RECONSTRUCTION OF THE MARINE PALEO-HABITAT OF DOBROGEA/DOBRUDJA AREA FROM THE TRIASSIC PERIOD

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ABSTRACT

This article analyzes a method for reconstructing the marine paleo-habitat from the Triassic Period in Dobrogea. A reconstruction of a paleo-habitat, in general, requires a good understanding of the natural setting and the living conditions of the animal organisms that are representative of it. To realize that, it was necessary to use the free Quantum GIS (QGIS) application, designed for data processing in a GIS environment, and the SQLite file format for temporary data storage. Data processing provided a general picture of the northwestern boundary of the Paleo-Tethys Ocean, an area with shallow, warm waters (temperatures of 20-25°C), medium salinity, well-aerated conditions, and a generally sandy substrate.

RÉSUMÉ: Reconstruction du paleo-habitat marin dans la région de Dobrogea/Dobrudja à partir de la période triasique.

Cet article analyse une méthode de reconstitution du paleo-habitat marin triasique en Dobrogea. Reconstituer un paleo-habitat nécessite généralement une bonne compréhension du milieu naturel et des conditions de vie des organismes animaux qui le représentent. Pour atteindre cet objectif, il a été nécessaire d'utiliser l'application gratuite Quantum GIS (QGIS), conçue pour le traitement des données dans un environnement SIG, et le format de fichier SQLite pour le stockage temporaire des données. Le traitement des données a permis d'obtenir une image générale de la limite nord-ouest de l'océan Paleo-Téthys, une zone aux eaux peu profondes et chaudes (températures de 20-25°C), à la salinité moyenne, bien aérées et au substrat généralement sableux.

REZUMAT: Reconstituirea paleo-habitatului marin din zona Dobrogei/Dobrudja din perioada triasică.

Acest articol analizează o metodă de reconstituire a habitatului marin din perioada triasică din Dobrogea. Reconstituirea unui habitat, în general, necesită o bună înțelegere a cadrului natural și a condițiilor de viață ale organismelor animale reprezentative pentru acesta. Aceasta implică acumularea unui volum semnificativ de informații care trebuie analizate și procesate. Pentru realizarea acesteia, a fost necesară utilizarea aplicației gratuite Quantum GIS (QGIS), concepută pentru prelucrarea datelor într-un mediu GIS, și a formatului de fișier SQLite pentru stocarea temporară a datelor. Prelucrarea datelor a oferit o imagine generală a limitei de nord-vest a Oceanului Paleo-Tethys, o zonă cu ape puțin adânci, calde (temperaturi de 20-25°C), salinitate medie, condiții bune de aerare și un substrat în general nisipos.

INTRODUCTION

For the past 18 years, I have aspired to achieve a spatial distribution of fossil species within "Gavrilă Simion" Eco-Museum Research Institute, which would allow us to reconstruct the paleo-habitat of Dobrogea across various geological periods. One of the primary challenges we faced was the lack of a free and open-source spatial database format capable of accommodating 255-character fields and provide good data security. These requirements were extremely important for accurately storing data about our studied specimens.

Thus, we were very happy to discover that the latest version of the SpatiaLite database offers all the necessary conditions to achieve this desire. This development is significant; without spatial data concerning the distribution of the fauna species identified in our museum, any effort to reconstruct the paleo-habitat of the Triassic Period would have been impossible.

To begin, only 80 pieces from the Paleontology sub-collection – those displayed in "The Testimonies from the Depths of the Paleo-seas" exhibition – were added to the SQLite spatial database. Later, after all elements from the sub-collection are included in the SQLite vector spatial database, the data will be exported through QGIS to a PostgreSQL object-oriented relational database and a free replacement for Oracle database. For now, however, only the data within the SQLite vector spatial database were analyzed and mathematically processed.

The next step in reconstructing the Triassic paleo-habitat was the identification of the living paleo-habitat for the exposed species. At the same time, the period in which they are believed to have lived was also identified. This stage is important because the values necessary for mathematical processing have been obtained.

MATERIAL AND METHODS

In this study, the **first step** was to transfer information regarding the Geology-Paleontology Collection from paper format (on the collection notebook) to electronic format within the DOCPAT database, which was developed based on the Microsoft Access application by specialists from the National Institute of Heritage (formerly cIMeC – Institute of Cultural Memory).

The **second step** was to extract data from the DOCPAT database using Access's export function to Microsoft Excel format. This was followed by selecting only the necessary information in Excel or LibreOffice Calc and then exporting it, along with the table header, to a separate file. This stage also involved a joint effort with Ms. Iuliana Varvara Poștaru, curator of the Geology-Paleontology Collection, to select the representative samples presented in the exhibition "The Testimonies from the Depths of the Paleo-seas". These selected samples were the central subject of this study.

The **third step** involved downloading the Geological Map of Romania from 1964-1968 (scale 1:200,000) and the contour of Romania, in polygon vector shapefile format, both from the geo-spatial.org website (*; **). The downloaded datasets were georeferenced in the Stereo 70 projection system (the 1970 Stereographic projection, with a Black Sea – referenced elevation system, is the official cartographic projection of Romania, adopted in 1973, replacing the old Gauss-Kruger projection). Also at this stage, both cartographic materials were imported into Quantum GIS (QGIS). Subsequently, a "Clip Raster by Mask Layer" operation was performed using the vector layer with the outline of Romania as a mask, setting the areas outside the mask to a "no data" value of –9999.

In the **fourth step**, a new QGIS project was initiated that initially contained only the Geological Map of Romania (***), cropped. Subsequently, a spatial database was created by right-clicking on the “SpatiaLite” option in the Browser panel. After creating it, again from the Browser panel, after right-clicking on the new database, the “New Layer” option was selected. This action opened a dialog box that allowed us to choose the type of vector layer desired. In our case, point vectors were selected and we then proceeded to create the table header, correlating it with the DOCPAT database structure. Finally, the newly created point vector layer was loaded into the Layers panel. Based on the information from the MS Excel file, created after DOCPAT 2000 data and the Geological Map of Romania, we located the position of each individual fossil sample on the map. Once the sample locations were fixed, the corresponding attributes for each representative sample were also entered.

The **fifth step** was critical, involving querying Internet databases to gather information on the paleo-habitat of each species and the information about the geological period characteristic of each species. The data gather by querying the Internet were compared with those obtained based on sites Ammonites et aliae spirae II (****), mindat.org (*****), GBIF (******), The Paleobiology Database (*******) and International Chronostratigraphic Chart (********) respectively. This data was integrated into spatial database. The entry of this data also facilitated the verification of fossil determinations and the numerical value of the characteristic periods of each species. The points in the spatial database were colored according to the Commission for the Geological Map of the World (CGMW)/International Commission on Stratigraphy (https://timescalefoundation.org/charts/rgb.html), using the specific color of each series within the Triassic Period (Fig. 1) and the numerical value of the specific periods of each species.

The **sixth step** was a documentation stage on the main types of marine paleo-habitat classification. Thus, two main types of marine paleo-habitat classification were identified as follows: NOAA’s Coastal and Marine Ecological Classification Standard (CMECS) and the European Nature Information System (EUNIS). These marine paleo-habitat classification aim to integrate multiple parameters into a hierarchical framework. They combine elements of depth, substrate, biological communities, energy regimes, and sometimes biogeographic regions. Of the two types of marine paleo-habitat classification, NOAA’s Coastal and Marine Ecological Classification Standard (CMECS) was chosen. Why CMECS was chosen? This happened because its benefits (comprehensiveness, standardization, hierarchical structure, integration capabilities) are likely the driving factors (Fig. 2). This choice aligns well with modern ecological mapping and data management practices, especially in a scientific or governmental context, given that CMECS is designed for global application. Most importantly, our review of the various documents related to this standard revealed that it fit itself very well to the characterization of marine paleo-habitats.

What surprised us in this research about CMECS is its modularity. Thus, each component is a stand-alone construct that can be used on its own or in combination with other components or settings. Basically, CMECS provides two broad based, complementary settings within which to partition the coastal and marine world – the Biogeographic Setting (BS) and the Aquatic Setting (AS). These may be used independently or together (CMECS, 2012).

The Biogeographic Setting (BS) identifies ecological units based on species aggregations and features influencing the distribution of organisms. Coastal and marine waters are organized into regional hierarchies composed of realms (largest), provinces and ecoregions (smallest) (CMECS, 2012).

For the Aquatic Setting (AS) CMECS also divides the coastal and marine environment into three Systems: marine, estuarine, and lacustrine (CMECS, 2012). Secondary and tertiary layers of the aquatic setting describe subsystems (e.g., nearshore, offshore, and oceanic within the marine system) and tidal zones within the estuarine system and marine nearshore subsystem (CMECS, 2012).

On the next level CMECS is organized into four components to record and define the attributes of environmental units and biota within each setting – the water column component (WC), the geoform component (GC), the substrate component (SC), and the biotic component (BC). Each component is a stand-alone construct that can be used on its own or in combination with other components or settings. CMECS components include a variety of modifiers to enhance the specificity and detail of resulting descriptions and classification (Fig. 2) (CMECS, 2012).

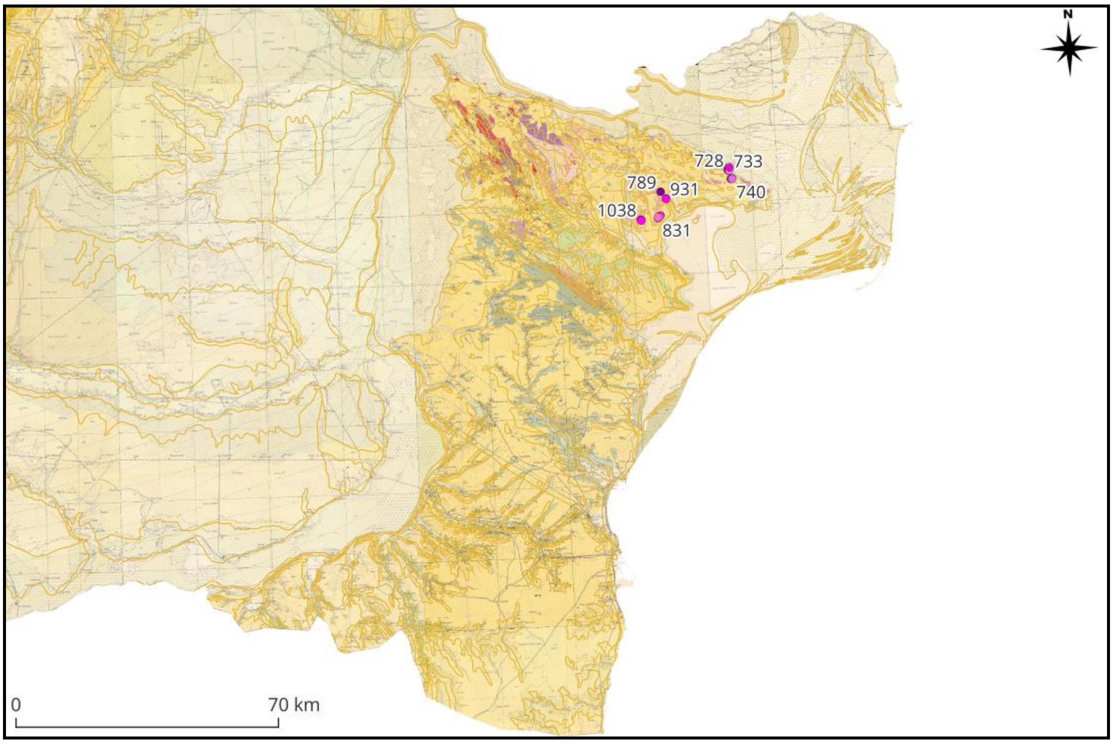

Figure 1: The Dobrogea location
and the samples distribution from QGIS.

While the core of CMECS lies in its hierarchical settings (biogeographic and aquatic) and components (water column, geoform, substrate, and biotic), modifiers play a crucial role in providing additional, more granular, or context-specific detail that might not be captured within the main classification units.

The key idea behind CMECS modifiers is flexibility. They allow to customize the classification to meet the needs without to create entirely new core units (CMECS, 2012).

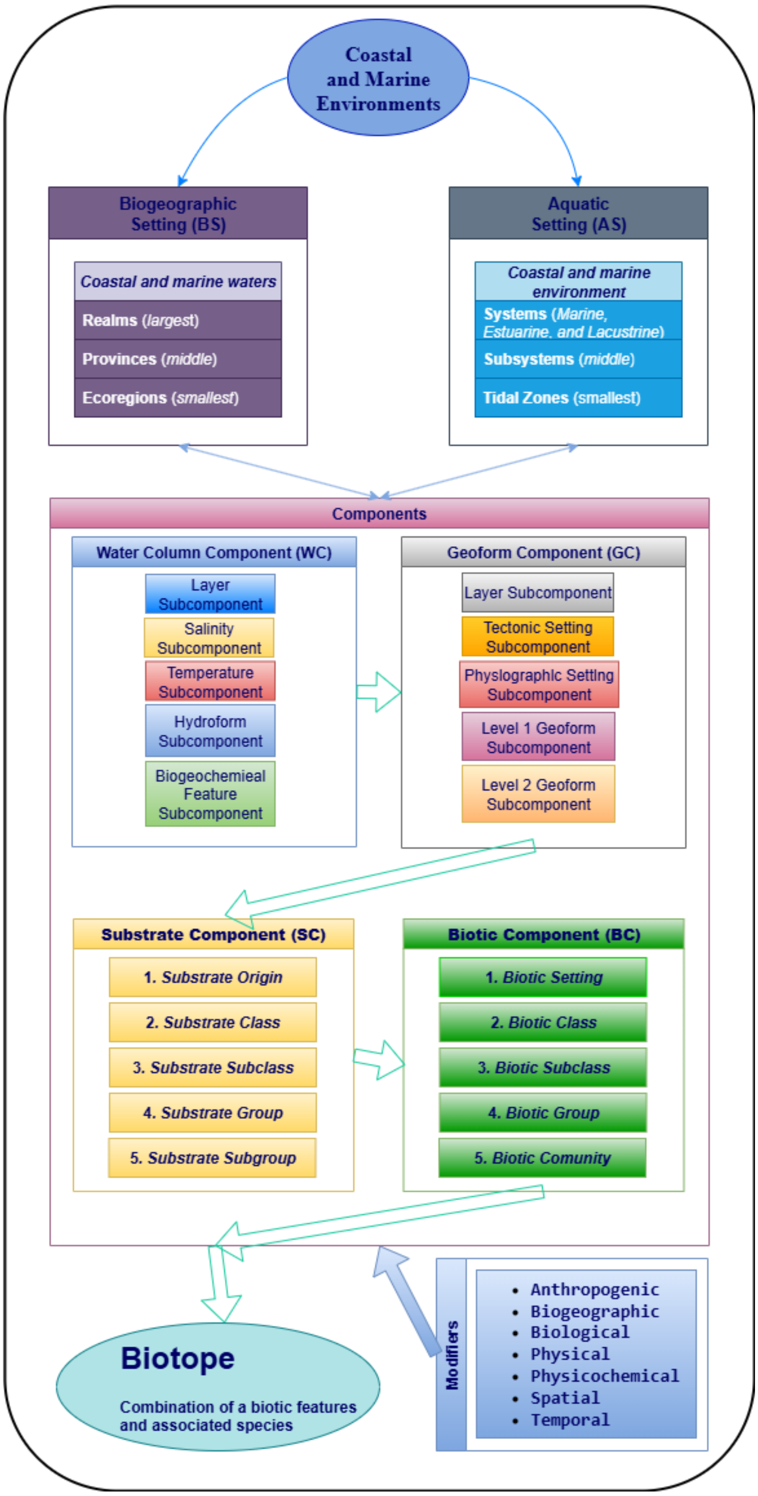

Figure 2: The modularity of CMECS.

In essence, while the main CMECS components give you the what (e.g., sandy seabed with seagrass), modifiers allow you to add the how or what else (e.g., sparse seagrass bed on fine sand, adjacent to a dredged channel). They are a vital tool for enriching the detail and utility of CMECS classifications (Fig. 2).

While both EUNIS and CMECS are comprehensive, hierarchical classification systems for marine paleo-habitats, they serve different primary geographical scopes (Europe vs. U.S. and potentially global for CMECS). They share similar underlying principles, focusing on physical environment and biological communities, but their specific codes, terminologies, and the emphasis on certain parameters may differ based on their regional focus and historical development (CMECS, 2012; Underpinning European policy on nature conservation – Revision of the EUNIS habitat classification, 2017).

So, in the case of CMECS, the modifiers also follow an **alpha-numeric** structure. While there’s a formal set, the system allows for the creation of **user-defined/provisional modifiers** to meet specific needs, with the potential for these to be formally adopted into the standard over time.

But to the specific question. What is the best classification for describing paleo-marine paleo-habitats? This is an excellent and nuanced question, as both CMECS and EUNIS were primarily developed for modern ecological mapping and management. However, when it comes to paleo-marine paleo-habitats, one generally offers more direct utility than the other, and there are specific considerations for either choice (CMECS, 2012).

For describing paleo-marine paleo-habitats, CMECS offers a more flexible and conceptually appropriate framework due to its component-based structure, strong emphasis on physical attributes (geoform, substrate), and the allowance for user-defined modifiers. These features enable paleontologists and paleoecologists to reconstruct and classify ancient environments using the geological evidence available, even when specific biological details are incomplete or unverifiable (CMECS structure information).

Therefore, the CMECS classification was used in the reconstruction of a marine paleo-habitat from the Triassic Period (Fig. 3). To achieve this goal, we first established specific modifiers for the available fossil species, based on the information we were able to gather about them. Secondly, we gathered information on the marine ecosystem of the Triassic, particularly that related to the Tethys Ocean (Fig. 3).

Figure 3: The Romania location on Triassic (processed based on Google Images).

Based on modifiers, a coding system was established. These codes were applied in the spreadsheet table and the spatial database. This step also involved a mathematical analysis of the time period data to establish the spatio-temporal distribution and association of fossils.

The **seventh step** was pivotal, as it involved utilizing the data acquired in the preceding stage to reverse-engineer the CMECS classification of marine paleo-habitats. By proceeding from the modifiers level to higher hierarchical levels, an overarching view of the Triassic, in the Dobrogea area, marine paleo-habitat was consequently obtained.

RESULTS AND DISCUSSION

About the paleo-habitat

A paleo-habitat is defined as the combination of abiotic habitat and associated species (Connor 1995, 1997; Connor et al. 2003). In this definition, the term habitat refers to a suite of environmental factors (such as sediment grain size, physiographic features, and specific physicochemical attributes) at a specific location; the term associated species refers to the biotic community or group of organisms that occur in that environment (CMECS, 2012).

General characterization of Paleo-Thetys Ocean in Triassic

Consistent with the marine characteristics of the Triassic fossil species housed in our museum, and corroborated by information retrieved from the Internet, our findings indicate that the territory of Romania was submerged by the waters of the Tethys Sea (more precisely by Paleo-Thetys Ocean) during this period of the Mesozoic Era (Fig. 3).

Tethys Sea, tropical body of salt water that existed from the end of the Paleozoic (541 million to about 252 million years ago) until the Cenozoic (66 million years ago to the present). Initially, it separated the supercontinent of Laurasia in the north from Gondwana in the south during much of the Mesozoic (252 to 66 million years ago) before these landmasses fragmented into the modern continents. Tethys was named in 1893, by the Austrian geologist Eduard Suess, after the sister and consort of the ancient Greek god Oceanus. (Tethys Sea, https://www.britannica.com/place/Tethys-Sea, 2025)

At least two Tethyan seas successively occupied the area between Laurasia and Gondwana during the Mesozoic. The first, called the Paleo-Tethys Sea, or Paleo-Tethys Ocean, was created during the convergence of all landmasses into what would become the supercontinent of Pangea late in the Paleozoic. During the Permian and Triassic (approximately 300 to 200 million years ago), Paleo-Tethys formed an eastward-opening oceanic embayment of Pangea in what is now the Mediterranean region. (Tethys Sea, https://www.britannica.com/place/Tethys-Sea, 2025)

The Paleo-Tethys Ocean was a vast and long-lived ocean that existed along the northern margin of Gondwana, beginning its opening in the Middle Cambrian and largely closing by the Late Triassic, spanning roughly 400 million years. The Triassic, in particular, represents a crucial phase in its closure and the concurrent opening of its successor, the Neo-Tethys (often just called the Tethys Ocean).

During the Triassic, the supercontinent Pangaea was largely assembled, and the Paleo-Tethys was an immense, eastward-opening embayment within this vast landmass.

Tropical climate. The Paleo-Tethys sat along the Equator, resulting in a mainly tropical climate, which would have significantly influenced its marine ecosystems. (Scotese, 2000)

Closing ocean. Throughout the Triassic, the Paleo-Tethys was in the process of closing, as the Cimmerian terranes (continental fragments that rifted off Gondwana, including parts of modern Turkey, Iran, and Tibet) moved northward, subducting the Paleo-Tethys oceanic crust beneath what would become Eurasia. This process also led to the opening of the Neo-Tethys to the south of the Cimmerian blocks. (Mills et al., 2021; Golonka, 2009; Scotese, 2000; Ziegler, 1983)

Variable depths. Paleo-Tethys would have encompassed a wide range of depths, from shallow continental shelves and epicontinental seas to deep oceanic basins and trenches associated with subduction zones. This would lead to diverse paleo-habitats. (Mills et al., 2021; Golonka, 2009; Scotese, 2000; Ziegler, 1983)

A few general points can be drawn about the paleo-habitats of the Paleo-Thetys Ocean. These elements are mainly related to the tropical character of the climate (Fig. 3).

Shallow marine platforms/shelves. These would have been extensive, especially along the northern margin of Gondwana (e.g., North Africa, Arabia) and the southern margin of Laurasia (Mills et al., 2021; Golonka, 2009; Scotese, 2000; Ziegler, 1983). (Fig. 3)

Substrates. Likely dominated by carbonates (limestones and dolomites) in warm, clear waters, but also siliciclastic sediments (sands, muds) closer to continental run-off (Mills et al., 2021; Golonka, 2009; Scotese, 2000; Ziegler, 1983).

Early reefs. The mid – to late Triassic saw the first development of modern-type stony corals (scleractinians), leading to modest reef-building activity in the shallower, sunlit waters of the Tethys. These were not as vast as later Jurassic or modern reefs but mark an important evolutionary step. (Mills et al., 2021; Golonka, 2009; Scotese, 2000; Ziegler, 1983)

Lagoons and peritidal environments. Protected, often hypersaline, along coastlines.

Basins and slopes. Characterized by fine-grained sediments, with anoxic conditions in deeper, restricted areas (Mills et al., 2021; Golonka, 2009; Scotese, 2000; Ziegler, 1983)

Pelagic zone. Represent the open water column, home to plankton and nektonic organisms (Mills et al., 2021; Golonka, 2009; Scotese, 2000; Ziegler, 1983)

Seafloor life became more complex and closer to present-day life, with an abundance of mollusks and coral reef builders, by the Middle Jurassic. Although modern fish became common in the Triassic seas, they shared the waters with ammonites, belemnites (fossil mollusks in the cephalopod class), and other squid-like organisms, as well as large reptiles (all now extinct) (Fig. 4). (Mills et al., 2021)

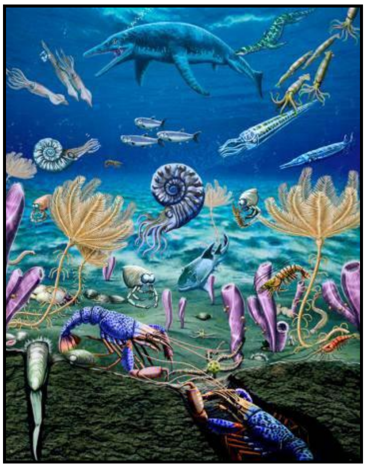

Figure 4: The life within Thetys Ocean on Triassic Period (Google Images).

Implications for Romania (Triassic Tethys)

Given the Romania present territory presence in the past within the Tethys realm during Triassic, you would expect to find fossil evidence consistent with these patterns. This includes marine invertebrates (ammonoids, bivalves, gastropods, and corals) and marine reptiles indicative of a warm, often shallow-marine environment, potentially with deeper basin deposits. The specific fossil assemblages in our museum would provide direct evidence to characterize these paleo-habitats using the CMECS framework (Fig. 4).

So, by integrating information and images from Internet (Tethys Sea, Britannica, 2025) searches with data provided by bibliographical references and CMECS data structure, we were able to create an overview of the Triassic marine paleo-habitat for the area of Romanania, including Dobrogea (Tab. 1).

Table 1: Triassic marine paleo-habitat for the area of Romania after CMECS.

Features	Level 1	Level 2	Level 3
Biogeographic Setting	Paleo-Tethys Realm (E1)	North Paleo-Thetys Province (E1.X)	Tropical Ecoregion (E1.X.X)
Aquatic Setting	Marine System (A1)	Marine Offshore Subsystem (A1.2)	Marine Offshore Subtidal Zone (A1.2.1)

We classify the Romanian paleo-habitat, placed between the Equator and the northern tropical area (with a tropical climate from a paleo-climatic perspective), from the Triasic as North Marine Paleo-Tethys Tropical Ecoregion (E1.X.X) and Marine Offshore Subtidal Zone (A1.2.1) (Figs. 5-6). Where X represent null values and can be used in code sentence where no information is available or in a new provisional lower-level unit. (CMECS, 2012)

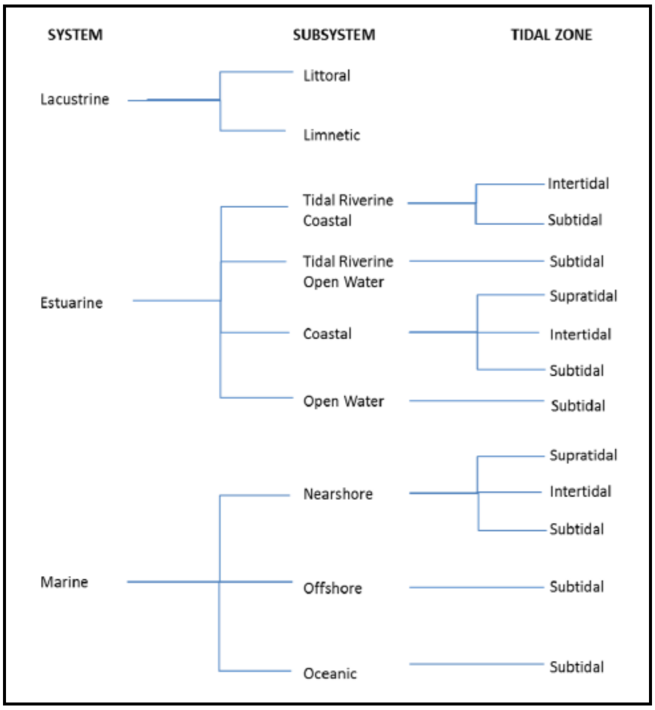

Figure 5: Aquatic Setting Hierarchy (CMECS, 2012).

The provisional code for biogeographic settings (BS) could be:

E-TR.PALEO.TETHYS.NORTH.TROPICAL (E1.X.X). (adapted based on CMECS, 2012)

And provisional code for Aquatic Settings could be:

Marine system. Marine offshore subsystem. Marine offshore subtidal tidal zone (A1.2.1). (Fig. 6)

On short we could described Triasic paleo-habitat of Romania as the north marine Paleo-Thetys tropical ecoregion from offshore with subtidal caracteristics.

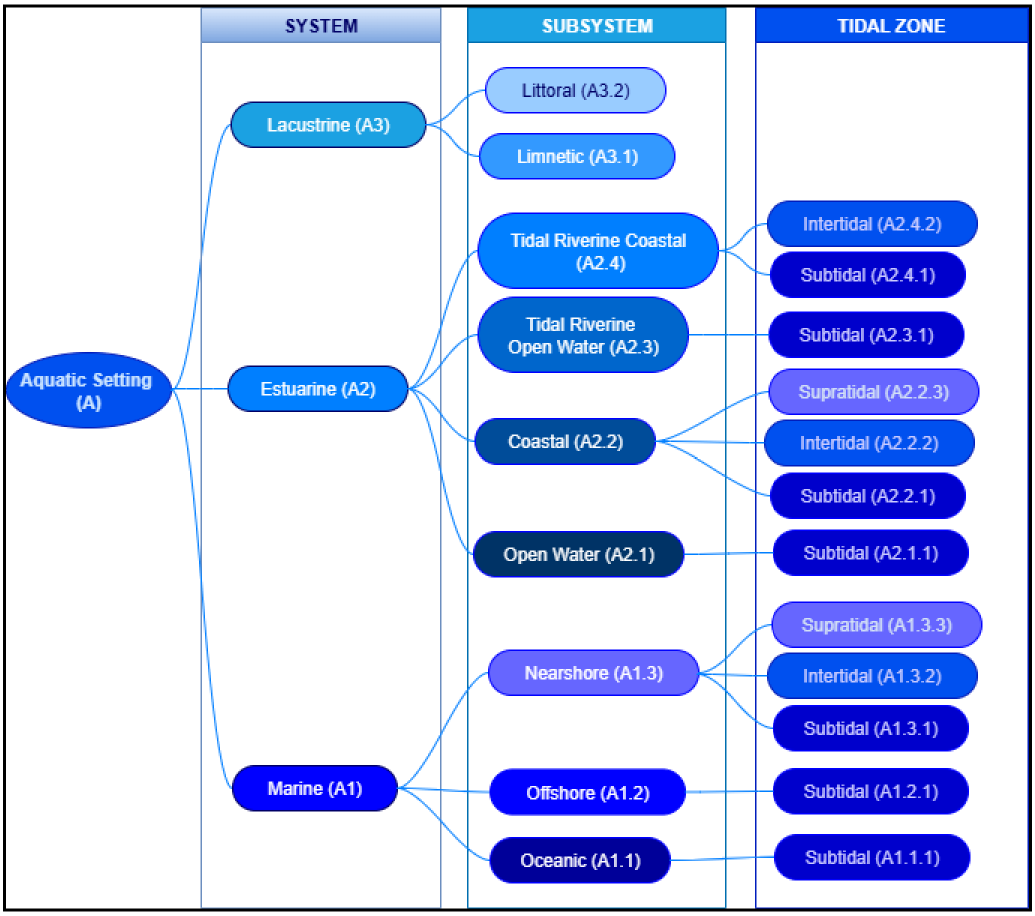

Figure 6: Aquatic setting hierarchy used in this study.

Life and environment condition within the Triassic in the Dobrogea region

Within our museum’s collection, the Triassic fossils from Dobrogea are marine, reflecting a dominant shallow sea environment. The ammonoids and nautiloids are key index fossils used for dating the Triassic layers. The bivalves and brachiopods were widespread in carbonate platforms, serve as indicators of reef-like or lagoon environments.

Life during the Triassic in the Dobrogea region was primarily marine, dominated by invertebrates like ammonites, belemnites, brachiopods, bivalves and gastropods, inhabiting warm, shallow seas along the Paleo-Tethys Ocean.

From the entire area of Dobrogea, the north Dobrogea during the Triassic hosted one of the richest known benthic invertebrate faunas in the Tethyan realm (Tab. 2).

However, the new studies to which I had access, confirm the personal observations made based on the fossil samples from the museum's collection (Tab. 2). These data confirm that a rich and diverse fauna, characteristic of shallow, bordering areas of the Paleo-Tethys Sea, existed in the Dobrogea region, particularly in its northern part.

Table 2: Some of the fossil species from the museum's collection used as indicator species for the Triassic paleo-habitat.

Name	Period	Paleo-habitat
Pseudomonotis haueri	Late Triassic	Common species in the warm, open shallow waters of the Tethys Ocean and its surrounding seas.
Protrachyceras furcatum	Late Triassic, Carnian	Common species widely distributed across the ancient Tethys Ocean and its surrounding seas, in warm to temperate waters.
Ammonite	Late Triassic, Carnian	Common species widely distributed across the ancient Tethys Ocean and its surrounding seas, in warm to temperate waters.
Monophyllites aonis	Late Triassic, Carnian	This species is likely to be found in various Triassic marine environments, from the tropical (Tethyan) sea to the boreal sea.
Trachyceras aon	Late Triassic, Lower Carnian	The paleo-habitat of this species was represented by the open Tethys Ocean in the Late Triassic and by the environments from the ocean shelf to the basin, characterized by fine sedimentation.
Cardita crenata and *Pseudomonotis* sp.	Late Triassic	Both species were common marine bivalves from the Late Triassic, with *Cardita crenata* living in shallow, warm, coastal marine areas as a benthic bivalve, probably either attached or shallowly buried, while P*seudomonotis* occupied mainly open shelf to basin environments.
Cardita crenata	Late Triassic	This species occupied a prosperous, shallow, warm, well-oxygenated, and often dynamic coastal marine environment as a bivalve that lived on muddy to sandy bottoms, near-shore.
Flexoptychites flexuosus	Middle Triassic, Anisian	As an ammonoid, it was a nektonic marine creature, with wide distribution in the Tethys Ocean and other marine basins.
Gastropod	Middle Triassic	Species that lived on sandy or muddy bottoms near seagrass beds and coral reefs.
Megalodon sp.	Middle Triassic	Common species that lived in marine environments, especially in the warm, shallow waters, buried in bottom sediments (often composed of sand, mud).
Megalodon hungaricus scutatus	Middle Triassic	Common species that lived in marine environments, especially in the warm, shallow waters, buried in bottom sediments (often composed of sand, mud).

Table 2 (continued): Some of the fossil species from the museum's collection used as indicator species for the Triassic paleo-habitat.

Name	Period	Paleo-habitat
Megalodon hungaricus scutatus	Middle Triassic	Common species that lived in ancient marine environments, especially in the warm, shallow waters, buried in bottom sediments (often composed of sand, mud).
Costatoria costata	Triassic	This species was a benthic, shallow water marine bivalve with Its paleo-habitat typically a well-oxygenated shelf environment where wave action provided a habitable zone for bottom-dwelling organism.
Ammonite	Middle Triassic	These species was common in tropical marine paleo-habitats with a wide distribution in shallow areas.
Trematoceras elegans	Middle Triassic	This species lived in a wide range of marine environments, including intraplatform basins with stratified water conditions (oxic at the surface, anoxic at the bottom).
Sturia sansovinii	Middle Triassic	This species has been found in various locations, indicating a wide distribution in the Middle Triassic seas.
Monophyllites confucii	Middle Triassic	*Monophyllites confucii* was a free-swimming ammonoid that inhabited the open, oxygenated marine waters of the Tethys Ocean and circum-Pacific regions, and was probably a pelagic or epineritic species.
Anolcites promontis	Middle Triassic, Landinian	A stenobiont species, possibly even endemic, that lived in the warm, open waters of the ancient Tethys Ocean and its marginal seas.
Pseudomonotis clarai	Early-Middle Triassic	A common species that could thrive in various marine environments, from shallow, wave-influenced areas to deeper areas.
Tirolites cassianus	Early Triassic	It was a free-swimming ammonoid that inhabited the oxygenated water column of marine environments with a paleo-habitat ranged from shallow to deeper shelf settings, extending into marginal basins
Claraia clarai	Early Triassic	*Claraia* may be an opportunistic genus that has filled the niche of many aquatic benthic invertebrates.
Tirolites subillyricus	Early Triassic	This species was common in plateau-type marine paleo-habitat, and enjoyed a wide distribution in shallow areas.

For coding at the component level, both biogeographic settings (BS) and aquatic setting (AS) were used from the table (Tab. 2). Within the present study, one of the species used for the reconstruction of the Triassic paleo-habitat, is *Anolcites promontis*. The choice of this species was established based on its stenobiont character. The *Anolcites promontis* fossils occur in offshore, fine-grained marine deposits, often deep subtidal, to Middle-Ladinian age (~241-237 Ma) environments rich in co-occurring cephalopods like *Protrachyceras* sp., which confirms the classification from biogeographic settings classification point of view in the northern part of Triassic Paleo-Thetys Ocean and included in tropical water zone (E-Tr.Paleo-Tethys.North.Tropical {TransitionZone, Marine}) and from point of view of aquatic setting in offshore subtidal environment (A1.2.1) (CMECS, 2012; Ziegler, 1983).

The Water Column Component (WC) (Fig. 2) characterizing this species have Euhaline, Warm Water, Oxic, Photic and Circalittoral parameters above 80 m (the limit of the photic zone in normal condition) on shallow shelf area and in the case of ecotone area, the Circalittoral condition extend to 200 m (subtidal areas below the photic zone, generally characterized by animal communities). So, the cod was the following: Wl2.2.l2.4.s5.t6.h1.5 {Oxic-Photic-Euhaline-Warm-Circalittoral}. In basin areas the mesobenthic (200 to < 1,000 m) condition could be find (Lemanis and Hoffmann, 2014; CMECS, 2012).

The geoform component (GC) (Tab. 2) could be marine shelf or precisely passive continental margin (Fig. 7-8) within continental shore complex on sediment sheet with low elevation profile values and in marine environment what was maintained in centuries (Gt7.p7.h2.1.42 {Marine-Horizontal-Low-Centuries}) (CMECS, 2012; Ziegler, 1983).

The substrate component (SC), for *Anolcites promontis* and nektonic organism in general, could be general unconsolidated mineral substrate (S1.2). But, for bivalve species as *Costatoria costata*, *Megalodon* sp. and *Cardita crenata* these could be found where wave action provided a habitable zone for bottom-dwelling organism or buried in bottom sediments (often composed of sand, mud or muddy sand), the substrate component could be geologic unconsolidated mineral substrate, fine unconsolidated substrate, muddy sand, silty sand (S1.2.2.2.3.1). The silty sand substrate subgroup was selected not only, because the distance from coastal zone is too high for a fully sandy substrate, but also because in list of species is included a gastropod with shell and is impossible for this species to live in fully muddy environment. Besides the presence of mollusks and gastropod only in a part of the studied area indicate a possibility of the algal vegetation existence at least on this part, so was choused algal sand as modifier and in this case the substrate component could look like S1.2.2.2.3.1 {Algal Sand}. This idea was sustained by the presence of calcareous rock from Triassic what adds carbonate ooze as modifier, for muddy part, so substrate component become S1.2.2.2.3.1 {Algal Sand, Carbonate Ooze} (CMECS, 2012; Harta Geologică a României scara 1: 200.000, 1960-1969).

A clarification here is brought by the use of mathematical modelling, based on the Fuzzy C-Means clustering method and the cartographic materials obtained based on it (Fig. 7).

Fuzzy C-Means (FCM) clustering is a data clustering technique that allows data points to belong to multiple clusters with varying degrees of membership, unlike k-means which assigns each point to a single cluster. This membership is the core of FCM, where each data point has a probability or degree of belonging to each cluster. On short, FCM is a clustering method that allows each data point to belong to multiple clusters with varying degrees of membership.

In our case, it was important to note the presence of an ammonite (*Trachyceras aon*) in an area with *Megalodon* sp. (Middle Triassic) and *Cardita crenata* (Late Triassic), but especially with a gastropod from the Middle Triassic (Figs. 7 and 8).

These discoveries guided us in confirmed for substrate component the following code S1.2.2.2.3.1 {Algal Sand, Shell Sand, Carbonate Ooze} (Geologic Unconsolidated Mineral Substrate. Fine Unconsolidated Substrate. Muddy Sand, Silty Sand; Modifiers = Algal Sand, Shell Sand, Carbonate Ooze) (Fig. 7 and Tab. 2). Another important aspect offered by figure 7 is the grouping of species into three classes. Basically, bivalves, gastropods and some ammonites (marked yellow) fall into a single class, and ammonites are grouped into two other classes (marked teal and red, respectively) (Fig. 7).

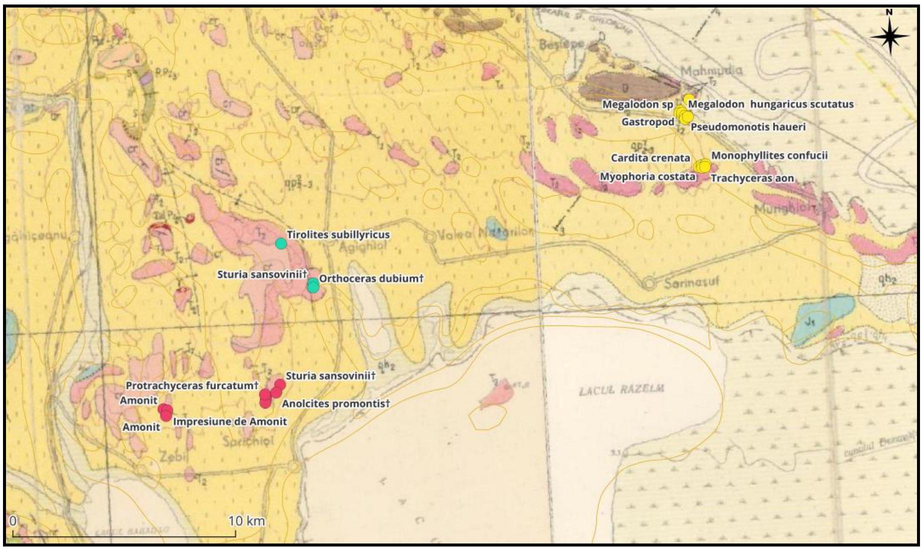

Figure 7: Species classification based on C-Means (FCM) clustering.

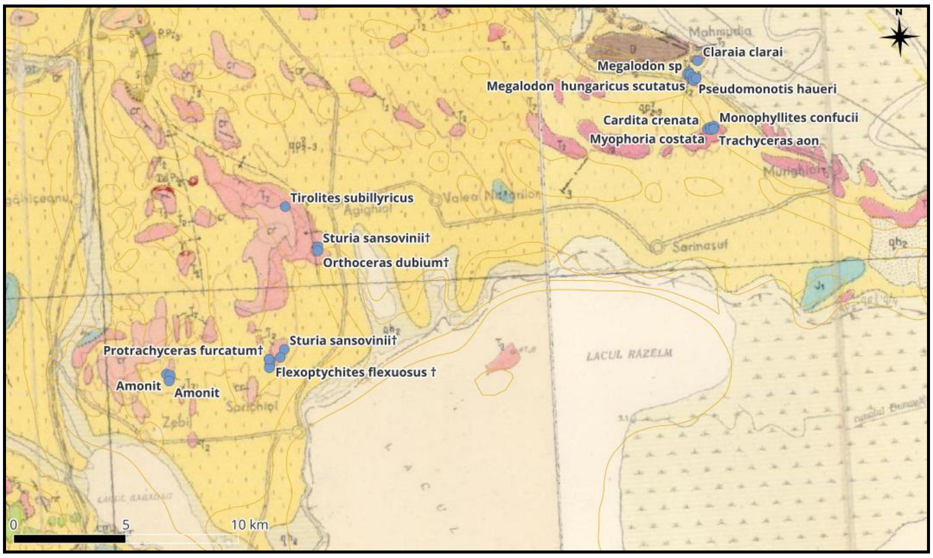

Figure 8: Species classification based on K-Means 2 clustering method, where all Triassic species fall in one cluster.

To clarify the situation and determine if there is a problem related to the low number of species in the Triassic Period in terms of the characterization of the living environment, a new clustering analysis was performed for all 74 species in the spatial database.

For this purpose, the K-Means 2 clustering method was used. This method is new and is included in a plugin (attribute based clustering) for QGIS. In general, QGIS offers K-means clustering functionality within its processing toolbox. This algorithm groups vector layer features into a specified number of clusters based on their proximity to centroids. It adds a new cluster ID field to the input layer, allowing for easy identification of cluster membership. K-means relies on a distance metric (e.g., euclidean distance) to determine how close a data point is to a cluster's centroid. Within this study, the clusters were determined without calculate the distance metric and used Elbow method. This method plots the within-cluster sum of squares (WCSS) for different values of K. The elbow points on the graph, where the decrease in WCSS starts to level off, can indicate a suitable K.

The clustering process was guided by the values of the geological periods and the coordinates in the Stereo 70 system for each point. The center of gravity was set on the average value of the geological period boundaries. The accuracy of this method was determined by correlating the value of the clusters with the characteristics of each fossil species. This method correctly placed terrestrial and aquatic organisms into separate clusters.

Surprisingly, all species from Triassic were placed in a single large cluster (Fig. 8). This means that, although the species share somewhat different environmental preferences (marked by their grouping into three clusters), the spatial distance over which they are distributed is still too small to be able to refer to three different habitats. Thus, we can extend the characterization, at least of the substrate, to the entire area of Dobrogea. So, for the substrate component (SC) all fossil species fall into the same category with SC1.1.1.2 code (Geologic Unconsolidated Mineral Substrate, Fine Unconsolidated Substrate, Muddy Sand).

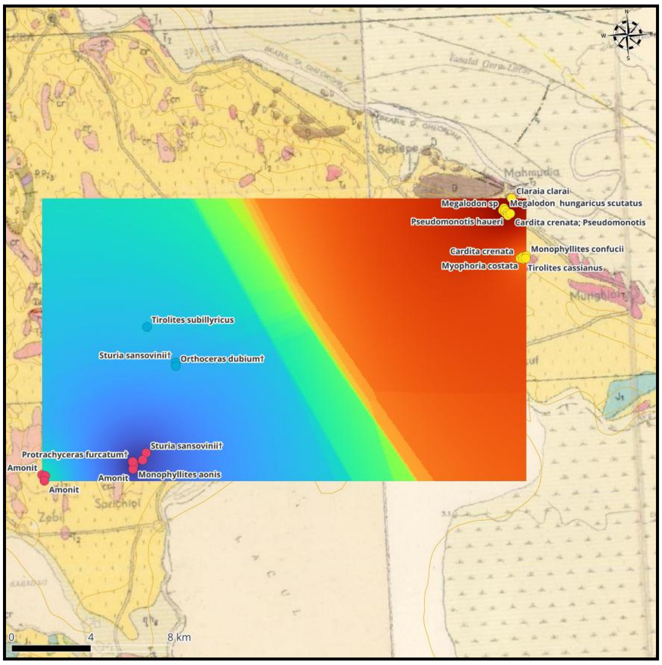

Figure 9: The cluster analysis performed on the basis of machine learning algorithms.

Within the Triassic marine habitat, for a more in-depth analysis of the distribution of paleopaleo-habitats the machine learning algorithms were used (Fig. 9).

Machine learning (ML) is a field of artificial intelligence (AI) focused on enabling computer systems to learn from data and improve their performance without explicit programming. Essentially, it empowers machines to analyze data, identify patterns, and make predictions or decisions based on that learning.

Thus, based on these algorithms, two clearly separated clusters resulted, with a border zone having distinct characteristics. Interestingly, the ammonites in cluster zero, colored teal, and the ammonites from the eastern part of the cluster marked in red fall into the same large cluster. However, the ammonites from the southwestern part of the cluster marked in red fall into an area marked with the same color as the border zone established by the artificial intelligence (machine learning) algorithms (Fig. 9). This dividing line may also mark two temporal situations, a fact reinforced by the presence of the species *Sturia sansovinii* in both the ecotone area (Fig. 10) and the central area of the red cluster identified by the artificial intelligence algorithms. Also of interest is the presence of the species *Protrachyceras furcatum* (a Late Triassic species) in the central area of the red cluster.

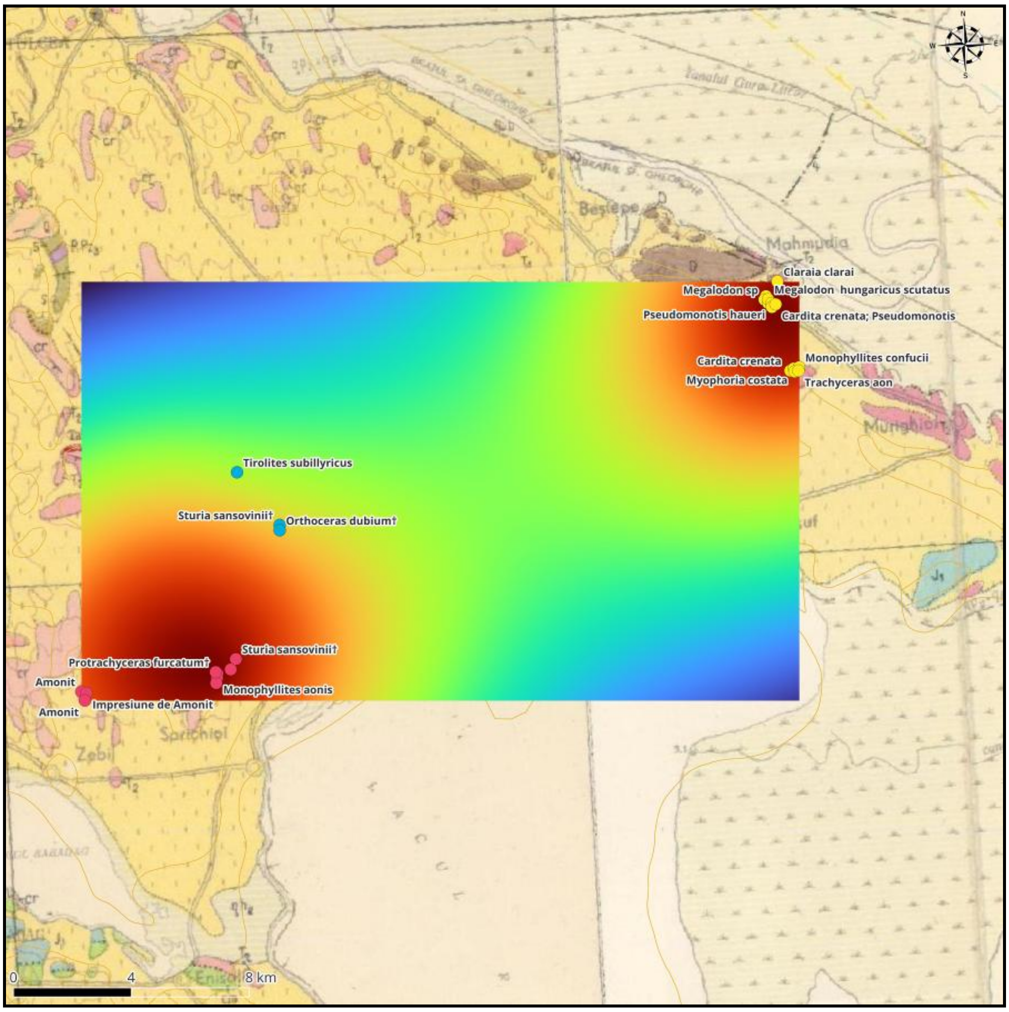

Figure 10: The prediction error (the high value with red) of Kriging Interpolation technics.

The use of Simple Kriging Interpolation a spatial prediction method of Kriging Interpolation to determine the fossiliferous potential of Dobrogea in the Triassic Period led to the emergence of an unexpected situation (Figs. 10 and 11).

Kriging Interpolation is a geostatistical technique used to estimate the value of a variable at an unknown location based on known values at nearby locations. It differs from simpler methods by considering the spatial correlation between data points, meaning it weighs closer data points more heavily than those farther away. This method not only provides interpolated values but also estimates the uncertainty associated with those predictions. Kriging relies on the principle that data points closer together are more likely to have similar values than those farther apart. This spatial correlation is crucial for accurate interpolation. The disadvantage of this method is represented by the computationally intensive for large datasets. (Kriging Interpolation, 2025) Although simple kriging is rarely used due to restrictive assumptions, however, considering the case presented in this paper, in which all fossil species are placed, following K-Means 2 clustering (Fig. 8), in a single cluster (a normal fact if we consider that it is a shelf area with characteristics that were maintained throughout the Triassic), then we can consider that the physically based model provides a known trend, allowing you to perform simple kriging on the residuals. Basically, Kriging Interpolation determined a high fossiliferous potential for cluster 0 and a low potential for clusters 1 and 2 (Figs. 10 and 11). The error calculated for data interpolation also determined that the two clusters identified through artificial intelligence (machine learning) represent situations with low fossiliferous potential (Figs. 9-11).

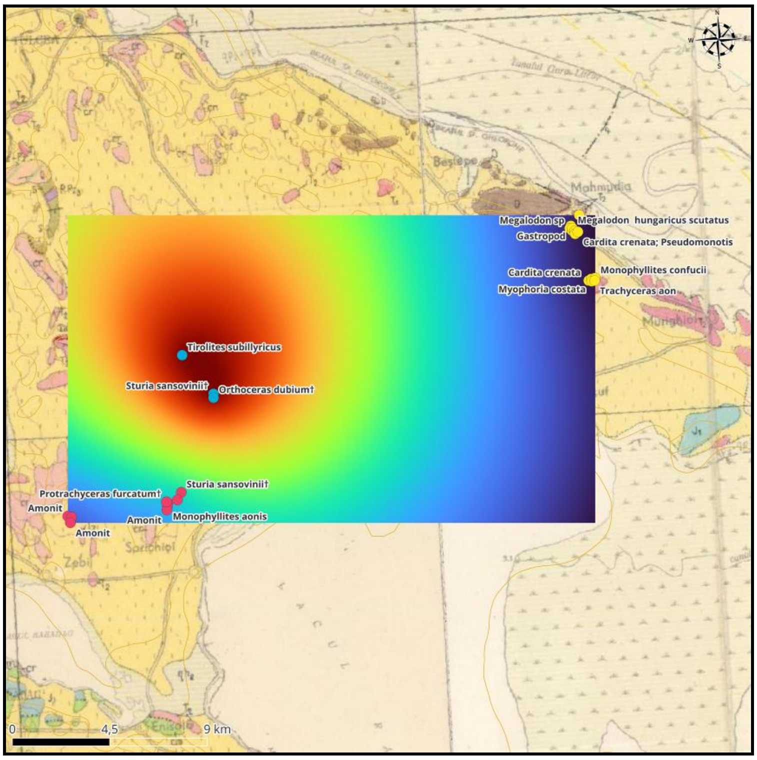

Figure 11: The Kriging Interpolation prediction (Simple Kriging) for high fossiliferous potential it is mark with red (the middle with green and lowest with blue).

The high fossiliferous potential for cluster 0 can be explained by the fact that the area marked in red on the Kriging Interpolation map (Fig. 11) corresponds to a buffer area between two distinct biotopes (Figs. 9 and 10). This cluster contains a group of species that lack clearly defined characteristics, which is why they do not have a distinct identification number, and most of them have broad ecological valences (Tab. 2). The broad ecological valences are common to species living in ecotone conditions.

The temporal aspects that represent one of the key elements of the coastal and marine ecological classification standard (CMECS) and in this case those related to the evolution of the Triassic paleo-habitat in Dobrogea, were analyzed based on the Sunburst Chart (Fig. 12).

Sunburst chart, known by multiple names such as ring chart and radial treemap, is used to visualize a hierarchical dataset. It shows hierarchy through a series of concentric rings, where each ring corresponds to a level in the hierarchy. Each ring is segmented proportionally to represent its constituent details. A pie chart can be used when breaking out a metric by a single dimension. In metabase, pies are donuts. A sunburst chart is a multi-dimensional pie chart with multiple breakouts (Fig. 12).

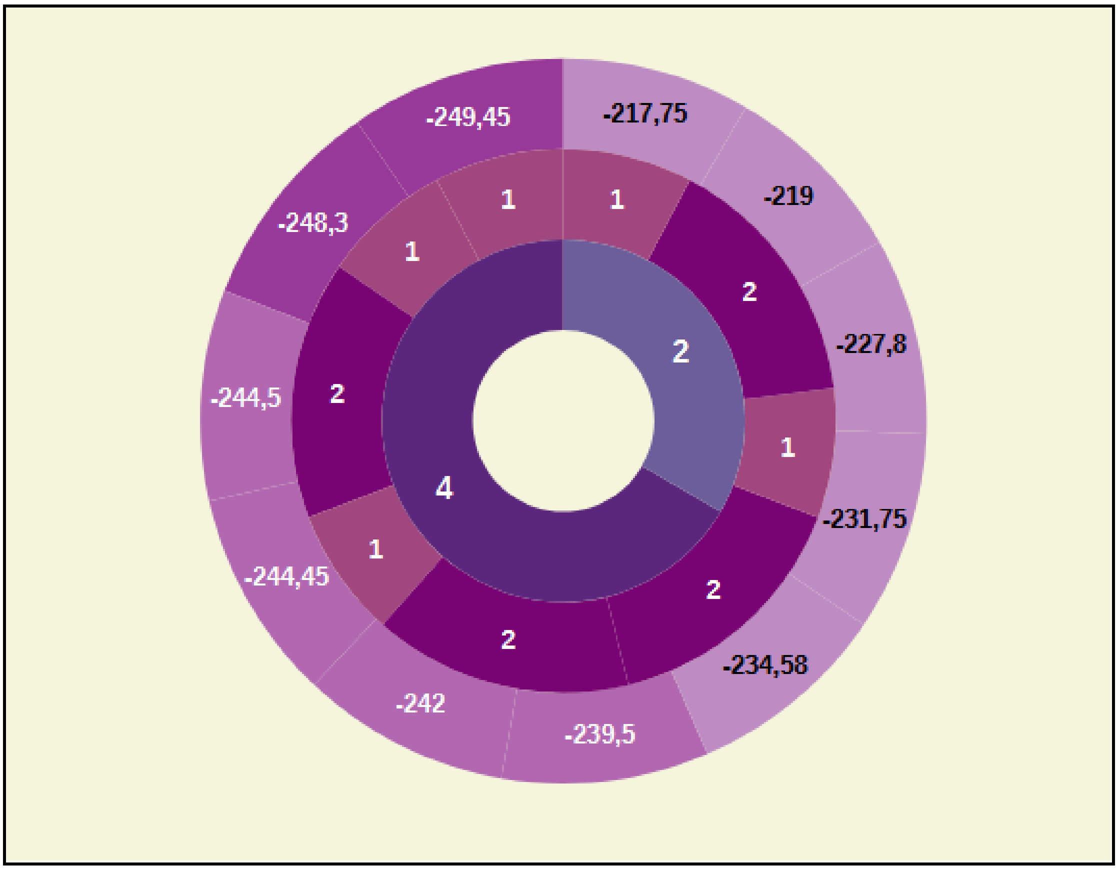

Figure 12: A sunburst chart
with the evolution of the Triassic paleo-habitat
in Dobrogea.

The explanation of the graph (Fig. 12) is rather a simple one. First of all, the inner circle represents the two studied biotopes, one of which is deeper water (marked with the number 4) and has an anoxic zone at the bottom of the water column, and the second with shallower, well-aerated waters (marked with the number 2). The middle circle contains the three clusters. Of which, clusters 1 and 2 are marked in their temporal alternation, and cluster 0, which contains cosmopolitan species (characteristic of the buffer area) is associated, in particular, with the deeper water biotope (marked with the number 4). It is worth noting, at this level, the presence of some species, especially ammonites, spatially characteristic of the shallow water biotope in the area of the deeper water biotope. The outer circle marks the geological periods, with colors characteristic of the three major stages: the Early Triassic (darker colors), the Middle Triassic (lighter colors), and the Late Triassic (lightest colors). This graph substantially modifies some aspects presented earlier. First, the Dobrogea area appears as a shelf area with shallow waters alternating with deeper water areas, a fact established based on previous data. But the second, and most importantly aspect, in the tectonic setting subcomponent (Gt) within the geoform component we have convergent active continental margin, that are the most common type of active margin (CMECS, 2012; Atudorei et al., 1997).

This is due to the seafloor rising over geological time. This process led to a transition from a region dominated by deeper water areas and anoxic sections of the water column in the basal part (basinal facies) in the Early Triassic to one dominated by shallow, well-aerated (Oxic) water areas in the Late Triassic (Fig. 12), with both basinal and platform facies (Atudorei et al., 1997). Based on these data, it appears that from the Early Triassic until the end of the Middle Triassic, the area of the Agighiol locality was an important ecotone zone (Figs. 11 and 12). This characteristic persisted until the Late Triassic (Late Carnian) period (Atudorei et al., 1997).

The way Dobrogea region looked in the Triassic period was based both on bibliographic data and, above all, on the information provided by the GPlates application (Fig. 13). This application allows the simulation of the appearance of the land area, the continental shelf and the depths of the sea. The data were extracted from the application in shapefile format, in the World Geodetic System 1984 (WGS84) and displayed in Quantum GIS (QGIS). The straight-line distance calculated from the seashore to the edge of the continental shelf is 78044.383 m.

An important clarification is provided by the observation: the tectonic evolution of the Black Sea, suggests a new conceptual kinematic model for further testing, one that involves movement of the continental fragment of Moesia NW along the TTZ during the early and middle Mesozoic. Such a displacement would represent the western most occurrence of the Cimmerian orogeny in the region of the western Black Sea. The escape of Moesia to the NW could possibly explain the polyphase extension of the western Black Sea crust, which developed on the continental Eurasian Plate as a back-arc basin due to the N-directed subduction of Tethys (Korniyenko-Sheremet et al., 2023).

Based on all this information the geoform component can be described as continental/island shelf (Figs. 7, 8 and 13) within convergent active continental margin, flats on sediment sheet with low elevation profile values, infralitoral to deep infralitoral, reef bank/shelf, mollusk moderate percent cover and in marine environment what was maintained in decades (CMECS, 2012; Atudorei et al., 1997).

So, this study followed the spatio-temporal distribution of fossil species. This distribution confirms for the Murighiol lithofacies (Murighiol Formation) the existence, in the Late Triassic Period, of a shelf area with shallow water and for the Zebil locality area of a deeper water lithofacies (basinal facies). Compared to other studies, a border area between two different types of biotopes was identified for the Cataloi lithofacies area. To this was added a confirmation of the fossiliferous potential for the Agighiol locality area with its marking as an ecotone zone (buffer area).

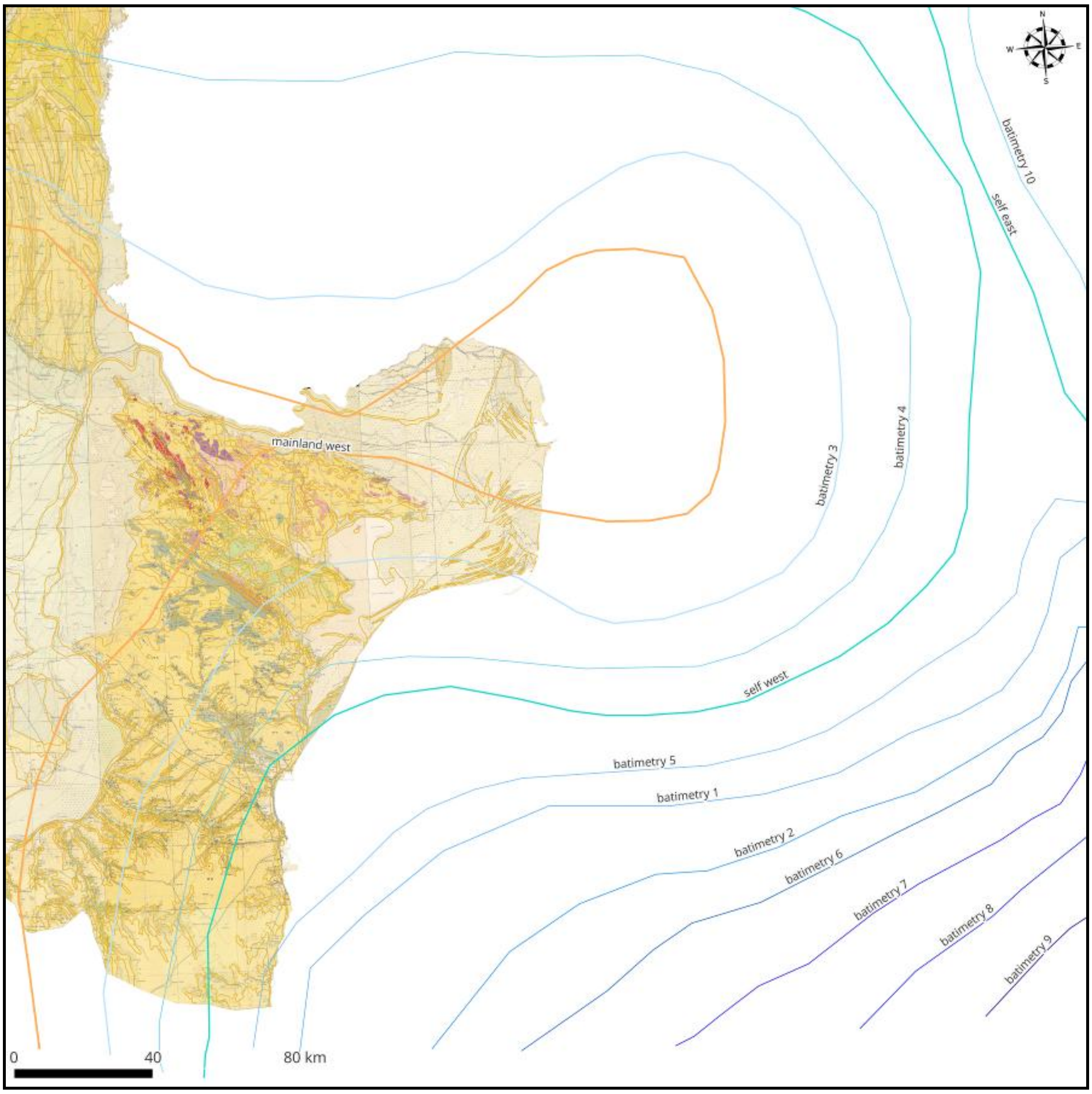

Figure 13: Dobrogea in the Triassic
(from the Early to the Late Triassic),
the mainland is mark with orange,
teal mark the limit of continental plate and blue the depth contour line.

Reconstruction of the Triassic paleo-habitat in the Dobrogea area

Based on the fossil samples from our museum's collection and the data previously presented, we can conclude that Dobrogea was part of a shallow marine shelf bordering the vast Paleo-Tethys Ocean. Within the collection, the predominance of sedimentary rocks from the Triassic Period (such as limestones, dolomites, marls, and sandstones) indicates that large areas were characterized by shallow seas, lagoons, and coastal settings.

The classification of marine paleo-habitat can be made as follows:

Biogeographic settings. In the north of Triassic Paleo-Thetys Ocean and in tropical water zone. This was an area with rich and diverse fauna, characteristic of shallow, bordering areas of the Paleo-Tethys Sea, existed in the Dobrogea region, particularly in its northern part.

Modifiers of biogeographical settings: unidirectional flow that is primarily marine water. Transition climatic zone from equatorial to tropical zone.

Aquatic setting. Offshore subtidal environment. The offshore environment refers to the marine area that is located away from the coast, typically beyond the nearshore or littoral zone. This zone is characterized by deeper water and is not directly influenced by processes associated with the coastline, such as river runoff or coastal erosion. The subtidal environment is the area of the seafloor and the water column that is permanently submerged below the lowest astronomical tide. This means it is never exposed to the air, even during the lowest of low tides. The subtidal zone is part of the larger neritic zone, which extends from the low-tide mark to the edge of the continental shelf. It is a biologically diverse area, as it provides a stable habitat for marine life that cannot tolerate desiccation or extreme temperature fluctuations.

Subtidal environments are presented with a different set of challenges in that oxygen, light, nutrients, and temperature are often reduced with respect to biological requirements and species and communities have developed characteristic strategies to optimize access to resources in these environments (CMECS, 2012). The subtidal environment in our case can be further divided into different zones, such as the predominantly euphotic (sunlit) area in north part and area with aphotic (dark) zones in south-southwest part.

Water column component. The water column component (WC) describes the water column environment of estuaries and oceans. The WC is a new approach to the ecological classification of open water. This describes the water column in terms of vertical layering, water temperature and salinity, hydroforms, and biogeochemical features (CMECS, 2012). The water column component that characterizes the species, used in this paper, have marine nearshore in the north and west part of Paleo-Thetys Sea, marine offshore, marine offshore upper water column and marine offshore lower water column in basinal areas, euhaline, warm water, wind-driven currents, tidal flow and tidal front in coastal part, thermohaline eddies, background mesoscale field, shelf wave, oxic to hypoxic, photic and circalittoral parameters.

The term marine nearshore refers to the coastal area of the sea or ocean, ranging from the high-tide line to the outer edge of the continental shelf, typically at around 55 m depth. It's a dynamic zone where land and sea interact. This area was characteristic for the north and west part of Dobrogea. The nearshore encompasses a wide range of habitats, like sandy beaches, rocky shores, mudflats, estuaries, and submerged reefs. The nearshore is a highly productive, playing a main role as a nursery ground for many marine species and supporting a vast amount of biodiversity. The nearshore is defined by the transition between the intertidal zone and the subtidal zone. It extends from the beach through the shallow water, reaching depths where ecological factors begin a transition from shallow to deep-water traits. That area was characterized by the presence of tidal flow and tidal front. The wind-driven current is a current caused by wind shear as distinguished by those caused by density differences, which result in thermohaline circulation. Though only a portion of the oceans are exposed to wind energy, winds are responsible for the great ocean gyres, dominant features of ocean circulation (Shallow-Water Habitats, 2024; CMECS, 2012). The term offshore defines a region of the sea located away from the coast or far from the influence of land. The shelf region is where most the offshore marine organism's activities occur due to its relatively shallow depth. The upper layer of the ocean, typically extending down to about 200 meters. Characteristic for this area is the well-mixed upper water column, where most nektonic aquatic organisms lived and implicitly where ammonites hunted. Of course, the upper water column zone have photic (> 2% of surface light and phototrophic organisms can photosynthesize) and oxic (4 to < 8) characteristics. The upper water column layer is in close contact with the atmosphere; usually oxygenated, well-mixed and well-lighted; and is generally marked by high rates of photosynthesis and net autotrophic production. Those waters are in generally clear (5 to < 20 m Secchi deep). The marine offshore lower water column refers to the portion of the ocean's water column that lies beneath the middle depths and extends to the seafloor. It's a region characterized by decreasing light penetration, lower temperatures, and potentially higher pressure compared to the upper layers. The euhaline term describes water with a salinity level that falls within the typical range for normal marine environments, which is approximately 30 to 40 parts per thousand (ppt). It indicates that the water is fully marine and not diluted by freshwater from rivers or estuaries, nor is it hypersaline like a salt lake. This range of salinity is crucial for the survival of most marine organisms. The warm water characteristic refers to a water temperature that is relatively high, generally above the average for the global ocean. While warm can be subjective, in oceanography, it typically relates to tropical and subtropical regions. The exact temperature can vary greatly, but it's a key factor influencing marine life, as warmer waters generally support higher metabolic rates and different species than colder waters. Warm, euhaline water is characteristic of many coral reef ecosystems. Due to the absence of deep polar water formation and its tropical and low-latitude location, it is highly unlikely that the Paleo-Tethys Ocean had deep-water formation to drives modern thermohaline circulation. In this case, the kinetic energy of the moving ocean water was transferred from the wind to the ocean's surface in the form of wind-driven current. Though only a portion of the oceans are exposed to wind energy, winds are responsible for the great ocean gyres, dominant features of ocean circulation. The largest ocean gyres are wind-driven, meaning that their locations and dynamics are controlled by the prevailing global wind patterns. These currents would have been crucial for transporting heat around the globe from shallow shelf water to deep ocean, which have contributed to the warmer global climates of that time. (Shallow-Water Habitats, 2024; CMECS, 2012)

Modifiers of water column component. While wind-driven currents are the main mechanism that produce a well-mixed water in Dobrogea shelf area, tidal currents also play a major role in mixing coastal and shelf waters, particularly in areas with a wide tidal range. The rhythmic ebb and flow of tides can create strong currents that promote vertical mixing. Besides, the energy in tropical waters can be temporary influenced by features like warm core eddies, the localized, rotating bodies of warm water, that sharp sea surface temperature gradients, and the depth of the ocean's mixed layer. The warm core eddies are currents temporary derived from wind-driven current and its could impinge on the edge of a continental shelf, their deep, powerful rotation can create localized upwelling and downwelling, and can stir up sediment. This process, known as shelf-slope interaction, can bring nutrient-rich water from deeper ocean regions onto the shelf. (Shallow-Water Habitats, 2024; CMECS, 2012)

Geoform component. Convergent active continental margin is an intense area where the oceanic lithosphere is subducted beneath the continental lithosphere. Convergent active continental margin is an intense area where the oceanic lithosphere is subducted beneath the continental lithosphere. Continental/island shelf is part of the continental margin that is between the shoreline and the continental slope (or a depth or 200 meters when there is no noticeable continental slope); it is characterized by its very gentle slope of 0.1°. Island shelves are analogous to the continental shelves, but surround islands. The seabed in the shelf area was flat. A general term for a level (or nearly level) surface or area of land marked by little or no relief; flats area are often composed of unconsolidated sediments (such as mud or sand). These forms are more commonly encountered in the intertidal (coastal part of the area) or in the shallow subtidal zones. Compared to the northern part of Dobrogea, in the west there were small basins. This is a general term for an area of the seafloor or land surface that lies below the surrounding bottom or terrain elevation. They are normally areas of low relief. The transition between the basins and the surrounding flat area, as well as between the shelf area itself and the deeper areas of the Paleo-Thetys Ocean, was achieved by slope. The slope is an inclined area of ground or substrate with a change in depth or elevation between its upper and lower limits. Based on the discovery, in the past, of a large number of mollusk species in the shelf area, by extrapolation we can assume, towards the coastal area, the existence of patch mollusk reef, a mounded, generally round or lobate reefs that have some vertical relief above the surrounding substrate. These are usually intertidal, but they can occur in subtidal settings. For deeper areas, taking into account that in the northern part samples of coralline limestone were taken and the fact that in the shelf area, in general, the water depth did not exceed 200 m, the existence of shallow/mesophotic coral reef, a light-dependent coral reefs that occur within the photic zone (the mesophotic reefs occur in the lower part of this zone at depths of 30-150 m), can be assumed. (CMECS, 2012)

Modifiers of geoform component. Primary water source was marine, what does it mean unidirectional flow that is primarily marine water. Energy direction was mixed, what it stands for a combination of more than one of above directions. Energy type was given by a coherent directional motion of the water (current) in shelf zone and on coastal area by a periodic horizontally oscillating water motion (tide) and a coherent directional motion of the atmosphere (wind). Substrate induration was given by a blend of hard and soft substrate materials (mixed), a fact determined based on the co-presence of some species of burrowing bivalves, that lives in substrates at a depth of 1-20 cm (Zhang et al. 2022) and gastropods, with species of ammonites that could be found in both the shelf and basin areas. The geological classification is followed here to characterize slope as flat (0 to < 5°) in all shelf area, Sloping (5 to < 30°) on ecotones areas between the surrounding self and basins as well as the deeper regions of the Paleo-Thetys Sea, in the South-Eastern part of Dobrogea and steeply sloping (30 to < 60°) on the area, from north-eastern part of Dobrogea, between shelf area and the deeper regions of the sea. Basin areas in Dobrogea during the Triassic were formed in an extensional tectonic setting. These basins were likely rift basins or passive margin basins associated with the opening of the Tethys Ocean. The substrate descriptors offers an interesting perspective, because based on what was presented previously in the paper the values seems to be carbonate and this means that geologic origin particles or substrates composed mainly of carbonate minerals. The surface pattern was biological with features such as roughness that appears due to bioturbation, fecal mounds, tunneling, feeding or locomotory activities of megafauna, or other faunal activities. Benthic depth zones was represented by circalittoral (30 to < 200 m) a subtidal area below the photic zone, generally characterized by animal communities (although very sparse algae may be present), with exception of the basin areas with the mesobenthic (200 to < 1,000 m) characteristics in the shelf area, as well as by infralittoral (0 to < 30 m) a subtidal areas within the photic zone, often characterized by macroalgae or rooted vascular plants and divided into shallow (0 to < 5 m) and deep zones (5 to < 30 m). (CMECS, 2012)

Substrate component. This is represented by geologic substrate surface layer contains no trace of gravel and is composed of 50% to < 90% fine sand (particles 0.0625 millimeters to < 0.25 millimeters in diameter); the remainder is composed of mud (particles less than 0.0625 millimeters in diameter). (CMECS, 2012)

Modifiers of substrate component. Within the shelf, itself, and ecotone areas, the biogenic substrate particles were composed mainly of carbonate minerals. The different elements within this biogenic substrate context unit are derived, especially, from shell hash, algal sand, shell sand and carbonate ooze, as well as organic mud. Well-mixed characteristic imply that the elements or particles are completely and relatively uniformly mixed, for example, sand and mud particles in an area of high bioturbation, that was found especially in ecotone area. In the basins area, the substrate component was characterized by for substrate layering which have a great importance, the related observations according to which compared to mud substrates, sand substrates have larger particles, which to some extent hinder predator foraging and may provide a safer shelter for burrowing bivalves (Zhang et al., 2022). Considering the relatively large number of species (large-sized) identified in the collection for the Triassic and the fact that the maximum depth for a shelter is 20 cm, as well as the observation that evidence of very-deep burrowing fauna will also be present in the top 15 cm, the structuring of distinctly layered sediments, for shallow shelf area, consists of a >7 cm muddy sand at the bottom, a 6 cm fine sand layer over it, and a 2 cm moderate (fine percent cover from 45 to < 70%) shell hash layer on top, with the shell hash being the uppermost material. And in the case of ecotone area the sediment layer can be characterized by finer sands on bottom and muddy sands on top. (CMECS, 2012; Zhang et al., 2022) Considering the evolution of the Paleo-Thetys Ocean, through the break-up of Pangaea, this pattern strongly suggests a marine transgression. The area that was once a shallower, more energetic environment that becomes progressively deeper and calmer. The deeper a marine environment gets, the less influence it has from waves and tides, which are the main transporters of coarse sediment as in the case of shallow shelf area. This results in the deposition of progressively finer-grained particles (mud and silt) on top of the coarser sands and a sparse (coarse percent cover from 1 to < 30%) shell hash layer in a buffer area between ecotone and shallow shelf area that were deposited earlier. This situation was extended to the basin area where the fine, parallel layers of sediments was formed by the settling of fine-grained particles (mud, silt) in a low-energy environment. And in that condition layers where grain size decreases from bottom to top, a classic sign of a turbidite current depositing sediment from a suspension flow. Early Triassic basin formations often consist of siliciclastic turbidites and fine-grained clastics, which were deposited in deeper water environments. In areas near the fault scarps, weathering and erosion generated large volumes of poorly sorted elastic debris that formed alluvial fans and braided streams. North Dobrogea was also marked by intraplate rifting, which led to significant volcanic activity. The substrate includes volcanic and subvolcanic rocks, such as pillow basalts of the Niculițel Formation, and tholeiitic dykes. These basaltic rocks indicate a period of crustal thinning and magma upwelling. Those indicate a total sediment layer thickness of over 15 centimeters on the bottom of the shelf area from the Triassic. (CMECS, 2012; Zhang et al., 2022; Atudorel et al., 1997) Because, the surface of the seafloor was flat (on a scale of centimeters or meters) and biological productivity was high, we can consider that the surface pattern presented a combination of a surface with biological and rippled characteristics, in the eastern part of the shelf area and towards the coastal area. To the west the surface pattern presented a combination of a surface with biological and physical characteristics in the ecotone part and especially physical in the basin area. (CMECS, 2012)

Biotic component. The biotic setting corresponded to the benthic/attached biota. This biotic setting describes areas where biota lives on, in, or in close association with the seafloor or other substrates (CMECS, 2012). The benthic shelf areas in Dobrogea would have been characterized by a diverse and abundant marine fauna, especially during the Middle to Late Triassic (Atudorei et al., 1997). This area was characterized by fine unconsolidated substrates (sand, mud) and in that time was dominated by infauna, sessile epifauna, mobile epifauna, mobile fauna that create semi-permanent burrows as homes, or by structures or evidence associated with these faunae. That type of fauna represented the soft sediment fauna. (CMECS, 2012)

Modifiers of biotic component. The biotic component in shallow-water shelf areas was dominated by groups that were successfully diversifying. This was a key zone for invertebrates. The presence of burrowing bivalves and gastropods would have been prominent. Bivalves, in particular, underwent an evolutionary radiation in the Triassic, with many developing the ability to borrow more deeply using siphons. Other important groups included new types of scleractinian corals (which would become the major reef builders of the Mesozoic), as well as brachiopods, ammonoids and other genera of marine organisms characteristic of this geographic area. Today, the non-living scleractinian coral reefs (or coral particles) constitute the dominant benthic substrate that can may or may not be inhabited by live corals. (CMECS, 2012) Microorganisms like foraminifera and calcareous algae were abundant. These organisms were crucial in forming bioclastic limestones and microbial buildups, which provided a suitable environment for other macroinvertebrates. (CMECS, 2012; Atudorei et al., 1997) The ecotone area, as the transition zone between the shallow shelf and the deep water basin, would have shown a mix of biotic components from both environments. The decline in light would have limited the growth of calcareous algae and other photosynthesizing organisms which is still characterized by a fine average coverage percentage (between 30 to < 40%). Burrowing species would still be present, though their diversity and abundance might decrease with water depth. As a transition to deeper waters, the ecotone would have been a prime habitat for ammonoids and other nektonic (free-swimming) cephalopods. The deep-water basin environment was characterized by different conditions, including lower oxygen levels and the absence of sunlight, which would have limited the types of life present. (CMECS, 2012; Atudorei et al., 1997) The deep water basin would have had a more limited benthic (bottom-dwelling) organisms community. The presence of burrowing organisms would have been restricted to those that could tolerate water low oxygen conditions. This specific zone would have been dominated by pelagic organisms, such as ammonoids, belemnoids, and various types of fish that could thrive in the open water column of the area. The deep basin environment, especially in anoxic conditions, is known for preserving exceptional fossils. In Dobrogea, this could lead to well-preserved fossils of ammonoids and other nektonic organisms in the reddish cherty limestones and marly shales. (CMECS, 2012; Atudorei et al., 1997)

CONCLUSIONS

According to the studies performed, we can concluded that in summary, the Triassic Dobrogea paleo-habitat was a complex mosaic of interconnected environments, where geological and oceanographic processes, such as plate tectonics and marine transgression, were the primary drivers shaping the distribution of marine life, from burrowing invertebrates to free-swimming cephalopods, across a gradient of depths.

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