius* Helms & Wolska, *P. nodocostatus* Branson & Mehl s.s., *P. pennatuloideus* Ulrich & Bassler, *P. triphyllatus* (Ziegler), *Spathognathodus amplus* (Branson & Mehl), *S. inornatus* (Branson & Mehl) and *S. strigosus* (Branson & Mehl). Samples with *Pa. quadrantinodosa inflexa* and *Pa. q. inflexoidea*, together with *Pa. q. marginifera*, indicate the Lower *Pa. quadrantinodosa* zone, while the occurrence of *Pa. q. marginifera* without the other two subspecies indicates the upper part of the zone.

The *Scaphignathus velifer* zone (Ziegler, 1962) was recognized at Compte (Table 1), La Guardia de Arés (Table 2) and Bellver (Table 6). The following index species were demonstrated: *Palmatolepis gracilis gracilis* Branson & Mehl, *Pa. helmsi* Ziegler, *Pa. minuta schleizia* Helms, *Pa. perlobata schindewolfi* Müller, *Polygnathus communis communis* Branson & Mehl, *P. nodocostatus* Branson & Mehl s.s., *Pseudopolygnathus granulosus* Ziegler, *Scaphignathus subserratus* (Branson & Mehl), *Scaphignathus velifer* Helms, *Spathognathodus bohleanus* Helms, *S. inornatus* (Branson & Mehl), *S. stabilis* (Branson & Mehl), *S. strigosus* (Branson & Mehl) and *S. werneri* Ziegler. Only the Upper *Scaphignathus velifer* zone could be positively identified, by the presence of *Ps. granulosus* and *P. communis communis*, since *Palmatolepis rugosa trachytera* Ziegler was not found.

In the *Polygnathus styriacus* zone (Ziegler, 1962), identified at Compte (Table 1), La Guardia de Arés (Table 2), Bellver (Table 6) and Castells (Table 9), the following index species were recognized: *Palmatolepis gracilis gracilis* Branson & Mehl, *Pa. helmsi* Ziegler, *Pa. minuta schleizia* Helms, *Pa. perlobata schindewolfi* Müller, *Polygnathus communis communis* Branson & Mehl, *P. obliquicostatus* Ziegler, *P. styriacus* Ziegler, *Spathognathodus bohleanus* Helms, *S. inornatus* (Branson & Mehl), *S. jugosus* (Branson & Mehl), *S. stabilis* (Branson & Mehl) and *S. strigosus* (Branson & Mehl). Only the Upper *P. styriacus* zone could be positively identified, by the presence of *S. jugosus*, since *Pseudopolygnathus granulosus* Ziegler was not recorded in this zone.

The *Spathognathodus costatus* zone (Ziegler, 1962) was recorded at Compte (Table 1), La Guardia de Arés (Table 2), Bellver (Table 6) and Castells (Table 9). The following index species were observed: *Palmatolepis gonioclymeniae* Müller, *Pa. gracilis gracilis* Branson & Mehl, *Pa. gracilis sigmoidalis* Mehl & Ziegler, *Pa. minuta schleizia* Helms, *Pa. perlobata schindewolfi* Müller, *Polygnathus communis communis* Branson & Mehl, *Pseudopolygnathus brevipennatus* Ziegler, *Ps. nodomarginatus* Branson & Mehl s.l., *Ps. trigonicus* Ziegler, *Spathognathodus aculeatus* (Branson & Mehl), *S. bohleanus* Helms, *S. costatus costatus* (Branson & Mehl), *S. costatus spinulicostatus* (Branson & Mehl), *S. costatus ultimus* Bischoff, *S. inornatus* (Branson & Mehl), *S. jugosus* (Branson & Mehl), *S. stabilis* (Branson & Mehl), *S. strigosus* (Branson & Mehl) and *S.* cf. *S. supremus* Ziegler. A distinction between the Lower, Middle and Upper *Spathognathodus costatus* zones is generally possible since both *Palmatolepis gonioclymeniae* and *Spathognathodus costatus ultimus* occur frequently in the material presented.

A dinstinction between the *Protognathodus* Fauna (Ziegler, 1969) and the *Protognathodus kockeli – Siphonodella sulcata* zone (Ziegler, 1969) could not be made, since *Siphonodella sulcata* (Huddle) could not be identified. It is possible that some specimens classified as *Pseudopolygnathus nodomarginatus* E. R. Branson s.l. should partly be classified as *Si. sulcata* and partly as *Si. praesulcata* Sandberg. If *Si. praesulcata* could be identified, which would indicate the *Siphonodella praesulcata* Fauna (Sandberg, Streel & Scott, 1972) (which upper part is an equivalent of the *Protognathodus* Fauna), we would also have an appropriate tool for distinguishing the *Protognathodus* Fauna from the *Protognathodus kockeli – Siphonodella sulcata* zone. However, a subdivision was not possible since the material classified as *Pseudopolygnathus nodomarginatus* could not be subdivided. Both stratigraphic intervals are combined into the *Protognathodus kockeli – Siphonodella sulcata* zone s.l. The zone was demonstrated at Compte (Table 1), La Guardia de Arés (Table 2) and Castells (Table 9). The following important species were recorded: *Polygnathus communis communis* Branson & Mehl, *P. longiposticus* Branson & Mehl, *P. inornatus* E. R. Branson s.l., *P. purus* Voges, *P. symmetricus* E. R. Branson, *Protognathodus collinsoni* Ziegler, *Pr. kockeli* (Bisschoff), *Pr. meischneri* Ziegler, *Pseudopolygnathus dentilineatus* E. R. Branson, *Ps. nodomarginatus* E. R. Branson s.l., *Spathognathodus inornatus* (Branson & Mehl), *S. plumulus* Rhodes, Austin & Druce and *S. stabilis* (Branson & Mehl).

The *Siphonodella – triangulus inaequalis* zone (Voges,

1959) was demonstrated at La Guardia de Arés (Table 2) and Castells (Table 9). The following species were recognized: *Polygnathus communis carinus* Hass, *P. communis communis* Branson & Mehl, *P. communis dentatus* Druce, *P. inornatus* E. R. Branson s.l., *P. longiposticus* Branson & Mehl, *P. purus* Voges, *Protognathodus collinsoni* Ziegler, *Pr. kockeli* (Bischoff), *Pseudopolygnathus nodomarginatus* E. R. Branson s.l., *Ps. dentilineatus* E. R. Branson, *Ps. triangulus inaequalis* Voges, *Siphonodella duplicata* (Branson & Mehl), *Si. obsoleta* Hass, *Spathognathodus inornatus* (Branson & Mehl) and *S. stabilis* (Branson & Mehl).

The *Siphonodella – triangulus triangulus* zone (Voges, 1959) was recorded at La Guardia de Arés (Table 2) and Castells (Table 9). The following species were observed: *Polygnathus communis communis* Branson & Mehl, *P. communis carinus* Hass, *P. inornatus* E. R. Branson s.l., *P. purus* Voges, *P. radinus* Cooper, *Pseudopolygnathus fusiformis* Branson & Mehl, *Ps. nodomarginatus* E. R. Branson s.l., *Ps. triangulus triangulus* Voges, *Siphonodella cooperi* Hass, *Si. obsoleta* Hass, *Si. quadruplicata* (Branson & Mehl) and *Spathognathodus stabilis* (Branson & Mehl).

The *Siphonodella crenulata* zone (Voges, 1959), demonstrated at La Guardia de Arés (Table 2) and Castells (Table 9), contains the following species: *Polygnathus communis communis* Branson & Mehl, *P. communis dentatus* Druce, *P. inornatus* E. R. Branson s.l., *P. radinus* Cooper, *P.* cf. *P. symmetricus* E. R. Branson, *Pseudopolygnathus dentilineatus* E. R. Branson, *Ps. fusiformis* Branson & Mehl, *Ps. nodomarginatus* E. R. Branson s.l., *Ps. triangulus triangulus* Voges, *Siphonodella cooperi* Hass, *Si. crenulata* (Cooper), *Si. lobata* (Branson & Mehl), *Si. quadruplicata* (Branson & Mehl), *Spathognathodus inornatus* (Branson & Mehl) and *S. stabilis* (Branson & Mehl). The samples belong to the Lower *Si. crenulata* zone, since *Gnathodus* is completely absent.

The *Scaliognathus anchoralis* zone (Voges, 1959) was recognized at Compte (Table 1), La Guardia de Arés (Table 2), Castells (Table 9) and Sahún (Table 13). The following species were recognized: *Gnathodus antetexanus* Rexroad & Scott, *G. cuneiformis* Mehl & Thomas, *G. delicatus* Branson & Mehl, *G. homopunctatus* Ziegler, *G. punctatus* (Cooper), *G. semiglaber* Bischoff, *G. symmutatus* Rhodes, Austin & Druce, *G. typicus* Cooper, *Polygnathus bischoffi* Rhodes, Austin & Druce, *Pseudopolygnathus triangulus triangulus* Voges, *Scaliognathus anchoralis* Branson & Mehl, *Spathognathodus campbelli* Rexroad and *S. inornatus* (Branson & Mehl), *Spathognathodus campbelli* Rexroad and *S. inornatus* (Branson & Mehl). The absence of *Doliognathus latus* Branson & Mehl is remarkable, while the absence of *Polygnathus communis communis* Branson & Mehl suggests that the samples belong to the upper part of the *Scaliognathus anchoralis* zone (see Marks & Wensink, 1970, p. 248).

The *Gnathodus typicus* zone (Marks & Wensink, 1970) was recognized at La Guardia de Arés (Table 2), Castellar de Nuch (Table 7), Bellver (Table 6), Castells (Table 9) and Sahún (Table 13). The following species were recognized: *Gnathodus antetexanus* Rexroad & Scott, *G. cuneiformis* Mehl & Thomas, *C. delicatus* Branson & Mehl, *G. homopunctatus* Ziegler, *G. semiglaber* Bischoff, *G. symmutatus* Rhodes, Austin & Druce, *G. texanus* Roundy, *G. typicus* Cooper and *Spathognathodus campbelli* Rexroad.

In the *Gnathodus commutatus* zone (Marks & Wensink, 1970), recorded at La Guardia de Arés (Table 2), Castellar de Nuch (Table 7), Bellver (Table 6) and Sahún (Table 13), the following species were recorded: *Gnathodus bilineatus* (Roundy), *G. commutatus* Branson & Mehl, *G. girtyi* Hass, *G. homopunctatus* Ziegler, *G. semiglaber* Bischoff, *G. symmutatus* Rhodes, Austin & Druce and *Spathognathodus campbelli* Rexroad. *G. semiglaber* was only recognized in the lowermost part of the zone.

In the *Gnathodus nodosus* zone (Marks & Wensink, 1970), recorded at La Guardia de Arés (Table 2), Bellver (Table 6) and Sahún (Table 13), the following species were observed: *Gnathodus bilineatus* (Roundy), *G. homopunctatus* Ziegler, *G. mononodosus* Rhodes, Austin & Druce, *G. multinodosus* Wirth, *G. nodosus* Bischoff, *G. symmutatus* Rhodes, Austin & Druce, *G. texanus* Roundy and *Spathognathodus campbelli* Rexroad.

In the *Gnathodus macer* zone (Marks & Wensink, 1970), only recorded at Sahún (Table 13), solely *Gnathodus macer* Wirth was recorded. *Polygnathodella ouachitensis* Harlton and *Streptognathodus wapanuckensis* (Harlton) were not observed.

CHAPTER 4

THE AGES OF THE FORMATIONS

It is in some cases somewhat problematic to interpret the palaeontological data by Dalloni (1910, 1930), since hardly any lithological descriptions are given. However, if the ages indicated are taken into consideration, the data can in most cases be placed in the lithological succession.

Dalloni (1910, 1930) did not recognize different sub-facies in the Devonian of the southern Pyrenees. His stratigraphic classification is solely based on palaeontological data, and not on stratigraphical criteria. This may explain why the Basibé Formation does not occur in his stratigraphical classification, and why Mey (1968a, 1968b, 1968), who apparently interpreted the 'Calcaire massif à polypiers' of Dalloni (1930) as Basibé Formation, proposed a Middle Devonian age for the Basibé Formation.

4.A. COMPTE SUB-FACIES

'Silurian'

The only limestone of the 'Silurian', sampled in the Compte sub-facies, is the Toloríu Limestone (Table 4), which has to be placed in the *eosteinhornensis* zone (Walliser, 1964) of the Ludlow.

Fossils of the 'Silurian' have been collected by many authors, e.g. Roussel (1904), Dalloni (1930), Schmidt (1931), Boissevain (1934), Llopis Lladó (1966) and Oliver (1967).

The graptolite faunas, which have been found in many places, are of special interest. Dalloni recognized faunas of Llandoverian, Wenlockian and possibly of Ludlowian age. Rich graptolite faunas of the 'Silurian' in the Compte sub-facies were collected at Camprodon (p. 67). From the often nodular black *Orthoceras* limestones, intercalated by black shales, Dalloni (p. 68) at Camprodon collected a rich fauna of brachiopods, molluscs, crinoids and some trilobites, which he placed in the Wenlock. Some other limestones, however, were placed in the Ludlow by Dalloni (p. 72).

Schmidt (1931, p. 36, 40) (fig. 5) recorded, from Torres, the following lithological succession, from top to bottom:

Gebankte Mergel mit Crinoidenstielen (= Rueda Formation)
Schiefer mit Kalkbanken (5 m)
Dichter Kalk (4 m)
Alaunschiefer
Orthocerenkalk

He assigned to the 'Orthocerenkalk' a Ludlowian age, in contrast to Dalloni (1930, e.g. p. 68), while he concluded a Gedinnian age from a fauna from the 'Schiefer mit Kalkbanken'. A Gedinnian age is also indicated by conodonts from the base of the Rueda Formation. It seems quite well possible that limestones similar to the 'Dichter Kalk' or limestones from the 'Schiefer mit Kalkbanken' have been sampled at Castells and Bahent (see 3.B) as *Orthoceras* limestones.

Rueda Formation

Samples of the Rueda Formation collected at the section of Schmidt (1931) at Torres (Table 3), and at Castellar de Nuch (Table 8), indicate a Gedinnian age, since the *Icriodus woschmidti postwoschmidti* Fauna is recorded.

The Gedinnian age is in accordance with the age concluded by Schmidt (1931, p. 40).

Basibé Formation

At Torres (Table 3) a sample from the lowermost part of the Basibé Formation indicates the *Ancyrodelloides – Icriodus pesavis* Fauna. Samples from the uppermost part of the formation at Castellar de Nuch (Table 8) and Villech (Table 5) indicate the upper part of the *Icriodus bilatericrescens bilatericrescens* – *Spathognathodus steinhornensis steinhornensis* – *Polygnathus* Fauna by the presence of *Polygnathus foveolatus*, while they indicate the lower part of the Fauna at La Guardia de Arés (Table 2) (Boersma, 1973b) by the presence of *P. lenzi*. Faunas indicating the *Icriodus huddlei curvicauda – I. rectangularis* s.l. – *I. angustoides* Fauna or the *I. huddlei curvicauda – I. huddlei huddlei* Fauna (Siegenian and lowermost Emsian) have not been found in the Basibé Formation of the Compte sub-facies. The question of the existence of a stratigraphic hiatus during the Siegenian is left open. The reduced thickness of the formation and the presence of brecciated limestones at Torres might be in favour of this.

However, we may conclude that the Basibé Formation in the Compte sub-facies ranges from the Upper Gedinnian to the lower Upper Emsian.

From the section of Schmidt (1931) at Compte, Ziegler (1959, p. 229) recorded a conodont fauna from the Basibé Formation which may be placed in the *Icriodus bilatericrescens bilatericrescens – Spathognathodus steinhornensis steinhornensis – Polygnathus* Fauna.

Villech Formation

In the lowermost part of the Villech Formation at La Guardia de Arés (Table 2), Villech (Table 5) and Castellar de Nuch (Table 8) conodonts from the *Icriodus bilatericrescens bilatericrescens – Spathognathodus steinhornensis steinhornensis – Polygnathus* Fauna were found, whereas faunas of the upper part of the formation should be placed in the *Polygnathus kockelianus* zone. The Villech Formation therefore ranges from the upper Lower or lower Upper Emsian into the uppermost Eifelian.

At Compte (Fig. 23) we have evidence that the top of the Villech Formation is somewhat younger than elsewhere.

Dalloni (1930, p. 83, 84, 85) collected trilobite and brachiopod faunas from the Villech Formation in the Feixa block from which he concluded (Upper?) Coblentzian (p. 90) and Lower Eifelian ages, so that the ages of the faunas presented are completely in accordance with his ages.

Compte Formation

Conodonts indicate that the age of the Compte Formation is not everywhere the same (Fig. 23). The ages of the three members will be separately dealt with.

A-Member. – The base of the A-Member is placed in the *Polygnathus kockelianus* zone (uppermost Eifelian) at La Guardia de Arés (Table 2) and Villech (Table 5), while at Castellar de Nuch (Table 7) it was questionable whether the *P. kockelianus* zone could be recognized. At Compte (Table 1), however, conodonts indicate the *Icriodus obliquimarginatus* zone (lowermost Givetian) in the lowermost part of the member. In the uppermost part of the A-Member at La Guardia de Arés (Table 2) and Villech (Table 5) conodonts indicate the *Polygnathus asymmetricus* zone (Lower Frasnian), while conodonts from the uppermost part of the member at Compte (Table 1) indicate the *Palmatolepis gigas* zone (Upper Frasnian) (Fig. 23).

From a coral fauna at Bellver, Dalloni (1930, p. 86) concluded a Givetian age, which is in accordance with the results presented.

B-Member. – In the lowermost part of the B-Member, both at La Guardia de Arés (Table 2) and at Villech (Table 5), the *Ancyrognathus triangularis* zone (Upper Frasnian) is demonstrated. At La Guardia de Arés and Compte the uppermost part of the B-Member has to be placed in the *Palmatolepis quadrantinodosa* zone (upper *Cheiloceras* 'Stufe'), while at Villech (Table 5) and Bellver (Table 6) the *Palmatolepis rhomboidea* zone (middle *Cheiloceras* 'Stufe') is recorded from the uppermost part of the member (Fig. 23).

The ages concluded from the conodont faunas mentioned by Ziegler (1959) from the B-Member at Compte and Isobol (p. 300), indicating the *Palmatolepis crepida* zone (fauna 12 at Compte; fauna 00 at Isobol), *Pa. rhomboidea* zone (fauna 11 at Compte; faunas 0, 1 at Isobol) and *Pa. quadrantinodosa* zone (fauna 10 at Compte) are evidently in agreement with the results presented.

Ammonoids of the B-Member were mentioned by Dalloni (1930, p. 86) and Schmidt (1931, p. 50). Dalloni concluded an Upper Frasnian and Famennian age from a fauna at Bellver containing *Gephyroceras retrorsum* v. Buch, *Cheiloceras amblylobum* Sandberger and *Bactrites carinatus* Frech. Schmidt placed the B-Member in the *Cheiloceras* and *Platyclymenia* 'Stufe', ages concluded from faunas at Isobol and Compte, containing *Cheiloceras verneuili* Munster, *C. sacculus* Sandberger, *C. amblylobum* Sandberger, *C. subpartitum* Munster, *Liorhynchus* sp. and *Platyclymenia annulata* Munster. The age of the upper boundary of the member is in agreement with the age indicated by Schmidt (p. 52), the lower boundary, however, should undoubtedly be placed in the *Manticoceras* 'Stufe'.

C-Member. – In the lowermost part of the C-Member the *Palmatolepis quadrantinodosa* zone (upper *Cheiloceras* 'Stufe') was demonstrated at Compte (Table 1) and La Guardia de Arés (Table 2), while at Villech (Table 5), Bellver (Table 6) and Castellar de Nuch (Table 7) the *Palmatolepis rhomboidea* zone (middle *Cheiloceras* 'Stufe') was recognized in the lowermost part. The uppermost part of the C-Member should be placed in the *Gnathodus nodosus* zone (Upper Viséan/lowermost Namurian) at La Guardia de Arés (Table 6) and in the *Gnathodus commutatus* zone (middle Viséan) at Castellar de Nuch (Table 7) (Fig. 23).

At La Guardia de Arés the Lower *Siphonodella crenulata* zone is overlain by the first bedded cherts, while at Compte the lowermost part of the *Siphonodella – triangulus inaequalis* zone (Ziegler, 1959, p. 299) is overlain by the first bedded cherts. At Bellver and Castellar de Nuch the first cherts seem to be absent. Both at Compte and at La Guardia de Arés the samples directly above the first bedded cherts indicate the *Scaliognathus anchoralis* zone. At La Guardia de Arés the Lower *Siphonodella crenulata* zone is overlain by the first bedded cherts, while at Compte the lowermost part of the *Siphonodella – triangulus inaequalis* zone (Ziegler, 1959, p. 299) is overlain by the first bedded cherts. At Bellver and Castellar de Nuch the first cherts seem absent. The stratigraphic extent of the Tournaisian hiatus will be dealt with in Chapter 5.B. Both at Compte and La Guardia de Arés the samples directly above the first bedded cherts indicate the *Scaliognathus anchoralis* zone.

At La Guardia de Arés the samples directly below the second bedded cherts indicate the *Gnathodus typicus* zone, while at Bellver and Castellar de Nuch, too, the samples below the first occurrence of bedded cherts (i.e. equivalents of the second bedded cherts) should be placed in this zone. At La Guardia de Arés a sample taken from a limestone lens in the second bedded cherts also indicates the *G. typicus* zone. At Bellver a sample from the lower part of the bedded cherts indicates the *G. typicus* zone, while samples from the middle and upper parts indicate the overlying *G. commutatus* zone. At Castellar de Nuch the bedded cherts are split up by a sequence of shales and nodular limestones, which all indicate the *G. commutatus* zone.

From the Col de Jou, at the boundary between Lérida and Gerona, Dalloni (1930, p. 102) recorded a rich fauna from limestones overlying the bedded cherts and grading upwards in calcareous shales. The fauna contains the following ammonoids: *Glyphioceras crenistria* Philips, *Pronorites cyclolobus* Philips and *Prolecanites*

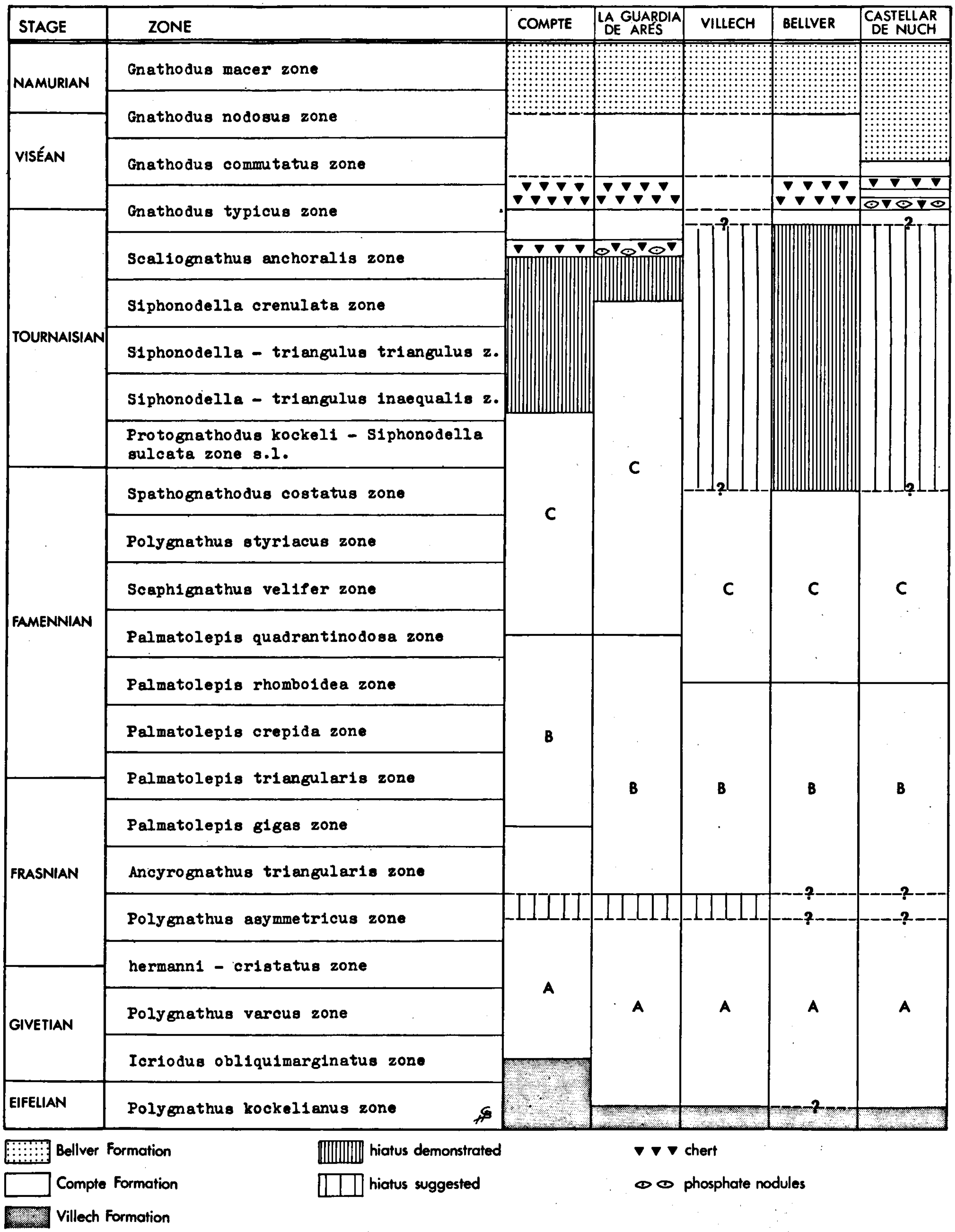


Fig. 23. Time stratigraphic correlation chart of the Compte Formation.

henslowi Sowbery. He dated this fauna as Viséan, while considering the cherts to be of Tournaisian age. The fauna recorded by Dalloni was probably collected from an identical limestone-shale transition at the uppermost part of the C-Member, as is recorded from Castellar de Nuch, so that his Viséan age is correct.

Schmidt (1931, p. 50) recorded from Isobol a fauna with *Gonioclymenia speciosa* Munster, *Orthoclymenia laevigata* Munster, *Oxyclymenia undulata* Munster, and *Sporadoceras orbiculare* Munster, which he placed in the *Gonioclymenia* 'Stufe'. At Compte he collected, from the lower part of the C-Member, *Platyclymenia annulata* Munster, which he placed in the *Platyclymenia* 'Stufe'.

Boissevain (1934, p. 57) recorded from Bor, from limestones overlying the bedded cherts, *Goniatites striatus* Sowbery, indicating an Upper Viséan age.

Ziegler (1959, p. 300, 304) recorded, from the C-Member at Compte and Isobol, faunas belonging to the *Palmatolepis quadrantinodosa* zone (fauna 9 at Compte; faunas 2, 3, 4 at Isobol), *Spathognathodus costatus* zone (faunas 5, 6, 7 at Compte; fauna 5 at Isobol), *Siphonodella – triangulus inaequalis* zone (fauna 4 at Compte) and *Scaliognathus anchoralis* zone (fauna 6 at Isobol).

The data provided by Schmidt (1930), Boissevain (1934) and Ziegler (1959) are completely in agreement with the present results.

Bellver Formation

Conodonts from a limestone in the lower part of the Bellver Formation at Bellver (Table 6) indicate the *Gnathodus nodosus* zone.

Since the uppermost part of the Compte Formation is well dated in several localities, we may conclude that the age of the boundary with the Bellver Formation is not everywhere the same. At La Guardia de Arés (Table 2) and Bellver (Table 6) the boundary is placed in the *Gnathodus nodosus* zone, while at Castellar de Nuch (Table 7) it is placed in the *Gnathodus commutatus* zone (Fig. 23).

There is an angular unconformity between the Bellver Formation and the overlying post-Hercynian deposits. The first post-Hercynian formation, the Aguiró Formation, is dated by means of plants as Upper Westphalian D – Lower Stephanian A (Hartevelt, 1970, p. 183). From a flora from the Bellver area Roussel (1904, p. 19) determined *Archaeocalamites*.

4.B. SIERRA NEGRA SUB-FACIES S.L.

Orthoceras limestones

Conodonts from the *Orthoceras* limestones at Castells (Table 9) and Bahent (Table 10) indicate a Lower Gedinnian age, the *Icriodus woschmidti postwoschmidti* Fauna.

Faunas from the 'Silurian' in the Sierra Negra subfacies were described by Dalloni (1910, 1913, 1930) and Llopis Lladó & Rosell Sanuy (1968).

Dalloni (1930) described rich graptolite faunas from the Castells block (p. 60, 61). Black shales with several species of *Monograptus* which indicate an Upper Llandoverian age are overlain by the *Orthoceras* limestones which contain a rich fauna of molluscs, brachiopods, crinoids and some trilobites. The presence of *Monograptus priodon* Bronn between these limestones indicates, according to Dalloni (p. 71, 72), an Upper Wenlockian age.

The most acceptable explanation for the discrepancy between the ages indicated by Dalloni and the present author, seems to be that the stratigraphic position of the limestones sampled by Dalloni is not the same as that of the limestones sampled by the present author. It is demonstrated by Mey (1967) and by Llopis Lladó & Rosell Sanuy (1968) that limestones rich in orthocerids exist lower down in the stratigraphic column. It therefore seems possible that the limestones sampled by the present author are not the true *Orthoceras* limestones.

Llopis Lladó & Rosell Sanuy (1968, p. 114) recognized zones 23–36 of Elles-Wood, indicating the Upper Ludlow, in section at Sarroca (Castells block) of the black shales intercalated by black nodular limestones. Zone 36, indicated by the presence of *Monograptus hercynicus* Pern., *M. uniformis* Přibyl and *M. praehercynicus* Jaeger, was recognized directly below the limestones of the Rueda Formation.

During the symposium 1968 the subcommission on the Silurian/Devonian boundary defined the boundary at the base of the zone of *Monograptus uniformis*, so that the fauna collected by Llopis Lladó & Rosell Sanuy from the uppermost part of the 'Silurian' should in fact be placed in the lowermost Gedinnian. However, the *Icriodus woschmidti woschmidti* Fauna, indicating the lowermost Gedinnian, is not found in the *Orthoceras* limestones. This might confirm the observation by Mashkova (1968), who reported *I. woschmidti woschmidti* from rocks just below those containing *Monograptus uniformis*.

Rueda Formation

Conodont faunas collected from the Rueda Formation at Castells (Table 9) indicate the *Icriodus woschmidti postwoschmidti* Fauna and the *Ancyrodelloides – Icriodus pesavis* Fauna (Gedinnian).

From a trilobite and brachiopod fauna, collected at the Coma de Monros, west of Sort, probably from the upper part of the formation, Schmidt (1931, p. 41) concluded a Lower Coblentzian age. North of the Coma de Monros (p. 41) he collected a trilobite fauna from which he concluded a Gedinnian age. Probably some of the 'schistes et grauwackes', placed by Dalloni (1910, p. 82) in the Coblentzian, belong to the Rueda Formation.

The age concluded from the material presented is consequently only partly in accordance with the ages indicated by Schmidt.

Basibé Formation

Conodont faunas collected at Castells (Table 9) indicate that the Basibé Formation ranges here from the *Ancyro-*

delloides – Icriodus pesavis Fauna (Upper Gedinnian) to the lower part of the *Icriodus b. bilatericrescens – Spathognathodus s. steinhornensis – Polygnathus* Fauna (upper Lower Emsian/lower Upper Emsian) (see Boersma, 1973b).

Although the faunas of the Basibé Formation at Castells are generally poor, and although some of the important species are not recorded, there seems to be no reason for suggesting breaks in the sedimentation. The *Ancyrodelloides – Icriodus pesavis* Fauna is also recorded from sample H 553 from the Rio Isabena Valley (Table 11). Considering the different positions of *Polygnathus pireneae* in the Basibé Formation at Castells and in the Rio Isabena Valley, it may be suggested that at least the lower part of the formation grows older towards the west.

The conodont species reported by Habermehl (1970, p. 10) were erroneously identified by the present author (compare Table 11).

Mey (1967, 1968a, 1968b) interpreted the description of the Mañanet Griotte of Dalloni (1910) as Basibé Formation, so that he erroneously concluded an Eifelian age. Dalloni (1910, 1913, 1930) himself did not date and recognize the limestones of the Basibé Formation.

Fonchanina Formation

Conodonts collected from the Fonchanina Formation at Castells (Table 11) indicate the upper part of the Lower Emsian and/or lower part of the Upper Emsian, the *Icriodus b. bilatericrescens – Spathognathodus s. steinhornensis – Polygnathus* Fauna.

Since no samples from the upper part of the formation have been collected, it seems quite well possible that the top of the formation contains the nonlatericrescid – *Icriodus – Polygnathus* Fauna and the *Icriodus corniger* zone. In this way the age conforms with the age indicated by Llopis Lladó & Rosell Sanuy (1968, p. 115), who from tentaculite faunas concluded an uppermost Emsian and Lower Couvinian age. Samples from the overlying Mañanet Griotte contain only *Polygnathus linguiformis linguiformis* Hinde, a species which in the Compte sub-facies was first recorded from the *I. corniger* zone (see 3.A).

Mañanet Griotte

Conodonts indicate that the Mañanet Griotte at Castells (Table 11) ranges from the Eifelian to the Viséan, although the top of the formation is not exposed. Not all conodont zones were recognized, since, especially in the lower part, the samples were not taken at small intervals. Both the Eifelian and the Givetian are incompletely demonstrated by the present material.

The incompleteness in the record of the Eifelian may be attributed to the great width of sampling, while the incompleteness in the record of the Givetian has to be attributed to its development as calcareous shales which did not favour good sampling.

The first Frasnian zone to be recorded is the *Palmatolepis gigas* zone. Although the section at Castells is in this place tectonically slightly disturbed, it seems doubtful whether all of the earlier Frasnian zones were deposited at all. In the Compte sub-facies the presence of a small hiatus in the *Polygnathus asymmetricus* zone is suggested, so that a similar hiatus might be suggested in the Mañanet Griotte above the unit consisting of calcareous shales (Fig. 18).

Just below the first bedded cherts the Lower *Siphonodella crenulata* zone is demonstrated, while above it the *Scaliognathus anchoralis* zone is recorded, in which, as in the Compte sub-facies, *Doliognathus latus* Branson & Mehl has not been found. Above the second bedded cherts, overlying the *Gnathodus typicus* zone, the Castells section is not exposed. Since the resemblance of the uppermost part of the Mañanet Griotte to the uppermost part of the C-Member of the Compte Formation at La Guardia de Arés is strong, it may be suggested that the top of the Mañanet Griotte, at least at Castells, ranges into the *Gnathodus nodosus* zone.

Dalloni (1910, p. 78) recorded an Eifelian fauna from the Pico Castanesa. In 1913 (p. 246, 247) he again recorded several Eifelian faunas which contain the following cephalopods: *Anarcestes subnautilus* d'Archiac & de Verneuil, *A. latiseptatus* Beyrich var. *plebeia* Barroi, *A.* sp. and *Phragmoceras subventriosum* de Verneuil & d'Archiac. *Gephyroceras retrorsum* v. Buch indicates the Frasnian.

Llopis Lladó & Rosell Sanuy (1968, p. 115) recorded several tentaculite faunas from localities near St. Sebastiá (Castells block), from which they concluded a Couvinian age. They placed the following cephalopods in the Frasnian (p. 116): *Beloceras* cf. *tenuistriatum* d'Archiac & de Verneuil, *B.* cf. *subacutum* G. Pet. and *Manticoceras intumensis* (Beyrich), while they placed *Kosmoclymenia* cf. *sedwicki* (Munster), *Cheiloceras verneuili* (Munster), *C.* sp., *Gonioclymenia* sp. and *Tornoceras simplex* (v. Buch) in the Famennian (p. 116). From the Dinantian (p. 116) they recorded *Pronorites cyclolobus* Philips.

The ages indicated by Dalloni (1910, 1913) and Llopis Lladó & Rosell Sanuy (1968) are in agreement with the present results.

Civis Formation

No data are available on the age of the Civis Formation. On the assumption that the Mañanet Griotte. at least at Castells, ranges into the *Gnathodus typicus* zone, it may be suggested that the lowermost part of the Civis Formation should be placed in this zone.

The Civis Formation is locally discordantly overlain by the Aguiró Formation (Mey, et al., 1968), which was dated by means of plants in the Baliera area by Roussel (1904), Dalloni (1913, 1930), Nagtegaal (1969) and Waterlot (1969a). The base of the Aguiró Formation should in this area probably be placed in the Westphalian B (Dalloni, 1930, p. 95; Waterlot, 1969a, p. 111).

4.C. RENANUE SUB-FACIES

Schmidt (1931, p. 43) recorded a Lower Coblentzian fauna from limestones from a limestone-quartzite sequence at Sahún.

Limestone sequence at Renanué
In the lower part of the lower half of the sequence (Table 12) the *Spathognathodus bidentatus* zone was recognized, while the upper part of the lower half of the sequence should probably be placed in the *Polygnathus kockelianus* zone.

In the lower part of the upper half of the sequence (Table 12) the *Polygnathus asymmetricus* zone was recognized, in the upper part of the upper half the *Ancyrognathus triangularis* zone was recognized.

Although the Givetian is not demonstrated, we may conclude that the limestone sequence at Renanué ranges from the *Spathognathodus bidentatus* zone (Eifelian) into the *Ancyrognathus triangularis* zone (Lower Frasnian).

Dalloni (1910, p. 80; 1930, p. 80) reported Frasnian brachiopod and trilobite faunas from the upper half of the sequence, which is in accordance with the age indicated by conodonts.

Limestone sequence at Sahun
In the lower limestone at Sahún (Table 13) the lowermost *Polygnathus asymmetricus* zone (lowermost Frasnian) was recognized. Samples below the *P. asymmetricus* zone could neither be placed with certainty in the *hermanni-cristatus* zone nor in the *Polygnathus varcus* zone, since no conodonts typical of either of them were recognized.

Samples from the dark grey calcareous and sandy shales did not yield any characteristic species.

Conodonts indicate that the massive limestones at Sahún (Fig. 14, Table 15) range from the *Scaliognathus anchoralis* zone (Upper Tournaisian) into the *Gnathodus macer* zone (Namurian). The absence of *Polygnathus communis communis* Branson & Mehl in the sample belonging to the *Scaliognathus anchoralis* zone suggests that it belongs to the upper part of the zone (see Marks & Wensink, 1970, p. 248).

CHAPTER 5

SYNTHESIS OF THE STRATIGRAPHIC DATA

5.A. CORRELATION BETWEEN THE SUB-FACIES

In comparing the three sub-facies a distinction should be made between a lithostratigraphic correlation, based on mappable units, and a bio-/chronostratigraphic correlation, based on the conclusions presented in Chapter 4.

Lithostratigraphic correlation between the sub-facies (Fig. 24)
Correlation may be carried out in an east to west direction, so that the Compte sub-facies is to be correlated with the Sierra Negra sub-facies s.l. and the Sierra Negra sub-facies s.l. with the Renanué sub-facies.

Compte sub-facies – Sierra Negra sub-facies s.l. – Although the difference in thickness between the Rueda Formation and Basibé Formation in the two areas is considerable, they are undoubtedly to be correlated with each other. The San Silvestre Quartzite-Dolomite Member pinches out towards the east (Habermehl, 1970).

Problems arise if we try to correlate the Fonchanina Formation and Mañanet Griotte with the Villech Formation and Compte Formation. The lower boundary of the Fonchanina Formation can be correlated with the lower boundary of the Villech Formation, and the upper boundary of the Mañanet Griotte with the upper boundary of the Compte Formation, but how the Fonchanina Formation/Mañanet Griotte boundary is to be correlated with the Villech Formation/Compte Formation boundary is not evident without further discussion. Hartevelt (1970) suggested a gradual transition of the Mañanet Griotte into the Compte Formation and Villech Formation, while the Fonchanina Formation wedges out. A more precise correlation is possible. In the Villech Formation a lower part may be recognized, con-

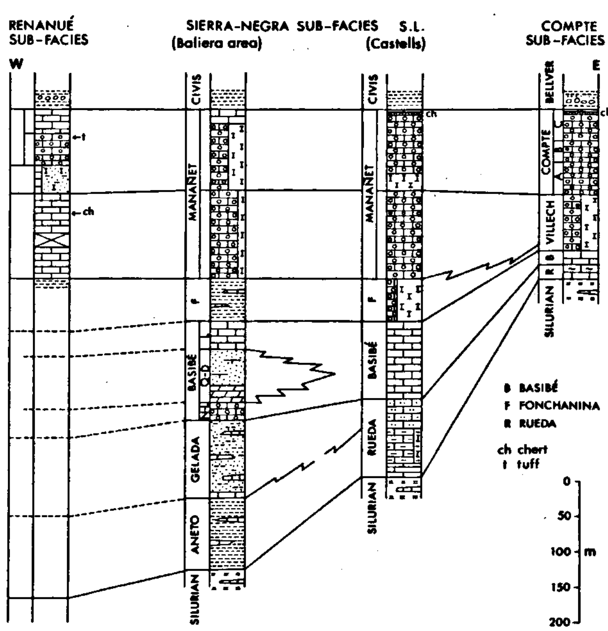


Fig. 24. Lithostratigraphic correlation between the sub-facies.

sisting of mainly greyish calcareous shales and limestones, which may be suggested to grade into the Fonchanina Formation. In the Mañanet Griotte at Castells a lower part may be recognized, consisting mainly of reddish and greenish nodular limestones, and an upper part, consisting mainly of calcareous shales and grey limestones. The boundary between these two parts may be correlated with the Villech Formation/Compte Formation boundary. In the Llavorsi syncline and Sierra Negra area no distinction can be made between the two parts of the Mañanet Griotte, but it is possible in the Baliera area. The lower part of the Mañanet Griotte may have the same appearance as the upper part of the Villech Formation, e.g. at Castellar de Nuch.

The Mañanet Griotte at Castells is certainly not typically developed. Firstly because calcareous shales do occur in the upper part, but do not predominate, secondly because bedded cherts occur in the uppermost part. Bedded cherts are nowhere else recorded in the Mañanet Griotte, but are always present in the uppermost part of the C-Member of the Compte Formation. The development of the Mañanet Griotte at Castells may consequently be considered intermediate between the typical Mañanet Griotte and the Compte Formation + upper part Villech Formation.

Sierra Negra sub-facies s.l. – Renanué sub-facies. – Since a large part of the Devonian and pre-Hercynian successions in the Renanué sub-facies is only approximately known (see Chapter 2.C), correlation between the two sub-facies is rather speculative. It seems justified to make three correlations: the Mañanet Griotte/Civis Formation boundary with the upper boundary of the limestone sequence at Sahún, the uppermost part of the limestone sequence at Renanué (= uppermost part of the lower limestones at Sahún) with the uppermost part of the lower part of the Mañanet Griotte, and the lower boundary of the limestone sequence at Renanué with the Mañanet Griotte/Fonchanina Formation boundary.

Mey (1967) reported that in the Baliera area the typical griotte character of the Mañanet Griotte decreases towards the west, together with its total thickness, which west of the Rio Isabena amounts to only about 80 m. It is also remarkable that the amount of shale in the upper part decreases towards the west. These changes in the Sierra Negra sub-facies s.l. may be interpreted as a more or less gradual transition into the Renanué sub-facies.

The limestones intercalated by quartzite layers, observed by Schmidt (1931, p. 43) south of Sahún, suggest an equivalence of the Basibé Formation within the Renanué sub-facies. Correlation of the Gelada Formation and Aneto Formation in the Renanué sub-facies is entirely speculative.

Chronostratigraphic correlation between the sub-facies (Fig. 25)

The basis for the chronostratigraphic correlations is formed by the ages concluded from the conodont determinations as discussed in Chapter 4. The ages of the formations are indicated in Fig. 25. Where the ages of the boundaries of the formations are not exactly known or assumed, the lines are dotted.

The chronostratigraphic correlations roughly conform with the lithostratigraphic correlations. Of three formations, however, it could be demonstrated that they are not isochronous. In Chapter 4.A it is demonstrated that the age of the Compte Formation is not everywhere the same (Fig. 23), while in Chapter 4.B it is argued that the age of the lower boundary of the Basibé Formation in the Sierra Negra sub-facies s.l. increases towards the west. Furthermore, the uppermost part of the Basibé Formation in the Compte sub-facies grows older towards the west (see Chapter 4.A). The lower boundary of the Bellver Formation is not isochronous either, it becomes older towards the east.

The following correlations can be added to the lithostratigraphic correlations. The base of the massive limestones at Sahún is a time equivalent of the limestones above the first bedded cherts in the Compte sub-facies

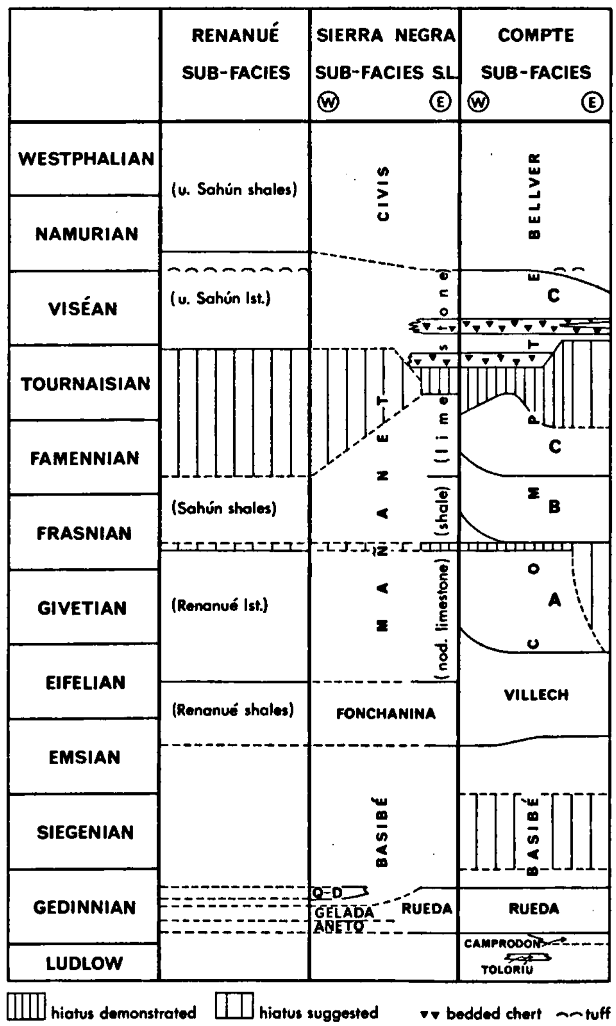


Fig. 25. Chronostratigraphic correlation between the sub-facies.

and at Castells. The green tuffs observed at Sahún may be correlated with the Mañanet Griotte/Civis Formation (at Castells) and Compte Formation/Bellver Formation (at La Guardia de Arés) boundaries, while of the same age as the tuffs in the Bellver Formation at Bellver. The calcareous shales low in the upper part of the Mañanet Griotte at Castells are approximately time equivalents of the A-Member of the Compte Formation and of the sandy shales observed in the Renanué sub-facies.

5.B. HIATUSES IN THE SEDIMENTATION

Hiatuses in the sedimentation may be expected if the small thicknesses of the formations are taken into account. Especially the Basibé Formation, the Compte Formation and the upper member of the Mañanet Griotte were deposited over large time intervals. The approximate rate of sedimentation can be computed with the aid of the absolute ages provided by Harland (1964), which suggest only small errors (Fig. 26). As was to be expected, the three possible hiatuses, suggested in Chapter 3, conform with a very low rate of sedimentation (less than 7 m/10^6 year). The evidence for the Siegenian hiatus, the Lower Frasnian hiatus and the Tournaisian hiatus will be further dealt with below.

Siegenian hiatus

It is suggested in 3.A that the deposition of the Basibé Formation was not continuous and that a hiatus existed during the Siegenian. Evidence in favour of the hiatus is not convincing. Arguments are the gap in the conodont record, approximately corresponding with the Siegenian, the presence of synsedimentary limestone breccias and the reduced thickness of the Basibé Formation.

In surrounding areas a Siegenian hiatus is not reported.

Lower Frasnian hiatus

At La Guardia de Arés and Villech (see 3.A) in the Compte sub-facies and at Castells (see 3.B) in the Sierra Negra sub-facies the presence of a hiatus is suggested during the Middle and Upper *Polygnathus asymmetricus* zone. At La Guardia de Arés and Villech the hiatus conforms with the boundary between the A and the B-Member of the Compte Formation, while at Castells the hiatus is located directly above the calcareous shales in the upper member of the Mañanet Griotte.

Other evidence supports the presence of a hiatus during part of the Lower Frasnian in the area studied:

1) At La Guardia de Arés synsedimentary breccias are observed in the top metres of the A-Member.
2) At Feixa Schmidt (1931, p. 71) recorded a conglomerate at the Compte A/B-Member boundary, and in one locality even an angular unconformity. Schmidt called this unconformity the 'leridische Phase der Bretonischen Faltung'.
3) In the Camprodon area Trouw (1969) recorded the absence of the A-Member and locally even of the B-Member of the Compte Formation.

In the western part of the Central Pyrenees, in the western and south-western part of the studied area,

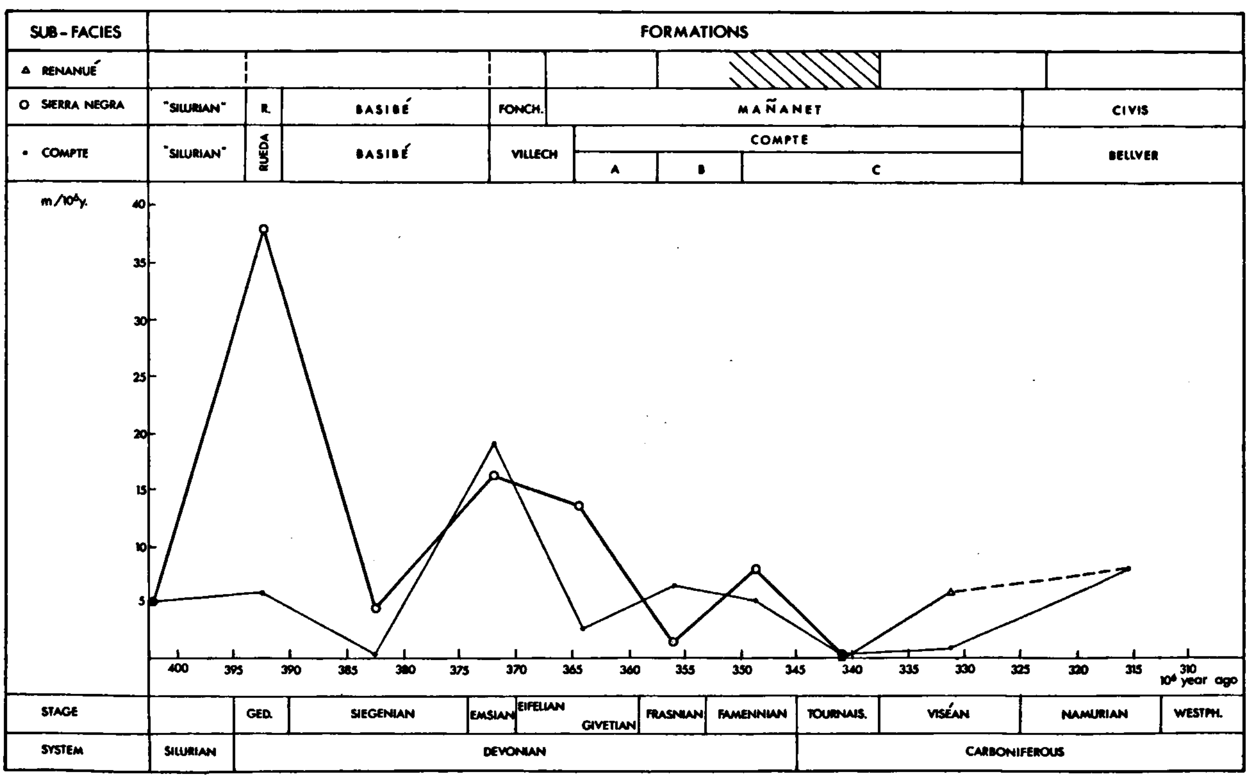


Fig. 26. Approximate rate of sedimentation during the Devonian and Lower Carboniferous in the three sub-facies.

Mirouse (1966) recorded a hiatus ranging from the Frasnian into the base of the Carboniferous (Tournaisian). The presence of a hiatus during part of the Frasnian seems well established, so that we may postulate that the 'leridian' (named after the province of Lérida) unconformity can be followed throughout the southern Central Pyrenees. Its extent, however, changes from place to place. It is remarkable in this respect that the hiatus conforms in the Renanué sub-facies with the change from limestones to sandy shales.

Tournaisian hiatus
In the French Pyrenees and Montagne Noir, Delépine (1937) suggested a hiatus between the Upper Devonian griotte limestones and the Viséan bedded cherts. Ziegler (1959) concluded, on the basis of conodonts sampled in the section of Schmidt (1931) along the Rio Noguera Pallaresa, that the Tournaisian hiatus did not exist. Immediately below the first bedded cherts he collected a fauna belonging to the *Siphonodella – triangulus inaequalis* zone. Careful sampling demonstrated, however, that in all sections at least part of the Tournaisian is absent.

There are three arguments in favour of an uppermost Tournaisian hiatus directly below the first bedded cherts:

1) At Compte the limestones directly below the first bedded cherts indicate the *Siphonodella – triangulus inaequalis* zone, while at La Guardia de Arés they indicate the Lower *Siphonodella crenulata* zone. The top of the first bedded cherts in both sections indicates the *Scaliognathus anchoralis* zone. Since the age of the second bedded cherts seems also to be the same in all localities, the picture arises of two isochronous bedded chert layers.
2) Phosphate nodules were observed in the base of the first bedded cherts at La Guardia de Arés and Castells. According to Krumbein & Sloss (1963, p. 185) 'Concentrations of phosphate nodules have been observed in many unconformities..'.*
3) Rhodes, Austin & Druce (1969) and Druce (1969) concluded a break in the sedimentation in Western Europe between the *Siphonodella crenulata* zone and *Scaliognathus anchoralis* zone; this is exactly where the hiatus is suggested.

At Bellver the break in the sedimentation is much greater (Fig. 23). Without any visible unconformity we pass from the Upper Devonian *Spathognathodus costatus* zone into the Viséan *Gnathodus typicus* zone, so that the uppermost Famennian, Tournaisian and lowermost Viséan are absent. This explains why at Bellver we find only one chert layer: the first is not deposited because the hiatus extended up to the *Gnathodus typicus* zone. At Castellar de Nuch (Fig. 23) two chert layers may be observed, but the limestones in between may be considered intercalations in the second bedded cherts, just as at Bellver where some limestones are also intercalated.

In conclusion it may be said that in the western part of the Compte sub-facies two isochronous chert layers are present, while in the eastern part only the second chert layer can be recognized, which is caused by the upwards extending range of the Tournaisian hiatus (Fig. 23).

At Sahún no data could be obtained from the Upper Devonian, but since the sequence closely resembles the sections in the Upper Aragón Valley (Marks & Wensink, 1970), a hiatus ranging from the upper part of the Famennian into the *Scaliognathus anchoralis* zone seems acceptable. At Sahún the hiatus may range somewhat higher into the *Sc. anchoralis* zone than in the Upper Aragón Valley, since *Polygnathus communis*, which becomes extinct in this zone, was not observed.

In the Sierra Negrà sub-facies a Tournaisian hiatus is only demonstrated at Castells. Here the lithological development and the datings of the bedded cherts are exactly the same as at the nearby La Guardia de Arés: the hiatus contains only the time of the Upper *Siphonodella crenulata* zone and the time between the *Si. crenulata* zone and the *Scaliognathus anchoralis* zone (Rhodes et al., 1969).

Mirouse (1966) reported that in the areas of the Western French Central Pyrenees where the Frasnian is absent the hiatus continues into the uppermost Devonian, and that the hiatus extends over a larger area in the uppermost Devonian than in the Frasnian (planche 2, fig. 4). He also recorded that the bedded cherts are especially absent along the margins of the area (planche 2, fig. 5).

We may conclude that the extent of the Tournaisian hiatus varies strongly in a west to east direction, especially its lower limit. Its upper limit should be placed approximately at the Tournaisian/Viséan boundary.

5.C. CORRELATION WITH SURROUNDING AREAS

Correlation with areas surrounding the area of study can be carried out in eastern, northern and western directions. For a number of reasons a choice was made in favour of correlations in lines rather than for correlations with the Northern, Central and Western facies areas (Mey, 1968a). Firstly, the area studied and the areas for comparison extend more to the east than the area discussed by Mey, so that a correlation towards the east is desirable too. Secondly, the facies (and sub-facies) are not defined by Mey, so that his designation of areas to different (sub-)facies is at times rather arbitrary. Thirdly, correlation to the north provides schematical stratigraphic cross sections through the Pyrenees, which will

* At Castellar de Nuch where only the second bedded cherts are present, also phosphate nodules occur. The same observations were made by van Lith (1968) and Marks & Wensink (1970) in the Western facies area. If the presence of phosphate nodules is accepted as an indication of an unconformity, a second hiatus might be suggested although no faunal break could be demonstrated.

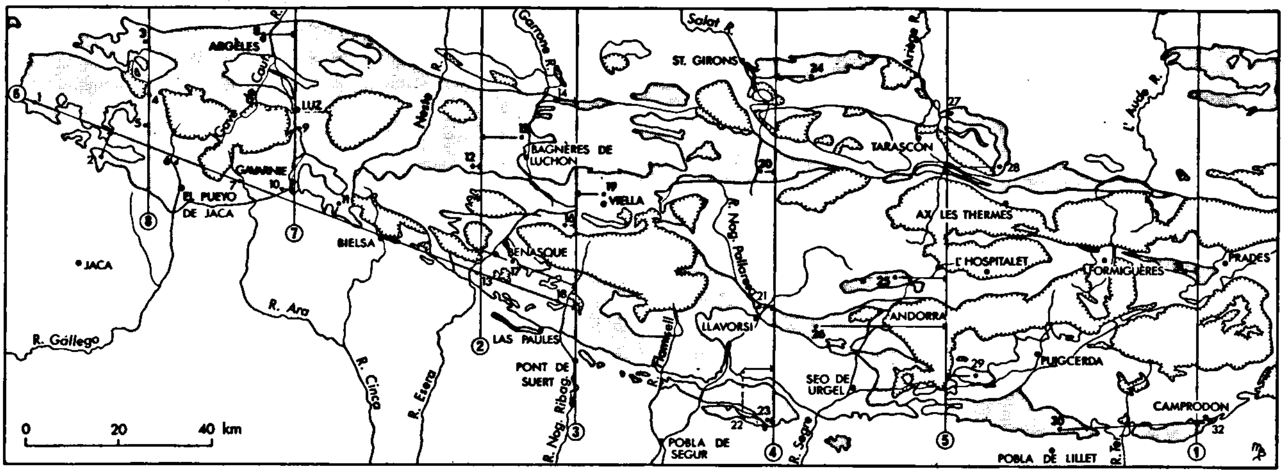


Fig. 27. Map (1 : 1,600,000) showing the location of stratigraphic cross sections 1–8 (Figs. 28–35). The shaded areas indicate the outcrops of the Devonian and pre-Hercynian Carboniferous (after Zwart, 1972). Numbers 1–32 refer to the sections used. (1: Schwarz, 1962; 2: van Lingen, 1960; 3: Mirouse, 1966; 4: Mirouse, 1966; Krylatov & Stoppel, 1971; 5: Mirouse, 1966; 6: Wensink, 1962; 7: Wensink, 1962; 8: Mirouse, 1966; 9: Mirouse, 1966; Krylatov & Stoppel, 1971; 10: Mirouse, 1966; 11: van Lith, 1965; 12: Clin, 1959; 13: Boersma; 14: de Sitter & Zwart, 1962; 15: Destombes, 1953; 16: Kleinsmiede, 1960; 17: Mey, 1968b; 18: Mey, 1968b; 19: Kleinsmiede, 1960; 20: Zandvliet, 1960; 21: Hartevelt, 1970; 22: Boersma; 23: Boersma; 24: Keizer, 1953; 25: Llopis Lladó, 1969; 26: Hartevelt, 1970; 27: Zwart, 1953; 28: Zwart, 1953; 29: Boersma; 30: Boersma; 31: Cavet, 1957; 32: Trouw, 1969).

be used in 5.D in an attempt at reconstructing the Pyrenean Basin. The locations of the sections selected for this purpose from the sections presented and from literature are indicated in Fig. 27.

Correlation to the east (Fig. 28)
The Devonian and Lower Carboniferous east of the area of study was described by Trouw (1969) in the Camprodon area and by Cavet (1957) in the Syncline of Villefranche.

As pointed out in 2.A, the Devonian and Lower Carboniferous in the Camprodon area are developed as Compte sub-facies. However, some differences occur. In this area no distinction can be made between the Rueda Formation and the Basibé Formation. The 'Lower Devonian' consists of an alternation of pure and more

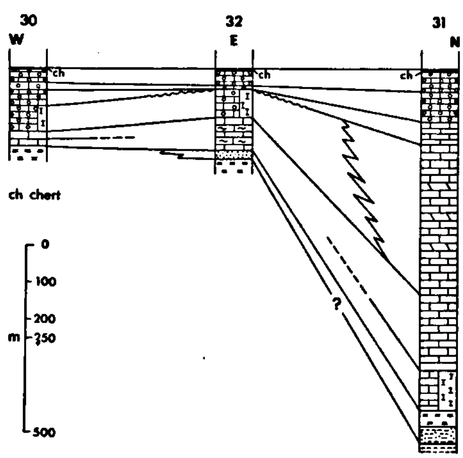


Fig. 28. Stratigraphic cross section 1.

marly limestones, conformably lying upon the Camprodon Formation. Trouw suggested an Upper Silurian age for the Camprodon Formation, but since similar deposits seem to occur in the Mouthoumet, for which a Gedinnian age is suggested (Ovtracht, 1968), a Gedinnian age seems more plausible.

The Compte Formation in the Camprodon area is certainly not complete: the A-Member is absent (see 4.B), while north of Bruguera the B-Member seems to be absent as well. Only in the western part of the area do some limestones (40 cm) occur above the bedded cherts.

Cavet (1957) gave an approximate succession of the Devonian strata in the Syncline of Villefranche. From top to bottom he distinguished: 1) grey nodular limestones, grading into multicoloured calcareous shales, with *Sporadoceras:* Famennian; 2) red griotte limestones with *Cheiloceras:* Frasnian and lowermost Famennian; 3) rose marble of Villefranche, presumably of Givetian age; 4) grey limestones and dolomites with silicified corals, rich in magnesia, up to 400 m: Eifelian; 5) the Gotlando-Devonian, consisting of multicoloured calcareous shales and limestones, intercalated by black shales and *Orthoceras* limestones, up to 400 m, with an Upper Silurian – Lower Devonian age. Cavet was not able to define the Silurian/Devonian boundary. Some sections, e.g. at the Puig d'Escoutou (p. 113, 114), allow a subdivision of the Gotlando-Devonian in, from top to bottom: a) about 200 m of black limestones rich in crinoid ossicles, with some calcareous shales in the lower part; b) grey or yellow limestones alternating with yellow and greenish calcareous shales (about 110 m); c) black shales, rich in pyrite, about 40 m; d) sandy shales, rich in mica, about 35 m; e) shales of Ashgillian age.

Units 1)–3), with a total thickness of about 200 m, are overlain by about 5 m of grey nodular limestone, intercalated by thinly bedded cherts, locally accompanied by phosphate nodules which were placed by Cavet in the Upper Tournaisian or Lower Viséan.

It is evident that the succession of strata briefly described above strongly resembles the succession in the Southern facies and especially the Compte sub-facies, and not the Central facies as might be expected geographically. Units 1)–3) and the overlying limestones with bedded cherts can be correlated with the three members of the Compte Formation. Units 5a) and 5b) strongly resemble the Basibé and Rueda Formations of the Sierra Negra sub-facies s.l., while the lower boundary of unit 5d) might be correlated with the lower boundary of the Camprodon Formation.

The Eifelian limestones and dolomites, probably equivalents of the Villech Formation, cannot be correlated with an equivalent in the Southern facies. Limestones and dolomites of the same age have, however, been reported from the Arize Massif (Keizer, 1953) and the Massif of St. Barthélemy (Zwart, 1953) so that we may conclude that the Devonian of the Syncline of Villefranche occupies an intermediate position between the Southern and Northern facies.

Correlation to the north

Comparing the Devonian and Lower Carboniferous of the Southern facies with more northerly areas we have to correlate it with the Central facies, and we have to correlate the Central facies with the Northern facies. Since both in the Southern facies and in the Northern facies different sub-facies are recognized (Mey, 1968a), it is desirable to make different stratigraphic cross sections. The location of the north to south cross sections is indicated in Fig. 27.

The most westerly cross section is approximately along a line from Sahún in the south to the Barousse Massif in the north. From south to north we pass through the Renanué sub-facies, the Sierra Negra sub-facies s.l., the western part of the Central facies and the western part of the Northern facies.

The Devonian and Lower Carboniferous of the western part of the Central facies area, between the 'Cirque de Troumouse' in the west and the 'Cirque du Lys' in the east, were described by Clin (1959). The so-called 'Série des Agudes – Cap de Pales' is described by Krylatov & Stoppel (1969).

South of the Col de Peyresourde in the Devonian, Clin recognized five limestone units, the lower three of which are intercalated with thinly bedded quartzites, the 'barégienne' (Bresson, 1903). The limestone units are separated from each other by dark arenaceous slates. The upper two limestones, the 'calcaire de Mal de l'Orp' and the 'calcaire des granges de Palenque' were placed by Clin in the Middle Devonian, on the basis of analogy of the limestones with limestones in the Northern facies. This means that the lower three limestones are probably of Lower Devonian age. The 'calcaire des granges de Palenque' is overlain by an approximately 700 m thick sequence of sandstones and shales, intercalated by some limestones, an equivalent of the Las Bordas Sandstones in the Valle de Aran (Kleinsmiede, 1960), which was described and dated by Krylatov & Stoppel (1969). Conodonts recovered from a limestone, directly underlying the sandstones and shales, probably an equivalent of the 'calcaire des granges de Palenque', were dated as Lower Frasnian (*to I a*). The sequence is overlain by about 50 m of nodular limestone which in the uppermost part contain some cherts. The base of the nodular limestones was dated by Krylatov & Stoppel as *to III a* (Famennian). The total thickness of the Devonian in this area is about 1700 m.

The nature of the overlying clastic Carboniferous is not known, since the 'Série des Agudes – Cap de Pales' was erroneously placed by Clin in the Dinantian.

It may be suggested that the top of the third limestone unit should be correlated with the top of the Basibé Formation (Fig. 29). The base of the 'calcaire de Mal de l'Orp' may be correlated with the base of the Mañanet Griotte, while the top of the nodular limestones has to be correlated with the top of the Mañanet Griotte.

In the Upper Pique River, west of Bagnières de Luchon, Destombes (1953) composed a section of the Devonian and Lower Carboniferous. He distinguished, from top to bottom: 1) shales with *Calamites* (Namurian); 2) Calcaires d'Ardengost à polypiers et *Productus*, about 80 m (Viséan); 3) terrestrial shales of Bourg d'Oueil with *Nereites* and *Oldhamia*, 30 m (Viséan); 4) bedded cherts with phosphate nodules (Tournaisian/Viséan boundary); 5) griotte limestones with *Clymenia*, 40 m (Upper Famennian); 6) shales and multicoloured calcareous shales with some limestones and dolomites, 100–120 m (Upper Devonian); 7)

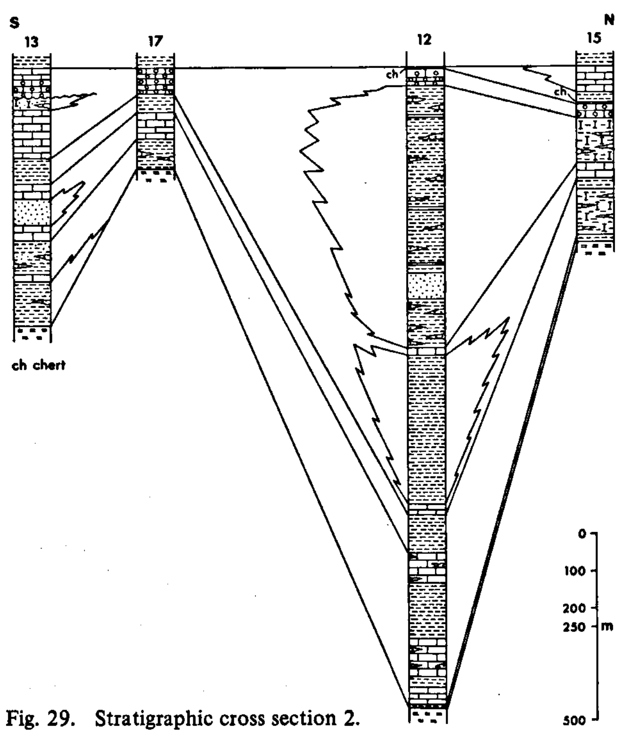


Fig. 29. Stratigraphic cross section 2.

crinoid limestones, 30–50 m (Middle Devonian); 8) blue grey shales with the trilobite fauna of Cathervielle, 20–30 m (Eifelian)*; 9) blue grey calcareous shales with some limestones, 80–150 m (Coblentzian); 10) black shales, 15–20 m (Lower Devonian).

The Lower Devonian hardly resembles the Lower Devonian of the area described by Clin (1959). Some correlations, however, may be suggested (Fig. 27). The top of the black shales might be correlated with the base of the first limestone in the Central facies, the top of the third limestone unit might be correlated with the base of the shales with the trilobite fauna of Cathervielle, while finally the fourth and fifth limestone units may be seen as equivalents of the crinoid limestones. The top of the griotte limestones may no doubt be correlated with the top of the bedded cherts.

A second stratigraphic cross section can be made, passing through the Sierra Negra sub-facies s.l., Pla de Estang sub-facies (Mey, 1968a), Val d'Arán sub-facies, into the central part of the Northern sub-facies.

The Devonian and Lower Carboniferous of the Val d'Arán was described by Kleinsmiede et al. (1957) and Kleinsmiede (1960), and of the Pla de Estang by Kleinsmiede (1960) and Waterlot (1964, 1969a, 1969b).

In the Val d'Arán Kleinsmiede (1960) recognized, from top to bottom: 1) the Viella Slates and Sandstones; 2) the Las Bordas Sandstones, consisting of sand/shale alternations, overlain by orthoquartzites, non-graded sandstones and graded sandstones; locally some limestone lenses are intercalated in the sandstones; 3) the Entecada Slates and Limestones, beginning with blue-black slates, intercalated by some thin limestones, followed by the Entecada Limestones, which are in turn overlain by some slates; 4) the Basal Limestone, with intercalations of black chert, fine-grained sandstone and slate.

In the Val d'Arán area the Carboniferous is only present in a syncline directly north of the Maladeta Granodiorite, at the Pla de Estang. The Carboniferous here lies unconformably upon the Devonian Basal Limestone and consists of thick-bedded, coarse-grained micaceous sandstones, with local conglomerates, greywackes, sub-arkoses, slates and limestones.

No palaeontological data are available from the Val d'Arán area. Krylatov & Stoppel (1969), however, by means of conodonts dated a westerly located equivalent of the Las Bordas Sandstones, the 'Série des Agudes – Cap de Pales', as Frasnian. This means that the Las Bordas Sandstones are time-equivalents of the Mañanet Griotte.

The following correlations may be suggested (Fig. 30): the top of the Basal Limestone with the top of the Basibé Formation and the base of the Entecada Limestone with the base of the Mañanet Griotte. The base of the Carboniferous, lying unconformably upon the Basal Limestone of the Pla de Estang, may be correlated with the base of the Civis Formation.

A section in the central part of the Northern facies was given by de Sitter & Zwart (1962) at Marignac. Here roughly four units may be recognized, from top to bottom: 1) griotte limestones (Upper Devonian); 2) shales with some limestone and griotte beds (Upper Devonian); 3) Middle Devonian Limestones; 4) Lower Devonian shales with some limestone beds, especially in the uppermost part. Since the non-dated Middle Devonian limestones were correlated by de Sitter & Zwart (p. 211) with the limestones dated as Middle Devonian, described by Destombes (1953) and Keizer (1953), the base of the limestones may be correlated with the base of the Entecada Limestone. The Upper Devonian griotte limestones are overlain by a chert horizon with a thickness of 20–50 m followed by a thick sequence of micaceous shales and sandstones which occasionally contain some limestones. De Sitter & Zwart (p. 212) concluded the absence of the uppermost part of the Famennian and of the Tournaisian.

A third stratigraphic north to south cross section can be constructed through the Castells block in the south. It is probable that, considering the development of the Devonian and Lower Carboniferous, which is intermediate between the Compte sub-facies and the Sierra Negra sub-facies s.l. in the Llavorsi Syncline, the Castells block, just as the Montsech de Tost (Hartevelt, 1970), has a northern origin, at least north of the Feixa block (Roberti, 1974). In the cross section the Castells block is therefore replaced towards the north, so that we consequently pass from south to north through the Compte sub-facies, Sierra Negra sub-facies s.l. (Castells block, Llavorsi Syncline), eastern part of the Central facies and Arize Massif (Northern facies).

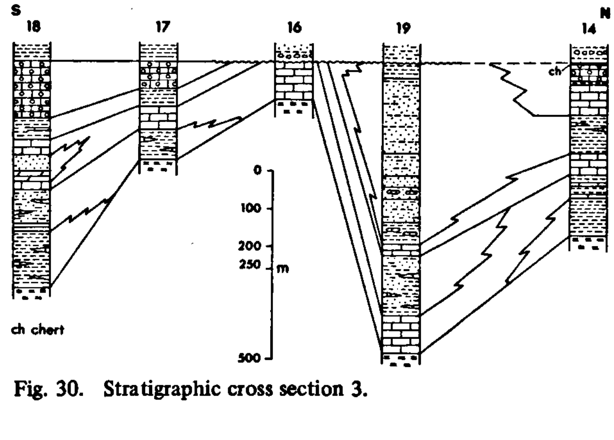


Fig. 30. Stratigraphic cross section 3.

* Originally the fauna of Cathervielle was placed by Barroi (1887) in the Lower Devonian, while Destombes placed it in the Middle Devonian. Cavet (1957) reported in a footnote (p. 187) that the fauna was placed by Erben in the Eifelian. Caralp (1888) placed the shales below the crinoid-limestones, while Destombes placed them above these, though admitting that he had hardly any arguments to do so (p. 121). Since the age of the fauna is now established as Eifelian, the original opinion on the stratigraphic position of the shales seems more probable.

The Devonian of the eastern part of the Central facies, the Upper Salat and Upper Alet areas, was described by Zandvliet (1960). The lower part of the Devonian is characterized here by an alternation of dark blue/bluish-grey limestones with pure dark slates. In the limestones thin slate intercalations occur, which become more siliceous towards the west. Generally five limestone units are present; locally, in the west of the area, six. These limestones seem to be followed in the fault-zone of Couflens – Arigail and north of it, by a maximum of 400 m griotte limestones alternating with some calcareous shales. Zandvliet suggested that the fourth and fifth limestone might be correlated with the massive Middle Devonian limestones of the Arize Massif and the Massif of St. Barthélemy. If this suggestion is accepted, it may be assumed that the top of the third limestone can be correlated with the top of the Basibé Formation and the base of the fourth limestone with the base of the Mañanet Griotte (Fig. 31).

Carboniferous does not occur in this part of the Central facies area.

The Devonian and Lower Carboniferous of the Arize Massif were described by Keizer (1953). From top to bottom he recognized in the Devonian: 1) griotte limestones, with locally synsedimentary conglomerates, 100–120 m (Upper Devonian); 2) calcareous shales with some limestone beds, 60–70 m (Upper Devonian); 3) grey dolomite, 100–150 m (Middle Devonian); 4) blue limestones, 30–120 m (Middle Devonian); 5) grey calcareous shales, alternating with some limestones, 80–100 m (Lower Devonian).

The griotte limestones are overlain by 0.2–20 m of bedded cherts, with locally phosphate nodules, and often with shale intercalations. Keizer placed the cherts in the Lower Viséan (cf. Delépine, 1935), while the Tournaisian is considered to be absent. In many places a nodular limestone bed occurs near the bedded cherts.

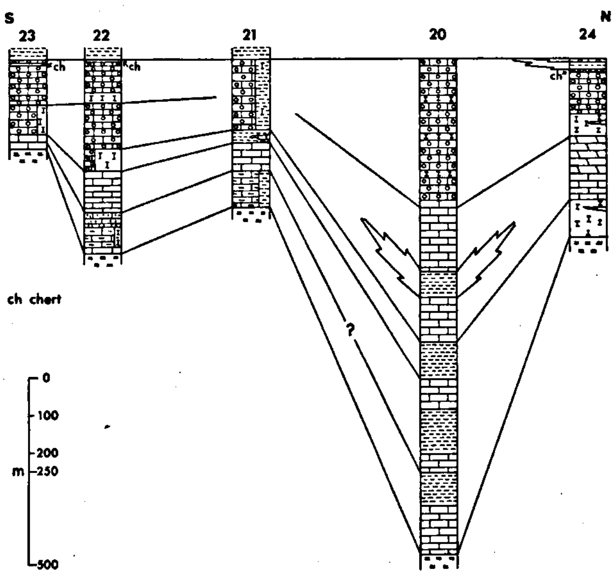


Fig. 31. Stratigraphic cross section 4.

The base of the Middle Devonian limestones can be correlated with the base of the fourth limestone in the Upper Salat area, while the top of the dolomites can be correlated with the top of the fifth limestone (Fig. 29).

The most easterly north to south cross section can be drawn from the Southern facies through the Tor Syncline into the Northern facies, viz. the Massif of St. Barthélemy.

The Devonian of the Tor Syncline was described by Zwart (1965) and Llopis Lladó (1969). The most complete section of Llopis Lladó, in the Valle del Casamanya, is considered here as representative, although he might have overlooked some tectonic complications (Zwart, pers. comm.). He recognized roughly, from top to bottom: 1) calcareous shales, the upper part of which is more calcareous, about 340 m; 2) calcareous shales, overlain by some limestones, about 600 m; 3) dark shales intercalated by some calcareous shales and limestones, about 380 m; 4) calcareous shales with some calcarenites in the lower part, about 450 m; 5) red and grey nodular limestones, intercalated by some shale beds, about 270 m (Famennian). Overlying Carboniferous does not occur in the Tor Syncline.

Although palaeontological data are not available from the Tor Syncline, the following correlations may be suggested: the base of the dark shales with the base of the Fonchanina Formation and the base of the overlying calcareous shales with the base of the Mañanet Griotte (Fig. 32). It seems hardly possible to make a distinction

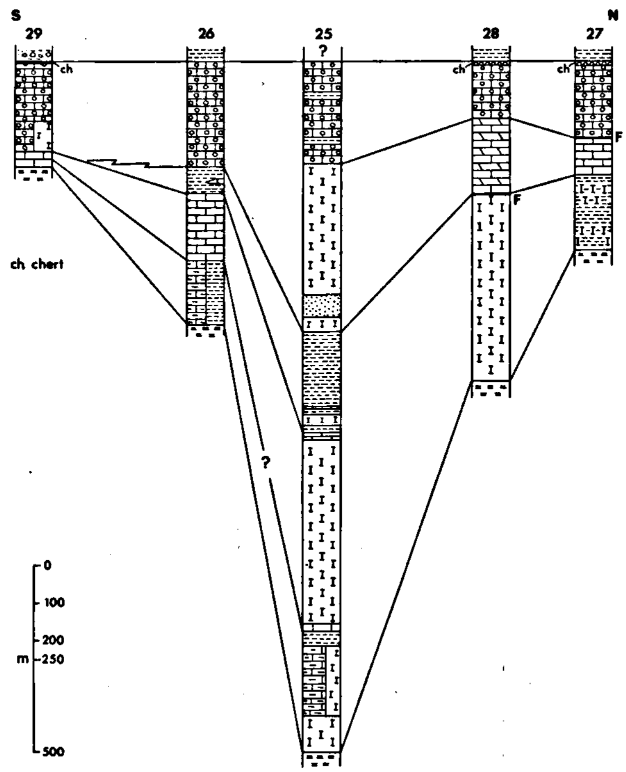


Fig. 32. Stratigraphic cross section 5.

between equivalents of the Basibé and Rueda Formations.

The Devonian and Lower Carboniferous of the Massif of St. Barthélemy is described by Zwart (1953), who recognized facial differences in the Devonian. In the north-west the Lower Devonian consists of, locally calcareous, shales, the Middle Devonian of dark blue or grey limestones, while the Upper Devonian, separated by a fault from the Middle Devonian, consists of grey and red griotte limestones. In the south-east both the Lower Devonian and the Middle Devonian are developed as grey and brown calcareous shales. In the Upper Devonian, again separated by a fault from the Middle Devonian, locally dolomitized white limestones or blue limestone breccias occur, followed by griotte limestones. Since the limestones are not dated, Zwart (p. 33) suggested that the dark blue breccias and white limestones might equally well be of Middle Devonian age. This suggestion seems more plausible than the possibility figured by Zwart (p. 37), so that consequently his correlations have to be partly revised, and it may be suggested that the age of the calcareous shales is only Lower Devonian.

The Upper Devonian griotte limestones are overlain by bedded cherts, only occasionally accompanied by phosphate nodules, followed by blue, grey and black shales with some sandstone and limestone beds.

The following correlations with the Tor Syncline seem logical: the base of the calcareous shales, overlying the dark shales, with the base of the Middle Devonian limestones and dolomites, and the nodular limestones of both areas (Fig. 32). The lithology of the Middle and Upper Devonian of the Massif of St. Barthélemy resembles the lithology of the Syncline of Villefranche.

Correlation to the west

The Devonian and Lower Carboniferous of the Spanish part of the Western Central Pyrenees, the Western facies area of Mey (1968a), was described, from east to west, by van Lith (1965), Wensink (1962), van Lingen (1960) and Schwarz (1962), while the Lower Carboniferous in the Upper Rio Aragón Valley was described and dated by Marks & Wensink (1970). The Devonian and Lower Carboniferous of the French part of the Western Central Pyrenees was described by Mirouse (1966) and Krylatov & Stoppel (1971). Mirouse recognized four different geographic areas which had partly a different development during the Devonian and Carboniferous. The development of the Western facies will be briefly outlined.

The Lower Devonian consists mainly of dark shales, sandy shales, quartzites and some sandy limestones. Quartzitic sandstones were placed in the Siegenian by Mirouse (e.g. p. 61). The Gedinnian is not positively demonstrated in the Western facies. Limestones of considerable thickness seem to occur only in the south-eastern part of the area: they were described by Mirouse from the area south of Gavernie and by van Lith from the Rio Cinca Valley. The thickness of the Lower Devonian attains about 700–800 m. The Lower Devonian is often separated from the Middle Devonian by an alternation of marly limestones and calcareous shales, which are called the 'couches de passage à l'Eifelien' by Mirouse.

The Middle Devonian generally consists of massive limestones, which are rich in corals and stromatoporoids and often contain small bioherms. Only in the 'région mediane' of Mirouse do thinly layered limestones occur. Wensink (1962, p. 22), Mirouse (1966, e.g. p. 116) and Krylatov & Stoppel (1971, p. 221) locally placed the top of the limestones in the Lower Frasnian. The thickness of the Middle Devonian attains over 400 m in the south.

In the western part of the area studied by Mirouse, in the Rio Cinca Valley (van Lith, 1965), Rio Ara Valley and Rio Gallego Valley (Wensink, 1962) the Middle Devonian limestones are overlain by thinly layered calcareous sandstones and shales, with some limestone intercalations and with a maximum thickness of about 400 m. Mirouse (e.g. p. 102) placed this sequence in the Frasnian and lower part of the Famennian. In the central part the sandstones of the approx. 500 m thick 'Série de Sia', placed by Mirouse in the Upper Carboniferous, but dated by Krylatov & Stoppel (1971) as Frasnian, overlies the lowermost Frasnian limestones. The Frasnian is absent in the south-west and possibly also in the north. The clastic sequence is overlain by Upper Famennian griottes or limestones. In the south-west, north and south of Gavernie the Upper Famennian is also absent.

Although van Lith (1965, p. 24) in the Rio Cinca area recorded some conodonts indicating the Tournaisian, the first Carboniferous deposits are in most places the bedded cherts. The bedded cherts are reported from the Rio Cinca Valley, Rio Ara Valley, Rio Gallego Valley and from the 'région mediane' and north-western part of the 'région sub-occidentale' of Mirouse. Thick Viséan limestones, up to 150 m, overlie the cherts or older substratum.

The Viséan limestones are overlain by Upper Carboniferous shales and sandstones, intercalated by some conglomerates and limestones, and sometimes with some plant debris. Only in the central part is the nature of the Upper Carboniferous unknown, since the 'Série de Sia' belongs to the Frasnian.

In 2.D the resemblance between the Renanué sub-facies and the Western facies is mentioned, so that the suggested section of the Renanué sub-facies can be correlated with the section derived from van Lith (1965) in the Rio Cinca Valley, and further towards the west as far as the Valley of the Rio Aragón – Subordan (Schwarz, 1960) (Fig. 33). The alternation of sandstones with calcareous shales and limestones occurs both in the Rio Esera and in the Rio Cinca Valley, Rio Ara and Rio Gallego Valleys. Bedded cherts and Upper Devonian griotte limestones are absent which is not so remarkable since they are also missing in the Rio Aragón and Rio Aragón – Subordan Valleys. Taking in account the suggested upper Lower Devonian age of the limestones in the Rio Cinca Valley, it seems logical to correlate the top of these limestones with the top of the Basibé

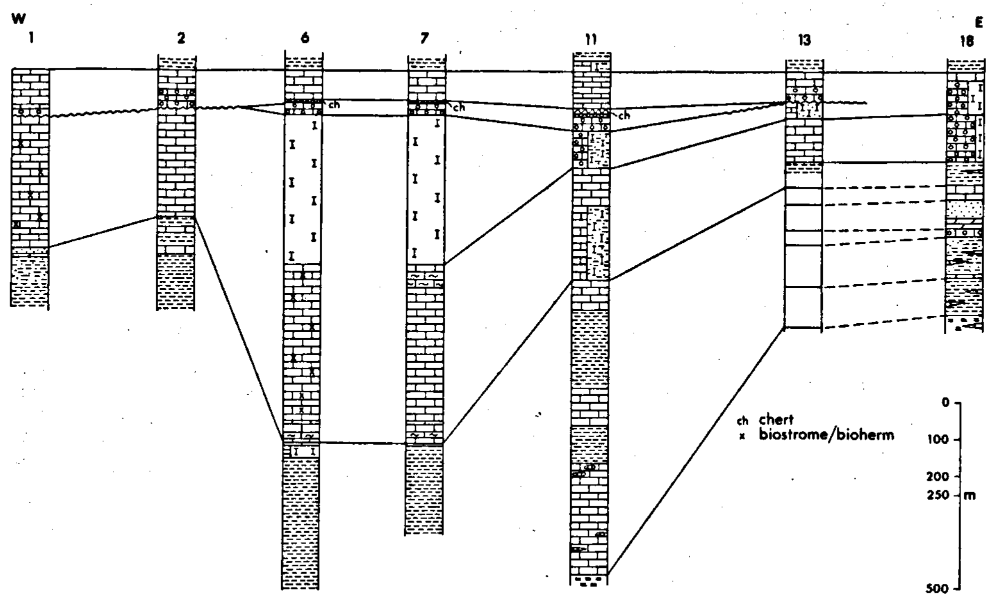


Fig. 33. Stratigraphic cross section 6.

Formation, which presence was only suggested in the Renanué sub-facies. Further correlation towards the west is quite easy since the only important changes are the disappearance towards the west of the sandstones, calcareous shales and limestones, together with the overlying bedded cherts and Upper Devonian griotte limestones.

From the extensive number of sections and descriptions of exposures of Mirouse it was possible to compose two north to south stratigraphic cross sections, one approximately through Gavernie (Fig. 34), the other through Laruns (Fig. 35) (see Fig. 27). For a description of the sections and the evidence of the correlations the reader is referred to Mirouse (1966) and Krylatov & Stoppel (1971).

5.D. ATTEMPT AT RECONSTRUCTION OF THE PYRENEAN BASIN

Reconstruction of the Pyrenean Basin may be attempted on the basis of the stratigraphic cross sections (Figs. 28–35) presented in 5.C. In this case a reconstruction is fairly speculative for a number of reasons. In the first place, the formations are only locally adequately dated. Secondly, different authors may have given different lithological descriptions for the same formation. Thirdly, in large areas of the Pyrenees the Devonian and/or Lower Carboniferous is not exposed. Fourthly, the transition between the Western facies and the Central and Northern facies is still fragmentarily known. An attempt is nevertheless made, because it may offer a

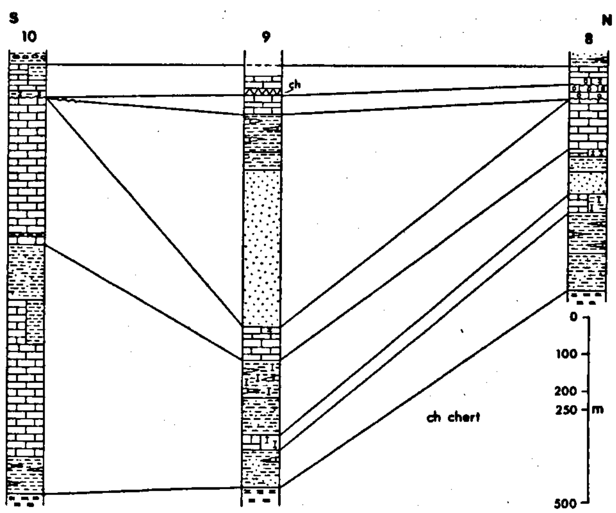


Fig. 34. Stratigraphic cross section 7.

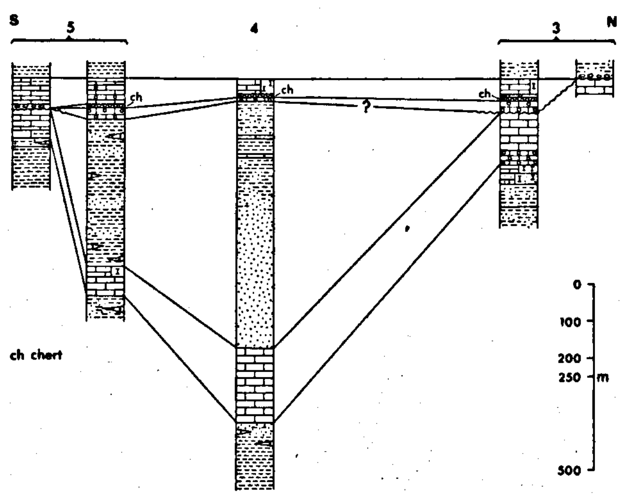


Fig. 35. Stratigraphic cross section 8.

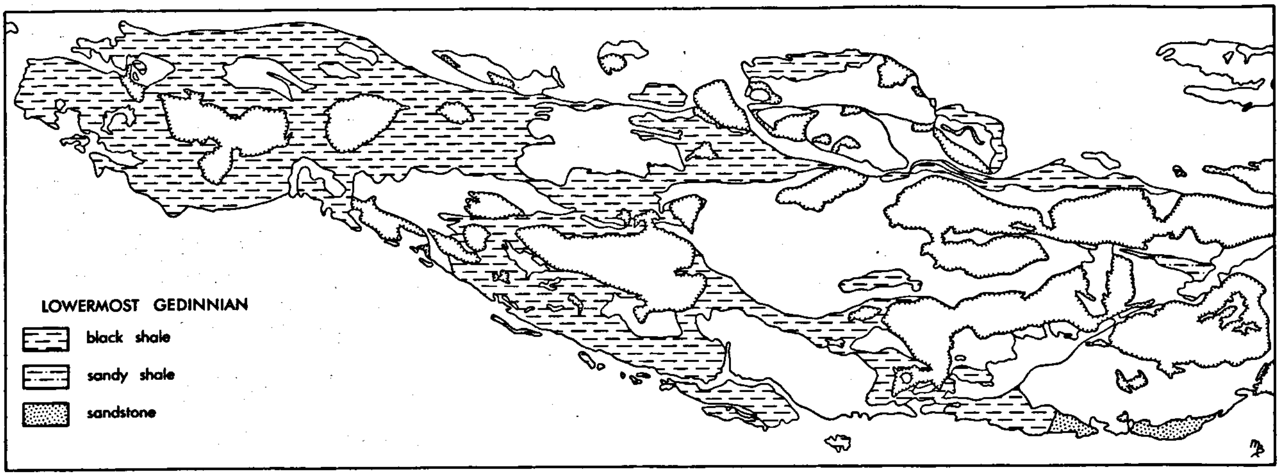


Fig. 36. Qualitative litho-facies map of the lowermost Gedinnian.

model which can be corrected in the future when more precise data become available. Furthermore, Mey (1968a) offered a model which is for a large part based on false assumptions of the age of the formations, so that a first correction seems desirable.

In Figs. 36–43 eight time intervals of the Devonian and Lower Carboniferous are presented. It should be stated emphatically that these maps have to be read as qualitative litho-facies maps in which only a limited number of litho-facies is indicated.

Earlier litho-facies maps of the Central Pyrenees were presented by Mey (1968a). Mirouse (1966) offered detailed litho-facies maps for the western part of the basin, and a scheme for the development during the Middle and Upper Devonian and Lower Carboniferous. Waterlot (1969a, 1969b) presented palaeogeographic maps for the (Upper) Carboniferous in the Pla de Estang and the Carboniferous basin of Feixa – Castellás – Espahent (Feixa block, Nogueras-zone). Clin (1959) offered a distribution map of the bedded cherts in the Central Pyrenees.

Lower Devonian

During the lowermost Gedinnian (Fig. 36) the deposition of black shales with some *Orthoceras* limestones continued over the entire Central Pyrenees, except in the eastern part of the Compte sub-facies, where the sandstones of the Camprodon Formation were deposited, and in the Syncline of Villefranche where sandy shales are recorded. Mirouse (1966) suggested that the Silurian black shales were deposited in a shallow reducing environment, so that a low hinterland and a basin with limited circulation may be suggested. The Camprodon Formation might indicate a higher relief of the hinterland in the neighbourhood, and may possibly be seen as an indication of the Ardennian phase of the Caledonian Orogeny.

Higher in the Gedinnian (Fig. 37) a differentiation in subareas occurred. In the Central facies a thick sequence of limestones, with sandy intercalations, developed, separated from each other by dark shales. In the Western facies, Northern facies, Sierra Negra sub-facies (except in the Castells block and the Montsech de Tost) and eastern

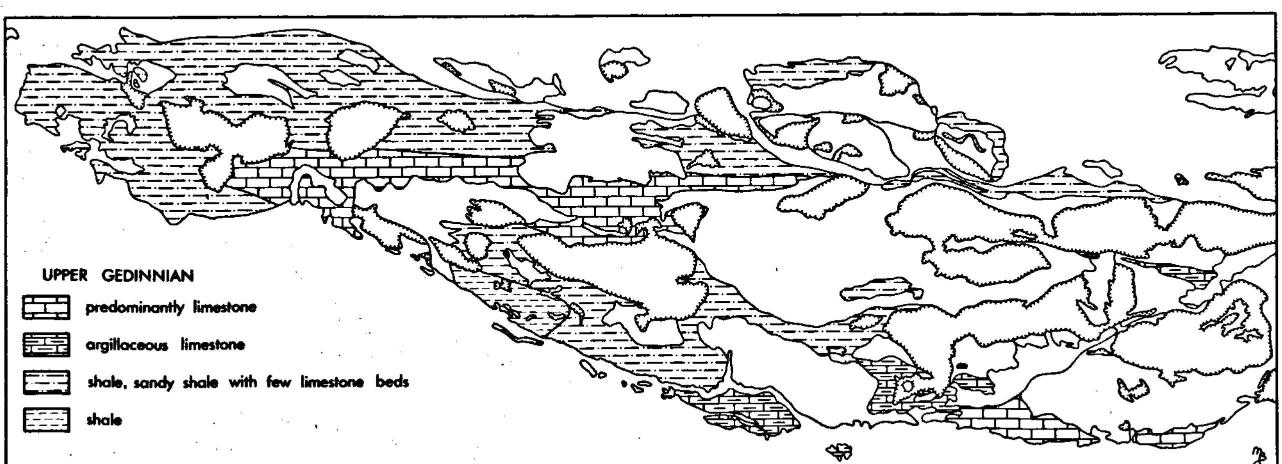


Fig. 37. Qualitative litho-facies map of the Upper Gedinnian.

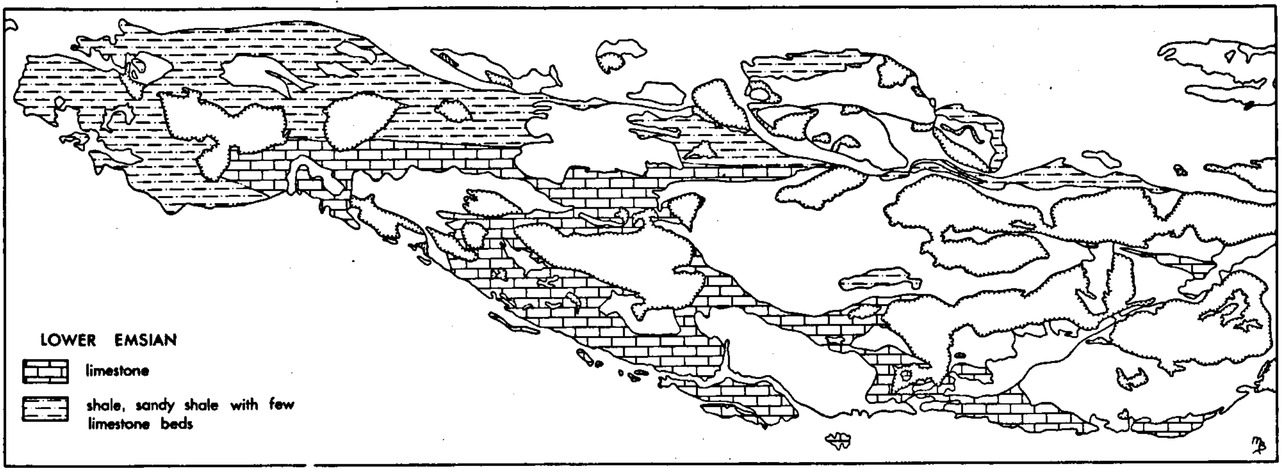


Fig. 38. Qualitative litho-facies map of the Lower Emsian.

part of the Baliera sub-facies, shales, sandy shales and some greywackes were deposited. In the western part of the Baliera sub-facies the deposition of finer clastics still continued (Aneto Formation) for a while, followed by the deposition of the sandy shales and impure limestones of the Rueda Formation. In the Compte sub-facies, Castells-block and Montsech de Tost marly limestones developed (Rueda Formation) which become more pure towards the east.

During the Siegenian and Lower Emsian mainly limestones were formed in the Central facies, Southern facies (Basibé Formation) and south-eastern part of the Western facies area. In the northern and western facies area the deposition of fairly coarse clastics continued (Fig. 38). In the Baliera area, probably in the Renanué sub-facies and also in the Western facies, quartzites occur. Habermehl (1970) concluded that the quartzites of the Basibé Formation were deposited as submarine bars or barrier islands, while the material, possibly derived by erosion from a stable lowland in the vicinity, was transported by longshore currents in a NW–SE direction. We may therefore conclude that, at least in the western part of the Central Pyrenees, there was a lowland in the vicinity, especially in the south. Habermehl concluded to a shallow southern basin which deepened towards the north (Central facies). The small thickness of the Rueda and Basibé Formations in the Compte sub-facies might also be an argument in favour of the shallowness of the basin in the south.

Higher in the Emsian, carbonate deposition ceased nearly over the entire Pyrenees, and influx of clayey material took place. Habermehl (1970) suggested that the reason for the sudden influx was a deepening of the basin, or changes in the hinterland, or that it was brought in by currents from an other part of the sea bottom. In the Western facies the sediments become more fine-grained to the end of the Emsian, which does not seem to be in favour of important changes in the hinterland, so that it is suggested that the fining here may have been caused by a gradual lowering of the relief of the hinterland. A picture arises of a low hinterland which provided fine-grained clastic material to a slowly deepening basin, in which the material was transported by currents. In the south-west and south-east the subsidence and supply of clayey material was probably less pronounced, since limestones, alternating with calcareous shales, were still deposited here.

Middle Devonian

During the lower part of the Eifelian the deposition of fine-grained clastic material continued in the Sierra Negra sub-facies (Fonchanina Formation) and the Renanué sub-facies, as well as in some areas of the Western and Northern facies. In the Compte sub-facies the deposition of nodular limestones and calcareous shales (Villech Formation) continued, while in the main part of the Western facies, Arize Massif, Massif of St. Barthélemy and Syncline of Villefranche the Middle Devonian appears to begin with the deposition of limestones. At the Pla de Estang, where the limestones correlated with the Basibé Formation are overlain by clastic Carboniferous, the Middle Devonian was not deposited and/or removed by erosion during the Frasnian. Here we encounter the first indication of the existence of a geanticlinal ridge, defined here as an area of little or no deposition which only locally and sometimes emerged above sea level, which ridge will further be called the Pyrenean Geanticline.

Higher in the Eifelian, nearly exclusively massive limestones were deposited in the Western facies area, the Northern facies area and the Renanué sub-facies area, which in the Western facies area contain biostromes and bioherms. In the Central facies area, too, limestones predominate, though intercalated here by fairly thick sequences of dark shale. In the Sierra Negra and Compte sub-facies and in the Syncline of Villefranche nodular limestones and some calcareous shales were deposited, in the Tor Syncline only calcareous shales.

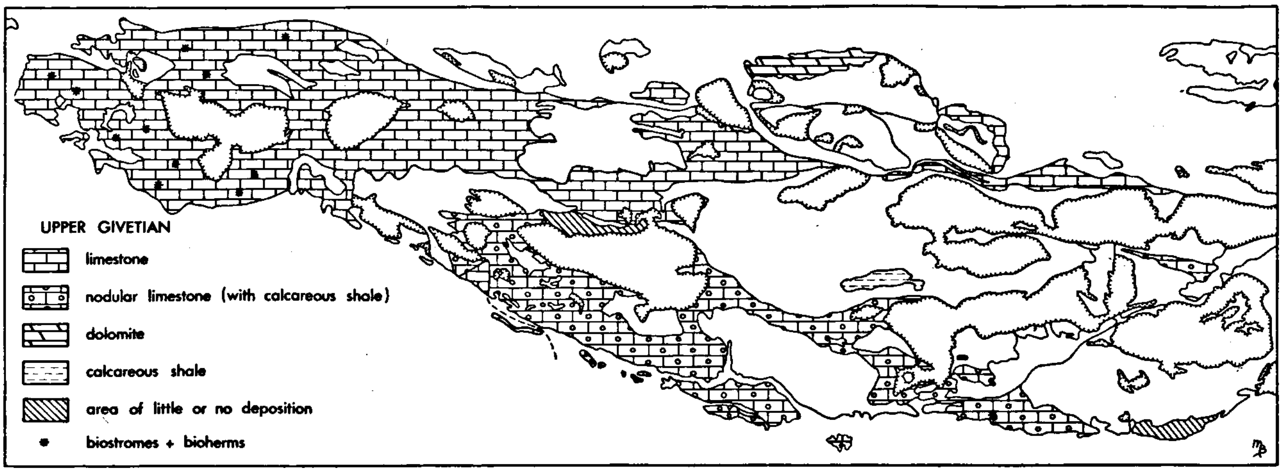


Fig. 39. Qualitative litho-facies map of the Upper Givetian.

The situation remained unchanged during the Givetian (Fig. 39). In the Northern facies area, however, dolomites were formed locally (Arize Massif). The eastern part of the Compte sub-facies area has probably been an area of non-deposition. For the Middle Devonian Mirouse (1966) suggested a shallow basin with a deeper central part, while the hinterland was in most places too low to provide clastic material, so that limestones could form. The origin of the fine-grained clastic material in the Central facies area is unknown. It might be suggested that the material was derived from the locally emerged Pyrenean Geanticline, and was spread out over the area by currents.

Upper Devonian

During the Frasnian sandstones and shales were deposited in the western and south-western part of the Western facies area and in the Renanué sub-facies, transported from the elevated basin margins towards the east and north (Mirouse, 1966) (Fig. 40).

Simultaneously, however, the 'Série de Sia' was deposited in the central part of the Western facies area, while the 'Série des Agudes – Cap de Pales' and the Las Bordas Sandstones were deposited in the Central facies area. The Las Bordas Sandstones were interpreted by Kleinsmiede (1960) as turbidites, a suggestion shared by Krylatov & Stoppel for the 'Série de Sia'. Kleinsmiede (p. 219) concluded that "Emergence in the west and contemporaneous subsidence in the east resulted in downsliding of accumulated sediments. Turbidity currents, repeatedly interrupting the normal sedimentation, longitudinally filled a rectangular trough. Presumably the turbidite association derived its material from eroded sedimentary beds....". Remains the problem of the origin of the clastic material. In the Western facies area elevated hinterlands were probably in the vicinity, since in large areas north and south of the central part the Frasnian is absent. The nature of the bordering sandstones and shales in the south, however, is probably different, since neither Mirouse nor Wensink claimed a turbidite association for these sandstones. For the Las Bordas Sandstones, bordered in the south by the Griotte limestones of the Mañanet Griotte, we have evidence in favour of a different origin of the material. At the Pla de

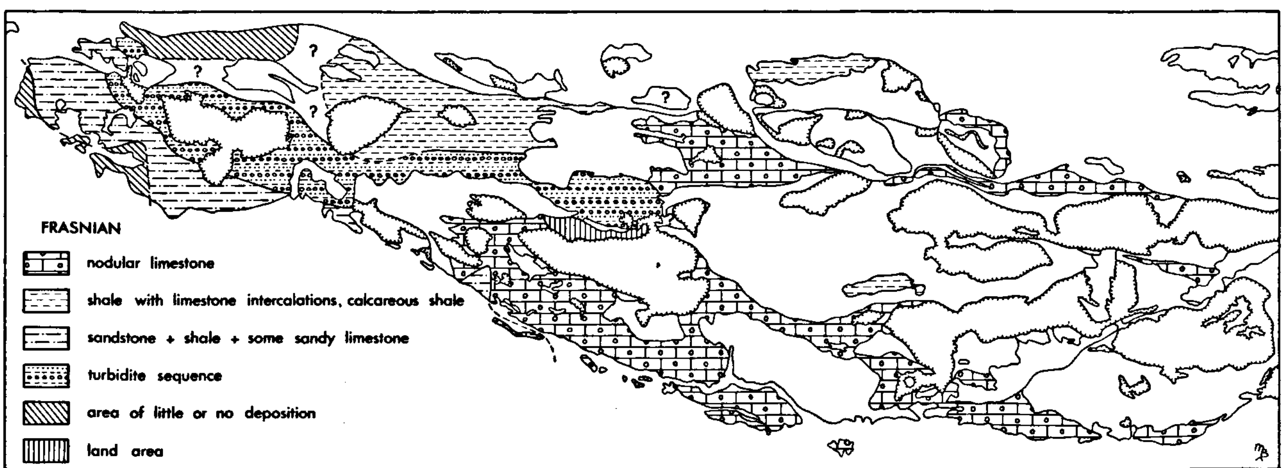


Fig. 40. Qualitative litho-facies map of the Frasnian.

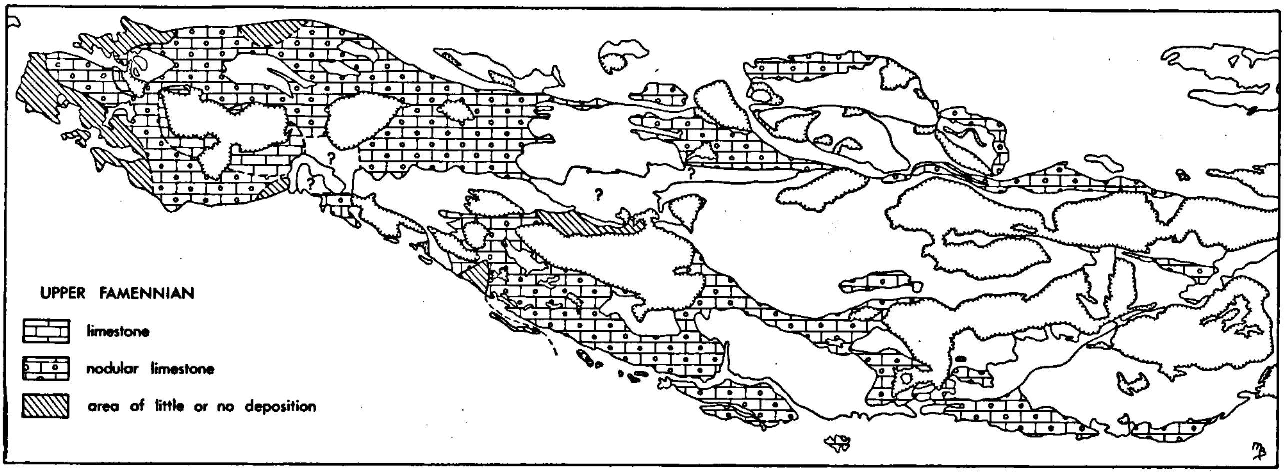


Fig. 41. Qualitative litho-facies map of the Upper Famennian.

Estang the Basal Limestone, which upper part is supposed to be an equivalent of the Basibé Formation (see 4.C), is unconformably overlain by the clastic Upper Carboniferous, which neither contains a basal conglomerate nor calcareous fragments of any importance. Consequently we may conclude that, taking into account the continuing regression of the sea from the Upper Famennian onwards, the unconformity developed before the Upper Famennian and after the Emsian, and that its development in the Lower Frasnian is quite probable. This results in the idea that the Pyrenean Geanticline developed during the Lower Frasnian, and may quite well be the source of the clastic material. Although objections to such interbasinal source lands were raised by Kuenen (1958), such an origin was argued by Dzulynski et al. (1959) for the Polish Carpathian Mountains and by Hsu (1960) for the Ultrahelvetic flysch basins in Switzerland. It seems to support also the idea of tectonically controlled sedimentation (Kingma, 1958; van der Lingen, 1969). The Pyrenean Geanticline was probably located at the western part of the Central Anticline and Lys-Caillauas Granite. We may suggest that uplift during the lowermost Frasnian steepened the primary palaeoslope, gave rise to slumping down the primary palaeoslope (Walker, 1970) and that the turbidites were deposited in a narrow basin, parallel to the tectonic strike of the region (Kuenen, 1957). Although in many cases 'flysch-type sediments' are considered to be deposited at a depth of 1,000 m or more (e.g. Kuenen, 1957), in the Pyrenees we have no reason to suppose that the turbidites were deposited at great depths. They overlie limestones which seem to have been formed in a somewhat deeper though still shallow environment (Mirouse, 1966). Furthermore, they are intercalated by some nodular limestones and overlain by griotte limestones which, according to Ovtracht & Fournié (1956), seem to indicate a shallow environment (see below).

In the western part of the Northern facies area, Arize Massif and Tor Syncline mainly multicoloured calcareous shales with some limestones and dolomites were deposited, although Pélissonnier (1958) recorded some quartzitic sandstones north of the Col de Peyresourde. The fine clastic material may have a southern or a northern origin. In the Southern facies area (except in the Renanué sub-facies area), the eastern part of the Central and Northern facies areas and in the Syncline of Villefranche multicoloured griotte limestones were deposited.

During the upper part of the Famennian (Fig. 41) the regression of the sea continued, resulting in the absence of the Upper Famennian in parts of the Western facies area and in the Renanué sub-facies. Later on all over the Pyrenees griotte limestones were deposited. Since not only the griotte limestones, but also the overlying Carboniferous are absent in the Val d'Arán area and in the Upper Salat area, nothing can be said regarding the lithology of the Upper Famennian in these areas. In the central part of the Western facies area banded limestones were formed, rich in manganese, which were interpreted by Mirouse as deposits of a slowly subsiding area. The manganese seems to have originated in more off-shore areas (Krylatov & Stoppel, 1971, p. 228).

Although the origin of griotte limestones and nodular limestones is still in discussion (compare e.g. Fisher & Garrison, 1967), an origin in shallow areas is suggested, close to emerged areas, for which evidence is mentioned by Ovtracht & Fournié (1956). The evidence is formed by the presence of intraformational breccias (e.g. in the Arize Massif, Massif of St. Barthélemy, Compte subfacies), vegetal debris, signs of karstification, dolomites (e.g. Arize Massif, Syncline of Villefranche, Compte) and manganese deposits.

Lower Carboniferous

The regression of the sea, begun during the Frasnian, continued in the Tournaisian. During the Tournaisian, only very locally recorded (Fig. 42), most areas of the Central Pyrenees had emerged, while during the uppermost Tournaisian probably the entire Central Pyrenees had emerged. In the lowermost Viséan, however, bedded cherts accompanied by phosphate nodules were depo-

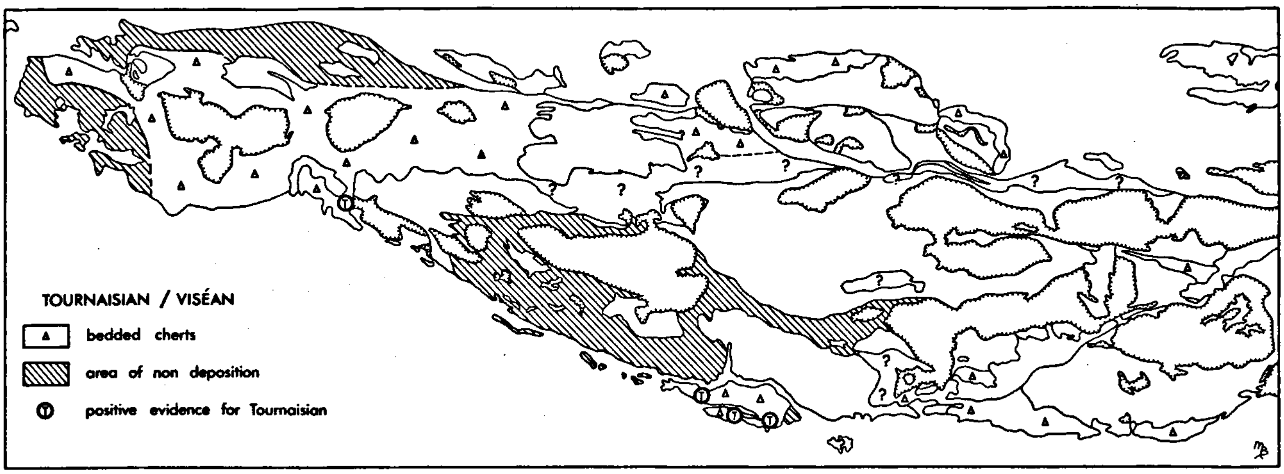


Fig. 42. Qualitative litho-facies map of the Tournaisian / Viséan boundary.

sited in restricted areas, indicating a transgression of minor extent (Fig. 43). In the Compte sub-facies we have evidence that two distinct isochronous chert layers were formed, while elsewhere this information is not available for want of precise datings. Mirouse (1966) noticed that it is quite remarkable that conglomerates are nowhere found at the base of the bedded cherts, a feature which he explained, as did Delépine (1935), by assuming an extremely low relief of the hinterland and a rapid transgression.

Although Radiolaria have locally been recorded from the cherts, they can hardly be responsible alone for their deposition, while it furthermore does not explain why the environment was suddenly so favourable to Radiolaria. Mirouse, following Pettijohn (1957), suggested that the formation of the silica was controlled by a low pH of the sea water, the supply of silica and the absence of clastic material. The low pH resulted in dissolution of the calcareous organic remains, so that only silica and phosphate could be deposited. However, the concentration of silica and phosphate in sea water seems too low to explain the thickness of the deposits, so that we have to accept that the sea water was enriched in silica and phosphate by organisms such as bacteria and/or by supply from the hinterland, as was suggested by Ovtracht & Fournié (1956). Krylatov & Stoppel (1971, p. 228) concluded that the phosphate nodules were deposited near the margins of the basin, which seems to be in favour of supply of phosphorus from the hinterland. A volcanic origin of the cherts, as suggested by Ovtracht (1960), does not seem very probable since other volcanic manifestations during or shortly before the deposition of the cherts were neither recorded by Mirouse nor by the present author. Wennekers (1968), discussing the relationship between the cherts and the tuffs at Sahún (see 2.D), followed Krylatov (1964) who suggested that in the Northern facies area a relationship exists between tuff and chert occurrences. It has, however, been convincingly demonstrated that the green tuffs at Sahún were deposited at the end of the Viséan and consequently may be seen related to the orogenic activity elsewhere in the Pyrenees at the end of the

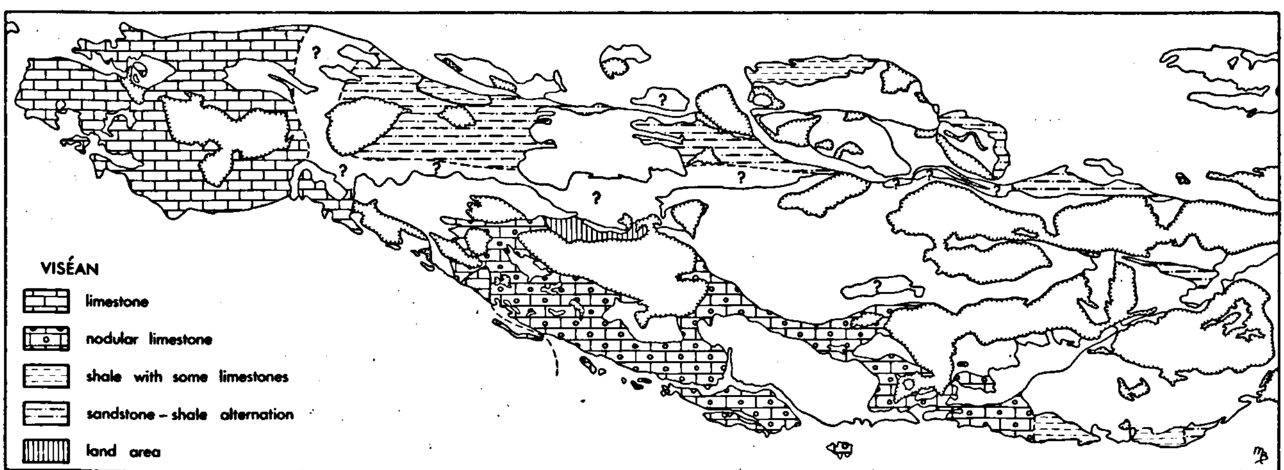


Fig. 43. Qualitative litho-facies map of the Viséan.

Viséan. The tuffs at Bellver, occurring above the bedded cherts of the Compte Formation, are of the same age as at Sahún.

After the formation of the bedded cherts in restricted areas the sea strongly transgressed. This resulted in the deposition of massive slightly nodular limestones, containing locally intraformational breccias, in the Western facies area and Renanué subfacies area (Fig. 43). In the Southern facies area a very thin but complete Viséan is found, developed as nodular limestones. In the eastern part of the Compte sub-facies, however, carbonate deposition ceased earlier, probably due to the circumstance that the activity of the Sudetic phase of the Hercynian Orogeny in the south-east preceded that in the south-west, where the massive limestones range into the Namurian.

North of the emerged Pyrenean Geanticline, sandstones and shales were deposited, together with some conglomerates. Only in restricted areas such as in the Arize Massif and north of the Bordères Granodiorite (Calcaires d'Ardengost; Perret, 1971) limestones of any importance were formed.

A correction for the litho-facies distribution in the Viséan will possibly prove necessary if data become available on the age of the top of the Mañanet Griotte in the Llavorsi Syncline; here the age is presumed to be the same as at Castells (see 3.B).

Upper Carboniferous

During the Namurian, deposition of coarse and finer clastic material, with locally some plant debris and some limestones, began throughout the Central Pyrenees. The material was transported into the sea from the reactivated hinterland and probably also from the emerged Pyrenean Geanticline. Mirouse (1966) interpreted the coarse and fine clastics as a molasse, deposited in a paralic environment. In the south of the Compte sub-facies area erosion locally removed the top of the Compte Formation.

In the Pyrenean Geanticline continental deposits were possibly formed locally at the Pla de Estang. Kleinsmiede (1960) considered the clastics at the Pla de Estang as molasse deposits. Waterlot (1969a, 1969b) argued that the material is deposited in a slender intramontane basin, in which the terrigenous material was first transported from the north, later both from the north and from the south. Clastic sedimentation continued during the lower part of the Westphalian.

The first post-Hercynian deposits are dated as Westphalian D in the east of the Compte sub-facies area, as Westphalian B in the Sierra Negra sub-facies area s.l., so that the pre-Hercynian sediments were folded during the Asturian phase of the Hercynian Orogeny.

Conclusions

We may conclude that the central part of the Central Pyrenees, corresponding roughly with the Central facies area and the Central Anticline, acted as a deeper part of the shallow basin in the Lower and Middle Devonian. The hinterland was activated during the Lower Devonian, mainly in the west and south-west, subsequently showing a progressively lower relief. During the uppermost Givetian or lowermost Frasnian the central part of the basin deepened and turbidites were deposited, for which the material was probably, at least partly, derived from the locally emerged Pyrenean Geanticline. That the Pyrenean Geanticline also extended further towards the east may be concluded from Llopis Lladó (1969, fig. 26), who recorded a Lower and Middle Devonian about 1,600 m in thickness, quickly diminishing towards the north.

The margins of the basin were also reactivated, resulting in erosion and deposition of clastic material in the western, south-western and central parts of the basin. From the Upper Famennian until the Tournaisian the sea progressively regressed, resulting in increasing areas of non-deposition. There is hardly any evidence of the Bretonic phase of the Hercynian Orogeny. In the Lower Viséan the sea again transgressed over large areas, only part of the Pyrenean Geanticline remained an area of non-deposition. During the Namurian, in some areas somewhat earlier in others somewhat later, the hinterland and Pyrenean Geanticline were highly reactivated, as a reflection of the Sudetic phase of the Hercynian Orogeny, and resulting in the deposition of molasse deposits near the coasts, and of finer material further away. In the Pyrenean Geanticline an intramontane basin was formed. During the Upper Westphalian the deposition of pre-Hercynian deposits came to an end, and the sediments were folded by the Asturian phase of the Hercynian Orogeny.

5.E. CORRELATION OF THE CENTRAL PYRENEES WITH THE PALENTINE FACIES OF THE CANTABRIAN MOUNTAINS

The history of the Pyrenean Basin resembles the history of the Cantabrian Basin as outlined by van Adrichem Boogaert (1967). He concluded that the Cantabrian Basin was divided into a northern and a southern part, separated from each other by the Asturian Geantlicline which "...emerged locally from time to time during the Lower, Middle and lower part of the Upper Devonian..." (p. 170). However, strong sub-aerial erosion only took place during the uppermost Frasnian and Lower Famennian. The Asturian Geanticline was supposed to have been peneplained before deposition of the transgressive, post-hiatus sandstones of the Ermita Formation (Upper Famennian). However, at the same time the calcareous shales and nodular limestones of the Vidrieros Formation were deposited in the Palentine facies (p. 173). A general regression followed during the Lower Tournaisian, followed by a short transgression, a renewed regression and finally another transgression during the Lower Viséan. During the Viséan the Asturian Geanticline disappeared as a high. In the Palentine Basin flysch-type sediments were deposited during the Namurian.

The geotectonic history of the Central Pyrenees and the Cantabrian Mountains is so similar that the question arises whether the lithology, reflecting at least partly the geotectonic history, may not also be compared or even correlated, so that consequently both basins may be interpreted as two parts of originally one continuous basin.

The idea of a relationship between the Pyrenees and the Cantabrian Mountains is not new. Laverdière (1930, p. 57) and Compte (1959, p. 322) noticed both faunistic and lithological relationships between the Lower Devonian, Middle Devonian and Lower Carboniferous of the Cantabrian Mountains and the Western Pyrenees. Van Veen (1965, p. 73) compared the lithology of the Lower Carboniferous of the Palentine facies with the Southern facies of the Central Pyrenees. Binnenkamp (1965, p. 55) reported that the brachiopod species mentioned by Mirouse (1962) show a similarity to the faunas of the La Vid Formation and Ferroñes Formation. Requadt (1972, p. 59) noted a general lithological resemblance between the Lower and Middle Devonian of the Western Pyrenees and the Cantabrian Mountains, especially between the Gustalapiedra Formation of the Palentine facies and the Argus 'Schiefer'. Llopis Llado et al. (1968) viewed the north Spanish Devonian areas as originally belonging to one sedimentary basin.

An attempt at lithostratigraphic correlation between both areas has, however, never been carried out. Taking into account the important facies changes in both areas, lithological correlation may only be successful if the eastern part of the Cantabrian Mountains, the Palentine facies, is correlated with the western part of the Central Pyrenees. As sections chosen to be correlated, the section in the Rio Ara Valley in the Western Pyrenees (Wensink, 1962) and the section at Cardaño de Arriba in the Palentine facies (van Veen, 1965) are taken. In the Palentine facies the formations were dated by means of conodonts by van Adrichem Boogaert (1967), while the Lower Carboniferous of the southern part of the Western facies was dated by means of conodonts by Marks & Wensink (1970).

The connection between both areas is evidently to be found in the Western Pyrenees. The Devonian and Carboniferous of the Western Pyrenees has, among others, been described by Laverdière (1930), Lamare (1936), Damestoy (1961), Heddebaut (1965, 1966, 1970), Wirth (1967) and by the team of the Geological Institute of the Technische Universität Claustal (e.g. Requadt, 1972; Pilger, 1973). Although facies changes occur in the Western Pyrenees, a section, representative in the opinion of the author, was composed from the Massif of Aldudes – Quinto Real. The section composed was, for the Lower Devonian, based on Damestoy (1961) and Requadt (1972), for the Middle Devonian on Requadt (1972) and Wirth (1967) and for the Upper Devonian and Carboniferous on Wirth (1967). The part of the section taken from Wirth was dated by himself by means of conodonts.

Comparing the three selected sections (Fig. 44) the following resemblances, which appear to justify a correlation, can be observed:

1) Black shales rich in silica with chert concretions or bedded cherts occur in all three areas. The age is everywhere the same: Upper Tournaisian to lowermost Viséan, while also a break in the sedimentation below the black shales is demonstrated in all three areas.
2) In the Palentine facies the cherts and black shales are overlain by the Alba Griotte, in the western part of the Central Pyrenees by limestones the lower part of which often consists of nodular limestones. In the Western Pyrenees, too, griotte limestones occur above the black shales with cherts.
3) Though not indicated in the schematical stratigraphic section (Fig. 44), Namurian limestones, the Mudá Formation, also occur in the Palentine facies, while in the Western Pyrenees limestones, dolomites and magnesites of the same age occur.
4) Quartzites, sandstones and shales are in all three areas dated as Upper Frasnian and Lower Famennian, so that it seems justified to correlate the base of the Murcia

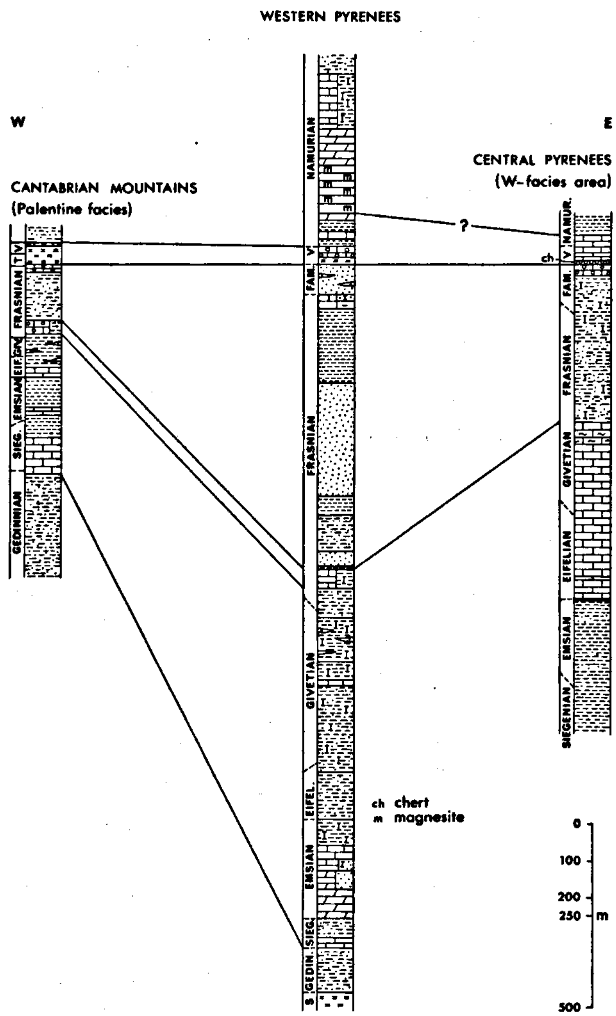


Fig. 44. Lithostratigraphic correlation of the Central Pyrenees with the Palentine facies of the Cantabrian Mountains.

Formation of the Palentine facies with the base of the coarse clastic part of the Irurita 'Gruppe' (Pilger, 1973), and with equivalents in the Western facies area of the Central Pyrenees.
5) The Cardaño Formation of the Palentine facies is not only a lithological equivalent of the limestones in the upper part of the Argus Schiefer, but also a time equivalent. The lithology of the Gustalapiedra Formation (Palentine facies) strongly resembles the lithology of the Argus 'Schiefer' (Requadt, 1972).
6) The lithology of the Carazo Formation (Palentine facies) strongly resembles the lithology of the Gedinnian quartzites in the Western Pyrenees.
7) The Siegenian and Emsian in the Western Pyrenees, with its limestones, dolomites, sandstones and quartzites, resembles the Siegenian and Emsian in the Baliera area (Basibé Formation). Limestones alternating with clastic material of the same age (Lebanza Formation and Abadiá Formation) also occur in the Palentine facies. In the western part of the Central Pyrenees the Siegenian and Emsian consist nearly entirely of coarse and fine clastic material.

Although important differences exist between the three areas, especially between the Lower and Middle Devonian of the Western Pyrenees and the Western facies area of the Central Pyrenees, the differences are not more striking than in the Central Pyrenees itself. On the contrary, the resemblances are so strong that it seems to support the idea that the Cantabrian Mountains and the Pyrenees belonged to the same sedimentary basin.

After more or less important orogenic movements of the Ardennian phase, several sub-basins developed, each with its own history, which seems for a large part to be destined by the differences in supply of clastic material. In the Frasnian large parts of the geanticlines and hinterlands emerged, resulting in the deposition of clastic material. In the Central facies area of the Pyrenees turbidites were deposited in a deeper part of the basin. In the eastern part of the Pyrenees the influence of the emerged areas was much less, so that the deposition of limestones could continue. From the Lower Frasnian onward regression of the sea continued, reaching its climax in the Tournaisian. Only in the Asturo – Leonese Basin it was interrupted by a rapid transgression, causing the deposition of the Ermita Formation, and by a possibly minor transgression, causing the deposition of the Vegamian Shales in the Cantabrian Mountains and equivalents in the Western Pyrenees. During the uppermost Tournaisian the entire northern Spanish basin emerged. A strong transgression followed over the entire area in the Lower Viséan. In the Lower Namurian the geanticlinal ridges and basin margins became strongly reactivated by the Sudetic orogenic movements. Only locally, in isolated basins, could carbonate sedimentation continue higher in the Namurian, resulting in the deposition of the Escapa and Mudá Formations in the Cantabrian Mountains and in the deposition of a thick sequence of limestones, dolomite and magnesites in the Western Pyrenees. During the Asturian phase of the Hercynian Orogeny the entire north Spanish basin was folded.

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TABLES

Table 1. Distribution chart of section 03.

COMPTE (1)

Formation	Member	Sample	Icriodus sp.indet.	Icriodus cf.I.eslaensis	Icriodus latericrescens ssp.A Klapper & Ziegler,1967	Icriodus obliquimarginatus	Polygnathus linguiformis linguiformis	Polygnathus ? variabilis	Polygnathus xylus	Polygnathus robusticostatus	Spathognathodus planus	Polygnathus varcus	Polygnathus cf.P.xylus	Polygnathus linguiformis mucronatus	Polygnathus decorosus s.l.	Pelekysgnathus sp.	Polygnathus cristatus	Polygnathus dengleri	Polygnathus cf.P.dengleri	Polygnathus asymmetricus asymmetricus	Polygnathus asymmetricus ovalis	Icriodus symmetricus	Schmidtognathus sp.indet.	Palmatolepis transitans	Icriodus alternatus	Ancyrodella nodosa	Palmatolepis subrecta	Palmatolepis punctata	Palmatolepis hassi	Palmatolepis sp.indet.	Ancyrognathus triangularis	Polygnathus webbi	Ancyrodella ioides	Palmatolepis foliacea	Ancyrognathus asymmetricus	Palmatolepis gigas	Palmatolepis unicornis
COMPTE FORMATION	B – MEMBER	0329																												X							
		0328																												•							
		0327																												\							
		0326																												•							
		0325																							\					X							
		0324														•									\					X							
		0323														•														▧							
		0322	X												•	•									•					▧							
		0321													▧												▧			▧		•			•		\
	A – MEMBER	0320													▧												X			X					•	?	?
		0319													•												•	•		\				?			
		0318													•											•	X	•		X			•				
		0317	\												\										\	\	\	•	•	\	•	•					
		0316	•									•			X				•	•	•	•	•	•													
		0315										•			\		•	•																			
		0314										•			•																						
		0313						?							\																						
		0312					\					\																									
		0311					\	•				•																									
		0310		•			\					\		•																							
		0309					•									?																					
		0308	•	\			•					•			•																						
		0307										•		•																							
		0306					X					X																									
		0305					•					X																									
		0304	•	•			•					\	•																								
		0303					•	•	•	•	•																										
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		0301	•																																		

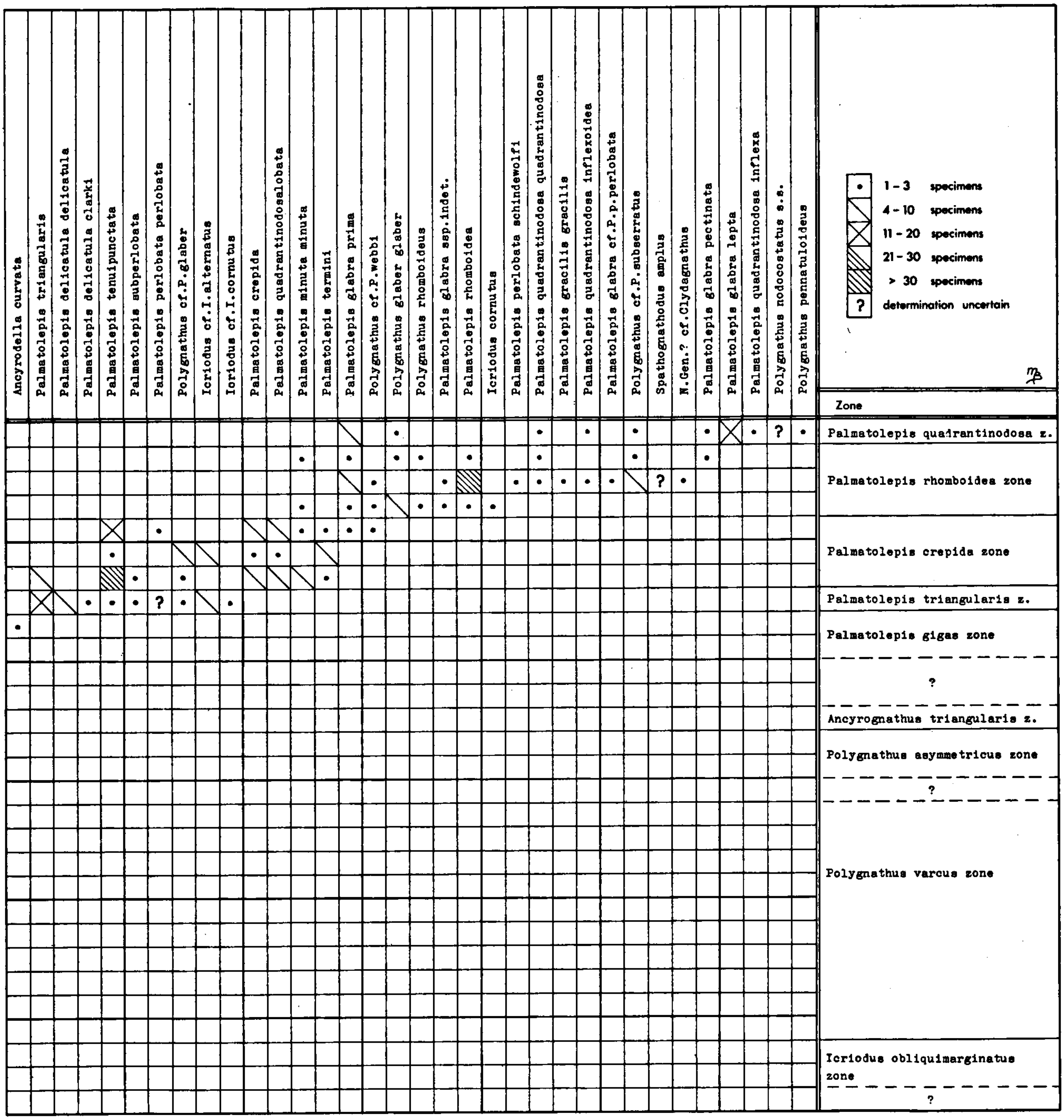
Ancyrodella curvata
Palmatolepis triangularis
Palmatolepis delicatula delicatula
Palmatolepis delicatula clarki
Palmatolepis tenuipunctata
Palmatolepis subperlobata
Palmatolepis perlobata perlobata
Polygnathus cf.P.glaber
Icriodus cf.I.alternatus
Icriodus cf.I.cornutus
Palmatolepis crepida
Palmatolepis quadrantinodosalobata
Palmatolepis minuta minuta
Palmatolepis termini
Palmatolepis glabra prima
Polygnathus cf.P.webbi
Polygnathus glaber glaber
Polygnathus rhomboideus
Palmatolepis glabra ssp.indet.
Palmatolepis rhomboidea
Icriodus cornutus
Palmatolepis perlobata schindewolfi
Palmatolepis quadrantinodosa quadrantinodosa
Palmatolepis gracilis gracilis
Palmatolepis quadrantinodosa inflexoidea
Palmatolepis glabra cf.P.p.perlobata
Polygnathus cf.P.subserratus
Spathognathodus amplus
N.Gen.? cf.Clydagnathus
Palmatolepis glabra pectinata
Palmatolepis glabra lepta
Palmatolepis quadrantinodosa inflexa
Polygnathus nodocostatus s.s.
Polygnathus pennatuloideus
1 - 3 specimens
4 - 10 specimens
11 - 20 specimens
21 - 30 specimens
> 30 specimens
? determination uncertain
Zone
Palmatolepis quadrantinodosa z.
Palmatolepis rhomboidea zone
Palmatolepis crepida zone
Palmatolepis triangularis z.
Palmatolepis gigas zone
?
Ancyrognathus triangularis z.
Polygnathus asymmetricus zone
?
Polygnathus varcus zone
Icriodus obliquimarginatus zone
?

Table 1. (continuation)

COMPTE (2)		Sample	Palmatolepis glabra prima	Palmatolepis quadrantinodosa inflexoidea	Palmatolepis glabra pectinata	Palmatolepis glabra acuta	Palmatolepis distorta	Palmatolepis quadrantinodosa marginifera	Palmatolepis sp.indet.	Polygnathus glaber glaber	Polygnathus nodocostatus s.s.	N.Gen.? cf. Clydagnathus	Palmatolepis minuta minuta	Palmatolepis perlobata schindewolfi	Palmatolepis gracilis gracilis	Palmatolepis glabra lepta	Palmatolepis minuta schleizia	Polygnathus cf.P.subserratus	Polygnathus sp.indet.	Spathognathodus sp.indet.	Palmatolepis quadrantinodosa inflexa	Polygnathus pennatuloideus	Spathognathodus stabilis	Polygnathus glaber medius	Polygnathus cf.P.pennatuloideus	Polygnathus glaber bilobatus	Scaphignathus subserratus	Spathognathodus inornatus	Spathognathodus bohleanus	Scaphignathus velifer	Palmatolepis helmsi	Spathognathodus werneri	Spathognathodus strigosus	Polygnathus ? n.sp.?	Pseudopolygnathus granulosus	Polygnathus communis communis	Polygnathus styriacus
COMPTE FORMATION	C – MEMBER	0357																										•									
		0356																										•									
		0355																		•																•	
		0354																		•			•													•	
		0353																		\			X					•								X	
		0352																					•													\	
		0351												\						•			\										•			\	
		0350												\						•			\													X	
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		0348												X									\					\					•			\	
		0347												•									\					X								▧	
		0346																					•					•									
		0345												\						•			\					•								\	
		0344												X									▧					X								▧	
		0343												\						•			\													•	
		0342											?	▧						•			▧					\									
		0341											X	▧									▧					•								X	•
		0340							•				X	▧						•			▧										X			X	•
		0339							\				\	X									X				X								•	\	
		0338							\				\	▧		\							\				\		•	\	\	•	•	•	?		
		0337							\				•	\		•							•				•	•	\								
		0336			▧	•	▧	\	▧				X	X	\	\		•	•				•		•	\											
		0335			•	•		•	\				\	•		\								•													
		0334							•		•		•			•	•					?	•														
		0333			\	\	\	\	X		•	•	•		•	\			•	•																	
		0332	•		•	•	•		\					\	•	•		•		•																	
		0331	\		•	\	•	\	X	X	\		•	\	\	\	X	•	•	•																	
		0330	•	•	\	\	•	•	\	•	•	•																									

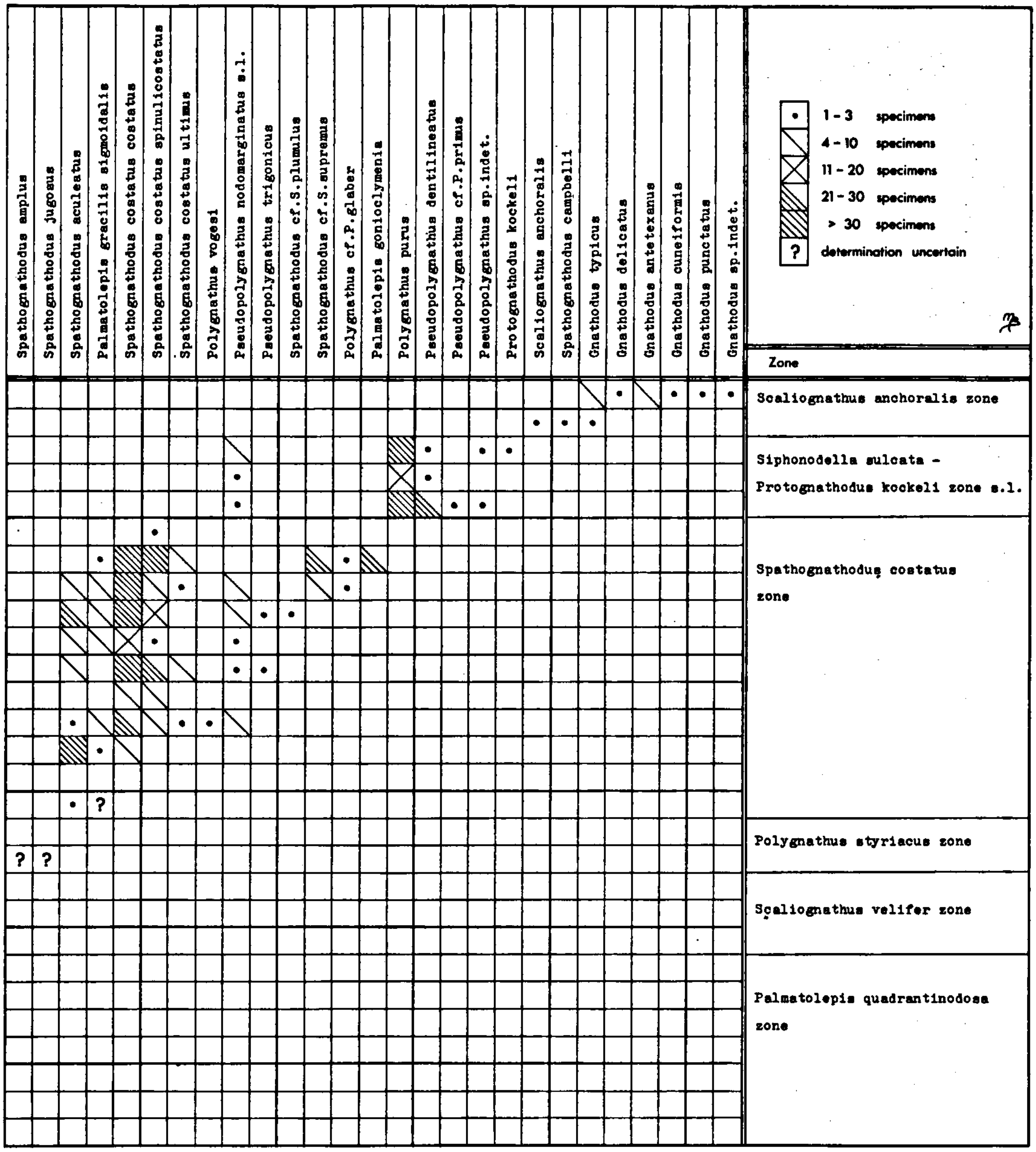
Spathognathodus amplus
Spathognathodus jugosus
Spathognathodus aculeatus
Palmatolepis gracilis sigmoidalis
Spathognathodus costatus costatus
Spathognathodus costatus spinulicostatus
Spathognathodus costatus ultimus
Polygnathus vogesi
Pseudopolygnathus nodomarginatus s.l.
Pseudopolygnathus trigonicus
Spathognathodus cf.S.plumulus
Spathognathodus cf.S.supremus
Polygnathus cf.P.glaber
Palmatolepis gonioclymenia
Polygnathus purus
Pseudopolygnathus dentilineatus
Pseudopolygnathus cf.P.primus
Pseudopolygnathus sp.indet.
Protognathodus kockeli
Scaliognathus anchoralis
Spathognathodus campbelli
Gnathodus typicus
Gnathodus delicatus
Gnathodus antetexanus
Gnathodus cuneiformis
Gnathodus punctatus
Gnathodus sp.indet.
1 - 3 specimens
4 - 10 specimens
11 - 20 specimens
21 - 30 specimens
> 30 specimens
? determination uncertain
Zone
Scaliognathus anchoralis zone
Siphonodella sulcata - Protognathodus kockeli zone s.l.
Spathognathodus costatus zone
Polygnathus styriacus zone
Scaliognathus velifer zone
Palmatolepis quadrantinodosa zone

Table 2. Distribution chart of section 01.

LA GUARDIA DE ARÉS (1)		Sample	Polygnathus lenzi	Spathognathodus steinhornensis steinhornensis	Icriodus huddlei huddlei	Icriodus angustus	Icriodus sp.indet.	Icriodus bilatericrescens bilatericrescens	Icriodus sigmoidalis	Spathognathodus sp.indet.	Icriodus corniger	Icriodus cf.I.corniger	Polygnathus cf.P.foveolatus	Icriodus cf.I.bilatericrescens bilatericrescens	Polygnathus cf.P.lenzi	Polygnathus linguiformis linguiformis	Polygnathus costatus	Polygnathus sp.indet.	Polygnathus kockelianus	Icriodus nodosus	Icriodus symmetricus	Polygnathus xylus	Polygnathus eiflius	Polygnathus pseudopoliatus	Polygnathus angustipennatus	Polygnathus trigonicus	Polygnathus robusticostatus	Polygnathus latus	Polygnathus kluepfeli	Spathognathodus planus	Polygnathus linguiformis transversus	Schmidtognathus hermanni	Polygnathus varcus	Polygnathus cf.P.robusticostatus	Polygnathus decorosus s.l.	Polygnathus strongi	Spathognathodus sannemanni sannemanni
COMPTE FORMATION	A – MEMBER	0145																																	•		
		0144																																			
		0143																																	\		•
		0142																																	X		
		0141																																	▨		
		0140																																	•		
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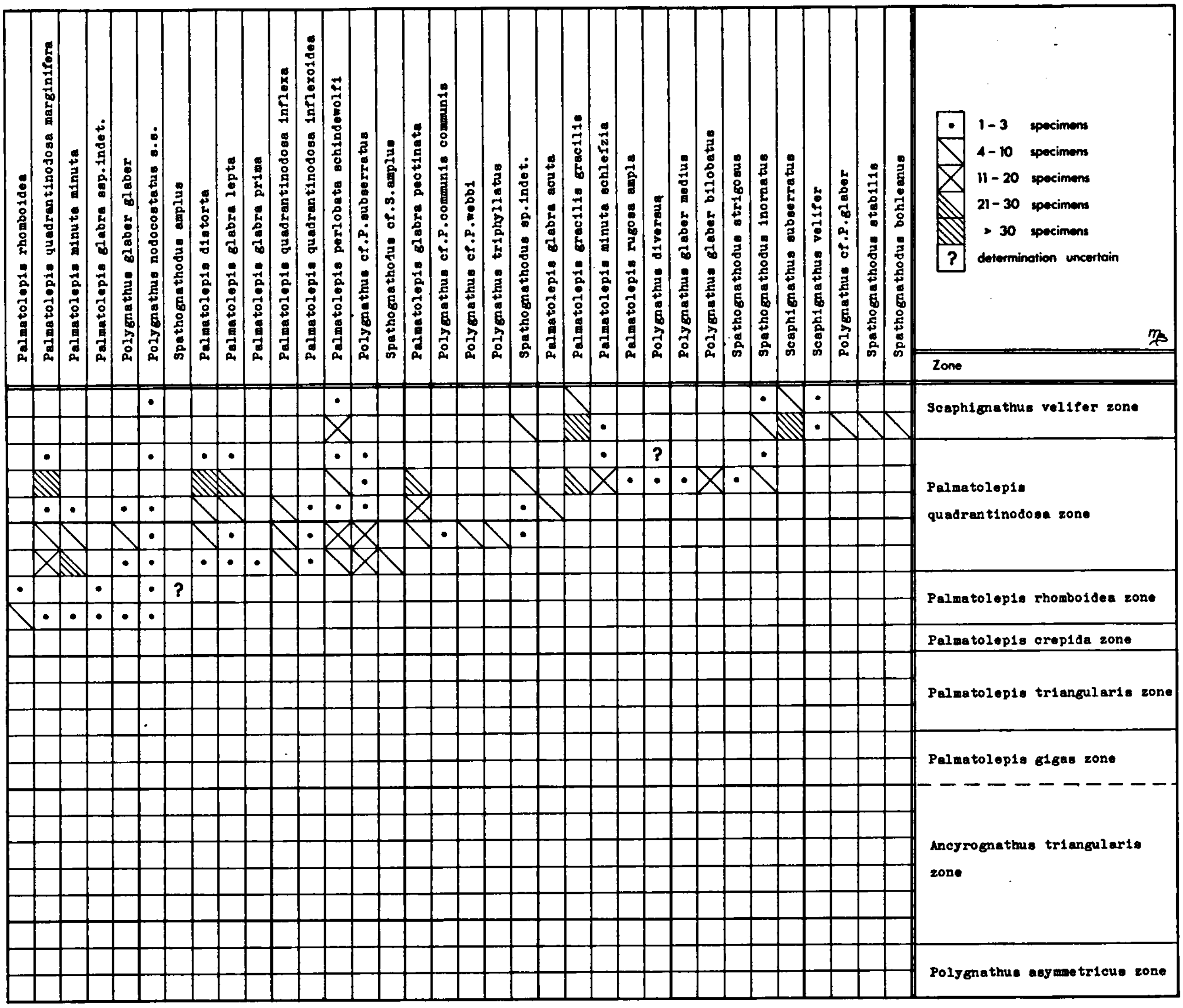
		0138																																			
		0137																																	▨		•
		0136																																	•	?	•
		0135					•											•			•																
		0134								•						\		•															▨	•			
		0133														•																					
		0132														•															•	•					
		0331														\		•				•					?		•	•							
		0130														\	?					•	?					•									
		0129					\												•					•			•										
		0128					•									•																					
		0127																•																			
		0126																•																			
		0125																•																			
VILLECH FORMATION		0124					•									\	•		•	•			•	•	•	•											
		0123															•					•															
		0122					\									\			•	X	•																
		0121																•																			
		0120															?																				
		0119									•					•																					
		0118														•																					
		0117													•																						
		0116					•				•	•	•	•																							
		0115									?																										
		0114																																			
		0113																																			
		0112				•							?																								
		0111																																			
		0110	\	X	•	?	•	\			•	•																									
		0109	\	X						•																											
		0108		X			•	\	•																												
		0107	?																																		
		0106																																			
BASIBÉ FM.		0105	\	•	•	?	\																														

•	1 – 3 specimens
⧅ (single diagonal)	4 – 10 specimens
☒ (crossed)	11 – 20 specimens
(hatched)	21 – 30 specimens
(dense hatched)	> 30 specimens
?	determination uncertain

Polygnathus dengleri	Polygnathus cf.P.rugosus	Ancyrodella rotundiloba rotundiloba	Ancyrodella rotundiloba alata	Polygnathus asymmetricus ovalis	Ancyrodella rotundiloba ssp.indet.	Polygnathus asymmetricus asymmetricus	Polygnathus cf.P.ancyrognathoideus	Palmatolepis transitans	Scmidtognathus sp.indet.	Icriodus cornutus	Fauna or zone
											Polygnathus asymmetricus zone
				•		•			?	•	
				•		•	•	\	•	?	
	•				•						
	•										
		\	•	•							
•	•	•									
											?
											Polygnathus varcus zone
											Icriodus obliquimarginatus z.
											Polygnathus kockelianus zone
											Spathognathodus bidentatus z.
											Icriodus corniger zone
											non laterigrescid - Icriodus - Polygnathus Fauna
											Icriodus b.bilatericrescens - steinhornensis - Polygnathus Fauna

Table 2. (continuation)

Formation	Member	LA GUARDIA DE ARÉS (2) Sample	Polygnathus decorosus s.l.	Polygnathus cf.P.dengleri	Ancyrodella rotundiloba ssp.indet.	Ancyrodella sp.indet.	Polygnathus webbi	Palmatolepis transitans	Palmatolepis cf.P.proversa	Palmatolepis hassi	Palmatolepis sp.indet.	Icriodus curvatus	Icriodus sp.indet.	Ancyrodella nodosa	Polygnathus sp.indet.	Spathognathodus ? n.sp.sensu Ziegler,1958	Ancyrodella ioides	Ancyrognathus triangularis	Palmatolepis subrecta	Palmatolepis punctata	Palmatolepis gigas	Ancyrodella curvata	Palmatolepis foliacea	Icriodus alternatus	Palmatolepis triangularis	Palmatolepis tenuipunctata	Palmatolepis marginata marginata	Palmatolepis subperlobata	Icriodus alternatus cf. Pelekysgnathus	Palmatolepis quadrantinodosalobata	Palmatolepis cf.P.regularis	Palmatolepis crepida	Pelekysgnathus sp.	Ancyrognathus sinelamina	Ancyrolepis cruciformis	Palmatolepis perlobata perlobata	Icriodus cf.I.cornutus
COMPTE FORMATION	C – MEMBER	0170																																			
		0169									╲																										
		0168									•																										
		0167									╳				•																						
		0166									╲				╲																						
	B – MEMBER	0165	╲								╲				╲																						
		0164	•								╲																										
		0163																																			
		0162	•				•				•		•											•													
		0160/61	╲				╲				▨		╲									•		▨	╲	╳				▨	•	╳	•	?	•	•	╳
		0159					•				╲														╲		•	•	•								
		0158									╲		•											╲	╲	?											
		0156/57	╲				•															•			▨												
		0155	▨				•			?	╲								╳				•	•													
		0154	╲				•				•								•	•																	
		0153	•				╲			•			•	╲	•		•	•	▨	╲		•															
		0152					•				•		•						•	•	?																
		0151				•				•	•	•	•				•	•																			
		0150				•				•	•		•		•	•																					
		0149						•							•																						
		0148	▨	•			•	╳	•	•	╲	•	╲	?																							
	A	0147	•		•	•																															
		0146	▨	╲																																	



Palmatolepis rhomboidea
Palmatolepis quadrantinodosa marginifera
Palmatolepis minuta minuta
Palmatolepis glabra ssp.indet.
Polygnathus glaber glaber
Polygnathus nodocostatus s.s.
Spathognathodus amplus
Palmatolepis distorta
Palmatolepis glabra lepta
Palmatolepis glabra prima
Palmatolepis quadrantinodosa inflexa
Palmatolepis quadrantinodosa inflexoidea
Palmatolepis perlobata schindewolfi
Polygnathus cf.P.subserratus
Spathognathodus cf.S.amplus
Palmatolepis glabra pectinata
Polygnathus cf.P.communis communis
Polygnathus cf.P.webbi
Polygnathus triphyllatus
Spathognathodus sp.indet.
Palmatolepis glabra acuta
Palmatolepis gracilis gracilis
Palmatolepis minuta schleizia
Palmatolepis rugosa ampla
Polygnathus diversus
Polygnathus glaber medius
Polygnathus glaber bilobatus
Spathognathodus strigosus
Spathognathodus inornatus
Scaphignathus subserratus
Scaphignathus velifer
Polygnathus cf.P.glaber
Spathognathodus stabilis
Spathognathodus bohleanus
1 - 3 specimens
4 - 10 specimens
11 - 20 specimens
21 - 30 specimens
> 30 specimens
? determination uncertain
Zone
Scaphignathus velifer zone
Palmatolepis quadrantinodosa zone
Palmatolepis rhomboidea zone
Palmatolepis crepida zone
Palmatolepis triangularis zone
Palmatolepis gigas zone
Ancyrognathus triangularis zone
Polygnathus asymmetricus zone

Table 2. (continuation)

LA GUARDIA DE ARÉS (3)

COMPTE FORMATION — C – MEMBER

Sample	Palmatolepis perlobata schindewolfi	Palmatolepis sp.indet.	Palmatolepis gracilis gracilis	Palmatolepis minuta schleizia	Spathognathodus inornatus	Spathognathodus sp.indet.	Polygnathus styriacus	Polygnathus cf.P.brevilaminus	Bactrognathus sp.	Polygnathus sp.indet.	Spathognathodus strigosus	Spathognathodus stabilis	Spathognathodus bohleanus	Polygnathus cf.P.glaber	Polygnathus communis communis	Palmatolepis helmsi	Polygnathus obliquicostatus	Spathognathodus jugosus	Spathognathodus costatus costatus	Spathognathodus aculeatus	Pseudopolygnathus brevipennatus	Spathognathodus costatus spinulicostatus	Spathognathodus sp.B sensu Ziegler,1962	Spathognathodus cf.S.amplus	Spathognathodus costatus ultimus	Spathognathodus cf.S.supremus	Palmatolepis gracilis sigmoidalis	Pseudopolygnathus nodomarginatus s.l.	Pseudopolygnathus trigonicus	Palmatolepis gonioclymenia	Polygnathus inornatus s.l.	Protognathodus kockeli	Protognathodus collinsoni	Polygnathus purus	Pseudopolygnathus dentilineatus
01108																																			
01107																																			
01106																																			
01105																																			
01104																																			
01103																																			
01102																																			
01101																																			
01100																																			
0199																																			
0198						•																													
0197																																			
0196																																			
0195										•																									
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0193																																			
0192																																			
0191																																			
0190						╳				•		╳			▧													╳						╲	╲
0189						•						╲			▧													•						•	
0188												╳			▧													╳			•		•	◪	•
0187												╲			•																			▧	╳
0186												•																			•	╲	•	╳	•
0185			╲									╲			◪				╲			•		•		╲	•	•							
0184			╳									╲			╲				╳			╲					•	•			•				
0183			╲							•		•			╳				╳			•				╲	•								
0182			╲								•	╲			╲				▧			╳			╲	╳		•							
0181												╲			╲																				
0180			╲			╲				•	•	╳			╲				◪	╳		╲	•		•	•	╲	╲		•					
0179			•		╲					•		•			•				╲	╲		╲			•	•	•	╲	•						
0178			╲		◪										◪			•	╲	╲		•	•	•											
0177			╳		╳						╲	•			╲			•	╲	•															
0176			▧		▧	•					▧	▧			▧				╳	╲	•														
0175			╲		╲	•					•	╳	╲					╲																	
0174			╳	•	•	•					•	╲	◪			•		•																	
0173	•	•	▧	╲	╲	╲	╲				•	╲	◪		◪	•	•	╲																	
0172		•	•	•		•	•		?	•	•	╳	╳	•	•																				
0171	•	•	╲	•	•	•	•	•	?																										

Pseudopolygnathus sp.indet.	Polygnathus communis carinus	Polygnathus communis dentatus	Polygnathus longiposticus	Pseudopolygnathus triangulus inaequalis	Siphonodella duplicata	Pseudopolygnathus triangulus triangulus	Siphonodella obsoleta	Polygnathus cf.P.symmetricus	Siphonodella lobata	Siphonodella cooperi	Siphonodella crenulata	Gnathodus delicatus	Gnathodus typicus	Gnathodus cuneiformis	Gnathodus antetexanus	Gnathodus semiglaber	Gnathodus texanus	Gnathodus sp.indet.	Gnathodus punctatus	Gnathodus symmutatus	Gnathodus homopunctatus	Polygnathus bischoffi	Gnathodus bilineatus	Gnathodus commutatus	Gnathodus cf.G.homopunctatus	Spathognathodus campbelli	Gnathodus cf.G.multinodosus	Gnathodus nodosus	Zone
																		•			•		╲	•				•	
																					•		•	•		╲		╲	Gnathodus nodosus zone
																					•		•			╲		•	
																							•			•			
																							•	•		•		•	
																					╲		◣	╲		•			
																					╲		X	X		•	•		
																							▨	▨		╲			Gnathodus commutatus zone
																					•		╲	•					
																		•		•	╲		╲	╲		•			
																				•	•		◣	•	•				
													•	•															
												X	◣	▨		◣		X			•								Gnathodus typicus zone
												X	X	X		╲		•											
						•						•	•	•				•			•								
						•						▨	╲	╲	•	?		╲	╲	•	•	•							Scaliognathus anchoralis zone
												X	•	•				╲											
						•						▨	◣	▨	X	•	•	◣											
						▨		╲	▨	◣	•																		Siphonodella crenulata zone
•	•	▨				╲	╲																						S.- triangulus triangulus zone
	╲	▨	•	•	•																								S.- triangulus inaequalis zone
•																													Siphonodella sulcata - Protognathodus kockeli zone s.l.
																													Spathognathodus costatus zone
																													Polygnathus styriacus zone

- • 1 - 3 specimens
- ╲ 4 - 10 specimens
- X 11 - 20 specimens
- ◣ 21 - 30 specimens
- ▨ > 30 specimens
- ? determination uncertain

de Aris(3)

Table 3. Distribution chart of section 09.

TORRES	Sample	Spathognathodus steinhornensis repetitor	Spathognathodus inclinatus inclinatus	Icriodus woschmidti ssp.indet.	Polygnathus pirenese	Spathognathodus inclinatus wurmi	Spathognathodus sp.indet.	Fauna
BASIBÉ FM.	0915							
	0914							
	0913						•	
	0912						•	?
	0911							
	0910				•	?	•	Ancyrodelloides - I.pesavis ?.
RUEDA FM.	0909							?
	0908			•				Icriodus woschmidti postwoschmidti Fauna
	0907							
	0906		•					
	0905		•					
	0904							
	0903							
	0902	•	•					
	0901							

• 1 - 3 specimens
? determination uncertain

Table 4. Distribution chart of section 10.

BAR	Sample	Spathognathodus eosteinhornensis	Spathognathodus inclinatus inclinatus	Spathognathodus steinhornensis repetitor	Zone
RUEDA FM.	1001				?
	1002			?	
	1003				
TOLORÍU LIMESTONE	1004				
	1005	•			eosteinhornensis zone
	1006		•		
	1007	\			
	1008				?

- • 1-3 specimens
- \ 4-10 specimens
- ? determination uncertain

Table 5. Distribution chart of section 04.

VILLECH		Sample	Spathognathodus steinhornensis steinhornensis	Polygnathus foveolatus	Icriodus huddlei huddlei	Icriodus sp.indet.	Icriodus fusiformis	Icriodus sigmoidalis	Icriodus cf.I.corniger	Polygnathus xylus	Polygnathus robusticostatus	Polygnathus costatus	Icriodus regularicrescens	Spathognathodus bidentatus	Polygnathus angusticostatus	Polygnathus sp.indet.	Polygnathus linguiformis linguiformis	Spathognathodus intermedius	Polygnathus kluepfeli	Polygnathus eiflius	Icriodus obliquimarginatus	Polygnathus varcus	Polygnathus decorosus s.l.	Spathognathodus planus	Polygnathus linguiformis mucronatus	Polygnathus asymmetricus asymmetricus	Palmatolepis ? disparalvea	Schmidtognathus sp.indet.	Polygnathus cristatus	Polygnathus dengleri	Polygnathus asymmetricus ovalis	Icriodus alternatus	Schmidtognathus hermanni	Ancyrognathus triangularis	Ancyrodella curvata	Ancyrodella nodosa	Palmatolepis subrecta
COMPTE FORMATION	C – MEMBER	0445																																			
		0444														•																					
		0443																																			
		0442																																			
		0441																																			
	B – MEMBER	0440																																			
		0439																																			
		0438																																			
		0437														\																▧					
		0436																					▧									X					
		0435																					\									\		•	•	▧	\
	A – MEMBER	0434				•																•	\				\		?	•	•	•	•				
		0433																				•	•					•	•	•							
		0432																				•	\			•	•										
		0431															\					▧			•												
		0430															•					•															
		0429															\					X	•	\	•												
		0428				•											•					\															
		0427				•															•																
		0426														•	•																				
		0425				•											•		•	•																	
		0424								•							\	•																			
		0423														•																					
VILLECH FM.		0422													•																						
		0421				•				•	•	•	?	•																							
		0411																																			
		0410	•	•																																	
		0409	•	\																																	
		0408	\																																		
		0407	•																																		
		0406	\	•																																	
		0405	\			•																															
BASIBÉ FM.		0404	X																																		
		0403	X	•		•	•	•	•																												
		0402	▧	\	\	\																															
		0401	\																																		

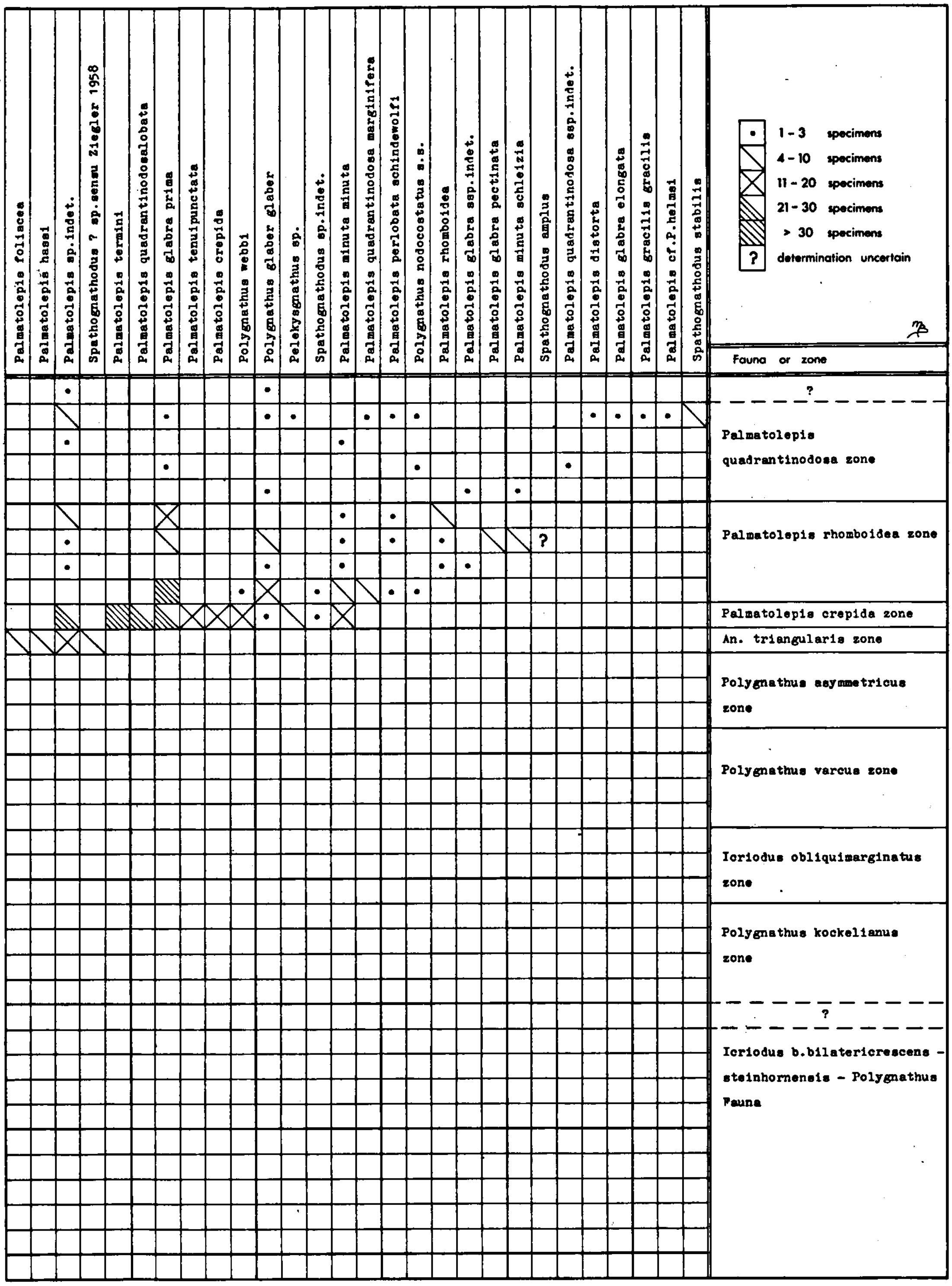
Palmatolepis foliacea
Palmatolepis hassi
Palmatolepis sp.indet.
Spathognathodus ? sp.sensu Ziegler 1958
Palmatolepis termini
Palmatolepis quadrantinodosalobata
Palmatolepis glabra prima
Palmatolepis tenuipunctata
Palmatolepis crepida
Polygnathus webbi
Polygnathus glaber glaber
Pelekysgnathus sp.
Spathognathodus sp.indet.
Palmatolepis minuta minuta
Palmatolepis quadrantinodosa marginifera
Palmatolepis perlobata schindewolfi
Polygnathus nodocostatus s.s.
Palmatolepis rhomboidea
Palmatolepis glabra ssp.indet.
Palmatolepis glabra pectinata
Palmatolepis minuta schleizia
Spathognathodus amplus
Palmatolepis quadrantinodosa ssp.indet.
Palmatolepis distorta
Palmatolepis glabra elongata
Palmatolepis gracilis gracilis
Palmatolepis cf.P.helmsi
Spathognathodus stabilis
1 - 3 specimens
4 - 10 specimens
11 - 20 specimens
21 - 30 specimens
> 30 specimens
determination uncertain
Fauna or zone
?
Palmatolepis quadrantinodosa zone
Palmatolepis rhomboidea zone
Palmatolepis crepida zone
An. triangularis zone
Polygnathus asymmetricus zone
Polygnathus varcus zone
Icriodus obliquimarginatus zone
Polygnathus kockelianus zone
?
Icriodus b.bilatericrescens - steinhornensis - Polygnathus Fauna

Table 6. Distribution chart of section 05.

Formation	Member	Sample	Palmatolepis rhomboidea	Palmatolepis perlobata schindewolfi	Palmatolepis minuta schleizia	Palmatolepis minuta minuta	Palmatolepis glabra prima	Palmatolepis glabra pectinata	Palmatolepis glabra ssp. indet.	Palmatolepis quadrantinodosa inflexa	Palmatolepis sp. indet.	Polygnathus glaber glaber	Polygnathus cf. P. subserratus	Polygnathus nodocostatus s.s.	Palmatolepis glabra acuta	Palmatolepis distorta	Palmatolepis quadrantinodosa quadrantinodosa	Palmatolepis quadrantinodosa marginifera	Polygnathus sp. indet.	Polygnathus cf. P. webbi	Spathognathodus sp. indet.	Palmatolepis glabra lepta	Palmatolepis quadrantinodosa inflexoidea	Polygnathus cf. P. pennatuloideus	Palmatolepis gracilis gracilis	Palmatolepis quadrantinodosa ssp. indet.	Palmatolepis rugosa grossi	Polygnathus glaber bilobatus	Spathognathodus stabilis	Spathognathodus amplus	Scaphignathus velifer	Scaphignathus subserratus	Palmatolepis helmsi	Spathognathodus bohleanus	Spathognathodus inornatus	Spathognathodus jugosus	Polygnathus cf. P. glaber
BELLVER		0529																																			
COMPTE FORMATION	C – MEMBER	0528																																			
		0527																																			
		0526																																			
		0525																																			
		0524																																			
		0523																																			
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		0521																																			
		0520																	•																		
		0519																																			
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		0512																	•		\				•												
		0511																			•				X				X								
		0510																			•				•				X						\		
		0509																			•				X				\						•		
		0508									•														\				\						•		
		0507		•																					▧				X						X	\	•
		0506		•							•														\						•	\	\	•			
		0505		\			•	•			\							\			•				\		\	\	\	•							
		0504		•	•			•			\	•						•			•				•	•											
		0503		\	•	•	•	X		\	\	\			\	•	•	\				\	•	•													
	B	0502	X		•	•	\	\			\	\	•	•	X	\	\	\	•	•	•																
		0501	X	\	\	\	\	•	\	•	•	•	•	•																							

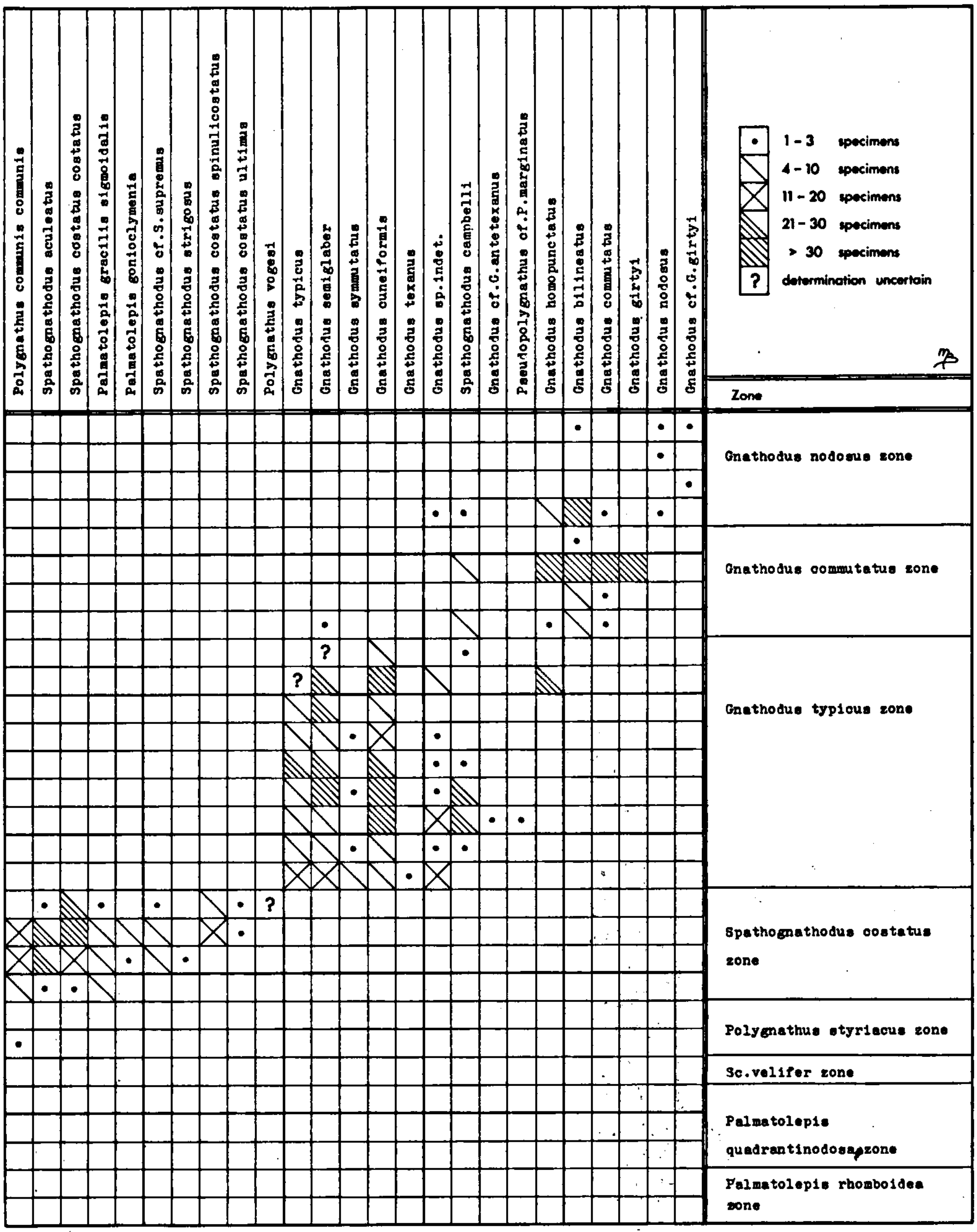
Polygnathus communis communis
Spathognathodus aculeatus
Spathognathodus costatus costatus
Palmatolepis gracilis sigmoidalis
Palmatolepis gonioclymenia
Spathognathodus cf.S.supremus
Spathognathodus strigosus
Spathognathodus costatus spinulicostatus
Spathognathodus costatus ultimus
Polygnathus vogesi
Gnathodus typicus
Gnathodus semiglaber
Gnathodus symmutatus
Gnathodus cuneiformis
Gnathodus texanus
Gnathodus sp.indet.
Spathognathodus campbelli
Gnathodus cf.G.antetexanus
Pseudopolygnathus cf.P.marginatus
Gnathodus homopunctatus
Gnathodus bilineatus
Gnathodus commutatus
Gnathodus girtyi
Gnathodus nodosus
Gnathodus cf.G.girtyi
1 - 3 specimens
4 - 10 specimens
11 - 20 specimens
21 - 30 specimens
> 30 specimens
? determination uncertain
Zone
Gnathodus nodosus zone
Gnathodus commutatus zone
Gnathodus typicus zone
Spathognathodus costatus zone
Polygnathus styriacus zone
Sc.velifer zone
Palmatolepis quadrantinodosa zone
Palmatolepis rhomboidea zone

Table 7. Distribution chart of sections 06-BCD.

CASTELLAR DE NUCH (2)		Sample	Polygnathus linguiformis linguiformis	Polygnathus angusticostatus	Spathognathodus bidentatus	Polygnathus costatus	Polygnathus pseudofoliatus	Polygnathus robusticostatus	Icriodus nodosus	Palmatolepis glabra prima	Palmatolepis glabra pectinata	Palmatolepis minuta schleizia	Palmatolepis rhomboidea	Palmatolepis perlobata schindewolfi	Palmatolepis quadrantinodosa inflexa	Palmatolepis sp. indet.	Polygnathus webbi	Polygnathus nodocostatus s.s.	Polygnathus glaber glaber	Polygnathus decorosus s.l.	Polygnathus sp. indet.	Spathognathodus stabilis	Palmatolepis glabra acuta	Palmatolepis quadrantinodosa quadrantinodosa	Polygnathus triphyllatus	Polygnathus cf. P. webbi	Palmatolepis minuta minuta	Palmatolepis quadrantinodosa marginifera	Palmatolepis quadrantinodosa inflexoidea	Polygnathus rhomboideus	Palmatolepis distorta	Palmatolepis glabra lepta	Palmatolepis gracilis gracilis	Polyphodonta gryatilineata	Gnathodus semiglaber	Gnathodus cuneiformis	Gnathodus typicus
COMPTE FORMATION	C – MEMBER	0628																																			
		0627																																			
		0626																																			
		0625																																			
		0624																																			
		0623																																			
		0622																			•														▨	▨	▨
		0621								•	\	\		•		•		•	\	•							•					\	\				
		0620								•	▨	\				\		\	•								•	•			X	\	▨	?			
		0619								\	▨				\	\		•	X			•						X	\		X	\	•				
		0618									▨	•	▨	\	\	X	•		X	\	•	\	X				•	X	\								
	B	0617								•	\	•		\	\	X	•	•	X	•		•	•	\			\	•	?	•							
		0616									•		•	•		\						•	•	•	•	X											
		0615								\	\	•	•	•	•	\	\	•	•	•	•	•															
	A	0614				X	•		•																												
		0613	\					•																													
VILLECH FM.		0612	▨			•	•																														
		0611	▨	?	•																																
		0610	•																																		

•	1 - 3 specimens
\	4 - 10 specimens
☒	11 - 20 specimens
▧	21 - 30 specimens
▩	> 30 specimens
?	determination uncertain

Gnathodus antetexanus	Gnathodus sp.indet.	Spathognathodus campbelli	Gnathodus bilineatus	Gnathodus commutatus	Zone
					Gnathodus commutatus zone
		•	•		
			\	•	
			•		
		•	•	•	
			\		
•	\	•			Gnathodus typicus zone
					Palmatolepis quadrantinodosa zone
					Palmatolepis rhomboidea zone
					Polygnathus kockelianus zone ?

Table 8. Distribution chart of section 06-A.

CASTELLAR DE NUCH (1)	Sample	Icriodus woschmidti ssp.indet.	Spathognathodus inclinatus inclinatus	Spathognathodus inclinatus wurmi	Spathognathodus sp.indet.	Spathognathodus steinhornensis steinhornensis	Icriodus sigmoidalis	Icriodus sp.indet.	Polygnathus foveolatus	Icriodus angustus	Polygnathus cf.P.foveolatus	Polygnathus linguiformis linguiformis	Polygnathus costatus	Icriodus corniger	Icriodus cf.I.latericrescens n.ssp.A Klapper & Ziegler, 1967	Fauna or zone
VILLECH FM.	0609							•				╲	•	•	•	Icriodus corniger zone
	0608										•					non latericrescid - Icriodus - Polygnathus Fauna
	0607									•						
	0606					▨			•							Icriodus b.bilatericrescens - steinhornensis - Polygnathus Fauna
BAS. FM.	0605					▨	•	•	◣							
	0604				•											
RUEDA FM.	0603	•	•	•												Icriodus woschmidti postwoschmidti Fauna
	0602	•	•	•												
	0601	•	╲													

•	1 - 3 specimens
╲	4 - 10 specimens
◣	21 - 30 specimens
▨	> 30 specimens

Table 9. Distribution chart of section 02.

CASTELLS (1)

• 1-3 specimens
\ 4-10 specimens
X 11-20 specimens

Formation	Sample	Spathognathodus inclinatus inclinatus	Spathognathodus steinhornensis repetitor	Icriodus woschmidti postwoschmidti	Spathognathodus sp.indet.	Pelekysgnathus serrata n.ssp.A Carls,1969	N.gen.n.sp. Boersma,1973	Polygnathus pireneae	Spathognathodus steinhornensis n.ssp.A Carls,1969	Spathognathodus inclinatus wurmi	Spathognathodus steinhornensis ssp.indet.	Icriodus rectangularis s.l.	Icriodus huddlei curvicauda	Spathognathodus steinhornensis cf.S.s.steinhornensis	Icriodus sp.indet.	Icriodus sigmoidalis	Polygnathus lenzi	Icriodus huddlei huddlei	Spathognathodus steinhornensis steinhornensis	Fauna
FONCHANINA FM.	0241														•				\	Icriodus b.bilatericrescens - steinhornensis - Polygnathus Fauna
	0240																	•		
BASIBÉ FM.	0239																	\	•	
	0238														•	•	•			
	0237														•					Icriodus huddlei curvicauda - I.huddlei huddlei Fauna
	0236	•								•			•	\	•					
	0235									•										
	0234																			
	0233									•			X	\						
	0232				•															
	0231													•						
	0230																			
	0229													•						
	0228													•						
	0227													\						
	0226												\	\						
	0225											•								Icriodus huddlei curvicauda - rectangularis s.l. - angustoides Fauna
	0224	•								•	•									
	0223									•										
	0222								•											Ancyrodelloides - Icriodus pesavis Fauna
	0221									•										
	0220																			
	0219		•						\											
	0218		•					•												
	0217																			
	0216					•	•	•												
RUEDA FM.	0215																			
	0214																			
	0213																			
	0212					•														
	0211			•																Icriodus woschmidti postwoschmidti Fauna
	0210				•															
	0209	•	•																	
	0208																			
	0207	•	•																	
"SILURIAN"	0206	•	•	\																
	0205			\																
	0204		•																	
	0203																			
	0202																			
	0201	•																		

Table 9. (continuation)

CASTELLS (2)	Sample	Spathognathodus steinhornensis steinhornensis	Icriodus sp.indet.	Icriodus sigmoidalis	Icriodus bilatericrescens bilatericrescens	Icriodus huddlei huddlei	Icriodus fusiformis	Polygnathus foveolatus	Polygnathus linguiformis linguiformis	Polygnathus costatus	Icriodus nodosus	Spathognathodus bidentatus	Polygnathus angustipennatus	Polygnathus sp.indet.	Polygnathus robusticostatus	Polygnathus xylus	Icriodus latericrescens n.ssp.A Klapper & Ziegler,1967	Polygnathus decorosus s.l.	Icriodus expansus	Palmatolepis glabra prima	Palmatolepis quadrantinodosalobata	Palmatolepis minuta minuta	Palmatolepis subperlobata	Palmatolepis sp.indet.	Icriodus alternatus	Polygnathus nodocostatus s.s.	Polygnathus glaber glaber	Spathognathodus sp.indet.	Palmatolepis subrecta	Palmatolepis cf.P.subrecta	Palmatolepis gigas	Polygnathus webbi	Ancyrognathus asymmetricus	Ancyrodella curvata	Icriodus cf.I.cornutus	Palmatolepis cf.P.regularis
	0266													▨																						
	0265													\																						
	0264																											\								
	0263																											•								
	0262																											X								
	0261																											\								
GRIOTTE	0260													\								\		▨		\	▨	\								
	0259													•											\											
	0258		\											\				\			▨	•	\	X	X		\									•
	0257																	▨						▨	▨				▨	X	?	X	\	\	\	
	0256													•				▨		\	▨	\	•	\	▨	▨	•	•								
	0255																		•																	
	0254										•							•																		
	0253		•						•	•					\	•	•																			
MAÑANET	0252										•		•	•																						
	0251								•	\	•	•																								
	0250								•																											
	0249																																			
	0248								•																											
	0247	\	\		•	•	?	•																												
	0246	X																																		
FONCHANINA FM.	0245			•																																
	0244				•																															
	0243			•																																
	0242	•	•																																	

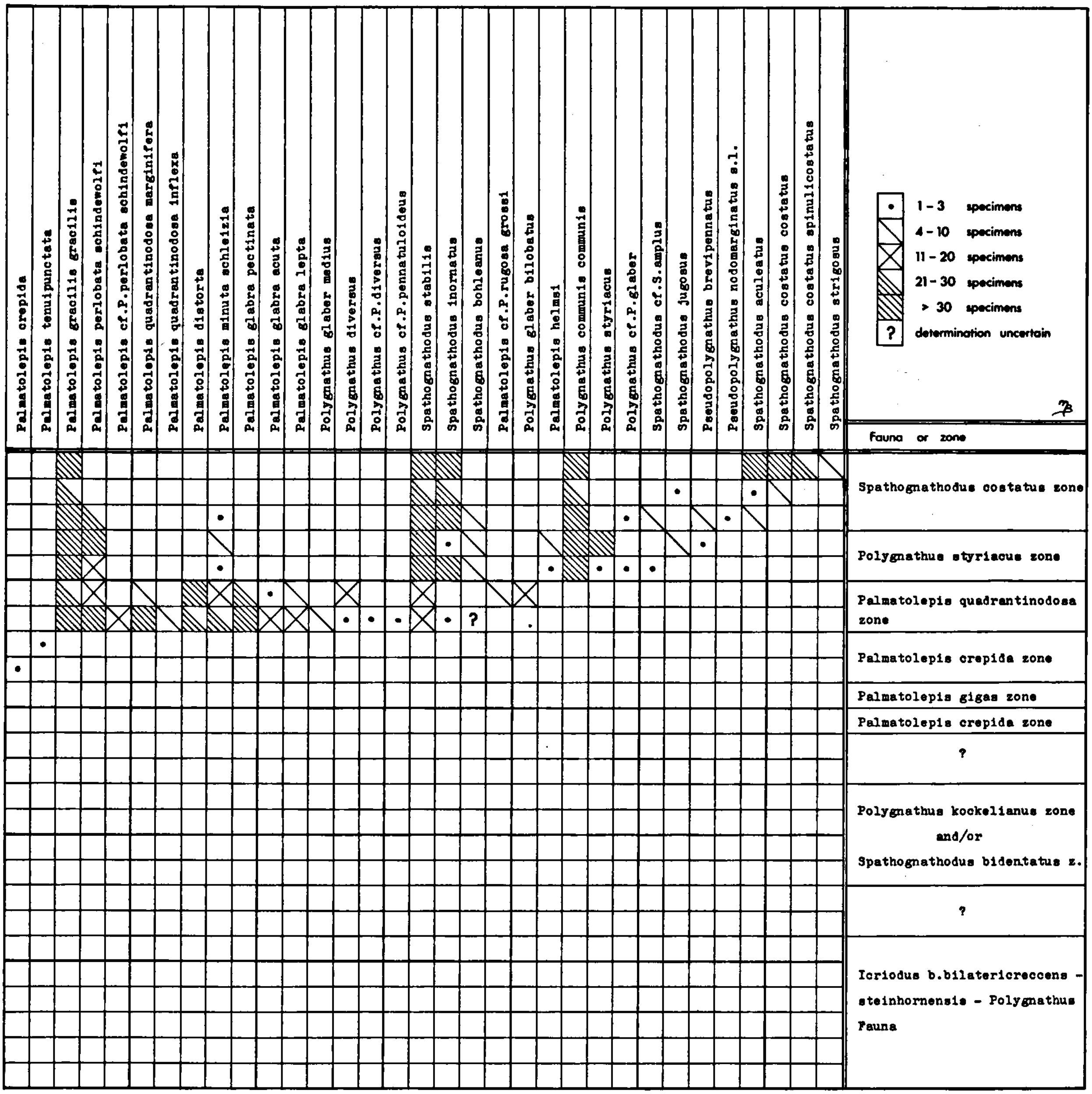
Palmatolepis crepida
Palmatolepis tenuipunctata
Palmatolepis gracilis gracilis
Palmatolepis perlobata schindewolfi
Palmatolepis cf.P.perlobata schindewolfi
Palmatolepis quadrantinodosa marginifera
Palmatolepis quadrantinodosa inflexa
Palmatolepis distorta
Palmatolepis minuta schleizia
Palmatolepis glabra pectinata
Palmatolepis glabra acuta
Palmatolepis glabra lepta
Polygnathus glaber medius
Polygnathus diversus
Polygnathus cf.P.diversus
Polygnathus cf.P.pennatuloideus
Spathognathodus stabilis
Spathognathodus inornatus
Spathognathodus bohleanus
Palmatolepis cf.P.rugosa grossi
Polygnathus glaber bilobatus
Palmatolepis helmsi
Polygnathus communis communis
Polygnathus styriacus
Polygnathus cf.P.glaber
Spathognathodus cf.S.amplus
Spathognathodus jugosus
Pseudopolygnathus brevipennatus
Pseudopolygnathus nodomarginatus s.l.
Spathognathodus aculeatus
Spathognathodus costatus costatus
Spathognathodus costatus spinulicostatus
Spathognathodus strigosus
1 - 3 specimens
4 - 10 specimens
11 - 20 specimens
21 - 30 specimens
> 30 specimens
? determination uncertain
Fauna or zone
Spathognathodus costatus zone
Polygnathus styriacus zone
Palmatolepis quadrantinodosa zone
Palmatolepis crepida zone
Palmatolepis gigas zone
Palmatolepis crepida zone
?
Polygnathus kockelianus zone and/or Spathognathodus bidentatus z.
?
Icriodus b.bilatericreccens - steinhornensis - Polygnathus Fauna

Table 9. (continuation)

CASTELLS (3)

MAÑANET GRIOTTE

Sample	Palmatolepis gracilis gracilis	Palmatolepis gracilis sigmoidalis	Palmatolepis gonioclymeniae	Polygnathus communis communis	Polygnathus sp. indet.	Pseudopolygnathus nodomarginatus s.l.	Pseudopolygnathus sp. indet.	Spathognathodus stabilis	Spathognathodus aculeatus	Spathognathodus costatus costatus	Spathognathodus costatus spinulicostatus	Spathognathodus costatus ultimus	Spathognathodus cf. S. supremus	Spathognathodus strigosus	Pseudopolygnathus dentilineatus	Spathognathodus cf. S. amplus	Polygnathus inornatus s.l.	Spathognathodus sp. indet.	Polygnathus purus	Spathognathodus plumulus	Polygnathus symmetricus	Polygnathus longiposticus	Spathognathodus cf. S. stabilis	Protognathodus meischneri	Protognathodus kockeli	Pseudopolygnathus cf. P. triangulus	Pseudopolygnathus fusiformis	Pseudopolygnathus triangulus inaequalis	Siphonodella duplicata	Siphonodella obsoleta	Siphonodella sp. indet.	Polygnathus radinus	Pseudopolygnathus triangulus triangulus	Siphonodella cooperi	Siphonodella quadruplicata
0283																		•																	
0282																																	╲		
0281				▨			╲										▨	◣				╲					▨					╲	▨	▨	▨
0280				◣	•	╲	•										•	╲									╲					▨	╲	▨	╲
0279				╲		╲									•				╲									•							
0278				X		•									╲				X	?								•							
0277				▨		•									•		•		╲				╲		•			╲		◣	•				
0276				▨		X	•								•		•	X	╲			╲					?	•	╲						
0275				▨	•	▨	X								╲		▨	X	X				X	◣	╲	•									
0274				▨		╲	•	◣									X		╲	•	•	•	▨												
0273				▨	╲	•		X					╲		◣			╲	▨	╲															
0272	╲	╲		╲	•	X		╲		▨	▨	X	◣				X																		
0271	▨	▨		▨	•	▨		▨		▨	▨	X	▨			?																			
0270	◣	X		▨	╲	X		▨		▨	▨	╲	▨																						
0269	╲	•		X	•			X		▨	▨	X	▨		•																				
0268	◣	X	•	▨	X	X		▨	▨	▨	▨	╲	▨	X																					
0267	▨	X	╲	▨	╲	◣	•	◣	▨	▨	▨	╲	X																						

Siphonodella crenulata	Scaliognathus anchoralis	Gnathodus antetexanus	Gnathodus cuneiformis	Gnathodus delicatus	Gnathodus symmutatus	Gnathodus typicus	Gnathodus sp. indet.	Polygnathus bischoffi	Spathognathodus campbelli	Gnathodus semiglaber	Gnathodus texanus	Zone
			•			•			•	\	\	Gnathodus typicus zone
	•	?	•	•	\	\	•	\	•			Scaliognathus anchoralis zone
\												Siphonodella crenulata zone
												S.-triangulus triangulus zone
												Siphonodella-triangulus inaequalis zone
												Siphonodella sulcata - Protognathodus kockeli zone s.l.
												Spathognathodus costatus zone

- • 1 - 3 specimens
- \ 4 - 10 specimens
- ⊠ 11 - 20 specimens
- 21 - 30 specimens
- > 30 specimens
- ? determination uncertain

Table 10. Distribution chart of section 11.

BAHENT	Sample	Icriodus woschmidti postwoschmidti	Icriodus angustoides bidentatus	Icriodus rectangularis s.l.	Icriodus sp.indet.	Spathognathodus remscheidensis	Spathognathodus steinhornensis repetitor	Spathognathodus carlsi	Spathognathodus inclinatus inclinatus	Spathognathodus sp.indet.	Icriodus cf.I.angustoides(trans. to Pelekysgnathus)	Fauna
RUEDA	1101											
"SILURIAN"	1102						11 - 20					Icriodus woschmidti postwoschmidti Fauna
	1103						•					
	1104				•		11 - 20	11 - 20	•		•	
	1105	•					11 - 20	21 - 30			•	
	1106	11 - 20	•	•	4 - 10	4 - 10	11 - 20	•	•	•		

• 1 - 3 specimens
4 - 10 specimens
11 - 20 specimens
21 - 30 specimens

Table 11. Distribution of samples 553 and H 31.

	Sample	Polygnathus pireneae	Icriodus rectangularis s.l.	Spathognathodus steinhornensis ssp.indet.	Fauna
BASIBÉ FM.	H 31		•	•	Ancyrodelloides - Icriodus pesavis Fauna
	H 553	•			

• 1 - 3 specimens

Table 12. Distribution chart of sections 08-AB.

RENANUÉ

Sample	Icriodus curvatus	Icriodus regularicrescens	Icriodus cf. I. regularicrescens	Icriodus nodosus	Icriodus symmetricus	Icriodus sp. indet.	Polygnathus linguiformis linguiformis	Polygnathus pseudofoliatus	Polygnathus xylus	Polygnathus eiflius	Polygnathus costatus	Polygnathus robusticostatus	Polygnathus sp. indet.	Spathognathodus obliquus	Ancyrodella curvata	Polygnathus decorosus s.l.	Palmatolepis hassi	Palmatolepis subrecta	Palmatolepis sp. indet.	Icriodus cf. I. symmetricus	Icriodus cornutus	Polygnathus webbi	Spathognathodus sannemanni sannemanni	Ancyrodella sp. indet.	Palmatolepis punctata	Ancyrodella ioides	Ancyrognathus triangularis	Icriodus alternatus	Ancyrodella nodosa	Zone
0801															•	•											•	•	•	
0802						•							•					•									•	•		Ancyrognathus triangularis zone
0803																•												•		
0804																11-20														
0805																		•												
0806						•										11-20											•			
0807																4-10												•		
0808					•	•									•	4-10	•	4-10	•		4-10	•				?	•	4-10		
0809						•										•														Polygnathus asymmetricus zone
0810																•					•		•		•					
0811															•	4-10						•		•						
0812						•										•		•			•	•	•							
0813						•										4-10		•			•	•								
0814																4-10	•	•	•	•										
0815																•	?													
0816															•	•														
0829																														?
0828																														
0827									4-10																					Polygnathus kockelianus zone ?
0826							•	•	•																					
0825						•	4-10	•	4-10																					
0824							> 30		4-10		•			•																Spathognathodus bidentatus zone
0823																														
0822																														
0821							4-10							•																
0820							11-20		•					?																
0819							> 30	•	4-10																					
0818	> 30	> 30	4-10	4-10	•	> 30	> 30	> 30	> 30	4-10	11-20	•	> 30	•																

•	1 - 3 specimens
4 - 10	specimens
11 - 20	specimens
> 30	specimens
?	determination uncertain

Table 13. Distribution chart of section 07.

SAHÚN (1)

Sample	Polygnathus linguiformis linguiformis	Polygnathus decorosus s.l.	Polygnathus sp.indet.	Schmidtognathus sp.indet.	Polygnathus webbi	Polygnathus varcus	Polygnathus dengleri	Icriodus cf. I. curvatus	Icriodus sp.indet.	Palmatolepis cf. P? disparalvea	Palmatolepis transitans	Schmidtognathus hermanni	Polygnathus cf. P. ancyrognathoideus	Polygnathus asymmetricus ovalis	Icriodus alternatus	Zone
0715																
0714																
0713																
0712																
0711																
0710															•	?
0709		11 – 20						•			•	•	•	•		
0708																
0707	•		•						•							Polygnathus asymmetricus zone
0706		21 – 30	4 – 10		•	4 – 10	•	4 – 10	4 – 10	•	•					
0705		•		?												
0704																?
0703		•	•													
0702	•															
0701																

- • 1 – 3 specimens
- 4 – 10 specimens
- 11 – 20 specimens
- 21 – 30 specimens
- ? determination uncertain

Table 13. (continuation)

SAHÚN (2)

Sample	Scaliognathus anchoralis	Gnathodus typicus	Gnathodus antetexanus	Gnathodus cf. G. cuneiformis	Gnathodus delicatus	Gnathodus sp. indet.	Polygnathus bischoffi	Spathognathodus inornatus	Spathognathodus campbelli	Spathognathodus sp. indet.	Gnathodus symmutatus	Gnathodus semiglaber	Gnathodus bilineatus	Gnathodus homopunctatus	Gnathodus commutatus	Gnathodus nodosus	Gnathodus girtyi	Spathognathodus cf. S. campbelli	Gnathodus multinodosus	Gnathodus nomonodosus	Gnathodus cf. G. bilineatus	Gnathodus texanus	Gnathodus macer	Zone
0744																								?
0743																								
0742																							4-10	Gnathodus macer zone
0741																								
0740																							•	
0739																							•	
0738																								?
0737															•	•								Gnathodus nodosus zone
0736													•			•								
0735																								
0734										•			•		•	•								
0733													11-20	•	4-10	•								
0732													4-10	•	•									
0731													11-20	•	•					•				
0730													4-10		•									
0729													>30	•	11-20	11-20			•			•		
0728													4-10		•	4-10			•	•				
0727						•			•				>30	•	4-10	4-10				•				
0726													11-20	4-10	•	•								
0725													4-10	?		•					•			
0724										•			•	•		•								
0723						•							>30	•	?									
0722													11-20		4-10	•		•		•				
0721						•							11-20	.	•	4-10	•		•					
0720						4-10				•	21-30		>30	11-20	11-20	>30		•						
0719						•			•				•		•	•	•							
0718				•		•					•		21-30	•	•									Gnathodus commutatus zone
0717						•					4-10	?												Gnathodus typicus zone
0716	•	4-10	11-20	•	•	•	•	•	4-10	•														Scaliognathus anchoralis zone

- • 1 - 3 specimens
- 4 - 10 specimens
- 11 - 20 specimens
- 21 - 30 specimens
- > 30 specimens
- ? determination uncertain

Table 14. Succession of conodont zones and Faunas.

SERIE	STAGE	AMMONOID STUFE			CONODONT ZONES AND FAUNAS	AUTHOR
UPPER CARBONIF.	NAMURIAN	Eumorphoceras	E2		Gnathodus macer zone	Marks & Wensink, 1970
			E1		Gnathodus nodosus zone	
LOWER CARBONIFEROUS	VISÉAN	Goniatites	cu III		Gnathodus commutatus zone	
					Gnathodus typicus zone	
	TOURNAISIAN	Pericyclus	cu II		Scaliognathus anchoralis zone	Vöges, 1959
				U L	Siphonodella crenulata zone	
		Gattendorfia	cu I		Siphonodella - triangulus triangulus zone	
					Siphonodella.- triangulus inaequalis zone	
					Protognathodus kockeli - Siphonodella sulcata zone s.l.	Voges, 1959 Ziegler, 1969
UPPER DEVONIAN	FAMENNIAN	Clymenia / Wocklumeria	to VI	U M L	Spathognathodus costatus zone	Ziegler, 1962, 1971
		Gonioclymenia	to V	U M L	Polygnathus styriacus zone	
		Platyclymenia	to IV to III	U M L	Scaphignathus velifer zone	
		Cheiloceras	to II	U L	Palmatolepis quadrantinodosa zone	
					Palmatolepis rhomboidea zone	
				U M L	Palmatolepis crepida zone	
		Manticoceras	to I	U M L	Palmatolepis triangularis zone	
	FRASNIAN			UM U L	Palmatolepis gigas zone	
					Ancyrognathus triangularis zone	
				U M L LM	Polygnathus asymmetricus zone	
MIDDLE DEVONIAN	GIVETIAN			U L	hermanni - cristatus zone	Ziegler, 1965
					Polygnathus varcus zone	Wittekindt, 1965 Ziegler, 1971
				U L	Icriodus obliquimarginatus zone	
	EIFELIAN				Polygnathus kockelianus zone	
					Spathognathodus bidentatus zone	
					Icriodus corniger zone	
LOWER DEVONIAN	EMSIAN				non latericrescid - Icriodus - Polygnathus Fauna	Ziegler, 1971
					Icriodus bilatericrescens bilatericrescens - steinhornensis - Polygnathus Fauna	
					Icriodus huddlei curvicauda - Icriodus huddlei huddlei Fauna	
	SIEGENIAN				Icriodus huddlei curvicauda - rectangularis s.l.- angustoides Fauna	
	GEDINNIAN				Ancyrodelloides - Icriodus pesavis Fauna	
					Icriodus woschmidti postwoschmidti Fauna	
					Icriodus woschmidti woschmidti Fauna	
SIL.	LUDLOVIAN				eosteinhornensis zone	Walliser, 1964

Table 15. Range of the sections sampled in the succession of conodont zones and Faunas. The dotted lines indicate unobserved zones and Faunas, although the section is continuous.

CONODONT ZONES & FAUNAS
Gnathodus macer zone
Gnathodus nodosus zone
Gnathodus commutatus zone
Gnathodus typicus zone
Scaliognathus anchoralis zone
Siphonodella crenulata zone
Siphonodella - triangulus triangulus zone
Siphonodella - triangulus inaequalis zone
Protognathodus kockeli - Siphonodella sulcata zone s.l.
Spathognathodus costatus zone
Polygnathus styriacus zone
Scaphignathus velifer zone
Palmatolepis quadrantinodosa zone
Palmatolepis rhomboidea zone
Palmatolepis crepida zone
Palmatolepis triangularis zone
Palmatolepis gigas zone
Ancyrognathus triangularis zone
Polygnathus asymmetricus zone
hermanni - cristatus zone
Polygnathus varcus zone
Icriodus obliquimarginatus zone
Polygnathus kockelianus zone
Spathognathodus bidentatus zone
Icriodus corniger zone
non latericrescid - Icriodus - Polygnathus Fauna
Icriodus bilatericrescens bilatericrescens - steinhornensis - Polygnathus Fauna
Icriodus huddlei curvicauda - Icriodus huddlei huddlei Fauna
Icriodus huddlei curvicauda - rectangularis s.l.- angustoides Fauna
Ancyrodelloides - Icriodus pesavis Fauna
Icriodus woschmidti postwoschmidti Fauna
Icriodus woschmidti woschmidti Fauna
eosteinhornensis zone