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RESEARCH ARTICLE

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Middle Triassic gastropods from the Besano Formation of Monte San Giorgio, Switzerland

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Abstract

For the first time gastropods from the Besano Formation (Anisian/Ladinian boundary) are documented. The material was collected from three different outcrops at Monte San Giorgio (Southern Alps, Ticino, Switzerland). The taxa here described are *Worthenia* (*Humiliworthenia*)? aff. *microstriata*, *Frederikella* cf. *cancellata*, ?*Trachynerita* sp., ?*Omphaloptycha* sp. 1 and ?*Omphaloptycha* sp. 2. They represent the best preserved specimens of a larger collection and document the presence in this formation of the clades Vetigastropoda, Neritimorpha and Caenogastropoda that were widespread on the Alpine Triassic carbonate platforms. True benthic molluscs are very rarely documented in the Besano Formation, which is interpreted as intra-platform basin sediments deposited in usually anoxic condition. Small and juvenile gastropods could have been lived as pseudoplankton attached to floating algae or as free-swimming veliger planktotrophic larval stages. Accumulations of larval specimens suggest unfavorable living conditions with prevailing disturbance in the planktic realm or mass mortality events. However, larger gastropods more probably were washed in with sediments disturbed by slumping and turbidite currents along the basin edge or storm activity across the platform of the time equivalent Middle San Salvatore Dolomite.

Keywords: Gastropods, Middle Triassic, Environment, Besano Formation, Southern Alps, Switzerland

Introduction

The Middle Triassic Besano Formation (formerly called "Grenzbitumenzone" in most publications) is exposed in the Monte San Giorgio area, across the boundary of Southern Switzerland (Canton Ticino) and Northern Italy (Province Varese), was registered in 2003 as a UNESCO World Heritage Site because of its important vertebrate fauna from the Middle Triassic (Furrer 2003). However, invertebrate fossils are also relatively common in this formation and some of the main clades of marine molluscs such as ammonoids, coleoids and bivalves (especially the genus *Daonella*) have been documented, notably by Airaghi (1911, 1912), Rieber (1965, 1968, 1969, 1970, 1973a, b, 1974a, b) and Schatz (2005a, b). They represent mostly nektonic cephalopods or bivalves adapted to an environment characterized by anoxic condition in bottom waters of an intraplatform basin (Bernasconi 1991; Schatz 2005a). Findings of benthic molluscs, which are abundant on carbonate platforms, are scarce in this environment. In particular macrofossils such as gastropods are relatively rare and usually poorly preserved in the Besano Formation. Bassani (1886) provided the first report of gastropods from this formation and assigned his single specimen to *Chemnitzia* sp., giving only a description without illustration. This poorly preserved specimen had a turriculate shape, but its location is now uncertain. Rieber (1973b) also cited some unassigned turriculate gastropods from Monte San Giorgio (Point 902, "lower Grenzbitumenzone"), and Röhl et al. (2001: Fig. 4) documented the relative abundance of gastropods in the section of the Besano Formation ("Grenzbitumenzone") during the largest excavation at Point 902/Mirigioli from 1950–1965 by the University of Zurich. Furrer and Vandelli (2014, fig. p. 64) figured specimen PIMUZ 29952 as an indeterminate gastropod. Two specimens probably belonging to Coelostylinidae are figured by López-Arbarello et al. (2016, p.

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30/61, Fig. 18A) in association with a fish from the Upper Besano Formation of Mirigioli.

Here we document for the first time identifiable gastropods from the Besano Formation (Anisian/Ladinian boundary) of Monte San Giorgio (Canton Ticino, Southern Switzerland). The gastropod material illustrated here comes from the most important collection of Besano Formation fossils housed in the Paläontologisches Museum der Universität Zürich, with one specimen from the Museo Cantonale di Storia Naturale Lugano.

Locations and age

Four of the described specimens herein come from the site referred to as Point 902 or Mirigioli (Meride, today part of the community Mendrisio, Canton Ticino), located 800 m WSW of Monte San Giorgio, where the biggest paleontological excavation was done in the Besano Formation from 1950 to 1965 under direction of Emil Kuhn-Schnyder from the University of Zurich. About 600, mostly small gastropods were registered in the inventory during the bed-by-bed excavation (Fig. 1), together with the famous vertebrate remains, cephalopods, bivalves, dasycladacean algae and terrestrial plants (Rieber 1973a). The four described specimens were found in the lower and middle Besano Formation with a late Anisian age (Reitzi and Secedensis Zone). One single specimen comes from an outcrop of the middle Besano Formation close to the old mine in the Val Porina Valley, 750 m SW of Monte San Giorgio. Accumulations of small turriculate gastropods derive from Point 902/Mirigioli and the old mine Valle Stelle (Tre Fontane), 1300 m WSW of Monte San Giorgio.

Materials and methods

The described gastropods from the Besano Formation are preserved usually as external molds covered or partially filled with dolomite crystals (Fig. 2). The molds are not deformed in shape which allowed silicon casts to be produced for the study. Some specimens are also preserved as internal molds. HF used also unpublished data referring to gastropods from the PIMUZ excavations at Monte San Giorgio.

Institutional abbreviations

MCSN: Museo Cantonale di Storia Naturale, Lugano, Switzerland
PIMUZ: Paläontologisches Institut und Museum der Universität Zürich, Switzerland

Systematic palaeontology

Vetigastropoda Salvini-Plawen, 1980
Basal gastropod taxa not assigned to order
Superfamily Trochonematoidea Zittel, 1895
Family Lophospiridae Wenz, 1938
Genus *Worthenia* de Koninck, 1883
Type species. *Turbo tabulatus* Conrad, 1835
Subgenus *Worthenia* (*Humiliworthenia*) Yin & Yochelson, 1983
Type species. *Worthenia nuda* Koken, 1900, Middle Triassic, Ladinian, China.

***Worthenia* (*Humiliworthenia*)? aff. *microstriata* Nützel, Kaim & Grădinaru,** 2018 Fig. 3a–d
aff. 2018 *Worthenia* (*Humiliworthenia*) *microstriata* Nützel, p. 11, Fig. 10A-I.

Material Specimen MCSN 3002, preserved as external mold covered with fine dolomite crystals.

Measurements The spire consists of c. 6 whorls and is 20.82 mm high (first whorls missing) and 14.25 mm wide; spire angle 50°.

Occurrence Val Porina (750 m SW Monte San Giorgio, at 812 m.a.s.l.), Meride, Canton Ticino. Middle Besano Formation, uppermost Anisian.

Description The specimen MCSN 3002 shows a gradate, slightly pagodiform shell with whorls having two angulations, both with a strong spiral crest-like carina; the adapical carina is at the angle between the ramp and the outer whorl face, at about mid-height of the whorl, forming the periphery; the abapical carina is broader but less pronounced than the upper one; it is situated just in suprasutural position and forms edge towards base. The ramp is steeply inclined and convex, with a faint but distinct spiral cord at mid-height. The growth lines are strongly prosocline and slightly prosocyrt between the upper suture and the midwhorl angulation, where the selenizone seems to be present. The outer face between the spiral carinae is concave, and almost parallel to shell axis. The base is flatly conoidal; its wall is convex and smooth with slightly opisthocyrt and orthocline growth lines, and has a rather broad umbilicus. The umbilicus is surrounded by an angular rim.

Discussion The available specimen seems to be closely related to *Worthenia* (*Humiliworthenia*) *microstriata* Nützel et al. 2018, differing in having a broad umbilicus. *Worthenia* (*Humiliworthenia*) Yin & Yochelson 1983 is also characterised by the absence of any axial ornament and a smooth surface except for crest-like angulations and a fine spiral striation. These are seen in the specimen on hand, although the growth lines are poorly preserved.

Order Trochida Rafinesque, 1815
Superfamily Trochoidea Rafinesque, 1815

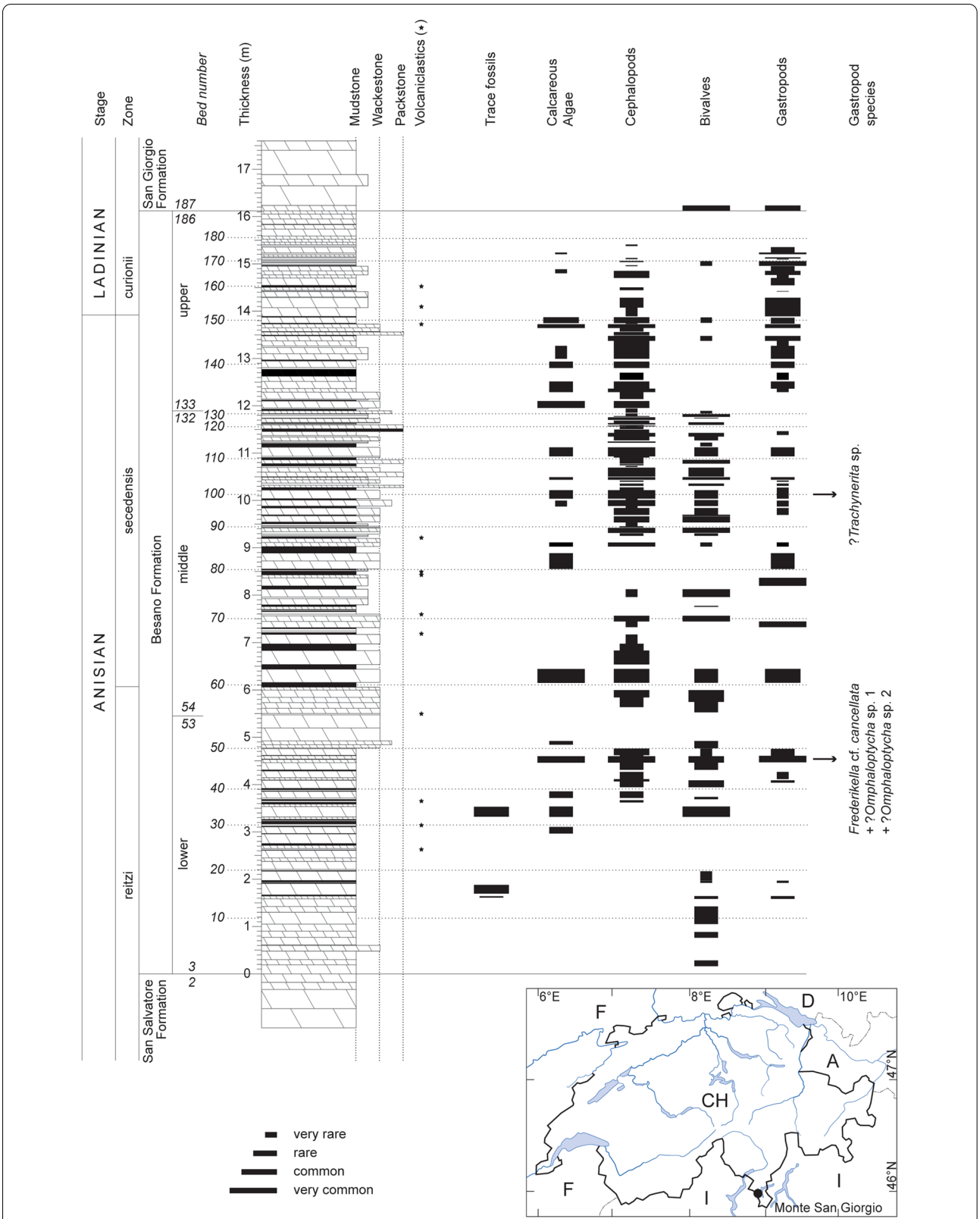

Fig. 1 Stratigraphic section of the Besano Formation at site Point 902/Mirigioli, with distribution and relative abundance of trace fossils, calcareous algae, cephalopods, bivalves and gastropods. Modified after Röhl et al. 2001 (Fig. 4), based on the internal inventory of the PIMUZ collection. The stratigraphic positions of four described specimens are indicated

Fig. 2 *Frederikella* cf. *cancellata* (Zardini 1978). The original specimen PIMUZ 29952 with external mold (apical side) in association with *Daonella* cf. *angulata* Rieber 1968. Point 902/Mirigioli (Monte San Giorgio), Lower Besano Formation (bed 47)

Family Liotiidae Gray, 1850
Subfamily Liotiinae Gray, 1850
Genus *Frederikella* Bandel, 1993
Type species. *Brochidium cancellatum* Zardini, 1978

***Frederikella* cf. *cancellata* (Zardini,** 1978) Fig. 3e–h
cf. 1978 *Brochidium cancellatum* Zardini: p. 24, pl. 8, Fig. 12.
cf. 1993 *Frederikella* cf. *cancellata* (Zardini): Bandel, 1993, p. 10, pl. 2, Figs. 3, 4.

Material Specimen PIMUZ 29952, preserved partially as external mold covered with fine dolomite crystals, and partially as internal mold covered by shell (small portion of last whorl).

Measurements D max = 25.48 mm, 4 whorls. At D = 21 mm: H = 8.66 mm; O = 9.43; O %D = 44.9; pleural angle = 165°; H of whorl = 7.33, corresponding inner whorl H = 3.98 (measurements obtained from silicon cast, slightly incomplete in the peripheral area).

Occurrence Point 902/Mirigioli (800 m WSW Monte San Giorgio), Meride, Canton Ticino. Lower Besano Formation (bed 47, in association with *Daonella* cf. *angulata* Rieber, 1968), Reitzi Zone, uppermost Anisian.

Description The specimen PIMUZ 29952 shows a very low-spired, widely phaneromphalous shell with very slightly elevated spire. The whorls are well rounded. The spire has deeply impressed suture, numerous thick spiral threads and collabral riblets forming a network. About 19 regularly spaced, thick threads are present on the last whorl between the suture and the rim of the umbilicus. Slightly above the periphery two of these (the seventh and the eighth from the adapical suture) appear sharper and almost fused together, while, below and above, the others are more widely spaced. The six adapical spiral lines are crossed by densely and regularly distributed collabral riblets, which form knobby intersections. The spiral and radial lines are hardly visible on the base, because of poor preservation. Gentle nodes or folds are present on the rounded umbilical wall.

Discussion Bandel (2016) compared the genus *Frederikella* Bandel, 1993 with modern Liotiinae Gray, 1850. This genus was based on *Frederikella cancellata* (Zardini, 1978) from the San Cassiano Formation as documented by Bandel (1993, pl. 2, Figs. 2–4). The holotype described by Zardini (1978) is represented by a very small shell (less than 3 millimetres), and the juvenile specimen described by Bandel (1993) measures only 1.4 mm in diameter. The present specimen differs from the shells from the San Cassiano Formation in the much larger dimensions, the disposition of spiral elements at periphery and the presence of nodes/folds on the umbilical wall. However, because of the scarcity of specimens, the intraspecific and ontogenetic variability of this form is unknown. The species *Frederikella axialocostata* Gründel, 1998 (Dogger of Germany) strongly differs from the present one mainly because of its higher spire and narrower umbilicus. The genus *Klebiella* Gründel, 1998 differs in having a completely planispiral conch, and more evident and dense axial collabral riblets. In the present specimen, a presence of a selenizone is not completely excluded by the direction of the collabral ribblets. Unfortunately the peripheral region is not so well preserved.

Neritimorpha Golikov & Starobogatov, 1975
Order Neritoina Rafinesque, 1815
Superfamily Neritoidea Rafinesque, 1815
Family Neritariidae Wenz, 1938
Subfamily Neritariinae Wenz, 1938
Genus *Trachynerita* Kittl, 1894b
Type species. This genus is based on *Turbo quadratus* Stoppani, 1858 (Esino Limestone) = *Trachynerita fornoensis* Kittl, 1894b (Marmolada Limestone). Kittl established this genus in his Marmolada paper (1894b, pp. 120, 133) and it is accepted by Böhm in his paper on the same fauna (1895, p. 239), as well as by Cossmann (1915, p. 185) and Wenz (1938, p. 415). Cossmann (1915) designated *T. fornoensis* as the genotype, but since this species was declared by its author (Kittl 1899, p. 72) to be a junior synonym of *Turbo quadratus* Stoppani, the latter must be considered the type species. Because of the absence of a

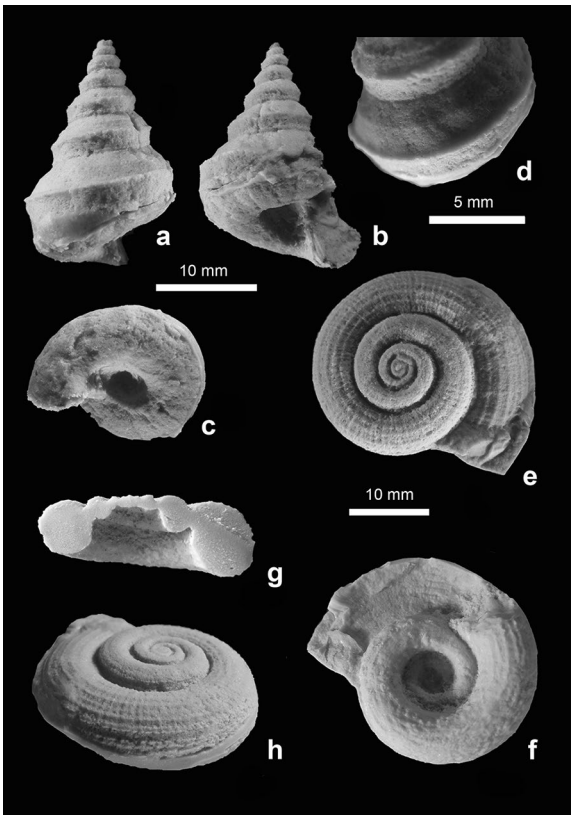

Fig. 3 **a-d** *Worthenia* (*Humiliworthenia*)? aff. *microstriata* Nützel et al. 2018, Middle Besano Formation, uppermost Anisian. MCSN 3002: **a** abapertural view, **b** apertural view, **c** basal view, and **d** detail with growth lines on the ramp. **e–h** *Frederikella* cf. *cancellata* (Zardini 1978), Lower Besano Formation, uppermost Anisian. PIMUZ 29952: **e** apical and **f** umbilical view, **g** transversal section, **h** apical side view. All images have been obtained producing positive silicon casts from negative external mold

holotype, Haas 1953 designated as holotype the specimen depicted by Kittl (1894b, Fig. 12, pl. 3; reproduced by Böhm 1895, textfig. 25, and by Wenz 1938, Fig. 1007).

?*Trachynerita* sp. Fig. 4a–d

Material Specimen PIMUZ 37303, preserved partially as external mold and partially as a poorly preserved and slightly deformed shell.

Measurements D = 20.90 mm, 2 last whorls preserved. H = 16.60 mm (first whorls missing); pleural angle = 95°.

Occurrence Point 902/Mirigioli (800 m WSW Monte San Giorgio), Meride, Canton Ticino. Middle Besano Formation (bed 100), Secedensis Zone, uppermost Anisian.

Description The specimen PIMUZ 37303 shows a broadly globular shell with a low spire and gradate shape. The whorls rapidly increase in size and are separated by well-marked suture. The whorl outline is convex. The apex is missing. The suture is slightly impressed. There is a large subsutural flattened ramp, nearly perpendicular to the axis. The abaxial edge of this ramp is a well-marked angular shoulder. For the last whorl, a rounded angulation developed in midwhorl position. The base is rounded convexly and partially covered by matrix. The aperture is obliquely teardrop-shaped and clearly higher than wide. Prosocline growth lines are poorly preserved on the flanks. Ornaments are not observable.

Remarks This specimen appears quite similar to *Trachynerita quadrata* (Stoppani, 1858). The type specimen for this taxon, collected from the Esino Limestone, is lost. After intense research in the main gastropod collections it is clear that this species is very rare in the Esino Limestone, while somewhat more common in the Latemar Limestone. Two specimens from the Latemar Limestone, belonging to this taxon, are present in the collection of the Paläontologisches Museum der Universität Zürich (PIMUZ 37301; PIMUZ 37302). A positive comparison has been made between the present specimen and those from the Latemar Limestone. The form illustrated by Leonardi and Fiscon (1959) from the San Cassiano Formation (Carnian) has a general shape similar to *Trachynerita quadrata*, but differs in having a more convex whorl face and narrower whorls. The specimen illustrated by Nützel & Senowbari Daryan (1999) from Iran (Norian/Rhaetian) shows orthocline growth lines, while in the specimens figured by Stoppani (1858) and Kittl (1894b, 1899) the growth lines are clearly prosocline. Furthermore, the specimen from Iran has a more inflated last whorl, while the aperture is smaller than that of the type. Very similar to *Trachynerita quadrata* is the specimen illustrated by Zardini (1985) from the San Cassiano Formation, however this is a juvenile specimen.

Subclass **Caenogastropoda** Cox, 1960
Clade **Hypsogastropoda**
Unassigned to Superfamily
Family Coelostylinidae Cossmann, 1908
Genus *Omphaloptycha* (Ammon, 1893) Böhm, 1895
Type species. *Chemnitzia* (*Microschiza*) *nota* Ammon, 1893

?*Omphaloptycha* sp. 1 Fig. 4e

Material Specimen PIMUZ 37312, preserved as external mold covered with fine dolomite crystals.

Measurements ca. 7 whorls; W = 20.00 mm; H = 52.00 mm (first whorls missing); pleural angle = 30°.

Occurrence Point 902/Mirigioli (800 m WSW Monte San Giorgio), Meride, Canton Ticino. Lower Besano Formation (bed 47), Reitzi Zone, uppermost Anisian.

Description The specimen PIMUZ 37312 shows a conical to slightly pupiform shell. The last whorl occupies approximately two-fifths of the total shell height. The juvenile whorls are flattened, while the last whorls are rounded and slightly convex. The suture is slightly impressed. The base is conoidal with convex wall. The umbilicus is not observable and growth lines are not visible. The whorls appear smooth but their surface is poorly preserved. This specimen appears similar to *Omphaloptycha heeri* (Kittl, 1894) and in particular to the specimen from the Marmolada Limestone figured by Kittl (1894b, pl. 6, Fig. 17). Böhm (1895) misidentified his specimens generating confusion (see Kittl 1899, p. 114).

?*Omphaloptycha* sp. 2 Fig. 4f–g

Material Specimen PIMUZ 29951, preserved as external mold covered with fine dolomite crystals.

Measurements 6 whorls; W = 24.00 mm; H = 52.00 mm (first whorls missing); pleural angle = 40°.

Occurrence Point 902/Mirigioli (800 m WSW Monte San Giorgio), Meride, Canton Ticino. Lower Besano Formation (bed 47), Reitzi Zone, uppermost Anisian.

Description The shell is conical and moderately high-spired with last whorl about ½ of total height. The whorls are flattened to slightly convex. The penultimate whorl is flattened to slightly swollen and the last whorl is slightly inflated. A well-rounded peripheral angle at the mid-height of the last whorl distinguishes the flank from the base, and the ramp is flattened and slightly inclined. The suture is shallow but distinct. The base is rounded convexly and conical. The slit-like umbilicus is not observable. The surface of shell is poorly preserved. The aperture is obliquely oval and has an anterior siphonal beak. This specimen appears in general shape similar to *Omphaloptycha escheri* (Hörnes, 1856).

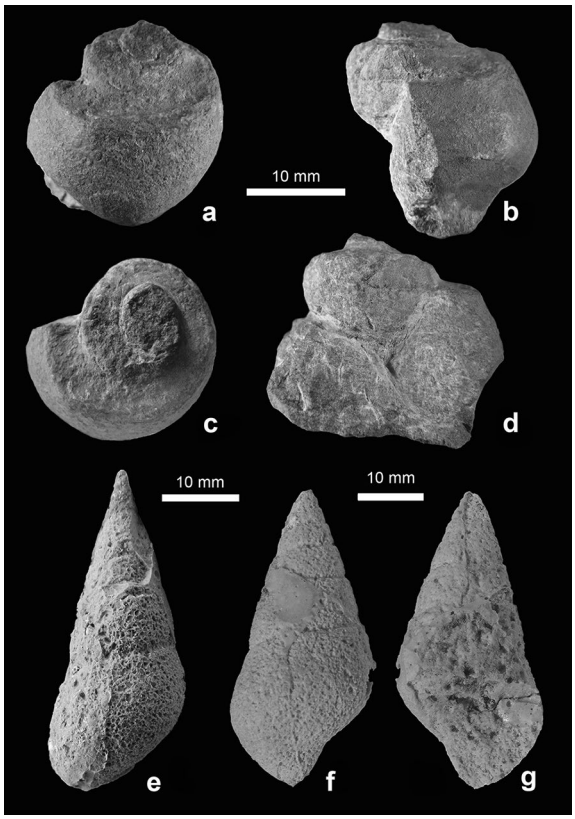

Fig. 4 **a**–**d** ?*Trachynerita* sp., Middle Besano Formation, uppermost Anisian. PIMUZ 37303: **a** apical side view, **b** side, **c** apical, and **d** apertural view. **e** ?*Omphaloptycha* sp. 1, Lower Besano Formation, uppermost Anisian. PIMUZ 37312: Abapertural view. **f**, **g** ?*Omphaloptycha* sp. 2, Lower Besano Formation, uppermost Anisian. PIMUZ 29951: **f** abapertural and **g** apertural view. Images **a**–**d** have been obtained from original specimen; images **e**–**g** from silicon casts

Taphonomy and environment

The gastropods are preserved in the dolomitic beds throughout the Besano Formation, but not in the bituminous shales, a distribution noted as similar to cephalopods (Rieber 1973a). The gastropods are preserved as partly flattened internal molds and external molds imprinting the shell in the finely laminated bituminous dolomites (mudstone), whereas undeformed external molds, partly cemented by dolomite crystals, are typical for the massive dolomite beds (wackestone). Gastropods are relatively common in the upper Besano Formation (mainly beds 173, 163 and 144; Lower Ladinian), but rare in the middle and lower Besano Formation, with the exception of beds 118, 76 and 47 (Upper Anisian; Fig. 1). A maximum of 295 specimens was noted during the excavation in dolomite bed 118 (Middle Besano Formation), however these gastropods are poorly preserved

and not identifiable. Better preserved molds were found in bed 47 (Lower Besano Formation). Of note is bed 76 with a dense accumulation of juvenile gastropods, found together with cephalopods (ceratitid ammonoids, Fig. 5a), and bed 69 with partly silicified shells of tiny gastropods and ceratitid ammonoids (Fig. 5b).

Benthic molluscs are rarely found in the Besano Formation, which is interpreted as being deposited in an isolated intra-platform basin characterized by usually anoxic conditions (Bernasconi 1991, 1994; Furrer 1995; Röhl et al. 2001; Furrer and Vandelli 2014). The abundance of gastropods correlates partly with the occurrence of cephalopods and dasycladacean algae, but not with that of bivalves (Fig. 1), known mainly from shellbeds in the middle and lower Besano Formation. Rieber (1968, 1973b) suggested that the common bivalve *Daonella* and the small posidoniids (*Peribositra*) lived as pseudoplankton attached to floating algae in the surface waters. Schatz (2005a, b) could not find any means to attach to a float in daonellids and proposed that these paper clams lived as epibenthic, pleurothethic organisms on soft, soupy sediments in dysoxic conditions.

However, benthic gastropods could not live on the seabed in the basin due to the usually stagnant, probably hypersaline bottom waters and depletion of oxygen by decaying organic matter. Small gastropods could have lived as pseudoplankton attached to floating algae in the superficial waters, as suggested by Rieber (1973b). The present small turriculate gastropods seem to be larval-postlarval stages belonging to Caenogastropoda, which have a multispiral protoconch. A free-swimming veliger planktotrophic larva occurs in these forms (Ponder and Lindberg 2008; Nützel, 2014). Accumulations of larval specimens suggest unfavorable living conditions with prevailing disturbance in the planktic realm or mass mortality events. Larger gastropods were probably washed in with sediments disturbed by slumping and turbidite currents along the basin edge or by storm activity across the platform. Similar gastropods were found in the time equivalent shallow water carbonates of the middle San Salvatore Dolomite at Rasa di Varese, East of Monte San Giorgio (Pieroni 2011; Pieroni and Nützel 2014) and Monte San Salvatore further North (*Rasatomaria gentilii* Pieroni and Nützel 2014, unpublished material, collection Zorn 1971).

Conclusion

The specimens described herein belong to the three main clades of the Class Gastropoda, which characterized the Middle Triassic faunas of the Alps. Despite the scarcity of identifiable gastropods, this limited fauna shows an unexpected biodiversity similar to those of Middle Triassic carbonate platforms of the Southern Alps (e.g. Esino Limestone, Marmolada/Latemar Limestone, see Kittl 1894b, Böhm 1895), as well as the San Cassiano Formation (Carnian, Dolomites, see Kittl 1894a).

True benthic molluscs are very rarely documented in the Besano Formation, which is interpreted as intra-platform basin sediments deposited in usually anoxic condition. Small and juvenile gastropods could have been lived as pseudoplankton attached to floating algae or as free-swimming veliger planktotrophic larval stages. However,

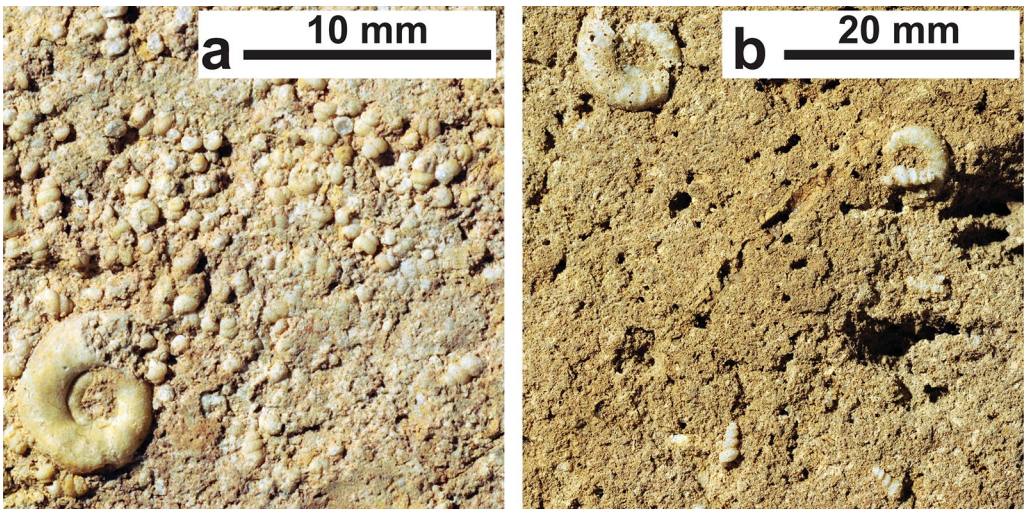

Fig. 5 Accumulations of small turriculate gastropods: larval-postlarval stages belonging to Caenogastropoda: **a** PIMUZ 37341 with a ceratitid ammonoid (lower left). Point 902/Mirigioli (Monte San Giorgio), Middle Besano Formation (bed 76); **b** PIMUZ 37340, three silicified gastropods (bottom and upper right) together with two silicified ceratitid ammonoids (*Repossia acutenodosa* Rieber, 1973). Valle Stelle (Monte San Giorgio), Middle Besano Formation (bed 69)

larger gastropods more probably were washed in with sediments disturbed by slumping and turbidite currents along the basin edge or storm activity across the platform of the time equivalent Middle San Salvatore Dolomite.

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Authors' contribution
VP and HF designed and wrote the study. VP selected, classified and photographed the specimens and treated the systematics of the gastropods. HF contributed with the localities, stratigraphy, taphonomy and environment. Both authors read and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

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