STRATIGRAPHY

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LOCALITIES (ROCKS AND FOSSILS)
(ATTILA VÖRÖS, TAMÁS BUDAI & IMRE SZABÓ)

The Pelsonian strata have been known in many smaller outcrops at the Balaton Highland since the second half of the eighteenth century (ZEPHAROVICH 1856, BÖCKH 1872, 1873, LÓCZY 1913, 1916, etc.). In the course of our recent project, we have tried to identify and sample these classical localities but we have only partly been successful. In the hills above Balatoncsicsó, we have not found fossiliferous Pelsonian beds. On the Recsek-hegy at Hidegkút and the Som-hegy (“Gyúrtető, “Hegyes-gyūr” in the classical literature) at Nemesvámos, fragments of Pelsonian ammonoids were collected but a closer examination was hindered by the vegetation and soil. The very important classical Pelsonian localities on the hillsides above Balatonfüred were also inaccessible due to the expansion of settlements.

We were more successful at other places. Suitable sections were exposed in artificial trenches at four classical localities (Köveskál, Mencshely, Aszófő, Felsőörs), where detailed, bed-by-bed collection of fossils was also carried out (Figure S-1). A few other surface outcrops provided important lithological or palaeontological data. In the course of the geological mapping programme of the Geological Institute of Hungary several deep boreholes were drilled which penetrated the Pelsonian sequence; part of the data obtained from these cores are used in the present synthesis.

MEASURED SECTIONS

Köveskál, Horog-hegy

This locality was first mentioned in an early report by ZEPHAROVICH (1856) and the brachiopod species “Spiriferina” koeveskalyensis (STUR 1865), and the genus Koeveskallina were named after the village Köveskál. These records refer to a small hill called Horog-hegy (or Mezőmál in the earlier literature), two kilometres east of the village, where Middle Triassic limestones were quarried in small pits.

BÖCKH (1872, 1873) described the fundamental geological features of the locality. In the northward dipping sequence, he distinguished a basal, platy limestone overlain by a dolomite forming the hilltop, followed by brachiopod
limestone ("Recoaro" limestone) and bituminous, platy limestone, and, finally, the grey "Reifling" limestone. BÖCKH (l. c.) listed a rich brachiopod fauna from the "Recoaro" limestone and observed that "Ammonites Balatonicus" (nomen nudum at that time) occurred both in the brachiopod limestone and in the bituminous, platy limestone. LÓCZY (1913, 1916) drew a sketchy but informative geological profile of the Horog-hegy. Later stratigraphical reviews (e.g. BALOGH et al. 1983, CROS & SZABÓ 1984) merely summarised the results of the previous authors.

PÁLFY (1986, 1991) made new collections at the locality. He recognised that two different types of "Recoaro" limestone occurred: a reddish-brown and another, grey, bituminous, siliceous, organodetrital limestone, but their stratigraphical relationship remained unclear.

During a short visit in 1995, T. Budai, L. Dosztály, I. Szabó and A. Vörös collected ammonoids from loose blocks in the area, which indicated the presence of both the Middle Anisian Balatonicus Zone and the uppermost Anisian "Lardaroceras" beds.

In 2001, J. Pálfy, I. Szente and A. Vörös made a more detailed field survey on the northern slope of the Horog-hegy, excavated a few small artificial exposures and collected fossils (brachiopods, ammonoids, bivalves) at four points (VÖRÖS & PÁLFY 2002).

The section

The Horog-hegy (265 m) lies 2 km ENE of the village of Köveskál. The bulk of the hill is formed by Megyehegy Dolomite, overlain by gently dipping beds of Felsőörs Limestone (Pelsonian to Illyrian), about 40 m in thickness. The fossiliferous localities occur on the forested northern slope of Horog-hegy, between the hilltop and an E–W running forest track. Four small outcrops were excavated and studied.

**Horog-hegy I.** (Figure S-2) The lowermost exposed unit is a more than 50 cm thick, light grey, slightly siliceous, unfossiliferous limestone (mudstone). This is overlain, with a sharp contact, by a 40 cm thick, light-brown, coarse-grained bioclastic limestone with brachiopods of rock-forming amount ("upper Recoaro"; this rock-type is very widespread on the hillside and provided the brachiopod fauna of the previous collections by PÁLFY (1986). On the irregular top of the brachiopod limestone, a thin (5–10 cm) layer of ochre-yellow, fine-grained crinoidal limestone follows which yielded a moderately rich, poorly preserved ammonoid fauna.

**Horog-hegy II.** The exposed sequence is almost the same as in Horog-hegy I., but here the lowest mudstone is well-bedded, slightly bituminous and yielded a poorly preserved *Bulogites*, and the brachiopod limestone ("upper Recoaro") attains only 20 cm thickness.

**Horog-hegy III.** Nearer to the hilltop, 40 m southwards from Horog-hegy I, a small pit exposes a few thin beds of monotonous, dark grey, bituminous limestones which provided some ammonoids. The measured dip is 20° to the NNW (320°).

**Horog-hegy IV.** Another small pit 10 m southwards from the previous one. A thin (10–15 cm) layer of brachiopod-rich, light grey bioclastic limestone ("lower Recoaro"), intercalated between dark grey, bituminous limestone layers is exposed here. About 20 cm below, a yellowish-grey, mottled, pebbly mudstone layer appears. The measured dip is 20° to the NNW (320°).
ured dip is 18° to the NNW (330°). Apart from brachiopods and bivalves, this biodetrital bed also yielded a few ammonoids.

On the basis of the scattered outcrops, a composite lithological column of the Middle to Upper Anisian sequence at the northern slope of Horog-hegy was constructed (Figure S-3). The eight metres thick, measured part of the section (between Horog-hegy I and IV) was complemented by observations on the distribution of loose rock fragments. Altogether, considering an average dip of 15°, the thickness of the Felsőös Limestone Formation (FLF) seems to exceed 35 m.

Above the Megyehegy Dolomite the sequence starts with a dolomitised “transitional unit”, and higher up it contains a level with mud intraclasts embedded in a yellow-mottled matrix, which can be interpreted as a slope derived debris flow. The next, 10 cm-thick brachiopod limestone layer (“lower Recoaro”) corresponds to the Horoghegy Member of the FLF and is interpreted as an accumulation of biodetritus redeposited from neighbouring shallow marine areas. The following, 5 m thick, well-bedded, bituminous limestone unit represents the Bocsár Member of the FLF. In its upper one-third, it contains a thin bedded, laminated interval which is also characteristic to the correlative horizons of other basinal sections of FLF (e.g. at Aszófő). The unique feature of this section is that the Horoghegy Member appears again, in a higher, separate level, in the form of a few dm thick, brownish brachiopod limestone bed (“upper Recoaro”). The next, ochre-yellow, fine-grained crinoidal limestone layer with many poorly preserved ammonoids has no known counterpart in other Anisian sections of the Balaton Highland. It probably forms a transition to the overlying mudstone layers of the FLF which become more and more siliceous and cherty higher up and commonly contain silicified ammonoid remains (“Förtráshegy Member”).

**Fossils**

The localities described above yielded bivalves, ammonoids and extremely large amount of brachiopods. A few gastropods and nautilids were also collected but were not identified more precisely. The determined taxa are listed below, according to localities and systematic order. Their detailed descriptions, including specimen number data are presented in the respective chapters of this volume. Microfossils were not studied.

**Horog-hegy I + II.**

Ammonoidea (determined by A. Vörös):

- *Bulogites* ? sp.
- *Beyrichites* cf. beneckei (MOJSISOVICS, 1881)
- *Schreyerites* ? cf. binodosus (HAUER, 1851)
- *Ptychites* ? sp. indet.
- *Judicarites* cf. euryomphalus (BENECKE, 1866)

Bivalvia (determined by I. Szente and A. Vörös):

- *Bakevellia* ? sp.
- *Leptochondria* ? sp.
- *Praechlamys* sp.
- *Newaagia* ? sp.
- *Mysidioptera* ? sp.

Brachiopoda (determined by J. Pálfy):

- *Discinisca* sp.
- *Lingula* cf. tenuissima (BRONN, 1837)
- *Decurtella decurtata* (GIRARD, 1843)
- *Volirhynchia vivida* (BITTNER, 1890)
- *Volirhynchia tommasii* (BITTNER, 1890)
- *Costirhynchopsis mentzeli* (BUCH, 1843)
- *Caucasorhynchia altaplecta* (BÖCKH, 1872)
- *Piarorhynchella trinodosi* (BITTNER, 1890)
- *Sinucosta pectinata* (BITTNER, 1890)
- *Costispiriferina manca* (BITTNER, 1890)
- *Dinarispira* cf. *dinarica* (BITTNER, 1890)
- *Dinarispira avarica* (BITTNER, 1890)
- *Punctospirella fragilis* (SCHLOTHEIM, 1814)
- *Mentzelia mentzeli* (DUNKER, 1851)
- *Koeveskallina koeveskalyensis* (STUR, 1865)
- *Tetractinella trigonella* (SCHLOTHEIM, 1820)
- *Schwagerispira schwageri* (BITTNER, 1890)
- *Schwagerispira* cf. *mojsisovicsi* (BÖCKH, 1872)
Coenothyris vulgaris (SCHLOTHEIM, 1822)
Angustothyris ? angustaeformis (BÖCKH, 1872)
(Note: Rhynchonellid brachiopods were systematically described by PÁLFY 1988.)

Horog-hegy III + IV.

Ammonoidea (determined by A. Vörös):
Norites gondola (MOJSISOVICS, 1869)
Balatonites balatonicus (MOJSISOVICS, 1872)

Bivalvia (determined by I. Szente and A. Vörös):
Solemya cf. abbreviata (FRECH, 1904)
Septifer ? sp.
Prototis cf. waageni (SCHNETZER, 1934)
Bakevella sp.
Cassianella sp.
Pleurorectites ? sp.
Entolium ? sp.
Newaagia ? sp.
Leptochondria ? sp.
Mysidioptera ? sp.
Myoconcha (Pseudomyoconcha) ? sp.
Unionites subrectus (BITTNER, 1901)
Schaabrautia ? sp.

Brachiopoda (determined by J. Pálfy):
Decurtella cf. decurtata (GIRARD, 1843)
Volirhynchia tommasi (BITTNER, 1890)
Volirhynchia cf. projectifrons (BITTNER, 1890)
Costirhynchopsis mentzeli (BUCH, 1843)
Caucasorhynchia cf. altapecta (BÖCKH, 1872)
Piarorhynchella trinodosi (BITTNER, 1890)
Homoeorhynchia ? sp.
Costispiriferina manca (BITTNER, 1890)
Dinarispira cf. dinarica (BITTNER, 1890)
Punctospirella fragilis (SCHLOTHEIM, 1814)
Mentzelia mentzeli (DUNKER, 1851)
Koeveskallina koeveskalyensis (STUR, 1865)
Thecocystella horogensis n. sp.
Tetractinella trigonella (SCHLOTHEIM, 1820)
Schwagerispira schwageri (BITTNER, 1890)
Schwagerispira cf. mojsisovici (BÖCKH, 1872)
Coenothyris vulgaris (SCHLOTHEIM, 1822)
Coenothyris ? aff. kraffti (BITTNER, 1902)
Sulcatinella incrassata (BITTNER, 1890)
Angustothyris ? angustaeformis (BÖCKH, 1872)

Menschely, Cser-tető III

Cser-tető is a small hill on the eastern side of the road between Menschely and Nagyvázsony; it used to be a fossil hunting place for ages. The Benedictine monk and explorer RÖMER (1860, p. 180) collected “[countless, mainly smaller, entire ammonites from the boulders of the Cserjés-hegy]”. The geological description by BÖCKH (1872, 1873) informs us that the “dark, very bituminous limestones” of Cser-tető provided “Amm. Balatonicus, Amm. cfr. Gondola and Arc. cfr. Domatus”. The holotype of Balatonites balatonicus (MOJSISOVICS 1873, pl. 13, Fig. 3; 1882, pl. 4, Fig. 2) was collected here by J. Böckh.

Subsequent records in the “Balaton monograph” (DIENER 1899, 1900, ARTHABER 1903, 1911, LÓCZY 1913, 1916), refer to the extremely rich ammonoid fauna of the Reitzi Zone of Cser-tető (VÖRÖS 1998).

During geological mapping and surveys in the last two decades, G. Csillag and T. Budai, later on L. Dosztály, J. Pálfy and A. Vörös collected several well preserved specimens of Balatonites; one of these was figured by Vörös (1998). In 2000, T. Budai, I. Szabó, I. Szente and A. Vörös made a detailed bed-by-bed collection in the section Cser-tető III.
The section

In the course of our previous and recent projects, three artificial trenches were excavated on the hill. The sections Cser-tetõ I and II were aimed to get better knowledge of the tuffaceous limestones of the Reitzi Zone (see VÖRÖS 1998), whereas the section Cser-tetõ III exposes the Pelsonian strata.

The section Cser-tetõ III is exposed in a 25 m long, NW to SW directed shallow artificial trench. The upper part of the grey cherty limestone beds of the Felsõörs Formation shows irregular bedding with very inconsistent dip directions. Therefore, the bed-by-bed collection was restricted to the lower 12 m thick, regularly bedded part of the exposed sequence.

The stratigraphic column of the section is shown in Figure S-4. The lowermost exposed, grey to beige, marly limestone layers are interbedded by cm-thick clay seams. Some of the well preserved ammonoids were found in these clayey interlayers. Thicker limestone beds of nodular structure follow upwards (Beds 20–22). The bituminous limestone layers (16–19) are again well bedded and contain numerous Balatonites specimens. Above a 1.5 m thick, poorly bedded, jointed limestone complex, laminated, bituminous limestone layers appear with mass occurrence of small Posidonia shells as pavements on the bedding planes (Beds 10–12). After some greyish, slightly siliceous limestone beds, from Bed 7, chert nodules and lenses become frequent and in some horizons the chert forms continuous layers.

Fossils

The detailed collection resulted in a rich ammonoid fauna; brachiopods and bivalves (apart from the mass occurrences of small Posidonia) were rarely found. A few vertebrate remains (probably ichthyosaurid vertebrae) were also collected and mass occurrence of very small gastropods in Bed 20 was recorded, but they were not identified more precisely. The determined taxa are listed below, according to systematic order. Their detailed descriptions, including specimen number data are presented in the respective chapters of this volume. Microfossils were not studied.

Ammonoidea (determined by A. Vörös):

*Proavites hueffeli* ARTHABER, 1896
*Proavites* sp.
*Norites* cf. *gondola* (MOJSISOVICS, 1869)
*Norites* sp.
*Acrochordiceras* sp.
*Balatonites balatonicus* (MOJSISOVICS, 1873)
*Balatonites egregius* ARTHABER, 1896, morphotype *jovis*
*Bulogites* cf. *mojsvari* (ARTHABER, 1896)
*Bulogites* sp.
*Beyrichites* sp.
*Schreyerites ragazzonii* (MOJSISOVICS, 1882)
*Schreyerites* ? cf. *binodosus* (HAUER, 1851)
*Discoptychites domatus* (HAUER, 1851)
*Discoptychites* sp.
*Ptychites* sp.

Bivalvia (determined by I. Szente and A. Vörös):
*Bakevellia (B.) binneyi* (BROWN, 1841)
*Posidonia* sp.
*Pleuranectites* ? sp.
*Entolium* ? sp.
*Unionites subrectus* (BITTNER, 1901)

Brachiopoda (determined by J. Pálfy):
*Piarorhynchella trinodosi* (BITTNER, 1890)
Holcorhynchella delicatula (Bittner, 1890)
Mentzelia cf. mentzeli (Dunker, 1851)
Angustothyris ? sp.

Aszófő

This locality has been known from 1907, when, during vineyard planting, “[dark brown and greyish-yellow limestone plates with Balatonites jubilans and ‘Ceratites’ superbus came to the surface]” (Lóczy 1913, 1916).

The artificial trench was excavated by workers hired by the Geological Institute of Hungary following the instructions of I. Szabó. The detailed bed-by-bed collection was done in several phases between 1982–1986, supervised by A. Vörös. The higher part of the section (Aszófő I) was described earlier (Vörös 1987). The geological description (Budai & Vörös 1988) and biostratigraphy of the whole section was also published (Vörös 1998) and a comparison with the Grossreifling sections was made by Tatzeiter & Vörös (1991). In the present volume, the complete fauna is revised and the biostratigraphy is re-evaluated.

The section

The locality lies 2 km north of Aszófő near the forestry road leading to Balatonszőlős. The Pelsonian sequence is exposed in two parallel, partly overlapping trenches of 50 m length.

The deepest part of the 20 m thick sequence exposed in the eastern trench (Aszófő II) belongs to the “transitional unit” between the Megyehegy Dolomite and the Felsőörs Formation (Figure S-5). Higher up the rock becomes more and more calcareous, marly and nodular; in the yellow-mottled beds (Beds II/40–42) poorly preserved, large ammonoids (Balatonites, Acrochordiceras) have been found. In the next few metres of the sequence greyish limestone intraclasts embedded in a yellow marly matrix prevail (Figure S-6). This “pebbly mudstone” complex is interpreted as a result of sub-marine gravity sliding (Budai & Haas 1997). In the higher part of these resedimented beds the amount of ammonites and especially of crinoids and brachiopods rapidly increases, and the interval of Beds II/16–28 consists of “Recoaro-type” biodetrital limestone, representing the Horoghegy Member. The most common elements of the fauna are the brachiopods but ammonites and thick-shelled gastropods and bivalves are also frequent. The very diverse brachiopod assemblage is characterized by a significant percentage of disarticulated valves, and medium to large mean size of specimens. It is interpreted as a taphocoenosis, i.e. a mixture of brachiopods brought together from different habitats by gravitational sediment movements (Pálfy 1986).

The upper beds of the “Recoaro-type” limestone (Beds II/17–19) form a small-scale recumbent fold which is interpreted as a slump-fold (Tatzeiter & Vörös 1991, Budai & Vörös 1992). The overlying two metres of cherty limestone is poorly bedded and strongly fractured what can also be due to slumping.

With a distinct lithological change, dark-grey or dark-brown, well-bedded, sometimes laminated, highly bituminous limestone follows. The fauna is markedly different from the previous one. The ammonite assemblage is extremely rich (Balatonites, Norites, Beyrichites, Provities, Discoptychites, etc.); in addition, small, thin-shelled burrowing bivalves (Solemya, Unionites) are rather common.

The sequence of beds continues in the other, western trench (Aszófő I; Figure S-7). The lower part (Beds I/1–40) consists of planar beds of nearly uniform thickness with marly partings on their lower division. Silicified fossils and dif-
fuse silicification are common phenomena; from Bed I/38 upward, chert nodules appear. Between beds I/40–65, the bituminous limestone becomes finely laminated (Figure S-8), and the bedding surfaces are covered by *Posidonia* and *Daonella* shells. The undisturbed “pavements” made by the flat shells of these pelagic bivalves, the absence of benthos and bioturbation indicate anaerobic bottom conditions. Considering the absence of ammonites, it is probable that most of the water column was also oxygen-depleted.

Higher up, the burrowing bivalves reappear and the limestone becomes cherty and nodular from bed I/77 upward. This part contains rare and poorly preserved ammonites (*Bulogites, Beyrichites*) and a few brachiopods.

**Fossils**

The detailed collection resulted in an extremely rich ammonoid and brachiopod fauna; the gastropod, nautilid and bivalve associations are also diverse. Besides frequent crinoid skeletal elements, plant (imprints of conifer twigs), echinoid and vertebrate remains (fish and/or reptile bone fragments, teeth and scales) were found rarely but were not identified more precisely. Microfossils were determined partly from

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**Figure S-6.** The trench Aszófõ II showing the interval between Beds 1 to 34. Dashed line (below the hammer in centre) at Bed 28 marks the base of the Balatonicus Zone (= base of Pelsonian)

**Figure S-7.** The trench Aszófõ I showing the interval between Beds 59 to 96

**Figure S-8.** Laminated limestone beds with shaly marl interlayers. Aszófõ I, around Bed 60
thin sections (foraminifers), partly isolated by dissolving (radiolarians, conodonts). The determined taxa are listed below, according to systematic order. Their detailed descriptions, including specimen number data are presented in the respective chapters of this volume (or elsewhere, if noticed).

Foraminifera:
A. Oravec-Scheffer (pers. comm.) recognised the very important Pelsonian guide foraminifer Paulbronnimannia judicariensis (Premoli Silva, 1971) in Bed 57 of the Aszófő I section.

Radiolaria:
Poorly preserved radiolarians were found by Dosztály (1988) in the lower part of the Aszófő I section; from beds 25–27, the following taxa were determined:
- Astrocentrus sp.
- Spongopallium sp.
- Stylosphaera sp.
- Weverisphaera sp.

Gastropoda (after Vorós 1987):
- Discohelix sp.
- Omphaloptychia ? sp.
- Trypanostylus ? sp.
- Coelostylin a ? sp.
- Coelochrysalis ? sp.
- Neritaria ? sp.
- Trachynerita ? sp.
- Promathilda sp.
- Undularia ? sp.
- Sisenna sp.
- Worthenia sp.
- Natiria ? sp.
- Naticopsis ? sp.
(Note: this fauna is presently under detailed revision by J. Szabó)

Nautiloidea (nautilids systematically described by Vorós 2001):
- Michelinoceras ? sp.
- Anoploceras cf. rolleri (Arthaber, 1896)
- Encoiloceras balatonicum Vorós, 2001
- Encoiloceras lajosi Vorós, 2001
- Mojsvaroceras ? cf. binodosum (Hauer, 1887)
- Pleuronautilus mosis Moissovics, 1882
- Trachynautilus cf. nodulosus (Arthaber, 1896)
- Germanonautilus cf. salinarius (Moissovics, 1882)
- Paranautilus cf. indifferens (Hauer, 1892)
- Syringonautilus cf. lilianus (Moissovics, 1882)
- Sybillonautilus cf. pertumidus (Arthaber, 1896)

Ammonoidea (determined by A. Vorós):
- Proavites hueffeli Arthaber, 1896
- Norites gondola (Moissovics, 1869)
- Norites falcatus Arthaber, 1896
- Alanties ? sp.
- Ismidites cf. marmarensis Arthaber, 1915
- Ismidites sp., aff. marmarensis Arthaber, 1915
- Acrochordiceras cf. damesii (Noetling, 1880)
- Acrochordiceras carolinae Moissovics, 1882
- Balatonites cf. ottonis (Buch, 1849)
- Balatonin cas balatonicus (Moissovics, 1873)
- Balatonites balatonicus (Moissovics, 1873) morphotype zitteli
- Balatonin cas gemmatus Moissovics, 1882
- Balatonites egregius Arthaber, 1896, morphotype jovis
- Bulogites gosaviensis (Moissovics, 1882)
Stratigraphy

Bulogites zoldianus (MOJSISOVICS, 1882)
Bulogites multinodosus (HAUER, 1892)
Bulogites mojsvari (ARTHABER, 1896)
Beyrichites cadoricus (MOJSISOVICS, 1869)
Beyrichites beneckeii (MOJSISOVICS, 1882)
Beyrichites cf. reutensis (BEYRICH, 1867)
Beyrichites ? sp.
Schreyerites loretsi (MOJSISOVICS, 1882)
Schreyerites ragazzonii (MOJSISOVICS, 1882)
Schreyerites sp., aff. splendens ARTHABER, 1896
Schreyerites ? binodosus (HAUER, 1851)
Semiornites sp.
Discoptychites domatus (HAUER, 1851)
Noetlingites sp.

Coleoidea (determined by A. Vörös):
Mojsisovicsteuthis ? sp.
Breviconoteuthis sp.

Scaphopoda (determined by A. Vörös):
Dentalium (Antalis) sp.

Bivalvia (determined by I. Szente and A. Vörös):
Palaeoneilo praecursor (FRECH, 1904)
“Palaeoneilo” minutissima (FRECH, 1904)
Solemya abbreviata (FRECH, 1904).
Parallelodon sp.
Septifer ? sp.
Mysidiella ? sp.
Protopis ? sp.
Bakevellia (B.) binneyi (BROWN, 1841)
Gervillaria cf. hartmanni (MÜNSTER, 1834)
Cassianella praecursor FRECH, 1904
Daonella boecckhi MOJSISOVICS, 1874
Posidonia wengensis (WISSMANN, 1841)
Mysidioptera ? sp.
Plagiostoma striatum (SCHLOTHEIM, 1823)
Plagiostoma sp.
Limea (Pseudolimea) sp.
Serania ? sp.
Limidae ? gen. et sp. indet.
Pleuronencites laevigatus (SCHLOTHEIM, 1820)
Leptochoodria cf. viezzenensis (WILCKENS, 1909)
Leptochoodria ? sp.
Entolium discites (SCHLOTHEIM, 1820)
Entolium cf. kellneri (KITTL, 1903)
Entolioides ? sp.
Newaagia ? sp.
Myophoria cf. proharpa FRECH, 1904
Schafohaeutlia ? sp.
Unionites subrectus (BITTNER, 1901)
Pseudocorbula gregaria (MÜNSTER in GOLDFUSS 1838)
Pleuromya elongata (SCHLOTHEIM, 1822)

Brachiopoda (determined by J. Pálfy):
Costirhynchopsis mentzeli (BUCH, 1843)
Decurtella decurtata (GIRARD, 1843)
Decurtella cf. illyrica (BITTNER, 1903)
Piarorhynchella trinodosi (BITTNER, 1890)
Volhrhynchia projectifrons (BITTNER, 1890)
Volhrhynchia productifrons (BITTNER, 1890)
**Volirhynchia tommasi** (BITTNER, 1890)  
**Trigonirhynchella attilina** (BITTNER, 1890)  
**Homoeorhynchia** ? sp.  
**Holcorhynchella delicatula** (BITTNER, 1890)  
**Punctospirella fragilis** (SCHLOTHEIM, 1814)  
**Mentzelia mentzeli** (DUNKER, 1851)  
**Koeveskallina koeveskalyensis** (STUR, 1865)  
**Koeveskallina paleotypus** (LORETZ, 1875)  
**Tetractinella trigonella** (SCHLOTHEIM, 1820)  
**Schwagerispira schwageri** (BITTNER, 1890)  
**Schwagerispira cf. mojsisovicsi** (BÖCKH, 1872)  
**Coenothyris vulgaris** (SCHLOTHEIM, 1822)  
**Coenothyris cf. krafti BITTNER, 1890**  
**Coenothyris aff. krafti BITTNER, 1902**  
**Coenothyris cf. cuccensis BITTNER, 1890**  
**Angustothyris? angustaeformis** (BÖCKH, 1872)  
**Sulcatinella incrassata** (BITTNER, 1890)  

(Note: Rhynchonellid brachiopods were systematically described by PÁLFY 1988.)

Conodonta (determined by S. Kovács):

- **Gondolella bifurcata** (BUDUROV & STEFANOV, 1972)  
- **Gondolella bulgarica** (BUDUROV & STEFANOV, 1975)  
- **Gondolella hanbologi** (SUDAR & BUDUROV, 1979)  
- **Neospathodus kockeli** TATGE, 1956  
- **Neospathodus germanicus** KOZUR, 1970  
- **Gondolella aff. praehungarica** KOVÁCS, 1994

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**Felsőörs**

The Middle Triassic section at Felsőörs (also known as Forrás-hegy or Malom-völgy) is one of the most famous geological localities of Hungary, discovered by J. Böckh in 1870. The locality became a kind of sacred place of pilgrimage for Hungarian geologists and later, due to its outstanding importance for the Anisian/Ladinian boundary problem, was frequently visited by international symposia. Therefore an ample literature describing the section is available (BÖCKH 1872, 1873, LÓCZY 1913, 1916, SZABÓ et al. 1980, KOVÁCS et al. 1990, BUDAI 1991, VÖRÖS et al. 1996, MARTON et al. 1997, VÖRÖS 1998, VÖRÖS et al. 2003).

Detailed bed-by-bed collection of fossils from the Pelsonian beds was made in the scope of a “Laczkó Dezső fossil hunting campaign” sponsored by the Hungarian Natural History Museum, organised by J. Pálfy and A. Vörös in 1992.

**The section**

The first systematic artificial outcrops (trenches) were excavated in the 1970s, in the scope of the National Key Section Program, following the instructions of I. Szabó. Owing to its outstanding scientific value, and a possible interest for the public, the section was recently re-excavated and preserved from erosion, partly covered by shelters. It is now a protected geological conservation site and an educational geological trail. The lower part of the section is a cleaned natural outcrop on the hillside whereas in the higher part of the section the Felsőörs Formation and the overlying tuffaceous Vászoly Formation (Reitzi Zone) were excavated in artificial trenches.

The Pelsonian sequence is exposed in the lower outcrops on the hillside (Figure S-9). It starts with thick-bedded dolomicrosparite that belongs to the Megyehegy Formation (Beds 0–22). The overlying yellowish-grey bituminous, thin-bedded dolomite and clayey dolomite of restricted basin facies (Beds 23–43) represent a “transitional unit” towards the Felsőörs Formation. The next part of the section (Forráshegy Member) consists of grey, bedded limestone, in many horizons with chert nodules (Beds 44–67). Around Bed 61, the thinner, nodular limestone beds alternate with marly interlayers (Figure S-10). The high-

Figure S-9. The measured stratigraphical column and ammonoid range chart of the Pelsonian part of the Felsőörs section  
For legend see Figure S-3
The most part of the exposed Pelsonian sequence is represented by
crinochelal-brachiopodal marly limestones (Beds 68–82), that belongs to
the Horoghegy Member of the Felsőörs Formation.

The microfossils and microfacies were studied by A. Oravecz-
Scheffer and Gy. Lelkes (in ŠABÓ et al. 1980), respectively.

Fossils

In the course of our detailed collecting work, a very diverse bra-
chiopod and a poor ammonoid fauna was found in the Horoghegy
Member (Beds 68–82). It is puzzling that, neither during the visits
by hundreds of geologists, nor by the regular cleaning of the out-
crops, nobody ever found ammonites in the deeper part of the Pelsonian sequence at Felsőörs. (The occurrence of
Balatonites margaritatus FRECH, 1903 at Felsőörs is an enigma because the single, large specimen came allegedly from
the beds of the Reitzi Zone.) The apparent absence of bivalves is also surprising.

Microfossils were determined partly from thin sections (foraminifers), partly isolated by dissolving (conodonts). The
determined taxa are listed below, according to systematic order. Their detailed descriptions, including specimen number
data are presented in the respective chapters of this volume (or elsewhere, if noticed).

Foraminifera: [After ŠABÓ et al. (1980) and ORAVECZ-SCHIFFER (1987)]

Trochammina almtalensis KOEHN-ZANINETTI, 1968
Earlandia tintinniformis (MÍSK, 1971)
Paulbronnimannia judicariensis (PREMOLI SILVA, 1971)
Endothyra salaji GAŽDZICKI, 1972
Endothyra badouxi ZANINETTI & BRÖNNIMANN, 1972
Endothyra obturata BRÖNNIMANN & ZANINETTI, 1972

Glomospira cf. sinensis HO, 1959
Eoophthalmidium tricki (LANGER, 1967)
Planinovoluta carinata LEISCHNER, 1961
Tolyapammina ? gregaria WENDT, 1969
Placospilina cf. hyrensis (BRÖNNIMANN & ZANINETTI, 1972)
Ammodiscus sp.
Glomospirella sp.
Nodosaria sp.
Lenticulina sp.

Nautiloidea (determined by A. Vörös):
Germanonaulus sp.
Trachynautilus sp.

Ammonoidea (determined by A. Vörös):
Proavites sp.
Beyrichites ? sp.
Schreyerites ? binodosus (HAUER, 1851)
Semiornites sp.
Discoptychites sp.

Ostracoda (systematically described by MONOSTORI, 1995):
Polycope sp.
Reubenella angulata MONOSTORI, 1995
“Hungarella” felsoorsensis (KÖZUR, 1970)
“Hungarella” reniformis (MÉHES, 1911)
“Hungarella” anisica (KOZUR, 1970)
“Hungarella” sp.
Bairdia cassiana rotundidorsata MONOSTORI, 1995
Bairdia finalyi (MÉHES, 1911)
Bairdia humilis MONOSTORI, 1995
Urobairdia sp.
Bairdiolites cf. compactus KRISTAN-TOLLMANN, 1970
Lobobairdia zapfei KOZUR, 1971
Nodobairdia ? martinssoni (KOZUR, 1971)
Nodobairdia sp.
Acratia cf. goemoeryi KOZUR, 1970
Bairdiacypris anisica KOZUR, 1971
Spinocypris vulgaris KOZUR, 1971

Brachiopoda (determined by J. Pálfy):
Decurtella decurtata (GIRARD, 1843)
Piarorhynchella trinodosi (BITTNER, 1890)
Volhrhynchia vivida (BITTNER, 1890)
Volhrhynchia projectifrons (BITTNER, 1890)
Caucasorhynchia cf. altaplecta (BÖCKH, 1872)
Trigonirhynchella attilina (BITTNER, 1890)
Mentzelia mentzelii (DUNKER, 1851)
Mentzelia balatonica (BITTNER, 1890)
Koeveskallina koeveskalyensis (STUR, 1865)
Tetractinella trigonella (SCHLOTHEIM, 1820)
Schwagerispira schwageri (BITTNER, 1890)
Schwagerispira cf. mojsisovici (BÖCKH, 1872)
Coenothyris vulgaris (SCHLOTHEIM, 1822)
Angustothyris ? angustaeformis (BÖCKH, 1872)
(Note: Rhynchonellid brachiopods were systematically described by PÁLFY 1988.)

Conodonta (determined by S. Kovács):
Gondolella bifurcata (BUDUROV & STEFANOV, 1972)
Gondolella bulgarica (BUDUROV & STEFANOV, 1975)
Gondolella hanbulogi (SUDAR & BUDUROV, 1979)
Gondolella aff. praehungarica KOVÁCS, 1994
Gondolella aff. szaboi KOVÁCS, 1983
Neospathodus kockeli TATGE, 1956
Neospathodus germanicus KOZUR, 1970
Gladigondolella malayensis budurovi KOVÁCS & KOZUR, 1980

**IMPORTANT BOREHOLES**

Several boreholes penetrated or reached Pelsonian strata at the Balaton Highland; three of these, providing important palaeontological and stratigraphical data will shortly be presented below.

**Szentantalfa, Szaf–1**

The borehole, drilled in 1977 with continuous core sampling (supervised by I. Szabó), penetrated Middle Triassic formations. Starting from the Füred Limestone, below the Buchenstein and Vászoly Formations, it crossed the Tagyon Limestone in more than...
one hundred metres thickness and ended in the Megyehegy Dolomite (Figure S-11). A short description of the section was given by Oraveczné Scheffer (1980).

The Pelsonian Substage is represented by the massive beds of Tagyon Limestone of subtidal to subaerial facies with frequent vadose early diagenetic overprint. The cores were cut and the thin sections were investigated for microfossils (Oraveczné Scheffer 1980) and for calcareous algae, sedimentary structures and microfacies (O. Piros and Gy. Lelkes in Budai et al. 1993). The cores happened to be regrettably lost but the thin section are available for further studies.

**Fossils**

The foraminifer fauna and the calcareous algae assemblages are exceptionally rich throughout the Tagyon Limestone. Ostracods, fragments of molluscan shells and echinoderm skeletal elements occur sporadically.

**Calcareous algae (determined by O. Piros):**
- *Oligoporella pilosa* var. *pilosa* Pia ex Bystricky, 1964
- *Physoporella pauciforata* var. *sulecata* Bystricky, 1962
- *Physoporella pauciforata* var. *undulata* Pia, 1935
- *Physoporella pauciforata* var. *pauciforata* Pia ex Bystricky, 1964

**Foraminifera (after Oravecz-Scheffer 1980):**
- *Glomospira sinensis* Ho, 1959
- *Glomospirella elbursorum* Brönnimann et al., 1972
- *Glomospirella triphonensis* Baud et al., 1971
- *Ammobaculites radstadensis* Kristan-Tollmann, 1964
- *Earlandia tintinniformis* (Mišík, 1971)
- *Earlandia amplituinalis* Pantic, 1972
- *Earlandinita oberhauseri* Salaj, 1967
- *Paleomubecularia minuta* Brönnimann et al., 1972
- *Endothyra badouxii* Zaninetti & Brönnimann, 1972
- *Endothyranella wirzi* (Koehn-Zaninetti, 1968)
- *Haplophragmella inflata* Zaninetti & Brönnimann, 1973
- *Meandrospira dinarica* Kochansky-Devide & Pantic, 1966
- *Diplostremina astrophimbrata* Kristan-Tollmann, 1960
- *Duostomina magna* Trifonova, 1974
- *Variostoma* sp.

**Dörgicse, Drt–1**

The borehole, drilled in 1985 with continuous core sampling (supervised by T. Budai), penetrated the Lower Carnian Füred Limestone, the Ladinian Buchenstein and Vászoly Formations, and crossed the Pelsonian Tagyon Limestone in more than 70 m thickness. A comprehensive description of the section is given in Budai et al. 1993, 1999 (Figure S-12).

The cores of Tagyon Limestone were cut and the thin sections were investigated for microfossils (Oravecze Scheffer, manuscript in Budai et al. 1990) and for calcareous algae and microfacies (O. Piros and Gy. Lelkes in Budai et al. 1993).

**Fossils**

The calcareous algae assemblages and the foraminifer fauna are extremely rich throughout the Tagyon Limestone. Ostracods, fragments of molluscan shells and echinoderm skeletal elements occur sporadically.

**Figure S-12.** Stratigraphical column of the lower part of Dörgicse Drt–1 borehole (after Budai et al. 1990)

Legend: 1 — platform dolomite; 2 — subtidal platform limestone; 3 — peritidal platform limestone; 4 — limestone and tuffaceous limestone of basin facies; 5 — oncoids; 6 — desiccation cracks; 7 — gastropods; 8 — foraminifers; 9 — dasycladaceans; 10 — ammonoids; 11 — crinoid fragments; 12 — brachiopods; B. = Bithynian
Calcareous algae (determined by O. Piros):

- Teutloporella peniculiformis Ott, 1963
- Physoporella pauciforata var. undulata Pia, 1935
- Physoporella pauciforata var. pauciforata Pia ex Bystrický, 1964

Foraminifera (after Oravecz-Scheffer, in Budai et al. 1990):

- Calcitornella sp.
- Diplotremina astrofimbriata Kristan-Tollmann, 1960
- Earlandia sp.
- Earlandia tintinniformis (Mšík, 1971)
- Earlandinita elongata Salaj, 1967
- Earlandinita sp.
- Endothyra cf. obturata Brönnimann & Zaninetti, 1972
- Endothyra salaji Gáždicki, 1972
- Endothyra sp.
- Endothyranella wirzi (Koehn-Zaninetti, 1968)
- Glomospira sp.
- Glomospirella trip honensis Baud et al., 1971
- Haplophragmella sp.
- Meandrospira ? deformata Salaj, 1967
- Meandrospira dinarica Kochansky-Devidé & Pantíc, 1966
- Trochammina almtalensis Koehn-Zaninetti, 1968

Balatonfüred, Bfü–1

This 300 m deep borehole was drilled in 1978 (supervised by I. Szabó) with continuous core sampling. It crossed the Carnian Veszprém Formation and Fűred Limestone, the Ladinian Buchenstein and Vászoly Formations, penetrated the Anisian Felsőörs Formation in 70 m thickness, and ended in the Megyehegy Dolomite (Figure S-13).

The Pelsonian Substage is represented by the lower 38 m of the Felsőörs Formation. The thin sections were investigated for microfossils (Oravecz-Scheffer 1987) and sporomorphs were extracted and identified (Góczán & Oravecz-Scheffer 1993).

Fossils

The sporomorph assemblages and the foraminifer fauna are rather rich throughout the Pelsonian part of the Felsőörs Formation. Ostracods, sponge spicules, fragments of molluscan shells and echinoderm skeletal elements are also frequent but were not determined.

Sporomorpha (after Góczán & Oravecz-Scheffer 1993):

- Verrucisporites div. sp.
- Cyclotrilletes div. sp.
- Triadispora div. sp.
- Uvaesporites fueredensis Góczán, 1993
- Striatoabieites aytugi Vißcher, 1966
- Strotersporites tozeri Brugman, 1986
- Stellapollenites thiergartii (Mädlér, 1964)
- Dyupetalum vicentinense Brugman, 1983

Foraminifera (after Oravecz-Scheffer 1987 and Góczán & Oravecz-Scheffer 1993):

- Eoophthalmidium tricki (Langer, 1967)
- Ophthalmidium ubeyliense Dager, 1978
- Paulbronnmannia judiciensis (Premoli Silva, 1971)

Figure S-13. Stratigraphical column of the lower part of Balatonfüred Bfü–1 borehole (after Szabó et al. 1981)

Legend: 1 — dolomite of ramp facies; 2 — limestone/dolomite alternation (“transition member”); 3 — dolomitised limestone of basin facies; 4 — limestone and argillaceous limestone of basin facies; 5 — tectonized zone; 6 — plastoclasis; 7 — slump structures; 8 — ammonoids; 9 — forams; 10 — filaments; B. = Bithynian
**Other Localities**

**Paloznak**

The borehole Paloznak Pat–1 was drilled in 1986 with continuous core sampling (supervised by T. Budai), penetrated the Lower Carnian Füred Limestone, the Buchenstein and Vászoly Formations, the dark grey, marly limestone beds of the Anisian Felsőörs Formation and ended in the Megyehegy Dolomite.

**Fossils**

From the depth 125.8 m T. Budai collected a poorly preserved ammonoid, determined by A. Vörös as *Balatonites* sp. indet.

**Veszprém**

About five km to the south of Veszprém, abundant slabs of greyish, bituminous limestone lie dispersed along the road No. 73, leading to Csopak. The nearest settlement is marked on the recent maps as “Szabadság-puszta”, or “Miklósháza-puszta”. This locality is probably identical with the classical site “Veszprém, Alsó-erdő” of LACZKÓ (1911).

**Fossils**

From the loose rock slabs, T. Budai and A. Vörös collected several ammonoids of various state of preservation.

Ammonoidea (determined by A. Vörös):

- *Balatonites balatonicus* (MOJSISOVICS, 1873)
- *Balatonites balatonicus* (MOJSISOVICS, 1873) morphotype *zitteli*
- *Balatonites cf. gemmatus* MOJSISOVICS, 1882
- *Discoptychites cf. domatus* (HAUER, 1851)

**Szentkirályszabadja**

Near the local military airport, an abandoned quarry exposes the upper part of the massive or thick-bedded, dolomitised Tagyon Formation (Figure S-14) (the whole thickness of the formation is approximately one hundred metres). The “Tagyon Dolomite” is paraconformably overlain by brownish, dolomitised limestone beds of the Vászoly Formation of Late Illyrian age, whereas its lower boundary towards the Megyehegy Dolomite is not seen. The section was described by BUDAI et al. (1993), by BUDAI & HAAS (1997) and more precisely illustrated by BUDAI et al. (2001) (Figure S-15).

Several pieces of the “Tagyon Dolomite” were cut and the thin sections were investigated for calcareous algae, sedimentary structures and microfacies (O. Piros and Gy. Lelkes in BUDAI et al. 1993).

**Fossils**

The “Tagyon Dolomite” of subtidal to subaerial facies is very rich in calcareous algae. Fortuitously, O. Piros noticed two ammonoid specimens in the massive dolomite. Various bioclasts were identified in thin sections, including calcified cyanobacterial mats, dasycladaceans, unbroken gastropods, other molluscs, benthonic foraminifers, echinoderms and ostracods.

Calcareous algae (determined by O. Piros):

- *Physoporella varicans* PIA, 1935
- *Physoporella pauciforata var. pauciforata* PIA ex BYSTRICKÝ, 1964
- *Physoporella pauciforata var. undulata* PIA, 1935
- *Physoporella pauciforata var. sulcata* BYSTRICKÝ, 1962
**Physoporella pauciforata var. gemerica** Bystrický, 1962
**Physoporella minutuloidea** Herak, 1967
**Anisoporella anisica** (Zanin Buri, 1965) Hurka, 1969
**Poncetella hexaster** (Pia, 1912) Güvenç, 1979
**Teutloporella peniculiformis** Ott, 1963

Ammonoidea (determined by A. Vörös):
- **Balatonites balatonicus** (Mosisovics, 1873)

Balatontalmádi

This section, in the road-cut between Vörösserény (Balatonalmádi) and Szentkirályszabadja (Budai & Vörös 1989), on the slope of the Megye-hegy, was collected bed-by-bed for the Anisian–Ladinian boundary interval (Vörös 1993). The uppermost part of the Felsőörs Formation (limestone beds with clay seams) is exposed in a few metres thickness and only Bed 38 seems to belong to the Pelsonian.

**Fossils**

Bed 38 provided a few ammonoids and a poorly preserved brachiopod fauna of low diversity.

Ammonoidea (determined by A. Vörös):
- **Proavites** cf. hueffeli Arthaber, 1896

Brachiopoda (determined by J. Pálfy):
- **Decurtella decurtata** (Girard, 1843)
- **Volirhynchia vivida** (Bittener, 1890)
- **Schwagerispira** cf. schwageri (Bittener, 1890)

**BIOSTRATIGRAPHY**

**AMMONOID BIOSTRATIGRAPHY**

(ATTILA VÖRÖS)

Subdivision and boundaries of the Pelsonian Substage at the Balaton Highland

On the basis of the ammonoid data sets recorded in the measured sections, five successive biostratigraphical units, termed here as subzones, can be recognised and correlated within the studied stratigraphic interval of the Balaton Highland (Figure S-16, Table S-1). The names of these subzones are only partly identical with those suggested earlier by Vörös (1987, 1998).

The elements of the proposed subzonal scheme, from bottom to top: Ottonis Subzone, Balatonicus Subzone, Cadoricus Subzone, Zoldianus Subzone, Binodosus Subzone. The previously defined Balatonicus Subzone is now divided into three subzones. The Zoldianus Subzone remained unchanged. The Binodosus Subzone (used as “unnamed subzone” in Vörös & Pálfy 2002) was transferred from the Trinodosus to the Balatonicus Zone. Table S-1 shows the vertical distribution of ammonoid taxa within the subzones.

The subzones can be best recognised and are most completely represented in the Aszófő section.

**Ottonis Subzone.** Beds II/40–41 of Aszófő provided a scarce and poorly preserved ammonoid fauna with a few specimens of **Balatonites** cf. ottonis and **B. egregius** morphotypus jovis, and a single, extremely large **Acrochordiceras** cf. dame-
Figure S-16. The ammonoid subzones recognised in the Aszófi section and their correlation with other measured sections of the Balaton Highland. Dashed line = lower boundary of Pelsonian. For legend see Figure S-3.
### Table S-1. The vertical distribution of ammonoid taxa determined from the Pelsonian of the Balaton Highland within the recognised subzones

<table>
<thead>
<tr>
<th>Ammonoids</th>
<th>Ottonis</th>
<th>Balatonicus</th>
<th>Cadocious</th>
<th>Zoldianus</th>
<th>Binodosus</th>
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<tr>
<td>Acrochordiceras <em>cf. damesii</em></td>
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<tr>
<td>Balatonites <em>cf. ottonis</em></td>
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<tr>
<td>Balatonites egregius <em>m. jovis</em></td>
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<td>Noetlingites sp.</td>
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<td>Ismidites sp., aff. <em>marmarensis</em></td>
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<td>Balatonites gemmatus</td>
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<tr>
<td>Ismidites <em>cf. marmarensis</em></td>
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<tr>
<td>Balatonites balatonicus</td>
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<td>Norites gondola</td>
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<td>Balatonites balatonicus <em>m. zitteli</em></td>
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<td>Discopyctiches domatus</td>
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<td>Norites falcatus</td>
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<td>Acrochordiceras caroliniae</td>
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<td>Proavites hueffeli</td>
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<td>Alanites ? sp.</td>
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<td>Beyrichites cadoricus</td>
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<td>Schreyerites sp., aff. <em>splendens</em></td>
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<td>Schreyerites loretzi</td>
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<td>Beyrichites beneckeii</td>
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<tr>
<td>Bulogites <em>gosaviensis</em> s.l.</td>
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<tr>
<td>Bulogites <em>multinodosus</em></td>
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<td>Bulogites <em>mojsvari</em></td>
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<td>Bulogites <em>zoldianus</em></td>
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<tr>
<td>Schreyerites <em>razzagonii</em></td>
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<tr>
<td>Semiornites sp.</td>
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<tr>
<td>Beyrichites <em>cf. reuttensis</em></td>
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<td>Schreyerites <em>binodosus</em></td>
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<tr>
<td>Judicarites cf. <em>euryophalus</em></td>
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sii. This fauna can well be separated from that of the succeeding subzone containing *B. balatonicus* as well. This subzone was recognised only in the Aszófő section.

**Balatonicus Subzone.** The next interval of the Aszófő section, from Bed II/28 to I/7, is characterised by the continuous presence of *B. balatonicus*; furthermore *B. egregius* morphotype *jovis*, *B. gemmatus* and *Norites* species play important role. Besides the representatives of the genera *Proavites*, *Acrochordiceras* and *Discopyctiches*, the sporadic occurrence of *Noetlingites* and *Ismidites* is worth of special attention because these genera are usually regarded as peculiar to the Bithynian faunas. This subzone can be recorded also in the lowermost part of the Mencshely section (Beds 22–23) and the “lower Recoaro” horizon of the Horog-hegy IV locality is also attributed to the Balatonicus Subzone.

**Cadocious Subzone.** The almost simultaneous appearance of several taxa of Beyrichitidae (*Beyrichites cadoricus, B. beneckeii, Schreyerites loretzi*) indicates the base of the next interval (between Beds I/8–58). The genus *Proavites, Balatonites balatonicus* and *Norites gondola* persist from the subjacent subzone, and some “Bithynian” forms (*Ismidites cf. marmarensis, Alanites ? sp.*) occur sporadically. This subzone is well represented in the Mencshely section (Beds 12–20), and can be recognised at Köveskál (Horog-hegy III) as well.

**Zoldianus Subzone.** Perhaps the most pronounced change of ammonoid faunas is connected to the base of this subzone: the long-ranging genera *Acrochordiceras, Balatonites* and *Norites* disappear and *Bulogites* appears with several species (in the order of appearance: *B. gosaviensis, B. multinodosus, B. mojsvari* and *B. zoldianus*). Other new elements of the fauna are *Schreyerites razzagonii* and the genus *Semiornites*. This subzone comprises the interval I/59–88 in the Aszófő section, and is clearly proved (though restricted to single layer) in Mencshely (Bed 10) and in Horog-hegy II/3.

**Binodosus Subzone.** The uppermost beds of the Aszófő section (I/90–96) provided a scarce fauna characterised by the appearance of *Schreyerites ? binodosus* and *Beyrichites cf. reuttensis*, accompanied by *B. beneckeii* and *Schreyerites razzagonii*, which appear already in the Zoldianus Subzone. This subzone is widespread, it was recognised in Felsõörs (between Beds 72–78), Mencshely (Bed 9) and in Horog-hegy I/1, where *Judicarites cf. euryophalus* also occurred. The interpretation (content) of the Binodosus Subzone is almost the same as it was described earlier by VÖRÖS (1987 and 1998).

### Correlation with other European areas

The subzones recognised in the Pelsonian of the Balaton Highland can be correlated with other European regions from the Germanic Basin to the Kocaeli Peninsula (Turkey) (Figure S-17). The figure was compiled using the stratigraphic columns and ammonoid data published by Fantini Sestini (1988), Balini (1993), Balini et al. (1993), Muttoni et al. (1998), Brack et al. (1999), Tatzreiter (2001) and Kozur (1974).

The Ottonis Subzone of Aszófő (with *Balatonites cf. ottonis, B. egregius* morphotype *jovis* and *Acrochordiceras cf. damesii*) has its closest counterpart, naturally, at the type locality of *B. ottonis*, in the Germanic facies area. Here, especially in the Silesian Lower Muschelkalk, in the upper Gogolin Beds, other *Balatonites* (tentatively ranged to the *B. egregius* group, e.g. *B. “jovis”*), *Noetlingites* and *Acrochordiceras damesii* were found (Kozur 1974, Kaim & Niedźwiecki 1999, Brack et al. 1999) which underline the close correlation. This horizon (“Assemblage-Zone mit Myophoria vulgaris, Beneckeia buchi und Dadocrinus”) was placed into the Lower Anisian (“Hydasp”), i.e. Bithynian by Kozur (1974).
Figure S-17. Correlation of upper Bithynian and Pelsonian ammonoid subzones between some important Anisian sections of the western Tethys and the Germanic Basin.
A similar fauna with *Balatonites ottonis* group and *Acrochordiceras* was found in the Angola Limestone of Lombardy (Schilpario, Valle Gatti) by Brack et al. (1999); they correlated this horizon with that in the upper Gogolin Beds.

The Ottonis Subzone was also recognised in Turkey (Kocaeli Peninsula, Bay of Izmit), where, in the section Gezbe VI, measured by Assereto (1974) and Fantini Sestini (1988), at least the beds T 160 and T 161 are attributed to here.

In the classical Grossreifling section, the Rahnbauerkogel level (RK/A-D in Tatzreiter 2001) with the rich *Balatonites egregius* fauna may also correspond to the Ottonis Subzone. Based on the new finding of *Noetlingites strombecki* in this horizon, and recognition the affinity of some Silesian Lower Muschelkalk *Balatonites* (Rassmuss 1915, Kaim & Niedzwiedzi 1999) to *B. egregius*, Tatzreiter (2001) put this level to the Bithynian (Ismidicus Zone).

The **Balatonicus Subzone** of Aszófõ, defined by the FAD of *B. balaticus* (accompanied with a diverse ammonoid fauna) can be recognised in the Bed T 63 of the section Gezbe VI, by the single occurrence of the index species.

The Balatonicus Subzone is suspected in the highest beds of the Anglo Limestone in the Val dei Gatti section and in the transitional beds above the Dossi dei Morti Limestone in the Stabol Fresco section (Lombardy).

In the Grossreifling section, the faunal horizon TG/L 2 is attributed to the Balatonicus Subzone, on the basis of *B. ex gr. balaticus* and *B. cf. hystrix*. The single *Bulogites* (Tatzreiter 2001) is a juvenile specimen and may rather be a *Reiflingites*.

The Balatonicus Subzone gives another correlation possibility with the Germanic facies area, namely with a part of the Göradze Beds in Silesia, where *Balatonites*, younger than *B. ottonis* or the *egregius* group, were found (Assmann 1937). One of these (*B. nobilis* Assmann, 1937) may be closely related to *B. balaticus*. These *Balatonites* species were listed by Kozur (1974) among the fossils of the “Decurtata-Zone” of Pelsonian age.

The **Cadoricus Subzone** of Aszófõ, comprising many surviving faunal elements of the Balatonicus Subzone, and defined by the appearance of the index species and *Schreyerites loreti*, has rather limited record outside the Balaton Highland.

This subzone and the higher Pelsonian intervals did not yield ammonoids in the Gezbe sections and in Silesia.

Some beds above the Dossi dei Morti Limestone in the Stabol Fresco section may belong to the Cadoricus Subzone on the basis of the occurrence *Balatonites cf. balaticus* (Brack et al. 1999) and of *Beyrichites cf. cadoricus* (Balini et al. 1993), though this latter was found in the same layer with *Bulogites aff. zoldianus* (Gaetani 1969).

In the Tiefengraben section of Grossreifling, the horizons TG 7–8 and TG 12 probably belong to this Subzone as suggested by the presence of the *Balatonites balaticus* group and the absence of *Bulogites*.

The **Zoldianus Subzone** of Aszófõ, defined practically by the range of the genus *Bulogites*, can be properly correlated with the lower part of the Dont section in the Dolomites (Italy), where Balini (1993) and Muttoni et al. (1998) recorded *Bulogites* from Bed C to T, with mass occurrence of *B. zoldianus* in Bed R.

In the Stabol Fresco section, Bed G25 yielded *Bulogites aff. zoldianus* (Gaetani 1969, Balini et al. 1993) and although it was found together with *Beyrichites cf. cadoricus*, this layer may indicate the base of the Zoldianus Subzone.

The uppermost fossiliferous beds (TG 1 to TG 3/4) of the Tiefengraben section at Grossreifling provided a rich assemblage of *Bulogites*, and was previously correlated with the Zoldianus Subzone of Aszófõ by Tatzreiter & Vörös (1991) as well.

The genus *Bulogites* was frequently recorded in the Germanic Lower Muschelkalk (Urlichs & Mundlos 1985). The Karchowice Beds of Silesia yielded *B. zoldianus* as well (Assmann 1937). Kozur (1974) listed *B. zoldianus* among the important fossils of the Pelsonian “Decurtata-Zone”.

The **Binodosus Subzone**, as based on the FAD of the index species, accompanied by *Beyrichites reuttenensis* and *Judicarites* was recognised in all four measured sections at the Balaton Highland. However, its applicability elsewhere in Europe seems to be very ambiguous.

The taxonomic interpretation of the index species is frustratingly contradictory. Tatzreiter & Balini (1993), when erecting the new genus *Schreyerites*, intentionally excluded the species *Ceratites binodosus* (Hauser, 1851) and Balini (pers. comm. 2002) still holds this opinion. On the other hand, Mietto & Manfrin (1995) found the suture of their “C.” *binodosus* as a proper basis for assigning this species to *Schreyerites*. Better than nothing, this wider interpretation is tentatively used in the present work.

The stratigraphic occurrence of “C.” *binodosus* in the important Anisian reference section of Dont is also debated. Balini (1993) found it in the level β [corresponding to the upper part of Niveau 3 of Assereto (1971), and to the Binodosus Subzone of Vörös (1987 and this work)], and this record is subsequently confirmed (Muttoni et al. 1998, Balini, pers. comm. 2002). On the other hand, Mietto & Manfrin (1995, and pers. comm. 2002) collected their “C.” *binodosus* from the lower level R [corresponding to the lower part of Niveau 3 of Assereto (1971), and to Zoldianus Subzone of Vörös (1987, and this work)]. The arguments of both groups of authors are reasonable, but the proper documentation (monographic descriptions or at least detailed logs with range charts) is still lacking in both cases. Therefore, the correlation of the Binodosus Subzone of Aszófõ with horizon β of the Dont section is doubtful, because there the range of *S.? binodosus* may partly overlap the *Bulogites* range.

The correlation with the interval SF67 to SF85b of the Stabol Fresco section is also dubious, because *Judicarites* is the single ammonoid taxon indicating the presence of our Binodosus Subzone there.
From the uppermost fossiliferous layers of the Tiefengraben section at Grossreifling (TG 1 and TG 1/2) “Ceratites sp. (sensu C. binodosus ARTH. 1896)” was doubtfully recorded (TATZREITER 2001). This would imply overlapping ranges of “binodosus” and Bulogites.

The alleged occurrence of the index species in the Germanic Basin (e.g. “Ceratites gorazdzensis ASSMANN, 1937, in KOZUR 1974) does not seem to be endorsed. On the other hand, the other guide fossil of our Binodosus Subzone, the genus Judicarites occurs frequently in the uppermost Lower Muschelkalk (BRACK et al. 1999) deserving an independent “Assemblage-Zone mit Judicarites und Neoschizodus orbicularis” in KOZUR (1974).

The record of S. ? binodosus from Gebze (Turkey) by FANTINI SESTINI (1988) is taken as doubtful because the suture of the figured specimen is ceratitic, not of Schreyerites type, and because the specimens were found in the deeper levels of the sections, together with Balatonites ottonis-like forms.

The subzones defined at the Balaton Highland are believed to partly differ from, partly correspond to the subzones proposed by MIEETTO & MANFERN (1995). The supposed relationship of the subzones, along with those suggested by VÖRÖS (1987), is shown in Table S-2.

### Correlation outside Europe

Representatives of the genus Balatonites, as the most convenient, indicative marker of the Pelsonian in wide sense, have been found at many places in South Asia, along the Alpine–Himalayan mountain ranges, including Tibet (GU et al. 1980) and Thailand (KUMMEL 1960); the farthest, well known record being in North America (Nevada: BUCHER 1992).

GU et al. (1980) regarded the fauna found at Doilungdeqen as Late Anisian (Trinodosus Zone). However, many ammonoid taxa, described and figured by them, seem rather typical Pelsonian elements e.g. Proavites hueffeli ARTHABER, Acrochordiceras carolinae MOJSISOVICS, Bulogites gosaviensis (MOJSISOVICS) (as Reiflingites in GU et al.) and Balatonites egregius ARTHABER, morphotype jovis (as B. balaticus in GU et al.). Therefore, agreeing with BUCHER (1992), at least a part of the Doilungdeqen fauna must be considered to be Pelsonian. Detailed stratigraphy of the locality and range charts were, however, not published, therefore a direct correlation with the Balaton Highland sections is not possible.

The best documented counterpart of the Alpine Pelsonian is known in Nevada (North America). After the early finds of Balatonites by HYATT & SMITH (1905), the Shoshonensis Zone was recently revised by BUCHER (1992). Apart from the majority of the ammonoid species apparently endemic in North America, there are important elements common with those of the Balaton Highland fauna. The species of the genus Balatonites, B. shoshonensis HYATT & SMITH and B. whitneyi BUCHER, appear in two distinct subzones. Acrochordiceras carolinae MOJSISOVICS ranges through the Shoshonensis Zone. Ismidites cf. marmarensis ARTHABER occurs only in the lowermost subzone, while Bulogites cf. mojsvari (ARTHABER) appears in the uppermost subzone. These distributions fit rather well to those found in the Aszófõ section; only the Binodosus Subzone of the Balatonicus Zone does not seem to be represented in the fauna of the Shoshonensis Zone. Based on these scarce data it is supposed that the Shoshonensis Zone corresponds to the major (lower) part of the Balatonicus Zone.

### Boundaries of the Pelsonian Substage

The lower boundary of the Pelsonian Substage is drawn between the Ottonis and Balatonicus Subzones, at the FAD of Balatonites balaticus, i.e. at Bed II/28 of the Aszófõ section. This concept is justified by the inter-regional correlation presented above (Figure S-17). Especially the practice developed in some classical regions and sections was taken as decisive. In the Germanic facies area, the horizons containing the early Balatonites (i.e. the B. ottonis-group of BRACK et al. 1999) is definitely ascribed to the uppermost Lower Anisian (“Hydasp” = Bithynian) (KOZUR 1974). Similarly, the new results from the Grossreifling section led TATZREITER (2001) to assign the Rahnbauerkogel horizon (correlated here with the Ottonis Subzone of Aszófõ) to the Bithynian.

This judgement would put an end to the previous, common practice of using the appearance of the genus Balatonites as a marker of the base of the Pelsonian.

It is worth saying some words about the alleged occurrence of the genus Cucoceras at certain localities of the Balaton Highland, what would indicate the presence of the Bithynian Substage (LOCZY 1916, pp. 111 and 113, in faunal lists). The original specimens, kept in the collections (National Geological Museum, Budapest), were examined and turned out to be small inner whorls (nuclei) of Balatonites.

The suggested upper boundary of the Pelsonian Substage should be drawn above the Binodosus Subzone, at the FAD of Paraceratites trinodosus. For the time being, this boundary can not be pinpointed at the Balaton Highland.

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<table>
<thead>
<tr>
<th>Subzone</th>
<th>Guide Fossil</th>
<th>Correlation</th>
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<tr>
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<td>Adelaide</td>
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<tr>
<td>ZoelHanus</td>
<td>ZelHanus</td>
<td>Binodous</td>
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<td>Suberbus</td>
<td>Céderkes</td>
<td>Balatonites</td>
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<tr>
<td>Balatonicus</td>
<td>Shoshonensis</td>
<td>? C. big.</td>
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**Table S-2.** The supposed relationship between the proposed sub-zonal scheme and those suggested in the last decades.
because detailed collection has not been possible in the relevant parts of the measured sections. Although *P. trinodosus* was recorded in several localities (Kőveskál, Felsőörs, Vörösberény, etc., see VÖRÖS 1998, VÖRÖS & PÁLFY 2002), the transitional beds from the Binodosus to the Trinodosus Subzone were unfossiliferous or not well exposed. Due to its scanty fossil record in this interval, the Dont section is also not suitable in this respect. The Giudicarie sections (e.g. Stabò Fresco, BALINI *et al.* 1993) seem to be best suited for drawing this boundary, i.e. the base of the Trinodosus Subzone.

**CONODONT BIOSTRATIGRAPHY**

*(SÁNDOR KOVÁCS)*

**Introduction**

Systematic conodont studies were carried out in two Pelsonian measured sections at the Balaton Highland. In 1978, the Felsőörs section, renewed at that time, was sampled bed-by-bed, including the Pelsonian part (Beds No. 43a and 44 to 83). The preliminary results are included in the contribution by SZABÓ *et al.* (1980). In the same year a small trench at Aszóftő existing at that time and corresponding to the uppermost part of the present day Aszóftő II section, exposing the main level with the *Balatonites balatonicus* fauna, was sampled (Beds No. 1–9/1978 from top to down). The whole Aszóftő I and II sections were sampled in 1990 (not all beds). On the conodont chart of Figure S-18, S-19 only those samples are shown, which yielded determinable conodonts.

**Distribution of conodonts**

*Felsőörs (Figure S-18)*

The basal part (Beds No. 43a, 44–53) of the cherty limestone member contains a fairly rich, almost monospecific *Gondolella bulgarica* conodont fauna (see Table C-1 in KOVÁCS, this volume), represented mostly by medium ontogenetic stages. Juvenile forms are less frequent. Subadult and adult forms also occur. Part of these latters, according to the morphological criteria by KOVÁCS & PAPŠOVÁ (1986), correspond to *G. hanbulogi* and *G. bifurcata*. However, many specimens of the medium ontogenetic stage having a pointed out platform end, thus corresponding to *G. bulgarica* according to that criteria, have platform margins tending to be parallel, thus showing a transitional feature to *G. bifurcata*. In bed No. 53 the first representative of *Neospathodus kockeli* was found.

Beds No. 54–60 are very poor in conodonts.

In the higher part (Beds No. 61–68) of the cherty limestone member *G. hanbulogi* and *G. bifurcata* becomes more frequent on the expense of *G. bulgarica*.

In the “Recoaro-type” crinoidal–brachiopodal limestone member (Beds No. 69–80) of slope facies large, massive adult and hyperadult forms of *G. bifurcata* become absolutely predominating, represented by hundreds of specimens in each bed. The lowermost beds (No. 69 and 70) of this member are still characterized by primitive forms of this species. Most of the specimens, even higher up in the section, have no bifurcation of the carina posteriorly, but do have a rounded platform end and characteristically thickened platform margins. Typical forms according to BUDUROV & STEFANOV (1972), with

**Figure S-18.** Frequency distribution of of platform conodont taxa in the Felsőörs section, showing the extent of the two conodont dominance zones

For legend see Figure S-3
bifurcated posterior end of carina, are also found, such as asymmetrical ones having only on one side posteriorly an accessory denticle. (The latters were identified in Szabó et al. (1980), pp. 794–795 and Pl. 59, figs. 12–13 as “Gondolella prava” KOZUR 1968 and “Paragondolella bifurcata” BUDUROV & STEFANOV (1972) was regarded as junior synonym of the former.)

G. bulgarica and G. hanbulogi are subordinate in this member and are represented mostly by smaller forms (median and subadult ontogenetic stages). The former becomes rarer and rarer higher up; its last few representatives were found in Bed No. 81. Although this frequency trend of G. bulgarica against G. bifurcata and G. hanbulogi corresponds to the general evolutionary trend (cf. BUDUROV 1975; BUDUROV et al. 1983), the environmental control on the overrepresentation of large, massive forms of G. bifurcata is obvious.

Neospathodus germanicus and N. kockeli can be usually found in small number throughout the crinoidal–brachiopodal limestone member; the last representative of the former was found in Bed No. 81 (see in Szabó et al. 1980, Pl. 59, Fig. 4).

Although mass occurrence of eupelagic conodonts in the basinal facies of Balaton Highland took place much higher, e.g. in the Avisianum Subzone (in sense of VÖRÖS 1998) of the Reitzi Zone (KOVÁCS 1993, 1994), ramiform elements of the Gladigondolella apparatus can be found very rarely in this slope facies. Even one or two juvenile specimens of Gladigondolella buduroi were found in Beds No. 77–78. Rare occurrence of representatives of the G. szaboi – G. trammeri lineage indicates also slight eupelagic influence: they occur from Bed No. 74 upward in all beds. GERMANI (2000) reported from about the same interval the occurrence of G. praeszaboi bystrickyi and G. praeszaboi praeszaboi (described in KOVÁCS et al. 1996) in the South Alpine sections.

However, our forms have a laterally more compressed platform and seem to be closer to G. szaboi (for description of which see KOVÁCS 1994). Therefore they are assigned to „G. aff. szaboi” herein. More strangely, from Beds No. 74 to 79 rare forms resembling in the outline of the posterior platform end ?G. praehungarica KOVÁCS, 1994 (and/or “Neogondolella” aequidentata KOZUR, 1995) were found. In shape of the platform they would correspond to G. hanbulogi, however, the cusp is not in terminal position, but there are still two smaller denticles behind it. (An “aborted” evolutionary event, homeomorphic to the Ladinian raise of ?G. praehungarica?) They are assigned as G. aff. praehungarica herein.

The uppermost two beds of the section (No. 82 and 83), already free of crinoids and brachiopods, contain only Gondolella bifurcata and some G. hanbulogi. Conodonts are less frequent here (several tens of specimens in both samples).

On the basis of distribution of conodonts two dominance zones can be recognised in the Felsőörs section: a Gondolella bulgarica Dominance Zone comprising the interval between Beds No. 43a to 53 (or higher up to Bed 68), and a Gondolella bifurcata Dominance Zone from Bed 69 upwards (Figure S-18).

**Aszófő II section (Figure S-19)**

The first positive sample, Bed No. 41, yielded mostly specimens of Gondolella bulgarica, but besides them, G. hanbulogi and G. bifurcata also occurred (the number of specimens is shown on Table C-2 in KOVÁCS, this volume). The highest part of the section, i.e. the main horizon of with Balatonites balatonicus, yielded only a few conodonts (probably due to the unsuitable quality of acetic acid used for dissolution). A short, small trench existed in the time of the sampling in 1978, exposing this part of the section and sampled bed-by-bed (samples Af–1–9/1978, Figure S-20). All samples yielded 50–100 or even more platform conodont specimens. G. bulgarica and primitive representatives of G. bifurcata predominate over G. hanbulogi in each sample. A few specimens of Neospathodus germanicus and N. kockeli were also found in the latter samples.
Aszófő I section (Figure S-19)

Conodonts from samples below the Bed No. 41 of this section have not been found. Nevertheless, no significant difference is likely between the top part of the eastern section and the higher part of this section above bed No. 41. Samples from Bed No. 41 to 102 yielded specimens of both *Gondolella bulgarica* and *G. bifurcata*, largely in the same number (see Table C-2), and subordinately of *G. hanbulogi*. *G. bifurcata* is represented mostly by forms of juvenile and more frequently of medium ontogenetic stages; massive, adult forms which are characteristic in the crinoidal–brachiopodal limestone of the Felsőörs section are missing here. Transitional forms between *G. bulgarica* and *G. bifurcata* are common. *Neospathodus germanicus* and *N. kockeli* are very rare. Rare forms corresponding to "G. aff. praehungarica" mentioned in the Felsőörs section, were also found in Beds No. 41, 59 and 81.

Due to the relatively small specimen number of conodonts, the dominance zones recognised in Felsőörs, can not be ascertained in the Aszófő sections.

**Correlation**

The conodont data suggest, that the basal part of the conodont bearing basin-al facies in the Felsőörs section (Beds No. 43a, 44–53) is probably older, than the first bed of basal facies in the Aszófő II (Bed No. 41), which yielded also representatives of *Balatonites*, unless this difference in conodont distribution is not linked to the difference in facies.

Higher up, however, in the intervals of the Balatonicus, Zoldianus and Binodosus Subzones, the facies control on the distribution of *Gondolella bulgarica*, *G. hanbulogi* and *G. bifurcata* is evident, i.e. these ammonoid subzones cannot be distinguished by means of conodonts.

Primitive forms of *G. bifurcata* are common in the main Balatonicus horizon of Aszófő II section (Beds No. 1–7), whereas in the Felsőörs section they are characteristic for the basal part of the crinoidal–brachiopodal limestone mem-

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**Figure S-20.** Frequency distribution of conodont species in the uppermost part of the Aszófő II section (from the sampling in 1978)

**Figure S-21.** Tentative correlation between the Aszófő and Felsőörs section on the basis of conodonts. The existence of the lower correlation horizon is especially doubtful

For legend see Figure S-3
ber (Beds No. 69–70). However, a correlation between these horizons on the basis of conodonts is unrealistic, as in Bed No. 72 of the Felsőörs section already Schreyerites? binodosus was found.

Stratigraphically the most important result of our studies is the documentation of the joint occurrence of Gondolella bulgarica and Schreyerites? binodosus. In the Aszófő I section the latter was found in Bed No. 90, whereas the former up to Bed No. 102. In the Felsőörs section S.? binodosus was found from Bed No. 72 to 78, whereas G. bulgarica up to Bed No. 80. The latter does not occur in the two, uppermost thin beds (No. 81 and 82) of the section.

Correlation between the Aszófő and Felsőörs sections by means of conodonts stands on rather weak grounds (Figure S-21). The highest part of the Pelsonian sequence in the Felsőörs section may correspond to the Bed 102 of Aszófő I section (not collected for ammonoids), and this horizon may lie close to the base of the Illyrian. An even more vague correlation may be supposed between the lower parts of the two section, namely Bed 41 of Aszófő II seems to be younger than Bed 53 of Felsőörs.

Discussion

Although Germani (2000), applying the morphological criteria by Kovács & Papšová (1986), unambiguously documented the co-occurrence of Gondolella bulgarica, G. hanbulogi and G. bifurcata in the eupelagic facies of Kocaeli Peninsula, NW Turkey, from the middle part of the Osmani Zone, i.e. from the beginning their ranges, an early G. bulgarica Dominance Zone can be still recognized in some of the sections studied in Hungary. These include the basal part of the cherty limestone in the Felsőörs section (Kovács, 1991 and in Marton et al. 1997), and several eupelagic sections of Aggtelek–Rudabánya Mts, NE Hungary (Kovács et al. 1989). This stratigraphic level may be older, than the Balatonicus Zone s.s., but in the lack of ammonoid data this cannot be proved.

The documentation of the joint occurrence of Gondolella bulgarica and Schreyerites ? binodosus in the Aszófő and Felsőörs sections is of prime importance. In the Felsőörs section S.? binodosus was found from Bed No. 72 to 78, whereas G. bulgarica up to Bed No. 80. The latter does not occur in the two, uppermost thin beds (Nos. 81 and 82) of the section, therefore Kovács (1991 and in Marton et al. 1997) distinguished this part as G. bifurcata Zone and assigned it already to the Illyrian, according to previously published data (Budurov & Sudar 1991 and references therein). However, data from the Southern Alps by Nicora and Balini (in Kovács et al. 1990) and by Germani (2000) clearly document, that the LAD of Gondolella bulgarica and the FAD of Paraceratites gr. trinodosus slightly overlap in the Stabolist Fresco section.

Nicora and Balini (in Kovács et al. 1990, p. 185) reported from Bed No. SF 92 “Ceratites” abichi and Paraceratites cf. trinodosus, and from Bed No. SF 96 still G. bifurcata, together with transitional forms between G. bulgarica and G. hanbulogi, as well as between G. bifurcata and G. constricta cornuta. On the other hand, on pl. 1 of the same paper G. bifurcata, G. bulgarica and transitional form between G. bifurcata and G. constricta cornuta were figured from Bed No. SF 96.

Germani (2000, p. 16 and pp. 55–57) reported the following first, respectively last occurrences in the Stabolist Fresco section:

SF 92 (= SF 85A): FAD of P. gr. trinodosus  
LAD of G. bulgarica and G. hanbulogi
SF 93: FAD of G. constricta cornuta
SF 96: LAD of G. bifurcata

In the interval from Bed SF 93 to SF 96 G. bifurcata, G. praeszaboi (not present in the Balaton Highland) and G. constricta cornuta overlap. This narrow overlapping zone at the basal part of the Trinodosus Zone is well documented in other sections in the Southern Alps, as well: Sotto le Rive (Farabegoli & Perri 1998a), Nosgieda (Farabegoli & Perri 1999b) and Dont (Balini & Nicora 1998); without G. bulgarica, but already with ammonoids of the Trinodosus Zone in the former two. Our studied sections at the Balaton Highland do not reach this zone.

Conclusions

(1) The Balatonicus, Zoldianus and Binodosus Subzones (according to Vörös 1998 and this volume), cannot be distinguished on the basis of the phyllogenetically related gondolellids (G. bulgarica, G. hanbulogi, G. bifurcata) due to the evident facies control on their distribution.

(2) A lower, G. bulgarica and an upper, G. bifurcata Dominance Zone can be recognized in most of the studied areas in Europe: Balkanide Triassic of Bulgaria and Inner Dinarides of former Yugoslavia (Budurov 1975, 1980; Sudar 1982; Budurov & Sudar 1991), the Southern Alps in Italy (Farabegoli & Perri 1998a, b; Balini & Nicora 1998) and in Hungary (Kovács et al. 1989, Kovács 1991 and in Marton et al. 1997). However, as opposed to ammonoid zones, these can rather be used only for intra-regional and not for Tethyan correlations between the middle part of the Osmani Zone and upper boundary of Binodosus Subzone.
(3) Neospathodus kockeli and N. germanicus, which appear to be good stratigraphic markers within the Germanic Basin (KOZUR 1972, 1980) are rare in most of the above mentioned areas. Moreover, they are related to a quite different evolutionary lineage, they occur together throughout the studied sections herein, therefore cannot be used for precise stratigraphic correlation within the relevant time interval.

(4) Based on the ammonoid and conodont data from the Aszófő and Felsőörs sections at the Balaton Highland and from the Stabol Fresco section in the Southern Alps, the re-integration of the Binodosus Subzone (or Binodosus Zone s.s.) into the Pelsonian Substage (which was originally defined by this ammonoid) seems reasonable and well supported.

(5) The most significant conodont evolutionary event in the Anisian that is marked by the disappearance of the G. bulgarica, G. hanbulogi and G. bifurcata association and with the appearence of the G. constricta group (= Neogondolella for some workers), associated with a distinctly different gondolelloid association, can be recognized at the basal part of the Trinodus Zone (the IVth ammonoid horizon of ASSERETO, 1971). It supports the definition of the Pelsonian and Illyrian substages by the FAD of Paraceratites trinodosus group and of the Gondolella constricta group (e.g. of G. constricta cornuta). At present, the Stabol Fresco section appers to be the best candidate for the boundary stratotype of the Pelsonian and Illyrian Substages.

**FORAMINIFER BIOSTRATIGRAPHY**
(compiled by ATTILA VÖRÖS with the contribution ANNA ORAVECZ-SCHIEFFER)

The abundant and diverse Pelsonian foraminifer fauna was studied in thin sections by A. Oravecz-Scheffer; she described and illustrated the assemblages from the Felsőörs Formation (in SZABÓ et al. 1980) and the Tagyon Formation (ORAVECZ-NÉ SCHEFFER 1980). The results are summarised in the profusely illustrated monograph on the Triassic foraminifers of the Transdanubian Range (ORAVECZ-SCHIEFFER 1987).

The recognised Pelsonian foraminifer taxa are listed according to the localities (Aszófő, Felsőörs, Szentantalfa, Dörgicse, Balatonfüred) in the respective parts of this chapter.

The foraminifer assemblages of the Tagyon Formation (shallow water carbonate platform) and the Felsőörs Formation (deeper marine, basin facies) are almost totally different in taxonomical composition, therefore a direct biostratigraphical correlation between them is not possible. Nevertheless, the Pelsonian age of the two formations can be proved independently.

The lowermost samples of the Tagyon Limestone in the borehole Szentantalfa (Szaf–1) contains “Diplotremina astrofimbriata KRISTAN-TOLLMANN” and this species occurs upward in the cores throughout the formation. This is taken as a positive evidence for the Anisian age of the Tagyon Formation (ORAVECZ-NÉ SCHEFFER 1980, ORAVECZ-SCHIEFFER 1987).

From the rich foraminifer association of the Felsőörs Formation, Paulbronnimannia judicariensis (PREMOLI SILVA) was highlighted by ORAVECZ-SCHIEFFER (1987) as a Pelsonian guide fossil. It occurs in the Felsőörs and Aszófő sections and in the borehole Balatonfüred (Bfü–1). Its first appearance in Bed 57 in the Aszófő section (ORAVECZ-
Scheffer, pers. comm.) nearly coincides with the base of the Zoldianus Subzone (Bed 59). The first appearance of Paulbronnimania judicariensis was recorded in Bed 59 of the Felsőörs section (Szabó et al. 1980). It is very remarkable that this level is five metres below the base of the Binodosus Subzone and may correspond to the Zoldianus Subzone (not yet proved in the Felsőörs section). This may give an independent tool for correlation between the two important Pelsonian sections Aszófő and Felsőörs (Figure S-22).

**Stratigraphy**

The Megyehegy Dolomite Formation and the Tagyon Limestone Formation.

The Megyehegy Dolomite Formation locally contains crinoid and dasycladacean fragments [e.g. in the surroundings of Tótvázsóny (Budai & Csillag 1998)]. On the basis of the Dasycladacean species (Physoporella pauciforata var. pauciforata Pia ex Bystrický 1964, Physoporella pauciforata var. undulata Pia 1935, Oligoporella sp.) the age of the formation is Anisian. Because these species are common from the bottom to top of the Anisian beds there is no possibility to classify the Megyehegy Dolomite into any defined Dasycladacean assemblage zones.

The Tagyon Formation is made up by the alternation of light grey bedded limestone and of yellow to beige, laminated (stromatolitic) limestone with birdseye structures. In the borehole Dörgicse–1 (Drt–1) the bedded dasycladacean and the yellow stromatolitic limestones alternate rhythmically, forming peritidal-lagoonal cycles akin to the Lofer cycles (Budai 1992). The dolomite in the quarry near the military airport of Szentkirályszabadja (also part of the Tagyon Formation) contains large oncoids and intraclasts (Budai et al. 1993), which alternate rhythmically with thinner stromatolitic laminated horizons. In the sections of boreholes Szentantalfa–1 (Szf–1), Dörgicse–1 (Drt–1) and the quarry near the Szentkirályszabadja the most frequent fossils are dasycladaceans and foraminifers. The dasycladaceans are: Poncetella hexaster (Pia 1912) Güvenç 1979, Physoporella pauciforata var. pauciforata Pia ex Bystrický 1964, Physoporella pauciforata var. undulata Pia 1935, Physoporella pauciforata var. sulcata Bystrický 1962, Physoporella varicans Pia 1935, Physoporella minutuloidea Herak 1967, Teutloporella peniculiformis Ott in Granier et Deloffre 1995, non 1963. Based on dasycladacean investigations 4 assemblage zones could be distinguished in the Anisian. (Piros 2002). In the Tagyon Formation only aI and aII assemblage zones can be found (Table S-3).

**Dasycladacean Biostratigraphy**

(Olga Piros)

Triassic platform carbonates are widely extended in the Transdanubian Range. The platform limestones (and dolomites) of predominantly lagoonal facies, sporadically contain dasycladaceans in rock-forming quantities. Two lithostratigraphic units of platform carbonate facies belong to the Anisian on the Balaton Highland: the Megyehegy Dolomite Formation and the Tagyon Limestone Formation.

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Assemblage zone aI (Poncetella hexaster – Physoporella pauciforata pauciforata Zone). The main species is Poncetella (Diplopora) hexaster (Pia 1912) Güvenç 1979. Well-preserved specimens of Poncetella hexaster occur only in this zone. Due to small diameter of its central stem and thick-walled undivided skeleton, P. hexaster does not belong to the most fragile alga species. It could survive in an environment of rather strong water agitation e.g. in the zone where oncoids and grapestones were formed. In this zone Physoporella pauciforata var. pauciforata Pia ex Bystrický was also encountered.

Assemblage zone aII (Teutloporella peniculiformis, Physoporella pauciforata, Oligoporella pilosa). The zone can be distinguished on the basis of the first occurrence (FO) of Teutloporella peniculiformis. The predominance of Physoporella pauciforata is also characteristic of this zone. In addition to this species Physoporella pauciforata var. undulata, var. sulcata, var. gmerica, Physoporella varicans and Anisoporella anisica are also common. The alga specimens are well-preserved. Branches and whorls of oblique sections are also distinctly visible. The alga sections are common and in some beds of lagoonal facies they occur in rock-forming quantity.

Based on these zones, the age of the Tagyon Formation in the Transdanubian Range is Pelsonian. On the basis of Dasycladacean zones the Tagyon Formation can be correlated with the Steinalm Limestone, but the deposition of the Tagyon Formation finished at the end of the Pelsonian.

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<th>Table S-3. Anisian Dasycladacean zones (after Piros 2002)</th>
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Sampling for magnetostratigraphic investigations was carried out by E. Márton and her team in the Aszófő and the Felsőörs sections. The samples from Aszófő did not provide conclusive result.

Magnetostatigraphy of the Felsőörs section was summarised and discussed by MÁRTON et al. (1997). The lower part of the section, including the Pelsonian strata, was sampled in 1981–1982. The short description of the methods, demagnetisation curves and VGP "latitude" data were given in the above paper.

The uppermost part of the Megyehegy Dolomite and the overlying beds of the dolomitised "transitional unit" (up to Bed 34) provided frequently opposing VGPs, i.e. many short reversal events. This part is here considered to be older than Pelsonian. No data were obtained from Beds 35 to 42.

Figure S-23 shows the Pelsonian portion of the Felsőörs section with the magnetic polarity column redrawn after MÁRTON et al. (1997). It starts with a rather long interval of reversed polarity (Beds 43 to 58), followed by a shorter normal polarity interval (Beds 59 to 65). The conclusive and continuous data set ends with a short reversed and another normal polarity interval (Beds 66 to 70, and 69 to 71, respectively). Further six samples from the top of the Pelsonian (Binodosus Subzone, Beds 75 to 81) yielded "ambiguous" or "transitional" VGPs, i.e. the palaeolatitudes were near-equatorial. It is important to note that, according to the palaeoecological and facies analysis, reworking (redepotation and/or bioturbation) played a significant role in the deposition of these calcarenitic beds.

The biostratigraphical correlation of the Pelsonian part of the Felsőörs section with the Aszófő section is rather ambiguous. Still, one may tentatively conclude that the major part of the Pelsonian (~ Balatonicus and Cadoricus Subzones) can be characterised by a long reversed polarity interval. The Zoldianus Subzone may correspond to a predominantly normal polarity interval, whereas the Binodosus Subzone (which is definitely proved biostratigraphically) provided ambiguous palaeomagnetic directions. The long Pelsonian reversed polarity interval found in Felsőörs seems to fit rather well into the composite polarity sequence of MUTTONI et al. (1998) except the long normal interval they put at the lowermost part of the Pelsonian. However, it should be borne in mind that the biostratigraphical correlation (between the Balaton Highland sections and the Nderlysaj and Kçira sections in Albania) is far from being reliable.

SEQUENCE STRATIGRAPHY

(PUBLIC BUDA)

Pelsonian age is generally considered as one of the main transgressive periods during the Triassic history of the Transdanubian Range (BUDAI & HAAS 1997, HAAS & BUDAI 1999). It is worth emphasizing that in the area of the Balaton Highland the relative change in the sea level was predominantly determined by extensional tectonic movements during the Middle Anisian (BUDAI & VOROS 1992, 1993). As a consequence of the disintegration of the Early Anisian carbonate ramp at the turn of the Bithynian/Pelsonian basins were formed on the subsided blocks while isolated carbonate platforms evolved on the uplifted ones. Tectonically controlled platform-basin boundary could have been reconstructed near Aszófő by the abrupt lateral change of coeval platform and basin facies and by the occurrence of redeposited slope sediments (BUDAI & HAAS 1997, VOROS et al. 1997). Extensional conditions are attributed to strike-slip movements in the Southern Alps (DOGLIONI 1987, GIANOLLA et al. 1998, GAETANI et al. 1998). It is plausible that mainly this type of tectonics controlled the basin evolution of the western end of the Tethys shelf during the Middle Anisian. However, eustatic sea-level rise may have also been contributed to the relative rise of the sea level in the Pelsonian. It is also reflected in the appearance of Tethyan faunal elements in the Germanic Basin (HAGDORN 1991, VOROS 1992) in connection with a maximum flooding interval (AIGNER & BACHMANN 1992).
The Pelsonian Substage of the Balaton Highland comprises basinal successions (Felsőörs Formation) and coeval carbonate platforms (Tagyon Formation).

The age of the carbonate platforms was dated by their foraminifer and dasycladacean associations, and by a single find of *Balatonites balatonicus* (at Szentkirályszabadja), as Pelsonian. The two local carbonate platforms (the Dörgicse platform, represented by the boreholes Szentantalfa–1 and Dörgicse–1, and the Szentkirályszabadja platform, exposed in the quarry at the military airport of Szentkirályszabadja, respectively) have been correlated by dasycladacean stratigraphy: both platforms belong to the Assemblage Zones aI and aII of PIROS (2002). Neither the foraminifer, nor the dasycladacean associations provide possibility for precise intercalibration between the platform and basinal successions.

The basinal successions, on the other hand, have been successfully correlated, first of all by their successive ammonoid associations. The four important surface sections (Köveskál, Meneschely, Aszófő and Felsőörs) have been subdivided into ammonoid Subzones (Baltaticus, Cadoricus, Zoldianus and Binodosus) which were traceable consistently along the Balaton Highland (see Figure S-16) and even in the Alpine region (Figure S-17). Multiple stratigraphic investigations have been restricted to the Aszófő and Felsőörs sections offering an opportunity to correlate these two sections more precisely and develop their integrated stratigraphy.

The biostratigraphy of the Aszófő section is fair enough: the ammonoid and conodont record is detailed and comprehensive; important foraminifer data are also available. Unluckily, the section did not provide conclusive palaeomagnetic data. In the Felsőörs section, the ammonoids are restricted to the uppermost part; the conodont and foraminifer stratigraphy is well developed and there is a reliable palaeomagnetic data set.

The major problem in the correlation of the two important sections lies in the absence of ammonoid record in the lower (greater) part of the Felsőörs section; only the Binodosus Subzone can be proved in both sections. Moreover, the conodont studies resulted in a rather vague subdivision, because the boundary of the lower, *G. bulgarica* and the upper, *G. bifurcata* Dominance Zones is apparently blurred and influenced by environmental factors (“facies control”: KOVÁCS, this chapter).

After all, the reliable point of the correlation is the record of the Binodosus Subzone, the upper limit of which is also proved by the FAD of the *Gondolella constricta* group (Figure S-24). A little lower, the FAD of the guide foraminifer *Paulbronnimannia judicariensis* offers a useful correlation horizon between the Beds 1/57 of the Aszófő and 59 of the Felsőörs sections. The lower conodont correlation horizon between Beds 41 of Aszófő II and 53 of Felsőörs (suggested by KOVÁCS, this chapter) is admittedly vague and not acceptable for the present author. Instead, the first appearance of conodonts (in Beds No. II/41 of Aszófő and 43a of Felsőörs, respectively) is preferred here as an “ecostratigraphic” datum. The
intervening part of the Felsőörs section (barren of ammonoids) may tentatively be subdivided and correlated with the respective ammonoid subzones of the Aszófő section, if a similar and more or less steady rate of sedimentation is supposed.

With a very tentative extrapolation of the ammonoid subzones, established in Aszófő, to the Felsőörs section, the magnetostratigraphic reversals recorded in Felsőörs may be intercalibrated with the ammonoid subzones as follows. The Ottonis, Balatonicus and Cadoricus Subzones, and consequently the base of the Pelsonian Substage, fall into a longer, reverse polarity interval. The Zoldianus Subzone corresponds to a dominantly normal polarity interval whereas the Binodosus Subzone did not provide consistent VGP directions.

THE STRATOTYPE OF THE PELSONIAN SUBSTAGE

(ATTILA VÖRÖS)

According to the rules of the International Commission on Stratigraphy the substages are formal units of the stratigraphical nomenclature, therefore their definition may follow the same rules as those of stages. However, the Triassic System is, as yet, short in “golden spikes” (GSSPs); even the stage boundaries are needed to be defined and/or ratified. Therefore the selection of a Triassic substage GSSP seems to be untimely. Nevertheless, a scientific definition of a substage, in this case the Pelsonian, may involve at least an informal selection of a “stratotype”.

MONISIOVICS, WAAGEN & DIENER (1895, p. 179, in table) regarded the Balaton region as the type area of the substage “Balatonisch”. PIA (1930, figs 2, 3), when introducing the substage name “Pelson” indicated the Dont valley as type section. From this time onwards, the Pelsonian Substage name has been widely used for the middle part of the Anisian but without properly defined stratigraphical and palaeontological content.

In his revealing work ASSERETO (1971) threw new light on several open problems and contradictions of the Middle Triassic stratigraphy, but did not touch the subdivision of the Anisian (i.e. the Pelsonian). The same holds true for the paper by SUMMESBERGER & WAGNER (1972) giving important information by the description of the classical Grossreifling section, the proposed stratotype of the Anisian.

When introducing two new Anisian Substages (Aegean and Bithynian), ASSERETO (1974) dealt also with the Pelsonian Substage and suggested that the upper boundary should be drawn at the appearance of “Paraceratites binodosus”. At the same time — since the ammonoid record was not continuous even in the candidate Grossreifling section — he left open the question of the lower boundary of the Pelsonian.

KOZUR (1974) published a detailed faunistical documentation of the Germanic Middle Triassic and discussed its possible correlation with the Tethyan stratigraphic units. According to him the Germanic “Myophoria vulgaris–Beneckeia buchi–Dadocrinus assemblage zone”, containing (among others) the ammonoid species Acrochordiceras damesi, Noetlingites strombecki and Balatonites ottonis, belongs to the Lower Anisian (“Hydasp”) Substage, whereas the subsequent “Decurtata Zone”, with Balatonites cf. corvini, B. nobilis, Bulogites zoldianus, Paraceratites binodosus and other ammonoid species, comprises the Pelsonian. KOZUR (1974, p. 16) suggested also that the oldest layers with Balatonites at Rahnbauerkogel and at the Balaton Highland should be taken as deepest Pelsonian.

In Hungary, DETRE (1974, 1975) called the attention to the unsolved problems in the Middle Triassic stratigraphy. SZABÓ et al. (1980) improved the knowledge on the Pelsonian Substage in the Felsőörs section with new micropalaeontological data. The first detailed Pelsonian ammonoid record of the Balaton Highland, based on bed-by-bed collection, was published by VÖRÖS (1987) who proposed a new subzonal scheme as well. Afterwards, the deeper part of the Aszófő section was also presented (VÖRÖS 1998), and by this, Aszófő became one of the most significant Pelsonian sections in the Alpine region.

As further progress, a comparative study of the Grossreifling sections and Aszófő was published (TATZREITER & VÖRÖS 1991). Later, TATZREITER (2001) reached to the conclusion that the deeper (Rahnbauerkogel) ammonoid horizon at Grossreifling belonged to the Bithynian Substage and, because there was a 80 m thick unexposed part between this and the overlying, Upper Pelsonian (Tiefengraben) ammonoid horizons, the Grossreifling section did not seem to be suitable for defining the base of the Pelsonian.

BALINI et al. (1993) proved that the well-exposed sections in the Giudicarie region with good ammonoid record (e.g. Stabol Fresco) comprise only the upper part of the Pelsonian Substage (Balatonicus Zone). More or less the holds true for the classical Dont section (BALINI 1993, MUTTONI et al. 1998). MIETTO & MANFRIN (1995) indicate some South Alpine sections straddling the lower boundary of the Pelsonian Substage, however, the relevant detailed palaeontological and/or stratigraphical documentation of these sections is still awaited.

In contrast to the above mentioned localities, the sections of the Kocaeli Peninsula in Turkey (e.g. Gebze VI) provide splendid record of the Bithynian/Pelsonian boundary interval, but do not give palaeontological information on the higher part of the Pelsonian (ASSERETO 1974, FANTI S SESTINI 1988).

A very important fauna with Balatonites ottonis group and Acrochordiceras was found in the Angolo Limestone of Lombardy (Schilpario, Val dei Gatti) by BRACK et al. (1999) what was correlated with the upper Gogolin Beds of the Germanic facies area (Silesia). The higher part of the exposed sequence did not yield diagnostic fossils.
As it is seen from the above review and from Figure S-17, the Aszófő section is the only one among the well studied European sections, where all of the Pelsonian subzones and the underlying Ottonis Subzone can be recorded, in superimposed order in sequence. The conodont record is also good here. These facts render Aszófő to be the most suitable candidate for being the type section of the Pelsonian Substage. It is complemented with the important reference section at Felsőörs where magnetostratigraphy and even more detailed conodont record are available. Their geographic location, near the shores of the lake Balaton (Lacus Pelso, lending the name of the substage), supports this choice. The proposed base of the Pelsonian Substage is at Bed II/28 of the Aszófő section, at the FAD of *Balatonites balatonicus*.

The stratigraphical and palaeontological content of the Pelsonian Substage in its type area (Balaton Highland) is documented in the following respective chapters of this volume.