Revision of the Conodont *Mockina slovakensis* and Its Paleogeographic Implications for the Upper Triassic Intraplatform Basins of the Alps

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ABSTRACT: *Mockina slovakensis*, **thought to have evolved from** *Epigondolella praeslovakensis*, **is an important species of the Norian (Upper Triassic), generally considered as the representative of the uppermost Alaunian to upper Sevatian in the Tethys. The previous description of** *M. slovakensis* **was incomplete, thus has led to some misidentifications. We thus update the description of** *M. slovakensis* **and discuss its comparisons and occurrence based on the new conodont investigations in Dolomia di Forni and the data from previous literatures. The conodont assemblage in the succession of Dolomia di Forni is dominated by** *M. slovakensis*, **along with rare** *M. postera* **and** *E. praeslovakensis*. **We described two morphotypes of** *M. slovakensis* **(morphotypes A and B), on the basis of shape of the lateral profile. These two morphotypes can also be observed in the** *E. praeslovakensis*. **Moreover,** *M. slovakensis* **is usually documented as almost monospecific conodont association in intraplatform basins, thus its paleogeographic implications are also discussed.**

KEY WORDS: *Mockina*, **conodont, morphotype, intraplatform basin.**

0 INTRODUCTION

Mockina slovakensis is a kind of small pectiniform conodont element with distinctive characteristics occurring in the Upper Triassic. Its evolution from *Epigondolella praeslovakensis* was suggested by Moix et al. (2007), based on materials from Turkey. It has been chosen for the index species of the *M. slovakensis* Zone (uppermost Alaunian) due to its easy identification and widespread distribution in all marine environments (Rigo et al., 2018). Nevertheless, *M. slovakensis* caused some contentions since it was established by Kozur in 1972. The arguments mainly focused on the diagnosis and its stratigraphic range (Moix et al., 2007; Budai and Kovács, 1986). The integration of data from the new studies on the Dolomia di Forni Formation and available literature (Mazza et al., 2012; Balini et al., 2010; Belvedere et al., 2008; Moix et al., 2007; Bazzucchi et al., 2005; Channell et al., 2003; Donofrio et al., 2003; Kaya et al., 2001; Martini et al., 2000; Mastandrea et al., 1997; Gullo, 1996; Roghi et al., 1995; Budurov and Sudar, 1990; Kovács and Nagy, 1989; Budai and Kovács, 1986; Kozur, 1972) points

to the fact that *M. slovakensis* shows various morphological characteristics. These diversiform characteristics make the classification of *M. slovakensis* more confusing, however, it also provides traces of the evolutionary process.

Mockina slovakensis is also a typical, almost monospecific, conodont element usually collected from intraplatforms basins, and it has been used to understand the geodynamic evolution of the Late Triassic sector of the western Tethys.

Roghi et al. (1995) reported "*Epigondolella*" *slovakensis* and its clusters in Dolomia di Forni Formation, northeastern Italy. Based on new data from several sections in Forni area and the data from the previous studies, this study aims to discuss the morphological variety of *M. slovakensis*, the distribution of this species and the evolutionary process from *E. praeslovakensis* to *M. slovakensis*. The authors try to make a more complete understanding of this simple but also intricate Upper Triassic pectiniform conodont.

1 GEOLOGICAL SETTING

The Carnian Prealps (CP) belongs to the Eastern Alps and Southern Alps structural units. During Late Triassic the CP were a part of the Friuli-Dinaric Platform bordered to the north and east by the Carnian-Slovenian Basin (Fig. 1), the former links to the passive margin of the western Tethys (Schmid et al., 2004; Haas et al., 1995).

The Carnian Prealps is characterized by the presence of

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mainly shallow-water carbonate platform facies flanked by basinal ones, Upper Triassic–Lower Jurassic in age (Carulli et al., 2000). The Norian sedimentary succession started with the deposition of the peritidal deposits of the shallow-water carbonate platform represented by the Dolomia Principale Formation, followed by the Dachstein Limestone Formation, above a flat paleotopography originated by the partial filling of the pre-existing Carnian basins due to the increased terrigenous input during the Carnian Pluvial Event (e.g., Dal Corso et al., 2019; Rigo at al., 2007; Simms and Ruffell, 1989). During the Norian a series of NNE-SSW fault-bounded intraplatform basins were formed by an extensional tectonic phase. These intraplatform basins were characterized by limited vertical circulation and developed dysoxic to anoxic conditions. They are present in many sectors of the peritidal Dolomia Principale carbonate platform such as in Lombardy, Austria, Dolomites and NE Italy (Friuli-Venezia Giulia region) (Berra et al., 2007). In Lombardy, these intraplatform basins are represented by the Dolomie Zonate and Zorzino Limestone formations (Aralalta Group) (Berra et al., 2010; Jadoul, 1985); in the central Austroalpine by Ortles and Quattervals nappes (Berra and Jadoul, 1999; Berra, 1995); in the Northern Calcareous Alps (South Austria) by the Seefeld Schichten (Donofrio et al., 2003; Brandner and Poleschinski, 1986; Fruth and Scherreiks, 1984). In the eastern sector of the Southern Alps where the Carnian Prealps are located (Friuli-Venezia Giulia region), these intraplatform basins are represented by the Forni Dolomite Formation (Carulli et al., 1997; Mattavelli and Rizzini, 1974). The Forni Dolomite Formation is characterized by several hundred meters of laminated foetid dark limestones, dolostones and shales deposited mostly as calciturbidites and showing frequent graded and laminated bedding. In particular, the northern Mt. Verzegnis area has been interpreted as the depocenter area of Forni Dolomite intraplatform basin. In fact, the two Seazza and Forchiar sections consist of dark-gray to black or brown bituminous dolostone, sometimes in laminated thin layers, with chert nodules and lenses, but without (or rare) resedimented materials (Dalla Vecchia and Muscio, 1991).

In the westernmost part of the Carnian Prealps (Mt. Pramaggiore area), the Rovadia and Poschiedea sections are instead composed by laminated dolostones with resedimented breccias and calcarenites, while the Valmenone Section (Fig. 2) consists of thin intercalations of dark dolostones within the upper part of the Dolomia Principale Formation (Cozzi and Hardie, 2003; Cozzi, 2002; Cozzi and Jäger, 2000). Similar outcrops are found in the southernmost part of Carnian Prealps, where dark and laminated dolostones and organic-rich laminated marls are intercalated within the Dolomia Principale Formation. Also, in the eastern Julian Prealps (Fig. 2), the same lithofacies are always intercalated within the Dolomia Principale Formation and they have been named Dolomia del Resartico Member (previously named "Rio Resartico organic laminated unit") with a thickness of tens of meters (Ponton, 2017; Fantoni et al., 1998).

To the east of the Dolomia Principale carbonate platform, the pelagic Slovenian Basin is characterized by the Norian-Rhaetian Bača and Slatnik formations (Rožič et al., 2009; Buser, 1996, 1989; Cousin, 1981, 1973). The connection between the southern Alps and the northern Calcareous Alps is instead represented by the basinal successions of the Transdanubian Central Range (Hungary), i.e., the Rezi Dolomite Formation in the southwestern Balaton Highland and the Feketehegy Formation in the Pilis Hills, characterized by restricted and suboxic
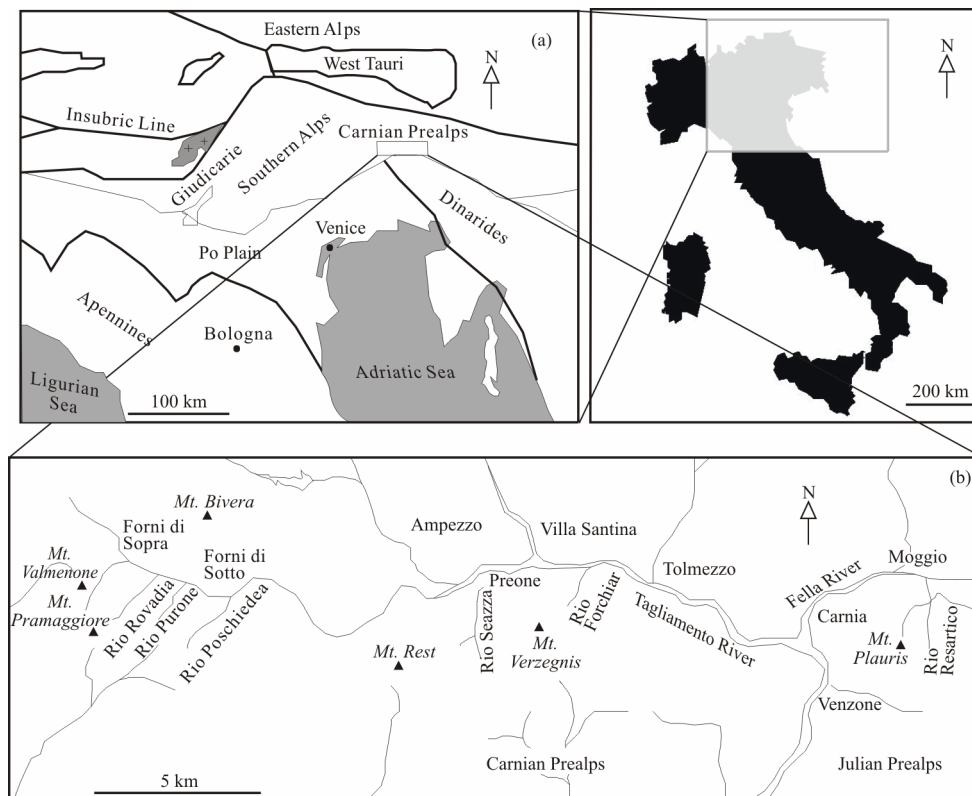

Figure 1. Structural map of NE Italy with the position of the Carnian Prealps (a) and the main localities of the studied sections (b).
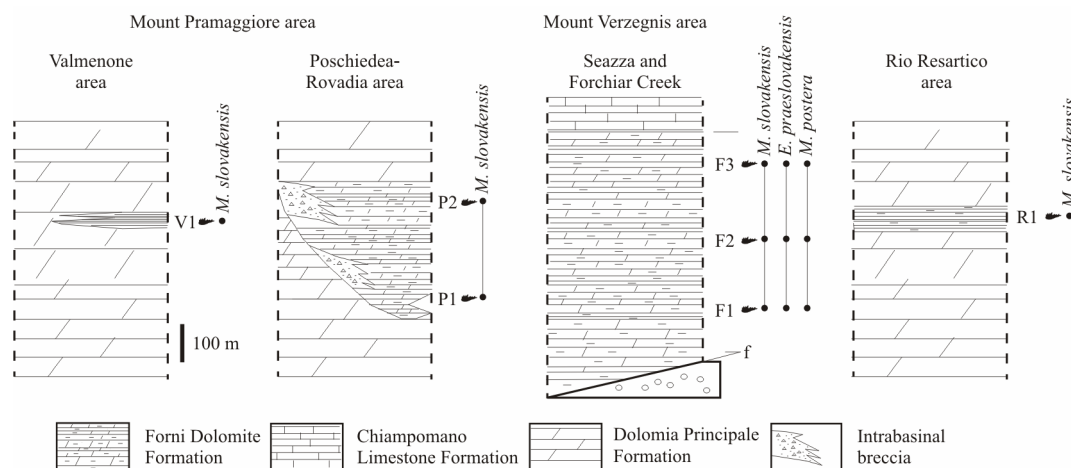
Figure 2. Schematic studied sections with the distribution of conodonts. See Fig. 1b for the geographic locations of the sections.

basins during the Norian (Haas, 2002; Csillag et al., 1995; Kovács and Nagy, 1989; Budai and Kovács, 1986).

2 CONODONT BIOSTRATIGRAPHY

The samples collected in the fossiliferous sections, that are the Valmenone, Poschiedea-Rovadia, Seazza and Forchiar Creek, and Rio Resartico, of the Dolomia di Forni area (Fig. 2), yielded large quantities of conodonts, including pectiniform elements, ramiform elements and clusters (Roghi et al., 1995). The reviewed conodont assemblage in this succession is dominated by *Mockina slovakensis* (Fig. 3), and there are also small numbers of concomitant *M. postera* and *Epigondolella praeslovakensis*. A previous study (Roghi et al., 1995) on conodonts in this area reported "*Epigondolella*" *slovakensis*, but some of the specimens, which own a bifurcated keel end are, instead, *E. praeslovakensis*. The conodont assemblage belongs to *M. slovakensis* Zone according to the Upper Triassic conodont biozonation of the Tethys by Rigo et al. (2018).

Mockina slovakensis is an important species of the Norian, generally considered as the representative of the uppermost Alaunian to upper Sevatian in the Tethys (Rigo et al., 2018).

3 DISCUSSION
3.1 Previous Description of *Mockina slovakensis*

In the original description of *Mockina slovakensis* (Kozur, 1972), the platform is about 2/3 as long as the entire conodont element, being almost the same width everywhere. The anterior platform margins have three to five long denticles, but the posterior part of the platform is smooth with a rounded end. Some denticles can be accompanied by an accessory denticle. The blade is very high in the front and the denticles are strongly fused. Approximately in the middle, the blade breaks off like a cliff and three to four small and widely separated nodes follow to the rear but within the platform. The basal pit is shifted far forward and is approximately centrally located. However, Budai and Kovács (1986) emended the original description, since they thought the original description of *M. slovakensis* was based on a single and pathologic form. In their new description, the carina is the highest in the middle, then gradually decreases in height in phylogenetically earlier forms, but sharply drops down without transition in advanced elements.

The free blade is slightly inward bent and it comprises four to five completely fused denticles in adult. The wide keel extends along the whole length of the basal edge. The narrow, inverted pit is located near to center. Although they proposed some new diagnostic features, the abrupt decline of the blade and the strongly fused blade denticles were still the most distinctive characteristics of *M. slovakensis*. The new revision in Budai and Kovács (1986) optimized the description of *M. slovakensis*.

Furthermore, as more and more reports of *M. slovakensis* came out (e.g., Mazza et al., 2012; Rigo et al., 2012; Belvedere et al., 2008; Moix et al., 2007; Donofrio et al., 2003), we have found that there are large differences between certain individuals. We propose an improved description of the *M. slovakensis* population which is based on the integration data of the new investigation and the previous literature.

3.2 Emended Description of *Mockina slovakensis*

The platform of *M. slovakensis* is usually short. The shapes of the platform terminal are various and it could be pointed, rounded or blunt; the rounded and blunt platform terminal are likely to occur in the transitional forms; the pointed platform end almost only occurs in advanced form. The platform has 3–11 denticles (nodes) on the margins, generally with two high and sharp denticles on the external anterior margin and one on the internal anterior margin. The advanced form of *M. slovakensis* usually has 3–5 denticles on the anterior platform margins, and the posterior platform margins are nearly unornamented. In contrast, the posterior platform margins of the primitive forms or transitional forms between *M. slovakensis* and *E. praeslovakensis* are usually ornamented by small denticles or nodes. The pit is forward shifted and located in front of the middle of the platform, but it could backwardly lie in the central platform in the primitive forms. The keel end could be rounded or pointed but never bifurcated. The carina is composed of 2–6 denticles (nodes); generally, the carina of the advanced forms is shorter than those of the primitive and transitional forms. The posterior carina of the most *M. slovakensis* does not reach the end of the platform, but it could extend to the termination in some primitive and transitional forms, just like the *E. praeslovakensis*. The free blade usually consists of 2–6 strongly fused denticles and it has a wall-like termination where it descends abruptly to
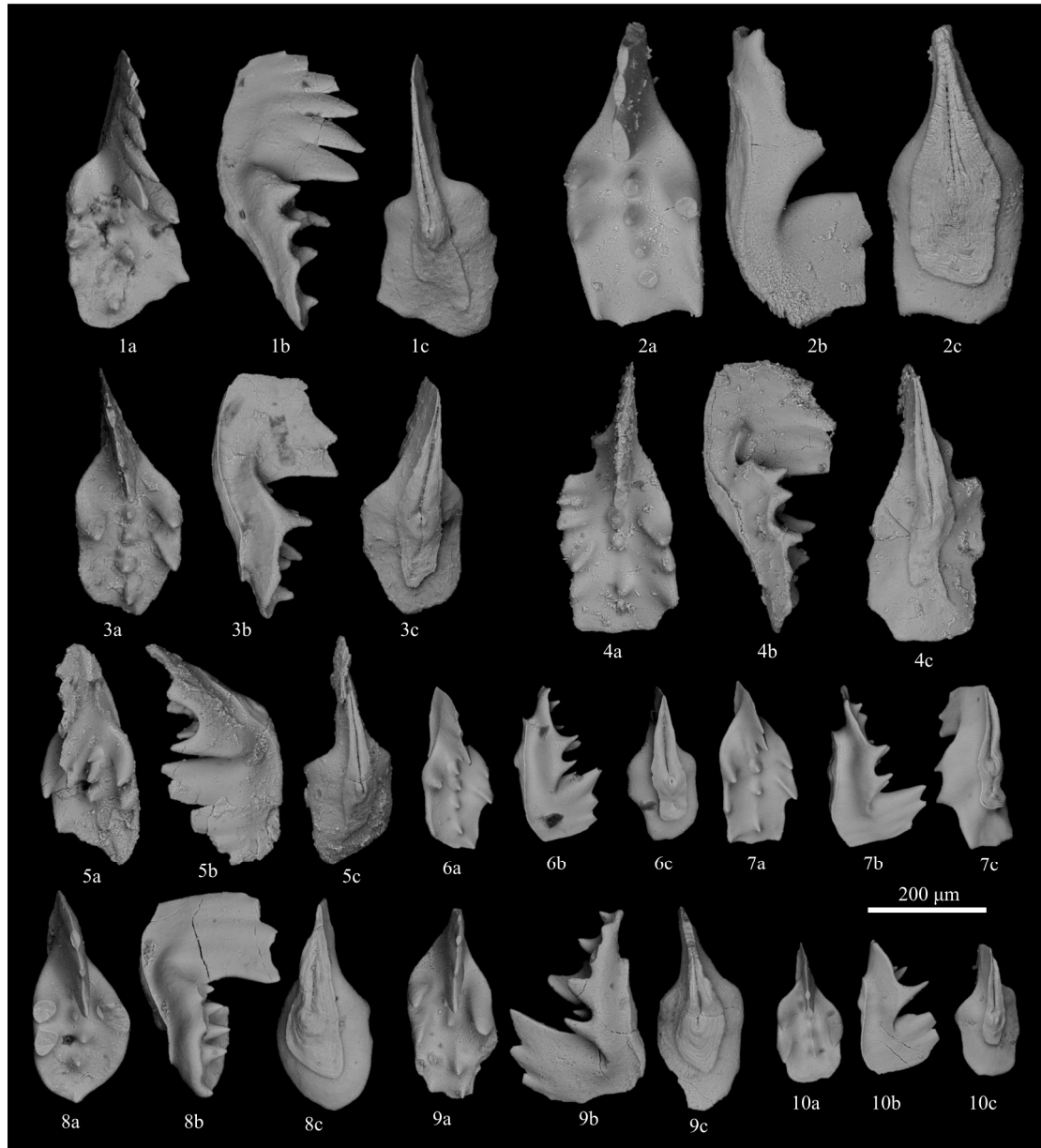
Figure 3. SEM photographs of conodonts from Dolomia di Forni. 1. *Mockina slovakensis*, P2, Poschiedea-Rovadia; 2. *M. slovakensis*, R1, Rio Resartico; 3. *M. slovakensis*, F1, Seazza and Forchiar Creek; 4. *Epigondolella praeslovakensis*, P1, Poschiedea-Rovadia; 5. *M. slovakensis*, P2, Poschiedea-Rovadia; 6. *M. slovakensis*, V1, Valmenone; 7. *M. slovakensis*, V1, Valmenone; 8. *M. slovakensis*, F1, Seazza and Forchiar Creek; 9. *M. slovakensis*, F2, Seazza and Forchiar Creek; 10. *M. slovakensis*, V1, Valmenone; a. upper view; b. lateral view; c. lower view.

the carina. The last denticle of the blade is usually huge and projected backwards. In lateral view, the morphotype A of the *M. slovakensis* population has an obviously elevated platform, making the profile of the element stepped; the lateral profile of morphotype B is slightly elevated or nearly straight.

3.3 Morphotypes

As more and more forms of the *M. slovakensis* population have been identified, Kovács and Nagy (1989) firstly divided the *M. slovakensis* into five morphotypes according to the shapes of platform and the distribution of ornamentation. But, in fact, the variation of the platform is diverse and it is not only five types.

During the investigation, we find that the shape of lateral profile shows two different forms in *M. slovakensis* population

(Fig. 4). The profile of the majority is stepped because of the elevated platform, but there is a small number of *M. slovakensis* shows a nearly straight profile. Thus, we classify the *M. slovakensis* into two morphotypes, A and B, on the basis of shape of the lateral profile. *Mockina slovakensis* Morphotype A owns a stepped profile. In contrast, the lateral profile of *M. slovakensis* Morphotype B is nearly straight. These two morphotypes can also be found in the *E. praeslovakensis*.

In our study area, the two morphotypes are found together, but the occurrence of each morphotype is unclear in the other places. There are usually fewer figured specimens found in most previous literatures. In other literatures, *M. slovakensis* composes a monospecific fauna without any other age diagnostic fossils. Thus, the exact range of the two morphotypes is still unknown at present.
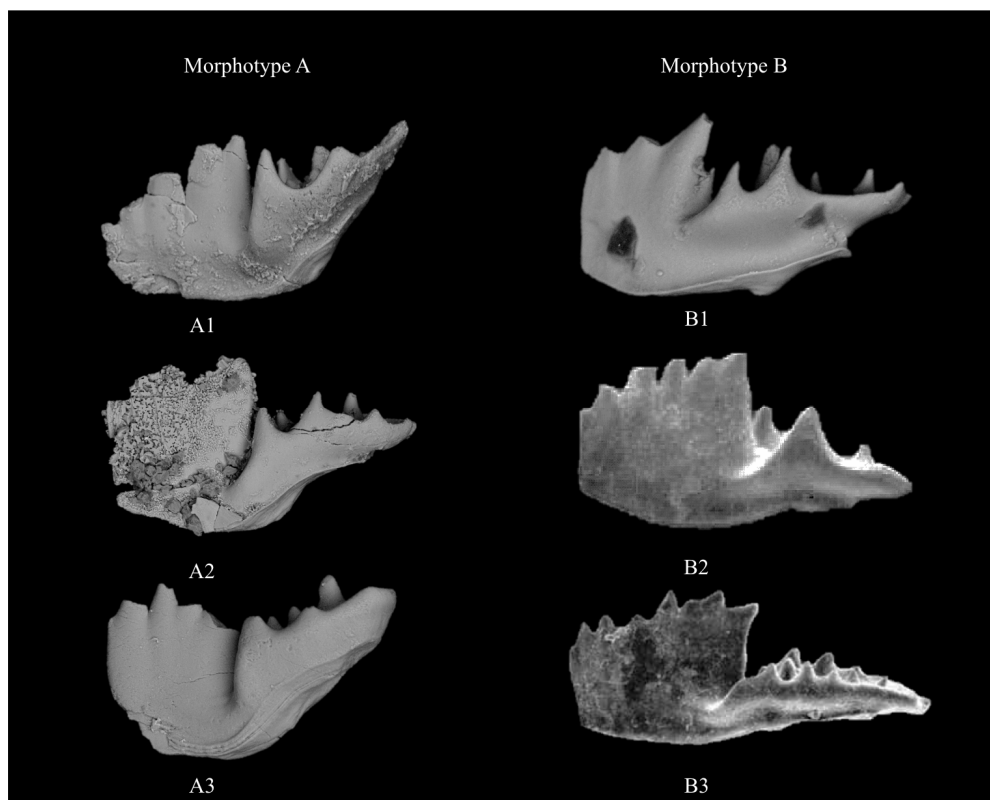
Figure 4. Examples of the two morphotypes (A and B) of *Mockina slovakensis.* Samples A1 (P2, Poschiedea-Rovadia); A2 (F1, Seazza and Forchiar Creek); A3 (R1, Rio Resartico); B1 (V1, Valmenone); B2 (Onoue and Tanaka, 2005, fig. 3/22a); B3 (Mastandrea et al., 2003, plates 1, 3).

3.4 Comparison

Although the *M. slovakensis* is very common species, it is misidentified frequently. The species owns some distinctive characteristics, especially the abrupt, wall-like posterior end of the blade, which is not present in any other Triassic platform conodont except for its ancestor *E. praeslovakensis* (Moix et al., 2007). Therefore, the *E. praeslovakensis* is the species most often thought of as the *M. slovakensis* in previous literatures. These two species resemble in the abrupt posterior end of the blade and the lateral profile of element. The main reason for the misidentification is the insufficient consideration of the lower side of the conodont element (Moix et al., 2007). The most prominent difference between these two species is the shape of the keel end, *E. praeslovakensis* owns a distinctive bifurcated keel end but *M. slovakensis* has a pointed or rounded keel terminal which is never bifurcated.

In addition to *E. praeslovakensis*, *M. slovakensis* is also easily confused with *Mockina postera* and *Mockina zapfei*. *Mockina postera* also has a short platform like *M. slovakensis*, but the platform terminal of *M. postera* is always pointed and the posterior platform margins are often asymmetrical. In contrast, the posterior platform end of *M. slovakensis* is mostly pointed or narrowly rounded, but some specimens have a broad, blunt posterior platform end. *Mockina postera* has a distinctive anterior denticulation commonly consisting of one prominent denticle on one platform margin and two on the other; *M. slovakensis* usually has three to five denticles on the anterior platform, but there could be also some small nodes occur on the posterior part of the platform, especially in the transitional

forms. The blade descends relatively abruptly onto the platform in some *M. postera* specimen, but in general the last denticle is distinctly smaller than the preceding one; in other specimen, the blade descends gradually into the low carina. Moreover, the blade denticles of *M. slovakensis* are strongly fused, especially in the adults, which never occur on *M. postera*.

Mockina zapfei has a relatively short platform like other *Mockina* species, but the platform of *M. zapfei* is asymmetric due to the curvature of the carina to one side. The most prominent disparities between *M. zapfei* and *M. slovakensis* are that *M. zapfei* owns high blade and it descends gradually into the low carina and the last denticle of carina is projected beyond the platform.

3.5 Occurrence

Mockina slovakensis was found by Kozur firstly from beds immediately above the uppermost Norian *Misikella hernsteini* Zone and below the Rhaetian *Misikella posthernsteini* Zone. Thus, *M. slovakensis* was assigned to the uppermost Sevatian, but the age of Rhaetian also cannot be excluded (Moix et al., 2007; Kozur, 1972). Budai and Kovács (1986) assigned *M. slovakensis* to the middle Norian by comparing their fauna with Krystyn's unpublished middle Norian material from Timor Island. Subsequently, Kovács and Nagy (1989) also assigned *M. slovakensis* to the middle Norian mainly based on the unpublished data of Krystyn from Timor and the published data of Budai and Kovács (1986). But they did not exclude early Sevatian age because the occurrence of *M. slovakensis* together with *Rhabdoceras suessi* (Moix et al., 2007). Roghi et al. (1995) reported a conodont fauna which was marked by "*Epigondolella*"

slovakensis in Dolomia di Forni. They assigned the "*Epigondolella*" *slovakensis* to the middle–late Alaunian (middle Norian) based on the unpublished data of Krystyn from Timor and the published data of Budai and Kovács (1986) and Kovács and Nagy (1989). Meço (1999) reported the occurrences of "*Epigondolella*" *slovakensis* at the upper part of Sevatian in Albania. Krystyn illustrated the "*Epigondolella*" *slovakensis* from Timor in Martini et al. (2000). In the caption of the plates, the "*Epigondolella*" *slovakensis* were assigned to the lower Norian, but in the main text they were in the age of middle Norian. The lower Norian could be a literal mistake, because the middle Norian (Alaunian) age was confirmed by the ammonites (Moix et al., 2007; Martini et al., 2000). Nevertheless, the three specimens (in Martini et al., 2000, pl. V, figs. 13–14, 17–18, 21–22) which were assigned to "*Epigondolella*" *slovakensis* are actually not the true *M. slovakensis*, cause the wall-like posterior end of the blade which is the most prominent character of *M. slovakensis* is missed. There is one species (pl. V, figs. 21–22) which has a similar shape of platform and it seems also own a bifurcated keel end from the upper view, but the blade denticles of this specimen is not strongly fused like *M. slovakensis*. In general, the conodonts presented in Martini et al. (2000) are not real *M. slovakensis*. Therefore, the approximately Alaunian 1 (middle Norian) age of their "*slovakensis*" which was confirmed by the ammonites is controversial. Donofrio et al. (2003) reported a conodont fauna which are dominated by *M. slovakensis* in sediments of the restricted intraplatform basin of the Seefeld Formation, Alps. The middle Norian age of the Seefeld Formation of the Alps is based on two further species, "*Epigondolella*" *carinata* and "*Epigondolella*" *postera*. However, Kozur held the opinion of that the "*Epigondolella*" *carinata* in Donofrio et al. (2003) are actually *M. slovakensis*, due to the two illustrated specimens determined as "*E.*" *carinata* have a wall like posterior end of the anterior carina. Donofrio et al. (2003) assigned *M. slovakensis* to Alaunian 2 because that it is concomitant with "*E. postera*" in "*Epigondolella*" *postera* Zone. Channell et al. (2003) found that the *M. slovakensis* occurred in Silická Brezová (Slovakia), and it was assigned to the latest Alaunian. Moix et al. (2007) discussed and revised some of the misidentifications of *M. slovakensis* in previous literature, and then came up with a new species, *E. praeslovakensis*, by using paleontological and biostratigraphic criteria. The *E. praeslovakensis* was regarded as direct ancestor of *M. slovakensis*. Moreover, Moix et al. (2007) concluded that monospecific faunas which consist only of true *M. slovakensis* belong to the Sevatian up to the top of the *M. hernsteini* Zone, even if its first appearance datum (FAD) is confirmed in latest Alaunian (Channell et al., 2003), where it occurs together with advanced *E. praeslovakensis*. Monospecific faunas which consist exclusively of *E. praeslovakensis* belong to the middle to late, but not latest Alaunian. Belvedere et al. (2008) recovered a transitional form of *M. slovakensis* which characterized by a slightly bifurcated keel end along with a real *M. slovakensis*. They assigned the co-occurrence of *E. praeslovakensis* and *M. slovakensis* to latest Alaunian in age according to the discussion in Moix et al. (2007). Balini et al. (2010) found the occurrence of "*Epigondolella*" *slovakensis* in Sevatian (upper Norian) in Pizzo Mondello Section. Mazza et al. (2012) also recovered *M. slovakensis* in the same section and the occurrence of it ranges from

Mockina bidentata Zone to *Misikella hernsteini* Zone (Sevatian 1 to Sevatian 3). Rigo et al. (2012) documented at Sasso di Castalda Section (Lagonegro Basin, Italy) the first occurrence (FO) of *M. slovakensis* after the *M. serrulata* and before the FO of *M. bidentata*, and its last occurrence after the FO of *Parvigondolella andrusovi* and before the FO of *M. hernsteini*. *Mockina slovakensis* is also found in the Pignola-Abriola Section in the Lagonegro Basin (Rigo et al., 2016) and Inuyama area, central Japan (Yamashita et al., 2018) in the age of Sevatian. Rigo et al. (2018) took *M. slovakensis* as the index species of the uppermost Alaunian *M. slovakensis* Zone in their new Upper Triassic conodont biozonations. The occurrence of *M. slovakensis* was assigned to the uppermost Alaunian to upper Sevatian.

Combining almost all the information of the distribution of *M. slovakensis* (Table 1), the occurrence of this species ranges from the base of *M. slovakensis* Zone (uppermost Alaunian) to the uppermost part of *M. hernsteini* Zone (uppermost Sevatian) (Rigo et al., 2018). It's worth to mention that *M. slovakensis* was apparently collected in the same layers of *M. posthernsteini* by Mastandrea et al. (1997). However, the illustrated specimens of *M. posthernsteini* are instead transitional forms with the ancestor (*M. hernsteini*) because they exhibit more than 3 denticles on the blade and/or they don't show a clear notch on the backside of the cusp, which are the main features of *M. posthernsteini* (Karádi et al., 2020; Rigo et al., 2018, 2016; Bertinelli et al., 2016; Giordano et al., 2010).

3.6   Morphocline between *Epigondolella praeslovakensis* and *Mockina slovakensis*

The *Epigondolella praeslovakensis* is the typical epigondolellid with strongly ornamented platform, considered as the progenitor of *Mockina slovakensis* (Moix et al., 2007). The adult forms of *E. praeslovakensis* have a typical lower side of genus *Epigondolella* with broad and always distinctly bifurcated keel end (Moix et al., 2007). The pit usually lies in behind the central platform. In contrast, the *M. slovakensis* is usually smaller and simpler than its ancestor. It shows the characteristic features of genus *Mockina*. The short platform is ornamented at the anterior part of platform margins, but the posterior platform margins is almost smooth. The pit of *M. slovakensis* usually lies in front of the central platform. The keel end could be pointed or rounded but never bifurcated. The evolutionary trend characterizing the morphocline between *E. praeslovakensis* and *M. slovakensis* consists of a decrease in the number of denticles and a simplification of the platform ornament and the keel end. The platform of *E. praeslovakensis* tends to simplify by losing ornamentation on the posterior part of the platform margins. The keel end evolves from bifurcated to pointed or rounded. Different transitional forms between *E. praeslovakensis* and *M. slovakensis* were commonly recorded, of which the most common ones maintain the main characteristics of *E. praeslovakensis* but without the typical bifurcated keel end, however, it is also different from the advanced *M. slovakensis* because of its strongly ornamented posterior platform margins.

In summary, the evolution trend from *E. praeslovakensis* (e.g., bifurcated keel end; ornamented posterior platform margins) to transitional forms (e.g., slightly bifurcated or rounded keel end; ornamented posterior platform margins) and then to

Table 1   The occurrence of *M. slovakensis* in different areas

Year	Authors	Occurrence of *M. slovakensis*	Place	MA	MB
1972	Kozur	Upper Sevatian to lower Rhaetian	Maly Mlynsky Vrch, Slovak Karst, Slovakia	×	
1986	Budai and Kovács	Monospecific, exact age unclear	Keszthely Hills, Transdanubian Range, Hungary	×	×
1989	Kovács and Nagy	Monospecific, exact age unclear	Pilis Hills, Transdanubian Range, Hungary	×	×
1993	Amodeo et al.	Sevatian	Vietri di Potenza, Lagonegro Basin, Italy	No figure	
1995	Roghi et al.	Monospecific, exact age unclear	Dolomia di Forni, Carnia, Southern Alps, Italy	×	
1997	Mastandrea et al.	Late Norian to Rhaetain	Colle del Crapio, Catena Costiera, Calabria, Italy	×	×
1999	Meço	Upper Sevatian	Ura Shtrenjte, Cukali zone, Albania		×
2003	Donofrio et al.	Supposedly upper Alaunian/lower Sevatian	Seefeld Formation, Tirol, northern Calcarous Alps, Austria	×	×
2003	Channell et al.	Sevatian	Silická Brezová, Slovak Karst, Slovakia	×	×
2003	Mastandrea et al.	Monospecific, exact age unclear	Valle Corvino, Calabria, Italy		×
2005	Onoue and Tanaka	Presumably upper Alaunian	Sambosan accretionary complex, Japan	×	×
2007	Moix et al.	Uppermost Alaunian to upper Sevatian	Gavuruçtuğu Block, Mersin Mélange, Turkey	No figure	
2008	Belvedere et al.	Uppermost Alaunian	Monte Pasubio, Southern Alps, Italy	×	
2010	Balini et al.	Sevatian	Pizzo Mondello, Sicani Basin, Sicily, Italy	No figure	
2012	Mazza et al.	Sevatian 1 to Sevatian 3	Pizzo Mondello, Sicani Basin, Sicily, Italy	×	×
2012	Rigo et al.	Alaunian 3 to Sevatian 2	Sasso di Castalda, Lagonegro Basin, Italy	No figure	
2016	Rigo et al.	Sevatian	Pignola-Abriola, Lagonegro Basin, Italy	×	
2018	Yamashita et al.	Sevatian	Inuyama area, Japan	×	

MA. Morphotype A; MB. morphotype B. Cross mark only represents the occurrence, but not the exact range of the morphotypes in the relevant section.

M. slovakensis (e.g., pointed or rounded keel end; usually neat posterior platform margins) is a process of simplification and miniaturization. Coincidentally, the process of simplification and miniaturization from *E. praeslovakensis* to *M. slovakensis* is consistent with the trend of the whole conodont evolution during the Norian (Karádi et al., 2020; Rigo et al., 2018).

3.7   Potential Lifestyle of *Mockina slovakensis*

Mockina slovakensis was thought to solely live in restricted environments as it was usually found in the Upper Triassic intra-platform basins, such as the Rezi Dolomite Formation and Fe-ketehegy Formation in Hungary (Kovács and Nagy, 1989; Budai and Kovács, 1986), Dolomia di Forni Formation in Italy (Roghi et al., 1995) and Seefeld Formation in Austria (Donofrio et al., 2003). Nevertheless, Meço (1999) reported the occurrences of "*Epigondolella*" *slovakensis* in a pelagic environment in Albania. Channell et al. (2003) stated that this species is rare in open sea environments, while it is very common in Norian intraplatform basins, which can be only dated by *M. slovakensis*. More and more reports indicate that the open marine environments are also suitable for subsistence of *M. slovakensis* (Rigo et al., 2016, 2012; Mazza et al., 2012; Balini et al., 2010), and also in bedded cherts deposited below the CCD (Yamashita et al., 2018). It was even found in shallow water limestone belong to carbonate platform condition (Belvedere et al., 2008). *Mockina slovakensis* was also analyzed for oxygen isotopic composition, the analyses of which suggest that this species throve in the warmer and upper part of the column water (Trotter et al., 2015).

In summary, *M. slovakensis* is surface dweller species living in different marine environments, from (hemi)pelagic deep ocean to shallow water carbonate platform, including intraplatform basins (Fig. 5).

3.8   Paleogeographic Implications

The evolution of the Norian shallow-water carbonate platforms and adjacent basins is controlled by the rifting phases connected to the westward propagation of the Neotethys Ocean opening and to the early phases of the Ligurian-Piedmont Ocean opening in the west. Extensional tectonic phases in the Norian re-activated the NNE-SSW, NE-SW and E-W oriented faults, controlling the establishment and position of the Dolomia Principale shallow-water carbonate platform together with the development of the intraplatform basins represented by the Dolomia di Forni Formation (Cozzi, 2000). The presence of different outcrops of the Dolomia di Forni in the Carnian and Julian Prealps might be explained as portions of a single deeper basin, named Carnian Basin, fragmented during the Alpine orogeny (Scotti et al., 2002) or as isolated intraplatform basins developed due to the Triassic synsedimentary tectonic.

In the studied sections of the Dolomia di Forni Formation (i.e., Valmenone, Poschiedea-Rovaia area, Verzegnis, Seazza and Forchiar Creek, Rio Resartico area), *M. slovakensis* was documented as almost monospecific conodont association. This species was also documented in other coeval intraplatform basins, such as in the Seefeld Schichten, in the northern Calcareous Alps (southern Austria) (Donofrio et al., 2003), in the Rezi Dolomite Formation and the Feketehegy Formation in Hungary (Kovács and Nagy, 1989; Budai and Kovács, 1986) and in the lower part of the "metacarbonate unit" cropping out in the NW Anatolia (Kaya et al., 2001). Even if *M. slovakensis* represented the majority of the collected species from the intraplatform basins where it was documented, this species has occurred in the Dolomia di Forni and Seefeld Schichten along with other rare species, that are *M. postera*, *M. carinata* and *E. praeslovakensis* (Donofrio et al., 2003). *Mockina slovakensis* was also documented in open pelagic/hemipelagic basins, such as Lagonegro Basins (Rigo et al., 2012), Albania (Meço, 1999), Slovakia (Channell et al., 2003), Mount Cocuzzo basinal succession in southern Italy (Mastandrea et al., 1997), in Sicily at Pizzo Mondello (Mazza et al., 2012) and in the Inuyama area, Japan
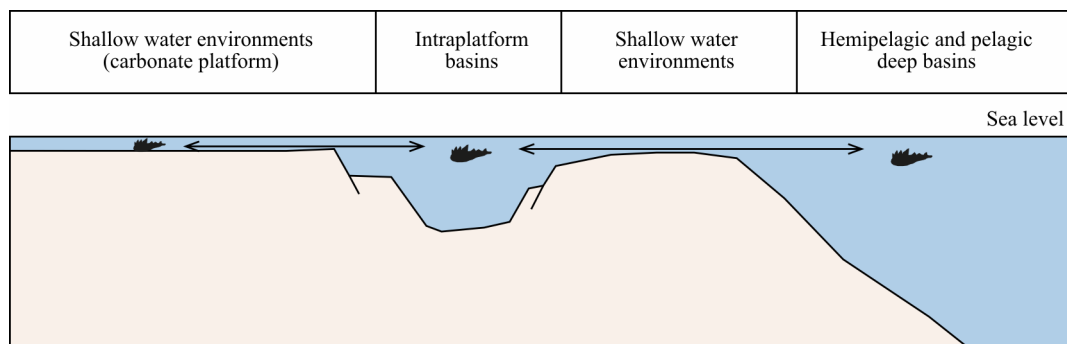
Shallow water environments (carbonate platform)	Intraplatform basins	Shallow water environments	Hemipelagic and pelagic deep basins

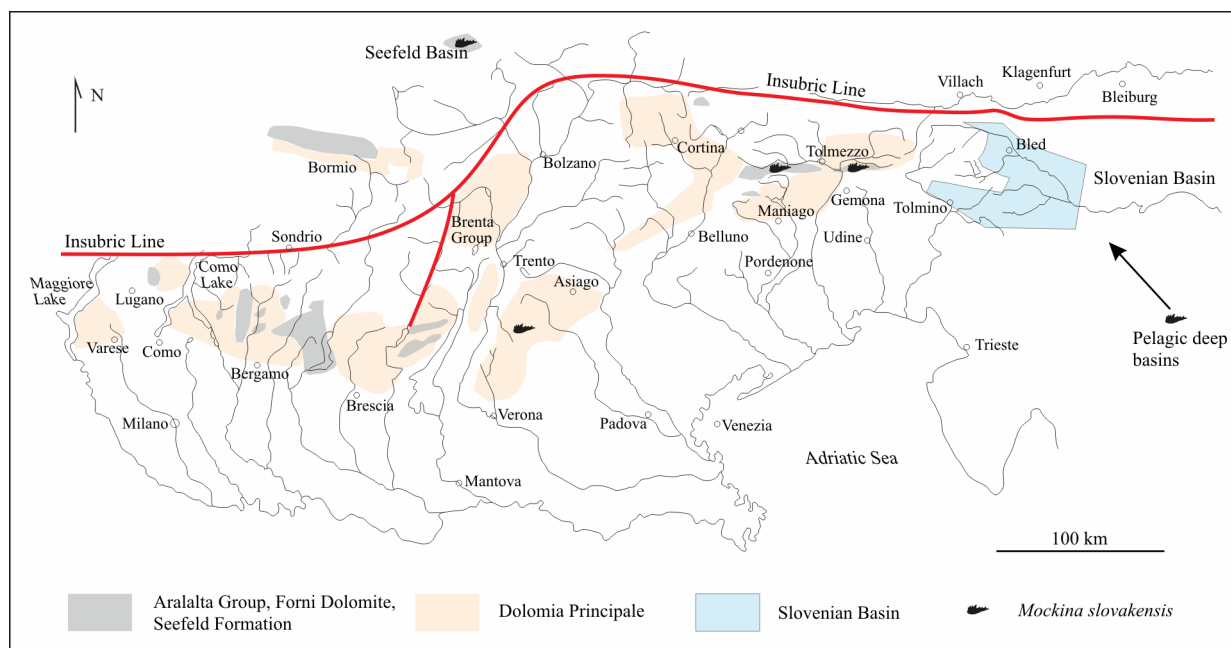**Figure 5.** Schematic lifestyle interpretation of *Mockina slovakensis*.

Figure 6. Outcrops of the Dolomia Principale Formation (in pink) and the intraplatform basins (in gray) in the Alps. Pelagic, open marine sediments are shown in light blue (Slovenian Basin). The stylized black conodonts testified the findings of the conodont *M. slovakensis*.

(Yamashita et al., 2018). Moreover, it was also documented in the very shallow water environment like the carbonate platform represented by the Dolomia Principale Formation (Belvedere et al., 2008).

The versatility of *M. slovakensis* can thus explain its spreading through different depositional environments and its prolificacy in intraplatform basins where other species probably suffered from the restricted conditions. However, the finding of other species, such as *M. postera*, *M. carinata* and its ancestor *E. praeslovakensis*, allows suggesting direct connections among the Tethys Ocean and the intraplatform basins of the Forni Dolomite and Seedfeld Schichten, at least for a limited period of geologic time. It is noteworthy that further to the west, the Lombardy intraplatform basins (e.g., Aralalta Group) have not provided any conodonts yet, and it needs to be investigated together with the Ortles and Quattervals Nappes in the central Austroalpine to understand if the Tethyan connection extended also to the western sectors. The spreading of this species might be fundamental to unravel the presence of a possible passageway from the Tethys Ocean to the western sector of the southern and northern Alps, at least during the Late Triassic (Fig. 6).

4 CONCLUSIONS

New conodont assemblage in the successions of Dolomia di Forni Formation is dominated by *Mockina slovakensis*, along with a small number of *Mockina postera* and *Epigondolella praeslovakensis*. The integration of data from the new studies and available literature points out that the *M. slovakensis* population shows various morphological characteristics. We thus suggested two new morphotypes of *M. slovakensis*, morphotypes A and B, on the basis of shape of the lateral profile. These two morphotypes have been documented also in its ancestor *E. praeslovakensis*. We emended the description of *M. slovakensis*; we discussed its occurrence and its stratigraphic range that is uppermost Alaunian 3 to upper Sevatian 2.

The versatile lifestyle of *M. slovakensis* permitted this species to adapt to different environments from shallow to deep open marine environments. It is also a typical conodont element usually documented as almost monospecific conodont association in coeval intraplatform basins and it proved being a useful fossil to understand the geodynamic evolution of the Late Triassic sector of the western Tethys.

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