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The first Cyclida from the Triassic of Italy

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Abstract

A well-preserved carapace of the crustacean *Halicyne* is here described. The finding comes from the Sostegno Basin (Piedmont, Italy). This is the first occurrence of a well-preserved arthropod from the Middle Triassic San Salvatore Formation of the Biellese area and the first report of a Triassic Cyclida from Italy. Cyclida often occurs in shallow marine environments with rapidly changing salinity conditions. The finding from the Sostegno area suggests a hypersaline paleoenvironment similar to that of Monte San Salvatore (Ticino, Switzerland) upper levels, where the same taxon was previously documented. These fossiliferous localities are shortly compared with that of Rasa di Varese (Lombardy, Italy).

Keywords Cyclida, Ladinian, Carbonate platform, Environment, Western Southern Alps

Introduction

The first paleontological investigations in the San Salvatore Formation (=Salvatoredolomit von Buch, 1827; Middle Triassic carbonate platform), date back to the nineteenth century (e.g., Stabile, 1854, 1856), in the area of the Monte San Salvatore (Lugano, Ticino, Switzerland), the type locality widely described by Zorn (1971), and in the Italian localities between Varese and the Lago Maggiore (Airaghi, 1935; Mariani, 1901; Tommasi, 1885).

In the last years, further researches into this formation yielded material (e.g., ammonoids, nautiloids, gastropods, bivalves, echinoderms, and vertebrate remains) that was published in several works (Jaselli & Pieroni, 2023; Pieroni, 2011; Pieroni & Nuetzel, 2014; Pieroni & Prinoth, 2021; Renesto & Pieroni, 2013). Special attention was dedicated to the locality of Rasa di Varese where a rich and diverse fauna was discovered, expanding greatly our knowledge of the San Salvatore Formation biodiversity and its paleoenvironment. These Middle Triassic dolostones, cropping out in many localities between the Lago di Como and northern Piedmont (Fig. 1; see also Jaselli & Pieroni, 2023), yielded rich faunas only from a few small outcrop areas mostly between the Lago di Lugano and the Lago di Varese.

The macrofossil documentation from the Piedmont Middle Triassic outcrops is extremely scarce. The Biellese area (Sostegno and Monte Fenera Basins) was described in several geological works (e.g., Berra et al. 2009; Bertrando et al. 2015; Decarlis et al. 2017; Fantoni et al. 2005), but usually the attention was concentrated on the Monte Fenera Basin (see the section published by Fantoni et al. 2005). Decarlis et al. (2017) recently provided a sketch section for the Sostegno Basin, citing some paleontological remains (dasycladacean algae and crinoids).

This work describes the first well-preserved arthropod from the Middle Triassic San Salvatore Formation of the Biellese area: a small crustacean carapace corresponding to the genus *Halicyne* (von Meyer, 1844).

Cyclida embraces an enigmatic group of crustaceans ranging in age from Early Carboniferous (Mississippian) to Late Cretaceous (Maastrichtian). The Order was recently revised with descriptions of all known species (Schweitzer et al. 2020).

Cyclida is rare in Europe and essentially known from the epicontinental Triassic of Germany and the Alpine Triassic of Austria and Switzerland (e.g., Schweigert, 2007 and references within; Furrer, 2019: fig. 96). One record

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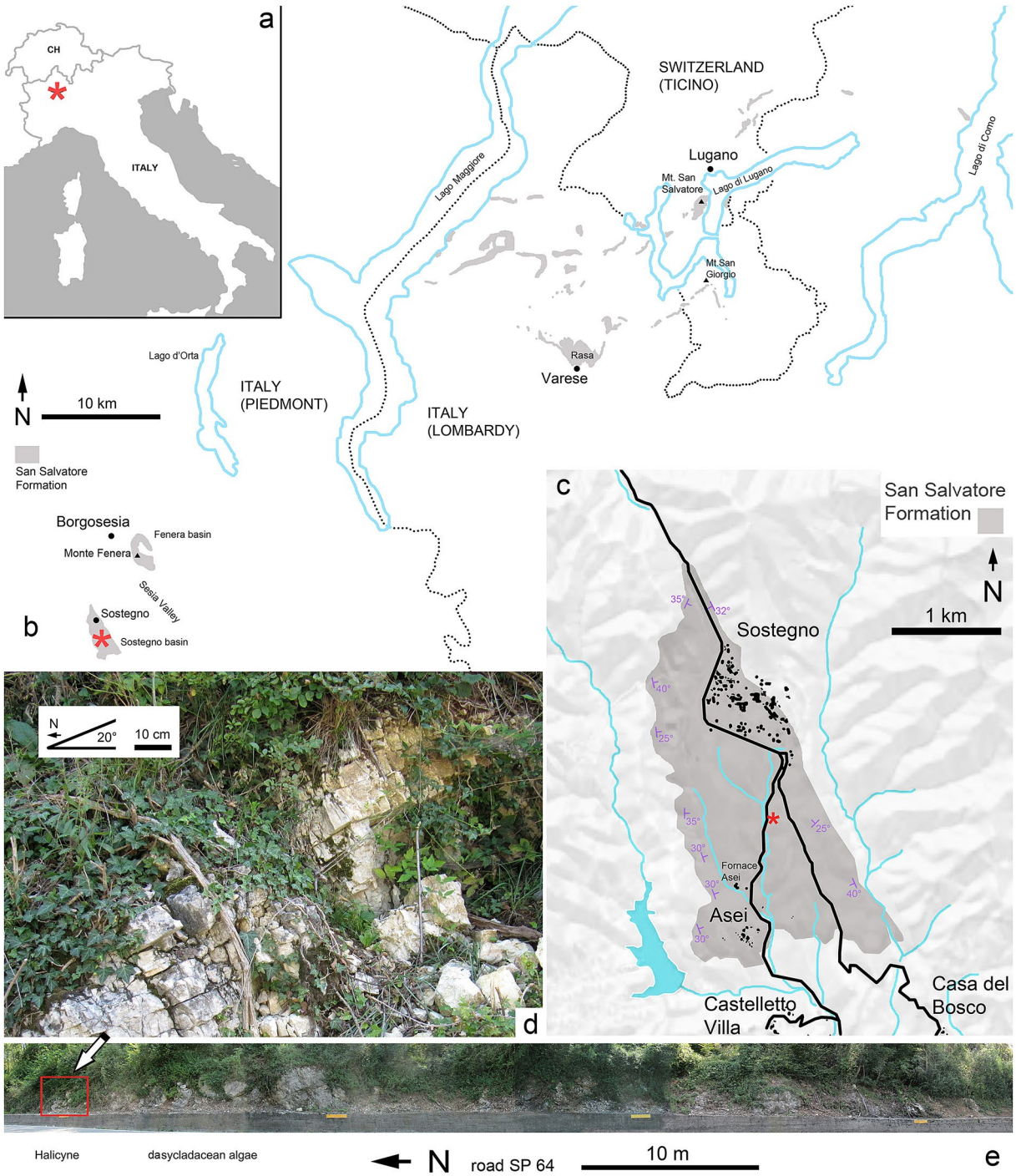

Fig. 1 Geographic location and outcrop of the *Halicyne* fossil discussed in this study. **a** locality of find, the asterisk indicate the fossiliferous outcrop here described; **b** outcrops (grey areas) of the San Salvatore Formation in the subalpine foothills of Lombardy, Piedmont (Italy) and Canton Ticino (Switzerland); **c** geological map of the San Salvatore Formation in the Sostegno area (after Zantonelli, 2011, simplified); **d** photograph of the site with *Halicyne*; **e** complete section exposed along road SP 64 (Sostegno-Asei), the red rectangle indicates the outcrop figured in **d**

was published from the Late Cretaceous (Fraaije et al. 2003) and the Early Jurassic (Schweigert, 2007). Cyclida often occurs in shallow-marine neritic or somewhat restricted lagoonal habitats, such as the dolomitic facies of the Triassic Upper Muschelkalk (Alexandrowicz, 1973; Linck, 1961; Trümpy, 1957; von Meyer, 1838) or in the

Permian 'Zechstein' dolomite (Schauroth, 1854). This strongly contrasts with some other Cyclida that occurs in carbonates, such as the Triassic 'Hallstätter Kalke' facies (Trauth, 1918).

The present specimen is the first occurrence of a Triassic Cyclida from Italy.

Only the cyclide crustaceans *Oonocarcinus insignis* Gemmellaro, 1890 and *Paraprosopon reussi* Gemmellaro, 1890 have been described from Italy (Permian olistholithic limestone block "Pietra di Salomone" at Sosio, Sicily) by Gemmellaro (1890) (see also Dzik, 2008 and Schweitzer et al. 2020).

Regional geology

In the western region of the Alps, near the Lago Maggiore, the exposure of the Mesozoic sediments is poorly represented. In the northern Piedmont Biella-Canavese zones, the Sostegno and Monte Fenera basins were established onto Permian volcanic rocks (e.g., Berra et al., et al. 2009; Bertrando et al., et al. 2015; Fantoni et al., et al. 2005). At Monte Fenera, Permian volcanic rocks are overlain by a thin succession of sandstones (Fenera Annunziata sandstone) and conglomerates. Above these thin beds start the deposition of Middle Triassic dolostones (Berra et al., et al. 2009; Decarlis et al., et al. 2017). The San Salvatore Formation at Monte Fenera is about 300 m thick and consists of the following lithozones (from the base): dark dolostones=Pissone dolomite, bedded dolostones, bituminous dolostones, breccias, massive dolostones, dolomitic limestones, mainly micritic and partly stromatolithic (Fantoni & Fantoni, 1991). In the upper part of the Pissone dolomite were collected palynomorphs such as *Sellaspora foveorugulata* and *Deltoidospora minor* suggesting a Late Anisian to Ladinian age (Berra et al., et al. 2009, p. 339). The dasycladacean alga *Diplopora annulata* was described by Farabegoli and De Zanche (1984) in the same levels. The massive dolostones (top of the sequence) at Monte Fenera were considered of Early Ladinian age (Berra et al., et al. 2009).

In the Sostegno area the Pissone dolomite was not deposited, so that the Fenera Annunziata sandstone is overlain directly by light-grey fine-grained dolostones of the San Salvatore Formation (Berra et al. 2009). Decarlis et al. (2017) cited dasycladacean algae and crinoid remains. Up to now, the age of the dolostone beds at Sostegno is unknown, however, the authors consider these beds as equivalent to the upper Monte Fenera dolostone sequence, which could be considered of Early Ladinian age (see Berra et al. 2009; Decarlis et al. 2017). The top of the Triassic carbonate rocks in the Monte Fenera-Sostegno area is characterized by a widespread unconformity, locally accompanied by karstified levels and followed by a thin succession of dolomitic breccias, conglomerates, and micro-conglomerates with oxidized reddish matrix (Fig. 2a). The dolomitic breccias and conglomerates with reddish pelites are interpreted as originated from Early Jurassic paleosol which was successively deposited in a shallow water basin (Berra et al. 2009; Decarlis et al. 2017). Above the unconformity, well-bedded Lower Jurassic sediments are also present in the southern area of the Sostegno Basin (near Casa del Bosco village).

The dolostones in the Sostegno area dipped in different directions (see Fig. 1 map, after Zantonelli, 2011), with about 250 m of thickness according to Decarlis et al. (2017), who figured the more complete section of the Sostegno area (Fig. 2a).

Locality and section

The new fossil comes from a site along road SP 64 (between the village Sostegno and the village Asei) where some beds of the San Salvatore Formation are exposed (Figs. 1 and 2). The section is easily observable for about 70 m along the eastern roadside. This section, with a thickness of about 20 m, is composed of subtidal/intertidal dolostone beds with an inclination of about 20° towards N-NE. From the base to the top are observable: white–grey massive beds; chaotic layers (slump folds); massive grey beds with cavities partly cemented by dolomite crystals); massive to stratified grainstone with planar microbial lamination and dasycladacean algae (*Diplopora*?); about two meters of fine-grained (wackestone-mudstone) well-bedded (bed thickness: 10–20 cm) white–grey to yellowish dolostone with few small, partly cemented fenestrae. The specimen here described was found by the author in the uppermost beds (coordinates N 45°64,404, 8°27,358, altitude 363 m). The top of the section is covered by vegetation.

Systematic paleontology

The systematics and morphological terminology follow Schweitzer et al. (2020).

Class Multicrustacea Regier et al., 2010
Order Cyclida Schram, Vonk & Hof, 1997
Family Halicynidae Gall & Grauvogel, 1967
Genus *Halicyne* von Meyer, 1844
Type species: *Limulus agnotus* von Meyer, 1838
Halicyne cf. *agnota* (von Meyer, 1838) Fig. 3a–d.
cf. 1971 *Halicyne agnota* (von Meyer, 1838): Zorn, p. 80, pl. 15, fig. 36, (morphotype 2).

Material examined a single small specimen MSNVI-SOST-01 (repository: MSNVI, Museo di Storia Naturale "A. Stoppani" Venegono Inferiore, VA, Italy). Other fossils were not found in the same level.

Description Carapace ovate, slightly longer than wide, narrowing posteriorly, smooth to more or less finely

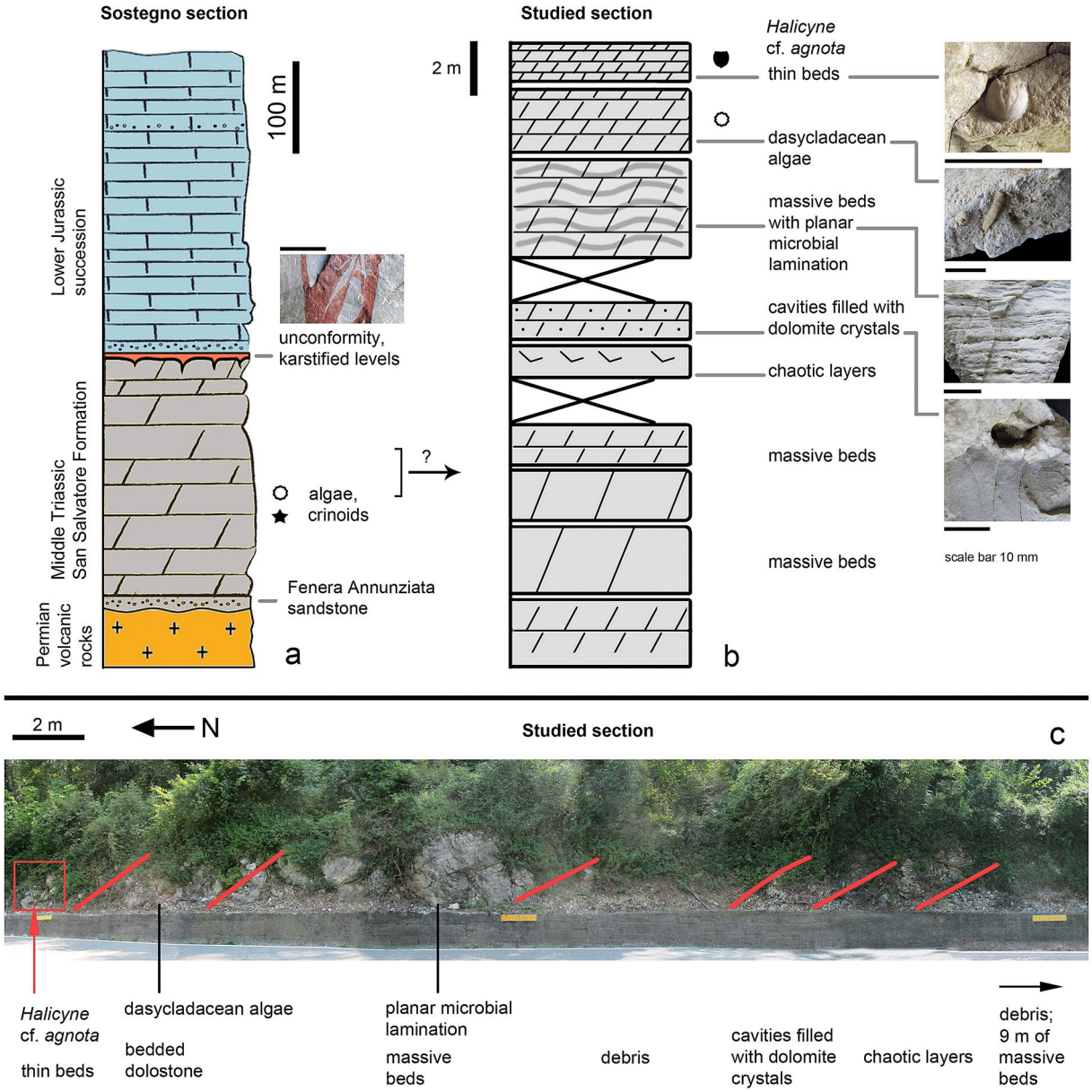

Fig. 2 Stratigraphic sections at Sostegno. **a** complete section of the Sostegno area, after Decarlis et al. (2017), modified, with a sample of breccia with oxidized reddish matrix, outcropping in the Sostegno village (southern area). Algae and crinoids cited by Decarlis et al. (2017) are indicated. The arrow indicates a possible stratigraphic position of the studied section; **b** studied section with lithology and fossils, on the right: corresponding samples; **c** the section exposed along road SP 64 (part), whit descriptions of lithology and palaeontological content (red lines indicate the boundaries of lithological units and inclination of beds)

granular. Frontal margin overall straight, with concavities at distal extremes that may be orbital notches. Marginal rim flat, beginning at outer-orbital angle, extended at the second lateral lobe and laterally reduced, terminating in a strong posterior spine. Marginal rim positioned below remainder of carapace surface, rim with smooth surface and smooth margin. Axial region long, narrow, extending more than 75 percent length of carapace. Posterior axial lobe elongate, slightly constricted at about mid-length; first axial lobe polygonal, weakly differentiated from posterior axial lobe, second axial lobe elongate, flattened, wider at mid-region; first lateral lobes elongated, narrow; second lateral lobes oblique, strongly inflated, slightly reniform, elongate, terminating anteriorly just posterior to orbital notch. Third lateral lobes subdivided posteriorly towards the first axial lobe. Inner lyrate keel weak, short,

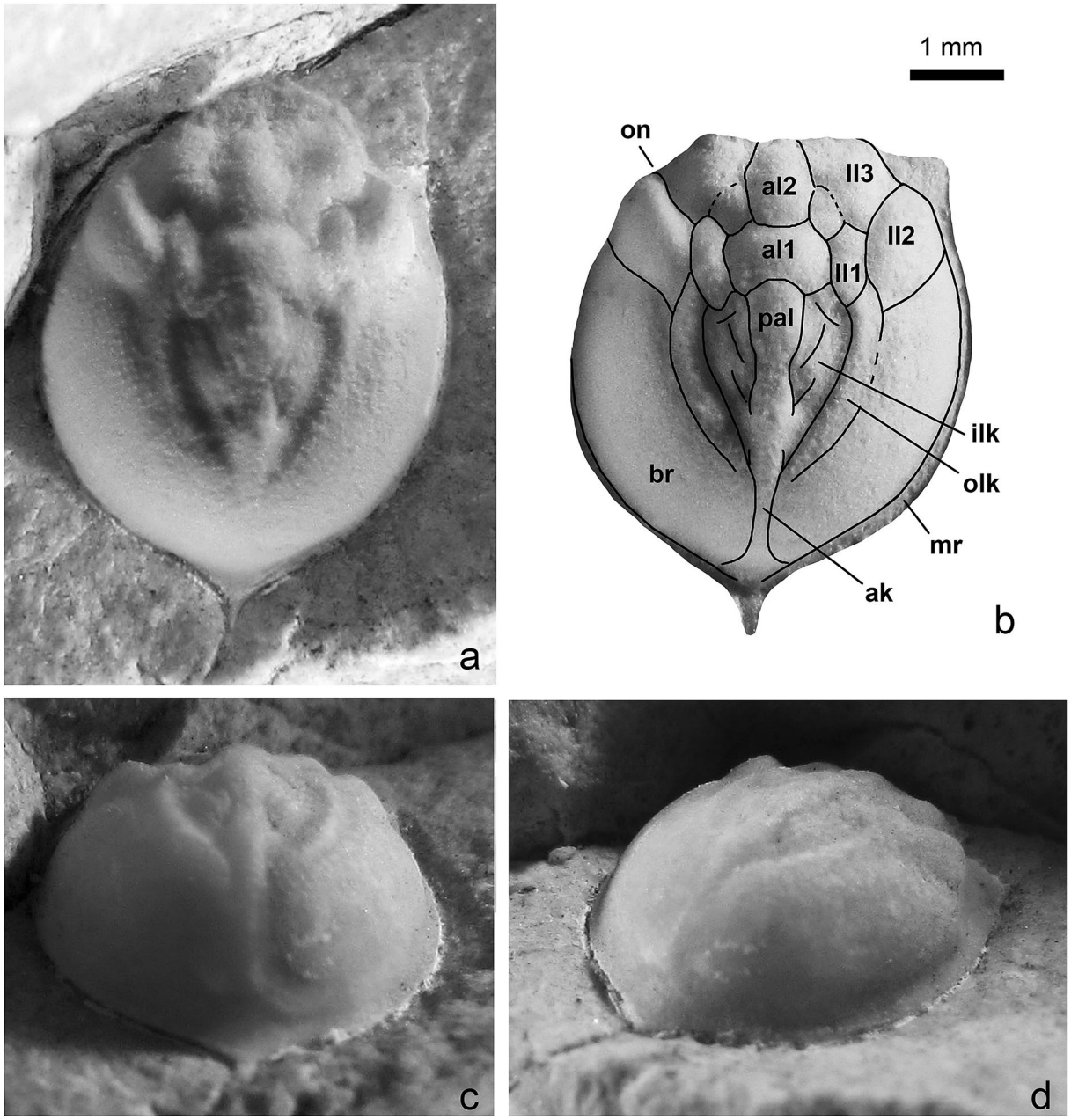

Fig. 3 Specimen MSNVI-SOST-01. **a** dorsal view; **b** the same image with marked morphological features [*ak* axial keel, *al 1–al 2* axial lobes 1–2, *br* branchial region, *ilk* inner lyrate keel, *ll 1–ll 3* lateral lobes 1–3, *mr* marginal rim, *olk* outer lyrate keel, *on* optic notch, *pal* posterior axial lobe]; **c** posterior view; **d** lateral view

separated from long outer keel extending from posterior of second lateral lobe, arcing axially crossing axis.

Measurements (carapace) length 5 mm; width 4.3 mm; maximum thickness 1.7 mm; total width of the lateral lobes area 3.7 mm; total length of the axial region 3.8 mm.

Remarks Zorn (1971) described three specimens from Monte San Salvatore (uppermost Middle San Salvatore Dolomite, Gervillienhorizont, Early Ladinian, Curionii Zone, 70 m E from P. 856). He described also other specimens from the localities near Kaisten (Canton Aargau, CH, Trigonodusdolomit) and Edlisberg (near Waldenburg, Canton Baselland, CH, Middle Muschelkalk). Among these specimens, Zorn identified three morphotypes. The first one has a carapace wider than long (two specimens from Monte San Salvatore);

the second one has a carapace longer than wide, with a reduced marginal rim and well-developed anterior lateral lobes (one specimen from Monte San Salvatore); the third one based on juvenile specimens, with carapace longer than wide and large keel region (from other localities). The present specimen fits very well with the second morphotype.

Occurrence The present specimen was found in the San Salvatore Formation of Sostegno (BI, Italy), probably in a Lower Ladinian bed.

Other occurrences The species *H. agnota* was previously documented from the epicontinental Middle Triassic of Germany (Baden-Württemberg, Rottweil Formation, Muschelkalk) and northern Switzerland (Trigonodusdolomit and Middle Muschelkalk), from the Middle Triassic of the Eastern Alps in Switzerland (Ducan-Landwasser area, Silveretta Nappe, Prosanto Formation) and from the Middle Triassic of the Southern Alps in Switzerland (see Bürgin et al. 1991; Furrer, 2019; Schweitzer et al. 2020, and the varieties described by Zorn, 1971 from Monte San Salvatore).

Paleoecology and environment

According to Zorn (1971), *H. agnota* could have lived in a hypersaline environment corresponding to the intertidal environment of the Lower Ladinian Gervillienhorizont at Monte San Salvatore. The specimens described by Zorn from Monte San Salvatore were collected with only two species of bivalves: *Modiolus salzstettensis* Hohenstein, 1913 and *Bakevellia costata* (von Schlotheim, 1820), one fragment of ammonoid (*Monophyllites* sp.) and a reptile remain (vertebra). *H. agnota* was documented also in the upper Prosanto Formation (Early Ladinian) of the south-eastern Swiss Alps (Ducan and Landwasser region near Davos, Canton Graubünden, Austroalpine Silvretta Nappe), with a paleoenvironment well comparable to the Besano/Monte San Giorgio Basin (Bürgin et al., et al. 1991; Furrer, 2019), characterized by anoxic to dysoxic bottom water conditions. Rare Cyclida were cited by Stockar and Garassino (2013) from the Sceltrich beds (Early Ladinian, lowermost part of Upper Meride Limestone, Monte San Giorgio, Ticino, Switzerland) and also by Furrer and Vandelli (2014: fig. at p. 89) from the lower Meride Limestone (Early Ladinian) (two unpublished specimens in the Cava superiore beds near Meride: personal information by Heinz Furrer, 21/10/2023). The neighboring partly time-equivalent San Salvatore Formation, Besano Formation, Meride Limestone, and San Giorgio Dolomite were deposited mainly between Lugano and Varese (Monte San Giorgio/Besano Basin). However, the geographical distribution of the San Salvatore Formation is wider (Fig. 1b) and the here-described locality represents the southwestern region. Therefore, the geographical distribution of *H. agnota* (and its varieties) extended from the Muschelkalk basin of southwestern Germany (Baden-Württemberg) to the Tethys realm of the western part of the Eastern Alps (Ducan-Landwasser area, Canton Graubünden) to the western part of the Southern Alps (Monte San Giorgio/Besano and also Biellese area).

Nothing definitive is known about the mode of life of Cyclida. Gall and Grauvogel (1967) suggested a benthic, predatory lifestyle of the Triassic *Halicyne* whereas Müller (1955) tentatively supposed a parasitic lifestyle, having lived on fishes. The latter interpretation would be supported by the abundance of fishes and other nektonic vertebrates in the finding horizons, where benthic organisms are almost lacking. Schram et al. (1997) suggested that the frequent association of many Paleozoic Cyclida with plant material might reflect a herbivorous or detritus-eating habit. There are several cyclidan species known from transitional marine or brackish environments to lake conditions (Schweigert, 2007; Schweitzer et al. 2020). For example, *Halicyne plana* (von Seebach, 1857) was documented from the Ladinian Erfurt Formation in Thuringia (Germany), where different kinds of fish, amphibians, and archosauriforms have been found, suggesting a lake or brackish environment (Schweitzer et al. 2020).

Conclusion

The finding of *Halicyne* cf. *agnota* represents the first paleontological significative occurrence of invertebrate fossil in the San Salvatore Formation cropping out in the Sostegno area. The present small specimen possesses some features (e.g., thin marginal rims, wide outer lyrate keels, longer outline) not seen in the holotype or other typical forms of *H. agnota*, but it corresponds with the morphotype 2 of Zorn which is atypical to *H. agnota* and, so far, exclusive of the San Salvatore Formation. Because of the rarity, the intraspecific and ontogenetic variations of this taxon, and other similar forms, are still unknown.

Cyclida often occurs in shallow-marine neritic or somewhat restricted lagoonal habitats or estuarine environments with rapidly changing salinity conditions (Schweigert, 2007). *Halicyne* was previously documented from the middle San Salvatore Formation at Monte San Salvatore (Gervillienhorizont, Early Ladinian, according to Zorn, 1971) associated with few other fossil remains. The Sostegno Basin represents the southwestern outcrop area of the San Salvatore Formation. The finding of *Halicyne* from this locality in supposed Lower Ladinian beds here described, could suggest a similar environment of the same age. In the Rasa dolostone, although the rich fauna collected and partially documented in the literature (see introduction) as well as the material stored in the

museums (unpublished data at the hand of the author of this paper), Cyclida was not found so far. This lack could be justified by a different environment corresponding to the Rasa dolostone beds so far investigated, probably characterized by more regular salinity conditions. Moreover, up to now the occurrence of *Halicyne*, as well as other Cyclida, is considered rare everywhere.

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Author contributions
VP designed, wrote the study, select, made images for figures, classified and treated the systematics of the material herein described. VP photographed the specimen of *Halicyne* (MSNVI-SOST-01).

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Availability of data and materials
The material described and illustrated here comes from the collection of San Salvatore Formation fossils in the Museo di Storia Naturale "A. Stoppani" di Venegono Inferiore (MSNVI), where all data are available. The specimen of *Halicyne* and other samples of rocks herein described are stored in the deposit of the above cited museum.

Declarations

Competing interests
The author declares that he has no competing interests.

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