GSSP (Global Boundary Stratotype Section And Point) PROPOSAL FOR THE BASE OF LADINIAN (TRIASSIC)

A proposal for the GSSP at the base of the Reitzi Zone (sensu stricto) at Bed 105 in the Felsöörs section, Balaton Higland, Hungary

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1. NAME AND STRATIGRAPHIC RANK OF BOUNDARY

Base of the Ladinian Stage (=Anisian/ Ladinian stage boundary) within the Middle Triassic Series.

2. THE PROPOSED GSSP: GEOGRAPHICAL AND GEOLOGICAL DESCRIPTION

Geographic location and access

The village of Felsöörs is located in the northeastern part of the Balaton Highland, a chain of rolling hills north of Lake Balaton and south of the Veszprém Plateau (Fig. 1). The Balaton Highland forms the southern slopes of the broad Transdanubian Range, rising some 200 m above the lake level. Felsöörs is 5 km north of the northern shore of Lake Balaton.

Felsöörs is served by scheduled bus service from towns along the northern shore of Lake Balaton (Balatonalmádi and Alsóörs) and from Veszprém, an important regional centre and seat of Veszprém County. Both Balatonalmádi and Veszprém has railway stations on main lines from Budapest. Felsöörs is accessible on a secondary road from either Balatonalmádi or Veszprém, which in turn are connected to Budapest by main highways 7 then 71, and 7 then 8, respectively. Driving time from Budapest to Felsöörs is approximately 2 hours.

The section lies on the southwest slope of Forrás-hegy (Forrás Hill), above the Malomvölgy (Malom Valley), only 200 m from the edge of the village (Fig. 2). Access is via a newly developed footpath that serves as an educational trail featuring this important geological and paleontological site. The trailhead is signposted on Malomvölgy Street.

The latitude and longitude of the proposed GSSP is 47°01.006'N, 17°56.589'E, the elevation is 220–230 m above sea level. Hungarian topographic map sheet 503-444 (1:10 000 scale, stereographic projection) and tourist map "Balaton" (1:40 000) covers the area of the locality.

Geological setting

The Felsöörs area is located in the north-eastern part of the Balaton Highland that forms the southern flank of the Transdanubian Range's synclinorium. The area is made up by the following main stratigraphic units (Budai 1991): Upper Permian red sandtsones of fluviatile-lacustrine facies (Balatonfelvidék Sandstone Fm.) overlying the Hercynian anchimetamorphic basement; Lower Triassic shallow marine siliciclastic-carbonate series of mixed ramp facies ("Werfen Group"); Lower-Middle Anisian carbonates of shallow marine ramp facies (Aszófö Dolomite, Iszkahegy Limestone, Megyehegy Dolomite); Middle-Upper Anisian (Felsöörs Fm.), Ladinian (Vászoly and Buchenstein Fm.) and lowermost Carnian (Füred Fm.) limestones of pelagic basin facies; tongues of Lower and Middle Carnian platforms (Budaörs and Sédvölgy Dolomite) which are intercalated into the basin successions (Veszprém Marl); and finally Upper Carnian platform carbonates (Main Dolomite).

The Middle Anisian to Upper Ladinian section at Felsöörs is exposed in three, partly overlapping trenches (Szabó et al., 1980) (Fig. 3). The first trench begins with bedded dolomicrosparite of the Megyehegy Formation (Beds 0-22). The overlying yellowish-grey bituminous, thin-bedded dolomites and dolomitic marls of restricted basin facies (Beds 23-43) represent a transition towards the Felsöörs Formation ("transitional unit"). The next part of the section consisting of grey, bedded limestones with chert nodules (Beds 44-67) and crinoidal-brachiopodal marly limestones (Beds 68-81) belongs to the Felsöörs Formation. At the base of the second trench poorly exposed

crinoidal limestones are visible which are probably equivalent to the uppermost beds of the first trench. Above these layers grey, flaser-bedded limestone occurs. It is followed by 1 m thick tuffitic intercalation.

The overlying well-bedded sequence (Beds 87-99/C) consists of 8-20 cm thick, grey limestone layers with 5-30 cm thick, yellow clay interlayers (Fig. 2b). At the top of the second trench an uneven bedding surface has been exposed - the footwall of the overlying tuffaceous succession. In the original third trench, the artificial exposure has been recently enlarged as a cutbank. Here, a 18 m thick tuffitic sequence is exposed (Vászoly Fm.). It consists of greenish-white, locally brownish-yellow K-trachyte tuffs with thin limestone interlayers or lenses ("pietra verde"). The tuffaceous sequence is overlain by pinkish-grey, nodular limestones which are exposed at the end of the trench. Higher up on the hillside, red, cherty limestones crop out representing the Nemesvámos Limestone Member of the Buchenstein Formation.

LOCATION OF LEVEL AND SPECIFIC POINT

The proposed GSSP level is at the base of Bed 105 in the highest, artificially exposed cutbank that is now protected by a wooden cover. Within the sequence of tuffite and interbedded thin limestone layers or lenses, Bed 105 is 38 cm in thickness and it represents three separate layers of nodular limestone in tuffaceous matrix. The nodular limestone yielded an ammonoid fauna characterized by the first appearance of *Reitziites reitzi*. Stratigraphically it is 11 m above Bed 99/C which is exposed as a large bedding plane at the base (southeastern end) of the cutbank.

CONSIDERATION OF STRATIGRAPHIC COMPLETENESS

At the level of resolution afforded by ammonoid biostratigraphy, the Felsöörs section appears complete. In the critical interval, it contains all of the ammonoid biostratigraphic subdivisions (zones and subzones) recognized elsewhere in key sections of the Balaton Highland and the Southern Alps. No hiatus could be detected by any other biostratigraphic or magnetostratigraphic method, or by sedimentological observations. High-resolution radiometric dates with overlapping errors from below and above the boundary level also argue against any significant gap. Sedimentological features suggest that deposition of limestone layers may represent longer time intervals than the thicker volcaniclastic strata.

THICKNESS AND STRATIGRAPHIC EXTENT OF BOUNDARY SECTION

The well bedded higher part of the FelsQörs Formation represents parts of the Trinodosus Zone in which the Trinodosus, Camunum and Pseudohungaricum Subzones were revealed (Vörös et al. 1996). Its thickness is about 8-9 m.

The overlying tuffaceous succession of the Vászoly Formation starts at the top of the exposed bedding surface of

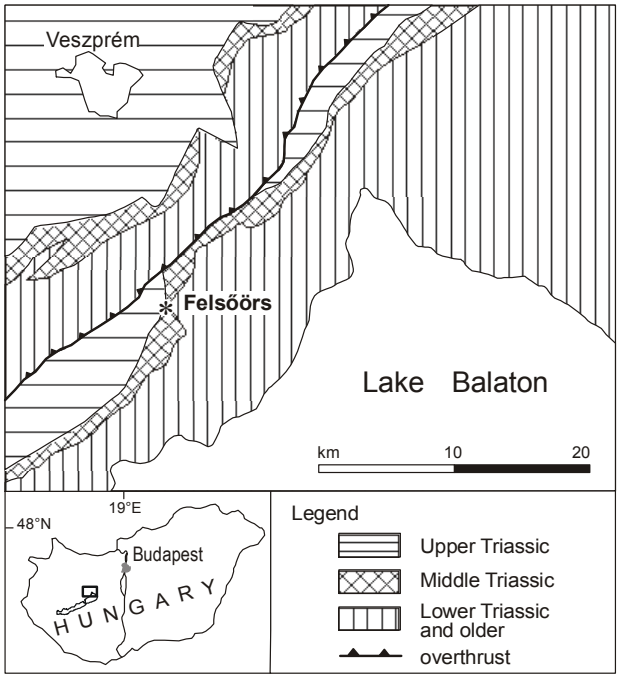

Fig. 1. Location of the Felsöörs section on a simplified geological map of the northeastern Balaton Highland and the Veszprém Plateau. Inset: Location of the study area within Hungary.

Bed 99/C (Fig. 4). The lower part of this sequence consists of greenish-white, sometimes brownish-yellow potassium-trachyte tuffs ("pietra verde", "reitzi-tuff") with thin ochre-yellow cherty limestone interlayers or rows of lenses. The first limestone interlayer (Bed 100/E) in the overlying tuffaceous succession of the Vászoly Formation yielded *Kellnerites felsoeoersensis* proving the Felsoeoersensis Subzone. In limestone interlayers higher up, the Liepoldti and the Reitzi Subzones (the latter marking the base of the Reitzi Zone) have been recorded (Beds 102 and 105, respectively). The whole thickness of the tuffitic succession is about 18 m. Detailed biostratigraphy of this critical part of the section is shown on Fig. 5.

In the higher part of the Vászoly Formation, the carbonate sedimentation predominates again in the form of pinkish-grey, nodular limestones; tuffaceous clay becomes subordinate. The lowermost, still ochre-yellow, limestone beds (110 or 111) are assigned to the Avisianum Subzone of the Reitzi Zone on the basis of a few ammonoids including *Latemarites latemarensis*. The higher beds (111/A–111/K) provided a rich and diverse ammonoid fauna, with a Ticinites-horizon at the top. In the next, massive, cherty limestone bed, *Stoppaniceras* cf. *variabile* appears; whereas the limestone layers in the overlying tuffaceous clay yielded specimens of *Chieseiceras*, *Repossia* and *"Stoppaniceras"* ex. gr. *ellipticum*. This assemblage indicates the Secedensis Zone. The successive appearance of the genera *Hungarites*, *Parakellnerites*, *Ticinites*, *Stoppaniceras* and *Repossia* shows the same order as it was recorded in the South Alpine sections (M. S. Giorgio, Bagolino) by Brack & Rieber (1993).

With diminishing amount of tuffite, a thick, continous se-

Fig. 2. Aerial photograph of the village of Felsöörs and its vicinity, with location of the Felsöörs section marked by an arrow (in left central part of photograph).

quence of red, cherty limestone develops upsection. This typical pelagic, basinal limestone succession (Nemesvámos Member of the Buchenstein Formation) is poorly exposed on the hillside. In October 2002, we started detailed collection for ammonoids in the lower part of this formation. A poorly preserved specimen of *Eoprotrachyceras* cf. *curionii* was found just below Bed 129, indicating the Curonii Zone. No detailed collection was made higher up, but a few poorly preserved pieces of *Arpadites* ? were found in the scree, suggesting the presence of the Gredleri Zone in the reddish cherty limestone. The Upper Ladinian strata are exposed on the NW side of a left tributary valley. These light grey, slightly nodular limestones with clayey interlayers represent the Füred Limestone Formation. Ammonoids (*Clionites* sp. and *Celtites epolensis*), found in loose blocks, suggest the Regoledanus Zone.

Provisions of conservation and protection

The Felsöörs area is part of the Balaton Highland National Park, founded in 1997. The outcrops are one of the most famous, classical geological localities of Hungary and were listed as a geological key section (Haas, 1986) already several years before the establishment of the National Park. In recognition of its special importance, an educational geological trail was developed in 1999. It is protected as a geological conservation site. A 23x3 m wooden cover was built to protect the section that contains the proposed GSSP from weathering and erosion. The footpath and the site is regularly maintained by the Municipality of Felsöörs, in collaboration with the Balaton Highland National Park and the Hungarian Geological Institute.

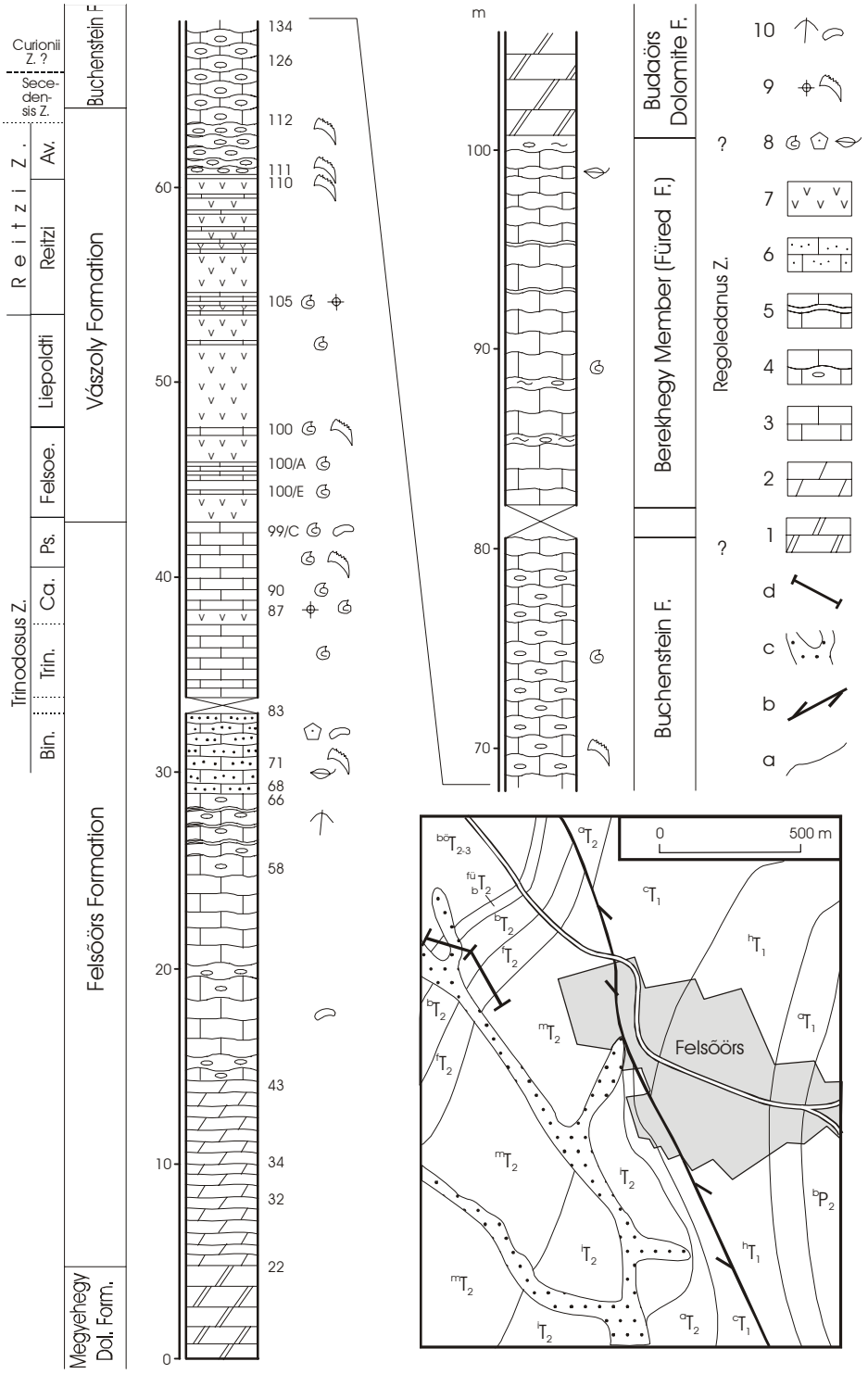

Fig. 3. Stratigraphic column and locality map of the entire section at Felsöörs (slightly modified after Budai et al. 2001). Legend: a - stratigraphic boundary, b - strike-slip fault, c - alluvial deposits, d - geological conservation site, 1 - bedded dolomite, 2 - bituminous dolomite, 3 - bedded, laminated limestone. 4 - cherty, nodular limestone, 5 - flaser-bedded limestone with marl intercalation, 6 - crinoidal limestone, 7 - tuff, tuffite, 8 - ammonoids, crinoids, brachiopods, 9 - radiolarians, conodonts, 10 - sponge spicules, ostracods, bP2 - Balatonfelvidék Sandstone Fm., aT1 - Arács Marl Fm., hT1 - Hidegkút Fm., cT1 - Csopak Marl Fm., aT2 - Aszófö Dolomite Fm., iT2 - Iszkahegy Limestone Fm., mT2 - Megyehegy Dolomite Fm., fT2 - Felsöörs Limestone F., bT2 - Vászoly +Buchenstein Fm., füT2 - Füred Limestone Fm. (Berekhegy Member), böT2-3 - Budaörs Dolomite Fm., Bin. - *Binodosus*, Trin. - *Trinodosus*, Ca. –*Camunum*, Ps. – *Pseudohungaricum*, Felsoe. – *Felsoeoersensis*, Av. - *Avisianum*

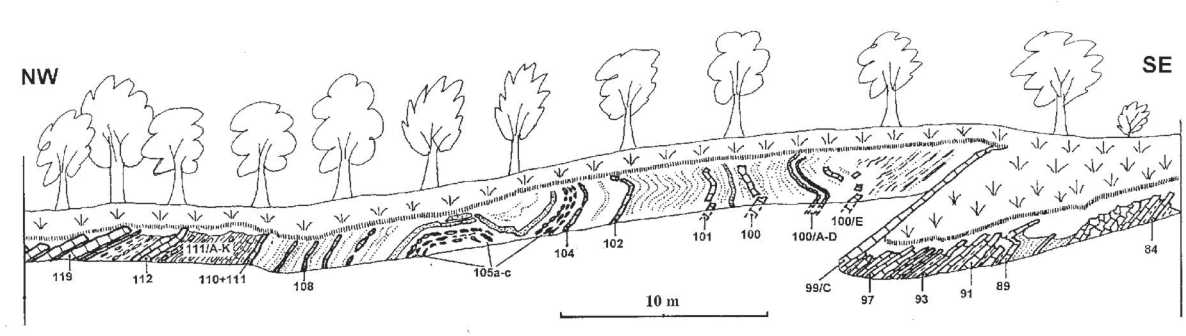

Fig. 4. Panoramic sketch of the upper part of the Felsöörs section after the new excavations of the cutbank in 2000.

PRIMARY AND SECONDARY STRATIGRAPHIC MARKERS AND CORRELATION

PRINCIPAL CORRELATION EVENT (MARKER) AT THE GSSP LEVEL

The proposed GSSP level at Felsöörs section is Bed 105, defined by the first appearance (FAD) of the ammonoid species *Reitziites reitzi* (Böckh, 1872). This species is the index fossil of the Reitzi Zone and its Reitzi Subzone (Vörös et al. 1996). It is a reliable guide fossil and provides excellent correlation with the South Alpine key section Bagolino (FAD at 56.6 m: Brack & Rieber 1993). Moreover, *R. reitzi* is a suitable tool for long-distance correlation between widely separated areas of the Tethys and the western Pacific: it is also recorded from the Himalayas (L. Krystyn, pers. comm.), China (H. Kozur, pers. comm.) and Japan (Bando 1964).

DEFINITION USING OTHER STRATIGRAPHIC METHODS

OTHER BIOSTRATIGRAPHY

Apart from *Reitziites reitzi*, Bed 105 of the Felsöörs section also yielded *Parakellnerites cf. boeckhi* and *Hungarites sp*. This ammonoid assemblage characterizes the Reitzi Subzone of the Reitzi Zone in the section.

Bed 105 also yielded radiolarians of the *Oertlispongus* fauna (Dosztály 1993, Vörös et al. 1996) (Fig. 6). The FAD of the genus *Oertlispongus* marks the most pronounced change (turnover) in the radiolarian faunas of the Triassic and one of the strongest changes in the whole Phanerozoic (Kozur 1995a). This distinct change, that coincides with the FAD of Reitziites, is an important and useful correlation tool. It was recognised not only in the Tethyan but also in the Boreal and Notal realms of the Panthalassa, including the widespread area with radiolarites, where ammonoids are absent and conodonts are rare, represented by indeterminable juvenile forms only (Kozur 1995a, and references therein).

Unfortunately, the Vászoly Fm. in the Felsöörs section is almost barren of conodonts. The upper part of the underlying Felsöörs Fm. (Beds 87 to 99A) is characterized by *Gondolella constricta cornuta* and *G. liebermani*. The conodonts of the Felsoeoersensis and Liepoldti Subzones are well documented by the FAD of *G. constricta postcornuta* in the former subzone in the complementary Vászoly P-11/a section. The Reitzi Subzone is poor in conodonts in all the investigated sections of the Balaton Highland (Kovács et al., 1995). The FAD of *Paragondolella alpina* coincides with the FAD of *R. reitzi*, as documented from the Reitzi Subzone in the Bagolino section (Nicora & Brack 1995) and in the Vászoly P-2 section (S. Kovács, unpublished data). *P. alpina* has a wide distribution within and even outside the Tethys. Also synchronous with the FAD of *R. reitzi* is the FAD of another conodont species, referred to as *G. aff. eotrammeri* by Nicora & Brack (1995) but assigned to *Paragondolella praetrammeri* by Kozur. Regardless of the difference in taxonomic assignment, both Nicora & Brack (1995) and Kozur & Mostler (unpublished data from Bagolino) agree that the FAD of this taxon coincides with the FAD of *R. reitzi* in the Bagolino section.

A major change is recorded in the Avisianum Subzone, beginning in the Felsöörs section at Bed 111, with the appearence of eupelagic elements (*gladigondolelloids*) and typical Ladinian forms such as *G. trammeri* and *G. fueloepi* (the former most probably ranging up to the top of the Archelaus Zone, as documented in the Köveskál section). However, this change is much better documented in the complementary Mencshely section, where the Avisianum Subzone is represented by red crinoidal limestones (beds -6 to -1), rich in conodonts. This event was evidently facies controlled and no data is known from the lower subzones about the earlier history of the evolutionary lineages leading to these stratigraphically important forms. No changes in the conodont fauna is recorded in the higher part of the Vászoly Fm., which includes the Ticinites horizon and the Secedensis Zone.

Bed-by-bed conodont collections were made from the Nemesvámos Mb. of the Buchenstein Fm. (Kovács, 1993, 1994). Beds 120 to 155 yielded a rich eupelagic associa-

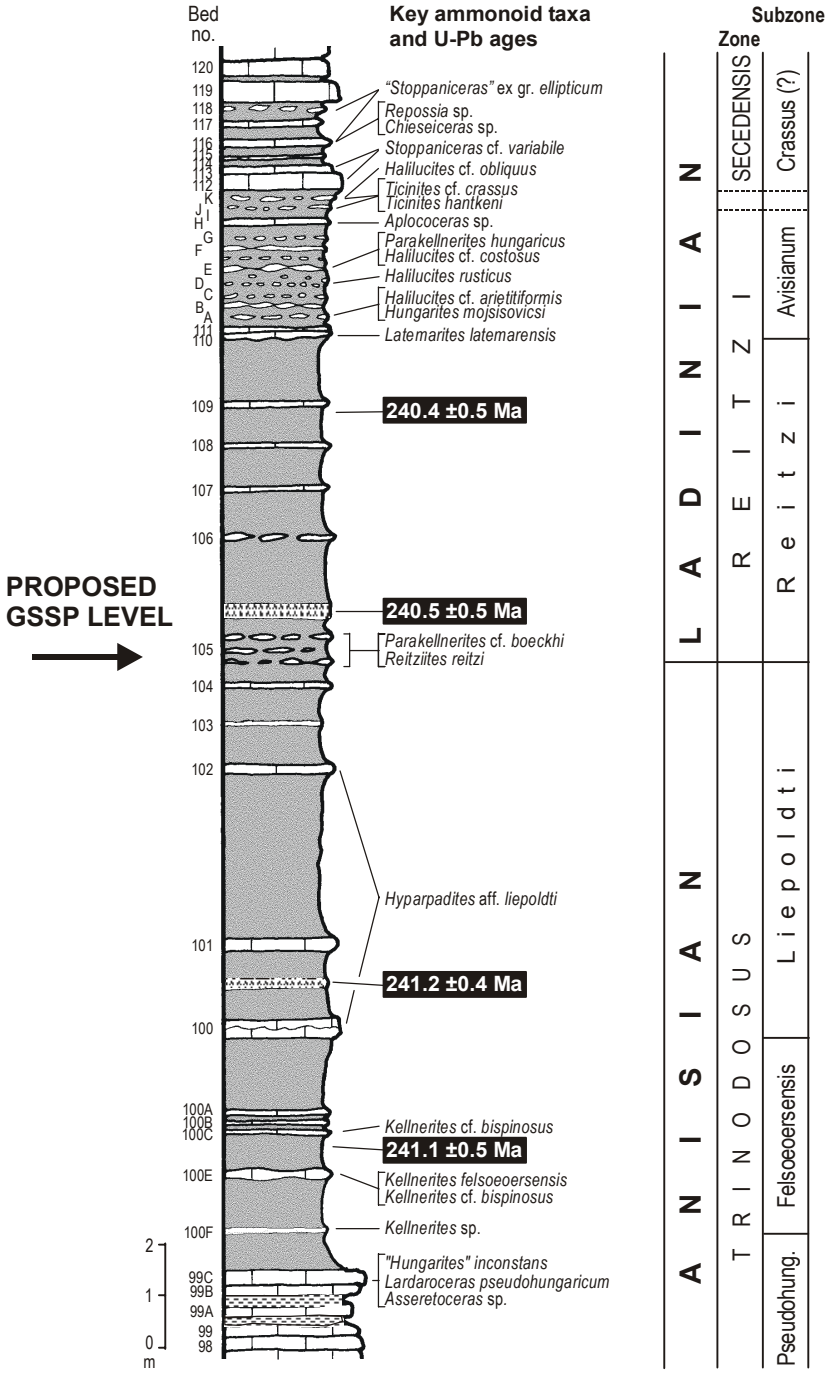

Fig. 5. Measured stratigraphic section at Felsöörs, showing the biostratigraphic subdivision based on occurrences of age diagnostic ammonoid taxa, the U-Pb ages of dated tuff layers, and the proposed GSSP level (modified from Pálfy et al. in press).

tion. The lowest ?*G. praehungarica* was found in Bed 123; in the Southern Alps it is known from slightly below the Curionii Zone (Nicora and Brack, 1995). *"Metapolygnathus" hungaricus*, an index for the upper part of the Curionii Zone and/or the Gredleri Zone, was obtained from Bed 151, which is above the range of *?G. praehungarica*.

The Felsöörs section contains one of the richest known Triassic palaeopsychrosphaeric ostracod faunas of the world (Kozur 1970, 1991). This cold bottom water fauna has a global distribution in the world oceans with the same composition in Boreal and tropical areas and provides a good correlation tool.

MAGNETOSTRATIGRAPHY

The thermally unaltered conodonts (CAI =1) in the Felsöörs section provide evidence for the lack of thermal overprint, allowing reliable magnetostratigraphic (and chemostratigraphic) studies. The proposed GSSP falls

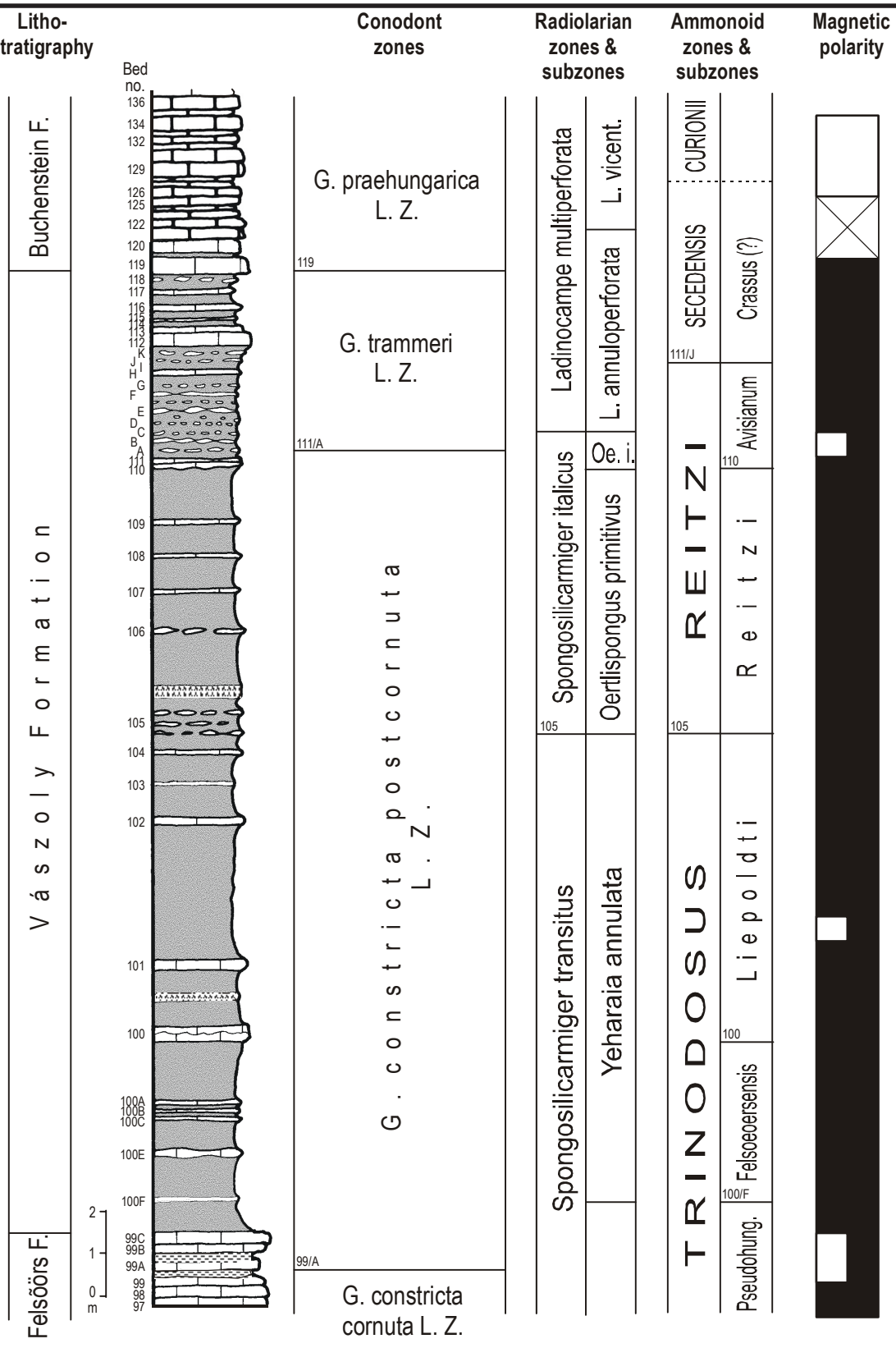

Fig 6. Integrated conodont, radiolarian, and ammonoid biostratigraphy of the Felsöörs section (modified from Márton et al. 1997). Abbreviations: Oe. i. – *Oertlispongus inaequispinosus*; L. vicent. – *Ladinocampe vicentinensis*.

within an extended normal polarity interval. Magnetostratigraphy of the Felsöörs section was summarised and discussed by Márton et al. (1998). Due to irregularly spaced and sporadic sampling at that time, the obtained magnetic polarity column was rather discontinuous. New sampling and recent results complemented the earlier data set and proved that the whole interval of the upper Trinodosus, Reitzi and lower Secedensis Zones

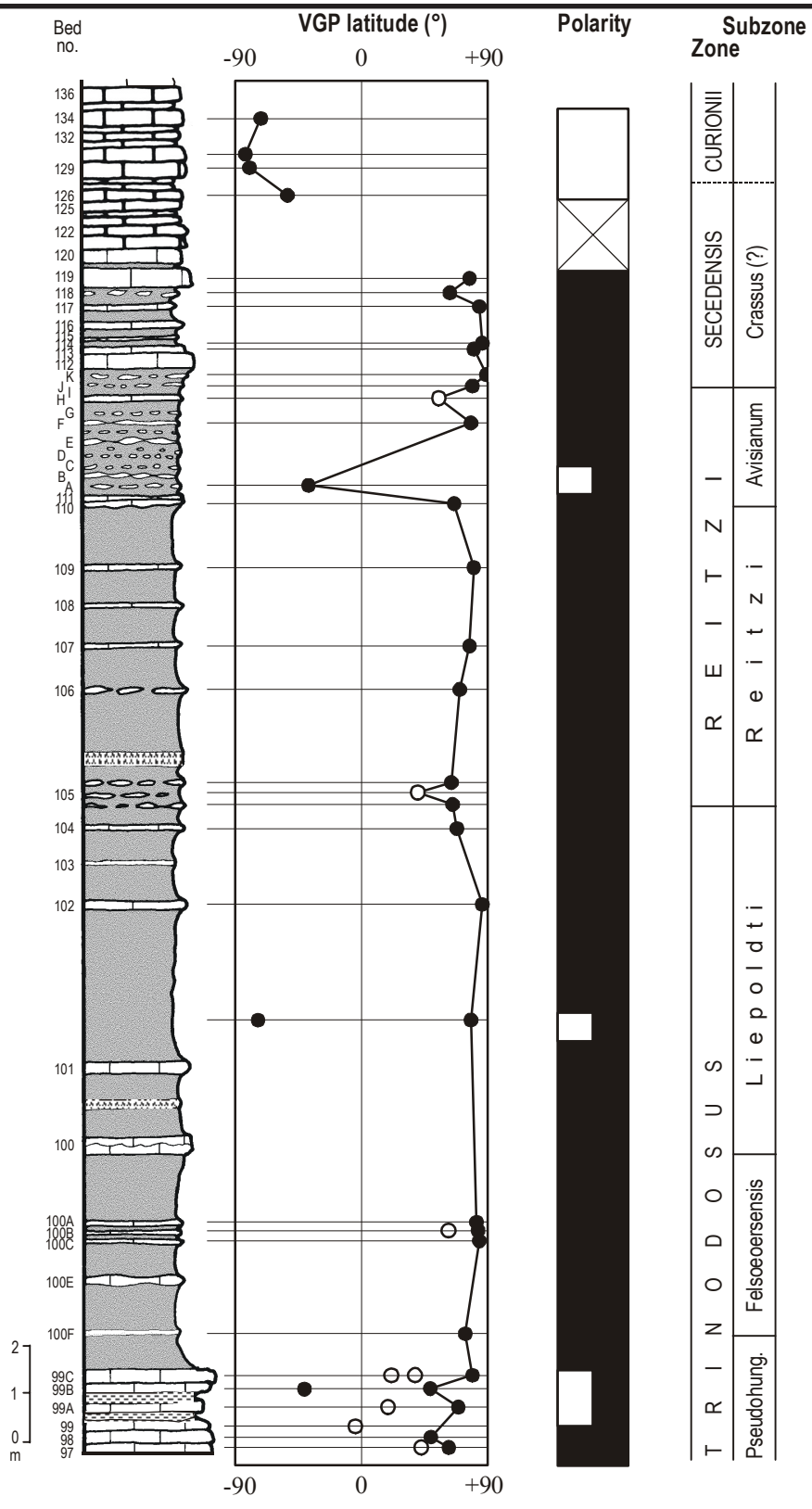

Fig 7. Magnetostratigraphy of the Felsöörs section

is characterised by normal polarity with a few hints to minor reverse episodes (Fig. 7, Vörös et al. 2002).

CHEMOSTRATIGRAPHY

The chemostratigraphy of the Felsöörs section was studied by Korte (1999). Within the Anisian/Ladinian boundary interval, francolite from conodont elements were analyzed for Sr isotope ratios from three samples in the Trinodosus Zone (beds 91, 99 and 100) and seven samples from the Avisianum Subzone of Reitzi Zone and the Secedensis Zone. The obtained values, mostly between 0.70777 and 0.70767, suggest a falling trend of the sea-

water $^{87}Sr/^{86}Sr$ ratio. It represents the best available dataset for this stratigraphic interval and contributes to the construction of the global Sr reference curve (Veizer et al. 1999). The decrease in the Sr isotopic ratio appears to be an overall trend for the entire Middle Triassic (Korte 1999). The Sr isotope stratigraphy holds global correlation potential, as amply demonstrated in other parts of the stratigraphic column. Specifically, it proves useful in correlation between the Tethys and the Muschelkalk basin in the Middle Triassic (Korte 1999).

Further Sr, together with carbon and oxygen isotopic data, were obtained from brachiopod shells in the Pelsonian crinoidal-brachiopodal limestone of the Felsöörs Fm in the lower part of the section (Korte 1999). Although the $\delta^{13}C$ and the $\delta^{18}O$ curves are too flat to be stratigraphically useful, the paleotemperatures calculated from $\delta^{18}O$ values provide independent isotopic evidence that the area belonged to the tropical climatic belt in the Middle Triassic.

SEQUENCE STRATIGRAPHY

The lower part of the Felsöörs section represents the third sequence within the Anisian of the Balaton Highland (Haas and Budai, 1999). The lower part of the Middle Anisian depositional sequence is composed of the restricted inner ramp facies of the Megyehegy Dolomite Formation. The overlying flaser bedded cherty limestones (Felsöörs Fm.) represent the maximum flooding interval, while the brachiopod-crinoid bearing limestones (Binodosus Subzone, Márton et al., 1997) mark definite shallowing (HST). Dark grey limestones with marl intercalations in the upper part of the section represent the initial stage of the next transgression period (Trinodosus Subzone). Detailed investigation of the ostracode assemblage and ammonoids of the Vászoly Formation (Vörös, 1996) revealed a deepening trend up to the top Reitzi Zone. The proposed GSSP level lies within this transgressive systems tract.

OTHER EVENT STRATIGRAPHY

The Reitzi Zone at FelsQörs is dominated by tuffites. A radiometrically dated, greenish brown weathering, coarse-grained, feldspar-rich crystal tuffite layer of 20 cm thickness lies 45 cm above bed 105. Correlation of individual tuff horizons between distant areas may seem hazardous, nevertheless it is assumed that this layer can be correlated with one of the higher tuffs in the Reitzi Zone, below the tuff labeled Tb in the Bagolino section (Brack and Rieber 1993).

CYCLOSTRATIGRAPHY

No record of cyclic sedimentation is preserved in the section.

MARINE–TERRESTRIAL CORRELATION POTENTIAL

Although no sporomorhs were found in the FelsQörs section, boreholes in the neigbourhood (e.g. Balatonfüred Bf-1) yielded a rich assemblage from the boundary interval (Góczán & Oravecz-Scheffer, 1993) that makes possible the correlation of the marine and continental successions. There is a radical change in the palynomorph association slightly below the top of the Felsöörs Formation, i.e. just below the base of the Reitzi Zone. This is registered by the first occurrence of genera *Cannanoropollis* and *Kuglerina* and a significant change in the species of genus *Triadispora* (Góczán, 1994). Above this event no significant change could be detected in the association up until the basal part of the Longobardian.

GEOCHRONOMETRY

The Anisian/Ladinian boundary interval contains abundant tuff layers that are amenable to radiometric age determination. Zircons extracted from four layers were dated using the U-Pb method (Pálfy et al., in press). Stratigraphically closest to the proposed GSSP is a 15 cm thick, brown weathering, coarse-grained, feldspar-rich crystal tuff layer that lies 45 cm above Bed 105 (Fig. 5). The sample yielded abundant, colourless zircons of excellent clarity. Of the four analysed multi-grain fractions, three intersect the concordia curve and overlap one another, whereas one fraction is discordant suggesting minor inheritance. We use their concordia age of 240.5±0.5 Ma, calculated on the basis of the three concordant fractions, as the best estimate of the crystallization age of the tuff. This estimate is also used for the numeric age of the proposed Anisian/Ladinian boundary. It is consistent with three other U-Pb dates obtained from the Felsöörs section: 241.1±0.5 and 241.2±0.4 Ma from the underlying Felsoeoersensis and Liepoldti Subzones, respectively, and 240.4±0.4 Ma from the higher part of the Reitzi Subzone. These dates are also in agreement with single crystal U-Pb dates from slightly higher Ladinian horizons in the Southern Alps (Mundil et al., 1996).

Further U-Pb dating using single zircons from FelsQörs will be carried out in 2003. The tuff layers can also be dated by the $^{40}Ar/^{39}Ar$ method.

DEMONSTRATION OF REGIONAL AND GLOBAL CORRELATION

The base of the Reitzi Subzone is well defined by the FAD of *Reitziites reitzi* (and other, perhaps synonymous species of *Reitziites*, e.g. *R. cholnokyi*) in many sections of the Balaton area: at Bed 105 in Felsöörs, Bed 5 in Mencshely (Cser-tetQ II) and Bed 10 in Szentkirályszabadja (Vörös 1993, 1998, Vörös et al. 1996) (Fig. 8). The same distinct horizon, with the appearance of *Reitziites* species, was also recorded in Bed 14 at Vászoly (P-11/a), and Bed –9 at Mencshely (Cser-tetQ I), where the occurrence of *Ticinites hantkeni* hints to sedimentary condensation (Vörös 1993, Vörös et al. 1996).

As mentioned above, the FAD of *Reitziites reitzi* is an excellent tool for correlation with South Alpine sections: it was clearly demonstrated in Bagolino (at 56.6 m, Brack & Rieber 1993); *R. reitzi* was also recorded at Pertica, in the topmost layer of the lower section (Brack et al. 1995). Moreover, findings of *R. reitzi* from the Himalayas, China and Japan demonstrate the long-distance correlation potential of this level.

SELECTION PROCESS

Relation of the GSSP to historical usage

The Reitzi Zone at Felsöörs has historical priority as the basal biostratigraphic unit of the Ladinian. The fossiliferous beds at Felsöörs provoked the interest of the scientific community as early as the 1870's when bed-by-bed collections were made and some peculiar ammonoids were described from the "yellow, siliceous limestones of Forráshegy" by Roth (1871), Böckh (1873), and Stürzenbaum (1875). The results were included in the monograph of Mojsisovics (1882) who defined his "Zone des *Trachyceras Reitzi*" partly by the findings from Felsöörs. He placed this zone to the base of his "Norische Stufe" which was later renamed by Bittner (1892) as Ladinian. The content, range and status of Mojsisovics' Reitzi Zone has subsequently changed several times. Its upper part was formally separated as the Curionii Zone. The „Avisianus zone" was established as a replacement or it referred to the underlying unit. The Reitzi Zone was also substituted by the "*Parakellnerites*" and/or the "*Nevadites*" zones and consequently, it was transferred to the Anisian by some authors. The Reitzi Zone was redefined at Felsöörs (Vörös 1993) and, on the basis of a more inclusive interpretation, the FAD of *Kellnerites* was suggested as the base of the Ladinian (Vörös et al. 1996).

The proposed GSSP (Bed 105 of the FelsQörs section) corresponds to the base of the Reitzi Subzone of Vörös et al. (1996). This sensu stricto interpretation of the Reitzi Zone is in agreement with the usage of Vörös & Pálfy (1989), Kozur (1995b) and Kozur et al. (1995), who used the FAD of *Reitziites reitzi* as the base of the Ladinian.

OTHER CANDIDATES AND REASONS FOR REJECTION

Three other formerly suggested candidate levels for drawing the base of Ladinian are rejected here for the following reasons:

Candidate 1, at the first appearance of *Kellnerites* (i.e. Reitzi Zone sensu lato) fulfils the requirements of integrated biostratigraphic approach and is useful for correlation. However, as repeated (partly informal) voting has demonstrated, it seems unlikely to be accepted by the entire community of Triassic stratigraphers.

Candidate 2, at the first appearance of *Nevadites*, has serious shortcomings in terms of biostratigraphic correlation potential because of the debated taxonomy and rare occurrence of *Nevadites* in the Alpine sections, and because no distinct microfaunal changes are observed at this horizon.

Candidate 3, at the first appearance of *Eoprotrachyceras* (i.e. base of the Curionii Zone) is rejected because (1) the alleged advantage of intercontinental correlation on the basis of FAD of the genus *Eoprotrachyceras* is problematic. Numerous other Mesozoic examples illustrate that first appearances of ammonoid genera are often diachronous between Europe and North America. Independent evidence for synchrony of the " *Eoprotrachyceras* datum" between the Tethyas and eastern Pacific is still lacking; (2) the microbiostratigraphic tools of correlation are limited to conodonts, but the FAD of the diagnostic *Budurovignathus truempyi* postdates and ?*Gondolella praehungarica* demonstrably predates the FAD of *Eoprotrachyceras*; and (3) this time horizon would undesirably cut across vast carbonate platform bodies in the Alpine region (major portion of Wetterstein-type carbonate platforms, traditionally regarded Ladinian in age, would thus be transferred chronostratigraphically to the Anisian).

Selected publications

The key references describing various aspects of the stratigraphy of the Felsöörs section are the following (many more relevant papers are listed in the References):

Dosztály, L. 1993. The Anisian/Ladinian and Ladinian/Carnian boundaries in the Balaton Highland based on Radiolarians. Acta Geologica Hungarica, 36 (1): 59-72.

Kovács, S. 1993. Conodont biostratigraphy of the Anisian/Ladinian boundary interval in the Balaton Highland, Hungary and its significance in the definition of the boundary (Preliminary report). Acta Geologica Hungarica, 36 (1): 39–57.

Kovács, S., Dosztály, L., Góczán, F., Oravecz-Scheffer, A. and Budai, T. 1994. The Anisian/Ladinian boundary in the Balaton Highland, Hungary — a complex microbiostratigraphic approach. Albertiana, 14: 53–64.

Márton, E., Budai, T., Haas, J., Kovács, S., Szabó, I. and Vörös, A. 1997: Magnetostratigraphy and biostratigraphy of the Anisian-Ladinian boundary section Felsöörs (Balaton Highland, Hungary). Albertiana, 20: 50–57.

Pálfy, J., Parrish, R. R., David, K., and Vörös, A. 2003 (in press). Middle Triassic integrated U-Pb geochronology and ammonoid biochronology from the Balaton Highland (Hungary). Journal of the Geological Society (London), 160 (2).

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OTHER USEFUL SECTIONS

There are further sections in the Balaton area (Mencshely, Vászoly, Szentkirályszabadja) which provided important additional information to the knowledge of ammonoid and conodont stratigraphy of the Felsöörs section and which may help in the correlation of the proposed GSSP horizon (i.e. base of the Reitzi Subzone). The sections were described in Vörös (1993, 1998), Vörös et al. (1996).

Mencshely (CsertetQ I. and II.). The lowermost beds of these sections belong to the Anisian Felsöörs Formation (grey limestone beds with clay intercalations). This is followed by ash-grey tuffites of the Vászoly Formation in

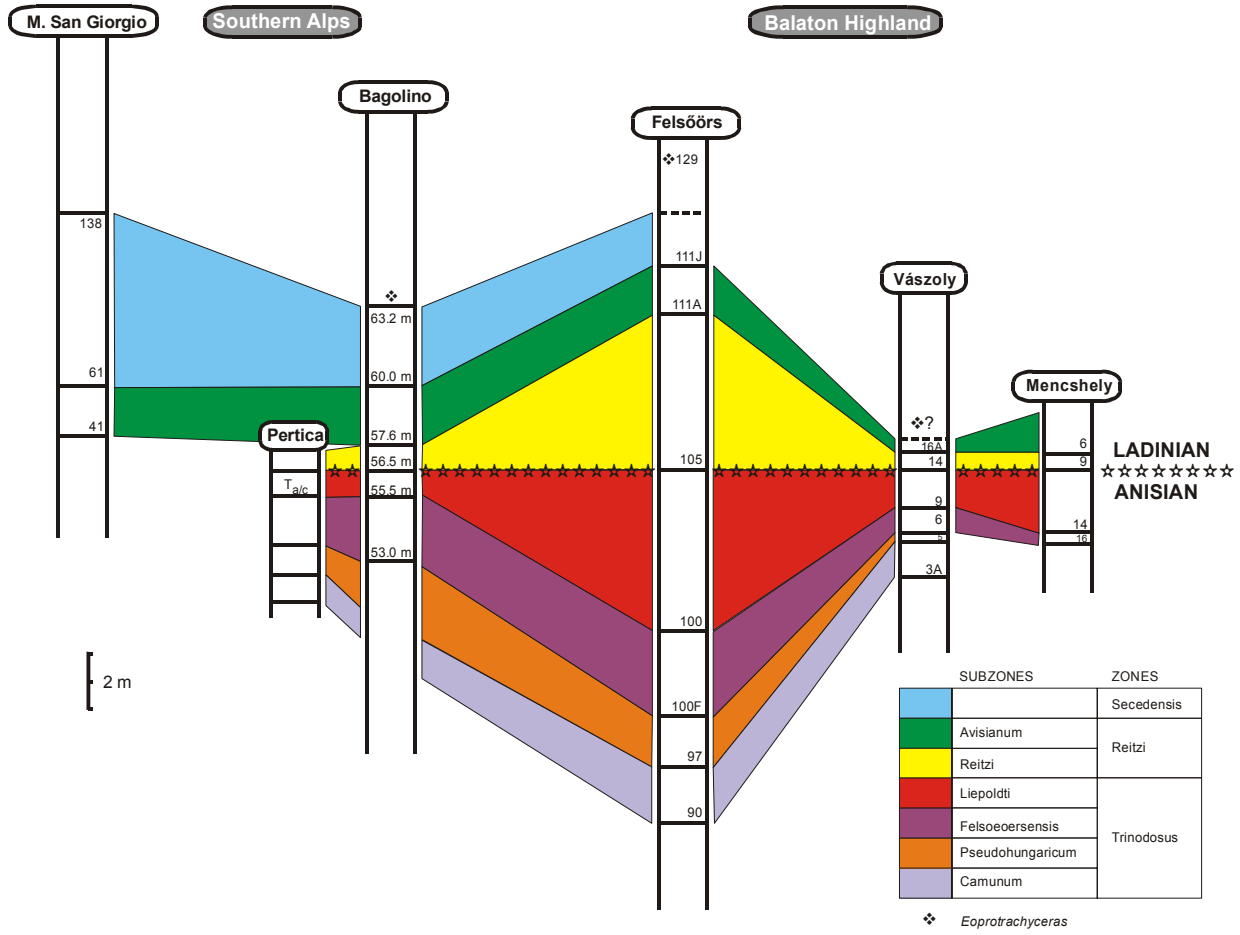

Fig. 8. Correlation of Felsöörs and other key Anisian/Ladinian boundary sections in the Balaton Highland and Southern Alps.

about 4 m thickness, containing a few, thin (8-10 cm) yellow and grey cherty limestone intercalations. The higher part of the tuffitic sequence becomes pinkish and passes into reddish-bown clay with limestone lumps. These crinoidal, tuffitic limestone lumps yielded a very rich ammonoid fauna. With gradually decreasing amount of clay, massive crinoidal limestone beds appear. The uppermost member of the exposed sequence is light-coloured micritic limestone. The sequence accumulated in a basin of low sedimentary rate and represents the Felsoeoersensis to Avisianum Subzones of the Reitzi Zone. The base of the Reitzi Subzone can be pinpointed at Bed –9 in Cser-tetQ I. and at Bed 5 in Cser-tetQ II., by the appearance of *Reitziites reitzi*, *R. cholnokyi*, *Hungarites ? arthaberi*, *Latemarites ? conspicuus* and *Ticinites* cf. *hantkeni*.

Vászoly. From the numerous localities of the Öreg-hegy (Öreg Hill) between the villages Vászoly and Pécsely, the section "P-11/a" was best studied. Here the Anisian Megyehegy Dolomite is followed by yellow tuffites alternating with limestone and massive dolomite layers in 2 m thickness (Vászoly Formation). Above this, the yellowish tuffites become dominant and contain sporadic calcareous lumps. The higher part of this 3 m thick sequence consists of tuffitic clay containing big blocks of yellow crinoidal limestone with plenty of ammonites. The exposed sequence is terminated with massive beds of light-coloured micritic limestone (Vászoly Limestone). The sequence was deposited on the top of a submerged platform (pelagic plateau) and represents the uppermost part of the Trinodosus Zone and the Reitzi Zone (Camunum to Avisianum subzones). The base of the Reitzi Subzone was drawn at Bed 14, where *Reitziites reitzi*, *R. cholnokyi*, *Ticinites* cf. *hantkeni* and *Nevadites ?* cf. *symmetricus* were found, suggesting stratigraphic condensation.

Szentkirályszabadja. The lower part of the sequence consists of thick dolomite beds alternating with yellow clays. Higher up the dolomite becomes thin-bedded and crumbly and contains volcanoclastic admixture; then alternates with limestone, but the crumbly and tuffitic character remains constant throughout the sequence. The uppermost beds are again pure dolomites but since they contain a few poorly preserved ammonite "ghosts" they must have been pelagic limestones dolomitized secondarily. The sequence was deposited during a pelagic episode on a drowned and later revived carbonate platform and represents the the uppermost part of the Trinodosus Zone and the Reitzi Zone (Pseudohungaricum to Reitzi Subzones). The base of the Reitzi Subzone is at Bed 10, where

Reitziites reitzi occurs.

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