Comments and proposals about the Valanginian-Lower Hauterivian ammonite zonation of south-eastern France

0012-9402/99/020183-15 $1.50 + 0.20/0
Birkhäuser Verlag, Basel, 1999

Eclogae geol. Helv. 92 (1999) 183–197

Comments and proposals about the Valanginian-Lower Hauterivian ammonite zonation of south-eastern France

STÉPHANE REBOULET & FRANÇOIS ATROPS

Key words: Valanginian-Hauterivian, south-east France, ammonites, turnovers, zonation

ABSTRACT

A modified zonation for the Valanginian-Lower Hauterivian is proposed on the basis of 9 reference sections in the Vocontian basin and compared with other zonations in the same area. The biostratigraphic subdivisions proposed here reflect the evolution of the ammonite faunas. The main modifications of the zonal scheme concern the Upper Valanginian. The Neocomiensis horizon is abandoned. The former Trinodosum zone is replaced by the Peregrinus zone for its lower part and by the Furcillata zone for its upper part. The Callidiscus zone is retained only as horizon of the Furcillata zone. In the Lower Hauterivian, the Kiliani horizon (new) is proposed to replace the Bargemensis horizon. The Radiatus zone is still maintained at the base of the Hauterivian. However, the main faunal caesura takes place at the base of the Loryi zone. This new scheme has the advantage of avoiding the introduction of new biostratigraphical units.

RESUME

L'étude détaillée de la succession des ammonites du Valanginien et de l'Hauterivien inférieur, sur neuf coupes de référence situées dans le bassin Vocontien, nous conduit à apporter des modifications à la zonation qui a été précédemment établie dans la même région. Les subdivisions biostratigraphiques que nous proposons sont mieux en accord avec l'évolution des faunes d'ammonites.

Les principales modifications de l'échelle zonale concernent le Valanginien supérieur. L'Horizon à Neocomiensis est abandonné. L'ancienne Zone à Trinodosum est remplacée, dans sa partie inférieure, par la Zone à Peregrinus et, dans sa partie supérieure, par la zone à Furcillata. La Zone à Callidiscus est désormais utilisée seulement comme un horizon au sommet de la Zone à Furcillata. Pour l'Hauterivien inférieur, nous proposons le nouvel horizon à Kiliani à la place de l'horizon à Bargemensis.

La zone à Radiatus est maintenue à la base de l'Hauterivien. Cependant, la coupure faunique majeure est située à la base de la Zone à Loryi.

Ce schéma zonal a l'avantage d'éviter l'introduction de nouvelles unités biostratigraphiques.

Introduction

The Valanginian-Lower Hauterivian ammonite zonation of south-eastern France has been developed during more than a century (see Thieuloy 1977). It is the most detailed zonation available for the Tethyan paleobiogeographic realm. Except for the Pachydicranus zone (Company 1987), all the biostratigraphic units of the Mediterranean zonation of Valanginian-Lower Hauterivian (Hoedemaeker & Cecca 1995) were defined in south-east France.

Over almost ten years, works by two independant groups allowed to refine the zonal scheme at horizon level (Thieuloy et al. 1990; Bulot & Thieuloy 1993, 1996 – Reboulet et al. 1992; Atrops & Reboulet 1993, 1995a, b; Reboulet 1996). We propose here to compare the biostratigraphic scales of both groups (table 1).

In spite of its precision, the Valanginian-Lower Hauterivian zonation classically recognized (Hoedemaeker & Bulot 1990; Hoedemaeker & Company 1993; Hoedemaeker & Cecca 1995), did not sufficiently take into account the evolution of the ammonite fauna. The boundaries of horizons, zones or stages were often difficult to recognize and to characterize because they did not always correspond to major changes in the ammonite fauna. So, the second aim of this contribution is to

U. F. R. des Sciences de la Terre, Université Claude Bernard – Lyon I, ERS 2042, Centre de Paléontologie Stratigraphique et Paléoécologie, 27–43 boulevard du 11 Novembre 1918, F–69622 Villeurbanne Cedex, France, e mail: Stephane.Reboulet@univ-lyon1.fr, e mail: Francois.Atrops@univ-lyon1.fr

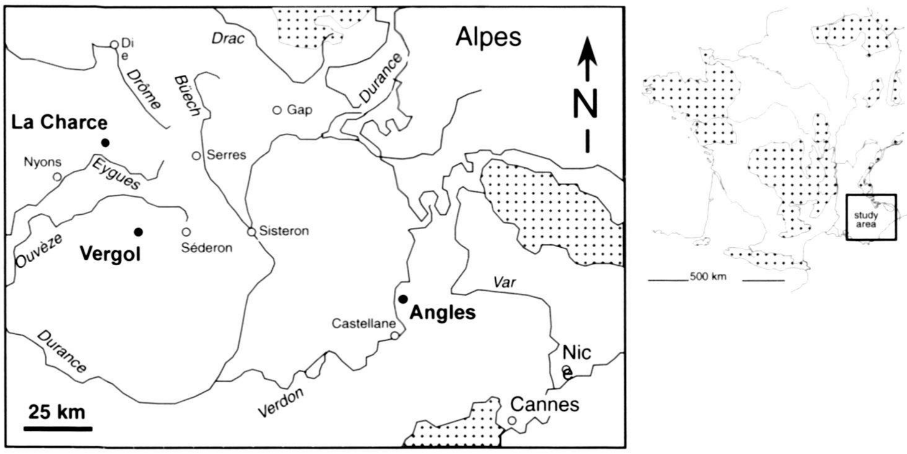

Fig. 1. Location map of the main sections.

propose a modified zonal scheme in order to correlate more precisely ammonite evolution with biostratigraphic subdivisions. These proposals have been recently introduced during the APF-SGF meeting (Reboulet & Atrops 1997a: 35) and the second French Symposium on Stratigraphy (Reboulet & Atrops 1998:132).

Our biostratigraphic study is based on more than 23600 ammonites collected from nine continuous pelagic sections of the Vocontian basin, located in the subalpine chains of southeast France (Reboulet 1996). Only three sections are presented here (Fig. 1): Angles (Fig. 2) (Alpes de Haute-Provence), La Charce (Fig. 3) and Vergol (Fig. 4) (Drôme) because they show the most complete paleontological record of ammonites. Detailed lithologic columns are given as well as a brief description of the lithology.

Lithology and facies

The successions consist of a monotonous repetition of decimetric to metric binary cycles with beige calcareous beds and dark grey marly interbeds. The sections are typical of the Vocontian facies. The cyclic sedimentation in Cretaceous sequences of the Vocontian basin has been well-studied by a research team at the University of Lyon which has executed a pluridisciplinary approach of stratinomy, mineralogy, organic and inorganic geochemistry and micropaleontology (Cotillon et al. 1979, 1980; Darmedru 1982, 1984; Darmedru et al. 1982; Cotillon & Rio 1984; Tribovillard 1988; Ferry 1991; Giraud 1995). More recently, we have examined the ammonite assemblages in a rhythmic sedimentation pattern. A quantitative analysis has shown a strong faunal contrast between beds and interbeds (Reboulet 1996; Reboulet & Atrops 1995; 1997b).

The succession is dominated by limestones in the lowest part of the Valanginian (Otopeta and Pertransiens zones) and then gradually becomes more marly in the uppermost part of the Lower Valanginian (Campylotoxus zone). The Upper Valanginian is marl dominant in the Verrucosum zone and becomes gradually more calcareous towards the Valanginian-Hauterivian boundary. The Lower Hauterivian is characterized by a limestone dominated succession and a well alternating bed-interbed.

In the Valanginian, the cycles appear as composite bundles (parasequence sets) becoming more calcareous towards the top. Seven parasequence sets have been recognized in the studied interval (Reboulet 1996). Some groups of beds (Peregrinus bundle) correspond to key horizons, precisely correlatable over the whole Vocontian basin (Cotillon et al. 1980; Atrops & Reboulet 1993, 1995a; Reboulet 1996).

The successions of the Vergol, La Charce and Angles sections have been deposited in pelagic environments. In addition sedimentological data and several palaeoecological lines of evidence suggest bathyal deposition.

The ammonites represent almost the totality of the macrofauna. The assemblages consist of six families: *Neocomitidae*, *Olcostephanidae*, *Haploceratidae*, *Bochianitidae*, *Phylloceratidae*, and *Lytoceratidae*. But the ammonite spectra are often dominated by *Phylloceratidae*, *Haploceratidae* and *Lytoceratidae* (Reboulet 1996); their abundance characterizes deep palaeo-environments (Company 1987; Bulot 1993; Westermann, 1993). Other nektonic megafossils are represented by numerous belemnites and a nautiloid. A few benthic megafossils have been found such as bivalves and gastropods.

All sections are intensively bioturbated, with both limestone beds and marly interbeds affected. Many *Zoophycos* feeding burrows are often present in calcareous beds. Cretaceous *Zoophycos* facies indicate rather deep marine depositional paleoenvironments (Olivero 1996).

In conclusion, the uniformity of facies is advantageous for biostratigraphic analyses because the biostratigraphy is continuous and not disturbed by facies changes. Only slight slumpings disturb the succession (Reboulet 1996). They are located in the upper part of the Campylotoxus zone in the Vergol section and near the Valanginian-Hauterivian boundary in Angles and La Charce sections.

Ammonite zonation

All zones presented here are biozones. Ammonite chronozones are the counterparts of the biostratigraphic ammonite biozones. For example, the chronostratigraphic counterpart of the *Busnardoites campylotoxus* (UHLIG) zone is the Campylotoxus zone (species name not in italics and with an initial capital letter) (Callomon 1985).

The conversion of biozones into chronozones requires the selection and the designation of type-section; only chronozones can be used to define stages. However, for convenience both are called zones by ammonite paleontologists.

In the studied stratigraphic interval, ammonite zones are interval zones and they are defined by the interval between the first occurences of two successive ammonites-index (Hedberg 1979; Whittaker et al. 1991; Rey 1997). A bed does not define definitively the base of a biostratigraphic unit which can be modified according to the samplings. Subdivisions in biohorizons was preferred to subzones.

Each zone defined in this paper will be discussed as follows: author(s), index-species, status, ammonite association, subdivisions.

Valanginian stage.

The Otopeta zone and the Pertransiens zone are not discussed here because we have not studied this stratigraphical interval. We retain the Campylotoxus zone; the Stephanophorus and the Inostranzewi zones proposed by Bulot and Thieuloy (1996) for the upper part of the Lower Valanginian are not maintained.

The main modifications of the zonal scheme concern the Upper Valanginian. The subdivision of the Verrucosum zone is not notably modified except the suppression of the Neocomiensis horizon, previously proposed by Atrops and Reboulet (1993). As *Himantoceras trinodosum* THIEULOY is often rare in the Vocontian basin or even absent on the platform and *Teschenites callidiscus* (THIEULOY) has a very narrow range, it is more pratical to replace the former Trinodosum and Callidiscus zones by the Peregrinus and the Furcillata zones. The Callidiscus zone is retained only as a horizon of the Furcillata zone. These new proposals will be discussed for each zone.

The Campylotoxus zone

Author – Cotillon (1971) as horizon.

Index-species – *Busnardoites campylotoxus* (UHLIG).

Status – Busnardo & Thieuloy (1979) have placed the lower boundary of the Campylotoxus zone at the base of the bed 67 of the Barret-le-Bas section (Hautes-Alpes), which corresponds to the first occurrence of *B. campylotoxus*.

The total range of the index-species extends over almost all the zone (Fig. 3 and 4) (Reboulet 1996, Fig. 39, p. 256). *B. campylotoxus* has a very wide distribution in the Mediterranean region (Nikolov 1977; Reboulet 1996; Bulot & Thieuloy 1996).

Recently, Bulot and Thieuloy (1996) proposed a new denomination for the upper part of the Lower Valanginian, the Stephanophorus and Inostranzewi zones. We do not support this alternative because we consider that their arguments are not justified. Bulot and Thieuloy (1996) mention four successively appearing species of *Busnardoites*: *B. roberti* nom. nud. (Bulot 1995, unpublished), *B. subcampylotoxus* NIKOLOV, *B. campylotoxus* and *B. meganae* nom. nud. (Bulot 1995, unpublished). In this conception, the late appearance of *B. campylotoxus* does not justify abandoning the Campylotoxus zone only because the index-species would occur only in the upper part of this zone. The base of the Campylotoxus zone has been placed by Bulot and Thieuloy (1979) at the first appearance of *B. campylotoxus*, which corresponds in their conception to the Subcampylotoxus-Campylotoxus group.

It would be necessary to make a revision of the genus *Busnardoites* in order to know the precise range and distribution of species in the Mediterranean region. Indeed, if for Nikolov (1977) *B. subcampylotoxus* starts earlier than *B. campylotoxus*, Company (1987) recorded *B. subcampylotoxus* at the top of his Salinarium zone, just before the appearance of *Saynoceras verrucosum* (D'ORBIGNY).

Moreover, the introduction of the new Inostranzewi zone by Bulot and Thieuloy (1996) is mainly based on paleontological and biostratigraphical data of Bulot's thesis which is unpublished. So it is impossible to know their paleontological conception of these species.

Ammonite association – The lower part of the Campylotoxus zone corresponds to a significant faunal turnover mainly affecting the Neocomitids (*Busnardoites*, *Karakaschiceras* and *Neohoploceras*) and the Olcostephanids (*Baronnites*, *Valanginites*, *Saynoceras*) (Reboulet 1996, Fig. 31, p. 229). Except for *Neocomites*, no new genera appear in the upper part of the Campylotoxus zone. This biostratigraphical unit is also characterized by the presence of the last typical lower Valanginian taxa such as *Kilianella* and many species of *Sarasinella*, *Neolissoceras* and *Lytoceras*.

Subdivisions – The Campylotoxus zone includes the Quadristrangulatum, Fuhri, Biassalensis and Platycostatus horizons.

According to Klein (1997), it is not opportune at present to use these horizons in all the Mediterranean area because of the limited information available on their distribution.

– The Quadristrangulatum horizon begins with the appearance of *B. campylotoxus* associated with *Karakaschiceras quadristrangulatum* (SAYN) (Atrops & Reboulet 1995a). The systematic and stratigraphic range of this primitive species of *Karakaschiceras* has been well-detailed by Kutek et al. (1987) and Reboulet (1996). The index-species is the first species of

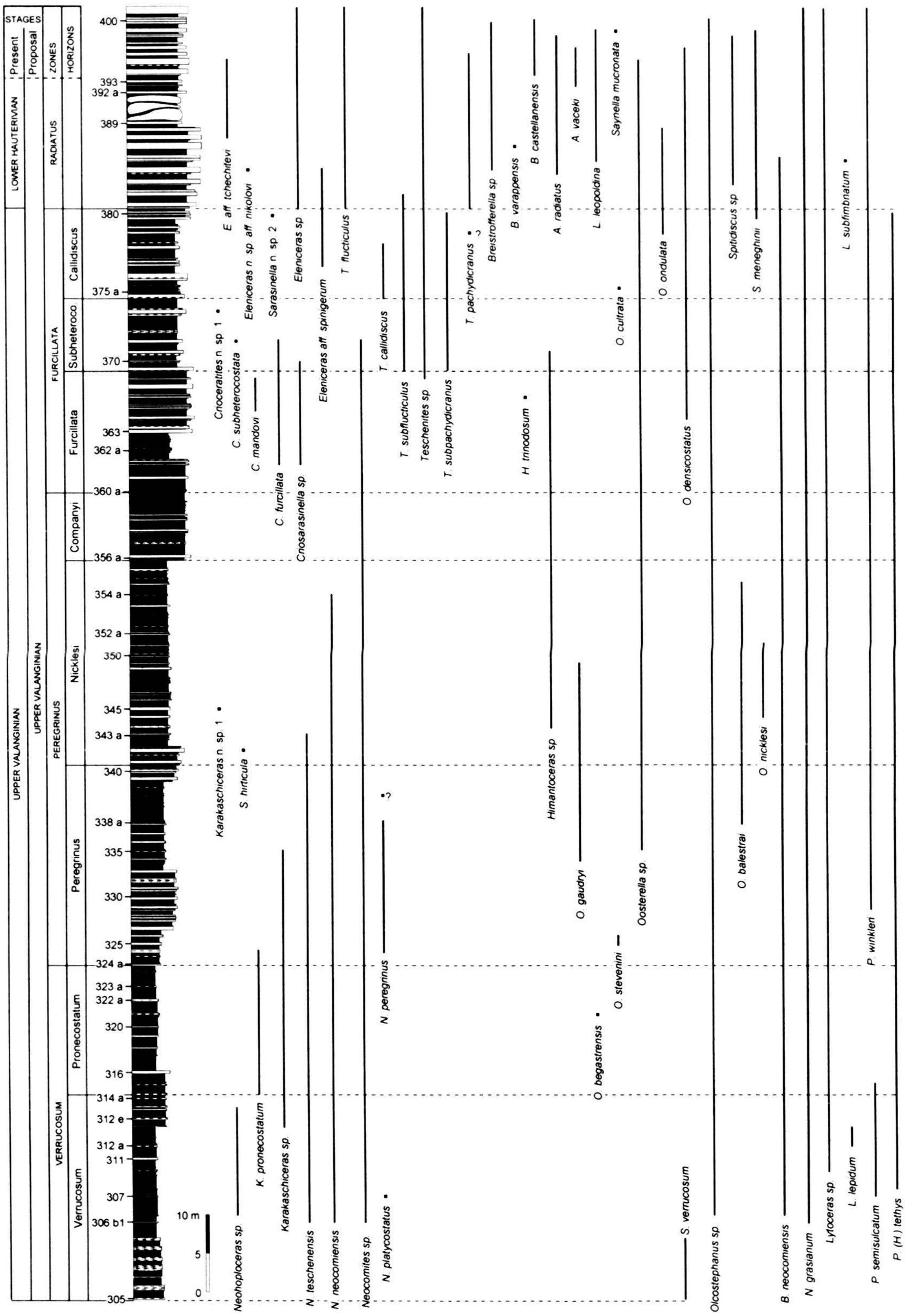

Fig. 2. Range of the ammonites and zonation in the Angles section (Alpes de Haute-Provence).

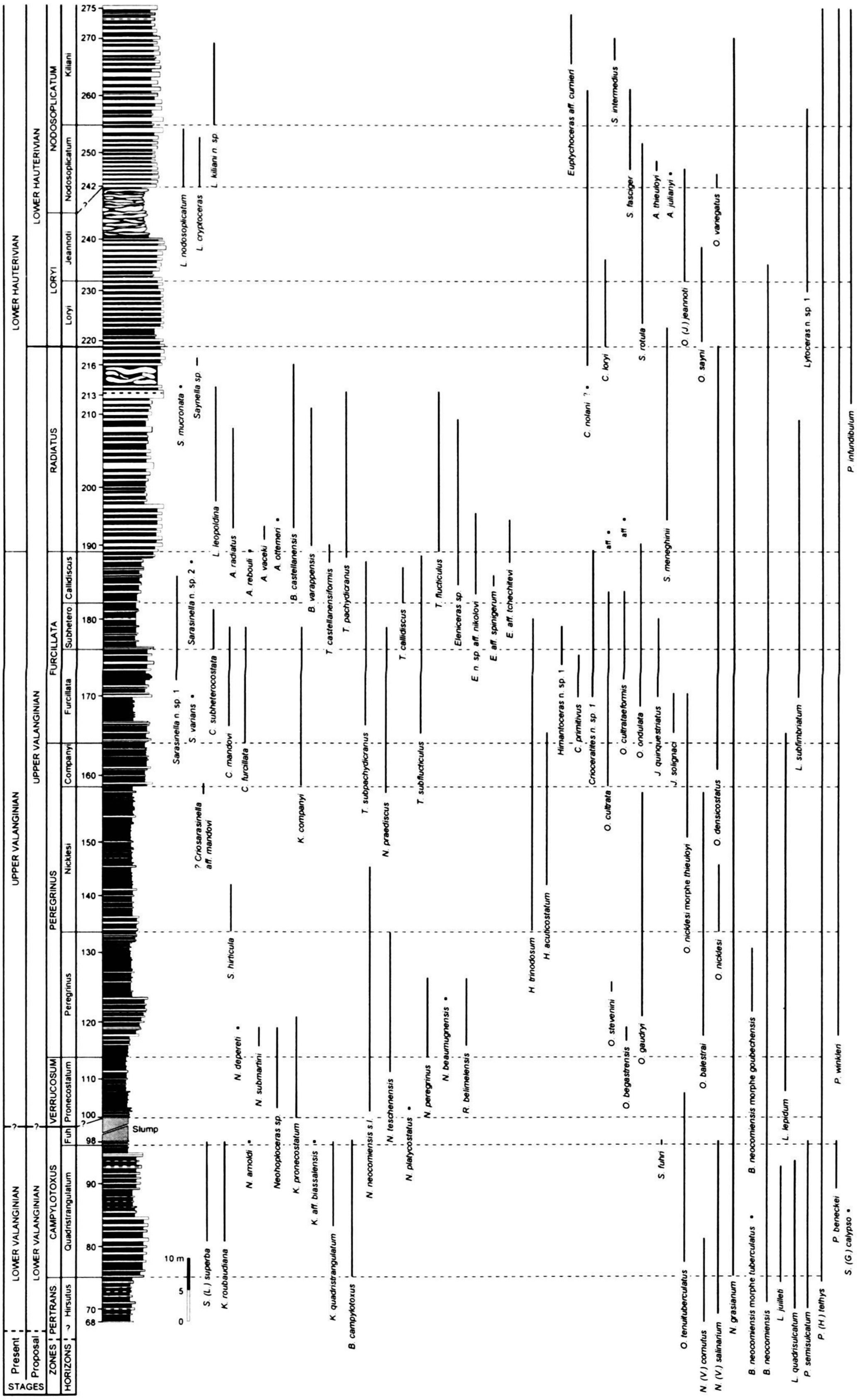

Fig. 3. Range of the ammonites and zonation in the La Charce section (Drôme).

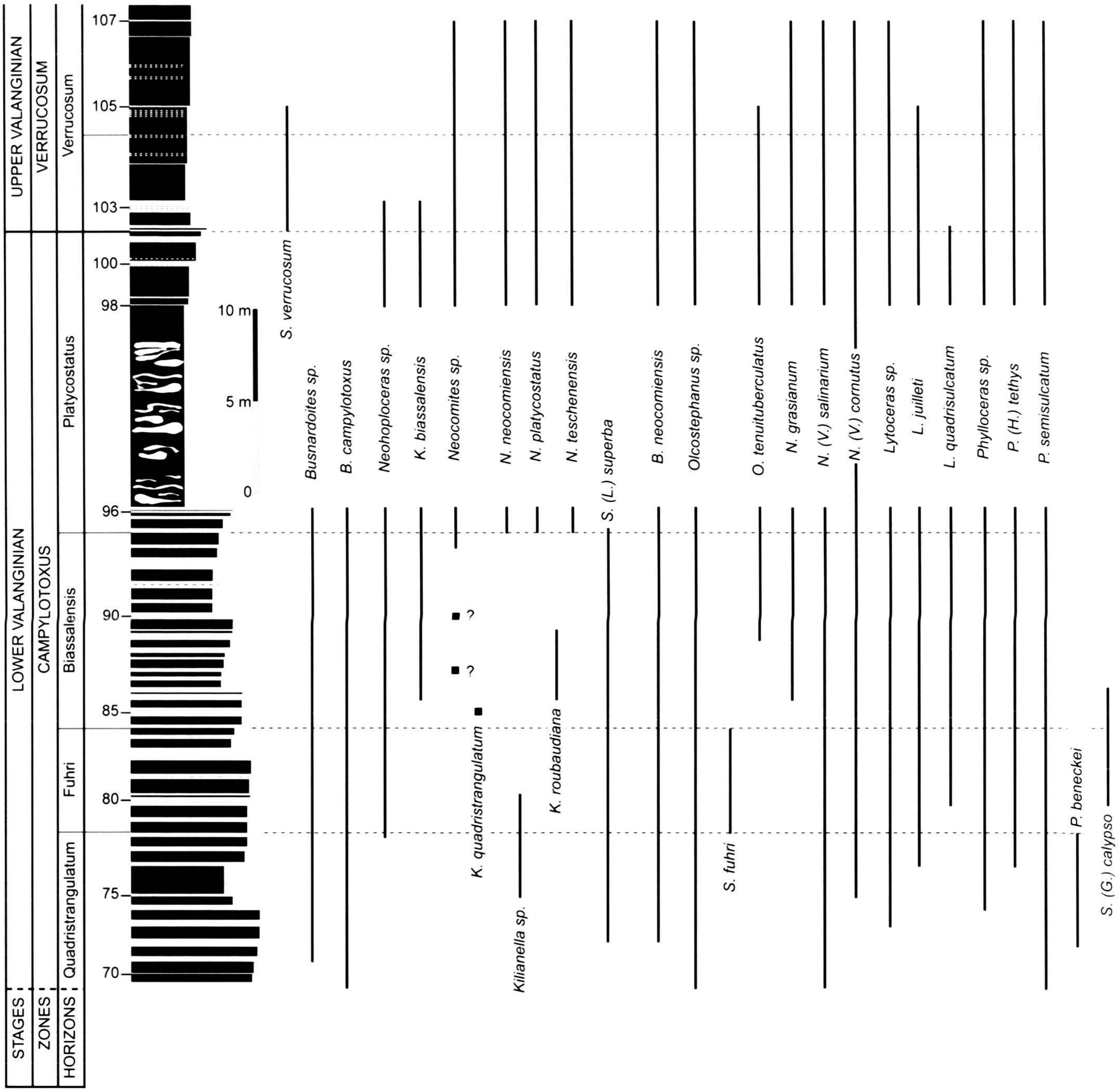

Fig. 4. Range of the ammonites and zonation in the Vergol section (Drôme).

the genus *Karakaschiceras* in south-east France and it is very different from *Karakaschiceras biassalensis* (KARAKASCH) and *Karakaschiceras pronecostatum* (FELIX). We can also find *Kilianella roubaudiana* (D'ORBIGNY), *Sarasinella (Luppovella) superba* (SAYN), *Neolissoceras (Vergoliceras) salinarium* (UHLIG) (Atrops & Reboulet 1996), *N. (V.) cornutus* ATROPS & REBOULET 1995b (= *Haploceras (Neolissoceras) extracornutum* CECCA 1995), *Ptychophylloceras semisulcatum* (D'ORBIGNY), *Phyllopachyceras* aff. *benecke* (ZITTEL), *Lytoceras quadrisulcatum* (D'ORBIGNY) and *Lytoceras juilleti* (D'ORBIGNY). The base of this horizon is characterized by the last *Baronnites hirsutus* (FALLOT & TERMIER). The top of this horizon is placed below the firs occurrence of *Saynoceras fuhri* BULOT, COMPANY & THIEULOY. The type-section has been chosen at La Charce levels 76 to 96 (Fig. 3) (Atrops & Reboulet 1995a).

– The Fuhri horizon is defined in the Vergol type-section, levels 79–83 (Fig. 4) (Atrops & Reboulet 1995a). This horizon corresponds to the range of the index-species which is associated with the species previously named in the quadristrangulatum horizon. *S. fuhri* is well defined and easily identifiable. In the reference section and in La Charce, the nominative species is relatively abundant (Reboulet 1996). *S. fuhri* has been found in the *Karakaschiceras* beds of the Provençal platform (Cotillon collection FSL 63678, *in* Bulot et al. 1990).

If we take into account table 3 of Bulot and Thieuloy (1996: 35), the base of Fuhri horizon corresponds to the base of the Inostranzewi zone.

– The Biassalensis horizon proposed by Cotillon (1971) has been well characterized by Atrops and Reboulet (1995ab). Its base is defined by the disapppearence of *S. fuhri* and its top by the first occurrence of *Neocomites platycostatus* SAYN. This stratigraphic interval is marked by a maximum abundance of *K. biassalensis*, associated with the youngest *B. campylotoxus*. The Biassalensis horizon is restricted to levels 84–94 of the Vergol type-section (Fig. 4).

– The Platycostatus horizon begins with the first appearance of *N. platycostatus*, which is associated with the first *Neocomites neocomiensis* (D'ORBIGNY) and *Neocomites teschenensis* (UHLIG) and, only at the base, with the last *B. campylotoxus* (Atrops & Reboulet 1995b). This biostratigraphical interval corresponds to levels 95–101 of the Vergol type-section (Fig. 4).

The Verrucosum zone

Author – Lory (1898).

Index-species – *Saynoceras verrucosum* (d'ORBIGNY).

Status – The base of the Verrucosum zone is defined by the first occurrence of *S. verrucosum*. The total range of index-species is restricted to the lowest part of this zone; levels 305 to 306a5 of the Angles type-section (Fig. 2) (Atrops & Reboulet 1993; Bulot et al. 1993).

Ammonite association – The Verrucosum zone corresponds to a low diversity faunal assemblage. Indeed, most of the typical Lower Valanginian taxa have disappeared before the Lower-Upper Valanginian boundary. This zone is mainly characterized by *N. neocomiensis* which is very abundant (Reboulet 1996, Fig. 31, p. 229).

Subdivisions – The Verrucosum zone is here subdivided into only two horizons: the Verrucosum horizon and the Pronecostatum horizon.

In agreement with Bulot et al. (1996) and Klein (1997), the Neocomiensis horizon (Atrops & Reboulet 1993) is abandoned. This horizon was defined as the stratigraphical interval between the last occurrence of *S. verrucosum* and the first appearence of *K. pronecostatum*. The Neocomiensis horizon was mainly marked by numerous pyritic ammonites and specially *N. neocomiensis* but it was not accompanied by other characteristic species (Reboulet 1996). Moreover, the range of *N. neocomiensis* is not limited to this biostratigraphic interval but it ranges from the top of Campylotoxus zone to the top of the Peregrinus zone.

– The Verrucosum horizon (Busnardo & Thieuloy 1979) begins with the first appearance of the index-species, *S. verrucosum*. The sections of Angles and Saint-Firmin (Alpes de Haute-Provence) have been chosen by Bulot et al. (1993) as type-sections. *S. verrucosum* is restricted to only 6 beds on the Angles section; levels 305 to 306a5 (Fig. 2) (Atrops & Reboulet 1993).

We can also find numerous *N. neocomiensis*, *N. platycostatus*, a few *N. teschenensis* and the last *N. (V.) salinarium*, *N. (V.) cornutus* and *L. juilleti* (Fig. 2 and 3). This stratigraphical interval is very rich in pyritic ammonites.

The index-species is very abundant in the Vocontian succession (Reboulet 1996), and is also well represented in the Provençal platform (Masse et al. 1975; Bulot et al. 1990; Thieuloy et al. 1990).

– The Pronecostatum horizon (Reboulet et al. 1992): This horizon appears for the first time in figures 1–3 and 1–4 (p. 30 and 33) of the guide book of the symposium "Platform Margins" (9–12 May 1992) (Bulot et al. 1992). No definition is given here nor in the report of the second workshop (Mula, 2–5 July 1992) on Lower Cretaceous (Hoedemaeker & Company 1993). These authors note that "Bulot and Thieuloy still need further study before they will introduce these horizons formally" (p. 119).

The first, we have clearly defined this horizon in Geobios (Reboulet et al. 1992, 25, 4, with paleontological priority of 31 October 1992, manuscript received 12 Febuary 1992).

The Pronecostatum horizon begins with the first appearance of the index-species, which is associated with *N. neocomiensis* and a few *N. teschenensis* (Fig. 2). The Pronecostatum horizon corresponds to the levels 100–113 of the La Charce type-section (Fig. 3).

The Peregrinus zone.

Authors – Reboulet et al. (1992) as horizon (for the date of publication and priority see discussion of Pronecostatum horizon because they were defined in the same publication).

Index-species – *Neocomites peregrinus* (RAWSON & KEMPER).

Status – The base of the Peregrinus zone is defined by the first occurrence of *N. peregrinus*. We have chosen the La Charce section as type-section; the lower boundary of this zone has been placed at the base of the bed 114 (Fig. 3).

The distribution and the frequency of *N. peregrinus* are in favor of this species as marker of the zone. First described from north Germany (Rawson & Kemper 1978), *N. peregrinus* was found in south-eastern France (Thieuloy et al. 1990; Reboulet et al. 1992; Reboulet 1996) and Spain (Klein 1997). According to Bulot and Thieuloy (1996), the specimen *Eleniceras* cf. *stevrecensis* BRESKOVSKI reported by Mandov (1976) in Bulgaria is probably a *N. peregrinus*. So, the Peregrinus zone is expected to be recognized all over the Mediterranean and has potential for Boreal-Tethys stratigraphic correlation. Moreover, the index-species is easily determinable when it is complete.

It is more practical to replace the former Trinodosum zone by the Peregrinus zone at its base because *Himantoceras trinodosum* THIEULOY is often rare in the Vocontian basin or even absent on the platform. Moreover, the appearance of *H. trinodosum* does not correspond to a faunal turnover.

Ammonite association – The lower part of the Peregrinus zone corresponds to a minor faunal turnover mainly characterized by the presence of new neocomitids and the development of *Oosterella* (Reboulet 1996, Fig. 31, p. 229).

The upper part of the Peregrinus zone is marked only by a few species, not very abundant, such as *H. trinodosum*, *Olcostephanus nicklesi* WIEDMANN & DIENI, *Karakaschiceras* n. sp. 1 (*sensu* Reboulet 1996), *Karakaschiceras companyi* REBOULET and *Neocomites praediscus* REBOULET (Reboulet 1996).

Subdivisions – Within this zone, three horizons could be distinguished: the Peregrinus, Nicklesi and Companyi horizons.

– The Peregrinus horizon (Reboulet et al. 1992): for priority see discussion of Pronecostatum horizon because they have been defined in the same publication. The Peregrinus horizon begins with the appearance of the index-species, *N peregrinus*, which is very abundant in the Vocontian succession (Reboulet 1996, Fig. 22, p. 216). *N. peregrinus* is associated with *N. neocomiensis*, *N. teschenensis* and new neocomitids such as *Neocomites beaumugnensis* SAYN and *Rodighieroites belimelensis* (MANDOV) (Fig. 2 & 3). This horizon is also well characterized by the development of *Oosterella (O. begastrensis* COMPANY, *O. stevenini* NICKLES, *O. gaudryi* NICKLES *sensu* Reboulet 1996) and the appearance of *Phyllopachyceras winkleri* (UHLIG) and *Olcostephanus balestrai* (RODIGHGIERO). We can also find *Bochianites neocomiensis* (D'ORBIGNY) morphotype *goubechensis* MANDOV and the last *Neohoploceras* and *P. semisulcatum*. *K. pronecostatum* disappears at the base of the Peregrinus horizon, implying a slight overlap of both species (Reboulet 1996). The Peregrinus horizon corresponds to levels 114–133 of the La Charce type-section (Fig. 3).

The Peregrinus horizon has been recognized in the Provençal platform (Bulot et al. 1993) and in the Vocontian basin (Reboulet et al. 1992; Reboulet 1996; Bulot & Thieuloy 1996).

– The Nicklesi horizon (Thieuloy et al. 1990) is defined at the first appearance of *O. nicklesi* which is associated with the first *Himantoceras. O. nicklesi* is limited to the base of this horizon (Fig. 2 and 3). In this stratigraphical interval, the abundance and the diversity of the ammonite fauna are very low because numerous species of neocomitids have desappeared (Reboulet 1996, Fig. 33, p. 232). However, we can also find *O. balestrai* and a few *Sarasinella hirticula* THIEULOY & BULOT and *Karakaschiceras* n. sp. 1. This biostratigraphical interval corresponds to levels 134–158 of the La Charce section (Fig. 3), chosen by Bulot et al. (1993) as type-section.

– The Companyi horizon (Reboulet 1996) begins with the first occurrence of the index-species, *K. companyi*. Even if the diversity of this stratigraphical interval is very low, it can be characterized by some species such as *H. trinodosum*, *N. praediscus*, *Oosterella cultrata* (D'ORBIGNY) and *Olcostephanus nicklesi thieuloyi* AUTRAN. La Charce has been chosen as type-section, levels 159 to 163 (Fig. 3).

Unfortunately, the nominative species is not yet reported from other areas outside south-east France, limiting the potential of the horizon for biostratigrahic correlations in the Mediterranean region.

The Furcillata zone

Authors – Busnardo & Thieuloy, 1979 as subzone.

Index-species – *Criosarasinella furcillata* THIEULOY.

Status – The Furcillata zone is defined by the first occurrence of *C. furcillata* which appears in level 164 of the La Charce type-section (Fig. 3).

C. furcillata is well represented in the Vocontian basin (Thieuloy 1977; Bulot et al. 1993; Reboulet 1996) and it has been found on the Provençal platform (Thieuloy et al. 1990; Autran 1993). This species has a wide distribution in all Mediterranean areas (Thieuloy et al. 1990; Bulot et al. 1993; Bulot & Thieuloy 1996). So, its potential for correlation is very important, as recognized since the first workshop of the Lower Cretaceous Cephalopod team (Hoedemaeker & Bulot 1990).

It is more practical to replace the former Callidiscus zone by the Furcillata zone because *Teschenites callidiscus* THIEULOY is very scarce on the platform area. Moreover, the appearance of *T. callidiscus* does not correspond to a faunal turnover.

Ammonite association - The lower part of the Furcillata zone corresponds to a major faunal turnover affecting mainly the Neocomitids (*Teschenites*, *Criosarasinella* and *Eleniceras*) (Reboulet 1996, Fig. 31, p. 229). This zone is also characterized by the presence of the last *Karakaschiceras* and *Sarasinella*.

Subdivisions – Three horizons can be distinguished: the Furcillata horizon, the Subheterocostata horizon and the Callidiscus horizon.

– The Furcillata horizon (Busnardo & Thieuloy 1979) is defined by the first occurrence of *C. furcillata*. The index-species is associated with *Criosarasinella mandovi* THIEULOY, *N. praediscus* and *O. cultrata* (Fig. 2 and 3). We can also find a few *Teschenites subflucticulus* REBOULET, *K. companyi* and

Jeanthieuloyites. The upper part of this stratigraphical interval is marked by the first *Oosterella cultrataeformis* (UHLIG), *Oosterella ondulata* REBOULET and *Himantoceras* n. sp. 1 *sensu* Reboulet 1996.

The total range of *C. furcillata* is restricted to levels 164 to 179 of the La Charce section (Fig. 3). The biostratigraphic interval corresponds to levels 164 to 175 of the La Charce type-section which has been chosen by Bulot et al. (1993). The index-species is very abundant in the Vocontian succession (Reboulet 1996, Fig. 22, p. 216).

This horizon has been also recognized at Terre Masse (Entrages, Alpes de Haute-Provence) (Thieuloy et al. 1990), within condensed horizons of the Arc de Castellane (Autran 1993) and on the Carajuan section (Alpes de Haute-Provence) (Atrops & Reboulet 1995a).

– The Subheterocostata horizon (Reboulet 1996) is defined by the first occurrence of *Criosarasinella subheterocostata* REBOULET. It seems that the horizon corresponds to the total range of the index-species; levels 176 to 181 in the La Charce type-section (Fig. 3).

The Subheterocostata horizon is characterized by *T. subflucticulus*, *Teschenites subpachydicranus* REBOULET, *O. cultrata*, *O. cultrataeformis*, *O. ondulata* and a few *Jeanthieuloyites quinquestriatus* (BESAIRIE) (Fig. 2 and 3). Also found in the lower part of this horizon are the last *C. furcillata*, *C. mandovi*, *N. praediscus*, *K. companyi* and *Himantoceras* n. sp. 1 (Reboulet 1996).

This biostratigraphical unit has been recognized in many sections of the Vocontian basin such as Angles, Chateauvieux (Hautes-Alpes) and Les Sias (Drôme) (Reboulet 1996). *C. subheterocostata* has been also found on the Provençal platform (Carajuan section, Alpes de Haute-Provence) (Atrops & Reboulet 1995a).

– The Callidiscus horizon (Busnardo & Thieuloy 1979) does not correspond to the total range of the index-species as it was previously accepted (Bulot et al. 1993; Reboulet 1996), but we define it by the interval between the first appearance of *T. callidiscus* and the first occurrence of the genus *Acanthodiscus*. So, *T. callidiscus* disappears before the top of its zone.

The La Charce section has been chosen by Bulot et al. (1993) as type-section. This horizon covers the stratigraphical interval between levels 182 to 188 (Fig. 3).

The index-species is associated with very rare *T. subflucticulus and T. subpachydicranus*. We can also find *O. cultrata*, *O. cultrataeformis* and *O. ondulata* and very rare *Olcostephanus densicostatus* (WEGNER) and *Eleniceras*.

The lithological correlations bed by bed between many sections of the Vocontian basin show that the range of *T. callidiscus* is restricted to only 5 beds and that this first occurrence is synchronous (Fig. 2 and 3) (Reboulet 1996).

This species is always abundant in the pelagic sections of the Vocontian basin (Reboulet 1996) but it is very scarce on the platform area. *T. callidiscus* has been found only in the condensed horizons of a few sections of the Arc de Castellane (Autran 1993). So, this species is not very suitable for correlation in south-east France. For this reason, we follow the proposition of Hoedemaeker & Company (1993) to use the Callidiscus biostratigraphical unit only as horizon.

Hauterivian stage

The Hauterivian stage begins with the Radiatus zone. In the Nodosoplicatum zone *sensu* Bulot et al. (1993), the Kiliani horizon (new) takes the place of the Bargemensis horizon *sensu* Reboulet (1996).

The Radiatus zone

Author – Paquier (1900).

Index-species – *Acanthodiscus radiatus* (BRUGUIERE).

Status – It is traditionally accepted that the Radiatus zone begins with the first *A. radiatus* (Birkelund et al. 1984), which appears at level 193 of the La Charce type-section (Fig. 3) (Thieuloy 1977; Bulot et al. 1993). One of us suggested that the base of the Radiatus zone should be defined by the first occurrence of the ammonite genus *Acanthodiscus* (Reboulet 1996: 263) (see detailed discussion of the Valanginian-Hauterivian boundary below and Klein 1997). This proposition has also been recommended by the Working Group of the Second International Symposium on Cretaceous Stage Boundaries at Brussels (Mutterlose 1996). The lower boundary of the Radiatus zone is then placed at level 189 of the La Charce type-section (Fig. 3) (Reboulet 1996, Fig. 22, p. 216).

Ammonite association – The index-species is mainly associated with numerous *Teschenites flucticulus* THIEULOY (Reboulet 1996, Fig. 22, p. 216). We find *Teschenites pachydicranus* THIEULOY, abundant in the lower part of the zone, associated with *Eleniceras*. *Phyllopachyceras infundibulum* (D'ORBIGNY) appears at the top of this unit (Fig. 2 and 3). The Radiatus zone is also characterized by the appearance of the genera *Breistrofferella*, *Leopoldia* and *Spitidiscus (Spitidiscus meneghini* ZIGNO *in* RODIGHIERO) (Reboulet 1996, Fig. 39, p. 256).

Subdivisions – The subdivision of the Radiatus zone into the *Breistrofferella castellanensis* (D'ORBIGNY) and *Leopoldia buxtorfi* BAUMBERGER horizons, proposed by Bulot et al. (1993), is unsuitable because the latter species is only well represented in condensed sections of the platform (Jura – Arc de Castellane) and it is absent in deep-water facies.

The Loryi zone

Authors – Moullade and Thieuloy (1967).

Index-species – *Crioceratites loryi* (SARKAR).

Status – The Loryi zone, introduced by Moullade and Thieuloy (1967), is defined by the first occurrence of the index-species, *C. loryi* (Bulot et al. 1993). The Loryi zone begins at level 219 of the La Charce section (Fig. 3) which has been chosen as type-section.

Ammonite association – This biostratigraphical interval is characterized by a low diversity ammonite fauna because most of typical upper valanginian neocomitids have desappeared before the top of the Radiatus zone (Fig.3). Only a few *Saynella* mark the lower part of the Loryi zone. We can also find numerous *Olcostephanus* and *Spitidiscus*. This stratigraphic interval is mainly marked by the abundance of *Crioceratites*.

Subdivisions – Within this zone, two horizons could be distinguished: the Loryi horizon at the base and the Jeannoti horizon at the top.

– The Loryi horizon was introduced by Hoedemaeker and Bulot (1990) and defined by (Bulot et al. 1992). This biostratigraphic unit begins with the appearance of *C. loryi*, level 219 of the La Charce type-section (Fig. 3).

The index-species is very abundant in the Vocontian basin (Reboulet 1996, Fig. 23, p. 218) but less abundant in the shallow-water facies (Busnardo & Thieuloy 1989; Autran 1993; Bulot et al. 1993: 41). This is a disadvantage for correlation between the two areas. The base of this horizon is characterized by the disappearance of *S. meneghini*, *O. densicostatus* and *Oosterella* genus (see *Oosterella* sp. *in* Reboulet 1996 Fig. 23, p. 218).

– The Jeannoti horizon has been defined by Bulot et al. (1993). This horizon begins with the first occurence of *Olcostephanus (Jeannoticeras) jeannoti* (D'ORBIGNY), level 232 of the La Charce section (Fig. 3). The La Charce and Salérans (Drôme) sections has been chosen by Bulot et al. (1993) as type-sections. This biostratigraphical unit is marked by the disappearance of *C. loryi*, *Olcostephanus sayni* (KILIAN) and *B. neocomiensis*. The index-species is well represented in deep-water facies and on the Provençal platform (Autran 1993) but it has not been found on the Jura platform (Busnardo & Thieuloy 1989).

The Nodosoplicatum zone.

Authors – Moullade and Thieuloy (1967).

Index-species – *Lyticoceras nodosoplicatum* (KILIAN & REBOUL).

Status – The Nodosoplicatum zone is defined by the first occurrence of *L. nodosoplicatum* and ends with the first appearance of *Subsaynella sayni* (PAQUIER), index-species of the first zone of the Upper Hauterivian. Bulot et al. (1993) have placed the base of the Nodosoplicatum zone at level 85 of the Salérans type-section (Drôme).

Ammonite association – This biostratigraphical interval is characterized by quite a low diversity of ammonite (Reboulet 1996, Fig. 23, p. 218), particularly in the upper part of the zone (Bulot et al. 1993). It is characterized by the presence of *Abrytusites* and *Olcostephanus variegatus* (PAQUIER) (Fig. 3).

Subdivisions – Two horizons have been distinguished: the Nodosplicatum horizon and the Kiliani horizon (new) (= Bargemensis horizon *sensu* Reboulet (1996)).

– The Nodosoplicatum horizon was introduced by Hoedemaeker and Bulot (1990), without definition, as subzone. It was later replaced by the Variegatus horizon (Bulot et al. 1993). These authors chose *O. variegatus* because this index-species has a wide distribution (France, Tanzania, Peru, Colombia, Mexico and Great Britain) while *L. nodosoplicatum* is known only from France (Reboulet 1996; Bulot et al. 1996) and Spain (Klein 1997). However, it is not necessary to introduce a new Variegatus horizon for the same interval characterized by the association of *O. variegatus* and *L. nodosoplicatum*. Moreover, if both species appear in the same bed in the type-section at Salérans (Bulot et al. 1993), *O. variegatus* seems to appear earlier than *L. nodosoplicatum* in the La Charce section (Bulot et al. 1993). So, the base of the Variegatus horizon does not correspond to the appearance of *L. nodosoplicatum*.

The Nodosoplicatum horizon begins with the appearance of the index-species, level 85 of the Salérans section (Bulot et al. 1993). *L. nodosoplicatum* is associated with *Lyticoceras cryptoceras* (D'ORBIGNY), *Spitidiscus rotula* (SOWERBY), *Spitidiscus fasciger* THIEULOY, *Abrytusites thieuloyi* VASICEK & MICHALIK and *Abrytusites julyani* (HONNORAT-BASTIDE) (Fig. 3). In the lower part of this biostratigraphical unit, we can also find the last *O. variegatus* et *O. (J.) jeannoti*. This association is very characteristic even when the index-species is absent.

– The Kiliani horizon (new) = the Bargemensis horizon *sensu* Reboulet 1996.

The name of "*Hoplites (Leopoldia)" bargemensis* KILIAN, 1910 and therefore the Bargemensis horizon (Reboulet 1996) must be abandoned because this species is an objective synonym of *Breistrofferella varappensis* (BAUMBERGER, 1906) which has the same type (holotype) (*Ammonites castellanensis* D'ORBIGNY *in* de Loriol, 1861, Pl. 2, Fig. 1–2). Kilian & Reboul (1915) described and figured (Pl. 11, Fig. 1–2) many specimens from the Provençal platform which they named *Leopoldia dubisiensis* BAUMBERGER, 1906 variety *bargemensis* KILIAN. These specimens were misinterpreted by Kilian & Reboul. They belong neither to "*Acanthodiscus (Hoplites)*" *dubisiensis* BAUMBERGER (= *Neohoploceras schardti* BAUMBERGER) nor to the *Breistrofferella varappensis (=bargemensis)* group but to the genus *Lyticoceras*, whose stratigraphic position is quite different. So we propose to create a new species for these forms which are characteristic of the upper part of the Nodosoplicatum zone. The one of Pl. 11, Fig. 1 in Kilian & Reboul (1915) corresponds exactly to our new species.

Fig. 5. *Lyticoceras kiliani* n. sp., holotype, FSL 489850, collection Reboulet, level 263 of the La Charce section, Drôme (Fig. 3). Lower Hauterivian, Nodosoplicatum zone, Kiliani horizon.

1915 *Leopoldia dubisiensis* var. *bargemensis* KILIAN, Kilian and Reboul, p. 244, Pl. 11, Fig. 1.

1996 *Lyticoceras bargemensis* (KILIAN), Reboulet, p. 135, Pl. 15, Fig. 2, 4; Pl. 16, Fig. 2.

- *holotypus*: FSL 489850 (collection Reboulet), Pl. 15, Fig. 2 *in* Reboulet (1996), level 263 of the La Charce section (Fig. 3);
- *locus typicus*: Serre de l'âne, La Charce, Drôme, France;
- *stratum typicum*: Lower Hauterivian, Nodosoplicatum zone;
- *derivatio nominis*: species dedicated to Kilian;
- *paratypus*: FSL 489851 (collection Reboulet), Pl. 15, Fig. 4 and FSL 489849 (collection Reboulet), Pl. 16, Fig. 2 *in* Reboulet (1996); Pl. 11, Fig. 1 *in* Kilian & Reboul (1915).

The description of this new species is given in Reboulet (1996: 136–137).

The range is given in Fig. 3 (see also Fig. 23, p. 218 *in* Reboulet, 1996).

L. kiliani is very different from *Lyticoceras collignoni* BULOT (= *L. cryptoceras* non D'ORBIGNY *in* Kemper et al. 1981, Pl. 42, Fig. 1–2) in its thicker primary ribs which are slightly retrocostate.

The Kiliani horizon (new) is defined as the interval between the first occurrence of *L. kiliani* n. sp. and the first appearance of *S. sayni*. The index-species is associated, in the lower part of its range, with the last *S. fasciger* and in its upper part with the first *Spitidiscus intermedius* (D'ORBIGNY) and *Euptychoceras* aff. *curnieri* THIEULOY (Fig. 3). The Kiliani horizon (new) begins with level 255 of the La Charce type-section.

Chronostratigraphic subdivisions (table 1).

The Berriasian-Valanginian boundary.

The Berriasian-Valanginian boundary has been the subject of many discussions over the last 20 years, since Busnardo & Thieuloy (1979). Four different boundaries have been proposed so far: the base of the Pertransiens subzone *sensu* Le Hégarat (1973); the base of the Otopeta zone *sensu* Busnardo and Thieuloy (1979); the base of the Alpillensis subzone *sensu* Hoedemaeker (1982); the base of the Pertransiens zone *sensu* Bulot (1995).

For the sake of stability, the successive Cephalopod Working Groups (Hoedemaeker & Bulot 1990; Hoedemaeker &

Authors:		3 rd Workshop (Piobbico), 1995			Reboulet, 1996		Bulot and Thieuloy, 1996		Ammonite-zonation proposed	
STAGES		ZONES	SUBZONES	HORIZONS	ZONES	HORIZONS	ZONES	HORIZONS	ZONES	HORIZONS
HAUTERIVIAN	UPPER *p.p.*	Sayni			Sayni	Unstudied	Sayni		Sayni	Unstudied
				Cruasense				Cruasense		
	LOWER	Nodosoplicatum			Nodosoplicatum	Bargemensis	Nodosoplicatum		Nodosoplicatum	kiliani (new)
						Nodosoplicatum		Variegatus		Nodosoplicatum
		Loryi		Jeannoti	Loryi	Jeannoti	Loryi	Jeannoti	Loryi	Jeannoti
				Loryi		Loryi		Loryi		Loryi
									Proposal	
		Radiatus			Radiatus		Radiatus	Buxtorfi	Radiatus	
								Castellanensis		
VALANGINIAN	UPPER	Pachydicranus			Callidiscus		Callidiscus		Furcillata	Callidiscus
				Callidiscus		Callidiscus		Callidiscus		
			Trinodosum	Furcillata	Trinodosum	Subheterocostata	Trinodosum	Furcillata		Subheterocostata
						Furcillata				Furcillata
				Nicklesi		Companyi		Nicklesi	Peregrinus	Companyi
						Nicklesi				Nicklesi
		Verrucosum			Verrucosum	Peregrinus	Verrucosum	Peregrinus		Peregrinus
						Pronecostatum		Pronecostatum	Verrucosum	Pronecostatum
						Neocomiensis		Verrucosum		Verrucosum
						Verrucosum				
	LOWER	Campylotoxus			Campylotoxus	Platycostatus	Inostranzewi		Campylotoxus	Platycostatus
						Biassalensis				Biassalensis
						Fuhri				Fuhri
						Quadristrangulatum	Stephanophorus	Campylotoxus		Quadristrangulatum
								Subcampylotoxus		
		Pertransiens			Pertransiens	Hirsutus		Hirsutus	Pertransiens	Hirsutus
						Unstudied	Pertransiens			Unstudied
		Otopeta			Otopeta		Boissieri *p.p.*	Otopeta	Otopeta	
BER. *p.p.*		Boissieri *p.p.*	Alpillensis		Boissieri *p.p.*			Alpillensis	Boissieri *p.p.*	

Table 1. Correlation of the Valanginian-Lower Hauterivian main zonal schemes and the new ammonite-zonation proposed for the south-east France.

Company 1993; Hoedemaeker & Cecca 1995) retained the base of Otopeta zone as the Berriasian-Valanginian boundary for the standard Mediterranean succession, following the solution recommended by the Cretaceous Subcommission at Copenhagen (Birkelund et al. 1984).

More recently, the Working Group of the Second International Symposium on Cretaceous Stage Boundaries at Brussels provisionally recommended that the boundary should be placed at "the base of Calpionellid Zone E, which corresponds almost exactly to the base of the ammonite zone of *Thurmanniceras pertransiens*" (Bulot et al. 1993, 1996; Blanc et al. 1994). The calpionnellids allow recognition of the boundary where ammonites are missing.

In the work of Bulot et al. (1993), the lack of ammonite paleontological review and detailed sections of the Upper Berriasian-Early Valanginian beds does not allow consideration of the turnover identified by these authors. Until there is revision of the whole ammonite fauna, we have decided to keep the Berriasian-Valanginian boundary at the base of the Otopeta zone.

The Lower-Upper Valanginian boundary

This boundary is much less contentious. Since Busnardo and Thieuloy (1979), placing the boundary at the base of the Verrucosum zone as proposed by Moullade (1966), has been widely accepted. Nevertheless, Hoedemaeker (1982) refuted this view because he considered that the faunal association of the Campylotoxus zone is characteristic of the Upper Valanginian.

More recently, Bulot and Thieuloy (1993) proposed a three-fold division of the Valanginian into Thurmanniceratien, Karakaschiceratien and Teschenitien. They placed the Lower-Upper Valanginian boundary at the base of the Inostranzewi zone (*sensu* Bulot 1995) which corresponds to the base of the *Karakaschiceratien* (Bulot & Thieuloy 1993).

For these authors, this three-fold division of the Valanginian reflects the evolution of the ammonite fauna. However, our analysis of the ammonite distribution based on more abundant material, shows a different evolution of the assemblages and different stratigraphic ranges of many taxa (Reboulet et al. 1992; Reboulet 1996). The lack of recent illustrations by Bulot and Thieuloy, does not allow us to consider if these differences are due to a different systematic interpretation.

The Lower-Upper Valanginian boundary is placed at the base of the Verrucosum zone as it is traditionaly recognized. This boundary corresponds to a major faunal caesura. In south-east France basin, at the top of the Campylotoxus zone and at the base of the Verrucosum zone, a large majority of the typically Lower Valanginian ammonite genera, subgenera and species disappears, such as *Busnardoites*, *Kilianella*, *Saynoceras*, *Valanginites*, *Sarasinella* (*Luppovella*), *Neolissoceras* (*Vergoliceras*), *Salfeldiella* (*Gyrophyllites*), *P. beneckei*, *L. juilleti* and *L. quadrisulcatum* (Reboulet 1996, Fig. 31, p. 229). Even if the genera *Karakaschiceras*, *Neohoploceras* and *Sarasinella* cross this extinction phase, they decline rapidely and are much less abundant in the Upper Valanginian. This event is distinct from the major faunal turnover which occurs in the lower part of the Campylotoxus zone and which is characterized by the appearance of *Busnardoites*, *Karakaschiceras*, *Neohoploceras*, *Baronnites* and *Saynoceras*. The genus *Neocomites* appears a little upper in the stratigraphic column, and it will be at the origin of the Upper Valanginian neocomitids.

The stratigraphic interval located on the both sides of the Lower-Upper Valanginian boundary corresponds to a high diversity of the ammonite fauna, because the diversity of such transitional association is the sum of the old and the new faunal elements. So, the Lower-Upper Valanginian boundary is well characterized and can be recognised over a wide geographic area. This solution is in accordance with the provisional recommendation of the Working Group of the Second International Symposium on Cretaceous Stage Boundaries (Bulot 1996).

We propose to choose the Vergol section as possible boundary stratotype of the Lower-Upper Valanginian placed at the base of the Verrucosum zone (Fig. 4) because this outcrop is richer in ammonites than the Angles section previously proposed by Bulot and Thieuloy (1996). The Lower-Upper Valanginian boundary is placed at the base of bed 102. The Vergol section has been investigated in detail and all beds are rich in ammonites (Reboulet 1996). Moreover, this locality is not so far from the Muntbrun-les-Bains section (Drôme) which has been proposed for the Berriasian-Valanginian boundary (Blanc et al. 1994). Only minor slumping, located a little below the boundary, disturbs the stratigraphic succession. However, the complete succession can be followed at the Morenas section (Drôme), located near the Vergol section. Unfortunately, this section is not very rich in ammonites and the Lower Valanginian is represented only by the uppermost part of the Campylotoxus zone.

The Valanginian-Hauterivian boundary

In the Tethys, the base of the Hauterivian is traditionally defined by the first appearance of *A. radiatus* (see Thieuloy 1977) or by the first appearance of *B. castellanensis* (Company 1987). It was recently suggested by Reboulet (1996) to place the base of the Radiatus zone at the first appearance of the genus *Acanthodiscus*. This proposal has been accepted by Mutterlose (1996) (see Klein 1997 for discussion). This solution is better because there are no taxonomic problems with the definition of the genus *Acanthodiscus*. This allows a solution of problems raised by the discovery of earlier representatives of *Acanthodiscus* and *Breistrofferella*. It was previously shown that the genus *Breistrofferella* appears in the Callidiscus zone *sensu* Reboulet (1996) on the Provençal platform (Atrops et al. 1996). The discovery of primitive *Breistrofferella*, interpreted as the microconch equivalent of *Acanthodiscus* (Reboulet 1996), suggests that *Acanthodiscus* would first appear in the Callisdiscus zone *sensu* Reboulet (1996).

However, *Acanthodiscus* is especially abundant in shallow-water facies and very rare or even absent in the deep-water facies of the Tethyan Realm (Betic Chains, Company 1987; Hoedemaeker 1995; Atlantic High Atlas, Ettachfini 1991). This is a problem for the recognition of the base of the Radiatus zone in Mediterranean areas.

Moreover, this traditional boundary does not correspond to a major faunal caesura in ammonites. The ammonite association of the Radiatus zone is very closely related to the underlying levels but it is greatly different from the Loryi zone (Fig. 2 and 3). Taking into account the evolution of the whole ammonite fauna (Reboulet 1996, Fig. 31, p. 229), it would be better to place the base of the Hauterivian at the base of the Loryi zone.

Indeed, the boundary between the Radiatus and the Loryi zones coincides with an important turnover in the ammonite faunal succession (Reboulet 1996). The assemblages of the Loryi and Nodosoplicatum zones are very different from that of the Radiatus zone which is well characterized by numerous genera such as *Teschenites*, *Acanthodiscus*, *Breistrofferella*, *Leopoldia*, *Eleniceras* and *Oosterella*. The disappearance of all Valanginian neocomitid taxa before the top of the Radiatus zone makes possible the development of *Olcostephanus* and *Spitidiscus* in the Loryi and Nodosplicatum zones (Reboulet 1996). However, this stratigraphic interval is mainly marked by the abundance of *Crioceratites*.

The Lower-Upper Hauterivian boundary is placed at the base of the Sayni zone, defined by the first appearance of *S. sayni* (Bulot et al. 1993). At this boundary, the subfamily *Neocomitinae* disappears (Reboulet 1996).

Conclusion

A detailed study of the Valanginian-Lower Hauterivian ammonite succession of south-east France has enabled comparison with other biostratigraphic schemes, particularly with different works of Bulot and Thieuloy. The biostratigraphic scale here proposed is now more closely related to the evolution of ammonites. This approach has required consideration of the whole ammonite fauna, well studied on the systematic level (Reboulet 1996). But, for stability of stratigraphical nomenclature, in some cases we preferred to use existing biostratigraphic units.

For these reasons, we think that, at this moment, it is not appropriate to change the Berriasian-Valanginian boundary. We maintain the Lower-Upper Valanginian boundary at the base of the Verrucosum zone and the Valanginian-Hauterivian boundary at the base of the Radiatus zone. However, taking in account the important caesura in ammonite evolution between Radiatus and Loryi zones, the possibility of placing the Valanginian-Hauterivian boundary at this level should be further examined. In this scheme, the biostratigraphic boundaries coincide with main caesura in ammonite faunas and separate three main ammonites associations well characterized (Reboulet 1996).

In the Upper Valanginian, the Peregrinus zone and the Furcillata zone previously used as horizons are raised to zones. The Neocomiensis horizon is abandoned. Only one new horizon is established in the Lower Hauterivian: the Kiliani horizon.

Acknowledgements

We should like to acknowledge P. Rawson (University College of London) and the anonymous reviewer, who revised the manuscript, and J. Remane (University of Neuchâtel) for their useful comments about the paper. Thanks to N. Morton (Birkbeck College of london) for his helpful contribution to the English version.

REFERENCES

ATROPS, F. & REBOULET, S. 1993: Nouvelles données sur la zonation par ammonites du Valanginien supérieur de l'hypostratotype d'Angles (Alpes de Haute-Provence) et sur ses corrélations. C. R. Acad. Sci. (Paris) 317, 499–506.

– 1995a: Le Valanginien-Hauterivien basal du bassin vocontien et de la bordure provençale : zonation et corrélations. C. R. Acad. Sci. (Paris) 320, 985–992.

– 1995b: *Neolissoceras* (*Carinites*), nouveau sous-genre d'ammonites du Valanginien du bassin vocontien (SE de la France). C. R. Acad. Sci. (Paris) 321, 1203–1210.

– 1996: *Vergoliceras*, nouveau nom pour *Carinites* ATROPS et REBOULET, 1995 (Ammonitina, Valanginien), non *Carinites* WIEDMANN, 1973. Geobios 29, 6, 670.

ATROPS, F., AUTRAN, G. & REBOULET, S. 1996: Nouvelles données sur la systématique et l'évolution des *Breistrofferella* (*Ammonitina, Neocomitidae*) du Sud-Est de la France, à la limite Valanginien-Hauterivien. C. R. Acad. Sci. (Paris) 323, 721–728.

AUTRAN, G. 1993: L'évolution de la marge Nord-Est provençale (Arc de Castellane) du Valanginien moyen à l'Hauterivien à travers l'analyse biostratigraphique des séries de la région de Peyroules : séries condensées, discontinuités et indices d'une tectogenèse distensive. Paléobiologie. Ann. Mus. Hist. Nat. Nice 10, 240 p.

BAUMBERGER, E. 1906: Fauna der unteren Kreide im westschweizerischen Jura. Abh. schweiz. paläont. Ges. 33, 1–30.

BIRKELUND, T., HANCOCK, J.M., HART, M.B., RAWSON, P.F., REMANE, J., ROBASZYNSKI, F., SCHMID, F. & SURLYK, F. 1984: Cretaceous stage boundaries – proposals. Bull. geol. Soc. Denmark 33, 3–20.

BLANC, E., BULOT, L. & PAICHELER, J. C. 1994: La coupe de référence de Montbrun-les-Bains (Drôme, SE France) : un stratotype potentiel pour la limite Berriasien-Valanginien. C. R. Acad. Sci. (Paris) 318, 101–108.

BULOT, L. 1993: Stratigraphical implications of the relationships between ammonites and facies: examples taken from the Lower Cretaceous (Valanginian-Hauterivian) of the western Tethys. In: The Ammonoidea: environment, ecology and evolutionary change (Ed. by HOUSE, M. R.). Systematics Assoc. sp. vol., Clarendon Press, Oxford, 47, 243–266.

BULOT, L. 1995: Les formations à ammonites du Crétacé inférieur dans le SE de la France (Berriasien-Hauterivien) : Biostratigraphie, paléontologie et cycles sédimentaires. Unpublished thesis, Paris.

BULOT, L. (reporter), 1996: The Valanginian stage. Second International Symposium on Cretaceous Stage Boundaries. Brussels (1995) (Ed. by RAWSON, P. et al.). Bull. Inst. r. Sci. nat. Belg. 66 supPl., 11–18.

BULOT, L., COMPANY, M. & THIEULOY, J.P. 1990: Origine, évolution et systématique du genre Valanginien *Saynoceras* (*Ammonitina, Olcostephaninae*). Geobios 23, 4, 399–413.

BULOT, L., ARNAUD-VANNEAU, A. & BLANC, E. 1992, In Arnaud-Vanneau A. & Arnaud H. Basin type successions: biostratigraphic tools, stratigraphic gaps and reworked sediments. Transition from platform to basin in the Subalpine chains. Platform Margins Symposium Guide-book, 9–12 May 1992, Grenoble, 25–41.

BULOT, L., THIEULOY, J.P., BLANC, E. & KLEIN, J. 1993: Le cadre stratigraphique du Valanginien supérieur et de l'Hauterivien du Sud-Est de la France : définition des biochronozones et caractérisation de nouveaux biohorizons. Géol. alp. (Grenoble) 68 (1992), 13–56.

BULOT, L. & THIEULOY, J.P. 1996: Les biohorizons du Valanginien du Sud-Est de la France : un outil fondamental pour les corrélations au sein de la Tethys occidentale. Géol. alp. (Grenoble) h. s. 20 (1994), 15–41.

BUSNARDO, R. & THIEULOY, J.P. 1979: Les Zones d'ammonites du Valanginien. In Hypostratotype mésogéen de l'étage Valanginien (Sud-Est de la France) (Ed. by BUSNARDO R., THIEULOY J.P.& MOULLADE M.). Les stratotypes français, C.N.R.S. 6, 58–68, 127–134.

– 1989: Les ammonites de l'Hauterivien jurassien : révision des faunes de la région du stratotype historique de l'étage hauterivien. Mém. Soc. neuchât. Sci. nat. 11, 101–147.

CALLOMON, J. H. 1985: Biostratigraphy, chronostratigraphy and all that – again! Proc. internat. symp. Jurassic stratigraphy, Erlangen 1984. 3, 611–624.

CECCA, F. 1995: Late Valanginian ammonites from Monte Catria (Umbria-Marches Apennines, Italy). Mem. Descr. Carta geol. d'It. LI, 47–57.

COMPANY, M. 1987: Los Ammonites del Valanginiense del sector de las Cordilleras Béticas (SE de Espana). Tesis Doctoral Univ. Granada, 1–294.

COTILLON, P. 1971: Le Crétacé inférieur de l'arc subalpin de Castellane entre l'Asse et le Var, stratigraphie et sédimentologie. Mém. Bur. Rech. géol. et min. 68, 1–243.

COTILLON, P., FERRY, S., GAILLARD, C., JAUTÉE, E., LATREILLE, G. & RIO, M., 1979: A la recherche des facteurs oscillants de la sédimentation marine ancienne par l'étude des alternances marno-calcaires. C. R. Acad. Sci. (Paris) 289, 1121–1124.

– 1980: Fluctuation des paramètres du milieu marin dans le domaine vocontien (France Sud-Est) au Crétacé inférieur: mise en évidence par l'étude des formations marno-calcaires alternantes. Bull. Soc. géol. France 22, 5, 735–744.

COTILLON, P. & RIO, M. 1984: Cyclic sedimentation in the Cretaceous of Deep Sea Drilling Project sites 535 and 540 (Gulf of Mexico), 534 (Central Atlancic), and in the Vocontian basin (France). Init. Rep. Deep Sea Drilling Proj. 77, 339–378.

DARMEDRU, C. 1982: La microfaune dans les alternances marne-calcaire pélagiques du Crétacé inférieur vocontien (sud-est de la France). Mise en évidence d'oscillations climatiques. Thèse Université Lyon (unpublished).
– 1984: Variations du taux de sédimentation et oscillations climatiques lors du dépôt des alternances marne-calcaire pélagiques. Exemple du Valanginien supérieur vocontien (Sud-Est de la France). Bull. Soc. géol. France 7, 26, 1, 63–70.
DARMEDRU, C., COTILLON, P. & RIO, M. 1982: Rythmes climatiques et biologiques en milieu marin pélagique. Leurs relations dans les dépôts crétacés alternants du bassin vocontien (Sud-Est de la France). Bull. Soc. géol. France 7, 24, 3, 627–640.
ETTACHFINI, M. 1991: Le Valanginien de l'Atlas Atlantique (Maroc) : stratigraphie et ammonitofaune. Strata (Toulouse) 15, 1–153.
FERRY, S. 1991: Une alternative au modèle de stratigraphie séquentielle d'Exxon: la modulation tectono-climatique des cycles orbitaux. Géol. alp. (Grenoble) 18 h. s., 47–99.
GIRAUD, F. 1995: Recherche des périodicités astronomiques et des fluctuations du niveau marin à partir de l'étude du signal carbonaté des séries pélagiques alternantes. Application au Crétacé inférieur du Sud Est de la France (bassin vocontien), de l'Atlantique central (Site 534 DSDP) et du golfe du Mexique (Site 535 DSDP). Docum. Lab. Geol. Lyon 134, 1–279.
HEDBERG, H. 1979: Guide stratigraphique international : classification, terminologie et règles de procédures. Doin ed., Paris, 1–233.
HOEDEMAEKER, P.J. 1982: Ammonite biostratigraphy of the uppermost Tithonian, Berriasian and Lower Valanginian along the Rio Argos (Caravaca, SE Spain). Scripta Geol. 65, 1–81.
HOEDEMAEKER, P.J. 1995: Biostratigraphy and sequence stratigraphy of the Berriasian-lowest Aptian (Lower Cretaceous) of the Rio Argos succession, Caravaca, SE Spain. Cretaceous Research 16, 195–230.
HOEDEMAEKER, P.J. & BULOT, L. 1990 (reporters): Preliminary ammonite zonation for the lower Cretaceous of the mediterranean region. Géol. alp. (Grenoble) 66, 123–127.
HOEDEMAEKER, P.J. & COMPANY, M. (reporters) 1993: Ammonite zonation for the Lower Cretaceous of the mediterranean region; basis for the stratigraphic correlations within IGCP-project 262. Rev. espan. Paleont. 8, 1, 117–120.
HOEDEMAEKER, P.J. & CECCA F. (reporters) 1995: Report on the third international Workshop on the standard Lower Cretaceous ammonite zonation of the Mediterranean region. Mem. Descr. Carta geol. Ital. 51, 213–215.
KEMPER, E., RAWSON, P. F. & THIEULOY, J. P. 1981: Ammonites of Tethyan ancestry in the early Lower Cretaceous of north-west Europe. Paleontology 24, 251–311.
KILIAN, W. 1910: Das Mesozoicum, Kreide. In: Lethaea geognostica. (Ed. by FRECH F.). Schweizerbart, Stuttgart 3, 2 : 1–398.
KILIAN, W. & REBOUL, P. 1915: Contribution à l'étude des faunes paléocrétacées du Sud-Est de la France. II. Sur quelques ammonites de l'Hauterivien de la Bégude (Basse-Alpes). Mém. Serv. Carte géol. France 14, 223–288.
KLEIN, J. 1997: Ammonite stratigraphy for the Valanginian and lower Hauterivian of the mediterranean region. Newsletter 9, 6–15.
KUTEK, J., MARCINOWSKI, R. & WIEDMANN, J. 1987: The Waval section, Central Poland. An important link between boreal and tethyan Valanginian. Cretaceous of the western Tethys (Ed. by WIEDMANN J.). Proc. 3 rd Int. Cretaceous Symp., 717–754.
LE HÉGARAT, G. 1973: Le Berriasien du Sud-Est de la France. Docum. Lab. Géol. Fac. Sci. Lyon 43, 1–576.
LORIOL, P. DE 1861: Description des animaux invertébrés fossiles contenus dans l'étage néocomien moyen du Mont-Salève. Georg. Genève/Bâle, 1–214.
LORY, P. 1898: Sur le Crétacé inférieur du Dévoluy et des régions voisines. Bull. Soc. géol. France 3, 26, 132–138.
MANDOV, G. 1976: L'étage Hauterivien dans les Balkanides occidentales (Bulgarie de l'Ouest) et sa faune d'ammonnites. Ann. Univ. Sofia 67, 1–99.
MASSE, J.P., BUSNARDO, R., GERVAIS, J., HUMBERT, P. & THIEULOY, J.P. 1975: Précisions sur l'âge des marnes inférieurs hauteriviennes de la région de Marseille. C.R. Acad. Sci. (Paris) 280, 1429–1431.
MOULLADE, M. 1966: Etude stratigraphique et micropaléontologique du Crétacé inférieur de la fosse vocontienne. Doc. Lab. Géol. Fac. Sci. Lyon 15, 1–369.
MOULLADE, M. & THIEULOY, J.P. 1967: Les zones d'ammonites du Valanginien supérieur et de l'Hauterivien vocontiens. C.R. somm. Soc. géol. France 6, 228–230.
MUTTERLOSE, J. (reporter) 1996: The Hauterivian stage. 2nd Int. Symp. Cretaceous Stage Boundaries. Brussels (1995) (Ed. by RAWSON, P. et al.). Bull. Inst. royal Sci. Nat. Belgique 66 suppl., 19–24.
NIKOLOV, T.G. 1977: On the ammonite genus *Busnardoites* NIKOLOV, 1966 (*Berriasellidae*, Lower Cretaceous). Geol. balcanica 7/4, 107–118.
OLIVERO, D. 1996: *Zoophycos* distribution and sequence stratigraphy. Examples from the Jurassic and Cretaceous deposits of southeastern France. Palaeogeogr., Palaeoclimatol., Palaeoecol. 123, 273–287.
PAQUIER, V. 1900: Recherches géologiques dans le Diois et les Baronnies orientales. Thèse Univ. Grenoble, 1–410.
RAWSON, P.F. & KEMPER, E. 1978: *Varlheideites*, n. gen. (Ammonoidea, Neocomitinae) aus dem Obervalangin NW-Deutschlands. Geol. Jb. A45, 163–181.
REBOULET, S. 1996: L'évolution des ammonites du Valanginien-Hauterivien inférieur du bassin vocontien et de la plate-forme provençale (S-E de la France): relations avec la stratigraphie séquentielle et implications biostratigraphiques. Docum. Lab. Géol. Lyon 137 (1995), 1–371.
REBOULET, S., ATROPS, F., FERRY, S. & SCHAAF, A. 1992: Renouvellement des ammonites en fosse vocontienne à la limite Valanginien-Hauterivien. Geobios 25, 4, 469–476.
REBOULET, S. & ATROPS, F. 1995: Rôle du climat sur les migrations et la composition des peuplements d'ammonites du Valanginien supérieur du bassin vocontien (Sud-Est de la France). Géobios mém. sp. 18, 357–365.
– 1997a: Zonation par ammonites et limites stratigraphiques du Valanginien du sud-est de la France. In Réunion spécialisée APF-SGF "De la biostratigraphie à la Paléobiogéographie ", Lyon 27–28 Novembre 1997, abstract p. 35, Fig. 1. Soc. géol. France éd. ISBN 2–85363–078–1.
– 1997b: Quantitative variations of the valanginian ammonite fauna of the Vocontian basin (southeastern France) between limestones-marls and within parasequence sets. Palaeogeogr., Palaeoclimatol., Palaeoecol. 135, 145–155.
– 1998: Implications biostratigraphiques de l'étude des renouvellements fauniques : l'exemple des ammonites du Valanginien du bassin Vocontien (SE France). In 2 ème Congrès Français de Stratigraphie, Strati 2000, Paris 8–11 Septembre 1998. Book of abstracts, p. 138.
REY, J (reporter) 1997: Stratigraphie, terminologie française. Bull. Centres Rech. Explor.-Prod., Elf Aquitaine Pau 19, 1–164.
THIEULOY, J.P. 1973: The occurence and distribution of boreal ammonites from the Neocomian of Southeast France (Tethyan Province). Geol. Jb. 5, 289–302.
– 1977: La zone à Callidiscus du Valanginien supérieur vocontien (Sud-Est de la France). Lithostratigraphie, ammonitofaune, limite du Valanginien-Hauterivien, corrélations. Géol. alp. (Grenoble) 53, 83–143.
THIEULOY, J.P., FUHR, M. & BULOT, L. 1990: Biostratigraphie du Crétacé inférieur de l'Arc de Castellane (Sud-Est de la France). 1: Faunes d'ammonites du Valanginien supérieur et âge de l'horizon de "La grande lumachelle". Géol. Méditer. 17, 1, 55–99.
TRIBOVILLARD, N.P. 1988: Contrôles de la sédimentation marneuse en milieu pélagique semi-anoxique : exemples dans le Mésozoïque du sud-est de la France et de l'Atlantique. Thèse Université Lyon (unpublished).
WESTERMANN, G. E. G. 1993: Hydrostatics and hydrodynamics of cephalopod shells: form, structure and function. Anal. Acad. Nac. Cs. Ex. Fis. Nat. 45, 183–204.
WHITTAKER, A., COPE, J. C. W., COWIE, J. W., GIBBONS, W., HAILWOOD, E. A., HOUSE, M. R., JENKINS, D. G., RAWSON, P. F., RUSHTON, A. W. A., SMITH, D. G., THOMAS, A. T. & WIMBLEDON, W. A. 1991: A guide to stratigraphical procedure. J. Geol. Soc. 148, 813–824.

Manuscrit reçu le 27 janvier 1998
Révision acceptée le 4 juin 1999