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## A new ammonite zonation for the Maastrichtian Stage in Poland

**Marcin Machalski**

Institute of Paleobiology, Polish Academy of Sciences, ul. Twarda 51/55, 00-818 Warszawa, Poland,  
email: mach@twarda.pan.pl

Recent progress in research of ammonite faunas from the uppermost Campanian and Maastrichtian of central and eastern Poland (Machalski, 2005a, b, 2010, 2012, in prep.; Machalski *et al.*, 2008; Kin, 2010, 2011) enables a new biostratigraphic zonation of the Maastrichtian Stage in this country to be proposed, which is potentially applicable to other parts of the Boreal Realm in Europe.

All ammonite zones proposed herein (Fig. 1) are interval zones, with the base of each defined by the first occurrence (FO) of the index species and the top defined by the FO of the index species of the overlying zone (except for the highest one). A correlation of new ammonite zones with the biostratigraphic subdivision of the Maastrichtian in Poland as used by Błaszkiwicz (1980) and with the inoceramid zonation established by Walaszczyk (2004) is also attempted (Fig. 1).

***Pachydiscus neubergicus* Zone.** The base of this zone is defined by the FO of the index species, its top by the FO of *Acanthoscaphites tridens* (Fig. 1). According to Machalski (2012), the lowest well-localised specimen of *Pachydiscus neubergicus* in the classic Middle Vistula River section (central Poland) is from the bottom of the Dziurków succession, which corresponds to the lower part of the *Endocostea typica* Zone of the inoceramid subdivision (Walaszczyk, 2004). However, imprecisely located specimens from the underlying Kłudzie and Kamień North sections indicate that the FO of this species occurs some distance below, possibly in the upper part of '*Inoceramus*' *redbirdensis* Zone of Walaszczyk (2004). This would be in agreement with the situation at Tercis les Bains (Landes, southwest France) where the Global Stratotype Section and Point (GSSP) for the base of Maastrichtian is located (Odin & Lamaurelle, 2001). The first specimens of *Pachydiscus neubergicus* in

Tercis les Bains occur in the uppermost part of the '*Inoceramus*' *redbirdensis* Zone (Walaszczyk *et al.*, 2002; Machalski, 2012). As the lowest specimen of *Pachydiscus neubergicus* was found exactly at the level of the GSSP at Tercis les Bains (Machalski, 2012), the base of the *Pachydiscus neubergicus* Zone equals the lower boundary of the Maastrichtian Stage. The base of the *Belemnella lanceolata* Zone, which for a long time was used as the traditional belemnite-marked base of the Maastrichtian Stage in the Boreal Realm of Europe (e.g. Błaszkiwicz, 1980; Christensen, 1996; Niebuhr *et al.*, 2011), is situated significantly lower than the base of the *Pachydiscus neubergicus* Zone (Machalski, 2012; see Fig. 1 here).

STAGE	Błaszkiwicz 1980	Walaszczyk 2004	Machalski herein	Selected ammonite ranges
MAASTRICHTIAN	<i>Hoploscaphites c. crassus</i>	<i>B. kazimiroviensis</i>	<i>H.c.johnjagti</i>	
	<i>Belemnitella junior</i>		<i>Hoploscaphites constrictus livvensis</i>	<i>Acanthoscaphites varians varians</i> <i>Menuites terminus</i> <i>Hoploscaphites constrictus crassus</i> <i>Hoploscaphites constrictus johnjagti</i>
	<i>Belemnella occidentalis</i>	<i>Trochoceras radiosus</i>	<i>Acanthoscaphites tridens</i>	<i>Acanthoscaphites varians blaszkiewiczii</i> <i>Hoploscaphites constrictus livvensis</i>
		<i>Endocostea typica</i>	<i>Pachydiscus neubergicus</i>	
CAMPANIAN	<i>Belemnella lanceolata</i>	' <i>Inoceramus</i> ' <i>redbirdensis</i>	<i>Nostoceras hyatti</i>	<i>Pachydiscus neubergicus</i> <i>Acanthoscaphites tridens</i> <i>Acanthoscaphites varians blaszkiewiczii</i>
		' <i>Inoceramus</i> ' <i>costaecus</i>		
	<i>Nostoceras pozaryskii</i>	' <i>Inoceramus</i> ' <i>inkermanensis</i>	<i>Hoploscaphites quadrispinosus</i>	

**Figure 1.** A new ammonite zonation for the Maastrichtian of central and eastern Poland (M. Machalski, herein), plotted against the ammonite and belemnite zonation of Błaszkiwicz (1980) and inoceramid zonation of Walaszczyk (2004, with taxonomic nomenclature readjusted according to Walaszczyk *et al.*, 2009). Ranges of selected ammonites in Poland are based on papers quoted in the text. Solid lines are documented ranges; dashed lines are possible ranges. The position of the Campanian/Maastrichtian boundary follows the GSSP definition (Odin & Lamaurelle, 2001). Inserted on the right-hand side in the box corresponding to the extent of the *Hoploscaphites constrictus crassus* Zone of Błaszkiwicz (1980) is the correlation with the *Belemnella kazimiroviensis* Zone in conventional belemnite zonal terms within the Borealm Realm of Europe (e.g., Christensen, 1996).

***Acanthoscaphites tridens* Zone.** The base of this zone (Fig. 1) is defined by the FO of the index species as defined by Kin (2010), i.e. comprising large representatives of *Acanthoscaphites* with siphonal tubercles, and excluding the stratigraphically older forms which lack this siphonal tuberculation and are thus referred to herein as *Hoploscaphites quadrispinosus* (compare Landman *et al.*, 2010; Machalski, in prep.). The top of the *Acanthoscaphites tridens* Zone is marked by the FO of *Hoploscaphites constrictus livvensis* as defined by Machalski (2005b). The *Acanthoscaphites tridens* Zone is not exposed in the Middle Vistula River section, the record of *Acanthoscaphites tridens* from Dziurków by Machalski (2012, p. 92) being an error. In contrast, the *Acanthoscaphites tridens* Zone is well documented in the Hrebenne section (Roztocze area, southeast Poland), which represents the *Trochoceras radiosus* Zone and the lower part of the *Belemnella occidentalis* Zone as defined by Błaszkiwicz (1980) (see Kin, 2010). The occurrence of *Acanthoscaphites tridens* in the upper part of the *Endocostea typica* Zone of Bliżów (Roztocze area) documented by Kin (2011), indicates that the lower boundary of the *Acanthoscaphites tridens* Zone is situated in the middle of the last-named inoceramid zone (see also Kin, 2010, fig. 8). A distinct stratigraphic separation of large scaphitids without siphonal tubercles (*Hoploscaphites quadrispinosus*), which occur up to the lower portion of

the *Endocostea typica* Zone, from the specimens with siphonal tuberculation, which start in the upper part of the *Endocostea typica* Zone, invalidates the views of Kennedy & Summesberger (1987), who regarded these forms as representatives of a single, highly variable species, *Acanthoscaphites tridens* (Kin, 2010; Machalski, in prep.).

***Hoploscaphites constrictus lvivensis* Zone.** The base of this zone is defined by the FO of the index subspecies, its top by the FO of *Hoploscaphites constrictus crassus* as defined by Błaszkiwicz (1980) and Machalski (2005b) (Fig. 1). To date, the eponymous zone is documented only for sections in eastern Poland and near Lviv (Lwów, Ukraine), which correspond to the lower part of the *Belemnitella junior* Zone (*Spyridoceramus tegulatus-Belemnitella junior* Zone *sensu germanico*; see Machalski, 2005b; Dubicka & Peryt, 2011). Thus, the base of the *Hoploscaphites constrictus lvivensis* Zone is situated closely to the base of the Upper Maastrichtian as currently understood for central Europe (Fig. 1). The *Hoploscaphites constrictus lvivensis* Zone at Chełm (eastern Poland; see Dubicka & Peryt, 2011), yielded specimens of *Acanthoscaphites varians blaszkiewiczzi* (Jagt *et al.*, 1999; Machalski *et al.*, 2008; see Fig. 1 here).

***Hoploscaphites constrictus crassus* Zone.** The base of this zone (Fig. 1) is defined by the FO of the index subspecies as defined by Błaszkiwicz (1980) and Machalski (2005b), its top by the FO of *Hoploscaphites constrictus johnjagti* as defined by Machalski (2005b). According to Błaszkiwicz (1980) and Machalski (2005b), the base of *Hoploscaphites constrictus crassus* Zone is situated at Podgórz in the Middle Vistula River section. The extent of the *Hoploscaphites constrictus crassus* Zone is not equal to that of the *Belemnella kazimiroviensis* range Zone, which is the uppermost belemnite zone for the Maastrichtian (Christensen, 1996). The FO of the latter species is situated in Męcimierz (Kongiel, 1962), where the deposits slightly younger than those at Podgórz crop out (Dubicka & Peryt, 2011). The *Hoploscaphites constrictus crassus* Zone is widely distributed in central and eastern Poland; this is the highest ammonite zone in the Middle Vistula River section (Machalski, 2005a, b). The lower part of the *Hoploscaphites constrictus crassus* Zone as exposed in Kazimierz Dolny (Middle Vistula River section) and Rejowiec (eastern Poland), has yielded specimens of *Acanthoscaphites varians varians* (Jagt *et al.*, 1999; Machalski, 2005b; see Fig. 1 here). The upper part of the *Hoploscaphites constrictus crassus* Zone was assigned by Machalski & Jagt (1998) to the *Menuites terminus* range Zone, based on rare records of the eponymous pachydiscid species from Nasiłów, Middle Vistula River section (Fig. 1).

***Hoploscaphites constrictus johnjagti* Zone.** The base of this zone is defined by the FO of the index subspecies as defined by Machalski (2005b), its top by the last occurrence (LO) of unreworked specimens of this taxon, which in Poland coincides with the top of Maastrichtian (Fig. 1). In Denmark, however, and possibly in the Netherlands, populations of *Hoploscaphites constrictus johnjagti* survived for a short time after the Cretaceous-Paleogene (K/Pg) boundary event (Machalski & Heinberg, 2005; Machalski *et al.*, 2009; Jagt & Jagt-Yazykova, 2012). To date, the *Hoploscaphites constrictus johnjagti* Zone in Poland has been recorded from a single locality only, namely Mełgiew, near Lublin. The short vertical range of the population-defined (*sensu* Dzik, 1985) subspecies *Hoploscaphites constrictus johnjagti*, as documented in Denmark (Machalski, 2005a, referred to therein as *Hoploscaphites constrictus* subsp. B), suggests a great potential of that taxon for recognition of terminal Maastrichtian deposits in the Boreal Realm, not only in Europe (Machalski, 2005b), but also in Central Asia (Machalski *et al.*, in press).

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