A new *Janulus* species (Gastropoda, Pulmonata, Gastrodontidae) from the Zanclean (early Pliocene) of Tuscany (central Italy)

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**INTRODUCTION**

The genus *Janulus* Lowe, 1852 is regarded as a European palaeoendemite of the Tertiary warm climatic phases, associated with moist forest biotopes (Esu, 1999). It survives in the Macaronesian refuges (Walden, 1983, 1984; Cameron et al., 2002) and includes only three Recent species: *J. bifrons* (Lowe, 1831) and *J. stephanophorus* (Deshayes, 1850) from Madeira and the probably recently extinct *J. pomplius* (Shuttleworth, 1852) from La Palma, Canary Islands (Riedel, 1980; Fontaine et al., 2007). Another Madeiran species, *J. calathoides* (Lowe, 1863), tentatively added by Riedel (1998), is actually a species of *Discus* Fitzinger, 1833 (Bank et al., 2002). However, there is no definitive evidence that the three species really belong to the same genus, because only one of them (*J. bifrons*) is known anatomically. *Janulus* has a holopod foot and distal genitalia with a penial dart-sac and an accessory duct connecting penis and free oviduct (Pilsbry, 1947). Holopod snails with apertural palatal teeth, a penial dart-sac and an accessory duct connecting penis and free oviduct (Pilsbry, 1946; Riedel, 1980; Gittenberger et al., 1984). Consequently the monophyly of the family, as currently conceived, is not certain, like the number of genera/subgenera it includes (see different accounts by Hausdorf, 1998; Riedel, 1998; Schileyko, 2003; Slapcinsky & Cole, 2004).

Recent *Janulus* species have a discoidal to trochiform shell, angled or shouldered at periphery, with small umbilicus, narrow ribbing on dorsal surface of teleoconch whorls and peristome simple and not reflexed. One species (*J. bifrons*) is larger, with less tightly coiled and less narrowly ribbed whorls and peristome internally thickened (it strongly recalls the shells of hygromiids such as *Trockulus* Chemnitz, 1786, *Monachoides* Gude & Woodward, 1921, etc.). Finally, at least one species (*J. stephanophorus*) has radial rows of palatal teeth at 120 degrees to each other, each row consisting of three-four teeth: one adaxial, very small and knob-like, one medial, short and pleat-like and one abaxial, larger and inverted comma-like or sometimes V-like, split into a longer outer branch and a shorter inner branch (Pl. 1, fig. 9).

Although the fossil record is much poorer than it was formerly thought (see for example Wenz, 1923), sure reports spanning from the Oligocene (e.g. *Janulus schottleri* Wenz, 1922) to the end of the Pliocene and ecology of Recent species (Seddon, 2008) are in line with lacking. Moreover, this duct may not be homologous: it is absent in *Pilsbryna* and connects penial dart-sac and duct of bursa copulatrix in *Gastrodonta*, penis and free oviduct in *Janulus*, and penis and duct of bursa copulatrix in all the others (however, in *Zonitoides*, a second accessory duct joins duct of bursa copulatrix and free oviduct according to Pilsbry, 1946; Riedel, 1980; Gittenberger et al., 1984). Consequently the monophyly of the family, as currently conceived, is not certain, like the number of genera/subgenera it includes (see different accounts by Hausdorf, 1998; Riedel, 1998; Schileyko, 2003; Slapcinsky & Cole, 2004).

**KEY WORDS** - Gastropods, Pliocene, Zanclean, Tuscany, Janulus spadinii n. sp.
the palaeoecological meaning attributed to the genus in the literature.

In this paper we describe a new *Janulus* species from the Zanclean of Balze di Caspreno (Tuscany), already reported as *Janulus suttonensis* (Wood, 1872) by De Stefani (1880). We also shortly survey all the nominal taxa of the species-group assigned to this genus, many of which may belong to other groups of land snails.

**GEOLOGICAL SETTING**

The Siena Basin is a post-collisional basin of the inner Northern Apennines, a collisional belt formed during the Cenozoic in response to the interaction between the Adria and the Corso-Sardinian microplates (Carmignani et al., 2001). It corresponds to approximately the middle part of an elongated depression (Fig. 1a) extending for about 200 km in a NNW-SSE direction. The tectonic setting responsible for the origin and evolution of this basin is still debated, and has been explained in different ways: according to many authors (Costantini et al., 1982; Martini & Sagri, 1993; Pascucci et al., 1999; Carmignani et al., 2001; Brogi, 2011) its origin is connected with an extensional regime acting until the late Miocene, while other researchers postulate a dominantly compressional tectonic setting (Boccaletti & Sani, 1998; Finetti et al., 2001; Bonini & Sani, 2002).

Regardless of its structural origin, the Siena Basin was interested by a continental and marine deposition during the Neogene, and to limited and discontinuous sedimentation of alluvial deposits (Aldinucci et al., 2007) and travertine (Brogi et al., 2010) during the Quaternary. Its Neogene basin-fill history dates back to the latest...
Miocene (Messinian) with the deposition of a thick fluvio-lacustrine succession that unconformably overlies pre-Neogene bedrock. Most of these Miocene deposits are buried beneath Pliocene sediments and crop out in limited western marginal areas of the basin (Lazzarotto & Sandrelli, 1977; Bossio et al., 2000). Marine conditions in the Siena Basin began at the base of the Zanclean (Costantini et al., 1982; Bossio et al., 1993), with the deposition of a thick sedimentary succession, ranging from nearshore (sands and conglomerates) to offshore (mud) environments (Costantini et al., 1982; Manganelli et al., 2010; Martini et al., 2011). Marine sedimentation persisted until the late Piacenzian, when uplifting of southern Tuscany caused emergence of the Siena Basin (Costantini et al., 1982; Bossio et al., 1993). Local episodes of continental sedimentation have been reported within the marine deposits in the southwestern sector of the basin (Bossio et al., 1992, 1993).

*Janulus* material was collected along the Arbia River (Montaperti-Pianella area, northern sector of the Siena Basin), where continental deposits crop out discontinuously in small scattered outcrops (Fig. 1b), most of which are now covered by recent alluvial deposits, vegetation or rubble from quarries. The best exposures of continental deposits crop out in natural cliffs on the left bank of the Arbia river (the “Balze di Caspreno”, fossiliferous sites 5 and 6 in Fig. 1b). According to Martini et al. (2011) these sediments are indicative of a generic fluviatile setting, with dominantly clayey floodplain silts (locally containing peat horizons) and fine sands, with subordinate lens-shaped bodies of fluvial gravelly sand. The age of these deposits has long been debated: De Stefani (1880), who first described this fossiliferous site, attributed these deposits to the lower part of the Pliocene, on the basis of lithological and palaeontological similarities with analogous sediments exposed close to Siena, where they are interbedded with certainly Pliocene marine strata (De Stefani, 1876). De Stefani (1880), and later De Castro & Pilotti (1933), also described fossil remains of brackish gastropods in these muddy sediments, implying connection with a nearby marine area. Since marine conditions in the Siena Basin started in the earliest Pliocene, De Stefani (1880) and De Castro & Pilotti (1933) took this fact as an indirect evidence of the Pliocene age of these deposits. The deposits of the Balze di Caspreno area were later attributed to a generic Neogene (Signorini, 1966, 1967) and recently assigned to the Messinian (Lazzarotto et al., in press), due to strong lithological similarities with the “Argille del Casino” Fm. cropping out in the nearby Casino Basin (Lazzarotto & Sandrelli, 1977). Partially in contrast with this attribution, Manganelli et al. (2007) reported some continental molluscs (*Strobilops* cf. *romani* Wenz, 1915 and *Eostrobilops aloisii* Manganelli, Delle Cave & Giusti, 1989), which in Europe have been recorded only from the Zanclean.

Finally, Martini et al. (2011) reported the discovery of cobbles showing evidence of bio-erosion (e.g. borings) in gravelly fluvial facies, indicating provenance from recycled marine nearshore gravels. According to the geological history of the Siena Basin (Costantini et al., 1982; Lazzarotto et al., in press) these cobbles could only be derived from unknown Pliocene deposits or at least from the Serravallian Ponsano Sandstone Fm. exposed in the northern Casino Basin (Bossio et al., 1998). However, micropalaeontological analysis carried out in fine floodplain sediments (Bambini, pers. comm.) shows a lack of recycled Serravallian calcareous nannofossils, while bedrock-derived nannofossils are common. These findings suggest that the deposits date back to the Pliocene. According to Martini et al. (2011), integrated palaeontological and stratigraphical analysis of the continental and marine succession exposed in the surrounding area also enables assignment of these deposits to the MPI3 Zone of planktonic foraminifera zonation (zonal scheme of Foresi et al., 2001).

**SYSTEMATIC PALAEONTOLOGY**

*Janulus spadini* n. sp.

(Pl. 1, figs 2-7)

*Diagnosis* - A species of gastroodontid *Janulus* with shell very similar to that of Recent Madeiran *Janulus stephanophorus* by virtue of its shape, dorsal sculpture and radial rows of palatal teeth (three internal radial rows of teeth at 120 degrees to each other; each row consisting of three teeth, the more external of which larger and inverted comma-like), but differing by virtue of its lesser size and the more depressed shell.

*Description* - Shell (Pl. 1, figs 2-7) dextral, very small in size, lenticular in shape, with about six, very narrow and tightly coiled whorls, separated by deep sutures; last whorl angled at periphery; umbilicus small, narrow and cylindrical; aperture semilunar, with light parietal callus and peristome not thickened or reflexed; protoconch sculpture unknown; teleoconch with many strong, regular, slightly prosocline ribs, stopping just below periphery (in one specimen: 54 ribs in first teleoconch whorl, 61 in second, 63 in third, Pl. 1, fig. 2); internally, three radial rows of palatal teeth at 120 degrees to each other; each row consisting of three teeth: one adaxial, very small and knob-like, one medial, small and knob-like and one abaxial, larger and inverted comma-like.

*Dimensions* - The largest specimen, an incomplete shell, is 4.2 mm wide. The holotype, a juvenile shell, is 1.4 mm high and 2.8 mm wide.

*Type locality and horizon* - Balze di Casapreno, along Arbia River (Montaperti-Pianella area, east of Siena), lacustrine grey clays of Zanclean age (MPI3 Zone of planktonic foraminifera zonation of Foresi et al., 2001). For collecting sites, see Fig. 1.

*Type material* - Holotype (Pl. 1, fig. 2), a juvenile shell from site 4 (Manganelli collection, Dipartimento di Scienze Ambientali, University of Siena, no. 39588); about 60 paratypes consisting of 110 shell fragments (corresponding to at least 55 specimens) from Site 2 (Manganelli collection, Dipartimento di Scienze Ambientali, University of Siena, no. 39587); 3 shells from Site 4 (Manganelli collection, Dipartimento di Scienze Ambientali, University of Siena, no. 39589); 7 shell fragments (corresponding to at least 5 specimens) from
Site 6 (Manganelli collection, Dipartimento di Scienze Ambientali, University of Siena, no. 39590).

**Derivation of name** - The new species is named after our dear friend Valeriano Spadini from Lucignano (Arezzo), passionate naturalist and scholar of fossil corals and molluscs.

**Remarks** - Shell features of the species from the Zanclean of Balze di Caspreno are sufficient to establish that it really belongs to *Janulus*: it is very similar to the Recent *J. stephanophorus* (the type species of the genus) with which it shares shape, dorsal sculpture and radial rows of palatal teeth.

In *Fossilium Catalogus*, Wenz (1923, pp. 300-306) listed 12 *Janulus* species, one of which - *Janulus striatus* (Eichwald, 1830) - only tentatively assigned to this genus. Subsequently, Schlickum (1979), Schlickum & Geissert (1980), Yü & Zhang (1982) and Harzhauser & Binder (2004) described four other putative *Janulus* species (see Appendix 1). Unfortunately information about most of them, especially on the presence and structure of the internal radial rows of palatal teeth, is scarce or absent and this prevents sure generic assignment. Only the late Miocene *J. gottschicki* (Jooss, 1912) and *J. schottleri* Wenz, 1922 are known to have palatal teeth but information on the former is inadequate (see Jooss, 1912). On the contrary the pattern of palatal teeth of *J. schottleri* is consistent with that of the Recent *J. stephanophorus* and consequently its inclusion in *Janulus* is well supported. Some other species may belong to *Janulus* on the basis of their shell shape and dorsal sculpture, but we lack information about radial rows of palatal teeth. They are: *J. angustiumbilicus* (Sacco, 1886, sensu Ferrero Mortara et al., 1994), *J. austriacus* Harzhauser & Binder, 2004, *J. olisipponensis* (Roman, 1907) and *J. suttonensis* (Wood, 1872). On the contrary nothing sure can be said about all the other species, most of which may belong to completely different genera. For example, according to Lueger (1981), *J. joossi* Schlickum, 1970 is a species of *Discus* (Discidae), namely *Discus pleuradras* (Bourgignat, 1881).

Among fossil species which belong or may belong to this genus, Caspreno *Janulus* matches the alleged syntype of *Patula angustiumbilicata* illustrated by Ferrero Mortara et al. (1984: Pl. 54, figs 1a-b), *Janulus austriacus* Harzhauser & Binder, 2004 (Pl. 7, figs 12-15) from the late Miocene of Lower Austria, *Helix suttonensis* Wood, 1872 (Pl. 1, figs 2a-c) from the Pliocene of England and *Patula olisipponensis* Roman, 1907 (fig. 8) from the Neogene of Portugal. Unfortunately, at the present state of the art, no well supported distinction can be proposed until more detailed descriptions of these taxa become available. As far as we know, it differs from *Janulus suttonensis*, of which we examined a detailed drawing of the holotype by Gordon Riley, kindly made available by Richard Preece, and from *Janulus austriacus* by virtue of its lenticular shape (trochiform shape in *Janulus suttonensis*; discoidal shape in *Janulus austriacus*). It is very similar to the shells of “*Janulus* angustiumbilicus” published by Ferrero Mortara et al. (1984), but they are different from Sacco’s description and figures of this taxon (see Appendix). Finally it differs from *Janulus olisipponensis*, on the basis of Roman’s (1907) figure only, by virtue of its lenticular shape and slightly prosocline ribs (discoidal shape and markedly prosocline ribs in *Janulus olisipponensis*).

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**EXPLANATION OF PLATE 1**

Fig. 1 - *Janulus stephanophorus* (Deshayes, 1850). SEM apical view of a shell from Ilha da Madeira: Ribeira da Porto Novo, A.H. Walden leg. 11.11.1972 (Götterborgs Naturhistoriska Museum 72-13.386); scale bar: 2 mm.

Figs 2-7 - *Janulus spadini* n. sp. from Balze di Caspreno.

2 - Holotype (a juvenile shell) from Site 4 (Manganelli collection, Dipartimento di Scienze Ambientali, University of Siena, no. 39588); SEM apical (a) and apertural (b) views; scale bar: 2 mm.

3 - A juvenile shell from Site 4 (Manganelli collection, Dipartimento di Scienze Ambientali, University of Siena, no. 39589); SEM apical view; scale bar: 2 mm.

4-7 - Shell fragments from Site 2 (Manganelli collection, Dipartimento di Scienze Ambientali, University of Siena, no. 39590); SEM views of palatum illustrating the internal radial rows of palatal teeth; scale bar: 2 mm.

Fig. 8 - *Janulus bifrons* (Lowe, 1831): apical (a), apertural (b) and umbilical (c) views of a shell from Ilha da Madeira: Garajau, A.H. Walden leg. 2.4.1893 (Götterborgs Naturhistoriska Museum 83-16.180); scale bar: 4 mm.

Fig. 9 - *Janulus stephanophorus* (Deshayes, 1850): apical (a), apertural (b) and umbilical (c) views of a shell from Ilha da Madeira: Ribeira da Porto Novo, A.H. Walden leg. 11.11.1972 (Götterborgs Naturhistoriska Museum 72-13.386); scale bar: 4 mm.

Fig. 10 - *Janulus pongilus* (Shuttleworth, 1852): apical (a), apertural (b) and umbilical (c) views of a shell from La Palma, Canary Islands, B.F. Blauner leg. 1851 (syntype, Naturhistorisches Museum Bern 18777). Photo by Eike Neubert (© Centre Suisse de Cartographie de la Faune, reproduced by permission); scale bar: 2 mm.
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Museum of Zoology, Cambridge, UK) with a drawing of the holotype of Janulus suttonensis, Henrik Walden and Ted von Proschwitz (Göteborgs Naturhistoriska Museum, Göteborg, Sweden) loaned material, Eike Neubert (Naturhistorisches Museum der Burggemeinde Bern, Switzerland) provided photos of a syntype of Janulus pumilus; publication of which was approved by GBIF Switzerland (GBIF Switzerland, Centre Suisse de Cartographie de la Faune, Neuchâtel).

REFERENCES


APPENDIX - putative fossil Janulus species

Patula (Janulus) angustiumbilicata Sacco, 1886: 190-1, Pl. 1, figs 17a-b.

**Type locality**: “Alluvioni pliocene che […] di Fossano” (Sacco, 1886: 169).

**Status**: uncertain. According to Sacco’s description and figures, the species has a punctiform umbilicus, but Ferrero Mortara et al. (1984: Pl. 54, figs 1a-c) figured a putative syntype with a small umbilicus. The material reported by Ferrero Mortara et al. (1984) consists of about ten specimens, all consistent with the one illustrated. However, there is no evidence that they constitute the actual type material because the only label accompanying them dates back to the 1970s (Daniele Ormezzano, pers. comm., September 2010). Although no information is available on radial rows of palatal teeth, the specimen illustrated by Ferrero Mortara et al. (1984) is similar to the Recent Janulus stephanophorus (Deshayes, 1850) and the Caspreno species.


**Type locality**: “Richardhof” (sample RH A/2) close to Mödling in Lower Austria (Vienna Basin); marls deposited in a Pannonian (late Miocene) swampy lake adjacent to Lake Pannon; mammalian zone MN9.

**Status**: probably a Janulus species: although no information is available on radial rows of palatal teeth, it is very similar to the Recent Janulus stephanophorus (Deshayes, 1850).

**Janulus decorous** Yi & Zhang, 1982: 64-5, Pl. 7, figs 4-6.

**Type locality**: Baoyue formation, Sanshui Basin, Guangdong; Middle Eocene.

**Status**: uncertain. Based on very poorly preserved specimens.

**Patula densestrata** Klika, 1891: 40, figs 32a-c.

**Type locality**: “bei Wärzen” (Bohemia).

**Status**: uncertain. Probably a Janulus species: although no information is available on radial rows of palatal teeth, it is very similar to Janulus schottleri Wenz, 1922.

**Helix disilis** Shchitler, 1886: 818, Pl. 52, figs 12-15.

**Type locality**: “Côte Saint-Martin, près d’Etampes … Calcaire de Beauce.”

**Status**: uncertain. Probably not a Janulus, but a discid species.

**Janulus germainae** Schlickum & Geissert, 1980: 237-8, Pl. 14, fig. 31.

**Type locality**: “Obere Pliozän, Triptychia-Mergel … Kiesgrube Mary Kocher, Sessenheim, Unterelsass.”

**Status**: uncertain. Probably not a Janulus, but a discid species.

**Patula gottschicki** Jooss, 1912: 32-3, Pl. 2, fig. 2.

**Type locality**: “Phurion’s Sandgrube in Steinheim, Pupasschicht.”

**Status**: uncertain. Jooss’s description and figure are consistent with a Janulus species (especially due to palatal teeth), but re-examination is needed.

**Helix gyrorbis** Klein, 1846: 72, Pl. 1, figs 14a-c.

**Type locality**: “… bei Oepringen in der Nähe von Eihingen…”

**Status**: uncertain. Probably a Discus species. Sandberger (1872: Pl. 21, figs 7-7') depicted a completely different species.


**Type locality**: “Oberpannon, Süsswassermargel … Öcs, Komitat Veszprém, Ungarn.”

**Status**: uncertain. According to Lueger (1981) a junior synonym of Discus pleuradras (Bourguignat, 1881).

**Janulus mörsingensis** Jooss, 1918: 289-90.

**Type locality**: “… unteren Obermiocän – den Sylviana-Schichten – von Mörsingen.”

**Status**: uncertain. Probably not a Janulus, but a punctid or a discid species. According to Lueger (1981), the specimen assigned to this species by Schlickum (1978: Pl. 19, fig. 16) belongs to Discus pleuradras (Bourguignat, 1881).

**Patula (Janulus) olisipponensis** Roman, 1907: 82-3, text-fig. 8.

**Type locality**: “Casaes de Valle d’Obidos près Rio Maior. – Eto Pontique.”

**Status**: probably a Janulus species: although no information is available on radial rows of palatal teeth, it is very similar to the Recent Janulus stephanophorus (Deshayes, 1850).

**Helix rysa** Wood, 1848: 4, Pl. 1, figs 1a-c.

**Type locality**: “Red Crag, Walton Naze.”

**Status**: uncertain. First assigned to Janulus by Sandberger (1875), it recalls J. bifrons from which it differs by virtue of a wider umbilicus, more reflexed peristome and blunt peripheral keel (absent in J. bifrons).

**Janulus schottleri** Wenz, 1922: 48, text-figs 1a-d.

**Type locality**: “Häufig in den Süsswasserschichten am Streßberg bei Treis a. d. Lumda und bei Ilschhausen.”

**Status**: very similar to Janulus stephanophorus (Deshayes, 1850). The species has radial row of palatal teeth at 90 degrees to each other; each row consisting of three teeth: adaxial and marginal teeth in the form of a short fold; abaxial tooth larger and V-like. Apparently very similar to Patula densestrata Klika, 1891.

**Helix striata** Eichwald, 1830: 215, 300 (depicted by Eichwald, 1852: Pl. 11, figs 9a-d).

**Type locality**: “près de Holoweczyne, aux environs de Mendzibosh, dans un calcaire tertiaire d’eau douce” (Eichwald, 1853).

**Note**: junior primary homonym of Helix striata Müller, 1774, now Helicopsis striata (Pulmonata, Hygromiidae).

**Status**: uncertain. Eichwald’s (1852-53) description and figures may be consistent with a Janulus species, but re-examination is needed.


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Patula (Janulus) supracostata Sandberger, 1872: Pl. 29, figs 2a-2c (described by Sandberger, 1875: 584).

Type locality: “Vermes bei Delsberg (Ct. Bern), Birk bei Mörsingen (v. Zell) Georgsgemünd und Hasenmühle bei Eichstädt (Gümbel) im Kalke mit Helix sylvana, Undorf bei Regensburg in gleichaltem Braunkohlen-Thone (Gümbel), an beiden Orten selten” (Sandberger, 1875).

Status: uncertain. Sandberger’s description and figure may be consistent with a Janulus species, but re-examination is needed. According to Moser et al. (2009) the specimen figured by Sandberger (1872), representing the holotype, cannot be identified. However they thought that it may belong to the “Discus-convergent Janulus germainae group”.

Helix suttonensis Wood, 1872: 2, Pl. 1, figs 2a-c.

Type locality: “Coralline Crag, Sutton.”

Status: probably a Janulus species: although no information is available on radial rows of palatal teeth, it is very similar to the Recent Janulus stephanophorus (Deshayes, 1850).