Paleogeographic significance of Upper Triassic basinal succession of the Tamar Valley, northern Julian Alps (Slovenia)

LUKA GALE[1✉], BOGOMIR CELARC[2], MARCELLO CAGGIATI[3], TEA KOLAR-JURKOVŠEK[2], BOGDAN JURKOVŠEK[2] and PIERO GIANOLLA[3]

[1]University of Ljubljana, Faculty of Natural Sciences and Engineering, Department of Geology, Privoz 11, SI-1000 Ljubljana, Slovenia; ✉luka.gale@ntf.uni-lj.si
[2]Geological Survey of Slovenia, Dimičeva ul. 14, SI-1000 Ljubljana, Slovenia; tea.kolar@geo-zs.si; bogdan.jurkovsek@geo-zs.si; bogomir.celarc@geo-zs.si
[3]University of Ferrara, Physics and Earth Sciences Department, Via Saragat 1, 44122 Ferrara, Italy; piero.gianolla@unife.it; marcello.caggiati@unife.it

(Manuscript received November 7, 2014; accepted in revised form June 23, 2015)

Abstract: The Julian Alps (western Slovenia) structurally belong to the eastern Southern Alps. The Upper Triassic succession mostly consists of shallow water platform carbonates of the Dolomia Principale-Dachstein Limestone system and a deep water succession of the Slovenian Basin outcropping in the southern foothills of the Julian Alps. In addition to the Slovenian Basin, a few other intraplatform basins were present, but they remain poorly researched and virtually ignored in the existing paleogeographic reconstructions of the eastern Southern Alps. Herein, we describe a deepening-upward succession from the Tamar Valley (north-western Slovenia), belonging to the Upper Triassic Tarvisio Basin. The lower, Julian-Tuvalian part of the section comprises peritidal to shallow subtidal carbonates (Conzen Dolomite and Portella Dolomite), and an intermediate carbonate-siliciclastic unit, reflecting increased terrigenous input and storm-influenced deposition (Julian-lowermost Tuvalian shallow-water marlstone and marly limestone of the Tor Formation). Above the drowning unconformity at the top of the Portella Dolomite, Tuvalian well-bedded dolomite with claystone intercalations follows (Carnitza Formation). The latter gradually passes into the uppermost Tuvalian–lowermost Rhaetian bedded dolomite with chert and slump breccias, deposited on a slope and/or at the toe-of-slope (Bača Dolomite). Finally, basinal thin-bedded bituminous limestone and marlstone of Rhaetian age follow (Frauenkogel Formation). The upper part of the Frauenkogel Formation contains meter-scale platform-derived limestone blocks, which are signs of platform progradation. The Tarvisio Basin may have extended as far as the present Santo Stefano di Cadore area, representing a notable paleogeographic unit at the western Neotethys margin.

Key words: Southern Alps, Late Triassic, paleogeography, Tarvisio Basin, carbonate platform.

Introduction

The Late Carnian levelling of the topography (Bosellini et al. 2003; Breda et al. 2009; Roghi et al. 2010; Breda & Preto 2011) and the following relative sea level rise (Haas & Budai 1999; Gawlick & Böhm 2000; Gianolla et al. 2003; Berra et al. 2010) created suitable conditions for the growth of one of the most extensive Mesozoic carbonate platforms lining the western embayment of the Neotethys Ocean (Fig. 1, Bosellini 1967; Gawlick 2000; Mandl 2000; Golonka 2002; Bosellini 2004; Haas 2004; Vlahović et al. 2005; Krystyn et al. 2009;

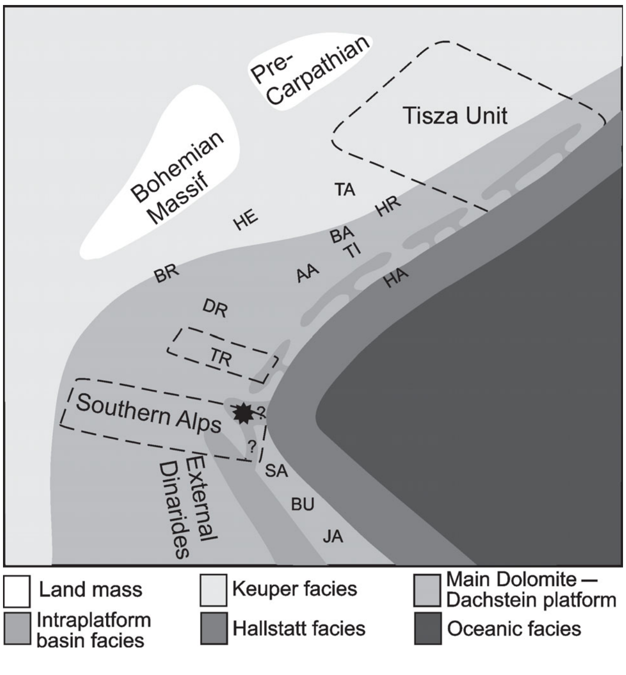

Fig. 1. Paleogeographic position of the Southern Alps during Late Triassic. A suggested position of the Tamar tectonic unit (as a subunit of the Southern Alps) is marked by a black star. Modified after Haas et al. (1995, 2010). **TR** — Transdanubian Range, **SA** — Sava Unit, **BU** — Bükk Unit, **JA** — Jadar block, **DR** — Drauzug, **BR** — Briançonnais Unit, **HE** — Helvetic Unit, **AA** — Austroalpine units, **BA** — Bajuvaricum, **TI** — Tirolicum, **HA** — Hallstatt Unit, **TA** — Tatricum, **HR** — Hronicum.

Haas et al. 2010). The peritidal Dolomia Principale/Hauptdolomit/Main Dolomite deposited in its proximal part, towards the present east passing into the peritidal to shallow subtidal Dachstein Limestone (Kuerschner et al. 2007). Basins of different depths formed inside the platform area and along its edge (Kuss 1983; Jadoul et al. 1992; Carulli et al. 1998; Haas 2002; Haas & Tardy-Filácz 2004; Hornung 2005; Ciarapica 2007; Pálfy et al. 2007; Jadoul et al. 2012). At least two such basins are known from the eastern Southern Alps. The exposures of the better known Ladinian to Upper Cretaceous Slovenian Basin form the southern foothills of the eastern Julian Alps (Winkler 1923; Cousin 1981; Buser 1986, 1989, 1996; Rožič et al. 2013). A Carnian–Lower Jurassic(?) deepening-upward succession was described from the Hahnkogel (in Slovenian termed Klek) tectonic block of the Karavanke Mountains (Krystyn et al. 1994; Lein et al. 1995; Schlaf 1996), and Tuvalian deeper water carbonates were described from the Cave del Predil (Lieberman 1978; De Zanche et al. 2000; Gianolla et al. 2003), Vrata Valley and Martuljek Mountain Group (Ramovš 1986; Schlaf et al. 1997; Ramovš 1998; Sattler 1998; Celarc & Kolar-Jurkovšek 2008) in the northern Julian Alps (Fig. 2). These basinal facies were included by Gianolla et al. (2010) among the remnants of the much less known Tarvisio Basin, which has been considered a distinct branch of the Slovenian Basin.

In this paper, a Carnian to Rhaetian deepening-upward succession from the Tamar Valley in the northern Julian Alps, NW Slovenia (Fig. 2), is described for the first time. This sec-

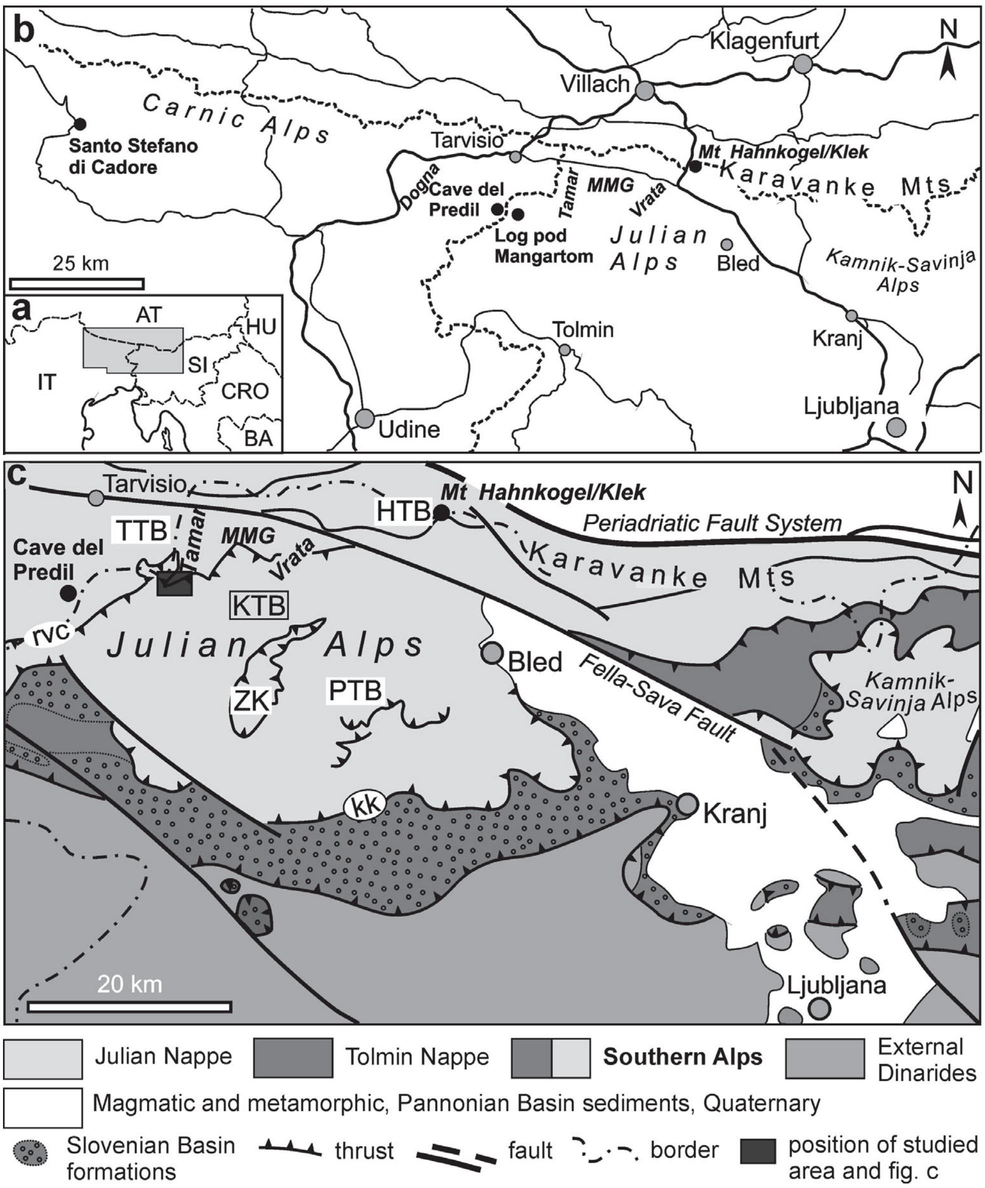

Fig. 2. Position and geological setting of the studied area. **a** — Position of the area depicted in Fig. 2b (shaded), **b** — Detailed map with positions of the sections mentioned in the text, **c** — Structural subdivision of north-western Slovenia. Modified after Buser & Draksler (1993), Placer (1999), and Goričan et al. (2013). **HTB** — Hahnkogel/Klek thrust block, **kk** — Krn-Kobla thrust, **KTB** — Krn thrust block, **PTB** — Pokljuka thrust block, **rvc** — Resia-Val Coritenza backthrust, **TTB** — Tamar thrust block, **ZK** — Zlatna klippe.

tion provides a clear link between the Cave del Predil and the Mt Hahnkogel/Klek area. The Tarvisio Basin is now recognized as an important element of the eastern Southern Alps' paleogeography. Furthermore, the emerging correlation between seemingly disjunct sections is a further step towards Late Triassic carbonate platform-margin reconstruction, similar to those described from the Northern Calcareous Alps (e.g. Mandl 1999; Krystyn et al. 2009) and the Oman Mountains (Bernecker et al. 2005).

Geological setting

The eastern part of the Southern Alps geographically includes the Julian Alps, the southern Karavanke Mts and the Kamnik-Savinja Alps (Placer 1999, 2008). The studied section of the Tamar Valley is located in the northern part of the eastern Julian Alps (Fig. 2), structurally and geographically separated from the Karavanke Mountains to the north by the Fella-Sava line, a dextral WNW-ESE oriented strike-slip fault (Venturini 1990; Placer 1999, 2008; Vrabec & Fodor 2006; Jamšek Rupnik et al. 2012).

Geological research on the valley and its closer surroundings includes work by Peters (1856), Diener (1884), Selli (1963), Ramovš (1981), Ogorelec et al. (1984), and Jurkovšek (1986, 1987). The geological map of Jurkovšek (1986) was later updated by Buser & Draksler (1993) and Buser (2009). The structure of this region is rather complex due to the Alpine tectonics (Doglioni & Bosellini 1987; Poli & Zanferarri 1995; Placer 1999; Castellarin & Cantelli 2000): the Late Cretaceous to Paleogene NE-vergent Dinaric thrusts partially overlap with Neogene N-verging Alpine thrusts (Doglioni & Bosellini 1987; Placer 1999, 2008; Kastelic et al. 2008), both being further cut and displaced by dextral strike-slip faults active since the Pliocene (Castellarin et al. 2006; Vrabec & Fodor 2006; Kastelic et al. 2008; Caputo et al. 2010; Bavec et al. 2012; Kastelic & Carafa 2012). In this complex array of structural features, the Tamar Valley area belongs to the informal "Tamar" tectonic block of the Southern Alps, which is separated from the Krn tectonic block by the Resia-Val Coritenza backthrust (Cousin 1981; Venturini & Carulli 2002; Figs. 2–3).

The herein described succession of the Tamar Valley paleogeographically belongs to the Tarvisio Basin in Gianolla et al. (2010).

Methods

The Upper Triassic lithological units of the Tamar Valley were investigated in two successive sections (Fig. 3): the Črna voda section (46°26′14.19″ N, 13°42′48.82″ E), which consists of the lower part of the succession, and the Travnik section (46°25′53.35″ N, 13°42′36.24″ E), which spans the upper part. A portion of the succession is missing due to faulting.

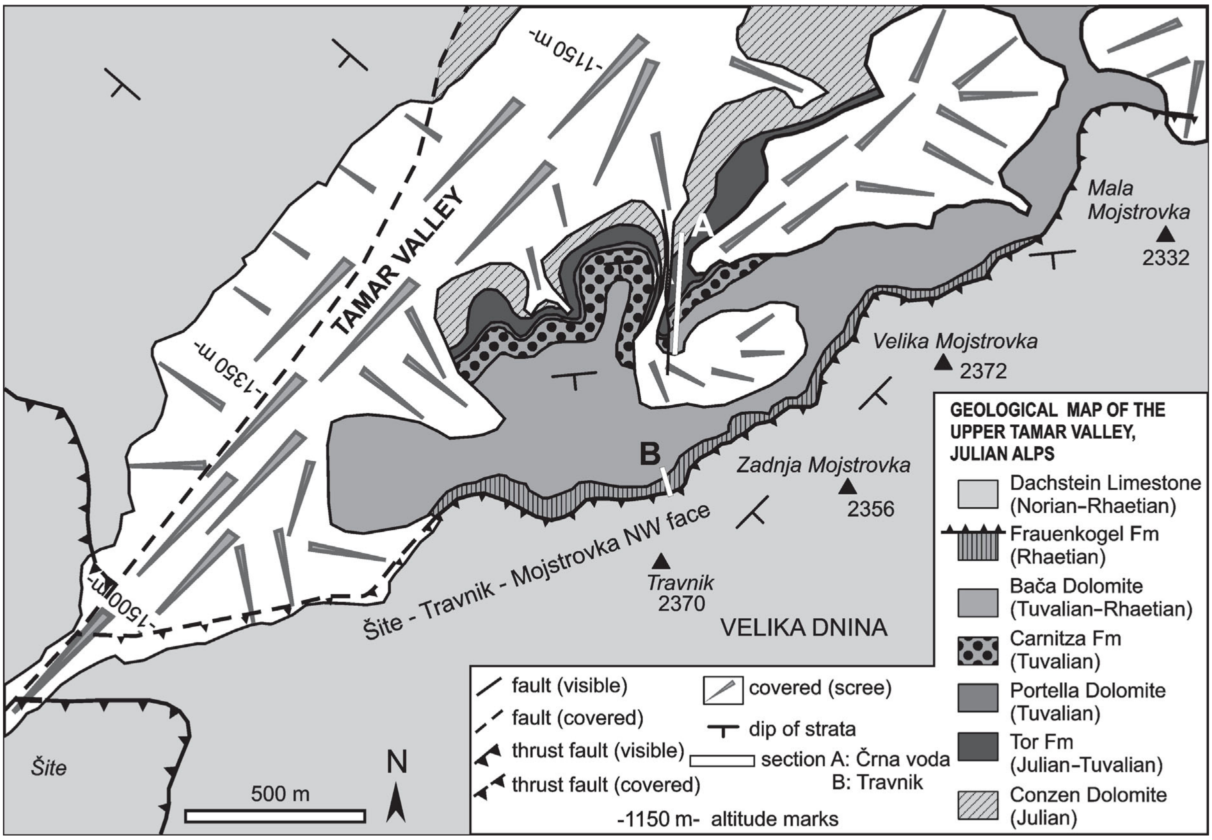

Fig. 3. Geological map of the Tamar Valley with the positions of the Črna voda (**A**) and Travnik (**B**) sections.

Eleven conodont samples of 2.5–3 kg were taken to establish the basic biostratigraphy. Five of the samples were positive. The samples were crushed and treated with diluted acetic acid following standard procedures. The conodont supra-species taxonomy follows Orchard (1991a,b), Kozur (1989, 2003) and Orchard (2007). For the study of benthic foraminifera, 26 thin sections 47×28 and 75×49 mm in size were prepared from 24 stratigraphic levels. The positions of the collected samples are indicated in Fig. 4. Some foraminiferal species are shown in Fig. 5 according to their position in the different lithological units, whereas conodonts are illustrated in Fig. 6. Samples are stored at the Geological Survey of Slovenia, Department for Stratigraphy and Paleontology. In addition to the present sampling, Ogorelec et al. (1984) listed several species of dasycladacean algae, molluscs and benthic foraminifera from the Črna voda section.

Description of the Tamar Valley succession

Lithological units of the Črna voda section

Conzen Dolomite

Description: Bedding is often poorly pronounced, resulting in massive facies (Fig. 7.1). Light brown dolomitized lime mudstone alternates with fenestral dolomite, laminated stromatolitic and oncoid-bearing dolomite (Fig. 7.2) in decimeter to meter scale thick beds.

The foraminifera *Aulotortus friedli* (Kristan-Tollmann) sensu Piller (1978), *Turrispirillina minima* Pantić and small planispiral Involutinaceae were identified.

Discussion: This unit probably represents a time equivalent of the Conzen Limestone described from the Cave del Predil area (cf. De Zanche et al. 2000). The latter becomes more dolomitized and increasingly more shallow-water eastwards (Assereto et al. 1968; De Zanche et al. 2000). *Aulotortus friedli* suggests a Ladinian to Rhaetian age (Piller 1978; Senowbari-Daryan et al. 2010; Gale 2012).

Depositional setting: The presence of stromatolites and oncoids points to peritidal sedimentation, and the dolomitized mudstone suggests deposition in a shallow subtidal zone (e.g. Ogorelec & Rothe 1993; Satterley 1996; Sattler & Schlaf 1999; Haas 2004; Haas et al. 2007).

Tor Formation

Description: The Tor Formation lies on the Conzen Dolomite. A gradual increase in siliciclastic input coincides with the thinning of the dolomite beds (Fig. 7.3). The lower part consists of siltstone, marly limestone with crinoid ossicles, small gastropod shells and undetermined mollusc fragments, and nodular limestone. Coalified plant debris is present. Brownish dolomite and bioclastic dolomite, bivalve lumachelle, and micritic limestone with crinoids are followed by alternating micritic limestone and marlstone. Small megalodontids and bivalve lumachella beds and lenses are present (Fig. 7.5), and there is occasional packstone above erosional surfaces (Fig. 7.6). Bioturbation is common. The uppermost part, consisting of marly dolomite and claystone, is in sharp contact with the overlying Portella Dolomite (Fig. 7.4).

The foraminifera "*Trochammina*" *almtalensis* Koehn-Zaninetti, *Aulotortus friedli*, small planispiral Involutinaceae (?*Triadodiscus eomesozoicus* (Oberhauser)), *Angulodiscus impressus* Kristan-Tollmann, ?*Glomospirella vulgaris* Ho, ?*Hoyenella sinensis* Ho and "*Frondicularia woodwardii* Howchin" auct. were identified (Fig. 5.2–5). Ogorelec et al. (1984) identified, among other fossils, the bivalve *Lopha montiscaprilis* (Klipstein) [*Umbrostrea*? *montiscaprilis* in Szente et al., 2010], foraminifera *Pilamminella kuthani* (Salaj), and dasyclads *Clypeina besici* Pantić and *Poikiloporella duplicata* (Pia).

Discussion: *Umbrostrea? montiscaprilis* indicates the topmost part of the Julian (Ruvinetti, 2004). The Carnian age is further supported by *Clypeina besici* and *Poikiloporella duplicata* (see Senowbari-Daryan, 2003). The lower Tor Formation in Log pod Mangartom (see Fig. 2) belongs to the *Patinasporites densus* (Leschik)–*Partitisporites maljawkinae* (Klaus) palinomorph zone (Ogorelec et al., 1984). The elements of this zone can be found in the *Lagenella martini* assemblage in Roghi et al. (2010), suggesting a correlation with the Dibona Member of the Heiligkreuz Formation in the Dolomites (Roghi 2004; Preto et al. 2005).

Depositional setting: A shift to a more clastic sedimentation in the uppermost Early Carnian is attributed to climate change towards more humid conditions ("Carnian Pluvial Event"; Simms & Ruffell 1989). Bivalve coquinas with internal erosional surfaces are interpreted as tempestites (Schlaf 1996; Pérez-López & Pérez-Valera 2012), and they support the idea of an episodically high-energy environment above the storm wave base, whereas the fossil assemblage suggests normal marine conditions. A nearshore, shallow water depositional setting was suggested by De Zanche et al. (2000) for the Tor Formation at Cave del Predil.

Portella Dolomite

Description: Crystalline dolomite over 4 m thick (Fig. 7.4) is followed by thick to very thick bedded dolomite.

Discussion: A Early Tuvalian age is assumed on the basis of superposition.

Depositional setting: Loss of primary sedimentary structures by dolomitization prevents interpretation of the depositional environment. In the Cave del Predil area, stromatolites are visible in some parts (De Zanche et al. 2000), and the Portella Dolomite has been interpreted as a carbonate bank deposited in a shallow water environment (De Zanche et al. 2000; Gianolla et al. 2003; Preto et al. 2005).

Carnitza Formation

Description: This formation is lithologically uniform, consisting of slightly marly thin to medium bedded dolomite. Bedding is planar or nodular, dolomite beds are often separated by claystone interbeds a few centimeters thick (Fig. 7.7). In the dolomite, parallel lamination is sometimes visible, as well as rare micritic(?) intraclasts and bioturba-

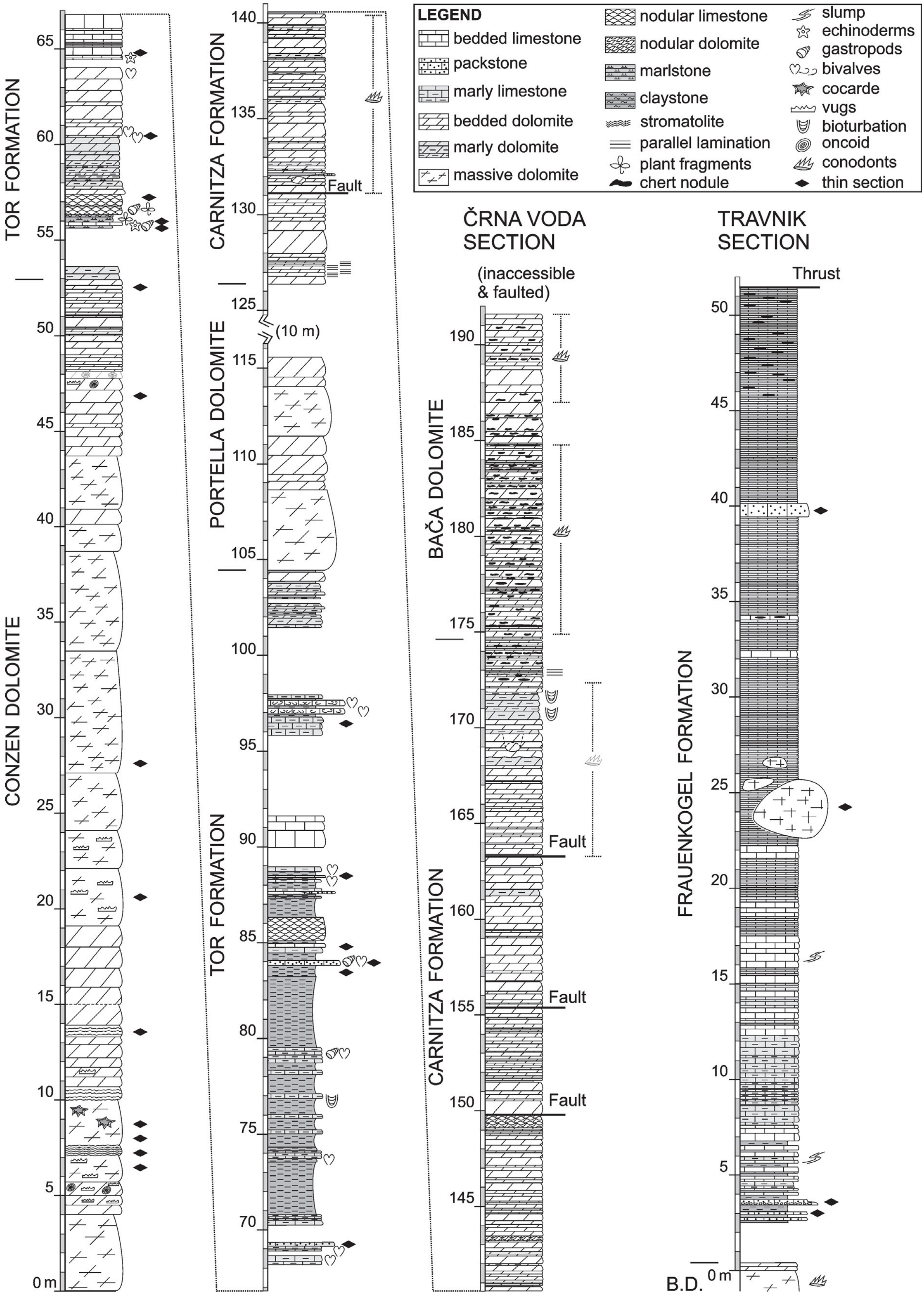

Fig. 4. Lithological log and lithostratigraphy of the measured sections of the Tamar Valley. Only positive conodont samples are indicated. **B.D.** — Bača Dolomite.

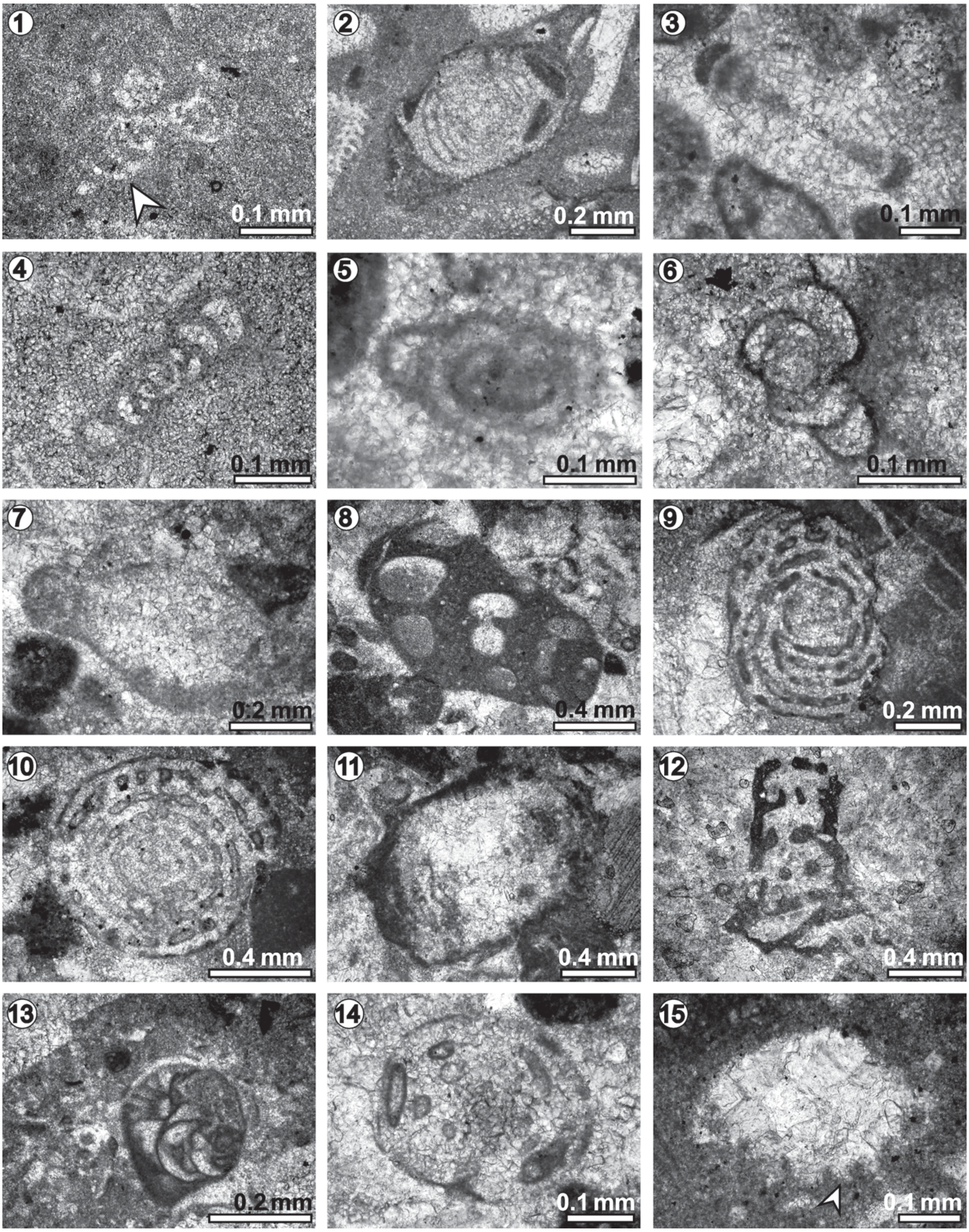

Fig. 5. Upper Triassic foraminifera from the Tamar Valley section. **1** — *Turrispirillina minima* Pantić (arrowhead), Conzen Dolomite; **2** — *Aulotortus friedli* (Kristan-Tollmann), Tor Formation; **3** — *Triadodiscus eomesozoicus* (Oberhauser), Tor Formation; **4** — ?*Glomospirella vulgaris* Ho, Tor Formation; **5** — ?*Hoyenella sinensis* Ho, Tor Formation; **6** — *Hoyenella inconstans* (Michalik et al.) or *Hoyenella sinensis*, Frauenkogel Formation; **7** — *Aulotortus tenuis* Kristan, Frauenkogel Formation; **8** — *Variostoma cochlea* Kristan-Tollmann, Frauenkogel Formation; **9** — *Triasina hantkeni* Majzon — axial section, Frauenkogel Formation; **10** — *Triasina hantkeni* — equatorial section, Frauenkogel Formation; **11** — *Aulotortus sinuosus* Weynschenk, Frauenkogel Formation; **12** — *Alpinophragmium perforatum* Flügel, Frauenkogel Formation; **13** — *Galeanella tollmanni* (Kristan), Frauenkogel Formation; **14** — *Aulotortus friedli* (Kristan-Tollmann), Frauenkogel Formation; **15** — *Trocholina umbo* Frentzen, Frauenkogel Formation.

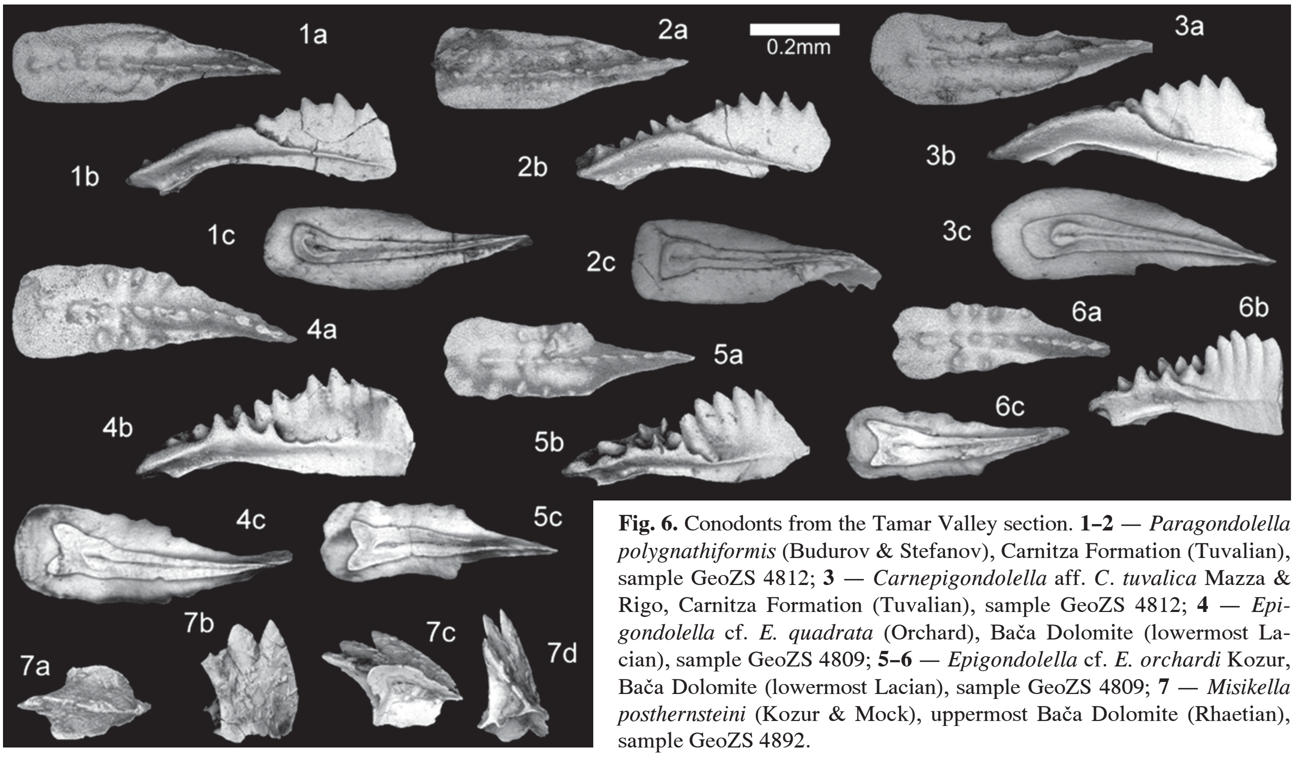

Fig. 6. Conodonts from the Tamar Valley section. **1–2** — *Paragondolella polygnathiformis* (Budurov & Stefanov), Carnitza Formation (Tuvalian), sample GeoZS 4812; **3** — *Carnepigondolella* aff. *C. tuvalica* Mazza & Rigo, Carnitza Formation (Tuvalian), sample GeoZS 4812; **4** — *Epigondolella* cf. *E. quadrata* (Orchard), Bača Dolomite (lowermost Lacian), sample GeoZS 4809; **5–6** — *Epigondolella* cf. *E. orchardi* Kozur, Bača Dolomite (lowermost Lacian), sample GeoZS 4809; **7** — *Misikella posthernsteini* (Kozur & Mock), uppermost Bača Dolomite (Rhaetian), sample GeoZS 4892.

tion. More coarsely crystalline dolomite horizons with sharp lower boundaries were found in a few places above more fine-grained dolomite.

The upper boundary of the Carnitza Formation is placed at the last claystone intercalations, closely coinciding with an increase in abundance of chert nodules.

The conodonts *Paragondolella polygnathiformis* (Budurov & Stefanov), *Paragondolella carpathica* (Mock) and *Carnepigondolella* aff. *C. tuvalica* were recovered from the lowermost 10 m of the Carnitza Formation. The composite sample from the uppermost 10 m of the Carnitza Formation yielded *P. polygnathiformis* and *Metapolygnathus primitius* (Hayashi).

Discussion: In contrast to its type locality in the Cave del Predil area (Lieberman 1978), the Carnitza Formation in the Tamar Valley consists entirely of dolomite. This feature is common in other outcrops of the Italian Julian Alps (De Zanche et al. 2000; Caggiati 2014), and complete dolomitization is also reported in the Southern Karavanke Mts (Krystyn et al. 1994).

Paragondolella carpathica suggests a Tuvalian age for the lower part of the Carnitza Formation (Kolar-Jurkovšek 1991; Muttoni et al. 2001; Krystyn et al. 2002; Buser et al. 2008; Mazza & Krystyn 2013). *Metapolygnathus primitius* in combination with *P. polygnathiformis* from the uppermost part indicates a Late Tuvalian age (Muttoni et al. 2001; Buser et al. 2008; Mazza et al. 2012).

Depositional setting: As for the Portella Dolomite, dolomitization largely obscures the primary sedimentological features and prevents undisputed interpretation of the depositional environment. Parallel lamination may suggest deposition from distal turbidite currents, and the coarser horizons are likely related to the coarse-grained sediment occasionally deposited as distal turbidites or as grain flows (Gale 2010). Its position between the peritidal/shallow water (?)Portella Dolomite and the slope to base-of-slope Bača Dolomite (see below), is in agreement with a progressive deepening, as is the upward-increase in chert nodules observed in the Črna voda section. In the Cave del Predil area De Zanche et al. (2000) and Gianolla et al. (2003) interpreted the lower boundary of the Carnitza Formation as a drowning unconformity.

Bača Dolomite

Description: The Bača Dolomite consists of thin to medium-thick beds of dolomite with common chert nodules and lenses. The sequence continues with massive dolomitized mud-supported breccia with chert clasts and dolomite intraclasts (Fig. 8.1), but this part was not measured due to inaccessibility and disruption by faults. The uppermost part of the Bača Dolomite is accessible in the Travnik section, and the thickness of the entire formation is estimated to be approximately 200 m.

The conodonts *Paragondolella polygnathiformis* and *M. primitius* were recovered from the basal 10 m of the unit. *Epigondolella abneptis* (Huckriede), *Epigondolella* aff. *E. orchard* Kozur and *Epigondolella quadrata* Orchard were found somewhat higher up in the section. The uppermost part of the Bača Dolomite, accessible in the Travnik section (see description there), yielded *Misikella posthernsteini* Kozur & Mock.

Discussion: *Paragondolella polygnathiformis* and *M. primitius* suggest a Late Tuvalian age for the lowermost part of the Bača Dolomite. *Epigondolella quadrata* from a sample taken higher up indicates an Early Norian age (Muttoni et al. 2001; Krystyn et al. 2002, 2009; Mazza et al. 2012).

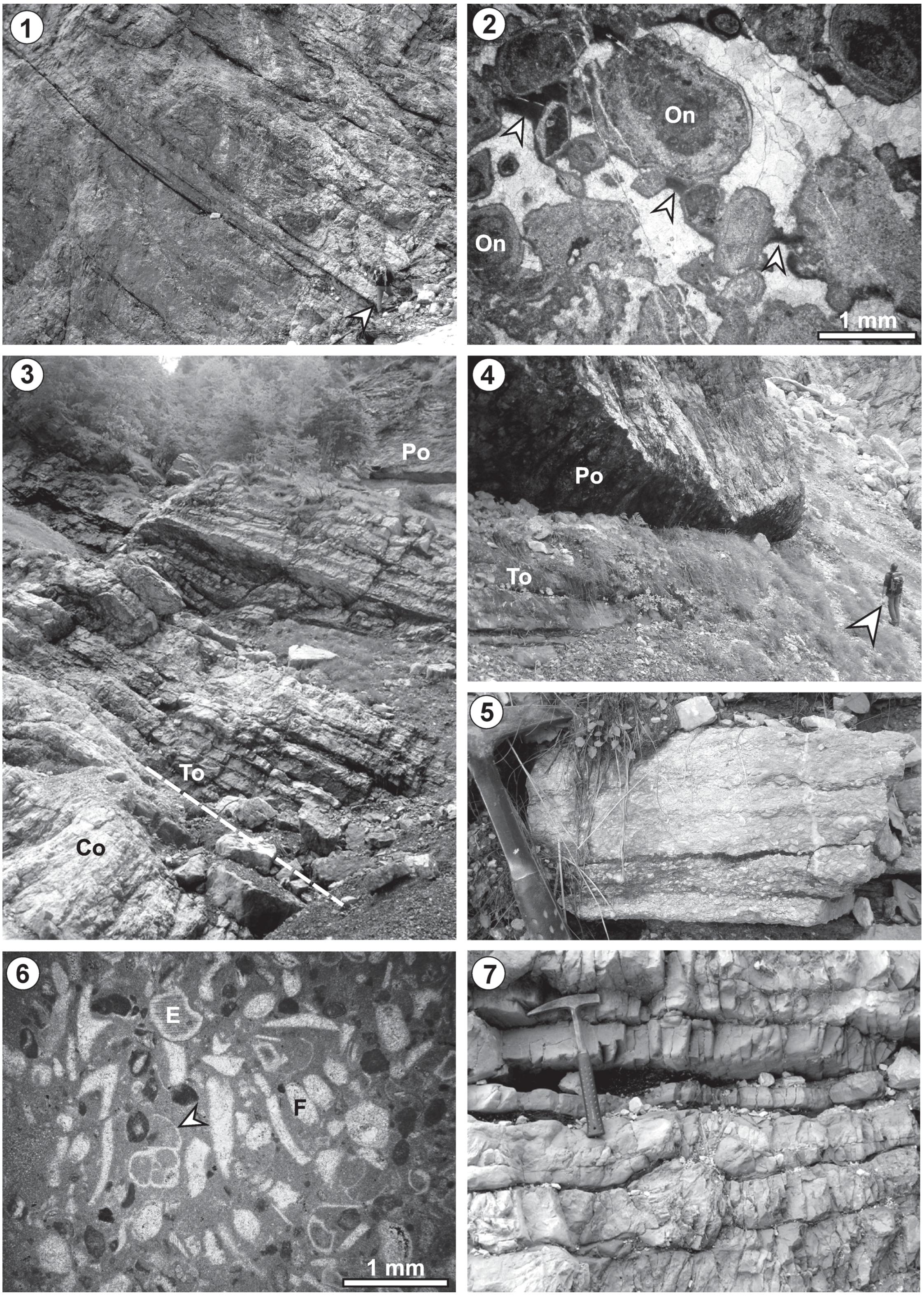

Fig. 7. Field photographs and thin section photomicrographs of lithostratigraphic units of the Črna voda section. **1** — Indistinctly bedded peritidal Conzen Dolomite. Note person for scale (arrowhead); **2** — Oncolitic grainstone (Conzen Dolomite). Note meniscus cement (arrowhead) between oncolites (On) and micritic intraclasts; **3** — Uppermost Conzen Dolomite (Co), Tor Formation (To) and Portella Dolomite (Po). The boundary between the Conzen Dolomite and the Tor Formation is marked by a dashed line; **4** — Transition between the Tor Formation (To) and the Portella Dolomite (Po). Note person (arrowhead) for scale; **5** — Bivalve lumachella (tempestite) in the Tor Formation; **6** — Bioclastic packstone of the Tor Formation. Fossils include gastropods (arrowhead), foraminifera (F), and echinoderms (E). The majority of spar grains, however, are mollusc fragments; **7** — Dolomite intercalated with black claystone in the Carnitza Formation.

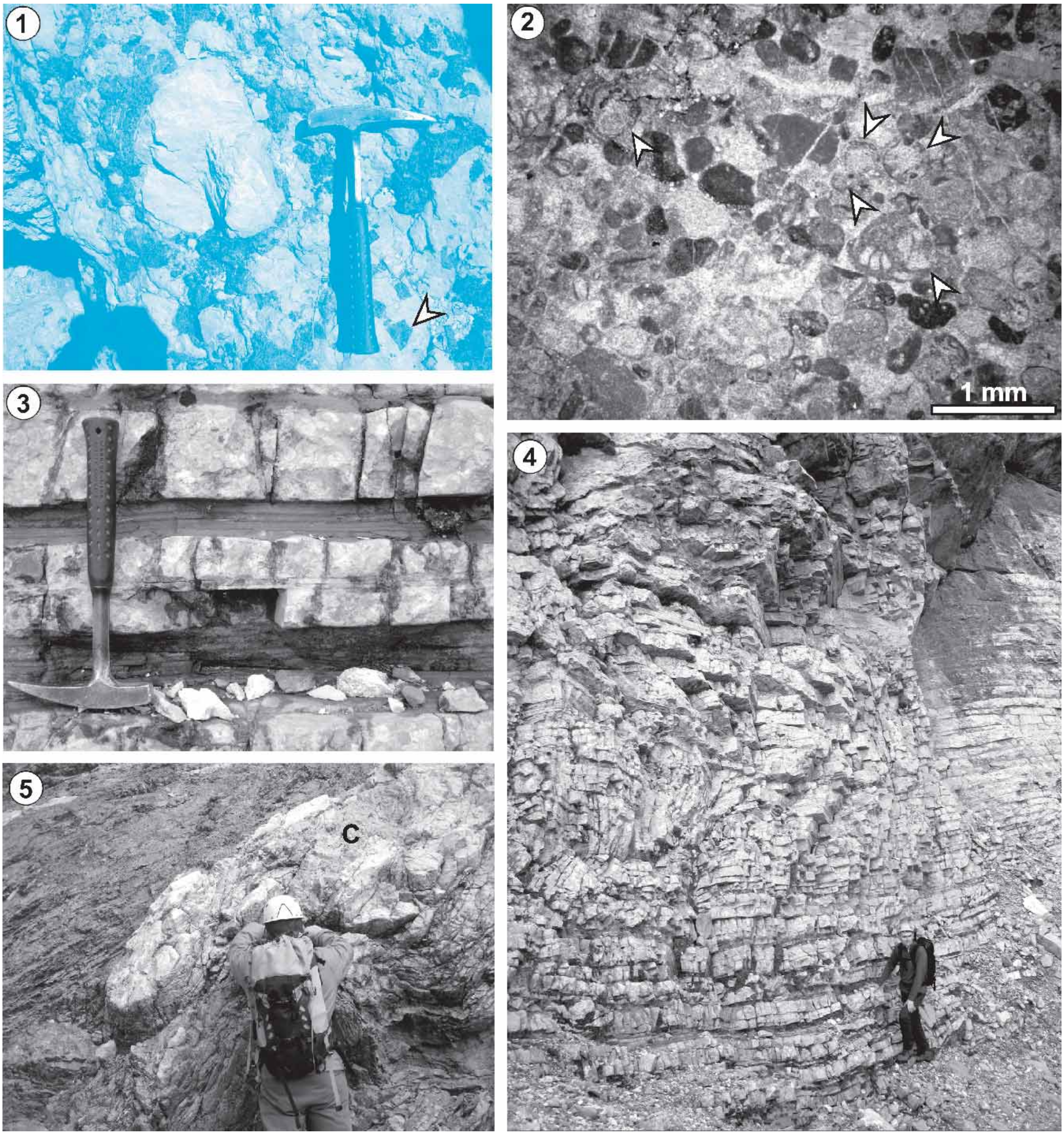

Fig. 8. Field photographs and thin section photomicrographs of lithostratigraphic units of the Travnik section. **1** — Breccia with dolomitic and chert intraclasts of the middle part of the Bača Dolomite (ex situ). Note brittle deformation of chert clasts (arrowhead), suggesting early chertification of the sediment (D. Skaberne, pers. com.); **2** — Grainstone with abundant benthic foraminifera, mostly *Triasina hantkeni* Majzon and Duostominidae (arrowheads); **3–4** — Thin-bedded to laminated bituminous limestone and claystone/marlstone of the Frauenkogel Formation; **5** — A large olistolith of Dachstein Limestone (C) embedded in the Frauenkogel Formation.

Misikella posthernsteini was recovered from the uppermost Bača Dolomite, indicating proximity to the Norian-Rhaetian boundary (e.g. Krystyn et al. 2008, 2009; Giordano et al. 2010; Hüsing et al. 2011).

Depositional setting: Mud-supported breccia with chert clasts and dolomite intraclasts are interpreted as debris flow deposition on an inclined slope. The Bača Dolomite is better characterized in the Tolmin Nappe of the Southern Alps from the succession of the Slovenian Basin (Kossmat 1914; Buse, 1986; Gale 2010). Sedimentological analysis of the non-dolomitized horizons within the Bača Dolomite from the proximal-most preserved part of the Slovenian Basin points to deposition on the slope and at the foot of the slope (Gale 2010).

Lithological units of the Travnik section

Frauenkogel Formation

Description: The Frauenkogel Formation overlies the Bača Dolomite with a sharp boundary. The Frauenkogel Formation in its lowermost part contains marlstone and a few graded and laminated fine- to medium- coarse rudstone and grainstone beds (Fig. 8.2). A uniform sequence of dark bituminous and laminated platy limestone follows, alternating with marlstone (Fig. 8.3–4). Small nodules and thin lenses of chert are rare. Bedding is often disrupted by slumps. In the upper part of the sequence, boulders measuring up to 3 m of beige wacke- to packstone and dark grey packstone lie among platy limestones (Fig. 8.5). They contain peloids, ooids, a few lumped clasts, and subordinate bioclasts (foraminifera, echinoderms, brachiopods, bivalves). The Travnik section is truncated at the top by the Resia-Val Coritenza thrust, bringing it in tectonic contact with subtidal to peritidal Dachstein Limestone.

Rudstone from the basal part of the Frauenkogel Formation yielded a rich assemblage of benthic foraminifera (Fig. 5.6–15): *Gandinella falsofriedli* (Salaj et al.), "*Trochammina*" *almtalensis*, *Alpinophragmium perforatum* Flügel, "*Tetrataxis*" *inflata*, *Triasina hantkeni* Majzon, *Aulotortus friedli*, *Aulotortus sinuosus*, *Aulotortus tumidus*, *Aulotortus tenuis* Kristan, *Trocholina umbo* Frentzen, *Auloconus permodiscoides* (Oberhauser), *Hoyenella inconstans* (Michalik et al.) or *Hoyenella sinensis*, "*Orthotrinacria expansa*" auct., *Galeanella tollmanni* (Kristan), *Decapoalina schaeferae* (Zaninetti et al.), *Variostoma cochlea* Kristan-Tollmann, *Variostoma helicta* (Tappan), *Duostomina biconvexa* Kristan-Tollmann and *Lenticulina* sp. From the olistoliths we identified the following species: *Aulotortus friedli*, *Aulotortus sinuosus*, *Triasina hantkeni* and *Hoyenella sinensis*. *Trocholina crassa* Kristan, Involutinidae and *Lenticulina* sp. were identified in the packstone bed 38 m above the base of the section.

Discussion: Biostratigraphic data suggest a correlation with the Frauenkogel Formation described from the Hahnkogel/Klek tectonic block of the Southern Karavanke Mts, although at the type locality, the Frauenkogel Formation lacks marlstone and the limestone is often bioturbated and in part contains chert nodules (Krystyn et al. 1994; Lein et al. 1995; Schlaf 1996). Foraminifera from the Travnik section were derived in majority from shallow water reef-rimmed carbonate platform environments (see Gale 2012 and references therein). *Triasina hantkeni* from the basal part of the unit is an indicator for a Rhaetian age of this unit (see Gale et al. 2012).

Depositional setting: Common slumping indicates deposition on a slope. Coarse-grained, graded and laminated rudstone and grainstone are interpreted as turbidity current deposits (Tucker 2001; Flügel 2004). Blocks of Dachstein Limestone found in the upper part of the unit are interpreted as cipit boulders derived from the adjacent shallow water platform (Russo et al. 1997; Trombetta 2011), as suggested by a foraminiferal assemblage typical of shallow water carbonate platforms (*Triasina hantkeni*, Aulotortidae). Beds in which only horizontal lamination is observed could be related to a low-energy setting, poorly ventilated water and suboxic or even anoxic conditions, as suggested by the absence of bioturbation and the smell of bitumen (Carulli et al. 1997; Brenchley & Harper 1998). Such conditions can occur in a variety of depositional environments; however, deposition in deeper water is suggested due to the presence of cipit boulders and turbidite deposits.

Discussion

Although numerous occurrences of Upper Triassic deep water successions are known from the eastern Southern Alps (e.g. Ramovš 1989), only a handful of them have been studied in detail, and their relationships are not completely understood. The lateral extent of the Tarvisio Basin can be followed to the western Julian Alps and the Southern Carnic Alps.

In the Cave del Predil massive and thick-bedded shallow water limestone and dolomite of the Schlern Formation is overlain by thin-bedded dolomite, doubtfully attributed to the Lower Carnian (Assereto et al. 1968; Lieberman 1978; De Zanche et al. 2000; Roghi 2004).

Massive clinobeds of the Schlern Dolomite are interfingered with and then onlapped by the thick carbonate-siliciclastic Julian sequence of the Predil Limestone and the Rio del Lago Formation (Assereto et al. 1968). The latter passes upward to the Conzen Formation, followed by the Upper Julian to Lower Tuvalian Tor Formation, overlain by the Portella Dolomite and the Lower to Upper Tuvalian Carnitza Formation (Lieberman 1978; De Zanche et al. 2000).

The Hahnkogel/Klek tectonic block (see Fig. 2) is located on the northern side of the Fella-Sava fault in the Southern Karavanke Mountains (Ramovš 1993; Krystyn et al. 1994; Lein et al. 1995; Schlaf 1996). The Ladinian (and Julian?) Schlern Dolomite is followed by massive- to thick-bedded dolomite with stromatolites of the Conzen Dolomite, presumably Julian in age. The contact between the Conzen Dolomite and the terrigenous "Raibl beds" is tectonically disturbed. The latter consists of limestone, marlstone, marly limestone and bivalve coquinas with features of tempestites (Krystyn et al. 1994; Lein et al. 1995; Schlaf 1996), and they are coeval to the Tor Formation. The terrigenous "Raibl beds" terminate with Upper Carnian thin- to medium-bedded dolomite with stromatolites, shallow water replacement chert and desiccation cracks (Krystyn et al. 1994) coeval to the Portella Dolomite. A progressive deepening starts with the Upper Tuvalian(?) Carnitza Formation (Krystyn et al. 1994; Lein et al. 1995; Schlaf 1996) and the overlaying Lacian to Alaunian Bača Dolomite (Krystyn et al. 1994). Synsedimentary tectonics is evident through slumps and debris-flow breccias (Krystyn et al. 1994; Lein et al. 1995). The dolomitic unit grades upwards into platy and thin bedded bioturbated hemipelagic limestone with chert nodules of the Upper Sevatian to Rhaetian Frauenkogel Formation, featuring in its lower part three massive mass-flow breccias (Krystyn et al. 1994).

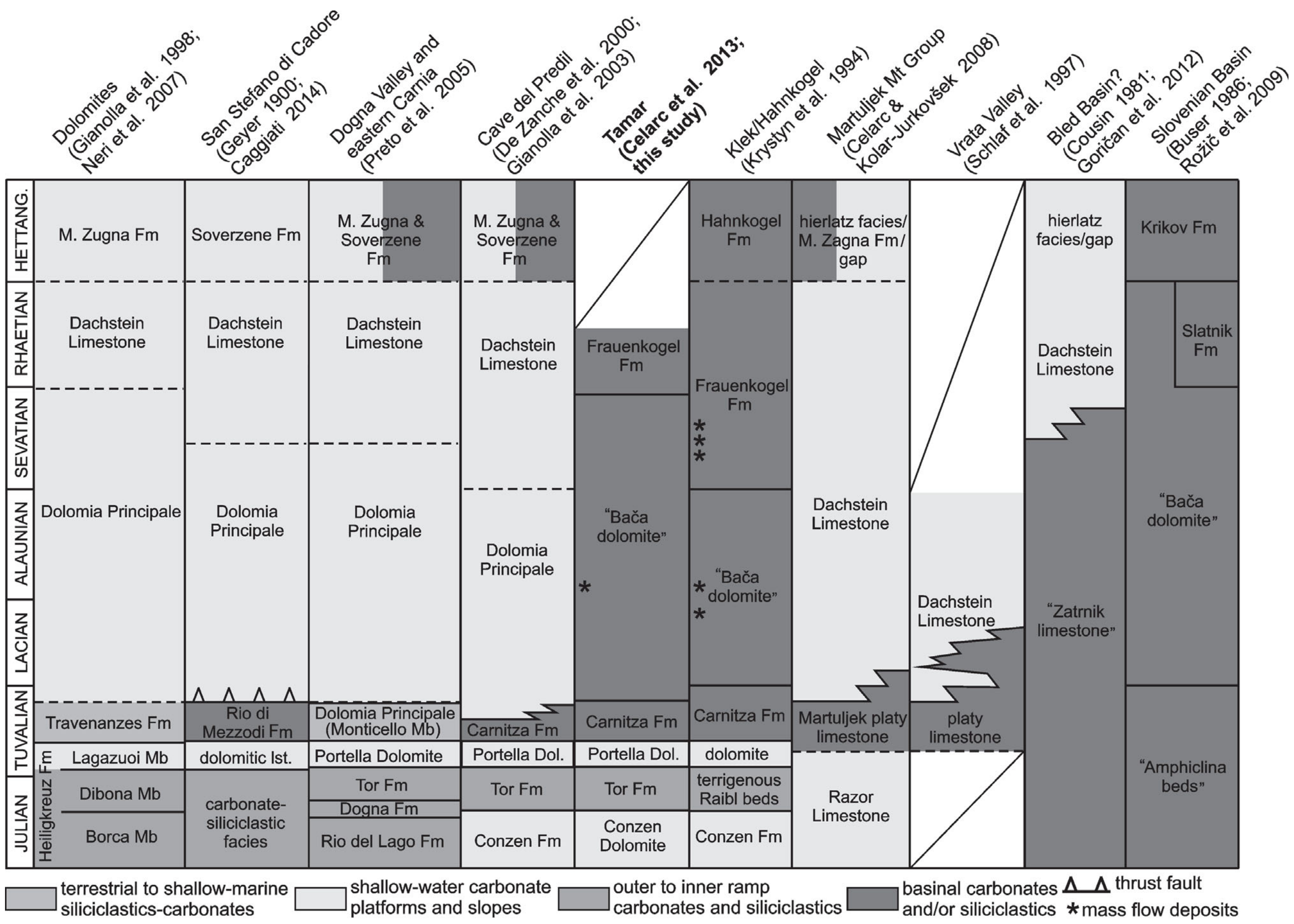

Fig. 9. Correlation chart for Upper Triassic basinal successions of the Southern Alps. Note that in the majority of cases (especially for the Norian to Rhaetian interval; dotted lines), stratigraphic resolution based on the present knowledge does not allow exact correlation of the formation boundaries.

The youngest lithological unit of the Hahnkogel/Klek area consists of medium thick beds of micritic limestone of Rhaetian? and Early Jurassic age (Hahnkogel Formation) rich in sponge spicules and radiolarians (Krystyn et al. 1994; Lein et al. 1995; Schlaf 1996).

A hypothetical Cave del Predil-Tamar Valley-Mt Hahnkogel/Klek transect depicts a progressive deepening towards the present northeast (Fig. 9). The most proximal position of the Cave del Predil area can be assumed on the basis of a stronger terrigenous influence in the pre-Tuvalian units and according to the early sealing of the basin by the Dolomia Principale clinobeds. The distal-most position of the Hahnkogel/Klek section is finally supported by the continued deep water sedimentation in the Early Jurassic and the diminishing supply of the platform derived carbonate, reflected in a shorter stratigraphic time span of the Bača Dolomite.

Evidence of a western extension of the Tarvisio Basin is found at least up to the upper Dogna Valley (Sompodogna) where the Carnitza Formation overlays the Portella Dolomite (Preto et al. 2005). In the same place, there is evidence of a margin-slope system connected to a shallow inner lagoon area (Monticello Member of Dolomia Principale — Roghi & Dalla Vecchia 1997; Preto et al. 2005; Caggiati 2014). Further to the west, basinal conditions in the Late Tuvalian are only reported in the Santo Stefano di Cadore area (Geyer 1900; Gianolla et al. 1998, 2010; Caggiati 2014), but the spatial connection with the Tarvisio Basin can only be assumed due to the lack of Upper Triassic successions in most of the Carnic Alps.

Towards the present east Gianolla et al. (2010) proposed a link between the Tarvisio Basin and the Slovenian Basin. Such a connection was also envisaged by Krystyn et al. (1994), who considered the Hahnkogel/Klek succession as part of the Slovenian Basin. However, there is currently no evidence for or against this connection.

Conclusions

The Tamar Valley (NW Slovenia) structurally belongs to the Tamar tectonic block of the eastern Southern Alps and is bordered by the Resia-Val Coritenza backthrust to the southeast and the Fella-Sava line to the north (Placer 1999; Venturini & Carulli 2002). The Upper Triassic succession of the Tamar Valley is composed of Julian peritidal to shallow subtidal dolomite (the Conzen Dolomite), Julian to Lower

Tuvalian marlstone and marly limestone, deposited above the storm wave-base (the Tor Formation), Lower Tuvalian peritidal to shallow subtidal dolomite bank (the Portella Dolomite), Upper Tuvalian well-bedded dolomite with claystone intercalations (the Carnitza Formation), Upper Tuvalian to lowermost Rhaetian bedded dolomite with chert and slump breccias (the Bača Dolomite), and Rhaetian thin-bedded, slightly bituminous and laminated limestone and marlstone (the Frauenkogel Formation). This succession, ending at a thrust plane, records platform drowning during the Tuvalian (top of the Portella Dolomite) and a progressive deepening of the area during the Norian.

According to the deduced paleobathymetric setting, the Tamar Valley succession was deposited in deeper water with respect to the Cave del Predil succession, belonging to the same structural unit (i.e. the Tamar tectonic block). Both of these, however, were deposited in shallower setting with respect to the Hahnkogel/Klek section (belonging to the Hahnkogel/Klek tectonic block), suggesting a bathimetric trend among these three successions. This trend probably reflects a proximal to distal evolution along a section of the passive margin of the Neotethys Ocean, preserved in the eastern Southern Alps.

Acknowledgments: This study was financially supported by the Slovenian Research Agency (Project No. P1-0011), and by the Italian PRIN 2010-2011 funds (Project No. 20107ESMX9_004). Thin sections and conodont samples were prepared by the laboratory staff of the Geological Survey of Slovenia. The manuscript has been improved following constructive remarks by J. Pálfy, N. Preto and an unnamed third reviewer. Their help in improving the manuscript is greatly appreciated.

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