Annales de Paléontologie 104 (2018) 291–300

Disponible en ligne sur
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com

Original article

Terrestrial Gastropoda from the Pleistocene of Beni Saf, NW Algeria

Gastropodes terrestres du Pléistocène de Beni Saf, Nord Ouest de l'Algérie

Rodrigo B. Salvador[a,*], Mohammed Adaci[b], Madani Benyoucef[c]

[a] *Museum of New Zealand Te Papa Tongarewa, Wellington, New Zealand*
[b] *Earth and Universe Sciences, Research Laboratory no. 25, Abou-Bekr Belkaid University, Tlemcen, Algeria*
[c] *Faculty of Natural and Life Sciences, Mustapha Stambouli-Mascara University, Mascara, Algeria*

ARTICLE INFO

Article history:
Received 2 May 2018
Accepted 31 July 2018
Available online 22 November 2018

Keywords:
Caenogastropoda
Pliocene-Quaternary
Stylommatophora
Tafna Basin
Villafranchian

ABSTRACT

A study of the terrestrial gastropods of the Pliocene-Quaternary succession of the Beni Saf sea cliff, NW Algeria, at the Playa Port locality, is presented herein. The sedimentary succession is subdivided into four lithostratigraphic units, on the basis of their lithologic and biogenic contents: the three first units (A, B and C) are of marine origin; the last unit (D) is of continental origin and includes three beds yielding terrestrial gastropod fossils, which form laterally traceable horizons. Herein, we describe the section's lithology, present stratigraphical considerations regarding its age and thoroughly described its terrestrial gastropod fossil fauna. In total, 13 species are reported here from Beni Saf: 2 caenogastropods (family Pomatiidae) and 11 stylommatophorans (family Achatinidae and superfamily Helicoidea). The sedimentological data indicate that the depositional setting at Beni Saf was a dune system flanked by wadi floodplains deposits (snail levels); the ecological preferences of the gastropods largely agrees with this scenario.

Mots clés :
Caenogastropoda
Stylommatophora
Plio-Quaternaire
Bassin de la Tafna
Villafranchien

RÉSUMÉ

Le présent travail montre l'étude des gastéropodes terrestres de l'affleurement plio-quaternaire du Port Playa situé sur la falaise maritime de Beni Saf, NW Algérie. La série sédimentaire est subdivisée en quatre unités lithostratigraphiques informelles, dont chacune est dotée de ses propres caractères lithologiques et paléontologiques. Les trois premières unités (A, B et C) sont d'origine marine ; la dernière unité (D) est d'origine continentale, formée de trois bancs, en bonne continuité latérale, à fossiles de gastéropodes terrestres. Ici, nous présentons la lithologie, l'attribution stratigraphique et la description minutieuse des gastéropodes terrestres de chaque banc. Au total, 13 espèces sont signalées à Beni Saf : 2 cénogastéropodes (famille des Pomatiidae) et 11 stylommatophores (superfamille des Helicoidea et famille des Achatinidae). Les données sédimentologiques indiquent que le milieu de dépôt, à Beni Saf, était un système de dunes encadré par des dépôts de plaine d'inondation alluviale (niveaux à escargots). Les préférences écologiques des gastéropodes s'accordent largement avec ce scénario.

1. Introduction

Cenozoic fossil outcrops are widely distributed and well exposed at several localities in Algeria. They have been known for a long time (e.g., Crosse, 1861, 1862; Bourguignat, 1862), but most remain understudied to this day, especially regarding their gastropod fauna. Since gastropods may be useful index fossils (e.g., Esu, 1999; Höltke et al., submitted) and may also act as paleoenvironmental proxies (e.g., Goodfriend, 1992; Moine et al., 2002), studying this fossil fauna can prove worthwhile.

The fossil outcrops in the region of Beni Saf in northwestern Algeria are one of such understudied occurrences, as only a short report on its terrestrial gastropods (Pallary, 1901: 96–97) and an unpublished geological study (Guardia, 1975) exist. Pallary (1901) briefly mentioned four distinct sedimentary beds bearing gastropods, assigning them to the Quaternary. He listed 10 gastropod species, including "*Helix*" spp. and *Rumina decollata* (Linnaeus, 1758). Guardia (1975) offered a more in-depth analysis of the

* Corresponding author.
E-mail address: salvador.rodrigo.b@gmail.com (R.B. Salvador).

https://doi.org/10.1016/j.annpal.2018.07.002
0753-3969/

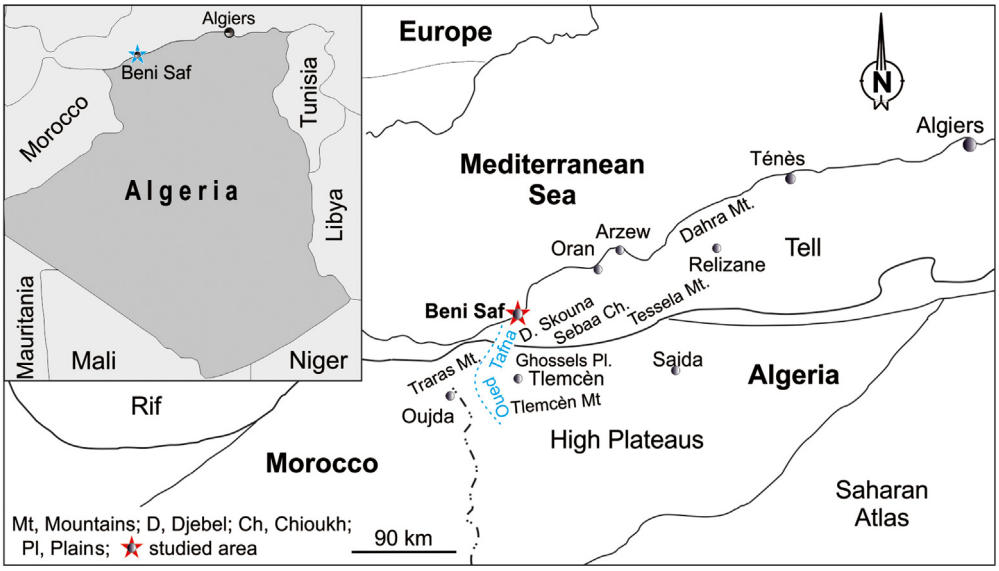

Fig. 1. Location map showing the position of the study area.
Carte de localisation montrant la position de la zone d'étude.

geodynamics of the northwestern Orania region, only briefly mentioning the presence of terrestrial gastropods ("Hélix").

New excavations were conducted in the fossil outcrop of Beni Saf (Fig. 1) during two field expeditions (2016–2017), bringing to light a fauna of terrestrial gastropods. Here we describe the lithology and stratigraphy of this fossil outcrop, focusing especially on the gastropod-bearing levels, and propose a Pleistocene age for them. Furthermore, we present an inventory of the fossil land snail fauna of Beni Saf, alongside a brief paleoenvironmental interpretation.

2. Geological setting

2.1. General overview of study area

The study area is part of the Tafna Basin, which was defined during the period when the early Miocene sea occupied the whole western Orania region. Its paleogeographic history reveals several distinct cycles during the Neogene and Quaternary dominated by transgressive-regressive events (Gentil, 1903; Dalloni, 1915; Perrodon, 1957). The Tafna Basin encompasses the hills and plains crossed by Oued Tafna (Tafna River) and its tributaries. It is delimited by the Tlemcen range to the south, the Trara mountain range and the Mediterranean Sea to the north, and to the east by the Sebaa Chioukh Mountains and the westernmost extension of the Tessala range (Fig. 1).

We studied the outcropping sections of the Playa Port on the right bank of the Oued Sidi Boucif. It is morphologically shaped as a cliff (Fig. 2A), circa 100 m high, on the north coast of Beni Saf (coordinates 35°18′29″N 01°22′42″W).

2.2. Description of the section

The Pliocene-Quaternary outcrops along the Beni Saf sea cliff were deposited over an angular unconformity with the Paleozoic basement. They consist of siliciclastic rocks that can be divided into four informal units (Figs. 2B, C) based on lithology and fossil content. From bottom to top, the units are:

- **Unit A** (~24 m)**:** The exposed sections of this unit consist of a thin basal conglomerate, containing reworked dark Paleozoic pebbles (schist, quartzite, sandstone and limestone; of 3–10 cm in diameter) in a brownish sandstone matrix, showing an erosional base. It is overlain by brownish, moderately- to poorly-sorted, medium-grained sandstone rich in bivalve fragments. The upper portion of this unit is interbedded with thin micro-conglomerate channels alternating with sandstone levels rich in echinoid fossils (*Clypeaster* spp.).
- **Unit B** (~5 m)**:** This unit begins with a thin channeled conglomerate bed (10–30 cm), being mainly composed of angular clasts (usually centimetric in diameter and variable in lithology and age: Paleozoic schist and quartzite, Messinian reef limestone) embedded in a brownish sandstone matrix. The conglomerate lithofacies grades upwards into a 4 meter thick section of yellowish fine- to coarse-grained bioclastic sandstones, showing horizontal and low-angle cross-stratification on its uppermost portion.
- **Unit C** (~32 m)**:** This unit is well developed along the maritime coastline of Beni Saf. It is composed mainly of yellowish fine-gained sandstone in the form of tabular beds. These beds, higher on, show erosional bases (sometimes very sharp) and a wide variety of sedimentary structures, such as: wave-ripple cross-stratification, hummocky cross-stratification, mud-drape, and planar and herringbone cross-stratification. They are overlain by a centimeter-thick conglomerate bed consisting of rounded clasts embedded in a fine sandstone matrix.
- **Unit D** (~35 m)**:** This unit is the subject of the present study. It is composed of three distinct subunits: **D1:** this basal subunit consists mostly of soft hematite-rich sandstone (red bed), containing root structures (pedotubules), and paleosol. Terrestrial snails are commonly found in one level of the D1 subunit, which is here addressed as "Gastropod Level 1". **D2:** the second subunit shows a sharp lower contact with subunit D1. It is 2.5 meter thick, mainly composed of yellowish mega-rippled fine-grained sandstones. No gastropods were found in this subunit. **D3:** the third subunit consists mostly of a grey massive stratum, showing a very homogeneous appearance with irregular stratification surfaces. It contains gastropod fossils (molds) at the base (Gastropod Level 2) and towards the top of the Unit (Gastropod Level 3). Unit D is overlain by a thin irregular calcrete bed.

This profile is distinct from the four layers described by Pallary (1901), but the base of the present Unit D correlates to the "*Helix*"-bearing layer of Guardia (1975: "sables fins rubéfiés à Hélix").

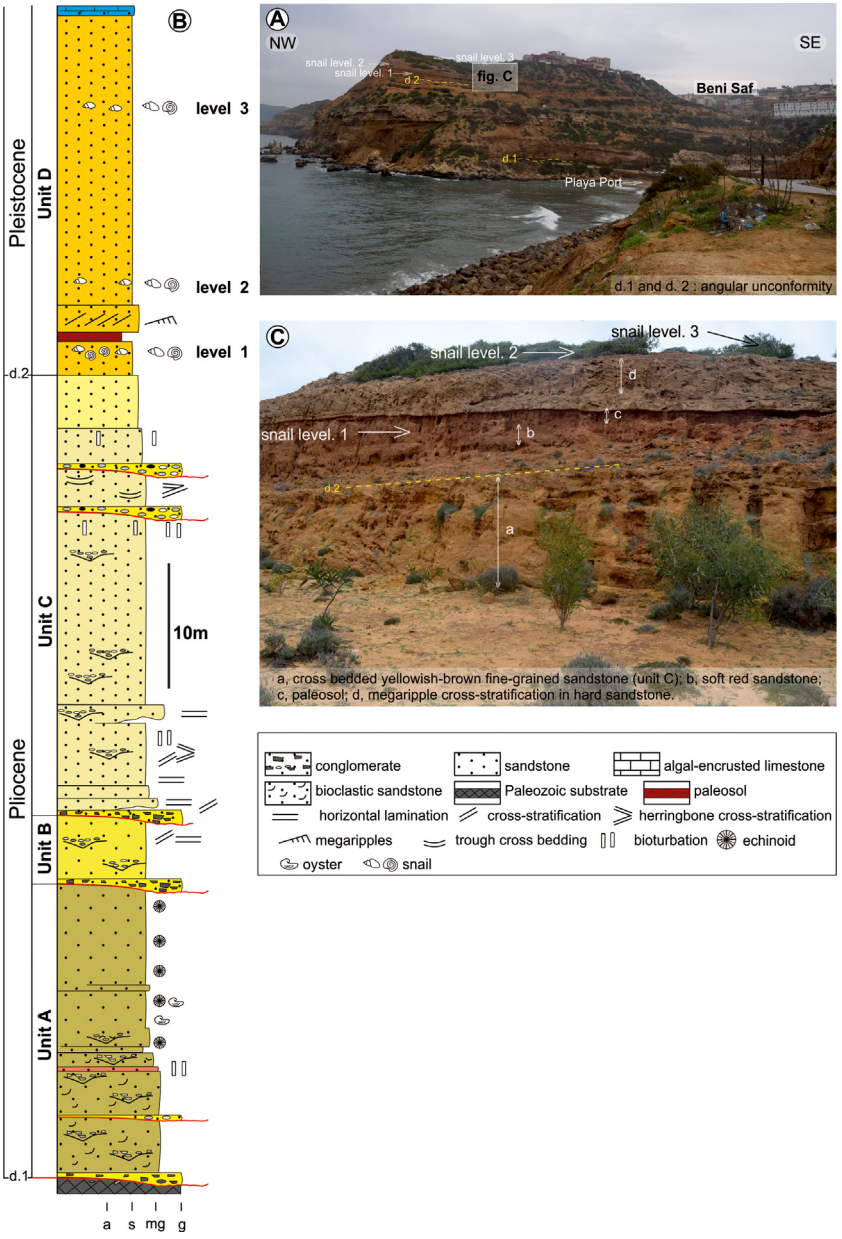

Fig. 2. A. Panoramic view of the Beni Saf maritime cliff. **B.** Lithostratigraphic log of the Plio-Quaternary Playa Port outcrop. **C.** Closer view of Unit D showing the positions of the three gastropod-bearing levels.
A. *Vue panoramique de la falaise maritime de Beni Saf.* **B.** *Colonne lithostratigraphique de l'affleurement plio-quaternaire du Port Playa.* **C.** *Vue rapprochée montrant la position des trois niveaux à gastéropodes.*

2.3. Stratigraphy and age

Both the marine (Units A to C) and continental deposits (Unit D) of the sea cliffs overhanging Beni Saf have always been problematic from a stratigraphic standpoint due to the scarcity of index fossils. For lack of well-dated intercalated marine levels, they have been variedly assigned to the Miocene (Gentil, 1903; Sadran, 1958), Mio-Pliocene (Neurdin-Trescartes, 1992), and Pliocene-Quaternary (Guardia, 1975).

Unit A lies unconformably over the Paleozoic substratum, displaying reworked pebbles from the coral reef limestones of Messinian age (the latter outcrop in the Sebaa Chioukh Mountains, at a higher elevation than in Beni Saf). Units B and C follow conformably, but the continental Unit D overlies an angular unconformity. In the study site, Unit D is overlain by a calcrete bed. However, some hundred meters west of the Playa Port of Sidi Boucif, Unit D is overlain by basaltic flows. The volcanic activity of the Tafna area generated several volcanic flows, with ages ranging from Pliocene to Quaternary (Megartsi, 1985). The flow overlying Unit D in Beni Saf was assigned to the upper part of the Lower Pleistocene (Guardia, 1975); the age of the most recent flows is 1.45 Ma (Louni-Hacini, 2002).

The fossils from the Beni Saf outcrops are largely not helpful as biostratigraphic indexes for defining the age of the sediments. The marine beds consist of common fossils: echinoids (*Clypeaster* spp.), cirripedes (*Balanus* spp.), and bivalve (pectinids and oysters) fragments (personal observation). The continental sediments contain mostly internal molds of terrestrial gastropods which can be assigned to Recent species (see below). The only exception is *Rumina atlantica* (Pallary, 1891a), which is only know from the Pliocene beds of Oran (Pallary, 1891b, 1901), a geographically close locality to Beni Saf. The age of these beds has not

Table 1
List of land snail species occurring in Beni Saf, also indicating the amount of specimens recovered from each of the Gastropod Levels. Unidentifiable specimens (see Appendix) are indicate by an asterisk (*).
Liste des espèces d'escargots terrestres de Beni Saf. Le tableau indique également la quantité des spécimens récupérés de chacun des niveaux de gastéropodes. Les spécimens non identifiables (voir Annexe) sont signalés par un astérisque (*).

Species	Gastropod Level		
	1	2	3
Pomatiidae			
Tudorella sulcata (Draparnaud, 1805)	2	–	–
Leonia sp.	1	–	–
Achatinidae			
Rumina decollata (Linnaeus, 1758)	4	1	–
Rumina atlantica (Pallary, 1891)	6	–	–
**Rumina* sp.	75	3	–
Geomitridae			
Trochoidea trochoides (Poiret, 1789)	4	–	–
Xerosecta sp.	12	2	–
Cernuella sp.	13	4	–
**Xerosecta* sp. vel *Cernuella* sp.	100	2	–
Sphincterochilidae			
Sphincterochila sp.	–	2	–
Helicidae			
Massylaea massylaea (Morelet, 1851)	7	3	1
Massylaea vermiculata (O.F. Müller, 1774)	36	4	–
Otala sp. 1	32	3	–
Otala sp. 2	9	–	–
Eremina sp.	17	–	2
**Helicidae indet.*	16	5	–

been revised for a long time and the last geological map assigned them to the Pliocene-Quaternary (Geological map of Beni Saf; scale 1:50,000, published in 1995), while Guardia (1975) refer them to the lower Villafranchian. Therefore, the Pliocene assignment of Pallary (1891b) must be taken with caution, as other similar beds have later been deemed to belong to the Pleistocene (e.g., Pallary, 1901). Given all the above, a reasonable time span of Villafranchian can be assumed for the beds.

The marine Units A to C were assigned by Guardia (1975) to the second Pliocene cycle (*sensu* Guardia, 1975), while Unit D, studied herein, more likely belongs to the early Pleistocene.

3. Material and methods

The fossil gastropods collected in Beni Saf were deposited in the collections of the Abou Bakr Belkaid University of Tlemcen (UTl; Tlemcen, Algeria) and the Museum of New Zealand Te Papa Tongarewa (MNZ; Wellington, New Zealand). We also tried to locate the material from Beni Saf studied by Pallary (1901), but without success.

A systematic account of the fossils is presented below. The majority of the specimens consist of internal molds, but some have parts of the recrystallized shell remaining. In some cases, the material can be identified to species level with a reasonable degree of confidence, but some could only be classified to genus level (Table 1). Juvenile and fragmentary shells that could not be confidently assigned to any of the taxa herein are listed in the Appendix. All helicoid specimens with portions of shell remaining (even if recrystallized) were examined under ultraviolet light to check for color patterns, which could help with identification. However, no pattern could be unambiguously observed. The best preserved specimens of each species are illustrated herein (Figs. 3–5).

The synonymy provided herein includes only mentions of the fossil record. Furthermore, ranges of shell dimensions are provided for adult or sub-adult shells, but due to the poor preservation of the specimens, these values should be treated as best approximations. All measurements were taken with a digital caliper.

The following abbreviations are used throughout the text: Institutions: MNHN, Muséum national d'Histoire naturelle (Malacology collection), Paris, France; MNZ, Museum of New Zealand Te Papa Tongarewa (Malacology collection), Wellington, New Zealand; UTl, Abou Bakr Belkaid University of Tlemcen (Research Laboratory 25, Beni Saf collection), Tlemcen, Algeria. Shell dimensions: H, shell length (parallel to columellar axis); D, greatest shell width (perpendicular to H); W, number of whorls.

4. Systematic palaeontology

Caenogastropoda
Superfamily Littorinoidea
Family Pomatiidae
Genus ***Tudorella*** P. Fischer, 1885
Type species: *Cyclostoma ferruginea* Lamarck, 1822.

Tudorella sulcata (Draparnaud, 1805)
(Figs. 3A–C)
Cyclostoma sulcatum: Bourguignat, 1862: 93; Pallary, 1891a: 203; Pallary, 1891b: 386.
Cyclostoma (*Ericia*) *sulcatum*: Pallary, 1901: 161.

Occurrence in Beni Saf: Level 1.
Material analyzed: MNZ M.326502 (1 spm), UTl.lab25.-BS1-1 (1 spm).
Shell dimensions: H = 18.8–20.5 mm; D = 14.0–14.5 mm; W = 4–4½.
Remarks: The present specimens can be assigned to the genus *Tudorella* based on the conical and broad shell, the strongly convex whorls that rapidly increase in size, and the deeply marked suture. All available specimens are internal molds, so identification is tentative; nevertheless, the shell size and detached body whorl, as well as the scarce preserved teleoconch sculpture (Fig. 2B), compare very well to *T. sulcata* (Draparnaud, 1805). This species is known from present-day Algeria (in rocky habitats with open vegetation like pines or shrubs; Welter-Schultes, 2012) and from the Pliocene beds of Oran and Cap de Garde, Annaba (Pallary, 1891b, 1901).

Genus ***Leonia*** Gray, 1850
Type species: *Cyclostoma mammillaris* Lamarck, 1822.

***Leonia* sp.**
(Figs. 3D–E)
Occurrence in Beni Saf: Level 1.
Material analyzed: UTl.lab25.-BS1-2 (1 spm).
Shell dimensions: H = 22.7 mm; D = 10.9 mm; W = ~6.
Remarks: The shell of the present specimen displays a tall narrow and conical spire and convex whorls. The aperture is obstructed by sediment and partially broken; almost no vestige of the shell remains. Nevertheless, on the second whorl, part of the teleoconch sculpture seems to be preserved, albeit severely eroded. This sculpture consists of circa five strongly marked spiral cords; such cords are diagnostic of pomatiids among land snails.

The tall and narrow spire suggests an identification as *Leonia*. Species in this genus often have fainter teleoconch sculpture than other members of the family. However, they often retain a stronger sculpture pattern on their first whorls. It is not possible to offer a more precise identification, but the present specimen is akin to *Leonia mammillaris* (Lamarck, 1822), known from Algeria, Morocco and Spain, inhabiting calcareous substrates with scarce vegetation, either pines or shrubs (Welter-Schultes, 2012).

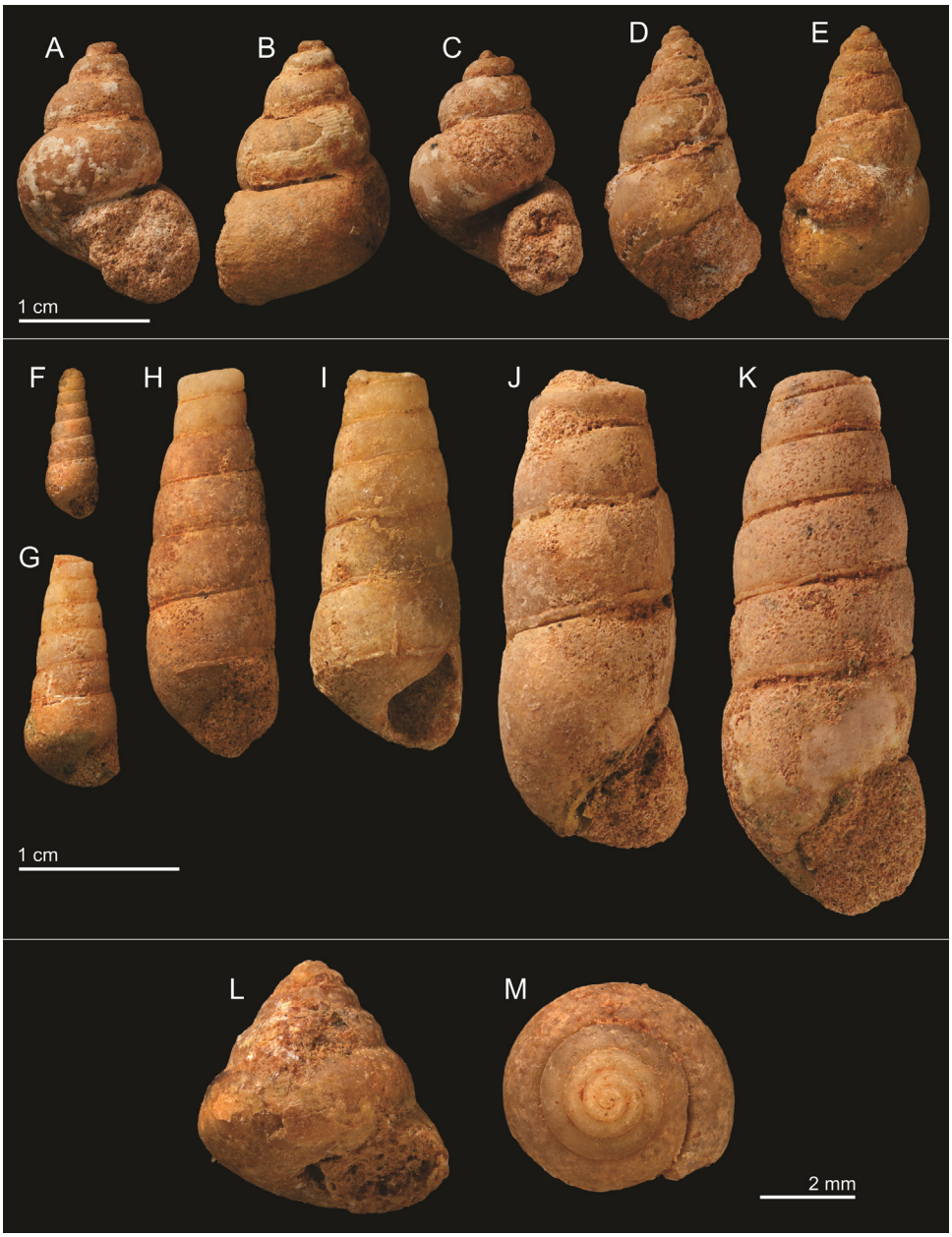

Fig. 3. A–B. *Tudorella sulcata* (MNZ M.326502). **C.** *Tudorella sulcata* (UTl.lab25.-BS1-1). **D–E.** *Leonia* sp. (UTl.lab25.-BS1-2). **F–I.** *Rumina* sp., four juveniles in different growth stages (MNZ M.326505). **J.** *Rumina decollata*, adult (MNZ M.326504). **K.** *Rumina atlantica*, adult (MNZ M.326503). **L–M.** *Trochoidea trochoides*, two specimens (MNZ M.326506). **A–B.** Tudorella sulcata *(MNZ M.326502).* **C.** Tudorella sulcata *(UTl.lab25.-BS1-1).* **D–E.** Leonia *sp. (UTl.lab25.-BS1-2).* **F–I.** Rumina *sp., quatre juvéniles dans différents stades de croissance (MNZ M.326505).* **J.** Rumina decollata, *adulte (MNZ M.326504).* **K.** Rumina atlantica, *adulte (MNZ M.326503).* **L–M.** Trochoidea trochoides, *deux spécimens (MNZ M.326506).*

The type species of the genus *Tudorella*, *T. ferruginea* (Lamarck, 1822), also presents a tall and narrow spire like the present specimen. However, this species is endemic to the Balearic Islands (Welter-Schultes, 2012).

Eupulmonata
Stylommatophora
Superfamily Achatinoidea
Family Achatinidae
Genus ***Rumina*** Risso, 1826
Type species: *Helix decollata* Linnaeus, 1758.
Remarks: This genus is easily identifiable by the elongated shell and decollate spire apex. There are clearly two forms present in Beni Saf, diagnosed by the conchological features observable in adult specimens. The juveniles (Figs. 3F–I; see also the Appendix) cannot be assigned confidently to any of the species.

Rumina decollata (Linnaeus, 1758)
(Fig. 3J)
Bulimus decollatus: Bourguignat, 1862: 70; Pallary, 1891b: 385.
Rumina decollata: Pallary, 1901: 141.
Rumina decollata decollata: Wenz, 1923: 875.
Rumina decollata: Jodot, 1958: 28, pl. 4, fig. 12.

Occurrence in Beni Saf: Levels 1 and 2.
Material analyzed: MNZ M.326504 (2 spm), UTl.lab25.-BS1-3 (2 spm), UTl.lab25.-BS2-1 (1 spm).
Shell dimensions: H = 28.0 mm; D = 11.1 mm; W = 5–5½ (Fig. 3J).
Remarks: The present specimens fall well within the conchological variation of Recent *R. decollata*. The diagnostic features include

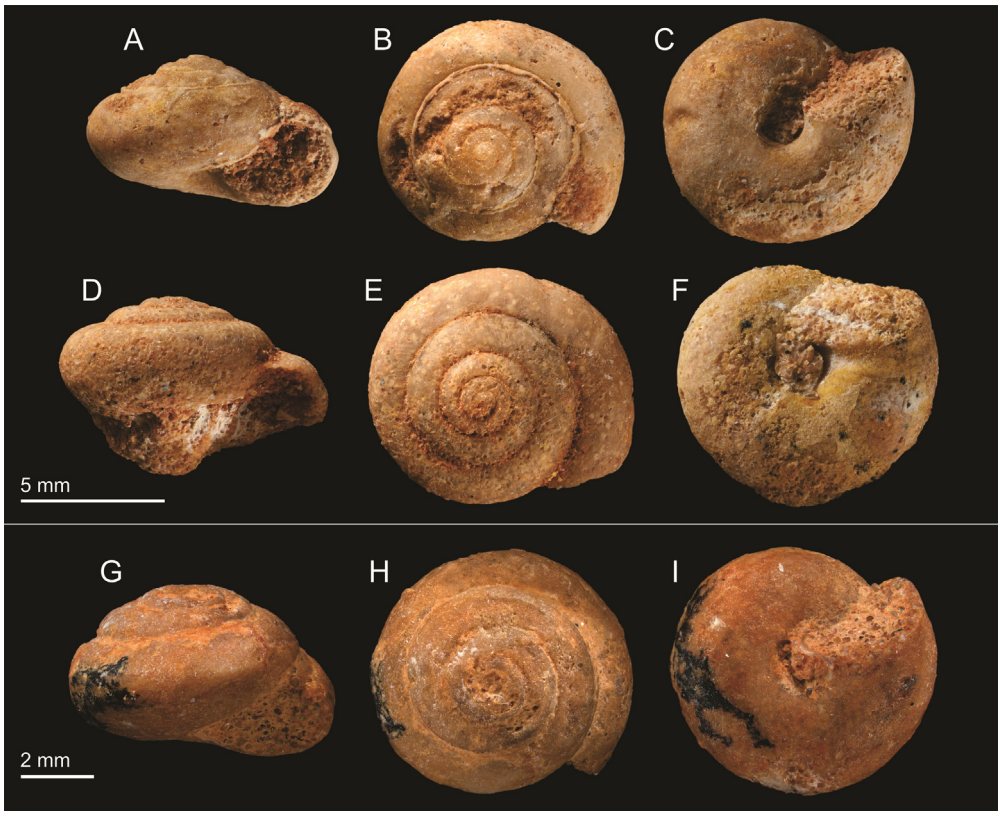

Fig. 4. A–C. *Xerosecta* sp. (MNZ M.326507). **D–E.** *Cernuella* sp. (MNZ M.326508a). **F.** *Cernuella* sp. (MNZ M.326508b). **G–I.** *Sphincterochila* sp. (MNZ M.326514).
A–C. Xerosecta *sp. (MNZ M.326507).* **D–E.** Cernuella *sp. (MNZ M.326508a).* **F.** Cernuella *sp. (MNZ M.326508b).* **G–I.** *Sphincterochila sp. (MNZ M.326514).*

the tall whorls (especially the body whorl, which accounts for roughly half the shell height), the low number of whorls in adult shells, the relatively broader shells, and wider aperture when compared to congeners. The species is known since the late Miocene of Algeria, while reports from the Miocene of Spain and the Oligocene of Algeria remain unconfirmed (Pallary, 1901; Cardona, 2017).

Rumina decollata is widely distributed through the Mediterranean region, including northern Africa (Welter-Schultes, 2012). In present-day Algeria, the species is recorded from a variety of habitats, but it is typically more abundant in drier areas (Douafer and Soltani, 2014), preferring grasslands and semideserts (Welter-Schultes, 2012). Nevertheless, the species is very tolerant and has been introduced to several places worldwide, inhabiting anthropically-modified areas.

Rumina atlantica (Pallary, 1891)
(Fig. 3K)
"Bulime qui est une bonne variété du *Decollatus* et qu'il décrit sous le nom d'*Atlantica*" Pallary, 1891a: 203 [nomen nudum].
Bulimus decollatus var. *atlantica* Pallary, 1891b: 386, text fig.
Rumina atlantica: Pallary, 1901: 142, pl. 1, figs. 29–30.
Rumina decollata paivae: Wenz, 1923: 876 [in part].

Occurrence in Beni Saf: Level 1.
Material analyzed: MNZ M.326503 (1 spm), UTl.lab25.-BS1-4 (5 spm).
Shell dimensions: H = 32.4 mm; D = 12.1 mm; W = 6½ (Fig. 3K).
Remarks: This species was originally described from the Pliocene of Oran, Algeria (type locality: "sandy cliffs bordering the small plateau of the Batterie Espagnole"; Pallary, 1891b, our translation) as a variety of *R. decollata*. It was later raised to species rank by Pallary (1901).

Wenz (1923) placed *R. atlantica* in synonymy of *R. paivae* (Lowe, 1861), a recent species described from Morocco. However, *R. paivae* is indistinguishable from *R. decollata* and was recently considered its synonym (Prévot et al., 2013). *Rumina atlantica* presents a clear set of conchological features that easily diagnoses it from *R. decollata*: it has a greater number of whorls, a broader shell, and shorter (in terms of height) whorls. As such, the species rank of *R. atlantica* is maintained here. Furthermore, *R. atlantica* can also be easily distinguished from the co-occurring congener *R. saharica* Pallary, 1901. The latter has a much smaller and slenderer cylindrical shell.

Superfamily Helicoidea
Family Geomitridae
Genus ***Trochoidea*** T. Brown, 1827
Type species: *Trochus terrestris* Pennant, 1777.

Trochoidea trochoides (Poiret, 1789)
(Figs. 3L–M)
Helix cfr. *trochoides*: Pallary, 1901: 39.

Occurrence in Beni Saf: Level 1.
Material analyzed: MNZ M.326506 (2 spm), UTl.lab25.-BS1-6 (2 spm).
Shell dimensions: H = 5.0–5.5 mm; D = 5.1–5.4 mm; W = ~5.
Remarks: *Trochoidea trochoides* can be diagnosed from its congeners by its smaller size (albeit with a larger number of whorls), taller and more conical spire, more quadrangular aperture, and narrower umbilicus. The species is presently distributed in the western Mediterranean area, including Algeria, typically in habitats with drier vegetation (Welter-Schultes, 2012). *Trochoidea trochoides* was reported from the Quaternary of Aïn-el Bey, Algeria (Pallary, 1901). A similar species, *T. pyramidata* (Draparnaud, 1805)

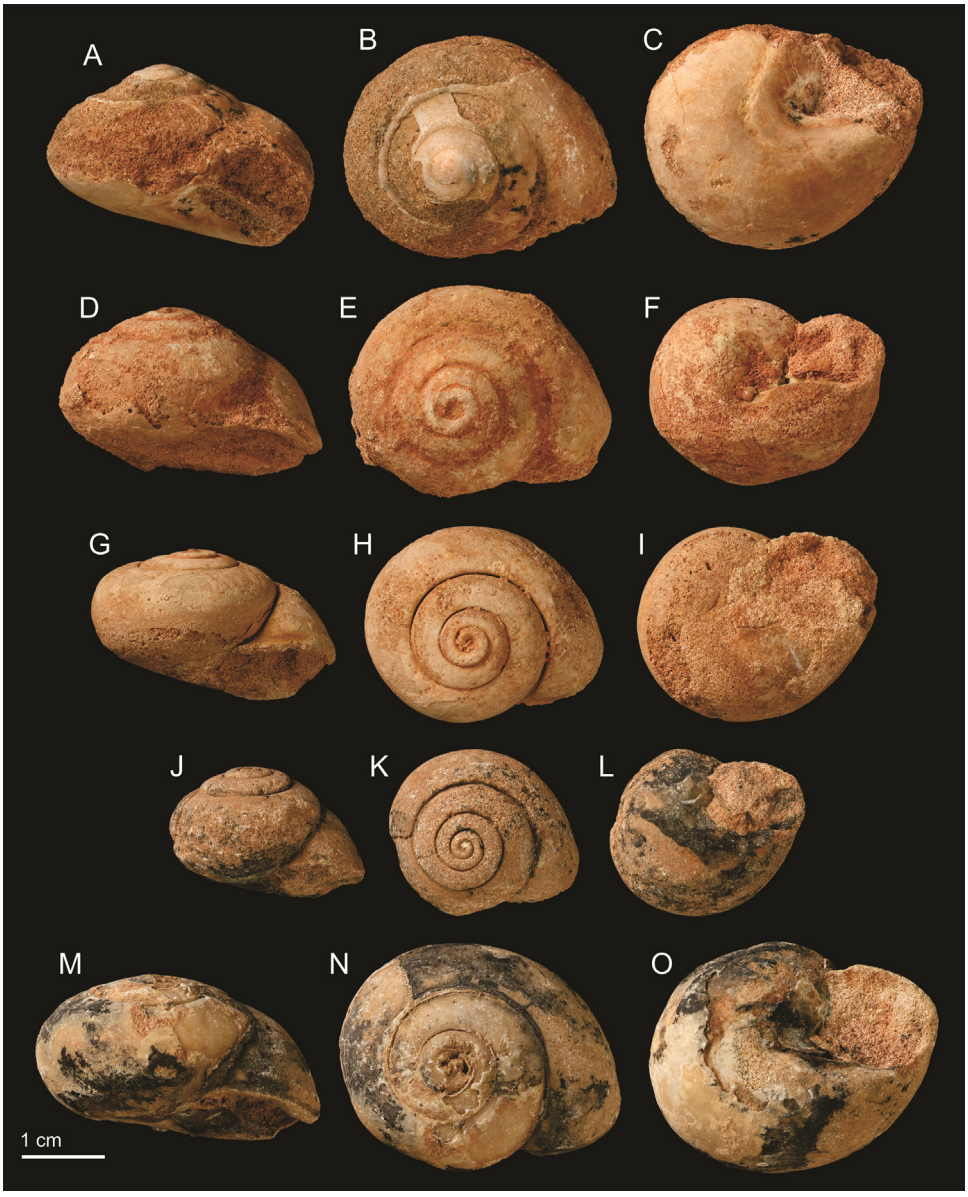

Fig. 5. A–C. *Massylaea massylaea* (MNZ M.326510). **D–E.** *Massylaea vermiculata* (MNZ M.326511a). **F.** *Massylaea vermiculata* (MNZ M.326511b). **G–I.** *Otala* sp. 1 (MNZ M.326512). **J–L.** *Otala* sp. 2 (MNZ M.326509). **M–O.** *Eremina* sp. (MNZ M.326513).
A–C. Massylaea massylaea *(MNZ M.326510).* **D–E.** Massylaea vermiculata *(MNZ M.326511a).* **F.** Massylaea vermiculata *(MNZ M.326511b).* **G–I.** Otala *sp. 1 (MNZ M.326512).* **J–L.** Otala *sp. 2 (MNZ M.326509).* **M–O.** Eremina *sp. (MNZ M.326513).*

was reported from Pliocene and Quaternary outcrops in Algeria, including Oran, which is geographically close to Beni Saf (Pallary, 1891b, 1901; Wenz, 1923).

Genus ***Xerosecta*** Monterosato, 1892
Type species: *Helix explanata* Müller, 1774.

***Xerosecta* sp.**
(Figs. 4A–C)
Occurrence in Beni Saf: Levels 1 and 2.
Material analyzed: MNZ M.3265067 (2 spm), UTl.lab25.-BS1-7 (10 spm), UTl.lab25.-BS2-5 (2 spm).
Shell dimensions: H = 6.4–7.4 mm; D = 10.5–11.5 mm; W = 4½–5.
Remarks: The genus *Xerosecta* includes forms with typically keeled shells to forms with smooth round whorls. The present specimens present a light keel-like angulation, but otherwise have a rounded body whorl. Other conchological characters agree with *Xerosecta*, such as shell size, the slowly-growing whorls (closely-packed together), the nearly flattened profile of the spire's whorls, the shallow suture, the presence of a seemingly uncovered umbilicus, and the small simple round aperture. The poor preservation precludes a more definitive identification, but the overall shell profile of the fossils is reminiscent of some present-day Iberian and Moroccan species, such as *X. adolfi* (Pfeiffer, 1854) and *X. albezini* (Pallary, 1933), typically found in dry open habitats (Welter-Schultes, 2012). Furthermore, *X. explanata* was reported from some Pliocene outcrops in Algeria, including Oran (Pallary, 1901).

Genus ***Cernuella*** Schlüter, 1838
Type species: *Helix variabilis* Draparnaud, 1801.

***Cernuella* sp.**
(Figs. 4D–F)
Occurrence in Beni Saf: Levels 1 and 2.
Material analyzed: MNZ M.326508 (2 spm), UTl.lab25.-BS1-8 (11 spm), UTl.lab25.-BS2-6 (4 spm).
Shell dimensions: H = ~6.5 mm; D = 10.5–11.0 mm; W = ~4½.
Remarks: These fossils can be identified by their more discoid shape, with rounder whorls, step-like spire, deeper suture, the larger and laterally-elongated aperture, and the positioning of the upper portion of the aperture lower on the body whorl. These are consistent with the genus *Cernuella*, species of which were reported from the Pliocene and Pleistocene of Algeria (Pallary, 1901). In particular, *C. virgata* (Da Costa, 1778) was reported from the Pliocene beds of Oran (Pallary, 1891b: as *Helix lauta*). Recent *Cernuella* spp. typically live in dry calcareous habitats and grasslands (Welter-Schultes, 2012).

Family Sphincterochilidae
Genus ***Sphincterochila*** Ancey, 1887
Type species: *Helix Boissieri* Charpentier, 1847.

***Sphincterochila* sp.**
(Figs. 4G–I)
Occurrence in Beni Saf: Level 2.
Material analyzed: MNZ M.326514 (1 spm), UTl.lab25.-BS2-7 (1 spm).
Shell dimensions: H = 5.5 mm; D = 7.5 mm; W = 4¼ (Figs. 4G–I).
Remarks: The compact conical shell, with an irregular whorl profile on the spire (in especial the penultimate whorl), and simple rounded aperture, are consistent with the genus *Sphincterochila*. Recent species of this genus are usually much larger, about twice the size of these fossils. However, the present specimens compare very well with one species, which is diagnosed by its small size and the lack of an umbilicus, namely *S. debeauxi* (Kobelt, 1881), known from present-day Morocco and Algeria (Pallary, 1901). The genus was reported from fossil outcrops in Algeria dating back to the Oligocene, and one Recent species, *S. candidissima* (Draparnaud, 1801), is known from the Pliocene (Pallary, 1901).

Family Helicidae
Remarks: Identification of the Helicidae based only on internal molds is tricky at best, so the names proposed below should be taken as a tentative first approach until better preserved specimens can be found. Nevertheless, there are some conchological features that, when taken together, are reasonable indicators of generic affiliation. These features include: size (at the same number of whorls); outline of the spire and its proportion to the remainder of the shell; shape of the body whorl; degree of "bending" of the final portion of the body whorl; aperture size and position. Based on these features, five distinct groups can be recognized within the fossils from Beni Saf.

Genus ***Massylaea*** Möllendorff, 1898
Type species: *Helix massylaea* Morelet, 1851.
Remarks: The well-known genus *Eobania* Hesse, 1913 has recently been considered synonymous with *Massylaea* (Bouaziz-Yahiatene et al., 2017).

Massylaea massylaea (Morelet, 1851)
(Figs. 5A–C)
Helix (*Macularia*) *Massylaea*: Pallary, 1901: 136.
Occurrence in Beni Saf: Levels 1, 2 and 3.
Material analyzed: MNZ M.326510 (2 spm), UTl.lab25.-BS1-11 (7 spm), UTl.lab25.-BS2-9 (3 spm), UTl.lab25.-BS3-1 (1 spm).
Shell dimensions: H = 18.5–22.0 mm; D = 28.0–33.5 mm; W = 4.
Remarks: This species can be identified by its broad conical spire, the even broader body whorl, and the comparatively small and somewhat quadrangular aperture, which is strongly bent abapically. The best preserved fossil specimen retained part of its shell (Figs. 5A–C), comparing extremely well with the syntype of *M. massylaea* (MNHN-IM-2000-32831). The species currently inhabits northern Algeria (Bouaziz-Yahiatene et al., 2017), but it is not reported for the northwestern portion of the country where Beni Saf is located. This could either represent a lack of sampling in the region at present or indicate that the species had a broader distribution in the past. Fossils of this species have been reported from Quaternary outcrops near Constantine, Algeria (Pallary, 1901).

Massylaea vermiculata (O.F. Müller, 1774)
(Figs. 5D–F)
Helix vermiculata: Bourguignat, 1862: 50.
Helix (*Macularia*) *vermiculata*: Pallary, 1901: 135.
Occurrence in Beni Saf: Levels 1 and 2.
Material analyzed: MNZ M.326511 (2 spm), UTl.lab25.-BS1-12 (34 spm), UTl.lab25.-BS2-10 (4 spm).
Shell dimensions: H = 20.0–23.0 mm; D = 29.5–31.5 mm; W = 4–4½.
Remarks: A second species of *Massylaea* can be identified in the present material by the usually smaller size (with 4–4½ whorls), a more compact shell outline, with a higher and more rounded body whorl and proportionately shorter spire. These features compare well with the widespread species *M. vermiculata*, which is presently distributed along the whole Mediterranean region. The species, however, is unknown from western Algeria and Morocco (Welter-Schultes, 2012; Bouaziz-Yahiatene et al., 2017), but it has been reported from the Pliocene of Oran (Bourguignat, 1862; Pallary, 1901). As for *M. massylaea* above, this could indicate a broader past distribution. Presently, *M. vermiculata* inhabits a wide variety of habitats, but it is more typically found in drier vegetation (Welter-Schultes, 2012). Until very recently, this species was classified in the genus *Eobania*.

Genus ***Otala*** Schumacher, 1817
Type species: *Helix lactea* Müller, 1774.

***Otala* sp. 1**
(Figs. 5G–I)
Occurrence in Beni Saf: Levels 1 and 2.
Material analyzed: MNZ M.326512 (2 spm), UTl.lab25.-BS1-14 (30 spm), UTl.lab25.-BS2-11 (3 spm).
Shell dimensions: H = 19.0–21.0 mm; D = 27.5–31.0 mm; W = 4–4½.
Remarks: This species can be identified by its large shell, flattened spire, quickly expanding whorls (especially the final section of the body whorl), rounded but somewhat flattened body whorl, and relatively large aperture. These features are very reminiscent of *O. punctata* (O.F. Müller, 1774), which occurs in present-day Algeria, Morocco and Spain (and introduced elsewhere) in dry rocky substrates (Welter-Schultes, 2012; Holyoak and Holyoak, 2017).

***Otala* sp. 2**
(Figs. 5J–L)
Occurrence in Beni Saf: Level 1.

Material analyzed: MNZ M.326509 (2 spm), UTl.lab25.-BS1-13 (7 spm).

Remarks: This species can be diagnosed from the other helicid fossils of Beni Saf by its much smaller size. The globose shell profile and the small aperture, strongly bent ventrally, are consistent with the species formerly classified as *Dupotetia* Kobelt, 1904, which was recently placed in synonymy of *Otala* by Holyoak and Holyoak (2017). The present specimens bear similarities with some species previously reported as fossils from Algeria.

Pallary (1891a) listed *O. xanthodon* (Anton, 1838) (as *Helix dupotetiana* Terver, 1939) from the Pliocene outcrops of Oran. Furthermore, the present specimens could belong to one of the species described by Crosse (1861, 1862: as *Helix*) from (likely) late Tertiary beds near Constantine, NE Algeria: *O. jobaeana* (Crosse, 1861) and *O. dumortieriana* (Crosse, 1862). These species have been considered allied to *O. xanthodon* by Holyoak and Holyoak (2017).

Genus ***Eremina*** Pfeiffer, 1855

Type species: *Helix desertorum* Forskål, 1775.

***Eremina* sp.**

(Figs. 5M–O)

Occurrence in Beni Saf: Levels 1 and 3.

Material analyzed: MNZ M.326513 (2 spm), UTl.lab25.-BS1-15 (15 spm), UTl.lab25.-BS3-2 (2 spm).

Shell dimensions: H = 21.0–30.0 mm; D = 32.5–40.0 mm; W = 4–4¾.

Remarks: These fossils are distinguished by their large size, depressed spire, quickly expanding whorls, rounded body whorl, and large aperture. The genus is widespread in northern Africa, inhabiting rocky arid areas (some species, like *E. desertorum*, even thrive in desert sand; Heller, 1984; Arad, 1993).

5. Concluding remarks

In total, 13 species of terrestrial gastropods are reported here from the Pleistocene deposits (Unit D) at Beni Saf. Given this age, most of the specimens can be assigned to extant species; the single exception is *Rumina atlantica*, which is only known as fossils from Oran. In fact, *R. atlantica* might still prove to be a reasonable index fossil for the Pliocene-Pleistocene beds of Algeria. However, the dating of the Oran beds is in need of revision and the occurrence (or absence) of *R. atlantica* in outcrops other than Oran and Beni Saf should be carefully ascertained and their age re-determined.

Given the sedimentological and paleontological features of Unit D, we conclude that the depositional setting at Beni Saf was a dune system (due to the mega-rippled sands; subunit D2) flanked by laterally continuous wadi floodplains deposits (snail levels of subunits D1 and D3). This later paleoenvironment is documented by the red-colored fine-grained sediments (soft hematite-rich sandstone), the frequency of pedotubules, and by the gastropod content. The gastropods would be of allochthonous origin, having been brought into the depositional setting by flood events. As discussed above, these species typically inhabit preferentially dry environments, as grasslands and/or rocky substrates. The representatives of *Sphincterochilus* and *Eremina*, in particular, might indicate the presence of a more arid environment. The Gastropod Levels 1 and 2 (subunits D1 and D3) are very similar in species composition (Table 1); the only significant difference is the presence of rare specimens of pomatiids on level 1. Pomatiids could be indicative of a more forested area (of pines or shrubs) somewhere in the vicinities. Gastropod Level 3 (subunit D3) is almost free of gastropods (Table 1).

Disclosure of interest

The authors declare that they have no competing interest.

Acknowledgements

We are very grateful to Jean-Claude Stahl (MNZ) for the photos used in the present work; and to an anonymous reviewer, whose comments and suggestions greatly improved the quality of this work. RBS acknowledges the bequest of Bruce Fraser Hazelwood and the MNZ.

Appendix A. Appendix A

Below are listed the juvenile and fragmentary shells that could not be confidently assigned to any of the taxa herein. In all likelihood, they should represent one of the taxa already identified in the main text rather than distinct species. These are: ***Rumina* sp.:** MNZ M.326505 (5 spm, Level 1), UTl.lab25.-BS1-5 (70 spm, Level 1), UTl.lab25.-BS2-2 (3 spm, Level 2). ***Xerosecta* sp. vel *Cernuella* sp.:** UTl.lab25.-BS1-9 (~100 spm, Level 1), UTl.lab25.-BS2-4 (2 spm, Level 2). **Helicidae indet.:** UTl.lab25.-BS1-10 (16 spm, Level 1), UTl.lab25.-BS2-8 (5 spm, Level 2).

Furthermore, two ichnofossils were found (UTl.lab25.-BS2-3: Level 2; 2 spm) that are typically referred to in the paleontological literature as "*Palaeoglandina* eggs" (e.g., Wenz, 1923; Müller, 1972). These structures are circa 1.5 cm in their greatest length and indeed resemble eggs in shape. *Palaeoglandina* spp. are large-sized fossil representatives of the carnivorous gastropod family Spiraxidae. The large size of the supposed eggs in comparison to the adult shell, however, is not consistent with Spiraxidae biology (e.g., Tompa, 1984).

These structures have also been variously described as internal molds of other eggs (birds, snakes and other snail families, such as Strophocheilidae), ichnofissils of arthropods or annelids (e.g., burrows, brood chambers, cocoons), cyanobacteria colonies, and even considered inorganic in origin (e.g., Witte, 1859; Edwards et al., 1998; Ott et al., 2009). The "eggs" described in the literature typically stem from lacustrine carbonates, and it is unlikely that each instance of these ichnofossils has the same origin. In any event, one thing is certain: given what is presently known about the gastropod species of Beni Saf (faunal composition, adult size, and the reproductive biology of living representatives), these ichnofossils do not represent snail eggs.

References

Arad, Z., 1993. Water relations and resistance to desiccation in three Israeli desert snails, *Eremina desertorum*, *Euchondrus desertorum* and *Euchondrus albulus*. Journal of Arid Environments 24, 387–395.

Bouaziz-Yahiatene, H., Pfarrer, B., Medjdoub-Bensaad, F., Neubert, E., 2017. Revision of *Massylaea* Möllendorff, 1898 (Stylommatophora, Helicidae). ZooKeys 694, 109–133.

Bourguignat, M.J.R., 1862. Paléontologie des Mollusques Terrestres et Fluviatiles de l'Algérie. Chez Baillière et Fils, Paris, 126 p.

Cardona, J.Q., 2017. Descripción de *Rumina iamonae* sp. nov. (Pulmonata: Subulinidae), un nuevo gasterópodo endémico de Menorca (Islas Baleares, Mediterráneo Occidental). Spira 6, 129–135.

Crosse, H., 1861. Diagnoses d'helicéens fossiles des environs de Constantine (Algérie). Journal de Conchyliologie 9, 356–357.

Crosse, H., 1862. Description de mollusques terrestres du gisement de Coudiat-Aty et d'Aïn-el-Hadj-Baba, suivie de considérations sur les caractères de cette faune. Journal de Conchyliologie 10, 152–172.

Dalloni, M., 1915. Le Miocène supérieur dans l'Ouest de l'Algérie ; couches à hipparion de la Tafna. Compte Rendu de l'Académie des Sciences de Paris 16, 639–641.

Douafer, L., Soltani, N., 2014. Inventory of land snails in some sites in the northeast Algeria: correlation with soil characteristics. Advances in Environmental Biology 8 (1), 236–243.

Edwards, N., Jarzembowski, E.A., Paint, T., Daley, B., 1998. Cocoon-like trace fossils from the lacustrine-palustrine Bembridge Limestone Formation (Late Eocene), Southern England. Proceedings of the Geologists' Association 109, 25–32.

Esu, D., 1999. Contribution to the knowledge of Neogene climatic changes in western and central Europe by means of non-marine molluscs. In: Agustí, J., Rook, L., Andrews, P. (Eds.), Hominid Evolution and Climatic Change in Europe, Vol. 1. The Evolution of Neogene Terrestrial Ecosystems in Europe. Cambridge University Press, Cambridge, pp. 328–354.

Gentil, L., 1903. Etude géologique du Bassin de la Tafna. Bulletin du Service de la Carte Géologique d'Algérie 4, 1–442.

Goodfriend, G.A., 1992. The use of land snail shells in paleoenvironmental reconstruction. Quaternary Science Reviews 11, 665–685.

Guardia, P., 1975. Géodynamique de la marge alpine du continent africain d'après l'étude de l'Oranie nord-occidentale. Relations structurales et paléogéographiques entre le Rif externe, le Tell et l'avant-pays atlasique, Thèse Université de Nice, 286 p. [unpublished].

Heller, J., 1984. Desert as refugia for relict land snails. In: Solem, A., van Bruggen, A.C. (Eds.), World-Wide Snails: Biogeographical Studies on Non-Marine Mollusca. E.J. Brill, Leiden, pp. 107–123.

Höltke, O., Salvador, R.B., Rasser, M.W., submitted. Biogeographic relationships of the land snail communities of the Middle Miocene *silvana*-beds of Germany.

Holyoak, D.T., Holyoak, G.A., 2017. A revision of the land-snail genera *Otala* and *Eobania* (Gastropoda, Helicidae) in Morocco and Algeria. Journal of Conchology 42 (6), 419–490.

Jodot, P., 1958. Les faunes des mollusques continentaux réparties dans le sud-est de l'Espagne entre le Miocène supérieur et le Quaternaire. Memorias y Communicaciones del Instituto Geológico 17, 3–133.

Louni-Hacini, A., 2002. La Transition du magmatisme calco-alcalin ou magmatisme alcalin dans l'oranie (Algérie nord occidentale), Thèse Université des Sciences et de la Technologie Houari-Boumediene, Bab Ezzouar, 200 p. [unpublished].

Megartsi, M., 1985. Le volcanisme Moi-Plio-Quaternaire de l'Oranie Nord occidentale : Géologie, Pétrologie, Géodynamique, Thèse Université des Sciences et de la Technologie Houari-Boumediene, Bab Ezzouar, 296 p. [unpublished].

Moine, O., Rousseau, D.D., Jolly, D., Vianey-Liaud, M., 2002. Paleoclimatic reconstruction using mutual climatic range on terrestrial mollusks. Quaternary Research 57, 162–172.

Müller, E.D., 1972. Die Oligozän-Ablagerungen im Gebiet des Nördlinger Rieses, PhD thesis Ludwig-Maximilians-Universität München, 230 p. [unpublished].

Neurdin-Trescartes, J., 1992. Le remplissage sédimentaire du bassin néogène du Chélif, modèle de référence de bassins intramontagneux, Thèse Université de Pau, 605 p. [unpublished].

Ott, W., Kadolsky, D., Wiesner, E., 2009. Von einer Lagune zum "trockenen Kalkhügel": Geologischer Untergrund und Fossilien des Lohwaldes bei Offenbach am Main. Abhandlung des Offenbacher Vereins für Naturkunde 10, 113–213.

Pallary, P., 1891a. Les faunes malacologiques Pliocène et Quaternaire des environs d'Oran. Compte Rendu de l'Association Française pour l'Avancement des Sciences 20 (1), 202–203.

Pallary, P., 1891b. Les faunes malacologiques Pliocène et Quaternaire des environs d'Oran. Compte Rendu de l'Association Française pour l'Avancement des Sciences 20 (2), 383–387.

Pallary, P., 1901. Sur les mollusques fossiles terrestres, fluviatiles et saumâtres de l'Algérie. Mémoires de la Société Géologique de France, Paléontologie 22, 1–213.

Perrodon, A., 1957. Etude géologique des bassins néogènes sublittoraux de l'Algérie occidentale. Bulletin du Service de la Carte Géologique d'Algérie 12, 1–328.

Prévot, V., Jordaens, K., Sonet, G., Backeljau, T., 2013. Exploring species level taxonomy and species delimitation methods in the facultatively self-fertilizing land snail genus *Rumina* (Gastropoda: Pulmonata). PLoS ONE 8 (4), e60736.

Sadran, G., 1958. Les formations volcaniques tertiaires et quaternaires du Tell Oranais. Publication du Service de la Carte géologique de l'Algérie 18, 1–533.

Tompa, A.S., 1984. Land snails (Stylommatophora). In: Tompa, A.S., Verdonk, N.H., van den Biggelaar, J.A.M. (Eds.), The Mollusca, Vol. 7. Reproduction. Academic Press, Orlando, pp. 48–141.

Welter-Schultes, F., 2012. European Non-marine Molluscs, a Guide for Species Identification. Planet Poster Editions, Gottingen, 760 p.

Wenz, W., 1923. 1923–1930. Gastropoda extramarina tertiaria. In: Diener, C. (Ed.), Fossilium Catalogus, I, Animalia, vols. 17, 18, 20, 21, 22, 23, 32, 39, 40, 43, 46. W. Junk, Berlin, pp. 1–3387.

Witte, F.E., 1859. Über fossile Eier. Neues Jahrbuch für Mineralogie, Geognosie. Geologie und Petrefaktenkunde 1859, 863–864.