Studia breviora

Advancement in ammonite zonal subdivision of the Aalenian in Bulgaria

Evidence of Aalenian strata is provided by ammonites in the earliest subdivision of the Jurassic System in Bulgaria (Zlatarski, 1908). Initially, these rocks were regarded as Bajocian and this view has been adhered to for a long time by many Bulgarian stratigraphers. When introducing the *Leioceras opalinum* Zone in Bulgaria, Sapunov (1959) considered its base to be the dividing point between the adjacent Lower Jurassic strata and the base of the Aalenian Stage of the Middle Jurassic above. Subsequently, Sapunov (1964a) changed his opinion, arguing that the Aalenian should be removed from the scheme of Middle Jurassic stages of Bulgaria. It was not until the publications of Sapunov (1968, 1969) that the Aalenian was formally separated in Bulgaria from the Bajocian as the lowest stage of the Middle Jurassic. Before this time and through to the present, a few contributions on the Aalenian have appeared in the literature, and most of them contain only short lists of ammonite species cited (e.g., Sapunov and Nachev, 1959; Sapunov, 1961; Nachev *et al.*, 1963). This procedure continues today, mainly due to the rarity of ammonites in the Aalenian rocks. Despite the lack of common specimens, we are able to propose here a sufficiently complete Aalenian ammonite zonation (Table 1). The present biostratigraphical account is mostly based on the results and specimens from the papers of Sapunov (1964b, 1968, 1969, 1970), Sapunov *et al.* (1996), Metodiev (2000), Metodiev and Sapunov (2001) and Metodiev *et al.* (2014), as well as on recently obtained data. Our scheme matches adequately with that for the current Aalenian zonal succession for Northwest Europe (Contini *et al.*, 1997). The efforts in dividing the Aalenian on the basis of ammonites have been guided and facilitated by the use of the comprehensive results attained in the UK by Callomon and Chandler (1990), Chandler and Callomon (2009), Chandler (1997) and Chandler *et al.* (2006). These works were based on superbly preserved specimens, collected bed-by-bed, and provide a good foundation for the construction of

Aalenian biostratigraphy in Bulgaria. Based on the stratigraphical distribution of the ammonite family Graphoceratidae, four Aalenian ammonite zones and nine subzones have been recognized: *Leioceras opalinum* Zone (comprising the *L. opalinum* and *L. bifidatum* subzones); *Ludwigia munchisonae* Zone (containing the *Staufenia sehndensis*–*Ancolioceras opalinoides* and *Ludwigia munchisonae* subzones); *Brasilia bradfordensis* Zone (including the *B. bradfordensis* and *B. gigantea* subzones); and *Graphoceras concavum* Zone (embracing the *G. cavatum*, *G. formosum* and *Eudmetoceras amplexans* subzones). Other ammonites associated with the Aalenian are those of the family Hammatoceratidae, but they have even more restricted distribution and are of less biostratigraphical significance. This abridged report includes reduced faunal and reference lists and will be presented in more details elsewhere.

The *Leioceras opalinum* Zone is based on the range of the genus *Leioceras*. In most cases, the very base of the zone is too poor in ammonites and we were unable to date the rocks more precisely. In particular, we are lacking in detail about the transition between the upper Toarcian members of the genus *Pleydellia* and the first graphoceratids (those of *Leioceras*). Thus, the lower limit of this zone (and of the Aalenian respectively) is drawn at the sudden appearance of small, suboxyconic, smooth or finely ornamented examples of *Leioceras*. The latter are succeeded, at about the middle of the zone, by larger-sized *Leioceras* with stouter whorls and stronger, bundled or bifurcating ribbing. Around this level, the first appearance of the *Leioceras*-allied genus *Cylicoceras* has been recorded in Bulgaria (Sapunov, 1970). This evidence was used to divide the *L. opalinum* Zone into two subzones: the *L. opalinum* Subzone (to include the occurrence of the finely ornamented *Leioceras*), which is almost certainly the equivalent of the respective subzone in NW Europe, and the *L. bifidatum* Subzone (to include the distribution of the coarsely ribbed *Leioceras* and the occurrence of *Cylicoceras*), which possibly corre-

Table 1

Correlation between the Bulgarian Aalenian ammonite (sub)zones and the standard (sub)zones in NW Europe, according to Contini *et al.*, 1997 (see also Callomon and Chandler, 1990; Chandler, 1997; Chandler *et al.*, 2006).

Bulgaria		Northwest Europe		
Zone	Subzone	Horizon	Subzone	Zone
Graphoceras concavum	Eudmetoceras amplexens	Eudmetoceras amplexens	Graphoceras formosum	Graphoceras concavum
	Graphoceras formosum	Graphoceras formosum		
	Graphoceras cavatum	Graphoceras concavum	Graphoceras concavum	
		Graphoceras cavatum		
Brasilia bradfordensis	Brasilia gigantea	Brasilia gigantea	Brasilia gigantea	Ludwigia munchisonae
	B. bradfordensis	B. bradfordensis	Brasilia bradfordensis	
Ludwigia munchisonae	Ludwigia munchisonae	Staufenia staufensis		
		Ludwigia munchisonae		
	Staufenia sehndensis–Ancolloceras opalinoides	Staufenia sehndensis	Ludwigia haugi	
		Ludwigia obtusifomis		
		Ludwigia haugi	Ludwigia haugi	
	Staufenia sinon			
Leioceras opalinum	Leioceras bifidatum	Leioc. crassicostatum	Leioceras bifidatum	Leioceras opalinum
		Leioceras bifidatum		
		Leioceras lineatum	Leioceras comptum	
	Leioceras opalinum	Leioceras opalinum	Leioceras opalinum	
		Leioceras subglabrum		

sponds to the total extent of the *L. comptum* and *L. bifidatum* subzones *sensu* Contini *et al.* (1997). This division should remain provisional until more evidence is obtained as coarse ribbed variants of *Leioceras* do occur rarely in the *L. opalinum* Subzone of NW Europe and persist well into the *Ludwigia munchisonae* Zone *sensu stricto*. The *Leioceras bifidatum* Subzone now fully replaces the earlier used *Leioceras comptum* Subzone (Metodiev, 2000), in agreement with the arguments advanced by Contini *et al.* (1997). In the present usage of the *L. opalinum* Subzone, six characteristic *Leioceras* species, including the zonal and subzonal indices, have been determined (Sapunov, 1959, 1961, 1964, 1968; Sapunov *et al.*, 1996; Metodiev, 2000), and seem to be relatively good matches of the corresponding coeval taxa in NW Europe (see Contini *et al.*, 1997, pp. 37–38). In addition to the genera *Leioceras* and *Cylicoceras*, occasional representatives of the genera *Pseudammatoceras*, *Rhodaniceras* and *Bredya*

were found in the lower subzone, whereas sporadic specimens of the genus *Csernyeiceras* were detected in the upper subzone of the *L. opalinum* Zone.

The *Ludwigia munchisonae* Zone as now interpreted is less extensive in Bulgaria than the equivalent Aalenian ammonite zone of Contini *et al.* (1997) in NW Europe. We follow the approach of the UK stratigraphers (*e.g.*, Callomon and Chandler, 1990; Chandler, 1997; Chandler *et al.*, 2006), according to whom the abundant *Brasilia* assemblages should be excluded from the extent of this zone and assigned to the *Brasilia bradfordensis* Zone. The lower boundary of the *L. munchisonae* Zone is taken at the transition where the ammonites of the genus *Leioceras* are replaced by *Ancolloceras* (a late leioceratid), and the first *Ludwigia* and *Staufenia* appear. Both *Ludwigia* and *Staufenia* are present throughout the total extent of the zone, but they have sparse occurrence in the lower part, and are much more common

into the upper part of the zone. Scattered hammatoceratids, such as *Planammatoceras*, *Pseudammatoceras* and *Spinammatoceras*, also occur. No data exist to support extending the range of the genus *Cylicoceras* into the *L. munchisonae* Zone of Bulgaria. This suggests that either the oldest *Murchisonae* strata may be missing or the *Cylicoceras* group did not reach the zone. The first abundant appearance of *Brasilia* delimits the upper boundary of the *L. munchisonae* Zone in Bulgaria.

We have retained in our scheme (Table 1) a two-fold division of the *Ludwigia munchisonae* Zone into the *Staufenia sehdensis*–*Ancolioceras opalinoides* Subzone and the *L. munchisonae* Subzone, as proposed by Metodiev (2000). However, this subdivision remains somewhat local and has not yet been widely recognized. The identification of the *S. sehdensis*–*A. opalinoides* Subzone is based on the co-occurrence of the morphotypes of *Staufenia* and *Ancolioceras*, including *Staufenia sinon* (Bayle), *S. sehdensis* (Hoffmann) and *A. opalinoides* (Mayer), as well as that of *Ludwigia crassa* Horn and several poorly preserved *Ludwigia* ex gr. *haugi* Douvillé and *Ludwigia* ex gr. *pustulifera* Buckman. More specimens are needed to recognize the presence of this subzone in Bulgaria, and an alternative name may need to be found as index. At the current state of knowledge, the *S. sehdensis*–*A. opalinoides* Subzone should be construed as no more than an approximate correlation with both the *Ludwigia haugi* Subzone and the *Staufenia sehdensis*–*Ludwigia obtusifformis* horizons in NW Europe (see Table 1). The *Ludwigia munchisonae* Subzone has been recognized by the co-occurrence of two assemblages: a *Ludwigia* assemblage (including the index-species, but also *L. gradata* Buckman and *Ludwigia* (*Pseudographoceras*) *subtuberculata* Rieber), as well as an assemblage that consists of *Staufenia discoidea* (Quenstedt) and *S. staufensis* (Hoffmann). We believe that the decline of the genus *Staufenia* and most of *Ludwigia* species precedes the first abundant appearance of the genus *Brasilia*, and therefore the extent of the *L. munchisonae* Subzone is slightly shifted up compared to the coeval subzone in NW Europe. Accordingly, this subzone is comparable to the top of the *L. munchisonae* Subzone and the *S. staufensis* Horizon of the *Brasilia bradfordensis* Subzone in the scheme of Contini *et al.* (1997).

The *Brasilia bradfordensis* Zone is defined by the occurrence of characteristic species of the genus *Brasilia*. Previously, the presence of these distinctive ammonites was founded on isolated specimens from a few localities (e.g., Sapunov, 1969) and interpreted as a subgenus of the genus *Ludwigia*. This concept was followed by Metodiev (2000) in

the incorporation of *Brasilia* faunas into the Aalenian ammonite zonal scheme, and the *Brasilia bradfordensis* Zone was initially incorporated as the topmost subzone of the *L. munchisonae* Zone. The results of a long period of research in the UK (e.g., Cope *et al.*, 1980; Callomon and Chandler, 1990; Chandler, 1997; Chandler *et al.*, 2006) and other significant localities in Western Europe (e.g., Contini, 1969; Rieber, 1963; Goy and Ureta, 1981; Rulleau *et al.*, 2001) have perfectly demonstrated the evolutionary transition between the latest members of the *Ludwigia munchisonae* group and those of the genus *Brasilia*. This transition is so gradual that it is difficult to set apart these forms from each other. The range of *Brasilia*, however, is prominent biostratigraphical marker and should be considered as a separate ammonite zone. We have, therefore, removed the *Brasilia* assemblages from the *L. munchisonae* Zone and recognized it as a separate zone in line with other authors (e.g., Chandler, 1997; Chandler *et al.*, 2006). The *Brasilia bradfordensis* Zone is defined herein with two subzones: *Brasilia bradfordensis* and *Brasilia gigantea*. Our records from the *B. bradfordensis* Subzone include almost entirely small specimens (probably macroconchs and microconchs) ascribed to the genus *Brasilia* and to the subgenus *Graphoceras* (*Ludwigella*). The *Brasilia gigantea* Subzone contains mostly small-sized *Ludwigia* (*Pseudographoceras*) and *Brasilia* (*Apedogyria*) (microconchs), as well as big *Brasilia* examples (macroconchs often attaining large sizes). We should point out that our evidence comes from a single locality, and that the validity of this division still needs verification from further sections. In this framework, the *Brasilia bradfordensis* Subzone is based on the dominance of the index-species and several allied taxa, such as *Brasilia falcifera* (Althoff), *B. deleta* (Buckman), *B. bayley* (Buckman), and *B. subcava* (Buckman). Examples of *Graphoceras* (*Ludwigella*) ex gr. *arcitenens* (Buckman) and very scarce *Ludwigia* also occur, although only at the base of the subzone. Hammatoceratids of the genera *Pseudammatoceras* and *Accardia* were occasionally recorded. The *Brasilia gigantea* Subzone was recognized by the presence of the index, associated with *Brasilia nitens* (Buckman), *B. similis* (Buckman), *B. decipiens* (Buckman) and common *Brasilia* (*Apedogyria*) ex gr. *rugosa*–*subcornuta* (Buckman) and *Ludwigia* (*Pseudographoceras*) *umbilicata* (Buckman). That means that the *Brasilia bradfordensis* Zone in Bulgaria matches the *B. bradfordensis* Horizon of the *B. bradfordensis* Subzone, whereas the *Brasilia gigantea* Subzone accords with the *B. gigantea* Subzone of the *L. munchisonae* Zone in NW Europe (Contini *et al.*, 1997).

The *Graphoceras concavum* Zone forms the highest subdivision of the Aalenian in Bulgaria. As elsewhere, it is characterized by the occurrence of the genus *Graphoceras*, which has been recorded at several localities in Bulgaria (Sapunov, 1961, 1964a; Sapunov, 1969; Metodiev, 2000; Metodiev *et al.*, 2014). This zone is not well developed or fossiliferous. Sufficiently detailed stratigraphy of the localities is not yet available. The presence of *Graphoceras concavum* (J. Sowerby) itself still remains doubtful, as the examples previously cited in older Bulgarian literature are either not available for revision or no new ammonites have been collected. Nevertheless, this zone is reliably recognizable and can be locally divided in the same manner as in NW Europe. We recognize the *G. concavum* Zone by the presence of *Graphoceras* (*Graphoceras*) [M], despite being sporadic in occurrence. Except these ammonites, we have also recorded common occurrence of *Graphoceras* [m], referred to the subgenus *Graphoceras* (*Ludwigella*). Our material includes several characteristic species of well-dated stratigraphical distribution in NW Europe that we found in three levels, and allowed us to separate three succeeding subzones, which, however, have condition-

ally erected indices and need to be better evidenced: *Graphoceras cavatum*; *G. formosum*; and *Eudmetoceras amplexens* (Table 1). The lower subzone is defined by the presence of *G. cavatum* (Buckman) and an association of *Graphoceras* (*Ludwigella*) ex gr. *rudis-cornu* Buckman and, therefore, it presumably corresponds to the *G. concavum* Subzone in NW Europe (Contini *et al.*, 1997). The middle subzone is specified by examples of *Graphoceras* cf. *formosum* Buckman, *G. cf. fallax* Buckman and an assemblage of *Graphoceras* (*Ludwigella*) ex gr. *latum-attenuatum* (Buckman), and it appears to corresponding to the *G. formosum* Horizon of the *G. formosum* Subzone as proposed by Contini *et al.* (1997). The upper subzone comprises the occurrence of *Eudmetoceras amplexens* Buckman, *E. klimakomphalum* (Vacek), *Parammatoceras boyeri* Elmi, *Graphoceras* aff. *decorum* Buckman and *Euhoploceras* spp., and it seems to be equivalent of the *Euaptetoceras amplexens* Horizon of the *G. formosum* Subzone as used by Contini *et al.* (1997). The latter assemblage indicates an age close to the top of the Aalenian (*i.e.*, Aa-15 or Aa-16 of Callomon and Chandler, 1990, from which the first sonniniids are known in the UK).

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