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Distephanopsis concavus Horvat: a revised silicoflagellate species from the Middle Miocene of the Central Paratethys

Revizija srednjemiocenske silikoflagelatne vrste *Distephanopsis concavus* Horvat

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Abstract

The silicoflagellate species *Distephanopsis concavus* Horvat is revised based on further research of the type material. This species is characterized by having a basal ring with strongly concave sides which reduce the basal ring area and by four symmetry planes which are morphological characteristics not known in other *Distephanopsis* species. The species was found in Middle Miocene deposits of the Central Paratethys. Its occurrence at type locality in SE Slovenia is dated to late Middle Badenian and is correlated to the upper part of the nannoplankton biozone NN5.

Izvleček

V prispevku je na osnovi detajlnje študije tipskega materiala podana revizija silikoflagelatne vrste *Distephanopsis concavus* Horvat. Za vrsto so značilne izrazito konkavne stranice bazalnega obroča in štiri simetrijske ravnine, kar niso morfološke značilnosti ostalih poznanih vrst rodu *Distephanopsis*. Vrsta je najdena v srednjemiocenskih plasteh zahodnega dela Centralne Paratetide. Stratigrafska razširjenost vrste v tipskem najdišču je zgornji del srednjega badenija in je korelirana z zgornjim delom nanoplanktonske biocone NN5.

Introduction

After the isolation of the Paratethys from the Tethys, silicoflagellates became rare and their occurrences were limited to the Badenian and Sarmatian (Middle Miocene). Their rare occurrence in the Central Paratethys is due to the varying ecological conditions resulting from intense tectonics, eustatic changes and seaway connections to the Mediterranean sea and Indo-Pacific area. In the Central Paratethys silicoflagellates only appear in the sequences of eustatic maxima (Bachmann et al., 1963; Bachmann, 1971; Hajós, 1968; Dumitrică, 1978). This is also the case in Slovenia where Middle Miocene diatomaceous sediments with silicoflagellates have only been discovered in fragmentary sections in the Krško basin (Horvat, 2004).

So far the occurrences of silicoflagellates are well known only in the central part of the Pannonian basin, that is, in the Intracarpathian area and Vienna basin in Austria, Hungary and Chech Republic (Bachmann et al., 1963; Bachmann, 1971; Hajós, 1968; Dumitrică, 1978). From the western part of the Central Paratethys, only two localities with Badenian silicoflagellates have been reported so far (Horvat, 2004). Siliceous microfossils occur around the localities Šmarjeta and Šentjernej in the Krško basin (Fig. 1) where a silicoflagellate assemblage comparable to that of other Badenian Paratethys localities was found. This assemblage contained a new species *Distephanopsis concavus* (Horvat, 2004), which was only introduced by a short description in Slovenian with no type designation. The aim of this paper is to provide all the data necessary to establish the validity of this species in accordance with the International Code of Zoological Nomenclature. Biostratigraphy and palaeoecoly of the assemblage with *Distephanopsis concavus* at its type locality are discussed as well.

Paleogeographic framework and geological setting

The Miocene sedimentary successions of western part of Central Europe are generally related to the Paratethys, which resulted from a process of final disintegration of the Tethys Ocean due to movement and subduction of Africa beneath the European plate and the counterclockwise rotation of the Eastern Alps (Rasser & Harzhauser, 2008). A new paleogeographic unit formed, called the Paratethys, whose development was at times independent of that of the Mediterranean. Within the Paratethys, two main sedimentary basins - the Central Paratethys in the west and the Eastern Paratethys in the east can be distinguished that were separated from each other by land. Their evolution was controlled by regional tectonic events, sea-level changes and by sediment infill. The combination of these processes resulted in changes in marine, brackish and freshwater ecological conditions in the sedimentary basins as well as in the restricted connections of the Central Paratethys with the Mediterranean sea, and across it with the Atlantic to the west, and with the Eastern Paratethys and the Indo-Pacific to the east. Middle Miocene diatomaceous sedimentary rocks rich in silicoflagellates and diatoms have been recorded from the entire Central Paratethys. In spite of their wide geographical distribution, diatomaceous sediments in the Central Paratethys occur in temporally limited sequences, usually in sedimentary rocks with low carbonate content. Therefore, they are rarely found in continuous sections and generally can not be traced laterally over large distances and they are not easily attributed to defined formations. This is also the case in Slovenia where Middle Miocene diatomaceous sediments have only been discovered in fragmentary sections in the Krško basin and in the Tuhinj syncline (Horvat, 2004). All localities are situated south of the Sava and Donat faults (Fig. 1). Miocene sediments in the westernmost parts of the Pan-

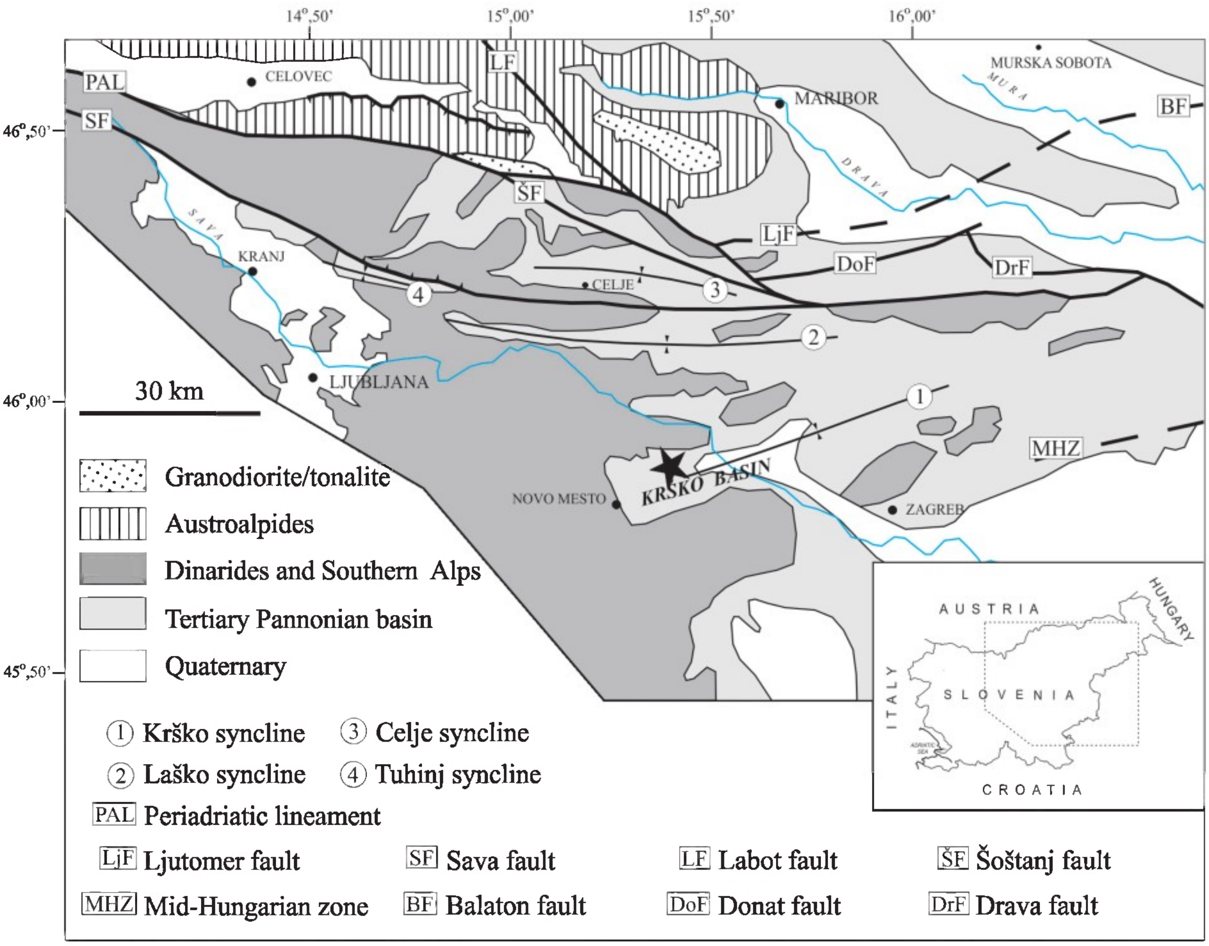


Fig. 1. Simplified tectonic map with location (star symbol) of the Šmarjeta section, Distephanopsis concavus type locality (from Horvat, 2004).

nonian basin (*sensu lato*) unconformably overlie Mesozoic sedimentary successions of the Internal and External Dinarides.

The type section Šmarjeta was logged in the roadcut of the Šmarjeta - Zbure road (45°51'252"N; 15°14'48" E; elev. 208 m). The section consists of dark grey to green grey carbonate siltstone beds usually termed "Baden Tegel", which is a typical Badenian formation of the Central Paratethys (Fig. 2). The under- and overlying beds are not exposed in the area. In the succession frequent fragments of Badenian turritellids and rare remains of scaphopods, oysters, and very rare pereiraeas [*Pereiraea gervaisi* (Vézian)] also occur. Siliceous microfossils in all samples are rare. In general, only remains of sponge spicules and rare endoskeletal dinoflagellates occur. Modest diatom and silicoflagellate assemblage were found only in the sample Šm-5 (Fig. 2). Rare fragments of silicoflagellates are found also in the nearby Šentjernej location, where a rich Badenian malacofauna (Mikuž, 2009) and diatom flora (Horvat, 2003a) also occur.

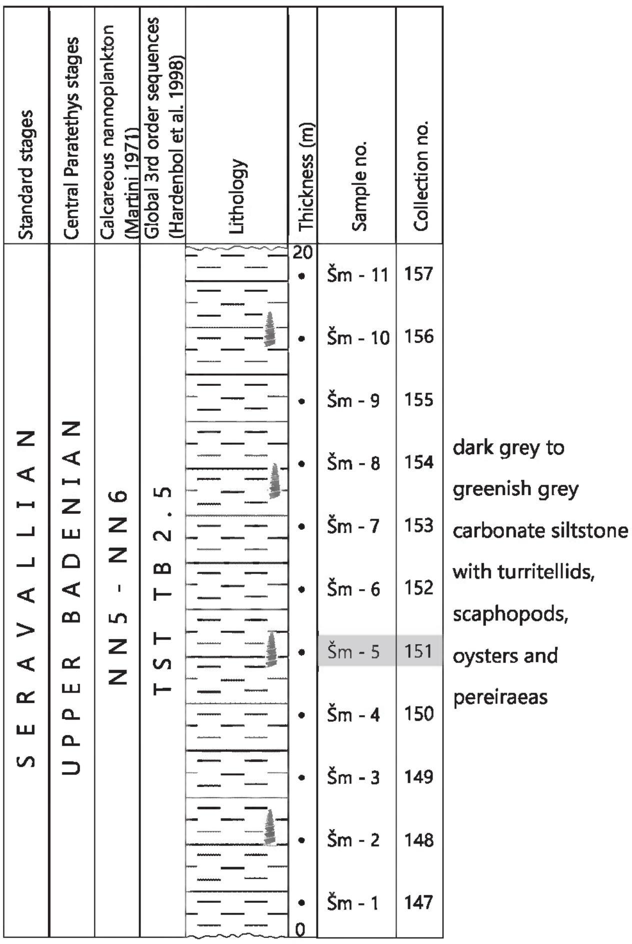


Fig. 2. Stratigraphic column of the Distephanopsis concavus type section (section Šmarjeta). Shaded area marks the sample with the type material.

Materials and methods

For micropaleontological preparation 3 g of dry sediment were treated following the method of Schrader & Fenner (1976). For slides preparation 2 ml of suspension were placed on a glass slide. After the water was evaporated, the slide was covered by 18 × 18 mm cover-glass. The mounting medium was Entellan. Slides were examined using a Carl Zeiss-Amplival light microscope with planchromatic objective under 1000× magnification.

Systematic description

Systematic classification is given after Desikachary & Prema (1996), and two internet databases (Internet 1 and Internet 2).

Kingdom Chromista Corliss, 1994
Phyllum Heterokonthophyta Van de Hoek, Mann & Jahns, 1995
Classis Dictyochophyceae Silva, 1980
Order Dictyochales Haeckel, 1894
Family Distephanaceae Locker, 1974
Genus *Distephanopsis* Dumitrică, 1978
Type species *Distephanopsis crux* (Ehrenberg) Dumitrică, 1978

Distephanopsis concavus Horvat
(Pl. 1, figs. 1-10)

2004 *Distephanopsis concavus* n. sp.; Horvat: 29, pl. 5, figs. 1-5.

Note: Because of the incomplete original descriptions in Horvat (2004) the species is revised and fully described herein.

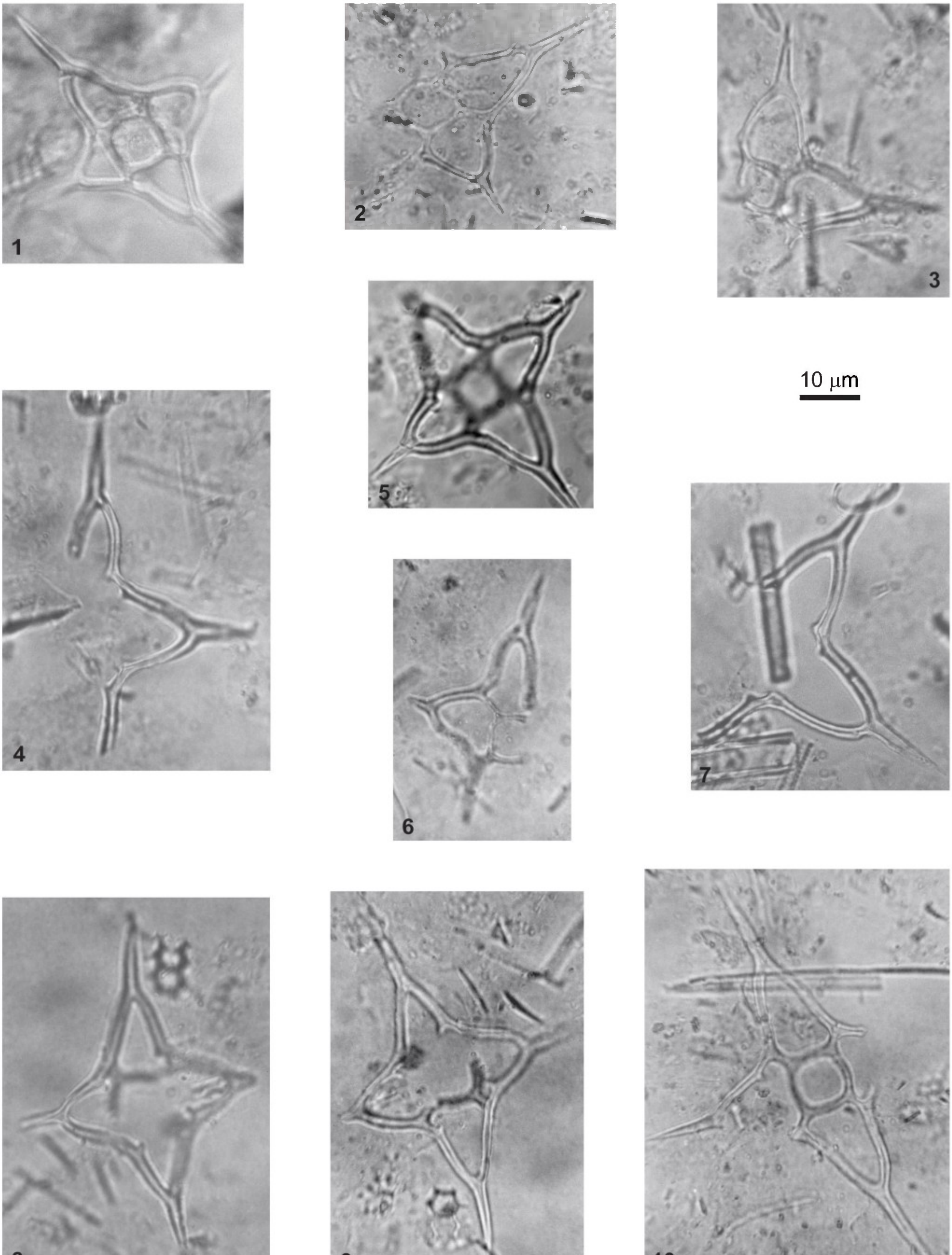
Derivation of name: The name was given after characteristically concave shape of the basal ring.

Diagnosis: A species of *Distephanopsis* with concave sided basal ring.

Type designation: Holotype: Pl. 1, fig. 1, paratypes: Pl. 1, figs. 2-10. Section Šmarjeta, SE Slovenia, sample Šm-5. The slide is stored at the Ivan Rakovec Institute of Palaeontology Research Centre of the Slovenian Academy of Sciences and Arts. The collection number of the slide is D151.

Type locality: Šmarjeta section (45°51'25"N; 15°14'48"E; elev. 208 m) on the northern part of the Krško basin, SE Slovenia.

PLATE 1



1 – 10 *Distephanopsis concavus* Horvat
1 holotype; 2-10 paratypes, section Šmarjeta, sample Šm-5 (coll. no. D-151)

Description: Large square basal ring with concave sides. Apical ring square, connected to basal ring in the places of maximum constriction and with sides parallel with the major and minor axes of skeleton. Basal spines are long and of equal length. The concavity of the basal ring and equal basal spines resulted in four symmetry planes. Sustaining spines very short and always on the right of lateral bars.

Dimensions: Length of basal ring without spines 33–46 µm (holotype 33 µm) and width of basal ring without spines 27–42 µm (holotype 27 µm).

Remarks: *Distephanopsis concavus* is distinguished from other *Distephanopsis* species by the advanced concavity of the basal ring, which reduces the basal ring area. The function of the basal ring is in controlling the sinking rate and orientation of the organism (Sarjeant et al., 1987; McCartney & Loper, 1989). McCartney & Loper (1989) indicated the importance of minimizing silicoflagellate surface area in minimizing the utilization of skeletal material but their model only considered the apical surface area while the basal ring was excluded. The reason for the geometric simplification of the protist skeletons that are so extremely sensitive to environmental changes has been explained by ecological stress whereas stable environment conditions favour evolution towards more complex geometries and increase of symmetry (Guex, 2006). In this sense *Dss. concavus* can be regarded as an advanced morphotype that evolved from *Dss. crux* during times of ecological stability.

Dss. crux Ehrenberg and other *Distephanopsis* species have straight or slightly convex basal ring. In addition, *Dss. crux* Ehrenberg usually has differentiated radial spines, those lying in the major axis being longer than those lying in the minor axis, while *Dss. concavus* has radial spines of equal length.

A basal ring of *Distephanopsis stradneri* (Jerković) Desikachary & Prema is sometimes slightly concave in the middle part of the skeleton (Jerković, 1965: figs. 43-45; Jerković, 1969: pl. 2, fig. 2; Perch-Nielsen, 1985: figs. 20/16, 17) but this concavity is less pronounced than that of *Dss. concavus*. *Dss. stradneri* also has a smaller apical ring and radial spines of different length.

By size and concavity of the basal ring *Distephanopsis concavus* is similar to *Distephanus norvegiensis* Perch-Nielsen (Perch-Nielsen, 1985, fig. 19/2), but *Ds. norvegiensis* has 5-sided basal ring, 5 radial spines, and smaller apical ring.

Age: Late Middle Badenian (Middle Miocene), upper part of the nannoplankton biozone NN5.

Discussion

Stratigraphy

The following silicoflagellate assemblage (Pl. 2, figs. 1-11) was observed and described from the Middle Miocene sections in the Krško basin (Horvat, 2004): *Septamesocena apiculata apiculata* (Schulz) Bachmann, *Mesocena diodon diodon* Ehrenberg, *Dictyocha fibula* Ehrenberg, *Distephanopsis crux crux* (Ehrenberg), *Distephanopsis longispinus* (Schulz) Desikachary & Prema, *Distephanopsis crux parvus* (Bachmann) Bukry, *Distephanopsis crux scutulatus* (Bukry) Desikachary & Prema, *Distephanopsis stradneri* (Jerković) Desikachary & Prema, *Distephanus speculum* (Ehrenberg) Haeckel, *Cannopilus hemisphaericus* (Ehrenberg) Haeckel, *Paracannopilus picassoi* (Stradner), and *Distephanopsis concavus* Horvat. The assemblage is comparable to those of other Badenian localities in the Paratethys (Bachmann et al., 1963; Bachmann, 1971; Hajós, 1968; Dumitrică, 1978).

The standard silicoflagellate biozonation of Martini (1971, 1972) attributes the upper part of the Lower Miocene and the Middle Miocene to the unique *Corbisema triacantha* biozone. Bukry (1981) and Perch-Nielsen (1985) divided Martini's *Corbisema triacantha* biozone into two subzones: the lower *Cannopilus schulzii* subzone (corresponding to the NN4 and NN5) and the upper *Distephanus stauracanthus* subzone (corresponding to NN6 and NN7). Dumitrică (1978) distinguished two silicoflagellate assemblages in the Central Paratethys: the Lower Badenian '*Paracannopilus picassoi* assemblage' and the Upper Badenian '*Distephanopsis stauracanthus* assemblage'. The assemblage from the Šmarjeta section can be compared with Dumitrică's '*Paracannopilus picassoi* assemblage' (Horvat, 2004).

Hajós (1986) proposed for the Badenian the *Dyctyocha fibula - Distephanus crux* v. *longispina* biozone that chronologically corresponds the late Early Badenian and Middle Badenian.

Based on calcareous nannofossil dating, the Šmarjeta section can be placed in the upper part of the biozone NN5 which can be correlated with the upper part of the Middle Badenian. Nannofossils in all samples are moderately to well preserved. Individual samples contain 9-21 species (15 on average). The presence of very rare specimens of *Sphenolithus heteromorphus* Deflandre in most samples, including the top sample, together with the absence of *Helicosphaera ampliaperta* Bramlette &Wilcoxon, allow the assignment of the studied interval to the biozone NN5. The presence of rare specimens of the large morphotype (>7μm) of *Reticulofenestra pseudoumbilica* (Gartner) Gartner in samples Šm-1, Šm-4, and Šm-7 as well as rare specimens of *Sphenolithus abies* Deflandre in samples Šm-4 and Šm-10 is consistent with the upper part of the nannoplankton biozone NN5 (Bartol, pers. com.).

Despite the absence of *Corbisema triacantha* as the type species of the upper part of Middle Badenian and comparison of the Dumitrică's (1978) Central Paratethys Lower Badenian assemblage the age of *Distephanopsis concavus* could not be Lower Badenian but late Middle Badenian.

Paleoecology

The paleoecology of the Badenian silicoflagellates of the Krško basin could be deduced from co-occuring diatoms. The Badenian diatom assemblage in the Krško basin has a transgressive character. It is dominated by resting spores of *Chaetoceros* spp. and *Thalassionema nitzschioides* (Grunow) Mereschkowsky (Horvat, 2003b, 2012) which are usually thought to reflect stronger coastal upwelling conditions and high seasonal primary production (Barron, 1986; Bárcena & Abrantes, 1998; Bárcena et al., 2001; Burckle, 1984; Maynard, 1976; Abrantes, 1991; Sancetta, 1999, Nave et al., 2001; Booth et al., 2002). The structure of the diatom assemblage of the Krško basin suggests nutrient-enriched waters, which were transported laterally from the center of upwelling that was located to the west of the study area, presumably in the zone of mixing of warm proto-Mediterranean and cool Atlantic water masses (Horvat, 2004, 2012; Bartol et al., 2014).

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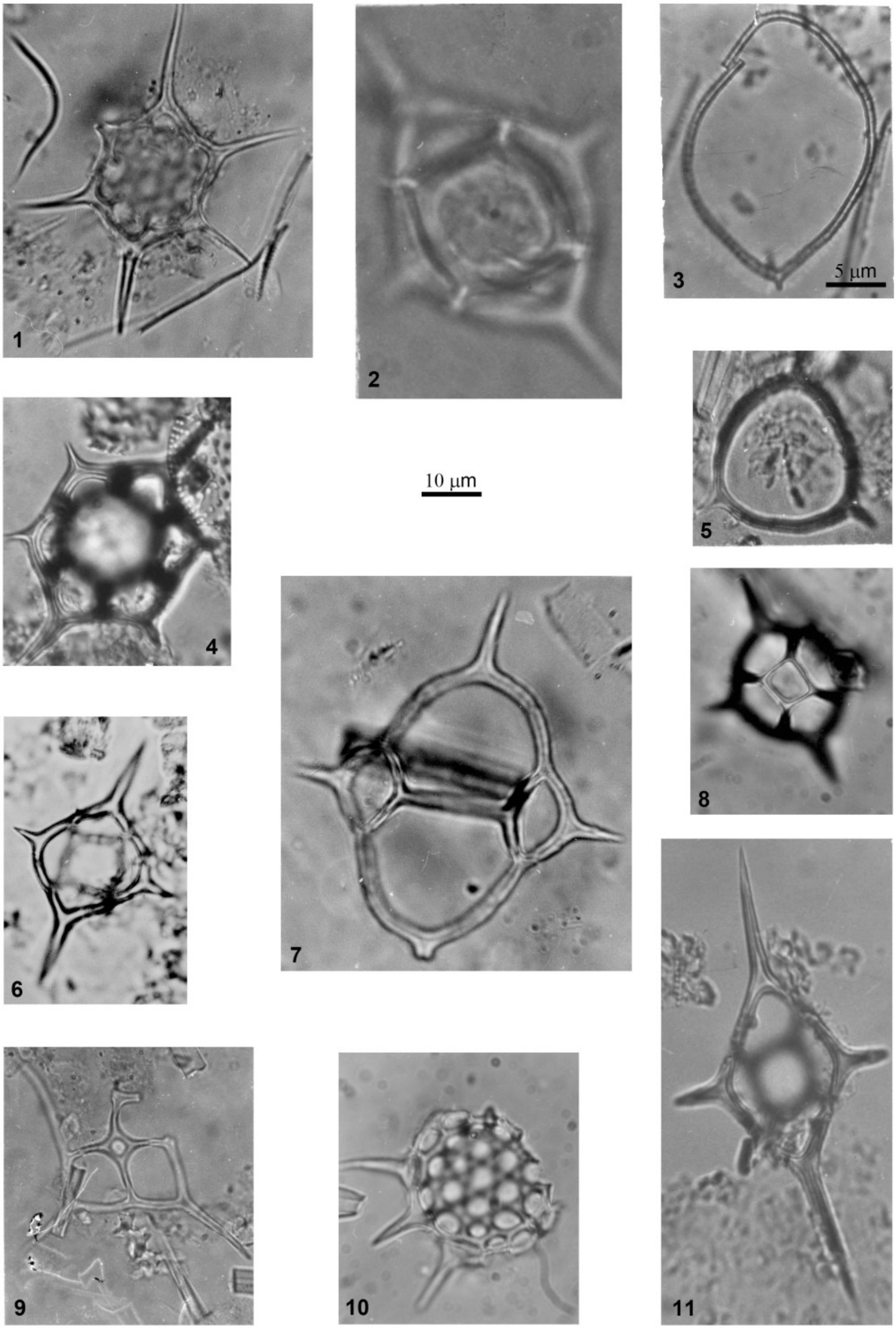
PLATE 2

Silicoflagellate assemblage of the *Distephanopsis concavus* type section Šmarjeta (sample Šm-5).

1 *Cannopilus hemisphaericus* (Ehrenberg) Haeckel
2 *Distephanopsis crux crux* (Ehrenberg)
3 *Mesocena diodon diodon* Ehrenberg
4 *Distephanus speculum* (Ehrenberg) Haeckel
5 *Septamesocena apiculata apiculata* (Schulz) Bachmann
6 *Distephanopsis crux scutulatus* (Bukry) Desikachary & Prema
7 *Dictyocha fibula* Ehrenberg.
8 *Distephanopsis crux parvus* (Bachmann) Bukry
9 *Distephanopsis stradneri* (Jerković) Desikachary & Prema
10 *Paracannopilus picassoi* (Stradner)
11 *Distephanopsis longispinus* (Schulz) Desikachary & Prema

Scale bar 10 μm except fig. 3 (5 μm)

PLATE 2



References

Abrantes, F. 1991: Increased upwelling off Portugal during the last glaciation: Diatom evidence. Marine Micropaleontology, 17: 285–310.

Bachmann, A. 1971: Sillicoflagellaten aus dem obern Badenien von Walbersdorf, Burgenland. Sitzungsberichte der Österreichische. Akademie der Wissenschaften. Mathematisch-naturwissenschaftliche Klasse. Abteilung 1, 179 (1970): 52–72.

Bachmann, A., Papp, A. & Stradner, H. 1963: Mikropalaontologische Studien im "Badener Tegel" von Frattingsdorf N. O. Mitteilungen der Geologischen. Gesellschaft. Wien, 56: 117–210.

Bárcena, M.A. & Abrantes, F. 1998: Evidence of a high productivity area off the coast of Málaga from studies of diatoms in surface sediments. Marine Micropaleontology, 35: 91–103.

Bárcena, M.A., Cacho, I., Abrantes, F., Sierro, F.J., Grimalt, J.O. & Flores, J.A. 2001: Paleoproductivity variations related to climatic conditions in the Alboran Sea (Western Mediterranean) during the last glacial-interglacial transition: the diatom record. Palaeogeography, Palaeoclimatology, Palaeoecology, 167: 337–357.

Barron, J.A. 1986: Response of equatorial Pacific Diatoms to Polar Cooling during the Middle Miocene. In: Picard, M. (ed.): Proccedings of the Eight International Diatom Symposium 1984. Koeltz Scientific. Books, Koenigstein, 591–600.

Bartol, M., Mikuž, V. & Horvat, A. 2014: Palaeontological evidence of communication between the Central Paratethys and the Mediterranean in late Badenian/early Serravalian. Palaeogeography, Palaeoclimatology, Palaeoecology, 394: 144–157. doi:10.1016/j.palaeo.2013.12.009

Booth, B.C., Laraouche, P., Bélanger, S., Klein, B., Amiel, D. & Mei, Z.-P. 2002: Dynamics of *Chaetoceros socialis* blooms in the North Water. Deep-Sea Research II, 49: 5003–5025.

Bukry, D. 1981. Synthesis of silicoflagellate stratigraphy for Maastrichtian to Quaternary marine sediments. Special Publication of Society of Economic Paleontologists and Mineralogists, 32: 433–444.

Burckle, L. 1984: Diatom distribution and paleoceanographic reconstruction in the southern ocean: present and last glacial maximum. Marine Micropaleontology, 9: 241–261.

Desikachary, T.V. & Prema, P. 1996: Silicoflagellates (Dictyochophyceae). Bibliotheca Phycologica, 100: 1–298, 83 pls.

Dumitrică, P. 1978: Badenian Silicoflagellates from Central Paratethys. In: Papp, A., Cicha, I., Seneš, J. & Steininger, F. (eds.): Chronostratigraphie und Neostratotypen. Miozän der Zentralen Paratethys. M4. Badenien. Verlag der Slowakischen Akademie. der Wissenschaften, Bratislava, 207–229.

Guex, J. 2006: Reinitialization of evolutionary clocks during sublethal environmental stress in some invertebrates. Earth and Planetary Science Letters, 242/3-4: 240–253. doi:10.1016/j.epsl.2005.12.007.

Hajós, M. 1968: Die Diatomeen der Miozänen Ablagerungen des Matravorlandes. Fasciculi Instituti Geologici Hungariae Series Paleontologica, 37: 1–402, Pls. 1–63.

Hajós, M. 1986: Stratigraphy of Hungary`s Miocene diatomaceous earth deposits. Fasciculi Instituti Geologici Hungariae Series Paleontologica, 49: 1–339, Pls. 1–61.

Hardenbol, J., Thierry, J., Farley, M.B., Jacquin, T., de Graciansky, P.C. & Vail, P.R. 1998: Mesozoic and Cenozoic sequence chronostratigraphic framework of European Basins. In: de Graciansky, P.C., Hardenbol, J., Jacquin, T. & Vail, P.R. (eds.): Mesozoic and Cenozoic sequence stratigraphy of European Basins. SEPM Spec. Publ., 60: 3–13.

Horvat, A. 2003a: Badenian (Middle Miocene) diatoms (Bacillariophyta) from the western part of Central Paratethys. Razprave 4. razreda SAZU, 44/1: 5–55.

Horvat, A. 2003b: Upper Badenian diatom paleoecology of the western part of Central Paratethys. Geologija, 46: 251–262.

Horvat, A. 2004: Middle Miocene siliceous algae of Slovenia. ZRC Publishing House, Ljubljana: 255 p.

Horvat, A. 2012: Middle Miocene opal-rich facies of the Paratethys - evidence of upwelling or increased continental runoff stimulated productivity? In: Missoni, S. & Gawlick, H.-J. (eds.): 29th IAS Meeting of Sedimentology Abstract Book, Schladming, pp. 536.

Jerković, L. 1965: Sur quelques silicoflagellidés de Yougoslavie. Revue Micropaléontologie, 8: 121–130.

Jerković, L. 1969: Silicoflagellides fossiles des environs de Zagreb, de Bosanska Kostajnica et de Derventa (Yougoslavie). Godišnjak Biološkog Instituta Unierziteta Sarajevo, 22: 21–128.

Martini, E. 1971: Standard Tertiary and Quaternary calcareous nannoplankton zonation. In: Farinacci, A. (ed.): Proceedings of the second planktonic conference, Vol. II. Edizioni Technoscienza, Roma, 739–786.

Martini, E. 1972: Silicoflagellate zones in the late Oligocene and early Miocene of Europe. Senckenbergiana Lethaea, 53: 119–122.

Maynard, N.G. 1976: Relationship between diatoms in surface sediments of the Atlantic Ocean and physical oceanography of overlaying waters. Paleobiology, 2: 99–121.

McCartney, K. & Loper, D.E. 1989: Optimized skeletal morophologies of silicoflagellate genera *Dictyocha* and *Distephanus*. Paleobiology, 15: 283–298.

Mikuž, V. 2009: Miocene gastropods from the vicinity of Šentjernej and from other localities in the Krka basin, Slovenia. Folia Biologica et Geologica (Razpave 4. razreda SAZU), 50/2: 5–65.

Nave, S., Freitas, P. & Abrantes, F. 2001: Coastal upwelling in the Canary Island region: spatial variability reflected by the surface sediment diatom record. Marine Micropaleontology, 42: 1–23.

Perch-Nielsen, K. 1985: Silicoflagellates. In: Bolli, H. M., Saunders, J. B. & Perch-Nielsen, K. (eds.): Plankton stratigraphy. Cambridge University Press, Cambridge-London, 811–849.

Rasser, M.W. & Harzhauser, M. coord. 2008. Paleogene and Neogene. In: McCann, T. (ed.): The Geology of Central Europe. Vol. 2: Mesozoic and Cenozoic. Geological Society London, London, 1031–1139.

Sancetta, C. 1999: Diatoms and marine paleoceanography. In: Stoermer, E.F. & Smol, J.P. (eds.): The diatoms: Applications for the environmental and earth sciences. Cambridge Uni. Press, Cambridge, 374-386.

Sarjeant, W.A., Lacalli, T. & Gaines, G. 1987: The cyst and skeletal elements of dinoflagellates: speculation on the ecological causes for their morphology and development. Micropaleontology, 33: 1–36.

Schrader, H.-J. & Fenner, J. 1976: Norwegian Sea Cenozoic diatom biostratigraphy and taxonomy. Part I: Norwegian Sea Cenozoic diatom biostratigraphy. In: Talwani, M. (ed.): Initial Reports of the Deep Sea Drilling Project, 38: 921–1099, U.S. Gov. Print. Off., Washington.

Internet resources:

Internet 1: http://www.algaebase.org/ (1. 10. 2016).

Internet 2: http://www.gbif.org/ (1. 10. 2016).