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Ichnofossils from Cretaceous-Paleogene flysch of Mide locality (Budva Zone, southern Montenegro)

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Abstract. Cretaceous-Paleogene flysch represents the youngest formation in the Budva Zone. Although the Maastrichtian-Lower Eocene age of these rocks has been well documented in the literature, trace fossils are only mentioned as abundant and not described. In the present paper, only a small number of ichnotaxa from Mide locality has been described, including *Lorenzinia carpathica* (Zuber), *Nereites irregularis* (Schafhäut), *Scolicia plana* Książkiewicz and *Paleodictyon latum* Vialov & Golev. They confirm deep-sea environment.

Key words: Cretaceous-Paleogene flysch, ichnofossils, Budva Zone, Mide.

Апстракт. Кредно-палеогени флиш представља најмлађу формацију у Будва зони. Иако је маастрихтска до доњоеоценска старост ових стијена добро документована у литератури, фосилни трагови организама су само поменути као чести, али не и описани. У овом раду, описан је мали број ихнотаксона са локалитета у Мидама, укључујући *Lorenzinia carpathica* (Zuber), *Nereites irregularis* (Schafhäut), *Scolicia plana* Książkiewicz и *Paleodictyon latum* Vialov & Golev). Сви ихнотаксони потврђују дубоководну средину.

Кључне речи: Кредно-палеогени флиш, ихнофосили, Будва зона, Миде.

Introduction

Cretaceous-Paleogene flysch formation of the Budva Zone stretches along the Montenegrian coastal region from the cities of Herceg-Novi towards Budva and Bar, from where it passes along the southern side of Rumija mountain into Albania. At present state of knowledge, the Budva Zone is interpreted as an intra-platform deep-water basin (Schmid et al., 2008), developed between two shallow-water units, i.e. the South Adriatic and the High Karst zones. It is characterized by deep-water sedimentary rocks of Triassic, Jurassic, Cretaceous and Paleogene age, developed in several thrust units. Cretaceous-Paleogene flysch formation represents the youngest formation within the Budva Zone. In general, it is characterized by the repeated cycles of calcareous sandstones and marls, with rare intercalations of limestone. Sedimentological features, as well as the determined age (Maastrichtian-Lower Eocene), have been described in many publications (Miladinović, 1960, 1964; Pavić, 1970; Antonijević et al., 1973; Kalezić et al., 1976; Mirković et al., 1978). This formation has also been found in deep boreholes for oil exploration in Buljarica (Čanović, 1958). However, trace fossils from this formation have not been described so far, but are mentioned as abundant. Grubić (1961) described *Lorenzinia carpathica* (Zuber) from a locality near Mide. Vjalov & Golev (1963) also describe representatives of ichnogenus *Paleodictyon* from the Eocene flysch of Montenegro. Since Eocene flysch sediments are more common in the South Adriatic Zone of the Montenegro coastal region, which is underlying the Budva Zone, it is more likely that these ichnofossils originate from these sediments.

Four ichnotaxa: *Lorenzinia carpathica* (Zuber), *Nereites irregularis* (Schafhäut), *Scolicia plana* Książkiewicz and *Paleodictyon latum* Vialov & Golev have been identified from the Cretaceous-Paleogene flysch of the Budva Zone. *Nereites irregularis*

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(SCHAFHÄUT) is found on the upper bed-surface of the sandstone layer, while other ichnospecies originate from the lower surface of the layers. Even though there are only four ichnospecies found, they all indicate deep-water environment, of the *Nereites* ichnofacies (UCHMAN & WETZEL, 2012).

Geological setting

Sediments of Cretaceous-Paleogene flysch formation have an avarage thickness of 120 m and are the youngest rocks of the Budva Zone (KALEZIĆ et al., 1976). In general, they are represented by carbonate breccias, sandstones, sandy limestones and marls. Underlying this formation are the *Globotruncana* limestone facies with chert nodules and interlayers of Maastrichtian age. The Cretaceous-Paleogene flysch is capped by Triassic rocks of High Karst Unit.

Description of the studied section

The Mide locality is situated in the southern Montenegro, ca. 15 km ESE from the town of Bar (Fig. 1). The Budva Zone deposits in this area are represented by Cretaceous-Paleogene flysch and Cretaceous *Globotruncana* limestones, which are in inverted position to each other due to tectonic deformations caused by rock masses of the Southern Adriatic and High Karst zones.

The Cretaceous-Paleogene flysch formation in the Mide locality is 67 m thick (Fig. 2). Based on fossil content, only Paleocene and Lower Eocene have been determined in this locality. Lower part of the section, 48 m thick, is comprised of grey and greenish-grey sandstones and marls, that are 2–15 cm thick, with rare intercalations of limestones. Sandstones are made of quartz, rock fragments and feldspar, with rare mica fragments. In the limestone intercalations, only *Chilo-*

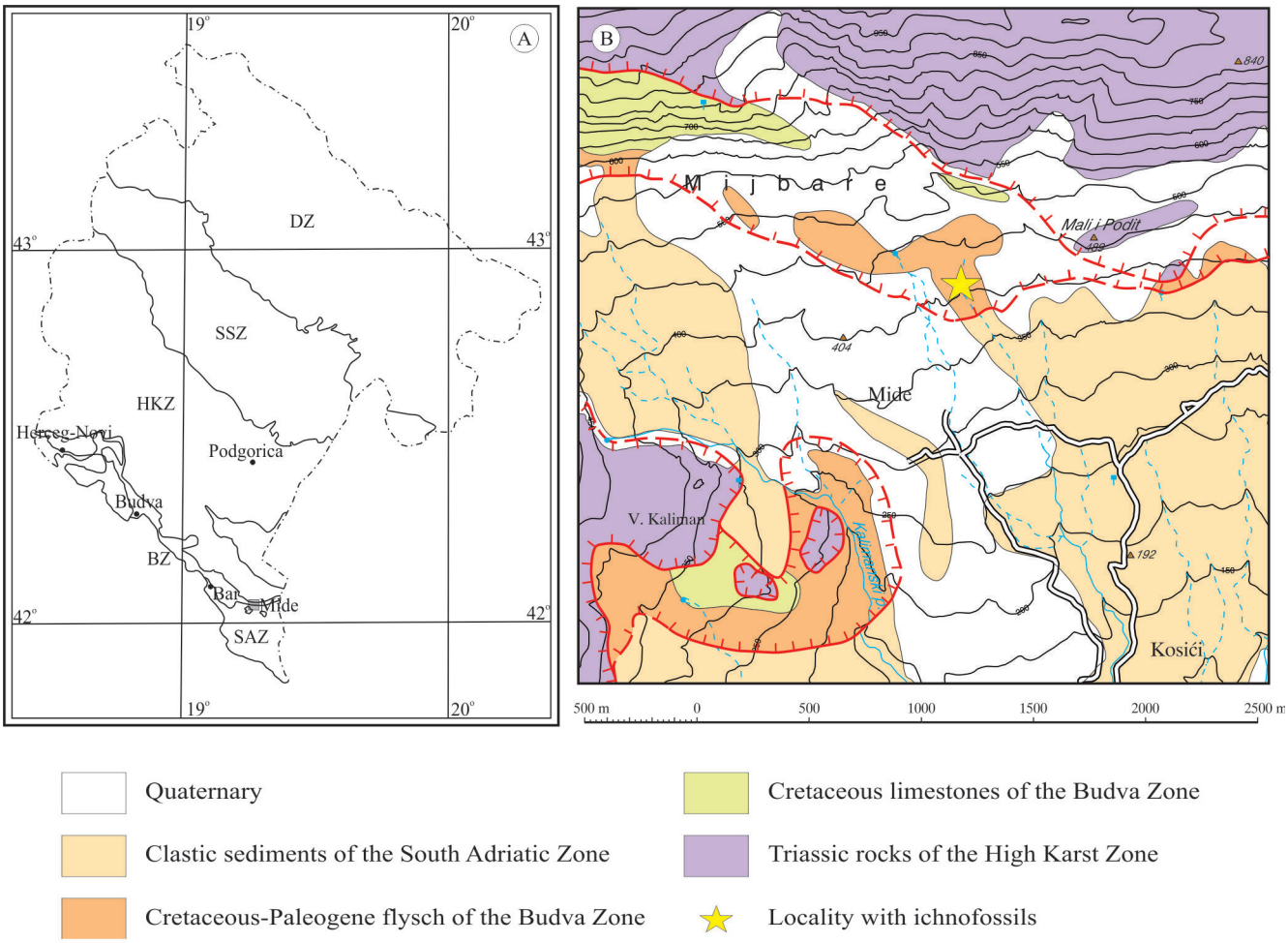
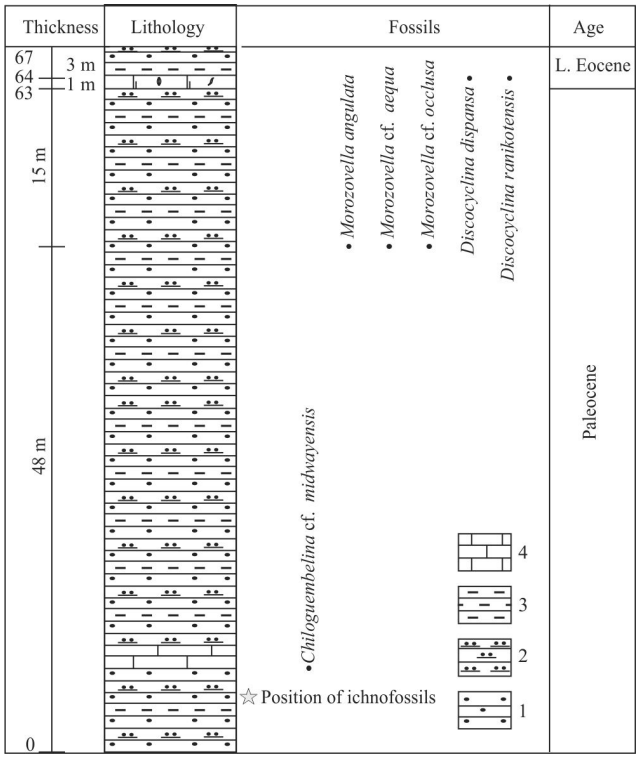


Fig. 1. **A.** Position of the Mide locality in Montenegro (abbrevations **SAZ,** South Adriatic Zone; **BZ,** Budva Zone; **HKZ,** High Karst Zone; **SSZ**, Sarajevo Sigmoide Zone; **DZ,** Durmitor Zone; modified after DIMITRIJEVIĆ, 1995 and SCHMID et al., 2008); **B.** Simplified geological map of the investigated area.



guembelina cf. *midwayensis* (CUSHMAN) (Fig. 3A) has been determined. Ichnofossils described in this paper occure in the lowermost part of this interval and are found mostly on the lower bed-surface of sandstone layers. Only *Nereites irregularis* (SCHAFHÄUT) is found on the upper surface of the layer. Next interval, 15 m thick, is composed of red sandstones (Fig. 3B) intercalated with green marls, where the sandstone layers are 5–8 cm thick. In them, the pelagic foraminifera *Morozovella angulata* (WHITE) (Fig. 3C), *Morozovella occlusa* (LOEBLICH & TAPPAN) and *Morozovella* cf. *aequa* (CUSHMAN & RENZ) have been determined, which point to the Paleocene age. On top of this interval, there is a 1 m thick gray brecciated limestone (Fig. 3D) with the large, Lower Eocene benthic foraminifera *Discocyclina ranikotensis* DAVIES & PINFOLD and *Discocyclina dispansa* SOWERBY. Above this limestone bed, there are 3 m of red sandstones and green marls, which are covered by Quaternary sediments.

Fig. 2. Geological coulmn of Cretaceous-Paleogene flysch in Mide locality with marked position of ichnofossils (**1** – sandstone; **2** – alevrolite; **3** – marl; **4** – limestone).

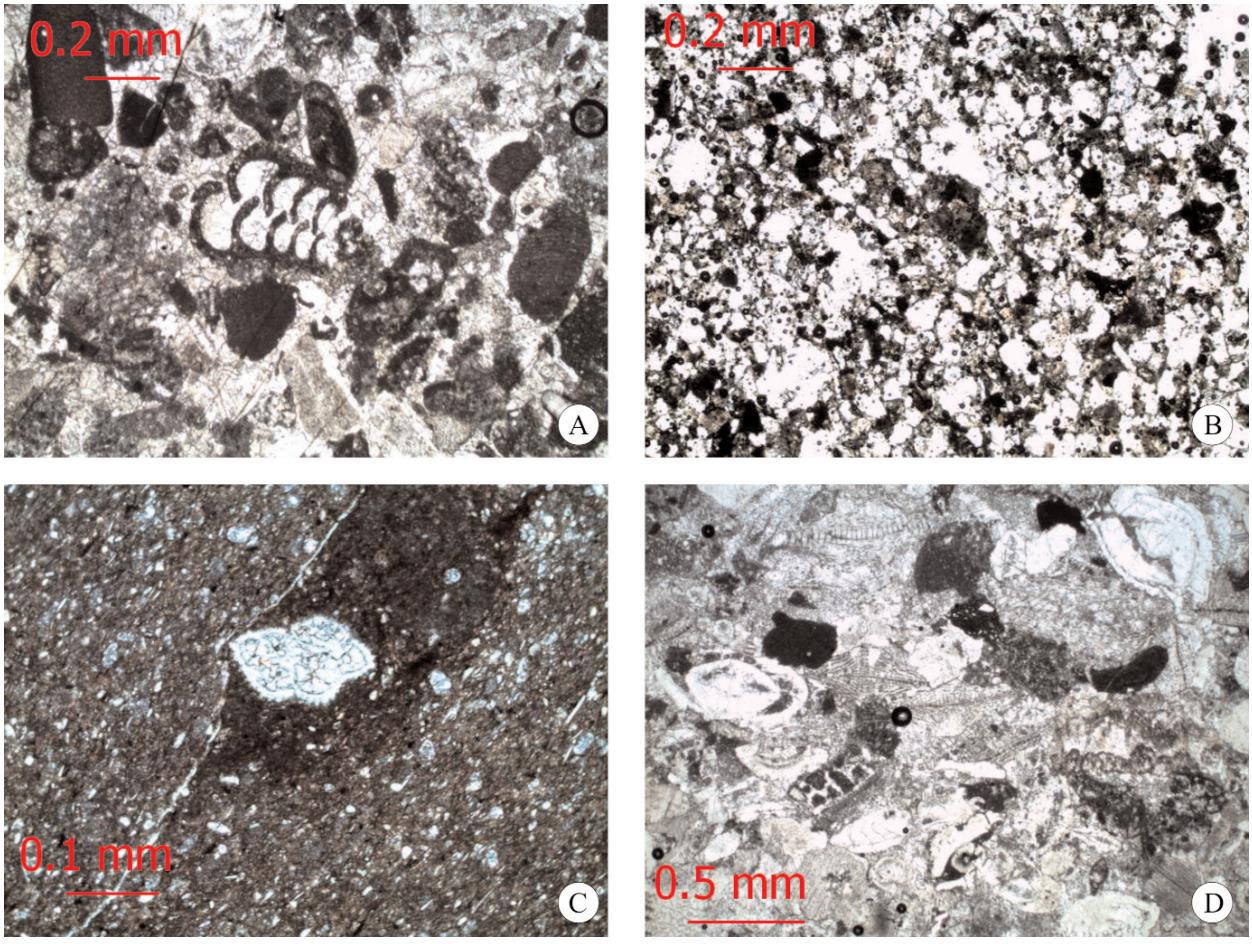


Fig. 3. **A.** Foraminiferal biosparite with *Chiloguembelina* cf. *midwayensis* (CUSHMAN); **B.** Sublitharenite with quartz, rock fragments and feldspar; **C.** Marlstone with *Morozovella angulata* (WHITE); **D.** Foraminiferal biosparite with large, benthic foraminifera.

Trace fossils

Up to the present day, there is no unified systematics for ichnofossils. BERTLING et al. (2006) propose that morphology of trace fossils is the most important criterion for their evaluation, and not size, producer, age, facies or preservation, but they don't introduce a new systematic scheme. In the present paper, description of ichotaxa follows the ones given by KSIĄŻKIEWICZ (1977) and UCHMAN (1998), which are based on morphological features of ichnospecies.

The collection is kept in the Geological Survey of Montenegro. Each specimen has an inventory number, which consists of abbreviations for the locality, number of the specimen and the abbreviation for the year when the specimen was found (e.g. MID 1/15).

Ichnogenus *Lorenzinia* DA GABELLI, 1900

Lorenzinia carpathica (ZUBER, 1910)
Fig. 4

1961 *Lorenzinia carpathica* (ZUBER) – GRUBIĆ: 53–55, figs. 1–2.
1977 *Lorenzinia carpathica* (ZUBER) – KSIĄŻKIEWICZ: 89–90, pl. 6, figs. 2–7.
1977 *Lorenzinia curticostata* n. ichnosp. – KSIĄŻKIEWICZ: 91, pl. 6, fig. 11.
1977 *Lorenzinia perlata* KSIĄŻKIEWICZ – KSIĄŻKIEWICZ: 92, pl. 6, figs. 9–10.
1977 *Lorenzinia morae* RENZ – KSIĄŻKIEWICZ: 92-93, pl. 6, figs. 12–13.
1977 *Lorenzinia* aff. *morae* RENZ – KSIĄŻKIEWICZ: 93, pl. 6, figs. 14–16.
1998 *Lorenzinia carpathica* (ZUBER) – UCHMAN: 134, figs. 34–36.

Material. One specimen (inventory number MID 1/15).

Description. The star and the areola have an elliptical shape. Maximum width of the diameter of the star is 41 mm and maximum diameter of the areola is 23.4 mm. There are 22 riblets that have rounded outer and inner ends and are all of similar size. Their length and width haven't been measured because of the poor preservation of the specimen. Dimensions of the specimen and the relation between the star and areola (D:d is 1.75) as well as the number of riblets fit into the description of the ichnospecies as described by KSIĄŻKIEWICZ (1977).

Remarks. GRUBIĆ (1961) described two specimens of *Lorenzinia carpathica* (ZUBER) from the Eocene flysch of Montenegro, one of which was found between the locations of V. Kaliman and Mide. However, the exact locality is not shown in the paper. In this area, both Eocene flysch of the South Adriatic Zone and the Cretaceous-Paleogene flysch of the Budva Zone are developed, so it is not clear in which layers was this specimen found, but it is more likely that it originates from Paleocene sediments of the Budva Zone.

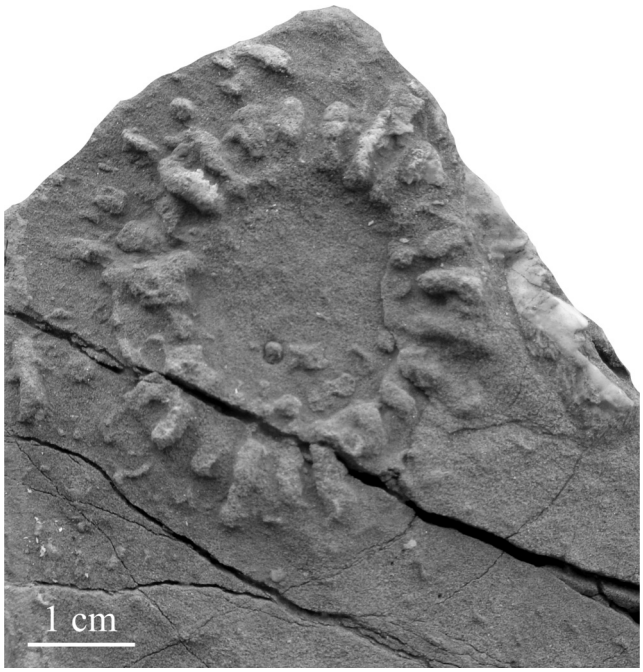


Fig. 4. *Lorenzinia carpathica* (ZUBER), MID 1/15.

UCHMAN (1998) revised the ichnogenus *Lorenzinia*, including part of the material described by KSIĄŻKIEWICZ (1977) as different ichnospecies, into ichnospecies *Lorenzinia carpathica* (ZUBER). In the literature, *Lorenzinia* was interpreted as a trace of holothurians, crabs or annelids (UCHMAN, 1998, and references therein).

Ichnogenus *Nereites* MACLEAY, 1839

Nereites irregularis (SCHAFHÄUTL, 1851)
Fig. 5

1977 *Helminthopsis irregularis* (SCHAFHÄUTL) – KSIĄŻKIEWICZ: 119–120, pl. 12, fig. 2.
1977 *Helminthoida labyrinthica* HEER – KSIĄŻKIEWICZ: 158, pl. 21, fig. 1.
1977 *Helminthoida serrata* n. ichnosp. – KSIĄŻKIEWICZ: 159, pl. 21, fig. 2.
1998 *Nereites irregularis* (SCHAFHÄUTL) – UCHMAN: 151–152, fig. 56.
2004 *Nereites irregularis* (SCHAFHÄUTL) – UCHMAN et al.: 217, fig. 13D.

Material. One specimen (inventory number MID 3/15).

Description. Horizontal, meandering ribbon-like structure, with a central string and two side lobes. The

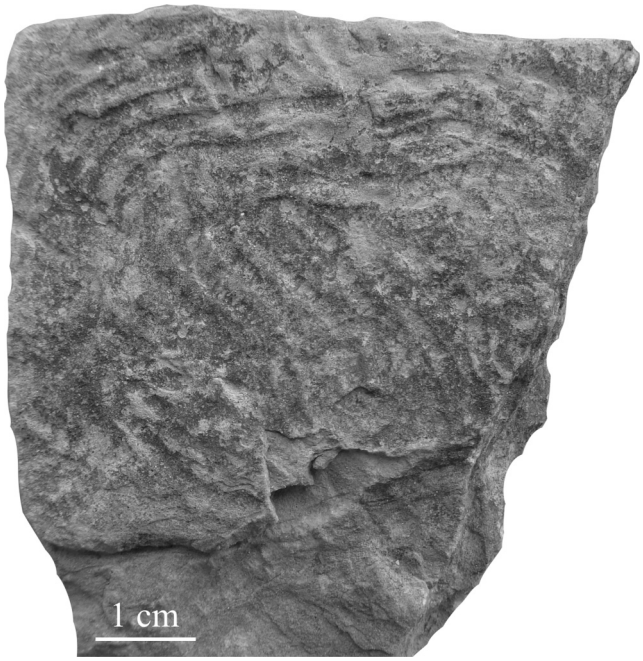


Fig. 5. *Nereites irregularis* (SCHAFHÄUT), MID 3/15.

central string is about 2 mm wide, while the width with two lobes goes to about 5 mm. Meanders are closely packed and the distance between them is less than 1 mm. They are developed in only one level. The central string and the side lobes are of the same colour.

Remarks. The specimen from the Mide locality mostly resembles the ones described by KSIĄŻKIEWICZ (1977) as *Helminthoida labyrinthica* HEER. UCHMAN (1995, 1998) revised the material of previous author and concluded that it represents a junior synonym of the ichnospecies *Nereites irregularis* (SCHAFHÄUTL), based on the morphological features of the specimens.

The origin of the tracemaker is still unknown.

Ichnogenus *Scolicia* DE QUATREFAGES, 1849

Scolicia plana KSIĄŻKIEWICZ, 1970
Fig. 6

1977 *Scolicia plana* KSIĄŻKIEWICZ – KSIĄŻKIEWICZ: 127–128, pl. 14, figs. 2–5, 7.
1977 *Subphyllochorda striata* KSIĄŻKIEWICZ – KSIĄŻKIEWICZ: 132–133, pl. 15, fig. 1.
1977 *Subphyllochorda rudis* n. ichnosp. – KSIĄŻKIEWICZ: 133–134, pl. 15, fig. 2.
1998 *Scolicia plana* KSIĄŻKIEWICZ – UCHMAN: 153–156, figs. 59–60.

Material. Two partial traces, probably of the same trace (inventory number MID 2A/15).

Description. The specimen represents the hypichnial form of this ichospecies. It is a convex, arcuate ridge, with two sediment strings and a small crest in the middle, on which faecal pellets are visible. The width of the ridge varies from 18.6 to 24.3 mm. The crest is 11.5 to 12.8 mm wide and the strings are from 1.4 to 2.6 mm wide.

Fig. 6. *Scolicia plana* KSIĄŻKIEWICZ, MID 2A/15.

Remarks. *Scolicia plana* KSIĄŻKIEWICZ from Mide locality was found on the lower bed-surface of sandstone layer. It was previously described as *Subphyllochorda striata* KSIĄŻKIEWICZ. UCHMAN (1998) has described the link between this form and *Scolicia plana* KSIĄŻKIEWICZ, that is described from an upper surface of layers and considers them the same ichospecies. Both forms represent traces made by irregular echinoids.

Ichnogenus *Paleodictyon* MENEGHINI, 1850

Paleodictyon latum VIALOV & GOLEV, 1965
Fig. 7

1963 *Paleodictyon* (*Glenodictyum*) *latum* VIALOV & GOLEV – VJALOV & GOLEV: 9–10, fig. 1, nomen nudum.
1977 *Paleodictyon latum* VIALOV & GOLEV – KSIĄŻKIEWICZ: 191–192, pl. 27, fig. 5.
2004 *Paleodictyon latum* VIALOV & GOLEV – UCHMAN et al.: 224, fig. 18H.

Material. One specimen (inventory number MID 2B/15).

Description. Hexagonal network of small size. The string is 0.6 mm wide, while the maximum mesh

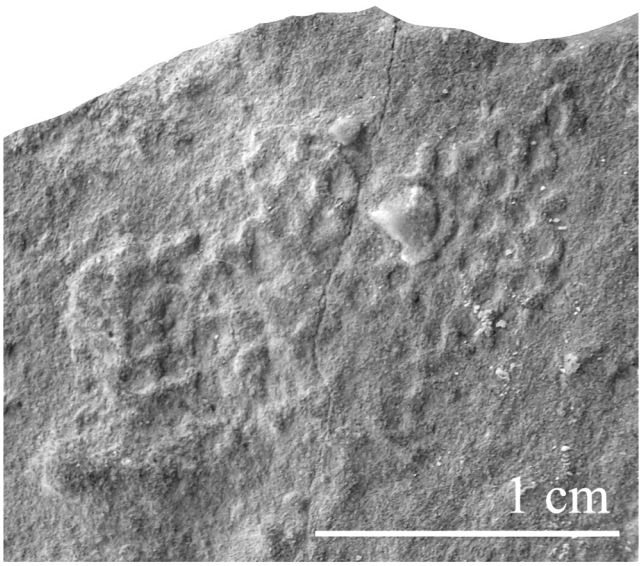


Fig. 7. *Paleodictyon latum* VIALOV & GOLEV, MID 2B/15.

width varies from 1.9 to 2.4 mm. The meshes are mostly uniform in shape, although some are more elongated.

Remarks. KSIĄŻKIEWICZ (1977) and UCHMAN (1998) mention that VIALOV & GOLEV described this ichnospecies as sp. nov. in 1965, when they designated a holotype from the Carpathians. For this reason, the use of the name *Paleodictyon latum* in the paper from 1963 represents a nomen nudum.

Even though incipient *Paleodictyon* has been found in recent sediments on the deep-sea floor (RONA et al., 2009), it is still unknown what kind of organism produce this trace fossil.

Discussion

UCHMAN & WETZEL (2012, and references therein) describe a large number of examples of *Nereites* ichnofacies, that is characteristic for deep-sea turbidite-dominated environments. Based on the dominance of specific trace fossils (meandering forms, rosette and network traces etc.), authors distinguish proximal and distal facies in the turbidites. Since there are only four ichnotaxa described from the Mide locality, it is not possible to argue what are the dominant forms, but all of them are characteristic for *Nereites* ichnofacies as described by UCHMAN & WETZEL (2012), i.e. they indicate a deep-sea environment.

In the area near the Mide locality, both Cretaceous-Paleogene flysch formation of the Budva Zone and Adriatic flysch formation (Upper Eocene-Oligocene, ČAĐENOVIĆ et al., 2010) of the South Adriatic Zone are developed. These formations do not differ only in age and tectonic units they belong to, but also contain different ichospecies. In Adriatic flysch formation of this area *Scolicia strozzi* (SAVI & MENEGHINI), *Paleodictyon hexagonum* MARCK and *Paleodictyon praedictum* VIALOV & GOLEV trace fossil have been determined (ĐAKOVIĆ et al., 2018). Trace fossils of the Cretaceous-Paleogene flysch formation are represented by ichnospecies described in the present paper. However, all ichnotaxa indicate a deep-sea environment of the *Nereites* ichofacies (UCHMAN & WETZEL, 2012).

New finding of *Lorenzinia carpathica* (ZUBER) in the Cretaceous-Paleogene flysch formation of the Mide locality indicates that the specimen described by GRUBIĆ (1961) found between the the locations of V. Kaliman and Mide also probably originates from these deposits.

Conclusion

The present paper represents a contribution to the knowledge of ichnofossils in Cretaceous-Paleogene flysch of the Budva Zone. Trace fossils are very important tools for interpretation of the environments. The trace fossils from Mide locality, even though they are represented by four ichnotaxa, clearly indicate a deep-water environment, of the *Nereites* ichnofacies (UCHMAN & WETZEL, 2012).

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Резиме

Ихнофосили кредно-палеогеног флиша локалитета Миде (Будва зона, јужна Црна Гора)

Формација кредно-палеогеног флиша Будва зоне простире се дуж Црногорског приморја од Херцег-Новог према Будви и Бару, гдје пролази дуж јужне стране планине Румије у Албанију. Према данашњим тумачењима, Будва зона је интерпретирана као интраплатформни дубоководни басен (Schmid et al., 2008), развијен између двије плитководне јединице, тј. Јужнојадранске зоне и зоне Високог крша. Карактеришу је дубоководне седиментне стијене тријаске, јурске, кредне и палеогене старости, развијене у неколико краљушти. Формација кредно-палеогеног флиша представља најмлађу формацију у Будва зони. Генерално, карактеришу је понављајући циклуси кречњачких пешчара и лапораца, са ријетким прослојцима кречњака. Седиментолошке особине, као и утврђена старост (мастрихт-доњи еоцен), описане су у бројним публикацијама (Миладиновић, 1960, 1964; Антонијевић и др., 1973; Калезић и др., 1976; Мирковић и др., 1978). Ова формација такође је пронађена у дубоким бушотинама урађеним за нафтна истраживања у Буљарици (Чановић, 1958). Ипак, фосилни трагови из ове формације до сада нису били описани, већ су само помињани као чести. Грубић (1961) је описао ихноврсту *Lorenzinia carpathica* (Zuber) са локалитета у близини села Миде. Вјалов и Голев (1963) такође описују представнике ихнорода *Paleodictyon* из еоценског флиша Црне Горе.

Четири ихнотаксона: *Lorenzinia carpathica* (Zuber), *Nereites irregularis* (Schafhäut), *Scolicia*

plana Książkiewicz и *Paleodictyon latum* Vialov & Golev су одређена из кредно-палеогеног флиша Будва зоне. *Nereites irregularis* (Schafhäut) је пронађен на горњој површини пешчарског слоја, док се друге ихноврсте налазе на доњој слојној површини. Иако су пронађене само четири ихноврсте, све указују на дубоководну средину стварања, *Nereites* ихнофације (Uchman & Wetzel, 2012).

Локалитет Миде налази се у јужној Црној Гори, око 15 km ИЈИ од Бара (Сл. 1). Депонати Будва зоне у овој области су представљени кредно-палеогеним флишем и кредним кречњацима са глоботрунканама, који су у преврнутом положају услед тектонских деформација изазваних стијенским масама Јужнојадранске зоне и зоне Високог крша. Дебљина формације на локалитету Миде износи 67 m (Сл. 2). На основу фосилног садржаја, само палеоценски и доњоеоценски слојеви су констатовани. Доњи дио стуба, дебљине 48 m, изграђен је од сивих и зелено-сивих пешчари и лапорци са ријетким интеркалацијама кречњака. Ихнофосили описани у овом раду потичу из најдоњег дијела овог интервала. Наредни дио стуба, дебљине 15 m, изграђен је од црвених пешчара са интеркалацијама зелених лапораца, са пелашким фораминиферама палеоценске старости. Преко ових слојева јавља се кречњачка breча дебљине 1 m, са бентоским фораминиферама доњоеоценске старости. Након овог слоја, развијено је још 3 m црвених пешчара и зелених лапорава, а преко њих су развијени квартарни седименти.

До данас не постоји јединствена систематика ихнофосила. Bertling et al. (2006) предлажу да морфологија фосилних трагова буде најважнији критеријум за њихову оцјену, а не величина, организам који их је направио, старост, фација или степен очуваности. У овом раду описи ихнофосила прате оне које су дали Książkiewicz (1977) и Uchman (1998), који су засновани на морфолошким особинама ихноврста. Збирка се чува у Заводу за геолошка истраживања Црне Горе. Сваки примјерак има инвентарски број, који се састоји од скраћенице за локалитет, броја примјерка и скраћенице за годину када је пронађен (нпр. МИД 1/15).

Uchman & Wetzel (2012, и литература наведена у овом раду) описују велики број примјера *Nereites* ихнофације, која је карактеристична за дубоководне средине у којима доминирају турбидити. На основу доминације појединих фосилних трагова (меандрирајуће форме, трагови у облику розета или мрежа итд.), аутори одвајају проксималне од дисталних фација турбидита. Обзиром да су са локалитета у Мидама описана само четири ихнотаксона, није могуће утрвдити које су доминантне форме, али су они сви карактеристични за *Nereites* ихнофацију како је описују Uchman & Wetzel (2012), односно све указују на дубоководну средину.

Овај рад представља допринос познавању ихнофосила кредно-палеогеног флиша Будва зоне. Фосилни трагови су веома важни као инструмент за интерпретацију средина у којима су седименти таложени. Збирка прикупљена на локалитету Миде, иако садржи само четири примјерка, јасно указује на дубоководну средину, односно *Nereites* ихнофацију (Uchman & Wetzel, 2012).

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