Biostratigraphy

Comprehensive historical reviews of the development of the Triassic biostratigraphic scheme and the ammonoid-based biostratigraphic scale were given recently by BALINI et al. (2010) and JENKS et al. (2015). As far as the Middle Triassic scales are concerned, we may state proudly that the results from the Balaton Highland have been in the foreground from the beginning, by the contributions of BÖCKH (1872, 1873, 1874), MOJSISOVICS (1882), DIENER (1899, 1900), ARTHABER (1903) and FRECH (1903). Owing to the historical priority and the high-level, up to date biostratigraphical results achieved in the last decades, the Balaton area, and especially the Felsőörs section, seemed to fulfil the severe requirements of the Ladinian GSSP. Our efforts to receive the "golden spike" failed, but the painstaking work was not useless: the detailed ammonoid collections from dozens of well-dated sections resulted in a refined local ammonoid scale for the Middle Anisian (Pelsonian: VÖRÖS et al. 2003a) and for the Late Anisian (VÖRÖS et al. 1996, 2003b; VÖRÖS 1998). These scales were successfully correlated with those established in other European regions (VÖRÖS et al. 2003a, b, 2014; VÖRÖS et al. 2009).

The recent collections and the results of the taxonomical revision of the Upper Anisian ammonoid fauna of the Balaton Highland give good reason for supplementing and re-defining subzonal schemes proposed in the above mentioned papers.

The stratigraphical distribution of the Upper Anisian ammonoid taxa of the Balaton Highland in the successive subzones of the Trinodosus, Reitzi and Secedensis zones is shown in Table 16. On the basis of the ammonoid data sets recorded in the measured sections, nine successive subzones can be recognized and correlated within the studied stratigraphic interval of the Balaton Highland. The elements of the proposed subzonal scheme, from bottom to top (Figure 16): Trinodosus Subzone, Camunum Subzone, Pseudohungaricum Subzone (parts of the Trinodosus Zone), Felsoeoersensis Subzone, Liepoldti Subzone, Reitzi Subzone, Avisianum Subzone (parts of the Reitzi Zone), Crassus Subzone, Secedensis Subzone (parts of the Secedensis Zone). The subzones can be best recognized and are most completely represented in the Felsőörs section.

The base of the **Trinodosus Subzone** was nowhere recorded at the Balaton Highland, therefore its delimitation from the subjacent Binodosus Subzone remains unknown. The Trinodosus Subzone is well documented in the Felsőörs and the Vörösberény sections by at least five metres thick bed complexes, below Bed 90, and Bed 18, respectively. Its fauna consists of, besides the subzonal index species, *Paraceratites rothi, P. elegans, Semiornites cordevolicus, Megaceratites subnodosus* and abundant specimens of *Ptychites* and *Flexoptychites* species. It can be more or less correlated with the SF97A to SF105A interval of the Stabol Fresco section in Giudicarie (Figure 17).

The **Camunum Subzone** is rather widespread in the Balaton Highland: it is well documented in the Felsőörs section (between Beds 90 to 96), the Vászoly P–11a section (below Bed 4) and the Szentantalfa section (Beds 2/a to 5). It is surely present in the Vörösberény and Szentkirályszabadja sections, though with doubtful delimitations. Besides the subzonal index species, its fauna is characterized by the appearance of *Lardaroceras krystyni, L. barrandei, Norites gondola* and *Semiornites aviticus*. It corresponds to the "*Lardaroceras* beds" in Giudicarie (e.g. between the beds SF105A and SF111A in Stabol Fresco: BALINI 1992a, and the beds above 51 m in Bagolino [Pertica] section [Figure 17]: BRACK et al. 2005).

The **Pseudohungaricum Subzone** is best documented in Felsőörs (between beds 97 and 99C) and is well known in the sections Mencshely I (below Bed 16), Vászoly P–11a (Beds 4 and 5), Szentantalfa (Bed 1) and in Szentkirályszabadja (below Bed 16). It is present also in Vörösberény, but its delimitation from the Camunum Subzone is uncertain here. Besides the first appearance of the subzonal index species, the fauna comprises *Longobardites breguzzanus, Beyrichites reuttensis*; some elements of the subjacent subzones (*Norites, Megaceratites* and even *Asseretoceras camunum*) appear again here. Correlation is evident with the Giudicarie sections (Figure 17): above Bed SF111A in Stabol Fresco (BALINI 1992a) and beds around 52 m at Bagolino (BRACK et al. 2005).

The **Felsoeoersensis Subzone** is well documented in Felsőörs (between Beds 100E and 100), Vászoly P–11a (Beds 6 to

Table 16. The stratigraphical distribution of the late Anisian ammonoid taxa of the Balaton Highland in the successive zones and subzones

	Trinodosus	Camunum	Pseudohungaricum	Felsoeoersensis	Liepoldti	Reitzi	Avisianum	Crassus	Secedensis
	Trinodosus			Reitzi				Secedensis	
Paraceratites cf. *rothi* (Mojsisovics, 1882)	▪▪▪▪▪								
Paraceratites trinodosus (Mojsisovics, 1882)	▪▪▪▪▪	▪▪							
Semiornites cf. *cordevolicus* (Mojsisovics, 1882)	▪▪▪▪▪	▪▪▪▪▪							
Paraceratites cf. *elegans* (Mojsisovics, 1882)	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪						
Megaceratites cf. *subnodosus* (Mojsisovics, 1882)	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪						
Ptychites cf. *oppeli* Mojsisovics, 1882	▪▪▪▪▪	▪▪▪▪▪	———	▪▪▪▪▪					
Discoptychites cf. *megalodiscus* (Beyrich, 1867)	▪▪▪▪▪	———	———	———	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪		
Flexoptychites cf. *acutus* (Mojsisovics, 1882)	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	
Flexoptychites flexuosus (Mojsisovics, 1882)	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	
Semiornites cf. *aviticus* (Mojsisovics, 1882)		▪▪▪▪▪	▪▪▪▪▪						
Asseretoceras camunum (Assereto, 1963)		▪▪▪▪▪	▪▪▪▪▪						
Lardaroceras krystyni Balini, 1992		▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪					
Lardaroceras barrandei(Mojsisovics, 1882)		▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪					
Norites gondola (Mojsisovics, 1869)		▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	———	▪▪▪▪▪	▪▪▪▪▪		
Longobardites zsigmondyi (Böckh, 1874)		▪▪▪▪▪	▪▪▪▪▪	———	———	▪▪▪▪▪	▪▪▪▪▪		
Flexoptychites angustoumbilicatus (Böckh, 1872)		▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	
Beyrichites cf. *reuttensis* (Beyrich, 1867)			▪▪▪▪▪						
Lardaroceras pseudohungaricum Balini, 1992			▪▪▪▪▪	▪▪▪▪▪					
Longobardites breguzzanus Mojsisovics, 1882			▪▪▪▪▪	———	———	———	▪▪▪▪▪		
Kellnerites felsoeoersensis (Stürzenbaum, 1875)				▪▪▪▪▪					
Kellnerites cf. *bispinosus* (Hauer, 1896)				▪▪▪▪▪					
Kellnerites bosnensis (Hauer, 1887)				▪▪▪▪▪	?				
Epikellnerites tamasi n. sp.				?	?	?			
Hungarites mojsisovicsi (Roth, 1871)				▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	
Tropigymnites sp.				?	?	?	?		
Hyparpadites liepoldti (Mojsisovics, 1882)				?	▪▪▪▪▪	———	?		
Hyparpadites szaboi n. sp.				?	▪▪▪▪▪				
Semiornites ? cf. *falcifer* (Hauer, 1896)					▪▪▪▪▪				
Epikellnerites aff. *tamasi* n. sp.					▪▪▪▪▪				
Hyparpadites aff. *liepoldti* (Mojsisovics, 1882)					▪▪▪▪▪				
Epikellnerites vaszolyensis n. sp.					▪▪▪▪▪	▪▪▪▪▪			
Epikellnerites angustecarinatus (Hauer, 1896)					▪▪▪▪▪	▪▪▪▪▪			
Parakellnerites frauenfelderi Rieber, 1973					▪▪▪▪▪	▪▪▪▪▪	▪▪		
Parakellnerites boeckhi (Roth, 1871)					▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪		
Parakellnerites cf. *rothpletzi* (Salomon, 1895)					▪▪	▪▪▪▪▪	▪▪▪▪▪		
Parakellnerites loczyi (Arthaber, 1903)					▪▪	▪▪▪▪▪	▪▪▪▪▪		
Epikellnerites pseudocholnokyi n. sp.						▪▪▪▪▪			
Epikellnerites spinatus n. sp.						▪▪▪▪▪			
Reitziites reitzi (Böckh, 1872)						▪▪▪▪▪			
Ticinites ? aff. *hantkeni* (Mojsisovics, 1882)						▪▪▪▪▪			
Japonites ? sp.						▪▪▪▪▪			
Flexoptychites cf. *studeri* (Hauer, 1857)						▪▪▪▪▪			
Reitziites reitzi (Böckh, 1872) morphotype *cholnokyi*						▪▪▪▪▪	▪▪		
Reitziites ecarinatus (Hauer, 1896)						▪▪▪▪▪	▪▪		
Bullatihungarites semiplicatus (Hauer, 1896)						▪▪▪▪▪	▪▪▪▪▪		

Table 16. Continuation

	Trinodosus	Camunum	Pseudohungaricum	Felsoeoersensis	Liepoldti	Reitzi	Avisianum	Crassus	Secedensis
	Trinodosus			Reitzi				Secedensis	
Parakellnerites stuerzenbaumi n. sp.						▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	
Proarcestes sp.						▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪
Latemarites bavaricus (Reis, 1901)							▪▪▪▪▪		
Parakellnerites hungaricus (Mojsisovics, 1882)							▪▪▪▪▪	▪▪▪▪▪	
Megaceratites ? cf. *friccensis* (Arthaber, 1916)							▪▪▪▪▪		
Parahungarites solyensis n. sp.							▪▪▪▪▪		
Detoniceras ? sp.							▪▪▪▪▪		
Halilucites cf. *arietitiformis* (Hauer, 1896)							▪▪▪▪▪		
Stoppaniceras cf. *ellipticum* (Hauer, 1887)							▪▪▪▪▪		
Aplococeras laczkoi (Arthaber, 1903)							▪▪▪▪▪		
Celtites ? sp. B							▪▪▪▪▪		
Gymnites sp.							▪▪▪▪▪		
Epigymnites ecki (Mojsisovics, 1882)							▪▪▪▪▪		
Parasturia ? sp.							▪▪▪▪▪		
Aplococeras avisianum (Mojsisovics, 1882)							▪▪▪▪▪	?	
Parakellnerites aff. *hungaricus* (Mojsisovics, 1882)							▪▪▪▪▪		
Hungarites sinuosus n. sp.							▪▪▪▪▪	▪▪▪▪▪	
Halilucites rusticus (Hauer, 1896)							▪▪▪▪▪	▪▪▪▪▪	
Stoppaniceras hermanni n. sp.							▪▪▪▪▪	▪▪▪▪▪	
Stoppaniceras budaii n. sp.							▪▪▪▪▪	▪▪▪▪▪	
Hungarites costosus Mojsisovics, 1882							▪▪▪▪▪	▪▪▪▪▪	
Stoppaniceras rieberi n. sp.							▪▪▪▪▪	▪▪▪▪▪	
Celtites ? sp. A							▪▪▪▪▪	▪▪▪▪▪	
Parakellnerites aff. *rothpletzi* (Salomon, 1895)								▪▪▪▪▪	
Parakellnerites cf. *zoniaensis* Brack & Rieber, 1993								▪▪▪▪▪	
Ticinites crassus (Hauer, 1896)								▪▪▪▪▪	
Nodihungarites bocsarensis (Arthaber, 1903)							?	▪▪▪▪▪	
Nodihungarites vinczei n. sp.								▪▪▪▪▪	
Halilucites cf. *obliquus* (Hauer, 1896)								▪▪▪▪▪	
Stoppaniceras cf. *variabile* Rieber, 1973								▪▪▪▪▪	
Stoppaniceras aff. *rieberi* n. sp.								▪▪▪▪▪	
Repossia cf. *acutenodosa* Rieber, 1973								▪▪▪▪▪	
Ticinites cf. *ticinensis* Rieber, 1973								▪▪▪▪▪	
Ticinites hantkeni (Mojsisovics, 1882)								▪▪▪▪▪	
Chieseiceras sp.								▪▪▪▪▪	
Nevadites cf. *avenonensis* Brack & Rieber, 1993									▪▪▪▪▪
Chieseiceras chiesense (Mojsisovics, 1882)									▪▪▪▪▪

8) and Mencshely I (Beds 14 to 16). It is definitely present in Vörösberény and Szentkirályszabadja, but in these sections its upper limit can not be drawn. Besides the subzonal index, other *Kellnerites* species (*K. bosnensis, K. bispinosus*) are the distinctive elements of this subzone. *Lardaroceras* species appear again here. The correlation is good with the Bagolino section (Figure 17) on the basis of the appearance of *Kellnerites* species at 53 m (Brack et al. 2005, Vörös et al. 2009).

The **Liepoldti Subzone** is well defined in Felsőörs (between Beds 100 and 102), Vászoly P–11a (above Bed 9) and Mencshely I (above Bed 12). It is present in the Szentkirályszabadja section, but here its lower limit is not proved, because the ranges of the subzonal index species *K. felsoeoersensis* and *Hyparpadites liepoldti* overlap. The characteristic faunal element of this subzone are the *Hyparpadites* species, furthermore the first appearances of the genera *Epikellnerites* and

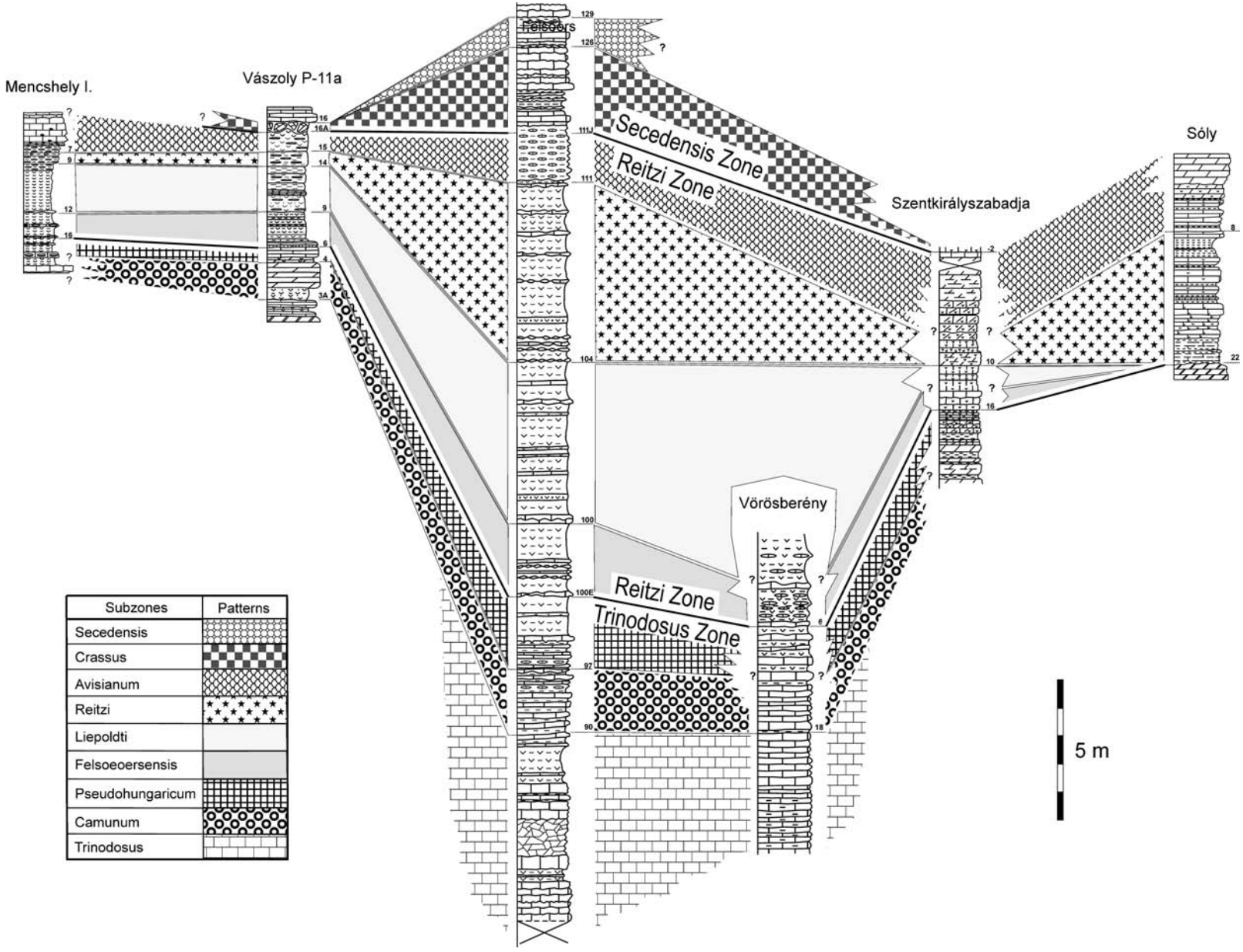

Figure 16. The Upper Anisian ammonoid subzones and zones recognized in the Balaton Highland and their correlation between the measured sections of the area

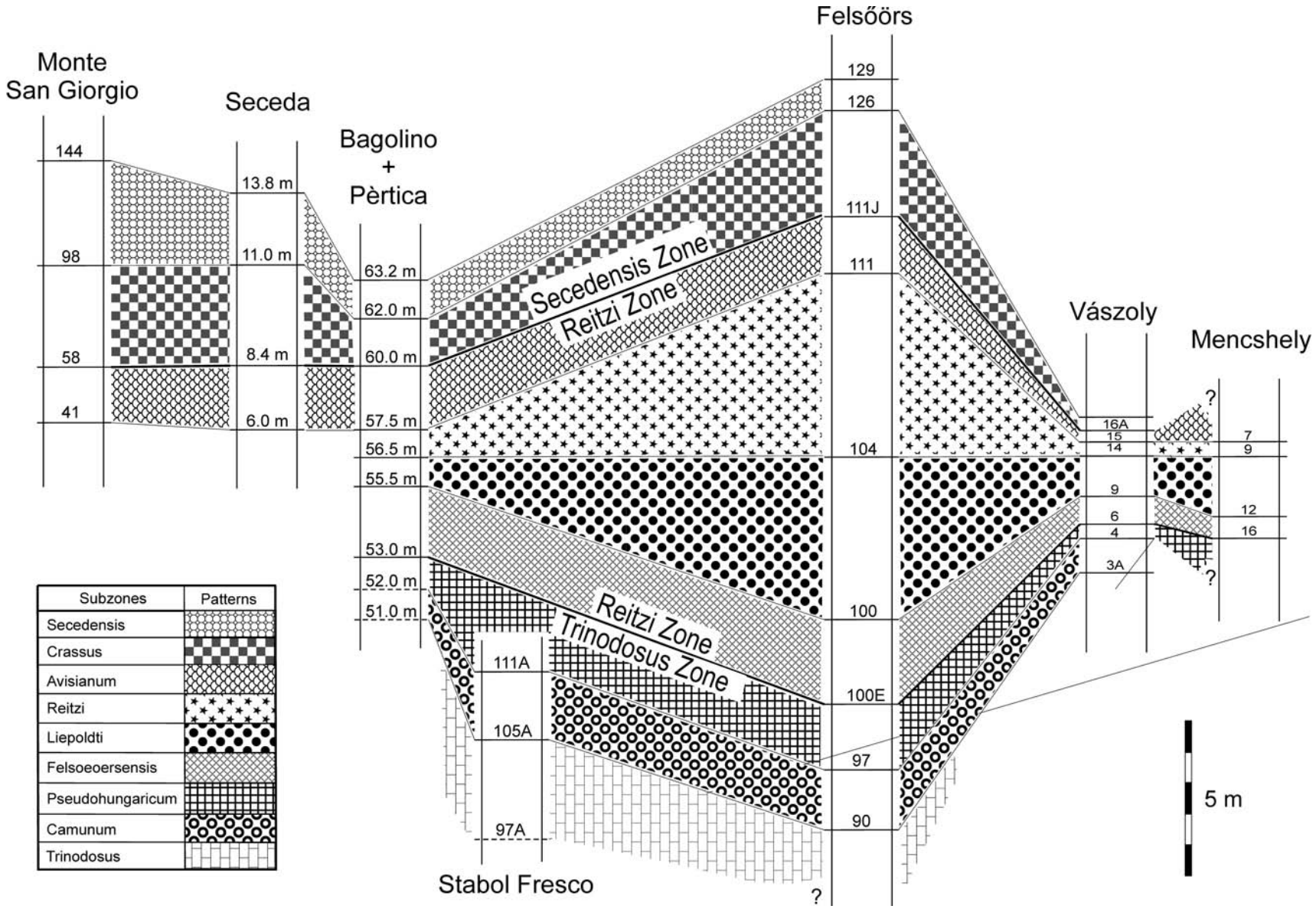

Figure 17. The Upper Anisian ammonoid subzones and zones and their correlation between selected sections of the Balaton Highland and the Southern Alps. Southern Alpine data from RIEBER (1973), BRACK & RIEBER (1993), BRACK et al. (2003, 2005), BALINI (1992a), MIETTO et al. (2003) and MANFRIN et al. (2005)

Parakellnerites were recorded here. This subzone can well be recognized in the interval 55.5 to 56.5 m in the Bagolino section (Figure 17).

The **Reitzi Subzone** is classically recognized and recently proved again in Felsőörs (between Beds 104 and 108), well documented in Vászoly P–11a (Bed 14), Vászoly P–2 (Bed 4), Mencshely I (Beds 8 and 9) and Sóly (Bed 21). It is definitely present in the Szentkirályszabadja section (in Bed 10), but here it appears together with *Aplococeras avisianum*, the index of the next subzone. The fauna of the Reitzi Subzone is diverse: besides the *Reitziites* species, the representatives of the genera *Epikellnerites, Parakellnerites, Parahungarites, Hungarites* and *Bullatihungarites* frequently occur. The correlation is good with the interval 56.5 to 57.5 m of the Bagolino section (Figure 17).

The **Avisianum Subzone** is the most widespread subzone of the Reitzi Zone in the Balaton Highland and perhaps also in the Southern Alps. It is perfectly documented in Felsőörs (Beds 111 to 111/I) Mencshely (Beds 1 to 7) and Sóly (Beds 1 to 8), and it is present in Vászoly P–11a (Bed 15) and Szentkirályszabadja, although here it overlaps the subjacent subzone. The ammonoid fauna is extremely diverse; besides the subzonal index *Aplococeras avisianum* and *A. laczkoi*, *Latemarites bavaricus*, *Megaceratites* ? cf. *friccensis* and several species of *Hungarites*, *Halilucites* and *Parakellnerites* are abundant here. The correlation is excellent with Bagolino (57.6 to 60 m interval) and Monte S. Giorgio (Beds 41 to 57) and even with sections in the Dolomites (Figure 17): Seceda (6 to 8.5 m interval) and Latemar (Beds LB 3 to LB 4, according to MANFRIN et al. 2005).

The **Crassus Subzone** is well documented in the Felsőörs section (between Beds 111J and 118), proved by a rich fauna in a single, condensed bed of the Vászoly P–11a section (Bed 16A) and in the topmost exposed bed of the Szentkirályszabadja section (Bed –2). The fauna is rather diverse, with the dominance of *Ticinites hantkeni*; besides *Nodihungarites bocsarensis,* some species of the genera *Parakellnerites, Halilucites, Stoppaniceras* and *Repossia* are frequent. The correlation (Figure 17) is good with Bagolino (60 to 62 m interval), Monte S. Giorgio (Beds 58 to 87) and with Seceda (8.4 to 11 m interval) and Latemar (Beds L 2 to LA 83: MANFRIN et al. 2005).

The **Secedensis Subzone** is equivalent to the Serpianensis and Chiesense subzones, as defined previously by MIETTO & MANFRIN (1995). Recently MANFRIN et al. (2005, p. 487) used the name Secedensis Subzone, containing a higher, tentatively divided Chiesense Subzone. In fact, the "Chiesense Subzone" in most places (Bagolino, Seceda, Felsőörs) is restricted to a few beds or a single bed ("chiesense groove"), therefore it does not seem to be reasonable to define this horizon as a separate subzone. At the Balaton Highland, the Secedensis Subzone was proved only in the Felsőörs section (between Beds 126 and 129A). Here its fauna is extremely poor: only a few specimens of *Nevadites* cf. *avenonensis* and *Chieseiceras chiesense* were collected. The correlation (Figure 17) is good with Bagolino (62 to 63.2 m interval), Monte S. Giorgio (Beds 98 to 144) and with Seceda (11 to 13.8 m interval) and Latemar (Beds LA 101A to LA 0: MANFRIN et al. 2005).

The recently revised Upper Anisian scale, the ammonoid zones and subzones defined at the Balaton Highland, are demonstrated in Figure 16. The possible correlation of the subzones recognized at the Balaton Highland with selected, well documented sections of the Southern Alps is shown in Figure 17. The good correlation with the Latemar succession is not shown for graphical reasons, because the Latemar stratigraphic column is extraordinarily large, more than twenty times thicker than any other compared sections. The correlation between Felsőörs and Bagolino is almost perfect. The lower part (Trinodosus and Camunum subzones) of the Felsőörs section is well correlated with the basinal sections (Stabol Fresco) of Lombardy (Giudicarie). Starting from the Avisianum Subzone, the other South Alpine sections (Monte San Giorgio, Seceda) show also good correlation with the more condensed sections of the Balaton Highland (Vászoly, Mencshely).