

Paleozoic stratigraphy of the Central and Northern part of the Catalanian Coastal Ranges (NE Spain)

M. JULIVERT and H. DURÁN

Univ. Autònoma de Barcelona, Dpt. de Geologia, 08193 Bellaterra (Barcelona, Spain)

ABSTRACT

The Paleozoic stratigraphic succession in the Catalanian Coastal Ranges spans the interval from Cambrian(?) to Carboniferous, with only one break, separating the pre-Carboniferous part of the sequence from the Carboniferous. The oldest rocks exposed form a sequence of schists, fine grained sandstones, gneisses (laminar pre-Hercynian intrusions), marbles, orto- and para-amphibolites and calcisilicate rocks. Comparison with other localities suggests an Early Cambrian age (or perhaps in part older). Upwards the sequence becomes more monotonous and consists only of schists (or slates where the metamorphic grade is lower) and thin fine-grained sandstone layers (Cambrian-Ordovician). Still higher in the sequence, an alternation of greywackes and slates is found, with interlayered mud-supported conglomerates at its lower part and acid volcanic rocks which occur throughout the whole sequence. This part of the sequence has provided the oldest faunas known in the Catalanian Coastal Ranges, which indicate the Caradoc. Finally, in its uppermost part, the Ordovician sequence contains some thin limestone layers that contain Ashgill faunas. The Silurian, from Llandovery to Lower Ludlow, consists of black graptolitic shales with dolerite sills, whilst the upper Ludlow, Pridolian and Devonian consist of nodular limestones and marls with pelagic and hemipelagic faunas. The youngest Devonian faunas found correspond in general to the Emsian. The existence of a gap at this point of the sequence suggests the possibility that part of the Devonian could have been eroded. The Carboniferous is characterized by a thick culm sequence (Visean to Westphalian?), resting on thin chert and limestone layers (Tournaisian and Visean). A comparison with neighbouring areas shows a similarity regarding succession and facies with other Paleozoic massifs around the Western Mediterranean.

Key words: Catalanian Coastal Ranges. Paleozoic stratigraphy.

RESUMEN

La serie estratigráfica paleozoica en las Cadenas Costeras Catalanas comprende desde un probable Cámbrico al Carbonífero, si bien con una interrupción, que separa la serie pre-carbonífera de la

carbonífera. Las rocas más antiguas que afloran forman una sucesión esencialmente de esquistos, areniscas de grano fino, gneises (intrusiones laminares pre-hercinianas), mármoles, orto- y para-amfibolitas y rocas calcosilicatadas. Una comparación con otras localidades permite asignar a estas rocas una edad del Cámbrico inferior (o tal vez más antigua, en parte). Hacia arriba, la serie se hace más monótona y pasa a una alternancia de esquistos (o pizarras donde el grado metamórfico es menor) y capas delgadas de areniscas de grano fino (Cámbrico-Ordovícico). Por encima, se encuentra una sucesión de grauwacas y pizarras, con niveles de cantos englobados en una matriz pelítica, intercalados cerca de su base y con niveles de rocas volcánicas distribuidas por toda la sucesión. Este conjunto ha proporcionado las faunas más antiguas de las Cadenas Costeras Catalanas, que indican una edad del Caradoc. Finalmente, en su parte más alta, la sucesión ordovícica contiene unas delgadas capas de caliza que han proporcionado faunas del Ashgill. El Silúrico, del Llandovery al Ludlow inferior, consiste en pizarras negras con sills de doleritas, mientras que el Ludlow superior, el Pridoliense y el Devónico inferior están formados por calizas nodulosas y margas ricas en faunas pelágicas y hemipelágicas. Los niveles más modernos del Devónico que se han reconocido corresponden en general al Emsiense. La existencia de una discontinuidad estratigráfica con el Carbonífero permite pensar que existía un Devónico más completo que ha sido erosionado. El Carbonífero se caracteriza por estar formado esencialmente por una espesa sucesión de tipo culm (Viseense-Westfaliense?), que se apoya sobre unos delgados niveles de lilitas y de calizas (Tournaisiense y Viseense). Una comparación con los otros macizos paleozoicos alrededor del Mediterráneo occidental pone de manifiesto la existencia de una gran similitud tanto en el tipo de sucesión como en las facies.

Palabras clave: Cadenas Costeras Catalanas. Paleozoico.

INTRODUCTION

The Paleozoic stratigraphical sequence in the Catalanian Coastal Ranges can be divided into two separate parts divided by a disconformity (or may be by an

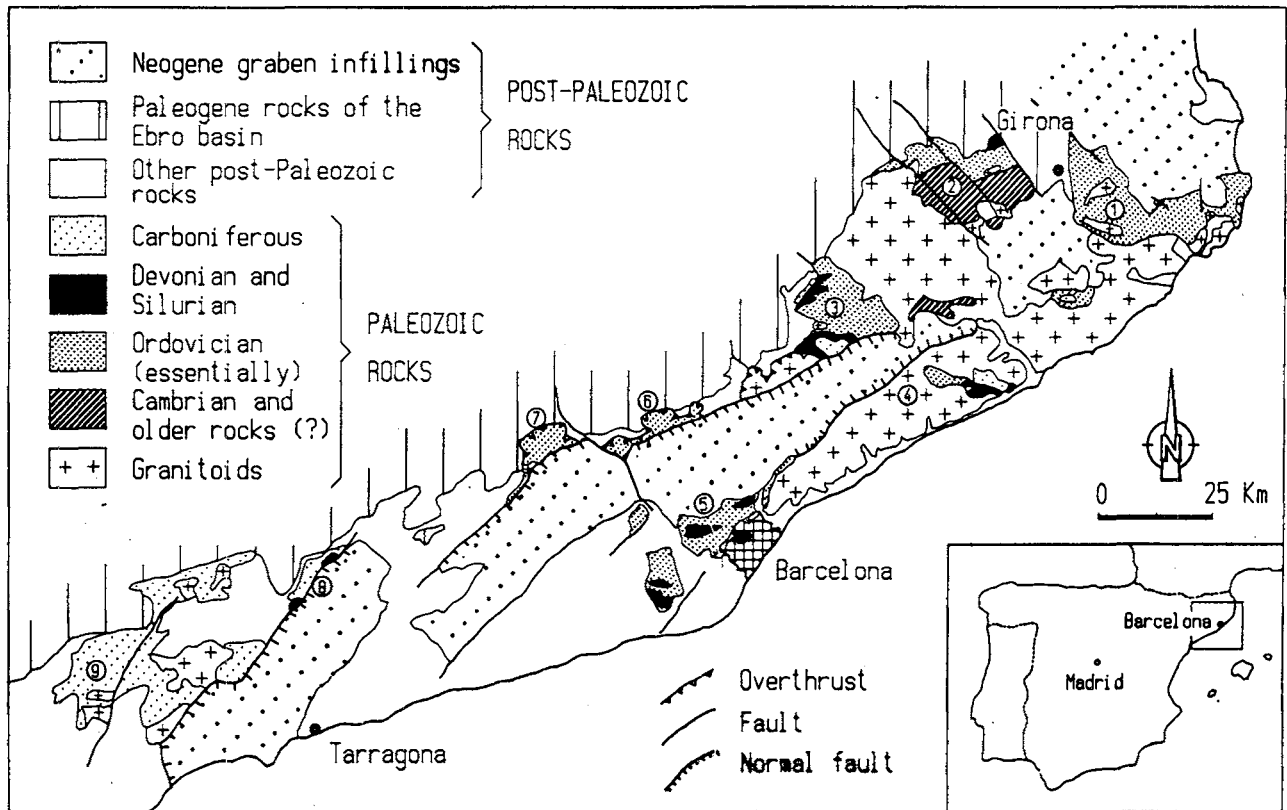


Figure 1.- Geological sketch of the Catalonian Coastal Ranges. 1, Gavarres. 2, Guillerries. 3, Montseny. 4, Montnegre. 5, Collserola (Tibidabo). 6, Pedritxes. 7, Capellades area. 8, Serra de Miramar. 9, Priorat-Prades block.

angular unconformity). These parts are: 1) the pre-Carboniferous sequence, forming a conformable succession from the lower Cambrian (?) to the lower Devonian, and, 2) the Carboniferous, essentially formed by a thick terrigenous sequence (culm facies).

Pre-Carboniferous rocks are mainly found from Barcelona to the north, separated in several areas by late Hercynian granitoids and by Mesozoic and Tertiary cover sediments (Fig. 1). Carboniferous rocks crop out mainly in the southernmost part of the Catalonian Coastal ranges (Priorat-Prades).

Paleozoic rocks were affected by polyphase deformation and metamorphism during the Hercynian orogeny. However, high-grade metamorphism is restricted to small areas (southern Guillerries and southwestern Montseny) in the lowest stratigraphical levels. Most rocks in the Catalonian Coastal Ranges have suffered metamorphism under greenschist facies conditions, and the highest part of the stratigraphical sequence (Carboniferous) either lack metamorphism or has at most undergone anchimetamorphism.

The pre-Silurian sequence is rather monotonous and almost unfossiliferous. The oldest known faunas correspond to the Caradoc and have been found only in a few localities. The scarcity of pre-Silurian faunas, together with strong deformation, abundance of granitoids and lack of good mapable horizons in the pre-Silurian sequence, have been the reasons for the slow progress in the knowledge of the Paleozoic stratigraphy since the early papers by Almera (1891, 1896, 1901) and Barrois (1893, 1913), and the synthesis by Faura Sans (1913), Schriel (1929) and Ashauer and Teichmüller (1935). However, during the last decade active research has been in progress on the structure, metamorphism, plutonism, volcanism and metalogeny of the Catalonian Coastal Ranges. Several areas have been carefully mapped and a new search for Caradoc, Silurian and Devonian faunas has been undertaken (Julivert 1989; Julivert *et al.* 1985, 1987; Villas *et al.* 1987; García-López *et al.* 1990).

In this paper, the Paleozoic stratigraphy of the central and northern Catalonian Coastal Ranges will

be presented, giving the general sequence for the Ranges and also some local successions on the most representative localities. Attention will be focussed on the pre-Carboniferous rocks, although a brief description of the small Carboniferous outcrops existing will also be included.

CAMBRIAN AND ORDOVICIAN

The oldest rocks are exposed in the southern part of Les Guilleries and the southwestern part of the Montseny massifs (Fig. 2). They form essentially a succession of schists with interlayered fine-grained sandstones, gneisses, marbles, amphibolites and calcsilicate rocks. Some of these rocks have been known since last century (Vidal, 1886; Faura Sans, 1913); however, a systematic survey was not undertaken until several decades later (Van der Sijp, 1951; Viladevall, 1978). A detailed study has been carried out more recently by Durán (1985, 1990) in Les Guilleries and Huerta (1989) in the southwestern part of the Montseny massif.

The sequence can be best observed at Les Guilleries. In this massif, the gneisses apparently form concordant bodies, representing pre-Hercynian sheet-shaped intrusions and/or volcanic material. The gneisses seem to form several layers, and the main body separates two units named by Durán (1986, 1990) the Osor and Susqueda formations. The Osor Formation, exposed below the gneisses, consists of schists, amphibolites and some calcsilicate layers. The Susqueda Formation consists of interlayered schists and fine-grained sandstones, with a 20 m thick marble horizon some 50 metres above the top of the gneisses. Marbles, probably corresponding to the same horizon, and gneisses similar to those of Les Guilleries are also found in the southwestern part of the Montseny massif (Huerta, 1989).

All the above quoted rocks show a metamorphism above the andalusite isograd, and in Les Guilleries even the sillimanite/K-feldspar zone is reached. In consequence, no fossils are found and the ages must be assigned by comparison. A comparison with the Pyrenees (Cavet, 1957; Hartevelt, 1970) shows a strong similarity between the Susqueda and the Canavellas formations. However, as in the Catalanian Coastal Ranges, no fossils older than the Caradoc have ever been found in the central and eastern Pyrenees. Their age has been tentatively assigned to the Cambrian, by lithological comparison (existence of a carbonate horizon) with the Montagne Noire and the Iberian massif. However, an age assignment based upon the existence of a major carbonate unit is doubtful, since more than one carbonate horizon occurs in the Cambrian (and very Late Precambrian?) of neighbouring Hercynian domains, where there is a better paleontological con-

trol. Two possibilities for correlation exist: 1) a correlation with the Cambrian carbonate formation of northwestern Spain (Láncara-Vegadeo Formation, Early and Middle Cambrian), central Spain or the Iberian Chain (Navalucillos Limestone and Ribota Dolostone respectively, Late Early Cambrian), and 2) a correlation with the carbonates of the Cambrian-Precambrian boundary or the uppermost Precambrian (carbonates in the lower part of the Herrería-Candana Formation in northwestern Spain, carbonates near the Precambrian-Cambrian boundary in central Spain).

Upwards, the sequence becomes monotonous and consists only of schists (or slates, where the metamorphism decreases) with interbedded fine-grained sandstone layers. This sequence likely forms most of the Montseny massif, between its southeastern part where the marbles and gneisses are exposed and its northwestern part where Caradoc fossils have been found and where the upper Ordovician could be mapped. In the northern part of the Montseny, and at a lower position than the faunas, laminated facies exist which could be compared to the Jujols Formation of the Pyrenees. In any case, the first Caradoc fossils occur (perhaps more than 1000 m) above the carbonate horizon found in southeastern Montseny.

In the Montseny massif, the uppermost part of the Ordovician sequence (Figs. 2 and 3) consists of a 30-60 m thick horizon of grey-green slates (or shales) somewhat sandy, which in its upper part contains brachiopod and bryozoa fauna. A few metres above this fauna is a thin limestone bed (10-30 cm). This bed, although discontinuous, can be followed fairly easily in the Avencó creek area. Above the limestone bed there are some 100 m of dark-grey pelites with a pencil structure formed due to the intersection of a weak cleavage with a diagenetic foliation parallel to bedding. Above, the typical black graptolite bearing Silurian shales are found.

The described sequence can be compared to that of the Pyrenees, and possibly correlated with it. The limestone bed corresponds to the Estana Limestones, the shales above to the Ansovell Formation, and the fossiliferous beds below to the Cavà Formation. The boundary between Cavà and Jujols, outlined in the Pyrenees by a conglomerate horizon (Rabassa Conglomerate; Hartevelt, 1970), can not be traced at present in the Montseny massif. The ages assigned could be the same as in the Pyrenees. The brachiopod fauna found below the limestone horizon indicates an age between the Late Caradoc and the Middle Ashgill, the limestones may be Ashgill, and the shales above could be Ashgill and/or Silurian. A list of the species found and a discussion on their stratigraphical implications can be found in the papers by Villas *et al.* (1987) and Julivert *et al.* (1987).

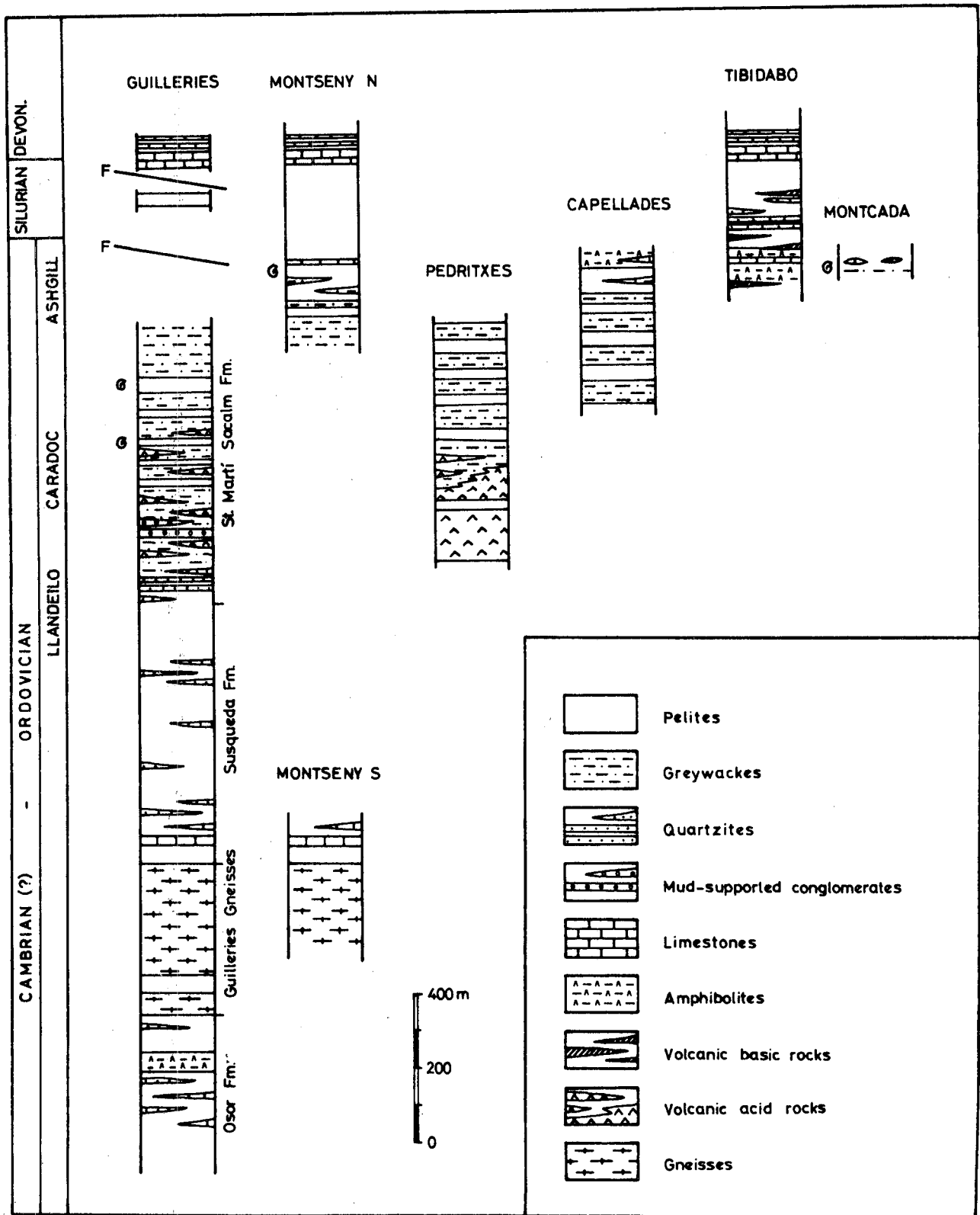


Figure 2.- Paleozoic stratigraphic sequences of the Catalonian Coastal Ranges, based on Durán (1985, 1990; Guillerries), Huerta (1990; Southeast Montseny), Ubach (1990, Pedritxes), Serra (1990; Capellades), and Julivert and Durán (1981, Tibidabo, and this paper, Northwest Montseny). F, fault.

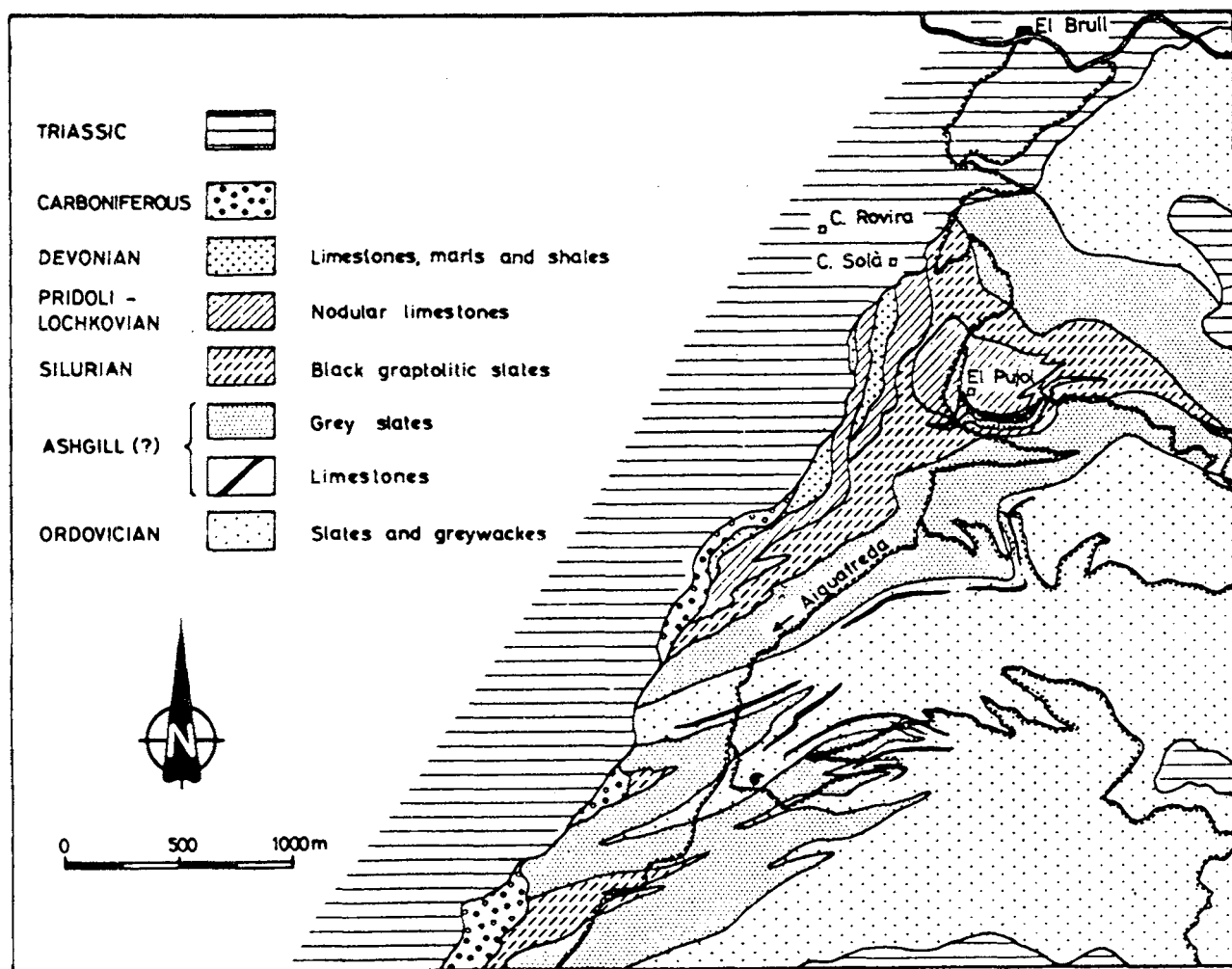


Figure 3.- Geological map of the northwestern part of the Montseny massif (Avencó creek area).

In the Guillerries massif the sequence is somewhat different. The upper part of the Ordovician is formed by a sequence of greywakes, slates, acid volcanic rocks (Durán, 1990; Durán *et al.* 1984) and some layers of mud-supported conglomerates near its base (Puig Sa Calm Formation of Durán, 1990, about 1000 m thick). Below the conglomerates, there is an alternation of slates and quartzites, faulted against the above quoted high-grade rocks which form the oldest beds exposed in Les Guillerries. Towards the top, the sequence is again faulted, so that the top of the Ordovician and its stratigraphical contact with the Silurian cannot be observed. The stratigraphical units seen in northwestern Montseny are not observed in Les Guillerries. Two fossiliferous localities have been found in the sequence containing acid volcanic rocks (Durán 1985). The faunas indicate a Caradoc or Caradoc to middle

Ashgill age. For a more complete discussion and the list of species found the reader is referred to the papers by Villas *et al.* (1987) and Julivert *et al.* (1987).

A comparison with the Pyrenees makes possible the correlation of the sequence containing acid volcanics with the Pyrenean Cavà Formation. This is supported by the Caradoc faunas found in both areas. Also the conglomerates of Les Guillerries can be compared to the Rabassa Conglomerate of the Pyrenees.

With respect to the correlation with the Montseny massif, the faunas are similar in both areas (see Villas *et al.*, 1987, for a discussion). However, the volcanic sequence of Les Guillerries must be older than the upper Ordovician beds described in the Montseny massif, since these are the latest Ordovician beds found immediately below the Silurian, this part of the sequence

being faulted out in Les Guilleries. Nevertheless, no volcanic rocks have been reported up to now in the Montseny massif in a lower stratigraphical position.

Acid volcanic rocks are found once more to the south in the Serra de les Pedritxes (Durán *et al.* 1984, Ubach, 1990) where they are associated with a sequence of slates and greywackes which in some localities (near Olesa, for example) show abundant sole marks. Slates and greywackes form the entire Paleozoic outcrops which override the Tertiary beds of the Ebro Basin, between Les Pedritxes and Capellades, although acid volcanic rocks are restricted to Les Pedritxes. The sequence of the Serra de les Pedritxes can be tentatively correlated with the sequence with acid volcanics of Les Guilleries, although there is no paleontological evidence to support this. In the Capellades area, a small limestone outcrop (Serra, 1989) could represent the Ashgill carbonate horizon.

Brachiopod faunas assigned to the Caradoc were reported last century from several localities from the surroundings of Barcelona (Barrois, 1893; Almera, 1898). However, these localities have yielded, besides brachiopods, a cystoid fauna (in Montcada, for example) which can be better attributed to the Asghill (Meléndez and Chauvel, 1981). The horizon containing these faunas is probably the same carbonate horizon referred to previously. Carbonate beds also crop out at Collcerola (=Tibidabo massif), between Barcelona and Molins de Rei. These beds are associated with interlayered basic rocks (Gil-Ibarguchi and Julivert, 1988). The stratigraphic position of these carbonate beds is doubtful, however they are found near the contact with the Silurian, also containing interlayered basic rocks. For these reasons, the carbonates have been tentatively assigned to the Asghill (Julivert and Durán, 1981). Also in this area a quartzite horizon is found, apparently at the contact with the Silurian black shales. This horizon could be the equivalent of the Bar Quartzite in the Pyrenees, although no quartzites have been found in the northern Montseny massif where the contact with the Silurian is well exposed.

The remainder of the Ordovician sequence in Collcerola and the outcrops west of the Llobregat river consist mainly of slates, locally with silt laminae, and some interlayered quartzites, but no key horizon to correlate with the Ordovician sequences of other massifs has been found.

SILURIAN BLACK SHALES

The Silurian consists mostly of black shales or slates with abundant graptolite faunas. These faunas have already been reported at the end of last century (Barrois, 1983, 1901), and new collections were made

some decades later by Puschmann (1968a, 1968b). A recent revision based upon new collected faunas of the Paleozoic area near Barcelona has allowed the recognition of several graptolite zones (Julivert *et al.* 1985). The *-atavus* and *-tumescens* zones are respectively the oldest and the youngest zones found. In addition, Greiling and Puschmann (1965) recognized the existence of *M. fritschi linearis* Bouček, probably near the top of the black shales, in the transition to the next formation. The *-atavus* zone is the oldest zone recognized. The lack of older faunas could be simply due to unfavourable environmental conditions. The existence of a certain thickness of sediments between the Asghill faunas and the first occurrence of graptolites allows to interpret the sequence as continuous. However, it could also be that a small hiatus exists between the Silurian and Ordovician, as is common in the Iberian massif (Truyols and Julivert, 1983).

Although black shales are the most common rock type, the sporadic occurrence of other rocks coupled with differences in the slates, allows the recognition of a certain lithostratigraphical succession (Fig. 4). The most striking lithologic variations, as observed in the area near Barcelona, are: 1) the existence of chert layers and basic volcanic rocks and/or sills in the lower part of the sequence (Llandoverly), 2) the existence of interlayered thin quartzite beds in the middle part (Wenlock) of the Silurian sequence, 3) the existence of black shales with sulphide layers and nodules (Wenlock or lower Ludlow), and 4) the existence of thin limestone layers in the uppermost part, indicating the transition to the overlying La Creu Formation, although the contact is never clearly seen because of tectonisation, due to ductility contrast.

The above succession is based upon the localities near Barcelona. Some of the features described can also be found in other localities. The black shales with sulphides are found also in Malgrat and in Esluga de Francolí (Prades Mountains), which indicates that they probably occur throughout the entire Catalan Coastal Ranges. Also the part of the sequence with interlayered thin quartzite beds is found in the Montseny massif, and is probably widespread. However, the basic rocks seem to be restricted to the area near Barcelona or, if present in other areas, they are minor in occurrence.

UPPER SILURIAN AND DEVONIAN CARBONATES

Above the black Silurian shales is a carbonate sequence which is best exposed at Santa Creu d'Olorda, near Barcelona. The sequence can be divided into two formations. The lower part (La Creu Formation) is a

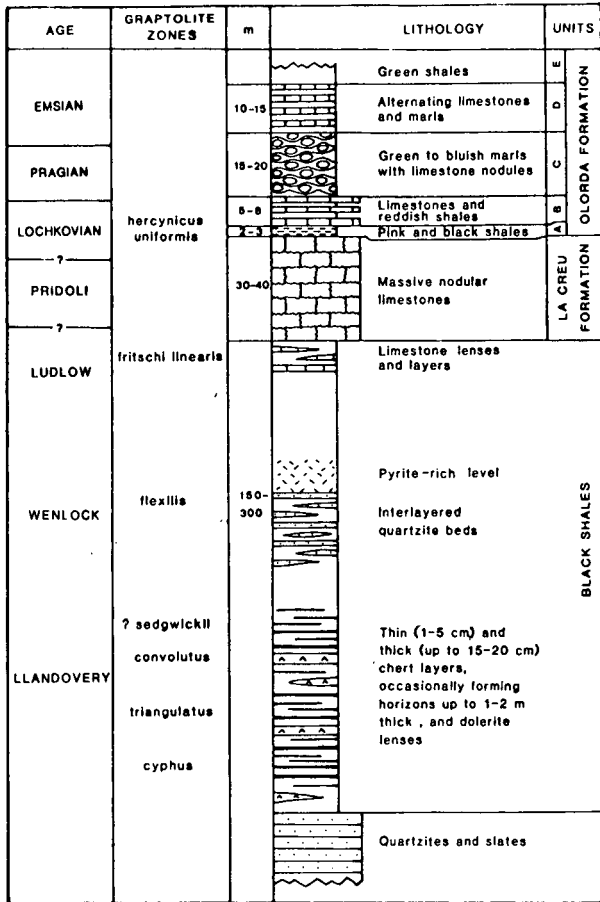


Figure 4.- Stratigraphical sequence of the Silurian and Lower Devonian based on the outcrops around Barcelona, according to Julivert *et al.* (1985). Devonian ages modified according to García-López *et al.* (1990).

30-40 m thick massive nodular limestone, containing abundant crinoids and «Orthoceras». The upper part (Olorda Formation) is more varied and consists of limestones, nodular marls and red, green and blue marls and shales. Due to its greater variety, the Olorda Formation in the locality of Santa Creu d'Olorda, can be divided into several members, represented in figure 4. A detailed stratigraphical succession, paleontological and facies description, as well as the structure of the Santa Creu, are given in another paper included in this volume (García-López *et al.*, 1990).

The La Creu Formation has yielded a conodont fauna, reported by Walliser (1964). This fauna gives

the age to be essentially Pridoli, although the lowermost part is still Ludlow and the last few metres are Devonian (Lochkovian).

The Olorda Formation has yielded a Lochkovian graptolite fauna (Greiling and Puschmann, 1965; Julivert *et al.* 1985) in its lower part (Member A), and dracrioconarids and conodonts in members B, C and D (Julivert *et al.* 1987). New collections of conodonts (S. García-López) and dracrioconarids (M. Truyols-Massoni) have allowed the definition of the Lochkovian, the Pragian and the Emsian. For a list of species and age discussion see García-López *et al.* (1990).

The above formations are found throughout the Catalonian Coastal Ranges, although no detailed stratigraphical sequences have been described for other localities. The two formations can be recognized through the lithological and fossil descriptions of previous authors, in the following localities: 1) Malgrat, where Almera (1913) reported the existence of «tentaculites» (Olorda Fm.), as well as «Orthoceras» limestones (La Creu Fm.), 2) Several localities in Barcelona (Gracia, Montcada), where also «Orthoceras» limestones and «tentaculites» were quoted by Almera (1891), 3) El Papiol, where the classical locality of Can Amigonet is found, 4) Gavà (Ermita de Bruguers), where the fauna described by Barrois (1893) came from the Olorda Formation, 5-6) northwest (Aiguafreda-Avencó creek) and southwest (Figaró) Montseny, where Puschmann (1968a, 1968b) described the two formations under the name of «Orthoceras Kalken» (=La Creu Fm.) and «Tentaculiten Schiefer» (=Olorda Fm.), and 7) northern Guillerics massif, where Durán (1986,1990) has also reported the existence of both formations, with a dracrioconarid fauna in the Olorda Formation.

Between Devonian and Carboniferous there is a break in the stratigraphic sequence. Devonian beds younger than the Emsian could have been laid down and subsequently eroded, before the deposition of the Carboniferous sequence. There is only one locality (El Papiol) where Fammenian conodonts have been reported (Puschman, 1968a), from a horizon below the Tournaisian black chert. Two possibilities exist to explain this occurrence: 1) the sequence at El Papiol is more complete than in other localities, and 2) the break in the sequence is below the Fammenian faunas. No detailed stratigraphical or paleontological work has been carried out in this locality, and in consequence the question remains open.

CARBONIFEROUS

Small outcrops of Carboniferous rocks are found in the northeastern (Avencó creek area, Fig. 2) and west-

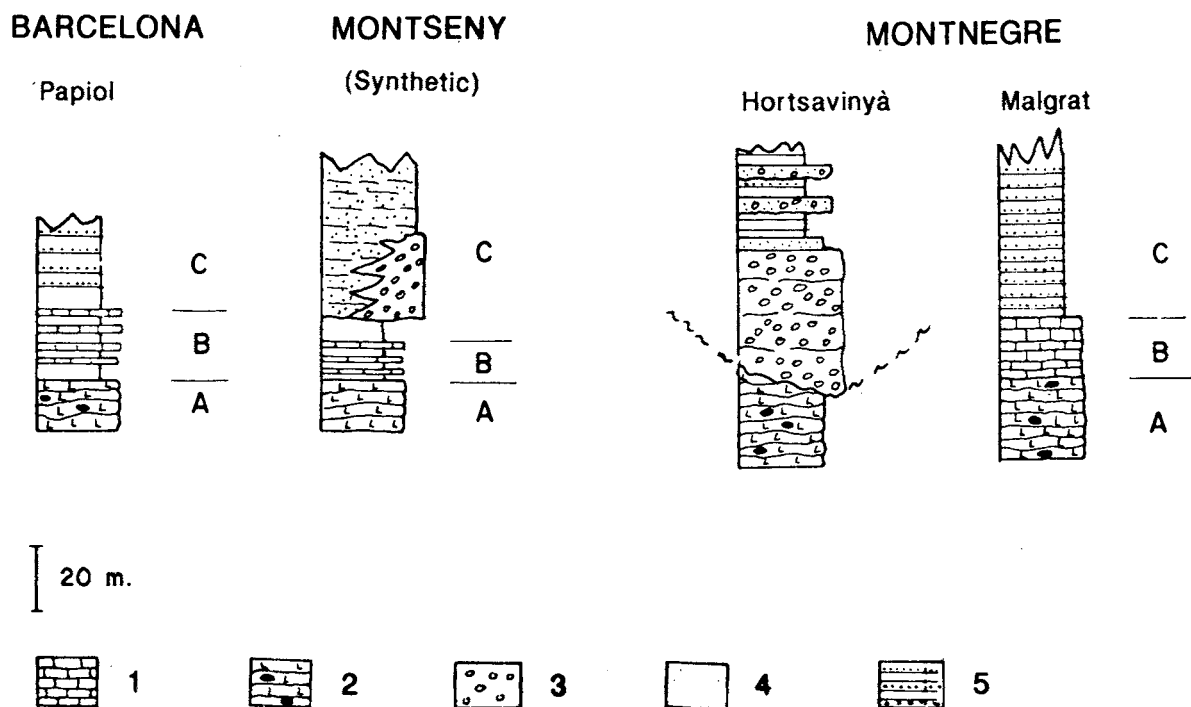


Figure 5.- Stratigraphic sequences of the lower part of the Carboniferous, according to Anadón *et al.* (1985), simplified. A, black cherts (Tournaisian). B, carbonate horizon (Visean). C, lower part of the culm sequence. 1, Limestones; 2, Chert with phosphate modules; 3, Conglomerates; 4, Pelites; 5, Culm sequence.

ern (Canoves) areas of the Montseny massif, El Montnegre, several points near Barcelona (El Putxet, Santa Creu d'Olorda, Sant Bertomeu), El Papiol, and Gavà.

In all these localities (Fig. 5) the sequence starts by a 10-20 m horizon of black chert with phosphate nodules. Above is a carbonate/shale horizon, some 10-25 m thick. The carbonate content of this horizon is variable. In Malgrat (El Montnegre) it forms a rather homogeneous limestone level, whilst in Papiol it consists of an alternation of pink or purple shales with interlayered thin dolostone and limestone beds, and in El Montseny it forms a sequence of alternating limestones and green shales (Anadón *et al.* 1985).

These horizons are quite constant throughout the northern part of the Catalonian Coastal Ranges. They are followed by a thick terrigenous succession (shales, greywackes and conglomerates) with the sedimentary structures and trace fossils peculiar to turbiditic sequences (culm facies, found throughout the Hercynian chain of Europe). In El Priorat (southern Catalonian Ranges) this terrigenous sequence reaches a thickness of about 2500 m (Anadón *et al.* 1985), but in the

northern part of the ranges only thin to moderate thick sequences have been preserved.

A somewhat different succession is found in Hortsavinyà (Montnegre), where directly overlying the black cherts there is a mud-supported conglomerate, so that the shale/limestone horizon is missing. This is, however, a local feature and can be interpreted as due to erosion, the conglomerates representing the infilling of a paleochannel.

Concerning the ages, the basal cherts have been attributed to the Tournaisian, the shale and limestone horizon has yielded a fauna with *Posidomya becheri* and *Drevermania pruvosti* which indicates the Visean. The overlying «culm» sequence must still be Visean for its lower part, whilst the age of its upper part depends on the thickness of the sequence preserved. In this respect, except in El Montnegre and western Montseny, the thickness preserved is very small, and the «culm» sequence includes probably only the Visean. Where a thick sequence exists, as in El Priorat, it probably reaches the Westfalian, as in the Montalbán massif (Iberian Chain; Quarch, 1975).

CONCLUSIONS AND COMPARISON WITH NEIGHBOURING AREAS

The Paleozoic stratigraphic succession in the Catalonian Coastal Ranges has strong similarities with those of Central and Eastern Pyrenees, and differs remarkably from those of the Iberian massif and the Iberian Chain.

The pre-Caradoc sequence can in broad terms be correlated with the Jujols and Canavelles formations of Central Pyrenees, and like in the Pyrenees it has not yielded any fauna. Also, as in the Pyrenees, orthogneiss bodies probably representing Late Precambrian or/and Late Precambrian-Early Cambrian intrusions (but still subject to controversy), are found at or near the base of the sequence.

The Caradoc-Ashgill is similar in facies and faunas between the Catalonian Coastal Ranges, the Pyrenees, and also in Sardinia and other Paleozoic massifs around the western Mediterranean, although in the Catalonian Coastal Ranges the sequence seems to be thicker. One peculiarity of the Caradoc sequence is the existence of a major acid volcanic event.

The Silurian consists mainly of its characteristic black graptolitic shales, so widespread throughout western Europe, and do not shows any peculiarity worth noting.

The Devonian (and uppermost Silurian) forms a sequence of marls and limestones with an abundance of conodonts and dactriocorids and a paucity of benthonic faunas. Although with some peculiarities, the Devonian facies in the Catalonian Coastal Ranges are similar to those of the Pyrenees, Sardinia, and other Paleozoic areas of the Western Mediterranean, whilst they have no equivalent in the Iberian massif, the only exception being the Pisuerga-Carrión Province, of the Cantabrian zone.

The Carboniferous is characterized by its thick «culm» sequence, forming most of the Carboniferous succession and starting in the Viséan. This is the kind of succession found in most of western and central Europe, differing from that found in northwestern Spain (Cantabrian zone) and the western Pyrenees, where a thick limestone formation of Namurian age is found.

REFERENCES

ALMERA, J., 1891: Mapa geológico y topográfico de la provincia de Barcelona. Región Primera o de contornos de la Capital. E. 1:40000, Dip. Prov. Barcelona.

- ALMERA, J., 1898: Compte-rendu de l'excursion du mercredi 5 Octobre, à Gava, Begas et Vallirana. *Bull. Soc. Géol. France*, 26: 789-800.
- ALMERA, J., 1901: Zonas graptolíticas de Barcelona. *Akten d. fünften Int. Kongr. Kathol. Gelehrten* (München 1900): 413-414.
- ANADON, P., JULIVERT, M. and SAEZ, A., 1985: Aportación al conocimiento del Carbonífero de las Cadenas Costeras Catalanas. *C. R. Xème Congr. Internat. Strat. Géol. Carbon.* (Madrid 1983), 1: 99-106.
- ASHAUER, H. and TEICHMÜLLER, R., 1935: Die variszische und alpidische gebirgsbildung Kataloniens. *Abh. Ges. Wiss. Gött. math.-phys. Kl.*, 3: 1-79.
- BARROIS, Ch., 1893: Observaciones sobre el terreno Silúrico de los alrededores de Barcelona. *Bol. Com. Map. Geol. España*, 19: 245-260.
- BARROIS, Ch., 1901: Note sur les graptolites de la Catalogne et leurs relations avec les étages graptolitiques de la France. *Bull. Soc. Géol. Fr.*, 1: 637-648.
- CAVET, P., 1957: Le Paléozoïque de la zone axiale des Pyrénées orientales françaises entre le Roussillon et l'Andorre. *Bull. Serv. Carte Géol. France*, 254 (55): 303-518.
- DURAN, H., 1985: *El Paleozoico de Les Guilleries*. Unpublished Ph. D. Thesis Univ. Autònoma de Barcelona: 1-243.
- DURAN, H., 1990: El Paleozoico de Les Guilleries. *Acta Geol. Hispànica*, 25(1/2): 83-103.
- DURAN, H., GIL IBARGUCHI, J.I., JULIVERT, M. and UBACH, J., 1984: Early paleozoic acid volcanism in the Catalonian Coastal Ranges (NW Mediterranean). In: F.P. Sassi and Julivert Eds., *IGCP 5, Newsletter* 6: 33-43.
- FAURA SANS, M., 1913: Síntesis estratigráfica de los terrenos primarios de Cataluña, con una descripción de los yacimientos fosilíferos más importantes. *Mem. R. Soc. Hist. Nat.*, 9 (1): 1-202.
- GARCÍA-LÓPEZ, S., JULIVERT, M., SOLDEVILA, J., TRUYOLS-MASSONI, M. and ZAMARREÑO, I., 1990: Biostratigrafía y Facies de la sucesión carbonatada del Silúrico Superior y Devónico Inferior de Santa Creu d'Olorda (Cadenas Costeras Catalanas, NE de España), *Acta Geol. Hispànica*, 25(1/2): 141-168.
- GIL-IBARGUCHI, J. I., and JULIVERT, M., 1988: Petrología de la aureola metamórfica de la granodiorita de Barcelona en la Sierra de Collcerola (Tibidabo). *Estudios Geol.*, 44: 353-374.
- GREILING, L. and PUSCHMANN, H., 1965: Die Wende Silurian/Devon am St. Creu d'Olorde bei Barcelona (Katalonien). *Senckenberg. lethaea*, 45: 453-457.
- HARTEVELT, J.J.A., 1970: Geology of the Upper Segre and Valira valleys, Central Pyrenees, Andorra/Spain. *Leidse Geol. Mededelingen*, 45: 167-236.
- HUERTA, J., 1990: El Paleozoico inferior del SE del Montseny. *Acta Geol. Hispànica*, 25(1/2): 105-111.
- JULIVERT, M. and DURAN, H., 1981: The Tibidabo area. In: *Guide to the field trips in the Eastern Pyrenees and Catalonian Coastal Ranges (13-15 June 1981)*, IGCP nº 5, Univ. Autònoma Barcelona: 53-59.
- JULIVERT, M., DURAN, H., RICHARDS, R.B. and CHAPMAN, A., 1985: Siluro-Devonian graptolite stratigraphy of the Catalonian Coastal Ranges. *Acta Geol. Hisp.*, 20 (3/4): 199-207.
- JULIVERT, M., DURAN, H., GARCIA-LOPEZ, S., GIL IBARGUCHI, I., TRUYOLS-MASSONI, M. and VILLAS, E., 1987: Pre-Carboniferous rocks in the Catalonian Coastal Ranges: volcanism, stratigraphic sequence and fossil content. In: H. W. Flügel,

- F. P. Sassi y P. Grecula Eds., Pre-Variscan and Variscan events in the Alpine-Mediterranean mountain belts, *Mineralia Slovaca* (Monography): 313-322.
- MELLENDEZ, B. and CHAUVEL, J., 1981: Sur quelques Cystoïdées cités par les Drs. J. Almera et M. Faura dans l'Ordovicien de Barcelona. *Acta Geol. Hispànica*, 14: 318-321.
- PUSCHMANN, H. 1968a: Stratigraphische Untersuchungen in Paläozoikum der Montseny (Katalonien/Spainien). *Geol. Rundschau*, 57 (3): 1006-1088.
- PUSCHMANN, H. 1968b: La série paléozoïque du massif du Montseny (Catalogne, Espagne du Nord-Est). *C. R. Ac. Sc. Paris*, 266: 657-659.
- QUARCH, H., 1975: Stratigraphie und Tectonik des Jungpaläozoikums im Sattel von Montalbán (Östliche Iberische Ketten, NE-Spanien). *Geol. Jb.*, 16: 3-43.
- SERRA, M., 1990: Geología de los materiales paleozoicos del área de Capellades. *Acta Geol. Hispànica*, 25(1/2): 123-132.
- TRUYOLS, J. and JULIVERT, M., 1983: El Silúrico en el Macizo Ibérico. In: J. Comba Edit., *Geología de España* (Libro Jubilar J. M. Ríos), I.G.M.E., 1:246-265.
- SCHRIEL, W., 1929: Der geologische Bau des katalonischen Kustengebirgen Ebromündung und Ampurdan. *Abh. Ges. Wiss. Gött. Math. Phys. Kl.*, 14(1): 62-141
- SIIP, J. W. C. M. VAN DER, 1951: *Petrography and geology of Montseny-Guilleries (NE Spain)*. Tesis Univ. Utrecht: 1-99.
- UBACH, J., 1990: Geología de los materiales paleozoicos de las escamas de la Cordillera Prelitoral Catalana al Este del río Llobregat. *Acta Geol. Hispànica*, 25(1/2): 113-121.
- VIDAL, L.M., 1886: Reseña geológica y minera de la provincia de Gerona. *Bol. Com. Map. Geol. Esp.*, 13: 209-380.
- VILADEVALL, M., 1978: *Estudio petrológico y estructural de las rocas metamórficas y graníticas del sector N-oriental del Macizo del Montseny*. Resumen Tesis Doct. Univ. Barcelona: 1-12.
- VILLAS, E., DURAN, H. and JULIVERT, M., 1987: The Upper Ordovician clastic sequence of the Catalanian Coastal Ranges and its brachiopod fauna. *N. Jb. Geol. Paläont. Abh.* 174 (1). 55-74.
- WALLISER, O.H., 1964: Conodonten des Silurs. *Abh. Gess. Land. Bodenforsch.*, 41: 1-106.