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MIDDLE TRIASSIC ECHINODERMS FROM THE SAN SALVATORE FORMATION OF LOMBARDY (ITALY) AND CANTON TICINO (SWITZERLAND)

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Abstract. An echinoderm fauna from the San Salvatore Formation (Middle Triassic, Southern Alps) is here described in detail for the first time. Identifiable crinoids and echinoids were collected from three different localities: Mt. San Salvatore (Ticino, Switzerland), Rasa di Varese and San Michele (Lombardy, Italy). Crinoid taxa include *Encrinus* cf. *aculeatus*, *Holocrinus* sp. indet., *Zardinicrinus* cf. *granulosus*, Encrinidae gen. et sp. indet. Echinoid taxa include "*Cidaris*" cf. *roemeri*, *Serpianotiaris* sp. indet., *Triadocidaris transversa*, *Triadocidaris* sp. indet., and an indetermined form (Cidaridae). Most of the material was collected from Rasa di Varese, along with a rich upper Anisian ammonoid and conodont fauna, belonging to the upper Reitzi Zone and the Secedensis Zone. Migration of crinoids have been documented during the upper Anisian (from upper Pelsonian to lower Illyrian), mainly from the westernmost Tethyan Realm northward to the Germanic basin. Crinoid taxa already reported in the lower and upper Illyrian of the Germanic basin have also been collected, dated here to the late Illyrian (upper Reitzi Z.-Secedensis Z.) suggesting that several taxa migrated southwards in the Tethys realm during the late Illyrian.

Introduction

In the Southern Alps, echinoderms from upper Anisian-Ladinian carbonate platforms are poorly known. In the Esino Limestone platform, widely cropping out in Lombardy, Stoppani (1857, 1859: 123) described some columnals assigned to *Encrinus liliiformis* Lamarck, 1801 (incorrectly in Stoppani 1859: 335 = *Encrinites liliiformis* Schlotheim, 1820) and *E. granulosus* Münster, 1841. Similar finds were cited by other authors (e.g., Jadoul et al. 1992, crinoids columnals from Parina Valley, Bergamo). In the Marmolada Limestone platform (Dolomites), Salomon (1895) described some fragmentary remains of echinoids.

More recently, Hagdorn et al. (2018) described some crowns and columns of *Encrinus aculeatus* von Meyer, 1849 from an uncertain Pelsonian or lower Illyrian single bedding plane coming from Roncobello (Brembana Valley, Orobic Alps, Italy).

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The exact locality of this last find is unknown, so this interesting material lacks of any detailed geological and stratigraphic information [some comparable specimens from the area between Baita dei Muffi and Cima di Menna, housed at the Museo di Storia Naturale "Antonio Stoppani" di Venegono Inferiore (Seminario Arcivescovile di Milano, hereinafter referred as MSNVI)] can be assigned to the Ladinian Varenna Limestone.

In the nineteenth century, during the first attempts of stratigraphic correlation between the Northern Alps and Southern Alps Triassic faunas, some crinoid beds were considered possible biostratigraphic markers. Lepsius (1878) identified the *Dadocrinus gracilis* Zone (Horizont bei Recoaro) = Lower Muschelkalk of Val Trompia as corresponding to the Wellenkalk (Germanic Lower Muschelkalk, Pelsonian). In this way, through some columnals assigned to this species, different and geographically distant Triassic formations were regarded to be coeval. However, Mojsisovics (1880) assigned about the same levels to the Zone des *Ceratites binodosus* (Kleinknollige Kalk + Guttersteiner Kalke). Bittner (1881, 1883) considered the *Ceratites binodosus* Zone younger than the *Dadocrinus gracilis* Zone (Horizont von Recoaro). Arthaber (1906) considered the *Dadocrinus gracilis* Schichten (Süd-Alpen) as coeval of the Guttersteiner Schichten (Nord-Alpen). After several attempts to redefine the *Dadocrinus gracilis* Zone, Gaetani (1969, p. 486) considered it as unusable. This because the *Dadocrinus gracilis* (von Buch, 1845) (see rev. by Hagdorn 1996), type locality Recoaro (Vicentinian Alps), is difficult to ascertain due to the columnalia variability and the rarity of cups.

The San Salvatore Formation (Salvatoredolomit according to von Buch 1827; Plattendolomit + Diploporendolomit + Korallen-Dolomit, in Senn 1924) crops out in western Lombardy, northern Piedmont (Italy) and in the Lugano Lake area (Switzerland) (Fig. 1).

In Lombardy, the San Salvatore Formation crops out from the Maggiore Lake to the Como Lake, and in particular, around the Monte Chiusarella (Varese) known in the nineteenth century as "Monte Rasa". This locality was mentioned for the first time by Stoppani (1857) who, together with Gaetano Negri, figured a fossil-rich dolomitic sample collected from the area (Negri 1874, fig. 80). Later, several authors briefly reported some fossil remains yielded from the "Monte Rasa" outcrops (Mojsisovics 1882; Tommasi 1885; Mariani 1901). The short note (devoid of any figures) by Airaghi (1935) provided the first scientific study of the twentieth century on the Triassic fauna of the Rasa Valley. In this work, Airaghi introduced the informal name "Dolomia della Rasa" named here Rasa dolostone, an informal unit of the San Salvatore Formation (Plattendolomit + Diploporendolomit + Korallen-Dolomit, in Senn 1924). The informal Rasa dolostone indicates the facies of the San Salvatore Formation with the richest and most diversified macrofossil contents, represented by abundant cephalopods (ammonoids, nautiloids and coleoids, see Pieroni 2011; Pieroni & Prinoth 2021), whereas in most of San Salvatore Formation cephalopods are very rare. The San Salvatore Formation, characterized essentially by bivalve faunas (Zorn 1971), is also more uniform in the thickness of beds, usually massive, and in the color of rock, usually white-grey. Bed thickness in the fossiliferous facies of the San Salvatore Formation (Rasa dolostone) is extremely variable from few centimeters to several meters, and secondary mineral components staining the rock usually white-rosy, hazel or yellowish. Decades of work of excavation and road maintenance in and around the Rasa village provided a great number of fossil remains.

The fossil record consists of a highly diversified upper Anisian (Middle Triassic) marine fauna, largely represented by gastropods and bivalves, but also ammonoids and both, marines and terrestrial, vertebrates remain. Ammonoid association corresponds to the uppermost Anisian fauna documented by Rieber (1973) in the Besano Formation (Grenzbitumenzone) of Mt. San Giorgio (Canton Ticino, Switzerland). In the Mt. San Giorgio area, echinoderm occurrences have been very rarely reported (Jeannet 1933) in the Meride Limestone (Cava Superiore beds, Ladinian), overlapping the Besano Formation. Crinoids were cited from several outcrops in the San Salvatore Formation, but commonly, they are poorly preserved. Up to now, echinoids were never reported in the San Salvatore Formation.

Recently, the San Salvatore Formation faunas provided material for some paleontological investigations (Pieroni 2011; Renesto & Pieroni 2013; Pieroni & Nützel 2014; Conti 2017; Pieroni & Prinoth 2021).

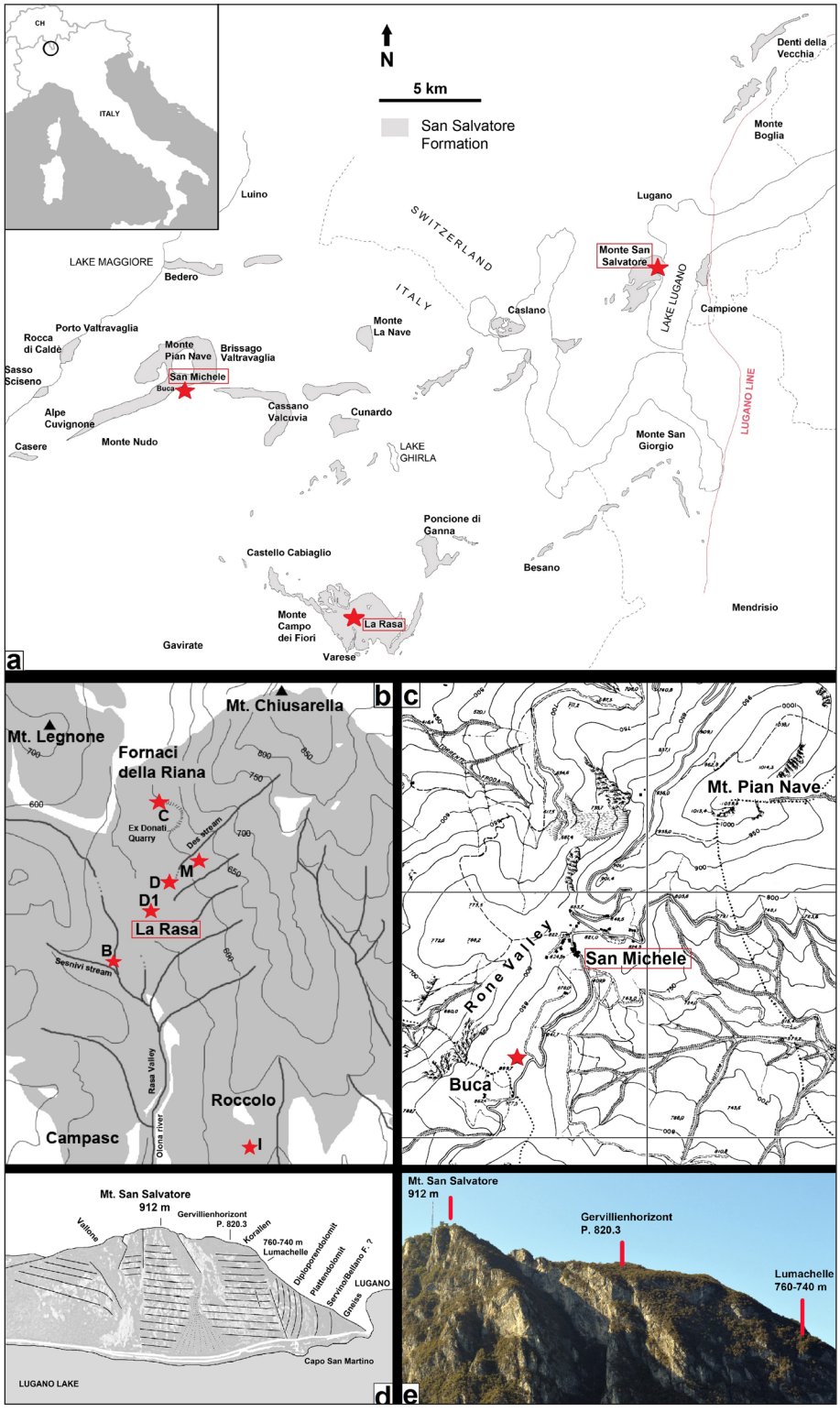

Fig. 1 - Geographic location and distribution of the specimens discussed in this study. a) outcrops (grey areas) of the San Salvatore Formation in the subalpine foothills of Lombardy (Italy) and Canton Ticino (Switzerland). The stars indicate the fossiliferous outcrops here described; b) geographical sketch of Rasa di Varese. The stars indicate the location of the outcrops considered in this paper; c) geographical map of San Michele village and surroundings; d-e) Mount San Salvatore (Lugano, Switzerland) with a stratigraphical sketch according to the study of Zorn, 1971.

The present work aims to integrate our knowledge about the biodiversity and palaeoenvironment of the San Salvatore Formation with the description of the crinoid and echinoid assemblages from Mt. San Salvatore (the type locality), Rasa Valley, and San Michele-Alpe Buca outcrops.

Previous echinoderm findings

Echinoderms from the San Salvatore Formation were reported for the first time by von Buch (1827) who documented crinoid columnals (*Encrinitenglieder*), and listed these forms without provid-

ing a description or illustration. In the second half of the nineteenth century, Giuseppe Stabile examined the locality of Cappella di San Martino (M. San Salvatore, Lugano) which yielded a rich fossil content. Stabile shared his findings with Merian (1854) who published a list of these fossils (1854: 88). He reported the taxon *Encrinites liliiformis* Schlotheim, 1820, also in this case not providing a description or an illustration. In the same year, Stabile (1854) published a "Memoria" adding new species, not previously described by Merian. Stabile shared this material with Hauer (1855) who published a new study, where the list provided by Merian was revised. However, Hauer did not go beyond the illustration of several invertebrate remains and he simply listed *Encrinites liliiformis*.

Stabile (1856) provided new material from Mt. San Salvatore, that was described again by Hauer (1857), but no echinoderms were reported. Later Stabile sent to Stoppani (1860) all the material already determined by Merian and Hauer, together with new specimens. Stabile donated these samples to the Museo Civico di Storia Naturale of Milano.

Stoppani revised the fossil list with the identification of 56 species. However, he simply listed his identifications of the crinoid remains. He noted that *E. liliiformis* is a common species in the Esino Limestone, San Cassian Formation as well as the Muschelkalk of Silesia.

Mariani (1901) revised the San Salvatore fauna considering the specimens deposited in the Museo Civico di Storia Naturale of Milano and in the Museo di Storia Naturale di Lugano. In this work, 51 species were identified, including *Encrinus liliiformis*. After the 1943 bombing (World War II) the main historical collections stored in the Museo Civico di Storia Naturale of Milano resulted, more or less, completely lost (Teruzzi 2015).

Tornquist (1902: 56), according to Frauenfelder (1916), reported from Mt. San Salvatore (100 m NE from the point 820.3, see Schmidt & Steinmann 1890) *Encrinites liliiformis* but without description. Zorn (1971) reported crinoid remains (devoid of any descriptions) in the San Salvatore Formation from Mt. San Salvatore and other localities around the Lake of Lugano (in particular in the following facies: Riffschutt-Fazies = back-reef bioclastic grainstone; Korallenschwammbiolithit-Fazies = boundstone with corals and calcareous sponges associated with patch reefs sediments in a back-reef area; Grapestone-Fazies = grainstone probably deposited in a shallow sheltered lagoon; Lumachellen-Gervillienhorizont = bioclastic fossil-rich dolostone with *Bakevellia costata ticinensis* Zorn, 1971.

In the preliminary work of Pieroni (2011), echinoderm remains from the San Salvatore Formation are figured for the first time and described in detail. The first occurrence of echinoid species in this formation is reported and the specimen is illustrated. Pieroni (2011) documented material from Rasa di Varese, both newly collected and from the MSNVI deposits: this material represents the base of the present work.

Stratigraphy

The San Salvatore Formation is a thick-bedded or massive light gray, white-pinkish, or hazel dolostone. Zorn (1971, 1972) described this formation at the Mt. San Salvatore, where he identified three members (Fig. 2): lower, middle, and upper San Salvatore Formation, late Anisian (Illyrian) to Ladinian in age (see also Furrer 1995). The macrofossils (mainly several species of bivalves) occur essentially between the middle and the upper members of the San Salvatore Formation, in particular below the "Gervillienhorizont" (identified by Frauenfelder, 1916, emended by Zorn, 1971: probably corresponding to the Anisian/Ladinian boundary; Zorn, 1972 assigned this level only to the lower Ladinian, but no one followed this opinion). Slightly above the equivalent "Gervillienhorizont" in the Rasa Valley, a small outcrop of the Cunardo Formation (Allasinaz 1968) is documented by Renesto & Pieroni (2013). The Cunardo Formation is usually represented by yellowish or whitish well-bedded dolostones and limestones, early to late Ladinian in age according to its ammonoid fauna (Calabrese & Balini 1995) and vertebrate remains (Lombardo et al. 2005). The San Salvatore Formation (Zorn 1971) derived from a shallow-water carbonate platform mainly in a reef and back-reef environment close to the Monte San Giorgio basin (in particular the middle San Salvatore Formation and the Besano Formation are considered time-equivalent, see Zorn 1971, Bernasconi 1991).

Echinoderms were collected by Zorn (1971) essentially in the "Lumachelle" facies of the north-eastern slope of Mt. San Salvatore, at 740-760 m of

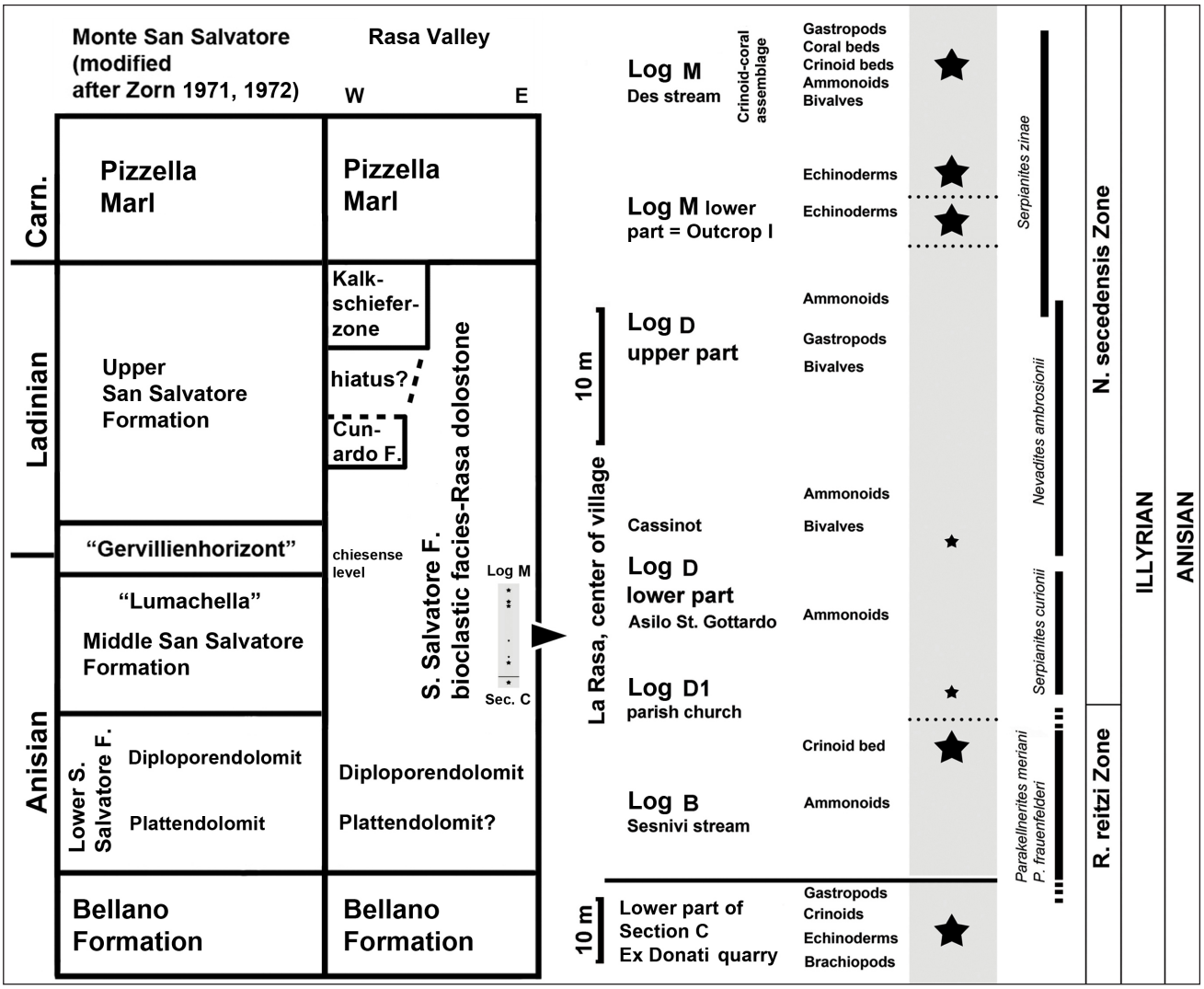

Fig. 2 - On the left, lithostratigraphic units (Bellano Formation, San Salvatore Formation and Pizzella Marl) at Monte San Salvatore (modified after Zorn 1971, 1972) correlated with corresponding units in the Rasa Valley (not in scale). The small grey interval (from section C to Log M) on the left marks the studied beds (enlarged on the right side of the figure) with a simplified center of Rasa village section, based on ammonoid biostratigraphy considered in this paper. A different scale is used for section C = ex Donati quarry, with strongly massive beds. The stars indicate the echinoderm occurrences (big stars = fossils very abundant; small stars = fossils rare). Dotted lines represent the main interruptions in the section of Rasa village.

altitude. This facies was determined to be in the Secedensis Zone (late Illyrian; Zorn 1971 and Rieber 1973) based on a few findings of ammonoids such as *Serpianites luganensis* (Merian, 1854). Along the Rasa Valley, the Middle Triassic succession is exposed in several outcrops. The thickness is variable from 400 meters at Rasa to about 900 meters (according to Senn 1924), between the Motta Rossa pass and the Bregazzana village (Varese), with strata dipping southward at an angle of about 30°: here fossiliferous beds and lenses are present.

Findings occur in many outcrops and the fossil content is abundant. These are mainly characterized by a rich ammonoid fauna (Pieroni 2011) associated with nautiloids (Pieroni & Prinoth 2021) brachiopods, bivalves, echinoderms, gastropods (Pieroni & Nützel 2014), and vertebrate remains (Renesto & Pieroni 2013). The discovery of large terrestrial vertebrate remains suggested a depositional environment close to an emerged area.

In the center of the Rasa village as well as the surrounding areas, at least 25 fossiliferous outcrops (stratigraphic sections, usually not completely exposed, are subdivided in outcrops or "sub-sections" with beds clearly observable) were examined and named as follow: A, A1, A2, B, B1, B2, C, C1, C2, D, D1, D2, E, E1, F, G, H, H1, H2, I, J, K, L, M, N (see Pieroni 2011; Renesto & Pieroni 2013; Conti

2017), identified and named by distinctive letters from "A" to "N". Specimens described in the work herein were collected in outcrops B, C, D, D1, I and M (as detailed in Materials). The biostratigraphy of the material described in the present work is largely based on the work on ammonoids of the Rasa Valley, currently in preparation by one of us (VP).

According to biozones of uppermost Anisian (Illyrian) and Anisian/Ladinian boundary (Brack et al., 2005), the older fossil assemblages were collected in outcrop B and section C belonging to the upper *Reitzi* Zone, whereas outcrops D, I, and M belong to the slightly more recent *Secedensis* Zone (Fig. 2; see also Pieroni 2011). This age is confirmed by Conti (2017) who documented a rich conodont fauna from outcrops B, I, and M (in particular the occurrence of *Neogondolella aequidentata* Kozur et al., 1994 in outcrops I and M; other species need further studies, S. Conti personal communication). These new biostratigraphic data integrated relative age based on ammonoid biozones and confirmed the late Anisian age.

In the bioclastic-rich facies of the San Salvatore Formation (Rasa dolostone) echinoderms occur essentially at the base of the more fossiliferous beds (lowermost beds of section C), at the top of outcrop B (clusters of crinoid columnals in a thin bed), in the whole outcrops I and M (uppermost Secedensis Z. with *Serpianites serpianensis* Airaghi, 1912 and *S. zinae* Airaghi, 1912) below the *C. chiesense* level (outcrop B1, probably corresponding to the Gervillienhorizont, see Pieroni 2011). Echinoderms were not found in the overlying levels.

A stratigraphic study of the San Michele-Alpe Buca outcrop is still not available. Houten (1929) refers to the "Crinoidenbank" also the occurrence of *Diplopora* beds (= Diploporendolomit?), small gastropods, and bivalves. However, biostratigraphic markers are not documented.

Fossiliferous localities

The San Salvatore Formation outcrops between the Lake of Lugano and Lake Maggiore (Fig. 1; see Senn 1924; Leuzinger 1926; Houten 1929; Mattirolo et al. 1932; Nangeroni 1932; De Sitter 1939; Zorn 1971; Bernasconi 1991) and cannot be considered an isolated small carbonate platform, as suggested by Zorn (1971), but a much larger one. The San Salvatore Formation covers with small outcrop areas, a large region between northern Piedmont (Canavese Zone and Cusio-Biellese area of Sostegno Basin and Fenera Basin, see Bertotti et al. 1993; Berra et al. 2008; Beltrando et al. 2015; Decarlis et al. 2017; Festa et al. 2020) and the Lake Lario (north of Menaggio, see Bernasconi 1991; Bertotti 1991).

The type locality of the San Salvatore Formation is Mt. San Salvatore, close to Lugano (Switzerland). From this locality (close to the top of this mountain, at Point 820.3, see Zorn 1971) only local accumulations of columnals were collected by Zorn (1971; unpublished material stored in the Paläontologisches Museum der Universität Zürich). Few additional poorly preserved specimens are stored in the Museo Cantonale di Storia Naturale of Lugano and they were probably collected in the same locality by Silvio Calloni (a nineteenth century collector).

The Rasa di Varese is a small village located in the Subalpine foothills (North of Varese, Italy; Fig. 1) at an elevation of 553 meters above sea level, along the Olona river. From a San Salvatore Formation outcrop located near the village of San Michele (Mt. Pian Nave, Travaglia Valley, northwestern Lombardy) several specimens of crinoids are here described for the first time.

This locality was previously documented by Houten (1929: 9-10), who observed in the "Untere Dolomitserie" near Alpe Buca a massive bed with "Encrinus-Stielgliedern" (= columnals of Encrinus). The locality Alpe Buca was cited as very fossiliferous by Nangeroni (1932), who did not refer to any crinoid finds.

Materials

Most of the specimens described in the present study were collected from the Rasa di Varese (or "La Rasa"). This material comprises 63 samples which provided 143 echinoderm specimens of crinoids and echinoids (115 crinoids and 28 echinoids) as detailed in Supplementary Table 1. These specimens were collected from outcrops (section C and outcrop I) and logs (B, D, D1, and M) according to the following:

Log B (WGS84 coordinates 45°51'50"N, 8°48'15"E) - strata outcropping near the confluence of the Olona river and the Sesnivi stream, yielded 12 crinoid and four echinoid specimens.

Section C (WGS84 coordinates 45°52'10"N, 8°48'26"E) - Ex Donati quarry, yielded four cri-

noid and two echinoid specimens. Beds of section C are considerably thicker with respect to beds of the main section (composed by logs B, D, D1 and M) in the center of Rasa village.

Log D and D1(D = WGS84 coordinates 45°51'19"N, 8°48'23"E; D1 = WGS84 coordinates 45°51'57"N, 8°48'22"E) - two different outcropping sites, located in the center of the village, yielded two crinoid and six echinoid specimens.

Outcrop I (WGS84 coordinates 45°51'24"N, 8°48'38"E) - southward of the village and close to the "Roccolo", yielded 32 crinoids and 10 echinoid specimens. This small outcrop stratigraphically correspond to the lower beds of log M.

Log M (WGS84 coordinates 45°52'03"N, 8°48'29"E) - beds outcropping at NE of the Rasa village, yielded 47 crinoid and six echinoid specimens.

All this material is housed at the Palaeontological Collection of Museo di Storia Naturale "Antonio Stoppani" di Venegono Inferiore (Seminario Arcivescovile di Milano).

We also examined 27 crinoid specimens from Alpe Buca, close to the village of San Michele, Varese (WGS84 coordinates 45°56'20"N, 8°42'33"E). All these crinoids are embedded in a gray-hazel bioclastic calcarenite block belonging to the San Salvatore Formation. This material is also housed at MSNVI and identified by the inventory number prefix "MSNVI-MIC".

Three samples with crinoid columnals collected by Zorn in 1970, near the top of Mt. San Salvatore (slightly towards NE of the Point 820.3, Lugano, Switzerland) in the "Lumachelle" (Middle Salvatore Formation) with coral assemblage "Korallenstock", were also studied. The co-occurrence (see Zorn 1971, p. 14; H. Furrer, personal communication, 20/06/2021) with three specimens of *Serpianites luganensis* (Merian 1854) (vidit V. Pieroni) suggests a latest Anisian age (Secedensis Zone). They are currently stored in the Paläontologisches Museum der Universität Zürich (PIMUZ) with the inventory number PIMUZ 6702, PIMUZ 37719, PIMUZ 37720.

Systematic Palaeontology

Class **CRINOIDEA** Miller, 1821
Superorder **Articulata** Zittel, 1879
Order **Holocrinida** Jaekel, 1918
Family Holocrinidae Jaekel, 1918
Genus *Holocrinus* Wachsmuth & Springer, 1887

Type species*: Encrinus beyrichi* Picard, 1883

Holocrinus sp. indet.

Fig. 3a-d

Material: one 1.33 mm wide columnal MSNVI-I-51a; one 1.7 mm wide columnal MSNVI-I-51b; one 2.7 mm wide columnal MSNVI-I-51c; one incomplete 3 mm wide columnal MSNVI-I-51d.

Description. Four very small columnals, stellate, diameter 1.33, 1.7, 2.7, and 3 mm wide. Lumen is small and circular. Articular facet with moderate thick marginal and denticulate adradial crenulae arranged in five bands. The areola is slightly depressed. Petal floor well developed, wide and lanceolate.

Remarks. This very small-sized material was sampled, prepared, and documented in the work of Conti (2017). The etching process pointed out some diagnostic characters (stellate outline, lumen small and circular, thick marginal crenulae) useful to assign these samples to *Holocrinus*.

Occurrence. This species is distributed in lower Anisian-Pelsonian and occurs in Hungary, Germany, and Poland (Hagdorn & Gluchowski 1993; Gluchowski & Salamon 2005). In the present paper, *Holocrinus* was reported for the very first time in the Secedensis Zone of Rasa di Varese.

Order **Encrinida** Matsumoto, 1929
Family Encrinidae Dujardin & Hupé, 1862
Genus *Encrinus* Lamarck, 1801

Type species: *Encrinus liliiformis* Lamarck, 1801

Encrinus cf. ***aculeatus*** von Meyer 1849

Fig. 3e-f

Material: one proximal cirrinodal MSNVI-I-45.

Description. One proximal cirrinodal (MSNVI-I-45) with a strongly thickened rim and circular epifacets; two cirral scars protruding as lateral extensions of this nodal, articulation multiradiate. According to Hagdorn et al. (2018), *E. aculeatus* could have up to five cirrus scars, but as

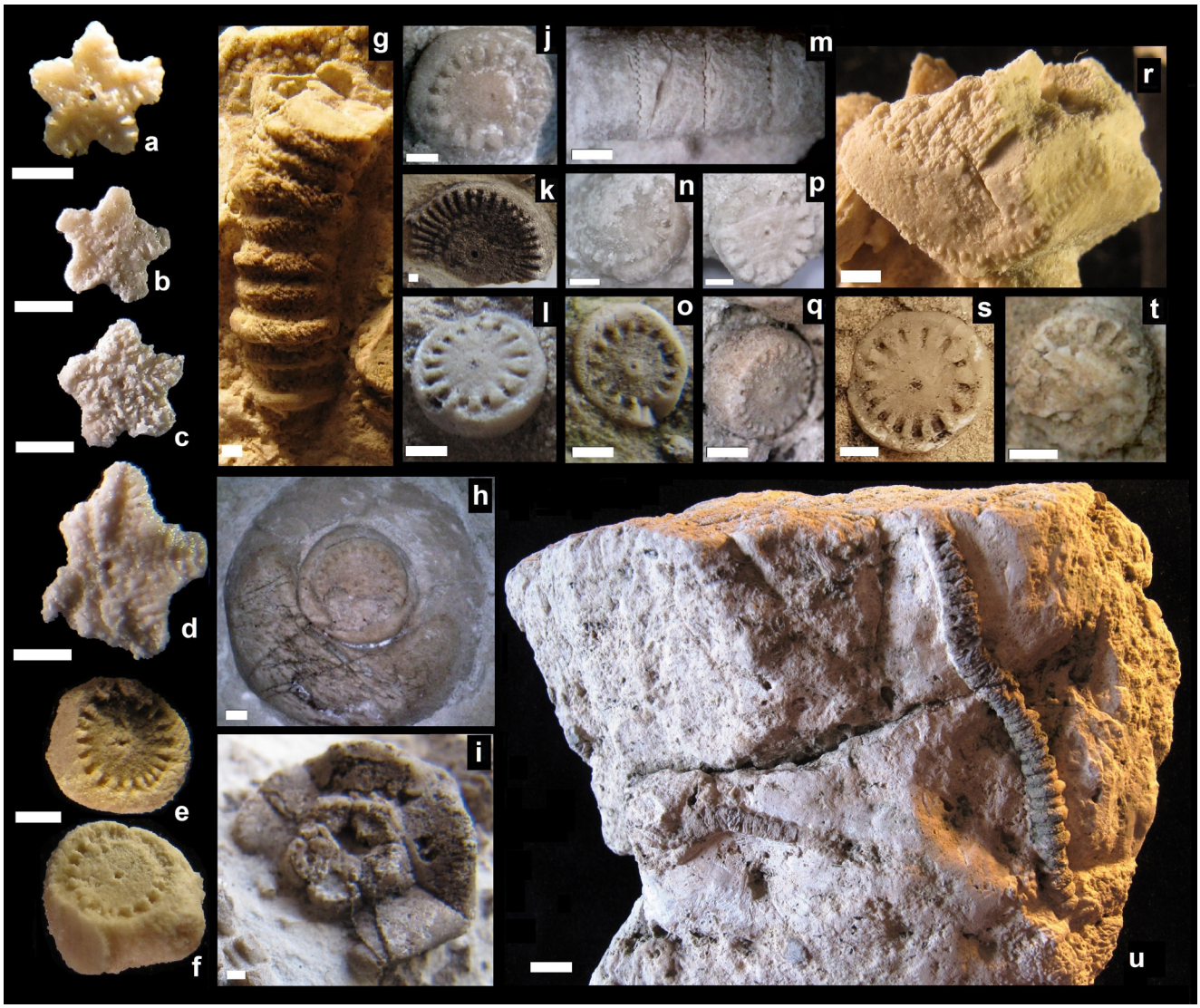

Fig. 3 - a-d) *Holocrinus* Sp. indet. a - columnal MSNVI-I-51a. Scale bar 0.5 mm; b - columnal MSNVI-I-51b; c - columnal MSNVI-I-51; d - incomplete columnal MSNVI-I-51d; e-f) *Encrinus* cf. *aculeatus* von Meyer, 1849; e - columnal, f - proximal cirrinodal MSNVI-I-45; g-u) Encrinidae gen. et sp. indet. g - proximal or medial stem portion MSNVI-M-03; h - subcircular cup in dorsal view MSNVI-I-09; i - cup with low basals MSNVI-MIC1a; j - medial or distal columnal MSNVI-C-09b; k - columnalia and a pluricolumnal of 5 columnalia MSNVI-MIC2a-d; l - low proximal columnal MSNVI-I-10; m - pluricolumnal MSNVI-I-45o; n - medial or distal columnal MSNVI-I-45g; o - proximal columnal MSNVI-M-24a; p - medial or distal columnal MSNVI-I-45h; q - proximal columnal MSNVI-M-09d; r - Zygosynostosial facet of 1st or 2nd primaxillary MSNVI-I-45p; s - low proximal columnal MSNVI-I-10; t - medial or distal pluricolumnal MSNVI-B-84f; u - crushed calyx fragment and a stem portion MSNVI-M-02. Scale bar 1 mm.

this feature is common to other species, isolated cirrinodal is not diagnostic with certainty.

Occurrence. *Encrinus aculeatus* is middle to late Anisian (Pelsonian - early Illyrian) in age and occurs in Upper Silesia (Poland), Germany, Italy, and Hungary. This species was described by several authors (Assmann 1926, 1937; Hagdorn & Gluchowski 1993; Hagdorn et al. 1996; Hagdorn et al. 1997; Niedźwiedzki et al. 2011; Hagdorn et al. 2018). The present material from the Secedensis Zone of San Salvatore Formation (first report from this unit) probably belongs to this species.

Encrinidae gen. et sp. indet.

Fig. 3g-u, 4, 5a-c

Material: proximal dissociated columnal (MSNVI-I-10, MSNVI-M-09c, MSNVI-I-45d, MSNVI-M-24a, MSNVI-M-08a, MSNVI-M-09d); proximal or medial stem portion MSNVI-M-03; medial or distal dissociated nodal (MSNVI-B-86, MSNVI-B-88, MSNVI-D-30, MSNVI-I-45f. MSNVI-I-45i, MSNVI-I-45n, MSNVI-B-85a); one very long proximal-medial stem portion of ca. 35 columnalia, one crushed calyx fragment and one stem portion of 9 columnalia MSNVI-M-02; medial or distal dissociated columnal (MSNVI-B-84c, MSNVI-B-89, MSNVI-C-09a, MSNVI-C-09b, MSNVI-I-45b, MSNVI-I-45g, MSNVI-I-45h, MSNVI-MIC1c, MSNVI-MIC4d-r, MSNVI-MIC1b); medial or distal pluricolumnal (MSNVI-M-01b-n, MSNVI-M-04a, MSNVI-M-04b, MSNVI-

Fig. 4 - Encrinidae gen. et sp. indet. a) medial or distal nodal MSNVI-B-85a; b) medial or distal columnal MSNVI-I-45n; c) first columnal (stem basal) MSNVI-D-68; d) proximal pluricolumnal MSNVI-I-45d; e) medial pluricolumnal MSNVI-M-23c; f) distal pluricolumnal MSNVI-MIC3a; g-h) medial or distal pluricolumnal MSNVI-M-04a; i) medial or distal pluricolumnals MSNVI-M-04c-k; j) medial pluricolumnal MSNVI-M-23e; k) a dissociated proximal columnals MSNVI-M-08a; l) proximal pluricolumnal MSNVI-M-09c; m-p) numerous pluricolumnals and dissociated columnalia embedded in the rock matrix. m-n) PIMUZ-6702; o) PIMUZ-37719; p) PIMUZ-37720. Scale bar 1 mm.

M-04c-k, MSNVI-M-05a, MSNVI-M-05c-d, MSNVI-M-06a, MSNVI-M-06b, MSNVI-M-09a, MSNVI-C-10, MSNVI-B-84f); medial pluricolumnal (MSNVI-M-23c, MSNVI-M-23d, MSNVI-M-23e, MSNVI-M-23f, MSNVI-M-23g, MSNVI-M-23h); one very long (38 mm) medial or distal stem portion of 21 columnalia MSNVI-M-07a; one distal pluricolumnal of 4 very higher than wide columnalia MSNVI-MIC3a; one rock block with numerous pluricolumnals and dissociated columnalia embedded (PIMUZ-6702, PIMUZ-37719, PIMUZ-37720) first columnal (stem basal) MSNVI-D-68; pluricolumnals (MSNVI-I-45m, MSNVI-I-45o, MSNVI-MIC2a-d, MSNVI-MIC3b, MSNVI-MIC4a-c); Zygosynostosial facet of 1st or 2nd primaxillary MSNVI-I-45p; one subcircular cup in dorsal view MSNVI-I-09; one subpentagonal cup in dorsal view (MSNVI-M-01a); one subpentagonal cup in dorsal view (MSNVI-M-08c); one cup with low basals (MSNVI-MIC1a).

Description. Specimens are characterized by latera straight, swollen or slightly convex, somewhat high. Robust crenellae on the marginal rim, sometimes short which do not reach the margin. Numerous isolated columnals and pluricolumnals from the medial or distal portion of the stem, even barrel-shaped (MSNVI-MIC3a, one distal pluricolumnal comprised of four columnals, high barrel shape, higher than wide (height even double than width), except for the proximal columnal MSNVI-M-09d. Outline from subcircular to circular, from low to somewhat high and high (somewhat high on ave-

rage). Diameter 2-10 mm wide (5 mm on average); articulation multiradiate, articular facet with robust, thick, and short marginal crenulae, sometimes articular facet shorter than the whole columnal, suture line depressed and sometimes coarsely crenulated; lumen small and rounded (large in MSNVI-MIC2a-d, surrounded by a less discernible pentalobate perilumen in MSNVI-C-09a); latera straight or slightly convex, cirral scar rounded (MSNVI-B-85a, MSNVI-M-23h) but not always discernible, pluricolumnal swollen with undulated latera outline. Proximal columnals are circular and low with a robust multiradiate crenulation, nodals are wider than internodals, in the typical encrinid-like structure. Some stem portions are preserved in section (MSNVI-M-23g). Proximal-medial stem portions are sometimes very long (MSNVI-M-02 has ca. 35 columnalia).

Some variability can be observed but it is known that encrinid columnals are highly variable depending on their position within the column.

Three flat and bowl-shaped cups are visible in dorsal view, from circular to subcircular, radials are trapezoid and inflated (dorsal side) with deepened interradial suture line; rounded proximal columnal (MSNVI-I-09) with multiradiate articulation facet, culmina short and thickened rim. These three cups are very different from MSNVI-MIC1a which shows low basals visible in dorsal view, flat and low, pentagonal shaped; basalia large and erected against the stem axis, radial facet directed outward; no other features discernible. A medial or distal columnal, circular and rather high, latera straight; articular facet multiradiate comprised of stout and long crenulae. Lumen is small and rounded. This cup shows a very strong resemblance to *Carnallicrinus carnalli* (Beyrich, 1856) figured by Hagdorn (2010: fig. 4b).

Remarks. All these specimens cannot be confidently attributed to any genus and species. This is also true for the most complete sample MSNVI-M-02, represented by one crown fragment and a stem portion consisting of nine columnals. However, the rushed surface and poor preservation prevent any further identification.

Most of the characters here described are common to *Encrinus*, *Chelocrinus,* and *Carnallicrinus*. According to this, all these specimens cannot be attributed to any encrinid genus and species with certainty. Morphologies of these encrinids resemble that of Encrinidae gen. et sp. indet. from the Lower Muschelkalk of Raciborowice (SW Poland) as documented by Gluchowski & Salamon (2005: 88, fig. 4), Encrinidae gen. et sp. indet. 1 from the Middle Triassic of the Aggtelek platform (NE Hungary), described by Hardorn & Velledits (2006, fig. 6 a-d), and the indetermined encrinid described and figured by Hagdorn et al. (1997, pl. 2, figs a-c).

Genus *Zardinicrinus* Hagdorn, 2004

Type species: *Apiocrinites? granulosus* Münster, 1834

Zardinicrinus cf. ***granulosus*** (Münster, 1834)

Fig. 5d-i

Material: one 7 mm wide and 5 mm long pluricolumnal of 7 columnalia MSNVI-B-41; one 5 mm wide and 2 mm long distal pluricolumnal of two columnalia MSNVI-B-84a; one 6 mm wide columnal MSNVI-B-84e; one 2 mm wide and 7 mm long small pluricolumnal of 9 columnalia MSNVI-B-85b; one 11 mm wide and 8 mm long pluricolumnal of 10 columnalia MSNVI-B-87.

Description. Circular or subcircular and low columnals, slightly tuberculated, diameter 2-11 mm wide; no nodal scars visible, multiradiate articulation with long marginal and bifurcating crenulae toward the border, crenulated suture depressed, lumen narrow and circular.

Occurrence. *Zardinicrinus* is known from the Southern Alps in the lower Carnian Cassian Formation of the Dolomites and in the Ladinian of Mt. Clapsavon (Udine) and it was described by several authors (Tommasi 1900; Zardini 1976; Hagdorn 2004). The specimens studied herein resemble very closely *Zardinicrinus granulosus* figured by Hagdorn (2011, pl. 1, fig. u) and Zardini (1976, pl. 1, fig. 20), and according to the description provided, they were tentatively assigned to this taxon. In the present paper, a species of *Zardinicrinus* is reported for the first time from the San Salvatore Formation. The specimens described herein were collected in the upper Reitzi Zone from the informal unit of Rasa dolostone of the San Salvatore Formation of Rasa di Varese.

Encrinida fam. et gen. indet.

Fig. 5j-l

Material: indetermined almost complete (calyx + stem) MSNVI-C-30; indetermined encrinid radial showing distal facet MSNVI-I-45a; indetermined calcitic 2.7 mm wide pluricolumnal of 2 very low columnalia MSNVI-I-45c; large basal in lateral view MSNVI-M-05b encrinid ossicle MSNVI-B-84d; crinoid ossicle (MSNVI-I-51f, MSNVI-I-51g, MSNVI-M-04l, MSNVI-I-45e).

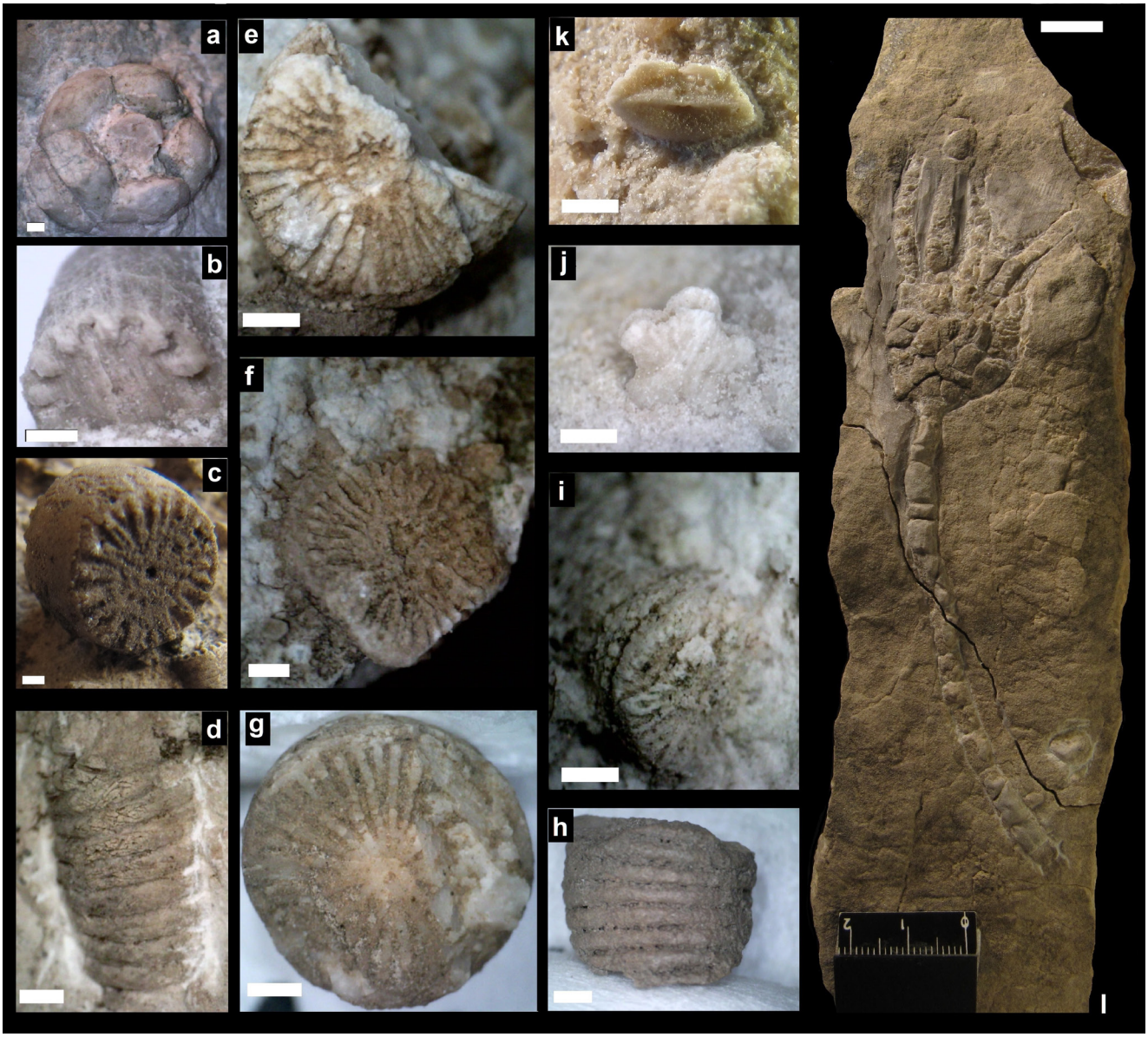

Fig. 5. a-c) Encrinidae gen. et sp. indet.; a - subpentagonal cup in dorsal view MSNVI-M-01a; b - pluricolumnal MSNVI-I-45m; c - columnal MSNVI-MIC1b; d-i) *Zardinicrinus* cf. *granulosus* (Münster, 1834); d - small pluricolumnal MSNVI-B-87; e - pluricolumnal MSNVI-B-84a; f - distal pluricolumnal MSNVI-B-84e; g-h) columnal MSNVI-B-41; i - pluricolumnal MSNVI-B-85b; j-l) Encrinida fam. et gen. indet. j - indetermined pluricolumnal MSNVI-I-45c; k - indetermined encrinid radial showing distal facet MSNVI-I-45a; l - indetermined almost complete (calyx + stem) MSNVI-C-30 (scale bar 10 mm). Scale bar 1 mm (otherwise is mentioned).

Description. MSNVI-C-30 is a poorly preserved crinoid sample provided of stem and calyx. Devoid of any significant diagnostic character, it is very resemblant to a species of *Encrinus* but could also belong to *Dadocrinus* or *Holocrinus*. Assessed as indetermined encrinid because the surface does not show plating but rather weathering.

MSNVI-I-45a indetermined encrinid radial showing distal facet. Radials are large, low, with trapezoidal aboral sides; radial facets directed upward, with a distinct transverse ridge. Other parts are not known. MSNVI-I-45c is a poorly preserved and calcitic pluricolumnal comprised of two very low columnals (internodals), pentalobate, diameter 2.7 mm wide, lumen small, no further features discernible. MSNVI-M-05b is an indetermined and large basal, visible in lateral view. MSNVI-B-84d, MSNVI-I-51f, MSNVI-I-51g, MSNVI-M-04l, and MSNVI-I-45e do not show any diagnostic character and were assessed as indetermined ossicles.

Remarks. All these specimens were identified at the order level as the family or the genus cannot be identified due to poor preservation of the sample, weathering, significant embedding of the specimen in the rock matrix, or broken/incomplete remains.

Class **ECHINOIDEA** Leske, 1778
Genus *Cidaris* Leske,1778

"Cidaris" cf. ***roemeri*** Wissmann, 1841
Fig. 6a

Material: one ornamented spine MSNVI-D-161e.

Description. One thorny, club-shaped spine, with funnel-shaped ribs, centrally depressed (longitudinally), with its apical portion partially eroded.

Remarks. Wissmann (1841, p. 47-48, pl.4, figs 3a-g) erected this species from the lower Carnian Cassian-Formation of the Dolomites on the base of its spines. MSNVI-D-161e resembles very closely the specimens figured by this author. The present specimen was collected in the Secedensis Zone from the informal unit of Rasa dolostone of the San Salvatore Formation of Rasa di Varese.

Cidaridae gen. et sp. indet.
Fig. 6b-d

Material: portion of one spine MSNVI-B-84h; portion of one 6 mm long spine MSNVI-B-84g; portion of one 4 mm long spine MSNVI-B-85c; one spine MSNVI-C-09d.

Description. Four incomplete club-shaped spines, unornamented or ornamented with fine parallel longitudinal ribs, 4-6 mm long. These fragmented spines cannot be assigned with certainty to a genus or a species.

Family Serpianotiaridae Hagdorn, 1995
Genus *Serpianotiaris* Jeannet, in Peyer, 1933

Type species: *Miocidaris (Serpianotiaris) hescheleri* Jeannet, 1933.

Serpianotiaris sp. indet.
Fig. 6e-k

Material: one partially embedded spine MSNVI-B-84b; one spine MSNVI-D-161d; one fragment of one spine MSNVI-D-161f; one 6 mm long spine MSNVI-M-24b; one interambulacrum MSNVI-M-07b; one interambulacrum from inside MSNVI-M-08d; one single interambulacral plate MSNVI-M-09b.

Description. Four long (up to 6 mm) and slender blade-shaped spines, unornamented; two fragments of an interambulacrum, one of them visible from inside; one dissociated interambulacral plate. The interambulacrum MSNVI-M-07b shows three primary tubercles and four secondary tubercles, with crenulate parapet. Primary tubercles, secondary tubercles and miliary tubercles have perforate mamelons. Interambulacra are denticulate at their adradial margins (MSNVI-M-08d).

Occurrence. *Serpianotiaris* was discovered for the first time by Peyer (1928) in the fossiliferous outcrop Acqua del Ghiffo (Cava Superiore beds, Meride Limestone, Ladinian, Fassanian). This genus was originally described from the Middle Triassic of Serpiano (Switzerland), and later in all morphological details by Hagdorn (1995) and Hagdorn & Schulz (1996) from the Lower and Upper Muschelkalk of Germany. A species of the genus *Serpianotiaris* is here reported for the first time from the San Salvatore Formation. The present material comes from the upper Reitzi Zone and Secedensis Zone, in the informal unit of the Rasa dolostone of the San Salvatore Formation of Rasa di Varese.

Family Triadocidaridae Smith 1994
Genus *Triadocidaris* Döderlein 1887

Type species: *Cidaris subsimilis* Münster in Wissmann & Münster, 1841

Triadocidaris transversa Meyer, 1851
Fig. 6r-y

1851 *Cidaris transversa* Meyer p. 276, pl. 32, figs 28-32.
1859 *Cidaris transversa* Meyer - Schauroth, p. 293, pl. 1, fig. 8.
1864 *Cidaris transversa* Meyer - Alberti, p. 55.
1894 *Cidaris transversa* Meyer - Tommasi, p. 62, pl. 1, figs 2a-b.

Material: four ornamented spine (MSNVI-I-45l, MSNVI-D-161a, MSNVI-D-161b, MSNVI-D-161c); portion of one spine (MSNVI-I-51e); five portions of ornamented spine (MSNVI-I-51i, MSNVI-I-51j, MSNVI-I-51k, MSNVI-I-51l, MSNVI-I-51m).

Description. Nine small, club-shaped cylindrical spines with thorny ornamentation. Thorns are verticillate, more or less developed and distally inclined.

Remarks. *Triadocidaris transversa* presents some variability in primary spines which can be short, granulated, or thorny (Hagdorn & Gluchowski 1993, fig. 10 [10-15]). Tommasi (1894) accurately described some spines from the Trinodosus Zone (Prezzo Limestone?) of Lenna (Val Brembana). Tommasi underscored the resemblance of his material with the type material of Meyer collected at Mikülschitz (Muschelkalk, Upper Silesia).

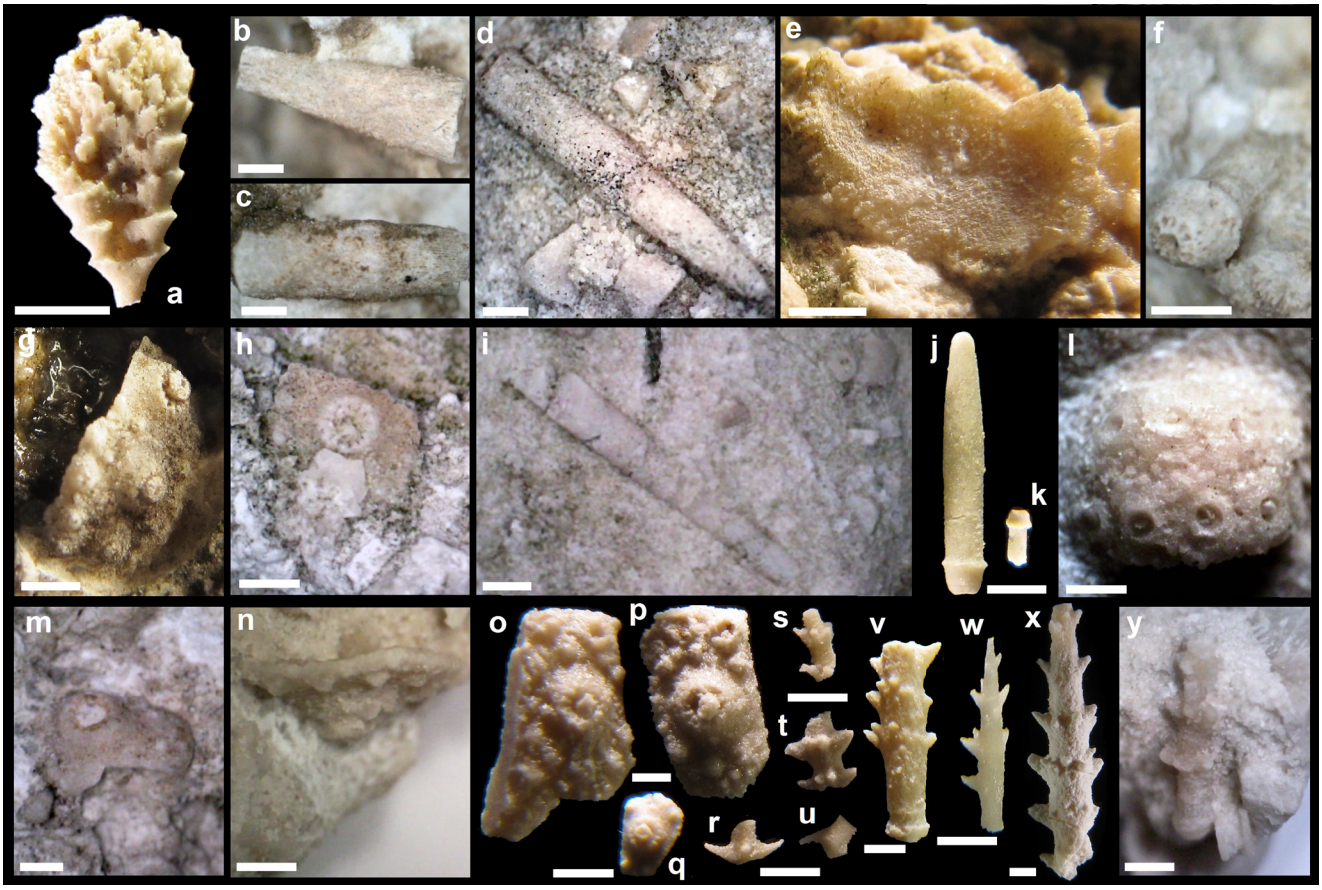

Fig. 6 - a) "*Cidaris*" cf. *roemeri* Wissmann, 1841, ornamented spine MSNVI-D-161e; b-d) Cidaridae gen. et sp. indet. b - portion of a spine MSNVI-B-84h; c - portion of a spine MSNVI-B-85c; d - spine MSNVI-C-09d; e-k) *Serpianotiaris*? sp. Jeannet, 1933 e - interambulacrum from inside MSNVI-M-08d; f - partially embedded spine MSNVI-B-84b; g - interambulacrum MSNVI-M-07b; h - single interambulacral plate MSNVI-M-09b; i - 6 mm long spine MSNVI-M-24b. j - spine MSNVI-D-161d; k - fragment of a spine MSNVI-D-161f; l-q) *Triadocidaris*? Döderlein, 1887; l - interambulacrum MSNVI-C-09c; m - single interambulacral plate MSNVI-I-45k; n - single interambulacral plate MSNVI-M-04n; o - interambulacral plate MSNVI-I-51o; p - interambulacral plate MSNVI-I-51n; q - a single interambulacral plate MSNVI-I-51h; r-y) *Triadocidaris transversa* Meyer, 1851; r - portion of an ornamented spine MSNVI-I-51j; s - portion of an ornamented spine MSNVI-I-51k; t - ornamented spine MSNVI-D-161b; u - portion of an ornamented spine MSNVI-I-51l; v - ornamented spine MSNVI-D-161c; w - ornamented spine MSNVI-I-51m; x - ornamented spine MSNVI-D-161a; y - ornamented spine MSNVI-I-45l. Scale bar 1 mm.

Occurrence. Upper Anisian of the Tethyan and Germanic Paleobioprovinces. In the present paper, the species *Triadocidaris transversa* is documented for the first time from the San Salvatore Formation and in particular in the Secedensis Zone from the informal unit of the Rasa dolostone of the San Salvatore Formation of Rasa di Varese.

Triadocidaris sp. indet.

Fig. 6l-q

Material: an interambulacrum MSNVI-C-09c; single interambulacral plate (MSNVI-I-45k, MSNVI-I-51h, MSNVI-I-45b, MSNVI-M-04m, MSNVI-M-04); interambulacral plate (MSNVI-I-51n, MSNVI-I-51o).

Description. An interambulacrum, and six dissociated interambulacral plates.

The interambulacrum MSNVI-C-09c has strongly recrystallized surface. Two columns with seven plates are preserved and their mamelons show foramen slightly elongated dorsoventrally; scrobicular circles, not well preserved, elevated; deep scrobicule. In the other specimens (single interambulacral plates) are also observable irregular miliary tubercles.

Remarks. This material was embedded in a rock block together with several thorny spines and identified as belonging to a species of the genus *Triadocidaris*. It is likely that the interambulacral remains here described belong to species of the same genus if not to the same species.

Discussion

The echinoderm specimens described above show that locally the San Salvatore Formation (Rasa

dolostone) is rich in marine invertebrates of this phylum. They occur in several fossiliferous sites (B, C, D, D1, I, and M) outcropping in the surrounding of the Rasa village. One hundred and forty-three echinoderm specimens (among crinoids and echinoids) were collected, thus this can be considered indicative of the significant presence of echinoderms in this formation (more than 10% of the collected macrofauna).

Even if all these sites are close to each other, we can recognize some differences in relative age, faunal diversity, preservation status, and fossilization conditions.

Specimens from log B and section C are assigned to the upper part of the Reitzi zone (Illyrian - Anisian) on the base of the ammonoid fauna. They are represented by both crinoids (encrinids) and echinoids (spines assigned to species of "*Cidaris*" and *Triadocidaris*). In log B, specimens are isolated columnalia which occur in piles, whereas in the lower part of section C (probably the lowermost fossiliferous beds of informal unit of the Rasa dolostone) they are represented by partially articulated, but also disarticulated, ossicles, with some echinoid remains. Specimens from outcrop I and log M have been assigned to the Secedensis Zone (Illyrian - Anisian) based on the ammonoid fauna. These outcrops yielded most of the studied material, represented by both crinoids (Encrinidae, *Encrinus aculeatus*, *Holocrinus* sp. indet.) and echinoids ("*Cidaris" roemeri*, and species of *Serpianotiaris* and *Triadocidaris*). In log M, the association of benthic taxa as algae, colonies of associated mixed corals and sponges with brachiopods, gastropods, and bivalves (not described in the present work) and crinoids, could be interpreted as a bioherm similar to those documented in the upper Silesian Muschelkalk (Bodzioch 1997; Szulc & Hagdorn 2007). Still, in log M, the examined crinoid stem portions are embedded in the rock matrix (wackestones and mudstones, beds 30-40 cm thick) and are comprised of several columnals in anatomical connection. Often, these stem portions occur in assemblages, with several of them lying in parallel patterns and close to the others. This kind of preservation can be interpreted as a sudden burial of the organism during life or a slope accumulation.

According to Hagdorn (1985), most of the Anisian crinoid species described in literature were provided by the Germanic Muschelkalk facies. On the contrary, the report of the Middle Triassic crinoid faunas of the Tethys is very incomplete. Diversity in the Tethys itself was probably higher than what appears from the documented fossil record.

The San Salvatore Formation represents a shallow carbonate platform environment surrounding an intraplatform basin with restricted water circulation (Mt. San Giorgio/Besano basin). In the palaeoenvironment of the studied facies of the carbonate platform, fossil assemblages are dominated by crinoids (pluricolumnals, dissociated columnals, stems, and calyx portions). In the Middle Triassic carbonate platforms, crinoid faunas significantly contributed to carbonate production (Hagdorn & Velledits 2006).

Besides indetermined crinoids, identified species are in comparison represented in small number. Crinoids and echinoids recognized in the present study have also been described from upper Silesia by Hagdorn & Gluchowski (1993) (*Holocrinus* sp., *Eckicrinus radiatus, Encrinus aculeatus, Carnallicrinus carnalli, Serpianotiaris* sp., *Triadocidaris* sp.; ranging from Pelsonian to mid-Illyrian), from SW Poland by Gluchowski & Salamon (2005) (undetermined Encrinidae, *Holocrinus acutangulus, Eckicrinus radiatus*; ranging from lower Anisian to Pelsonian), and from Hungary by Hagdorn et al. (1997) and Hagdorn & Velledits (2006) (undetermined Encrinidae; ranging from upper Pelsonian-early Illyrian to upper Illyrian). In the study of Hagdorn & Gluchowski (1993) and Hagdorn (1997), an echinoderm biozonation was proposed for the Anisian Muschelkalk of the Germanic basin. Hagdorn (2011) provided also the basis for a Ladinian/Carnian biozonation for the Western Tethys. Up to now, the knowledge of the echinoderm Tethyan faunas is too scarce for a possible upper Anisian echinoderm biozonation in the Southern Alps formations. During the late Anisian, the Southern Alps were connected to the Germanic basin (Germany, Poland), and it is suggested (Hagdorn 1985; Hagdorn et al. 2018; Pei et al. 2022) that these forms migrated northwards. In the reconstruction of the Muschelkalk basin history proposed by Hagdorn (1985) and Pei et al. (2022), the Germanic basin was connected with the Tethys ocean only by narrow straits that changed their positions due to epeirogenetic movements. The first marine immigration occurred during the early Anisian through the East Carpathian gate, while during middle and early late Anisian times the main connection was

through the Silesian-Moravian gate. A salinity crisis in the middle Muschelkalk (middle and upper Anisian) is represented by evaporite deposit occurring in large parts of the basin. This event wiped out the marine invertebrate fauna in the area, with the exception of the Silesian gate, where a highly diverse fauna of Tethyan affinities persisted for some time. The upper Muschelkalk transgression (latest Anisian to early Ladinian) entered the basin through the Burgundian gate in the Southwest and reached its peak in the early Ladinian. Certain crinoid taxa already reported in the lower and upper Illyrian of the Germanic basin have also been collected and dated here to the late Illyrian (upper Reitzi Z.-Secedensis Z.) demonstrating that several taxa migrated southwards in the Tethys realm during the late Illyrian (Baeza Carratalà et al. 2018; Escudero-Mozo et al. 2015).

At the end of the Anisian (uppermost Secedensis Z.), echinoderms suddenly disappeared from the investigated localities around the Rasa village. Starting from the lower Ladinian beds, up to the uppermost Ladinian cropping out in the southeastern area of Mt. Chiusarella and near the locality Campasc, taxa are restricted to gastropods (Coelostylinidae), rare bivalves, and rare ammonoids.

Conclusion

The echinoderm faunas from the San Salvatore Formation were previously documented only in the old literature (von Buch 1827; Merian 1854; Stabile 1854; Hauer 1855; Stabile 1856; Hauer 1857; Stoppani 1860; Mariani 1901). Although the San Salvatore Formation is cropping out in many localities (from southwest to northeast: Canavese, Sostegno, Mt. Fenera, Sasso Sciseno, Rocca di Caldè, Alpe Cuvignone, Bedero, Mt. Pian Nave, San Michele, Cassano Valcuvia, Castello Cabiaglio, Monte La Nave, Cunardo, Rasa di Varese, Poncione di Ganna, Mt. Minisfreddo, Caslano, Besano, Mt. San Salvatore, Mt. San Giorgio, Campione, Mt. Boglia, Denti della Vecchia, La Gaeta near Menaggio) between the northern Piedmont and the Como Lake, the outcrops which yielded crinoid and echinoid specimens are very few. At Mt. San Salvatore and in the locality of San Michele, only some specimens of crinoids have been collected. In the Rasa Valley, rich bioclastic facies of the San Salvatore Formation (informal unit of the Rasa dolostone), crop out and provide the most complete paleontological documentation also including some rare echinoid remains. In the upper Anisian facies, crinoids are represented by a species of *Holocrinus* and *Encrinus* cf. *aculeatus* (known from the Pelsonian of the Germanic basin), *Zardinicrinus* cf. *granulosus* (known from the Ladinian and lower Carnian of Dolomites); echinoids are represented by "*Cidaris*" cf. *roemeri* (known from the lower Carnian Cassian Formation, Dolomites), *Serpianotiaris* sp. indet. (known from the Anisian of Germanic basin and the Ladinian of Switzerland), *Triadocidaris transversa* (known from the Germanic basin and doubtfully from the Anisian of Brembana Valley, northern Italy). The crinoid and echinoid faunas have been collected along with a rich ammonoid fauna and conodonts, belonging to the upper Reitzi Zone and the Secedensis Zone.

During the latest Anisian corresponding to the lower part of the upper Muschelkalk, probably through the Burgundian gate, several echinoderm taxa immigrated from the Germanic basin to the Tethys realm. This immigration is here documented by crinoid species as well as echinoid species (*Holocrinus* sp. indet., *Encrinus* cf. *aculeatus* and *Triadocidaris transversa*) collected in the uppermost Anisian San Salvatore Formation, which were previously described from the lower and middle Anisian of Germanic basin. The genus *Serpianotiaris* known from the lower Ladinian beds of Mt. San Giorgio and from the Lower and Upper Muschelkalk of Germany, is here reported from the uppermost Anisian San Salvatore Formation of Rasa di Varese, demonstrating its wider geographical occurrence and stratigraphic distribution (from Pelsonian to Fassanian). This suggests its immigration from the Germanic basin to the San Salvatore carbonate platform during the latest Anisian, and then to the Mt. San Giorgio basin in the early Ladinian. The present new data improve our knowledge about relationships and migrations of the echinoderm faunas between the Germanic basin and the Tethys during the Anisian/Ladinian boundary.

Moreover, the genus *Zardinicrinus* known from the lower Carnian Cassian Formation of the Dolomites and in the Ladinian of Mt. Clapsavon (Udine), is here described in the upper Reitzi Z. (uppermost Anisian), showing its wide stratigraphic distribution.

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SUPPLEMENTARY TABLE 1

Middle Triassic echinoderm specimens from the San Salvatore Formation (bioclastic facies, informal unit of the Rasa dolostone) of Rasa di Varese, exceptions are indicated. *Specimens from the San Salvatore Formation of Alpe Buca, close to the village of San Michele, Varese. **Specimens from M. San Salvatore (Switzerland).

Description	Reference	Outcrops	Biozone	Stage/substage
CRINOIDS				
Encrinus cf. *aculeatus* von Meyer, 1849	MSNVI-I-45	I	Secedensis	Illyrian - upper Anisian
Encrinidae gen. et sp. indet.	MSNVI-MIC1a-b*	n/a	undet.	Illyrian - upper Anisian
	MSNVI-B-84c	B	Reitzi	Illyrian - upper Anisian
	MSNVI-B-84f	B	Reitzi	Illyrian - upper Anisian
	MSNVI-B-89	B	Reitzi	Illyrian - upper Anisian
	MSNVI-C-09a	C	Reitzi	Illyrian - upper Anisian
	MSNVI-C-09b	C	Reitzi	Illyrian - upper Anisian
	MSNVI-I-09	I	Secedensis	Illyrian - upper Anisian
	MSNVI-I-45b	I	Secedensis	Illyrian - upper Anisian
	MSNVI-I-45g	I	Secedensis	Illyrian - upper Anisian
	MSNVI-I-45h	I	Secedensis	Illyrian - upper Anisian
	MSNVI-I-45m	I	Secedensis	Illyrian - upper Anisian
	MSNVI-I-45o	I	Secedensis	Illyrian - upper Anisian
	MSNVI-I-45p	I	Secedensis	Illyrian - upper Anisian
	MSNVI-M-01a	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-09d	M	Secedensis	Illyrian - upper Anisian
	MSNVI-MIC1c*	n/a	undet.	Anisian
	MSNVI-MIC2a-d*	n/a	undet.	Anisian
	MSNVI-MIC3b*	n/a	undet.	Anisian
	MSNVI-MIC4a-r*	n/a	undet.	Anisian
	MSNVI-B-85a	B	Reitzi	Illyrian - upper Anisian
	MSNVI-B-86	B	Reitzi	Illyrian - upper Anisian
	MSNVI-B-88	B	Reitzi	Illyrian - upper Anisian
	MSNVI-C-10	C	Reitzi	Illyrian - upper Anisian
	MSNVI-D-30	D	Secedensis	Illyrian - upper Anisian
	MSNVI-I-10	I	Secedensis	Illyrian - upper Anisian
	MSNVI-I-45f	I	Secedensis	Illyrian - upper Anisian
	MSNVI-I-45i	I	Secedensis	Illyrian - upper Anisian
	MSNVI-M-01b-n	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-04a	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-04b	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-04c-k	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-05a	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-05c-d	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-06a	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-06b	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-07a	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-08a	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-08c	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-09a	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-23c	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-23d	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-23e	M	Secedensis	Illyrian - upper Anisian

Description	Reference	Outcrops	Biozone	Stage/substage
	MSNVI-M-23f	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-23g	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-23h	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-24a	M	Secedensis	Illyrian - upper Anisian
	MSNVI-I-45n	I	Secedensis	Illyrian - upper Anisian
	MSNVI-MIC3a*	n/a	undet.	Anisian
	PIMUZ-6702**	n/a	undet.	Anisian
	PIMUZ-37719**	n/a	undet.	Anisian
	PIMUZ-37720**	n/a	undet.	Anisian
	MSNVI-M-09c	M	Secedensis	Illyrian - upper Anisian
	MSNVI-I-45d	I	Secedensis	Illyrian - upper Anisian
	MSNVI-M-02	M	Secedensis	Illyrian - upper Anisian
	MSNVI-M-03	M	Secedensis	Illyrian - upper Anisian
	MSNVI-D-68	D	Secedensis	Illyrian - upper Anisian
Encrinida fam. et gen. indet.	MSNVI-C-30	C	Reitzi	Illyrian - upper Anisian
	MSNVI-I-45a	I	Secedensis	Illyrian - upper Anisian
	MSNVI-I-45c	I	Secedensis	Illyrian - upper Anisian
	MSNVI-M-05b	M	Secedensis	Illyrian - upper Anisian
	MSNVI-B-84d	B	Reitzi	Illyrian - upper Anisian
	MSNVI-I-51f	I	Secedensis	Illyrian - upper Anisian
	MSNVI-I-51g	I	Secedensis	Illyrian - upper Anisian
	MSNVI-M-04l	M	Secedensis	Illyrian - upper Anisian
	MSNVI-I-45e	I	Secedensis	Illyrian - upper Anisian
Holocrinus sp. indet.	MSNVI-I-51a	I	Secedensis	Illyrian - upper Anisian
	MSNVI-I-51b	I	Secedensis	Illyrian - upper Anisian
	MSNVI-I-51c	I	Secedensis	Illyrian - upper Anisian
	MSNVI-I-51d	I	Secedensis	Illyrian - upper Anisian
Zardinicrinus cf. *granulosus* Muenster, 1834	MSNVI-B-84a	B	Reitzi	Illyrian - upper Anisian
	MSNVI-B-41	B	Reitzi	Illyrian - upper Anisian
	MSNVI-B-84e	B	Reitzi	Illyrian - upper Anisian
	MSNVI-B-85b	B	Reitzi	Illyrian - upper Anisian
	MSNVI-B-87	B	Reitzi	Illyrian - upper Anisian
ECHINOIDS				
Cidaridae gen. et sp. indet.	MSNVI-B-84h	B	Reitzi	Illyrian - upper Anisian
Cidaridae gen. et sp. indet.	MSNVI-B-84g	B	Reitzi	Illyrian - upper Anisian
Cidaridae gen. et sp. indet.	MSNVI-B-85c	B	Reitzi	Illyrian - upper Anisian
Cidaridae gen. et sp. indet.	MSNVI-C-09d	C	Reitzi	Illyrian - upper Anisian
"Cidaris" cf. roemeri	MSNVI-D-161e	D	Secedensis	Illyrian - upper Anisian
Serpianotiaris? sp. Jeannet in Peyer, 1933	MSNVI-B-84b	B	Reitzi	Illyrian - upper Anisian
Serpianotiaris? sp. Jeannet in Peyer, 1933	MSNVI-D-161d	D	Secedensis	Illyrian - upper Anisian
Serpianotiaris? sp. Jeannet in Peyer, 1933	MSNVI-D-161f	D	Secedensis	Illyrian - upper Anisian
Serpianotiaris? sp. Jeannet in Peyer, 1933	MSNVI-M-07b	M	Secedensis	Illyrian - upper Anisian
Serpianotiaris? sp. Jeannet in Peyer, 1933	MSNVI-M-08d	M	Secedensis	Illyrian - upper Anisian
Serpianotiaris? sp. Jeannet in Peyer, 1933	MSNVI-M-09b	M	Secedensis	Illyrian - upper Anisian
Serpianotiaris? sp. Jeannet in Peyer, 1933	MSNVI-M-24b	M	Secedensis	Illyrian - upper Anisian
Triadocidaris? Döderlein, 1887	MSNVI-C-09c	C	Reitzi	Illyrian - upper Anisian
Triadocidaris? Döderlein, 1887	MSNVI-I-45k	I	Secedensis	Illyrian - upper Anisian
Triadocidaris? Döderlein, 1887	MSNVI-I-51h	I	Secedensis	Illyrian - upper Anisian
Triadocidaris? Döderlein, 1887	MSNVI-I-51n	I	Secedensis	Illyrian - upper Anisian
Triadocidaris? Döderlein, 1887	MSNVI-I-51o	I	Secedensis	Illyrian - upper Anisian
Triadocidaris? Döderlein, 1887	MSNVI-M-04m	M	Secedensis	Illyrian - upper Anisian
Triadocidaris? Döderlein, 1887	MSNVI-M-04n	M	Secedensis	Illyrian - upper Anisian
Triadocidaris transversa Meyer, 1851	MSNVI-I-51e	I	Secedensis	Illyrian - upper Anisian
Triadocidaris transversa Meyer, 1851	MSNVI-D-161a	D	Secedensis	Illyrian - upper Anisian
Triadocidaris transversa Meyer, 1851	MSNVI-D-161b	D	Secedensis	Illyrian - upper Anisian
Triadocidaris transversa Meyer, 1851	MSNVI-D-161c	D	Secedensis	Illyrian - upper Anisian
Triadocidaris transversa Meyer, 1851	MSNVI-I-51i	I	Secedensis	Illyrian - upper Anisian
Triadocidaris transversa Meyer, 1851	MSNVI-I-51j	I	Secedensis	Illyrian - upper Anisian
Triadocidaris transversa Meyer, 1851	MSNVI-I-51k	I	Secedensis	Illyrian - upper Anisian
Triadocidaris transversa Meyer, 1851	MSNVI-I-51l	I	Secedensis	Illyrian - upper Anisian
Triadocidaris transversa Meyer, 1851	MSNVI-I-51m	I	Secedensis	Illyrian - upper Anisian