Research Article
Hittite Journal of Science and Engineering, 2023, 10 (4) 287-299
ISSN NUMBER: 2148-4171
DOI: 10.17350/HJSE19030000318

Strontium Isotopes, Ostracod Fauna, and Paleoenvironmental Characteristics in the Late Miocene Sequence of the Mut/Dağpazarı Region, Southern Turkey

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ABSTRACT

The primary focus of this study was the Dağpazarı village in the Mut region of Mersin, southern Turkey. In this research area, two stratigraphic sections were meticulously measured. The study conducted a comprehensive examination of the Middle-Late Miocene period in the Dağpazarı, Ballı, and Mut Formations by analyzing the ostracod fauna and utilizing strontium isotope chemostratigraphic dating. This research determined that the upper levels of the Mut/Köselerli formations, specifically from the Burdigalian to Serravallian, signify the commencement of the Miocene succession in the study area.The Dağpazarı Formation, characterized by abundant silty-clay, Ostrea fossils, and lignite layers, is deposited unconformably just above these levels.This formation contains the following ostracod taxa; *Bairdia subdeltoidea, C. glypta, Cytheridea acuminata acuminata, Acanthocythereis hystrix, Krithe monosteracensis, Neomonoceratina mouliana, Hemicyprideis sp., Cistacythereis caelatura, Cyherella terguemi, T. prava, K. langhiana, A. ulicznyi, Pokornyella deformis minor, Loxoconcha alata, Tenedocythere salebrosa.* Furthermore, the planktonic foraminifera species are; *O. universa, Globigerinoides trilobus, Glb. ruber, Orbulina bilobata, Glb. sacculifer, O. suturalis*, and the formation includes abundant bryozoa, echinoid spines, gastropods such as Terebralia at distinct levels, and fish otolith. The formation, dating from the late Serravallian to the early Tortonian, exhibits the shallow reef characteristics that continued to develop in the late Miocene.The formation consists of dark green, bulbous weathered claystone, *Bairdia subdeltoidea* and *Ostrea* which are reduced in size at the levels that pass into hard clayey sandstone, abundant benthic foraminifera with abundant echinoid spines. The formation consists of benthic foraminifera, hard clayey sandstone, and weathered dark green claystone, which contains numerous echinoid spines.*Ostrea* and *Bairdia subdeltoidea* are also present. The upper section of the analyzed succession concludes with silty, compact, clayey limestone layers and light-colored limestone bands. The Tırtar Ballı Formation, which conformably overlays the Dağpazarı Formation, signifies the culmination of a relatively recent reef formation during the Tortonian period.Ostracod species such as *Aurila pigadiana, Thalmannia hodgii, Buntonia sublatissima dertonensis, Bairdia subdeltoidea, Aurila sp. Bassiouni* have been defined. The limestones also contain abundant benthic foraminifera and echinoid spines. The $^{87}Sr/^{86}Sr$ ratio analyzed from the carbonate sample obtained from the Dağpazarı formation is 0.708920. Based on these isotope data, the age of the Dağpazarı formation was calculated to be 8.7 million years (Ma).

Keywords:
Mut; Dağpazarı; Planktonic foraminifera; Strontium isotope; Ostracod

Article History:
Received: 2023/02/18
Accepted: 2023/11/29
Online: 2023/12/31

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INTRODUCTION

The study area is situated in the northern part of the town center of Mut, within the Central Taurus Mountains (Fig. 1). In the initial geological investigations conducted in the research area and its vicinity, particular emphasis was placed on studying the structural evolution of the region since the Paleozoic, mapping the rock formations, and analyzing tectono-stratigraphic developments. Following this, numerous researchers conducted comprehensive studies in the fields of general geology, paleontology,

Cite as:
U. SAFAK, H. SONSUN and N. NURLU, "Strontium Isotopes, Ostracod Fauna, and Paleoenvironmental Characteristics in the Late Miocene Sequence of the Mut/Dağpazarı Region, Southern Turkey" Hittite Journal of Science and Engineering, vol. 10, no. 4, pp. 287–299, 2023. doi:10.17350/hjse19030000318

and stratigraphy [1-23]; [24-33]. Economic geology studies have predominantly focused on oil and coal [34-35]. Furthermore, there has been a significant increase in studies related to carbonate precipitation in Neogene rocks. This research was conducted to provide a comprehensive analysis of the Neogene sediments exposed in the Dağpazarı area, with a primary focus on ostracod fauna. In the Mut Basin, situated in the Middle Taurus Belt, calcareous nannofossil biochronology has been documented in the Mut-Ermenek section, specifically in the Dağpazarı reef. This reef developed as a result of the Miocene marine transgression and is primarily found in the upper sections of the reef, known as the Dağpazarı Formation. Coral biofacies were identified by Gürler [22] ,and Ilgar et al. [137] documented the late Serravallian to early Tortonian dug valley fill sediments, known as the Dağpazarı Formation [33-23]. The main objective of this study was to conduct a comprehensive analysis, including stratigraphic, chemostratigraphic (Sr isotopic), and micropaleontological examinations, with a specific focus on ostracod fauna. The research highlights the relatively recent reef sediments found in the Dağpazarı Formation, which is the primary subject of this study, as well as the overlying Tırtar/Ballı Formation.

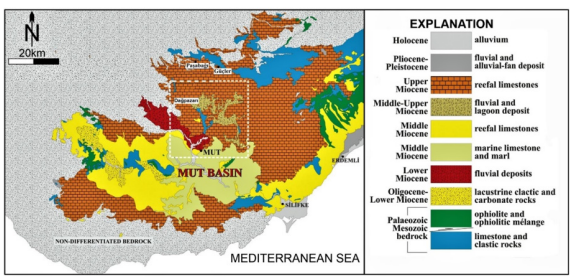

Figure 1. Geological map of the Dağpazarı research area and its vicinity [23].

The ostracod assemblages from the Late Miocene (Tortonian) in this research were examined and compared with ostracod faunas from Late Miocene (Tortonian) studies conducted in other regions of the Eastern Mediterranean in Turkey. Additionally, isotope data reported from nearby areas were analyzed in conjunction with the data obtained in this study. Ostracod assemblages from the Tortonian period in these Eastern Mediterranean-origin basins, namely Antalya/Serik, Mut, Mut/Dağpazarı, Karaman, Silifke-Erdemli/Mersin, Adana, and Antakya basins, were compared with the ostracod assemblage in this study. It was observed that they shared similar species. This study elucidates the formation of a young reef during the Tortonian period in the Adana Basin (Kuzgun Formation) [36], as well as in Silifke-Erdemli (Sarıaydın Formation) [37]. Similar depositional conditions and young reef characteristics were also identified in the Antakya Basin (Nurzeytin Formation) [38-39] (Fig. 8).

MATERIAL AND METHODS

Paleontological Analysis

The research was carried out on the 1/25000 scaled Mersin O30b3 map sheet. Measured sections were taken from two different areas in Dağpazarı Village and 50 washing samples were collected for micropaleontological analyses. The laboratory washing method was performed to obtain the ostracod fauna. 150 grams of each of the hard and moderately soft samples obtained from the sections were taken and divided into small pieces by placing them between thick paper and hitting them with a hammer Crumbled samples were placed in 1-liter glass beakers and hot water and 15% diluted hydrogen peroxide (H_2O_2) were added to disintegrate and left for 24 hours to dissolve. The samples have been washed under pressurized water with a set of 60, 120, 230 mesh sieves and then dried in an oven and put into separate bags according to their sieve numbers. After the separation of the microfossils contained in the samples from the grains, the genus and species of the samples collected in the collection slides were determined. 28 ostracod genera and 44 taxa have been defined in the research.

Identified species and genera have been counted, lateral and vertical distribution of ostracods have been enumerated and their numerical abundances have been defined. Symbols describing the semiquantitative frequency of ostracodes are used in this distribution table. Very rare (1-2 cover) ve rare (3-5 cover) frequencies are denoted by symbols such as r + and ○, common (6-15 cover), frequent (16- 25 cover) and very frequent (>25 cover) and frequencies ●,□,■. Paleoenvironmental interpretation of the research area was conducted based on the statistical and relative data. This interpretation was carried out in accordance with previous works by Morkhoven [110], Doruk [111], Bassiouni [112], and Freels [40-43]. Plate 1-2 was created by choosing scanning electron microscope (SEM) images of specific ostracod species and genera that were identified in these studies.

Petrographical and Isotopical Analyses

Thin sections of the samples were analyzed using binocular microscopes under polarized light (Leica DMEP). Subsequently, these thin sections were further examined using an optical microscope that utilized both transmitted and reflected light.Two of the most commonly utilized classifications are those developed by Folk and Dunham [44-45,46]. The thin sections of the limestones from the Divlek and Maz Formations were prepared by the Department of Geological Engineering at Çukurova University. The petrographic examination was conducted using the Leica DMEP microscope at Çukurova University. Strontium isotope geochemistry experiments were carried out at the Radiogenic Isotope Laboratory, R & D Training, and Mea-

surement Center of METU (Sr Isotope Ratio Analysis Experimental Instruction), following the detailed procedures and conditions outlined by Köksal et al. [47]. The isotope analyses were conducted by METU and involved using ultrapure water and chemicals. Weighing, chemical dissolution, and chromatographic operations were performed in a clean laboratory setting that met class 100 cleanroom standards. Specifically, certain sedimentary (limestone) samples underwent $^{87}Sr/^{86}Sr$ isotopic analyses at the METU Central Laboratory's Radiogenic Isotope Laboratory in Ankara, following the analytical techniques outlined by Köksal and Göncüoğlu [48].

RESULTS

Stratigraphy

The Miocene units in the research region can be listed from bottom to top as follows: Langhian-Serravallian Mut Formation, late Serravalian-early Tortonian Dağpazarı Formation, and Tortonian Tırtar/Ballı Formation (Fig. 2).

Lithostratigraphy

Mut Formation

The Mut Formation was initially named by Sezer [119], and later Gedik et al. [34] also used this name [49, 34]. The reefal Mut Formation can be correlated with the following formations: Silifke Formation [27], Göktepe Reef Limestone Member defined around Ermenek-Karaman [11], Mut Formation around Ermenek [50], and Karaisalı Formation in the Adana Basin [51]. The Mut Formation is characterized by reefal limestone and is found at the base of the succession in a relatively low thickness in this study. The age of the formation has been defined by different researchers as late Burdigalian-Langhian [23], Langhian-Serravalian [28-30,17], Middle Miocene [19-21], and late Serravallian-Tortonian [22]. When analyzing the age of the Mut Formation based on the age given by the overlying unit in this study, it is reported as Burdigalian-Serravalian (Fig. 3).

Dağpazarı Formation

The Dağpazarı Formation was initially defined by Atabey et al. [87], while Gedik et al. [34] referred to it as the Köselerli Formation [17,34]. This formation begins with silt, clay, and clayey limestone, and includes ostreal silty and sandy layers, greenish claystone with vegetation, and lignite. Towards the upper part of the succession, there is a lithological transition to fossiliferous sandstones and hard clayey sandstones (Fig. 2).

The age of the Dağpazarı Formation has been previously reported as Serravallian [17] and late Serravallian-Tortonian [23]. In this study, the age of the formation was determined as late Serravallian-early Tortonian, primarily based on the ostracod content and supported by strontium isotope data.

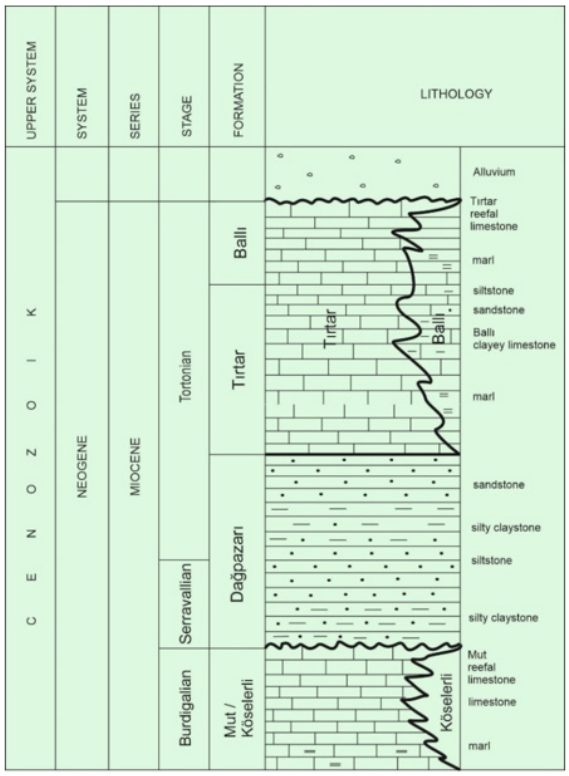

Figure 2. Generalized stratigraphic section of the research region of Dağpazarı [47].

Figure 3. a. General view of the outcrops of Mut formation (view to north) b-c. General outcrop of Dağpazarı formation and clayey limestone.

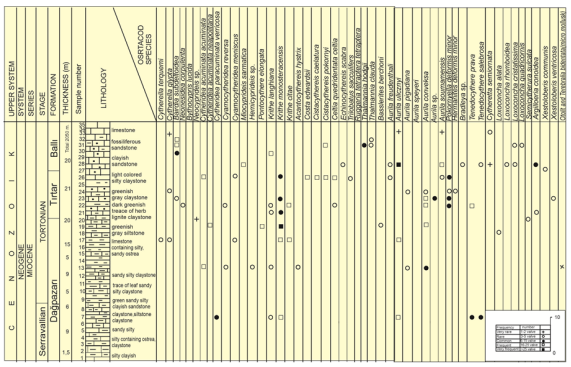

Figure 4. The distribution of the ostracod species in the Dağpazar 1 measured stratigraphic section.

Tırtar Formation

The Tırtar Formation was initially named by Atabey et al. [87]. This unit is characterized by limestone as the predominant lithology and contains algae, corals, benthic foraminifers, and mollusks [17]. Atabey et al. [87] and Ilgar et al. [93] proposed the age of the formation as Tortonian (Fig. 2) [17,34]. In this study, a predominant consideration of ostracod content and strontium isotope data led to the determination of the formation's age as Tortonian.

Ballı Formation

Atabey et al. [87] the unit was named for the first time and this name was given because the type section location is in the village of Ballı [17]. Planktonic foraminifera and nannoplanktons have been defined in the formation where claystone, marl and clayey limestone form the dominant lithology (Fig.2). Atabey et al. [87] found Globigerinoides obliquus extremus in the unit [17]. In addition, Ilgar et al. [93] suggested the age of the formation as Tortonian [23]. In this study, when the ostracod content and strontium isotope data are evaluated predominantly, the age of the formation is considered as Tortonian.

Measured Stratigraphic Sections

Stratigraphic sections were measured from two distinct ridges by selecting strategic locations within the research area. These locations offered the best exposure of successions providing Late Miocene age information in the Dağpazarı region.

Dağpazarı I Measured Stratigraphy Section

The section was measured between coordinates X1: 36.829371, Y1: 33.464047, Z1: 1287 m, and X2: 36.828976, Y2: 33.464154, Z2: 1492 m, with a total thickness of 205 meters. The section begins at the base with ostreid-rich, clayey, and silty layers belonging to the Dağpazarı Formation. As we move upwards, it transitions into weathered, greenish-gray claystone, silty clay, and fossiliferous clay-siltstone layers. Above this, the Tırtar/Ballı Formation is found, showing a smooth transition. The upper part of the succession is characterized by clayey sandstone, fossiliferous clayey sandstone, which remains relatively intact. This formation characterizes a reef in unweathered silty, clayey limestone (Tırtar) and upwardly unweathered limestone (Ballı) lithology. The following ostracod taxa were reported at the base levels of the Dağpazarı Formation in the section: *Cytherella terguemi, Cytheridea acuminata acuminata, Cytheridea acuminata verrucosa, Krithe monosteracensis, Krithe langhiana, Aurila ulicznyi, Cytherella glypta, Cytheridea acuminata neapolitana, Miocyprideis sarmatica, Hemicyprideis sp., Krithe monosteracensis, Krithe citae, Aurila convexa, Ruggieria tetraptera tetraptera, Aurila soummamensis, Tenedocythere salebrosa, Pokornyella deformis minor, Tenedocythere prava, Echinocythereis scabra.* In the upper levels, *Bairdia subdeltoidea, Thalmannia hodgii, Thalmannia clauda, Aurila soummamensis,* and *Aurila ulicznyi* were identified in the middle level of the formation. At the bottom levels, gastropods like Terebralia and fish otoliths were found. It's also notable that there is an increase in shallowing, and lagoonal conditions seem to dominate the environment.The ostracod genera identified in this formation generally suggest an epineritic environment, including *Ruggieria, Tenedocythere, Cytheretta, Aurila,* and *Pokornyella.* Additionally, ostracod species that typically indicate infraneritic environments, like *Krithe, Echinocythereis*, and *Buntonia*, have also been reported. The presence of ostracod species characterizing lagoon-littoral environments suggests a transitional feature from very shallow marine conditions to partially deep-sea conditions, including species like *Hemicyprideis, Loxoconcha*, and *Loxocorniculum*.Hence, it can be concluded that there is data indicating the presence of reef front and back textures in the Late Miocene (Tortonian) sequence. Shallow-water (epineritic depth) ostracod species like *Bairdia subdeltoidea, Aurila ulicznyi,* and *Aurila soummamensis* symbolize the reef's back and roof within the clay layers between the limestone beds of the Tırtar/Ballı Formation.

In the stratigraphic section, the Tırtar/Ballı Formation contains a wealth of b*ryozoa, echinoid spines,* and *gastropods*, including Terebralia, which is also observed at various levels within the section.

Dağpazarı II Measured Stratigraphy Section

The section was measured between coordinates X1: 36.826641, Y1:33.460034, Z1:1315 m., and X2: 36.826871, Y2:33.461080, Z2:1420 m. The section has a total thickness of 135 m and consists of cream-colored clayey limestone, clayey limestone-sandstone alternation, and sandstone belonging to the Dağpazarı Formation, which are observed at the lower, middle, and upper levels of the succession.The Dağpazarı Formation is succeeded by the reefal Tırtar/Ballı Formation, which consists of claystone, hard clayey limestone, and hard limestone, conformably overlaying it (Fig.5).

The ostracod species observed at the base levels of the Dağpazarı Formation in the section include *Cytherella glypta, Neonesidea corpulenta, Bairdoppilata supradentata, Neomonoceratina mouliana, Ruggieria tetraptera tetraptera, Aurila convexa, Aurila albicans, Aurila soummamensis, Aurila woodwardii.* Planktonic foraminifera species reported at the base of the section comprise *Trilobatus sacculifers, Orbulina suturalis, Morozovella angulosa.* Planktonic foraminifera species identified in the middle and upper levels include *Cytherella terquemi, Aurila sp.* Additionally, ostracoda species such as *Globigerinoides ruber, Orbulina bilobata, Orbulina suturalis, Orbulina universa* have been reported.The ostracod species identified in the claystone and clayey limestone levels of the Tırtar/Ballı Formation include *Aurila convexa, Krithe langhiana, Pokornyella deformis minor, Ruggieria tetraptera tetraptera, Acanthocythereis hystrix, Aurila speyeri, Aurila soummamensis, Aurila ducasseae, Tenedocythere mediterranea, Loxoconcha tumida, Argilloecia conoidea* (Fig.5). This assemblage characterizes the reef lagoon and the core of a young reef, indicating that the section is influenced by lagoon-littoral conditions as well as the neritic marine environment.

Strontium Isotope Chemostratigraphy

Strontium isotope chemostratigraphy plays a crucial role in deciphering the Earth's geological history. The $^{87}Sr/^{86}Sr$ pattern in seawater can be employed for robust correlations when other chemostratigraphic, lithostratigraphic, or biostratigraphic indicators prove to be inadequate.The accuracy of reconstructing seawater strontium isotopes depends significantly on two factors: the quality and reliability of chronological control in the reference data and the preservation of the samples, both of which can vary with the age of the period under examination.

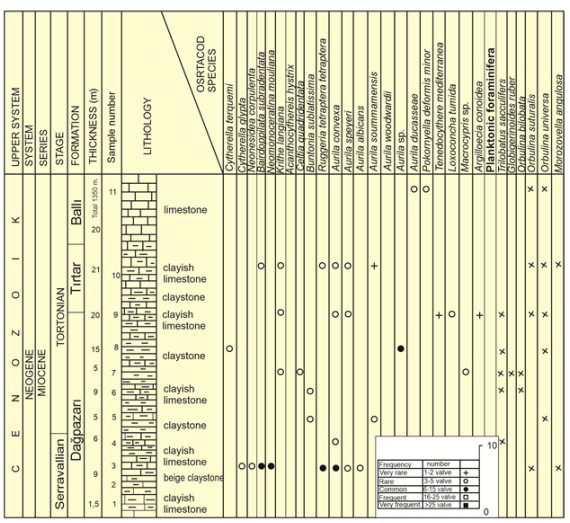

Figure 5. The distribution of the ostracod species in the Dağpazar 2 measured section

Marine strontium ratios ($^{87}Sr/^{86}Sr$) have evolved over the Earth's history, primarily driven by the interplay between unradiogenic strontium sourced from the Earth's mantle and radiogenic strontium from terrestrial input (continental crust) [54-55], as illustrated in Fig. 6 [52-53].

Three samples (Dp-1; 0,708920±15, Dp-2; 0,709644±8, Dp-3; 0,709733±7) were gathered from the studied area in order to analyze strontium and two of these samples did not yield results due to effects such as contamination and diagenesis. The ratio of $^{87}Sr/^{86}Sr$ analyzed from the limestone sample collected from the Dağpazarı formation is 0.708920. The age of the Dağpazarı formation was estimated as 8.7 Ma based on these isotope data.

DISCUSSION

Ostracod fauna-based correlation of Late Miocene (Tortonian) lithostratigraphic units of the study area with other Late Miocene (Tortonian) lithostratigraphic units in the Eastern Mediterranean region of Turkey is depicted in Fig. 7.

Antalya (Serik), Karpuzçay Formation

Karpuzçay formation was first named and reported by Akay et al. [57]. The type locality of the formation is Karpuzçay Village in the Antalya Miocene Basin. This formation comprises siltstone, thin-bedded sandstone, and sandy limestone alternations. The ostracod assemblage identified in the formation includes *Bairdia subdeltoidea, Miocyprideis sarmatica*, and *Aurila soummamensis* [57-58] (Fig.8).

Dağpazarı/Mut, Dağpazarı and Tırtar/Ballı Formations

The Dağpazarı/Mut, Dağpazarı, and Tırtar/Ballı formations were initially named by Atabey et al. [17]. The Dağpazarı Formation is characterized by clayey, weathered, greenish-gray siltstone at its base, which transitions into ostreal-bearing clayey siltstone, and further up

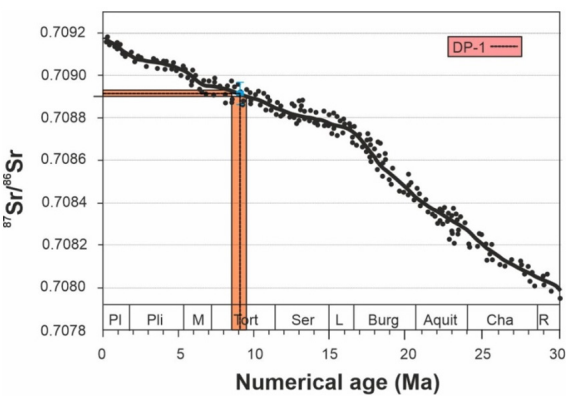

Figure 6. Strontium isotope variation curve for the Miocene interval [56].

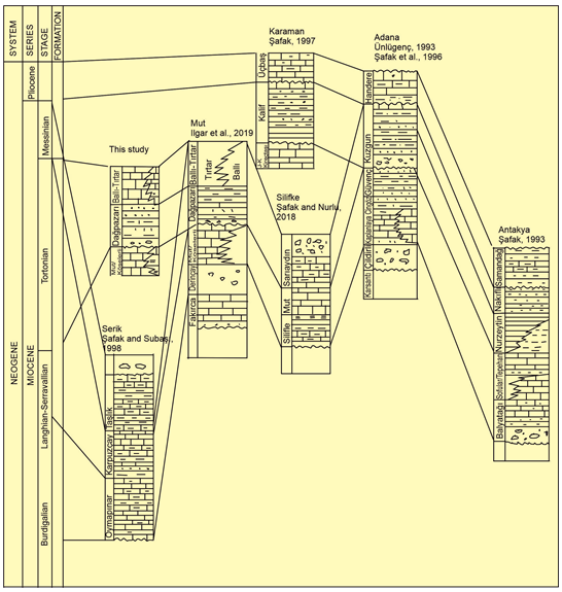

Figure 7. Correlation of Miocene-Pliocene Formations deposited in Antakya, Mut, Karaman, Silifke-Erdemli, Adana, Antakya basins (Eastern Mediterranean)

the succession, cream-colored clayey limestone, clayey limestone-sandstone alternations, and sandstones are present.The ostracod assemblage in the Dağpazarı Formation includes the following species: *Bairdia subdeltoidea, Hemicyprideis sp., Acanthocythereis hystrix, Aurila soummamensis, Pokornyella deformis minor, Ruggieria tetraptera tetraptera, Loxoconcha tumida,* and *Xestoleberis glabrescens* [23]. The formation has been assigned a middle (Serravallian) age [17] and a middle-late Miocene age (late Serravalian-Early Tortonian) [23]. The Tırtar Formation is primarily composed of light-colored, silty, hard clayey limestone. It exhibits both lateral and vertical transitions with the Ballı Formation [17,23]. These formations are dated to the Tortonian age [17,23], as shown in Fig. 8.

Kalif (Karaman) Formation

The Kalif (Karaman) Formation was initially defined by Koçyiğit in [129], based on the unit exposed in and around Karaman [59]. The formation's type locality, as first investigated by Koçyiğit in 1978, is best observed in Karaman Province and its surrounding areas [59]. The Kalif (Karaman) Formation comprises fossiliferous clayey limestone, sandy limestone, marl, mudstone shale, and evaporite layers. The ostracod assemblage in this formation is diverse and includes many species, listed as follows: *Neomonoceratina interiecta, N. acupicta, Sylvestra posterobursa, Cyprideis seminulum, C. sohni, Cytheridea acuminata acuminata, Chrysocythere paradisus, Krithe monosteracensis, Loxoconcha cristatissima,* and *Xestoleberis ventricosa.* The formation is assigned a late Miocene age [60] (Fig. 8).

Sarıaydın (Silifke-Erdemli/Mersin) Reef Limestone

The Sarıaydın Formation, also known as Sarıaydın Reef Limestone, was originally described by Gökten [97] based on exposures in Sarıaydın Village [27]. The formation's type locality is in Sarıaydın Village. It primarily consists of cream-colored limestone interbedded with clay sediments, marl, and caliche [37]. The ostracod assemblage

bu bilgisayar konumuna kaydedildi

Serik/Antalya Şafak ve Subaşı (1998)	Karaman Şafak(1997)	Dağpazarı Ilgar et al. (2019)	Mut/Mersin This study	Silifke-Erdemli MERSİN Şafak and Nurlu (2018)	Adana Basin Ünlügenç(1993) Şafak(1996)	Antakya Şafak(1993)	Ostracod species identified in the Eastern Mediterranean Tortonian
	×			×	×		*Cytherella vandenboldi*
					×		*Cytherella vulgata*
					×		*Cytherella obulus*
	×		×		×		*Cytherella glypta*
					×		*Cytherelloidea variopunctata*
							Cytherella petrosa
						×	*Cytherella postdenticulata*
				×			*Cytherella creutzburgi*
				×			*Cytherella sordida*
			×	×			*Cytherella terquemi*
×	×	×	×		×		*Bairdia subdeltoidea*
	×		×	×	×		*Neonesidea corpulenta*
						×	*Bairdia mediterranea*
			×	×			*Bairdoppilata subradentata*
				×			*Neomonoceratina interiecta*
	×			×			*Neomonoceratina acupicta*
	×						*Neomonoceratina laskaravi*
	×		×		×	×	*Neomonoceratina mouliana*
				×	×		*Schneidrella dromas*
	×					×	*Leptacythere multipunctata*
			×				*Cyprideis torosa*
				×		×	*Cyprideis anatolica*
				×		×	*Cyprideis sohni*
	×			×	×		*Cyprideis pannonica*
	×			×	×		*Cyprideis seminulum*
×			×	×	×		*Miocyprideis sarmatica*
	×		×	×	×		*Cytheridea acuminata acuminata*
	×		×	×	×		*Cytheridea acuminata neapolitana*
						×	*Sylvestra posterobursa*
	×		×	×		×	*Cyamocytheridea reversa*
	×				×	×	*Cyamocytheridea obstipa*
	×		×		×	×	*Cyamocytheridea meniscus*
	×					×	*Cyamocytheridea polygona*
						×	*Cyamocytheridea devexa*
		×	×				*Hemicyprideis sp.*
	×		×			×	*Pontocythere elongata*
	×		×				*Krithe citae*
	×		×	×		×	*Krithe monosteracensis*
			×				*Krithe langhiana*
					×	×	*Krithe papillosa*
				×			*Parakrithe robusta*
	×	×	×		×		*Acanthocythereis hystrix*
	×		×		×	×	*Costa edwardsii*
				×			*Costa tricostata*
	×				×	×	*Chrysocythereis paradisus*
	×		×	×	×		*Cistacythereis pokornyi*
			×	×		×	*Cistacythereis caelatura*
	×				×		*Carinocythereis antiquata*
	×		×		×		*Celtia quadridentata*
	×		×				*Echinnocythereis scabra*
	×				×		*Incongruellina rotundata*
	×	×	×		×		*Ruggieria tetraptera tetraptera*
	×		×		×		*Thalmannia hodgii*
					×	×	*Thalmannia procera*
					×		*Thalmannia dolabrata*
	×					×	*Heterocythereis albomaculata*
×		×	×	×			*Aurila soummamensis*
	×		×		×	×	*Aurila speyeri*
	×		×		×	×	*Aurila convexa*
	×		×		×		*Aurila freudenthali*
	×		×				*Aurila ulicznyi*
					×	×	*Aurila skalae*
			×		×	×	*Aurila ducasseae*
						×	*Aurila cicatricosa*
			×		×	×	*Aurila albicans*
	×	×	×	×	×	×	*Pokornyella deformis minor*
	×				×		*Procythereis sulcatopunctatus*
	×		×		×	×	*Hermanites haidingeri minor*
	×		×		×	×	*Tenedocythere mediterranea*
	×		×		×	×	*Tenedocythere prava*
	×		×		×	×	*Tenedocythere salebrosa*
	×			×	×	×	*Urocythereis favosa(Nonucythereis)*
	×					×	*Urocythereis seminulum*
						×	*Bosquetina carinella*
						×	*Occultocythereis bireticulata*
					×		*Cytheretta orthozensis*
	×		×		×		*Cytheretta semiornata*
				×			*Cytheretta simplex*
			×		×	×	*Loxoconcha rhomboidea*
	×	×	×	×			*Loxoconcha tumida*
	×				×		*Loxoconcha subovata*
	×		×				*Loxoconcha cristissima*
	×				×		*Loxoconcha stallifera*
				×			*Loxoconcha alata*
			×	×		×	*Xestoleberis communis*
	×			×	×		*Xestoleberis reymenti*
	×		×	×	×		*Xestoleberis ventricosa*
		×			×	×	*Xestoleberis glabrescens*
	×		×				*Loxocorniculum quadricornis*
	×	×			×	×	*Paracypris polita*
			×				*Semicytherura sulcata*
	×		×				*Argilloecia conoidea*

Figure 8. Ostracod species identified in the Eastern Mediterranean Late Miocene

within this formation includes the following genera and species: *Cytherella vandenboldi, C. creutzburgi, C. sordida, C. seminulum, Neomonoceratina acupicta, N. interiecta, Miocyprideis sarmatica, Parakrithe robusta, Cyprideis anatolica, Krithe monosteracensis, C. pannonica, Cytheridea acuminata acuminata, Cistacythereis pokornyi, C. caelatura, Loxoconcha tumida,* and *Paracypris polita*. The age of the Sarıaydın Formation was given as Tortonian? [27] (Gökten, [97]) and Late Serravallian-Tortonian [37], (Fig.8).

Kuzgun (Adana) Formation

The Formation (Adana) Formation was originally defined by Schmidt [51], and its type locality is situated in Kuzgun Village along the Adana-Karaisalı road. This formation is characterized by a transition from meandering river sediments at the base to shallow marine conditions in the upper levels. During the Tortonian, the region experienced sea level fluctuations, with alternating rises and falls [61]. Within this formation, you can find substantial fossiliferous greenish claystone, light-colored clayey limestone, and well-sorted yellowish-cream colored sandstones with a reefal character, particularly at the İncirlik locality, situated to the southeast of Adana [36]. The ostracod community in this formation is exceptionally diverse, including the following species: C*ytherella vulgata, C. glypta, Neomonoceratina mouliana, Schneidrella dromas, Cyamocytheridea meniscus, Carinocythereis antiquata antiquata, Aurila soummamensis, Loxoconcha rhomboidea, Paracypris polita*. The formation is attributed to the Tortonian age [36,61-62].

Nurzeytin (Antakya Basin) Formation

The Nurzeytin Formation in the Antakya Basin was initially designated by Selçuk in [63]. The type locality is situated in the vicinity of Nurzeytin, Yazır, Sivrikavak, and Babatorun. This formation is characterized by reef-like lithologies including sandstone, clayey limestone, marl, and claystone. The ostracod assemblage in this formation is highly diverse, and the following taxa have been identified: *Cytherella glypta, Cyprideis torosa, Acathocythereis hystrix, Aurila convexa, A. speyeri, Hermanites haidingeri minor, Ruggieria tetraptera tetraptera, Tenedocythere prava, T. mediterranea, Xestoleberis ventricosa, X. communis.* The formation has been suggested to span the Late Serravalian-Tortonian and Tortonian ages [38-39,63].From these descriptions, it's clear that the Tortonian development in these six significant locations in the Eastern Mediterranean Region of Anatolia is remarkably similar in terms of lithology, environmental conditions, and ostracod fauna.The ostracod fauna of the Dağpazarı Formation in this new study closely resembles the ostracod species identified from these six locations, with the exception of *Cyprideis* species, which were not encountered in this study.The environment exhibits distinct back-reef facies characteristics with lagoon-like *Neocyprideis* and lagoon-litoral ostracod species like *Hemicyprideis* and *Loxoconcha*. It also displays distinct shallow reef front and core characteristics with ostracod genera adapted to epineritic depths, such as *Acanthocythereis, Aurila, Pokornyella, Tenedocythere, Neomonoceratina, Pontocythere,* and *Ruggieria*. Furthermore, ostracod genera indicative of infraneritic depths and bathyal environments, such as *Macrocypris, Argilloecia, Bythocypris, Krithe,* and *Bradleya*, are typical of deep reef front facies (Fig. 7).The Mut Basin is situated in the Eastern Mediterranean region of the Alpine-Himalayan Mountain Belt (AHMB) and in the Central Taurus sector of the Taurus Mountains in southern Turkey.

The late Burdigalian marine transgression led to the submersion of the Antalya, Mut, and Adana basins, initiating the deposition of the first marine sediments in these basins during the Neogene. Consequently, the Burdigalian-Serravallian period witnessed the formation of the reefal limestones of the Mut Formation and the marl-clay limestones of the Köselerli Formation in the Mut Basin. As a result of the decrease in sea level in the Late Serravallian, the basin started to become shallow and a young reef deposition took place on the Mut formation reef limestones in the Late Serravallian-early Tortonian. This unit is the Dağpazarı Formation, and the reef limestones of the Tırtar Formation and the layered limestones of the Ballı Formation were deposited on the unit in the north of the Mut Basin. In the vicinity of Dağpazarı Village, the sedimentary layers consisting of mudstone, silty claystone, and sandstone that overlay the Mut Formation were initially considered part of the Köselerli Formation and examined. However, due to variations in lithology, deposition environment, and age, these layers were later designated as the Sertavul Formation.The formation typically represents a lagoon environment situated behind the reef. It is occasionally associated with fluvial deposits, coastal sand, coal seams, and limestone deposits. This rock unit has been identified as the Dağpazarı Formation, indicating its characteristics of a back-reef lagoon and alluvial fan environment. [17]. It was also stated by these authors that the Dağpazarı formation is transitional with the Köselerli and Mut formations deposited in the completely regressive phase of the sea. Early-middle Miocene sea level changes in the Mut Basin have also been studied, but clear data are not available [20, 22].

It is detailed that an incised valley, formed as a result of the late Serravallian eustatic sea-level decline, is observed, where the Dağpazarı Formation overlies the Mut reefal limestones with erosive unconformity [23]. It is mentioned that the sedimentary facies identified in the formation were deposited within this valley, following a subsequent relative

sea-level rise that occurred in the early Tortonian. A comprehensive study of planktonic foraminifera was conducted using mudstone and marl samples obtained from the Dağpazarı and Ballı Formations.

The study employed Mediterranean planktonic foraminiferal biostratigraphy and the ATNT52004 magnetic chronostratigraphy table to determine the Serravallian and Tortonian ages.It was also noted that due to the isostatic uplift of the Taurus Mountains in the late Tortonian, marine sedimentation in the Mut Basin ceased, leading to the exposure of the basin [65-67]. In this research, the fossil content of the unconformable Dağpazarı Formation overlying the Mut limestones at the base and the Tırtar/Ballı Formations, based on the ostracod fauna, was documented.These three lithological units (Dağpazarı, Tırtar/Ballı Formations) have developed with a young reef character and contain ostracod genera and species that accurately represent the back-reef-lagoon, core, and fore-reef facies.

In this new study, the Dağpazarı Formation exhibits a lagoon character with ostracod species like *Neocyprideis*, while the back reef is characterized by ostracod species such as *Hemicyprideis* and *Loxoconcha*, displaying lagoon-littoral characteristics. Additionally, the shallow reef fore-core is marked by ostracod genera with epineritic depth, including *Acanthocythereis, Aurila, Pokornyella, Tenedocythere, Neomonoceratina, Pontocythere*, and *Ruggieria*. The deep reef front is identified by ostracod genera with infraneritic depth, including *Macrocypris, Argilloecia, Bythocypris, Krithe*, and *Bradleya*. Additionally, this study identified significant genera indicative of lagoon sediments and marine input. [23].

The study notably provided a comprehensive presentation of the ostracod genera and species specific to the fore-reef facies, marking the first such detailed account in this research. Additionally, banded levels of Ostrea were identified in the littoral sections of the middle levels of the Dağpazarı Formation.The presence of the genus Ostrea is recognized as an indicator of shallowing in the environment [68-69]. This study was conducted in a succession characterized by the deposition of a young reef, which culminated in the Tortonian age in the northern part of the Mut Basin.

CONCLUSIONS

This study was conducted in and around Dağpazarı Village, located to the north of the Mut Basin. The research area includes sandy, clayey, silty, fossiliferous, and relatively younger sequences that overlay the Mut limestones (Mut Formation).The fossil content of the Dağpazarı, Tırtar/Ballı formations, which are very thin and unconformably emplaced on the Mut formation, has been revealed by predominantly using the ostracod assemblage and strontium isotopic data. Within this assemblage, ostracod genera indicative of a deepening neritic environment with a shallow neritic core, along with a litoral reef next to a lagoon, have been identified. This reefal succession, which originated during the Tortonian, has been investigated from lithological, chronostratigraphic, and chemostratigraphic perspectives. Furthermore, the ostracod assemblages from late Miocene (Tortonian) studies within the Eastern Mediterranean bioprovince of Turkey were also compared. In the lithostratigraphic and chronostratigraphic correlation from west to east, it was observed that the ostracod assemblages in the Tortonian of the Antalya, Mut, Karaman, Silifke-Erdemli, Adana, and Antakya basins closely resemble the ostracod assemblages found in the Tortonian of the Dağpazarı region.

Late Miocene reef-like sedimentary deposits with young reef characteristics were identified in the Late Tortonian (Miocene) successions within the Antalya, Dağpazarı/Mut, Karaman, Silifke-Erdemli, and Adana Basins, which are part of the Turkey-Eastern Mediterranean Province.

The ostracod assemblage has confirmed that the late Miocene (Tortonian) sediments in the Antakya Basin exhibit a shallow reefal character, characterized by creamy-white clayey units and marls. The $^{87}Sr/^{86}Sr$ ratio obtained from the carbonate sample within the Dağpazarı Formation is 0.708920. Based on this isotope data, the age of the Dağpazarı Formation has been calculated as 8.7 million years (Ma).

ACKNOWLEDGEMENT

Financial support for this research was generously provided by the Çukurova University Research Foundation under Project No: FBA-2021-13446. We would like to express our gratitude to two anonymous reviewers for their valuable comments, which have greatly improved this paper. We extend our thanks to Dr. Köksal for conducting the strontium isotopic analyses..

CONFLICT OF INTEREST

Authors approve that to the best of their knowledge, there is not any conflict of interest or common interest with an institution/organization or a person that may affect the review process of the paper.

AUTHOR CONTRIBUTION

The authors shared all the roles and contributed equally to the paper.

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Plate I

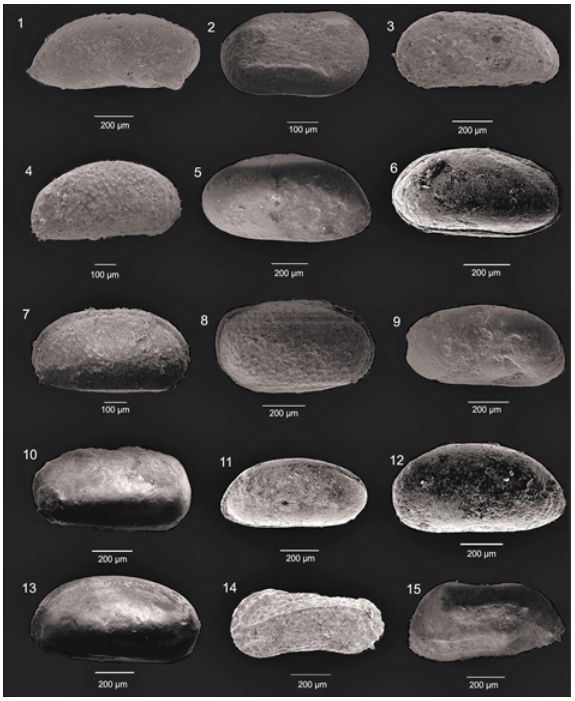

Figure 1. Bythocypris lucida (Sequenza)
1. Left cover, side view, Dağpazarı 1 Measured Stratigraphy Section, Sample 21
Figure 2. Cytherella glypta Doruk
2. Shell, left exterior view, Dağpazarı 2 Measured Stratigraphy Section, Sample 3
Figure 3. Cytheridea acuminata neapolitana Kollmann
3. Left cover, side view, Dağpazarı 1 Measured Stratigraphy Section, Sample 7
Figure 4. Cytheridea acuminata acuminata Bosquet
4. Right cover, side view, Dağpazarı 1 Measured Stratigraphy Section, Sample 26
Figure 5-6. Cyamocytheridea reversa (Egger)
5. Carapace, right external view, Dağpazarı 1 Measured Stratigraphy Section, Sample 22
6. Shell, right external view, Dağpazarı 1 Measured Stratigraphy Section, Sample 13
Figure 7-8. Cyamocytheridea meniscus Doruk
2. Shell, left exterior view, Dağpazarı 1 Measured Stratigraphy Section, Sample 26
3. Carapace, right side view, Dağpazarı 1 Measured Stratigraphy Section, Sample 17
Figure 9-10. Pontocythere elongata (Brady)
9. Shell, right external view, Dağpazarı 1 Measured Stratigraphy Section, Sample 21
10. Carapace, right side view, Dağpazarı 1 Measured Stratigraphy Section, Sample No. 21
Figure 11-12. Krithe citae Oertli
11. Shell, right external view, Dağpazarı 1 Measured Stratigraphy Section, Sample 23
12. Right cover, side view, Dağpazarı 1 Measured Stratigraphy Section, Sample 13
Figure 13. Krithe monosteracensis (Sequenza)
13. Shell, right external view, Dağpazarı 1 Measured Stratigraphy Section, Sample 26
Figure 14. Cistacythereis pokornyi (Ruggieri)
14. Shell, left exterior view, Dağpazarı 1 Measured Stratigraphy Section, Sample 31
Figure 15. Ruggieria tetraptera tetraptera (Sequenza)
15. Shell, left exterior view, Dağpazarı 2 Measured Stratigraphy Section, Sample 10

Plate II

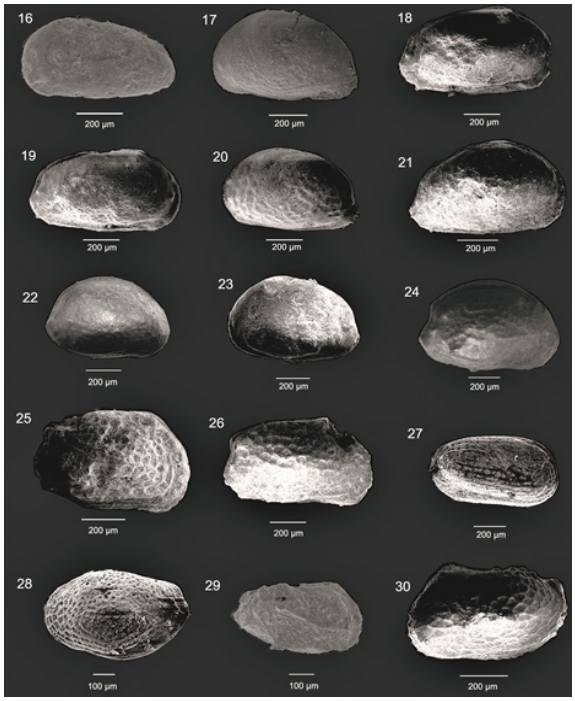

Figure 16. Thalmannia clauda (Doruk)
16. Shell, left exterior view, Dağpazarı 1 Measured Stratigraphy Section, Sample 32
Figure 17. Aurila convexa (Baird)
17. Shell, left exterior view, Dağpazarı 2 Measured Stratigraphy Section, Sample 10
Figure 18-19. Aurila freudenthali Sissingh
18. Shell, right external view, Dağpazarı 1 Measured Stratigraphy Section, Sample 26
19. Shell, right external view, Dağpazarı 1 Measured Stratigraphy Section, Sample 26
Figure 20-21. Aurila ulicznyi Sissingh
20. Shell, left exterior view, Dağpazarı 1 Measured Stratigraphy Section, Sample 28
21. Shell, right external view, Dağpazarı 1 Measured Stratigraphy Section, Sample 17
Figure 22. Aurila speyeri (Brady)
22. Shell, right external view, Dağpazarı 2 Measured Stratigraphy Section, Sample 9
Figure 23. Aurila soummamensis Coutelle and Yassini
23. Shell, left exterior view, Dağpazarı 1 Measured Stratigraphy Section, Sample 28
Figure 24. Pokornyella deformis minor Moyes
24. Shell, right external view, Dağpazarı 2 Measured Stratigraphy Section, Sample 11
Figure 25. Tenedocythere prava (Baird)
25. Shell, right external view, Dağpazarı 1 Measured Stratigraphy Section, Sample 22
Figure 26. Tenedocythere salebrosa Uliczny,
26. Shell, right external view, Dağpazarı 1 Measured Stratigraphy Section, Sample 28
Figure 27. Cytheretta semiornata (Egger)
27. Shell, right external view, Dağpazarı 1 Measured Stratigraphy Section, Sample 34
Figure 28. Loxoconcha rhomboidea (Fischer)
28. Shell, left exterior view, Dağpazarı 1 Measured Stratigraphy Section, Sample 28
Figure 29. Loxoconcha cristatissima Ruggieri
29. Shell, right external view, Dağpazarı 1 Measured Stratigraphy Section, Sample 31
Figure 30. Loxocorniculum quadricornis (Ruggieri)
30. Shell, left exterior view, Dağpazarı 1 Measured Stratigraphy Section, Sample 31