Ammonite biostratigraphy of the uppermost Tithonian, Berriasian, and lower Valanginian along the Río Argos (Caravaca, SE Spain)

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This paper deals with the ammonite biostratigraphy of the lower 312 m of the Miravetes Formation (sections Y and Z) exposed 500 m north and northwest of Los Miravetes along the Río Argos, 3 km west of Caravaca (SE Spain). This sequence embraces the uppermost Tithonian, Berriasian, and lower Valanginian. The succession of ammonite assemblages is similar to the one described by Le Hégarat (1971) from SE France. Le Hégarat's results are, where possible, completed and, where necessary, corrected. Arguments are adduced for a stratigraphic position of the Tithonian-Berriasian boundary, which should also be the Jurassic-Cretaceous boundary, between the *Pseudosubplanites grandis* and *Subthurmannia (Strambergella) subalpina* subzones. The Berriasian was divided into two zones, the lower *Subthurmannia (Strambergella) occitanica* Zone and the upper *Subthurmannia (Subthurmannia) rarefurcata* Zone. The latter comprises only the *Berriasella (Malbosiceras) paramimouna* and *Berriasella (Berriasella) picteti* subzones. Also arguments were adduced for a stratigraphic position of the Berriasian-Valanginian boundary between the *B. (B.) picteti* Subzone and the here proposed *Tirnovella alpillensis* Subzone. The latter can be correlated with the 'Sous-zone à Callisto' of Le Hégarat & Remane (1968), which is inadequately characterized with respect to its ammonite association. The *T. alpillensis* Subzone is the lowest subzone of the *Thurmanniceras (Kilianella) retrocostatum* Zone, here proposed, which also encloses Le Hégarat's *Tirnovella pertransiens* Subzone in the middle and the here proposed *Sarasinella trezanensis* - *Thurmanniceras (Kilianella) pexiptychum* Assemblage-subzone at the top. The *Pseudosubplanites euxinus* Zone (Wiedmann in Allemann et al., 1975), which is shown to embrace the *Berriasella (Hegaratella) jacobi* and *Pseudosubplanites grandis* subzones, is adopted as the name for the topmost Tithonian zone. Finally Neumayr's (1871) *Paraulacosphinctes transitorius* Zone and Kilian's (1888) *Subthurmannia (Subthurmannia) boissieri* and *Thurmanniceras (Kilianella) roubaudianum* zones are reinstated in their original faunistical sense and treated as superzones.

For a better understanding of the author's interpretation of some taxa, palaeontological notes are added. In these a new genus, *Pseudoneocomites*, is introduced.

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Introduction

The Lower Cretaceous sequence along the Río Argos and its tributaries is about 1500 m thick, well exposed and little disturbed. This is exceptional for the Subbetic tectonic zone of the Betic Cordilleras in southern Spain, in which the Cretaceous rocks are generally highly disturbed. This epibathyal marine sequence consists of a monotonous, rhythmic alternation of grey marlstone beds and light grey, marly coccolite limestone beds. It is fairly fossiliferous (mainly ammonites, tintinnids, benthic and planktic foraminifera, calcareous nannoplankton, pollen, and dinoflagellates) and without lacunas (except for an unconformity of regional extent where the upper Aptian up to and including the middle Albian is missing), and therefore particulary well-suited for a detailed investigation of the integrated biostratigraphy of the Lower Cretaceous, which is here not obscured by facies changes. It has all the requisites to serve as a standard for the Lower Cretaceous of southern Spain and to test whether and to what extent the biostratigraphic zonations, set up for this series in southern France, are applicable in other parts of the Mediterranean region.

The study of the biostratigraphy of this sequence is a research project of the National Museum of Geology and Mineralogy of the Netherlands; the field work of our equipe in the summers of 1973, 1974, 1975, and 1980 was financially supported by the Netherlands Organization for the Advancement of Pure Research, which is gratefully acknowledged. Also I am obliged to the 'Comisión Nacional de Geología' of Spain for giving me permission to carry out this investigation. Finally I am very grateful to all those who participated in the accurate collecting of the many thousands of ammonites in the field and to those who restored and prepared them for me.

During the field work 24 sections were accurately measured. They are distributed over two areas: one in the neighbourhood of the farms of Los Miravetes, the other near the farms and water-mills of Las Oicas, some 6 km farther west. These sections comprise the type and reference sections of the Miravetes, Argos, and Represa formations of van Veen (1966, 1969) and cover the stratigraphic interval from the uppermost Tithonian to the Albian-Cenomanian boundary. Since the delimitation of biozones is the ultimate goal of this study, the correlation of the Miravetes sequence with the Oicas sequence was done exclusively lithologically by finding identical patterns in the succession of beds. Taking into account the distance of 6 km, this method proved to be successful and in the overlapping parts of the Los Miravetes and Las Oicas sequences every bed could be traced in both sequences. Only for the lower part of the Berriasian of the Las Oicas sequence, which is very incomplete and chaotic as a result of slumping and sliding, exact bed by bed correlation with the Los Miravetes sequence is still doubtful.

All limestone beds were given a number and from each a rock sample was taken for the study of tintinnids and *Nannoconus*. Each bed was thoroughly searched for macrofossils and some 8000 ammonites were collected. Only 1% of the total fauna consists of belemnites, gastropods, bivalves, brachiopods (mainly pygopids), and echinoids; the trace fossil *Zoophycos* occurs in abundance throughout the sequence. Most ammonites are sufficiently well preserved to allow identification for biostratigraphical purposes. Each fossil was marked with the number of the bed it was taken from; loose fossils were given two numbers marking the lowest and the highest bed from which it could possibly have been derived. The material is registered in the Museum's collections (numbers prefixed RGM). Also some material belonging to the Geological Institute, University of Amsterdam (numbers prefixed G.I.A.) was studied. Stratigraphical columns were constructed for the thirteen sections that cover the whole Argos sequence. The letter codes of the main sections are in stratigraphical order: Z, Y, M, N, P, A, I, Q, O, S, V, U, T. The other sections are mere parallel sections and only produced complementary faunas.

This paper deals with the ammonite biostratigraphy of the stratigraphically lowest part of the Argos sequence, viz. the sections Z and Y, embracing a 312.5 m thick interval; the ammonite fauna of section Y was completed by the ammonites collected from the parallel section X and from the lower part of section M (Fig. 1).

Previous investigations on the Lower Cretaceous along the Río Argos

The presence of Berriasian rocks along the Río Argos was irrefutably demonstrated by van Veen (1966, 1969) and Geel (1966) in the Los Miravetes and Las Oicas areas. In 1975, Allemann, Grün & Wiedmann published a biostratigraphic study of the Berriasian and lower Valanginian near Caravaca. In that study they incorporated our sections Z and Y, which they sampled in 1970 and 1971. Grün & Allemann (1975) also published a separate paper on the nannofossils of these sections. During our field work the bed numbers of Allemann were still visible.

This paper, which also deals with the Berriasian and lower Valanginian of Los Miravetes, may therefore seem superfluous, but Allemann et al. did not give this part of the sequence the credit it deserves and it forms the inevitable first part of a series of papers to be published on the biostratigraphy of the Lower Cretaceous along the Río Argos. Moreover, Allemann et al. made some mistakes with respect to the amount of overlap of the three sections in which they divided the sequence studied by them. These mistakes have important consequences with respect to the correlation of the zones they drew up and to the biostratigraphical characterization they gave to the lower and upper boundary of the Berriasian.

Delimitation of biostratigraphic units

The diversity graph (Enclosure 4) constructed for the upper Tithonian, Berriasian, and lower Valanginian ammonite associations of Los Miravetes shows a revealing picture of pronounced highs and lows. We must keep in mind, of course, that the shape of such a graph is highly influenced by local factors. Its shape highly depends on the local palaeoecological circumstances during the timespan under consideration. Tuberculated ammonites, for instance, are relatively rare; also *Dalmasiceras* and *Subalpinites* are scarce; *Proniceras* was not found, whereas phylloceratids, lytoceratids, and *Neolissoceras* are abundant. Also the changing degree of exposure influences the diversity of the ammonites found. In less exposed parts the diversity appears to be markedly lower than could be expected, for instance at the beginning of the various sections, where-

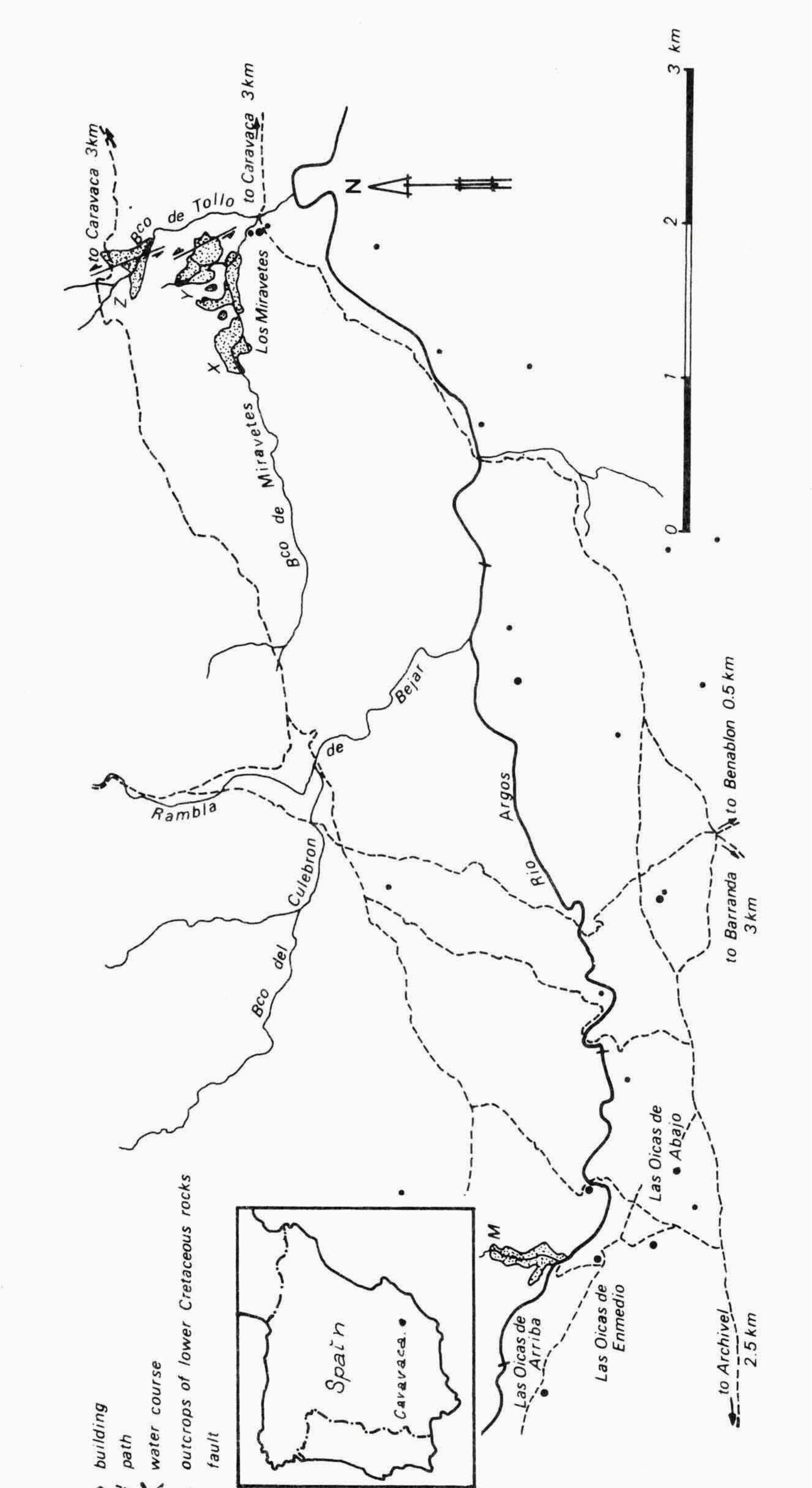


Fig. 1. Location of the sections discussed in this paper.

as well-exposed beds produce small diversity peaks in the curve. Besides these influences, the shape of the diversity graph also depends on collection failure and last but not least on the subjective art of delimiting 'species'; many of them may eventually turn out to be mere varieties, successional subspecies, or sexual dimorphs.

Nevertheless the facies remains unchanged ad nauseam throughout the sequence, so that influences by changing facies can be eliminated. Because of the remarkable fact that diversity curves with equally pronounced highs and lows in similar stratigraphic positions could be constructed from the ammonite range charts of the uppermost Tithonian, Berriasian, and lower Valanginian from SE France and Tunisia (Enclosure 4), we may properly assume that the major highs and lows are not merely local aberrations, but are of supraregional extent and significance and undoubtedly of important time-stratigraphic value.

The diversity curve shows three broad major highs separated by two deep major lows. Each high consists of an initial increase in ammonite diversity, a diversity peak, and a final decrease in diversity. The high in the middle is the broadest, the upper high the highest and the lower low the deepest. Each high has its proper diagnostic fauna of 'species' and species groups; several of the latter have been given generic or subgeneric status. Across a diversity minimum the transformation of the fauna is rapid and profound, whereas in between the minima the successive ammonite faunas imperceptibly shade off into one another. The major highs, which are bounded by the deep minima, clearly represent distinct stages in the development of the ammonite faunas and they constitute successive natural ammonite assemblages, which form the raw material for the distinction of major biostratigraphic units in the Mediterranean faunal province, whereas the deep minima clearly delimit the distinct steps in the development of the ammonite faunas. Similar steps can be demonstrated for the ammonite faunal successions reported from Bulgaria, Roumania, and The Crimea. The lower boundaries of these major units should preferably coincide with those supra-regional diversity minima, above which the renewed increase in diversity is predominantly due to the rapid entry of many new faunal elements diagnostic for the following zone. Such supra-regional diversity minima, which are pinched between supra-regional diversity highs and which usher in an almost total taxonomical renewal of the ammonite fauna, are of great importance with respect to the recognition and delimitation of superzones, stages, systems, etc. and provide the only means to give that delimitation the objective basis that stratigraphers are so eager to obtain. A quick reconnaissance through the ammonite records learns that such natural biostratigraphic boundaries are quite numerous.

The following criteria were used here to distinguish and delimit the biostratigraphic units in the sequence of Los Miravetes: 1) The deep major diversity minima that can be shown to be of supra-regional significance and that appear to be attended with rapid and profound turnovers in the Mediterranean faunal succession were chosen to delimit high-ranking biostratigraphic units, which are as a matter of course represented by the broad major highs in the diversity graph. 2) The faunal composition of the basal part of such a high-ranking biostratigraphic unit (setting aside notoriously long-ranging forms such as haploceratids, phylloceratids, and lytoceratids) differs 100% (or nearly so) from the faunal composition of the basal parts of the adjacent high-ranking biostratigraphic units. 3) The high-ranking biostratigraphic units so defined can be subdivided into low-ranking ones on account of the successive acmes of common, short-ranging forms. As the various ammonite faunas within a major high imperceptibly shade off into one another, the number of these low-ranking units and the stratigraphic positions of their boundaries depend on the subjective choice of the defining ammonite associations and are in this respect rather artificial and arbitrary. They could therefore change in scope and concept with increasing knowledge; their identification is restricted to the geographic extent of the ammonite species forming part of these associations. 4) If within one of the high-ranking units the faunal composition of the basal low-ranking unit differs 100% (or nearly so) from the topmost low-ranking unit (which is invariably the case at Los Miravetes), the low-ranking units within the high-ranking unit may be grouped into two biostratigraphic units of medium rank, which would of course have several ammonite forms in common. A subdivision into more units of medium rank would make them less readily recognizable. The grouping of low-ranking units into units of medium rank may perhaps be induced also by the presence of subordinate highs, provided they are of supra-regional significance. 5) The high-ranking biostratigraphic units are referred to as superzones and their identification is restricted to the geographic extent of the ammonite genera that form part of their associations. The medium-ranking biostratigraphic units are referred to as zones, the low-ranking ones as subzones. The three major highs of the Miravetes diversity graph can be separated without difficulty as distinct high-ranking biostratigraphic units. From below to above they correspond to the upper part of the *Par. transitorius* Superzone, the *S. boissieri* Superzone, and the lower part of the *Th. roubaudianum* Superzone.

Each superzone recognized in Los Miravetes could be subdivided into: 1) a basal subzone in which the new fauna appears, but is still appreciably mixed with the last representatives of the preceeding superzone; 2) a subzone of major increase in the diversity of the new genera; 3) a transitional subzone between the lower and upper part of the superzone; 4) a subzone representing the diversity peak; 5) a subzone of major decrease in the diversity at the top of the superzone. These subzones appear to be well recognizable steps in the development of the ammonite faunas within the superzones and their definition can therefore be based on rather objective criteria.

So it appears that the 'episodic faunal revolutions', as Wiedmann (1973) called the ammonite faunal turnovers that are used to determine the lower boundaries of the Triassic and Jurassic systems, also occur at the stage/substage level, but that the latter generally take place at the genus/species level only. Even the five phases recognized by Wiedmann (1973) in the development of the ammonite faunas can with slight modifications be distinguished within the diversity highs of Los Miravetes and form the basis for the recognition of the subzones. The shape of the diversity graph is comparable to the one predicted mathematically by Carr & Kitchell (1980).

The biostratigraphic units distinguished in this paper can be referred to as Oppel-zones.

Abbreviations used in ammonite names

In order to save space, it was decided to omit the authors of the species names in the faunal lists and to abbreviate the genus names as follows. A complete list of the species collected during the present investigation is given with authors and dates in an appendix.

A.	*Ammonites*
As.	*Aspidoceras*
Au.	*Aulacosphinctes*
B. (B.)	*Berriasella (Berriasella)*
B. (D.)	*B. (Delphinella)*
B. (H.)	*B. (Hegaratella)*
B. (M.)	*B. (Malbosiceras)*
Bo.	*Bochianites*
Bu.	*Busnardoites*
Ch.	*Chamalocia*
Co.	*Corongoceras*
Cy.	*Cyrtosiceras*
Da. (Da.)	*Dalmasiceras (Dalmasiceras)*
Da. (Sa.)	*Da. (Subalpinites)*
Du.	*Durangites*
Hi.	*Himantoceras*
Hm.	*Himalayites*
Ho.	*Holcophylloceras*
Hp.	*Hoplites*
Hy.	*Hypophylloceras*
L.	*Lytoceras*
Li.	*Lissonia*
Lp.	*Leptoceras*
Mi.	*Micracanthoceras*
N.	*Neocomites*
Nc.	*Neocosmoceras*
Ne.	*Neolissoceras*
O. (Mx.)	*Olcostephanus (Mexicanoceras)*
O. (O.)	*O. (Olcostephanus)*
O. (R.)	*O. (Rogersites)*
O. (Sb.?)	*O. (Subastieria?)*
P.	*Pseudosubplanites*
Pa.	*Parandiceras*
Par.	*Paraulacosphinctes*
Pe.	*Perisphinctes*
Pg.	*Protetragonites*
Po. (Ma.)	*Pomeliceras (Mazenoticeras)*
Po. (Po.)	*Po. (Pomeliceras)*
Pp.	*Parapallasiceras*
Pr.	*Protancyloceras*
Ps.	*Pseudoneocomites* gen. nov.
Pt.	*Ptychophylloceras*
Ri.	*Riasanites*
S. (J.)	*Subthurmannia (Jabronella)*
S. (S.)	*S. (Subthurmannia)*
S. (St.)	*S. (Strambergella)*
Sn.	*Saynoceras*
Sp. (G.)	*Spiticeras (Groebericeras)*
Sp. (Ki.)	*Sp. (Kilianiceras)*
Sp. (Ng.)	*Sp. (Negreliceras)*
Sp. (Pn.)	*Sp. (Proniceras)*

Sp. (Sp.)	*Sp. (Spiticeras)*
Sr.	*Sarasinella*
Ss.	*Substeueroceras*
Su.	*Substreblites*
T.	*Tirnovella*
Th. (E.)	*Thurmanniceras (Erdenella)*
Th. (K.)	*Th. (Kilianella)*
Th. (Th.)	*Th. (Thurmanniceras)*
U.	*Uhligites*

Exact meaning of the Latin abbreviations

cf. x : identification with some reserve;
aff. x : differs only in a few aspects from x, may be a variety or a succesional subspecies;
n. sp.? aff. x : possibly a new species, may be a variety of x;
n. sp. aff. x : new species systematically close to x;
n. sp. ex gr. x : new species, morphologically in the neighbourhood of x;
n. sp. : new species, sufficiently preserved to be described or already figured in the literature;
n. sp. indet. : new species, but insufficiently preserved to be adequately described;
n. sp.? indet. : possibly a new species, insufficiently preserved to be determined as such;
sp. indet. : not identified, may be a new species;
sp. : only identification of the genus was possible.

Lower boundary of the investigated stratigraphic interval

The stratigraphically lowest bed incorporated in our study (bed Z1) is the graded calciturbidite bed (van Veen, 1969, p. 32, 33; Allemann et al., 1975, p. 15, fig. 1; Seyfried, 1978, p. 44, 126, fig. 5) that van Veen has from the outset regarded as the boundary bed between the Jurassic Tollo Formation and the almost entirely Lower Cretaceous Miravetes Formation (van Veen, personal communication). It is situated in the Barranco de Tollo, 3 km west of Caravaca, in the middle of a few metres thick interval in which typical Tollo lithology passes into typical Miravetes lithology (van Veen, 1969, p. 39). In fact the change in lithology below and above this bed is more pronounced than van Veen cautiously formulated in his doctor's thesis.

The tintinnid association below bed Z1 (Allemann et al., 1975) clearly indicates the *Crassicolaria intermedia* Zone of Allemann et al., (1971) and, on account of the absence (or scarcity?) of *Cr. parvula*, could be correlated with Remane's (1964) subzone A2, or the basal part of his subzone A3, or both. Bed Z2 clearly belongs to the *Calpionella alpina* Zone of Allemann et al. (1971) and, on account of the additional presence of *Cr. brevis* up to bed Z9 (Geel, personal communication), could be correlated with the basal part of this zone. At the base of the calciturbidite bed there is therefore a hiatus comprising at least the upper part of Remane's subzone A3, which can be correlated with the Subzone of *Crassicolaria massutiana/Cr. parvula* of Trejo (1975).

We did not find any ammonites below bed Z15, but Wiedmann (in Allemann et al., 1975) reports from a level some 4 m above the hiatus (their sample 71 118 from our bed Z10): *B. (H.) chaperi, B. (H.) tarini, Sp. (Pn.) praenegreli*, and *Mi. microcanthum*. He incorporated this association in the *Berriasella jacobi* Zone. From a level 1 m below the hiatus (sample 71 114) Wiedmann identified *B. (H.) jacobi, B. (H.) tarini*, and *Mi. microcanthum*. He included this association also in the *Berriasella jacobi* Zone. From the same beds Geyer (in Seyfried, 1978) identified *Holcophylloceras* sp., *Ptychophylloceras* sp., *Lytoceras* sp., *Dalmasiceras* sp., *Protacanthodiscus* spp., and *Parapallasiceras* cf. *praecox* (Schneid).

Pseudosubplanites euxinus Zone (Wiedmann, in Allemann et al., 1975)

Index species: *Pseudosubplanites euxinus* (Retowski).

Ammonite fauna

The lower maximum in the Miravetes ammonite diversity plot constitutes a faunistically well-separable unit characterized by the presence of *P. euxinus, P. grandis, P. lorioli, P. ponticus, P. combesi, P. berriasensis, P.* n. sp. (= *H. ponticus* in Simionescu, 1899, pl. 1, fig. 1), *P.* n.sp.? aff. *combesi* (= *Pe. Lorioli* in Kilian, 1889, pl. 28, fig. 3), *B. (H.) jacobi, B. (H.) paramacilenta, B. (H.) subcallisto, B. (H.) oppeli, B. (H.) elmii, B. (H.) chomeracensis, B. (H.) oxycostata, B. (D.) berthei, B. (D.) delphinensis, B. (D.) obtusenodosa, B. (D.) tresannensis, B. (D.) crimensis, B. (D.)* aff. *obtusenodosa* (= *D. boisseti* Le Hégarat, 1971, only pl. 41, fig. 5, probably a coarse-ribbed morphotype of *B. (D.) obtusenodosa*), *B. (D.) consanguinea, B. (D.)* n. sp. ex gr. *crimensis, Dalmasiceras* sp., *S. (St.) carpathica, S. (St.) floquinensis, S. (St.)* n. sp. (= *N. allobrogensis* in Arnould-Saget, 1951, pl. 8, fig. 1), *Ss. beneckei, Ps. allobrogensis, Hm. stoliczkai* (probably a morphotype of *Hm. cortazari*), *Hy. serum, Pt. semisulcatum, Pt. inordinatum, L. liebigi, L. juilleti, Pg. quadrisulcatus*, and *Ne.* cf. *carachtheis*. This association consists of ammonites, that characterize the *B. jacobi* and *P. grandis* zones of Le Hégarat (1971).

Subdivision

Le Hégarat (1971) has demonstrated that the well-known horizons of Aizy (= *Hp. chaperi* Subzone of Kilian, 1907) and of La Boissière near Chomérac (= *Hp. delphinensis* Subzone of Kilian, 1907) are contemporaneous. He introduced for this fauna the *B. jacobi* Subzone, which cannot be subdivided on faunistical grounds.

During the 'Colloque sur la limite Jurassique-Crétacé' (1975) it has repeatedly been argued that the *B. jacobi* and *P. grandis* zones had better be taken together as one zone. This zonal combination was then provisionally called the 'zone à *Jacobi/Grandis*' by Enay & Geyssant (1975), the '*Berriasella grandis* zone (sensu lato)' by Yegoyan (1975), and the '*Pseudosubplanites ponticus-P. euxinus* zone' by Drushchits (1975). The reason for this combination becomes clear at once when looking at the range charts of Le Hégarat (1971) which show that all ammonite forms of the *P. grandis* Zone also occur in the *B. jacobi* Zone, though in different proportions. On the same grounds this combination was already proposed by Toucas (1890), when he argumented, that the total ammonite fauna he had described from Chomérac (he described only ammonites diagnostic for the *B. jacobi* and *P. grandis* zones) should constitute one single zone. I fully agree with this zonal combination.

The *P. grandis* Zone can be characterized only negatively by the absence of certain taxa and therefore identified only when it is underlain in a continuous section by a well-recognizable *B. jacobi* ammonite assemblage. Because of the difficulty of identifying the *P. grandis* fauna with only a handful of ammonites from isolated outcrops, we agree that the former should not rank higher than subzone. Conversely the identification of the *B. jacobi* Zone in an isolated outcrop does not exclude the presence of the *P. grandis* Zone in the same outcrop; therefore neither the *B. jacobi* Zone should rank higher than subzone.

Wiedmann (in Allemann et al., 1975) introduced the name *P. euxinus* Zone for a stratigraphic interval near Los Miravetes that he originally correlated with Le Hégarat's *P. grandis* and *S. subalpina* subzones but which, after our exhaustive search for ammonites, proved to be exactly equivalent to the '*Jacobi/Grandis*' zone. Wiedmann's name is preferred here for the zone consisting of the *B. jacobi* and *P. grandis* subzones, because it has only one index fossil and he was the first to designate a reference section in an uninterrupted succession.

Lower boundary

The exact development of the ammonite fauna in the '*Durangites*' Zone of Enay & Geyssant (1975), which occupies the interval between the *Mi. microcanthum* Zone (sensu Enay & Geyssant, 1975) and the *B. jacobi* Subzone, is still obscure, because well-documented bed by bed studies that bridge the famous 'lacune de nos connaissances' of Mazenot (1939) and Le Hégarat (1971) are wanting; the only exception is the section in the Sierra de Quipar (SE Spain) described by Barthel et al. (1966). Hitherto Enay & Geyssant (1975), Yegoyan (1975), Sapunov (1977), and Tavera (1979) gave only a concise characterization of the faunal change in this interval, which they qualified as profound but gradual. This change mainly consists of a marked increase in the number and diversity of ammonites that belong to the (sub)genera *Pseudosubplanites, Hegaratella, Delphinella, Dalmasiceras, Strambergella,* and *Proniceras*, whereas the Himalayitinae strongly decrease in number and diversity. Since this faunal change has not been studied in our investigation, the following discussion is based on the literature.

From the Sierra de Quipar section (Barthel et al., 1966) it appears that the ammonite association that hitherto would exclusively have characterized the *B. jacobi* Subzone already appears in bed B42, in which Barthel identified *B. (H.) moreti, B. (H.)* cf. *jacobi, B. (D.) delphinensis, Par. transitorius*, and *Pg. quadrisulcatus*.

This bed can however be correlated with the lower part of Remane's calpionellid subzone A2, because the next lower sample, from bed B41, 3.4 m below B42, still contains the calpionellid association of his subzone A1 and *Mi.* sp. ex gr. *microcanthum*, whereas the next higher sample, from bed B42a, 2 m above B42, was correlated with the middle part of his subzone A2 (Remane, in Barthel et al., 1966). Bed B43, 2 m above B42a, yielded *P. ponticus, B. (H.) aizyensis, Da (Da.) kiliani, Da. (Da.)* n. sp. aff. *djanelidzei*, and *S. (St.)* n. sp. aff. *carpathica*. Remane correlated this bed with the lower part of his calpionellid subzone A3. The boundary between Remane's calpionellid zones A and B is situated in bed B43a, 1.4 m above B43.

The stratigraphical interval embracing the calpionellid subzones A2 and A3 has approximately been correlated with the interval occupied by the '*Durangites* zone' (Enay & Geyssant, 1975; Oloriz & Tavera, 1979b). If this is true the study of Barthel et al. (1966) now shows that, of the genera that otherwise would exclusively have characterized the *B. jacobi* Subzone, *Hegaratella* (which according to Enay & Geyssant, 1975, made its timid entry below their '*Durangites*' Zone) and *Delphinella* are already present at the base of that interval, whereas *Pseudosubplanites*, the berriasellids of the *B. chaperi* group (incorporated here in *Hegaratella*, including '*Hp.*' *tarini* Kilian), *Strambergella* (which includes '*N.*' *cabrensis* Fallot), *Dalmasiceras*, and perhaps *Spiticeras (Sp.) pseudogroteanum* in bed E2, Barthel et al., 1966) are already present in upper part of that interval, viz. the lower part of calpionellid subzone A3.

As to the other generic groups that are present in the *B. jacobi* Subzone, also *Protacanthodiscus* sensu stricto timidly appears below the '*Durangites* zone' and has its maximal development in that 'zone' (Oloriz & Tavera, 1979a, b); it has been reported to continue into the *B. jacobi* Subzone by Enay & Geyssant (1975), Sapunov (1976, 1977) and Tavera (1979); if '*Malbosiceras*' *nikolovi* Le Hégarat belongs to this genus, its range would even extend into the *P. grandis* Subzone. One specimen of *Substeueroceras* has been reported from the Spanish '*Durangites* zone' (Oloriz & Tavera, 1979b). As I prefer to include '*Pseudargentiniceras*' *flandrini* Le Hégarat and '*Neocomites*' *beneckei* (Jacob) in Roman & Mazenot in this genus, its range extends into the *P. grandis* Subzone too.

According to the data collected by Enay & Geyssant (1975), Drushchits (1975), Sapunov (1976, 1977), Oloriz & Tavera (1979a, b), Tavera (1979), Memmi (1968), Le Hégarat (1965, 1971), Allemann et al. (1975), Memmi & Salaj (1975), and Busnardo et al. (1976), the ranges of the ammonite groups referred to as *Himalayites, Corongoceras, Parapallasiceras, Aspidoceras, Cyrtosiceras, Proniceras, Protancyloceras, Haploceras,* and *Neolissoceras* (including '*A*'. *carachtheis* Zeuschner) start below the stratigraphic interval comprising Remane's calpionellid subzones A2 and A3 and continue into the ammonite subzones above that interval, whereas *Pseudodiscosphinctes, Aulacosphinctes, Paraulacosphinctes, Durangites,* and *Micracanthoceras* disappear below or just above the end of that interval. From Kef Krakrmat and Kef Khouadja (Djebel Nara, Tunisia) for instance, Memmi (1968) and Memmi & Salaj (1975) reported *Co. rhodanicum, Mi. microcanthum, Au.* aff. *hundesianus*, and *Par.* cf. *senex* only from their 'Horizon à *Berriasella chomeracensis, Dalmasiceras sublaevis, Micracanthoceras microcanthum*', which has been correlated with the lower part of the *B. jacobi* Subzone (Le Hégarat, 1971; Memmi & Salaj, 1975; Busnardo et al., 1976), but this horizon may well represent the top part of the '*Durangites* zone'.

The ammonites hitherto reported from the calpionellid subzones A2 and A3 of Remane (Barthel et al., 1966; Le Hégarat, 1971; Enay & Geyssant, 1975; Sapunov, 1977; Tavera, 1979; Oloriz & Tavera, 1979b) are:

Pseudargentiniceras abscissum (Oppel), *S. (St.) cabrensis* (Fallot), *S. (St.) carpathica* (Zittel), *B. (H.) jacobi* Mazenot, *B. (H.) moreti* Mazenot, *B. (H.) tarini* (Kilian), *B. (H.) aizyensis* Mazenot, *B. (D.) delphinensis* (Kilian), '*B.*' *moravica* (Oppel), '*Pe.*' *fischeri*(?) Kilian, '*Pe.*' *falloti* Kilian, *Co. rhodanicum* Mazenot, *Co.* ex gr. *symbolum* (Oppel), *Mi. microcanthum* (Oppel), *Protacanthodiscus andeaei* (Kilian), *Du. vulgaris* Burckhardt, *Du. astillerensis* Imlay, *Durangites* spp., *Par. senex* (Oppel), *Par. transitorius* (Oppel), *Aulacosphinctes* spp., *Pseudodiscosphinctes* spp., *P. ponticus* (Retowski), *Da. (Da.) kiliani* (Djanélidzé), *Da. (Da.) progenitor* (Oppel), *Da. (Da.)* aff. *djanelidzei* Mazenot, *As. cienequitense* Steuer, *As. neoburgense* (Oppel), *Himalayites* sp., *Sp. (Pn.) pronum* (Oppel), *Sp. (Pn.) gracile* Djanélidzé, *Sp. (Pn.)* ex gr. *toucasi* (Retowski), *Substeueroceras* sp., *Kossmatia* sp., *Cy. macrotelum* (Oppel), *Haplo-*

ceras elimatum (Oppel), *Ne. carachtheis* (Zeuschner), and probably also: *Sp. (Sp.) pseudogroteanum* Djanélidzé, *B. (H.) oppeli* (Kilian), *B. (H.) chaperi* (Pictet), and *P. lorioli* (Zittel). The 'lacune de nos connaissances' of Mazenot (1939) and Le Hégarat (1971) has been filled up a little but much detailed research is still badly needed.

According to the scarce data available up to now, one can say that without exception all genera, and even many species, allegedly diagnostic for the *B. jacobi* and *P. grandis* subzones are already present in the interval occupied by the calpionellid subzones A2 and A3 and that their diversity and number augments progressively in the course of that interval at the cost of the genera that appeared below that interval. This interval, included in the '*Durangites* zone' by Enay & Geyssant (1975) and Oloriz & Tavera (1979b), can therefore be biostratigraphically typified as an interval of transitional character in which the ammonite taxa that hitherto characterized only the *B. jacobi* Subzone gradually replace the old ones to become predominant in that subzone.

The faunal liaisons between the '*Durangites* zone' sensu Enay & Geyssant (1975) and Wiedmann's *P. euxinus* Zone are so tight and their faunal relations so close that both biostratigraphic units should at least form part of one and the same biostratigraphic unit of higher rank, which can be referred to as *Paraulacosphinctes transitorius* Superzone sensu Neumayr (1871, p. 517) and Sapunov (1977). This superzone, which embraces the entire upper Tithonian Substage, constitutes a well separable and well recognizable biostratigraphic unit. The most important break in the faunal succession of the Mediterranean Tithonian is clearly situated at the base of the upper Tithonian (Enay & Geyssant, 1975; Sapunov, 1977; Oloriz & Tavera, 1979a, b; Kauffman, 1979).

The lower zone of this superzone, which can be referred to as *Micracanthoceras microcanthum* Zone (sensu Enay, 1971, and Sapunov, 1977; non sensu Enay & Geyssant, 1975; Oloriz & Tavera, 1979a, b), embraces three subzones: the '*Simplisphinctes*' (which perhaps should include a part of the '*Burckhardticeras*' Subzone), '*Par. transitorius*', and '*Durangites*' subzones (Oloriz & Tavera, 1979a, b; Enay & Geyssant, 1975). The *P. euxinus* Zone of Wiedmann (1975) embraces the *B. jacobi* and *P. grandis* Subzones.

As the ammonite fauna of the '*Durangites*' Subzone sensu Enay & Geyssant (1975) is a mixture of faunal elements of the *Mi. microcanthum* and *P. euxinus* zones, the faunistical characterization of the boundary between this subzone and the *B. jacobi* Subzone is still obscure. As a consequence the stratigraphic position of that boundary cannot be determined yet.

According to Sapunov (1977), for instance, the lower boundary of his '*M.*' *chaperi* Zone, interpreted to be equivalent to Le Hégarat's *B. jacobi* Subzone, is marked by the entry of berriasellids of the *B. chaperi* group, *Pseudosubplanites*, and *Neolissoceras*. This would imply that bed B43 of the Quipar section, which contains *B. (H.) aizyensis* and *P. ponticus* and which is correlated with the lower part of calpionellid subzone A3, already belongs to the *B. jacobi* Subzone, but also the level 1 m below bed Z1 near Los Miravetes, which contains *B. (H.) jacobi*, *B. (H.) tarini*, and *Mi. microcanthum* (Wiedmann, in Allemann et al., 1975).

According to Enay & Geyssant (1975) and Oloriz & Tavera (1979b), however, the base of the *B. jacobi* Subzone is situated close to the boundary between Remane's calpionellid zone A and B. This would imply that the level 1 m below bed Z1, which could be correlated with calpionellid subzone A2 or lower A3, should instead be included in the '*Durangites*' subzone.

As the *P. euxinus* Zone is negatively characterized by the (near) absence of ammonites that also would characterize the *Mi. microcanthum* Zone, it seems preferable to draw the lower boundary of the *P. euxinus* Zone at the end of the mixture of forms that hitherto would have characterized only the *Mi. microcanthum* Zone or only the *P. euxinus* Zone.

In accordance with this view also bed Z10 (= sample 71 118 of Allemann et al., 1975) was tentatively included in the *'Durangites'* Subzone on account of Wiedmann's (in Allemann et al., 1975) identification of *B. (H.) tarini* and *Mi. microcanthum* from this bed. The base of the *B. jacobi* Subzone was therefore provisionally drawn at the base of bed Z15, in which the first *P. combesi* was collected and above which no *Mi. microcanthum* was found.

Berriasella (Hegaratella) jacobi Subzone (Le Hégarat & Remane, 1968)

Index species: *Berriasella (Hegaratella) jacobi* Mazenot.

In Los Miravetes the following species were found to be restricted to the interval between bed Z15 and Z136: *B. (D.) delphinensis, B. (D.) consanguinea, B. (D.) obtusenodosa, B. (D.) crimensis, B. (D.)* aff. *obtusenodosa* (= *D. boisseti* Le Hégarat, 1971, only pl. 41, fig. 5, probably a coarse-ribbed morphotype of *B. (D.) obtusenodosa*), *B. (D.)* n. sp. ex gr. *crimensis, P.* n. sp. (= *H. ponticus* in Simionescu, 1899, pl. 1, fig. 1), *Dalmasiceras* and *Pt. inordinatum.*

Also *B. (H.) oxycostata* and *Ss. beneckei*, which in France have their acme in the *B. jacobi* Subzone, and *P. grandis* were found to be restricted to these beds, but in SE France (Mazenot, 1939; Le Hégarat, 1971) and in Tunisia (Memmi, 1968; Memmi & Salaj, 1975) they range into the *P. grandis* Subzone. The only Miravetes specimen of *Himalayites* found in the *B. jacobi* Subzone was identified as *Hm. stoliczkai*, but this form may be a variety of *Hm. cortazari*, which would extend the range of the latter down into the *B. jacobi* Subzone. Two specimens of *B. (D.) tresannensis* were found below bed Z136, but a doubtful specimen was found well above bed Z140.

Plate 1

All figures x 1.

Fig. 1. *Pseudosubplanites euxinus* (Retowski), RGM 160 231, bed Z124, *B. jacobi* Subzone.

Fig. 2. *Pseudoneocomites allobrogensis* (Mazenot), RGM 160 237, bed Z174, *P. grandis* Subzone (plaster-cast).

Fig. 3. *Substeueroceras beneckei* (Jacob), RGM 160 236, bed Z 132, *B. jacobi* Subzone (plaster-cast).

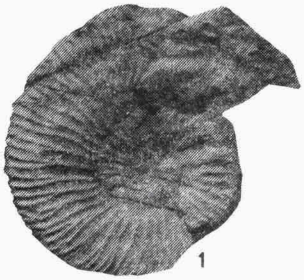
Fig. 4. *Berriasella (Dephinella) tresannensis* (Le Hégarat), RGM 160 235, bed Z124, *B. jacobi* Subzone.

Fig. 5. *Pseudosubplanites grandis* (Mazenot), RGM 160 232, beds Z102-108, *B. jacobi* Subzone (plaster-cast).

Fig. 6. *Berriasella (Hegaratella) oppeli* (Kilian), RGM 160 233, beds Z150-153, *P. grandis* Subzone.

Fig. 7. *Berriasella (Hegaratella) jacobi* Mazenot, RGM 160 234, bed Z95, *B. jacobi* Subzone.

Plate 1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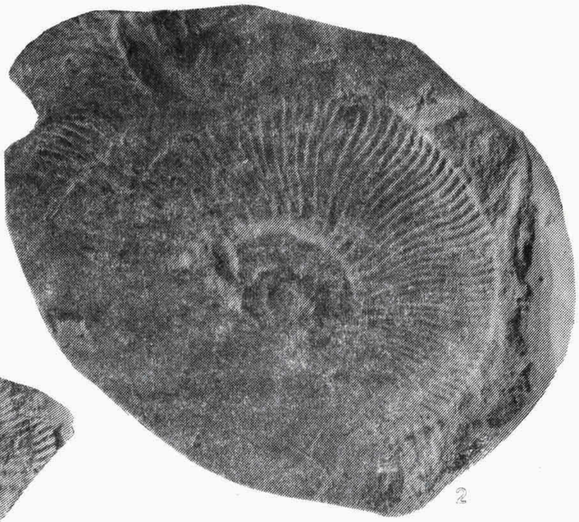
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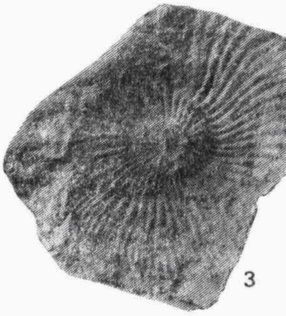
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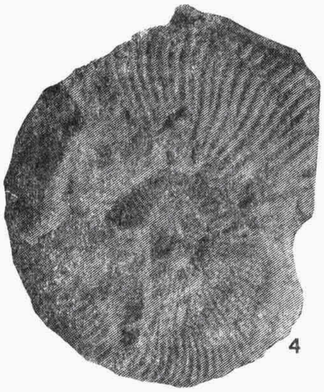
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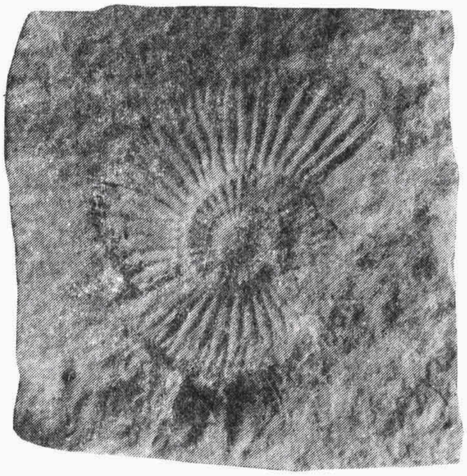
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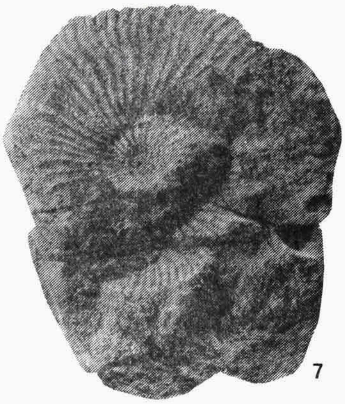

7

The transition from the *B. jacobi* to the *P. grandis* Subzone is, according to le Hégarat (1971), mainly characterized by the sharp decline of *Delphinella* and *Dalmasiceras* (*Proniceras* should be added) followed by the acme of *Pseudosubplanites*. This faunal change can well be observed in section Z and is situated between bed Z136 and Z140, an interval of 2.15 m. Le Hégarat's characterization of this boundary can therefore be maintained.

The stratigraphically highest find of *B. (D.)* cf. *delphinensis* is a loose specimen, which could have been derived only from bed Z136, Z137, Z138, or Z139. In bed Z140 clearly begins the acme of *Pseudosubplanites*.

Pseudosubplanites grandis Subzone (Busnardo & Le Hégarat, 1965)

Index species: *Pseudosubplanites grandis* (Mazenot).

Ammonite fauna

Since all ammonite species of the *P. grandis* Subzone can also be found in the *B. jacobi* Subzone, the circumstance that in section Z *P. berriasensis* (which in France has its acme in the *P. grandis* Subzone), *P.* n. sp.? aff. *combesi* (= *Pe. Lorioli* in Kilian, 1889, pl. 28, fig. 3), *B. (D.) berthei* (which in France ranges into the next higher subzone), *B. (H.) subcallisto* (which ranges into the next higher subzone), *B. (H.) elmii* (also found in parallel section M bed M8, correlated with the *B. jacobi* Subzone), and *S. (St.) floquinensis* (whose range continues into the next higher subzone) were only found from bed Z140 upward, may therefore be explained by collection failure. Only *S. (St.)* n. sp. (= *N. allobrogensis* in Arnould-Saget, 1951, pl. 8, fig. 1) was hitherto found restricted to the *P. grandis* Subzone.

Worth mentioning is the specimen of *B. (H.) oppeli*, thought to be restricted to the *B. jacobi* Subzone (Le Hégarat, 1971), but found above bed Z140 within the peak zone of *Pseudosubplanites*. Also Memmi (1968) and Memmi & Salaj (1975) reported *B. (H.) oppeli* from the interval at Kef el Khouadja (Djebel Nara, Tunisia) that has been correlated with the *P. grandis* Subzone. Also should be mentioned that one specimen of *Ps. allobrogensis*, though identified with some reserve, was collected in the overlying *S. subalpina* Subzone.

Upper boundary

It is particulary conspicuous from the range charts of Le Hégarat (1971) from sections in southern France, that almost the entire ammonite fauna of the *P. grandis* Subzone disappears below its upper boundary. This disappearance is not a local event; it is also conspicuous from the range charts and faunal lists of Memmi & Salaj (1975) and Busnardo et al. (1976) from sections in Tunisia, of Wiedmann (in Allemann et al., 1975) and ours in southern Spain, of Drushchits (1975) and Kvantaliani & Lysenko (1979) in The Crimea, and of Patrulius & Avram (1976) in Roumania; it affected the fauna of at least the entire Mediterranean Province. Moreover, this disappearance affected nearly all ammonite lineages. The total number of about 90 perisphinctacean ammonite forms (probably including several varieties and sexual dimorphs) that hitherto have been distinguished in the Mediterranean *B. jacobi* Subzone (Djanélidzé, 1922; Mazenot, 1939; Arnould-Saget, 1951; Le Hégarat, 1971; Memmi & Salaj, 1975) is cut down by half in the *P. grandis* Subzone.

As to *Hm. cortazari*, which according to Le Hégarat's range chart would appear in the *P. grandis* Subzone, the finding of *Hm. stoliczkai*, possibly a morphotype of *Hm. cortazari*, in the *B. jacobi* Subzone of Los Miravetes would extend the range of the latter into the *B. jacobi* Subzone. As the *B. jacobi* Subzone specimens assigned by Le Hégarat (1971) to *D. boisseti* may possibly belong to a coarsely ornamented morphotype of *B. (D.) obtusenodosa*, *B. (D.) boisseti* Le Hégarat sensu stricto becomes restricted to the *S. subalpina* and *B. privasensis* subzones. Therefore, and because it is likely that also the range of *Hm. cortazari* (which has been recorded only from the upper part of calpionellid subzone B, the major part of which is correlatable with the *P. grandis* Subzone) does not cross the upper boundary of that subzone, only the ranges of ten perisphinctacean forms of the *P. grandis* Subzone have actually been recorded to cross its upper boundary; they disappear however soon afterwards (Le Hégarat, 1971; Memmi & Salaj, 1975). The comparison of all available data shows that all forms of *Pseudosubplanites, Parapallasiceras, Aspidoceras, Protacanthodiscus, Himalayites, Substeueroceras, Cyrtosiceras, Haploceras, Proniceras*, and berriasellids of the *B. chaperi* group died out. Of the 13 forms of *Hegaratella* only four have been reported to continue their ranges into, but not further than, the *S. subalpina* Subzone (Le Hégarat, 1971; Memmi & Salaj, 1975); also *Delphinella* and *Dalmasiceras* lost heavily in importance.

A comparable extinction of ammonite forms occurs at the Berriasian-Valanginian boundary, but the ammonite disappearance in the *P. grandis* Subzone is particulary remarkable in that it is not compensated by new appearances; new taxa appear only above the upper boundary of the *P. grandis* Subzone. A possible exception may be *S. (St.) shipkovensis* (Le Hégarat, non Nikolov & Mandov) and *S. (St.) allobrogensis* Arnould-Saget, non Mazenot, who's absence in the *B. jacobi* Subzone may be due to collection failure (Le Hégarat, 1971, p. 296). Above the upper boundary of the *P. grandis* Subzone new appearances of ammonite forms highly predominate over extinction; at least 54 new forms appear in the *S. occitanica* Zone (Le Hégarat, 1971; Memmi & Salaj, 1975; our range chart). In this zone 11 new '(sub)genera' appear, viz. *Negreliceras* (*'N.' praenegreli* Djanélidzé of the *B. jacobi* Subzone was included in *Proniceras*), *Subalpinites* (excluding *Da. (Da.) aristides* (Kilian) of the *B. jacobi* Subzone), *Pomeliceras, Mazenoticeras* (which does not include *'Hp.' Tarini* Kilian), *Berriasella, Malbosiceras, Neocosmoceras, Euthymiceras, Subthurmannia, Jabronella*, and *Erdenella*.

The faunal change is important and therefore easily detectable. The gradual reduction in the number of species is clearly expressed in the ammonite diversity graph of Los Miravetes (enclosure 4) and reaches its climax in the lower diversity minimum after which several new forms appear. In Los Miravetes this boundary is situated in a 4.27 m thick interval between bed Z203, in which the last *Pseudosubplanites* was found, and bed Z206 with the first fragment of *S. (St.)* cf. *subalpina*. Bed Z206 is directly followed by beds from which *S. (St.) subalpina, B. (B.) privasensis* and *Nc. sayni* were collected together with the last *B. (H.) subcallisto* and the last *S. (S.) floquinensis*, an association diagnostic for the *S. subalpina* Subzone of Le Hégarat (1971).

Correlations of the *P. euxinus* Zone

So in Miravetes the ammonite fauna diagnostic for the *P. euxinus* Zone was found from the base of bed 15 up to the top of limestone Z203 comprising a 62.87 m thick interval. The beds that were provisionally incorporated in the *'Durangites'* Subzone, bed Z1 to Z10, embrace an interval of 5.03 m. The barren interval between the top of limestone Z10 and the base of bed Z15 is 1.43 m thick. The diagnostic *B. jacobi* ammonite association was found between the base of bed Z15 and the top of limestone Z136 (or perhaps of Z139), an interval of 30.48 m (or perhaps 31.65 m) thickness; the *P. grandis* fauna between the base of bed Z140 and the top of limestone Z203, a 31.22 m thick interval.

If we compare these data with the zonation and correlation adopted by Wiedmann (in Allemann et al., 1975) in the same section, it appears that the samples 71 114 and 71 118, which he correlated with the *B. jacobi* Subzone, can provisionally be correlated with the *'Durangites'* Subzone, whereas the beds for which Wiedmann introduced the *P. euxinus* Zone (their sample numbers 17 120 (= our bed Z20), up to and including 17 143 (= our bed Z202)) can be correlated with Le Hégarat's *B. jacobi* and *P. grandis* subzones. Bed Z15, the provisional base of the *B. jacobi* Subzone, corresponds with their sample 71 119, 1.5 m below their sample 71 120. The base of the *P. grandis* Subzone (bed Z140) is situated between their samples 71 135 and 71 136, whereas bed Z203 with the last *Pseudosubplanites*, 10 cm above Z202, exactly corresponds with the level where Wiedmann draws the upper boundary of his *P. euxinus* Zone.

Allemann (in Allemann et al., 1975) reported the first *Calpionella elliptica* from his sample 17 143 (= our bed Z202). This was confirmed by T. Geel, who studies the calpionellid biostratigraphy in the present investigation; she found the first *C. elliptica* in bed Z200, one metre below Z202. Also in the Cañada Lengua section (SE of Caravaca) Allemann (in Allemann et al., 1975) found the first *C. elliptica* one metre below the bed with the last *P. grandis* Subzone ammonites and in Tunisia Busnardo et al. (1976) recorded the first appearance of *C. elliptica* between the ammonite association of the *P. grandis* Subzone and the lowest association of the *S. occitanica* Zone. It can therefore be considered well established that the lower boundary of the *Calpionella elliptica* Zone of Allemann et al. (1971) practically coincides with the upper boundary of the *P. grandis* Subzone and that the *Calpionella alpina* Zone of Allemann et al. (1971) can be correlated with the *B. jacobi* and *P. grandis* subzones. Reversely the *'Durangites'* Subzone can be correlated with Remane's (1964) calpionellid subzones A2 and A3 and the *B. jacobi* Subzone with the lower part of the *C. alpina* Zone.

Probably (1) because of the fact that Allemann (in Allemann et al., 1975) correlated the base of his *C. elliptica* Zone with that of Remane's calpionellid zone C, and (2) in accordance with the correlation scheme between the ammonite and calpionellid biozones set up by Le Hégarat & Remane (1968), and last but not least (3) due to the scarcity of ammonites above their sample 71 143 in the Barranco de Tollo section (for instance, Wiedmann dit not found *S. subalpina*), Wiedmann assumed that his *P. euxinus* Zone could be correlated with the combined *P. grandis* and *S. subalpina* subzones.

This probably caused them to correlate sample 71 166, which is from the basal bed of section B of Allemann (in Grün & Allemann, 1975) (= our section Y, 250 m W of section Z) and at the same time the base of their 'Zone of *B. privasensis*', approximately with sample 71 143 of Allemann's section A (= our section Z), which is the base of the *C. elliptica* Zone and at the same time the top of the *P. euxinus* Zone. Allemann (in Grün & Allemann, 1975) writes that the correlation between their sections A and B, which show an overlap of more than 30 m, was based on dip measurements, but that he did not found a marker bed and that, 'when correlated faunistically and by lithological indications, there would be no overlap of A and B'. Our dip measurements, however, performed on enlarged aerial photographs, leave a gap of about 50 m between Z and Y. But two left-lateral wrench-faults between Z and Y striking parallel to the dip of the beds result in a horizontal shift of approximately 50 m, which makes the stratigraphic columns of these sections nearly contiguous or perhaps even slightly overlapping. As, however, no decisive resemblance could be found between the patterns in the succession of beds of the two sections, we either must conclude to a small observational hiatus of a few metres, or to a small overlap (perhaps the last four beds of section Z may be the same as the four first beds of section Y).

The appearance of *C. elliptica*, not far above that of *Remaniella cadischiana*, marks the onset of an important change in the tintinnid faunas, which consists mainly in a marked, though gradual and fluctuating increase and decrease in the percentages of *Tintinnopsella carpathica* and *Calpionella alpina*, respectively. When the percentage of *T. carpathica* constantly remains above 40% of the total number of tintinnids, one has entered zone C of Remane (as defined in Le Hégarat & Remane, 1968). This condition was reached in bed Z240 near the top of the *S. subalpina* Subzone. This is in accordance with the stratigraphic position of the boundary between Remane's calpionellid zones B and C in SE France.

Subthurmannia (Subthurmannia) boissieri Superzone (Kilian, 1888)

Index species: *Subthurmannia (Subthurmannia) boissieri* (Pictet).

History of the *S. (S.) boissieri* Superzone

In his thesis Kilian (1888) established the *S. boissieri* Zone as follows: (p. 191) 'Nous avons vu qu'au-dessus des dernières assises à *Pygope janitor, Am. Calisto, Am. transitorius*, se presentaient, en transition ménagée, des couches plus marneuses, souvent encore bréchiformes et contenant une faune à caractère nettement crétacé. Il n'est pas difficile, lorsqu'on étudie ces dépôts, de voir les espèces qu'ils renferment sont celles dont Pictet a fait connaître l'association dans une étude classique sur les couches de Berrias (Ardèche). C'est à cette zone, par consequent, qu'appartiennent les calcaires marneux que nous nous proposons de décrire dans ce chapitre .....' (p. 196) 'A Côté de ces espèces which these limestones have in common with the lower and higher units , nous ferons remarquer qu'il en est un certain nombre dont l'extension est moins grande et qui paraissent cantonnées dans l'assise dite de Berrias. C'est ainsi que *Hoplites Euthymi, H. Malbosi, H. curelensis, H. Boissieri, H. occitanicus, H. Dalmasi, Holcostephanus Negreli*, donnent à cette faune un caractère tout particulier. C'est, en effet, dans les calcaires de Berrias seulement, que se rencontrent ces formes intéressantes de *Hoplites* et de *Holcostephanus* qui suffisent à mettre en évidence l'individualité paléontologique de cette zone. C'est parmi ces espèces qu'il convient de choisir les fossiles caractéristiques du niveau de Berrias, aussi nous sommes-nous arrêté aux *Am. Boissieri* et *occitanicus*, qui joignent à leur faible extension verticale une répartion horizontale très étendue dans l'horizon de Berrias'.

So the ammonite association diagnostic for Kilian's *S. boissieri* Zone is the ammonite fauna described by Pictet (1867), among which Kilian selected several species that would be particularly characteristic for this zone. Kilian (1890, 1892, 1893, 1894, 1896, 1907, 1910) ever since insisted on the autonomy and individuality of this zone and on its inclusion in the Cretaceous. As Coquand (1869, 1870, 1871, 1875) also regarded Pictet's fauna as diagnostic for the stratigraphic interval that he later (1871, 1875) called 'Berriasien', the *S. boissieri* Zone represented for Kilian the 'Berriasien des anciens auteurs' (1894, p. XIV), or 'Berriasien proprement dit' (1895, p. 686, p. 713), or 'Berriasien sensu stricto' (1895, p. 706; 1907, p. 16), which is not equivalent to the Berriasian sensu Toucas (1890), who disputed the independence of Kilian's Boissieri zone.

Mainly as a result of imprecise identification, Toucas (1890) argued that the ammonite fauna he had found near Chomérac was a complete mixture of ammonites that occur in Stramberg (= upper Tithonian) as well as in Berrias (= Berriasian) and should constitute one single zone. On account of the Tithonian affinity of the fauna he made Berriasian a synonym of upper Tithonian and placed the Jurassic-Cretaceous boundary at the base of the 'marnes et calcaires feuilletés à *Rhynchonella contracta, Belemnites latus* et grand *Hoplites neocomiensis*' which he considered the base of the Valanginian. However, the ammonite fauna described by Toucas turned out eventually to be diagnostic for the *B. jacobi* and *P. grandis* zones sensu Le Hégarat (1971), which should indeed be united into one zone, but does not contain one single ammonite of the *S. boissieri* Zone sensu Kilian (1888).

Later Kilian became aware that at the base of the marly limestones of the 'couches de Berrias', below (and separated by ammonite-poor beds from) the beds that contain the characteristic *S. boissieri* fauna, but above the sublithographic limestones that he incorporated in the Tithonian (because they contain ammonites that also occur in the 'Stramberger Schichten'), a thin interval could be differentiated with an ammonite fauna of strong Tithonian affinities. He (1896) called these beds 'niveau de Gensiac' (= Jansiac, Montagne de Lure) and regarded them as the transition beds between his Tithonian and Berriasian sensu stricto. He included however this level as 'niveau inférieur' in his 'Infravalanginien', which is therefore not synonymous with his *S. boissieri* Zone.

Still later Mazenot (1939) equated this 'niveau inférieur' with his 'horizon inférieur à *Berriasella paramacilenta* n. sp. et *B. grandis* n. sp.' which according to Busnardo & Le Hégarat (1965) and Le Hégarat (1971) would correspond with their 'zone à *B. grandis*' (= 'Zone à *B. (P.) paramacilenta*' of Breistroffer, 1964, p. 289, 284). Mazenot put this lower horizon at the base of the Berriasian, which view was followed by Busnardo & Le Hégarat (1965) and by Le Hégarat (1971).

In the 'Fosse Vocontienne' in SE France, the 'couches de Berrias' are overlain by the 'marnes à *Belemnites latus*' (Pictet, 1867). The lower part of these marls contains an entirely different, often pyritized ammonite fauna that characterizes the *Th. roubaudianum* Zone of Kilian (1888). Kilian (1896, 1910) did not report any ammonites from the top beds of the 'couches de Berrias'. Therefore these beds could not possibly belong to his *S. boissieri* Zone. He incorporated these beds as the 'niveau supérieur, à *Belemnites Orbignyi, Bel. conicus* et *Rhynchonella contracta*' in his 'Infravalanginien' and regarded them as the transition between his *S. boissieri* and *Th. roubaudianum* zones.

Later Mazenot (1939) found a few ammonites in these top beds ('horizon de Beaucels') which he equated with Kilian's 'niveau supérieur' and which he included under the name 'horizon supérieur à *Kilianella* aff. *pexiptycha* (Uhl.) et *Thurmannites* aff. *pertransiens* Sayn' in the Berriasian. The Infravalanginian sensu Kilian and the Berriasian sensu Mazenot are therefore synonymous.

On account of additional ammonite finds, Busnardo & Le Hégarat (1965) rightly included these upper beds of the 'couches de Berrias' in the Valanginian *Th. roubaudianum* Zone, which view was accepted by the attendants of the 'Colloque sur le Crétacé inférieur' (1965). The *S. boissieri* Zone sensu Kilian is therefore faunistically the same as the *S. boissieri* Zone sensu the general stratigraphical conclusions of this colloquium and comprises the biostratigraphic unit between the *P. grandis* Zone and the *Th. roubaudianum* Zone.

In 1968, however, Le Hégarat (in Le Hégarat & Remane, 1968) brought into evidence that the real *S. (S.) boissieri* only occurs in the upper part of the interval occupied by the *S. boissieri* Zone in the sense of the Colloquium. He thought it therefore unprofitable, even erroneous, to maintain this species as an index for the biostratigraphic unit between the *P. grandis* and *Th. roubaudianum* zones. In 1971, consequently, he subdivided the interval previously occupied by the *S. boissieri* Zone sensu 'Colloque sur le Crétacé inférieur' (1965) (= sensu Kilian, 1888) into a lower *S. occitanica* Zone and an upper *S. boissieri* Zone; he adapted the concept of the *S. boissieri* Zone to the range of its index species. So there are two *S. boissieri* Zones now, one sensu Kilian (1888), the other sensu Le Hégarat (1971). This condition facilitates confusion, which becomes apparent in the 'Colloque sur la limite Jurassique-Crétacé' (1975) where both senses were used alternatingly.

Though in 1981 the present author still used Le Hégarat's subdivision, the concept of the *S. boissieri* Zone is here restored in its original sense and used as the superzone between the top of the *P. euxinus* Zone and the base of the *Th. roubaudianum* Superzone. The *S. boissieri* Superzone thus conceived is undoubtedly a well defined biostratigraphic unit comprising exactly one broad high of the ammonite diversity graph bounded by two conspicuous diversity minima, each of which is at the same time the beginning of a rather quick and radical renewal of the ammonite fauna. Only *Sp. (Ng.) paranegreli* is probably present in all subzones of the *S. boissieri* Superzone, but it would not be wise to let the familiar name '*boissieri*' drop in favour of '*paranegreli*'.

Before we can discuss the subdivision of the *S. boissieri* Superzone we have to discuss its limits first.

Upper boundary of the *S. (S.) boissieri* Superzone

Tirnovella alpillensis Subzone

In order to delimit the *S. boissieri* Superzone, it only remains for us to characterize faunistically the *S. boissieri* - *Th. roubaudianum* zonal boundary; its lower boundary is already characterized in the previous chapter.

In SE France the appearance and diversification of the *Th. roubaudianum* ammonite fauna is as abrupt as the almost total disappearance of the *S. boissieri* fauna (Le Hégarat, 1965; Busnardo & Le Hégarat, 1965; Le Hégarat, 1971; Remane & Thieuloy, 1973a, b). No *Th. roubaudianum* ammonites occur in the *S. boissieri* Superzone. The few and rare representatives of the genus *Olcostephanus* that appear in Kilian's (1910) ammonite list of the *S. boissieri* Superzone, are likely derived from those beds of the 'calcaire de Berrias' that either since the 'Colloque sur le Crétacé inférieur' (1965) have rightly been incorporated in the *Th. roubaudianum* Superzone, or that in this paper will be incorporated in that zone. The almost simultaneous appearance of a rather diverse assemblage of representatives of the (sub)genera *Thurmanniceras* (sensu stricto = *Th. thurmanni* group), *Tirnovella* (comprising the *'Th.' pertransiens* and the *'Th.' gratianopolitense* groups), *Kilianella, Sarasinella, Neocomites*, and *Olcostephanus* marks the lower boundary of the *Th. roubaudianum* Superzone in SE France.

In Los Miravetes this faunal change is far less abrupt than in SE France, but nevertheless relatively rapid. Let us follow this change step by step. The peak in the broad middle high of the ammonite diversity graph of Los Miravetes, which comprises the upper part of the *B. paramimouna* Subzone and the lower part of the *B. picteti* Subzone, is followed by a decrease in diversity due to the disappearance (in the 17.3 m thick interval between Y191 and Y230) of:
B. (B.) tzankovi, B. (B.) haemusensis, B. (B.) evoluta, B. (B.) aff. *simplicicostata* (with many fascicules), *B. (B.)* aff. *haemusensis* (only present above the diversity peak), *B. (B.)* n. sp. indet. ex gr. *haemusensis* (only present above the diversity peak), *B. (B.)* n. sp. D (= *B.* aff. *Janus* in Mazenot, 1939, pl. 6, fig. 20, 21) (only present above the diversity peak), *B. (M.) pouyannei, Sp. (Sp.) obliquenodosum, Sp. (Sp.) kiliani laevigatum, Sp. (Sp.) fauriense, Sp. (Sp.) tobleri, Sp. (Sp.) elegans* (only present above the diversity peak), *Sp. (Sp.) drumense* (only present above the diversity peak), *Sp. (Ng.) negreli, Sp. (Ng.) subnegreli, Sp. (Ng.) planissimum* (only one specimen above the diversity peak), *Th. (E.) balkanicum, Th. (K.)* n. sp.? aff. *leptosomum, Th. (K.)* n. sp. B (= cf. *A. malbosi* Pictet, 1867, pl. 14, fig. 2), and *Po. (Ma.)* cf. *curelense*.

Above the diversity peak also begin the ranges of *T. alpillensis, T. donzei, Th. (K.)* n. sp. ex gr. *roubaudianum* (= *K. roubaudi* in Fülöp, 1964, pl. 24, fig. 3), *Sp. (G.)* aff. *bifrons*, and *Th.? (E.?)* n. sp. indet. C, which continue into the overlying subzone.

This decrease in diversity comes about quite rapidly for the ammonite groups that characterize the *S. boissieri* Superzone, but in the course of their severe decline there is the appearance (in bed Y230) and the quite rapid increase in diversity of new ammonite taxa, which were hitherto exclusively attributed to the *Th. roubaudianum* Superzone. In the 5.6 m interval between the top of bed Y230 and the base of bed Y235 appear namely:
Ps. n. sp. (= *N. neocomiensis* in Sayn, 1907, pl. 3, fig. 14), *Th. (K.)* aff. *grossouvrei* (= *K.* aff. *grossouvrei* in Memmi, 1965, pl. 31a, fig. 5), *Th. (K.) retrocostatum, Th. (Th.)* aff. *thurmanni* (= *Th. Thurmanni*, échantillon presque typique, in Sayn, 1907, pl. 5, fig. 14), *Th. (Th.)* sp. indet. A, *T. gratianopolitensis, T.* n. sp. aff. *gratianopolitensis* (= *Th. Thurmanni* in Sayn, 1907, pl. 5, fig. 1 = *Hp. Thurmanni* in Kilian, 1891, pl. 5. fig. 3), *Sr.* n. sp. aff. *trezanensis* (= *N. trezanensis* in Sayn, 1907, pl. 4, fig. 15), *Sr. longi, Th. (Th.)* n. sp. B (= *Hp. Thurmanni* in Kilian, 1891, pl. 4, figs. 2, 3), *Neocomites* sp., *N. premolicus, N.* n. sp.? aff. *neocomiensis* (umbilicus wider than in the typical form).
This association would hitherto have indicated the *Th. roubaudianum* Zone.

Together with these forms appear however: *Sp. (Sp.) tenuicostatum, Sp. (Ki.) incertum*, and *Uhligites* sp. indet. In this interval were also found the last *B. (B.) picteti, Sp. (Sp.) multiforme, Sp. (Sp.)* n. sp.? aff. *kiliani*, and only in bed Y230 were found single specimens of *B. (B.) panini, Sp. (Sp.) kiliani gigas*, and *Bochianites* sp.

This association would hitherto have indicated the *S. boissieri* Superzone.

Between beds Y235 and Y244 appear: *Th. (K.)* n. sp. G (= *Th. (K.) Roubaudi* in Sayn, 1907, pl. 6, fig. 9), *Th. (K.) chamalocense, Th. (K.)* cf. *lucense, Th. (K.)* cf. *collignoni, O. (O.)* sp., *N.* n. sp.? aff. *premolicus*, and *O. (O.)* cf. *sublaevis* (= *A. Astierianus* in Pictet, 1867, pl. 18, figs. 3, 4).

Between beds Y244 and Y258 of this interval appear: *Pr.* cf. *kurdistanense, O. (O.) sakalavensis, O. (O.)* ex gr. *salinarius*, and *N. neocomiensis.*

These forms were hitherto exclusively attributed to the *Th. roubaudianum* Superzone.

However in the entire interval between beds Y235 and Y258 were found in addition to *Th. (E.) paquieri, T. alpillensis*, and the last representatives of *T. donzei, Sp. (Sp.) tenuicostatum, Sp. (Ki.) incertum, B. (B.) callisto, S. (S.) boissieri*, and *S. (S.) rarefurcata* also:

Lp. studeri, Pr. cf. *depressum, Sp. (Sp.)* n. sp. aff. *oppeli* (with 28 close-spaced umbilical tubercles), *Sp. (Ki.)* ex gr. *gratianopolitense, Su. zonarius*, and *Th. (E.?)* n. sp. indet. B, which in Los Miravetes are restricted to this interval. In this interval were also found the last representatives of: *B. (B.) jauberti, B. (B.)* n. sp. indet. B, *Th. (K.)* aff. *pexiptychum* (Uhlig, 1902, non 1882), *Th. (K.)* n. sp. ex gr. *roubaudianum* (= *K. roubaudi* in Fülöp, 1964, pl. 24, fig. 3), and *Sp. (G.)* aff. *bifrons.*

Between the beds Y258 and Y261 only a few loose ammonites were found: upon limestone Y258 were found the last *S. (S.) boissieri* and the first *O. (Mx.?)* sp. indet., which could be derived only from bed Y258, Y259, Y260, or Y261; upon limestone Y259 was sampled the last specimen of *B. (B.) callisto*, which could only be derived from bed Y259, Y258, or Y257. It should be mentioned here that Wiedmann (in Allemann et al., 1975) reported *Sp. (Ng.)* cf. *negreli* from his sample 71 214, which is derived from our bed Y261.

Directly above the disappearance of the last ammonite forms that hitherto would have indicated the *S. boissieri* Superzone, especially *T. donzei, S. (S.) boissieri, S. (S.) rarefurcata, B. (B.) callisto, Sp. (Sp.) tenuicostatum*, and *Sp. (Ki.) incertum*, but below the disappearance of *T. alpillensis* appear (in the 6.8 m thick interval between the tops of the limestones Y261 and Y267): *T. pertransiens* and its morphotype *valdrumensis* Sayn, *T.* n. sp. aff. *gueymardi* (= *Th.* aff. *pertransiens* in Mazenot, 1939, pl. 32, fig. 16), *T.* n. sp.? aff. *alpillensis* (= *T.* aff. *alpillensis* in Arnaud et al., 1981, pl. 1, fig. 1), *Th. (Th.) otopeta, Th. (Th.) allobrogicum, Th. (Th.) salientinum, Th. (Th.)* n. sp.? indet. C (with small umbilicus), *Th. (K.)* n. sp. aff. *bochianense* (= *Th. (K.) bochianensis.* Variété comprimée, in Sayn, 1907, pl. 6, fig. 4), *Th. (K.) grossouvrei, Th. (E.)* cf. *hystricoides*, and *Pr.* n. sp. indet. This ammonite association clearly designates the *T. pertransiens* Subzone of Le Hégarat & Remane (1968). *Sp. (Sp.) correardi* was found only in this interval. Only *Th. (E.) paquieri, Sp. (Sp.)* aff. *guttatum*, and *Spiticeras* spp. continue their ranges above the last *T. alpillensis* (in bed Y267).

The faunal change as scetched here from Los Miravetes is quite different from that of SE France, for directly above the interval that contains the ammonite association of Le Hégarat's *B. picteti* Subzone appear (from bed Y230) almost simultaneously with the first *Lorenziella hungarica* (in bed Y226) the first ammonite forms that hitherto exclusively characterized the *Th. roubaudianum* Superzone. Though the number of the *roubaudianum* ammonite forms is small in the outset, their diversity is already great and increases progressively. Nevertheless, *S. (S.) rarefurcata, S. (S.) boissieri, B. (B.) callisto, T. donzei*, and several species of *Spiticeras* and *Kilianiceras* remain frequent and their ranges continue at least up to bed Y258.

On account of the mixture of ammonites characteristic for the *S. boissieri* Superzone with those characteristic for the *Th. roubaudianum* Superzone, the interval between bed Y230 and the top of limestone Y261 constitutes a well-separable and well-recognizable biostratigraphic unit, which is introduced here as a new Oppel-subzone.

The choice of *B. (B.) callisto* as index for this biostratographic unit would be an unfortunate one, because the faunal composition of this unit is fundamentally different from that of the *B. callisto* Subzone sensu Le Hégarat (in Le Hégarat & Remane, 1968; Le Hégarat, 1971). In Los Miravetes this interval is especially typified by the appearance and the great frequency of *Tirnovella*, such as *T. gratianopolitensis, T. alpillensis, T. donzei*, and *T.* n. sp. aff. *gratianopolitensis* (= *Th. Thurmanni* in Sayn, 1907, pl. 5, fig. 1, = *Hp. Thurmanni* in Kilian, 1891, pl. 5, fig. 3). *T. alpillensis* was chosen as the index species for this biostratigraphic unit, because it is undoubtedly the most common of these species in this unit, in SE France as well as in Los Miravetes.

The *T. alpillensis* Subzone contains the faunal transition, in which the ammonite fauna of the *S. boissieri* Superzone gradually disappears to make room for new faunal elements that gradually, but simultaneously with this disappearance, increase in number and diversity to reach their maximum in the *Th. roubaudianum* Superzone.

The faunal change, brought about by the rapid entry of these new faunal elements and their progressive increase in diversity at the expense of the old ones, is profound and rapid enough to warrant even the delimitation of biostratigraphic units of higher rank than subzone. The ammonite association below bed Y230 is characteristic for the *B. picteti* Subzone of Le Hégarat, which still should remain in the *S. boissieri* Superzone, as it does not contain any ammonite diagnostic for the *Th. roubaudianum* Superzone.

On account of the entry of many ammonite forms diagnostic for the *Th. roubaudianum* Superzone at the base of the *T. alpillensis* Subzone and because several forms that since the work of Sayn (1907) have been considered diagnostic for the *Th. roubaudianum* Superzone were found only in the *Th. alpillensis* Subzone, such as *Th. (K.)* n. sp. G (= *Th. (K.) Roubaudi* in Sayn, 1907, pl. 6, fig. 9), *Th. (K.)* cf. *lucense, Sr. longi, Sr.* n. sp. aff. *trezanensis* (= *N. trezanensis* in Sayn, 1907, pl. 4, fig. 15), this subzone was incorporated in the *Th. roubaudianum* Superzone. In this way the ammonites considered diagnostic for the *Th. roubaudianum* Superzone remain diagnostic for that zone.

Finally also *Th. (Th.)* n. sp. B (= *Hp. Thurmanni* in Kilian, 1891, pl. 4, figs. 2, 3), *Th. (Th.)* sp. indet. A, *N.* aff. *neocomiensis*, and *N.* aff. *premolicus* were collected only from the *T. alpillensis* Subzone.

Correlations of previously proposed boundaries

The virtually total renewal of the perisphinctacean ammonite faunas near the Berriasian-Valanginian boundary has since long been a well-known fact, but the exact unfolding of this renewal has not yet been reported from France. Unfortunately, Wiedmann (in Allemann et al., 1975) could not describe this faunal change correctly from Los Miravetes, because Allemann wrongly assumed that two successive marlstone intervals, which are almost in line due to tectonic dislocations, represented one and the same interval (Grün & Allemann, 1975, p. 149). Because of this error Allemann equated the beds Y220 - 226 with the beds Y259 - 282 with the result that Wiedmann described a fauna for his '*B. callisto* Zone', which in reality is a mixture of the faunas of the *T. alpillensis* Subzone and the overlying *T. pertransiens* Subzone.

This error has important consequences with respect to the biostratigraphic characterization they gave to the Berriasian-Valanginian boundary and probably the main reason for Wiedmann's introduction of the *Th. thurmanni* Zone for the biostratigraphic interval between the last *B. (B.) callisto* and the first *Th. (K.) roubaudianum*. For, according to Wiedmann (1975), *T. pertransiens* would already appear (due to the correlation error) in great numbers at the base of his *B. callisto* Zone and would therefore be unsuitable to function as index for the lowest zone of the Valanginian Stage as well as of the Cretaceous System. He therefore chose the base of his *Th. thurmanni* Zone as such.

However, the base of Wiedmann's *Th. thurmanni* Zone should in reality be chosen at the end of the range of *B. (B.) callisto*, i.e. between the beds Y257 and Y259, but due to this correlation error it was actually drawn between his samples 71 223 (= bed Y277) and 71 224 (= bed Y285) more than 10 m above the entry of *Th. (K.) roubaudianum* and 29 m above the last *B. (B.) callisto*. So the beds that Wiedmann attributed to his *Th. thurmanni* Zone in Los Miravetes entirely fall outside the biostratigraphic interval that the zone was supposed to represent. Moreover, the species *Th. (Th.) thurmanni* (Pictet & Campiche 1860) is difficult to interpret because of the inadequate preservation of the holotype. If '*Th. Thurmanni*, échantillon presque typique', depicted by Sayn (1907, pl. 5, fig. 14; in this paper provisionally referred to as *Th. (Th.)* aff. *thurmanni*), would turn out to be conspecific with the holotype of *Th. (Th.) thurmanni*, as is generally assumed, then the range of *Th. (Th.) thurmanni* would start at the base of the *T. alpillensis* Subzone far below the end of the range of *B. (B.) callisto*.

Allemann's correlation error also perturbed Wiedmann's concept of the *B. callisto* Zone. Wiedmann applied this perturbed concept to the Cañada Lengua sections south of Caravaca, which are very incomplete because of lacunas, but where the ammonite ranges are not disturbed by correlation errors.

The boundary between Le Hégarat's *B. picteti* and *B. callisto* subzones can be correlated with a level close to bed Y230 on account of the end of the acmes of *B. (B.) picteti* and *B. (B.) jauberti*, the beginning of the acmes of *T. alpillensis* and *T. donzei*, and on account of the start of the range of *Lorenziella hungarica* directly below that level (bed Y226). Moreover the part of the association that is composed of reputedly 'Berriasian' ammonites between bed Y230 and the top of limestone Y261 is similar to the one that according to Le Hégarat (1971) would characterize his *B. callisto* Subzone, viz. *S. (S.) boissieri, S. (S.) rarefurcata, B. (B.) callisto, T. alpillensis, T. donzei*, and *Th. (E.) paquieri*. In SE France however, Le Hégarat's *B. callisto* Subzone does not contain ammonite forms that characterize the *Th. roubaudianum* Superzone; only *Th. (K.) chamalocense* has been reported from beds that have been correlated with the *B. callisto* Subzone (Remane & Thieuloy, 1973b). This remarkable circumstance is unexplicable yet. For several French sections, for instance the Berrias section, the existence of a hiatus, along which the main part of the *B. callisto* Subzone and the basal part of the *T. pertransiens* Subzone are missing, may be the explanation (Donze & Le Hégarat, 1965; Le Hégarat & Remane, 1968; Le Hégarat, 1971). This explanation, however, will no longer serve for other sections in SE France, for instance the La Faurie-Pusteau section, in which no trace of a hiatus has been detected. For these sections we must think of collection failure or of facial and ecological factors to account for the absence of 'Valanginian' ammonites.

Whatever it may be, the association, by which the *B. callisto* Subzone, the topmost subzone of the *S. boissieri* Superzone, has been defined, could not be found near Los Miravetes. Conversely, the association that defines the *T. alpillensis* Subzone has not yet been reported from SE France.

When we try to correlate the lower boundary of the *T. pertransiens* Subzone sensu Le Hégarat (in Le Hégarat & Remane, 1968; Le Hégarat, 1971), which has been chosen as the lower boundary of the Valanginian since 1963, several aspects should be taken into account.

Firstly, Le Hégarat characterized the base of the *T. pertransiens* Subzone by the sudden appearance of renownedly 'Valanginian' ammonite forms in SE France. However most of the ammonites, reported by Le Hégarat (1965, 1971) and Le Hégarat & Remane (1968) to occur in the basal part of the *T. pertransiens* Subzone, turn out to appear low in the *T. alpillensis* Subzone, except *T. pertransiens, Th. (Th.) salientinum* and *T.* n. sp. aff. *gueymardi* (= *Th.* aff. *pertransiens* in Mazenot, 1939, pl. 32, fig. 16). The latter characterizes Mazenot's (1939) 'horizon supérieur de Beaucels'.

Secondly, Le Hégarat characterizes his *T. pertransiens* Subzone negatively by the absence of reputedly 'Berriasian' ammonite forms, except *Po. (Po.) nieri*, whose range is overlapping those of *T. pertransiens* and *Th. (Th.) salientinum*. However, Wiedmann (in Allemann et al., 1975) showed in the Cañada Lengua sections that also the end of the ranges of the 'typically Berriasian' *B. (B.) callisto, S. (S.) boissieri, Sp. (Ng.) negreli*, and *Lp. studeri* are just overlapping a few metres the beginning of the range of *T. pertransiens*.

Near Los Miravetes, however, *T. pertransiens* appears in bed Y261, from which Wiedmann (in Allemann et al., 1975) reported the last *S. (Ng.)* cf. *negreli* and from which also the last specimen of *S. (S.) boissieri*, which was found loose upon bed Y258, may be derived. *T.* n. sp. aff. *gueymardi* (= *Th.* aff. *pertransiens* in Mazenot, 1939, pl. 32, fig. 16) appears in the same bed as *T. pertransiens* and is directly followed by the entry of *Th. (Th.) salientinum* in bed Y266b. Therefore the top of limestone Y261 was chosen as the lower boundary of the *T. pertransiens* Subzone. The last *B. (B.) callisto* and *Lp. studeri* were found in Los Miravetes just below bed Y261, viz. in the beds Y259 and Y251 respectively.

When we try to correlate the base of the *Th. otopeta* Zone of Busnardo & Thieuloy (1979), which they regarded as the new base of the Valanginian, it must be taken into account that from the lowest 3 m of the interval attributed to this zone in SE France (beds 170-177 of the Angles section and beds -28 to -23 of the Barret-le-Bas Les Sausses section (Remane & Thieuloy, 1973a; Thieuloy, 1979)) only 'Berriasian' ammonites were reported, viz. *S. (S.) boissieri, B. (B.)* aff. *callisto, T.* cf. and aff. *alpillensis*, and *T.* cf. *donzei. Th. (Th.) otopeta* appears only above these three basal metres together with the sudden massive entry of typically Valanginian ammonite forms, such as *Th. (Th.)* cf. *allobrogicum, Th. (Th.)* cf. and aff. *salientinum, Th. (E.)* cf. *hystricoides*, and in the La Faurie-Pusteau section (Remane & Thieuloy, 1973b) also with *T. pertransiens, T. gratianopolitensis, Th. (Th.) salientinum, Th. (K.)* aff. *pexiptychum*, and *Th. (K.)* cf. *grossouvrei*. This massive entry of renownedly Valanginian forms marks in SE France the base of the *T. pertransiens* Subzone. Also at Los Miravetes these ammonite forms make their appearance in the basal part of the *T. pertransiens* Subzone with the exception of *T. gratianopolitensis*, which appears at the base of the *T. alpillensis* Subzone, and of *Th. (Th.)* aff. *salientinum* and *Th. (K.)* aff. *pexiptychum*, which were not found in the Miravetes section.

However, Thieuloy (1979) and Busnardo & Thieuloy (1979) interpreted their *Th. otopeta* Zone to incorporate the total known range of *B. (M.) foraticostata* (Thieuloy), which starts its range within the basal 3 m that produced only 'Berriasian' ammonites below the massive entry of Valanginian forms. Therefore the lower boundary of the *Th. otopeta* Zone is probably slightly lower than the base of the *T. pertransiens* Subzone and may approximately be correlated with a level at or just below the base of bed Y257, in which the last *T. donzei* was found and which is situated just below the end of the ranges of *B. (B.) callisto* and *S. (S.) boissieri*.

Subdivision of the *S. (S.) boissieri* Superzone

The ostensible faunal jump between the lower and upper fauna of this superzone in SE France, appearing from Le Hégarat's (1971) range charts, is probably caused by particular, local ecological circumstances, which resulted in a great proliferation of *Da. (Da.) dalmasi* and its sexual dimorph *Da. (Da.) punctatum* at the cost of other ammonite species and, consequently, in the differentiation of the *Da. dalmasi* Subzone. In Los Miravetes this jump is far less marked, because it turned out that several of Le Hégarat's ranges should be extended upward, but also downward into the *Da. dalmasi* Subzone. So the successive ammonite faunas shade off into one another in a less perceptible way than Le Hégarat's range charts would suggest; each higher one more and more resembles the uppermost fauna.

The subdivision of the middle diversity high into merely a few subzones, as was done in the outset by Le Hégarat (in Le Hégarat & Remane, 1968), seems the most appropriate solution, but this solution ignores the general stratigrapher's desire of drawing up as many readily recognizable biozones as possible. Should the broad middle diversity high be subdivided into two zones, as was done later by Le Hégarat (1971) and Wiedmann (1975), or into three zones, as was done by the Russian stratigraphers (Drushchits, 1975; Sakharov, 1975; Louppov et al., 1975)? The central portion of the middle high contains, besides its own ammonite species, a mixture of the lower and the upper fauna. The distinction of a separate zone in the middle, in which tuberculated ammonites of the (sub)genera *Neocosmoceras, Euthymiceras, Pomeliceras, Mazenoticeras,* and *Subalpinites* are particularly abundant, is not as rejectable as it seems, but then we have to cope twice with the same difficulty of delimitation. Moreover the representatives of these tuberculated ammonite genera are very rare in Los Miravetes.

The perisphinctacean ammonites from the lower end of the broad middle high in the Miravetes ammonite diversity graph do not occur in its upper end and vice versa. This justifies the distinction of at least two biozones. The *Da. dalmasi* Subzone can be regarded as the transitional subzone between the lower and the upper zone in which the middle diversity high can be divided. It is a question of personal taste whether its faunal affinity is regarded closer to the fauna of the *B. paramimouna* Subzone or the *B. privasensis* Subzone. We chose for the latter solution. The lower zone that can be differentiated in Los Miravetes is therefore equivalent to the *S. occitanica* Zone of Le Hégarat (1917). The upper zone, which contains the diversity peak, appears to be equivalent to the combined *B. paramimouna* and *B. picteti* Subzones of Le Hégarat and approximately equivalent to Wiedmann's '*B. picteti* - *B. malbosi* Zone' (in Allemann et al., 1975). As a consequence, the rank of Kilian's *S. boissieri* Zone has to be altered into superzone.

The upper zone of the *S. boissieri* Superzone should receive a new name, because *S. (S.) boissieri* is not available anymore as its index. Neither are *B. (B.) picteti* (proposed by Wiedmann, 1975), nor *B. (B.) callisto*, nor *B. (M.) paramimouna*. Wiedmann's choice of *B. (M.) malbosi* as a second index for this zone is also an unfortunate one because of the uncertainty of its taxonomical scope. Le Hégarat (1971) complained that the specimens grouped in this species still lack homogeneity. They probably belong to more than one species. Moreover only one badly preserved specimen, tentatively assigned to this species, was found in this zone near Los Miravetes, whereas the ammonites of this zone that closely resemble the smaller specimen of '*A. malbosi*' depicted by Pictet (1867, pl. 14, fig. 2) are here referred to as *Th. (K.)* n. sp. B. The common *B. (B.) jauberti* has the disadvantage that it is difficult to separate from *B. (B.) picteti* with which it may be conspecific. Also *B. (B.) evoluta* is common throughout this zone, but can easily be confounded with *B. (B.) callisto*. Therefore I prefer *S. (S.) rarefurcata* as index for this zone: it is easily identifiable and common in this zone. According to the range charts of Le Hégarat (1971), and ours, this species starts its range near the lower boundary of this zone. Its presence in the *Da. dalmasi* Subzone, from which only one specimen was reported by Wiedmann (sample 71 183 of Allemann et al., 1975, from our bed Y98) in Los Miravetes, does not abate its value as index fossil.

Subthurmannia (Strambergella) occitanica Zone (Le Hégarat, 1971)

Index species: *Subthurmannia (Strambergella) occitanica* (Pictet).

Ammonite fauna

1) Near Los Miravetes this zone produced only few ammonites, which is partly due to the poor exposure of its lower part. As in France it contains: *B. (B.) privasensis, S. (St.) subalpina, S. (St.) clareti*, and *Da. (Da.) punctatum*. In addition to these also *B. (B.)* aff. *privasensis* (= *B. privasensis* in Mazenot, 1939, pl. 2, fig. 4), *Pr. punicum, Sp. (Sp.)* cf. *groteanum, Sp. (Sp.) bulliforme, Sp. (Ng.) paranegreli* n. subsp. (= *Sp. (Ng.) paranegreli*, éch. C, Djanélidzé, 1922, pl. 6, fig. 2), *Sp. (Sp.) kiliani kiliani, Th. (K.) busnardoi, Th. (K.)* n. sp. indet. A (with convex ribs which are not ventrally thickened), and *Th. (K.)* n. sp. indet. C (with lateral tubercles) are at Los Miravetes restricted to this zone. In the sequence near Las Oicas *S. (St.) cisternensis, Th. (K.)* n. sp. H (= *B.* aff. *simplicicostata* Mazenot, 1939, pl. 22, fig. 2), *B. (M.) paramimouna alutensis*, and *Pr. bicostatum* were found exclusively in the interval considered to belong to this zone. Unfortunately the beds from which they were collected could not be correlated exactly with the beds of the Miravetes sequence. In Los Miravetes also *S. (St.) patruliusi, Da. (Da.) dalmasi, Nc. sayni*, and *Neocosmoceras* sp. are restricted to this zone, though they were found also in the next higher zone in SE France (Le Hégarat, 1971).

2) As in France this zone zone has in Los Miravetes *B. (H.) subcallisto* and *S. (St.) floquinensis* in common with the *P. euxinus* Zone, but also one specimen identified as *Ps.* cf. *allobrogensis* was found.

3) Like in France the *S. occitanica* Zone has here the following forms in common with the next higher zone: *B. (B.) moesica, B. (M.) paramimouna paramimouna, S. (S.) gallica, S. (S.) gauthieri, Po. (Ma.) broussei*, and *Sp. (Ng.) subnegreli*. Contrary to Le Hégarat's data, however, the ranges of *B. (B.) evoluta* (which includes *B. ('Picteticeras') moesica* in Le Hégarat, 1971, pl. 39, figs. 10, 11, and the two specimens of *B. paramacilenta* Mazenot, 1939, pl. 20, fig. 3, pl. 21, fig. 1), *B. (B.) picteti, B. (M.) malbosi, Sp. (Ng.) negreli* (from the Oicas sequence), *Th. (E.) isare*, and *Th. (K.)* n. sp. aff. *busnardoi* (tuberculated relative of *Th. (K.) busnardoi*), already start in this zone, whereas *S. (St.) occitanica, S. (S.) berriasensis*, and *Ps. retowskii* continue in Los Miravetes into the next higher zone.

4) Among the long-ranging ammonite species were identified: *Pt. semisulcatum, Hy. serum, Ho. calypso, Ne. carachtheis, Ne. grasianum, L. liebigi, L. juilleti, Pg. quadrisulcatus*, and *Pg. honnoratianus.*

Subdivision of the *S. occitanica* Zone

Like in France the lower part of the *S. occitanica* Zone of Los Miravetes can be differentiated firstly on account of the mixture of the few ammonites inherited from the *P. euxinus* Zone with those that make their appearance above the top of the *P. euxinus* Zone and secondly on account of the common presence of *S. (St.) subalpina*. The upper part can be marked off on account of the presence of *Da. (Da.) dalmasi* and *Da. (Da.) punctatum*. The middle part is however difficult to characterize in Los Miravetes, because it is poorly exposed. For this reason the pattern in the succession of beds in that part of section M (in the Las Oicas region) that is approximately correlatable with this middle part, could not be recovered in Los Miravetes. This correlation is extra thwarted by the incompleteness of this part in section M as a result of slumping and sliding.

Nevertheless the threefold division of the *S. occitanica* Zone as proposed by Le Hégarat (1971) seems well workable and therefore quite acceptable. Le Hégarat's *S. subalpina, B. privasensis*, and *Da. dalmasi* subzones could clearly be recognized in the Los Miravetes area.

Subthurmannia (Strambergella) subalpina Subzone (Le Hégarat & Remane, 1968)

Index species: *Subthurmannia (Strambergella) subalpina* (Mazenot).

The interval that contains the ammonite association that characterizes the *S. subalpina* Subzone is very thin in comparison with the other subzones. It is delimited in Los Miravetes by the first bed (Z206) and the last bed (M62, correlated with Z251) in which *S. (St.) subalpina* was found. In this interval occur also the last *B. (H.) subcallisto*, the last *S. (St.) floquinensis*, the last *Ps.* cf. *allobrogensis*, the first and only *Nc. sayni*, the first *B. (B.) privasensis*, and the first *Pr. punicum*.

In bed Z240 (correlated with bed M55) we enter calpionellid zone C of Remane (1964); sample 71 153 of Allemann et al. (1975) is from this bed.

Berriasella (Berriasella) privasensis Subzone (Le Hégarat & Remane, 1968)

Index species: *Berriasella (Berriasella) privasensis* (Pictet).

Somewhere between bed Z244 and bed Z252 the first *Sp. (Ng.) paranegreli* n. subsp. (= *Sp. (Ng.) paranegreli* éch. C, Djanélidzé, 1922, pl. 6, fig. 2) has been collected, which according to the range chart of Le Hégarat (1971, p. 232), would already designate his *B. privasensis* Subzone. As the last *S. (St.) subalpina* was found in a level correlatable with bed Z251, *Sp. (Ng.) paranegreli* n. subsp. is probably already present in the *S. subalpina* Subzone unless it was actually derived from bed Z252, which cannot be ascertained. The lower boundary of the *B. privasensis* Subzone was therefore provisionally chosen at the top of bed Z251. Unfortunately the stratigraphic position of the lower boundary of this subzone cannot be controlled yet by more ammonite finds and for the time being we have to be content with this meagre characterization of the boundary in Los Miravetes.

The upper boundary of the *B. privasensis* Subzone near Los Miravetes was provisionally delimited by the last occurrence of *S. (St.) clareti* in bed Y39, halfway between samples 71 172 and 71 173 of Allemann et al. (1975). The uppermost part of section Z and the lowermost part of section Y, 250 m west of Z belong to this subzone. They yielded however only a few ammonites. In addition to *B. (B.) privasensis* (whose range started in the *S. subalpina* Subzone), *Sp. (Ng.) paranegreli* n. subsp., and *S. (St.) clareti*, the *B. privasensis* Subzone of the Miravetes sequence produced the first *S. (S.) berriasensis*, whose range continues up to the top of the *B. paramimouna* Subzone, and the first *Pg. honnoratianus*, which was not found in older beds here. In section M (of the Oicas sequence) the interval approximately correlatable with the *B. pri-*

Plate 2

All figures x 1.

Fig. 1. *Subthurmannia (Strambergella) subalpina* (Mazenot), RGM 160 242, beds M53-54 (= Z237-238), *S. subalpina* Subzone (plaster-cast).

Fig. 2. *Berriasella (Berriasella) privasensis* (Pictet), RGM 160 239, Z245, *S. subalpina* Subzone (plaster-cast).

Fig. 3. *Spiticeras (Negreliceras) paranegreli* Djanélidzé nov. subsp. (this subspecies includes éch. C, in Djanélidzé, 1922, pl. 6, fig. 2), G.I.A./J. 9932, beds Z243-252, just below or above the boundary between the *S. subalpina* and *B. privasensis* subzones.

Fig. 4. *Berriasella (Malbosiceras) malbosi* (Pictet), RGM 160 250, bed Y90, *D. dalmasi* Subzone.

Fig. 5. *Berriasella (Berriasella) picteti* (Jacob), RGM 160 240, bed Y57, *D. dalmasi* Subzone (plaster-cast).

Fig. 6. *Lissonia riveroi* (Lisson), RGM 160 247, beds Y169-170, *D. dalmasi* Subzone (plaster-cast).

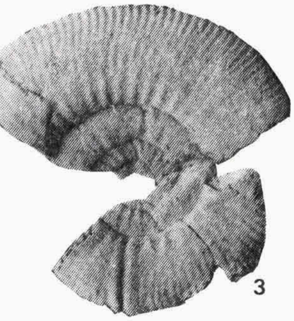
Fig. 7. *Pseudoneocomites retowskyi* (Sarasin & Schöndelmayer), RGM 160 238, bed Y114, *D. dalmasi* Subzone.

Fig. 8. *Dalmasiceras (Dalmasiceras) dalmasi* (Pictet), RGM 160 248, bed Y51, *D. dalmasi* Subzone.

Plate 2


1


2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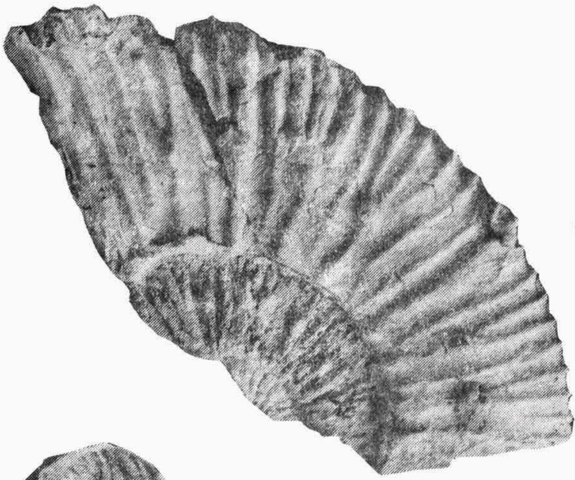
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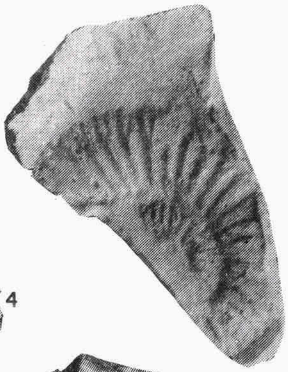
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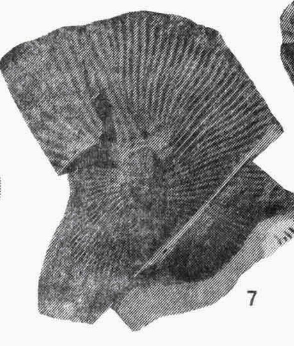
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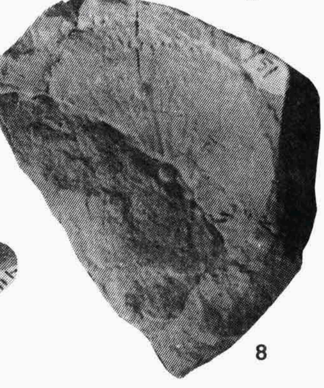
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vasensis Subzone yielded: *S. (St.) cisternensis, Th. (K.)* n. sp. (= *B.* aff. *simplicicostata* Mazenot, 1939, pl. 22, fig. 2), *Pr. bicostatum, B. (M.) paramimouna alutensis*, and, like in the sections Z and Y, *B. (B.) privasensis.*

Dalmasiceras (Dalmasiceras) dalmasi Subzone (Le Hégarat & Remane, 1968)

Index species: *Dalmasiceras (Dalmasiceras) dalmasi* (Pictet).

Lower boundary

Fortunately Le Hégarat's *Da. dalmasi* Subzone is well recognizable by the presence of *Da. (Da.) dalmasi* and its sexual dimorph *Da. (Da.) punctatum*. Le Hégarat (1971) characterized this subzone additionally by the incoming of: *S. (J.) subisaris, B. (M.) paramimouna paramimouna* (Wiedmann, in Allemann et al., 1975, reported the first specimen of this species from their sample 71 177 derived from our bed Y68), *S. (S.) gallica, S. (St.) patruliusi*, and *B. (B.) 'moesica'* Le Hégarat, non Nikolov & Mandov (= *B. (B.) evoluta*). Except for *S. (J.) subisaris*, which in Los Miravetes was found only in the *B. paramimouna* Subzone, these species also appear low in the *Da. dalmasi* Subzone of Los Miravetes. Therefore the lower boundary of the *Da. dalmasi* Subzone was drawn at the base of bed Y44 (sample 71 173 of Allemann et al., 1975) in which the first *S. (St.) patruliusi* was found. If it would turn out, however, that *S. (St.) patruliusi* starts its range in the *B. privasensis* Subzone, the lower boundary of the *Da. dalmasi* Subzone had better be drawn at the base of bed Y51 (sample 71 175), in which the first *Da. (Da.) dalmasi* and the first *S. (S.) gallica* were found.

Upper boundary

According to Le Hégarat (1971) his *Da. dalmasi* Subzone is characterized also by the disappearance of *B. (B.) privasensis, Da. (Da.) punctatum*, and *S. (S.) occitanica*. In Los Miravetes, however, the latter species was also encountered in the *B. paramimouna* Subzone. Of the species that according to Le Hégarat (1971) start their ranges in the *B. paramimouna* Subzone *Th. (E.) isare, Sp. (Ng.) negreli, B. (B.) evoluta* (which includes *B. (B.) moesica* Le Hégarat, non Nikolov & Mandov), *B. (B.) picteti*, and *B. (M.) malbosi* already appear in the lower half of the *Da. dalmasi* Subzone near Los Miravetes. Therefore these species could not possibly be used to characterize the boundary between the *Da. dalmasi* and *B. paramimouna* Subzones. This makes the faunal jump at the *Da. dalmasi* - *B. paramimouna* subzonal boundary far less pronounced than suggested by Le Hégarat's range charts.

Of the other ammonites that according to Le Hégarat (1971) appear in the *B. paramimouna* Subzone, only *B. (B.) jauberti, B. (B.) simplicicostata, B. (M.) pouyannei, Da. (Sa.)* n. sp. (= *Sa.* aff. *aristides* in Le Hégarat, 1971, pl. 53, fig. 1), *S. (S.) boissieri*, and *S. (S.) rarefurcata* begin in this subzone in the Los Miravetes area. To this list should be added *B. (B.) callisto*, which, according to Wiedmann (in Allemann et al., 1975) and our own investigations, appears low in the *B. paramimouna* Subzone. According to Le Hégarat's data, therefore, the boundary between the *Da. dalmasi* and *B. paramimouna* Subzones should be situated between the end of the range of *Da. (Da.) punctatum* in bed Y118 and the first occurrence of *S. (S.) boissieri* in bed Y132.

In bed Y122, however, begins the range of *Th. (E.) zianidia*, which hitherto has been found only together with a *B. paramimouna* ammonite association in the Ouled Mimoun section in Algeria (Pomel, 1889; in bed 313 of Benest et al., 1977). In bed Y122 was also found the last *Th. (K.) busnardoi*, which has hitherto been cited only from the beds of the 'Berriasian moyen' below the Calpionellopsis datum in the Carhaga Valley in Roumania (Patrulius & Avram, 1976); these beds are therefore correlatable with the *S. occitanica* Zone of Le Hégarat. So, on account of these two species the boundary between the *Da. dalmasi* and *B. paramimouna* subzones was drawn at the upper surface of limestone Y122.

This boundary is situated 5.27 m above the bed in which Allemann (sample 71 188 of Allemann et al., 1975 from bed Y115) recorded the first *Calpionellopsis simplex*. Geel (personal communication) found the first *C. simplex* in nearly the same stratigraphic position, viz. in bed Y106, which is only 5.18 m below bed Y115 and 0.80 m below sample 71 186 of Allemann et al. (1975).

I cannot understand why Le Hégarat drew in his columns the boundary between his *Da. dalmasi* and *B. paramimouna* Subzones at the base of the bed in which the first *C. simplex* appears (Berrias: bed 162; Lacisterne: bed 3412; La Garenne: bed 4025. Le Hégarat & Remane, 1968, tables 7-10; Le Hégarat, 1971, pp. 320, 345, 347, tables 17, 20, 21). The stratigraphic position of Le Hégarat's boundary in his columns is in conflict with the ammonite ranges in his tables, for according to his columns the last *Dalmasiceras* of the *dalmasi-punctatum* dimorphic pair occurs above the *C. simplex* datum, but still below the entry of *B. (B.) jauberti, B. (M.) pouyannei, Da. (Sa.)* n. sp. (= *Sa.* aff. *aristides* in Le Hégarat, 1971, pl. 53, fig. 1), and *S. (S.) boissieri*, which have not yet been reported to be associated with *Da. (Da.) dalmasi*. We may therefore assume that *Da. (Da.) dalmasi* disappears before the beginning of the *B. paramimouna* Subzone.

Ammonite fauna

In addition to the species already mentioned in relation to the delimitation of the *Da. dalmasi* Subzone, we should mention that in Los Miravetes *Th. (K.)* sp., *Th. (K.) busnardoi, Th. (K.)* n. sp. indet. A (with convex ribs without ventral thickenings), *Th. (K.)* n. sp. indet. C (with lateral nodes), *S. (St.) patruliusi* (also found in the *B. paramimouna* Subzone in SE France), *Da. (Da.) dalmasi, Da. (Da.) punctatum, Sp. (Sp.)* cf. *groteanum, Sp. (Sp.) bulliforme, Sp. (Sp.) kiliani kiliani, B. (B.)* aff. *privasensis* (= *B. privasensis* in Mazenot, 1939, pl. 2, fig. 4), and *Po. (Po.)* sp. indet. were only found in this subzone, whereas the ranges of *Th. (K.)* n. sp. aff. *busnardoi* (tuberculated relative of *Th. (K.) busnardoi), B. (B.) moesica, Ps. retowskii, Ne. grasianum*, and *Hy. tethys* continue into the *B. paramimouna* Subzone or higher.

Although reported from lower beds elsewhere, *Ho. calypso, Po. (Ma.) broussei*, and *Sp. (Ng.) subnegreli* appear for the first time in the *Da. dalmasi* Subzone of Los Miravetes, whereas the last specimen of *Neocosmoceras* was sampled in this subzone.

In Los Miravetes the first *S. (S.) berriasensis* was collected from the *B. privasensis* Subzone. In the *Da. dalmasi* Subzone no specimens of this species were found, but in the *B. paramimouna* Subzone two specimens were collected that were identified as '*Neocomites* sp. ind. aff. *N. neocomiensis* (d'Orb.)' échantillon No 2 in Mazenot, 1939, pl. 35, fig. 3 from the upper Berriasian of Eygalières. Le Hégarat (1964, 1971) included this form in his *'Tirnovella' berriasensis*. If this inclusion is justified, as it seems, the range of *S. (S.) berriasensis* should be extended upward into the *B. paramimouna* Subzone.

Correlations of the *S. (St.) occitanica* Zone

So the ammonite association diagnostic for the *S. occitanica* Zone was found between the base of bed Z206 (sample 71 146 of Allemann et al., 1975) and the top of bed Y122 (sample 71 189). The stratigraphic interval containing the diagnostic *S. subalpina* association is limited by the base of bed Z206 and the top of bed Z251; it is only 13.79 m thick. The interval with the diagnostic *B. privasensis* association is limited by the top of bed Z251 (sample 71 156) and the top of bed Y39 (halfway between samples 71 172 and 71 173); it comprises an interval of at least 31 m, but which may be some 40 m thick. The interval that yielded the diagnostic *Da. dalmasi* association is limited by the base of bed Y44 (sample 71 173) and the top of bed Y122 (sample 71 189); it is 44.63 m thick. No ammonites were found in the 2.05 m thick interval between the top of bed Y39 and the base of bed Y44.

As we have seen, Allemann et al. (1975) erroneously correlated their sample 71 166 of their section B (Grün & Allemann, 1975), which is the lower boundary of Wiedmann's *'B. privasensis* Zone', with a level 1 m above their sample 71 143 of their section A. This latter sample marks the lower boundary of Allemann's *Calpionella elliptica* Zone, but is also situated 10 cm below the top of the interval to which the *P. euxinus* ammonite association is restricted. Like Le Hégarat (1971) also Wiedmann (in Allemann et al., 1975) let the upper boundary of his *'B. privasensis* Zone' coincide with the lower boundary of Allemann's *Calpionellopsis* Zone (their sample 71 188). Therefore Wiedmann's *'B. privasensis* Zone' is the exact faunistical and stratigraphical equivalent of Le Hégarat's *S. occitanica* Zone and consequently abandoned as a junior synonym of the latter.

According to the correlations of Le Hégarat & Remane (1968), Le Hégarat (1971), Allemann et al. (1975), and Allemann & Remane (1979), the interval occupied by the *C. elliptica* Zone would be exactly equivalent to the *S. occitanica* Zone. We have argued that, with respect to the ammonites, the upper boundary of the *Da. dalmasi* Subzone and consequently of the *S. occitanica* Zone should be shifted a little upward: in section Y, for instance, 10.45 m above the *Calpionellopsis simplex* datum. The upper quarter of the *Da. dalmasi* Subzone can therefore be correlated with the lowest part of the *Calpionellopsis* Zone.

Subthurmannia (Subthurmannia) rarefurcata Zone (designated herein)

Index species: *Subthurmannia (Subthurmannia) rarefurcata* (Pictet).

The reason for a new name for this biozone and the choice of that name are discussed in the paragraph on the subdivision of the *S. boissieri* Superzone. Its lower boundary is also the upper boundary of the *S. occitanica* Zone; its upper boundary is also the upper boundary of the *S. boissieri* Superzone. Remains only the enumeration of its ammonite fauna, the discussion of its subdivision, and its correlations.

Ammonite fauna

1) In accordance with the range charts of Le Hégarat (1971) the following species are confined to this zone in Los Miravetes: *B. (B.) simplicicostata, B. (B.) panini, B. (M.) pouyannei, S. (J.) discrepans*, and *Da. (Sa.)* n. sp. (= *Sa.* aff. *aristides* in Le Hégarat, 1971, pl. 53, fig. 1). Although found in earlier subzones by Le Hégarat, *Po. (Ma.)* cf. *curelense, Po. (Ma.)* cf. *malbosiforme, S. (J.) jabronensis*, and *S. (J.) subisaris* were found restricted to the *S. rarefurcata* Zone of Los Miravetes.

In contrast with Le Hégarat's range charts also: *S. (S.) latecostata* and *S. (S.)* n. sp. aff. *romani* (= *T. romani* in Le Hégarat, 1971, pl. 49, fig. 4) were found only in this zone. Apart from these also the following forms are restricted to the *S. rarefurcata* Zone of Los Miravetes: *B. (B.) haemusensis, B. (B.)* n. sp. aff. *haemusensis* (with small umbilicus and many fasciculated ribs), *B. (B.)* n. sp. indet. ex gr. *haemusensis, B. (B.) tzankovi, B. (B.)* n. sp. ex gr. *tzankovi, B. (B.)* n. sp. aff. *simplicicostata* (with small umbilicus and many fasciculated ribs), *B. (B.)* n. sp. D (= *B.* aff. *Janus* in Mazenot, 1939, pl. 6, figs. 20, 21), *B. (B.)* n. sp. E (= *B.* aff. *simplicicostata* Mazenot, 1939, pl. 22, fig. 1), *B. (B.)* aff. *callisto* (small umbilicus, projected ribs, not flexuous ribs), *B. (B.)* n. sp. ex gr. *callisto* with fasciculated ribs), *B. (B.)* n. sp.? aff. *jauberti* (with ventrally thickened ribs like *B. (H.) berthei), B. (B.)* n. sp. indet. A (heterocostate with straight clavate ribs in the adult stage), *B. (B.)* n. sp. indet. C (with distant flexuous ribs and intercalatories), *B. (M.)* n. sp. (= *B.* sp. gr. de *B. Chaperi* éch. 3 in Mazenot, 1939, pl. 10, fig. 5), *Th. (K.)* aff. *chamalocense, Th. (K.)* n. sp.? aff. *retrocostatum, Th. (K.)* cf. *koellikeriforme, Th. (K.)* n. sp.? aff. *leptosomum, Th. (K.)* n. sp.? D (= *Hp.* n. f. cfr. *barowae* in Parona, 1897, pl. 2, fig. 3), *Th. (K.)* n. sp. E (= *B. oxycostata* in Mazenot, 1939, pl. 3, fig. 10), *Th. (K.)* n. sp. B (= cf. *A. Malbosi* Pictet, 1867, pl. 14, fig. 2), *Th. (E.) zianidia, Th. (E.) balkanicum, Th. (E.)* n. sp.? aff. *isare* (close-ribbed with lateral tubercles in young), *Th. (E.)* n. sp. indet. A., *Sp. (Sp.) obliquenodosum, Sp. (Sp.) fauriense, Sp. (Sp.) kiliani laevigatum, Sp. (Sp.) tobleri, Sp. (Sp.) drumense, Sp. (Sp.)* cf. *kiliani gigas, Sp. (Sp.)* cf. *scriptum, Sp. (Sp.) elegans, Sp. (Ng.) planissimum, Sp. (Ng.) paranegreli paranegreli, Sp. (G.) rocardi, Dalmasiceras* sp. indet., *Dalmasiceras* sp., *Riasanites*? sp., *Lissonia riveroi*, and *Bochianites* sp.

2) Conform to Le Hégarat's range charts the *S. rarefurcata* Zone of Los Miravetes contains the last *B. (B.) moesica, B. (M.) paramimouna paramimouna, S. (S.) gallica, S. (S.) gauthieri, Sp. (Ng.) subnegreli*, and *Po. (Ma.) broussei*, which had their start in an earlier zone. In contrast with the range charts of Le Hégarat (1971) *B. (B.) evoluta, B. (M.) malbosi, Sp. (Ng.) negreli*, and *Th. (E.) isare* appear in an earlier zone. As in SE France they have their end in the *S. rarefurcata* Zone.

At variance with the data of Le Hégarat (1971) the ranges of *S. (St.) occitanica* and *S. (S.) berriasensis* continue into this zone. Apart from these ammonite forms the *S. rarefurcata* Zone has also *Th. (K.)* n. sp. aff. *busnardoi* (tuberculated relative of *Th. (K.) busnardoi*) and *Ps. retowskii* in common with the preceeding zone.

3) In harmony with Le Hégarat's range charts the following forms continue their ranges into the next higher zone: *B. (B.) callisto, S. (S.) rarefurcata, S. (S.) boissieri, Th. (E.) paquieri*, and *T. alpillensis*. Apart from these forms also *B. (B.) jauberti, B. (B.)* n. sp. indet. B (with many simple ribs and many constrictions), *Th. (K.)* n. sp. ex gr. *roubaudianum* (= *K. roubaudi* in Fülöp, 1964, pl. 24, fig. 3), *Th. (K.)* n. sp. aff. *grossouvrei* (= *K.* aff. *grossouvrei* in Memmi, 1965, pl. 31a, fig. 5), *Th. (K.)* aff. *pexiptychum* (Uhlig, 1902, non 1882), *Th.? (E.?)* n. sp. indet. (relatively narrow umbilicated, bituberculated berriasellid with fasciculated ribs in the adult), *Sp. (Sp.)* n. sp. aff. *kiliani*, and *Sp. (G.)* aff. *bifrons* continue their

ranges into the following zone.

Contrary to the ranges given by Le Hégarat (1971) the last specimen of *Sp. (Sp.) multiforme* was found just above the upper boundary of the *S. rarefurcata* Zone, where as the range of *T. donzei* begins in this zone.

4) The range of *B. (B.) picteti* already starts in the *Da. dalmasi* Subzone and ends just above the upper boundary of the *S. rarefurcata* Zone. Among the long-ranging species the following were collected from the *S. rarefurcata* Zone: *Pt. semisulcatum, Ho. calypso, Hy. serum, Hy. tethys, L. liebigi, L. juilleti, Pg. quadrisulcatus, Pg. honnoratianus, Ne. carachtheis*, and *Ne. grasianum*.

Subdivision of the *S. (S.) rarefurcata* Zone

Le Hégarat (in Le Hégarat & Remane, 1968; Le Hégarat, 1971) has distinguished two subzones in the interval occupied by our *S. rarefurcata* Zone, viz. a lower *B. paramimouna* Subzone and an upper *B. picteti* Subzone. These subzones are, however, difficult to distinguish, because the ammonites of these subzones constitute the peak in the diversity maximum of the *S. boissieri* Superzone. The faunal difference between these subzones is small and can only be detected when large faunas are collected. Wiedmann (in Allemann et al., 1975), therefore, did not subdivide the interval that he correlated with these subzones. Nevertheless the difference between the ammonite faunas of the lower and upper part of this interval in Los Miravetes is great enough to warrant the distinction of two separate subzones, for which we use the definitions given by Le Hégarat (1971).

In accordance with these definitions the stratigraphic position of the boundary between the *B. paramimouna* and *B. picteti* subzones in Los Miravetes was chosen within the smallest interval between the disappearance of *Po. (Ma.) broussei, B. (B.) moesica, B. (M.) paramimouna paramimouna, S. (S.) gauthieri, S. (J.) jabronensis, S. (J.) subisaris, Th. (E.) isare*, and *Da. (Sa.)* n. sp. (= *Sa.* aff. *aristides* in Le Hégarat, 1971, p. 53, fig. 1) and the appearance of *Th. (E.) paquieri*, but also between the end of the acme of *S. (S.) gallica* and *B. (M.). malbosi*, and the beginning of the acme of *B. (B.) simplicicostata, B. (B.) picteti, S. (S.) rarefürcata*, and *S. (S.) boissieri*.

This interval embraces bed Y170, in which the acmes of *S. (S.) rarefurcata*

Plate 3

All figures x 1.

Fig. 1. *Dalmasiceras (Dalmasiceras) punctatum* (Djanélidzé) and *Neolissoceras grasianum* (d'Orbigny), RGM 160 249, bed Y90, *D. dalmasi* Subzone.

Fig. 2. *Thurmanniceras (Erdenella) zianidia* (Pomel), RGM 160 253, bed Y122, base of the *B. paramimouna* Subzone.

Fig. 3. *Berriasella (Berriasella) callisto* (d'Orbigny), RGM 160 241, bed X197, *B. paramimouna* Subzone.

Fig. 4. *Berriasella (Malbosiceras) paramimouna paramimouna* (Mazenot), RGM 160 251, bed X1 (= Y150), *B. paramimouna* Subzone.

Fig. 5. *Subthurmannia (Strambergella) occitanica* (Pictet), RGM 160 243, bed X1 (= Y150), *B. paramimouna* Subzone (plaster-cast).

Plate 3

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and *S. (S.) boissieri* begin, bed Y171 with the first *Th. (E.) paquieri* and with the last *S. (S.) gallica* and *Da. (Sa.)* n. sp. (= *Sa.* aff. *aristides* in Le Hégarat, 1971, pl. 53, fig. 1), and bed Y172 with the last *B. (B.) moesica* and the beginning of the acme of *B. (B.) simplicicostata*. The boundary was drawn at the top of limestone Y171.

Berriasella (Malbosiceras) paramimouna Subzone (Le Hégarat & Remane, 1968)

Index species: *Berriasella (Malbosiceras) paramimouna paramimouna* Mazenot.
1) In accordance with the range charts of Le Hégarat (1971) *Da. (Sa.)* n. sp. (= *Sa.* aff. *aristides* in Le Hégarat, 1971, pl. 53, fig. 1) is restricted to the *B. paramimouna* Subzone of Los Miravetes. Also *Th. (E.) zianidia* is confined to this subzone in Los Miravetes. The restriction of *Po. (Ma.)* cf. *malbosiforme, S. (J.) jabronensis*, and *S. (J.) subisaris* to this subzone in Los Miravetes may be due to collection failure, for in SE France their ranges start in the *S. occitanica* Zone. Also the restriction of *B. (B.)* n. sp. E (= *B.* aff. *simplicicostata* Mazenot, 1939, pl. 22, fig. 1), and *Th. (K.)* n. sp. E (= *B. oxycostata* in Mazenot, 1939, pl. 3, fig. 10) to this subzone may be due to collection failure, because Le Hégarat (1971, p. 168) mentions these forms only from his *B. picteti* Subzone. Apart from these forms also the following are found restricted to the *B. paramimouna* Subzone: *B. (B.)* aff. *callisto* (small umbilicus, projected ribs, no flexuous ribs), *B. (B.)* n. sp. ex gr. *callisto* (with fasciculated ribs; one specimen of uncertain identification was collected in the *B. picteti* Subzone), *B. (B.)* n. sp.? aff. *jauberti* (with ventrally thickened ribs like *B. (H.) berthei), B. (B.)* n. sp. indet. A (heterocostate with straight clavate ribs in the adult), *B. (B.)* n. sp. indet. C. (with distant flexuous ribs and intercalatories reminiscent of *Blanfordiceras), B. (M.)* n. sp. (= *B.* gr. de *B. Chaperi* éch. 3 in Mazenot, 1939, pl. 10, fig. 5), *Th. (K.)* cf. *koellikeriforme, Th. (K.)* aff. *chamalocense, Sp. (G.) rocardi, Dalmasiceras* sp., *Dalmasiceras* sp. indet., and *Li. riveroi* (one specimen of uncertain identification was found in the *Da. dalmasi* Subzone).

2) Similar to Le Hégarat's ranges (1971) the *B. paramimouna* Subzone of Los Miravetes contains the last *B. (B.) moesica, B. (M.) paramimouna paramimouna, Po. (Ma.) broussei, S. (S.) gauthieri*, and *Th. (E.) isare*. Also the last *Ps. retowskii* was found in this subzone. *S. (S.) gallica* was not found above the *B. paramimouna* Subzone in Los Miravetes as it was in SE France. As distinot from the ranges given by Le Hégarat (1971) those of *S. (S.) berriasensis* and *S. (St.) occitanica* also have their end in the *B. paramimouna* Subzone of Los Miravetes.

Plate 4

All figures x 1.
Fig. 1. *Subthurmannia (Subthurmannia) rarefurcata* (Pictet), RGM 160 244, bed X30 (= Y171), base of *B. picteti* Subzone (plaster-cast).
Fig. 2. *Riasanites*? sp., RGM 160 252, bed Y167, *B. paramimouna* Subzone.
Fig. 3. *Spiticeras (Groebericeras)* aff. *Sp. (G.) bifrons* (Leanza), RGM 160 276, beds Y186-195, *B. picteti* Subzone.
Fig. 4. *Subthurmannia (Subthurmannia) boissieri* (Pictet), RGM 160 245, bed Y219, *B. picteti* Subzone (plaster-cast).

Plate 4


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3) In accordance with the range charts of Le Hégarat (1971), the *B. paramimouna* Subzone of Los Miravetes the first *B. (B.) simplicicostata, B. (B.) jauberti, B. (M.) pouyannei, S. (S.) boissieri*, and *S. (S.) rarefurcata* (one specimen was reported from the *Da. dalmasi* Subzone of Los Miravetes by Wiedmann, in Allemann et al., 1975) were found.

At variance with the findings of Le Hégarat (1971) *B. (B.) callisto* appears rather low in the *B. paramimouna* Subzone of Miravetes. In addition to these species also *Th. (K.)* n sp.? D (= *Hp.* n. f. cfr. *barowae* in Parona, 1897, pl. 2, fig. 3), *Th. (K.)* aff. *pexiptychum* (Uhlig, 1902, non 1882), *Th. (K.)* n. sp.? aff. *leptosomum, Th. (E.) balkanicum, Th. (E.)* n. sp. indet. A, *B. (B.) haemusensis, Sp. (Sp.) paranegreli paranegreli*, and *Sp. (Sp.) kiliani laevigatum* appear in this subzone in Los Miravetes. Probably due to collection failure *Ho. calypso* was not found below the *B. paramimouna* Subzone in Los Miravetes.

4) As opposed to the data of Le Hégarat (1971) the ranges of *B. (B.) picteti, B. (B.) evoluta*, and *B. (M.)* cf. *malbosi* cross the lower as well as the upper boundary of the *B. paramimouna* Subzone.

Berriasella (Berriasella) picteti Subzone (Le Hégarat & Remane, 1968)

Index species: *Berriasella (Berriasella) picteti* (Jacob).

1) In accordance with the findings of Le Hégarat (1971) *B. (B.) panini* is confined to the *B. picteti* Subzone of Los Miravetes.

Contrary to Le Hégarat's findings *Po. (Ma.)* cf. *curelense* and *S. (J.) discrepans* were found only in this subzone, whereas these forms were not reported from beds above the *B. paramimouna* Subzone of SE France. Apart from these forms also the following forms were found to be restricted to the *B. picteti* Subzone of Los Miravetes: *B. (B.) tzankovi, B. (B.)* n. sp. aff. *haemusensis, B. (B.)* n. sp. aff. *simplicicostata, B. (B.)* n. sp. ex gr. *tzankovi, B. (B.)* n. sp. D (= *B.* aff. *Janus* in Mazenot, 1939, pl. 6, figs. 20, 21), *B. (B.)* n. sp. ex gr. *haemusensis, Th. (E.)* n. sp. indet. A, *Th. (E.)* n. sp.? aff. *isare* (close-ribbed with lateral tubercles in young), *Th. (K.)* n. sp.? aff. *retrocostatum, Th. (K.)* n. sp. B (= cf. *A. Malbosi* Pictet, 1867, pl. 14, fig. 2), *S. (S.) latecostata, Sp. (Sp.) obliquenodosum, Sp. (Sp.) elegans, Sp. (Sp.) fauriense, Sp. (Sp.)* cf. *scriptum, Sp. (Sp.) tobleri, Sp. (Sp.) drumense, Sp. (Ng.) planissimum*, and *Bochianites* sp.

2) In accordance with the range charts of Le Hégarat (1971) this subzone contains the last *B. (B.) evoluta, B. (M.)* cf. *malbosi, Sp. (Ng.) paranegreli paranegreli, Sp. (Ng.) subnegreli*, and *Sp. (Ng.) negreli*. In this respect it should be mentioned that Wiedmann (in Allemann et al., 1975) reported *Sp. (Ng.)* cf. *negreli* from his sample 71 214, which is derived from our bed Y261, which is the top of our *T. alpillensis* Subzone.

Contrary to Le Hégarat's findings the range of *B. (M.) pouyannei* continues into the *B. picteti* Subzone. The B. picteti Subzone of Los Miravetes has also the following forms in common with the *B. paramimouna* Subzone: *B. (B.) haemusensis, Th. (K.)* n. sp.? D (= *Hp.* n.f. cfr. *barowae* in Parona, 1897, pl. 2, fig. 3), *Th. (K.)* n. sp.? aff. *leptosomum, Th. (E.) balkanicum, Th. (E.)* n. sp. indet. A, and *Sp. (Sp.) kiliani laevigatum*.

3) Like in France (Le Hégarat, 1971), the ranges of *Th. (E.) paquieri* and *T. alpillensis* begin in the *B. picteti* Subzone and continue into the following zone, but also the ranges of *Sp. (Sp.) multiforme*, which according to Le Hégarat (1971) begins in the *B. paramimouna* Subzone, and of *T. donzei*, which according to Le Hégarat (1971) would begin above the upper boundary of the *B. picteti* Subzone, cross the upper boundary of the *B. picteti* Subzone.

ed berriasellid with fasciculated ribs in the adult), *B. (B.)* n. sp. indet. B (with many simple ribs and constrictions), *Sp. (Sp.)* n. sp. aff. *kiliani*, and *Sp. (G.)* aff. *bifrons* appear in the *B. picteti* Subzone of Los Miravetes and continue into the next higher zone.

4) Just as in France (Le Hégarat, 1971), the ranges of *S. (S.) boissieri* and *S. (S.) rarefurcata* cross the lower as well as the upper boundary of the *B. picteti* Subzone. In Los Miravetes, however, the range of *B. (B.) callisto* also crosses both boundaries, though Le Hégarat (1971) has not found this species in the *B. paramimouna* Subzone of SE France.

Contrary to the range charts of Le Hégarat (1971) *B. (B.) picteti* and *B. (B.) jauberti* were found to continue their ranges into the *T. alpillensis* Subzone. Finally also the range of *Th. (K.)* aff. *pexiptychum* (Uhlig, 1902, non 1882) crosses the lower as well as the upper boundary of the *B. picteti* Subzone near Los Miravetes.

Correlations of the *S. (S.) rarefurcata* Zone

The ammonite association diagnostic for the *S. rarefurcata* Zone was found between the top of limestone Y122 (sample 71 189 of Allemann et al., 1975) and the top of limestone Y230 (1.5 m below sample 71 208). This zone is 68.24 m thick. The interval that contains the diagnostic *B. paramimouna* association is limited by the top of limestone Y122 and the top of limestone Y171 (halfway between samples 71 197 and 71 198); this interval is 36.58 m thick. The interval containing the diagnostic *B. picteti* association is limited by the top of limestone Y171 and the top of limestone Y230, thus comprising a thickness of 31.66 m.

Grün (in Grün & Allemann, 1975) found the first coccolithophorid *Retacapsa crenulata* and the first *Speetonia colligata* in the same sample, viz. 71 197 (our bed Y169), only 2.2 m below the top of the *B. paramimouna* Subzone. Thierstein (1975), however, correlated the lowest occurrence of *R. crenulata* in SE France approximately with the base of the *B. paramimouna* Subzone, which Le Hégarat (1971) and Wiedmann (in Allemann et al., 1975) drew at the base of the bed in which the first *Calpionellopsis simplex* appears (in bed Y106, 44.8 m below bed Y169). This not unimportant discrepancy between the data of Grün and Thierstein may be due to the mediocre preservation of the coccolites in the Argos sections.

The *S. rarefurcata* Zone plus the upper quarter of the *Da. dalmasi* Subzone approximately correspond with Remane's calpionellid subzones D1 and D2. The first *C. simplex* was found 10.45 m below the base of the *S. rarefurcata* Zone, whereas Geel (personal communication) reported the first *Lorenziella hungarica* from bed Y226, just below the upper boundary of the *S. rarefurcata* Zone. Also in Berrias and La Cisterne (SE France) the *L. hungarica* datum is approximately the level where Le Hégarat drew the lower boundary of his '*B. callisto* Subzone' (Le Hégarat & Remane, 1968; Le Hégarat, 1971; Allemann & Remane, 1979).

Thurmanniceras (Kilianella) roubaudianum Superzone (Kilian, 1888)

Index species: *Thurmanniceras (Kilianella) roubaudianum* (d'Orbigny).

History and subdivision

Kilian (1888) made it clear that the ammonite fauna reported by Leenhardt (1883) from the 'marnes et calcaires marneux à *Ammonites neocomiensis*' could be subdivided into two successive units with distinct ammonite associations: the lower unit he called 'marnes à *Ammonites Roubaudi* et *neocomiensis*', which he referred to as zone, the upper 'calcaires marneux à *Ammonites Jeannoti*', which he regarded as the transition between the 'marnes à *Am. Roubaudi*' and the 'couches à *Crioceras Duvali*'. In 1896 he changed the designation of the upper unit into 'calcaires marneux à *Hoplites regalis* et *amblygonius*'.

Due to better fossil material Lory (1898) was able to recognize that the upper part of Kilian's 'Marnes à *Roubaudi* et *neocomiensis*', or 'Marnes à Ammonites ferrugineuses' as Lory called it, had better be separated from the lower part and included in his upper Valanginian 'Zone à *Hoplites neocomiensis* d'Orb. sp. var., *Hopl.* gr. de *regalis* Pavl. et *amblygonius* N. et Uhl., *Saynoceras verrucosum* d'Orb. sp.'; Paquier (1900) rebaptized the latter unit in 'Zone à *Duvalia Emerici* et *Saynoceras verrucosum*'. The lower part of Kilian's 'Marnes à *Roubaudi*' was referred to by Lory as 'Zone à *Duvalia lata* Blainv. sp., *Hoplites pexiptychus* Uhl. etc.' (he considered *Th. (K.) roubaudianum* as a subjective synonym of *Th. (K.) pexiptychum*), which represented the lower Valanginian and which Paquier (1900) rebaptized in 'Zone à *Duvalia conica* et *Hoplites pexiptychus*'.

Lory (1898) preferred to distinguish two separate faunal associations in his upper Valanginian zone, viz. a lower 'Niveau à *Saynoceras verrucosum* d'Orb. sp.' situated in the upper part of the 'Marnes à Ammonites ferrugineuses' and an upper 'Niveau à *Hoplites* cf. *longinodus* N. et Uhl.', which he equated with Kilian's 'Calcaires marneux à *Hoplites regalis* et *amblygonius*'. According to Paquier (1900), however, the latter fauna did not warrant its separation as an independent biostratigraphic unit. Nevertheless he referred to it as 'calcaires marneux à *Hoplites neocomiensis*'.

After Sayn (1901, 1907) had given the descriptions of the pyritized ammonites of the Valanginian marls (i.e. of the interval occupied by the 'marnes à *Am. Roubaudi*' of Kilian, 1888) and their distribution, Kilian (1907, 1910), who adopted Paquier's subdivision, finally produced extensive faunal lists of the fossil associations that characterize the various zones. By this, these zones were sufficiently diagnosed. The *Th. roubaudianum* Zone became equivalent to the lower Valanginian, the *Sn. verrucosum* Zone to the upper Valanginian. Since then the faunal concepts of these zones have not changed until the 'Colloque sur le Crétacé inferieur' (1965).

During this colloquium Busnardo (in Debelmas & Thieuloy, 1965) proposed, on the evidence provided by the geological mapping of Flandrin and his pupils, the 'zone à *Lyticoceras* l.s. sp.', which contains Paquier's 'calcaires marneux à *Hoplites neocomiensis*'. Busnardo preferred, regarding the evolution of the neocomitids, to place this zone at the base of the Hauterivian, the more so as it contains the first crioceratids (*Himantoceras* Thieuloy, 1964). Busnardo's view as to the stratigraphic position of the Valanginian-Hauterivian boundary was accepted by the attendants of the colloquium. Thus the *Sn. verrucosum* Zone sensu 'Colloque sur le Crétacé inférieur' (1965) became, with respect to its diagnostic ammonite association, equivalent to the original concept of the *Sn. verrucosum* Zone sensu Lory (1898). However, Busnardo's view was afterwards rejected by Moullade (1966) and Moullade & Thieuloy (1967a), who returned to the view of Lory, Kilian, and Paquier.

In 1966 Moullade also proposed that the base of the upper Valanginian and of the *Sn. verrucosum* Zone should coincide with the apparition of *Sn. verrucosum*, which has only a very short range. This view was maintained by Moullade & Thieuloy (1967b) and by Thieuloy (1971, 1973, 1977a, b, 1979). At first the upper boundary of the *Th. roubaudianum* Zone was still interpreted to coincide with the base of the *Sn. verrucosum* Zone in the restricted sense of Moullade (cf. Cotillon, 1971; Thieuloy, 1971). It appeared, however, that several ammonite forms previously considered diagnostic for the upper Valanginian *Sn. verrucosum* Zone (Sayn, 1907; Kilian, 1910; Thieuloy, 1971), for instance *Luppovella superba, Bu. campylotoxus, Eristavites platycostatus, Erist. teschenensis, Karakaschiceras quadristrangulatum*, several other species of *Karakaschiceras*, and *Valanginites* made their appearance well below that of *Sn. verrucosum*. These ammonites do not form part of the association diagnostic for the *Th. roubaudianum* Zone in the sense of Lory (1898), Paquier (1900), Sayn (1907), Kilian (1910), and the 'Colloque sur le Crétacé inférieur' (1965). Therefore Moullade and Thieuloy in fact proposed an upward shift of the base of the upper Valanginian. Because of this shift even the so-called 'Calcaire roux' rockunit of the Valanginian stratotype became entirely incorporated in the lower Valanginian (Donze & Thieuloy, 1975; Busnardo & Thieuloy, 1979a). Apparently they adapted the concept of the *Sn. verrucosum* Zone to the range of its index species, by which they changed the faunal characterization and stratigraphic scope of the unit without changing its name. This is against the recommendations of the Hedberg Code (1976).

The discrepancy between the old concept of the upper Valanginian and Thieuloy's concept of this substage is clearly demonstrated by Cotillon (1971, fig. 12 bis), who correlated his rockunits 3-11 with the upper Valanginian *Sn. verrucosum* Zone, whereas Thieuloy (1973, 1977) correlated only the rockunits 10 and 11 with this zone.

Inspired by the upper Valanginian 'horizon à *Neocomites campylotoxus*' of Cotillon (1971), Thieuloy (1973) proposed the 'lower' Valanginian *Bu. campylotoxus* Zone to cover the biostratigraphic interval between the interval occupied by the ammonite association that according to Sayn (1907) and Kilian (1910) characterizes their *Th. roubaudianum* Zone and the entry of *Sn. verrucosum*. In fact all ammonites indicated by Sayn (1907) and Kilian (1910) to occur in the *Sn. verrucosum* Zone form part of the ammonite fauna of the combination of the *Bu. campylotoxus* Zone and the *Sn. verrucosum* Zone sensu Thieuloy (1973, 1977a, 1979), so that the lower boundary of the *Bu. campylotoxus* Zone can in principle be determined by the appearance of the ammonite forms that according to Sayn (1907) and Kilian (1910) constitute their *Sn. verrucosum* ammonite association. In Los Miravetes this happens to be *Bu. campylotoxus*, which appears in bed M258, 24 m above the top of bed Y319. Nevertheless, Thieuloy (1977b) and Busnardo & Thieuloy (1979) still correlated the base of their *Sn. verrucosum* Zone with the base of Lory's *Sn. verrucosum* Zone; the scope of the latter zone however includes Thieuloy's *Bu. campylotoxus* Zone.

Van Hinte (1976) incorporated Thieuloy's *Bu. campylotoxus* Zone in the *Th. roubaudianum* (Super?)zone. This view, which was followed by Kauffmann (1979), is very attractive, as the *Bu. campylotoxus* fauna indeed forms part of the ammonite diversity high of the *Th. roubaudianum* Zone, but also the fauna of the *Sn. verrucosum* Zone sensu Moullade (1966), Moullade & Thieuloy (1967b), and Thieuloy (1971) forms part of this high. The ranges of several pre-*campylotoxus* ammonite forms continue into the *Bu. campylotoxus* Zone and higher, for example *Th. (K.) roubaudianum, Th. (K.) retrocostatum, Th. (K.) lusense, N. neocomiensis, N. subtenuis, T. pertransiens, Sr. trezanensis, Sr. eucyrta, Sr. subquadrata*, and even *Su. zonarius*.

The diversity low between the *roubaudianum* high and the high formed by the ammonites of the *trinodosum-callidiscus-radiatus* zonal group (Thieuloy, 1973, 1977a, b, 1979) is, at least in the Mediterranean subprovince, situated in the biostratigraphic gap between the thin *Sn. verrucosum* Zone sensu Moullade (1966), Moullade & Thieuloy (1967b), and Thieuloy (1971), and the *Hi. trinodosum* Zone of Moullade & Thieuloy (1967). Later this gap has been incorporated in the *Sn. verrucosum* Zone (Thieuloy, 1973, 1977a, 1979; Busnardo & Thieuloy, 1979b). This diversity low is clearly discernable in the ammonite distribution given by Thieuloy (1979) for the Angles section and clearly represents the most important coupure in the Mediterranean faunal succession of the upper Valanginian - lower Hauterivian sequence. *Neocomites* (except *N. neocomiensis*, which has been reported from the basal part of the *Hi. trinodosum* Zone by Thieuloy, 1979), *Kilianella, Neohoploceras* (except *N. schradti* reported from the 'couche à Astieria'), *Tirnovella, Chamalocia, Busnardoites, Paquiericeras, Julianites, Saynoceras, Luppovella, Eristavites* (except *E. teschenensis*, reported from the basal part of the *Hi. trinodosum* Zone by Thieuloy, 1977b), and most representatives of *Sarasinella* and *Karakaschiceras* do not cross that boundary and are replaced by *Teschenites, Eleniceras, Criosarasinella, Oosterella, Pseudoosterella* (only one species was recorded from the *Sn. verrucosum* Subzone by Thieuloy, 1979), *Dicostella, Distoloceras, Himantoceras, Phyllopachyceras*, and perhaps *Eodesmoceras* (Thieuloy, 1977b, 1979). Only most representatives of *Olcostephanus* appear to cross this boundary without noticible change.

Moreover the incorporation of the *Bu. campylotoxus* and *Sn. verrucosum* zones sensu Thieuloy (1973, 1977a, 1979) in a *Th. roubaudianum* Superzone would make the latter correspond faunistically to its original sense (Kilian, 1888 = 'Marnes valanginiennes à Ammonites pyriteuses' of Sayn, 1901, 1907). Therefore there is no reason at all to abandon Kilian's original concept of the *Th. roubaudianum* Zone, nor to abandon Lory's (1898) concept of the *Sn. verrucosum* Zone in its original faunistical sense. Why should we change the original concepts when it is not necessary and especially when they represent real, clearly delimitable steps in the succession of ammonite faunas. Accordingly it is proposed here to restore the *Th. roubaudianum* Zone in Kilian's original sense, but to raise it to the rank of superzone. Though *N. neocomiensis* appears to be present in all the subzones of the *Th. roubaudianum* Superzone, it would not be wise to let the well-known and familiar name '*roubaudianum*' drop in favour of '*neocomiensis*'.

From this point of view also Busnardo's idea to let the Valanginian-Hauterivian boundary coincide with the supraregional ammonite diversity minimum between Thieuloy's (1973, 1977, 1979) *Sn. verrucosum* and *Hi. trinodosum* zones, which boundary is also closest to the lower boundary of the Hauterivian (cf. Donze & Thieuloy, 1965) as it was originally indicated by Renevier (1873), is preferable above that of Lory(1898), Paquier (1900), Kilian (1907, 1910), Moullade (1966), Moullade & Thieuloy (1967a, b), Thieuloy (1971, 1973, 1977a, b, 1979), Busnardo & Thieuloy (1979, and Kemper et al. (1981).

Lorry (1898) and Paquier (1900) rightly divided Kilian's *Th. roubaudianum* Superzone in its original faunistical sense into two distinct biostratigraphic units. For the upper zone the name *Sn. verrucosum* Zone (sensu Lory) can be retained. Though the range of *Sn. verrucosum* is restricted to an interval of only a few decimetres to a few metres thickness in the upper part of this zone (Thieuloy, 1979), the *Sn. verrucosum* Zone is the first and only zonal name available for this biostratigraphic unit, which was sufficiently characterized by Sayn (1907) and Kilian (1910) by a substantial faunal association. Thieuloy's *Bu. campylotoxus* Zone necessarily becomes a subzone of the *Sn. verrucosum* Zone sensu Lory. It definitely does not deserve a higher rank. The upper subzone of the *Sn. verrucosum* Zone should preferably receive a new name, as *Sn. verrucosum* is not available anymore as index for this subzone. Also the lower zone of the *Th. roubaudianum* Superzone needs a new name, for *Th. (K.) roubaudianum* is neither available as index anymore.

We confine ourselves to this lower zone of the *Th. roubaudianum* Superzone. The upper zone is not discussed further in this paper.

Thurmanniceras (Kilianella) retrocostatum Zone (designated herein)

Index species: *Thurmanniceras (Kilianella) retrocostatum* Sayn.

Subdivison

When discussing the upper boundary of the *S. boissieri* Superzone, the *B. callisto* Subzone of Le Hégarat & Remane (1968) and Le Hégarat (1971), whose faunistical characterization appears to be totally inadequate, was replaced by the *T. alpillensis* Subzone. In contrast with the characterization of the former subzone, which involves only reputedly 'Berriasian' ammonites, the *T. alpillensis* Subzone is characterized by a fifty-fifty mixture of 'Berriasian' and renownedly 'Valanginian' ammonite forms. At Los Miravetes it comprises the stratigraphic interval between, on the one side the entry of *T. gratianopolitensis*, which appears practically at the same level as the first representatives of *Thurmanniceras (Thurmanniceras), Sarasinella, Neocomites*, and *Olcostephanus*, and on the other side the entries of *T. pertransiens* and *T.* n. sp. aff. *gueymardi* (= *Th.* aff. *pertransiens* in Mazenot, 1939, pl. 32, fig. 16), which are immediately followed by the appearance of *Th. (Th.) otopeta* and *Th. (Th.) salientinum*. The 'Berriasian' species *B. (B.) callisto, T. alpillensis, T. donzei, S. (S.) boissieri, S. (S.) rarefurcata, Lp. studeri*, and several forms of *Spiticeras (Spiticeras)* and *Spiticeras (Kilianiceras)* remain frequent throughout the entire interval occupied by this subzone. Because of the rapid entry of renownedly 'Valanginian' faunal elements and their rapid increase in number and diversity at the expense of the retarded 'Berriasian' ones, this subzone was incorporated in the *Th. roubaudianum* Superzone and constitutes its basal subzone. By this procedure the base of the *Th. roubaudianum* Superzone was stratigraphically lowered and consequently also the base of the Valanginian.

In Los Miravetes the biostratigraphic interval between the first appearance of *T. pertransiens* (in bed Y261) and that of *Bu. campylotoxus* (in bed M258) corresponds to the 'Zone à *Duvalia conica* et *Hoplites pexiptychus*' of Paquier (1900). From 1968 on, several attempts have been made to introduce a separate biostratigraphic unit for the lower part of this biostratigraphic interval. First Le Hégarat (in Le Hégarat & Remane, 1968; Le Hégarat, 1971) recognized the 'Subzone à *Pertransiens*' as a distinct subzone in the lower part of the *Th. roubaudianum* Zone sensu Moullade (1966) and Thieuloy (1971), i.e. a *Th. roubaudianum* Zone that reaches up to the *Sn. verrucosum* Zone sensu Moullade (1966), Moullade & Thieuloy (1967a, b), and Thieuloy (1971). Le Hégarat explicitly included Mazenot's (1939) 'horizon supérieur à *Kilianella* aff. *pexiptycha* et *Thurmannites* aff. *pertransiens*' in that subzone. No upper boundary was defined, only a lower boundary characterized by the sudden appearance of typical Valanginian ammonites in SE France (Le Hégarat, 1965, 1971; Le Hégarat & Remane, 1968). In 1973 Thieuloy raised the *T. pertransiens* Subzone to zonal rank and gave it an upper boundary. In the Barret-le-Bas Les Sausses section, for instance, he drew the boundary at the base of bed L40 at the end of the local range of *T. pertransiens* below the local entry of *Th. (K.) roubaudianum* (Remane & Thieuloy, 1973a). The interval between his *T. pertransiens* and *Bu. campylotoxus* zones was however still referred to as *Th. roubaudianum* Zone (sensu Thieuloy, 1973). In Los Miravetes, however, the range of *T. pertransiens* continues into the *Bu. campylotoxus* Subzone and is largely overlapping the range of *Th. (K.) roubaudianum*. The upper boundary of the *T. pertransiens* Zone is therefore still insufficiently characterized.

In December of the same year Wiedmann (1968) separated virtually the same beds with the same fauna, which also include the 'horizon supérieur' of Mazenot (1939), from the remainder of the *Th. roubaudianum* Zone sensu the 'Colloque sur le Crétacé inférieur' (1965) as the 'Zone der *Kilianella lucensis*', which would contain the beds BE198-200 of the Berrias section (Le Hégarat, 1965). He motivated this separation by stating that these beds could not possibly be incorporated in the *Th. roubaudianum* Zone because of the absence of *Th. (K.) roubaudianum*, which would not appear until later in the Valanginian. The *T. pertransiens* Subzone has however priority above Wiedmann's zone, which accordingly should be abandoned.

Later Wiedmann (in Allemann et al., 1975; Wiedmann, 1975) proposed the *Th. thurmanni* Zone for the biostratigraphic interval between the end of the range of *B. (B.) callisto* and the entry of *Th. (K.) roubaudianum*, which is in fact the same biostratigraphic characterization as meant for the '*K. lucensis* Zone'. According to him, *T. pertransiens* and *Th. (K.) lucense* are not suited to function as index fossils, because they abundantly occur in the interval that he, erroneously, correlated with Le Hégarat's *B. callisto* Subzone. The anomalous occurrence that he found for *T. pertransiens* near Los Miravetes is however due to the error in the amount of overlap he assumed between the sections he sampled. After correction of this error *T. pertransiens* appears just above the last *B.*

(B.) callisto, whereas the stratigraphic interval that Wiedmann attributed to his *Th. thurmanni* Zone turns out to begin at sample 71 224 (from our bed Y285), which is more than 10 m above the entry of *Th. (K.) roubaudianum*. Besides, the range of *Th. (Th.)* aff. *thurmanni* (= *Th. Thurmanni* échantillon presque typique, in Sayn, 1907, pl. 5, fig. 14) already starts near the upper boundary of the *B. picteti* Subzone, far below the end of the range of *B. (B.) callisto*. As the motives for the introduction of the *Th. thurmanni* Zone are without foundation, the concept of that zone should be abandoned too.

Finally, as the result of the study of the successions at Barret-le-Bas Les Sausses and at Angles, Thieuloy (1977a, 1979) split off the lower part of his former *T. pertransiens* Zone (sensu Thieuloy, 1973) as a separate zone, the *Th. otopeta* Zone, in which he also explicity included Mazenot's 'horizon supérieur'. The upper boundary of the *Th. otopeta* Zone was drawn at the base of bed L1 of the Barret-le-Bas Les Sausses section (Thieuloy, 1979), 29 m below bed L40, where Thieuloy drew the top of the *T. pertransiens* Zone in 1973. At the same time the *T. pertransiens* Zone, allegedly still characterized by the appearance of *T. pertransiens* but also by the appearance of *Th. (K.) lucense* (Busnardo & Thieuloy, 1979b), was shifted upward to become contiguous with the *Bu. campylotoxus* Zone and therefore with the *Sn. verrucosum* Zone sensu Lory (1898). By this procedure the *Th. roubaudianum* Zone sensu Thieuloy, 1973 (non sensu Thieuloy, 1971, van Hinte, 1976, and Kauffmann, 1979; non sensu 'Colloque sur le Crétacé inférieur', 1965; non sensu Lory, 1898 and Paquier, 1900; non sensu Kilian, 1888) became incorporated in the *T. pertransiens* Zone sensu Thieuloy, 1977 (non sensu Thieuloy, 1973; non sensu Le Hégarat & Remane, 1968 and Le Hégarat, 1971). This is very confusing, especially as according to the ammonite ranges presented by Le Hégarat & Remane (1968), Le Hégarat (1971), Remane & Thieuloy (1973a, b), and Thieuloy (1979), *T. pertransiens* already appears very low in the *Th. otopeta* Zone (Barret-le-Bas Les Sausses, La Faurie - Pusteau, Ginestoux - Les Oliviers, and Ginestoux - La Garenne sections) and *Th. (K.) lucense* probably even lower (Le Hégarat, 1965; Allemann et al., 1975; our investigations). Also the upper boundary of the *Th. otopeta* Zone is therefore insufficiently characterized.

As Le Hégarat & Remane (1968) and Le Hégarat (1971) did not give a faunistical characterization of the upper boundary of their *T. pertransiens* Subzone, but in fact only characterized its basal part, it is impossible to separate the lower part of the original *T. pertransiens* Subzone as a distinct biostratigraphic unit, because this would always and inevitably be identical with the *T. pertransiens* Subzone, which has priority over the *Th. otopeta* Zone. Moreover, the ammonite distribution of Los Miravetes shows that the *Th. otopeta* Zone totally lacks faunistical individuality with respect to the *T. pertransiens* Subzone; Thieuloy merely perfected the ammonite association of the basal part of that subzone. Also the concept of the *Th. otopeta* Zone should therefore be abandoned.

Should the totality of Paquier's (1900) 'Zone à *Duvalia conica* et *Hoplites pexiptychus*', whose faunal association is the same as the one that occurs between the top of the *T. alpillensis* Subzone (top of limestone Y261) and the base of the *Bu. campylotoxus* Subzone (top of limestone M258), be equated with the *T. pertransiens* Subzone, or is it indeed possible to subdivide this biostratigraphic interval? In other words, are the ammonite associations of its lower and upper part distinct enough to warrant the introduction of separate subzones and how should their mutual boundary be characterized faunistically?

Thieuloy (1973, 1977b, 1979) is apparently of the opinion that this biostratigraphic interval can be subdivided into two distinct biostratigraphic units, although he could not produce a convincing faunistical characterization of the boundary between these units. Wiedmann (1968, 1975) is in this respect more specific and argues that the entry of *Th. (K.) roubaudianum* should set off these units. But the entry of only one species does not create an ammonite association that is distinct enough to warrant the separation of subzones. Besides, in Los Miravetes *Th. (K.) roubaudianum* appears amidst an unadulterated *pertransiens* association. Nevertheless, also in Los Miravetes a subdivision into two subzones is possible, though their mutual boundary cannot be characterized unambiguously either.

The composition of the fauna in the upper part of the interval between bed Y261 and M258 is perceptibly distinct from that of the lower part of this interval and represents the gradual faunal transition between the fauna of Le Hégarat's *T. pertransiens* Subzone, which should of necessity occupy the lower part of that interval, and that of Thieuloy's *Bu. campylotoxus* Subzone. In Los Miravetes the faunal change from the *pertransiens* fauna to the upper fauna is primarily brought about by the disappearance of *N. premolicus, T. gueymardi gueymardi, T.* n. sp. aff. *gratianopolitensis* (= *Hp. Thurmanni* in Kilian, 1891, pl. 5, fig. 3, = *Th. Thurmanni* in Sayn, 1907, pl. 5, fig. 1), *Th. (Th.) salientinum, Th. (Th.) allobrogicum, Th. (K.) ischnoterum*, and *Th. (K)* n. sp. aff. *bochianense* (= *Th. (K.) bochianensis*. Variété comprimée, in Sayn, 1907, pl. 6, fig. 4), and by the appearance of *Sr. trezanensis, Sr. subquadrata, N. subtenuis, Th. (K.) pexiptychum* (typical form), *T. gueymardi crassicostata, O. (R.)* aff. *schenki* (= *O. (R.)* aff. *schenki* in Spath, 1939, pl. 2, fig. 8), *O. (R.) ambikyi, Th. (K.)* n. sp. (= syntype of *Hp. pexiptychus* Uhlig, 1882, pl. 4, fig. 5), and *Ch. aenigmatica*. However, the interval occupied by the upper fauna contains in addition to the acme of *Th. (K.) roubaudianum* also abundant *T. pertransiens*, whereas the ranges of *Th. (Th) otopeta* and *T. gratianopolitensis* end halfway this subzone. This upper fauna is however still too fragmentary to define a distinct Oppel-subzone in the proper way. This biostratigraphic unit is therefore provisionally kept in the state of assemblage-subzone and referred to as '*Sarasinella trezanensis - Thurmanniceras (Kilianella) pexiptychum*' Assemblage-subzone.

The stratigraphic interval occupied by this assemblage-subzone contains, on account of the acme of *Th. (K.) roubaudianum* and its stratigraphic position directly below the entry of *Bu. campylotoxus*, the 'horizon with *Saynoceras hirsutum*' (Remane & Thieuloy, 1973; Thieuloy, 1973, 1977; Busnardo & Thieuloy, 1979b), which was also referred to as 'horizon of Piloubeau' (Hautes-Alpes, Thieuloy, 1973, 1977). This horizon was raised to the rank of subzone by Busnardo & Thieuloy (1979c) and approximately corresponds to the *Th. (K.) roubaudianum* Zone in the restricted sense of Thieuloy (1973). However, with the exception of *Th. (K.) retrocostatum* and *Th. (K.) roubaudianum* none of the perisphinctacean ammonites reported from this subzone were found in Los Miravetes yet, so that an exact correlation of our *Sr. trezanensis - Th. (K.) pexiptychum* Assemblage-subzone with the *Sn. hirsutum* Subzone could not be made. When the ranges of the various ammonite forms are better known, this biostratigraphic interval may eventually become a real Oppel-subzone.

Ammonite fauna

1) Near los Miravetes the following forms were found to be restricted to the *Th. retrocostatum* Zone: *Ho.* aff. *calypso* (= *Ho.* sp. in Memmi, 1965, pl. 31a, fig. 2), *O. (O.)* cf. *sublaevis* (= *A. Astierianus* in Pictet, 1868, pl. 17, figs. 3, 4), *O. (O.) sakalavensis, O. (O.)* aff. *globulus, O. (O.)* ex gr. *salinarius, O. (O.)* cf. *collignoni, O. (R.)* aff. *schenki* (= *O. (R.)* aff. *schenki* in Spath, 1939, pl. 2, fig. 8), *O. (R.) ambikyi, O. (R.)* cf. *inordinatus, O. (Sb.?)* sp. indet., *O. (Mx.?)* sp. indet., *Sp. (Sp.) correardi, Sp. (Sp.) tenuicostatum, Sp. (Sp.)* aff. *guttatum, Sp. (Sp.)* n. sp. aff. *oppeli* (with 28 close-spaced umbilical tubercles), *Sp. (Ki.)* ex gr. *gratianopolitense, Sp. (Ki.) incertum, T.* n. sp. indet., *T. gratianopolitensis, T.* n. sp. aff. *gratianopolitensis* (= *Hp. Thurmanni* in Kilian, 1891, pl. 5, fig. 3; = *Th. Thurmanni* in Sayn, 1907, pl. 5, fig. 1), *T.* n. sp. aff. *gueymardi* (= *Th.* aff. *pertransiens* in Mazenot, 1939, pl. 32, fig. 16), *T. gueymardi gueymardi, T. gueymardi crassicostata, T.* n. sp.? aff. *alpillensis* (= *T.* aff. *alpillensis* in Arnaud et al., 1981, pl. 1, fig. 1), *Th. (Th.)* aff. *thurmanni* (= *Th. Thurmanni*, échantillon presque typique in Sayn, 1907, pl. 5, fig. 14), *Th. (Th.)* aff. *kingi, Th. (Th.)* cf. *thurmanni, Th. (Th.) loryi, Th. (Th.) otopeta, Th. (Th.) salientinum, Th. (Th.) allobrogicum, Th. (Th.)* n. sp. B (= *Hp. Thurmanni* in Kilian, 1891, pl. 4, figs. 2, 3), *Th. (Th.)* n. sp. A, *Th. (Th.)* n. sp.? indet. C (with small umbilicus), *Th. (K.) ischnoterum, Th. (K.) grossouvrei, Th. (K.) chamalocense, Th. (K.)* aff. *bochianense* (= *Th. (K.) bochianensis*, var. comprimée, in Sayn, 1907, pl. 6, fig. 4), *Th. (K.)* aff. *bochianense* (= *Th. (K.) bochianensis* in Sayn, 1907, pl. 6, fig. 12), *Th. (K.)* cf. *bochianense* (closest to holotype), *Th. (K.)* n. sp.? aff. *lucense* (with several fasciculated ribs), *Th. (K.)* cf. *lucense* (we did not find well preserved specimens of this form), *Th. (K.) pexiptychum* (identical with holotype), *Th. (K.)* n. sp. aff. *grossouvrei* (= *K.* aff. *grossouvrei* in Memmi, 1965, pl. 31a, fig. 5), *Th. (K.)* n. sp. F (= syntype of *Hp. pexiptychus* Uhlig, 1882, pl. 4, fig. 5), *Th. (K.)* n. sp. G (= *Th. (K.) Roubaudi* in Sayn, 1907, pl. 6, fig. 9), *Th. (K.)* aff. *roubaudianum* (with straight, radial ribs), *Th. (K.)* cf. *collignoni, Sr. varians, Sr.* n. sp. aff. *trezanensis* (= *N. trezanensis* in Sayn, 1907, pl. 4, fig. 15), *Sr. trezanensis, Sr. eucyrta, Sr. longi, Sr. subquadrata, Sr.* sp. indet., *Uhligites* sp. indet., *Uhligites* sp., *Su. zonarius, Pa.* cf. *theodori, S. (S.) lissonoides, Th. (E.)* cf. *hystricoides, Th. (E.)* sp. indet. B, *Chamalocia* n. sp., *N. premolicus, N. neocomiensis, N. subtenuis, N.* n. sp.? aff. *premolicus, N.* n. sp.? aff. *neocomiensis* (wider umbilicus than typical form), *N.* n. sp.? indet. (= cf. *N. neocomiensis* in Sayn, 1907, pl. 3, fig. 6), *Ps.* n. sp. (= *N. neocomiensis*, var. plate à côtes fines et fasciculées, in Sayn, 1907, pl. 3, fig. 14), *Lp. studeri, Lp. sapunovi, Lp.* cf. *jelevi* sive *brunneri, Pr.* cf. *kurdistanense, Pr.* cf. *depressum, Pr.* n. sp. indet., *Pr.* sp.

2) The *Th. retrocostatum* Zone has the following forms in common with the *S. boissieri* Superzone: *B. (B.) picteti, B. (B.) jauberti, B. (B.) callisto, B. (B.)* n. sp. indet. B (with many simple ribs and constrictions), *Th. (K.)* aff. *pexiptychum* (Uhlig, 1902, non 1882), *Th. (K.)* n. sp. B (= cf. *A. Malbosi* Pictet, 1867, pl. 14, fig. 2), *Th. (K.)* ex gr. *roubaudianum* (= *K. roubaudi* in Fülöp, 1964, pl. 24, fig. 3), *Th. (E.) paquieri, Th.? (E.?)* n. sp. indet. (relatively narrow-umbilicated, bituberculated berriasellid with fasciculated ribs in the adult), *T. alpillensis, T. donzei, S. (S.) rarefurcata, S. (S.) boissieri, Spiticeras* sp., *Sp. (Sp.) multiforme, Sp. (Sp.)* n. sp. aff. *kiliani, Sp. (G.)* aff. *bifrons*. Except *Th. (E.) paquieri, T. alpillensis*, and *Spiticeras* sp. all these ammonites became extinct in the *T. alpillensis* Subzone. It should be noted that Wiedmann (in Alllemann et al., 1975) reported *Sp. (Ng.)* cf. *negreli* from his sample 71 214, which is derived from our bed Y261.

3) The *Th. retrocostatum* Zone of Los Miravetes has *Neocomites* sp., *N. neocomiensis, T. pertransiens, Th. (K.) roubaudianum, Th. (K.) retrocostatum, Th. (K.)* sp., *Ch. aenigmatica*, and *Olcostephanus* sp. in common with the *Sn. verrucosum* Zone. According to the data of Thieuloy (1979) and Cotillon (1971) *Th. (K.) lucense, N. subtenuis, Sr. trezanensis, Sr. eucyrta, Sr. subquadrata*, and *Su. zonarius* range into the next higher zone.

4) The following long-ranging ammonite species were collected from the *Th. retrocostatum* Zone: *Pt. semisulcatum, Ho. calypso, Hy. tethys, Hy. serum, L. juilleti, Pg. quadrisulcatus*, and *Pg. honnoratianus*.

Tirnovella alpillensis Subzone (designated herein)

Index species: *Tirnovella alpillensis* (Mazenot).

It would be superfluous to repeat the ammonites that have already been listed when discussing the upper boundary of the *S. boissieri* Superzone. It should however be mentioned that a comparable ammonite association has not been described earlier in the literature and has hitherto remained unnoticed. For a detailed description see pages 21 to 24.

Plate 5

All figures x 1.

Fig. 1. *Tirnovella alpillensis* (Mazenot), RGM 160 267, bed M194 (= Y244), *T. alpillensis* Subzone (plaster-cast).

Fig. 2. *Thurmanniceras (Kilianella)* cf. *Th. (K.) lucense* Sayn, G.I.A./J.9941 (= Y249), *T. alpillensis* Subzone.

Fig. 3. *Thurmanniceras (Kilianella) retrocostatum* Sayn, RGM 160 255, beds Y244-251, *T. alpillensis* Subzone.

Fig. 4. *Olcostephanus (Olcostephanus)* cf. *O. (O.) sublaevis* Spath (= *Ammonites Astierianus* d'Orb. in Pictet, 1867, pl. 17, figs. 3, 4), RGM 160 279, beds X233-249, *T. alpillensis* Subzone.

Fig. 5. *Thurmanniceras (Kilianella)* aff. *Th. (K.) lucense* Sayn, RGM 160 256, beds X244-249, *T. alpillensis* Subzone.

Fig. 6a,b. *Olcostephanus (Olcostephanus) sakalavensis* Besairie, RGM 160 280, beds Y249-251, *T. alpillensis* Subzone.

Fig. 7. *Neocomites premolicus* Sayn, RGM 160 271, beds Y233-235, *T. alpillensis* Subzone.

Fig. 8. *Tirnovella gratianopolitensis* (Sayn), RGM 160 268, beds X249-251, *T. alpillensis* Subzone.

Fig. 9. *Tirnovella gratianopolitensis* (Sayn), RGM 160 269, beds X249-251, *T. alpillensis* Subzone.

Fig. 10. *Thurmanniceras (Thurmanniceras)* aff. *Th. (Th.) thurmanni* (Pictet & Campiche), RGM 160 261, bed X253, *T. alpillensis* Subzone.

Fig. 11. *Thurmanniceras (Thurmanniceras)* aff. *Th. (Th.) thurmanni* (Pictet & Campiche), RGM 160 260, beds Y233-235, *T. alpillensis* Subzone.

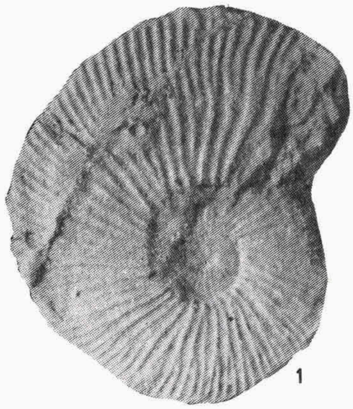
Fig. 12. *Thurmanniceras (Thurmanniceras) otopeta* Thieuloy, RGM 160 266, bed Y266b, *T. pertransiens* Subzone.

Fig. 13. *Thurmanniceras (Kilianella) roubaudianum* (d'Orbigny), RGM 160 258, beds X269-276, *T. pertransiens* Subzone.

Fig. 14. *Thurmanniceras (Thurmanniceras) salientinum* Sayn, RGM 160 262, beds M201-208 (= Y276b-278), *T. pertransiens* Subzone.

Fig. 15. *Sarasinella varians* (Uhlig), RGM 160 273, beds X269-276, *T. pertransiens* Subzone.

Plate 5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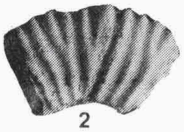
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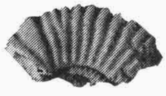
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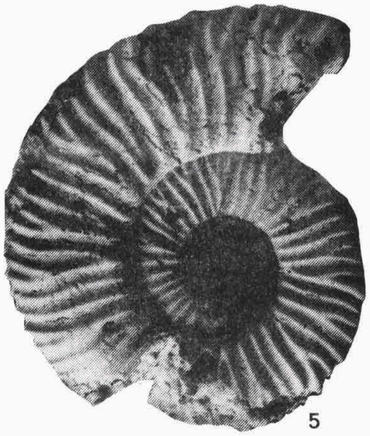
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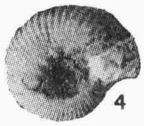
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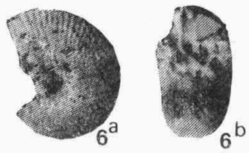
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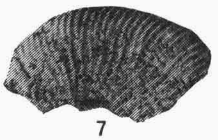
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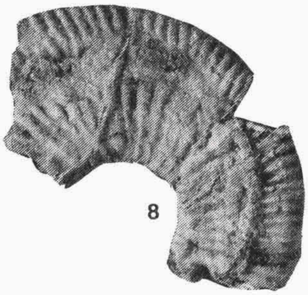
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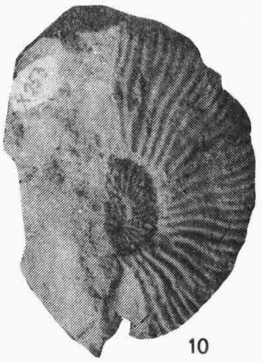
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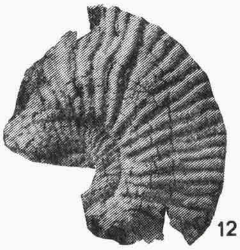
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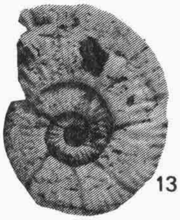
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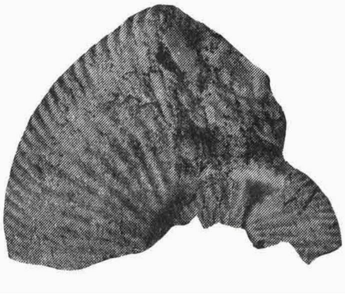
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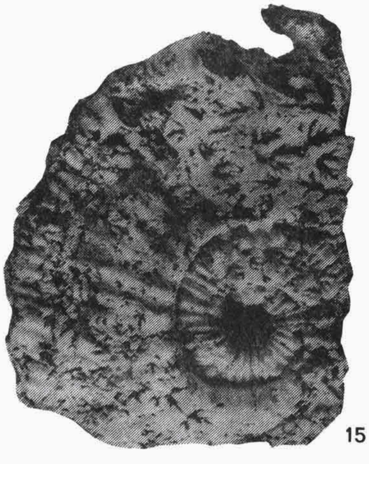
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Tirnovella pertransiens Subzone (Le Hégarat & Remane, 1968)

Index species: *Tirnovella pertransiens* (Sayn).

1) In Los Miravetes the following ammonite forms were found restricted to the *T. pertransiens* Subzone: *O. (O.)* cf. *collognoni, Th. (Th.)* n. sp.? indet. C (with narrow umbilicus), *Th. (K.) grossouvrei, Th. (K.) ischnoterum, Th. (K.)* aff. *bochianense* (= *Th. (K.) bochianensis* in Sayn, 1907, pl. 6, fig. 12), *Th. (E.)* cf. *hystricoides, T.* n. sp. indet., *T.* n. sp. aff. *gueymardi* (= *Th.* aff. *pertransiens* in Mazenot, 1939, pl. 32, fig. 16), *T.* n. sp.? aff. *alpillensis* (= *T.* aff. *alpillensis* in Arnaud et al., 1981, pl. 1, fig. 1), *Sr. varians, Sr. eucyrta* (in SE France also reported from the *Th. campylotoxum* Subzone (Thieuloy, 1979)), *S. (S.) lissonoides, Pa.* cf. *theodori, Pr.* n. sp. indet., *Protancyloceras* sp., *Lp. sapunovi,* and *Sp. (Sp.) correardi.*

2) The following ammonite forms disappear in the *T. pertransiens* Subzone of Los Miravetes: *O. (Mx.?)* sp. indet., *O. (O.)* ex gr. *salinarius, Th. (Th.)* aff. *thurmanni* (= *Th. Thurmanni,* échantillon presque typique in Sayn, 1907, pl. 5, fig. 14), *Th. (K.)* aff. *lucense* (with fasciculated ribs), *Th. (K.) chamalocense, N. premolicus, Pr.* cf. *kurdistanense, T. alpillensis,* and *Ps.* n. sp. (= *N. neocomiensis,* var. plate à côtes fines et fasciculées in Sayn, 1907, pl. 3, fig. 4). Except for *T. alpillensis,* all these forms make their first appearance in the *T. alpillensis* Subzone.

3) In the *T. pertransiens* Subzone of Los Miravetes the following ammonite forms appear: *Ho.* aff. *calypso* (= *Ho.* sp. in Memmi, 1965, pl. 31a, fig. 2), *O. (O.)* aff. *globulus, O. (Sb.?)* sp. indet., *O. (R.)* cf. *inordinatus, Th. (Th.) otopeta, Th. (Th.) loryi, Th. (Th.) salientinum, Th. (Th.) allobrogicum, Th. (K.) roubaudianum, Th. (K.)* n. sp. aff. *bochianense* (= *Th. (K.) bochianensis,* var. comprimée in Sayn, 1907, pl. 6, fig. 4), *T. pertransiens* (the morphotype *valdrumensis* is restricted to the *T. pertransiens* Subzone), *T. gueymardi gueymardi,* and *Chamalocia* n. sp.

Plate 6

All figures x 1.

Fig. 1a-c. *Thurmanniceras (Thurmanniceras)* aff. *Th. (Th.) kingi* (Uhlig), RGM 160 263, bed Y276a (loose), *T. pertransiens* Subzone.

Fig. 2a,b. *Parandiceras* cf. *Pa. theodori* (Uhlig), RGM 160 275, bed Y276e (loose), *T. pertransiens* Subzone.

Fig. 3. *Subthurmannia (Subthurmannia) lissonoides* Spath, RGM 160 246, beds Y269 (loose), *T. pertransiens* Subzone.

Fig. 4. *Thurmanniceras (Thurmanniceras)* cf. *Th. (Th.) thurmanni* Pictet & Campiche), RGM 160 264, beds Y283-309, *Sr. trezanensis - Th. pexiptychum* Assemblage-subzone.

Fig. 5. *Tirnovella pertransiens* (Sayn), RGM 160 270, beds X300-304, *Sr. trezanensis - Th. pexiptychum* Assemblage-subzone.

Fig. 6a,b. *Sarasinella trezanensis* (Lory), RGM 160 274, beds X276i-278, *Sr. trezanensis - Th. pexiptychum* Assemblage-subzone.

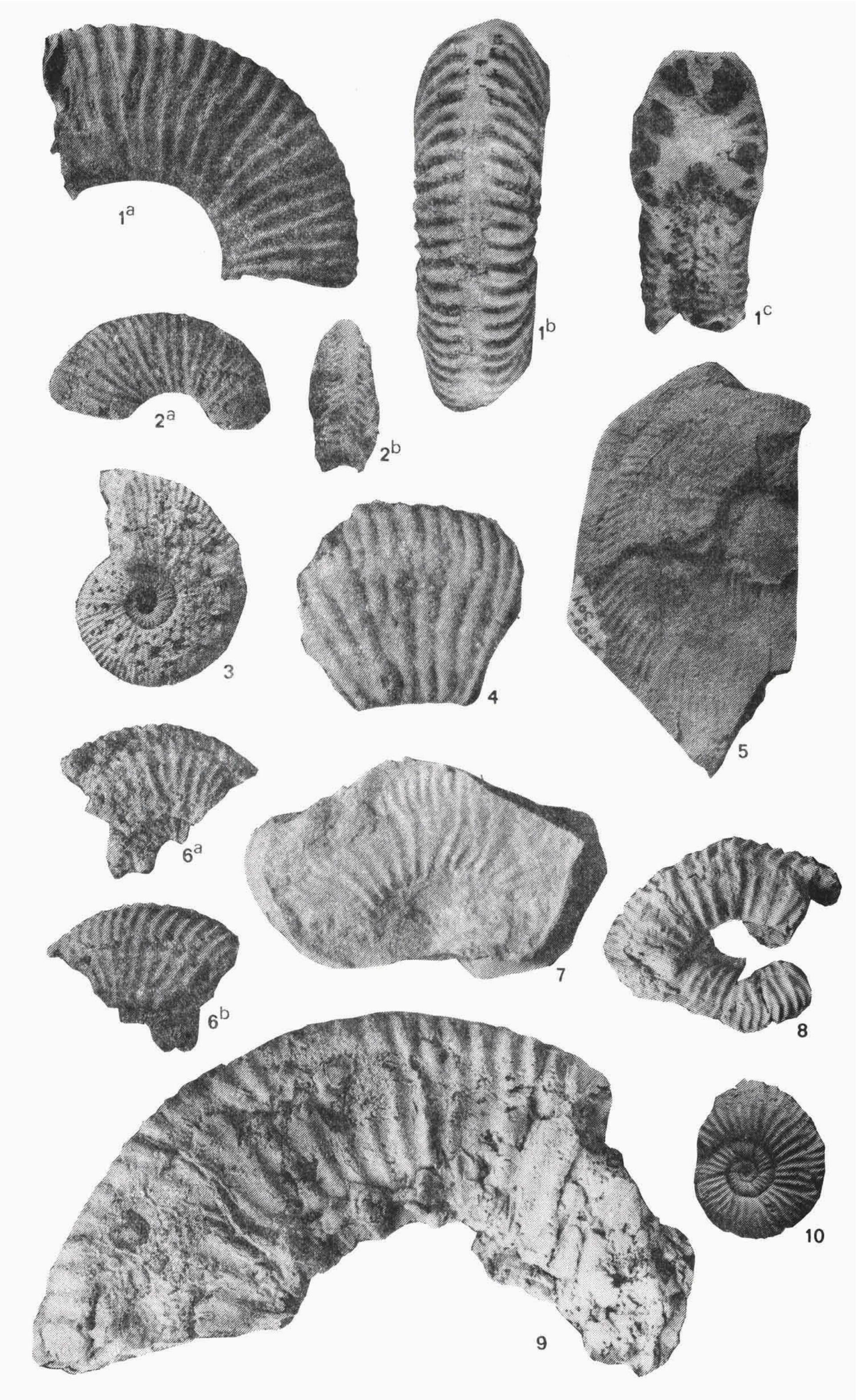
Fig. 7. *Thurmanniceras (Thurmanniceras) otopeta* Thieuloy, RGM 160 265, bed M242 (= Y312), *Sr. trezanensis - Th. pexiptychum* Assemblage-subzone (plaster-cast).

Fig. 8. *Thurmanniceras (Kilianella) pexiptychum* (Uhlig), RGM 160 257, beds X288-309, *Sr. trezanensis - Th. pexiptychum* Assemblage-subzone.

Fig. 9. *Thurmanniceras (Erdenella) paquieri* (Simionescu), RGM 160 254, beds X278-309, *Sr. trezanensis - Th. pexiptychum* Assemblage-subzone.

Fig. 10. *Thurmanniceras (Kilianella) roubaudianum* (d'Orbigny), RGM 160 259, beds X276i-278, *Sr. trezanensis - Th. pexiptychum* Assemblage subzone.

Plate 6



4) The ranges of the following ammonite forms cross the lower as well as the upper boundary of the *T. pertransiens* Subzone: *Olcostephanus* sp., *O. (O.)* cf. *sublaevis* (= *A. Astierianus* in Pictet, 1867, pl. 17, figs. 3, 4), *O. (O.) sakalavensis, Th. (K.) retrocostatum, Th. (K.)* n. sp. aff. *grossouvrei* (= *K.* aff. *grossouvrei* in Memmi, 1965, pl. 31a, fig. 5), *T. gratianopolitensis, T.* n. sp. aff. *gratianopolitensis* (= *Th. Thurmanni* in Sayn, 1907, pl. 5, fig. 1; = *Hp. Thurmanni* in Kilian, 1891, pl. 5, fig. 3), *N. neocomiensis, Neocomites* sp., *Spiticeras* sp., *Sp. (Sp.)* aff. *guttatum*, and *Th. (E.) paquieri*. Except for *Th. (E.) paquieri* all these ammonites appear in the *T. alpillesis* Subzone.

Sarasinella trezanensis - *Thurmanniceras (Kilianella) pexiptychum* Assemblage-subzone

1) In Los Miravetes the following forms were found restricted to this subzone: *Sr.* sp. indet., *Sr. subquadrata* (ranging up to the top of the *Bu. campylotoxus* Subzone (Thieuloy, 1979)), *Sr. trezanensis* (ranging high into the *Bu. campylotoxus* Subzone (Cotillon, 1971)), *N. subtenuis* (ranging up to the top of the *Sn. verrucosum* Zone (Thieuloy, 1979)), *N.* n. sp.? indet. (= cf. *N. neocomiensis* in Sayn, 1907, pl. 3, fig. 6), *Th. (K.) pexiptychum* (identical with holotype), *Th. (K.)* n. sp. F (= syntype of *Hp. pexiptychus* Uhlig, 1882, pl. 4, fig. 5), *Th. (K.)* cf. *bochianense* (closest to type), *Th. (K.)* aff. *roubaudianum* (with straight, radial ribs), *Th. (Th.)* cf. *thurmanni* (closest to type), *T. gueymardi crassicostata, O. (R.) ambikyi, Lp.* cf. *jelevi* sive *brunneri*, and *Uhligites* sp. Of each of these forms only one specimen was found.

2) The following ammonites disappear in this assemblage-subzone: *N. premolicus, T. gueymardi gueymardi, T. gratianopolitensis, T.* n. sp. aff. *gratianopolitensis* (= *Hp. Thurmanni* in Kilian, 1891, pl. 5, fig. 3 = *Th. Thurmanni* in Sayn, 1907, pl. 5, fig. 1), *Th. (Th.) otopeta, Th. (Th.) loryi, Th. (Th.) allobrogicum, Th. (Th.) salientinum, Th. (E.) paquieri, Th. (K.)* n. sp. aff. *bochianense* (= *Th. (K.) bochianensis*, var. comprimée in Sayn, 1907, pl. 6, fig. 4), *Chamalocia* n. sp., *Th. (K.)* n. sp. aff. *grossouvrei* (= *K.* aff. *grossouvrei* in Memmi, 1965, pl. 31a, fig. 5), *O. (O.)* cf. *sublaevis* (= *A. Astierianus* in Pictet, 1867, pl. 17, figs. 3, 4), *O. (O.) sakalavensis, O. (O.)* aff. *globulus, O. (R.)* aff. *schenki* (= *O. (R.)* aff. *schenki* in Spath, 1939, pl. 2, fig. 8), *O. (R.)* cf. *inordinatus, O. (Sb.?)* sp. indet., *Sp. (Sp.)* aff. *guttatum*, and *Spiticeras* sp. It should be noted that Wiedmann (in Allemann et al., 1975) reported *Sp. (Ki.) gratianopolitense* from bed 71 226 (= our bed Y293), which is situated within this assemblage-subzone.

3) *Ch. aenigmatica* begins in this assemblage-subzone and continues into the *Bu. campylotoxus* Subzone of Las Oicas.

4) This assemblage-subzone also contains the acme of *Th. (K.) roubaudianum* and abundant *T. pertransiens*. These two forms, which appear in the *T. pertransiens* Subzone, range into the *Bu. campylotoxus* Subzone. Also *Th. (K.) retrocostatum* and *N. neocomiensis* cross the lower as well as the upper boundary of this assemblage-subzone.

The *Bu. campylotoxus* Subzone of Thieuloy (1973) along the Río Argos (sequence of Las Oicas) is characterized by the appearance of: *Bu. campylotoxus, Th. (Eristavites) platycostatum, Th. (Eristavites) teschenense, Th. (Eristavites) drumense, O. (R.) schenki*, and, like in SE France (Lory, 1898), the beginning of the acme of *Bo. neocomiensis*.

Correlations of the *Th. (K.) retrocostatum* Zone

The ammonite fauna diagnostic for the *Th. retrocostatum* Zone was found between the top of limestone Y230 (2 m below sample 71 208 of Alleman et al., 1975) and the top of limestone M256. This interval is 102.63 m thick. It contains two marlstone intervals, one between Y234 and Y244 (15.07 m thick and only exposed in the eastern part of section Y) and the other between Y 267 and Y269 (11 m thick and only exposed in the western part of section Y). These marlstone intervals are almost in line due to tectonic dislocations, but in section X, 400 m farther west, they are separated by a 20 m thick, more calcareous interval.

Allemann erroneously assumed that these two marlstone intervals represented one and the same interval (Grün & Allemann, 1975, p. 149). His error in the correlation resulted in an overlap of 40 m, which virtually covers the entire *B. callisto* Zone sensu Wiedmann (in Allemann et al., 1975). In reality the overlap of their sections B and C is only 5.5 m: their sample 71 216 (from bed Y259) is situated only 1 m below their sample 71 214 (from bed Y261), whereas their samples 71 215 and 71 217 were derived from the same bed Y263 and their sample 71 218 from bed Y266. This explains the anomalous ammonite association reported by Wiedmann (in Allemann et al., 1975) from his *B. callisto* Zone, which is a combination of the faunas of the *T. alpillensis* and *T. pertransiens* Subzones.

The ammonite association diagnostic for the *T. alpillensis* Subzone was found between the top of limestone Y230 and the top of limestone Y261 (sample 71 214); it comprises an interval of 31.29 m. The diagnostic ammonite association of the *T. pertransiens* Subzone was found between the top of bed Y261 and the top of bed Y276i, an interval of 28.05 m. The *Sr. trezanensis-Th. pexiptychum* ammonite assemblage was collected between the top of limestone Y276i and the top of limestone M256 22.14 m above Y319, an interval of 22.29 m.

Allemann (in Allemann et al., 1975) reported the first appearance of *Lorenziella hungarica* from his sample 71 209, which is situated 2 m above his sample 71 208 from our bed Y234. Geel (personal communication) found it in bed Y226, 2 m below Y230. This implies that the lower boundary of the *Th. retrocostatum* Zone practically coincides with the first appearance of *L. hungarica.* In the same paper Allemann did not report the presence of *Calpionellites darderi* in Los Miravetes, but only marks the end of the range of *Calpionellopsis oblonga* in his sample 71 232 (our bed Y311). In the sections along the Barranco de Cañada Lengua, however, he reported an overlap of the ranges of *C. oblonga* and *C. darderi*, which is in accordance with the findings of Allemann & Remane (1979). Geel neither could find *C. darderi* in the Miravetes section. So the boundary between Remane's calpionellid zones D and E, which approximately would mark the otherwise uncharacterizable upper boundary of Thieuloy's *Th. otopeta* Zone (Allemann & Remane, 1979), has not been determined yet in Los Miravetes.

Grün (in Grün & Allemann, 1975) did not mention the coccolite *Calcicalathina oblongata* from Los Miravetes, so that the lower boundary of the *C. oblongata* Zone, which according to Manivit (1979) should be situated halfway the *Sr. trezanensis-Th. pexiptychum* Assemblage-Subzone as conceived in this paper, cannot be drawn yet in Los Miravetes. We should await the results of the investigations of K. Perch-Nielsen (T.U., Zürich) and P. Aguilar (ADARO, Madrid), who study the coccolites from the Argos sections, before we can solve this problem.

Addendum

On the basis of recent data on calpionellid biostratigraphy and additional ammonite collecting, it became evident that the base of the *Bu. campylotoxus* Subzone along the Río Argos should be drawn at a higher level, viz. between bed M256 and M258, 22 m higher than bed Y319.

Stage and system boundaries

Tithonian-Berriasian boundary

The debate on the Tithonian-Berriasian boundary ('Colloque sur la limite Jurassique-Crétacé', 1975) still pivots around the same controversy as some 100 years ago: should it be placed where Toucas (1890) drew it (which is, translated in biostratigraphical terms, at the base of the *B. jacobi* Subzone), or where Mazenot (1939) drew it (i.e. at the base of the *P. grandis* Subzone), or should it be drawn in accordance with the original characterization of the Berriasian by Coquand (1871), viz. at the base of the *S. boissieri* Superzone sensu Kilian (1888)?

The boundary of Mazenot (1939), which is also the traditional boundary between the Jurassic and Cretaceous systems (the concept of which has largely been developed under the authority of Kilian), has for a long time been accepted by most stratigraphers and has without hesitation been accepted by nearly all attendants of the 'Colloque sur le Crétacé inférieur' (1965), apart from a few dissidents, in casu Wiedmann and Casey. They (in Barbier & Thieuloy, 1965) preferred to draw the boundary at the base of the *S. boissieri* Zone sensu Kilian (1888): Wiedmann because a boundary between two systems should, in the interest of stability in stratigraphy, correspond with a faunal discontinuity, and Casey because this boundary would better correspond with the base of the Ryazanian Stage in the U.S.S.R., considering the reported association of *S. boissieri* and *Ri. rjasanensis* in the Caucasus Mountains.

The investigations of Le Hégarat (1971) have highly improved our knowledge of the ammonite distribution and subsequent studies have revealed that Le Hégarat's zonal succession is reproducible in other parts of the Mediterranean area (Tunisia, Roumania, The Crimea, Bulgaria, Spain). Since then it became clear that the *B. jacobi* and *P. grandis* zones had better be united into one zone because of the difficulty to differentiate them faunistically, a fact already fully recognized by Toucas (1890). He only failed to recognize that the fauna from Chomérac did not include ammonites of the *S. boissieri* Zone of Berrias, and this caused the scientific battle between him and Kilian.

As the biostratigraphic interval at Los Miravetes that comprises the *B. jacobi* and *P. grandis* zones appears to be exactly equivalent to the *P. euxinus* Zone of Wiedmann (in Allemann et al., 1975; Wiedmann, 1975), the latter name was adopted for this biostratigraphic interval.

So the traditional Tithonian-Berriasian boundary turned out to be a level halfway the *P. euxinus* Zone, which is difficult to recognize by ammonite biostratigraphy, but also a level halfway the *Calpionella alpina* Zone, which is just as difficult to recognize by calpionellid biostratigraphy. This level thus proves to be most unsuitable for the Tithonian-Berriasian boundary, let alone the Jurassic-Cretaceous boundary.

It is an unwritten law that conventional boundaries should as little as possible be meddled with and tradition favours the use of ammonite zones to define the Mesozoic stages. For the attendants of the Colloquium, therefore, the most qualified boundaries were obviously the lower and upper limit of the *P. euxinus* Zone. As the provisional results of the investigations of Enay & Geyssant (1975) in Spain showed that the base of the *Calpionella alpina* Zone approximately coincides with the base of the *P. euxinus* Zone, most attendants of the 'Colloque sur la limite Jurassique-Crétacé' ((1973) 1975) were brought round to vote for the lower boundary of this zone as the boundary between the Tithonian and the Berriasian, which is at the same time the Jurassic-Cretaceous boundary.

Nevertheless, during this colloquium Casey still clung to his view (cf. Casey, 1973) that the lower boundary of the Berriasian should be at the base of the *S. boissieri* Zone, but now this zone was meant in the sense of Le Hégarat (1971) (= approximately our *S. rarefurcata* Zone) instead of in the sense of Kilian (1888) and the 'Colloque sur le Crétacé inférieur' (1965). Casey's view is untenable with respect to the unfolding of the Mediterrannean ammonite faunas. For, as we have seen, the stratigraphic position of that boundary is quite arbitrary and could only be identified by collecting very large ammonite faunas. *Berriasella, Malbosiceras, Kilianella, Neocosmoceras, Euthymiceras, Pomeliceras, Mazenoticeras, Dalmasiceras, Subalpinites, Subthurmannia, Jabronella, Strambergella, Erdenella, Spiticeras, Negreliceras, Kilianiceras*, and *Pseudoneocomites* gen. nov. (see palaeontological notes) cross that boundary without gaining or loosing in importance. Notwithstanding the unparalleled richness in ammonites of the deposits of the Fosse Vocontienne, the succession in SE France is inadequate to solve the problem of the stratigraphic position of the lower and upper boundary of the Berriasian, although it took almost a century to realize this.

The lower boundary of the *B. jacobi* Subzone, for instance, has never been determined nor characterized, for it is situated within the notorious 'lacune de nos connaissances' of Mazenot (1939) and Le Hégarat (1971). It is not recommendable to vote for such an ill characterized boundary between the Tithonian and the Berriasian, let alone between the Jurassic and Cretaceous.

The scarce data hitherto available for the '*Durangites*' Subzone of Enay & Geyssant (1975), which partly fills the 'lacune de nos connaissances', clearly suggest that the faunal change at this boundary is a gradual one. All ammonite genera and subgenera that constitute the fauna of the *P. euxinus* Zone are without exception already present in the '*Durangites*' Subzone and their diversification augments progressively in the course of that biostratigraphic unit at the cost of the generic and subgeneric groups that originated below the '*Durangites*' Subzone. More than 10 species have already been reported to occur in both the '*Durangites*' and *B. jacobi* subzones. The faunal liaisons between these subzones are so tight, that both biostratigraphic units should at least form part of one and the same biostratigraphic unit of higher rank, the *Par. transitorius* Superzone sensu Neumayr (1871, p. 517), which embraces the entire upper Tithonian substage. It is not possible to speak of a caesura or break in the ammonite succession at the lower boundary of the *P. euxinus* Zone; the replacement of the old fauna by the new one is too gradual.

The lower boundary of the *B. jacobi* Subzone is therefore as difficult to recognize and as unsuited to be a stage or system boundary as its upper boundary had been.

Quite different, however, is the nature of the faunal change between the *P. euxinus* and the *S. occitanica* Zones. The upper boundary of the *P. euxinus* Zone can pre-eminently be typified as an interval in which extinction of ammonite species is general, and remarkably enough not compensated by the appearance of new taxa. This extraordinary event merits full attention. At the boundary between the *B. jacobi* and *P. grandis* subzones already half of the *B. jacobi* fauna had disappeared, whereas during the *P. grandis* Subchron the disappearance of ammonite taxa undiminishedly continues, so that at the end of this subchron the *P. euxinus* fauna was nearly wiped out. *Pseudosubplanites, Parapallasiceras, Aspidoceras, Protacanthodiscus, Himalayites, Corongoceras,* berriasellids of the *B. chaperi* group, *Substeueroceras, Cyrtosiceras, Proniceras,* and *Haploceras* died out, whereas of the 13 forms of *Hegaratella* only four have been reported (Le Hégarat, 1971; Memmi, 1968; Memmi & Salai, 1975) to cross the upper boundary to become extinct soon afterwards. Also *Delphinella* and *Dalmasiceras* lost heavily in importance. The main difference between this faunal change and the one in the course of the *T. alpillensis* Subzone is that the ecological niches that fell vacant were not filled until *S. subalpina* times, when only a few retarded *P. euxinus* forms were left, which disappeared soon afterwards. Therefore this boundary can rightly be designated as a caesura in the Mediterranean faunal succession; it coincides with the deep ammonite diversity minimum of supraregional extent between the diversity highs of the *P. euxinus* and *S. boissieri* zones. The scarcity of ammonites near the *P. euxinus* - *S. occitanica* zonal boundary is apparent from the columns and range charts of Le Hégarat (1971), Memmi & Salaj (1975), and ours. The drastic reduction of the number of ammonite species in the course of the *P. grandis* Subchron may probably have been effected by the Purbeck regression and confined to the Mediterranean faunal province.

Nevertheless at least 15 lineages must have passed the *P. euxinus* - *S. occitanica* boundary of which 9 gave rise to new radiations of perisphinctaceans (which do not disappear until the Hauterivian). *Hegaratella* rapidly made room for multifarious new generations of *Berriasella* (with its tuberculated offshoots grouped into *Malbosiceras* and the ones with fasciculated ribs referred to as the *B. haemusensis* group) and *Kilianella* (with its tuberculated pendant *Erdenella*); *Strambergella* gradually deversified and (iteratively?) blended into *Subthurmannia* and its tuberculated counterpart *Jabronella; Kilianiceras* and *Spiticeras* (from which *Negreliceras* and *Groebericeras* descended) became prolific and even *Delphinella* and *Dalmasiceras* (which gave rise to tuberculated *Subalpinites*) managed to produce more or less successful radiations. The thick-whorled *Pomeliceras* (and its compressed relative *Mazenoticeras*), which represents the continuation of *Himalayites*, and the trituberculated *Neocosmoceras* (including *Euthymiceras*), which may have been derived from *Protacanthodiscus*, also begin their development at the base of the *S. occitanica* Zone. Only *Pseudoneocomites* gen nov. (see palaeontological notes) continued apparently undisturbed as one lineage.

It is an accidental but very fortunate circumstance that this coupure in the Mediterranean perisphinctacean ammonite faunas practically coincides with the entry of *Calpionella elliptica*, which marks the base of the *C. elliptica* Zone, just below the base of zone C of Remane (1964). Allemann (in Allemann et al., 1975) characterized the base of the *C. elliptica* Zone as 'one of the most important and most easily definable breaks in the calpionellid faunas'. It provides a reliable means for worldwide correlation of this boundary.

As this boundary, which is - at least in the Mediterranean area - easily detectable by ammonites and worldwide correlatable by calpionellids, is also closest to the traditional boundary, it is proposed here to define the boundary between the Tithonian and Berriasian stages as coinciding with the boundary between the *P. euxinus* and *S. occitanica* Zone. Ironically this boundary scored only one vote in the inquiry set up after the 'Colloque sur la limite Jurassique-Crétacé' (1975). The boundary advocated here is quite acceptable as the lower boundary of the Berriasian, because it does not obviate Coquands (1869, 1870, 1871, 1875) original, faunistical concept of the Berriasian. On the contrary, it consolidates this concept, for Coquand regarded the ammonite fauna described by Pictet (1867) as diagnostic for the stratigraphic interval that he later (1871) called 'Berriasien'. This fauna contains only ammonites of the *S. occitanica* and *S. rarefurcata* zones. The Berriasian as conceived here is equivalent to the 'Berriasian sensu stricto' of Kilian (1896, 1907).

When Oppel (1865) introduced his Tithonian Stage as the transitional stage between the Alpine Kimmeridgian (sensu Oppel) and the lowest Alpine Neocomian (sensu Oppel), he explicitly stated that the faunal characterization he gave was only meant for provisional guidance and that the sharper delimitation of the true boundaries should only be the result of more thorough comparisons and better established correlations. Therefore the ammonite association of the *Th. roubaudianum* Zone, by which he provisionally characterized the beds overlying the stratigraphic interval that comprises his Tithonian Stage, should not be considered to define the upper boundary of that stage as was argumented by Wiedmann (1968, p. 355). The upper boundary of the Tithonian should by definition coincide with the base of the Neocomian (sensu Oppel). In this respect it should be noted that Oppel (1865, p. 535, 558) explicitly considered the Purbeck strata a true Jurassic formation, undoubtedly correlatable with a part of the Tithonian. Therefore, these Purbeck strata could not possibly form part of his concept of the Neocomian. As a consequence, the Neocomian sensu Oppel has to be interpreted to begin with the socalled 'Inferior oolitic limestone', and 'Marbre Bâtard' rockunits, which cannot form part of the Tithonian by definition. The stratigraphic interval that Coquand (1871) called 'Berriasien' has however been shown to be equivalent in age to at least a part of the 'Inferior oolitic limestone' rockunit and the entire 'Marbre Bâtard' rockunit (Kilian, 1894; Donze, 1965; Le Hégarat, 1971; Donze & Le Hégarat, 1972; Remane, 1973; Persoz & Remane, 1976). The integral incorporation of the mainly Berriasian 'ciment de la Porte-de-France' near Grenoble in the Tithonian by Oppel (1865) must therefore be attributed to erroneous correlation and cannot be adduced as an argument that the Berriasian per definition should form part of the Tithonian (Wiedmann, 1968). The fauna of the Berriasian, first described by Pictet (1867), was unknown to Oppel, who died in 1865. Anecdotically can be added that the 'ciment de la Porte-de-France' yielded mainly ammonites of the *P. grandis* Subzone (here incorporated in the Tithonian) and a few of the *S. subalpina* Subzone (Mazenot, 1939; Le Hégarat, 1971), whereas the remainder of the Berriasian at that locality hitherto has not produced any ammonite, so that with respect to the ammonites its incorporation in the Tithonian by Oppel (1865) was not too erroneous a correlation after all.

Unfortunately Oppel did not designate a stratotype for his Tithonian Stage, but, mainly due to Zittel's (1868) description of its fauna, the 'Stramberger Schichten' in Czechoslovakia attained a kind of stratotypical appreciation for the upper Tithonian. Housa recently (1978) indicated that the top of the Stramberk Limestone is situated within the *Calpionella alpina* Zone, so that the boundary proposed here is also quite acceptable as the upper boundary of the Tithonian.

An advantage of the stratigraphic position of the Tithonian-Berriasian boundary proposed here is that none of the ranges of the perisphinctacean ammonites listed by Oppel (1865) for the Tithonian do cross that boundary and that the perisphinctacean ammonite association described by Zittel (1868) from the 'Stramberger Schichten' will still remain characteristic for the Tithonian. This would not be the case when the lower boundary of the *P. euxinus* Zone would be chosen as the Tithonian-Berriasian boundary, as was recommended by the 'Colloque sur la limite Jurassique-Crétacé' (1975). It should be mentioned that the stratigraphic position of the Tithonian-Berriasian boundary proposed here is not in disaccord with the recommendations of the Stratigraphic Subcommission for the Jurassic and Cretaceous Systems of the German Federal Republic (Barthel et al., 1973).

Berriasian-Valanginian boundary

Desor (1854, p. 172) proposed to designate the lower part of the Neocomian between the top of the Jurassic 'calcaires compactes et blancs' and the 'marnes de Hauterive' as Valanginien after the hamlet of Valangin, where these rocks are reasonably well exposed. It soon became evident that the lowest rock unit implicitly comprised in this definition, the socalled 'Terrain Dubisien' (Desor & Gressly, 1859), which is not exposed near Valangin, could be correlated with the 'Purbeck beds' and had better be excluded from the Valanginian (Desor & Gressly, 1859) and included in the Jurassic (Loriol & Jaccard, 1865; Oppel, 1865; Jaccard, 1869; Maillard, 1884, 1886), an opinion shared by the author.

When it became clear that the lower part of the Valanginian (excl. Dubisian) was time equivalent with Coquand's Berriasian (Kilian, 1894; Donze, 1965; Le Hégarat, 1971; Donze & Le Hégarat, 1972; Remane, 1973; Persoz & Remane, 1976), the remaining part of the Valanginian (or 'Valanginian sensu stricto') was, in terms of ammonite zones, inevitably to begin with the *Th. roubaudianum* Superzone of Kilian (1888). Though at the outset regarded as a substage of the Valanginian, the Berriasian gradually acquired stage appreciation and the Valanginian (or 'Valanginian sensu stricto') became restricted to the interval between the Berriasian and the Hauterivian ('Colloque sur le Crétacé inférieur', 1965).

Kilian (1896, 1910) did not report any ammonite from the beds between those that yielded the ammonite fauna of the Berriasian 'Zone des *Hp. (Th.)*

Boissieri' and those that produced the fauna of the Valanginian 'Zone des *Th. (K.) roubaudiana*'. Therefore these beds could not possibly belong to either of these zones then. Nevertheless he included these beds in his 'Infravalanginien' and referred to them as 'niveau supérieur à *Belemnites Orbignyi, Bel. conicus* et *Rhynchonella contracta*'. Also Mazenot (1939), who did find a few ammonites in these beds, still included them in the Berriasian as 'horizon supérieur à *Kilianella* aff. *pexiptycha* (Uhl.) et *Thurmannites* aff. *pertransiens* Sayn'.

However, additional ammonite finds in these beds compelled Busnardo & Le Hégarat (1965) to transfer them from the Berriasian into the Valanginian *Th. roubaudianum* Zone sensu 'Colloque sur le Crétacé inférieur', for they contained only ammonites considered typical for that zone. This procedure resulted in a lowering of the Berriasian-Valanginian boundary.

This sudden entry of 'Valanginian' ammonites in these beds simultaneously characterizes the base of the *T. pertransiens* Subzone, which Le Hégarat (1971) regarded as the lowest subzone of the *Th. roubaudianum* Zone sensu Moullade (1966) and Thieuloy (1971).

The *Th. lucense* Zone introduced by Wiedmann (1968) for virtually the same beds with the same fauna as the *T. pertransiens* Subzone, should be regarded as a junior synonym of the latter, whereas the *Th. thurmanni* Zone introduced by him (1975) to replace the *T. pertransiens* and *Th. lucense* zones, should also be abandoned, because the motives for its introduction are without foundation. However, he showed that in the Cañada Lengua sections the ranges of *B. (B.) callisto, S. (S.) boissieri, Sp. (Ng.) negreli*, and *Lp. studeri* are overlapping a few metres the range of *T. pertransiens*.

Busnardo & Thieuloy (1979) preferred to draw the lower boundary of the Valanginian still lower, viz. with the entry of *B. (M.) foraticostata* Thieuloy, which marks the base of their *Th. otopeta* Zone. They regarded this unit as the lowest zone of the Valanginian Stage. This species, however, appears already slightly below the massive entry of ammonites that characterize the *Th. roubaudianum* Superzone in SE France amidst an ammonite association that hitherto would indicate the *B. callisto* Subzone. Besides we adduced arguments that the introduction of the *Th. otopeta* Zone is unnecessary and that the *T. pertransiens* Subzone has priority.

The abrupt and virtually total renewal of the ammonite fauna at the *S. boissieri - Th. roubaudianum* superzonal boundary in SE France (Busnardo & Le Hégarat, 1965; Le Hégarat & Remane, 1968; Le Hégarat, 1971; Remane & Thieuloy, 1973; Thieuloy, 1973, 1977, 1979) has since long been a well-known fact: all 'Berriasian' perisphinctacean (sub)genera are suddenly replaced by 'Valanginian' ones. A nearly complete segregation existed between the perisphinctaceans of the *S. boissieri* and the *Th. roubaudianum* superzone. In SE France only the ranges of *S. (S.) boissieri* and *Po. (Po.) nieri* seem to be overlapping a few metres the sudden massive entry of ammonites that typify the *Th. roubaudianum* Superzone. This is the reason why so many stratigraphers prefer to choose this boundary as the limit between the Jurassic and Cretaceous systems (Zeiss, 1965; Wiedmann, 1968, 1974, 1975; Drushchits, 1975; Badaluta, 1975; Patrulius et al., 1976; and all those attendants of the 'Colloque sur la limite Jurassique-Crétacé' who voted for this boundary, among which Le Hégarat, Enay, de Flandrin, and Thieuloy).

In the Miravetes sequence it is shown that a conspicuous number of ammonite forms that since the work of Sayn (1907) have been considered characteristic for the *Th, roubaudianum* Superzone appear at the base of the *T. alpillensis* Subzone. In this subzone reputedly 'Berriasian' faunal elements gradually disappear to make room for new, renownedly 'Valanginian' faunal elements, which graudally, though rather rapidly and simultaneously with this disappearance, increase in number and diversity to reach their maximum diversity in the *Th. roubaudianum* Superzone.

The faunal turnover, though important because it involves the nearly complete renewal of the ammonite fauna in a relatively short lapse of time, is slower than previously thought and comes about in the course of the entire *T. alpillensis* Subchron, a substitute for Le Hégarat's (1971) *B. callisto* Subchron, whose faunal characterization is highly inadequate. Our investigation revealed that the typically 'Berriasian' (sub)genera *Berriasella, Malbosiceras, Subthurmannia, Pomeliceras, Spiticeras, Kilianiceras*, and *Groebericeras* disappear not far below or above the top of this subzone, whereas the typically 'Valanginian' (sub)genera *Tirnovella* (= *'Thurmanniceras'* auct. pro parte), *Thurmanniceras* (sensu stricto), *Neocomites, Olcostephanus, Rogersites*, and *Sarasinella* first appear not far below or above the base of this subzone. It should be noted that *Kilianella* and *Erdenella* appear deep in the Berriasian and continue, as *Spiticeras*, high into the Valanginian. So the successive extinctions of taxa typical for the *S. boissieri* Superzone were at the same time well compensated by successive appearances of new taxa typical for the *Th. roubaudianum* Superzone, which progressively increase in number and diversity at the expense of the old ones, which practically disappear in the vicinity of the upper boundary of the *T. alpillensis* Subzone. The faunal change definitely has not the abruptness that invited so many stratigraphers to choose this boundary as the one between the Jurassic and Cretaceous systems.

Nevertheless the faunal turnover in the *T. alpillensis* Subzone is profound and rapid enough to warrant the delimitation of Superzones, but where should the boundary between these superzones be drawn? The *T. alpillensis* Subzone was included in the *Th. roubaudianum* Superzone for the following reasons:
a) the entry of a conspicuous number of new ammonite species that since the work of Sayn (1907) characterize the *Th. roubaudianum* Superzone is biostratigraphically more important than the end of the ranges of retarded species of the *S. boissieri* Superzone;
b) several ammonite forms that since the work of Sayn (1907) have been considered characteristic for the *Th. roubaudianum* Superzone appear even to be restricted to the *T. alpillensis* Subzone of Los Miravetes;
c) the ammonite fauna of the *T. alpillensis* Subzone clearly forms part of the broad ammonite diversity high of the *Th. roubaudianum* Superzone and is situated directly above the diversity minimum that everywhere in the Mediterranean province separates the fauna of the *S. boissieri* Superzone from the fauna of the *Th. roubaudianum* Superzone. The deepest point of this minimum is situated between the *B. picteti* and *T. alpillensis* subzones.

As the lower boundary of the *Th. roubaudianum* Superzone should preferably remain coinciding with the base of the Valanginian, also the base of the Valanginian is lowered to coincide with the boundary between the *B. picteti* Subzone and *T. alpillensis* Subzone, which still represents the boundary between the *S. boissieri* and *Th. roubaudianum* Superzones. In Los Miravetes this boundary is materialized at the top of limestone Y230. This level coincides with the deepest part of the ammonite diversity minimum between the diversity highs of the *S. boissieri* and *Th. roubaudianum* superzones and practically coincides with the beginning of the range of *Lorenziella hungarica*.

Valanginian-Hauterivian boundary

We have adduced arguments in favour of the same stratigraphic position for the Valanginian-Hauterivian boundary as the one that has been adopted by the attendants of the 'Colloque sur le Crétacé inférieur' in 1963 (1965), i.e. between the *Sn. verrucosum* Zone and the *Hi. trinodosum* Zone sensu Thieuloy (1971, 1973, 1977, 1979), because it coincides with one of the deepest diversity minima in the Mediterranean succession of ammonite faunas and is attended by a rapid and radical change in the generic composition of these faunas.

As a consequence not only the stratigraphic scope of the Berriasian but also of the Valanginian is reduced, each comprising only one superzone. The stage appreciation that the Berriasian has gradually acquired should therefore be reconsidered. The possibility of subdividing the original scope of the Valanginian Stage (excluding the socalled 'Terrain Dubisien') into a lower substage, the Berriasian (Coquand, 1871), and an upper substage, for which the name Nemausian (Sarran d'Allard, 1875, 1881) is available, is an attractive alternative. The Nemausian (from Nemausus = Latin for Nîmes) has explicitly been introduced as the stage between the Hauterivian (Renevier, 1873) and Berriasian; it would constitute together with the Berriasian the two divisions that compose the 'Terrain valanginien'. The rockunit that has originally been indicated to represent the Nemausian (type area: neighbourhood of Alès, Gard, France) was referred to by Dumas (1846) as 'marnes argileuses à Bélemnites plates', which is the same rockunit as the 'marnes à *Belemnites latus*' of Pictet (1867) and the 'marnes à *Ammonites Roubaudi* et *neocomiensis*' of Kilian (1888). This alternative implies that the Berriasian would correspond with the *S. boisssieri* Superzone and the Nemausian with the *Th. roubaudianum* Superzone as conceived here.

Jurrasic-Cretaceous boundary

As to the stratigraphic position of the boundary between the Jurassic and Cretaceous systems many views have been expressed. During the 'Colloque sur la limite Jurassique-Crétacé', 1973 (1975) no agreement could be reached as to which of the five proposed boundaries should be chosen. If we follow the ideas of Wiedmann (1968) and Hölder & Zeiss (1972), who advocate that the boundaries of systems should preferably be chosen where the changes in the fossil record are the profoundest, i.e. where new orders and superfamilies begin their definite radiation, the Jurassic-Cretaceous boundary had best be chosen somewhere in the lower part of the Hauterivian, in which the perisphinctaceans and the calpionellids had their final decline, the radiation of the hoplitaceans, desmocerataceans and ancylocerataceans took its definite shape, the globigerinaceans started their development, and the first angiosperms appeared. Kauffmann (1979, p. 441) once again drew our attention to the major radiation of typical Neocomian invertebrates at the beginning of the late Tithonian. The same consideration has brought Hébert (1869) and Paquier (1900) to favour the stratigraphic position of the Jurassic-Createaceous boundary at the base of the upper Tithonian. In short, the calpionellid-bearing stratigraphic interval that approximately comprises the upper Tithonian, Berriasian, Valanginian, and lowest Hauterivian constitutes a well separable and recognizable unit with respect to its fossil content.

From this point of view none of the boundaries situated within this stratigraphic interval are suited to be boundaries between systems in the way advocated by Wiedmann (1968) and Hölder & Zeiss (1972). The ammonite faunal turnover at the Tithonian-Berriasian and Barriasian-Valanginian boundaries for instance takes place merely at the genus level within the superfamily of the Perisphinctaceae. Therefore there are as many, or as few, reasons to incorporate the Valanginian in the Jurassic as there are for the Berriasian. Therefore we are forced to choose the least unsuited one among these boundaries, unless we want to make a drastic change in the firmly established concepts of stages and systems and their succession.

However, so drastic a change is not attainable and not preferable, because if too large a deviation from the traditional views is made, geological maps and literature cannot be read anymore. Once more one must come to realize that stage and system boundaries are in fact primarily determined by convention and tradition and that stratigraphers are merely allowed to make minor rectifications and corrections.

The stratigraphic interval that Coquand in 1871 (p. 232, 233) happened to call 'Berriasien' has been shown to be equivalent in age to at least a part of the so-called 'Inferior oolitic limestone' and 'Marbre Bâtard' rockunits (Kilian, 1894; Donze, 1965; Le Hégarat, 1971; Donze & Le Hégarat, 1972; Remane, 1973; Persoz & Remane, 1976), which have never been considered a part of the Jurassic nor of the Tithonian, but always as the lowest part of the Cretaceous Neocomian, even by Wiedmann (1968). Therefore convention dictates, and we follow this view on the basis of the faunal succession found, that the Berriasian should remain the lowest stage (or substage) of the Cretaceous System, which implies that the Jurassic-Cretaceous boundary should be the same as the Tithonian-Berriasian boundary and, according to the views expressed in this paper, should coincide with the boundary between the *P. grandis* and *S. subalpina* subzones. Of all the boundaries between the base of the upper Tithonian and the top of the lower Hauterivian that are potentially eligible as system boundaries, this boundary is the best suited one, because it is closest to the traditional boundary and well correlatable all over the world by calpionellids and because it represents a well-marked and easily detectable break in the faunal development of the perisphinctacean ammonites in the Mediterranean faunal province. In Los Miravetes this boundary lies between bed Z203 and Z206 along the Barranco de Tollo. A break of equal importance can be found between the '*Sn. verrucosum*' and *Hi. trinodosum* subzones of Thieuloy (1976) which should mark the Valanginian-Hauterivian boundary.

The Jurassic-Cretaceous boundary proposed here, has the advantage that the Purbeck beds of the Jura Mountains, though originally excluded from the Jurassic by d'Orbigny (1842), are left in their totality in the Jurassic, where they were conceived to belong on account of their fauna for more than a century since the investigations of de Loriol & Jaccard (1865) and sustained by Oppel (1865). This view is supported by the fact that from the marine intercalations in the upper part of these beds the ostracode *Protocythere revili* Donze and the ammonites *Pseudosubplanites lorioli* (Zittel) and *Richterella richteri* (Zittel) (probably also *P. lorioli*, with which the middle Tithonian *R. richteri* is often confounded) have been reported (Arkell, 1956, p. 85, 88; Donze, 1973, p. 129). The known ranges of these species do not cross the upper limit of the *P. euxina* Zone (Le Hégarat, 1971; Donze, 1975). Persoz & Remane

(1976) correlated the sudden appearance of kaolinite, which they interpreted to be isochronous, in various sections. In this way they correlated a level within the *P. grandis* Subzone of Le Chévallon and the Bec de l'Echaillon (Le Hégarat, 1971, p. 450, 445) with a level just above the base of the Pierre Châtel Formation and of the 'inferior oolitic limestone', the lowest rockunit of the Neocomian in the Jura Mountains. Donze (1965), Le Hégarat (1971) and Donze & Le Hégarat (1972) have shown that in the Jura Mountain region Purbeckian fresh and brackwater conditions must have persisted into the latest *S. subalpina* Subchron, in consequence of which the base of the fully marine 'Marbre Bâtard' could approximately be correlated with a level at or not far above the base of the *B. privasensis* Subzone. If the correlations of Persoz & Remane are correct, this would mean that the 'Inferior oolitic limestone' unit comprises at least the *P. grandis* and *S. subalpina* subzones. This correlation is not in conflict with those of Donze and Le Hégarat, because this unit contains the last lacustrine and brackwater deposits, which alternate with more or less marine deposits, before the fully marine 'Marbre Bâtard' was deposited, which has generally been considered to represent the onset of the spasmodic Cretaceous transgression. This also means that accidentally, though fortunately, the Jurassic - Cretaceous boundary as proposed here, is closest to the lower boundary of the stratotype of the Valanginian. The appearance and diversification of new ammonite forms follows directly upon the onset of the spasmodic Cretaceous transgression, as was to be expected.

Conclusions

The zonal subdivision adopted in this paper for the upper Tithonian, Berriasian, and Valanginian is primarily based on the presence of deep minima of supraregional significance in the ammonite diversity spectrum of the Mediterranean faunal succession. Each minimum ushers in an almost total renewal of the ammonite fauna and clearly delimits superzones. It was shown that these superzones are very real and well-recognizable biostratigraphic units. They practically correspond to the original faunistical concepts of Neumayr's (1871) *Par. transitorius* Zone, and Kilian's (1888) *S. boissieri* and *Th. roubaudianum* zones, which have been sufficiently defined when they were introduced.

The faunal development within each superzone seems to come about in five well-recognizable steps, which are the basis for the recognition of subzones. This fivefold faunal development becomes particularly apparent when diversity graphs are constructed from bed by bed studies of several fossil-rich, bedded successions without lacunas and are compared with each other. The zonation recently set up for the upper Tithonian, Berriasian, and Valanginian by Oloriz & Tavera (1979a, b), Enay & Geyssant (1975), Le Hégarat (1971), Thieuloy (1973), and Busnardo & Thieuloy (1979b) comes up to, and can be reconciled with, this fivefold development. Ample arguments were adduced to adopt the following scheme (Fig. 2).

One of the principles in setting up this zonal subdivision was the view that formerly sufficiently defined zones and subzones should not unnecessarily be abandoned or subsequently adapted to the range of the index species and that

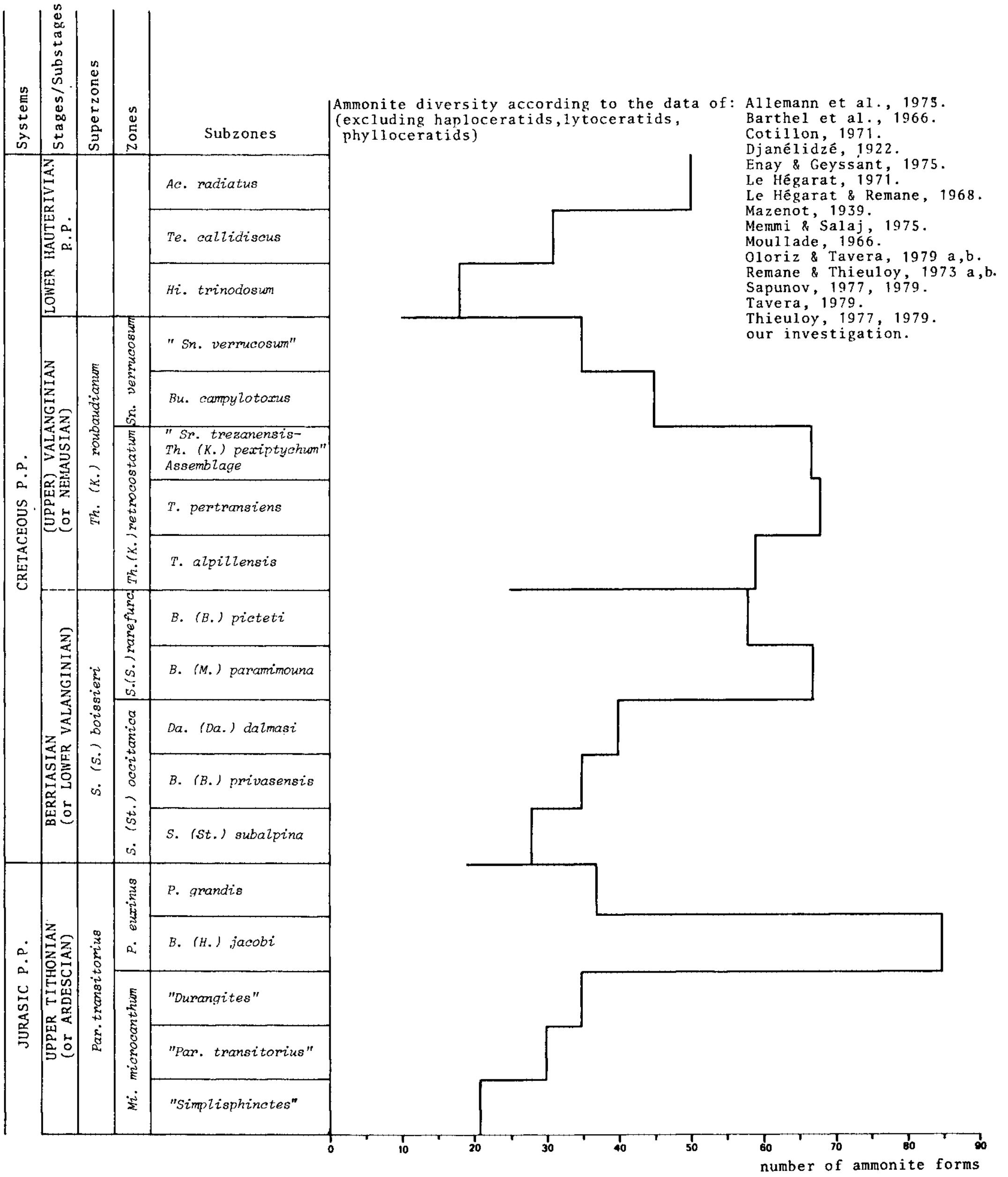


Fig. 2. Chronostratigraphic subdivision adopted in this paper.

they should be respected as much as possible. Detailed biostratigraphic work constantly completes and corrects the faunal association by which the zone is characterized.

The salient points of the zonal scheme presented here are:

1) The stratigraphic positions advocated here for the Tithonian-Berriasian, Berriasian-Valanginian, and Valanginian-Hauterivian boundaries; the first is also the boundary between the Jurassic and Cretaceous systems.

2) The replacement of the *B. callisto* Subzone by the *T. alpillensis* Subzone and the insertion of the *Sr. trezanensis - Th. pexiptychum* Assemblage-subzone between Le Hégarat's (1971) *T. pertransiens* Subzone and Thieuloy's (1973) *Bu. campylotoxus* Subzone.

3) The introduction of the *S. rarefurcata* and *Th. retrocostatum* zones.

4) The reinstatement of the original concepts of the *Par. transitorius* (by Neumayr, 1871), *S. boissieri* (by Kilian, 1888), and *Th. roubaudianum* (by Kilian, 1888) biostratigraphic units as superzones.

5) The reintroduction of the Nemausian (Sarran d'Allard, 1881) as the only available alternative name for the chronostratigraphic unit between the Berriasian and the Hauterivian.

Based on the development of the now reasonably well-known ammonite fauna, we could make the following correlations with the subdivisions proposed by other investigators for the Mediterranean region (Enclosure 5).

No attempt was made to correlate the zonation adopted here with those set up for the mid- and north-European regions, for only one juvenile specimen reminiscent of *Riasanites* was found in the upper part of the *B. paramimouna* Subzone. Serious attempts with respect to such a correlation have been made by Thieuloy (1973, 1977b) and Kemper et al. (1981). Remarkable, however, is the presence of a few ammonite forms hitherto thought to be restricted to the East-Pacific province. Of these forms the representatives of *Substeueroceras* (*Ss. flandrini* (Le Hég.), *Ss. beneckei* (Jac.) and *Ss.* sp. (in Oloriz & Tavera, 1979b)) are restricted to the upper Tithonian, whereas *Lissonia riveroi* (Lisson) occurs in the middle part of the Berriasian of Miravetes and *Spiticeras* (*Groebericeras*) aff. *S. (G.) bifrons* (Leanza) extends its range through the *B. picteti* and *T. alpillensis* subzones. These finds contribute to a better correlation with the East Pacific province.

The finding of *Th. (Th.)* aff. *kingi, Pa.* cf. *theodori, S. (S.) lissonoides, Sr. varians, O. (O.) sakalavensis*, and *O. (O.)* aff. *globulus* in the *T. pertransiens* Subzone of Los Miravetes, makes it possible to identify this subzone in the Himalayan province (especially in the Himalayan and Salt Ranges).

Palaeontological notes

These notes are necessary for a better understanding of the conception of the generic groups and their stratigraphic implications mentioned in this paper. The upper Tithonian, Berriasian, and lower Valanginian ammonites from Los Miravetes will be described in a forthcoming paper.

1) The scope of *Hegaratella* Nikolov & Sapunov, 1977 (subgenus of *Berriasella* Uhlig, 1905), type species: *Berriasella paramacilenta* Mazenot, 1939, was

emended here to comprise all those species of the genus *Berriasella* sensu Le Hégarat, 1971 (including those referred to as *'Picteticeras'* by Le Hégarat, 1971) that occur in the *P. euxinus* Zone and lower, and the bituberculated berriasellids of the *Ammonites Chaperi* group (= *Chapericeras* Hoedemaeker, 1981) which includes *Hoplites Tarini* Kilian, 1889.

2) *Picteticeras* Le Hégarat, 1971, type species: *Berriasella Picteti* (Jacob) in Mazenot, 1939, is here considered a subjective synonym of *Berriasella (Berriasella)* Uhlig, 1905.

3) To *Substeueroceras* Spath, 1923, type species: *Odontoceras Koeneni* Steuer, 1897, were assigned *Neocomites Beneckei* (Jacob) in Mazenot, 1939, and *Pseudargentiniceras flandrini* Le Hégarat, 1971.

4) *Pseudoneocomites* gen. nov., type species: *Hoplites Retowskyi* Sarasin & Schöndelmayer, 1901. Diagnosis: compressed platycones with narrow umbilicus and steep to overhanging umbilical walls, rounded venter, and smooth siphonal band generally only in young. The very fine, serrated, slightly flexuous ribs originate by twos and threes from umbilical crests or are bundled. The majority of the ribs do not branch. Ribs efface on living chamber. It comprises besides its type species *Neocomites suprajurensis* Mazenot, 1939, *N. allobrogensis* Mazenot, 1939, *Tirnovella davidi* Le Hégarat, 1971, and *Neocomites neocomiensis*, variété plate à côtes fines et fasciculées, in Sayn, 1907, pl. 3, fig. 14. This genus ranges from the *B. jacobi* Subzone (upper Tithonian) up to and including the *Bu. campylotoxus* Subzone (upper Valanginian).

5) *Fauriella* Nikolov, 1966, type species: *Berriasella gallica* Mazenot, 1939, is here considered a subjective synonym of *Subthurmannia (Subthurmannia)* Spath, 1939.

6) In *Strambergella* Nikolov, 1966 (subgenus of *Subthurmannia* Spath, 1939), type species: *Ammonites carpathicus* Zittel, 1868, were included those species of *Subthurmannia* in which fasciculation of ribs appears relatively late in the ontogeny, such as *Fauriella shipkovensis* Le Hégarat, 1971 (non Nikolov & Mandov, 1967), *F. floquinensis* Le Hégarat, 1971, *F. clareti* Le Hégarat, 1971, *Neocomites cabrensis* Fallot, 1922, *N. subalpinus* Mazenot, 1939, and its descendant *Ammonites occitanicus* Pictet, 1867, *Jabronella cisternensis* Le Hégarat, 1971, *J. patruliusi* Le Hégarat, 1971, and *Neocomites allobrogensis* Arnould-Saget, 1951, non Mazenot, 1939.

7) In *Jabronella* Nikolov, 1966 (subgenus of *Subthurmannia* Spath, 1939), type species: *Berriasella jabronensis* Mazenot, 1939, were left only *S. (J.) subisaris* (Mazenot, 1939) and *S. (J.) discrepans* (Retowski, 1894) (= *Protacanthodiscus troiani* Nikolov & Mandov, 1967).

8) *Erdenella* Nikolov, 1979 (objective synonym: *Pomeliceras* Hoedemaeker, 1981, non Grigorieva, 1938; subgenus of *Thurmanniceras* Cossmann, 1901), type species: *Hoplites Paquieri* Simionescu, 1899, includes besides its type species, *Ammonites isaris* Pomel, 1889, *A. zianidia* Pomel, 1889, *Hoplites hystricoides* Uhlig, 1902, *H. Michaelis* Uhlig, 1902, *Hoplites (Acanthodiscus) asiaticus* Uhlig, 1910, *H. (A.) spitiensis* Uhlig, 1910, and *Berriasella balkanica* Nikolov, 1960.

9) The subgenus *Thurmanniceras (Thurmanniceras)* Cossmann, 1901, contains in addition to its type species *Ammonites Thurmanni* Pictet & Campiche, 1860, the species *Th. (Th.) otopeta* Thieuloy, 1979, *Th. Kingi* (Uhlig, 1910), *Th. (Th.) salientinum* Sayn, 1907, *Th. (Th.) loryi* Sayn, 1907 (pro var.), and *Th. (Th.) allobrogicum* (Kilian, 1891).

10) The scope of *Tirnovella* Nikolov, 1966, type species: *Berriasella alpillensis* Mazenot, 1939, as conceived in this paper, differs radically from that of Le Hégarat (1971) and comprises in addition to its type species (to which belongs the form depicted by Sayn, 1907, in pl. 5, fig. 5 under the name *Thurmannia Thurmanni* Pictet et Campiche, variété à large ombilic) also *Thurmannia pertransiens* Sayn, 1907, *Thurmannia gueymardi* Sayn, 1907, *Thurmannia gratianopolitensis* Sayn, 1907, *Thurmannia Thurmanni* Pictet et Campiche in Sayn, 1907, pl. 5, fig. 1 (= *Hoplites Thurmanni* Pict. et Camp. in Kilian, 1891, pl. 5, fig. 3), *Tirnovella* aff. *alpillensis* (Maz.) in Arnaud et al., 1981, *Thurmannites* aff. *pertransiens* Sayn in Mazenot, 1939, pl. 32, fig. 16, and *Tirnovella donzei* Le Hégarat, 1971.
11) *'Hoplites' aristides* Kilian, 1896, of the *B. jacobi* Subzone is here considered a *Dalmasiceras (Dalmasiceras)* Djanélidzé, 1921 instead of a *Dalmasiceras (Subalpinites)* Mazenot, 1939.
12) *Spiticeras ('Negreliceras') praenegreli* Djanélidzé, 1922, of the *B. jacobi* Subzone is here considered a *Spiticeras (Proniceras)* Burckhardt, 1919.
13) *'Dalmasiceras' panini* Le Hégarat, 1971, of the *B. picteti* Subzone is here considered a *Berriasella (Berriasella)* Uhlig, 1905.
14) *Ammonites carachtheis* Zeuschner, type species of subgenus *Neoglochiceras* Patrulius & Avram, 1976, is here included in *Neolissoceras* Spath, 1923, type species: *Ammonites grasianus* (d'Orbigny, 1841).

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Appendix: Alphabetical list of ammonite forms

The following species were collected by our equipe from the lower 312 m of the Miravetes Formation along the Río Argos (see enclosures 1 - 3).

Berriasella (Berriasella) n. sp. indet. A (heterocostate with clavate ribs in adult)
Berriasella (Berriasella) n. sp. indet. B (with many simple ribs and constrictions)
Berriasella (Berriasella) n. sp. indet. C (with distant flexuous ribs and intercalatories)
Berriasella (Berriasella) n. sp. D
  = *Berriasella* aff. *Janus* (Retowski) in Mazenot, 1939, pl. 6, figs. 20, 21
Berriasella (Berriasella) n. sp. E
  = *Berriasella* aff. *simplicicostata* Mazenot, 1939, pl. 22, fig. 1
Berriasella (Berriasella) callisto (d'Orbigny, 1842)
Berriasella (Berriasella) aff. *B. (B.) callisto* (d'Orbigny, 1842)
Berriasella (Berriasella) n. sp. ex gr. *B. (B.) callisto* (d'Orbigny, 1842)
Berriasella (Berriasella) evoluta Le Hégarat, 1964
Berriasella (Berriasella) haemusensis Nikolov & Mandov, 1967
Berriasella (Berriasella) n. sp. aff. *B. (B.) haemusensis* Nikolov & Mandov, 1967
Berriasella (Berriasella) n. sp. indet. ex gr. *B. (B.) haemusensis* Nikolov & Mandov, 1967
Berriasella (Berriasella) jauberti Mazenot, 1939
Berriasella (Berriasella) n. sp.? aff. *B. (B.) jauberti* Mazenot, 1939
Berriasella (Berriasella) moesica Nikolov & Mandov, 1967
Berriasella (Berriasella) panini (Le Hégarat, 1971)
Berriasella (Berriasella) picteti (Jacob) in Mazenot, 1939
Berriasella (Berriasella) privasensis (Pictet, 1867)
Berriasella (Berriasella) aff. *B. (B.) privasensis* (Pictet, 1867)
  = *Berriasella privasensis* (Pictet) in Mazenot, 1939, pl. 2, fig. 4
Berriasella (Berriasella) simplicicostata Mazenot, 1939
Berriasella (Berriasella) n. sp. aff. *B. (B.) simplicicostata* Mazenot, 1939
Berriasella (Berriasella) tzankovi Nikolov & Mandov, 1967
Berriasella (Berriasella) n. sp. ex gr. *B. (B.) tzankovi* Nikolov & Mandov, 1967
Berriasella (Delphinella) spp.
Berriasella (Delphinella) berthei (Toucas, 1890)
Berriasella (Delphinella) consanguinea (Retowski, 1894)
Berriasella (Delphinella) crimensis (Burckhardt, 1912)
Berriasella (Delphinella) n. sp. ex gr. *B. (D.) crimensis* (Burckhardt, 1912)
Berriasella (Delphinella) delphinensis (Kilian, 1889)
Berriasella (Delphinella) obtusenodosa (Retowski, 1894)
Berriasella (Delphinella) aff. *B. (D.) obtusenodosa* (Retowski, 1894)
  = *D. boisseti* Le Hégarat, 1971, pl. 41, fig. 5
Berriasella (Delphinella) tresannensis (Le Hégarat, 1971)
Berriasella (Hegaratella) spp.
Berriasella (Hegaratella) chomeracensis (Toucas, 1890)
Berriasella (Hegaratella) elmii Le Hégarat, 1971
Berriasella (Hegaratella) jacobi Mazenot, 1939
Berriasella (Hegaratella) oppeli (Kilian, 1889)
Berriasella (Hegaratella) oxycostata (Jacob) in Mazenot, 1939
Berriasella (Hegaratella) paramacilenta Mazenot, 1939
Berriasella (Hegaratella) subcallisto (Toucas, 1890)
Berriasella (Malbosiceras) n. sp.
  = *Berriasella* sp. gr. de *B. Chaperi*, éch. 3 in Mazenot, 1939, pl. 10, fig. 5
Berriasella (Malbosiceras) malbosi (Pictet, 1867)
Berriasella (Malbosiceras) paramimouna alutensis (Patrulius & Avram, 1976)
Berriasella (Malbosiceras) paramimouna paramimouna Mazenot, 1939

Berriasella (Malbosiceras) pouyannei (Pomel, 1889)
Bochianites sp.
Chamalocia n. sp.
Chamalocia aenigmatica (Sayn, 1907)
Dalmasiceras (Dalmasiceras) sp.
Dalmasiceras (Dalmasiceras) sp. indet.
Dalmasiceras (Dalmasiceras) dalmasi (Pictet, 1867)
Dalmasiceras (Dalmasiceras) punctatum (Djanélidzé, 1922)
Dalmasiceras (Subalpinites) n.sp.
 = *Subalpinites* aff. *aristides* (Kilian) in Le Hégarat, 1971, pl. 53, fig. 1
Himalayites stoliczkai Uhlig, 1910
Holcophylloceras calypso (d'Orbigny, 1841)
Holcophylloceras aff. *H. calypso* (d'Orbigny, 1841)
 = *Holcophylloceras* sp. in Memmi, 1965, pl. 31a, fig. 2
Hypophylloceras serum (Oppel, in Zittel, 1868)
Hypophylloceras tethys (d'Orbigny, 1841)
Leptoceras cf. *L. jelevi* (Nikolov, 1966) sive *L. brunneri* (Ooster, 1860)
Leptoceras sapunovi (Nikolov, 1967)
Leptoceras studeri (Ooster, 1860)
Lissonia riveroi (Lisson, 1907)
Lytoceras juilleti (d'Orbigny, 1841)
 = *Ammonites sutilis* Oppel, in Zittel, 1868
Lytoceras liebigi (Oppel) in Zittel, 1868
Neocomites spp.
Neocomites n. sp.? indet.
 = cf. *Neocomites neocomiensis* d'Orb. Echantillon recueilli par Lory en Lus-la-Croix-Haute, in Sayn, 1907, pl. 3, fig. 6
Neocomites neocomiensis (d'Orbigny, 1841)
Neocomites n. sp.? aff. *N. neocomiensis* (d'Orbigny, 1841) (wider umbilicus than typical form)
Neocomites premolicus Sayn, 1907
Neocomites n. sp.? aff. *N. premolicus* Sayn, 1907 (few fasciculated ribs in young)
Neocomites subtenuis Sayn, 1907
Neocosmoceras sp.
Neocosmoceras sayni (Simionescu, 1899)
Neolissoceras sp.
Neolissoceras carachtheis (Zeuschner, 1846)
Neolissoceras grasianum (d'Orbigny, 1841)
Olcostephanus spp.
Olcostephanus (Mexicanoceras?) sp. indet.
Olcostephanus (Olcostephanus) cf. *O. (O.) collignoni* Besairie, 1936
Olcostephanus (Olcostephanus) aff. *O. (O.) globulus* Spath, 1939
Olcostephanus (Olcostephanus) sakalavensis Besairie, 1936
Olcostephanus (Olcostephanus) ex gr. *O. (O.) salinarius* Spath, 1939
Olcostephanus (Olcostephanus) cf. *O. (O.) sublaevis* Spath, 1939
 = *Ammonites Astierianus* d'Orbigny, in Pictet, 1867, pl. 17, figs. 3, 4
Olcostephanus (Rogersites) ambikyi Besairie, 1936
Olcostephanus (Rogersites) cf. *O. (R.) inordinatus* Tzankov, 1942
Olcostephanus (Rogersites) aff. *O. (R.) schenki* (Oppel, 1863)
 = *Olcostephanus (Rogersites)* aff. *schenki* (Oppel) in Spath, 1939, pl. 2, fig. 8
Olcostephanus (Subastieria?) sp. indet.
Parandiceras cf. *P. theodori* (Uhlig, 1910)
Pomeliceras (Mazenoticeras) broussei (Mazenot, 1939)
Pomeliceras (Mazenoticeras) cf. *P. (M.) curelense* (Kilian, 1888)
Pomeliceras (Mazenoticeras) cf. *P. (M.) malbosiforme* Le Hégarat, 1971)

Pomeliceras (Pomeliceras) sp. indet.
Protancyloceras sp.
Protancyloceras n. sp. indet.
Protancyloceras bicostatum Arnould-Saget, 1951
Protancyloceras cf. *P. depressum* Arnould-Saget, 1951
Protancyloceras cf. *P. kurdistanense* Spath, 1950
Protancyloceras punicum Arnould-Saget, 1951
Protetragonites honnoratianus (d'Orbigny, 1841)
    = *Ammonites municipalis*, Oppel, in Zittel, 1868
Protetragonites quadrisulcatus (d'Orbigny, 1841)
Pseudoneocomites n. sp.
    = *Neocomites neocomiensis* d'Orb. Variété plate à côtes fines et fasciculées, in Sayn, 1907, pl. 3, fig. 14
Pseudoneocomites allobrogensis (Mazenot, 1939)
Pseudoneocomites retowskyi (Sarasin & Schöndelmayer, 1901)
Pseudosubplanites spp.
Pseudosubplanites n. sp.
    = *Hoplites ponticus* Retowski, in Simionescu, 1899, pl. 1, fig. 1
Pseudosubplanites berriasensis Le Hégarat, 1971
Pseudosubplanites combesi Le Hégarat, 1971
Pseudosubplanites n. sp.? aff. *P. combesi* Le Hégarat, 1971
    = *Perisphinctes Lorioli* Zitt., in Kilian, 1889, pl. 28, fig. 3
Pseudosubplanites euxinus (Retowski, 1894)
Pseudosubplanites grandis (Mazenot, 1939)
Pseudosubplanites lorioli (Zittel, 1868)
Pseudosubplanites ponticus (Retowski, 1894)
Ptychophylloceras inordinatum (Toucas, 1890)
Ptychophylloceras semisulcatum (d'Orbigny, 1841)
    = *Ammonites ptychoicus* Quenstedt, (1845 - 1847)
Riasanites? sp.
Sarasinella n. sp. indet.
Sarasinella eucyrta (Sayn, 1907)
Sarasinella longi (Sayn, 1907)
Sarasinella subquadrata (Sayn, 1907)
Sarasinella trezanensis (Lory, in Sayn, 1907)
Sarasinella n. sp. aff. *S. trezanensis* (Lory, in Sayn, 1907)
    = *Neocomites trezanensis* Lory. Variété à tours étroits, in Sayn, 1907, pl. 4, fig. 15
Sarasinella varians (Uhlig, 1910)
Spiticeras spp.
Spiticeras (Groebericeras) aff. *S. (G.) bifrons* (Leanza, 1945)
Spiticeras (Groebericeras) rocardi (Pomel, 1889)
Spiticeras (Kilianiceras) ex gr. *S. (K.) gratianopolitense* (Kilian, 1891)
Spiticeras (Kilianiceras) incertum Djanélidzé, 1922
Spiticeras (Negreliceras) negreli (Matheron, 1880)
Spiticeras (Negreliceras) paranegreli Djanélidzé nov. subsp.
    = *Spiticeras (Negreliceras) paranegreli* éch. C, in Djanélidzé, 1922, pl. 6, fig. 2
Spiticeras (Negreliceras) paranegreli paranegreli Djanélidzé, 1922
Spiticeras (Negreliceras) planissimum Djanélidzé, 1922
Spiticeras (Negreliceras) subnegreli Djanélidzé, 1922
Spiticeras (Spiticeras) bulliforme Uhlig, 1903
Spiticeras (Spiticeras) correardi (Kilian, in Djanélidzé, 1922)
Spiticeras (Spiticeras) drumense (Sayn, in Kilian, 1910)
Spiticeras (Spiticeras) elegans Djanélidzé, 1922
Spiticeras (Spiticeras) fauriense Djanélidzé, 1922
Spiticeras (Spiticeras) cf. *S. (S.) groteanum* (Oppel, 1863)

Spiticeras (Spiticeras) aff. *S. (S.) guttatum* (Uhlig, 1903)
Spiticeras (Spiticeras) n. sp. aff. *S. (S.) kiliani* Djanélidzé, 1922
Spiticeras (Spiticeras) cf. *S. (S.) kiliani gigas* Djanélidzé, 1922
Spiticeras (Spiticeras) kiliani kiliani Djanélidzé, 1922
Spiticeras (Spiticeras) kiliani laevigatum Djanélidzé, 1922
Spiticeras (Spiticeras) multiforme Djanélidzé, 1922
Spiticeras (Spiticeras) obliquenodosum (Retowski, 1894)
Spiticeras (Spiticeras) n. sp. aff. *S. (S.) oppeli* Uhlig, 1903
Spiticeras (Spiticeras) cf. *S. (S.) scriptum* Uhlig, 1903
Spiticeras (Spiticeras) tenuicostatum Djanélidzé, 1922
Spiticeras (Spiticeras) tobleri Uhlig, 1903
Substeueroceras beneckei (Jacob, in Mazenot, 1939)
Substreblites zonarius (Oppel, in Zittel, 1868)
Subthurmannia sp.
Subthurmannia (Jabronella) discrepans (Retowski, 1894)
Subthurmannia (Jabronella) jabronensis (Mazenot, 1939)
Subthurmannia (Jabronella) subisaris (Mazenot, 1939)
Subthurmannia (Strambergella) n. sp.
    = *Neocomites allobrogensis* Mazenot, in Arnould-Saget, 1951, pl. 8, fig. 1
Subthurmannia (Strambergella) carpathica (Zittel, 1868)
Subthurmannia (Strambergella) cisternensis (Le Hégarat, 1971)
Subthurmannia (Strambergella) clareti (Le Hégarat, 1971)
Subthurmannia (Strambergella) floquinensis (Le Hégarat, 1971)
Subthurmannia (Strambergella) occitanica (Pictet, 1867)
Subthurmannia (Strambergella) patruliusi (Le Hégarat, 1971)
Subthurmannia (Strambergella) subalpina (Mazenot, 1939)
Subthurmannia (Subthurmannia) berriasensis (Le Hégarat, 1964)
Subthurmannia (Subthurmannia) boissieri (Pictet, 1867)
Subthurmannia (Subthurmannia) gallica (Mazenot, 1939)
Subthurmannia (Subthurmannia) gauthieri (Le Hégarat, 1971)
Subthurmannia (Subthurmannia) latecostata (Kilian, in Mazenot, 1939)
Subthurmannia (Subthurmannia) lissonoides Spath, 1939
Subthurmannia (Subthurmannia) rarefurcata (Pictet, 1867)
Subthurmannia (Subthurmannia) n. sp. aff. *S. (S.) romani* (Mazenot, 1939)
    = *Tirnovella romani* (Mazenot) in Le Hégarat, 1971, pl. 49, fig. 4
Thurmanniceras (Erdenella) n. sp. indet. A
Thurmanniceras (Erdenella) sp. indet. B
Thurmanniceras? (Erdenella?) n. sp. indet. C
Thurmanniceras (Erdenella) balkanicum (Nikolov, 1960)
Thurmanniceras (Erdenella) cf. *T. (E.) hystricoides* (Uhlig, 1902)
Thurmanniceras (Erdenella) isare (Pomel, 1889)
Thurmanniceras (Erdenella) n. sp.? aff. *T. (E.) isare* (Pomel, 1889)
Thurmanniceras (Erdenella) paquiri (Simonescu, 1899)
Thurmanniceras (Erdenella) zianidia (Pomel, 1889)
Thurmanniceras (Kilianella) spp.
Thurmanniceras (Kilianella) n. sp. indet. A (convexicostate)
Thurmanniceras (Kilianella) n. sp. B
    = cf. cotype of *Ammonites Malbosi* Pictet, 1867, pl. 14, fig. 2
Thurmanniceras (Kilianella) n. sp. C (with lateral tubercles)
Thurmanniceras (Kilianella) n. sp.? D
    = *Hoplites* n. f. cfr. *barowae* Uhlig, in Parona, 1887, pl. 2, fig. 3
Thurmanniceras (Kilianella) n. sp. E
    = *Berriasella oxycostata* (Jacob) in Mazenot, 1939, pl. 3, fig. 10
Thurmanniceras (Kilianella) n. sp. F
    = cotype of *Hoplites pexiptychus* Uhlig, 1882, pl. 4, fig. 5

Thurmanniceras (Kilianella) n. sp. G
= *Thurmannia (Kilianella) Roubaudi* d'Orb. Variété à tours plus embrassants, in Sayn, 1907, pl. 6, fig. 9
Thurmanniceras (Kilianella) n. sp. H
= *Berriasella* aff. *simplicicostata* in Mazenot, 1939, pl. 22, fig. 2
Thurmanniceras (Kilianella) cf. *T. (K.) bochianense* Sayn, 1907
Thurmanniceras (Kilianella) aff. *T. (K.) bochianense* Sayn, 1907
= *Thurmannia (Kilianella) bochianensis* Sayn, 1907, pl. 6, fig. 12
Thurmanniceras (Kilianella) n. sp. aff. *T. (K.) bochianense* Sayn, 1907
= *Thurmannia (Kilianella) bochianensis*. Variété comprimée, in Sayn, 1907, pl. 6, fig. 4
Thurmanniceras (Kilianella) busnardoi (Patrulius & Avram, 1976)
Thurmanniceras (Kilianella) n. sp. aff. *T. (K.) busnardoi* (Patrulius & Avram, 1976) (lateral tubercles persist into adult)
Thurmanniceras (Kilianella) chamalocense (Mazenot, 1939)
Thurmanniceras (Kilianella) aff. *T. (K.) chamalocense* (Mazenot, 1939)
Thurmanniceras (Kilianella) cf. *T. (K.) collignoni* (Fatmi, 1977)
Thurmanniceras (Kilianella) grossouvrei Sayn, 1889
Thurmanniceras (Kilianella) n. sp. aff. *T. (K.) grossouvrei* Sayn, 1889
= *Kilianella* aff. *grossouvrei* (Sayn) in Memmi, 1965, pl. 31a, fig. 5
Thurmanniceras (Kilianella) ischnoterum Sayn, 1907
Thurmanniceras (Kilianella) cf. *T. (K.) koellikeriforme* (Patrulius & Avram, 1976)
Thurmanniceras (Kilianella) n. sp.? aff. *T. (K.) leptosomum* (Uhlig, 1910)
Thurmanniceras (Kilianella) cf. *T. (K.) lucense* Sayn, 1907
Thurmanniceras (Kilianella) aff. *T. (K.) lucense* Sayn, 1907 (with fasciculated ribs)
Thurmanniceras (Kilianella) pexiptychum (Uhlig, 1882)
Thurmanniceras (Kilianella) aff. *T. (K.) pexiptychum* (Uhlig, 1902, non 1882)
Thurmanniceras (Kilianella) retrocostatum Sayn, 1907
Thurmanniceras (Kilianella) n. sp.? aff. *T. (K.) retrocostatum* Sayn, 1907
Thurmanniceras (Kilianella) roubaudianum (d'Orbigny, 1850, in Kilian, 1888)
Thurmanniceras (Kilianella) aff. *T. (K.) roubaudianum* (d'Orbigny, 1850, in Kilian, 1888) (with straight radial ribs)
Thurmanniceras (Kilianella) n. sp. ex gr. *T. (K.) roubaudianum* (d'Orbigny, 1850)
= *Kilianella roubaudi* (d'Orbigny) in Fülöp, 1964, pl. 24, fig. 3
Thurmanniceras (Thurmanniceras) sp. indet. A
= cf. *Berriasella carpathica* (Zittel) in Mazenot, 1939, pl. 13, fig. 2
Thurmanniceras (Thurmanniceras) n. sp. B
= *Hoplites Thurmanni* Pict. et Camp. Variété extrême à tubercules, in Kilian, 1891, pl. 4, figs. 2, 3
Thurmanniceras (Thurmanniceras) n. sp.? indet. C (with relatively narrow umbilicus)
Thurmanniceras (Thurmanniceras) allobrogicum (Kilian, 1891)
Thurmanniceras (Thurmanniceras) aff. *T. (T.) kingi* (Uhlig, 1910)
Thurmanniceras (Thurmanniceras) loryi Sayn, 1907
Thurmanniceras (Thurmanniceras) otopeta Thieuloy, 1979
Thurmanniceras (Thurmanniceras) salientinum Sayn, 1907
Thurmanniceras (Thurmanniceras) cf. *T. (T.) thurmanni* (Pictet & Campiche, 1860)
Thurmanniceras (Thurmanniceras) aff. *T. (T.) thurmanni* (Pictet & Campiche, 1860)
= *Thurmannia Thurmanni* Pictet et Campiche. Echantillon presque typique, in Sayn, 1907, pl. 5, fig. 14
Tirnovella n. sp. indet.
Tirnovella alpillensis (Mazenot, 1939)
Tirnovella n. sp.? aff. *alpillensis* (Mazenot, 1939)
= *Tirnovella* aff. *alpillensis* (Mazenot) in Arnaud et al., 1981, pl. 1, fig. 1
Tirnovella donzei Le Hégarat, 1971
Tirnovella gratianopolitensis (Sayn, 1907)

Tirnovella n. sp. aff. *T. gratianopolitensis* (Sayn, 1907)
  = *Thurmannia Thurmanni* Pictet et Campiche, in Sayn, 1907, pl. 5, fig. 1
Tirnovella n. sp. aff. *T. gueymardi* (Sayn, 1907)
  = *Thurmannites* aff. *pertransiens* Sayn, in Mazenot, 1939, pl. 32, fig. 16
Tirnovella gueymardi crassicostata (Nikolov, 1960)
Tirnovella gueymardi gueymardi (Sayn, 1907)
Tirnovella pertransiens (Sayn, 1907)
Uhligites sp.
Uhligites sp. indet.

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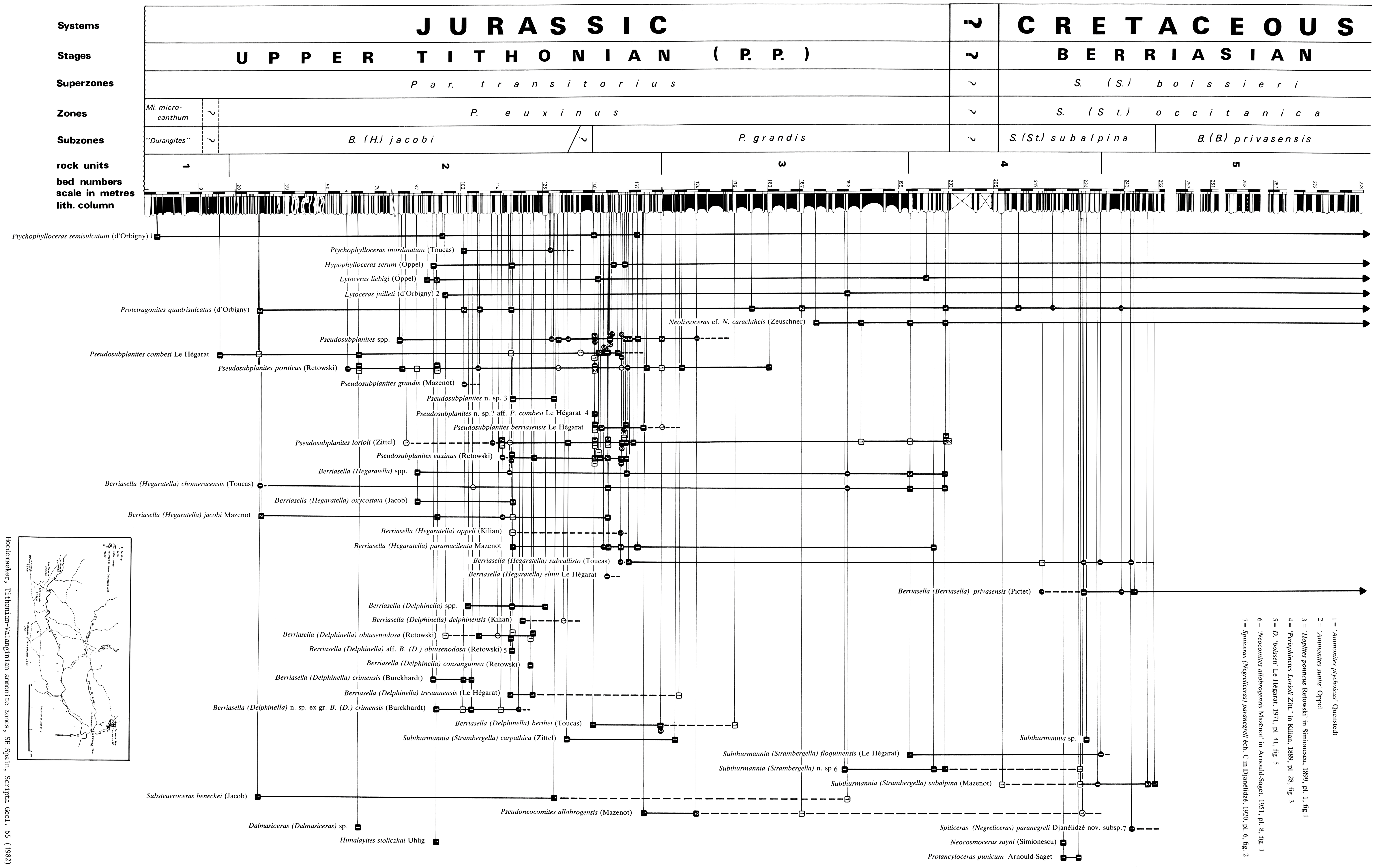
SECTION Z
Barranco de Tollo

Enclosure 1: Ammonite distribution



1 = '*Ammonites ptychoicus*' Quenstedt
2 = '*Ammonites sutilis*' Oppel
3 = '*Hoplites ponticus* Retowski' in Simionescu, 1899, pl. 1, fig.1
4 = '*Perisphinctes Lorioli* Zitt.' in Kilian, 1889, pl. 28, fig. 3
5 = *D.* '*boisseti*' Le Hégarat, 1971, pl. 41, fig. 5
6 = '*Neocomites allobrogensis* Mazènot' in Arnould-Saget, 1951, pl. 8, fig. 1
7 = *Spiticeras (Negreliceras) paranegreli* éch. C in Djanélidzé, 1920, pl. 6, fig. 2

Legend

	in situ	*loose*
identification certain	▣	●
identification uncertain	□	○

(figures indicate number of specimens)

Loose specimens indicated on the lowest bed of the interval from which they could possibly be derived.

▯ limestone
▮ marlstone
▨ marly limestone
☒ observational hiatus of known thickness
unconformity
slipplane

—— range certain
------ range uncertain

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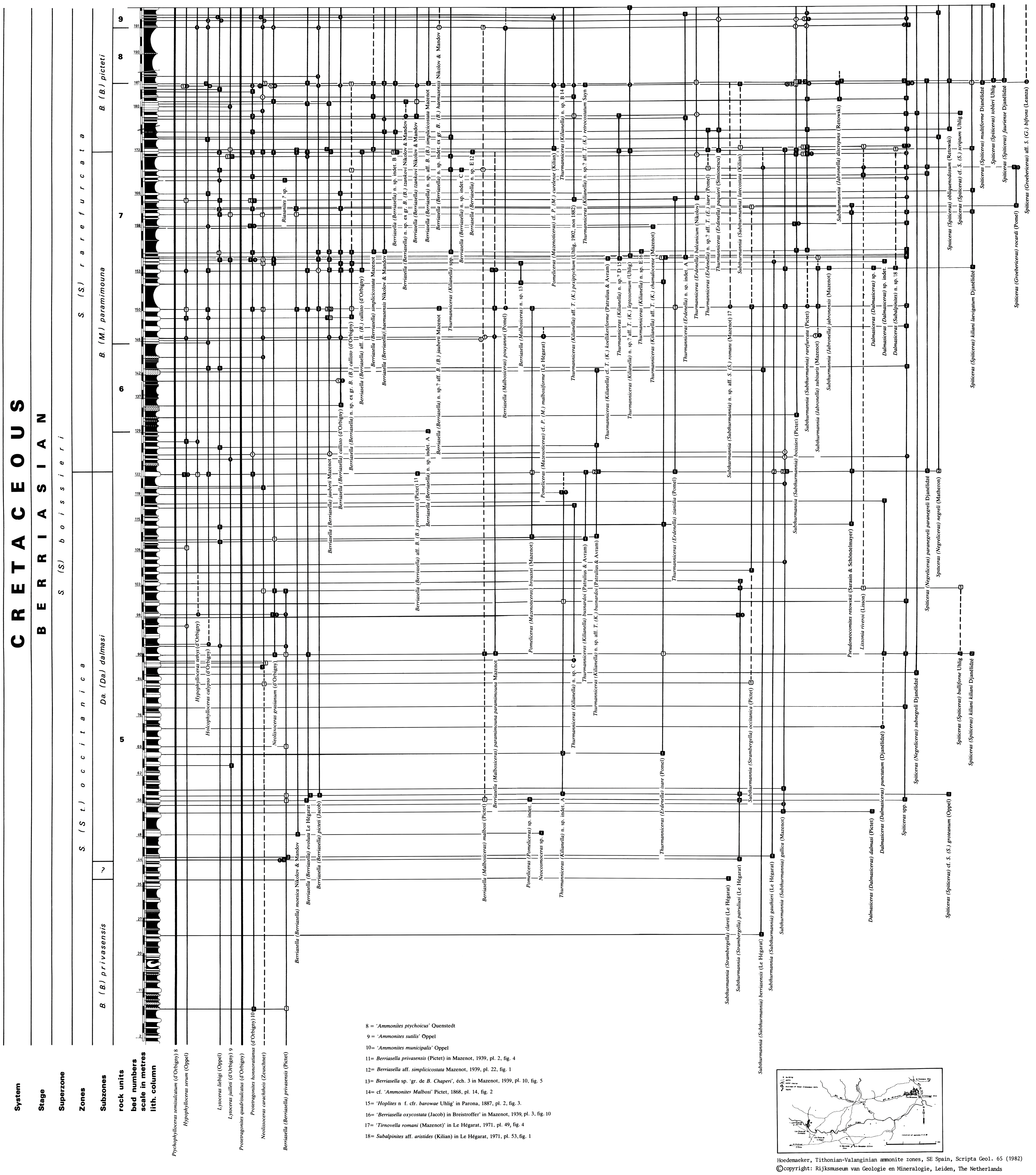

8 = '*Ammonites ptychoicus*' Quenstedt
9 = '*Ammonites sutilis*' Oppel
10= '*Ammonites municipalis*' Oppel
11= *Berriasella privasensis* (Pictet) in Mazenot, 1939, pl. 2, fig. 4
12= *Berriasella* aff. *simplicicostata* Mazenot, 1939, pl. 22, fig. 1
13= *Berriasella* sp. 'gr. de *B. Chaperi*', éch. 3 in Mazenot, 1939, pl. 10, fig. 5
14= cf. '*Ammonites Malbosi*' Pictet, 1868, pl. 14, fig. 2
15= '*Hoplites* n f. cfr. *barowae* Uhlig' in Parona, 1887, pl. 2, fig. 3.
16= '*Berriasella oxycostata* (Jacob) in Breistroffer' in Mazenot, 1939, pl. 3, fig. 10
17= '*Tirnovella romani* (Mazenot)' in Le Hégarat, 1971, pl. 49, fig. 4
18= *Subalpinites* aff. *aristides* (Kilian) in Le Hégarat, 1971, pl. 53, fig. 1

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Enclosure 2: Ammonite distribution

SECTION Y (lower part)

Barranco de Miravetes

Legend

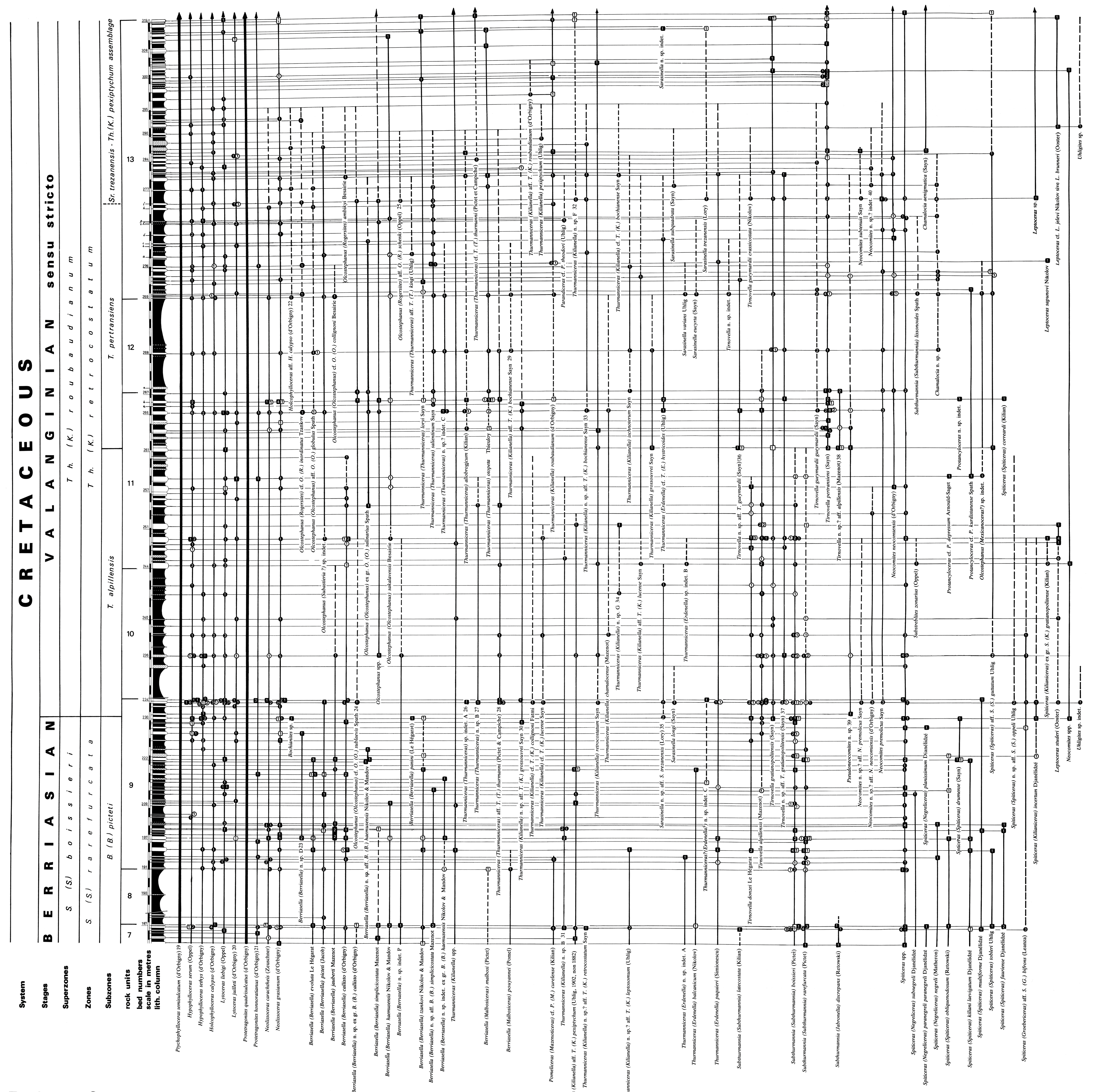
	in situ	loose
Identification certain	■	●
Identification uncertain	□	○

(figures indicate number of specimens)

Loose specimens indicated on the lowest bed of the interval from which they could possibly be derived.

☐ limestone
■ marlstone
▨ marly limestone
☒ observational hiatus of known thickness
〰 unconformity
▨ slipplane

—— range certain
------- range uncertain



Enclosure 3: Ammonite distribution

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SECTION Y (upper part)

Barranco de Miravetes

Legend

	in situ	*loose*
Identification certain	❸	❷
Identification uncertain	①	④

(figures indicate number of specimens)

Loose specimens indicated on the lowest bed of the interval from which they could possibly be derived.

☐	**limestone**
■	**marlstone**
▤	**marly limestone**
☒	**observational hiatus of known thickness**
∿	**unconformity**
▨	**slipplane**
━━	**range certain**
-------	**range uncertain**

19= *'Ammonites ptychoicus'* Quenstedt

20= *'Ammonites sutilis'* Oppel

21= *'Ammonites municipalis'* Oppel

22= *Holcophylloceras* sp. in Memmi, 1965, pl. 31a, fig. 2

23= *Berriasella* aff. *Janus* (Retowski) in Mazenot, 1939, pl. 6, fig. 20, 21

24= *'Ammonites Astierianus* d'Orbigny' in Pictet, 1868, pl. 17, fig. 3, 4

25= *Olcostephanus (Rogersites)* aff. *schenki* (Oppel) in Spath, 1939, pl. 2, fig. 8

26= cf. *'Berriasella carpathica* (Zittel)' in Mazenot, 1939, pl. 13, fig. 2

27= *'Hoplites Thurmanni* Pict. et Camp.' in Kilian, 1891, pl. 4, fig. 2, 3

28= *Thurmannia Thurmanni* Pictet et Campiche. 'Echantillon presque typique' in Sayn, 1907, pl. 5, fig. 14

29= *Thurmannia (Kilianella) bochianensis* Sayn, 1907, pl. 6, fig. 12

30= *Kilianella* aff. *grossouvrei* (Sayn) in Memmi, 1965, pl. 31a, fig. 5

31= cf. *'Ammonites Malbosi'* Pictet, 1868, pl. 14, fig. 2

32= syntype of *'Hoplites pexiptychus'* Uhlig, 1882, pl. 4, fig. 5

33= *Thurmannia (Kilianella) 'bochianensis.* Variété comprimée' in Sayn, 1907, pl. 6, fig. 4

34= *Thurmannia (Kilianella) 'Roubaudi* d'Orb. Variété à tours plus embrassants' in Sayn, 1907, pl. 6, fig. 9

35= *'Neocomites trezanensis* Lory. Variété à tours étroits' in Sayn, 1907, pl. 4, fig. 15

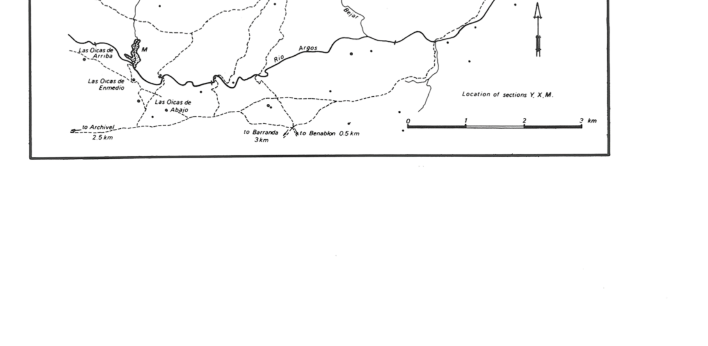
36= *'Thurmannites* aff. *pertransiens* Sayn' in Mazenot, 1939, pl. 32, fig. 16

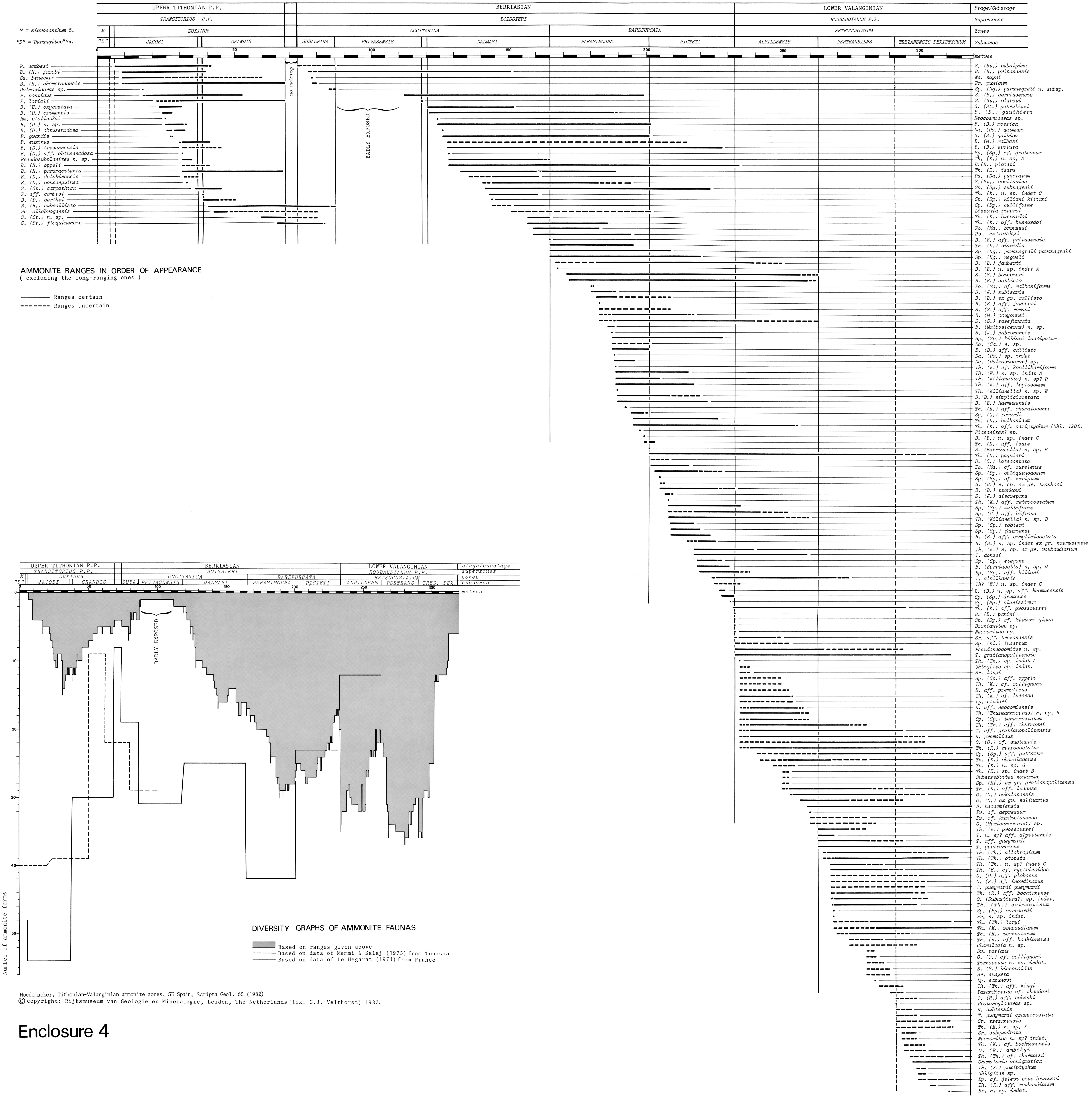
37= *'Thurmannia Thurmanni* Pictet et Campiche' in Sayn, 1907, pl. 5, fig. 1

38= *Tirnovella* aff. *alpillensis* (Mazenot) in Arnaud et al., 1981, pl. 1, fig. 1

39= *'Neocomites neocomiensis* d'Orb. Variété plate à côtes fines et fasciculées' in Sayn, 1907, pl. 3, fig. 14

40= cf. *Neocomites neocomiensis* d'Orb. Echantillon recueilli par Lory en Lus-la-Croix-Haute, in Sayn, 1907, pl. 3, fig. 6





AMMONITE RANGES IN ORDER OF APPEARANCE
(excluding the long-ranging ones)

DIVERSITY GRAPHS OF AMMONITE FAUNAS

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Enclosure 4

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LEGEND

- - - Lithologically determined boundary
— Faunistically determined boundary
═ ═ (Sub)stage boundary, lithologically determined
═ (Sub)stage boundary, faunistically determined
∿ Boundary correlation approximate

Enclosure 5: Correlation tables