

++ORIGINAL ARTICLE

The first report of fossil shark remains in the Aitamir Formation and determination of its precise age based on Foraminifera in the Behkadeh Razavi section, western part of the Kopet-Dagh sedimentary basin

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Abstract

The Aitamir Formation is one of the most important Cretaceous units in the Kopet-Dagh sedimentary basin in northern and northeastern Iran. The dominant lithology of this formation consists of sandstone, olive-green glauconitic shales, and three coquina beds. The Behkadeh Razavi section is situated west of Ashkhaneh. In this study, a total of 44 fossil shark teeth were collected from the shaly deposits of the upper part of the Aitamir Formation near Behkadeh Razavi. After cleaning the samples, microscopic investigations and systematic descriptions were conducted, leading to the identification of four species across four genera: *Ptychodus decurrens*, *Scapanorhynchus raphiodon*, *Cretodus crassidens*, and *Cretoxyrhina* sp. Comparative analysis of these specimens with similar material from other parts of the world, along with the comparison of their relative ages and the fact that all specimens were discovered within the same stratigraphic horizon in the studied Aitamir Formation, indicates that the age of the fossil-bearing deposits is Cenomanian. The obtained age is in complete agreement with age determinations based on foraminifera. Furthermore, the presence of these fossils and their associated paleoecological implications provide important information for reconstructing the paleoenvironment.

Keywords: Kopet-Dagh sedimentary basin, Aitamir formation, Behkadeh Razavi, Shark teeth, Foraminifera

INTRODUCTION

The Kopet-Dagh sedimentary basin is located in northern and northeastern Iran, extending across large parts of Turkmenistan and northern Afghanistan. The Iranian sector of the Kopet-Dagh basin lies between 35°30' and 38°15' north latitude and 54°00' and 61°13' east longitude. The Kopet-Dagh sedimentary basin is an intracontinental basin formed following the closure of the Hercynian Ocean and the Early Cimmerian orogenic phase during the Late Triassic (Berberian 1991). According to Stocklin (1968), the basement of the Kopet-Dagh represents a continuation of the Hercynian basement of Turan. However, Eftekharnajad & Behrooz (1991), based on the presence of Paleozoic outcrop areas in parts of the southern and western regions of this region, suggested that the Kopet-Dagh basement is a continuation of the Afro-Arabian platform.

From a geographical perspective, the Kopet-Dagh represents the eastern continuation of the Alborz and Binalud mountains; however, its geological and structural characteristics differ from those of adjacent

regions (Nabavi 1976). Geomorphologically, the Kopet-Dagh is a mountainous region whose present-day morphology has been strongly influenced by the Late Alpine orogenic phases (Mousavi Harami & Adabi 1986). The region's morphology is relatively young, and its topography is directly controlled by its geological structures. Typically, anticlines form elevated sections, while synclines correspond to plains. The carbonate formations of Mozduran (Upper Jurassic) and Tigran (Lower Cretaceous) constitute the main ridge-forming units of the region (Afshar Harb 1994). The plains of the area—such as the Sarakhs, Gorgan, Mashhad–Quchan, and Shirvan–Bojnurd plains—represent subsided parts of the Kopet-Dagh basin. Aghanabati (2004) considered the Kopet-Dagh as the southern margin of the Turan plate and part of the Eurasian supercontinent. However, there are currently two differing viewpoints regarding the tectonic position of this zone—Eurasian and Gondwanan. In general, this boundary is marked by discontinuous outcrops of accretionary prisms related to the Paleo-Tethys Ocean. Pre-Jurassic basement



Fig.1. The access way to the study area is shown by arrows on the satellite image. The circle on the right is the Ashkhaneh city and the circle on the left is the Razavi Behkadeh section. (Google Earth).

rocks in the Kopet-Dagh sedimentary basin are exposed only in the northern part of the Torbat-e Jam–Fariman depression and in the Agh Darband erosional window (Aghanabati 2004).

MATERIAL AND METHODS

Access routes to the studied section: There are two routes to reach the study section:

1) The best access is via the paved Ashkhaneh–Kalaleh road (Gelidagh road). To reach the section, one should travel approximately 76km westward from the city of Ashkhaneh along the Ashkhaneh–Kalaleh road (about 90 km from Kalaleh) until reaching the Ashkhaneh–Kalaleh–Behkadeh junction. From this junction, by proceeding about 15 km southward, the village of Behkadeh Razavi is reached. The studied section is located approximately 5km west of Behkadeh Razavi village, before an abandoned building-stone quarry. The coordinates of the base of the section are 37.81658°N latitude and 56.128817°E longitude.

2) The second route is via the main Ashkhaneh–Galikesh road. In this case, one should pass near the Mirza Baylu ranger station and proceed northward along an unpaved road toward the Sulugerd ranger station. After approximately 35km, the study section is reached. This road passes through the Golestan National Park and requires prior coordination with

park authorities. This route is not accessible during rainy conditions (Figs. 1 and 2).

Lithostratigraphy of the Aitamir formation: The name of this formation is derived from the village of Aitamir, located approximately 70km northeast of Gonbad-e Kavus city. The type section of this formation is situated 5km southeast of Aitamir village, south of the abandoned village of Big Quyi. In the type section, the Aitamir Formation has a thickness of about 1,000 meters and is composed of two main parts: a lower sandstone unit and an upper shale unit. Both units are glauconitic and are typically characterized by an olive-green color.

The lower sandstone unit has a thickness of 611m and consists predominantly of ridge-forming glauconitic sandstones. Some deposits contain clay and are therefore softer, forming depressions between the more resistant, ridge-forming layers. According to Afshar Harb (1994), the sandstone unit can be subdivided from base to top as follows:

Sandstone, light gray to greenish-gray and olive-greenish gray in color; glauconitic, very fine-grained, subangular, with moderate sorting; locally containing interbeds with calcareous cement; thickness: 205m.

Sandstone, light greenish-gray; very fine-grained, glauconitic, subrounded, clay-bearing; thickness: 120m.

Sandstone, light greenish-gray; very fine-grained,

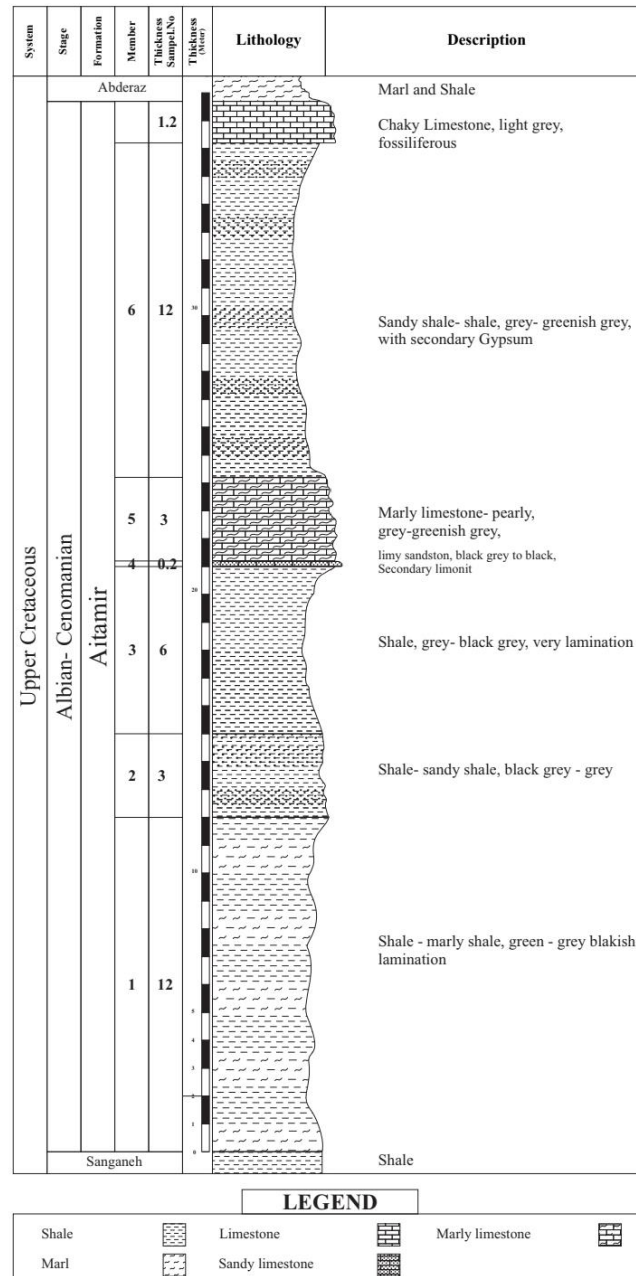


Fig.2. Stratigraphic column of the Aitamir Formation in the Behkadeh Razavi section.

glauconitic, moderately sorted; thickness: 40m.

Sandstone, olive-greenish gray; very fine-grained, glauconitic, subrounded, clay-bearing; thickness: 45m.

Sandstone, olive-greenish gray; very fine-grained, glauconitic, subrounded, well sorted; thickness: 100m.

Sandstone, light greenish-gray; very fine-grained, glauconitic, subrounded, moderately to well sort; containing fine fractures filled with calcite; locally porous; thickness: 101m.

The upper shale unit has a thickness of 389m and consists of olive-gray shales with a greenish color, glauconitic in composition, with thin bedding and minor sandstone intercalations near the base, as follows:

7. Alternating olive-gray, glauconitic, silty shales with thin layers of fine-grained glauconitic sandstone; thickness: 70m.

8. Olive-gray, glauconitic, silty shale; thickness: 319m.

Although in the type section the lower boundary of the

SHARK TOOTH MORPHOLOGY

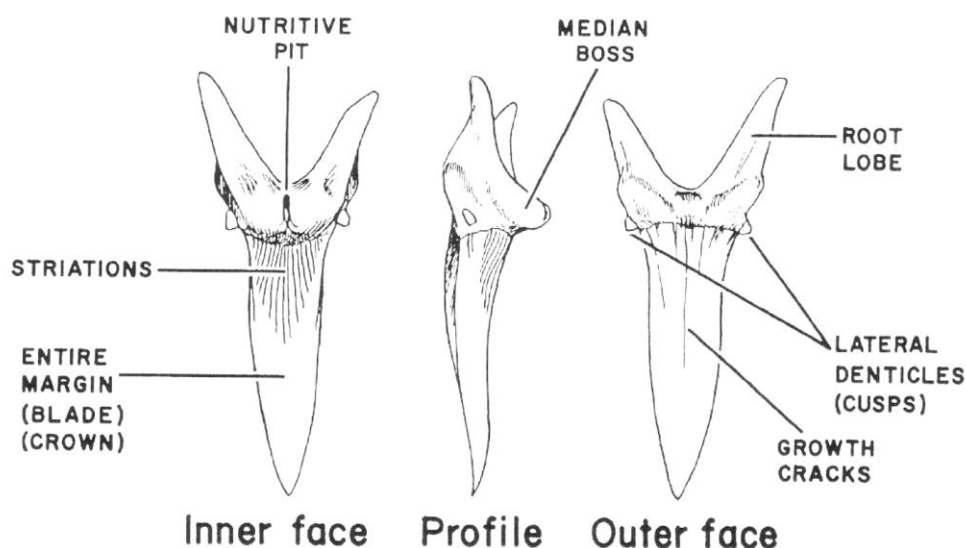


Fig.3. Important features in the study of fossil shark teeth: the left view shows the lingual (internal) side of the tooth, the middle view shows the lateral (side) view, and the right view shows the labial (external) side.

formation is clearly defined, in most sections the transition from the Sanganeh Formation to the Aitamir Formation is gradual. The upper boundary of this formation with the Abderaz Formation is an erosional surface, indicating a regression during the early Late Cretaceous. The thickness of this formation is controlled by synsedimentary strike-slip faults. In general, its thickness decreases from north to south. For example, south of the Korkhod–Rabat-e Qareh Bil fault, in the Jozak section, the thickness of this unit is only 16 m, and in even more southern areas, north of the Jajarm fault, the formation is entirely absent. Cenomanian glauconitic sandstones and shales, similar to those of the Aitamir Formation, also crop out south of Isfahan outside the Kopet-Dagh zone and show comparable stratigraphic position and fossil content. The shales and sandy shales of the Aitamir Formation commonly contain ammonites; these are particularly abundant in areas north of the Atrak Valley, north of Maraveh Tappeh, in the northern Qatlish syncline, as well as in Baba Faraji, Hammam Qaleh, and Taherabad. Overall, the age of the Aitamir Formation has been determined as Late Albian–Cenomanian (Afshar Harb, 1994) and Late Aptian–Middle Cenomanian (Aghanabati 2004).

Stratigraphic section of Behkadeh Razavi village:

Behkadeh Razavi village is located in the central district of Maneh and Samalqan County, in the Jeyransu rural district, approximately 90 km from

Ashkhaneh and 130 km northwest of Bojnurd. It lies between the Atrak River and the eastern margin of Golestan National Park, along the border between North Khorasan and Golestan provinces.

This section is situated on the northern flank of the Korkhod Mountains extending toward Mount Divarkajin. Due to faulting along the Korkhod–Rabat-e Qareh Bil fault, the Aitamir Formation has a limited outcrop here and exhibits a total thickness of only 36.2 m. The lithology of this formation, from base to top, is as follows:

1. Shale to marly shale, green to dark green, fossil; thickness: 12m.
2. Shale to sandy shale, gray to dark gray; thickness: 3m.
3. Shale, gray to dark gray-black, strongly fossil; thickness: 6m.
4. Calcareous sandstone, dark gray to black, containing secondary limonite; thickness: 20cm.
5. Marly, fossiliferous limestone, gray to greenish-gray; thickness: 3m.
6. Sandy shale to shale, gray to greenish-gray, containing secondary gypsum; thickness: 12m.

The lower boundary of the Aitamir Formation in this section is covered by alluvial deposits and is therefore not observable. The upper boundary with the Abderaz Formation is marked by an erosional discontinuity (disconformity). (Fig 2)

Paleontological studies of the investigated section:

In this study, paleontological investigations include two parts: (1) the study of shark fossils and (2) the study of foraminifera for precise age determination of the investigated section.

A) Study and analysis of shark fossils: A total of 44 shark teeth were systematically collected from the shaly and marly deposits in the upper part of the Aitamir Formation and the basal part of the Abderaz Formation.

After washing, the tooth samples were dried in open air. Subsequently, at least six images of each specimen were taken with different exposure settings using the auto-bracketing technique, with a Canon EOS Rebel T3i camera. Multiple images taken from the same angle were then merged using the *Automate* → *Merge to HDR* function in Adobe Photoshop CS5 to produce high-dynamic-range (HDR) images, enhancing the visibility of fine details. This imaging method has previously been applied by Khosravi & Hyzny (2016) in fossil documentation.

The discovered specimens have been archived in the Toos Museum of Paleontology and Science under catalog numbers TMPS-pal-2956 to TMPS-pal-3000.

Biology of Sharks: Sharks (Vertebrata: Chondrichthyes: Elasmobranchii: Selachii) and primitive shark-like cartilaginous fishes have been present in marine environments since at least the Silurian Period and have constituted one of the most important and abundant groups of aquatic vertebrates from the early evolution of vertebrates to the present day (Khosravi & Mohammadi-Azad 2009). They form an essential component of consumer levels within ecological pyramids; therefore, the identification and interpretation of their remains greatly contribute to paleoecological reconstructions of ancient environments. In addition, the study of fossil remains of many shark taxa is of considerable importance due to their biostratigraphic value and their role in estimating the relative age of geological deposits.

The cartilaginous skeleton of sharks is rarely preserved in the fossil record. Consequently, the most common remains of sharks in fossil deposits are their teeth and, occasionally, their tooth-like dermal denticles. In some cases, calcified vertebrae may also be preserved, and only in very rare instances does the cartilaginous skeleton fossilize. Therefore, most

taxonomic knowledge of fossil sharks is based on the morphology of their teeth (Kobrāyī et al. 2009).

Shark teeth are continuously replaced throughout their lifetime. They are not firmly attached to the jaw cartilage but are embedded in a soft tissue layer known as the dental lamina. In many species, upper and lower teeth differ in shape, mainly reflecting functional differences related to grasping and cutting prey. Teeth are typically arranged within grooves in the jaw cartilage and gradually move forward, eventually emerging from the soft tissue covering replacement teeth and forming functional rows. Measurements of tooth replacement rates in sharks indicate that, during the first year of life, each tooth is typically replaced every 8 to 15 days. Because sharks exert strong biting forces, their teeth often become worn or broken; continuous replacement compensates for this, and teeth also increase in size as the shark grows (Compagno 1988).

In the study of fossil shark teeth, attention to certain structural details is of great importance; these features are briefly illustrated in Figure 1.

Nutritive pit: vascular foramen; **Striation:** parallel ridges; **Entire margin:** cutting edge (crown margin); **Median boss:** central protuberance; **Root lobe:** root lobe; **Lateral denticles:** accessory cusplets; **Growth cracks:** growth fractures.
(After Case 1973)

The dentition of sharks is organized such that new, small teeth are continuously developing within grooves in the inner jaw cartilage of the upper jaw. Larger teeth, which are attached to the jaw only by fragile and soft cartilaginous tissue, become loosened due to mechanical stresses associated with feeding and predation and eventually fall out. Tooth morphology may vary across different regions of the jaw, with larger teeth typically occurring in the anterior part. As a result, each shark may produce thousands of teeth of varying shapes and sizes over its lifetime (Fig. 2). This factor must be carefully considered in the identification and taxonomic classification of shark teeth. Another important point in the identification of shark teeth is the distinction between normal wear surfaces and pathological alterations caused by disease.

The record of shark fossil discoveries from Iran is relatively limited, with only one case related to

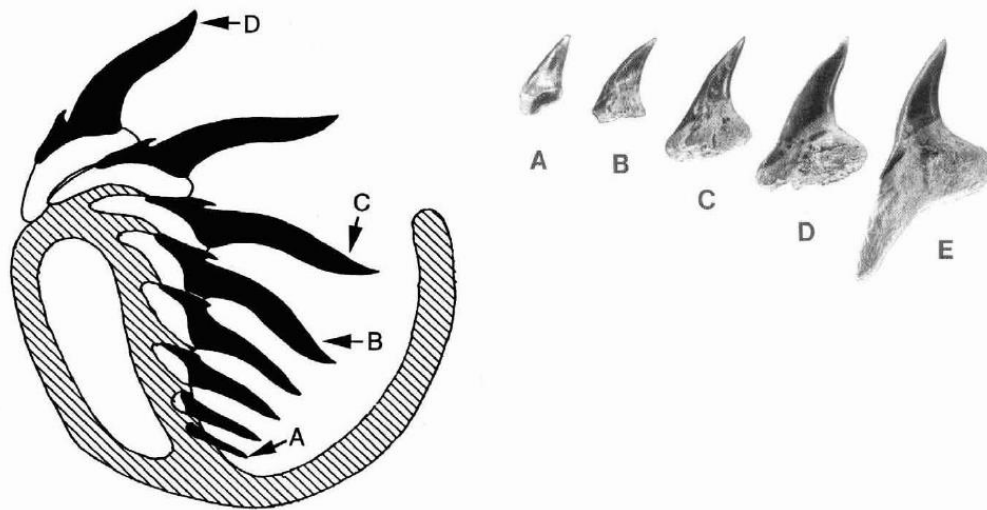


Fig.4. Sequence of tooth development in the shark jaw (Meckel's cartilage shown schematically). While the immature tooth (A) is covered only by an enamel-like cap, the mature teeth (D and E) possess a fully developed crown and root (after Welton & Farish 1993).

remains found in Cretaceous deposits. Other studies reporting shark remains from Iran are either that related to the Paleozoic (Hairapetian & Ginter 2009) or the Cenozoic (Trif et al. 2020). Notably, prior to the present study, no shark fossil—even informally—had been reported or collected from the Kopet-Dagh sedimentary basin. The first and only report of the genus *Ptychodus* from Iran pertains to Santonian deposits of the Ilam Formation (Hosseinzadeh & Ghaseminejad 2007). In that report, the specimen was assigned to "*P. polygrus*" [as cited in the original text], which most likely refers to *P. polygyrus*.

RESULTS

Systematic Paleontology

Superfamily *Hybodontidae* (Erich Zangerl, 1981)

Family *Ptychodontidae* (Otto Jaekel, 1898)

Genus *Ptychodus* (Louis Agassiz, 1835)

Species *Ptychodus decurrens* Agassiz, 1843

Description: A species of *Ptychodus* characterized by a short crown, approximately quadrangular in shape, with relatively elongated teeth along the median-distal axis in the anterior and middle rows of the anterolateral dentition. The crowns show a gradual transition from flat to more convex in the anterolateral series, becoming flatter toward the distal anterolateral regions. The large, symmetrical upper median and anterolateral teeth in both jaws exhibit approximately ten distinct opposing ridges; this number decreases to five or six in the more posterior rows. The termini of these opposing ridges merge near the tooth margin,

forming finer and more delicate secondary ridges between them. These ridges extend to the margin of the tooth and are oriented perpendicular to the crown edges. The roots are porous, smooth, and lack nutritive grooves (*anaulacorrhizous*), and the dental tissue is solid (*osteodont*) (Vullo & Courville 2014).

Referred material: A single ptychodont tooth, exhibiting features clearly attributable to *Ptychodus decurrens*, was recovered from the sediments of this area (specimen no. TMPS-pal-2956). The short crown, the presence of opposing ridges, and the convergence of these ridges at the tooth margins distinguish this specimen from *Ptychodus polygyrus*, previously reported from the Ilam Formation (under the name "*P. polygrus*"). The morphology and structure of the tooth are consistent with posterior ptychodont teeth. Cenomanian-Turonian. (Fig. 5).

Order *Lamniformes* (Lev Berg, 1958)

Family *Mitsukurinidae* (David Starr Jordan, 1898)

Genus *Scapanorhynchus* (Arthur Smith Woodward, 1889)

Species *Scapanorhynchus raphiodon* (Louis Agassiz, 1844)

Description: Anterior teeth possess tall and slender crowns; lateral denticles are either absent or represented by a very small pair. The lingual (internal) surface of the tooth exhibits distinct, narrow striations that extend nearly to the apex, whereas the labial (external) surface is smooth. The root lobes are spatulated to club-shaped and clearly separated. The

lingual side of the root is convex and contains a nutritive groove. The crowns of lateral teeth are compressed in the labio-lingual direction, broad-based, and bear two small, triangular lateral denticles. The roots are bilobate (*holaulacorhizous*), and the dental tissue is dense (*osteodont*) (Underwood & Cumbaa 2010; Cappetta 2012).

Referred material: At least 12 tooth specimens exhibit clear scapanorhynchid morphology and have been catalogued under numbers TMPS-pal-2957 to TMPS-pal-2969. The presence of parallel striations on the lingual surface of all these teeth, traces of a nutritive pit or groove in some specimens, and—in one particular specimen—the occurrence of small, triangular lateral denticles, along with the distinctive morphology of the roots, clearly indicate the presence of *Scapanorhynchus raphiodon* in these deposits (Fig. 4).

Order *Lamniformes* (Lev Berg, 1958)

Family *Cretoxyrhinidae* (Gluckman, 1958)

Genus *Cretodus* (Sokolov, 1965)

Species *Cretodus crassidens* (Frederick Dixon, 1850)

Description: The teeth of this species are characterized by a robust, thick, and broadly triangular main crown, which shows an oval outline in basal cross-section. On both sides of the main crown, a pair of relatively large, sturdy, and often divergent lateral cusplets is present (their height typically ranges from 25% to 55% of the height of the main crown). The root is very thick and bulky, with a well-developed lingual protuberance. In this species, the root is generally devoid of a distinct nutritive groove or may exhibit only a very shallow and weak one (Hamm 2020; Amalfitano et al. 2022).

Family *Cretoxyrhinidae* (Gluckman, 1958)

Genus *Cretoxyrhina* (Glikman, 1958)

Species *Cretoxyrhina* sp.

Description: The teeth are characterized by a broad, triangular main crown that is strongly compressed in the labio-lingual direction. The crown edges are smooth, sharp, and lack any serrations. In adult specimens, lateral cusplets are typically absent (especially in anterior positions); however, in posterior teeth or juvenile specimens, a small pair of cusplets may be present.



Fig.5. Specimen TMPS-pal-2956; occlusal (top) view. Scale bar= 1cm.

The root is bilobate, with open and divergent lobes. A distinct lingual protuberance is present, but a deep nutritive groove is absent (*anaulacorhizous* root type), and typically only a small foramen is observed on the lingual surface of the root (Siverson 1996; Cappetta 2012). This taxon ranges from the late Albian to the late Campanian of the Late Cretaceous..

Remarks: These teeth most likely belong to *Cretoxyrhina mantelli* (a characteristic species of this time interval). However, due to factors such as edge wear or incomplete preservation of the root in some specimens, the authors have preferred to retain the identification at the genus level.

B) Study of foraminiferal microfossils: For the study of foraminifera, a total of 32 samples were collected at regular intervals, of which 27 samples were shaly and marly, and 5 samples were hard and lithified.

For the shaly samples, approximately 500g of unweathered material—i.e., from the primary lithology—was collected. After labeling, the samples were transferred to the preparation laboratory of Ferdowsi University of Mashhad. In the laboratory, about 300 g of each sample, after removal of organic matter and plant roots, was placed into disposable containers, and approximately 1 liter of water and 10 mL of hydrogen peroxide were added. After about 12 hours, the samples were washed using 50, 70, and 100 mesh sieves. The remaining residues were dried and



Fig.6. Specimens TMPS-pal-2957–2959; three examples of scapanorhynchid teeth, from left to right; all belonging to *Scapanorhynchus raphiodon*. Scale bar= 1cm.



Fig.7. Specimen TMPS-pal-2970; *Cretodus crassidens*.

then transferred to the paleontology laboratory for microscopic analysis.

The sediments were evenly spread in trays, and fossil picking was carried out using a fine paintbrush. Subsequently, the fossils were placed into microfossil cells and finally mounted on stubs for SEM imaging. Imaging was performed at the central laboratory of Ferdowsi University of Mashhad, capturing dorsal, ventral, and lateral views.

For the hard lithified samples, after labeling, the specimens were transferred to the geology workshop, where five thin sections with an approximate

thickness of 30µm were prepared.

After studying the samples with a binocular microscope and in some cases with a polarizing microscope, 25 genera and 48 species of benthic and planktonic foraminifera have been identified. It should be noted that the following sources have been used in the identification of foraminiferal microfossils.

Loeblich A.R and Tappan H., 1988. Permoli silva I and Verga D, 2014. Kalantari A., 1969. Joseph A Cushman, 1965

The most important genera and species identified in this research are:

Ammodiscus pennyi, *Buliminella fabilis*, *Cibicides subcarinatus*, *Dentalina consobrina*, *Dentalina soluta*, *Fronicularia inversa*, *Gaudryina stephensoni*, *Gumbelina excolata*, *Guembelitria* sp., *Gyroidinoides globosa*, *Haplophragmium taylorense*, *Haplophragmoides calcula*, *Haplophragmoides coronata*, *Haplophragmoides rugosa*, *Hastigerinoides alexanderi*, *Hedbergella* sp., *Lagena* sp., *Lenticulina rotulata*, *Marginulina jarvisi*, *Nonionella rubosta*, *Nodosaria affinis*, *Quinqueloculina antiqua*, *Quinqueloculina coonensis*, *Reophax clavulinus*, *Reophax dentalinoides*, *Robulus navarroensis*, *Robulus pondi*, *Rotalipora cf appenninica*, *Schackoina cenomana*, *Schackoina maltese*, *Schackoina bicornis* and *Stensioeina americana*.

Based on index planktonic foraminifera such as *Schackoina cenomana*, *Schackoina bicornis*, *Schackoina multispinata*, *Rotalipora cushmani*, *Rotalipora Cf appenninica*, and *Guembelitria cenomana*, the age of the Formation is assigned to the Late Cretaceous (Cenomanian stage).

DISCUSSION AND CONCLUSIONS

Based on the examination of shale and marl samples prepared using the washing method, as well as lithified samples from which thin sections were prepared, the main results of this study are as follows: Considering that the thickness of the Aitamir Formation is about 1000m in the type section but decreases to approximately 40m in the studied section—and shows similar variations in other sections—it can be concluded that the thickness of this Formation varies significantly across different regions. These variations may be attributed to tectonic

activity or paleo-topographic features of the basin floor (paleoheight).

The lithology of the Aitamir Formation in the type section consists of sandstones in the lower part and shales with intercalations of coquina limestone, especially in the northeastern part of the basin. However, in the studied section, the Formation is predominantly composed of shale with thin sandstone interbeds. These features, together with paleontological evidence particularly shark fossil remains—indicate deposition in a relatively deeper marine environment in this area.

From the lower to the upper parts of the Formation, the fossil content (both microfossils and macrofossils) increases progressively.

A total of 12 samples (9 shaly and marly samples and 3 lithified samples) were analyzed for foraminifera. In total, 25 genera and 48 species of benthic and planktonic foraminifera were identified (12 genera and 22 species planktonic; 13 genera and 26 species benthic). Based on index planktonic foraminifera such as *Schackoina cenomana*, *Schackoina bicornis*, *Schackoina multispinata*, *Rotalipora cushmani*, *Rotalipora Cf appenninica*, and *Guembelitra cenomana*, and *Hedbergella sigali*, the age of the Formation is assigned to the Cenomanian stage. This age is consistent with age determinations based on other fossil groups particularly ammonites and foraminifera from other sections, indicating that the studied beds correspond to the upper part of the Aitamir Formation.

A total of 44 shark teeth were collected from marly deposits at the boundary between the Aitamir Formation and the Abderaz Formation. After preparation and microscopic study, four species belonging to four genera were identified: *Ptychodus decurrens*, *Scapanorhynchus raphiodon*, *Cretodus crassidens*, and *Cretoxyrhina* sp. Based on these identified teeth particularly *Ptychodus decurrens* and *Scapanorhynchus raphiodon*—the age of this part of the Formation is determined to be Cenomanian stage. The presence of *Ptychodus decurrens*, which is known to have fed on shelled organisms such as ammonites and benthic bivalves like *Inoceramus*, suggests that this species inhabited deeper marine environments and foraged near the sea floor. Sharks must swim continuously to breathe; if they stop swimming, they

may suffer from oxygen deficiency and suffocate. Therefore, most sharks tend to avoid shallow environments where obstacles may impede their movement. The morphological and paleoecological interpretations of these species are consistent with the findings of Amalfitano et al. (2022) and Bazzi et al. (2021).

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Plate 1:

Figs. 1-4: *Haplophragmoides rugosa*, Aitamir Formation, Behkadeh village section, Cretaceous- Holocene, sample no: 1

Fig. 5: *Gumbelina excolata*, Aitamir Formation, Behkadeh village section, Late Cretaceous, sample no: 3

Figs. 6-7: *Lenticulina navarroensis*, Aitamir Formation, Behkadeh village section, Late Cretaceous- Paleocene, Sample no: 2

Figs. 8-9: *Haplophragmoides coronata*, Aitamir Formation, Behkadeh village section, Cretaceous, sample no: 1

Figs. 10- 11: *Nonionella rubosta*, Aitamir Formation, Behkadeh village section, Late Cretaceous, sample no: 2

Figs. 12- 13: *Lenticulina* sp., Aitamir Formation, Behkadeh village section, Late Cretaceous, sample no: 11

Figs. 14-15: *Lenticulina rotulata*, Aitamir Formation, Behkadeh village section, Late Cretaceous, sample no: 10

Fig. 16: *Haplophragmoides calcula*, Aitamir Formation, Behkadeh village section, Late Cretaceous, sample no: 8.

Plate 2:

Figs. 1-2: *Reophax clavulinus*, Aitamir Formation, Behkadeh village section, Late Cretaceous, sample no: 2

Figs. 3-6: *Reophax dentalinoides*, Aitamir Formation, Behkadeh village section, Late Cretaceous, sample no: 3

Fig. 7: *Haplophragmium taylorense*, Aitamir Formation, Behkadeh village section, Late Cretaceous, sample no: 3

Fig. 8: *Lenticulina rotulata*, Aitamir Formation, Behkadeh village section, Late Cretaceous, sample no: 2

Fig. 8: *Gaudryina stephensoni*, Aitamir Formation, Behkadeh village section, Cretaceous-Paleogene, sample no: 4

Fig. 9: *Ammodiscus pennyi*, Aitamir Formation, Behkadeh village section, Late Cretaceous- Paleocene, sample no: 5

Fig. 10: *Guembelitra* sp., Aitamir Formation, Behkadeh village section, Late Cretaceous, sample no: 7

Fig. 11: *Nodosaria affinis*, Aitamir Formation, Behkadeh village section, Late Cretaceous, sample no: 5

Figs. 12-14: *Quinqueloculina antiqua*, Aitamir Formation, Behkadeh village section, Late Cretaceous, sample no: 4

Figs. 15-16: *Quinqueloculina coonensis*, Aitamir Formation, Behkadeh village section, Cretaceous- Recent, sample no: 6.

Plate 3:

Fig. 1: *Buliminella fabilis*, Aitamir Formation, Behkadeh village section, Late Cretaceous, Sample no: 5

Figs. 2-3: *Fronicularia inversa* Aitamir Formation, Middle Jurassic to Recent. Behkadeh village section, 2

Fig. 4: *Cibicides stephensoni*, Aitamir Formation, Behkadeh village section, Late Cretaceous, Sample no: 5

Figs. 5-8: *Cibicides subcarinatus*, Aitamir Formation, Behkadeh village section, Late Cretaceous, Sample no: 4

Figs. 9-12: *Dentalina* sp., Aitamir Formation, Behkadeh village section, Late Cretaceous-Recent, sample no: 6

Fig. 13: *Gyroidinoides globosa*, Aitamir Formation, Behkadeh village section, Late Cretaceous- Eocene, sample no: 6

Fig. 14: *Hastigerinoides alexanderi*, Aitamir Formation, Behkadeh village section, Late Cretaceous, Sample no: 5

Fig. 15: *Lagena* sp, Aitamir Formation, Behkadeh village section, Late Cretaceous, sample no: 3

Figs. 16: *Robulus pondi*, Aitamir Formation, Behkadeh village

section, Late Cretaceous, sample no: 3.

Plate 4:

Figs. 1-4: *Marginulina jarvisi*, Aitamir Formation, Behkadeh village section, Late Cretaceous, sample no: 6

Figs. 5-7: *Lenticulina navarroensis*, Aitamir Formation, Behkadeh village section, Late Cretaceous- Paleocene, sample no: 7

Fig. 8: *Robulus stephensoni*, Aitamir Formation, Behkadeh village section, Late Cretaceous, sample no: 5

Fig. 9: *Haplophragmoides excavata*, Aitamir Formation, Behkadeh village section, Cenomanian, sample no: 9

Fig. 10: *Schackoina cenomana*, Aitamir Formation, Behkadeh village section, Cenomanian, sample no: 12

Fig. 11: *Schackoina maltese*, Aitamir Formation, Behkadeh village section, Cenomanian, Sample no: 11

Fig. 12: *Schackoina* sp., Aitamir Formation, Behkadeh village section, Late Albian- Early Cenomania, sample no: 11

Fig. 13: *Stensioina americana*, Aitamir Formation, Behkadeh village section, Late Cretaceous- Late Paleocene, Sample no: 10

Figs. 14-15: *Cibicides subcarinatus*, Aitamir Formation, Behkadeh village section, Late Cretaceous, sample no: 5

Fig. 16: *Haplophragmoides* sp., Aitamir Formation, Behkadeh village section, Cretaceous- Late Eocene, sample no: 10.

Plate 5:

Figs. 1-5: *Dentalina catenula*, Aitamir Formation, Behkadeh village section, Upper Cretaceous, sample no: 5

Fig. 6: *Dentalina consobrina*, Aitamir Formation, Behkadeh village section, Upper Cretaceous- Middle Miocene, sample no: 5

Figs 7-8: *Dentalina soluta*, Aitamir Formation, Behkadeh village section, Upper Cretaceous- Eocene, Sample no: 11

Fig. 9: *Dentalina* sp., Aitamir Formation, Behkadeh village section, Middle Jurassic to Recent, sample no: 3

Figs. 10-11: *Dorothia* sp., Aitamir Formation, Behkadeh village section, Upper Cretaceous- Paleocene, sample no: 4

Figs. 12-13: *Gaudryina painoides*, Aitamir Formation, Behkadeh village section, Upper Cretaceous, sample no: 9

Figs. 14-16: *Gumbelina excolata*, Aitamir Formation, Behkadeh village section, Upper Cretaceous, sample no: 7.

Plate 6:

Fig. 1: *Nodosaria proboscidea*, Aitamir Formation, Behkadeh village section, Upper Cretaceous, sample no: 7

Figs. 2-3: *Hedbergell* sp, Aitamir Formation, Behkadeh village section, Upper Cretaceous, sample no:

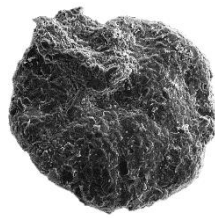
Figs. 4-6: *Hedbergell* sp., Aitamir Formation, Behkadeh village section, Upper Cretaceous, sample no: 8

Fig. 7-8: *Haplophragmoides excavata*, Aitamir Formation, Behkadeh village section, Cenomanian, sample no: 10

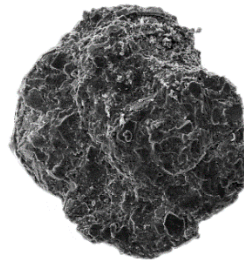
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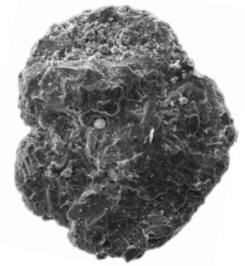
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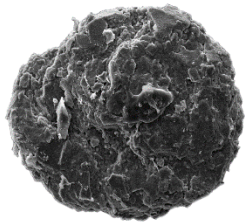
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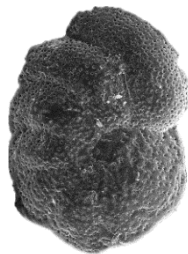
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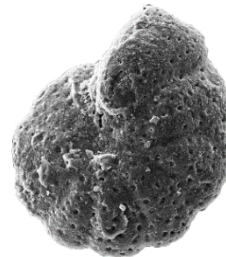
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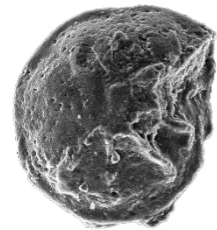
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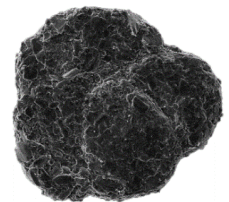
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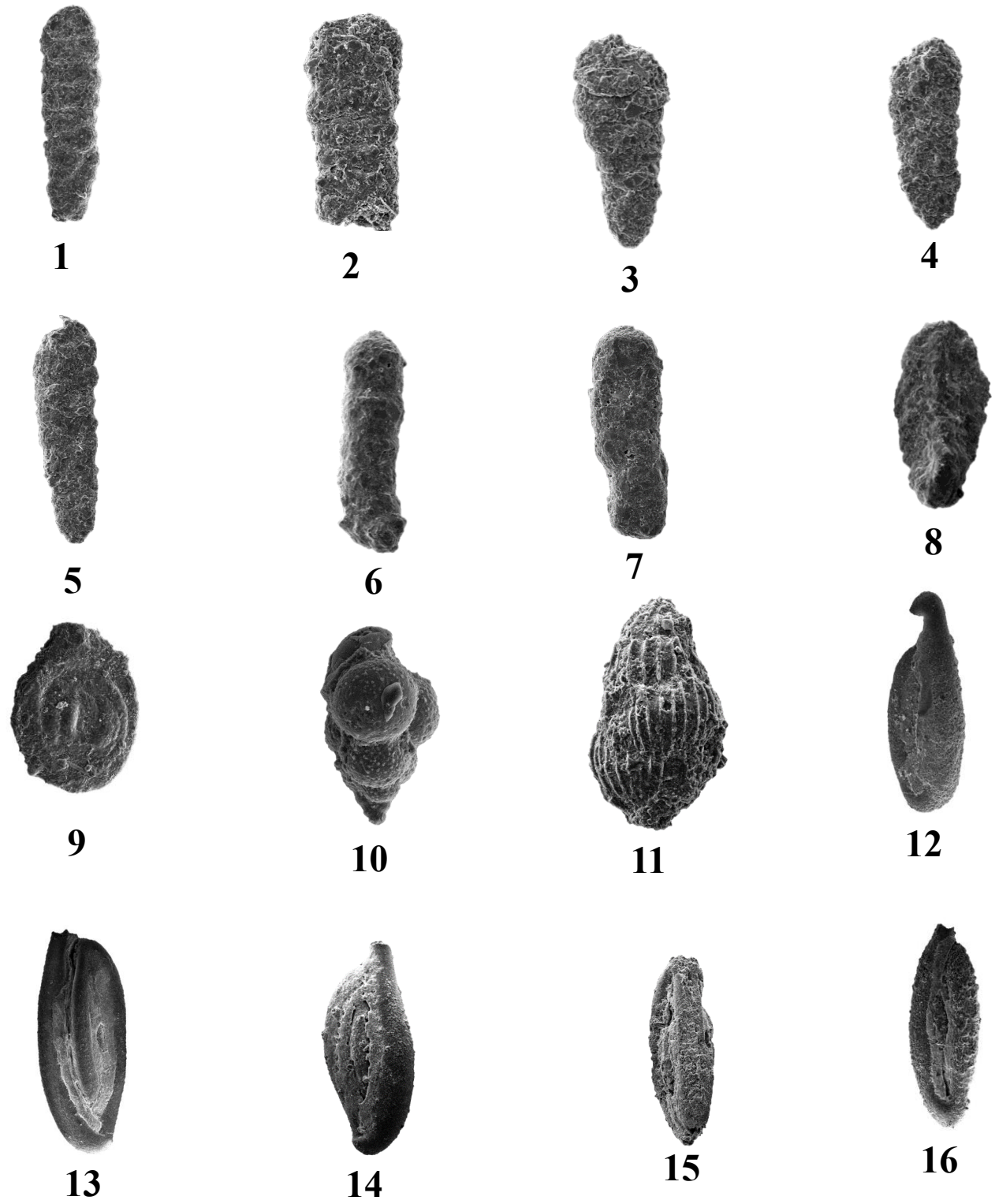
Plate 2

Plate 3



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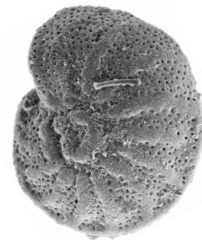
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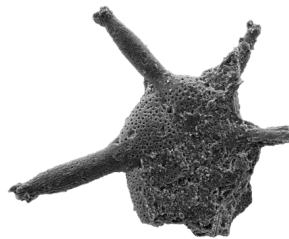
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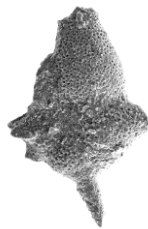
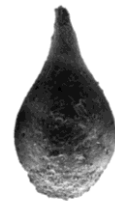
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Plate 5

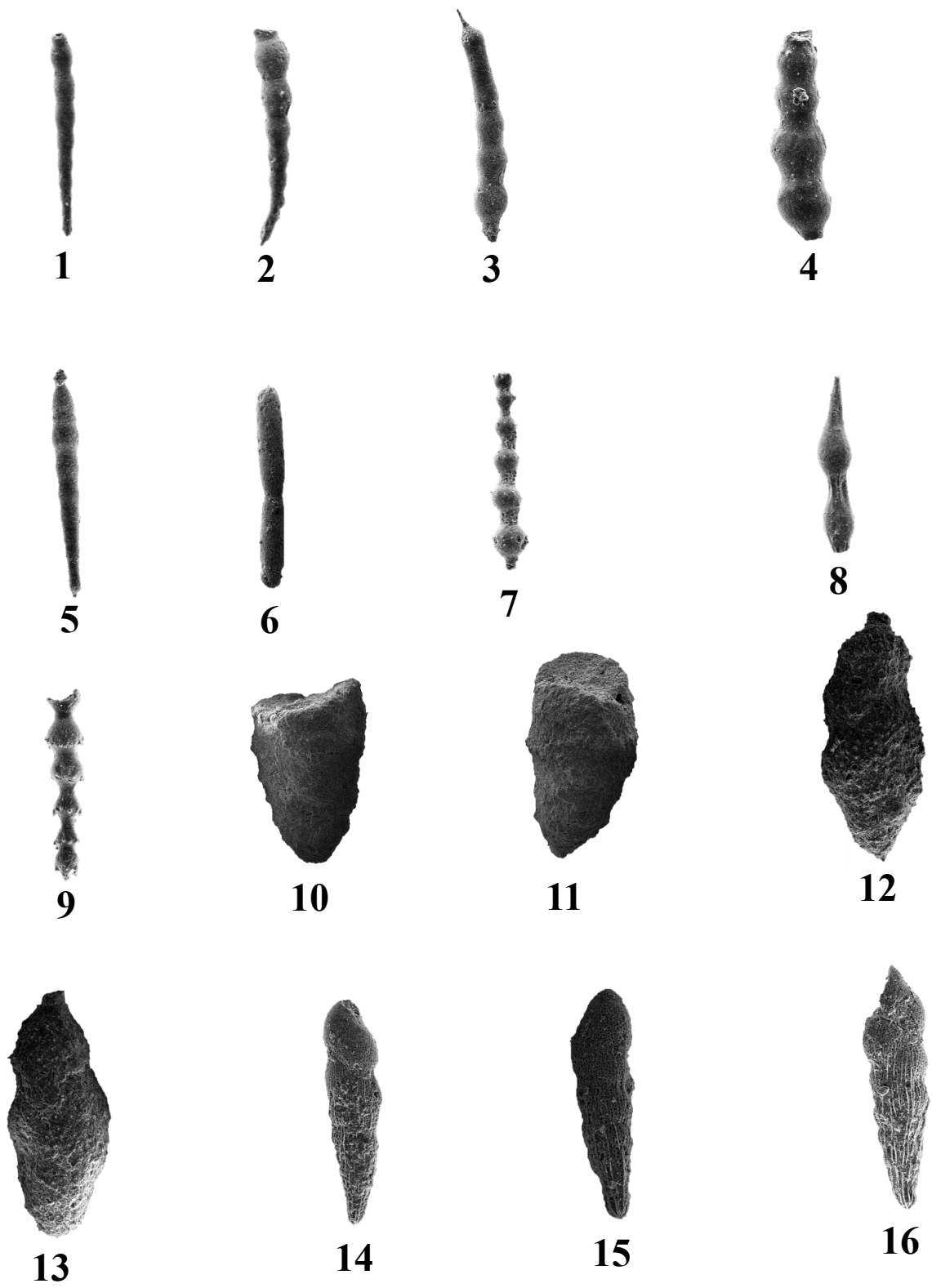


Plate 6



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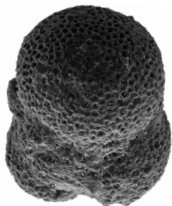
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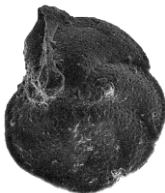
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مقاله کامل

نخستین گزارش از بقایای سنگواره‌های کوسه در سازند آیتامیر و نیز تعیین سن دقیق آن براساس فرامینیفرها در برش بهکده رضوی (غرب حوضه رسوبی کپه داغ)

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چکیده: سازند آیتامیر یکی از مهم‌ترین واحدهای کرتاسه در حوضه رسوبی کپه‌داغ در شمال و شمال‌شرقی ایران است. سنگ‌شناسی غالب این سازند شامل ماسه‌سنگ، شیل‌های گلوکونیته سبز زیتونی و سه لایه کوکینا است. برش بهکده رضوی در غرب آشخانه واقع شده است. در این مطالعه، در مجموع ۴۴ دندان فسیل کوسه از رسوبات شیلی بخش بالایی سازند آیتامیر در نزدیکی بهکده رضوی جمع‌آوری شد. پس از شستشو و پاک‌سازی نمونه‌ها، بررسی‌های میکروسکوپی و توصیف سیستماتیک انجام گرفت که به شناسایی چهار گونه از چهار جنس *Ptychodus decurrens*، *Scapanorhynchus raphiodon*، *Cretodus crassidens* و *Cretoxyrhina* sp. منجر شد. تحلیل تطبیقی این نمونه‌ها با مواد مشابه از دیگر نقاط جهان، به‌همراه مقایسه سن نسبی آنها و این واقعیت که تمام نمونه‌ها در یک افق چین‌شناسی واحد در سازند آیتامیر مورد مطالعه کشف شده‌اند، نشان می‌دهد که سن رسوبات فسیل‌دار، سنومانین (Cenomanian) است. سن به‌دست‌آمده تطابق کاملی با سن‌سنجی‌های مبتنی بر روزن‌داران (فرامینیفرها) دارد. علاوه بر این، حضور این فسیل‌ها و مفاهیم دیرینه‌بوم‌شناسی مرتبط با آنها، اطلاعات مهمی را برای بازسازی محیط دیرینه فراهم می‌کند.

کلمات کلیدی: حوضه رسوبی کپه‌داغ، سازند آیتامیر، بهکده رضوی، دندان کوسه، روزن‌داران