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Interpretation of the Miocene fossils in the Strymon basin in Northern Greece to determine their habitat

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Abstract: *The sedimentary sequences of the upper Miocene in the Strymon basin in Northern Greece are composed of sedimentary rocks and are separated on an entirely new lithostratigraphic shape. Fossil-fauna has been collected from specific parts of the described geological sections, which mainly include mollusks from Bivalvia and Gastropoda. From laboratory research on the micro-fauna and micro-flora a number of taxonomic units of Foraminifera were determined and representatives of Actinozoa, Bryozoa, Crinoidea, Ostracoda, Otolithus, Diatomeae and Charophyta were found, which give a more-complete biostratigraphical image of the sediments. Based on these investigations with the use of the biofacial analysis, through the study of palaeoecology data of the fossils, three basic types of palaeohabitat and development of organisms were identified and a new palaeogeographic interpretation of the depositional environments in the Miocene basin is given.*

Keywords*:* Interpretation; Miocene fossils; Habitat; Strymon basin; Northern Greece.

Introduction

The Strymon basin occupies the northern part of Greece where Miocene sedimentary sequences are generally accessible and well exposed. They are formally subdivided into four formations in ascending order: Lefkonas Formation, Dafni Formation, Houmnikon Formation and Kriopigi Formation [16].

During the field work 22 sedimentological sections were measured (Fig.1). The 22 studied sections are geographically distributed mainly in the northwest, southeast and east of the basin.

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Fourteen of them (1-14) are located in the northern side of the Strymon basin, eight (15-22) - in its southern side, next to the Strymonikos gulf. The first seven (1-7) are located in the northwestern part, near the city of Serres and the remaining seven (8-14) are located in the northeastern part of the basin near the border with Drama field.

Their numbering was made from west to east, depending on their position in the region and their transfer on the map was made with the help of GPS.

The described sections are as follows: In the northern side,1. Section Kato Christos, 2. Section Ano Christos, 3. Section Kato Christos-Lefkonas, 4. Section Lefkonas-1, 5. Section Vissiani, 6. Section Lefkonas-2, 7. Section Perdikari,

8. Section Nea Zichni, 9. Section Tris Ierarches, 10. Section Lefkothea-1, 11. Section Lefkothea-2, 12. Section Palia Lefkothea, 13. Section Kriopigi, 14. Section Alistrati.

In the southern side, 15. Section Therma, 16. Section Kastri, 17. Section Strymon-1, 18. Section Kerdylia-2, 19. Section Kerdylia-1, 20. Section Paleokomi, 21. Section Amfipoli, 22. Section Kormista [2].

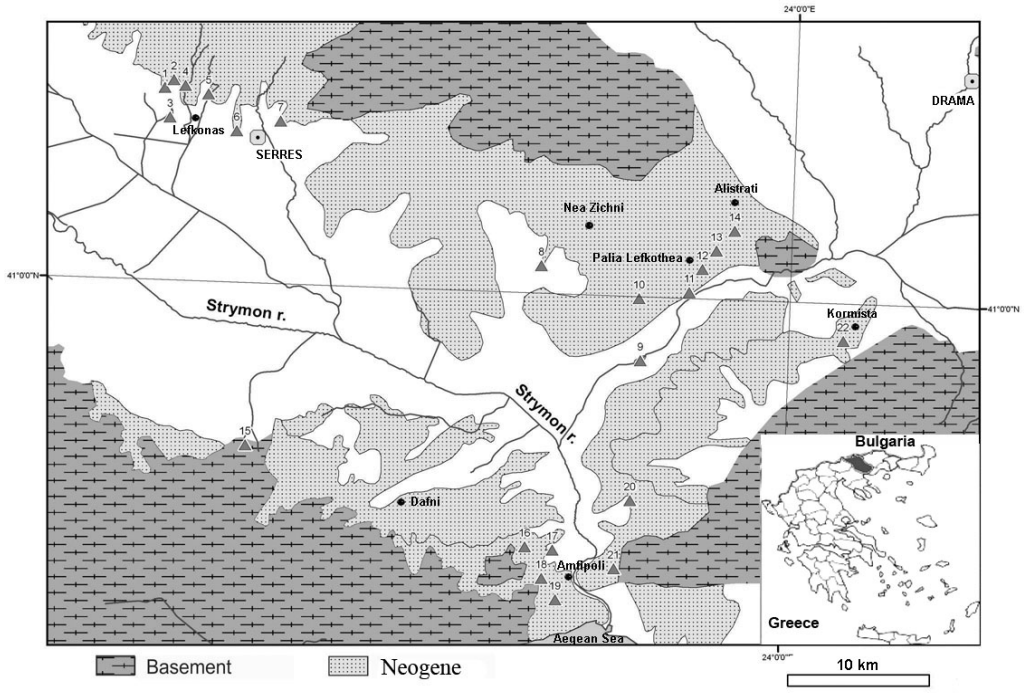

Fig.1. Simplified geological map of the Strymon basin with measured section location

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For the purpose of biofacial analysis fossil-fauna has been collected from specific parts of the described geological sections of the study area. Interpretation of the fossils was done in order to restore the living environment.

Methods of field and laboratory tests

During outdoor work standard methods of recognition, sharing and description of sedimentary rock sequences were used. They are described in packets with characteristics of the rock type and structure characteristics. The lithostratigraphic approach is used as the basis of fieldwork. The position of the fossil records is attached to packets in the sections.

In some individual packets rich macro-fauna is found and during lab work 44 taxons of the Bivalvia and Gastropoda class are defined. A total of 60 samples from 19 geological sections are examined in order to identify the micro- fauna. 200 fractions with dimensions 1.00; 0,63; 0,315; 0,25 mm are observed and 42 taxons of the Foraminifera class and a single copy of the Radiolaria class are defined.

The established foraminiferal micro-fauna contains only benthic species while planktonic Foraminifera is entirely absent. There are only single specimens of benthic Foraminifera with agglutinated shells. Almost all samples contain Ostracoda, while in some of them there are found only Ostracoda.

During the micropaleontological analysis copies of Diatomeae and Charophyta were also found.

Interpretation of the fossils in order to restore the living environment

In biofacial analysis the study of the fossils' content in the rocks is extremely important and sometimes decisive for determining the environments of sedimentation. The organic world on the one hand, is one of the main components of any physical and geographical situation today and in the geological past, and on the other hand, the organisms are closely related to the characteristics and changes of the environment in which they live and thus react to these changes.

By studying the fossils, it is possible to determine the palaeoenvironment at a certain point and its evolution over time. In bio-facial analysis it is the systematic composition of individual genera and species of organisms that must be established first, which defines the fossil biocoenosis (Fig.2).

The richness and diversity of the systematic composition of species and genera in a fossil biocoenosis, show living conditions in warm, shallow and normal salinity sea waters.

In the researched area some macro-fauna rich in systematic composition and diversity was established in the geological sections Ano Christos in p.2 to p.4, Kato Christos-Lefkonas in p.1,

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Vissiani in p.2, Perdikari in p.3, Kastri in p.1 to p.5, Kerdylia-2 in p.1 to p.2 and the whole section of Paleokomi.

It is mainly bound in the sediments of the formation Dafni, which is represented by bivalves, gastropods, ehinids, corals and shows shallow marine environments of deposition.

The waters were of normal salinity, only in places slightly refreshed and the fossil organisms lived in the littoral, sublittoral and in the shallowest parts of the neritic area, in warm waters with a minimum temperature not lower than 10°C.

The monotonous fauna, although represented by a large amount of copies shows deviations in the gas and salt regime of the basin.

In the geological sections Kato Christos (whole), Ano Christos from p.5 to p.7, Kato Christos-Lefkonas in p.2, Lefkonas-1 from p.2 to p.3, Vissiani in p.3, the whole section Lefkonas- 2, Perdikari from p.4 to p.12, the whole sections of Nea Zichni, Tris Ierarches, Lefkothea-1 and Lefkothea-2, the whole section Terma, Kastri from p.6 to p.9, the whole section Strymon-1, Kerdylia-2 from p.3 to p.8 and the whole section of Kerdilya-1, the sediments are attached to Houmnikon formation.

In these sediments rich in specimens but poor in systematic composition macro-fauna is defined, represented mainly by bivalves and less by gastropods.

Also micro-fauna and micro-flora represented mainly by identical foraminifera, with the presence of only two genera (in the sediments of p.4 and p.5 in section Ano Christos), and Charophyta (at the sediments in p.3 in section Lefkonas-1 and in the sediments of p.1 in section Kerdylia-1).

The shape and sizes of the organisms, the thickness and dimensions of their shell, their preservation, orientation and sorting in the rocks, are the main signs which are examined for establishing the living environment and deposition.

In tropical seas organisms are larger in dimensions (Kato Christos-Lefkonas, p.1, Vissiani, p.2) and with thicker, richly ornamented shells, but in cold water they are with small and thin shells.

Well decorated and highly sculpted forms are characteristic for Coastal quite shallow marine conditions (Kato Christos-Lefkonas, p.1, Vissiani, p.2, Lefkothea-1, p.2), while those living in deep-sea environments are slightly or not ornamented at all.

The sorting of organisms is also an important genetic indication, as in the beach zone mussel shells are turned with the convex part up (section Perdikari, p.8). Elongated shell fossils are indicators of the direction of transport, as if they are arranged in one direction, their sharp end is always in the direction of the flow.

They show the position of the coast-line when they are deposited parallel to one another, but their tapered end is in a different direction. Organismal remains may be distributed evenly or be

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attached to strictly defined layers, indicating the existence of particularly favourable living conditions during the precipitation of this layer (Lefkonas-1, p.3, organogenic sandy limestones, Lefkonas-2, p.7, detritus limestones, Lefkothea-2, p.3, shell limestones, Terma, p.8, organogenic limestones, Kastri, p.5, organogenic limestones, Strymon-1, p.6, organogenic limestones, Kerdilya-2, p.2, dense limestones).

The most part of the defined in the surveyed sections fossils, of class Bivalvia, and Gastropoda are attached to a particular living habitat, showing depth and salinity of the basin of living, preference of substrate, of water temperature, of streams, content of oxygen and other factors of the abiotic environment [1],[27], [22].

Fig.2. List of designated fauna and flora

Bivalvia: *Dreissena (Modiolodreissena) simplex, Dreissena (Dreissena) tenuissima tenuissima,Congeria (Andrusoviconcha)* cf. *Navicula, Dreissena* sp.

Congeria (Rhombocongeria) cf. *Subrhomboidea, Congeria (Mytilopsis)* ex. gr. *Balatonica, Congeria (Andrusoviconcha) navicula, Dreissena rostiformis corniculata, Callista* cf. *Chione,* Veneridae sp. Indet, *Parvivenus widhalmi*

Cardita (Cardita) calyculata, Cardiidae sp. indet., *Limnocardium (Euxinicardium) subodessae, Eupatorina littoralis, Paradacna abichi abichiformis, Pseudocatilus pseudocatilus, Anadara (Anadara)* sp., *Anadara (Anadara)* sp. aff. *diluvii* Plagiodacna *arcaeformis, Anomia ephippium, Lutraria (Lutraria) lutraria, Pecten (Oppenheimopecten)* cf. *Aduncus, Chama gryphoides gryphoides*

*Abra tellinoides***,** *Musculus* sp. indet., *Ostrea* sp., *Abra* sp. indet., *Pycnodonte* sp. *Crassostrea gryphoides, Cerastoderma arcella mithridatis.*

Gastropoda: *Diodora graeca, Theodoxus* ex. gr. *Micans, Valvata* sp.**,** *Kosovia bouei*

Viviparus (Viviparus) viquesneli, Melanopsis sp. indet., *Melanopsis impressa*

Melanopsis cf. *impressa, Alvania* sp., *Cerithiella* sp., *Gyraulus (Gyraulus)* sp.

Nassarius (Hinia) sp., *Triphora* cf. *Perversa.*

Foraminifera: *Sinoloculina consobrina, Ammonia beccari, Borelis mello*

Quinqueloculina sp., *Cycloforina* sp., *Triloculina inflata* var. *meotica*

Elphidium crispum, Elphidium macellum, Asterigerina aff. *planorbis*

Porosononion subgranosum, Porosononion sp., Miliolidae, *Miliolina* sp.

Porosononion granosum, Pseudotrilogulina consobrina, Triloqulina sp.

Cornuspira sp., *Hauerina* sp., *Nodobaculariella* sp., *Cycloforina* aff. *gracilis*

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Discorbis sp., *Spirolina* sp., *Elphidium* sp., *Cibicides badenensis, Affinetrina* aff. *Voloschinovae, Baggina* sp., *Pseudotriloculina nitens, Gyroidina soldani*
Heterolepa dutempley, Cibicides lobatulus, Eponides sp., *Pyrgo bulloides*
Planulina sp., *Amphistegina sp., Nonion bogdanowiczi, Dendritina* sp.
Protelphidium aff. *Martkobii*, *Amphicorina badenensis.*
Radiolaria: *Radiolaria* sp.
Other: Bryozoa, Crinoidea, Ostracoda, Otolithus
Diatomeae : *Aulacoseira* sp.
Charophyta : *Chara* sp.

Life conditions of the defined fauna

In the study of the Miocene sediments, the defined fossil fauna from precisely marked levels of the above mentioned geological sections in the studied area, also showed the conditions of its life.

The representatives of the genus *Anomia* of the determined macro-fauna of these sediments inhabit rocky, pebble, sandy or shell detritus substratum in seas with normal salinity. They do not tolerate significant refresh of the waters. They are usually found in the upper part of the sublittoral (to 130 m), rarely in significant depths (to 2000m). Mass populations are at a depth of 2-3 to 10-15 m. Eurythermal organisms.

Lutraria are free infaunal sestonophagous with two siphons. They inhabit sandy, sandy-clay or clay-limestone substratum to a depth of 0-50 m, rarely more, in normal saline waters. Moderate, eurythermal, stenooxybiotical organisms. *L. lutraria* is met from several m. (Coastal detritus bottom) to circalittoral included, predominantly in sandy substratum and normal salinity and positive temperatures. It does tolerate some fluctuations in salinity and water temperature.

The representatives of the genus *Pecten* are with byssal foramen and were attached in the early stages of ontogenesis. In most cases they lose this property in the adult stage of development and become one of the most mobile forms of marine benthos.

They are met in a diverse substratum-sandy, sandy-clay with gravel, clay, but mostly in sandy and sandy-clay. These are epifaunal, sestonophagous organisms.

They live at various depths-from littoral to about 900m, mostly from 10 to 40-50m in seas with warm to temperate waters.

Most species do not tolerate significant refresh of the water. They live in well-aerated waters and are sensitive to oxygen deficiency. They prefer areas influenced by sea currents, but avoid the surf.

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Anadara (Anadara) sp., possess adaptive convergence regarding their situation with respect to the substratum and mobility. Some species are free skin-deep burrowing infaunal sestonophagous, others with epibyssal foramen.

This affects the morphology and L/H ratio of the shell. The infaunals have short rounded shell and L/H <1,35. These with byssal foramen– L/H>1,35, while the half-buried L / H = 1,35. They are found exclusively in sandy substratum at 0-50 m depth, rarely at up to 130m.

They prefer normal salinity, but some species tolerate refresh rate to 24‰. Most of them love warm, calm waters. They bear considerable oxygen deficit.

The representatives of the genus *Cardita* are typical sestonophagous organisms. The absence of siphons shows that they are typical epifaunal forms. They inhabit sandy, gravy and rock-bound substratum in not great depths (1-180 m, usually 30-50m. Most of them are relatively thermophilic, but there exist cryophylic as well. Stenohaline (normal ocean salinity 32-35‰). They inhabit waters with relatively intense hydrodynamics.

Chama gryphoides are rigidly attached epifaunal sestonofagous organisms. They are mostly found on a solid substratum, rock-bound, sandy with shell detritus. They inhabit warm waters with normal or slightly reduced (to 25‰) salinity, to a depth of some to 30m, rarely more, in significant water dynamics. *Chama gryphoides* live mainly in infralittoral zone in tropical and subtropical seas and in contemporary seas mainly in shallow waters (2-15 m), rarely up to 30 m.

The representatives of the Ostreidae family are cement-attached to the bottom with their left shaft, which often repeats its unevenness. These are also epifaunal sestonofagous organisms.

They live on a solid substrate, rocks and even a sealed sandy clay base, usually at a small depth (0.5-50m), rarely deeper. They inhabit water with normal salinity, but they develop very well with varying degrees of refreshment. They are also found in refreshed bays.

As salinity increases, the shells become smaller, sharper and jagged. In periods of decreased salinity, ostreids grow rapidly, forming grape colonies of elongated, thinner specimens. They are adapted to short-term O_2 deficiency and even to the presence of considerable amounts of H_2S. Thermophilic. They occupy sections under more or less influence of strong currents.

The representatives of the genus *Pycnodonte* live in deep waters.

The representatives of the genus *Musculus* are epibyssal foramen sestonophagous eurychaline organisms. They can tolerate refreshment up to 20-15‰. Eurybatic, typically found in depths from 0-5 to 200m, and some species up to 250m (*M. discors*). They inhabit diverse substrates, stony, sandy, clay-sandy, sandy clays with clayey detritus, clayey. The majority of species are eurythermic (the contemporary - cryophilic). They tolerate certain oxygen deficiency.

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Crassostrea gryphoides are predominantly found on sandy and sandy limestone substrates in an infralittoral zone in brackish waters.

The contemporary *C. Virginica* live in up to 27m depth, with water salinity not lower than 15 and not higher than 30‰ (optimum for breeding 15-19‰), at a temperature of 0 to 32° C as below 5° C they stop feeding.

Cerastoderma arcella mithridatis are free infanual sestonophagous organisms with two siphons. They inhabit mostly sandy or clayey substrate at a depth of 0-100m. Eurychaline, they tolerate salinity from 60 to 5‰, some species up to 2.5 ‰. They do not tolerate oxygen deficiency. They occur both in subtropical and in boreal seas.

The representatives of the genus *Abra* are deep-burying (up to 5 times the length of the shell) infaunal detritofagous with siphons. They inhabit predominantly clayey or clay-sandy substratum of varying depths (5 to 450m, but the Neogene to 200m, rarely more). Most populations are in quiet areas (calm conditions or moderate depth). Eurychaline (70-4‰), eurythermiic and eury-oxibionate.

The representatives of the genus *Alvania* are free-moving epiphaunal phytophagous organisms. They inhabit from hard to soft substrate in the upper part of the sublittoral, in saline waters of normal to 18 ‰ and moderate hydrodynamics. Eurytermic and steno-oxybionate.

Triphora are species that live buried in the substrate.

The representatives of *Spirolina sp*. of the micro fauna live at depths not exceeding 40-50m. [7], relatively shallow waters with salinity close to normal [5].

The presence of the genus *Borelis* shows a wide connection of the basin where they live, with the open sea. [21]. Taxa *Borelis mello* and *Spirolina sp.* of the micro fauna were found in the sediments of p.2 at the section of Kerdylia-2 and the taxon Spirolina sp. in the sediments of p.3 at the section Perdicari, belonging to the Dafni formation.

This confirms, along with the data of the macro fauna, that the sediments of this lithostratigraphic unit have been deposited in an environment with normal salinity, shallow and warm sea waters.

The next identified monotonous fauna shows life in waters with reduced salinity, small depth, and sometimes in calm and rather deep waters. It is found entirely in the sediments of the Hoummiko formation and shows the gradual transition from normal salty shallow conditions of deposition to refreshed (brackish).

Contemporary representatives of the genus *Dreissena* are byssus-attached sestonophagous organisms. They predominantly inhabit shallow waters, but some can also be met at up to 200-250 m. depth. They prefer a compacted substrate or one with a mixture of hard particles. Brackish forms - they

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live at salinity of no more than 16 ‰, but the range of tolerance in individual populations is too narrow. They prefer clean water, poor in organic detritus and are too sensitive to O_2 content.

Most species of subgenus *C.(Mytilopsis),* some of subgenus *C.(Andrusoviconcha)* and *C.(Rhombocongeria)* are epifaunal byssus-attached sestonopfagus organisms. Subgenus *C.(Congeria)* and some *C.(Rhombocongeria)* are free-footed. The majority of *Congeria* inhabit shallow waters at a depth of several to the first tens of meters, rarely up to 300m. Subgenus *C.Mytilopsis* is found in coastal areas with compacted substrate. The rest of them prefer deeper and calmer waters and a softer substrate. Extremely eurychaline, they prefer refreshed or fresh waters. The majority of the dead species are eurythermic organisms.

Probably, some living in deeper water can suffer a certain deficiency of O_2 *(Congeria s.str.).* With the prevalence of sea conditions in the Paratethys basins, the *Congeria* lived in shallow water refractory, refreshed lagoons and river deltas.

Contemporary *Congeria* are byssus-attached. They live in rivers, lakes and refreshed lagoons and deltas. They are a little more eurythermic than contemporary *Dreissena.*

Parvivenus widhalmi in the Euxinian part is found on shallow-water communities developed on shellfish, clay-shell, rarely sandy or clay-sandy substrate. It is found along with *Prosodacna litoralis, Pseudocatilus pseudocatilus, Dreissena simplex, etc.*, as well as with deeperwater communities developed on a clay substrate with the predominance of *Paradacna abichi* and *Congeria digitifera.*

Lymnocardium (Euxinicardium) subodessae are infaunal sestonophagous organisms, living in shallow waters, inhabiting detritus-shell, sandy, clay-shell, clay-sandy substrate. They live in conditions of reduced salinity and under normal O_2 regime. Eurythermic organisms.

The representatives of *Pseudocatillus pseudocatillus* are infaunal sestonophagous forms. At a considerable depth, they live in a clay substrate, but in highly refreshed water they live along with eurychaline freshwater forms. They can tolerate a certain oxygen deficiency. Eurythermic organisms.

Paradacna abichi abichiformis are more shallowly self burying infaunal sestonophagus forms. They live in conditions of reduced salinity. They can tolerate a certain oxygen deficiency. Eurythermic organisms.

The representatives of *Eupatorina littoralis* live in shallow waters, in a detritus-shell, sandy, clay-shell, clay-sandy substrate. They live in heavily refreshed water along with eurychaline freshwater forms and under normal O_2 regime. Eurythermic organisms.

Plagiodacna arcaeformis are epiphaunal sestonophagous organisms. They rest on the front of the shell and are positioned at an angle to the substrate. They are shallow-water organisms inhabiting a

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detritus-shell, sandy, clay-shell, clay-sandy substrate. They live in conditions of reduced salinity and under normal O_2 regime. Eurythermic organisms.

Diodora are usually attached to the leaves of the underwater macro flora. Phytophagous. Freely moving in search of food but returning to the point of attachment. They inhabit rocky shores, at a shallow depth which do not drain at tide. They live under normal sea salinity, but most species can tolerate a refreshment to 21‰. Eurythermic, but with a wide tolerance range with regard to the temperature of the environment (today are massive in the northern seas). Stenooxybionate.

The representatives of *Theodoxus* are free-moving phytophagous organisms. They inhabit a hard substrate of brackish and fresh water at depths of up to 40-60m in moderate to high hydrodynamics. Eurythermic organisms, stenooxybionate.

Contemporary *Viviparus* inhabit a variety of freshwater ponds with running or stagnant water at depths of several centimeters to ten meters. They can tolerate a minimum temporary salinity increase of up to 3‰. Freely moving, underlying organisms, living on clay, sandy, clay-sandy or muddy bottom. They are usually displaced in the areas of aquatic macro-flora. Phytophagous-necrophagous and Eurythermic organisms. In fast-water basins, flat shells with flat turns are predominant.

The representatives of the genus *Valvata* are free-flowing phytophagous-detritophagous organisms. In the winter they are buried in the mud.

They live in flowing or stagnant fresh waters on the plants or on the sealing substrate at low depths. Eurythermic organisms, stenooxybionate.

The majority of contemporary *Melanopsis* lives in rivers and streams with rapid and strong currents. They are free-moving phytophagous-detritophagous organisms living on solid and compact substrates. Relatively eurythermic organisms. Stenooxybionate. *M. impressa* is a polytype species known from freshwater and brakish sediments of Neogene in Europe.

Cerithiopsis are free-moving predators. They inhabit clayey and clay-shell substrate at salinity of waters from normal to 18-16 ‰ at depths up to 100m. Eurythermic organisms. They prefer moderate hydrodynamics. Stenooxybionate.

Nassarius are freely moving predators and necrophagous which do not pierce the victim's shell. Epifaunal, but they also spend considerable time buried in the substrate (in faunal) in anticipation of their victim. They are met at a diverse substrate, but they prefer clayey sand or shell substrate. They are mostly shallow forms (0-80m), some up to 300m. Eurychaline (from 37 to 10‰). The majority is eurythermic, but they also occur in the boreal area. Stenooxybionate.

At the same levels with the macro-faunal representatives, many microfossils have been found, with mass recrystallization on the majority, most of which are foraminifers and ostrakods. All the

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extracted foraminifers are benthic and their composition found in the sections of the studied field is very poor and monotonus in genus and species.

From the benthic foraminifers, singular specimens with agglutinated shells were observed at the sections of Kormista, p.2 and Nea Zihni, p.2. The limited genus composition suggests a possible decrease in salinity of the basin [14]. Most of the designated foraminifers are eurychalins and very easily adaptable in different habitat environments.

The representatives of Miliolidae in contemporary seas inhabit the inner shelf and the open areas in warm tropical and subtropical waters at a depth of 0 to 100m [12]. Their most widespread development is in seas with normal salinity, but they can adapt well also into reduced salinity basins [5].

Many representatives of *Elphidium* are eurychalins are commonly found at shallow depths, coastal facies and sometimes they are the only foraminiferous fauna of lagoons [29]. Easily adaptable to reduced salinity, along with *Porosononion* and to shallower basins [13].

Taxon *Amonia beccari* can occur both in marine environment and into reduced salinity and freshwater basins. The species is known from the contemporary Black and Caspian Sea. It is also known from the refreshed parts of the North Sea [15]. Widespread species in sea basins, lagoons, estuaries and other shallow water basins [28].

In the upper parts of the Houmnikon formation and more precisely at the sections of Lefkonas-1 and Kerdylia-1, *Chara sp.*, algae have been found, indicating a freshwater lake of sedimentation. This fact shows that gradually the waters were refreshed and the overlying Kriopigi formation was entirely deposited into a lake environment. This is evidenced by the found diatom fossil flora, which typically indicate fresh water.

In the sections of Palia Lefkothea (whole), Kriopigi at p.9 and the entire sections of Amphipoli and Kormista, which are attached to the Kriopigi formation, there was also found a certain rich in places, but very poor in systematic composition micro-flora, represented only by the *g. Aulacoseira* indicating a freshwater habitat.

In the samples from these sections examined for micro-fauna, there is no fauna at all, a fact possibly associated with freshwater facies.

All these data on ecological habitat preferences, from macro-faunal and micro-faunal representatives found in the sediments into the packets of the sections belonging to the Houmnikon formation, confirm that these deposits were formed in an environment with reduced salinity and a tendency of gradual refreshing, a fact proven by the freshwater facies in which the sediments of the overlying Kriopigi formation have been deposited.

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Results and discussion

During the elaboration of this work a thorough study of the upper Miocene sequences in the Strymon basin was carried out while at the same time a paleogeographic interpretation of the conditions of sediment deposition in the Miocene basin and the fossil fauna was identified.

Based on the study of fossils of bivalvia, gastropoda, diatomea and foraminifera, the chronostratigraphic range of Neogene sediments in the Strymon basin is specified. The specified fossils are attached to precisely marked levels in the described sections. The Neogen sediments in the area under study are shared on the Maeotian and Pontian stage.

For the first time, 22 sections were described in the Strymon basin, 17 of them are new, 2 were completed or refined and 3 are given schematically without being described in detail.

The new sections are: Kato Christos, Kato Christos Lefkonas, Lefkonas-1, Vishiani, Lefkona-2, Nea Zichini, Lefkothea-1, Lefkothea-2, Palia Lefkothea, Kriopigi, 1, Amphipoli and Kormista, the completed are Paleocomi and Tris Hierarches. The sections of Ano Christos, Perdicari, and Kerdila-2 are given schematically by Karistineos (1984) and Syrides (1998).

Conclusion

As a result, from the study of the palaeoecology data, for the first time a biofacial analysis of the specified macro- and micro-fossils was conducted and three basic types of habitat environments and development of organisms were identified.

1st type: Shelf's environment habitat with a depth of 2-3 m to 150-200 m, with a normal salinity, slightly reduced to 25-20 ‰, with warm to moderately warm waters with a minimum temperature of not less than 10ºC.

The habitat was a well aerated zone, but sometimes somewhat deficient in oxygen, having moderate to intense hydrodynamics of water and a diverse composition of the seabed substrate. This environment is characterized by the presence of bivalves: *Crassostrea gryfoides, Anomia ephippium, Lutraria (Lutraria) lutraria, Anadara (Anadara) sp.* and gastropods: *Triphora cf. Perversa.*

2nd type: The habitat of this type of environment is characterized by deeper water reaching up to 300m, a reduced salinity of 20-16 ‰ to 10 ‰, a tendency of

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the waters to be refreshed in areas with the salinity not exceeding a percentage of 3 ‰. The water was moderately warm to cool, with a normal oxygen regime, but in
places with little to large tolerance of its deficiency.

The composition of the substrate was varied and the hydrodynamics of the water ranged between moderate and high. In this environment, predominates the presence of bivalves: *Limnocardium (Euxinicardium) subodessae, Paradacna abichi abichiformis, Pseudocatilus pseudocatilus* and gastropods: *Melanopsis impressa*.

3rd type: This type of habitat is characterized by fresh, comparatively shallow to deeper, calm waters and a clay-calcitic substrate and is characterized by the presence of Charophyta *Chara sp*. and Diatomeae represented by the *Aulacoseira sp.*

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References

[1]. Bagdasaryan, K.; et.al., “Spravochnik po ekologii morskikh dvustvorok”, *Nauka, Moskva,* **1966,** 5-352.

[2]. Beratis, I., “Stratigraphy and Palaeoenvironments of the Neogene sediments in the Strymon basin in Northern Greece”, *PhD thesis, Faculty of Geology and Geografy, Department of Geology, Paleontology and Fossil Fuels, University of Sofia Sant Kl.Ochridski, (in Bulgarian)* **2011**, 162 p.

[3]. Beratis, I.; Kojumdgieva, E., **“**Deux gisements neogenes dans le basin de Serres (Gréce Septentrionale) et leur faune de Mollusques”, *Bulgarian Academy of Sciences. Palaeontology, Stratigraphy, and Lithology, 1 Pl., Sofia,* **1988,** *25,* 27-36,

Corresponding author: beratioan@gmail.com

DOI: 10.2478/asn-2019-0024

[4]. Boger, H.; Dermitzakis, M., "Neogen Palaeogeography in the central Aegean region" *Ann.Inst.Geol. Publ. Hung. Budapestini,***1987,** *LXX.*, 217-220.

[5]. Bogdanovich, A.K., "Miliolidy I Peneroplidy – Isk. Foraminiferi" *SSSR. Tr. BNIGRI, nov. Ser., Leningrad,* **1952,** *64,* 334

[6]. Dermitzakis, M.; Georgiades-Dikeoulia, E., **"**Biostratigraphic and chronostratigraphic correlations of the late Cenozoic bivalves of the Hellenic area", *Ann. Geol. Pays Hellen, Athens,* **1984,** *XXXII,* 197-209.

[7]. Didkovsukiy, V.YA., "Vikopni peneroplidi Pivdennozakhdnoi shastini Ryadansukogo soyuzu", *Tr. Ins. geol. nauk. ANURSR, Kiiv, str. Nal.,* **1959,** *28,* 69.

[8]. Gramman, F., **„**Das Neogen im Strimon-Becken (Griechisch-Ostmazedonien), Teil II Ostracoden und foraminiferen aus dem Neogen des Strimon-Beckens", *Geol. Jb. 87, 2 Abb., 6 Taf. Hannover,* **1969,** *S,* 485-528.

[9]. Gramman, F.; Kockel, F., **„**Das Neogen im Strimonbecken (Griechisch-Ostmazedonien)", *Geol. Jb., B 87, Hannover,* **1969**, *S,* 445-484.

[10]. Karistineos, N.; Ioakim, C., "Palaeoenvironmental and palaeoclimatic evolution of the Serres basin (N. Greece) During the Miocene", *Pal. Pal. Pal.,* **1989,** *70,* 275-285.

[11]. Kojumdgieva, E., **"**Evolution geodynamique du basin Egeen pendant le Miocene Superieur et ses relations a la Paratethys Orientale", *Geol. Balc., Sofia,* **1987,** *17,* No 1, 3-14.

[12]. Luczkovska, E., **"**Miliolidae Foraminifera from the Miocene of Poland. - *Part II", Biostratygraphy, palaeoecology and Systematics, Acta Paleon. Warszawa, Polonica,* **1974,** *19(1),* 3-176.

[13]. Maysuradze, L. S., "Foraminifery sarmata Zapadnoy Gruziy", *Izd. "Metshnireba" Tbilisi,* **1971,** 115.

[14]. Maysuradze, L. S., "K Paleobiologicheskoy istorii foraminifery pozdnego miotshena chernomorsko-kaspiysko basseyna", *Izd. "Metshnireba" Tbilisi,* **1980,** 106.

[15]. Myatlyuk, E., "Spirilinidy, Rotaliidy, Epistominidy I Asterigerinidy. Isk. Foraminifery SSSR", *Leningrad,* **1953,** *71,* 261.

[16]. Pimpirev, Chr.; Beratis,I., "Lithostratigraphy of the Miocene sedimentary sequences in strymon basin, northern Greece", *Comptes rendus de l'Académie bulgare des Scienses, Geologie, Stratigraphy, Sofia,* **2010**, *63(8),*1177-1190.

[17]. Popov, S.V.; Georgiades-Dikeoulia, E.; Pinchuk, T.N., "Pontian of the Aegean region", *Materials of Symposium Neogene Stratigraphy and palaeontology of Kerch and Taman Peninsulas, Russian Committee for IGCP.* **1996,** 31-34.

Corresponding author: beratioan@gmail.com

DOI: 10.2478/asn-2019-0024

[18]. Popov, S.; Nevesskaya, L., **"**Late Miocene Brackish-Water Mollusks and the History of the Aegean Basin", *Stratigraphy and Geological Correlation, 8, (in Russian),* **2000,** *2,* 97-107.

[19]. Popov, S.V.; et al., **"**Late Miocene to Pliocene palaeogeography of the Paratethys and its relation to the Mediterranian", *Palaeogeography, Palaeoclimatology, Palaeoecology,* **2006,** *238,* 91-106.

[20]. Psilovikos, A.; Syrides, G., **"**Stratigraphy, Sedimentation and palaeogeography of the Strymon Basin, Eastern Macedonia/Northern Aegean Sea, Greece", *Clausthaler Geol. Abhandlungen,* **1983,** *44,* 55-87.

[21]. Serova, M.YA., "Stratigrafiya I fauna foraminifer Miotshenovykh otlozheniy Predkarpatuya. B", *Materialy po biostratigrafii zapadnykh oblastey Ukrainskoy SSSR, Moskva,* **1955,** 261-394.

[22]. Stanley, S.M., **"**Relation of Shell Form to life Habits of the Bivalvia (Mollusca): *The Geological Society of America, Memoir,* **1970,** *125,* 1-296.

[23]. Syrides, G., **"**Preliminary report on a new locality with Neogene mollusk fauna from Strymonikos gulf (Macedonia, Greece)", *Bull. Geol. Soc. Greece, Vol. XXVIII/3 Athens,* **1993,** pag.145-149.

[24]. Syrides, G., **"**Neogene mollusk faunas from Strymon basin, Macedonia, Greece", *First results for biochronology and palaeoenvironment. Geobios,* **1995,** *M.S. 18,* 381-388.

[25]. Syrides, G. Paratethyan mollusk faunas from the Neogene of Macedonia and Thrace, Northern Greece. *Rom. J. Stratigraphy, 78, Bucuresti,* **1998,** p. 171-180.

[26]. Syrides, G. Neogene marine cycles in Strymon basin, Macedonia, Greece. *Geological Society of Greece, Special Publication, No 9,* **2000,** 217-225.

[27]. Tatishvili, K.; et. al., "Spravochnik po ekologii morskikh bryukhonogikh", *Nauka, Moskva,* **1968,** 5-169.

[28]. Venglinsukiy, I.V., "Foraminiferi Miotshenu Zakarpattya", *Izd. AN URSR, Kiiv,* **1958,** 167

[29]. Voloshinova, H.A.; Dain, L.G., "Nonionidy, Kassidulinidy I Khilostomellidy, - Isk. Foraminifery *SSSR"., Tr. VNIGRI, Leningrad, nov. Ser.,* **1952,** *63,* 139.

[30]. Zagortcev, I.; Ognianova-Roumenova, N., "First finds of diatom clay and silt in the Neogene filling of the Serres graben, Struma rift, northern Greece", *Geol. Soc.Greece, Sp. Publ., No 4, Proceedings of the XV Congress of the Carpatho-Balcan Geological Association, Athens,* **1995,** 304-310.

[31]. Zagortcev, I.; Ognianova, N.; Stoykova, K.; Dimadis. L., **"**Pontian lagustrine regimes and marine ingressions in the Strymon area, northern Greece", *Geologica Carpathica, Special Issue-Proceedings of the XVII th Congress Carpatho-Balcan Geological Association,* **2002,** 53- 58.

Corresponding author: beratioan@gmail.com

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