Société Géologique du Nord

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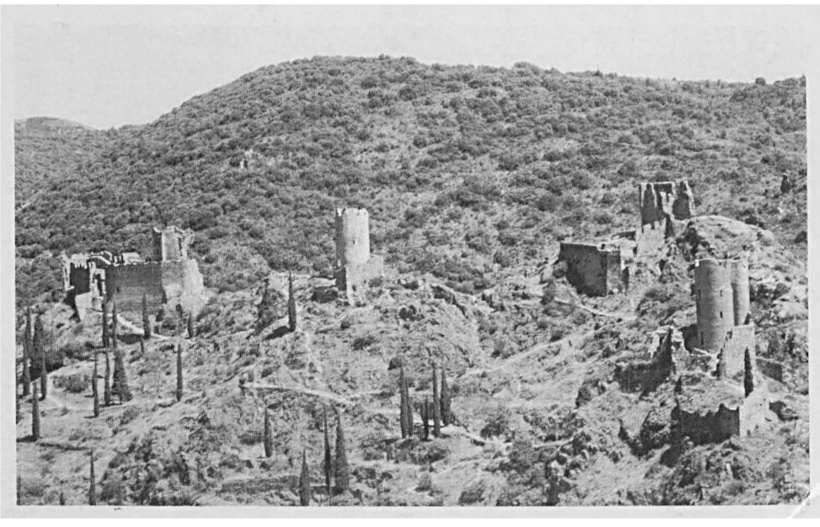
THE CAMBRIAN AND LOWER ORDOVICIAN OF THE SOUTHERN MONTAGNE NOIRE (LANGUEDOC, FRANCE). A SYNTHESIS FOR THE BEGINNING OF THE NEW CENTURY.

LE CAMBRIEN ET L'ORDOVICIEN INFÉRIEUR DE LA MONTAGNE NOIRE MÉRIDIONALE (LANGUEDOC, FRANCE). UNE SYNTHÈSE À L'AUBE DU NOUVEAU SIÈCLE.



SOCIÉTÉ GÉOLOGIQUE DU NORD
59655 VILLENEUVE D'ASCQ CEDEX

ISSN 0767-7367

SOCIÉTÉ GÉOLOGIQUE DU NORD

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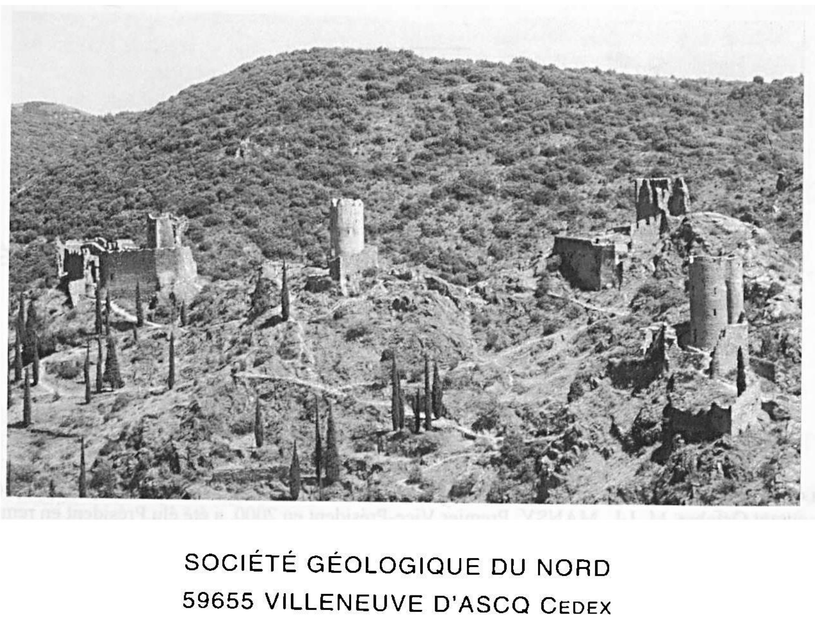

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Ann. Soc. Géol. du Nord.
T. 8 (2ème série), p. 183-184, Juin 2001.

THE CAMBRIAN AND LOWER ORDOVICIAN OF THE SOUTHERN MONTAGNE NOIRE (LANGUEDOC, FRANCE) A SYNTHESIS FOR THE BEGINNING OF THE NEW CENTURY

Le Cambrien et l'Ordovicien inférieur de la Montagne Noire méridionale (Languedoc, France) Une synthèse à l'aube du nouveau siècle.

One decade after Robert Courtessole's death (1990), the research in the Lower Paleozoic Paleontology of the Minervois, Pardailhan and Peyroux mountains (Languedoc) follows the path made by *l'abbé* of Carcassonne. His works represent the culmination of more than one century of field work studies made by naturalists, geologists and paleontologists who tried to understand the Lower Paleozoic biodiversity hidden in the relics of an old sea dispersed across isolated sierras and ranges, such as those reported in this monography. The erosion of the southern Montagne Noire by ravines and rivers, and the construction of paths and roads have permitted to discover a substrate full of folded and faulted sedimentary rocks famous by their wealth in fossils.

At the beginning of the 21st century it was necessary to summarize the enormous work made by more than 150 years of paleontological findings. This is a first step because the fossil collections of the Montagne Noire are dispersed all over the world, and some of the holotypes described in the 19th century unfound. A new generation of amateur and professional geologists and paleontologists are already looking for new key pieces of the Natural History of the Oc Country. The description of outcrops, stratigraphic sections and fossil systematics written several decades ago are read ceaseless, and the spirit of those the spent several years of their lives collecting fossils in the mountains of Languedoc is living again.

the editors

Ann. Soc. Géol. du Nord.
T. 8 (2ème série), p. 185-189, Juin 2001.

THE SOUTHERN MONTAGNE NOIRE: A KEY REGION FOR THE RESEARCH ON LOWER PALEOZOIC PALEONTOLOGY

La Montagne Noire méridionale : une région clé pour l'étude paléontologique du Paléozoïque inférieur

by J. Javier ALVARO (*) and Daniel VIZCAÏNO (**)

Abstract. — This paper presents an updated summary of the paleontological and stratigraphic contributions related to the Cambrian and Lower Ordovician of the southern Montagne Noire, from the 1850s until present day. The historical approach of this research is divided into three periods: (i) the pioneers' contributions (1850s-1930s) in which the research ativity of a Languedocian network of amateurs and the printed discussions between Bergeron (Sorbonne), de Rouville (Montpellier) and Miquel (Barroubio) are summarized; (ii) Thoral's legacy (1930s-1950s), who established a litho- and biostratigraphic framework of the entire Montagne Noire that has served as a general agreement for about 30 years; and (iii) the contemporary period (1950s-1980s) in which the contributions of two geologists are detailed: Courtessole's improvement of the Cambro-Ordovician taxonomic and stratigraphic knowledge, and Geze's structural sketch of the Montagne Noire, from the Cévennes to the southern nappes of the Montagne Noire, in which this monography is focused.

Résumé. — *Ce travail présente un résumé des contributions paléontologiques et stratigraphiques sur le Cambrien et l'Ordovicien inférieur du versant méridional de la Montagne Noire, depuis les années 1850 jusqu'à nos jours. Cette approche historique est subdivisée en trois périodes : (1) celle des naturalistes pionniers (1850s-1930s), comprenant les recherches d'un réseau d'amateurs languedociens et les discussions publiées parmi lesquelles, celles de Bergeron (Sorbonne), de Rouville (Montpellier) et Miquel (Barroubio) ; (2) l'héritage que Thoral a établi concernant un ensemble litho et biostratigraphique accepté et utilisé pendant trois décennies ; et (3) la période contemporaine (1950s-1980s) où les contributions de deux géologues sont détaillées : l'amélioration apportée par Courtessole dans les domaines de la taxinomie et de la stratigraphie cambro-ordovicienne, et le cadre structural de la Montagne Noire (depuis les Cévennes jusqu'aux nappes méridionales) apporté par Gèze, qui a publié la première cartographie moderne des nappes du Minervois et de Pardailhan sur lesquelles cette monographie est basée.*

I. — INTRODUCTION

The plateau of the Massif Central covers about one-sixth of the area of France. The Massif Central borders the Rhône-Saône valley on the east, the Languedoc lowlands on the south, the Aquitaine Basin on the southwest, and the Paris Basin on the north. Post-Hercynian planation removed the ancient mountain chains, but the block was uplifted under the impact of the Alpine mountain-building movements, with a steep descent on the east and southeast, nearest the Alps, and a gentle decline under the later sediments of the Aquitaine Basin to the west, and the Paris Basin to the north. Downfaulted basins filled with Tertiary and later sediments are common, associated with volcanic activity, which in the central part of the region formed the vast and complex structures of the massifs of Cantal and Monts Dore, where the Sancy Hill (Puy de Sancy) at 1,886 m is the highest summit of the Massif Central. The eastern and southern portions of the massif, from the Morvan through the Cévennes to the final southwestern termination of the massif in - the Montagne Noire (studied in this monography), are marked by a series of hill masses that overlook the lowlands of the Rhône-Saône river valley and the region of Languedoc-Roussillon. To the southwest the rocks of the massif are overlain by a great thickness of Jurassic limestones (causses), across which flow rivers that trench giant gorges in the massif, notably that of the Tarn.

From a geologic point of view, the southernmost prolongation of the Massif Central or Montagne Noire is a segment of the external regions of the southern French Variscan belt surrounded by post-Hercynian outcrops. The Montagne Noire appears as a framework of numerous tectonic units, which have been classically grouped into three main structural domains (Bergeron, 1889 ; Gèze, 1949) : a metamorphic axial zone bounding two areas, the southern and northern flanks (see Demange, in this volume). The southern Montagne Noire comprises a thick and complete non-metamorphic, Lower Cambrian to Lower Carboniferous succession exposed as inverted limbs of south-facing

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recumbent fold nappes (Gèze, 1949; Arthaud, 1970; Demange, 1994) (fig. 1). The papers reported in this monography are focused on the southern Montagne Noire, where its Lower Paleozoic rocks are composed of a fossiliferous, continuous and complete succession reaching more than 3000 m in thickness.

This area has become famous for two raisons: (i) the grapevines grown at his foot, which have received several 'appellation' names, such as Minervois, Saint-Chinian, Corbières, etc.; and (ii) the Cathar or Albigensian Crusade, proclaimed by Pope Innocent III (1198-1216) against the cathar heretics living in the Oc Country. The Paleozoic outcrops of the southern Montagne Noire belong to the so-called Cathar country.

The purpose of these papers is to present an updated synthesis of the paleontological wealth in the Lower Paleozoic of the southern Montagne Noire. Our aim is only to offer a new step to further research workers because the abundance of bibliography is becoming too abundant and complex to be checked. This volume is subdivided into seven chapters. After a tectonostratigraphic introduction of the thrust nappes recognized in the southern Montagne Noire, three chapters are devoted to the updated litho- and biostratigraphic revision of the Lower Cambrian, Middle-Upper Cambrian, and Lower Ordovician. Special attention is focused in the biodiversity patterns of trilobites and echinoderms. The following chapter is the field-trip guide for the excursion that will take place next 28th and 29th of September. Finally, the last chapters offer a revision of the holotypes defined until present-day in the Cambrian and Lower Ordovician of the southern Montagne Noire, and a bibliographic list of published papers related to this topic. Let us begin summarizing the paleontologic and stratigraphic studies and discussions in this study area from the 1850s until present day.

II. — HISTORIC APPROACH

1) First period: the pioneers (1850s-1930s).

Jules Bergeron (Sorbonne, Paris), Paul G. de Rouville (University of Montpellier) and Jean Miquel (amateur) were the first research workers to discuss and establish a stratigraphic framework in the older Paleozoic rocks of Languedoc (fig. 2). After the finding of the first Lower Paleozoic fossils near Neffièz (Fournet & Graff, 1849) a network of amateur naturalists began to visit the best exposed outcrops of the Minervois, Pardailhan and Corbières mountains, mainly along valleys, paths, roads and villages. As a result, some inhabitants of these villages became key pieces in the puzzle of the Paleontology during the 19th century, whose private collections were frequently studied by professional paleontologists. Some amateurs gave their names to fossil species, such as *filacovi* (after Mr Filachou, priest of Cassagnoles), *villebruni* (Mr Villebrun, doctor in Saint-Chinian), *sallesi* et *lignieresi* (Mr Salles et Lignières, teachers in Ferrals-les-Montagnes and Babeau, respectively),

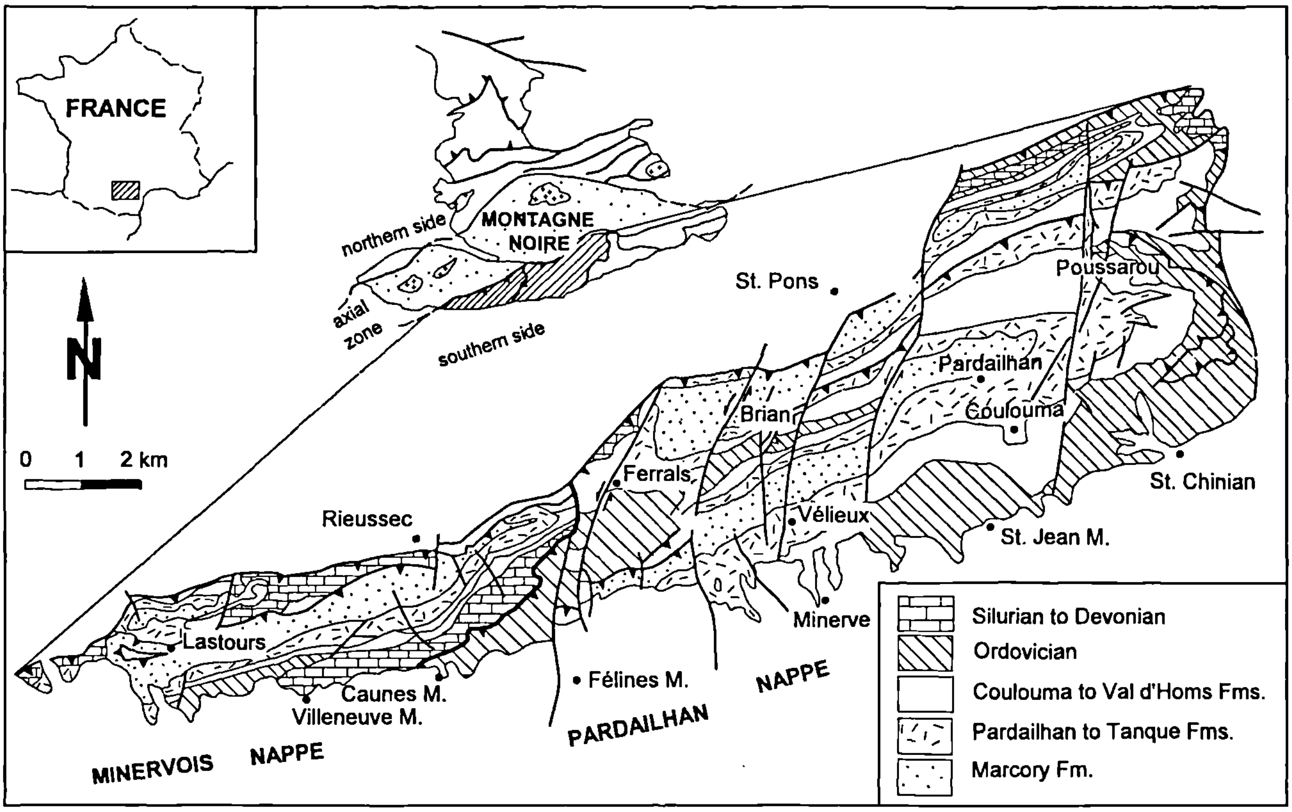


Fig. 1. — Geologic sketch of the Minervois and Pardailhan nappes (southern Montagne Noire; after Guerangé-Lozes & Burg, 1990).

Fig. 1. — Schéma géologique des nappes du Minervois et de Pardailhan (versant sud de la Montagne Noire; d'après Guerangé-Lozes & Burg, 1990).

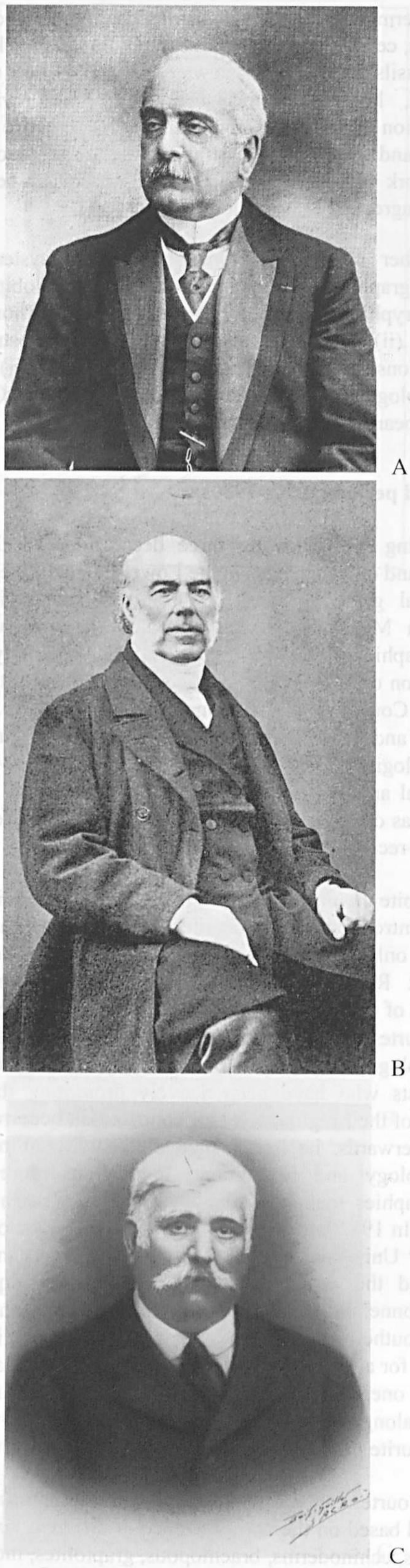


Fig. 2.— Portraits of Jules Bergeron (A), Joachim Barrande (B), and Jean Miquel (C).

Fig. 2. Portraits de Jules Bergeron (A), Joachim Barrande (B), et Jean Miquel (C).

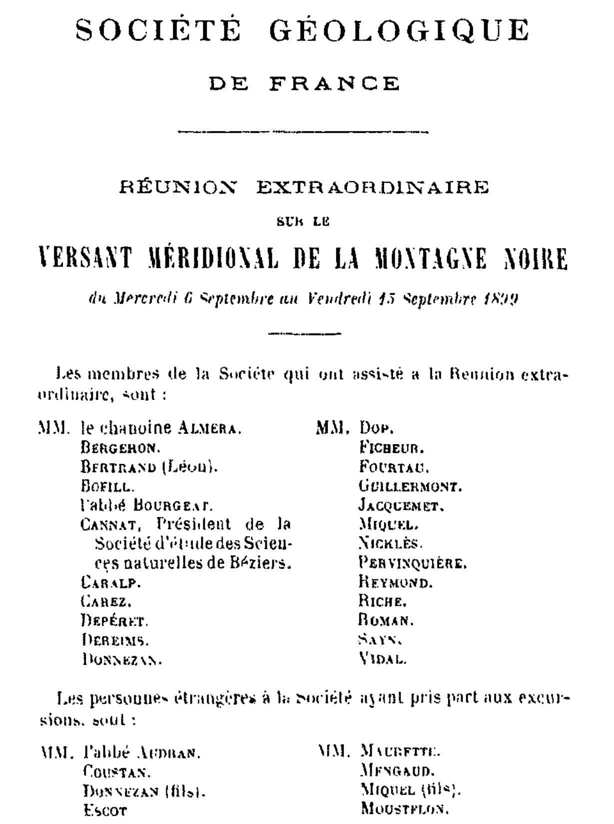
rouayrouxi (Mr Rouayroux, major of Cassagnoles), *escoti* (Mr Escot, inhabitant of Cabrières), *miqueli* (Mr Miquel, Barroubio), etc. Only Miquel (1905) erected his own species: six trilobite and echinoderm species.

Obviously, this pioneer work was sharply influenced by the descriptions of fossil record and stratigraphy reported in other areas. Three regions of influence can be found in the French works: (i) the British charts of Murchison, Sedgwick and Lapworth, (ii) the Bohemian stratigraphic framework of Barrande, and (iii) the Cambrian Walcott's scale of North America. Bergeron (1887) was the first to assign some trilobite faunas to the lowermost Ordovician British scale. He proposed them as early Arenig due to the ambiguity in the definition of the Lower Ordovician Series in the British Isles. They were properly recognized as Tremadoc by Brögger (1898) and Pompeckj (1902). Bergeron (1888) was as well the first author to recognize the presence of the Bohemian 'primordial' fauna of Barrande in the Montagne Noire. This fossil assemblage is associated with the trilobite genus *Paradoxides* and, at present day, considered as Middle Cambrian. Finally, the Arenig was dated according to the occurrence of brachiopods (such as *Lingula lesueuri*), trilobite, graptolites (mainly described by Barrois, University of Lille) and trace fossils, the latter correlated with those previously described in the Armorican Massif.

Unfortunately, the cooperative research between Bergeron, de Rouville and Miquel during the 1890s became a matter of conflict, accusations and publication of private letters in scientific papers. As the classic misunderstandings between Murchison and Sedwgick, the conflict went on until the death of Rouville (1907) and Bergeron (1919). The last works of Miquel (1933) are overlapped by the occurrence of a new generation of paleontologists, mainly Joseph Blayac (dead in 1937) and his student, Marcel Thoral.

During this first period, the whole stratigraphic units proposed were based on mixed litho- and biostratigraphic patterns, which encouraged an everlasting discussion concerning the similarities of lithologies and faunas inside and outside the Montagne Noire, the possibility of correlating rocks devoid of fossils and the stratigraphic order of some outcrops. Only Miquel (1894) proposed a seeming chronostratigraphic unit, named the Barroubian, as spanning the 'azoic' interval from the disappearance of the 'primordial' fauna (Middle Cambrian) to the occurrence of the Arenig-type fossils. This concept has evolved becoming a lithostratigraphic unit: the Barroubio Group (Álvaro *et al.*, 1998).

Three important Geological Meetings involved the Montagne Noire during the 19th century. In 1868, a meeting of the French Geological Survey (SGF) took place in Montpellier, which permitted to evidence the first problems of correlation in the Arenig rocks, where the fossils had been recently discovered (proceedings edited by de Rouville, 1869). The finding of the 'primordial fauna' encouraged the SGF to visit again the Montagne Noire, meeting organized by Bergeron (see Bergeron, 1899) (fig. 3). Finally, some of the outcrops were re-visited in the International Geological Meeting of Paris (Bergeron, 1900).



SOCIÉTÉ GÉOLOGIQUE

DE FRANCE

RÉUNION EXTRAORDINAIRE

SUR LE

VERSANT MÉRIDIONAL DE LA MONTAGNE NOIRE

du Mercredi 6 Septembre au Vendredi 15 Septembre 1899

Les membres de la Société qui ont assisté à la Réunion extraordinaire, sont :

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COUSTAN.	MENGAUD.
DONNEZAN (fils).	MIQUEL (fils).
ESCOT	MOUSTELON.

Fig. 3.— Cover page of the Meeting of the French Geological Society in the Montagne Noire (1898), in which is remarkable the abundance during the last 1890s of amateurs (mainly priests and grammar school teachers) interested in the Paleontology.

Fig. 3.— Page de couverture du Congrès de la Société Géologique de France en Montagne Noire (1898) ; il est remarquable l'abondance au cours des années 1890s d'amateurs (principalement abbés et instituteurs) intéressés dans la Paléontologie.

2) Second period: Thoral's legacy (1930s-1950s).

The topic of research of Thoral's doctoral thesis (proposed by Blayac) was the geology and paleontology of the Lacaune mountains (northern Montagne Noire). In his first monography (Thoral, 1935a) (A, fig. 4). Thoral presented a complete description of Precambrian and metamorphic, Cambrian, Lower Ordovician, 'Gothlandian', lowermost Devonian and Carboniferous rocks. Despite the multidisciplinary aspect of this volume, he focused his research on the analysis of Cambrian and Lower Ordovician fossil faunas both on the northern and southern Montagne Noire. As a result, his second monography (Thoral, 1935b) displays a quick revision and description of Cambrian trilobites, archaeocyaths, echinoderms and brachiopods (including three new species). The description of trilobites was sharply influenced by the contributions made by Cobbold (1931, 1935), who visited the area during the 1930s studying the Lower Cambrian trilobites, and Howell (1935) who analysed the Cambro-Ordovician agnostids. The systematics of Lower Ordovician fossils represents the core of his contributions. He described and defined graptolites, echinoderms, brachiopods, gastropods, hyoliths, conularids, bivalves, cephalopods, ostracodes, 'phyllopods', trilobites and ichnofossils: as a whole, 4 new genera and 44 new species. In addition, he participated directly in the revision and publication of several geological maps of the entire Montagne Noire, and developed a stratigraphic and paleontological framework of the Montagne Noire, which has served as a general agreement for about 30 years.

Further contributions include (i) two systematic and biostratigraphic monographies about three trilobite families (conocoryphids, solenopleurids and liostracids; Thoral, 1946a, 1948), (ii) some detailed litho- and biostratigraphic correlations with the Iberian Peninsula, and (iii) the deep paleontological research developed in the Lower Ordovician nodule-bearing shales (Thoral, 1946b).

3) Third period (1950s-1980s).

During the following three decades or so there were further and quick changes in the Lower Paleozoic regional and structural geology, stratigraphy and paleodiversity of the southern Montagne Noire. A proliferation of papers and monographies were published indicating the activity of a new generation of geologists and paleontologists, such as Arthaud, Boyer, Courtessole, Debrenne, Gèze, Pillet, G. and M. Termier and Ubaghs, among others, as well as the revision of the geological maps of the area by the BRGM. A new structural and stratigraphic sketch of the southern Montagne Noire was developed related to new findings and descriptions of fossil record.

Despite the importance of all the authors, there is no place in this introduction to a detailed description of their works. We are only going to remember the works of two research workers: Robert Courtessole, priest and grammar school teachers of Carcassonne (B, fig. 4) and Bernard Gèze (C, fig. 4). Courtessole (1904-1990), the paradigm of amateur paleontologist, represents a new step of the Languedocian naturalists who have been actively promoting the Natural History of their region. His first contribution occurred in 1967 and, afterwards, he has pushed the activity of research in Paleontology and Stratigraphy publishing more than 20 monographies, mainly in the Société d'Etudes Scientifiques de l'Aude. In 1982 he received an *honoris causa* doctorate in the German University of Würzburg. His energy and activity permitted the development of a kind of headquarters in Carcassonne: any research worker ready to study the Geology of the southern Montagne Noire visited his house in order to ask him for advice. His death in 1990 left the Montagne Noire without one of the most important 'lovers of Nature' who walked along its ravines and hills. Maybe, if you cross one of his favourite paths you will hear the echo of his words.

In Courtessole's works, a new biostratigraphic subdivision emerged based on the co-occurrence of different taxa, such as trilobites, echinoderms, brachiopods, graptolites, molluscs and trace fossils. The Middle Cambrian of the Montagne Noire was subdivided into 10 paleontological levels (A_1 to H_2) or assemblage zones, and the Lower Ordovician into 13 ones (A to M), which were very useful in the correlations across south-western Europe and northern Africa. At the same time, all the lithostratigraphic units were formaly erected in the Cambrian and Lower Ordovician outcrops, and more than 20 trilobite

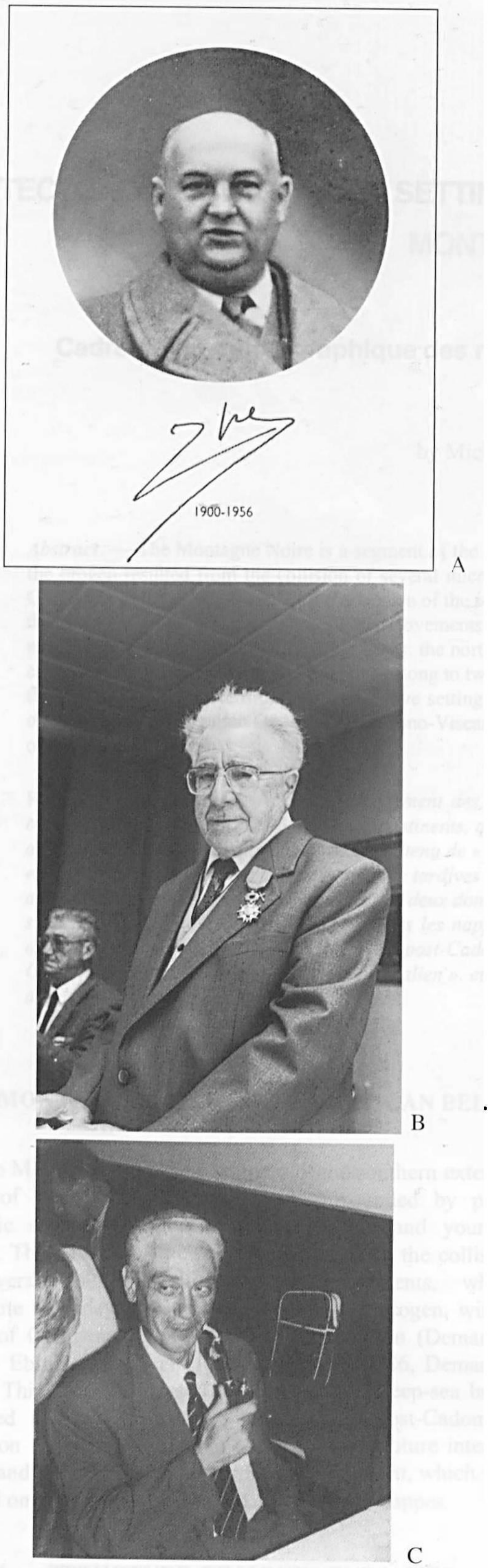

Fig. 4.— Portraits of Marcel Thoral (A), Robert Courtessole (B), and Bernard Gèze (C).

Fig. 4.— Portraits de Marcel Thoral (A), Robert Courtessole (B), et Bernard Gèze (C).

species defined, increasing successfully the biodiversity known in the Lower Paleozoic of France.

Bernard Gèze (1913-1997) finished in 1949 a doctoral thesis ('thèse de doctorat d'état') in the Sorbonne University under the direction of Marcel Thoral, in which he presented new complete and detailed geological maps covering ~ 7000 km^2 throughout the Cévennes, the Albigeois and the Montagne Noire. This manuscript was synthetized in a Memoir of the SGF, which included 110 hand-made figures, 7 plates of stratigraphic sections and a synthetic map (1/200,000). He demonstrated the Hercynian age of the broad metamorphism recognized in the axial Montagne Noire, but may be his most famous contribution is the description and mapping of the nappes distinguished on the southern Montagne Noire, explained as inverted recumbent folds. The provenance of these nappes has been a matter of discussion that goes on nowadays. Gèze was known too by his activities in speleology: he was the first president in 1963 of the French Speleological Federation.

Recently, Álvaro *et al.* (1998) proposed a revision of the Cambrian, litho- and biostratigraphic units of the southern Montagne Noire, presenting an updated list of their fossil record. This allows a better estimation of the Cambrian biodiversity although new findings will change quickly our concepts. By contrast, the Lower Ordovician is still a matter of discussion due to the flooding of papers in the last three decades. A complete taxonomic and stratigraphic revision is necessary, partly initiated in this monography.

In summary, more than 230 fossil species have been formaly defined in the Cambrian and Lower Ordovician rocks of the southern Montagne Noire. At the end of this monograhy, you will find a report of them (*).

ACKNOWLEDGEMENTS. — We are indebted to all the colleagues who, directly or indirectly, have contributed to the elaboration of this volume, such as Mme Corsin et Mr Dégardin (Lille), G. Breton (Le Havre), T.P. Fletcher (Edinburgh) and A.R. Palmer (Boulder), and the French Geological Society. This monography is a contribution to project PB 98-1625.

(*) At the end of the following papers, a short bibliographic list is reported. All the references concerning the southern Montagne Noire are only written once in the last chapter.

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TECTONO-STRATIGRAPHIC SETTING OF THE SOUTHERN SLOPE NAPPES OF MONTAGNE NOIRE

Cadre tectonostratigraphique des nappes du Versant sud de la Montagne Noire

by Michel DEMANGE (*)

Abstract. — The Montagne Noire is a segment of the southern French external zones of the Variscan belt. This branch of the orogen resulted from the collision of several microcontinents (that form the present internal zones), with a prong of Gondwana. This collision caused the extrusion of the sedimentary content of the 'Centralian Ocean', which was stacked on the craton as a pile of thrust nappes. Later movements deformed the entire framework in a large anticline. The nappes are nowadays cropping out as two separate zones: the northern and southern slopes of Montagne Noire. Paleozoic successions cropping out on the southern slope nappes belong to two sedimentary cycles. The Cambro-Ordovician cycle corresponds to the post-Cadomian distension: the progressive setting of a passive margin on the edge of the Gondwana craton and the opening of the 'Centralian Ocean'. The Devono-Visean cycle corresponds to the formation of a foreland basin at the front of the Variscan orogen.

Résumé. — *La Montagne Noire est un segment des zones externes méridionales de l'orogène varisque français. Cet orogène provient de la collision de microcontinents, qui en constituent les actuelles zones internes, avec un promontoire du Gondwana. Lors de cette collision, le contenu de « l'océan centralien » a été éjecté et est venu s'empiler sur le craton en un complexe de nappes. Des déformations tardives replient cette pile de nappes en un vaste anticlinal (l'actuelle Zone axiale), de sorte que les nappes affleurent en deux domaines disjoints, les versants sud et nord de la Montagne Noire. Les successions paléozoïques qui affleurent dans les nappes appartiennent à deux cycles sédimentaires : le cycle cambro-ordovicien qui correspond à la distension post-Cadomienne, installation d'une marge passive en bordure de craton Gondwanien et ouverture de « l'océan centralien », et le cycle dévono-viséen qui correspond à l'installation d'un bassin d'avant-pays au front de l'orogène varisque.*

I. — MONTAGNE NOIRE IN THE VARISCAN BELT

The Montagne Noire is a segment of the southern external zones of the French Variscan belt, surrounded by post-orogenic sediments of mid Stephanian age and younger (fig. 1). This branch of the orogen resulted from the collision of several 'blocks', probably microcontinents, which constitute nowadays the internal zones of the orogen, with a prong of Gondwana (fig. 2): the Catalan craton (Demange, 1994 = Ebroia, Autran *et al.*, 1996) (Matte, 1986, Demange, 1999). This collision caused the closure of a deep-sea basin so-called 'Centralian ocean', opened by post-Cadomian extension between the Catalan craton and the future internal zones, and the extrusion of its sedimentary content, which was stacked on the Catalan craton as a pile of thrust nappes.

II. — STRUCTURE OF MONTAGNE NOIRE

Montagne Noire (figs. 3-4) appears as a patchwork of numerous tectonic units (about 50 have been already named),

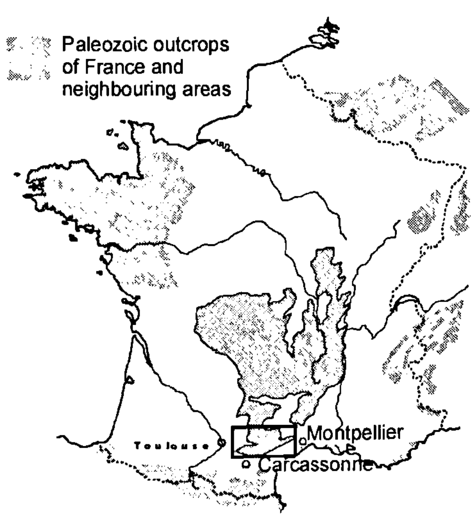

Fig . 1. — Geological setting of the Montagne Noire in France.

Fig . 1. — Situation géologique de la Montagne Noire en France.

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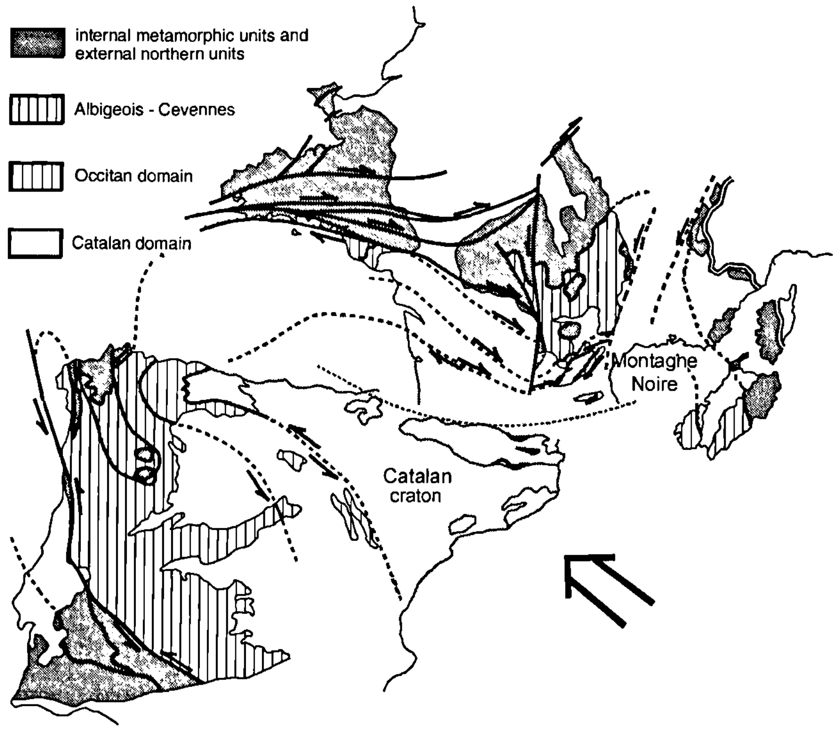

Fig. 2. — The Montagne Noire in the context of the Variscan orogen.

Fig. 2. — Situation de la Montagne Noire dans le contexte de la chaîne varisque.

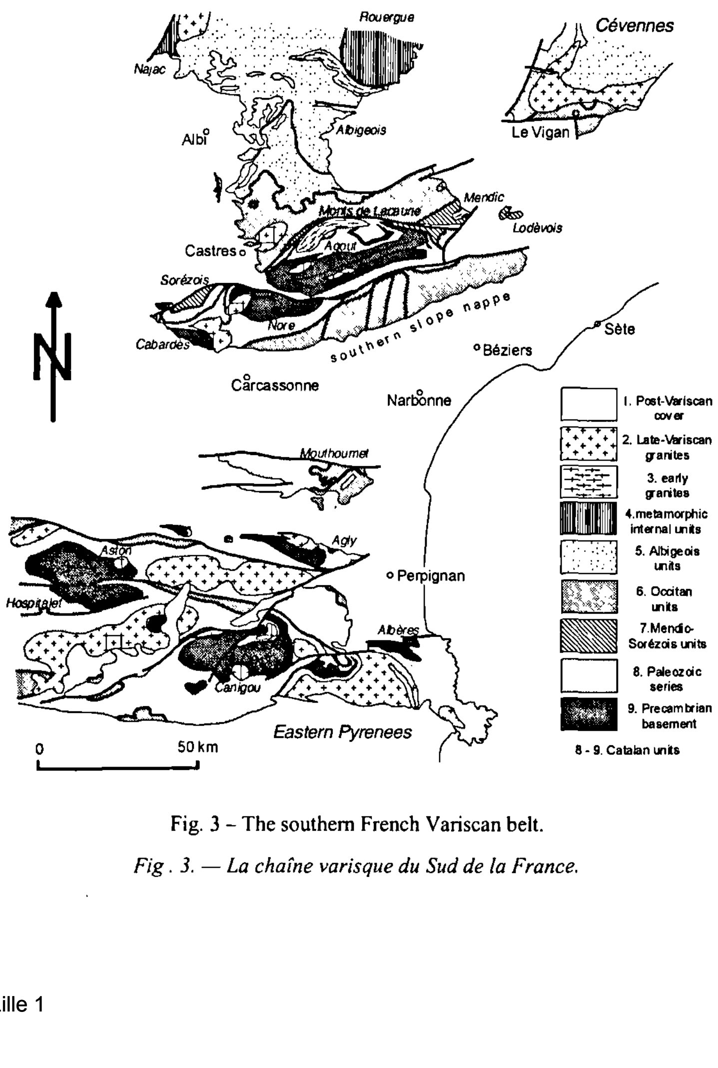

Fig. 3 – The southern French Variscan belt.

Fig. 3. — La chaîne varisque du Sud de la France.

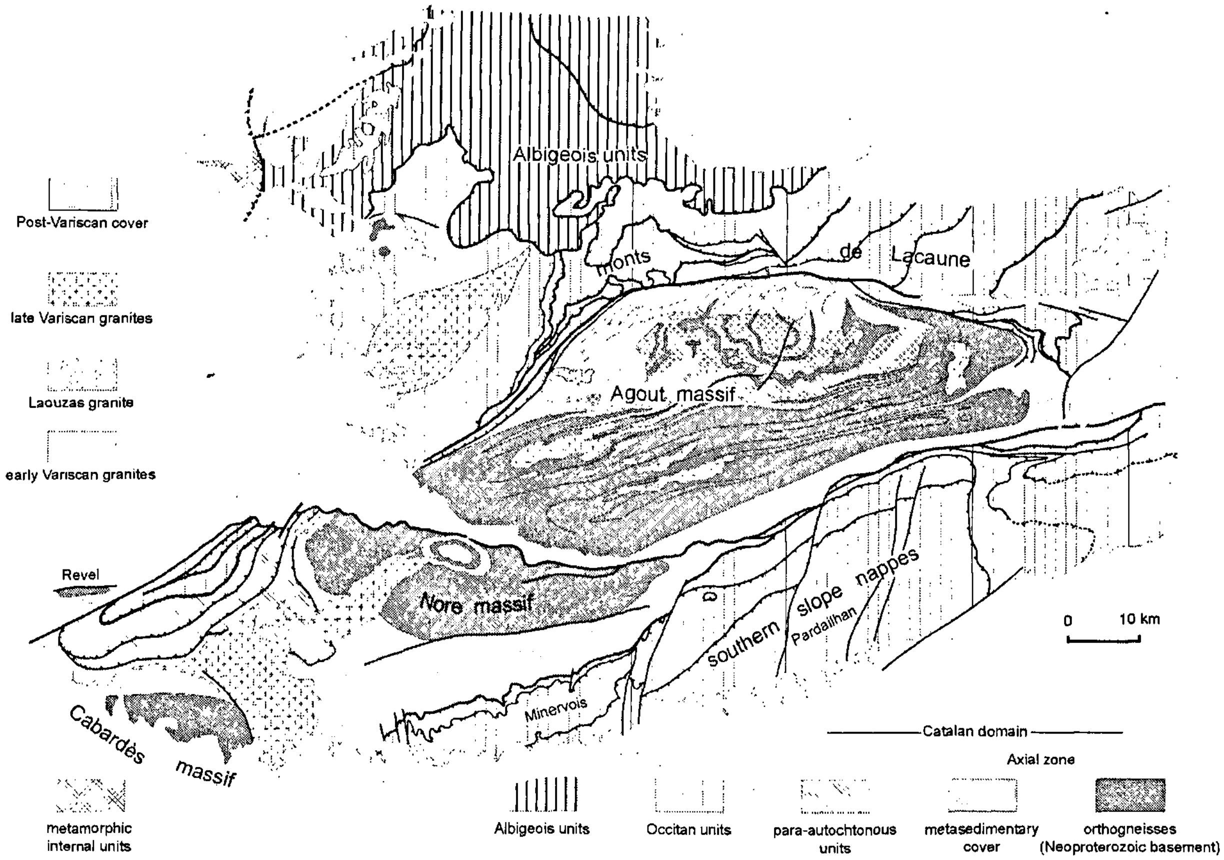

Fig. 4. — Geological map of the Montagne Noire.

Fig. 4. — Carte géologique de la Montagne Noire.

differing by their lithostratigraphic successions, structural style and metamorphic grade, separated by tectonic accidents of various importance and age. Classically (Bergeron, 1889; Gèze, 1949), Montagne Noire is divided into three tectonic domains: (i) the metamorphic Axial zone, made of complex domes of gneiss and migmatites surrounded by micaschists (Roques, 1941; Schuiling, 1960; Ellenberger, 1967; Ellenberger & Santarelli, 1974; Demange, 1975, 1982, 1998); (ii) the Southern Slope composed of large nappes involving anchi- to epi-metamorphic successions of Early Cambrian to Carboniferous age (Arthaud, 1970; Engel *et al.*, 1981); and (iii) the Northern Slope made of imbricated tectonic slices that involve epi- to meso-metamorphic Lower Cambrian to Silurian successions (Thoral, 1935; Donnot & Guérangé, 1978).

This subdivision is based on differences of metamorphic grade and late Variscan tectonics. However, it does not take into account obvious similarities between units belonging to different zones and it is unaware of the existence of tectonic klippes (Monts de Saint-Gervais, Durfort in Sorézois) on the Axial zone, the successions of which are similar to those of Northern or Southern slope units. In a recent synthesis, Demange (1994) defined four major domains separated by major thrust faults based on their lithostratigraphy, sedimentology, paleogeography, tectonic patterns, and degree and type of metamorphism. They are from bottom to top:

(i) The lowest Catalan domain comprises the Gondwana Precambrian basement (paragneisses, only known in eastern Pyrenees and orthogneisses interpreted as Neoproterozoic granites), and its sedimentaty cover. The latter consists of thick, monotonous, mostly siliciclastic successions at the bottom (which are not dated but are assumed to be Early Paleozoic). They are unconformably covered by Upper Ordovician–Silurian, mostly terrigenous sediments, and finally by Devonian successions of distal character. The Catalan domain crops out largely in the eastern Pyrenes and in the Catalanides (NE Spain). In Montagne Noire it appears as a tectonic window, the Axial zone, below the Occitan units. To the north of the Axial zone, the para-autochtonous units, thrusted above the Axial zone, show similar lithostratigraphic successions.

(ii) The Occitan domain is made of Cambrian to Lower Carboniferous sediments deposited at the margin of the Catalan domain. The successions are arranged into two sedimentary cycles: the lowest one from Early Cambrian to Early Ordovician, and the second one from (Silurian)-Early Devonian to Mid Carboniferous. In the Pyrenees, the Occitan domain is only represented by restricted klippes. In Montagne Noire, it crops out on three areas, separated by the late dome of the Axial zone: the large complex of the southern slope nappes, some klippes preserved above the Axial zone, and the Monts de Lacaune. The Mendic–Sorézois domain, made exclusively of Lower Cambrian successions with a characteristic development of acidic volcanism, forms a small tectonic sliver, between the 'true' Monts de Lacaune units and the Catalan units.

(iii) The Albigeois domain consists of mostly siliciclastic sediments of more distal character, with volcanic intercalations of assumed Cambro-Ordovician age (Guérangé-Lozes, 1987; Guérangé-Lozes & Burg, 1990). The internal metamorphic units (Rouergue and Najac nappes; Bodinier & Burg, 1980-1981; Burg *et al.* 1986) are thrusted above this domain.

III. — THE SOUTHERN SLOPE NAPPES

The southern slope nappes (figs. 5-6) are separated from the Axial zone by a complex major accident: the basal thrust of the Occitan domain, which frequently reworked as a late Variscan wrench fault. It is separated by the Cesse wrench faults and the Orb flexure into three parts : the western (Minervois), central (Saint-Ponais – Pardailhan) and eastern (Monts, Peyroux, Monts de Faugères and Visean flysch basin) regions.

1) The western region: the Minervois nappes

The lowest Occitan unit is the Fournes nappe made of Lower Cambrian to Upper Devonian sediments (Demange *et al.*, 1986). Its sedimentary succession is characterized by an important pre-Devonian erosion: Lower Devonian rocks occur directly overlying the Lower to Middle Cambrian formations, indicating an important pre-Devonian erosion. The Devonian is also represented by successions of reduced thickness and distal character (fig. 7). The successions are in reverse position and are structured as isoclinal folds: the Cabrespine anticline (with a core of Middle and Upper Devonian calcschists surrounded by Lower Devonian limestones), and the Salsigne syncline (with a core of Cambrian formations). The Cabrespine and Salsigne folds are oblique on the limits of the nappe and crosscut by lower and upper thrusts.

The Minervois nappe shows a complete cross-section from Lower Cambrian to Lower Carboniferous. The unconformity between the first and second sedimentary cycles is less important than in the Fournes nappe: the Lower Devonian rocks rest upon Lower Ordovician to Middle Cambrian ones. The Minervois nappe appears as a large recumbent fold sheared at the bottom. This structure reworks earlier isoclinal folds associated with a strain slip foliation of minor importance. Its reverse limb may be observed in its north-eastern part (and in the Source de la Cesse unit), but the largest part of the outcropping domain is located in the hinge where the successions are vertical. The classical cross-sections of the Orbiel and Clamoux valleys show monoclinal vertical series, with Lower Cambrian to the north and Devonian to the south; a subvertical strain slip early foliation (close to the bedding), and a sub-horizontal fracture foliation (axial plane of the recumbent fold) can be observed.

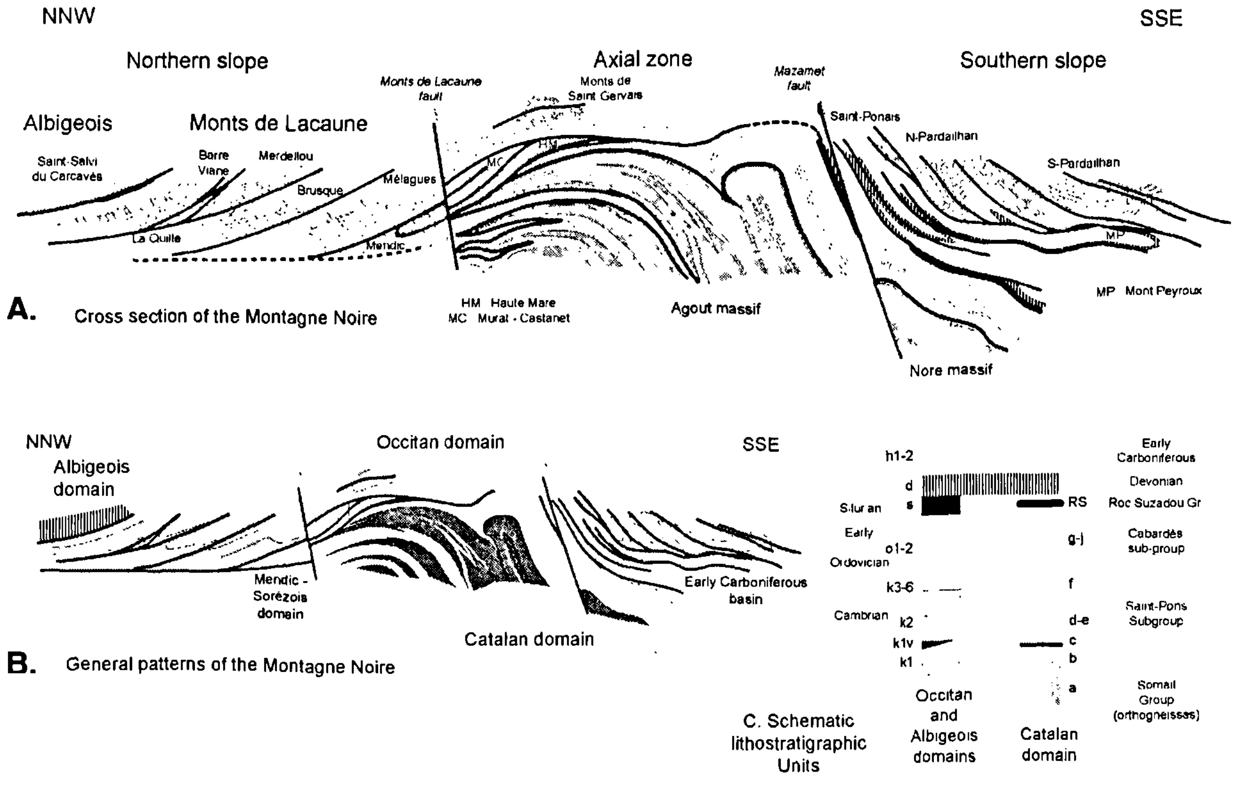

Fig. 5. — A : Cross-section of the Montagne Noire ; B : General patterns of the Montagne Noire ; C : Simplified lithostratigraphic successions.

Fig. 5. — A : Section de la Montagne Noire ; B : Caractères générales de la Montagne Noire ; C : Schéma simplifié des unités lithostratigraphiques.

To the east of the Massagine wrench fault, the Sources de la Cesse unit is the equivalent of the Minervois nappe, with upside-down series structured into a syncline. The small tectonic windows of Peyrefiche and La Pode are the equivalent of the Fournes nappe. Southwards the Source de la Cesse unit is thrusted above the southern Minervois unit.

The southern Minervois unit is made up of Lower Ordovician flysch-type siliciclastic rocks. This unit is considered to be the equivalent of the larger Pardailhan nappe that crops out eastwards. However, the Lower Ordovician facies are quite different (richer in sandstones). This unit is clearly overlain by the Minervois and Source de la Cesse nappes; some structural geologists explain that by a late reverse fault.

2) The central region: Saint-Ponais and Pardailhan

From north to south, and from lower to upper, the following nappes can be distinguished (fig. 6):

(i) The northern Saint-Ponais nappe (Source du Jaur unit), is made of Devonian rocks, very similar to the Fournes nappe and of Visean distal flysch. The formations are strongly deformed in isoclinal syn-folial folds, which are variously crosscut by the thrusts that limit the unit. Around the city of Saint-Pons, the successions rest in monoclinal, normal position.

(ii) The central and southern Saint-Ponais nappes are made of Ordovician and Devonian, inverted rocks. The Devonian rocks differ from the successions of the northern Saint-Ponais – Fournes nappes by a more proximal character, with a large development of Lower Devonian dolomites and Middle Devonian peri-reefal facies. The Ordovician is represented by dark pelites of distal character.

(iii) The Les Verreries and Premian units show Lower Cambrian to Upper Devonian formations in inverted position. These differ from those of the surrounding units by a reduced thickness or absence of Ordovician rocks due to important pre-Devonian erosive processes.

(iv) The Pardailhan nappe is made of thick Lower Cambrian to Lower Ordovician successions, commonly preserved in reverse position. It is deformed into three 'synform' structures (synclines affecting reverse series) associated with a regional strain slip foliation. They are, from north to south: (a) the Ferrals-Malviès unit (northern Pardailhan), arranged as a large U-shaped syncline at the west: the Ferrals-les-Montagnes cross-section is located on the

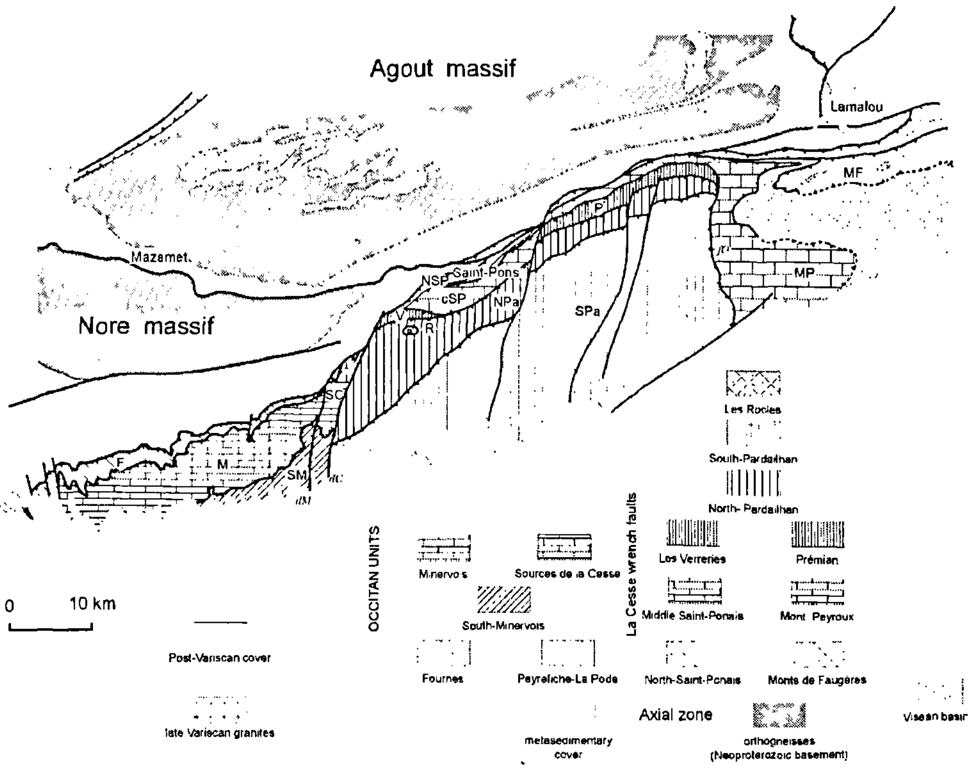

Fig. 6. — Sketch of the southern slope nappes. CSP, central and south Saint-Ponais ; F, Fournes ; M, Minervois ; MF, Monts de Faugères ; MP, Mont Peyroux ; NPa, Nord-Pardailhan ; NSP, northern Saint-Ponais ; P, Prémian ; R, Les Rocles ; SC, Sources de la Cesse ; SM, Sud Minervois ; SP, Saint-Ponais ; SPa, Sud Pardailhan ; V, Les Verreries-de-Moussans ; dC, décrochement de la Cesse, dM, décrochement de Masnaguine, fO, flexure de l'Orb.

Fig. 6. — Schéma des nappes du versant Sud. CSP, *central and south Saint-Ponais ;* F, *Fournes ;* M, *Minervois ;* MF, *Monts de Faugères ;* MP, *Mont Peyroux ;* NPa, *Nord-Pardailhan ;* NSP, *northern Saint-Ponais ;* P, *Prémian ;* R, *Les Rocles ;* SC, *Sources de la Cesse ;* SM, *Sud Minervois ;* SP, *Saint-Ponais ;* SPa, *Sud Pardailhan ;* V, *Les Verreries-de-Moussans ;* dC, *décrochement de la Cesse,* dM, *décrochement de Masnaguine,* fO, *flexure de l'Orb.*

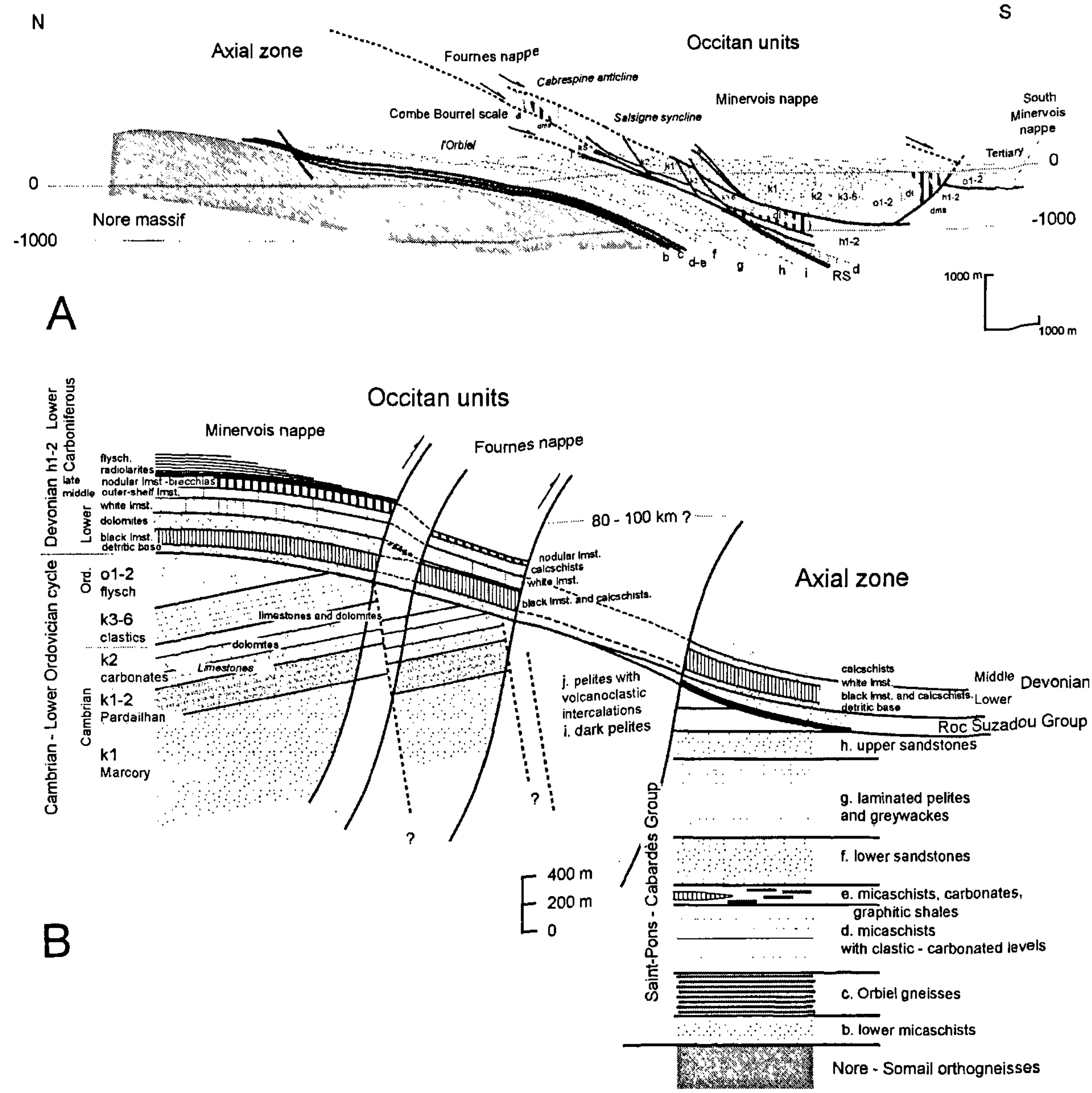

Fig. 7. — A : Cross-section of the Minervois nappe; B : Paleogeographic setting and lithostratigraphy of the Minervois nappe.

Fig. 7. — A : Section de la nappe du Minervois ; B : Cadre paléogéographique et lithostratigraphique de la nappe du Minervois.

southern limb of this syncline; towards the east, its northern limb is laminated, so that this unit becomes more or less monoclinal; (b) the intermediate Lucamis - Naudet unit is a half-syncline with Cambrian formations at the core surrounded by Ordovician ones; it disappears westwards between the adjacent units; (c) the Camplong-Poussarou unit is a large synfolial recumbent fold with well-preserved reverse and normal limbs; towards the south-east, the normal limb is sheared and its upper parts thrusted southwards. The famous Coulouma cross-section belongs to this normal sheared limb.

(v) The Les Rocles unit is formed of small klippes of Middle Cambrian formations resting horizontally over the Lower Cambrian Marcory Formation preserved in reverse position on the core of the Ferrals–Malviès syncline.

3) The eastern region: the Mont Peyroux and Monts de Faugères nappes and the Visean basin

The Pardailhan nappe lies eastwards, through a series of small tectonic slivers of Devonian carbonates on the Mont Peyroux nappe. That nappe is formed of Lower Ordovician, Devonian and Visean formations preserved in reverse position. The whole structure has been lately deformed by upright axial plane folds: the Vieussan antiform at the north, with a core of Visean terranes, and the Roquebrun synform in the south, with a core occupied of Ordovician formations. The Landayran series belong to the southern part of this synform. Below the Mont Peyroux nappes, the Monts de Faugères nappes are several slivers of Devonian an Visean terranes mostly observed in normal position. Both the Mont Peyroux and Monts de Faugères nappes are surrounded by Visean flysch formations. These successions are preserved in inverted position at the front of the Mont Peyroux nappe; they become eastwards progressively verticalized, and finally turns into normal subhorizonal position: this pattern emphasizes the syn-sedimentary deformation of the flysch sequence. Further evidence of the syn-tectonic deposition is given by the fact that (i) this flysch, first of distal character, becomes progressively proximal, (ii) many olistoliths appear within the flysch, gradding from lower plurimetric blocks, to pluri-hectometric, or even kilometric units, and turns into a wildflysch: these 'Cabrières slivers' demonstrate the syn-sedimentary emplacement of the nappes during Late Visean–Early Namurian times.

IV. — TECTONIC EVOLUTION

Three main phases can be distinguished in the tectonic evolution of the Montagne Noire (see an overview in Demange, 1998, 1999):

1) Pre-nappe folding and metamorphism.

The tectonic deformation of the internal zones of the orogen occurred before Mid Devonian times, and the orogenesis migrated progressively southwards. The culmination of the metamorphism (that pre-dated the thrust tectonics) is dated at 350 Ma in Rouergue, 343 Ma in Albigeois and 333 Ma in the southern Monts de Lacaune. In the Axial zone, this early tectonics formed large fold nappes contemporaneous with the development of the main regional metamorphism. This metamorphism is dated as Early Carboniferous by stratigraphic (Devonian terranes are involved) and geochronological (346-330 Ma) evidences; early granites are emplaced at the end of this stage.

2) Emplacement of the nappes.

The structure of the nappes results of several fold phases (fig. 8), for instance, the main synform and antiform patterns of the Pardailhan nappe are isoclinal folds associated with the main regional foliation; two stages of folding, both associated with foliation, occur in the Minervois nappe. But, in their final emplacement, these nappes are clearly thrust nappes because the shearing planes at their base clearly crosscut the internal folds. The syn-sedimentary emplacement of the nappe complexes during the late Visean to Early Namurian interval is testified by the presence of olistostroms on the eastern part of the southern slope.

3) Post-nappe folding and faulting.

The whole pile of nappes and their substratum were lately folded by several phases, so that the Axial zone appears as two domes (Agout-Nore and Cabardès) cropping out as a tectonic window below the nappes. Therefore, the Occitan domain outcrops in distinct areas: the southern slope, some klippes on the Axial zone and the Monts de Lacaune.

Late to post-tectonic granites are emplaced at different structural levels. A second low-pressure metamorphism was developed in the center of the Agout massif. The accidents at the edge of the Axial zone, and at the contact of the Monts de Lacaune thrust slices, the Mazamet fault and the large NNE-SSW faults that carve the southern slope, worked as brittle wrench faults, forming at the scale of the Montagne Noire a large dextral system. The Stephanian Graissessac basin appears as a pull-apart basin on the Monts de Lacaune fault. Post-Variscan tectonics include Permian extension (with the Lodève and Saint-Affrique basins) and Pyrenean compression: the Monts de Lacaune and Mazamet faults worked then as reverse faults; the offset of the Mazamet fault is about 1200 m.

V. — PRE-OROGENIC RECONSTRUCTIONS

Reconstructions of the pre-Variscan evolution greatly depends on the hypothesis that may be formulated about the origin of the different allochtonous units. Unfortunately, tectonic data and paleogeography are often difficult to reconcile (Gèze, 1949; Gèze *et al.*, 1952; Arthaud, 1970). The model presented here (Demange, 1994) takes into account the new data accumulated during the last 20 years, and considers the vergence of the structures, the displacements along the late wrench faults, and sedimentological and paleogeographic data. We tried to regroup in the same paleogeographic domains the different units nowadays scattered by Variscan tectonics, which show the same lithostratigraphic content deposited in similar environments. This reconstruction is mostly based on the Lower Cambrian and Devonian successions, which show the most important variation in time and space. There is not enough sedimentological studies on the thick, Middle-Upper Cambrian and Lower Ordovician, siliciclastic successions in order to use them in such reconstructions. We also include in this reconstruction data from the eastern Pyrenees, where the successions are similar to those of the Montagne Noire. Another problem is the interpretation and the age of the metamorphic formations on the Axial zone (see the discussion of this model in Demange, 1998).

The relative position of the different tectonic nappes may be very likely evaluated, but their absolute position remains unknown. We can only propose a minimum estimation for the gap between the main nappes because balanced cross-section techniques cannot be used in domains that have been deformed by polyphasic syn-folial tectonics.

VI. — PRE-OROGENIC SEDIMENTARY EVOLUTION

The pre-Variscan successions of Montagne Noire (and eastern Pyrenees) consist of a Precambrian basement and a Paleozoic cover corresponding to two distinct sedimentary cycles: the lower one from Early Cambrian to Early Ordovician, and the second one from Late Ordovician to Mid Carboniferous.

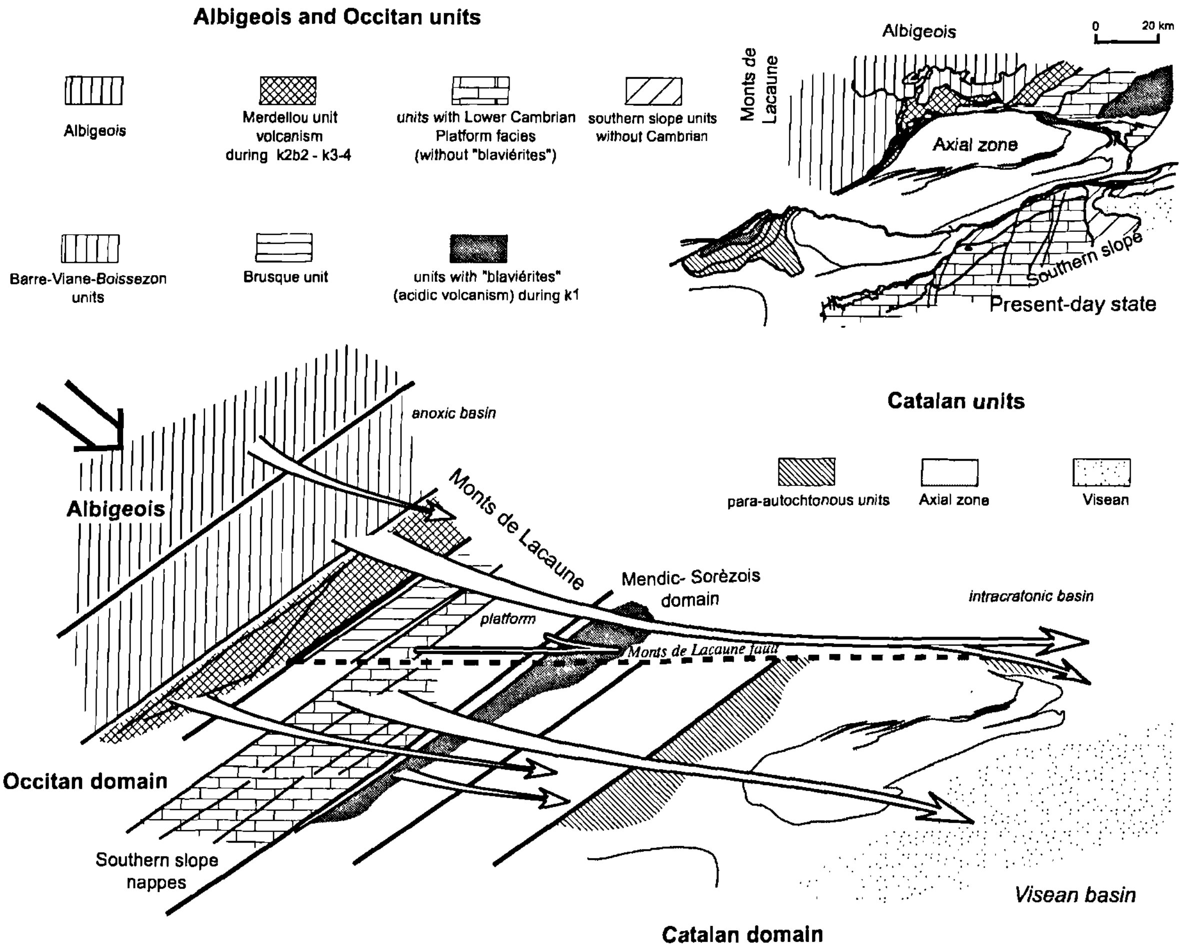

Fig. 8. — Paleogeographic reconstructions of the emplacement of the thrust nappes (late Visean-Namurian) of the Albigeois, Occitain and Catalan domains.

Fig. 8. — Reconstitutions paléogéographiques de l'emplacement des nappes (Viséen supérieur-Namurien) des unités albigeoises, occitaines et catalanes.

1) A Gondwana Precambrian basement

The existence of a Precambrian basement in Montagne Noire and the eastern Pyrenees is mostly supported by geological considerations (Guitard, 1970). Recent geochronological studies (Alexandrov, 2000) interpret the orthogneiss of the Canigou as Ordovician, but U/Pb diagrams given in that work rather support an age of about 600 Ma or even older for some facies. Further evidence of a Precambrian basement is given by clastic minerals of Pan-African age in Lower Cambrian formations (Gebauer & Grünenfelder, 1976), by zircons in Middle Cambrian sediments of the Pardailhan nappe, and by micaschists of the Axial zone that provide a Gondwana age spectrum (Gebauer *et al.*, 1989). In the eastern Pyrenees, the basement complex is made of paragneiss and orthogneisses derived from Pan-African granites (Guitard *et al.*, 1996). In Montagne Noire, the Somail orthogneiss represent such Pan-African granites. The presence of Precambrian paragneisses in Montagne Noire remains debatable; we rather consider that the paragneisses and micaschists of the Axial zone derived from Infracambrian/Cambrian sediments.

2) The Cambrian-Early Ordovician passive margin cycle

This first sedimentary cycle (fig. 9) corresponds to the progressive setting of a passive margin on the edge of the Gondwana craton:

(i) The pre-rifting stage. The transgression of molassic sediments after the Pan-African orogeny took place during Early Cambrian times. In the southern slope nappes, the Marcory Formation (k1 after the BRGM maps) represents tidal flat sediments. In the Mendic-Sorézois domain, acidic volcanism of potassic ferriferous meta-aluminous character ('blaviérites') appears at the end of this period; the equivalent of this volcanism in the Axial zone is the Murat-Rouvials Formation (dated at 532 ± 15 Ma; Ducrot *et al.*, 1979) and in the Pyrenees, a part of the G_1 gneisses. In the southern slope nappes, changes in sedimentary supply (in particular the abundance of potash feldspar) in the upper Marcory and Pardailhan Formations is interpreted as the distal effect of this volcanism (Issard, 1984).

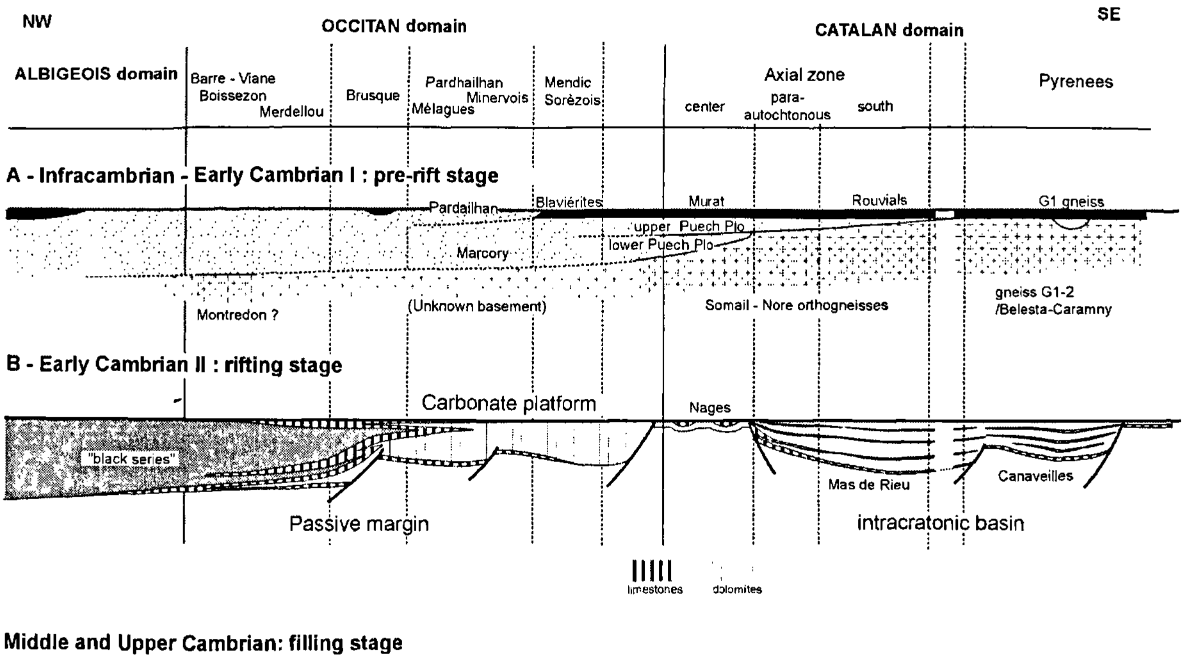

Fig. 9. — Early Cambrian paleogeography. A : Pre-rift stage (Early Cambrian I) ; B : Rifting stage (Early Cambrian II).

Fig. 9. — Paléogéographie du Cambrien inférieur. A : Etage pré-rift (Cambrien inférieur I) ; B : Etage rifting (Cambrien inférieur II).

(ii) Several distinct paleogeographic domains appear at the rifting stage during the Early Cambrian II (k2):

The Catalan domain corresponds to an intracratonic, mostly clastic basin (Mas de Rieu and Canaveilles Formations) with some biochemical deposits (dolomites and graphitic shales) that involved into a confined euxinic basin.

To the north, a carbonate platform settles in the southern part of the Occitan domain (Courjault-Radé, 1988). Synsedimentary faults with breccias occur in Minervois (Lépine, 1989); this platform evolved in space and time from supratidal to lagoonal conditions (dolomites with stromatolites, relics of evaporites), to internal platform conditions (limestones rich in organic matter and cherts: Lastours Formation) and finally to external platfom conditions (Pont de Poussarou Formation).

Northwards (northern part of the Occitan and Albigeois domains), the carbonate platform graded rapidly in space and time to a distal anoxic basin (clastic 'black series' rich in phosphate nodules); a basic or bimodal volcanism of tholeitic character appears locally (Medellou unit).

During these times the open-sea domain was probably located to the north of the Montagne Noire: it is the 'Centralian ocean', although this 'ocean' never had an oceanic crust.

(iii) Post-rifting stage. The drowning of the carbonate platform (marked by the nodular limestones and shales of the La Tanque and the lower part of the Coulouma Formations) occurred across the Lower-Middle Cambrian transition. Post-rift deposits consist of thick and rather uniform siliciclastic filling. The current stage of research does not allow an outline of the basin's paleogeography. Anyway, one can recognize a Mid-Late Cambrian phase, where the sedimentary supply consisted of mature, well-sorted quartzites and shales. In the southern slope nappes, after the Coulouma Formation, three (mega)sequences are recognized: massive coarse-grained laminated quartzites, pelites and silts with current ripples, and finally thin laminated pelites. During Late Cambrian and earliest Ordovician, the re-apparition of limestones, sometimes alternating with nodular and variegated pelites, marks an event that remains questionable. The Early Ordovician sedimentary supply contrasts very much with the Mid Cambrian one: sediments are now very immature (rich in feldspar and micas) and poorly sorted; the successions consist of a very thick, monotonous rhythmic succession of greywackes and shales, classically interpreted as flysch deposits. Recent studies performed in its upper part suggest rather platform sediments (Dabard & Chauvel, 1991). In Albigeois, basic volcanism somewhat similar to MORBS announces oceanisation.

3) The Late Ordovician –Early Devonian inversion of the paleogeographic sketch

During Late Ordovician to Early Devonian times, the sedimentation returned to nearshore platform conditions, and a progressive transgression was spread on the more or less eroded Cambro-Ordovician successions. These paleogeographic changes did not result from compressive movements, but from distensive tectonics: a flexure with tilted blocks where the series may be eroded down to Early Cambrian I may be traced from what is nowadays the northern Minervois to Les Verreries-Premian units (Issard, 1984). Paleogeography is the opposite than that of the Cambro-Ordovician cycle: in the Catalan domain, a transgression occurred during Late Ordovician, whereas the southern Occitan domain was reached during Early Devonian; the transgression did not reach the Monts de Lacaune.

4) The Devonian–Visean foreland basin cycle

The Devonian of the Montagne Noire does not record the orogeny that affected the internal zones (and maybe the Albigeois domain; Guérangé-Lozes, 1987) during Mid Devonian times. The sedimentation went on with progressive evolution from carbonate platform to slope conditions in Late Devonian and later on, to pelagic conditions during Early Carboniferous. The Devonian successions vary from proximal in the uppermost tectonic units (Cabrières scales) to distal in the lowest tectonic units (Fournes, Northern Saint-Ponais, Axial zone): the paleogeographic setting is now inverted in relation to the Cambro-Ordovician cycle; the distal zones are now located southwards. The Devono-Carboniferous basin represents a foreland framework with respect to the Variscan orogeny. The most distal conditions are reached during the Tournaisian with condensed deposits of radiolarites. The basin was subsequently filled by thick turbiditic sequences, first distal then becoming more and more proximal. At latest Visean and earliest Namurian, deposition of olistostromes announces the syn-sedimentary emplacement of the nappes (Engel *et al.*, 1981).

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THE LOWER CAMBRIAN OF THE SOUTHERN MONTAGNE NOIRE

Le Cambrien inférieur de la Montagne Noire méridionale

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Abstract. — The Lower Cambrian sedimentary succession of the southern Montagne Noire consists of a lower subtrilobite, siliciclastic succession (Marcory Formation) overlain by a carbonate-dominant succession (Pardailhan, Lastours and Pont de Poussarou Formations). The chronostratigraphic units reported in this area are twofold: the Siberian chart (based on archaeocyaths) and the Iberian chart (based on trace fossils, archaeocyaths and trilobites). Both the Precambrian-Cambrian and the Lower-Middle Cambrian boundaries are not recognisable due, respectively, to the thrusted bottom of the Marcory Formation, and the highly recrystallized character of the Pont de Poussarou limestones.
The Lower Cambrian trilobite colonization took place throughout three steps comprising, in chronological order, the input of (i) redlichiids (genus *Blayacina*), (ii) doleroleniids (*Granolenus*), redlichiids (*Eoredlichia*) and protolenids (*Limouolenus*), and (iii) palaeolenids (*Ferralsia*). A seeming endemic pattern of the three trilobite assemblages is remarkable because only one species (*Granolenus midi*) is reported outside the Montagne Noire. The archaeocyath-bearing limestones are limited to few horizons of the Pardailhan Formation on the Minervois and Pardailhan nappes. There are no endemic archaeocyathan genera in the southern Montagne Noire: *Afiacyathus-Sibirecyathus*, *Anthomorpha*, *Dictyocyathus*, *Erismacocisnus*, *Inessocyathus*, *Protopharetra* and *Retecoscinus* are known in northern Africa, western Europe and Siberia. All of them are Botoman in age (Siberian chart).

Résumé. — *La sédimentation du Cambrien inférieur dans le versant méridional de la Montagne Noire comprend une succession inférieure (avant l'apparition des premiers trilobites) ou Formation Marcory, et une succession supérieure riche en carbonates (Formations de Pardailhan, Lastours et Pont de Poussarou). Deux unités chronostratigraphiques sont utilisées en Montagne Noire : l'échelle sibérienne (à partir de la corrélation des archéocyathes) et celle de la Péninsule Ibérique réalisée à partir de l'étude des ichnofossiles, des archéocyathes et des trilobites. Les limites du Précambrien-Cambrien et du Cambrien inférieur/moyen ne sont pas reconnaissables compte tenu, respectivement, de la base faillée de la Formation de Marcory et du degré de recristallisation des calcaires de la Formation Pont du Poussarou.*
La colonisation par les trilobites du Cambrien inférieur s'est réalisée en trois phases, par ordre chronologique, (i) les redlichidés (genre Blayacina*), (ii) les dolerolenidés (*Granolenus*), les redlichidés (*Eoredlichia*) et les protolenidés (*Limouolenus*), et (iii) les palaeolenidés (*Ferralsia*). Le caractère endémique des trois assemblages à trilobites est remarquable car une seule espèce (*Granolenus midi*) apparaît hors de la Montagne Noire. Les archéocyathes se limitent à quelques horizons carbonatés, souvent lenticulaires, de la Formation de Pardailhan dans les nappes du Minervois et de Pardailhan. Les genres d'archéocyathes ne sont pas endémiques en Montagne Noire méridionale:* Afiacyathus-Sibirecyathus, Anthomorpha, Dictyocyathus, Erismacocisnus, Inessocyathus, Protopharetra *et* Retecoscinus *sont connus en Afrique du Nord, Europe occidentale et Sibérie. Ils permettent de dater la série comme botomienne (échelle sibérienne).*

I. — INTRODUCTION

The Lower Cambrian sedimentary succession of the southern Montagne Noire displays a lithology similar to that known on the Iberian Peninsula, the Armorican Massif and Sardinia. Its lowermost part exhibits a monotonous, siliciclastic pattern (Marcory Formation), very poor in shelly fossils. Its paleoichnological record shows a seeming low degree of diversity, and the organic-walled microfossils have no good preservation in surface. The upper half of the Lower Cambrian rocks displays a dominant carbonate character that goes on across the Lower-Middle Cambrian transition; this feature is also recognized in the Cantabrian Mountains and Sardinia. The carbonate-dominant succession contains, at the lower part, scarce trilobites interbedded with archaeocyathan and microbial buildups. Its uppermost part is complex and very poor in biostratigraphically significant fossils. As a result, the biochronologic control is absent in two formations, in which the Lower-Middle Cambrian boundary is tentatively situated.

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II. — CHRONOSTRATIGRAPHIC SCALES

Two chronostratigraphic charts are used in the Lower Cambrian of the Montagne Noire: (i) the classic Siberian scale based on archaeocyaths (Rozanov & Chernysheva, 1983; Rozanov & Sokolov, 1984; Spizarskhi *et al.*, 1986), and (ii) the Iberian scale (Liñán *et al.*, 1993) based on assemblages of trilobites, archaeocyaths and ichnofossils. The detailed correlation of the Lower Cambrian rocks in the southern Montagne Noire is a matter of controversy due to the scarcity of biostratigraphically significant fossils: e.g., (i) only one significant ichnospecies has been reported, (ii) the whole studied archaeocyaths belong to the Botoman stage (Siberian chart), and (iii) only one trilobite species is correlatable outside France. In addition, the Precambrian-Cambrian boundary is not located due to the thrust contact at the bottom of the Cambrian outcrops, and the Lower-Middle Cambrian boundary seems unrecognisable because of the high degree of neomorphism and dolomitization processes displayed by the carbonates across the transition.

III. — STRATIGRAPHY

The Lower Cambrian lithostratigraphic units of the southern Montagne Noire are, in ascending order, the Marcory, Pardailhan, Lastours and Pont de Poussarou Formations (fig. 1).

1) The Marcory Formation

The Marcory Formation (after the Signal de Marcory, a hill situated at the NW of Pardailhan, Hérault) consists of an alternation of sandstone and shale beds (more than 1000 m thick) bearing isolated conglomeratic layers. The bottom of the formation is unknown and its upper boundary is located at the occurrence of decimetric carbonate lenticular and tabular beds bearing archaeocyathan debris. The oldest biostratigraphic control is based on trace fossils due to the appearance of *Psammichnites gigas* (Álvaro & Vizcaïno, 1999), whose presence indicates a late Tommotian-early Atdabanian age (or late Cordubian-early Ovetian age). Some centimetre-thick nodules and layers of limestone located at the upper part of its lectostratotype (Orbiel valley) have yielded hyoliths and chancelloriid sclerites (*Allonia tripodophora* Doré & Reid, 1965 and *Chancelloria* sp.; Geyer 1984, 1986) indicating a broad Cambrian age.

Interbedded at the lower part of the Marcory Formation, a discontinuous system of white lenticular limestones (named the Salsigne limestones) crop out between the Clamoux valley and the city of Salsigne (Minervois nappe), in a ENE-SWS-trending transect paralleling a major thrust system. There were mapped by Gèze (1949) as belonging to the Pardailhan Formation, later considered as a lowermost part of the Marcory Formation by Boyer (1963), Issard (1984) and Demange *et al.* (1986), and finally reported as Devonian by Lépine (1989) according to the presence of unpublished microfossils. The age of these limestones is still a matter of discussion and may correspond to an earliest Cambrian episode of carbonate productivity.

2) The Pardailhan Formation

The Pardailhan Formation (named after the Pardailhan mountains) is composed of limestones and dolostones with intercalations of sandstones, conglomerates and green shales, 25-200 m thick. Its upper boundary is located at the disappearance of siliciclastic intercalations. The limestone beds are discontinuous laterally and their total number is variable. The first shelly metazoans are trilobites, *Blayacina miqueli* Cobbold, 1932 and *Thoralaspis thorali* Cobbold, 1932 (the latter a junior synonym of the former according to Geyer, 1992), located within a sandstone level, 5-6 m below the first limestones bearing archaeocyaths. The number of carbonate intercalations in the Pardailhan Formation is laterally variable, which has introduced some ambiguity in the subdivisions of the formation on different tectonostratigraphic settings. Boyer (1962) subdivided the succession of alternating sandstones and limestones (Pardailhan Formation) into three intervals. Debrenne (1964) described ten limestone levels, arranged into four units: I/ alternances1-5, II/ alt.6-7, III/ alt. 8-9-10 and IV/Masse carbonatée. Debrenne *et al.* (1990) referred the whole archaeocyathan distribution in the southern Montagne Noire to the Botoman or Atdabanian-Botoman by comparison to western Europe, but lacking subdivisions. Álvaro *et. al.* (1998c) also suggested four archaeocyathan units. Courjault-Radé (pers. commun.) proposes a subdivision into three horizons more or less corresponding to the Boyer's subdivisions: horizon 1 or H1, alt. 1(pioneer reef)-alt. 7; H2, alt. 8-9-10 (10 = lower half of calcaires dolomitiques); H3 or 'Masse carbonatée' = upper half of the 'calcaires dolomitiques' horizons based on lithology and facies succession. The distribution of archaeocyathan fauna sharply depends upon variation of facies and, except for the ranges of *Retecoscinus boyeri* Debrenne, 1964 and of *Anthomorpha immanis* Debrenne, 1964, the faunal assemblage is almost constant. *Anthomorpha* is present throughout the whole section with probably 3 species (*A.* sp. in pioneer reefs, *A. margarita* Debrenne, 1964 in alt. 6 and *A. immanis* Bornemann, 1886, from alt.7 to the top of the formation). This stratigraphic framework makes very difficult to distinguish archaeocyathan zones.

At the base of the Pardailhan Formation the first small, carbonate lenses correspond to 'pioneer reefs' dominated by calcimicrobes and *Protophareta (stipata-circula–polymorpha)* and rarer *Retecoscinus boyeri*, all with diameters less than 6 mm. In some lateral lenses Regular archaeocyaths are dominant [particularly *Retecoscinus boyeri, Inessocyathus* sp., rare Ajacicyathina, and probable rotundocyathids impossible to determine at generic level because of their small size (diameter<2.5mm)] associated with scarce irregular archaeocyaths. It is remarkable that the first specimens of *Anthomorpha* sp. occur as small cups or ribbon-like fragments. Above the pioneer horizon, pure and larger limestone lenses contain scattered, small sized, stick-shaped cups, commonly broken.

The transition between the lower and upper intervals of the Pardailhan Formation is commonly marked by a relatively thick siliciclastic intercalation. Upwards, the frequency of carbonate lenses increases gradually containing scattered but more abundant archaeocyaths, such as ?*Afiacyathus* sp.,

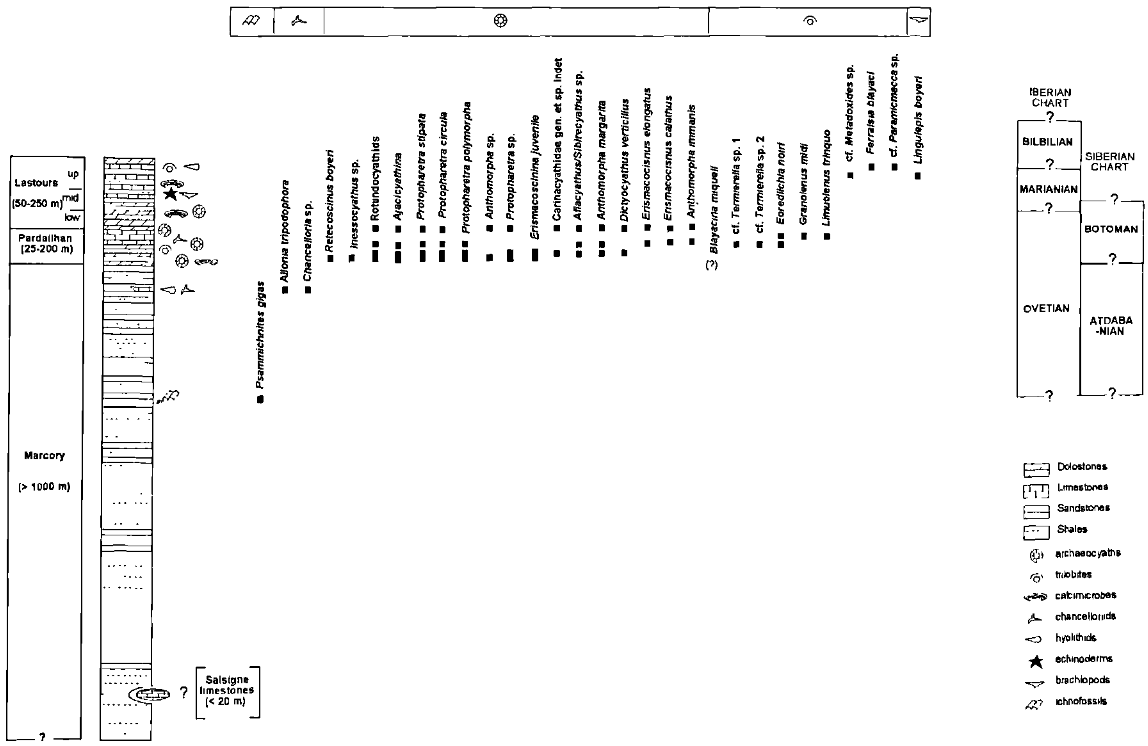

Fig. 1. — Lower Cambrian litho- and chronostratigraphy of the southern Montagne Noire, and stratigraphic ranges of reported taxa (modified after Álvaro *et al.*, 1998c).

Fig. 1. — Charte litho- et chronostratigraphique du versant méridional de la Montagne Noire, et distribution stratigraphique des taxons (modifiée d'après Álvaro et al., *1998c).*

Sibirecyathus sp., juveniles of Ajacicyathidae and Erismacoscinina, but lacking *Retecoscinus*; the assemblage is dominated by the abundance of *Anthomorpha* specimens, characterized by relatively small cups to ribbon-like fragments of *Anthomorpha margarita* Bornemann, 1886. The previous species of *Protopharetra* are almost replaced by *Dictyocyathus verticillus* (Bornemann, 1891).

In the upper part of the Pardailhan succession, the alternating sandstones became thinner, while the limestone layers increase in thickness and homogeneity. The same facies and fauna occur at the top of the formation. The fauna is more abundant with *Erismacoscinus calathus* (Bornemann, 1886), *Erismacoscinus elongatus* (Bornemann, 1886), *Erismacoscinus* sp., *Inessocyathus* sp., and rare Carinacyathidae (ex Porocyathidae). *Anthomorpha margarita* is the dominant taxon, recognized as cylindrical cups (up to 35 mm of height) to mushroom-shaped and ribbon-like fragments. *Anthomorpha immanis* Debrenne, 1964, bearing a very large saucer-like cup with remote septa, appears as isolated long ribbons; it persists until the top of the 'Masse carbonatée' (level K2b of Berger *et al.*, 1993). The presence of *Anthomorpha* species since the lower carbonate lenses permits the correlation of the whole archaeocyathan levels with the Botoman stage of the Siberian chart.

On the other hand, the sandy intercalations have yielded an assemblage of hyoliths and trilobites (Courtessole *et al.*, 1971) composed of *Eoredlichia noiri* (Jago, 1980), cf. *Termierella* sp.1, cf. *Termierella* sp. 2, *Granolenus midi* Jago, 1980 and *Limouolenus trinquo* Jago, 1980 (*in* Courtessole & Jago, 1980). *Granolenus midi* occurs in the upper Ovetian beds of the Toledo mountains (Liñán & Gámez-Vintaned, 1993).

3) The Lastours Formation

The Lastours Formation (after the village of Lastours) consists of massive and stratified limestones and dolostones with rare shaly intercalations. This formation has been subdivided into three members: (i) its lower member is composed of massive and bedded limestones (up to 50 m in thickness), (ii) its middle one of grey limestones and yellow and black dolostones (20 to 60 m in thickness), with rare green and purple shaly intercalations, and (iii) the upper member of bedded limestones and dolostones alternating with green and purple shales (40 to 150 m thick). The last member has yielded (Cobbold, 1935; Courtessole *et al.*, 1971; Termier & Termier, 1974; Pillola, 1991) trilobites (*Ferralsia blayaci* Cobbold, 1935, cf. *Paramicmacca* sp. and cf. *Metadoxides* sp.), brachiopods (*Lingulepis boyeri* Termier & Termier, 1974) and hyoliths. According to Álvaro *et al.* (1998a), *Ferralsia blayaci* is latest Marianian to earliest Bilbilian in age.

4) The Pont du Poussarou Formation

The Pont de Poussarou Formation (named after a bridge above the Ilouvre river, at the NW of Saint-Chinian) consists of massive white limestones (20-80 m thick), partly dolomitized, rich in bioclastic debris, which locally exhibits a gradual transition into the overlying La Tanque Formation. Its age is probably latest Early Cambrian (Bilbilian)-earliest Middle Cambrian but the horizon of the Lower-Middle Cambrian is not recognisable due to the important diagenetic processes recorded in the limestones.

IV. — SEDIMENTARY CONTROLS ON BIODIVERSITY

The sub-trilobite Marcory Formation exhibits monotonous, shaly features and dramatic lack of shelly fossils. Only in its uppermost part, the first small shelly fossils (hyoliths and chancelloriids) occur in centimetre-thick limestone nodules. As remarked above, other significant taxa (such as organic-walled microfossils) and ichnotaxa have not yet been studied in detail. As a result, the lack of biodiversity knowledge does not allow the study of the Precambrian-Cambrian transition in the southern Montagne Noire. The first trilobites occur underlying the first archaeocyathan colonization of carbonate substrates.

During this first phase of carbonate development, siliciclastic inputs are still important, preventing the lateral continuity and the volume of the microbial bioconstructions, locally containing small cups of archaeocyaths. The volume of siliciclastic levels decreases progressively, alternating with well-developed calcareous bodies with a more continuous regional extension. This succession is well-represented in the southern Minervois nappe and occurs more randomly in the northen Minervois and Pardailhan nappes.

The last episodes of archaeocyathan colonization are confined to the upper part of the Pardailhan Formation. The episodes share similar lithological characters and faunas. Archaeocyaths are commonly of small size, and randomly distributed except in some bioclastic lenses or layers as broken or corroded fragments. At the topmost of the Pardailhan Formation the lithofacies of the archaeocyathan-bearing limestones differ from one tectonic unit to other: grey to dark-grey limestones with large isolated saucer-like archaeocyath cups (southern Pardailhan); patchly distributed bioclastic lenses (northern Pardailhan and southern Minervois); isolated cups and more abundant ribbons representing very large cups become more frequent and commonly well-preserved in the last colonization episode. The classic 'calcaires à *Archaeocyathus*' unit, known from the 19th century, has not yielded archaeocyaths.

The Lower Cambrian trilobite colonization took place in three episodes comprising, in chronological order, the input of (i) redlichiids (genus *Blayacina*), (ii) doleroleniids (*Granolenus*), redlichiids (*Galloredlichia*) and protolenids (*Limouolenus*), and (iii) palaeolenids (*Ferralsia*). It is remarkable the seeming endemic patterns of these trilobite assemblages because only one species (*Granolenus midi*) is reported outside the Montagne Noire. The poor trilobite diversity can be explained as the interplay of several factors, such as the abundance of archaeocyathan-microbial carbonates devoid of trilobites, the high recrystallization degree of limestones (due to neomorphism and dolomitization), the shallow character of the Lastours sediments (which exhibit local subaerial exposures; Álvaro *et al.*, 1998b) and, perhaps the most important, sampling biases.

In addition, the sedimentological and paleogeographic patterns are poorly understood. The presence of evaporite relics, oolitic limestones and build-ups in the Lastours Formation has been related to subtropical arid conditions in the western Mediterranean area (Álvaro *et al.*, 2000).

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THE MIDDLE-UPPER CAMBRIAN OF THE SOUTHERN MONTAGNE NOIRE

Le Cambrien moyen-supérieur de la Montagne Noire méridionale

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Abstract. — The Middle-Upper Cambrian sedimentary succession of the southern Montagne Noire consists of two mixed (siliciclastic-carbonate) intervals bounded by a middle coarse-grained, siliciclastic one. Five formations are distinguished, from bottom to top, the La Tanque, Coulouma, Ferrals, La Gardie and Val d'Homs Formations. A three-fold chronostratigraphic subdivision is reported here for the Middle Cambrian, comprising the Leonian, Caesaraugustian and Languedocian stages, a chart used in the entire Mediterranean area. The Lower-Middle Cambrian boundary is not recognized in the southern Montagne Noire: the first Leonian trilobites occur across the La Tanque-Coulouma transition. A late Leonian-Caesaraugustian trilobite radiation is recognized coinciding with a broad transgression, indicated by the stepwise immigration and evolution of relative cosmopolitan trilobites, such as the paradoxidids, conocoryphids and solenopleurids. A substantial decline in trilobite diversity is recorded across the latest Caesaraugustian-mid Languedocian interval. By contrast, echinoderms were not greatly affected: they increased in diversity across the lower Languedocian and disappeared at the middle middle Languedocian. Finally, an abrupt increase in trilobite diversity, related to transgressive pulses and immigration of previously known families and new Asiatic invaders, occurs throughout late Languedocian and Late Cambrian times. The Upper Cambrian echinoderm assemblages represent a diversification event pre-dating the Ordovician radiation, and comprise mitrates, glyptocystitid cystoids, and edrioasteroids.

Résumé. — *La succession sédimentaire du Cambrien moyen et supérieur de la Montagne Noire méridionale consiste en deux ensembles à caractère mixte (silicoclastique-carbonaté), limités par un ensemble gréso-pélitique. Cinq formations y ont été distinguées, qui sont, de bas en haut, les Formations de La Tanque, Coulouma, Ferrals, La Gardie et Val d'Homs. Trois subdivisions chronostratigraphiques sont reconnues : les étages Léonien, Caesaraugustien et Languedocien, qui sont utilisés pour l'ensemble de la province méditerranéenne. La limite Cambrien inférieur-moyen n'est pas reconnue en Montagne Noire: les premiers trilobites léoniens apparaissent à la transition des Formations de La Tanque et de Coulouma. Une importante diversification des trilobites intervient entre le Léonien terminal et le Caesaraugustien en relation avec une importante phase de transgression, comme en témoignent l'immigration progressive et l'évolution de trilobites relativement cosmopolites comme les paradoxididés, les conocoryphidés et les solenopleuridés. Un déclin substantiel de la diversité des trilobites est enregistré entre le Caesaraugustien terminal et le Languedocien moyen. La diversité des échinodermes s'accroît durant le Languedocien inférieur et chute très fortement au cours de la partie médiane du Languedocien moyen. Enfin, la diversité des trilobites augmente de manière soudaine entre le Languedocien terminal et le Cambrien supérieur, en relation avec différentes transgressions et l'apparition de trilobites appartenant à des familles déjà connues ainsi que de migrants asiatiques. L'assemblage d'échinodermes du Cambrien supérieur, composé de mitrates, de cystoïdes glyptocystitides et d'édrioastéroïdes, témoigne d'une première phase de diversification annonçant la grande radiation ordovicienne*

I. — INTRODUCTION

The Middle Cambrian succession of the southern Montagne Noire has been known since 1888, when Bergeron discovered the 'primordial fauna' of Barrande (1846) in the Ferrals-les-Montagnes area. The first attempts at a biostratigraphic Middle Cambrian division in the Montagne Noire are due to Bergeron (1889, 1893), Rouville *et al.* (1893, 1894) and Miquel (1894), who recognized three series or 'assises'. Thoral (1935, 1947, 1948) subdivided the Middle Cambrian into three zones; the so-called *Paradoxides rouvillei*, *P. mediterraneus* and *P. forchhammeri* Zones. The presence in the Montagne Noire of *P. forchhammeri* was proposed by Miquel (1905) after studying an isolated librigena, which was reported to be the previous trilobite species biostratigraphically important for the Baltic biozonation of the upper Middle Cambrian. However, this assignation is ambiguous and does not represent a level of correlation. Afterwards, Courtessole (1967, 1973) and Courtessole *et al.* (1988) established ten paleontological levels (from A1 to H2) for the Middle Cambrian, characterized by assemblages of trilobites, echinoderms and linguliform brachiopods. This sketch has been recently confirmed in south-western Europe: Álvaro & Vizcaïno (1998) proposed a new chronostratigraphic framework for the Middle Cambrian sedimentary rocks of south-western Europe, based on the stages previously erected in the Iberian Peninsula and Courtessole's paleontological levels. As a result, a three-fold

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chronostratigraphic subdivision was proposed, comprising the Leonian (defined by Liñán *et al.*, 1993; revised by Sdzuy *et al.*, 1999), the Caesaraugustian (defined by Liñán *et al.*, 1993; revised by Álvaro & Vizcaïno, 1998, who proposed only interval and assemblage biozones in order to avoid diachronism in some range zones), and the Languedocian (defined by Álvaro & Vizcaïno, 1998). The three names are related to three geographical areas in which the paleontological record is rich and diverse: the Cantabrian Mountains (northern Spain), the Iberian Chains (NE Spain) and the Montagne Noire (France). This chart is nowadays used in the whole Mediterranean region, from Morocco to Turkey. Some Leonian trilobites have been recently discovered in the Pardailhan nappe (Álvaro & Vizcaïno, 2000). The Caesaraugustian fossil assemblages comprise Courtessole's levels A1 to D (partly). Finally, the Languedocian stage is characterized by a terrigenous succession, up to 700 m thick, which includes the uppermost part of the Coulouma Formation, the whole Ferrals and partly the La Gardie Formation. In its stratotype, the Ferrals-les-Montagnes section, 36 trilobite and 13 echinoderm taxa are known (Courtessole, 1973; Courtessole *et al.*, 1988; Álvaro *et al.*, 1999). The Sallèles-Cabardès section is also considered as the upper boundary reference section. The first record of the trilobite species *Solenopleuropsis (Manublesia) thorali* and the genus *Palaeodotes* (Feist & Courtessole, 1984; Shergold *et al.*, 2000) are respectively considered as the lower and upper boundary points of the stage. However, its upper boundary could be modified in the future according to the discussions involved in the International Subcommission on Cambrian Stratigraphy concerning the definition of the Middle-Upper Cambrian boundary. The Languedocian stage is subdivided into three substages, comprising interval and assemblage zones.

Concerning the Upper Cambrian, it was reported for the first time in 1984 (Feist & Courtessole, 1984). The Upper Cambrian was previously considered absent in the southern Montagne Noire by condensation or erosive unconformities (Gèze, 1949; Courtessole, 1973). However, the Ferrals-les-Montagnes section has yielded enough well-preserved trilobites, described by Shergold *et al.* (2000). They show an Australo-Sinian character, and comprise the genera *Ammagnostus*, *Kormagnostus*, *Proceratopyge*, *Prochuangia*, *Palaeadotes*, *Olentella*, *Stigmatoa*, *Paraacidaspis*, *Shengia* and *Abharella*. A slightly younger trilobite assemblage (in preparation) occurs between Rieussec and Aigues-Vives. It contains species of *Prochuangia*, *Proceratopyge*, *Probilcunaspis*, *'Parakoldinia'* and *Rhaptagnostus*, but is dominated by a species of *'Maladioidella'*. Elements of these two Late Cambrian assemblages occur elsewhere in the southern Montagne Noire in the vicinities of Sallèles-Cabardès and the ravin du ruisseau des Refescals, southwest of Coulouma.

Several localities in the Pardailhan Mountains have yielded a diverse echinoderm fauna described by Ubaghs (1998). This assemblage comprises stylophorans (undetermined cornutes and *Lobocarpus vizcainoi*, the oldest recorded mitrate), glyptocystitid cystoids (*Barroubiocystis radiata*, *Velieuxicystis ornata*), edrioasteroids (?*Stromatocystites* sp.), and an enigmatic form (*Scoteinocystis cambriensis*). This assemblage represents, with Australia (Jell *et al.*, 1985; Smith & Jell, 1990, 1999) and western USA (Ubaghs, 1963; Sumrall *et al.*, 1997), one of the most diverse echinoderm assemblages described so far in the Upper Cambrian (Vizcaïno & Lefebvre, 1999).

No biostratigraphic units are yet defined in the Upper Cambrian of the southern Montagne Noire, but new findings and descriptions of conodonts, brachiopods, trilobites and acritarchs are in course, and the next years will offer a key opportunity to consider this region as a reference in the biochronology of the Upper Cambrian.

II. — STRATIGRAPHY

The Minervois and Pardailhan nappes provide a good area of reference for the study of the Middle-Upper Cambrian because of their stratigraphic continuity, paleontological wealth, and the presence of both endemic and cosmopolitan faunas, useful for intercontinental correlation. The Middle-Upper Cambrian lithostratigraphic units are the La Tanque, Coulouma, Ferrals, La Gardie and Val d'Homs Formations, which are described below.

1) The La Tanque Formation

The La Tanque Formation (after a ravine in Ferrals-les-Montagnes, Hérault) is composed of a centimetric alternation of bioclastic limestones and shales (up to 60 m in thickness), characterized by reddish and purple colours. The formation represents the 'griotte' facies described in south-western Europe across the Lower-Middle Cambrian transition. Its upper boundary is located at the appearance of green shales. It contains debris of bioclasts (trilobites, brachiopods, sponge spicules, chancelloriid sclerites, echinoderms, etc.). The age of its upper boundary is diachronous and biostratigraphically controlled: in the Coulouma area, the first recognized Leonian trilobites occur in the overlying Coulouma Formation, whereas the last purple shales (La Tanque Formation) in the Ferrals-les-Montagnes area are middle Caesaraugustian due to the presence of the trilobite species *Pardailhania hispida*.

2) The Coulouma Formation

The Coulouma Formation (named after the locality of Coulouma, Hérault) is a monotonous succession (30-80 m thick) composed of green (and rarer purple) shales with carbonate nodules paralleling stratification. Its fossil content (after Thoral 1935, 1946, 1947, 1948; Howell, 1935; Cabibel *et al.* , 1958; Boyer & Courtessole, 1964; Courtessole, 1967, 1973; Termier & Termier, 1973, 1974; Smith, 1985; Ubaghs, 1987; Courtessole *et al.*, 1988; Friedrich, 1993; Álvaro & Vizcaïno, 1997, 1998, 2000) is very rich containing miomeroid trilobites (genera *Calodiscus*, *Condylopyge*, *Gallagnostus*, *Leiagnostus*, *Phalacroma*, *Phalagnostus*, *Pleuroctenium* and *Pseudoperonopsis*), polymeroid trilobites (genera *Agraulos*, *Badulesia*, *Bailiella*, *Conocoryphe*, *Corynexochus*, *Ctenocephalus*, *Eccaparadoxides*, *Jincella*?, *Liosolenopleura*, *Parabailiella*, *Pardailhania*, *Solenopleurina*, *Solenopleuropsis*, and *Velieuxia*), brachiopods (genera *Acrothele*, *Acrotyra*, *Glyptacrothele* and *Paterina*), and several echinoderms, such as edrioasteroids (genus *Cambraster*), cinctans (genera *Elliptocinctus*, *Gyrocystis*, *Sucocystis*), eocrinoids (*Gogia)*, primitive stylophorans (genus *Ceratocystis*), ctenocystoids (genus *Ctenocystis)* and one class of uncertain affinity (*Eocystites languedocensis* Ubaghs, 1987). The wealth in trilobites, echinoderms and brachiopods of this formation has permitted the definition of seven paleontological levels (A1-F; Courtessole, 1973), from Leonian to mid Languedocian (Middle Cambrian).

3) The Barroubio Group and the Ferrals Formation

Overlying the Coulouma Formation a complex lithostratigraphic unit has been proposed: the Barroubio Group. This group (named after Barroubio village, Hérault) consists of an alternation of sandstones and green shales (550 to 700 m thick) showing thin limestone intercalations in its upper part. It has been subdivided into four formations, from bottom to top, the Ferrals, La Gardie, Val d'Homs and La Dentelle Formations (the last one will be described in the following paper). The Ferrals Formation (after the locality of Ferrals-les-Montagnes, Hérault) consists of alternating white sandstones and green shales, 130 to 200 m thick. The formation is devoid of shelly fossils and only trace fossils are recognized.

4) The La Gardie Formation

The La Gardie Formation (named after the La Gardie hill situated at the SE of Ferrals-les-Montagnes, Hérault) is a siliciclastic succession, 200 to 500 m thick, composed of green shales with thin sandy intercalations at the top. It has been subdivided into three members whose fossil content is as follows (Courtessole, 1973; Courtessole *et al.*, 1988; Friedrich, 1993):

(i) The lower member (80 m thick) consists of green sandy shales and contains trilobites [*Bailiaspis souchoni* (Courtessole, 1973) and *Paradoxides* (s.l.)] and cinctan echinoderms [*Sucocystis melendezi* (Schröeder, 1973), *Sucocystis acrofera* Friedrich, 1993 and *Sucocystis* aff. *quadricornuta* Friedrich, 1993].

(ii) The middle member, 15 m thick, is composed of alternating green shales and grey sandstones and can exhibit centimetric limestone nodules at the top. It contains trilobites (genera *Bailiaspis*, *Conocoryphe*, *Chelidonocephalus*, *Derikaspis*, *Eccaparadoxides*, *Grandagnostus*, *Holocephalina*, *Jincella*?, *Pseudoperonopsis* and *Skreiaspis*), and the cinctan echinoderm *Sucocystis melendezi* (Schröeder, 1973).

(iii) The upper member, 0.5 to 5 m thick, consists of grey sandstone beds and thin green shaly intercalations, and contain the trilobites *Chelidonocephalus melchiori* Pillet, 1988, *Dorypyge vizcainoi* Pillet, 1988, *Grandagnostus major* Pillet, 1988 (*in* Courtessole *et al.*, 1988), *Eccaparadoxides* sp. and *Abharella* sp., and undetermined brachiopods and hyoliths.

The lower member has been reported to the paleontological level G (Courtessole *et al*, 1988) or middle Languedocian (Álvaro & Vizcaïno, 1999), the middle member to the paleontological levels H (Courtessole, 1973), H1 (Courtessole *et al.*, 1988) or late Languedocian (Álvaro & Vizcaïno, 1999), and the upper member to the paleontological level H2 (Courtessole *et al.*, 1988) or late Languedocian (Álvaro & Vizcaïno, 1999).

5) The Val d'Homs Formation

The Val d'Homs Formation (named after the Val d'Homs valley near the locality of Villeneuve-Minervois, Aude) consists of green and purple shales containing centimetric and decimetric, white, reddish and purple, lenticular to bedded limestones and yellow dolostones. Although it was recently re-defined (Álvaro *et al.*, 1998), we present here a new definition of its thickness and upper boundary in order to uniformize it with the new concept of the overlying La Dentelle Formation (see next paper in this volume). The Val d'Homs Formation displays a variable thickness from 60 up to 300 m thick. It can occur directly overlying both the Ferrals and the La Gardie Formations. Its upper boundary is located at the occurrence of the sandstones of the La Dentelle Formation. A lenticular limestone in Ferrals-les-Montagnes has yielded the trilobites *Ammagnostus (A.)* aff. *sinensis* Peng, 1987, *Kormagnostus*? sp., *Olentella* cf. *africana* Feist (*in* Destombes & Feist, 1987), *Stigmatoa courtessolei* Shergold *et al.*, 2000, *Sthengia* cf. *spinosa* Yang, 1978, *Proceratopyge (P.)* sp., *Palaeadotes latefalcata* (Feist & Courtessole, 1984), *Paraacidaspis ultima* Shergold *et al.* (2000), *Prochuangia gallica* (Feist & Courtessole, 1984) and *Abharella* sp. (Shergold *et al.*, 2000), and the brachiopod *Lingulella* cf. *delgadoi* Walcott (Termier & Termier, 1974). In addition, several outcrops have yielded the echinoderms *Lobocarpus vizcainoi* Ubaghs, 1998, *Barroubiocystis radiata* Ubaghs, 1998, *Velieuxicystis ornata* Ubaghs, 1998, ?*Stromatocystites* sp. and *Scoteinocystis cambriensis* Ubaghs, 1998. These assemblages were reported from paleontological level I by Courtessole *et al.* (1988), Late Cambrian.

Finally, Sdzuy (1958) reported the first Lower Ordovician trilobite *Proteuloma geinitzi* (Barrande, 1868) in reddish limestones just underlying the La Dentelle Quartzites in the Combes de Barroubio area. As these limestones belong to the new concept of the Val d'Homs Formation, the Cambrian-Ordovician boundary must be placed in the upper part of the Val d'Homs Formation, a lithostratigraphic unit with important lateral variations in facies and thickness that needs complementary studies.

III. — SEDIMENTARY CONTROLS ON BIODIVERSITY

1) The Leonian-Caesaraugustian trilobite radiation

The Leonian/Caesaraugustian recovery from a Lower-Middle Cambrian extinction (described in the Iberian Peninsula; Álvaro *et al.*, 1999) can be regarded as an adaptative radiation of an immigrant trilobite community that progressively invaded the western Gondwana margin from outer environments. The immigration is characterized by the abrupt and stepwise appearance of relatively cosmopolitan trilobites, which are, in order of appearance, paradoxidids, conocoryphids and solenopleurids.

Paleogeographic changes throughout the Leonian/Caesaraugustian interval suggest that the higher diversity assemblage was associated with more open-aspect facies brought in by a major transgression. Diversity increased and species proliferated during Caesaraugustian times, an interval characterized by environmental stability.

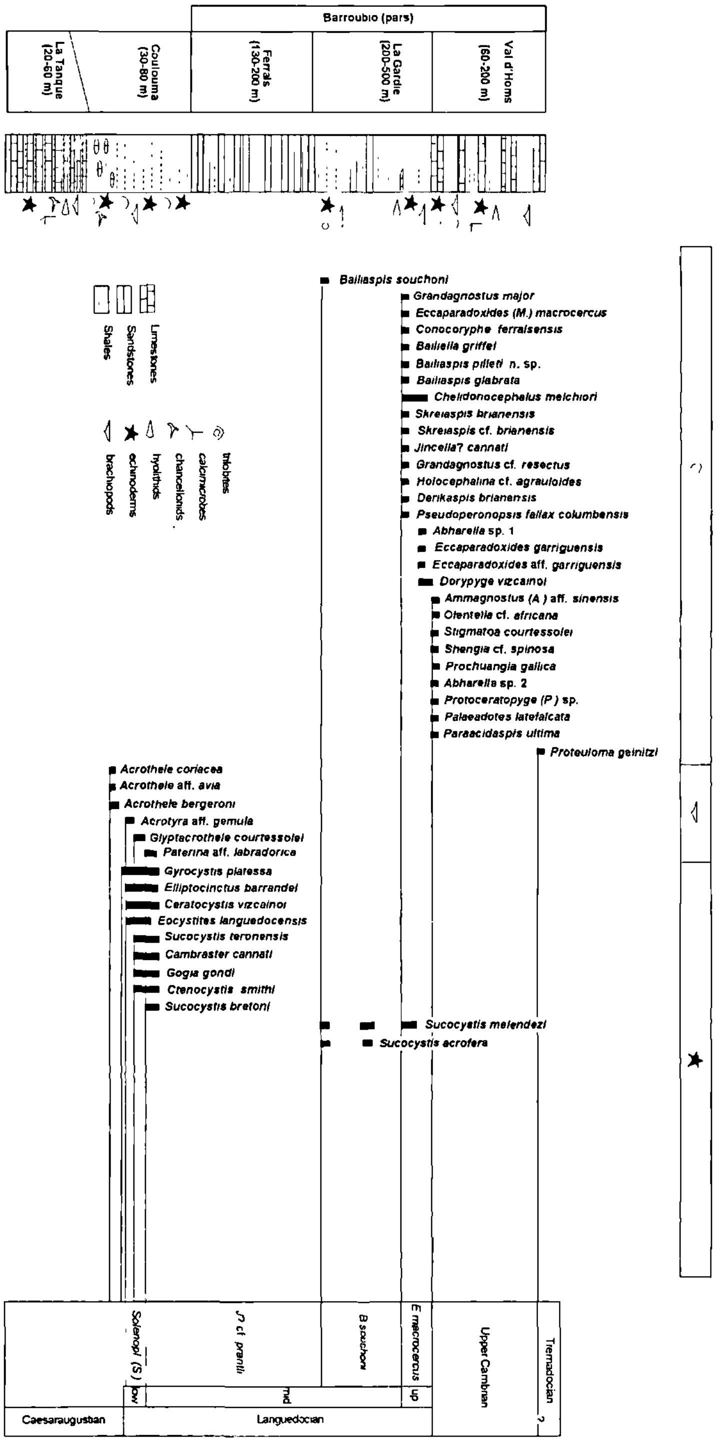

Fig. 1. — Stratigraphic ranges of trilobite, brachiopod and echinoderm species in the Middle-Upper Cambrian of the southern Montagne Noire.

Fig. 1. — Distribution stratigraphique des trilobites, brachiopods et échinodermes du Cambrien moyen-supérieur du versant sud de la Montagne Noire.

Apart from the trilobites, the echinoderms are the only group with a high fossilization potential and diversity in the Middle Cambrian deposits of south-western Europe. Although the variation in number of echinoderm taxa could possibly represent an artefact of the fossil record due to taphonomic biases, a significant diversification of echinoderms took place where muddy substrates persisted in the early and earliest middle Languedocian. The echinoderm diversification reported in south-western Europe is based largely on the faunas found in the southern Montagne Noire, which have yielded 9 species of cinctans, as well as eocrinoids, stylophorans, ctenocystoids, and other echinoderms of uncertain affinity. In summary, two different peaks of diversity are described for trilobites and echinoderms in the southern Montagne Noire, reported across the late Leonian-Caesaraugustian for trilobites, and the early-earliest mid Languedocian for echinoderms.

2) **The Lower-Middle Languedocian biocrisis**

A substantial decline in trilobite diversity is recorded across the latest Caesaraugustian/mid Languedocian interval. This diachronous decline was catastrophic for some trilobite forms, such as the Solenopleuropsinae Subfamily that disappeared in the area over this interval. By contrast, echinoderms were not greatly affected: they increased in diversity across the lower Languedocian and disappeared in the middle middle Languedocian.

This biocrisis is not a major extinction at familial level for trilobites, but it represents a high generic turnover. This faunal turnover sharply coincides with a rapid prograding shoaling which brought widespread areas in coarse-grained sandstones and, therefore, seems to be produced by geographically extensive environmental changes. Two opportunistic taxa are identified in the middle Languedocian siliciclastic succession (330-500 m thick) of the Montagne Noire: the trilobite species *Bailiella souchoni* and the cinctan species *Sucocystis melendezi*.

3) **The Late Languedocian diversification**

The La Gardie Formation is characterized by an abrupt increase in trilobite diversity (for genera and families). The turnover at the base of the late Languedocian occurs in shale and limestone intercalations, for which the appearance of the trilobite-index species *Eccaparadoxides macrocercus* provides a widespread marker. The appearance of this new assemblage of trilobites represents an immigration event related to transgressive pulses. Episodic migration of off-shelf trilobite taxa took place towards the inner platform leading to a strict facies control on the lithofacies differentiation.

Late Languedocian trilobites from the Montagne Noire include typical genera of the Leonian/Caesaraugustian diversification, and new Asiatic invaders, such as *Chelidonocephalus*, *Derikaspis*, *Abharella* and *Dorypyge* (King, 1937; Kushan, 1973; Wolfart, 1974; Wolfart & Kürstein, 1974; Fortey & Rushton, 1976; Dean, 1982; Courtessole *et al.*, 1988; Peng *et al.*, 1999). This influence illustrates the immigration of faunas from the northern Gondwana margin, which went on during Late Cambrian times (Feist & Courtessole, 1984; Shergold *et al.*, 2000).

4) **The Upper Cambrian diversification**

During the time of deposition of the Val d'Homs Formation, trilobite faunas are dominated by genera which are either cosmopolitan or from other regions of Gondwanaland, particularly China and Australia (see Shergold *et al.*, 2000, Table 1 for distribution patterns). This diversification event is directly related to the deposition of carbonates over the sandstones and shales of the underlying formations, and represents a significant flooding event (Courtessole *et al.*, 1988; fig. 18).

The Upper Cambrian echinoderm wealth recorded in the southern Montagne Noire 'announces' the sharp increase in biodiversity of the earliest Ordovician. This is indicated by the occurrence of the primitive mitrate *Lobocarpus* (the three defined mitrate suborders are present across the Tremadoc-Arenig), several primitive glyptocystitid cystoids close to the Upper Cambrian genus *Cambrocrinus* from Poland (related to the Ordovician glyptocystitids such as *Macrocystella*). Other 'primitive' groups, such as cinctans and ctenocystoids, have definitively disappeared in the Upper Cambrian, whereas the stromatocystoids (such as *Stromatocystites*) still persist in the Upper Cambrian but will not re-occur in the Ordovician. Therefore, this Upper Cambrian echinoderm assemblage represents a diversification event pre-dating the Ordovician radiation. In other platforms (e.g. Australia and Laurentia; Jell *et al.*, 1985; Smith, 1985; Smith & Jell, 1990; Sumrall *et al.*, 1997), the Upper Cambrian echinoderm assemblages exhibit the same transitional pattern including the co-occurrence of Lower-Middle Cambrian holdover (survival) species, and progenitor taxa that rapidly radiated during Early Ordovician times: e.g., the cornute *Drepanocarpos* from the Upper Cambrian of Australia is a progenitor taxa of one of the cornutan suborders.

5) **Biogeographic significance**

The Middle-Upper Cambrian biogeographic patterns in the western Gondwana margin illustrates an open system which reflects the interaction between speciation, migration and extinction rates. At the beginning of diversifications, migration produced patterns of increase comparable to those of speciation; the former pattern was mainly developed for trilobites in the middle part of the Leonian/Caesaraugustian radiation. Almost without exception, the Middle Cambrian trilobite species from south-western Europe compare with those recovered from the western Gondwana margin from Iberia to Turkey; in addition, a connection of faunas with Avalonia was developed during the Caesaraugustian transgression. Apart from *Bailiaspis glabrata*, known from Baltica (Westergård, 1950), none of the benthic species is known from contemporary rocks in Baltica and Laurentia.

The variability of the biogeographic distribution documented in the studied populations is directly related with species diversity: the earliest Middle Cambrian trilobite assemblages tend to be relatively pandemic (occurring from Avalonia to Turkey), in which the greater biogeographic distribution coincides with the Caesaraugustian flooding and the subsequent connection of platforms.

A similar biogeographic pattern characterizes the echinoderms, mainly the cinctans. Across the Middle Cambrian this class is only known on the western Gondwana margin (Montagne Noire, Iberian Peninsula, Morocco, Sardinia, Bohemia, Wales and Germany). The echinoderm genera reported in the Montagne Noire occur in Morocco and Sardinia (*Sucocystis*), the Iberian Peninsula (*Sucocystis* and *Gyrocystis*) and Wales [*Elliptocinctus*; Avalonia (Friedrich, 1995; Vizcaïno & Lefebvre, 1999)]. The primitive stylophoran *Ceratocystis* occurs both in Gondwana and Baltica, whereas the ctenocystoids occur in Gondwana and Laurentia, and the eocrinoid *Gogia* in the Iberian Peninsula and Laurentia. The edrioasteroid genus *Cambraster* is reported in Australia.

The combination of eurytopy and high dispersal capability allow us to recognize greater biogeographic ranges, in spite of their short time durations, due to the Caesaraugustian transgression, which produced widespread offshore depositional conditions in western Gondwana. In contrast, percentage of pandemic species decreased across the Languedocian, and geographic distribution decreased because a widespread regressional trend took place.

IV. — CONCLUSIONS

The first major Middle Cambrian trilobite radiation occurred at the earliest Leonian and culminated across the Caesaraugustian/Languedocian transition. A peak in diversity of trilobites is documented during this episode, whereas cinctan echinoderms were widely developed across the lower-middle Languedocian transition. A major reduction in generic number of trilobite fauna occurred across the Caesaraugustian-Languedocian transition, at a time of widespread coarse-grained terrigenous input which was associated with a well-documented regressional trend. The decline was prolonged until mid Languedocian times in some areas of the southern Montagne Noire, where argillaceous substrates persisted. Hence, the disappearance of trilobite and echinoderm taxa is related to the disappearance of the habitat to which they were adapted.

A second diversification of trilobite fauna was developed during the late Languedocian, which coincided with trangressional pulses and the establishment of suitable muddy substrates. Despite the apparently slow recovery of trilobite faunas in the late Languedocian, several immigrant forms, with Asiatic affinity, made their appearance in the Montagne Noire and went on during Late Cambrian times.

Early and latest Languedocian extinctions indicate a marked fall of trilobite diversity. This reflects a stepwise decline in the number of trilobite genera. The extinctions also affected other groups such as the cinctans.

The observed fluctuations of species diversity do not necessarily imply concomitant changes in environmental stability: increased diversity was not a consequence of increased spatial heterogeneity. Low diversity at the base of the Leonian/Caesaraugustian radiation was probably associated with relatively unstable and heterogeneous depositional conditions, whereas the subsequent increase in species diversity can be correlated with increased environmental stability. The greater species diversity (late Caesaraugustian) coincides with the maximum flooding in the Mediterranean basins.

Appendix: *Bailiaspis inflata* is considered here as *nomen nudum* because a previous species was defined with the same generic and specific names : *Bailiapspis inflata* (Cobbold, 1913) in Lake, 1940 (pp. 287-288, pl. XLI, figs. 5-7); holotype from the Breccia in the Hill House Grits of Comley England (*Paradoxides intermedius* Zone). In order to avoid this misunderstanding, we propose to call the French species *Bailiaspis pilleti* after the name of its author (J. Pillet); see Pillet (*in* Courtessole *et al.*, 1988) for further information.

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THE LOWER ORDOVICIAN OF THE SOUTHERN MONTAGNE NOIRE

L'Ordovicien inférieur de la Montagne Noire méridionale

by Daniel VIZCAINO (*), J. Javier ÁLVARO (**) & Bertrand LEFEBVRE (***)

Abstract. — The Lower Ordovician sedimentary succession of the southern Montagne Noire represents a thick and siliciclastic-dominant deposition. Six formations are distinguished, from bottom to top, the La Dentelle, Saint-Chinian, La Maurerie (including the Setso Member), Cluse de l'Orb, Foulon and Landeyran Formation, although the occurrence of limestones overlying the first formation in some outcrops will permit to improve this sketch in future works. Nine biostratigraphically significant 'faunizones' are classically recognized in the southern Montagne Noire, named C to M, and identified after trilobite assemblages. The peaks in biodiversity coincide with fine-grained deposition episodes (Saint-Chinian and Landeyran Formations), representing immigration and radiation events. The biodiversity of the Tremadocian-Arenigian in the southern Montagne Noire is remarkable, comparing with that recognized in other neighbouring platforms of south-western Europe: a total of 132 trilobite species, 44 echinoderm species, four rostroconchia species, 15 gastropod and related species, 9 brachiopod species, 5 hyolith species, 2 machaeridian species, 2 conularid species, 6 cephalopod species and 9 bivalve species are already recognized. However, important revisions are necessary in other taxa in order to improve the knowledge of biodiversity patterns, such as conodonts, acritarchs, graptolites and ostracodes.

Résumé. — *La succession sédimentaire de l'Ordovicien inférieur en Montagne Noire méridionale est composée de dépôts à dominance silicoclastique. Six formations y sont distinguées comprenant, du bas vers le haut, les Formations de La Dentelle, Saint-Chinian, La Maurerie (et son Membre Setso), Cluse de l'Orb, Foulon et Landeyran. La présence de calcaires en sommet de la première formation permettra d'envisager une redéfinition lithostratigraphique dans les travaux à venir. Neufs 'faunizones' à caractère biostratigraphique ont été distinguées dans le versant sud de la Montagne Noire, dénommées C à M sur la base des assemblages de trilobites. Le maximum de biodiversité coïncide avec les épisodes de dépôts schisteux (Formations de Saint-Chinian et de Landeyran) représentant des événements d'immigration et de radiation. La biodiversité du Trémadocien-Arénigien est remarquable en Montagne Noire par rapport à celles d'autres régions du SW de l'Europe : 132 espèces de trilobites, 44 d'échinodermes, 4 de rostroconches, 15 de gastéropodes et similaires, 9 de brachiopodes, 5 d'hyolithes, 2 de machaeridiens, 2 de conularidés, 6 de céphalopodes et 9 de lamellibranches sont reconnues. Toutefois, une importante révision est nécessaire pour certains taxons afin d'améliorer la connaissance sur la biodiversité, notamment l'étude des conodontes, des acritarches, des graptolites et des ostracodes.*

I. — INTRODUCTION

The first Lower Ordovician fossil fauna of the southern Montagne Noire was discovered by Fournet & Graff (1849) in the vicinity of Neffiès. During the last decades of the 19th century, four taxa were studied preferentially in order to improve correlations with the British chart and the Armorican massif: brachiopods, trilobites, graptolites and trace fossils. The first distinct Arenigian brachiopod was *Lingula lesueuri* [*Ectonoglossa lesueuri* (Rouault, 1850)], previously described in the Armorican massif (Tromelin & Gasset, 1877; Tromelin, 1879). The first Lower Ordovician trilobites (asaphids and calymenids) were reported by Bergeron (1888 a,b), who presented them as the first distinctive faunal-type overlying the 'primordial fauna'. The former assemblage was definitively assigned to the British Tremadoc by Brögger (1896) and Pompeckj (1902). The first Arenigian graptolites were found near Cabrières and within the Landeyran valley (Frech, 1887; Bergeron, 1889; de Rouville, 1889), but it is Barrois (1892, 1893) who presented complete descriptions of this new fauna, correlating it with the middle Arenig of Wales. Finally, the first ichnofossils reported from the southern Montagne Noire were compared with those better known in the Armorican massif, such as *Bilobites* (mainly *Cruziana* d'Orbigny, 1842) and *Fucoides*. De Rouville (1893b) and de Rouville *et al.* (1894) described an informal stratigraphic unit based on trace fossils, the sandy Shales rich in *Cruziana*, *Bilobites* and *Vexillum*, and Miquel (1895) the Armorican Quartzite rich in *Bilobites*.

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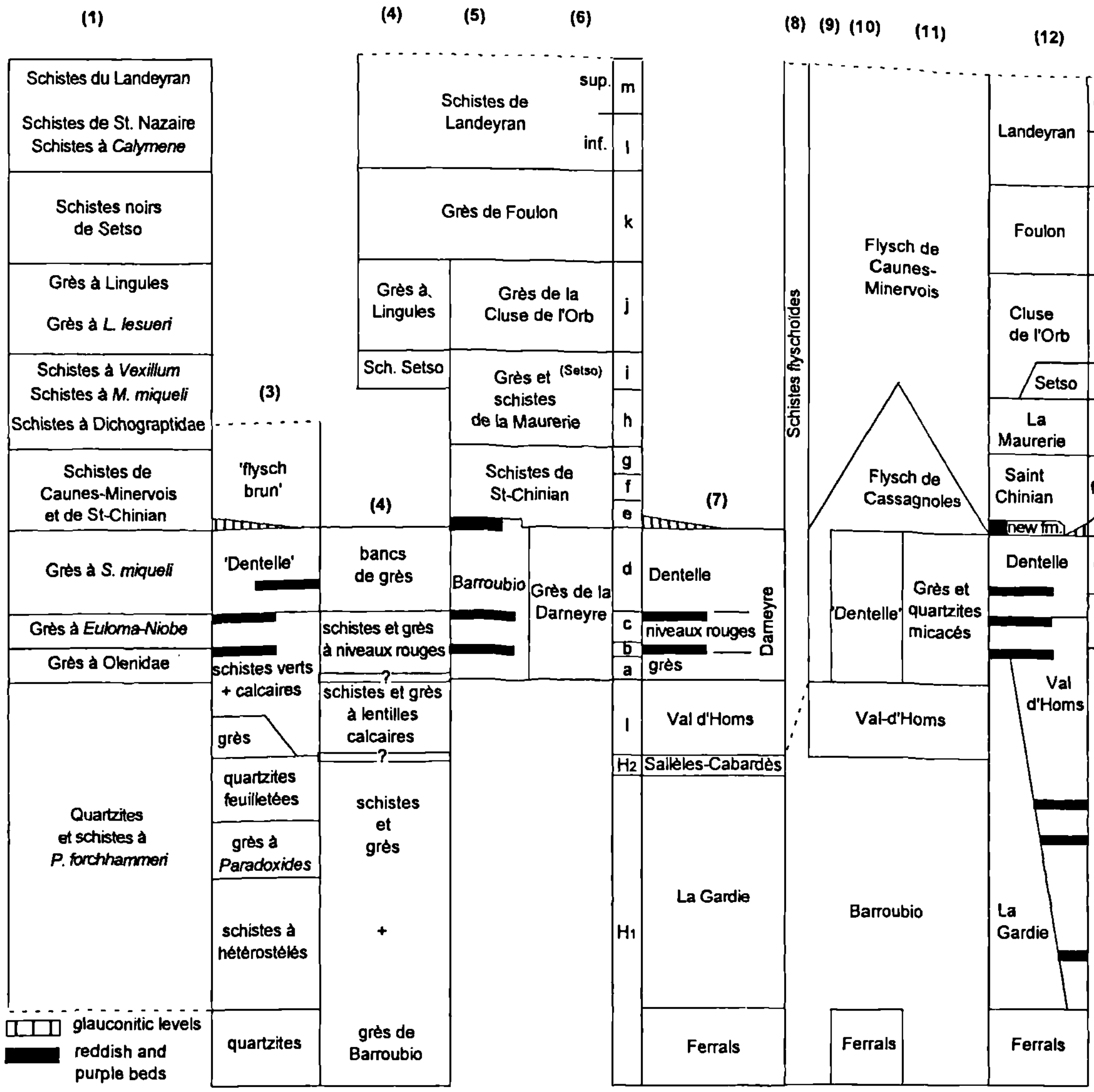

(1) Thoral, 1941; (2) Boyer & Guiraud 1964; (3) Courtessole, 1967; (4) Dean, 1966; (5) Courtessole *et al.*, 1981; (6) Courtessole *et al.*, 1985; (7) Courtessole *et al.*, 1988; (8) Alabouvette *et al.*, 1982; (9) Berger *et al.*, 1990; (10) Alabouvette & Demange, 1993; (11) Berger *et al.*, 1993; (12) this work.

Fig. 1. — Lithostratigraphic proposals from 1941 until present day in the southern Montagne Noire.

Fig. 1. — Propositions lithostratigraphiques réalisées en Montagne Noire méridionale depuis 1941 jusqu'à nos jours.

On the other hand, during the 20th century, the Lower Ordovician sedimentary succession of the southern Montagne Noire has been frequently described and interpreted as flysch deposits (Hupé, 1953; Andrieux & Matte, 1963). It was mapped as 'brownish flysch', 'flysch shales', and Cassagnoles and Caunes-Minervois flysch units in the BRGM's geological charts (Boyer & Guiraud, 1964; Alabouvette *et al.*, 1982; Berger *et al.*, 1990, 1993; Alabouvette & Demange, 1993; fig. 1). However, the record of slumping, breccia deposits and other slope-related sedimentation is not generalized (Eschard, *in* Courtessole *et al.*, 1985; Dabard & Chauvel, 1991; Noffke & Nitsch, 1994). Thoral (1941, 1947), Dean (1966), Courtessole *et al.* (1981, 1985) and others divided the Lower Ordovician succession into several formations, related to trilobite assemblages, reflecting the alternations between shale- and sandstone-dominant intervals. Unfortunately, some of the lithostratigraphic boundaries were directly associated with biostratigraphic changes mixing litho- and biostratigraphic data.

II. — STRATIGRAPHY

Although the stratigraphic nomenclature of the Lower Ordovician rocks in the southern Montagne Noire has been in a continuing state of flux (fig. 1), the Tremadocian-Arenigian sedimentary rocks are classically subdivided into the La Dentelle, Saint-Chinian, La Maurerie, Cluse de l'Orb, Foulon and Landeyran Formations (fig. 2).

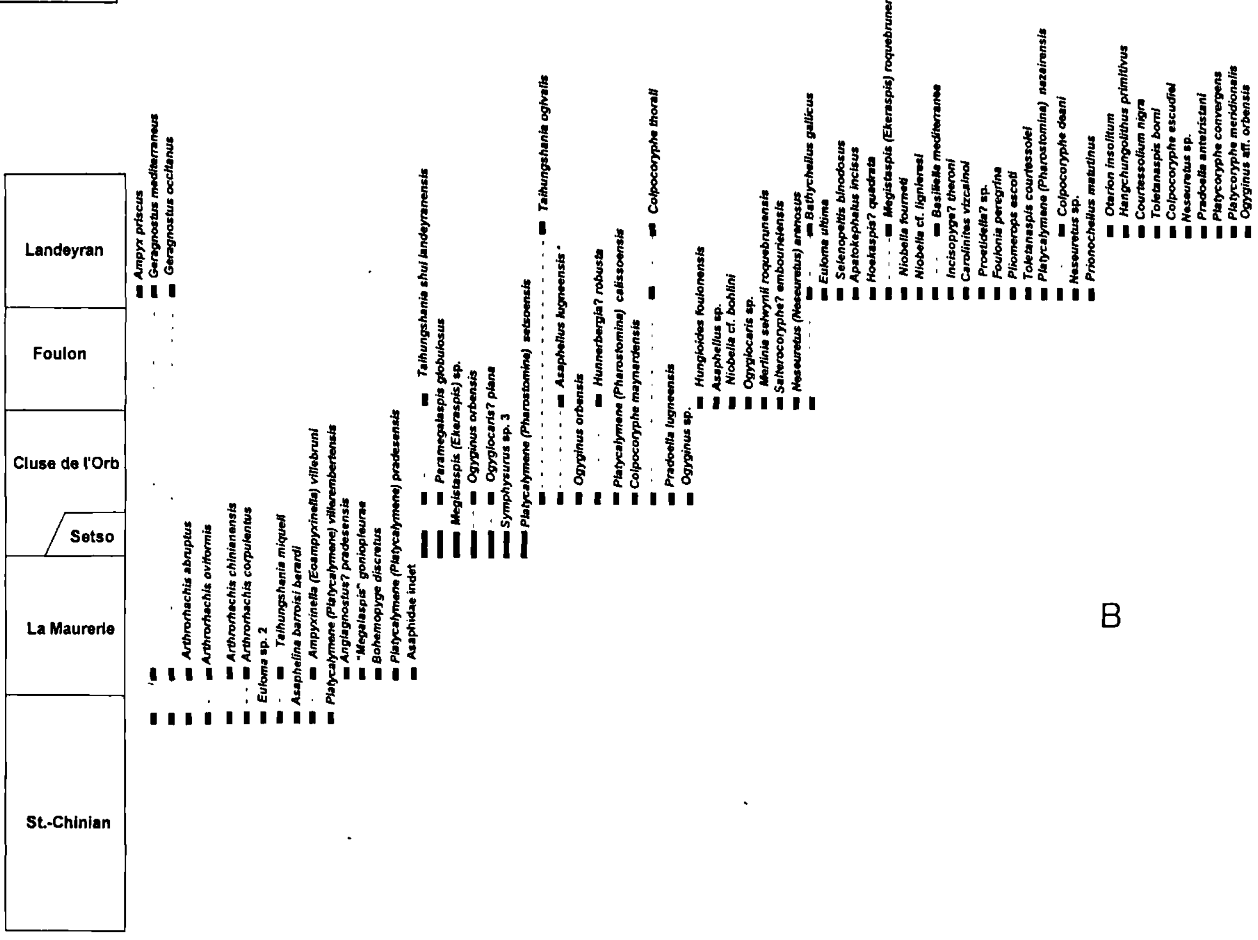

Fig. 2. — Stratigraphic ranges of trilobites across the 'faunizones' C to H (A), and G to M (B).

Fig. 2. — Distribution stratigraphique des trilobites des « faunizones » C à H (A), et G à M (B)

1) The La Dentelle Formation

The lithostratigraphy of the Cambrian-Ordovician transition has been a classic matter of discussion in the Montagne Noire. The lack of confident stratigraphic levels of correlation, and the abundance of reddish to purple limestone intercalations lacking biostratigraphic control encouraged the research workers to define facies patterns as lithostratigraphic units with local application. As a result, several names were proposed, such as the La Dentelle (Boyer, 1962) and La Darneyre (Courtessole *et al.*, 1988). In this paper, the variegated limestones and shales just underlying the La Dentelle sandstones and quartzites are considered as belonging to the Val d'Homs or La Gardie Formations, so that the overlying coarse-grained unit is recognized as Boyer's concept of the La Dentelle Formation (named after the geometric aspect of its outcrops after meteorization, remembering a lace). The re-occurrence of metre-thick reddish limestones overlying the La Dentelle Formation in several areas will permit to erect a new formation of reduced areal extension (reported in the figures of this chapter as 'new formation'). The La Dentelle Formation (20-100 m thick) consists of white and grey sandstones, with rare shale intercalations, bearing isolated centimetre-thick, limestone and dolostone nodules. The age of the La Dentelle is uncertain since no fossils have been found; however, the uppermost reddish limestones and shales of the underlying Val d'Homs and La Gardie Formations contain the first Tremadocian trilobite fauna (comprising agnostids such as *Anglagnostus*, *Geragnostella* and *Leiagnostus*, and polymeroids such as *Hemibarrandia*, *Holubaspis*, *Macropyge*, *Niobella*, *Onchonotellus*, *Platycalymene*, *Proteuloma*, *Symphysurina*, *Symphysurus* and *Triarthrus*), and echinoderms (*Macrocystella*). At the top of the La Dentelle Formation a discontinuous glauconitic siltstone, up to 0.5 m thick, occurs bounding locally the La Dentelle and Saint-Chinian Formations.

2) The Saint-Chinian Formation

The Saint-Chinian Formation (after the locality of the same name) consists of monotonous, dark-grey and green claystones and siltstones, bearing fine- to medium-grained sandstone intercalations, in which parallel lamination is abundant and bioturbation is common. In several areas, a metre-thick alternation of reddish limestones and shales occur, which is here considered as a new formation. The total thickness of the Saint-Chinian Formation is unknown; it is best exposed in the Saint-Chinianais area where it is at least 500 m thick. This formation has yielded a rich and diverse fossil fauna, which has been arranged into four biostratigraphically significant assemblages (see below a discussion). Trilobite genera comprise agnostids such as *Anglagnostus*, *Arthrorhachis*, *Geragnostus* and *Homagnostoides*, and polymerids such as *Agerina*, *Ampyx*, *Ampyxinella*, *Aocaspis*, *Apatokephalus*, *Asaphelina*, *Asaphellus*, *Asaphopsoides*, *Bohemilla*, *Courtessolium*, *Cyclopyge*, *Cyrtometopus*?, *Degamella*, *Euloma*, *Falanaspis*, *Glaphurina*, *Harpides*, *Illaenopsis*, *Lichakephalus*, *Megitaspis*, *Niobella*, *Novakella*, *Paramegalaspis*, *Parapilekia*?, *Platycalymene*, *Pliomerops*, *Pradesia*, *Pricyclopyge*, *Prionocheilus*, *Raymondaspis*, *Shumardia*, *Symphysurus* and *Taihungshania*. Other taxa are echinoderms (genera *Aethocrinus*, *Amygdalotheca*, *Ampullaster*, *Anatifopsis*, *Arauricystis*, *Balantiocystis*, *Balanocystites*, *Chauvelicystis*, *Chinianaster*, *Chinianocarpos*, *Cothurnocystis*, *Galliaecystis*, *Hemicystites*, *Macrocystella*, *Minervaecystis*, *Peltocystis*, *Phyllocystis*, *Pradesura*, *Proscotiaecystis*, *Thoralicystis*, *Trigonocarpus*, *Villebrunaster* and *Vizcainocarpus*), gastropods (such as *Archinacella*, *Carcassonnella*, *Eobucania*, *Lesueurilla*, *Peelerophon*, *Sinuites* and *Thoralispira*), brachiopods (*Conotreta*, *Lingulella*, *Plectorthis*, *Pleurorthis*, *Spondyglossella*, and *Yorkia*?), hyoliths (*Circotheca*, *Elegantilites* and *Nephroteca*), machaeridians (*Lepidocoleus*), conularids (*Eoconularia*), bivalves (*Babinka*, *Ekaterodonta*, *Norodonta*, *Redonia* and *Thoralia*) and cephalopods. This formation contains the first record of graptolites in the southern Montagne Noire (genus *Tetragraptus*).

3) The La Maurerie Formation

The La Maurerie Formation (after the village of the same name) is an alternance of sandstones and sandy shales (more than 400 m thick) bearing centimetric, siliceous nodules. The uppermost part is distinguished as the Setso Shales (after the Setso stream, SE of Roquebrun), proposed by Thoral (1935) as a member of the La Maurerie Formation. They consist of black to grey shales that have yielded graptolites (such as *Clonograptus*, *Dictyonema* and *Temnograptus*), trilobites (*Ampyx*, *Ampyxinella*, Asaphidae indet, *Asaphopsoides*, *Megistaspis*, *Ogygiocaris*?, *Paramegalaspis*?, *Platycalymene*, *Symphysurus*, and *Taihungshania*), echinoderms (*Anatifopsis*, *Balantiocystis*, *Balanocystites*, *Cheirocystella* and *Lingulocystis*), gastropods (*Carcassonnella*, *Lesueurilla*, *Pararaphistoma*, *Sinuites* and *Thoralispira*), hyoliths (*Circotheca*), cephalopods (six species of the unformally defined '*Orthoceras*'), conocardioids (*Eopteria*), monoplacophorans (*Archinacella*) and bivalves (*Babinka*, *Coxiconcha*, *Ekaterodonta* and *Redonia*).

4) The Cluse de l'Orb Formation

The Cluse de l'Orb Formation (named after the Orb river) was classically recognized as lingulid-rich sandstones or the Languedocian 'Armorican' Quartzite. The assignation to the Armorican Quartzite was rejected after evidencing the sharp diachroneity of both formations. The presence of the brachiopod species *Ectenoglossa lesueuri* was one of the best biostratigraphically significant levels of correlation with the British and Armorican Arenigian at the beginning of the 20th century. The formation (150-220 m) consists of an alternance of white quartzites and grey sandstones and sandy shales, bearing some siliceous, fossiliferous nodules, and glauconitic remains (Dabard & Chauvel 1995), representing deposition on a storm-dominated platform (Eschard, *in* Courtessole *et al.* 1985). Both lithologies are relatively rich, respectively, in brachiopods (genera *Ectenoglossa*, *Lingulepis* and *Lingulobolus*), and trilobites (genera *Asaphellus*, *Colpocoryphe*, *Ogyginus*, *Paramegalaspis*, *Platycalymene*, *Pradoella* and *Taihungshania*). Other taxa found in the formation are echinoderms (*Lingulocystis*), gastropods (*Thoralispira*) and bivalves (*Coxiconcha* and *Ekaterodonta*).

5) The Foulon Formation

The Foulon Formation (place-name found at the left bank of the Orb river), 60-100 m thick, is composed of fine-grained sandstones and sandy shales bearing limestone and siliceous nodules rich in fossil fauna and glauconitic remains. The fossil assemblage of the formation is rich, and comprises trilobites (genera *Asaphellus*, *Bathycheilus*, *Hungioides*, *Merlinia*, *Neseuretus*, *Niobella*, *Ogygiocaris* and *Salterocoryphe*?), brachiopods (*Rafanoglossa*), bivalves (*Coxiconcha*, *Cymatonota*?, *Ekaterodonta*, *Modiolopsis*, *Redonia* and *Thoralia*), rostroconchia (*Ribeira*), gastropods (*Thoralispira*), problematica (*Hanadirella* and *Solandangella*), echinoderms (*Lingulocystis*), and graptolites (*Didymograptus*).

6) The Landeyran Formation

The Landeyran Formation (named after the Landeyran valley), 200-400 m thick, consists of brown, green and grey, homogeneous shales bearing siliceous nodules. It contains a rich and diverse fauna of trilobites (*Ampyx*, *Apatokephalus*, *Basiliella*, *Bathycheilus*, *Carolinites*, *Colpocoryphe*, *Courtessolium*, *Hoekaspis*?, *Euloma*, *Foulonia*, *Geragnostus*, *Hangchungolithus*, *Incisopyge*?, *Megistaspis*, *Neseuretus*, *Niobella*, *Ogyginus*, *Otarion*, *Platycalymene*, *Platycoryphe*, *Pliomerops*, *Pradoella*, *Prionocheilus*, *Proetidella*, *Selenopeltis*, *Taihungshania* and *Toletanaspis*), echinoderms (*Ampelocarpus*, *Anatifopsis*, *Balanocystites*, *Balantiocystis*, *Cheirocystella*, *Cothurnocystis*, *Lagynocystis*, *Lingulocystis*, *Lyricocarpus*, *Nanocarpus*, *Ovocarpus*, *Proscotiaecystis*, *Pyrgocystis*?, *Ramseyocrinus*, rhombiferans and *Thoralicystis*), gastropods (*Carcassonnella*, *Lesueurilla* and *Thoralispira*), brachiopods (*Aportophylla*, *Conotreta*, *Hesperonomia*, *Rafanoglossa*, *Ocorthis*, *Orthambonites*, *Paralenorthis*, *Paurorthis*, *Prantlina*, *Progonambonites*, *Ranorthis*, *Sinorthis* and *Spondyglossella*), hyoliths (*Elegantilites* and *Nephroteca*), machaeridians (*Lepidocoleus* and *Plumulites*), conularids (*Eoconularia*), bivalves (*Babinka*, *Coxiconcha*, *Ekaterodonta*, *Redonia*, *Synek*, *Thoralia*), rostroconchia (*Ribeiria* and *Tolmochovia*), graptolites (*Didymograptus*, *Phyllograptus* and *Tetragraptus*), and ostracodes (in study).

III. — THE LOWER ORDOVICIAN BIOZONATION

The regional biostratigraphic scale of the Montagne Noire has been proposed and completed by Courtessole's works (Courtessole *et al.* 1981, 1983, 1985, 1991). As a result, the Lower Ordovician rocks of the Montagne Noire were subdivided into twelve assemblage zones or 'faunizones' (A to M) based on trilobite associations. The zones A and B are only recognized in the northern Montagne Noire and will not be discussed here.

1) The 'Faunizone' C

The reddish and purple limestones and shales of the uppermost part of the Val d'Homs and La Gardie Formations, in contact with the La Dentelle Formation, have yielded a rich trilobite assemblage composed of agnostids, calymenids (*Platycalymene*), asaphids (*Niobella* and *Symphysurina*), neleids (*Hemibarrandia*), remopleurids (*Macropyge*) and other genera of uncertain affinity (such as *Onchonotellus* and *Holubaspis*). The presence of *Proteuloma geinitzi*, *Niobella innotata*, *Holubaspis perneri* and *Platycalymene* (*P.*?) *ferentaria* permits the correlation of this fossil assemblage with the Tremadocian of Bohemia and Germany (Sdzuy, 1958).

2) The 'Faunizone' D

The zone comprises an impoverished trilobite assemblage composed of agnostids, ptychopariids (*Euloma*) and the occurrence of shumardiids (*Shumardia*). It is recognized at the bottom of the Saint-Chinian Formation and in the carbonate-rich 'new formation' to be defined. The presence of *Shumardia (C.) pusilla* permits a direct correlation with the middle Tremadocian of England and Norway (Brögger, 1882; Lake, 1907).

3) The 'Faunizones' E and F

Traditionally, the 'faunizones' E and F (Capéra *et al.*, 1978) have been considered as two different zones. However, both units have never been found in a same section, but in different outcrops of the Saint-Chinian Formation. It would be better to consider them as one zone representing two trilobite assemblages. The trilobite assemblage E comprises agnostids (*Arthrorhachis* and *Homagnostoides*), ptychopariids (*Euloma*), asaphids (*Asaphellus* and *Megistaspis*), cyclopygids (*Delgamella*), nileids (*Aocaspis* and *Symphysurus*), calymenids (*Platycalymene*) and the only occurrence of styginids (*Raymondaspis*). The trilobite assemblage F shows higher diversity patterns: the main bioevents are (i) the co-occurrence of several species of the previous assemblage, excepting the genera *Arthrorhachis*, *Apatokephalus* and *Raymondaspis*; (ii) the FAD of the following new families: taihungshaniids (*Asaphelina*), dikelokephalids (*Asaphopsoides*), raphiophorids (*Ampyx*) and cheirurids (*Courtessolium* and *Pliomerops*); (iii) other genera of previously known families are *Paramegalaspis* and *Niobella* (asaphids), *Novakella* and *Pradesia* (cyclopygids), *Illaenopsis* (nileids), and (iv) the only occurrence of harpidids (*Harpides*), alsataspirids (*Falanaspis*), bathyurids (*Agerina*), glaphurids (*Glaphurina*) and bohemilliids (*Bohemilla*). According to the presence of *Apatokephalus serratus* (found in Scandinavia; Tjernvik, 1956), Capéra *et al.* (1978) proposed the 'faunizone' E as upper Tremadocian. However, the determination of *A. serratus* in the southern Montagne Noire needs revision. Therefore, the 'faunizones' E and F represent the Tremadocian-Arenigian transition.

4) The 'Faunizone' G

It represents the last fossil association of the Saint-Chinian Formation, and comprises agnostids (*Geragnostus* and *Arthrorhachis*), calymenids (*Platycalymene*), raphiophiorids (*Ampyx* and *Ampyxinella*), taihungshaniids (*Taihungshania* and *Asaphelina*). Traditionally, this 'faunizone' was considered as lower Arenigian (Capéra *et al.*, 1978 and following authors) based on the presence of taihungshaniids, but this age needs confirmation.

5) The 'Faunizone' H

This zone is identified within the La Maurerie Formation. The 'faunizone' is characterized by the same trilobite assemblage than that of the zone G, including the agnostid *Anglagnostus*, new asaphids and the disappearance of

Asaphelina. The trilobite assemblage does not permit a confident datation due its endemic character. Anyway, the abundance of graptolites will allow to improve its biostratigraphic patterns in future works.

6) **The 'Faunizone' I**

It is recognized only in the outcrops of the Setso Member, and comprises a trilobite assemblage composed of asaphids (*Megistaspis*, *Paramegalaspis*, *Ogyginus* and *Ogygiocaris*?), calymenids (*Platycalymene*) and taihungshaniids (*Taihungshania*). This association is traditionally considered as Arenigian due to correlation at the trilobite generic level, and the presence of *Didymograptus v-fractus* (Thoral, 1935).

7) **The 'Faunizone' J**

The 'faunizone' is identified in the Cluse de l'Orb Formation, and is characterized by the first occurrence of some calymenids (*Colpocoryphe* and *Pradoella*) and assigned to the Arenigian on the base of graptolites (Thoral, 1935).

8) **The 'Faunizone' K**

The Foulon Formation contains a new trilobite assemblage including asaphids (*Merlinia* and *Niobella*) calymenids (*Bathycheilus* and *Neseuretus*) and dikelokephalinids (*Hungioides*), which configure the 'faunizone' K.

9) **The 'Faunizone' L**

It is recognized in the lower part of the Landeyran Formation, and contains asaphids (*Megistaspis*), calymenids (*Colpocoryphe*, *Platycalymene* and *Prionocheilus*), cheirurids (*Foulonia* and *Pliomerops*), komaspidids (*Carolinites*), odontopleurids (*Selenopeltis*), pterygometopids (*Toletanaspis*), ptychopariids (*Euloma*) and remopleurids (*Apatokephalus*).

10) **The 'Faunizone' M**

The upper part of the Landeyran Formation contains the last Arenigian fossil fauna, defined by the co-occurrence of asaphids (*Ogyginus*), calymenids (*Colpocoryphe*, *Platycalymene* and *Pradoella*), cheirurids (*Courtessolium*), proetids (*Otarion*), pterygometopids (*Toletanaspis*) and trinucleids (*Hangchungolithus*).

IV. — SEDIMENTARY CONTROLS ON BIODIVERSITY

The Tremadocian-Arenigian is largely represented by inner- and outer-platform facies composed of alternating limestones and shales (upper part of the Val d'Homs Formation and the 'new formation'), coarse-grained sandstones and siltstones (La Dentelle, La Maurerie, Cluse de l'Orb and Foulon Formations), and monotonous shales with minor sandstone intercalations (Setso Member, and Saint-Chinian and Landeyran Formations).

After the record of Upper Cambrian trilobite-rich lenticular and bedded strata (Feist & Courtessole, 1984; Shergold *et al.*, 2000), an abrupt faunal change is recorded at the reddish and purple shales and limestones just underlying the La Dentelle Formation. The lower Tremadocian represents a sharp immigration of new faunas and diversity increased markedly. A fall in diversity is recognized in the middle Tremadocian. A distinct increase in trilobite diversity is recorded across the Tremadocian-Arenigian transition, in which the expansion of asaphids, nileids and cheirurids is particularly significant. This immigration process is closely linked to the change in sedimentary conditions, associated with the establishment of the distal platform facies of the Saint-Chinian Formation. The diversity diminishes across the G and H time intervals (earliest Arenigian?), associated with a shallowing-upward tendency recorded across the Saint-Chinian/La Maurerie transition. The trilobite expansion seems to be related to the active inner-platform progradation that characterizes the La Maurerie Formation. During the time interval of the zones I and J, the sedimentary features reflect a deepening (Setso Member) and the record of storm processes in an open-sea platform (Cluse de l'Orb Formation; Eschard, *in* Courtessole *et al.* 1985). Trilobite diversity is low during this time span. The Foulon Formation has yielded a trilobite assemblage exhibiting similar diversity patterns that those recorded in the previous intervals (I and J). The trilobite fauna is still dominated by asaphids and calymenids. The relative paucity of trilobites and the coeval faunal turnover may be related to the regressive and proximal conditions recorded in the Foulon Formation (Dabard & Chauvel, 1991). Finally, another notable increase in diversity is recorded in the offshore deposits of the Landeyran Formation. The increase of trilobite diversity was again related to immigration and expansion of genera, likely associated with shoreline retrogradation.

The diversity patterns of echinoderms are comparable to that of trilobites. Contrary to the situation in the Val d'Homs Formation (Upper Cambrian), which has yielded abundant echinoderm remains (such as stylophorans, cystoids and edrioasteroids), echinoderms are extremely scarce in lower to middle Tremadocian deposits (*Macrocystella*). The echinoderm diversity dramatically increases across the Tremadocian-Arenigian transition, probably in response to severe environmental changes (e.g. deepening and establishment of muddy substrates). The 'faunizones' F and G have yielded 23 echinoderm genera, which represent one of the richest or diverse lower Arenigian echinoderm faunas of the world. This echinoderm assemblage is dominated by stylophorans (13 genera) and shows strong affinities with other echinoderm faunas from the Tremadocian of Shropshire (e.g. *Anatifopsis*, *Vizcainocarpus*), the Arenigian of Morocco (e.g. *Anatifopsis*, *Balantiocystis*, *Chauvelicystis*, *Macrocystella*, *Phyllocystis*, *Thoralicystis*) and Wales (e.g. *Anatifopsis*, *Cothurnocystis*). The diversity severely decreased in the La Maurerie Formation, probably in response to shallowing environmental conditions. The only stylophorans recorded in the 'faunizone' H are environmental generalists, such as some kirkocystids (*Anatifopsis*, *Balanocystites*). The La Maurerie Formation is also characterized by the presence of abundant remains of the eocrinoid *Lingulocystis*. The persistence of shallow, proximal conditions in the next 'faunizones' I to K is confirmed by the low diversity displayed by echinoderms and the abundance of skeletal remains of *Lingulocystis*. Finally, a second increase in echinoderm diversity occurred within the Landeyran Formation, which is associated with a drastic change in

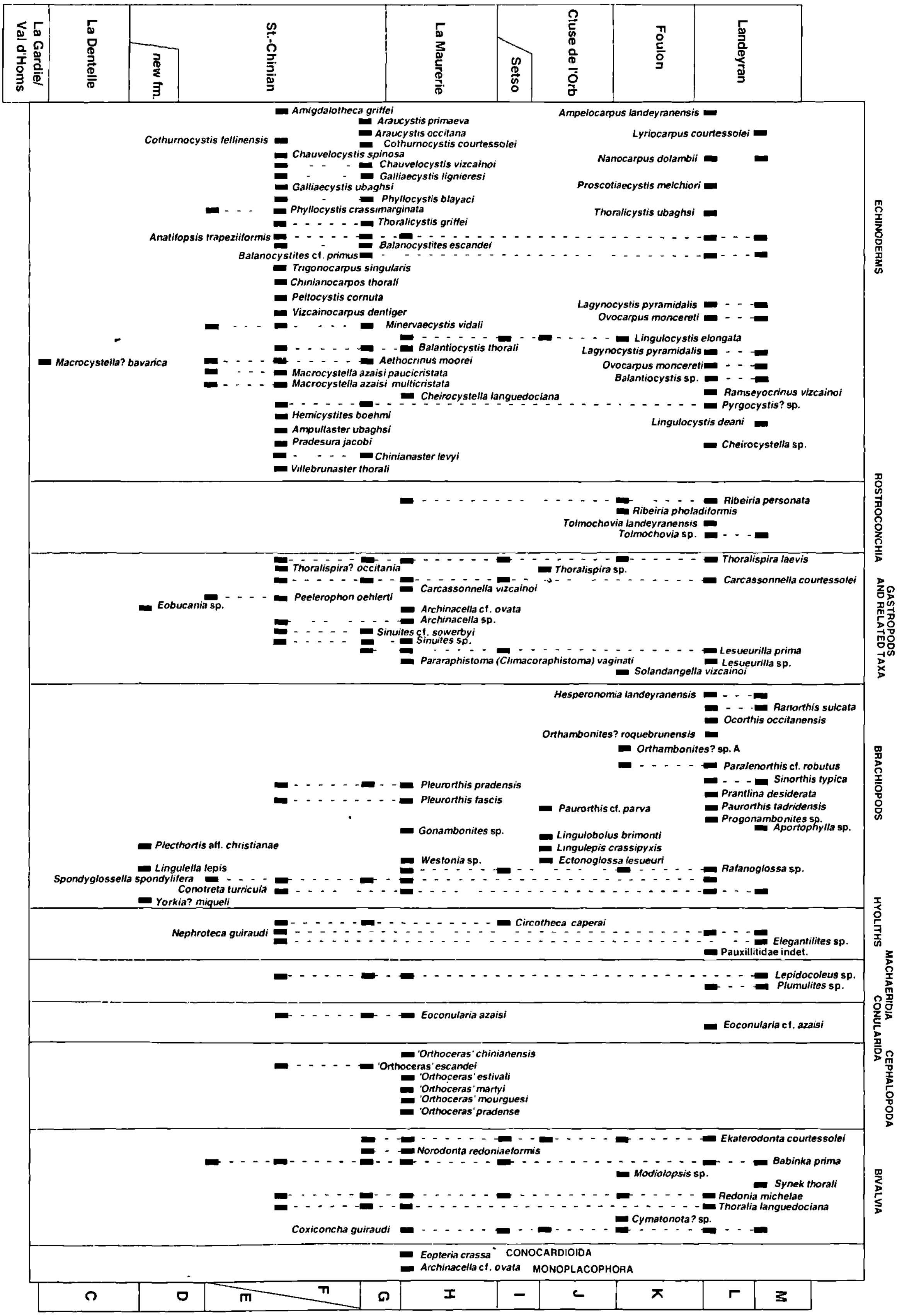

Fig. 3. — Stratigraphic ranges of echinoderms, rostroconchs, gastropods, brahiopods, hyoliths, machaeridians, conularids, cephalopods and bivalves in the Lower Ordovician of the southern Montagne Noire.

Fig. 3. — Distribution stratigraphique des échinodermes, rostrocouches, gastéropodes, brachiopodes, hyolithes, machaeridiens, conularidés, céphalopodes et lamellibranches de l'Ordovivien inférieur de la Montagne Noire méridionale.

environmental conditions (deepening and development again of muddy substrates). This environmental turnover is characterized by the presence of a rich and diverse echinoderm assemblage (14 genera) dominated by stylophorans (9 genera), which reminds the situation in 'faunizones' F and G. However, the presence of *Lingulocystis* in the 'faunizone' M suggests shallower environmental conditions than in the Saint-Chinian Formation and/or a regressive tendency in the upper part of the Landeyran Formation. The echinoderm assemblage of the Landeyran Formation shows obvious affinities with other echinoderm faunas reported in the Arenigian of Wales (e.g. *Anatifopsis*, *Lagynocystis*, *Ramseyocrinus* and possibly *Ovocarpus*) and Morocco (e.g. *Anatifopsis*, *Lingulocystis*, *Nanocarpus*, *Ramseyocrinus*, *Thoralicystis*), and the lower Oretanian of Spain (e.g. *Anatifopsis*, *Ovocarpus*)

V. — CONCLUSIONS

Several Lower Ordovician faunal, immigration and radiation processes occurred in the platforms of the southern Montagne Noire. However, the scarcity of detailed sedimentological studies, and the necessity of improving the biostratigraphy of these deposits do not permit, by the moment, to envisage a detailed history of colonization/diversifi-cation/extinction patterns of taxa. Anyway, these outcrops contain one of the most diverse and rich, Tremadocian-Arenigian fossil assemblages of south-western Europe, in which a total of 132 trilobite species, 33 echinoderm species, 4 rostroconchia species, 15 gastropod and related species, 9 brachiopod species, 5 hyolith species, 2 machaeridian species, 2 conularid species, 6 cephalopod species, and 9 bivalve species have been defined. Important revisions are necessary in other taxa in order to improve the knowledge of the biodiversity patterns, such as conodonts, acritarchs, ostracodes and graptolites. Küppers & Pohler (1992) described some Lower Ordovician conodonts in a lenticular limestone of the Clamoux valley reported to the Val d'Homs Formation; although the stratigraphic position has not been checked again, this is the first reference to conodonts on the Lower Paleozoic of the southern Montagne Noire.

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T. 8 (2ème série), p. 221-225, Juin 2001.

FIELD TRIP TO THE MINERVOIS, PARDAILHAN AND MONT DE PEYROUX NAPPES

Excursion aux nappes du Minervois, Pardailhan et Mont de Peyroux

by J. Javier ÁLVARO (*) & Daniel VIZCAINO (**)

I. — FRIDAY, SEPTEMBER 28TH

1) Stop 1: the Lower Cambrian stratotype of the Orbiel valley.

The Orbiel valley (after Or-biel, *gold-old* in Occitain language) was known from the Gallo-Roman's age because of the gold mines. During the Middle Age, an important network of towers and castles were built, whose relics occur in the Lastours city (Las-tours, *the-towers*). The section of the Orbiel valley (along the D101 road) has been considered from the 19th century as the Lower Cambrian type area of the southern Montagne Noire. The lectostratotype of the Marcory Formation, and the stratotypes of the Pardailhan and Lastours Formations have been selected here (Álvaro *et al.*, 1998), where some relics of old open quarries still occur.

The Lower Cambrian outcrops of the Orbiel valley belong to the so-called Salsigne 'district', which contains several mines still yielding Fe (Salsigne), Cu (Limousis), Cu-Ag (Barrencs), and Fe-Pb-Ag (La Caunette, close to the stratotype road). The presence of Au was discovered in 1892 by Ms Esparseil (engineer of Carcassonne) and, since then, more than 90 T. of Au (until 1989) with an average of 2000 kg./year were extracted, as well as 25% of the worldwide As production. The mineral association rich in Fe-Cu-Zn-Pb occurs in the 'Calcaires à *Archaeocyathus*' (lower member of the Lastours Formation), as stratiform ores associated with a basic volcanism.

The Marcory Formation: after several faults at the lowermost part, the formation shows an homogeneous, shaly-dominant succession with common intercalations of fine-grained sandstones. It is remarkable the presence of *Psammichnites gigas*, the occurrence of centimetre-thick limestone nodules yielding small shelly fossils (hyoliths and chancelloriids), and a distinct geochemical increase in feldspar interpreted as a consequence of a magmatic activity reported in the northern Montagne Noire.

The limestone intercalations of the Pardailhan Formation have yielded a complete archaeocyathan assemblage (Debrenne, 1964), overlying deposition of channelled conglomerates and sandstones.

The Pont de Poussarou, La Tanque and Coulouma Formations crop out episodically at the top of the section, bounded by minor faults and partly covered.

2) Stop 2: the Middle-Upper Cambrian transition in the Sallèles-Cabardès section.

One of the classic reference sections of the Middle-Upper Cambrian transition in the southern Montagne Noire crops out along the road D 611, in the vicinities of Sallèles-Cabardès. Three trilobite assemblages are recognisable across the transition between the La Gardie and Val d'Homs Formations. The bottom of the La Gardie outcrops (levels SC_1 1-2) has yielded the trilobites *Conocoryphe*? *ferralsensis* and *Bailiella griffei* (Courtessole's level H1), whereas the Sallèles Member (levels SC_1 7-8) contains a centimetre-thick shaly intercalation rich in *Chelidonocephalus melchiori* (Courtessole's level H2). Both levels represent the *Eccaparadoxides macrocercus* Zone (upper Languedocian, Middle Cambrian). The first limestone nodules of the Val d'Homs Formation have yielded *Bergeronites* sp., and an undescribed Upper Cambrian fossil assemblage (see chapter 4 of this monography), both in white and reddish limestones, alternating with green and reddish shales. No Ordovician fauna has been described in this section.

3) Stop 3: the Middle Cambrian stratotype of Ferrals-les-Montagnes.

The 'primordial fauna' was discovered by several amateurs in the Ferrals-les-Montagnes area in the 19th century, and described in 1889 by Bergeron. Two sections are visited in this field trip: that along the road D 147 (Ferrals-

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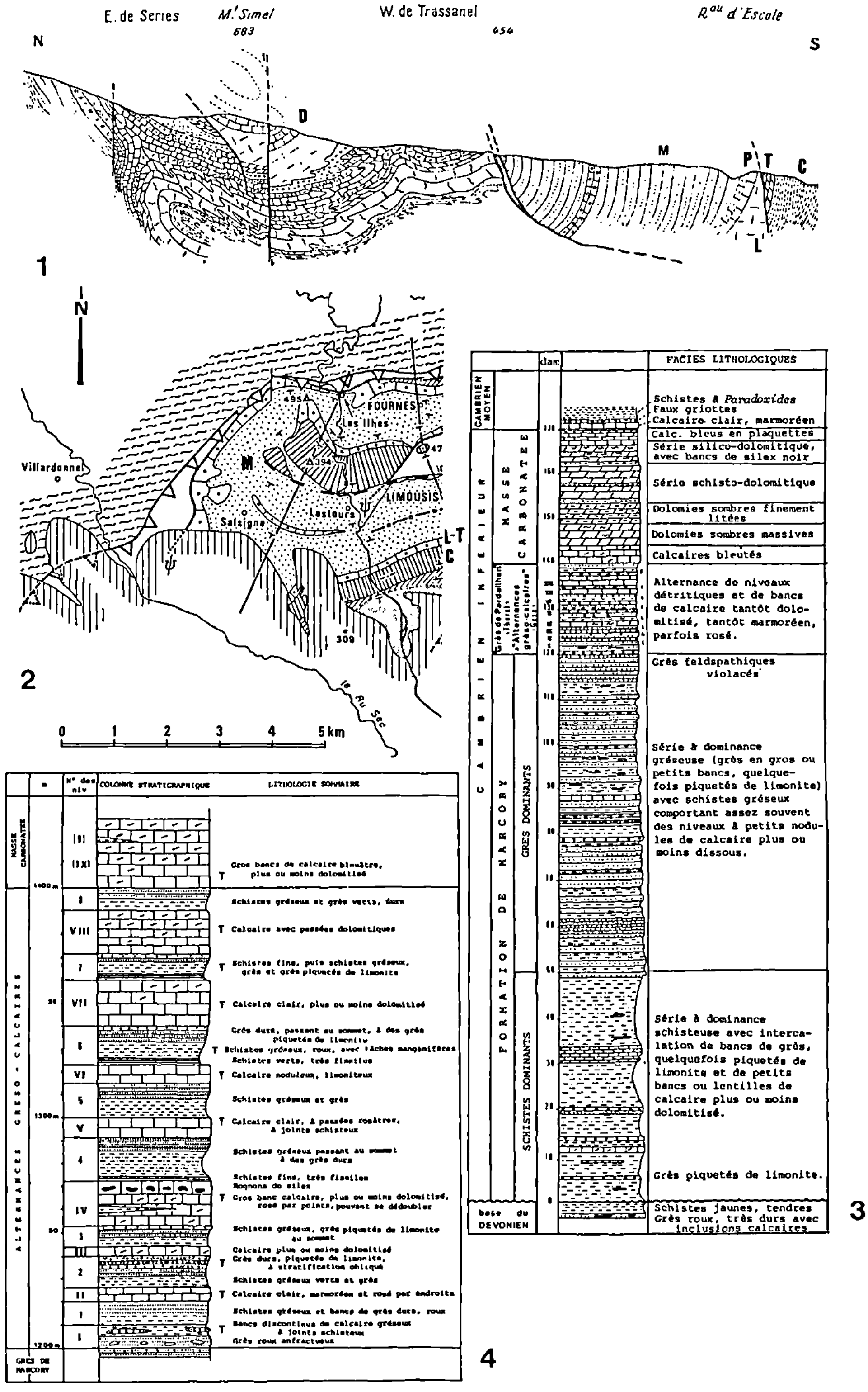

Fig. 1. — 1 : Synthetic cross-section of the Fournes-Lastours fold exhibiting the monoclinal features of the Marcory-to-Coulouma section of • the Orbiel valley on the right side (after Boyer, 1963). M- Marcory, P- Pardailhan, L- Lastours, T- La Tanque, C- Coulouma, D- Devonian ; 2 : Geologic sketch of the Orbiel valley (after Klein, 1983) ; 3 : Lower Cambrian stratigraphic log of the Orbiel valley (after Courtessole & Jago, 1980) ; 4 : Log of the Pardailhan Formation in the Orbiel valley (after Courtessole & Jago, 1980).

Fig. 1. — 1 : Sections synthetiques du pli de Fournes-Lastours montrant le caractère monoclinal de la coupe de la vallée de l'Orbiel (Formations de Marcory à Coulouma, d'après Boyer, 1963). M- *Marcory,* P- *Pardailhan,* L- *Lastours,* T- *La Tanque,* C- *Coulouma,* D- *Devonian ;* 2 : *Schéma géologique de la vallée de l'Orbiel (d'après Klein, 1983) ;* 3 : *Coupe stratigraphique du Cambrien inférieur dans la vallée de l'Orbiel (d'après Courtessole & Jago, 1980). ;* 4 : *Coupe de la Formation de Pardailhan dans la vallée de l'Orbiel (d'après Courtessole & Jago, 1980).*

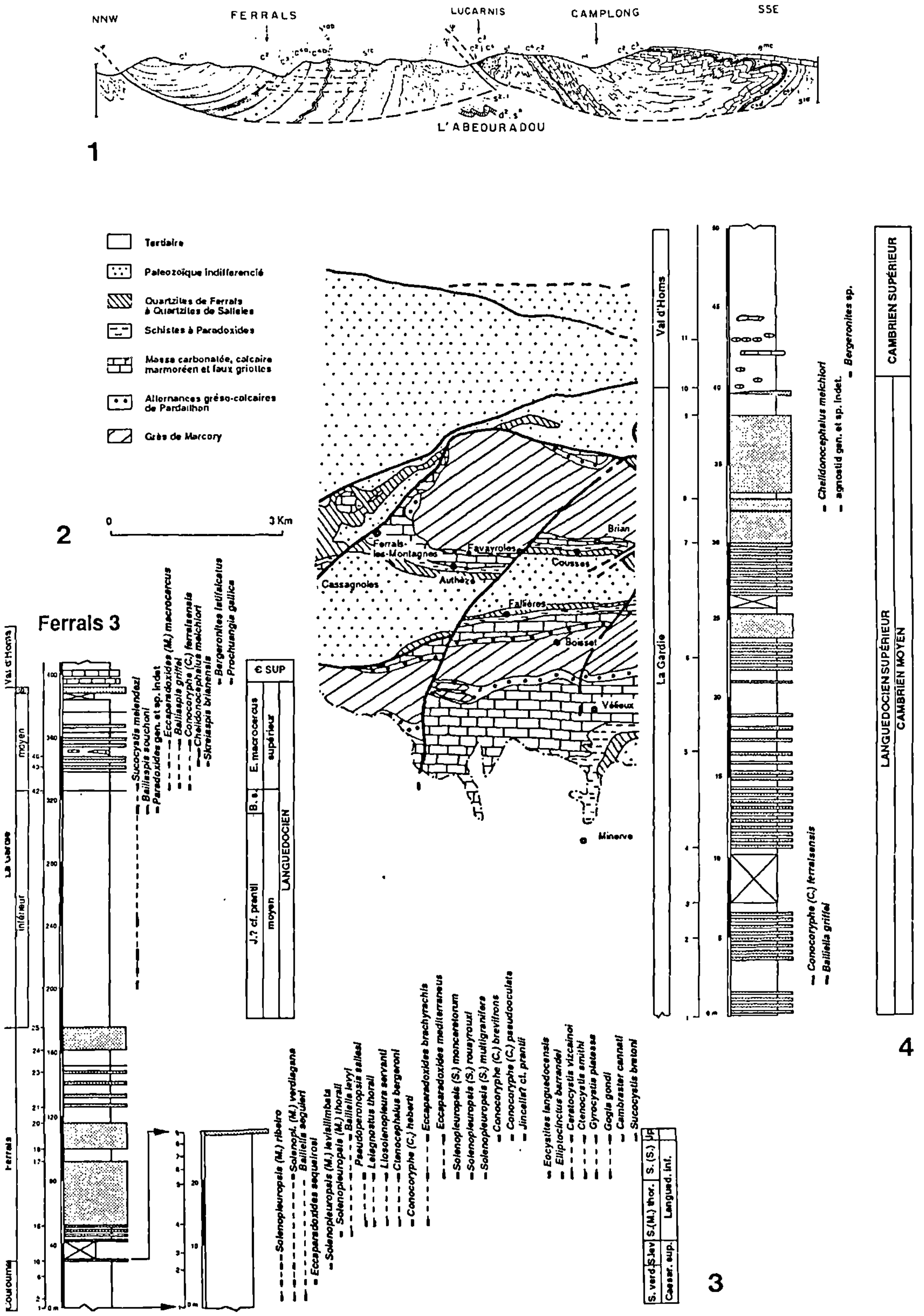

Fig. 2. — 1 : Synthetic cross-section of the western Pardailhan area showing the inverted fold of the Ferrals outcrops. C[1]- Marcory, C[2]- Pardailhan to La Tanque, C[3]- Coulouma, C[4a-h]- Ferrals to La Dentelle (after Guiraud, 1968) ; 2 : Synthetic geological sketch of the Ferrals-les-Montagnes area (modified after Gèze, 1949) ; 3 : Middle Cambrian log of the Ferrals-les-Montagnes area (Languedocian stratotype); after Álvaro & Vizcaïno, 1998 ; 4 : Log of the Middle-Upper Cambrian transition in the Sallèles-Cabardès area (after Álvaro & Vizcaïno, 1998).

Fig. 2. — 1 : Section synthétique du Pardailhan occidental montrant le pli inversé des affleurements de Ferrals. C[1]*- Marcory,* C[2]*- Pardailhan to La Tanque,* C[3]*- Coulouma,* C[4a-h]*- Ferrals à La Dentelle (d'après Guiraud, 1968) ; 2 : Schéma géologique synthétique du secteur de Ferrals-les-Montagnes (modifié d'après Gèze, 1949) ; 3 : Coupe du Cambrien moyen du secteur de Ferrals-les-Montagnes (stratotype du Languedocian); d'après Álvaro & Vizcaïno, 1998 ; 4 : Coupe de la transition Cambrien moyen-supérieur à Sallèles-Cabardès (d'après Álvaro & Vizcaïno, 1998).*

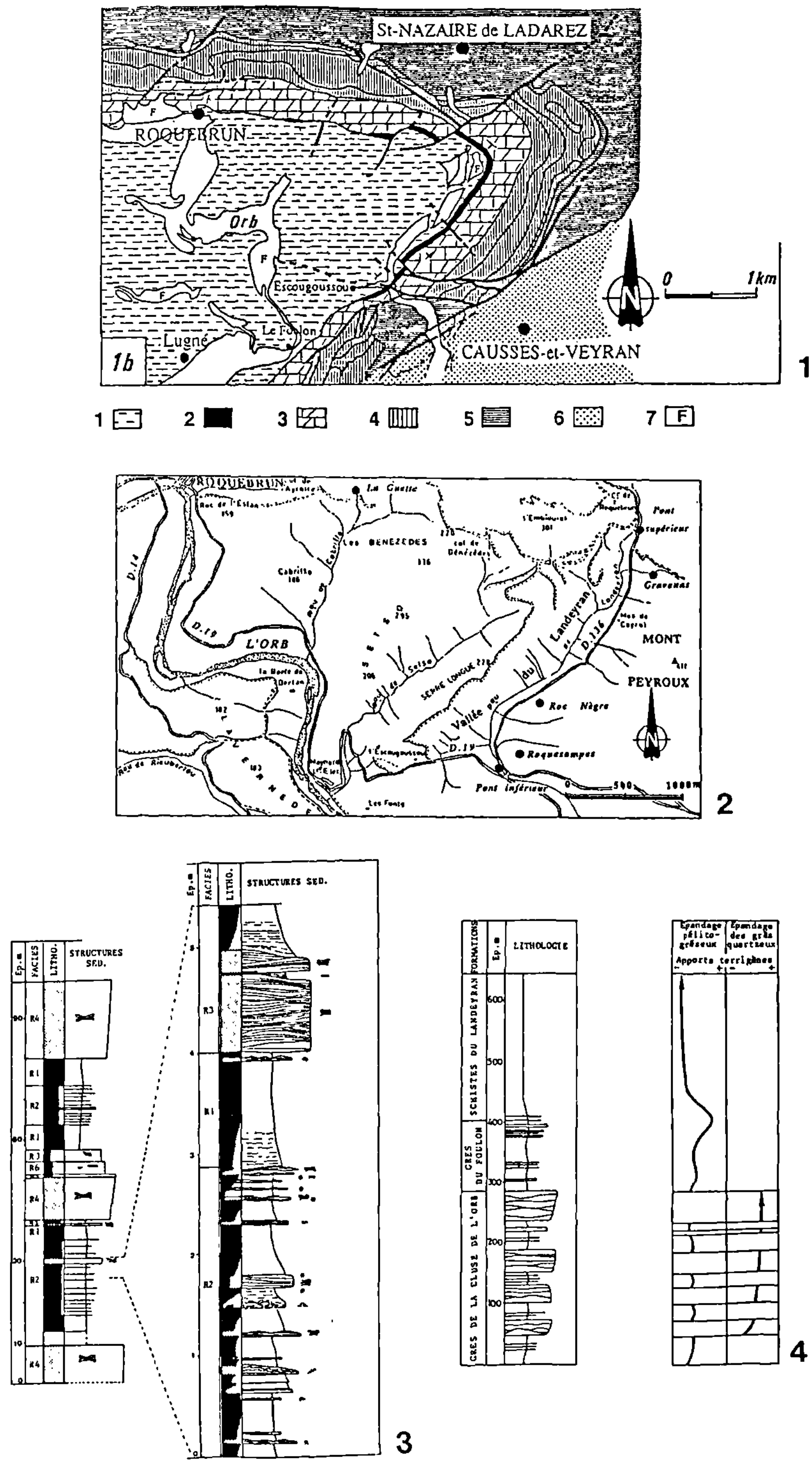

Fig. 3. — 1 : Geological sketch of the contact between the Mont de Peyroux and Faugères nappes (after Quémart *et al.*, 1993). 1- Lower Ordovician, 2- terrigenous Lower Devonian, 3- carbonate Lower Devonian, 4- Middle to Upper Devonian, Tournasian and middle Visean, 5- terminal Visean, 6- Mesozoic and Tertiary ; 2 : Geological map of the Landeyran valley (after Quémart *et al.*, 1993) ; 3 : Cluse de l'Orb stratotype showing the stratigraphic relationships of storm-induced shoals (after Eschard, *in* Courtessole *et al.*, 1985) ; 4 : Evolution of terrigenous input across the Cluse de l'Orb, Foulon and Landeyran Formations displaying an upward deepening (after Eschard, *in* Courtessole *et al.*, 1985).

Fig. 3. — 1 : Schéma géologique du contact entre les nappes du Mont de Peyroux et de Faugères (d'après Quémart et al., *1993). 1-Ordovicien inférieur, 2- Dévonien inférieur silicoclastique, 3- Dévonien inférieur carbonaté, 4- Dévonien moyen à supérieur, Tournasien et Viséen moyen, 5- Viséen terminal, 6- Mésozoïque et Tertiaire ; 2 : Carte géologique de la vallée de Landeyran (d'après Quémart* et al., *1993) ; 3 : Stratotype de la Cluse de l'Orb montrant les relations stratigraphiques des barrières hydrauliques (d'après Eschard,* in *Courtessole* et al., *1985) ; 4 : Evolution des apports silicoclastiques au cours des Formations de la Cluse de l'Orb, Foulon et Landeyran, caractérisées par un approfondissement majeur (d'après Eschard,* in *Courtessole* et al., *1985).*

Authèze), and that crossing the La Gardie hill, both of them cropping out as inverted beds. The section of the road (F_1) comprises the upper member of the Lastours Formation, the Pont de Poussarou, La Tanque and Coulouma Formations. The former member has yielded *Ferralsia blayaci* in an open quarry along a key section for the study of microbial carbonates. The Pont de Poussarou Formation (containing doleritic nodules) and the La Tanque Formation contain an undetermined fossil fauna, and the first trilobite assemblage (in the last reddish shales of the La Tanque Formation) belongs to the middle Caesaraugustian. Therefore, the Lower-Middle Cambrian transition is not recognized.

The section cropping out across the La Gardie hill is the Languedocian stratotype (latest Middle Cambrian stage). The F_3 section cross the upper part of the Coulouma Formation, the whole Ferrals and La Gardie Formations, and the lowermost part of the Val d'Homs Formation. The uppermost part of the Coulouma Formation is very rich in trilobites and echinoderms: the deposition of shales until mid Languedocian times contrasts with the classic sections of the Iberian Peninsula where the Caesaraugustian stage was defined. After deposition of the coarse-grained Ferrals Formation (devoid of fossil fauna excepting ichnofossils), the La Gardie Formation has yielded a continuous record of trilobites and echinoderms allowing recognition of the upper Languedocian in sandy shales. Finally, the first bioclastic, lenticular limestone of the Val d'Homs Formation contains the first described, Upper Cambrian trilobites of the southern Montagne Noire.

4) Stop 4: the Campelou section.

A new section has recently been exposed across the Campelou area along a forest path. The section shows in continuity the Coulouma, Ferrals, La Gardie, La Dentelle and lower part of the Saint Chinian Formations. Limestones, potentially reported to the Val d'Homs Formation, do not occur. In contrast, common slumping and convoluté beds are recognized in the fine-grained siliciclastic units: they represent slope-related deposits on an instable margin of an intra-shelf ramp.

II. — SATURDAY, SEPTEMBER 29TH

1) Stop 1: panorama of the Saint-Chinianais type area.

A sightseeing of the Saint-Chinianais valley, from the southern road D 20, permits the observation of the homogeneous, dark, Saint-Chinian Shales in their type area. As a whole, three nappes are recognisable: the Pardailhan, Mont de Peyroux and Faugères ones. This area is bounded by a southern contact with Upper Cretaceous limestones, the western Illouvre river that cuts the Poussarou Cambrian outcrops (next stop), a northern contact with the Axial Zone of the Montagne Noire (with the Caroux Massif), and an eastern contact with the Devonian outcrops of the Peyroux nappe.

2) Stop 2: the Pont de Poussarou area.

The outcrops of Pont de Poussarou (or Poussarou bridge) shows an inverted fold, associated with a larger thrust system, in which the Lastours, Pont de Poussarou, La Tanque and Coulouma Formations are involved. The latter exhibits vertical beds on the road bearing numerous carbonate nodules paralleling stratification.

3) Stop 3: the Saint-Chinian/La Maurerie transition.

Along the road D 177, between Saint-Chinian and Berlou, the transition between the Saint-Chinian and La Maurerie Formations is exposed. The road permits differentiation between the left Saint-Chinian, homogeneous dark shales and the right brownish, fine-grained sandstones of the La Maurerie Formation. This outcrop has yielded numerous graptolites and trilobites.

4) Stop 4: the Cluse de l'Orb stratotype.

The stratotype of the Cluse de l'Orb Formation crops out along the Rieuberlou valley (road D 14), between Roquebrun and Lugné. This is the classic area from which all the fossils assemblages described in the previous chapter have been reported, mainly including trilobites, brachiopods and trace fossils. A sedimentologic study was too presented by Eschard (*in* Courtessole *et al.* 1984). The Cluse de l'Orb Formation represents the 'Armorican Quartzite'-type sediments of the southern Montagne Noire. The alternances of shales and storm-induced sandstones have yielded common brachiopods (such as *Ectenoglossa lesueuri*) and ichnofossils (*Daedalus halli*). The lower part of the overlying Foulon Formation crops out in continuity with the previous stratotype.

5) Stop 5: the Landeyran stratotype.

Finally, the Landeyran valley is the type area of the Landeyran Formation, along the road D 136 between Cessenan and Saint-Nazaire-de-Ladarez. The first Arenigian graptolites and trilobite assemblages of the southern Montagne Noire were found here, in a shaly lithostratigraphic unit named Saint-Nazare Shales across the 19-20th centuries. The homogeneous shales have yielded a rich fossil record composed of trilobites, brachiopods, echinoderms, graptolites, etc., in which two Arenigian zones are recognized (L and M). Our trip across the Lower Ordovician will end here, in the contact with the vertical Devonian limestones that laterally change from conformable to discordant contact.

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CATALOGUE OF THE FOSSIL SPECIES DEFINED IN THE LOWER PALEOZOIC OF THE SOUTHERN MONTAGNE NOIRE

Catalogue des espèces fossiles décrites dans le Paléozoïque inférieur de la Montagne Noire méridionale

by J. Javier ÁLVARO (*), Bertrand LEFEBVRE (**) & Daniel VIZCAINO (***)

(Plates XIII to XVII)

Abstract. — An updated list of the fossil species defined in the Cambrian and Lower Ordovician of the southern Montagne Noire is presented here. The list comprises archaeocyaths, bivalves, brachiopods, cephalopods, conocardiorids, conularids, echinoderms, gastropods, hyoliths, rostroconchia, trilobites, and *incertae sedis*. This catalogue represents a first step in the revision of the fossil holotypes from the southern Montagne Noire: several holotypes defined in the 19th century are disappeared (such as those of the Bergeron collection housed in the Sorbonne university, Paris) and their illustrations based on drawings. An illustrated catalogue is in preparation comprising the definition of lectotypes for unfound holotypes.

Résumé. — *Ce travail présente une mise à jour de la nomenclature des espèces fossiles décrites dans le Cambrien et l'Ordovicien inférieur du versant sud de la Montagne Noire. La liste est composée d'archéocyathes, brachiopodes, céphalopodes, conocardioridés, conularides, échinodermes, gastéropodes, hyolithes, lamellibranches, rostroconches, trilobites et incertae sedis Ce catalogue représente un premier échelon dans la révision des holotypes fossiles du versant sud de la Montagne Noire : plusieurs holotypes définis au cours du XIXe siècle sont disparus (tels que ceux de la collection Bergeron déposés a l'université de la Sorbonne, Paris) et ses illustrations sont fréquemment des dessins. Un catalogue illustré est en préparation comprenant la définition des lectotypes pour replacer les holotypes disparus.*

I. — ARCHAEOCYATHS

boyeri, *Retecoscinus* Debrenne, 1964; pp. 184-185, pl. 30, figs. 5-6. MNHN, Paris: M 84110.

II. — BIVALVES

courtessolei, *Ekaterodonta* Babin, 1982; pp. 38-39, pl. 8, fig. 1. Brest: LPB 8872.

guiraudi, *Coxiconcha* (Thoral, 1935); p. 174, pl. 13, fig. 6. Lyon: Guiraud collection.

languedociana, *Thoralia* (Thoral, 1935); p. 164, pl. 13, figs. 2-3. Brest: LPB 10720 [paratype].

michelae, *Redonia* Babin, 1982; p. 41, pl. 10, fig. 1. Brest: LPB 9091a.

redoniaeformis, *Norodonta* (Thoral, 1935); pp. 169-170, pl. 13, fig. 8. Lyon: Villebrun collection.

thorali, *Synek* Babin, 1982; p. 43, pl. 10, figs. 8-9. Brest: LPB 10770.

III. — BRACHIOPODS

boyeri, *Lingulepis* Termier & Termier, 1974; p. 36, pl. 1, figs. 1-3. Le Havre.

courtessolei, *Glyptacrothele* Termier & Termier, 1974; pp. 45-46, pl. 5, fig. 2. Le Havre.

crassipyxis, *Lingulepis* Havlíček, 1980; pp. 3-4, pl. 1, fig. 7. Carcassonne, Courtessole-Vizcaïno collection: OBi 38-39.

fascis, *Pleurorthis* Mélou (*in* Babin *et al.*, 1982), p. 29-30, pl. 5, fig. 9 Brest: LPB 10954.

landeyranensis, *Hesperonomia* Mélou (*in* Babin *et al.*, 1982), pp. 23-24, pl. 1, fig. 1 Brest: LPB 10838.

miqueli, *Yorkia* Walcott, 1912.

occitanensis, *Ocorthis* Mélou (*in* Babin *et al.*, 1982), pp. 25-26, pl. 1, fig. 10 Brest: LPB 10891.

pradensis, *Pleurorthis* (Thoral, 1935); p. 139-141. Topotype (specimen no. 1 of Thoral), Montpellier.

roquebrunensis, *Orthambonites* Mélou (*in* Babin *et al.*, 1982), pp. 27-28, pl. 4, fig. 1 Brest: LPB 10919.

spondylifera, *Spondyglossella* Havlíček, 1980; p. 5, pl. 2, figs. 13-14. Carcassonne, Vizcaïno collection: VOMN 381a-b.

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sulcata, Ranorthis Mélou (*in* Babin *et al.*, 1982); pp. 24-25, pl. 2, fig. 1 Brest: LPB 10847.

turricula, Conotreta Havlíček, 1980; p. 5, pl. 2, fig. 1. Carcassonne, Courtessole-Vizcaïno collection: OBi 196a-b.

IV. — CEPHALOPODS

chinianensis, 'Orthoceras' Thoral, 1935; pp. 182-184, pl. 15, fig. 8, pl. 16, fig. 5. Montpellier.

escandei, 'Orthoceras' Thoral, 1935; pp. 186-187, pl. 5, figs. 2-3. Montpellier.

estivali, 'Orthoceras' Thoral, 1935; pp. 187-189, pl 15, fig. 6. Montpellier.

estivali brevicellae, 'Orthoceras' Thoral, 1935; pp. 189-190, pl. 15, fig. 4. Montpellier.

martyi, 'Orthoceras' Thoral, 1935; pp. 180-181, pl. 15, fig. 9. Montpellier.

mourguesi, 'Orthoceras' Thoral, 1935; pp. 185-186, pl. 5, fig. 10. Montpellier.

pradense, 'Orthoceras' Thoral, 1935; pp. 190-191, pl. 15, fig. 5, pl. 16, fig. 3. Montpellier.

V. — CONOCARDIOIDS

crassa, Eopteria (Thoral, 1935); pp. 175-176, pl. 13, figs. 10-11. Brest: LPB 10777.

VI. — CONULARIDS

azaisi, Eoconularia (Thoral, 1935); p. 176, fig. 8. Brest: LPB 10777.

VII. — ECHINODERMS

acrofera, Sucocystis Friedrich, 1993; pp. 91-93, pl. 12, fig. 1a-b. Würzburg: PIW 92V43a.

azaizi multicristata, Mimocystites (Thoral, 1935); pp. 110- 115, pl. 7, fig. 2. Montpellier: UM 307.

azaizi paucicristata, Mimocystites (Thoral, 1935); pp. 110-115, pl. 7, figs. 1, 3, 4. Montpellier: UM 308, 309.

barrandei, Elliptocinctus (Munier-Chalmas & Bergeron, 1889); p. 339, pl. 3, fig.6 [unfound holotype in the Sorbonne university].

blayaci, Phyllocystis Thoral, 1935; pp. 104-105, pl. 6, fig. 3. Montpellier: UM 312 [lectotype].

boehmi, Hemicystites (Thoral, 1935); pp. 117-119, pl. 8, fig. 5. Montpellier: UM 451.

bretoni, Sucocystis Friedrich, 1993; pp. 83-84, pl. 11, fig. 1a-b. Würzburg: PIW 92V36a

cambriensis, Scoteinocystis Ubaghs, 1998; pp. 825-827, figs. 14.6-7, 16.1-2. Carcassonne, Vizcaïno collection: VCMN 378.

cannati, Cambraster (Miquel, 1894); pp. 482-483, fig. 5. Le Havre: MHNH 9035.

cornuta, Peltocystis Thoral, 1935; pp. 91-94, figs. 1a-b, pl. 10, figs. 1a-b. Montpellier: UM 455 [lectotype].

courtessolei, Cothurnocystis Ubaghs, 1969a; pp. 50-53, fig. 22, pl. 6 figs. 2a-d. Paris, MNHN: Courtessole-Griffe collection.

courtessolei, Lyricocarpus Ubaghs, 1994; pp. 120-124, fig. 5, pl. 3, figs. 1-3. Carcassonne, Vizcaïno collection: VOMN 584.

crassimarginata, Phyllocystis Thoral, 1935; pp. 105-106, pl. 7, figs. 8a-b. Montpellier: UM 338 [lectotype].

deani, Lingulocystis Ubaghs, 1994; pp. 132-134, fig. 8, pl. 1, figs. 5-6. Carcassonne, Vizcaïno collection: VOMN 147.

dentiger, Vizcainocarpus Ruta, 1997; pp. 366-376, figs. 2, 4-8, pl. 1, figs. 1-4, pl. 2, figs. 1-5. Paris, MNHN: IPM-B 49101.

dolambii, Nanocarpus Ubaghs, 1991; pp. 161-167, figs. 2, 3a-b. Carcassonne, Vizcaïno collection: VOMN 140.

elongata, Lingulocystis Thoral, 1935; pp. 94-96, pl. 8, figs. 3-4, 6. Montpellier: UM 305, 452 [syntypes].

escandei, Balanocystites (Thoral, 1935); pp. 212-213, pl. 11, fig. 6. Montpellier: UM 396.

fellinensis, Cothurnocystis Ubaghs, 1969a; pp. 44-50, figs. 19-21, pl. 7, figs. 1-4. Lyon: FSL 168715.

gondi, Gogia Ubaghs, 1987; pp. 13-17, fig. 4d-e, pl. 2, figs. 1-2, 5. Châteauroux, Gond collection: G1335/1-G1336/1.

griffei, Amygdalotheca Ubaghs,1969a; pp. 64-67, fig. 26.1-3, pl. 11, figs. 1-5. Béziers: Griffe collection.

griffei, Thoralicystis (Ubaghs, 1969a); pp. 57-63, figs. 24, 25.1-2, pl. 9 figs. 1-5, pl. 10, fig. 2-3. Béziers: Griffe collection.

jacobi, Pradesura (Thoral, 1935); pp. 123-127, pl. 9, fig.2. Montpellier: UM 139 [lectotype].

landeyranensis, Ampelocarpus Lefebvre & Vizcaïno, 1999; pp. 444-445, figs. 21.3-4, 22.6-7. Carcassonne, Vizcaïno collection: VOMN 3062.

languedocianus, "Eocystites" Ubaghs, 1987; pp. 18-21, pl. 3, fig. 1. Carcassonne, Vizcaïno collection: VCMN 241.

languedociana, Cheirocystella (Thoral, 1935); pp. 115-117, pl. 7, figs. 5. Montpellier: UM 448, 449 et 450 [syntypes].

levyi, Chinianaster Thoral, 1935; pp.127-129, pl. 9, fig. 1a-b. Montpellier: Villebrun collection [lectotype].

lignieresi, Galliaecystis Ubaghs, 1969a; pp. 68-72, fig. 27, pl. 12, figs. 1-5. Lyon: FSL 168 717.

melchiori, Proscotiaecystis (Ubaghs, 1983); pp. 35-40, figs. 7a,d,f-g, pl. 9, figs. 1a-b. Carcassonne, Courtessole-Vizcaïno collection: OE 1.

moncereti, Ovocarpus Ubaghs, 1994; pp. 126-129, fig. 6c, pl. 2, fig. 1. Narbonne, Monceret-Goujon collection: M-G III.

moorei, Aethocrinus Ubaghs, 1969b; pp. 2-16, figs. 5-6, pl. 1, figs. 1a-b. Lyon, Lignières collection: 624.

occitana, Arauricystis (Ubaghs, 1994); pp. 111-114, fig. 2, pl. 1, figs. 1-3. Carcassonne, Vizcaïno collection: VOMN 109.

ornata, Velieuxicystis Ubaghs, 1998; pp. 821-823, figs. 9.7-8, 11. Carcassonne, Vizcaïno collection: VCMN 546.

platessa, Gyrocystis Jaekel, 1918; pp. 114, fig. 105a-b. Greifswald: FGWG 97/1 [lectotype].

primaeva, Arauricystis (Thoral, 1935); pp. 99-101, pl. 6, figs. 1a-b. Montpellier, Villebrun collection.

radiata, Barroubiocystis Ubaghs, 1998; pp. 816-821, figs. 7, 9.3-4. Carcassonne, Vizcaïno collection: VCMN 389.

singularis, Trigonocarpus Ubaghs, 1994; pp. 115-118, fig. 3; pl. 1, fig. 4. Carcassonne, Vizcaïno collection: VOMN 145.

smithi, Ctenocystis Ubaghs, 1987; pp. 6-8, fig. 2a-b, pl. 1 figs. 1-2. Carcassonne, Vizcaïno collection: VCMN 238.

spinosa, Chauvelicystis Ubaghs, 1969a; pp. 53-56, fig. 23, pl. 8, figs. 1a-c. Lyon: FSL 168718.

theronensis, Sucocystis Cabibel, Termier & Termier, 1959; p. 291, fig. 9a-b; pl. 2, figs. 7-9. Le Havre: MHNH 8597 [syntypes].

thorali, Balantiocystis Ubaghs, 1983; p. 46. Montpellier : UM 446.

thorali, Chinianocarpos Ubaghs, 1961; pp. 1-3, fig. 1a. Montpellier: UM 442.

thorali, Villebrunaster Spencer, 1951; pp. 93-98, fig. 3, pl. 2, fig. 29. Montpellier, Villebrun collection.

trapeziiformis, Anatifopsis Thoral, 1935; pp. 211-212, pl. 11, fig. 5. Montpellier: UM 210 [lectotype].

ubaghsi, Ampullaster Fell, 1963 ; pp. 145-146, pl. 1, Lyon : PS 193.

ubaghsi, Galliaecystis Cripps, 1989; pp. 236, fig. 24. Béziers: Griffe collection.

ubaghsi, Thoralicystis Lefebvre & Vizcaïno, 1999; pp. 447-450, figs. 22.8, 23.2. Carcassonne, Courtessole-Vizcaïno collection: OE8.

vidali, Minervaecystis (Thoral, 1935); pp. 107-110, pl. 6 fig. 5. Montpellier: UM 302 [lectotype].

vizcainoi, Ceratocystis Ubaghs, 1987; pp. 9-13, pl. 1, fig. 4; Carcassonne, Vizcaïno collection: VCMN 275.

vizcainoi, Chauvelicystis Daley, 1992; pp. 128, fig. 1. Carcassonne, Courtessole-Vizcaïno collection: OE9..

vizcainoi, Lobocarpus Ubaghs, 1998; pp. 812-814, figs. 3, 5.1-2. Carcassonne, Vizcaïno collection: VCMN 656.

vizcainoi, Ramseyocrinus Ubaghs, 1983; pp. 48-52, fig. 11, pl. 8, figs. 5a-b. Carcassonne, Courtessole-Vizcaïno collection: OE12.

VIII. — GASTROPODS AND RELATED PROBLEMATICA

courtessolei, Carcassonnella (Yochelson, 1982; *in* Babin *et al.*, 1982); p. 56, figs. 15.5, 8.9. Brest: LPB 9047.

laevis, Thoralispira (Thoral, 1935); p. 146, pl. 12, fig. 6. Montpellier: USTL 367 (*in* Horny & Vizcaïno, 1995) [lectotype].

occitana, Thoralispira? Horny & Vizcaïno, 1995; pp. 35-37, figs. 16-18. Carcassonne, Vizcaïno collection: VOMN 223.

oehlerti, Peelerophon (Bergeron, 1889); p. 343, pl. 4, figs. 10-11 [unfound holotype in the Sorbonne university].

vizcainoi, Carcassonnella Hony & Peel, 1996; pp. 316-317, pl. 5, figs. 8-12. MNHN, Paris : IPMB 49613.

vizcainoi, Solandangella Horny, 1995; pp. 1-11, pl. 1, figs. 1-4. Carcassonne, Vizcaïno collection: VOMN 434.

IX. — HYOLITHS

caperai, Circotheca Marek (*in* Courtessole *et al.*, 1983); p. 57, pl. 1, figs. 1-2 [unfound holotype].

guiraudi, Nephrotheca (Thoral, 1935); pp. 53-56, pl. 14, figs. 1-6. Montpellier.

X. — ROSTROCONCHIA

landeyranensis, Tolmochovia Babin (*in* Babin *et al.*, 1982); pp. 46-47, pl. 12, figs. 7-8. Brest: LPB 10781.

personata, Ribeiria Thoral, 1935; p. 201, pl. 10, fig. 6. Brest: LPB 11313.

XI. — TRILOBITES

abruptus, Arthrorhachis (Howell, 1935); p. 235, pl. 23, fig. 15. Montpellier: H 58.

anteristani, Pradoella (Dean, 1966); pp. 310-313, pl. 13, figs. 3-5. Natural History Museum, London: IN 57475.

antiquus, Ctenocephalus (Hartella) Thoral, 1946; pp. 53-58, pl. 4, fig. 8, pl. 8, figs. 1-7. Montpellier: Miquel collection.

arenosus, Neseuretus (Neseuretus) Dean, 1966; pp. 313-318, pl. 14, figs. 7, 9, 11. Natural History Museum, London: IN 57754.

azaisi, Degamella (Thoral, 1935); pp. 281-284, pl. 32, figs. 12-14. Montpellier.

barroisi barroisi, Asaphelina Bergeron, 1889; p. 475, pl. 4, figs. 1-2 [unfound holotype in the Sorbonne university].

barroisi berardi, Asaphelina Courtessole, Pillet & Vizcaïno, 1981; p. 16, pl. 7, fig. 2 Carcassonne, Vizcaïno collection: OT 60.

barroubioensis, Anglagnostus Howell, 1935; p. 233, pl. 23, fig.11. Montpellier: H 54.

bergeroni, Ctenocephalus (Ctenocephalus) Thoral, 1946; pp. 58-64, pl. 9, figs. 2-6. Montpellier.

binodosus, Selenopeltis Dean, 1966; pp. 334-337, pl. 20, figs. 4, 7-8. Natural History Museum, London: IT 180.

blayaci, Fallagnostus Howell, 1935; p. 230, pl. 23, figs. 1-2. Montpellier: H 20.

blayaci, Ferralsia Cobbold, 1935; pp. 33-35, pl. 4, fig. 2. Montpellier.

borni, Toletanaspis (Dean, 1966); pp. 292-298, pl. 9, figs. 4, 9-10. Natural History Museum, London: IN 57447.

brevifrons, Apatokephalus Thoral, 1935; pp. 293-296, pl. 9, figs. 5-6. Montpellier.

brevifrons, Conocoryphe (Thoral, 1946); pp. 48-50, pl. 6, figs. 1-4, pl. 7, figs. 4-8. Montpellier.

brianensis, Derikaspis (Courtessole, 1973); p. 174-176, pl. 17, fig. 2. MNHN, Paris: R

brianensis, Skreiaspis Courtessole, 1973; pp. 140-142, pl. 10, fig. 11. MNHN, Paris: R

bucculenta, Novakella (Thoral, 1935); p. 284, pl. 24, fig. 9. Montpellier: Azaïs collection.

calissoensis, *Platycalymene (Pharostomina)* Courtessole, Pillet & Vizcaïno, 1983; p. 17, pl. 2, fig. 8. Carcassonne, Vizcaïno collection: OT 116.

cannati, *Jincella*? (Thoral, 1948), pp. 22-27, pl. 6, fig. 1. Lyon: PC 501.

caunesensis, *Arthrorhachis* Capéra, Courtessole & Pillet, 1978; pp. 85-86, pl. 7, figs. 1-5 [unfound holotype in MNHN, Paris].

chinianensis, *Arthrorhachis* (Howell, 1935); p. 234, pl. 23, figs. 12-13. Montpellier: H 54.

convergens, *Platycoryphe* Dean, 1966; pp. 318-320, pl. 14, figs. 3, 10, 13. Natural History Museum, London: IN 57756.

corpulentus, *Arthrorhachis* (Howell, 1935); pp. 234-235, pl. 23, fig. 14. Montpellier: H 57.

couloumana, *Velieuxia* (Miquel, 1905); p. 480-481, pl. 15, fig. 3. Montpellier.

courtessolei, *Stigmatoa* Shergold, Feist & Vizcaïno, 2000; p. 612, pl. 3, fig. 4. Montpellier: UM2 SFV 70.

courtessolei, *Toletanaspis* Henry, Vizcaïno & Destombes, 1992; pp. 285-288, figs. 3C, 4D. Rennes: IGR 2631.

coussesensis, *Ctenocephalus (Ctenocephalus)* Thoral, 1946; pp. 63-65, pl. 9, fig. 7. Lyon: PC 363.

deani, *Colpocoryphe* Courtessole, Pillet & Vizcaïno, 1983; pp. 17-20, pl. 4, fig. 6. Carcassonne, Vizcaïno collection: OT 97.

delagei, *Corynexochus* Miquel, 1905; pp. 481-482, pl. 15, fig. 4. Montpellier.

embourielensis, *Salterocoryphe*? Courtessole, Pillet & Vizcaïno, 1983; pp. 22-23, pl. 5, fig. 9. Carcassonne, Vizcaïno collection: OT 154.

escoti, *Pliomerops* (Bergeron, 1895); p. 472, pl. 4, fig. 18 [unfound holotype in the Sorbonne university].

escudiei, *Colpocoryphe* Courtessole, Pillet & Vizcaïno, 1983; p. 23, pl. 3, fig. 1. Carcassonne, Vizcaïno collection: OT 126.

fallax columbensis, *Pseudoperonopsis* (Pillet, *in* Courtessole *et al.*, 1988); p. 35, pl. 1, fig. 4. MNHN, Paris.

fedouensis, *Arthrorhachis* Capéra, Courtessole & Pillet, 1978; p. 86, pl. 6, fig. 10 [unfound holotype].

felinesensis, *Platycalymene (Pharostomina)* Courtessole, Pillet & Vizcaïno, 1983; p. 17, pl. 2, fig. 10. Carcassonne, Vizcaïno collection: OT 118.

ferralsensis, *Conocoryphe* Courtessole, 1967; pp. 501-505, pl. 4, fig. 4. MNHN, Paris: R 9856.

ferralsensis, *Homagnostoides* Bergeron, 1889 [unfound holotype in the Sorbonne university]. Lectotype in MNHN, Paris [*in* new Treatise (Shergold), p. 376, fig. 237.1c-d]: IPMB 49010.

filacovi, *Euloma* (Bergeron, 1899) [unfound holotype in the Sorbonne University].

filacovi bergeroni, *Megitaspis (Ekeraspis)* (Thoral, 1935); p. 226, pl. 20, fig. 7. Montpellier: Miquel collection.

filacovi filacovi, *Megitaspis (Ekeraspis)* (Bergeron, 1889); p. 340, pl. 4, figs. 3-4 [unfound holotype in the Sorbonne university].

foulonensis, *Hungioides* Pillet, Courtessole & Vizcaïno, 1985 (*in* Courtessole *et al.*, 1985); pp. 46-47, pl. 7, fig. 1. Carcassonne, Vizcaïno collection: OT 258.

fourneti, *Niobella* (Thoral, 1946); pp. 74-82, pl. 2, fig. 1. Lyon.

foveolatus, *Calodiscus* Howell, 1935; pp. 224-225, pl. 22, figs. 12-15. Montpellier: A 130.

frequens, *Asaphelus* (Thoral, 1935); pp. 243-248, pl. 29, fig. 1. Lyon: Escande collection.

gallica, *Prochuangia* Feist & Courtessole, 1984; p. 181, fig. 6. Lyon: DSTL 350254-350260.

gallicus, *Bathycheilus* Dean, 1965; p. 5, pl. 2, figs. 1-9. Natural History Museum, London: IN 57485.

garriguensis, *Eccaparadoxides* (Pillet, 1985; *in* Courtessole *et al.*, 1985); pp. 41-43, pl. 3, figs. 9-10. Carcassonne, Vizcaïno collection: CV 590.

geminus, *Gallagnostus* Howell, 1935; pp. 227-228, pl. 22, fig. 22. Montpellier: H 13.

globosus, *Paramegalaspis* Pillet, Courtessole & Vizcaïno, 1985 (*in* Courtessole *et al.*, 1985); p. 41, pl. 1, fig. 1.

goniopleurae, '*Megalaspis*' Thoral, 1935; pp. 231-234, pl. 24, figs. 7-8. Montpellier: Azaïs collection.

granieri, *Badulesia* (Thoral, 1935); p. 52, pl. 3, fig. 4. Montpellier: USTM-ACI 293.

granulosus, *Eccaparadoxides* (Courtessole, 1973); pp. 131-132, pl. 8, figs. 4-5. MNHN, Paris: R 9673.

griffei, *Bailiella* Courtessole, 1967; pp. 498-500, pl. 3, fig. 1. MNHN, Paris: R 9906.

griffei, *Illaenopsis* Courtessole & Pillet, 1975; pp. 267-269, pl. 27, fig. 5. MNHN, Paris: R 9408.

guiraudi, '*Paramegalaspis*' Thoral, 1935; pp. 251-253, pl. 23, fig. 8, pl. 25, fig. 5, pl. 30, fig. 5. Montpellier.

heberti, *Conocoryphe* Munier-Chalmas & Bergeron, 1889 [unfound holotype in the Sorbonne university].

hispida, *Pardailhania* (Thoral, 1935); p. 57, pl. 3, fig. 2. Montpellier: USTM-ACI 291.

immarginata, *Paramegalaspis* Thoral, 1935; pp. 248-251, pl. 18, fig. 4, pl. 28, figs. 4-6, pl. 29, figs. 4-5, pl. 30, figs. 1-2. Montpellier.

immensum, *Phalacroma* (Howell, 1935); p. 228, pl. 22, fig. 22. Montpellier: H 14.

imperator, *Condylopyge* Howell, 1935; p. 229, pl. 22, figs. 23-24. Montpellier: H 15.

incisus, *Apatokephalus* Dean, 1966; pp. 339-345, pl. 20, figs. 1-2. Natural History Museum, London: IT 176.

inflata, *Bailiaspis* Pillet, 1988 (*nomen nudum* changed into *Bailiaspis pilleti* in this volume).

insolitum, *Otarion* Dean, 1966; pp. 337-338, pl. 19, figs. 11, 13-14. Natural History Museum, London: IN 57472.

lacaunensis, *Anglagnostus*? Capéra, Courtessole & Pillet, 1975; p. 362, pl. 2, figs. 4-7, 18-19 [unfound holotype].

languedocensis, *Parabailiella* (Thoral, 1946); pp. 31-38, pl. 4, fig. 1. Lyon: PC 1001.

languedocensis, *Prionocheilus* (Courtessole & Pillet, 1975); p. 70, pl. 1, fig. 7 [unfound holotype in the Capéra collection].

latefalcata, *Palaeadotes* (Feist & Courtessole, 1984); p. 178, fig. 10. Lyon: DSTL 350261-350266.

latifalcatus (changed into *Palaeadotes latefalcata*).

levisilimbata, *Solenopleuropsis (Manublesia)* Thoral, 1948; pp 45-48, pl. 1, fig. 3; pl. 2, fig. 9. Lyon: FSL 16438-16439.

levyi, *Bailiella* Munier-Chalmas & Bergeron, 1889 [unfound holotype in the Sorbonne university]. Lectotype in MNHN, Paris: R-9880.

lignieresi, *Niobella* (Bergeron, 1895) [unfound holotype in the Sorbonne university].

lugneensis, *Asaphellus* Pillet, Courtessole & Vizcaïno (*in* Courtessole *et al.*, 1985); pp. 39-40, pl. 4, figs. 1-2. Carcassonne, Vizcaïno collection: OT 219-220.

lugneensis, *Pradoella* (Courtessole, Pillet & Vizcaïno, 1983); p. 25, pl. 7, fig. 1. Carcassonne, Vizcaïno collection: OT 170.

macrocercus, *Eccaparadoxides* (Courtessole, 1967); pp. 495-498, pl. 1, fig. 1. MNHN, Paris: R 9678.

macrophtalmus, *Aocaspis* (Thoral, 1935); p. 273, pl. 32, figs. 10-11. [Lectotype *in* Courtessole & Pillet (1975): Thoral, pl. 32, fig. 10. Montpellier: Azaïs collection].

magnificum, *Pleuroctenium* Howell, 1935; p. 229, pl. 22, figs. 25-26. Montpellier: H 17.

major, *Grandagnostus* Pillet (*in* Courtessole *et al.*, 1985); p. 36, pl. 1, fig. 8 [unfound holotype in MNHN, Paris].

martyi, *Pradesia* Thoral, 1935; p. 311, pl. 21, fig. 1. Lyon, Montpellier: Marty collection.

matutinus, *Prionocheilus* Dean, 1966; p. 272, pl. 10, fig. 7. Natural History Museum, London: IN 57434.

maynardensis, *Colpocoryphe* Courtessole, Pillet & Vizcaïno, 1983; pp. 20-22, pl. 3, fig. 2. Carcassonne, Vizcaïno collection: OT 127,

mediterranea, *Basiliella* Dean, 1966; pp. 320-323, pl. 17, figs. 1-4. Natural History Museum, London: IT 399.

mediterraneus, *Geragnostus* Howell, 1935; pp. 231-232, pl. 23, figs. 6-7. Montpellier: H 47.

melaguesensis, *Eccaparadoxides* (Thoral, 1935); pp. 48-50, pl. 4, fig. 10. Lyon: Thoral collection.

melchiori, *Chelidonocephalus* Pillet (*in* Courtessole *et al.*, 1985), pp. 38-39, pl. 4, fig. 4. MNHN, Paris: R

meridionalis, *Platycoryphe* Courtessole, Pillet & Vizcaïno, 1983; p. 28, pl. 5, fig. 18. Carcassonne, Vizcaïno collection: OT 161.

midi, *Granolenus* Jago, 1980 (*in* Courtessole & Jago, 1980); pp. 16-17, pl. 2, fig. 1. MNHN, Paris: R 9375.

minervensis, *Platycalymene (Platycalymene)* Courtessole, Pillet & Vizcaïno, 1983; p. 14, pl. 2, fig. 13. Carcassonne, Vizcaïno collection: OT 121.

miqueli, *Blayacina* Cobbold, 1931; pp. 568-570, pl. 27, figs. 14-15. Montpellier: Thoral collection.

miqueli, *Leiagnostus* Sdzuy, 1958; pp. 260-262, pl. 1, figs. 12, 15. Senckenberg Museum, Stuttgart: SMF 1007.

miqueli, *Pseudoperonopsis* (Howell, 1935); p. 226, pl. 22, fig. 16. Montpelllier: H 1.

miqueli, *Skreiaspis* Álvaro & Vizcaïno, 2000; p. 282, pl. 2, fig. 6. MNHN, Paris: R 62996.

miqueli, *Taihungshania* (Bergeron, 1893) [unfound holotype in the Sorbonne university; lectotype, MNHN, Paris: R-9533].

monceretorum, *Solenopleuropsis (Solenopleuropsis)* Álvaro & Vizcaïno, 1997; pp. 556-557, fig. 5.8. MNHN, Paris: R 62397.

monspelliensis, *Onchonotellus* (Capéra, Courtessole & Pillet, 1975); pp. 357-358, pl. 1, figs. 1-7, 13 [unfound holotype in MNHN, Paris].

multigranifera, *Solenopleuropsis (Solenopleuropsis)* Thoral, 1948; pp. 41-43, pl. 1, fig. 2 ; pl. 2, fig. 6. Lyon: FSL 16436-16437.

multispinosa, *Pardailhania* Thoral, 1948; pp. 55-57, pl. 3, figs. 8-9. Lyon: FSL 16454-16455.

nazairensis, *Platycalymene (Pharostomina)* Courtessole, Pillet & Vizcaïno, 1983; p. 17, pl. 2, fig. 16. Carcassonne, Vizcaïno collection: OT 124.

niger, *Geragnostella* Sdzuy, 1958; pp. 259-260, pl. 1, figs. 8-9. Senckenberg Museum, Stuttgart: SMF 10005.

nigra, *Courtessolium* Pillet, 1988; p. 95, pl. 1, fig. 4 [unfound holotype].

noiri, *Eoredlichia* (Jagô, *in* Courtessole & Jago, 1980); pp. 15-16, pl. 1, fig. 1. MNHN, Paris: R 9370.

occitanus, *Geragnostus* Howell, 1935; p. 231, pl. 23, figs. 4-5. Montpellier: H 44.

ogivalis, *Taihungshania* Pillet, Courtessole & Vizcaïno, 1985 (*in* Courtessole *et al.*, 1985), p. 46, pl. 7, fig. 12. Carcassonne, Vizcaïno collection: OT 268.

orbensis, *Ogyginus* Pillet, Courtessole & Vizcaïno, 1985 (*in* Courtessole *et al.*, 1985); pp. 44-45, pl. 6, fig. 5. Carcassonne, Vizcaïno collection: OT 247.

oviformis, *Arthrorhachis* (Howell, 1935); p. 235, pl. 23, fig. 16. Montpellier: H 60.

peregrina, *Foulonia* (Dean, 1966); pp. 287-290, pl. 7, figs. 1-3, 6-7. Montpellier: Guiraud collection.

pilleti, *Bailiaspis* Álvaro, Lefebvre, Shergold & Vizcaïno, 2001. Figured in Courtessole *et al.* (1988), pl. 6, fig. 3. Carcassonne, Vizcaïno collection: CV 260.

pilleti, *Geragnostus* Rábano, Pek & Vanek, 1985 [illustrated *in* Capéra *et al.* (1978), p. 82, pl. 5, figs. 11, 15. Unfound holotype].

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pradesensis, *Platycalymene (Platycalymene)* Courtessole, Pillet & Vizcaïno, 1983; pp. 15-16, pl. 2, fig. 2. Carcassonne, Vizcaïno collection: OT 111.

prepater, *Courtessolium* (Courtessole & Pillet, 1975); pp. 67-68, pl. 1, fig. 1. [unfound holotype in MNHN, Paris].

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robusta, *Hunnerbergia*? Pillet, Courtessole & Vizcaïno, 1985 (*in* Courtessole *et al.*, 1985); pp. 37-38, pl. 1, fig. 9. Carcassonne, Vizcaïno collection: OT 197.

roquebrunensis, *Megitaspis (Ekeraspis)* Courtessole, Pillet & Vizcaïno, 1981; p. 20, pl. 4, fig. 6 Carcassonne, Vizcaïno collection: CVOT 34.

rouayrouxi, *Solenopleuropsis (Solenopleuropsis)* (Munier-Chalmas & Bergeron, 1889) [unfound holotype in thè Sorbonne university; lectotype in MNHN, Paris: R 62393].

rouvillei, *Eccaparadoxides* (Miquel, 1905); pp. 478-479, pl. 15, fig. 1. Montpellier:

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serventi, *Liosolenopleura* Thoral, 1948; pp. 69-74, pl. 5, figs. 1-3. Lyon: PC 419.

setsoensis, *Platycalymene (Pharostomina)* Courtessole, Pillet & Vizcaïno, 1983; pp. 16-17, pl. 13, fig. 5. Carcassonne, Vizcaïno collection: OT 187.

shui landeyranensis, *Taihungshania* (Thoral, 1935); p. 257, pl. 21, figs. 5-7 [unfound holotype].

sidenblahi gallicus, *Geragnostus* Howell, 1935; p. 231, pl. 23, fig. 3. Montpellier: H 42.

souchoni, *Bailiaspis* Courtessole, 1967; pp. 500-501, pl. 4, fig. 1. MNHN, Paris: R 9907.

subinsignis, *Niobella* (Thoral, 1935); pp. 262-265, pl. 26, fig. 2. Villebrun collection.

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ultima, *Euloma* Pillet, 1988, pp. 89-90, pl. 1, figs. 8-9. Carcassonne, Vizcaïno collection: VOMN 1354.

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viallai, *'Liostracus'* Thoral, 1948; pp. 74-79, pl. 5, fig. 4-6, pl. 6, figs. 4-7. Lyon: Thoral collection.

villebruni, *Ampyxinella (Eoampyxinella)* (Thoral, 1935); pp. 307-311, pl. 26, figs. 7-10. Montpellier: Azaïs, Miquel and Villebrun collections.

villebruni, *Asaphopsoides* (Bergeron, 1895); p. 5, figs. 1-2 [unfound holotype in the Sorbonne university].

villebruni, *Harpides (Dictyocephalites)* (Bergeron, 1895) [unfound holotype in the Sorbonne university].

villerembertensis, *Platycalymene (Platycalymene)* Courtessole, Pillet & Vizcaïno, 1983; p. 15, pl. 13, figs. 6-9. Carcassonne, Vizcaïno collection: OT 188.

vizcainoi, *Carolinites* Pillet, 1988; p. 97, pl. 1, fig. 7. Carcassonne, Vizcaïno collection.

vizcainoi, *Dorypyge* Pillet, 1985 (*in* Courtessole *et al.*, 1985); p. 37, pl. 5, fig. 13. Carcassonne, Vizcaïno collection.

EXPLANATION OF PLATE XIII

Fig. 1. — *Chauvelicystis spinosa* Ubaghs 1969, Saint-Chinian Formation, FSL 168718 (holotype), x 5: upper thecal surface.

Fig. 2. — *Nanocarpus dolambii* Ubaghs 1991, Landeyran Formation, VOMN 141, x 10: aulacophore and lower thecal surface.

Fig. 3. — *Chauvelicystis vizcainoi* Daley 1992, Saint-Chinian Formation, OE9, x 10: aulacophore and lower thecal surface.

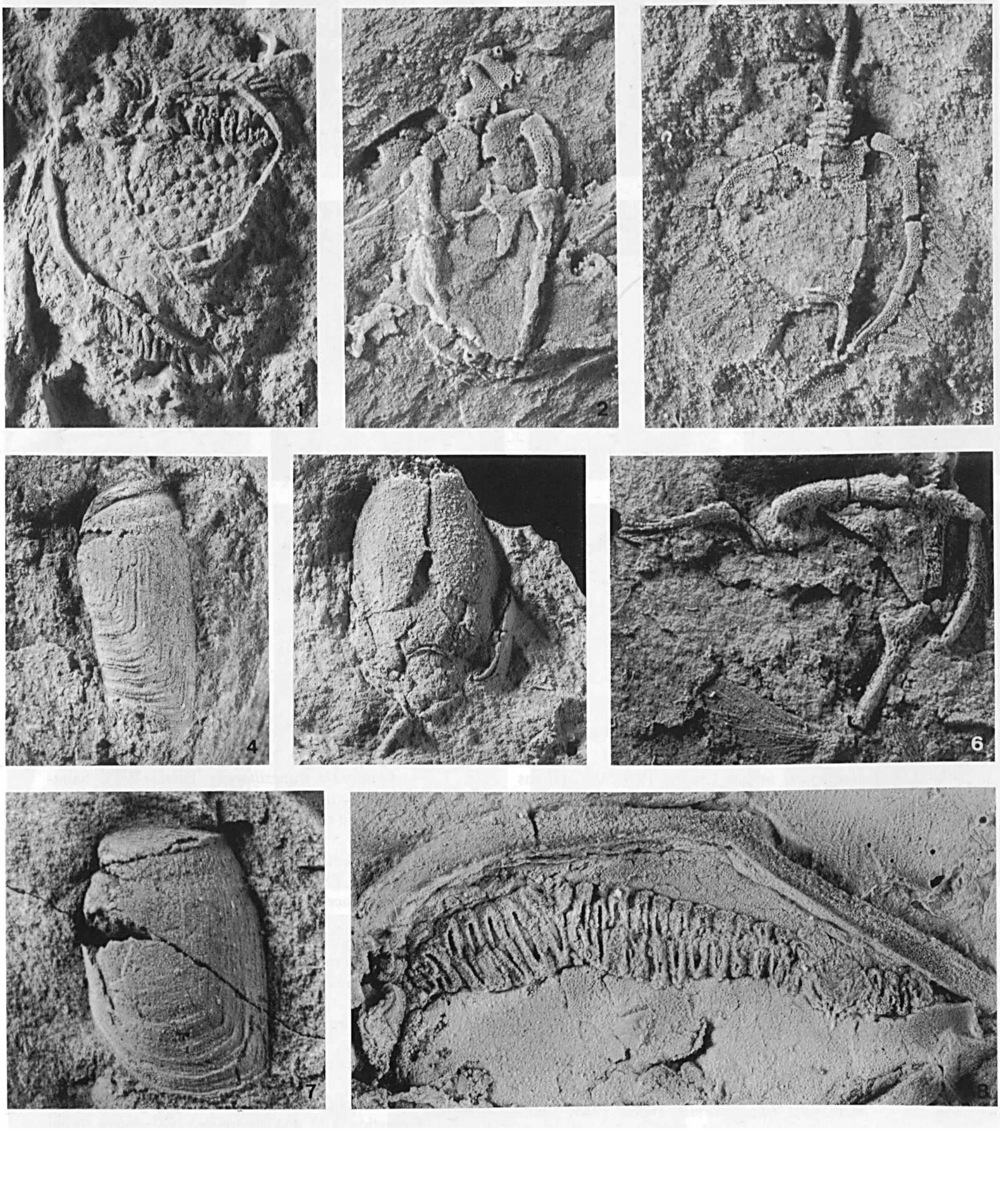
Fig. 4. — *Balanocystites escandei* (Thoral 1935), Saint-Chinian Formation, UM 328, x 5: internal mould of left adoral plate.

Fig. 5. — *Peltocystis cornuta* Thoral 1935, Saint-Chinian Formation, FSL 168708, x 3; upper thecal surface.

Fig. 6. — *Thoralicystis ubaghsi* Lefebvre & Vizcaïno 1999, Landeyran Formation, OE8 (holotype), x 9: lower thecal surface.

Fig. 7. — *Anatifopsis trapeziiformis* Thoral 1935, Saint-Chinian Formation, FSL 170884, x 10: internal mould of left adoral plate.

Fig. 8. — *Proscotiaecystis melchiori* (Ubaghs 1983), Landeyran Formation, OE1 (holotype), x 8: right anterior corner of upper thecal surface with cothurnopores.



EXPLANATION OF PLATE XIV

Fig. 1. —*Velieuxicystis ornata* Ubaghs 1998, Val d'Homs Formation, VCMN 523, x 8; theca and proximal portion of the stem.

Fig. 2. — *Chinianocarpos thorali* Ubaghs 1961, Saint-Chinian Formation, FSL 170930, x 3: lower thecal surface.

Fig. 3. — *Ampelocarpus landeyranensis* Lefebvre & Vizcaïno 1999, Landeyran Formation, VOMN 3062 (holotype), x 10 : aulacophore and upper thecal surface.

Fig. 4. — *Barroubiocystis radiata* Ubaghs 1998, Val d'Homs Formation, VCMN 389 (holotype), x 6: theca and proximal portion of the stem.

Fig. 5. — *Anatifopsis trapeziiformis* Thoral 1935, Saint-Chinian Formation, UM 210 (lectotype), x 5: internal mould of right adoral plate.

Fig. 6. — *Balanocystites escandei* (Thoral 1935), Saint-Chinian Formation, UM 396 (holotype), x 5: internal mould of left adoral plate.

Fig. 7. — *Anatifopsis trapeziiformis* Thoral 1935, Saint-Chinian Formation, FSL 170880, x 5: aulacophore and theca in right lateral view.

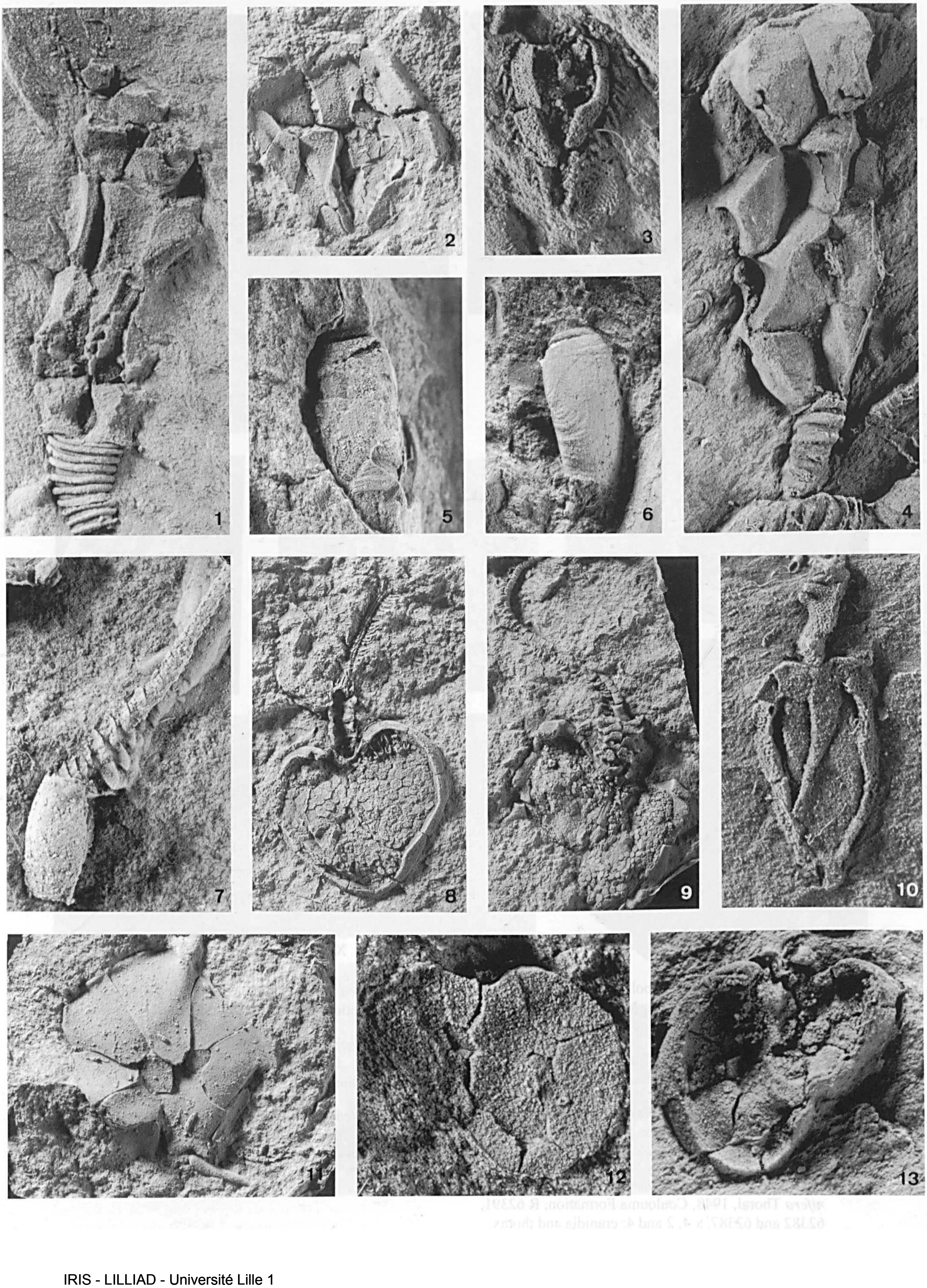
Fig. 8. — *Phyllocystis blayaci* Thoral 1935, Saint-Chinian Formation, FSL 168704, x 2: aulacophore and upper thecal surface.

Fig. 9. — *Cothurnocystis fellinensis* Ubaghs 1969, Saint-Chinian Formation, FSL 168715 (holotype), x 2: aulacophore and lower thecal surface.

Fig. 10. — *Nanocarpus dolambii* Ubaghs 1991, Landeyran Formation, VOMN 140 (holotype), x 10: aulacophore and lower thecal surface.

Fig. 11. — *Peltocystis cornuta* Thoral 1935, Saint-Chinian Formation, UM 455 (lectotype), x 3: lower thecal surface.

Fig. 12-13. — *Lobocarpus vizcainoi* Ubaghs 1998, Val d'Homs Formation, VCMN 656 (holotype), x 12. 12: lower thecal surface; 13: upper thecal surface.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EXPLANATION OF PLATE XV

Fig. 1-2. — *Ferralsia blayaci* Cobbold, 1935, upper member of the Lastours Formation, MPZ 17073 and 17074, x 6.5 and 4.5: cranidia.

Fig. 3. — *Pardailhania hispida* (Thoral, 1935), Coulouma Formation, R 62366, x 3: cranidium.

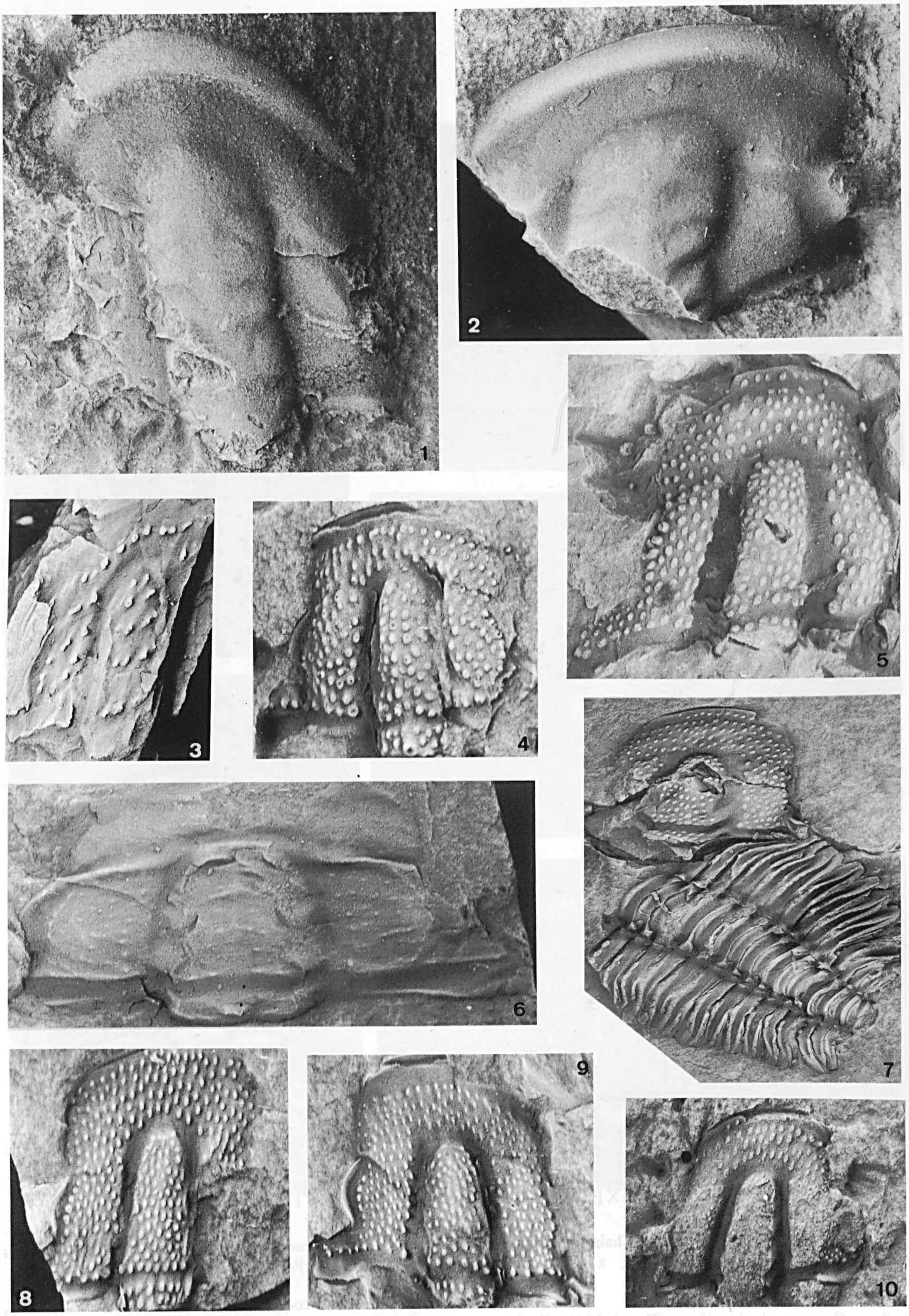
Fig. 4. — *Solenopleuropsis (Manublesia) ribeiro* (Verneuil & Barrande, 1860), Coulouma Formation, R 62375, x 4: cranidium.

Fig. 5, 7-8. —*Solenopleuropsis (Solenopleuropsis) multigranifera* Thoral, 1948, Coulouma Formation, R 62391, 62382 and 62387, x 4, 2 and 4: cranidia and thorax.

Fig. 6. — *Velieuxia couloumana* (Miquel, 1905), Coulouma Formation, R 62398, x 2: cranidium.

Fig. 9. — *Solenopleuropsis (Manublesia) verdiagana* Sdzuy, 1958, Coulouma Formation, R 62376, x 5: cranidium.

Fig. 10. — *Solenopleuropsis (Solenopleuropsis) moncereto-rum* Álvaro & Vizcaïno, 1997, Coulouma Formation, R 62395, x 3: cranidium (holotype).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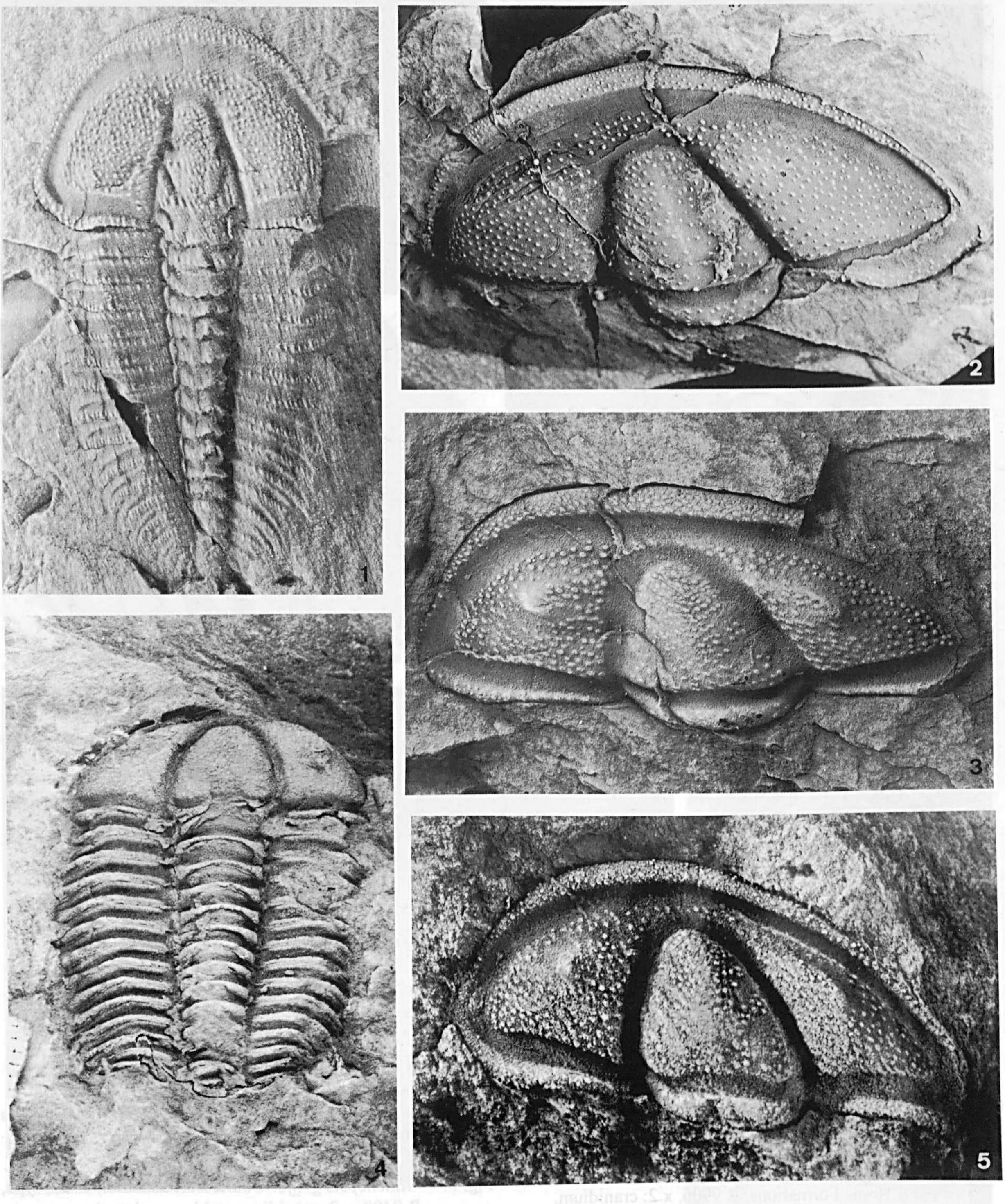
EXPLANATION OF PLATE XVI

Fig. 1. — *Conocoryphe heberti* Munier-Chalmas & Bergeron, 1889, Coulouma Formation, R 9833, x 3.7: complete specimen.

Fig. 2. — *Conocoryphe brevifrons* (Thoral, 1946), Coulouma Formation, R 9849, x 1.8: cranidium.

Fig. 3. — *Conocoryphe*? *pseudooculata* Miquel, 1905, Coulouma Formation, R 9855, x 3: cranidium.

Fig. 4-5. — *Conocoryphe*? *ferralsensis* Courtessole, 1967, Coulouma Formation, R 9868 and 9856 (holotype), x 4 and x 3: cranidium and thorax, and cranidium.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EXPLANATION OF PLATE XVII

Fig. 1. — *Eccaparadoxides melaguesensis* (Thoral, 1935), Coulouma Formation, R 9672, x 1.2: pygidium.

Fig. 2. — *Bailiella griffei* Courtessole, 1967, La Gardie and Val d'Homs Formations, R 9906, x 2: cranidium.

Fig. 3. — *Conocoryphe tenuispinosa* Courtessole, 1973, Coulouma Formation, R 9846 (holotype), x 2: cranidium.

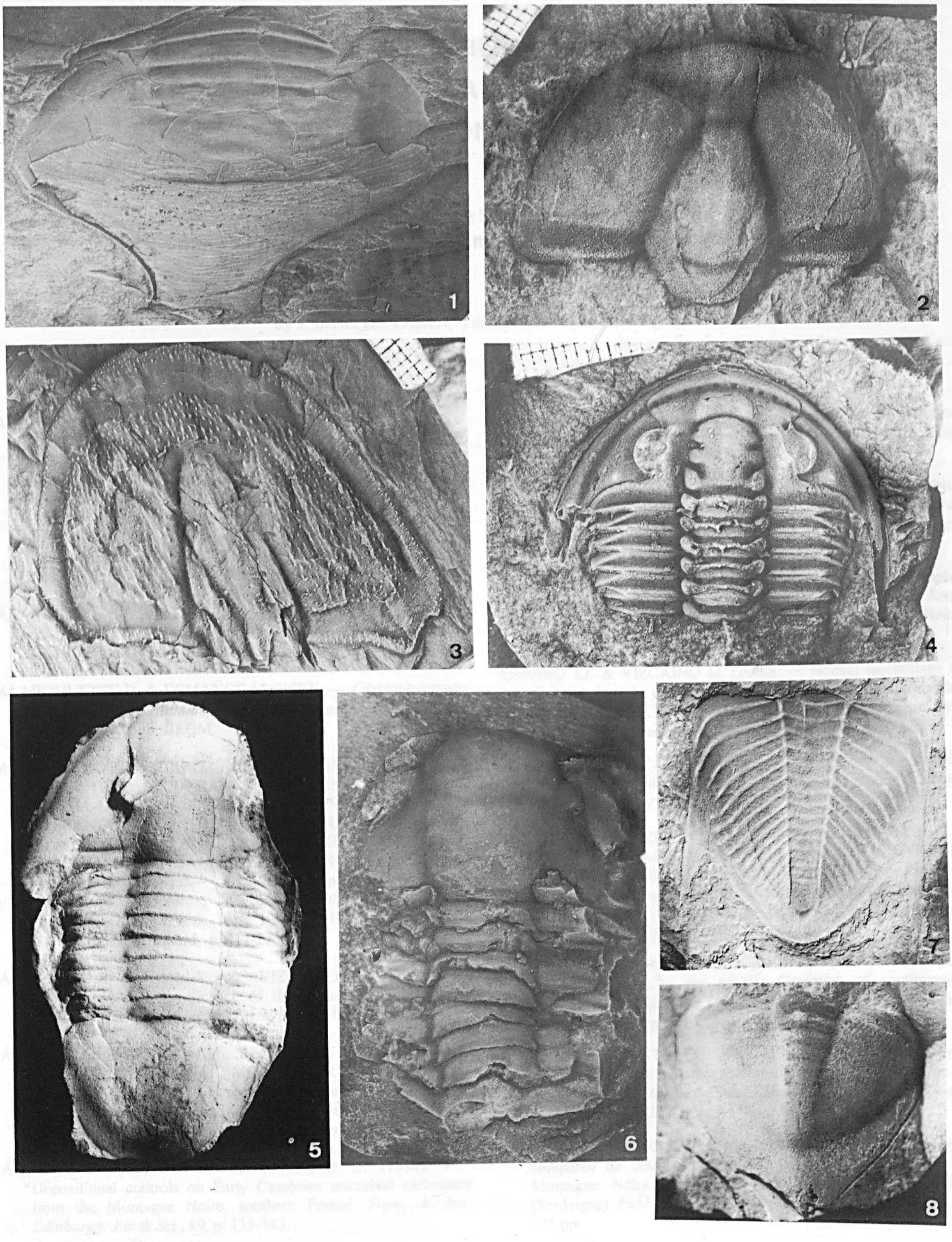
Fig. 4. — *Euloma filacovi* (Bergeron, 1899) ; R 9397, x 2: cranidium and incomplete thorax.

Fig. 5. — *Paramegalaspis immarginata* Thoral, 1935 ; Gs 2000/24G/4-44, x 2: complete specimen.

Fig. 6. — *Illaenopsis griffei* Courtessole & Pillet, 1975, type, R 9408, x 2: cranidium and incomplete thorax.

Fig. 7. — *Taihungshania miqueli* (Bergeron, 1894), Gs 2000/35, x 1: pygidium.

Fig. 8. — *Megitaspis (Ekeraspis) filacovi bergeroni* (Thoral, 1935), Gs 2000/216/3-29, x 1.5: pygidium.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THE CAMBRIAN AND LOWER ORDOVICIAN OF THE SOUTHERN MONTAGNE NOIRE (LANGUEDOC, France A SYNTHESIS FOR THE BEGINNING OF THE NEW CENTURY

Le Cambrien et l'Ordovicien inférieur de la Montagne Noire méridionale (Languedoc, France) Une synthèse à l'aube du nouveau siècle.

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