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THE FAMENNIAN OF THE IBERIAN PENINSULA

by

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(11 figures)

ABSTRACT. - The stratigraphy, sedimentology and paleogeography of the Iberian Peninsula during the Famennian is discussed against the background of the classic geotectonic zones in this region.

Shallow siliciclastic seas covered Cantabria, southern Central Iberia, northern Ossa Morena and the South Portuguese zones, whereas a carbonate platform persisted in the Pyrénées since the Middle Devonian. Stratigraphic and sedimentologic evidence indicate a late Famennian transgression in the Cantabrian Zone, and a late Famennian to early Dinantian regressive tendency of the sea in the South Portuguese Zone. Biostratigraphy is mainly based on conodonts goniatites and ostracodes. But also brachiopods prove to be reliable stratigraphic indicators.

Famennian sediments are missing in large areas of Iberia. Presumably this is caused by tectonic denudation (western Astur-Leones and southern Ossa Morena zones) or non-deposition on emerged lands (parts of the Central Iberia Zone and Astur-Ebro High).

Global paleogeographic reconstructions suggest the existence of a large ocean (Paleotethys) separating northern Iberia from the Ossa Morena and South Portuguese zones. This hypothesis has some geological support, but the position of the Ossa Morena Zone remains questionable.

RESUME. - La stratigraphie, la sédimentologie et la paléogéographie de la Péninsule Ibérique au Famennien est discutée en regard des zones géotectoniques classiques dans cette région.

Des mers peu profondes, à apports siliciclastiques, ont recouvert la Cantabrie, le sud de l'Ibérie centrale, le nord de l'Ossa Morena et les zones portugaises méridionales, tandis qu'une plateforme carbonatée persistait dans les Pyrénées depuis le Dévonien moyen. Les évidences stratigraphiques et sédimentologiques indiquent une transgression à la fin du Famennien dans la zone cantabrique, et une tendance régressive de la mer de la fin du Famennien au début du Dinantien dans la zone sud-portugaise. La biostratigraphie est principalement fondée sur les conodontes, les goniatites et les ostracodes. Mais les brachiopodes se sont révélés être aussi des indicateurs stratigraphiques fiables.

Des sédiments famenniens manquent dans de larges régions de l'Ibérie. Probablement, ceci est-il le résultat d'une dénudation tectonique (zones occidentales Astur-Leones et méridionales Ossa Morena) ou de l'absence de dépôt sur des terres émergées (parties de la zone centrale ibérienne et le "haut" Astur-Ebre).

Des reconstructions paléogéographiques globales suggèrent l'existence d'un large océan (Paleotethys) séparant l'Ibérie du Nord de l'Ossa Morena et des zones portugaises méridionales. Cette hypothèse a quelques supports géologiques mais la position de la zone Ossa Morena reste incertaine.

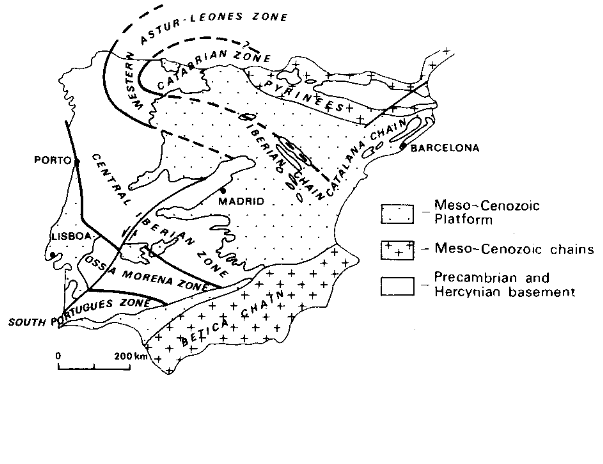

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Figure 1. -- The geotectonic zones of the Iberian Peninsula. Simplified from Julivert *et al.,* 1974.

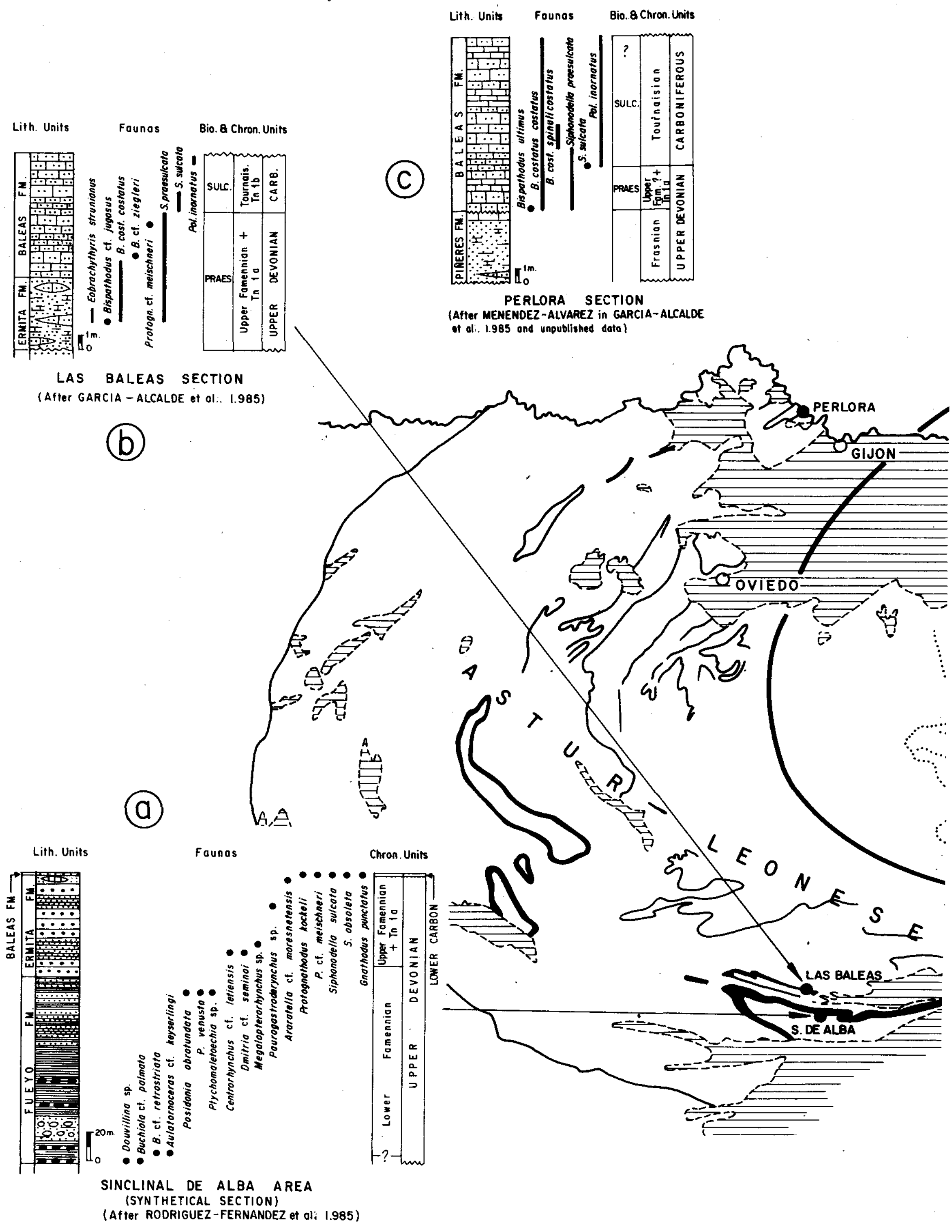
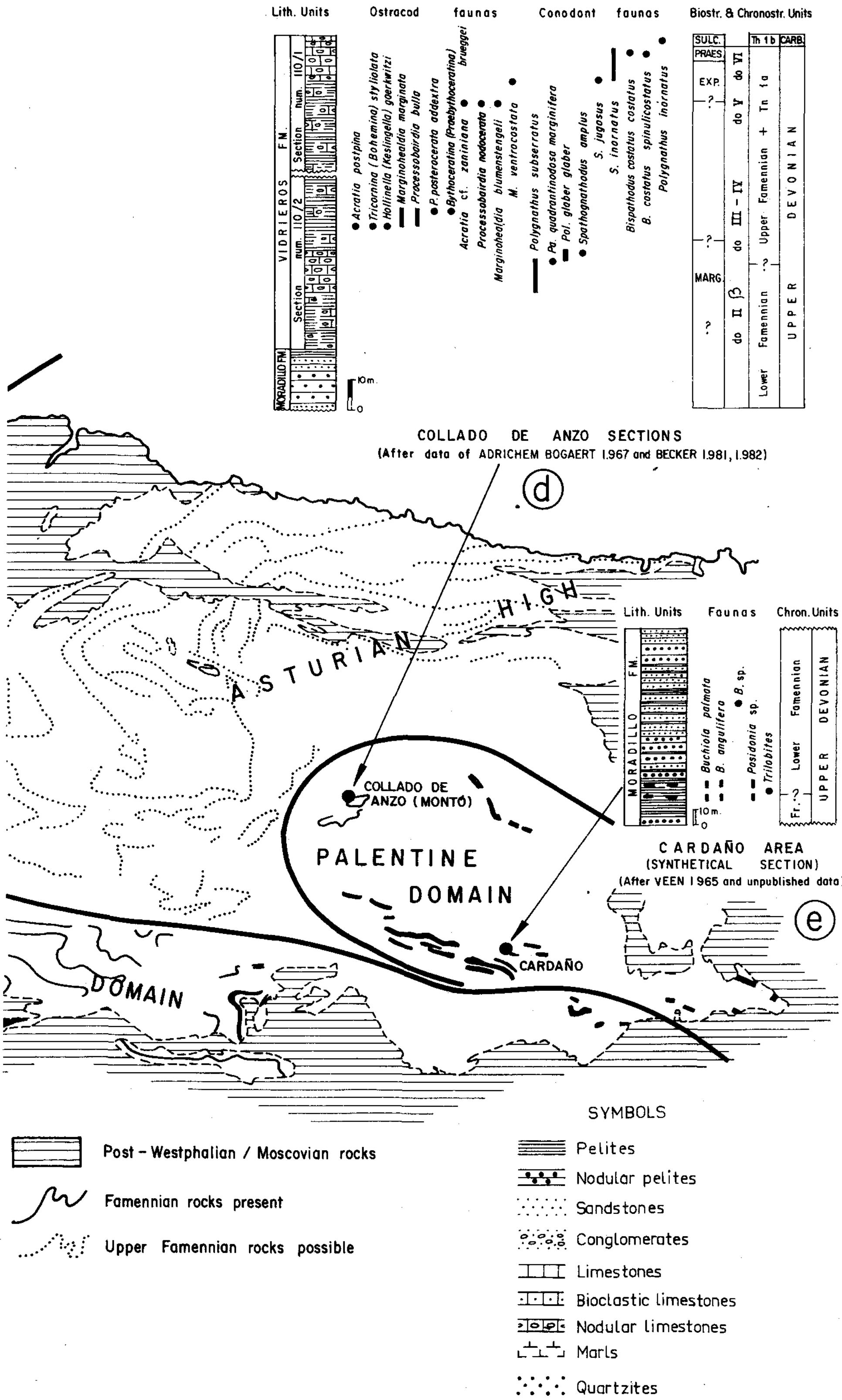


Figure 2. - Geographic distribution and representative sections of the Famennian rocks in the Cantabrian Mountains (Cantabrian Zone). Conodont biozones : MARG., *Palmatolepis marginifera*. - EXP., *Pa. expansa*. - PRAES., *Siphonodella praesulcata*. - SULC., *S. sulcata*.


Lith. Units
Ostracod faunas
Conodont faunas
Biostr. & Chronostr. Units
VIDRIEROS FM.
Section num. 110/1
Section num. 110/2
MORADILLO FM.
Acratia postpina
Tricornina (Bohemina) styliolata
Hollinella (Kesingella) goerkwitzi
Marginohealdia marginata
Processobairdia bulla
P. posterocerata addextra
Bythoceratina (Praebythoceratina) brueggei
Acratia cf. zaniniana
Processobairdia nodocerata
Marginohealdia blumenstengeli
M. ventrocostata
Polygnathus subserratus
Pa. quadrantinodosa marginifera
Pol. glaber glaber
Spathognathodus amplus
S. jugosus
S. inornatus
Bispathodus costatus costatus
B. costatus spinulicostatus
Polygnathus inornatus
SULC.
PRAES.
EXP.
MARG.
Th 1 b
CARB.
do VI
do V
do III - IV
do II β
Lower Famennian
Upper Famennian + Tn 1 a
UPPER DEVONIAN
10m
0
COLLADO DE ANZO SECTIONS
(After data of ADRICHEM BOGAERT 1.967 and BECKER 1.981, 1.982)
d
ASTURIAN HIGH
COLLADO DE ANZO (MONTÓ)
PALENTINE DOMAIN
CARDAÑO
DOMAIN
Lith. Units
Faunas
Chron. Units
MORADILLO FM.
Buchiola palmata
B. angulifera
B. sp.
Posidonia sp.
Trilobites
Fr.
Lower Famennian
UPPER DEVONIAN
10m
0
CARDAÑO AREA
(SYNTHETICAL SECTION)
(After VEEN 1965 and unpublished data)
e
SYMBOLS
Post - Westphalian / Moscovian rocks
Famennian rocks present
Upper Famennian rocks possible
Pelites
Nodular pelites
Sandstones
Conglomerates
Limestones
Bioclastic limestones
Nodular limestones
Marls
Quartzites

1. - INTRODUCTION

It is common usage to distinguish a number of geotectonic zones in the Iberian Peninsula (fig. 1). This division appears also adequate for the description of the Famennian sedimentary environments and is followed in this paper. Our knowledge of the Famennian in Iberia varies significantly from zone to zone. The best studied area is the Cantabrian Chain, which is reasonably well known stratigraphically and sedimentologically. Elsewhere, Famennian outcrops are scarce (Central Iberia and Ossa Morena zones) or absent (Western Astur-Leones Zone) or need further research (South Portuguese Zone and Pyrénées). Very little is known about the possible existence of Famennian sediments in the Catalan and Betic Chains.

Moreover, there are several lithostratigraphic units whose possible Famennian age is still open to debate. This is the case of the following flyschoid sequences : San Clodio (Lugo) in the western Astur-Leones Zone, Bragança-Alcanices in the Central Iberia Zone, the Tercena Formation of the Ossa Morena Zone, and the units of the Pulo do Lobo Antiform in the South Portuguese Zone. In order to avoid speculations which are clearly beyond the purposes of this synthesis, only units of undisputed Famennian age are considered.

Frequently, the Famennian rocks in each geotectonic zone have a distinct marine shelf character. This gives some clues to the understanding of the paleogeography of the Iberian Peninsula during the Upper Devonian. Biostratigraphy is mainly based on conodonts, ostracodes and goniatites. But brachiopods may play a special role, particularly when the other fossil groups are absent.

It should be noticed that part of the biostratigraphic information in this report is based on earlier published papers. In most cases we have decided to use the terminology of the former authors even when this has become out of date (as is partly the case for the conodont zonation for the Iberian Cordillera, Pyrenees and South Portuguese Zone).

This synthesis is the result of fruitful discussions between the authors. It is however important to mention that their contributions have been as follows : Garcia-Alcalde - Central Iberia, Ossa Morena and Cantabrian zones; Liñan - Iberian Cordillera and part of the Pyrenees; Truyols - parts of the Cantabrian Zone and of the Pyrénées; Oliveira - South Portuguese Zone. The last author has also prepared the final version of the manuscript.

2. - CANTABRIAN ZONE

The Devonian outcrops of the Cantabrian Zone are usually grouped in the Astur-Leones and Palentine domains which are separated by the so-called Asturian High (Brouwer, 1967. fig. 2). A paleogeographic differentiation during the Devonian is clearly recognized in the stratigraphic record. Lithostratigraphic units of almost all Devonian stages are known in these domains, whereas on the Asturian High only a thin film of Upper Famennian rocks occurs. Although keeping Brouwer's divisions for descriptive purposes, we have however a different interpretation of the paleogeography of the Cantabrian Zone as will be discussed further on.

2.1.- ASTUR-LEONES DOMAIN

Three lithostratigraphic units in this domain have been ascribed to the Famennian : the Fueyo and Ermita formations (Comte, 1936) and the Baleas Formation (Wagner *et al.,* 1971).

2.1.1.- Fueyo Formation

This formation is only known in the external part of the domain (fig. 2a). It is composed of dark nodular pelites and sandstones with intercalations of conglomerates. The thickness varies from 25 to 150 m. These sediments were deposited in a subtidal environment (Leyva *et al.,* 1981). The age of this unit has long been disputed. Recent work (Rodriguez-Fernandez *et al.,* 1984) suggests that the base of the formation may be of Frasnian age, but the remaining part belongs already to the early Famennian.

2.1.2.- Ermita Formation

The best exposed and more complete section of this unit is found in the Alba Syncline (figs. 2a and 2b). There the formation consists of alternating sandstones and pelites probably representing intertidal to supratidal environments. These yielded brachiopods and conodonts of late Famennian age (Rodriguez-Fernandez *et al.,* 1984, Garcia-Alcalde *et al.,* 1985). The unit rests disconformably on a varied substrate which changes from Upper Devonian rocks in the southern part of the Astur-Leones Domain to successively Silurian, Ordovician and Cambrian rocks towards the central portion of the Asturian High. This disconformity is also marked by a reduction in the thickness of the Ermita Formation, from some 100 m in the South to less than 5 m in the North. These facts suggest an important transgressive event during the Famennian.

In the Valsurbio and San Martin-Ventanilla regions the lithology of the upper part of the Camporredondo Formation (Koopmans, 1962) is very similar to that of the Ermita Formation. However, the correlation between these units needs further biostratigraphic support (no reliable fossils were recovered from the Camporredondo Formation).

2.1.3.- Baleas Formation

This formation crops out in many places of the Astur-Leones Domain and is well-exposed in the Baleas and Perlora sections (figs. 2b and 2c). It consists of bioclastic limestones (thickness 1 - 12 m) which were

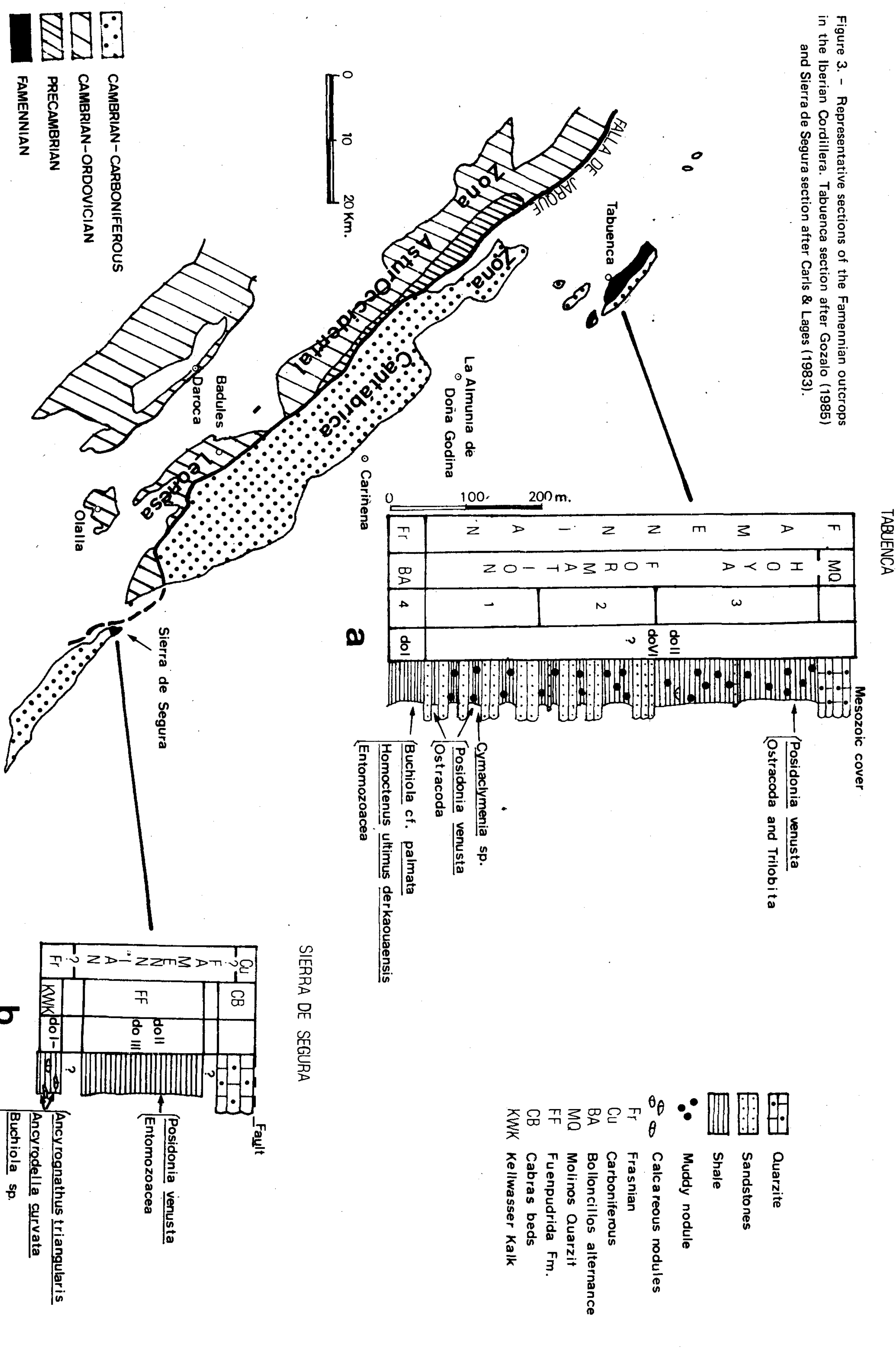


Figure 3. - Representative sections of the Famennian outcrops in the Iberian Cordillera. Tabuenca section after Gozalo (1985) and Sierra de Segura section after Carls & Lages (1983).

laid down in a subtidal environment (Sanchez de la Torre, 1982). These yielded conodonts of the *praesulcata* and *sulcata* zones indicating that the Devonian-Carboniferous boundary lies within this unit.

2.2.- PALENTINE DOMAIN

The Famennian in this domain is represented by the Vidrieros Formation (Veen, 1965) and possibly by part of the Moradillo Formation (Wagner & Wagner-Gentis, 1963).

2.2.1.- Moradillo Formation (= Murcia Formation of Veen, 1965).

This unit is mainly exposed in the Montó region (fig. 2e). It comprises a pelitic band at the base and more sandy lithologies towards the upper part. The thickness is about 100 m. The pelites have yielded Frasnian bivalves (Veen, 1965). However, the discovery of an early Famennian trilobite in the upper part of the pelitic band (Arbizu, pers. comm.), and the presence of the goniatite *Aulatornoceras bicostatus* (cf. Wagner & Wagner-Gentis, 1963) suggest that a large part of this formation might be already of Famennian age. The available stratigraphic and sedimentologic data suggest a lateral correlation with the Fueyo Formation in the Astur-Leones Domain.

2.2.2.- Vidrieros Formation

The best exposed section is that of the Collado de Anzo in the Montó region (fig. 2d). This unit is composed of about 50 m of pelites with interbedded lenses of limestones and nodular limestones. Ammonoids (Kullmann, 1960), trilobites (Arbizu, 1985), conodonts (Budinger & Kullmann, 1964; Van Adrichem Boogaert, 1967) and ostracodes (Becker, 1981) indicate that the age of this unit ranges from late Lower Famennian to early Tournaisian. The sediments of the Vidrieros Formation were deposited in a probably deeper environment than their almost coeval equivalents of the Ermita Formation in the Astur-Leones Domain.

2.3.- GEOLOGICAL SETTING

Brouwer (1967) has proposed the existence of an emerged land (Asturian High) during the Devonian, which separated two different sedimentary basins (Astur-Leones and Palentine Basins). Early and Middle Devonian stratigraphic and sedimentologic data, as well as the lateral correlations for the Upper Devonian suggested in this report, indicate that the emerged land was bordered by an extensive, mixed carbonate-siliciclastic marine platform. The stratigraphic gaps recorded throughout the Devonian point to shoreline fluctuations in an overall regressive context. A slight eastward tilting of the marine platform during the late Famennian produced an important transgressive event, which went on during the early Carboniferous. This paleogeographic interpretation implies that the Palentine Domain originally formed part of the marine platform and probably represents the southeastern and deeper continuation of the Astur-Leones depositional area.

The present geological setting is a result of the nappe tectonics which affected the Cantabrian Zone during late Carboniferous times. This means that the Palentine Domain is considered as an allochtonous sheet over the Asturian High (Marcos, 1979; Frankenfeld, 1983; Marquinez & Marcos, 1984).

3. - IBERIAN CORDILLERA

The Famennian sediments in this Cordillera are restricted to the outcrops of the Sierra de Tabuenca and the Sierra de Segura (fig. 3).

3.1.- SIERRA DE TABUENCA

Upper Devonian rocks are exposed in two small outcrops covering an area of less than 25 km^2. In spite of this, these form a sedimentary pile of some 1200 m thickness, consisting of alternating decametric packets of quartzitic sandstones and pelites. The Famennian is restricted to the upper 565 m of that sequence. Two main Famennian units are recognized (Gozalo, 1985; fig. 3), the Hoya Formation and the Molino Quartzite.

3.1.1.- Hoya Formation

The sandstone/shale ratio is higher in the lower than in the upper part of this unit. Moreover, this formation is more sandy to the South-East and more pelitic to the North-West. The sandstones are well-sorted and locally display massive and graded bedding and ripples. Fining- and thinning-upward cycles can also be found. The pelites are finely laminated and frequently bear muddy and sideritic nodules. The transition between the Hoya Formation and the underlying Frasnian rocks is marked by a sudden increase in sandstones and by faunal differentiation. The recovered faunas consist of goniatites, bivalves, trilobites and ostracodes indicating an early to late Famennian age.

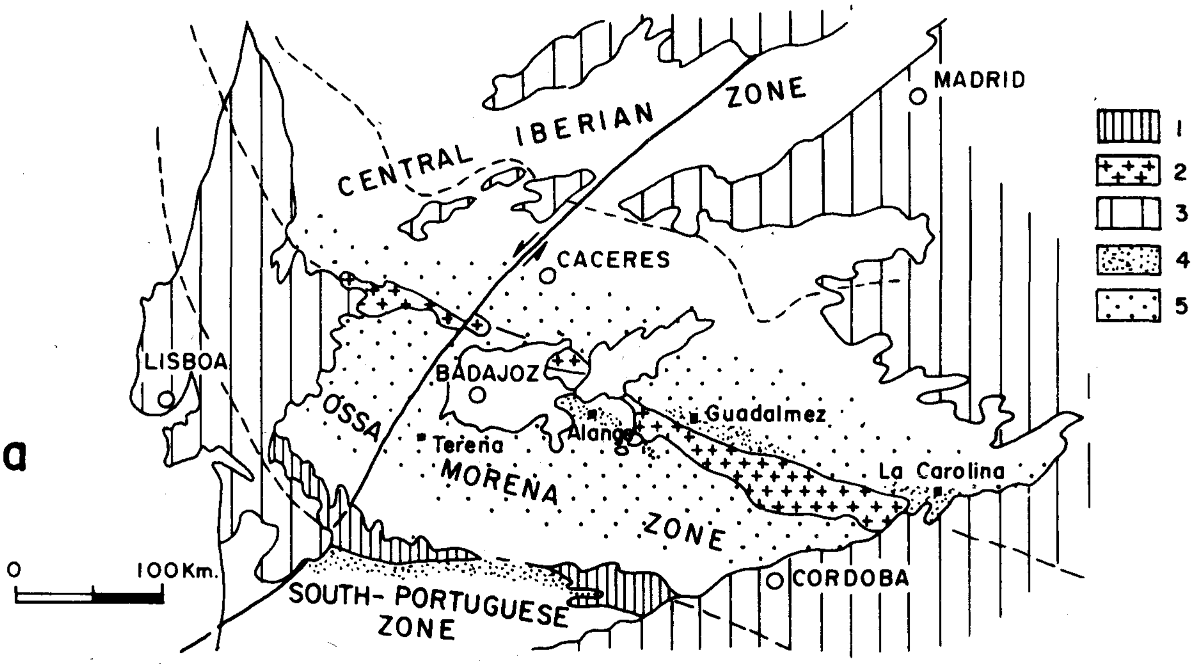
3.1.2.- Molino Quartzite

This forms an up to 40 m thick sheet of well-sorted sandstones. No fossils have been recognized. But the lithologic affinities with the Hoya Formation sandstones suggest that the Molino Quartzite is of late Fammenian age.

3.2.- SIERRA DE SEGURA (MONTALBAN)

Famennian rocks are found in a small outcrop. Because of the poor quality of the exposure, the lithologic succession is not exactly known. Two lithostratigraphic units (fig. 3b) have been described (Quarch, 1973; Carls & Lages, 1983; Lages, 1984).

a



b

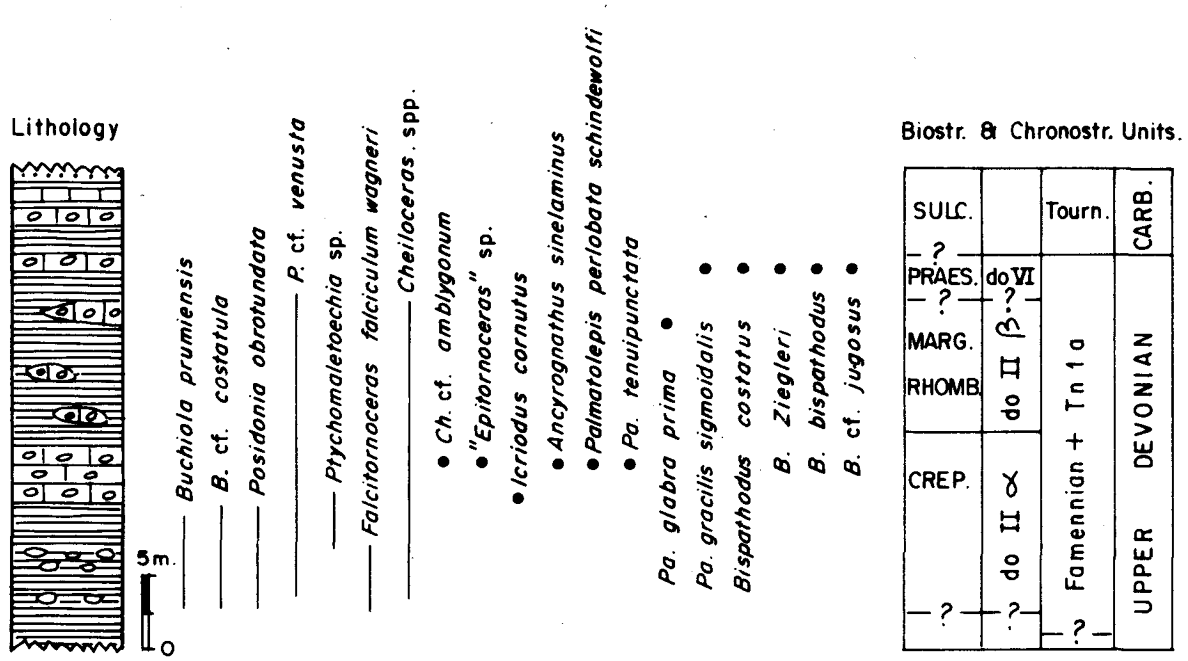


Figure 4a. - Distribution of the Famennian sediments in the southern part of the Central Iberia and Ossa Morena Zones.
1. Precambrian and Paleozoic rocks of the Beja-Aracena Massif. - 2. Los Pedroches batholite. - 3. Mesozoic and Tertiary rocks. - 4. Famennian outcrops. - 5. Famennian rocks eroded or poorly documented.

Figure 4b. - Guadalmez section (modified after Garcia-Alcalde *et al.*, 1984). Symbols as in fig. 2.
Conodont biozones : CREP., *Palmatolepis crepida.* - RHOMB., *Pa. rhomboidea.* - MARG., *Pa. marginifera.* - PRAES., *Siphonodella praesulcata.* - SULC., *S. sulcata.*

3.2.1.- Fuenpudrida Formation

This unit is composed of fine-laminated shales with scaterred interbedded, marly nodules. The base of this formation is not exposed. Bivalves and ostracodes indicate an early to middle Famennian age.

3.2.2.- Cabra Beds

Consisting of micaceous sandstones with intercalations of dark pelite. This unit forms a fining and thinning upward sequence, up to 50 m thick (the top is not exposed due to faulting). Although no fossils have been recorded, lateral correlations with the Tabuenca outcrops suggest a late Famennian age for the Cabra Beds.

3.3.- GEOLOGIC SETTING

Comparison between the Famennian sediments of the Iberian Cordillera and those of the Cantabrian Mountains show close stratigraphic and sedimentologic affinities. This suggests that both depositional areas once were in continuity and belong to the same geotectonic zone (Cantabrian Zone), as already pointed out by Liñan (1983).

4.- CENTRAL IBERIA AND OSSA MORENA ZONES

Famennian outcrops are scarce and practically restricted to the areas bordering the boundary between these zones (fig. 4a). Owing to insuffícent research it is not clear if this scarcity of outcrops is due to non-deposition or to tectonic denudation (as proposed by Puschmann, 1970; Garcia-Alcalde *et al.,* 1984, and others). The preserved Famennian lithologies in both zones have some characteristics in common.

4.1.- CENTRAL IBERIA

The Famennian rocks in the southern part of the Central Iberia Zone are mainly exposed around the Pedroches Batholite. They are tectonically disturbed. The single exception is the Guadalmez section (fig. 4b) where the Frasnian succession is conformably overlain by Famennian rocks. The latter comprise dark, nodular pelites and nodular limestones. The pelites have yielded floras and faunas (goniatites, conodonts) of early (do IIα) Famennian age.

The nodular limestones provided conodonts of the remaining part of the Famennian (do IIβ to do VI), whereas conodonts of late Tournaisian age occur in the upper part of the lithologic succession (Garcia-Alcalde *et al.,* 1985; Pardo & Garcia-Alcalde, 1984).

The Guadalmez stratigraphic succession has been compared with the Campana Formation (Peran & Tamain, 1967) of the eastern Sierra Morena. The latter is however more sandy in nature and possibly slightly younger. The base of the Campana Formation has yielded Upper Famennian ostracodes (Charpentier *et al.,* 1976).

4.2.- OSSA MORENA

In the northern part of the Ossa Morena Zone the Upper Devonian stratigraphic sequence has a sandy shale character and lies unconformably on an older substrate (Herranz, 1984). Within that sequence, the Famennian sediments comprise pelites, fine greywackes and lenses of bioclastic limestones. Near Alange these sediments bear a fauna of brachiopods, bivalves, trilobites, ostracodes and goniatites indicating a late Frasnian to late Famennian age (Marez, 1981; Herranz, 1984).

4.3.- GEOLOGIC SETTING

The poor quality of the Famennian exposures and the need for further research do not allow reliable stratigraphic and sedimentologic correlations between the sections. In spite of this, it seems that deposition occurred in pelagic (outer shelf ?) environments, both in Central Iberia and Ossa Morena Zones.

5. - SOUTH PORTUGUESE ZONE

Four main tectono-stratigraphic domains are distinguished in the South Portuguese Zone : Pulo do Lobo Antiform, Pyrite Belt, Flysch Basin and the Aljezur and Bordeira Antiforms (fig. 5). Undoubted Famennian strata are only known in the Pyrite Belt (Phyllite-Quartzite Formation or PQ Formation) and in the Aljezur and Bordeira Antiforms (Tercena Formation).

Lithologies of PQ Formation character are absent in the Cercal Anticline, the western outcrop of the Pyrite Belt (Carvalho, 1976). However, the tuffites at the top of the Volcano Sedimentary Complex in that area have yielded a fauna with *Cyrtospirifer verneuili* and *Whidbornella caperata* suggesting a late Famennian age. This would mean that here the top of the Volcano Sedimentary Complex is older than elsewhere in the Pyrite Belt, where it is of lower late Visean age. The stratigraphic information provided by that fauna must be considered with caution since the fossils are poorly preserved and tectonically deformed.

The age of the lithostratigraphic units of the Pulo do Lobo Antiform is still uncertain. Therefore, these units are not further discussed here.

5.1.- BORDEIRA AND ALJEZUR ANTIFORMS

The sediments of the Tercena Formation crop out in the core of these antiforms. They consist of sandstones and shales. The base of the succession is unknown. The exposed thickness is about 120 m. The unit is conformably overlain by the Bordalete Formation of late Tournaisian age. *Cymaclymenia* sp. and solitary corals

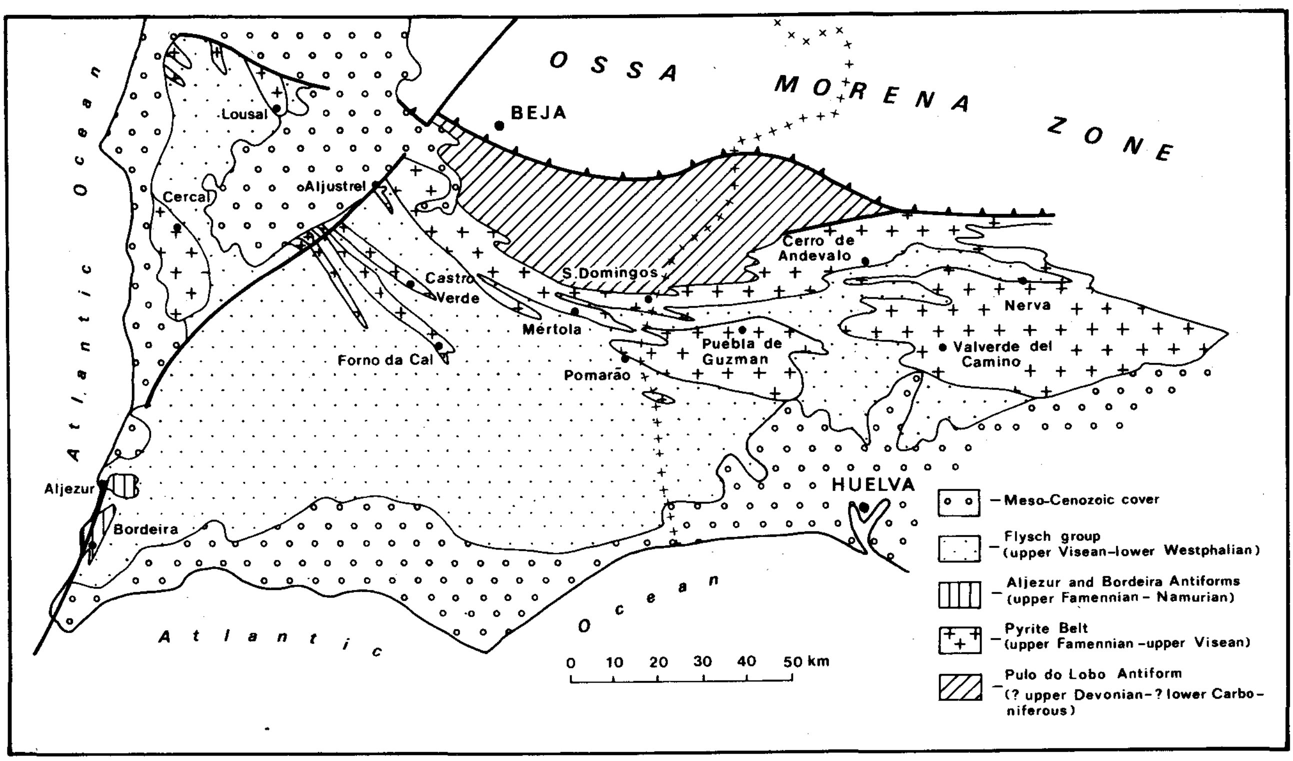


Figure 5.- Tectono-stratigraphic domains of the South Portuguese Zone.

from the lowest exposed dark shale band, as well as incomplete specimens of *Rugosochonetes* sp., *Syringothyris* sp. and Spiriferacea indet. from the uppermost sandstones (fig. 6) point to a late Famennian to early Carboniferous age for the Tercena Formation (Oliveira *et al.,* 1985).

Figure 6 shows three schematic sedimentary logs of the best exposed sections of the Tercena Formation in the Bordeira Antiform. These show that this formation consists of two - about 20 m thick - units of quartzitic sandstones, which alternate with heterolithic sand/shale lithologies. The sedimentary structures of the thick-bedded sandstones mainly exhibit tabular, herringbone and tangential cross-stratification, and convolute beds towards the base of the sandy units. Low-angle to parallel stratification occurs in some of the sandstone beds. This is probably related to large-scale amalgamated hummocks (a swash type stratification is not excluded). The heterolithic sandstones are lenticular (linsen and flaser bedding) or show lateral continuity at the outcrop scale. Burrows are frequent. Paleocurrents flowed predominantly to the northeastern quadrant.

Well-exposed sections are scarce in the Aljezur Antiform, where they are tectonically disturbed. However, the sedimentary features of the sandstones and interbedded shales closely resemble those of the Bordeira Antiform. The vertical succession of the sandstones and heterolithic facies of the Tercana Formation strongly suggest deposition in a tide-dominated shelf environment, occasionally affected by storm events (fig. 7).

5.2.- PYRITE BELT

The Famennian sediments of the Pyrite Belt are represented by the Phyllite-Quartzite (PQ) Formation. The PQ Formation has been subdivided into two lithostratigraphic units in its type area of the Pomarao Anticline (Boogaard, 1967; fig. 8), namely the Eira do Garcia Formation and the Nascedios Formation.

The Eira do Garcia Formation consists of decametric, thick-bedded quartzites with intercalated shales and thin-bedded siltstones. The minimum thickness is about 120 m (base of formation not exposed). No fossils have been recorded.

The Nascedios Formation is composed of shales with a metric intercalation of limestone lenses and nodules. The thickness varies between 20 and 50 m.

The limestones and enclosing shales have yielded conodonts (middle *velifer* and *styriacus* zones), arenaceous foraminifera (*Tolypammina* sp., *Hyperammina* sp.) and macrofossils *(Phacops granulata, Clymenia laevigata, Orthis arcuata, Petraia radiata, Cypricardina scalaris)* indicating a late Famennian age (Pruvost, 1914; Boogaard, 1963). The Nascedios Formation is conformably overlain by the Dinantian rocks of the Volcano Sedimentary Complex.

The Upper Famennian sediments of the Puebla de Guzman and Valverde del Camino Anticlines in Spain,

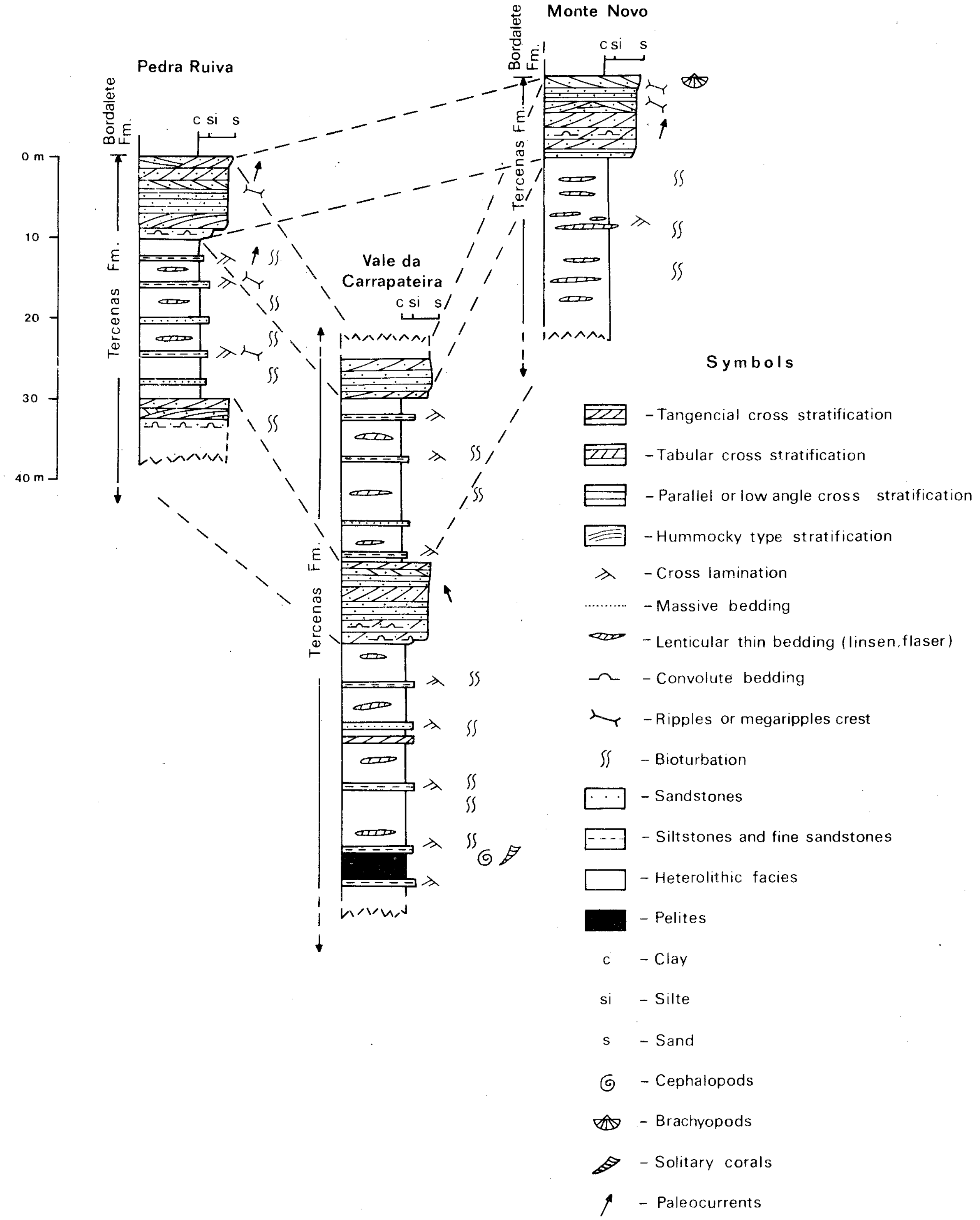


Figure 6. - Schematic sedimentary logs of the Tercena Fm, Bordeira Antiform.

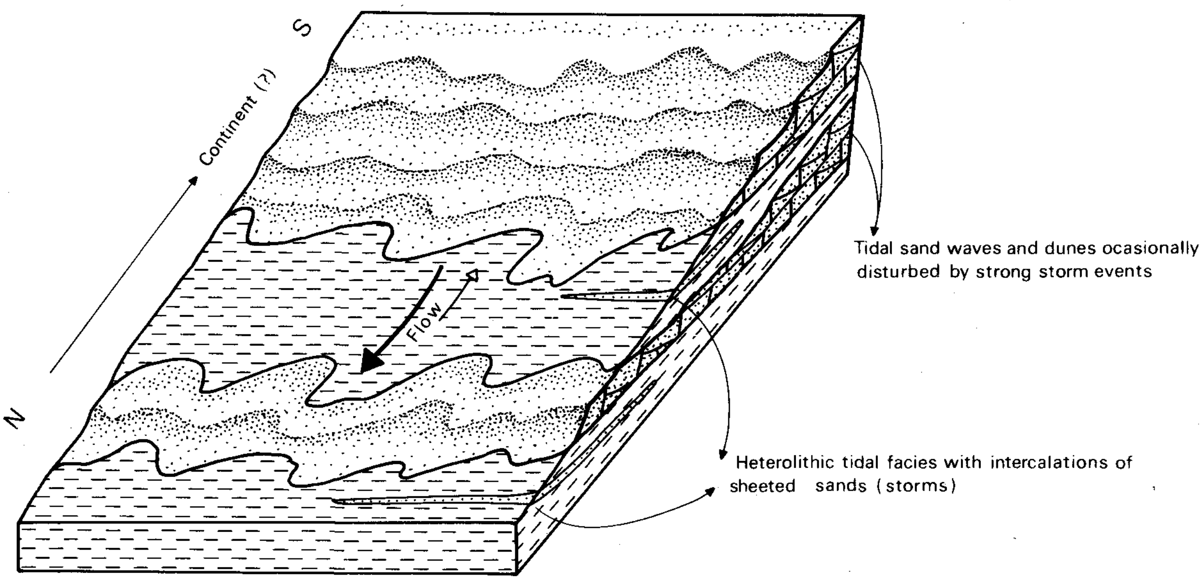


Figure 7. - Generalized environmental interpretation of the Tercena Fm sandstones.

and to the South-West of Castro Verde in Portugal exhibit a lithostratigraphic sequence which is very similar to that of the Pomarão area (Boogaard & Schermerhorn, 1980, 1981; Routhier *et al.*, 1980). However, the conodont-bearing limestones appear somewhat older in the South-West (Lower *marginifera* zone in Forno da Cal, Castro Verde) than in the North-West (*costatus*, zone in the Nerva area).

In the northern branch of the Pyrite Belt (Lousal, Aljustrel, Mértola and Cerro de Andevalo) the quartzites laterally grade into or interfinger with more impure sandstones (greywackes and quartzwackes). Because of this change in the lithology and the strong tectonic deformation no reliable stratigraphic correlation can be made with the type area of the PQ Formation, the Pomarão Anticline. Upper Famennian faunas consisting of conodonts and clymenids have been recovered from centimetric limestone nodules near Mértola (Fantinet *et al.*, 1976). and even a *Cymaclymenia* sp. from the quartzites, West of São Domingos (kindly identified by J. Kullmann).

The thick-bedded quartzites in the tectonically less deformed sandstone intervals display mainly massive, graded, parallel and convolute bedding, and locally large-scale and herringbone cross-bedding and dunes. Amalgamation is common. The thin-bedded siltstones usually show parallel, small-scale cross-lamination and are burrowed. These sedimentary structures, the interfingering of quartzites and greywackes, and also the occurrence of slump folds and olistoliths indicate that the sediments of the PQ Formation were laid down in complex sedimentary environments, probably controlled by a tectonically induced basin floor differentiation. This differentiation into shallow areas and deep depressions is the first manifestation of Hercynian tectonism in the South Portuguese Zone.

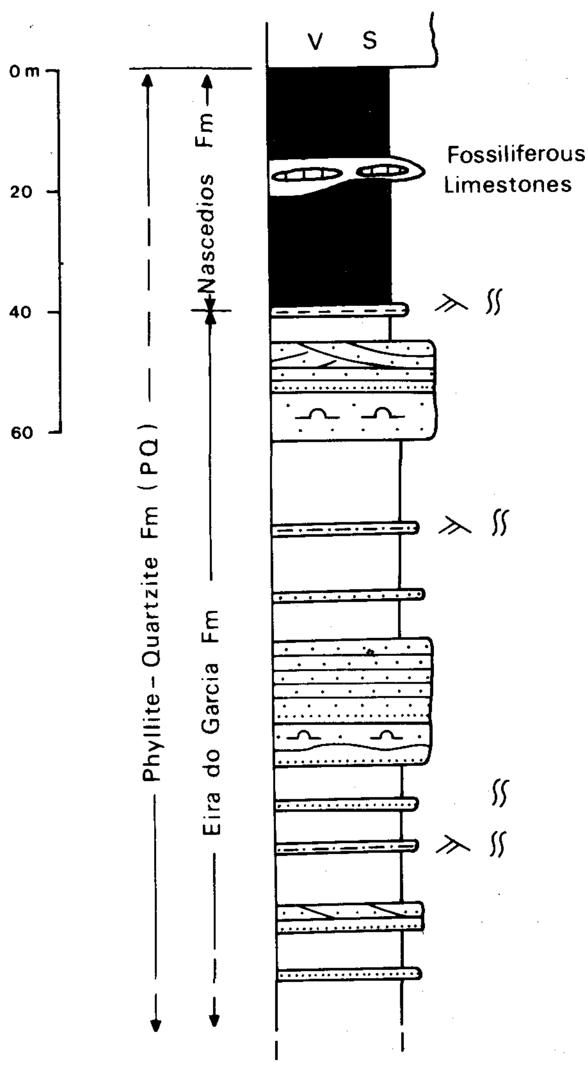


Figure 8. - The PQ Fm stratigraphy in the Pomarão type area (schematic).

	Cephalopods (x)		Conodonts (●)	Pyrite Belt Nerva (1)	El Villar (1)	Calanas (1)	Tharsis (1)	C. Pasto (1)	Pomarão (2)	S. Domig. (2)	Mértola (2)	F. da Cal (2)
Famennian	Gonioclym.	VI	B. costatus	● x	●			●				
		V	P. styriacus		●	●	●	●	● x	x	●	
	Platyclym.	IV, IIIβ, IIIγ	S. velifer		●	● ●		●	●		● x ●	
		IIβ	P. marginifera									●
			P. rhomboidea									
		IIγ	P. crepida									
		Iδ	P. triangularis									

1 – Spain
2 – Portugal

Figure 9. - Cephalopod and conodont zonation of the upper part of the PQ Fm.

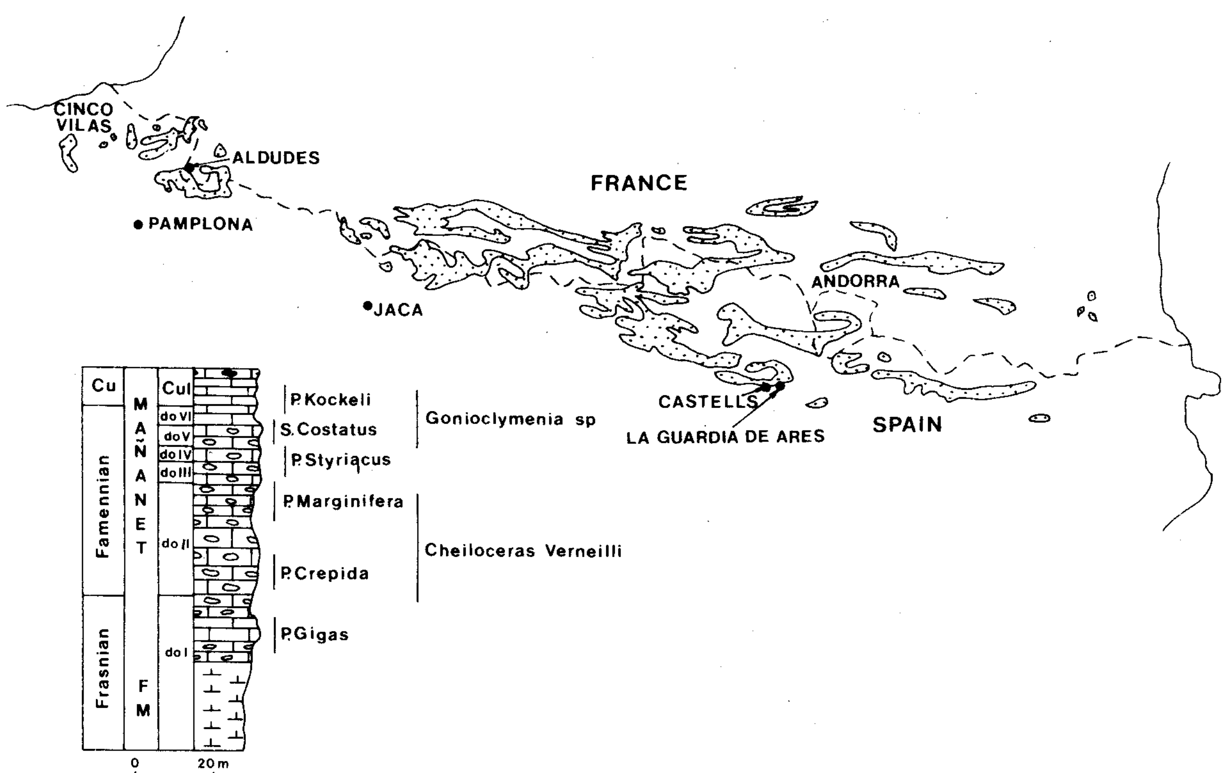


Figure 10. - Famennian outcrops in the axial Pyrenees and the representative section of Castells. (after Boersma, 1973). Symbols as in Fig. 2.

The shaly limestone character of the upper part of the lithostratigraphic succession suggests the development of a transitory mud-carbonate platform in late Famennian times.

6. - PYRENEES

Famennian sediments are widespread in the axial part of the Pyrenees (fig. 10). However, the present state of the stratigraphic research differs considerably from area to area. Two main geographic regions are distinguished, the Central Pyrenees and the Basque Massifs.

6.1.- CENTRAL PYRENEES

The Middle Devonian to Dinantian sediments are predominated by grey and pink nodular limestones ("griotte"). The thickness varies from some 300 m in the central part of the basin to a few tens of meters on the basin margins. Minor lateral changes of the lithofacies have been used for the elaboration of a somewhat confusing lithostratigraphic terminology. In this report only one main unit, the Mañamet Griotte, is considered.

The best exposed and most complete section (up to 220 m thick) is at Castells, between the Noguera Pallaresa and Segre Valleys (Mey, 1967). There, the Mañamet Griotte consists of nodular, multicoloured limestones with intercalations of red and green, marly limestones and shales. The Famennian only comprises 65 m of the lithologic sequence. This section has yielded conodonts of the *crepida* to *costatus* zones (Boersma, 1973). Slightly further to the West (near Baent), goniatites of the do II to do V stages were found by Llopis & Rosell (1968). Goniatites of the same age were also collected near Espaent and in the Segre Valley (Schmidt, 1931; Llopis, 1969).

The Compte Formation in the Compte and La Guardia de Ares regions has been subdivided into three members : A, B and C (Hartevelt, 1970). This formation shows strong lithologic and faunal affinities with the Mañamet Formation (Ziegler, 1969; Mark & Wensink, 1970; Boersma, 1973). The main difference is the occurrence of intraformational breccias in Member A (of Frasnian age) of the Compte Formation. The thickness of the Famennian limestones diminishes progressively towards the basin margins : 10 m in the eastern Pyrénées (Ter Valley) and 20 to 30 m in the West (Gallego, Ara, Aragon and Hecho Valleys). In the latter area also intercalations of red shales and calcareous sandstones occur (Van Lingen, 1960; Schwarz, 1962; Wensink, 1962).

The Upper Devonian limestones of the Spanish Pyrénées represent a characteristic shallow water environment. The occurrence of intraformational breccias, and red shales and calcareous sandstones in the West, suggest the proximity of an emerged land (the Astur-Ebro High).

6.2.- BASQUE MASSIFS

These constitute the northwestern continuation of the Pyrenees. The Famennian stratigraphy is still poorly known. Therefore, only a very general description is presented here.

The Famennian in the Los Aldudes-Quinto Real Massif comprises from bottom to top : green shales, pink ferruginous sandstones and marly limestones. *Centrorhynchus* cf. *letiensis* (recovered from the ferruginous sandstones, Heddebaut, 1973) and conodonts (occurring in the limestones, Wirth, 1967) indicate an early to middle Famennian age.

Blue and green pelites with intercalated thin limestone layers in the Cinco Villas Massif to the West have also been ascribed to the Famennian (Heddebaut, 1973).

7. - PALEOGEOGRAPHIC INTERPRETATION

The distribution of the sedimentary facies in the various geotectonic zones allows a general, but in many aspects tentative, paleogeographic interpretation of the Iberian Peninsula during the Famennian (fig. 11). We have shown that the Asturian High in the Cantabrian Zone was bordered by an extended siliciclastic shelf opening to the South, East and West. The Asturian High was the source area for the detritus introduced on this shelf.

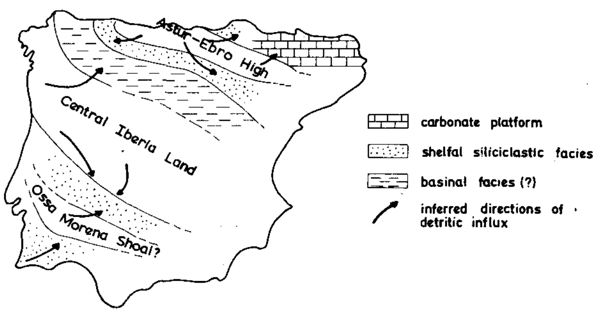


Figure 11. - Tentative paleogeographic reconstruction of Iberia during Famennian times.

Some geologists (Llopis-Lado *et al.*, 1967; Carls, 1983) have suggested the existence of emerged lands (the Ebro Massif) to the East of the Cantabrian Mountains. These would have acted as a clastic source area since the Lower Cambrian. However, Carls (1983) assumes that the Ebro Massif ceased to be a source area during Upper Devonian times, and that the Upper Devonian clastics may have been derived from a southern land, Central Iberia. This assumption is partly based on the predominance of pelagic sediments in the Montalban area (Quarch, 1973). However, the thick pile of Upper Devonian Tabuenca Sandstones (Gozalo, 1985), their occurrence near the Ebro Massif, and the stratigraphic and sedimentologic affinities between the sediments of the Cantabrian Mountains and the Iberian Cordillera indicate that the Ebro Massif was still a high during the Upper Devonian. Presumably, the Ebro Massif and the Asturian High formed one geomorphologic entity, which is here termed the Astur-Ebro High. The great thickness of the Tabuenca succession may have been caused by the high rate of shelf subsidence, possibly related to late Devonian synsedimentary faults (transverse to the structural trend of the Astur-Ebro High ?). This hypothesis fits well with the eastward tilting of the Cantabria Platform which has been responsible for the late Famennian transgression in that area.

Only Lower Devonian sediments are known in the Western Astur-Leones Zone. These are exposed in small synformal structures, and are unconformably overlain by flyschoide sequences of doubtful (? late Devonian – ? early Carboniferous) age. Since the Cantabria Platform opened to the South during the entire Devonian period, it has been argued that the Western Astur-Leones Zone continued to be a marine depocenter during the Middle and Upper Devonian (Carls, 1983; Julivert *et al.*, 1983). Parts of that Western Astur-Leones basin may have been uplifted and eroded as a consequence of a Middle Devonian epeirogenic (?) event. Thus, the flyschoide sediments might be considered as the result of post-orogenic deposition.

A similar paleogeographic reconstruction might be proposed for the Central Iberia Zone. Because of petrological evidence, Frankenfeld (1982) and Rodriguez-Fernandez (1985) have argued that some of the Upper Devonian sediments of the Cantabrian Zone were derived from the metamorphic terrains of Galicia and northern Portugal. This implies erosion of this part of the Central Iberia Zone during the Upper Devonian. A Middle Devonian stratigraphic gap has been recognized throughout the Central Iberia Zone. And therefore, the unconformable flyschoide sediments of northern Portugal may also be post-orogenic (Ribeiro *et al.*, 1982). Upper Devonian sediments are only preserved in the southern part of this geotectonic zone. Most of these sediments are of pelagic nature and suggest deposition on the outer shelf.

The Upper Devonian sedimentary facies of the northern Ossa Morena Zone have many characteristics in common with those of the southern Central Iberia Zone. Elsewhere in the Ossa Morena Zone the Famennian rocks are absent, presumably because of tectonic denudation. The occurrence of unconformable flyschoide deposits and the recognition of a Middle Devonian orogenic event have already been mentioned (Ribeiro *et al.*, 1982).

The sedimentation in the South Portuguese Zone took place in a shallow, siliciclastic sea. The detritus was probably derived from the South. Rapid facies changes in the northern part of this zone indicate synsedimentary tectonism (block faulting ?). The distribution of the Famennian lithofacies in southwestern Portugal point to a regressive tendency of the sea.

The carbonate platform of the southern Pyrénées persisted from the Middle Devonian until the late Dinantian. The original paleogeographic position of this platform has been open to debate. As already noticed above, the western and southern margins of the Pyrénées Platform have possibly been influenced by the influx of terrigenes derived from the Astur-Ebro High. This suggests that in Upper Devonian times the southern part of the Pyrenees carbonate Platform and the Astur-Ebro High already were assembled in their present position. This means that a proposed late Carboniferous strike/slip fault affecting the northern edge of the Iberian Peninsula (Arthaud *et al.*, 1977) should be located to the North of the Axial Pyrénées.

The Astur-Ebro High may have played an important role in the Upper Devonian paleogeography of the Iberian Peninsula. The deposits to the South of this high are mainly siliciclastic (indicating agitated sea water), whereas those to the North contain more carbonates (calm water). This suggests predominantly northward wind directions which were interrupted by the Astur-Ebro High.

These paleogeographic reconstructions as delineated above are only based on sedimentologic and lithostratigraphic information gathered from the different geotectonic zones. However, these were certainly not assembled as they are today.

Most of the published global reconstructions link the entire Iberian Peninsula with northern Europe via France and southern England, after the closure of the Bay of Biscay. Perroud *et al.*, (1984) suggest however a different scheme. Northern Iberia would have been a part of a single plate, Armorica, which moved northwards since the late Ordovician and collided with the Baltica and Laurentia plates to form the Caledonian Chain (Old Red Continent). Southern Iberia (Ossa Morena, South Portuguese Zone) would have remained attached to the northern edge of Gondwana. Moreover, the Old Red Continent and Gondwana were separated by an ocean, the Paleotethys, of about 30° latitudinal width during the Upper Devonian.

This hypothesis has some support in the geological record, namely the Lower Paleozoic crustal thinning of the Ossa Morena Zone and the Middle Devonian orogenic event recognized in northern Iberia. However, the same orogenic event has been distinguished in the Ossa Morena Zone. And close faunal and lithologic affinities seem to exist between the Ossa Morena Zone, Central Iberia, Bretagne, Montagne Noire and South Germany (*Falcitornoceras* and *Cheiloceras* faunal assemblages and widespread dark shales and pelagic limestones in the early Famennian).

These contradictions demonstrate the need for further research in order to clarify the paleogeographic position of the Ossa Morena crustal segment in late Devonian times.

8. - CONCLUSIONS

The most suitable biostratigraphic zonations and correlations in the Iberian Peninsula are based on conodonts, goniatites and ostracodes. Where these fossils are absent, the brachiopods may be of special importance.

The Famennian sediments in all the geotectonic zones or Iberia have been laid down on marine siliciclastic shelfs. An exception is the Pyrenees Zone, where a carbonate platform persisted from the Middle Devonian until the late Dinantian.

The marine depocenters were probably separated by uplifted lands or shoals : the Astur-Ebro High, the Central Iberia High and the Ossa Morena Shoal. During the Famennian the long-lasting Astur-Ebro

High was bordered by a carbonate platform (Pyrenees) to the North and by a siliciclastic shelf to the South. Upper Devonian sea level fluctuations and a late Famennian transgression are clearly recognized in the stratigraphic record of the Cantabrian Chain. The axial and northern parts of the Central Iberia Zone were probably emerged during the Upper Devonian. This was the source area for the siliciclastics in the bordering Famennian seas.

The paleogeographic position of the Ossa Morena Zone is still problematic because of insufficient stratigraphic and sedimentologic data. This geotectonic zone is here interpreted as a large shoal, of which parts have been uplifted from the Middle Devonian onwards.

In the Astur-Leones, Central Iberia and Ossa Morena zones some flyschoide units of doubtful age unconformably overlap Middle Devonian or older strata. The dating of these units may contribute to clarify the long discussed occurrence of a Middle Devonian orogenic event in the Iberian Peninsula.

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