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Devonian and Carboniferous pre-Stephanian rocks from the Pyrenees

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ABSTRACT

A stratigraphic description of the Devonian and Carboniferous pre-Variscan rocks of the Pyrenees is presented. The successions are grouped into sedimentary domains that replace the "facies areas" proposed by previous authors for areas with homogeneous stratigraphy. The description of the sedimentary filling is divided into temporal intervals, where the previous stratigraphic correlation, based on lithological criteria, is supplemented by faunal data, especially conodont findings. A simple palaeogeographic model of the sedimentation during the Upper Palaeozoic and data related to southern boundary between the Pyrenean basin and the Cantabro-Ebroian Massif are discussed.

Keywords: Devonian, Carboniferous, conodonts, Pyrenees, stratigraphy.

RESUMEN

Se ha realizado una descripción estratigráfica de las rocas devónicas y carboníferas pre-variscas de los Pirineos. Las sucesiones son agrupadas en dominios sedimentarios que sustituyen a las "áreas de facies" propuestas por los autores previos para zonas con una estratigrafía homogénea. La descripción del relleno sedimentario está dividida en intervalos de tiempo, donde la correlación estratigráfica basada en criterios litológicos está incrementada por los datos faunísticos, sobre todo los hallazgos de conodontos. Se discute un modelo paleogeográfico simple de la sedimentación durante el Paleozoico Superior y algunos de los datos sobre el límite entre la cuenca pirenaica y el macizo Cantabro-Ebroico.

Palabras clave: Carbonífero, conodontos, Devónico, estratigrafía, Pirineos.

INTRODUCTION

Black shales with limestone beds are usually dominating the Silurian successions of the Pyrenees. This homogeneous sedimentation contrasts with that described for the younger Devonian rocks. The lateral changes among the Devonian lithologies from the central and eastern Pyrenees, were divided into facies areas by Mey (1967, 1968a), Boersma (1973) and Zwart (1979). Based on his studies in the western Pyrenees, Mirouse (1965, 1966) had already conceived a Devonian Pyrenean basin subdivided into longitudinal isofacial grooves or bands trending with W-NW to E-SE and bordered by fractures.

The use of groups of similar Devonian sequences in the so-called facies (and subfacies) areas has a stratigraphically limited application, because it attempts to establish the sequence type for each facies and the boundaries of units often coincide with Alpine or Variscan structures. Consequently, it seems preferable to use a division into domains without an original relation with structures (Fig. 1).

The facies area division was also defined for pre-Variscan Carboniferous rocks, but more recent stratigraphic studies have not applied that division, because the Pyrenean middle-upper Famennian to upper Viséan condensed sequence of limestones and cherts, very widely distributed (Infra-Culm Limestones Group of Perret, 1993). It is similar to the episode described for the European Variscides and is termed the “levelling phase” in the Cantabrian Mountains (Kullmann and Schönenberg, 1975) or “pelagic interlude” of Engel *et al*. (1978). This phase was followed by a regime of flysch sedimentation (shales and greywacke-turbidites) with local sedimentation of thick series, where younger ages are progressively found in the south and west of the Pyrenees. The flysch filling of the troughs was accompanied by the propagation of the Variscan orogeny (see Delvolvé, 1981; Engel, 1984; Delvolvé *et al.*, 1996; and Perret, 1993).

The present text proposes a revision of the sedimentary domains differentiated for the Devonian rocks of the Pyrenees. It provides an initial structure on which a synthesized description of the Pyrenean Devonian to pre-Variscan Carboniferous successions can be based. Finally, the general character of the preserved parts of the basin is discussed.

DEVONIAN PYRENEAN DOMAINS

Carreras and Santanach (1983) proposed a stratigraphic domain for the Devonian Basque massifs (mainly located in the Navarra Country, Fig. 1), where thick siliciclastic deposits occur in the Lower and Upper Devonian successions (Heddebaut, 1975). Upper Devonian siliciclastic rocks are also located in the Central domain of the Pyrenean Axial zone (see Palau and Sanz, 1989), the Central facies area of Mey (1968a) or longitudinal depocentre after Pehalte and Mirouse (1980).

South of the Central domain, Emsian siliciclastic systems, Middle Devonian reefal development and sedimentary gaps below Famennian to Tournaisian rocks can be recognised in the Gavarnie Alpine unit (western Pyrenees, also termed "région sub-occidentale" of Mirouse, 1966; Benartuora-Lapazosa and Otal-Sallent units of Ríos *et al.*, 1990). It is here named the Sallent sub-domain, included in the Sierra Negra domain in the sense of Boersma (1973) for the central Pyrenees (Benasque Alpine unit). Similar sequences can be observed north of the western Axial zone, Ferrières and Col d'Aubisque units of Mirouse (1966) and here named Ferrières sub-domain. The Sierra Negra domain includes the Baliera and the Sierra Negra sub-domains (Mey, 1967), while the Plan d'Estan and Renanué sub-domains (Mey, 1968b) are omitted, because they include only the upper part of the succession (Middle Devonian to Carboniferous). Sedimentary gaps between the Upper Devonian and the Tournaisian, and the presence of Bashkirian limestones, are here considered as indicators of the Sierra Negra domain.

The el Comte domain (or subfacies area after Hartevelt, 1970) includes the Variscan Segre unit of Casas *et al.* (1989), located in the Benasque Alpine unit. Furthermore, the domain is recognised in Alpine units located to the southwards, such as the Cadí nappe of Muñoz (1985) and the Upper Nogueres units of Muñoz (1992). The Castells and Montsec de Tost units (Upper Nogueres units) have a stratigraphic succession similar to hat of the el Comte domain (see Sanz López, 1995; Montesinos and Sanz-López, 1999) but with the lithological features are intermediate between those of the el Comte and those of the Sierra Negra domain.

The boundary of the North domain (Northern facies of Mey, 1968) with the Central domain is unclear, because it seems to be a lateral facies change complicated by fault development. The major differences between the two domains are the loss of the Upper Devonian sandstones present in the Central successions and thinner sequences.

Thin sequences with prevailing carbonate content occur in the eastern part of the central and north Pyrenean successions. Raymond (1983) grouped these carbonate Devonian sequences from the Agly massif, the Pîc d'Ourtiset unit (Haut Pays de Sault), els Asprès and Thuir massifs, and the Villefranche synclinorium, as a unit that was displaced southwards during the Variscan. All these areas have sequences coinciding with those shown in the el Comte domain, although we prefer differentiate them in a separate, East domain.

STRATIGRAPHY

Detailed lithostratigraphic descriptions can be found in the literature and an extended description of sections was published in Majesté-Menjoulas *et al.* (1996). The description of the successions is grouped into temporal intervals to emphasize the relationship among the sedimentation in the different domains. Figure 2 summarizes the correlation of the lithostratigraphic units among several domains.

Lochkovian to early Lower Emsian rocks

Shale sedimentation prevails in the lower Lochkovian of the Pyrenees, except in the eastern part of the chain. Dark shales with silty or sandy millimetric to centimetric beds are located in the Basque domain. The Arnéguy Formation (700 m thick) contains lower Lochkovian brachiopods (Heddebaut, 1973) and Prídolí to Lochkovian conodonts (Requadt, 1974). The siliciclastic content and the thickness decrease in the southern part of the western Axial zone (Sallent sub-domain), where there are dark-coloured slates ("Basal Shales" of Valero, 1974; Serre Llongue Shales of Joseph, 1973), including some argillaceous limestone beds in the Baliera sub-domain, central Pyrenees (Aneto Shales of Mey, 1967). Shales are generally 40-80 m in thickness, although locally they reach 200 m in areas with a complicated stratigraphy.

To the north and to the east (Sierra Negra sub-domain), condensed sequences of black shales with carbonate beds were named the "Upper Graptolitic Shales" by Schmidt (1931), traditionally included in the Silurian. However, the base of the Devonian is located in some limestones with *Monograptus uniformis* (Llopis Lladó, 1969) and in limestones with crinoids and molluscs (Haude, 1992; Valenzuela-Ríos, 1994; Sanz-López *et al.*, 1999) in the el Comte domain. Above, shales with crinoids (Llopis Lladó and Rosell Sanuy, 1968) incorporate limestone beds upwards, where Llopis Lladó and Rosell Sanuy (1968) collected Lochkovian graptolites. In the same beds, Boersma (1973) and Valenzuela-Ríos (1994) reported lower Lochkovian conodonts, such as *Icriodus angustoides bidentatus*, *Ozarkodina carlsi*, and *I. w. transiens*. A similar alternation of shales and limestones at Bencarrech-Sentein (North domain) provided the Lochkovian graptolites *M. uniformis* and *M. hercynicus* (Donnot, 1974).

An increase in oxygen content is interpreted during the sedimentation of a hemipelagic ramp during the middle-upper Lochkovian in the Torres Member (Sanz-López *et al.*, 1999) of the Rueda Formation of Mey (1967). It is formed of 10-20 m of carbonate decimetric beds interbedded among marls, succeeded by nodular limestones with hard-undissolved parts. Limestones sometimes show bioturbation, containing orthoceratids and small brachiopods, and conodonts from the *Lanea omoalpha-L. eleanorae* Zone to the *Pedavis gilberti* Zone (Valenzuela-Ríos, 1994; Murphy and Valenzuela-Ríos, 1999). The member was also described in the North domain (Bouquet and Stoppel, 1975) and in the East domain (Cygan and Raymond, 1979). A shallow-water laterally equivalent unit from the Basque domain corresponds to the 200 m of shales and bioclastic limestones with Lochkovian to lower Pragian conodonts and brachiopods from the upper part of the Arnéguy Fm (Klarr, 1974; Requadt, 1974; Heddebaut, 1973, 1975).

Shaly lime wackestone and shales with carbonate greywackes (typical Rueda Formation) are 50-120 m thick. The siltstone content increases towards the south-western Pyrenees and, particularly, in the upper half of the formation. It contains some rich trilobite associations, such as those described by de Villalta and Rosell (1969), Barrouquére and Pillet (1969), and Feist *et al.* (1985). Lower Pragian conodonts have also been found, such as *I. steinachensis* β and *Pelekysgnathus serratus brunsvicensis* (Valenzuela-Ríos, 1994; Sanz López, 1995) and the dacryoconarid *Nowakia acuaria* (Llopis Lladó, 1969). The Rueda Fm has been named the Cour de Vic alternation (Dommanget, 1977), "Alternancia Paralela" (Palau and Sanz, 1989), and Mandilar Fm (Valero, 1974) in the Central, North and Sallent domains, respectively (Fig. 2). The formation is more condensed and calcareous towards the eastern Pyrenees. In contrast, an increase in the sandstone supply occurs in the Basque domain, where about 200 m of green shales with sandstones and dolostones (Ondarolle Formation) are succeeded by the Aldudes quartzites (500 m thick) in the southwestern part of the Aldudes massif. Some brachiopod associations indicate a Pragian age (Carls in García-Alcalde *et al.*, in press). Clastic supplies were derived from the Cantabro-Ebroian massif (Heddebaut, 1973, 1975).

The uppermost part of the Rueda Fm evolved into a carbonate ramp corresponding to the Basibé and Castanesa formations (Mey, 1967) and the Pacino Formation (Valero, 1974; Bixel *et al.*, 1985). Other carbonate units are described in the north and eastern Pyrenees, although with local names. The Basibé Fm includes a prograding siliciclastic system (San Silvestre Member) located in the Baliera sub-domain and probably coeval with the Aldudes Quartzites system in the Basque domain. The San Silvestre Mb wedges out from the southwest to the northeast (Mey 1967b; Habermehl, 1970), where the Castanesa Fm comprises 30-60 m of dark-grey limestones. The Castanesa and Basibé basal beds yield Pragian conodonts from the *P. pireneae* Zone, such as *Pedavis mariannae* and *Polygnathus pireneae* (Boersma, 1973; Valenzuela-Ríos 1994; Valenzuela-Ríos in García-Alcalde *et al.*, in press). *Icriodus* aff. *vinearum* and *I. curvicauda* are below the San Silvestre Mb in a section where the member is thin (Sanz López, 1995), and they indicate the obsolete middle Siegennian after Carls (1987).

A deepening periodic tendency took place during the sedimentation of the black platy limestones of the Llaviero Member (Basibé Fm) and upper part of the Castanesa Fm, where dacryoconarid limestones prevail. However, shallow sedimentation corresponds to crinoidal limestones with corals in some parts of the Cadí nappe. The upper part of the Castanesa Fm and the Llaviero Mb contain *P. pireneae* with *I. curvicauda* and the successive entries of the conodonts *Icriodus celtibericus* and *Polygnathus excavatus* (Boersma, 1973; Valenzuela-Ríos, 1994; Sanz López, 1995; Valenzuela-Ríos, 2001; this volume), and consequently includes the base of the Lower Emsian. The top of the Castanesa Fm is correlated with the Middle *P. excavatus* Zone while a Zlichovian age is considered for the top of the Llaviero Mb, if the presence of *Icriodus b. bilatericrescens* is confirmed (Valenzuela-Ríos, 1994). The progressive Lower Emsian deepening in the southern Pyrenees can be equivalent in age with the d3bγ to d3cα units of the Santa Cruz Fm in Aragón described in Carls (1988); this pulse is also recorded in the Basque domain, where shallow carbonate-siliciclastic sedimentation ceased at the upper Siegennian (Carls in García-Alcalde *et al*., in press), now formal Lower Emsian, and is followed by the 100-200 m thick “Brachiopod Shale” of Klarr (1974).

Emsian to Eifelian rocks

The widespread Lower Emsian carbonate ramp was drowned below the Fonchanina (Mey, 1967) and Villech formations (Hartevelt, 1970; redefined after Sanz-López *in* Montesinos and Sanz López, 1999b). The shaly sedimentation was widely distributed in the Sierra Negra, Central and North domains, where the Fonchanina Fm is composed of around 15-60 m of dark shales with dark platy limestones. The upper part of an equivalent unit in the North domain, the Aulà Shales (Dommanget, 1977; Bodin, 1988; Sanz López, 1995), contains Lower Emsian *Polygnathus excavatus*, *O. steinhornensis* and *Icriodus latus* conodonts. It can also be correlated with the “Brachiopod Shales” in the Basque domain, Zlichovian-in age at the top.

Carbonates and marls form a sequence 30 m thick in the Castells thrust sheet (Nogueres zone), termed the Castells Beds (Sanz López *in* Montesinos and Sanz López, 1999b). The alternation changes to condensed ochre lime packstones with shales in the lower part of the Villech Fm, characteristic of the el Comte domain. The conodonts indicate the Middle *P.*

excavatus Zone to *P. gronbergi* Zone, Lower Emsian. In addition, white limestones are described in the East domain (Cygan and Raymond, 1979; Raymond and Weyant, 1982).

The shaly sedimentation evolved to the hemipelagic mixed ramp of the Villech Fm (el Comte domain) and Mañanet Fm (Sierra Negra domain). These formations are composed of nodular and argillaceous limestones with different amounts of red and green shales. The thickness of the Mañanet Fm increases from the north east (35-70 m, similar to the thickness of the Villech Fm) to the south west (80-280 m thick). The southern shallow-water, thicker sections contain some favositids, thamnoporids and brachiopods (Dalloni, 1930; García-López *et al.*, 1990) in the lower half. Bioherms are occasionally cited (Arche, 1971); tentaculitoids and ostracods were studied locally by Gross-Uffenorde *et al.* (1972), and Llopis Lladó (1969) found beds with "*Odontochile hausmanni*" in the Tor-Cassamanya syncline. Conodonts from the base were correlated with the *P. gronbergi* Zone, while the top contains *P. cooperi cooperi* and *P. costatus*, from around the Emsian/Eifelian interval (Buthroithner, 1978; García-López *et al.*, 1990). The top of the Mañanet Fm grades to shaly sedimentation, where Gourdon (in Dalloni, 1910) collected the brachiopod *Paraspyrifer cultrijugatus*.

In the Villech Fm, de Villalta and Rosell (1969) cited the trilobite *Odontochile* cf. *hausmanni* and *Proetus bohemicus*, and Llopis Lladó (1969) reported the dacryoconarid *Nowakia barrandei* below *N. cancellata* from the Zlichovian/Dalejian transition. Ammonoid findings are sporadic in the lower half, and common in the upper part of the Villech Fm and lower beds of the overlying Comabella Formation (Sanz López 1995; Montesinos and Sanz López, 1999b). It was termed the "*Anarcestes* horizon" (Dalloni, 1911), where Upper Emsian *Latanarcestes noeggerathi*, *Sellanarcestes* cf. *tenuior*, *Anarcestes* sp. and *Agoniatites* sp. occur. Upper Emsian conodonts of the *Polygnathus serotinus* or from the basal *P. c. patulus* zones are found in the upper beds (Sanz López, 1995). Undoubted *Polygnathus costatus patulus* is obtained in the Comabella Fm, composed of nodular limestones with the local development of crinoidal limestones (Cadí nappe).

One or several nodular limestone horizons are differentiated among shales in the Upper Frasnian of the central North domain (Dommanget, 1977; Bodin, 1988; Sanz López, 1995). Limestones and shales are also described for the Central domain, where they received different names (García Sansegundo, 1992), although Upper Emsian shales are abundant there, in the lower part of the so-called Entecada Fm (Kleinsmiede, 1960) and the Boneu Fm (Joseph, 1973, around 150 to 500 m thick).

A carbonate succession, with nodular, white and shaly limestones, was described in the Emsian of the East domain (Cavet, 1957; Cygan *et al.*, 1980; Raymond and Weyant, 1982).

The equivalent unit to the upper Villech and lower Comabella formations could be the cherty limestones and shales with corals and trilobites (Cavet, 1957; Cavet and Pillet, 1958, Cygan *et al.*, 1980), where *P. cultrijugatus* is also cited (els Aspres). This sedimentation indicates a low rate of subsidence with local shallow sedimentation.

The Emsian sequence has a significant clastic content and rhenish fauna in some units of the Basque domain, the Sallent and Ferrières sub-domains. Shales and nodular limestones are also present in the Sallent sub-domain (Formigal Formation of Valero, 1974). Limestones contain the *Anarcestes* horizon, but in conjunction with rhenish brachiopods from the sandy levels (Dalloni, 1910; Wensink, 1962). Thickness is estimated at around 200-400 m. Above, shales some 400 m thick have a sandy content and incorporate progressively more greywackes with bryozoans and quartzites upwards (Socotor and Acherito Beds). Dalloni (1910), Schmidt (1931) and Wensink (1962) reported rhenish brachiopods from some localities. Above these beds, marls and limestones (20-50 m) contain brachiopods such as *Anathyris esquerrai* and *Eryspirifer paradoxus*, and are followed by other limestones assigned to the *P. cultrijugatus* Zone by Wensink (1962). These carbonate beds are described from the Ferrières sub-domain by Mirouse (1966) with a rich rhenish fauna and, the trilobite *Asteropyge punctata* (see Mirouse and Pillet, 1961), indicating an Upper Emsian to lowermost Eifelian age. As for conodonts, Mirouse (1966) cited *Icriodus rectirostratus*, while *I. corniger* is reported by Valenzuela Ríos and Carls (1994), together with a basal Eifelian brachiopod association.

In the Basque domain, the “Brachiopod Shale” is replaced by carbonate greywackes south west of the Aldudes massif. The Urepel Formation (500-600 m thick) is a quartzite and dolostone complex of earliest to early Upper Emsian age (Carls in García-Alcalde *et al.*, in press) comprising 150 m of crinoidal and coralline limestones at Château-Pignon (Heddebaut, 1973). Above, the Urquiaga Formation consists of around 500 m of dolostones, limestones and shales. At the upper part of the formation reefal development has been locally described and there are brachiopods of the Emsian-Eifelian transition such as *Plicathyris alejensis* and *Paraspirifer cultrijugatus* from the Kalforro to the Marquesenea formations (Requadt, 1974; Juch and Schafer, 1974).

Eifelian rocks

A deepening episode is considered in the nodular limestones from the *P. c. costatus* Zone and condensed red beds are located in the upper Eifelian (*T. kockelianus* Zone) from the Comabella Fm in the el Compte domain (Sanz López, 1995). The Comabella Fm is intontegued with 40 m of black to bluish-grey shales and green marls with abundant dacryoconarids, trilobites, conodonts and the ammonoid *Anarcestes plebeius* (Taús Beds after Sanz López, *in* Montesinos and Sanz López, 1999b) in the Castells unit. These shales are the lateral equivalent to the Vilaller Formation (Sierra Negra domain) and the Entecada Formation (Central domain) in the central Pyrenees. It is interpreted having been produced in relation to an increment in the acommodation space and siliciclastic supplies during the Eifelian (Sanz López, 1995). The Vilaller Fm (=Civis Fm) consists of 100-400 m of brown and green shales with some inter-bedded limestone and lenticular calcareous sandstones with *I.* cf. *culicellus* (lower Eifelian age, Sanz López, 1995). Shaly sedimentation prevails in the North domain, where the thickness decreases from the north to the east, to about 60 to 100 m (Domanget, 1977; Bodin, 1988). It was termed the la Fajolle Shales (Raymond and Weyant, 1982), shales with trilobites in the Arize massif (Barrouquère, 1968), and shales and limestones in the Saint Barthélemy massif (Mangin, 1969). In contrast, nodular and white limestones correspond to carbonate sedimentation in the eastern French part of the chain (Raymond and Weyant, 1982; Cygan *et al*., 1980).

Eifelian marls, shales and limestones are followed by condensed nodular, crinoidal and brachiopod limestones, located in the first few metres of the Coral Limestones (Bresson, 1903) in the Sallent sub-domain, with middle to upper Eifelian conodonts (Mirouse, 1966; Joseph *et al.*, 1980). Eifelian condensation contrasts with shale deposition in the Sierra Negra and Central domains. Siliciclastic shallow facies of the Eznazu Formation (ca 200 m thick) are located in the southern part of the Basque domain. It consists of silty shales with Renish brachiopods and an increase in the enriched iron sandstone beds upwards, reflecting prograding siliclastic systems. Upper Eifelian conodonts occur at the top, correlated with the *P. ensensis* Zone (Requadt, 1979).

Uppermost Eifelian to lower Frasnian

Condensed hemipelagic limestones are observed in the el Comte domain, specifically, the upper Givetian contains strongly condensed sedimentation, with dacryoconarid calciturbidites and hardground development. In contrast, crinoidal limestones interpreted as slope-apron bodies and reefal biostromes are locally observed in thick sequences from the south western part of the Cadí nappe, mainly from the basal Givetian to the Frasnian (Sanz López, 1995). As mentioned before, the Coral Limestones (150-500 m thick) were deposited from the middle or upper Eifelian (Mirouse, 1966) in the western Sallent and Ferrières sub-domains. Biostromal limestones are recognised during the Givetian to the lower Frasnian (Lower to Middle *M. asymmetricus* zones after Mirouse, 1966, and Joseph *et al.*, 1984), with coral associations described by Mirouse (1966), Joseph and Tsien (1975) and Joseph *et al.* (1980, 1984). A carbonate platform also developed in the Baliera and Sierra Negra sub-domains, termed the Renanué Formation (120-130 m thick, Buchroithner, 1978) and the La Renclusa Limestone (Ríos, 1977). The base of the Renanué Fm furnished uppermost Eifelian to lowermost Givetian conodonts (*P. pseudofoliatus*, *P. eiflius*, *P. l. linguiformis* and icriodids). Givetian and lower Frasnian conodonts were obtained by Boersma (1973) and Liao (2000). La Renclusa limestones contain crinoidal and coralline beds (Waterlot, 1969).

Shaly sedimentation is described in the Central domain, locally has a sandy content, such as the so-called Auba Sandstones (130 m thick, García-Sansegundo 1992). Above, crinoidal limestones with coralline beds are located in the southern part of the domain, the Sant Esteve Limestone and “Coral Limestone” (95 m thick) in the vall d’Aran. These rich crinoids carbonates are replaced northwards by the dacryoconarid nodular Bandolers Limestone (Palau and Sanz, 1989), termed the Gabiedou and Pic de Larrue limestones westwards. These limestones provided conodonts from the Middle *varcus* Zone (middle Givetian) at the base, and Lower to Middle *M. asymmetricus* zones (lower Frasnian) at the top (Perret *et al*., 1972, Palau and Sanz, 1989; García-López *et al*., 1991).

The pattern is repeated in the Basque domain: coralline limestones are present to the south, the Oroz-Betelu outcrop (Chesterikoff, 1964), and limestones are also described in a small area (the Iturrumburu Limestone, ca. 250 m thick). In contrast, most localities are characterised by shales with some carbonate beds (Argus Shale, 800-1000 m thick). Conodonts from levels of these formations range from the Upper *P. ensensis* or the Lower *P. varcus* Zone to the Lower *M. asymetricus* Zone (Wirth, 1967; Requadt, 1974, 1979).

Eifelian and lower Givetian shales with limestone beds (60-100 m thick) are described from the North domain: Garonne area (Bouquet and Stoppel, 1975), Salat-Aulus (Domanget, 1977; Bodin, 1988), Saint Barthélémy massif (Mangin, 1969), the Fajolle series (Raymond and Weyant, 1982). The sedimentation changed to nodular limestones during the Givetian (Bodin, 1988). Nodular limestones, pink and white limestones (“Flambé de Villefranche”) and grey limestones are located in the East domain (Cygan *et al*., 1980).

Lower to upper Frasnian

In the Sallent sub-domain, several different lithologies lie above the Coral Limestones (Joseph *et al.*, 1984). Marls with interbedded nodular limestones were assigned to the Upper *M. asymmetricus* Zone (Joseph, 1973). The Ferreturas Formation of Wensink (1962, or the Lariste Series after Mirouse, 1966) is often described as 300-350 m of shales with sandstones and scarce limestones yielding Frasnian brachiopods, conodonts and rare corals (Joseph *et al.*, 1980). The lower part must be equivalent to the Lazerque Series (120 m thick) in the southern sections of the Subordán valley. It is composed of sandy limestones and shales, transported and sliced limestone blocks, with Frasnian brachiopods, corals and conodonts (e.g. *Ancyrodella curvata*, Joseph *et al.*, 1980).

Frasnian rocks are rare in the Baliera and Sierra Negra sub-domains. Sandy limestones (Renanue Limestones), interpreted as storm deposits in an inner platform (Sanz López, 1995), contain conodonts (Boersma, 1973) probably not much younger than the *Palmatolepis jamieae* Zone in the central Pyrenees Zone. It is followed by alternating shale and carbonates, the so-called Sahún Slates (Buchroithner, 1978), corresponding to distal tempestites. It is similar to the Ferreturas Fm and yields Frasnian brachiopods (Dalloni, 1910) and upper Frasnian conodonts (Sanz López, 1995).

In the southern outcrops of the Central domain, shales, sandstones and limestones have been described, many of them calciturbidites, (La Tuca Shales and limestones of García Sansegundo, 1992; 170 m thick in the vall d'Aran). Frasnian conodonts are assigned to the Upper *M. asymmetricus* Zone (García-López *et al.*, 1991) to *A. triangularis* or *P. rhenana* zones (Sanz López, 1995). These beds could be equivalent to the distal carbonate-clastic series described by Majesté-Menjoulas *et al.* (1991) in the western Pyrenees. In this region, about 40 m of nodular limestones, shales and sandstone in the Pic de Larrue yields conodonts from the Middle to Upper *M. asymmetricus* (Perret *et al*., 1972). In contrast, the typical sections of the Central domain are characterised by Frasnian quartzites above limestones with conodonts from the Lower *M. asymmetricus* Zone, basal Frasnian. The maximum thickness of the Frasnian siliciclastic formations reaches up to 600 m (Les Bordes Sandstones of Kleinsmiede, 1960), and several names have been used to designate them, such as the Sa Cal (García Sansegundo, 1992) and Montgarri formations (Palau and Sanz, 1989), and the Sia Series (Krylatov and Stoppel, 1971). This sandy sedimentation evolves upwards into turbiditic-like systems (Riu Nere sandstones and shales, 300-600 m thick), with Frasnian conodonts such as *A. curvata* and *A. lobata* and *Palmatolepis transitans* (Krylatov and Stoppel, 1971; Joseph, 1973). The grain and thickness of the siliciclastic beds decrease to the north, where it has been named the Tourmalet horizon (Bouquet *et al*., 1982).

Sandy sedimentation is substituted by shales in the North domain, for example, in the Haut Garonne (Pélissonnier, 1958; Crilat, 1983). Shales, marls and carbonate nodules are interlayered in the lower Frasnian (Middle to Upper *M. asymmetricus* zones after Bodin,

1988) in condensed nodular limestone of the northern outcrops, the Arize and Saint Barthélémy massifs (Barrouquère, 1968; Mangin, 1969).

Siliciclastic systems are also described in the Basque domain. The highest accumulation rate in the Aldudes-Quinto Real basin is recorded in the lower Frasnian, where several formations of quartzites and shales of the Irurita Group are 800-1500 m of thickness (de Boer *et al.*, 1974). Several beds yield lower Frasnian cephalopods and conodonts (Kulllman, 1973; Requadt, 1979). The Irurita coarse-grained unit is followed by finer-grained sedimentation, the Artesiaga Shales (500 m thick). Shallow deposits are represented by upper Frasnian bioclastic limestones (Picuda Formation) and shales with rhenish brachiopod, corals and conodonts (Wirth, 1967). Red sandstones (60-120 m, Abartán Formation) form a system intertonguing with shales and limestones.

Nodular limestones and bioclastic limestones are located in the eastern Pyrenees. Shales, caltiturbidites and intraformational carbonate breccias are common in the Lower Frasnian of the el Compte domain (Boersma, 1973; Sanz López, 1995). The presence of Frasnian intraformational breccia in the north Pyrenees has been interpreted as deriving from the activity of faults and differential subsidence (Raymond, 1987). The upper part of the nodular limestones provided Frasnian ammonoids such as *Beloceras* cf. *tenuistriatum*, *B.* cf. *subacutum* and *Manticoceras intumescens* (Llopis Lladó 1969; Llopis Lladó and Rosell, 1968). Reefal development and debris slope deposits are described in the Cadí nappe, where the thickness is considerably greater than for the hemipelagic nodular limestones. The reefal deposits were drowned as evidenced by nodular limestones with conodonts from the Late *P. rhenana* Zone to the lower Famennian *P. triangularis* Zone in the Comabella Fm (Sanz López, 1995, and unpublished data). This uppermost Frasnian pulse may be represented in black shales and limestones cropping out in parts of the Central and Basque domains.

Famennian rocks

The Frasnian /Famennian boundary is poorly studied in the Pyrenees. It is located within condensed nodular limestones although, locally, a discontinuity is observed in the Cadí nappe (this volume). Lower Famennian rocks are usually referred as the “Griotte” or as red nodular limestones in the Pyrenees, and the La Mena Fm in the Cadí nappe (Sanz López, 1995). It consists of 12-30 m of dark red, nodular limestones with local carbonate bars and storm layers with brachiopods. Abundant lower Famennian ammonoids occur, such as *Cheiloceras verneuili*, *Ch. subpartitum* and *Ch. amblylobum* (Dalloni, 1930; Schmidt, 1931; Cavet, 1957; Llopis Lladó 1969). At the top of the unit, Famennian conodonts of the Lower *P. marginifera*

Zone have been found (Sanz López, 1995). Red nodular limestones with cephalopods appear above nodular limestones more recently in deeper settings (Upper to Uppermost *P. crepida* zones after Sanz López, 1995).

The La Mena Fm is present in the Compte, East and a part of the North domains as a hemipelagic condensed carbonate ramp. The lack of red colour in the nodular limestones and an increase in shale content is described in the southern outcrops of the North domain (Bouquet and Stoppel, 1975), while marls and carbonate nodules are the lateral equivalent in the Arize massif (Barrouquère, 1968, Cygan, 1979). To the south and in the Central domain, they are replaced by poorly oxygenated black shales and limestones with increased thickness: the Campalias Shale in the vall d'Aran (Palau and Sanz, 1989). It is also recognised in the Mendibeltza (Heddebaut, 1975) and Aldudes massifs (ca. 30 m) of the Basque domain. Laterally, the shales increase in sand content and are then included in the upper parts of the Sia Series. The lower Famennian is also represented in the upper part of the Ferreturas Fm (Sallent domain), as evidenced by conodont *I. cornutus* and *P. semiscostatus* (Mirouse, 1966). Locally, bioclastic limestones are preserved in a few sections where they lie above unconformities (Perret, 1993), but lower Famennian rocks are lacking in many localities of the Sierra Negra domain.

Middle Famennian to Tournaisian rocks

The Barousse Formation (Perret, 1993) is composed of 25-706 m of light-grey, often nodular, micritic and cephalopod limestones. Schmidt (1931) and Llopis Lladó (1969) reported Famennian ammonoids from the el Compte domain. Middle-upper Famennian conodont standard zones are recognised by some authors, from the Lower *P. marginifera* Zone and other zones (Sanz López, 1995), because the Barousse Fm appears widely throughout the Pyrenees. It was deposited in a deep carbonate ramp with a low rate of subsidence, but it is extensively distributed and constitutes part of an expansive onlap above older Devonian rocks of the south-western Pyrenees. Thus, there is a sedimentary gap between Famennian crinoidal or nodular limestones of the Barousse Fm and older Devonian rocks (Mirouse, 1966; Perret, 1993) in some localities of the western Pyrenees. The Barousse Fm overlapps sedimentary highs and unconformably overlies Ordovician rocks in the Basque Cinco Villas massif (Hebbebaut, 1975).

The upper part of the Barousse Fm includes a "B" shale level, and a "C" nodular limestone (Boyer *et al.*, 1974, Perret 1993, Sanz López 1995). The former horizon is composed of shales a few to some tenths of centimetres thick, locally 2 m in the Central domain (Bouquet and

Stoppel, 1975). It is less extensive than the lower part of the Barousse Fm, and is a condensed sedimentation equivalent to the Hangenberg Event of Walliser (1985). The C limestone (about 2 m thick) has yielded the first Carboniferous conodonts of the *Siphonodella sulcata* Zone to the *S. cooperi*, or probably *S. crenulata* zones (Boersma, 1973; Perret, 1993).

Tournasian to Serphukovian rocks

Black radiolarian “Lydiennes”, cherts and shales, often contain phosphatic nodules and have been termed the Saubette Cherts by Perret (1993). It is located throughout the Pyrenees except for the southern marginal area and sedimentary highs. Delepine (1935a) described crustacean and ammonoid fauna, and Gourmelon (1987) reported radiolaria and spongia spicules, although a Tournaisian age is usually assigned based on its stratigraphic position. Condensed sandy transgressive limestones from the lower part of the Aspe-Brousset Formation (Perret, 1993), placed above an unconformity in marginal areas from the Sallent and Ferrières domains, are equivalent to the upper cherts in the basinal setting. These limestones have Devonian conodonts reworked with Tournaisian conodonts (Perret, 1993; Perret and Weyant, 1994), specifically, we think that the presence of *Pseudopolygnathus pinnatus* is indicative of the Upper *G. typicus* Zone. The Aspet-Brousset Fm is usually formed by 25-30 m of nodular to massive limestones with cephalopods. Frequently, conodonts from the first nodular carbonate beds of the Aspe-Brousset Fm correspond to the Upper Tournaisian *S. anchoralis* Zone, in which case the limestones lie above the Saubette Mbr or older eroded rocks. Aspe-Brousset Limestones include cherts of the Louron Member (Perret, 1993) in many localities. These cherts are light greenish with inter-bedded graded tuff layers and green shales (Krylatov, 1963).

Crilat (1983) differentiated two kinds of chert sequences. A condensed sequence with abundant phosphate nodules and carbonaceous matter (the Cierp-Crohuens) located towards the marginal areas. The other sequence (the Peyresourde-Vielle Aure) is thicker, with Louron cherts directly above Saubette cherts. The second sequence from deeper settings crops out in the Basque domain, the Central domain, parts of the North domain (Haut Salat, the eastern part of the Saint Barthélemy massif and the Fajolle series) and the eastern part of the el Comte domain.

The biostratigraphy from the Aspe-Brousset limestones is primarily based on Viséan to Serphukovian conodonts (Marks and Wensink, 1970; Buchroithner, 1979; Perret and Weyant, 1994; among others). The upper beds of the Aspet-Brousset Fm contain conodonts from *the L. nodosa* Zone, from upper Viséan to Serpukhovian in age. Only the Arnsbergian ammonoid

Delepinoceras sp. is cited in the upper beds of the formation in the Sallent sub-domain (Skompski *et al.*, 1995). Some green shale beds can be found among the Aspet-Brousset limestones, but they are often located above in the North domain (the Larbont facies of Clin, 1959), and in part of the Basque domain (the Arga Formation). These shales were interpreted as the drowned surface of the foreland Variscan basins by Delvolvé *et al.* (1983). The shales yielded an upper Viséan goniatite association in the Mouthoumet massif (Bessière *et al.*, 1980), North and Basque domains (Mandette fauna of Delépine, 1935b), but Serpukhovian (Arnsbergian) ammonoids also occur in the latter area.

Lower Carboniferous siliciclastic rocks

The Aspet-Brousset Fm can have an unconformable contact below the overlying siliciclastics rocks on Culm Facies, termed the Bellver Formation in the el Comte domain (Brower in Hartevelt, 1970). Culm rocks include a large diversity of lithologies; Delvolvé *et al.* (1983) and Delvolvé *et al.* (1996) interpreted siliciclastic rocks as flysch sediments, corresponding to deep fan systems. The systems have poor lateral continuity, with patchy outcrops, but these authors recognised the presence of slope, canyon and fan facies. However, Sanz López (1992) has locally interpreted some lower bodies in the Bellver Fm as fan delta deposits, below turbiditic facies. These shallow-water facies fossilize olistoliths, exo-karstic sheets, palaeokarst fillings and faults with a normal component. Bichot (1986) previously described tensional faulting of the underlying formations during the Bellver sedimentation, and normal faults were actives in places during the early development of the foreland basin. On the other hand, palaeokarst development with iron and manganese ore bodies was located below the Bellver Fm and related in origin with pre-concentration in the La Mena Fm in several localities of the north and eastern Pyrenees (Jaeger *et al.*, 1956, 1958; Fournié, 1956; Sanz López, 1992).

The younger age of the flysch deposition from the Viséan at the Montagne Noire and the eastern Pyrenees to the Bashkirian and Moscovian in the westernmost Pyrenees has been interpreted as reflecting the south-westward migration of the synorogenic Variscan flysch trough. (Mirouse *et al*., 1983; Engel, 1984; Delvolvé and Perret, 1989). Flysch sedimentation predated the deformation of rocks and the setting of thrust sheets, and was consequently in front of the advancing orogenic belt. The age of the flysch is based on scarce fossils, the age considered for the underlying formations, and the presence of reworked carbonate clasts from shallow-water facies. The occurrences of these carbonate clasts in the gravity deposits of the Culm rocks evidences the collapse of platforms, whose remains have not been found in situ in the Pyrenees. Lower to middle Viséan shallow-water facies are reworked as limestone turbidites in the Montagne Noire and form a tectonic unit in the Mouthoumet massif (Bessière and Perret, 1977). Carbonate breccia and bedded limestones are composed of blocks eroded from the Viséan platform with a younger Viséan V3b/c age (Bessière *et al.*, 1984). An upper Viséan age for carbonate reworked clasts is deduced by Delvolvé *et al.* (1994) in the Arize massif (North domain) with an uppermost Viséan age for the first siliciclastic beds on Culm facies. Viséan clasts can be found in the north and eastern Pyrenees, while the top of the Aspe-Brousset Fm. has an upper Viséan age. An Arnsbergian age was reported for shallow-water carbonates in the Arize massif (Vachard *et al.*, 1991) and north central Pyrenees (Ardengost limestones, Perret and Vachard, 1977). Reworked clasts have a Yeadonian age (Bashkirian) in the south western Pyrenees (Delvolvé and Perret, 1987; Vachard *et al.*, 1989). The siliciclastic beds contain beds with Kinderscoutian and Yeadonian ammonoids (Schmidt, 1931, 1951; Waterlot, 1969; Kullmann, 1973; Kullmann and Delvolvé, 1985) and other groups (see Devolvé *et al.*, 1996) in the central and western part of the southern Pyrenees (Sierra Negra and Basque domains). Younger reworked algae and foraminifera come from the Kashirskian (Westfalian C) in the Basque Cinco Villas massif (Delvolvé *et al.*, 1987).

The Iraty Formation (Perret, 1983) is located between the Aspe-Brousset and Bellver formations in the Sierra Negra and Basque domains. The Iraty Fm is composed of laminated limestones with gravity flow deposits corresponding to carbonate ramps that developed on the passive margin of foreland basins. Its age ranges from upper Sepukhovian at the base to different horizons in the Baskhirian (Perret, 1983, 1993), based on the southward progressive back-stepping of carbonate ramp sedimentation at the distal margin during flexural-induced transgression of the southern foreland. The outer ramp facies are located in the central and north western Pyrenees, where Bresson differentiated 150-200 m of limestones, marls and shales as the Cambasque unit (Mirouse, 1966).

DISCUSSION

Major tendencies can be deduced from the distribution of the Devonian to Carboniferous pre-Variscan rocks and facies throughout the Pyrenean chain. Devonian shallow-water conditions are located in a marginal southern area of the Pyrenees, where a high rate of subsidence is linked to the development of carbonate platforms and siliciclastic systems (Mirouse, 1966; Raymond, 1987; Carls, 1988; Majesté-Menjoulas *et al.*, 1991; Sanz López, 1995). Thus, the Pragian siliciclastic systems (Baliera sub-domain and Basque domain) developed a wedge shape from the southwest to the northeast (Mey, 1967; Requadt, 1974; Heddebaut, 1975). Reefal limestones are located in a south west Middle Devonian platform in the Sierra Negra domain.

The southern sedimentary high or Cantabro-Ebroian massif (Llopis Llado *et al*., 1968; Carls, 1988), is not clearly delimited, since southern Alpine units have no preserved Devonian rocks below the Mesozoic and Tertiary formations in the central and eastern part of the chain. Heddebaut (1975) recognised a western margin for the Devonian of the Pyrenees in the Basque Cinco Villas massif, where middle Famennian rocks are placed above Ordovician rocks. Upper Devonian or at least Carboniferous limestones were drilled in the western Pyrenees below the cover thrust sheets (Cámara and Klimowitz, 1985; boreholes 109 and 152 in Lanaja, 1987). These rocks can lie unconformably above older, tilted Devonian rocks, as observed in the southern outcrops of the western and central Pyrenees.

North of the marginal area, there is a central subsiding trough (Central domain) that was poorly differentiated during the Eifelian and had an asymmetric geometry from the lower Frasnian. Majesté-Menjoulas *et al*. (1991) proposed the subdivision of the trough into some blocks bounded by listric faults, based on differences in sedimentation. The southern margin of the trough has reefal-influenced carbonate deposits, while thick siliciclastic bodies with high accumulation rates are located towards the inner part of the trough. Thick accumulation and shallow-water sedimentation is recognised in the Basque domain, where many of the clastic supplies may have entered the basin. Clastic influx and deeper conditions extended southwards during the middle Frasnian (Middle-Upper *M. asymmetricus* Zone), and the reef development ceased.

Another problem is the continuation of the central trough (Central domain) towards the eastern Pyrenees. Frasnian sandstones are lacking east of the Noguera Pallaresa river and shaly formations are present in the successions of the Tor synclinorium (Sierra Negra domain) and the La Fajolle series (North domain), but no sandy bodies have been described. One possibility is the continuation of the trough towards the La Fajolle series, North domain, where Tournasian cherts show a sequence of deep basin type in the sense of Crilat (1983). Consequently, the Frasnian trough took had very low subsidence and, probably, coarse-grained supplies did not arrive to the eastern Pyrenees.

From the Central domain to the North domain (northern border of the Axial zone and the North-Pyrenean massifs), the thickness of the sequences and the grain-size progressively decrease in the Frasnian siliciclastic rocks. Thus, first shales prevail, followed by condensed carbonates. These carbonates were formed in a wide hemipelagic sedimentary area with low subsidence that is located towards the north east Pyrenees. Along the same lines, Cygan (1995) concluded some deeper water conditions in the northern and eastern areas of the Pyrenees than in the southern and western ones, based on his conodont biofacies studies.

A west to east progressive decrease in subsidence and a deeper-water environment is juxtaposed to the south-north scheme with a central trough. This consideration derives from the observation of Lower Devonian rocks where detrital supplies did not arrive to the eastern part of the Pyrenees. It is also based on the greater development of the reefal carbonate platform and siliciclastic systems in the south west (Sallent sub-domain) than in the east. The same circumstance is observed throughout the Baliera sub-domain and in the Cadí nappe (Sanz López, 1995). In this scheme, the occurrence of the Ferrières sub-domain in the western Pyrenees agrees with the hemipelagic limestones and shales prevailing in the central North domain and carbonates to the east (East domain). The condensed east carbonate area has affinities with the Devonian stratigraphy from the Mouthoumet massif and Montagne Noire (Raymond, 1987; Demange, 1994), indicating an epicontinental platform somehow barred from clastic influx, and where sedimentary highs and small basins can be differentiated from the upper Eifelian on (Crilat, 1983).

Finally, the Cantabro-Ebroian massif could also tilt eastwards, because Lower Devonian rocks preserved in the Catalan coastal chains are characterised by pelagic facies. Middle to Upper Devonian rocks are usually lacking in the Catalan coastal chains, except some siliciclastics preserved in small areas linked to faulted blocks in the southern outcrops (Melgarejo, 1992). Furthermore, a thick, supposed Devonian succession passes through the central Ebro basin subsoil (drill 97, Ballobar, see Lanaja, 1987). The local presence of the Upper Devonian successions can be explained not only by the tilting of the Cantabro-Ebroian massif (as in the Cantabrian Mountains, see van Loevezijn 1986), but also by the creation of longitudinal troughs along the massif, as Carls (1988) proposed in the Iberian chains.

The end of the massif as a sedimentary high took place from the uppermost Famennian-upper Tournasian to Viséan biochemical condensed sequences above a widespread unconformity. Since the Viséan, the onset of the flysch sedimentation is younger towards the southwest, where Devonian marginal and shallow-water areas are inferred for the Pyrenees. Kinderscoutian limestones deposited in front of the synorogenic siliciclastic wedges are located in the central and western parts of the southern Pyrenees and its counterpart was described in the southern outcrops of the Catalan coastal ranges (Sanz-López *et al*., 2000).

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FIGURE CAPTIONS

Figure 1. Geological sketch of the Pyrenean Palaeozoic based on García Sansegundo (1992) showing the sedimentary domains used in the text.

Figure 2. Correlation chart among the lithostratigraphical units from different domains of the Pyrenees, based on Sanz-López (1995). The references to the units are found in the manuscript. Vertical lines-plot corresponds to sedimentary gaps.

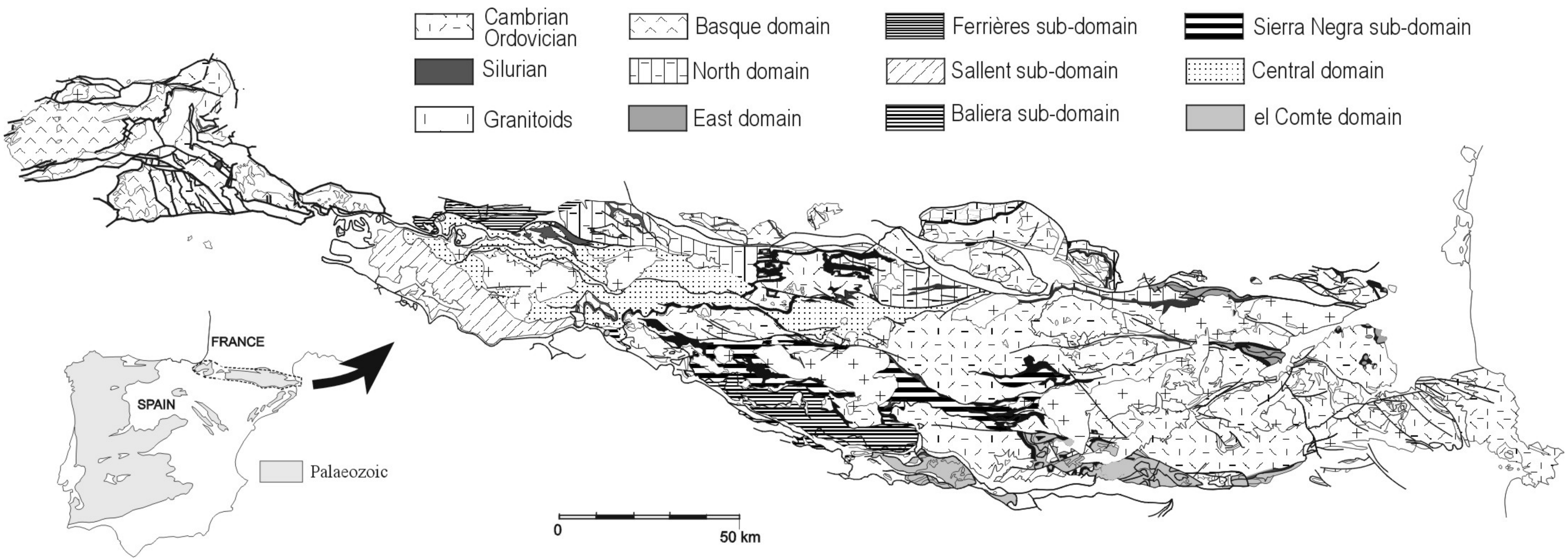
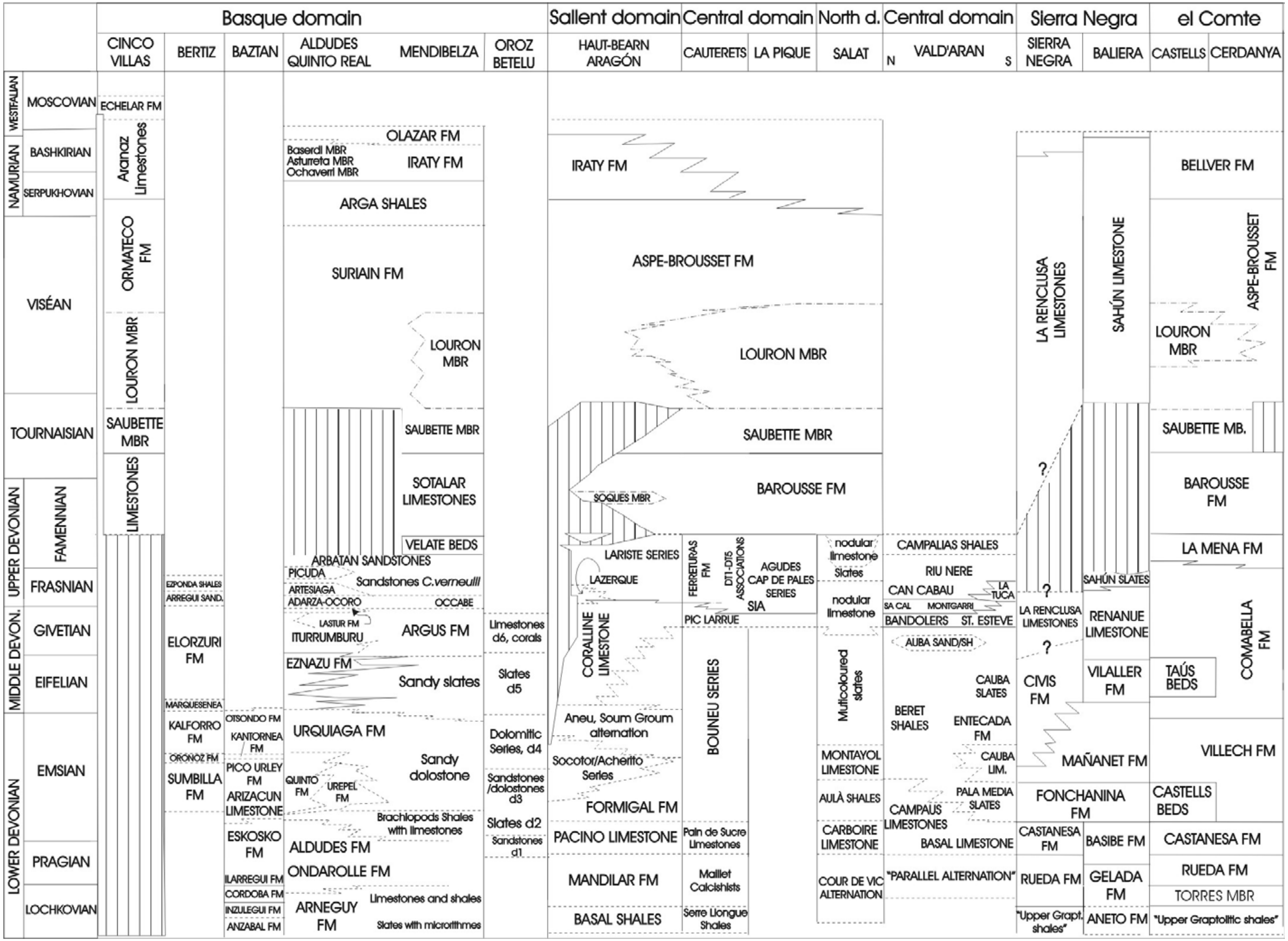

Cambrian
Ordovician
Silurian
Granitoids
Basque domain
North domain
East domain
Ferrières sub-domain
Sallent sub-domain
Baliera sub-domain
Sierra Negra sub-domain
Central domain
el Comte domain
FRANCE
SPAIN
Palaeozoic
0
50 km

FIGURE 1


Basque domain
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Central domain
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Central domain
Sierra Negra
el Comte
CINCO VILLAS
BERTIZ
BAZTAN
ALDUDES QUINTO REAL
MENDIBELZA
OROZ BETELU
HAUT-BEARN ARAGÓN
CAUTERETS
LA PIQUE
SALAT
N VALD'ARAN S
SIERRA NEGRA
BALIERA
CASTELLS
CERDANYA
WESTFALIAN
MOSCOVIAN
NAMURIAN
BASHKIRIAN
SERPUKHOVIAN
VISÉAN
TOURNAISIAN
UPPER DEVONIAN
FAMENNIAN
FRASNIAN
MIDDLE DEVON.
GIVETIAN
EIFELIAN
LOWER DEVONIAN
EMSIAN
PRAGIAN
LOCHKOVIAN
ECHELAR FM
Aranaz Limestones
ORMATECO FM
LOURON MBR
SAUBETTE MBR
LIMESTONES
OLAZAR FM
Baserdi MBR
Asturreta MBR
Ochaverri MBR
IRATY FM
ARGA SHALES
SURIAIN FM
LOURON MBR
SAUBETTE MBR
SOTALAR LIMESTONES
VELATE BEDS
ARBATAN SANDSTONES
PICUDA
Sandstones C.verneulli
ARTESIAGA
ADARZA-OCORO
OCCABE
LASTUR FM
ITURRUMBURU
ARGUS FM
EZNAZU FM
Sandy slates
URQUIAGA FM
Sandy dolostone
QUINTO FM
UREPEL FM
Brachiopods Shales with limestones
ALDUDES FM
ONDAROLLE FM
Limestones and shales
ARNEGUY FM
Slates with microrithmes
EZPONDA SHALES
ARREGUI SAND.
ELORZURI FM
MARQUESENEA
KALFORRO FM
ORONOZ FM
SUMBILLA FM
OTSONDO FM
KANTORNEA FM
PICO URLEY FM
ARIZACUN LIMESTONE
ESKOSKO FM
ILARREGUI FM
CORDOBA FM
INZULEGUI FM
ANZABAL FM
Limestones d6, corals
Slates d5
Dolomitic Series, d4
Sandstones /dolostones d3
Slates d2
Sandstones d1
IRATY FM
ASPE-BROUSSET FM
LOURON MBR
SAUBETTE MBR
BAROUSSE FM
SOQUES MBR
LARISTE SERIES
LAZERQUE
CORALLINE LIMESTONE
Aneu, Soum Groum alternation
Socotor/Acherito Series
FORMIGAL FM
PACINO LIMESTONE
MANDILAR FM
BASAL SHALES
FERRETURAS FM
DT1-DT5 ASSOCIATIONS
AGUDES CAP DE PALES SERIES
SIA
PIC LARRUE
BOUNEU SERIES
Pain de Sucre Limestones
Malliet Calcishists
Serre Llongue Shales
nodular limestone
Slates
nodular limestone
Multicoloured slates
MONTAYOL LIMESTONE
AULÀ SHALES
CARBOIRE LIMESTONE
COUR DE VIC ALTERNATION
CAMPALIAS SHALES
RIU NERE
CAN CABAU
LA TUCA
SA CAL
MONTGARRI
BANDOLERS
ST. ESTEVE
AUBA SAND/SH
CAUBA SLATES
BERET SHALES
ENTECADA FM
CAUBA LIM.
PALA MEDIA SLATES
CAMPAUS LIMESTONES
BASAL LIMESTONE
"PARALLEL ALTERNATION"
LA RENCLUSA LIMESTONES
?
LA RENCLUSA LIMESTONES
?
CIVIS FM
MAÑANET FM
FONCHANINA FM
CASTANESA FM
RUEDA FM
"Upper Grapt. shales"
SAHÚN LIMESTONE
SAHÚN SLATES
RENANUE LIMESTONE
VILALLER FM
BASIBE FM
GELADA FM
ANETO FM
BELLVER FM
ASPE-BROUSSET FM
LOURON MBR
SAUBETTE MB.
BAROUSSE FM
LA MENA FM
COMABELLA FM
TAÚS BEDS
VILLECH FM
CASTELLS BEDS
CASTANESA FM
RUEDA FM
TORRES MBR
"Upper Graptolitic shales"