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Cover page: Natural pavement of typical polygonal sandstone blocks on Debeli rtič extends from cliff foot far into the shallow sea where stands the only Slovenian lighthouse built up directly in the sea. The winning photo in a photo competition about Flysches at the 4th Slovenian Geological Congress in Ankaran. Author: Barbara Vidmar

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Uvodnik

Spoštovane bralke in bralci!

Ob letošnji številki *Geologije*, ki je prva po 4. Slovenskemu geološkemu kongresu, me je glavna urednica kot organizatorja kongresa zaprosila za uvodnik. Ob tem povabilu so se mi misli vrtele večinoma okrog nedavnega kongresa, ampak v ozadju mi je nenehno odmeval slavni filmski citat Michaela Corleoneja iz *Botra III*: »*Just when I thought I was out, they pull me back in.*« Pravkar sem namreč zaključil s predsedstvom Slovenskega geološkega društva (SGD) in z organizacijo kongresa, pa imam že spet s tem opravka! Dajmo filme na stran, šale pa še ne: preden boste brali uvodnik, vam za lažje razumevanje opomb v oklepajih, ki sledijo, priporočam še poslušanje pesmi iz albuma *Pozdrav iz zemlje Safari* skupine *Zabranjeno pušenje*, ki so tudi vplivale na pisanje uvodnika ...

Tako kot prva pesem albuma se je tudi naš mandat v društvu (2010–2014) začel brez težav, bolj ali manj brez skrbi in brez večjih pretresov (»*Posao je dobar, a para laka* ...«*: pesem Bos ili hadžija*). Nadaljevali smo z ustaljenim delom: izvajali strokovna predavanja in ekskurzije ter organizirali nekaj okroglih miz o tematiki članstva SGD v mednarodnih združenjih, o spremembah zakonodaje glede sprememb Zakona o ohranjanju narave in o Geoparkih ipd.

V tem času sem spoznal precej ljudi, ki delujejo na res raznovrstnih področjih geologije. Ta pestrost se je pozneje pokazala tudi v prispevkih na 4. Slovenskem geološkem kongresu, ki je potekal v hotelskem kompleksu Adria Ankaran v Ankaranu med 8. in 10. oktobrom 2014. Organizacijo kongresa je vodil Oddelek za geologijo Naravoslovnotehniške fakultete Univerze v Ljubljani v sodelovanju s Slovenskim geološkim društvom. Lokacijo kongresa smo izbrali precej na začetku mandata, v organizacijskem odboru pa smo imeli pred očmi predvsem dejstvo (poleg motivacije *»A sada, pravac more, viknu Žuga iz sveg glasa ...«: pesem Pišonja i Žuga*), da imamo v Sloveniji precej fliša, ki si zato zasluži samostojno obravnavo, kar smo skušali doseči z izvedbo ekskurzij in njihovimi opisi v kongresnem zborniku. Med številnimi možnimi kongresnimi lokacijami v Portorožu, Strunjanu in Ankaranu smo se nazadnje odločili za slednjo, ker je prijetno mirno okolje nudilo več možnosti za druženje. K dobremu vzdušju je pripomoglo tudi izredno lepo jesensko vreme, tako da smo lahko izvedli tudi vse predvidene ekskurzije.

Prva dva dneva kongresa sta se začela z vabljenima predavanjema, kjer sta predavatelja povzela številne nove ugotovitve glede geofizikalnih in strukturnih raziskav ter geokemičnih raziskav morja in sedimentov Tržaškega zaliva. Sledila so predavanja v treh vzporednih sekcijah, v Stekleni dvorani, Sejni sobi in Kapeli (prvotno smo načrtovali dve sekciji, a smo zaradi velikega števila prispevkov ugotovili, da potrebujemo tri) ter predstavitve posterjev v dveh sekcijah. Prvi dan smo organizirali popoldanski ekskurziji; na soline in v izbrane vinograde ter na priobalne fliše v Strunjanu, kjer smo na številnih točkah predstavili sedimentološke in strukturne značilnosti fliša. Tretji dan smo izvedli celodnevne ekskurzije; bazično geološko od morja do Bohinja, inženirsko geološko v Vipavsko dolino in hidrogeološko po slovenski obali. Povzetki s kongresa so zbrani v 121 strani dolgem tiskanem zborniku povzetkov, ki je poleg programa, fotografij in drugega materiala dostopen na strani http://web.geo.ntf.uni-lj.si/4-sgk/datoteke.

Ob sklepu kongresa smo z veseljem ugotovili, da so bila na srečanju zastopana vsa področja geologije, od klasičnih bazičnih in aplikativnih ved pa do geoturizma, povezav z geodezijo, geografijo, krajinskimi parki, solinami, geoparki ipd. S še večjim veseljem pa smo spoznali, da so bili v glavnem vsi udeleženci zelo zadovoljni z izvedbo, tako z organizacijo in vsebino predavanj kot tudi z okoljem in druženjem. Udeležba je presegla pričakovanja, saj se je kongresa udeležilo 177 udeležencev iz Slovenije in tujine, od tega je bilo prijavljenih 84 predavanj in 61 posterjev. Predavanja in posterje so avtorji predstavili v naslednjih 18 sekcijah: *Sedimentologija in stratigrafija, Kras, Geokemija, Geološka dediščina in geoturizem, Geomorfologija, Paleontologija, Strukturna geologija, Ranljivost in upravljanje z vodnimi viri v spreminjajočem se podnebju, Mineralne surovine in tehnična mineralogija, Paleontologija, Hidrogeologija, Geofizika, Hidrogeokemija, Geomehanika in inženirska geologija, GIS in podatkovne baze, Mineralogija in petrologija, Inženirska geologija ter Digitalna geologija in obdelava podatkov*. Zelo dejavni so bili na kongresu tudi študentje, ki so se v velikem številu udeležili srečanja, številni izmed njih pa so tudi predstavili svoje prispevke. Drugi dan kongresa smo organizirali svečano večerjo, na kateri smo podelili nagrade zaključnih natečajev, ki smo jih razpisali za udeležence kongresa, in sicer natečaje za najboljšo fotografijo na tematiko fliša, za najboljši poster in za najboljših pet študentskih prispevkov. Nagrajenci so objavljeni na spletni strani kongresa, nagrajena fotografija pa krasi tudi tokratno naslovnico *Geologije*. Večerji je sledila še skupščina SGD, kjer smo predali funkcije novemu vodstvu društva.

Organizacija kongresa brez pomoči kolegov (»*Dobre jarane para kupit ne može* ...«*: pesem Dobri jarani*) nikakor ne bi uspela, zato se tudi ob tej priložnosti ponovno vsem zahvaljujem za pomoč in profesionalno izvedbo.

No, poleg kongresa in ustaljenih zadev, povezanih s preteklim delovanjem društva, smo v zadnjih štirih letih uvedli še nekaj novosti. Tako smo v sodelovanju z Zavodom za varstvo naravne dediščine uvedli delovne akcije (»*Sve što je imao od oružja, to su srce, ruke i lopata* …«*: pesem Srce, ruke i lopata*) za čiščenje geoloških profilov, letos pa smo se lotili že druge tovrstne akcije, ki je bila prav tako dobro sprejeta. Upam, da se bo podobno delo nadaljevalo. Študentska sekcija je izvedla tudi delavnico preparacije fosilov. Kakor smo se zavezali na prejšnjem kongresu v Bovcu, smo vsako leto izdali tudi letno poročilo delovanja društva v reviji *Geologija* in v biltenu *Mineralne surovine*.

Nekaj idej, ki zadevajo širši krog geologov, pa je seveda še neuresničenih. Izpostaviti želim le dve bolj pomembni: precej živahna debata se je razplamtela v povezavi z nazivom Evrogeolog, četudi pridobivanje naziva pri nas sploh še ni zaživelo, čeprav smo ustanovili komisijo za podelitev naziva. Problematika je torej še aktualna. Predvsem pa smo se soočili s še bolj resnim problemom, ki je povezan z dejstvom, da geološki stroki manjkajo številne pravne podlage za izvajanje določenih geoloških del in raziskav pred raznimi posegi v prostor ipd., kar bi z dvema besedama sodilo pod t. i. »geološki zakon«. Iniciativo moramo prevzeti sami tukaj in zdaj (»*Žao mu je što neki misle, da je život negdje drugdje ...*«*: pesem Dan republike)*, česar se zaveda tudi novo vodstvo SGD.

Naj sklenem: veseli me, da je mandat našega odbora v društvu vsaj po mojem osebnem mnenju uspešno zaključen (hvala vsem za vse!) in da je bil kongres kot pika na i vsakega mandata tudi kvaliteten, kar se kaže v raznovrstnosti člankov, ki so zbrani v tej številki *Geologije* in so bili večinoma prvotno predstavljeni kot prispevki na kongresu. V zvezi s prihodnostjo društva me veseli tudi, da je novi predsednik društva, dr. Matevž Novak, sprejel »*ponudbo, ki je ni mogel zavrniti*«. Dela je še kar nekaj, a usmeritev je prava.

Želim vam torej prijetno branje omenjenih prispevkov, obenem pa se že veselim novih raziskav v naslednjih letih. Glede na pestrost področij in dejavnost kolegov teh zagotovo ne bo malo!

Timotej Verbovšek

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New data on the progradation of the Dachstein carbonate platform (Kamnik-Savinja Alps, Slovenia)

Novi podatki o progradaciji Dachsteinske karbonatne platforme (Kamniško-Savinjske Alpe, Slovenija)

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Ključne besede: Karnij/norij, Južne Alpe, Kamniško-Savinjske Alpe, progradacija platforme, dachsteinska karbonatna platforma, Slovenija

Abstract

Upper Triassic basin-platform succession in the Kamnik-Savinja Alps (N-central Slovenia) is similar to the succession known from the Julian Alps (Martuljek Mountain Group). It was part of the same Late Triassic depositional edifice, with the progradation of the Dachstein Platform in the SW-NE direction (recent orientation) from Julian Alps toward the Kamnik-Savinja Alps. Tectonic blocks with the same/similar stratigraphic record, were displaced as a consequence of the Alpine and later tectonic displacements. In the Kamnik-Savinja Alps, the upper part of the Martuljek platy limestone was dated with the conodonts as Late Carnian – Early Norian in the Mt. Kočna. In the Mt. Skuta area, Limestone with chert is positioned above Martuljek platy limestone and under the Dachstein carbonate platform. Uppermost part of the Limestone with chert is Late Norian. Mutual vertical and lateral relationship, age of the lithological units, especially upper part of the deeper-water limestone, points to the progradation of the Dachstein carbonate platform in the Early Norian and possible aggradation in the part of the Middle and in the Late Norian.

Izvleček

Zgornjetriasno bazensko – platformno zaporedje v Kamniško – Savinjskih Alpah (S Slovenija) je zelo podobno zaporedju v Julijskih Alpah (Martuljkova gorska skupina). V mlajšem triasu je tvorilo enoten sedimentacijski prostor s progradacijo dachsteinske platforme v smeri JZ-SV (današnja orientacija) iz Julijskih Alp v Kamniško-Savinjske Alpe. Bloki z istim/podobnim stratigrafskim zapisom so bili kasneje zaradi alpske in mlajše tektonike premaknjeni v današnji položaj. V Kamniško-Savinjskih Alpah je bil zgornji del Martuljških apnencev v Kočni s konodonti datiran v mlajši karnij – starejši norij. Na območju Skute se nad Martuljškimi apnenci in pod dachsteinsko platformo pojavi še zaporedje apnencev z roženci, katerih vrhnji del je datiran v mlajši norij. Medsebojni vertikalni in lateralni odnos, ter starost litoloških členov, predvsem zgornjega dela globljevodnih apnencev, kaže na progradacijo dachsteinske karbonatne platforme v starejšem noriju, ter možno agradacijo v delu srednjega in v mlajšem noriju.

Introduction

Recent investigations in the northern part of the Julian Alps (Martuljek Muntain Group) (Celarc & Ogorelec, 2006; Celarc & Kolar-Jurkovšek, 2008), together with the previous works (Ramovš, 1986, 1987; Jurkovšek, 1987; Sattler, 1998) established a firm model for stratigraphic and paleogeographic evolution model for this area. It is marked by the widespread drowning of the Middle Carnian carbonate platform (Razor limestone), which formed submarine topographic high, with deposition of the thin horizon of reddish Upper Carnian – Lower Norian pelagic platy or nodular basinal limestone (Martuljek platy limestone). This topographic high was probably connected with the shallow-water area, from where the rimmed Dachstein carbonate platform started to form and rapidly prograded in the NE direction (1200m/Myr, Celarc & Kolar-Jurkovšek, 2008) towards the basin with well-developed facies zones (slope, coral reef margin and the Lofer cyclic Dachstein Limestone in the peritidal area behind the reef). In the NW face of the Mt. Škrlatica, onlap of the cyclic Dachstein Limestone on the coral reef, slope clinoforms and intrefingering of the lower slope with the basinal limestone are well exposed. According to the dip direction of these surfaces, NE progradation

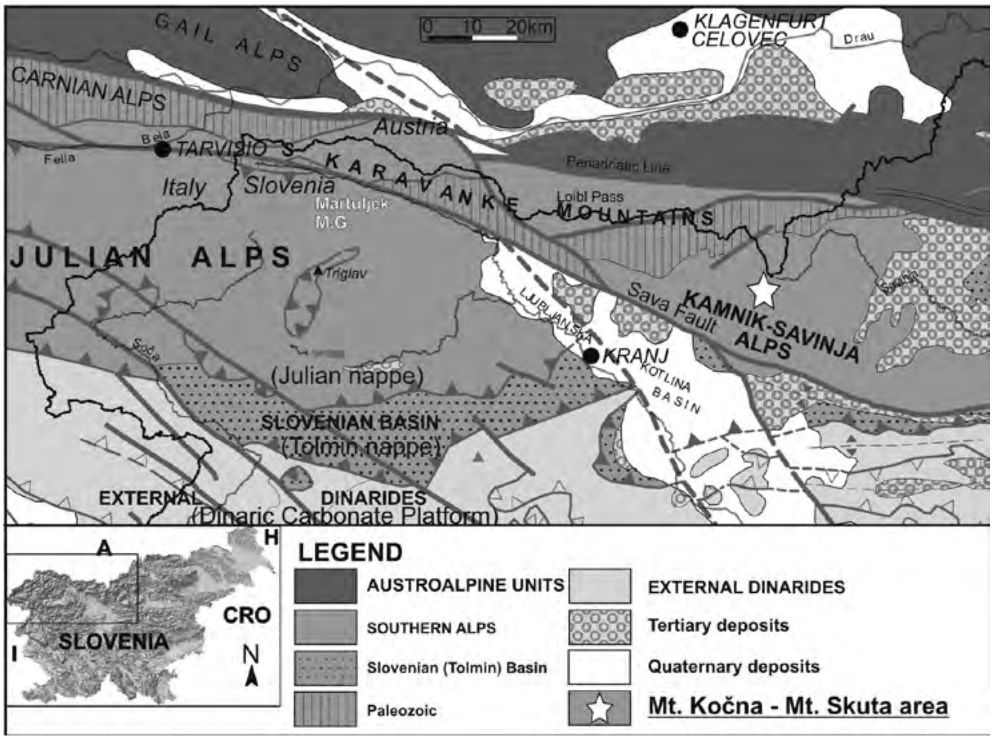


Fig. 1. Structural scheme of the N-central and NW Slovenia. The research area in the Kamnik-Savinja Alps is marked with star. Tectonic units after Placer (2008).

direction of the platform was established, which was also confirmed by the progressively younger age of the uppermost part of the Martuljek platy limestone in that direction. Similar stratigraphic situation is also reported in the Kamnik-Savinja Alps, more to the east (Ramovš, 1989; Jamnik et al., 1990; Ramovš & Jamnik, 1991; Jamnik & Ramovš, 1993). The horizon with the Martuljek platy limestone of the Carnian age was also discovered there, together with occurrence of Lower Norian bedded basinal limestones with chert nodules. The transition of these limestones to massive coral reef limestones was observed. The lithostratigraphic succession and its spatial position, particularly relationship between Martuljek platy limestone and limestone with chert is, however, unclear. The aim of the study is threefold:

(1) On the basis of geological mapping to clearly establish spatial position and extent of the mapped formations;
(2) to test the hypothesis, that progradation in the Kamnik-Savinja Alps is younger than in the Julian Alps, according to the progradation direction established in the Martuljek Mountain Group;
(3) to interpret the platform – basin dynamics and propose a paleogeographic position of this system.

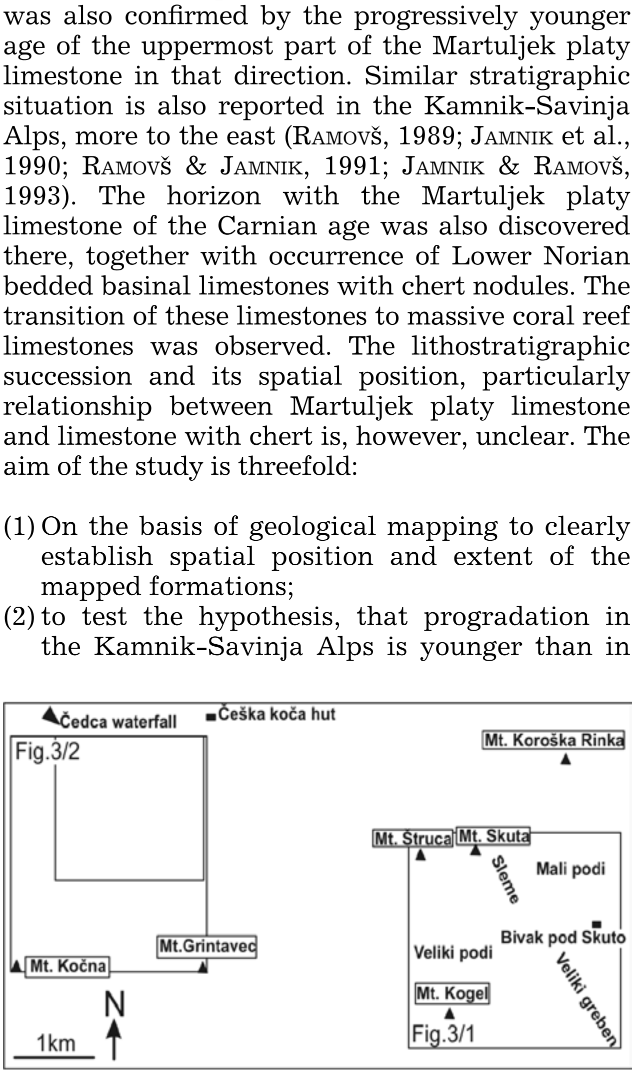


Fig. 2. Position of the geological maps, shown in the Fig. 3.

Presented results are only of preliminary character, based on the relatively low amount of the collected samples and a small area mapped.

Geological setting

The study area belongs to the central part of the Kamnik-Savinja Alps (Fig. 1), which together with the westerly lying Julian Alps and the northerly lying Southern Karavanke Mountains form the eastern part of the Southern Alps (Placer, 1999, 2008; Vrabec & Fodor, 2006, Celarc et al., 2013). In the Late Triassic, this area was located on the passive margin of the Neotethys Ocean (Haas et al., 1995; Schmid et al., 2008). The research area is part of the Julian Nappe, later dextrally offset along the Sava fault for around 30-40 km with respect to the Julian Alps (Placer, 1996). The major part of the Julian Nappe is therefore now positioned in the westerly lying Julian Alps. The lower boundary of the Julian Nappe in the K-S Alps is not yet clearly defined and structural investigations are in the progress.

New mapping and lithostratigraphic succession

The research area is positioned along W-E directed ridge between Mt. Kočna (2520 m) and Mt. Koroška Rinka (2433 m) (Fig.2). Southern slopes of this ridge include the prominent plateaus (Veliki podi Plateau, Mali podi Plateau) separated by the NW-SE directed Sleme – Veliki

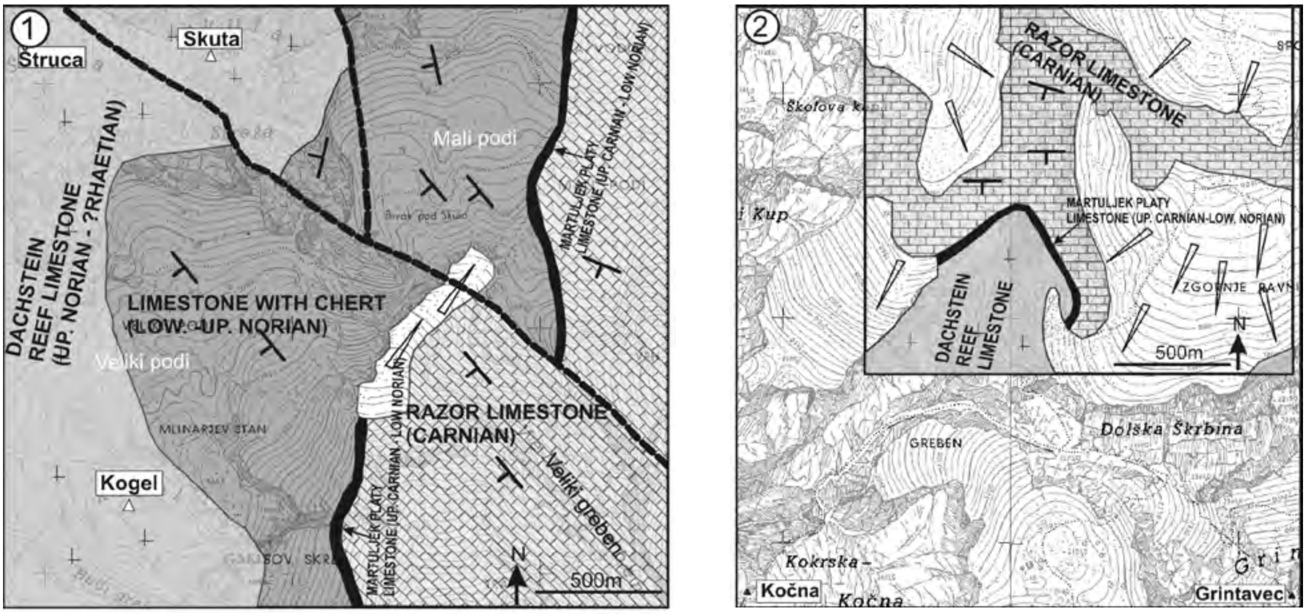


Fig. 3. Geological maps of the selected areas in the Mt. Kočna – Mt. Koroška Rinka ridge (Kamnik-Savinja Alps). 1 – Mt. Skuta area; 2 – Mt. Kočna slopes above the Češka koča hut.

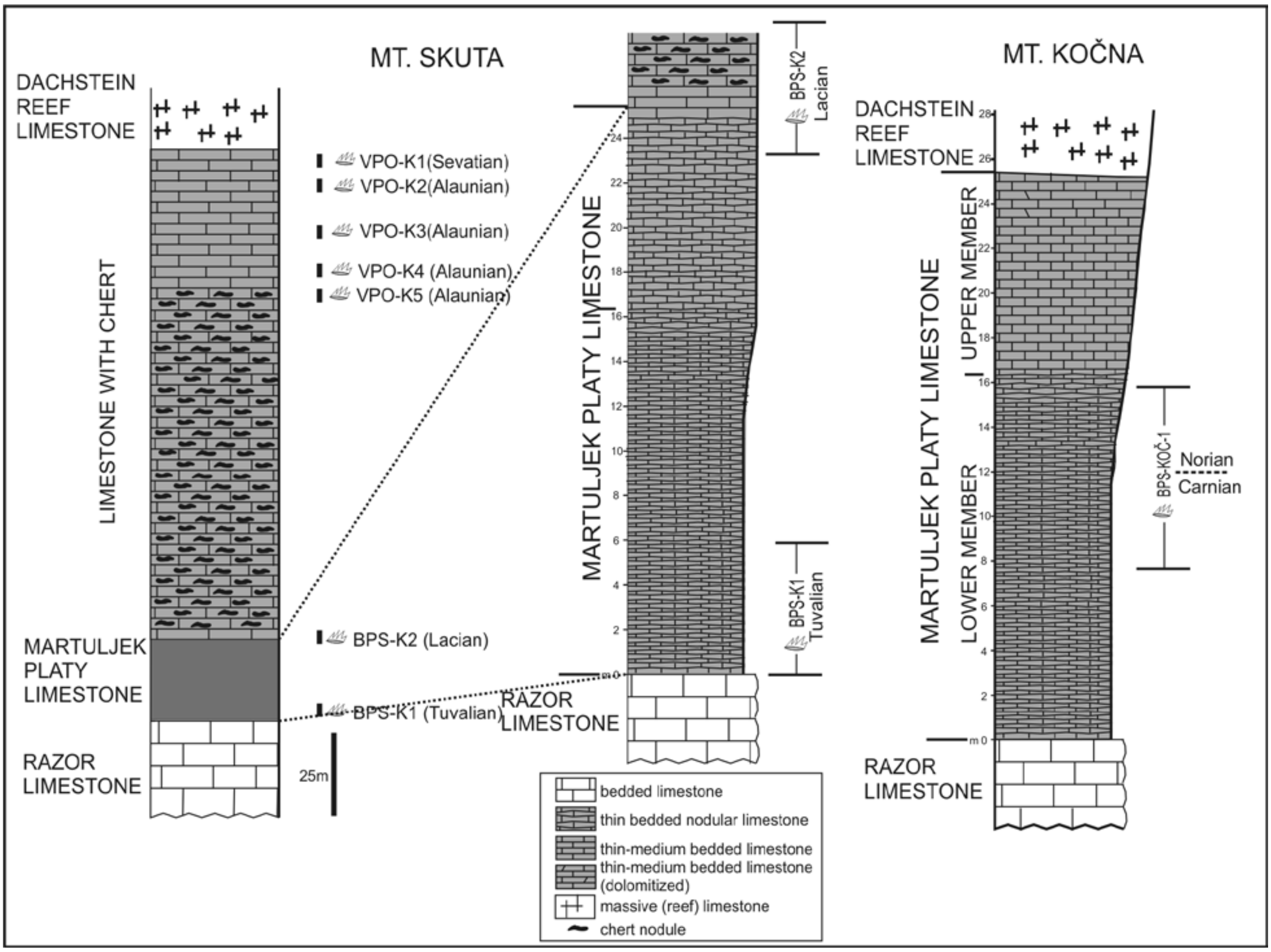


Fig. 4. Stratigraphical columns with conodont samples. 1 – Mt. Kočna; 2 – Mt. Skuta area.

greben ridge. Southern part of the Veliki podi Plateau is confined with Mt. Kogel (2100 m) and its SW face. The new mapping was limited to the Mt. Skuta area with Veliki and Mali podi Plateaus, lower part of the Mt. Kogel SW face (Fig. 3/1) and Mt. Kočna slopes above the Češka koča hut (Fig. 3/2), and is still in progress. The strata generally dip to the SW in the Mt. Skuta area and to the S in the Mt. Kočna, respectively, with moderate to the medium-steep inclination.

The geological succession is composed from bottom to top of 5 lithostratigraphic units, which names are informal and are the same as in the Martuljek Mountain Group of the Julian Alps (Celarc & Kolar-Jurkovšek, 2008), except for the limestone with chert, which is only present in the Kamnik – Savinja Alps:

- Razor limestone (Lower Carnian)
- Martuljek platy limestone (Upper Tuvalian – Lower Norian)
- Limestone with chert (Lower Norian – Upper Norian)
- Dachstein reef limestone - reef rim, reef slope (Lower Norian – Upper Norian)
- Dachstein Limestone (Norian – Rhaetian).

Two stratigraphical sections were measured. The Kočna section comprises the upper part of the Razor limestone, the Martuljek platy limestone and lower part of the Dachstein reef limestone (Fig.4/1).

The Mt. Skuta area section contains the upper part of the Razor limestone, the Martuljek platy limestone, Limestone with chert the and lower part of the Dachstein reef limestone (Fig. 4/2).

Razor limestone (Lower Carnian)

Razor limestone represents a footwall unit of the described succession. Its sedimentological characteristics haven't been studied yet in the Kamnik-Savinja Alps. Based on the first investigations, they are similar to the Razor bedded limestone from the Julian Alps (Ramovš, 1987; Celarc & Kolar-Jurkovšek, 2008). The Razor reef limestone, which is known from the Julian Alps, is not present in the Kamnik-Savinja Alps. The Razor limestone appears as thick-bedded peritidal limestone, organized into 1–1.5 m thick asymmetric cycles. Subtidal parts are composed of packstones and grainstones with abundant pellets and intraclasts. Upper parts of the subtidal beds are predominately composed oncoids. The supratidal facies contains microbial laminites, fenestral pores and small cavities filled with laminated crusts. Exposure surfaces are rarely overlain with thin horizons of the rip-up clasts. This unit is very similar to the younger Dachstein Limestone and can be easily mistaken for it, if the exact stratigraphic position of the unit is not known.

Martuljek platy limestone (Upper Tuvalian – Lower Norian)

This, around 25 m thick unit (Plate 1, Figs.1, 2), is represented by red and grey pelagic limestone with wavy to planar bedding (Plate 1, Fig. 3). It is positioned with the sharp and almost planar contact on the underlying Razor limestone (Plate 1, Fig. 4). This surface represents a major drowning event in the Julian Alps (Gianolla et al., 1998; Sattler, 1998; De Zanche et al., 2000; Gianolla et al., 2003; Celarc & Kolar Jurkovšek, 2008). In the Kamnik-Savinja Alps it was first described in the Mt. Skuta area, some 50 m west of Bivak pod Skuto locality (Ramovš, 1989). The actual extent of this unit was unknown until recent mapping of the area, when new outcrops were found in the SW face of the Mt. Kogel (Gamsov skret locality, south from Mt. Skuta), and on the Veliki podi below the south face of Mt. Skuta. From the Bivak pod Skuto, this unit extends towards the Mt. Kranjska Rinka (Plate 1, Fig. 2). Isolated outcrops in the form of erosional remains were found in the Veliki greben ridge. The outcrop belt of this unit is also positioned on the slopes of Mt. Kočna, above the Češka koča hut and above the Čedca waterfall (Plate 1, Fig. 1). Similar limestones were already described by Teller (1898) from the scree below Mt. Kočna, but the in situ outcrop was discovered now for the first time. In the Mt. Kočna, two members (the Lower and the Upper Member), very similar as in the Julian Alps (Celarc & Kolar-Jurkovšek, 2008), could be distinguished (Fig. 4), while in the Mt. Skuta area, the composition is similar to the whole thickness of the Martuljek platy limestone (Fig. 4). The Lower Member (Mt. Kočna) and the whole succession (Mt. Skuta area) is composed of the indistinctly reddish, in the upper part more greyish, wavy, thin bedded, slightly dolomitized packstone with glauconite, with rare fragments of the bivalves, filaments, lagenide foraminifers and peloids (Plate 1, Fig. 5). In the upper part, fine grained bioclastic packstone, with transition to wackestone prevails, with filaments, brachiopods and foraminifers (Plate 1, Fig. 6). Bedding planes are undulating in the lower part, giving nodular

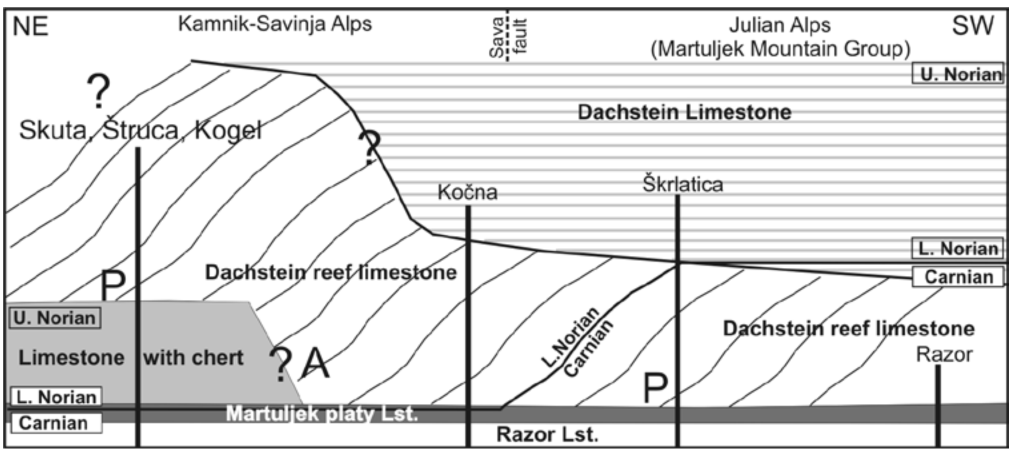
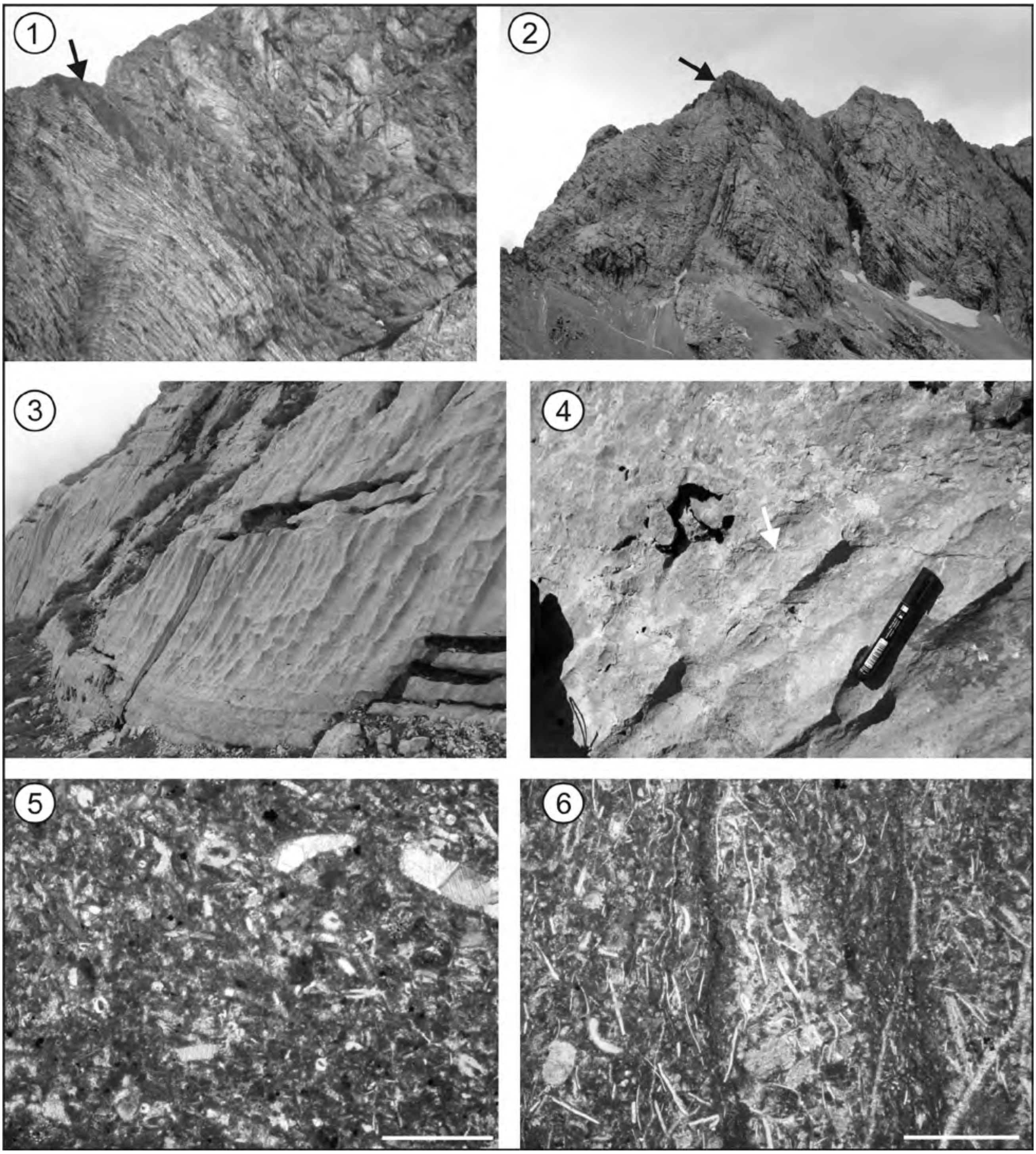


Fig. 5. Schematic cross-section of the SW – NE progradation of the Dachstein carbonate platform from Julian Alps towards Kamnik-Savinja Alps. (A: aggradation; P: progradation). Razor profile according to the Ramovš (1987) and Sattler (1998), Škrlatica profile according to the Celarc & Kolar-Jurkovšek (2008).

PLATE 1



1 – Slopes of the Mt. Kočna above the Čedca waterfall, the Martuljek platy limestone is marked with arrow (grass covered ledge);
2 – Mt. Štajerska Rinka, Martuljek platy limestone (darker belt) is marked with arrow;
3 – Indistinctly wavy bedding of the lower part of the Martuljek platy limestone;
4 – Drowning surface (marked with the arrow) between the underlying Razor limestone and the overlying Martuljek platy limestone;
5 – Microfacies of the Martuljek platy limestone (lowermost part): slightly dolomitized packstone with glauconite (Mt. Kočna area), scale bar = 1 mm;
6 – Microfacies of the Martuljek platy limestone (uppermost part): bioclastic packstone, with transition to the wackestone with filaments (Mt. Skuta area), scale bar = 1 mm.

appearance of the limestones and becoming more planar in the upper part.

The Upper Member occurs only in the Mt. Kočna (Fig. 4) and is very similar to the Upper Member from the Julian Alps (Celarc & Kolar-Jurkovšek, 2008). It contains a lot of redeposited shallow-water elements, particularly reef debris from the adjacent platform. It is composed of thin to medium bedded light grey limestones (coral and crinoid grainstones in the lower part and coral rudstones in the upper part). Bedding planes are planar and sharp. Some rare beds of the pelagic limestone without shallow-water elements are found between beds with reef detritus. Transition to the massive Dachstein reef limestone in the hangingwall is sharp. The thickness of the Upper Member is less than 10 m.

Limestone with chert (Lower Norian – Upper Norian)

According to the new mapping, this around 150 m thick unit is positioned with the sharp transition above the Martuljek platy limestone in the Mt. Skuta area. It is not present in the Mt. Kočna, and the nature of the lateral pinching-out of this unit was not yet observed. Although Teller (1898) and Seidl (1907) already mentioned occurrences of chert among the Dachstein Limestone in this area, they were not described on the Basic Geological Map of the (former) SFRJ (Mioč et al., 1983). This unit was therefore described only later (Ramovš & Jamnik, 1991; Jamnik & Ramovš, 1993). They established an Early Norian age based on the conodont dating and compared it with the Hallstatt facies of the Northern Calcareous Alps. The stratigraphic position of this unit, particularly the relationship with the Martuljek platy limestone was unclear (Jamnik & Ramovš, 1993).

Two members could be distinguished in this unit. The Lower Member is composed of the medium bedded limestone with brown chert nodules and lenses (Plate 2, Fig. 1). Its composition and microfacies is uniform through the succession and is composed predominately of fine grained bioclastic packstone with filaments. Wackestone with brachiopods, crinoids, peloids, spicules and radiolarians are also present (Plate 2, Figs. 2, 3).

The Upper Member is slightly more thick-bedded, chert nodules and lenses are not present any more. Bioclastic, intraclastic, peloidal grainstone (Plate 2, Fig. 4) intercalations are common between pelagic beds. In the uppermost part, rudstone (reef breccia) is common. The transition to the Dachstein reef limestone is gradual.

Dachstein reef limestone

The large masses of massive reef limestones (Plate 2, Fig. 5) are positioned above the Martuljek platy limestone in the Mt. Kočna or above the Limestone with chert in the Mt. Skuta area. Reef crest and slope, there built of the redeposited reef material are macroscopically almost impossible to distinguish. Corals are the most important and prevailing reef builders, sponges and hydrozoans are subordinate. The coralites are overgrown with sponges, microbialites and microproblematica (*Baccanela floriformis*). The most common

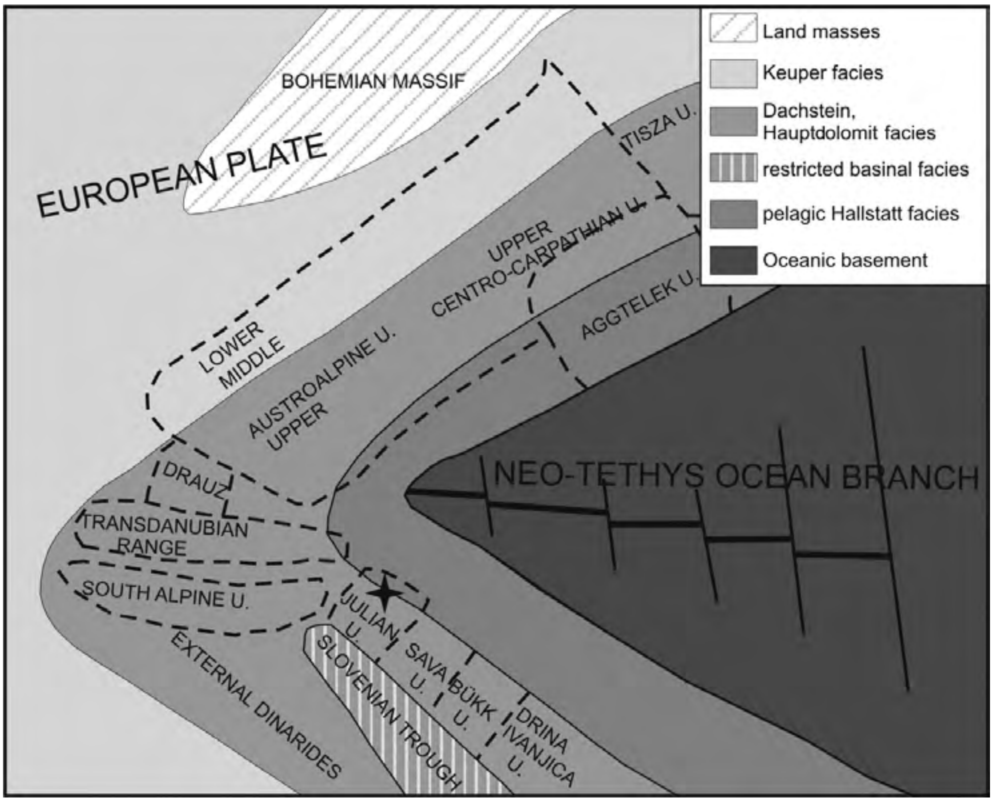
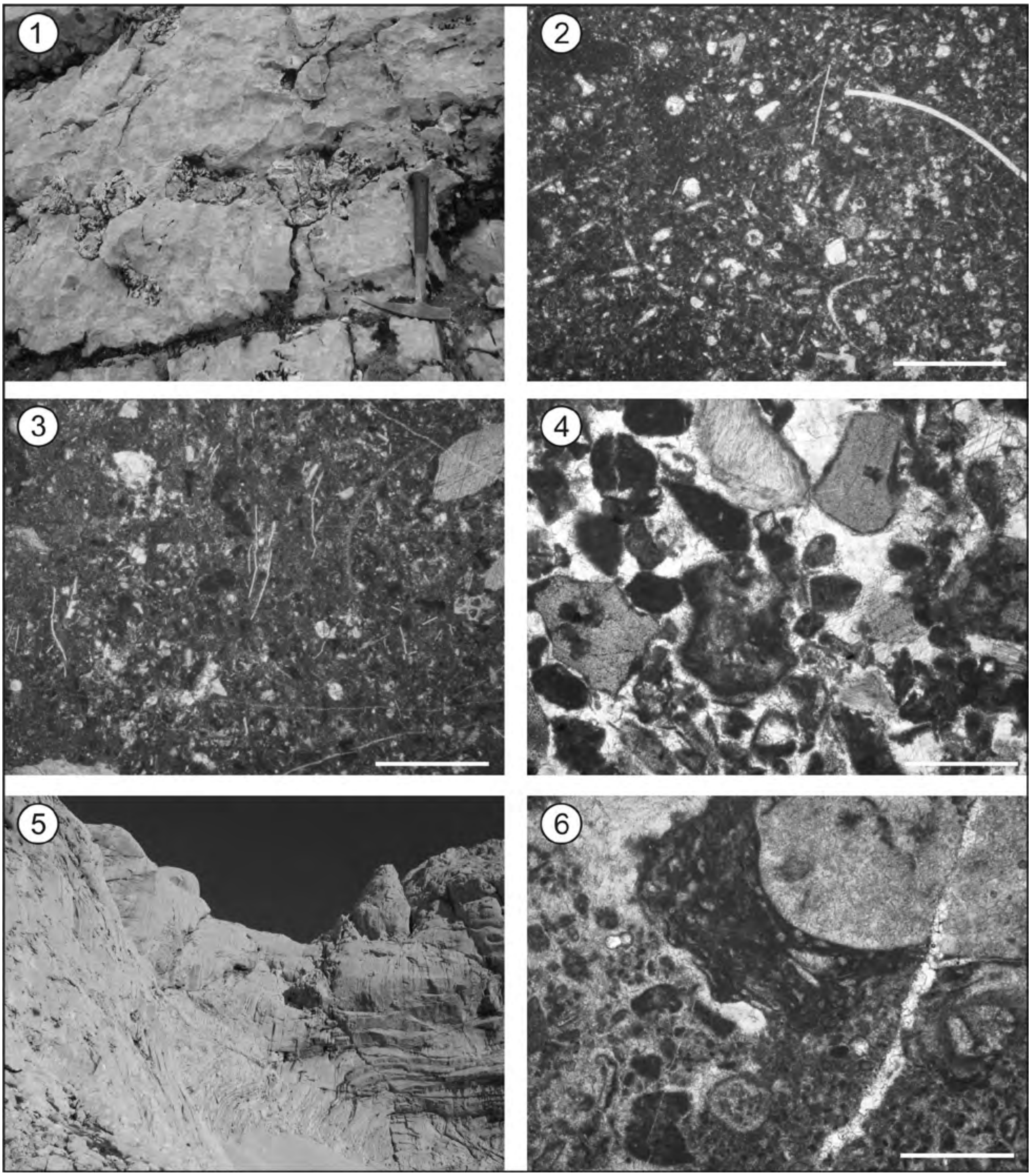


Fig. 6. Paleogeographic reconstruction of the western Tethys in the Norian time (modified after Haas et al., 1995). Proposed position of the Julian Alps – Kamnik-Savinja Alps Late Carnian - Norian basin-platform system is marked with star.

PLATE 2



1 – Limestone with chert - field view;
2 – Microfacies of the Limestone with chert: wackestone with peloids, spicules and radiolarians, scale bar = 1 mm;
3 – Microfacies of the Limestone with chert: wackestone with peloids, spicules, rare radiolarians and crinoids, scale bar: 1 mm;
4 – Upper Member of the Limestone with chert: bioclastic, intraclastic, peloidal grainstone, scale bar = 1 mm;
5 – Reef limestone (reef crest and slope) of the Mt. Skuta and Mt. Kočna;
6 – Bafflestone from the reef crest, redeposited along the slope, scale bar = 1 mm.

microfacies is bafflestone from the reef crest, which in this case delivered along the slope in the form of the ?boulder (Plate 2, Fig. 6).

The thickness of the Dachstein reef limestones in the Mt. Kočna is estimated at around 300 m. In the Skuta area it seems thicker (more than 400 m), but the exact thickness could not be determined, due to the lack of the hangingwall (Dachstein Limestone above the reef).

Dachstein limestone

Peritidal Dachstein Limestone is according to the new mapping, the dip of the strata and present day surface, present only on the top and on the NW slopes of the Mt. Kočna. The mapping of this area is still in progress. Based on the view from the distance, bedding attitude is the same as in the Martuljek Mountain group from the Julian Alps (Celarc & Kolar-Jurkovšek, 2008). The nature of the lower boundary with the reef limestone is also not (yet) evident. Nevertheless, the spatial extent and the stratigraphic position of the Dachstein Limestone are now clearly established in the Kamnik-Savinja Alps. It comprises significantly less spatial extent and thickness as in the Julian Alps.

Conodont dating of the Martuljek platy limestone and Limestone with chert.

Conodont composite samples were collected in the Martuljek platy limestone and Limestone with chert (Fig. 4) in order to test the age of those lithostratigraphic units.

Martuljek platy limestone

In the Mt. Kočna only one composite sample was taken (Fig. 4; BPS-KOČ-1) and it yields *Epigondolella* ex gr. *abneptis* (Huckriede), *Metapolygnathus primitius* (Hayashi) and *Metapolygnathus polygnathiformis* (Budurov & Stefanov). The age of the sample is Late Carnian – Early Norian. The uppermost part of the Martuljek platy limestone hasn’t been sampled, and could be younger, probably late Early Norian age.

In the Mt. Skuta profile (Fig. 4), two composite samples were taken, one in the lower part (BPS-K1) with *Neocavitella cavitata* (Sudar & Budurov*), Paragondolella polygnathiformis* (Budurov & Stefanov), *Paragondolella* cf. *tadpole* (Hayashi) of Carnian (Tuvalian) age, and one in the uppermost part (BPS-K2) with *Epigondolella* ex gr. *abneptis* (Huckriede) and *Epigondolella* sp., of the Early Norian (Lacian) age.

Limestone with chert

5 composite conodont samples were collected in the upper part of the Limestone with chert unit (Fig. 4) in order to test the age of the uppermost part of this unit. Samples yielded the following stratigraphically important species: *Epigondolella bidentata* (Mosher) in the uppermost sample (VPO-K1) (Late Norian – Sevatian) and *Epigondolella postera* (Kozur & Mostler) in all the other four samples (VPO-K2 to the VPO-K5) below (Middle Norian – Alaunian).

Discussion and conclusions

The Carnian – Norian lithostratigraphic development in the Kamnik-Savinja Alps bears a significant resemblance with the successions in the Julian Alps (Martuljek Mountain Group). The Mt. Kočna succession is almost completely the same as in the Julian Alps. According to the age of the Martuljek platy limestone, it correlates well with the NE-most profiles in the Martuljek Mountain Group (Celarc & Kolar-Jurkovšek, 2008; ŠP and JG profiles). Even the subdivision of the Martuljek platy limestone in the two members is the same in both areas, owing to similar depositional processes.

The most striking difference is the presence of the relatively thick succession of the Early – Late Norian Limestone with chert in the Kamnik-Savinja Alps (Mt. Skuta area). The other difference is the fact, that Martuljek platy limestone contains no shallow water elements, where the Limestone with chert is positioned directly above it. The age of the uppermost part of the basinal sequence bellow the prograding reef is here significantly younger (Late Norian -Sevatian) with comparison to the NE-most part of the Martuljek Mountain group, where it is established as Lacian. There are no clear geometrical evidences yet of the platform progradation direction in the Kamnik-Savinja Alps, against the clinoform-based SW-NE orientated progradation, established in the Julian Alps (Celarc & Kolar-Jurkovšek, 2008). However, the age of the uppermost part of the basinal sequence in the Kamnik-Savinja Alps is younger in the roughly W-E direction (Early Norian in the W and Late Norian in the E). Without other indicators (geometry, planar and not only rather linear position of the age-measurements points) this is of course only an apparent progradation direction. Nevertheless, it closely resembles directions from the Julian Alps and some basic reconstructions could be made (Fig. 5). If the position of the Kamnik-Savinja Alps is palinspastically corrected in respect to the Julian Alps (Martuljek Mountain Group), the distance would amount 20 km from the SW-most part (Mt. Razor, Mt. Škrlatica), to the NE-most part (Mt. Skuta area). The age of the uppermost part of the basinal succession in the SW-most part is Late Tuvalian and the age of the NE-most part is Sevatian. The time span of the Norian is roughly 20 Myr (Gradstein et al., 2012) and the progradation rate is calculated to 1000 m/Myr, which is in agreement with the rates established in the Martuljek Mountain Group (1200 m/Myr; Celarc & Kolar-Jurkovšek, 2008). The lateral extent and the thickness changes of the Limestone with chert is unknown in the Kamnik-Savinja Alps. The Martuljek platy limestone shows no significant changes in its thickness in the lateral direction, while Limestone with chert reaches thickness up to 150 m, but laterally it thins out. This kind of geometry points to the aggradation of the system in the Middle Norian. Similar aggradation of the same age was reported also from the Carnian Prealps (Italy) connected with the Middle-Late Norian extensional tectonic activity, related to the aborted westward opening of the Neotethys Ocean and the incipient rifting phase of the Ligurian-Piedmont Ocean (Carulli et al., 1998; Cozzi, 2000; Cozzi, 2002; Cozzi & Hardie, 2003). The Alaunian aggradation is also reported from the Northern Calcareous Alps (Berra, 1995; Krystyn et al., 2009).

If the platform aggraded in the Middle and Late Norian, then the progradation in the Late Carnian – Early Norian could be even faster. New preliminary findings in the Kamnik-Savinja Alps open new perspectives in the research of the Carnian-Norian progradation of the Dachstein carbonate platform. Besides the progradation – aggradation dynamics and the age control of the Dachstein reef, reflected in the basin, the fundamental question is, if this system was directly connected with the Hallstatt facies of the deep shelf bordering the Neo-Tethys Ocean branch (Fig. 6). In the next phase of our research, further mapping and denser re-sampling of this very interesting area are planned.

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The Lower Triassic platy limestone in the Jajce area (Bosnia and Herzegovina)

Spodnjetriasni ploščasti apnenec iz okolice Jajca (Bosna in Hercegovina)

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Ključne besede: biostratigrafija, mikrofacies, spodnji trias, okolica Jajca, Bosna in Hercegovina

Abstract

The study presents palaeontological and sedimentological data of the Lower Triassic strata of the Jajce area in Bosnia and Herzegovina. Four microfacies types were differentiated: coarse grained bioclastic packstones, fine grained bioclastic packstones, laminated mudstone and laminated calcisiltites. Sedimentary characteristics of the depositional environment indicate the distal part of a wide, shallow shelf/ramp, in keeping with some other locations spanning the Dinaride chain. Characteristic ichnofossils and macrofauna are present, including ammonoids, bivalves, and gastropods, dominated by *Natiria costata* (Münster). Conodont elements provide a biostratigraphic framework. The older part of the section is characterized by the conodont *Triassospathodus hungaricus* (Kozur & Mostler) and the foraminiferans *Nodosaria* ex gr. *skyphica* Efimova, *Ammodiscus* ex gr. *minutus* Efimova, *Glomospirella triphonensis* Baud, Zaninetti & Broennimann and *Glomospirella shengi* Ho. A younger fauna yields *T. triangularis* (Bender), *Meandrospira cheni* (Ho) and *M. pusilla* (Ho). The older fauna belongs to the *T. hungaricus* conodont Zone based on presence of Spathian conodont elements, while the younger fauna belongs to the *T. triangularis* conodont Zone.

Izvleček

V članku so prikazani paleontološki in sedimentološki podatki iz spodnjetriasnih plasti pri Jajcu v Bosni in Hercegovini. V profilu so litološko definirani štirje mikrofaciesni tipi: grobozrnati bioklastični packstone, drobnozrnati bioklastični packstone, laminirani mudstone in laminirani karbonatni siltit. Na osnovi raziskanih sedimentoloških značilnosti lahko okolje sedimentacije primerjamo z distalnim delom odprtega in plitvega šelfa/rampe, kot je pogosto intererpretiran za ostale lokalnosti vzdolž celotnega področja Dinaridov. Izdvojene litotipe označujejo ihnofosili in prisotnost makrofavne, najpogosteje amonitov, školjk in polžev s prevladujočo vrsto *Natiria costata*. Dobljenja mikrofavna vsebuje pomembne konodontne elemente, ki omogočajo veliko biostratigrafsko ločljivost. Starejšo favno označuje konodontna vrsta *Triassospathodus hungaricus* in foraminifere *Nodosaria* ex gr. *skyphica*, *Ammodiscus* ex gr. *minutus*, *Glomospirella triphonensis* in *G. shengi*. Mlajša favna vključuje vrste *T. triangularis*, *Meandrospira cheni* in *M. pusilla*. Na osnovi najdenih konodontnih vrst spathijske starosti je starejša združba v raziskanem profilu uvrščena v *T. hungaricus* konodontno cono, medtem ko mlajša združba pripada *T. triangularis* konodontni coni.

Introduction

The Jajce old town and the well known mills at Pliva River are often paved by Lower Triassic platy limestones, exposed in a narrow valley west of Bravnice village, southeast of Jajce (Fig. 1).

Bravnice is located in the northeastern part of the Ključ-Raduša Nappe, near the town of Jajce (Fig. 2) in the central Dinarides of Bosnia and Herzegovina. The Ključ-Raduša Nappe can be traced along the NW-SE strike for ca. 150 km. Its frontal parts override the Glamoč-Drežnica-Gacko Nappe, and it is underlain along its northeastern margin by the Bosnia Flysch Nappe. The Ključ-Raduša Nappe is composed largely of Triassic carbonates, subordinate coeval clastic and igneous rocks, and sparse Permian sediments. In its frontal parts, Middle/Late Permian evaporites are exposed which may have lubricated the basal thrust plane. The northern part of the Ključ-Raduša Nappe adjoins the Paleozoic complex of the Mid-Bosnian Schist Mts. tectonic block (Hrvatović, 2006).

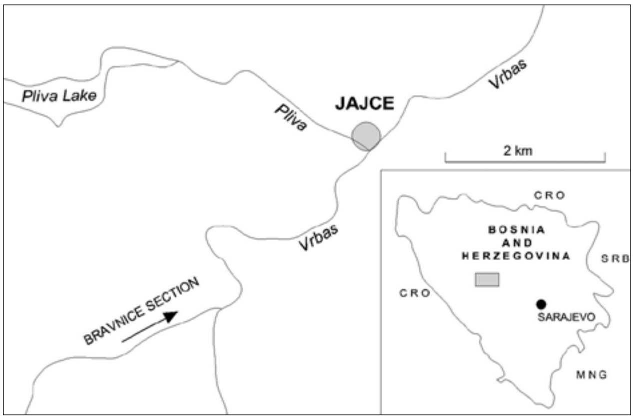

Fig. 1. Location of the Lower Triassic strata of the Bravnice section in Bosnia and Herzegovina.

The Bravnice section lies in the Otomalj-Bukovica-Oborci tectonic unit. This unit is mainly composed of sandstone, siltstone and platy limestone of Early Triassic age. In the southeast part of this unit are sediments of Late Permian and Permian-Triassic age from the edge of the Palaeozoic Mid-Bosnian Schist Mts. (Vujnović, 1980, 1981).

The uppermost part of the Early Triassic strata of the Jajce area were discussed in numerous older works (Katzer, 1921; Puizina et al., 1969; Vujnović, 1981), in which the section has been divided into older »Seis« beds and younger »Campil« beds. The upper part of the Lower Triassic limestone (»Campil« beds) can be easily recognized by presence of ammonoids, bivalves, gastropods and ichnofossils. The basic petrographic composition of the samples from the Bravnice section does not differ significantly from the younger part of the Lower Triassic in the Dinarides and the wider Tethys area (Fig. 3), sharing dominance of micritic carbonate, occasional biodetrital accumulation of shells of molluscs, gastropods and echinoderms, as well as rare presence of siliciclastic detritus in thin layers or individual laminae. The aim of this work is to document biota and microfacies of the strata near Jajce, calibrate their age within the Olenekian based on microfossil associations, and determine the environment of deposition.

Material and methods

The material examined for this study was collected in the course of field work carried out in 2011-12 in the Jajce area in central Bosnia and Herzegovina. The Lower Triassic section, 222 m thick, was measured and sampled (Fig.4). Altogether, 18 samples (BR 1 - 18) were collected for conodont processing. A minimum 2 kg of rock were prepared for conodont study using standard laboratory techniques. One to four thin sections from each level of conodont sampling were prepared to study foraminifera and carbonate petrography. The locations of the collected samples is shown in Fig. 4. The laboratory work was carried out at Geological Survey of Slovenia / Geološki zavod Slovenije where the studied material is stored under catalogue numbers 5079 - 5087, 5113 - 5122 and abbreviated GeoZS. The conodont elements were illustrated using the JEOL JSM 6490LV Scanning Electron Microscope at the Geological Survey of Slovenia. Some macrofossil specimens are stored in the Jajce town museum.

Lithology

Four microfacies were differentiated in the Bravnice section (Fig. 5), as follows:

1) Laminated mudstones
2) Laminated calcisiltites
3) Fine grained bioclastic packstones
4) Coarse grained bioclastic packstones

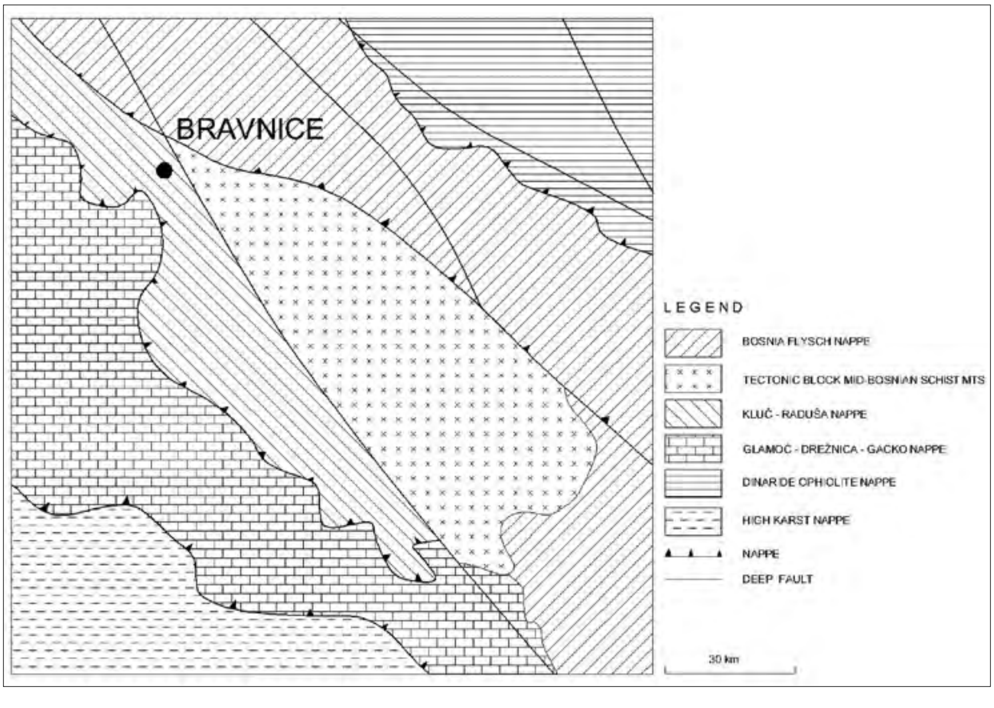

Fig. 2. Section from the geotectonic map of Bosnia and Herzegovina with the Bravnice section marked, modified from Hrvatović (2006).

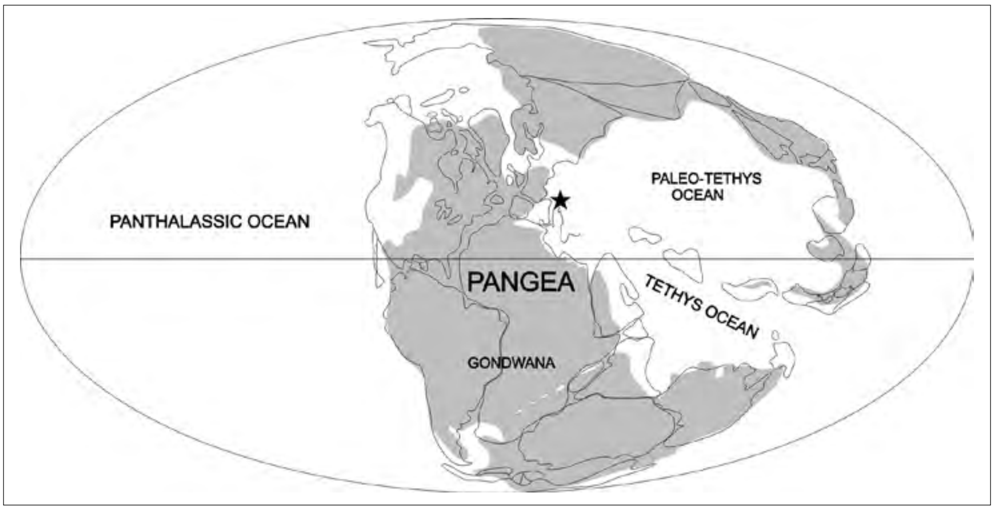

Fig. 3. Palaeogeographic map for the Early Triassic with position of the Bravnice section marked (star), modified from SCOTESE (2001).

Some samples represent transitional variations between coarse- and fine grained bioclastic packstones (biomicrites) (BR 13) or between laminated micritic mudstones and calcareous siltstones(BR 18).

1) Laminated mudstones (micrites) - samples: BR 4, BR 8, BR 11, BR 12B, BR 16/1, BR 16/2, BR 17.

This microfacies type is characterized by laminated carbonate mud (Fig. 5A), mostly calcitic apart from sample BR 17 which is partly dolomitized. Extremely fine lamination is due to alternation of silty siliciclast-rich and carbonate mud-rich laminae. Siliciclastic component grains are mostly quartz and partly feldspar grains. Sometimes pyrite crystals accumulate along laminae. Sample BR 12B is an exception, where the carbonate mud is not laminated, but has been disintegrated in irregular fragments due to bioturbation. Rare crinoidal elements are present. With increase in siliciclastic detritus, a graded transition occurs to laminated calcisiltites.

2) Laminated calcisiltites - samples: BR 12A, BR 15 (Fig. 5B).

In this microfacies type, thin siliciclast-rich laminae or thin beds rich in quartz and feldspar alternate with laminae of carbonate mud or silt-sized bioclasts. Siliciclastic particles are poorly rounded, irregular or long and prismatic. Some laminae are extremely rich in pyrite, or in finely preserved foraminifera tests (*Glomospirella, Meandrospira*).

3) Fine-grained bioclastic packstones (biomicrites) - samples: BR 6, BR 7, BR 14.

This microfacies type consists dominantly of fine-grained biodetritus in a micritic matrix. Alternation of bioclastic- with matrix- rich laminae can be observed in some samples, while in others, reworking by organisms results in a chaotic distribution of fossils and carbonate mud. Among the bioclastic debris, well sorted plates of echinoderms prevail (Fig. 5C). Fairly well preserved foraminifera tests (*Glomospirella, Meandrospira*) are rare. Some sporadic laminae with well sorted peloids or fine grained siliciclastic detritus are present. Sample BR 13 shows lamination due to alternation of coarse- and fine-grained biodetritus.

4) Coarse-grained bioclastic packstones (biomicrites) - samples: BR 1, BR 3, BR 5, BR 15.

The lithotype consists of coarse-grained bioclasts consisting of bivalves, gastropods, echinoderms and ostracods within dense micrite (Fig. 5D). Molluscan fragments exceed 2 mm in size and are usually preferentially oriented parallel to bedding. Plates of echinoids and ostracod carapaces are smaller than 2 mm. Size grading from coarser bioclastic detritus to carbonate mud can be observed in sample BR 1. Bioturbation was observed in sample BR 3. Bioclasts are occasionally silicified. Euhedral pyrite crystals are often present.

Depositional environment

A common characteristic of Early Triassic sedimentary facies in the Dinarides is dominance of carbonate mud with sporadic accumulation of coarser bioclastic detritus (bivalves, gastropods and echinoderms), and rarely, thin bedded calcisiltites. The composition and petrographic features of the Bravnice section do not differ significantly from this pattern (ALJINOVIĆ, 1995, KOLAR-JURKOVŠEK et al., 2013).

The data may be explained as a background deposition of fine carbonate mud in a low energy environment (laminated mudstone facies) signifies slow deposition in where the vast quantities of finest carbonate particles can be accumulated. Pyrite indicates partly anaerobic or disaerobic episodes within the low energy environment. Settling of carbonate mud of the laminated limestone facies in a quiet-water environment alternates with sporadic influx of terrigenous quartz or feldspar grains transported by traction currents. The evidence implies deposition in deeper/distal parts of a ramp, sometimes poorly aerated, and is in line with other late Early Triassic deposits elsewhere in the Dinarides (e.g. KOLAR- JURKOVŠEK et al., 2013).

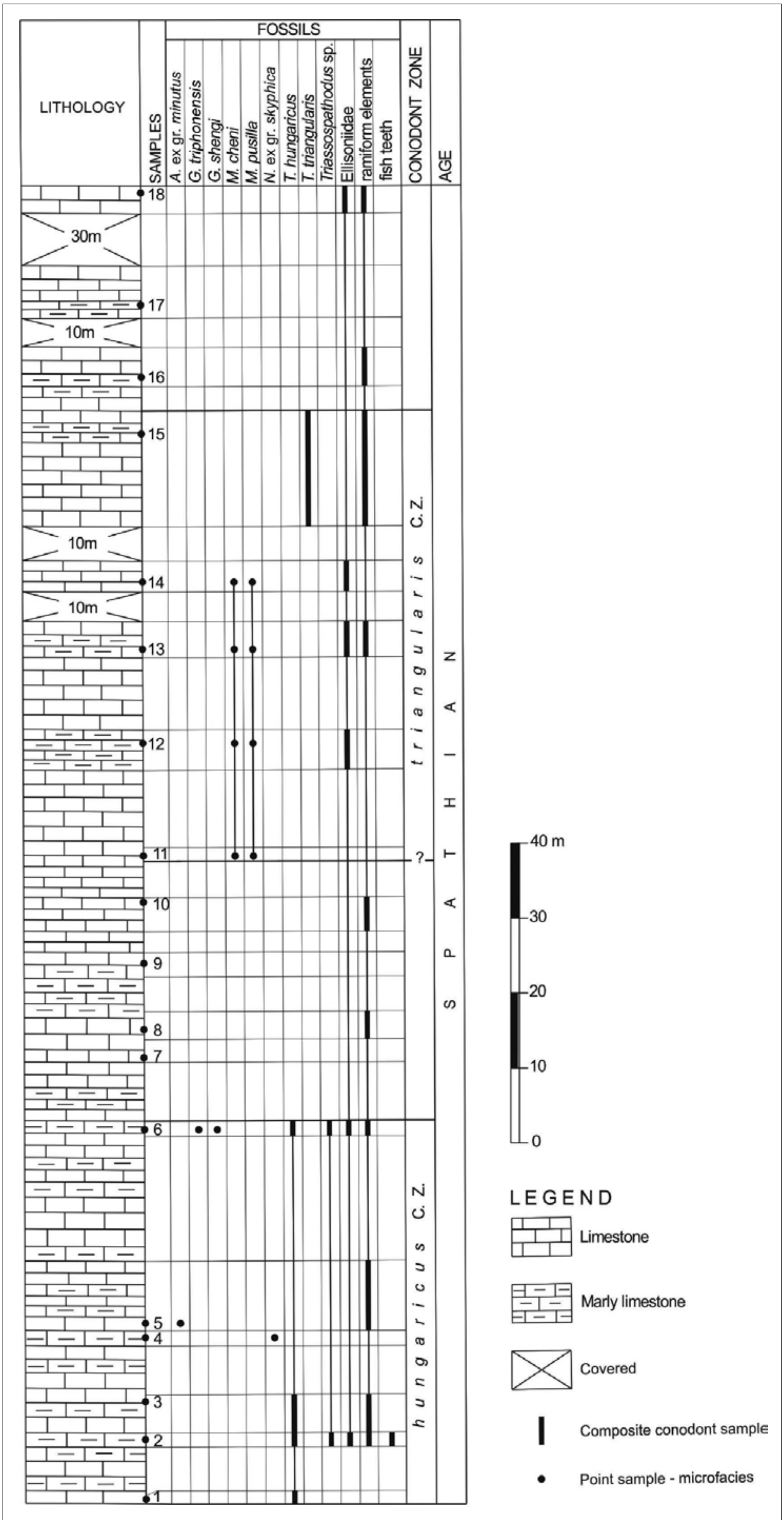

Fig. 4. Stratigraphic column of the Lower Triassic strata at Bravnice.

Abbreviations :

A. - Ammodiscus,
G. – Glomospirella,
M. - Meandrospira,
T. – Triassospathodus.

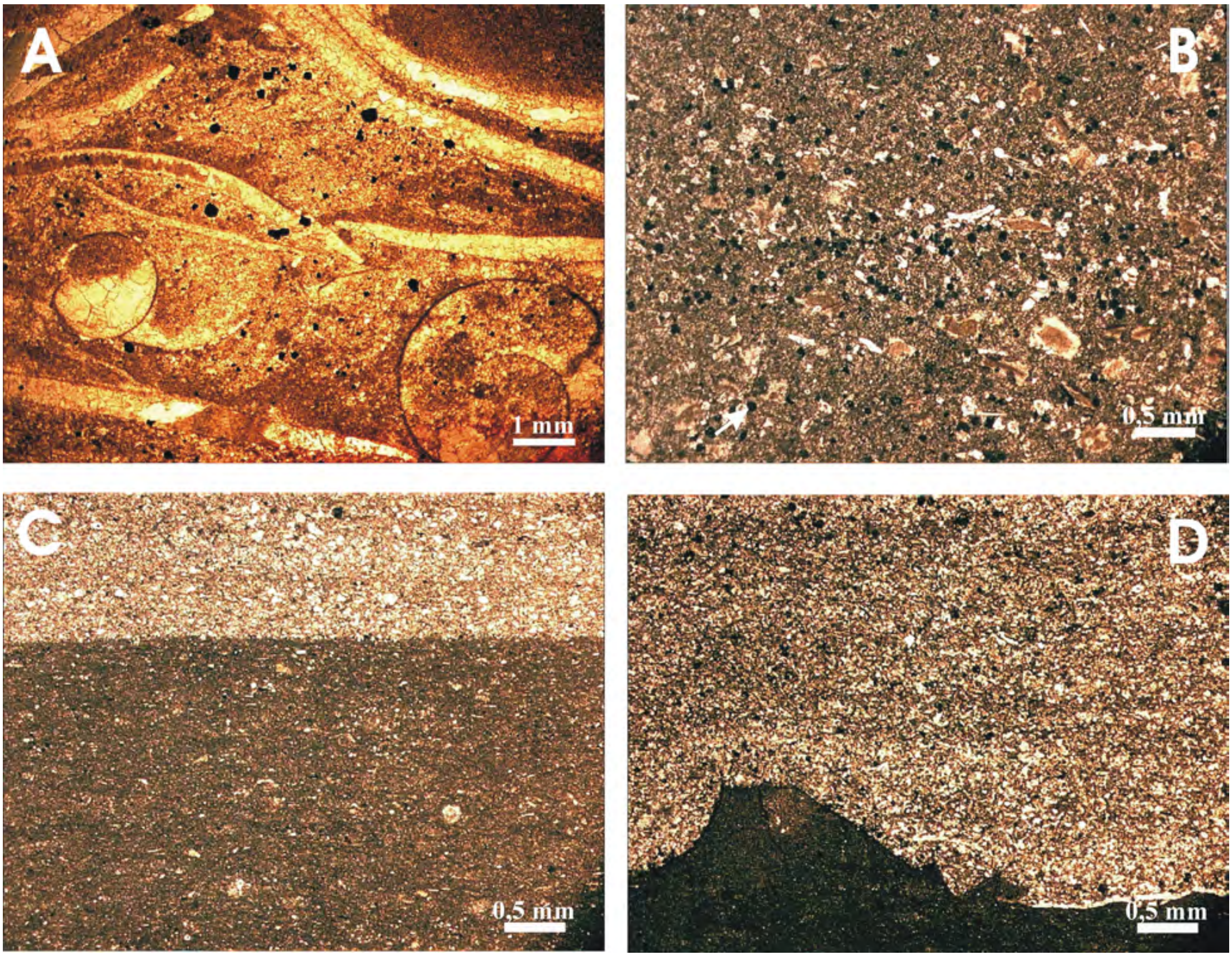

Fig. 5. Microfacies types of the Early Triassic Bravnice section.
A Laminated mudstone (sample BR 11).
B Laminated calcisiltites (sample BR 12A).
C Fine grained bioclastic packstones (sample BR 14).
D Coarse grained bioclastic packstones (sample BR 15).

The laminated calcisiltite microfacies formed by transport of siliciclastic or fine-grained bioclastic material to the distal parts of a ramp by weak currents. Such resedimentation of terrigenous material from the shallow ramp into the laminated mudstones may be attributed to distal storm-induced currents. Infaunal bioturbation took place in the undisturbed intervals between stormy periods (sample BR 12 B).

Storm activity also explains the finer- or coarser-grained bioclastic detritus. Fine-grained bioclastic packstones with faint lamination and foraminifera tests along laminae were formed by distal transport by weak currents of molluscan bioclasts, echinoid plates and foraminifera from the shallower part of ramp. Storm transport is supported by the high degree of sorting of bioclastic material and by presence of foraminifera tht usually inhabit the shallow proximal ramp. The coarse-grained bioclastic packstones (biomicrites) represent stronger influence of short-term storm events into the outer ramp where carbonate mud was deposited from suspension. Peak storm currents caused bottom-shear conditions that concentrated shells of living and dead organisms on the sea floor, by exhuming buried shells, ripping up weakly consolidated sediments forming lags, and followed by burial by the influx of storm suspended particles. In this way coarse grained bioclastic detritus including large fragments and sometimes unbroken fossils were preferentially preserved by storm burial, protecting them from normal destructive processes. Preferential orientation of valves parallel to bedding plane also suggests deposition under short-term high energy conditions such as storms. Grading of bioclasts as observed in sample BR 1 takes place in the course of slow settling of the sediment storm cloud. Presence of pyrite indicates low-energy and partly anaerobic/disaerobic conditions in between storms.

Biostratigraphy

Macrofauna (Fig. 6)

The rich gastropod, bivalve (Fig. 6. 3-4), and ammonoid molluscan fauna of the Bravnice section, as well as (Fig. 6. 2) numerous ichnofossils

(Fig. 6. 1, 5-6) can be seen on bedding planes of the limestone pavements of the Old Jajce town, as well as at the Pliva mills. The gastropod species *Natiria costata* (Fig. 6. 3) is most common, whereas genus *Turbo* appears rarely. Poor preservation of ammonoids and bivalves does not permit their determination. Some well-preserved specimens from the Bravnice section are housed in the Jajce town museum / Zavičajni etno muzej u Jajcu. *Natiria costata* is the most typical gastropod of the Early Triassic Werfen Formation in Europe, suggesting equivalence of the outcrops with

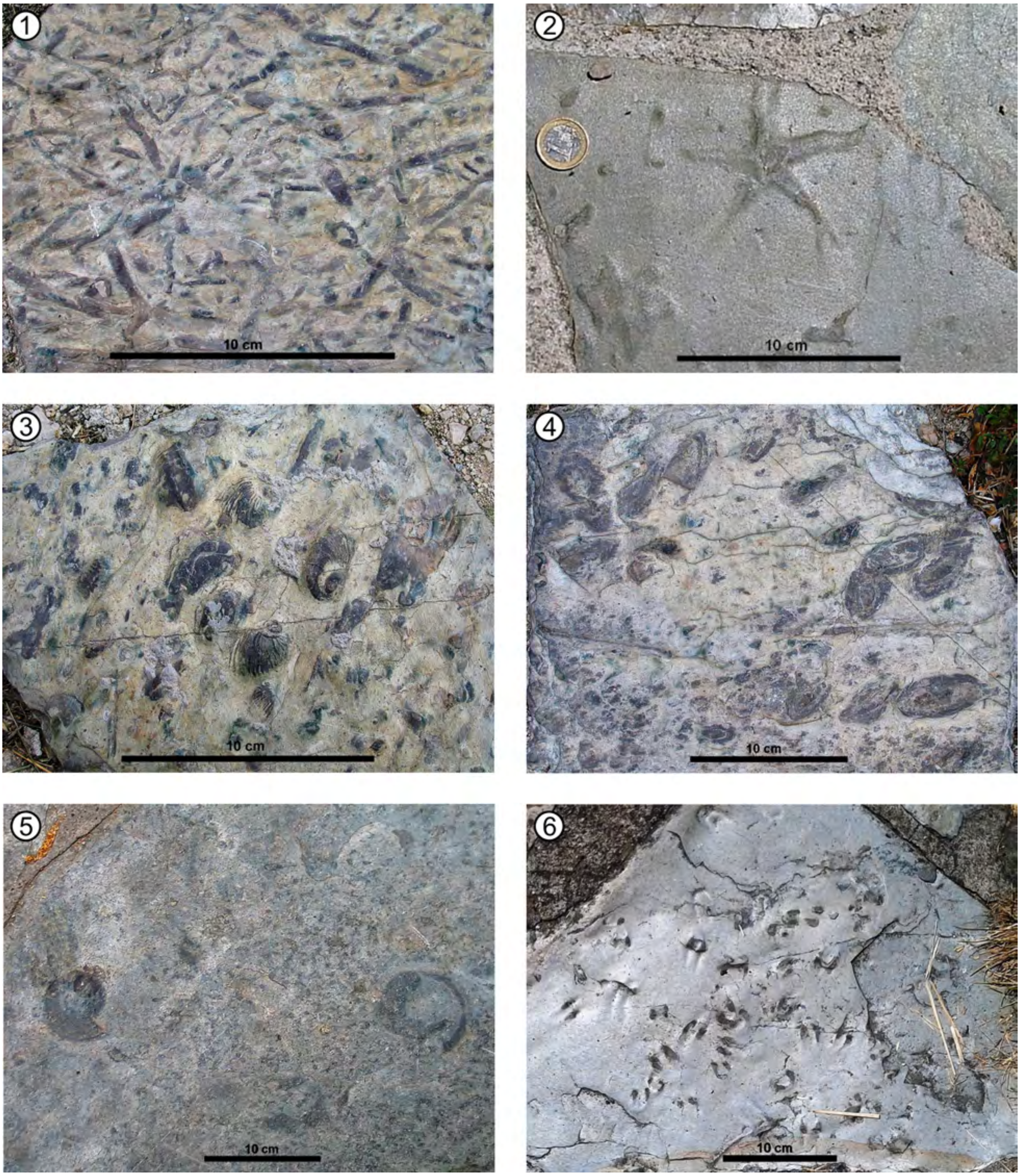

Fig. 6. Ichnofossils and macrofossils from the Early Triassic strata in the Jajce area.

1 Asteroid imprint (plate in a pavement to the entrance of the Jajce fortress).
2 Ammonoids (plate in a stairway to the tower in Jajce old town).
3 *Natiria costata* (Münster) and *Turbo* sp. (Museum of Jajce town / Zavičajni etno muzej u Jajcu).
4 Poorly preserved bivalves (plate in a pavement of Jajce old town).
5 Bioturbated limestone (plate in a pavement of Jajce old town).
6 Ichnofossil (plate in a pavement of the mill at Pliva River).

that formation (Kolar-Jurkovšek et al., 2013). Recently, poorly preserved *Natiria* cf. *costata* has also been reported from Spathian of Utah, USA (Hofmann et al., 2013) and Slovenia (Kolar-Jurkovšek et al., 2013). This gastropod is present also in the equivalent strata near Muć (Dalmatia, Croatia), that has been proposed as a candidate for the European stratotype section of the late Early Triassic (Herak et al., 1983; Prlj-Šimić, 2006).

Microfauna

The microfossil material recovered from the Bravnice section includes foraminifera and conodonts, with occurrence and abundance of taxa summarized in Fig. 7. The Conodont Colour Alteration index CAI value sensu Rejebian et al. (1987) is 5.5.

Foraminifera faunas

The genera *Glomospirella* and *Meandrospira* dominate the taxonomic composition of the foraminifera assemblages (Fig. 8) from the Bravnice locality. The foraminifera are very small and their preservation is not very good. Two assemblages can be distinguished:

a) The lower part of the Bravnice section (samples BR 4 - 6) yields *Nodosaria* ex gr. *skyphica*, *Ammodiscus* ex gr. *minutus*, *Glomospirella triphonensis* and *G. shengi*. Among these taxa, *Glomospirella* is most abundant.

b) The assemblages from the upper part of the section (samples BR 11 - 14) are marked by abundant of *Meandrospira cheni* and *M. pusilla*.

SAMPLE / TAXA	BR 1	BR 2	BR 3	BR 4	BR 5	BR 6	BR 7	BR 8	BR 9	BR 10	BR 11	BR 12	BR 13	BR 14	BR 15	BR 16	BR 17	BR 18	BR 19
Ammodiscus ex gr. *minutus*					x														
Glomospirella triphonensis						x													
Glomospirella shengi						x													
Meandrospira cheni											x	x	x	x					
Meandrospira pusilla											x	x	x	x					
Nodosaria ex gr. *skyphica*				x															
Triassospathodus triangularis											1				1				
Triassospathodus hungaricus	4	2	6			1													
Triassospathodus sp.		1				1													
Ellisoniidae		16				7						12	9	30				1	1
ramiform elements		4	5		5	25		6		1			17		15	3		1	1
fish teeth		4																	

Fig. 7. Distribution of microfossils in the Bravnice section. Vr – very rare (1 specimen), r – rare (2 – 4 specimens), a – abundant (5–10 specimens), va – very abundant (more than 11 specimens).

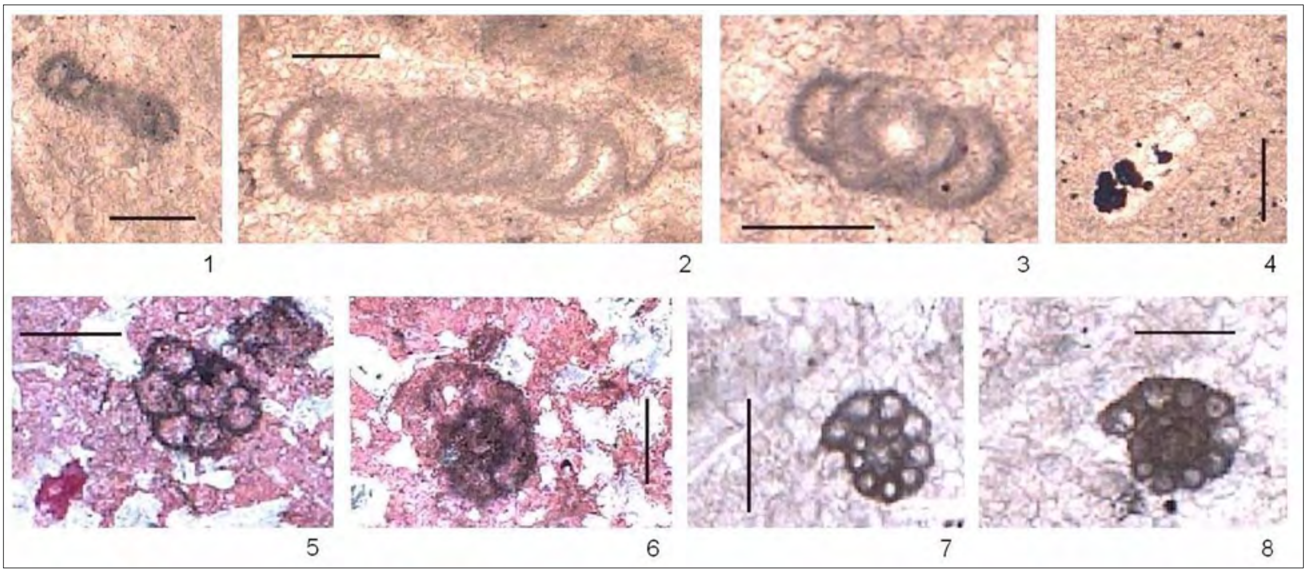

Fig. 8. Foraminifera of the Early Triassic Bravnice section, Bosnia and Herzegovina. 1–4 *hungaricus* Zone, 5–8 *triangularis* Zone. Scale bar 100 microns.

1 *Ammodiscus* ex gr. *minutus* Efimova, 1974. Sample BR 5, subaxial section.
2 *Glomospirella triphonensis* Baud, Zaninetti & Broennimann. Sample BR 6, subequatorial section.
3 *Glomospirella shengi* Ho, 1959. Sample BR 6, subequatorial section.
4 *Nodosaria* ex gr. *skyphica* Efimova, 1974 . Sample BR 4, sublongitudinal section.
5, 6 *Meandrospira cheni* (Ho), 1959. 5 – sample BR 12A/2, 6 – sample BR 12A/3, subequatorial sections.
7, 8 *Meandrospira pusilla* (Ho), 1959. Sample BR 14/1, subequatorial sections.

Taxonomic remarks

Meandrospira cheni (Ho) and *M. pusilla (*Ho) are very similar, and Zaninetti (1976) combined these two taxa in *M. pusilla* (Ho). On the other hand, later studies (Salaj et al., 1983; Trifonova, 1993; Rettori, 1995) considered the two forms as separate species. Both of these species can be distinguished in the Bravnice section.

Occurrence

G. shengi was first found in the Lower Triassic of China (Ho, 1959). Later this species was described from the Lower and Middle Triassic (Anisian) of the Dinarides, Hungary, East Carpathians, Bulgaria, Turkey, Caucasus (Zaninetti, 1976; Pantić, 1970; Urošević & Jeličić, 1973-1974; Dragastan, & Grădinaru, 1975; Dager, 1978; Oravecz-Scheffer, 1987; Efimova, 1991; Trifonova, 1992; Rettori, 1995; Kolar-Jurkovšek et al., 2013) and from the Rhaetian of the West Carpathians (Salaj et al., 1983).

G. triphonensis was first described in the Upper Anisian of the Switzerland (Baud et al., 1971). It is known from the Lower and Middle Triassic (Anisian) of the of the Alps, North-Sudetic Basin, Dinarides, Carpathians, Hungary, Bulgaria, Hellenides, Turkey, Israel, Caucasus, Iran (Pantić & Rampnoux, 1972; Zaninetti, 1976; Pantić & Radošević, 1977a; Dager, 1978; Salaj et al., 1983; Oravecz-Scheffer, 1987; Salaj et al., 1988; Efimova, 1991; Trifonova, 1992; Rettori, 1995; Bucur et al., 1997; Chrząstek, 2002).

M. cheni was first found in the Lower Triassic of China (Ho, 1959). Later this species was described from the Lower Triassic of the Dinarides, Carpathians, Bulgaria, Hellenides, Israel, United Arab Emirates (Salaj et al., 1983, 1988; Trifonova, 1993; Rettori, 1995; Maurer et al., 2008; Korngreen et al., 2013).

M. pusilla was first described in the Lower Triassic of China (Ho, 1959). It is known from the Lower and Middle Triassic (Anisian) of the of the Alps, Apennines, Dinarides, Carpathians, Hungary, Bulgaria, Hellenides, Turkey, Israel, Crimea, Caucasus, Iran, Pakistan, Thailand, Malaysia; British Columbia (Đurđanović, 1967; Pantić, 1970; Urošević, 1971; Pantić & Rampnoux, 1972; Ramovš, 1972; Zaninetti, 1976; Pantić & Radošević, 1977a, b; Dager, 1978; Salaj et al., 1983; Oravecz-Scheffer, 1987; Salaj et al., 1988; Efimova, 1991; Trifonova, 1993; Rettori, 1995; Bucur et al., 1997; Popescu & Popescu, 2005; Vuks, 2007; Krainer & Vachard, 2011; Sano et al., 2012).

N. skyphica was first found in the Olenekian of the Eastern Precaucasus and Western Caucasus (Efimova, 1974). Later this species was described from upper Olenekian and Middle Triassic (Anisian) of Bulgaria, Anisian of Hellenides and Carpathians (Efimova, 1991; Trifonova, 1994; Bucur et al., 1997).

A. minutus was first described in the Lower Olenekian of the Western Caucasus; Efimova (1974) wrote that some *Ammodiscus incertus* d'Orbigny identified by some micropalaeontologists from the Lower Triassic of the Western Europe were in her opinion *A. minutus*.

All species from the Bravnice section are known from the Lower Triassic and Anisian, except *M. cheni*, which is typical for the Lower Triassic only.

Comparison

The generic composition of the foraminiferan assemblages from the Bravnice is similar to Early Triassic assemblages from different parts of the Tethys, from the Alps to China. There are some species in common with foraminiferan assemblages from the Lower Triassic of China (Ho, 1959; He, 1993), the Olenekian of the Caucasus area (Efimova, 1991), the Lower Triassic of Bulgaria (Trifonova, 1992; 1993), Hungary (Oravecz-Scheffer, 1987), Alps (Zaninetti, 1976; Broglio Loriga et al., 1990; Rettori, 1995), British Columbia (Sano et al., 2012).

Foraminiferan assemblages with similar taxonomical composition are mainly known in the Lower Triassic and Anisian of the several areas of Dinarides (Đurđanović, 1967; Dimitrijević et al., 1968; Pantić & Rampnoux, 1972; Ramovš, 1972; Pantić-Prodanović & Radošević, 1977a, b). The joined findings of the mentioned species of *Meandrospira* are possible in the Spathian (Salaj et al, 1983; Trifonova, 1993) or in the Spathian without lowermost part (Rettori, 1995). Therefore it is reasonable to conclude that both foraminiferan assemblages from the Bravnice section in Bosnia and Herzegovina is within the Olenekian.

Conodont faunas (Fig. 9)

Conodont faunas of Bravnice section are predominantly ramiform elements and some can be attributed to Ellisoniidae. The fragmentation of conodont elements does not permit apparatus reconstruction. All collected P elements belong to *Triassospathodus* Kozur. In a contrast to *Neospathodus* Mosher (Mosher, 1968), elements of *Triassospathodus* can be easily distinguished due to downcurved posterior end of the lower margin of the basal cavity (Kozur et al., 1998).

The segminate P_1 elements from the lower part of the section (samples BR 1-3, 6) are short and high. They bear three to five denticles, and the expanded basal cavity is symmetrical. Such elements are attributed to *T. hungaricus* (Fig. 9. 1–8) and thus the lower part of the Bravnice section is placed in the *hungaricus* conodont Zone.

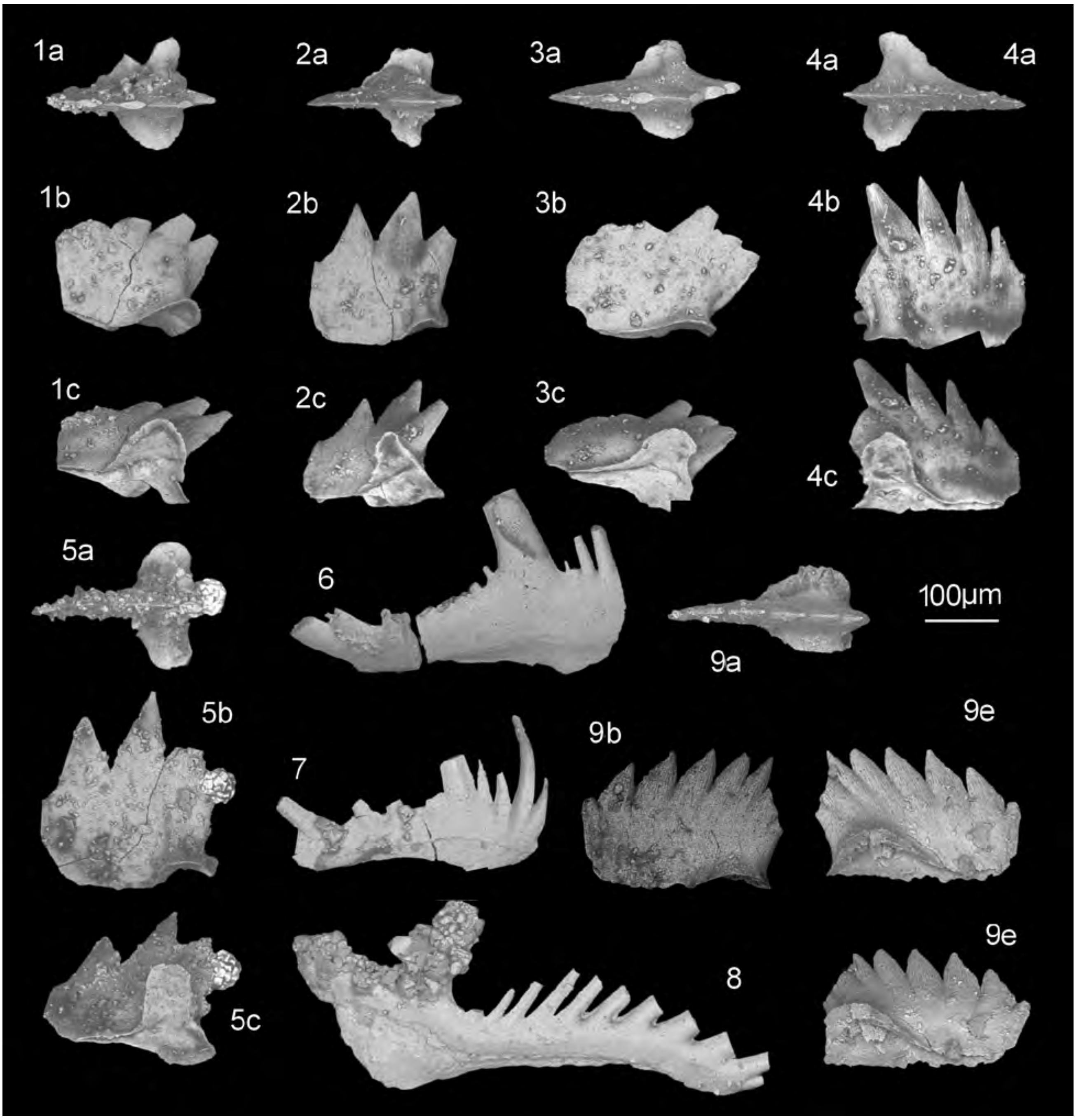

Fig. 9. Conodonts of the Early Triassic Bravnice section, Bosnia and Herzegovina. 1–8 *hungaricus* Zone, 9 *triangularis* Zone. Scale bar 100 microns.

1–8 Triassospathodus hungaricus (Kozur & Mostler). 1–5 P-elements: 1–4 sample BR 1 (GeoZS 5113), 5 sample BR 3 (GeoZS 5114); 6–8 ramiform elements (S3 or S4): 6–7 sample BR 2 (GeoZS 5079), 8 sample BR 3 (GeoZS 5114).
9 Triassospathodus triangularis (Bender). Sample BR 15 (GeoZS 5120).
a – upper, b – lateral, c – oblique lower views.

The samples BR 11 and 15 yield rare segminate elements that are relatively short with subtriangular basal cavity developed in the posterior half. Denticles, eight or nine in number are slightly increasing in height and reveal posterior inclination. One smaller denticle is developed behind the cusp. This specimens are attributed to *T. triangularis* and some forms probably represent an intermediate stage (Fig. 9. 9). This portion of the section is placed into the *T. triangularis* conodont Zone.

Taxonomic remarks

The classification of the Early Triassic segminate pectiniform elements is still uncertain. Several views on their relationships have been put forward. According to Orchard (1995) *Neospathodus* species may belong to any of several Lower Triassic groups depending on their basal profile, development of cusp, or inclination of denticles. In his opinion there exist also some unrelated homeomorphs. This genus evolved from *Neogondolella* in the Induan as demonstrated by similarities in composition of their apparatuses (ORCHARD, 2010). On the other hand, KOZUR et al. (1998) placed most Spathian segminate elements in the genus *Triassospathodus,* and this view is adopted in this paper.

Occurrence

T. hungaricus was first described from the *Tirolites* beds of Felsöörs in Hungary (KOZUR & MOSTLER, 1970). The species has been known in Slovenia so far from the Spathian of the Idrija-Žiri and Krško areas (KOLAR-JURKOVŠEK, unpublished data) and Julian Alps (KOLAR-JURKOVŠEK et al., 2013). Some similar specimens collected in the Thaynes Group of Elko County in Nevada were illustrated and determined as »*Neospathodus*« cf. *hungaricus* (LUCAS & ORCHARD, 2007). The full stratigraphic range of the lowermost Spathian species *T. hungaricus* is not yet known and its occurrence above the *T. hungaricus* Zone has not yet been reported.

T. triangularis was first described from the Marmarotrapeza Formation at Chios by BENDER (1970). The latest Spathian spathodid faunas that include *T. triangularis* were hitherto reported from the central Slovenia (DOZET & KOLAR-JURKOVŠEK, 2007) and the Idrija-Žiri area (KOLAR-JURKOVŠEK, unpublished data). In the southeastern continuation of the Dinarides, the species was collected also from the Muć section in Croatia that was proposed as a standard section for the European Upper Scythian (HERAK et al., 1983). The fauna with co-occuring elements of *T. homeri* and *T. triangularis* was also reported from the Spathian of Krivi potok in NW Serbia (SUDAR, 1986a, b).

Discussion

The biostratigraphic scheme of KOZUR (2003) of the Late Olenekian is largely based on *Triassospathodus* (Fig. 10), and the stratigraphic importance of this genus for the Spathian strata was pointed out by KOZUR et al. (1998). There are six conodont zones in in the Spathian, and *T. hungaricus* is the nominal index species of the basal Spathian, that is equivalent to the *Tirolites cassianus* ammonoid zone. *T. triangularis* is the marker of the fourth zone (KOZUR, 2003). In the shallow western Tethys, the *T. hungaricus* fauna lies within the lower Spathian, in the absence of the *Icriospathodus collinsoni* (Solien) fauna (H. KOZUR - pers. comm., 2012).

Comparison of conodont faunas:

The genera *Triassospathodus* and *Spathicuspus* are dominant in the Olenekian, whereas the long-ranging late Olenekian species assigned to ž*N.'* *triangularis* is an uncommon conodont taxon, that ranges up to the Olenekian/Anisian boundary in the Guandao section (ORCHARD et al., 2007b).

In the Deşli Caira section the LAD of characteristic conodont species determined as ž*N.' triangularis* was recorded in the sample GR7 representing a major faunal change of the succession (Datum 3) that involves also the FADs of *Chiosella timorensis* Nogami and *Chiosella* n. sp. A (ORCHARD et al., 2007a).

According to ORCHARD et al. (2007b) species of the *T.* ex gr. *homeri* that includes *T. symmetricus* (Orchard), *T. brochus* (Orchard), *T. sosioensis* (Kozur, Krainer & Mostler) are most common and ubiquitous elements of late Spathian faunas in Eurasia and North America. The assemblage of the *T. homeri* group indicates late Smithian-Spathian interval in the Cache Creek Terrane succession of British Columbia (SANO et al., 2012).

T. triangularis is a widespread late Spathian taxon, present in Deşli Caira in Romania and Guandao in China (ORCHARD et al., 2007a, b). It is part of the Fauna 3 that is equivalent to the *Prohungarites/Subcolumbites* beds within the context of North American ammonoid succession (ORCHARD, 2010).

Conclusions

This study presents new sedimentological and palaeontological documentation of the remarkable Lower Triassic limestone of the Jajce area (Bosnia and Herzegovina), a candidate for the UNESCO World Heritage Site. The bio- and litho- stratigraphy of the Bravnice section near Jajce has been investigated. The material is rich in ichnofossils and molluscan macrofauna dominated by *Natiria costata*, a widely distributed and characteristic species for the Early Triassic. The strata yield significant Spathian (Olenekian) faunas based on a *Triassospathodus* dominated conodont assemblage. The older fauna is marked by *Triassospathodus hungaricus* and the foraminifera *Nodosaria* ex gr. *skyphica*, *Ammodiscus* ex gr.

Stage/ Substage	Ammonoid Zone	Conodont Zone
Late Olenekian (Spathian)	*Neopopanoceras haugi*	*Chiosella gondolelloides*
		Triassospathodus sosioensis
	Prohungarites-Subcolumbites	*Triassospathodus triangularis*
	Procolumbites	*Triassospathodus homeri*
	Columbites parisianus	*Icriospathodus collinsoni*
	Tirolites cassianus	*Triassospathodus hungaricus*

Fig. 10. Correlation of Late Olenekian (Spathian) ammonoid and conodont zonations after KOZUR (2003).

minutus, *Glomospirella triphonensis* and *G. shengi*, that can be attributed to the lower Spathian *T. hungaricus* conodont Zone. A younger fauna marked by presence of *T. triangularis* in association with *Meandrospira cheni* and *M. pusilla* is placed into the *T. triangularis* conodont Zone.

Well bedded Spathian limestones of the type exploited by local inhabitants for construction and paving in the old Jajce town, have been investigated from east from the Bravnice village. Four microfacies types were differentiated: 1) laminated mudstone – micrite, 2) laminated calcareous siltstone, 3) fine-grained bioclastic packstone – biomicrite and 4) coarse-grained bioclastic packstone – biomicrite. The depositional environment is characteristic of the outer part of a wide shallow shelf/ramp, but subject to distal storm events. Between storms, bioturbated sediments are formed, but may be interrupted by episodes of poor aeration and anoxia. These features have similarly been suggested also for other locations along entire Dinaride area.

The Bravnice section represents an important reference section for the Olenekian of Bosnia and Herzegovina based on Spathian (Olenekian) conodont faunas and the accompanied fossil association. The recovered faunas consist of important correlative elements for comparison with co-eval faunas elsewhere in the Dinaride area, and for the Early Triassic Tethys worldwide.

These Lower Triassic limestones of Bravnice are of great importance for the restoration of old buildings in this area, and particularly for reconstruction of the Jajce town, a candidate for the UNESCO World Heritage List. They can also be used for new architectural projects that should conform to the local style. Such source materials should play a much more significant role in reconstruction, and are much preferred to non-autochthonous magmatic and metamorphic rocks that have unfortunately been used in the past.

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Lower Jurassic foraminiferal biostratigraphy of Podpeč Limestone (External Dinarides, Slovenia)

Spodnjejurske foraminifere podpeškega apnenca (Zunanji Dinaridi, Slovenija)

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Ključne besede: taksonomija, biostratigrafija, foraminifere, Dinarska karbonatna platforma, sinemurij, pliensbachij, litiotidni apnenec

Abstract

The "Podpeč limestone" outcropping south of Ljubljana (Central Slovenia), deposited at the northern edge of the Dinaric Carbonate Platform, comprises mostly dark grey and black thick bedded oolitic limestone, and is renowned for several horizons of lithiotid bivalves. Foraminifera, especially *Orbitopsella* spp., are rather frequent, but no detailed distribution of foraminiferal taxa was given. Furthermore, documentation of foraminiferal species is scarce, with few photographs. In order to give a comprehensive picture of foraminiferal assemblage of the "Podpeč limestone" and its distribution, three sections were measured in detail and sampled. The foraminiferal assemblage consists of 17 species, described in detail. On the basis of foraminifera, the investigated part of the "Podpeč limestone" belongs to the *Lituosepta recoarensis* and *Orbitopsella praecursor* biozones of early Late Sinemurian and Early Pliensbachian age, respectively.

Izvleček

Temno sivi in črni plastnati ooidni "podpeški apnenec", ki ga najdemo južno od Ljubljane (osrednja Slovenija), je nastajal na severnem robu Dinarske karbonatne platforme in je znan po več horizontih litiotidnih školjk. Poleg ostale makrofavne, so v njem dokaj pogoste tudi foraminifere, posebno *Orbitopsella* spp. Žal so ta poročila slikovno slabo dokumentirana in ponavadi brez natančne stratigrafske umestitve. Da bi proučili celotno foraminiferno združbo in razpon posameznih taksonov, sem posnel tri detajlne sedimentološke profile. Na podlagi presekov v zbruskih sem določil 17 vrst bentoških foraminifer in ugotovili, da raziskani del združbe "podpeškega apnenca" pripada *Lituosepta recoarensis* in *Orbitopsella praecursor* bioconama zgodnje poznesinemurijske in zgodnjepliensbachijske starosti.

Introduction

Following the devastating effects of the alleged biocalcification crisis at the Triassic-Jurassic boundary in the Neotethys area (e.g., Hautmann et al., 2008; Črne et al., 2011), the Early Jurassic saw a gradual reestablishment of shallow water benthic communities, in which agglutinated large benthic foraminifera played a prominent role (Septfontaine, 1988; Bassoullet, 1997; Mancinelli et al., 2005; BouDagher-Fadel & Bosence, 2007; Velić, 2007; BouDagher-Fadel, 2008). Transition from poorly diversified Hettangian fauna with small involutinids and pfenderinids into Sinemurian *Siphovalvulina*- and *Textularia*-dominated assemblages, and further from simple into internally complicated lituolids of the Pliensbachian is well recorded (BouDagher-Fadel, 2008), and provides a useful tool in biostratigraphic studies throughout the present-Mediterranean area (e.g., Septfontaine, 1984, 1988; Bassoullet, 1997; Mancinelli et al., 2005; BouDagher-Fadel & Bosence, 2007).

Biostratigraphic division of Jurassic shallow water carbonates of the central Dinaric Carbonate Platform has been given by Radoičić (1966) and recently by Velić (2007). The key to a detailed subdivision of Lower Jurassic strata elsewhere in the Karst Dinarides is thus at hand.

The aim of this paper is to give a systematic account of foraminifera in the lithiotid bivalves-rich "Podpeč limestone", an informal Pliensbachian stratigraphic unit of central Slovenia, and to present their distribution in three

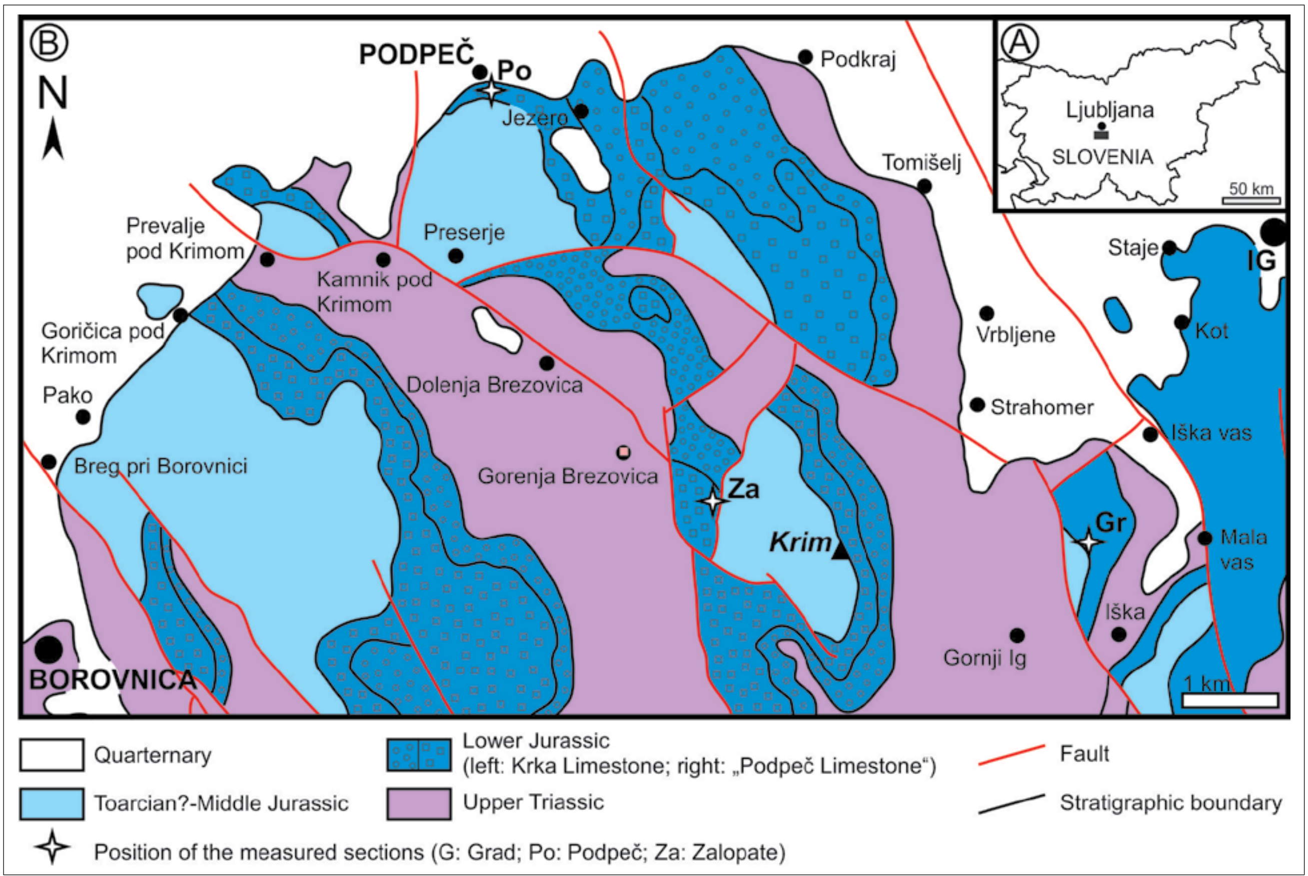


Fig. 1. Geological map of the Mt. Krim area with the position of the measured sections. Redrawn and modified after Buser et al. (1967) and Buser (1968).

Sl. 1. Geološ ka karta območja Krima in položaj posnetih profilov. Prerisano in prirejeno po Buser et al. (1967) in Buser (1968).

detailed sedimentological sections from the Mt. Krim area: the classical locality of the Podpeč quarry, supplemented by data from Zalopate and Grad sections (Fig. 1).

Previous research

The stratigraphic succession of the Krim Mountain area was more extensively described by Pleničar (1970), Buser (1974), and recently by Miler and Pavšič (2008). As an informal lithostratigraphic unit, the Pliensbachian "Podpeč limestone", characterized by lithiotid bivalves, attracted the most attention due to its architectural value (Ramovš, 1961, 2000) and due to the local abundance of fossil brachiopods and molluscs, most notable lithiotid bivalves (Buser, 1965; Buser & Debeljak, 1996; Debeljak & Buser, 1997; Ramovš, 2000; Miler & Pavšič, 2008). Coral patches can also occur locally (Turnšek, 1997; Turnšek & Košir, 2000; Miler & Pavšič, 2008).

Shallow-water carbonates with lithiotid bivalves can be followed over the area of Slovenia in an over 100 km long belt (Buser & Debeljak, 1996). Locally, Dozet and Strohmenger (2000) introduced a Lower Jurassic Podbukovje Formation, or Predole Beds with five members (Dozet, 2009). The correlation of the "Podpeč limestone" with these units is unclear, due to the lack of definitions and biostratigraphic studies of the lower and upper boundaries of the "Podpeč limestone". Furthermore, no type sections for the Podbukovje/Predole Formations and their members were selected either, and a more detailed description and definitions of lithostratigraphic boundaries are missing as well. The "Podpeč limestone" may thus correspond to one, two or all of the three successive middle members of the Podbukovje/Predole Formations, i.e. *Orbitopsella* limestone, *Lithiotis* limestone and Oolitic limestone sensu Dozet (2009).

Foraminifera were first recognized in the "Podpeč limestone" by Ramovš (1961) and Buser (1965, 1974). Scattered reports on other species of foraminifera from the "Podpeč limestone" or from equivalent units are also given by Šribar (1966), Strohmenger and Dozet (1991), Dozet (1992, 1996), Dozet and Strohmenger (2000), Turnšek et al. (2003), Miler and Pavšič (2008), and Dozet (2009).

According to Dozet (2009), "*Orbitopsella* limestone" contains *Orbitopsella praecursor*, *Lituosepta recoarensis* Cati, *Planisepta compressa*, *Involutina farinacciae*, *Haurania deserta*, *Agerina martana*, *Glomospira* sp., *Aeolisaccus dunningtoni*, *Amijiella amiji* (mentioned in figure, not in the text), *Paleomayncina termieri*, *Pseudocyclammina liassica* (names are spelled as written in Dozet, 2009). In the "*Lithiotis* limestone", the following taxa were determined (Dozet, 2009): *A. amiji*, *P. liassica*, *P. termieri* (mentioned only in figure). In addition, from the middle Early Jurassic *Orbitopsella praecursor* subzone of the Early Jurassic *Palaeodasycladus mediterraneus* cenozone, Dozet (1996) mentiones *O. praecursor*, *Orbitopsella* cf. *dubari*, *Mayncina termieri*, *Haurania amiji*, *H. deserta*, *L. recoarensis*, *Vidalina martana*, *Neoangulodiscus leischneri*, *Involutina turris* and *Permodiscus sinuosus* (all names as in original).

All these reports lack a detailed sedimentological section and the details of foraminiferal distribution.

Methods of study

In order to investigate foraminifera from the "Podpeč limestone", three sedimentological sections were measured bed-by-bed in the wider Mt. Krim area (Fig. 1). Samples were collected from 55 beds, and 62 thin sections made, in which foraminifera were determined. Foraminiferal systematics follows BouDagher-Fadel (2008). Terminology follows Hottinger (2006) and Basi et al. (2006). The positions of thin sections and the distribution of foraminifera are given in Figures 2–4.

Geological setting

Geological mapping of the Mt. Krim area was performed by Lipold (1858), Kramer (1905), Vetters (1933), Buser et al. (1967), Buser (1968), and Miler and Pavšič (2008). The area structurally belongs to the External Dinarides (Placer, 1999, 2008). The Lower Jurassic succession consists of shallow-water carbonates, deposited at the northern margin of the Dinaric Carbonate Platform, facing the Slovenian Basin to the present north (Buser, 1989, 1996). At the time, the opening of the Piemont-Liguria Ocean on the far west caused a gradual deepening of the Slovenian Basin (Rožič, 2009), and a partial disintegration of the Dinaric Carbonate Platform margin (Miler & Pavšič, 2008). The latter, however, remained relatively stable until the end of the Cretaceous (Buser, 1989, 1996). The Lower Jurassic succession comprises: Hettangian and Sinemurian (?) coarse-grained dolomite, micritic and subordinately fine-grained oolitic limestone, locally dolomitic breccia (Buser, 1965; Miler & Pavšič, 2008; Ogorelec, 2009), Pliensbachian oolitic limestone and lithiotid limestone ("Podpeč limestone"; Pleničar, 1970; Buser, 1974; Miler & Pavšič, 2008), and Toarcian thin bedded micritic limestone (A. Košir, pers. com., see also Dozet, 2009). The age of these units is determined on the basis of superposition, or fossils determined from individual levels within the stratigraphic units (Miler & Pavšič, 2008).

Description of measured sections

The Zalopate section (see position on Fig. 1) is located at approximate coordinates 45°56´09´´ latitude and 14°27´21´´ longitude, a few meters above the road. The section starts with micritic limestone, which may be banded (straight dark and white, 5 mm thick lamina). Black fine-grained oolite soon appears and then represents the dominant lithology. Accumulations of bivalves, brachiopods, intraclasts and oncoides are locally present at the base of oolite. Irregular reddish bedding planes are interpreted as short-time emersion levels (see Martinuš et al., 2012). Grading, parallel lamination, occasional scour structures and ripples are present.

The Podpeč 1 section (45°58´22´´ lat., 14°25´16´´ long.; Fig. 3 left) spans the "classical" locality with lithiotid bivalves (see Buser & Debeljak, 1996) at the eastern side of the now abandoned quarry (Fig. 1). The Podpeč 2 section (Fig. 3 right) starts with the outcrop in a private garden some meters further towards the east and overlaps with the Podpeč 1 section. The dominant lithology is medium- to very thick bedded gray oolite. Various amounts of mm- to cm-sized intraclasts and oncoids are locally present, as well as fragmented or complete fossil bivalves, gastropods and terebratulid brachiopods, sometimes forming floatstone or rudstone textures. At least nine lithiotid horizons were counted. Lithiotid shells are embedded in limestone or red claystone matrix and form coquinas, sometimes in lens-like bodies, which laterally thin-out. Though not in life position, shells are probably preserved in situ as testified by the presence of unseparated and unbroken valves. Wackestone and black mudstone are subordinate and bedding thin- to medium-thick. Irregular bedding planes and red clayey surfaces are frequent. They were interpreted as emersion levels (Buser & Debeljak, 1996). Parallel lamination and grading are common. Cross-lamination was found in an outcrop located outside the quarry.

The Grad section (45°55´46´´ lat., 14°30´14´´ long.) is the shortest of the measured sections (Fig. 4). Thick to very thick bedded oolite predominates. Lithiotid bivalves are present in two oolite levels, but are not in life position. Concentrations of broken mollusc shells are common.

Systematic palaeontology

Order Foraminiferea J. J. Lee, 1990

Suborder Textulariina Delage & Hérouard, 1896
Superfamily Verneulinacea Cushman, 1911
Family Verneulinidae Cushman, 1911
Subfamily Verneulinoidinae Suleymanov, 1973
Genus *Duotaxis* Kristan, 1957
(type species: *Duotaxis metula* Kristan, 1957)

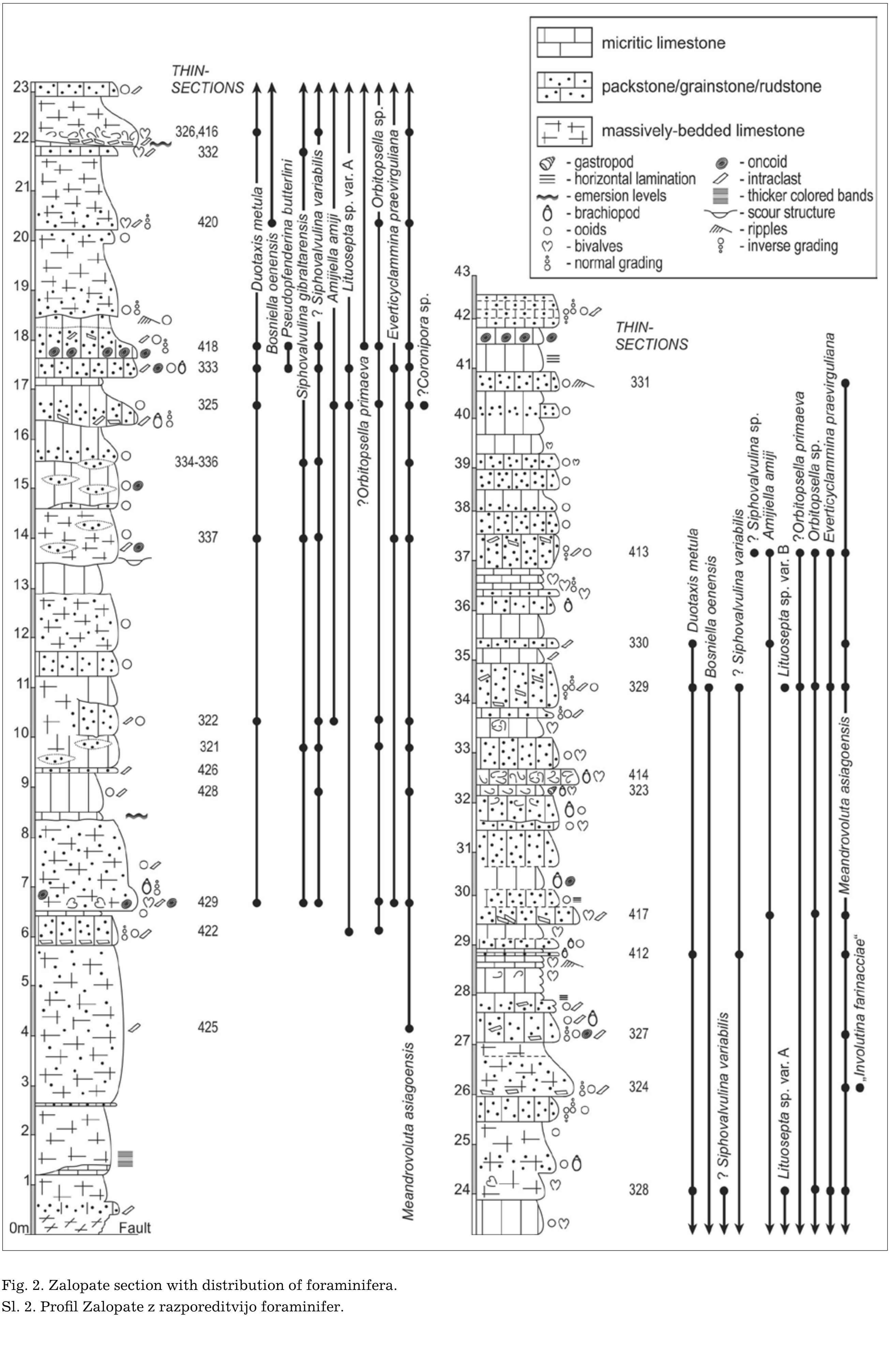


Fig. 2. Zalopate section with distribution of foraminifera.
Sl. 2. Profil Zalopate z razporeditvijo foraminifer.

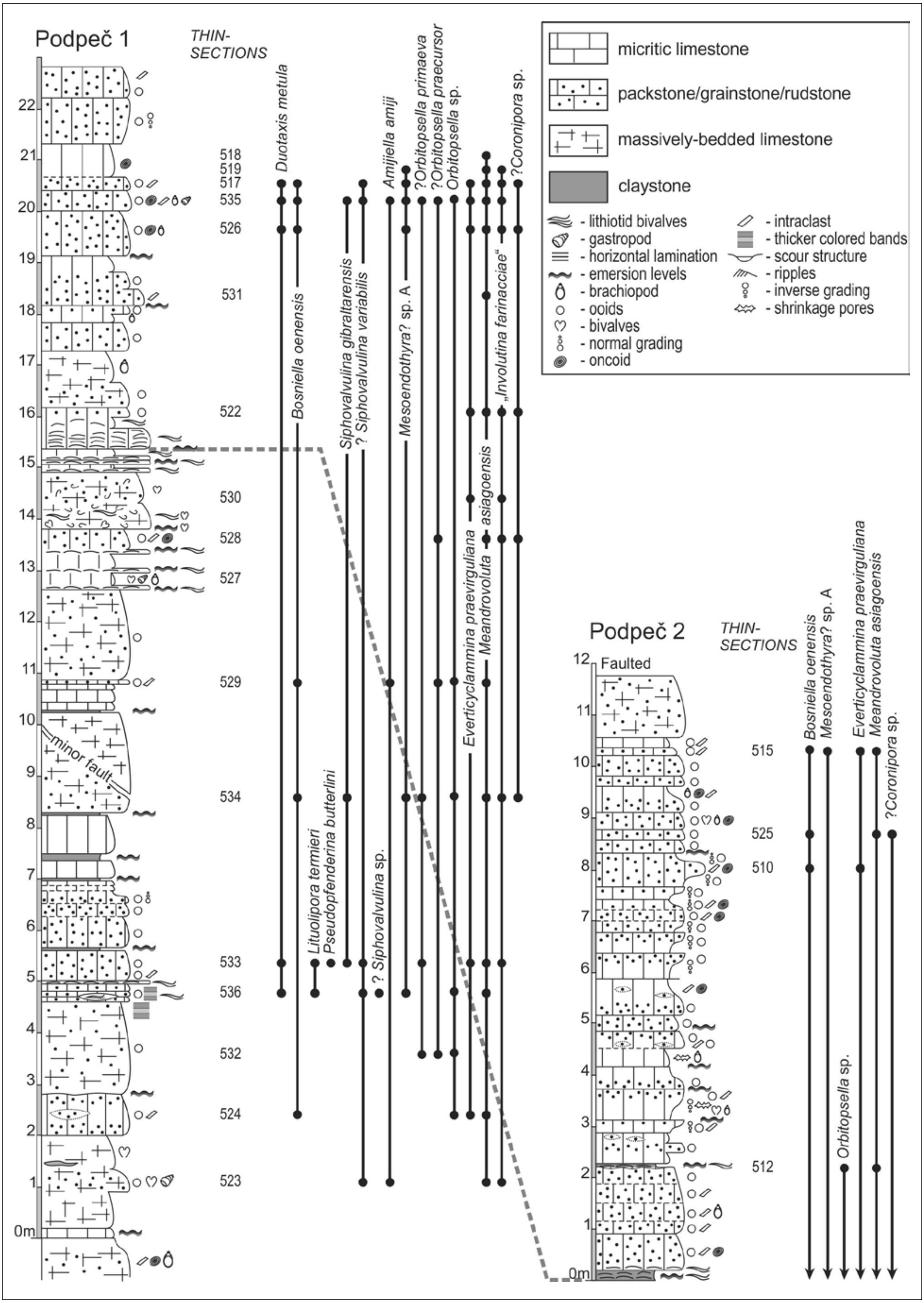


Fig. 3. Podpeč sections with distribution of foraminifera.

Sl. 3. Profila Podpeč z razporeditvijo foraminifer.

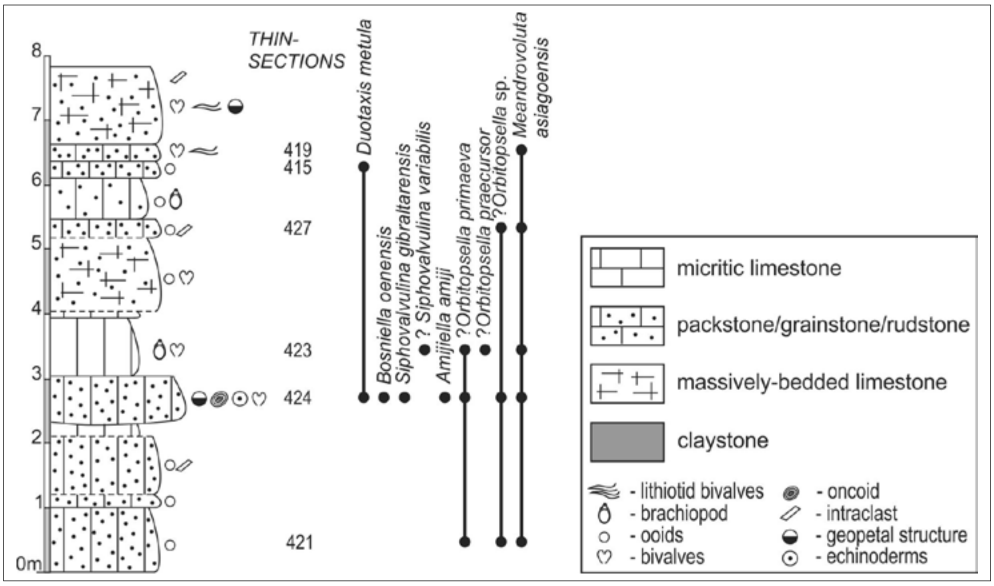


Fig. 4. Grad section with distribution of foraminifera.

Sl. 4. Profil Grad z razporeditvijo foraminifer.

Duotaxis metula Kristan, 1957
(Pl. 1, figs. 1-2; Pl. 2, fig. 5)

*1957 *Duotaxis metula* nov. gen. nov. spec. – Kristan, p. 295, Pl. 27, figs. 5a-d, 6.
1996 *Duotaxis metula* Kristan, 1957 – Fugagnoli, p. 388, Pl. 1, figs. 1-5; Fig. 2a-h.
1999 *Duotaxis metula* Kristan, 1957 – Bassoullet et al., p. 226, Pl. 4, fig. 8.
2001 *Duotaxis metula* Kristan, 1957 – BouDagher-Fadel et al., p. 606, Pl. 2, figs. 1-4.

Material: Thin sections 322, 325, 326, 328, 329, 330, 333, 337, 412, 415, 418, 424a, 424b, 429a, 517, ?526, 533, 535, 535b, 536.

Description: The test is 0.27-0.51 mm high, and 0.29-0.54 mm wide, with the ratio between height and width 0.86-1.00. A simple proloculus is followed by chambers in a trochospiral arrangement. Most specimens have 4 or 5 trochospiral coils, but the largest bears 8 coils. No endoskeletal elements are present. The test wall is simple, agglutinated.

Geographic distribution and stratigraphic range: The type specimen of *D. metula* was described from Rhaetian of Northern Calcareous Alps (Kristan, 1957). Early Jurassic examples are cited from Southern Alps (Fugagnoli, 1996, 1998; Fugagnoli & Loriga Broglio, 1998), Sinemurian of Gibraltar (BouDagher-Fadel et al., 2001), Pliensbachian of Middle Atlas, Morocco (Bassoullet et al., 1999). According to Velić (2007), this species lasts until the end of Pliensbachian in the Karst Dinarides of Croatia.

Superfamily Biokovinoidea Gušić, 1977
Family Biokovinidae Gušić, 1977
Genus *Bosniella* Gušić, 1977
(type species: *Bosniella oenensis* Gušić, 1977)

Bosniella oenensis Gušić, 1977
(Pl. 1, figs. 3-9)

* 1977 *Bosniella oenensis* n. gen., n. sp. – Gušić, p. 13, Pl. 11, figs. 1-2; Pl. 12, figs. 1-4; Pl. 13.
1998 *Bosniella oenensis* Gusic, 1977 – Fugagnoli, p. 173-175, Pl. 19, figs. 1-9; Pl. 20, figs. 1-2.
1998 *Bosniella oenensis* Gušić, 1977 – Fugagnoli & Loriga Broglio, p. 63, Figs. 10.1-5.
2007 *Bosniella oenensis* Gušić 1977 – BouDagher-Fadel & Bosence, p. 8, Pl. 5, figs. 4, 6; Pl. 7, figs. 3-4; Pl. 8, fig. 6.

Material: Thin sections ?329, 420, 424b, 510, 513, 515, 517, 524, 525, 526, 529, 534, 535, 535b. One specimen is possibly of microspheric generation, 49 specimens of megalospheric generation.

Description: Most of the material is identified as tests of megalospheric generation. The majority of specimens has only planispirally coiled part of the test. In a few cases the planispiral part is followed by uniserial part of the test. Protoconch is complex (bilocular cf. Gušić, 1977), 0.11-0.19 mm in diameter. It is followed by 1-2 planispiral coils, amounting to the outer test diameter of 0.56-1.00 mm. Chambers (3-5?) are hardly discernibly in the first coil. The second coil comprises 6-9 reniform chambers, separated by thick, short and obliquely positioned septa. The uniserial part of the test is 0.61-1.11 mm high, consisting of 3-8 chambers. The height of these chambers remains approximately constant (lumen height 0.13-0.14 mm), whereas the chamber width may stay unchanged or slightly increases (lumen width 0.42-0.61 mm). The aperture is initially simple basal, towards the end of the second coil becoming centrally situated, and in the uniserial part multiple/cribrate. Stolons are 0.04-0.07 mm in width, widely separated. The outer test wall and the septa near the outer wall (the gradual loss of perforations in septa was commented also in Gušić & Velić, 1978) are agglutinated, riddled with large and densely packed pseudopores (alveoles in BouDagher-Fadel & Bosence, 2007), i.e., in the literature called a keriothecal wall (e.g. Septfontaine, 1988; Bassoullet, 1994; Tasli, 2001; Schlagintweit & Velić, 2011). The outer wall and the septa are

0.06-0.08 mm thick. In the axial section the coiled part of the test appears biumbilical or with parallel, slightly compressed sides, 0.42 mm wide. The periphery of the test is widely rounded. The degree of chamber overlap is not distinctly visible.

Remarks: According to Gušić (1977), the planispiral part of the *Bosniella oenensis* comprises 2-3 (megalospheric) or 3-4 (microspheric test) coils. Megalospheric tests with 1-1.5 coils, however, were described also by Fugagnoli (1998).

The wall was originally described as having bifurcating alveoles (Gušić, 1977). It was later mostly described as keriothecal (Bassoullet, 1994; Fugagnoli, 1998; Tasli, 2001; Schlagintweit & Velić, 2011). The original distinction from *Mesoendothyra* Dain was based on the different wall texture (simple microgranular in *Mesoendothyra* vs. complex in *Bosniella*). However, Septfontaine (1988) considered *Bosniella* a junior synonym of *Mesoendothyra*. Because *M. croatica* differs from the type species of *Mesoendothyra*, Bassoullet (1994) later considered *Bosniella* a valid Jurassic genus, comprising *B. oenensis*, *B. fontainei* and *B. croatica*. Fugagnoli (1998) also considered both genera distinct, but due to the lack of revision of the type material of *Mesoendothyra*. Tasli (2001) acknowledged both possibilities by considering *Bosniella* a junior synonym of *Mesoendothyra* or, alternatively, placing *M. croatica* into the valid genus *Bosniella*. I prefer the latter option, due to the presence of specimens referred to *Mesoendothyra* sp., which probably has a simple microgranular wall.

Bosniella fontainei Bassoullet from Middle Jurassic of Thailand has slighly smaller megalospheric tests, larger microspheric tests, less globular chambers and strongly inclined septa (Bassoullet, 1994). It is safe to add that *B. fontanei* has more numerous chambers (9-10 or 10-11) in the last whorl of megalo- and microspheric tests, respectively.

Bosniella croatica Gušić is smaller (mostly 0.5-0.6 mm in diameter), is more globular, with shorter, wider and involute chambers (cf. Bassoullet, 1994).

Bosniella bassoulleti Schlagintweit & Velić from Late Aalenian to Early Bajocian (?) is of the same size as *B. oenensis*. It has, however, 11-14 chambers in the last whorl (compared to 7-9 in *B. oenensis*), thinner septa (0.04-0.08 mm, compared to 0.12-0.13 mm for *B. oenensis*), and a well developed uniserial part with chambers retaining constant size or becoming only slightly wider, whereas these progressively increase in *B. oenensis* (Schlagintweit & Velić, 2011).

Geographic distribution and stratigraphic range: Sinemurian-Pliensbachian of Karst Dinarides, Bosnia (Gušić, 1977); Sinemurian – Early Pliensbachian of Betic Cordillera, Spain, and Sinemurian – Pliensbachian of High Atlas, Morocco (BouDagher-Fadel & Bosence, 2007); Sinemurian-Pliensbachian of Southern Alps, northern Italy (Fugagnoli, 1998; Fugagnoli & Loriga Broglio, 1998). Late Sinemurian – Pliensbachian according to Bassoullet (1997).

Genus *Lituolipora* Gušić & Velić, 1978
(type species: *Lituolipora polymorpha* Gušić & Velić, 1978)

Lituolipora termieri (Hottinger, 1967)
(Pl. 1, figs. 10-12)

* 1967 *Mayncina termieri* n. sp. – Hottinger, p. 31, Pl. 3, figs. 4-10; Fig. 14.
1978 *Lituolipora polymorpha* n. gen., n. sp. – Gušić & Velić, p. 74, Pl. 1, figs. 1-4; Pl. 2, figs. 1-5; Pl. 3, figs. 1-3; Pl. 4, figs. 1-6; Pl. 5, figs. 1-5; Pl. 6, figs. 1-6, pars 7; Pl. 7, figs. 1-4; Pl. 8, figs. 1-6; Pl. 9, figs. 1-11; Pl. 10, figs. 3, 4, 6.
1986 "*Mayncina*" *termieri* – Septfontaine, Pl. 2, fig. 1.
1998 *Paleomayncina termieri* (Hottinger), 1967 – Fugagnoli, p. 153, Pl. 7, figs. 1-5.
1998 *Paleomayncina termieri* (Hottinger), 1967 – Fugagnoli & Loriga Broglio, p. 58, Figs. 8.1-8.2.
1999 *Paleomayncina termieri* (Hottinger) – Bassoullet et al., p. 222, Pl. 4, figs. 1-3.
?2003 *Paleomayncina termieri* (Hottinger, 1967) – Azerêdo et al., Pl. 10, fig. 8.
2003 *Lituolipora termieri* (Hottinger, 1967) – Kabal & Tasli, p. 345, Pl. 1, figs. 1-20.
2005 *Lituolipora termieri* (Hottinger) – Cai et al., Pl. 4, figs. 13-21.

Material: Thin sections 533, 536. Three specimens; one certainly belonging to microspheric generation.

Description: Specimens likely belong to a microspheric generation. The initial, irregularly coiled part consists of few chambers. It is followed by a planispiral part, approximately in two coils. The last whorl has 9-11 chambers, separated by obliquely set septa of thickness approximately equal to the wall. The total diameter of the coiled part is 0.40-0.54 mm. The uncoiled part of the test is short, not well developed, with only 1-2 free chambers. They are 0.04-0.05 mm high (lumen) and 0.2-0.26 mm wide, of boxwork shape. The aperture is at first a single opening, later becoming multiple (see Pl. 1, fig. 10). The outer test wall is coarsely alveolar, 0.04-0.08 mm thick.

Remarks: *Lituolipora termieri* was described from the Lower Jurassic of Morocco as *Mayncina termieri* with a simple finely agglutinated wall (Hottinger, 1967). Gušić and Velić (1978) later introduced a new genus and species, *Lituolipora polymorpha*, from the Lower Jurassic of Croatia. The new genus was established on the basis of coarsely perforated wall. Gušić and Velić (1978) were aware of the close similarity with *M. termieri*, but they came to a conclusion that the wall of *M. termieri* is not diagenetically altered. Septfontaine (1988) later decided for the contrary, and introduced a new genus *Paleomayncina* with the type species *M. termieri*. Kabal and Tasli (2003) proposed to retain *Lituolipora* as a valid genus name for the sake of priority over *Paleomayncina*, and recognized *L. polymorpha* to be a junior synonym of *L. termieri*. Their opinion is followed in this paper. Kabal and Tasli (2003) further documented the variability of the species and recognized three morphotypes, two corresponding to different onthogenetic stages of the megalospheric generation and one to microspheric tests (Kabal & Tasli, 2003). Septfontaine (1988) and Kabal and Tasli (2003) describe the wall as coarse keriothecal with polygonal canaliculi, though Gušić and Velić (1978) argued for the inapropriate use of the term keriothecal. The open perforations in Gušić and Velić (1978) specimens were interpreted as result of test abrasion (Septfontaine, 1988).

The specimen in Azerêdo et al. (2003) is considered doubtful, as only uniserial part is shown, though with a cribrate (or multiple?) aperture and flat chambers.

Geographic distribution and stratigraphic range: Sinemurian-Pliensbachian of southern Tibet, China (Cai et al., 2005); Late Sinemurian – Pliensbachian of Southern Alps, northern Italy (Fugagnoli, 1998; Fugagnoli & Loriga Broglio, 1998); Late Sinemurian – Pliensbachian of Karst Dinarides, Croatia (Gušić & Velić, 1978; Velić, 2007); Pliensbachian of Atlas, Morocco (Hottinger, 1967; Septfontaine, 1986; Bassoullet et al., 1999); Late Sinemurian – Toarcian of Central Taurides, Turkey (Kabal & Tasli, 2003). Latest Sinemurian – Pliensbachian according to Bassoullet (1997).

Superfamily Pfenderinoidea Smouth & Sugden, 1962

Family Pfenderinidae Smouth & Sugden, 1962

Subfamily Pseudopfendermininae Septfontaine, 1988

Genus *Pseudopfenderina* Hottinger, 1967

(type species: *Pfenderina butterlini* Brun, 1962)

Pseudopfenderina butterlini (Brun, 1962)

(Pl. 1, figs. 13-14)

*1962 *Pfenderina butterlini* – Brun, p. 188, Pl. 1, figs. 3-9; Pl. 2, fig. 3.

1967 *Pseudopfenderina butterlini* (Brun) 1962 – Hottinger, p. 87, Pl. 19, figs. 7-22; Fig. 44.

1967 *Pseudopfenderina* nov. spec. – Hottinger, p. 89, Pl. 19, figs. 1-6.

1996 *Pseudopfenderina* aff. *butterlini* (Brun) – Zambetakis-Lekkas et al., Pl. 1, figs. 4-6.

1998 *Pseudopfenderina* cf. *butterlini* – Fugagnoli, p. 156, Pl. 7, figs. 7-9.

2003 *Pseudopfenderina buterllini*? (Brum, 1962) [sic] – Azerêdo et al., Pl. 10, figs. 5-6.

pp. 2007 *Pseudopfenderina* cf. *butterlini* (Brun 1962) – BouDagher-Fadel & Bosence, p. 3, Pl. 7, fig. 2 [non Pl. 10, fig. 6].

Material: Thin sections 333, 418, 533, 533b. Specimens are in basal sections (perpendicular to the coiling axis, one in slightly oblique section.

Description: The test is free, roughly elliptical in outline. Test wall is dark, agglutinated and undifferentiated, simple. The outline of the test is continuous, without obvious sutures. Septa are of the same thickness as the outer test wall, and appear perpendicular or slighly oblique to the outer test wall. They divide the interior of the test in 5-10 chambers per whorl. A single solid micritic mass of circular outline (columella) occupies the center of the test. Columella is bordered by large, resorbed foramina (cf. Bassi et al., 2006).

Test diameter ranges from 0.11 to 0.54, with larger tests having greater chamber number.

Remarks: According to literature descriptions (e.g., Hottinger, 1967) *Pseudopfenderina* has a high trochospiral form, which, however, cannot be visible in the observed material due to the lack of axial sections. The genus is distinguished from similar genera posessing axial columella in its lack of complicated wall structure (subepidermal reticular network in *Kurnubia* Henson; primitive hypodermal network in *Praekurnubia* Redmond) or in the absence of subcameral tunnel, which is present in *Pfenderina* Henson and *Paleopfenderina* Septfontaine (Hottinger, 1967; Septfontaine, 1988; Loeblich & Tappan, 1987). The columella of *Pseudopfenderina* consists of pillars and secondary (?) carbonate deposits, forming a solid structure (Hottinger, 1967). As pillars are sometimes not visible, some authors prefer determination as *Pseudopfenderina* cf. *butterlini* (e.g., Fugagnoli, 1998; BouDagher-Fadel & Bosence, 2007). Part of the material in BouDagher-Fadel and Bosence (2007) is attributed to *Duotaxis metula* Kristan in basal section, as no columella is visible and the umbilicus appears unfilled.

Hottinger (1967) distinguished two-times smaller specimens with fewer chambers per whorl (5-7 compared to 7-9 of *P. butterlini*) as an unnamed new species. His opinion was later followed by Fugagnoli (1998), who counted 5-6 chambers per coil in material from the Southern Alps. However, Hottinger's (1967) figures show 8-9 chambers per coil, and the size difference is here argued to derive from the different position of sections according to test's height (even though the test has fairly parallel sides in the later stage of growth). Larger equatorial sections have more chambers than smaller ones.

Geographic distribution and stratigraphic range: Sinemurian – Pliensbachian of High Atlas, Morocco; Sibillini Mountains, central Italy; Dorsales Range, Tunisia; Iberian Basin, Spain (BouDagher-Fadel & Bosence, 2007); Late Sinemurian of Southern Alps, northern Italy (Fugagnoli, 1998); Late Sinemurian of Algarve Basin, South Portugal (Azerêdo et al., 2003); Sinemurian – Early Pliensbachian of

Tripolitza platform, Greece (ZAMBETAKIS-LEKKAS et al., 1996). Latest Sinemurian to Early Pliensbachian according to BASSOULLET (1997).

Genus *Siphovalvulina* Septfontaine, 1988
(type species: *Siphovalvulina variabilis* Septfontaine, 1988)

Siphovalvulina gibraltarensis BouDagher-Fadel, Rose, Bosence & Lord, 2001
(Pl. 1, figs. 15-16)

p.p. 1998 *Siphovalvulina variabilis* Septfontaine, 1988 – FUGAGNOLI, p. 157, Pl. 8, fig. 8.
p.p. 1998 *Siphovalvulina variabilis* Septfontaine – FUGAGNOLI & LORIGA BROGLIO, p. 60, Fig. 9.2.
2001 *Siphovalvulina gibraltarensis* sp. nov. – BOUDAGHER-FADEL et al., p. 605, Pl. 1, figs. 6-11.
2007 *Siphovalvulina gibraltarensis* BouDagher-Fadel, Rose, Bosence & Lord 2001 – BOUDAGHER-FADEL & BOSENCE, p. 9, Pl. 2, figs. 1-2; Pl. 4, fig. 2; Pl. 6, figs. 3-5; Pl. 9, fig. 6; Pl. 11, figs. 1, 5.

Material: Thin sections 321, 328, 332, 335, 337, 424b, 429b, 533, 534, 535.

Description: Test is trochospirally coiled, with an apical angle 90-130°. The spire comprises up to 5 coils. The test is 0.18-0.44 mm high, 0.16-0.46 mm wide. The test wall is simple, microagglutinated. The umbilical opening is wide, continuing into a wide, twisted umbilical canal. Apertural faces of chambers are well rounded.

Remarks: The high apical angle is a distinctive mark of this species (see BOUDAGHER-FADEL et al., 2001).

Geographic distribution and stratigraphic range: Sinemurian of Gibraltar; Sinemurian – Early Pliensbachian of Betic Cordillera, Spain; Sinemurian of Iberian Range, Spain; Sinemurian – Pliensbachian of High Atlas, Morocco; Sinemurian of Dorsales Range, Tunisia; Sinemurian – Pliensbachian of Sibillini Mountains, central Italy; Sinemurian – Pliensachian of Evvia, Greece (BOUDAGHER-FADEL & BOSENCE, 2007); Early Jurassic of Southern Alps, northern Italy (FUGAGNOLI, 1998); Sinemurian – Toarcian of Karst Dinarides, Croatia (VELIĆ, 2007).

? *Siphovalvulina variabilis* Septfontaine, 1988
(Pl. 1, figs. 17-18; Pl. 2, figs. 1-2)

nom. nudum 1980 "*Siphovalvulina*" – SEPTFONTAINE, Pl. 2, fig. 10.
L 1988 *Siphovalvulina* n. gen. – SEPTFONTAINE, p. 244.
p.p. 1998 *Siphovalvulina variabilis* Septfontaine, 1988 – FUGAGNOLI, p. 157, Pl. 8, figs. 1-2, 4-5.
p.p. 1998 *Siphovalvulina variabilis* Septfontaine – FUGAGNOLI & LORIGA BROGLIO, p. 60, Fig. 9.1.
2001 *Siphovalvulina colomi* sp. nov. – BOUDAGHER-FADEL et al., p. 605, Pl. 1, figs. 1-4.
2003 *Siphovalvulina variabilis* Septfontaine, 1988 – AZERÊDO et al., Pl. 10, fig. 7.
2003 *Siphovalvulina* sp. – KABAL & TASLI, Pl. 4, figs. 9-10.
p.p. 2007 *Siphovalvulina colomi* BouDagher-Fadel, Rose, Bosence & Lord 2001 – BOUDAGHER-FADEL & BOSENCE, p. 8, Pl. 9, fig. 4; Pl. 10, fig. 1; Pl. 11, figs. 4-5.

Material: Thin sections 321, 322, 326, 329b, 333, 412, 418, 423, 428, 429a, ?335, 337, 513, 517, 523, 533, 535b, 536.

Description: The test is trochospiral, with an apical angle 45-75° and up to 6 coils. Three chambers are visible in basal section of the last coil. The total test height is 0.25-0.77 mm, the width 0.20-0.51 mm. The twisted umbilical canal is clearly visible, indented on the inner side of the chambers. The chamber lumen is rounded to reniform. The wall is simple, microagglutinated.

Remarks: The specimens ascribed here to *S. variabilis* differ from *S. gibraltarensis* in having a narrower apical angle. The holotype of *S. variabilis* was figured by SEPTFONTAINE (1980) and described in SEPTFONTAINE (1988) as having a very variable morphology. At the time, *Siphovalvulina* was considered a monospecific genus, ranging from Hettangian to the Cretaceous. BOUDAGHER-FADEL et al. (2001) later described *Siphovalvulina colomi* from Lower Jurassic strata. The later author considered *S. colomi* and *S. gibraltarensis* the only Early Jurassic species of this genus. *Siphovalvulina colomi* in their opinion differs from *S. variabilis* in having a more compact test, less visible sutures and smoothly convex septa, which are not highly arched and oblique to the main axis. Some of the specimens figured by the same author (e.g. BOUDAGHER-FADEL & BOSENCE, 2007, Pl. 9, fig. 4; Pl. 11, fig. 4), including the holotype of *S. colomi* (BOUDAGHER-FADEL et al., 2001, Pl. 1, fig. 1) in my opinion fail to meet this criteria. I thus consider *S. colomi* a probable junior synonym of *S. variabilis*.

Geographic distribution and stratigraphic range: Early Jurassic specimens derive from: Sinemurian of Gibraltar; Sinemurian – Early Pliensbachian of betic Cordillera, Spain; Sinemurian of Dorsales Range, Tunisia; Sinemurian – Pliensbachian of Sibillini Mountains, central Italy; Sinemurian – Pliensbachian of Evvia, Greece (BOUDAGHER-FADEL et al., 2001); Early Jurassic of Southern Alps, northern Italy (FUGAGNOLI, 1998); Late Sinemurian of Algarve, Portugal (AZERÊDO et al., 2003); Pliensbachian – Toarcian? of Central Taurides, Turkey (KABAL & TASLI, 2003).

SEPTFONTAINE (1988) considered *S. variabilis* as Hettangian to Early (also Late?) Cretaceous in age. According to VELIĆ (2007), this species in the Karst Dinarides first appears at the end of the Hettangian.

? *Siphovalvulina* sp. A
(Pl. 2, fig. 4)

p.p. 2007 *Siphovalvulina colomi* BouDagher-Fadel, Rose, Bosence & Lord 2001 – BouDagher-Fadel & Bosence, p. 8, Pl. 6, fig. 6; Pl. 9, fig. 5.

Material: Thin sections 413, 536.

Description: A high trochospiral test with remiform to rounded trapezoidal chambers in 6 coils measures 0.68 mm in height and 0.36 mm in width. The apical angle is 45°. The siphonal canal is relatively narrow.

Remarks: These specimens differ from *S. variabilis* in more flattened chambers. More specimens, however, would be needed to confirm the difference. The specimens resemble part of the material figured by BouDagher-Fadel and Bosence (2007) as *Siphovalvulina colomi.*

Geographic distribution and stratigraphic range: Similar specimens have been figured from Sinemurian – Pliensbachian of Sibillini Mountains, Italy and from Sinemurian of Dorsales Range, Tunisia by BouDagher-Fadel and Bosence (2007).

Superfamily Lituoloidea de Blainville, 1827
Family Hauraniidae Septfontaine, 1988
Subfamily Amijiellinae Septfontaine, 1988
Genus *Amijiella* Loeblich & Tappan, 1985
(type species: *Haurania amiji* Henson, 1948)

Amijiella amiji (Henson, 1948)
(Pl. 2, figs. 6-10)

1948 *Haurania amiji* – Henson, p. 12, Pl. 15, figs. 5-10.
1966 Lituolidés – Radoičić, Pl. 23, fig. 1 pars.
1967 *Haurania amiji* Henson 1948 – Hottinger, p. 52, Pl. 8, figs. 1-6, 20-21; Fig. 25.
1977 *Haurania amiji* Henson – Velić, Pl. 2, figs. 6-8.
1981 *Haurania amiji* Henson 1948 – Baloge, p. 130, Fig. 2, Pl. 1, figs. 1-7; Pl. 2, figs. 1-3, 5-7, 11-12.
1994 *Amijiella amiji* (Henson) – Chiocchini et al., Pl. 2, fig. 14; Pl. 27, figs. 2-4.
1997 *Amijiella amiji* (Henson) – Banner et al., Pl. 1, fig. 8;
1998 *Amijiella amiji* (Henson, 1948) – Fugagnoli, p. 161, Pl. 12, figs. 1-9.
1998 *Amijiella amiji* (Henson), 1948 – Fugagnoli & Loriga Broglio, p. 53, Figs. 7.5, 6.
1999 *Amijiella* sp. – Bassoullet et al., p. 217, Pl. 4, fig. 4.
2000 *Amijiella amiji* (Henson) 1948 – Perelis Grossowicz et al., Pl. 1, fig. 2.
2003 *Amijiella amiji* (Henson) – Kabal & Tasli, Pl. 4, figs. 1-6.
2005 *Amijiella amiji* (Henson) – Cai et al., Pl. 4, figs. 1-7
2007 *Amijiella amiji* (Henson 1948) – BouDagher-Fadel & Bosence, p. 7, Pl. 1, fig. 5; Pl. 3, fig. 5, Pl. 7, fig. 1; Pl. 8, fig. 1.
2008 *Amijiella amiji* (Henson) – Al-Saad, Pl. 2, fig. 1.

Material: Thin sections 322, ?325, ?330, 413, 417, 424b, 513, 523, 529, 535. Two specimens of megalospheric generation and ten microspheric tests, all in longitudinal sections. Two transverse sections.

Description: The test is elongated, with pronounced dimorphism, expressed in the development of the planispiral part, followed by chambers in uniserial rectilinear or curvilinear arrangement. The aperture is not clearly visible; it could be multiple or circular. In some specimens, a single central opening is observed. The uniserial part of the test is circular in cross-section. Thick radial beams of the exoskeleton are pronounced, reaching far towards the centre of chamber. The wall is of variable thickness (0.04-0.06 mm).

Type 1: The test is uniserial throughout, or perhaps with a very small coiled initial part, which is not discernible. The number of chambers in uniserial part ranges from 4 to 8. They are fairly constant in height (lumen around 0.04-0.06 mm) and width, resulting in a test with roughly parallel sides, 0.65-1.00 mm long and 0.32-0.39 mm wide.

Type 2: The initial part of the test is planispiral, 0.19-0.34 mm in diameter. The number of coils is not clearly visible (2?). The coiled part is followed by 4 uniserial chambers in total length of 0.48 mm. Individual chambers are 0.05-0.06 mm high (lumen), maintaining approximately constant width.

Remarks: A reconstruction of *A. amiji* is given by Baloge (1981). Radial partially developed beams (incipient septula?) are clearly visible in sections perpendicular to the axis of growth. Rafters are also depictured. BouDagher-Fadel and Bosence (2007) interpreted aperture as multiple, later reduced to a single central opening. Loeblich and Tappan (1987) and Septfontaine (1988) write about cribrate aperture. Smaller (1.2 mm) specimens with planispiral initial part were originally interpreted as microspheric tests, and the specimens lacking planispiral part as megalospheric. Hottinger (1967), however, could not confirm this. Fugagnoli (1998) on the basis of the literature survey allowed for a possibility that both generations could possess a planispiral part.

Geographic distribution and stratigraphic range: Middle Liassic of Dinarides, Montenegro (Radoičić, 1966); Middle Liassic of Central Apennines, central Italy (Chiocchini et al., 1994); latest Hettangian to end of Pliensbachian of Dinarides, Croatia (Velić, 1977); Sinemurian – Early Pliensbachian of Betic Cordillera, Spain; Sinemurian – Pliensbachian of High Atlas, Morocco (BouDagher-Fadel & Bosence, 2007); Late Sinemurian - Pliensbachian of Southern Alps, northern Italy (Fugagnoli, 1998; Fugagnoli & Loriga Broglio, 1998); Late Sinemurian of Poitou, France (Baloge, 1981); Pliensbachian of Middle Atlas, Morocco (Bassoulet et al., 1999); Middle Liassic and Toarcian of southern Tibet, China (Cai et al., 2005); Late Sinemurian to Late Pliensbachian-Toarcian(?) of Central Taurides, Turkey (Kabal & Tasli, 2003); Toarcian of Middle East (Banner et al., 1997); Late Sinemurian to Bathonian of Israel (Perelis Grossowicz et al., 2000); Early Bajocian of Quatar (Al-Saad, 2008). According to Bassoullet (1997) and Banner et al. (1997) the species ranges from Late Sinemurian to end of Bathonian.

Family Mesoendothyridae Voloshinova, 1958
Subfamily Mesoendothyrinae Voloshinova, 1958
?Genus *Mesoendothyra* Dain, in Bykova et al., 1958
(type species: *Mesoendothyra izumijana* Dain, in Bykova et al., 1958)

Mesoendothyra? sp. A
(Pl. 2, figs. 11-13)

1998 *Mesoendothyra* sp. – Fugagnoli, p. 155, Pl. 23, figs. 4-5.
2000 "*Mesoendothyra*" sp. – Perelis Grossowicz et al., Pl. 1, fig. 7.
2007 *Mesoendothyra* sp. – Velić, Pl. 2, figs. 1-4.

Material: Thin sections 515, 517, 519, 526, 534, 535b, 536.

Description: The test is mostly circular in equatorial section; planispiral coils are rarely followed by the uniserial part of the test. The outer test wall is microagglutinated. A keriothecal structure is suggested, but not clearly visible. The wall is 0.02-0.03 mm thick. Septa are approximately of the same thickness, situated slightly oblique. The aperture is simple basal, in the uncoiled part multiple.

Microspheric (?) test: The proloculus is not distinguishable. The planispiral part consists of (2?) 2.5-3 coils. Counting from the aperture backwards, the last coil comprises 7-10 chambers. The uniserial part is present in only one of the specimens, consisting of 4 chambers. Chambers are approximately as high as they are wide. The planispiral part of the test measures 0.22-0.43 mm in diameter. The total test length of the test with the uniserial part is 0.69 mm. The higher number of planispiral coils suggests these tests belong to the microsphaeric generation.

Megalospheric test: The proloculus is circular, 0.03-0.04 mm in diameter. It is followed by 1.5-2.5 planispiral coils, with 9 chambers in total (6 are counted in the last whorl). The entire spiral part is 0.26-0.39 mm in diameter.

Remarks: The shape of the test and the test size correspond to *Mesoendothyra* sp. described by Fugagnoli (1998), Perelis Grossowicz et al. (2000), and Velić (2007). The wall was determined by Fugagnoli (1998) as simple, without exoskeletal structure. If this is the case, then it is appropriate to place this species into genus *Mesoendothyra* (although the stratigraphic gap between this and later species of this genus is not considered). However, the simple structure may be the product of diagenetic alteration of keriothecal wall, and the species should be assigned into genus *Bosniella*. The specimens presented here do not offer reliable evidence for this. The uniserial part in some specimens figured by Velić (2007) bears much flatter chambers.

Geographic distribution and stratigraphic range: Early Jurassic of Southern Alps, northern Italy (Fugagnoli, 1998); Sinemurian – Pliensbachian of Karst Dinarides of Croatia (Velić, 2007); Toarcian-Early Bajocian (undiffirentiated) of Israel (Perelis Grossowicz et al., 2000).

Subfamily Orbitopsellinae Höttinger & Caus, 1982
Genus *Lituosepta* Cati, 1959
(type species: *Lituosepta recoarensis* Cati, 1959)

Lituosepta sp. var. A
(Pl. 2, figs. 14-16)

Cf. 1959 *Lituosepta recoarensis* n. gen. n. sp. – Cati, p. 104, Pl. 1, figs. 1-14, Fig. 1.
Cf. 1962 *Lituosepta recoarensis* Cati – Sartoni & Crescenti, p. 274, Pl. 13, fig. 2; Pl. 47, fig. 7.
pars 1977 *Labyrinthina recoarensis* (Cati) – Velić, Pl. 2, figs. 3, 5 [non Pl. 2, figs. 1, 2, 4].
pars 1994 *Lituosepta recoarensis* Cati – Chiocchini et al., Pl. 2, fig. 7 [? Pl. 2, fig. 15].
1998 *Lituosepta recoarensis* – Fugagnoli, p. 150-152, Pl. 5, figs. 1-8.
2000 *Planisepta compressa* (Hottinger) 1967 – Perelis Grossowicz et al., Pl. 1, fig. 4.
2003 *Lituosepta recoarensis* Cati, 1959 – Azêredo et al., Pl. 10, figs. 1, 2, 9.
pars 2003 *Lituosepta recoarensis* Cati – Kabal & Tasli, Pl. 2, figs. 1-3, 5-7 (non Pl. 2, fig. 4).
2007 *Lituosepta recoarensis* Cati 1959 – BouDagher-Fadel & Bosence, p. 7, Pl. 1, fig. 3; Pl. 2, fig. 3.
2007 *Lituosepta compressa* (Höttinger 1967) [sic]– BouDagher-Fadel & Bosence, p. 7, Pl. 1, fig. 6; Pl. 3, figs. 2, 4.
2007 *Lituosepta recoarensis* Cati – Velić, Pl. 2, figs. 5-8.

Material: Thin sections 325, 328, 333, 422. Megalospheric tests.

Description: The total length of the test is 0.46-1.00 mm. A simple megalospheric proloculus measures 0.08-0.09 mm in diameter (the exception is specimen from thin section 333 with diameter of 0.07 mm). A planispiral part in 1.5 coils follows. Six to nine chambers are visible in the last coil, whereas the chambers are poorly visible in the initial part of the spire. The total diameter of the coiled part is 0.28-0.42 mm. In most of the specimens a uniserial part consisting of up to 12 chambers follows. Chambers are flat, 0.04-0.05 mm high (lumen) and separated by septa 0.03-0.05 mm thick (never thicker than the chamber lumen). Scattered endoskeletal pillars are visible crossing the chamber lumen. The wall appears undifferentiated, microagglutinated. The aperture is multiple in the uncoiled part, not visible in the planispiral one.

Remarks: The specimens figured herein correspond best to *Lituosepta recoarensis*, originally described by Cati (1959) from the Lower Jurassic of Southern Alps. Hottinger (1967) later refigured some of Cati's (1959) specimens, adding some new specimens from High Atlas of Morocco, as well as a wealth of specimens, which he attributed to a new species, *Lituosepta compressa*. According to Hottinger (1967), the new species differs from *L. recoarensis* in having smaller test, a more pronounced flattening, a better developed pillars in the endoskeleton, a tighter coiling and a smaller proloculus in megalospheric forms (0.06-0.08 mm compared to 0.08-0.10 for *L. recoarensis*). In his opinion, transverse sections of *L. recoarensis* in Cati (1959) possibly belong to *Haurania*. Both species of *Lituosepta* should thus be laterally compressed. In contrary to Hottinger, Septfontaine (1984) believed Cati was right about *L. recoarensis* having circular cross section, and he subsequently established a new genus, *Planisepta*, to comprise flattened ex *L. compressa* (Septfontaine, 1988). Furthermore, Septfontaine (1984) regarded specimens designated by Hottinger (1967) as *L. recoarensis* as belonging to *P. compressa*. Fugagnoli (1998) and Fugagnoli and Loriga Broglio (1998) later accepted Hottinger's (1967) interpretation, disregarding validity of genus *Planisepta*. Loeblich and Tappan (1987) considered *Lituosepta* as a junior synonym of *Labyrinthina* Weynschenk. According to Septfontaine (1988), the initial coiled stage is more pronounced in the latter (3 coils compared to 1.5 coild in *Lituosepta*), whereas BouDagher-Fadel (2008) mentiones also a fan-shaped flabelliform test and a canalicular wall in *Lituosepta*.

In my opinion, the distinction between the two species is not well established. The size difference proves to be irrelevant (see specimens in Fugagnoli, 1998, and BouDagher-Fadel & Bosence, 2007). In fact, the only useful quantitative parameter seems to be the size of the proloculus, but the latter overlap at 0.08 mm. Based on the material figured by Cati (1959) and Hottinger (1967), the difference may be in the tightness of coiling, i.e. the planispiral part of the megalospheric form opens after 1.5 coils in *L. recoarensis* and after 2 in *L. compressa*, and in the number of endoskeletal pillars, which are better developed (more numerous) in the latter species. It is also true, that Cati's microsphaeric specimen does not show a pronouncely fan-shaped uncoiled part. Thus, I agree with Septfontaine's opinion and regard Hottinger's specimens as belonging to *L. compressa* only. However, as the type material of *L. recoarensis* needs to be re-examined, I refrain from species designation. Regarding the genus name, I agree with Fugagnoli (1998) and Fugagnoli and Loriga Broglio (1998) that the degree of flattening is not a generic criterion. The name *Planisepta* is thus regarded as a junior synonym of *Lituosepta*, especially since there is no equivocal proof of the *L. recoarensis* cross section.

One of the specimens, figured by Chiocchini et al. (1994), does not show endoskeletal pillars. Its determination is thus considered doubtful.

Lituosepta differs from *Orbitopsella* Munier-Chalmas in having a simple megalospheric proloculus, and from *Haurania* Henson in a simple exoskeleton and in a laterally flattened test (Hottinger, 1967; Loeblich & Tappan, 1987).

Geographic distribution and stratigraphic range: Bassoullet (1997) regards *L. recoarensis* and *L. compressa* as stratigraphically very useful species, as the former is of Sinemurian and the latter of Pliensbachian age. However, due to taxonomic uncertainties regarding the distinction of both species, a careful re-examination of material is needed. The specimens from the synonymy list were collected in: middle Early Jurassic of Apennines, central Italy (Cati, 1959; Sartoni & Crescenti, 1962; Chiocchini et al., 1994); Late Sinemurian of Central Taurides, Turkey (Kabal & Tasli, 2003); Late Sinemurian of Algarve Basin, Portugal (Azerêdo et al., 2003); Late Sinemurian – Early Pliensbachian of Karst Dinarides (Velić, 2007); Pliensbachian of Israel (Perelis Grossowicz et al., 2000); Sinemurian – Early Pliensbachian of Betic Cordillera, Spain; Sinemurian – Pliensbachian of High Atlas, Morocco; Sinemurian – Pliensbachian of Evvia, Greece (BouDagher-Fadel & Bosence, 2007); and Pliensbachian of Southern Alps, northern Italy (Fugagnoli, 1998).

Lituosepta sp. var. B
(Pl. 2, fig. 18)

Cf. 1967 *Lituosepta compressa* n. sp. – Hottinger, p. 36-38, Pl. 4, figs. 1-13; Figs. 17-18.

Material: Thin sections 329, 329b. Microspheric test.

Description: A relatively small coiled (planispiral?) part of the test, 0.43 mm in diameter, is not clearly visible, so the number of coils (possibly 2) is poorly defined. In the outer part, however, more than 12 chambers can be counted, prior to the following uniserial part. In the latter, chambers, while retaining a constant height of 0.05 mm, become increasingly wider, producing a flaring test of total length of 2.07 mm. The uniserial part consists of 26 chambers. Septa and the outer test wall are 0.03 mm thick. Chamber lumen is crossed by numerous pillars. The wall is presumably simple in structure, microagglutinated. The aperture is multiple in the last part of the coiled and in the uniserial part at least.

Remarks: Tests of distinct fan shaped planispiral part are here described separately from the rest of the *Lituosepta* material, as they better correspond to Hottinger's (1967) specimens, which he regarded as belonging to *L. recoarensis*, but which, according to Septfontaine (1984), belong to *L. compressa* instead. Radoičić (1966; Pl. 144, fig. 2; Pl. 145, fig. 1) shows microspheric tests of supposedly *L. recoarensis* from middle Lower Jurassic of Karst Dinarides (Žumberak, Croatia), which have fewer chambers than specimens figured herein.

Genus *Orbitopsella* Munier-Chalmas, 1902
(type species: *Orbitolites praecursor* Gümbel, 1872)

?*Orbitopsella primaeva* Henson, 1948
(Pl. 2, fig. 18; Pl. 3, figs. 1-5)

*1948 *Coskinolinopsis primaevus* Henson – Henson, p. 27, Pl. 10, figs. 4-5.
1967 *Orbitopsella primaeva* (Henson) – Hottinger, p. 46, Pl. 4, figs. 17-18; Figs. 23k-s.
1998 *Orbitopsella primaeva* (Henson, 1948) – Fugagnoli, p. 147, Pl. 1, figs. 1-9; Pl. 2, figs. 1-10.
1998 *Orbitopsella primaeva* (Henson), 1948 – Fugagnoli & Loriga Broglio, p. 50, Figs. 6.1-5.
2000 *Orbitopsella primaeva* (Henson) – Perelis Grossowicz et al., Pl. 1, figs. 8, 9, 10.
2003 *Orbitopsella primaeva* (Henson) – Kabal & Tasli, Pl. 3, figs. 1-3.
2007 *Orbitopsella primaeva* (Henson 1948) – BouDagher-Fadel & Bosence, p. 6, Pl. 1, figs. 1, 2 , 4; Pl. 2, fig. 4.
?2007 *Haurania deserta* Henson, 1948 – BouDagher-Fadel & Bosence, Pl. 8, figs. 2-5.
2007 *Orbitopsella primaeva* (Henson) – Velić, Pl. 2, figs. 9-11; Pl. 3, figs. 1-4.

Material: Thin sections ?329b, 413, 418, 421, 424a, 424b, 513, 532, 533, 534, 535b.

Description: Dimorphism is strongly pronounced.

Megalospheric test: In equatorial view the test appears fan shaped, semicircular, whereas in axial view the test is strongly elongated with parallel sides. Protoconch is complex, though the wall separating the proloculus from the deuteroloculus is usually not preserved. The size of the protoconch (lumen) is 0.18-0.31 mm. A short planispiral part follows with up to 12 chambers, and in the last stage of growth numerous uniserially arranged strongly arched chambers. These maintain constant height while gradually becoming wider. The total diameter of the test amounts to 2.14-2.35 mm.

The outer wall and the septa are 0.03 mm thick. A notable difference among specimens is in the size of agglutinated grains: while some specimens have uniformly thick wall, in others incorporated grain size exceeds the basic wall thickness by as much as 6.4-times. The exoskeleton is simple, with poorly visible beams. The endoskeleton consists of widely spaced and few pillars. Four to five stolon planes are visible.

Microspheric test: The test is in »axial« section flat, with parallel sides, or with a gradually higher periphery, becoming biconcave. The total test diameter is 2.50-6.22 mm. The protoconch and the initial spiral part were not observed. The exoskeletal and endoskeletal features are as described above.

Remarks: Despite the large number of specimens attributed to *Orbitopsella* only a few were determined to the species level. The criteria used in distinguishing *O. primaeva* from *O. praecursor* (Gümbel) and *O. dubari* Hottinger are: protoconch size and the test size (both smaller in *O. primaeva*) in megalospheric tests, and fewer stolon planes and much microspheric smaller test for *O. primaeva* (see Hottinger, 1967). The number of spiral chambers could not be observed due to insuitable orientation of specimens. Compared to specimens in Hottinger (1967), the megalospheric specimens from the Krim area belong to A1 generation. The difference in coarseness of the wall is considered a phenotypic character (Fugagnoli, 1998).

Geographic distribution and stratigraphic range: Sinemurian – Early Pliensbachian of Betic Cordillera, Spain (BouDagher-Fadel & Bosence, 2007); Late Sinemurian – Early Pliensbachian of Southern Alps, northern Italy (Fugagnoli, 1998; Fugagnoli & Loriga Broglio, 1998); Late Sinemurian – Early Pliensbachian of Karst Dinarides, Croatia (Velić, 2007); Pliensbachian of High Atlas, Morocco (Hottinger, 1967); Early Pliensbachian of Israel (Perelis Grossowicz et al., 2000); Early Pliensbachian of Central Taurides, Turkey (Kabal & Tasli, 2003). Latest Sinemurian and Early Pliensbachian according to Bassoullet (1997).

?*Orbitopsella praecursor* (Gümbel, 1872)
(Pl. 3, figs. 6-8)

1962 *Orbitopsella praecursor* (Gümbel) – Sartoni & Crescenti, p. 274, Pl. 47, fig. 1.
1966 *Orbitopsella praecursor* (Gümbel) – Radoičić, Pl. 20, figs. 1-2; Pl. 72, figs. 1-2.
1967 *Orbitopsella praecursor* (Gumbel) 1872 – Hottinger, p. 40, Pl. 5, figs. 1-12; Fig. 20.
1977 *Orbitopsella praecursor* (Guembel) – Velić, Pl. 1, figs. 1-5
1987 *Orbitopsella praecursor* (Gümbel) - Ulcigrai et al., Figs. 5-7.
1994 *Orbitopsella praecursor* Gümbel – Chiocchini et al., Pl. 2, figs. 12-13; Pl. 27, fig. 10.
1998 *Orbitopsella praecursor* (Gümbel), 1872 – Fugagnoli & Loriga Broglio, p. 52, Figs. 6.6-9.
1998 *Orbitopsella praecursor* (Gümbel, 1872) – Fugagnoli, p. 148, Pl. 3, figs. 1-9.
1999 *Orbitopsella praecursor* (Gümbel), 1872 – Bassoullet et al., p. 224, Pl. 1, figs. 1-8.
2003 *Orbitopsella praecursor* (Gümbel) – Kabal & Tasli, Pl. 3, figs. 4-11.
2005 *Orbitopsella praecursor* (Gümbel) – Cai et al., Pl. 3, figs. 17-25.

2007 *Orbitopsella praecursor* (Gümbel 1872) – BouDagher-Fadel & Bosence, p. 7, Pl. 3, fig. 3.
2007 *Orbitopsella praecursor* (Gümbel) – Velić, Pl. 3, figs. 5-6; Pl. 4, figs. 1-4.

Material: Thin sections 427, 528, 529, 532, 535b.

Description: Few specimens are in appropriate section to allow for the recognition of this species. The endoskeletal pillars are few and widely spaced. The wall structure is not visible. The wall thickness is around 0.04 mm. The protoconch of megalospheric forms measures 0.44 mm in diameter and the total test diameter is 1.46-1.75 mm. The initial part of the test is often wider than the rest of the test. The microspheric form measures 10.71 mm in diameter. The initial spiral part consists of 14 chambers.

Remarks: According to Hottinger (1967), Fugagnoli (1998) and Bassoullet et al. (1999), *O. circumvolata* probably represents a junior synoynm of *O. praecursor*. Hottinger (1967) retained it as a special morphotype.

Geographic distribution and stratigraphic age: Middle Early Jurassic of Apennines, central Italy (Sartoni & Crescenti, 1962; Chiocchini et al., 1994); middle Early Jurassic of southern Tibet, China (Cai et al., 2005); Sinemurian – Early Pliensbachian of Betic Cordillera, Spain; Sinemurian – Pliensbachian of High Atlas, Morocco (BouDagher-Fadel & Bosence, 2007); Late Sinemurian – Pliensbachian of Southern Alps, northern Italy (Ulcigrai et al., 1987; Fugagnoli, 1998; Fugagnoli & Loriga Broglio, 1998); Pliensbachian of Middle Atlas, Morocco (Bassoullet et al., 1999); Early Pliensbachian of Central Taurides, Turkey (Kabal & Tasli, 2003); Early to Middle Pliensbachian of Karst Dinarides, Croatia (Velić, 2007). Middle part of Pliensbachian according to Bassoullet (1997).

Suborder Loftusiina Kaminski & Mikhalevich, in Kaminski, 2004
Superfamily Loftusiacea Brady, 1884
Family Everticyclamminidae Septfontaine, 1988
Genus *Everticyclammina* Redmond, 1964
(type species: *Everticyclammina hensoni* Redmond, 1964)

Everticyclammina praevirguliana Fugagnoli, 2000
(Pl. 3, figs. 9-15)

* 2000 *Everticyclammina praevirguliana* n. sp. – Fugagnoli, p. 127, Pl. 1, figs. 1-9; Pl. 2, figs. 1-10; Pl. 3, figs. 1-8.
2001 *Everticyclammina praevirguliana* Fugagnoli, 2000 – BouDagher-Fadel et al., p. 611, Pl. 2, fig. 12.
2007 *Evertyciclammina praevirguliana* Fugagnoli 2000 – BouDagher-Fadel & Bosence, p. 3, Pl. 3, fig. 6; Pl. 4, figs. 1, 5; Pl. 5, fig. 3; Pl. 9, figs. 2-3.
? 2011 *Everticyclammina praevirguliana* Fugagnoli, 2000 – Schlagintweit & Velić, p. 96, Figs. 15a-d.

Material: Thin sections 328, 329, 329B, 333, 337, 413, 429B, 510, 513, 515, 517, 522, 524, 526, 530, 533, 535, 535b. Specimens of megalo- and microspheric generation. One specimen in axial section, 10 specimens in equatorial section.

Description: Fairly large specimens have thick, finely agglutinated alveolar wall with widely spaced alveolae. Both generations (micro- and megalospheric) usually comprise well developed planispirally coiled initial part, followed by few uniserially arranged chambers. Chambers of the coiled part appear remiform, whereas chambers are triangular in shape in the uncoiled part of the test, tapering towards distal end. Aperture is a simple, large, centrally situated opening. Septa are of the same thickness (0.03 to 0.10 mm) as the outer test wall. The thickness of both, however, varies largely even in the same specimen.

Microspheric test: The coiled part of the test comprises 2-2.5 coils; the first is very small, with an indistinguishable number of chambers. The second coil consists of 3-4 chambers. The diameter of the coiled part is 0.16-0.41 mm. The rectilinear or curvilinear uniserial part, 0.5-0.67 mm long, consists of 2-5 chambers. The width of these in some sections appears equal to diameter of the initial coiled part. The maximum height of chambers (lumen, measured to the top of aperture, i.e. with septa thickness included) in the uncoiled part is 0.11-0.23 mm. A proloculus is too small to be measured.

Megalospheric test: The initial part measures 0.26-0.48 mm in diameter and has 2 coils with 3 (?) and 5-7 chambers, respectively. The uncoiled part, 0.35-0.75 mm long, consists of 3-4 chambers, which are up to 0.11-0.28 mm high and 0.17-0.42 mm wide. A simple spheric proloculus measures 0.03-0.11 mm in diameter. In axial section, the initial coiled part appears biconcave, with chambers of the last whorl by 1/2 wider than the first whorl. The periphery is rounded, yet with box-like outline.

Remarks: According to BouDagher-Fadel et al. (2001) and BouDagher-Fadel and Bosence (2007), *E. praevirguliana* represents the only species of *Everticyclammina* from the Early Jurassic. Based on the original diagnosis of the species (Fugagnoli, 2000), it seems difficult to distinguish *E. praevirguliana* from other species of this genus. Fugagnoli (2000) mentiones a smaller test size and a more uniform chamber growth in *E. praevirguliana* in comparisson to *Everticyclammina virguliana* (Koechlin), the next species in phylogeny. The biumbilical axial section and the triangular, tapering chambers (compared to rounded chambers of *E. virguliana*) of the uniserial part of the test might provide a better distinguishing character, but the range of chamber shape from triangular to semi-circular is present also in the original material of FUGAGNOLI (2000). The two species may thus be synonyms, but a further discussion is needed. SCHLAGINTWEIT and VELIĆ (2011) described specimens of the genus *Everticyclammina* from Aalenian of the Dinarides in Croatia as *E. praevirguliana*, extending the stratigraphic range of this species into younger strata. Due to the similarity between the two species, their species might also be determined as *E. virguliana*. Alternatively, the two species may have coexisted for some time.

Geographic distribution and stratigraphic range: Latest Hettangian to end of Toarcian of Karst Dinarides, Croatia (VELIĆ, 2007); Sinemurian of Gibraltar (BOUDAGHER-FADEL et al., 2001; BOUDAGHER-Fadel & BOSENCE, 2007); Late Sinemurian-Pliensbachian of Southern Alps, northern Italy (FUGAGNOLI, 2000); Sinemurian – Early Pliensbachian of Betic Cordillera, Spain; Sinemurian of High Atlas, Morocco; Sinemurian – Pliensbachian of Dorsales Range, Tunisia; Sinemurian – Pliensbachian of Sibillini Mountains, central Italy; Sinemurian – Pliensbachian of Evvia, Grece (BOUDAGHER-FADEL & BOSENCE, 2007).

Suborder Miliolina Delage & Hérouard, 1896
Superfamily Cornuspiracea Schultze, 1854
Family Cornuspiridae Schultze, 1854
Subfamily Meandrospirinae Saidova, 1981
Genus *Meandrovoluta* Fugagnoli & Rettori, 2003
(type species: *Meandrovoluta asiagoensis* Fugagnoli & Rettori, 2003)

Meandrovoluta asiagoensis Fugagnoli & Rettori, 2003
(Pl. 3, figs. 16-18)

1966 *Glomospira* sp. – RADOIČIĆ, Pl. 92, fig. 2; Pl. 111, fig. 2; Pl. 124, fig. 2 pars; Pl. 125, figs. 1-2 pars.
1994 *Glomospira* sp. – CHIOCCHINI et al., Pl. 2, figs. 19, 21; Pl. 27, fig. 7.
p.p. 1998 *Glomospira* sp. Rzehak, 1885 – FUGAGNOLI & LORIGA BROGLIO, p. 66-68, Fig. 9.12 [non Figs. 9.10-9.11].
1999 *Meandrospiranella* sp. ? – BASSOULLET et al., p. 228, Pl. 4, figs. 12-13.
1999 *Hoyenella* sp. ? – BASSOULLET et al., p. 228, Pl. 4, figs. 14-17.
*2003 *Meandrovoluta asiagoensis* Fugagnoli & Rettori gen. et sp. nov. – FUGAGNOLI et al., p. 45, Pl. 1, figs. 1-12; Pl. 2, figs. 1-16.
?2005 *Glomispira tingriensis* sp. nov. – CAI et al., p. 45, Pl. 1, figs. 27-32.

Material: Thin sections 321, 322, 324, 325, 326, 327, 328, 329, 329B, 330, 331, 333, 335, 337, 412, 413, 415, 417, 418, 419, 420, 421, 423, 424a, 424b, 425, 427, 428, 429a, 429b, 429c, 512, 515, 517, 518, 519, 522, 523, 524, 525, 526, 528, 529, 531, 533, 534, 535, 535b, 536.

Description: Specimens are morphologically very variable. A globular proloculus is followed by an undivided second chamber, which coils mostly in irregular fashion, or at some stage remaining close to one plane, producing roughly globular or disc-like test. The test wall dark and dense, sometimes brownish in appearance. The size of the measured specimens (a few of the total number) is 0.17-0.36 mm. The lumen hight in the outermost preserved deuteroloculus is 0.03-0.05 mm. Up to 11 coils were counted on either side of the proloculus. The microspheric and megalospheric generations are currently not distinguished due to the lack of centered sections.

Remarks: *Meandrovoluta* is among the most common benthic foraminifera in Early Jurassic carbonates, often described as *Glomospira* sp. The distinction from the latter, however, is in its wall structure, which is porcelaneous in *Meandrovoluta* and finely agglutinated in *Glomospira* Rzehak (FUGAGNOLI et al., 2003). Its morphological variability, its presence in a variety of facies and assemblages, and a locally high abundance in low-diversity assemblages (personal observation in resediments of Perbla Formation, depositiory of B. Rožič, University of Ljubljana) suggest it is an opportunistic species (see DODD & STANTON, 1990, p. 288). A somewhat similar Triassic genus *Hoyenella* Rettori has an initial mioliod coiling and a regularly developed last planispiral stage (RETTORI, 1994, 1995).

Finally, CAI et al. (2005) described three new species from the Middle? Jurassic of Tibet: *Glomospira wolongensis*, *Glomospira tingriensis* and *Glomospirella minuscula*. The latter has a pronounced planispiral stage, and *G. wolongensis* appears smaller and with fewer coils, but *G. tingriensis* may prove to be a junior synonym of *M. asiagoensis*.

Geographic distribution and stratigraphic range: The specimens cited in the synonymy list belong to Sinemurian – Toarcian of Southern Alps, northern Italy (FUGAGNOLI, 1998; FUGAGNOLI et al., 2003); Sinemurian – Toarcian of Karst Dinarides, Croatia (VELIĆ, 2007), and Bosnia (RADOIČIĆ, 1966); middle Early Jurassic of Apennines, central Italy (CHIOCCHINI et al., 1994), Pliensbachian of Middle Atlas, Morocco (BASSOULLET et al., 1999).

Suborder Involutinina Hohenegger & Piller, 1977
Superfamily Involutinoidea Bütschi, 1880
Family Involutinidae Bütschli, 1880
Subfamily Involutininae Bütschli, 1880
Genus *Involutina* Terquem, 1862
(type species: *Nummulites liassicus* Jones, in Brodie, 1853)

"*Involutina farinacciae* Brönnimann & Koehn-Zaninetti, 1969"
(Pl. 4, figs. 1-3)

*1969 *Involutina farinacciae*, n. sp. – BRÖNNIMANN & KOEHN-ZANINETTI, p. 76, Figs. 1c, 2a-g.
pars 2011 *Involutina farinacciae* Bronnimann & Koehn-Zaninetti – RADOIČIĆ & JOVANOVIĆ, Pl. 1, figs. 3-5; Pl. 2, figs. 1-4; Pl. 3, figs. 1-6; Pl. 4, figs. 1-6, 8-9.

Material: Thin sections 324, 517, 519, 522, 523, 526, 528, 530, 533, 534, 535, 535b.

Description: Tests are small, recrystallized into spar (originally aragonitic), mostly overgrown by ooid or micritic coatings. All specimens identified with confidence are in axial section. A planispiral coil is visible. Only lumen of a few last coils is visible; the total number of coils is probably around 5. The umbilical part is strongly thickened on both sides, being biconvex and bearing numerous papillae. The last 1-2 coils are evolute. The test diameter is 0.15-0.27 mm.

Remarks: Based on the original description, "*Involutina farinacciae*" differs from other species of this genus by its small size and the shape of the chamber lumen. However, Rigaud et al. (in press) say there is no reliable criterion to separate "*I. farinacciae*" from *Involutina liassica* (Jones), due to the large variability of the species.

Geographic distribution and stratigraphic range: The type material derives from early Early Jurassic of Monte Lacerone, Italy (Brönnimann & Koehn-Zaninetti, 1969). Radoičić and Jovanović (2011) add numerous localities in Inner Dinarides, Karst Dinarides, Budva Basin and from Avroman Range area in Iraq, advocating "*I. farinacciae*" as a marker of middle Early Jurassic. The Podpeč quarry is among the listed localities.

Family Trocholinidae Kristan-Tollmann, 1963, emend. Rigaud et al., 2013
? Subfamily Lamelliconinae Zaninetti et al., 1987, emend. Rigaud et al., 2013
? Genus *Coronipora* Kristan, 1958
(type species: *Coronella austriaca* Kristan, 1957)

? *Coronipora* sp.
(Pl. 4, figs. 4?-5?, 6-17)

?Cf. 1957 *Semiinvoluta clari* nov. gen. nov. spec. – Kristan, p. 276, Pl. 22, figs. 11a-c, 12-15, 16a-c, 17.
Cf. 1957 *Coronella austriaca* nov. gen. nov. spec. – Kristan, p. 281, Pl. 23, figs. 10a-c, 11-13.
Cf. 1966 *Lasiodiscus* (?) *etruscus* n. sp. – Pirini, p. 91, Pl. 1, figs. 1-3
Cf. 1966 *Lasiodiscus* (?) sp. – Pirini, p. 92, Pl. 1, figs. 4-9.
?Cf. 1986 *Semiinvoluta clari* Kristan – Kristan-Tollmann, Fig. 1.6.
Cf. 1986 *Coronipora austriaca* (Kristan) – Kristan-Tollmann, Fig. 1.7-1.8.
Cf. 1975 *Semiinvoluta* sp. 1 (cf. *S. clari* Kristan) – Gušić, p. 30-31, Pl. 10, figs. 1-10; Pl. 11, figs. 8?-9?, 11?-12?.
Cf. 1975 *Semiinvoluta* sp. 3 – Gušić, p. 31, Pl. 11, figs. 4-7, ?10.
Cf. 1975 *Semiinvoluta* sp. 4 – Gušić, p. 31, Pl. 10, fig. 12.
Cf. 1975 Genus cf. *Coronipora* Kristan – Gušić, p. 33, Pl. 12, figs. 1-7, ?8; Pl. 13, figs. 1?-8?.
Cf. 1978 *Semiinvoluta* ? sp. – Piller, p. 88, Pl. 21, figs. 6-8.
Cf. 1987a *Coronipora etrusca* (Pirini, 1966) – Blau, p. 503, Pl. 4, figs. 2-6.
Cf. 1987a *Coronipora deminuta* n. sp. – Blau, p. 504, Pl. 4, figs. 7-9.
Cf. 1987b *Coronipora etrusca* (Pirini, 1966) – Blau, p. 9, Pl. 5, figs. 1-9.
Cf. 1987b *Coronipora gusici* n. sp. – Blau, p. 9, Pl. 3, figs. 10-13.
Cf. 1987b *Coronipora* sp. 1 cf. *austriaca* (Kristan, 1957) – Blau, p. 10, Pl. 4, figs. 8-11; Fig. 1e.
Cf. 1987b *Semiinvoluta violae* n. sp. – Blau, p. 10, Pl. 2, figs. 1-8.
Cf. 1991 *Coronipora* sp. 1 cf. *austriaca* (Kristan 1957) – Blau & Haas, p. 18, Figs. 7a-e.
2013 *Coronipora* Kristan – Rigaud et al., Figs. 6.2-6.4.

Material: Thin sections 325, 517, 522, 525, 526, 528, 534.

Description: The test is in low trochospiral, consisting of circular proloculus (0.03 mm in diameter) and undivided second chamber coiling in 4-6 coils (in one specimen 7 coils or more are visible). Calcareous material is added (?) from the outer coil towards umbilicus, leaving a shallow umbilical depression. In tangential or transverse sections, the lower side thus appears flat and completely filled, whereas a depression is seen in the axial plane. The upper side of the test is more or less convex, without secondary thickening. The chamber lumen is open towards the spiral (upper) side through wide perforations (canals?). The total test diameter is 0.24-0.40 mm (mostly around 0.31 mm), and the test height 0.08-0.17 mm (mostly 0.12 mm).

The wall is recrystallized into spar, originally aragonitic.

Remarks: The determination of this species is problematic at the genus and species level.

Kristan (1957) introduced two new genera: *Semiinvoluta* and *Coronella*. *Semiinvoluta* was described as planispiral, evolute and with sutural canals on one side and coated with secondary material on the other side. Its type species, *S. clari* Kristan, has diameter of 0.62 mm and 5-9 coils. Some of the figures draw by hand, show a very low trochospiral coil. The description of *Coronella* is practically the same as of *Semiinvoluta*, except that the test is evolute on the coated side also. The type species, *C. austriaca*, measures 0.93 mm in diameter has 5 coils. Later, Kristan (1958) substituted *Coronella* with *Coronipora* Kristan.

Gušić (1975) later changed the orientation of *Semiinvoluta* and reminded of the lack of appropriate comparative material for this "aberrant" group of involutinids. He emphasised that the type material was shown by hand-drawings only. His specimens were thus left in open nomenclature and species distinguished on the basis of different contour of the test, and the thickness of calcite deposits.

PILLER (1978) defined *Coronipora* as having one evolute side and the other coved by lamellae; the coiling is plani- to trochospiral. He hinted at the synonymy with *Planispirillina* Bermudez, but due to the lack of observation of the lamination in the latter, left both species valid. The distinction between *Coronipora* and *Semiinvoluta* was likevise questioned.

RIGAUD et al. (2013) greatly revised the Trocholinidae family. The genus *Coronipora* was redefined as having ridge-like lamellae and large perforations or short canals on the spiral side, and interfingering lamellae on the umbilical side, while *Semiinvoluta* possesses papillae on the umbilical side, shortened lamellae on the apical side and a depressed apical thickening. According to RIGAUD et al. (2013), "*Coronipora*" *serraforma* Senowbari-Daryan et al. is a junior synonym of *S. clari*.

According to the emendation of *Coronipora* and *Semiinvoluta* (RIGAUD et al., 2013), the specimens figured herein should belong to *Coronipora*, as no apical lamellae are visible. This distinction, however, is not obvious in the type material figured by KRISTAN (1957), and I consider this interpretation doubtful.

The species determination is likewise tentative. Considering a wide variety in size, *Coronipora austriaca* (Kristan), *Semiinvoluta clari* Kristan and *Coronipora etrusca* (Pirini) are likely candidates. The distinction from similar species is mostly lacking in the first description of these species, and the thorough revision seems necessary.

Geographic distribution and stratigraphic range: Poorly defined due to the unclarity of determination. The stratigraphic range is probably Rhaetian (?) – Early Jurassic.

Biostratigraphy

Several biostratigraphic schemes based on foraminifera exist for the Early Jurassic, and only a few more recent are discussed herein.

KABAL and TASLI (2003) named three zones in the Early Jurassic of Central Taurides. Late Sinemurian *Lituosepta recoarensis* lineage zone (1) starts with the first occurence of *L. recoarensis*, and ends with the first occurence of *Orbitopsella primaeva*. *Amijiella amiji* is also present, and *Lituolipora termieri* and *Lituosepta compressa* occur for the first time. The latest Sinemurian – Early Pliensbachian *Orbitopsella* lineage zone (2) starts with the first occurence of *O. primaeva* and ends with the last occurence of *O. praecursor*. Algae *Palaeodasycladus mediterraneous* Pia is present. The *Lituolipora termieri* interval zone (3) begins with the last occurrence of *Orbitopsella*. This zone also represents the acme of *L. termieri*. The upper boundary is poorly defined and the zone may reach into the Toarcian, below the early Middle Jurassic *Bosniella croatica* zone.

From the Apennines, MANCINELLI et al. (2005) described three Early Jurassic zones. The *Thaumatoporella parvovesiculifera* (Reineri) interval zone (1) is Hettangian – Early Sinemurian in age. The lower boundary is the last occurrence of *Triasina hantkeni* Majzon, and the upper the first occurrence of *P. mediterraneus*. *Duotaxis metula* and *Siphovalvulina variabilis* first occur in the upper part of this zone. The Late Sinemurian *P. mediterraneus* local taxon range zone (2) starts with the first occurrence of its nominal species, and ends with its last occurrence. The Pliensbachian *Orbitopsella* local taxon range zone (3) follows.

BOUDAGHER-FADEL and BOSENCE (2007) described five foraminiferal biozones for the Hettangian – Early Pliensbachian interval based on investigation of several complete sections in the Mediterranean area. In the Hettangian *Siphovalvulina gibraltarensis* zone (1) only a few foraminifera are present. *Textularia* and *Siphovalvulina* dominate. *Involutina liassica* first appears in this zone. Foraminifera remain rare also in the Early – Middle Sinemurian *Siphovalvulina colomi* zone (2), but biodiversity somewhat increases. *Pseudopfenderina butterlini* appears in this zone for the first time. *Duotaxis metula* is a Late Triassic Lazarus species. The first appearance of *Everticyclammina praevirguliana* marks the beginning of Middle Sinemurian *E. praevirguliana* zone (3). The Late Sinemurian is recognized by the *Lituosepta recoarensis* and *Orbitopsella* spp. Zone (4). *Lituosepta recoarensis* and *Orbitopsella praecursor* appear for the first time, along with *Amijiella amiji*, *Haurania deserta*, and *Bosniella oenensis*. The following Early Pliensbachian *Lituosepta compressa* biozone is marked by the first appearance of its nominal species. *Pseudocyclammina* sp., *Orbitopsella circumvulvata*, and *Buccicrenata* first appear in this zone.

Finally, the biostratigraphic scheme for the Karst Dinarides was devised by VELIĆ (2007). The Late Rhaetian (?) – Early Sinemurian is marked by the *Triasina hantkeni* – *Mesoendothyra* sp. interval zone (1). Only small valvulinids and lituolids (i.e., *D. metula*, *A. amiji*, *S. variabilis*, *E. praevirguliana*) are present. The first occurrence of *Mesoendothyra* sp. marks the beginning of its Early – Late Sinemurian lineage zone (2). The upper boundary is marked by the first occurrence of *L. recoarensis*. *Lituolipora termieri* is an important taxon of this zone. The early Late Sinemurian *L. recoarensis* lineage zone (3) ends with the first occurrence of *O. primaeva*. The *O. primaeva* lineage zone (4) ranges from Late Sinemurian to the early Early Pliensbachian. It ends with the first occurrence of *O. praecursor*. VELIĆ (2007) divided this zone into Late Sinemurian – earliest Early Pliensbachian *O. primaeva* – *L. recoarensis* concurrent-range subzone, ranging from the first occurrence of *O. primaeva* to the last occurrence of *L. recoarensis*, and into Early Pliensbachian *L. recoarensis* – *O. praecursor* interval subzone. The following *O. praecursor* taxon-range zone (5) marks the Early Pliensbachian. *Orbitopsella* is represented

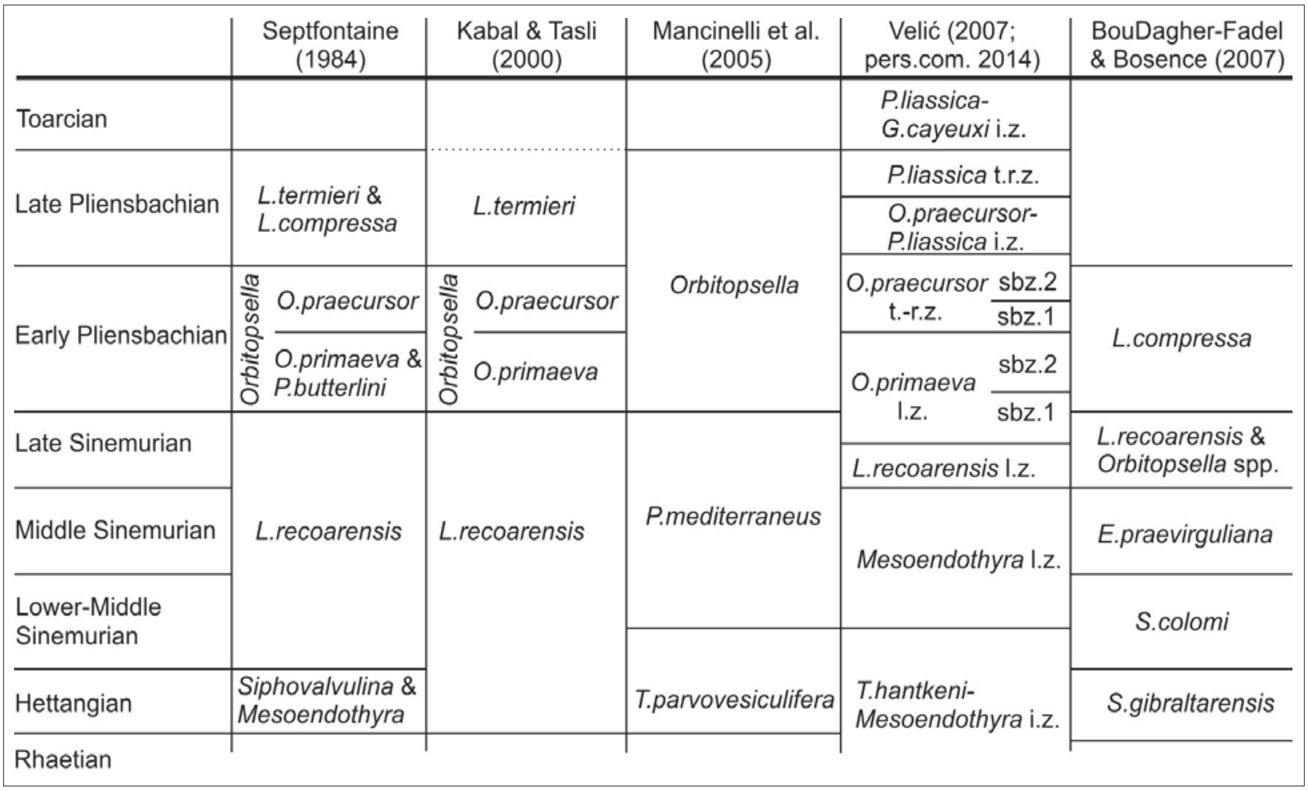


Fig. 5. A schaematic comparisson between foraminiferal (foraminiferal-green algae) biostratigraphic schemes for Early Jurassic as proposed by Septfontaine (1984), Kabal and Tasli (2000), Mancinelli et al. (2005), Velić (2007) and BouDagher-Fadel & Bosence (2007). Not to scale.

i.z.: interval zone; l.z.: lineage zone; sbz.: subzone; t.-r.z.: taxon-range zone.

Sl. 5. Shematska primerjava foraminifernih (foraminiferno-algnih) biostratigrafskih shem za zgodnjo juro po Septfontaine (1984), Kabal in Tasli (2000), Mancinelli et al. (2005), Velić (2007) in BouDagher-Fadel in Bosence (2007). Ni v razmerju.

i.z.: intervalna cona; l.z.: evolucijska cona; sbz.: podcona; t.-r.z.: razponska cona

by *O. primaeva*, as well as *O. praecursor*. In the late Early Pliensbachian *O. praecursor* – *O. primaeva* concurrent-range subzone (from the first occurrence of *O. praecursor* to the last occurrence of *O. primaeva*), *Biokovina gradacensis* (Gušić) and *Bosniella oenensis* also occur. The *O. praecursor* abundance subzone is late Early Pliensbachian to early Late Pliensbachian in age. The following *O. praecursor* – *Pseudocyclammina liassica* Hottinger interval zone (6) starts with the last occurrence of *O. praecursor* and ends with the first occurrence of *P. liassica*. It is Late Pliensbachian in age, but perhaps includes also the beginning of Toarcian. The *P. liassica* taxon-range zone (7) marks the late Late Pliensbachian. The Early Jurassic then ends with the *P. liassica* – *Gutnicella cayeuxi* interval zone (8), ranging from the last occurrence of *P. liassica* to the first occurrence of *G. cayeuxi*. *Bosniella croatica* is present. This zone is Toarcian – Earyl Aalenian in age (Velić, 2007).

According to biostratigraphic scheme of Velić (2007), the Podpeč and the Grad sections belong to *Orbitopsella praecursor* taxon range zone of the Early Pliensbachian. The highest occurrence of *Orbitopsella* is at the top of Podpeč 1 section, or at the 2nd metre of the lateral Podpeč 2 section, so there is a possibility that the uppermost part of the measured

PLATE 1

1–2 *Duotaxis metula* Kristan. 1: Thin section 337. 2: Thin section 412.

3–9 *Bosniella oenensis* Gušić. 3-8: Thin section 510. Multiple aperture is indicated with arrowhead in figure 6. 9: Note clearly visible keriothecal structure of the wall (white arrowhead) and *Meandrovoluta* incorporated into the wall (black arrowhead). Thin section 526.

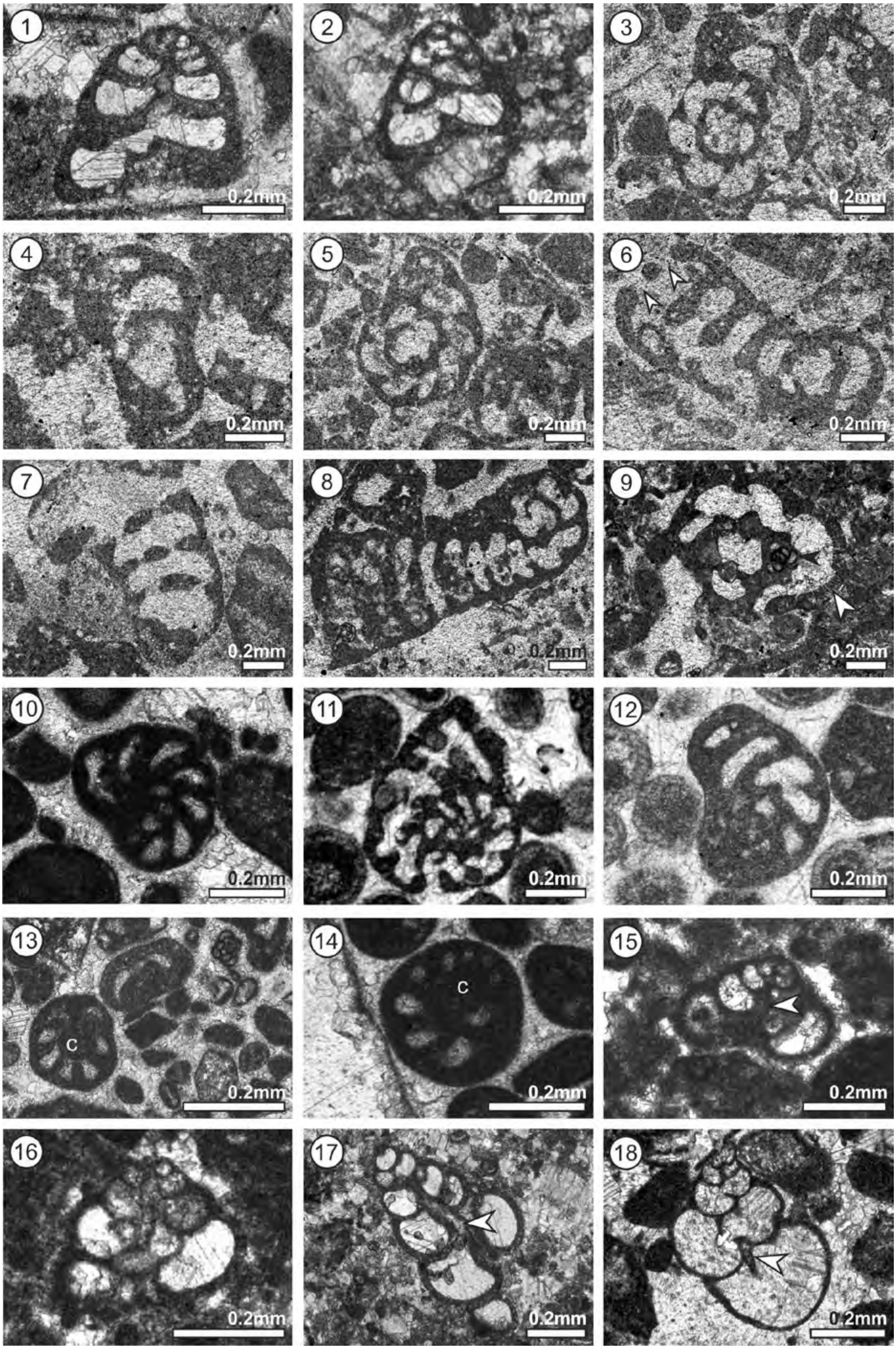
10–12 *Lituolipora termieri* (Hottinger). 10: Thin section 533. 11–12: Thin section 536.

13–14 *Pseudopfenderina butterlini* (Brun). Columella (C). 13: Thin section 418. 14: Thin section 533.

15–16 *Siphovalvulina gibraltarensis* BouDagher-Fadel et al.. Note the siphonal canal (arrowhead). 15: Thin section 328. 16: Thin section 321.

17–18 ?*Siphovalvulina variabilis* Septfontaine. Note the siphonal canal (arrowhead). 17: Thin section 412. 18: Thin section 525.

PLATE 1



section reaches the early Late Pliensbachian (the start of *P. liassica* zone). However, no index taxa of *P. liassica* zone were found to support this possibility. The Pliensbachian age of these three sections is in agreement with the previous determination of age on the basis of lithiotid bivalves (e.g., Buser & Debeljak, 1996), although lithiotid bivalves are known also from Toarcian (Debeljak & Buser, 1998; Sabatino et al., 2013).

On the other hand, the Zalopate section, at least from the 6th meter up, to the 34th meter belongs to the early Late Sinemurian *L. recoarensis* zone sensu Velić (2007), marked by the presence of *L. recoarensis* and absence of *Orbitopsella*. The section from the 34th meter up could belong to the next, *O. primaeva* lineage zone of Late Sinemurian age. It has to be noted here, that no lithiotid bivalves were recorded in the Zalopate section and that the attribution to the "Podpeč limestone" lies solely on lithological similarity and the geological map. The lack of a proper, lithostratigraphic definition of this unit is here obvious, and we would either have to correct the geological map, using a more strictly defined "Podpeč limestone", or extend the stratigraphic span of the "Podpeč limestone" to the Late Sinemurian. The Late Sinemurian – Pliensbachian age is also established for the Rotzo Member of the Calcari Grigi Formation of the Trento Plateau in Italy (Fugagnoli & Loriga Broglio 1998; Masetti et al., 1998; Fugagnoli et al., 2003), which lithologically corresponds to the "Podpeč limestone" (Buser & Debeljak, 1996).

Conclusions

The foraminiferal assemblage of the "Podpeč limestone" was investigated in three sections located in the wider Mt. Krim area, south of Ljubljana.

The Zalopate section spans the lower part of the "Podpeč limestone". No lithiotid bivalves were found. *Orbitopsella* first occurs 34 meters from the base of the section. Based on the presence of its nominal taxon, this part of the section belongs to the *Lituosepta recoarensis* zone of early Late Sinemurian age. The upper part of the section, marked by the presence of *Orbitopsella primaeva*, belongs to Late Sinemurian *O. primaeva* lineage zone. The Podpeč 1 and Podpeč 2 sections sample the classical locality of the "Podpeč limestone". Numerous lithiotid bivalve coquinas are present. The presence of *Orbitopsella praecursor* and *Bosniella oenensis* indicate Early Pliensbachian *Orbitopsella praecursor* taxon range zone. The same zone was determined in the Grad section.

The results of this study thus confirm the Pliensbachian age of the "Podpeč limestone" at its classical locality. The lower boundary of the "Podpeč limestone" is now extended to the Late Sinemurian.

Acknowledgements

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PLATE 2

1–2 ?*Siphovalvulina variabilis* Septfontaine. Arrowhead is pointing at twisted siphonal canal. 1: Thin section 329b. 2: Thin section 337.

3 *Siphvalvulina* sp., transverse section. Note the siphonal canal (arrowhead). Thin section 519.

4 ?*Siphovalvulina* sp. A. Thin section 536.

5–8 ?9, 10: *Amijiella amiji* (Henson). 5: Thin section 424b. Arrowhead pointing at Duotaxis metula. 6: Thin section 413. 7: Thin section 513. 8: Thin section 424b. 9: Radial beams are indicated by the arrowhead. Thin section 330. 10: Thin section 535b.

11–13 *Mesoendothyra*? sp. A. 11: Thin section 515. 12: Thin section 517. 13: Thin section 534.

14–16 *Lituosepta* sp. var. A. Note the endoskeletal pillars (arrowheads). 14: Thin section 328. 15 Thin section 422. 16: Thin section 333.

17 *Lituosepta* sp. var. B. Thin section 329.

18 ?*Orbitopsella primaeva* Henson. Thin section 413.

PLATE 2

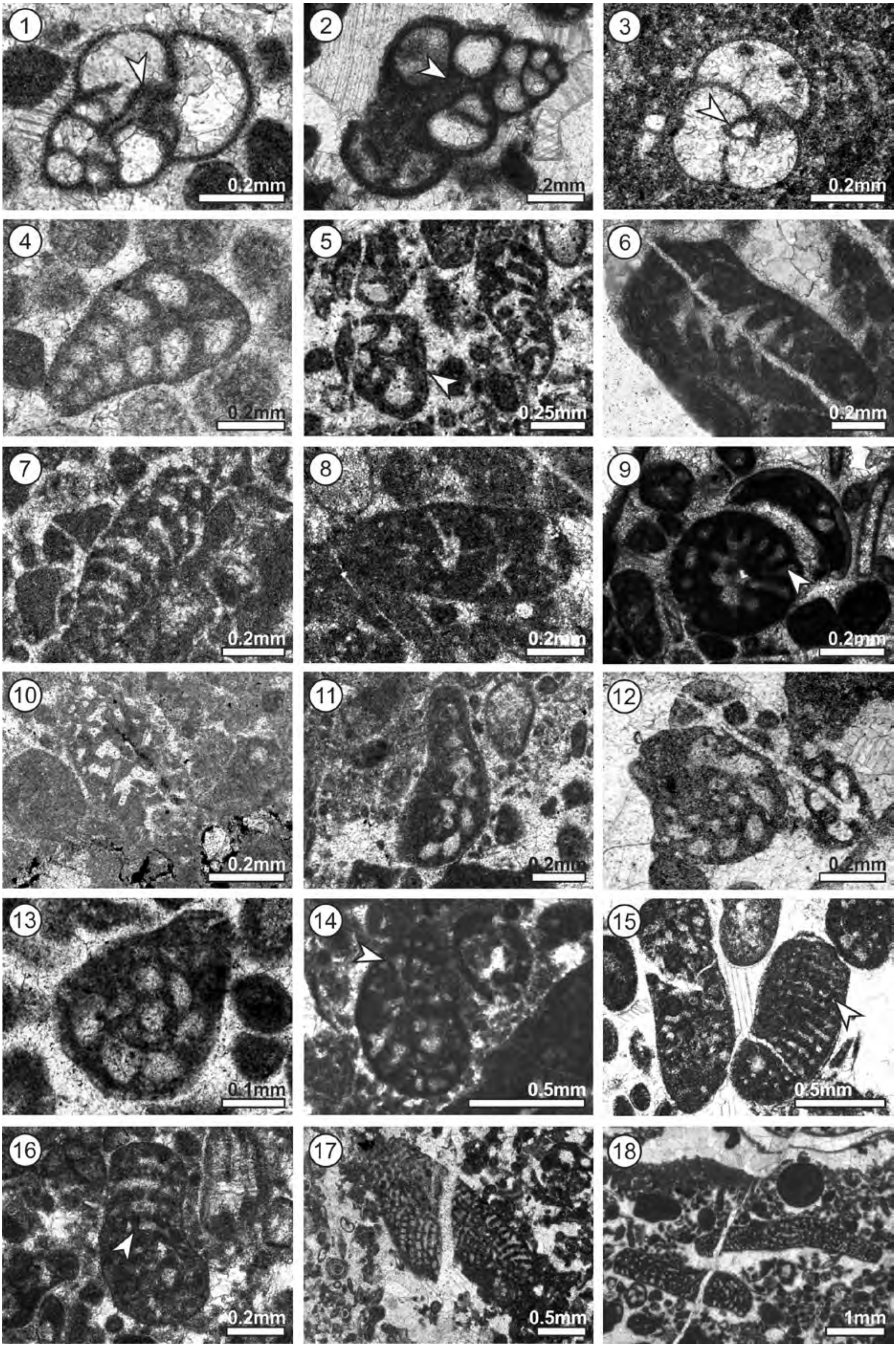

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PLATE 3

1–5 ?*Orbitopsella primaeva* Henson. One of the stolon axis is indicated by an arrowhead.

1–2 hin section 413. 3-4: Thin section 532. 5: Thin section 535b.

6–8 ?*Orbitopsella praecursor* (Gümbel). 6: Thin section 427. 7: Arrow pointing at *Bosniella oenensis*. Thin section 529. 8: Thin section 535b.

9–15 *Everticyclammina praevirguliana* Fugagnoli. Note the wide alveolae (arrowheads). 9: Axial section. Thin section 328. 10: Arrow pointing at *Meandrovoluta asiagoensis*. Thin section 328. 11: Arrow pointing at *Meandrovoluta asiagoensis*. Thin section 413. 12: Thin section 510. 13: Thin section 515. 14-15: Thin section 526.

16–18 *Meandrovoluta asiagoensis* Fugagnoli & Rettori. 16: Thin section 330. 17: Thin section 535b. 18: Thin section 415.

PLATE 3

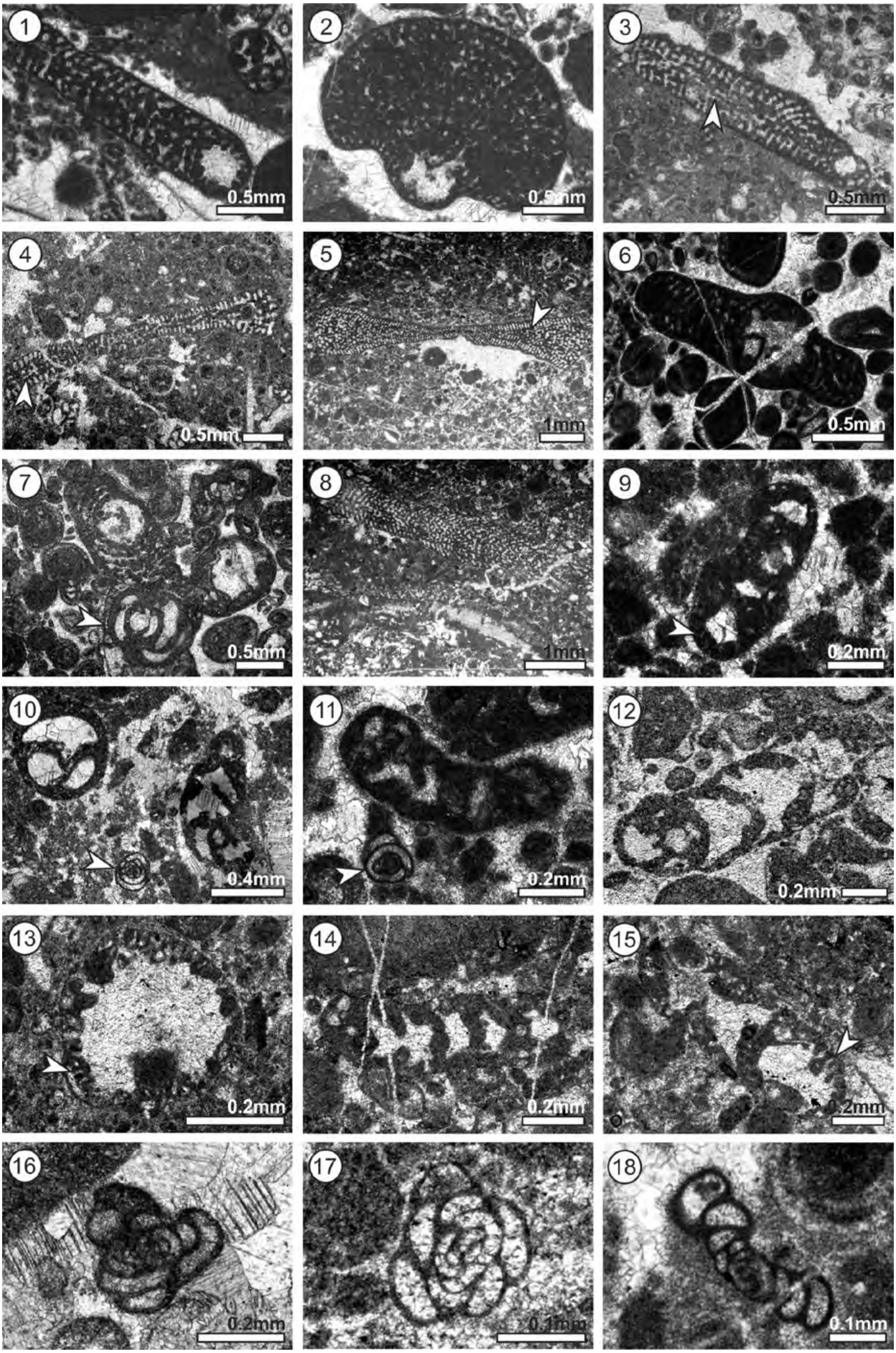
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PLATE 4

1–3 "*Involutina farinacciae* Brönnimann & Koehn-Zaninetti". 1: Thin section 526. 2: Thin section 528. 3: Thin section 535b.

4–5 ?*Coronipora* sp. or oblique section of "*Involutina farinacciae*".

6–17 ?*Coronipora* sp. Thin section 528. Arrowhead in figure 5 is pointing at proloculus.

18 ?*Trocholina* sp. Thin section 325.

PLATE 4

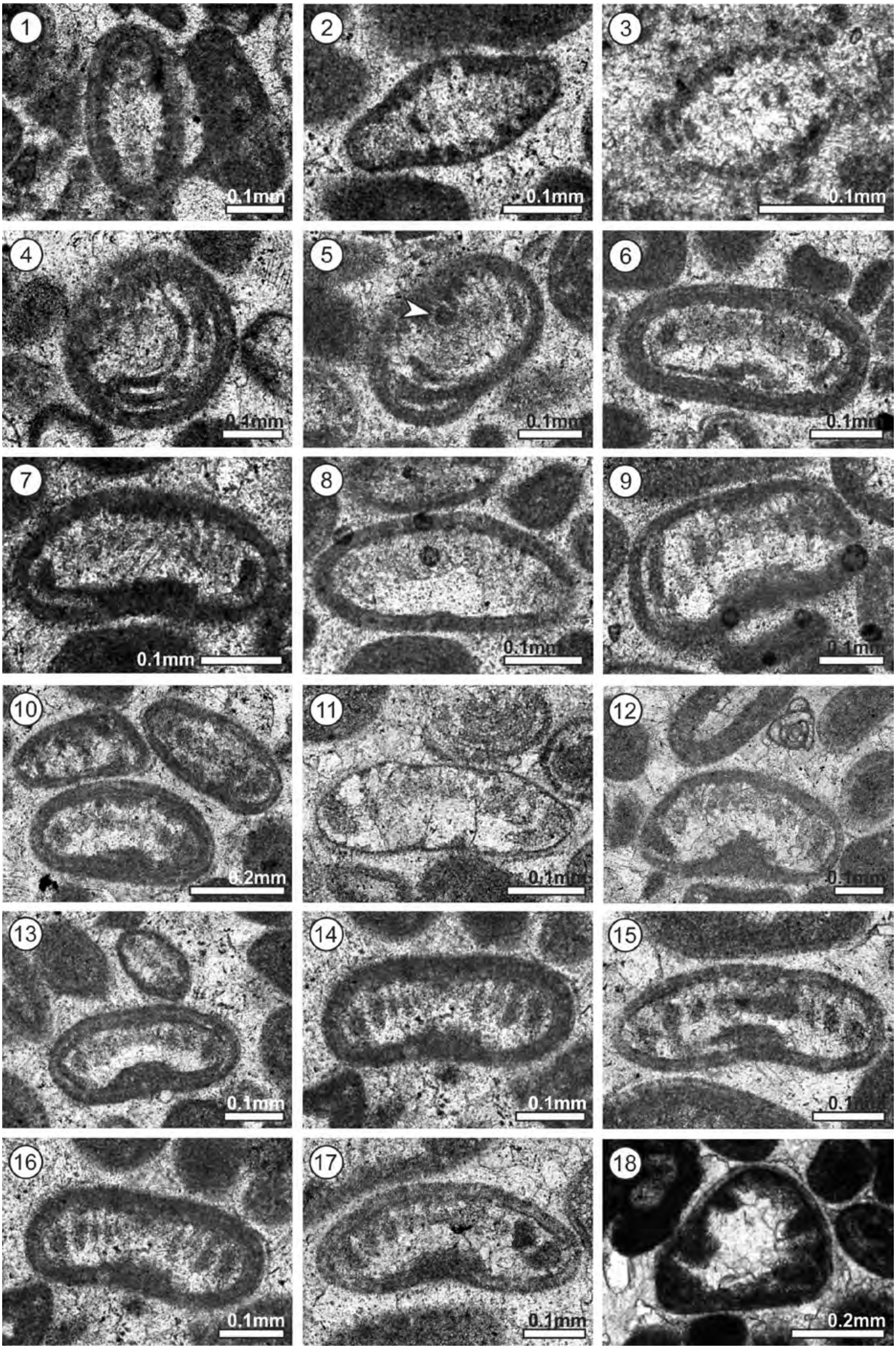
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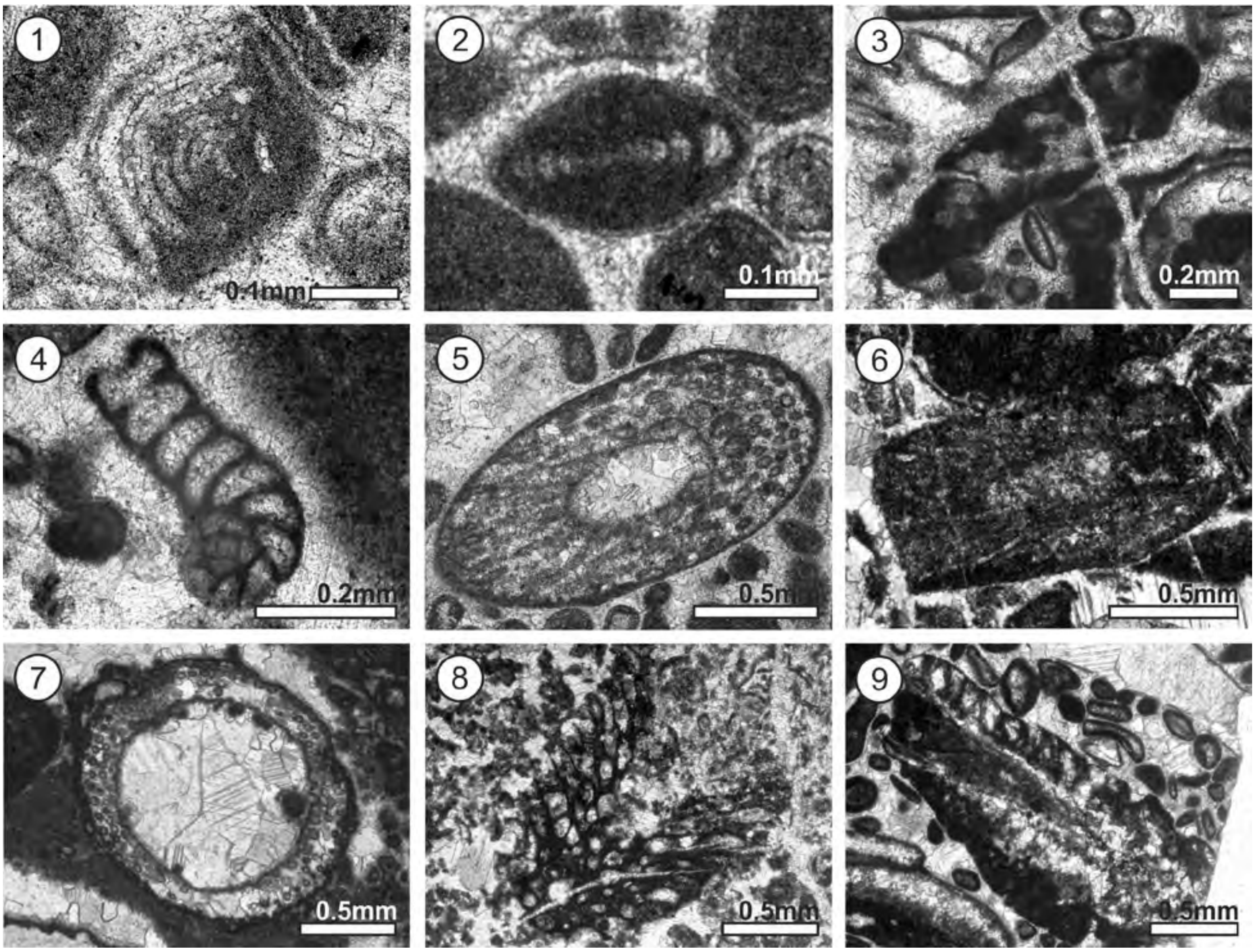
PLATE 5



1–2 *Ophthalmidium* sp. 1: Thin section 522. 2: Thin section 528.

3 *Reophax* sp. Thin section 429.

4 *Ammobaculites* sp. Thin section 324.

5–9 Dasycladales. 5: Thin section 325. 6: Thin section 420. 7: Thin section 413. 8: Thin section 428. 9: Thin section 324.

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Oligocenski morski psi iz okolice Poljšice pri Podnartu

Oligocene sharks from vicinity of Poljšica near Podnart, Slovenia

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Izvleček

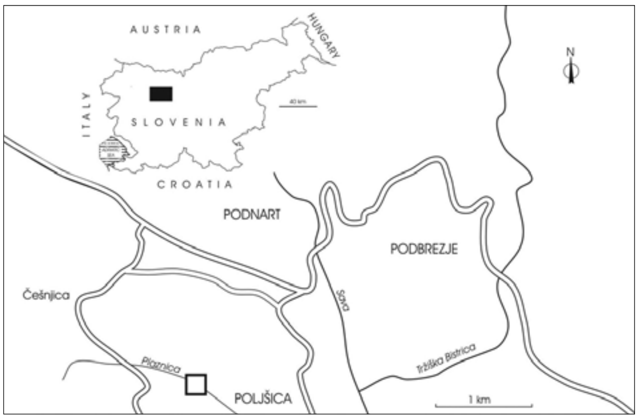
Poljšica in njena okolica sta poznani po številnih zanimivih fosilnih ostankih. Med najredkejše fosilne ostanke sodijo vretenčarski, v poljšiškem oligocenu so to dosedaj izključno ribji ostanki. V prispevku je obravnavanih šest zob morskih psov, pet jih pripada vrsti *Carcharias cuspidatus* (Agassiz, 1843). En zob je problematičen, najverjetneje pripada rodu *Cosmopolitodus*.

Abstract

Poljšica and surroundings are known for numerous interesting fossil remains. Among the rarest fossil remains are vertebrates, and in the Poljšica Oligocene these consist exclusively of fish remains. In this contribution are considered six teeth of sharks, five belonging to species *Carcharias cuspidatus* (Agassiz, 1843), except a single problematic tooth that can be attributed most probably to genus *Cosmopolitodus*.

Uvod

Okolica Poljšice pri Podnartu (sl. 1) je znana predvsem po številnih in različnih mikro in makrofosilnih ostankih, zato so tamkajšnje sklade pregledovali in raziskovali številni geologi in paleontologi, že nekako od začetkov 19. stoletja dalje. V tamkajšnjih kamninah ob potoku Plaznica so ugotovljeni: kalcitni nanoplankton in ostanki drugih alg, predvsem rdečih nečlenjenih koralinej, ostanki kopenskih rastlin, luknjičark, solitarnih in grebenskih koral, polžev, školjk, mahovnjakov, morskih ježkov in rib. Med najredkejše fosilne ostanke v okolici Poljšice prav gotovo sodijo ribji zobje hrustančnic in ostanki kostnic. Po dolgoletnem, točneje po 32 letnem in zelo pogostnem pregledovanju ter iskanju fosilnih ostankov v izdankih pod Poljšico ob Plaznici, je Viliju Rakovcu uspelo najti samo šest ribjih zob, ki jih predstavljamo v prispevku.



Sl. 1. Položaj najdišča zob morskih psov pri Poljšici
Fig. 1. Location of site of shark teeth near Poljšica

V oligocenskih gornjegrajskih skladih Poljšice je najden še en ribji ostanek in sicer del repnega plavutnega trna bentoške ribe hrustančnice iz družine Myliobatidae. Primerek je v zbirki Franceta Stareta iz Žabnice pri Škofji Loki. V mehkejši, drobno zrnati in mlajši morski glini je najden tudi skelet kostnice.

Dosedanje raziskave poljšiških fosilnih ostankov

Morlot (1850: 393, Fig. 1) predstavlja geološki profil, ki poteka tudi skozi Rovte in Poljšico pri Podnartu. V profilu med omenjenima krajema pogledajo v podlagi poljšiški »eocenski skladi«. Morlot (1850: 397-398) znova omenja kraje Rovte in Poljšico ter z njima povezane peščene laporovce, peščenjake s koralami in poljšiške plasti s številnimi fosilnimi ostanki. Korale, školjke, polže in foraminifere vzporeja s fosilnimi ostanki Gornjega Grada. Lipold (1857: 223) poroča, da izdanjajo eocenske plasti z bogato fosilno vsebino v grapi med Poljšico in Rovtami. Večina organizmov je najdenih v eocenskem peščenjaku, navaja pa mehkužce in korale. O ostankih rib ne poroča.

Poznejši raziskovalci plasti pri Poljšici uvrščajo v oligocen. Fuchs (1874: 129-130) poroča o oligocenskih numulitnih skladih pod kmetijo Jozl in pod Rovtami pri Poljšici. Tamkajšnje sklade razvršča in jih primerja z italijanskimi vičentinskimi skladi: spodaj so konglomerati, sledijo plasti Sangonini, plasti Crosara in plasti Gomberto. Sicer pa poljšiške sklade s paleontološko vsebino vzporeja z gornjegrajskimi skladi. Med fosili Fuchs (1874) ne omenja nobenih ribjih ostankov. Kinkelin (1890: 73-74) omenja iz Poljšice predvsem sklade s koralami in horizont konglomerata s kroglastimi natikami. Oppenheim (1896: 272-274) je opisal dve numulitni vrsti, 16 koral, osem školjk in sedem polžev. Tudi Oppenheim (1896: 277-278) omenja dve najdišči pod kmetijo Jozl (Jozlbauer) pri Poljšici in Rovte pri Poljšici. Pri prvem najdišču ločuje spodnje konglomerate, sledijo sangonini plasti in crosara plasti. Pri Rovtah omenja samo gomberto plasti. Poljšiške plasti primerja in enači z italijanskimi (Sangonini, Crosara, Castelgomberto) in gornjegrajskimi ter jih uvršča med srednjeoligocenske. Med fosili ne omenja nobenih ribjih ostankov. Papp (1959: 35-36) je obravnaval predvsem dve numulitni obliki, *Nummulites chavannesi* De la Harpe, kaže na zgornjeeocensko do oligocensko starost, *N. fichteli* De la Harpe pa na spodnjeoligocensko starost poljšiških plasti. Pavlovec (1961: 404) je iz srednjeoligocenskih plasti Poljšice proučeval numulite A oblike vrste *Nummulites intermedius* D'Archiac. Cimerman (1967: 252-253) je raziskoval predvsem foraminifere iz zgornjih gornjegrajskih plasti in iz morske kiscellske gline. Ugotovil je, da so združbe foraminifer iz morske gline Poljšice zelo podobne oziroma skoraj enake združbam kiscellske gline na Madžarskem. Barta-Calmus (1973) je raziskovala in revidirala oligocenske korale Poljšice in Gornjega Grada. Pavšič (1983: 97) je vzorčeval nanoplankton pod kmetijo pri Jozlu in južno od Poljšice. Po ugotovljenih vrstah sklepa, da je v spodnjem delu oligocenske morske gline na Poljšici nanoplanktonski horizont spodnjerupelijske starosti, ki ustreza bioconi NP 23. K. Drobne in sod. (1985: 81) omenjajo iz oligocena Poljšice foraminiferi *Nummulites fichteli* D'Archiac in *Planoperculina complanata* Defrance. Pavlovec (1985: 166) iz oligocenskih plasti Poljšice znova omenja foraminifere *Nummulites fichteli* D'Archiac, *N. chavannesi* De la Harpe in vrsto *Planoperculina complanata* Defrance. Pavšič (1985: 175) je raziskoval nanofloro bazalnega dela morske gline Poljšice in Bohinja. S pomočjo ugotovljenih nanoplanktonskih oblik uvršča ta del oligocenske morske gline v spodnji del srednjega oligocena oziroma v biocono NP 23. Mikuž (2000: 119) je iz Češnjice pri Poljšici opisal dva oligocenska skutelidna morska ježka. Mikuž in Čvorovič-eva (2001: 108) sta iz poljšiškega oligocena opisala velike krasatele. Mikuž (2002: 64-66) je predstavil rezultate o raziskavah poljšiških polžev. Mikuž (2006a: 64) je prvikrat opisal oligocensko kamnovrto školjko iz potoka Plaznica. O oligocenski ksenofori iz Poljšice je poročal Mikuž (2006b: 236), o oligocenskih tibijah tudi Mikuž (2007: 226). Šinkovec (2007: 103-104) piše, da je v kamninah Poljšice ugotovil 11 različnih polžjih in 16 školjčnih vrst. Nadalje navaja, da so ugotovljeni mehkužci bentoški, živeli so v litoralu plitvega morja do globine 30 m nekje med laguno in koralnim grebenom. Poseljevali so kamnito, peščeno, muljasto in grebensko podlago. Gale (2008: 198-199) je v spodnjeoligocenskih gornjegrajskih skladih pri Poljšici raziskoval nečlenjene koralineje in ugotovil šest različnih rodov: *Lithoporella, Neogoniolithon, Spongites, Lithothamnion, Mesophyllum* in *Sporolithon*. Gale (2009: 90) znova poroča o oligocenskih nečlenjenih koralinejah iz Poljšice in ugotavlja oblike: *Lithoporella melobesioides* (Foslie), *Neogoniolithon contii* (Mastrorilli) *Spongites* sp., *Lithothamnion* sp. 1 in 2, *Mesophyllum* sp. 1, 2 in 3 ter *Sporolithon* sp. Križnar, Žalohar in Hitij (2009: 93) so v kiscellski morski glini ob potoku Plaznica našli skoraj v celoti ohranjen skelet kostnice, ki so ga pripisali vrsti *Proantigonia* cf. *cosmovicii* Baciu, Bannikov & Tyler iz družine Caproidae in skupine Acanthomorpha.

Morda je zanimivo, da sodobni ihtiolog in sistematik Nelson (2006: 441) znotraj družine Caproidae ne omenja fosilnega rodu *Proantigonia*, temveč samo rod *Antigonia*, ki je poznan v oligocenu in miocenu ter živi še danes z okrog desetimi vrstami. Po podatkih Nelson-a (2006) družina Caproidae ne sodi v skupino Acanthomorpha, ampak v red Perciformes, serijo Percomorpha, nadred Acanthopterygii in poddivizijo Euteleostei. Razlog, da Nelson (2006) ne omenja rodu *Proantigonia,* je verjetno v nepoznavanju vzhodnoevropske literature, saj nima nobenega citata Gorjanović a-Krambergerja. Prav tako ne citira drugih avtorjev, ki so se nekoč in se še danes ukvarjajo z določevanjem fosilnih rib iz nekdanje Paratetide in ostalega evropskega prostora.

Stratigrafija najdišča

Rakovec (1933:156) piše, da so pri Poljšici blizu Podnarta oligocenski skladi, ki ustrezajo gornjegrajskim skladom. V najnižjem delu je sivica, v kateri se pojavljajo premoške plasti, nad sivico je konglomerat, sledijo peščeni apnenci, znova konglomerat s številnimi polži in nazadnje so apnenci z litotamnijami, koralami, školjkami in polži. Iz poljšiških skladov Rakovec (1933: 157) omenja številne fosilne ostanke: numulite, korale, školjke in polže. Ostankov rib ne omenja.

Cimerman (1967: 251) poroča, da se oligocenski skladi pri Poljšici sestoje iz spodnjih gornjegrajskih plasti, zgornjih gornjegrajskih plasti, morske kiscellske gline in menjavanja morske gline s tufi. Cimerman (1979: 66-68) piše, da je pri Poljšici podoben razvoj gornjegrajskemu. Bazalne plasti pripisuje spodnjim gornjegrajskim skladom. Zgornji gornjegrajski skladi sestoje pretežno iz apnenčevih peščenjakov s številnimi numulitinami, mehkužci in koralami. Najmlajši člen predstavlja oligocenska morska glina ali kiscellska glina s številnimi foraminiferami rodov *Tritaxia*, *Vaginulopsis* in *Planularia*.

Če povzamemo podatke po Šinkovcu (2006: 16), je najdišče zgrajeno iz oligocenskih rupelijskih bazalnih konglomeratov, nad njimi so apnenčevi peščenjaki v menjavanju s peščenimi laporovci, sledi laporna »kiscellska glina«. Na vrhu je kvartarni prod.

Zobje morskih psov so najdeni v členu zgornjih gornjegrajskih skladov s številnimi in različnimi fosilnimi ostanki.

Paleontološki del

Sistematika po: Cappetta 1987, Reinecke, Stapf & Raisch 2001 in Reinecke et. al. 2005

Classis Chondrichthyes Huxley, 1880
Subclassis Elasmobranchii Bonaparte, 1838
Cohort Euselachii Hay, 1902
Subcohort Neoselachii Compagno, 1977
Superordo Galeomorphii Compagno, 1973
Ordo Lamniformes Berg, 1958

Familia Odontaspididae Müller & Henle, 1839
Genus ***Carcharias*** Rafinesque Schmaltz, 1810

Schultz (2003: 189-190) piše, da morski psi rodu *Carcharias* živijo v tropskem, subtropskem in zmernem pasu in da sodijo med litoralno pelagične ribe. Predstavniki družine Odontaspididae (sand tiger sharks) živijo v tropskih in zmernih morjih na globinah od 1 do 1600 m v Atlantiku, Indijskem in Tihem oceanu (Nelson 2006: 57). Po podatkih Marsili (2009: 83) so predstavniki rodu *Carcharias* še danes tudi v Mediteranskem morju.

Carcharias cuspidatus (Agassiz, 1843)
Tab. 1, sl. ?1, sl. 2-6

1843 *Lamna cuspidata* Agass. – Agassiz, 290, Vol. 3, Tab. 37a, Figs. 43-44
1925 *Odontaspis cuspidata* Ag. – Schaffer, 40-42
1971 *Odontaspis (Synodontaspis) cuspidata* (L. Agassiz, 1844) – Brzobohatý & Schultz, 727, Taf. 2, Fig. 6
1971 *Odontaspis (Synodontaspis) cuspidata cuspidata* (Agassiz, 1844) – Schultz, 319, Taf. 1, Fig. 6
1973 *Odontaspis cuspidata* (Agassiz) 1843 – Bauzá & Plans. 78, Lám. 5, Figs. 36-38
1990 *Eugomphodus cuspidatus* (Agassiz) – Rückert-Ülkümen, 34, Taf. 3, Figs. 1-5
1991 *Carcharias cuspidata* (Agassiz 1844) – Pharisat, 22, Fig. 6
1996 *Carcharias cuspidata* (Agassiz, 1844) – Hiden, 58, Taf. 2, Fig. 2
2001 *Carcharias cuspidatus* (Agassiz, 1843) – Holec, 121, Tab. 1, obr. 6a-6b
2001 Carcharias cuspidata (Agassiz), 1843 – Purdy et al., 102, Fig. 18, b-d
2001 Carcharias cuspidatus (Agassiz, 1844) – Reinecke, Stapf & Raisch, 13, Taf. 20, Figs. b, d
2003 Carcharias cuspidatus – Schultz, 187
2005 Carcharias cuspidata (Agassiz, 1844) – Mikuž, 116, Tab. 1, Sl. 2-4
2005 Carcharias cuspidatus (Agassiz, 1843) – Reinecke et al., 24, Taf. 9, Figs. 1a-c
2007 Carcharias cuspidatus (Agassiz, 1843) – Kocsis, 32, Figs. 4.12-13

Material in opisi: V obdelavi je bilo šest zob morskih psov, en izoliran in pet v kamnini. Zobje št. 1, 4 in 6 so v apnenčevem konglomeratu oziroma biokalkruditu, zoba št. 3 in št. 5 sta v apnenčevem peščenjaku oziroma biokalkarenitu, drugi poljšiški zob (št. 2) je izoliran. Vsi primerki zob so iz geološke zbirke Vilija Rakovca v Kranju.

Prvi primerek (tab. 1, sl. 1a-c): Manjši izoliran koničast zob ima rahlo asimetrično krono, s ploščato ustnično in izbočeno jezično stranjo. Krona ima gladka rezalna robova, stranskih konic ni videti. Koreninski del je okrnjen in brez rogljev. Osrednji del med rogljema je zelo razprt, kar pomeni, da gre za stranski zob iz spodnje čeljustnice. Oblika zoba malce odstopa od tipične karharijske oblikovanosti zob in morda ne pripada rodu *Carcharias*. Bolj široka in čokata krona ter njena asimetričnost kažeta bolj na rod *Cosmopolitodus*.

Drugi primerek (tab. 1, sl. 2): Ohranjen je bazalni del krone in del korenine. Rezalna robova krone sta gladka. Kot med koreninskima rogljema je razmeroma velik, nad rogljem ob kroni je nastavek za stranski trnasti izrastek. Najverjetneje gre za stranski zob iz spodnje čeljustnice.

Tretji primerek (tab. 1, sl. 3): Srednje velik zob je v celoti prekrit s kalcitno prevleko. Krona je simetrična in ukrivljena proti jezični strani, konica krone je odlomljena. Ohranjen je koreninski del z dvema močnima rogljema, kot med njima je razmeroma oster. Drugih podrobnosti ni videti. Zob je verjetno iz sprednjega dela zgornje čeljustnice.

Četrti primerek (tab. 1, sl. 4a-b): Dobra polovica zoba je v apnenčevem konglomeratu ali biokalkruditu. Ohranjen je del krone, konica krone je odlomljena, koreninski del je dobro ohranjen z obema bolj razprtima rogljema. Ploščata ustnična stran je v kamnini, jezična polkrožno izbočena je vidna. Rezalna robova sta gladka. Ob bazi krone sta vidna stranska trnasta izrastka, na sredini izbočenega koreninskega dela je izrazita zajeda. Po oblikovanost koreninskega dela sklepamo, da gre za stranski zob iz spodnje čeljustnice.

Peti primerek (tab. 1, sl. 5): Zob je v apnenčevem konglomeratu, na površini je izbočena lingvalna stran zobne krone z delno ohranjeno korenino. Dolga, ozka, precej simetrična in rahlo ukrivljena krona ima odlomljeno konico. Rezalna robova krone sta gladka. Leva stran korenine je ohranjena, desna stran je odlomljena. Najverjetneje so za rod *Carcharias* značilne lateralne konice ob kroninem bazalnem delu prekrite s kamnino.

Šesti primerek (tab. 1, sl. 6): Srednje velik zob z dokaj simetrično krono je v biokalkruditu. Krona je visoka, precej konična, rezalna robova sta gladka. Labialna stran je ploščata in rahlo ukrivljena proti lingvalni strani, sama konica krone je povita proti labialni strani. Lingvalna stran je v kamnini. Blizu kronine baze sta ostanka odlomljenih stranskih konic. Levi koreninski rogelj je ohranjen v celoti, desni do polovice. Oba koreninska roglja tvorita kot okrog 80°. Zob je iz sprednjega dela zgornje čeljustnice.

Dimenzije zob iz oligocena Poljšice (Size of teeth from Oligocene of Poljšica):

Primerek/ Specimen	1 T. 1, sl. 1	2 T. 1, sl. 2	3 T. 1, sl. 3	4 T. 1, sl. 4	5 T. 1, sl. 5	6 T. 1, sl. 6
Višina in širina zoba/ Height and width of tooth mm	26 × ?	?	36 × 23	?	29 × 18	40 × 22
Višina krone/ Crown height mm	21	?	~22	?	~19	27
Debelina krone/ Crown thickness mm	4	?	?	?	?	?
Širina krone/ Crown width mm	13	12	14	13,5	7	13,5

Primerjava: Prvi primerek (tab. 1, sl. 1a-c) iz Poljšice je deloma primerljiv z zobmi iz spodnje čeljustnice vrste *Carcharias cuspidatus* v članku (Reinecke, Stapf in Raisch 2001: Taf. 16). Širina, višina krone in njena asimetričnost pri poljšiškem zobu kažejo podobnosti tudi z zobmi vrste *Cosmopolitodus hastalis*. Drugi poljšiški zob (tab. 1, sl. 2) je zelo slabo ohranjen, zato je njegova primerljivost težka, vsekakor pa pripada vrsti *Carcharias cuspidatus,* na kar sklepamo po nastavku odlomljenega stranskega trna in drugih morfoloških znakih. Tretji poljšiški zob (tab. 1, sl. 3) je primerljiv z zobom vrste *Carcharias cuspidatus* iz zgornje čeljustnice, ki ga prikazujejo Reinecke, Stapf in Raisch (2001: Taf. 20, Fig. a). etrti poljšiški zob (tab. 1, sl. 4a-b) z ohranjenima in izrazitima stranskima trnoma je primerljiv s stranskimi zobmi spodnje čeljustnice, ki jih prikazujejo Reinecke, Stapf in Raisch (2001: Taf. 16). Peti zob (tab. 1, sl. 5) je deloma primerljiv s primerkom iz spodnje čeljustnice, ki ga prikazujejo Reinecke, Stapf in Raisch (2001: Taf. 18, Fig. d). Žal se stranske konice pri zobu iz Poljšice ne vidijo. Šesti zob (tab. 1, sl. 6) iz oligocenskih skladov pri Poljšici je primerljiv z zobmi iz zgornje čeljustnice vrste *Carcharias cuspidatus*, ki jih prikazujejo Reinecke, Stapf in Raisch (2001: Taf. 20, Figs. b, d) ter Reinecke in sod. (2005: Taf. 9, Figs. 1a-c).

Stratigrafska in geografska razširjenost: Agassiz (1844) to vrsto opisuje kot *Lamna cuspidata* iz švicarske molase. Obravnavani originalni zobje so iz muzeja v Neuchâtelu. Schaffer (1925) poroča, da je v Eggenburgu med številnimi ribjimi ostanki najdena tudi vrsta *Carcharias cuspidatus*. Nadalje še piše, da je ta vrsta registrirana v eocenskih, oligocenskih in miocenskih skladih in da je rod *Carcharias* prebival v litoralu in na odprtem morju tropskega, subtropskega in zmernega pasu. Brzobohatý (1969: 8) tudi opisuje isto vrsto iz spodnjemiocenskih eggenburgijskih skladov Moravske. Njena regionalna stratigrafska razširjenost je od spodnjega oligocena do zgornjega miocena. Brzobohatý in Schultz (1971) pišeta, da je vrsta kozmopolitska in da je ugotovljena v skladih od spodnjega oligocena do zgornjega miocena. Najbolj pogostna je od srednjega oligocena do srednjega miocena, v Paratetidi je pogostna v morskem miocenu. Schultz (1971) navaja številna najdišča v Avstriji, kjer so bili najdeni zobje te vrste v badenijskih skladih. Nadalje še piše, da je omenjena oblika morskega psa najdena v Evropi v skladih paleocenske do pliocenske starosti. Bauzá in Plans (1973) jih opisujeta iz neogenskih plasti Balearov in še poudarjata, da je vrsta pogostna v neogenu Španije. Rückert-Ülkümen (1990) predstavlja zobe te oblike morskega psa iz sarmatijskih plasti pokrajine Trakije v Turčiji in navaja, da je na ozemlju Turčije razširjena od oligocena do pliocena. Pharisat (1991) opisuje in prikazuje z risbami zobovje in vretenca vrste *Carcharias cuspidatus* (Agassiz 1844) iz rupelijskih skladov ozemlja Belfort v Franciji. Hiden (1996) vrsto *Carcharias cuspidatus* opisuje iz badenijskih plasti Štajerskega bazena in navaja, da je vrsta v Evropi razširjena od spodnjega oligocena do srednjega miocena. Purdy in sod. (2001) zobe vrste *Carcharias cuspidatus* opisujejo iz burdigalijskih skladov Severne Karoline, pišejo pa tudi, da je vrsta registrirana tudi v pliocenskih skladih Yorktown-a. Reinecke, Stapf in Raisch (2001) zobe vrste *Carcharias cuspidatus* opisujejo iz rupelijskih skladov Mainške kotline (Mainzer Becken). Holec (2001) vrsto *Carcharias cuspidatus* (Agassiz, 1843) predstavlja iz badenijskih skladov najdišča Sandberg in eggenburgijskih plasti najdišča Mučín na Slovaškem. Reinecke in sod. (2005) vrsto opisujejo iz zgornjega oligocena Nemčije. Od istih avtorjev (2005: 80, Text-Fig. 15) lahko razberemo, da je v Severnomorskem sedimentacijskem bazenu vrsta *Carcharias cuspidatus* razširjena od spodnjega oligocena do spodnjega miocena (burdigalija). Schultz (2003) piše, da so primerki vrste *Carcharias cuspidatus* najdeni v grundskih plasteh Avstrije. Mikuž (2005) je zobe vrste *Carcharias cuspidatus* opisal iz spodnjemiocenskih plasti opuščenega peskokopa Tomc pri Moravčah. Iz spodnjemiocenskih skladov Madžarske predstavlja Kocsis (2007) posamezne zobe vrste *Carcharias cuspidatus*.

Zaključki

V oligocenskih apnenčevih peščenjakih in konglomeratih v okolici Poljšice je izredno veliko ostankov nekdanjih organizmov, ki so takrat živeli v pravem morskem in relativno plitvem priobalnem, tudi v predgrebenskem in grebenskem okolju. Ugotovljeni so ostanki kalcitnega nanoplanktona, koralinej, luknjičark, koral, polžev, školjk, mahovnjakov, morskih ježkov in rib. Na podlagi kamnin, koralinej, koral, ostrig in drugih mehkužcev sklepamo na razmeroma plitvo obrežno morje. Med makrofosili prevladujejo ostanki mehkužcev in koral. Ostanki rib so zelo redki, saj je bilo dozdaj najdenih le šest razmeroma slabo ohranjenih zob in večji fragment repnega trna morskega goloba. Po velikosti in njihovih morfoloških značilnostih ugotavljamo, da so nekateri zobje iz zgornje, drugi iz spodnje čeljustnice. Večino obravnavanih in predstavljenih ribjih zob iz rupelijskih skladov Poljšice (tab. 1, sl. 2-6) smo pripisali morskemu psu vrste *Carcharias cuspidatus* (Agassiz, 1843). Določitev izoliranega zoba (tab. 1, sl. 1a-c) je problematična, najverjetneje pripada rodu *Cosmopolitodus*.

Oligocene sharks from vicinity of Poljšica near Podnart, Slovenia

Conclusions

In Oligocene calcareous sandstones and conglomerates in environs of Poljšica are present extremely numerous remains of various organisms that have lived in relatively shallow marine near shore, also fore-reef and reef environments. Recognized were remains of calcitic nanoplankton, corallinaceas, foraminifers, corals, gastropods, bivalves, bryozoans, sea urchins and fishes. The rocks, corallinaceas, corals, ostreas and other mollusks are indicating a relatively shallow near-shore sea. Among macrofossils prevail remains of mollusks and corals. Fish remains are very rare, so far only six relatively poorly preserved teeth were found and a larger sized fragment of tail spine of the common eagle ray. According to their size and morphological characteristics the teeth were from the upper and lower jaw. The majority of studied fish teeth from Rupelian beds of Poljšica (pl. 1, fig. 2-6) could be attributed to shark species *Carcharias cuspidatus* (Agassiz, 1843). Determination of the isolated tooth (pl. 1, fig. 1a-c) is problematic, most probably it belongs to the genus *Cosmopolitodus*.

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TABLA 1 – PLATE 1

1 *Cosmopolitodus* ? sp.; a) jezična stran, b) s strani, c) jezična stran, zob iz istega najdišča, × 1,8
Cosmopolitodus ? sp.; a) lingual view, b) lateral view, c) labial view, the tooth from the same site, × 1.8

2 *Carcharias cuspidatus* (Agassiz, 1843); jezična stran, primerek iz istega najdišča, × 2
Carcharias cuspidatus (Agassiz, 1843); lingual view, specimen from the same site, × 2

3 *Carcharias cuspidatus* (Agassiz, 1843); jezična stran, primerek iz istih plasti, × 1,3
Carcharias cuspidatus (Agassiz, 1843); lingual view, specimen from the same beds, × 1.3

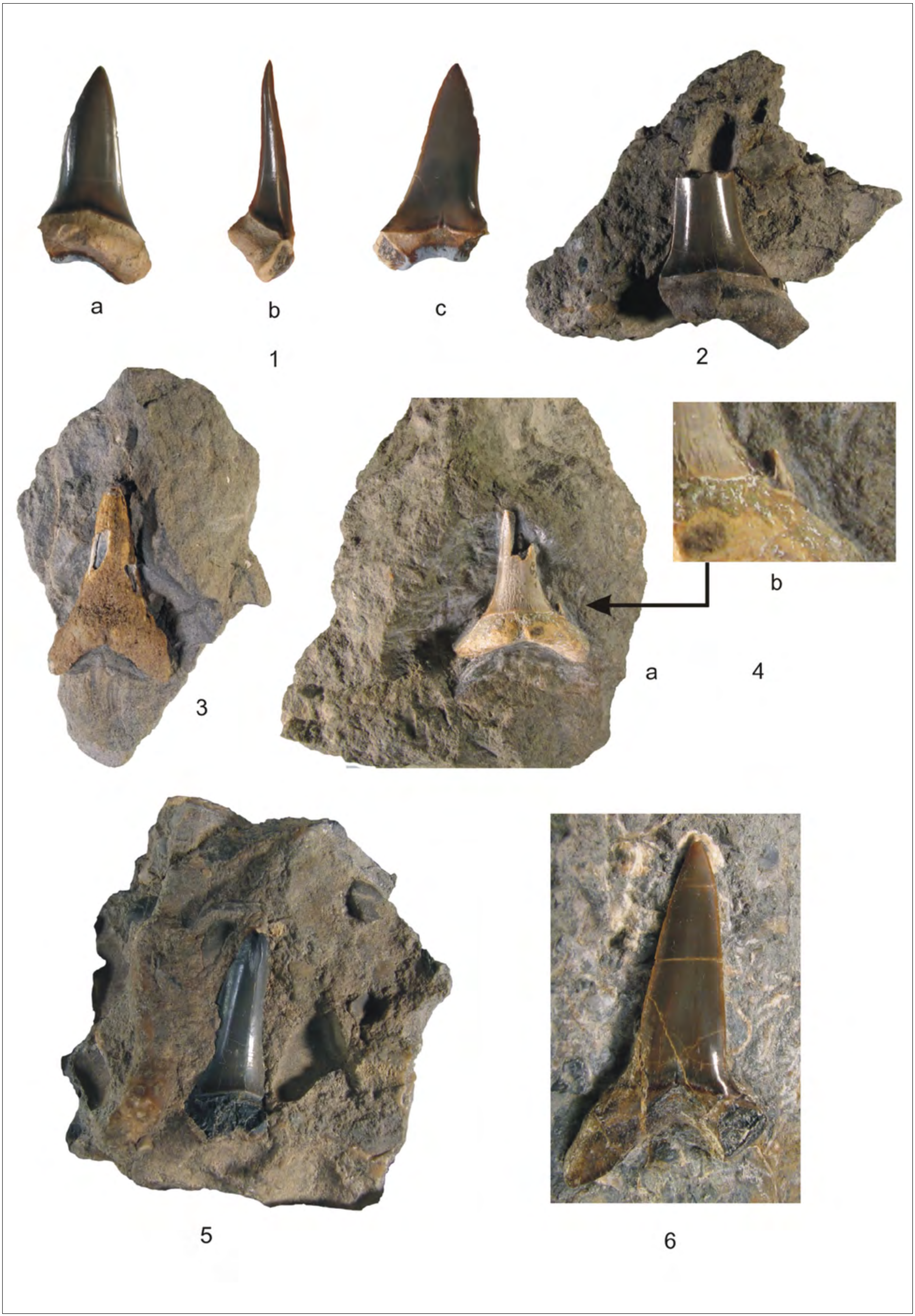
4 *Carcharias cuspidatus* (Agassiz, 1843); a) jezična stran, × 1,3 b) stranski trn, iz istih oligocenskih plasti, × 8
Carcharias cuspidatus (Agassiz, 1843); a) lingual view, × 1.3 b) lateral cusplet, from the same Oligocene beds, × 8

5 *Carcharias cuspidatus* (Agassiz, 1843); jezična stran, spodnji oligocen, Poljšica, × 1,6
Carcharias cuspidatus (Agassiz, 1843); lingual view, Lower Oligocene, Poljšica, × 1.6

6 *Carcharias cuspidatus* (Agassiz, 1843); ustnična stran, spodnji oligocen, Poljšica, × 2
Carcharias cuspidatus (Agassiz, 1843); labial view, Lower Oligocene, Poljšica, × 2

Foto (Photo): Aleš Šoster

TABLA 1 – PLATE 1



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Nekaj redkih fosilov iz Slovenskih goric

Some rare fossils from Slovenske gorice, Slovenia

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Key words: bivalves, ophiuroids, Miocene, Central Paratethys, Slovenske gorice

Izvleček

V prispevku so predstavljeni ostanki zelo redkih školjk iz miocenskih skladov Meljskega hriba, Vukovskega dola in okolice Lenarta v Slovenskih goricah. Ugotovljene so školjke vrst *Solemya doderleini* (Mayer, 1861), *Lentipecten denudatus* (Reuss, 1867), *Limaria labani* (Meznerics, 1936), *Cubitostrea digitalina* (Dubois, 1831) in *Ostrea lamellosa* Brocchi, 1814. Na severnovzhodnem obrobju Maribora, so v peščenih in sljudnih laporovcih Meljskega hriba najdeni poleg školjk tudi ostanki kačjerepov. Raziskovani inventar mehkužcev in iglokožcev pripada miocenskim skladom južnega dela štajerskega bazena Centralne Paratetide.

Abstract

This contribution presents remains of very rare bivalves from Miocene beds of Meljski hrib, Vukovski dol and surroundings of Lenart in Slovenske gorice. Determined were bivalves *Solemya doderleini* (Mayer, 1861), *Lentipecten denudatus* (Reuss, 1867), *Limaria labani* (Meznerics, 1936), *Cubitostrea digitalina* (Dubois, 1831) and *Ostrea lamellosa* Brocchi, 1814. In northeastern borders of Maribor were found in sandy and micaceous marlstones of Meljski hrib next to bivalves also remains of ophiuroids. The studied inventory of mollusks and echinoderms belongs to Miocene beds of the southern part of the Styrian basin of the Central Paratethys.

Uvod

V Sloveniji je na površju veliko neogenskih kamnin, ki so običajno bogate s fosilnimi ostanki. To velja predvsem za miocenske plasti s številnimi mehkužci v Slovenskih goricah (sl. 1). Posebnost so miocenske plasti v Vukovskem dolu, v katerih smo našli zelo redke školjke. Enako velja za Meljski hrib z zelo redkimi školjkami in prvimi in edinimi miocenskimi kačjerepi v Sloveniji. V okolici Lenarta smo našli ostrige. Nekaterih fosilnih ostankov nismo našli še v nobenih drugih miocenskih kamninah pri nas. Zaradi redkosti fosilnih ostankov iz Slovenskih goric in naše želje, da jih spozna tudi širša javnost, jih predstavljamo v krajšem prispevku. Nekaj izbranih paleontoloških posebnosti smo predstavili na 4. slovenskem geološkem kongresu v Ankaranu (Mikuž & Gašparič, 2014: 46).

Vse obravnavane in predstavljene školjke in ostanke kačjerepov je našel Rok Gašparič in jih v letu 2014 posredoval ter podaril študijski paleontološki zbirki Oddelka za geologijo.

Sl. 1. Nahajališča miocenskih fosilov v Slovenskih goricah; 1 - Meljski hrib, 2 - Vukovski dol, 3 - Lenart v Slovenskih goricah
Fig. 1. Sites of Miocene fossils in Slovenske gorice

Geološke razmere najdišča in bližnje okolice

Žnidarčič in Mioč (1988; 1989) ozemlje Slovenskih goric z najdiščem Vukovski dol vred pripisujeta v širšem smislu k Panonskemu bazenu, v ožjem pa k tektonski enoti Slovenske gorice in k Jareninskemu bloku. Na navedenem bloku izdanjajo konglomerati, peščenjaki, laporovci in peščeni laporovci, ki jih uvrščata v helvetij oziroma danes v ottnangij in karpatij. Pavšič (2002: 228-231) je v okolici Lenarta raziskoval badenijski nanoplankton in pteropode. Na podlagi nanoplanktona je tamkajšnje laporovce uvrstil v biocono NN5 in NN6, kar ustreza srednjemu in zgornjemu badeniju. Bartol (2009: 37) je raziskoval kalcitni nanoplankton v Slovenskih goricah. V bližnjem, vzhodneje ležečem Jakobskem dolu je s pomočjo nanoflore določil coni MuN4 (NN4) in MuN5a (NN5), torej so tamkajšnje kamnine nekako s prehoda karpatijskih v spodnjebadenijske plasti. Bartol in sod. (2014: 149) poročajo, da nanoplanktonska flora iz plasti pri Lenartu določa tamkajšnjim skladom cono NN6, kar ustreza zgornjemu badeniju oziroma spodnjemu serravalliju.

Paleontološki del

Sistematika po: Cox et al. 1969, Schultz 2001, 2003, 2005, Mandic 2004 in Harzhauser, Mandic & Schlögl 2011

Classis Bivalvia Linné, 1758
Subclassis Protobranchia Pelseneer, 1889
Ordo Solemyoida Dall, 1889
Superfamilia Solemyoidea Adams & Adams, 1857
Familia Solemyidae Adams & Adams, 1857
Genus **Solemya** Lamarck, 1818

Riedl (1983: 347) predstavlja mediteransko vrsto *Solemya togata* (Poli, 1795) in piše, da so te školjke redke in živijo na plitvem mehkem dnu med algami rodu *Posidonia*. Tudi Milišić (1991: 22-23) predstavlja in opisuje jadransko oziroma mediteransko vrsto *Solemya togata* (Poli, 1795), ki je zelo podobna miocenski vrsti *S. doderleini* (Mayer, 1861). Njegov opis lupin je korekten, ne strinjamo pa se z opisom njihovega življenjskega okolja. Milišić (1991: 23) navaja, da so te školjke v Jadranu zelo redke in živijo na kamnitem dnu ter na morskih pozidonijskih livadah, kjer so pritrjene na kamen ali alge. Prave podatke o ekologiji teh školjk najdemo v delu Abbott-a in Dance-a (1991: 289), ki pišeta, da te školjke živijo zakopane v morskem mulju, nekaj vrst živi v plitvem morju od 1 do 12 m globine, druge so prebivalke globljih morij. Predstavljata dve sedanji obliki, zahodno atlantsko vrsto *Solemya velum* Say, 1823 in vrsto *S. australis* Lamarck, 1818 z območja južne Avstralije in Tasmanije. Tudi navedeni recentni solemiji sta morfološko zelo podobni miocenski vrsti *S. doderleini*.

Solemya doderleini (Mayer, 1861)
Tab. 1, sl. 1, 2

1861 *Solenomya Doderleini*, Mayer. – Mayer, 364
1870 *Solenomya Doderleini* Mayer. – Hörnes, 257, Taf. 34, Figs. 10a-10b
1875 *Solenomya Doderleini* Mayer. – Hoernes, 376, Taf. 13, Figs. 9-12
1967 *Solemya (Solemya) doderleini* (Ch. Mayer, 1861) – Tejkal, Ondrejíčková & Csepreghy-Meznerics, 186, Taf. 8B, Figs. 10-11
1973 *Solenomya (Solenomya) doderleinei* Mayer, 1861 – Steininger, 463, Taf. 11, Figs. 10, 12
1998 *Solemya (Solemya) doderleini* (Mayer, 1861) – Tomašových, 364, Tab. 6, obr. 7
2001 *Solemya doderleini* (Mayer, 1861) – Schultz, 29, Taf. 2, Fig. 8
2011 *Solemya doderleini* Mayer, 1861 – Harzhauser, Mandic & Schlögl, 221, Figs. 10.1-2

Material: Kos sivorjavega miocenskega laporovca velikosti 162×125×30 mm s številnimi drobnimi lističi sljude iz Vukovskega dola z dvema ostankoma solemij. Večji ostanek v laporovcu predstavlja solemijino notranje kameno jedro (Vukovski dol-1), manjši je odtis druge solemije (Vukovski dol-2).

Opis: Zunanja oblika kamenega jedra je podolgovato ovalna, na njem ni ostankov lupine. Na površju je leva stran tankega školjkinega kamenega jedra. Sprednja stran je gladka, nizka, brez opazne radialne rebratosti, zadnja je visoka in ornamentirana z značilnimi radialno potekajočimi odtisi širokih reber (tab. 1, sl. 1–2).

Primerki iz: (Specimens from):	Dolžina (Length) mm	Višina (Height) mm	Avtorji (Authors)
Vukovski dol -1 (Slovenia)	51	19	v članku this paper
Vukovski dol -2 (Slovenia)	43	17	v članku this paper
Italija (Italy)	56	16	Mayer, 1861
Avstrija (Austria)	45	15	Hörnes, 1870
Avstrija (Austria)	75	27	Hoernes, 1875
Avstrija (Austria)	61	11	Steininger, 1973
Avstrija (Austria)	73	23	Schultz, 2001

Primerjava: Primerka iz Vukovskega dola sta v celoti primerljiva s primerki, ki jih prikazujejo Hörnes (1870), Hoernes (1875), Tejkal s sod. (1967), Steininger (1973) in Schultz (2001). Primerka, ki jih prikazujejo Harzhauser s sod. (2011: 222, Fig. 10. 1-2) sta po obliki primerljiva, sta pa bistveno manjša, saj merita v dolžino le 6 mm in v višino 2,5 mm.

Opomba: Abbott in Dance (1991: 289) imenujeta školjke iz družine Solemyidae – awning clams, to so školjke z nekakšnimi ponjavami. Razlog za takšno poimenovanje sta njihovi zelo tanki lupini, ki sta spredaj in zadaj lokasto razprti. Te školjke imajo v predelu ob vrhu močan ligament. Cox in sod. (1969: N242) pišejo, da imajo te školjke veliko nogo, prilagojeno za kopanje, in živijo zakopane v blatnem ali peščenem substratu.

Stratigrafska in geografska razširjenost: Mayer (1861: 364-365) omenja školjko iz tortonskih skladov najdišča Pino blizu Torina v Italiji. Hörnes (1870: 257) piše, da so primerki te vrste redki in omenja najdišča Vöslau, Perchtsdorf, Obergrabern pri zaselku Hollabrunn, Grussbach in Brunnengrabung v Avstriji. Fuchs (1874: 113) školjko vrste *Solenomya doderleini* Mayer omenja iz miocenskih plasti najdišč Hall in Lärchenwaldes pri kraju Kremsmünster v Zgornji Avstriji. Hoernes (1875: 376, 393) jih opisuje iz najdišča Ottnang v Avstriji, kjer so pogoste, omenja pa jih še iz miocena Poljske, Italije ter iz najdišč Hall in Kremsmünster v Avstriji. Friedberg (1934: 13-14) jih opisuje iz miocena Poljske. Meznerics (1936: 123) vrsto omenja iz miocena Štajerske oziroma Slovenskih goric, iz helvetijskih in tortonijskih plasti Dunajske kotline, helvetijskih Italije in Poljske. Sieber (1955: 171) piše, da je ugotovljena v mlajših terciarnih skladih Dunajske kotline. Tejkal in sod. (1967: 186) pišejo, da je školjka te vrste prisotna v Paratetidi od oligocena do badenija, sicer pa je ugotovljena v karpatiju štajerskega in severnomadžarskega bazena. Steininger (1973: 463) jo opisuje iz ottnangijskih skladov Avstrije. Tomašových (1998: 364) predstavlja školjko iz badenijskih plasti vzhodne Slovaške. Schultz (2001: 30-31) primerke vrste *Solemya doderleini* (Mayer, 1861) omenja iz številnih najdišč Avstrije in sicer iz eggenburgijskih, spodnjeottnangijskih in badenijskih skladov. Omenja jih še iz podobno starih plasti v preostali Centralni Paratetidi, iz zgornjeoligocenskih skladov Severnomorske province, iz spodnjeoligocenskih in miocenskih plasti Mediterana, iz Atlantske province pa je ne omenjajo. Mandic (2003: 219) omenja vrsto *Solemya doderleini* Mayer, 1861 iz karpatijskih skladov Dunajske kotline in vzhodnega dela Slovaške kotline. Bajraktarević in Pavelić (2003: 144) omenjata vrsto *Solemya doderleini* iz karpatijskih plasti Hrvaške. Harzhauser in sod. (2011: 211, 222) pišejo, da je favna v najdišču Cerová na Slovaškem zgornjekarpatijske starosti, kar ustreza zgornjemu burdigaliju zunaj Paratetide. Nadalje še navajajo, da je vrsta *Solemya doderleini* prisotna v oligocenu in miocenu v globokomorskih usedlinah Mediterana ter od kiscellija do badenija v Paratetidi.

Subclassis Autobranchiata Grobben, 1894
Superordo Pteriomorphia Beurlen, 1944
Ordo Pectinoida Adams & Adams, 1858
Superfamilia Pectinoidea Rafinesque, 1815
Familia Pectinidae Wilkes, 1810
Genus **Lentipecten** Marwick, 1928

Lentipecten denudatus (Reuss, 1867)
Tab. 1, sl. 3

1867 *Pecten denudatus* Rss. – Reuss, 139, Taf. 7, Fig. 1
1875 *Pecten denudatus* Reuss. – Hoernes, 383, Taf. 14, Figs. 21-22
1907 *Amussium corneum* Sow. var. *denudata* Reuss. – Ugolini, 234, Tav. 21, Fig. 1
1916 *Amussium corneum* var. *denudata* (Reuss). – Stefanini, 173, Tav. 5, Fig. 8
1936 *Amussium (Pseudamussium) denudatum* Reuss. – Friedberg, 256, Tabl. 42, Fig. 13
1968 *Pseudamussium denudatum* (Reuss, 1867) – Zelinskaja et al., 155, Tabl. 40, Fig. 16
1973 *Lentipecten (Lentipecten) corneum denudatum* (Reuss, 1867) – Steininger, 470, Taf. 12, Figs. 5, 6
1985 *Pseudamussium denudatum* (Reuss, 1867) – Atanacković, 41, Tab. 6, Fig. 1
1998 *Lentipecten denudatus* (Reuss, 1867) – Mikuž, 85, Tab. 1, sl. 3-4
1998 *Lentipecten (Lentipecten) corneus denudatus* (Reuss) – Schultz, 82-83, Taf. 34, Fig. 2
1998 *Amusium denudatum* (Reuss, 1867) – Tomašových, 366, Tab. 8, obr. 1
2001 *Lentipecten (Lentipecten) corneus denudatus* (Reuss, 1867) – Schultz, 153, Taf. 15, Fig. 2
2003 *Korobkovia denudata* (Reuss, 1867) – Mandic, 219

Material: Manjši kos sivega peščenega laporovca z veliko sljude, velikosti 84×80×24 mm z Vukovskega dola. Ohranjeno je kameno jedro prvega in deloma notranjost lupine drugega primerka.

Opis: Kameno jedro je okrogle oblike (tab. 1, sl. 3) z dorzalno nakazanimi stranskimi ušesci. Površina rahlo izbočenega kamenega jedra je gladka. Pod njim je notranja stran ostanka lupine, na njenem ventralnem robu je opazna skromna in prikrita radialna narebrenost, ki je ena izmed značilnosti te vrste. Mislimo, da je na površju desna stran kamenega jedra.

Primerki iz: (Specimens from):	**Dolžina (Length) mm**	**Višina (Height) mm**	**Avtorji (Authors)**
Vukovski dol (Slovenia)	41	40	v članku this paper
Avstrija (Austria)	29	28	Reuss, 1867
Avstrija (Austria)	47	46	Hoernes, 1875
Poljska (Poland)	46	45	Friedberg, 1936
Avstrija (Austria)	44 29	45 28	Steininger, 1973
Bosna (Bosnia)	42	45	Atanacković, 1985
Avstrija (Austria)	40	41	Schultz, 1998
Avstrija (Austria)	30	30	Schultz, 2001

Primerjava: Oblika in ornamentacija lupine Reuss-evega primerka (1867, Taf. 7, Fig. 1) ustreza značilnostim obravnavanega primerka, le da je primerek iz Vukovskega dola večji. Tudi primerki Hoernes-a (1875), Friedberg-a (1936), Steininger-ja (1973), Atanacković-a (1985) in Schultz-a (1998; 2001) so večinoma ustrezno primerljivi s primerkom iz Slovenskih goric oziroma Vukovskega dola.

Opomba: Ta miocenska pektenidna vrsta ima zelo tanki lupini, ki sta na obeh površinah bolj kot ne gladki. Spodnja lupina je močnejša zaradi zelo neznatne radialne narebrenosti, ki je pri podobni obliki oziroma badenijski podvrsti *Amussium cristatum badense* (Fontannes, 1882) bistveno bolj poudarjena. Po podatkih iz literature sklepamo, da velikost njihovih lupin zelo variira.

Stratigrafska in geografska razširjenost: Reuss (1867: 182) predstavlja primerek vrste *Pecten denudatus* iz miocenskega peščenega laporovca (šlira) najdišča Ottnang v Avstriji. Hoernes (1875: 383, 394) predstavlja primerke te vrste iz najdišča Ottnang v Avstriji, omenja pa jih tudi iz miocenskih skladov na otoku Malta ter iz miocena Italije in Poljske. Fuchs (1876: 69) tudi omenja iz miocenskih plasti otoka Malta vrsto *Pecten denudatus* Reuss. Ugolini (1907: 234) jih omenja iz miocenskih plasti v okolici Cagliarija na Sardiniji. Stefanini (1916: 173) zelo podobno obliko pektenide opisuje iz akvitanijskih in langhijskih skladov Veneta v Italiji. Kautsky (1928: 266) poroča, da je ta pektenidna oblika najdena v spodnjemiocenskih (helvetijskih) in badenijskih (tortonijskih) skladih Spodnje Avstrije. Friedberg (1936: 256-257) pektenide te vrste opisuje iz miocenskih plasti Poljske. Meznerics (1936: 124) jo omenja iz Štajerske oziroma Slovenskih goric, iz helvetijskih in tortonijskih skladov Dunajske kotline, Italije in Malte. Sieber (1955: 173) omenja vrsto *Amussium denudatum* (Reuss) iz mlajšeterciarnih skladov Dunajske kotline. Tejkal in sod. (1967: 158) vrsto *Pseudamussium denudatum* (Reuss, 1867) opisujejo iz karpatijskih plasti štajerskega, severnomadžarskega in južnoslovaškega bazena. Omenjajo tudi, da je vrsta prisotna v Paratetidi od oligocena do badenija. Zelinskaja in sod. (1968: 155) jo omenjajo iz spodnje in srednjemiocenskih skladov Ukrajine. Steininger (1973: 470) piše, da je ta školjčna oblika pogostna v najdišču Ottnang in drugod v Avstriji, na Madžarskem je razmeroma redka. Steininger, Schultz in Stojaspal (1978: 341) v tabeli prikazujejo, da je vrsta *Amussium denudatum* v Paratetidi razširjena od egerija do spodnjega badenija. Atanacković (1985: 43-44) jih predstavlja iz več najdišč badenija v Bosni in še omenja, da so jih registrirali tudi v spodnjem in srednjem miocenu Francije, Italije, Avstrije, Madžarske, Republike Češke, Poljske in Ukrajine. Mikuž (1998: 85) predstavlja dva razmeroma majhna primerka vrste *Lentipecten denudatus* (~14×15 mm) iz badenijskih skladov v okolici Šentilja v Slovenskih goricah. Schultz (1998: 82) predstavlja primerek opisane vrste iz ottnangijskega šlira Avstrije. Tomašových (1998: 366) predstavlja vrsto *Amusium denudatum* iz badenijskih plasti vzhodne Slovaške. Mandic (2003: 219) omenja vrsto z novim rodovnim imenom *Korobkovia denudata* (Reuss, 1867) iz karpatijskih skladov Dunajske kotline, vzhodne Slovaške kotline in iz kotline med južno Slovaško in severno Madžarsko.

Ordo Limida Waller, 1978
Superfamilia Limoidea Rafinesque, 1815
Familia Limidae Rafinesque, 1815
Genus **Limaria** Link, 1807

Limaria labani (Meznerics, 1936)
Tab. 1, sl. 4-6

1905 *Lima inflata*, Chemn. nov. mut. *undulata*. – Gaál, 297, 2. ábra. 6
1936 *Lima (Mantellina) lábáni* nov. spec. – Meznerics, 127, Taf. 4, Figs. 9-14
1967 *Lima (Mantellum) labani* Meznerics, 1935 – Tejkal, Ondrejíčková & Csepreghy-Meznerics, 162, Taf. 1B, Fig. 22
2011 *Limaria labani* (Meznerics, 1936) – Harzhauser, Mandic & Schlögl, 224, Figs. 12.5-7

Material: V obdelavi smo imeli notranje odtise treh primerkov brez ohranjenih lupin. Odtis leve lupine (Meljski hrib-1), odtis celotne desne in obvrhnji del leve lupine (Meljski hrib-2) in notranji odtis leve lupine (Meljski hrib-3). Kamnina je rumenkastorjav peščeni laporovec z lističi sljude in številnimi rahlo pooglenelimi ostanki morske trave.

Opis: Školjke so majhne, ploščate in elipsoidne oblike (tab. 1, sl. 4-6). Vsi primerki so brez ohranjenih lupin. Za vrsto *Limaria labani* je značilna izrazita koncentrično potekajoča undulacija grebenov, zelo podobna krednim inoceramidom. Ornamentacija je ob vršnem delu slabotna, proti ventralnemu robu pa vse bolj poudarjena. Primerki z Meljskega hriba imajo od 13 do 16 koncentričnih grebenov in vmesnih dolov. Ob zadnjem robu so opazna tanka radialno potekajoča rebrca (tab. 1, sl. 5). Vrh je majhen in rahlo povit.

Velikost primerkov (Size of specimens):

Primerki iz: (Specimens from):	Dolžina (Length) mm	Višina (Height) mm	Avtorji (Authors)
Meljski hrib-1 (Slovenija)	15	20	v članku this paper
Meljski hrib-2 (Slovenija)	11	15	v članku this paper
Meljski hrib-3 (Slovenija)	11	15	v članku this paper
Slov. gorice (Slovenija)	20	40	Meznerics, 1936
Kapušany (Slovakia)	č16	č23	Tejkal et al., 1967
Slovaška (Slovakia)	č13	č20	Harzhauser et al., 2011
Slovaška (Slovakia)	č6,3	č9,3	Harzhauser et al., 2011
Slovaška (Slovakia)	č10	č12,5	Harzhauser et al., 2011

Stratigrafska in geografska razširjenost: Meznerics-eva (1936: 127) poroča, da so našli več kot 50 primerkov v laporovcih na Vukovskem vrhu pri Jarenini (Wolfsberg bei Jahring). Omenjene so še lokacije, morda kmetije Ruesser, Gromberg, Ferental in Repnik, vse iz Slovenskih goric, za katere pa ne poznamo slovenskih poimenovanj. Tejkal, Ondrejíčková in Csepreghy-Meznerics (1967: 162) predstavljajo primerek iz najdišča Hlinné, omenjajo pa še najdišča Kapušany na Slovaškem, najdejo se tudi v štajersko-severnomadžarski kotlini. Schultz (2001: 301) piše, da je ta vrsta značilna za karpatij, v Avstriji ni najdena. Navaja tudi, da so jih našli predvsem v Slovenskih goricah in na Madžarskem. Mandic (2003: 220) vrsto *Limaria (Limaria) labani* Meznerics, 1935 omenja iz karpatijskih skladov na vzhodu Slovaške. Harzhauser, Mandic & Schlögl (2011: 224) vrsto *Limaria labani* predstavljajo iz miocena Slovaške z ozemlja, ki je sestavni del Dunajske kotline. V Paratetidi je najdena samo v karpatiju in badeniju. Našli so jih v slovenskem delu štajerskega bazena v spodnjem badeniju, na severnem robu Panonskega bazena, na severu Madžarske v karpatijsko-badenijskih plasteh in na vzhodu Slovaške v karpatijskih skladih.

Subordo Ostreina Férussac, 1822
Superfamilia Ostreacea Rafinesque, 1815
Familia Ostreidae Rafinesque, 1815
Subfamilia Ostreinae Rafinesque, 1815
Genus **Cubitostrea** Sacco, 1897

Cubitostrea digitalina (Dubois, 1831)
Tab. 2, sl. 1, 1a-1d

1870 *Ostrea digitalina* Dub. – Hörnes, 447, Taf. 73, Figs. 1-3
1960 Ostrea digitalina Dubois 1831 – Kojumdžieva, 76, Tabl. 27, Figs. 1a-1b
2001 Ostrea (Ostrea) digitalina (Dubois, 1831) – Schultz, 343, Taf. 2a-2b, 3a-3b

Material: En v celoti ohranjen primerek iz okolice Lenarta, z nekoliko večjo spodnjo in manjšo zgornjo lupino.

Opis: Ostriga ima obe lupini, ki sta trikotne oblike. Njuna notranjost je zapolnjena s peščenim muljevcem. Debela spodnja ali leva lupina je večja od zgornje in zelo reliefna zaradi poudarjenih koncentričnih prirastnic in radialnih grebenov, predvsem na ventralnem delu lupine (tab. 2, sl. 1a). Precej tanjša desna lupina ima na zunanji strani številne široke koncentrične prirastnice (tab. 2, sl. 1). V notranjosti desne lupine je ob vrhu tipično tridelno in dolgo sklepno polje, blizu posteriornega roba je nekako na sredini skledaste notranjosti kroglast odtis aduktorske mišice v velikosti 26×18 mm (tab. 2, sl. 1c). Na odtisu je ostala na muljasti zapolnitvi bela površina iz nitastih kristalov sadre (tab. 2, sl. 1b, 1d). Sklepna površina primerka iz okolice Lenarta je takšna kot pri rodu *Crassostrea*.

Primerki iz: (Specimens from):	Dolžina (Length) mm	Višina (Height) mm	Avtorji (Authors)
Lenart (Slovenija)	90	117	v članku this paper
Avstrija (Austria)	65	75	Hörnes, 1870
Bolgarija (Bulgaria)	35	48	Kojumdžieva, 1960
Avstrija (Austria)	59	74	Schultz, 2001

Pripombe: Kojumdžieva (1960: 76) piše, da so lupine vrste *Ostrea digitalina* najdene v miocenu Bolgarije in da so dolge od 45 do 80 mm. Verjetno so imeli v mislih višino in ne dolžino lupin?

Primerjava: Mandic in Harzhauser (2003: 100, Pl. 2, Figs. 4-7) prikazujeta ostanke lupin vrste *Cubitostrea (Ostrea) digitalina* (Dubois, 1831) iz badenijskih plasti najdišča Mühlbach v severnovzodnem delu Avstrije. Primerki, ki so po obliki primerljivi, so zelo majhni, določene lupine pa po našem mnenju ne pripadajo omenjeni vrsti.

Stratigrafska in geografska razširjenost: Hörnes (1870: 448-450) piše, da je vrsta *Ostrea digitalina* pogostna v miocenu Avstrije, in da je zelo razširjena tudi drugod, v Franciji, Italiji, Romuniji, na Hrvaškem, Madžarskem, Poljskem, Češkem in drugje. Fuchs (1875: 95-97) omenja vrsto *Ostrea digitalina* iz miocenskih litotamnijskih apnencev in zelenih peskov ter heterosteginskega apnenca otoka Malte. Kojumdžieva (1960: 76-77) jo predstavlja iz srednjega miocena Bolgarije, primerki te vrste so najdeni še v spodnje in srednjemiocenskih skladih Francije, Avstrije, Madžarske, Belgije, Češke in Romunije. Tomašových (1998: 368) omenja primerke vrste *Cubitostrea (O.) digitalina* Dubois, 1831 iz badenijskih plasti na vzhodu Slovaške. Schultz (2001: 346-351) omenja številna avstrijska najdišča z ostrigo vrste *Ostrea digitalina*, ki je bila najdena v miocenskih skladih od eggenburgija do badenija. Najdena je tudi drugod v miocenskih plasteh Centralne Paratetide in Vzhodne Paratetide, v Severnomorski, Atlantski in Mediteranski provinci. Mandic (2003: 220) omenja vrsto *Cubitostrea digitalina* (Dubois, 1831) iz karpatijskih skladov Avstrije (Korneuburg).

Ostrea lamellosa Brocchi, 1814
Tab. 3, sl. 1a-1b

1870 *Ostrea lamellosa*. Brocchi. – Hörnes, 444, Taf. 72, Fig. 1
2001 *Ostrea (Ostrea) lamellosa* Brocchi, 1814 – Schultz, 358, Taf. 55, Figs. 1a-1b

Material: Ena zgornja lupina iz miocenskih plasti v okolici Lenarta.

Opis: Zunanja površina razmeroma tanke, kroglaste, desne ali zgornje lupine je prekrita s številnimi koncentričnimi prirastnicami (tab. 3, sl. 1a). Na notranji strani je ob vrhu kratko sklepno polje, sledi poglobljena skledasta površina in proti ventralnemu delu lupine ledvičast odtis aduktorske mišice (tab. 3, sl. 1b).

Primerki iz: (Specimens from):	Dolžina (Length) mm	Višina (Height) mm	Avtorji (Authors)
Lenart (Slovenija)	65	75	v članku this paper
Avstrija (Austria)	63	85	Hörnes, 1870
Avstrija (Austria)	65	82	Schultz, 2001

Stratigrafska in geografska razširjenost: Hörnes (1870: 446-447) piše, da je vrsta *Ostrea lamellosa* pogosta v miocenskih skladih Avstrije, ugotovljena je tudi v miocenskih in pliocenskih plasteh Francije, Italije, Grčije, Cipra, Armenije, Madžarske in drugod. Vrsta živi še danes ob obalah Korzike, Italije, Trsta, Zadra in drugje. Fuchs (1875: 96) omenja vrsto *Ostrea lamellosa* iz miocenskih zelenih peskov in heterosteginskega apnenca otoka Malte. Schultz (2001: 360-363) jo omenja iz eggenburgijskih do badenijskih plasti Avstrije. Najdena je tudi v številnih lokacijah preostale Paratetide ter Atlantske in Mediteranske province. Ta vrsta ostrige živi še danes v Mediteranu, Atlantiku in v Severnem morju. Mandic (2003: 220) primerke opisane vrste omenja iz karpatijskih skladov Korneuburške kotline v Avstriji. Hladilová & Fordinál (2013: 39, 41) predstavljata vrsto *Ostrea lamellosa* (Brocchi) iz zgornjebadenijskih plasti najdišča Modra na Slovaškem.

Sistematika po: Spencer & Wright 1966, Kutscher et al. 2004

Classis Ophiuroidea Gray, 1840
Ordo Ophiurida Müller & Troschel, 1840

Genus et species indet.
Tab. 3, sl. 2a-2b

Material: Najdenih je več primerkov v miocenskem rumenkastorjavem peščenem in sljudnatem laporovcu na Meljskem hribu nad Mariborom. Obravnavamo in prikazujemo samo en kos laporovca z ostankoma dveh kačjerepov.

Opis: Osrednji del ali centralni disk ima peterokoten obris (tab. 3, sl. 2a-2b). Na sredini oralne strani diska je zvezdasto oblikovan ustni aparat (tab. 3, sl. 2b). Na centralnem disku so na poljih med rameni temnejše lise sestavnih skeletnih delov. Iz petih kotov diska izraščajo kačasti kraki ali ramena. Kraki sestoje iz številnih členkov ali vretenc, ki imajo na straneh kratke trne ali bodice. Po ukrivljenosti krakov sklepamo, da primerki z Meljskega hriba sodijo v skupino kačjerepov z relativno veliko oziroma vsestransko gibljivostjo ramen.

Velikost kačjerepov z Meljskega hriba (Size of brittle stars from Meljski hrib):

premer osrednjega dela
(Diameter of central disk) = 8 mm

premer ustnega aparata
(Diameter of mouth frame) = 3 mm

dolžina ramen
(Length of arms) = ~ 40 mm

širina ramen
(Width of arms) = 3,5 to 1,5 mm

Primerjava: O neogenskih kačjerepih iz Centralne Paratetide so pisali Küpper (1954), Binder in Steininger (1967), Kroh (2003; 2004; 2007) in drugi. V navedenih delih nismo našli ustrezne primerljivosti med kačjerepi z Meljskega hriba s primerki iz avstrijskih najdišč. Po obliki centralnega diska in krakov so naši primerki primerljivi z recentnima rodovoma *Amphiura* in *Ophioderma*, ki jih prikazujejo Luther in Fiedler (1961: 97, Taf. 18) ter Riedl (1983: 615, Taf. 226).

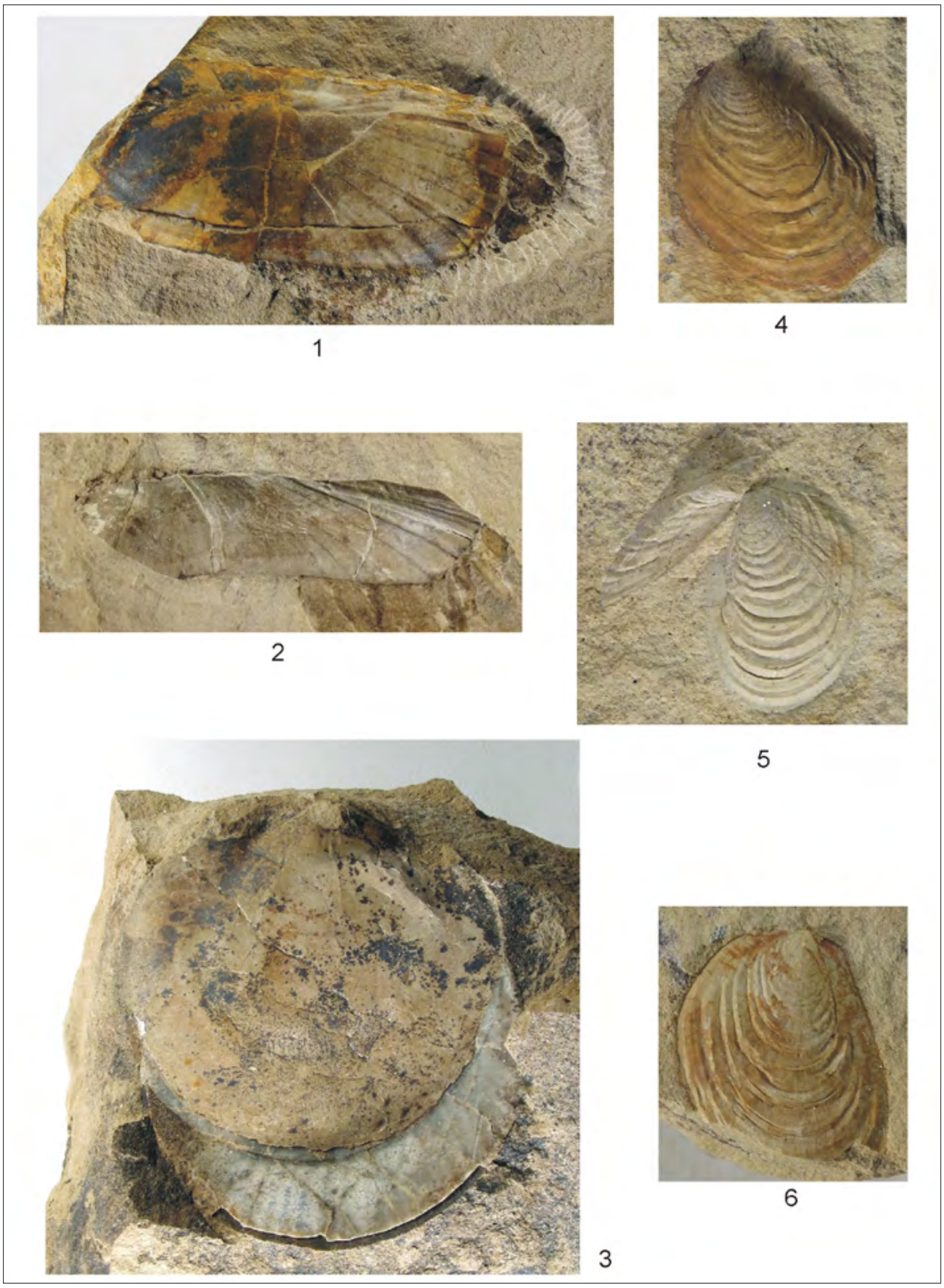
Stratigrafska in geografska razširjenost kačjerepov (Ophiurida) v Centralni Paratetidi: Izredno lep pregled ostankov kačjerepov iz Centralne Paratetide najdemo v Kroh-ovem članku (2007: 196-198). Po njegovih podatkih so ostanki kačjerepov ugotovljeni v eggenburgijskih, ottnangijskih, karpatijskih in badenijskih skladih Centralne Paratetide. V popisu so navedene lokacije iz Avstrije, Republike Češke, Republike Slovaške, Madžarske, Poljske, Romunije in Ukrajine. Največ najdišč kačjerepov je v badenijskih plasteh Avstrije.

Zaključki

V obravnavi smo imeli deset fosilnih ostankov iz Slovenskih goric, osem školjk in dva kačjerepa (tab. 1-3). Na Meljskem hribu na severnovzhodnem obrobju Maribora je bila ugotovljena školjka vrste *Limaria labani* (Meznerics, 1836) in ostanki več kačjerepov reda Ophiurida. V miocenskih karpatijsko-badenijskih plasteh oziroma iz stratigrafskega horizonta med nanoplanktonskima conama NN4 in NN5 v Vukovskem dolu (Bartol 2009) sta bili determinirani školjki *Solemya doderleini* (Mayer, 1861) in *Lentipecten denudatus* (Reuss, 1867). Iz okolice Lenarta smo prepoznali dve vrsti miocenskih ostrig *Cubitostrea digitalina* (Dubois, 1831) in *Ostrea lamellosa* Brocchi, 1814. Tamkajšnje plasti pripadajo nanoplanktonski coni NN6 in so zgornjebadenijske oziroma spodnjeserravallijske starosti (Bartol in sod. 2014).

V slovenskih miocenskih kamninah so do sedaj znani ostanki školjk vrst *Solemya doderleini* in *Limaria labani* izključno iz Slovenskih goric. Ostanki miocenskih kačjerepov so pri nas zaenkrat najdeni samo na Meljskem hribu. Obravnavani in predstavljeni fosilni ostanki so spodnje do srednjebadenijske starosti.

TABLA 1 – PLATE 1



1 *Solemya doderleini* (Mayer, 1861); primerek Vukovski dol-1, × 1,7
Solemya doderleini (Mayer, 1861); specimen Vukovski dol-1, × 1.7

2 *Solemya doderleini* (Mayer, 1861); primerek Vukovski dol-2, × 1,7
Solemya doderleini (Mayer, 1861); specimen Vukovski dol-2, × 1.7

3 *Lentipecten denudatus* (Reuss, 1867); Vukovski dol, × 1,7
Lentipecten denudatus (Reuss, 1867); Vukovski dol, × 1.7

4 *Limaria labani* (Meznerics, 1936); Meljski hrib-1 pri Mariboru, × 2,7
Limaria labani (Meznerics, 1936); Meljski hrib-1 near Maribor, × 2.7

5 *Limaria labani* (Meznerics, 1936); Meljski hrib-2 pri Mariboru, × 2,6
Limaria labani (Meznerics, 1936); Meljski hrib-2 near Maribor, × 2.6

6 *Limaria labani* (Meznerics, 1936); Meljski hrib-3 pri Mariboru, × 2,6
Limaria labani (Meznerics, 1936); Meljski hrib-3 near Maribor, × 2.6

S pričujočim prispevkom in ustreznim slikovnim gradivom (tab. 3, sl. 2a-2b) dokazujemo, da so ostanki miocenskih kačjerepov Centralne Paratetide najdeni tudi v Sloveniji. Zaradi slabše ohranjenosti njihovih skeletnih elementov pa je njihova natančnejša določitev otežena in nezanesljiva.

Some rare fossils from Slovenske gorice, Slovenia

Conclusions

Considered were ten fossil remains from Slovenske gorice, belonging to eight bivalves and two ophiuroids (pl. 1-3). On Meljski hrib, at northeastern borders of Maribor, the bivalve species *Limaria labani* (Meznerics, 1836) and remains of several ophiuroids of order Ophiurida were registered. In Miocene Carpathian-Badenian beds, that is, in stratigraphic horizon between nanoplankton zones NN4 and NN5 in Vukovski dol (Bartol 2009) the bivalves *Solemya doderleini* (Mayer, 1861) and *Lentipecten denudatus* (Reuss, 1867) were determined. In environs of Lenart we recognized two species of Miocene oysters, *Cubitostrea digitalina* (Dubois, 1831) and *Ostrea lamellosa* Brocchi, 1814. These beds belong to the nanoplankton zone NN6, and are of Late Badenian, resp. Early Serravallian age (Bartol et al. 2014).

In Miocene rocks of Slovenia were known so far remains of bivalves of species *Solemya doderleini* and *Limaria labani* exclusively in Slovenske gorice. Remains of Miocene ophiurids were found so far only at Meljski hrib. The studied and presented fossil remains are of Early to Middle Badenian age.

In this paper (pl. 3, fig. 2a-2b) we demonstrate the existence of remains of Miocene ophiurids of Central Paratethys also in Slovenia. Owing to poor state of preservation of their skeletal elements, however, their detailed determination is not possible.

Zahvale

Za prevode v angleščino se zahvaljujemo zaslužnemu profesorju dr. Simonu Pircu, za fotografske usluge pa sodelavcu Marijanu Grmu.

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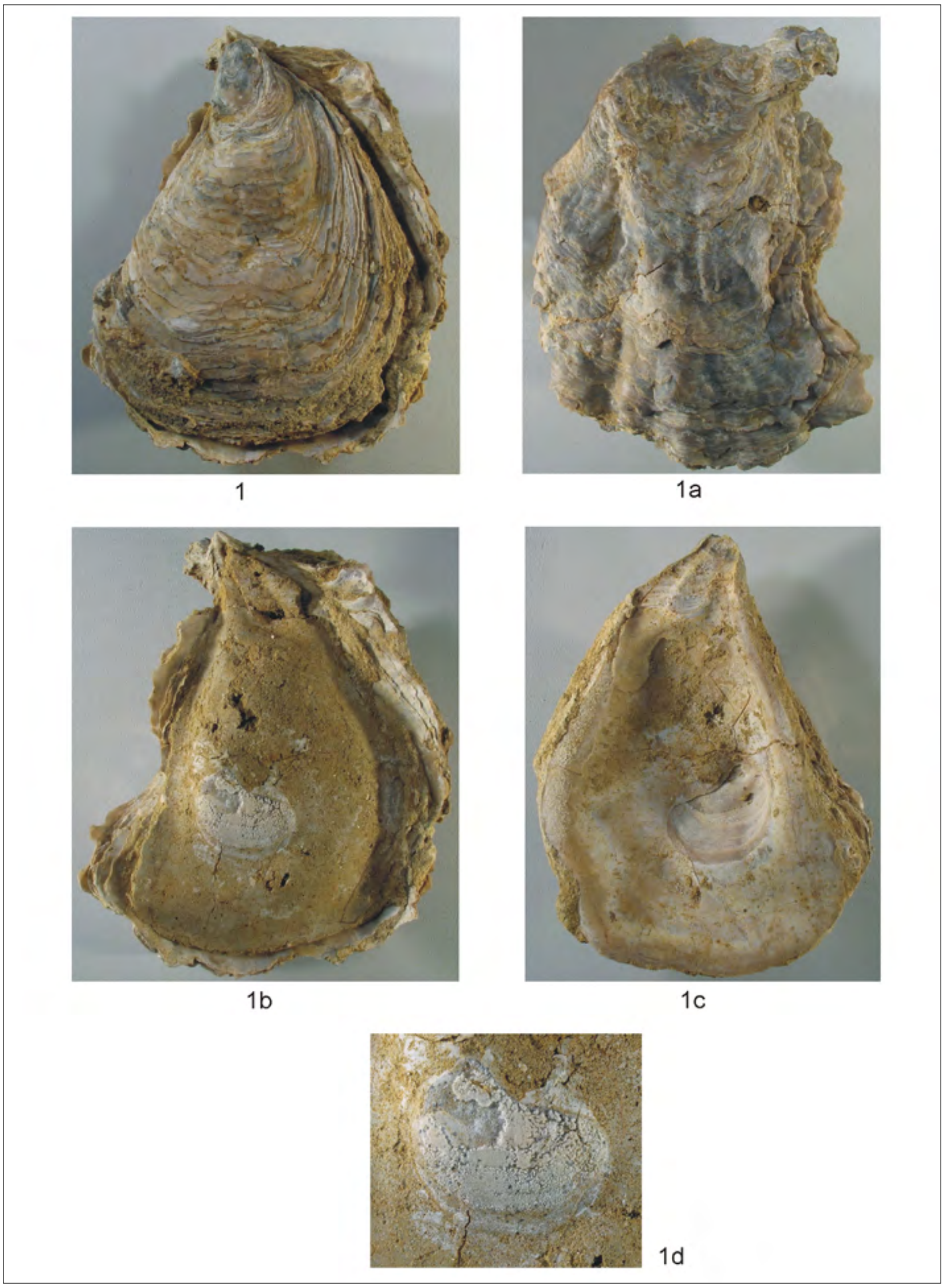
TABLA 2 – PLATE 2



1 *Cubitostrea digitalina* (Dubois, 1831); bližnja okolica Lenarta, × 0,7
Cubitostrea digitalina (Dubois, 1831); vicinity of Lenart, × 0.7

1a *Cubitostrea digitalina* (Dubois, 1831); bližnja okolica Lenarta, × 0,7
*Cubitostrea digitalin*a (Dubois, 1831); vicinity of Lenart, × 0.7

1b *Cubitostrea digitalina* (Dubois, 1831); bližnja okolica Lenarta, × 0,7
Cubitostrea digitalina (Dubois, 1831); vicinity of Lenart, × 0.7

1c *Cubitostrea digitalina* (Dubois, 1831); bližnja okolica Lenarta, × 0,7
Cubitostrea digitalina (Dubois, 1831); vicinity of Lenart, × 0.7

1d Odtis zadnjega aduktorja vrste *Cubitostrea digitalina* (Dubois, 1831), prekrit z belimi kristali sadre; bližnja okolica Lenarta, × 1,5
The impression of posterior adductor muscle of *Cubitostrea digitalina* (Dubois, 1831) covered with white gypsum crystals; vicinity of Lenart, × 1.5

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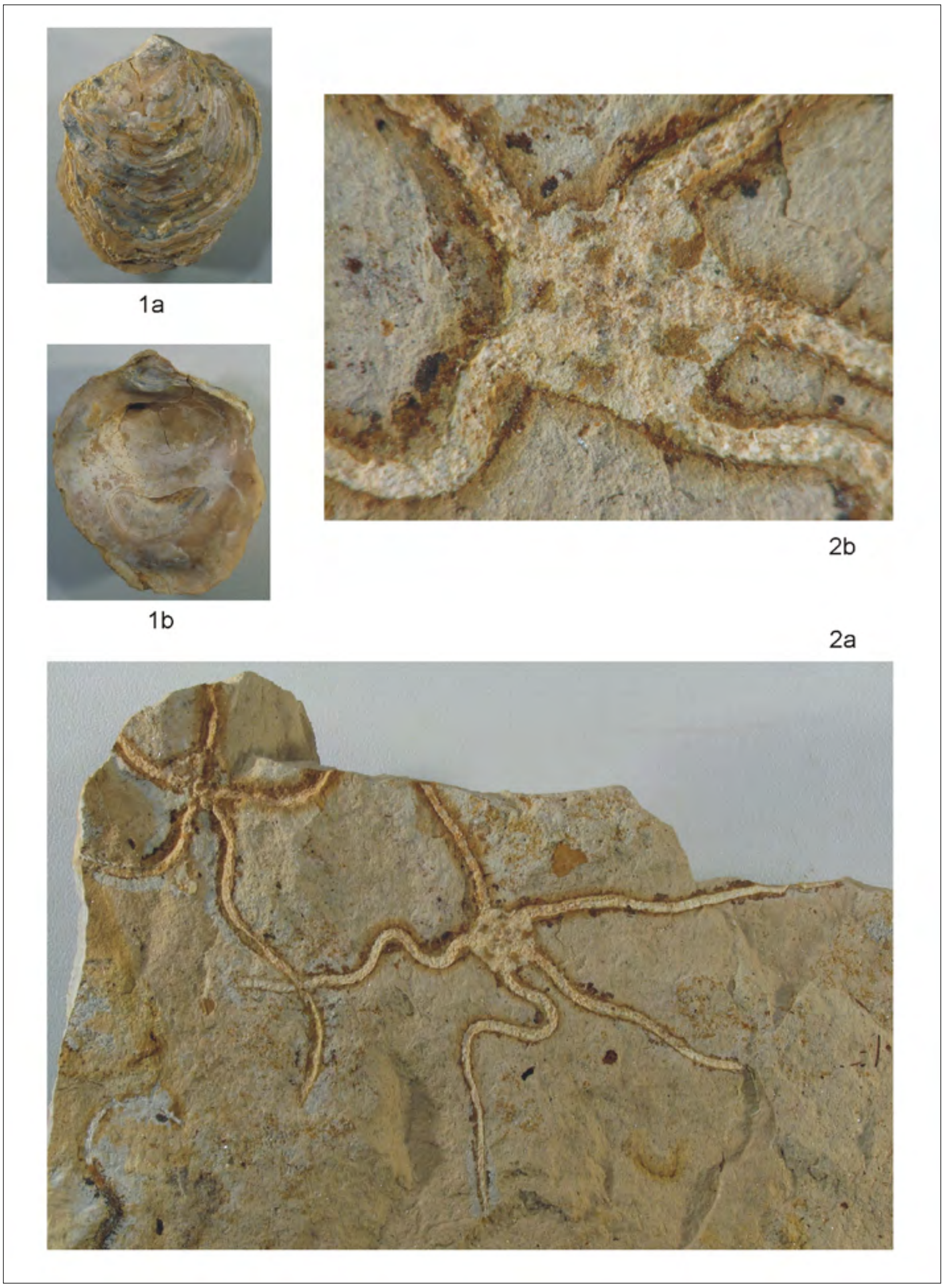
TABLA 3 – PLATE 3



1a *Ostrea lamellosa Brocchi*, 1814; okolica Lenarta v Slovenskih goricah, × 0,6
Ostrea lamellosa Brocchi, 1814; vicinity of Lenart in Slovenske gorice, × 0.6

1b *Ostrea lamellosa Brocchi*, 1814; okolica Lenarta v Slovenskih goricah, × 0,6
Ostrea lamellosa Brocchi, 1814; vicinity of Lenart in Slovenske gorice, × 0.6

2a Dva kačjerepa v miocenskem sljudnem laporovcu Meljskega hriba pri Mariboru; × 1,3
Two ophiurids in the Miocene micaceous marl of Meljski hrib near Maribor; × 1.3

2b Osrednja plošča kačjerepa z Meljskega hriba pri Mariboru; × 5
Ophiurid central disk of specimen from Meljski hrib near Maribor; × 5

Fotografije (Photographs): Marijan Grm

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Peloid iz zaliva Makirina (Severna Dalmacija, Republika Hrvaška) – njegova potencialna uporaba v balneoterapiji

Makirina bay peloid (N Dalmatia, Republic of Croatia) – its potential use in balneotherapy

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Key words: peloid, Makirina bay, potentially toxic elements (PTE), benthic algae *Codium bursa*, transfer factor (TF)

Izvleček

Recentne morske sedimente iz zaliva Makirina lahko glede na njihove organoleptične lastnosti obravnavamo kot zdravilno blato ali peloid, ki ga nekateri domačini in turisti že uporabljajo v obliki blatnih oblog. Uporaba peloidov v balneoterapiji je namenjena predvsem zdravljenju mišičnih, kostnih in kožnih obolenj ter sproščanju in velnesu. Številne nedavne raziskave peloidov so pokazale, da so eni izmed glavnih dejavnikov, ki pogojujejo (ne)uporabo peloida v balneoterapevtske namene, zrnavost, mineraloška sestava, kationska izmenjevalna kapaciteta (KIK), elementna in mikrobiološka sestava izvornega »geološkega materiala«. Iz rezultatov predhodnih raziskav je razvidno, da peloid iz zaliva Makirina gradi zelo slabo sortiran peščen mulj z visoko kationsko izmenjevalno kapaciteto (63,82 meq/100g). V mineralni sestavi peloida prevladujeta dolomit in kremen, sledijo ilit/muskovit, aragonit, kalcit, halit in pirit. Povprečne koncentracije potencialno toksičnih elementov (PTE) v peloidu iz zaliva Makirina, določenih v tokratni raziskavi znašajo: As (17,6 mg/kg), Cr (92,09 mg/kg), Cu (44,5 mg/kg), Mo (31,8 mg/kg), Pb (28,9 mg/kg) in Zn (69,2 mg/kg) in so primerljive z rezultati preteklih študij. Koncentracije PTE v bentoški algi *Codium bursi* (*C. bursa*) so sledeče: As (8,8 mg/kg), Cr (15,7 mg/kg), Cu (5,6 mg/kg), Mo (0,7 mg/kg), Pb (3,6 mg/kg) in Zn (16,3 mg/kg). Izračunani faktorji prenosa (TF) za PTE iz površinskega peloida (0–5 cm) v bentoško algo *C. burso* so manjši od 1, kar pomeni, da se PTE iz peloida ne prenašajo oziroma se v *C. bursi* ne akumulirajo. Rezultati prisotnosti koliformnih bakterij in *E. coli* se ujemajo s preteklimi rezultati, ki so pokazali, da jih v peloidu ni, kar nakazuje, da peloid ni fekalno kontaminiran. Peloid iz zaliva Makirina ima (z izjemo povišanih koncentracij Cr in Mo) primerljive lastnosti s peloidi, ki se trenutno že uspešno uporabljajo v različnih spa-centrih po svetu, vendar je treba pred potencialno uporabo opraviti dodatne raziskave, kot je na primer določitev mobilnosti Cr in Mo.

Abstract

Recent marine sediments from Makirina bay are according to their organoleptic properties, treated as peloid or healing mud, already frequently used by local people and tourists as pomades. The application of peloids in balneotherapy is mainly intended for therapeutic treatment generally related to muscle-bone skin pathologies and purposes of wellness and relaxation. Recent studies point out that one of the main factors determining the final characteristics of peloids are grain size distribution, mineralogy, cation exchange capacity (CEC), elemental and microbiological composition of initial »geological material«. As reported by previous studies Makirina Bay peloid is represented mostly by sandy silt with relatively high CEC value (63.82 meq/100g). Peloid mineral composition is dominated by dolomite and quartz, followed by illite/muscovite, aragonite, halite, calcite, and pyrite. The average concentrations of potentially toxic elements (PTE) in Makirina bay peloid determined in this research are: As (17.6 mg/kg), Cr (92.09 mg/kg), Cu (44.5 mg/kg), Mo (31.8 mg/kg), Pb (28.9 mg/kg) and Zn (69.2 mg/kg) and are comparable to previous results. PTE contents in benthic algae *Codium bursa* (*C. bursa*) are: As (8.8 mg/kg), Cr (15.7 mg/kg), Cu (5.6 mg/kg), Mo (0.7 mg/kg), Pb (3.6 mg/kg) and Zn (16.3 mg/kg). Calculated Transfer factors (TF) from surficial peloid (0-5 cm) to benthic algae *C. bursa* are <1 for all analysed PTE, indicating no PTE transfer or bioaccumulation of PTE in *C. bursa*. Results of microbiological research correspond to previous studies and showed no coliforms and *E. coli* presence in Makirina bay peloid. Our studies have shown the adequate comparability of Makirina Bay peloid with peloids already successfully used in various spa centres around the world in purposes related to wellness and therapy, but additional researches (determination of Cr and Mo mobilities) are necessary before potential use of Makirina bay peloid.

Uvod

Zaliv Makirina (severna Dalmacija, Republika Hrvaška) predstavlja plitvomorsko sedimentacijsko okolje, znotraj katerega se usedajo recentni (holocenski) sedimenti, bogati z organsko snovjo (Šparica et al., 1989). Le-te sedimente lahko glede na organoleptične lastnosti obravnavamo kot zdravilno blato ali peloid (Šparica et al., 1989), ki ga nekateri domačini in turisti že uporabljajo v obliki blatnih oblog.

Peloid je mulj oz. muljasta disperzija z zdravilnimi in/ali kozmetičnimi lastnostmi, sestavljena iz kompleksne zmesi drobnozrnatega materiala geološkega in/ali biološkega izvora, mineralne ali morske vode ter zelo pogosto tudi organskih spojin, ki so nastale kot posledica biološke metabolne aktivnosti (Gomes et al., 2013).

Zdravilni učinki peloidov so bili poznani že v obdobju starih Grkov in Rimljanov, ki so jih kot antiseptične obloge uporabljali za zdravljenje kožnih bolezni, brazgotin in celo kačjih ugrizov (Carretero et al., 2006). V zadnjih letih se je uporaba peloidov v zdraviliščih precej razširila, predvsem zaradi vse večjega zanimanja za naravna zdravilna sredstva (Veniale et al., 2007; Mihelčić et al., 2012). Uporaba peloidov v tako imenovani balneoterapiji, natančneje peloterapiji, je namenjena predvsem zdravljenju mišičnih, kostnih in kožnih obolenj ter sproščanju in velnesu (Veniale et al., 2007; Rebelo et al., 2010).

Številne nedavne raziskave peloidov so pokazale, da so eni izmed glavnih dejavnikov, ki pogojujejo uporabo oziroma neuporabo peloida v balneo- oziroma pelo-terapevtske namene, zrnavost, mineraloška sestava, kationska izmenjevalna kapaciteta (KIK) in elementna sestava izvornega »geološkega materiala« (Summa & Tateo, 1998; Mascolo et al., 1999; Veniale et al., 2004; Karakaya et al., 2010; Kalkan et al., 2012). Poleg že naštetih dejavnikov je eden izmed ključnih kazalnikov kakovosti mikrobiološka sestava izvornega »geološkega materiala«, kakor tudi »zrelega« peloida oziroma peloida, namenjenega direktni uporabi. Prisotnost patogenih bakterij (*Escherichie coli* in drugih koliformnih bakterij), ki so povzročiteljice različnih bolezni, lahko omeji ali celo izključi uporabo peloida v zdravstvene in/ali terapevtske namene (Bovonsombut et al., 2009; Quintela et al., 2012). Pri raziskavah primernosti uporabe peloidov v balneo- oziroma pelo-terapevtske namene so izredno pomembne tudi termične ter reološke lastnosti peloida (Rebelo et al., 2011).

Kljub številnim raziskavam na področju peloidov še vedno ni izoblikovanih smernic, ki bi določale mejne vrednosti PTE v peloidih in s tem njihovo kakovost. Zaradi tega se v literaturi večkrat uporabljajo smernice za kakovost kozmetičnih in/ali farmacevtskih produktov (Quintela et al., 2012). Tudi v Sloveniji in na Hrvaškem je zakonodaja na področju kakovosti peloidov pomanjkljiva. Smernicam za kakovost teh se tako v Republiki Sloveniji najbolj približa Zakon o naravnih zdravilnih sredstvih in o naravnih zdraviliščih (Uradni list SRS, 1964), Uredba (ES) o kozmetičnih izdelkih iz leta 2009 (Uradni list EU, 2009) ter Uredba o izvajanju Uredbe (ES) o kozmetičnih izdelkih (Uradni list RS, 2013), medtem ko v Republiki Hrvaški Zakon o predmetima opće uporabe (Narodne novine RH, 2013), Pravilnik o zdravstvenoj ispravnosti predmeta široke potrošnje (Narodne novine RH, 2009), Uredba (EZ) o kozmetičkim proizvodima (Uradni list EU, 2009) ter Zakon o provedbi Uredbe (EZ) o kozmetičkim proizvodima (Narodne novine RH, 2013). Je pa na Hrvaškem že v pripravi pravilnik »Kriteriji kakvoće prirodnih ljekovitih činitelja i njihove primjene u medicini i turizmu Hrvatske«, ki bo urejal uporabo naravnih zdravilnih sredstev (Krešić-Jurić, 2014) in bo temeljil predvsem na smernicah Evropskega združenja zdravilišč (ESPA-European Spas Assotiation) (Internet).

Na področju karakterizacije peloidov iz zaliva Makirina so v preteklosti že bile narejene posamezne študije (Šparica et al., 1989; Vreča, 1998; Lojen et al., 2004; Vreča & Dolenec, 2005; Šparica et al., 2005; Miko et al., 2007; Miko et al., 2008; Komar et al., 2013), vendar so bile raziskave bolj kot pa ne osredotočene samo na površinski peloid, to je zgornjih 5 cm. Celotni profili so bili sicer narejeni na treh mestih v zalivu, a le na enem v centralnem delu zaliva, to je točka M3/3 (Vreča, 1998).

Cilji tokratne raziskovalne naloge so: (i) podrobneje določiti vsebnost PTE (arzen (As), krom (Cr), baker (Cu), molibden (Mo), svinec (Pb) in cink (Zn)) v centralnem delu zaliva, kjer je peloid najbolj reprezentativen in dobljene rezultate primerjati z do sedaj znanimi rezultati (Vreča, 1998; Komar et al., 2013) (ii) vrednosti omenjenih PTE v peloidu iz zaliva Makirina primerjati z vrednostmi PTE v peloidih, ki se že uspešno uporabljajo v številnih spa-centrih po svetu, (iii) določiti koncentracije PTE v zalivu zelo razširjeni bentoški algi *Codium bursi*, (iv) oceniti faktorje prenosa (Transfer factors) iz peloida v *Codium burso* za obravnavane PTE, z namenom, da se predstavi, koliko se PTE akumulirajo v okolju in se poda ocena mobilnosti, ter (v) analizirati prisotnost morebitnih patogenih bakterij, kot so *Escherichia coli* in druge koliformne bakterije v peloidu iz zaliva Makirina.

Opis raziskovanega območja

Zaliv Makirina se nahaja v severni Dalmaciji (Republika Hrvaška), 18 km od mesta Šibenik in 44 km od mesta Zadar (Sl. 1). Je manjši zaliv (1250 m v dolžino in 350 m v širino), ki se razteza v smeri S–J in predstavlja južni krak večjega Pirovaškega zaliva. Globina vode v južnem delu redko preseže pol metra, medtem ko se v smeri proti severu poveča na 4,5 m (Šparica et al., 1989).

Okolica zaliva je kultivirana (vrtovi, vinogradi, nasadi oljk) in redko poseljena. Edino večje naselje v bližini je mesto Pirovac s približno 2000 prebivalci (Šparica et al., 1989).

Dno zaliva je prekrito z 0–3 m debelo plastjo peloida, poraščenega predvsem z morsko travo (*Cymodocea nodosa*) in bentoško algo (*Codium bursa*). Količina peloida je ocenjena na 410.000 m^3 (Šparica et al., 1989).

Širše območje zaliva Makirina gradijo karbonatne kamnine spodnje- in zgornje-kredne starosti ter kvartarni sedimenti (Šparica et al., 1989). Glede na litološke značilnosti in mikrofosilno združbo so bile določene naslednje litostratigrafske enote: dolomiti Ivinja ($K_{1,2}$), apnenci in dolomiti Makirine ($K_2^{1,2}$), rudistni apnenci Kamene (K_2^3) ter kvartarni sedimenti Ivinj Drage (Šparica et al., 2005).

Zrnavost, mineralna sestava in kationska izmenjevalna kapaciteta (KIK) peloida iz zaliva Makirina

Rezultati predhodnih raziskav (Komar et al., in press) kažejo, da peloid iz zaliva Makirina gradi zelo slabo sortiran peščen mulj. V vseh vzorcih prevladuje muljasta frakcija (glina+melj) nad peščeno, kar je posledica relativno mirnega sedimentacijskega okolja (Šparica et al., 1989; Šparica et al., 2005). Povprečna vsebnost peščene frakcije je 27 %, povprečna vsebnost muljaste frakcije pa znaša 73 %. Ugotovitve se ujemajo s preteklimi raziskavami (Šparica et al., 1989; Vreča et al., 1998; Šparica et al., 2005), ki dodajajo, da je v celotnem zalivu delež glinaste, meljaste in peščene frakcije relativno konstanten, medtem ko se v priobalnem delu znatno poviša delež prodnate frakcije (Vreča, 1998). Zrnavost peloida iz zaliva Makirina je posledica mineraloške sestave in izvora, saj kremen in delci lupin mehkužcev povečajo peščeno frakcijo. Ker v peščeni frakciji prevladuje razred drobnega peska (<250 µm), peščeni delež v peloidu ne prispeva bistveno k njegovi abrazivnosti, oziroma se lahko predhodno (pred potencialno uporabo) tudi odstrani (Komar et al., v tisku).

V mineralni sestavi peloida iz centralnega dela zaliva Makirina prevladujeta dolomit in kremen, nato pa še ilit/muskovit, aragonit, kalcit, halit in pirit. Pretekle raziskave mineralne sestave peloida iz zaliva Makirina dodajajo, da so vsebnosti glinenih mineralov, evaporitov, pirita in aragonita najvišje v sredini zaliva in se zmanjšujejo proti obali, medtem ko so koncentracije kremena in dolomita v centralnem delu zaliva nižje kot bližje obali (Vreča, 1998). Prevlada karbonatnih mineralov nad nekarbonatnimi sovpada z geološko sestavo ozadja zaliva Makirina, ki je zgrajeno predvsem iz dolomitov in apnencev. Glinene minerale predstavljata ilit/muskovit in v manjšem deležu klinoklor (Komar et al., in press). Le-ti so v peloidih pomemben faktor predvsem zaradi sposobnosti visoke kationske izmenjevalne kapacitete, ustreznih reoloških lastnosti (vplivajo na viskoznost in konsistenco peloida), visoke sorpcijske sposobnosti in sposobnosti ohranjanja toplote (Carretero et al., 2006). Prav tako lahko v peloidu iz zaliva Makirina izpostavimo tudi prisotnost organizmov, kot so školjke, saj se njihove biserne plasti (*nacre*), predvsem v tradicionalni (kitajski) medicini, že dolgo uporabljajo kot sredstvo za pospeševanje regeneracije kože (Lee et al., 2012). Karbonatni minerali prevladujejo tudi v zdravilnem blatu iz Mrtvega morja (Khlaifat et al., 2010) in peloidu zaliva Morinje (Mihelčić et al., 2012).

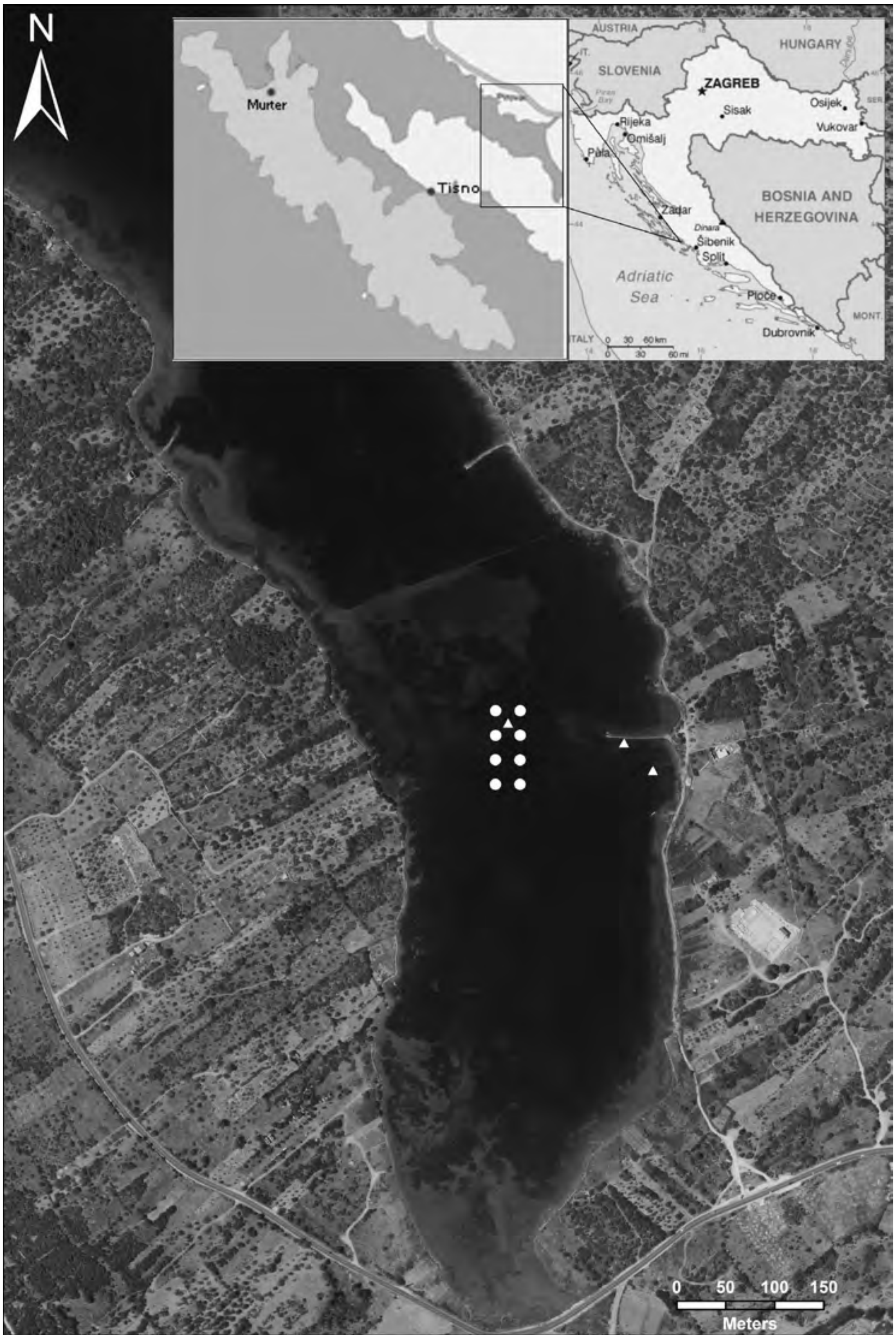
Peloid iz zaliva Makirina ima visoko KIK (63,82 meq/100g) (Komar et al., in press). Ker znaša KIK glinenih mineralov, kot je ilit, med 10 in 40 meq/100g (Weaver & Pollard, 1973), je ta najverjetneje povezana z vsebnostjo organske snovi v peloidu. KIK sedimentov je odvisna od prisotnosti glinenih mineralov in tudi od deleža organske snovi ter Fe in Al oksidov (Evans, 1989; Du Laing et al., 2009). Organski material v peloidu lahko poviša njegovo izmenjevalno kapaciteto in plastičnost kljub dejstvu, da je v peloidu prisoten majhen delež glinenih mineralov (Jobstraibizer, 2002; Carretero, 2006). Vsebnost organskega ogljika (C_{org}) v peloidu iz zaliva Makirina je med 4,08 in 5,53 % (Komar et al., v tisku). Kopičenje organske snovi v peloidu je predvsem posledica razpada vodnih rastlin (*Codium bursa*, *Cymodocea nodosa*), ki so v zalivu zelo razširjene. Visoka KIK peloidov omogoča izmenjavo hranilnih snovi, medtem ko je peloid v stiku s kožo, čisti telo z absorpcijo toksinov in bakterij ter ne nazadnje znotraj peloida zadrži morebitne PTE, ki bi lahko bili škodljivi za zdravje uporabnika (Carretero et al., 2006; Matike et al., 2011; Quintela et al., 2012).

Metode dela

Vzorčenje in analitika

Vzorčenje peloida je bilo izvedeno v poletnih mesecih leta 2010 na osmih različnih lokacijah v centralnem delu zaliva (sl. 1), kjer je peloid najbolj reprezentativen. Peloid je bil odvzet ročno, s plastičnimi jedrniki dolžine 50 cm in z notranjim premerom 5 cm. Globina vzorčenja je bila 25 cm, z izjemo na enem mestu, kjer je znašala 20 cm. Po odvzemu so bila peloidna jedra nemudoma zamrznjena. V laboratoriju so bili jedrniki razrezani na 5 cm dolge kose in zračno posušeni. Zatem so bili iz peloida odstranjeni ne-reprezentativni delci, kot so večji organski delci in delci kamnin. Peloid je bil strt v ahatni terilnici vse do homogeniziranega finega prahu (<63 µm).

Vzorci morske alge *C. burse* so bili pobrani v centralnem delu zaliva, na isti lokaciji kot je bil vzorčen peloid (sl. 1), na globini okoli 0,5 m. Vzorci *C. burse* so bili po vzorčenju nemudoma zamrznjeni. V laboratoriju so bili vzorci sprani z destilirano vodo, posušeni do konstantne mase ter pred nadaljnjimi elementnimi analizami zmleti in homogenizirani.



Sl. 1. Lokacija zaliva Makirina z označenimi mesti vzorčenja, (○) peloidni jedrniki in bentoška alga *C. bursa*, (Δ) vzorci peloida za mikrobiološke analize (DOF 1:5000, DGU Hrvaška)

Fig. 1. Research area of Makirina bay with sampling sites, (○) peloid corers and benthic algae *C. bursa*, (Δ) peloid samples for microbiological analyses (DOF 1:5000, DGU Croatia)

Elementna sestava peloida (vsebnost PTE kot so As, Cr, Cu, Mo, Pb in Zn) je bila določena s prenosnim rentgenskim fluorescenčnim analizatorjem (XRF-analizator) NITON model XL3t GOLDD 900S-He, na Oddelku za geologijo, Naravoslovnotehniška fakulteta, Univerza v Ljubljani. Meje zaznavnosti so za obravnavane elemente bile naslednje: As (5 mg/kg), Cr (22 mg/kg), Cu (13 mg/kg), Mo (3 mg/kg), Pb (10 mg/kg) in Zn (15 mg/kg). Pri merjenju sta bila uporabljena dva različna modula originalnega proizvajalca Soil in Mining. V času analize je bil dovajan plin helij zaradi boljše detekcije lahkih elementov (Mg, Si, Al, Ti in S). Čas merjenja na vsaki točki je bil za oba modula 180 sekund. Vsak vzorec je bil izmerjen dvakrat. Analitična točnost in natančnost sta bili preverjeni z uporabo referenčnih materialov (NIST-2709a, NRCC MESS3 in TILL-4). Primerjava med certificiranimi in izmerjenimi vrednostmi je podana v tabeli 1.

Koncentracije PTE (As, Cr, Cu, Mo, Pb in Zn) v bentoški algi *C. bursi* so bile izmerjene v akreditiranem kanadskem laboratoriju Actlabs (Activation laboratories, Canada), in sicer z visokoločljivostnim ICP-MS (masni spektrometer z induktivno sklopljeno plazmo) ter mikrovalovnim razklopom (microwave digestion) po raztopitvi v kislini (Aqua Regia). Meje detekcije za obravnavane elemente so bile sledeče: As (0,005 mg/kg), Cr (0,01 mg/kg), Cu (0,02 mg/kg), Mo (0,001 mg/kg), Pb (0,01 mg/kg) in Zn (0,2 mg/kg). Natančnost instrumenta in točnost analiz sta bili kontrolirani glede na referenčen material NIST 1575a (borove iglice). Meritve vzorcev so bile podvojene, primerjava med certificiranimi in izmerjenimi vrednostmi je podana v tabeli 1.

V vzorcih so bili izračunani tudi faktorji prenosa (TF), ki predstavljajo enega izmed pristopov za oceno mobilnosti posameznih PTE (Dean, 2007). TF je opredeljen kot razmerje med koncentracijo PTE v rastlini in koncentracijo istega PTE v sedimentu. Višji kot je TF, bolj je PTE mobilen oziroma dostopen okoliškemu ekosistemu (Dean, 2007). TF>1 označuje bioakumulacijo PTE v organizmih (Kalfakakou & Akrida-Demertzi, 2000).

Prisotnost patogenih bakterij (*Escherichie coli* in drugih koliformnih bakterij) je bila določena leta 2014, na treh različnih točkah (sl. 1) in sicer na eni v centralnem delu zaliva ter na dveh na obali, kjer je peloid dejansko že v uporabi. Vzorec peloida je za mikrobiološke analize moral biti svež (<24 h od časa vzorčenja do analiz). Vzorčenje je bilo ročno, s plastično (polietilensko) lopatko. Vzorci so bili spravljeni v sterilne plastične posodice in dani v hladilno torbo. Mikrobiološke analize peloida so bile opravljene v akreditiranem Nacionalnem laboratoriju za zdravje, okolje in hrano, Oddelku za mikrobiološke analize živil, vod in drugih vzorcev okolja, Enota Ljubljana, s kvalitativno mikrobiološko preiskavo in uporabo internih standardov, kot sta ŽIVILA-LJ-08 in ŽIVILA-LJ-14.

Rezultati in diskusija

Vsebnost PTE v peloidu iz zaliva Makirina in bentoški algi *C. bursi*

Vsebnosti PTE (As, Cr, Cu, Mo, Pb in Zn) v peloidu iz zaliva Makirina, v bentoški algi *C. bursa* in izračunani faktorji prenosa (TF) so podani v tabeli 2.

Vsebnosti obravnavanih PTE, pridobljene v pričujoči raziskavi so primerljive s koncentracijami preteklih študij (Vreča, 1998; Komar et al., 2013). Manjše odstopanje, ki se pojavlja gre pripisati uporabi različnih metod, saj so bile koncentracije PTE v predhodnih raziskavah (Vreča, 1998; Komar et al., 2013) določene z metodami ICP in ICP-MS, medtem ko v tokratnem delu z metodo XRF, ki pred merjenjem za razliko od metod ICP in ICP MS ne zahteva posebne predpriprave vzorcev.

V primerjavi z uporabljenimi smernicami za kozmetične in farmacevtske proizvode so v peloidu iz zaliva Makirina opažene povišane vsebnosti As, Cr, Mo in Pb (tabela 2), ki pa so že bile ugotovljene v preteklih študijah (Vreča, 1998; Šparica et al., 2005; Miko et al., 2007; Miko et al., 2008; Komar et al., 2013). Povišane vrednosti Pb avtorji pripisujejo antropogenim dejavnikom, natančneje posledici odtoka padavinske vode s cestišča (Šparica et al., 2005; Miko et al., 2007; Miko et al., 2008; Komar et al., 2013), medtem ko koncentracije As, Cr in Mo, avtorji preteklih študij opredeljujejo kot posledico anoksičnih pogojev v peloidu. Anoksični pogoji se v zalivu Makirina pojavijo že v najvišjem delu sedimentnega stolpca (Lojen et al., 2004). As, Cr in Mo so redoks občutljivi elementi, za katere je značilno, da se obogatijo v anoksičnih sedimentih (Legeleux et al., 1994).

Koncentracije obravnavanih PTE (z izjemo Cr in Mo) v peloidu iz zaliva Makirina ne presegajo vrednosti v peloidih, ki se trenutno že uporabljajo v različnih velnes centrih po svetu (Quintella et al., 2012).

Cr in Mo sta esencialna elementa za človekovo zdravje. Za esencialne elemente je značilno okno esencialnosti oziroma optimalna koncentracija. Njihovo pomanjkanje tako izzove poslabšanje bioloških funkcij in določene simptome, kadar pa je njihova koncentracija v telesu presežena, pride do toksičnih učinkov (Černe, 2009).

Tabela 1. Primerjava certificiranih in izmerjenjih vrednosti (enote: mg/kg)
Table 1. The comparison of certified and measured values (units: mg/kg)

Standard	As	Cr	Cu	Mo	Pb	Zn
NIST-2709a	*10,5±0,3*	130±9	*33,9±0,5*		17,3±0,1	*103±4*
NIST-2709a izmerjene/measured c	9,1±2,1	138,0±15	39±7,6		16,2±2,9	96,7±6,1
TILL-4	111		237	16	50	70
TILL-4 izmerjene/measured c	114,8±13,9		236±11,5	17,4±1,4	53,8±6,3	61,3±9,8
NRCC MESS3	21,2±1,1	105±4	33,9±1,6	2,78±0,07	21,1±0,7	159±8
NRCC MESS3 izmerjene/measured c	20,5±2,5	105±17,5	34,9±8,0	< DL	19,5±3,2	136,5±7,2
NIST 1575a			2,8±0,2		*0,167± 0,015*	38±2
NIST 1575a izmerjene/measured c			2,98		0,12	40,2

Referenčne vrednosti - Reference values
DL – Detection Limit (Meja detekcije)

Tabela 2. Povprečne vsebnosti PTE±Standardni odkloni (SD) v peloidu iz zaliva Makirina, bentoški algi *C. bursi* in izračunani faktorji prenosa (TF).
Table 2. Mean PTE concentrations±Standard deviation (SD) in Makirina bay peloid, benthic algae *C. bursa* and calculated Transfer factors (TF).

Globina/Depth [cm]	n	As [mg/kg]	As [mg/kg] (Vreča, 1998)	Cr [mg/kg]	Cr [mg/kg] (Vreča, 1998)	Cu [mg/kg]	Cu [mg/kg] (Vreča, 1998)	Mo [mg/kg]	Mo [mg/kg] (Vreča, 1998)	Pb [mg/kg]	Pb [mg/kg] (Vreča, 1998)	Zn [mg/kg]	Zn [mg/kg] (Vreča, 1998)
0–5	8	15,2±2,2	14	74,8±31,1	110	41,9±8,7	45	18,3±4,7	47***	27,4±5,0	36	67,8 ±6,7	68
5–10	8	15,7±5,0	19	88,3±29,3	110	46,7±10,5	36	29,3±9,6		30,5±4,9	28	71,3±10,3	57
10–15	8	17,8±1,9	16	91,6±40,3	110	49,9±17,2	24	31,1±7,7		29,7±5,5	24	72,4±10,5	56
15–20	8	19,2±5,5	15	103,4±49,4	88	44,9±13,0	16	39,1±14,6		29,1±5,5	23	68,5±12,0	45
20–25	7	19,9±3,3	18	99,0±40,3	120	38,9±8,4	19	42,3±11,8		27,7±5,9	25	66,2±11,5	54
Povprečna koncentracija±SD/ Mean concentration±SD		17,6±4,2	16,4±2,1	92,09±38,1	107,6±11,8	44,5±12,1	28±12,2	31,8±12,8		28,9±5,2	27,2±5,3	69,2±10,0	56±8,2
QUINTELA et al., 2012		n.p.-39		n.p.-68,2		n.p.-601,1		n.p.-4,4		n.p.-37,5		n.p.-160,4	
Smernice/ Guidelines		3*		<25**		<250**		<25**		<10*		<1300**	
Codium bursa		8,8		15,7		5,6		0,7		3,6		16,3	
TF (razpon)/TF (range)		0,48-0,73		0,13-0,45		0,1-0,2		0,03-0,06		0,11-0,19		0,21-0,29	

n=število vzorcev v tokratni raziskavi/number of samples in present research
n.p.: ni prisoten/not present
*kozmetični produkti (HEALTH CANADA, 2009)/cosmetic products (HEALTH CANADA, 2009)
**farmacevtski produkti (EMEA, 2008)/pharmaceutical products (EMEA, 2008)
*** točka M1/2/sampling site M1/2

Cr se v okolju najpogosteje pojavlja v dveh različnih oksidacijskih stanjih, in sicer Cr(III) ter Cr(VI). Cr(III) je esencialen, saj prispeva k presnovi glukoze in uravnava krvni sladkor (Gomes in Silva, 2007), medtem ko bolj toksičen Cr(VI) v okolju najpogosteje nastopa kot rezultat različnih industrijskih procesov (EPA, 2000). Z ozirom na ICH (International conference on harmonisation – Mednarodna konferenca za harmonizacijo) Q3D (Guideline for elemental impurities) Cr pripada razredu 3, kamor ICH uvršča nečistoče z razmeroma nizko toksičnostjo in visoko dovoljeno dnevno izpostavljenostjo (PDE - Permitted daily exposure). To sicer velja le za peroralno uporabo zdravil/farmacevtskih sredstev (zaužitje skozi usta) in ne za druge poti vnosa zdravil/farmacevtskih sredstev (kot sta npr. inhalacija in parenteralna uporaba), ki pri oceni tveganja zahtevajo dodatno obravnavo. Med aplikacijo peloidov esencialni elementi in PTE prehajajo iz peloida v telo, ter obratno (Carretero et al., 2010). Carretero in sodelavci (2010) so določevali mobilnost elementov (vključno s Cr) v interakciji peloid-umeten pôt ter ugotovili, da krom ni mobilen oziroma se je v primeru naravnega lagunskega peloida (Lo Pagán, Španija; totalna koncentracija Cr je 42,3 mg/kg) izlužil v zelo majhnih koncentracijah (manj kot 0,05 mg/kg).

Mo je esencialen element, saj prispeva k naravni rasti in razvoju (Gomes & Silva, 2007). ICH Q3D uvršča Mo v razred 2, k elementom, katerih toksičnost je bolj ali manj odvisna od načina uporabe. Evropska agencija za zdravila (EMEA, 2008) je za Mo v farmacevtskih proizvodih pripisala koncentracije <25 mg/kg.

Izračunani TF iz površinskega peloida (0–5 cm) v *C. burso* so za vse obravnavane PTE manjši od 1 (tabela 2). To pomeni, da PTE iz peloida okoliškemu ekosistemu niso dostopni, oziroma se v *C. bursi* ne akumulirajo.

Mikrobiološka sestava peloida iz zaliva Makirina

Sedimenti služijo kot rezervoar za številne mikroorganizme, kajti veliko število mikroorganizmov se po izpustu v morsko okolje usede na morsko dno. Vsebnost mikroorganizmov je po navadi višja v sedimentih kot pa v morski vodi, saj so v sedimentu pogoji preživetja ustreznejši (zaščita, višje vsebnosti hranilnih snovi) (Jimenez, 2009). Ravno zaradi tega je pri oceni kakovosti določenega vodnega okolja, poleg mikroorganizmov v vodi, pomembna tudi določitev mikroorganizmov (fekalnih indikatorjev) v sedimentu (Jimenez, 2009).

E. coli in druge koliformne bakterije so pomembni indikatorji fekalnega onesnaženja okolja; predvsem *E. coli*, prisotnost katere nakazuje na nedavno fekalno onesnaženje (Jimenez, 2009).

Rezultati mikrobioloških analiz, natančneje analiza prisotnosti koliformnih bakterij in *E. coli*, so podani v tabeli 3. Rezultati preiskav so pokazali, da v peloidu ni prisotnih obravnavanih bakterij, kar nakazuje, da peloid iz zaliva Makirina ni fekalno kontaminiran in je s tega vidika varen za uporabo.

Med patogene mikroorganizme, ki se lahko pojavijo v peloidu ESPA, poleg *E. coli* in drugih koliformnih bakterij, uvršča še *Pseudomonas aeruginoso*, *Staphylococcus aureus*, *Candido albicans*, *Salmonello* in *Aspergillus niger* (ESPA, 2006). Mikrobiološki pogoji za kozmetične izdelke so podani tudi v 7. členu Uredbe o izvajanju Uredbe (ES) o kozmetičnih izdelkih (Uradni list RS, 2013), ki pravi, da kozmetični izdelki ne smejo vsebovati mikroorganizmov, kot so *Pseudomonas aeruginosa*, *Staphylococcus aureus* in *Candida albicans*.

V standardih ESPE iz leta 2006, je zapisano, da mora biti kontrola kakovosti peloida izvedena na vsakih 10 let. Šparica in sodelavci (1989) so v peloidu iz zaliva Makirina določevali prisotonost sledečih mikroorganizmov: *Salmonelle sp.*, *Pseudomonas aeruginose*, *Sulfitred. clostridium*, *Streptococcus faecalis*, koagulaza pozitivne stafilokoke in koliformne bakterije. Ugotovili so, da vzorci peloida niso vsebovali mikroorganizmov v takšnih količinah, da bi lahko ogrozile zdravje tistih ljudi, ki bi peloide uporabljali kot naravno zdravilno sredstvo. Mikrobiološke analize je ponovil Miko s sodelavci (2008), ki prav tako v peloidu iz zaliva Makirina ni določil prisotnosti patogenih bakterij iz družin *Streptococcaceae*, *Enterobacteriaceae*, *Bacillaceae* in *Pseudomonadaceae*, oziroma rodov *Streptococcus*, *Escherichia*, *Salmonella*, *Schigella*, *Clostridium* in *Pseudomonas*.

Iz pregleda preteklih in rezultatov sedanjih raziskav lahko zaključimo, da se obravnavane patogene bakterije v peloidu iz zaliva Makirina ne pojavljajo, kar potrjuje kakovost peloida. Prihodnje raziskave bodo vsekakor usmerjene v ponovno določitev drugih mikrobioloških parametrov (predvsem ostalih patogenih bakterij), ki so nujni za oceno kakovosti peloida iz zaliva Makirina.

Tabela 3. Rezultati mikrobiološke preiskave peloida iz zaliva Makirina

Table 3. Results of microbiological analysis of Makirina bay peloid

Parameter	Preiskovana količina/Sample quantity	Rezultat /Result	Enota/Unit
Koliformne bakterije/Coliforms	100g	ni najdeno/not found	v 100 g/In 100 g
E. coli	100g	ni najdeno/not found	v 100 g/In 100 g

Zaključki

Iz predstavljenih rezultatov je razvidno, da so koncentracije potencialno toksičnih elementov v peloidu iz zaliva Makirina podobne vrednostim, ki so bile določene v preteklih študijah. Izračun faktorja prenosa je pokazal, da PTE iz peloida okoliškemu ekosistemu niso dostopni, oziroma se v *C. bursi* ne akumulirajo. Večina PTE v peloidu iz zaliva Makirina ne presega koncentracij v peloidih, ki se že uspešno uporabljajo v različnih velnes centrih po svetu. Tako ima peloid iz zaliva Makirina (z izjemo povišanih koncentracij Cr in Mo) primerljive lastnosti, vendar je treba pred morebitno potencialno uporabo peloida opraviti dodatne raziskave. Posebna pozornost mora biti v prihodnjih raziskavah namenjena morebitni prisotnosti patogenih organizmov kot so *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Candida albicans*, *Salmonella* in *Aspergillus niger* ter PTE, še posebej Cr in Mo, določiti njuno speciacijo, mobilnost ter s tem njuno biodostopnost. V bodoče je potrebno podrobneje raziskati tudi vpliv elementov, kot so kadmij (Cd), kobalt (Co), nikelj (Ni) in živo srebro (Hg), ki v tej študiji niso bili podrobneje raziskani, so pa prav tako lahko problematični.

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Morfološke značilnosti in vzroki za obarvanost kristalov kalcita iz Liboj

Morphological characteristic and causes of color for the crystals of calcite from Liboje

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Key words: calcite, morphology of crystals, goethite, marcasite, Liboje, Slovenia

Izvleček

Raziskali smo kristale kalcita iz kamnoloma Liboje in jih primerjali s kristali kalcita iz drugih kamnolomov v širši okolici Celja. Pri kristalih kalcita iz kamnoloma Liboje prevladujejo kristalne forme položnega romboedra (012), ki se jim v kasnejši fazi kristalizacije pridružijo kristalne forme strmih romboedrov. Kristalizacija je potekala iz segretih vodnih raztopin znotraj razpok v karbonatnih kamninah. Ugotovili smo, da je rast kristalov kalcita iz Liboj povezana z vsaj dvema dogodkoma v geološki zgodovini, ko so se segrele vodne raztopine in posredno povzročile kristalizacijo mineralov v razpokah znotraj karbonatnih kamnin. Barva kristalov kalcita pa je povezana tako z vključki trde faze, kot so manganovi oksidi in goethit, kot s tekočinskimi vključki - vodo. Mineralno sestavo vključkov smo določili z ramansko mikrospektroskopijo.

Abstract

The crystals of calcite from the quarry Liboje were investigated and compared with calcite crystals from other quarries in the surrounding area of Celje. In calcite crystals from the Liboje quarry, the crystal form of flat rhombohedron faces were predominant (012). At a later stage of crystallization, the crystal form of steep rhombohedrons prevailed. They crystallised from hot aqueous solution in the fissures within carbonate rocks. It was ascertained that the crystal growth of calcite from Liboje was related to at least two events in geological history. The colour of calcite crystals is associated with both the solid phase inclusions, such as manganese oxide and goethite, and by liquid inclusions - water. Mineral composition of inclusions was determined by Raman microspectroscopy.

Uvod

V širši okolici Celja je več kamnolomov v karbonatnih kamninah triasne starosti v katerih lahko znotraj votlinic in razpok najdemo kristale kalcita, ki imajo razvite različne kristalne forme, včasih pa lahko na istem vzorcu ugotovimo več generacij kristalov kalcita. Ti kamnolomi so Velika Pirešica, Pečovnik, Sv. Andraž, Podgora in Liboje. Kalciti iz Liboj so navidezno morfološko najbolj preprosti, vendar različnih barv, dosedanje najdbe pa nakazujejo tudi rasti fantomskih kristalov kalcita (Jeršek & Pajtler, 2006).

Kalcit je eden pogostejših mineralov v Zemljini skorji in nedvomno eden najbolj razširjenih mineralov na površju Slovenije, saj gradi kamnino apnenec, ki je najbolj razširjena kamnina pri nas. Tako je kalcit tudi najpogostejši mineral, ki ga najdemo v kamnolomih na Slovenskem, saj je velika večina odprtih kopov prav v karbonatnih kamninah. Kristale kalcita najdemo v votlinicah in zaprtih razpokah znotraj apnenca ali pa v odprtih razpokah, ki sekajo okolne kamnine. Dosedanje morfološke raziskave kristalov kalcita v povezavi z različnimi kinematskimi fazami nam razkrivajo, da lahko posamezne razpoke in s tem rast kristalov kalcita v njih, povezujemo z različnimi prelomi (Žalohar & Jeršek, 2006) in s tem sklepamo tudi na rast kristalov kalcita v več generacijah.

Morfološke značilnosti kalcita nam lahko veliko povedo o razmerah, pri katerih so nastali. Dokazano je, da je prav oblika njegovih kristalov tesno povezana s temperaturo in tlakom geološkega okolja ob njihovem nastanku (Jeršek, 2003). Prav tako na njihovo morfologijo vplivajo razmerje Ca^{2+}/CO_3^{2-} in pH, vsebnost posameznih prvin kot so Sr^{2+}, Mg^{2+} in Mn^{2+} ali prisotnost SO_4^{2-}, pa tudi organske spojine v vodni raztopini iz katere kristali kalcit (Kostov & Kostov, 1999). Številne raziskave o morfologiji kalcita dokazujejo, da relacije med morfologijo in razmerami v času kristalizacije nekega minerala sploh niso tako zelo preproste, kot bi si to morda želeli. Očitno je pomembna tudi kombinacija posameznih parametrov in ne samo odvisnosti od temperature in tlaka, ampak tudi od pH/Eh in/

ali prisotnosti različnih ionov v vodni raztopini (Jeršek & Mirtič, 2005).

Generalno velja, da nastajajo pri najvišjih temperaturah tankoploščati, skoraj lističasti kristali kalcita. Nato sledi kristalizacija skalenoedrskih kristalov, romboedrskih kristalov z različnimi tipi kristalnih likov, prizmatskih kristalov ter na koncu kristalizacija strmoromboedrskih in strmoskalenoedrskih kristalov (Kostov & Kostov, 1999). Lističaste do tankoploščaste kristale kalcita so v dosedanjih raziskavah kristalov kalcita iz slovenskih nahajališč našli samo na Pohorju. Skalenoedrske oblike kalcitov so pogoste v razpokah znotraj apnencev. Običajno so preraščene s kristali kalcita mlajših generacij, za katere so značilni predvsem strmoromboedrski kristali kalcita, ki se zaključujejo s položnimi romboedri (Jeršek & Herlec, 2009).

V nekaterih kamnolomih apnenca zgornjetriasne starosti v okolici Celja lahko najdemo morfološko pestro oblikovane kristale kalcita. Kamnolomi z bolj ali manj popolnimi kristali kalcita so: Velika Pirešica (Jeršek et al., 2006), Sv. Andraž pri Polzeli, Podgora pri Šmartnem ob Paki, Liboje (Jeršek & Pajtler, 2006), Pečovnik (Jeršek & Podgoršek, 2006) in Sotensko (Rečnik, 2006). Kristali kalcita iz omenjenih kamnolomov, ki jih lahko občudujemo s prostim očesom, so vezani predvsem na razpoke in votlinice znotraj apnencev. Te so lahko tudi zaglinjene. Večinoma so kristali kalcita priraščeni na podlago ali pa se nahajajo kot odlomki v glini znotraj razpok. Včasih so najdeni kristali, ki so z vseh straneh omejeni s kristalnimi ploskvami. Kot skoraj edina spremljajoča minerala kalcitu v omenjenih nahajališčih, ali vsaj takšna, da ju lahko prepoznamo s prostim očesom, sta pirit ali markazit. Zaradi oksidacijskih pogojev sta v kamnolomih običajno limonitizirana. Tako je v primeru mineralne združbe v kamnolomu Pečovnik (Jeršek & Podgoršek, 2006), iz Sotenskega (Rečnik, 2006) in Velike Pirešice (Jeršek et al., 2006).

Velika večina kristalov kalcita v obravnavanih kamnolomih je brezbarvna. Prevleke železovih hidroksidov jih lahko navidezno obarvajo rumeno (Jeršek et al., 2006). Če je limonita več, lahko povsem prekriva kristale in podlago tako, da so skupki kristalov kalcita povsem rumeni do oranžni, rdečkasti, ponekod v Libojah skoraj povsem rjavi. Kalcit iz Liboj je lahko zaradi drobnih kepastih vključkov koloidnih delcev, ki so svetlo do temno rjave in celo črne barve, v obliki fantomskih kristalov (Jeršek & Pajtler, 2006).

Kristali kalcita iz Liboj imajo razvite samo položne romboedre (012), ki so jih po njihovi značilni formi poimenovali *libojski tip* kalcita. Zaradi vključkov je prepoznana tudi fantomska rast kristalov kalcita (Jeršek & Pajtler, 2006).

Kamnolom Liboje leži v gričevnatem predelu ob južnem robu spodnje Savinjske doline, na

Sl. 1. Kristali kalcita iz Liboj so brezbarvni do beli in prosojni do prozorni, 45 × 40 mm.

Fig. 1. Calcite crystals from Liboje are colorless to white and translucent to transparent, 45 × 40 mm.

Sl. 2. Oranžni do oranžno rjavi kristali kalcita iz Liboj so obarvani zaradi tanke prevleke iz goethita, 35 × 20 mm.

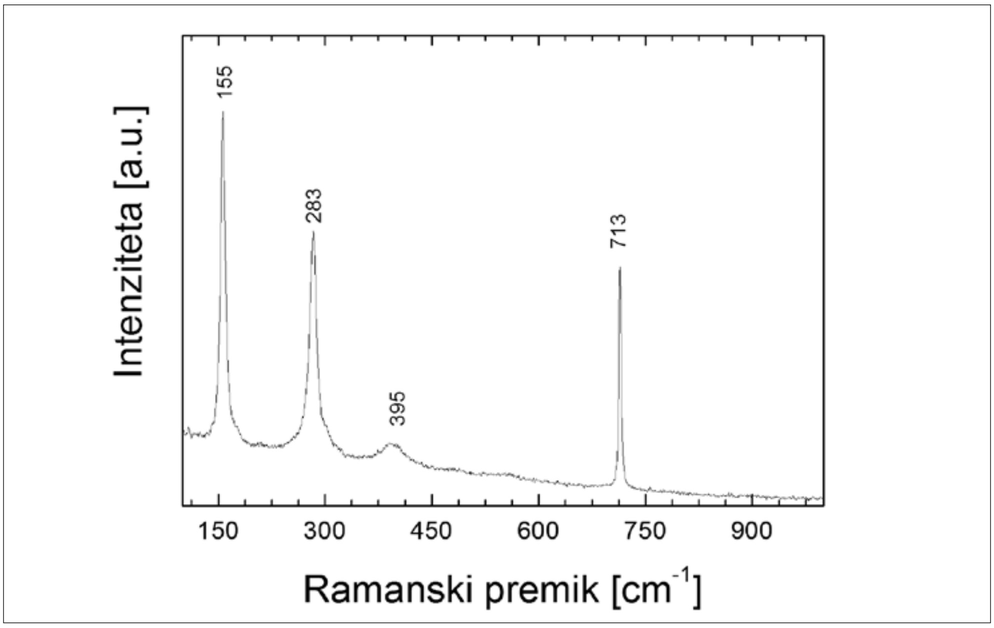
Fig. 2. Orange to orange- brown crystals of calcite from Liboje are colored due to a thin coating of goethite, 35 × 20 mm

Sl. 3. Temno sivi do skoraj črni kristali kalcita iz Liboj so obarvani zaradi vključkov manganovih oksidov, 45 × 30 mm.

Fig. 3. Dark gray to almost black crystals of calcite from Liboje are colored due to inclusions of manganese oxides, 45 × 30 mm.

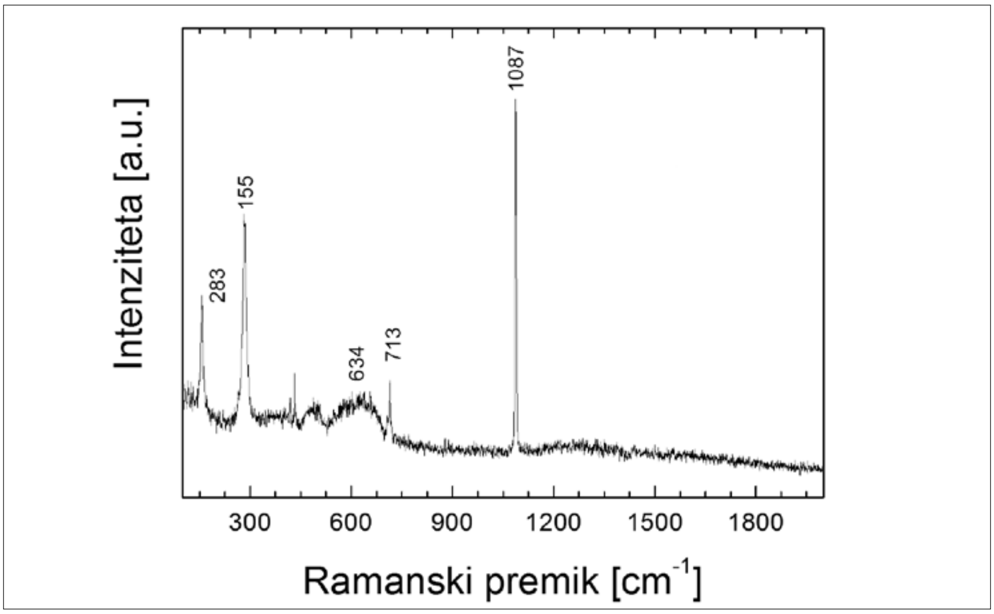
Sl. 4. Beli kristali kalcita iz Liboj imajo v zunanjih delih kristalov številne tekočinske vključke, ki vplivajo na videz kristalov, 40 × 25 mm.

Fig. 4. White crystals of calcite from Liboje have in the outer parts of the crystals a lot of fluid inclusions, which affecting on the appearance of the crystals, 40 × 25 mm.



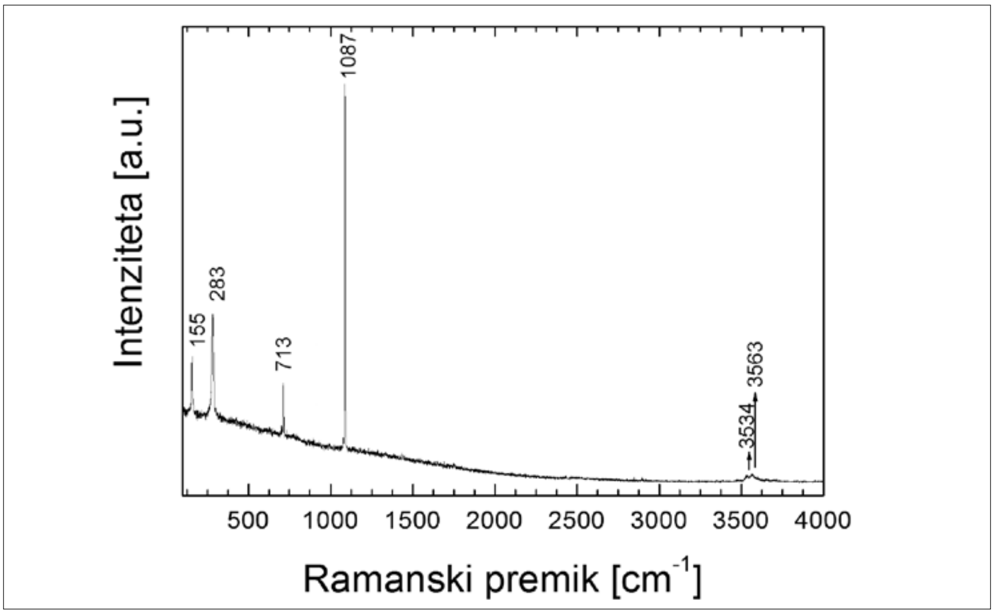
Sl. 5. Ramanski spekter nam v oranžnem vzorcu kalcita poleg kalcita razkriva prisotnost goethita (ramanski trak pri 395 cm^{-1}).

Fig. 5. Raman spectrum shows in orange coloured sample of calcite the presence of calcite and goethite (Raman band at 395 cm^{-1}).



Sl. 6. Ramanski spekter temno sivo obarvanega kalcita nam poleg kalcita razkriva prisotnost manganovega oksida (ramanski trak pri 634 cm^{-1}).

Fig. 6. Raman spectrum shows in dark gray coloured sample of calcite the presence of calcite and manganese oxide (Raman band at 634 cm^{-1}).



Sl. 8. Ramanski spekter nam v belih vzorcih kalcita poleg kalcita razkriva prisotnost tekočinskih vključkov – vode (ramanska trakova pri 3534 in 3563 cm^{-1}).

Fig. 8. Raman spectrum show us in white samples of calcite the presence of calcite and water (Raman bands at 3534 and 3563 cm^{-1}).

pobočju hriba Kotečnik (772 m) ob potoku Bistrica, v zgornjetriasnem apnencu v bližini tektonskega stika s predorninami (keratofir, diabaz s tufi) ladinijske stopnje. Ob Libojskem prelomu so ladinijske predornine ločene od zgornjetriasnega apnenca. Manjši prečni prelomi so mlajši in kamnina je ob njih bolj zdrobljena. Plasti apnenca so zakrasele (Ciglar, 1980; Iskra, 1981).

Materiali in metode

Pregledali smo 40 vzorcev kristalov kalcita iz kamnoloma Liboje iz zbirke Prirodoslovnega muzeja Slovenije in iz zasebnih zbirk. Od tega smo podrobneje analizirali 18 vzorcev, ki so se razlikovali po barvi, vključkih in morfoloških značilnostih.

Pri pregledu vzorcev je bila uporabljena stereolupa znamke WILD, model M8 z uporabo hladne svetlobe in s povečavami od 6,5 do 40×.

Analize vzorcev so bile izvedene z ramanskim mikrospektrometrom LabRAM HR900 (Horiba Jobin-Yvon) povezan z mikroskopom Olympus BXFM. Za analizo je bil uporabljen laser valovne dolžine 633 nm. Spektri so bili posneti z uporabo CCD detektorja s spektralno resolucijo cca. 1 cm^{-1}. Kalibracija spektrometra je bila izvedena s silicijevim kristalom. Spektri so bili posneti v območju 100 cm^{-1} do 4000 cm^{-1}.

Risbe kristalov kalcita smo narisali z računalniškim programom Kristall2000 na osnovi osnega razmerja a : c = 1 : 0,855.

Rezultati

Kristali kalcita iz Liboj so večinoma brezbarvni (sl. 1) ali pa rahlo rumenkasto oranžni (sl. 2), rjavi do skoraj črni (sl. 3) in beli (sl. 4). Vzroki za obarvanost so predvsem trdni vključki, ki smo jih analizirali z metodo ramanske mikrospektroskopije in ugotovili, da so rumeni in oranžni odtenki povezani s prevleko iz železovih hidroksidov, tj. goethita (sl. 5). Temno rjavi do skoraj črni kalciti imajo veliko vključkov manganovih oksidov (sl. 6), ki so ponekod tudi kot prevleka ali pa jih je celo toliko, da tvorijo brezoblične mase med kristali kalcita (sl. 7). Beli kristali kalcita imajo brezbarvna jedra. Z ramansko mikrospektroskopijo smo ugotovili, da zgornji deli kristalov kalcita vsebujejo vodo (sl. 8). To nas navaja na dejstvo, da imajo beli kristali kalcita v zgornjih delih tekočinske vključke. Morda so bili v kalcit zajeti kot posledica zmrzali in ponovne rekristalizacije.

Pri pregledu vzorcev kristalov s pomočjo stereolupe smo odkrili, da so poleg kristalov kalcita z razvitimi položnimi romboedri (012) (sl. 9) tudi takšni, ki imajo bolj ali manj izražene strme romboedre (sl. 10 in 11). Idealizirane oblike kristalov kalcita so prikazane na sliki 12.

Obarvanost kristalov kalcita iz Liboj nam razkriva več faz kristalizacije. Zaradi obarvanosti starejše generacije kalcita, je njihova morfologija dobro vidna. Ugotovili smo, da imajo tudi kristali kalcita starejše generacije razvite položne romboedre (012). Mlajša generacija kristalov kalcita je običajno brezbarvna. Lepo je opazna, kadar so se na ploskve romboedra starejše generacije odložili trdni vključki manganovih oksidov in/ali markazita (sl. 13). Na nekaterih kristalih kalcita smo namreč našli še drobne snežno bele skupke kristalov kalcita, ki so nastali med zadnjimi (sl. 4).

Diskusija

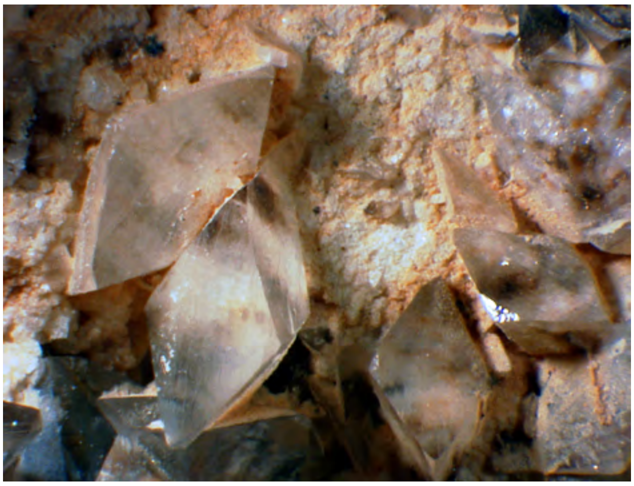
Kristali kalcita iz Liboj so morfološko dokaj preprosti, saj v večini primerov na kristalih kalcita prevladujejo forme položnega romboedra (012) (Jeršek & Pajtler, 2006). Prav na osnovi morfoloških značilnosti pa smo ugotovili, da so kristali kalcita iz Liboj rastli v dveh fazah. Za starejšo fazo kristalizacije so značilni kristali z izključno kristalnimi formami položnega romboedra, ki so ga do sedaj popularno imenovali »libojski tip« kalcita (Jeršek & Pajtler, 2006). V mlajši fazi kristalizacije pa se kristalnim formam pridružujejo še kristalne forme strmih romboedrov, ki so na kristalih kalcita bolj ali manj izražene. To se sklada z generalnim kristalogenetskim trendom (Kostov & Kostov, 1999), podobno zaporedje kristalizacije kalcita pa so odkrili tudi pri kalcitih iz drugih kamnolomov. Tako strmoromboedrski kristali kalcita preraščajo skalenoedrske kristale kalcita v Veliki Pirešici (Jeršek et al., 2006) in v kamnolomu Sv. Andraž pri Polzeli, enako pa je tudi v drugih nahajališčih kalcita v Sloveniji, kot na primer v kamnolomu Povodje (Žalohar & Jeršek, 2006). Kristali kalcita s prevladujočo kristalno formo položnega romboedra so znani iz kamnolomov v širši okolici Celja; Libojah (Jeršek & Pajtler, 2006), Pečovniku (Jeršek & Podgoršek, 2006) in Veliki Pirešici (Jeršek et al., 2006). Razlika med njimi je le v tem, da smo v primeru kristalov kalcita iz Liboj odkrili, da se je rast kristalov kalcita s prevladujočo kristalno formo položnega romboedra ustavila in se nato nadaljevala v mlajši fazi kristalizacije. Vmes so se izločili sulfidni minerali in minerali manganovih oksidov. Vse omenjeno nas navaja na hipotezo, da so morfološko enaki kristali kalcita v votlinicah in razpokah v karbonatnih kamninah rastli v isti fazi kristalizacije. Danes jih najdemo v različnih kamnolomih in zgolj od odprtosti razpok in njihove relativne globine je odvisno kateri tip kristala kalcita bomo našli. Na osnovi morfoloških značilnosti kristalov kalcita lahko zaključimo, da se je rast kristalov kalcita v določeni fazi ustavila in se nadaljevala, ko so se vodne raztopine dovolj segrele, da so nastali kristali kalcita mlajše generacije. Ker je njihova oblika kristalov drugačna od kristalnih form, ki so značilne za kraške jame (Zupan Hajna, 2006; Pogačnik et al, 2006), in so povezane z relativno višjimi temperaturami in/ali tlaki (Kostov &

Sl. 7. Manganovi oksidi so ponekod ohranjeni kot brezoblične mase med kristali kalcita, 40 × 30 mm.

Fig 7. Manganese oxides are sometimes preserved as amorphous mass between the crystals of calcite, 40 × 30 mm .

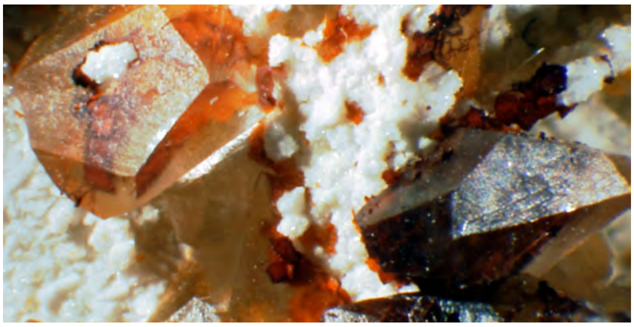
Sl. 9. Kristali kalcita iz Liboj z razvitimi kristalnimi formami položnega romboedra (012), 20 × 15 mm.

Fig. 9. Calcite crystals from Liboje with developed crystal form of a flat rhombohedron (012), 20 × 15 mm.



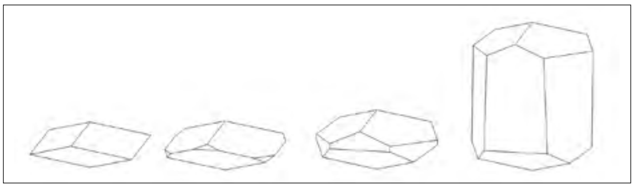
Sl. 10. Kristalom kalcita iz Liboj z razvitimi kristalnimi formami položnega romboedra (012) se pridružujejo drobne kristalne forme strmih romboedrov, 20 × 15 mm.

Fig. 10. Crystal of calcite from Liboje with developed crystal form of flat rhomohedron (012) together with tiny crystal forms of steep rhomohedrons, 20 ×1 5 mm



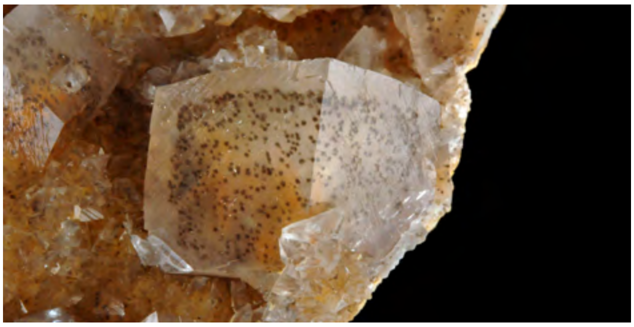
Sl. 11. Kristali kalcita iz Liboj s prevladujočo kristalno formo položnega romboedra (012) in z jasno vidnimi in prepoznavnimi kristalnimi formami strmih romboedrov, 15 × 10 mm.

Fig.11. Calcite crystals from Liboje with the predominant crystal form of a flat rhombohedron (012) and clearly visible and identifiable crystal form of a steep rhombohedrons, 15 × 10 mm



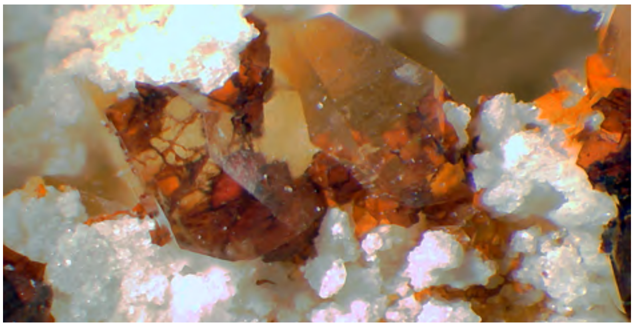
Sl. 12. Idealizirani kristali kalcita iz Liboj. Od leve proti desni si sledijo: kalcit s kristalno formo položnega romboedra (012) in nato primeri z vedno bolj izraženimi kristalnimi formami strmega romboedra.

Fig. 12: Idealized crystals of calcite from Liboje. From left to right are: calcite with a crystal form of a flat rhomohedron (012), and then examples with increasingly expressed crystal form of steep rhombohedron.



Sl. 13. Vključki manganovih oksidov in markazita so nastali po končani starejši fazi kristalizacije kalcita in so ujeti v mlajšo fazo kristalov kalcita iz Liboj, 35 × 22 mm.

Fig. 13. Inclusions of manganese oxides and marcasite crystallized after the older stage of crystallization of calcite and are trapped in a younger crystals of calcite crystals from Liboje, 35 × 22 mm.



Sl. 14. Med zadnjimi minerali v kamnolomu Liboje so nastali snežno beli kristali kalcita najmlajše generacije.

Fig. 14. Among the youngest minerals in the quarry Liboje are snow - white crystals of calcite.

Kostov, 1999), lahko kristalizacijo kristalov kalcita povežemo z vsaj nekoliko segretimi vodnimi raztopinami.

Dosedanje raziskave kristalov kalcita iz Liboj so razkrile različno obarvanost tega minerala (Jeršek & Pajtler, 2006). Z ramansko mikrospektroskopijo smo ugotovili, da na rumeno in rumeno rjavo barvo kristalov kalcita vplivajo prevleke goethita, na sivo do črno barvo pa vključki manganovih oksidov. Le ti so lahko tudi kot vključki na starejših kristalih kalcita in zaradi tega sta starejša in mlajša generacija kalcita dobro vidni, včasih že s prostim očesom. Na barvo kristalov kalcita vplivajo tudi drobni kristali markazita. Posebno zanimivi so beli kristali kalcita, ki so v jedrih brezbarvni, vrhnji deli kristalov pa vsebujejo tekočinske vključke, kar smo dokazali z ramansko mikrospektroskopijo.

Zaključki

Tipi kristalov kalcita nam vsak zase ne pomenijo veliko, če ne ugotovimo njihovih medsebojnih odnosov. Z raziskavami kalcita iz Liboj smo ugotovili, da se je rast kristalov vsaj enkrat prekinila in nato nadaljevala, ob tem pa se morfološki tip kristala kalcita ni spremenil. To pomeni, da se je rast kristalov kalcita samo ustavila in nadaljevala ob naslednjem dogodku, ki je sprožil izločanje kalcijevega karbonata v obliki kristalov kalcita na jedrih starejših kristalov kalcita pod bolj ali manj enakimi pogoji kristalizacije. V nekaterih primerih je bilo možno nedvoumno določiti vrstni red kristalizacije že na osnovi makroskopskega opazovanja pod povečavo. To pomeni, da lahko kristalizacijo kalcita povezujemo z vsaj dvema dogodkoma iz geološke preteklosti. V vmesni fazi so se izločili drugi nekarbonatni minerali (goethit, manganovi oksidi, markazit), ki so lepo ohranjeni na ploskvah kristalov kalcita starejše generacije. Ugotovili smo tudi, da pri kristalih kalcita iz Liboj prevladujejo oblike položnega romboedra (012), pridružujejo se jim pa kristalne ploskve strmega romboedra. Takšne kristale kalcita so našli tudi v drugih kamnolomih, kar pomeni, da so kristalizirali v podobnih razmerah oziroma ne bi bilo prav nič nenavadnega, če bi s širitvijo kamnoloma in z novimi najdbami odkrili tudi kristale kalcita, ki so do sedaj opisani iz drugih kamnolomov v širši okolici Celja. Zanimivo pa je, da se morfološke značilnosti posamezne generacije kristalov kalcita iz Liboj niso bistveno spremenile, saj v večini primerov prevladujejo enake kristalne forme položnega romboedra. Nadaljnje raziskave morfoloških značilnosti bodo značilno prispevale k razumevanju dogodkov v geološki zgodovini območja v širši okolici Celja.

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Electrical resistivity tomography investigations along the planned dykes of the HPP Brežice water accumulation basin

Raziskave z električno upornostno tomografijo vzdolž trase nasipov akumulacijskega bazena HE Brežice

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Ključne besede: geofizika, HE Brežice, Krško-Brežiško polje, električna upornostna tomografija, sedimenti, jet grouting, električna upornost, geoelektrični model

Abstract

Geophysical investigations were conducted using electrical resistivity tomography (ERT) along planned dykes of the HPP Brežice water accumulation basin. The ERT profile is 7.3 km long and is located on the right riverbank of the Sava River on the Krško-Brežice field (E Slovenia). A purpose of the investigations was to determine a boundary between semipermeable Miocene and permeable Plio-Quaternary (Pl-Q) and Quaternary (Q) sediments for the proper design of the jet grouting sealing curtain, which will prevent lateral outflow of water from the accumulation basin. In this paper we present processing of the section between 5100 and 6100 m of the profile line. In this section the measurement template was set to 25 depth levels, because a significant increase in a thickness of the Pl-Q sediments was expected. Modelling of the measured apparent electrical resistivity data was carried out with RES2DINV and RESIX 2DI inversion software. Different inversion parameters were used to create 15 geoelectrical models for each program, which were then compared and evaluated based on borehole data and on previous geological investigations of the area. With the final geoelectrical models it was possible to successfully determine areas of three expected stratigraphic members and limit an electrical resistivity range for each one of them. The boundary is well defined between Q and Pl-Q and also between Q and Miocene sediments with sharp contrast in electrical resistivity between them. A boundary between Pl-Q and Miocene sediments was not that obvious, but it was possible to determine its shape by the use of different inversion parameters. We propose a simplified geological cross section based on the interpreted geoelectrical models and borehole data.

Izvleček

Geofizikalne raziskave z metodo električne upornostne tomografije so bile izvedene po 7,3 km dolgemu profilu, ki poteka vzdolž načrtovanih nasipov za HE Brežice na desnem bregu Save na Krško-Brežiškem polju. Namen raziskav je bil določiti mejo med polprepustnimi miocenskimi ter prepustnimi pliokvartarnimi (Pl-Q) in kvartarnimi (Q) sedimenti za načrtovanje t.i. jet grouting tesnilne zavese, ki bo preprečevala lateralni odtok vode iz akumulacijskega bazena. V članku predstavljamo obdelavo odseka med 5100 in 6100 m profila na katerem smo pričakovali začetek pojavljanja večje debeline Pl-Q sedimentov, zato smo meritve izvedli na 25 globinskih nivojih. Modeliranje izmerjenih podatkov navidezne električne upornosti je potekalo s programoma RES2DINV in RESIX 2DI z uporabo različnih parametrov pri izdelavi modelov. Te smo med seboj primerjali in vrednotili na podlagi preteklih geoloških raziskav območja in podatkov vrtin. Z vsakim programom smo izdelali 15 različnih modelov. S končnimi modeli smo lahko uspešno opredelili območja pojavljanja treh pričakovanih stratigrafskih členov in za vsakega podali razpon modeliranih električnih upornosti. Na modelih je dobro viden potek meje med Q in Pl-Q ter med Q in miocenskimi sedimenti z velikim medsebojnim kontrastom v električni upornosti. Nekoliko slabše je definirana meja med Pl-Q in miocenskimi sedimenti, vendar je bilo z uporabo različnih postopkov modeliranja tudi mogoče opredeliti njeno obliko. Na podlagi izdelanih modelov in podatkov vrtin smo za obdelan odsek podali poenostavljen geološki profil, na katerem so predstavljene glavne geoelektrično ugotovljene meje med stratigrafskimi členi.

Introduction

Electrical resistivity tomography (ERT) investigations were conducted along planned dykes of the HPP Brežice water accumulation basin (Fig. 1a). The profile is 7.3 km long and located on the right riverbank of the Sava River. Investigations on the left riverbank were conducted by another contractor and were not yet ready for comparison with our results. A purpose of the investigations was to determine a boundary between semipermeable Miocene and permeable Plio-Quaternary (Pl-Q) and

Quaternary (Q) sediments in order to properly design a jet grouting sealing curtain, which will prevent lateral outflow of water from the accumulation basin. Based on previous investigations of the area (e.g. Lapajne, 1975), gradual thickening of the Pl-Q sediments was expected in a section between 5100 and 6100 m of the profile line. Geoelectrical differentiation of Pl-Q sediments presents an interesting challenge for a geophysicist, which is why we decided to present this section in the paper.

Electrical resistivity tomography

ERT investigations combine 1D techniques of vertical electrical sounding and resistivity mapping. Investigations are conducted along a continuous profile line for different depth levels, defined by a different spacing between electrodes. In this way we are able to observe lateral and vertical (2D) variations in electrical resistivity (Car, 1995; Møller et al., 2006).

Before data acquisition a certain number of electrodes is laid along a profile line and connected with a multicore cable to an electrode switcher, which defines a number and a role (current/potential) of each electrode. The whole process is automatically controlled by a central processing unit (CPU) with an electrical resistivity meter. Parameters required to successfully conduct the measurements for chosen depth levels, electrode array and spacing are inserted into the CPU or a laptop computer. For each measurement, an electrical impulse is transmitted into the ground through the chosen pair of current electrodes and as a result potential drop is measured on

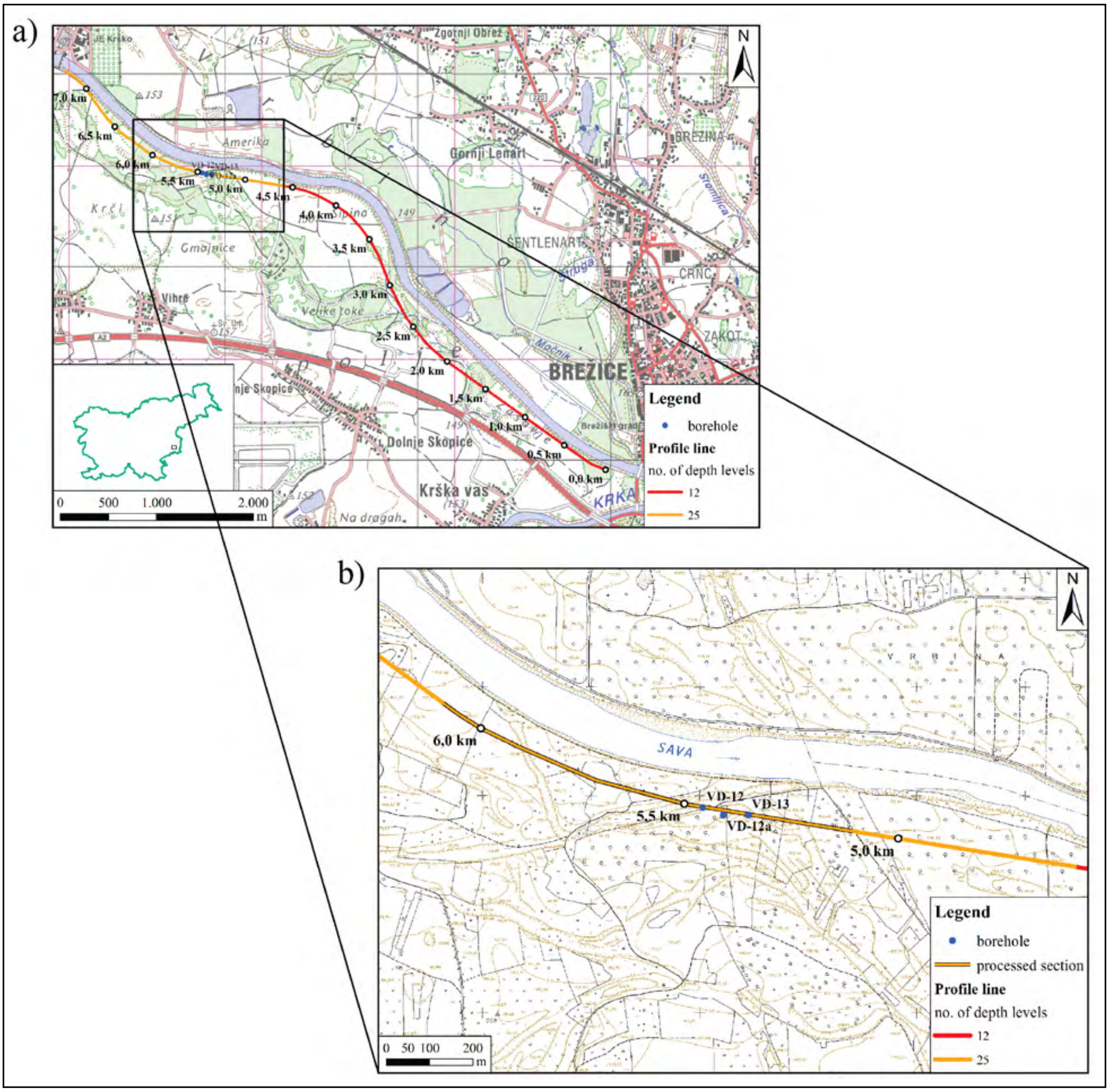

Fig. 1. a) Location of geoelectrical profile and b) situation of processed section with borehole locations.

Sl. 1. a) Položaj geoelektričnega profila in b) podrobnejša situacija obdelanega odseka in vrtin.

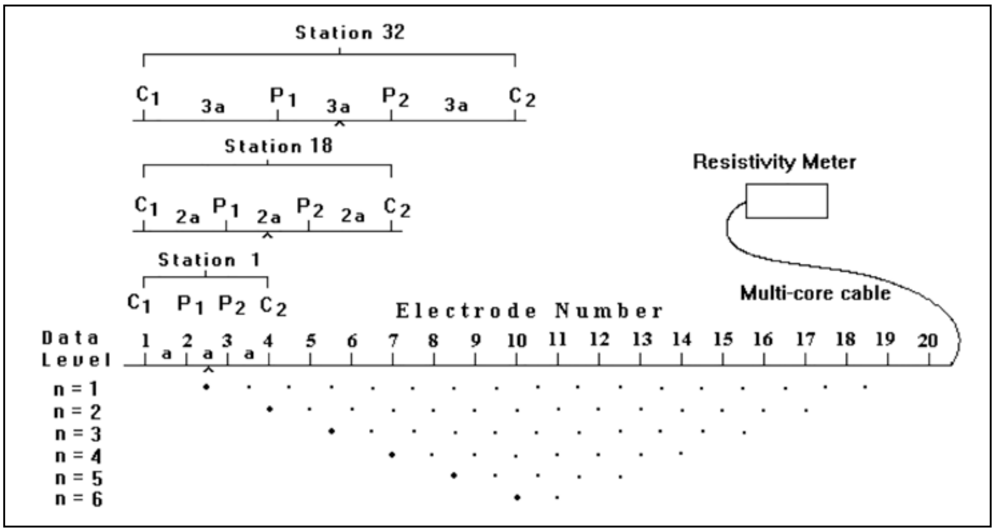

Fig. 2. Electrical resistivity tomography data acquisition process for Wenner electrode array (Loke, 2014).

Sl. 2. Shematski prikaz globinskih nivojev merskih točk psevdosekcije za Wennerjevo elektrodno razvrstitev (Loke, 2014).

the chosen pair of potential electrodes at a time. The whole system is powered by a battery or a power generator. Measurements are conducted for all pre-defined electrode combinations on different depth levels. Each depth level is defined by the spacing between the electrodes. A process of data acquisition is schematically shown on Figure 2. Measured apparent resistivity values are shown on a resistivity pseudosection, which is of a trapezoidal shape (Car, 1995; Møller et al., 2006; Loke, 2014).

For an interpretation of data acquired by ERT, different inversion programs are used. A modelling procedure includes a 2D inversion of measured data by using an iterative least squares method, for which adjustments are made based on a model response, calculated by a finite element method. Each consecutive model is iteratively adjusted until fit between measured and calculated data (RMS error) converges at a certain value. A RMS error can be a good quantitative indicator for a model quality, but not necessary for actual geological conditions in subsurface. If possible, every model should be evaluated based on existing geological investigations of an area and borehole data (Fehdi et al., 2011; Loke, 2014).

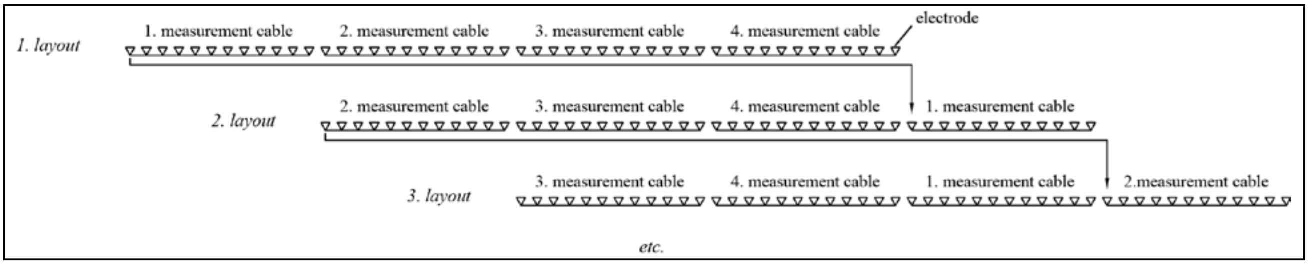

Fig. 3 Cables manoeuvring by using roll-along technique.

Sl. 3. Shematski prikaz premeščanja merskih kablov s tehniko „roll-along“.

Fig. 4. Syscal R2 central processing unit (left) and electrode switchers (right).

Sl. 4. Centralna procesna enota Syscal R2 (levo) in elektrodni preklopniki (desno).

Measurements and modelling

ERT measurements were conducted in the December 2013 during dry and stable weather conditions and in relatively moist ground. On the selected section we used the Wenner electrode array for 25 depth levels. Multicore measurement cables with 12 electrode take-outs on every 5 m were used. The electrode line of eight measurement cables layout was horizontally extended using a roll-along technique, where a first cable is disconnected and placed to the end of a profile line, when all predefined electrode combinations on its length are completed (Fig. 3). This process of cable replacement is repeated on all consecutive cables, until a needed profile length is achieved. The technique was introduced to ERT by van Overmeeren and Ritsema (1988). We used the Syscal R2 CPU and electrode switchers from Iris instruments (Fig. 4).

Modelling of measured apparent electrical resistivity data was carried out using RES2DINV v. 3.59 (Geotomo Software, Loke, 2010) and RESIX 2DI v. 4.17 (Interprex Limited, Stoyer & Butler, 2001) computer inversion programs. Both programs allow manual determination of different inversion parameters and values.

Table 1. Data from boreholes VD12, VD12a and VD13.

Tabela 1. Podatki vrtin VD12, VD12a and VD13.

Borehole (position on the profile)	boundary silt/Q gravel	boundary Q gravel/ Pl-Q gravel	boundary Pl-Q gravel/ Miocene marl
VD13 (5380 m)	1 m	10,1 m	11 m
VD12a (5430 m)	2,2 m	11,2 m	17,9 m
VD12 (5600 m)	1,3 m	11 m	42,4 m

Table 2. Overview of chosen parameters and values for models 1, 2 and 3.

Tabela 2. Prikaz izbranih parametrov in vrednosti za modele 1, 2 in 3.

Parameter	Choice/value(model number)
density of finite element mesh	normal(1,2,3)
number of nodes per unit electrode spacing	2(1,2,3)
width of model blocks	same as electrode spacing(1,2,3)
factor to increase cell thickness with depth	1,10(1,2,3)
maximum number of iterations	5(1,2,3)
smoothing of model resistivity	YES(1,2,3)
use combined inversion method	YES(3)/NO(1,2)
recalculate Jacobian matrix	first two iterations(1,2,3)
Jacobian matrix calculation	Gauss-Newton for first two iterations, then quasi-Newton(1,2,3)
use robust optimization method	YES(2)/NO(1,3)
damping factor (initial/ minimum/first layer)	0,3/0,03/5(2,3), 0,3/0,1/0(1)
change of damping factor with depth	automatic calculation(1)/fixed value (1,1)(2,3)
type of initial model	homogeneous half-space(1,2,3)
vertical/horizontal flatness ratio	1(2,3), 0,7(1)

Table 3. Overview of chosen parameters and values for models 4, 5 and 6.

Tabela 3. Prikaz izbranih parametrov in vrednosti za modele 4, 5 in 6.

Parameter	Choice/value(model number)
horizontal element width	1 m(4,5,6)
vertical element height within topography	0,25 m(4,5,6)
vertical element height below topography (number of elements)	1 m (5)(4,5,6)
deep pad vertical element height (factor to increase with depth)	1 m (1,2)(4,5,6)
maximum number of iterations	5(4,5,6)
influence sphere	10 electrodes(4,5,6)
inversion method (regularization)	ridge regression(4), Occam's(5,6)
Jacobian matrix calculation for first iteration	approximate(4,5,6)
Jacobian matrix calculation for other iterations	quasi-Newton(4,5,6)
calculation of damping factor	automatic, fast(4,5,6)
damping factor (minimum/ maximum)	0,0004/0,05(4,5,6)
type of initial model	homogenous half-space(4,5,6)
vertical/horizontal flatness ratio	1(4,5), 0,7(6)

Available data

For the investigated area, borehole data and data from previous geophysical investigations were available. Data from three boreholes (Fig. 1b) are presented in Table 1 and on Figure 5, where distinctive thickening of Pl-Q silty and sandy gravel towards the NW is visible. Based on previous geophysical investigations conducted on the Krško-Brežice field (Lapajne, 1975; Car & Stopar, 2008), we limited electrical resistivity ranges of modelled values for each geoelectrical layer, representing different stratigraphic members (Fig. 6). A range of the expected electrical resistivity for Q gravel and sandy gravel was ascertained to 300-5000 Ωm. Lower values, i.e. 100-300 Ωm, correspond to Pl-Q silty and sandy gravel and 10-100 Ωm to Miocene marl, sandy marl and sandy silt sediments.

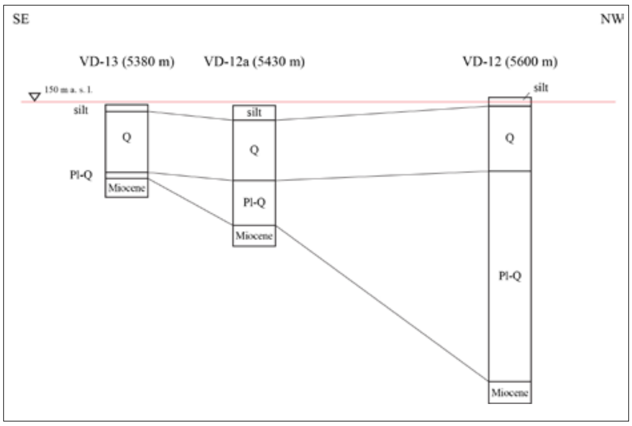

Fig. 5. Schematic view of borehole data.

Sl. 5. Shematski prikaz podatkov vrtin.

Results

Results from the ERT measurements were analysed using pseudosection, model response and model as on Figure 7. In the modelling process, different inversion parameters were used to create a total of 15 geoelectrical models for each program. In this paper we show three selected geoelectrical models for each program (Fig. 9 and 10), which best represent the difference between the chosen parameters (Tables 2 and 3).

RES2DINV

With RES2DINV we created models using the identical model grid (Fig. 8). The models created with this program are shown on Figure 9 and corresponding parameters are presented in Table 2. We fixed a logarithmic colour scale for an easier comparison between the models. On all presented models we see three layers with different electrical resistivity values. The shallowest layer with the highest values (360-1100 Ωm) is approximately 10 m thick and enclose two layers with lower electrical resistivities. The SE part of the models on Figure 9 is characterised by electrical resistivities 15-70 Ωm. On the other hand, resistivity values between 80 and 220 Ωm are observed in the NW part of the models. At both ends, the thickness of two electrical units exceeds 50 m. However, in the central part of the profile the thickness of the unit with 80-220 Ωm increases towards the NW and it seems that the lower resistivity unit deepens under the higher resistive one.

From the comparison of presented models we see that the use of the robust optimization method gave us model 2 (Fig. 9b) with very low RMS error of 3.5 %. Despite its low error value

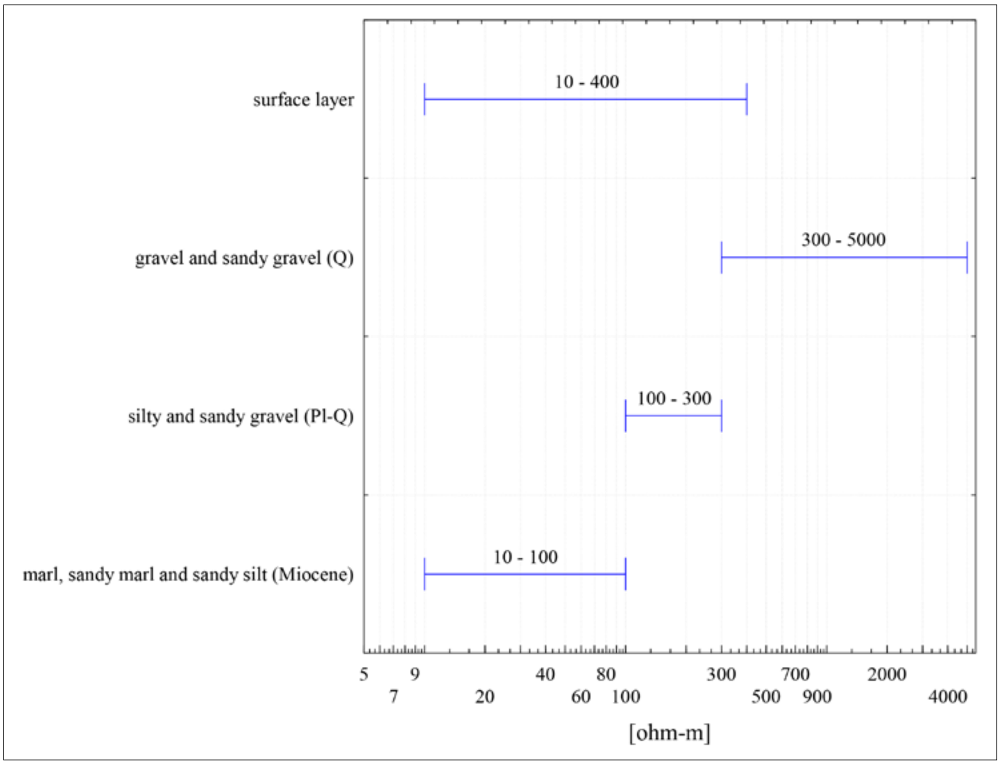

Fig. 6. Modelled electrical resistivity ranges for individual stratigraphic members at Krško-Brežice field (after Lapajne, 1975; Car et al., 2008).

Sl. 6. Modelirani intervali el. upornosti za posamezne stratigrafske člene na Krško-Brežiškem polju (po Lapajne, 1975; Car et al., 2008).

this model is only an approximation of actual subsurface geological conditions, due to the unrealistic resistivity distribution and steep boundaries between different resistivity areas (bodies). Models 1 and 2, on Figures 9a and 9b respectively, show more homogenous bodies, because we used different inversion methods and higher values of damping factors. Lower vertical/horizontal flatness ratio also played a key role, by making oblique boundaries smoother in model 1.

RESIX 2DI

Models created with RESIX 2DI are shown on Figure 10 and used parameters in Table 3. The colour scale was again fixed for all models. Layers of different electrical resistivities appear similarly as with RES2DINV. The one with the highest values (300-6000 Ωm) of electrical resistivity and a thickness of 10-15 m, extends over the entire upper part of the models. Underneath are two thicker layers. One in the SE part of the models with electrical resistivity values up to 100 Ωm and another one in the NW part with the values of 100-300 Ωm. The oblique boundary between them is not that well defined as it was on models created with RES2DINV, but we are still able to approximate it by the comparison of presented models.

Presented RESIX 2DI models were created by choosing different inversion methods and lower vertical/horizontal flatness ratio. The ridge regression inversion method, used in modelling of model 4 (Fig. 10a), gave the most homogenous body in the SE part of the profile. In this area the Occam's inversion method produced model 5 (Fig. 10b) with lense shaped bodies, which are elongated in the NW direction. These bodies were partially smoothed out with the use of lower vertical/horizontal flatness ratio to create model 6 (Fig. 10c).

Conclusions

Selected geoelectrical models were compared and evaluated considering existing geological investigations of the area and borehole data. With two chosen geoelectrical models (Fig. 11) it was

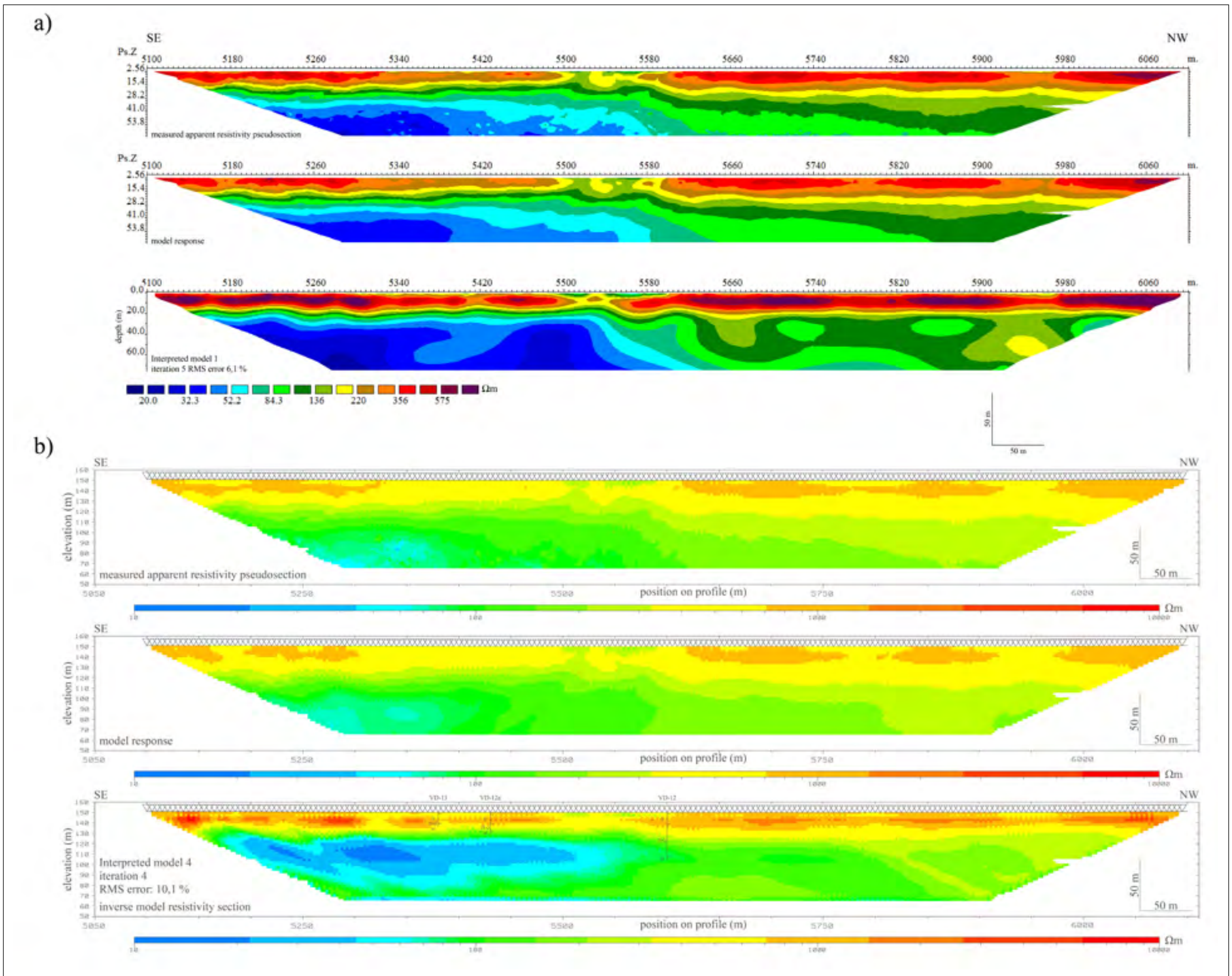

Fig. 7. Modelling result shown with pseudosection, model response and model for a) RES2DINV and b) RESIX 2DI.

Sl. 7. Rezultat modeliranja prikazan z upornostno psevdosekcijo, odzivom modela in modelom za a) RES2DINV and b) RESIX 2DI.

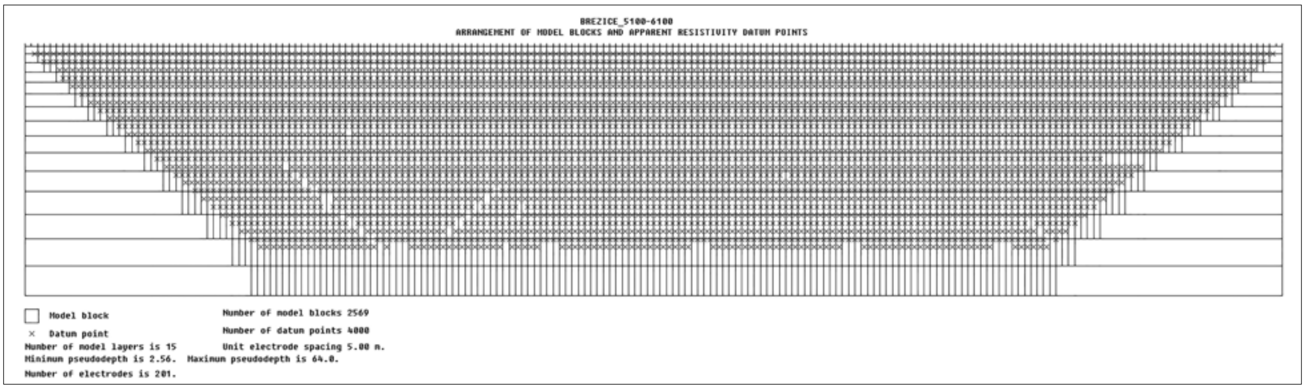

Fig. 8. Distribution of model grid with measured data points for presented models.
Sl. 8. Razporeditev mreže celic s prikazanimi merskimi točkami za predstavljene modele.

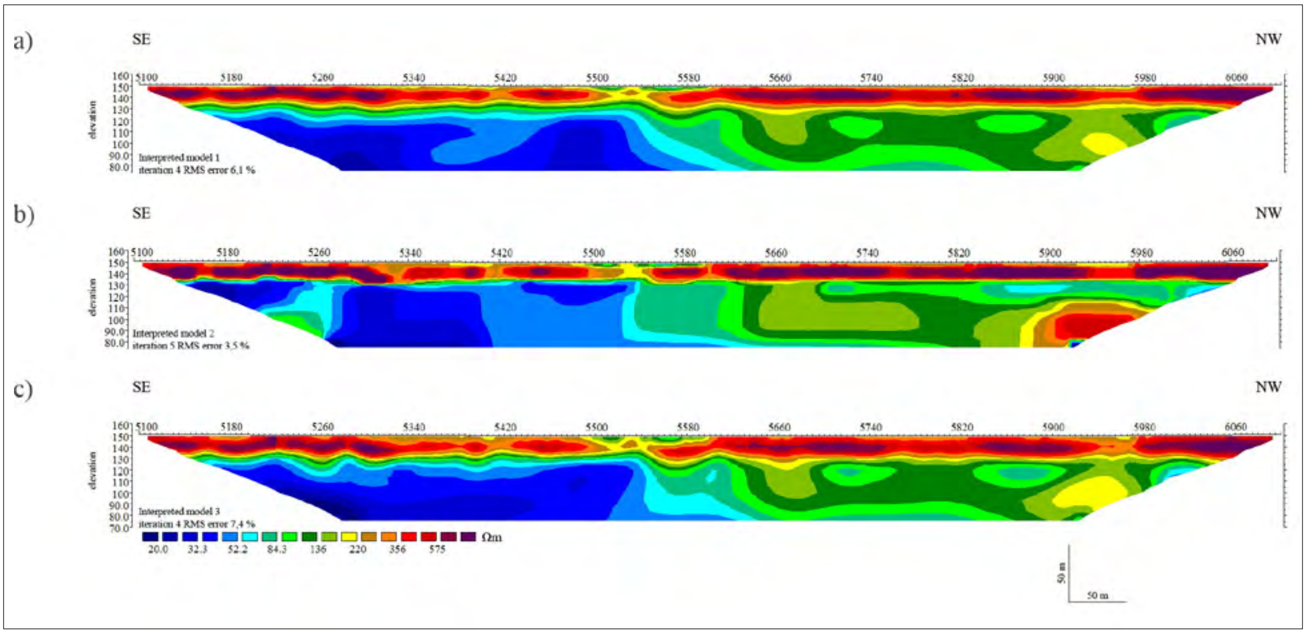

Fig. 9. Models created with RES2DINV: a) Model 1, b) Model 2 and c) Model 3.
Sl. 9. Modeli izdelani s programom RES2DINV: a) model 1, b) model 2 in c) model 3.

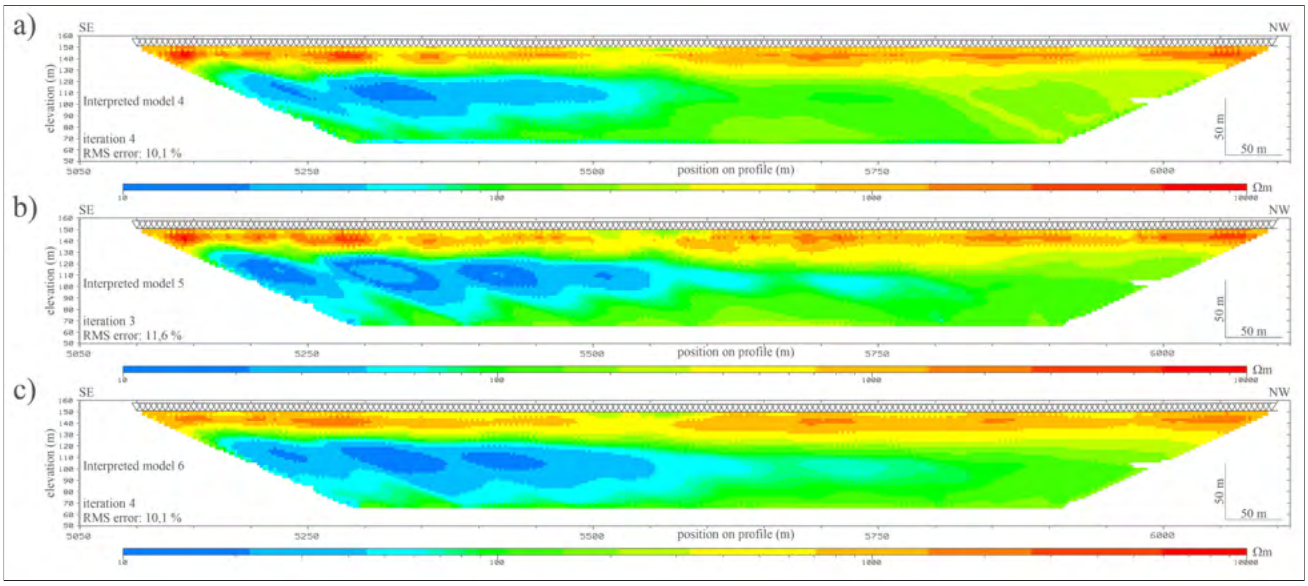

Fig. 10. Models created with RESIX 2DI: a) Model 4, b) Model 5 and c) Model 6.
Sl. 10. Modeli izdelani s programom RESIX 2DI: a) model 4, b) model 5 in c) model 6.

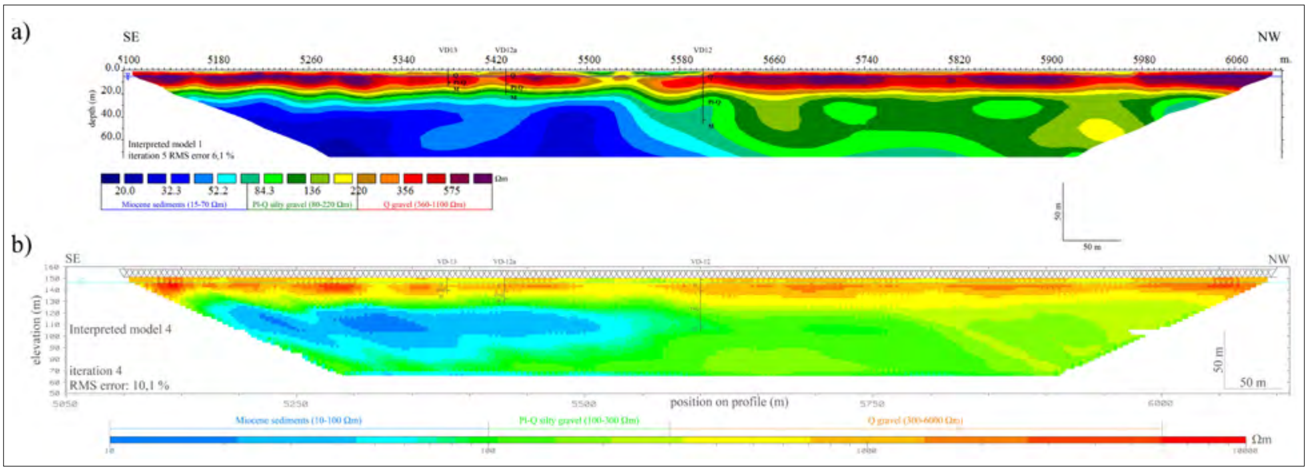

Fig. 11. Final two models with electrical resistivity scales and borehole data for each program: a) RES2DINV and b) RESIX 2DI.
Sl. 11. Izbrana modela za vsakega izmed programov s podanima skalama električne upornosti: a) RES2DINV in b) RESIX 2DI.

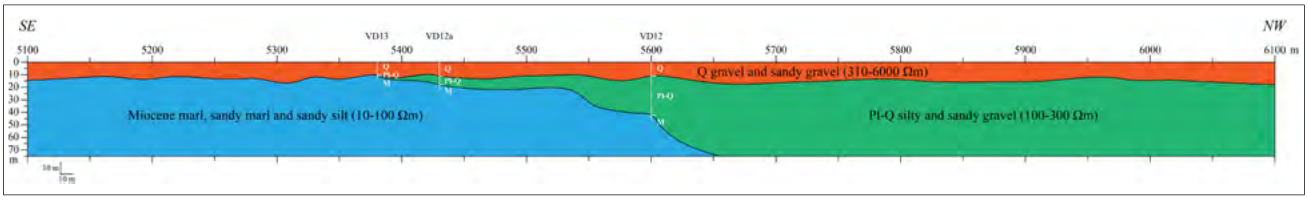

Fig. 12. Simplified geological cross section based on interpreted geoelectrical models and borehole data.
Sl. 12. Poenostavljen geološki prerez, izdelan na podlagi geoelektričnih raziskav in podatkov vrtin.

possible to successfully determine areas of three expected stratigraphic members and limit the electrical resistivity range for each. The highest values (310-6000 Ωm) represent Q gravel, which overlies the older sediments along the entire section to a depth of 10-15 m. A layer with very low electrical resistivities is deposited between profile station points of 5100 and 5400 m. It belongs to the response of Miocene (sandy) marl sediments. From 5400 m towards NW, presence of the medium resistive layer is evident, which we believe is a response of Pl-Q silty and sandy gravel. Its thickness increases gradually from 0 to over 50 m. Moreover, it is obvious that very low resistive Miocene sediments are deposited under the Pl-Q layer.

The boundary is well defined between Q and Pl-Q and also between Q and Miocene sediments with distinctive contrasts in electrical resistivity. The oblique boundary between Pl-Q and Miocene sediments was not defined so well, but with the use of different inversion parameters it was possible to determine its shape. However, as long as the Pl-Q layer is thinner than 3 m, its appearance is not evident on the geoelectrical models. This limitation cannot be surpassed with the existing modelling tools. After our analysis the extent of the Pl-Q layer is better visible on the models created with RES2DINV.

Parameters were evaluated based on the interpreted models. For our case the Occam's regularization method produced best models when used with lower vertical/horizontal flatness ratio. In the case of RES2DINV, better results were achieved with the use of different damping factors and combination of Occam's and ridge regression inversion methods.

As the final conclusion we propose a simplified geological cross section based on the interpreted geoelectrical models and borehole data (Fig. 12). From this cross section we are able to better determine suggested depth of the jet grouting sealing curtain along the investigated profile, which is certainly needed in the Q gravel and at least in upper parts of Pl-Q silty and sandy gravel. For the deeper parts of Pl-Q silty and sandy gravel, an additional evaluation is necessary to ponder on the construction costs and lateral outflow loss.

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Izpostavljenost prebivalstva, objektov in infrastrukture zaradi pojavljanja zemeljskih plazov – primer petih slovenskih občin

Exposure of inhabitants, buildings and infrastructure to landslides – a case of five Slovenian municipalities

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Ključne besede: MASREM, zemeljski plazovi, karte verjetnosti, izpostavljenost, Bovec, Laško, Slovenj Gradec, Trbovlje, Železniki
Keywords: MASPREM, landslides, susceptibility map, exposure, Bovec, Laško, Slovenj Gradec, Trbovlje, Železniki

Izvleček

V okviru nacionalnega razvojno-raziskovalnega projekta MASPREM smo izdelali ocene in karte izpostavljenosti prebivalstva, objektov in infrastrukture zaradi pojavljanja zemeljskih plazov za pet slovenskih občin. Karte izpostavljenosti predstavljajo nadgradnjo kart verjetnosti pojavljanja zemeljskih plazov in temeljijo na podatkovni bazi zemeljskih plazov in terenskih raziskavah. Izdelane so bile za občine Bovec, Laško, Slovenj Gradec, Trbovlje in Železniki, ki so bile izbrane na podlagi njihove izpostavljenosti pojavom zemeljskih plazov. Osnovni podatek za izdelavo izpostavljenosti prebivalstva, objektov in infrastrukture so karte verjetnosti pojavljanja zemeljskih plazov v merilu 1 : 25.000, ki so bile izdelane v okviru projekta Geohazard 14. Analize izpostavljenosti elementov zaradi verjetnih pojavov zemeljskih plazov v izbranih občinah smo opravili z enostavno metodo prekrivanja v programskem orodju ArcMap. Stopnjo izpostavljenosti smo razdelili na šest kategorij, pri čemer prva kategorija predstavlja zanemarljivo izpostavljenost, šesta pa zelo veliko izpostavljenost prebivalstva, objektov in infrastrukture pojavljanju zemeljskih plazov. Izdelane ocene izpostavljenosti predstavljajo dobro osnovo za nadaljnje določanje ogroženosti zaradi plazenja in posledično boljše upravljanje z njihovimi posledicami.

Abstract

In the frame of national research and innovation project MASPREM exposure maps of inhabitants, buildings and infrastructures to landslide occurrence were developed for five selected Slovenian municipalities. Maps represent an upgrade of the landslide susceptibility maps that were elaborated based on synthesis of analysis of event-based landslide inventory and field investigations. Exposure maps were developed for five municipalities: Bovec, Laško, Slovenj Gradec, Trbovlje and Železniki. Exposure of inhabitants, construction and infrastructures to landslide occurrence was analysed using simple cross-analysis of landslide susceptibility maps at scale of 1:25,000 with locations of exposed elements. All analyses were conducted in the GIS with software tool ArcMap. Exposure maps, based on landslide susceptibility, were classified into six classes, with values ranging from one to six where class one represents areas with negligible exposure and class six areas with very high exposure to landslide occurrence. Exposure maps of selected municipalities provide the basis for further assessment of risk and consequentially better risk management.

Uvod

V sklopu projekta MASPREM– Sistem zgodnjega opozarjanja za primer nevarnosti proženja zemeljskih plazov, financiranega s strani Ministrstva za obrambo (Uprava RS za zaščito in reševanje), smo izdelali karte in ocene izpostavljenosti prebivalstva, objektov ter infrastrukture zaradi pojavljanja zemeljskih plazov v merilu 1 : 25.000 za pet izbranih slovenskih občin, in sicer Bovec, Laško, Slovenj Gradec, Trbovlje in Železniki (Šinigoj et al., 2013a, b).

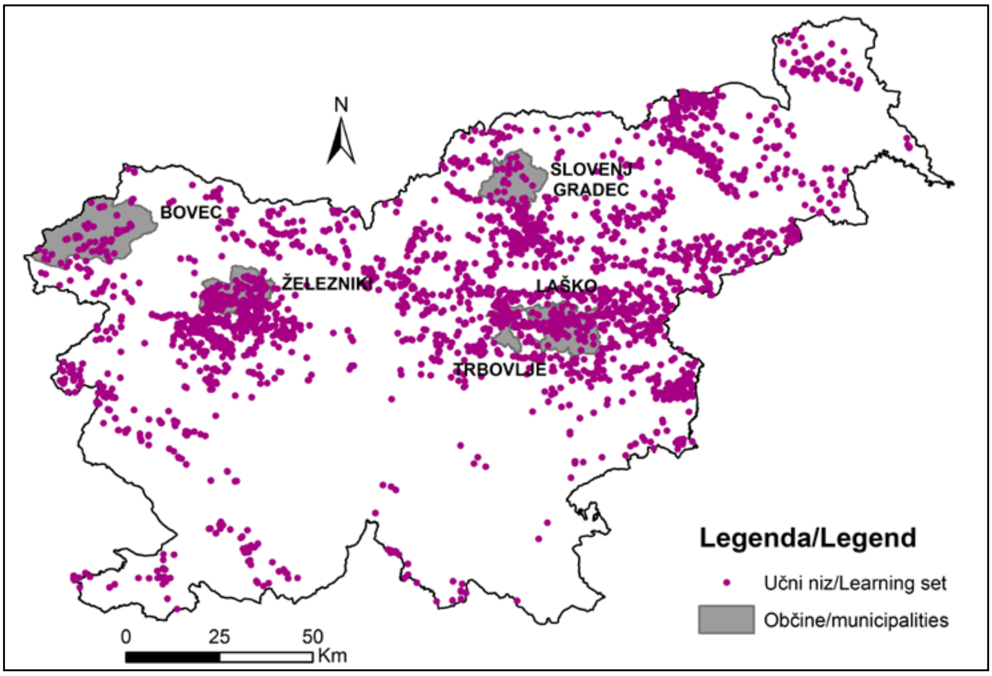
Karte verjetnosti pojavljanja zemeljskih plazov predstavljajo osnovo nadaljevalnim izračunom nevarnosti (*ang. hazard*), ogroženosti (*ang. risk*) in ranljivosti (*ang. vulnerability*), kjer je glavni poudarek na proučevanju posledic za ljudi in njihovega imetja. Številni raziskovalci širom po svetu (Mejia-Navarro et al., 1994; Leone et al., 1996; Ragozin & Tikhvinsky, 2000; Hollenstein, 2005) so v svoje raziskave vključili elemente ogroženosti in njihovo ranljivost, ki vplivajo na prebivalstvo, družbeno in zasebno lastnino, družbene ter ekonomske aktivnosti ogrožene na danem območju. Stopnja ogroženosti in ranljivosti je izražena z vrednostmi med 0 in 1. V pričujočem članku so predstavljene ocene izpostavljenosti, ki predstavljajo ohlapnejšo različico ocen (in kart) ogroženosti zaradi pojavov zemeljskih plazov, saj ne vsebujejo ekonomskih izračunov škod. Karte izpostavljenosti prebivalstva, objektov ter infrastrukture so nadgradnja modelov verjetnosti pojavljanja zemeljskih plazov slovenskih občin, izdelanih v okviru sestrskega projekta GeoHazard 14 – Izdelava prostorske baze podatkov in spletnega informacijskega sistema geološko pogojenih nevarnosti zaradi procesov pobočnega premikanja, poplavnih, erozijskih kart ter kart snežnih plazov kot del nalog javne službe Geološkega zavoda Slovenije (Bavec et al., 2012).

Izbrana območja

Ocene in karte izpostavljenosti prebivalcev, objektov in infrastrukture zaradi pojavljanja zemeljskih plazov v merilu 1 : 25.000 smo izdelali za pet slovenskih občin (sl. 1) (Šinigoj et al., 2013b).

Prva izbrana občina Bovec leži v Julijskih Alpah. Površina občine je 367 km², povprečna nadmorska višina občine znaša 1.254 m. V občini živi 3.181 ljudi, od tega več kot polovica v občinskem središču in v naseljih v dolinah (SURS, 2014). Skozi občino potekata dve glavni prometni osi, in sicer glavna cesta (G2 203) med Predelom in Gorico ter regionalna cesta (R1 206), ki povezuje Posočje z Gorenjsko. Z gospodarskega vidika ima občina Bovec izredno dobro razvito turistično dejavnost.

Občina Laško leži v Spodnji Savinjski dolini, v Posavskem hribovju. Površina občine je 197,5 km², povprečna nadmorska višina je 474 m. V občini živi 13.409 ljudi, od tega 25 % prebivalstva v občinskem središču (SURS, 2014). Prometne osi na tem območju so glavna cesta (G1 5), ki povezuje Celje in Zidani most in regionalne povezave Laškega s Kozjanskim (R3 681), Šentjurjem ter Hrastnikom (R1 221). Z gospodarskega vidika je v občini Laško trenutno najbolj aktivna živilska industrija.



Sl. 1. Lega petih izbranih občin in lokacije 3.437-ih zemeljskih plazov, ki predstavljajo t.i. učni niz oziroma reprezentativno populacijo plazov za območje Slovenije.

Fig. 1. Location of five selected municipalities and location of 3.437 landslides which present a representative population of landslides for territory of Slovenia.

Tabela 1. Število zemeljskih plazov z znano lokacijo, ki so bili kot učni niz vključeni v analizo in izdelavo modela verjetnosti pojavljanja plazov v merilu 1 : 250.000 (Komac & Ribičič, 2006) in njihova porazdelitev po izbranih občinah.

Table 1. Number of landslides with known location that were included in the elaboration of landslide susceptibility model of Slovenia at a scale 1 : 250,000 (Komac & Ribičič, 2006) and their distribution by selected municipalities.

Občina/ *Municipalities*	Število zemeljskih plazov (učni niz) po občinah/ *Number of landslides (learning set) by municipalities*	Odstotek zemeljskih plazov (učni niz) po občinah (%)/*Percentage of landslides by municipalities*	Število zemeljskih plazov na km² občine/*Number of landslides per km² of municipalities*
Bovec	56	1,63	0,15
Laško	116	3,38	0,59
Slovenj Gradec	33	0,96	0,20
Trbovlje	55	1,60	0,95
Železniki	175	5,09	1,06
Slovenija	**3.437**	**100 %**	

Občina Slovenj Gradec leži na meji Vzhodnih Karavank, Strojne in Pohorja. Površina občine je 174 km^2 s povprečno nadmorsko višino 659 m. Občina ima 16.947 prebivalcev, od katerih jih 45 % živi v občinskem središču (SURS, 2014). Slovenjgraška kotlina predstavlja zgostitveno območje poselitve, po kateri poteka tudi glavna prometna os (G1 4), ki povezuje Koroško s Savinjsko statistično regijo.

Četrta izbrana občina Trbovlje obsega površino 58 km^2. Trbovlje je največje mesto v Zasavski regiji in hkrati tudi upravno središče Zasavja. Po zadnjih podatkih v občini Trbovlje živi 16.814 ljudi, od tega več kot 80 % v občinskem središču (SURS, 2014). V občini Trbovlje obratuje pomembna industrijska panoga (termoelektrarna Trbovlje), skozi občino pa potekajo tudi pomembne prometne povezave, glavna cesta (G2 108) med Ljubljano in Zidanim Mostom ter železniška proga Ljubljana – Zagreb.

Občina Železniki se nahaja v Selški dolini na meji Julijskih Alp in Škofjeloškega hribovja. Površina občine je 165 km^2, povprečna nadmorska višina znaša 895 m. V občini je 6.817 prebivalcev, od tega jih okrog 45 % živi v občinskem središču (SURS, 2014). Pomembnejša prometna povezava je regionalna cesta (R2 403), ki povezuje Selško dolino s Škofjo Loko.

Iz prekrivanja sloja občin z lokacijami plazov t.i. učnega niza, ki predstavlja reprezentativno populacijo plazov za območje Slovenije in je bil uporabljen pri razvoju modela verjetnosti pojavljanja plazov (Komac & Ribičič, 2006), je razvidno, da v občini Bovec znaša število zemeljskih plazov na km^2 0,15; v občini Laško 0,59; v občini Slovenj Gradec 0,20 in v občini Trbovlje 0,95. (Tabela 1). Glede na celotno reprezentativno populacijo zemeljskih plazov za območje Slovenije se v izbranih občinah največ zemeljskih plazov na km^2 nahaja v občini Železniki, in sicer 1,06. (sl. 1).

Vhodni podatki in opis metodologije

Izpostavljenost opazovanega objekta je verjetnost, da se ta nahaja v območju nevarnosti (Mikoš et al., 2004). Pri naravnih pojavih pomeni izpostavljenost izključno gibanje ali statičnost elementov tveganja na območjih z različno verjetnostjo pojavljanja naravnih nesreč (Mikoš et al., 2004).

Verjetnost sočasnosti (interakcije) elementa tveganja (V), ki se nahaja v določeni točki (x, y, z) ravno v trenutku (t), ter nastopa pojava na mestu (x, y, z) v trenutku (t) lahko izračunamo po naslednji enačbi (Mikoš et al., 2004):

$$K=N*I=[P(N\rightarrow x,y,z)*P(N\rightarrow t)]*[P(V\rightarrow x,y,z)*P(V\rightarrow t)] \quad (1)$$

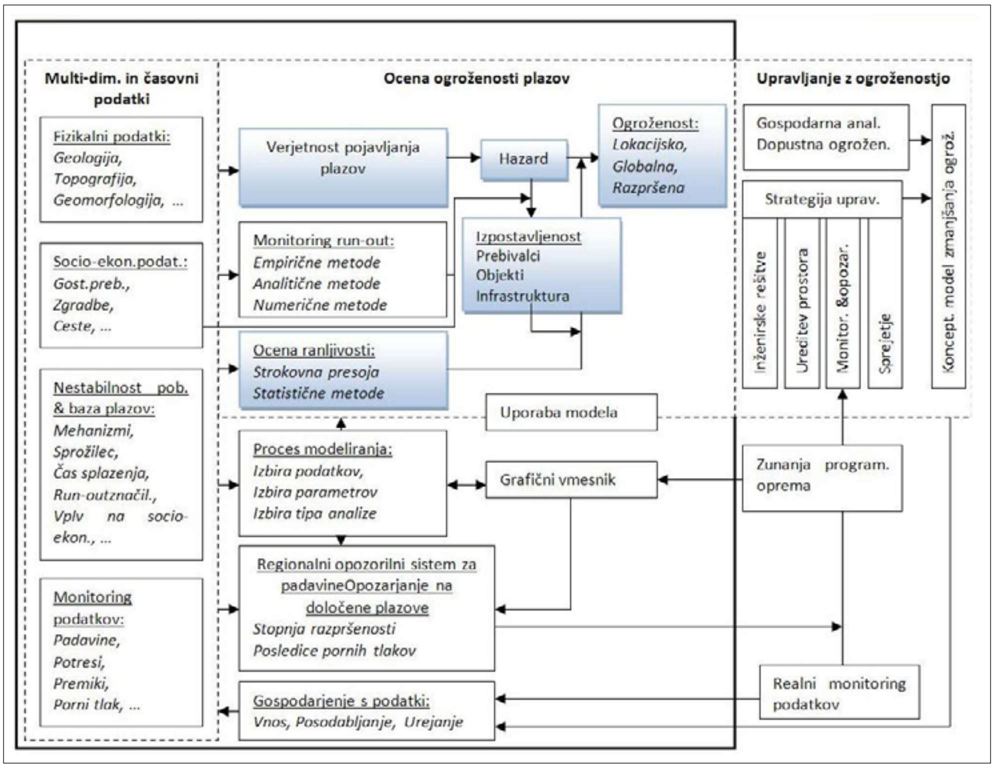
kjer K predstavlja verjetnost sočasnosti (interakcije), N verjetnost nastopa nevarnosti, I izpostavljenost elementov tveganja in V element tveganja.

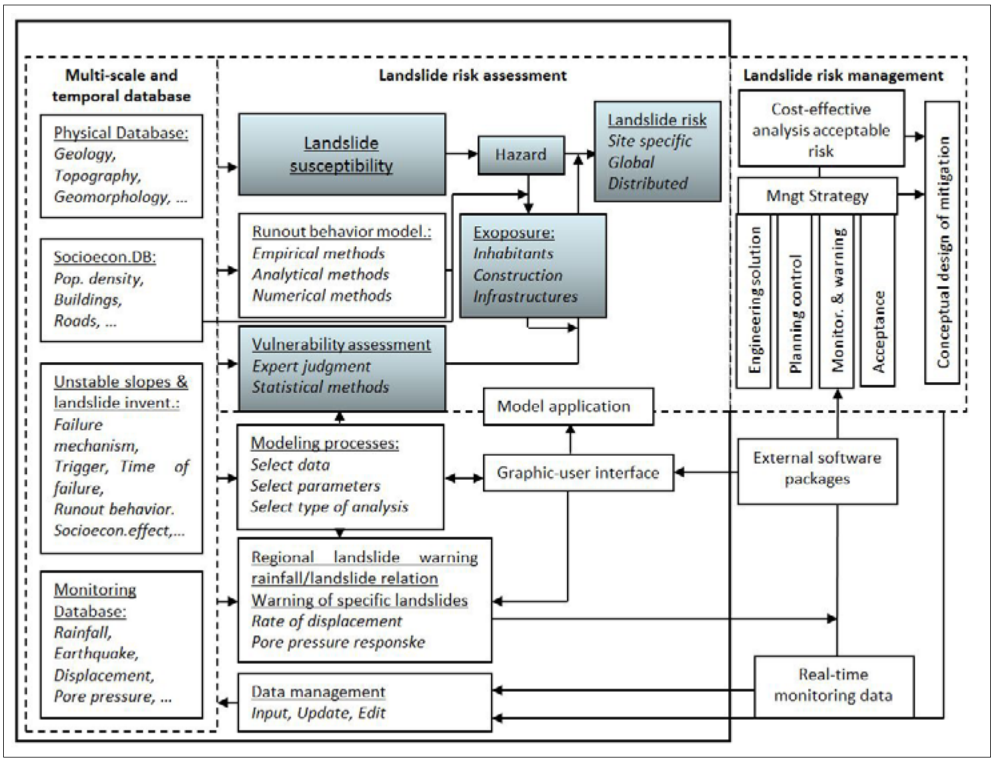
Elementi tveganja (*V*) se določijo z identifikacijo in popisom ljudi, zgradb ali ostalih elementov na nekem območju, ki so potencialno podvrženi nevarnosti. Sledi ocenitev njihove ekonomske vrednosti in določanje vrednosti elementov tveganja, ki so dejansko izpostavljeni posledicam nevarnosti oziroma učinku pričakovane verjetnosti nastopa nevarnosti na določenem območju (Mikoš et al., 2004).

Prostorski in časovni nastop dogodka in prisotnost ter položaj elementa tveganja so slučajne spremenljivke z različnimi verjetnostmi porazdelitve, ki so odvisne od različnih dejavnikov, kot so npr. hitrosti prečkanja območja, hitrosti pojava, odziva elementa tveganja, opaznosti pojava in možnosti umika (Mikoš et al., 2004).

Za določanje ocene ogroženosti zaradi pojavov zemeljskih plazov in načine upravljanja z njimi, uporabljajo v tujini različne pristope, katerih pa večji del temelji na zbiranju skupnih osnovnih podatkov, ki predstavljajo osnovo za določanja ogroženosti zaradi zemeljskih plazov ter upravljanja z njimi (Dai et al., 2002; Fell et al., 2008). V nadaljevanju je predstavljen le eden izmed konceptualnih modelov, ki prikazuje celovit pregled izdelave ocene ogroženosti (sl. 2). Tovrstne metode določanja omogočajo lažje razumevanje procesov plazenja in nevarnosti zemeljskih plazov ter tako pripomorejo k racionalnejšem upravljanju z zemeljskimi plazovi. S takšnimi pristopi se lahko ublažijo številne posledice, ki nastanejo zaradi zemeljskih plazov, posledično zmanjšajo tudi ekonomske in socialne izgube.

Shematski prikaz na sliki 2, ki predstavlja konceptualni model za določanje ocene ogroženosti zaradi zemeljskih plazov, prikazuje osnovne vhodne podatke in postopke pri določanju ogroženosti ter upravljanja z zemeljskimi plazovi. V prvi fazi določanja se izdela model verjetnosti pojavljanja, ki temelji na določitvi tipov pobočnih premikov. Model verjetnosti pojavljanja je izdelan na podlagi različnih metodologij, ki so odvisne od razpoložljivosti podatkov in opreme (hevristični, izkustveni, statistični ali deterministični pristop) (Komac, 2005; Komac & Ribičič, 2006; Komac, 2006; Komac, 2012). Sledi transformacija modela verjetnosti pojavljanja v model hazarda (nevarnost), ki zahteva časovne pa tudi amplitudne podatke sproženih zemeljskih plazov. Transformacijo je mogoče izvesti z vzpostavitvijo vzročno-posledičnih korelacij med zemeljskimi plazovi in njihovimi sprožitvenimi dejavniki (v primeru, ko je znana frekvenca in dobro opredeljena korelacija). Za določitev frekvence zemeljskih plazov v preteklosti in za izdelavo ekstrapolacije prihodnje frekvence je treba modelirati različne scenarije na podlagi trendov, ki izhajajo iz analiz časovnih intervalov pojavljanja zemeljskih plazov. Če v model hazarda vključimo elemente kot so prebivalstvo, objekti in infrastruktura, dobimo model izpostavljenosti.



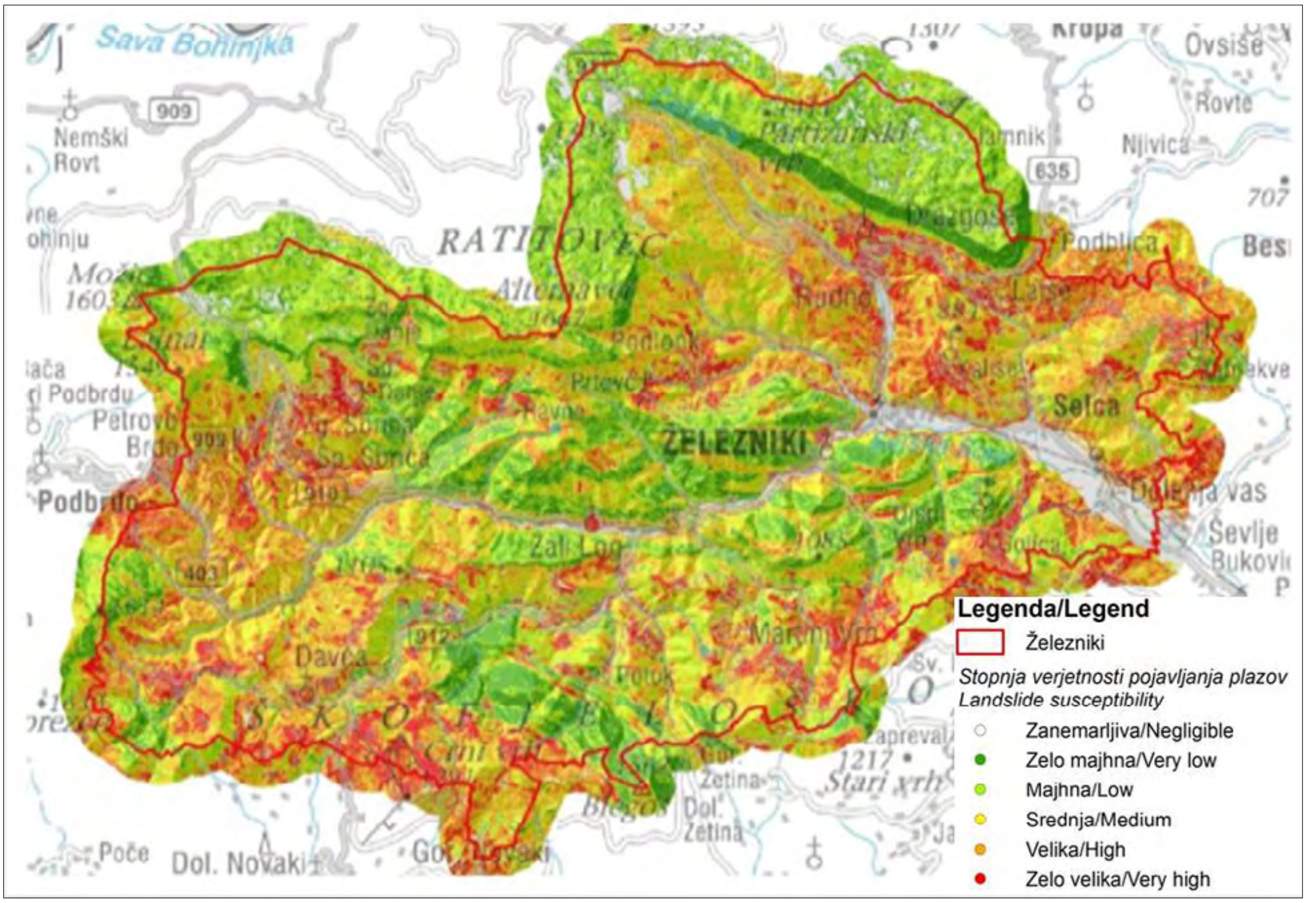


Sl. 2. Konceptualni model za določanje ocene ogroženosti zaradi zemeljskih plazov (DAI et al., 2002).

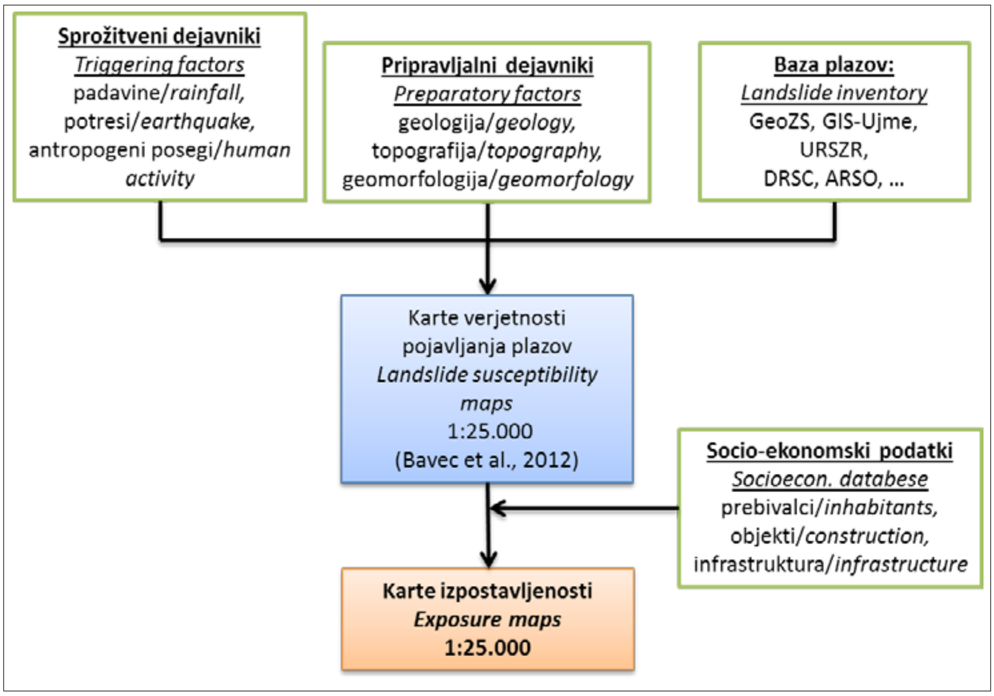
Fig. 2. Conceptual integrated system for landslide risk assessment and management (DAI et al., 2002).

Za izdelavo modela ranljivosti se upošteva analiza škode, ki je bila povzročena zaradi preteklih zemeljskih plazov na izpostavljenih elementih (prebivalstvo, objekti, infrastruktura in socialno-ekonomske aktivnosti). Izpostavljeni elementi so izraženi kot razmerje med škodo in ceno posameznega elementa. V tem primeru je ranljivost izražena kot razmerje med izgubo izkustvenih izpostavljenih elementov in njihovo vrednostjo. Ocena posrednih izgub je bolj kompleksna, predvsem zaradi običajnega pomanjkanja podatkov. Za vzpostavitev modela ranljivosti je treba izpostaviti morebitne posredne izgube in opredeliti možne scenarije. Na podlagi izračuna modela nevarnosti, modela ranljivosti in izpostavljenosti se določi končni model ogroženosti (DAI et al., 2002).

V nadaljevanju prispevka predstavljamo metodologijo in rezultate ocen izpostavljenosti prebivalcev, objektov in infrastrukture vplivom zemeljskih plazov za pet izbranih občin.



Sl. 3. Karta verjetnosti pojavljanja zemeljskih plazov v merilu 1 : 25.000 za občino Železniki (Bavec et al., 2012).
Fig. 3. Landslide susceptibility map at a scale of 1:25,000 for the municipality Železniki (Bavec et al., 2012).



Sl. 4. Shematski prikaz izdelave ocene in kart izpostavljenosti prebivalstva, objektov in infrastrukture verjetnosti pojavljanja zemeljskih plazov v merilu 1 : 25.000 za pet občin.

Fig. 4. Schematic representation of determination/elaboration of exposure assessment and maps of inhabitants, construction and infrastructures to landslide susceptibility at a scale of 1 : 25,000 for five municipalities.

V nasprotju od predstavljenega teoretičnega modela (sl. 2) smo v prvi fazi, pri izračunu izpostavljenosti elementov (sl. 4), zaradi manjkajočih podatkov o pogostosti pojavljanja zemeljskih plazov in njihovi razsežnosti v prostoru, uporabili pristop brez ocene škod (Šinigoj et al., 2013b).

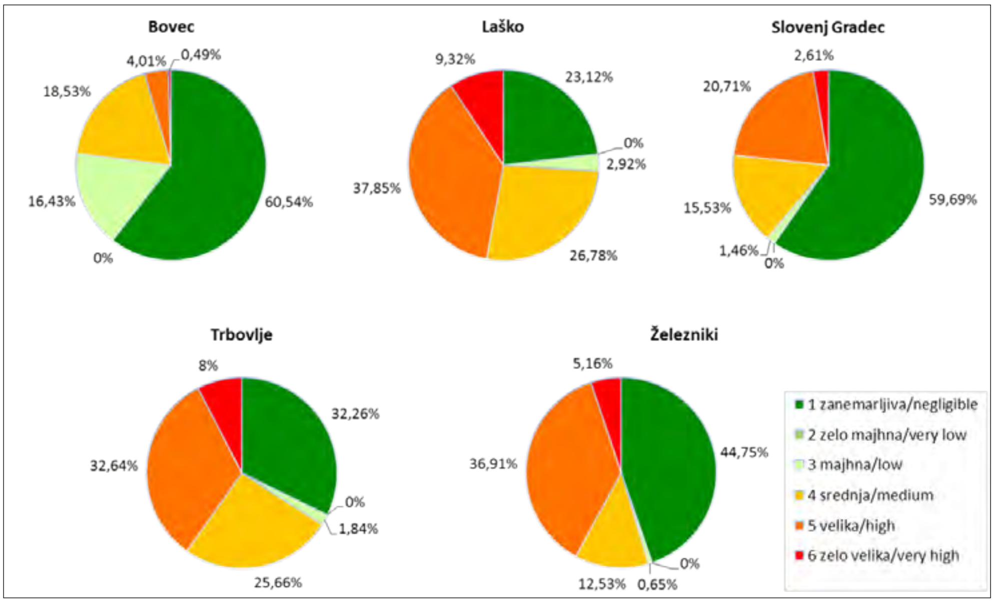
Za osnovni vhodni podatek smo uporabili karte verjetnosti pojavljanja plazov v merilu 1 : 25.000, ki opisujejo obstoječe in predvidene pojave zemeljskih plazov inso bili izdelani v okviru projekta »Izdelava prostorske baze podatkov in spletnega informacijskega sistema geološko pogojenih nevarnosti zaradi procesov pobočnega premikanja, poplavnih, erozijskih kart ter kart snežnih plazov (GeoHazard 14)«, ki ga je Geološki zavod Slovenije vzporedno projektu MASPREM izvedel po naročilu Ministrstva za okolje in prostor (Bavec et al., 2012). Karte verjetnosti pojavljanja zemeljskih plazov predstavljajo rastrski sloj z velikostjo celice 5×5 m. Na sliki 3 je prikazan primer karte verjetnosti pojavljanja zemeljskih plazov v merilu 1 : 25.000 za občino Železniki (Bavec et al., 2012).

Ocena in karte izpostavljenosti temeljijo na statističnem prekrivanju kart verjetnosti pojavljanja plazov v merilu 1 : 25.000 s podatki o številu in porazdelitvi prebivalcev, objektov, in infrastrukture (GURS, 2005a; 2005b) (sl. 4).

V okviru kart izpostavljenosti smo analizirali sledeče infrastrukturne tipe in njihove elemente (sl. 5):

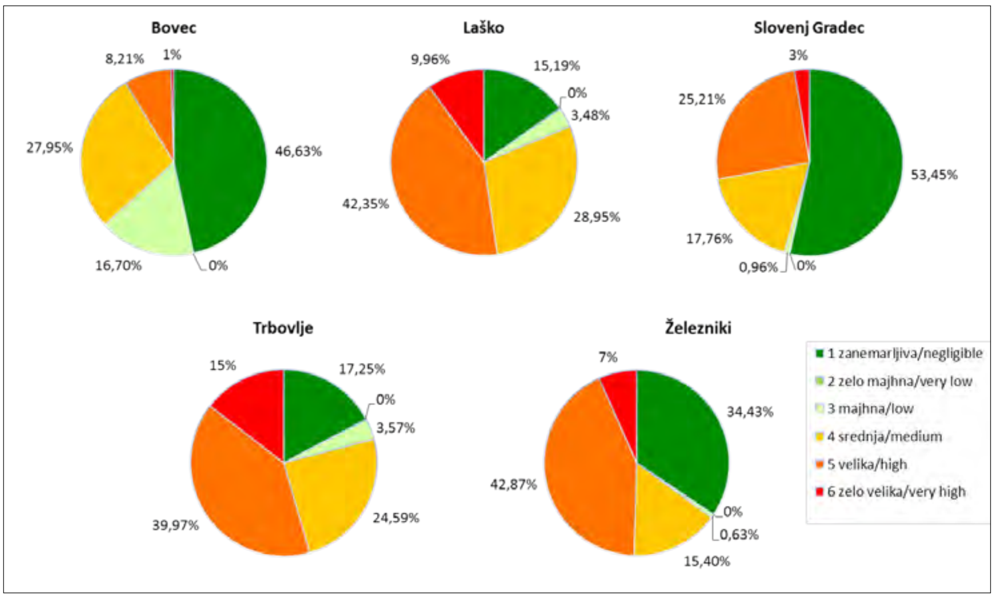
- ceste med katere prištevamo glavne ceste (G1, G2), regionalne ceste (R1, R2, R3), javne poti (JP), lokalne ceste (LC), gozdne ceste,
- železnico,
- električno omrežje (kablovod, polizolirani daljnovod in prosto zračni daljnovod),
- kanalizacijsko omrežje (kanalizacijski vodi),
- plinovodno omrežje (katodne zaščite in plinovod),
- toplotno omrežje (kinete, toplovod),
- vodovodno omrežje (vodooskrbne cevi).

Analize izpostavljenosti elementov zaradi pojavljanja zemeljskih plazov v občinah Bovec, Laško, Slovenj Gradec, Trbovlje in Železniki smo izdelali v GIS-u, s programskim orodjem ArcMap. Za izdelavo ocene izpostavljenosti smo uporabili orodje *Spatial Analyst,* ki omogoča prekrivanje podatkovnih podatkov (število in porazdelitev prebivalcev, objektov in infrastrukture) in kart verjetnosti pojavljanja plazov. Za točkovne podatke smo uporabili algoritem *Extract Values to Points*, ki omogoča izbrani točki pripisati vrednost celice rastrskega sloja kateri pripada. Vrednost se zapiše v atributni tabeli točke. Tako smo točkovnima slojema »prebivalstvo« in »objekti« dodali vrednost verjetnosti pojavljanja zemeljskih plazov v merilu 1 : 25.000.



Sl. 5. Izpostavljenost prebivalcev zaradi pojavljanja zemeljskih plazov.

Fig. 5. Exposure of inhabitants to landslides.



Sl. 6. Izpostavljenost objektov zaradi pojavljanja zemeljskih plazov.

Fig. 6. Exposure of construction to landslides.

Za linijske podatke smo uporabili algoritem *Overlay,* s katerim smo liniji pripisali vrednost celice rastrskega sloja, kateri pripada. Vrednosti so določene na podlagi izračuna geometrijskega presečišča rastrskega sloja in vektorskega linijskega sloja. Rezultati so segmenti infrastrukturnih linijskih tipov, ki nosijo vrednost verjetnosti pojavljanja plazov v merilu 1 : 25.000.

Rezultati

Verjetnost izpostavljenosti prebivalcev, objektov in infrastrukture verjetnosti pojava zemeljskih plazov se odraža v obliki šest stopenjske lestvice: (1) zanemarljiva, (2) zelo majhna, (3) majhna, (4) srednja, (5) velika in (6) zelo velika. Vsak razred tudi grafično ponazarja oceno izpostavljenosti. Tako dobljena izpostavljenost pove kje so prebivalci, objekti in infrastruktura zanemarljivo do zelo veliko izpostavljeni verjetnosti pojavljanju zemeljskih plazov. Rezultati analize izpostavljenosti so v obliki grafov predstavljeni na sliki 5, 6 in 7.

Slika 5 prikazuje izpostavljenost prebivalcev zaradi pojavljanja zemeljskih plazov. Največji delež izpostavljenega prebivalstva živi v občinah Laško in Železniki. Delež z veliko do zelo veliko izpostavljenostjo prebivalcev v občini Laško je 47,17 %, medtem ko v občini Železniki 42,07 %. Med analiziranimi občinami je najvišji delež z zanemarljivo stopnjo izpostavljenosti ocenjen za občino Bovec (60,54 %) in Slovenj Gradec (59,69 %).

Slika 6 prikazuje rezultat analize izpostavljenosti objektov (različni tipi objektov) zaradi pojavljanja zemeljskih plazov. Analiza je pokazala, da je veliki do zelo veliki izpostavljenosti podvrženo kar 54,97 % objektov v občini Trbovlje in 52,31 % objektov v občini Laško. Delež objektov z zanemarljivo izpostavljenostjo je največji v občini Slovenj Gradec (53,45 %).

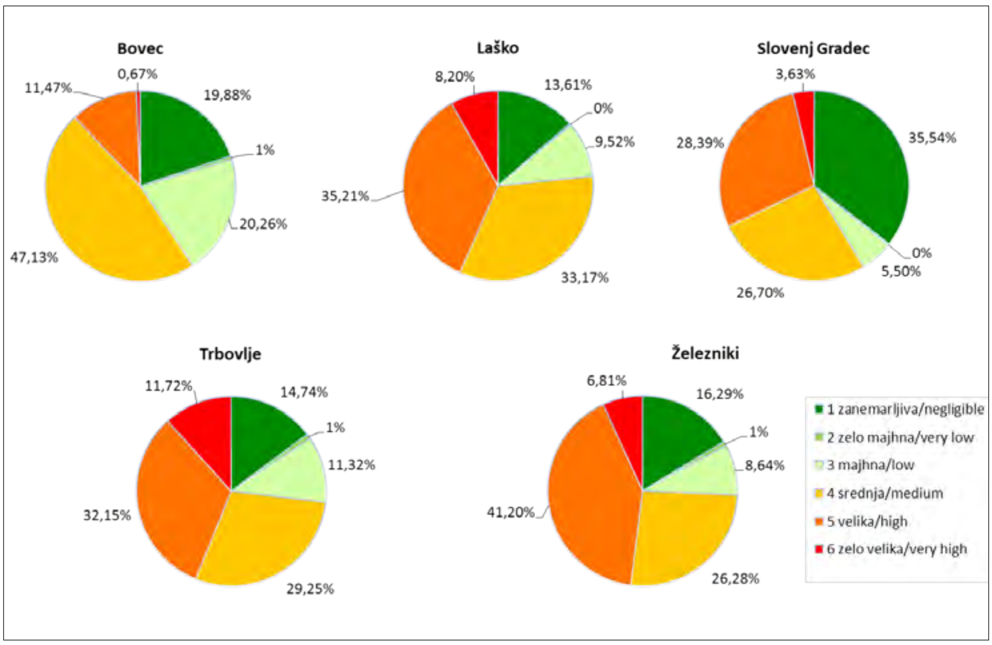
Izpostavljenost različnih tipov infrastrukture (železnica, ceste, električno, kanalizacijsko, plinovodno, toplotno in vodovodno omrežje) prikazuje slika 7. Rezultati analize izpostavljenosti so pokazali, da se na območju z veliko do zelo veliko izpostavljenostjo nahaja 48,01 % infrastrukturnih elementov v občini Železniki in 43,87 % v občini Trbovlje. Najnižja stopnja izpostavljenosti infrastrukture je bila ocenjena za občino Slovenj Gradec (35,54 %).

Rezultati prekrivanja različnih slojev so prikazani kot karte izpostavljenosti, ki izražajo stopnjo izpostavljenosti posameznih elementov (prebivalcev, objektov in infrastrukture) zaradi pojavljanja zemeljskih plazov. Karte izpostavljenosti smo izdelali za prebivalce, objekte in za vsak infrastrukturni element posebej.

V nadaljevanju podajamo zgolj dva primera kart izpostavljenosti verjetnosti pojavljanja zemeljskih plazov, in sicer karto izpostavljenosti prebivalstva (sl. 9) za primer občine Laško in karto izpostavljenosti cest v občini Železniki (sl. 10). V končnem poročilu MASPREM pa so bile izdelane vse različice kart izpostavljenosti za vse izbrane občine.

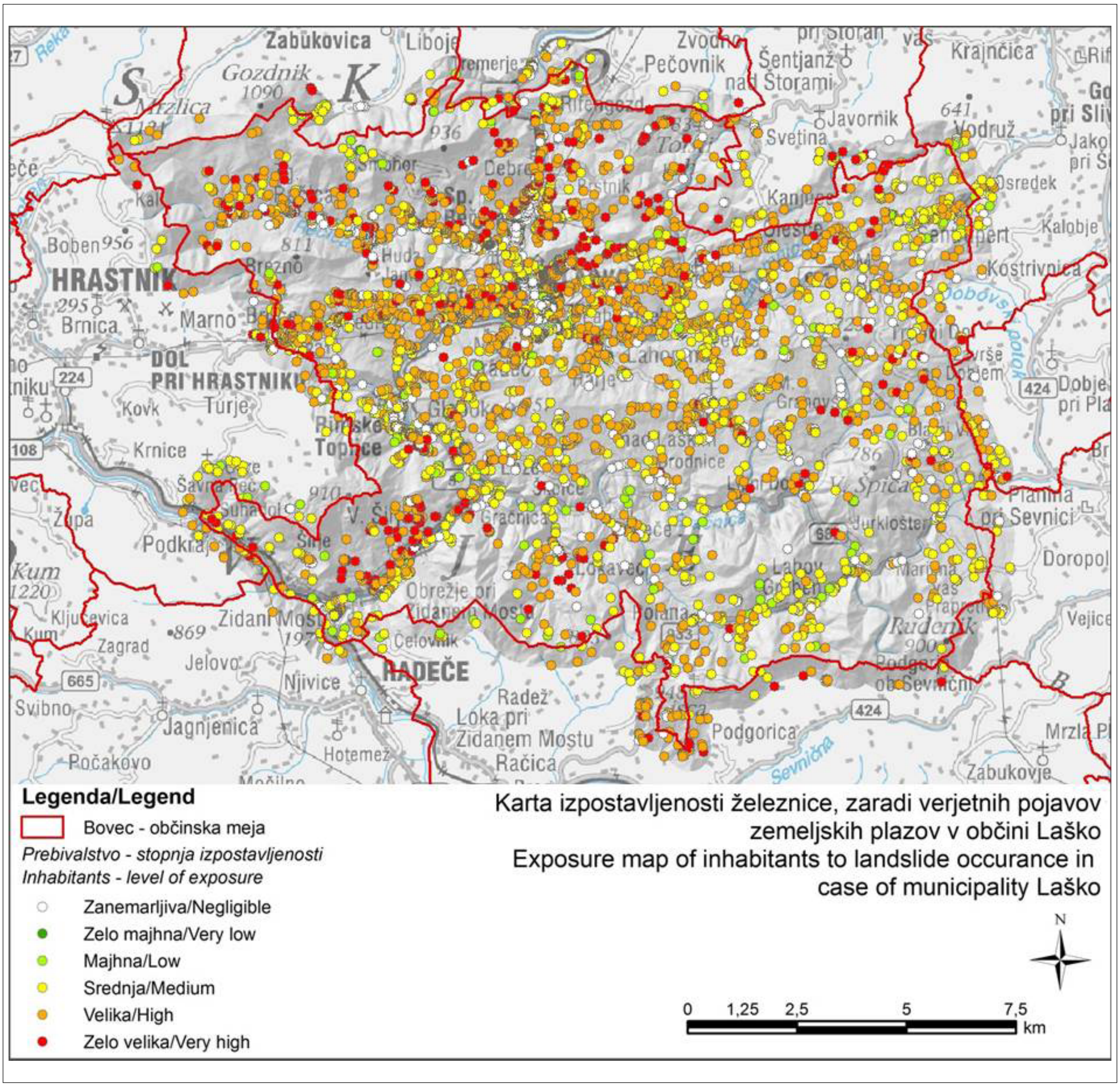
Sklep

Ocena izpostavljenosti nekega objekta je verjetnost, da se le-ta nahaja v območju nevarnosti in predstavlja eno izmed predhodnih faz izdelave ocene (in karte) ogroženosti. Izdelane karte in ocene izpostavljenosti zaradi zemeljskih plazov prebivalstva, objektov in infrastrukture predstavljajo poenostavljeno oceno ogroženosti, saj ne vključujejo izračunov ekonomske škode. Rezultati izpostavljenosti različnih elementov pojavom plazov in pravilna ocena ogroženosti ter vseh vmesnih členov (izpostavljenost) omogočajo racionalno in kvalitetno upravljanje z zemeljskimi



Sl. 7. Izpostavljenost infrastrukture zaradi pojavljanja zemeljskih plazov.

Fig. 7. Exposure of infrastructure to landslides.



Sl. 9. Karta izpostavljenosti prebivalstva zaradi verjetnih pojavov zemeljskih plazov v občini Laško (Šinigoj et al., 2013b).
Fig. 9. Inhabitants exposure maps to potential landslide occurrence for the municipality Laško (Šinigoj et al., 2013b).

plazovi oziroma njihovimi posledicami. Tako karte izpostavljenosti predstavljajo dobro osnovo pri izdelavi nadaljnjih kart in ocen ogroženosti ter upravljanja z zemeljskimi plazovi, pri prostorskem načrtovanju in pri vzpostavljanju sistema za zgodnje opozarjanje za primer proženja zemeljskih plazov. Izdelane karte izpostavljenosti v merilu 1 : 25.000 so lahko tudi smernice končnemu uporabniku pri poseganju v prostor in varnejši gradnji objektov.

Zahvala

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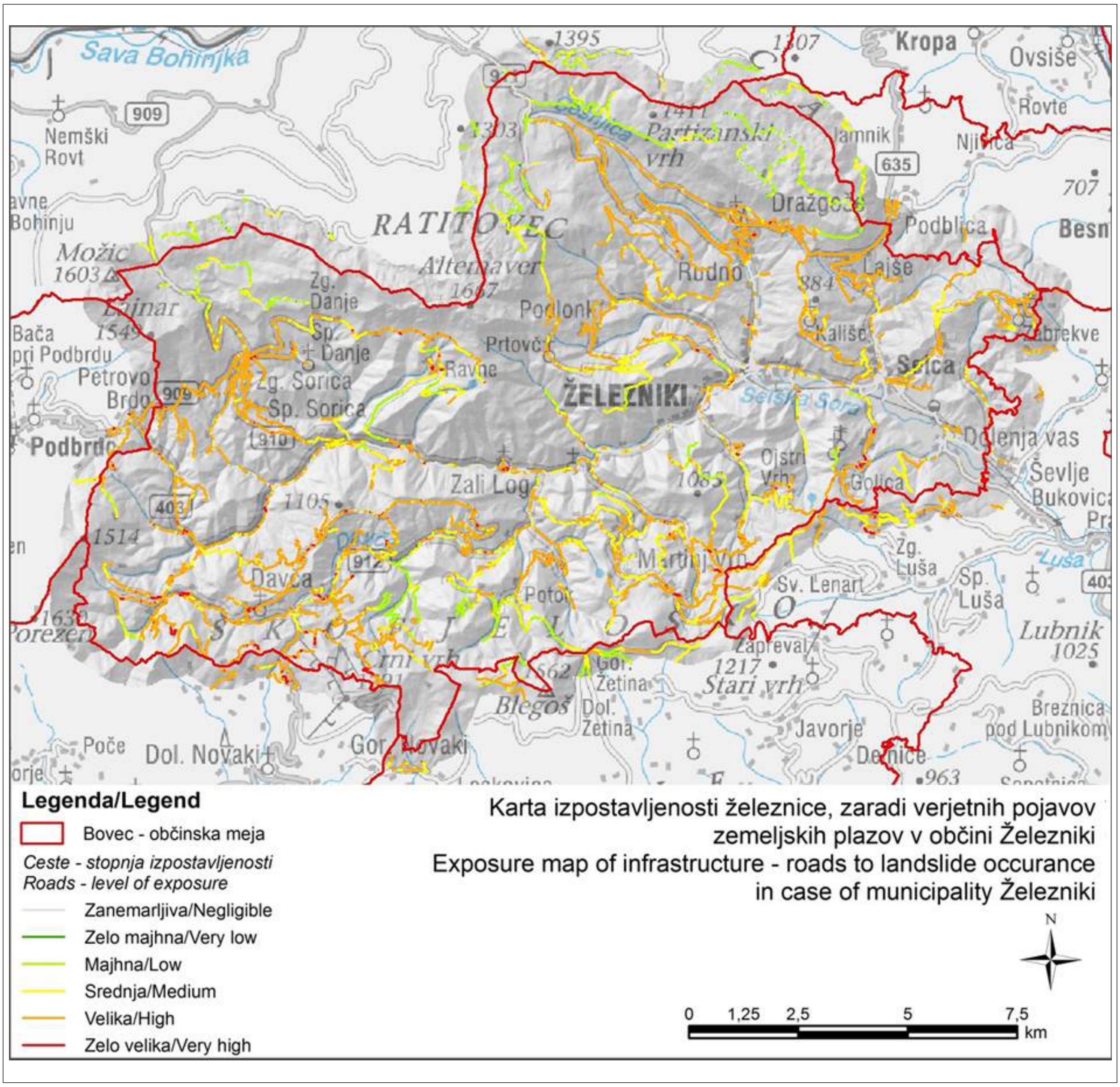

Sl. 10. Karta izpostavljenosti cest zaradi verjetnih pojavov zemeljskih plazov v občini Železniki. (Šinigoj et al., 2013b)
Fig. 10. Road exposure map to potential landslide occurrence for the municipality Železniki. (Šinigoj et al., 2013b)

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Rock shelters in Slovenian Istria as a potential for the development of geotourism in the region

Spodmoli v Slovenski Istri kot potencial za razvoj geoturizma v regiji

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Kjučne besede: geoturizem, geološka znamenitost, geomorfološka znamenitost, geodiverziteta, varovanje geo-dediščine, spodmoli, Slovenska Istra

Abstract

Geotourism is a special form of tourism which focuses on visiting geological and geomorphological sites. In the article we discuss the basic terms regarding geotourism, geodiversity and geoconservation, and then present the main features of rock shelters, i.e. landforms whose formation has not yet been elucidated. In our opinion rock shelters in Slovenian Istria have a potential to become sites for geotourism. We evaluated the geotourism potential of five rock shelter locations: Veli Badin, Štrkljevica, Mišja peč, Stena and Kavčič. The results of the evaluation show that three of the chosen rock shelter locations have a potential to develop as geotourist sites. Research confirmed our assumptions that the lack of scientific knowledge about rock shelters is a weakness from the geotourist point of view. Beside more detailed research on rock shelters, other activities, e.g. management of the sites, creating tourist activities, information material etc. are also needed if we want rock shelters to become geotourist sites in the future.

Izvleček

Geoturizem je posebna oblika turizma, ki se osredotoča na obiskovanje geoloških in geomorfoloških naravnih znamenitosti. V članku najprej predstavimo glavne pojme, ki se tičejo geoturizma, geodiverzitete in ohranjanja geo-dediščine, nato pa se osredotočimo na spodmole – reliefne oblike, katerih nastanek zaenkrat še ni pojasnjen. Po našem mnenju imajo spodmoli v Slovenski Istri potencial, da se razvijejo kot geoturistične znamenitosti. Ovrednotili smo geoturistični potencial petih lokacij spodmolov: Veli Badin, Štrkljevica, Mišja peč, Stena in Kavčič. Rezultati ocenjevanja so pokazali, da imajo tri lokacije potencial, da se razvijejo kot geoturistične znamenitosti. Z raziskavo smo potrdili naše domneve, da je z geoturističnega vidika pomanjkanje znanja o spodmolih slabost. Poleg bolj poglobljenih raziskav o spodmolih bodo potrebne tudi druge aktivnosti, npr. upravljanje z lokacijami, nudenje turističnih aktivnosti, izdelava informacijskega materiala o spodmolih itd., če želimo, da spodmoli v prihodnosti postanejo lokacije geoturističnega obiska.

Introduction

The most impressive landforms (caves, canyons, waterfalls etc.) will always be attractive to visitors. As well as being part of geodiversity (variety within abiotic nature), some of them can carry different values in humans' point of view: scientific, cultural, aesthetic, ecological, economic, educational etc. Some of them are, because of their importance, recognized as a natural heritage and consequently protected for future generations. These so-called geosites and geomorphosites can play an important role in the development of geotourism in the areas where they are located. Geotourism, with its focus on geological heritage, is a special form of tourism and by following the concept of sustainable tourism it encourages synergy between conservation of geological heritage and tourism development, which brings satisfaction to both tourists and the local community. Its goals are raising people's interest in geoscience by visiting geosites and geomorphosites and learning on the field as well as enhancing further research in the field of geology and geomorphology.

Slovenian Istria is known for being a region where rock shelters (or abris) occur. These are shallow cave-like openings, formed mostly in the lower parts of rock faces/cliffs. So far little is known about rock shelter formation, but our opinion is that they are interesting landforms and can be attractive to tourists. With the aim to figure out which rock shelter locations have the highest potential for the development of geotourism we decided to evaluate five locations: Veli Badin, Štrkljevica, Mišja Peč, Stena and Kavčič. The selection of these sites was based on their official recognition as valuable natural features (Official Gazette RS, 2010), and our knowledge of these locations from the field (all are part of ongoing research of rock shelter morphogenesis). The evaluation of their geotourist potential was made according to a method proposed by Kubalíková (2013). Results showed that three of the chosen rock shelter locations have a potential for geotourist development. The evaluation also revealed the fact that with the intent to increase geotourist potential, more detailed research on these landforms should be made, as scientific and educational values of the sites are the basis for geotourism development.

Geodiversity, geoheritage and geoconservation

In order to understand the concept of geotourism we should first discuss three terms which in principle represent the basis of this special type of tourism: geodiversity, geoheritage and geoconservation.

Geodiversity is a variety within abiotic nature, a diversity of geological (rocks, minerals, fossils), geomorphological (landforms, processes) and soil features, "including their assemblages, relationships, properties, interpretations and systems" (Gray, 2004; Erhartič, 2007). Seen from a man's point of view, geodiversity has different values (Gray, 2004; Reynard, 2004; Kubalíková, 2013):

a) intrinsic/scientific value (independent of human evaluation; for understanding the history of the Earth);
b) cultural, historical, archaeological, spiritual, religious values;
c) aesthetic value (very important for geotourist activities);
d) ecological value (flora and fauna depend on particular geomorphological and geological conditions)
e) economic/functional value (use of mineral resources, geoheritage, geotourist potential and activities);
f) research/educational value (for understanding the origin of life and landforms, evolution of the landscape and climate and paleogeographical reconstructions).

Scientific and partly ecological value can be regarded as objective values and all the other as subjective values (dependent of the culture, education, social level…of the assessor) (Reynard & Panizza, 2005).

With the aim to minimize negative impacts on natural features considered to carry special values for humans, some parts of abiotic nature are protected as natural heritage. Natural heritage is described as a part of nature "which the society of a particular place and time accepts as a value" (Skoberne & Peterlin, 1988, as cited in Erhartič, 2010). The definition also covers the abiotic part of natural heritage, i.e. geoheritage, which represents geosites and geomorphosites. The act of "protecting geosites and geomorphosites from damage, deterioration or loss through the implementation of protection and management measures" (Hose, 2012, p. 16) is geoconservation. With geoconservation the most valuable parts of the geodiversity are preserved for the future generations.

In Slovenian documents about nature conservation the term "valuable natural feature" (Official Gazette RS, 2014) is used instead of the term natural heritage. According to the Decree on the categories of valuable natural features (Official Gazette RS, 2003) valuable natural features are of different categories: geomorphological valuable natural feature, subsurface geomorphological valuable natural feature, geological valuable natural feature, hydrological valuable natural feature, botanical valuable natural feature, zoological valuable natural feature, ecosystemic valuable natural feature, dendrological valuable natural feature, designed landscape, valuable landscape and also minerals and fossils. Parts of nature are officially recognized as valuable natural features because of following characteristics: extraordinary, typical, complexly bound, preserved, rare, scientifically or historically important parts of nature (Official Gazette RS, 2003). In our case we are interested in geological valuable natural features – geosites, and geomorphological valuable natural features – geomorphosites. Geosites according to the Decree on the categories of valuable natural features represent mineral and fossil deposit locations and different types of geological features: tectonic, mineralogical, petrological, paleontological, stratigraphical, glacial, hydrogeological and sedimentological. Minerals and fossils are a special category of valuable natural features. Geomorphosites, which can be single objects or wider landscapes (Reynard & Panizza, 2005), according to the same Decree represent two types of landforms: surface landforms (karstic, glacial, fluvial-denudational, polygenetic and coastal landforms) and subsurface landforms (caves and shafts). The main difference between geosites and geomorphosites is that geosites can be found also in urban environments, for example mines and quarries (Dowling, 2011). Another difference between the two types of sites is in the assessment of their values. Geosites were in the past assessed only through the aspect of their scientific value, while methods for geomorphosites evaluation always included other values, for example aesthetic, cultural and economic. But scientific value is always the basis of evaluation for geotourist purposes as well (Reynard 2005; Kubalíková, 2013).

Geotourism, geotourists and geoparks

The term geotourism is a coinage of two words – "geological" and "tourism". The first part of the word refers to geological and geomorphological sites, the second to tourist visits, planning, management and infrastructure (accommodation, transport) (Dowling, 2011). As it can be seen from the term itself, geotourism is a form of "special interest tourism" (Hose, 2012, p. 8) or niche tourism (Hose, 2005) with a single focus of interest, and is as such close to other types of special interest tourism, for example ecotourism and cultural tourism. In the same way as ecotourism focuses on biotic environment (flora and fauna) and the basis of cultural tourism is the contact with different cultures, geotourism focuses on abiotic environment: forms (landforms, rock outcrops, rock types, sediments, soils, crystals) and processes (erosion, glaciation, volcanism etc.) (Dowling, 2011).

Geotourism is actually quite a new global phenomenon (Dowling, 2008), but it has a widespread potential, because it can develop on a small or large scale and in natural or urban environments (Dowling, 2011). The beginnings of its development were in the late 1980s with accelerating loss of mines and quarries, some geological exposures (road side exposures) and geomorphosites (hard coastal defenses) in the UK (Hose, 2012). Its purpose was primarily to "promote and possibly fund geoconservation, especially for mines and quarries" (Hose, 2012, p. 7). It was recognized as a special form of tourism in the early 1990s by Hose, a geologist who made the first modern geotourism definition, which was "the promotion and explanation to a non-specialist audience of the geologic features and/ or significance of a delimited area by either a fixed facility and/or populist publication" (Hose, 1994, p. 2, as cited in Hose, 2012). The same author later redefined his definition and in 2012 (p. 11) again made a new definition of geotourism: "The provision" of interpretative and service facilities for geosites and geomorphosites and their encompassing topography, together with their associated in situ and ex situ artefacts, to constituency-build for their conservation by generating appreciation, learning and research by and for current and future generations." Although "HOSE" is an authority in the field of geotourism, in the years after his first definition of geotourism many authors tried to make their own definition. Dowling and Newsome for example defined geotourism as "…a form of natural area tourism that specifically focuses on geology and landscape. It promotes tourism to geosites and the conservation of geo-diversity and an understanding of earth sciences through appreciation and learning. This is achieved through independent visits to geological features, use of geo-trails and viewpoints, guided tours, geo-activities and patronage of geosite visitor centres." (Dowling & Newsome, 2010, as cited in Dowling, 2011, p. 1). Their definition includes the term geodiversity which refers to geological and geomorphological natural features, but the basic focus of geotourism is according to them only on geosites. A solely geological component of geotourism is also found in the definitions of some other authors, for example Slomka & Kicinska-Swiderska (2004), Sadry (2009) and Amrikazemi (2010). But on the other hand even broader definitions of geotourism exist, for example from National Geographic, which includes not only geoheritage and its conservation, but also culture and history of the regions (Internet 1).

Just as there is no unified definition of geotourism, there is no such definition of a visitor – a geotourist. Geosites and geomorphosites are not visited only by specialists from the geoscientific field, but also by other people who admire natural features. Grant (2010, as cited in Dowling, 2011) describes two sorts of geotourists:

- visitors, who can be unaware, aware or interested in geological tourism
- geotourists, who are geo-amateurs, geo-specialists and geo-experts.

According to his definition everyone is a potential geotourist, the difference is only in the knowledge about the geo- and geomorphosites. And by good management of the sites, even people who have little knowledge of Earth processes and forms, can get interested in this topic and understand the need of protection and conservation of natural heritage. Which is all in all one of the basic goals of geotourism.

The point of geotourism is not only in admiring geoheritage but also in establishing a tourist product and promoting it. This entrepreneurial part of geotourism involves different actions: planning and management of the sites, transportation, accommodation and trained team (guides), which are usually operated by local communities. These actions consequently enhance people's interest in visiting geosites and geomorphosites. The development of geotourism is a result of cooperation between nature conservation authorities, educational institutions, local community and investors (Dowling, 2011). Ideally expectations of all the cooperating sides meet and geotourism can consequently fund geoconservation (Martini, 2000). As geotourism tries to follow the concept of sustainable tourism it encourages synergy between conservation of geoheritage and touristic development, which brings satisfaction to both tourists and the local community. One of the best examples of sustainable geotourism development are geoparks. A geopark is "a nationally protected area containing number of geological heritage sites of particular importance, rarity or aesthetic appeal (UNESCO, 2009). Geoparks can act as an alternative to UNESCO World Heritage Site (Hose, 2012). These areas represent a combination of geoconservation, geo-education and tourism, which brings economic benefit to local people. For a geotourist experience geoparks offer tourists different activities (visiting information centres and museums, hiking on geotrails, organized guided tours and school excursions, seminars etc.) and information material (maps, educational material, leaflets, etc.) (Dowling, 2011). In Slovenia we have two geoparks which are both on the list of European Geoparks Network (EGN), therefore on the list of Global Geoparks Network (GGN) and by that under the auspices of UNESCO. These are Idrija Geopark and Geopark Karavanke/ Karawanken (Slovenian-Austrian cooperation) (Internet 2 & 3), and they can act as a good example for any potential geotourist actions in other parts of the country.

Characteristics of rock shelters in Slovenian Istria

Rock shelters (or abris) are shallow cave-like openings, formed mostly in the lower parts of rock faces/cliffs. In the past they attracted people's attention as potential housing, shelters from the weather and storage places, now they are more interesting as objects of scientific research and tourist visits. In Slovenian Istria rock shelters occur in two areas: Kraški rob (Karst edge) and Dragonja river valley. Kraški rob, where most of the rock shelters can be found, represents an area of specific landscape from source of Timavo river in Italy to Mt. Učka and Raša bay at eastern coast of (Croatian) Istria (Placer, 2007). In our case we are interested in part of this area between villages Osp and Socerb at Slovenian-Italian border and villages Sočerga and Rakitovec at Slovenian-Croatian border. This part of Kraški rob covers an area of approximately 17 km in length and from 2 to 15 km in width (Placer, 2007). The formation of Kraški rob is related to geological events which had a great impact on the area on a larger scale. Kraški rob represents a contact belt between Adriatic-Apulian foreland and External Dinarides. The overthrusting of External Dinarides in the end of Eocene and in the beginning of Oligocene, followed by the underthrusting of the Adriatic-Apulian foreland underneath External Dinarides in the Middle Miocene resulted in a specific landscape, a series of geomorphological steps, where Eocene alveoline-numulite limestones, more resistant to weathering, are thrust on less resistant Eocene flysch (Placer, 2007; 2008). Kraški rob as a landscape thus represents a combination of steep limestone rock faces and more gently sloping flysch slopes (Natek, Repe & Stepišnik, 2012). Elevation of limestone rock faces in the area varies between 750 m above sea level (e.g. at Kavčič) to 50 m above sea level (e.g. at Osp). The area is also a contact between continental and coastal part of Slovenia and a climate border. Kraški rob is therefore unique in Slovenia by its geomorphological, geological, and biological characteristics (rock faces are habitats of special flora and fauna) and is as such officially recognized as valuable natural feature (Official Gazette RS, 2010; Internet 4). The same is with limestone rock faces, where rock shelters occur – they were already recognized among nature conservation authorities as a part of natural heritage (Official Gazette RS, 2010). The other rock shelter location, a limestone hill Stena, is in Dragonja river valley. The elevation of this site is lower than of those at Kraški rob – approximately 30 m above sea level. According to Placer (2007) this location is not a part of subthrusting belt. It represents the western part of Buje anticline (Pleničar et al., 1973), from which it is separated by the river bed of Dragonja. Alveoline-numulite limestones are in contact with flysch and with alluvial sediments of Dragonja (Fuks, 2010). This location was like in the case of Kraški rob recognized as a part of natural heritage (Official Gazette RS, 2010).

In the Slovenian literature we can find definitions, which describe rock shelters as small horizontal caves (for example Stepišnik, 2011), but in case of Slovenian Istria these landforms are shallow caverns, which have more or less disctinctive overhangs and roofs, but they are not caves. In research paper about Kraški rob (Natek et al., 1993) authors named different phenomena from this area as rock shelters. Among them were large caverns (e.g. rock shelters at Veli Badin, for sizes see Table 1), which partly resemble cave entrances, but in the paper there are examples of describing overhangs on limestone-flysch contacts as rock shelters. Placer et al. (2011) defined three types of rock shelters in Slovenian Istria: corrosion-freeze thaw type (e.g. caverns of Veli Badin), structural-tectonic type (overhang that represents a small thrust) and litologic-facial type (overhang, which is a result of differential weathering on a limestone-flysch contact). We are interested in first type (corrosion-freeze thaw rock shelters), as shapes of these landforms are the closest to description in definition of rock shelters (cave-like openings in rock faces), and not in other two types. The reason is that for now no agreement exist, if we can regard these two types of overhangs as rock shelters or not.

Rock shelters in Slovenian Istria vary in size and shape. But their form in crossection can be in general described as following: at the bottom their shape traverses from short slope of 30-40 degrees to subhorizontal bench, which continues to a concave, hollow part of rock shelters. The hollow part is covered with a roof, which can be straight or slighty sloping. In transitional part from the concave part of rock shelters to vertical slope above them, they have a slightly convex shape (Kunaver & Ogrin, 1992). In the walls and roofs of rock shelters at most of the locations in Slovenian Istria calcareous formations (tufas), which resemble shape of speleothems, can be found.

Rock shelters similar to these in Slovenian Istria occur at various locations on Earth. They can be found just across the border in Croatian Istria, for example in Mirna river valley and close to Buzet. They occur in Velebit Mountains (Croatia) close to Ravni Dabar and Baške Oštarije and on rock faces of Kornati islands (Croatia). We spotted them north from Shiraz in Iran, on the coast of lake Van in Turkey, and near town Perissa in Santorini, Greece. According to the literature rock shelters of such shapes can be also found near Eyzes-de-Tayac at river Vezere (France), at Mesa Verde (Cliff Palace) in southwestern Colorado (USA) (Kunaver, 2007), in northwestern Sahara (Smith, 1978), and in the Golden Gate Reserve, South Africa (Mol & Viles, 2010; 2011), if we cite just some of the examples. As rock shelters can be found in different rock types (limestone, marble, sandstone etc.) and climate types (coastal, desert, mountain climates etc.), it is difficult to link their formation to only one factor or process. There is a possibility that different processes are involved in their formation, but as the final shape of rock shelters is similar, they can be for now regarded as convergent landforms.

Slovenian researchers, whose main focus was on rock shelters in Slovenian Istria and not on rock shelters from other locations, through years discussed different possible causes of their formation:

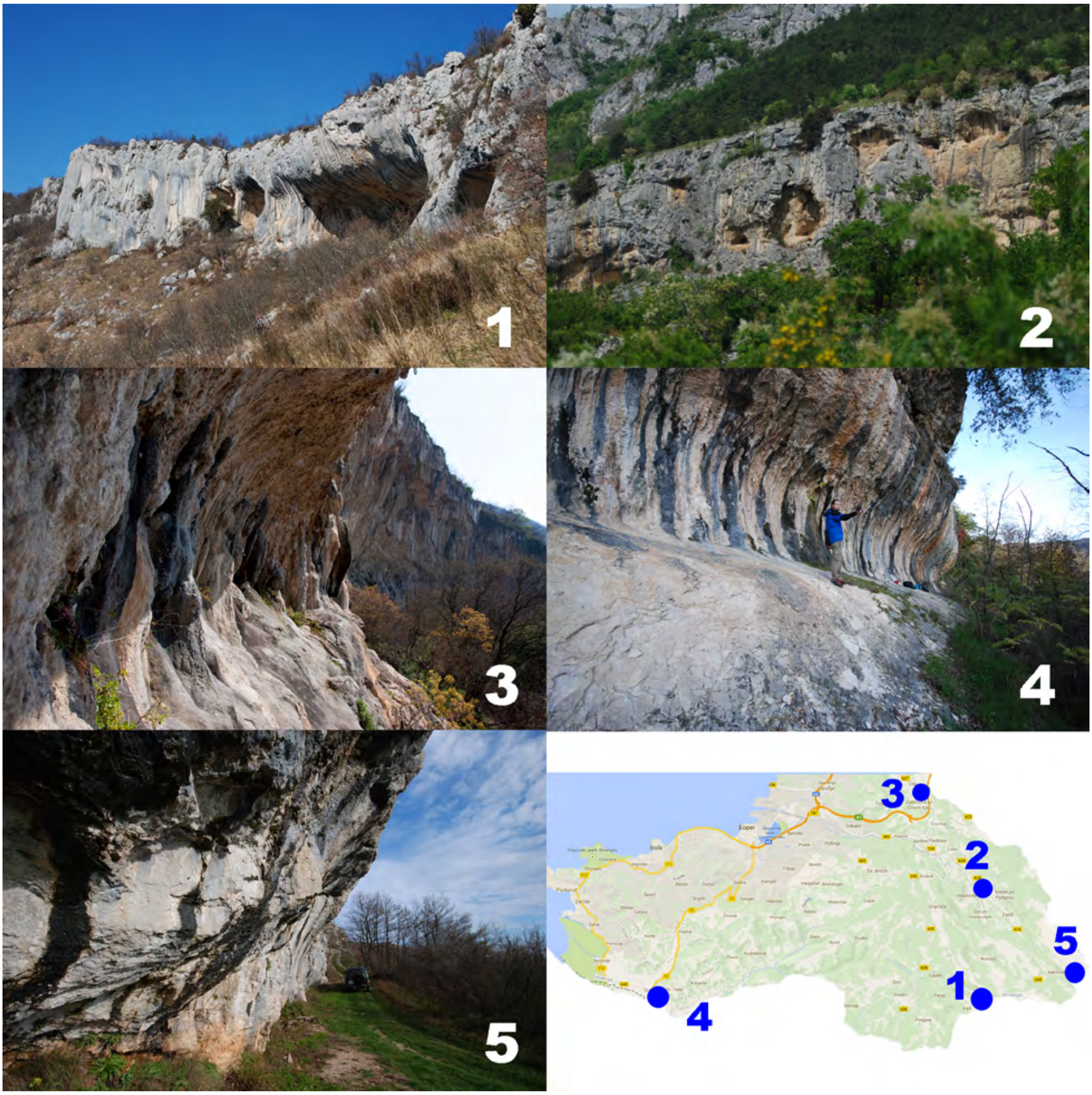

Fig. 1. Rock shelter locations, chosen for evaluation of geotourist potential: 1 – Veli Badin, 2 – Štrkljevica, 3 – Mišja peč, 4 – Stena, 5 – Kavčič, and their position on the map showing the major part of Slovenian Istria. Author of the photos 1–5 (2012–2014): L. Ozis. Source of the map: Google maps, 2014.

Sl. 1. Lokacije spodmolov, ki so bile izbrane za ocenjevanje geoturističnega potenciala: 1 – Veli Badin, 2 – Štrkljevica, 3 – Mišja peč, 4 – Stena, 5 – Kavčič, in njihov položaj na zemljevidu, ki prikazuje večji del Slovenske Istre.

- combination of mechanical weathering, corrosion and denudation, probably in the time of Würm glaciation (Habić et al., 1983);
- combination of tectonically crushed limestones on limestone-flysch contact and exfoliation due to microclimatic conditions (high temperatures of rock faces in all seasons – result of SW-S-SE exposition of rock faces) (Kunaver & Ogrin, 1992; Ogrin, 1995);
- combination of selective weathering of limestones on limestone-flysch contact and microclimatic conditions (Kunaver & Ogrin, 1993);
- combination of mechanical weathering, denudation and corrosion; possible lithological differences among limestone layers (Natek et al., 1993);
- influence of lithological and tectonic features of limestones, intensive mechanical weathering on a bedding plane, partly exfoliation; impact of colder climatic conditions in the past (Grmovšek, 2001);
- river erosion and unroofed caves (Gogala, 2007);
- selective weathering (mechanical and chemical) and denudation of limestones on limestone-flysch contact; climatically exposed rock faces (Kunaver, 2007);
- combination of different factors: lithological and tectonic features, temperatures, corrosion and probably biological influence; "corrosion-freeze thaw" rock shelters (Placer et al., 2011).

Table 1. The chosen rock shelter locations for evaluation of geotourist potential.

Tabela 1. Izbrane lokacije spodmolov za vrednotenje njihovega geoturističnega potenciala.

Name of valuable natural feature	*Category of valuable natural feature*	*Brief description*	*Range of importance (and consequent protection)*
Veli Badin – Krog	geomorphological, geological, botanical, ecosystemic	limestone scale with picturesque rock shelters, natural bridge, kamenitzas, representative thermophilic vegetation, nesting place and habitat of endangered bird species sizes of rock shelters: - the largest rock shelters: 20-25 m in width, 10-13 m in height and 10-15 m in depth; - smaller rock shelters: 5-10 m in width, 3-5 m in height and 1-5 m in depth	national
Štrkljevica – rock face	geomorphological & subsurface geomorphological, botanical, zoological	rock face of Kraški rob (Karst edge) between villages Podpeč and Zanigrad with rock shelters, cave and three occasional waterfalls, habitat of rare and endangered animal species sizes of rock shelters: due to protection of the rock face we did not measure sizes of rock shelters	national
Mišja peč – rock shelter	geomorphological	rock shelter in limestone rock face of collapsed cave Mišja peč size of rock shelter: w = 15,5 m, h = 5 m, d = 3 m	local
Stena	geomorphological, geological, botanical, ecosystemic	limestone rock face in Dragonja river valley, site of Mediterranean flora sizes of rock shelters: rock shelters are shallow, but longer in width, for example: w= 20 m, h = 3,5 m, d = 1,2 m	national
Kavčič – rock faces	geomorphological, geological, botanical	rock faces of Kavčič, thrust contact of limestone over flysch, east from village Rakitovec size of rock shelter: w = 28 m, h = 7 m, d = 3,5 m	local

Source: Official Gazette RS, 2010

As we can see many assumptions of their formation exist, but none of them has been proven yet. Their formation is obviously complex, a result of an interaction of many factors and processes. Our ongoing research on rock shelters led to the following new insights about these landforms:

a) they occur on the contact of two limestone layers, and not at limestone-flysch contact;
b) the influence of tectonic factors is important, at least in some cases, e.g. folded limestone layers at location Veli Badin (Štefančič, 2012);
c) rock shelters are not unroofed caves – numerous calcareous formations on their roofs and walls are tufas and not speleothems (Ozis & Šmuc, 2014), as many previous authors except for Placer et al. (2011) thought;

but nevertheless many questions regarding their formation remain unanswered for now. Although little is known about rock shelters in Slovenian Istria they are in our opinion still interesting landforms and can be promoted in the field of geotourism.

Method for evaluation of geotourist potential of rock shelters

With the aim to estimate the geotourist potential of rock shelters in Slovenian Istria, we decided to evaluate rock shelters from five different parts of the region: Veli Badin, Štrkljevica, Mišja peč, Stena and Kavčič. Rock shelter locations and their position in Slovenian Istria are presented in Figure 1. All the chosen examples are according to the document Rules on the designation and protection of valuable natural features officially recognized as valuable natural features (Official Gazette RS, 2010). Rock shelters are in this document in most cases listed as being a part of protected rock faces, but also as individual examples of natural heritage. These five examples were chosen because they have already been recognized as geoheritage, and we know them well from our field work (ongoing research on morphogenesis of rock shelters in Slovenian Istria). Descriptions of rock shelter locations in Table 1 are from the same document. To these short descriptions we added information about rock shelter sizes. Numbers present the largest sizes measured of width (w), depth (d) and height (h) of hollow part of rock shelters.

Table 2. Method for geosite and geomorphosite assessment for geotourism purposes.

Tabela 2. Metoda za ovredotenje geološko in geomorfološko zanimivih območij za namene turizma.

Scientific and intrinsic values	
Integrity	0 – totally destroyed site
	0.5 – disturbed site, but with visible abiotic features
	1 – site without any destruction
rarity (number of similar sites)	0 – more than 5 sites
	0.5 – 2-5 similar sites
	1 – the only site within the area of interest
diversity (number of different partial features and processes within the geosite or geomorphosite)	0 – only one visible feature/process
	0.5 – 2-4 visible features/processes
	1 – more than 5 visible features/processes
scientific knowledge	0 – unknown site
	0.5 – scientific papers on national level
	1 – high knowledge of the site, monographic studies about the site
Educational values	
representativeness and visibility/clarity of the features/ processes	0 – low representativeness/clarity of the form and process
	0.5 – medium representativeness, especially for scientists
	1 – high representativeness of the form and process, also for the laic public
exemplarity, pedagogical use	0 – very low exemplarity and pedagogical use of the form and process
	0.5 – existing exemplarity, but with limited pedagogical use
	1 – high exemplarity and high potential for pedagogical use, geodidactics and geotourism
existing educational products	0 – no products
	0.5 – leaflets, maps, web pages
	1 – info panel, information at the site

actual use of a site for educational purposes (excursions, guided tours)	0 – no educative use of the site
	0.5 – site as a part of specialized excursions (students),
	1 – guided tours for public
Economic values	
accessibility	0 – more than 1000 m from the parking place
	0.5 – less than 1000 m from the parking place
	1 – less than 1000 m from the stop of public transport
presence of tourist infrastructure	0 – more than 10 km from the site existing tourist facilities
	0.5 – 5 – 10 km tourist facilities
	1 – less than 5 km tourist facilities
local products	0 – no local products related to a site
	0.5 – some products
	1 – emblematic site for some local products
Conservation values	
actual threats and risks	0 – high both natural and atrophic risks
	0.5 – existing risks that can disturb the site
	1 – low risks and almost no threats
potential threats and risks	0 – high both natural and atrophic risks
	0.5 – existing risks that can disturb the site
	1 – low risks and almost no threats
current status of a site	0 – continuing destruction of the site
	0.5 – the site destroyed, but now with management measures to avoid the destruction
	1 – no destruction
legislative protection	0 – no legislative protection
	0.5 – existing proposal for legislative protection
	1 – existing legislative protection (Natural monument, Natural reservation...)
Added values	
cultural values: presence of historical/ archaeological/ religious aspects related to the site	0 – no cultural features
	0.5 – existing cultural features but without strong relation to abiotic features
	1 – existing cultural features with strong relations to abiotic features
ecological values	0 – not important
	0.5 – existing influence but not so important
	1 – important influence of the geomorphologic feature on the ecological feature
Aesthetic values	
number of colours*	0 – one colour
	0.25 – 2-3 colours
	0.5 – more than 3 colours
structure of the space*	0 – only one pattern
	0.25 – two or three patterns clearly distinguishable
	0.5 – more than 3 patterns
viewpoints	0 – no viewpoints
	0.25 – 1-2 viewpoints
	0.5 – 3 and more viewpoints

Source: KUBALÍKOVÁ, 2013

*values difficult to describe

In the literature we can find numerous methods for assessing natural features as potential geoheritage, but there are only a few methods for evaluation of geotourist potential of the sites. Kubalíková (2013) compared a number of methods for assessing geotourist potential of geosites and geomorphosites. Similar research did Erhartič (2010), but the difference between the two authors is that Erhartič (2010) tried to find the best examples for evaluation of geoheritage and not of geotourist potential. Kubalíková (2013) found out that methods are usually made on the same principle, the differences between them are in the authors' decision of which value they regard as more important. Scientific value is always basic in evaluations, followed by assessment of added values. According to Kubalíková (2013), methods for geotourist purposes should consider the following criteria of evaluation:

a) intrinsic/scientific values (diversity, importance of the natural feature, scientific knowledge of the site)
b) pedagogical potential and exemplarity (the site itself and availability of the supporting products – maps, trails, information centres, panels etc.)
c) accessibility and visibility of the site, accompanied by the presence of tourist infrastructure (accommodation, shops, restaurants, local products etc.)
d) threats and risks – current protection of the site
e) added values (aesthetic, cultural, historic, ecological etc.)

As Kubalíková (2013) actually concluded the previous knowledge of assessment for geotouristic purposes, we decided to use the method she proposed for our evaluation of the five rock shelter locations. The method is presented in Table 2. With this method sites are evaluated by most criteria with numerical values from 0 (the lowest value) to 1 (the highest value), except for the criteria of "aesthetic values" where the range of values is between 0 (lowest value) and 0.5 (highest value). The sites evaluated with highest values (1 or in the case of aesthetic values 0.5) in all the criteria reach the evaluation of 18.5 units.

In our case we joined two conservation values: "potential threats and risks" and "actual threats and risks", into one value, so the highest evaluation the sites could reach is 17.5 units and not 18.5 units as in case of Kubalíková (2013). At some criteria we could not attribute only one numerical value to sites, so we decided to evaluate them in range, for example 0 – 0.5, or 0.5 – 1. (Maybe creating a numerical value in between, for example 0.25 or 0.75, would be a better option.) Consequently, the geotourist potential of each site is not presented as one number, but as a range between the highest and lowest sum of numerical values. With the aim of a better representation and comparison of the results, we decided to calculate the average sums of geotourist potential for all the chosen locations.

Results

The results of the evaluation of geotourist potential of five rock shelter locations in Slovenian Istria are presented in Table 3.

As we can see the locations Štrkljevica and Veli Badin are closer to the highest value (17.5 units) than other locations, but the evaluation results of all the locations are overall close to each other. Kubalíková (2013) does not propose any guidelines for further explanation of numerical data calculated with her method, so we first wanted to figure out which locations are above and which below the average value (17.5 / 2 = 8.75 units). According to this calculation the locations Veli Badin, Štrkljevica, Stena and Mišja peč have geotourist potential that is above the average value and the location Kavčič the one below the average value. Because the evaluation results of all five locations are close, we decided to make another comparison of the results. We calculated the average value of the results (52.875 / 5 = 10.575 units). In this case the locations Veli Badin, Štrkljevica and Stena are above the average value, but the location Mišja peč has a geotourist potential below the average value, the same as the location Kavčič (see Table 3). This comparison more accurately shows the actual geotourist potential of the chosen five locations, as Mišja peč has a higher potential as a recreational site (climbing) than as a geotourist site. A more detailed explanation of the results according to each of the criteria for geotourist potential is thus:

Scientific and intrinsic values

a) Integrity: all the locations except Mišja peč were given the highest value (1) to be the sites without any destruction. Rock shelter Mišja peč is a part of a climbing area, so some impacts of human actions are present, but the site is not destroyed. Štrkljevica also used to be a hiking (via ferrata) and climbing area but due to the protection of Eurasian eagle-owl (Bubo Bubo) habitat (PZS, 2004; Mihelič, 2006), nature conservation authorities in 2003 closed the location for recreational use. Now is possible to observe the rock face from a viewpoint in village Zanigrad, or hike on a path below the rock face. A similar thing happened at Veli Badin where a part of the hiking path was closed for visitors (PZS, 2004). Nevertheless some hikers still use the closed paths at both locations (Internet 7 & 8).
b) Rarity: Although rock shelters are a common landform in the Slovenian Istria, we gave the location Veli Badin the highest value (1) as rock shelters at this location are the largest (see sizes in Table 1) and the most recognisable examples of such landforms in Slovenian Istria. Other locations were given the value 0-0.5, because more than 5 similar sites in the region exist, but in case of Slovenia, rock shelters occur mainly in Slovenian Istria, and are not typical for other parts of the country.

c) Diversity (number of different processes within the site): All rock shelter locations were given the value 0.5. Because morphogenesis of the rock shelters is still unknown, it is difficult to claim how many processes are involved in their formation, but most likely there are more than one.
d) Scientific knowledge: All the locations except Kavčič were evaluated the same (0.5). Some publications about rock shelters in Slovenia exist, but many questions about these landforms are still unanswered. In case of location Kavčič specific publications do not exist, it is included in the descriptions of Kraški rob.

Educational values

a) Representativeness/clarity of the features/ processes: All locations were given the value 0 – 0.5, because formation processes of rock shelters are still uncertain.
b) Exemplarity, pedagogical use: As being almost an unknown landform (this statement regards to rock shelter types that are typical for Slovenian Istria, and not to other types of these landforms, which formation is already known), these rock shelters have a great potential for pedagogical use in the future (value 1).
c) Existing educational products: Locations Veli Badin and Štrkljevica were given the value 0.5 – 1, because info panels are present on sites. In case of other locations pieces of information exist, but are of different kind: Mišja peč – climbing information (Internet 9), Stena – TV documentary about river Dragonja (Internet 10), Kavčič – information for hikers (Internet 11).
d) Actual use of a site for educational purposes: All sites except Kavčič are part of specialized excursions (students, different geosocieties - GMDS and DŠG (Internet 5 & 6)). Kavčič is visited by hikers and mountain bikers.

Economic values

a) Accessibility: Mišja peč and Stena were given the highest value (1), because they are close to stops of public transport, Veli Badin and Štrkljevica are close to parking space for cars, but Kavčič can only be reached by 4×4 vehicle and in that case parking is on the spot (Internet 17 & 18). The method of Kubalíková (2013) does not go into details in case of quality of the roads, so we have to add some comments on that issue. Mišja peč and Stena would still have the best accessibility, but in case of Veli Badin and Štrkljevica the quality of the roads can be quite problematic. One way to reach Veli Badin is a combination of regional and macadam roads, but the visitor should in that case cross the international border with Croatia. The other option is a local road on the other side of the hill which is in a very bad condition – half macadam, half "asphalt". Road to the village Zanigrad, where there is a view point for Štrkljevica, is also in a bad condition (half macadam, half "asphalt"), and the macadam road which runs below Štrkljevica can be accessed only by 4×4 vehicle. The road to Kavčič is also in a bad condition and the only option to reach the location by car is again with 4×4 vehicle. If we took the above facts into account, the results for this criteria would be quite different.
b) Presence of tourist infrastructure: Štrkljevica and Stena are close to tourist facilities (tourist information centre/point, restaurant, accommodation – villages Hrastovlje and Dragonja), Mišja peč is close to facilities (village Osp), but the tourist information point is in the more distant village Črni Kal. In case of Veli Badin and Kavčič tourist facilities are 5-10 km away from the location (Gračišče and Zazid). Although there are options for overnight accommodation near Veli Badin (Sočerga, Smokvica), village Gračišče is the main tourist centre of the area (Internet 12–16).
c) Local products: No local products related to site are found on any of the locations.

Conservation values

a) Actual threats and risks: All the locations except Mišja peč (climbing area) were evaluated to have the highest value (1), i.e. low risks and almost no threats. At locations Veli Badin and Stena some climbing bolts are present in rock face, but they are not assessed as potential threat. Veli Badin is like Štrkljevica under protection as a site of bird species habitat, so no special intervention on the site is allowed without the permission of nature conservation authorities.
b) Current status of the site: Again all the locations except Mišja peč were given the highest value (1) – no destruction.
c) Legislative protection: All the evaluated sites are officially recognized as valuable natural features and included in the corresponding legislative protection.

Added values

a) Cultural values: presence of historical/ archaeological/religious aspects related to the site: Only Štrkljevica fulfils the criteria of cultural values. In one part of the rock face are ruins of a ”castle”, which was actually a village fortress (Internet 8).
b) Ecological values: All of the locations were evaluated as geomorphological features which are also important habitats of fauna and (or) flora. Kraški rob is a climatic border, biodiversity is consequently high in this area. Stena as being a habitat for the Mediterranean flora and rare fauna was in 1990 declared a natural monument of Municipality of Piran (Turk, 2012).

Table 3. Evaluation of geotourist potential of five rock shelter locations in Slovenian Istria.
Tabela 3. Ocena geoturističnega potenciala petih lokacij s spodmoli v Slovenski Istri.

Criteria of geotourist potential assessment	Rock shelter locations				
	1) Veli Badin	Štrkljevica	Mišja peč	Stena	Kavčič
Scientific and intrinsic values					
integrity	1	1	0.5	1	1
rarity (number of similar sites)	1	0 – 0.5			
diversity (number of different processes within the geosite or geomorphosite)	0.5				
scientific knowledge	0.5				0
Educational values					
representativeness and visibility/ clarity of the features/ processes	0 – 0.5				
exemplarity, pedagogical use	1				
existing educational products	0.5 – 1	0.5 – 1	0 – 0.5	0 – 0.5	0 – 0.5
actual use of a site for educational purposes (excursions, guided tours)*	0.5				0
Economic values					
accessibility**	0.5	0.5	1	1	0 – 0.5
presence of tourist infrastructure**	0.5	1	0.5 – 1	1	0.5
local products	0				
Conservation values					
actual threats and risks & potential threats and risks	1	1	0.5	1	1
current status of a site	1	1	0.5	1	1
legislative protection	1				
Added values					
cultural values: presence of historical/ archaeological/religious aspects related to the site***	0	1	0	0	0
ecological values	1	1	1	1	1
Aesthetic values					
number of colours	0.25				
structure of the space	0.5	0.25	0 – 0.25	0	0
viewpoints	0.5	0.5	0.25	0.25	0.25
Geotourist potential (sum)	**11.25 – 12.25**	**11.5 – 13.5**	**8 – 10.25**	**10 – 11.5**	**7.5 – 9.75**
Geotourist potential (average sum)	**11.75**	**12.5**	**9.25**	**10.75**	**8.625**

*sources: Internet 5, 6, 11
**sources: Internet 12–18
***source: Internet 8

Aesthetic values

a) Number of colors: All of the locations were given the value 0.25 (2-3 colors). Colour combination is in all the examples of rock shelters grey limestone walls with different colours of tintenstriche (algae, lichen, mosses).
b) Structure of the space: The highest value (0.5) was given to the location Veli Badin, where different shapes of rock shelters dependent on tectonic structure of the site can be found. In case of Stena and Kavčič, rock shelters are of only one shape.
c) Viewpoints: Again the highest value was given to Veli Badin, which has more than 3 viewpoints, the same as Štrkljevica. Other locations were "given 0.25 points (1-2 viewpoints).

Discussion

As we expected, the results of Kavčič and Mišja peč were lower than the results of the other three locations. Although Kavčič is used for recreational purposes (hiking, mountain biking), it is a location distant from tourist facilities and is not so important regarding other values - scientific, educational and aesthetic. Mišja peč is a popular location for recreational use (climbing). Being popular as a climbing site is a fact which reduces other values (e.g. conservational), but it can be used as an example of informing the public about other rock shelters in the area. Stena has a good potential from the point of accessibility of touristic facilities, it is also an important ecological site, but the problem is that it is quite unknown, especially in the field of geosciences. We did not expect the results of Veli Badin and Štrkljevica to be so close and that Štrkljevica would even have a slightly higher tourist potential than Veli Badin. Although Veli Badin is the site with the largest rock shelters in the region (and can be thus regarded as one of the most beautiful locations – a subjective description), its problem is its remoteness from touristic facilities. The advantages of Štrkljevica compared to Veli Badin are closeness to tourist facilities (village Hrastovlje) and a cultural component (ruins of a village fortress) which is also important as one of the added values. Nevertheless both locations were evaluated to have the highest geotourist potential in the area and can be developed in the geotourist aspect. But we must not forget that the evaluation was made only with one method (Kubalíková, 2013) and that using another method could give us different results. We could also get different results by adding new values within each of the evaluation criteria (in our case "quality of the roads" can be added) or joining values within criteria in the same evaluation method.

Conclusions

Geotourism is a special form of tourism which focuses on visiting geosites and geomorphosites and thus learning about landforms and processes. One of its goals is raising people's interest in geoscience and also enhancing further research in this field. The importance of scientific research for geotourism development has been shown in case of our research. In our opinion, rock shelters in Slovenian Istria are interesting landforms which could in the future attract attention of potential geotourists to this region. We evaluated the geotourist potential of five rock shelter locations which are already recognized as part of Slovenian natural heritage (Official Gazette RS, 2010). Three of the chosen rock shelter locations - Veli Badin, Štrkljevica and Stena - have a potential to develop as geotourist sites. They have different values which are considered important for geotourism and have some tourist infrastructure already present on sites or at least close by. The research confirmed our assumptions that the lack of scientific knowledge on rock shelters (and consequent lack of their educational potential) is a weakness from the geotourist point of view. As scientific value of the sites is a basis for further geotourism development, our aim in the future is to fill the void in the geoscientific knowledge on rock shelters. Our research can thus act as an example that geotourism development is always interrelated with geoscientific knowledge.

Although scientific values of rock shelters are basic for geotourism development, there are still some actions needed to transform rock shelters into geotourist sites. These actions, which also the local community should be involved in, include the management of the sites, transportation, accessibility and accommodation improvement, the creating of tourist activities (e.g. geo-tours), information material (maps, leaflets, e-contents…) and promotion of the sites (e.g. creating an informational website, publishing popular articles about rock shelters, along with photographs of these landforms etc.). Only with such actions rock shelters can be recognized not only as natural heritage but also as geosites and geomorphosites which could attract geotourists to Slovenian Istria.

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Isotopic composition of precipitation at the station Ljubljana (Reaktor), Slovenia – period 2007–2010

Izotopska sestava padavin na postaji Ljubljana (Reaktor), Slovenija – obdobje 2007–2010

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Abstract

The stable isotopic composition of hydrogen and oxygen (δ^2H and δ^{18}O) and the tritium activity (A) were monitored in monthly collected precipitation at Ljubljana (Reaktor) during the period 2007–2010. Monthly and yearly isotope variations are discussed and compared with those observed over the period 1981–2006 and with the basic meteorological parameters for Ljubljana (Bežigrad) and Ljubljana (Hrastje) stations for the period 2007–2010. The mean values for δ^2H and δ^{18}O, weighted by precipitation amount at Ljubljana (Reaktor), are –59.4 ‰ and –8.71 ‰. The reduced major axis local meteoric water line ($LMWL_{RMA}$) is $\delta^2H = (8.19 \pm 0.22)\times\delta^{18}O + (11.52 \pm 1.97)$, while the precipitation weighted least square regression results in $LMWL_{PWLSR\text{-}Re}$ $\delta^2H = (7.94 \pm 0.21)\times\delta^{18}O + (9.76 \pm 1.93)$. The lack of significant difference in the LMWL slopes indicates a relatively homogeneous distribution of monthly precipitation as well as the small number of low-amount monthly precipitation events with low deuterium excess. The deuterium excess weighted mean value is 10.3 ‰ which indicates the prevailing influence of the Atlantic air masses. The temperature coefficient of δ^{18}O is 0.30 ‰/°C. Tritium activity in monthly precipitation shows typical seasonal variations, with a weighted mean tritium activity in this period of 8.5 TU. No decrease of mean annual activity is observed.

Izvleček

V prispevku obravnavamo rezultate meritev izotopske sestave vodika in kisika (δ^2H in δ^{18}O) ter aktivnosti tricija (A) v mesečnih vzorcih padavin, ki smo jo spremljali na postaji Ljubljana (Reaktor) v obdobju 2007–2010. Analizirali smo mesečne in letne spremembe izotopske sestave padavin ter jih primerjali z nizom podatkov za obdobje 1981–2006 ter z osnovnimi meteorološkimi parametri iz postaj Ljubljana (Bežigrad) in Ljubljana (Hrastje) za obdobje 2007–2010. Srednje tehtane vrednosti δ^2H in δ^{18}O določene ob upoštevanju izmerjene količine padavin na postaji Ljubljana (Reaktor) znašajo –59,4 ‰ in –8,71 ‰. Lokalno padavinsko premico ($LMWL_{RMA}$) lahko zapišemo kot $\delta^2H = (8,19 \pm 0,22)\times\delta^{18}O + (11,52 \pm 1,97)$, ob upoštevanju količine padavin pa kot $LMWL_{PWLSR\text{-}Re}$: $\delta^2H = (7,94 \pm 0,21)\times\delta^{18}O + (9,76 \pm 1,93)$. Nakloni izračunanih premic so si med seboj podobni, kar nakazuje, da je porazdelitev padavin relativno homogena in da je število mesečnih vrednosti z nizkim devterijevim presežkom majhno. Srednja tehtana vrednost devterijevega presežka znaša 10,3 ‰ in nakazuje prevladujoči vpliv zračnih mas iz Atlantika. Temperaturni koeficient za δ^{18}O pa znaša 0,30 ‰/°C. Tudi podatki o aktivnosti tricija v mesečnih padavinah kažejo sezonske spremembe. Srednja tehtana vrednost znaša 8,5 TU in ne nakazuje padajočega trenda.

Introduction

The Global Network of Isotopes in Precipitation (GNIP) was initiated in 1958 by the International Atomic Energy Agency (IAEA) and the World Meteorological Organisation (WMO), and became operational in 1961. The objective was to make a systematic collection of data on the isotopic composition, i.e. stable isotopes of hydrogen and oxygen and radioactive hydrogen isotope (tritium), of precipitation across the globe to determine temporal and spatial variations of isotope ratios in precipitation. Initially GNIP was focused on monitoring atmospheric thermonuclear test fallout through levels of radioactive tritium and, after 1970, became an observation network of stable hydrogen and oxygen isotope data for hydrologic investigations of water resources. In addition to isotope data for hydrological studies, during its more than 50 years of operation, GNIP has provided an important database for verifying and improving atmospheric circulation models, studying regional, global and temporal climates, studying the interactions between water in the atmosphere and biosphere, providing baseline information for the authentication of commodities, tracking migratory species and for forensic purposes (Internet 1).

The isotopic composition of precipitation in Ljubljana (Slovenia) has been performed by the Jožef Stefan Institute (JSI) since 1981. To begin with, monitoring was performed in cooperation with the Hydrometeorological Survey of Slovenia (now the Slovenian Environmental Agency, SEA), the Ruđer Bošković Institute (RBI; Zagreb, Croatia) and the IAEA. Since 2004 the JSI has also cooperated with Joanneum Research (JR; Graz, Austria). Details of the history of isotope monitoring since the beginning in 1981 until 2006, together with data evaluation, have been reported in Vreča et al. (2008).

Ljubljana station is an interesting location for monitoring isotopic composition of precipitation and has one of the longest continuous records in the area. The data constitute an important input into isotope investigations and were used in evaluations of GNIP data (e. g. Rozanski et al., 1993; Ichiyanagi, 2007; Hughes & Crawford, 2012), and in many hydrological and hydrogeological investigations (e. g. Krajcar Bronić et al., 1998; Pezdič, 1999, 2003; Brenčič & Vreča, 2006; Vreča et al., 2006, 2008; Ogrinc et al., 2008; Vodila et al., 2011; Kanduč et al., 2012; Horvatinčić et al., 2011; Zavadlav et al., 2012; Cerar & Urbanc, 2013; Marković et al., 2013; Mezga et al., 2014).

The main purpose of this paper is to present results concerning the isotopic composition of precipitation at Ljubljana (Reaktor) for the period 2007–2010 and to compare them with those for the long-term 1981–2006 record (Vreča et al., 2008).

Materials and methods

Sampling

Monthly composite precipitation has been sampled at the Reactor Centre of the JSI (46°06'N, 14°36'E; 282 m a.s.l.) in the vicinity of Ljubljana since September 2000 (Vreča et al., 2008). The GNIP station name is Ljubljana (Reaktor) and the GNIP code 1401502. Sampling station Ljubljana (Reaktor) is maintained by the staff of the Department of Environmental Sciences of JSI and is not part of the national meteorological network. Samples were collected from a precipitation gauge as soon as possible after a precipitation event. The volume of collected precipitation was measured in the laboratory and the sample poured into a 5-litre plastic bottle with a tight fitting cap. We removed impurities (e.g. dust, particles) from the composite monthly sample by filtration (Whatman Grade 589, Black Ribbon) before taking aliquots for different isotope analyses. 50 mL was stored for analysis of stable isotopes of hydrogen and oxygen and 1 L (or less if the sample volume was insufficient) for tritium analysis.

During the sampling period the tube that connects the rain gauge with the sampling bottle was blocked twice due to particles that accumulated at the top of the tube during severe storms being introduced into the gauge. Consequently, the water sample in May 2007 was exposed to evaporation. In September 2010 precipitation collected was very high, due mostly to heavy precipitation between 17/9/2010 and 19/9/2010. In 48 hours from Friday to Sunday on average from 170 to 180 mm of precipitation fell on the territory of Slovenia, reaching a maximum of 500 mm (Dolinar et al., 2011). During this event the tube was blocked and approximately one third of sample was assumed not collected. According to information from the automatic meteorological station at the Reactor Centre the amount of precipitation was 360 mm (Internet 2) but only 233 mm was registered. In April 2007 the amount of collected water (5 mm) was sufficient only for stable isotope analysis.

Stable isotope analysis

The oxygen isotopic composition ($\delta^{18}O$) was measured by means of the water–CO_2 equilibration technique (Epstein & Mayeda, 1953) on a dual inlet isotope-ratio mass spectrometer Finnigan DELTA^{plus} by means of the fully automated equilibration technique at JR until February 2007 (see also Vreča et al., 2008). Since then, it has been determined using a continuous flow isotope-ratio mass spectrometer IsoPrime (GV Instruments, UK) coupled to an automatic water-CO_2 equilibration system MultiFlow at the JSI. The isotopic composition of hydrogen was determined on a continuous flow Finnigan DELTA^{plus} XP mass spectrometer with a HEKAtech high-temperature oven, by reduction of water over hot chromium (Morrison et al., 2001) at JR. All measurements were carried out together with laboratory standards that were calibrated periodically against international standards, as recommended by the IAEA. Measurement precision was better than ±0.1 ‰ for $\delta^{18}O$ and ±1 ‰ for $\delta^{2}H$.

Tritium activity

Tritium activity (A) in monthly samples was determined at the Tritium Laboratory at the Department of Experimental Physics of the RBI. Results are expressed in Tritium Units (1 TU = 0.118 BqL^{-1}). The gas proportional counting technique (GPC) was used until 2007; since 2010, samples have been measured only by the liquid scintillation counting technique (LSC) following electrolytic enrichment (EE), while during 2008 and 2009 both GPC and LSC-EE techniques were used, depending on the available sample quantity. The GPC technique was replaced by the LSC-EE technique for the following reasons: (i) the tritium activity approached natural pre-bomb levels (<5–10 TU), therefore, the measurement of samples without tritium enrichment was not sufficiently precise, and (ii) the GPC technique did not satisfy requirements for a low detection limit and a high throughput of samples.

For GPC tritium activity measurement, CH_4 was obtained by reaction of water (50 mL) with aluminium carbide at 150 °C (HORVATINČIĆ, 1980), purified and used as a counting gas in a multi-wire GPC. Gas quality control was performed by simultaneous monitoring of the count rate above the tritium channel, i.e., above 20 keV (KRAJCAR BRONIĆ et al., 1986). The limit of detection (LOD) was 2.5 TU.

The LSC-EE technique consists of electrolytic enrichment of aliquots of 500 mL, distillation before and after the enrichment procedure, and measurement by the Ultra-low-level liquid scintillation counter Quantulus 1220 (Wallac, PerkinElmer). Mixtures of 8 mL of water and 12 mL of scintillation cocktail *Ultima Gold LLT* in plastic vials were used for counting in LSC. The limit of detection of the method is 0.3 to 0.5 TU, depending on measurement duration. If the quantity of sample was not large enough to perform EE, then a direct measurement in LSC Quantulus was performed, the limit of detection then being 6.0 TU (BAREŠIĆ et al., 2010, 2011; KRAJCAR BRONIĆ et al., 2013).

Tritium activity in two samples (March 2010 and July 2010) was determined by the Group for radiochemistry at the Department of Environmental Sciences of the JSI following electrolytic enrichment by liquid scintillation counting (LSC-EE) on a Tri Carb 3170 TR/SL Liquid Scintillation Counter (LSC, Canberra Packard) in accordance with method accredited by Slovenian Accreditation since 2009 (accreditation certificate LP-090). The limit of detection was 2.9 TU.

Data reduction

The approach of data reduction described by VREČA et al. (2008) for Ljubljana isotope records 1981–2006 was used. Basic descriptive statistics, i.e. mean, minimum and maximum values were determined. Deuterium excess ($d = \delta^2H - 8\times\delta^{18}O$; DANSGAARD, 1964) was calculated to characterize the deviation of isotopic composition of precipitation from the GMWL. As summarized by HARVEY (2005), d in precipitation was determined by air/sea interaction processes over the ocean surface during which the value of d is fixed and remains unchanged as air moves across the continents and loses moisture by rainout (CRAIG & GORDON, 1965; MERLIVAT & JOUZEL, 1979; GAT, 1996). However, d can alter as the air mass moves inland, due to secondary processes such as evaporation from an open surface water body which returns moisture to the air (GAT et al., 1994). In addition, d values can change as precipitation falls through the atmosphere (GAT, 1996; ARAGUAS-ARAGUAS et al., 2000; PENG et al., 2004) or as the precipitation sample sits in the precipitation collector (HARVEY, 2005). It was estimated that the initial d values should not be less than 3 ‰ and that lower values should be used with caution unless the source of their evaporative enrichment is known (HARVEY, 2005).

Furthermore, mean values weighted by the amount of precipitation collected during sampling at the Reactor Centre were calculated from all monthly data, and then summed over all collected samples per year and per month. Summation was also performed over each season: winter (December, January, February), spring (March, April, May), summer (June, July, August) and autumn (September, October, November). Data for May 2007 and September 2010 were not taken into account due to problems with sampling (see Materials and methods). The minimum required number of data fulfilled the requirement of eight monthly measured samples per year and more than 70 % of total precipitation amount collected per year (IAEA, 1992).

In the previous evaluation of isotopic data from Ljubljana (VREČA et al., 2008) we used meteorological parameters (amount of precipitation and air temperature), obtained from the SEA for meteorological station Ljubljana (Bežigrad; 46°03'N, 14°31'E; 299 m a.s.l.), situated in the city of Ljubljana. A similar approach was used in this study. Meteorological data were obtained from SEA internet database (INTERNET 3). The mean values, weighted by the amount of precipitation recorded at Ljubljana (Bežigrad), were compared with the mean values weighted by the amount of precipitation collected during sampling at the Ljubljana (Reaktor) site. Oxygen-temperature correlation was calculated using air temperature data provided by SEA from automatic meteorological station Ljubljana (Hrastje; 46°04'N, 14°33'E; 290 m a.s.l.) which is close to Ljubljana (Reaktor). For comparison with the previous data (VREČA et al., 2008) we also calculated the oxygen-temperature correlation, using Ljubljana (Bežigrad) air temperature data, and estimating the temperature difference between the city centre and its outer perimeter using Ljubljana (Bežigrad) and Ljubljana (Hrastje) data.

Linear correlations between δ^2H and $\delta^{18}O$ were calculated by methods usually applied in stable isotope studies – the ordinary least squares regression (OLSF) and the reduced major axis (RMA) regression (IAEA, 1992; HUGHES & CRAWFORD, 2012). Neither OLSF nor RMA take into account the precipitation amount, therefore a new, precipitation weighted least square regression (PWLSR) method, introduced by HUGHES & CRAWFORD in 2012, was also applied. The lines are defined as local meteoric water lines ($LMWL_{OLSF}$, $LMWL_{RMA}$ and $LMWL_{PWLSR}$) and were compared with the "Global Meteoric Water Line" (GMWL: $\delta^2H = 8\times\delta^{18}O + 10$) (CRAIG, 1961).

Results and discussion

Meteorological data: Precipitation and temperature

Variations in precipitation and temperature at Ljubljana (Bežigrad), in precipitation at Ljubljana (Reaktor) and in temperature at Ljubljana (Hrastje) for the period 2007–2010 are presented in Figures 1 and 2. Mean annual temperatures and annual amounts of precipitation in the period 2007–2010 are summarized in Table 1. The annual precipitation amount for Ljubljana (Bežigrad) station varied between 1196 mm in 2007 and 1798 mm in 2010, with a mean value of 1472 mm (Table 1). Precipitation was regularly lower at Ljubljana (Reaktor) , ranging from 1112 mm in 2007 to 1506 mm in 2010, with a mean annual value of 1338 mm (Table 1). At Ljubljana (Reaktor), mean monthly precipitation was lower than at Ljubljana (Bežigrad) in all months (Figure 1). Mean precipitation at Ljubljana (Bežigrad) was higher for January, February, March, July, September and December and lower for other months in 2007–2010 than in 1981–2010 (Figure 1).

The variations in monthly amount of precipitation may indicate some changes in air-mass movement, but the period is too short and more detailed investigations of atmospheric processes (e. g. backward trajectories of precipitating air masses and their rainout history and elementary circulation mechanisms) are needed for reliable conclusions. Monthly variations in precipitation during 2007–2010 are presented in Figure 2. The lowest value was observed in April 2007 and the highest in September 2010. Precipitation was, on average, 134 mm lower at Ljubljana (Reaktor) than at Ljubljana (Bežigrad). The largest differences between the two stations were observed in August 2009, June and August 2010, and can be related to local stormy events during the summer months

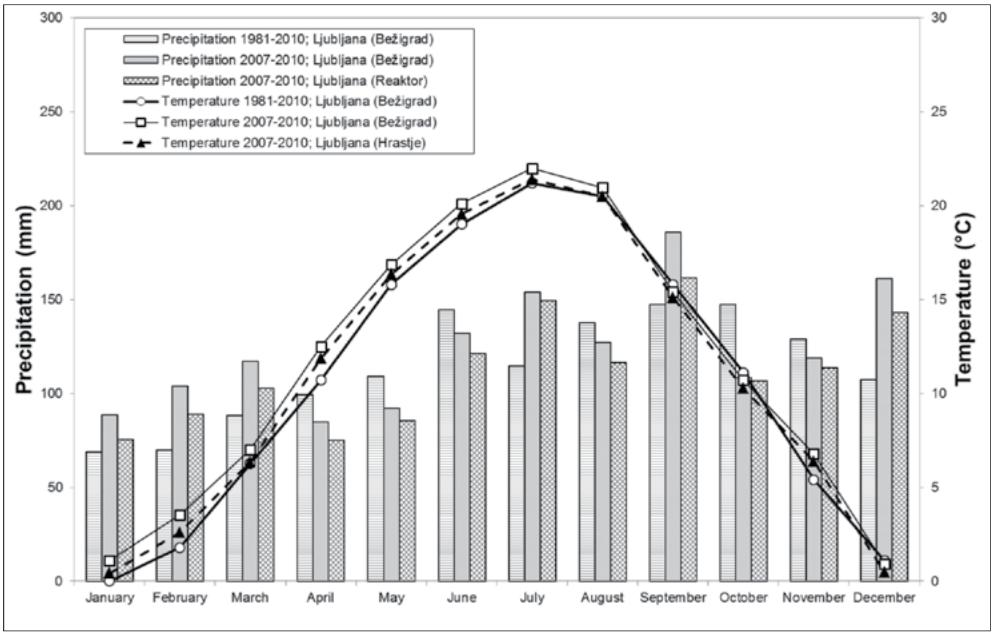

Figure 1. Mean monthly precipitation and mean monthly air temperatures at station Ljubljana (Bežigrad) for periods 1981–2010 and 2007–2010. Mean monthly precipitation at Ljubljana (Reaktor) and mean monthly air temperatures at station Ljubljana (Hrastje) for period 2007–2010 is shown for comparison.

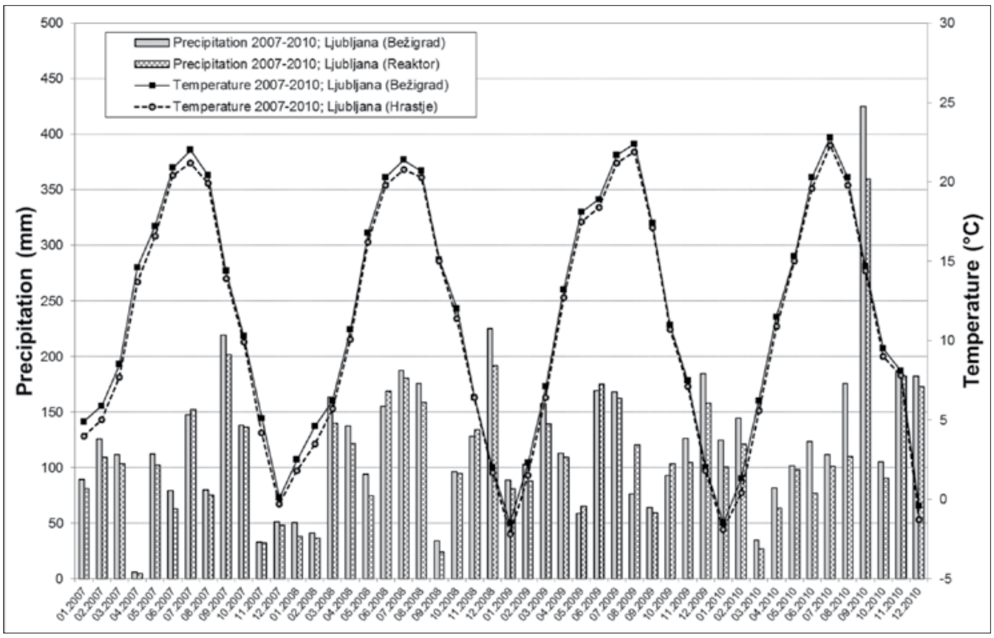

Figure 2. Monthly precipitation and mean monthly air temperatures at station Ljubljana–(Bežigrad), precipitation at Ljubljana (Reaktor) and mean monthly air temperature at station Ljubljana (Hrastje) for period 2007–2010.

(Figure 2). The correlation between monthly precipitation amount (P) at Ljubljana (Reaktor), P_{Re}, and Ljubljana (Bežigrad), P_{Be}, for the period 2007–2010 is:

$$P_{Re} = 0.9 \times P_{Be} + 2.0;\ r = 0.95,\ n = 46 \quad (1)$$

The warmest year in the period 2007–2010 was 2007 and the coldest 2010 (Table 1). The mean air temperature for Ljubljana (Bežigrad) during the isotope monitoring period 2007–2010 was 11.5 °C, on average 0.7 °C higher than that for 1981–2010 (Table 1). At Ljubljana (Hrastje) the mean air temperature during the period 2007–2010 was 10.9 °C (Table 1). Variations of mean monthly air temperature for Ljubljana (Bežigrad) and Ljubljana (Hrastje) for these four years are shown in Figure 1. The greatest deviations were in January to June. Variations of monthly air temperature for Ljubljana (Bežigrad) and Ljubljana (Hrastje) are shown in Figure 2. At Ljubljana (Bežigrad) the lowest monthly temperatures (–1.5 °C) were observed in January 2009 and 2010 and the highest in July 2010 (22.8 °C) (Figure 2). At Ljubljana (Hrastje) the lowest temperature was observed in January 2009 (–2.2 °C) and the highest in July 2010 (22.3 °C) (Figure 2). Air temperatures at the two stations correlate strongly (r > 0.99) and are systematically lower at Ljubljana (Hrastje) by, on average, 0.6 °C, than at Ljubljana (Bežigrad) (Figure 2). The differences in air temperature between Ljubljana (Bežigrad) and Ljubljana (Hrastje) can be explained by an urban heat island effect typical of cities (Mills, 2008).

Stable isotope data (δ^2H, δ^{18}O and d)

Results of monthly isotopic composition of precipitation parameters: δ^2H, δ^{18}O and d together with precipitation amount at the Reactor Centre from January 2007 to December 2010, are summarized in Table 2. Results for May 2007 and September 2010 are reported but not considered in calculations. Results are reported to one decimal point for δ^2H and d values and to two for δ^{18}O.

Variations of monthly isotopic composition of precipitation (δ^2H, δ^{18}O and d) at Ljubljana (Reaktor) in 2007 to 2010 are presented in Figure 3. Seasonal variations of δ^{18}O and δ^2H show patterns typical of continental stations, with maxima in summer and minima in winter (Rozanski et al., 1993). The highest δ^{18}O value was observed in August 2007 (–4.65 ‰) and the lowest in January 2009 (–14.52 ‰). Variations in δ^2H follow those for δ^{18}O, with a maximum δ^2H value of –27.9 ‰ and minimum value of –115.1 ‰ observed in August 2007 and January 2009, respectively. The mean δ^{18}O and δ^2H values for the observed period are –8.57 ‰ and –58.7 ‰ (n = 46), and are similar to those values from 1981 to 2006; i.e., –8.7 ‰ and –60 ‰ (n = 290) (Vreča et al., 2008).

Monthly variations of deuterium excess (d) are presented in Figure 3c. The highest d value for a given month was observed in October 2010 (18.0 ‰). The lowest value was obtained for the sample collected in May 2007 (0 ‰, Table 2, not shown in Figure 3) and confirms evaporation from the rain gauge due to the blocked tube (see Methods). Most d values range between 5 and 15 ‰. The mean value is 9.9 ‰ (n = 46) (Table 2), slightly higher than the mean value of 9.4 ‰ from the period 1981–2006 (Vreča et al., 2008). Values of d around 10 ‰ are typical of those for continental meteoric waters (Craig, 1961) and can be attributed to precipitation of Atlantic origin (Cruz-San et al., 1992).

Analysis of our data shows that d values <5 ‰ correspond to months with low precipitation or to the coldest months, and probably indicate secondary evaporation processes (e.g. evaporation of raindrops falling through a dry atmosphere). The highest values are characteristic of autumn months, especially for November when d values always exceeded 10 ‰, ranging between 13.1 and 17.6 ‰. Higher d values are typical of those for Mediterranean-derived precipitation (Cruz-San et al., 1992; Rozanski et al., 1993). During October and November south-western Slovenia is under the influence of the Mediterranean cyclogenesis (Rakovec & Vrhovec, 2000). The isotopic composition of precipitation in south-western Slovenia (Vreča et al., 2007) and in the central part of the country (Vreča et al., 2006, 2008) reflects the Mediterranean-derived precipitation.

Table 1. Annual amounts of precipitation (P_{Be}, P_{Re}) and mean annual air temperatures (T_{Be}, T_{Hr}) at stations Ljubljana (Bežigrad), Ljubljana (Reaktor) and Ljubljana (Hrastje). n. d. – not determined; * – data for period 2003–2006 (Vreča et al., 2008).

	P_{Be} (mm)	P_{Re} (mm)	T_{Be} (°C)	T_{Hr} (°C)
2007	1196	1112	12.0	11.4
2008	1490	1364	11.6	11.2
2009	1406	1369	11.7	11.2
2010	1798	1506	10.7	10.1
mean value 2007–2010	1472	1338	11.5	10.9
long-term mean value 1981–2010	1362	n. d.	10.8	n. d.
1971–2000	1368	n. d.	10.2	n. d.
1981–2006	1346	1126 *	10.6	n. d.

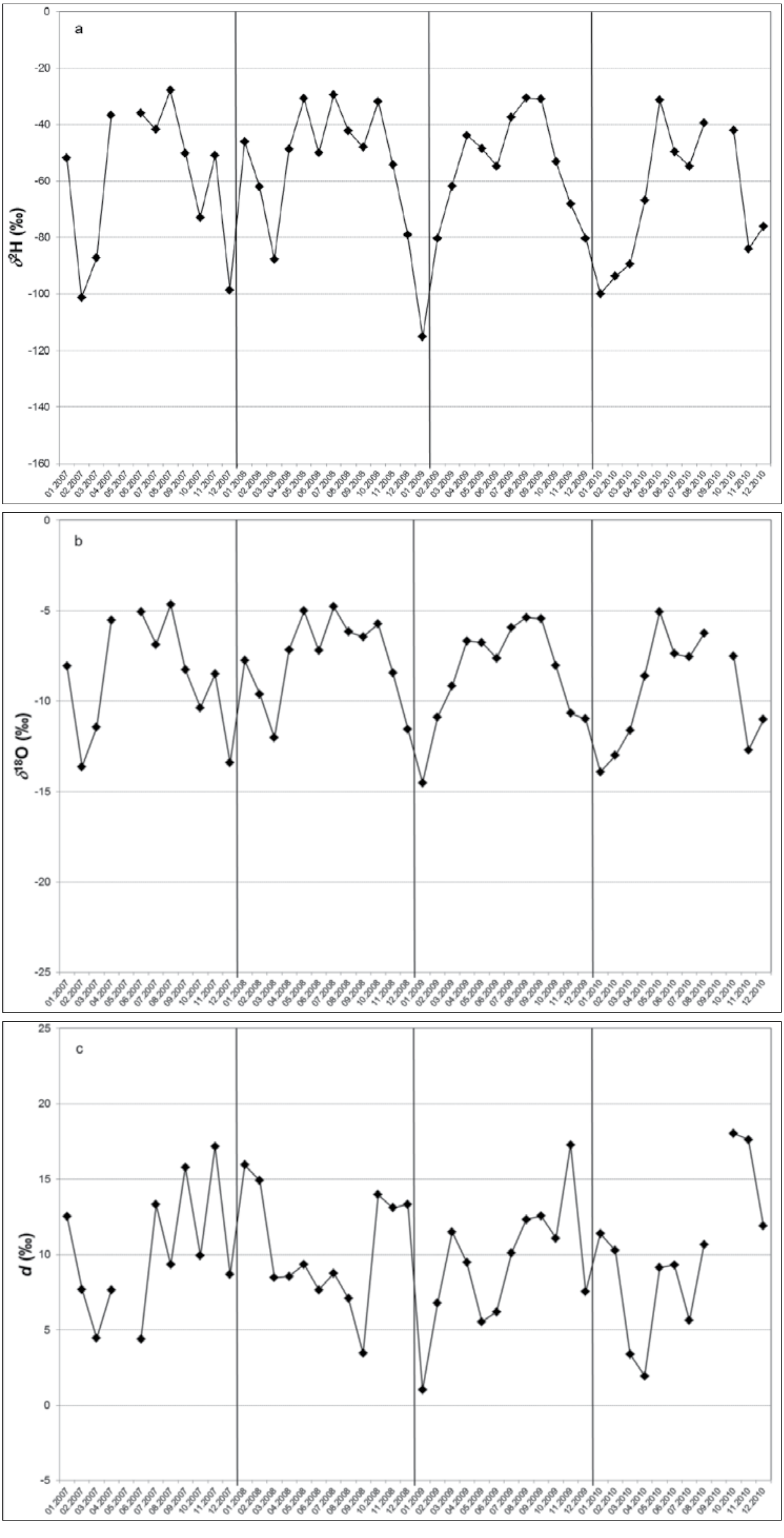

Figure 3. Monthly variations (a) of isotopic composition of hydrogen (δ^2H), (b) oxygen ($\delta^{18}O$) and (c) deuterium excess (*d*), in precipitation at Ljubljana (Reaktor), 2007–2010.

Annual mean $\delta^{18}O$, $\delta^{2}H$ and d values, weighted by amount of precipitation at Ljubljana (Reaktor) and Ljubljana (Bežigrad) for the period 2007–2010, are summarized in Table 3. The differences between weighted annual means at Ljubljana (Reaktor) and Ljubljana (Bežigrad) are within the range of analytical error. The maximum annual weighted mean $\delta^{18}O$ and $\delta^{2}H$ values were observed in 2008, when precipitation was higher during the spring-summer season and represent more than 60 % of the total precipitation in 2008. Changing weather conditions over Europe and the northern Mediterranean during summer months caused stormy weather with high precipitation (Cegnar, 2009) and consequently contributed to the higher weighted mean isotopic composition of precipitation. In addition, January and February were warm and, consequently, the isotopic composition of precipitation was higher than the long term mean values (Vreča et al., 2008). During 2007–2010 the lowest annual weighted mean $\delta^{18}O$ and $\delta^{2}H$ values were observed in 2010 and can be attributed to the lowest mean annual air temperature (Table 1), a cold January and February, with more than 100 mm of precipitation in each month (Figure 2) and air temperatures lower than the long-term records (Cegnar, 2011). 2010 was also characterised by 85 days with snow cover in Ljubljana and the highest annual amount of precipitation (1798 mm at Ljubljana (Bežigrad)). The highest annual weighted mean d value was observed in 2010 and is related mainly to the Mediterranean-derived precipitation in the autumn (Tables 2 and 3). The lowest annual weighted mean d value was observed for 2009. One of the reasons is the very low d value for January 2009 (Table 2), which probably indicates secondary evaporation processes but could not be attributed to sampling.

The weighted mean values for $\delta^{18}O$ and $\delta^{2}H$ are slightly lower than the long-term 1981–2006 values, while the weighted mean d values show an overall increase by 0.8 ‰ (Table 3). However, these differences are within the range of isotope analysis errors and caution is therefore needed in further interpretation. In addition, it has to be noted that the long-term 1981–2006 weighted averages were determined taking into account only precipitation data for Ljubljana (Bežigrad) and that precipitation has only been recorded at Ljubljana (Reaktor) since October 2002.

Seasonal mean $\delta^{18}O$, $\delta^{2}H$ and d values weighted by amount of precipitation at Ljubljana (Reaktor) are summarized in Table 4. The lowest $\delta^{18}O$ and $\delta^{2}H$ values are typical of those in winter and the highest of those in summer. The d values clearly indicate much higher values for autumn when the area is under the influence of Mediterranean-derived precipitation (Vreča et al., 2006).

Table 2. Isotopic composition ($\delta^{2}H$, $\delta^{18}O$, deuterium excess (*d*) and tritium activity (A)) of precipitation at Ljubljana (Reaktor) for period 2007–2010. n. d. – not determined; P_{Re} – precipitation amount of collected sample; GPC – gas proportional counter, LSC – liquid scintillation counter and electrolytic enrichment, LSC direct – liquid scintillation counter without enrichment, JSI – Jožef Stefan Institute, * – tube blocked, ** – calculated without 05/07 and 09/10 (n = 46).

Month/ Year	$\delta^{2}H$ (‰)	$\delta^{18}O$ (‰)	*d* (‰)	A (TU)	P_{Re} (mm)	Method of tritium activity measurement
01/07	–51.9	–8.05	12.5	9.1	81	GPC
02/07	–101.3	–13.62	7.7	4.7	109	GPC
03/07	–87.2	–11.45	4.4	6.4	103	GPC
04/07	–36.7	–5.54	7.6	n. d.	5	-
05/07	–51.2*	–6.38*	–0.1*	20.1*	102*	LSC direct
06/07	–36.0	–5.05	4.4	11.1	63	GPC
07/07	–41.7	–6.88	13.3	11.3	153	GPC
08/07	–27.9	–4.65	9.3	6.2	76	GPC
09/07	–50.3	–8.26	15.8	10.6	202	GPC
10/07	–73.1	–10.37	9.9	4.3	137	GPC
11/07	–50.9	–8.51	17.2	4.6	32	GPC
12/07	–98.6	–13.41	8.7	6.3	48	GPC
01/08	–46.1	–7.76	15.9	3.6	38	GPC
02/08	–62.1	–9.62	14.9	7.8	36	GPC

Month/ Year	δ^2H (‰)	δ^{18}O (‰)	*d* (‰)	A (TU)	P_{Re} (mm)	Method of tritium activity measurement
03/08	–87.7	–12.02	8.5	6.7	140	GPC
04/08	–48.7	–7.16	8.6	4.3	122	GPC
05/08	–30.8	–5.02	9.3	9.1	75	GPC
06/08	–50.0	–7.21	7.6	20.3	169	GPC
07/08	–29.5	–4.78	8.8	13.5	181	LSC
08/08	–42.3	–6.17	7.1	9.3	159	LSC
09/08	–48.1	–6.44	3.5	9.6	24	GPC
10/08	–31.9	–5.73	14.0	8.3	94	LSC
11/08	–54.3	–8.43	13.1	4.5	134	GPC
12/08	–79.0	–11.54	13.3	5.0	192	GPC
01/09	–115.1	–14.52	1.0	13.0	81	GPC
02/09	–80.3	–10.89	6.8	1.6	89	GPC
03/09	–61.8	–9.16	11.5	1.6	140	GPC
04/09	–43.9	–6.67	9.5	13.8	109	LSC
05/09	–48.5	–6.76	5.5	21.8	65	GPC
06/09	–54.8	–7.62	6.2	13.6	175	GPC
07/09	–37.4	–5.94	10.1	11.9	162	GPC
08/09	–30.6	–5.37	12.3	9.0	121	GPC
09/09	–31.0	–5.44	12.5	4.8	60	GPC
10/09	–53.3	–8.04	11.1	2.0	104	GPC
11/09	–68.1	–10.67	17.3	5.1	105	GPC
12/09	–80.3	–10.98	7.5	7.7	158	GPC
01/10	–99.9	–13.91	11.4	5.7	101	LSC
02/10	–93.7	–13.00	10.3	6.6	121	LSC
03/10	–89.4	–11.60	3.4	9.4	27	LSC, JSI
04/10	–66.9	–8.60	1.9	10.0	64	LSC
05/10	–31.3	–5.05	9.1	11.1	98	LSC
06/10	–49.7	–7.38	9.3	12.7	77	LSC
07/10	–54.8	–7.55	5.6	11.2	101	LSC, JSI
08/10	–39.4	–6.26	10.7	9.6	110	LSC
09/10	–52.4*	–6.97*	3.4*	6.5*	360*	LSC
10/10	–42.1	–7.51	18.0	6.1	91	LSC
11/10	–84.1	–12.71	17.6	5.1	183	LSC
12/10	–76.2	–11.01	11.9	5.6	173	LSC
min**	–115.1	–14.52	1.0	1.6	5	
max**	–27.9	–4.65	18.0	21.8	202	
mean**	–58.7	–8.57	9.9	8.3	106	
n	46	46	46	45	46	

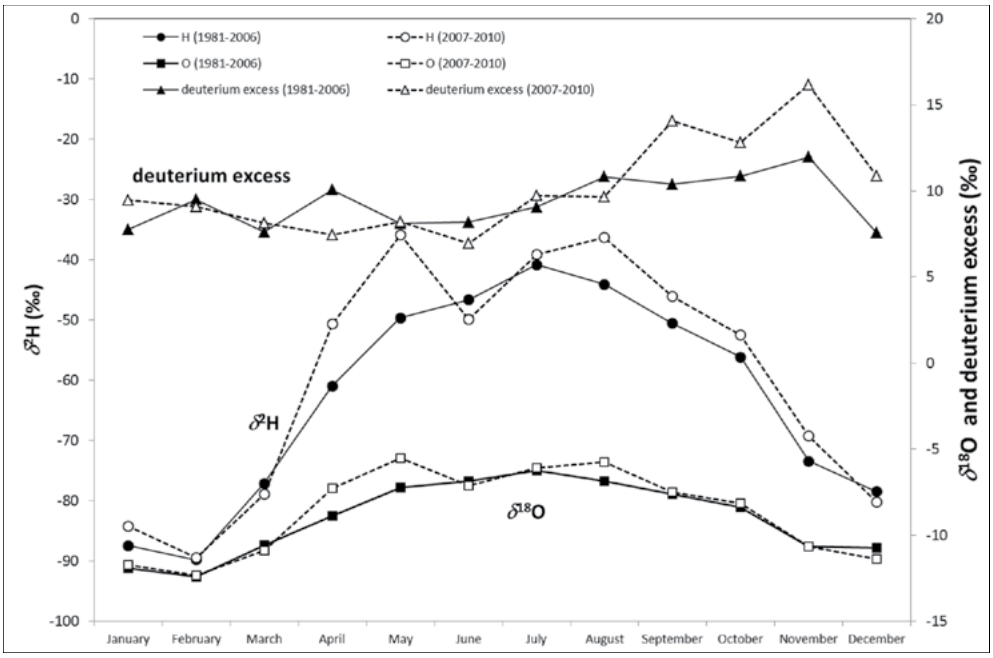

Figure 4. Monthly weighted mean δ^{2}H (in legend H), δ^{18}O (in legend O) and deuterium excess for periods 1981–2006 (Vreča et al., 2008) and 2007–2010.

Monthly mean δ^{18}O, δ^{2}H and d values, weighted by precipitation amount at Ljubljana (Reaktor), are summarized in Table 5 and presented in Figure 4, where they are compared with the 1981–2006 values (Vreča et al., 2008). The higher δ^{18}O and δ^{2}H values in spring and summer months, due to higher air temperatures, constitute a typical seasonal variation. The lowest values are observed in February, similarly to those for the period 1981–2006, and are related to snow as the prevailing type of precipitation. The highest positive deviations from long-term calculations are observed for April, May and August and can be attributed to higher temperatures and lower amounts of precipitation during sampling period 2007–2010. d values range around 10.3 ‰ (Table 5) with the lowest values in June (7.0 ‰) and the highest in November (16.2 ‰). The observed pattern is one of higher d values in autumn precipitation, with values above 10 ‰, and also above mean values for the long-term period 1981–2006, indicating the greater influence of Mediterranean air masses over the region during the observation period (Figure 4).

Local meteoric water lines

The local meteoric water lines (LMWLs) for the period 2007–2010 were calculated using different types of linear regression analysis. The OLSF regression line ($LMWL_{OLSF}$) for Ljubljana (Reaktor) is:

$$\delta^{2}H=(8.05\pm0.22)\times\delta^{18}O+(10.36\pm2.02);r=0.98,n=46 \quad (2)$$

The reduced major axis regression line ($LMWL_{RMA}$) is:

$$\delta^{2}H=(8.19\pm0.22)\times\delta^{18}O+(11.52\pm1.97);r=0.98,n=46 \quad (3)$$

For the precipitation amount recorded at Ljubljana (Reaktor) the PWLSR line ($LMWL_{PWLSR\text{-}Re}$) is:

$$\delta^{2}H=(7.94\pm0.21)\times\delta^{18}O+(9.76\pm1.91);r=0.99,n=46 \quad (4)$$

For the precipitation amount recorded at Ljubljana (Bežigrad), the PWLSR line ($LMWL_{PWLSR\text{-}Be}$) differs only slightly from $LMWL_{PWLSR\text{-}Re}$ (4):

$$\delta^{2}H=(7.93\pm0.21)\times\delta^{18}O+(9.68\pm1.93);r=0.99,n=46 \quad (5)$$

The LMWLs obtained are close to the long term LMWLs for the period 1981–2006 (Vreča et al., 2008) and also to the GMWL of Craig (1961) and to that calculated from the GNIP database for the period 1961–2000 by Gourcy et al. (2005). The absence of significant difference between the PWLSR slope and either the OLSF or the RMA slope indicates a relatively homogeneous distribution of monthly precipitation amounts as well as a small number of small monthly precipitation with low deuterium excess (Hughes & Crawford, 2012). The slope of all LMWLs is close to 8, so it is possible to equate the intercept with the deuterium excess concept (Gat, 2005).

Oxygen – temperature correlation

The linear correlation between δ^{18}O in monthly samples and mean monthly air temperature at Ljubljana (Hrastje), T_{Hr}, for the period 2007–2010 is:

$$\delta^{18}O = 0.30\times T_{Hr} - 11.80 \ (r = 0.82, n = 46) \quad (6)$$

The linear correlation between δ^{18}O in monthly samples and mean monthly air temperature at Ljubljana (Bežigrad), T_{Be}, for the period 2007–2010 is:

$$\delta^{18}O = 0.30\times T_{Be} - 11.99 \ (r = 0.82; n = 46) \quad (7)$$

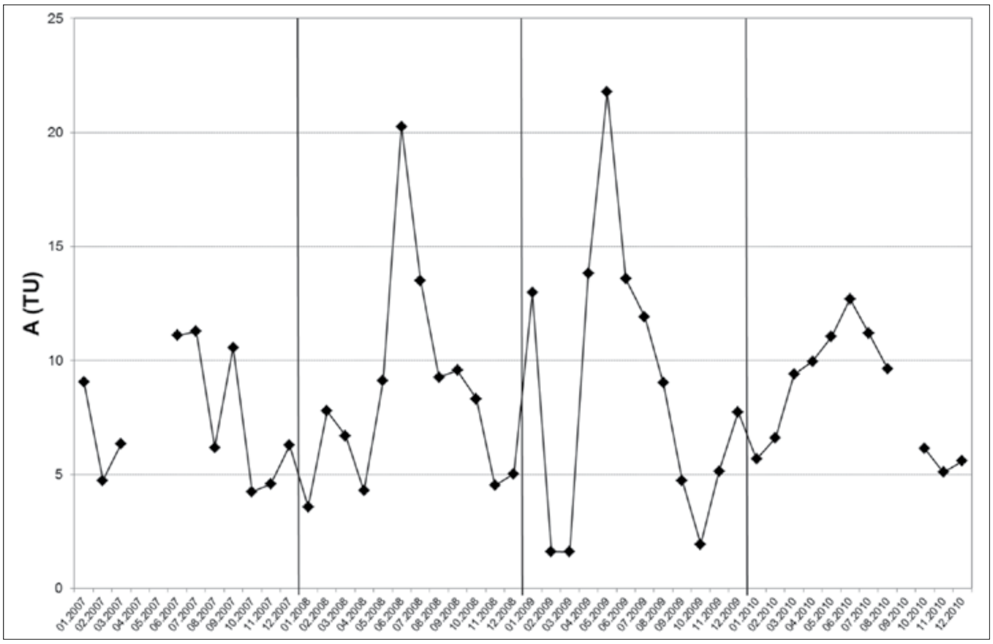

Figure 5. Monthly variations of tritium activity A (in TU) in precipitation at Ljubljana (Reaktor), 2007–2010.

The correlations obtained differ only slightly in their intercept values, have the same slope (0.30 ‰/°C) as that for the long term record (1981–2006; Vreča et al., 2008) and are typical of continental stations (Rozanski et al., 1993). For comparison, the long-term precipitation data for GNIP station Zagreb, Croatia, led to an average isotope temperature gradient of 0.33 ‰/°C (Krajcar Bronić et al., 1998; Vreča et al., 2006) and, for Debrecen, Hungary, of 0.32 ‰/°C for the period 2001–2009 (Vodila et al., 2011), while Mezga et al. (2014) estimated an average isotope temperature gradient of 0.25 ‰/°C for groundwater in Slovenia.

Tritium activity

Results of monthly tritium activity (A) of precipitation are summarized in Table 2 in which the technique used to determine tritium activity in a particular sample is indicated. Amount of precipitation weighted mean annual, seasonal and monthly values are summarized in Tables 3, 4 and 5. Variations of tritium activity in monthly precipitation at Ljubljana (Reaktor) during the sampling period 2007–2010 are presented in Figure 5. Seasonal fluctuations typical of continental/inland stations of the Northern hemisphere (Rozanski et al., 1991) are observed, with lower ^3H activities in autumn and winter and higher ones in spring and summer (Table 4). Maximal values are observed between May and July, mostly in June, and minimal between October and March (Table 5). The tritium activity distributions for 2008 and 2009 show the pronounced maxima in summer typical of the Northern hemisphere (Rozanski et al., 1991). The annual precipitation amounts and average air temperatures were very similar during these two years (Table 1). In contrast, much lower maxima were observed in 2007 and 2010 and can be attributed to warm summer periods with less precipitation. The seasonal fluctuations of tritium activity observed for the present short period 2007–2010 are the same as for the long-term period 1981–2006 (Vreča et al., 2008). However, the long-term data show a seasonal structure superposed on the basic decrease in mean annual tritium activities (Krajcar Bronić et al., 1998, 2006; Vreča et al. 2008), while data recorded since 1998 show no significant decrease of mean annual values. The mean tritium activity for the period 1998–2010 is 9.1 TU while, in the studied period, it is 8.3 TU (Table 2). Observations similar to those in our study are valid for the nearest continental GNIP station Zagreb, where mean annual tritium activities measured since 1996 cluster around 9 TU (Krajcar Bronić et al., 2006). Compared with the Ljubljana data, mean values for Zagreb precipitation are 8.6 TU and 9.0 TU for periods 1998–2010 and 2007–2010, respectively. Thus, no decrease in mean annual tritium activity is observed in the studied period, and the seasonal (Table 4) and monthly (Table 5) weighted mean values can be applied also for tritium activity.

A relatively good correlation between deuterium excess and tritium activity has been obtained for the mean monthly data with a slope of –0.38 ‰/TU (r = 0.48, n = 12). This confirms the seasonal fluctuations typical of continental/inland stations with the highest d values in autumn months when tritium activity is low, and lower d during summer when tritium activity has its seasonal maximum (Table 4). This finding corroborates the previous conclusion that, in autumn, Ljubljana receives a relatively higher share of the precipitation formed by moisture evaporated from the Adriatic and Mediterranean Seas.

Conclusions

The results of the isotopic composition of oxygen and hydrogen, and of tritium activity ($\delta^{18}O$, δ^2H and A) of precipitation collected at Ljubljana (Reaktor) in the period 2007–2010 are

Table 3. Annual weighted mean δ^2H, δ^{18}O, deuterium excess (*d*) values (in ‰) and tritium activity (A in TU). Subscript Be denotes annual mean values weighted by amount of precipitation at Ljubljana (Bežigrad); Re denotes annual mean values weighted by amount of precipitation at Ljubljana (Reaktor); * denotes for n = 10; n. d. – not determined.

Year	n	δ^2H_{Be}	$\delta^{18}O_{Be}$	d_{Be}	A_{Be}	δ^2H_{Re}	$\delta^{18}O_{Re}$	d_{Re}	A_{Re}
2007	11	–61.4	–9.01	10.7	7.9*	–61.2	–9.00	10.8	7.9*
2008	12	–53.1	–7.90	10.1	8.9	–52.5	–7.83	10.1	9.2
2009	12	–60.1	–8.68	9.3	8.5	–58.2	–8.44	9.3	8.8
2010	11	–66.2	–9.66	11.0	8.1	–67.4	–9.83	11.2	7.8
min		–66.2	–9.66	9.3	7.9	–67.4	–9.83	9.3	7.8
max		–53.1	–7.90	11.0	8.9	–52.5	–7.83	11.2	9.2
2007–2010 mean		–60.0	–8.78	10.3	8.3	–59.4	–8.71	10.3	8.5
1981–2006 weighted mean (Vreča et al., 2008)		–59.1	–8.57	9.5	n. d.	n. d.	n. d.	n. d.	n. d.

Table 4. Seasonal weighted mean δ^2H, δ^{18}O, deuterium excess (*d*) values (in ‰) and tritium activity (A in TU) for period 2007–2010. Subscript Re denotes monthly mean values weighted by amount of precipitation at Ljubljana (Reaktor); * denotes for n = 10.

Season	n	δ^2H_{Re}	$\delta^{18}O_{Re}$	d_{Re}	A_{Re}
Winter	12	–83.9	–11.74	10.0	6.3
Spring	11	–59.1	–8.38	7.9	8.4*
Summer	12	–41.6	–6.31	8.8	12.2
Autumn	11	–57.4	–8.98	14.4	6.0

Table 5. Monthly weighted mean δ^2H, δ^{18}O, deuterium excess (*d*) values (in ‰) and tritium activity (A in TU) for period 2007–2010. Subscript Re denotes monthly mean values weighted by amount of precipitation at Ljubljana (Reaktor); * denotes for n = 3.

Month	n	δ^2H_{Re}	$\delta^{18}O_{Re}$	d_{Re}	A_{Re}
January	4	–84.2	–11.71	9.5	8.3
February	4	–89.5	–12.32	9.1	4.9
March	4	–78.9	–10.87	8.1	5.1
April	4	–50.6	–7.26	7.5	9.1*
May	3	–35.8	–5.51	8.2	13.4
June	4	–49.9	–7.10	7.0	15.4
July	4	–39.1	–6.10	9.8	12.1
August	4	–36.2	–5.74	9.7	8.8
September	3	–46.1	–7.52	14.1	9.3
October	4	–52.5	–8.16	12.8	5.0
November	4	–69.2	–10.67	16.2	4.9
December	4	–80.2	–11.38	10.9	6.1
min		–89.5	–12.32	7.0	4.9
max		–35.8	–5.51	16.2	15.4
2007–2010 mean		–59.4	–8.71	10.3	8.5

presented and compared with the long-term data from the period 1981–2006. The observed seasonal fluctuations of $\delta^{18}O$ and $\delta^{2}H$ are significant and typical of continental stations. The local meteoric water lines (LMWLs) were calculated by applying three different types of regression analysis – in addition to the previously used ordinary least squares regression (OLSF) and the reduced major axis (RMA) regression analyses that do not take into account the amount of precipitation. A new precipitation weighted least square regression (PWLSR) method was also applied. All three LMWLs have similar slopes and intercepts, very high correlation coefficients (r ≥ 0.98) and are close to Craig's GMWL, indicating a homogeneous distribution of monthly precipitation and a small number of low-amount precipitation events with low d values. The deuterium excess, with a weighted mean value of 10.3 ‰, shows the predominating influence of Atlantic air masses in Ljubljana. However, much higher d values are observed in autumn (mean 14.4 ‰) and indicate the influence of Mediterranean air masses. The observed tritium activity distributions show patterns typical of the Northern Hemisphere, with pronounced maxima in summer, and no decrease in mean annual tritium activity is observed.

The results presented are important for further scientific and practical applications in hydrology and hydrogeology, and in climatology. The LMWLs obtained can be useful above all in investigating those hydrological systems in Slovenia that are fed directly by precipitation and in enabling the range of input parameters to be defined. However, as stressed by Gat (2005), any application beyond that is limited because of rain events associated with air masses of different origins. Taking into account the characteristic geographic diversity of Slovenia, which influences considerably the climate and the isotopic composition of precipitation, a more detailed investigation of the complete isotope data set (1981–2010) for Ljubljana needs to be performed, taking into consideration the atmospheric circulation patterns over Slovenia. In addition, it is necessary to separate those clusters of data with different air mass origins and different isotope distributions and to determine LMWLs for particular clusters. In such a way it would be possible to verify whether the calculated composite best-fit line for isotope data from Ljubljana represents a range of input parameters as a whole or is just an artefact.

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Applicability study of deuterium excess in bottled water life cycle analyses

Uporabnost devterijevega presežka v analizi življenjskega kroga embaliranih vod

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Abstract

Paper explores the possible use of *d*-excess in the investigation of bottled water. Based on the data set from Brencic and Vreca's paper (2006). Identification of sources and production processes of bottled waters by stable hydrogen and oxygen isotope ratios, *d*-excess values were statistically analysed and compared among different bottled water groups and different bottlers. The bottled water life cycle in relation to *d*-excess values was also theoretically identified. Descriptive statistics and one-way ANOVA showed no significant differences among the groups. Differences were detected in the shape of empirical distributions. Groups of still and flavoured waters have similar shapes, but sparkling waters differed to the others. Two distinctive groups of bottlers could be discerned. The first group is represented by bottlers with a high range of *d*-excess (from 7.7 ‰ to 18.6 ‰ with average of 12.0 ‰) exploring waters originating from the aquifers rich in highly mineralised groundwater and relatively high concentrations of CO_2 gas. The second group is represented by bottlers using groundwater from relatively shallow aquifers. Their *d*-excess values have characteristics similar to the local precipitation (from 7.8 ‰ to 14.3 ‰ with average of 10.3 ‰). More frequent sampling and better knowledge of production phases are needed to improve usage of isotope fingerprint for authentication of bottled waters.

Izvleček

Članek obravnava možnost uporabe devterijevega presežka pri raziskavah embaliranih vod. Delo temelji na podatkih o izotopski sestavi vod, ki so bili objavljeni v članku Brencic in Vreca (2006). Vrednosti devterijevega presežka so bile analizirane statistično in primerjane med različnimi skupinami embaliranih vod ter med različnimi polnilci. V okviru analize je bil teoretično identificiran življenjski cikel embaliranih vod. Opisne statistike in analiza variance – ANOVA so pokazale, da med skupinami ni značilnih razlik, razlike pa so bile opažene v oblikah empiričnih porazdelitev. Skupine naravnih vod in aromatiziranih vod imajo podobno obliko empiričnih porazdelitev, medtem ko je za gazirane vode drugačna. Znotraj slednjih lahko ločimo dve skupini. Prva skupina je sestavljena iz vod polnilcev z visokim razponom vrednosti devterijevega presežka (od 7,7 ‰ do 18,6 ‰ in povprečjem 12,0 ‰). Te vode izvirajo iz vodonosnikov bogatih z mineraliziranimi vodami in relativno visokimi koncentracijami plina CO_2. Drugo skupino predstavljajo vode polnilcev, ki uporabljajo vodo iz relativno plitvih vodonosnikov, vrednosti devterijevega presežka pa so podobne povprečnim vrednostim lokalnih padavin (od 7,8 ‰ do 14,3 ‰ in povprečjem 10,3 ‰). Za učinkovitejšo ugotavljanje skladnosti ustekleničenih vod s pomočjo izotopske sestave je potrebno izvesti pogostejša vzorčenja in izboljšati znanje o proizvodnih procesih.

Introduction

In climatic and hydrology studies, deuterium excess (*d*-excess; Dansgaard, 1964) has proven to be a useful parameter. It characterises the deviation of a stable hydrogen and oxygen isotopic composition in precipitation from an average global composition and reflects the origin of the moisture source as well as the condensation and evaporation processes in the hydrological cycle. Based on these properties it is supposed that *d*-excess can also be used to track the history of bottled water. The latter is a product of the food industry, however, it originates in the hydrological cycle and its isotopic characteristics reflect different paths through the environment. The isotopic composition of water in nature is the consequence of different fractionation processes; the same can be expected of bottled water where, besides the variability of isotopic composition in the parent water body, production processes and the interaction of bottles with the surrounding environment can also influence the isotopic fingerprint. Stable hydrogen and oxygen analyses of bottled water have already been applied to study its origin and the influences of production processes on its composition (Chesson et al., 2010; Dotsika et al., 2010; Rangarajan et al., 2011; Kim et al., 2012; Godoy et al., 2012; Raco et al., 2013). They can be regarded as an authentication tool where two investigative approaches can be used; that from hydrology and the other from food analysis. Application of stable isotope analysis in hydrology is widely used for the detection of water circulation history through the hydrological cycle, while in food analysis stable isotopes are mainly used for quality control and determination of artificial food ingredients that are chemically identical to natural ones (Brencic & Vreca, 2007).

According to the author's best knowledge no systematic study of *d*-excess in bottled water is available in the literature. The main intention of this paper is therefore to explore the possible use of *d*-excess in the investigation of bottled water. In this study, based on the already available data set (Brencic & Vreca, 2006), we (1) performed a statistical analysis of calculated *d*-excess from the available set of data and compared *d*-excess values among different bottled water groups, (2) compared the variability of *d*-excess values for different bottlers producing several different brands of bottled water, and (3) theoretically identified the bottled water life cycle in relation to *d*-excess. Final conclusions were then reached based on these results and recommendations for further work with *d*-excess in relation to bottled water presented.

Methods

Methodological basis

Deuterium excess is defined as d-excess=δ^2H–8δ^{18}O (Dansgaard, 1964) where δ^2H and δ^{18}O are the isotopic compositions of water molecules. It has shown potential in climatic studies for tracing past and present precipitation processes. It is also a measure of the relative proportions of δ^2H and δ^{18}O in water and can be visually depicted as an index of the deviation from the global meteoric water line (GMWL; Craig, 1961) in the 2D space defined by the coordinates δ^2H and δ^{18}O (Fig. 1). In natural conditions, *d*-excess correlates with physical conditions such as humidity, air temperature and water temperature (Fröhlich et al., 2001; Gat, 2010) and the chemical status of water. Influences of the same parameters are also expected in bottled water.

During circulation through the hydrological cycle, the isotopic composition of water changes as a consequence of equilibrium, diffusion and kinetic fractionation. These processes are well reflected in the δ^2H and δ^{18}O diagram (Fig. 1). The

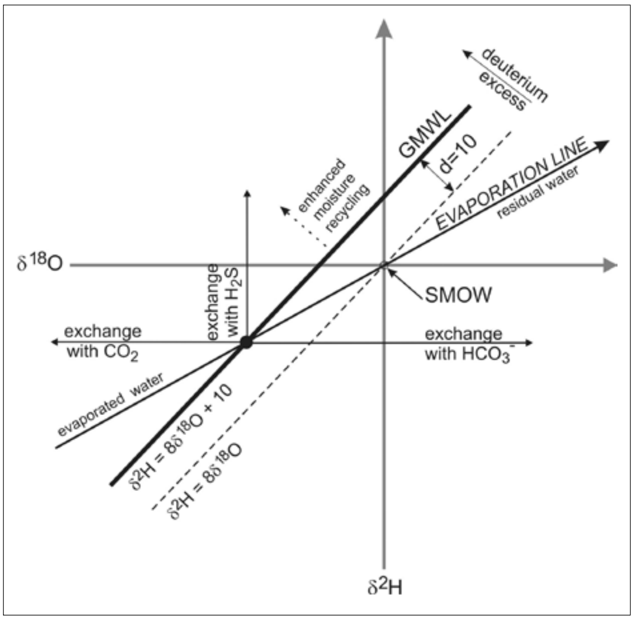

Fig. 1. Processes influencing the isotopic composition of water reflected in the δ^2H and δ^{18}O diagram (modified from Schotter et al., 1996; Fröhlich et al., 2001; Gat, 2010).

processes in the atmospheric part of the water cycle, from evaporation from the ocean surface to cloud condensation and precipitation, are well elucidated by the Craig and Gordon (Gat, 2010) model. Equilibrium fractionation and kinetic effects are reflected in the slope of the GMWL with a value of 8 (Fig. 1). During the equilibrium isotope fractionation in the hydrological cycle from ocean source water to water in another compartment (e.g. clouds) the isotopic composition changes along the line. Based on the Craig and Gordon (Gat, 2010) model, the assumption of evaporation taking place into the atmosphere of 75% humidity above the ocean accounts for a *d*-excess value of 10 ‰ (Fig. 1) in atmospheric moisture which confirms the world average for meteoric waters (Gat, 2010). Both the slope of the GMWL and the global *d*-excess value justified Dansgaard's (1964) definition. In higher saturation states of the atmosphere above the ocean, *d*-excess is lower; therefore, some paleo-groundwaters show lower *d*-excess values than present groundwater (Gat, 2010).

If additional transport and fractionation processes are present during such a process, *d*-excess differs from that of the liquid vapour transition under equilibrium conditions. In the natural environment, such waters are positioned on the line with a slope reduced relative to the equilibrium line of the GMWL (Gat, 2010). The isotopic composition of residual water from evaporation is positioned along the line below the GMWL (Fig. 1) and evaporated water is positioned above the GMWL. Deviations in water isotopic composition from the equilibrium line have also been reported from the exposure and evaporation experiments on sample containers (Stewart, 1981; Rozanski & Rzepka, 1991; Rozanski & Chmura, 2008), thereby showing that a stable isotopic composition of bottled water can be subject to change during its storage.

In deep and extensive aquifers, geochemical processes can also influence the isotopic composition of water. In mineral and thermomineral waters, aquifers might exchange with CO_2 and H_2S (Clark & Fritz, 1997). Exchange with CO_2 (Beck et al., 2005) and changes in the $CaCO_3$ – CO_2 – H_2O system appear during the production processes and can influence the isotopic composition of bottled water (Fig. 1). If oxygen is exchanged for CO_2 the isotopic composition of $\delta^{18}O$ in water will shift to the left and if exchanged for HCO_3^- it will shift to the right (Beck et al., 2005). In highly reduced environments, exchange with H_2S shifts the isotopic composition of the parent water in a predominantly vertical direction. In the presence of hydrated minerals in the aquifer matrix, the shift of the water fingerprint is also possible. A combination of all these processes is likely in deep-seated aquifers, and the direction of the shift in isotopic composition is oblique to the equilibrium line depending on the predominant process. Consequently, all these changes can be reflected in changes in *d*-excess values.

Sampling

Sampling was performed based on a consistent sampling plan where all waters and products advertised as waters available on the Slovenian market in September 2004 were collected (Brencic & Vreca, 2006). The data set presents a statistically consistent and representative sample of bottled waters available on the Slovenian market at the time of sampling. By the data set overall characteristics of bottled waters on the market are presented therein.

Isotopic analyses

The details of stable isotope analyses are given elsewhere (Brencic & Vreca, 2006). The results are expressed in standard delta notation (δ) as per mil (‰) deviation from the standard V-SMOW for δ^2H and δ^{18}O as:

$$\delta^{Y} X(‰) = \left(\frac{R_{sample}}{R_{std}} - 1 \right) \times 1000$$

where ^{Y}X is ^{18}O or ^{2}H and R_{sample} and R_{std} are $^{18}O/^{16}O$ or $^{2}H/^{1}H$ ratios of the sample and standard, respectively. The measurement reproducibility of duplicates was better than ±0.05 ‰ for δ^{18}O and ±1 ‰ for δ^2H.

Analytical uncertainty $u(d)$ of *d*-excess for routine measurements was estimated (Fröhlich et al., 2001) as:

$$u(d) = \sqrt{u(\delta^2 H)^2 + 8u(\delta^{18} O)^2}$$

In our case *d*-excess uncertainty $u(d)$ was 1.01 ‰.

Statistical analyses

Descriptive statistics, kernel density estimates with empirical distribution diagrams, the Anderson–Darling goodness of fit test for normal distribution and outlier detection, and analysis of variance (ANOVA) were used.

Empirical distribution functions (EDF) were used to analyse the exploratory data to detect the overall shape and symmetry of the empirical data distribution as well as any spurious observations in the data set.

In a classical statistical analysis, the empirical distribution of the data is usually represented by a histogram. Alternative graphical representations include the kernel density approach (Reiss & Thomas, 1997), which tries to mimic the hypothetical probability density function of the limit distribution. According to this method, the probability density $g_b(x,k(x))$ for particular data is estimated as:

$$g_b(x,k(x)) = \frac{1}{N_b} k\left(\frac{x - x_i}{b} \right)$$

where $k(x)$ is the kernel such that:

$$\int k(y)dy = 1$$

and where b is the bandwidth where $b>0$ and N_b is number of data inside of bandwidth interval. The Epanechnikov kernel was used:

$$k(x) = \frac{3}{4}(1 - x^2) \qquad I(-1 \le x \ge 1)$$

In summing the single terms, one gets the kernel density:

$$f_{N,b}(x) = \sum_{i \le N} g_b(x,k(x)) = \frac{1}{Nb} \sum_{i \le N} k\left(\frac{x - x_i}{b} \right)$$

Based on the trial and error procedures on different data sets we arbitrarily chose a bandwidth of b=2.592.

Brenčič & Vreča (2010) have already illustrated that the empirical distribution of δ^2H and δ^{18}O from the Slovenian market can be modelled with a normal (Gaussian) distribution. The normal probability model fit of δ^2H is nearly perfect with the Kolmogorov–Smirnov statistic d_{max} = 0.05, which confirms a good fit at the 5% significance level. For the empirical distribution of δ^{18}O the normal distribution model can be also used (Kolmogorov–Smirnov statistic d_{max}= 0.08); however, the visual inspection of the EDF showed larger discrepancies from the straight line in the probability scale diagram than in the case of δ^2H (Brenčič & Vreča, 2010). Based on these findings it is also supposed that the EDF of *d*-excess as a linear combination of both parameters can be modelled with the normal distribution model.

Contrary to the previous normality assessment of δ^2H and δ^{18}O (Brenčič & Vreča, 2010) the EDF in this study were tested with Anderson–Darling goodness of fit statistics A^2 according to the theory presented by Stephens (1986). In comparison to Kolmogorov–Smirnov statistics d_{max} Anderson–Darling A^2 is characterized by higher power and easier procedure for determining the exact significance level. The null hypothesis H_0 is valid when the random sample $X_1, \dots, X_n$ comes from a normal distribution $N(\mu,\sigma)$ and where both parameters μ and σ of N are unknown. Defined as *Case 3* test, the μ and σ parameters were estimated with the method of moments (average and variance, respectively) from the data set under the consideration. A significance level p of A^2 was calculated with the help of empirical equations (Stephens, 1986). Statistics A^2 is defined as:

$$A^2 = -n - \frac{1}{n}\sum_i \left[(2i-1)\ln Z_i + (2n+1-2i\ln(1-Z_i)\right]$$

where

n – number of data in the data set

i – rank of data

Z_i – probability integral transformation with parameters μ and σ

An outlier observation is datapoint that seems to deviate markedly from other members of the data set in which it occurs. The definition of the outlier depends on the scope of the data investigation. In this study, outliers are those data at the lower or upper tails that are the reason for the deviation of EDF from the normal probability model. For the detection of outlier statistics A^2 sensitive to lower and upper tails was used. Based on the visual inspection of EDF possible outliers were identified at its lower and upper tails. Statistics A^2 was calculated by excluding supposed outliers step by step from the EDF. Calculated A^2 values were compared at every step. When calculated A^2 stabilised after excluding several data from the tails of EDF this was a criterion that no influences on the normality model are present from the tail parts of EDF.

The normal distribution of data is also an assumption in ANOVA. Differences between the d-excess values in the groups of bottled waters were tested by one-way ANOVA, followed by Tukey's post-hoc significance difference at the 5% level of probability. The null hypothesis of ANOVA suggested that the means of all groups are equal. The probability p for the validity of the null hypothesis was calculated.

ANOVA was calculated using the STATISTICA® 6.0 statistical package. Kernel density estimates were calculated with the program $X_TR_EM_ES$ (Reiss & Thomas, 1997). Anderson–Darling goodness of fit test was calculated with macro procedures written in a spreadsheet program.

Results and discussion

The analytical results of oxygen (δ^{18}O) and hydrogen (δ^2H) isotopic composition have already been published (Brencic & Vreca, 2006). Calculated d-excess values are given in Tables 1, 2, and 3 for sparkling, still and flavoured waters, respectively. In Table 1, the column with CO_2-type classification (Brencic & Vreca, 2007) is included to discern waters where artificial CO_2 gas is introduced during the production process and waters originating from deeper aquifers. Bottler locations are illustrated in Figure 2, but bottled water originating from Italy and Switzerland is not shown.

Statistical analyses

Basic d-excess descriptive statistics of different bottled waters for different groups are given in Table 4 and the distribution of datapoints for the whole data set are illustrated in Figure 3. The lowest d-excess value 6.4 ‰ is observed in flavoured water and the highest 18.6 ‰ in natural sparkling waters. Except for natural sparkling waters average values among groups are similar and median values indicate that the EDF of particular groups are slightly asymmetrical. These can be confirmed with the inspection of box plot diagrams (Fig. 3) and the distributional illustrations presented in Figures 4, 5a, and 5b.

Owing to diverse possible influences on the d-excess values of bottled water it is expected that in the EDF of the whole data set some outliers are present. It can be hypothesised that d-excess outliers reflect special circumstances at the source or in production. In the upper tail of EDF outliers (Fig. 4), this can be interpreted as a consequence of natural conditions in the aquifers. In the lower tail of EDF outliers (Fig. 4), this could be an indicator of the influences of the production processes on the isotopic composition of water. Based on the Anderson–Darling A^2 statistics criteria in the upper tail of the data sets only two real vivid outlier values can be detected. These are d-excess values of 18.6 ‰ and 17.4 ‰ and are both obtained for water brand Donat-Mg™ (Table 1). By removing these values from the EDF A^2 becomes 0.47 and the zero hypothesis is significant at the level of p=0.25. If we remove further d-excess values (14.6 ‰, 14.3 ‰, and 14.0 ‰) from the upper tail of the EDF, A^2 drops from 0.42 to 0.39 and the significance level p rises from 0.31 to 0.38. When removing consecutive d-excess values A^2 starts to rise and p starts to drop. By removing values only in the lower tail of the EDF A^2 steadily grows and the p value drops. This indicates that these values are part of a supposed normally distributed population of d-excess values. The combination of removing values from the EDF at both tails simultaneously does not provide better results than just removing values at the upper tail. We conclude that only Donat-Mg™ represents a vivid outlier in the whole data set. According to the available information from the literature (Pezdič, 1997) those values can be interpreted as outliers showing natural conditions in the parent aquifer.

Table 1. *d*-excess values in sparkling waters

Bottled by	Origin	Brand	CO_2 type (Brencic & Vreca, 2007)	*d*-excess (‰)
Kolinska	Slovenia	Donat Mg™	natural	18.6
Kolinska	Slovenia	Donat Mg™ (G)	natural	17.4
Kolinska	Slovenia	Tempel™	natural	12.5
Kolinska	Slovenia	Tempel™ (B)	natural	13.1
Kolinska	Slovenia	Edina™	natural	12.5
Radenska	Austria	Sicheldorfer Josefsquelle™ (G)	natural	7.7
Bad Radgesburg	Austria	Long life™ – 2	natural	9.6
Radenska	Slovenia	Classic™ (G)	natural	12.0
Radenska	Slovenia	Classic™	natural	10.5
Radenska	Slovenia	Light Miral™	natural	9.9
San Benedeto	Italy	Guizza™	natural	7.8
Bad Radgesburg	Austria	Long life™ - 1	artificial	13.6
Jamnica	Croatia	Jamnica™	artificial	6.8
Jamnica	Croatia	Jamnica™ (S)	artificial	6.7
Tavina	Italy	Spar Sorgente Linda™	artificial	7.9
Sodavičarstvo Volk	Slovenia	Štirna™	artificial	12.9
Sodavičarstvo Volk	Slovenia	Štirna™ (S)	artificial	13.8
Spinone al Lago	Italy	Primula™	artificial	9.7
Fonte S. Antonio	Italy	San Antonio™	artificial	10.8

(G) – glass bottle; (B) – replicated bottle; (S) – replicated sample from the bottle

Table 2. *d*-excess values in still waters

Bottled by	Origin	Brand	*d*-excess (‰)
Radenska	Slovenia	Radin™	7.8
Radenska	Slovenia	Radin™ (S)	9.5
Radenska	Slovenia	Izvir™	9.7
Radenska	Slovenia	Iva™	8.1
Radenska	Slovenia	Iva™ (B)	10.0
Radenska	Slovenia	Iva™ (S)	8.0
Vino Brežice	Slovenia	Bistra™	9.6
Dana	Slovenia	Dana™	10.2
Danone	France	Evian™	8.1
Fructal	Slovenia	H2O™	14.3
Jamnica	Croatia	Jana™	10.8
Perne	Slovenia	Juliana™	12.2
Lasko Brewery	Slovenia	Oda™	11.8
Lasko Brewery	Slovenia	Oda™ (B)	11.3
Spinone al Lago	Italy	Primula™	11.0
San Benedeto	Italy	Guizza Silles™	8.9
Fonte S. Antonio	Italy	San Antonio™	13.1
Plastenka	Slovenia	Spar spring water™	10.2
Plastenka	Slovenia	Spar spring water™ (B)	9.1
Plastenka	Slovenia	Spar spring water™ (S)	9.7
Plastenka	Slovenia	Spar table water™	9.7
Plastenka	Slovenia	Živa™	11.4
Union Brewery	Slovenia	Zala™	10.0
Union Brewery	Slovenia	Zala™ (S)	11.4
Kolinska	Slovenia	Tiha™	10.9

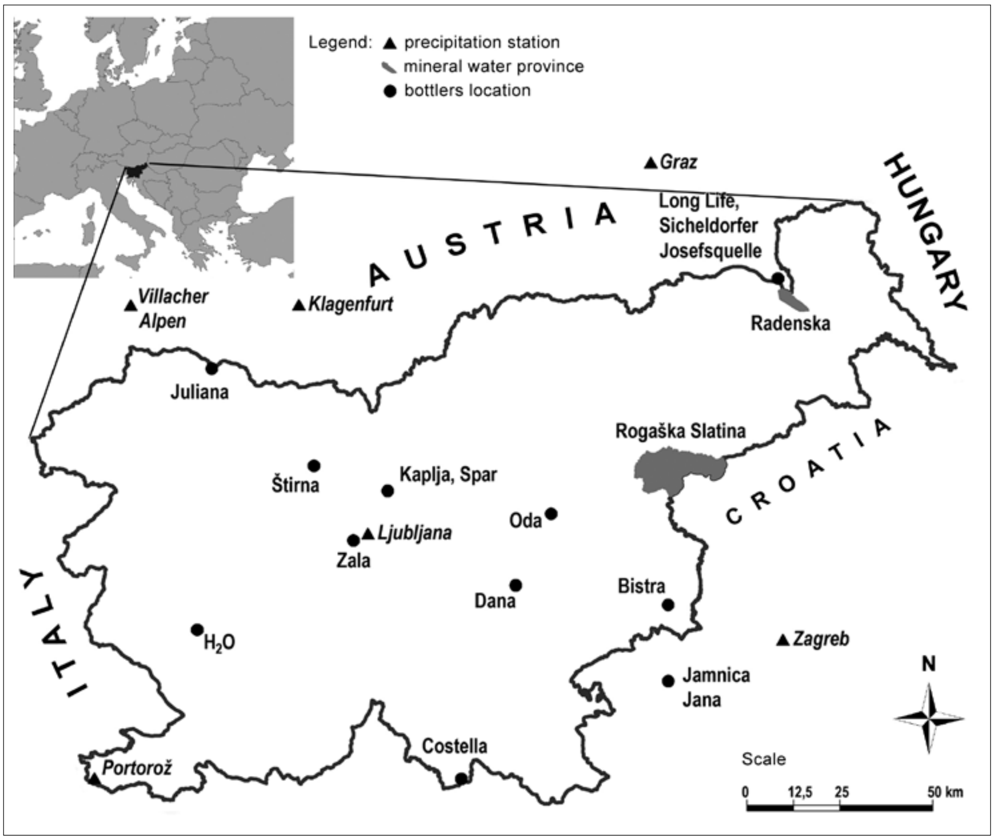

Fig. 2. Map showing the location of the sources of Slovenian bottled water and precipitation stations with stable isotope observations.

In Table 5, the results of the normality test with Anderson–Darling statistics A^2 are illustrated. In all groups, the significance level p of the null hypothesis is higher than the usual significance level of p=0.05. The only exception is the whole data set consisting of all groups indicating that outliers are present. In Figure 4, the EDF and cumulative kernel densities with the normal (Gaussian) theoretical model with parameters estimated from the whole data set are represented on the probability scale diagram. The EDF shows that data fluctuates around the straight line of the normal model and that the amplitude of fluctuation is relatively small, except at the tails. The lower tail does not influence the kernel density estimate, which is close to the normal model. The situation is different at the upper tail where outliers are the reason for the distinctive deviation from the normal model.

This relative irregularity of the kernel density estimates is more clearly seen in Figures 5a and 5b. Kernel density estimates in the frequency mode (Fig. 5a) are represented with the weight that represents a particular group's share in the whole data set. The kernel density for the whole data set represents the sum of particular groups, and the kernel density for sparkling water represents the sum of natural and artificial sparkling water. The distributions of the whole data set and flavoured and sparkling waters are symmetrical. However, for the whole data set and sparkling waters a small hump can be detected at the right part at the higher d-excess values (Fig. 5a). In the whole data set, this hump can be explained by the presence of natural sparkling waters. All sparkling groups show irregular behaviour with a polymodal shape. The artificial sparkling water group shows two peaks at approximately 7.5 ‰ and 12.5 ‰. Slightly different peaks are observed in natural sparkling waters where at the same time peak at an approximate value of 17.5 ‰ is identical to the hump of the whole data set. The latter indicates those waters originating from the Rogaška Slatina mineral water province. An asymmetry of data is also reflected in the cumulative mode diagram on the probability scale (Fig. 5b). Except in the lower tail shapes of the flavoured and still water groups, distributions are almost identical. Natural sparkling waters are positioned below the whole data set, indicating the irregular shape of their EDF. A similar irregularity is also detected in the group of artificial sparkling waters, showing a different shape of the upper tail.

The kernel densities shown in Figures 5a and 5b can be treated as an indicator of their probability density functions. Owing to the relatively low number of data estimates of the artificial sparkling water group and natural sparkling water group, these must be treated with caution. However, we believe that they indicate the complicated isotopic fractionation processes of the sparkling water group. Similarly, the flavoured and still water groups can be interpreted as the still water representing the parent water for the flavoured water.

It has been illustrated that in the δ^2H and δ^{18}O diagram the regression lines for each group of water are significantly different (Brencic & Vreca, 2006). Surprisingly, the ANOVA of d-excess for the same groups shows no significant differences. Tukey's post-hoc test confirms that the differences among the groups are very small.

Table 3. Deuterium excess values in flavoured waters

Bottled by	Origin	Brand	Flavour	*d*-excess (‰)
Vino Brežice	Slovenia	Active™	Elder lemon	9.9
Vino Brežice	Slovenia	Active™ (B)	Elder lemon	9.7
Vino Brežice	Slovenia	Active™	Fitness	10.0
Vino Brežice	Slovenia	Active™	Guava lime	6.4
Vino Brežice	Slovenia	Bistra™	Apple	11.6
Vino Brežice	Slovenia	Bistra™	Lemon	8.1
Vino Brežice	Slovenia	Mercator™	Lemon	10.6
Vino Brežice	Slovenia	Mercator™ (B)	Lemon	8.9
Vino Brežice	Slovenia	Spar Active™	Fitness	8.8
Vino Brežice	Slovenia	Spar Active™	Apple	11.9
Vino Brežice	Slovenia	Spar Active™	Orange	9.0
Dana	Slovenia	Dana™	Apple	9.8
Dana	Slovenia	Dana™ (S)	Apple	11.6
Dana	Slovenia	Dana™	Mango	11.4
Dana	Slovenia	Dana™	Lime	9.3
Dana	Slovenia	Spar™	Apple	10.6
Dana	Slovenia	Spar™	Lime	9.4
Dana	Slovenia	Spar™ (B)	Lime	9.8
Union Brewery	Slovenia	Za™	Lemon	11.2
Union Brewery	Slovenia	Za™ (B)	Lemon	10.1
Union Brewery	Slovenia	Za Life™	Apple	10.4
Radenska	Slovenia	Izvir™	Peach	8.5
Radenska	Slovenia	Izvir™	Guava	10.0
Radenska	Slovenia	Izvir™	Strawberry	9.5
Radenska	Slovenia	Izvir™ (B)	Strawberry	9.9
Radenska	Slovenia	Izvir™	Lemon balm	9.7
Jamnica	Croatia	Jana™	Strawberry guava	14.6
Jamnica	Croatia	Jana™	Lemon lime	14.0
Perne	Slovenia	Juliana™	Lemon	11.8
S.M.A.	Slovenia	Har Di™	Lemon	11.5

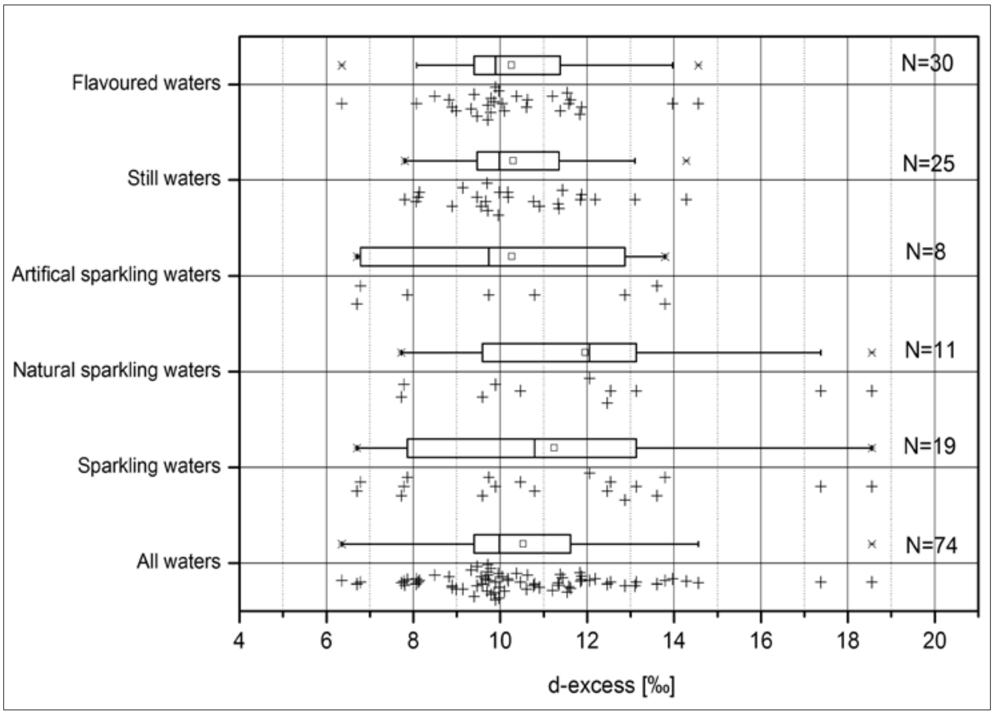

Fig. 3. Box plots of *d*-excess values with data point values for different groups of bottled waters.

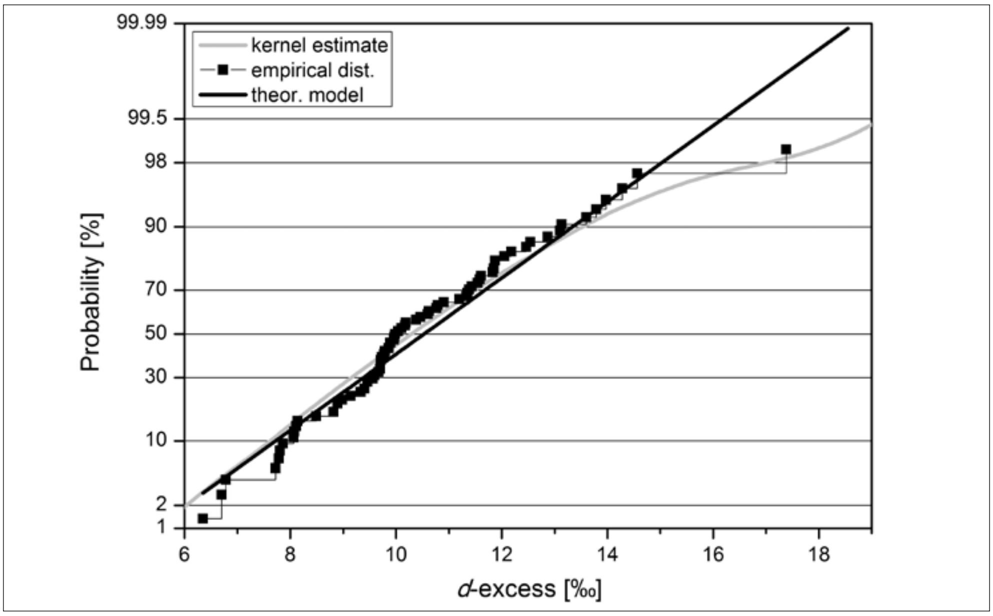

Fig. 4. Cumulative density diagram of the probability scale representing the empirical distribution, normal probability model and cumulative kernel density estimate for the whole set of bottled water

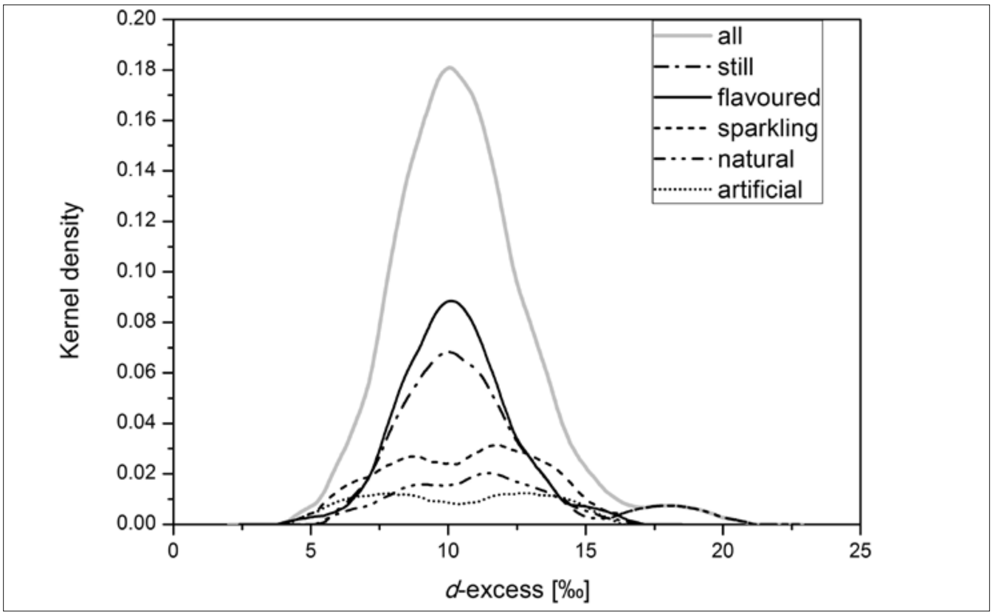

Fig. 5a. Probability density function estimates with kernel densities for different groups of bottled water.

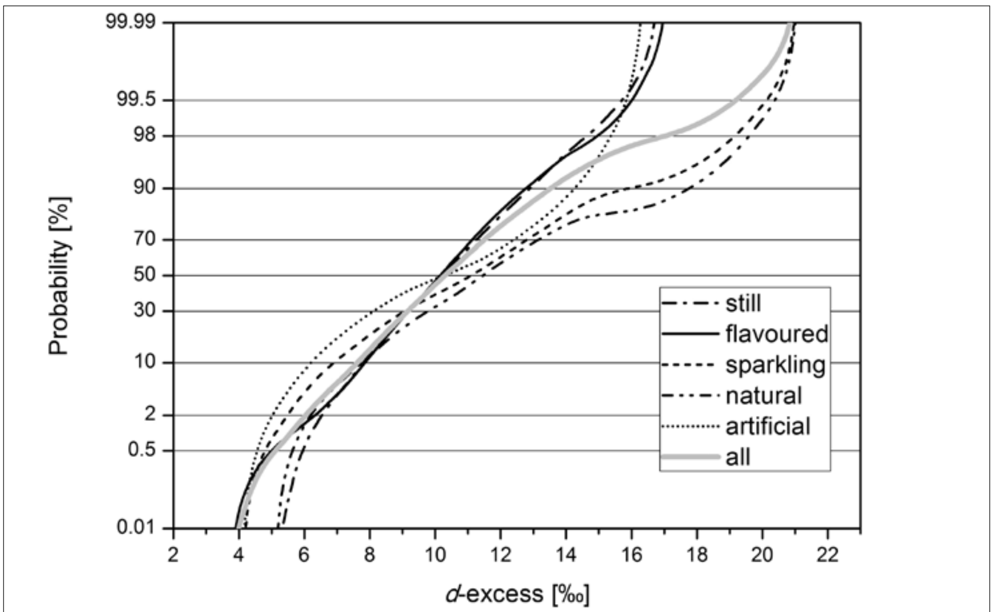

Fig. 5b. Cumulative density function estimates with kernel densities for different groups of bottled water on the probability scale diagram.

Table 4. Descriptive statistics of *d*-excess (‰) values for different types of bottled waters

	Average	Median	Std. dev.	Minimum	Maximum	Range	N
All waters	10.5	10.0	2.2	6.4	18.6	12.2	74
Sparkling waters	11.2	10.8	3.3	6.7	18.6	11.9	19
Natural sparkling waters	12.0	12.1	3.5	7.7	18.6	10.8	11
Artificial sparkling waters	10.3	10.3	3.0	6.7	13.8	7.1	8
Still waters	10.3	10.0	1.6	7.8	14.3	6.5	25
Flavoured *waters*	10.3	9.9	1.6	6.4	14.6	8.2	30

Table 5. Results of Anderson-Darling A^2 statistics and significaNce level of null hypothesis

	A^2	p
All	1.054	0.01
Flavoured	0.673	0.08
Still	0.303	0.43
Sparkling	0.374	0.24
Natural	0.440	0.16
Artificial	0.413	0.19

There is an apparent discrepancy between the results of the Anderson–Darling test and the kernel density estimates for both groups of sparkling waters. The test confirms the zero hypothesis that the EDF for all groups can be modelled with a normal probability model. However, the kernel densities show that the sparkling water groups are not distributed according to the expected bell-shaped curve of the normal probability model. These discrepancies are connected with the power and robustness of the statistical test and the power of the applied kernel method to properly represent the shape of the probability density curve with a low number of data. The question remains open for further investigation.

d-excess in relation to bottlers

If *d*-excess is considered in relation to the phases of the bottled water life cycle, analysis at a bottler level must also be performed. It is expected that production conditions as well as the condition in the parent water body are relatively homogenous. In the available data set, there are seven bottlers with several samples that can be used to analyse bottler-related influences on the isotopic fingerprint. According to the source water aquifers, these bottlers can be subdivided into two groups (Brenčič et al., 2010).

In the first group are bottlers exploiting deeper aquifers with natural source of CO_2. This group is represented by Kolinska (n=6) and Radenska (n=15), the biggest and oldest bottled water bottlers in the country. In this group, Jamnica (n=5) from Croatia should also be mentioned. These bottlers offer large ranges of products, including still waters, flavoured waters, and sparkling waters. In Slovenia, highly mineralised bottled water originates from two specific mineral water provinces (Fig. 2) with different geochemical characteristics and high natural CO_2 concentrations. In both cases, the bottled water is a mixture of shallow and deeper groundwater. It is supposed that deeper groundwater has a relatively long retention time. Pezdič (1997) reported for the Rogaška Slatina mineral province that waters represent a mixture of older waters with ages of more than 8,000 years and of several younger waters with different recharge areas no older than 35 years. According to the authors' best knowledge, the exact age of the water from the Radenska mineral water province has never previously been thoroughly investigated and no precise dating of water has been published until now. Žižek (1982) reported only ^{14}C ages in the interval of 12,500 and 40,000 years, which because of the high concentration of CO_2 in the aquifer (Pezdič, 1991) is too long estimate.

In the available data set for the Kolinska bottler, sparkling water predominates, and there is only one sample of still water (Tiha™) with a *d*-excess value of 10.9 ‰. This value is similar to values in the Ljubljana precipitation and no peculiarities can be reported. In sparkling waters, *d*-excess values are in the range 12.5–18.6 ‰, with upper two values representing outliers in the whole data set (Donat-Mg™). For Tempel™ and Edina™, slightly higher *d*-excess values than the average *d*-excess values of the precipitation at Ljubljana (Vreča et al., 2008) and Zagreb stations (Barešić et al., 2006) have been observed. Values from bottled waters can be compared with the *d*-excess values calculated from the values of δ^2H and $\delta^{18}O$ published by Pezdič (1997). These values are in the range of –4.9 ‰ to 10.7 ‰ and are lower than the values from our data set. A close inspection of this published data shows that these values are all distributed along the line with a slope of 5.9, clearly indicating that samples were probably exposed to secondary evaporation from sampling containers (Rozanski & Chmura, 2008). Based on only two samples it is difficult to interpret the reason for the relatively high *d*-excess values in Donat-Mg™. Pezdič (1997) argued that no water–rock interaction is present in the aquifer and that the isotopic composition is the consequence of water infiltration in the distant past with climatic regime different then the present one. These *d*-excess high values of Donat-Mg™ can be also a consequence of the aquifer processes and the presence of high CO_2 concentrations in the aquifer. The exact interpretation of these values remains open until further more detailed field investigations will be performed. The *d*-excess values of other water samples from Kolinska could be the consequence of mixing between shallow end members such as Tiha™ and deeper water end members such as Donat-Mg™.

The Radenska bottler is represented by three subgroups. In the first subgroup are sparkling waters with a range of *d*-excess values between 7.7 ‰ and 12.0 ‰, in the second subgroup are still waters with a range of *d*-excess values between 7.8 ‰ and 10.0 ‰, and in the third subgroup are flavoured waters with a range of *d*-excess values between 8.5 ‰ and 10.0 ‰. The average *d*-excess of all samples originating from Radenska is 9.5 ‰. These values can also be compared with the *d*-excess values calculated from the results of more than 60 boreholes from the Radenska mineral water province (Pezdič, 1991) ranging from 5.5 ‰ to 17.7 ‰ with an average value of 11.2 ‰. More than half of these reported data are in the range of 7.7 ‰ and 12.0 ‰, the range also defined for the Radenska bottled water. We conclude that based only on *d*-excess values it is not possible to assign isotopic changes to production processes or influences of storage conditions in the data set.

Jamnica (Croatia) should also be mentioned when interpreting bottler's *d*-excess values for waters originating from aquifers with higher concentrations of dissolved solids. According to its geological origin, the parent water is mineral water with a high CO_2 concentration. Jamnica sparkling water has *d*-excess values 6.7 ‰ and 6.8 ‰. Still water, which probably originates from shallow water, has a *d*-excess value of 10.8 ‰, which is close to the expected values in the precipitation in Zagreb (Barešić et al., 2006). Flavoured water samples have higher *d*-excess values of 14.0 ‰ and 14.6 ‰, respectively. It is assumed that these differences are the consequence of production processes with water aeration and gas removal/reinjection as well as different types of parent aquifers.

The second group of bottlers exploiting shallow aquifers is represented by Union Brewery (n=5), Plastenka (n=5), Dana (n=8), and Vino Brežice (n=12). These businesses use relatively shallow groundwater with a recharge area between 200 and 300 m above sea level (Brencic & Vreca, 2006). The residence times of the groundwater in this group of bottlers are supposed to be relatively short, no longer than several years. According to the authors' best knowledge, the exact age of this water has not previously been investigated and no dating of this water has been published until now.

The average *d*-excess value of Union Brewery products is 10.6 ‰ and the range is between 10.0 ‰ and 11.4 ‰, which is similar to that reported (Trček, 2006) in the parent aquifer. The average *d*-excess value of Dana products is 10.3 ‰ and the range is between 9.3 ‰ and 11.6 ‰. This range agrees with precipitation data for Ljubljana (Vreča et al., 2008). The same is valid for Plastenka, which has a range of *d*-excess values for still waters between 9.1 ‰ and 11.4 ‰ with an average of 10.0 ‰.

Vino Brežice offers numerous flavoured waters and one still water brand. The average *d*-excess value of all its products is 9.5 ‰ and the range is between 6.4 ‰ and 11.9 ‰. This range is the consequence of the variation in flavoured waters. From the isotopic data it follows that nearly all samples of flavoured waters are positioned in the left part of the δ^2H and δ^{18}O diagram below the still water sample, which represents the parent water (Brencic & Vreca, 2006). The distribution of these samples probably indicates the influence of production processes in relation to low pH. However, the *d*-excess values do not show any trends that clearly confirm this indication.

Bottled water life cycle

When interpreting geochemical and isotopic characteristics it must be recognised that bottled water is a food product with its own life cycle, which does not only depend on the natural processes from where it originates but also on various production processes and storage conditions (Brenčič et al., 2010). These processes can considerably change the isotopic image of the bottled water. To interpret the *d*-excess values of bottled water three main life cycle phases must be considered: i) processes in the atmosphere before the interaction with the parent water body; ii) processes in the parent water body, and iii) production and storage processes. Therefore, it is necessary to recognise that all waters in the data set (Brencic & Vreca, 2006) originate from the underground water bodies, namely aquifers from temperate and humid climates.

In general, in temperate and humid climates the stable isotopic composition of the groundwater closely matches that of the precipitation in the recharge areas (Gat, 2010). Relatively large fluctuations in stable isotopic characteristics in the precipitation are smoothed out in the groundwater, and fluctuations are reflected in values along the GMWL. Therefore, groundwater represents a homogenised sample of the isotopic composition of the precipitation in the recharge areas. Deviations in groundwater isotope characteristics from the present day overall precipitation characteristics in the recharge areas of the aquifers can be a result of evaporation processes in the surface water bodies or in the unsaturated zone of the aquifers– or water aquifers–rock interaction and, consequently, the exchange between the water and aquifer matrix. Deviations from the present day GMWL can be a consequence of the long-term residence times of water in the aquifers, indicating that water was infiltrated underground during a different climatic regime in the past.

In Slovenia, the isotopic composition of precipitation has been investigated at Ljubljana since 1981 (Vreča et al., 2008) and the station is central to all considered bottler locations (Fig. 2). Between 1981 and 2006 the *d*-excess values fluctuated on the monthly basis in the range between –19.9 ‰ and 19.4 ‰, with an average value and median of 9.3 ‰ and standard deviation of 3.8. In the SW part of Slovenia, the isotopic composition of precipitation was systematically monitored at the Portorož and Kozina stations for the period 2001–2003 (Vreča et al., 2006). The *d*-excess values fluctuated in the monthly samples at Portorož between 2.4 ‰ and 18.9 ‰ with an average of 9.2 ‰, median of 8.5 ‰, and standard deviation of 4.8, whereas at Kozina the values varied between 3.7 ‰ and 23.7 ‰ with an average of 11.6 ‰, median of 10.8 ‰, and standard deviation of 3.7. Daily observations showed even larger fluctuations (Vreča et al., 2007). In the analyses of *d*-excess in Slovenian bottled waters, foreign precipitation stations near the state borders must also be considered. In Austria, the mean *d*-excess value for the period 1973–1994 at Villacher Alpen was 9.6 ‰ (Froehlich et al., 2008) and at Graz for the period 1973–2002 it was 8.8 ‰ (IAEA, 2010). In Croatia, the *d*-excess value for the period 1976–1996 at Zagreb was 7.8 ‰ and daily fluctuations were between –9 ‰ and 18 ‰ (Barešić et al., 2006). For the period 2001–2003 a mean value of 9 ‰ was reported (Vreča et al. 2006).

In all bottled water groups, the average *d*-excess values (Table 4) were slightly higher than those reported in the precipitation data. The only exceptions are natural sparkling waters. From the available hydrogeological information in Slovenia, water rock interaction and water sediment interaction and the interaction with deeply originating CO_2 are possible only in the case of natural sparkling waters originating from the Radenska and Rogaška Slatina mineral water provinces (Fig. 2). These deviations are reflected also in the *d*-excess values of considered bottled water originating from these provinces.

In all other parent aquifers of Slovenian bottled water, deviations in *d*-excess from local precipitation characteristics are not expected. In fact, the literature data confirm this hypothesis. Ogrinc et al. (2008) reported that in the Sava basin, which represents the largest river basin in the country and is central to all considered bottlers locations, *d*-excess in the porous aquifers of the basin is 10.4 ‰ and the water in the river is close to 10.0 ‰. For the aquifer of Ljubljansko barje and the western part of Ljubljansko polje in the central Slovenia area, Trček (2006) reported a range of *d*-excess values between 10.6 ‰ and 12.6 ‰. Groundwater *d*-excess values from Slovenia are slightly higher than those reported in Ljubljana precipitation.

During the production of bottled water, several processes can influence the *d*-excess values of bottled water. Three subphases important for isotopic composition understanding must be considered: i) water pumping from the parent water body and the storage of water in buffer tanks; ii) the production and filling processes; and iii) storage in bottlers' facilities and sellers' locations.

During pumping from the aquifer water is usually transferred from a relatively closed thermodynamical system (e.g. confined aquifer) to an open system. During this process water is aerated and redox conditions drastically change towards a more oxidised environment. Water originating from aquifers with higher gas partial pressures is degassed. To avoid fluctuations of discharges from the well and to use energy more efficiently, in nearly all production facilities water is pumped into large buffer tanks from where it flows into the filling equipment. These tanks represent an open system where water is at least part of the time under a turbulent regime. In some cases, water is stored in tanks for several days before bottles are filled. During these processes the water temperature slightly rises compared with that of the parent water body. In the case of mineral and thermomineral water the temperature drops. In both cases, the water chemical equilibrium can be substantially changed. The exact changes in isotopic composition caused by production processes depend on the onsite conditions and were not studied in detail.

Large equilibrium changes are also present in the filling process during which bottlers often change the pH and concentrations of some dissolved species. One well-known example is the change of the $CaCO_3$ – CO_2 system equilibrium with the shift in pH and partial pressure of CO_2 (Beck et al., 2005). CO_2 degassing is a frequent production process that is allowed under mineral water legislation (EU, 1980). The aeration of water and consequent CO_2 degassing process is stimulated artificially to remove dissolved iron and manganese species. After the iron and manganese removal, CO_2 gas is reintroduced during the filling process. As illustrated in Figure 1, all these processes can potentially shift the isotopic composition of water from the parent body. However, precise analyses and interpretation of these processes can be given only based on more detailed information from the production process which at present are not available.

Substantial changes in the chemical equilibrium and subsequent isotopic fingerprint changes can also appear during the preparation of flavoured and functional water. Several flavours, sugars, organic acid-based and conservation chemicals are added. During these processes pH changes are substantial and, consequently, a relatively low pH was determined in some waters (Brencic & Vreca, 2007).

Finally, it is also well known that plastic packing materials are water soluble and porous. The solubility of plastic material can cause time-dependent changes of bottled water and, consequently, higher porosity and gas permeability. It is expected that the transport of gases through the walls of the bottle influences its chemical and isotopic composition. In some cases, where a higher concentration of dissolved calcite and dolomite are present in the water, precipitate can appear in the case of the diffusion of CO_2 from the bottle. If CO_2 is present the diffusion of other gases and evaporation is also possible. All these processes can be simply detected with the time-dependent change of plastic bottle hardness. Over time bottles become more and more deformed and soft. The aging of plastic material and gas diffusion processes lead to lower *d*-excess values in the parent water, as also reported for sample containers (Stewart, 1981; Rozanski & Rzepka, 1991; Rozanski & Chmura, 2008). The influence of bacteria and their time-dependent activities on the water's isotopic composition is also possible and can cause changes in chemical equilibrium.

Conclusions

Based on the available data set of δ^2H and δ^{18}O values from bottled waters on the Slovenian market, *d*-excess values were calculated and analysed. Basic descriptive statistics were performed, different groups of bottled waters were compared, and their EDF were investigated. Following the well-known principles of water isotopic geochemistry possible changes in the isotope footprint reflected in the *d*-excess values were interpreted.

The descriptive statistical analyses and one-way ANOVA demonstrated that there are no significant differences in *d*-excess values among the groups. Explicit differences among groups were detected with kernel densities estimates in the shapes of their empirical distributions. Still and flavoured waters have similar shapes of empirical distribution. Vivid differences are present among the shapes of sparkling waters and other waters. Sparkling waters also differ among each other; artificial sparkling waters have a different shape of EDF to natural sparkling water. Empirical distributions of different bottled water groups of sole δ^2H and δ^{18}O variables are symmetrical, contrary to the empirical distributions of *d*-excess values in sparkling bottled waters. These differences indicate the complicated processes that govern the isotopic composition of sparkling water in their parent aquifers and possibly also during production processes.

In the data set two distinctive groups of bottlers are present. The first group is represented by bottlers exploring waters originating from the natural aquifers rich in highly mineralised groundwater and relatively high concentrations of CO_2 gas. These produce a large range of products with waters originating from different aquifers with diverse recharge conditions. Consequently, their *d*-excess values have a larger range. In the second group are bottlers that use only groundwater from relatively shallow aquifers for the production of still and flavoured waters. This bottled water has similar *d*-excess values to the local precipitation and their empirical distributions are unimodal and symmetrical.

The considered data set represents only a single sampling from the whole national market performed during a relatively short time period. The data set presents a general overview of the isotopic characteristics of bottled water on the market. No significant differences among identical bottled water products and the same bottler can be observed with such sampling and consequently no detailed interpretation of the process in the source and production can be given. Based on the applied interpretation and theoretical considerations we conclude that the *d*-excess values can be an additional tool to δ^2H and δ^{18}O analyses in the interpretation of the bottled water life cycle and their authentication. However, for a better interpretation more frequent sampling of the same water brand is needed. A better knowledge of how the particular production phases influence the isotopic characteristics is also required. Usually information about particular production processes are not available, therefore additional experimental work is required to detect process that can influence the isotope footprint of bottled water. This knowledge can help to improve the bottled waters' authentication process.

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Author's note: Any uses of trade, product, or company names in this article are for descriptive purposes only and do not imply endorsement by the authors or their employers.

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Ekspertni sistem za podporo odločanju na aluvialnih telesih podzemnih voda Slovenije

An expert system as a support to the decision making process for groundwater management of alluvial groundwater bodies in Slovenia

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Key words: water management, water rights, groundwater, alluvial aquifers, numerical models of groundwater flow, Slovenia

Izvleček

Ekspertni sistem za podporo odločanju pri upravljanju s podzemnimi vodami na aluvialnih vodonosnikih povezuje numerične modele toka podzemne vode s podatkovnima zbirkama vodnih dovoljenj in koncesij, kar omogoča ocenjevanje izdatnosti vodonosnikov in zagotavljanje trajnostnega upravljanja podzemne vode. Samostojni numerični modeli toka podzemne vode pa se uporabljajo tudi pri oceni količinskega stanja podzemnih voda in pri spremljavi izdatnosti lokalnih vodnih virov v obdobju največjih potreb po vodi in najmanjšega količinskega obnavljanja podzemne vode.

Abstract

The expert decision support system for groundwater management in the shallow alluvial aquifers links numerical groundwater flow models with the water permits and concessions databases in order to help groundwater managers to quantify sustainable yield for a given groundwater body and provide additional information for sustainable groundwater management. Stand alone numerical groundwater models are used in the process of the assessment of groundwater quantitative status as well as for assessing local yield quantity during the period of maximum water demand and minimum groundwater recharge.

Uvod

Agencija RS za okolje izvaja projekt Nadgradnja sistema za spremljanje in analiziranje stanja vodnega okolja v Sloveniji, znanega pod akronimom **BOBER - B**oljše **O**pazovanje za **B**oljše **E**kološke **R**ešitve (Sirc, 2009; Vogrinčič et al., 2010). Projekt BOBER je del evropskega Operativnega programa za razvoj okoljske in prometne infrastrukture v obdobju 2007–2013. V okviru projekta BOBER smo izvedli tudi projekt »Ekspertno numerični sistem za podporo odločanju na aluvialnih telesih podzemnih voda Slovenije«.

Upravljanje podzemnih vodnih virov ter spremljanje in ocenjevanje stanja podzemnih vod zahteva dobro razumevanje vodonosnih sistemov in procesov za optimalno rabo ob zadostitvi ekoloških potreb mokrišč, izvirov in rek ter ohranjanju kakovosti površinskih in podzemnih voda. Ekspertni sistem in modeli podzemnih vod podpirajo intergracijo, validiacijo in kvantifikacijo hidrogeoloških informacij, ki so potrebne za razvoj strategij trajnostne rabe podzemnih vodnih virov.

Ekspertni sistem za podporo odločanju na aluvialnih vodonosnikih tako povezuje numerične modele toka podzemne vode s podatkovnima zbirkama vodnih dovoljenj in koncesij, upravljavcu pa pomaga pri oceni vodnih količin na danem vodnem telesu oziroma mu nudi dodatno informacijo o modelski izhodiščni količini podzemne vode za potrebe izdaje vodnih pravic, ki jih po zakonu o vodah (Uradni list RS, 2008), predstavljajo vodna dovoljenja in koncesije. Samostojni modeli toka podzemne vode se uporabljajo tudi kot pomoč pri oceni količinskega stanja podzemnih voda oziroma spremljanju količin vodnih virov v določenem časovnem obdobju. Zgrajenih je šest regionalnih modelov toka podzemne vode na območjih vodnih teles podzemnih voda: Mursko in Dolinsko Ravensko polje, Dravsko in Ptujsko polje, Spodnje Savinjsko polje, Krško polje, Kranjsko in Sorško polje ter Ljubljansko polje.

Pomemben cilj projekta je bil vzpostavitev hidrogeoloških modelov toka podzemnih voda na količinsko najbolj obremenjenih vodnih telesih podzemnih voda in zagotoviti kontrolne mehanizme, s katerimi se preverja podeljevanje vodnih pravic za njihovo trajnostno upravljanje. Ti mehanizmi omogočajo, da se Vodna knjiga, ki je zbirka računalniških aplikacij z registrom zaprošenih in podeljenih vodnih pravic, na čim bolj enostaven način poveže z ekspertnim sistemom in se s tem pridobi informacijo o izdatnosti vodonosnikov in o izhodiščni količinski shemi upravljanja ter o sovplivih načrtovanih odvzemov z bližnjimi že obstoječimi vodnimi pravicami. Definirani kontrolni mehanizmi upoštevajo tehnologijo, s katero sta izdelani aplikaciji Vodna dovoljenja in Koncesije.

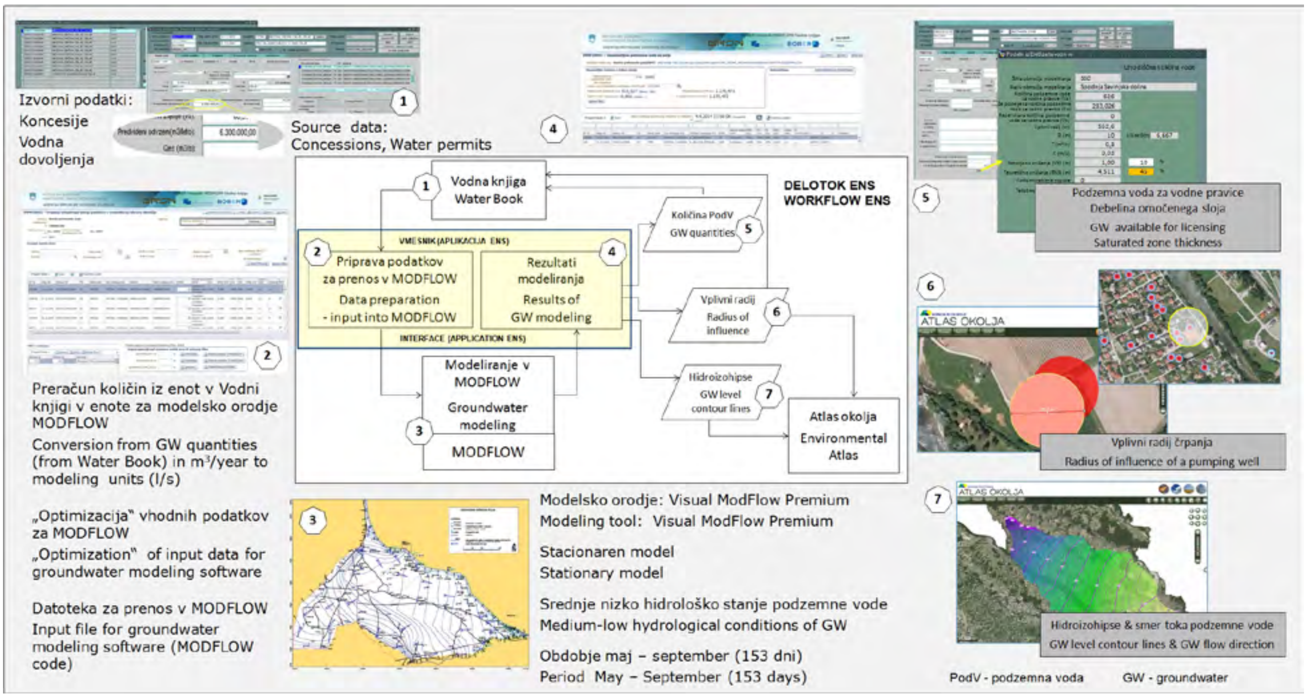
Ekspertno numerični sistem (ENS)

Izdelan <u>E</u>kspertno <u>N</u>umerični <u>S</u>istem (**ENS**) omogoča uporabo podatkov vodnih pravic (letni maksimalni odvzem podzemne vode v m^3 ali maksimalni trenutni odvzem v l/s) iz aplikacij Vodna dovoljenja in Koncesije (Vodna knjiga) in zagotavlja mehanizem za kontrolo znižanja gladine podzemne vode na izbrani lokaciji ter mehanizem za kontrolo poseganja v vplivno območje črpanja. Kriteriji odločanja so vgrajeni v prikazovalnik prostorskih podatkov - Atlas okolja. ENS tako omogoča medsebojno izmenjavo podatkov med aplikacijami: Vodna knjiga, Atlas okolja in VisualModFlow (sl. 1) (Celarc et al., 2014a).

V ekspertno numeričnem sistemu se najprej izvede inicialni prenos podatkov iz Vodne knjige (sl. 1, korak 1) v ENS vmesnik, temu sledi pregled in urejanje količinskih podatkov (sl. 1, korak 2), ter prenos v modelsko okolje MODFLOW (sl. 1, korak 3). Model toka podzemne vode umerimo s podatki o količini podzemne vode iz vodnih pravic in določimo izdatnost določenega aluvialnega vodonosnika. Modelski rezultati se prenesejo nazaj v ENS vmesnik (sl. 1, korak 4) in nato v Vodno knjigo ter na prikazovalnik prostorskih podatkov Atlas okolja (sl. 1, koraki 5, 6, 7).

Končni rezultati celotnega ekspertno numeričnega sistema so (Vižintin et al., 2012, Petauer et al., 2014a; Petauer et al., 2014b; Vižintin et al., 2014a, Vižintin et al., 2014b, Vižintin et al., 2014c):

- za vsak obravnavan aluvialni vodonosnik je opredeljena množica vodnih dovoljenj in koncesij, ki se po določenih kriterijih prenesejo v model MODFLOW in upoštevajo pri modeliranju,
- definirani so parametri za preračun podatkov o podeljenih vodnih pravicah iz Vodne knjige v enote, ki jih upošteva numerični model MODFLOW,
- vzpostavljeni in umerjeni so numerični modeli toka podzemne vode, ki dajejo optimalne rezultate glede na upoštevane podatke vodnih dovoljenj in koncesij,



Sl. 1. Delotok ekspertno numeričnega sistema za podporo odločanju pri upravljanju podzemnih voda (glej razlago posameznih oštevilčenih korakov v tekstu).

Fig. 1. Workflow of the expert decision support system for groundwater management (explanation of particular steps in the text).

- podan je predlog izhodiščne količinske sheme podzemne vode v vodonosniku s srednje nizkim hidrološkim stanjem, ki lahko predstavlja eno od upravljalskih izhodišč za politiko podeljevanja vodnih pravic,
- definirani so parametri za izračun vplivnega radija posameznega odjemalca, ki so rezultat umerjanja modela in
- pripravljen je mehanizem za spremljanje podeljevanja pravic za rabo podzmene vode in spremljanje vplivnih radijev ob podeljevanju novih vodnih pravic.

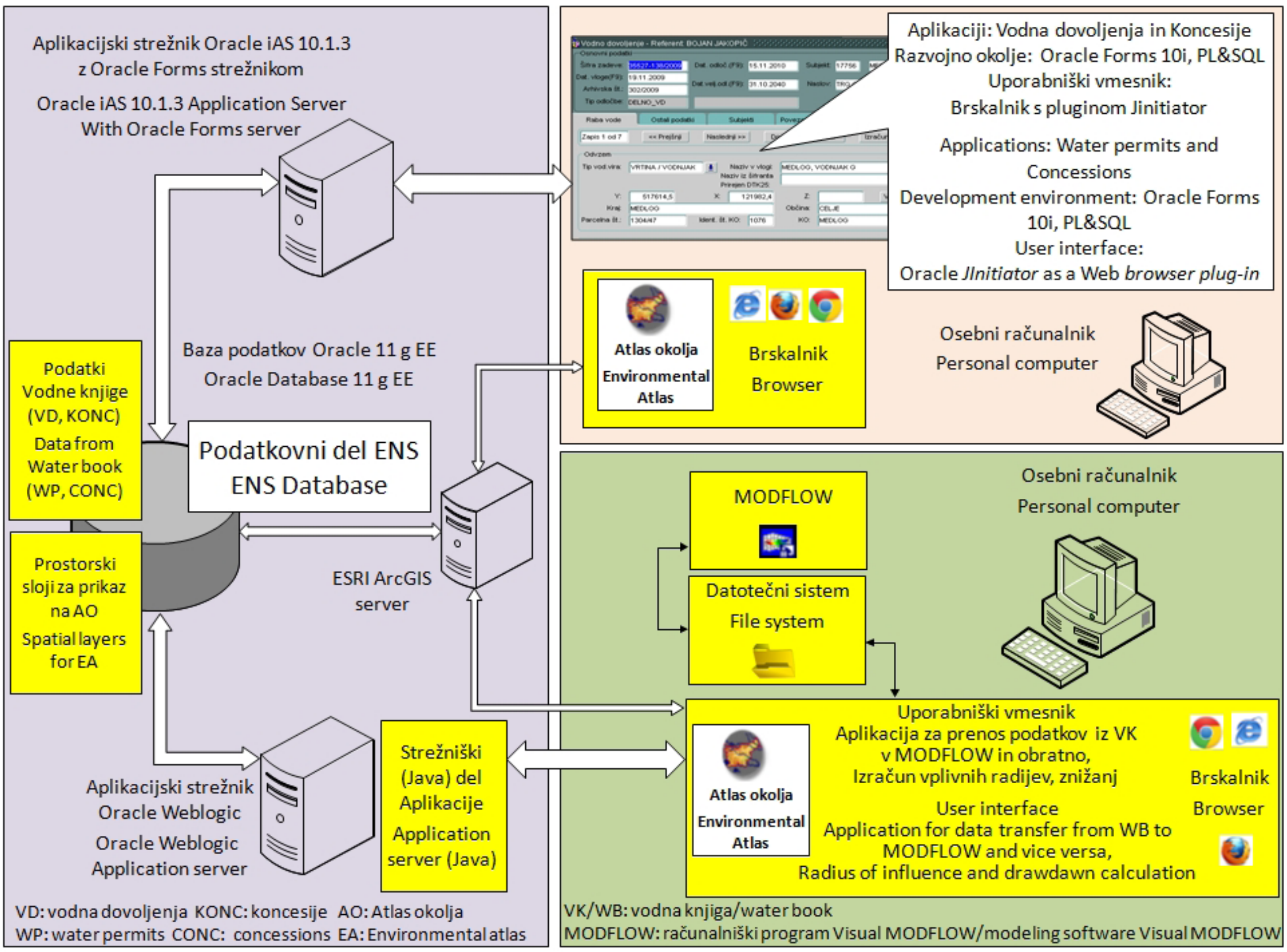
Tehnična infrastruktura ENS

Gradniki tehnične infrastrukture okolja ENS so (sl. 2) (Celarc et al., 2014b):

- Podatkovna zbirka (Oracle DB 11g Enterprise Edition), kjer so shranjeni vsi podatki, kot so Vodna knjiga, podatki ENS za prenos podatkov iz Vodne knjige v MODFLOW in obratno, izračun vplivnih radijev, znižanja gladin podzemne vode in podatki za prikaz na Atlasu okolja ter prostorski sloji za prikaz na Atlasu okolja.
- Aplikacijski strežnik (Oracle IAS 10.1.3) s Forms strežnikom, kjer tečeta aplikaciji Vodna dovoljenja in Koncesije.
- Obstoječe aplikacije Vodna dovoljenja in Koncesije so izdelane v razvojnem okolju Oracle Forms in programskemu jeziku PL/SQL. Izvajajo se v uporabniškem vmesniku brskalniku preko plugin-a Jinitiator.
- Aplikacijski strežnik (Oracle WebLogic 10.3.5) z Oracle ADF 11g izvajalnim okoljem, ki predstavlja strežniški del Aplikacije izdelan v okolju Oracle ADF 11g.
- Uporabniški vmesnik ENS.
- Programsko orodje za numerično modeliranje toka podzemne vode (koda MODFLOW).
- Vmesnik med Aplikacijo in sistemom MODFLOW je datotečni sistem, preko katerega se izvažajo in uvažajo datoteke.
- Za prostorski prikaz se uporablja Atlas okolja. Strežniški del Atlasa okolja teče na ESRI ArcGis strežniku, uporabniški del pa v brskalniku.
- Prostorski podatki so shranjeni v formatu Oracle Spatial.

Hidrogeološki numerični modeli toka podzemne vode v oviru ENS

Regionalni hidrogeološki numerični modeli toka podzemne vode so vzpostavljeni znotraj območij vodnih teles podzemnih voda na: Murskem in



Sl. 2. Tehnična infrastruktura ekspertno numeričnega sistema za podporo odločanju pri upravljanju podzemnih voda.
Fig. 2. Technical infrastructure of the expert decision support system for groundwater management.

Dolinsko Ravenskem polju, Dravskem in Ptujskem polju, Spodnje Savinjski dolini, Krškem polju (sl. 3), Kranjskem in Sorškem polju ter na Ljubljanskem polju. Za postavitev numeričnih modelov toka podzemne vode so ključni kakovostni in prostorsko razporejeni hidrološki in hidrogeološki podatki.

Za vse večje aluvialne vodonosnike v Sloveniji je bil vzpostavljen enotni pristop izdelave konceptualnega modela. Za vsak vodonosnik se je določilo kritično hidrološko obdobje, ki je najbolj problematično s stališča iskoriščanja podzemne vode, hidrogeološke enote, robne pogoje modelov, začetne vrednosti nivojev v modelu in režim toka podzemne vode. Poleg tega se je s pomočjo vodnobilančnega modela GROWA-SI ocenilo vodno bilanco zaledja posameznega vodonosnika.

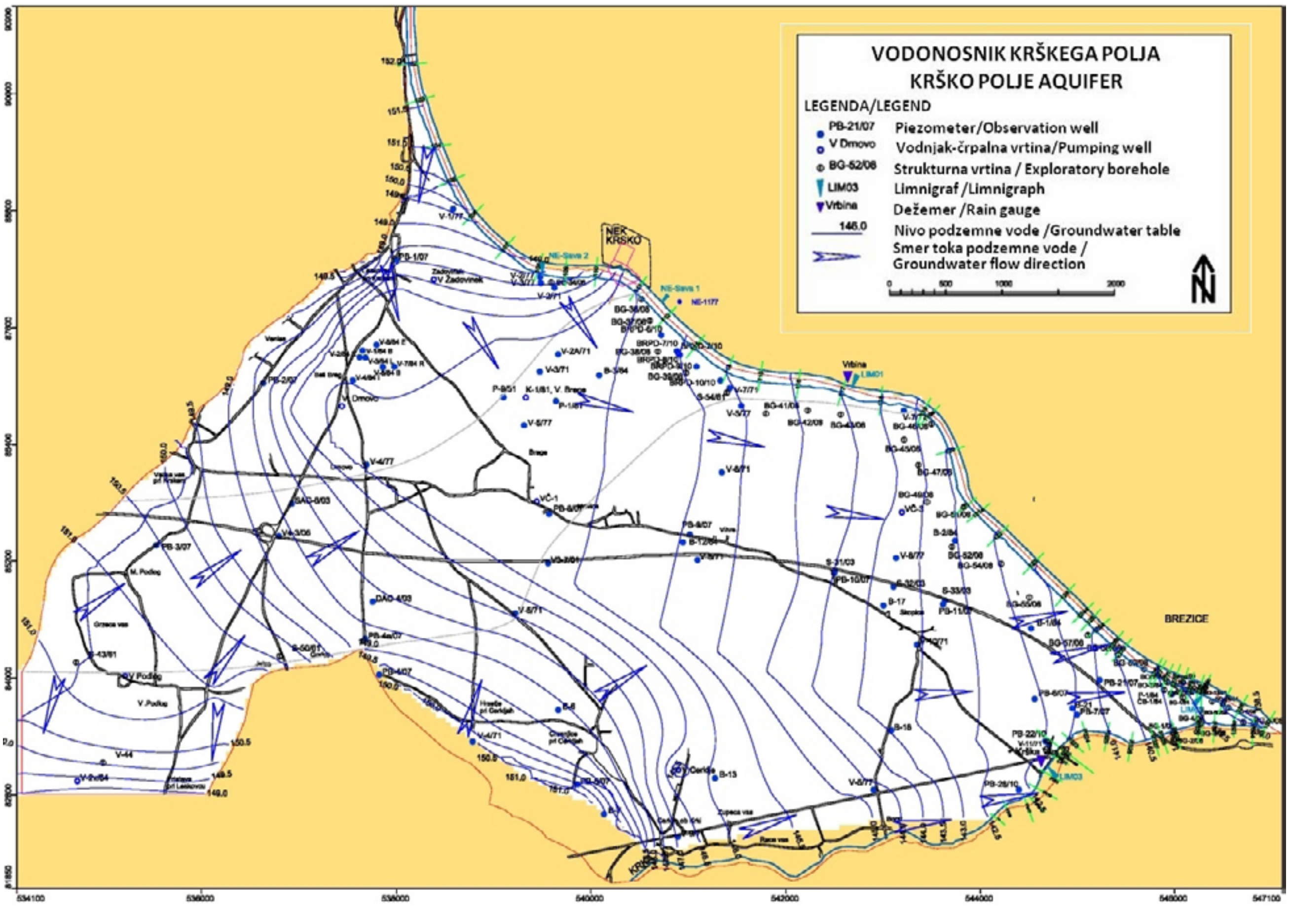
Kritično hidrološko obdobje je tisto obdobje leta, ko so pritiski uporabnikov na črpanje podzemne vode največji in ko je sposobnost obnavljanja aluvijalnega vodonosnika najmanjša. Na osnovi analize se je ugotovilo, da je kritično obdobje med majem in septembrom (153 dni).

Modeli so izdelani za stacionarni režim podzemne vode in so umerjeni na srednje nizke hidrološke razmere v kritičnem obdobju danega leta.

Sistem ENS kot podpora odločanju pri podeljevanju vodnih pravic

Z vpeljavo ENS je omogočeno sprotno spremljanje količin podzemne vode za podeljevanje pravic in morebitne medsebojne vplive med različnimi porabniki podzemne vode. Tako imajo uporabniki sistema ob vnosu vodnih dovoljenj in koncesij v svojih obstoječih aplikacijah vpogled v naslednje podatkovne informacije:

- izhodiščno količino podzemne vode za vodne pravice za posamezni aluvialni vodonosnik (modelsko območje),
- količino podzemne vode, ki je že odobrena (in porabljena) z veljavnimi vodnimi dovoljenji in koncesijami,
- količino podzemne vode, ki bo potencialno porabljena s strani novih prosilcev za vodno pravico (vloge v reševanju),
- izhodiščno količinsko shemo upravljanja z upoštevanjem količin, ki so že podeljene in pa tistih, ki so še v reševanju,
- seznam tistih prosilcev, ki imajo vloge v reševanju in bodo ob potencialni izdaji dovoljenja odvzemali podzemno vodo,
- vplivne radije obstoječih odvzemov in vlog, ki so v reševanju,



Sl. 3. Primer numeričnega modela toka podzemne vode: gladine podzemne vode vodonosnika Krškega polja po umeritvi modela na nizke hidrološke razmere.

Fig. 3. An example of numerical groundwater model: groundwater levels for Krško polje aquifer after calibration of the model to a medium-low hydrological field conditions.

- s črpalnim poskusom izmerjeno znižanje gladine podzemne vode na dani novi lokaciji (podatek iz hidrogeološkega poročila, ki je priloga vlogi za vodno pravico) in
- sistem opozoril, ko odvzemi dosegajo ali presegajo izhodiščno količino podzemne vode za vodne pravice.

Drevo odločanja (sl. 4), ki se opira na rezultate ekspertno numeričnega sistema, upravljavcu pomaga pri sprejemanju odločitev v postopku podeljevanja vodne pravice za črpanje podzemne vode.

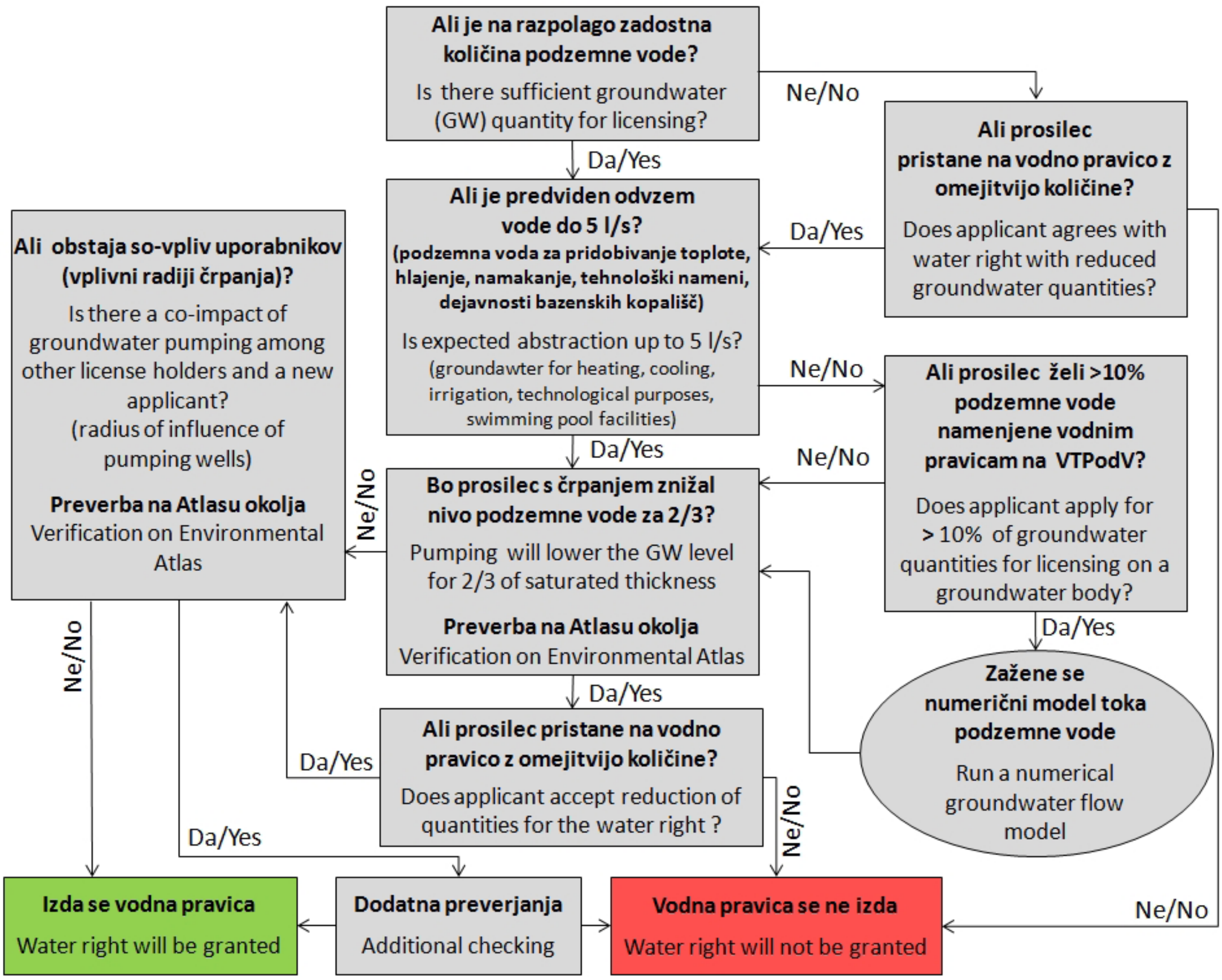
Sistem odločanja je postavljen ob zasledovanju petih načel, ki so upoštevana v drevesu odločanja:

1. Načelo trajnostne rabe podzemne vode in s tem ohranjanja dobrega količinskega stanja podzemne vode (*Ali je na razpolago zadostna količina podzemne vode?)*
2. Načelo upoštevanja dosedanjih kriterijev podeljevanja vodne pravice z možnostjo dodatne modelske simulacije (*Kolikšen je predviden odvzem podzemne vode?*)
3. Načelo neovirane rabe podzemne vode (*Ali obstaja so-vpliv uporabnikov?*)
4. Načelo preprečitve lokalne količinske preobremenjenosti vodonosnika (*Ali bo črpanje povzročilo znižanje gladine podzemne vode za več kot 2/3 omočenega dela vodonosnika?*)
5. Načelo sodelovanja stranke v postopku pridobitve vodne pravice (*Ali prosilec soglaša z vodno pravico z omejitvijo količine?)*

V primeru, da se pri procesu odločanja podeljevanja vodne pravice ugotovi, da se s črpanjem podzemne vode v novem vodnjaku vpliva na že obstoječega imetnika vodne pravice, je v drevesu odločanja (sl. 4) predvideno dodatno preverjanje (dodatne raziskave in analize).

Zaključek

Predstavljeni ekspertno numerični sistem (ENS) je orodje za podporo trajnostnemu upravljanju podzemnih voda pri odločanju o vodnih pravicah za odvzem podzemne vode. V procesu odločanja v okviru ENS je upravljavcu omogočena uporaba dodatnih informacij, vendar ga v nobenem koraku ne omejuje pri odločanju. Podatki, ki so uporabljeni v ENS, temeljijo na numeričnih modelih toka podzemne vode za



Sl. 4. Drevo odločanja v procesu podeljevanja vodne pravice za črpanje podzemne vode

Fig. 4. The decision tree for the process of granting groundwater rights.

posamezen aluvialni vodonosnik (izhodiščna količinska shema upravljanja podzemne vode, prostorski prikaz hidroizohips in smeri toka, ocena vplivnih radijev črpanja), ki predstavljajo modelsko okolje za simuliranje učinkov novih odvzemov podzemne vode. Zaradi navedenega so numerični modeli toka podzemne vode pomembni pri trajnostnem upravljanju podzemne vode.

Zahvala

Projekt Nadgradnja sistema za spremljanje in analiziranje stanja vodnega okolja v Sloveniji, znanega pod akronimom BOBER (Boljše Opazovanje za Boljše Ekološke Rešitve), je bil del evropskega Operativnega programa za razvoj okoljske in prometne infrastrukture v obdobju 2007–2013. Kohezijski sklad Evropske unije je prispeval 85 %, slovenski državni proračun pa 15 % vrednosti projekta. Avtorji članka se zahvaljujemo vsem članom projektne skupine za izvedbo projekta (HGEM d.o.o.: Ivan Supovec, Martin Tancar, GEORAZ d.o.o.: Darko Petauer, Tadej Hiti, FGG: prof. dr. Mitja Brilly, mag. Andrej Vidmar) in članom delovne skupine za spremljanje in svetovanje s strani naročnika Agencije RS za okolje (dr. Jože Uhan, dr. Mišo Andjelov, Urša Pavlič).

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Poročila

The XXth Congress of the Carpathian-Balkan Geological Association

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The XXth Congress of the "Carpathian-Balkan Geological Association" was held in Tirana (Albania) from September 24 to September 26, 2014. This Jubilee Congress that took place for the first time in Albania was organized by the Geological Society of Albania in cooperation with the most important and traditional Albanian educational and research institutions: Polytechnic University of Tirana, Geological Survey of Albania, Faculty of Geology and Mining, Institute of Geosciences, Water, Energy and Environment and the Academy of Sciences of Albania. The board members of the Organizing Committee were Prof. Dr. Arjan Beqiraj as Chairperson, Dr. Viktor Doda as Vice-chairperson, Dr. Arben Pambuku as General Secretary and Msc Andreea Uta as Executive Secretary.

The Welcoming Ceremony was opened by the President of the "CBGA 2014", Prof. Dr. Arjan Beqiraj and was greeted by the Rector of the Polytechnic University of Tirana, Acad. Jorgaq Kaçani, the CBGA councilor, Prof. Dr. Corina Ionescu – NR of Romania and the Minister of Energy and Industry of Albania, Mr. Damian Gjiknuri. The participants enjoyed a short video and photo retrospective featuring the research works performed by the Albanian and foreign geologists during the last 70 years.

The XXth CBGA Congress offered a wide and rich program comprised of 18 Special Sessions, 8 General Sessions, 3 Workshops and 5 Field Trips organized in different regions of Albania. Per total, 470 short and extended abstracts were accepted, of which 220 were oral presentations and 250 posters. The abstracts are published in two volumes, as special issues of the Albanian Journal "Buletini i Shkencave Gjeologjike". In addition, 5 field trip guide books were published and distributed to about 150 participants. The contribution of more than 550 participants coming from different countries all over the world made this congress to be an event of high scientific success. By bringing together scientists not only from the CBGA-countries (Albania, Austria, Bosnia and Herzegovina, Bulgaria, Czech Republic., Croatia, FYR of Macedonia, Greece, Hungary, Montenegro, Poland, Romania, Serbia, Slovakia, Slovenia, Ukraine), but also from other European and worldwide countries as Algeria, Australia, Canada, China, Cyprus, Egypt, England, France, Georgia, Germany, Iran, Italy, Jordan, Kosovo, Luxembourg, Moldavia, New Zealand, Norway, Portugal, Russia, South Korea Spain, Sweden, Switzerland, Turkey, USA, the congress was an excellent opportunity for presentation of outstanding scientific achievements and for a real exchange between scientists working in the world of geology and related sciences.

In particular, the participation of young geoscientists in the "CBGA 2014" was strongly encouraged. The Organizing Committee is pleased to confirm that, as a result of this policy, about 100 young researchers have submitted abstracts and presented their contributions in the different scientific sessions of the congress.

The CBGA Council meeting held on September 23, 2014, was mostly focused on three topics: i) Expanding of CBGA with other member countries. With the joining of Croatia and Bosnia and Herzegovina, CBGA counts now 16 member countries; ii) Preparations of "CBGA 2014". All the councilors present in the meeting have appreciated the serious and consistent work made by the local organizing Committee for the preparation of the "CBGA 2014"; iii) Nomination of the "CBGA 2018" organizer. The council unanimously agreed that the next congress (XXI^{rst}) of the CBGA will be held in Salzburg (Austria). The President of the Organizing Committee will be Prof. Dr. Franz Neubauer and he will constitute new Organizing Committee and will check for other geological events in order to decide the time when the "CBGA 2018" will be held. The councilors also agreed with the proposal of the The NR of Bulgaria, Prof. Peycheva, who announced that Bulgaria is going to organize the "CBGA 2022".

The Council meeting tasked the new President, Prof. Neubauer, with CBGA status improvements, updating the agreements between the CBGA and its official journals, "Geologica Carpathica" and "Geologica Balcanica" and maintaining regular reports with IUGS.

Several participants of CBGA 2014 congratulated us for the organization of the congress during the days of the scientific sessions and the closing ceremony. Other colleagues sent us their positive impressions concerning the organization of the congress and field trips. The Organizing Committee is really pleased with organizing such a successful congress of CBGA, thus saving its long-term tradition as one of the best geoscience events in Europe.

*This designation is without prejudice to positions on status, and is in line with UNSC 1244 and the ICJ Opinion on the Kosovo Declaration of Independence

7. Hidrogeološki kolokvij

Ljubljana, 4. 12. 2014

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Po enoletnem premoru je Oddelek za geologijo na Naravoslovnotehniški fakulteti skupaj s Slovenskim komitejem mednarodnega združenja hidrogeologov – SKIAH ponovno organiziral hidrogeološki kolokvij. Tokrat je dogodek potekal v okviru tedna univerze. S tem smo skromno prispevali k obeležitvi petindevedesete obletnice ustanovitve Univerze v Ljubljani. Kolokvij je potekal nekoliko drugače kot običajno, gostovanje tujega predavatelja smo nadomestili z razpravo o slovenski hidrogeološki terminologiji.

V prvem predavanju z naslovom »*Posledice izkoriščanja termalne vode v Mursko-Zalskem bazenu*« je **Nina Rman** z Geološkega zavoda Slovenije predstavila rezultate in nadgradnjo svoje doktorske disertacije. Pomurje ima v Sloveniji največji geotermalni potencial, zaradi tega je na tem območju tudi največ zajemov termalne vode, kljub temu je geološko, predvsem pa hidrogeološko relativno slabo poznano. Prav zaradi tega bi morali raziskave, predvsem pa monitoring geotermalnih vodonosnikov še izboljšati. To vrzel s svojim raziskovalnim delom v veliki meri zapolnjuje predavateljica. Predstavila nam je geološke razmere širšega območja Mursko Zalskega bazena v Avstriji, Sloveniji in na Madžarskem. Sledil je prikaz rezultatov monitoringa hidravličnih in temperaturnih razmer v vodonosnikih. Iz teh rezultatov izhaja, da so temperature vode relativno stabilne, s časom pa upada hidravlični potencial, kar je znak za ukrepanje. V zaključnem delu predavanja je sledila predstavitev numeričnega modela toka podzemne vode v globokih vodonosnikih Mursko-Zalskega bazena. To je prvi takšen model na tem območju, ki poleg izračuna vodnobilančnih razmerij omogoča scenarijsko napovedovanje razvoja hidravličnih razmer znotraj vodonosnih struktur. Po mnenju predavateljice zaradi upadanja hidravličnega potenciala razmere še niso kritične, vendar pa zahtevajo ukrepanje, predvsem izboljšano gospodarjenje in upravljanje vodonosnikov.

V drugem predavanju z naslovom »*Pliocenski vodonosnik Dravskega polja*« je **Matjaž Klasinc** z Geološkega zavoda Slovenije predstavil nadgradnjo svojega diplomskega dela. Izkoriščanje pliocenskega vodonosnika v osrednjem delu Dravskega in Ptujskega polja se z leti povečuje, saj njegova podzemna voda ni obremenjena z nitrati in pesticidi, tako kot voda zgoraj ležečega plitvega kvartarnega vodonosnika. Čeprav je s hidrogeološkimi raziskavami pliocenskega vodonosnika v šestdesetih letih prejšnjega stoletja pričel že Žlebnik s sodelavci, pa je Klasinc prvi, ki je naredil sintezo vseh razpoložljivih hidrogeoloških podatkov s tega območja ter jih umestil regionalno. V svojem delu je opredelil hidrostratigrafijo območja in prikazal porazdelitev hidravličnega potenciala v prostoru ter s tem pojasnil pogoje na robovih vodonosnika, smer toka podzemne vode in njenega iztekanja v reko Dravo in na njegovih južnih mejah. Predavatelj se je dotaknil tudi praktičnih problemov pri izkoriščanju pliocenskega vodonosnika, opozoril je predvsem na preizkoriščanje pliocenskega vodonosnika in na vdor podzemne vode iz plitvega kvartarnega vodonosnika.

Razpravo o slovenski hidrogeološki terminologiji je s kratko predstavitvijo »*Slovenska hidrogeološka terminologija – izhodišča za razpravo*« uvedel avtor tega zapisa. Čeprav se moderna znanost in stroka vedno bolj in bolj naslanjata na angleško terminologijo in v njej tudi komunicirata, je v praktičnih vedah, kot je hidrogeologija, razvoj slovenske strokovne in znanstvene terminologije še kako potreben, aktualen in tudi ključen. V praksi ugotavljamo, da znotraj hidrogeološke stroke ni enotne rabe terminov. Še večje težave nastopajo pri sodelovanju z drugimi strokami, s katerimi se hidrogeologi v praksi srečujemo. To pogosto vnaša nepotrebno zmedo, kar je potrebno preseči. V nadaljevanju predstavitve je sledil pregled dosedanjih slovenskih hidrogeoloških terminologij in drugih slovarskih ter terminoloških del v katerih se pojavlja. Zaključni del predstavitve je zajel prikaz terminov pri katerih v praksi srečujemo probleme. Sledila je razprava, v kateri so se potrdile teze iz uvodnega predavanja. Razpravljalci so poudarili težave, ki pri rabi terminologije nastajajo zaradi uvajanja evropske zakonodaje o vodah. Čeprav zakonodaja pojem vodnega telesa opredeljuje natančno in gre pri tem za upravljalski termin, se je ta termin pričelo mešati s terminom vodonosnik, kar je povsem neustrezno. V zaključku razprave je bilo sklenjeno, da se v okviru SKIAH prične z aktivnostjo zbiranja ključnih hidrogeoloških terminov in njihovih razlag, nato pa društvo v obdobju šestih mesecev organizira okroglo mizo z razpravo.

Tudi tokrat so bila na hidrogeološkem kolokviju predstavljena zanimiva predavanja. Prav tako kot v preteklih letih je vsakemu od predavanj sledila dolga in intenzivna razprava, ki je še dodatno osvetlila podane informacije. Letošnjega dogodka se je udeležilo nekaj manj kot trideset udeležencev, dogodek je bil slabše obiskan kot v preteklih letih. Morda je k temu botrovala sočasnost drugih dogodkov.

Slavnostna akademija na Oddelku za geologijo – ob življenjskih jubilejih profesorjev

Ljubljana 5. 12. 2014

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Temeljno poslanstvo univerze je izobraževanje visoko usposobljenega, motiviranega in inovativnega kadra, ki bo v praksi kos strokovnim in znanstvenim izzivom. To je mogoče le v primeru, da so učitelji, ki so zadolženi za tak prenos znanja, tudi sami aktivni na raziskovalnem področju. V današnji družbi, ki se je znašla v globoki krizi, se na to pogosto pozablja. Čeprav je politika polna besed o družbi temelječi na znanju, je podpora vzpostavljanju in vzdrževanja znanja šibka. Ob odsotnosti širše družbene podpore mora znanost vložiti še več naporov v poudarjanje svojega pomena, tudi tako, da izpostavi svoje pretekle dosežke. Pri tem geologija ni izjema. S tem namenom in v zahvalo za opravljeno delo smo ob okroglih življenjskih jubilejih naših profesorjev v tednu Univerze v Ljubljani na Oddelku za geologijo organiziral Slavnostno akademijo. V letošnjem letu so okrogle obletnice slavili univerzitetni profesorji prof. dr. Valerija Osterc, akademik prof. dr. Mario Pleničar, izr. prof. dr. Vida Pohar in prof. dr. Jernej Pavšič.

Ob tej priložnosti je izšla tudi redna številka revije RMZ – Geomateriali in okolje posvečena slavljencem. V reviji so na kratko orisane njihove življenske poti in znanstveno raziskovalni dosežki. Vsakemu od njih je posvečen tudi sklop znanstvenih člankov, ki so jih prispevali njihovi učenci, doktorandi in diplomanti.

Prireditev je z uvodnim nagovorom odprl predstojnik Oddelka za geologijo izr. prof. dr. Mihael Brenčič. Sledil je nagovor direktorja Geološkega zavoda Slovenije dr. Miloša Bavca. V simpozijskem delu slavnostne akademije je bilo predstavljeno pedagoško in znanstveno raziskovalno delo slavljencev ter podan kratek povzetek prispevkov iz številke RMZ posvečene slavljencem. Doc. dr. Luka Gale je orisal znanstveno raziskovalne in pedagoške dosežke izr. prof. dr. Vide Poharjeve na področju kvartarne geologije, predvsem paleontologije vretenčarjev in paleolitskih orodij. Prof. dr. Boštjan Rožič je orisal delo prof. dr. Jerneja Pavšiča na področju paleontologije terciarnih mikrofosilov in njegovo bogato uredniško in publicistično delo, kjer njegovo poljudnoznanstveno pisanje predstavlja nezanemarljiv delež. Prof. dr. Valerija Osterc je v Sloveniji orala ledino na področju tehnične mineralogije, kar je uspešno uvedla tudi v študij geologije. O njenem uspešnem paraktičnem delu pričajo številna strokovna poročila in članki, ki so prispevali pomemben delež k razvoju slovenske industrije. Njeno delo je predstavil doc. dr. Uroš Herlec. Akademik prof. dr. Mario Pleničar je eden najpomembnejših avtorjev osnovnih geoloških kart na območju Slovenije. Poleg tega je v širšem prostoru zelo pomemben njegov pripevek k paleontologiji rudistov. Njegovo delo je predstavil dr. Vasja Mikuž. Med predstavitvami in med prijetnim družabnim srečanjem, ki je sledilo akademiji, smo se spomnili prenekatere anekdote iz kariere slavljencev in študijskih let njihovih učencev.

Poročilo Društva študentov geologije za študijsko leto 2013/2014

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Društvo študentov geologije je samostojno, prostovoljno, nepridobitno združenje s sedežem na Privozu 11, 1000 Ljubljana. Z izvajanjem različnih obštudijskih dejavnosti širimo znanje pridobljeno v rednem študijskem programu. Prav tako si prizadevamo k vzpostavitvi vezi med študenti in geološkimi strokovnjaki ter strokovnjaki drugih znanosti, ki so pomembne in se povezujejo z geologijo. Upravni odbor društva sestavljajo: predsednica Anja Kocjančič, podpredsednica Klara Nagode, tajnica Neža Lapajne in blagajničarka Teja Polenšek; v društvu aktivno sodelujejo tudi drugi študentje geologije.

Društvo študentov geologije je bilo ustanovljeno z namenom:

- medgeneracijskega povezovanja študentov ter ljubiteljev geologije;
- povezovanja in sodelovanja s strokovnjaki geologije in sorodnih strok;
- organizacije geoloških taborov;
- organizacije strokovnih ekskurzij v Sloveniji in tujini;
- organizacije izobraževalnih delavnic, okroglih miz in predavanj;
- sodelovanja z javnimi in zasebnimi ustanovami, organizacijami ter društvi.

V društvo se lahko včlanijo študentje geologije in sorodnih strok, strokovnjaki, raziskovalci ter ljubitelji stroke ob predložitvi pristopne izjave in plačane članarine, ki znaša 10 EUR na leto. Društvo obvešča člane prek sestankov, elektronske pošte, plakatov in objav v sredstvih javnega obveščanja, na spletni strani in prek poročil ter zapisnikov organov društva.

V študijskem letu 2013/2014 so bile izvedene sledeče dejavnosti:

- Ekskurzija na Snežnik, 20. 10. 2013. Ekskurzija je obsegala več terenskih točk z geomorfološkimi in sedimentološkimi indikatorji poledenitve na Snežniku. Za strokovno vodstvo je poskrbela mlada raziskovalka geografije Manja Žebre. Organizator: Rok Brajkovič.
- Geodan, 23. 11. 2013. V soboto, 23. novembra, zjutraj smo se študenti geologije na povabilo Dejana Sedeja ter Društva Idrija 2020 zbrali pred Mladinskim centrom Idrija, da bi s svojim znanjem in dobro voljo priskočili na pomoč pri izvedbi prvega GeoDneva v Idriji. Za obiskovalce je bilo v prostorih Mladinskega centra najprej pripravljeno predavanje in projekcija, s katero se je predstavilo geologijo ter nastanek idrijskega rudišča. V nadaljevanju je sledila razdelitev sodelujočih v dve skupini. Prva se je z dr. Jože Čarjem spustila v jamo, druga pa se je s študenti geologije odpravila na kratek sprehod po idrijskih znamenitostih in geoloških čudesih. Strokovno vodstvo: dr. Jože Čar. Organizator: Dejan Sedej, razvojno društvo Idrija 2020 in Mladinski center Idrija.
- Geoavantura, 6. 12. 2013. Ekskurzija je potekala v rudnik granatov Radthein, Avstrija. Študenti smo se v zgodnjih jutranjih urah odpravili proti avstrijski pokrajini, kjer smo si ogledali izredno lepo urejen rudnik granatov, zbirko in muzej zgodovine pridobivanja le teh. Strokovno vodstvo: dr. Georg Kandutsch. Organizator: Aleš Šoster, Eva Mencin.
- Potopisno predavanje: Namibija, 15. 1. 2014. V sredo popoldne nam je čas prijetno popestrila dr. Nina Zupančič, ki nam je predstavila v obliki potopisnega predavanja svoje potepanje po Namibiji. Moderator: Eva Mencin.
- Geološko-geografski tabor, 21. 3. – 23. 3. 2014. Letošnji interdisciplinarni tabor geologov in geografov je potekal v Postojni. Prvi dan smo se zbrali pred Inštitutom za raziskovanje krasa (IZRK) v Postojni, kjer smo najprej poslušali predavanje dr. Mitje Prelovška o samem delu na inštitutu, krasoslovju, krasu v Sloveniji in po svetu, speleologiji ter meritvah v krasoslovju/speleologiji. Po predavanju smo si ogledali kataster jam in njihove laboratorije. Iz Postojne smo nato krenili proti Cerknici in kasneje še Križni jami, v kateri nam je dr. Prelovšek predstavil potek speleoloških meritev. Teren se je zaključil na Bloški planoti, kjer smo si ogledali ponore Farovščice in Bloščice ter zgornjo dolino Bloščice. Naslednji dan je bil posvečen predvsem geografiji in geografskemu pogledu na kraško okolico Postojne in Pivke. Po zanimivem terenu nas je vodil dr. Andrej Mihevc iz IZRK-ja. Zadnji dan je bil spet nekoliko bolj posvečen geologiji. Teren sta vodila dr. Mirjam Vrabec in dr. France Šušteršič. Slednji nas je vodil po poteh kraških polj: Logaško, Planinsko, Cerkniško, Loško. Predstavil nam je sistem kraške Ljubljanice, tj., njene kraške pritoke in podzemno "življenje" preden pride do Ljubljane in zavzame svojo pravo podobo. Pogovorili smo se tudi o samih geoloških strukturah okolja, ki so deloma vpletene v poplavljanje kraških polj ter vzroke in posledice poplav Planinskega polja. Organizatorji: Anja Jaklič in Klara Nagode.
- Evropski projekti (delavnica), 17. 4. 2014. Namen seminarja oz. delavnice je bilo izobraževanje bodočih diplomantov geologije z aktivnostmi oblikovanja, pridobivanja in izvajanja EU projektov ter črpanja evropskih sredstev za uresničitev lastnih projektov. Predavali so nam: dr. Barbara Čenčur Curk (NTF), Snježana Miletič (GeoZS), Urša Šolc (GeoZS), dr. Gorazd Žibret (GeoZS) ter dr. Marko Komac (GeoZS). Organizator: Sandi Kastelic.
- EUGEN, 4. 8. – 10. 8. 2014, okolica Gorjanskega na Krasu. V tednu med 4. in 10. avgustom je v okolici Gorjanskega na Krasu potekal 19. mednarodni tabor evropskih študentov geologije EUGEN 2014, ki se vsako leto organizira v drugi evropski državi. Tokrat je že drugič potekal v Sloveniji, prvič pa se je vršil pred enajstimi leti v okolici Kobarida. Letošnjega tabora se je udeležilo malo manj kot 150 študentov geologije in simpatizerjev iz petnajstih evropskih držav ter po en udeleženec iz Brazilije, Japonske in Palestine. Največ je bilo Nemcev, Italijanov in Slovencev, prisotni so bili tudi Hrvati, Belgijci, Madžari, Nizozemci, Poljaki, Litvanci, Srbi, Romuni, Finci, Avstrijci, Švicarji in Portugalci.
- Letošnji tabor je bil sestavljen iz več geoloških ekskurzij pod strokovnim vodstvom strokovnjakov iz Oddelka za geologijo Naravoslovnotehniške fakultete Univerze v Ljubljani ter strokovnjakov iz Inštituta za raziskovanje Krasa iz Postojne. Udeleženci so se tako lahko udeležili naslednjih strokovnih ekskurzij: Razpad Dinarske karbonatne platforme, Posočje, Julijske Alpe, Idrija in idrijski rudnik ter Škocjanske jame in Rakov Škocjan. Poleg tega je en dan bil namenjen tudi kulturnemu in turističnemu spoznavanju Slovenije, natančneje Ljubljane.
- Po povratku udeležencev iz strokovnih ekskurzij, smo zanje organizirali tudi strokovna večerna predavanja z diskusijo, katera so predavali strokovnjaki iz Oddelka za geologijo Naravoslovnotehniške fakultete Univerze v Ljubljani ter iz Instituta Jožef Stefan. En dan tabora je bil namenjen tudi športnemu udejstvovanju udeležencev, ki so se med seboj lahko pomerili v športnih in družabnih igrah na tako imenovani "GeOlimpijadi". Po zaključku športnih iger so udeleženci predstavljali svoje države ter možnosti študija in študijskih izmenjav v njih. Organizatorja: Andrej Novak in Ana Trobec.
- Ekskurzija v tujino: Makedonija, 21. 9. – 28. 9. 2014. V tednu med 21. in 28. septembrom se je nekaj članov društva in simpatizerjev DŠG-ja odpravilo obiskati balkansko lepotico in geološko izredno zanimivo državo Makedonijo. Čez teden so si študentje ogledali čudovit rudnik sadre, kamnolom

čistega marmorja, najvišjo jamo na Balkanu, kanjon Matke in še mnogo več. Izven programa so si ogledali tudi Skopje in nekatera manjša mesteca in vasi na poti njihovega potepanja. Organizatorja: Galena Jordanova, Martin Gaberšek.

- Ekskurzija na Medvednico, 24. 10. 2014. Odpravili smo se na ogled ofiolitnih sekvenc v Nacionalni park Medvednica nad Zagrebom. Po terenu sta nas vodila dr. Borna Lužar-Oberiter in dr. Ljubomir Babić iz Prirodoslovno matematične fakultete (PMF) v Zagrebu. Organizator: Eva Mencin.

V študijskem letu 2014/2015 so načrtovane sledeče dejavnosti:

- Eksurzija za študente prvega letnika geologije, 22. 11. 2014. Organizator: Anja Kocjančič
- Geoavantura, december 2014. Organizator: Neža Lapajne
- Potopisno predavanje, februar/marec 2015. Organizator: Anja Kocjančič
- Geološko-geografski tabor oz. slovensko-hrvaški geološki tabor, marec 2015. Organizatorji: Anja Skrbinek, Klara Nagode.
- Spomladanska ekskurzija, april 2015. Organizator: Ana Trobec
- Geotabor, julij 2015. Organizatorji: Janja Svetina, Uroš Novak, Anja Kocjančič.

V času od ustanovitve si je društvo pridobilo precejšne število članov in podpornikov. Cilj je, da se društvo zanesljivo uveljavi, zato pozivam k včlanitvi in aktivnem sodelovanju. Zahvaljujemo se vsem mentorjem, ki so poskrbeli za visok strokovni nivo izvedenih projektov Društva študentov geologije ter donatorjem, ki so omogočili kakovostno izvedbo le-teh. To so Geološki zavod Slovenije, Študentski svet Naravoslovnotehniške fakultete in Študentska organizacija Univerze v Ljubljani. Nenazadnje so zahvale posvečene tudi vsem članom društva, ki se ob organizaciji ekskurzij, taborov in projektov vedno potrudijo po svojih najboljših močeh.

IGCP – priložnost za mlade raziskovalce

Mirka TRAJANOVA

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Pobuda za ustanovitev Mednarodnega programa geoznanstvenega sodelovanja (International Geologic Correlation Programme-IGCP) je podala UNESCO leta 1969, aktivno pa je pričel delovati leta 1972. IGCP deluje pod okriljem UNESCO in hkrati tudi IUGS (The International Union of Geological Sciences). Po tridesetih letih uspešnega delovanja se je IGCP preimenoval v Mednarodni program za vede o Zemlji, odnosno Mednarodni geoznanstveni program (International Geoscience Programme), zadržana pa je stara kratica (IGCP).

V celotnem preko 40-letnem delovanju je IGCP stimuliral primerjalne študije znanosti o Zemlji in je v tem času podprl sodelovanje na 632 projektih, od katerih je več kot 340 zelo uspešnih in globalnega pomena. Kljub temu pa se je svetovna kriza močno odrazila na njegovem financiranju. V zadnjih letih so se sredstva UNESCO za IGCP več kot prepolovila. Neurejeno financiranje medprojektnega sodelovanja je pripeljalo do tega, da v letu 2012 sploh ni bilo razpisa za prijavo novih projektov. Na srečo je IUGS nadomestil izpad in sedaj za IGCP predstavlja glavni vir financiranja. Pri nas je zadnja tri leta omejeno le na nacionalne vire preko UNESCO Slovenija in nič več preko centrale v Parizu.

Cilj IGCP je obravnavanje in raziskovanje Zemlje kot celote ter s tem boljše razumevanje procesov na njej in dejavnikov, ki vplivajo na naše okolje. Tako so se programu priključile številne države z vsega sveta. Razviti so bili novi pristopi za reševanje geoloških problemov in iskanje mineralnih surovin ter vodnih virov. Zahvaljujoč naprednejšim in v geološke raziskave novo uvedenim raziskovalnim metodam, se spoznanja o našem planetu hitro razvijajo. Omogoča jih predvsem vključevanje raziskovalcev z različnih področij naravoslovnih ved. Rezultati raziskav na vseh nivojih povečujejo razumevanje dinamičnega ritma našega planeta tudi v široki javnosti, kar je edina garancija za razumni, trajnostni razvoj naše civilizacije. IGCP zato promovira predvsem projekte sodelovanja, ki imajo širšo korist za družbo. Za ta namen in zaradi drastičnega upada finančne podpore s strani UNESCO, je bila leta 2005 ustanovljena posebna IUGS/UNESCO komisija, ki je podala smernice za strukturne reforme in način delovanja IGCP. Od leta 2013 dalje ima IGCP podnaslov »Geoznanost v službi družbe« (ang. "*Earth Science in the Service of Society*"). Glede na spremenjeno poslanstvo geoznanosti v družbi, je v pripravi posodobljen logotip IGCP. Poseben poudarek delovanja IGCP je namenjen podpori in prenosu znanja med razvitimi državami in državami v razvoju.

IGCP letno financira okrog 30 projektov za obdobje do 5 let. Sredstva so nizka in znašajo le med 5.000 in 10.000 USD, vendar so namenjena izključno za udeležbo na sestankih in delavnicah v okviru projektov, ne pa za raziskave same, za kar je potrebno zagotoviti druge vire. Trenutno je v teku 28 projektov, od katerih se jih 12 konča letos. Razpisi so navadno objavljeni vsako jesen, prijave pa je treba oddati do sredine oktobra.

Znanstveni odbor IGCP je v letu 2012 podprl skupno 29 tekočih projektov in 5 novih predlogov projektov. Dodatnih 7 projektov je preko UNESCO dobilo finančno podporo od švedske mednarodne agencije za razvoj in sodelovanje (International Development Cooperation Agency, SIDA). Glavne teme so: Earth Resources: Sustaining our Society, Global Change: Evidence from the geological record, Geohazards: Mitigating the risks, Hydrogeology: Geoscience of the water cycle and Geodynamic: Control our environment.

Slovenski geoznanstveniki so se pridružili IGCP projektom leta 1978. Do sedaj so se vključili v več kot 40 projektov in na ta način popularizirali našo geologijo ter prispevali prepoznaven del v svetovno zakladnico geoloških znanosti. Od začetnih, predvsem paleontoloških in biostratigrafskih tem, se je sodelovanje razširilo na proučevanje dogodkov in okoljske geologije, v kateri ima študij kraških sistemov vidno mesto, na povezave med naravnimi geološkimi faktorji in zdravstvenimi problemi, na študij klimatskih sprememb, in na raziskave mineralnih surovin, podzemnih vodnih virov ter njihovega izkoriščanja. Obsežna problematika zahteva vključevanje širokega spektra geoloških in drugih raziskovalcev, zaradi česar so projekti resnično interdisciplinarni.

V Sloveniji so mladi raziskovalci uspešno sodelovali pri realizaciji IGCP projektov. Poleg pridobivanja dragocenih izkušenj v raziskovalni sferi, je njihovo vključevanje pomembno predvsem za odpiranje poti v mednarodno sodelovanje in vpetost v relevantne mednarodne objave, preko katerih so vrednoteni po sedanjem sistemu ARRS. Sodelovanje v projektih IGCP pomeni tudi večjo možnost pridobivanja nacionalnih sredstev za izvajanje raziskav. Kljub temu pa je število sodelujočih mladih raziskovalcev še vedno premajhno. Delno je to lahko posledica majhnega interesa, verjetno pa tudi nezadostne informiranosti o prednostih sodelovanja in načinu vključevanja v projekte. Geološki kongres je zato pomenil dobro priložnost, za seznanitev z osnovnimi podatki o delu Mednarodnega geoznanstvenega programa.

Najenostavnejša pot vključevanja je preko nosilcev posameznih IGCP projektov. Vsi podatki so na voljo na spletnih straneh IGCP, do katerih lahko dostopamo preko spletne strani *UNESCO.org/Earthsciences/International Geoscience Programme* ali preko strani *IUGS/Links/Joint programs/International Geoscience Programme*. Na IGCP strani lahko izberemo že obstoječi projekt, ki nas zanima (IGCP Projects) in se za vključitev povežemo z nosilcem/nosilci projekta ali pa predlagamo nov projekt (Proposal Submission), za kar so priložena navodila (Guidelines) in prijavni obrazci.

Prijave za IGCP projekte morajo zadostiti sledečim pogojem:

- visoka kvaliteta pomembna za znanstvene cilje IGCP;
- mednarodna in družbena pomembnost;
- vključuje interdisciplinarno sodelovanje;
- predstavlja mednarodno sodelovanje, vključno z znanstveniki iz držav v razvoju;
- dokazuje potencial za dolgoročne kot tudi kratkoročne geoznanstvene in/ali družbene koristi;
- jasno priznava pokroviteljstvo UNESCO, IUGS in IGCP; in
- promovira prepoznavnost svetovne geoznanosti; na primer, z objavo znanstvenih rezultatov s pomočjo mednarodno priznanih revij ali drugih medijev.

V zadnjih nekaj letih se je močno okrepilo delovanje Geoparkov, ki so prav tako vključeni v projekte IGCP. Pri nas sta uradno ustanovljena dva, Geopark Idrija in čezmejni Geopark Karavanke-Karawanken, ki sta že vključena v mrežo Evropskih in Globalnih geoparkov (ang. European/Global Geopark Network – EGN/GGN), v ustanavljanju pa je Geopark Kras. Geoparki imajo pomembno vlogo pri povezovanju geološke dediščine s celotno naravno, kot tudi kulturno snovno in nesnovno dediščino nekega območja, predvsem pa širijo zavest vsakega posameznika o njegovi vlogi in odgovornosti do te dediščine. To je eden od ključnih razlogov, da geoparki delujejo pod okriljem UNESCO in kot posebna skupina v okviru IGCP.

Združevanje znanja in dela pod okriljem IGCP projektov je vsekakor smiselno in potrebno. Poleg prednosti, ki smo jih že omenili, nas uči tudi skupinskega dela in sodelovanja, ki je bilo v dosedanji praksi pri nas dokaj zapostavljeno.

Devetdeset let akademika prof. dr. Maria Pleničarja

Malokomu je dano tako dolgo in plodno življenje, kot ga doživlja naš slavljenec. Rodil in šolal se je v Ljubljani. Že v gimnaziji ga je navduševalo naravoslovje, zato ni bila nenavadna odločitev za študij kemije in geologije na takratni Naravoslovno-matematični fakulteti v Ljubljani. Z njemu lastno marljivostjo in sistematičnostjo je hitro zaključil študij in se zaposlil na takratnem Geološkem zavodu v Ljubljani, kjer se je posvetil raziskovanju nafte in se zato preselil v severovzhodni del Slovenije v Lendavo. Po dveh letih tamkajšnjega službovanja se je vrnil v Ljubljano in prevzel vodenje Oddeleka za geološko kartiranje. Kmalu za tem je zagovarjal svojo doktorsko nalogo o stratigrafskem razvoju krede na južnem Primorskem in Notranjskem. Geološki zavod je v šestdesetih letih dobil priliko geološkega kartiranja v Alžiriji, ki se mu je priključil in tam kar šest let nabiral izkušnje v povsem drugačnih razvojih krede kot, jih je bil vajen v Sloveniji. Zaradi njegovega bogatega znanja, so ga ob upokojitvi prof. Ivana Rakovca, povabili na fakulteto, kjer je bil izvoljen za izrednega in kmalu tudi za rednega profesorja geologije. Predaval je osnove geologije, fizikalno geologijo, geološko kartiranje in stratigrafijo kenozoika. Prizadeval si je, da je študentom čimbolj olajšal delo, zato jim je dal v uporabo svoje tipkopise in izdal skripta Osnove geologije. Zaradi težav z vidom se je moral kmalu upokojiti. V času, ko je služboval na Geološkem zavodu se je pretežno ukvarjal z geološkim kartiranjem v okviru projekta Osnovna geološka karta SFRJ v merilu 1:100.000. Je avtor ali soavtor petih listov, ki pokrivajo ozemlje Slovenije: Postojna, Goričko, Trst, Ilirska Bistrica in Novo mesto z odgovarjajočimi tolmači, ki detajlno pojasnjujejo geološke razmere na omenjenih ozemljih. To je gotovo življenjsko delo jubilanta, ki je dalo osnovo za vsa nadaljnja geološka raziskovanja. Moramo vedeti, da se je terensko kartiralo na topografske karte v merilu 1: 25.000, kar je zahtevalo podrobno terensko raziskovanje in naporno sledenje geoloških struktur po razgibanem terenu Slovenije ter poleg umskega dela tudi velik fizični napor. Med izdelavo osnovne geološke karte je pridno objavljal znanstvene razprave in strokovne prispevke v takratno geološko periodiko.

Akademik prof. Pleničar je vsestranski geolog, morda eden zadnjih, ki je razgledan v vseh geoloških disciplinah. Posebno pa ga navdušuje tudi paleontologija, saj se je posvetil proučevanju priraslih krednih školjk - rudistov, ki jih je našel na območjih svojih terenskih pohodov ob kartiranju. Določil je več novih vrst rudistnih školjk in jih imenoval po slovenskih krajih. Pred nekaj leti je izdal tudi obsežen pregled v Sloveniji najdenih rudistov v znanstveni monografiji: Zgornjekredni rudisti v Sloveniji.

Pomembno je tudi njegovo poljudno pisanje za revijo Proteus. V šestdesetih letih je izšla izjemna poljudna knjižica Geologija in človek, v kateri je skupaj z dr. D. Ravnikom opisal geologijo kot naravoslovno disciplino s pretanjenim občutkom in njemu lastnim humorjem. Kdor je prebral to delo, se je moral navdušiti za študij ali vsaj spremljanje geologije. Sodeloval je pri pomembnih skupnih publikacijah: o mineralnih nahajališčih Slovenije, o geologiji Slovenije, geološkem terminološkem slovarju, kjer je bil več kot dvajset let gonilna sila zbiranja strokovnih izrazov.

Zaradi svojega milega značaja ni znal nikogar odsloviti, zato so mu naprtili številne odgovorne naloge v različnih odborih in komisijah, ki jih je vestno in z dobro voljo vedno odgovorno opravljal. Še vedno je član nekaterih uredniških odborov. Udeleževal se je mnogih znanstvenih srečanj doma in v tujini.

Njegovo znanstveno in visoko strokovno delo so opazili tudi izven geologije in ga v osemdesesetih letih izvolili za člana Slovenske akademije znanosti in umetnosti, kateri je izjemno predan. Prejel je nekaj državnih nagrad in odlikovanj. Stroka je njegove zasluge nagradila z Lipoldovo medaljo in drugimi pomembnimi priznanji.

Devetdeset let življenja in več kot šestdeset let znanstvenega in strokovnega dela je dolga doba, ki je v tako kratkem zapisu ne moremo v celoti zajeti. Njegovo delo pušča trajno sled v geološki znanosti, v tem času ni minil skoraj noben dogodek v geologiji brez njega ali vsaj omembe njegovega imena, lahko rečemo, da je sinonim za slovensko geologijo. Akademik. prof. Pleničar je kljub visoki starosti še vedno dejaven. Zato mu v imenu vse geološke javnosti želimo trdnega zdravja in da bi svojo vitalnost še naprej ohranjal v taki meri.

Jernej Pavšič

Navodila avtorjem

GEOLOGIJA objavlja znanstvene in strokovne članke s področja geologije in sorodnih ved. Revija od leta 2000 izhaja dvakrat letno. Članke recenzirajo domači in tuji strokovnjaki z obravnavanega področja. Ob oddaji člankov avtorji predlagajo **tri recenzente**, vendar pa si uredništvo pridržuje pravico do izbire recenzentov po lastni presoji. Avtorji morajo članek popraviti v skladu z recenzentskimi pripombami ali utemeljiti zakaj se z njimi ne strinjajo.

Avtorstvo: Za izvirnost podatkov, predvsem pa mnenj, idej, sklepov in citirano literaturo so odgovorni avtorji. Z objavo v GEOLOGIJI se tudi obvežejo, da ne bodo drugje objavili prispevka z isto vsebino.

Jezik: Članki naj bodo napisani v angleškem, izjemoma v slovenskem jeziku, vsi pa morajo imeti slovenski in angleški izvleček. Za prevod poskrbijo avtorji prispevkov sami.

Vrste prispevkov:

Izvirni znanstveni članek
Izvirni znanstveni članek je prva objava originalnih raziskovalnih rezultatov v takšni obliki, da se raziskava lahko ponovi, ugotovitve pa preverijo. Praviloma je organiziran po shemi IMRAD (**I**ntroduction, **M**ethods, **R**esults, **A**nd **D**iscussion).

Pregledni znanstveni članek
Pregledni znanstveni članek je pregled najnovejših del o določenem predmetnem področju, del posameznega raziskovalca ali skupine raziskovalcev z namenom povzemati, analizirati, evalvirati ali sintetizirati informacije, ki so že bile publicirane. Prinaša nove sinteze, ki vključujejo tudi rezultate lastnega raziskovanja avtorja.

Strokovni članek
Strokovni članek je predstavitev že znanega, s poudarkom na uporabnosti rezultatov izvirnih raziskav in širjenju znanja.

Diskusija in polemika
Prispevek, v katerem avtor ocenjuje ali dokazuje pravilnost nekega dela, objavljenega v Geologiji, ali z avtorjem strokovno polemizira.

Recenzija, prikaz knjige
Prispevek, v katerem avtor predstavlja vsebino nove knjige.

Oblika prispevka: Besedilo pripravite v urejevalniku Microsoft Word. Prispevki naj praviloma ne bodo daljši od 20 strani formata A4, v kar so vštete tudi slike, tabele in table. Le v izjemnih primerih je možno, ob predhodnem dogovoru z uredništvom, tiskati tudi daljše prispevke.

Članek oddajte uredništvu vključno z vsemi slikami, tabelami in tablami v elektronski obliki po naslednjem sistemu:
- *Naslov članka (do 12 besed)*
- *Avtorji (ime in priimek, naslov, e-mail naslov)*
- *Ključne besede (do 7 besed)*
- *Izvleček (do 300 besed)*
- *Besedilo*
- *Literatura*
- *Podnaslovi v slikam in tabelam*
- *Tabele, Slike, Table*

Citiranje: V literaturi naj avtorji prispevkov praviloma upoštevajo le tiskane vire. Poročila in rokopise naj navajajo le v izjemnih primerih, z navedbo kje so shranjeni. V seznamu literature naj bodo navedena samo v članku omenjena dela. Citirana dela, ki imajo DOI identifikator, morajo imeti ta identifikator izpisan na koncu citata. Za citiranje revije uporabljamo standardno okrajšavo naslova revije. Med besedilom prispevka citirajte samo avtorjev priimek, v oklepaju pa navajajte letnico izida navedenega dela in po potrebi tudi stran. Če navajate delo dveh avtorjev, izpišite med tekstom prispevka oba priimka (npr. Pleničar & Buser, 1967), pri treh ali več avtorjih pa napišite samo prvo ime in dodajte et al. z letnico (npr. Mlakar et al., 1992). Citiranje virov z medmrežja v primeru, kjer avtor ni poznan, zapišemo (Internet 1). V seznamu literaturo navajajte po abecednem redu avtorjev.

Imena fosilov (rod in vrsta) naj bodo napisana poševno, imena višjih taksonomskih enot (družina, razred, itn.) pa normalno. Imena avtorjev taksonov naj bodo prav tako napisana normalno, npr. *Clypeaster pyramidalis* Michelin, *Galeanella tollmanni* (Kristan), Echinoidea.

Primeri citiranja članka:

Mali, N., Urbanc, J. & Leis, A. 2007: Tracing of water movement through the unsaturated zone of a coarse gravel aquifer by means of dye and deuterated water. Environ. geol., 51/8: 1401–1412, doi:10.1007/s00254-006-0437-4.

Pleničar, M. 1993: Apricardia pachiniana Sirna from lower part of Liburnian beds at Divača (Triest-Komen Plateau). Geologija, 35: 65–68.

Primer citirane knjige:

Flügel, E. 2004: Mikrofacies of Carbonate Rocks. Springer Verlag, Berlin: 976 p.

Jurkovšek, B., Toman, M., Ogorelec, B., Šribar, L., Drobne, K., Poljak, M. & Šribar, Lj. 1996: Formacijska geološka karta južnega dela Tržaško-komenske planote – Kredne in paleogenske kamnine 1: 50.000 = Geological map of the southern part of the Trieste-Komen plateau – Cretaceous and Paleogene carbonate rocks. Geološki zavod Slovenije, Ljubljana: 143 p., incl. Pls. 23, 1 geol. map.

Primer citiranja poglavja iz knjige:

Turnšek, D. & Drobne, K. 1998: Paleocene corals from the northern Adriatic platform. In: Hottinger, L. & Drobne, K. (eds.): Paleogene Shallow Benthos of the Tethys. Dela SAZU, IV. Razreda, 34/2: 129-154, incl. 10 Pls.

Primer citiranja virov z medmrežja:

Če sta znana avtor in naslov citirane enote zapišemo:
Čarman, M. 2009: Priporočila lastnikom objektov, zgrajenih na nestabilnih območjih. Internet: http://www.geo-zs.si/UserFiles/1/File/Nasveti_lastnikom_objektov_na_nestabilnih_tleh.pdf (17. 1. 2010)

Če avtor ni poznan zapišemo tako:
Internet: http://www.geo-zs.si/ (22. 10. 2009)

Če se navaja več enot z medmrežja, jim dodamo še številko
Internet 1: http://www.geo-zs.si/ (15. 11. 2000)
Internet 2: http://www.geo-zs.si/ (10. 12. 2009)

Slike, tabele in table: Slike (ilustracije in fotografije), tabele in table morajo biti zaporedno oštevilčene in označene kot sl. 1, sl. 2 itn., oddane v formatu TIFF, JPG ali EPS z ločljivostjo 300 dpi. Le izjemoma je možno objaviti tudi barvne slike, vendar samo po predhodnem dogovoru z uredništvom. Obvezno je treba upoštevati zrcalo revije **172 x 235 mm**. Večjih formatov od omenjenega zrcala GEOLOGIJE ne tiskamo na zgib, je pa možno, da večje oziroma daljše slike natisnemo na dveh straneh (skupaj na levi in desni strani) z vmesnim »rezom«. V besedilu prispevka morate omeniti vsako sliko po številčnem vrstnem redu. Dovoljenja za objavo slikovnega gradiva iz drugih revij publikacij in knjig, si pridobijo avtorji sami. Table pripravite v formatu zrcala naše revije.

Če je članek napisan v slovenskem jeziku mora imeti celotno besedilo, ki je na slikah in tabelah tudi v angleškem jeziku. Podnaslovi naj bodo čim krajši.

Korekture: Te opravijo avtorji člankov, ki pa lahko popravijo samo tiskarske napake. Krajši dodatki ali spremembe pri korekturah so možne samo na avtorjeve stroške.

Prispevki so prosto dostopni na spletnem mestu: http://www.geologija-revija.si/

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All submitted manuscripts are peer-reviewed by at least two specialists. When submitting their paper, authors should recommend at least **three reviewers**. Note that the editorial office retains the sole right to decide whether or not the suggested reviewers are used. Authors should correct their papers according to the instructions given by the reviewers. Should you disagree with any part of the reviews, please explain why. Revised manuscript will be reconsidered for publication.

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Language: Papers should be written in English or Slovene, and should have both English and Slovene abstracts.

Types of papers:

Original scientific paper
In an original scientific paper, original research results are published for the first time and in such a form that the research can be repeated and the results checked. It should be organised according to the IMRAD scheme (**I**ntroduction, **M**ethods, **R**esults, **A**nd **D**iscussion).

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In a review scientific paper the newest published works on specific research field or works of a single researcher or a group of researchers are presented in order to summarise, analyse, evaluate or synthesise previously published information. However, it should contain new information and/or new interpretations.

Professional paper
Technical papers give information on research results that have already been published and emphasise their applicability.

Discussion paper
A discussion gives an evaluation of another paper, or parts of it, published in GEOLOGIJA or discusses its ideas.

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This is a contribution that presents a content of a new book in the field of geology.

Style guide:
Submitted manuscripts should not exceed 20 pages of A4 format (12 pt typeface, 1 line-spacing, left justification) including figures, tables and plates. Only exceptionally and in agreement with the editorial board longer contributions can also be accepted.
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