Lower Bathonian ammonites of Serra de la Creu
(Tivissa, Catalan Basin, Spain)

Sixto Rafael FERNÁNDEZ-LÓPEZ

Abstract
The study of ammonites of the Bajocian/Bathonian boundary from Serra de la Creu (Tivissa, province of Tarragona), a locality of the Catalan Basin, allows to recognize several bio- and chronostratigraphic units commonly missing in the Iberian Basin. The Parkinsoni Zone (Upper Bajocian) and the lowermost Zigzag Zone (Lower Bathonian) established for NW Europe areas can be identified in the Catalan and Iberian basins (Spain), although the ammonite fossil assemblages are composed by Submediterranean taxa.

Key words
Middle Jurassic, Ammonoids, taphonomy, biostratigraphy, chronostratigraphy, palaeobiogeography, Iberia.

INTRODUCTION
Ammonites of the Bajocian/Bathonian boundary are very scarce in the Iberian Basin, as a result of non-preservation in shallow water facies or gaps in the geological record. Several authors have mentioned the scarce occurrence of ammonites in the Iberian Basin during this chronostratigraphical interval (WESTERMANN, 1955; MENSINK, 1966; TINTANT & VIALLARD, 1970; BULARD, 1972; MARIN & TOULOUSE, 1972; HINKELBEIN, 1975; FERNÁNDEZ-LÓPEZ, 1976, 1985, 1997; FERNÁNDEZ-LÓPEZ et al., 1978, 1985, 1996; FERNÁNDEZ-LÓPEZ & AURELL, 1985; WILDE, 1988; FERNÁNDEZ-LÓPEZ & AURELL, 1988; THIERRY & WILDE, 1990). Lower Bathonian ammonites of this region, however, have never been figured. The ammonite succession discovered at the Serra de la Creu outcrop (Tivissa, province of Tarragona, Text-fig. 1), a locality of the Catalan Basin, allows to recognize several of these bio- and chronostratigraphic units commonly missing in the Iberian Basin.

The aim of this paper is to describe some Lower Bathonian ammonites from the Serra de la Creu (Tivissa) section, which until now were unknown from the Catalan and Iberian basins. The biochronological data obtained in this section are compared with those of the other European basins.

AMMONITE TAPHONOMY
At the Tivissa area, the Upper Bajocian-Callovian limestones of the La Tossa Fm overlie Upper Bajocian marnes of the Cardo Fm (FERNÁNDEZ-LÓPEZ et al., 1996, 1997, 1999). Beds of the Parkinsoni and Zigzag zones constitute the lowermost part of the La Tossa Formation in the Serra de la Creu outcrop (Text-fig. 2). At the type section of the La Tossa Fm, located in the Serra de la Creu outcrop (Tivissa), the lower part of this lithostratigraphic unit is composed by light yellow-brown, muddy limestones, regularly bedded, ranging in thickness from 10 to 120 cm, and alternating with marly intervals from 0 to 20 cm. These carbonate deposits are organized in shallowing-upwards sequences, of metric thickness, thickening upwards, which correspond to strati-
Text-fig. 2: Biostratigraphical data of Upper Bajocian/Lower Bathonian ammonites in Serra de la Creu (Tivissa), type section of the La Tossa Fm.

<table>
<thead>
<tr>
<th>Ammonites</th>
<th>Formation</th>
<th>Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Sphaeroceras tenuicostatum</em></td>
<td><em>STURANI</em></td>
<td>Upper Bajocian</td>
</tr>
<tr>
<td><em>Haumoceras sp.</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Durodorina</em> sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Lissoceras sp.</em></td>
<td><em>PARONA</em></td>
<td></td>
</tr>
<tr>
<td><em>Strigoceras sp.</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cadomoceras aff. nepos</em></td>
<td><em>PARONA</em></td>
<td></td>
</tr>
<tr>
<td><em>Phlycticeras dorsocavatum</em></td>
<td><em>QUENSTEDT</em></td>
<td></td>
</tr>
<tr>
<td><em>Oxycerites sp.</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Paroecotraustes sp.</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Polyplectites sp.</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Gonolkites sp.</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>G. convergens</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Parkinsonia sp.</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>P. cf. schloenbachi</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Lobosphinctes sp.</em></td>
<td><em>BUCKMAN</em></td>
<td></td>
</tr>
<tr>
<td><em>L. intersertus</em></td>
<td><em>BUCKMAN</em></td>
<td></td>
</tr>
<tr>
<td><em>Procerozigzag sp.</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Procerites sp.</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Planisphinctes sp.</em></td>
<td><em>BUCKMAN</em></td>
<td></td>
</tr>
<tr>
<td><em>P. planilobus</em></td>
<td><em>BUCKMAN</em></td>
<td></td>
</tr>
<tr>
<td><em>Zigzag sp.</em></td>
<td><em>d'ORBIGNY</em></td>
<td></td>
</tr>
<tr>
<td><em>Siemiradzkia sp.</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pseudodimorphinites sp.</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Morphoceras sp.</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>M. parvum</em> (WETZEL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>M. macrescens</em></td>
<td><em>BUCKMAN</em></td>
<td></td>
</tr>
<tr>
<td><em>M. patescens</em></td>
<td><em>BUCKMAN</em></td>
<td></td>
</tr>
<tr>
<td><em>Ebrayiceras sp.</em></td>
<td><em>ZIETEN</em></td>
<td></td>
</tr>
<tr>
<td><em>Bullatostrites</em> sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bullostrites sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. latecentratus</td>
<td><em>BUCKMAN</em></td>
<td></td>
</tr>
</tbody>
</table>

[Diagram with ammonite stratigraphic zones and thicknesses]
graphic cycles of 5th order, resulting from changes in water turbulence and rate of sedimentation (FERNÁNDEZ-LÓPEZ, 1997). Fossils, especially ammonites, are scarce. Bivalves, terebratulid brachiopods, crinoid ossicles and belemnite guards occur. The ammonites are commonly preserved as calcareous moulds of resedimented shells (i.e., displaced on the seabottom, before their burial), partially infilled with mud, although some specimens show mouth-border or lappets intact (Plate I, fig. 7). Accumulated elements, showing no evidence of removal after laying on the sea-bottom, are very scarce or absent. Reelaborated, calcareous or phosphatic, concretionary internal moulds (i.e., exhumed and displaced before their final burial) occur in some marly intervals (level CR227 in Text-fig. 2). However, the degree of taphonomic condensation (i.e., mixture of fossils of different age or different chronostratigraphic units) reaches zero values in all cases. Ammonite mixed assemblages composed of specimens representing several biozones or biohorizons in a single bed have not been identified and the chronostratigraphical completeness can reach 100%. Taphonomic 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 not represented (FERNÁNDEZ-LÓPEZ, 1991, 1997, 2000).

Shells of juvenile individuals are very scarce or absent, and shells of adult individuals are predominant. Biostratigraphic 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. Complete concretional internal moulds of the body chamber and phragmocone, indicative of low rates of sedimentation and accumulation, are scarce, and they are restricted to certain removal intervals (for example, level CR227 in Text-fig. 2). In contrast, compressed, partial internal moulds of body chambers (i.e., hollow ammonites sensu FERNÁNDEZ-LÓPEZ, 1997, 2000), indicative of very rapid sedimentary infill and high rate of sedimentation, are abundant. 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. 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 I, fig. 9). Fragmentary shells are common, but bearing no signs of rounding during resedimentation processes on the seabottom, due to the low turbulence near the water/sediment surface. 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.

These Last Bajocian/Early Bathonian ammonite shells represent ademic organisms and are interpreted as allochthonous elements having arrived at their present location by necroplanktic drift. The absence of taphonomic populations of type 1, showing no signs of sorting by necroplanktic drift or transport, is indicative of allochthonous biogenic production of shells (FERNÁNDEZ-LÓPEZ, 1991, 1997). These Upper Bajocian/Lower Bathonian deposits are interpreted as having been deposited in an open sea, below wave base, in distal areas of the 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), and exceptionally by reelaboration (i.e., exhumation and displacement on the sea-bottom, before their final burial). 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 Last Bajocian/Early Bathonian interval (FERNÁNDEZ-LÓPEZ, 1997).

AMMONITE BIO- AND CHRONOSTRATIGRAPHY

For the Upper Bajocian and Lower Bathonian, several biostratigraphic intervals have been distinguished in the lower part of the La Tossa Fm 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.

Upper Bajocian

In the Serra de la Creu (Tivissa) section, Sphaeroceras tenuicostatum STURANI has been identified in the last levels of the Cardo Fm (level CR2 in Text-fig. 2). The first bed of the La Tossa Fm (CR16) belongs to the Garantiana Zone (Upper Bajocian). This zone is characterized by scarce specimens of Hlawiceras, Spiroceras and Sphaeroceras. The most typical ammonites of the Parkinsonia Zone are Durotrigensia [M] and Parkinsonia [m]. A specimen of P. parkinsoni (SOWERBY) [m] has been identified in the level CR120 (Plate I, fig. 10). However, the scarcity of ammonites in the Parkinsonia Zone prevents recognition of subzones. Here the Parkinsonia Zone attains a maximum thickness of 14.0m (CR68-CR163) and is overlain by the Zigazag Zone, which attains a thickness of up to 7.0m.
Lower Bathonian

The stratigraphical interval CR164-CR240 belongs to the Lower Bathonian. Ammonites allow recognition of the Zigzag and Aurigerus zones, defined in the Submediterranean Province (CARIOU et al., 1985). The lowermost zone of the Bathonian yields abundant perissphinctids and morphoceratids: *Lobosphinctes* [M] - *Planisphinctes* [m], *Procerozigzag* [M] - *Zigzagiceras* [m], *Procerites* [M] - *Siemiradzkia* [m], *Pseudodimorphinites* [M+m] and *Morphoceras* [M] - *Ebrayiceras* [m].

Two subzones can be recognized in the Zigzag Zone, respectively Parvum and Macrescens, the former being the better developed at the Tivissa area. The first (levels CR164-1217) yields the earliest *Pseudodimorphinites* [M+m] and *Morphoceras* [M] - *Ebrayiceras* [m], proving the Submediterranean Parvum Subzone. The following taxa have been identified:

- *Lissoceras* sp. [M] (R)
- *Strigoceras* sp. [M] (R)
- *Cadomoceras* sp. [m] (R)
- *Phlycticeras dorsocavatum* (QUENSTEDT) [M] (R) (Plate I, fig. 8) (R)
- *Oxycerites* sp. [M] (C)
- *Paroecotraustes* sp. [m] (C)
- *Polyplectites* sp. [m] (R)
- *Gonolkites convergens* BUCKMAN [M] (R) (Plate I, fig. 1)
- *Parkinsonia* cf. *schloenbachii* (SCHLIPPE) [m] (R)
- *Lobosphinctes interseptus* BUCKMAN [M] (C) (Plate I, fig. 2)
- *Procerozigzag* sp. [M] (R)
- *Procerites* sp. [M] (C)
- *Planisphinctes planilobus* BUCKMAN [m] (VC) (Plate I, fig. 3)
- *Planisphinctes aff. gredingensis* (DORN) [m] (C) (Plate I, fig. 4)
- *Zigzagiceras* sp. [m] (C)
- *Siemiradzkia* sp. [m] (C)
- *Pseudodimorphinites* cf. *replicus* (BUCKMAN) (R)
- *Morphoceras parvum* (WETZEL) [M] (C) (Plate I, fig. 6)
- *Ebrayiceras sulcatum* (ZIETEN) [m] (C)

The second subzone of the Zigzag Zone (levels CR128-CR235), characterized by *Morphoceras macrescens* CR235), characterized by *Morphoceras* [M] - *Ebrayiceras* [m], belongs to the Submediterranean Macrescens Subzone. Above CR235, the Aurigerus Zone is characterized by the first occurrence of *Bullatimorphites* [M], associated with *Morphoceras* [M] - *Ebrayiceras* [m] and the last specimens of *Procerozigzag* [M] - *Zigzagiceras* [m]. The following species have been identified:

- *Zigzagiceras zigzag* (D’ORBIGNY) [m] (C) (Plate I, fig. 9)
- *Morphoceras patescens* (BUCKMAN) [M] (C)
- *Bullatimorphites latecentratus* (QUENSTEDT) [M] (R)

PALAEOBIOGEOGRAPHICAL REMARKS

Separate zonal schemes have been established in Europe, for the Upper Bajocian and Lower Bathonian, due to faunal differences (Text-fig. 3). A northern European faunal region or Subboreal Province, from Britain to southern Germany, has been distinguished by several authors (WESTERMANN & CALLOMON, 1988; CALLOMON & COPE, 1995; PAGE, 1996; DIETZE & CHANDLER, 1997) giving careful consideration to the abundance of Parkinsoniids. In contrast, Phyllo- and Lytoceratina characterizing the Mediterranean Province (CARIOU et al. 1985) are very common in the Subbetic Basin (SANDOVAL, 1983, 1990) and Majorca (ALVARO et al., 1989). These taxonomic groups (Parkinsoniids, Phyllo- and Lytoceratina) are very scarce in the so-called Sub-Mediterranean areas, such as Portugal, centre-west France, Nièvre, Macônnais and Jura (GALÁCZ, 1980; TORRENS, 1987; INNOCENTI et al. 1988; MANGOLD, 1990; RIOULT et al. 1997; MANGOLD & RIOULT, 1997; OLIVERO et al. 1997; GECZY & GALÁCZ, 1998).

In the Iberian Basin, Middle Jurassic Phylloceratina and Lytoceratina represent less than 1% of the whole of ammonoids (FERNÁNDEZ-LÓPEZ & MELÉNDEZ, 1996) and Lower Bathonian parkinsoniids are scarce. A Sub-Mediterranean zonation can be recognized in the Basque-Cantabrian and Iberian basins (FERNÁNDEZ-LÓPEZ et al., 1978, 1988; FERNÁNDEZ-LÓPEZ, 1985, 1988), and has also been applied to the Serra de la Creu (Tivissa) succession in the Catalan Basin. However, exceptional ammonoids recorded in the Iberian and Catalan basins at the uppermost Bajocian and Lower Bathonian correspond to adult individuals, arrived by necroplanktic drift from more open marine or oceanic areas.

In the Serra de la Creu (Tivissa) section, the total number of the Lower Bathonian studied ammonites is up 100 (Text-fig. 4). Specimens of the family Perissphinctidae are common (50.5 %, in Tex-fig. 4). Zigzagicertinae of the genera *Lobosphinctes* [M] - *Planisphinctes* [m] and *Procerites* [M] - *Siemiradzkia* [m] are the most common ammonites in the Zigzag Zone. *Procerozigzag* [M] - *Zigzagiceras* [m] are fairly common. Among the *Morphoceras* [M] - *Ebrayiceras* [m] are one of the most common ammonites in some levels of the Lower Bathonian. *Pseudodimorphinites* [M+m] occur. Parkinsoniinae of the genera *Gonolkites* [M] - *Parkinsonia* [m] are scarce. Representatives of the family Oppelididae are scarce (15.0 %), but macroconch *Oxycerites* and microconch *Paroecotraustes* forms occur. Very scarce are the families *Strigoceratidae* (2.8 %), *Tulitidae* (1.9 %), *Stephanoceratidae* (0.9 %) and *Lissoceratidae* (0.9 %). Consequently, the Parkinsoni Zone (Upper Bajocian) and the lowermost Ziazas Zone (Lower Bathonian) estab-
Lower Bathonian ammonites of Serra de la Creu (Tivissa, Catalan Basin, Spain)


Text-fig. 4: Distribution of the percentage of the ammonite taxonomic groups (109 specimens) in the Lower Bathonian of the Serra de la Creu (Tivissa) section.

<table>
<thead>
<tr>
<th>Subboreal Province</th>
<th>Submediterranean Province</th>
<th>Mediterranean Province</th>
</tr>
</thead>
<tbody>
<tr>
<td>NW Europe: England, Lorraine, Alsace, Germany.</td>
<td>Centre-west France, Nièvre, Maconnais, Jura, Portugal, Iberian Basin</td>
<td>Betic Basin</td>
</tr>
<tr>
<td><strong>Lower Bathonian</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zigzag</td>
<td>Tenuiplicatus</td>
<td>Tenuiplicatus</td>
</tr>
<tr>
<td>Yeovilensis</td>
<td>Aurigerus</td>
<td>Recinctus</td>
</tr>
<tr>
<td>Macrescens</td>
<td></td>
<td>Macrescens</td>
</tr>
<tr>
<td>Convergens</td>
<td></td>
<td>Parvum</td>
</tr>
<tr>
<td><strong>Upper Bajocian</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parkinsoni</td>
<td>Bomfordi</td>
<td>Parkinisoni</td>
</tr>
<tr>
<td>Truellei</td>
<td></td>
<td>Densicosta</td>
</tr>
</tbody>
</table>

CONCLUSIONS

The Lower Bathonian at the Serra de la Creu (Tivissa) section, in the Catalan Basin, has a much better developed biostratigraphical succession previously barely recognised in the Iberian Basin. These Zigzag beds represent an expanded succession in relation to other well-known successions of the Iberian Basin. This section provides the best-known stratigraphical record of the Catalan and Iberian basins for the Lower Bathonian. However, its importance lies not in any value for palaeontological purposes. The relevance of this Lower Bathonian deposits lies in regional geological purposes.

ACKNOWLEDGEMENT

This work is a contribution to the projects PB92-0011 (DGICYT-CSIC) and PB96-0838 (DGESICYT - CSIC). The manuscript was closed 10th January, 2000.

REFERENCES


CARIOU, E., D. CONTINI, J.L. DOMMERGUES, R. ENAY,


Plate

Fig 1: *Gonolkites convergens* BUCKMAN. Incomplete phragmocone of immature macroconch. Right view. Specimen 1CR227/1. x1. Zigzag Zone. Parvum Subzone.

Fig 2: *Lobosphinctes intersertus* BUCKMAN. Incomplete phragmocone of immature macroconch. Left view. Specimen 1CR206/1. x1. Zigzag Zone. Parvum Subzone.

Fig 3: *Planisphinctes planilobus* BUCKMAN. Incomplete shell of immature microconch. Right view. Specimen 1CR202/1. x1. Zigzag Zone. Parvum Subzone.


Fig 5: *Oxycerites* sp. Incomplete shell of immature macroconch. Left view. Specimen 1CR212/4. x2. Zigzag Zone. Parvum Subzone.


Fig 7: *Cadomoceras aff. nepos* PARONA. Complete shell of mature microconch with lateral lappets. Left view. Specimen 1CR112/1. x2. Parkinsoni Zone.

Fig 8: *Phlycticeras dorsocavatum* (QUENSTEDT). Incomplete shell of immature macroconch. Right view. Specimen 1CR216/2. x1. Zigzag Zone. Parvum Subzone.

Fig 9: *Zigzagiceras zigzag* (D’ORBIGNY). Incomplete shell of mature microconch. Right view. Specimen 1CR235/1. x1. Aurigerus Zone.

Fig 10: *Parkinsonia parkinsoni* (SOWERBY). Incomplete shell of immature microconch. Right view. Specimen 1CR120/1. x1. Parkinsoni Zone.

All the ammonites are in natural size, except for 5 and 7. Asterisk indicates end of phragmocone.


Accepté juillet 2000