

# Latest Triassic conodonts of the Slovenian Basin and some remarks on their evolution

## Zgornjetriasni konodonti Slovenskega bazena in njihov evlucijski razvoj

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*Ključne besede:* konodonti, zgornji trias, biostratigrafija, Koblja, Slovenski bazen

### Abstract

A stratigraphical importance of some latest Triassic conodont taxa from the Slovenian Basin with special regard on their distribution in the Slatnik Formation of the Mt. Koblja section (Julian Alps) is presented. Description of a new species *Misikella buseri* n. sp. is given. It is marked by a reduced segminate element and it represents a distinct stage at the decline of *Misikella* evolution.

### Izvleček

Prikazan je stratigrafski pomen nekaterih pomembnih zgornjetriasnih konodontnih rodov v Slovenskem bazenu s posebnim poudarkom na njihovem pojavljanju v Slatenski formaciji profila Koblja (Julijske Alpe). Opisana je nova vrsta *Misikella buseri* n. sp., za katero je značilen zmanjšan segminatni element in predstavlja eno od zaključnih stopenj ob koncu razvoja rodu *Misikella*.

### Introduction

The phylum Conodonta was one of the groups that became extinct at the Triassic–Jurassic boundary (TJB) when one of the five largest mass extinctions of the Phanerozoic marine record occurred (SEPKOSKI & RAUP, 1986). There are very few reports of Jurassic survivals and KOZUR (1993) documented *Neohindeodella detrei* from the earliest Hettangian of Csóvár in Hungary. During the latest Triassic conodonts therefore suffered major decline in diversity and their extinction can be interpreted as the cumulative result of several causal factors and not of a single catastrophic event (CLARK, 1983). There is an evident decline of conodont taxa from Carnian–Norian boundary strata. Many gondolellids last appeared in the Norian, but a few range into the lower Rhaetian, for example *E. bidentata* as the last epigondolellid representative. Only few gondolellids, such as *Norigondolella* and the platform-less *Parvigondolella* and *Misikella*, persisted during the latest Triassic.

The study of conodonts has resulted in the recognition of several stratigraphically significant conodont species belonging to the genera: *Budurovignathus*, *Epigondolella*, *Gladigondolella*,

*Metapolygathus*, *Misikella*, *Neogondolella*, *Nico-raella*, *Norigondolella* and *Paragondolella* in the Middle and Late Triassic strata of the Slovenian Basin (BUSER et al., 2007, 2008). The youngest Triassic conodont assemblages are marked by the presence of *Misikella*, a genus already described from western Slovenia of the Pokljuka plateau and from the Mt. Šija area (KOLAR-JURKOVŠEK et al., 1983; KOLAR-JURKOVŠEK, 1994).

The aims of this paper are to give a brief review of the Upper Triassic conodont genera known from Slovenia (KOLAR-JURKOVŠEK, 1991; BUSER et al., 2007, 2008), and to describe a new *Misikella* species, *Misikella buseri* n. sp., from the Rhaetian strata of the Slovenian Basin, sampled in the Mt. Koblja section (Fig. 1).

### Previous research

The existence of Late Triassic deep-water sediments in western Slovenia was recognized by many authors (WINKLER, 1923; AUBOUIN, 1960; COUSIN, 1973). They were later object of several basic studies conducted by Buser (BUSER, 1986, 1987, 1989, 1996, 2003; BUSER & DEBELJAK, 1996; BUSER et al., 2007, 2008; BUSER & OGORELEC, 2008)

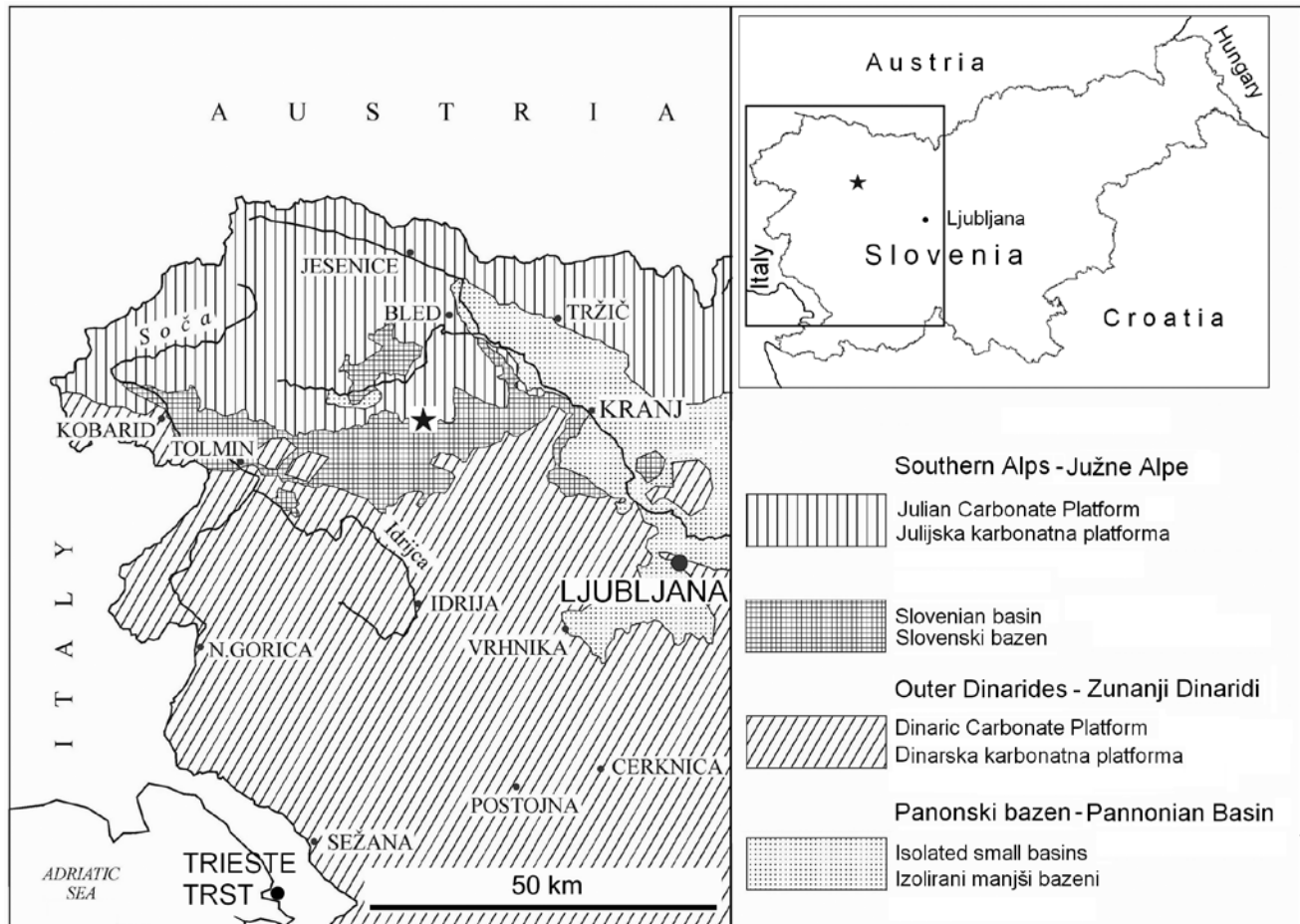


Fig. 1. Actual position of geotectonic units in western Slovenia with extension of sediments of the ancient Julian and Dinaric Carbonate Platforms and the intermediate Slovenian Basin with the position of the Mt. Koba section (star). Modified by BUSER et al. (2007).

and are currently object of multidisciplinary study carried out by Rožič and co-workers (Rožič, 2008, 2009; Rožič & KOLAR-JURKOVŠEK, 2007; Rožič et al., 2009; GALE, 2010).

The Slovenian Basin extends in an east-west direction of central Slovenia and became established during the Ladinian following disintegration of the Slovenian Carbonate Platform and it persisted continuously until the Late Cretaceous (BUSER, 1989; BUSER et al., 2007, 2008). The basin pinched out in the Soča river valley and was not connected to the Belluno Basin (BUSER, 1986). From the eastern part of present Slovenia, it continues across Croatia north of Zagrebačka gora to Hungary. The present exposed parts of the Slovenian Basin measure in length about 170 km and in width about 40 km (BUSER et al., 2007, 2008).

After the basic research by BUSER (1986, 1987; BUSER & OGORELEC, 2008) the Mt. Koba section was sampled and measured also by Rožič et al. (2009). They discriminated the non-dolomitized uppermost part of the Bača Dolomite Formation by formalizing this unit and introducing the Slatnik Formation formed of hemipelagic limestone alternating with resedimented limestone indicating a progradation of sedimentary environments from the the basin plain to the lower slope (Rožič, 2008). The Slatnik Formation is preserved in the

northern part of the basin where the latest Triassic succession experienced less intense diagenetic alteration. The Late Triassic part of the Mt. Koba section is documented by three upward prograding high-frequency cycles. The Triassic part of the section is followed by the Krikov Formation of Jurassic age. The authors also provided conodont data and they recognized three latest Triassic conodont zones: *Epigondolella bidentata*, *Parvigondolella andrusovi-Misikella hernsteini* and *Misikella hernsteini-Misikella posthernsteini* Zones (Rožič et al., 2009). A more detailed sampling of the interval with the finding of *M. posthernsteini* provided new data and enabled a more precise documentation of the latest zone. Thus, the *Misikella posthernsteini* Assemblage Zone can be divided into two units: the *Misikella hernsteini-Misikella posthernsteini* and the *Misikella koesenensis* Subzones (GALE et al., submitted). The recovered conodont faunas include representatives of *Epigondolella*, *Misikella*, *Norigondolella*, *Oncodella*, *Parvigondolella* and *Zieglerioconus*. The new species of *Misikella* was collected in the interval from 76,0 to 77,8 m of the Mt. Koba section (Fig. 2). A detail description of the investigated section along with biostratigraphic conclusions based on conodonts and foraminifers is given in GALE et al. (submitted).

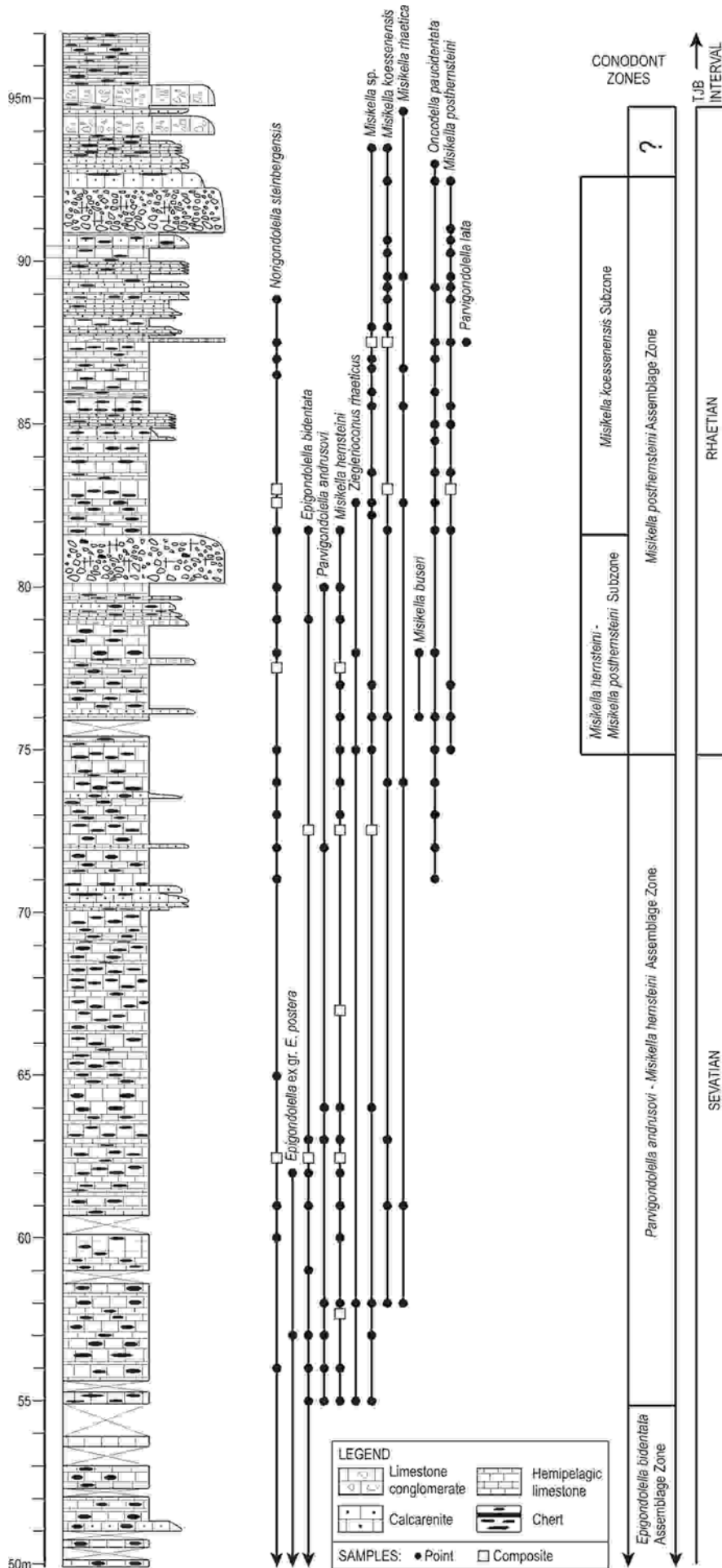


Fig. 2. Geological column of the Mt. Kobra section with conodont distribution. Modified after GALE et al. (submitted).

### Geological setting

The Mt. Kobra section (x = 5121,590, y = 5420,550, z = 1498 m) is located on the southern brim of the the Julian Alps (Fig. 1, 2) and preserves the Upper Norian – Lower Jurassic succession of the Slovenian Basin (Rožič et al., 2009). This area is part of the Tolmin Nappe that together with the overlying Julian Nappe structurally forms the eastern part of the Southern Alps (PLACER, 1999, 2008). The Slovenian Basin is one of the three paleogeographic units that existed during the Late Triassic in the territory of Slovenia. These are (from north to south): the Julian Carbonate Platform, the Slovenian Basin and the Dinaric Carbonate Platform (BUSER, 1986, 1989, 1996) (Fig. 1).

### Significant conodont taxa in the latest Triassic

*Norigondolella* is represented by the long-ranging species *N. steinbergensis*. It is an extremely facies dependant species that can be found in fully pelagic sediments of open sea (cherty limestone) of the latest Triassic and therefore it is not stratigraphically important outside this facies (KOZUR & MOCK, 1991). In the Mt. Kobra section in Slovenia, the LAD of *N. steinbergensis* is documented in the upper *Misikella posthernsteini* A. Z. (= *Misikella koessenensis* – *Misikella posthernsteini* Subzone) at 88,7 m.

Genus *Parvigondolella* evolved from *Epigondolella bidentata* as the ultimate stage in epigondolellid evolution. The genus however is quite rare as can be explained by its existence at the end of evolution of an important stock and it is represented by only few species: *P. andrusovi*, *P. ? lata*, *P. rhaetica*, *P. vrielyncki*. Some authors regard the platform-less gondolellid forms as juvenile forms of *E. bidentata*

named as the *andrusovi* stage (KRYSZYN, 1980; KRYSZYN et al., 2007). However, such a view was rejected based on different stratigraphic occurrences, as *Parvigondolella* ranges up high in the Rhaetian interval that is beyond the highest occurrence of *E. bidentata* or any other platform-bearing metapolygnathid (KOZUR & MOCK, 1991). The latter authors also supported their statement by noting the size of the different stages and that certain parameters (size and number of denticles, height of blade) of younger ontogenetic stages cannot exceed the parameters of the largest adult specimens. KOZUR & MOCK (1991) documented their view based on reports of the quite widespread appearance of *Parvigondolella* in the Rhaetian of Alps, Carpathians, Hungary, Lagonegro Basin that is also confirmed now with data from Slovenia.

Some **ramiform elements** are also present but are rather rare. Nevertheless in a few cases they permit apparatus reconstruction. Among them KOZUR & MOSTLER (1991) reported also a stratigraphically most important species *Neohindeodella detrei* as an index species for the youngest strata above the last occurrence of *Misikella* and these authors stated the form seems to be homeomorph with forms known from older strata of the Late Triassic.

**Zieglerioconus** has been known to appear with only one representative, *Z. rhaeticus*, but new Norian species have yet not been described (CHANNELL et al., 2003). It is a secondary single cone conodont with a widely expanded and excavated basal cavity. *Zieglerioconus* was first described from the Rhaetian (*M. koessenensis* Subzone) of Csővár in Hungary, and it is rare species that has been so far reported only from Great Britain what means it appears in sediments of the pelagic Tethys and non-pelagic of outer Tethys in the Germanic Basin (KOZUR & MOCK, 1991; SWIFT, 1989; PÁLFI et al., 2007). The hitherto known occurrences of the species are quite typical for the *M. koessenensis* Subzone, but *Zieglerioconus* begins in the uppermost Carnian and occurs throughout the Norian (CHANNELL et al., 2003; KOZUR, pers. comm.). New data from Slovenia confirm the existence of *Zieglerioconus* in the late Sevatian. In the Kobla section, *Zieglerioconus* ranges from *Parvigondolella andrusovi-Misikella hernsteini* A. Z. to lower *Misikella koessenensis* Sz. of the *Misikella posthernsteini* Zone. The origin of *Zieglerioconus* is still yet not known, but KOZUR & MOCK (1991, p. 277) suggested its forerunner could be a *Misikella* of the *M. longidentata* group or *Oncodella paucidentata*. According to recent data from Slovenia, *Zieglerioconus* and *M. hernsteini* made their first appearance together in the *Misikella hernsteini-Parvigondolella andrusovi* A. Z. in absence of *Oncodella* and thus, documenting the existence of *Zieglerioconus* in the latest Norian strata (Fig. 2; Pl. 1, Fig. 2). The forerunner of *Zieglerioconus* and *M. hernsteini* is therefore supported to be linked with the *M. longidentata* group.

***Oncodella paucidentata*** is a characteristic element that already appeared in the uppermost Sevatian and it is also a facies controlled species (KOZUR & MOCK, 1991). In Slovenia, it ranges from the upper part of the *Parvigondolella andrusovi-Misikella hernsteini* A.Z. up to an un-named *Misikella* Zone that corresponds to the known range of the species elsewhere.

Genus ***Misikella*** is most important for the stratigraphy of the Late Sevatian-Rhaetian interval. Some biostratigraphic schemes have been reported so far and they are slightly different (MOSTLER et al., 1978; GAZDZICKI et al., 1979; KRYSZYN, 1980, 1987; KOZUR, 2003; KRYSZYN et al., 2007). In 1991, KOZUR and MOCK made a report on stratigraphic value of certain conodont taxa. The main intent was to eliminate *M. rhaetica* (it appeared already in the uppermost Sevatian) as an index form for the zone introduced by MOSTLER et al. (1978) as it is strongly facies controlled and occurs already at levels with frequent *M. hernsteini*. From the upper part of the *M. posthernsteini* A.Z. they gave a description of the *Misikella koessenensis* Subzone (originally described by Kozur 1989) as a substitute of the *M. rhaetica* Zone of earlier schemes, and the author noted also to a shorter range of *Misikella koessenensis*. The first appearance of *Misikella posthernsteini* is an important biomarker used to define the Norian-Rhaetian boundary (KOZUR & MOCK, 1974b, 1991; KOZUR, 1996; KRYSZYN, 1980, 1987; BIRKENMAJER et al., 1990). On the other hand, *M. ultima* is a facies independent species and therefore it is very good boundary marker of the *M. ultima* A. Z. (the lower boundary is defined by FAD of the index species, but the upper boundary is marked by the disappearance of *Parvigondolella* and *Misikella*) (KOZUR & MOCK, 1991).

### Evolution of *Misikella*

The evolutionary trend *M. hernsteini* – *M. posthernsteini* – *M. ultima* is well known (KOZUR & MOCK, 1991). The phylomorphogenetic line between *M. hernsteini* and *M. posthernsteini* was documented first by MOSTLER et al. (1978) and was recently studied by GIORDANO et al. (2010) in which transitional forms are arranged in three evolutionary steps. *Misikella hernsteini* is characterized by a long blade composed of 5–6 denticles and an appropriately long and narrow basal drop-shaped basal cavity. The step 1 in the evolution of *M. hernsteini* – *M. posthernsteini* is marked by a shorter blade with a decreased number of denticles (four in number); the basal cavity is enlarged and has a markedly expanded posterior part with a rounded or triangle-like outline but is devoid of any incision. The increase of the height of denticles is obvious. The length : height ratio (L : H) in *M. hernsteini* is 2 : 1,5 whereas in the step 1 of the *H. hernsteini* – *H. posthernsteini* evolutionary trend is almost 1 : 1. This step corresponds descrip-

tion of *H. koessenensis*. In general, there are very rare *Misikella* specimens bearing denticles behind the cusp and all of them belong to *M. rhaetica*. The size of *M. koessenensis* is comparable to the size of *M. hernsteini*, whereas in the *M. posthernsteini* an increase in height may be seen. In this study, short and high elements that reveal no posterior denticle, composed of 3–5 denticles and an appropriate ratio L : H are included to *M. koessenensis* sensu lato rather than make a compromise to regard these forms as *Misikella* n. sp. B, as suggested by Kozur (pers. comm.). Mostler originally wrote that most specimens of *M. koessenensis* have slender denticle behind the cusp. Thus, the Slovenian specimens fit the original diagnosis of the taxon. However, most conodont workers so far included only specimens with posterior denticle(s) to this species, and therefore an emendation of *M. koessenensis* should be done. In the faunas of the investigated Kobla section such elements make their first appearance at 58 m, 3 metres above the first occurrence of *M. hernsteini*. The following two evolutionary steps 2 and 3 leading towards *M. posthernsteini* are marked by a progressive degree of incision in the posterior part of the basal cavity that causes a heart-shaped lower outline, and parallel to this also a reduction of denticles ending in three-dentate elements with a noticeable larger size.

Two lines can be seen in evolution of *Misikella*. They are represented by *M. hernsteini* and *M. posthernsteini*. The *M. hernsteini* evolutionary line is marked by a slight reduction of overall unit size, whereas in the *M. posthernsteini* line an enlargement of overall size is evident. Both lines are marked by a reduction in the number of denticles. The evolutionary trend in the two lines is practically identical if one takes into consideration the outline of the lower side that is drop-shaped in *M. hernsteini* and heart-shaped in *M. posthernsteini*, respectively.

We agree with observation of GIORDANO et al. (2010) that the outline of the basal side is important and it is used as the main criterion to distinguish *M. hernsteini* and *M. posthernsteini*. Their evolution from units with an oval basal area in *M. hernsteini* is documented with a series of transitional forms leading to elements with an evident inflexion ending in a heart-shaped basal side of *M. posthernsteini*. Arguments of MOIX et al. (2007) claiming that the lower area is important for recognition of Sevatian-Rhaetian taxa is in general supported. They argued the lower side of *M. rhaetica* does not extend to the full length of the lower side of the element but extends only 2/3. Therefore they assigned »M.« *rhaetica* to *Parvigondolella*. The original diagnosis of *M. rhaetica* includes elements bearing 1–3 smaller denticles behind the cusp and the basal cavity extends only 2/3 of the lower side in most specimens (MOSTLER et al. 1978). In this study, the elements of *Misikella* with 1–2 denticles of smaller size behind the cusp and with a widely opened

basal area extending nearly the full length are attributed to *M. rhaetica* as illustrated in Rožič et al. (2009, Fig. 9e). Thus, the species name *Misikella rhaetica* sensu lato is used herein. Similar specimens are regarded as long *M. hernsteini* by Kozur (pers. comm.) or are assigned to *Misikella* n. sp. A by MUTTONI et al. (2010). Emendation of *M. rhaetica* is therefore needed as the original diagnosis includes also specimens with longer basal area. However, based on the material from Slovenia, we may conclude that there exists a strong homeomorphism in morphology of *Misikella rhaetica* and *Parvigondolella rhaetica*.

The known origin of *Misikella* started with *M. hernsteini*, as its forrunner is yet still not known. However, it could be linked with *M. longidentata*. *M. hernsteini* appeared during the late Sevatian in the *M. hernsteini* – *P. andrusovi* A. Z. Soon after appearance of *M. hernsteini* two lines of evolution can be noted that markedly differ in outline of the basal area. One line retained the drop-shaped basal area, whereas a heart-shaped basal area is evident in the second:

1. Evolutionary line: *M. hernsteini* – (*M. rhaetica*) – *M. koessenensis* – *M. buseri*. Already in the lower *M. hernsteini* – *P. andrusovi* A. Z. two species, *M. koessenensis* and *M. rhaetica* evolved. According to data from Slovenia the two taxa appeared simultaneously where specimens of *M. koessenensis* with no denticles posterior to the cusp were collected. Such forms gave rise to *M. buseri* that represents a final step in this evolutionary line marked by obvious reduction of the overall size, decrease in number of denticles and proportional increase of the height of denticles.
2. Evolutionary line: *M. hernsteini* – *M. posthernsteini* – *M. ultima* – *M. kovacsi*:

This evolutionary line is marked by the evolution of a heart-shaped basal area in *M. posthernsteini* that was followed by *M. ultima* and *M. kovacsi*. *Misikella posthernsteini* evolved from *M. hernsteini* through several transitional forms and marks the lower bounday of the *M. posthernsteini* A. Z. The evolutionary trend *M. posthernsteini* – *M. ultima* – *M. kovacsi* is characterized by a decrease of overall size and in a marked reduction of number of denticles.

The two phylogenetic lineages share similar stages of evolution. *M. koessenensis* and *M. posthernsteini* evolved after common ancestor of both lines. At this stage two lines with a distinct forming of the basal area are evident. According to the Slovenian data, *M. koessenensis* and *M. rhaetica* evolved simultaneously from *M. hernsteini*. The intermediate stage is represented by *M. rhaetica* and *M. ultima*. The two species have been so far reported as a parallel step in *Misikella* evolution as they both reveal a secondary bar, but they

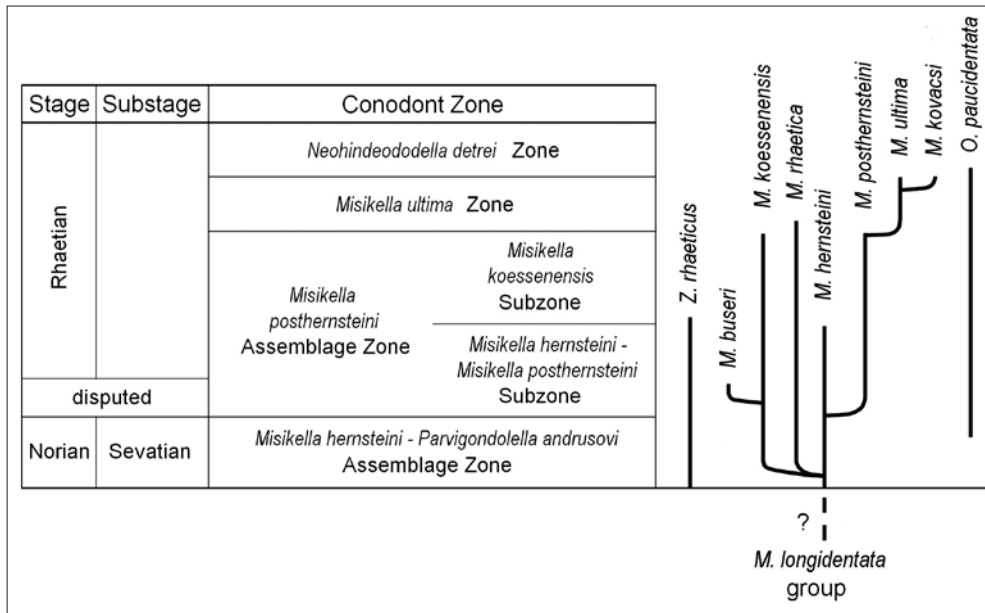


Fig. 3. Possible evolution of *Zieglerioconus* and *Misikella* from an unknown origin in the Middle Norian. The chart is based on occurrences in the Slovenian Basin except for the *M. ultima* and *M. kovacsi* occurrences are after KOZUR & MOCK (1991) and PÁLFIY et al. (2007); conodont zonation after KOZUR & MOCK (1991). Abbreviations: *M.* – *Misikella*, *O.* – *Oncodella*, *Z.* – *Zieglerioconus*.

retained the similar outline of its ancestor. Based on available data it seems that *M. rhaetica* was a parallel step in *Misikella* evolution. The final step in evolution of both lines is represented by *M. buseri* and *M. kovacsi* with forms characterized by very reduced elements bearing only two denticles. As the following expressed trend in evolution of *Misikella* its ultimate stage could be expected in secondary single cone forms, similar to *Zieglerioconus*. However, their direct relationship is excluded due to their co-occurrences in the Slovenian section. Available data suggest the origin of *Zieglerioconus* and *Misikella* from a common and still unknown ancestor (Fig. 3).

The evolution of the last representatives of gondolellid stock in the latest Triassic (platform type *Epigondolella* and non-platform types *Misikella* and *Parvigondolella*) share certain similarities. The evolutionary steps of *Epigondolella* have already been studied by TRAMMER (1974) who documented a trend in reduction of element size, reduction of platform length, decrease in number of lateral denticles along with increasing height of denticles in the carina. A strong reduction in size and total reduction of the platform was shown in the Middle Triassic lineage *Neogondolella* – *Celsigondolella* by KOZUR (1968). The end form, *Celsigondolella watznaueri* is very similar to *Parvigondolella*. A similar evolutionary trend can be observed also in the non-platform types, *Misikella* and *Parvigondolella*. Our study documents that a strong homeomorphism occurred in the evolution of the three genera leading to very reduced forms. This phenomenon was observed in the evolution of certain Late Triassic genera as has already been pointed out by KOZUR & MOCK (1974a). The specimen here illustrated (Pl. 1, Fig. 1) reveals a narrow basal area that is not typical for representatives of the genus *Misikella* at this level and morphologically stands close to *Parvigondolella*, therefore this element is here assigned to the genus »*Misikella*«.

### Systematic paleontology

Genus *Misikella* Kozur & Mock 1974

Type species: *Spathognathodus hernsteini*  
Mostler 1967

*Misikella buseri* n. sp.

Pl. 1, Fig. 3

Derivatio nominis. In honour of Prof. Dr. Stanko Buser, a Slovenian geologist for his outstanding contribution to the knowledge of the Slovenian Basin and the Slovenian geology in general.

Holotypus. The specimen on Pl. 1, Fig. 3, sample K2/ 76,0, repository number GeoZS 4242.

Locus typicus. The Kobla section, Tolmin Nappe, western Slovenia.

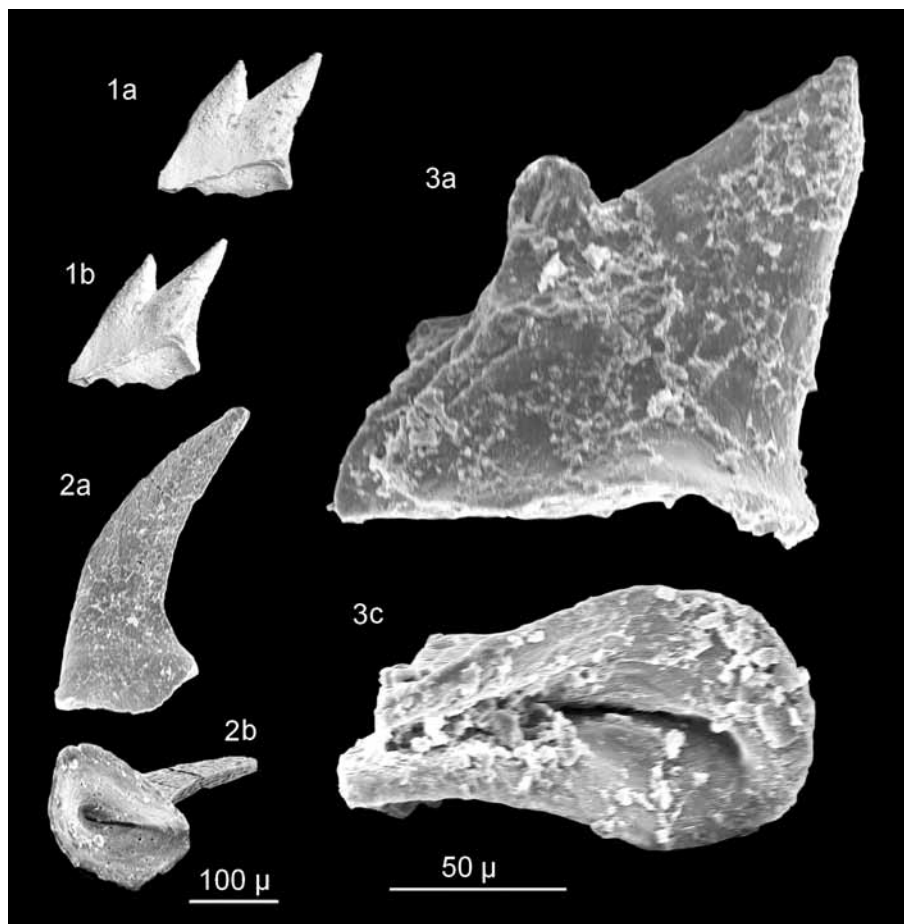
Stratum typicum. Sample K2/ 76,0, Rhaetian, lower *Misikella posthernsteini* A. Z. (= *Misikella hernsteini* – *Misikella posthernsteini* Subzone), Slatnik Formation.

Material. 5 specimens.

Diagnosis. The P1 element is a very reduced segminate element comparable to other species in *Misikella* marked by a big cusp and one more small denticle, a basal cavity rounded posteriorly and devoid of any incision.

Description. This species is characterized by very reduced segminate element with a large cusp and one more small denticle: in the holotype the denticle next to the cusp is very reduced. The basal area is very opened and has an oval posterior edge. The basal cavity is widely expanded appropriately to the large size of the cup.

Occurrence. Late Triassic: early Rhaetian, lower *Misikella posthernsteini* A. Z. (= *Misikella hernsteini* – *Misikella posthernsteini* Subzone), Slatnik Formation.



### PLATE 1

Conodonts from the Mt. Kobra section, Julian Alps, Slovenia; Slatnik Formation; Figs. 1, 2 – scale bar 100  $\mu\text{m}$ , Fig. 3 – scale bar 50  $\mu\text{m}$ .

1 *Misikella* sp., Pa – element, sample K2/64,0 (GeoZS 4234); *Parvigondolella andrusovi-Misikella hernsteini* A. Z.

2 *Zieglerioconus rhaeticus* Kozur & Mock, Pa – element, sample K2/58,0 (GeoZS 4228); *Parvigondolella andrusovi-Misikella hernsteini* A. Z.

3 *Misikella buseri* n.sp., Pa – element, holotype, sample K2/76,0 (GeoZS 4242); lower *Misikella posthernsteini* A. Z. (= *Misikella hernsteini* – *Misikella posthernsteini* Subzone).

a – lateral view, b – oblique lower view, c – lower view.

The illustrated conodont specimens were photographed at the JEOL JSM 6490LV Scanning Electron Microscope at the Geological Survey of Slovenia / Geološki zavod Slovenije and are housed in the micropaleontological collection of the same institution.

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