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Research Article

Neogene Stratigraphy of the Bozbelen area (Çayırhan, Nallıhan) and a New Vertebrate Fossil Locality

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ABSTRACT

Within the scope of the research, we present the vertebrate fossil findings for the first time around Çayırhan (W Ankara). Fossils are only in a single locality namely Bozbelen area and its vicinity within the lacustrine sediments mostly at clayey, marly levels. The paper aims to introduce the fossil findings of this locality, which is important in terms of geoheritage and Miocene-Pliocene geological history of Türkiye, and to revise stratigraphy of the study area that is located in the Beypazarı Neogene Basin. Field and laboratory works were carried out. Thin section samples and many vertebrate bones and teeth were collected. The Miocene basin comprises various lithological units. Stratigraphy based on field observations and satellite views are from bottom to top as follows: Paleogene-aged Karabayır formation (red coloured clastics), Miocene-aged Akpınar formation (=Çayırhan formation) (rhythmic greenish tuffite, claytone, sandstone), Kırmızıtepe formation (red-coloured sandstones, conglomerates), Miocene-Pliocene aged Bozbelen formation (marls, siltstones, mudstones), Aşağıbozbelen formation (sandstones, siltstones), Yukarıbozbelen formation (sandstones, conglomerates) and Quaternary alluvium and slope deposits. The formations have lateral and vertical facies that change each other. Various teeths and broken bones of *Hipparion* sp., *Gazelle*sp. and *Ictitherium* sp. are within the sediments of the Bozbelen formation. The age of the unit is late Miocene-early Pliocene. Reworked fossils into the lake muds and lithological features of the studied formation show a very shallow lake coast side paleoenvironment. Trace fossils and silica fillings in the muds originating from the volcanic activity are also noteworthy.
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1. Introduction

Various Neogene fluvial, lacustrine and volcanoclastic sediments known as the Beypazarı Neogene Basin are exposed widespread from Ayaş to Nallıhan in the west of Ankara. They are important economically for coal, gypsum and trona occurrences.

The study area is located in the Bozbelen area (NW Çayırhan, Nallıhan) within the Beypazarı Neogene Basin in the western part of Ankara (Figure 1). The earliest studies in the region were carried out by Stchepinsky [1], Rondot [2] and Kalafatcıoğlu and Uysal [3]. The Miocene series between Beypazarı and Nallıhan is named for the first time as the Beypazarı Group by Siyako [4]. Due to the economic importance of the Neogene formations, numerous studies have been conducted on stratigraphic, sedimentological, tectonic, and mining research [see references in 5].

To the north of the study area, widespread Mesozoic sediments show a parallel structure to the North Anatolian Fault. Overturned structural relation to the Paleogene sediments at the north of the study area [6], the Davutoğlan Fault at the south [7], Çayırhan Dome, and Beypazarı flexure [4] present interesting geological features. Between these two main tectonic lines, ancient fluvial and lacustrine sediments generally show nearly horizontal layering and provide thick and widespread exposures.

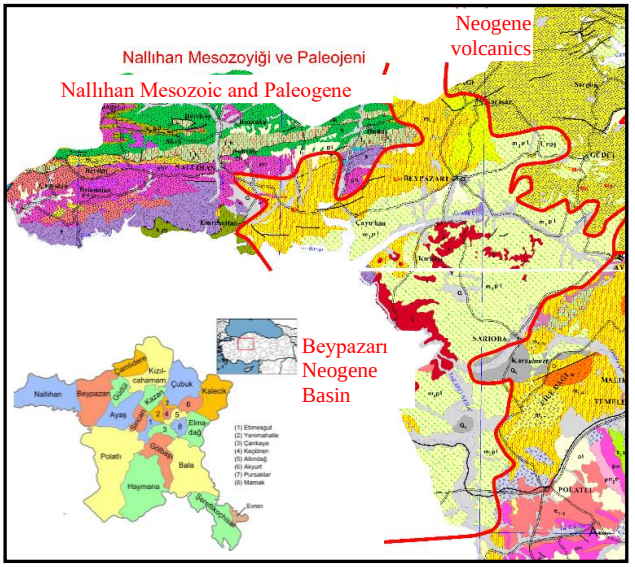

Figure 1. Ankara province and its surrounding district map (a) and geological map of W Ankara (b) [X], Q. Quaternary, pl. Pliocene, mpl. Miocene-Pliocene, m. Miocene, e. Eocene, pa. Paleocene, Cr. Cretaceous, JCr. Jurassic-Cretaceous, J. Jurassic, Tr. Triassic, pt. Permian-Triassic, pm. Permian, cp. Carboniferous-Permian, oph. Ophiolitic rocks, Red colour shows magmatic rocks

Saraç [9] addresses micro and macro vertebrate fossil findings in Turkey as MTA project and compiles it within a report. Furthermore, Erten and Görmüş [10] present a compilation of small mammal fossils in Turkey. Additionally, macro vertebrate fossils have also been well-documented in numerous studies. Vertebrate fossil deposits in Ayaş, Kızılcahamam, and surrounding areas in northern and western Ankara have been the subject of several articles. The nearest vertebrate fossil locality related to Neogene sediments is the Eminova-Beypazarı [9] (Figure 2).

The vertebrate fossils, discovered for the first time bring out age and paleoenvironmental approaches of the Neogene units. So, they have significant data in terms of geoheritage and the geological history of the Beypazarı Neogene basin in Türkiye. the main aims of this study are to introduce the fossil findings of this locality and to revise the Neogene stratigraphy of the area.

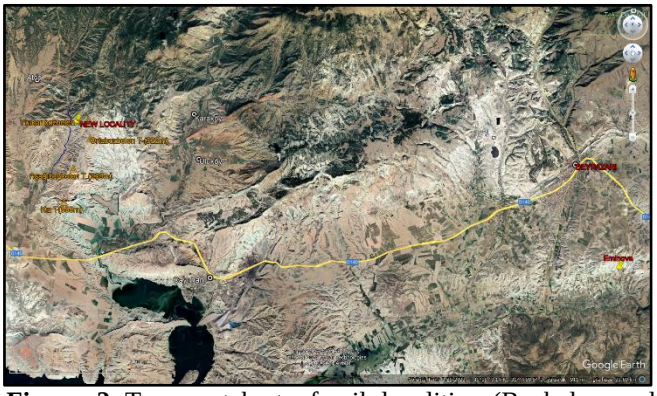

Figure 2 Two vertebrate fossil localities (Bozbelen and Eminova) in the Beypazarı area on Google Earth satellite view based on the previous data [9]

2. Materials and Methods

Vertebrate fossils were reported to Associate Professor Dr. Alaaddin Vural by İbrahim Uysal, President of the Çayırhan Hunters Association, Vice President Yaşar İlhan Tok, and Mechanical Engineer Erkan Koçak. Field and laboratory works were carried out at the beginning of 2024 using Google Earth satellite views to separate the geological units. Correlation of previous geological maps, general stratigraphical section columns and new maps obtained from the satellite view shows differences in the boundaries, names and lithologic characteristics. Colour differences, drainage patterns, plant covers, geomorphological topographic elevations, lineation features and human-made structures of the satellite image are the main criteria for the mapping. A section from the Bozbelen location was measured. Thin sections were prepared from the hard rocks. Teeth and bones of vertebrate fossil remains were collected. The vertebrate fossils were cleaned by using hydrogen peroxide solution and photographed in the Paleontology laboratory in the Geological Engineering Department of Ankara University. Related report documents and research papers were used for the stratigraphical revision and vertebrate fossil data of the area. Various software programs were used for drawings.

3. Stratigraphy

In the Beypazarı-Nallıhan area, the basement unit is known as Permo-Triassic aged metamorphics. Jurassic to Cretaceous sediments overlie unconformably the basement. Cretaceous deposits are referred to as the Dereköy Group while Paleogene units are identified as the Kızılçay Group [6]. As mentioned above, Siyako [4] called the Neogene sediments within the Beypazarı Group. Figure 3 generally shows the Miocene-aged Neogene formations around the study area in a Google Earth satellite image. There have been differences in previous literature regarding age determinations and names of formation or lithodem units. Therefore, a stratigraphic revision was conducted based on previous geological maps, stratigraphical approaches [4, 10-19] and Google Earth satellite images.

Stratigraphically, the names of the formations and lithodem mainly follow the nomenclature of Siyako [4]. Revised stratigraphical units in the study area, from bottom to top, are as follows: Paleogene aged Kızılbayır formation, Neogene aged Akpınar formation (ma), Kırmızıtepe formation (mk), Bozbelen formation (mplb). Aşağıbozbelen formation (mplab), Yukarıbozbelen formation (mplyb) and Quaternary sediments (Figures 3-6).

Kızılbayır formation (Pgk): It is seen at the north of the study area (Figure 4). It is composed of red-coloured siliciclastics. Sandstones and conglomerates with mudstone interbeds include various clasts derived from the basement rocks. Cretaceous-aged Dereköy Group sediments [6] are exposed around Yeşilyurt, Gökçeöz, Dudaş villages located in the north [5]. Overthrust relation between Permo-Triassic aged Sekli metamorphics and the Kızılbayır formation is also observed between Sekli and Karaköy villages [5]. The overlying unit of the Karabayır formation is Karaköy volcanoclastics around the Karaköy village [5]. However, Neogene sediments overlie unconformably around the Çayırhan area.

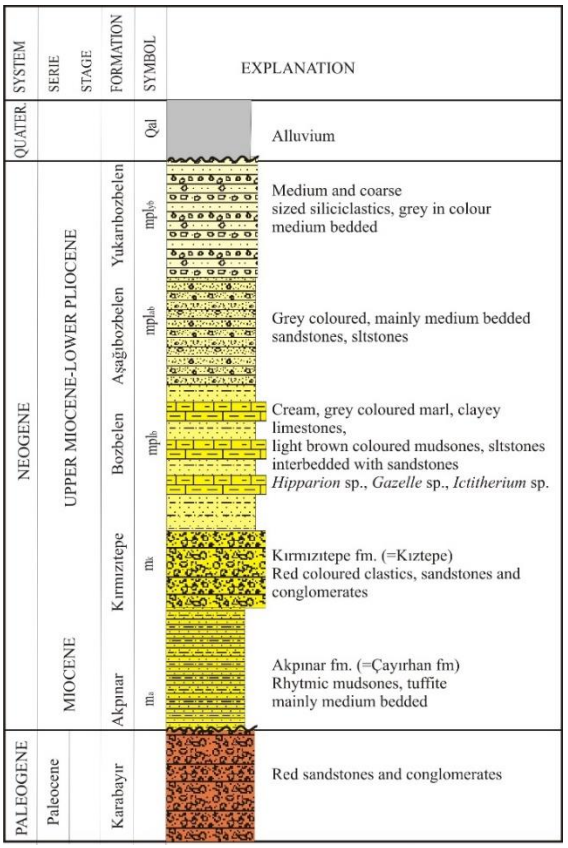

Figure 3 The revised and proposed Paleogene-Neogene stratigraphic sequence in the Çayırhan area.

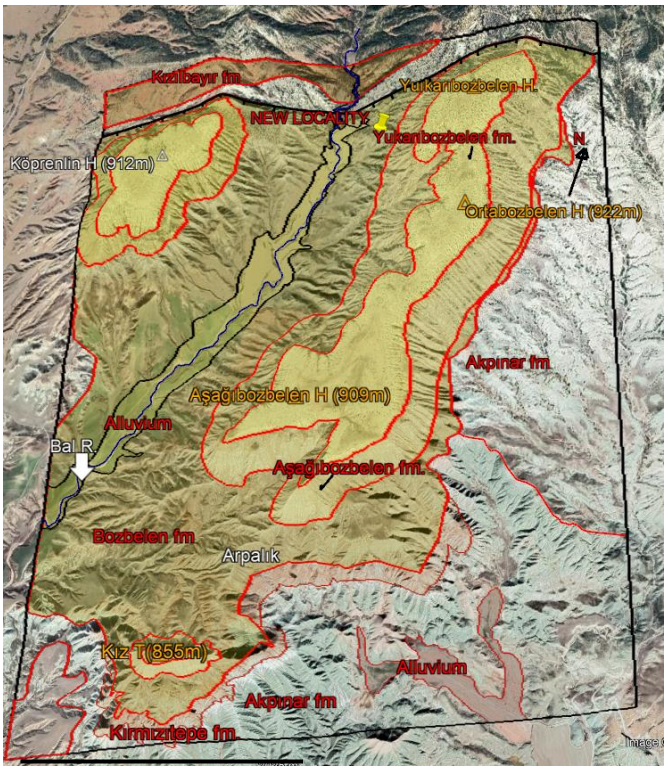

Figure 4 View of re-mapped geological units on Google Earth satellite image (date of Google Earth view: 10/12/2021; scale 2 km)

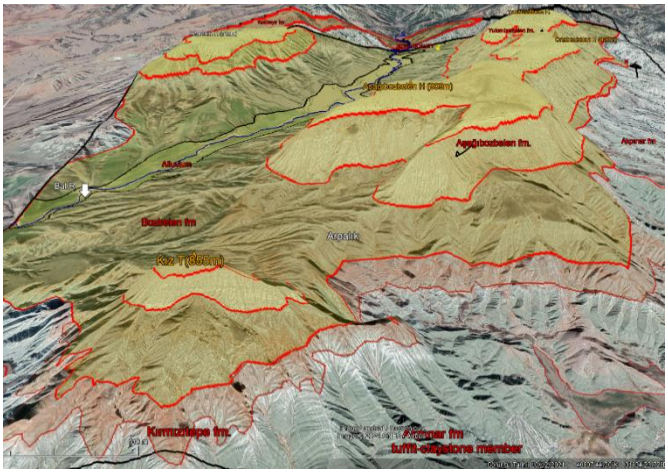

Figure 5 3D view on Google Earth satellite image showing the geological units in the study area (date of Google Earth view: 10/12/2021)

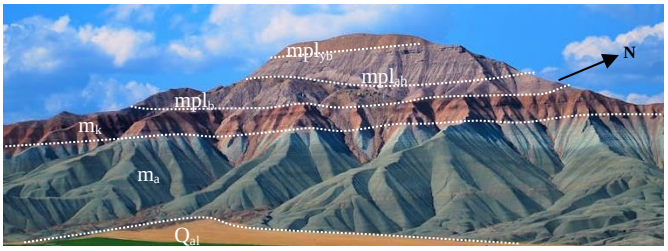

Figure 6 A view from the Kız Hill known as Nallıhan Bird Sanctuary, m_a Akpınar (=Çayırhan fm.), m_k Kırmızıtepe fm. (=Kıztepe), mpl_b Bozbelen fm., mpl_{ab} Aşağıbozbelen fm., mpl_{yb} Yukarıbozbelen fm., Q_{al} Aluvium, slope deposits.

The Neogene terrestrial sediments start with Çoraklar formation including brownish coloured clastics. The age of the Kızılbayır formation within the Kızılçay Group is known as Paleogene due to its stratigraphical position and lithologic composition [5]. It is related to fluvial paleoenvironments.

Akpınar formation (m_a) *(=Çayırhan formation*): In literature, there has been confusion on the name of the formation, its outcrops and lithologies in geological maps [4, 7, 8, 18, 19]. Siyako [4] describes the formation from the Akpınar area, the type locality located 6 km eastern of Uluköy village. However, the same name was also used for the limestones exposed in Karadoruk Hill next to Çayırhan by some researchers [7, 8, 18, 19]. In fact, the limestones overlying conformably the Hırka formation should be called as Karadoruk formation due to its type locality given by Siyako [4]. So, based on the stratigraphical nomenclature, we accept the name of the Akpınar formation reported for the first time by Siyako [4]. Outcrops of the formation in the study area were named as Çayırhan formation by Helvacı [18], Koral et al. [19] and Bozbelen formation by Ardahanlıoğlu et al. [8]. Siyako [4] has mapped Acısu formation in the southern part of the Kız Hill while the Akpınar formation includes the clastic sediments in the eastern part of the Kız Hill. We have shown these outcrops within the Akpınar formation (Figure 4). All these confusing matters bring out that details of the formation should be revised. The formation is composed of mainly greenish-coloured, medium-bedded rhythmic clastic sediments. Its overlying geological unit is the Kırmızıtepe formation while the underlying formation is the Karadoruk formation. Both contacts are conformable. According to the geological cross-section, the thickness of the formation in the study area is assumed to be more than 100 meters. The age of the formation is Miocene [4, 7, 8, 18, 19]. Lithological, exposing details show a lacustrine paleoenvironment.

Kırmızıtepe formation (m_k) (*=Kıztepe member*): It expose in the Kız Hill. The name of the formation was proposed for the first time from the Kırmızıtepe located south of the Sarıyer Dam by Siyako [4]. The formation may be correlated with the Kıztepe sandstone member defined by İnci et al [12]. It is composed of more or less horizontal, rhythmic red-coloured conglomerate, sandstone and siltstones. It covers conformably clastics of the Akpınar formation. The overlying unit is the Bozbelen formation. The thickness of the Kırmızıtepe formation is approximately 40 meters. The age of the formation is Miocene [4]. Lithologic composition shows fluvial to lacustrine environments.

Bozbelen formation (mpl_b): The name of the formation was used by İnci et al [12]. It may be correlated to deposits of the Acısu formation in the Bozbelen area mapped by Siyako [4]. The Bozbelen name was also used for bottom lithologies south of Kız Hill by Ardahanlıoğlu et al [8]. However, it is believed that this confusing naming needs to be revised in future studies. It has a widespread outcrop along the Bal stream under alluviums between Kız Hill and Yukarıbozbelen Hill (Figures 4-5). It comprises alternations of marls, mudstones, siltstones, and sandstones (Figures 6-7). Marls and clayey limestones are cream in colour and micritic composition. They include trace fossils (Figure 8), silicified circular nodules (Figure 9) and small ostracod or bivalve shells (Figure 10).

Figure 7. Field views of the new locality around Bozbelen Hill, mpl_b Bozbelen fm., mpl_{ab} Aşağıbozbelen fm., mpl_{yb} Yukarıbozbelen fm.,

Figure 8. Trace fossils from the marl layers in the Bozbelen formation (scale 1 cm).

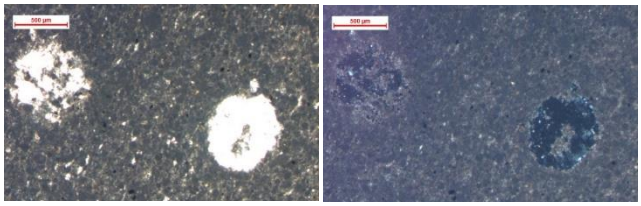

Figure 9. Thin section view including circular silicified relicts, marl layers in the Bozbelen formation (small dark allochems are pellets)

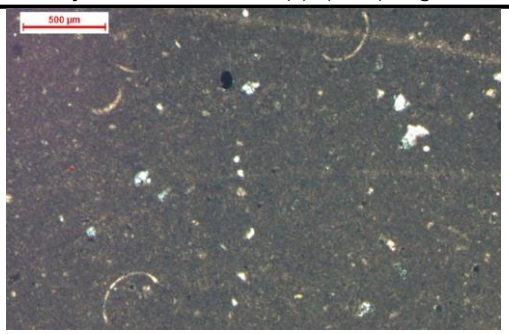

Figure 10. Thin section view showing small bivalve or ostracod shells within the micrite from the marl layers in the Bozbelen formation.

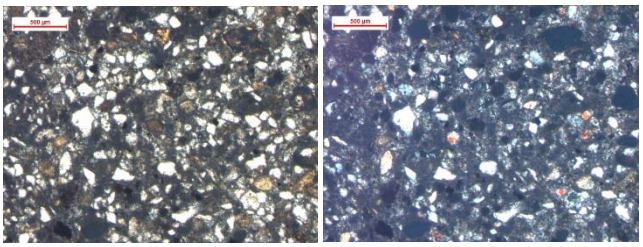

Figure 11. Thin section view showing small bivalve or ostracod shells within the micrite from the marl layers in the Bozbelen formation

The Bozbelen formation has a conformable contact with underlying the Akpınar formation. Aşağıbozbelen formation overlies conformably the formation. The thickness of the formation is more than 50 meters. Vertebrate fossil findings at the clayey limestones, marls and mudstones show late Miocene to early Pliocene in age. Faunal and lithologic features indicate a very shallow lacustrine environment.

Aşağıbozbelen formation (mpl_{ab}): The name of the formation was used for the first time in this study. Sandstones and siltstones are the predominant lithology of the formation. It was mapped as Softa1 formation by Siyako [4]. However, it is assumed that the lithologic composition of the Softa1 formation and this formation, and their stratigraphical position have differences. So, a new formation name was proposed in this study. The underlying unit is the Bozbelen formation while the overlying unit is the Yukarıbozbelen formation. Both boundaries are conformable. The age of the formation is late Miocene to early Pliocene based on its stratigraphical position. It is related to lacustrine paleoenvironments.

Yukarıbozbelen formation (mpl_{yb}): It was named for the first time in this study from the Yukarıbozbelen Hill. It includes medium to coarse-sized clastics. The formation was mapped as Softa2 formation by Siyako [4]. They are seen at the top of the Bozbelen Hills (Figure 4). The formation overlies conformably the Aşağıbozbelen formation clastics. The late Miocene to early Miocene age is attributed to the sediments. They are related to a regressive succession of lacustrine sediments.

Quaternary sediments (Q_{al}): They comprise unchosive silt, sand and pebble-sized clasts of recent sediments. These sediments are seen along the Bal Stream and southeast of Arpalık area (Figure 4).

4. Vertebrate fossil data

The vertebrate fossils in the Bozbelen area are seen within clayey carbonate and fine-grained siltstone, mudstone deposits. The schematic stratigraphical section of the lithologies and some field views are presented in Figures 12-13. As seen in the figures, rhytmitic deposits of mudstones and clayey limestones are predominant lithologies of the Bozbelen formation. They are green, and cream in colour, thick to medium in bedding. Figure 14 shows a thin section view of clayey limestones including small? vertebrate fossil sections.

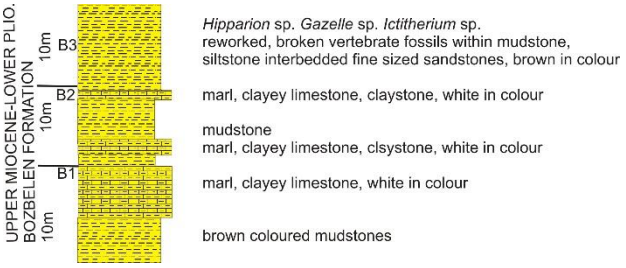

Figure 12. A schematic measured section of the new fossil locality from the Bozbelen formation.

Figure 13. A schematic measured section of the new fossil locality from the Bozbelen formation.

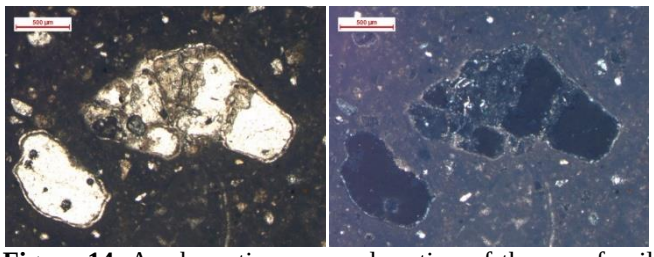

Figure 14. A schematic measured section of the new fossil locality from the Bozbelen formation.

This study includes preliminary data on the vertebrate fossil fauna in the area. Based on our observations the following are the described large mammal fossils from the Bozbelen locality.

Hipparion sp.
Gazelle sp.
?*Ovis* sp.
?*Ictitherium* sp.

The same fauna was also reported from the upper Miocene to early Pliocene sediments of Kızılören (Konya) area by Görmüş [20] and other localities in Türkiye [9]. In the most of literature, Miocene to Pliocene-aged sediments are not dated by using numerical age derived from the volcano-sedimentary rocks. Although Demirci [20] records that the overlying unit Kirmir formation age is Miocene in the Beypazarı-Ayaş area, Karadenizli [17] gives it as Miocene – Pliocene. It means that the age of the Neogene sediments is controversial and studied in detail in future studies.

The general characteristics of the described fauna are as follows:

Hipparion sp.: This genus belongs to the Equidae (horse family). It is generally believed that they lived in grasslands of the Northern Hemisphere during the Miocene and Pleistocene geological times. They were found in Europe, Eurasia, North America and Africa. It is presumed that their lineage became extinct in the middle Pleistocene period [22]. They were approximately 1.5 meters tall and belonged to the three-toed horse family [22]. Some of the horse teeth and bones in the study area are well-preserved but mostly separated and fragmented (Figure 13). Plate 1 shows closer views of the cheek teeth and bones of the *Hipparion* sp.

Gazelle sp.: It belongs to the Bovidae (antelope family). They are known to inhabit elevated areas with steppe climates in the Middle East [23]. The samples of this genus found in the Bozbelen area also appear broken. Horn views transported to the lake marsh deposits are presented in Plate 2.

?Ovis sp.: It is known as sheep and belongs to family Bovidae [24]. Plate 2 includes some views of *Ovis* sp. The specimens can also be correlated with the *Ovis* teeth figures presented from the Kızılören (W Konya) area by Görmüş and in the Taurida Cave, Crimea by Vislobokova [25].

?Ictitherium sp.: The genus belongs to the Suidae (pig family). It is noted that members of the pig family are medium-sized mammals with a barrel-shaped, agile body structure. *Ictitherium* were around 1.2 metres long and possessed a long body with short legs and a possibly short tail [26]. A few teeth views are presented in Plate 2

It is expected that systematic descriptions at the species level and paleoecologies of the fossils will be presented in more detail in future studies.

4. Conclusions

The stratigraphy of the studied area is revised. The basement unit in the Bozbelen area is the Paleogene Kızılbayır formation. The relationship between Paleogene and Miocene sediments is faulty. Revised stratigraphy of the Neogene in the area is as follows: Akpınar formation (=Çayırhan formation), Kırmızıtepe formation (=Kıztepe), Bozbelen formation, Aşağıbozbelen formation, Yukarıbozbelen formation. As a matter of fact, each unit should have a type locality and section including all lithological and faunal details. However, the mentioned units herein from the previous literature do not comprise type section details. So, problems with the name, age and paleoenvironmental interpretation of each geological unit appear. It is believed that vertebrate fossil findings, ostracod fauna of the lacustrine environment and other geochemical data may be used in future studies with type section locality of each stratigraphical unit. Vertebrate fossil findings (*Hipparion* sp., *Gazelle* sp., *Ictitherium* sp.) suggest the late Miocene and early Pliocene age to the Bozbelen formation. The fauna lived near the lake environment. Broken bones and teeth show reworking material in the lacustrine sediments. lacustrinal Both Miocene stratigraphy of the area and vertebrate fossils bring out that they have significant data for the geoheritage and Miocene-Pliocene geologic history.

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Conflict of Interest Statement

The authors declare no conflict of interest.

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Explanations for Plates

Plate 1
1-2. Teeth views of *Hipparion* sp. a upper side views, b. side views, c. closer view of one of the teeth.
3. Closer view of one of the teeth
4. Teeth view of *Hipparion* sp. a upper side view, b. side view
5-6. Chin views of *Hipparion* sp.
7, 9-11. Closer views of teeth of *Hipparion* sp.
8. Side view
Scale 1 cm

Plate 2
1-4. ?*Ictitherium* sp. teeth views
5. ?*Ictitherium* sp. teeth views
6-8. *Gazelle* sp.
9-13. Other bone views of vertebrate fossils from the Bozbelen area
Scale 1 cm


PLATE 1
1a
2a
1b
2b
1c
2c
3
4a
5
6
4b
7
8
9
10
11

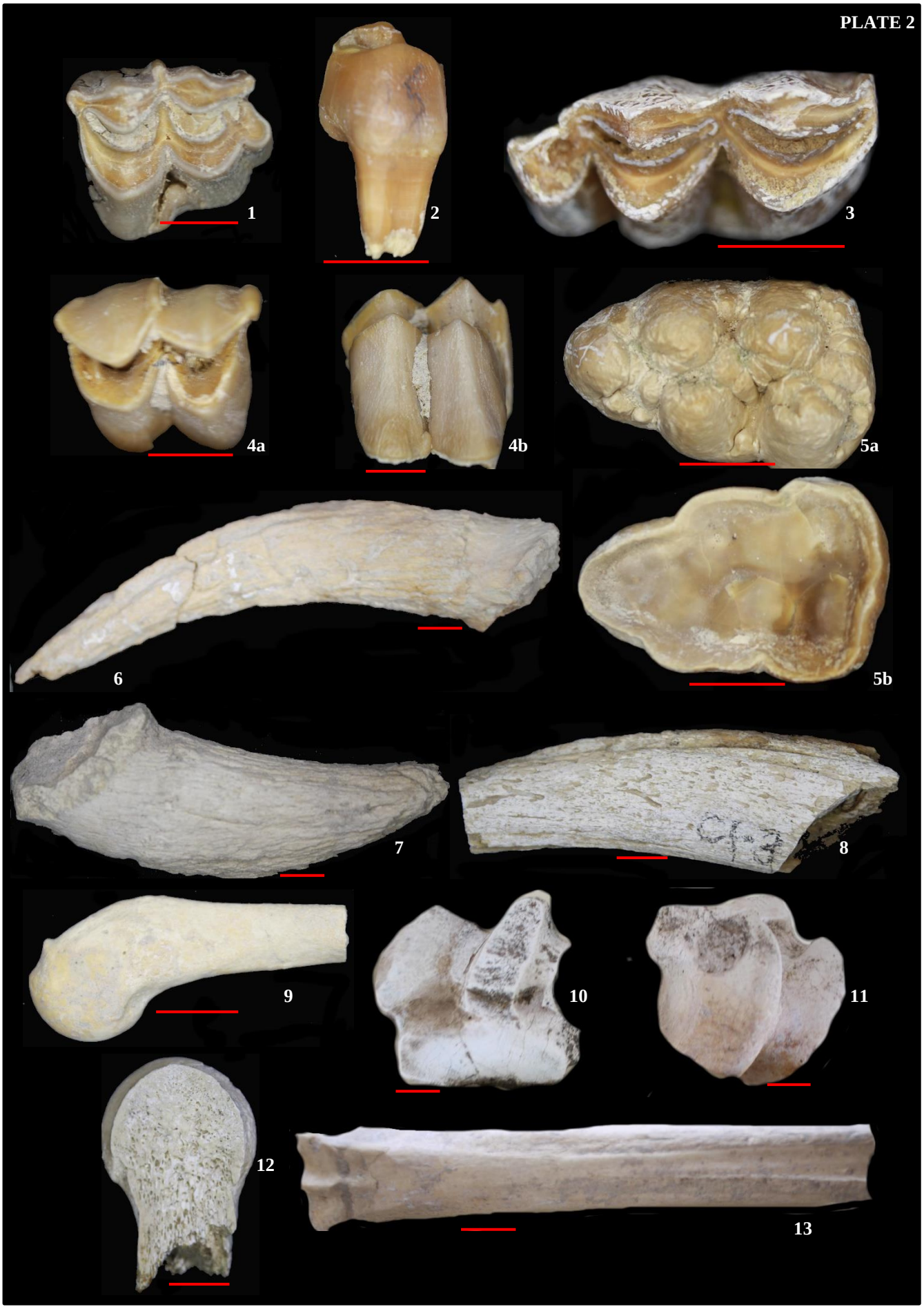
PLATE 2
1
2
3
4a
4b
5a
6
5b
7
8
9
10
11
12
13