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Eötvös University

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Remarks on the *Astarte* Bed (Upper Bajocian, Middle Jurassic) of Burton Bradstock (Dorset, Southern England)

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(With 1 figure and 4 plates)

The *Astarte obliqua* Bed of the Burton Bradstock district is subjected to detailed biostratigraphical examination. The bed is divisible by lithology and palaeontology into several horizons. However, the entire succession is not present at any of the closely spaced localities sampled, probably owing to local synsedimentary tectonics and penecontemporaneous erosion. At all the places sampled the entire bed probably belongs to the Acris Subzone of the Garantiana Zone of the Upper Bajocian. The lowest part of the bed contains an Acris Subzone ammonite fauna. With this are derived specimens, and rare well-preserved morphospecies that normally typify earlier strata ranging down to the Dichotoma Subzone. These specimens may represent an earlier age or be lingering ancestral morphs persisting into the Acris Subzone assemblage. A preliminary assessment of the taphonomic status of the fauna is also made.

Introduction

The *Astarte obliqua* Bed was first described at Vinney Cross (SY509928) east of Bridport in south Dorset, United Kingdom by HUDLESTON (1887) and later "dated" as "*Garantiana* Beds" by BUCKMAN (1910). BUCKMAN defines it as "an ironshot layer, the *Astarte* Bed, so called from the abundance of *Astarte* [now *Crassinella*] *obliqua*." Today the only permanent exposure of the bed in the Burton Bradstock region can be seen on the coast east of West Bay and along the beach to Burton Bradstock (BB–BC), (SY468894–485890) where it can be examined in large fallen blocks. Following BUCKMAN's (1893) account, the *Astarte* Bed here has often been cited in the literature, recently in "Addenda and Corrigenda" to CALLOMON & CHANDLER (1990), in CALLOMON & COPE (1995) and GAUTHIER et al. (2000). The *Astarte* Bed was placed in ammonite faunal horizon Bj–26b (*Parkinsonia rarecostata*), Acris Subzone, Garantiana Zone. PAVIA & MARTIRE (1997) pointed to the need to conducting a thorough taphonomic investigation of the *Astarte* Bed and claimed that the fauna listed from it in the literature represented species from a range of ages and therefore concluded that it must be condensed. These findings were used as the basis for discussion as to whether the Acris Subzone should be retained in the Garantiana Zone (British usage) or placed in the Parkinsoni Zone of continental authors.

New cliff falls in recent years at Burton Cliff and Hive Beach, Burton Bradstock, plus excavations at the nearby Freshwater Caravan Park Quarry (BB–FCP) (SY478900), have enabled us to examine the *Astarte* Bed in fine detail at a number of places along the exposure. The description of the Burton Bradstock succession published by GAUTHIER et al. (2000) relates to a single locality on the beach and therefore differs from the composite account given here.

Conventions are standard [M], [m], macroconch and microconch, (C), (O), (R), common, occurs, rare, respectively, *TA* = Type Ammonites, BUCKMAN (1909–1930). No attempt is made to list the entire fauna. Only the ammonites of biostratigraphical significance to this work are included. Names of ammonites are used exclusively in a morphospecific sense. [M & m] are indicated as morphodimorphic subgenera enclosed in parenthesis. Within faunal horizon Bj–26a the entire assemblage of morphospecies of Parkinsonids, and likewise the Garantianas, are probably biomonospecific, with a high variability for both genera at this point in time.

Figured specimens of the R. B. CHANDLER collection are to be placed in the Sedgwick Museum, Cambridge, UK. Photographs are by the authors. Specimens were coated with ammonium chloride prior to photography.

Burton Bradstock beach (BB–BC)

The strata of the Inferior Oolite Group are situated high in the sea cliffs above the beach and cannot therefore be examined *in situ*. However, cliff falls have produced huge blocks from which a detailed subdivision of the *Astarte* Bed has been made.

Figures 1a and 1b show a composite weathering profile section of the entire succession on the beach and 1b is that seen at BB–FCP. The *Astarte* Bed is bed 12. In any stratigraphical study of the bed and its lateral variation, it is important to understand that considerable changes occur in the succession over very short distances. The different sub–units come and go in an irregular fashion. At some locations the bed can be subdivided into two parts while at another nearby locality three distinct lithological sub–units can be identified with four horizons of fossils. It is therefore often difficult to decide from which part of the bed the ammonites come. In the past many ammonites were collected without a record of the exact location and position within the bed. Only recently did we observe that the bed is divisible and therefore we posses only limited numbers of specimens whose exact provenance is known. The rich ammonite fauna of the Burton Bradstock *Astarte* Bed has been listed previously, but not stratigraphically subdivided: see ARKELL (1933), CALLOMON & CHANDLER (1990 *in* "Addenda and Corrigenda"), CALLOMON & COPE (1995), PAVIA & MARTIRE (1997).
From below:

. erosion surface, planed–off top of bed **10b** ...

Bed 11: Red Conglomerate. A limonitic conglomerate with reworked fossils and small 'snuff–boxes'. The fauna is listed by CALLOMON & COPE (1995)

0–0.03m

slightly undulating parting . .

Bed 12: ***Astarte* Bed:** Brown to cream, fine–grained, locally densely ironshot oolitic wackestone and packstone. Somewhat irony, with micrite clouds and much calcified shell material. Divisible to different extents at different points along the outcrop.

0.1–0.3 m

Bed 12a: Yellow to brown bioturbated limestone, speckled by small brown ooliths. The bed undulates and often attenuates over short distances. The base is highly ferruginous and composed mostly of broken shell debris. It contains small limonitic pebbles (3–5 mm) and rolled belemnites fragments near the base. Gastropods and small ammonites occur at all angles in the bed.

Parkinsonia (*Parkinsonia) rarecostata* (BUCKMAN) [m] (O)
Garantiana sp. (innermost whorls) [M]
G. longidoides group (innermost whorls) [M]
Pseudogarantiana minima (WETZEL) [m] (O)
Bajocisphinctes curvatus FERNÁNDEZ LÓPEZ non BUCKMAN [M] (R)
Spiroceras sp.

0–0.08 m

--- wavy parting, sometimes with a thin limonite skin ---

Bed 12b: Yellow oolitic limestone, the ooliths dull, medium brown and larger than below; less shelly but many intact single valves of *Astarte*. Ammonites are common and mostly lie parallel to the bedding.

Parkinsonia (Parkinsonia) rarecostata (BUCKMAN) [m]
Garantiana longidoides group [M]

0.09 m

--- wavy parting ---

Beds 12c–d: Limestone, paler, less oolitic, light brown with micrite–filled patches and abundant complete shells. Bivalves, mostly *Astarte* sp., gastropods, belemnites and brachiopods occur. The bed is undulating, but planned–off to form a very flat upper surface, which is shallow bored and coated by delicate concentric stromatolitic rings and a few large bivalves *Ctenostrum* spp. The thickness of strata preserved varies along the outcrop. In places where the bed attains greater thickness it is divisible into two horizons of fossils, many of which are beautifully preserved with mouth border or lappets. Undamaged specimens are common (Pl. 4, figs 3a, b). The upper horizon contains large perisphinctids invariably planed–across by the erosion surface. There is no lithological discontinuity between the upper and lower horizon within the bed. Bed 12d was seen at only a few localities on the beach following cliff falls, but on a number of occasions over the years.

ammonites of bed 12c:

Parkinsonia (Parkinsonia) rarecostata (BUCKMAN) [m] (C)
P. (Durotrigensia) bradstockensis DIETZE [M] (C)
Garantiana longidoides group [M] (C)
Bigotites thevenini NICOLESCO var. *densicostata* NICOLESCO [M] (O)
Vermisphinctes (Prorsisphinctes) sp. [M] (O)
Cadomites cf. *stegeus* BUCKMAN [M] (Pl. 4, figs 4a, b) (O)

0.07 m

ammonites of bed 12d:

Vermisphinctes (Prorsisphinctes) aff. *meseres* (BUCKMAN) [M] (C)
V (Prorsisphinctes) aff. *pseudomartinsi* (SIEMIRADZKI) [M] (C)
V (Vermisphinctes) ssp. [m] (O)
Spiroceras sp. (C)

0–0.05 m

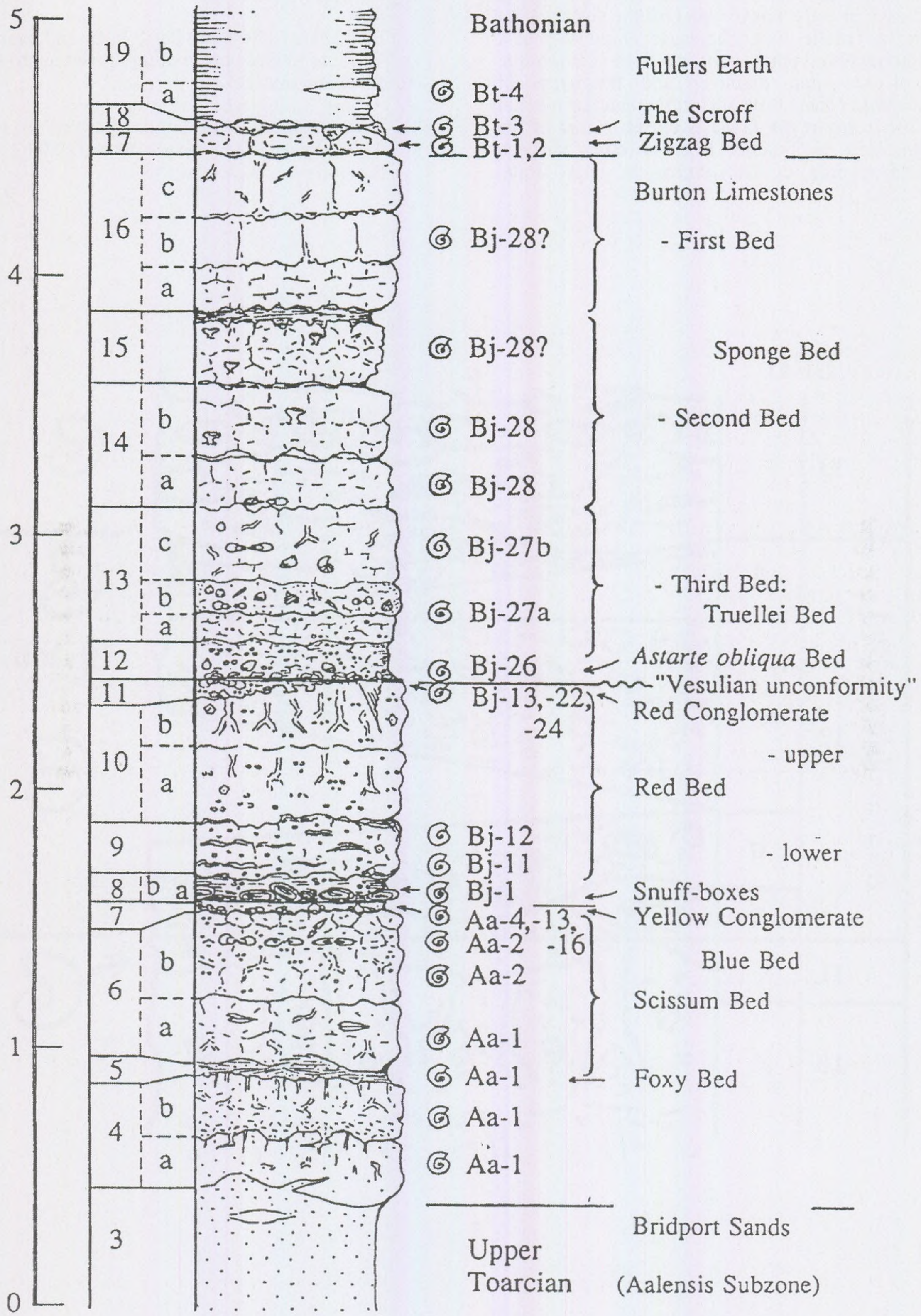

Fig. 1a. Diagrammatic section through the Inferior Oolite and basal Fullers Earth at Burton Cliff (BB–BC), Burton Bradstock after CALLOMON & COPE (1995). Note that the *Astarte* Bed (bed 12) is drawn to indicate the 'usual' thickness seen on the beach and has not been further subdivided

planned–off surface

Recently we have discovered a hard, lenticular, thin brown, irony, sparingly oolitic layer (0–0.04 m thickness) directly above the erosion surface, but below the Truellei Bed. The exact relationship of it to adjacent strata remains unclear. Two *Garantiana,* one of 110 mm diameter and fragments of *Parkinsonia* occur. With such little material it is not possible to say if the fauna is closer to that of the *Astarte* Bed or Truellei Bed, however we can confirm records of *Garantiana* in later strata, ?Truellei Subzone, both here and in Sherborne (CHANDLER et al. 1999).

Bed 13: Truellei Bed

Bed 13ai: Limestone, hard, buff, and sparingly oolitic in its lowest part grading upwards into a non oolitic cream micrite.

Parkinsonia (Parkinsonia) parkinsoni (SOWERBY) α [m] (C)
P (Durotrigensia) cf. *dorsetensis* (WRIGHT) [M] (C)
Garantiana longidoides group [M] (R)

0.17 m

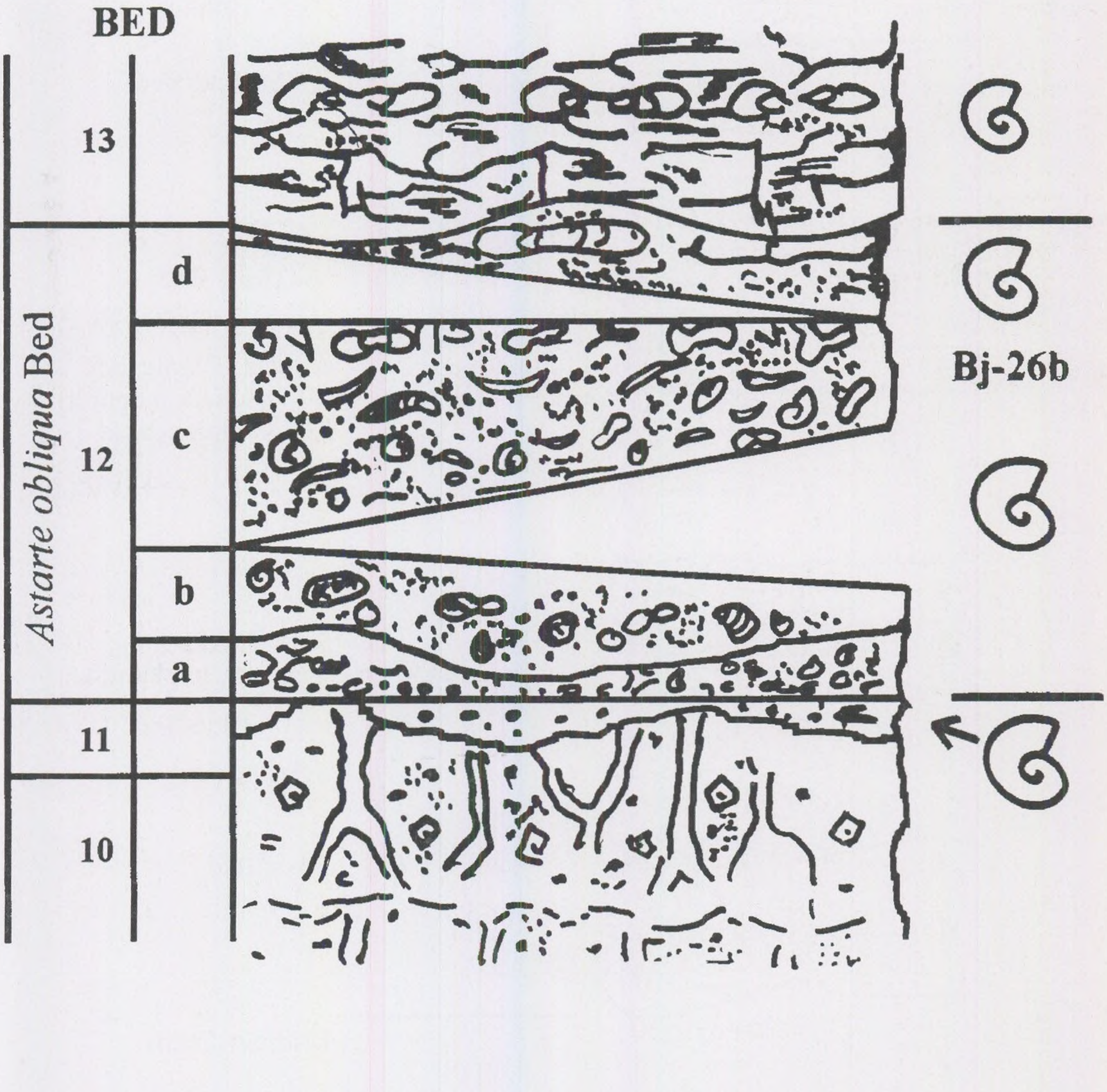

Fig. 1b. Diagrammatic section through the *Astarte obliqua* Bed (bed 12) at Freshwater Caravan Park (BB–FCP), Burton Bradstock. The composite thickness of 0.6 m is never seen in its entirety. The Red Bed (bed 10) and overlying Red Conglomerate (bed 11) persist over the entire exposure. The Truellei Bed (bed 13) is often degraded or removed. At the western end of the quarry, where part of the section was measured, bed 12d displayed an undulating upper surface forming the top of the quarry. Other rocks have been omitted.

Burton Bradstock, Freshwater Caravan Park (BB–FCP)

This important section lies just inland from the coast at Freshwater and was created by a northward enlargement of the Caravan Park. Here the overlying Parkinsoni Zone is much degraded due to its proximity to the surface. The underlying *Astarte* Bed has however provided some of the most beautifully preserved specimens available. The section recorded here was made at the western end of the quarry and describes only the *Astarte* Bed. The present exposure available for study is much thinner and lies about 30 m to the east.

Red Conglomerate

erosion surface

Bed 12: ***Astarte* Bed**

total 0.3–0.6 m

Bed 12a: An undulating bed of yellow stone speckled by brown ooliths. Mostly made up of broken shell debris. The ammonites are frequently small innermost whorls, mostly incomplete and damaged.

Parkinsonia (Parkinsonia) rarecostata (BUCKMAN) [m] (O)
P (Parkinsonia) subarietis WETZEL [m] (R)
P (Durotrigensia) bradstockensis DIETZE [M] (O)
Garantiana sp. [M] (indeterminable inner whorls)
Garantiana aff. *platyrryma* (BUCKMAN) [M]
(Pl. 1, figs 2a–c; Pl. 2, figs 3a–c) (R)
G. longidoides group [M] (innermost whorls) (O)
Pseudogarantiana minima (WETZEL) [m] (O)
P aff. *minima* (WETZEL) [m] (C)
Spiroceras annulatum (DESHAYES) [?m]

0.02–0.08 m

--- wavy parting ---

Bed 12b: Yellow oolitic limestone, less shelly, but with many intact *Astarte*. The ammonites are larger than in 12a but generally smaller than those of 12c above. Many are preserved with the shell and ornament intact. The ammonite fauna of this bed is the most diverse and is listed below.

0.06–0.10 m

indistinct undulating parting

Bed 12c: The upper surface of the bed terminates in a dead–flat, bored erosion surface. Near the top, limestone, paler, less oolitic with large *Garantiana* of the *longidoides* group (diameter 90–130 mm), sometimes extremely involute (*G. longidens* BUCKMAN non QUENSTEDT, now *G. longidoides* [GAUTHIER et al.]). These co–dominate with complete, but disarticulated valves of *Astarte* and belemnites. Parkinsonids, perisphinctids and other elements identical with the fauna of the lower part of bed 12c occur only rarely. In the lowermost 20 cm is a layer of large perisphinctids. Here the fauna of bed 12b continues, but is more common and of larger size. The ammonites are now often beautifully preserved with mouth border or lappets with common undamaged specimens. The following list includes the ammonites found in both 12b & c. The fauna of each level is identical, however there is a shift in the relative abundance of individual species.

Parkinsonia (Parkinsonia) rarecostata (BUCKMAN) [m]
(Pl. 1, figs 1a, b; Pl. 4, figs 2a, b) (C)
P (Parkinsonia) pseudoparkinsoni WETZEL [m]
(Pl. 2, figs 2a, b) (O)
P (Durotrigensia) bradstockensis DIETZE [M] (O)
P (Durotrigensia) aff. *dorsetensis* (WRIGHT) [M]
(Pl. 1, figs 3a, b; Pl. 2, figs 1a, b) (O)
Garantiana longidoides group [M]
(Pl. 3, figs 1a, b; figs 2a–c; figs 3a, b) (O)
Vermisphinctes (Prorsisphinctes) meseres (BUCKMAN) [M] (C)
V (Prorsisphinctes) cf. *meseres* (BUCKMAN) [M] (C)
V (Vermisphinctes) ssp. [m] (O)
Bigotites ssp. [m & M] (O)
Oxycerites flexus (BUCKMAN) [M] (O)
Oxycerites cf. *subradiatus* (WAAGEN) [M] (C)
Oecotraustes ssp. [m] (O)
Lissoceras ssp. [M] (O)
Microlissoceras sp. [m] (R)
Cadomites arkelli STURANI [M] (R)
Cadomites cf. *stegeus* BUCKMAN [M] (O)
Strigites septicarinatus BUCKMAN [M] (R)
Strigoceras aff. *truellei* (D'ORBIGNY) (R)
Cadomoceras sp. [m] (R)
Sphaeroceras tutthum (BUCKMAN) [?m] (R)
Sphaeroceras tenuicostatum STURANI [?m] (R)
Spiroceras cf. *annulatum* (DESHAYES) [?m] (O)

0.15–0.28 m

--- erosion plane and thin limonitic crust ---

Bed 12d: Oolitic limestone that contains exclusively large (200–300 mm) and very common macrconch parkinsonids, showing variability between *P. (Durotrigensia)* aff. *dorsetensis* (Pl. 1, figs 3 a–b; Pl. 2, fig. 3a, b) and *P. (Durotrigensia) bradstockensis.* These macroconchs occur infrequently in bed 12b, however *P (Durotrigensia) bradstockensis* is already present, but rare in bed 12a. The exact relationship of bed 12d at BB–FCP to 12d at BB–BC is not precisely known. These beds although in the same relative position may represent horizons of slightly different age.

Parkinsonia (Durotrigensia) bradstockensis DIETZE [M]
P (Durotrigensia) aff. *dorsetensis* (WRIGHT) [M]

0. 1–0.14 m

---indistinct parting or top soil at some points in the quarry---

Biostratigraphy and description of some elements of the ammonite fauna

CALLOMON & COPE (1995) and CALLOMON (1995) include the *Astarte* Bed of Burton Bradstock in their ammonite faunal horizon Bj–26b (*Parkinsonia rarecostata*) of the Acris Subzone. PAVIA & MARTIRE (1997) were of the view that the *Astarte* Bed of Dorset contained ammonites that occur elsewhere in three subzones (Garantiana, Tetragona and Acris Subzone) and that a taphonomic investigation would conclude that the bed contained a condensed assemblage.

It has long been the practice of British workers (e.g. TORRENS 1969) to include the Acris Subzone in the Garantiana Zone, at variance with continental authors' placement of it in the succeeding Parkinsoni Zone (i.e. GAUTHIER et al. 2000). The criteria for this decision are summarised by PARSONS (1976). The Burton Bradstock *Astarte* Bed has no bearing on this matter as the type area of the Garantiana Zone is exclusively the Sherborne area, not South Dorset (BUCKMAN 1893). Moreover the *Astarte* Bed of Southern England as a lithostratigraphical unit is diachronous. Its probable age range is the Dichotoma Subzone of the Garantiana Zone (Louse Hill, CALLOMON & COPE 1995) up to the Acris Subzone (Burton Bradstock, Loders Cross) but at some places possibly slightly later.

The lowest part of the *Astarte* Bed of Burton Bradstock contains small, but adult and nearly complete specimens of *Garantiana* aff. *platyrryma* (Pl. 1, figs 2a–c; Pl. 2, figs 3a–c) from bed 12a of FCP. These rare, but well–preserved specimens probably represent the extreme variant (small size) of an assemblage that is close to being isochronous. This characteristic species occurs elsewhere consistently earlier than the Acris Subzone. Its type area and horizon is the *Astarte* Bed of Louse Hill (near Sherborne, Southern England), dated as Dichotoma Subzone by CALLOMON & COPE (1995). At Louse Hill the *Astarte* Bed yields small *Leptosphinctes* (*Cleistosphinctes*) spp. that differ in their small size from the large specimens typical of the Acris Subzone. In the Acris Subzone such microconchs are usually labelled as *Vermisphinctes* spp. *Pseudogarantiana dichotoma* is very abundant at Louse Hill in marked contrast to its absence in bed 12a at Burton Bradstock. The *Astarte* Bed of Louse Hill is very thin (0.01–0.3 m) and highly variable. At the eastern end of the quarry it can be subdivided into two with a lower part containing ammonites of the Niortense Zone (*Caumontisphinctes* sp. VD & RBC coll.). GAUTHIER et al. (1997) and RIOULT et al. (1997) report French specimens of *Garantiana platyrryma* in the Dichotoma Subzone equivalent to those indicated by FERNÁNDEZ–LÓPEZ (1985) from the Spanish Cordillera Ibérica (Biohorizonte Tenuicostatus = Dichotoma Subzone). It is unusual that this mophospecies ranges in the Burton Bradstock *Astarte* Bed more than two subzones higher than found so far anywhere else in Europe, however specimens with features of the ancestral morphology may persist into later strata. We conclude that Bed 12a is entirely Acris Subzone, although it is possible that it contains derived fossils in addition, with an age range from at least Dichotoma Subzone to Acris Subzone age. We do not have adequate material to show conclusively that *G.* aff. *platyrryma* are extreme variants of the *Garantiana longidoides* assemblage of horizon Bj–26b or not. We observe that the morphological differences seen in these rare ammonites compared with the rich *longidoides*–assemblage is significant and may therefore be of a slightly earlier age. They are of much smaller size and lack the typical prominent ventral spines at the end of the ribs. These specimens show the same excellent state of preservation as the accompanying typical elements of the Acris Subzone. They are nearly complete and lack evidence of reworking. From a collection numbering hundreds of specimens from the *Astarte* Bed of Burton Bradstock we were unable to find any further characteristic Dichotoma Subzone faunal elements. A typical ammonite fauna for bed 12a includes *P.* (*Parkinsonia*) *rarecostata*, *P* (*Durotrigensia*) *bradstockensis* and *Garantiana* of the *longidoides* group in association with derived elements. The ammonites of bed 12a are often incomplete and small, large ammonites occur only rarely. The matrix of the bed shows a mixture of different lithologies and evidence of bioturbation.

We have not recorded ammonites of the *G. garantiana* group or *G. tetragona* in the *Astarte* Bed. The specimen published by BUCKMAN (1922) as *G. garantiana* (*TA*, pl. 358) certainly belongs to another species, probably of the *Garantiana longidoides* group. Some ammonites of the *Garantiana longidoides* group from the Burton Bradstock *Astarte* Bed show a great resemblance to those of the *G. garantiana/subgaranti* group, however the ventral aspect and style of ribbing differ in a characteristic way. We cannot agree with PAVIA & MARTIRE (1997) that *G. longidens* BUCKMAN *non* QUENSTEDT (= *G. longidoides* [GAUTHIER et al.]) of the Acris Subzone), *Pseudogarantiana minima* (range Garantiana Subzone to Acris Subzone), *Prorsisphinctes meseres* and *P stomphus* (both occur in the Acris Subzone) are typical of the Tetragona Subzone. The occurrence of *Bajocisphinctes curvatus* FERNÁNDEZ–LÓPEZ non BUCKMAN in bed 12a of the beach and *ex–situ* specimens from FCP may be a hint of the existence of the Garantiana or Tetragona Subzone in the lowermost part of the Burton Bradstock *Astarte* bed, but we have no firm evidence for this.

Parkinsonia (Parkinsonia) rarecostata (type horizon and area, Burton Bradstock *Astarte* Bed) and the last representatives of the genus *Garantiana* are typical elements of the Acris Subzone. Both occur in the Burton Bradstock *Astarte* bed from bed 12a up to bed 12c. It is of interest that *P (P.) rarecostata* exhibits two variants, one with a rather rounded venter and whorl section, the other with a more rectangular whorl section (Pl. 1, figs 1a, b). A typical additional element of the Acris Subzone is *P.* (*Durotrigensia*) *bradstockensis* [M] which is the macroconch counterpart *P (Parkinsonia) rarecostata* [m]. The *G. longidoides* group is characterised by thin, long spines that follow the direction of the ribs and emerge from the point of bifurcation. The morphological variability of *Garantiana* in the Burton Bradstock *Astarte* Bed has not so far been described but it appears that all variants are members of one clearly characterised group, differing slightly from WETZEL's syntypes of *G. alticosta* from Bielefeld (Northern Germany) and also from the *G. alticosta* group DIETZE non

WETZEL, described from the Eastern Swabian Alb (DIETZE 2000).

Of interest are specimens of parkinsonids in beds 12b, 12c and 12d (FCP) which stand apart from typical members of the *Parkinsonia rarecostata* group. The whorls are more rounded and show a more involute character. Lacking a more precise specific name, we have labelled the macroconchs as *P. (Durotrigensia)* aff. *dorsetensis* (Pl. 1, figs 3a, b; Pl. 2, figs 1a, b). The microconchs are morphologically identical to *P (Parkinsonia) pseudoparkinsoni* (Pl. 2, figs 2a, b). The latter species was described by GABILLY et al. (1971) from Saint–Maixent (Western France) from a slightly higher horizon than that with typical ammonites of the *P. rarecostata* group, but still in the "Subarietis" Subzone (=Acris Subzone). BUCKMAN (1910) pointed out that in the *Astarte* Bed of Burton Bradstock forms intermediate between *P. rarecostata* and *P parkinsoni* occur.

We conclude that beds 12b and c, both on the beach and at BB–FCP contain an association belonging to the Acris Subzone. The stratigraphically important faunal elements, *Garantiana* and *Parkinsonia* show no discernible evolutionary change within these beds, thus they belong to the same faunal horizon. We can make no further subdivision although the different species occur with different frequency in each level. Beds 12 b–c represent faunal horizon Bj–26b of CALLOMON & COPE (1995), while bed 12 a (BB–BC and BB–FCP) may contain some derived specimens. Faunal horizon Bj–26b can be subdivided in Western France perhaps into two. In Northern and Southern Germany (DIETZE 2000), Normandy (GAUTHIER et al. 1997) and in the Sherborne area of Southern England (CHANDLER et al. 1999) occur other faunal horizons, but also in the Acris Subzone.

Bed 12d (FCP) seems to contain a local accumulation of macrococh parkinsonids, which have not be found elsewhere and still belong in faunal horizon Bj–26b. They are more frequent than below, but do not differ in their specific composition.

Bed 12d (BB–BC) has only been observed just east of Freshwater. It probably represents a slight upward extension of the strata exposed at FCP where it has been planed–off. It contains large, smooth *Vermisphinctes* (*Prorsisphinctes)* aff. *meseres* together with *V. (Vermisphinctes*) spp. [m]. Most are cut through by the erosion surface. The same ammonites are prolific in the uppermost part of the *Astarte* Bed at Loders Cross, close to Vinney [=Vetney] Cross, east of Bridport. Another section was described at Stoney Head (SY496927) by PARSONS (1975). There only about 1 km west of Loders Cross it appears to have the *Vermisphinctes* bed missing, as the characteristic fauna was not recorded by PARSONS (1975). The section at Loders Cross has been recorded by CHANDLER (unpublished) and PAGE (unpublished). Both these workers independently observed the *Astarte* Bed was divisible into three parts. From below:

a) Grey to yellow, pyritic limestone with small dark brown ooliths. The most common ammonites are of the *Garantiana garantiana/subgaranti* group, typical elements of the Garantiana Subzone elsewhere. Ammonites of the genus *Parkinsonia* were not found at this level.

b) A thin marly, intraclastic band and

c) Cream limestone, micritic and scattered by clouds of pale brown ooliths. Large (up to 400 mm) *Vermisphinctes (Prorsisphinctes)* of the *meseres* group [M] are the dominant fossil (a more specific investigation is beyond the scope of this work). At the top of this bed is a rather variable, partly rotted shell bed with abundant gastropods, belemnites, *Spiroceras, Garantiana* and rare *Parkinsonia rarecostata,* thus probably still Acris Subzone.

d) This bed is overlain by a layer of poorly preserved *Parkinsonia* of the *parkinsoni* group presumably equivalent to the base of the Truellei Bed on the coast.

Parkinsonia is very rare in the *Vermisphinctes* bed. The influx of large perisphinctids and scarcity of parkinsonids is evidence of some marked ecological change at the time.

Taphonomy

An interpretation of the taphonomic status of the *Astarte* Bed fauna at Burton Bradstock will serve to increase the reliability of the biostratigraphy. FERNÁNDEZ–LÓPEZ (1991) defines three categories of post–mortem remains found in the fossil record: accumulated, re–sedimented and reworked elements. Each category can been identified in the succession at Burton Bradstock, however care must be exercised in the interpretation of old collections as they have not been collected by subdivision of the bed in the way described here. A thin succession of strata deposited over an extended time period is generally accepted to indicate homogeneous condensation as defined by CALLOMON (1985). The Inferior Oolite, including the *Astarte* Bed, displays a particular type of condensation, in which individual beds, probably deposited in a brief interval are separated by surfaces representing gaps of unknown duration. The *Astarte* Bed is divisible by discrimination of the ammonite fauna and by taphonomy. Bed 12a contains reworked fossils that display abraded surfaces, infill that differs from the host matrix and encrustation. A conglomerate is present at the base which contains small limonite oncolites, some surrounding ammonite fragments. Rounded fragments of broken shell occur and show evidence of sponge boring and biological attack. Contemporary, well–preserved material also occurs. Bed 12b and c in contrast show evidence of containing fossils of a very narrow age range (Acris Subzone). 12d (BB–BC) at present known only locally is also probably still Acris Subzone but characterised by a horizon of perisphinctids which do not occur abundantly below. Tens of specimens collected from each level are very well preserved, lack significant epifaunal colonization and possess intact thin mouth borders and lappets. Ammonites are frequently perfect and ornamented by thin, long spines such as the *Cadomites* cf. *stegeus* figured here (Pl. 4, figs 3a, b). Sexual dimorphs of characteristic species consistently occur together in the same faunal horizon at different localities. It is difficult to accept that such material can have suffered anything but a minimal pre–burial history. Some horizons do contain large quantities of broken material (re–sedimented bio–clasts), but these fragments are invariably cleanly broken with sharp edges and little abrasion evidence. The mode of preservation within each horizon is identical, but may differ between horizons. Both the colour and nature of the calcite are the same in the fragmentary and complete material within each horizon. Some horizons may well represent the accumulation of some debris from slightly different levels, possibly as a result of storm activity or bioturbation, however the possible range of ages incorporated in such levels is insignificant in geological terms. The composition of species recorded from individual faunal horizons is remarkably consistent across large geographical areas. In places where the succession is expanded (i.e. north Dorset) the same faunal composition has been recorded as that from thin individual beds on the coast. At some localities different horizons appear that are not well represented on the coast. A characteristic layer of *(Prorsisphinctes) Vermisphinctes* of the *meseres* group (Pl.4, figs 1a, b) occurs perfectly preserved in the upper part of the *Astarte* Bed at Loders Cross while on the beach the same is indicated by planed–through examples at the top of the bed.

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We are indebted to DAVID SOLE for collecting and providing much material over the years. He has generously allowed some of the authors (RBC, VD and VS) access to BB–FCP. Specimens collected by him are indicated in the plate legends. We thank JOHN CALLOMON and NICOL MORTON for critical appraisal of the text, KEVIN PAGE access to his unpublished section of Loders Cross, ROD CONDLIFFE and REX IRELAND of Freshwater Caravan Park and the Wessex Cephalopod Club: A. G. ENGLAND and W.J. E. JONES for continuing support in the field. R. B. CHANDLER thanks the University of Zurich, in particular H. RIEBER for assistance in preparing specimens. We are indebted to Sherborne Castle Estates and their tenants and to English Nature for allowing us access to the Sherborne localities.

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Plates

Plate captions

The last preserved septum of each specimen is indicated on the plates by a black dot. In cases where the preservation of the shell is perfect the indicated position of the last suture is approximate.

Plate 1

All specimens are from the Acris Subzone, faunal horizon Bj–26b

Figs 1a, b. *Parkinsonia* (*Parkinsonia*) *rarecostata* (BUCKMAN) [m] (coll. DIETZE), complete with mouth border from BB–FCP, bed 12c, (x 1), large variant.

Figs 2a–c. *Garantiana* aff. *platyrryma* (BUCKMAN) [M] (Sedgwick Museum X28016), nearly identical to the holotype from the *Astarte* Bed of Louse Hill, BB–FCP, bed 12a (x 1).

Figs 3a, b. *Parkinsonia* (*Durotrigensia*) aff. *dorsetensis* (WRIGHT) [M] (coll. DIETZE, collected by D. SOLE) fully septate phragmocone showing the innermost whorls, from BB–FCP, bed 12b, (x ½).

Plate 1

Plate 2

All specimens are from the Acris Subzone, faunal horizon Bj–26b

Figs 1a, b. *Parkinsonia* (*Durotrigensia*) aff. *dorsetensis* (WRIGHT) [M] (Sedgwick Museum X29053, collected by D. SOLE), nearly complete specimen from BB–FCP, bed 12c (x 1/3).

Figs 2a, b. *Parkinsonia* (*Parkinsonia*) *pseudoparkinsoni* WETZEL [m] (coll. DIETZE). Phragmocone from BB–FCP, bed 12c (x 1), large variant.

Figs 3 a–c. *Garantiana* aff. *platyrryma* (BUCKMAN) [M] (coll. DIETZE) with slightly more radiate ribbing than Pl. 1, figs 2 a–c, from BB–FCP, bed 12a, most probably Dichotoma Subzone (x 1).

Plate 2

Plate 3

All specimens are from the Acris Subzone, faunal horizon Bj–26b

Figs 1a, b. *Garantiana longidoides* (GAUTHIER, TRÉVISAN & JORON) [M] (Sedgwick Museum X28013), large, complete example from BB–BC, bed 12c, (x 1).

Figs 2a–c. *Garantiana longidoides* (GAUTHIER, TRÉVISAN & JORON) [M] (coll. DIETZE, collected by D. SOLE), evolute variety with slim whorls from BB–FCP, bed 12c, (x 1).

Figs 3a, b. *Garantiana longidoides* (GAUTHIER, TRÉVISAN & JORON) [M] (coll. DIETZE), typical morph from BB–FCP, bed 12b, (x 1).

Plate 3

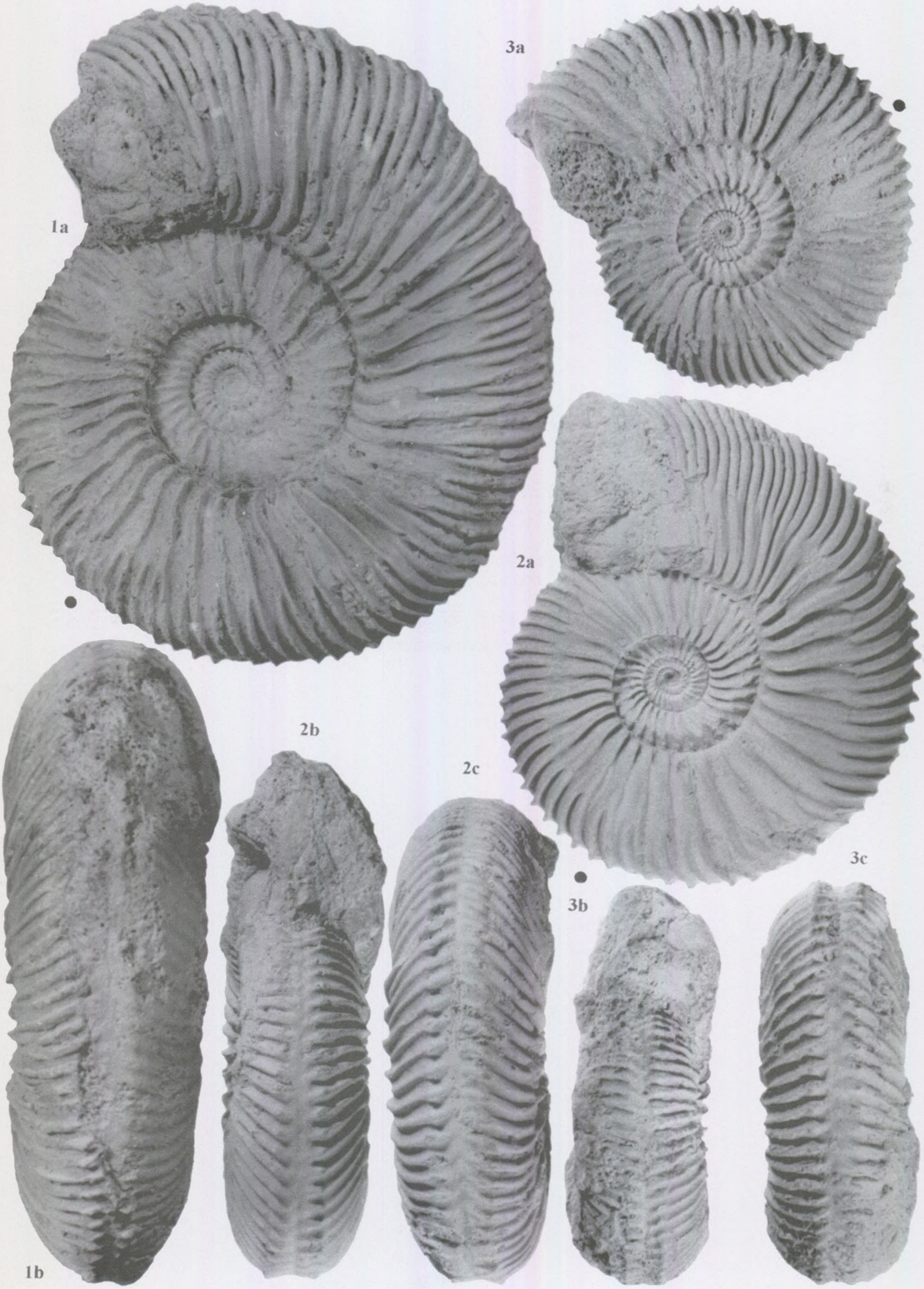

Plate 4

All specimens are from the Acris Subzone, faunal horizon Bj–26b

Figs 1a, b. *Vermisphinctes* (*Prorsisphinctes*) aff. *meseres* (BUCKMAN)[M] (Sedgwick Museum X28011) perfectly preserved specimen from the *Vermisphinctes* bed, Loders Cross near Bridport, (x ½).

Figs 2a, b. *Parkinsonia* (*Parkinsonia*) *rarecostata* (BUCKMAN) [m] (Sedgwick Museum X28015), phragmocone from BB–BC, bed 12c, Bj–26b, (x 1).

Figs 3a, b. *Cadomites* cf. *stegeus* BUCKMAN [M] (Sedgwick Museum X28017, collected by H. PRUDDEN), perfectly preserved and complete specimen from BB–BC, 12c, (x 1).

Plate 4

Hantkeniana 3, 25–39 (2001) Budapest

Upper Bathonian ammonites of the Catalan Basin (Tivissa and Cap Salou, Spain)

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(With 7 figures and 2 plate)

The two ammonite successions described in the present paper represent an unusually complete sequence of Upper Bathonian deposits. Ammonites of the Upper Bathonian from Tivissa and Cap Salou (province of Tarragona), two localities of the Catalan Basin, allow to recognize several bio– and chronostratigraphic units commonly missing in the Iberian Basin. The Retrocostatum and Angulicostatum zones (Upper Bathonian) and the lowermost Bullatus Zone (Lower Callovian) established for Submediterranean areas of Europe can be identified in the Catalan Basin. *Epistrenoceras* and *Parapatoceras* are common in certain levels. Phylloceratina and Lytoceratina are virtually absent. Two specimens of Upper Bathonian Clydoniceratinae have been identified. However, the Discus Zone established for NW European areas of the Subboreal Province has not been recognized. The ammonite fossil assemblages of the Catalan Basin are composed by Submediterranean taxa during the Late Bathonian – Early Callovian interval.

Introduction

Upper Bathonian ammonites are very scarce in the Iberian Peninsula, as a result of non–preservation in shallow water facies or gaps in the geological record. Several authors have mentioned the scarcity of ammonites in the Iberian Basin during this chronostratigraphical interval (FALLOT & BLANCHET 1927, MENSINK 1966, BULARD 1972, MARIN & TOULOUSE 1972, HINKELBEIN 1975, FERNÁNDEZ–LÓPEZ et al. 1978, 1996, 1997, 1999, MANGOLD 1981, WILDE 1988, THIERRY & WILDE 1990, PAGE 1996, 2000, FERNÁNDEZ–LÓPEZ 1997a, b, PAGE & MELÉNDEZ 1997, 2000). Upper Bathonian ammonites of the Iberian Basin, however, have never been figured. The ammonite succession discovered at Tivissa and Cap Salou outcrops (province of Tarragona, Fig. 1), two localities of the Catalan Basin, allows to recognise several of these bio– and chronostratigraphic units commonly missing in the Iberian Peninsula. This area form part of the faulted eastern margin of the Iberian epicontinental platform system developed during the Middle Jurassic (FERNÁNDEZ–LÓPEZ et al. 1994, 1996, 1997, 1999).

The purpose of this paper is to present a description and comparison of the ammonite recorded associations through the Upper Bathonian from two sections (Tivissa and Cap Salou), which until now were unknown from the Catalan and Iberian basins. The biostratigraphy is based on collections made bed by bed since 1977, mainly during the research project PB92–0011 (DGICYT–CSIC). The biochronological data obtained in these sections are compared with those of the other European basins.

Ammonite taphonomy

Upper Bajocian–Callovian limestones of the La Tossa Formation overlie Upper Bajocian marls of the Cardó Formation, at the Catalan Basin (FERNÁNDEZ–LÓPEZ et al. 1996, 1997, 1999, FERNÁNDEZ–LÓPEZ 2000b). Upper Bathonian beds constitute the middle part of the La Tossa Formation in the outcrops of Tivissa and Cap Salou.

At the type section of the La Tossa Formation, located in the Serra de la Creu outcrop (Tivissa), the middle part of this lithostratigraphic unit is composed by light yellow–brown, muddy limestones, regularly bedded, ranging in thickness from 10 to 90 cm, and alternating with marly intervals from 0 to 40 cm (Fig. 2). These carbonate deposits are organized in shallowing–upwards sequences, of metric thickness, thickening upwards, which correspond to stratigraphic cycles of 5th order, resulting from changes in water turbulence and rate of sedimentation (FERNÁNDEZ–LÓPEZ 1997a, b, 2000a). Textures and structures of bioturbation are common (*Zoophycos* in particular). Fossils, especially ammonites, are scarce. Bivalves (*Bositra*, in particular), terebratulid brachiopods, crinoid ossicles and belemnite guards occur. Those taxa which preferred firm or hard sedimentary grounds are absent.

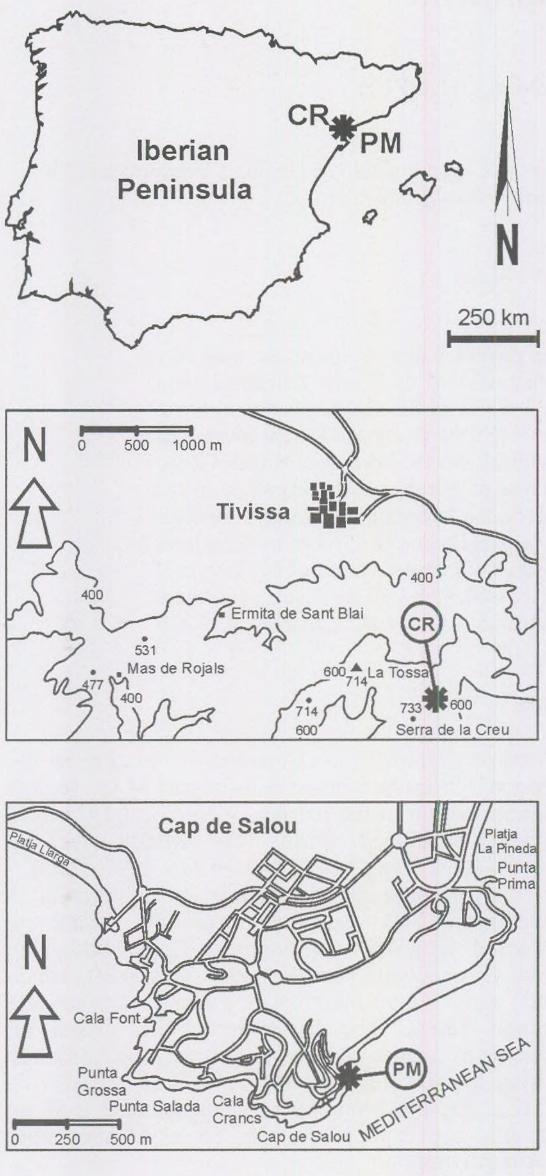

Fig. 1. Location map of the Tivissa (CR) and Cap Salou (PM) outcrops in the Iberian Peninsula (province of Tarragona, Catalan Basin).

The ammonites are commonly preserved as calcareous moulds of resedimented shells (*i.e.*, displaced on the sea–bottom, before their burial). Accumulated shells, showing no evidence of removal after laying on the sea–bottom, are very scarce. Moulds of fragmentary shells are common, but bearing no signs of rounding during resedimentation processes on the sea–bottom, due to the low turbulence near the water/sediment surface. Reelaborated, calcareous or phosphatic, concretionary internal moulds (*i. e.*, exhumed and displaced before their final burial) are absent. Ammonite mixed assemblages composed of specimens representing several biozones or biohorizons in a single bed have not been identified and the biostratigraphical completeness can reach 100%. Taphonic populations of type 3 (*i.e.* composed of polyspecific shells showing uni– or polymodal and asymmetric distribution of size frequencies, with negative skew) are dominant, those of type 1 being scarcely represented (FERNÁNDEZ–LÓPEZ 1991, 1997a, 2000a). Shells of juvenile individuals are very scarce, but they are predominant among the specimens of certain taxonomic groups, such as *Epistrenoceras* and *Parapatoceras,* in the upper part of the Retrocostatum Zone (Fig. 3; Plate 2, fig. 9). Biostratinomic processes of biodegradation–decomposition were intense. Before burial, ammonite shells commonly lose the soft–parts, the aptychi, the periostracum and the connecting rings. However, skeletal remains of encrusting organisms (such as serpulids, bryozoans or oysters) and biogenic borings are very scarce or absent. Shells are normally filled by homogeneous sediment, similar to the sedimentary matrix. Hollow phragmocones (*i.e.*, shells without septa) are scarce, and shells were usually compressed by increasing sedimentary loading during diagenesis (Plate 1, figs. 4 and 10). The older septa can disappear by early dissolution, whilst the wall of the shell may still stand, giving rise to compressed elements showing discontinuous deformation by gravitational diagenetic compaction (Plate 2, fig. 4). Complete concretionary internal moulds of the body chamber and phragmocone, indicative of low rates of sedimentation and accumulation, are very scarce. In contrast, compressed, partial internal moulds of body chambers (*i.e.*, hollow ammonites *sensu* FERNÁNDEZ–LÓPEZ 1997a, b, 2000a), indicative of very rapid sedimentary infill and high rate of sedimentation, are abundant. Ammonites with their long axes parallel to bedding surface are dominant, and normally appear dispersed in the sediment, showing no pattern of imbricated or encased clustering.

At the cliff section of Cap Salou, Upper Bathonian deposits comprise comparable muddy limestones, although they are less fossiliferous (Fig. 4). Textures and structures of bioturbation are common (*Zoophycos* and *Thalassinoides*, in particular). The ammonites are commonly preserved as calcareous moulds of resedimented shells. Taphonic populations are of type 3. Accumulated shells are absent. Reelaborated, calcareous, concretionary internal moulds, bearing signs of rounding during removal processes on the sea–bottom, are present in several marly levels (such as: PM23, PM25, PM27, PM29, PM73, in Fig. 4). However, ammonite mixed assemblages composed of specimens representing several biozones or biohorizons in a single bed have not been identified and the biostratigraphical completeness can reach 100%.

Most of these Upper Bathonian ammonite shells of the Catalan Basin represent ademic organisms and are interpreted as allochthonous elements having arrived at their present location by necroplanktic drift. However, the occurrence of taphonic populations of type 1 (FERNÁNDEZ–LÓPEZ 1991, 1997a, b), showing no signs of sorting by necroplanktic drift or transport, is indicative of autochthonous biogenic production of shells by *Epistrenoceras* and *Parapatoceras*.

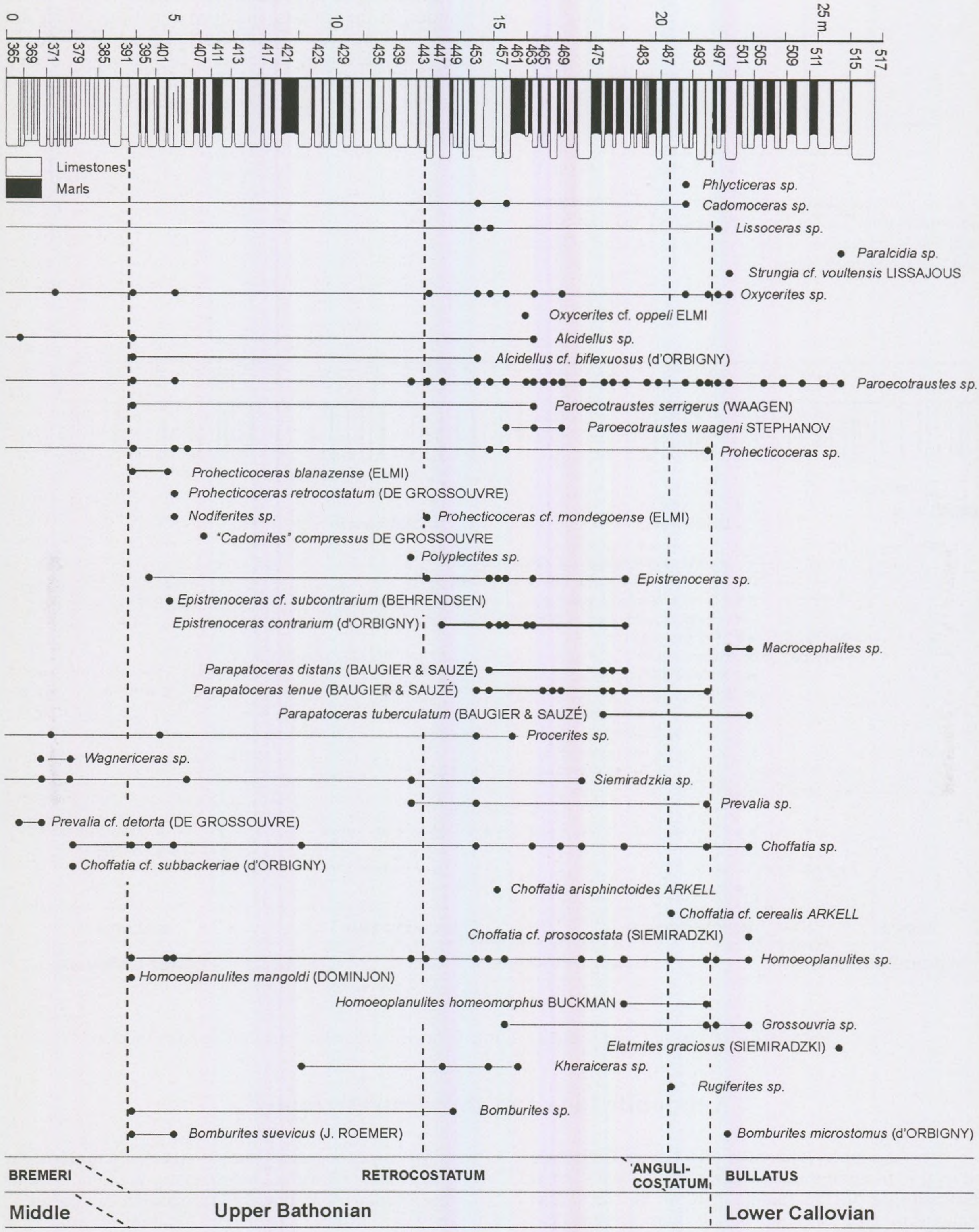

Fig. 2. Biostratigraphical data of Upper Bathonian/Lower Callovian ammonites from the Tivissa (Serra de la Creu) outcrop, type section of the La Tossa Formation.

These Upper Bathonian deposits are interpreted as having been deposited in an open sea, below wave base, in distal areas of a carbonate platform. The fine–grained nature of the mudstones suggests deposition in a low–turbulence setting. Currents were slight, but ammonite shells were reoriented on soft– to firmgrounds through resedimentation (*i.e.*, displacement on the sea–bottom, before their burial).

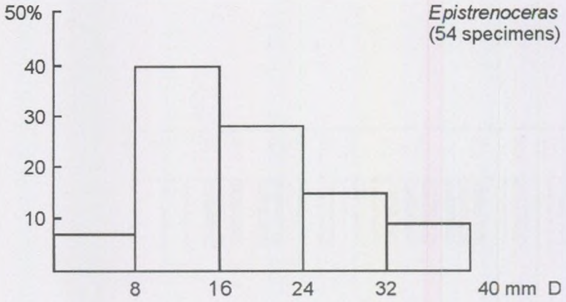

Fig. 3. Size–frequency distribution of *Epistrenoceras* specimens from Tivissa (Serra de la Creu) and Cap Salou sections. Total number of specimens up to 54, most of them showing the body chamber.

These regional results allow to corroborate the development of a last phase of advanced shallowing of a deepening/shallowing cycle of 3rd order, in the Catalan and Iberian basins, during the Late Bathonian (FERNÁNDEZ–LÓPEZ 1997a, b, 2000a). However, there is no sign of major hiatus, stratigraphical gap or lithological change associated to the Bathonian/Callovian boundary in the two studied localities.

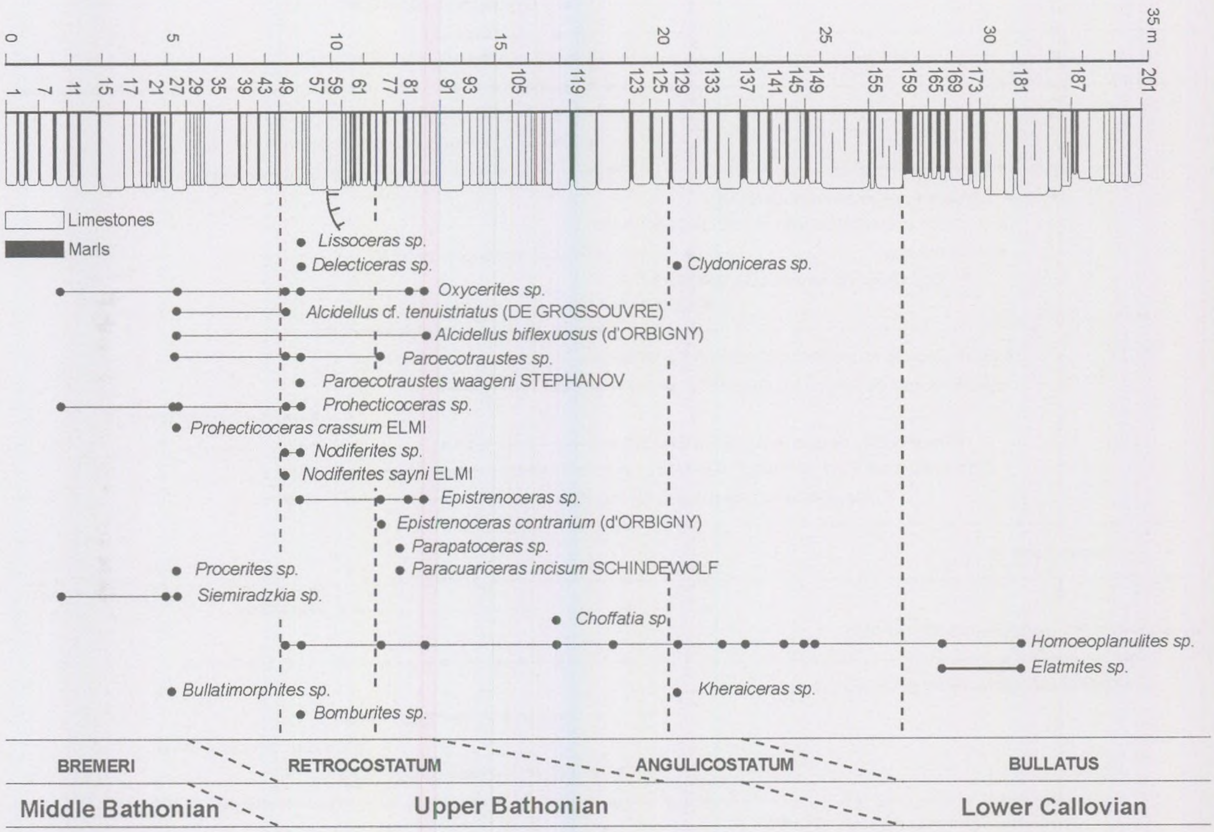

Fig. 4. Biostratigraphical data of Upper Bathonian/Lower Callovian ammonites from the Cap Salou outcrop.

Ammonite bio– and chronostratigraphy

For the Upper Bathonian and Lower Callovian, several biostratigraphic intervals have been distinguished in the middle part of the La Tossa Formation type section, taking into account the taxonomic data about the ammonites. The dimorphic status and abundance of specimens will be indicated by [M] and [m] macroconch and microconch forms; R, C, VC, scarce, common, very common respectively.

In the Tivissa section, *Wagnericeras* spp. [M] have been identified in the middle part of the La Tossa Fm., associated with specimens of *Prevalia* cf. *detorta* (DE GROSSOUVRE) (Plate 1, fig. 12) and *Choffatia* cf. *subbackeriae* (D'ORBIGNY). These taxa allow to recognized the Bremeri Zone (Middle Bathonian). However, the scarcity of ammonites in the Bremeri Zone prevents recognition of subzones. In this locality, the Upper Bathonian attains a maximum thickness of 18 m and is overlain by the Bullatus Zone, which attains a thickness of up to 10 m. The stratigraphical interval CR393 – CR496 belongs to the Upper Bathonian, mainly the Retrocostatum Zone defined in the Submediterranean Province (CARIOU et al. 1985, MANGOLD & RIOULT, 1997). Ammonites allow recognition of three biostratigraphic intervals. The lower interval of the Retrocostatum Zone (levels CR393 – CR444) yields fairly common perisphinctids: *Procerites* [M] –

Siemiradzkia [m] and *Choffatia* [M] – *Homoeoplanulites* [m]. The following taxa have been identified:

Oxycerites sp. [M] (R)
Alcidellus sp. [M] (R)
A. cf. *biflexuosus* (D'ORBIGNY) [M] (R) (Plate 1, fig. 8)
Paroecotraustes sp. [m] (R)
P serrigerus (WAAGEN) [m] (R)
Prohecticoceras sp. [M] (R)
P blanazense (ELMI) [M] (R) (Plate 1, fig. 11)
P retrocostatum (DE GROSSOUVRE) [M] (R) (Plate 1, fig. 10)
Nodiferites sp. [m] (R)
"*Cadomites*" *compressus* DE GROSSOUVRE [M] (R)
Polyplectites sp. [m] (R)
Epistrenoceras sp. [M] (R)
E. cf. *subcontrarium* (BEHRENDSEN) [M] (R)
Procerites sp. [M] (R)
Siemiradzkia sp. [m] (R)
Prevalia sp. [m] (R)
Choffatia sp. [M] (C)
Homoeoplanulites sp. [m] (R) (Plate 1, fig. 7)
H. mangoldi (DOMINJON) [m] (R) (Plate 1, fig. 6)
Kheraiceras sp. [M] (R)
Bomburites sp. [m] (R)
B. suevicus (J. ROEMER) [m] (R) (Plate 1, fig. 4)

The second biostratigraphic interval of the Retrocostatum Zone (levels CR445 – CR480), characterized by the common occurrence of *Epistrenoceras* [M + m] and *Parapatoceras* [M + m], contains abundant perisphinctids: *Choffatia* [M] – *Homoeoplanulites* [m]. The following taxa have been identified:

Cadomoceras sp. [m] (R)
Lissoceras sp. [M] (R)
Oxycerites sp. [M] (C)
Oxycerites cf. *oppeli* ELMI [M] (R)
Alcidellus sp. [M] (R)
Alcidellus cf. *biflexuosus* (D'ORBIGNY) [M] (R)
Paroecotraustes sp. [m] (C)
Paroecotraustes serrigerus (WAAGEN) [m] (R)
Paroecotraustes waageni (STEPHANOV) [m] (R)
Prohecticoceras sp. [M] (R)
Prohecticoceras cf. *mondegoense* (ELMI) [M] (R)
Epistrenoceras sp. [M] (C)
E. contrarium (D'ORBIGNY) [M] (C) (Plate 1, figs 1–3, 5)
Parapatoceras sp. [M + m] (C)
P. distans (BAUGIER & SAUZÉ) [M] (C) (Plate 2, fig. 13)
P tenue (BAUGIER & SAUZÉ) [M] (C) (Plate 2, fig. 12)
P. tuberculatum (BAUGIER & SAUZÉ) [M] (R) (Plate 2, fig. 11)
Procerites sp. [M] (R)
Siemiradzkia sp. [m] (R)
Prevalia sp. [m] (R)
Choffatia sp. [M] (C)
C. arisphinctoides ARKELL [M] (R)
Homoeoplanulites sp. [m] (C)
H. homeomorphus BUCKMAN [m] (R) (Plate 2, fig. 8)
Grossouvria sp. [m] (R)
Kheraiceras sp. [M] (R)
Bomburites sp. [m] (R)

The third biostratigraphic interval of the Upper Bathonian (levels CR487 – CR496) may represent the Angulicostatum Zone proposed in the Submediterranean Province (ELMI 1967, MANGOLD & RIOULT 1997). It is characterized by the common occurrence of perisphinctids: *Choffatia* [M] – *Homoeoplanulites* [m], but specimens of *Parapatoceras* [M + m] are very scarce and *Epistrenoceras* [M + m] are virtually absent. The following taxa have been identified:

Phlycticeras sp. [M] (R)
Cadomoceras sp. [m] (R)
Oxycerites sp. [M] (C)
Paroecotraustes sp. [m] (C)
Prohecticoceras sp. [M] (R)
P. tenue (BAUGIER & SAUZÉ) [M] (R)
Prevalia sp. [m] (R)
Choffatia sp. [M] (C)
C. cf. *cerealis* ARKELL [M] (R)
Homoeoplanulites sp. [m] (C)
H. homeomorphus BUCKMAN [m] (R)
Grossouvria sp. [m] (R)
Rugiferites sp. [M] (R)

Above CR497, the Bullatus Zone of the Lower Callovian is characterized by the first occurrence of *Macrocephalites* [M + m]. The following taxa have been identified:

Lissoceras sp. [M] (R) (Plate 2, fig. 4)
Paralcidia sp. [M] (R) (Plate 2, fig. 3)
Strungia cf. *voultensis* LISSAJOUS [M] (R) (Plate 2, fig. 2)
Oxycerites sp. [M] (R)
Paroecotraustes sp. [m] (C)
Parapatoceras sp. [M + m] (R)
Macrocephalites sp. [M + m] (R) (Plate 2, fig. 1)
Choffatia sp. [M] (R)
C. cf. *prosocostata* (SIEMIRADZKI) [M] (R)
Homoeoplanulites sp. [m] (R)
Grossouvria sp. [m] (R)
Elatmites graciosus (SIEMIRADZKI)[m] (R) (Plate 2, fig. 5)
Bomburites microstoma (D'ORBIGNY) [m] (R)

In the Cap Salou section, *Prohecticoceras crassum* ELMI [M] have been identified in the middle part of the La Tossa Fm. (level PM28 in Fig. 4; Plate 1, fig. 13), associated with specimens of *Oxycerites* sp., *Alcidellus* cf. *tenuistriatus* (DE GROSSOUVRE) (Plate 1, fig. 14), *Alcidellus biflexuosus* (D'ORBIGNY), *Paroecotraustes* sp, *Procerites* sp., *Siemiradzkia* sp. and *Bullatimorphites* sp. These taxa allow to recognized the Bremeri Zone (Middle Bathonian). The Upper Bathonian attains a maximum thickness of 18 m (stratigraphic interval PM49–PM158) and is overlain by the Bullatus Zone. Ammonites allow recognition of three biostratigraphic intervals. The lower interval of the Retrocostatum Zone (levels PM49–PM74) contains:

Lissoceras sp. [M] (R)
Delecticeras sp.[m] (R) (Plate 2, fig. 6)
Oxycerites sp. [M] (R)
Alcidellus cf. *tenuistriatus* (DE GROSSOUVRE) [M] (R)
Paroecotraustes sp. [m] (R)
P. waageni STEPHANOV [m] (R)
Prohecticoceras sp. [M] (R)
Nodiferites sp. [m] (R)
N. sayni ELMI [m] (R) (Plate 1, fig. 9)
Epistrenoceras sp. [M] (R)
Siemiradzkia sp. [m] (R)
Homoeoplanulites sp. [m] (R)
Bomburites sp. [m] (R)

The second biostratigraphic interval of the Retrocostatum Zone (levels PM76–PM86) is characterized by the common occurrence of

Epistrenoceras [M + m]. The following taxa have been identified:

Oxycerites sp. [M] (R)
Alcidellus biflexuosus (D'ORBIGNY) [M] (R)
Paroecotraustes sp. [m] (R)
Epistrenoceras contrarium (D'ORBIGNY) [M] (C)
Parapatoceras sp. [M + m] (R)
Paracuariceras incisum SCHINDEWOLF (R) (Plate 2, fig. 10)
Homoeoplanulites sp. [m] (C)

Above this second interval of the Retrocostatum Zone, and below beds containing *Elatmites* spp. [m] characterizing the Bullatus Zone, a specimen of *Clydoniceras* [M] (Plate 2, fig. 7) has been identified in the level PM130, associated with *Kheraiceras* sp. The occurrence of these taxa can be indicative of the Angulicostatum Zone.

Palaeobiogeographical remarks

Separate zonal schemes have been established in Europe, for the Upper Bathonian and Lower Callovian, due to faunal differences (Fig. 5).

	Subboreal Province NW Europe: England, Lorraine, Alsace, Germany.			Submediterranean Province South-East France, Nièvre, Macônnais, Jura, Iberian Basin, Portugal.			Mediterranean Province Betic Basin.		
Callovian	Lower Callovian	Herveyi	Kamptus	Lower Callovian	Bullatus		Lower Callovian		
			Terebratus						
			Keppleri						
Bathonian	Upper Bathonian	Discus	Discus	Upper Bathonian	Angulicostatum		Upper Bathonian		
			Hollandi						
		Orbis	Hannoveranus		Retrocostat.	Hannoveranus			Aspidoides
			Blanazense			Blanazense			
		Hodsoni				Quercinus			
				Middle Bathonian	Bremeri	Fortecostatum	Middle Bathonian	Costatus	Suspensum
						Bullatimorphus			Bullatimorphus
	Middle Bathonian	Morrisi			Subcon.	Morrisi			
		Subcontractus				Subcontractus			Sofanus
		Progracilis			Prograc.	Progracilis			
						Orbignyi			

Fig. 5. Ammonite zones and subzones of the Upper Bathonian and the lowermost Callovian in the so–called Subboreal (WESTERMANN & CALLOMON 1988, DIETL 1994, CALLOMON & COPE 1995), Sub–Mediterranean (CARIOU et al. 1985, MANGOLD 1990, RIOULT et al. 1997, MANGOLD & RIOULT 1997, THIERRY et al. 1997) and Mediterranean (GALACZ 1980, SANDOVAL 1983, SEQUEIROS et al. 1988, ZANY et al. 1990, OLIVERO et al. 1997, GÉCZY & GALÁCZ 1998) provinces of Europe.

A northern European faunal region or Subboreal Province, from Britain to southern Germany, has been distinguished by several authors (WESTERMANN & CALLOMON 1988, DIETL 1994, CALLOMON & COPE 1995, PAGE 1996) giving careful consideration to the occurrence of Clydoniceratids. In contrast, Phylloceratina and Lytoceratina characterizing the Mediterranean Province (CARIOU et al. 1985, ZANY et al. 1990, CARIOU & ENAY 1999) are very common in the Subbetic Basin (SANDOVAL 1981, 1983, SEQUEIROS et al. 1988). These taxonomic groups (Clydoniceratinae, Phylloceratina and Lytoceratina) are very scarce in the so–called Sub–Mediterranean areas, such as Portugal, Centre–West France, Nièvre, Macônnais South–Est France and Jura (GALÁCZ 1980, 1994, 1995a, b, TORRENS 1987, KRISHNA & CARIOU 1990, MANGOLD 1990, THIERRY 1994, MANGOLD & RIOULT 1997, THIERRY et al. 1997, OLIVERO et al. 1997, GÉCZY & GALÁCZ 1998). However, *Epistrenoceras* and *Parapatoceras* are widespread in very distant areas: Europe, Madagascar, South Mexico and northern Chile (Fig.

6, COLLIGNON 1958, SANDOVAL et al. 1990, FERNÁNDEZ–LÓPEZ et al. 1995).

Fig. 6. Palaeogeographical distribution of Late Bathonian *Epistrenoceras* representatives.

In the Iberian Basin, Middle Jurassic Phylloceratina and Lytoceratina represent less than 1% of the whole of ammonoids (FERNÁNDEZ–LÓPEZ & MELÉNDEZ 1996) and Upper Bathonian clydoniceratids are virtually absent. A Sub–Mediterranean zonation can be recognized in the Iberian Basin and has also been applied to the Catalan Basin (FERNÁNDEZ–LÓPEZ et al. 1978, 1996, 1997, 1999, FERNÁNDEZ–LÓPEZ 1997a, b, 2000b). However, Upper Bathonian ammonoids of the Iberian and Catalan basins have never been figured. In the Tivissa (Serra de la Creu) and Cap Salou sections, the total number of the Upper Bathonian studied ammonites is up 500 (Fig. 7). Specimens of the family Perisphinctidae are common (43,5 %). Pseudoperisphinctinae of the genera *Choffatia* [M] – *Homoeoplanulites* [m] are the most common ammonites in the Retrocostatum and Angulicostatum zones. Zigzagiceratinae of the genera *Procerites* [M] – *Siemiradzkia* [m] are fairly common. Among the Oppeliidae (26,7 %), *Oxycerites* [M] – *Paroecotraustes* [m] are one of the most common ammonites in some levels of the Upper Bathonian *Alcidellus* [M] occurrs. Stephanoceratidae (15,5%) are common in certain levels, in particular *Epistrenoceras* [M + m]. However, *Cadomites* [M] and *Polyplectites* [m] are very scarce. Spiroceratidae of the genre *Parapatoceras* (7,2 %) are common in several levels. A single specimen of *Paracuariceras* has been found. Very scarce are the families Glochiceratidae (3,2%), Tulitidae (2,4 %), Strigoceratidae (1,0 %), and Lissoceratidae (0,5 %). Clydoniceratinae of the group *Clydoniceras* [M] – *Delecticeras* [m] represent lower than 0,4% and correspond to post–juvenile individuals.

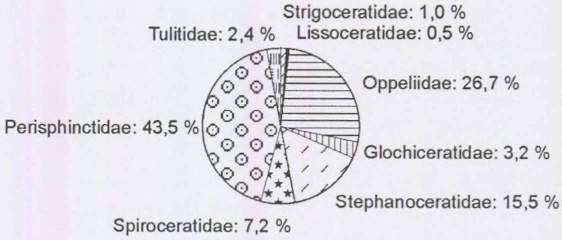

Fig. 7. Distribution of the percentage of the ammonite taxonomic groups (400 specimens) in the Upper Bathonian of the Tivissa (Serra de la Creu) section.

Consequently, the successive recorded associations of ammonites at the Catalan Basin reflect the transition between the influences of the Mediterranean and Subboreal provinces during the Late Bathonian. Some pandemic ammonites, such as *Epistrenoceras* and *Parapatoceras* inhabited this basin. The Retrocostatum and Angulicostatum zones (Upper Bathonian) and the Bullatus Zone (Lower Callovian) established for Submediterranean areas of Europe can be identified in the Catalan Basin. The Discus Zone established for NW European areas of the Subboreal Province has not been recognized, although several specimens of clydoniceratids have been discovered among the Upper Bathonian ammonite fossil assemblages.

Conclusions

The Upper Bathonian at the section of Tivissa (Serra de la Creu) provides the best–known biostratigraphical record of the Catalan and Iberian basins. Several specimens of Upper Bathonian Clydoniceratinae have been found in the outcrop of Cap Salou. However, the Discus Zone established for NW European areas of the Subboreal Province has not been recognized. The ammonite fossil assemblages of the Catalan Basin are composed by Submediterranean taxa during the Late Bathonian–Early Callovian interval.

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Plates

Plate captions

All the ammonites are in natural size, except for 1. Arrow indicates end of phragmocone

Plate 1

Fig. 1 *Epistrenoceras* sp. Incomplete immature shell. Right view. Specimen 4CR456/42. Retrocostatum Zone. Upper Bathonian.

Fig. 2. *Epistrenoceras contrarium* (D'ORBIGNY) [m]. Incomplete shell of immature microconch. Left view. Specimen 4CR456/32. Retrocostatum Zone. Upper Bathonian.

Fig. 3. *Epistrenoceras contrarium* (D'ORBIGNY) [m]. Complete shell of mature microconch without lateral lappets. Right view. Specimen 4CR456/31. Retrocostatum Zone. Upper Bathonian.

Fig. 4. *Bomburites suevicus* (J. ROEMER) [m]. Complete microconch. Left view Specimen 3CR406/3. x1.Retrocostatum Zone. Upper Bathonian.

Fig. 5. *Epistrenoceras contrarium* (D'ORBIGNY) [M]. Incomplete shell of immature macroconch. Left view Specimen 4CR458/4. Retrocostatum Zone. Upper Bathonian.

Fig. 6. *Homoeoplanulites mangoldi* (DOMINJON) [m]. Complete shell of mature microconch with lateral lappets. Right view Specimen 3CR394/13. Retrocostatum Zone. Upper Bathonian.

Fig. 7. *Homoeoplanulites* sp. [m]. Complete microconch with lateral lappets. Left view. Specimen 3CR394/28. Retrocostatum Zone. Upper Bathonian.

Fig. 8. *Alcidellus* cf. *biflexuosus* (D'ORBIGNY). Incomplete shell of immature macroconch. Right view. Specimen 3CR394/47. Retrocostatum Zone. Upper Bathonian.

Fig. 9. *Nodiferites sayni* ELMI. Incomplete microconch. Left view. Specimen 3PM58L50/1. Retrocostatum Zone. Upper Bathonian.

Fig. 10. *Prohecticoceras retrocostatum* (DE GROSSOUVRE). Incomplete shell of immature macroconch. Right view Specimen 3CR406/1. Retrocostatum Zone. Upper Bathonian.

Fig. 11. *Prohecticoceras blanasensis* (ELMI). Incomplete phragmocone of macroconch. Right view. Specimen 3CR396/2. Retrocostatum Zone. Upper Bathonian.

Fig. 12. *Prevalia* cf. *detorta* (DE GROSSOUVRE). Incomplete microconch. Right view. Specimen 3CR370/8. Bremeri Zone. Middle Bathonian.

Fig. 13. *Prohecticoceras crassum* ELMI [M]. Incomplete phragmocone of macroconch. Right view. Specimen 3PM28/1. Bremeri Zone. Middle Bathonian.

Fig. 14. *Alcidellus* cf. *tenuistriatus* (DE GROSSOUVRE) [M]. Incomplete phragmocone of macroconch. Right view Specimen 3PM28/3. Bremeri Zone. Middle Bathonian.

Plate 1

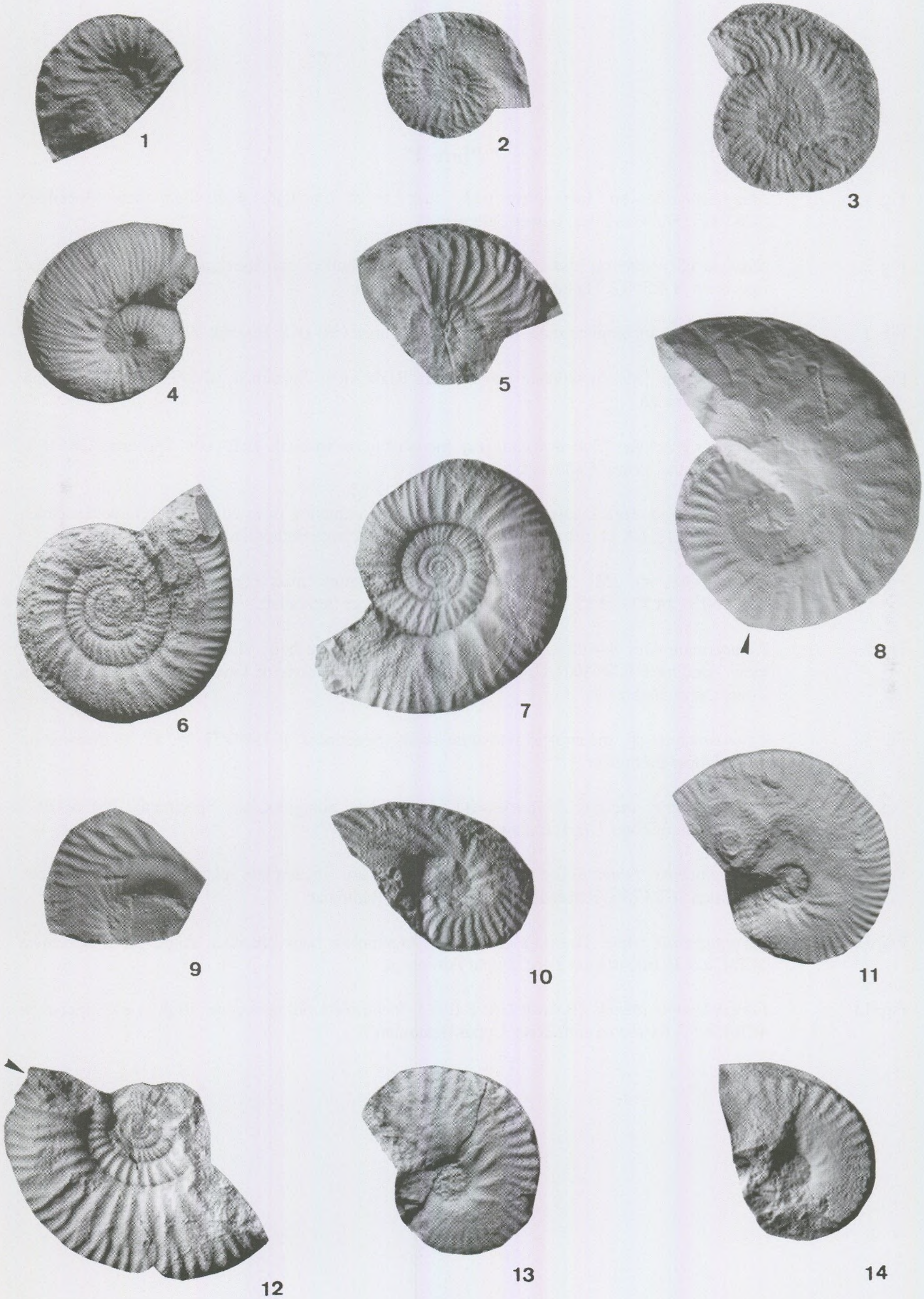

Plate captions

All ammonites are in natural size, except for 6B, 7B, 9 and 10. Arrow indicates end of phragmocone.

Plate 2

Fig. 1. *Macrocephalites* sp. Incomplete body chamber of immature shell. Left view. Specimen 3CR500/1. Bullatus Zone. Lower Callovian.

Fig. 2. *Strungia* cf. *voultensis* LISSAJOUS [M]. Incomplete shell of immature macroconch. Right view. Specimen 3CR500/7. Bullatus Zone. Lower Callovian.

Fig. 3. *Paralcidia* sp. Incomplete shell. Right view. Specimen CR516/8. Bullatus Zone. Lower Callovian.

Fig. 4. *Lissoceras* sp. [M]. Incomplete macroconch. Right view. Specimen 3CR498/8. Bullatus Zone. Lower Callovian.

Fig. 5. *Elatmites graciosus (*SIEMIRADZKI*)* [m]. Incomplete microconch. Left view. Specimen CR516/1. Bullatus Zone. Lower Callovian.

Fig. 6. *Delecticeras* sp. [m]. Incomplete body chamber of immature microconch. Left view. Specimen 3PM58L30/13. 6A x1. 6B x2. Angulicostatum Zone. Upper Bathonian.

Fig. 7. *Clydoniceras* sp. [M]. Incomplete shell of immature macroconch. Left view. Specimen 3PM130/1. 7A x1. 7B x2. Angulicostatum Zone. Upper Bathonian.

Fig. 8. *Homoeoplanulites homoeomorphus* BUCKMAN. Incomplete body chamber of microconch. Left view. Specimen 3CR480/6. Upper part of Retrocostatum Zone or lower part of Angulicostatum Zone. Upper Bathonian.

Fig. 9. *Epistrenoceras* sp. Incomplete immature shells. Specimens 4CR456/33–35. x2. Retrocostatum Zone. Upper Bathonian.

Fig. 10. *Paracuariceras incisum* SCHINDEWOLF. Incomplete phragmocone. Specimen 3PM76U30/1. Retrocostatum Zone. Upper Bathonian.

Fig. 11. *Parapatoceras tuberculatum* (BAUGIER & SAUZÉ). Incomplete phragmocone. Left view. Specimen 3CR476/3. Retrocostatum Zone. Upper Bathonian.

Fig. 12. *Parapatoceras tenue* (BAUGIER & SAUZÉ). Incomplete body chamber. Right view. Specimen 3CR470/6. Retrocostatum Zone. Upper Bathonian.

Fig. 13. *Parapatoceras distans* (BAUGIER & SAUZÉ). Incomplete phragmocone. Right view. Specimen 4CR456/57. Retrocostatum Zone. Upper Bathonian.

Plate 2

1

2

3

4

5

6A

6B

7A

7B

8

9

10

11

12

13

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Frogdenites, the early Sphaeroceratid ammonite from the lower Bajocian of the Bakony and Gerecse Hills, Hungary

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(With 1 plate)

Genus *Frogdenites* and its two species are described on the basis of new finds from the Bajocian of Hungary. The study supports the previously suggested conclusions on systematic and stratigraphy· the genus, which represents the earliest member of the family Sphaeroceratidae, is a rare, but very good index of the topmost part of the Laeviuscula Zone. Dimorphism is demonstrated in both species, with a very low size ratio between macro– and microconchs.

Introduction

Frogdenites BUCKMAN 1921, this rare Sphaeroceratid ammonite has been known only in some areas of Europe: in southern England, the type region (see PARSONS 1974, 1977), Portugal (FERNÁNDEZ–LÓPEZ et al. 1988), Spain (SANDOVAL 1983, 1990; FERNÁNDEZ–LÓPEZ 1985) and in Hungary (GALÁCZ 1982). Recently a fine specimen was figured (as *Otoites* sp.) from Morocco (BENSHILI 1989, pl.23, fig.7). The earlier record from Lókút, Transdanubian Hungary was based on a loose specimen, but now new finds from bed–by–bed collections of other localities are available. The new specimens represent the two species of BUCKMAN: *Frogdenites spiniger*, the genotype (BUCKMAN 1921, pl.215, figs 1–4) and *F. extensus* (BUCKMAN, 1921), where the other named species of BUCKMAN, *F profectus* also belongs. The two forms are easy to distinguish by size, coiling and sculpture. While all new specimens are macroconchs, other records and specimens kept in English collections from BUCKMAN original localities may help to conclude on the style of dimorphism and corresponding microconchs.

Localities

One of the localities is Gombáspuszta in the southern Bakony, where a greyish–yellowish marly limestone yielded a rich ammonite fauna from the Witchellia laeviuscula and Otoites sauzei Zones. The three specimens came from Beds 28 and 25, just below Bed 22 where *Labyrinthoceras*, a good index for the Sauzei Zone first appears. This is the lower part of the sequence, where *Sonninia, Skirroceras, Otoites, Emileia* spp. are common, with rarer *Witchellia* and *Amblyoxyites* spp. The first *Kumatostephanus* also occurs in this level.

The other locality is in the Gerecse Hills, in the Nagypisznice Quarry, where a section of 46 beds in the dark red Rosso Ammonitico exposed the Bajocian, from the Discites up to the Humphriesianum Zone. Beds 28 and 27 gave two specimens of *Frogdenites*. The accompanying fauna contains *Emileia, Otoites, Skirroceras, Papilliceras*, and *Mollistephanus*. The first *Kumatostephanus* also appears in Bed 27.

The stratigraphic position in both locality confirms the previous data (GALÁCZ 1982) that *Frogdenites* is a genus restricted to a very narrow stratigraphic interval, i.e. to the top of the Laeviuscula Zone (Bj–10, *Witchellia laeviuscula* faunal horizon in CALLOMON & CHANDLER 1990).

Descriptions

Order Ammonoidea ZITTEL, 1884
Suborder Ammonitina HYATT, 1889
Superfamily Stephanocerataceae NEUMAYR, 1875
Family Sphaeroceratidae BUCKMAN, 1920
Subfamily Sphaeroceratinae BUCKMAN, 1920

Genus *Frogdenites* BUCKMAN, 1921

Frogdenites spiniger BUCKMAN, 1921
Plate 1, figs 1 and 2.

*v 1921 *Frogdenites spiniger*, nov. – BUCKMAN, pl.240, figs 1–4.

v 1922. *Labyrinthoceras gibberulum*, nov. – BUCKMAN, pl.278, figs 1, 2.

v 1982. *Frogdenites spiniger* BUCKMAN, 1921 – GALÁCZ, p.25, text–figs 1,2.

1983. *Frogdenites spiniger* BUCKMAN, 1921 – SANDOVAL, p.200, pl.4, fig.3, text–fig.90H.

1989. *Emileia* (*Otoites*) sp. – BENSHILI, p.177, pl.23, fig.7

Material: Two specimens, one from Gombáspuszta, Bakony Mts, and one from Nagypisznice, Gerecse Hills.

Measurements

Specimen	D	H	H/D	W	W/D	U	U/D	Pr	S
Holotype GSM32039	45	14.5	0.33	32	0.71	13.5	0.30	27	76
	30.5	11.5	0.37	26.5	0.87	6.5	0.21		
"*L.gibberulum*" GSM47113	31	14.5	0.46	29.5	0.95	6	0.19	31	~96
	23.5	10.5	0.47	22.5	0.95	4.5	0.19		
GALÁCZ 1982, texfig.1	37	17	0.41	22.5	0.61	12	0.28	31	
	26	13	0.50	20.5	0.79	6.3	0.24	31	
Nagypisznice; Pl.. 1, fig.1	66	21	0.31	21	0.31	19	0.28	18*	38*
	41	20	0.48	39	0.95	9	0.21		
	31	12.5	0.40	30	0.96	5.5	0.17		
Gombáspuszta; Pl. 1, fig.3	62	22	0.35	33	0.53	19	0.30	16*	~39*
	48	22	0.46	37	0.77	19	0.39		

*counted on the last half whorl

Description: The holotype (Geol.Surv.Mus. 32039) is an incomplete form, the apertural piece of the body–chamber is missing. BUCKMAN estimated the entire diameter as 55 mm. The Hungarian specimens are somewhat bigger, attaining 65 mm at the aperture. The species has extremely depressed, broad inner whorls with narrow umbilicus up to the end of the phragmocone, where gradual contraction begins, resulting in opening of the umbilicus, and laterally narrowing cross–section on the body–chamber The ribbing is dense on the phragmocone, with fine, sharp inner ribs ending in tiny tubercles (see *"Labyrinthoceras" gibberulum* BUCKMAN 1922, pl.278, figs 1–2). The tubercles appear just above the maximal width of the whorl. The body–chamber shows strong, rounded ribs, which endure up to the aperture in gradually decreasing number. Suture–line cannot be seen.

The probable microconch is a 37–38 mm diameter form with contracted and strongly ribbed and tuberculate body–chamber. This is the form figured previously from the Bakony (Lókút, GALÁCZ 1982, text–figs 1–2) and recently from Moroccco by BENSHILI (1989, pl.7, fig.7).

Frogdenites extensus (BUCKMAN, 1921)
Plate 1, figs 2, 4–6.

* v 1921 *Labyrinthoceras extensum*, nov. – BUCKMAN, pl.214, figs 1–2.

1923. *Frogdenites profectus*, nov. – BUCKMAN, pl.430, figs 1–3.

non 1939. *Sphaeroceras profectum* BU. 1923 – HILTERMANN, p.196.

? 1985. *Frogdenites* sp. nov. – FERNÁNDEZ–LÓPEZ, p.376, pl.40, figs 5–6.

Material: Three specimens, two from Gombáspuszta, Bakony Mts, one from Nagypisznice, Gerecse Hills.

Measurements

Specimen	D	H	H/D	W	W/D	U	U/D	Pr	S
Holotype (GSM 32038)	32	14	0.43	30.5	0.95	7.8	0.24	32	~78
Frogdenites profectus type	43	18	0.42	28	0.65	10.5	0.25	29	~90
	27	10.5	0.44	23.5	0.88	3	0.12	30	
Gombáspuszta; Pl. 1, fig.5	48	17	0.38	26	0.54	19	0.39	16*	34*
Gombáspuszta; Pl. 1, fig.4	48	18	0.37	~37	~0.77	13	0.27	17*	36*
Nagypisznice; Pl. 1, fig 2	51	18	0.35	31	0.60	17	0.33	34; 17*	38*
Sherborne, Sedgwick Mus.J.24532	24.5	9.5	0.39	20.5	0.83	6	0.25	30	61
Pl. 1, fig.6	20	9.5	0.47	18.5	0.93	4	0.20	30	

*counted on the last half–whorl

Description: The holotype (Geol.Surv.Mus. 32038) is an incomplete specimen, septate up to 30 mm diameter, with only a portion of the body–chamber. It was originally ranged into *Labyrinthoceras* by BUCKMAN, but the presence of tubercles on the furcation points makes it as distinct (see PARSONS 1974; GALÁCZ 1982, 1990). The entire form can be better demonstrated by the conspecific specimen named by BUCKMAN as *Frogdenites profectus* from Dundry, the same locality as that of the type. This specimen shows that the general look is a barrell–shape cadicone, where the body–chamber becomes excentric only on the last 1/3 whorl, with strong contraction in width just before the aperture. The peristome is bordered by a flared, laterally extended mouth–

border. The sculpture changes with growth: while the dense inner ribbing consists of prorsiradiate primaries ending in tiny, sharp tubercles, and giving rise usually three, prorsiradiate secondaries, the ribs become rarer, stronger, radiate, and the tubercles disappear on the last 1/3 part of the body–chamber.

The Hungarian specimens are similar, though poorly preserved. They are of 48–51 mm diameter, and septate up to 30–35 mm diameter, densely ribbed on the middle whorls, but having rarer, rounded ribs on the last 1/2 – 2/3 whorl. The bigger specimen from Gombáspuszta (Pl.1,fig.5) indicates the aperture: a flared, extended peristomal border with strong lateral contraction just behind.

Suture–lines cannot be seen.

BUCKMAN's figured specimens and the here described Hungarian examples all are macroconchs. Two specimens of the possible microconchiate were found in the Sedgwick Museum (J.24531–24532, Walker Collection, from Stoke Knap, Sherborne). These specimens are tiny variants of the typical *F. extensus*. One (J.24532) is figured here on Pl. 1, fig 6. Additionally to the small size these forms differ in sculpture also: here the tubercles endure on the body–chamber. These specimens are very similar to the incomplete forms of FERNÁNDEZ–LÓPEZ (1985, pl.40, figs 5, 6), the only difference is that the Spanish forms seem to be less depressed, and the ribbing remains dense on the body–chamber.

Conclusions

The hithero known two species of genus *Frogdenites* seem to be clearly distinuished. *F. spiniger* is bigger, attaining 66 mm diameter near the aperture, while *F extensus* is smaller, with 45–47 mm maximum diameter. The excentric coiling is also different. *F. spiniger* has a gradually opening umbilicus on the last whorl, while abrupt opening of the last whorl's umbilicus appears behind the aperture in *F. extensus*.

The aperture, which is missing or incomplete in all the new specimens, indicates flared, laterally extended, but unlappetted peristome after a deep preapertural constriction, just as it is shown on BUCKMAN's *Frogdenites "profectus"* specimen.

The new specimens seem all to be macroconch forms. Microconchs possibly could not be distinguished by aperture, because in *Frogdenites*, just as in the later relative *Chondroceras/Sphaeroceras,* the peristome of the adult forms are similar: flared, but without lappets in microconchs. The distinguishing feature is most probably the size, but as it was suggested earlier (PARSONS 1977, p.114; GALÁCZ 1990, p.345), the size ratio in *Frogdenites* micro– and macroconchs is probably low. If it is the case, the previously described *Frogdenites spiniger* (in GALÁCZ 1982), and "*Emileia* (*Otoites*) sp." of BENSHILI, with their 37 and 38 mm maximum diameters could be microconchs of typical *F. spiniger* (ca. 66–67 mm adult size), and the small specimens of FERNÁNDEZ–LÓPEZ (1985, pl.40, figs 5, 6) could be matched with *F. extensus* as its microconch. In this latter species the macroconchs show 45–51 mm maximum diameter, while the suggested microconchs are of 20–25 mm. Thus the macrconch/microconch adult size ratio is 1.77 for *F. spiniger* and 2.1 for *F.extensus* – on the basis of the very limited available data.

As of phylogeny, the earlier suggestions (DONOVAN et al. 1981; GALÁCZ 1990) as to regard *Frogdenites* as the earliest Sphaeroceratid, of which lineage continues with *Labyrinthoceras/Manselites* and *Chondroceras/Sphaeroceras* in the Bajocian, stands the test of these new findings.

Stratigraphically *Frogdenites* is one of the best index to identify the uppermost level of the Lower Bajocian Laeviuscula Zone. All available data (PARSONS 1974, CALLOMON & CHANDLER 1990) suggests the beds just below the Sauzei Zone as the source of *Frogdenites* in the type area. These new Hungarian finds came also from the higher or topmost beds of the Laeviuscula Zone, and other, well–documented records (SANDOVAL 1983; FERNÁNDEZ–LÓPEZ 1985) indicate the same age.

Acknowledgements

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Plate

Plate 1

All figures natural size

Fig. 1. *Frogdenites spiniger* BUCKMAN, 1921 (M); Nagypisznice (Gerecse Hills), Bed 27, topmost Laeviuscula Zone. 1a: ventral view, 1b: lateral view.

Fig. 2. *Frogdenites extensus* (BUCKMAN, 1921) (M); Nagypisznice (Gerecse Hills), Bed 28, higher Laeviuscula Zone.

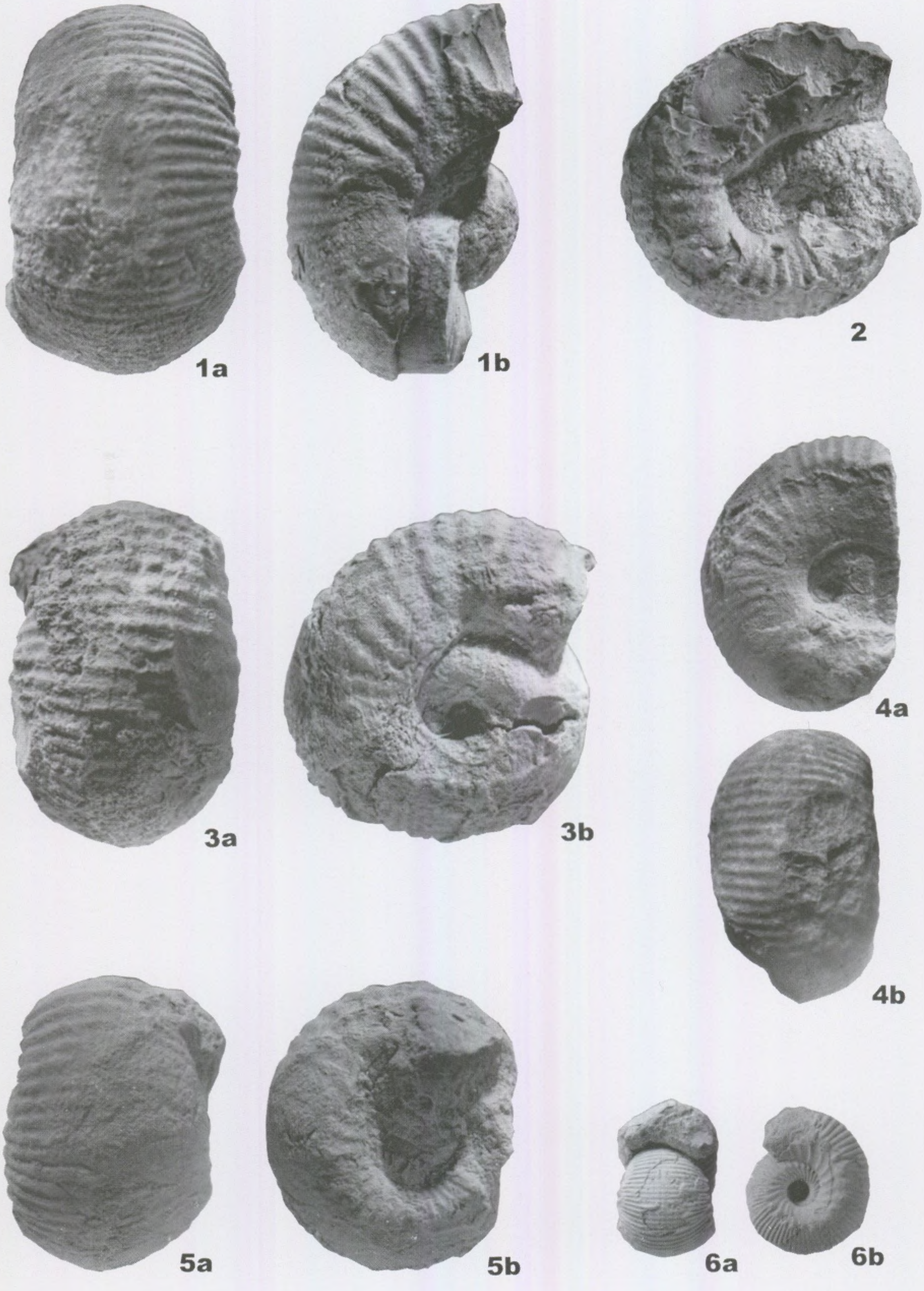
Fig. 3. *Frogdenites spiniger* BUCKMAN, 1921 (M); Gombáspuszta (Bakony Mts), Bed 25, topmost Laeviuscula Zone. 3a: ventral view, 3b: lateral view.

Fig. 4. *Frogdenites extensus* (BUCKMAN, 1921) (M); Gombáspuszta (Bakony Mts), Bed 25, topmost Laeviuscula Zone. 4a: ventral view, 4b: lateral view.

Fig. 5. *Frogdenites extensus* (BUCKMAN, 1921) (M); Gombáspuszta (Bakony Mts), Bed 28, higher Laeviuscula Zone. 5a: ventral view, 5b: lateral view.

Fig. 6. ? *Frogdenites extensus* (BUCKMAN, 1921) (m); Stoke Knap, Sherborne, Sedgwick Museum, Cambridge, J.51848. 6a: ventral view, 6b: lateral view.

Plate 1



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Ammonite stratigraphy of the Bajocian in Northern Chile

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(with 3 text–figures, 3 tables and 10 plates)

Ammonites of Bajocian age are found in Northern Chile at many localities, but sections with ammonite beds of different age of this stage are rare. The Bajocian is subdivided in ammonite horizons. The distinguishable number of horizons is much smaller than that in Europe and corresponds to the quantity of zones or subzones occuring there. Faunal diversity is much lower than in Europe and many of the South American species are likely to have a longer biostratigraphic range. The lower diversity is probably caused by the special paleogeographic and biogeographic back arc basin situation. The entrance to this basin was restricted and its dimensions was much smaller than the huge area of the European shelf with a high potential of ecologic possibilties.

Proof of the European Discites Zone is difficult. The Ovalis Zone is represented only by one horizon. The Laeviuscula to Subfurcatum Zones can each be subdivided into two horizons. It is not easy to ascertain the middle and upper part of the Upper Bajocian because ammonites of this age are very rare, endemic or unsuitable for an exact age determination.

Two new species are described being important for the biostratigraphy of the lowest Upper Bajocian.

Introduction

STEINMANN (1881) and MÖRICKE (1894) were the first to decribe and figure Bajocian ammonites from northern Chile. WESTERMANN & RICCARDI (1972, 1979) and RICCARDI & WESTERMANN (1991) published monographs on Middle Jurassic ammonites of the Argentine–Chilean Andes. These authors described Bajocian ammonites mainly from Argentina but also some Chilean localities were considered, and they included some ammonites of Bajocian age collected in northern Chile by the author. COVACEVICH & PIRACES (1976) described ammonites of Late Bajocian age from Central Chile and DAVIDSON et al. (1976) those of Lower Bajocian age from Northern Chile. The author (1977) published a new genus and some new species of the Stephanoceratidae from the Bajocian of Northern Chile. WESTERMANN & RICCARDI (1980) described *Strenoceras* and FERNÁNDEZ–LÓPEZ et al. (1994) Late Bajocian and Bathonian ammonites from Northern Chile. KOSSLER (1998) published Bajocian ammonites in her thesis on the Jurassic of the Coastal Cordillera of Iquique, Northern Chile. Ammonites of Bajocian age from Chile were also refigured in WESTERMANN (1992). Additionally, many authors (e.g. in explanations of geological maps) mentioned Bajocian ammonites from different sections and localities of Northern Chile.

The author investigated many sections and localities in Northern Chile with Bajocian ammonites in the period of 1966 to 1997. Only part of the material collected was published up to now.

This paper gives just an overall view of the most important sections and localities with Bajocian ammonites found in Northern Chile and known by the author. An attempt is made to subdivide the Bajocian of Northern Chile into ammonite horizons.

Only part of the existing ammonite material can be figured. Mainly ammonites of the upper part of the Lower and the lower part of the Upper Bajocian are selected because the ammonites of this stratigraphic period are not yet well known from South America and less well represented in Argentina. Stephanocerataceae are mainly considered because of their considerable importance for the biostratigraphy and correlation with Europe. Sonniniidae are frequent up to a horizon that can be correlated with the lower part of the European Humphriesianum Zone. Being very important for the biostratigraphy of the Lower Bajocian and the correlation with Europe, they shall be described separately.

Description of sections and localities

Many sections and localities with Bajocian ammonites are found in Northern Chile. Frequently only a single bed, sometimes a few beds with ammonites of this age occur. Sections with several ammonite horizons, subzones and zones are rarely found. Often the sections are folded, faulted or not well exposed and not useful for biostratigraphic investigations. Many localities yielded only poorly preserved ammonites which could not be determined on the species level and sometimes not even on the generic level.

Only sections and localities yielding Bajocian ammonites of biostratigraphic or taxonomic value are described. Most of the sections und localities are known from literature but only part of the ammonites found there was figured.

The sections and localities are described from north to south (Fig. 1).

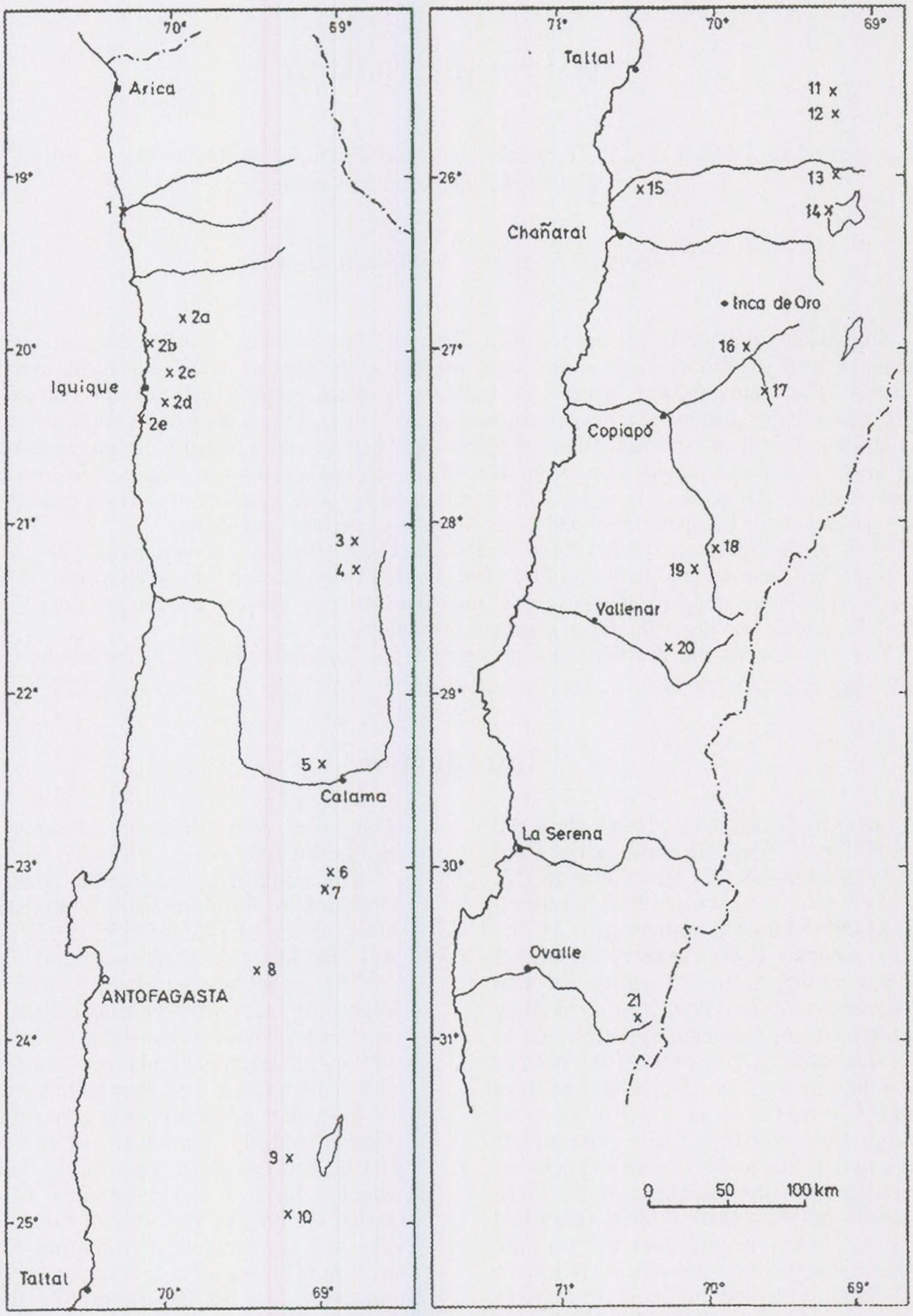

Fig. 1. Map of Northern Chile with Bajocian ammonite localities described. Locality numbers correspond to numbers in the text.

1. Caleta Camarones

The bay called Caleta Camarones is situated 80 km south of Arica. It is the northernmost Chilean outcrop with ammonites of Bajocian age. The locality was first mentioned by CECIONI & GARCIA (1960). The section was studied in detail by Sonja WITTMAN (TU–Berlin, thesis in preparation).

Volcaniclastic sediments are intercalated in volcanic rocks. The beds with ammonites are approximately 6 m thick and yielded the following ammonites (det. S. WITTMANN):

Lupherites dehmi (HILLEBRANDT)
Teloceras (?) sp.
Spiroceras orbignyi (BAUGIER & SAUZÉ)
Spiroceras sp.
Megasphaeroceras sp.

The coiled *Spiroceras* have a diameter of up to 27 cm. At the beginning, the diameter of the shell is 0.5 cm and at the end 4 cm.

The assemblage is of lower Late Bajocian age (*L. dehmi* Horizon).

2. Area of Iquique

Ammonites of Bajocian age from this area were first described by MÖRICKE (1894) and later on by various other authors. KOSSLER (1998) recently studied this area in detail and described Bajocian ammonites from many sections south, north and east of Iquique (Fig. 1, loc. 2a–e). The Humphriesianum Zone was proved with *Sphaeroceras*? sp. at one section. Mainly the *L. dehmi* Horizon, but probably also the *Leptosphinctes* Horizon (= Rotundum Zone in KOSSLER 1998) were found at different sections.The following ammonites were described:

Duashnoceras chilense (HILLEBRANDT)
Lupherites dehmi (HILLEBRANDT)
Teloceras ex gr. *crickmayi chacayi* WESTERMANN & RICCARDI
Megasphaeroceras magnum RICCARDI & WESTERMANN
M. spissum RICCARDI & WESTERMANN
Spiroceras sp.
Leptosphinctinae gen. et sp. indet.

Caumontisphinctes? sp. (? *Leptosphinctes* Horizon) was found approximately 90 m above a bed with *Duashnoceras chilense* (probably *L. dehmi* Horizon).

3. Quebrada Llaretuno

This valley is one of the tributaries of the Quebrada de Tambillo (or Seca) which crosses the Sierra de Moreno. Bajocian ammonites from north of Quebrada Llaretuno (21°31' – 68°52'30") were first cited by MAKSAEV (1978, tab. 1) (det. V. COVACEVICH). Ammonites from the same locality were collected by M. Gröschke in 1983. Two beds were found in a distance of 1 to 2 metres.

Lower bed: *Chondroceras* sp. A, *Oppelia* cf. *subradiata* (SOW.), *Dorsetensia* sp.

Upper bed: *Stephanoceras* ex gr. *St. pyritosum* (QUENSTEDT).

The ammonites of both beds are typical for the *Dorsetensis* ssp. Horizon.

4. Jurassic west of Cerro Jaspe

A Jurassic belt that can be traced from north to south for more than 20 kilometres is exposed east of the Sierra de Moreno and west of Cerro Jaspe. Sections from this belt were described by GRÖSCHKE & WILKE (1986), GRÖSCHKE & PRINZ (1986) and PRINZ (1991).

Bajocian ammonites were cited by GRÖSCHKE & WILKE (1986) from three sections of the northern part and by PRINZ (1991) additionally from one section in the southern part. The sections are numbered 1 to 7 in PRINZ (1991) (sections 1 to 3 are the same as in GRÖSCHKE & WILKE 1986):

Section 1 (beds from below to above):

1. Stephanoceratinae gen. et sp. indet.
2. *Chondroceras* sp. A, *Teloceras* s.l.
3. *Stephanoceras* ex. gr. *St. pyritosum* (QUEN–STEDT), *Teloceras* (?) sp.
4. *Megasphaeroceras magnum* RICCARDI & WES–TERMANN
5. *Megasphaeroceras spissum* RICCARDI & WESTERMANN, *Spiroceras orbignyi* (BAUGIER & SAUZÉ) (Pl. 9, figs 5A, B), *Leptosphinctes* cf. *leptus* BUCKMAN (Pl. 9, figs 7A, B; text–fig. 3b)

Section 2 (beds from below to above):

1 *Fissilobiceras* (?) sp.
2. and 3. *Emileia* cf. *giebeli* (GOTTSCHE),
4. and 5. *Sonninia* cf. *espinazitensis* TORNQUIST
6. *Teloceras* (?) sp.
7 *Duashnoceras chilense* (HILLEBRANDT), *Duashnoceras profetaense* n.sp.
8. *Duashnoceras* (?) sp.
9. *Megasphaeroceras* cf. *magnum* RICCARDI & WESTERMANN
10. *Cadomites* (?) sp.

Section 3 (beds from below to above):

1 *Sonninia* sp.
2. *Duashnoceras* (?) sp.
3. *Teloceras* (?) cf. *chacayi* WESTERMANN & RICCARDI, *Spiroceras* sp.
4. *Lupherites* sp. or *Duashnoceras* sp., *Spiroceras* sp.
5. *Megasphaeroceras spissum* RICCARDI & WESTERMANN
6. *Leptosphinctes* sp.
7 *Leptosphinctes* sp., *Megasphaeroceras magnum* R. & W., *M.* cf. *spissum* R. & W

Section 6 (beds from below to above):

1. Stephanoceratinae gen. et sp. indet.
2. Stephanoceratinae gen. et sp. indet., *Spiroceras* sp.
3. *Duashnoceras* cf. *chilense* (HILLEBRANDT), *Megasphaeroceras* sp.
4. *Teloceras* (?) sp.
5. *Duashnoceras*(?) *burroense* n.sp. (Pl. 8, figs 3A, B)
6. *Teloceras* (?) cf. *chacayi* WESTERMANN & RICCARDI,
7. *Megasphaeroceras magnum* (RICCARDI & WESTERMANN), *Leptosphinctes* sp.
8. *Leptosphinctes* sp.
9. *Megasphaeroceras spissum* RICCARDI & WESTERMANN
10. *Leptosphinctes* sp.
11 *Cadomites* (?) sp., *Megasphaeroceras* (?) sp.
12. *Megasphaeroceras* (?) sp.
13. *Cadomites* (?) sp., "*Cadomites/Garantiana*" sp., *Cobbanites* cf. *talkeetnanus* IMLAY

The following ammonite horizons could be proved in the Cerro Jaspe Jurassic:

E. giebeli giebeli Horizon (section 2 beds 1?, 2 to 5; section 3 bed 1)

Dorsetensia ssp. Horizon (section 1 beds 2, 3)

Duashnoceras caracolensis Horizon (section 2 bed 6?; section 3 bed 2?)

Lupherites dehmi Horizon (section 1 bed 4?; section 2 beds 7, 8?; section 3 beds 3, 4; section 6 beds 2 to 6)

Leptosphinctes Horizon (section 1 bed 5; section 2 bed 9?; section 3 beds 5?, 6, 7; section 6 beds 7 to 10)

?*Megasphaeroceras* Horizon (section 6 beds 11?, 12, 13?)

"*Cobbanites*" Horizon (section 6 bed 13)

The *Duashnoceras caracolensis* Horizon could not be proved with certainty. Bed 13 of section 6 is probably of Early Bathonian age.

5. Sierras de San Lorenzo

The Sierras de San Lorenzo are situated north of the Rio San Salvador and approximately 13 km east of Calama. Hettangian to Oxfordian marine sediments are exposed on the western and eastern side of an anticline. Bajocian strata occur in the valley west of the Sierras de San Lorenzo, north and west of point 2560 (topographic map 1:50 000, Cerros de Montecristo). Below these strata beds with Aalenian ammonites are exposed and above beds with Bathonian ammonites (GRÖSCHKE & HILLEBRANDT 1994). Reddish marls with two beds of calcareous concretions at a distance of one metre contain the following ammonites:

Stephanoceras exgr. *St. pyritosum* (QUENSTEDT)
(Pl. 2, figs 1–3, Pl. 4, fig. 2)

Chondroceras sp. A
(Pl. 2, figs 5, 6).

These beds prove the *Dorsetensia* ssp. Horizon.

A similar bed with *Stephanoceras* sp. (Pl. 4, fig. 3) and *Chondroceras* sp. A (Biese collection, National Museum of Natural History, Washington) was found at Cerritos Bayos, south of the Sierras de San Lorenzo. This bed corresponds to the "*Sphaeroceras*–Bank" of BIESE (1957). The "*Ctenostreon*–Bänke" of BIESE (1957) are of Aalenian age and the "Stephanoceraten–Kalk" (=*Peronoceras*) of the same author is of Middle Toarcian age (s.a. GRÖSCHKE & HILLEBRANDT 1994).

6. Caracoles

Many sections and outcrops with Middle to Upper Jurassic ammonites are found in the surroundings of the old silver mine Caracoles. Bajocian ammonites of this classical locality were described by STEINMANN (1881), HILLEBRANDT (1977) and WESTERMANN & RICCARDI (1979, 1980).

WESTERMANN & RICCARDI (1979, 1980) described and figured Bajocian ammonites from a section southwest of Cerro Torcazas that characterize mostly the *Duashnoceras caracolense* Horizon. Above beds with ammonites of this age were found *Strenoceras* cf. *latisulcatum* (QUENSTEDT) (= *Strenoceras* cf. *suevicum* DIETL 1983) and *Cadonites* n.sp. B aff. *C. deslongchampsi* (D'ORBIGNY). These ammonites are of Late Bajocian age (Subfurcatum Zone, probably *Leptosphinctes* Horizon). *Strenoceras suevicum* DIETL was found in the Baculata Subzone (upper subzone of the Niortense (= Subfurcatum) Zone of Southwest Germany (DIETL 1983).

The author studied a section approximately 1 km north of Cerro Torcazas (point 3035, topographic map 1 50 000, Cerros de Caracoles). The first ammonites were found approximately 120 m above the base (beds from below to above):

1. Stephanoceratinae gen. et sp. indet.
2. *Duashnoceras* sp.
3. *Duashnoceras caracolense* (WESTERMANN & RICCARDI) (micro– and macroconch) (Pl. 3, figs 1, 2), *Teloceras* (?) sp.
4. *Duashnoceras* sp., *Teloceras* (?) sp.
5. *Cadomites* sp., Eurycephalitidae gen. et. sp. indet.

Beds 1 to 4 (approx. 120 m thick) are of Bajocian age, at least beds 2 and 3 belong to the *D. caracolense* Horizon. Bed 5 (approx. 30 m above bed 4) is probably of Bathonian age.

Taxonomic note: STEINMANN (1881, pl. 12, fig. 7) described and figured from Caracoles a specimen he named "*Stephanoceras Humphriesianum*" This specimen was included in *Stephanoceras* (= *Duashnoceras*) *chilense* by HILLEBRANDT (1977) but probably it is the microconch of *Duashnoceras caracolense* (WESTERMANN & RICCARDI). A second, not figured, specimen of the STEINMANN collection was included in *Stephanoceras* (= *Duashnoceras*) *andinense* (HILLEBRANDT 1977). The holotype of *Duashnoceras chilense* (HILLEBRANDT) is the phragmocone of an incomplete macroconch from the *Lupherites dehmi* Horizon. *Duashnoceras caracolense* und *D. chilense* are different species from different horizons.

7. Quebrada San Pedro

The Jurassic area of Quebrada San Pedro is situated about 10 km south of Placilla de Caracoles. Ammonites of Late Bajocian to Oxfordian age are found.

The Late Bajocian to Early Callovian part of a section was described by JENSEN & QUINZIO (1981) and RICCARDI & WESTERMANN (1991). The Oxfordian part was published by GYGI & HILLEBRANDT (1991). FERNÁNDEZ–LÓPEZ et al. (1994) and GRÖSCHKE & HILLEBRANDT (1994) described the Bajocian to Bathonian part of the section described by JENSEN & QUINZIO (1981) and RICCARDI & WESTERMANN (1991).

FERNÁNDEZ–LÓPEZ et al. (1994) cite from the lower part of the section (SP33 – SP45 (= a_3 JENSEN & QUINZIO 1981 and sample 790321/2 in RICCARDI & WESTERMANN 1991) ammonites that are typical for the *Lupherites dehmi* Horizon and the *Leptosphinctes* Horizon (*Cadomites*, *Leptosphinctes*).

Only flattened impressions of ammonites occur in the following silty limestones and lutites (SP47 – SP87 in FERNÁNDEZ–LÓPEZ et al. 1994 = lower part of a_4 in JENSEN & QUINZIO 1981). These beds are probably of Late Bajocian age.

In the upper part of bioclastic limestones and lutites (SP87 – SP115 in FERNÁNDEZ–LÓPEZ et al. 1994 = upper part of a_4 in JENSEN & QUINZIO 1981) Eurycephalitidae are frequent which were determinated as *Megasphaeroceras magnum* by RICCARDI & WESTERMANN (1991) (sample 790321/3) and FERNÁNDEZ–LÓPEZ et al. (1994). The specimen figured as *Duashnoceras* aff. *undulatum* by FERNÁNDEZ–LÓPEZ et al. (1994) belongs probably to *Zigzagiceras* (?). Similar specimens were described by GRÖSCHKE & HILLEBRANDT (1994) from the Lower Bathonian. At least the ammonite fauna of beds SP101 – SP115 (FERNÁNDEZ–LÓPEZ et al. 1994) is probably not of late Bajocian but of Early Bathonian age. The specimen figured as *Strenoceras* sp. (FERNÁNDEZ–LÓPEZ et al. 1994, pl. 1, fig. 7) is not well enough preserved as to ensure this genus. *Xenocephalites* cf. *araucanus* (BURCKHARDT) is also cited from these beds. Up to now was described only from the Bathonian. This species *Megasphaeroceras magnum* and some species of *Eurycephalites* (mainly *E. steinmanni*) are very similar and the Eurycephalitids of these beds should be restudied. At least the ammonites of beds SP125 –

SP131 (FERNÁNDEZ–LÓPEZ et al. 1994) and samples 790321/4 to 8 (RICCARDI & WESTERMANN 1991 and GRÖSCHKE & HILLEBRANDT 1994) are of Middle Bathonian age.

8. Cerro Amarillo

GRÖSCHKE & HILLEBRANDT (1985, p.141, fig. 3a) described the Jurassic of this area. Bajocian ammonites are found at the localities 2 and 3. Four beds can be distinguished (from below to above):

1. *Emileia giebeli* s.l. (GOTTSCHE), *Sonninia* sp.
2. *Teloceras* (?) sp., *Chondroceras* sp., *Dorsetensia* cf. *liostraca* BUCKMAN
3. *Duashnoceras caracolense* (W. & R.), *Teloceras* (?) sp., *Megasphaeroceras* (?) sp.
4. *Teloceras* (?) sp., *Spiroceras* sp.
5. *Megasphaeroceras* sp., *Leptosphinctes* sp.

Bed 1 belongs to the *E. giebeli* Horizon, bed 2 to the *Dorsetensia* ssp. Horizon, bed 3 can probably be correlated with the *D. caracolense* Horizon, bed 4 with the *L. dehmi* Horizon, and bed 5 with the *Leptosphinctes* Horizon.

9. Aguada El Oro

BOGDANIC (1983) first described Jurassic sections of this area. Ammonites of Bathonian age were figured by GRÖSCHKE & HILLEBRANDT (1994), of Late Callovian and Early Oxfordian age by HILLEBRANDT & GRÖSCHKE (1995) and of Oxfordian age by GYGI & HILLEBRANDT (1991).

Four beds with Bajocian ammonites can be distinguished (from below to above):

1. *Sonninia espinazitensis* s.l.
2. *Duashnoceras andinense* (HILLEBRANDT) (Pl. 4, fig. 1), *D. caracolense* (WESTERMANN & RICCARDI.) (Pl. 2, figs 10, 11), *Chondroceras* sp. B (Pl. 2, fig. 9; Pl. 3, fig. 5; Pl. 4, fig. 5)
3. *Lupherites dehmi* (HILLEBRANDT), *Duashnoceras chilense* (HILLEBRANDT), *Spiroceras* sp., *Megasphaeroceras magnum* RICCARDI & WESTERMANN

The author received additionally Late Bajocian ammonites from Dr. G. CHONG D: (Universidad Católica del Norte, Antofagasta): *Teloceras* cf. *chacayi* WESTERMANN & RICCARDI, *Duashnoceras chilense* (HILLEBRANDT), *Orthogarantiana* cf. *conjugata* (QUENSTEDT), *Megasphaeroceras* (?) sp. A and *Leptosphinctes* sp..

Bed 1 belongs to the *E. giebeli* Horizon, bed 2 to the *D. caracolense* Horizon and bed 3 to the *L. dehmi* Horizon. *Leptosphinctes* sp. proves the *Leptosphinctes* Horizon. The very involute and coarsely ribbed *Megasphaeroceras* (?) sp. A (Pl. 10. figs 3A, B) was found in younger beds (*Megasphaeroceras* (?) Horizon).

10. Profeta Jurassic

The Jurassic outcrops at the upper course of the Quebrada del Profeta are called Profeta Jurassic. This area was mapped in detail by BOGDANIC (1983). The Jurassic is exposed in a wide syncline. The center of this syncline is built by Oxfordian and Kimmeridgian sediments and an evaporite at the Oxfordian/Kimmeridgian boundary. At the eastern end of the syncline, Lower Jurassic marine and Triassic terrestrial and marine sediments are faulted against and overthrusted by Paleozoic rocks of the Sierra de Varas. Mainly the Middle Jurassic and Oxfordian sediments show special folding, in part with isoclinal folds and imbricate structures. In the westernmost part Bajocian sediments are faulted against younger rocks.

Kimmeridgian ammonites were described and figured by FÖRSTER & HILLEBRANDT (1984), Oxfordian ammonites by GYGI & HILLEBRANDT (1991), HILLEBRANDT & GRÖSCHKE (1995) and HILLEBRANDT et al. (2000), Bathonian ammonites by FERNÁNDEZ–LÓPEZ et al. (1994) and GRÖSCHKE & HILLEBRANDT (1994), Bajocian ammonites by HILLEBRANDT (1977) and FERNÁNDEZ–LÓPEZ et al. (1994), Aalenian ammonites by BOGDANIC et al. (1985) and Early Jurassic ammonites by QUINZIO (1987) and HILLEBRANDT (2000).

The Bajocian sediments consist mainly of marls with calcareous concretions that often contain well–preserved ammonites.

Quebrada Aguada del Minero (western part)

The Bajocian localities described by HILLEBRANDT (1977, fig. 1, loc. 4 and 5) are situated in the westermost part of the Profeta syncline. Locality 4 is found 1.6 km SSW of point 3197 (topographic map 1 : 100 000, Sierra de Varas), immediately north of one of the main valleys called Quebrada Aguada del Minero and crossing the Profeta Jurassic.

The ammonite beds are repeated at locality 4 by isoclinal folding inclined to the east. Three ammonite horizons can be distinguished (from below to above):

1. *Duashnoceras chilense* (HILLEBRANDT) (Pl 5, fig. 2), *D. profetaense* n.sp. (Pl. 5, fig. 5, Pl. 6, figs 2–4; text–fig. 3a), *Lupherites dehmi* (HILLEBRANDT), *L.*(?) *chongi* (HILLEBRANDT), *Teloceras* cf. *chacayi* WESTERMANN & RICCARDI, *Teloceras*(?) sp., *Spiroceras orbignyi* (BAUGIER & SAUZÉ) (Pl. 9, fig. 4), *Megasphaeroceras magnum* (RICCARDI & WESTERMANN), *M. spissum* (R. & W.)
2. *Cadomites* sp. ex gr. *Cadomites. psilacanthus/ deslongchampsi* (Pl. 9, figs 6A, B), *Megasphaeroceras magnum* (RICCARDI & WESTERMANN), *Leptosphinctes* cf. *leptus* BUCKMAN (Pl. 10, figs 1, 2),
3. *Megasphaerocras* (?) sp. A (Pl. 10, figs 4A, B)

Horizon 1 belongs to the *L. dehmi* Horizon, horizon 2 to the *Leptosphinctes* Horizon and horizon 3 to the *Megasphaeroceras* (?) Horizon.

Aguada Colorada

Locality 5 in HILLEBRANDT 1977 (fig. 1) is situated 3.4 km to the north of locality 4 and corresponds to the basal part of the section described by FERNÁNDEZ–LÓPEZ et al. (1994) as section Aguada Colorada.

HILLEBRANDT (1977) figured from this locality *Duashnoceras chilense* (HILLEBRANDT) (Pl. 3, fig. 3), *Lupherites dehmi* (HILLEBRANDT) and *L.*(?) *chongi* (HILLEBRANDT). *Teloceras*(?) sp. (Pl. 5, fig. 3) and *Duashnoceras profetaense* n. sp. (Pl. 5, fig. 4) were also found at this locality. RICCARDI & WESTERMANN (1991) mentioned *Megasphaeroceras magnum* RICCARDI & WESTERMANN and *M. spissum* RICCARDI & WESTERMANN from the same locality (TUB–3–070672).

FERNÁNDEZ–LÓPEZ et al. (1994) described additionally from this locality *Liroxyites* cf. *kellumi* IMLAY, *Oppelia* cf. *subradiata* (SOW.), *Orthogarantiana*? sp., *Spiroceras orbignyi* (BAUGIER & SAUZÉ) and *Leptosphinctes (Leptosphinctes)* sp.. At least the *D. dehmi* Horizon is proposed at locality 5. The ammonites of the levels AC3 – AC5 (FERNÁNDEZ–LÓPEZ et al. 1994) are of Late Bajocian or Early Bathonian age and those of the levels AC7 – AC8 are of Early Bathonian and not of Late Bajocian age as proposed by FERNÁNDEZ–LÓPEZ et al. (1994).

Quebrada Aguada del Minero (eastern part)

Bajocian sediments are also found on the eastern side of the Oxfordian/Kimmeridgian syncline where they are exposed between Aalenian and Bathonian sediments.

A short and overturned section is exposed north of Quebrada Aguada del Minero (approx. 900 metres east of point 3616).

From below to above (in stratigraphic sense) following ammonite horizons can be distinguished:

1. Beds with *Emileia* sp. and *Sonninia espinazitensis* TORNQUIST (*E. giebeli giebeli* Horizon).
2. Bed with *Dorsetensia* cf. *romani* (OPPEL) (*Dorsetensia* Horizon).
3. Bed with *Duashnoceras* cf. *andinense* (HILLEBRANDT) (*D. caracolense* Horizon).
4. Beds with Stephanoceratinae, *Megasphaeroceras* and *Leptosphinctes* (*L. dehmi* and *Leptosphinctes* Horizons).

Aguada Profeta

North of Aguada Profeta, a Bajocian section is exposed with the following beds (from below to above):

1. Beds with *Emileia multiformis* (GOTTSCHE) and *Sonninia espinazitensis* TORNQUIST (*E. giebeli giebeli* Horizon).
2. Bed with ?*Skirroceras* sp. (? *Dorsetensia* Horizon)
3. Beds with Stephanoceratinae gen. et sp. indet. (? *D. caracolense* Horzon)
4. Bed with *Lupherites dehmi* (HILLEBRANDT) and *Megasphaeroceras* sp. (*L. dehmi* Horizon).
5. Bed with *Cadomites* (?) sp. and *Megasphaeroceras* (?) sp. A (? *Megasphaeroceras*(?) Horizon).

Additionally, the author received a specimen of *Orthogarantiana* cf. *conjugata* (QUENSTEDT) (macroconch) (Pl. 10, figs 5A, B) from Dr. Th. BOGDANIC (formerly Universidad Católica del Norte, Antofagasta) not found in situ at Quebrada Vizcachas (southernmost part of the Profeta Jurassic, topographic map 1 : 100 000, Sierra Vaquillas Altas).

11. Quebrada del Puntiagudo

The Quebrada del Puntiagudo is the type locality of *Duashnoceras andinense* (HILLEBRANDT, 1977, fig. 1, loc.3), occuring together with *Teloceras*(?) sp. and *Eocephalites*(?) cf. *primus* IMLAY (RICCARDI & WESTERMANN 1991, p.98, pl. 30, figs 2, 3). The locality was said to be of Late Bajocian age (Subfurcatum Zone) but *Duashnoceras andinense* is more typical for the *D. caracolense* Horizon.

12. Area between Quebrada Incaguasi and Quebrada Agua de La Piedra

In this area the type localities of *Lupherites dehmi* (HILLEBRANDT) and *Duashnoceras chilense* (HILLEBRANDT) (HILLEBRANDT 1977, fig. 1, loc. 1 and 2) appear. Sinemurian to Oxfordian sediments are exposed from east to west. The central and western part of this Jurassic belt with Toarcian to Oxfordian sediments is mainly repeated by folding and faulting. Ammonites of this area were figured as follows: Late Sinemurian ammonites by HILLEBRANDT (1981), Toarcian ammonites by HILLEBRANDT (1987), Bajocian ammonites by HILLEBRANDT (1977) and Oxfordian ammonites by HILLEBRANDT et al. (2000).

A typical fauna of the *L. dehmi* Horizon was found in lutites with calcareous concretions approximately 2.1 km south of the type locality of *Lupherites dehmi* and approximately 1.85 km north of Co. Agua de La Piedra (topographic map 1 : 100 000, Exploradora) (in continuation along the strike of the type locality of *L. dehmi*):

Duashnoceras chilense (HILLEBRANDT) (Pl. 5, figs 1A, B), *D. profetaense* n.sp., *Lupherites dehmi* HILLEBRANDT), *Teloceras*(?) sp. (Pl. 9, figs 3A, B) and *Megasphaeroceras* sp..

Sonninia cf. *espinazitensis* TORNQUIST and *Emileia* sp. (*E. giebeli giebeli* Horizon) occur approximately 1 km southwest of this locality and probably separated by folding and faulting.

Approximately 900 m west of this locality and approximately 1.7 km northwest of Co. Agua de La Piedra once more Bajocian beds are found. Mainly Toarcian and ?Aalenian sediments crop out between both localities. The locality is situated along the strike of the type locality of *D. chilense*, approximately 3km to the north. 5 to 10 m above beds (lutites with large calcareous concretions) with *Sonninia* cf. *espinazitensis* TORNQUIST a bed (lutites with small calcareous concretions) with the following ammonites is exposed:

Stephanoceras ex gr. *St. umbilicum* (QUENSTEDT) (Pl. 2, figs 4A, B), *Chondroceras* sp. A (Pl. 2, figs 7, 8) and *Dorsetensia*(?) sp.

This faunule belongs probably to the *Dorsetensia* ssp. Horizon.

13. Quebrada de Los Burros

The Quebrada de Los Burros is situated at the southern end of the topographic map 1 : 100000, Exploradora. The Lower Jurassic is mainly exposed in this valley and the Middle to Upper Jurassic series are found southeast of it. The complete Jurassic series are more than 2000 m thick. The Bathonian beds were described by GRÖSCHKE & HILLEBRANDT (1994) and ammonites of Late Callovian to Middle Oxfordian age by HILLEBRANDT & GRÖSCHKE (1995).

Beds with ammonites of Bajocian age occur in the lower part of a side valley of the Quebrada de Los Burros, 1.6 km south of point 3837. A series of marls containing several beds with calcareous concretions and Bajocian ammonites is exposed approximately 130 m above a bed with *Bredyia* of Early Aalenian age. The Bajocian beds are at least 250 m thick and the uppermost part is composed of calcareous arenites (layered centimetre to decimetre). From below to above following beds can be distinguished:

1. *Dorsetensia* cf. *liostraca* BUCKMAN
2. *Dorsetensia* cf. *liostraca* BUCKMAN, *D.* cf. *subtecta* BUCKMAN
3. *Dorsetensia* cf. *deltafalcata* (QUENSTEDT)

4. *Duashnoceras andinense* (HILLEBRANDT), *Chondroceras* sp. B
5. *Duashnoceras*(?) *burroense* n.sp. (Pl. 8, figs 2A, B)
6. *Duashnoceras*(?) sp., *Megasphaeroceras* (?) sp.
7 *Cadomites*(?) sp., *Megasphaeroceras*(?) sp.

Beds 1 to 3 belong to the *Dorsetensia* ssp. Horizon, bed 4 to the *D. caracolense* Horizon, bed 5 and ?6 to the *L. dehmi* Horizon and bed 7 probably to the *Leptosphinctes* Horizon.

The following series with more or less sandy limestones and volcanoclastic sediments are of Bathonian age (with Eurycephalitidae).

14. Salar de Pedernales

WESTERMANN & RICCARDI (1972, 1979) described and figured Bajocian ammonites (partly collected by the author) from the northwestern part of the Salar de Pedernales. These ammonites are found above beds with Aalenian ammonites and below beds with Callovian ammonites. Sediments between the Bajocian and Callovian beds contained no ammonites.

The following ammonites of Bajocian age are described by WESTERMANN & RICCARDI (1979):

Stephanoceras aff. *humphriesianum* (SOW.), *St. pyritosum* (QUENSTEDT), *St.* aff. *frechi* (RENZ), *Dorsetensia* aff. *deltafalcata* (QUENSTEDT) and *D. tecta* BUCKMAN.

This ammonite assemblage belongs to the *Dorsetensia* ssp. Horizon.

15. Sierra Minillas

The Sierra Minillas is part of the Coastal Cordillera. Volcanic rocks with intercalations of volcanoclastic sediments are exposed on the western side of the Sierra Minillas. The sediments are in part rich in fossils. Two beds with ammonites were described by DAVIDSON et al. (1976). Both beds can be correlated with the European Sauzei Zone, probably the upper part (*Skirroceras* Horizon). NARANJO (1978b) additionally named from this locality *Sonninia* cf. *espinazitensis* TORNQUIST (= ? *E. giebeli giebeli* Horizon) and NARANJO (1978a) figured a complete and well–preserved *Skirroceras.*

The author found a tuffaceous bed (10 cm thick) with frequent *Chondroceras* cf. sp. A (= ? *Dorsetensia* ssp. Horizon) in the uppermost part of these volcanoclastic rocks.

16. Sierra Fraga

Ammonites of Bajocian age were figured by DAVIDSON, GODOY & COVACEVICH (1976) from the Sierra Fraga. The authors distinguished three levels: A lower level with *Stephanoceras (Skirroceras)* sp., a middle one with *Sonninia* indet. and *Pseudotoites* sp. and an upper level without ammonites. They found *Teloceras* sp. in the Quebrada Pulpo. These ammonites at least prove the European Sauzei and Humphriesianum Zones.

The author found a section with several ammonite beds in the Quebrada Pulpo. Following beds can be distinguished from below to above:

1 and 2. *Dorsetensia* sp.
3. *Stephanoceras* ex gr. *St. umbilicum* (QUENSTEDT), *Chondroceras* cf. sp. A
4. *Duashnoceras* sp., *Chondroceras* sp. B

Beds 1 and 2 and probably also bed 3 belong to the *Dorsetensia* ssp. Horizon and bed 4 to the *D. caracolense* Horizon.

Emileia sp. (microconch) and *Sonninia* s.l. (= *E. giebeli giebeli* Horizon) were found at the Quebrada Corrales, near to the end of this valley and north of the pass crossing the Sierra Fraga.

17. Quebrada San Pedrito

A Toarcian to Bajocian section is exposed at the confluence of the Quebrada San Pedrito with the Quebrada Pelada (HILLEBRANDT 1973, p. 176). Intercalated in marls, a calcareous, lenticular concretion containing a rich and well–preserved Bajocian fauna (*Bositra* and ammonites) was found:

Emileia (Chondromileia) giebeli submicrostoma (GOTTSCHE) (micro– and macroconchs) (Pl. 1, figs 3, 4), *Euhoploceras* sp., *Pelekodites* ssp. and *Fissilobiceras*(?) sp..

This assemblage belongs to the *E. giebeli submicrostoma* Horizon.

18. Manflas

Many Lower to Middle Jurassic sections and outcrops of this famous locality are exposed south of the Hacienda Manflas. MÖRICKE (1894) was the first to describe Bajocian ammonites from this area, however not realizing that two iron–oolites exist, one of Early Aalenian and one of lower Late Bajocian age. Ammonites of Aalenian and Bajocian age were described by WESTERMANN & RICCARDI (1972), of Bajocian age by HILLEBRANDT (1977) and WESTERMAN & RICCARDI (1979) and Aalenian age by HILLEBRANDT & WESTERMANN (1985).

The author investigated various Bajocian sections south and southeast of the Hacienda Manflas (HILLEBRANDT 1977, fig. 2, loc. 1 to 6; HILLEBRANDT & WESTERMANN 1985, fig. 4, loc. 1 to 5).

The Jurassic east and south of the Hacienda Manfls is divided by a N–S fault. The two blocks differ little in facies, the western block having a thicker and more arenaceous development particularly in the Sinemurian. Facies differences are marked mainly in the Toarcian and Aalenian. The Jurassic of the western block from the uppermost Toarcian to the Callovian and some of the Bajocian ammonites were described by WESTERMANN & RICCARDI (1972, 1979). Aalenian and Bajocian ammonites of both blocks were described by HILLEBRANDT (1977) and HILLEBRANDT & WESTERMANN (1985).

Aalenian

The Puchenquia compressa and P mendozana Subzones of Late Aalenian age were proved at different localities. The *Podagrosiceras maubeugei* Horizon of latest Aalenian or earliest Bajocian age was only found at Portezuelo El Padre (HILLEBRANDT & WESTERMANN 1985, fig. 4, loc. 6).

Pseudotoites singularis Horizon

The *P singularis* Horizon occur at locality 4 (HILLEBRANDT & WESTERMANN 1985, Fig.4) with the following species:

Pseudotoites singularis (GOTTSCHE) (micro– and macroconchs), *P.* cf. *argentinus* (TORNQUIST), *Fissilobiceras*(?) *zitteli* (GOTTSCHE).

Pseudotoites sphaeroceroides Horizon

Some metres above the bed with ammonites of the *P singularis* Horizon a bed with ammonites of the *P sphaerocroides* Horizon appears:
Pseudotoites sphaeroceroides (TORNQUIST) (macroconch), *P.* cf. *corona* ARKELL & PLAYFORD (macroconch), *Emileia* cf. *quenstedti* WESTERMANN (macroconch), *Sonninia altecostata* TORNQUIST.

Emileia giebeli submicrostoma and *Emileia giebel giebeli* Horizons

On the ridge of Cerro de La Cuesta (HILLEBRANDT & WESTERMANN 1985, fig. 4, loc. 2) a section contains from below to above:
1. Lowest bed with *Emileia* cf. *brocchii* (SOW.)
2. 10 m higher several beds with *Sonninia espinazitensis* TORNQUIST
3 15 m higher bed with *Emileia (Chondromileia) giebeli giebeli* (GOTTSCHE) (Pl. 1, figs 1, 2)

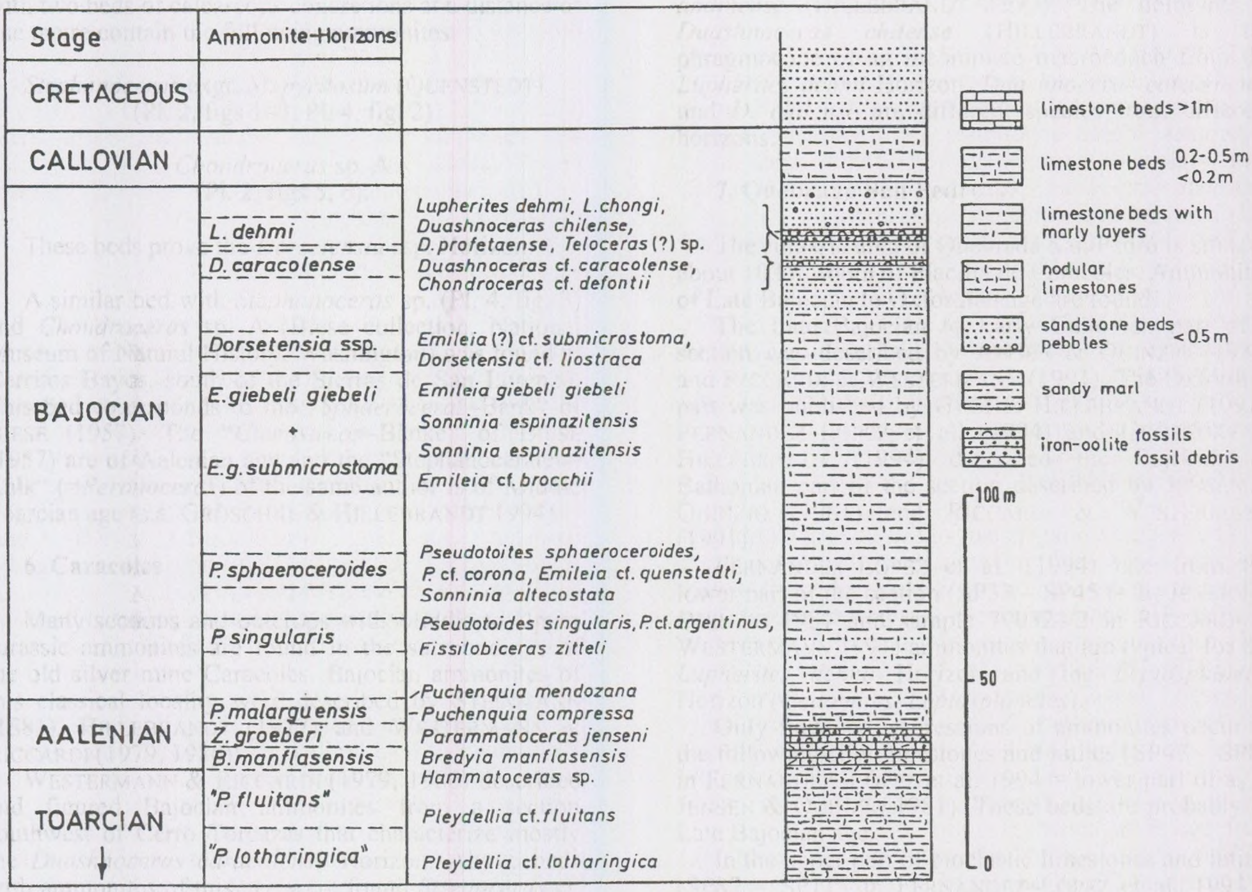

Fig. 2. Stratigraphic section of the uppermost Toarcian and Middle Jurassic of the Manflas area.

Bed 1 probably lies within the European Laeviuscula Zone. Perhaps this bed and the lower part of beds 2 represent the *E. giebeli submicrostoma* Horizon. The upper part of beds 2 and bed 3 belong to the *E. giebeli giebeli* Horizon.

Dorsetensia ssp. Horizon

At localities 3, 4 and 5 (HILLEBRANDT 1977, Fig. 2) *Emileia*(?) cf. *submicrostoma* (GOTTSCHE) (Pl. 1, figs 5A, B) occur above the beds with *Emileia giebeli giebeli* (GOTTSCHE) and *Sonninia espinazitensis* TORNQUIST. This is a transitional species between *Emileia (Chondromileia)* and *Chondroceras*. At locality 4 *Dorsetensia* sp. occurs together with a poorly preserved specimen of this species. *Dorsetensia* cf. *liostraca* BUCKMAN was also found at Portezuelo El Padre, 2 to 4 metres above a bed with *Emileia giebeli giebeli* (GOTTSCHE) and *Sonninia espinazitensis* TORNQUIST.

The beds with *Emileia*(?) cf. submicrostoma and *Dorsetensia* are probably part of the *Dorsetensia* ssp. Horizon.

Duashnoceras caracolense Horizon

A bed with mostly silicified *Chondroceras* and "*Rhynchonella*" *manflasensis* MÖRICKE was found approximately 20 m above the bed with *Emileia*(?) cf. *submicrostoma* (GOTTSCHE). WESTERMANN & RICCARDI (1979) figured from this bed *Chondroceras* cf. *defontii* (MCLEARN). MÖRICKE (1894, p.24) described from this bed *Sphaeroceras zirkeli* STEINMANN. Silicified specimens labelled by MÖRICKE under this name are preserved in the collection of the "Staatliches Museum für Naturkunde" in Stuttgart.

A coarsely ribbed *Megasphaeroceras*(?) sp. appears together with *Chondroceras* at locality 2 (HILLEBRANDT 1977, fig. 2), 5 m below the iron–oolite. Possibly this *Megasphaeroceras*(?) sp. originates from younger beds.

Duashnoceras cf. *andinense* (HILLEBRANDT) and *D.* cf. *chilense* (HILLEBRANDT) were found at locality 4 (HILLEBRANDT 1977, fig. 2) together with *Chondroceras* cf. *defontii* (MCLEARN).

The *Chondroceras* cf. *defontii* bed is probably part of the *D. caracolense* Horizon.

Lupherites dehmi Horizon

Approximately 4 to 6 metres above the bed with *Chondroceras* cf. *defontii* MCLEARN at localities 1 to 6 in HILLEBRANDT (1977) two beds are found, each 0.3 to 1.0 m thick and rich in ammonites. The lower bed is a more or less sandy and limonitic limestone and the upper bed is mostly an iron–oolite. Micro– and macroconchs of the following genera and species of Stephanoceratinae occur:

Duashnoceras chilense (HILLEBRANDT), *D. burroense* n.sp. (Pl. 9, figs 2 A, B), *D. profetaense* n.sp. (Pl. 6, fig. 1, Pl. 7, figs 1–4, Pl. 8, fig. 1), *Lupherites dehmi* (HILLEBRANDT), *L.*(?) *chongi* (HILLEBRANDT), *Teloceras*(?) sp. (Pl. 9, figs 1A, B).

Both beds are part of the *L. dehmi* Horizon. The lower bed cannot be assigned to the Humphriesianum Zone as formerly supposed by the author (HILLEBRANDT 1977).

19. Quebrada Cepones

The Quebrada Cepones is situated approximately 20 km southwest of Hacienda Manflas. A section was studied 500 m south of this valley and 2.5 km southeast of point 2904 (topographic map 1 : 50 000, Tres Morros) (HILLEBRANDT 1977, p. 43).

Above sediments of Aalenian age the following beds can be distinguished:

1. *Sonninia* cf. *espinazitensis* TORNQUIST
2. *Dorsetensia* cf. *romani* (OPPEL)
3. *Dorsetensia* cf. *liostraca* BUCKMAN
4. Stephanoceras sp., *Chondroceras* sp.
5. Stephanoceratinae gen. et sp. indet.
6. *Duashnoceras* cf. *caracolense* (WESTERMANN & RICCARDI), *Teloceras*(?) sp.

Volcanoclastic beds (derived from the volcanic arc in the west) are frequent. The Bajocian part of the overturned section is approximately 200 m thick.

Bed 1 is part of the *E. giebeli giebeli* Horizon, beds 2, 3 and probably 4 of the *Dorsetensia* ssp. Horizon and beds 5 and 6 of the *D. caracolense* Horizon.

20. Quebrada Chanchoquin

Many Middle Sinemurian to Bajocian sections were studied by the author north and south of the Rio Transito (HILLEBRANDT 1973, fig. 2). Identifiable Bajocian ammonites, however, were only found in the section between the Quebrada Chanchoquin and Acevedo. This is the thicker one of the sections originally described by the author (HILLEBRANDT 1973, fig. 2) under the name Quebrada La Totora, and again described by HILLEBRANDT & SCHMIDT–EFFING (1981, p. 29) and the upper part by HILLEBRANDT & WESTERMANN (1985, p. 13).

Above beds with Aalenian ammonites the following beds with Bajocian ammonites are found:

1. *Pseudotoites sphaeroceroides* (TORNQUIST), *Sonninia altecostata* TORNQUIST
2. *Emileia giebeli* cf. *giebeli* (GOTTSCHE), *Sonninia espinazitensis* TORNQUIST

Bed 1 is part of the *P. sphaeroceroides* Horizon and bed 2 of the *E. giebeli giebeli* Horizon.

21. Mina de Los Pingos

The Jurassic of the Mina de Los Pingos is the southernmost area in the High Cordillera of Northern Chile with Lower and Middle Jurassic sediments.

Jurassic sections were described by MPODOZIS et al. (1973), RIVANO & MPODOZIS (1974) and MPODOZIS & CORNEJO (1988). The author visited the area of the Mina de Los Pingos together with Mr. RIVANO in 1979. The sections Quebrada La Lunca, Ladera Sur (MPODOZIS & CORNEJO 1988, fig. 18, section a; fig. 19a) and a section at the hill south of the Los Pingos mine were studied.

Section Quebrada La Lunca (from below to above):

1. Volcanoclastic rocks and andesitic lavas of probably Aalenian age (level II in MPODOZIS & CORNEJO 1988, p. 62).
2. Conglomerates and calcareous arenites with the following ammonites were described by MPODOZIS & CORNEJO (1988):

Sonninia mammilifera JAWORSKI, *Sonninia (Papilliceras) espinazitensis* TORNQUIST, *Sonninia (Sonninia)* aff. *mirabilis* TORNQUIST, *Sonninia* sp. and *Lytoceras* sp. (*L. eudesianum* D'ORB. in GOTTSCHE).

The author found a microconch of *Pseudotoites* cf. *sphaeroceroides* (TORNQUIST) and *Sonninia* cf. *espinazitensis* TORNQUIST. The *Lytoceras* are very large (up to a diameter of 0.7 m).

The ammonite assemblage assumed to be part of the *P. sphaeroceroides* Horizon.

Section south of the Los Pingos mine

A series of calcilutites with some conglomeratic (?turbiditic) and arenitic beds contain ammonites of Aalenian age (*Tmetoceras* sp. and *Puchenquia* sp.) and is probably repeated by folding. Above calcilutites, limestones and arenites with *Puchenquia* sp. and *Bositra* sp. an ?olistostrome (4 to 6 m thick) with large clasts (diameter up to 0.5 m) was found. Gray limestone clasts contain *Emileia giebeli giebeli* (GOTTSCHE) and *Sonninia* sp. (= *E. giebeli giebeli* Horizon).

Sonninia occur also in the following arenites. Calcilutites with limestone beds are superposed by dm–bedded arenites with conglomeratic beds. This series contains poorly preserved Stephanoceratinae and ?*Megasphaeroceras* (probably *L. dehmi* Horizon).

MPODOZIS & CORNEJO (1988, p. 65) described from this series *Macrocephalites* sp. A, B, C, *Eurycephalites* cf. *rotundus* TORNQUIST and *Kamptokephalites* sp.. They supposed Early Callovian age for this assemblage. All these Eurycephalitidae are likely to belong to the genus *Megasphaeroceras* of early Late Bajocian age.

Biostratigraphy

WESTERMANN & RICCARDI (1979) and WESTERMANN in HILLEBRANDT et al. (1992) elaborated a detailed biozonation with ammonites of the Bajocian stage in South America. This biozonation was correlated with the European Standard Zones. CALLOMON & CHANDLER (1990) and CALLOMON & COPE (1993) introduced a detailed subdivision of the Bajocian of southern England into ammonite faunal horizons. 26 Early and 9 Late Bajocian ammonite faunal horizons are distinguished.

Different ammonite–bearing horizons of Bajocian age are found in Northern Chile but compared with Europe a much less detailed subdivision is possible. The reason could be that these horizons reflect in Northern Chile only part of the originally existing more complete succession of South American Bajocian ammonites. Already originally the possibilities of distinguishing faunal horizons in South America were restricted, at least in Northern Chile. Especially for the Lower Bajocian, sections exist with many beds of the same faunal horizon but representing a time span of an European zone or subzone. It is remarkable that the South American Bajocian ammonite assemblages are much less diverse than those in Europe. This fact at least could be one reason why the South American species had a longer biostratigraphic range. The low faunal diversity is probably connected with the special paleogeographic and paleobiogeographic situation of the South American Jurassic. The South American shelf was much narrower than the huge area of the European shelf with a high potential of ecologic possibilities. Additionally, the back arc basin of Northern Chile was limited by a volcanic arc in the west aggravating the connection with the Paleopacific Ocean.

Endemic South American genera and species often render a more difficult correlation with the European succession of horizons, subzones and zones. In most sections and localities of Northern Chile only one or a few horizons occur yielding Bajocian ammonites and sometimes in between them horizons are missing but found in other sections or localities. Often the horizons are only represented by a single bed or layer, also in sections with high sedimentation rates.

Podagrosiceras maubeugei Horizon

A Zonule/Horizon with *Podagrosiceras maubeugei* was introduced by HILLEBRANDT & WESTERMANN (1985) and correlated with the upper part of the European Concava Zone of uppermost Aalenian age or the lower part of the Discites Zone of lowermost Bajocian age. The last *Tmetoceras* occurs probably together with *P. maubeugei*. In Europe, this genus is restricted to the Aalenian. The endemic South American genus *Podagrosiceras* makes an exact correlation with other faunal provinces impossible.

Above the *P. maubeugei* Horizon two horizons may be distinguished containing the Pacific genus *Pseudotoites*.

Pseudotoites singularis Horizon

The horizon is characterized by *P singularis* (GOTTSCHE), *P.* cf. *argentinus* ARKELL and *Fissilobiceras* (?) *zitteli* (GOTTSCHE). The horizon was proved only at one section in the Jurassic of Manflas (locality 4 in HILLEBRANDT & WESTERMANN 1985, fig. 4). The horizon corresponds to the lower part of the *Pseudotoites singularis* Assemblage Zone of WESTERMANN & RICCARDI (1979) and WESTERMANN in HILLEBRANDT et al. (1992). *Pseudotoites* is an endemic genus of the Pacific Realm and *Fissilobiceras* appears in Europe in the Ovalis Subzone.

Up to now, no horizon was found lying within the European Discites Zone.

Pseudotoites sphaeroceroides Horizon

This horizon yields *P. sphaeroceroides* (TORNQUIST), additional species of *Pseudotoites*, *Emileia* cf. *quenstedti* WESTERMANN and the first *Sonninia (Papilliceras)* (*S. altecostata* TORNQUIST).

The horizon is found in the Manflas area above the *P singularis* Horizon and was also proved at various localities in Northern Chile (localities 20, 21 and localities not described in this paper).

The horizon corresponds to the upper part of the *P singularis* Assemblage Zone of WESTERMANN & RICCARDI (1979). The first *Sonninia (Papilliceras)* are found in Europe at the basis of the Laeviuscula Zone.

Emileia giebeli submicrostoma and *Emileia giebeli giebeli* Horizons

Various species of *Emileia* occur in the beds above the *P. sphaeroceroides* Horizon. In the Manflas area (section 2 in HILLEBRANDT & WESTERMANN 1985, fig. 4) *Emileia* cf. *brocchii* (SOW.) occur in the lowest part of these beds. The beds above this one are characterized by *Emileia (Chondromileia) giebeli giebeli* (GOTTSCHE) (micro– and macroconchs) and *Sonninia (Papilliceras) espinazitensis* TORNQUIST.

Large *Emileia giebeli giebeli* (GOTTSCHE) (micro– and macroconchs) appear together with *Sonninia espinazitensis* (TORNQUIST) at Portezuel El Padre (localities 6 and 7 in HILLEBRANDT & WESTERMANN 1985, fig. 4). Different species of *Euhoploceras* (e.g. *E.* cf. *adicrum* (WAAGEN)) und *Pseudotoite* cf. *sphaeroceroides* (TORNQUIST) occur together with *Emileia giebeli giebeli* (GOTTSCHE) and could not be collected bed by bed.

A well–preserved fauna with *Emileia giebeli submicrostoma* (GOTTSCHE) (micro– and macroconchs), *Euhoploceras* sp. (microconchs), *Sonninia (Papilliceras)* sp. (micro– and macroconchs), *Pelekodites* sp. (microconchs) and *Fissilobiceras*(?) sp. was found at Quebrada San Pedrito (locality 17).

Beds with *Sonninia (Papilliceras)* ex gr. *espinazitensis* (frequent) and *Emileia giebeli* s.l. (less frequent) are exposed at different localities in Northern Chile (localities 4, 8 to 10, 12, 15 to 21).

WESTERMANN & RICCARDI (1979) distinguished within the *E. giebeli* Assemblage Zone an *E. giebeli submicrostoma* Assemblage Subzone, an *E. multiformis* Assemblage Subzone and a *Dorsetensia blancoensis* faunule (? Assemblage Zone). WESTERMANN in HILLEBRANDT et al. (1992) defined these assemblage zones and subzones as standard zones and the *D. blancoensis* faunule was renamed as *D. blancoensis* Horizon.

In Northern Chile at least two horizons can be distinguished:

A lower *E. giebeli submicrostoma* Horizon and an upper *E. giebeli giebeli* Horizon.

The bed with *E.* cf. *brocchii* can be included in the *E. giebeli submicrostoma* Horizon. The *Dorsetensia blancoensis* Horizon was not directly proved in Northern Chile.

E. brocchii is found in England in the Laeviuscula Zone (Bj–8 and Bj–10 in CALLOMON & CHANDLER 1990) and the *E. giebeli submicrostoma* Horizon may be correlated with the upper part of the Laeviuscula Zone. The *E. giebeli giebeli* Horizon represents a time equivalent of part of the Sauzei Zone.

Skirroceras Horizon

Skirroceras sp. was found in the Sierra Minillas section (loc. 15) below beds that can be correlated with the lower part of the Humphriesianum Zone. The bed with *Skirroceras* characterizes probably an ammonite horizon in the upper part of the Sauzei Zone. The Argentinian *Dorsetensia blancoensis* Horizon is probably of the same age.

Dorsetensia ssp. Horizon

Beds with different species of *Dorsetensia* occur at some localities of Northern Chile (localities 8, 10, ?12, 13, 14, 16, 18, 19). Evolute to involute and smooth to more or less strongly and densely–ribbed species are found. *Stephanoceras* ex gr. *St. pyritosum* (QUENSTEDT) (loc. 3 to 5, 14), *St.* ex gr. *St. umbilicum* (QUENSTEDT) (loc. 12) and *Chondroceras* sp. A (loc. 3 to 5, 12) occur together with *Dorsetensia* ssp., at least in the upper part of these beds.

A bed with *Emileia* (?) cf. *submicrostoma* (GOTTSCHE) was found in the Manflas area above the beds with *Emileia giebeli giebeli* (GOTTSCHE). This species is transitional between the subgenus *Chondromileia* and the genus *Chondroceras*. At one of the Manflas localities (loc. 4 in HILLEBRANDT 1977) a poorly preserved specimen of *E.* (?) cf. *submicrostoma* appeared together with *Dorsetensia* sp..

The beds with *Dorsetensia* ssp. (*Dorsetensia* Horizon) can be correlated with the lower part of the European Humphriesianum Zone (Romani Subzone) and possibly with part of the middle part of this zone (Humphriesianum Subzone). WESTERMANN & RICCARDI (1979) and WESTERMANN IN HILLEBRANDT et al. (1992) used for this assemblage the Romani Subzone.

Duashnoceras caracolense Horizon

Above the layers with *Dorsetensia* ssp. beds are found that are dominated by Stephanoceratinae the most frequent genus of which is *Duashnoceras*. *Duashnoceras* is related to *Stephanoceras* s.l. and is distinguished from this genus mainly by curved primaries that often do not meet directly the tubercles and pass adorally around them. This character is found in finely and coarsely ribbed species and in species with a *Stephanoceras*–, *Stemmatoceras*– and *Teloceras*–like cross–section. The cross–section of the inner whorls is like that of *Stemmatoceras* to *Teloceras*. That of the outer whorls, especially the body–chamber, is like that of *Stephanoceras*, *Stemmatoceras* or *Teloceras*. The genus *Teloceras*(?) is maintained for species with a *Teloceras*–like cross–section during the complete ontogeny. The genus *Stemmatoceras* is not used. *Duashnoceras* is found in Mexiko and South America (SANDOVAL & WESTERMANN 1986).

Species of the genus *Duashnoceras* occur in Northern Chile in two horizons. The lower one is characterized by *Duashnoceras caracolense* (WESTERMANN & RICCARDI) and *D. andinense* (HILLEBRANDT). The type specimen of *D. caracolense* is a macroconch. At locality 6 microconchs (with lappets) and macroconchs of this species occur. The microconchs correspond to specimens described from the Caracoles area (locality 6) as *Stephanoceras* (= *Duashnoceras*) *chilense* (HILLEBRANDT 1977, WESTERMANN & RICCARDI 1979). It is striking that the mostly more coarsely ribbed specimens have a wider cross section than the more densely–ribbed ones. At locality 9 *Chondroceras* sp. B (a species related to the North American species *Chondroceras defontii* (MCLEARN)) is found together with microconchs of *Duashnoceras caracolense* and *D. andinense*. The beds with *Chondroceras* and "*Rhynchonella*" *manflasensis* of the Manflas area (loc. 18) also belong to the *D. caracolensis* Horizon.

The *Duashnoceras caracolense* Horizon lies within the upper part of the European Humphriesianum Zone (Blagdeni Subzone). This horizon corresponds to the *Stephanoceras chilense* Assemblage Subzone of WESTERMANN & RICCARDI (1979) (= *Duashnoceras chilense* Subzone of WESTERMANN in HILLEBRANDT et al. 1992).

Lupherites dehmi Horizon

The *L. dehmi* Horizon is the upper horizon with species of the genus *Duashnoceras*. *Duashnoceras chilense* (HILLEBRANDT), *D. burroense* n.sp. and *D. profetaense* n.sp. are found together with *Lupherites dehmi* (HILLEBRANDT) and *L.*(?) *chongi* (HILLEBRANDT). Additionally occur *Teloceras*(?) cf. *chacayi* WESTERMANN & RICCARDI and another species of this genus with a very wide but low cross–section. At least some microconchs of these *Teloceras*–like species show a *Duashnoceras*–like sculpture. Large *Spiroceras orbignyi* (BAUGIER & SAUZÉ), *Megasphaeroceras magnum* RICCARDI & WESTERMANN and *M. spissum* RICCARDI & WESTERMANN are also found in this horizon. *Orthogarantiana* cf. *conjugata* occurs at localities 9 and 10 but the exact beds and horizons are not known. *Orthogarantiana conjugata* (QUENSTEDT) was cited by DIETL & HUGGER (1979) from the middle part of the Subfurcatum Zone. FERNÁNDEZ–LÓPEZ (1985) described *Orthogarantiana* sp. cf. *O. conjugata* (QUENSTEDT) from the lower part of the Garantiana Zone. The first *Leptosphinctes*(?) appear probably also in this horizon.

The *L. dehmi* Horizon was proved at the localities 1, 2, 4, 7 to 10, 12, 13, 18 and ?21. The horizon can be correlated with the lower part of the European Subfurcatum (= Niortense) Zone. The horizon corresponds to the lower part of the (?)*Megasphaeroceras rotundum* Assemblage Zone of WESTERMANN & RICCARDI (1979) and the *Lupherites dehmi* Subzone of WESTERMANN in HILLEBRANDT et al. (1992).

Leptosphinctes Horizon

Above the beds of the *L. dehmi* Horizon beds without the genera *Lupherites*, *Duashnoceras* and *Teloceras* are found. The first specimen of the genus *Cadomites* occur together with *Spiroceras orbignyi* (BAUGIER & SAUZÉ), *Megasphaeroceras magnum* RICCARDI & WESTERMANN, *M. spissum* RICCARDI & WESTERMANN and *Leptosphinctes* ssp. (e.g. *L.* cf. *leptus* BUCKMAN).

The *Leptosphinctes* Horizon appears at localities 2?, 4 , 6 to 8, 10 and ?13. WESTERMANN & RICCARDI (1980) described a bed with *Strenoceras* cf. *latisulcatum* (QUENSTEDT) and *Cadomites* n. sp. B aff. *deslonchampsi* (D'ORB.) from Caracoles belonging to this horizon.

Leptosphinctes leptus BUCKMAN was found in England in the upper part of the Subfurcatum Zone (PARSONS 1976) and was described by SANDOVAL (1983, 1990, 1994) from the upper part of his *Leptosphinctes* Zone (= upper part of the Subfurcatum Zone) and by FERNÁNDEZ–LÓPEZ (1985) from his biohorizon XII (= middle part of the Subfurcatum Zone).

The *Leptosphinctes* Horizon corresponds probably to the upper part of the (?)*Megasphaeroceras rotundum* Assemblage of WESTERMANN & RICCARDI (1979) (not named by WESTERMANN in HILLEBRANDT et al. (1992).

Megasphaeroceras(?) Horizon

Above the *Leptosphinctes* Horizon at locality 10 a coarsely–ribbed, globular *Megasphaeroceras*(?) was found the body–chamber of which closes the narrow umbilicus. This species occurs also at locality 9. Additionally, at locality 10 (Quebrada Aguada del Minero, western part) together with a poorly preserved *Cadomites*(?) a similar, but strongly crushed *Megasphaeroceras*(?) was found dated by GRÖSCHKE & HILLEBRANDT (1994) as probabaly of Early Bathonian age. This apparently endemic *Megasphaeroceras*(?) could also be of Late Bajocian age (Garantiana or Parkinsoni Zone).

Evidence for the European Garantiana and Parkinsoni Zones is difficult to ascertain in Northern Chile, also in sections with continuous sedimentation from the Bajocian to the Bathonian. Ammonites are scarce in this part of the sections and mostly without biostratigraphic significance. FERNÁNDEZ–LÓPEZ et al. (1994) postulated a regional discontinuity for the localities 7 and 10 at the base of the Bathonian. In the opinion of the author this seems to be unlikely and beds designated as of Late Bajocian age are probably of Early Bathonian. Eurycephalitidae from the same beds were determined as *Megasphaerocras magnum* by RICCARDI & WESTERMANN (1991) (= *Megasph. magnum ss.* (? zone or horizon) of WESTERMANN in HILLEBRANDT et al. (1992, tab. 12.2).

"Cobbanites" Horizon

GRÖSCHKE & HILLEBRANDT (1994) cited a large *Cobbanites* cf. *talkeetnanus* IMLAY from the Jaspe Jurassic. *C. talkeetnanus* by CALLOMON (1984, p. 150) is said to be morphologically close to *Leptosphinctes (Vermisphinctes) meseres* (BUCKMAN) (= *Vermisphinctes (Prorsisphinctes) meseres* in SANDOVAL 1983, p. 393 and *Prorsisphinctes meseres* in FERNÁNDEZ–LÓPEZ 1985, p. 511) from the upper part of the Late Bajocian (Garantiana and Parkinsoni Zones) of Europe. Giant Leptosphinctinae are also found in beds of uppermost Bajocian or Early Bathonian age at the Quebrada San Pedro section (GRÖSCHKE & HILLEBRANDT 1994, p. 260). WESTERMANN in HILLEBRANDT et al. (1992, p. 61, fig. 1) figured a large *Lobosphinctes intersertus* BUCKMAN from the *Megasphaeroceras* range zone in Argentina. This species was found in England in the Parkinsoni Zone and in southeastern France and Spain in the lowermost Bathonian (SANDOVAL 1983, p. 414).

Together with *C.* cf. *talkeetnanus Cadomites* sp. and a specimen transitional between *Cadomites* and *Garantiana* appear.

At the moment, it is difficult to decide if these large to giant Leptosphinctinae are of upper Late Bajocian or Early Bathonian age or if they occur in both stratigraphic levels.

Stages	Substages	European Standard Zones	Horizons Northern Chile	Southamerican Zones, Subzones, Horizons HILLEBRANDT et al. 1992	
BAJOCIAN	upper	Parkinsoni	*„Cobbanites"*	Lobosphinctes	
		Garantiana	*Megasphaeroceras(?)*	Megasphaeroceras magnum ss.	
		Subfurcatum	*Leptosphinctes*	Rotundum Zone	
			Lupherites dehmi		L. dehmi Sz.
	lower	Humphriesianum	*Duashnoc. caracolense*	Humphries. Zone	D. chilense Sz.
			Dorsetensia ssp.		D. romani Sz.
		Sauzei	*Skirroceras*	Emileia giebeli Zone	D. blancoensis H.
			E. giebeli giebeli		E. multiformis Sz.
		Laeviuscula	*E. giebeli submicrostoma*		E submicrost. Sz.
			P. sphaeroceroides	Pseudotoites singularis Zone	
		Ovalis	*P. singularis*		
		Discites		?	
Aalenian		Concavum	*P. maubeugei*	Puchenquia malarguensis Zone	P. maubeugei Sz.
			P. mendozana		P. mendozana Sz.
			P. compressa		P. compressa Sz.

Table 1 Proposed ammonite horizons for the Bajocian of Northern Chile; compared with the European Standard Zones and the South American Zones proposed by WESTERMANN in HILLEBRANDT et al. (1992).

Description of new species

Two species are described as new being important for the biostratigraphy of the lowest horizon of the Late Bajocian.

Abbreviations: D = diameter, H = whorl height, W = whorl width, U = umbilicus.

Family Stephanoceratidae NEUMAYR, 1875
Subfamily Stephanoceratinae NEUMAYR, 1875

Genus *Duashnoceras* WESTERMANN, 1983

Type species: *Stephanoceras floresi* BURCKHARDT, 1927

Diagnosis:

Primary ribs gently concave forward, more or less densely to coarsely spaced and with tendency to be sharp. At least some of the primaries do not directly meet the tubercles around which they curve adorally. Whorl section of inner whorls stemmatoceratid to teloceratid, outer whorls (body–chamber) stemmatoceratid to stephanoceratid. Microconchs with lateral lappets. Suture–line with subvertical U_2, moderately retracted U_3 and well and deeply developed U_n.

Remarks:

The genus was originally placed by WESTERMANN (1983) in the Zigzagiceratinae, as a subgenus of *Zigzagiceras*. Later he transferred *Duashnoceras* to the Stephanoceratidae (WESTERMANN 1984).

Stephanoceras is distinguished from *Duashnoceras* by the position of the tubercles which are located exactly on the termination of the primaries. Some European and North American species of *Stephanoceras,* however, also show this tendancy. *Cadomites* is mostly more densely–ribbed, especially the outer whorls. The body–chamber slightly egresses and is contracted. The suture–line differs in the radial (not retracted) umbilical lobes. SANDOVAL & WESTERMANN (1986) postulated *Duashnoceras* probably being a transitional genus between *Stephanoceras* und *Cadomites*.

Duashnoceras(?) *burroense* n. sp.

Pl. 8, figs 2, 3; Pl. 9, figs 1, 2

Holotype (Pl. 8, figs 2A, B):

Macroconch, phragmocone, in part with shell, not deformed, but only figured side of umbilicus prepared. Outer whorl filled with a micritic sediment, inner whorls filled with calcite and in part hollow (TUB 790316/4/1).

Diagnosis:

Coronate conch with deep umbilicus. Curved primary ribs, densely spaced in inner whorls, more widely spaced in outer whorls. Some of the primaries do not meet directly the tubercles around which they curve adorally. Whorl section of innermost whorls teloceratid, of outer whorls stemmatoceratid. Suture–line with retracted umbilical lobes.

Derivatio nominis:

Referring to the type locality (Quebrada de Los Burros) where the holotype was found.

Locus typicus:

Quebrada de Los Burros (loc. 13, fig. 1), 1.6 km south of point 3837 (topographic map 1 : 100 000, Exploradora; x = 481.3, y = 7126.4).

Stratum typicum:

Marls with layers of calcareous concretions (bed 5), below (bed 4) layer with *Duashnoceras andinense* (HILLEBRANDT) and *Chondroceras* sp. B, above (bed 6) layer with *Duashnoceras* sp. and ?*Megasphaeroceras* sp..

Distribution:

Lower Late Bajocian, *Lupherites dehmi* Horizon (= lower part of the European Subfurcatum Zone).

Material:

1. Type locality: Only the holotype was found.
2. Jurassic West of Cerro Jaspe (loc. 4, fig. 1), section 6, bed 5: One incomplete specimen (microconch) (Pl. 8, figs 3A, B) with part of the body–chamber (inner mould with part of shell), calcitic phragmocone with shell (TUB 860206/15/1).
3. Manflas (loc. 18, fig. 1), locality 4 (HILLEBRANDT, 1977, fig. 2): Two large macroconchs (Ø 175 and 165 mm) (TUB 661203/4/3 and 4) and one small specimen (inner whorls of micro– or macroconch) (TUB 661203/4/2)(Pl. 9, figs 2A, B).

Measurements:

	D(mm)	*H(mm)*	*W(mm)*	*H : W*	*U(mm)*	*U% of D*	*Ribs/whorl*
Holotype 790316/4/1	151.0 106.0	43.0 32.5	77.0 52.0	0.56 0.63	69.0 47.0	45.7 44.3	ca. 23
661203/4/2	46.0	19.0	ca.27.0	0.70	16.0	34.8	22

Description of the holotype:

The whorls are moderately evolute. The umbilical seam is at the outer base of the thick lateral spines. The umbilicus is deep. The whorl section of the inner whorls cannot be seen. The width of the outer whorls is much larger than the whorl height (H : W ca. 0.6). The flanks are convex. They are separated from the gently convex external side by a narrowly rounded lateral edge below the middle of the whorl height. The inner whorls are densely–ribbed. The primary ribs are sharp on the inner whorls and rounded on the outer whorls. They are concave forward and the strongest curvature lies at the inner third of the flanks. They are widely extended forward in direction to the umbilical seam. Mostly the primaries do not meet directly the tubercles which they curve adorally. Three to four secondary ribs are found per primary on the outer whorl and the whorl before. The suture–line is only partially visible. The umbilical lobes are retracted.

Description of the paratypes:

The inner whorls of the specimen from the locality 4 (TUB 860206/15/1, Pl. 8, figs 3A, B) are very similar to those of the holotype. The preserved part of the outer whorl (body–chamber) starts with the last septum of the phragmocone. This specimen is probably a microconch. The whorl width in relation to the whorl height is smaller than found at the holotype. But no body–chamber is preserved at the holotype. The style of ribbing is very similar. The umbilical lobes are retracted.

The small specimen (TUB 661203/4/2, Pl. 9, figs 2A, B) from the Manflas locality 4 is a phragmocone (micro– or macroconch). The conch is filled with a calcareous iron–oolite. The shell is in part preserved. The whorl width is much larger than the whorl height (H W = 0.7). The specimen is densely–ribbed and the style of ribbing corresponds with that of the holotype.

The large macroconch specimens from the same locality are laterally slightly compressed and make suggest a lower whorl width. They are septate up to the end. The densely–ribbed inner whorls of both specimens are poorly preserved. The style of ribbing of the outer whorls corresponds with the holotype.

Discussion:

The densely–ribbed inner whorls are similar to those of *Duashnoceras andinense* (HILLEBRANDT) but the cross section of the new species is much wider than that of all other species of the genus *Duashnoceras*. The sculpture is *Duashnoceras*–like but the shell shape is stemmatoceratid. Additionally, specimens with a *Teloceras*–like cross section (H : W = 0.5) and a coarse ribbing that is less *Duashnoceras*–like are found in the same ammonite horizon (*L. dehmi* Horizon) of the Manflas area and other localities (e.g. Pl. 9, figs 3A, B). Transitional specimens (Pl. 5, fig. 3 and Pl. 9, fig. 1A, B) between both species also exist.

Age:

The holotype was found above a bed with *Duashnoceras andinense* (HILLEBRANDT) (= *D. caracolense* Horizon) and below a bed with *Duashnoceras* sp. and ?*Megasphaeroceras* sp. (= ?*L. dehmi* Horizon). The stratum typicum of *D.*(?) *burroense* n.sp. can be included in the *L. dehmi* Horizon. The new species was found in the Manflas area in an ammonite assemblage typical for the *L. dehmi* Horizon. In the Jaspe Jurassic (locality 4, section 6) it appears in beds of the *L. dehmi* Horizon.

Duashnoceras profetaense n. sp.

Pl. 5, figs 4, 5; Pl. 6, figs 2–4; Pl. 7, figs 2–4

Holotype (Pl. 6, figs 2A, B):

Macroconch, phragmocone, inner mould with shell remains, conch not deformed, last whorl only on figured side completely preserved, inner whorls preserved on both sides (TUB 720218/1/1).

Diagnosis:

Conch subcoronate (inner whorls) to planulate (outer whorls), umbilicus moderately deep. Widely spaced primary ribs on inner whorls. Primaries frequently do not meet directly the well–developed tubercles around which they curve adorally Two to four convexly curved secondaries. Whorl section of inner whorls (phragmocone) stemmatoceratid and of outer whorls (mainly body–chamber) stephanoceratid. Suture–line with retracted umbilical lobes.

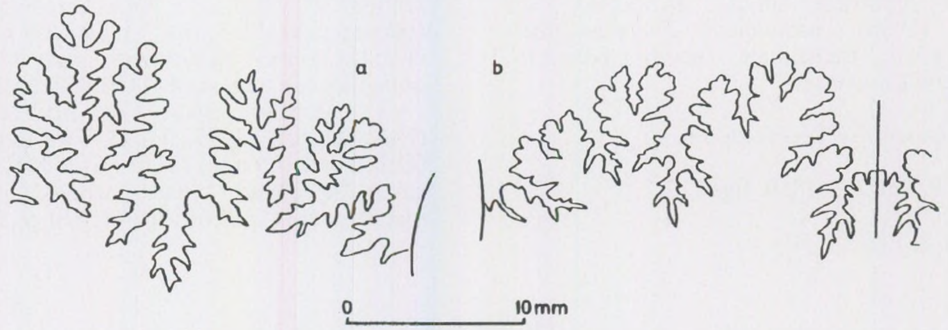

Fig. 3. Suture–lines. a. *Duashnoceras profetaense* n.sp., at whorl height 17.5 mm. b. *Leptosphinctes* cf. *leptus* BUCKMAN, at whorl height 18.0 mm.

Derivatio nominis:

Referring to the type locality (Profeta Jurassic) where the holotype was found.

Locus typicus:

Quebrada Aguada del Minero (loc. 10, fig. 1), section in the western part, locality 4 in HILLEBRANDT (1977, fig. 1), 1.6 km SSW of point 3197 (topographic map 1 100 000, Sierra de Varas; x = 476.4, y = 7243.0).

Stratum typicum:

Marls with layers of calcareous concretions, bed(s) with the ammonite fauna of the *L. dehmi* Horizon.

Distribution:

Lower Late Bajocian, *Lupherites dehmi* Horizon (= lower part of the European Subfurcatum Zone).

Material:

1. Type locality· A well preserved (both sides), incomplete specimen (phragmocone of a microconch) (TUB 670311/8/1 = Pl. 6, figs 1A, B), the inner whorls of a ?microconch (TUB 720218/1/2 = Pl. 6, figs 3A, B) and the phragmocone of a unilaterally preserved microconch (TUB 720218/1/3 = Pl. 5, fig. 5) were found additionally to the holotype.

2. Profeta Jurassic (loc. 10, fig. 1)(LF 22–2 of G. Chong D.): A probably nearly complete microconch (more than half a whorl body–chamber), inner whorls only preserved on figured side (Ch–943 = Pl. 5, fig. 4).

3. Jurassic West of Cerro Jaspe (loc. 4, fig. 1), section 2, bed 7: A laterally compressed and incomplete specimen, preserved part of last whorl body–chamber (TUB 831221/12/1).

4. Manflas (loc. 18, fig. 1): Specimens of the new species were found in the Manflas area at most localities (HILLEBRANDT, 1977, fig. 2).

a. Locality 1: Inner whorl of a phragmocone (Ø 98 mm), probably macroconch (iron–oolitic inner mould)(TUB 670115/5/1).

b. Locality 2: Inner whorls of a phragmocone, probably macroconch (iron–oolitic inner mould)(TUB 680129/6/1).

c. Locality 3: An incomplete, large (original Ø › 180 mm) phragmocone, inner mould (iron–oolite), septation not visible (TUB 670810/2/2 = Pl. 7, fig. 3), an incomplete microconch (phragmocone and ?part of body–chamber), inner mould (iron–oolite), septation not visible (TUB 670810/2/1 = Pl. 7, fig. 2, Pl. 8, fig. 1) and an incomplete microconch (Ø 107 mm), inner mould (iron–oolite), septation not visible (TUB 670810/2/3).

d. Locality 4: A very large phragmocone (Ø › 215 mm) of a macroconch, preserved from both sides (TUB 661203/5/5) and ?inner whorls of a ?phragmocone (Ø 127 mm) of a macroconch (TUB 661203/4/6).

e. Locality 6: A small ?microconch (Ø 46 mm), phragmocone, inner mould (iron–oolite)(TUB 720106/7/1 = Pl. 7, figs 4A, B).

5. 1.85 km north of Cerro Agua de La Piedra (localities 12, fig. 1): A probably nearly complete microconch (Ø ca. 144 mm) (TUB 790310/4/3).

Measurements:

	D(mm)	*H(mm)*	*W(mm)*	*H : W*	*U(mm)*	*U% of D*	*Ribs/diameter*
Macroconchs							
Holotype 720218/1/1	147.0 105.0	44.0 33.5	ca.60.0 45.0	ca.0.73 0.74	65.0 42.0	44.2 40.0	24/105 22/ca.75 mm 20/ca.50 mm 17/ca.25 mm
670810/2/2	114.0	37.0	ca.52.0	ca.0.71	49.0	43.0	18/114 mm
661203/4/5	194.0	52.0	73.5	0.71	94.0	48.5	21/194 mm
661203/4/6	124.0	ca.39.0	54.0	ca.0.72	52.5	42.3	ca.24/124 mm
Microconchs							
670311/8/1	 46.0	28.0 25.5 17.0	33.5 30.0 23.0	0.84 0.85 0.73	 18.0	 39.0	 18/ 46 mm
Ch–943	ca.126.0 ca.107.0	ca.37.5 ca.34.0	ca.36.0	0.94	53.0 43.0	ca.42.1 ca.40.2	28/ca.126 mm 26/ca.107 mm 22/ca.80 mm 19/ca.40 mm
720218/1/3	73.5	25.0	ca.30.0	0.83	28.0	38.1	ca.23/73.5
670810/2/1	117.0 88.0	41.0 31.0	ca.52.0 ca.32.0	ca.0.79 ca.0.97	45.0 35.0	38.5 39.8	20/117 mm 18/88 mm
670810/2/3	104.0	33.0	ca.36.5	ca.0.90	ca.44,0	42.3	20/104 mm
? Microconch 720218/1/2	 22.5	 7.5	 11.8	 0.65	 9.0	 40.0	15/22.5 mm

Description of the holotype:

The holotype is a probably incomplete phragmocone of a macroconch. The innermost whorls are not preserved, the following whorls are preserved on both sides. The moderately evolute shell is subcoronate and the umbilicus is not very deep. The inner flanks are slightly convex. They are separated from the convex external side by a rounded lateral edge at about the middle of the whorl height. The inner whorls are coarsely ribbed (17 to 18 robust ribs per whorl) and the primaries terminate in spines at the umbilical seam. On the following whorls the primaries are more and more curved forward. Some primaries do not meet directly the blunt (inner mould) tubercles. Striations parallel to the primaries are visible in the case of shell preservation. Two secondary ribs are found per primary at the end of the outer whorl and three at the whorl before. The secondaries curve convexly over the external side. The umbilical lobes are retracted on the inner flank.

Description of the paratypes:

Micro– and macroconchs were found. They are distinguished mainly by the size of the conch.

Macroconchs:

In addition to the holotype some specimens were found that can be assigned to macroconchs. None of these are preserved with the body–chamber or parts of it. Also the largest specimen (TUB 661203/4/5) with a diameter of 215 mm is completely septate. All specimens are subcoronate up to the end. The umbilical width in relation to the diameter increases during growth.

The distance of the primaries of the coarsely ribbed inner whorls is variable. The inner whorls of the holotype have a lower number of ribs per whorl than those of the figured specimen from Manflas (Pl. 7, fig. 3) and this is also the case for the largest specimen (TUB 661203/4/5) from the same locality. The innermost whorls of the figured Manflas specimen (Pl. 7, fig. 3) are not preserved. The curved and relatively sharp primaries of the following whorls do not meet directly the tubercles and pass adorally around them. The striation between the ribs is visible although the specimen is preserved as inner mould (iron–oolite). Three secondaries per tubercle exist and between them often intercalated ribs are present. The holotype is the sole specimen with only two secondaries per tubercle on the last whorl. There are also specimens with four secondaries per tubercle, at least on the inner whorls.

Microconchs:

The specimen CH–943 (Pl. 5, fig. 4) is preserved with a body–chamber which is more than ½ whorl long. The sculpture of the inner whorls of this specimen is very similar to that of the holotype. Primaries of *Duashnoceras*–like appearance are more frequent. The body–chamber slighly egresses. The cross–section of the inner whorls is not visible but the relatively deep umbilicus allows the conclusion of a stemmatoceratid cross–section. The last whorl shows a rounded, stephanoceratid cross–section with a whorl width not too much larger than the whorl height. Three secondary ribs per tubercle are mostly found and intercalatory ribs can be present. At the end of the preserved body–chamber two secondaries per tubercle and an intercalated rib exist. The secondaries are clearly directed forward and curve convexly over the external side.

Specimen TUB 670311/8/1 (Pl. 6, figs 4A, B) is completely septate. The stemmatoceratid cross–section of the penultimate whorl is visible due to the incomplete last whorl. The preserved part of the last whorl shows a rounded, stephanoceratid cross section (H : W ca. 0.85). The number of primaries (inner whorls) is lower than those in the holotype. *Duashnoceras*–like primaries are frequent. The ribs and tubercles of the outer whorl are in part slightly corroded. Three secondary ribs per tubercle and an intercalatory rib are mostly found. The suture–line is visible on most parts of the inner mould (micritic limestone). The U_2 is vertical and the U_3 is clearly retracted.

Specimen TUB 720218/1/3 (Pl. 5, fig. 5) is completely septate and corresponds very well to specimen Ch–943 (Pl. 5, fig. 4).

The small specimen TUB 720218/1/2 (Pl. 6, figs 3A, B) shows well preserved innermost whorls. The shell surface is smooth up to an umbilicus diameter of 0.8 mm. The tubercles appear earlier than the ribs. Weak ribs occur with an umbilical width of 2 mm and *Duashnoceras*–like ribs are developed with an umbilical width of 3 mm.

The Manflas specimen TUB 670810/2/1 (Pl. 7, fig. 2; Pl. 8, fig. 1) shows a relatively small number of primaries in the inner whorls, similar to the Profeta specimen TUB 670311/8/1 (Pl. 6, figs 4A, B). The specimen probably is slightly compressed laterally. The septa are not preserved. The transition from the stemmatoceratid to the stephanoceratid cross section takes place on the last whorl. The continuation of the umbilical seam is visible on the preceding whorl and the end of the last whorl slighly egresses. Two to three secondaries per tubercle and an intercalatory rib are found on the last whorl.

Specimen TUB 720106/7/1 (Pl. 7, figs 4A, B) shows the inner, stemmatoceratid whorls of a ?microconch.

The probably nearly complete micronch (TUB 790310/4/3) of the locality 1.85 km north of Cerro Agua de La Piedra shows a body–chamber with a length of 2/3 of the last whorl. The body–chamber is preserved only on one side. Part of the inner whorls are visible on the other side.

Discussion:

The typical *Duashnoceras*–like ornament is mostly better developed in the microconchs. *Duashnoceras floresi* (BURCKHARDT) shows a similar ribbing but the diameter of the macro– and microconchs of this Mexican species are much smaller. The inner whorls of the North American Late Bajocian microconch *Dettermanites vigorosus* IMLAY are similar. However, mainly the body–chamber of *D. profetaense* n. sp. is different. The macroconch of the North American *Stephanoceras (Stemmatoceras) dowlingi* (MCLEARN) is similar but does not show the *Duashnoceras*–like ribbing.

A specimen (TUB 661202/2/1 = Pl. 6, fig. 1, Pl. 7, fig. 1) was found at the Manflas locality 5 (HILLEBRANDT, 1977, fig. 2) which is transitional between *Duashnoceras profetaense* n. sp. and *Lupherites*(?) *chongi* (HILLEBRANDT). *L.*(?) *chongi* is more densely–ribbed and the planulate (stephanoceratid) stage starts earlier.

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Plates

Plate 1

(Small arrow marks the beginning of the body–chamber)

Figs 1, 2. *Emileia (Chondromileia) giebeli giebeli* (GOTTSCHE).
Manflas (loc. 18), Cerro de La Cuesta (HILLEBRANDT & WESTERMANN 1985, fig. 4, loc. 2), bed 3, *E. giebeli giebeli* Horizon.

1A–C. Macroconch, complete specimen with peristome, body–chamber inner mould mostly without shell, phragmocone mostly with shell (TUB 680130/9/1).

2A, B. Microconch, nearly complete specimen, at one side (not figured) peristome with lappets, body–chamber inner mould with shell remains, phragmocone with shell (TUB 670812/4/1).

Figs 3, 4. *Emileia (Chondromileia) giebeli submicrostoma* (GOTTSCHE).
Quebrada San Pedrito (loc. 17), *E. giebeli submicrostoma* Horizon.

3A, B. Macroconch, nearly complete specimen with part of peristome, body–chamber in part with shell, phragmocone with shell (TUB 711215/2/1).

4A, B. Microconch, complete specimen. Peristome with lappets, body–chamber nearly without shell (TUB 711215/2/2).

Figs 5A, B. *Emileia*(?) cf. *submicrostoma* (GOTTSCHE).
Manflas (loc. 18) (HILLEBRANDT 1977, fig. 2, loc. 3), probably *Dorsetensia* ssp. Horizon.
Macroconch, complete specimen with peristome, inner mould, boundary between body–chamber and phragmocone scarcely visible (TUB 670810/3/1).

(All figures in natural size)

Plate 1

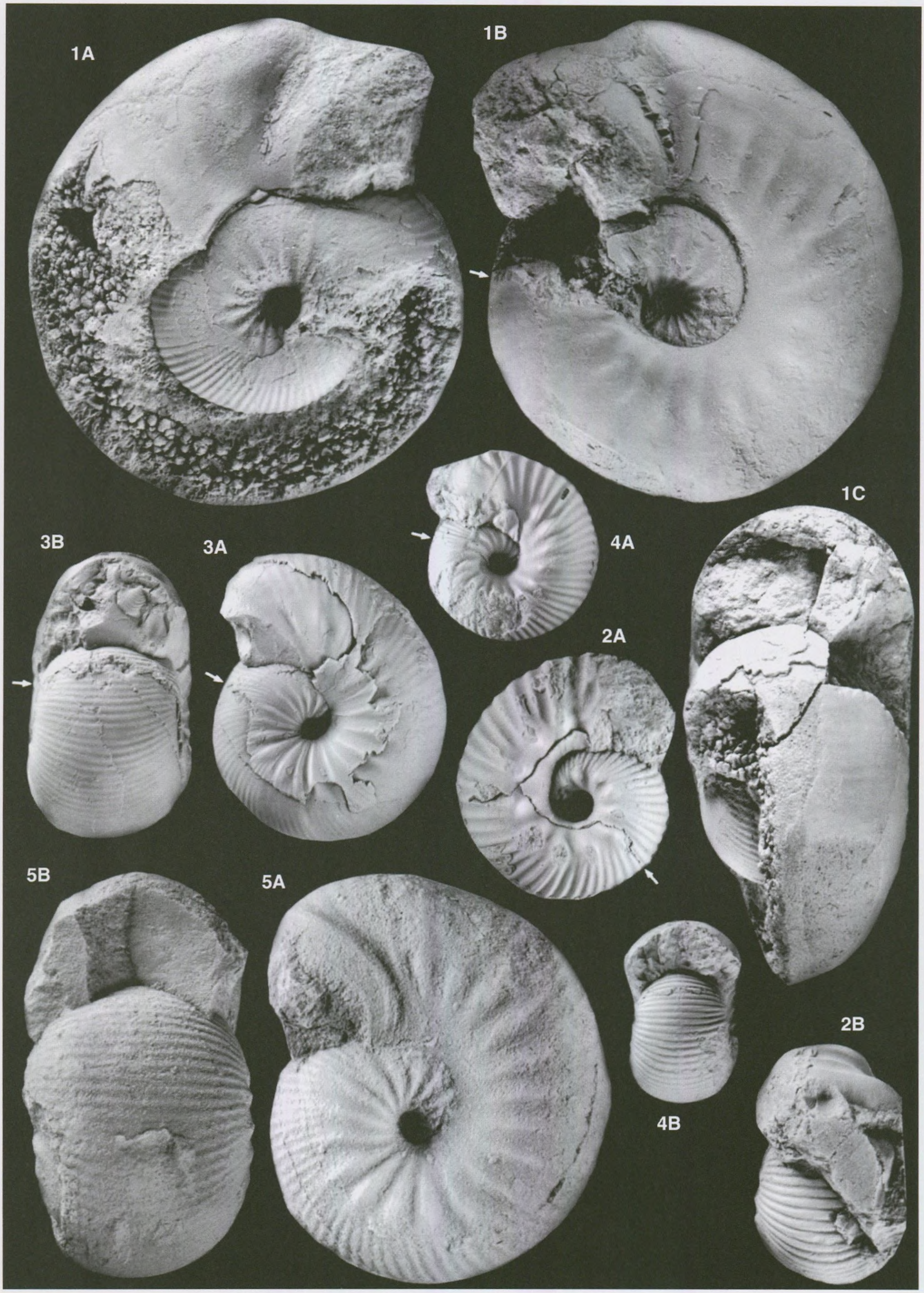


Plate 2

(Small arrow marks the beginning of the body–chamber)

Figs 1–4. *Stephanoceras* ex gr. *St. pyritosum* (QUENSTEDT).

1–3. Sierras de San Lorenzo (loc. 5), *Dorsetensia* ssp. Horizon.

1A, B. Phragmocone, in part with shell (TUB 860310/21/1).

2A, B. Phragmocone, mostly with shell (TUB 860310/21/2).

3A, B. Phragmocone with shell (TUB 860310/21/3).

4A, B. 1.7 km NW of Cerro Agua de La Piedra (loc. 12), *Dorsetensia* ssp. Horizon, phragmocone, in part with shell (TUB 790311/4/1).

Figs 5–8. *Chondroceras* sp. A.
5, 6. Sierras de San Lorenzo (loc. 5), *Dorsetensia* ssp. Horizon.

5. A., B. ?Macroconch, complete specimen with peristome and shell, boundary between body–chamber and phragmocone not visible (TUB 860310/21/4).

6. A., B. ?Macroconch, phragmocone with ? most part of body–chamber, body–chamber in part with shell, phragmocone with shell (TUB 860310/22/1).

7., 8. 1.7 km NW of Cerro Agua de La Piedra (loc. 12), *Dorsetensia* ssp. Horizon.

7. ?Microconch, phragmocone (with shell) and part of body–chamber (end compressed on body–chamber) (TUB 790311/4/2).

8. ?Microconch, ?complete body–chamber (external side incomplete), body–chamber mostly without shell, phragmocone with shell (TUB 790311/4/3).

Fig. 9. A., B. *Chondroceras* sp. B.
Aguada El Oro (loc. 9), bed 2, *D. caracolense* Horizon.
Phragmocone (with shell) and beginning of body–chamber (without shell) (TUB 890307/7/1).

Figs 10–11 *Duashnoceras caracolense* (WESTERMANN & RICCARDI).
Aguada El Oro (loc. 9), bed 2, *D. caracolense* Horizon.

10. Microconch, inner whorls phragmocone (mostly with shell), outer whorl body–chamber (inner mould) (TUB 890307//4).

11. Microconch, phragmocone mostly with shell, body–chamber inner mould (TUB 890307/7/5).

Fig. 12. *Duashnoceras* sp.
Aguada El Oro (loc. 9), bed 2, *D. caracolense* Horizon. Microconch, phragmocone with shell, coarsely ribbed variety with *Stemmatoceras*–like cross section (TUB 890307/7/6).

(All figures in natural size)

Plate 2

Plate 3

(Small arrow marks the beginning of the body–chamber)

Figs 1, 2. *Duashnoceras caracolense* (WESTERMANN & RICCARDI).
Caracoles (loc. 6), N Cerro Torcazas, bed 3, *D. caracolense* Horizon.

1A, B. Microconch, complete specimen, peristome with lappets (at both sides), mostly with shell (TUB 871218/5/1).

2. Macroconch, body–chamber mostly without shell, phragmocone mostly with shell (TUB 871218/5/2).

Fig. 3. *Duashnoceras chilense* (HILLEBRANDT).
Profeta Jurassic (loc. 10), Aguada Colorada, *L. dehmi* Horizon.
Microconch, body–chamber ¾ of the last whorl, most part laterally crushed inner mould (without shell), phragmocone mostly with shell (GCH 4–070672).

Figs 4, 5. *Chondroceras* sp. B.

4A, B. Quebrada de Los Burros (loc. 13), ?bed 4, *D. caracolense* Horizon. Phragmocone with beginning body–chamber, mostly with shell (TUB 790315/8a).

5A, B. Aguada El Oro (loc. 9), bed 2, *D. caracolense* Horizon. Phragmocone, mostly with shell (TUB 890307/7/2).

(All figures in natural size)

Plate 3

Plate 4

(Small arrow marks the beginning of the body–chamber)

Fig. 1. *Duashnoceras andinense* (HILLEBRANDT).
Aguada El Oro (loc. 9), bed 2, *D. caracolense* Horizon.
Microconch, body–chamber mostly with shell, phragmocone with shell (TUB 890307/7/7).

Figs 2, 3. *Stephanoceras* ex gr. *St. pyritosum* (QUENSTEDT).

2A, B. Sierras de San Lorenzo (loc. 5), *Dorsetensia* ssp. Horizon. Phragmocone, mostly with shell (TUB 860310/22/2).

3A, B. Cerritos Bayos (S loc. 5) (Biese collection, Nacional Museum of Natural History, Washington) (labelled: W L_{24} *Spaeroceras* Bank). Phragmocone, in part with shell.

Fig. 4. *Duashnoceras chilense* (HILLEBRANDT).
Aguada El Oro (loc. 9), *L. dehmi* Horizon.
Macroconch, body–chamber (nearly one whorl), in part with shell, phragmocone mostly with shell (GCH–98).

Fig. 5. *Chondroceras* sp. B.
Aguada El Oro (loc. 9), bed 2, *D. caracolense* Horizon.
Fragment of body–chamber, inner mould, in part with shell (TUB 890307/7/3).

(All figures in natural size)

Plate 4

Plate 5

(Small arrow marks the beginning of the body–chamber)

Figs 1, 2. *Duashnoceras chilense* (HILLEBRANDT).

1A, B. 1.85 km North of Cerro Agua de La Piedra (loc. 12), *L. dehmi* Horizon.
Macroconch, phragmocone, mostly with shell (TUB 790310/4/1).

2. Profeta Jurassic (loc. 10), Quebrada Aguada del Minero (western part), bed 1, *L. dehmi* Horizon.
Microconch, complete specimen with lappets, mostly with shell, boundary between body–chamber and phragmocone not visible, innermost whorls not preserved (TUB 670311/6/1).

Fig. 3. *Teloceras*(?) sp.
Profeta Jurassic (loc. 10), Aguada Colorada, *L. dehmi* Horizon.
Phragmocone, mostly with shell (GCH 3–070672).

Figs 4, 5. *Duashnoceras profetaense* n. sp.
4. Profeta Jurassic (loc. 10), Aguada Colorada, *L. dehmi* Horizon.
?Microconch (oppsite side of figured side not prepared), body–chamber (2/3 of last whorl) in part with shell, at the end slightly crushed and opposite side not preserved, phragmocone with shell (CH–943, LF 22–2).

5. Profeta Jurassic (loc. 10), Quebrada Aguada del Minero (western part), bed 1, *L. dehmi* Horizon.
Microconch, phragmocone, only one side preserved, in part with shell (TUB 720218/1/3).

(All figures in natural size)

Plate 5

Plate 6

Fig. 1. *Duashnoceras* cf. *profetaense* n. sp.
Manflas (loc. 18), locality 5 in HILLEBRANDT (1977, fig. 2), *L. dehmi* Horizon.
?Microconch, phragmocone, inner mould (iron–oolite), septation not visible (TUB 720106/7/1).

Figs 2–4. *Duashnoceras profetaense* n. sp.
Profeta Jurassic (loc. 10), Quebrada Aguada del Minero (western part), bed 1, *L. dehmi* Horizon.

2A., B. Holotype, phragmocone, inner mould with shell remains (TUB 720218/1/1).

3A., B. Inner whorls of phragmocone, inner mould with shell remains (TUB 720218/1/2).

4A., B. Microconch, phragmocone, inner mould with shell remains (TUB 670311/8/1).

(All figures natural size)

Plate 6

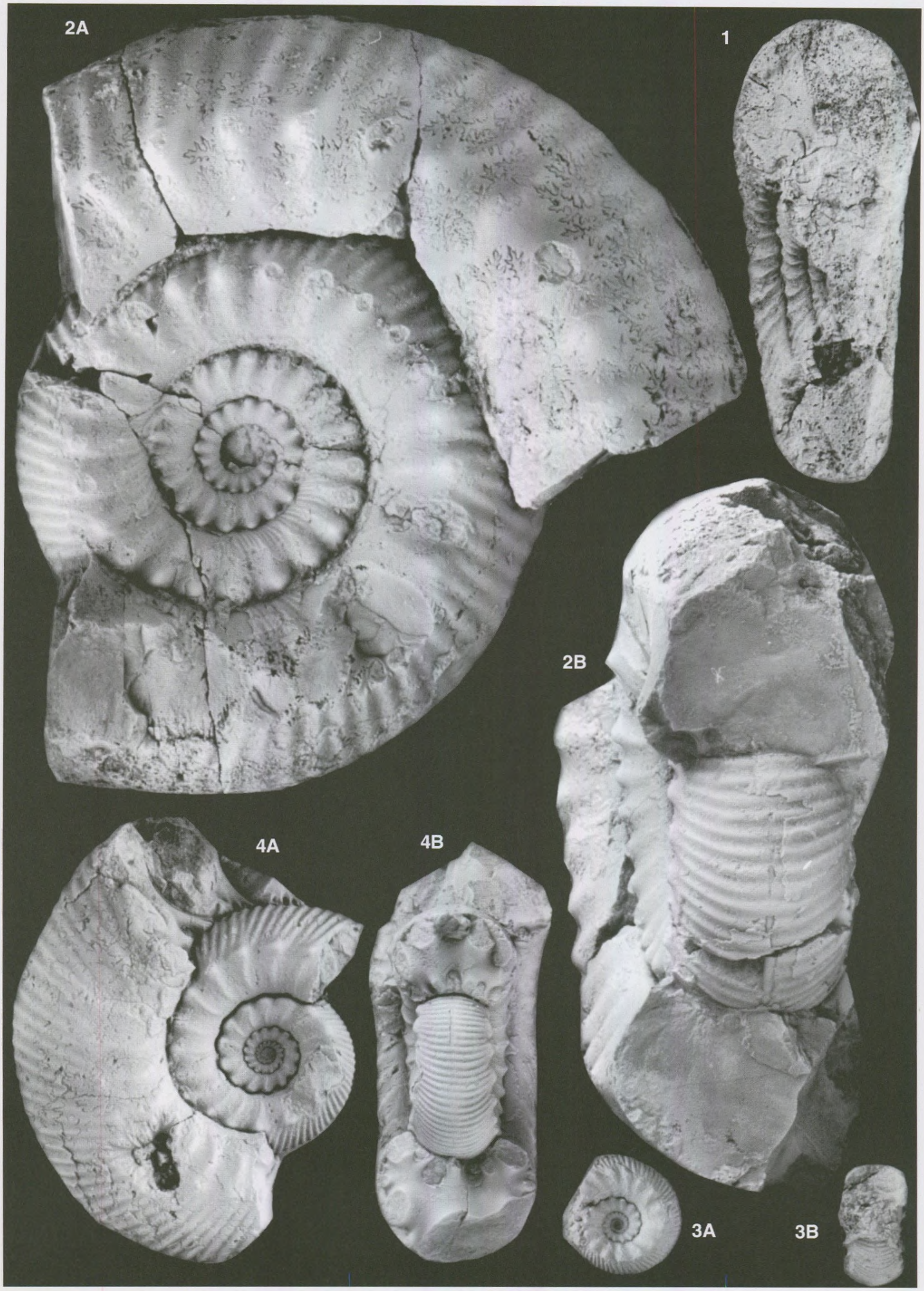


Plate 7

Fig. 1. *Duashnoceras* cf. *profetaense* n. sp.
= Pl. 6, fig. 1; Manflas (loc. 18), *L. dehmi* Horizon.

Figs 2–4. *Duashnoceras profetaense* n. sp.

2, 3. Manflas (loc. 18), locality 3 in HILLEBRANDT (1977, fig. 2), *L. dehmi* Horizon.

2. Microconch, phragmocone, inner mould (iron–oolite), septation not visible (TUB 670810/2/1).

3. Macroconch, phragmocone, inner mould (iron–oolite), septation not visible (TUB 670810/2/2).

4A, B. Manflas (loc. 18), locality 6 in HILLEBRANDT (1977, fig. 2), *L. dehmi* Horizon.
?Microconch, phragmocone, inner mould (iron–oolite) (TUB 720106/7/1).

(All figures natural size)

Plate 7

Plate 8

Fig. 1. *Duashnoceras profetaense* n. sp.
= Pl. 7, fig. 2; Manflas (loc. 18), *L. dehmi* Horizon.

Fig. 2, 3. *Duashnoceras*(?) *burroense* n. sp.

2A, B. Quebrada de Los Burros (loc. 13), bed 5, *L. dehmi* Horizon.
Holotype, macroconch, phragmocone, in part with shell (TUB 790316/4/1).

3A, B. Jurassic west of Cerro Jaspe (loc. 4), section 6, bed 6, *L. dehmi* Horizon.
Microconch, last whorl body–chamber (at the beginning with last septum), inner mould in part with shell, calcitic phragmocone with shell (TUB 860206/15/1).

(All figures natural size)

Plate 8

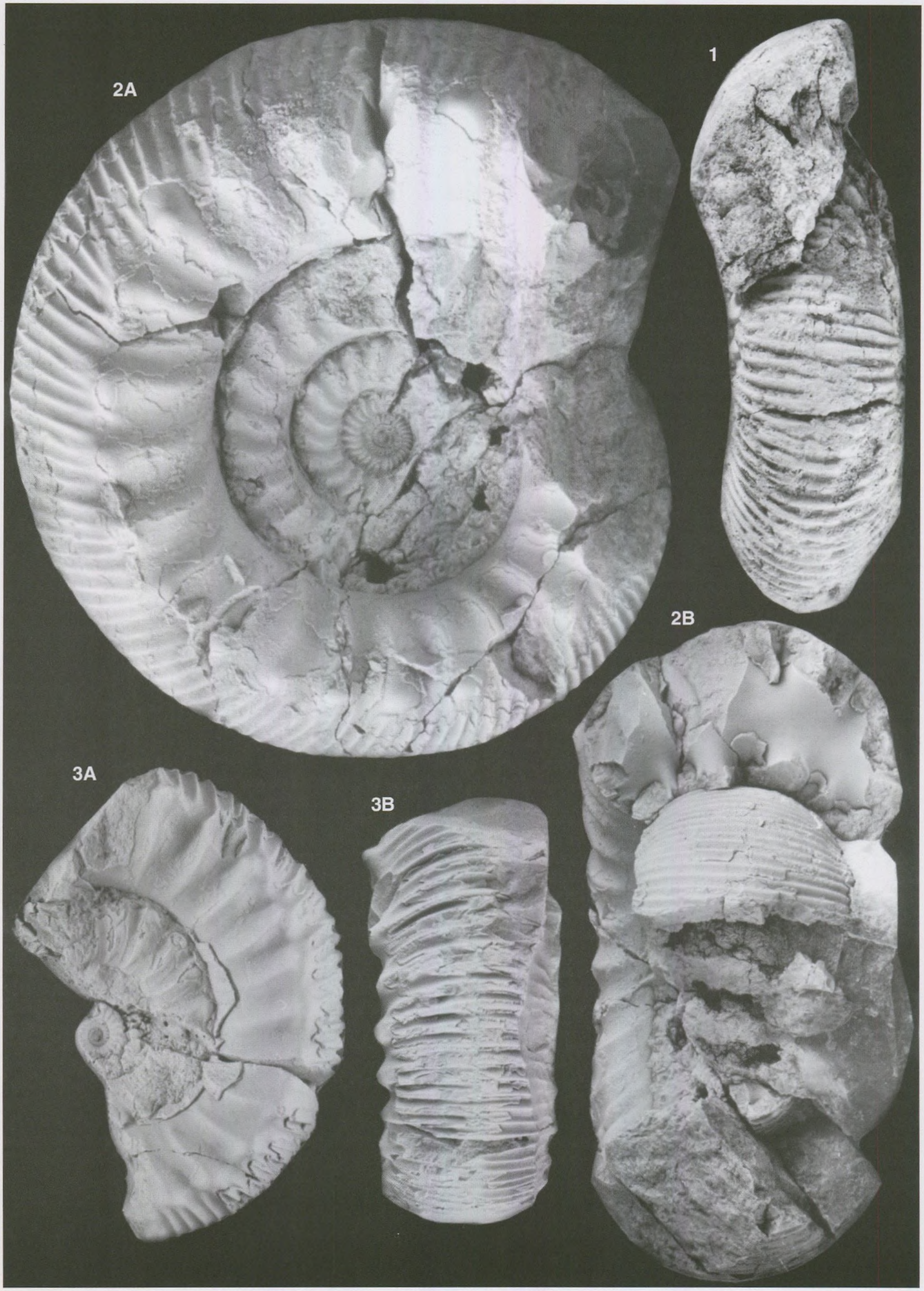


Plate 9

(The small arrow marks the beginning of the body–chamber)

Figs 1, 3. *Teloceras*(?) sp.

1A, B. Manflas (loc. 18), locality 4 in HILLEBRANDT (1977, fig. 2), *L. dehmi* Horizon.
Phragmocone, calcitic mould with shell (TUB 661203/4/1).

2A, B. *Duashnoceras*(?) *burroense* n. sp.
Manflas (loc. 18), locality 4 in HILLEBRANDT (1977, fig. 2), *L. dehmi* Horizon.
Phragmocone, mostly with shell (TUB 661203/4/2).

3A, B. 1.85 km N of Cerro Agua de La Piedra (loc. 12), *L. dehmi* Horizon.
Macroconch, phragmocone, mostly with shell (TUB 790310/4/2).

Figs 4, 5. *Spiroceras orbignyi* (BAUGIER & SAUZÉ).

4. Profeta Jurassic (loc. 10), Quebrada Aguada del Minero (western part), bed 1, *L. dehmi* Horizon.
?Macroconch, phragmocone and part of body–chamber (in part with shell) (TUB 720218/1/4).

5A, B. Jurassic west of Cerro Jaspe (loc. 4), section 1, bed 5, *Leptosphinctes* Horizon.
Phragmocone, inner mould (in part with shell) (TUB 830304/13/1).

Figs 6A, B. *Cadomites* sp. ex gr. *C. psilacanthus/deslonchampsi*.
Profeta Jurassic (loc. 10), Quebrada Aguada del Minero (western part), bed 2, *Leptosphinctes* Horizon.
Macroconch, fragment of outer whorl = body–chamber (in part with shell), phragmocone mostly with shell (TUB 670311/4/1).

Figs 7A, B. *Leptosphinctes* cf. *leptus* BUCKMAN.
Jurassic west of Cerro Jaspe (loc. 4), section 1, bed 5, *Leptosphinctes* Horizon.
?Macroconch, phragmocone, inner mould with remains of shell (TUB 830304/13/2).

(All figures natural size)

Plate 9

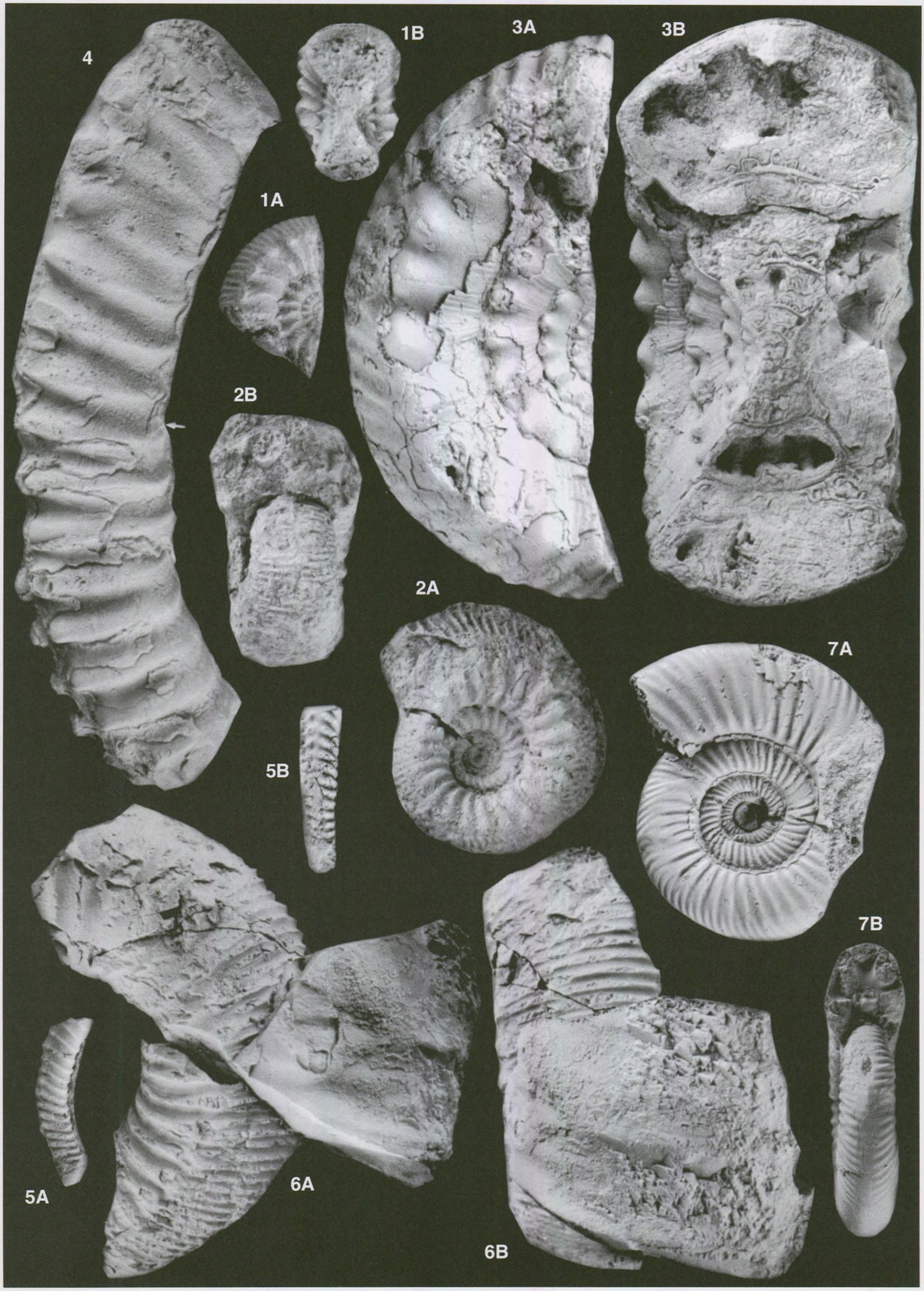


Plate 10

(The small arrow marks the beginning of the body–chamber)

Figs 1, 2. *Leptosphinctes* cf. *leptus* BUCKMAN.
Profeta Jurassic (loc. 10), Quebrada Aguada del Minero (western part), bed 2, *Leptosphinctes* Horizon.

1. ?Macroconch, nearly complete specimen with part of peristome (only one side preserved), body–chamber and phragmocone mostly with shell (TUB 720218/2/1).

Figs 2A, B. Microconch, nearly complete specimen with peristome and incomplete lappets, body–chamber preserved as inner mould (with shell remains), phragmocone plastic cast of outer mould (TUB 720218/3/1).

Figs 3, 4. *Megasphaeroceras*(?) sp. A.

3A, B. Aguada El Oro (loc. 9), *Megasphaeroceras*(?) Horizon.
Phragmocone (with shell) and inner border (umbilical seam) of ?beginning of body–chamber closing the umbilicus (ded. G. Chong, p–14).

Figs 4A, B. Profeta Jurassic (loc. 10), Quebrada Aguada del Minero (western part), bed 3, *Megasphaeroceras*(?) Horizon.
Phragmocone, mostly with shell (TUB 670311/9).

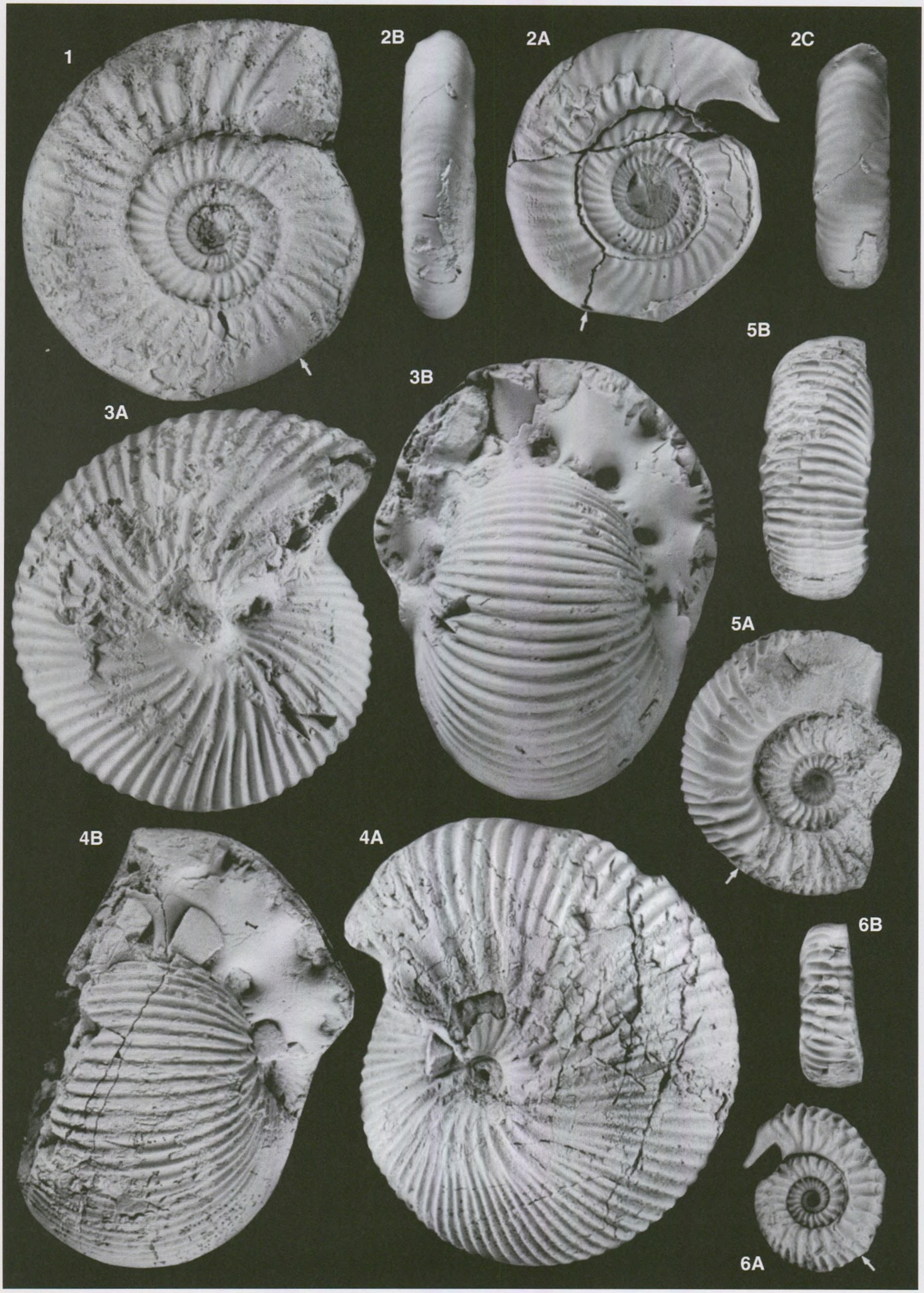
Figs 5, 6. *Orthogarantiana* cf. *conjugata* (QUENSTEDT).

5A, B. Profeta Jurassic (loc. 10), Quebrada Vizcachas, *L. dehmi* or *Leptospinctes* Horizon.
Macroconch, phragmocone (with shell) and part of body–chamber (inner mould) (leg. et ded. T. Bogdanic).

6A, B. Aguada El Oro (loc. 9), *L. dehmi* or *Leptosphinctes* Horizon.
Microconch with complete body–chamber and lappet (preserved only on figured side), body–chamber with shell remains, phragmocone with shell (ded. G. Chong, GCH–106).

(All figures natural size)

Plate 10



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Palaeogeographical distribution of early Bathonian ammonites of the *Asphinctites–Polysphinctites* group

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(With 4 figures and 2 plates)

The study of ammonites representing the dimorphic pair *Asphinctites tenuiplicatus* (BRAUNS) – *Polysphinctites secundus* (WETZEL) in the Tenuiplicatus Zone of Lower Bathonian in Central Poland, reveals their abnormal large sizes when compared with those occurring in other areas of Europe. The biogeographic distribution of the discussed ammonites, as well as older representatives of *Asphinctites* and *Polysphinctites* shows a general decrease in size of both forms towards south from the Submediterranean Province to the Mediterranean Province, and to the general disappearance of *Polysphinctites* in the Mediterranean Province. The phenomena may be related to changing environmental conditions which influenced the development of the discussed ammonites. We suggest that the ammonites inhabiting more distant areas from the Mediterranean Province, at the periphery of geographic range of the species, could have reached larger sizes due to prolonged time of maturation.

Introduction

The uppermost Bajocian and Bathonian deposits distinguished in the Częstochowa and Wieluń areas in Central Poland as the Ore Bearing Częstochowa Clay Formation (cf. KOPIK 1998) became famous since the XIX. century due to wealth of well–preserved ammonites. Detailed biostratigraphical study of these deposits were undertaken by REHBINDER (1913) who introduced here for the first time the standard Tenuiplicatus Zone at the top of the Lower Bathonian. This zone was defined by common occurrence of the species *"Perisphinctes" tenuiplicatus* = *Asphinctites tenuiplicatus* (BRAUNS). Common occurrence of this species in the Częstochowa and Wieluń areas has not been, however, the subject of any detailed palaeontological study for long time, beside the unpublished M.Sc. thesis of POTOCKI (1972) where the geological section of the Leszczyński's brick–pit at Częstochowa and a short palaeontological description and illustrations of the collected specimens of *Asphinctites tenuiplicatus* were given. The ammonites *Asphinctites* and *Polysphinctites* were reported also from Kromołów near Zawiercie (KOPIK 1998), and in the cores in the Bełchatów area west of Wieluń (KOPIK 1979).

A palaeontological study of ammonites from the uppermost Bajocian and Lower Bathonian exposed in brick–pits between Częstochowa and Wieluń carried out recently (MATYJA & WIERZBOWSKI 2000a) provided the basis for the standard biostratigraphical subdivision of these deposits. The common occurrence of *Asphinctites tenuiplicatus* (BRAUNS) and *Polysphinctites secundus* (WETZEL) indicative of the Tenuiplicatus Zone has been recognised in the Leszczyński's brick–pit at Częstochowa and in the Faustianka brick–pit about 20 km south of Wieluń (Fig. 1). These ammonites representing the dimorphic pair occur in profusion in this Zone, where, on the other hand, a marked impoverishment in other ammonite groups, abundantly occurring in older deposits of the Macrescens and Yeovilensis subzones of the Zigzag Zone in the area of study, is recognised. This impoverishment may be attributed to a change in environment which promoted from the beginning of the Tenuiplicatus Chron, high endemism and led to development of the special *Asphinctites* – *Polysphinctites* fauna (MATYJA & WIERZBOWSKI 2000a).

Although the general description of rich collection of *Asphinctites tenuiplicatus* (BRAUNS) and *Polysphinctites secundus* (WETZEL) consisting of more than 90 well–preserved specimens has been presented previously (MATYJA & WIERZBOWSKI, 2000a), its more detailed palaeontological study is given only nowadays. It is also a time to discuss the palaeogeographical distribution of all representatives of the two forms in Europe, as well as its comparison to that of an older fauna of *Asphinctites–Polysphinctites* (see also MATYJA & WIERZBOWSKI 2000b).

The ammonites of the *Asphinctites* – *Polysphinctites* group are essentially the forms occurring along the northern margin of the Tethys – both in wide areas of its northern shelf constituting the Submediterranean Province, and in northern part of the Mediterranean Province: from Portugal and Spain, through France and southern England, northern Austria, Germany and Poland to Rumania, and even further east up to northern and central Iran. The boundary between the Mediterranean and Submediterraean provinces corresponds generally to a marked increase in numerical abundance of deep–water phylloceratids (CARIOU et al. 1985), but it seems to be also recognizable in changes in other ammonite groups including that of *Asphinctites – Polysphinctites*.

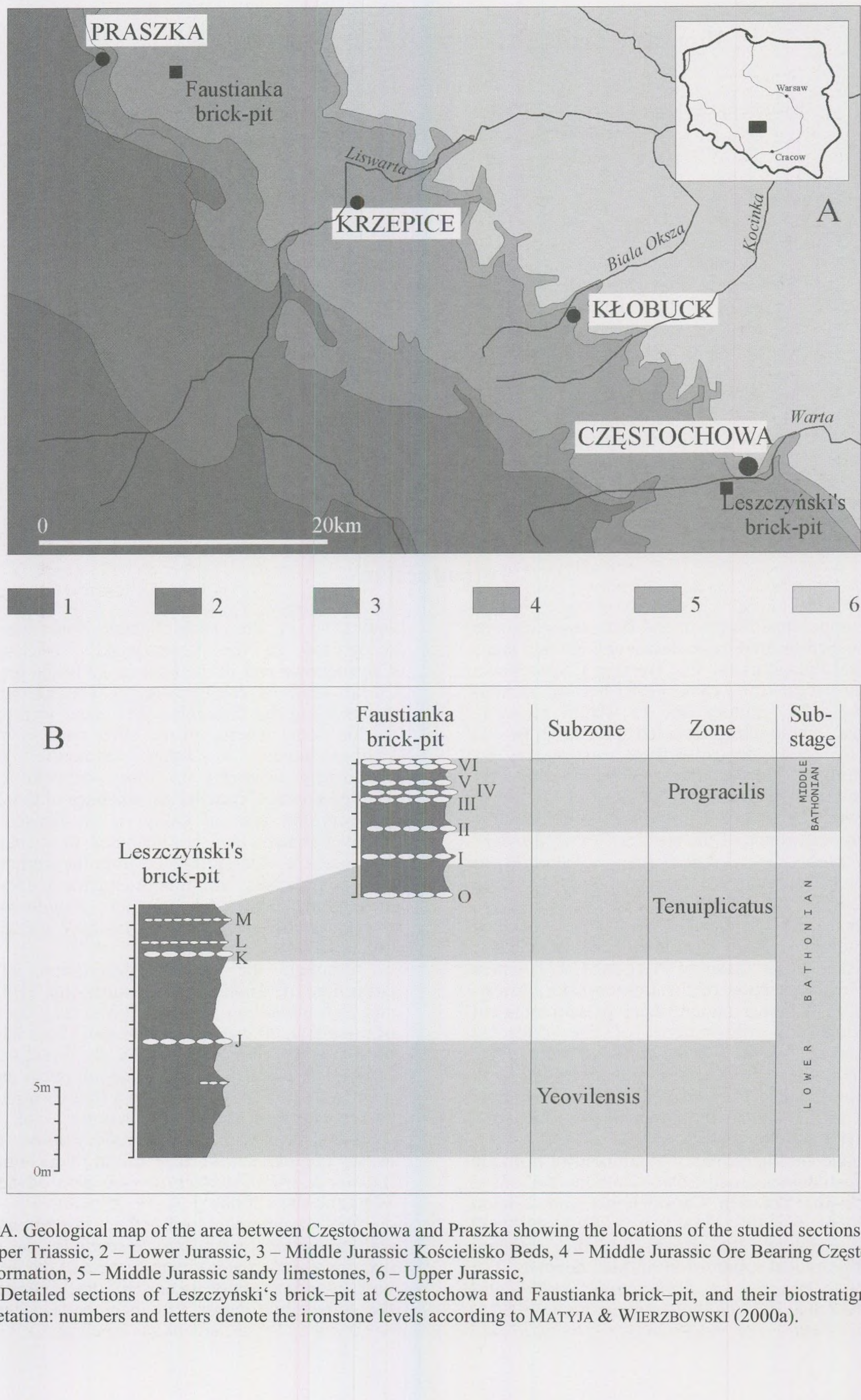


Fig. 1 A. Geological map of the area between Częstochowa and Praszka showing the locations of the studied sections. 1 – Upper Triassic, 2 – Lower Jurassic, 3 – Middle Jurassic Kościelisko Beds, 4 – Middle Jurassic Ore Bearing Częstochowa Clay Formation, 5 – Middle Jurassic sandy limestones, 6 – Upper Jurassic,

B. Detailed sections of Leszczyński's brick–pit at Częstochowa and Faustianka brick–pit, and their biostratigraphical interpretation: numbers and letters denote the ironstone levels according to MATYJA & WIERZBOWSKI (2000a).

Asphinctites tenuiplicatus – Polysphinctites secundus ammonite fauna from central Poland

This dimorphic pair of the family Morphoceratidae are represented in the studied material studied by large number of fully–grown and completely preserved specimens. This gives the basis for better understanding of their ontogeny.

The fully–grown specimens of *Asphinctites tenuiplicatus* are generally of large sizes (Pls. 1–2; Fig. 2). They range in final diameter from 72.0 mm to 119.5 mm, with a median final diameter of 103.1 mm as calculated for 30 specimens. The body–chamber is from 7/8 to $1^1/_{16}$ to $1^1/_8$ whorl long; the specimens of smallest final diameter show the shortest body–chambers, whereas of the largest diameter – generally the longest body–chambers. The final diameter of phragmocone is from 38.9 mm to 57.0 mm (the median value for 21 specimens is 47.2 mm)

The fully grown specimens of *Polysphinctites secundus* are fairly large as for this form (Pl. 2; Fig. 2). The final diameters range from 24.5 mm to 34.5 mm, with a median value 27.6 mm calculated for 12 specimens. The body–chamber is 7/8 whorl long. The final diameter of phragmocone is from 14.0 mm to 27 mm (the median value for 9 specimens is 19.7 mm).

The specimens are well–preserved what enables the recognition of particular phases of shell development from the ammonitella stage in both dimorphic forms. The ammonitella itself is about 1.2 mm in diameter. The ornamentation becomes clearly visible from about 12 mm in shell diameter. Initially, the ribs are swollen in periumbilical part of the whorls, showing the palmate type division into 4–5 secondary ribs about mid–height of whorl. This type of ribbing in *P secundus* continues up to about 20 mm diameter, then a slight rursiradiate course of ribs at their division appears what is a typical feature of the last stage of ornamentation in this form; moreover, the last 2–3 secondary ribs in *P. secundus* become sharpened at the ventrolateral and ventral parts of whorl, and the aperture shows the presence of lappets. In *A. tenuiplicatus* the palmate type of rib–division occurs up to about 30–40 mm diameter, being replaced there by the polyplocoid and virgatotome ones; the ribs are blunt, fairly thick and cross the ventral side of whorls without any weakening. The coiling is markedly evolute especially in *P. secundus* and inner whorls of *A. tenuiplicatus*. Close to the final diameter of *A. tenuiplicatus* the whorl–height diminishes markedly up to the final aperture which is simple. The outer half–whorl both in *P. secundus* and *A. tenuiplicatus* tends to coil more loosely. The constrictions in both forms are weakly developed, shallow and not numerous.

The median total length of a shell is about 5 and a half whorl in *P. secundus*, and about 7 and a half whorl in *A. tenuiplicatus*. The septal density as recognised in a few specimens changes over a small interval from 11 to 17 septa per whorl. At smallest diameters, up to about 9 mm (what corresponds to about 4 whorls) the septal density seems somewhat larger (17 septa per whorl) than at larger diameter, where it becomes nearly constant and equals 11 to 13 septa per whorl (but a few last crowded septa at the end of phragmocones).

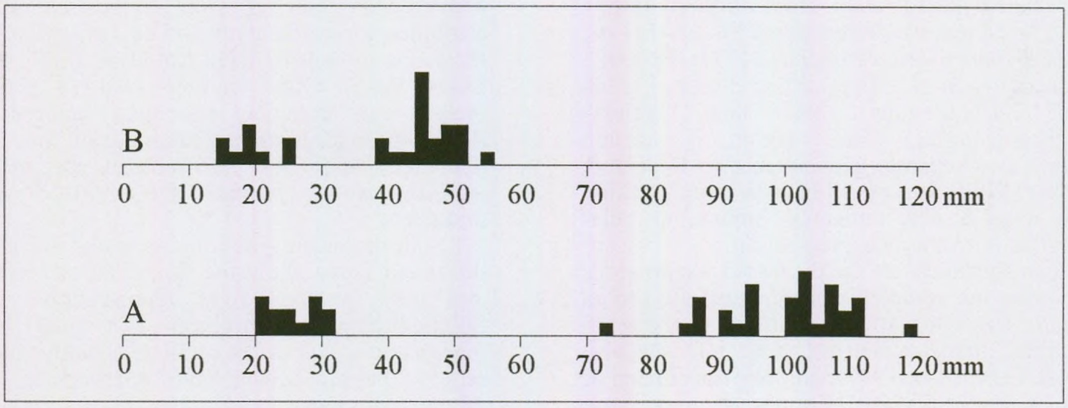


Fig. 2. Final diameters of shells (A) and final phragmocone diameters (B) of – *Asphinctites tenuiplicatus* (grey) and *Polysphinctites secundus* (black) from Central Poland.

Palaeogeographic distribution of *Asphinctites – Polysphinctites* ammonite faunas

Two ammonite faunas consisting of *Asphinctites* and *Polysphinctites* may be recognised in the Lower Bathonian in Europe (see e.g. MANGOLD 1970; PAGE 1996; DIETZE et al. 1997; DIETZE & CHANDLER 1997): (1) an older fauna of *Asphinctites pinguis* (DE GROSSOUVRE)/ *Asphinctites replictum* (BUCKMAN) (M) – *Polysphinctites polysphinctus* BUCKMAN (m) and allied forms in the Zigzag Zone, as well as (2) a younger fauna of *Asphinctites tenuiplicatus* (BRAUNS)/ *Asphinctites patrulii* HAHN (M) – *Polysphinctites secundus* (WETZEL) (m) and allied forms in the Tenuiplicatus Zone. These two ammonite faunas show a special palaeogeographic distribution depending on type of a shell (macro– and microconchs), as well as on final size of the specimens belonging to the same morph (see also MATYJA & WIERZBOWSKI 2000 b). The detailed analysis of the distribution of the two faunas is presented and discussed below (see Fig. 3).

Fauna of *Asphinctites pinguis* (DE GROSSOUVRE)/ *Asphinctites replictum* (BUCKMAN) – *Polysphinctites polysphinctus* BUCKMAN and allied forms

This fauna is poorly known in Poland, including a specimen referred to as "*Morphoceras pinguis* (DE GROSSOUVRE)" reported (but not illustrated) together with *Zigzagiceras zigzag* (D'ORBIGNY) and *Morphoceras polymorphum* (D'ORBIGNY) = *M. multiforme* ARKELL by RÓŻYCKI (1953, p. 105) from the Rudniki section south of Częstochowa, and a specimen of *Polysphinctites polysphinctus* (BUCKMAN) from the vicinity of Częstochowa (KOPIK 1998, p. 85). The fauna itself is, however, widely known from different parts of Europe, and even outside of it (Iran).

The macroconchs include *Asphinctites pinguis* (DE GROSOUVRE 1919) as based on original illustration of DE GROSSOUVRE (1919, pl. 14, fig. 7ab – holotype; refigured in ARKELL 1955, Text–fig. 49, left), and a very close if not conspecific *Asphinctites replictum* (BUCKMAN 1922), see also ARKELL (1955, pl. 16, fig. 9ab; 10ab – refigured holotype). The relation of the two forms were discussed recently by PAGE (1996) and DIETZE et al. (1997); see also synonymy of *A. pinguis* in MANGOLD (1970) and SANDOVAL (1983). For full synonymy of microconch *Polysphinctites polysphinctus* see e.g. HAHN (1970, p.56) with some corrections by DIETZE et al. (1997, p. 14).

The macroconchs as well as microconchs of the discussed ammonite fauna are distinguished from those of a younger *Asphinctites – Polysphinctites* fauna by presence of strong constrictions, and the macroconchs themselves additionally by more involute middle whorls. The discussed macroconchs (*A. pinguis/A. replictum*) as well as closely related macroconchs from northern Iran – such as *Pseudodimorphinites komsi* SEYED–EMAMI and *Pseudodimorphinites foersteri* SEYED–EMAMI – were placed by SEYED–EMAMI (in: SEYED–EMAMI et al. 1989) in his new genus– *Pseudodimorphinites*. This taxon is treated sometimes as a separate genus (see also DIETZE & CHANDLER 1997), but possibly it is more justified to treat it as a new subgenus embracing older *Asphinctites* forms, as accepted herein.

English specimens of the discussed *Asphinctites* include only one complete specimen referred to as *A. pinguis* (DE GROSSOUVRE) attaining about 45 mm in final diameter (DIETZE pers. inf., see also DIETZE & CHANDLER 1997), and two specimens of *A. replictum* (BUCKMAN) – about 64 mm , and about 70 mm in final diameters, respectively (ARKELL 1955, pl. 16, figs 9ab; DIETZE pers. inf., see also DIETZE & CHANDLER 1997). The maximum diameters of two fully–grown English specimens of *Polysphinctites polysphinctus* BUCKMAN range from 34 (MANGOLD 1970, pl. 7, fig. 21) to 39.5 mm (ARKELL 1955, pl. 16, fig. 8), whereas the corresponding end–diameters of phragmocones in both specimens equal about 22 mm. Other English specimens of *P. polysphinctus* and *A. replictum*, including the holotypes of the two forms (see ARKELL 1955, pl. 16, figs 7 and 10, respectively) are either incomplete or not fully–grown.

Of the most often cited French specimens is the holotype of *A. pinguis* (DE GROSSOUVRE) coming from the Niévre area at the southern border of the Paris Basin (DE GROSSOUVRE 1919, pl. 14, fig. 7ab). It is an incomplete specimen about 45 mm in diameter devoid of the body–chamber, and thus about one whorl longer when complete (MANGOLD 1970, p. 111): hence, the original diameter of this specimen may be calculated as about 65–70 mm. Other specimen of *A. pinguis* found more towards south, in the Barrême area of south–eastern France (MANGOLD 1970, pl. 3, fig. 13–14), is nearly complete (but without final peristome preserved); it is 68 mm in maximum diameter with end of phragmocone at 44 mm diameter. The corresponding microconchs *Polysphinctites polysphinctus*/ cf. *polysphinctus* were reported (but not illustrated) from the Niévre area (ZANY et al. 1995, p. 50), and from the French Jura Mts.(MANGOLD 1970, p. 114). In Portugal, the ammonites in question are poorly known: beside a single specimen of *Asphinctites pinguis* 26 mm in diameter representing the inner whorls only, there have been reported, but not illustrated specifically indeterminable specimens of *Polysphinctites* (see MANGOLD 1970, p. 111; MANGOLD 1979, p. 279).

The ammonites of the discussed fauna are recognised in southern Germany (Franconian and Swabian Albs, Oberpfalz area) where a few findings of *Polysphinctites polysphinctus* BUCKMAN come from. Two illustrated specimens of this form (SCHAIRER 1994, fig. 1; DIETZE & SCHWAIGERT 2000, pl. 2, fig. 2) are 35 mm and 37 mm in final diameters, respectively. Some specimens specifically indeterminable represented by inner whorls with strongly developed constrictions coming from this area may be attributed to *Asphinctites* and/or *Polysphinctites* of the fauna in question (DIETZE et al. 1997; see also DIETL 1986). Other findings (DIETZE pers. inf.) include one complete specimen referred to as *Asphinctites* cf. *replictum* attaining 68 mm in final diameter, and two incomplete specimens of *Asphinctites* cf. *pinguis* about 50–55 mm in diameters.

Both the macro– and microconchs of the above discussed fauna show the fairly uniform character and may be treated as representative of the Submediterranean Province. The final size of macroconchs seems to oscillate usually about 60 mm to 70 mm, whereas that of microconchs – about 35 mm to 40 mm.

Quite different in character assemblage of ammonites corresponding to the discussed fauna is recognised in the Mediterranean Province. In the Digne–Barrême area of south–eastern France, beside a single fairly large specimen of *Asphinctites pinguis* attaining 68 mm in final diameter discussed above, two other fully–grown specimens are of somewhat smaller sizes: from 49 mm in final diameter (STURANI 1966, p. 37, fig. 3ab; see also TORRENS 1987, pl. 2, fig. 4ab) to about 55 mm in final diameter (TORRENS 1987, pl. 2, fig. 3). In the Betic Cordillera of southern Spain both the species *Asphinctites replictum* (BUCKMAN) and *Asphinctites pinguis* (DE GROSSOUVRE) have been recognised (SANDOVAL 1983, pp. 357–359, pl. 28, figs 3, 5, 8–9). The complete specimens of the latter range from about 45 mm to 59 mm in final diameters (SANDOVAL 1983, p. 359, pl. 28, fig. 3); on the other hand, the specimens referred to as *A. replictum* are less complete – only a single specimen attaining about 36 mm in diameter (SANDOVAL 1983, pl. 28, fig. 8) shows a marked uncoiling of the last whorl what suggests it is mature. The smallest fully–grown specimen of *Asphinctites pinguis* was described from the Northern Limestone Alps in northern Austria (KRYSTYN 1972, pp. 264–265, pl. 8, fig. 4): it attains about 30 mm in final diameter only. None of the discussed areas yielded any well–documented (described or illustrated) specimens of *Polysphinctites*. The only possible indication on the occurrence of this forms comes from the Betic – Subbetic zones of southern Spain where a few specimens of *Polysphinctites* sp. have been recorded but not illustrated (MANGOLD 1979, p. 272; SANDOVAL 1983, p. 139).

Some representatives of *Asphinctites* were described from SE–Alborz area in northern Iran under the new genus name *Pseudodimorphinites* by SEYED–EMAMI (see SEYED–EMAMI et al. 1989; see also remarks above): these include such forms as *Asphinctites* (*Pseudodimorphinites*) *komsi* (SEYED–EMAMI) fully–grown at about 36 mm or even at somewhat smaller diameter, and showing the phragmocone/body–chamber boundary already at 20 mm diameter (SEYED–EMAMI et al. 1989, p. 85, pl. 1, figs 15–16), as well as *A.* (*P.*) *foersteri* (SEYED–EMAMI) which holotype is fully–grown at about 28 mm diameter and shows the phragmocone/body–chamber boundary at about 17 mm diameter (SEYED–EMAMI et al. 1989, pp. 85–86, pl. 1, fig. 14). Other, but incomplete specimens of *Asphinctites* represented by pyritized phragmocones were described from Central Iran, from the Tabas–Nayeband area (SEYED–EMAMI et al. 1991): the largest of them referred to as *Pseudodimorphinites pinguis* (DE GROSSOUVRE) = *Asphinctites* (*Pseudodimorphinites*) *pinguis* (DE GROSSOUVRE) is 22 mm in diameter (SEYED–EMAMI et al. 1991, pl. 4, fig. 11). It should be remembered that the only specimens referred to as *Polysphinctites* cf. *polysphinctus* BUCKMAN by SEYED–EMAMI et al. (1991, pl. 4, figs 14–15) are possibly too small for unequivocal interpretation: they attain only about 13–14 mm in diameter and they could represent the inner whorls of *Polysphinctites* and/or *Asphinctites* as well.

Fauna of *Asphinctites tenuiplicatus* (BRAUNS)/*Asphinctites patrulii* HAHN – *Polysphinctites secundus* (WETZEL) and allied forms

Several forms such as *Asphinctites recinctus* BUCKMAN 1924 (holotype refigured by ARKELL 1955, Text–fig.51), *Asphinctites* (= "*Morphoceras*") *transylvanicum* DE GROSSOUVRE 1919 (non SIMIONESCU 1905) – see DE GROSSOUVRE (1919, pl. 15, figs 1–2ab), *Asphinctites* (= "*Siemiradzkia*") *bajociformis* ARKELL 1951 (see ARKELL 1951, pl. 3, fig. 1ab), *Asphinctites bathonicus* WESTERMANN 1958 (see WESTERMANN 1958, pl. 46, fig.4a–c), *Asphinctites gaertneri* WESTERMANN 1958 (see WESTERMANN 1958, pl. 46, fig.3a–c), are considered as synonymous with *Asphinctites tenuiplicatus* (BRAUNS 1865) itself (see HAHN 1970; MANGOLD 1970; TORRENS 1987; PAGE 1996; DIETZE et al. 1997; see also full lists of synonymy in: HAHN 1970, p. 5; and DIETZE et al. 1997, p. 12). All the indicated specimens show markedly evolute coiling of inner and middle whorls, and relatively weakly–developed constrictions (see e.g. DIETZE et al. 1997). *Asphinctites patrulii* HAHN 1970 (see HAHN 1970, pp.53–55, pl. 8, figs 1–4, as well as the Rumanian specimen illustrated by PATRULIUS 1969, pl. 1, fig. 5ab put in synonymy of that form) is also close to *Asphinctites tenuiplicatus* but differs by having a more dense and fine ribbing (see HAHN 1970; TORRENS 1987; DIETZE et al. 1997).

Polysphinctites secundus (WETZEL 1950) the microconch counterpart of *A. tenuiplicatus* includs the vast list of formerly illustrated specimens as shown by HAHN (1970 p.57) and DIETZE et al. (1997, p.14). These specimens reveal strongly evolute coiling of whorls, and poorly marked constrictions (DIETZE et al. 1997). It should be remembered that some specimens attributed to *P. secundus*, such as those illustrated by TORRENS (1987, pl. 2, fig. 8ab), are too small for unequivocal interpretation: they do not show any modification of ribbing observed in fully–grown specimens of *Polysphinctites* (see MATYJA & WIERZBOWSKI, 2000a), and thus they could represent as well the innermost whorls of *Asphinctites*.

The largest macroconchs and microconchs of the discussed fauna are recorded from Central Poland (see MATYJA & WIERZBOWSKI, 2000 a, b; as well as the preceding chapter herein): the maximum diameter of the fully–grown macroconchs of *Asphinctites tenuiplicatus* ranges here between 72 and 119.5 mm (the median diameter is 103.1 mm), whereas that of the phragmocone is between 38.9 and 57.0 mm (the median diameter is 47.2 mm); the maximum diameter of fully–grown microconchs of *Polysphinctites secundus* ranges between 24.5 and 34.5 mm (the median diameter is 27.6 mm) whereas that of the phragmocone is between 14 and 27 mm (the median value is 19.7 mm).

In other areas of Europe the size variablity of the ammonites of the fauna is less known and could be deduced mostly from limited number of figured specimens. Nevertheless, general trends appear rather obvious.

In north–west Germany the only fully–grown specimens of *Asphinctites tenuiplicatus* (= *A. bathonicus* in: WESTERMANN 1958, p. 88, pl. 46, fig. 4a–c) is about 70 mm in close to maximum diameter, and 43 mm in phragmocone maximum diameter: all other specimens are not complete phragmocones about 35 mm in diameters, and hence not useful in general considerations on the end–size of this form. Of three fully–grown specimens of *Polysphinctites secundus* illustrated so far from north–west Germany, the largest one referred to as *P* cf. *secundus* by HAHN (1970, pl. 8, fig. 13) attains about 30 mm in final diameter, and 19 mm in maximum phragmocone diameter; two other specimens (lectotype of *P. secundus*, see SCHLOENBACH 1865, pl. 29, fig. 3ab, and specimen illustrated by WESTERMANN 1958, pl. 46, fig. 2a–c; see also HAHN 1970, p. 58) although devoid of final part of the body–chambers, show the presence of crowded septa marking the end of phragmocone already at 13 mm diameter (HAHN 1970, p. 58).

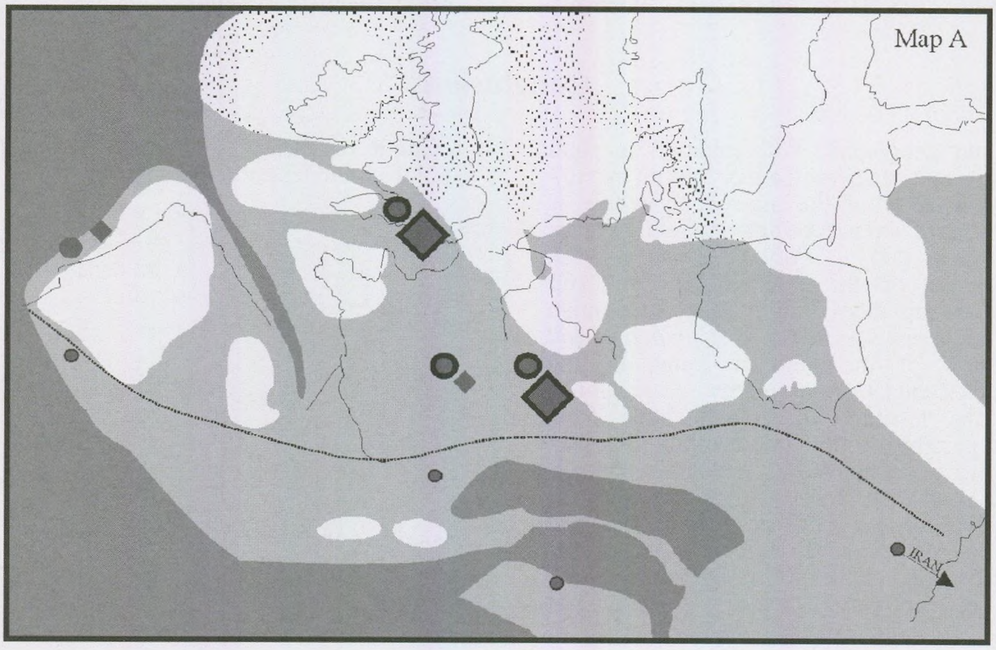
Three fully–grown specimens of *A. tenuiplicatus* from south–western Germany (Swabian and Franconian Albs) as illustrated by HAHN (1970, pl. 7, figs 1, 4, and pl. 8, fig. 1)) are between 68 mm and 79 mm in final diameters, and show the phragmocone/body–chamber boundaries at about 35 mm to 45 mm diameters. Similar size is shown also by the fully–grown (although devoid of final peristome) specimen of *A. tenuiplicatus* (=" *Siemiradzkia* " *bajociformis*) illustrated by ARKELL (1951, p.13, pl. 3, fig. 1ab): its final size ranges about 70 mm, and the phragmocone/body–chamber boundary is at about 45 mm diameter. The specimens illustrated by DIETZE et al. (1997, pl. 2) from Oberpflaz area in south–eastern Germany are mostly incomplete, and hence they have not to be smaller when fully–grown as suggested therein, in comparison with the specimens from south–western Germany. The largest ones (DIETZE et al. 1997, pl. 2, figs 1 and 8) show a marked uncoiling of the last whorl at about 45 mm and 55 mm, but still they do not reveal any decrease in whorl–height what is typical feature of fully–grown *A. tenuiplicatus*. Another specimen about 30 mm in diameter interpreted by DIETZE et al. (1997, p. 13, pl. 3, fig. 3) as "the completely preserved form with aperture" differs in its size and type of coiling from all the other specimens of *A. tenuiplicatus* (see e.g. DIETZE et al. 1997, pl. 1) and its systematic interpretation seems somewhat unclear. A few specimens of *A. tenuiplicatus* from the north–eastern Swabian Alb show fairly large end–sizes similar to those of the Polish specimens (DIETZE, pers. inf.). The illustrated specimens of *P. secundus* from south–western Germany (HAHN 1970, figs 7–13; SCHLEGELMILCH 1985, pl. 37, figs 2–3; see also DIETZE et al. 1997) are generally small, about 18 to 25 mm when fully–grown, and show the end of phragmocone marked by crowded septa already at 11–13 to 16 mm diameters. The specimens of *P. secundus* from the Oberpfalz area of south–eastern Germany (DIETZE et al. 1997, pl. 1, figs 5–11) are from 16 to 27 mm in final diameters showing the end of phragmocone from about 10 to 16 mm diameters.

From the aforegoing one may suggest that the German ammonites are in average smaller than those described from Central Poland, but nevertheless the total ranges of size variability both for macroconchs and microconchs in the two areas partly overlap. It is difficult to evaluate precisely the median end–sizes of *Asphinctites tenuiplicatus* and *Polysphinctites secundus* on the base of German material so far illustrated. It may be, however, suggested that the median value for *A. tenuiplicatus* in Germany should oscillate around 70 mm, and that for *P. secundus* about 20 mm. These values are about 30% smaller than the corresponding values recognised in Central Poland. The data enable distinguishing of the two assemblages of *Asphinctites tenuiplicatus–Polysphinctites secundus* in Submediterranean Europe differing in median sizes of macro– and microconchs – the larger–sized assemblage from central Poland, and the smaller–sized one from Germany.

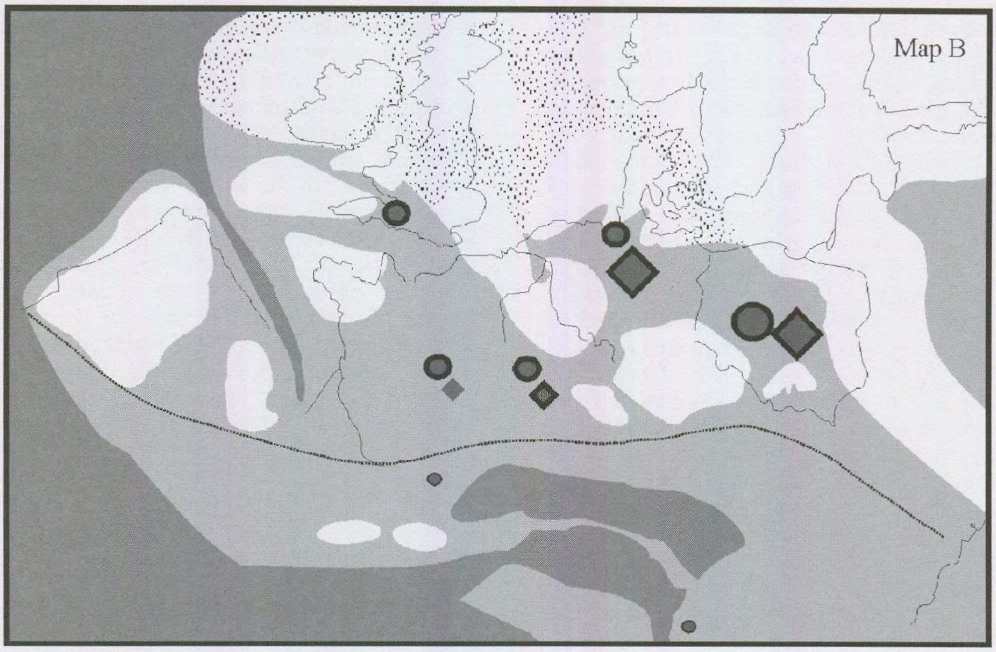
The representatives of the *A. tenuiplicatus – P. secundus* fauna are also known from other Submediterranean areas of western and north–western Europe, from England and France. The English specimen of *A. tenuiplicatus* (= *A. recinctus* BUCKMAN, see ARKELL 1955, Text–fig. 51) is about 64 mm in diameter, but although fully–grown it has not preserved the final peristome – thus, it end–size could be around 70 mm. The specimen is considered as the only undoubtful evidence of the Tenuiplicatus Zone in Britain (TORRENS 1980, fide PAGE 1996, see also DIETZE & CHANDLER 1997). The specimens of *A. tenuiplicatus* (= "*Morphoceras*" *transylvanicum* of DE GROSSOUVRE 1919, pl. 15, figs 1–2) coming from the Niévre area at the southern border of the Paris Basin are from about 50 to 52 mm in diameter, and although incomplete they show uncoiling of the last whorl. Another specimen of *A. tenuiplicatus* (see MANGOLD & RIOULT 1997, pl. 16, fig. 7) from the French Jura Mts is about 50 mm in diameter but still incomplete with missing part of the last whorl. The form *Polysphinctites* cf. *secundus* has been recorded from the Nièvre area (ZANY et al. 1995) but without any description or illustration. The discussed fauna from England and France, although poorly known, in its composition and final–sizes of the specimens seems close to coeval assamblege of *A. tenuiplicatus P secundus* from Germany, as discussed above.

Quite different character of the coeval ammonite fauna is stated in areas of southern and south–eastern France corresponding to the Mediterranean Province. The fauna consists of small–sized *Asphinctites*, both *Asphinctites tenuiplicatus* (BRAUNS) and allied *Asphinctites patrulii* HAHN. It is especially well recognised in the Digne–Barrême area of south–eastern France (STURANI 1966; TORRENS 1987). These specimens referred sometimes with reservation to *A. tenuiplicatus* (= *A. recinctus* in STURANI 1966, pp. 37–38, pl. 10, fig. 2ab, pl. 11, fig. 9; see also HAHN 1970, p. 53) are complete already at about 45 mm in diameter, and have body–chambers slightly more than a whorl long, thus showing the phragmocone/body–chamber boundary at about 20 – 22 mm. Another specimen possibly related to *A. tenuiplicatus* (*A.* aff. *tenuiplicatus* of TORRENS 1987, pl. 2, fig. 7; see also DIETZE et al. 1997) is about 45 mm in (?) final diameter. The specimens referred to as *A.* aff. *patrulii* HAHN by TORRENS (1987, p. 98, pl. 2, figs 5–6, 9–12) fall within the *A. tenuiplicatus* group, and some of them (pl. 2, figs 10–12) are fully–grown as shown by their markedly uncoiled last part of the whorls attaining from about 37.5 to about 43 mm in final diameter.

Other specimen of *A. patrulii* (= *Asphinctites transsylvanicus* of PATRULIUS 1969, pl. 1, fig. 5ab and earlier illustration of this specimen indicated in HAHN 1970, p.53) comes also from the Mediterranean Province – from the Bucegi Massive in Rumanian Carpathians: it has about 40 mm in diameter and seems fully–grown, although the final peristome is not preserved. It should be remembered, however, that the form *A. patrulii* is known also from south–western Germany corresponding to the southern part of the Submediterranean Province (southern Swabian Alb; see HAHN 1970, pp. 53–55, pl. 8, fig. 1ab): the specimen is fully–grown about 43 mm in final diameter (although without final peristome) having about 2/3 whorl long body–chamber which begins at 28 mm diameter.



1 2 3 4 5



1 2 3 4 5

Fig. 3. Palaeogeographic maps (compiled from CARIOU et al. 1985, and GOLONKA et al., 2000; partly modified) of the distribution of the *Asphinctites* (circles) – *Polysphinctites* (diamonds) faunas during Early Bathonian. 1 – land with prevailing erosion, 2 – areas of non–marine or brackish sedimentation, 3 – epicratonic seas, 4 – ocean basins, 5 – northern boundary of the Mediterranean Province
Map A. *A. pinguis*/*A. replictum* – *P polysphinctus* and allied form fauna
Map B: *A. tenuiplicatus*/*A. patrulii* – *P secundus* and allied form fauna
Size of symbols indicates relative size of ammonites; not–framed symbols correspond to ammonites of unknown size.

From the aforegoing it becomes evident that the third discussed assemblage of the considered ammonite fauna typical of the Mediterranean Province consists of the smallest–sized macroconchs of *A. tenuiplicatus – A. patrulii* ranging from about 37.5 to about 45 mm in final diameters, and is completely devoid of *Polysphinctites*–type microconchs.

Conclusions

A marked geographic differentiation in final sizes of shells and occurrence either of both macro– and microconchs or of the macroconchs only is recognised within two succeeding ammonite faunas of *Asphinctites* (M) – *Polysphinctites* (m) in particular areas of the Submediterranean and Mediterranean provinces during Early Bathonian (Fig. 3). The largest specimens of *Asphinctites* and *Polysphinctites* of the younger fauna of the Tenuiplicatus Zone (*A. tenuiplicatus – P secundus*) found in the territory of Poland come from peripheral, possibly highly stress–influenced, and thus showing to some degree endemic character part of the Submediterranean Province. Somewhat smaller representatives both of *Asphinctites* and *Polysphinctites* of the two ammonite faunas are widely distributed in bulk of the Submediterranean Province in Europe, whereas the smallest *Asphinctites* to the almost total absence of *Polysphinctites* are stated in the Mediterranean Province. These phenomena may be related with changing environmental conditions which influenced the ontogenic development of the ammonites what could result in time of maturation (as expressed by shell size) and existence of particular number of morphs (see MATYJA 1986).

The observed tendency to decrease in final size of *Asphinctites* macroconchs and *Polysphinctites* microconchs (including the complete disappearance of the latter) from Submediterranean Province to Mediterranean Province is more difficult for unequivocal detailed explanation. The phenomenon may be related with earlier maturation of ammonites towards lower latitudes, and replacing in that direction of two morphs by a single morph as a consequence of smaller contrast in seasonality of the environment (see MATYJA 1986). There are evidences from studies of some modern cepahalopods, especially modern squids (ZUEV et al. 1979; NESIS & NIGMATULLIN 1979), that marked difference in size of fully mature animals of the same sex, depends on environmental conditions, mostly the temperature of the sea–water. The squids from the tropical Atlantic attain their maturity at fairly small size in sea–water of higher temperature, whereas the same forms may attain maturity at larger size at the periphery of their geographic range as a consequence of delayed maturation in sea–water of lower temperature (Fig. 4). Similarly, we suggest that ammonites of the *Asphinctites–Polysphinctites* group which lived in remote areas of the Submediterranean Province, as in the discussed case of ammonites from Central Poland, could have reached their maturity at larger sizes due to lower temperature of sea–water.

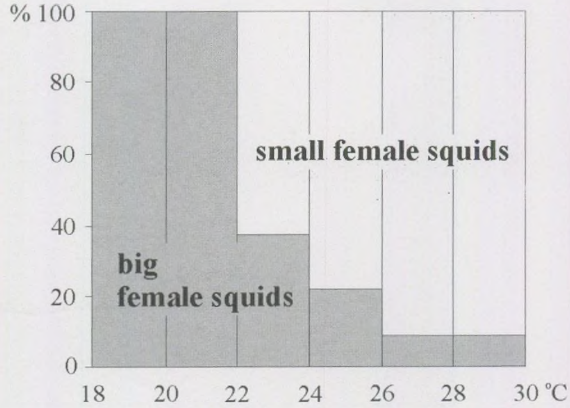


Fig. 4. Percentage of small sized and large sized mature females of the squid *Sthenoteuthis pteropus* versus sea–water temperature in eastern part of Central Atlantic (based on data of ZUEV et al. 1979)

Another possible explanation of the phenomenon could be the difference in rate of shell growth in particular areas or even the difference in size of ammonitella, which may be also related with changing environmental conditions (cf. MATYJA & WIERZBOWSKI, 2000c). The problem cannot be solved unequivocally without recognition of the growth rate of the ammonite shell expressed e.g. by septal density during ontogeny in ample number of specimens coming from different areas (see e.g. MATYJA & WIERZBOWSKI, 2000c, and earlier papers cited therein). The number of septa per whorl is known so far only for some Polish large specimens of *Asphinctites tenuiplicatus* (BRAUNS) and *Polysphinctites secundus* (WETZEL), and for a few specimens representing the incomplete phragmocones of small–sized *Asphinctites pinguis* (DE GROSSOUVRE) and allied forms from Central Iran (Text–fig. 3); in both cases the number of septa per whorl is similar, from 11 to 13 septa per whorl at 17 mm to about 45 mm diameters in Polish specimens (see chapter on Polish fauna herein), and from 10 to 11 septa per whorl at 11 to 21.5 mm diameters in Iranian specimens illustrated by SEYED–EMAMI et al.(1989, pl. 4, figs 10, 11, 15, after personal information from G.SCHAIRER), what suggests a similar growth–rate and marked differences in time of maturation of ammonites between the two areas.

Acknowledgements

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Plates

Plate 1

Asphinctites tenuiplicatus (BRAUNS)

Figs 1–4. Inner whorls and/or immature specimens, 1– No. IGPUW/A/38/9, 2 – No. IGPUW/A/38/39, 3 – No. IGPUW/A/38/5, all from Leszczyński's brick–pit level K, 4 – No. IGPUW/A/38/40 from Faustianka brick–pit level 0.

Figs 5–8. Fully–grown specimens, collection of K. DEMBICZ and T. PRASZKIER from Faustianka brick–pit, level 0.

All specimens in natural size

Plate 1

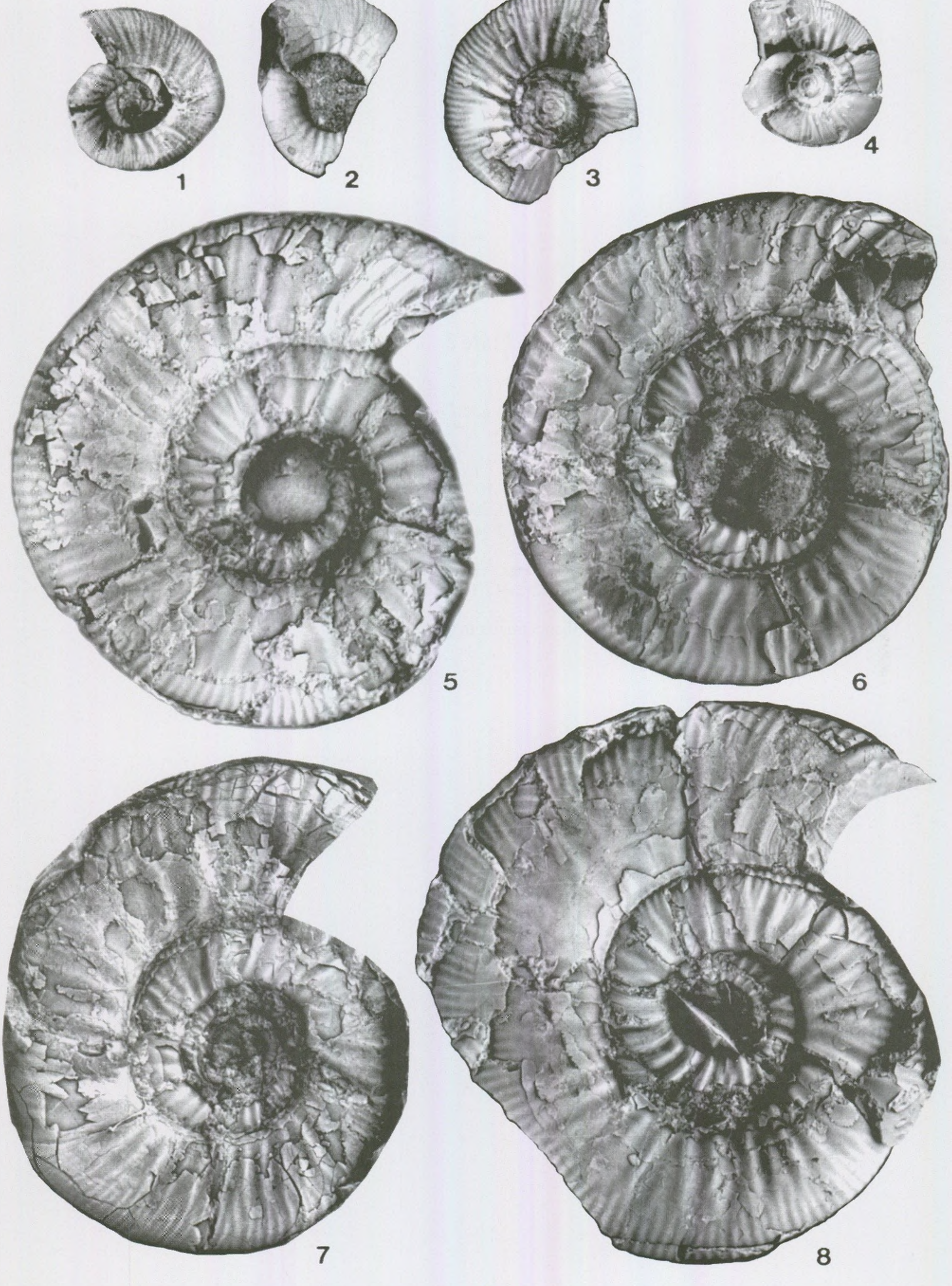


Plate 2

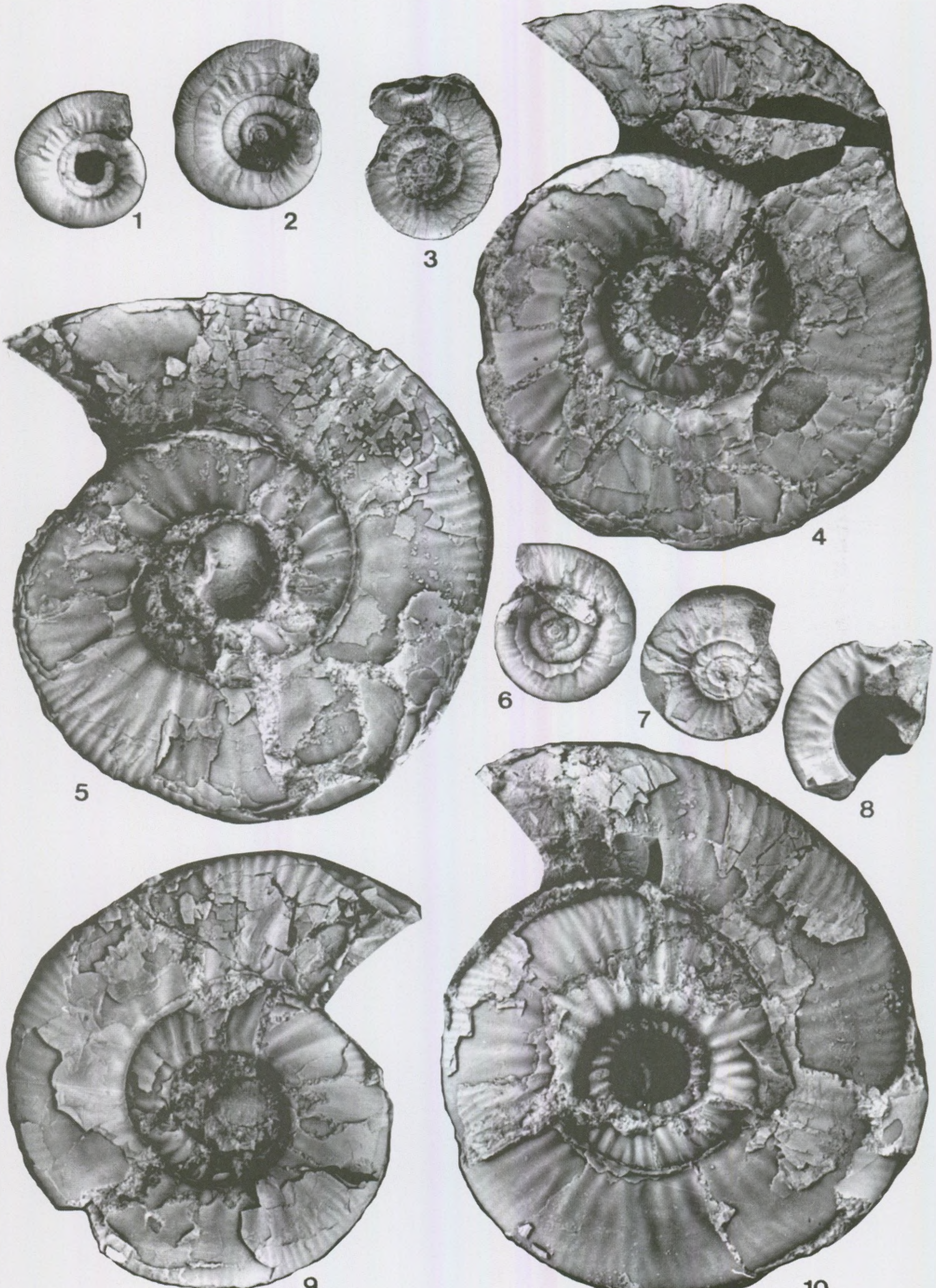
Asphinctites tenuiplicatus (BRAUNS) and *Polysphinctites secundus* (WETZEL)

Figs 1–3 and 6–8. *Polysphinctites secundus* (WETZEL), 1– No. IGPUW/A/38/7, 2 – No. IGPUW/A/38/13, 3 – No. IGPUW/A/38/6 and 6 – No. IGPUW/A/38/12, 7 – No. IGPUW/A/38/8a all from Leszczyński's brick–pit level K, 8 – No. IGPUW/A/38/28 from Faustianka brick–pit level 0

Figs 4, 5 and0 9, 10. *Asphinctites tenuiplicatus* (BRAUNS) fully–grown specimens, collection of K. DEMBICZ and T. PRASZKIER from Faustianka brick–pit, level 0

All specimens in natural size

Plate 2



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Distribution of the Bajocian–Bathonian ammonites in the South–West chains of Hissar Range

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(With 2 figures and 9 plates)

The stratigraphical distribution of the Bajocian and Bathonian ammonitids in the South–West Hissar range (Central Asia) is reviewed. The figures of the major taxas, including types of species, described on the local material, are given.

Introduction

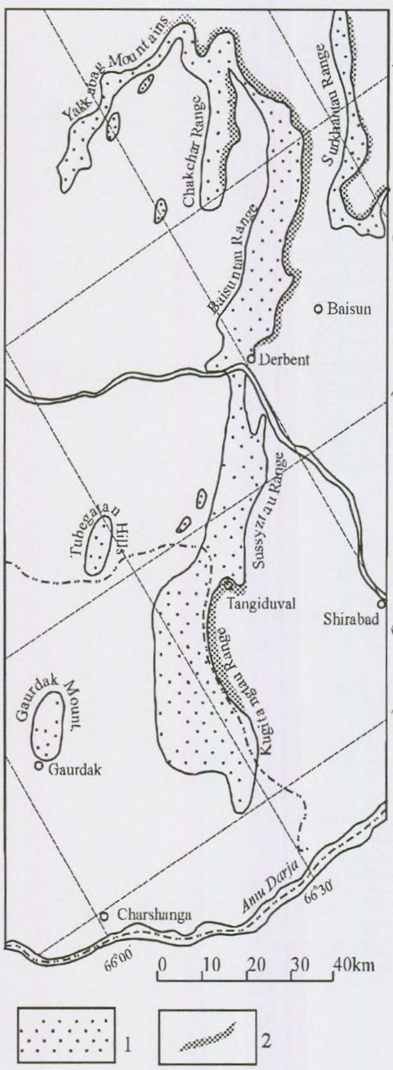

Fig. 1 Jurassic outcrops in the South–West chains of Hissar range: 1 – Callovian and Upper Jurassic, 2 – Bajocian and Bathonian.

Hissar range is located in Central Asia. It crosses through the territory of three states: Uzbekistan, Turkmenistan and Tadzhikistan. The South–West chains of Hissar range are mostly located in Uzbekistan and consist of the Yakkabag mountains, the Chakchar Range, the Baisuntau Range, the Surkhantau Range and the Sussyztau Range. The border between Uzbekistan and Turkmenistan follows the ridge of the southern range – Kugitangtau Range. Gaurdak Mountains and Tubegatan Mountains are located to the west from the Kugitangtau Range (Fig. 1).

The South–West chains of Hissar Range is one of the unique places in the world where we can observe a thick continuous section of the Middle Jurassic deposits. The Bajocian and specially the Bathonian rocks are represented here by predominantly marine carbonate deposits, which contain ammonites (Fig. 2).

The first description of Jurassic ammonites from the South–West Hissar Range was made by NIKITIN (1889) – *"Perisphinctes" bucharicus* [= *Procerites (Siemiradzkia) bucharicus* (Nikitin). This ammonite, initially considered as Callovian, appeared to be from Bathonian, as it was shown by AMANNIYAZOV (1967).

Subsequently Jurassic ammonites of South–West Hissar for a long time practically were not subjected to monographics analysis. Only in the second half of the XXth century, when in the Republic of Turkestan republics of the former USSR the extensive geologic works were unrolled, geologists had paid their attention to the Jurassic deposits of this region.

There were a few publications on the Bajocian–Bathonian ammonites of the South–West Hissar. Descriptions and figures of the separate taxas were published in small papers: KRYMHOLTS & ZAKHAROV 1971; KUTUZOVA 1975; BESNOSOV & KUTUZOVA 1975; 1982;

BESNOSOV 1982. But quality of illustrations was often unsatisfactory.

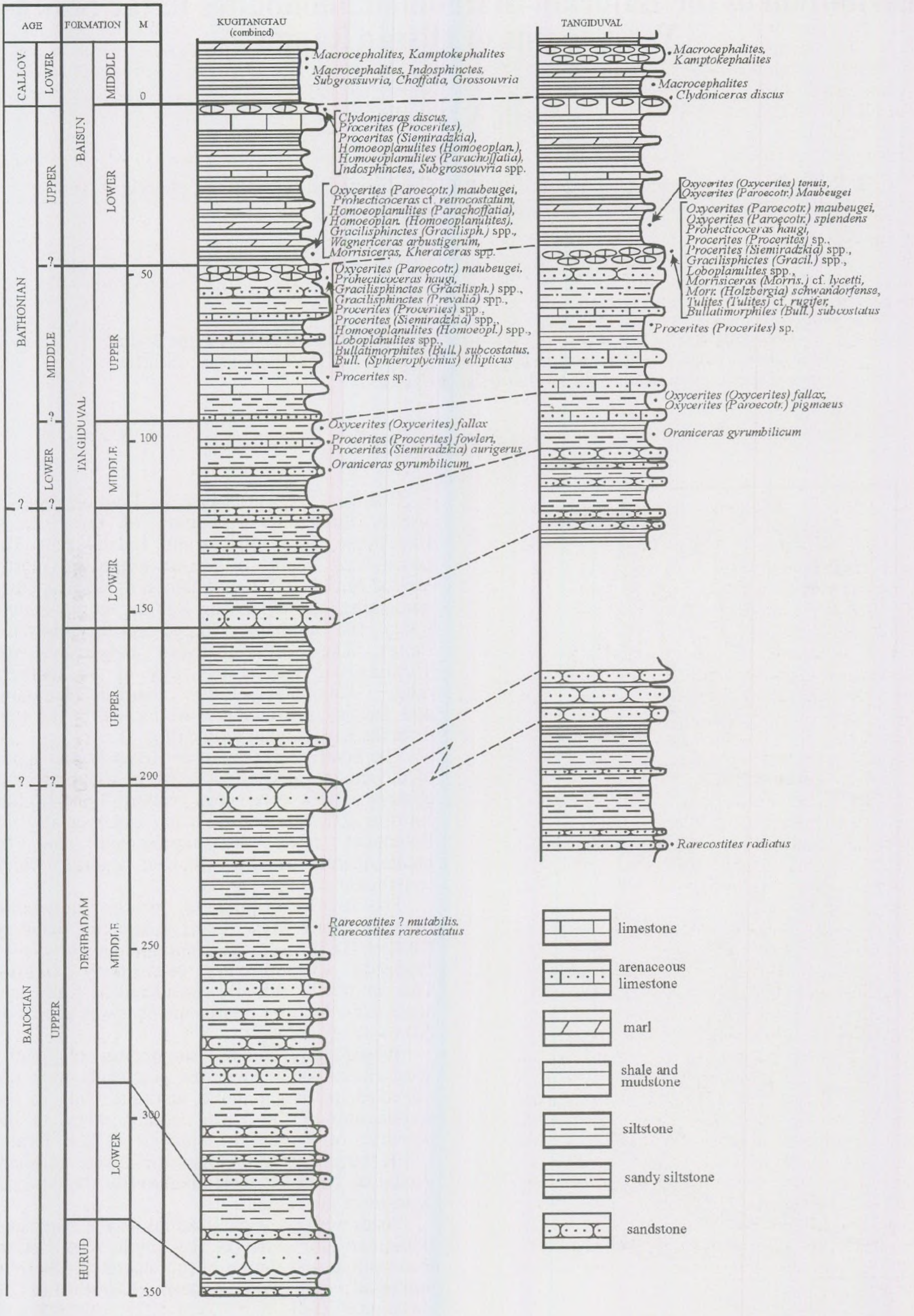

Fig. 2. Distribution of Bajocian and Bathonian ammonitids in the key sections of South–West Hissar: Kugitangtau range (combined) and Tangiduval village.

From the end of 60s to the beginning of 90s collections of Jurassic ammonites of Central Asia predominantly were concentrated in VNIGNI. These are collectings of collaborators of the Institute – N.V. BESNOSOV, V.V. KUTUZOVA, N.K. FORTUNATOVA, I.G. MIKHEEV, V.V. MITTA, and also geologists from Turkmenistan and Uzbekistan, first of all by V.V. KURBATOV from Tashkent and others, who sent ammonites for study and identification to the Institute. Thus, when the author together with the late N.V. BESNOSOV initiated the monographic treating of the Bajocian–Bathonian ammonites of Central Asia, in our disposal there were the richest collections from this area. As a result we published the monograph on the Upper Bajocian and Bathonian ammonitids of Central Asia and Northern Caucasus (BESNOSOV & MITTA 1993). The considerable large part of this work is compounded with ammonites from South–West Hissar. Unfortunately, poor quality of the images and numerous misprints decrease the value of this publication.

The main purpose of the present paper is to publish the valid images of the major taxas of ammonites, first of all of types of species, and to give representation of their vertical distribution. All errors and misprints in the monograph mentioned above, including designations of the types of species, are refined here.

The author carried out the field works in Central Asia (including the South–West chains of Hissar Range) in 1987–1991. However, five field seasons are not enough for complete stratigraphic study of Jurassic deposits of this territory, which is very complicated in geological sense. So not all the presented data are the achievements of the author. However it represents the recent state of our knowledge on ammonites biostratigraphy of the Bajocian–Bathonian deposits of South–West chains of Hissar Range.

Bajocian–Bathonian Formations and ammonites in South–West Hissar

Lithostratigraphic subdivisions are the most suitable units for geologists working on Mesozoic of Central Asia. If we take in account that the determinable ammonites are connected with few levels of thick sections, we may consider that it is also very suitable for biostratigraphers.

The Bathonian and partly the Bajocian, deposits of South–West Hissar are exposed as interrupted chain of outcrops in the eastern slopes of Kugitangtau Range, Baisuntau Range, Surkhantau Range and Chakchar Range and also in the northern part of the Yakkabag Mountains.

The deposits of our interest belong to three Formations: Degibadam, Tangiduval and Baisun. Each of them is divided onto three members.

The Degibadam Formation (Upper Bajocian and possibly the lowest Bathonian) is laying with washout on continental deposits of the Hurud Formation. In places, where the later one is absent, the former one is transgressively covered under Jurassic deposits.

The Lower Degibadam Member is represented by alternation of marine–coastal and continental–coastal slightly coal–bearing sandstone, aleurolite and argillite with thickness up to 25–30 metres. Ammonites have not been found here.

The Middle Degibadam Member is built by marine, laminated aleurolite with interbeds and benches of argillite and fine–grained sandstone in the south. Shelf covering sandstone with thickness up to 10 metres are laying in the roof of the Member. It gradually replaces strata of the Member from the south towards the North and transgressively covers the Hurud Formation and under Jurassic deposits. The Member's thickness is up to 150 m. Middle Degibadam Member contains ammonites of the Garantiana zone and possibly of the lower part of the Parkinsoni zone, Upper Bajocian:

Rarecostites rarecostatus (BUCKMAN)
R. radiatum (RENZ)
R. (?) *mutabilis* (NICOLESCO)

The endemic genus *Djanaliparkinsonia* KUTUZOVA, consisted of species *D. lutshnikovi* (KUTUZOVA), *D. tuadaensis* (KUTUZOVA), have been also described from Middle Degibadam Member in the south Baisuntau Range.

The Upper Degibadam Member (suggestively the Parkinsoni Zone) is represented by slightly coal–bearing continental–coastal aleurolite with interbeds of sandstone and argillite. Its thickness is up to 100 m. There are not any ammonites in it.

The Tangiduval Formation (Lower Bathonian – Lowest Upper Bathonian) is laying conformal or with washout on the Degibadam Formation with its different levels.

The Lower Tangiduval Member is represented by fine and irregular alternating fine–grained sandstone, aleurolite and argillite, which was accumulated in coastal flood plain environment. The Member is developed only in the South of the territory and it is pinching out towards the north. Its thickness is up to 25 m. Ammonites have not been found in it.

The Middle Tangiduval Member is made by argillite and argillaceous aleurolite with rare beds of calcareous sandstone and arenaceous detrital limestone with ammonites from the Zigzag Zone (the Macrescens Subzone) of the Lower Bathonian:

Oxycerites (Oxycerites) fallax (GUERANGER)
O. (Paroecotraustes) pygmaeus (ARKELL)
Procerites (Procerites) fowleri ARKELL
P. (Siemiradzkia) aurigerus (OPPEL)
Oraniceras gyrumbilicum (QUENSTEDT)

The Member's thickness is up to 40 m.

In the Kugitangtau Range the Upper Tangiduval Member is formed by calcareous sandy–argillaceous aleurolite with interbeds of detrital limestone and with coquina–lenses consisted of pelecypods and ammonites. To the north aleurolite changes to fine–grained calcareous sandstone. The later one changes to irregularly alternating of sandstone, sandy limestone, conglomerate and coquina–beds. The Member's thickness is up to 80 m.

Only poorly preserved Perisphinctidae have been found in the larger lower part of the Member. Abundant Middle Bathonian ammonites have been discovered in the upper 5–6 metres of the Upper Tangiduval Member. The following forms have been determined among them:

Oxycerites (Oxycerites) oxus (BUCKMAN)
O. (Oxycerites) tenuis MITTA
O. (Paroecotraustes) formosus (ARKELL)
O. (Paroecotraustes) splendens (ARKELL)
O.(Paroecotraustes) subtenuis MITTA
Prohecticoceras haugi (POPOVICI–HATZEG)
Cadomites (Cadomites) orbignyi GROSSOUVRE
C. (Cadomites) zlatarskii STEPHANOV
Procerites (Procerites) lissajousi BESNOSOV
P. (Siemiradzkia) bucharicus (NIKITIN)
Gracilisphinctes (Gracilisphinctes) imitator (BUCKMAN)
G. (Gracilisphinctes) densidecoratus (GALÁCZ)
G. (Gracilisphinctes) evolutus BESNOSOV
G. (Gracilisphinctes) kysylalmensis BESNOSOV
G. (Gracilisphinctes) paragracilis BESNOSOV
G. (Gracilisphinctes) pseudoimitator BESNOSOV
G. (Prevalia) stephanovi BESNOSOV
Loboplanulites subcranaiformis BESNOSOV
L. cerealiformis BESNOSOV
L. zakharovi BESNOSOV
L. choffatiaformis BESNOSOV
Homoeoplanulites (Homoeoplanulites) evolutus BESNOSOV
H. (Homoeoplanulites) paradifficilis BESNOSOV
Tulites cf. *rugifer* (BUCKMAN)
Morrisiceras (Morrisiceras) cf. *lycetti* (ARKELL)
M. (Holzbergia) schwandorfense (ARKELL)
Bullatimorphites (Bullatimorphites) subcostatus BESNOSOV

etc. The burials of ammonites are confined to coquina–lenses in calcareous aleurolite and sandy limestone. In the most cases sampling have not been made enough detailed for determining range of species, which are usually refer to the Subcontractus Zone and the Morrisi Zone and to the lowest Upper Bathonian also. The following forms have been determined from the roof of the Member:

Oxycerites (Paroecotraustes) maubeugei (STEPHANOV)
Gracilisphinctes (Gracilisphinctes) suprapalatinus ARKELL
G. (Prevalia) thressa (STEPHANOV)
G. (Prevalia) verciacensis (LISSAJOUS)
Homoeoplanulites (Homoeoplanulites) rotundatus (ROEMER)
Bullatimorphites (Sphaeroptychius) ellipticus (KRYSTYN)
Kheraiceras (Kheraiceras) cf. *subcosmopolita* (LISSAJOUS).

The Baisun Formation (Upper Bathonian – Lower Callovian) is laying conformal on the Tangiduval Formation. To the north it is transgressively covering more and more ancient beds down to the under Jurassic deposits in the northern part of the territory.

The Lower Baisun Member (Upper Bathonian, Hodsoni – Discus Zones) is represented by marl–clay with interbeds of marl, pelitomorphic and detrital oncolitic limestone in the south. Its roof is build up of regular bench of detrital oncolitic limestone with thickness 5–10 metres. The total thickness of the Member is 40–60 m. To the north from the Baisun Settlement the limestone laying in the Member's roof changes to calcareous sandstone, and the thickness of the larger lower clayey part of the Member decreases to 10 metres and even less. Two consequent fauna complexes may be determined in the Lower Baisun Member. Its lower part (possibly the Hodsoni Zone) contains:

Oxycerites (Oxycerites) aff. *tenuis* MITTA
O. (Paroecotraustes) maubeugei (STEPHANOV)
Prohecticoceras haugi (POPOVICI–HATZEG)
Gracilisphinctes (Gracilisphinctes) twinhoensis (ARKELL)
Homoeoplanulites (Parachoffatia) vandobensis BESNOSOV
Subgrossouvria sp.
Choffatia sp.
Wagnericeras arbustigerum (D'ORBIGNY)
Wagnericeras aff. *wagneri* (OPPEL)
Kheraiceras (Kheraiceras) cf. *subcosmopolita* (LISSAJOUS).

The bench of detrital oncolitic limestone in the Lower Baisun Formation's roof is considered to be the Discus Zone. It contains:

Clydoniceras (Clydoniceras) discus (SOWERBY)
C. (Delecticeras) delectum (ARKELL)
Procerites (Procerites) sp.
Procerites? (Siemiradzkia?) sp.
Homoeoplanulites (Parachoffatia) arisphinctoides BESNOSOV
H. (Homoeoplanulites) rambertensis (MANGOLD)
[M] *Subgrossouvria* sp.
[m] *Subgrossouvria hodjaikanensis* BESNOSOV
Indosphinctes sp.
Morrisiceras sp.

The Middle Baisun Member (the lowest part of the Hoyeri zone, Lower Callovian) is laying conformal on the Lower Baisun Member. There is a marl–clay with thickness 15–20 metres in the base of the Member in the southern part of the territory. It changes upward to fine alternation (10–15 centimetres) of marl–clay, marl and angle–laminated limestone with abundant bivalve's shells and detrital matter (thickness is up to 50 m). The Member's roof is built up of detrital oncolitic limestone bench with thickness up to 5 m. To the north of the territory this upper limestone bench (together with the Upper Baisun Member) is included into the Zarmass Formation. The biggest lower part of the Middle Baisun Member is represented there by clay with beds of calcareous sandstone and sandy limestone.

The Upper Baisun Member (the Hoyeri Zone, Lower Callovian) in the Kugitangtau Range is laying conformal on the Middle Member. It is represented by angle–laminated thinly flagged clayey limestone with a lot of detrital matter, and with delaminated intercalations and rare beds of marl. Total thickness is 40 m. To the north of the territory Upper Baisun Member is changed into gently flagged detrital and oolitic limestone of Kugitang series and could it not be determined.

The following forms have been found in the Middle and Upper Baisun Members: *Macrocephalites* ex gr. *compressus* (QUENSTEDT) – *lamellosus* (SOWERBY), *Kamptokephalites, Indosphinctes, Subgrossouvria, Choffatia, Grossouvria, Kheraiceras (Bomburites)* spp.

Thus we can consider that almost all zones of the standard ammonite scale are present in the Bathonian deposits of the South–West Hissar range. However in the recent time poor study of these deposits makes it impossible to constrain accurate boundaries of these zones.

Acknowledgements

I am grateful to the Organizing Committee of the Bajocian–Bathonian Working Groups Meeting in Budapest, August 2000, and personally Prof. Dr. A. GALÁCZ for friendly support, that made possible my participation in the Meeting.

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Plates

Plate 1

Figs 1–3. *Clydoniceras (Clydoniceras) discus* (SOWERBY).
Fig. 1– N 115/9241, Kugitangtau, Vandob.
Fig. 2– N 115/165, Kugitangtau, Derbent.
Fig. 3– N 115/3403, Kugitangtau, Kazanbulak. The upper part of the Lower Baisun Member.

Fig. 4. *Clydoniceras (Delecticeras) delectum* (ARKELL), N 115/9243, Kugitangtau, Savakbulak. Upper part of the Lower Baisun Member.

Fig. 5. *Oxycerites (Oxycerites) oxus* (BUCKMAN), N 115/3196, Kugitangtau, Vandob. Upper part of the Upper Tangiduval Member.

Figs 6, 7. *Oxycerites (Oxycerites) tenuis* MITTA.
Fig. 6– holotype N 115/3112,
Fig. 7– paratype N 115/3192; Kugitangtau, Vandob. Upper part of the Upper Tangiduval Member.

Fig. 8. *Oxycerites (Paroecotraustes) subtenuis* MITTA, holotype N 115/3162, Kugitangtau, Sarykamysh. Upper part of the Upper Tangiduval Member.

Fig. 9. *Oxycerites (Paroecotraustes) formosus* (ARKELL), N 115/7511, Tangiduval. Upper part of the Upper Tangiduval Member.

Fig. 10. *Oxycerites (Paroecotraustes) splendens* (ARKELL), N 115/3193, Kugitangtau, Vandob. Upper part of the Upper Tangiduval Member.

Fig. 11. *Oxycerites (Paroecotraustes) pygmaeus* (ARKELL), N 115/3097, Tangiduval. Middle Tangiduval Member.

Fig. 12. *Oxycerites (Paroecotraustes) maubeugei* (STEPHANOV). N 115/1206, Kugitangtau, Chashmabulak. Lower part of the Lower Baisun Member.

Fig. 13. *Oxycerites (Paroecotraustes)* aff. *maubeugei* (STEPHANOV), N 115/8030, South–West Hissar, borehole Berdykuduk–2P, depth 3307–3314. Lower part of the Lower Baisun Member.

Fig. 14. *Prohecticoceras* sp., N 115/3263, Tangiduval. Upper part of the Upper Tangiduval Member.

All figures natural size.

Plate 1


6b
6a
7a
7b
10b
10a
11b
11a
8a
8b
9a
9b
12a
14
2b
2a
2c
12b
13a
13b
5a
5b
4a
4b
1b
1a
3a
3b

Plate 2

Fig. 1. *Gracilisphinctes (Gracilisphinctes) evolutus* BESNOSOV, holotype, N 115/3290, Tangiduval. Upper part of the Upper Tangiduval Member.

Fig. 2. *Procerites (Procerites) lissajousi* BESNOSOV, holotype, N 115/1229, Kugitangtau, Kysylalma. Upper part of the Upper Tangiduval Member.

Fig. 3. *Procerites (Siemiradzkia) bucharicus* (NIKITIN), N 115/3790, Tangiduval. Upper part of the Upper Tangiduval Member.

All figures natural size.

Plate 2

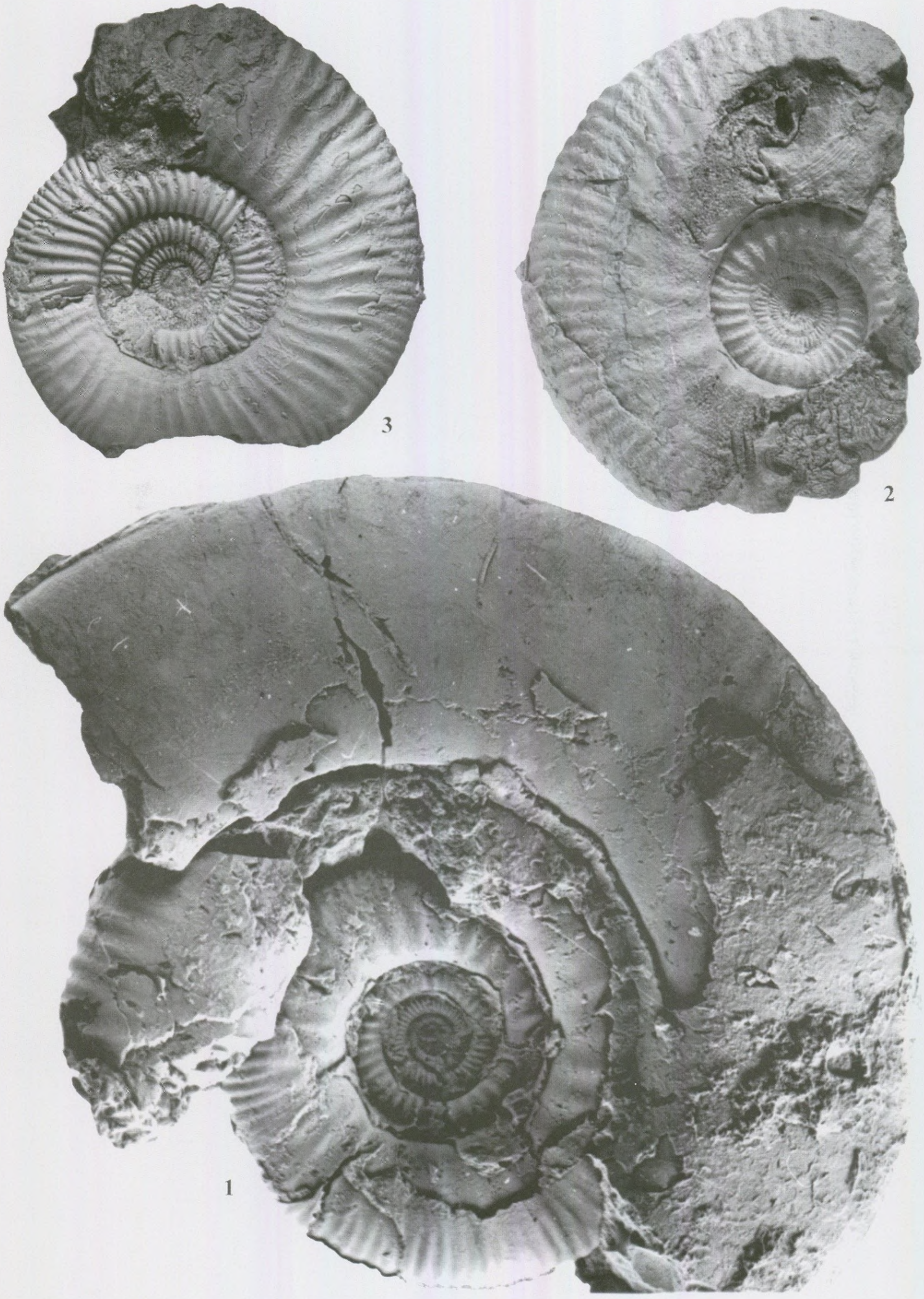


Plate 3

Fig. 1. *Gracilisphinctes (Gracilisphinctes) paragracilis* BESNOSOV, holotype, N 115/3385, Tangiduval. Upper part of the Upper Tangiduval Member.

Fig. 2. *Gracilisphinctes (Gracilisphinctes) kysylalmensis* BESNOSOV, holotype, N 115/1199, Kugitangtau, Kysylalma village. Upper part of the Upper Tangiduval Member.

All figures natural size.

Plate 3

2

1

Plate 4

Fig. 1. *Gracilisphinctes (Gracilisphinctes) densidecoratus* (GALÁCZ), N 115/3310, Tangiduval. Upper part of the Upper Tangiduval Member.

Fig. 2. *Gracilisphinctes (Gracilisphinctes) pseudoimitator* BESNOSOV, holotype, N 115/1235, Kugitangtau, Kysylalma. Upper part of the Upper Tangiduval Member.

Fig. 3. *Gracilisphinctes (Prevalia) stephanovi* BESNOSOV, holotype, N 115/3186, Kugitangtau, Vandob. Upper part of the Upper Tangiduval Member.

Fig. 4. *Procerites (Siemiradzkia) aurigerus* (OPPEL), N 115/3051, Kugitangtau, Vandob. Middle Tangiduval Member.

All figures natural size.

Plate 4

2

3a

3b

1

4b

4a

Plate 5

Fig. 1. *Loboplanulites subcranaiformis* BESNOSOV, holotype, N 115/3311, Tangiduval. Upper part of the Upper Tangiduval Member.

Fig. 2. *Loboplanulites cerealiformis* BESNOSOV, holotype, N 115/3287, Tangiduval. Upper part of the Upper Tangiduval Member.

All figures natural size.

Plate 5

2

1

Plate 6

Fig. 1. *Loboplanulites choffatiaformis* BESNOSOV, holotype, N 115/488, Kugitangtau, Vandob. Upper part of the Upper Tangiduval Member.

Figs 2–3. *Homoeoplanulites (Homoeoplanulites) evolutus* BESNOSOV.
Fig. 2– holotype, N 115/3811;
Fig. 3– paratype N 115/3173; Kugitangtau, Vandob. Upper part of the Upper Tangiduval Member.

Fig. 4. *Homoeoplanulites (Homoeoplanulites) rambertensis* (MANGOLD), N 115/1342, Kugitangtau, Vandob. Upper part of the Lower Baisun Member.

All figures natural size.

Plate 6

2b 4a 4b 3a 3b 1

All figures natural size.

Plate 7

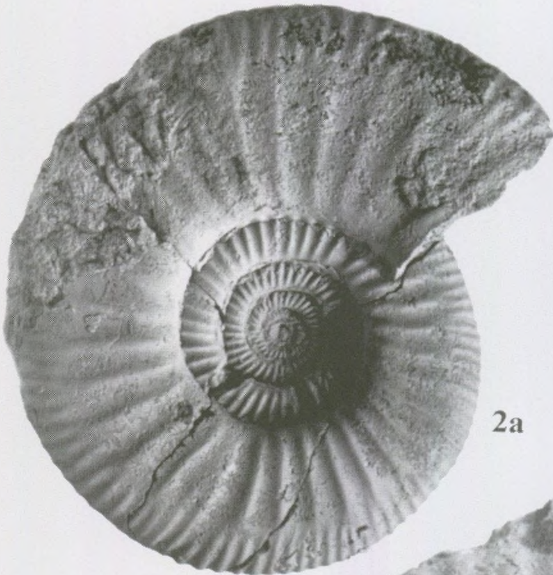
Fig. 1. *Loboplanulites zakharovi* BESNOSOV, N 115/9229, holotype, Kugitangtau. Upper part of the Upper Tangiduval Member.

Fig. 2 *Homoeoplanulites (Parachoffatia) vandobensis* BESNOSOV, holotype, N 115/769, Kugitangtau, Vandob. Lower part of the Lower Baisun Member.

Fig. 3. *Homoeoplanulites (Homoeoplanulites) paradifficilis* BESNOSOV, holotype, N 115/3126, Kugitangtau, Sarykamysh. Upper part of the Upper Tangiduval Member.

All figures natural size.

Plate 7



2a

3a

2b

1

3b

Plate 8

Fig. 1. *Djanaliparkinsonia lutshnikovi* (KUTUZOVA), paratype, N 115/578, Baisuntau, Baisun. Middle Degibadam member. The holotype of this species is lost.

Fig. 2. *Djanaliparkinsonia tuadaensis* (KUTUZOVA), paratype, N 115/570, Baisuntau, Tuada. Middle Degibadam member. The holotype of this species is lost.

All figures natural size.

Plate 8

2a 2b 1a 1b

Plate 9

Fig. 1. *Bullatimorphites (Bullatimorphites) subcostatus* BESNOSOV, holotype, N 115/9253, Tangiduval. Upper part of the Upper Tangiduval Member.

Fig. 2. *Bullatimorphites (Sphaeroptychius) ellipticus* (KRYSTYN), N 115/3130, Kugitangtau, Sarykamysh. Top of the Upper Tangiduval Member.

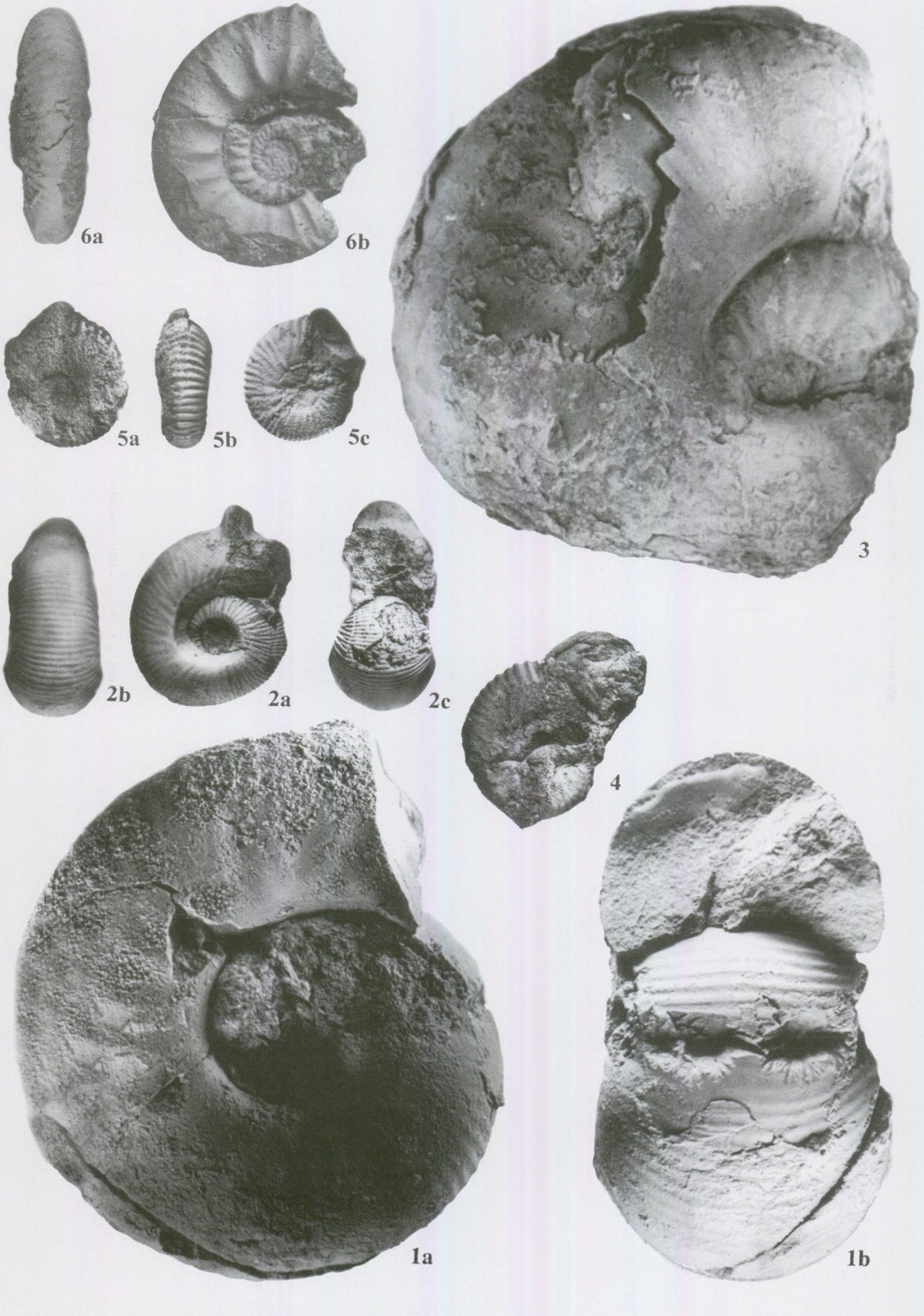
Fig. 3. *Kheraiceras (Kheraiceras)* cf. *subcosmopolita* (LISSAJOUS), N 115/2947, Kugitangtau. Lower part of the Lower Baisun Member.

Figs 4–5. *Morrisiceras (Holzbergia) schwandorfense* (ARKELL). 4– N 115/9234, 5– N 115/9235, Tangiduval. Upper part of the Upper Tangiduval Member.

Fig. 6. [m] *Subgrossouvria hodjaikanensis* BESNOSOV, holotype, N 115/1337, Kugitangtau, Kazanbulak. Upper part of the Lower Baisun Member.

All figures natural size.

Plate 9



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Up a Bathonian backwater – a review of the ammonite evidence for correlating sequences with interdigitating non–marine facies in central and northern England

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(With 4 figures)

In southern England, Bathonian ammonite sequences are relatively complete and show a strong affinity with those recorded in Submediterranean Province areas, such as eastern France and north eastern Spain. From Oxfordshire, in southern central England, however, to North Yorkshire, north–east England, a gradual replacement of normal marine deposits by non–marine and quasi– or restricted marine facies inevitably leads to a corresponding decrease in the ammonite occurrence. Despite the general absence of these key guide fossils, there have been various attempts to correlate central and northern English Bathonian facies using other fossil groups such as brachiopods, ostracods and dinoflagellates. Lithostratigraphical correlation inevitably predominate, however. Further north into East and North Yorkshire, and ultimately Scotland no Bathonian ammonites are known, an inevitable consequence of the virtual absence of any marine influence within regions dominated by fluvial sedimentation. This belt of non–marine facies completely separates a typical Northwest European [ammonoid] Province, from the Boreal Sea to the north. A review of the known ammonite occurrences in central and northern Britain region is provided, including taxonomic and stratigraphical revisions of ammonite faunas described by previous authors, in particular W J. ARKELL in a classic monograph.

This revision is used, in combination with stratigraphical information derived from other fossil groups, to present a provisional revised correlation of Bathonian lithostratigraphical units in central and eastern England (Oxfordshire to East Yorkshire).

Introduction

Bathonian sequences from Oxfordshire, southern central England, to North Yorkshire, north–east England, show a gradual replacement of normal marine deposits by non–marine and quasi– or restricted marine facies. Inevitably there is a corresponding decrease in the occurrence of marine stratigraphical indices, especially ammonites, with records gradual disappearing northwards.

First to disappear are Lower and Middle Bathonian ammonite faunas, with Zigzag to Morrisi chronozone assemblages (*Zigzagiceras*, early species of *Procerites*, *Tulites*, etc) which are apparently unknown north of Oxfordshire. Upper Bathonian records persist, with *Homoeoplanulites* of the Retrocostatum Chronozone, present in Northamptonshire and *Procerites* from similar levels last recorded in south Lincolnshire. The northernmost Bathonian ammonite faunas belong to the Discus Subchronozone (Discus Chronozone) of the terminal Bathonian, with both *Clydoniceras* and *Homoeoplanulites* known in central Lincolnshire. Further north into East and North Yorkshire, and ultimately Scotland no Bathonian ammonites are recorded, obviously linked to the virtual absence of any marine influence within regions dominated by fluvial sedimentation.

Ammonites only return in the Lower Callovian, within the shallow marine facies of the Fleet Member of the Abbotsbury Cornbrash Formation, but even then the lowest subchronozone of the substage (Keppleri Subchronozone, Herveyi Chronozone) is missing in more northern areas within a non sequence (PAGE 1986). This belt of non–marine facies completely separates a typical North West European [ammonoid] Province, from the Boreal Sea to the north, even though marine facies with Boreal Province, Bathonian cardioceratid faunas are already known in the southern North Sea (CALLOMON 1985). Further south in England, ammonite sequences are more complete and formed the basis of the review of

PAGE (1996), subsequently integrated within the proposed Submediterranean Standard Zonation of PAGE & MELÉNDEZ (1999).

Despite the general absence of suitable guide fossils, there have been various attempts to correlate central and northern English Bathonian facies, most notably by TORRENS (1969; 1980). Litho–stratigraphical correlations inevitably predominate, including the identification of correlatable sedimentary cycles in both marine and non marine / quasi marine facies. Other fossil groups, including brachiopods (e.g. in DOUGLAS & ARKELL 1932), nereneid gastropods (e.g. in BARKER 1994), ostracods and dinoflagellates are also locally useful (Sleaford memoir).

A review of the known ammonite occurrences in central and northern Britain region is provided below, including taxonomic and stratigraphical revisions of ammonite faunas described by previous authors, in particular by W. J. ARKELL in his classic monograph of English Bathonian ammonite faunas (1951–1958). This revision is used, in combination with stratigraphical information derived from other fossil groups, to present a revised correlation of the complex lithostratigraphy of the Bathonian in central and eastern England (Oxfordshire to East Yorkshire), the northern–most backwaters of the North West European Province.

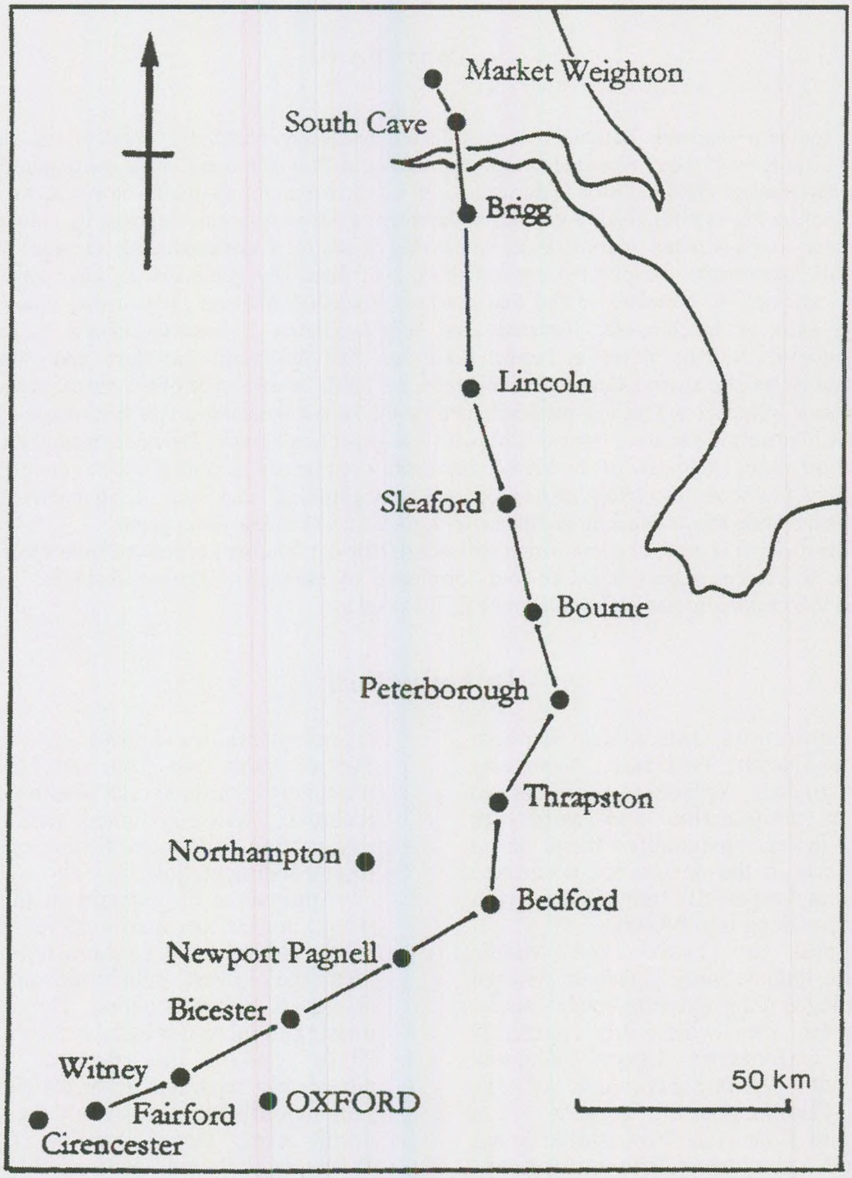

Figure 1· Central and northern England, showing major towns and the line of the section of Figure 3.

Bathonian ammonite faunas of central and northern England

The following review and discussion utilises the standard zonation of PAGE & MELÉNDEZ (1999). * indicates the source of a type specimen of a nominal species.

(a) *Upper Bajocian, Parkinsoni Chronozone, ?Bomfordi Subchronozone*: Evidence of the upper part of the Bajocian is last recorded in southwestern Oxfordshire in the Hook Norton district. ARKELL records and figures *Parkinsonia* [“*Durotrigensia*”] cf. *crassa* NICOLESCO apparently from the lowest part of the Chipping Norton Limestone (i.e. in the Hook Norton Limestone Member) of Workhouse Quarry at Chipping Norton (ARKELL 1951–1959, p. 162, text fig. 58 (right hand figure), 163). The Bajocian rather than Bathonian age of this fauna was later confirmed by TORRENS (1968, p. 228;1969c, p. 75). This specimen, if correctly interpreted, is very important as it indicates that the Chipping Norton Limestone Formation, at least locally, extends down into the Upper Bajocian and hence includes the Bajocian–Bathonian boundary (the formation is often restricted to the upper part of the Zigzag Chronozone, e.g. in SUMBLER et al.2000, table 12).

(b) *Lower Bathonian, Zigzag Chronozone, Convergens Subchronozone*: A number of sites in the North Cotswolds, spanning the Gloucestershire–Oxfordshire border have yielded rare ammonites of early Bathonian, Zigzag Chronozone age from the Chipping Norton Limestone Formation. Faunas of the Convergens Subchronozone appear to be the most frequent and include *Parkinsonia subgaleata* S. BUCKMAN at both Eyford and Longborough, near Stow–on–the–Wold (ARKELL 1951–1958, p. 160). *Parkinsonia*. sp. cf. ?*pachypleura* S. BUCKMAN from a “coarse shelly brownish oolite with many broken *Ostrea* cf. *acuminata*” at Fulwell Quarry, near Enstone (ARKELL 1951–1958, p. 150), would also be of a similar age, as possibly is the *Parkinsonia* (sp.) recorded by SUMBLER et al. (2000, p.56) from between Aston Blank and Clapton.

The *Trigonia signata* Bed at the top of the Hook Norton Limestone Member in Workhouse Quarry, Chipping Norton has also yielded, according to ARKELL (1951–1958), *Parkinsonia* (*Gonolkites*) *subgaleata* S. BUCKMAN (p.160) and the closely related **P.* (*Durotrigensia*) *oxonica* ARKELLL (p. 160–162, text fig. 39 = Holotype), in association with *Procerites subprocerus* (S. BUCKMAN), (p. 185). *Procerozigzag pseudoprocerus* (S. BUCKMAN) is also recorded here (ARKELL 1951–1958, p. 181), suggesting that higher levels in the quarry (in the Chipping Norton Limestone Member) are of Macrescens Subchronozone age. The locality is described by ARKELL (1947, p.32) and noted by TORRENS (1968, p. 228; 1969c, pp. 74–5).

(c) *Macrescens Subchronozone*: *Zigzagiceras* (*Procerozigzag*) *pseudoprocerus* from the Chipping Norton Limestone of Hook Norton Workhouse Quarry (ARKELL 1947, p. 32; TORRENS 1969c, p. 74; 1980, p. 39), indicates the Macresecens Subchronozone, as at Workhouse Quarry, Chipping Norton, as noted above, presumably also in Chipping Norton Limestone Member facies. *Oppelia limosa* (S. BUCKMAN) from Oakham Quarry, near Great Rollright and Lower Swell near Stow–on–the–Wold (ARKELL 1951–1958, p. 61 and pl. 6, fig. 5; TORRENS 1969c, p. 74) is likely to represent a Zigzag Chronozone species, but without associated parkinsonids or perisphinctids cannot be reliably assigned to any subchronozone.

Northwards and eastwards from the Hook Norton–Chipping Norton district there are no further records of Zigzag Chronozone ammonite faunas, although field mapping evidence suggests that the lowest member of the dominantly quasi–marine Rutland Formation (the Stamford Member) may be a lateral equivalent of the Chipping Norton Limestone Formation (M. SUMBLER pers. comm., 2001).

(d) *Zigzag Chronozone, Yeovilensis Subchronozone to Progracilis Chronozone, Orbignyi Subchronozone*: There are no clear records of this interval, and indeed the earlier part of the Zigzag Chronozone, from Oxfordshire north–eastwards – lithostratigraphical relationships suggesting that this is in part due to the presence of either quasi–marine facies (as indicated above) and possibly also a non–sequence between the basal Stamford Member of the Rutland Formation (previously known as the “Upper Estuarine Series”; TORRENS 1980, etc) and younger units.

(e) *Progracilis Chronozone, Progracilis subchronozone*: In the North Cotswolds, the development of fissile calcareous sandstones, suitable for use as roofing tiles, in the Eyford Member of the Fuller’s Earth [or “Sharps Hill”] Formation, led to an important historical industry.

These “Cotteswold Slates” have yielded a characteristic fauna of the Progracilis Subchronozone from a number of localities, including from Eyford (with **P vineta* ARKELL 1951–1958; p. 203, pl. 27, fig. 4, text figure 72.7 = Holotype; *P.* aff. *progracilis*, text fig. 72.3, pl. 28.1; *Procerites progracilis* (COX and ARKELL) 1951–1958, p. 199; **P. mirabilis* ARKELL, 1951–1958, p. 201, 203, text fig. 75, = Holotype, text fig. 72.5, pl. 27, fig. 3, pl. 28, fig. 9; and **Oxycerites oxus* (S. BUCKMAN), ARKELL 1951–1958, text fig. 16.2, pl. 6, fig.8 = Holotype. SAVAGE 1963, p. 181; TORRENS 1969c, p;. 71–72; SUMBLER et al. 2000, p.58), Huntsman Quarry, Naunton (section described by RICHARDSON 1929, p. 114: with *P mirabilis*, ARKELL 1951–1958, p. 201, pl. 28, fig. 8; TORRENS 1969c, p. 72; ARKELL also records *P.* aff. *vineta* ARKELL from “Naunton”, (p. 203, pl. 28, figs. 5), although notes that this small specimen could also be a “young *Choffatia*” (= *Homoeoplanulites*), Kiveton Thorns Quarry to the north of Naunton (with *P.*cf. *progracilis*, TORRENS 1969c, p.72) and from a temporary excavation northwest of Hazleton (“a large *Procerites*”; SUMBLER et al. 2000, p. 58).

Similar faunas are also known from the lithologically similar "tilestone" facies of the geologically famous "Stonesfield Slate" of Oxfordshire, a facies developed at at least four sucessive levels in the Taynton Limestone Formation (*sensu* SUMBLER 1999), as demonstrated by BONEHAM & WYATT (1994, although these authors divide the unit into separated Taynton Limestone and Charlbury formations). This sampling of a greater number of levels could account for the apparently greater diversity of the ammonite fauna from Stonesfield, when compared to that of the Eyford Member of the Cotswolds although the more extensive development of mines around Stonesfield, and a longer and more intensive period of working could also be significant. BONEHAM & WYATT believed that the typical Progracilis Chronozone ammonite fauna came from levels solely within their restricted Taynton Limestone Formation, obviously influenced by records by TORRENS (1980, p. 38), although they were unable to provide further proof through direct observation.

The fauna of the tilestone facies at Stonesfield includes: *Procerites progracilis* COX and ARKELL (ARKELL 1951–1958, p. 199), *P.* cf. *progracilis* (= pl. 27, fig. 5, pl. 28, fig. 3, 4), *P. mirabilis* ARKELL (pl. 28, fig .6), **P. magnificus* ARKELL (p. 201, 203, pl. 27, fig. 6 = Holotype, text fig. 72.5), **Micromphalites micromphalus* (PHILLIPS), (1951–1958, p. 47, pl. 4, figs. 1–6, fig. 4 = Lectotype), * "*Clydoniceras*" *tegularum* ARKELL (1951–1958, p. 42, pl. 4, fig. 7, text fig. 7.1 = Holotype – the specimen is very worn, however, and the apparently simplified *Clydoniceras*–like suture could be simply an artefact of this abrasion; generic assignment must therefore be considered tentative), *Oppelia* cf. *limosa* (S. BUCKMAN) ARKELL 1951–1958, p. 61, pl. 6, fig. 6) and "*Paroecotraustes*" *formosus* ARKELL (1951–1958, p. 22, pl. 8, figs. 8–10).

The Taynton Stone Formation has also yielded an apparently similar Progracilis Subchronozone fauna, with *P. mirabilis* Arkell (TORRENS 1968, p. 232; 1969c, p. 73; 1980, p. 38) and possibly also *P. progracilis* (ARKELL, 1951–1958, p. 199, text fig. 74) from Slade Quarry, Salperton, *Procerites* sp. at Snowshill Quarry (TORRENS 1968, p. 253; 1969a, p. 16) and *Procerites* "cf. *tmetolobus*" at Farmington Quarry (SUMBLER et al. 2000, p. 60).

**Procerites* ["*Zigzagites*"] *imitator* (BUCKMAN) from near the base of the Hampen Formation of Fritwell cutting near Bicester (TORRENS 1980, p. 385; ARKELL 1951–1958, 173 p. 192, 193, pl. 26, fig. 2, text fig. 69.2) appears to represent a post–*progracilis* fauna. The species is also recorded from the Acuminata Beds immediate below the Fullers Earth Rock of Somerset (TORRENS 1980, p. 385; ARKELL 1951–1958, pp. 173 ,192, 193), although records from higher horizons, such as the Twinhoe Ironshot Member, certainly include forms belonging to different species and possibly even genera (PAGE 1996, e.g. ARKELL, 1951–1958, pl. 26, fig. 3). The type section of the Hampen Formation has been redescribed by SUMBLER (1996) and a second *Procerites* from the Formation, at Northleach, recorded by SUMBLER et al. (2000, p. 60).

(f) *Subcontractus Chronozone*: The Sub–contractus Chronozone is clearly proved from Oxfordshire southwestwards, by the presence of *Tulites* ex grp. *modiolaris* (W. SMITH) in the Shipton Member of the White Limestone Formation. Records include *Tulites mustela* ARKELL, from around 1 m above the top of Hampen Marly Formation, WNW of Salperton Church (ARKELL 1951–1959, p. 103, pl. 12, fig. 1; = *Tulophorites tulotus* S. BUCKMAN *in* RICHARDSON 1929, p. 119; also recorded by SUMBLER et al. 2000, p.64); "*Tulites* cf. *subcontractus*" (MORRIS and LYCETT), from "16' to 18'" (= around 4.8 – 5.4 m) below the top of the White Limstone at Asthall, (ARKELL 1933, p. 292; 1931, pp. 607–8); **Tulites glabretus* (S. BUCKMAN) from near Ardley Wood (ARKELL 1951–1958, pp. 100–103, text fig. 32 = Holotype; "very probably....from the basal bed of the White Limestone" according to TORRENS 1980, p. 36; 1969c, p. 69 and probably also recorded by ARKELL 1933, p. 292); *Tulites* sp. from Kirtlington Station (GREEN 1864, p. 25; TORRENS 1969c, p. 69); and *T. glabretus* from ?Bed 1, Eton College Quarry, Asthall, Witney (ARKELL 1931, pp. 607–8, 1951–1958, p. 103, pl. 11, fig. 1; TORRENS 1980, pp. 36–37).

Tulites from the district are also noted by TORRENS (1988, p. 238), ODLING (1913, p. 490), BUCKMAN (1931, p. 52) and ARKELL et al. (1933, p. 344).

(g) *Morrisi Chronozone*: The Morrisi Chronozone is not recorded north of Gloucestershire, the most important locality in this region of the North Cotswolds being the well known Foss Cross Quarry. Records from here are all from the Shipton Member and include *Morrisiceras* sp. indet from the *Lucina* Beds (=Beds 18–19 of RICHARDSON 1911, p. 11), *Morrisiceras comma* (S. BUCKMAN) from 0.3 m below the top of Bed 2 of CALLOMON & TORRENS (*in* TORRENS 1969, p. 13; = "*Lycetticeras* sp."; also recorded by SUMBLER et al. 2000, p. 64) and *Morrisiceras* and "*Lycetticeras*" at around 0.9 m below the top of the Excavata Beds (BARKER 1976, fig 1.7 – "*Lycetticeras*" is a macroconch *Morrisiceras*).

Other scattered records include *Morrisiceras morrisi*, apparently from Bed 18 in Stony Furlong Cutting (TORRENS 1980, p. 35) and *M.* cf. *morrisi*, *c.*12–15 m above the base of the White Limestone in Chedworth Railway Cuttings (ARKELL 1951–1959, p. 121, TORRENS 1969c, p. 20).

(h) *Bremeri Chronozone*: There is no definitive evidence of the Bremeri Chronozone in central and northern England, the northernmost clear record being the type locality of **Bullatimorphites bullatimorphus* S. BUCKMAN (1921, p. 47, 1922, pl. 262) from the topmost White Limestone Formation at Tiltups End south of Nailsworth in Gloucestershire (ARKELL 1951–1958, pp. 12, 87, 106, 107. Text fig. 24 = Holotype. See also TORRENS 1980, p.32–33, ARKELL & DONOVAN 1952, p.241, CAVE 1977, pp. 143, 175, 196 and WITCHELL 1886).

Circumstantial evidence, however, suggests that at least one of the specimens of *Homoeoplanulites* from the Blisworth Limestone of Northamptonshire could belong to this chronozone. The specimen, a large macroconch around 325 mm in diameter, is recorded by ARKELL (1951–1958, pp. 219–222) and TORRENS (1980, p.40) as very likely to have come from within 0.4 m of the top of the *Kallirhynchia sharpi* Beds at the base of the formation, at Bank's Pit, Kingsthorpe, near Northampton itself (= Bed 11 of SHARPE 1870, pp. 357, 360). In the latter district a Nerinea Bed, up to 0.9 m thick is developed at this level, immediately above the *Kallirhynchia sharpi* Beds (TORRENS 1968), and is therefore highly likely to be the source of the specimen. This bed yields, according to TORRENS (1980, pp. 40–41), a fauna including *Eunerinea arduennensis* (BUVIGNIER), *Nerinella* cf. *acicula* (D'ARCHIAC), which is also characteristic of the Roach Bed at the base of the Ardley Member of the White Limestone Formation in Oxfordshire.

The latter bed lies above the Subcontractus and Morrisi Chronozone faunas of the topmost Shipton Member, and apparently below records of Quercinus Subchronozone faunas (lowest Retrocostatum Chronozone, as detailed below) at higher levels in the Ardley Member, i.e. in an interval likely to embrace the Bremeri Chronozone. *Procerites* sp. indet. associated with *Procerites* sp. ("transitional to *Choffatia"*) from the base of the Ardley Member, or 0.5 m above the base, in a quarry at Croughton (TORRENS 1980, p. 38, a locality also described by PALMER 1974) could also represent elements of a similar Bremeri Chronozone fauna.

(i) *Retrocostatum Chronozone, Quercinus Subchronozone*: Large *Procerites*, especially *P* ex grp *quercinus* ARKELL ?non TERQUEM & JOURDY is characteristic of the Quercinus Subchronozone throughout much of Europe, and central England is no exception. Records are few and scattered, but the fauna consistently occurs in the Ardley Member of the White Limestone Formation and includes *P. quercinus* from "above Bed 18" in railway cuttings between Chedworth and Cirencester (RICHARDSON 1911b; ARKELL 1931, 1933; ARKELL & DONOVAN 1952; p. 246; CALLOMON & TORRENS *in* TORRENS 1969, pp. 12–3) and also from Bed 3 of Dagham Downs / Daglingworth Quarry (TORRENS 1967, p.87, BARKER 1976, fig. 1; SUMBLER et al. 2000, p. 66), around 4.8 m above the top of the Shipton Member. Additional records from the Ardley Member in Oxfordshire include *Procerites* sp. from the "Great Oolite Bottom hard about half way down in quarry" at Enslow Bridge, probably from the Ardley Member, possibly from Bed 12 (of PALMER 1974, p. A13; TORRENS 1980, p. 38; BARKER 1976, fig. 1.19).

North–eastwards, the White Limestone Formation passes into the Blisworth Limestone Formation, which shows quasi–marine influence at various levels (including oyster–rich beds). Remarkably a few very rare ammonites have also been recovered, as far north as south Lincolnshire. In this region vast opencast ironstone mines were formerly active, working the Aalenian Northamptonshire Ironstone Formation, below a Bajocian–Bathonian sequence. Considering the enormous volume of material worked, it is not surprising, therefore, that a few ammonites were also recovered.

Procerites quercinus is again recorded in Northamptonshire, from close to the junction of Beds 5–6 of TAYLOR (1963, p. 96) at Twywell Ironstone Pit, around 0.3 m above the highest recorded *Kallirhynchia sharpei* of the *Kallirhynchia sharpi* Beds (TORRENS 1980, p. 40; see also 1968, p. 242, = Bed 4 of Pittham, 1970, p.63). Note that the Nerinea Bed is not present in the latter district and the presence of *P quercinus* at an apparently lower level in the Blisworth Limestone–Ardley Member succession than in Oxfordshire, may suggest that a non–sequence is developed at the top of the *Kallirhynchis sharpi* Beds.

P. quercinus is also recorded by ARKELL (1951–59, p. 194–196) from Bed 9 of SHARP (1870, p. 377–8) and THOMPSON (1927, p. 33), near the base of the Blisworth Limestone and also from not far above the top of the *Kallirhynchia sharpi* Beds in a quarry "to the east" [of Blisworth] (TORRENS 1967, p. 69). The relationship between this specimen and the possible Bremeri Chronozone *Homoeoplanulites* discussed above is unclear, however, and it is not known whether the Blisworth specimen was obtained from within or above a development of, or level equivalent to the Nerinea Bed. As *Homoeoplanulites* is often very rare elsewhere in Europe in the Quercinus Subchronozone (cf. PAGE & MELÉNDEZ 1999), some stratigraphical separation of the two faunas is most likely. The specimen of *P quercinus* figured by ARKELL (1951–9, p.194–195, text fig. 71) from a quarry at Kingsthorpe described by SHARPE (1870) is typical of the species, although regrettably unhorizoned. A possible "*Siemirazkia*", the microconch partner of *Procerites*, is also recorded from Field Burcote (TORRENS 1967, p. 81).

Smaller specimens of *Procerites* sp. are known from south Lincolnshire, including from Stamford (SHARPE 1873, p. 249, 264; TORRENS 1967, p. 79) and possibly also Belmesthorpe (ARKELL 1951–59, p. 15; TORRENS 1967, p. 81). Given that most Northamptonshire and Oxfordshire specimens of *Procerites* from the White Limestone appear to belong to the *quercinus* group, it is reasonable to suppose that these Lincolnshire specimens represent the northernmost limits of the same group.

(j) *Retrocostatum Chronozone, Hodsoni and Histricoides Subchronozones*: A single, worn nucleus of a possible ?*Homoeoplanulites* sp., although compared to *"Siemiradzkia pseudorjazanensis* (LISSAJOUS)" by ARKELL (1951–1958, p.228), from the Signet Member at the top of the White Limestone Formation (*teste* SUMBLER et al. 2000, p.67) near Westwell in Oxfordshire, is the only indication of a post–Quercinus Subchronozone fauna in the formation. The specimen came from field brash and was formerly, and mistakenly, referred to the "Kemble Beds" of the Forest Marble Formation (e.g. by ARKELL et al. 1961).

Further north, *Homoeoplanulites* sp. (or "*H.* cf. *cerealis*" in TORRENS 1967, p. 71) from Bed 5 (the "Paving") at Moulton Park House Pit, near

Kingsthorpe in Northamptonshire (THOMPSON 1927, p. 40; TORRENS 1967, p. 71; 1980, p. 40; ARKELL 1951–59, p. 219, text fig. 80.2), around 2.8 m above the top of the *Kallirhynchia sharpi* Beds also suggests a post–Quercinus fauna. *Homoeoplanulites* is typical of the highest part of the Retrocostatum Chronozone, the Histricoides Subchronozone, in Spain (cf. PAGE & MELÉNDEZ 1999) and this suggests a possible correlation for the specimen. In addition, as noted above, *Homoeoplanulites* is typically quite rare in Quercinus (and also Hodsoni) Subchronozone faunas, but is abundant and typical in the Histricoides Subchronozone.

Although no ammonites are present northwards into central and northern Lincolnshire, ostracod faunas prove the presence of the Quercinus–lower Hodsoni Subchronozones (= "Hodsoni Zone" auctt.) and the upper Hodsoni–Histricoides Subchronozones (BERRIDGE et al. 1999: GAUNT et al. 1992) in Rutland Formation and Blisworth Limestone facies respectively. The former indicate that the Rutland Formation–Blisworth Limestone base is diachronous, at least across Lincolnshire. The latter would confirm that at least part of the Blisworth Limestone is likely to be of Histricoides Subchronozone age, thereby lending credence to a suggestion that the *Homoeoplanulites* from Kingsthorpe may indeed be a specimen of *H.* ex grp. *rotundatus* (ROEMER), as is very characteristic of the upper part of the Histricoides Subchronozone in Spain (PAGE & MELÉNDEZ 1997; 1999).

A number of intriguing but unconfirmed old records from the Blisworth Limestone of the district include "*Ammonites bullatus* D'ORBIGNY" from between Alwalton and Peterborough (SHARP 1873, p. 279; ARKELL 1951–59, p. 244; TORRENS 1967, p. 80) and "a large example of *Ammonites macrocephalus*" from near Uffington (TORRENS 1967, p. 79; 1980, p. 42; SHARPE 1873, p. 258). Neither specimen has been traced, although it is not impossible that they represented nautiloids, which are occasionally found in the district.

A single *Macrocephalites*, however, in Peterborough Museum collections (see discussion below under Lower Callovian, Keppleri Subchronozone faunas, section (m)) is somewhat problematic as regards morphology and lithology and it cannot be ruled out that it could genuinely have come from the higher part of the Blisworth Limestone, and be of Upper Bathonian age

(k) *Discus Chronozone, Hollandi Subchronozone*: Confirmation of the age of the Forest Marble Formation is available to the southwest, in southern Gloucestershire near Cirencester, the type locality *of* **Clydoniceras hollandi* (S. BUCKMAN) itself (ARKELL 1951–1958, pp. 41–42, pl.1, figs 6a,b), and also to the northeast, where it passes into Blisworth Clay facies and has yielded ostracods typical of the Discus Chronozone (BERRIDGE et al. 1999, p.77). The "*Siemiradzkia pseudorjazanensis* " recorded by SUMBLER et al. (2000, p. 68) and others (ARKELL 1958; TORRENS 1974; PAGE 1996) from the Forest Marble Formation just south of Cirencester, is most likely to be a small Homoeoplanulites (i.e. a nucleus or a microconch).

(l) *Upper Bathonian, Discus Chronozone, Discus Subchronozone*: Discus Subchronozone ammonite faunas are the most persistent in the Bathonian in Britain, recorded from the Dorset coast in the south (as reviewed by PAGE 1996, etc) to northern Lincolnshire, in northern eastern England. Throughout this geographical range, the faunas occur solely in the thin, often shelly facies of the Berry Member of the Abbotsbury Cornbrash Formation (*sensu* PAGE 1986 = "Lower Cornbrash" auctt.).

At least two successive biohorizons can be recognised in southern and central England, the lower with *Clydoniceras* ex grp *discus* (J. SOWERBY) *sensu stricto* (probably including the microconch form "*Delecticeras*" *delectum* ARKELL) and possibly also very rare *Homoeoplanulites* ex grp *homoeomorphus* S. BUCKMAN, and the upper with *Clydoniceras* ex grp *discus*, including *C. hochstetteri* (OPPEL), and more frequent *Homoeoplanulites* ex grp *homoeomorphus* (see PAGE 1996). The presence of two successive *Clydoniceras* faunas in the Oxford district was first recognised by PRINGLE (1926). Known occurrences of Discus Subchronozone faunas are described below on a county by county basis along the outcrop, from south to north:

(i) *North Gloucestershire*: In the dip slopes of the north Cotswolds, on the northern edge of the wide Oxford Clay vales, scattered small quarries formerly showed sections in the Abbotsbury Cornbrash Formation.

Although just to the southwest of the present study area, recent quarrying operations have re–exposed one such section, as formerly visible in the now filled–in Shorncote Quarry of DOUGLAS & ARKELL (1928). *Homoeoplanulites* ex grp. *homoeomorphus* S. BUCKMAN is not infrequent in the new quarry, and was also recorded by DOUGLAS & ARKELL at the old locality, in both cases in apparent association with *Clydoniceras* ex grp *discus* (1928; ARKELL 1958, p. 227; PAGE 1988, p. 149; *pers obs.* 1993–5).

At least some of the *Clydoniceras* and *Homoeoplanulites* appear to come from Astarte–Trigonia Bed facies, at the top of the Berry Member (cf. Bed1 of DOUGLAS & ARKELL 1928), and the relative frequence of the latter suggests that the *hochstetteri* Biohorizon is potentially recognisable at Shorncote, although *C. hochsetteri* itself is not yet confirmed.

Additional records of *C.* ex grp. *discus* from the district include from the "Three Magpies Inn" quarry near Fairford (DOUGLAS & ARKELL 1928, p.133) and *C. hochsttetteri* from "Fairford", figured by BUCKMAN (1924) (SUMBLER et al. 2000, p.69) – the latter at least suggesting that the *hochstetteri* Biohorizon is recognisable here.

(ii) *Oxfordshire*: To the northeast and into Oxfordshire, *Clydoniceras* is not uncommon, records including *C. hochstetteri* from Filkins (ARKELL 1951–1958, pl. 3, figs. 2, 4; SUMBLER et al. 2000, p.69) and

Brize Norton (BLAKE 1905, pl. 6, fig. 2) and *C.* ex grp. *discus* "var. *crenellatus*" from Ducklington Lane, Witney (ARKELL 1951, pl. 3, fig. 1) – the *hochstetteri* Biohorizon, at least, being indicated.

Around Long Handborough, the terminal Bathonian – basal Callovian sequence is best characterised in Britain, as the Swan Inn Quarry is the only known locality in England where *Kepplerites keppleri* (OPPEL) of the basal Callovian *keppleri* Biohorizon has been recorded *in situ* (CALLOMON, 1971, p.124). Notably, the latter was recorded in the topmost Berry Member (= "Lower Cornbrash") facies, and not the Fleet Member (= "Upper Cornbrash") as already observed by PAGE (1988, pp.155–156; 1989). The succession of faunas in the Berry Member of the Swan Inn Quarry is as follows (bed numbers after DOUGLAS & ARKELL, 1928, p.129):

Bed 4: *K. keppleri, Homoeoplanulites* sp (*keppleri* Biohorizon).

Bed 3 (Astarte–Trigonia Bed): *Clydoniceras* incl. *C. hochstetteri* (*hochstetteri* Biohorizon).

Bed 1· *Clydoniceras* sp. incl. *C. discus* (Intermedia Bed) (*discus* Biohorizon, part?).

The locality is also recorded by POCOCK (1920, p. 15), PRINGLE (1926, p. 21) and RICHARDSON (1946, p.76).

The Long Handborough area has historically yielded a significant amount of additional, important material, but unfortunately without adequate stratigraphical information and often poorly localised (PAGE 1988, pp. 155–156). These faunas include a few additional *K. keppleri*, from Bed 4 or an equivalent, common *Homoeoplanulites* ex grp. *homoeomorphus* from beds 3 or 4 (including * "*H.* [*Loboplanulites*] *longilobata*" BUCKMAN 1925, pl. 596, = Holotype; ARKELL 1951–1958, text figs. 79.5, 81,= Holotype refigured, pp. 222–223; "*Choffatia subbakeriae*" (D'ORBIGNY), p. 218, pl. 32, fig. 9 and "*C. kranaiformis*" ARKELL, p. 225, pl. 31, fig.7, p. 225) and *Clydoniceras* ex grp. *discus* including "*C.* var. *crenellatus–hochstetteri*" probably from an equivalent of Bed 3 (ARKELL 1951, pl. 3, fig. 3, recorded as from "Lays Pit").

Additional perisphinctids from the district, presumably also from the Berry Member, include "*H. arisphinctoides* ARKELL" from near Charlbury (ARKELL 1951–1958, p. 219) and *H. homoeomorphus* from "near Oxford" (ARKELL, p. 229, pl. 31, fig. 1), although it is impossible to say whether they are of terminal Bathonian or basal Callovian age.

As noted above, PRINGLE (1926) was the first to record a sequence of *Clydoniceras* species in the Oxford district, for instance at Islip Quarry (p.20), Oxfordshire (not to be confused with Islip, Northamptonshire) with *C. discus* s.s. in his "1st *Clydoniceras* Bed" (= DOUGLAS & ARKELL 1932, p.124, Bed 3) and *C. discus* "var. *hochstetteri*" in a "2nd *Clydoniceras* Bed" (= DOUGLAS & ARKELL, Bed 5). Islip quarry is also described by WOODWARD (1892, p. 48), BLAKE (1905, p. 13), POCOCK (1908, p. 211), RICHARDSON (1946, p. 79) and reviewed by PAGE (1988, p. 158).

Clydoniceras also occurs at two levels in the Berry Member in the large and more recently disused Shipton–on–Cherwell Quarry, in Beds 3–5 and in Bed 8 (= Astarte–Trigonia Bed; PAGE 1988, pp. 150–162; 1989) and again at two levels in the nearby Upper Greenhill Quarry, Enslow Bridge (PRINGLE 1926, p. 24), although the presence of *C. hochstetteri* in the upper fauna is not yet confirmed. These sites are also described by DOUGLAS & ARKELL (1928, p. 130; 1935), RICHARDSON (1946, p. 77) and ARKELL (1947, p. 59) and *C. discus* from Shipton–on–Cherwell has been figured by ARKELL (1951–1958, pl. 2, fig. 5) and other specimens from the Enslow Bridge area include: *C.* "var. **digitatus* ARKELL" (1951–1958, pl. 2, fig. 6), *C.* "var. *blakei–crenellatus* ARKELL" (pl. 2, fig. 3), *C.* "var. *digitatus–crenellatus* ARKELL" (pl. 3, fig. 6), *C.* "aff. var. *blakei* ARKELL" (pl. 2, fig. 10) and, significantly, *C. hochstetteri* itself (pl. 3, fig. 7). *C. thrapstonense* ARKELL is also recorded from Enslow Bridge (1951, p. 41), although its stratigraphical significance here is unclear (PAGE 1988, p. 163 – although see discussion below regarding it's position in Northamptonshire). *C.* "var. *blakei*" is also recorded from Kidlington, nearer Oxford itself, by ARKELL (1951–1958, text fig. 5).

(iii) *Buckinghamshire*: There are scattered records of *Clydoniceras* in Buckinghamshire, including *C. discus* from Blackthorn Hill (ARKELL 1951–1958, p. 4, text fig. 6.18). An isolated record of *Homoeoplanulites* (as "*C. cerealis* ARKELL"), from Rectory Farm, Emberton, Olney (1951–1958, p. 222, pl. 31.3) may be of Bathonian age, although the relative frequence of *Macrocephalites* in old collections from this area (as reviewed by PAGE 1988), may suggest that a Callovian age is not impossible.

(iv) *Bedfordshire*: The most important records of *Clydoniceras* in Bedfordshire are from Bedford itself, the type locality of **C. discus* (J. SOWERBY) (ARKELL 1951, pl. 2, fig. = Holotype refigured, fig. 4, fig. 1, fig. 9) and also its microconch partner * "*Delecticeras*" *delectum* Arkell (1951–1958, text fig. 8.1, pl. 4, fig. 12 = Holotype). ARKELL also records from Bedford a range of his sutural "varieties", including *C.* "var. *discus* "(pl. 2, fig. 1), *C.* "var. **blakei* (pl. 2, fig. 4 = type of variety, text fig. 69A, B) and *C.* "var. *blakei–hochstetteri*" (pl. 1, fig. 9).

Unfortunately there is no recorded stratigraphy for any of these forms, and the Abbotsbury Cornbrash Formation is reduced to a very thin and hard band only 0.6 – 0.9 m thick which has also yielded early Callovian faunas, including the holotype of **Macrocephalites bedfordensis* SPATH (figured by BLAKE, 1905, pl.4, fig.1), a member of *M.* ex grp. *terebratus* (PHILLIPS) (PAGE 1988, p. 167–170) – there is little possibility here, therefore, of confirming the position of *C.discus*, *sensu stricto,* in a sequence with *C. hochstetteri* above. Sections near Bedford are also described by WOODWARD (1894, p. 451), CAMERON (1889) and DOUGLAS & ARKELL (1932, p. 123), although none now remain exposed.

(v) *Northamptonshire*: The Rushden district in Northamptonshire was formerly an important source of "Cornbrash" fossils (BLAKE 1905) and in addition to Callovian *M.* ex grp. *terebratus*, has yielded further *Clydoniceras,* including *C. discus* (ARKELL, 1951, pl. 3, fig. 10) and the microconch form "*Delecticeras" legayi* RIGAUX and SAUVAGE (1951, p. 44, pl. 4, figs. 11).

Much more significant, however, are the *Clydoniceras* faunas from the Thrapston district, to the northeast. The Berry Member here is reduced to a very thin development, only a few centimetres thick, but a significant number of specimens of *Clydoniceras* have relatively prominent secondary ribs, unlikely virtually all specimens found elsewhere in Britain, and were described as by ARKELL (1951) as *Clydoniceras thrapstonense* ARKELL (p. 41, pl. 3, figs. *12 = Holotype, 13). The type and topotype of the latter species came from a pit at nearby Islip (DOUGLAS & ARKELL 1932, p. 131; PAGE, 1988, p. 175) from a level equivalent to Bed 1 at the much better known "Thrapston Railway Station Pit", as described by DOUGLAS & ARKELL (1932, p. 130), PAGE (1988, pp. 173–175), TORRENS (1968, p. 249), TAYLOR (1963, p. 130) and others.

Amongst the various other *Clydoniceras* recorded from the district are *C. discus, s.s.* (including ARKELL 1951, pl. 3, fig. 9) and several *C. hochstetteri*, the latter from both Islip (1951, pl. 3, fig. 5) and Thrapston itself (ARKELL 1951, pl. 3, fig. 8), which provide some circumstantial evidence to suggest that the *thrapstonense* fauna occurs in the upper part of the Discus Subchronozone, although further confirmation is needed from elsewhere where successions are much more complete. The apparent absence of *Homoeoplanulites*, however, which is common in the *hochstetteri* Biohorizon further south, is significant and could, in contrast, suggest that the *thrapstonense* fauna predates the typical *hochstetteri* fauna of Oxfordshire. Rare specimens of *C. thrapstonense* in the latter county (see (i) above), which could help resolve this question, are unfortunately unhorizoned.

An isolated outlier of Berry Member at Stowe Nine Churches, west of Northampton has also yielded *Clydoniceras* ex grp. *discus* (DOUGLAS & ARKELL 1932, p. 129; PAGE 1988).

(vi) *Cambridgeshire*: *Clydoniceras* ex grp. *discus* is known near Peterborough, including between Stilton and Yaxley, south of the city (JUDD 1875, p.229, 291; WOODWARD 1894, p.453; DOUGLAS & ARKELL, 1932, p.33) and on Ailsworth Heath, immediately to the north (JUDD 1875, p.224; WOODWARD 1894, p.454). More typically, however, the Berry Member is absent in the district, removed by a widespread non–sequence at the base of the Fleet Member which can be traced from northern Cambridgeshire into southern Lincolnshire (PAGE 1988, 1989).

(vii) *Lincolnshire*: In central Lincolnshire, Berry Member facies reappear and again yield *Clydoniceras* ex grp. *discus*, most significant at Sudbroke near Lincoln, including the microconch form "*Delecticeras legayi"* RIGAUX and SAUVAGE (ARKELL 1951, pl. 4, figs. 9, 10) and *C. discus* "var. **blakei* ARKELL" (1951, pl. 2, fig. 8 = type of "variety", as previously figured by BLAKE 1905, pl. 6, fig. 1) (ARKELL 1951–1958; DOUGLAS & ARKELL 1932; PAGE 1988, pp. 203–204). *Homoeoplanulites* ex grp. *homoeomorphus* (recorded as "*Choffatia cerealis* ARKELL" (1951–1958, p. 224, text fig. 29.3, p. 222, pl. 31,fig. 5), is also recorded from Sudbroke, but it is unclear whether the specimens are of Discus or Herveyi chronozone age (i.e. Bathonian or Callovian).

Northwards, the last known occurances of *Clydoniceras* ex grp. *discus* include scattered records near Aunsby (DENNISON 1955, p. 253; TORRENS 1968, p. 251). Towards the Humber estuary, as the Jurassic thins and virtually disappears over the Market Weighton "axis" (KENT 1955), the Berry Member appears to persist as far as the Appleby district (USSHER 1890, p.88; CROSS 1874, pp. 122, 125; WOODWARD 1894, p.457), north of Scunthorpe, where brachiopods typical of the member in central and southern England (including *Obovothyris obovata* (J. SOWERBY)) prove the Discus Subchronozone.

(m) *Lower Callovian, Herveyi Chronozone, Keppleri Subchronozone*: The lowest Callovian, Keppleri Subchronozone is generally missing in central and eastern England and is only proved at a handful of localities in north Gloucestershire and Oxfordshire (PAGE 1988, 1989).

The basal *keppleri* Biohorizon of the subchronozone is only known in a few thin bands at the very top of the Berry Member, very locally preserved below a Terebratus Subchronozone erosive surface in Oxfordshire. Records of *Kepplerites keppleri*, include "* *Cereiceras cereale*" BUCKMAN (1922, pl. 286; ARKELL 1951–1958, p. 117, text. fig. 42,) from near Witney, several specimens from Kidlington, north of Oxford, in a preservation similar to that of the specimen from Bed 4 in the Swan Inn Quarry, Long Handborough (as discussed above) and the four other specimens from the same quarry in Oxford University Museum collections (PAGE 1988, p. 156). Some of the perisphinctids recorded from the district (and cited previously) are certainly of *keppleri* Biohorizon age as well, but without more precise records, it is presently impossible to correctly assign them to the terminal Bathonian or basal Callovian.

To the southwest, and into Gloucestershire, the Fleet Member sequence is more complete, but appears to lack the basal *keppleri* Biohorizon, the lowest faunas apparently being mainly *Macrocephalites* ex grp. *verus* BUCKMAN (e.g. in Beds 2–3 of the original Shorncote Quarry, ARKELL 1933, pl. 35, DOUGLAS & ARKELL 1928; PAGE 1988, pp. 148, 149, and at an equivalent level in the "new" quarry, *pers. obs.* 1993–5).

An ammonite from Poulton, recorded by DOUGLAS & ARKELL (1928, p.134) that "*may be a perisphinctid or even a stephanoceratid*" is the only tentative suggestion that *Kepplerites* might also occur in the area (PAGE 1988, p. 151), but the specimen has not yet been traced. The Fleet Member near Fairford has also yielded *H.* ex grp. *homoeomorphus* (= **H. stabilis* BUCKMAN 1924, pl. 515 = Holotype); despite being from an unrecorded level, the specimen is most likely to be of Keppleri Subchronozone age as there are no confirmed records of *Homoeoplanulites* in the Terebratus Subchronozone in Britain (PAGE 1988, p. 152; ARKELL 1958, p. 225–226, pl. 30.).

From Oxfordshire northwards, the lower part of the Fleet Member generally yields *Macrocephalites* ex grp. *terebratus* (PHILLIPS) indicating a widespread non–sequence at the base of the Callovian. An isolated specimen labelled "Peterborough", however (Peterborough Museum 282/G; PAGE 1988, p. 189, pl.1, figs 3a,b), appears to either represent *M. jacquoti* (DOUVILLÉ), a species of the *keppleri* Biohorizon, or an even earlier form of the latest Bathonian. It is preserved in a bluish–grey limestone, more closely recalling Blisworth Limestone lithologies than the Fleet Member in the district, which makes the specimen even more problematic.

Late Bathonian *Macrocephalites* do occur in Europe, both in the late Hodsoni–Histricoides subchronozone interval (= "Orbis Zone" auctt.) and in *hochsttetteri* Biohorizon faunas in Germany (DIETL 1981, 1997). The Peterborough specimen, an incomplete macroconch, is published here for the first time (Figure 2). The specimen is unique in Britain in that it has a relatively strongly triangular whorl section and very fine ribbing, and is closely comparable to specimens of *M. jacquoti* from the basal Callovian *keppleri* Biohorizon in southern Germany (PAGE 1988; CALLOMON et al. 1989, etc.), but also earlier forms figured by DIETL (1997) from the Discus Subchronozone. The specimen is so unusual, however, that until its source level is confirmed by new finds or lithological /palynological analysis, a definitive determination or correlation is not possible.

Correlations

The ammonite faunas detailed above provide a backbone or a structure for correlating the Bathonian sequences of central and northern eastern England, although the only really continuous "datum" is that provided by the lateral persistence of the Berry Member and it's Discus Subchronozone faunas.

In the absence of ammonites there has traditionally been little real age–control, with correlations being largely dependent on lithostratigraphical arguments (e.g. in TORRENS 1980 and earlier reviews). A range of other fossil groups are, however, present, including both macro– and microfaunal and floral elements, all with biostratigraphical potential. In compiling Figure 3, such information has been incorporated from various sources, including correlations based on Nereneid gastropods in the White Limestone Formation of the north Cotswolds and Oxfordshire (after BARKER 1994), brachiopods in the Berry and Fleet Members of the Abbotsbury Cornbrash Formation (after DOUGLAS & ARKELL 1928, 1932 and PAGE 1988, 1989) and ostracods in the Rutland, Blisworth Limestone and Blisworth Clay formations (after BERRIDGE et al. 1999 and GAUNT et al. 1992). Palynological information is also potentially very valuable in dominantly non–marine and quasi–marine formations, for instance in North Yorkshire outwith of the present study area complimentary new results will be published elsewhere (N. HOGG pers. comm., 2000).

As a considerable amount of work on the region remains unpublished, and in the absence of systematic contemporary micropalaeontological studies of much of the East Midlands sequence (especially the Rutland and Blisworth Limestone formations), the correlations presented as Figure 2 are inevitably provisional. Assumptions made regarding the chronostratigraphical age are often based on lithostratigraphical arguments – these require further independent testing. Key assumptions and correlative links include:

1. The Chipping Norton Limestone Formation appears to pass laterally into the Horsehay Sands Formation (formerly "White Sands") of Buckinghamshire, into the Stamford Member and ultimately the Thorncroft Sands of GAUNT et al. (1992), all are therefore likely to be of Zigzag Chronozone age (M. SUMBLER pers. comm., 1992).

2. The Taynton Limestone Formation passes laterally into the Wellingborough Limestone Formation (formerly the "Upper Estuarine Limestone") (M. SUMBLER pers. comm., 1992).

This and the assumed age of the Sharpi Beds of Northamptonshire constrain the age of the upper part of the Rutland Formation as Progracilis Subchronozone to pre Bremeri Chronozone (?Subcontractus Chronozone).

3. The Rutland Formation sequence comprises a succession of sedimentary rhythms, showing apparent cycles of progradation of saltmarsh–type conditions. Attempts have been made to correlate these rhythms (e.g. in TORRENS 1968) and even establish a lithostratigraphical terminology by naming various "cycles" (BRADSHAW 1978).

Each cycle has an erosive base, and the local absence of certain cycles has often been taken to indicate the presence of non–sequences. Nevertheless, although short distance correlations may be reliable, there is presently no independent biostratigraphical control on the assumptions made in correlating such cycles over larger distances. These cycles are therefore shown diagrammatically on Fig. 2.

Figure 2: *Macrocephalites* sp. cf. *jacquoti* (DOUVILLÉ); a problematic specimen preserved in matrix more closely resembling Blisworth Limestone Formation (Upper Bathonian, Retrocostatum Chronozone) than the expected Abbotsbury Cornbrash Formation, Fleet Member (Lower Callovian, Herveyi Chronozone). Locality given as "Peterborough" (Peterborough Museum, PM 282/G). Actual size (see text discussion on Herveyi Chronozone, Keppleri Subchronozone faunas, section (m

4. There is *no* independent stratigraphical control on the age of the pre–Wellingborough Limestone Formation / post Stamford Member Rutland Formation.

5. According to CRIPPS (19), the Shipton Member of the White Limestone Formation passes laterally into the Sharpi Beds at the base of the Blisworth Limestone Formation. If this assumption is true, then the latter is of Subcontractus or Morrisi Chronozone age and a non–sequence is therefore likely between this level and the succeeding Blisworth Limestone, especially where the Nerinea Bed, of presumed Bremeri Chronozone age (see discussion previously) is absent (i.e. the lower part of this succeeding sequence already yields *Procerites* ex grp. *quercinus* of the lower Retrocostatum Chronozone).

6. The detailed succession and position of erosional levels in the White Limestone Formation of north Cotswolds and Oxfordshire largely follows SUMBLER (1984 – as modified by BARKER 1994, Figure 4).

7. Evidence for the diachroneity of the Blisworth Limestone–(upper) "Rutland Formation" / Upper Priestland Clay (of GAUNT et al. 1992) junction is based on ostracod faunas cited under the discussion of Retrocostatum Chronozone faunas above. As the post Stamford Member / pre Sharpi Beds Rutland Formation appears to be equivalent to the "Lower Priestland Clay" of north Lincolnshire, it may be necessary to restrict the use of the lithostratigraphical term "Priestland Clay" solely to the mudrock–dominated unit into which the Blisworth Limestone appears to laterally pass in this area.

8. The lower part of the Blisworth Clay Formation appears to pass laterally into the Bladon Member of the White Limestone Formation in Oxfordshire (London and Thames Regional Guide; M. SUMBLER pers. comm., 2001).

9. The detailed correlation of the Abbotsbury Cornbrash Formation follows PAGE (1988, 1989).

Lithostratigraphical assignments on Figure 2 follow SUMBLER (1984, 1999, pers. comm., 2001), PAGE (1988, 1989) and the Grantham and Sleaford memoirs (GAUNT et al. 1992).

Conclusions

The general sequence of ammonite faunas in central and northern eastern England is summarised below. Other taxa are present in the region, as discussed above, although are excluded from this table as they are currently difficult to reliably place in the succession. Nominal species marked with an asterix (*) indicate the source level of type specimens, most of which are figured by ARKELL (1951–1958):

Lower Callovian, herveyi Chronozone, terebratus Subchronozone

Macrocephalites ex grp *terebratus* (PHILLIPS) (including **M. bedfordensis* SPATH?) [*terebratus* α Biohorizon; Abbotsbury Cornbrash Formation, Fleet Member =Upper Cornbrash auctt.; north Gloucestershire/ Oxfordshire to North Yorkshire coast]

Keppleri Subchronozone

Kepplerites keppleri (OPPEL) (including **Cereiceras cereale* S. BUCKMAN), *Homeplanulites* ex grp *homoeomorphus* S. BUCKMAN [*keppleri* Biohorizon; Abbotsbury Cornbrash Formation, Berry Member = Lower Cornbrash auctt.; Oxfordshire]

Upper bathonian, discus chronozone, discus Subchronozone

12. *Clydoniceras* ex grp *discus* (J. SOWERBY), including *C. hochstetteri* (OPPEL) and *Homoeoplanulites* ex grp *homoeomorphus* [*hochstetteri* Biohorizon; Abbotsbury Cornbrash Formation, Berry Member = Lower Cornbrash auctt.; north Gloucestershire/ Oxfordshire to North–amptonshire]

11. **Clydoniceras* ex grp *discus* (including *"*Delecticeras*" *delectum* ARKELL [m]); *Homoeoplanulites* ex grp *homoeomorphus* may also occur, although very rarely [*discus* Biohorizon; Abbotsbury Cornbrash Formation, Berry Member = Lower Cornbrash auctt.; north Gloucestershire/ Oxfordshire to ?mid Lincolnshire]

Hollandi Subchronozone

10. ? *Homoeoplanulites* sp. [Forest Marble Formation, north Gloucestershire]

Retrocostatum Chronozone, ?histricoides Subchronozone

9. *Homoeoplanulites* sp. [Blisworth Limestone Formation, Northamptonshire]

Hodsoni Subchronozone (no confirmed records)

Quercinus Subchronozone

8. *Procerites* ex grp. *quercinus* ARKELL ?non TERQUEM and JOURDY, *Homoeoplanulites* sp. [including *quercinus* Biohorizon; White Limestone Formation, Ardley Member; north Gloucestershire/ Oxfordshire to Blisworth Limestone Formation, Northamptonshire]

Bremeri Chronozone

7. *Homoeoplanulites* sp. [?Nerinea Bed, Blisworth Limestone Formation, Northamptonshire]

Morrisi Chronozone

6. *Morrisiceris* ex grp. morrisi (OPPEL) [*morrisi* Biohorizon, White Limestone Formation, topmost Shipton Member; north Gloucestershire]

Subcontractus Chronozone

5. Tulites ex grp *modiolaris* (W. SMITH) (including **T glabretus* S. BUCKMAN) [*modiolaris* Biohorizon, White Limestone Formation, Shipton Member; north Gloucestershire/ Oxfordshire]

Progracilis Chronozone, progracilis Subchronozone

4. **Procerites imitator* (BUCKMAN) [*imitator* Biohorizon, Hampen Marly Formation; Oxfordshire]

3. Procerites ex grp *progracilis* COX and ARKELL (including **P mirabilis* ARKELL, **P. vineta* ARKELL and **P. magnificus* ARKELL), **Micromphalites micromphalus* (PHILLIPS), **?Clydoniceras tegulum* ARKELL and **Oxycerites oxus* (S. BUCKMAN) [*progracilis* Biohorizon; Eyford Member, Sharps Hill Formation, north Gloucestershire and Taynton Limestone Formation, "Stonesfield Slate" facies, Oxfordshire]

Orbignyi Subchronozone and tenuiplicatus Chronozone (no confirmed records)

Zigzag Chronozone, yeovilensis Subchronozone (no confirmed records)

Macrescens Subchronozone

2. Zigzagiceras [*Procerozigzag*] *pseudoprocerus* (S. BUCKMAN) [*macrescens* Biohorizon, Chipping Norton Limestone Formation; Oxfordshire]

Convergens Subchronozone

1. Parkinsonia ex grp *convergens* (S. BUCKMAN) (?including **P. oxonica* ARKELL) [*convergens* Biohorizon, Chipping Norton Limestone Formation; north Gloucestershire/ Oxfordshire]

Upper Bajocian, parkinsoni Chronozone, ?bomfordi Subchronozone

Parkinsonia [*Durotrigensia*] cf. *crassa* NICO–LESCO [?basal Chipping Norton Limestone Formation, Oxfordshire]

The diversity of Bathonian ammonite faunas decreases significant from southern to northern Britain and there appears to be some ecological control on the northern known limits of various taxa. From south to north, various genera disappear successively, creating the impoverished faunas formerly considered to be characteristic of a Subboreal Province (e.g. in MANGOLD & RIOULT (1997). In reality, as discussed by PAGE (1996) and PAGE & MELENDEZ (1999), there are no fundamental differences between these so–called "Subboreal" faunas and those typical of Submediterranean areas, except the increasing impoverishment northwards. The latter is undoubtedly an ecological consequence of lowered salinities and unstable environments close to fluctuating low–lying coastlines surrounding the embayments and gulfs which characterised the northern margins of the seas which covered much of Europe at this time.

Figure 3 shows the northern limits of various genera known to occur contemporaneously in France and Spain for the pre Discus Chronozone Bathonian, in particular for the Bremeri–Retrocostatum Chronozone interval, which includes marine–influenced deposits at least as far north as northern Lincolnshire (i.e. the absence of various taxa in the most northerly areas is not, therefore, due to non–sequences). Disappearances are as follows *?Epistrenoceras* / *Prohecticoceras* (Somerset), *Oxycerites* (Somerset), *Bullatimorphites* (Gloucestershire), *Homoeoplanulites* (Northamptonshire), *Procerites* (south Lincolnshire). The last two genera, however, are typically recovered in northern areas as very rare and scattered, large mature specimens – the drifting and subsequent sedimentation of empty shells can also therefore be invoked to place them so far north.

Discus Chronozone faunas do not quite fit this pattern, however, not least because the Berry Member of the Abbotsbury Cornbrash Formation is remarkably uniform lithologically across England, and that *Clydoniceras* is almost always recorded where the Berry Member is exposed. Although *Homoeoplanulites* is also present, possibly as far north as central Lincolnshire, it is generally absent or very rare (excepting the *hochstetteri* Biohorizon faunas of Oxfordshire and southwards) and it is the relative frequence of *Clydoniceras* that is noteworthy. The latter genus is most typical of northern European faunas, including in Britain, Normandy and northern Germany (WESTERMAN 1958, DOUVILLÉ 1943, etc), but apparently considerably rarer to the south (e.g. in southern Germany; DIETL 1997) or absent (e.g. in Spain; PAGE & MELÉNDEZ 1999). Unlike all other Bathonian taxa, there does genuinely appear to be a preferred northern distribution here, and perhaps *Clydoniceras* really is characterising a northern subprovince on the margins and in the backwaters of the Submediterranean Province seas which covered most of the rest of Europe in the latest Bathonian.

When ammonites are absent, "conventional" Jurassic correlation can fail.

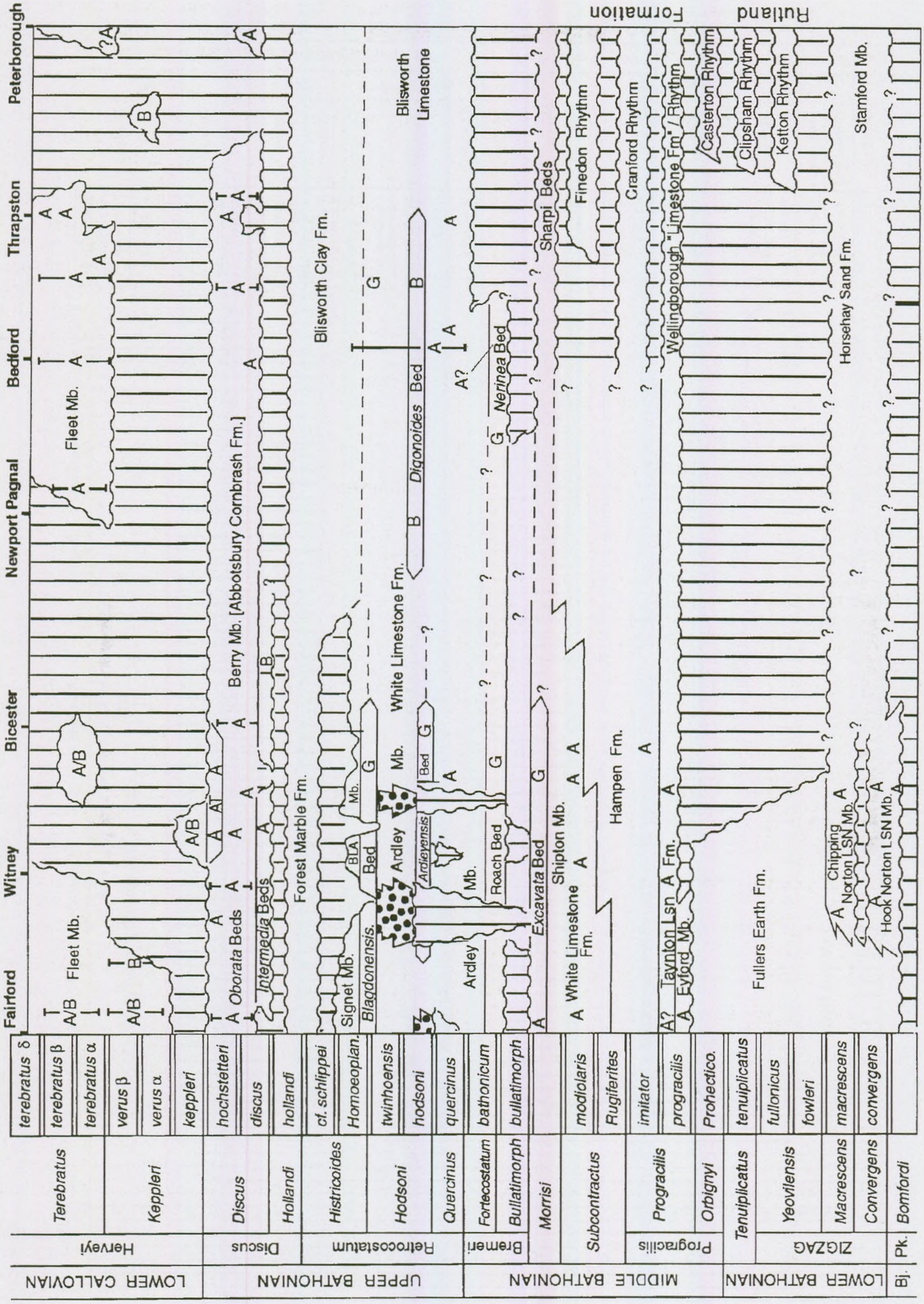

Figure 3a: A provisional correlation of Bathonian rocks in central and northern England. See text for discussion and sources of information. A = Ammonite; B = Brachiopod; G = Gastropod.

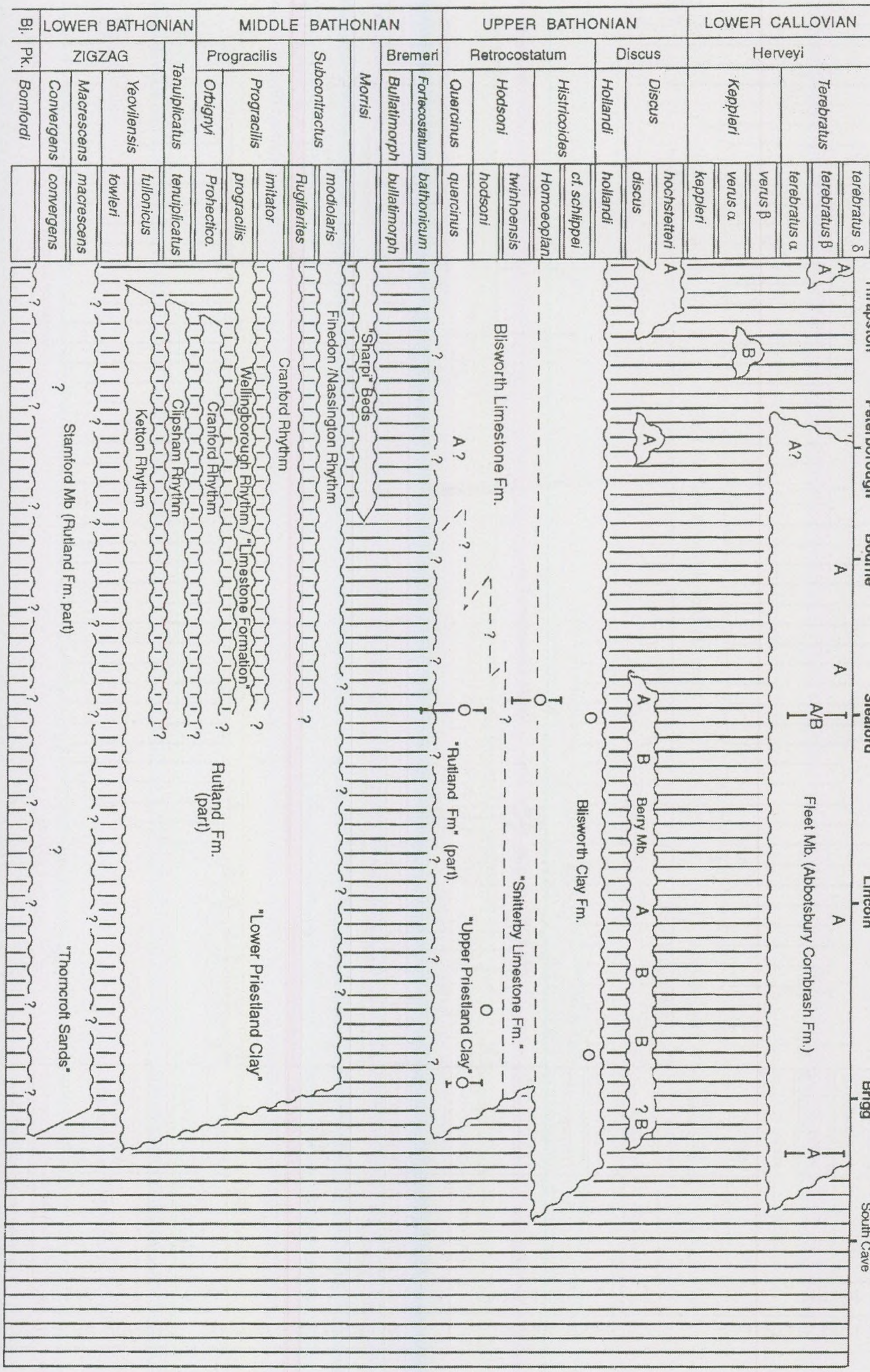

Figure 3b: A provisional correlation of Bathonian rocks in central and northern England. See text for discussion and sources of information. A = Ammonite; B = Brachiopod; G = Gastropod.

Nevertheless, it is clear from the Bathonian of central and northern England, that brachiopods, gastropods, ostracods and dinoflagellates can now offer a stratigraphical resolution, at least as refined as ammonite zones and occasionally, at least locally, as good as subzones. Combining such information together can only strengthen the use of standard chronozones in the Jurassic – considering ammonite-named zones solely as biozones, as is common, for instance in Britain, is clearly denying the full potential of the chronostratigraphical method for producing fully integrated correlation schemes and reliable correlations of facies where ammonites are rare or absent.

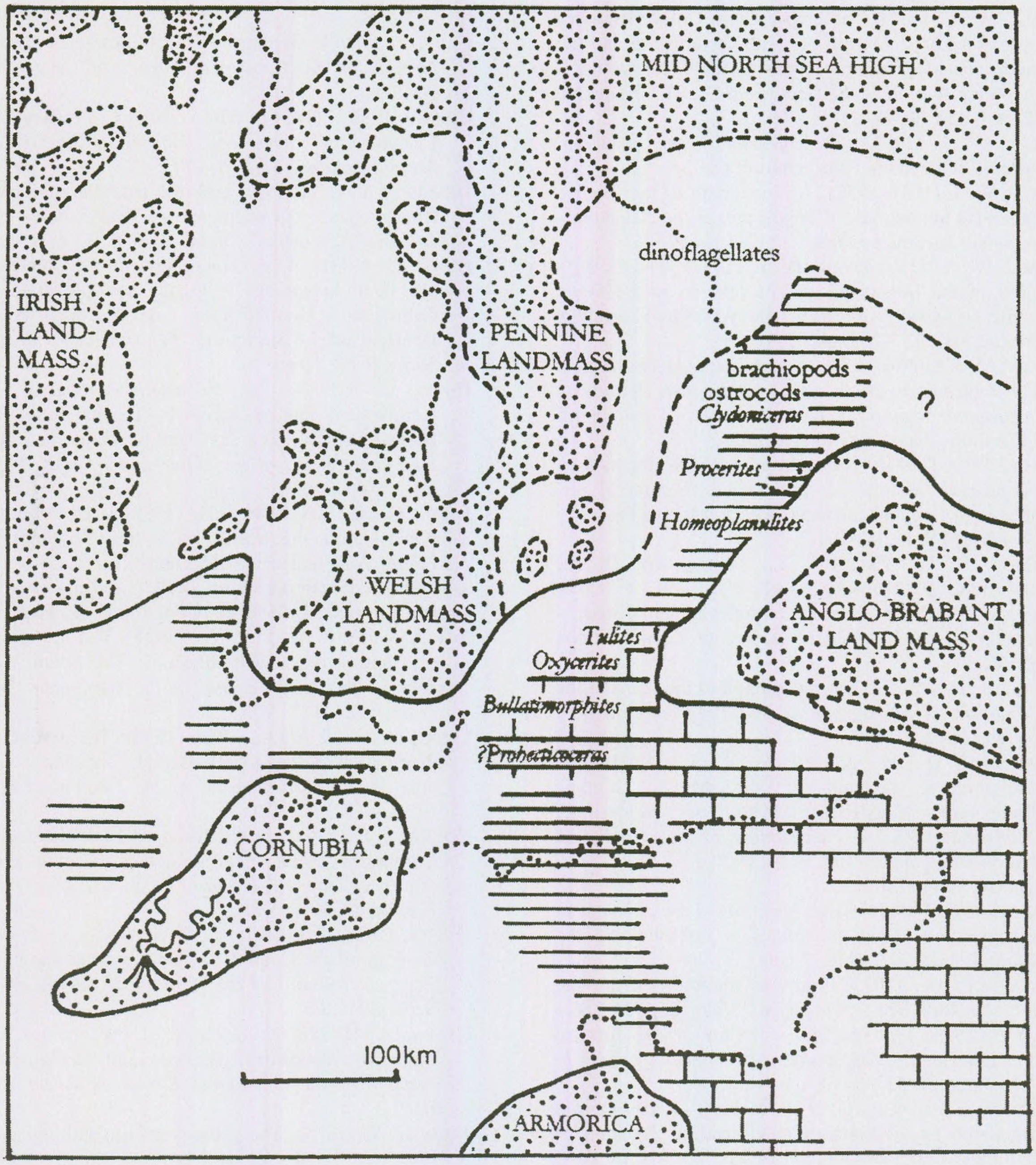

Figure 4: Palaeogeographical map of Britain and adjacent areas based on in COPE (1995), showing the northern limit of various characteristic Bathonian ammonite taxa.

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Monsoon–like climate during the Bajocian Clay mineralogical and geochemical study on a limestone/marl alternation (Komló Calcareous Marl Formation, Mecsek Mountains, Southern Hungary)

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(With 11 figures and 5 tables)

Jurassic formations are cropped out in the eastern part of the Mecsek Mountains in a relatively extended area. The Aalenian–Bajocian interval is characterised by bioturbated marls and clayey limestones (Fleckenmergel, Allgäu facies) named as Komló Calcareous Marl Formation. The most obvious feature of this formation is rhythmic alternation of carbonate–rich and carbonate–poor semicouplets. Our work deals with characterization of changes of palaeoenvironmental conditions of this sequence using an approach involving study of changes in clay mineral assemblages, determination of stable isotopic composition, and enrichment or impoverishment redox– and bioaffinity–controlled elements.

The clay fraction of the examined samples is dominated by illite and illite/smectite mixed–layer phases (with 40–70 percent illite content, R=0 or R=1 type interstratification). It has been formed by preferential replacement of smectite by illite during burial diagenesis. Discrete illites seem not to be altered by heating during burial. Kaolinite is rarely found, only in samples rich in shelf–derived redeposited material. Abundance of the clay mineral species does not show any covariance with the lithology and the position in the profile. This phenomenon suggests that the processes forming the alternation of carbonate–rich and carbonate–poor semicouplets did not directly and exclusively affect the genesis of the clay minerals. Clay mineral assemblage documents erosion of smectite–rich soils developed under warm and seasonally humid climate. Sparse occurrence of the kaolinite together with the high abundance of illite and illite/smectite suggest relatively distant source area during deposition.

Stable isotope ratios of the carbonate fluctuate between 0.2 and 2.1 ‰ for carbon and between –5.1 and –0.5 ‰ for oxygen. Positive correlations were found between the measured isotope ratios of the two elements and between the isotope ratios and $CaCO_3$–content of the samples, also it can be established that carbonate–rich semicouplets are enriched in heavy carbon and oxygen isotopes in comparison with carbonate–poor semicouplets. This pattern suggests enhanced productivity, relatively 'cool' and/or 'saline' surface water during deposition of carbonate–rich semicouplets and minor role of diagenetic carbonate redistribution.

Fluctuations of P in the carbonate–rich semicouplets seem to be controlled by carbonate dilution of the terrigenous material and enhanced surface–water productivity. Diagenetic enrichment under oxic pore water conditions seems to be the most plausible explanation for relative Mn–enrichment in the carbonate–rich samples. Enrichment of the elements such as Fe, Zn, Cu, V, Ni in carbonate–poor semicouplets cannot be explained by a pure detrital source. According to Ti–normalised major and trace element enrichment factors relative to the PAAS, excess concentrations (over detrital) may be derived from seawater and could have been (at least partially) associated with the organic fraction during sedimentation. During early diagenesis moderately oxic, dysoxic conditions were favourable to decomposition of organic complexes, adsorption onto surface of the clay minerals and/or incorporation in sulfide minerals.

Rhythmic organisation of the couplets may represent palaeoenvironmental changes. Palaeoceanographic conditions alternated from efficiently mixed, high–fertility surface water and well–oxygenated seafloor (carbonate–rich beds) to enhanced runoff and/or decreased evaporation with sluggish vertical circulation and moderately oxygenated bottom water (carbonate–poor beds). This scenario should be connected to alternating anti–estuarine and estuarine circulation. The corresponding climatic conditions alternated from more arid to more humid.

Introduction

Cyclic sedimentation recorded as rhythmic lithological changes (according to terminology of EINSELE et al. 1991) in pelagic and hemipelagic sequences has been the aim of many papers in the last few decades. Interest has been concentrated on Cretaceous and younger formations, which are often characterised by cyclicity expressed as alternations of beds with fluctuating carbonate content and by minimum late diagenetic overprint as source of misinterpretations (DUFF et al. 1967, SCHWARZACHER 1975, EINSELE & SEILACHER 1982, BERGER et al. 1984, RICKEN 1991, 1994). Jurassic successions has been rarely studied (MATTIOLI 1997, BUCEFALO PALLIANI et al. 1998, COLACICCHI et al. 2000, MORETTINI et al. 2000).

The mechanisms that may produce rhythmicity or cyclicity seem to be related to the variation of environmental factors. According to several researchers (ROCC Group 1986, FISCHER et al. 1990, DE BOER & SMITH 1994, SETHI & LEITHOLD 1994, BELLANCA et al. 1996, BICKERT et al. 1997, FRANCK et al. 1999, KUMP & ARTHUR 1999, MARTINEZ et al. 1999, COLACICCHI et al. 2000, MORETTINI et al. 2000) these factors include changes (fluctuations) in

i) the supply of calcareous or siliceous biogenic sediment produced by plankton (productivity cycles);

ii) the supply of terrigenous material (dilution cycles);

iii) the degree of saturation of seawater with respect to calcium carbonate (dissolution cycles);

iv) the amount of dissolved oxygen at the seafloor and the degree of organic matter preservation (redox cycles).

Even if Milankovitch–type cyclic patterns might be expressed by a combination of physical, chemical and geological fluctuations, many of the papers emphasized so far the palaeontological aspects in order to explain the mechanisms leading to the deposition of lithological rhythms (BOTTJER et al. 1986, SAVRDA & BOTTJER 1994, ERBA & PREMOLI SILVA 1994, PITTET & STRASSER 1998). A fairly new and less common approach focuses on the geochemical characterization of such rhythmic successions. Many works have been centered on isotope stratigraphy and organic geochemistry (WEISSERT & BRÉHÉRET 1991, JENKYNS et al. 1994, PATTERSON & WALTER 1994, BICKERT et al. 1997, BUCEFALO PALLIANI et al. 1998) and some papers used trace element geochemical data in an attempt to understand the palaeoceanographic meaning of the alternations of couplet–forming beds (MURRAY et al. 1990, 1991, 1992, 1993, MURRAY & LEINEN 1993, SUNDARARAMAN et al. 1993, BELLANCA et al. 1996). Clay minerals are known as very sensitive indicators of climatic changes in provenance and maximum heating during burial. Therefore, many authors applied clay mineral assemblage studies to determine the role of climatic, tectonic and eustatic effects in the cyclic and event stratigraphy (BISCAYE 1965, CHAMLEY 1967, CHAMLEY & DEBRABANT 1984, PACEY 1984, SINGER 1984, GYGI & PERSOZ 1986, HALLAM et al. 1991, ROBERT & KENNETT 1994, EGGER et al. 1997, GIBSON et al. 2000).

In Hungary, Triassic and Cretaceous formations from the Transdanubian Central Range have ever been analysed to describe the causes of rhythmicity and cyclicity (HAAS 1982, FOGARASI 1995). As far as the Jurassic in Hungary is concerned, description or analysis of a rhythmic or cyclic sequence was not published.

Stratigraphically uppermost part of the Fleckenmergel series named as Komló Calcareous Marl Formation (CSÁSZÁR 1997; Fig. 1) has Aalenian–Bajocian age. Its rhythmic character was first mentioned by FORGÓ et al. (1966). However, causes of the rhythmicity, causal relations between this character and possible palaeoenvironmental changes were not investigated. In this study we combine clay mineralogical and geochemical methods in order to model the palaeoenvironmental changes affecting the sedimentation of the Mecsek basin during the Bajocian.

Geological setting and lithology

The studied sections are located in the eastern part of the Mecsek Mountains (Figs 2, 3 and 4). The Mecsek Mountains belong to the Tisia Terrane, a structural megaunit of the Carpathian–Pannonian realm. According to results of research of the Apuseni Mountains (BLEAHU 1976, IANOVICI et al. 1976) and of the Great Hungarian Plain (BALÁZS et al. 1986, GROW et al. 1994), the Tisia Terrane is a basement nappe system overthrust with northern vergency during the Cretaceous Austroalpine tectogenesis.

In the Jurassic the area was part of the northern continental margin of the Tethys. Differentiation of the carbonate shelf into extensional structures started during the Late Triassic (NAGY 1969). This process has continued in the Early Jurassic as a result of rifting of the Penninic Ocean. Early Liassic is characterised by a continental and shallow marine sequence with arkose–type sandstones and coal measures (Gresten facies). The overlying sequence is usually compared with the Allgäu facies of the Northern Alps. Dominant lithofacies is abundant spotted, bioturbated marl and siltstone intercalated by mixed carbonate–siliciclastic turbidites, crinoidal limestones and interrupted by a black shale horizon in the Early Toarcian. This type of sedimentation prevailed until the Late Bajocian. The whole Jurassic succession up to the Bajocian *Strenoceras niortense* Zone developed to a maximum thickness of 3700 m.

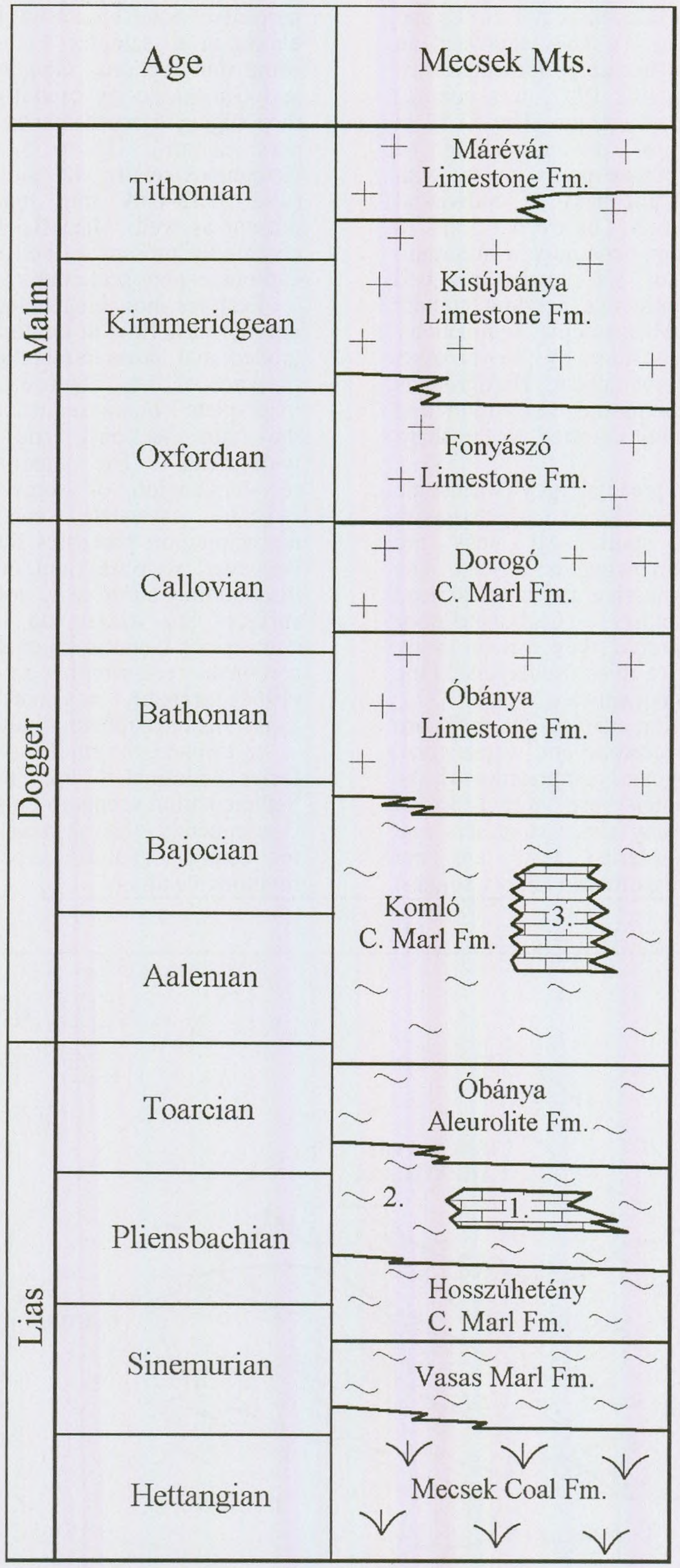

Fig. 1. Jurassic lithostratigraphic units of the Mecsek Mountains (CSÁSZÁR 1997). 1. Kecskehát Limestone Formation; 2. Mecseknádasd Sandstone Formation; 3. Pusztakisfalu Limestone Formation.
Different facies types are indiced as follows: coal swamp: symbolic plants; hemipelagic bioturbated marl: waves; crinoidal limestones: brickwall pattern; micritic pelagic limestones: crosses.

Two outcrop profiles north of village Püspökszentlászló belonging to the Komló Calcareous Marl Formation (Fig. 1) were studied in detail. They are named as Püspökszentlászló II, and Kecskegyűr, road cut (Fig. 4). They represent an Early to Middle Bajocian succession indicated by a *Kumatostephanus* sp. (GALÁCZ 1997, pers. comm.) found on the base of the succession. The 53.87 m thick section consists of an alternation of carbonate–rich and carbonate–poor layers with couplet character. The thickness of individual carbonate–rich layers alternates between 12 and 78 centimetre. Carbonate–poor beds have a minimum of 9 and a maximum of 106 centimetres bed thickness. Sharp and continuous bedding contact can also be observed. Macroscopic sedimentary structures indicating redeposition by gravity mass flows or contourites do not appear. Hardgrounds and other features of submarine dissolution and sediment starvation were not detected on the sharp bedding contacts.

The beds are grey and greenish grey (with some yellowish shade on the weathered surfaces) with abundant darker grey spots. All beds are macroburrowed, microburrowing is absent. The carbonate–rich beds are massive and characterised by conchoidal fracture. Carbonate–poor semicouplets are less massive, they can be easily splitted into 1–2 centimetre thick 'sublayers'. Fine and graded lamination do not appear.

According to thin section analyses the rocks are classified as bioclastic packstone and wackestone. The most abundant biogenic components of the carbonate–rich semicouplets are round–shaped calcified molds without any inner structures and filaments. A few radiolarian tests are not recrystallized. These microfossils may suggest radiolarian origin of the calcite–filled molds. Carbonate–poor beds are dominated by siliceous sponge spiculae. Echinoid fragments up to 10 percent of total bioclastic assemblage were found almost in all samples. Foraminifers are present in some thin sections. *Lenticulina* sp., *Spirillina* sp. and *Garantella* sp. cannot be used for dating but they suggest normal marine salinity (RESCH 1997, pers. comm.). Up to 5 percent of unrounded terrigenous quartz silt and very fine sand grains (with 0.02–0.09 mm maximum diameter) are present as well. Mica flakes (up to 0.5–0.6 mm) commonly present on bed surfaces in the case of carbonate–poor semicouplets.

Features indicating redeposition and erosion by gravity mass flow or contourite activity (gradation, graded and cross lamination, lenticular bedding, presence of fine, obscure silt lenses, complete or incomplete Bouma–sequence) were not observed in the thin sections, and the bioturbation is widespread. The partial dissolution and recrystallization of some biogenic constituents indicate carbonate and silica dissolution–reprecipitation processes during burial diagenesis. However, stylolites and other dissolution–related discontinuity surfaces do not appear Wavy bedding surfaces are widespread, nevertheless carbonate concretions have not been formed, i. e. diagenetic carbonate redistribution in the sense of HALLAM (1964) probably was not significant enough to cause this limestone/marl alternation.

In essence, the studied profiles represent basinal facies dominated by hemipelagic processes. Sedimentation seems to be presumably continuous. Consequently, this succession is a good candidate for detailed analysis to examine the origin of rhythmic bedding.

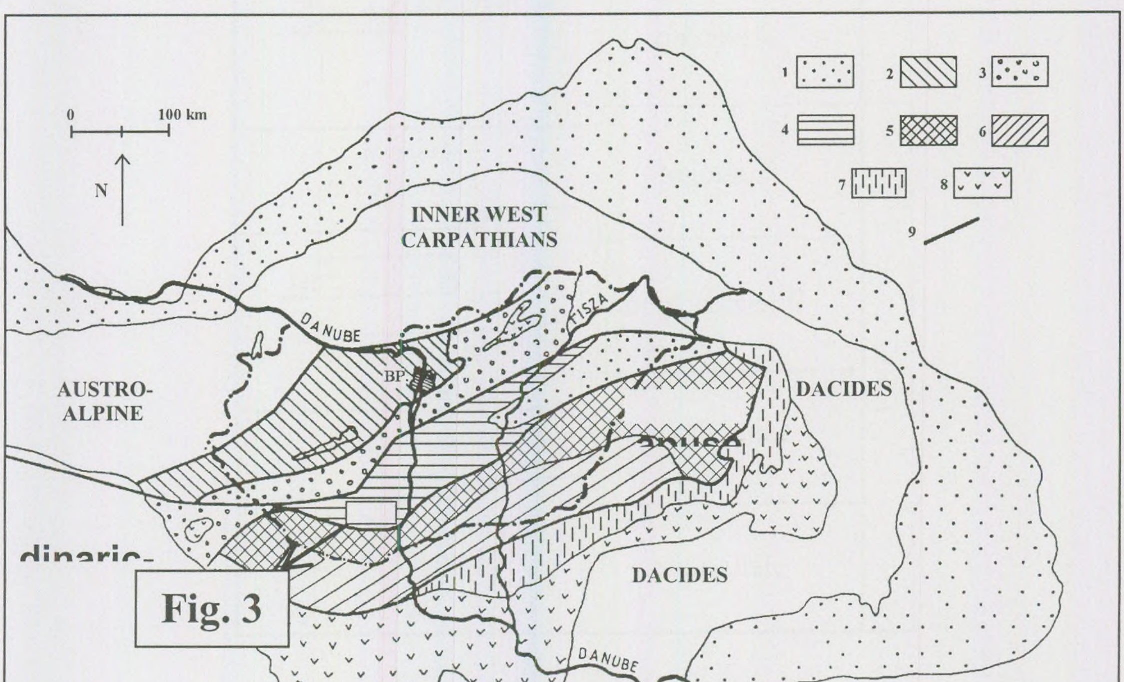

Fig. 2. The location of Mecsek Mountains in the Mesozoic tectonofacial units of Hungary, modified after TÖRÖK (1997a). 1. Foredeep and flysch units; 2. Transdanubian and Drauzug units; 3. Bükk and Inner Dinaric units; 4. Mecsek unit (area of the Mecsek Mts. is indicated by gray rectangle); 5. Villány–Bihor unit; 6. Papuk–Lower Codru unit; 7 N. Bačka–Upper Codru unit; 8. Oceanic nappes; 9. Boundaries of tectonofacial units

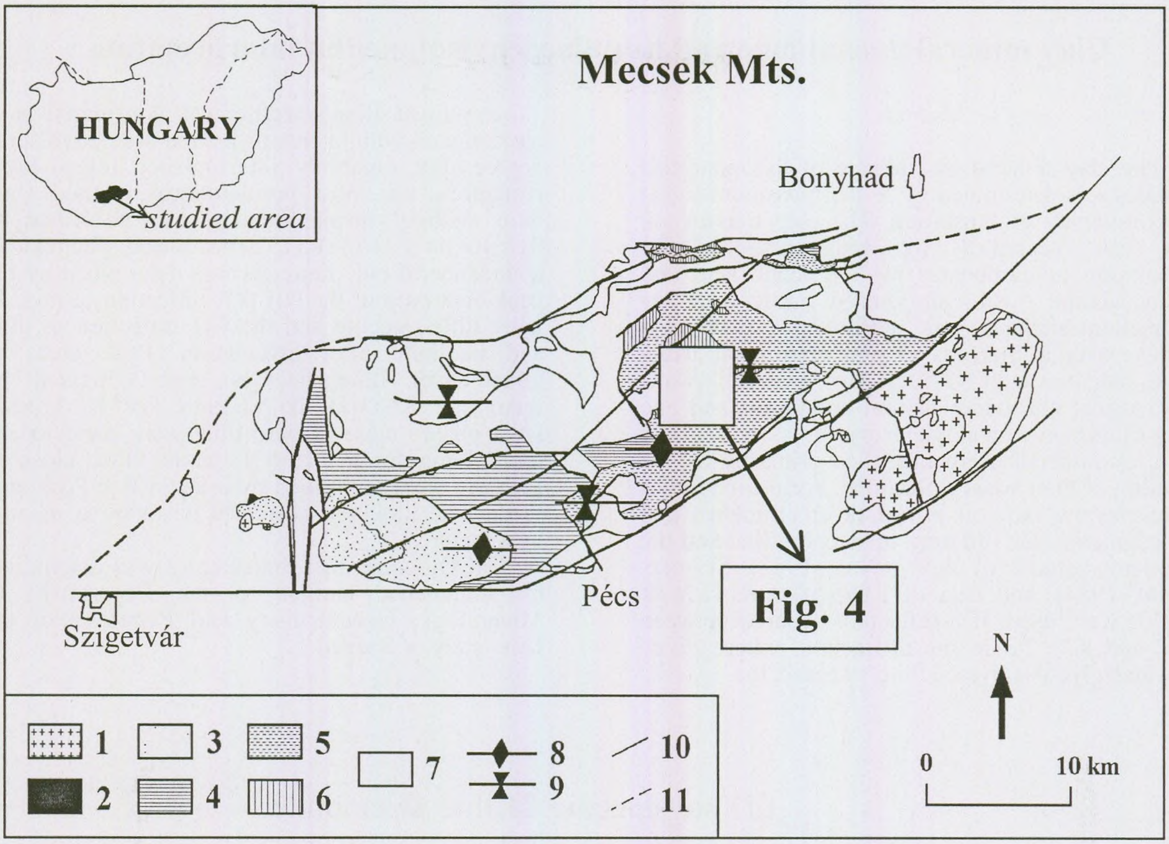

Fig. 3. Geological map of the Mecsek Mountains, simplified after TÖRÖK (1997b).
1 Carboniferous granite; 2. Permian rhyolite; 3. Upper Permian; 4. Triassic; 5. Jurassic; 6. Cretaceous; 7 Post–Cretaceous; 8. anticline; 9. syncline; 10. fault; 11. supposed fault.

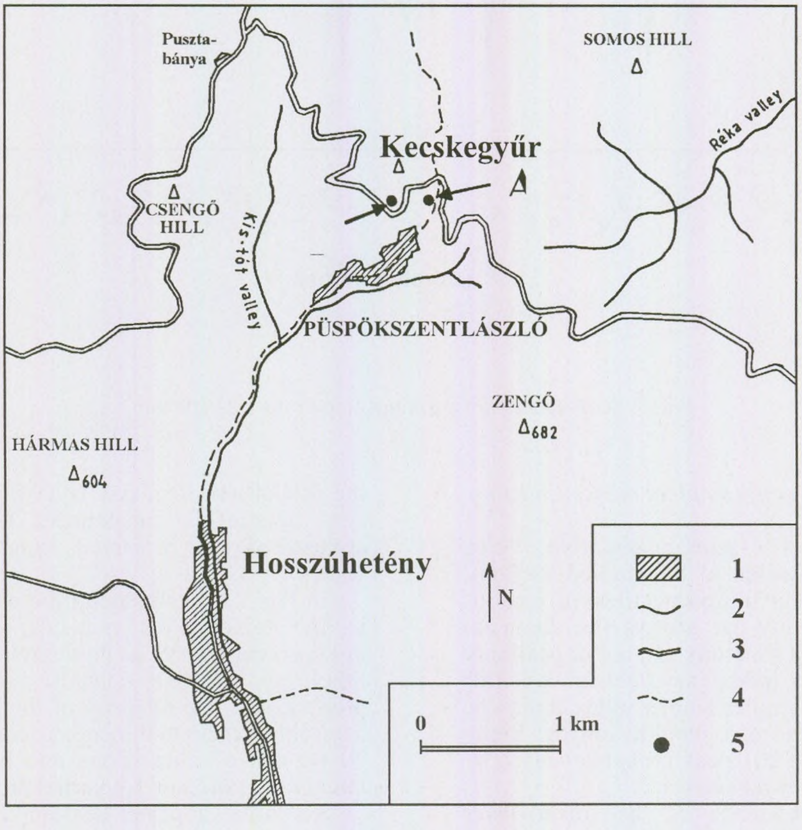

Fig. 4. Location map of the two examined sections. 1. settlement; 2. creek; 3. road; 4. path; 5. location of the examined sections; A: section Püspökszentlászló II; B: section Kecskegyűr, road cut.

Clay mineral assemblage and its palaeoenvironmental interpretation

Methods

The clay mineral assemblage of the examined samples was determined by X–ray measurements at the University of Innsbruck. The clay fraction <2 μm was separated by sedimentation after dissolution of carbonates by 3% acetic acid and deflocculation with desionized water. X–ray diffraction analysis was performed on oriented pastes, with a Siemens D–500 instrument using CuK_α radiation with Ni filter. Two X–ray diagrams were made: one under natural conditions and one after saturation with ethylene glycol.

Clay minerals were identified primarily by the position of their basal reflections. For estimation of illite/smectite ratio in mixed–layer structures and for estimation the ordering of interstratification the standard methods of WATANABE (1981), ŚRODON (1980, 1984), and data of REYNOLDS & HOWER (1970) were used. If a reflection occured between 5.3° and 8.7° 2Θ in the diffraction pattern of an ethylene glycol–solvated illite/smectite, the examined illite/smectite was considered as a clay mineral with interstratification ordered to some degree. For randomly interstratified mixed–layer structures, the most problematical method ('a/b ratio method') using intensity data published by REYNOLDS & HOWER (1970) was used. The relative abundance of clay minerals was determined by the peak area ratio of the 001/001 reflection of mixed–layer illite/smectite and the 001 reflection of illite and kaolinite after glycolation. Peak areas of mixed–layer illite/smectites were corrected by factors of RISCHÁK & VICZIÁN (1974). Mixed–layer phases close to pure illite were corrected by multiplying by a factor 2, while those close to smectite were multiplied by a factor 0.5. Peak area of discrete illite was corrected in a similar manner by a factor 2.

$CaCO_3$–content of the samples was determined by volumetric method at the Department of Mineralogy, Geochemistry and Petrology of the University of Szeged.

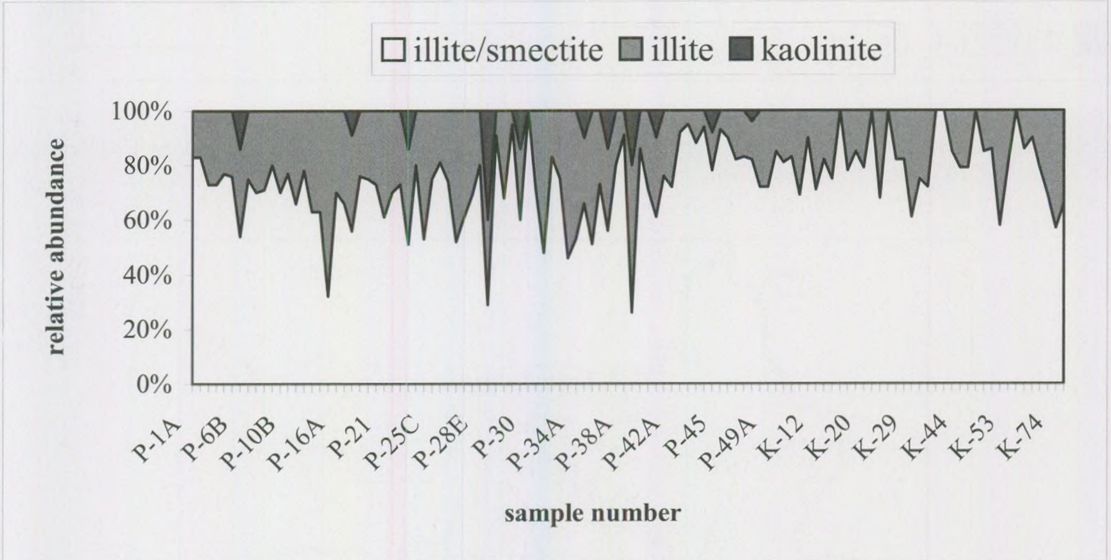

Fig. 5. Semi–quantitative composition of the clay fraction

Results of the clay mineralogical measurements

Fig. 5 shows semi–quantitative clay mineralogical composition of the studied sections. Illite and mixed–layer illite/smectites of various degree of expandability are always the dominant clay minerals. Illite is generally of poor crystallinity (values of the Kübler index vary between 0.6–1.0° 2Θ). In most of the samples Kübler index cannot be exactly measured due to a shoulder on the high–angle side of the illite 001 peak probably caused by the expanded mixed–layer phases.

The relative abundance of the mixed–layer phases in function of the $CaCO_3$–content of the samples is plotted in the Fig. 6. It is obvious that the proportion of mixed–layer illite/smectite in the clay fraction is independent from the $CaCO_3$–content of the measured samples (see the "*r*" values).

In Fig. 7 the estimated illite percentage intervals in the mixed–layer minerals are shown. It is obvious that there is no correlation between the lithology ($CaCO_3$–content) and the illite proportions. The majority of the examined mixed–layer illite/smectite minerals is characterised by 40–70 percent of illite layers and by mostly random interstratification or 1/4 partial ordering.

Kaolinite appears seldom (10% of all the measured samples), mostly in low amount (14.3% average abundance; maximum value = 40% in sample P–29A) and only in the carbonate–rich semicouplets (Fig. 5). However, there is no correlation between the $CaCO_3$–content of the samples and the abundance of this clay species (r =–0.2071) (Fig. 8).

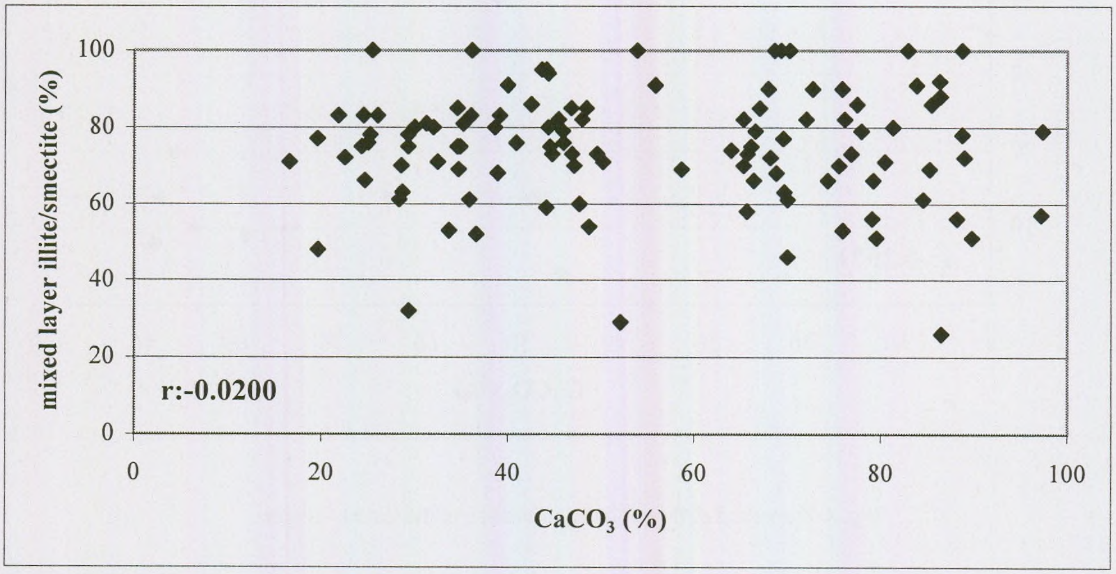

Fig. 6. Proportion of the illite/smectite mixed–layer minerals in function of the $CaCO_3$–content

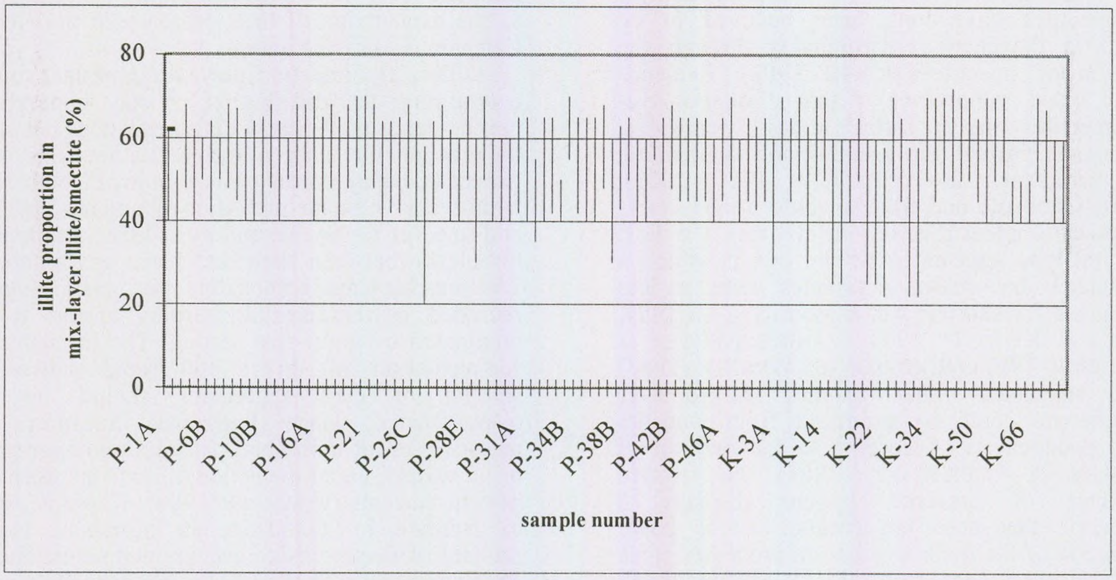

Fig. 7 Estimated illite proportion of the mixed–layer illite/smectite clay minerals

Discussion

In most regions of the world ocean, clay detrital assemblages reflect the combined influences of land petrography and continental climate (BISCAYE 1965). The common clay minerals used as environmental indicators are kaolinite, mixed–layer illite/smectite and illite.

In the modern oceans kaolinite abundance increases toward the Equator in all oceanic basins and therefore expresses a strong climatic dependence controlled by the intensity of continental hydrolysis. In modern marine sediments, kaolinite tends to increase in relative abundance in neighbouring regions of tropical continental weathering. The strong increase in kaolinite (together with goethite, gibbsite) could reflect very intensive weathering on the source area (CHAMLEY 1989, ROBERT & KENNETT 1994, GIBSON et al. 2000). As for Jurassic formations in the Mecsek Mountains, NAGY (1969), VICZIÁN (1987) reported high amount of kaolinite in the Mecsek Coal and Vasas Marl Formation.

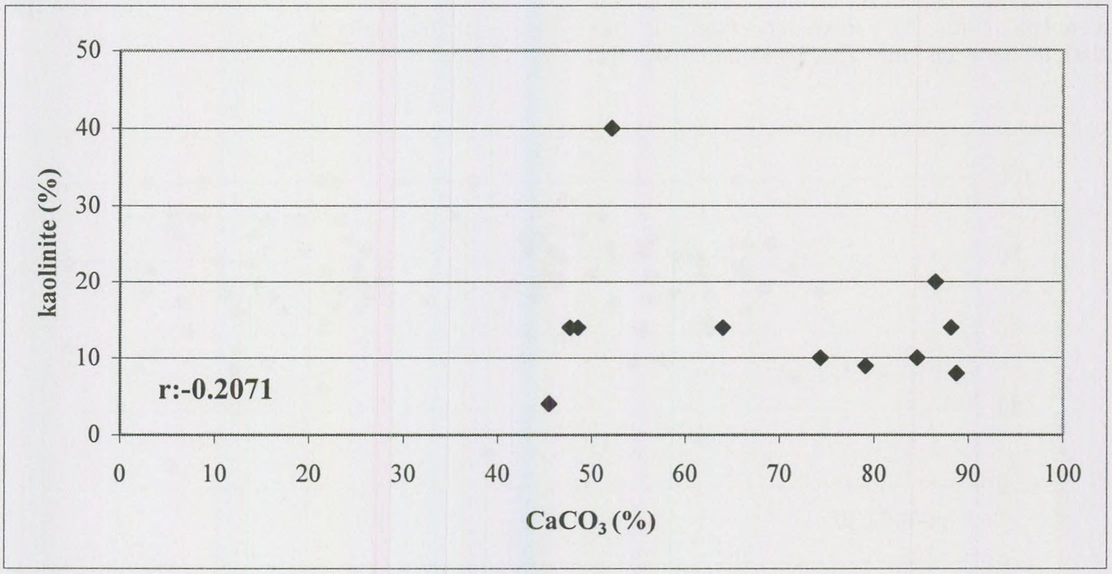

Fig. 8. Proportion of the kaolinite in function of the $CaCO_3$–content

The distribution of mixed–layer minerals in the present day oceans have strong geographic controls. This indicates continental sources rather than in situ diagenetic origin (BISCAYE 1965). Mixed–layer illite/smectites have long been believed to be formed in diagenetic environments through the alteration of smectite (HOWER 1981). Evidence does exist, however, that mixed–layer illite/smectites may form in a weathering environment through the leaching and degradation of a precursor illite (CHAMLEY 1967, 1989). Although smectite and illite/smectite mixed layers form recently under a variety of climates, the most important type appears to be the one in which a pronounced dry season alternates with a less pronounced (or shorter) wet season (SINGER 1984, ROBERT & KENNETT 1994, VANDERAVEROET & DECONINCK 1997). ROBINSON & WRIGHT (1987) have suggested that some mixed–layer illite/smectite could be produced from smectite during pedogenesis. According to the opinion of CHAMLEY & DEBRABANT (1984) the relative abundance of smectite largely displays a distribution that does not parallel to the zonal distribution of the main weathering processes. This could indicate the accessory control of climate and the dominance of other processes. The increase of Al–Fe–rich smectites and their abundance does not depend on deposition in marine environment but are chiefly attributed to the reworking of continental peneplanation of gently sloping and poorly drained areas. It must be noted that smectite may be entirely volcanogenic in origin, being derived directly from the weathering of lava or volcanic ash and tuffs, and thus having nothing to do with climate. In this case, however, distinctive accessory minerals must occur, such as biotite, sphene, cristobalite, zeolites and, rarely, relict glass shards (PACEY 1984, ÇELIK et al. 1999).

The occurrence of discrete illite in sediments probably has no particular climatic significance (HALLAM et al. 1991, ROBERT & KENNETT 1994), but SINGER (1984) claims that illite exhibiting high crystallinity signifies formation in either cold or dry conditions with minimum hydrolysation. Because of low crystallinity of illite in the measured samples, these conditions can hardly be considered as the explanation of their presence in the Komló Calcareous Marl Formation.

Differential transport plays an important role in determining the distribution of clay minerals in marine deposits. As early diagenesis does not seem to account for such a differentiation, one may expect that clay sorting was reinforced both by a hydrolysing climate providing abundant kaolinite and smectite to the sea, and by sudden variations of turbulence between shelf and basin environments. The mechanisms responsible for clay changes recorded on continental margins appear to be dominated by grain size sorting. The influence on sedimentation of direct and rapid subvertical sinking of clay aggregates should not be overestimated, since horizontal transport and resuspension of individual particles and aggregates occur widely, under the action of surficial, deep and bottom currents (CHAMLEY 1989). Kaolinite tends to increase in abundance in nearshore facies, probably reflecting its coarse–grained nature and its strong tendency to flocculate compared to most other clays (PARHAM 1966). Clay sorting usually determines the farther transportation of smectite and fibrous clays relatively to the most other clay species.

The sparse occurence of kaolinite in the rocks of the Komló Calcareous Marl Formation is restricted to a few carbonate–rich semicouplets rich in shelf–derived bioclasts. According to micropaleontological data there are Ostracods in the Komló Calcareous Marl Formation collected from other locations of Mecsek Mountains, which indicate shallow–water environment and certainly have resedimented from the platforms (MONOSTORI 1997, pers. comm.). These data suggest resedimentation from the neighbouring shallow shelf areas. However, based on the field and microfacies observations, presence of gravity mass flows is not evidenced in the studied succession. Extreme low density turbidites, nepheloid plumes or slow bottom currents could cause this type of resedimentation (TUCKER & WRIGHT 1990).

Another complication concerns diagenesis. Under conditions of increased temperature due to burial, smectite tends to transform to illite via an intermediate stage of mixed–layer minerals (HOWER et al. 1976). In the Hungarian literature VICZIÁN (1994) has summarized the application of the illite–smectite geothermometry. According to his paper the intensity of smectite–to–illite transition depends on the variables time, temperature, K^+ availability in the depositional environment and activation energy. He has presented an illite proportion in mixed layer structure versus maximum burial temperature trend line calculated from data of Pannonian Basin. Part of this line corresponding to 40–70% smectite in mixed–layer indicates 100–130°C heating temperature during burial diagenesis. According to fission track data presented by DUNKL (1992) a range of 100–175°C burial heating temperature was estimated in the case of the Jurassic sequence in the eastern part of the Mecsek Mountains. According to VICZIÁN (1990) illite contents in the mixed–layer phases of the underlying Mecsek Coal and the Vasas Marl Formations are 70–80%. This higher illite content – thus higher crystallinity – is due to deeper burial and higher degree of 'ripening' of illite/smectite phases in accordance with the deeper stratigraphic position of these Early Jurassic formations.

PARRISH et al. (1982), HALLAM (1984), KUTZBACH & GALLIMORE (1989) declared in agreement with each other, that both modelling and empirical research suggest that zonal winds were probably much less important on the Jurassic supercontinent than monsoonal winds. It seems evident that temperature was higher than recently, dry and wet seasons were alternating during these monsoon–controlled times. According to HALLAM et al. (1991) the pronounced increase in smectite abundance of the latest Jurassic rocks from England and France signifies a climate with a more pronounced and extended dry season in contrast that in the Cretaceous. Results of simulations presented by CHANDLER et al. (1992) show that increased ocean heat transport may have been the primary force generating warmer climates during the Early Jurassic. Three major features of the simulated Jurassic climate include the followings:

i) A global warming, compared to the present;

ii) Decreases in albedo, occurring because of reductions in sea ice, snow cover, and low clouds, and increases in atmospheric water vapour are the positive climate feedbacks that amplify the global warming;

iii) High rainfall rates are associated primarily with monsoons that originate over the warm Tethys Ocean.

These systems are found to be associated with localised pressure cells whose positions are controlled by topography and coastal geography. WEISSERT & MOHR (1996) studied carbon isotope composition of large amount of limestone samples representing the Oxfordian–Tithonian interval from the Helvetic nappes. They concluded that the climate in the northern Tethyan realm has been characterised by high atmospheric CO_2 level and by monsoonal rainfall pattern. No observation has been suggested so far that in the Bajocian stage in the Mecsek sedimentation basin climatic conditions were different.

Palaeoenvironmental interpretation

Dominance of illite/smectite mixed–layer phases indicate seasonally alternating monsoon–like climatic conditions during the Bajocian in the source area of the Mecsek sedimentary basin. Under this weathering condition, pedogenic smectite and/or disordered mixed–layer illite/smectite has been formed and carried into the basin. 40–70% illite proportion in mixed–layer and the moderate ordering are due to diagenesis and indicate 100–130°C heating temperature during burial. Discrete illites were not influenced by heating of such a degree. The sparse occurrence of kaolinite and abundant mixed–layer phases besides of illite and absence of chlorite can suggest a relatively distant source area during deposition.

Kaolinite was poor and were found only in limestone samples. Diagenetic alteration of kaolinite to illite or to chlorite (CHAMLEY 1989) can be excluded because of 100–130°C burial temperature suggested by mixed–layer illite/smectites (HUANG 1993). The following explanations can be reliable:

i) Morphological barriers or well–developed river–fed marginal basin existed which would prevent the carry into the ocean many of minerals pedogenically formed in the upstream zones;

ii) The kaolinite was resedimented by sporadic nepheloid plume activity and/or bottom currents from the neighbouring shallow–water shelf areas.

The clay mineral types do not correlate qualitatively and quantitatively with the lithologies. This observation suggests that processes forming the limestone/marlstone alternation could not affect exclusively the formation of the clay minerals.

Stable O– and C–isotope geochemistry

Determination and interpretation of stable isotopic composition of carbonate rocks have been extended during the last few decades. This geochemical method is preferentially used in palaeogeographic, palaeoclimatic and palaeo–ecologic modeling of rhythmic and cyclic sequences (KUMP 1989, LASAGA 1989, POPP ET AL. 1989, MAGARITZ & HOLSER 1990, GROSSMAN et al. 1991, 1993, LAFERRIERE 1992, HOLLANDER et al. 1993, LONG 1993, BARRERA & KELLER 1994, PELECHATY et al. 1996, WENZEL & JOACHIMSKI 1996, JOACHIMSKI et al. 1998, CAPLAN & BUSTIN 1999, FRANCK et al. 1999, JACOBSEN & KAUFMAN 1999, KUMP & ARTHUR 1999, PROKOPH & VEIZER 1999, MORETTINI et al. 2000).

The background process is that from sea– or porewater precipitated (biogenic, sedimentary or diagenetic) calcite can be enriched in heavy oxygen with 18 mass number. Degree of the enrichment is controlled by temperature and salinity of the water, therefore fluctuations in $\delta^{18}O$ of carbonate rocks show well changes in temperature and/or salinity of a given part of the water column or in temperature and/or salinity of the pore water. Diagentic carbonate dissolution and reprecipitation can be also recorded in oxygen isotopic composition (O'NEIL et al. 1969; FRIEDMAN & O'NEIL 1977).

Fluctuations in carbonate and organic $\delta^{13}C$ are widely used for modelling of changes of marine organic productivity and coexisting redox changes, because increased productivity causes relative enrichment of seawater in heavy carbon isotope due to preferred uptake of light carbon by phytoplankton during photosynthesis. However, long–term excursions of $\delta^{13}C$ during Earth's history seem to be caused by several other factors such as degree of weathering and burial fluxes of the carbon (intensity of carbon recycling) and evolutional state of the biosphere (KUMP 1989, LASAGA 1989, POPP et al. 1989).

In the Hungarian literature, the stable isotope approach in sedimentological and cyclo–stratigraphical research has been presented sporadically (CORNIDES et al. 1979, FOGARASI 1995). While the Komló Calcareous Marl Formation shows obvious rhythmic character, application of the stable isotopic method can be effective in the examination of the rhythmicity–forming factors.

Methods

25 bulk samples were milled in an agate mortar and the powder was analysed at the Geochemical Research Laboratory of the Hungarian Academy, Budapest. Carbon dioxide was produced following MCCREA (1950)'s standard method. The $^{13}C/^{12}C$ and $^{18}O/^{16}O$ ratios were determined using a Finnigan MAT Delta S mass spectromether. The isotope ratios are quoted in per mil relative to the PDB (Pee Dee Belemnite). The reprodubilicity of duplicate analyses is better than ± 0.1‰. The standard Harding Iceland Spar was also analysed, which yielded the following values:

$\delta^{13}C$: –4.88 ± 0.03 ‰; $\delta^{18}O$: 11.85 ± 0.07 ‰; n: 4. (Accepted values: $\delta^{13}C$: –4.80 ‰; $\delta^{18}O$: 11.78 ‰; LANDIS 1983)

The samples are collected from couplets. Only unweathered and hypergene transformation–free specimens were selected for the stable isotope analysis.

Results

Stable isotope data of the examined samples are collected in the Table I. Summarizing the following can be established:

i) In a given couplet, the $CaCO_3$–rich layers are isotopically heavier for both elements than the $CaCO_3$–poor ones.

ii) Relative strong correlations exist between the $CaCO_3$–content and the $\delta^{13}C$ and the $\delta^{18}O$ values (Figs 9 and 10).

iii) The $\delta^{13}C$ and the $\delta^{18}O$ values are corresponding to the 'normal' pelagic real.

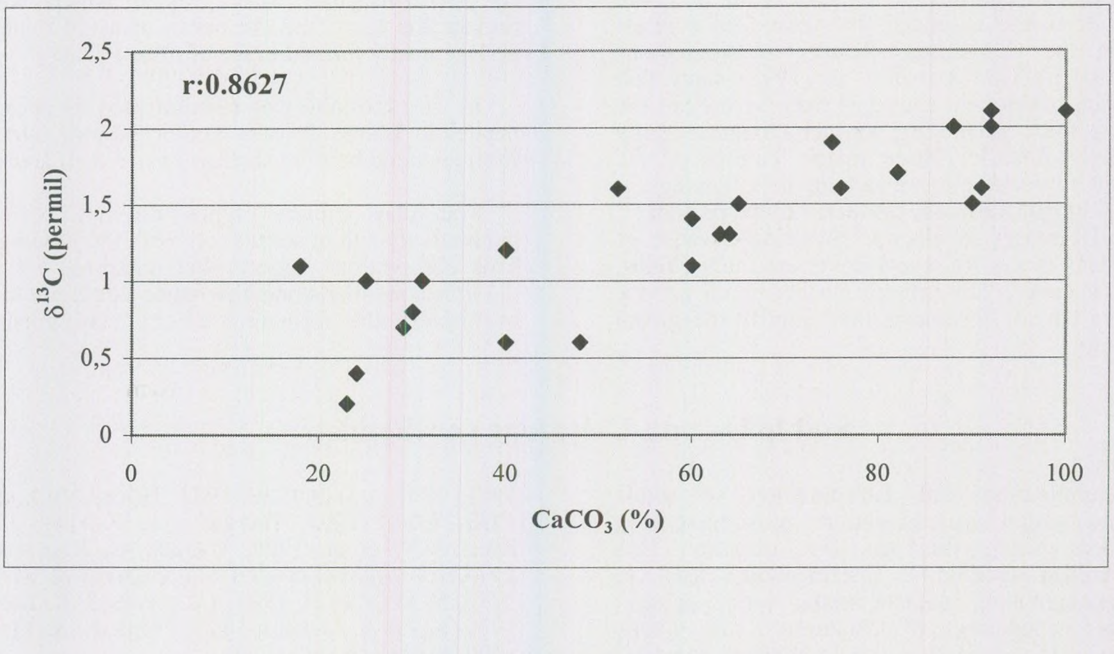

Fig. 9. Carbon isotope ratios versus $CaCO_3$–content diagram

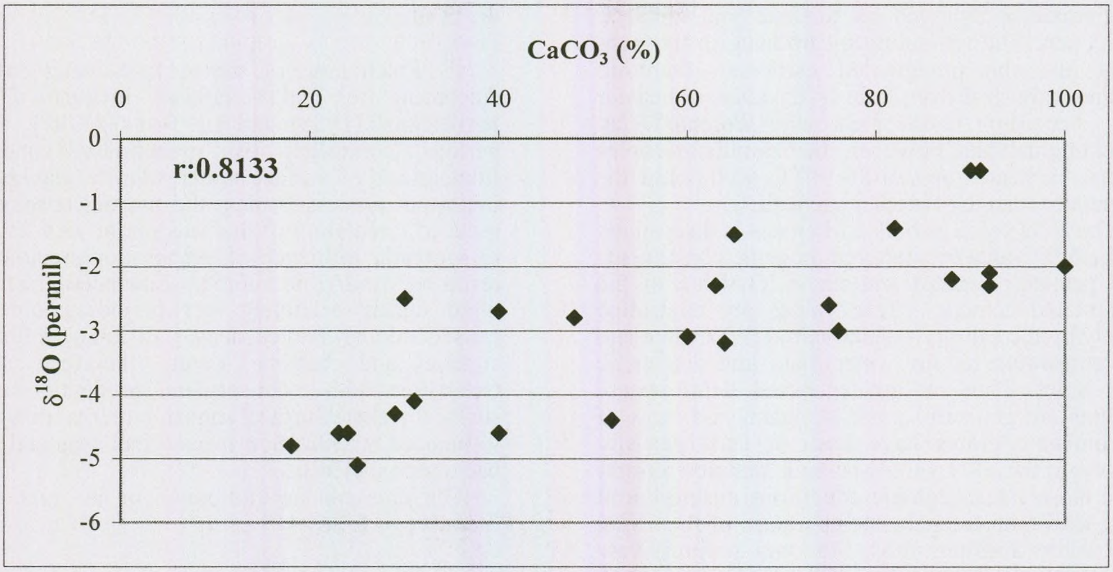

Fig. 10. Oxygen isotope ratios versus $CaCO_3$–content diagram

Discussion

ARTHUR et al. (1984, 1986) proposed that periodic changes of insolation, evaporation, wind stress, and/or rainfall in a wide variety of environments were able to cause changes of input of terrigenous matter, water mass stratification, deep–water oxygenation, surface water productivity and related chemical, biological, ecological factors. These changes could be very effective in the case of the intrashelf basins due to their small volume of water mass relatively to the oceanic realm. In contrast to the well documented Pleistocene and Holocene situation, changes in ratio of deep–water production during glacial–interglacial transitions and related changes in carbonate dissolution probably cannot be accounted for explain the rhythmic alternation of Jurassic sequences deposited during greenhouse conditions. Some of the above mentioned changes can be traced by stable isotopic data.

The examined samples contain carbonate fossils, abundant micritic matrix (primary and/or diagenetic) and diagenetic calcite spar–filled molds. The carbon isotopic composition of these constituents reflects the composition of the dissolved bicarbonate of the water from which their matter is precipitated. Main factors controlling of the carbon isotope signal are as follows:

The seawater surface is usually enriched in ^{13}C relative to the deep water (BERGER & VINCENT 1986, THUNELL et al. 1991, BELLANCA et al. 1995, 1996) which invokes ^{13}C enrichment of carbonate–secreting zooplankton as a result of an increase in productivity of phytoplankton. BARTOLINI et al. (1996) described positive $\delta^{13}C$ excursions in Early Bajocian and Callovian–Oxfordian carbonate rocks in Italy that may record changes in global climate toward warmer, more humid periods with increased carbon burial and nutrient mobilisation. Many workers emphasized that increased radiolarian abundance in sedimentary successions appears parallel with increased $\delta^{13}C$ values and other high productivity–related palaeontological and geochemical features (FÖLLMI et al. 1994, BILL et al. 1995, BARTOLINI et al. 1996, 1997, JENKYNS 1996, BARTOLINI & GUEX 1999, COLACICCHI 2000). In many cases, drastic shifts were found in global $\delta^{13}C$ pattern. However, these shifts do not show clear correlation with diagenesis– and productivity–related properties of the examined successions. For example, MII et al. (1997) pointed out that the very high $\delta^{13}C$ values of the Permian Svedrup Basin seems to be correlated the globally recognized $\delta^{13}C$ shift explained by changes in the size of the global organic carbon reservoir (KUMP 1991). Other plausible explanation of such drastic carbon isotope shifts is changes of the absolute amount of carbon dioxide in the ancient atmosphere (MARSHALL & BRENCHLEY 1998, PANCOST et al. 1998).

Diagenesis may alter the carbon isotopic composition of sedimentary rocks. However, this composition does not change a great deal during diagenesis because the volume of carbon within the pore–water reservoir is small and because the isotope fractionation between calcium carbonate and dissolved bicarbonate is small at low temperatures (EMRICH et al. 1970). JENKYNS & CLAYTON (1986) proposed a model to explain the very low $\delta^{13}C$ values associated to organic–rich sedimentary rocks in the Tethyan Lower Jurassic. In their model the lower $\delta^{13}C$ of the cement is compatible with the introduction of carbon dioxide derived from bacterial (anaerob) oxidation of organic matter According to RAISWELL (1987), during sulfate reduction and bacterial decomposition of organic matter lead to precipitation of ^{13}C–depleted calcite. RICKEN & EDER (1991) emphasize that with increasing overburden, the sediment passes into the methane production zone, where isotopically light bicarbonate is removed by the bacterial methane production. The remaining bicarbonate in the pore water and the precipitated carbonate therefore continuously shift from light $\delta^{13}C$ values to heavier ones. According to the previously presented clay mineralogical data, however, the examined samples seem to be heated up to 100–130°C, well below the temperature range of methanogenesis.

The $\delta^{18}O$ value of bulk carbonates is determined by the $\delta^{18}O$ value of unaltered biogenic constituents (and primary micrite) and the $\delta^{18}O$ value of the precipitated cement. These values are controlled mainly by the salinity–related initial $\delta^{18}O$ value and the temperature of the water mass and diagenetic pore water. Thus, at greater burial depth where cements are generally more abundant and most of the biogenic grains have been at least partially dissolved, the $\delta^{18}O$ values of bulk samples reflects more closely the geologic conditions during burial diagenesis than the palaeotemperature of the initial sea water shifting those to the progressively negative values (KILLINGEY 1983, COOK & EGBERT 1983). Highly negative oxygen isotope values are formed in freshwater–related and at high temperature precipitated carbonates. During diagenesis, oxygen isotope ratios are likely to be far more readily altered than carbon isotope ratios. The ratio of oxygen in pore water to oxygen in the rock in initially extremely porous carbonate oozes is high, the inverse is true with respect to carbon. In addition, there is a large temperature fractionation of oxygen isotopes which can play an important role during burial diagenetic cementation. Such effects have been noted in many pelagic sequences (SCHOLLE 1977). According to EINSELE & RICKEN (1991) the oxygen isotopic composition of marl and limestone beds of the rhythmic marl/limestone alternations may be homogenized by diagenetic processes.

There are several stable isotopically well studied sequences of ice–free periods of the Earth's history (WEISSERT et al. 1979, DE BOER 1983, KAUFFMAN 1988). According to these authors, two mechanisms should be considered to explain the relatively low oxygen isotope values of the carbonate of the marly (carbonate–poor) beds of such rhythmic pelagic–hemipelagic sequences:

i) Fluctuation of the surface water temperature. The temperature of the sea surface is controlled not only by the temperature and circulation of the atmosphere. In the zones characterised by intensive upwelling, oxygen isotopically heavy bottom water might have reached the photic part of the water column, therefore here carbonate secreting organisms might have formed carbonate skeleton with relatively high $\delta^{18}O$ values. In these cases the main controlling factor is the circulation pattern of the basin.

ii) Fluctuation of the surface water salinity. According to PRATT (1984), BARRON (1986), KAUFFMAN (1988) and DE BOER (1991), during periods controlled by greenhouse conditions fluctuations of surface water salinity was a more important process than in the present oceans. The reduced circulation of the seas might well have led to a greater influence of evaporation/precipitation, resulting a variable salinity. Enhanced freshwater input during relatively wet periods could have caused salinity–related density differences between surface and bottom water, therefore slower circulation and lower organic production in the surface water. Surface runoff patterns may have influenced stratification in marginal seas and could had a global effect.

Our data can be interpreted in the light of the literature as follows:

i) During deposition of the carbonate–rich layers characterised by high $\delta^{13}C$ values, surface water productivity seems to be increased relatively to the carbonate–poor semicouplets. This is in accordance with the observed radiolarian abundance: microfacies of the carbonate–rich semicouplets are dominated by recrystallized radiolarian tests.

ii) According to ARTHUR & DEAN (1991), $\delta^{18}O$ values –2.5 to –4.5 ‰ are reasonable isotopic composition for diagenetically marine carbonates formed in a warm, ice–free sea. Most of our samples have $\delta^{18}O$ values within this range.

iii) The carbonate–rich layers are isotopically heavier. If diagenetic carbonate redistribution had been the main factor in form the rhythmic character of the sequence, an opposite trend would have been observed. 1.5 to 2.5 ‰ difference between $\delta^{18}O$ values of the neighbouring beds also contradicts the dominance of the diagenetic redistribution.

iv) The above mentioned fluctuation in the $\delta^{18}O$ pattern points to differences in temperature and/or salinity during the sedimentation. Carbonate–rich beds seem to be formed during periods of 'cooler' and/or 'more saline' surface water.

v) However, redeposition of platform–derived shallow water carbonate mud by bottom currents and/or by nepheloid plume activity cannot be exluded as potential source of isotopically (for both measured elements) heavy carbonate.

Major and trace element geochemistry

Geochemical characterization of the rhythmic and cyclic sequences was mainly focused on stable isotopic composition of the examined material. Major and trace element examination of sediments and sedimentary rocks has served provenance studies and analysis of the weathering processes (NESBITT & YOUNG 1982, BHATIA 1983, HARNOIS 1988, ROSER & KORSCH 1988, NESBITT et al. 1997, HUISMAN et al. 2000, VALLADARES et al. 2000, VARGA et al. 2001). In the past decade, however, interpretation of the element composition of rhythmically alternated biogenic sediments went an effective tool in modelling of (i) changes of seawater chemistry (ELDERFIELD 1990, DYMOND et al. 1992, FILIPELLI & DELANEY 1996); (ii) environmental factors of biogenic sedimentation

(Schmitz 1987, Yamamoto 1987, Murray et al. 1991, 1992, Sundararaman et al. 1993, Fagel et al. 1997, Zwolsman et al. 1997, Reynard 1998, Zhang et al. 2000); (iii) rhythmicity–forming mechanisms in marine successions (Lyle et al. 1988, Abouchami et al. 1997).

Methods

45 samples were collected from six intervals of the studied succession to determine of their chemical composition by PIXE analysis. The name PIXE (Particle Induced X–Ray Emission) refers to a process in which characteristic X–rays are generated by ion–atom collision events as the consequence of the recombination of electron vacancies appearing in the inner shells. The spectroscopy of X–rays reveals analytical information on the elemental constituents of the samples. In such a way multielemental analysis with low detection limit can be performed on thin and thick samples of small absolute mass (Johansson 1988).

The 2 MeV energy proton beam of the 5 MeV Van de Graaff accelerator of the Institute of Nuclear Research of the Hungarian Academy of Sciences, in Debrecen has been used for PIXE analysis. Details on the experimental setup and its calibration have been given in Borbély–Kiss et al. (1985) as well as in Szabó & Borbély–Kiss (1993). Powdered bulk rock samples were pressed into pellets (1 mm thick and 10 mm in diameter). The beam current was typically between 1 and 10 nA, with a beam size of 5 mm in diameter and about 20 minutes bombardment was sufficient to detect elements in the sample. Spectra have been evaluated with the PIXYKLM programme package (Szabó & Borbély–Kiss 1993).

Standard deviations given in the tables include the statistical errors originating from the measuring conditions and the fitting of X–ray spectra. However, they do not include the error of data necessary for the determination of elemental concentrations. Those data (X–ray production cross section, respond probability of the Si(Li) detector, X–ray absorption in the sample and the used filter and the slowing down of proton beam in the sample) are calculated theoretically. Errors of those data are systematic, depend on the atomic number and can only be estimated. They are less than 10–15 % of the value of concentrations.

Results

Major and trace element data are listed in Tables II and III. Average values of the measured elements of the carbonate–rich semicouplets are indicated by 'average 1'; 'average 2' indicates those of the carbonate–poor beds. Values with higher than 10% standard deviations are indicated by bold numbers. Missing values in the Tables II and III mean that the concentrations of those elements are less than the detection limit. Calculated correlation matrix is presented in Tables IV and V. shows the Ti–normalised enrichment factors relative to the PAAS values for many elements (Taylor & McLennan 1985) calculated as follows:

$$(El/Ti)_{sample}/(El/Ti)_{PAAS}$$

where *El* refers to any measured element.

Tables of Dowdy & Wearden (1983) were used for statistical evaluation of data.

Discussion

While the studied rocks are fine–grained mixed carbonate–siliciclastic rocks, calcite– and phyllosilicate–related elements have been found as major constituents.

Two main sources of the silicon are the biogenic opal and the terrigenous matrial (quartz and silicate minerals). Si shows slight positive correlation with the titanium (r=0.700, n=25) that clearly indicates contribution of the terrigenous fraction to the total Si concentration. According to results of the microfacies analyses almost all the examined samples contain microfossils with silica skeleton and a small amount of diagenetically redistributed silica as cement. Biogenic and diagenetic fraction of the Si may cause the extremely high Si content of a few carbonate–rich semicouplets and the above mentioned value of the Si–Ti linear regression.

Aluminium and titanium concentrations are generally used to correct for the terrestrial influences in marine sediments while these elements are regarded as immobile under conditions of sedimentary and diagenetic environments (Murray et al. 1991, Murray & Leinen 1996, Cullers 2000). In $CaCO_3$–rich biogenic sediments, however, a part of the aluminium may be connected to the biogenic fraction (Murray et al. 1993, Murray & Leinen 1996). This biogenic effect on the aluminium distribution seems to be reasonable as the linear regression value between the Al and Ti (r=0.414, n=25) suggests. Also in the case of samples derived from the Komló Calcareous Marl Formation, using the aluminium normalisation and the Al/(Al+Fe+Mn) ratio proposed by Bellanca et al. (1996) seem to be unrealistic. In contrast of the Al, bioaffinity–related distortion of the Ti distribution (in normal marine environment) is unknown. Therefore, Ti seems to be a good tool to represent the terrigenous component of the samples.

Calcite content of the samples is the main factor controlling the concentrations of calcium. This is indicated by the average CaO values of the carbonate–rich and carbonate–poor semicouplets (39.20% and 23.24%, respectively) and by the significantly negative Ca–Ti linear regression value (r=–0.835, n=25).

In sedimentary rocks, concentration of potassium is mainly controlled by the amount of phyllosilicates. This idea is supported by the excellent correlation of the K–Ti (r=0.956, n=25).

Concentrations of iron show significant positive correlations to the terrigenous elements such as Ti (r=0.952, n=25) and K (r=0.935, n=25) showing detrital control on this element. However, there are samples characterised by significant Ti–normalised enrichment of the Fe relative to the PAAS (Table V.). This suggests another (probably seawater) source of the Fe in addition to the lattice–bound aluminosilicate contribution to the sediment (Murray & Leinen 1993). According to the macroscopic and microscopic observations, the excess amount of Fe is bound to pyrite, limonite and hematite (these latter are mostly pseudomorphs after iron sulfide) what may indicate role of diagenetic redistribution of the reactive iron (BERNER 1981, MORSE et al. 1987, HUERTA–DIAZ & MORSE 1992, LUTHER & MORSE 1998, LYONS et al. 1998).

Trace elements in sediments that accumulate on the seafloor have two sources: detrital clastic matter and seawater (KUMAR et al. 1996). The seawater–derived fraction also has two components: a portion that is incorporated into the marine organisms and a component that is scavenged from the dissolved load of seawater by organic and inorganic particles settling through the water column. Relation of the trace elements to an immobile detrital–related element (such that in our case the Ti) defined for PAAS (TAYLOR & MCLENNAN 1985), as stated above, seems to be an available tool to estimate excess amount (over detrital) of the trace elements. Enrichment factors of the phosphorous, manganese, vanadium, chromium, nickel, zinc and copper (Table V.) show significant contribution of the seawater–derived fraction to the total concentrations.

Phosphorous (with strontium and barium) in marine sediment is commonly affiliated with biogenic phases (FROELICH et al. 1982, FISHER et al. 1991, PINGITORE et al. 1992, MURRAY & LEINEN 1993) and as such is commonly enriched in sediment deposited beneath productive surface waters (FROELICH et al. 1982, BISHOP 1988, FISHER et al. 1991, INGALL & CLARK 1998, MATTENBERGER et al. 1998). P correlates well with the Ca (r=0.870). According to its Ti–normalised enrichment factors relative to the PAAS (Table V.) only a small part of the P may be explained by detrital terrigenous phases (presence of apatite and adsorption of the P onto clay minerals). A significant portion seems to be related to disseminated biogene apatite–group phases which originally incorporated into the siliceous and carbonate skeleton of organisms (BISHOP 1988). The transporting agents (opal and calcite or aragonite) partially degraded on the seafloor during early diagenesis leaving behind the P record as a dissolution residue. Two orders of magnitude Ti–normalised enrichment of the P relative to the PAAS seems to indicate enhanced productivity during deposition of the carbonate–rich beds.

The high sensitivity of manganese to environmental redox conditions is well known (DROMGOOLE & WALTER 1990; GOBEIL et al. 1997). In hemipelagic sediments subjected to a transition from suboxic (or anoxic) to oxic conditions, low Eh conditions can lead to a Mn enrichment in the pore water and the subsequent diffusion of dissolved Mn may concentrate this element in the solid phase, just above or below the redox boundary (JACOBS et al. 1985, LANDING & BRULAND 1987). DICKENS & OWEN (1994) have suggested that the redox–sensitive Mn oxi–hydroxide particulates dissolve upon entering an oxygen minimum zone. The resulting Mn^{2+} is subsequently redirected by advective and/or diffusive processes eventually to precipitate in more oxygenated environments. The record of Mn may reflect migration of the metal from the moderately oxygenated parts of the sediment and its diagenetic enrichment in the more oxygenated parts during early diagenesis. Thus the fluctuation of Mn values may be interpreted as an indicator of rhythmic changes in sedimentary redox conditions. The Ti–normalised enrichment factors of Mn are fluctuate from below unity to about 19 (Table V.). Maximum enrichment is related to the carbonate–rich layers, relative impoverishment appears in the case of the carbonate–poor ones what can be explained by the above–mentioned diagenetic redistribution model.

Vanadium fluctuates through the section exhibiting low values for carbonate–rich layers (average value is 102 ppm) and slightly higher values in the carbonate–poor intervals (average value is 137 ppm). V shows slight positive correlation with the Ti (r= 0.707, n= 16) and in the case of many samples significant enrichment relative to the PAAS (Table V.) suggesting that the affiliation with the aluminosilicates is not an exclusive control on the V concentration in the studied section. Vanadium solubility in natural waters, its precipitation from seawater and addition to the sediments are controlled by redox conditions and by adsorption and complexation processes. Dissolved vanadium may be strongly bound to metallo–organic complexes or adsorbed on biogenic particles (NORMAN & DE DECKKER 1990; BREIT & WANTY 1991). Adsorption and complexation of V are enhanced in anoxic environments where V is present as reduced V (IV) species. During post–depositional and diagentic alteration of sediments, V can be mobilised from degrading biogenic particles under oxic conditions, while it is less mobile in dysoxic and anoxic sediments.

Correlation between Ni and Ti is good (r=0.870, n=19). Many workers give account of lower redox–sensitivity of Ni relative to the other elements, above all to vanadium (SHAW et al. 1990, ODERMATT & CURIALE 1991, HUERTA–DIAZ & MORSE 1992, PIPER 1994). These features suggest that the main source of Ni is the terrigenous fraction, however some degree of diagenetically–controlled enrichment, cannot to be excluded.

The data indicate that the zinc and copper concentration (up to 102 ppm and 30 ppm, respectively) is about 1.5 to 7 times the amount can be explained from a pure aluminosilicate source (Table V.). The correlation between the Zn and the Ti is excellent (r=0.920, n=25), however, Cu show less good correlation with the main detritus–related element (r=0.769, n=22). Excess concentrations of these chalcophile elements may also be in sulfides. More likely, some of the excess amount of them was primarily associated with organic fraction, either as metal–organic complexes or adsorbed on organic coatings in particulate organic matter (BALISTRIERI et al. 1981, BRULAND 1983). It is noteworthy that organic matter derived from plankton has an average concentrations of Zn of 110 ppm (DEAN et al. 1997).

The studied rock samples are characterised by significantly higher carbonate content than that of PAAS. The observed enrichments suggest that fluctuations of the trace elements cannot be explained merely by dilution effects, because the examined trace elements show affinity to the incorporation in sulfides and aluminosilicates or adsorption on their surfaces. If dilution had controlled the trace element distribution, a significant impoverishment for most of the measured elements would have been observed relative to the PAAS. In the case of the manganese, redox–controlled diagenetic redistribution (and eventually incorporation into the lattice of calcite) seems to be a reliable explanation.The presented trace elements suggest occurrence of fluctuations in the redox state of the depositional environment. It seems probable that during well–oxygenated periods of sedimentation (during deposition of carbonate–rich semicouplets) organo–metal complexes oxydised then migrated in the sediment and in the seawater. During periods characterised by less oxygenated and, probably, dysoxic seafloor (deposition of carbonate–poor semicouplets) these metals and organo–metal complexes could remain in reduced, consequently less mobile state (NORMAN & DE DECKKER 1990, SHAW et al. 1990, MARCHITTO et al. 1998).

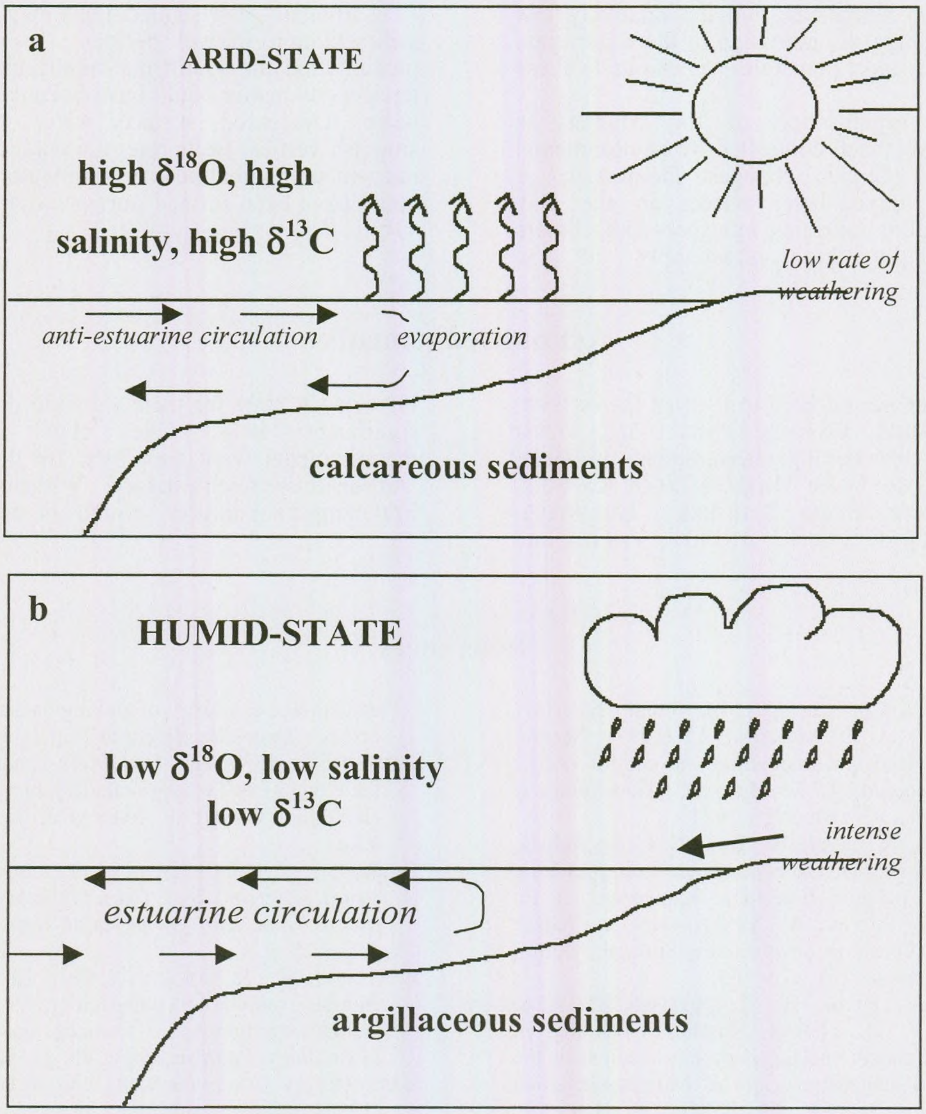

Fig. 11. Schematic view of the palaeoenvironmental scenario during a: arid episodes and b: humid episodes

Depositional model

Rhythmic bedding of the Komló Calcareous Marl Formation seems to be formed by primary processes. Diagenesis has just overprinted the primary signal due to the lack of pervasive dissolution features and the oxygen isotope data. Redeposition of the fine carbonate mud from the neighbouring shelf by nepheloid plumes and/or by bottom currents as autocyclic processes cannot be excluded from the rhythmicity–forming driving forces according to the presence of abundant shelf–derived bioclasts in microfacies of some carbonate rich samples and the maxima of the kaolinite abundance that closely relate to these samples.

During deposition of the carbonate–rich semicouplets, depositional environment seems to be characterised by (i) well oxygenation of the seafloor, (ii) relatively 'cooler' and/or 'more saline' surface water, with (iii) enhanced productivity according to (i) the pervasive bioturbation, (ii) the relatively high $\delta^{18}O$ values, (iii) the positive excursions of the enrichment of phosphorous, the high radiolarian abundance and the relatively high $\delta^{13}C$ values.

These factors seem to be controlled by intensive circulation of the water mass of the basin.

Contrarily, properties of the carbonate–poor semicouplets show (i) relatively poor oxygenation of the seafloor, (ii) relatively 'warmer' and/or 'less saline' surface water with (iii) normal or depressed productivity suggested by (i) the enrichment properties of the redox–sensitive trace elements, (ii) the relatively low $\delta^{18}O$ values, (iii) the negative excursions of the enrichment of phosphorous, the low radiolarian abundance and the relatively low $\delta^{13}C$ values. Sluggish circulation of the water mass seems to be the most plausible explanation of these phenomena.

Rhythmic organisation of the couplets is believed to have been controlled by environmental and probably climatic changes. Dominance of illite/smectite mixed–layer phases in the clay mineral spectrum indicates monsoon–like climate characterised by high seasonality in the precipitation during deposition of the Komló Calcareous Marl Formation. During dry periods, streams could carry low amount of terrigenous matter. Seawater salinity could have been increased, which could form intensive anti–estuarine circulation and well bottom oxygenation with abundant nutrient supply and enhanced productivity. Carbonate–rich semicouplets seem to be formed by this palaeoenvironmental conditions (Fig. 11a).

Carbonate–poor semicouplets may represent the sedimentation in wet periods. Due to abundant precipitation and continental runoff, high amount of terrigenous matter could have been carried into the basin. Decreased surface water salinity with sluggish vertical (estuarine–) circulation, decreased nutrient supply and poor bottom water oxygenation could have been formed during these periods (Fig. 11b).

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Table I. Results of the stable isotopic measurements

number of sample	$\delta^{13}C$ (PDB) values (‰)	$\delta^{18}O$ (PDB) values (‰)
P-24b	2.1	-2.0
P-26b	1.0	-5.1
P-34a	1.9	-2.6
P-34b	2.0	-2.2
P-34c	1.6	-4.4
P-37b	1.2	-4.6
P-38b	2.1	-2.1
P-42a	1.6	-3.0
P-42b	2.0	-2.3
P-43a	0.4	-4.6
P-47	0.2	-4.6
P-48a	1.1	-4.8
K-1a	1.7	-1.4
K-31	1.5	-0.5
K-32	0.8	-2.5
K-48	1.6	-0.5
K-52	1.3	-2.3
K-53	1.0	-4.1
K-54b	1.5	-1.5
K-54c	1.3	-3.2
K-56	1.4	-3.1
K-57	0.7	-4.3
K-58a	1.1	-3.1
K-58b	0.6	-2.8
K-59	0.6	-2.7

Table II. a. Major element concentrations of the examined samples. Data with high standard deviation values are indicated by bold characters

sample	Al_2O_3(%)	SiO_2(%)	CaO(%)	K_2O(%)	TiO_2(%)	MnO(ppm)	Fe_{TOT}(%)
P-24b	3.63±0.7	6.63±0.3	55.25±2.2	0.30±0.03	0.04±0.01	262±30	0.69±0.03
P-26b	5.74±0.8	59.68±2.4	18.33±0.7	1.11±0.50	**0.13±0.06**	188±30	1.08±0.04
P-28d	3.29±0.8	54.97±2.2	22.43±0.9	0.94±0.44	0.15±0.01	194±30	1.03±0.04
P-29a	3.36±0.7	43.10±1 7	27.98±1.1	0.61±0.33	0.13±0.01	247±50	0.85±0.04
P-33	5.63±0.8	51.08±0.5	24.69±1.0	1.07±0.49	0.17±0.01	214±30	1.24±0.05
P-34a	**0.76±0.7**	18.72±0.5	45.50±1.8	0.48±0.03	0.08±0.01	258±30	0.77±0.03
P-34b	3.29±0.7	8.56±0.4	52.27±2.1	0.29±0.03	0.07±0.01	235±30	0.72±0.03
P-34c	5.63±0.7	49.80±1.9	28.06±1.1	0.90±0.04	0.13±0.01	203±30	0.70±0.03
P-36a	37.79±2.0	62.69±2.5	29.02±1.1	0.75±0.04	0.13±0.01	141±20	0.59±0.02
P-37a	12.89±0.9	57.62±2.3	13.64±0.5	2.06±0.08	0.35±0.09	250±40	1.63±0.07
P-37b	5.48±0.9	47.83±1.9	26.06±1.0	1.26±0.06	0.21±0.02	216±30	1.21±0.05
P-38a	**1.10±0.8**	19.94±0.8	46.91±1.9	0.50±0.03	0.09±0.01	217±30	0.68±0.03
P-38b	1.93±0.7	11.89±0.5	50.48±2.0	0.53±0.03	0.10±0.01	239±30	0.69±0.03
P-40a	2.87±0.7	29.15±1.2	38.18±1.5	0.56±0.03	0.11±0.01	178±30	0.84±0.03
P-41	6.61±0.9	49.00±2.0	25.21±1.0	1.39±0.06	0.23±0.02	221±30	1.26±0.05
P-42a	4.61±0.7	16.17±0.7	46.89±1.9	0.42±0.03	0.07±0.01	225±30	0.72±0.03
P-43a	9.64±0.8	53.77±0.8	17.80±0.7	1.70±0.07	0.27±0.02	200±30	1.64±0.07
P-44b	**1.70±0.8**	9.05±0.4	53.43±2.1	0.43±0.03	0.12±0.02	488±50	0.85±0.03
P-45	8.50±0.9	48.11±2.0	24.92±1.0	1.47±0.06	0.26±0.02	234±30	1.33±0.05
P-46b	2.76±0.7	26.59±1.1	42.39±1.7	0.63±0.03	0.11±0.01	214±30	0.81±0.03
P-47	7.71±0.9	57.37±2.3	15.49±0.6	1.97±0.08	0.33±0.02	227±30	1.54±0.06
P-48a	4.27±0.7	47.93±1.9	28.62±1.1	0.77±0.04	0.15±0.01	196±30	0.98±0.04
P-49b	5.06±0.6	45.75±1.9	29.91±1.2	0.82±0.04	0.14±0.01	188±30	0.91±0.04
K-1a	2.42±0.8	13.80±0.6	51.89±2.1	0.30±0.02	**0.03±0.01**	638±50	0.51±0.02
K-22	6.20±0.8	44.17±1.8	29.92±1.2	1.19±0.05	0.16±0.01	296±40	1.06±0.04
K-23	13.79±1.0	57.54±2.3	16.45±0.7	2.36±0.10	0.32±0.02	247±40	1.62±0.07
K-29	6.24±0.8	40.83±1.7	31.62±1.3	1.28±0.06	0.17±0.01	359±40	0.96±0.04
K-32	6.92±0.9	46.84±1.9	21.03±0.8	2.51±0.10	0.30±0.02	258±40	1.70±0.07
K-34	4.35±0.7	40.28±1.6	29.67±1.2	1.57±0.07	0.21±0.02	332±40	1.16±0.05
K-35	4.27±0.8	47.55±1.9	22.47±0.9	2.32±0.10	0.28±0.02	235±40	1.53±0.06
K-36	**1.36±0.8**	23.57±1.0	43.33±1.7	0.66±0.04	0.08±0.01	318±40	0.85±0.04
K-44	3.78±0.7	37.05±1.5	29.39±1.2	1.85±0.08	0.23±0.02	376±40	1.34±0.05
K-45	8.05±0.7	38.91±1.6	27.67±1.1	2.10±0.90	0.27±0.02	341±40	1.39±0.06
K-48	4.16±0.7	9.15±0.4	49.65±2.0	0.33±0.03	**0.03±0.01**	385±40	0.40±0.01
K-52	4.16±0.9	11.74±0.5	51.65±2.1	0.36±0.03	0.04±0.01	542±40	0.59±0.02
K-53	9.11±0.9	45.73±1.9	22.66±0.9	2.37±0.10	0.30±0.02	372±40	1.64±0.07
K-54b	**0.76±0.8**	27.57±1.1	41.75±1.7	0.68±0.04	0.06±0.01	528±50	0.66±0.03
K-54c	5.18±0.8	23.14±1.0	43.15±1.7	0.55±0.03	0.06±0.01	580±50	0.77±0.03
K-56	5.03±0.8	31.25±1.3	37.02±1.5	0.80±0.04	0.11±0.01	452±40	0.69±0.03

Table II. b. Major element concentrations of the examined samples. Data with high standard deviation values are indicated by bold characters

K-57	11.79±0.8	43.59±1.8	23.53±0.9	2.67±0.11	0.32±0.02	381±40	1.60±0.07
K-58a	**1.02±0.9**	33.20±1.4	38.58±1.6	0.97±0.05	0.12±0.01	553±40	0.85±0.03
K-58b	6.20±0.8	40.21±1.6	29.63±1.2	1.43±0.06	0.19±0.02	520±50	1.58±0.06
K-59	12.40±0.9	47.10±1.9	20.45±0.8	3.43±0.14	0.41±0.02	435±40	2.02±0.08
K-60	3.67±0.9	28.92±1.2	40.33±1.6	0.96±0.05	0.13±0.01	600±50	0.89±0.04
K-61	11.71±0.9	40.71±1.7	27.06±1.1	2.41±0.10	0.27±0.02	524±50	1.50±0.06
ave-rage 1	5.06±0.8	29.58±1.2	39.20±1.6	0.80±0.04	0.11±0.02	347±40	0.85±0.03
ave-rage 2	7.94±0.8	48.47±1.9	23.24±0.9	1.75±0.08	0.26±0.02	288±40	1.42±0.05

Table III. a. Trace element concentrations of the examined samples. Data with high standard deviation values are indicated by bold characters

sample	Rb (ppm)	Sr (ppm)	V (ppm)	P (ppm)	Ni (ppm)	Cu (ppm)	Zn
P-24b	-	735±50	-	6303±410	-	-	14±6
P-26b	44±13	424±40	-	-	-	22±6	43±6
P-28d	45±17	500±50	-	-	-	20±7	36±7
P-29a	35±16	589±50	-	1966±520	-	-	27±1
P-33	**26±13**	468±40	-	**1012±550**	-	17±6	53±7
P-34a	31±14	721±50	-	5924±410	-	11±5	50±7
P-34b	40±15	862±50	-	5593±370	-	14±5	22±6
P-34c	29±13	464±40	98±45	3323±600	-	16±6	35±6
P-36a	**19±12**	449±40	**76±43**	3584±650	-	23±6	30±6
P-37a	47±13	190±30	-	1730±640	**31±16**	30±7	55±8
P-37b	36±14	420±40	104±54	2705±590	-	20±6	50±7
P-38a	44±14	692±50	-	5452±490	-	**12±6**	24±6
P-38b	37±14	700±50	-	6618±440	-	15±6	28±6
P-40a	41±14	563±40	-	3464±480	-	16±6	34±6
P-41	41±14	390±40	144±55	1750±570	-	17±6	51±8
P-42a	54±15	742±50	**90±53**	5126±420	-	**12±6**	21±6
P-43a	41±13	308±30	-	2278±580	**24±16**	24±6	67±8
P-44b	43±14	724±50	-	8739±550	**20±12**	14±6	24±6
P-45	40±13	335±30	-	2169±560	-	22±7	54±8
P-46b	43±12	586±40	-	4788±500	-	11±5	28±6
P-47	51±13	247±30	157±56	-	-	16±6	68±8
P-48a	40±14	534±40	137±45	2103±560	-	21±6	29±6
P-49b	35±14	471±40	-	2927±560	-	20±6	44±7
K-1a	25±11	377±30	-	8027±500	-	**11±6**	15±5
K-22	46±15	420±40	-	1914±540	-	20±7	46±8
K-23	52±15	225±30	121±53	-	**26±16**	23±7	62±8
K-29	52±14	376±40	-	2723±550	**24±13**	19±7	42±7
K-32	56±15	261±30	131±59	-	-	25±7	75±9
K-34	41±15	368±40	-	2762±530	**29±15**	19±7	52±8
K-35	38±14	259±30	-	2144±580	**28±16**	21±7	69±9
K-36	44±15	534±40	-	5404±490	**22±12**	15±6	37±7
K-44	55±15	284±30	**107±57**	3123±500	31±15	25±7	58±8
K-45	57±16	269±30	**107±59**	1883±510	31±15	23±7	68±8
K-48	**22±13**	488±40	-	7083±430	-	**10±6**	14±6
K-52	**19±13**	491±40	-	6880±460	-	14±6	20±6

Table III. b. Trace element concentrations of the examined samples. Data with high standard deviation values are indicated by bold characters

K-53	56±15	263±30	176±60	1334±600	**30±16**	16±7	87±9
K-54b	40±12	378±30	-	6536±520	-	-	17±6
K-54c	28±13	447±40	-	6919±490	**19±11**	**10±6**	33±6
K-56	**25±12**	383±30	84±41	5025±490	**20±11**	14±5	27±6
K-57	58±15	281±30	141±60	3877±540	32±16	25±7	83±9
K-58a	34±12	397±30	-	5720±560	23±11	13±6	29±6
K-58b	37±13	306±30	**102±55**	4722±550	**26±15**	15±6	53±7
K-59	54±15	197±30	137±67	3363±550	41±18	26±7	102±10
K-60	36±12	373±30	-	5984±530	**19±12**	**12±6**	35±6
K-61	54±15	277±30	-	4904±540	32±15	21±7	62±8
average 1	36±13	508±40	102±50	5150±500	**24±13**	15±6	32±6
average 2	45±14	321±30	137±60	2428±560	**31±16**	21±7	63±8

Table IV Correlation matrix calculated from the measured concentrations

	Al	Si	P	K	Ca	Ti	**V**	Mn	Fe	Ni	Cu	Zn	Rb	Sr
Al	1	0.544	-0.326	0.384	-0.449	0.414	-0.233	-0.213	0.290	0.615	0.523	0.332	0.009	-0.383
Si		1	-0.851	0.625	-0.959	0.700	0.301	-0.397	0.645	0.587	0.734	0.617	0.269	-0.670
P			1	-0.567	0.870	-0.679	-0.659	0.552	-0.623	-0.619	-0.695	-0.616	-0.344	0.470
K				1	-0.773	0.956	0.610	0.024	0.935	0.912	0.725	0.940	0.664	-0.809
Ca					1	-0.835	-0.654	0.338	-0.801	-0.686	-0.786	-0.761	-0.433	0.751
Ti						1	0.707	-0.144	0.952	0.870	0.769	0.920	0.652	-0.755
V							1	0.061	0.676	0.512	0.103	0.685	0.599	-0.473
Mn								1	-0.076	-0.314	-0.332	-0.082	-0.113	-0.256
Fe									1	0.830	0.709	0.932	0.628	-0.725
Ni										1	0.772	0.871	0.725	-0.694
Cu											1	0.654	0.494	-0.608
Zn												1	0.614	-0.708
Rb													1	-0.325
Sr														1

Table V Ti–normalised enrichment factors relative to the PAAS values (TAYLOR & MCLENNAN 1985). Data of samples from carbonate–rich semicouplets are indicated by bold characters. LOQ: under the limit of quantification

sample	SiO_2	Al_2O_3	Fe_{TOT}	MnO	CaO	K_2O	P	Rb	Sr	V	Ni	Cu	Zn
P-24B	**2.6**	**4.8**	**2.7**	**6.0**	**1062.5**	**2.0**	**98.5**	**LOQ**	**92.0**	**LOQ**	**LOQ**	**LOQ**	**3.9**
P-26B	**7.3**	**2.3**	**1.3**	**1.3**	**108.5**	**2.3**	**LOQ**	**2.1**	**16.5**	**LOQ**	**LOQ**	**3.4**	**3.7**
P-28D	5.8	1.2	1.1	1.2	115.	1.7	LOQ	1.9	16.5	LOQ	LOQ	2.6	2.7
P-29A	**5.3**	**1.4**	**1.0**	**1.7**	**165.6**	**1.3**	**9.4**	**1.7**	**22.5**	**LOQ**	**LOQ**	**LOQ**	**2.3**
P-33	4.8	1.8	1.1	1.2	111.7	1.7	3.8	0.9	14.0	LOQ	LOQ	2.0	3.4
P-34A	**3.7**	**0.5**	**1.5**	**2.9**	**437.5**	**1.6**	**46.3**	**2.4**	**45.0**	**LOQ**	**LOQ**	**2.8**	**7.0**
P-34B	**2.0**	**2.5**	**1.6**	**3.1**	**574.4**	**1.1**	**49.9**	**3.3**	**61.5**	**LOQ**	**LOQ**	**4.0**	**3.4**
P-34C	**6.1**	**2.3**	**0.8**	**1.5**	**166.0**	**1.9**	**16.0**	**1.4**	**18.0**	**5.0**	**LOQ**	**2.4**	**3.0**
P-36A	**7.7**	**15.4**	**0.7**	**1.0**	**171.7**	**1.6**	**17.3**	**0.9**	**17.5**	**3.9**	**LOQ**	**3.6**	**2.6**
P-37A	2.6	2.0	0.7	0.6	30.0	1.6	3.1	0.8	2.5	LOQ	1.5	1.8	1.8
P-37B	3.6	1.4	0.9	0.9	95.5	1.6	8.1	1.1	10.0	3.3	LOQ	2.0	2.7
P-38A	**3.5**	**0.7**	**1.2**	**2.2**	**400.9**	**1.5**	**37.9**	**3.1**	**38.5**	**LOQ**	**LOQ**	**2.6**	**3.0**
P-38B	**1.9**	**1.0**	**1.1**	**2.2**	**388.3**	**1.4**	**41.4**	**2.3**	**35.0**	**LOQ**	**LOQ**	**3.0**	**3.1**
P-40A	**4.2**	**1.4**	**1.2**	**1.5**	**267.0**	**1.4**	**19.7**	**2.3**	**25.5**	**LOQ**	**LOQ**	**3.0**	**3.4**
P-41	3.4	1.5	0.8	0.9	84.3	1.6	4.8	1.1	8.5	4.2	LOQ	1.4	2.4
P-42A	**3.7**	**3.5**	**1.6**	**2.9**	**515.3**	**1.6**	**45.8**	**4.8**	**53.0**	**8.6**	**LOQ**	**3.4**	**3.3**
P-43A	3.2	1.9	0.9	0.6	50.7	1.7	5.3	0.9	5.5	LOQ	1.5	1.8	2.8
P-44B	**1.2**	**0.8**	**1.1**	**3.7**	**342.5**	**1.0**	**45.5**	**2.3**	**30.0**	**LOQ**	**2.8**	**2.4**	**2.2**
P-45	3.0	1.7	0.8	0.8	73.7	1.5	5.2	0.9	6.5	LOQ	LOQ	1.6	2.3
P-46B	**3.9**	**1.3**	**1.1**	**1.7**	**296.4**	**1.6**	**27.2**	**2.4**	**26.5**	**LOQ**	**LOQ**	**2.0**	**2.8**
P-47	2.8	1.2	0.7	0.6	36.1	1.6	LOQ	0.9	3.5	3.2	LOQ	1.0	2.3
P-48A	**5.1**	**1.5**	**1.0**	**1.2**	**146.8**	**1.4**	**8.8**	**1.7**	**18.0**	**6.1**	**LOQ**	**2.8**	**2.1**
P-49B	5.2	1.9	1.0	1.2	164.3	1.6	13.1	1.6	17.0	LOQ	LOQ	2.8	3.4
K-1A	**7.3**	**4.3**	**2.6**	**19.4**	**1330.5**	**2.7**	**167.3**	**5.2**	**63.0**	**LOQ**	**LOQ**	**7.4**	**5.6**
K-22	4.4	2.1	1.0	1.7	143.9	2.0	7.5	1.8	13.0	LOQ	LOQ	2.6	3.2
K-23	**2.9**	**2.3**	**0.8**	**0.7**	**39.6**	**2.0**	**LOQ**	**1.0**	**3.5**	**2.5**	**1.3**	**1.4**	**2.1**
K-29	**3.8**	**1.9**	**0.9**	**1.9**	**143.1**	**2.0**	**10.0**	**1.9**	**11.0**	**LOQ**	**2.3**	**2.2**	**2.8**
K-32	2.5	1.2	0.9	0.8	53.9	2.3	LOQ	1.2	4.5	2.9	LOQ	1.6	2.8
K-34	**3.1**	**1.1**	**0.9**	**1.5**	**108.7**	**2.0**	**8.3**	**1.3**	**9.0**	**LOQ**	**2.3**	**1.8**	**2.8**
K-35	2.7	0.8	0.8	0.7	61.7	2.2	4.8	0.9	4.5	LOQ	1.7	1.6	2.8
K-36	**4.7**	**0.9**	**1.6**	**3.6**	**416.6**	**2.2**	**42.3**	**3.4**	**33.5**	**LOQ**	**4.7**	**3.8**	**5.1**
K-44	**2.6**	**0.9**	**0.9**	**1.5**	**98.3**	**2.2**	**8.5**	**1.5**	**6.0**	**3.1**	**2.2**	**2.2**	**2.8**
K-45	2.3	1.6	0.8	1.2	78.8	2.1	4.4	1.3	5.0	2.7	1.8	1.8	2.8
K-48	**4.9**	**7.3**	**2.0**	**11.6**	**1273.1**	**3.0**	**147.6**	**4.6**	**81.5**	**LOQ**	**LOQ**	**6.6**	**5.2**
K-52	**4.7**	**5.5**	**2.3**	**12.4**	**993.3**	**2.4**	**107.5**	**0.2**	**61.5**	**LOQ**	**LOQ**	**7.0**	**5.6**
K-53	2.4	1.6	0.8	1.1	58.1	2.1	2.8	1.2	4.5	3.9	1.7	1.0	3.2
K-54B	**7.3**	**0.7**	**1.7**	**8.0**	**535.3**	**3.0**	**68.1**	**4.2**	**31.5**	**LOQ**	**LOQ**	**LOQ**	**3.1**
K-54C	**6.1**	**4.6**	**2.0**	**8.8**	**553.2**	**3.1**	**72.1**	**2.9**	**37.5**	**LOQ**	**5.3**	**3.4**	**6.1**
K-56	**4.5**	**2.4**	**1.0**	**3.7**	**258.9**	**2.0**	**28.6**	**1.4**	**17.5**	**5.1**	**3.0**	**2.6**	**2.8**
K-57	2.2	2.0	0.8	1.1	56.6	2.3	7.6	1.1	4.5	2.9	1.7	1.6	2.9
K-58A	**4.4**	**0.5**	**1.1**	**4.2**	**247.3**	**2.2**	**29.8**	**1.8**	**16.5**	**LOQ**	**3.2**	**2.2**	**2.7**
K-58B	**3.4**	**1.7**	**1.3**	**2.5**	**120.0**	**2.0**	**15.6**	**1.2**	**8.0**	**3.6**	**2.3**	**1.6**	**3.1**
K-59	1.8	1.6	0.8	1.0	38.4	2.3	5.1	0.8	2.5	2.2	1.7	1.2	2.8
K-60	**3.5**	**1.5**	**1.1**	**4.2**	**238.6**	**2.0**	**28.8**	**1.8**	**14.5**	**LOQ**	**2.5**	**1.8**	**3.0**
K-61	2.4	2.3	0.9	1.7	77.1	2.4	11.4	1.3	5.0	LOQ	2.0	1.6	2.6

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Bajocian and Bathonian brachiopods in Hungary: a review

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(With 3 figures)

The Bajocian and Bathonian brachiopod faunas of Hungary, collected in the last decades, have been reviewed by the author. In the Pelsonia terrane (Bakony and Vértes Mts.), the Bajocian stage is especially rich in brachiopods: 18 species have been determined from the more than five hundred specimens. In the Tisia terrane (southern Transdanubia), the Bathonian beds provided very diverse brachiopod faunas: around 500 specimens and 9 species have been found in the Mecsek Mts., whereas the local occurrence in the Villány Mts. provided 11 specimens belonging to 4 species. The Pelsonia terrane belonged to the Mediterranean faunal province in the Bajocian, while the Tisia terrane was under the mixed influence of the NW–European and Mediterranean provinces in Bathonian times.

Introduction

Brachiopods have rather limited significance in stratigraphical subdivision of Jurassic strata, therefore they contribute little or none to the resolution of the Bajocian/Bathonian boundary problem. However, due to their relative abundance, they may help in a better paleontological definition of the respective stages in certain regions, in this case in Hungary.

The territory of Hungary can be subdivided into two main tectono–stratigraphic terranes of different Mesozoic facies, divided by the WSW–ENE trending Mid–Hungarian Lineament (see VÖRÖS 1993a; KOVÁCS et al. 2000) (Fig. 1). The northern terrane (named as *Pelsonia*) embraces roughly the Transdanubian Central Range where the Jurassic system is dominated by carbonates with faunas of Mediterranean character. The Jurassic rocks of the southern terrane (*Tisia*) crop out in southern Transdanubia, in the Mecsek and Villány Mts.; they are less calcareous (terrigeneous detrital in the Lower Jurassic) and their fauna shows NW–European affinity, at least in the first half of the Jurassic.

The Jurassic brachiopods of Hungary have been reviewed by VÖRÖS (1993b; 1997). The very diverse Sinemurian and Pliensbachian faunas were wiped out by the Early Toarcian global extinction event and after a slow recovery, the Bajocian and Bathonian saw a secondary flourishing period. Bajocian and Bathonian brachiopods were frequently found in the Transdanubian Central Range (Bakony, Vértes) and in southern Transdanubia (Mecsek, Villány Mts.), respectively (Fig. 1). A review of these faunas is given here, with some hints to their paleoecology and paleobiogeography.

Transdanubian Central Range

Middle Jurassic brachiopods were first mentioned by NOSZKY (1943) from the Bajocian of the Bakony Mts. and FÜLÖP et al. (1960) from the Vértes Mts. (attributed to the Bathonian). The new collections made in the last decades mainly by the workers of the Hungarian Geological Institute and A. GALÁCZ, J SZABÓ and A. VÖRÖS provided rich faunas from the Bakony Mts. and complemented the Vértes fauna.

Bajocian

The Lower Bajocian reddish, nodular limestones of the Lókút section (described by GALÁCZ 1976, 1991) yielded around 50 specimens belonging to the following species:

Septocrurella retrosinuata (VACEK) (Fig. 2–2)
Capillirhynchia ? *brentoniaca* (OPPEL)
"*Rhynchonella*" *etalloni* OPPEL

The Middle and Upper Bajocian shows diverse lithology: besides the usual pelagic limestone types, dark red, manganiferous limestones, biodetrital limestones occur. The latter two rock types sometimes appear as neptunian dykes. A detailed ammonoid biostratigraphy of this stage was worked out by GALÁCZ (1976, 1991). The density and diversity of brachiopods abruptly increases in the

Humphriesianum Zone and this bloom persisted until the end of the Bajocian.

More than 500 specimens were collected from three important localities (Hárskút, Gyenespuszta; Lókút, Fenyveskút; Bakonybél, Som–hegy) from the Bakony Mts. Recently, GALÁCZ (1995a) proved the presence of Bajocian beds, besides the formerly known Bathonian at Csókakő (Vértes Mts.). It is highly probable that the "Bathonian" brachiopods described from here by FÜLÖP et al. (1960) came from these Bajocian limestones. The following species were determined from the Middle and Upper Bajocian of the Bakony and Vértes Mts.:

Stolmorhynchia ? *dubari* ROUSSELLE
Apringia atla (OPPEL) (Fig. 2–1)
A. alontina (DI STEFANO)
Capillirhynchia ? *brentoniaca* (OPPEL)
Capillirhynchia ? *kardonikensis* KAMYSHAN
Cardinirhynchia galatensis (DI STEFANO) (Fig. 2–3)
Septocrurella ? *microcephala* (PARONA) (Fig. 2–4)
S. retrosinuata (VACEK)
S. micula (OPPEL)
Striirhynchia subechinata (OPPEL)
S. berchta (OPPEL) (Fig. 2–5)
Linguithyris nepos (CANAVARI) (Fig. 2–8)
Karadagithyris gerda (OPPEL) (Fig. 2–6)
Viallithyris ? *alamanni* (DI STEFANO)
Papodina ? *recuperoi* (DI STEFANO) (Fig. 2–7)
Zugmayeria ? *pygopoides* (DI STEFANO) (Fig. 2–10)
"*Terebratula*" *fylgia* OPPEL (Fig. 2–9)
"*Terebratula*" *laticoxa* OPPEL
"*Terebratula*" *seguenzae* DI STEFANO

The whole fauna has a markedly Mediterranean character and shows strong similarity to the South Alpine and some Sicilian faunas (VÖRÖS 1993a).

The Bajocian diversity peak was interpreted by VÖRÖS (1993b) in terms of local tectonic movements. An important factor, controlling the distribution of brachiopods was the hard substratum, necessary for attachment. In Jurassic times, the Bakony area was dominated by block–faulted submarine highs (GALÁCZ & VÖRÖS 1972; VÖRÖS 1986, VÖRÖS & GALÁCZ 1998). The tectonic movements produced fresh, empty rocky surfaces and triggered rock–falls (scarp breccias: GALÁCZ 1988). The big limestone boulders scattered at the feet of the escarpments of the highs, in the marginal zones of the adjacent basins might have served as rocky substrata in an otherwise muddy environment (VÖRÖS 1991).

The Bajocian extensional tectonics have been evidenced by (1) opening phases of neptunian dykes (e. g. Som–hegy, Humphriesianum Zone: GALÁCZ 1976) and (2) scarp–breccias (e. g. Fenyveskút, Garantiana Zone: GALÁCZ 1988). All these repeated tectonic movements greatly enhanced the proliferation of brachiopod communities. Another factor might be the changing activity of submarine cold seeps carrying nutrients to the starving environment, as suggested by VÖRÖS (1995a). The rejuvenation of tectonic movements might trigger stronger flow of submarine seeps along the fracture zones bordering the highs.

Fig. 1. Map of Hungary, showing the two main terranes and the most important Bajocian and Bathonian brachiopod localities. 1. Gyenes–puszta at Hárskút, Bakony Mts., 2: Fenyves–kút and Lókút Hill at Lókút, Bakony Mts., 3: Som Hill at Bakonybél, Bakony Mts., 4: Csóka Hill at Csókakő, Vértes Mts., 5: Hidasi Valley at Hosszúhetény, Mecsek Mts., 6: Zengővárkony, Mecsek Mts., 7: Templom Hill at Villány, Villány Mts.

Mecsek Mts.

BÖCKH (1881) was the first to mention Middle Jurassic brachiopods from the Mecsek Mts.; he described and figured some Bathonian species in his monograph devoted to the ammonoid fauna. Later, VADÁSZ (1935) listed a few brachiopods from the Bajocian and Bathonian beds. In the last decade, new, detailed collections (lead by A. GALÁCZ) resulted in a rich fossil material (see GALÁCZ 1995b for a lithological and stratigraphical description).

Bajocian

This stage is represented mainly by "spotted marls" (alternation of shale and limestone beds); the recently collected brachiopod fauna is poor (7 specimens). The following taxa were determined:

Capillirhynchia brentoniaca (OPPEL)
Karadagithyris eduardi VÖRÖS
Linguithyris sp.
Zittelina ? sp.

Bathonian

Following a marked change in facies, this stage is represented by red, nodular, ammonitic calcareous marl. The fauna is dominated by ammonoids (GALÁCZ 1995b), but bivalves and sponges are also frequent. The systematic description of the very rich brachiopod fauna (415 specimens) was given by VÖRÖS (1995b). The faunal list:

Caucasella voultensis (OPPEL) (Fig. 3–1)
Stolmorhynchia sp., aff. *stolidota* BUCKMAN
Apringia ? *penninica* (UHLIG)
Dichotomosella galaczi VÖRÖS
Capillirhynchia brentoniaca (OPPEL)
Linguithyris nepos (CANAVARI) (Fig. 3–2)
Karadagella zorae TCHORSZHEVSKY & RADULOVIC (Fig. 3–4)
Karadagithyris eduardi VÖRÖS
Zittelina ? *beneckei* (PARONA) (Fig. 3–3)

Both the Bajocian and the Bathonian brachiopod fauna show rather strong Mediterranean affinity; some species occurred in the NW–European province, as well. The close similarity to the fauna of the Pieniny Klippen Belt of the Carpathians is remarkable.

The marked increase of diversity and density of brachiopods in the Bathonian can be explained by the sudden decrease in the rate of sedimentation: the empty ammonite and other shells might have been exposed for a long time on the bottom as hard objects providing attachment surfaces for brachiopods and other sessile benthic organisms. This might be enhanced by a collecting bias: the Bathonian red limestones, by their rich ammonoid fauna, specially attracted the collectors, and the more comprehensive collecting work resulted in more brachiopods.

Villány Mts.

Bathonian

Bathonian brachiopods were mentioned in faunal list by LÓCZY (1915), however these turned to be of Lower Jurassic (Pliensbachian) in age (AGER & CALLOMON 1971).

In the very incomplete Jurassic sequence of the Villány Mts. the Bathonian is represented only in a single quarry at the village Villány. Here, a local lense of sandy limestone, less than 10 cm thick and two metres across, rests on the eroded surface of a Pliensbachian, massive, crinoidal limestone and is covered by the famous Callovian ammonite–rich bank. For a more detailed stratigraphy, see GÉCZY & GALÁCZ (1998) who ranged the sandy limestone into the Upper Bathonian Retrocostatum Zone. Due to the exhaustive collecting work done by J. FÜLÖP, G. VIGH, A. GALÁCZ, B. GÉCZY and A. VÖRÖS, the local lense was completely destroyed. The poorly preserved, few brachiopods (11 specimens) represent the following taxa:

Acanthorhynchia cf. *panacanthina* (BUCKMAN & WALKER) (Fig. 3–5)
Cererithyris cf. *fleischeri* (OPPEL) (Fig. 3–6)
Dorsoplicathyris cf. *dorsoplicata* (DESLONGCHAMPS)
Aulacothyris cf. *pala* (BUCH) (Fig. 3–7)

By its dominant NW–European elements, the fauna might belong to the "Submediterranean" faunal region.

This faunal affinity seems to be in contrast with the more Mediterranean character of the contemporaneous brachiopod fauna of the Mecsek Mts., considering that both territories are held to belong to the same, Tisia terrane. The Tisia crustal fragment was part of the European shelf complex, on the northern side of the Tethys Ocean in Early Mesozoic times (GÉCZY 1973), then, in the Middle Jurassic, it started to move as a separate microcontinent (VÖRÖS 1988; 1993a). This movement is in synchrony with the appearance of definitely Mediterranean brachiopods in the deep–water Bathonian of the Mecsek, while the shallow marine Villány region remained under the influence of the NW–European province. It seems that in this case we have to count with the interplay between paleobiogeography and paleoecology, i. e. the general pattern of brachiopod distribution may be overprinted by the environmental control.

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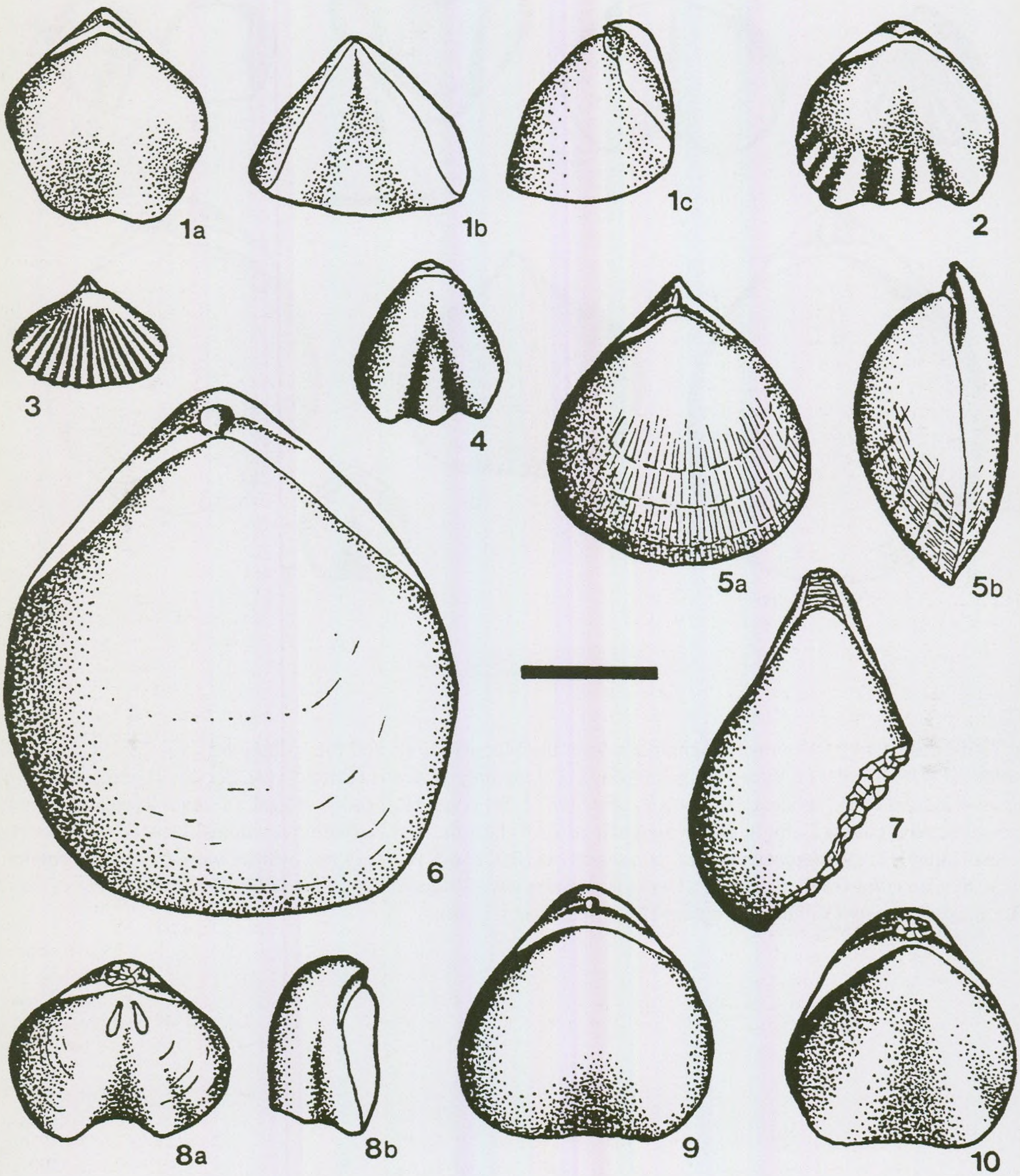
Fig. 2. Representative Bajocian brachiopods from the Bakony Mts.. 1 *Apringia atla* (OPPEL), in dorsal (a), anterior(b) and lateral (c) views (Bakonybél, Som Hill) ; 2: *Septocrurella retrosinuata* (VACEK), dorsal view (Lókút, Lókút Hill); 3: *Cardinirhynchia galatensis* (DI STEFANO), dorsal view (Hárskút, Gyenes–puszta); 4: *Septocrurella ? microcephala* (PARONA), dorsal view (Hárskút, Gyenes–puszta); 5: *Striirhynchia berchta* (OPPEL), in dorsal (a) and lateral (b) views (Lókút, Fenyves–kút); 6: *Karadagithyris gerda* (OPPEL), in dorsal view (Lókút, Fenyves–kút); 7: *Papodina ? recuperoi* (DI STEFANO), dorsal view (Lókút, Fenyves–kút); 8: *Linguithyris nepos* (CANAVARI), in dorsal (a) and lateral (b) views (Bakonybél, Som–hegy); 9: *"Terebratula" fylgia* Oppel, dorsal view (Bakonybél, Som–hegy); 10: *Zugmayeria ? pygopoides* (DI STEFANO), dorsal view (Lókút, Fenyves–kút) (Scale bar = 1 cm).

Fig. 2.



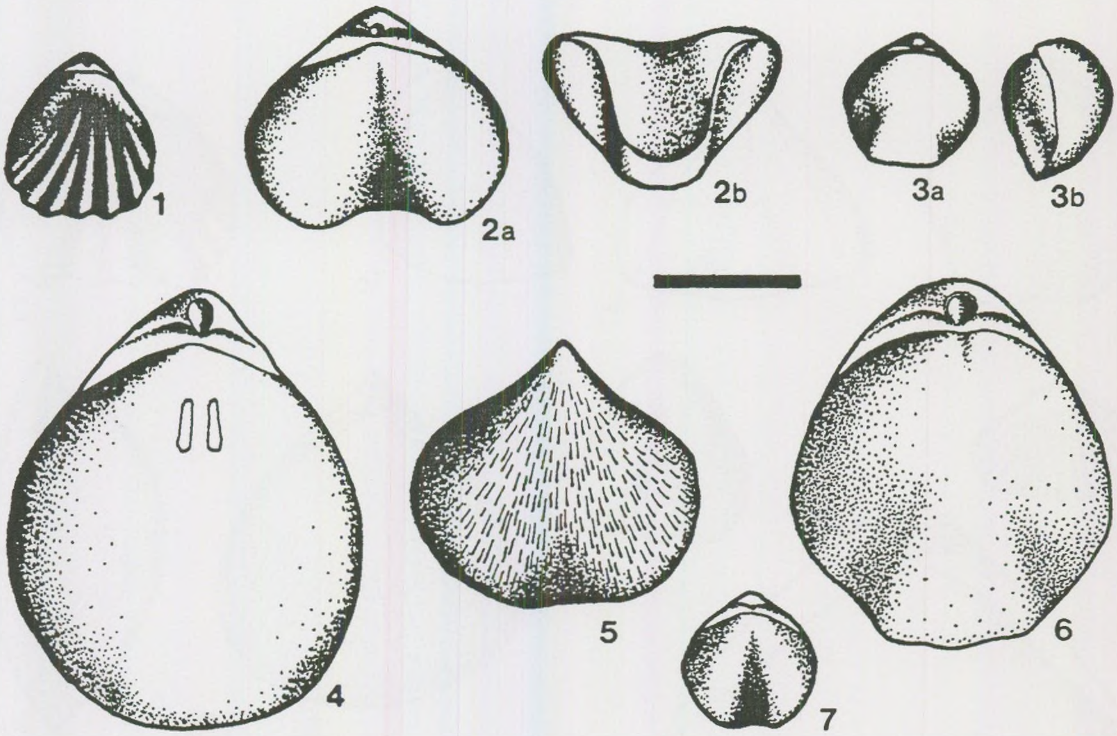


Fig. 3.Representative Bathonian brachiopods from the Mecsek (1–4.) and the Villány Mts. (5–7.):1: *Caucasella voultensis* (OPPEL), dorsal view (Zengővárkony); 2: *Linguithyris nepos* (CANAVARI), dorsal (a) and anterior (b) views (Hosszúhetény, Hidasi Valley); 3: *Zittelina* ? *beneckei* (PARONA), dorsal (a) and lateral (b) views (Hosszúhetény, Hidasi Valley); 4: *Karadagella zorae* Tchorszhevsky & Radulovic, dorsal view (Hosszúhetény, Hidasi Valley); 5: *Acanthorhynchia* cf. *panacanthina* (BUCKMAN & WALKER), ventral view (Villány, Templom Hill); 6: *Cererithyris* cf. *fleischeri* (OPPEL), dorsal view (Villány, Templom Hill); 7: *Aulacothyris* cf. *pala* (BUCH), dorsal view (Villány, Templom Hill) (Scale bar = 1 cm).

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