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# Terrestrial gastropod assemblages and paleoenvironmental implications from Quaternary coastal deposits of the Dhar Eddoum Formation (Moroccan Atlantic)

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## ABSTRACT

The present study investigates fossil terrestrial gastropod assemblages from the Quaternary Dhar Eddoum Formation near Moulay Bousselham on the northwestern Atlantic coast of Morocco. The main objective is to characterize the taxonomic composition of the malacological assemblage and to assess its paleoenvironmental significance within coastal depositional systems of the Rharb Basin. Fieldwork was conducted in two stratigraphic sections (Dhar Eddoum 1 and 2), where fossil-bearing clay–silt deposits were systematically sampled and lithologically described. The collected specimens were identified through morphological comparison with reference collections from the Scientific Institute of Rabat and taxonomically classified following MolluscaBase nomenclature. The assemblage includes seven species belonging to three gastropod families: Helicidae (*Theba pisana, Otala lactea, Cornu aspersum*), Trissexodontidae (*Caracollina lenticula*), and Geomitridae (*Cochlicella acuta*, *Cochlicella conoidea*). The fossils occur within fine-grained sedimentary units interpreted as low-energy coastal deposits, locally reaching up to 12 m in thickness and associated with lagoonal to backshore environments. The results indicate a mixed terrestrial malacofauna dominated by xerophilous and psammophilous taxa, suggesting the presence of open sandy habitats such as dunes and back-dune systems, alternating with more stabilized and locally humid microenvironments. This ecological heterogeneity consists of a dynamic coastal system influenced by alternating phases of aeolian activity, sediment stabilization, and possible post-depositional transport processes. However, this research has limitations, particularly the absence of new independent chronological dating specifically conducted on the examined levels. The adopted chronological model therefore relies on the dates already available in previous research, which allows the deposits to be placed in a general temporal and paleoenvironmental context. Despite these constraints, the studied assemblage constitutes the first documented record of fossil terrestrial gastropods from the Dhar Eddoum Formation and provides a reference dataset for the region. The study contributes to filling a significant gap in the malacological record of the northwestern Moroccan Atlantic margin and provides a basis for future stratigraphic, taphonomic, and geochronological investigations aimed at refining Quaternary coastal evolution models.

**Keywords:** paleontology, Moulay Bousselham, gastropod mollusks, Gharb, Atlantic coast of Morocco, Miocene-Pliocene-Quaternary.

## INTRODUCTION

The Quaternary coastal deposits of Morocco have long been considered key indicators of eustatic fluctuations, particularly thru the analysis of shell levels. These elements are essential for defining coastal paleoenvironments and for establishing a relative time sequence of the different sedimentary layers (Gigout, 1960).

The northwestern area of the Moroccan Atlantic coast, which extends from Rabat to Larache, represents a coastal stretch located at the

crossroads between the Meseta, rather stable to the south, and the Rif foothills to the north. In this region, the Quaternary formations bear witness to the combined effect of sea level variations, coastal and wind-related dynamics, as well as, locally, recent neotectonic movements.

One commonly observes paleobeaches, coastal ridges, consolidated dunes such as eolianites or calcarenites, intercalated rubefied paleosols, as well as fine facies related to lagoonal environments or backshore areas in sedimentary archives.

Numerous studies have been dedicated to these sedimentary associations, particularly in the Rabat-Salé area. The Mamora Formation was addressed by Texier, Lefèvre, and Raynal (1992). At the regional level, the Quaternary formations of the Gharb margins were addressed in the synthesis studies by Aberkan (1989), enriched by thermoluminescence dating conducted on the coastal formations' northeast of Rabat (Aberkan, 2000).

The Rabat-Témara sector also proves to be a key element for research in paleontology and paleoenvironment. The study of ancient beaches and marine deposits from the Pleistocene era has revealed highly rich malacofauna strata, including the identification of several species. The gastropod Stramonita haemastoma stands out among these species as a predominant taxon, suggesting coastal environments like those of today, characterized by the presence of rocky and sandy substrates (Chakroun et al., 2017).

Further north, studies conducted in the Tanger–Cap Achakar area have revealed marine formations dating from the Pleistocene, housing a fauna described as "cold," notably illustrated by Buccinum undatum and Neptunea contraria.

According to Alouane (1997), these associations reflect the paleobiogeographical diversity of the Atlantic coast of Morocco during the Quaternary.

A recent analysis of the Kenitra–Skhirat sector, located in the Rabat region, detailed the structure of coastal ridges and dune sequences, emphasizing the changes between recent dunes, paleosols, and shell-rich levels. This research also highlights the importance of Nassarius shells, used as ornamental objects in various caves and shelters in the area (Chahid et al., 2022).

Despite this extensive body of work, terrestrial gastropod assemblages from lagoonal or marginal coastal deposits remain poorly documented, particularly in the Rharb Basin. In addition, the Dhar Eddoum formation, located near Moulay Bousselham, has received limited attention in terms of its malacological content, and no detailed taxonomic or paleoenvironmental study of its fossil gastropods is currently available. This represents a significant gap, as terrestrial malacofauna can provide valuable insights into local environmental conditions, including substrate stability, humidity, and vegetation cover. Gastropods constitute one of the most diverse classes of Mollusca, with estimates ranging from about 40,000 to 90,000 living species (Ponder et al., 2020) and are widely used as paleoenvironmental indicators due to their ecological specificity and high preservation potential (Erwin and Signor, 1991; Tracey et al., 1993). In coastal settings, terrestrial gastropod assemblages are particularly informative for reconstructing interactions between aeolian, continental, and marginal marine environments.

The present study aims to characterize the fossil terrestrial gastropod assemblage from the Quaternary Dhar Eddoum Formation and to use this assemblage as a proxy for reconstructing paleoenvironmental conditions and coastal system dynamics in northwestern Morocco.

We test the following hypotheses:

1) the gastropod assemblage reflects predominantly terrestrial conditions associated with coastal dune or back-dune environments;
2) the co-occurrence of taxa with different ecological preferences indicates environmental heterogeneity and/or temporal variability within the depositional system.
3) the presence of terrestrial gastropods within fine-grained deposits interpreted as lagoonal may reflect post-depositional transport or reworking processes.

## DATA AND METHODS

### Geological and geographical context

The Dhar Eddoum Formation is located near Moulay Bousselham on the western Atlantic coast of the Rharb Basin (34°53′22″N; 6°17′13″W). According to Redouani et al. (2026), the formation extends over approximately 2 km² and displays an elongated morphology parallel to the present shoreline. Geographically, the Dhar Eddoum hill belongs to the Khlot region (Bled Khlot), a subzone of the western High Rharb located near the pre-Rifain boundary (Toto et al., 2012).

The regional geological setting corresponds to a Quaternary coastal margin characterized by marine and aeolian Plio-Quaternary calcarenitic ridges, dunes, and paleosols (Figure 1). These formations are distributed northwest of Rabat along the edge of the Rharb Basin (Gigout, 1960; Beaudet, 1969; Beaudet et al., 1967; Stearns, 1978; Aberkan, 2000; Lefèvre and Raynal, 2002; Chahid, 2011). The modern shoreline is sub-parallel to these ridges (Guilcher and Joly, 1954; Chahid et al., 2012). Sections 1 and 2 of the Quaternary deposit of Dhar Eddoum were the sites of the fossil gastropod shell sample. This scientific procedure uses a trowel to remove the stratum's hollow to obtain representative samples of a population.

## Stratigraphic framework

Two stratigraphic sections (Dhar Eddoum 1 and Dhar Eddoum 2) were investigated and sampled for fossil gastropods. Stratigraphic logs were established in the field by measuring vertical successions using standard sedimentological methods (e.g., bed thickness measurement, lithological description, and identification of sedimentary structures) (Figure 2, Figure 3).

### *Dhar Eddoum 1 section*

The Dhar Eddoum 1 section is organized into three main lithostratigraphic units.

The basal unit corresponds to a reddish clayey-sandy layer approximately 8 m thick, associated with calcarenites attributed to the Soltanian. This attribution to the Late Pleistocene does not result from original absolute dating carried out as part of the present study but is based on lithostratigraphic and morphostratigraphic correlation with Quaternary coastal formations previously described in the Rharb Basin and along the Moroccan Atlantic coast. Previous studies, particularly those of Aberkan (2000), have shown that some comparable calcarenitic and coastal levels were dated by thermoluminescence, thereby helping to refine their chronostratigraphic framework.

Intermediate unit: Gray green to light brown clays, approximately 8 m thick, interpreted as low-energy lagoonal or marsh deposits (Akil, 1990; Idrissi, 2004). The upper unit of the Dhar Eddoum 1 section corresponds to a clayey-silty level approximately 2 m thick, directly overlying an underlying unit whose thickness ranges from 8 to 10 m. This unit, whose color varies from ochre to black, is organized into decimetric to metric beds and occupies the upper part of the studied stratigraphic succession. The gastropod shells were collected from these clayey-silty deposits, which extend approximately from 8–10 m to 10–12 m above the base of the Dhar Eddoum 1 section. They are generally well preserved and correspond to seven species distributed among three families (Figure 2).

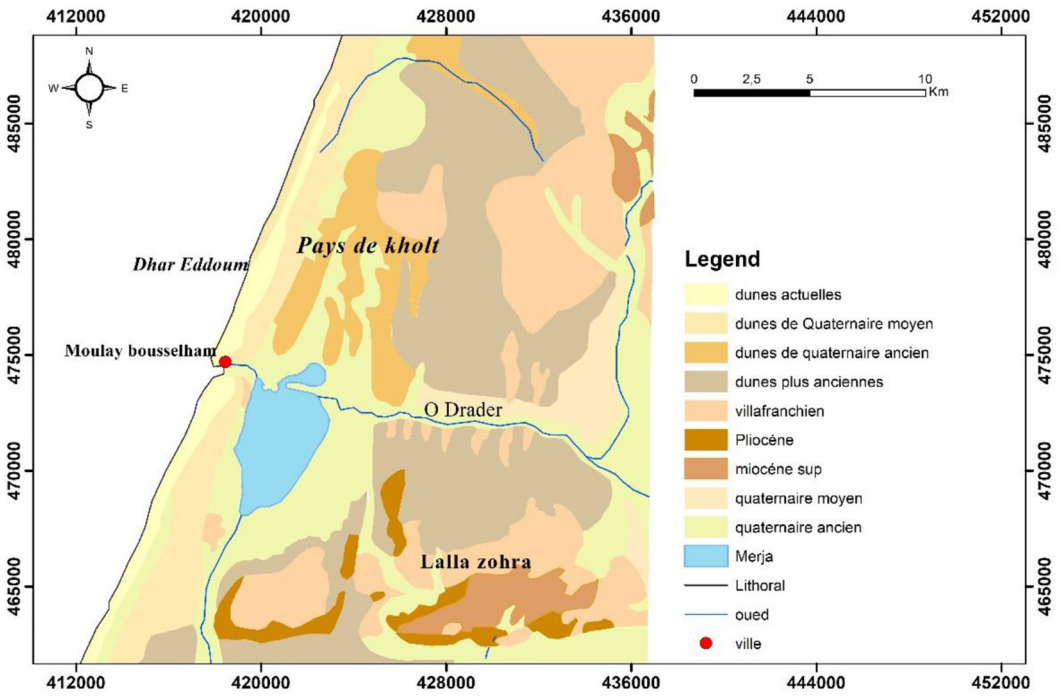


**Figure 1.** Simplified geology of the study area

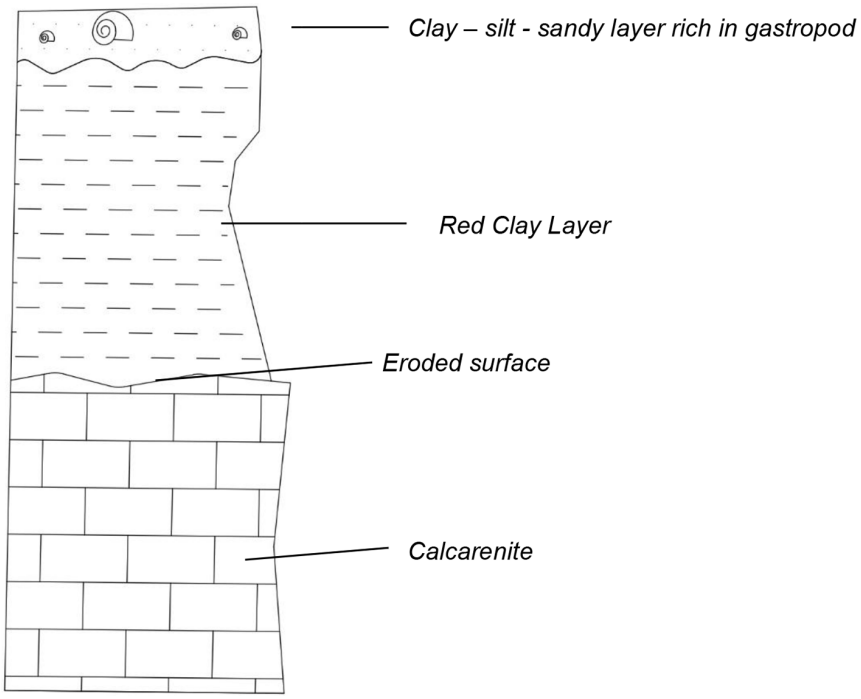


**Figure 2.** Stratigraphic log of the Dhar Eddoum 1 cross section

*Dhar Eddoum 2 section*

The Dhar Eddoum 2 section shows a vertically organized sedimentary succession composed of several distinct units:

1. Basal unit: Consolidated gray sand with horizontal stratification, interpreted as a low-energy depositional environment or sediment stabilization phase.
2. Overlying unit: Sand layer with oblique stratification, indicating higher-energy depositional conditions possibly related to current activity, aeolian transport, or coastal dynamics.
3. The main fossiliferous unit corresponds to a clay-silty layer approximately 12 m thick, rich in gastropod shells. The dominance of fine particles indicates calm depositional conditions, consistent with a low-energy environment. This interpretation is supported by the clay-silty nature of the deposits, the abundance and good preservation of the shells, as well as the presence of terrestrial gastropods, suggesting a humid continental or backshore/coastal hinterland environment. This unit can therefore be interpreted as a deposit formed in a protected setting, probably corresponding to a humid back-dune area, a temporary marsh, or a lagoonal margin. In the absence of original geochemical data, this interpretation is mainly based on lithological, sedimentological, and paleontological observations.
4. Upper unit: A conglomeratic layer with rounded to flattened pebbles, interpreted as a higher-energy depositional episode possibly linked to coastal or fluvial processes. This stratigraphic succession reflects a transition from relatively stable sandy environments to fine-grained fossiliferous deposits, followed by a phase of higher-energy reworking (Figure 3).

## Sampling strategy

The fossil gastropods were collected from fossiliferous levels identified within the two stratigraphic sections, Dhar Eddoum 1 and Dhar Eddoum 2.

The fossil gastropods were collected from fossiliferous levels identified within the two stratigraphic sections, Dhar Eddoum 1 and Dhar Eddoum 2. Bulk sediment samples were manually collected using a trowel. To ensure the reproducibility of the sampling protocol, we collected 2 to 3 samples from each of the two stratigraphic sections examined. The samples were collected from the identified fossiliferous strata, considering their stratigraphic configuration relative to the base of each segment. In the sampling of the Dhar Eddoum 1 section, the collection was carried out between 0 and 1.5 meters above the base, while for the Dhar Eddoum 2 section, the sample

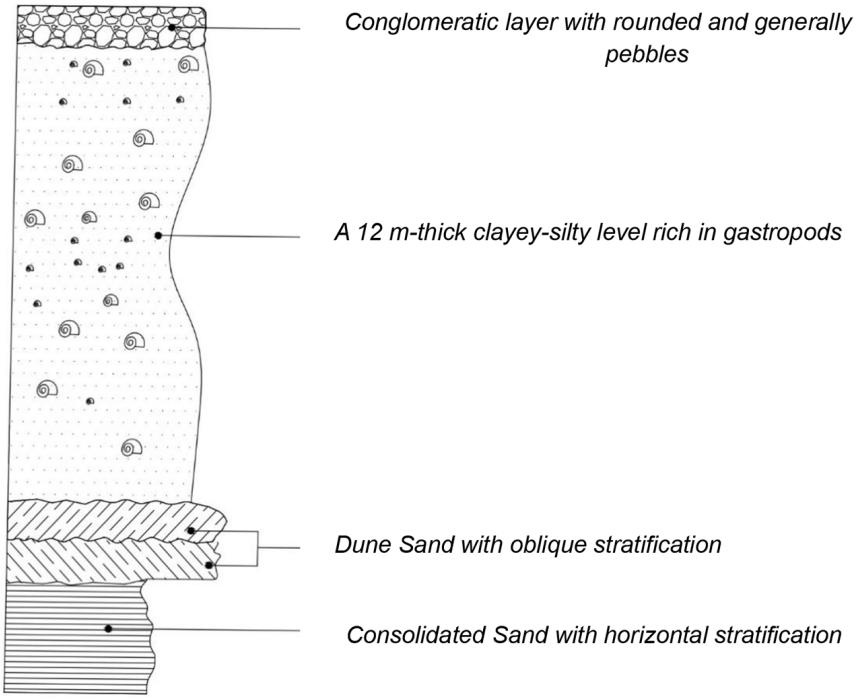


**Figure 3.** Section 2 of the Dhar Ed Doum formation shows the lateral development of the fine detrital facies with gastropods and the recent conglomeratic spreads reminiscent of Villafranchian detrital deposits from the pre-Rif

was collected approximately two meters above the same level. Each sample corresponds to an approximate mass of 1 kg of sediment, collected manually using a trowel. When multiple sampling points were carried out within the same level, they were spaced laterally by approximately 1 to 2 meters. Representative samples were selected from the horizons where gastropod shells were visible, relatively abundant, well-preserved, and representative of the observed lithology.

## Laboratory processing

Within the laboratory, sediment samples were handled using paleontological approaches adapted for the recovery of gastropod shells. First, the samples were submerged in water to soften the sediments and promote their gradual disaggregation, while limiting the fragmentation of the shells. Following this step, the decomposed sediments were air-dried for 24 hours, then placed in an oven at 90 °C for a period of 48 hours to ensure complete drying. The dried residues were then subjected to dry sieving using sieves with mesh sizes ranging from 4 mm to 40 µm, to distinguish the different grain size fractions and optimize the recovery of the shells. A manual sorting was then carried out under a low-magnification binocular microscope. Only whole and identifiable shells were sorted, preserved, and selected for taxonomic analysis; incomplete or unidentifiable fragments were not included in the systematic study.

## Taxonomic identification

Fossil gastropods were identified through morphological comparison with reference specimens housed in the collections of the Scientific Institute of Rabat (Departments of Geology and Zoology). These collections include more than 12,000 geological samples, of which 9.437 are paleontological specimens (Fedan, 2014).

The taxonomic identification of fossil gastropods has essentially been carried out based on the morphological characteristics of the shell. The criteria examined included the general configuration of the shell, its total height, its widest diameter, the harmony between height and width, the number of whorls, the shape of the apex, the depth of the sutures, as well as the characteristics of the aperture. The external ornamentation was also given particular consideration, notably the presence of growth lines, ribs, bands, or superficial sculptures, when the shells were sufficiently well-preserved. We also took into account the characteristics of the aperture, such as its shape, dimensions, the thickness of the peristome, and the presence or absence of an umbilicus. The identifications were conducted

**Figure 4. (**a) Natural deposits of the Dhar Eddoum formation rich in fossilized gastropod shells; (b) surface of the fossil dune with numerous shells of different specimens


**Figure 5.** Main specimens of gastropods found in the Quaternary of Atlantic Morocco at the Dhar Eddoum formation: A) *Theba pisana*; B) *Otala lactea*; C) Otala (Otala) lactea; D) *Cornu aspersum*; E) *Caracollina lenticula*

based on published taxonomic descriptions, specialized identification keys, and reference collections. The classification system used follows the currently recognized names in MolluscaBase, using the WoRMS platform.

## RESULTS AND DISCUSSION

The paleontological results obtained from the two stratigraphic sections of Dhar Eddoum 1 and Dhar Eddoum 2, located near Moulay Bousselham, have made it possible to distinguish an assemblage of fossil terrestrial gastropods comprising seven different taxa: *Theba pisana, Otala lactea*, Otala (Otala) lactea, *Cornu aspersum, Caracollina lenticula* (Figure 5), *Cochlicella acuta* and *Cochlicella conoidea* (Figure 6). These seven taxa were identified in the two analyzed sections, indicating a rather uniform distribution of the malacological assemblage across the studied fossil strata, without any species appearing significantly. The specimens are generally well-preserved, most of the shells being intact and facilitating precise taxonomic identification. These results demonstrate that the fossiliferous levels of the Dhar Eddoum Formation host a diverse group of terrestrial gastropods, well-preserved and present in both analyzed sections.

### Systematic study of the seven specimens:

These results demonstrate that the fossiliferous levels of the Dhar Eddoum Formation host a diverse group of terrestrial gastropods, well-preserved and present in both analyzed sections. Differentiation mainly occurs within the families, including Helicidae, Geomitridae, and Trissexodontidae. The assemblage is largely dominated by the Helicidae, which includes *Theba pisana, Otala lactea,* Otala (Otala) lactea, and *Cornu aspersum*. The Geomitridae are represented by *Cochlicella acuta* and *Cochlicella conoidea*, while the Trissexodontidae is represented by *Caracollina lenticula*. The presence of several species belonging to the same genera (Otala, Cochlicella) indicates a systematic relationship and a certain degree of internal diversification (Figure 7).

#### *Theba pisana (Müller, 1774): Euparypha pisana: original name Helix pisana (DE Müller, 1774)*

In Morocco, stratified fossil traces of *T. pisana* are well established in the Upper Pleistocene coastal sequence of Dar Bouazza (Casablanca region). In this section, *Theba pisana* is present in the malacofauna of several levels. The associated deposits are mainly continental/coastal: pink silty sands rich in shells, pedogenized red sands, and dune levels (paleodunes/windblown sands).


**Figure 6.** Main specimens of gastropods found in the Quaternary of Atlantic Morocco at the Dhar Eddoum formation in Moulay Bousselham: F) *Cochlicella acuta* (Müller, 1774); G) *Cochlicella conoidea* (Draparnaud, 1801)

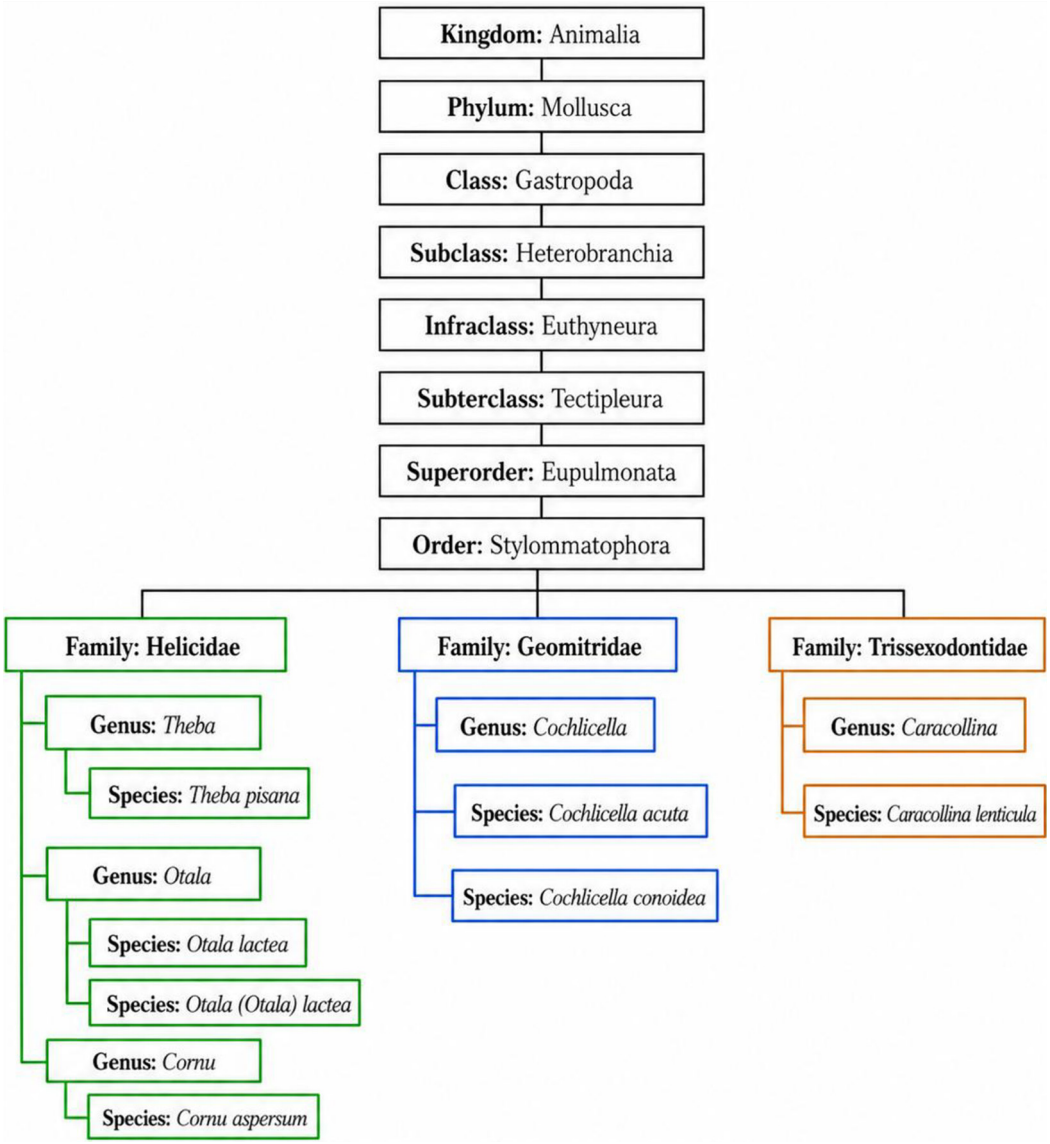


**Figure 7.** Systematic classification tree of the studied fossil gasteropods

Chronostratigraphically, this places the species in the Quaternary, especially in the Upper Pleistocene (with a possible extension towards the beginning of the Holocene (Rué et al., 2016), (Figure 5A). *Otala lactea* (Müller, 1774) [= *Archelix ahmarina* (Bourguignat, 1884)] and Otala (Otala) lactea (DE Müller, 1774), original name *Helix lactea* (DE Müller, 1774) (Figure 5C).

The shells historically attributed to Archelix ahmarina (Bourguignat, 1884) correspond to the synonymy of *Otala lactea* (Müller., 1774) in current reference systems. The specimen studied, labeled in the ISR collection under the name *Archelix ahmarina* (Bourguignat (cap ghir 24.11.1936) (MOGADOR), has a depressed shell with reddish-brown spiral bands and a strongly browned aperture. In Morocco, *Otala lactea* is a Quaternary species whose presence has been documented since at least the upper Pleistocene (approximately 94,000 BP) and which has been found in Holocene contexts (snail farms and archaeological sites). This species is therefore present on Moroccan territory during the period spanning the upper Pleistocene-Holocene interval (Rué et al., 2016; Chennaoui et al., 2005; Hutterer et al., 2014), (Figure 5B, Figure 5C).

### *Cornu aspersum: original name Helix aspersa Müller 1774*

*Cornu aspersum*, or *Helix aspersa* as indicated in the ISR collection, has been found in Quaternary deposits (upper Pleistocene–Holocene) and is mainly found in archaeological contexts where shells are often the result of human

accumulation (consumption). At Taforalt, in the Pigeons Cave, the species has been reported in snail-shell deposits belonging to the Grey Series. The intensification of the formation of such deposits was particularly marked around 14,000 years BP, which places this occurrence in the Upper Pleistocene (Taylor., 2017).

As part of research conducted on the Bizmoune cave located in the Essaouira region, an in-depth study was conducted on the presence of Helicidae. Analyses were performed on the shells of this species, attributed to *Helix aspersa* (*Cornu aspersum*), and carbon-14 dating was carried out on layers dated between 6641- and 6009-years BP, corresponding to the Middle Holocene. These results indicate the continuous presence of the species in the stratified layers of the cave and highlight a direct correlation between the dating obtained by shell analysis and the dating of the layers (Fernandez et al., 2015). Finally, Holocene sites such as Taghit Haddouch illustrate the same type of occupation deposits (Epipaleolithic–Neolithic levels dated to ~9717 ± 105 to 4898 ± 45 cal BP), even though the published assemblage there is dominated by other taxa (Otala, Alabastrina, Sphincterochila, Cernuella) (Hutterer et al., 2011), (Figure 5D).

### *Caracollina lenticula Original Name Helix lenticula Michaud, 1831*

*Caracollina lenticula* (Michaud., 1831) is a terrestrial gastropod (Helicoidea) belonging to the Trissexodontidae family (reference taxonomy MolluscaBase/WoRMS).

Its chronostratigraphic record is Quaternary (Pleistocene–Holocene), particularly in the Canary Islands (Yurena et al., 2011). It is reported in continental/littoral deposits: paleodunes/aeolianites, paleosols, as well as colluvial deposits and valley fillings (e.g., La Gomera; Bajamar/Tejina in Tenerife) (Margry, and Groh, 2025). With the Pleistocene/Holocene boundary set at 11.7 ka (ICS, 2024), these occurrences range from the Late Glacial to the present (Figure 5E).

### *Cochlicella acuta (Müller) "dar bel hamri fedala 1923" original name Helix acuta DE Müller, 1774*

*Cochlicella acuta* (originally named *Helix acuta* by Muller., 1774) is a terrestrial mollusk belonging to the Geomitridae family, with a slender, conical shell, often associated with arid coastal habitats (GBIF Secretariat, n.d.). In Morocco, the best chronostratigraphic data for this species come from the Quaternary sequence at Dar Bouazza (Casablanca), where it has been observed in OSL-dated layers from approximately 94 to 8 ka BP (Rué et al., 2016). In this sequence, it is linked to slope deposits (silty sands, pedogenized red sands), stratified aeolian sands (paleodunes), and karst cave fillings (Rué et al., 2016). Currently, this species is also reported at Moroccan coastal sites (e.g., Sidi Boughaba, Oued Sous estuary), corresponding to sandy/coastal environments (Irikov and Gerdzhikov., 2013) (Figure 6F).

### *Cochlicella conoidea (Draparnaud, 1801)*

*Cochlicella conoidea* (Draparnaud., 1801) is a small terrestrial gastropod with a conical and elongated shell. It is now classified in the Geomitridae family (MolluscaBase, n.d.). In the context of the study of Moroccan fossils, the most documented occurrence is that observed in the Quaternary coastal sequence of Dar Bouazza, located in the Casablanca region. In this region, *C. conoidea*, designated by the term "occidentalis" in the malacofauna, has been associated with units dating from the Upper Pleistocene. C. conoidea is mainly preserved in (sub)fossil form in aeolian and slope deposits, as well as in karstic cavities, characteristic of Quaternary coastal systems (MolluscaBase, n.d.; Rué et al., 2016). (Figure 6G).

The identification of terrestrial gastropods in the two sections of Dhar Eddoum has considerable paleoenvironmental significance. The simultaneous presence of *Theba pisana, Otala lactea,* Otala (Otala) lactea, *Cornu aspersum*, *Cochlicella acuta, Caracollina lenticula*, and *Cochlicella conoidea* indicates a terrestrial environment influenced by the coastal area, likely open, sandy, or silty with sparse vegetation. The identical presence of taxa in the Dhar Eddoum 1 and Dhar Eddoum 2 sites suggests a lateral continuity of paleoecological conditions across the formation. This taxonomic uniformity indicates that it is likely that the two sections originated from the same sedimentary system or nearby environments. Moreover, the variety of the malacofauna and the absence of dominance by a single taxon reflect a relatively stable environment, conducive to the evolution of various terrestrial gastropods. The presence of complete and recognizable shells may indicate limited transport before their burial, or at least calm deposition conditions, favorable for the preservation of the specimens.

## CONCLUSIONS

The analysis of the Dhar Eddoum assemblage indicates that the main objective of the research, namely the taxonomic determination and interpretation of the Quaternary gastropod paleoenvironment, has been successfully achieved, although some limitations remain. The taxonomic aspect is solid, with the identification of seven taxa belonging to three major families. However, paleoenvironmental interpretations must be approached with caution due to the lack of detailed quantitative data regarding the abundance of taxa and new independent chronological dating.

The identified malacofauna is consistent with the typical terrestrial assemblages of Mediterranean coastal environments and confirms the presence of well-established Quaternary taxa on the Atlantic margin of Morocco. The identified species are not new to science; their occurrence within the Dhar Eddoum formation provides the first documented association for this locality, thus filling a regional gap in the malacological and paleoenvironmental archives of the Rharb basin. The co-occurrence of psammophilic and xerophilic taxa (for example, *Cochlicella* spp., Theba pisana) with species that prefer more stable and locally humid microhabitats (such as *Otala lactea*, *Cornu aspersum*) indicates a heterogeneous coastal landscape. This combination is consistent with a mosaic-type environment, combining dynamic sandy substrates (dunes or back-dunes) and more stabilized areas influenced by pedogenesis or increased moisture availability. The presence of terrestrial gastropods in the fine sediments of the Dhar Eddoum Formation, considered lagoonal, probably suggests the proximity of continental environments such as dunes, back-dune areas, or sandy zones. It is, however, possible that these shells were moved to the deposition site by runoff, slope reworking, or localized flooding. The main contribution of this study is therefore to document, for the first time, an assemblage of fossil terrestrial gastropods in the Dhar Eddoum Formation, providing a reference base for future research on the Quaternary of the Moroccan Atlantic coast.

### Acknowledgments

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