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Siliceous phytoplankton assemblage from Sarmatian beds in the Markuševec area (Mt. Medvednica, NW Croatia)

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The section of sedimentary profile that has been investigated is located on the southwest part of Mt. Medvednica, in the Markuševec area. This paper focuses on paleontological analysis and the identification of the siliceous phytoplankton (silicoflagellates, diatoms) composition of Sarmatian sediments (marls, clays) in the geological column Mrzljak. The *Distephanus longispinus* Zone has been proposed, on the basis of the silicoflagellate index taxa and their assemblage, for the upper part of the Middle Miocene. Fourteen diatom species have been found for the first time in this region: *Coscinodiscus rothii* (Ehrenberg) Grunow, *C. subtilis* Ehrenberg, *Actinoptychus senarius* (Ehr.) Ehrenberg, *A. heliopelta* Grunow, *Actinocyclus octanarius* var.. *tenella* (Brebisson) Hendey, *A. tenellus* (Breb.) Andrews, *Anaulus simplex* Hajós, *Bacteriastrum varians* Lauder, *Grammatophora macilenta* var. *subtilis* Grunow, *Cocconeis scutellum* var. *scutellum* Sheshuk, *Diploneis subovalis* Cleve, *Navicula marina* Ralfs, *Nitzchia imperforata* Andrews and *Delphineis lineata* Andrews. A few ebridians, such as: *Hermesinum adriaticum* Zucharias, *Ebria triparita* (Schum.) Lemmermann, *Cardiuifolia gracilis* Hovasse and *Ammodochium prismaticum* Hovasse, and one endoskeletal dinoflagellate *Actiniscus pentasterias* Ehrenberg were determined.

Key words: silicoflagellates, fossil diatoms, Sarmatian, Markuševec, Croatia

Introduction

The first investigations on micro-macro fauna in SW Mt. Medvednica region have been performed in the 19 century by VUKOTINOVIĆ (1874), GORJANOVIĆ-KRAMBERGER (1883, 1908), PILAR (1883), BRUSINA (1884), KISELJAK (1889) and FRANZENAU (1892–1894). The stratigraphy of the region has been described, based on fossil microfauna byŠIKIĆ (1967), KOCHANSKY-DEVIDE and BAJRAKTAREVIĆ (1981), and (BAJRAKTAREVIĆ 1976). In the vicinity of the region, investigation of the micro- and nanofossils has been carried out by JURILJ (1957), JERKOVIĆ (1965, 1969, 1974) and BAJRAKTAREVIĆ (1983). As part of the work carried out in preparation for the basic geological map M 1:100000, Zagreb sheet, with accompanying explanatory notes, made by ŠIKIĆ et al. (1979), the lower Sarmatian stage (s.

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str.) was determined on the basis of the micro and macro-fauna. BASCH (1983) correlated these lower Sarmatian sediments (including the micro and macrofossils) with the volhyn of Eastern Paratethys. The Sarmatian sediments that are parts of the sedimentation area of Central Paratethys from northern Croatia have been defined on the basis of the micro-foraminiferal association and the associated calcareous and siliceous phytoplankton by BAJRAKTAREVIĆ (1984a). AVANIĆ et al. (1995), for the field guide book of Mt. Medvednica (Fig. 1), described the vertical succession of Sarmatian sediments in the geological column »Mrzljak« including their fossil assemblages. GALOVIĆ (1997) gave analyses of that column relating to siliceous phytoplankton. New names of taxa are given in table 1, with synonyms in brackets.

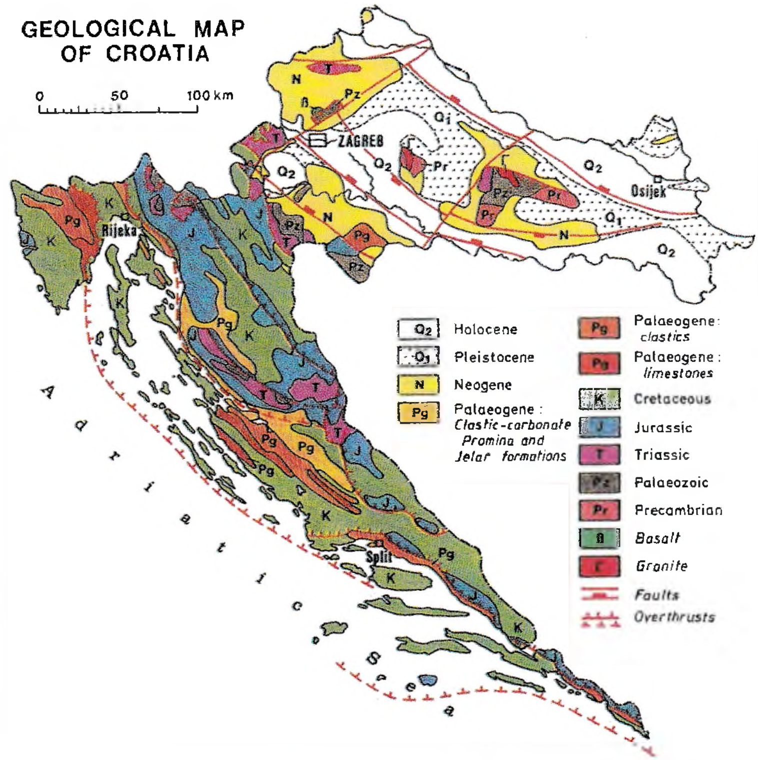

Fig. 1. Geological map of Croatia and position of Markuševec locality (arrow)

Material and Methods

Sampling was carried out in partially consolidated sediments (Fig. 2). From a sample as small as a nut, approximately 1/2 cm^3 of sediment was taken out and then put into a standard test tube (16 × 160 mm) and soaked in distilled water until it was completely disaggregated. Some samples (2, 3, 4, 5) were treated with 20 ml of 30% hydrogen peroxide (H_2O_2) solution in order to remove organic matter from sediments, but some of them (1, 2, 3 in table 1) were treated with 20 ml of 15% hydrochloric acid (HCl). Then distilled water

Tab. 1. The abundances of siliceous phytoplankton from marls and clays from the Sarmatian in Markuševec (NW Croatia). ☺☺☺ – very abundant, ☺☺ – common, ☺ – rare

taxa	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Silicoflagellates:					
Dictyocha fibula Ehrenberg				☺	
Distephanopsis crux (Ehr.) Dumitrica *(Distephanus crux* Ehrenberg)				☺☺☺	☺☺☺
Ds. stradneri (Jerković) Desik. et Prema *(D. stradneri* (Jerkovic) Bukry)				☺	
Ds. schauinslandlii (Lemmermann) Desik. et Prema *(D. schauinslandii* Lemmermann)				☺☺☺	☺☺☺
Distephanus sp.cf.*Ds. longispinus* Schulz		☺		☺☺	
D. sp. *cf.Ds. hannai* Bukry				☺☺	
D. sp.*cf.Ds. quiqungellus* Bukry et Forester				☺	
Ebriides:					
Ammodochium prismaticum Hovasse				☺☺	☺
Cardiuifolia gracilis Hovasse				☺☺	☺
Ebria triparita (Shum.) Lemmermann				☺☺	☺☺
Hermesinum adriaticum Zacharias				☺☺	☺
Diatoms:					
Paralia sulcata (Ehr.) Cleve				☺☺☺	☺☺☺
Hyalodiscus scoticus (Kutz.) Grunow				☺	
Coscinodiscus rothii (Ehr.) Grunow				☺☺	
C. subtilis Ehr.				☺☺	☺
C. oculus iridis Ehr.				☺☺	☺
Actinoptychus heliopelta Grunow				☺☺	☺☺☺
A. senarius (Ehr.) Ehr.				☺☺	☺☺☺
A. undulatus (Bail.) Ralfs				☺	
Asteromphalus hungaricus Pant.				☺☺	☺
Actinocyclus ehrenbergii var. *tenella* (Berbisson) Hustedt					☺
Ac. octonarius var. *tenellus* (Breb.) Hendey				☺☺	
Ac. tenellus (Breb.) Andrews				☺	
Bacteriastrum varians Lauder				☺☺	☺
Grammatophora macilenta var. *Subtilis* Grun.				☺☺	
G. oceanica Ehr.				☺☺	☺☺☺
G. robusta Ehr.				☺☺	☺☺
G. sp. A				☺☺	☺
Rhaphoneis amphiceros (Ehr.) Ehr.				☺	☺
Anaulus simplex Hajos				☺☺	☺☺
Thalassionema nitzschioides (Grun.) Hust.		☺		☺☺	☺☺☺
Achnanthes saeptata var. *sussedana* Jurilj				☺	☺☺☺
Cocconeis canaliculata Jurilj				☺	☺
Co. scutellum Ehr.				☺☺☺	
Co. scutellum var. *scutellum* Ehr.				☺☺	☺
Diploneis gemmatula (Grun.) Cleve					☺
D. subovalis Cleve					☺
Lyrella hennedyi (Smith) Stickle et Mann				☺☺	☺
Navicula marina Ralfs				☺	☺
Nitzschia imperforata Andrews				☺	
Rhopalodia gibberula (Ehr.) Müller				☺	☺
Delphineis lineata Andrews					☺☺
Endoscelet of dinoflagellate:					
Actiniscus pentasterias Ehr.				☺☺	☺☺

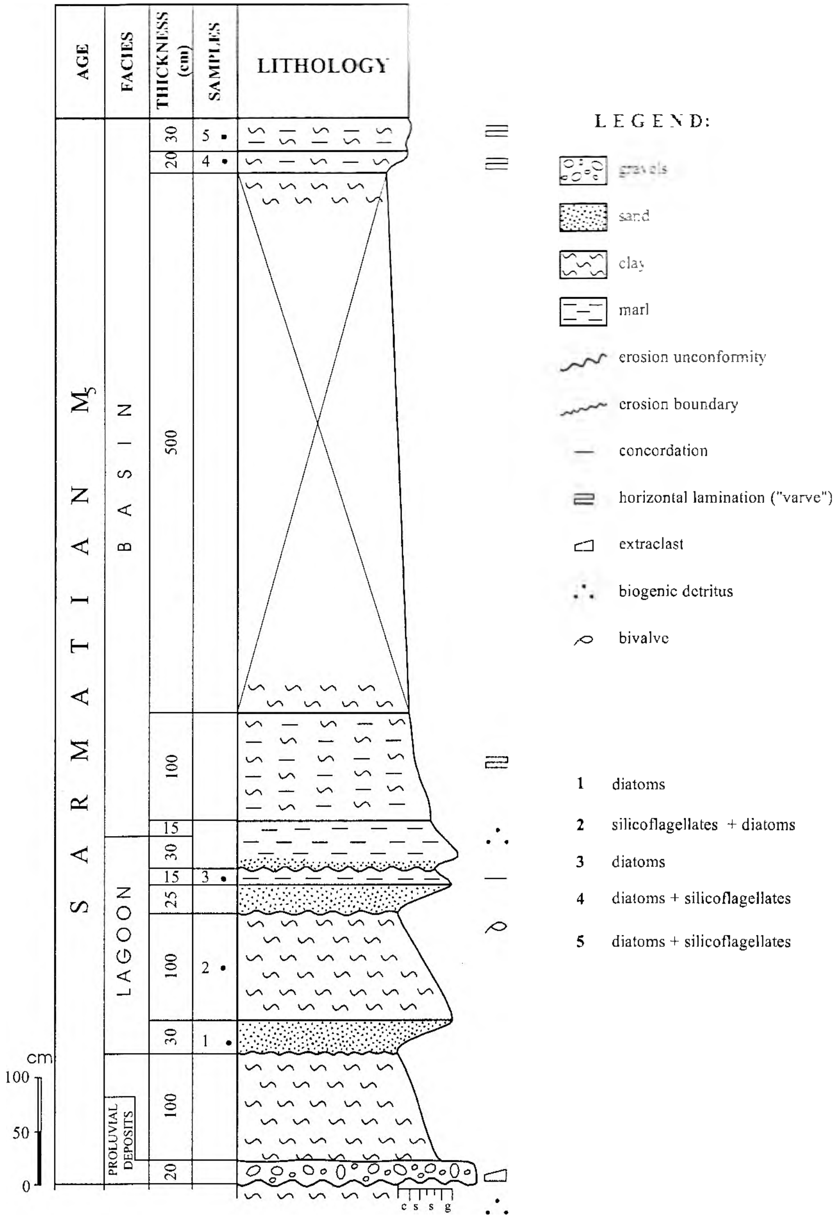

Fig. 2. Geological column Mrzljak

was added and decanted to neutral. Some of the samples (4 and 5) were put into an ultrasonic tank for approx. 15 seconds for better disaggregation. After that we proceeded with slide preparation. A few drops of a sample were put with a pipette onto a glass slide, dried, and mounted with Canada balsam. The slide was then viewed at a magnification of 200 to 500 × with immersion oil.

Results and Discussion

Regional classifications for the area of Central and East Paratethys were proposed forty years ago from the Regional Committee on Mediterranean Neogene Stratigraphy. Such a division was based upon so-called »Integrated Assemblage Zones«, which were founded on numerous fossil organisms. This work attempted to define the assemblage zones using taxa of stratigraphic importance (Tab. 2).

The silicoflagellate species *Dictyocha rhombica* (*s. l.*) was not found in the samples, and the lower Sarmatian cenozon with *Distephanus soljanii* (*s. str.*), could not be determined (DUMITRICA et al. 1975, BAJRAKTAREVIĆ 1984). The upper Sarmatian is determined by *Ds.* sp. *cf. Ds. longispinus*, which belongs to the *Ds. longispinus* zone (NN6-NN9a; MARTINI and MÜLLER 1976). The absence of the Middle Miocene species *Corbisema triacantha* and the appearance of *Distephanus* sp. cf. *Ds.. longispinus*, stratigraphically sensu stricto forms noted only in the Middle Miocene (BUKRY and FOSTER 1973), define the base of this zone. The last appearance of *Ds.* sp. *cf. Ds. longispinus* and first appearance of *Ds. quinquangellus* determine the upper boundary of this zone. Other species in the zonal assemblage include: *Ds. crux, Ds. schauinslandii, Ds.* sp. *cf. Ds. quinquangellus*, a characteristic Middle Miocene species (BUKRY and FOSTER 1973) and *Ds.* sp. *cf. Ds. hannai* (Lower – Middle Miocene species; BUKRY 1980). If we include Cornell´s correlation of this zone (CORNELL 1977) for Europe, it belongs to Serravallian N13-N15 planctonic foraminifera Zones (BLOW 1969). In the stratigraphic correlation table constructed by HAJÓS (1986) for Central Paratethys, silicoflagellates indicate Lower Sarmatian in the investigated region (JERKOVIĆ 1969). The layer is equivalent to NN8 (MARTINI 1972), as well as the *Discoaster kugleri* nanoplankton zone of BALDINE and NAGYMAROSY (1984). The biostratic zonation of the diatoms was determined by HAJÓS (1986). She correlated her *Anaulus simplex* Zone with *Coscinodiscus doljensis* Zone of REHAKOVA (1977) for Central Paratethys (Tab. 2).

The species in the first three samples were excluded from the analysis. They cannot be determined with any certainty because of damage caused to their skeletons by displacement from older sediments, only damaged or partially dissolved parts of them being found. This could imply that in the lower part of the Sarmatian deposition basin, the condition for siliceous phytoplankton growth was not completely established, which can be seen from the column (Fig. 2). This paper does not specify which taxa have been reworked from the older sediments, but the characteristic fossils for the Sarmatian period are given in table 2.

Tab. 2. Stratigraphic position of Sarmatian based on phytoplankton in the Central Paratethys

Age	Tethys	Paratethys	Mil. y	Phytoplankton zones				
				Calcareous nannoplankton		Silicoflagellates BURKY and FOSTER (1973)		Diatoms
				MARTINI and MÜLLER (1976)	BAJRAKTAREVIĆ (1984)	DUMITRICA (1975) Tropical	LING (1973)	REHAKOVA (1977) HAJÓS (1986)
Middle miocene	Serravallian	Sarmatian	10.7	NN 9a		»poor zone«	*Distephanus schauinslandi*	
			11	NN 8	»calcareous elements«	*Distephanus longispinus*		*Coscinodiscus doljensis, Anaulus simplex*
			12	NN 7				
			13	NN 6		*Distephanus soljanii*		

The ratio of *Dictyocha/Distephanus* species in the upper Sarmatian deposits shows that the climate was relatively temperate. The ratios must be explained not by temperature alone, but in terms of productivity and other factors, like available nutrients, including hydrography (TAKAHASHI 1989). The fluxes of *Distephanus* species, as a productivity indicator, were negatively correlated with the diversity index of silicoflagellates. Optimum growth conditions for *Dictyocha fibula* are 10 °C and 24‰ salinity (VAN VALKENBERG and NORRIS 1970). Temperature and salinity, lower than optimum, may result in the abnormal skeletal forms of this species often seen in shallow coastal waters due to selective dissolution of their skeletal elements (LING 1980), or possibly due to seasonal oscillations in temperature and salinity (JERKOVIĆ and KOVAČIĆ 1970). Domination of *Ds. crux* indicates a near-shore environment with a middle latitudes temperate climate (BUKRY and FOSTER 1973). Quadratic forms of Ds. *crux* and *Ds. stradneri* are evidence of sporadic influence by a colder climate or inflow of colder water into the basin (upwelling). On the basis of what has been mentioned above it could be concluded that in the area covered by these investigations at the end of the Sarmatian there were three seasonal episodes of temperate climate (»varve«). Evidence for this could also be found in the diatom population. Apart from there being a decreasing salinity of the Sarmatian sea at the end of the Sarmatian (JURILJ 1957, HAJÓS 1986, STEININGER and WESSELY 2000), Paratethys was also characterised by populations of typically marine species *Actiniscus*, (HAJÓS and REHAKOVA 1974). *Coscinodiscus oculus iridis* is a marine diatom characteristic of colder waters, as is sporadic abundance of *Thalassionema nitzschioides* known from a subpolar near-shore area (VENRICK 1971). On the basis of the open water fossil remains recovered from deposits of the deeper-water basin portions, the salinity of the water must have been higher than is usual in Sarmatian deposits. These species could have been brought into the basin in the colder part of the season, when the upwelling was established. Increases in the abundance of *T. nitzschoides* from sample 2–5 are considered to be favored in waters of temperate coastal influence; »a temperate taxon that is typically found at the seaward edge of coastal upwelling zones« (BARRON 2000). *Lyrella hennedyi* indicates tropical marine water from the same level (4 in Fig. 3), which could be explained by its distribution in warmer seasonal periods. The presence of the near-shore species (*Grammatophora* and *Navicula*) indicates turbulence in the bottom area generated by bottom currents. The following species are indicative of the marginal area of the Sarmatian sea: *Paralia sulcata, Achnanthes saeptata var. sussedana* and *Cocconeis scutellum* for subtropical / subpolar water. The connection with the Mediterranean area is demonstrated by the

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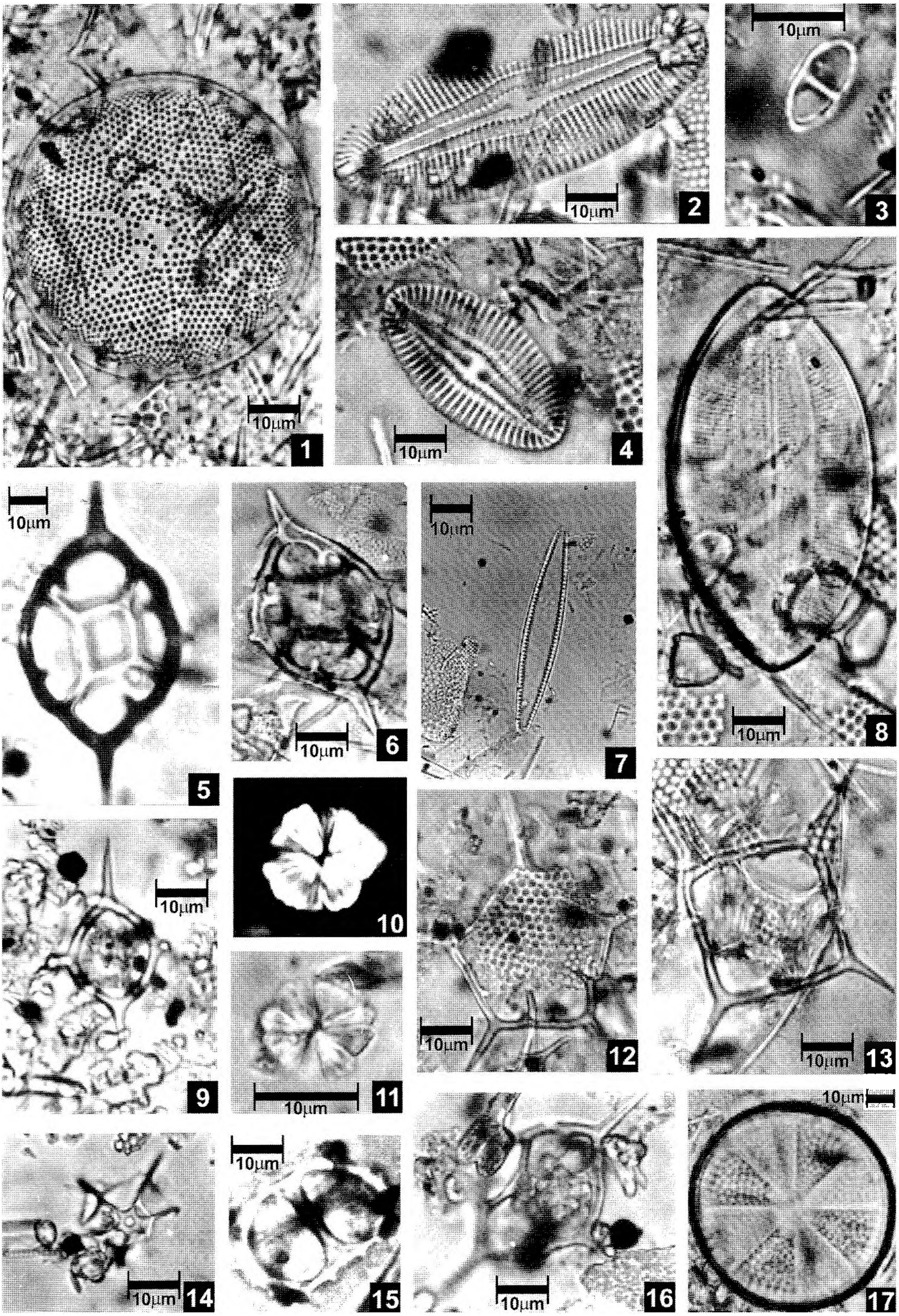
Fig. 3. The most abundant microfossils in marls and clays of Mrzljak's column. 1 – *Actinocyclus ehrenbergii var. tenella* (Brebisson) Hustedt. 2 – *Diploneis gemmatula* (Grunow) Cleve. 3 – *Anaulus simplex* Hajós. 4 – *Diploneis subovalis* Cleve. 5 – *Distephanopsis schauinslandii* (Lemmermann) Desik. and Prema. 6 – *Distephanopsis crux* (Ehrenberg) Dumitrica. 7 – *Thalassionema nitzschioides* (Grunow) Hustedt. 8 – *Lyrella hennedyi* (Smith) Stickle and Mann. 9 – *Distephanus sp. cf. Ds. longispinus* (Schulz) Bukry. 10 – »Calcareous elements«, cross nicols. 11 – »Calcareous elements«. 12 – *Distephanus sp. cf. Ds. quinquangellus* Bukry and Forester. 13 – *Distephanopsis stradneri* (Jerković) Desik and Prema. 14 – *Actiniscus pentasterias* Ehrenberg (dinofl.). 15 – *Ammodochium prismaticum* Hovasse. 16 – *Distephanus sp. cf. Ds. hannai* Bukry. 17 – *Actinoptychus senarius* (Ehr.) Ehrenberg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presence of *Actinoptychus senarius*. The domination of diatom forms (marine, brackish) in the upper layers could suggest a further decrease of salinity, near-shore water or geochemical changes in the water caused by climate and / or water currents.

Conclusion

The alternation of light and dark thin layers of »varve-like« sediments shows an alternation of reductive and oxidative phases in the basin, generated by seasonal changes of climate in an estuarine type of a semi-enclosed basin circulation. The Croatian part of Central Paratethys belongs to the boreal Sarmatian Sea, with a middle latitude temperate climate. Climatic changes might have decreased or increased the abundance of certain groups of phytoplankton in particular horizons.

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