# THE LADINIAN FLORA FROM THE CASSINA BEDS (MERIDE LIMESTONE, MONTE SAN GIORGIO, SWITZERLAND): PRELIMINARY RESULTS

RUDOLF STOCKAR [1] & EVELYN KUSTATSCHER [2]

*Abstract*. A newly opened excavation in the Cassina beds of the Lower Meride Limestone (Monte San Giorgio UNESCO WHL, Canton Ticino, Southern Alps) has yielded a small collection of Ladinian plant fossils, together with vertebrate (mostly fish) and invertebrate remains. The flora contains at least five species; conifer remains assignable to the genera *Elatocladus*, *Voltzia* and ?*Pelourdea* are the most common elements. A new species, *Elatocladus cassinae* n. sp., is formally described. Co-occurring with the conifers are seed ferns *(Ptilozamites)* and a few putative cycadalean remains (?*Taeniopteris*). Among the identified genera, only *Voltzia* has previously been reported from Monte San Giorgio. The fossils presented in this paper indicate that a diversified flora thrived in the region during the Ladinian. Floral composition and preservation patterns are suggestive of a taphonomically-biased record and a relatively far-away source area.

*Riassunto*. Un nuovo sito di scavo paleontologico recentemente aperto negli "strati di Cassina" del Calcare di Meride Inferiore (Monte San Giorgio UNESCO WHL, Canton Ticino, Alpi Meridionali) ha consentito di portare alla luce, oltre a fossili di vertebrati (prevalentemente pesci) e invertebrati marini, anche resti di piante terrestri. La macroflora appare composta da almeno 5 specie, tra cui prevalgono le conifere, riferite ai generi *Elatocladus*, *Voltzia* e ? *Pelourdea*. Felci con semi *(Ptilozamites)* e presunti resti di cycadali (?*Taeniopteris*) sono riconosciuti per la prima volta nel giacimento del Monte San Giorgio. Viene descritta una nuova specie, *Elatocladus cassinae*. Dei generi identificati, solo *Voltzia* era sinora segnalato dal Monte San Giorgio. Questo primo studio di dettaglio della macroflora fossile proveniente dal nuovo scavo suggerisce pertanto un'associazione floristica ben più diversificata rispetto a quanto desumibile dalla letteratura. Inoltre, la composizione della flora fossile e la sua conservazione fanno supporre che l'area di provenienza fosse relativamente lontana.

## Introduction

The Cassina beds belong to the famous fossiliferous levels of the Middle Triassic Monte San Giorgio Lagerstätte (UNESCO World Heritage List, Canton Ticino, Southern Alps; Fig. 1), which is renowned for its rich fauna of Middle Triassic marine vertebrates (e.g. Kuhn-Schnyder 1974; Bürgin et al. 1989; Bürgin 1999). Fossils have been collected at the Italian side of the Monte San Giorgio since the mid-19th century (Cornalia 1854; Stoppani 1857) and on the Swiss side since 1924 (for a review see Furrer 2003). In addition to the marine (and terrestrial) reptiles and fishes, a highly diverse invertebrate fauna composed of ammonoids, bivalves, gastropods, echinoderms, foraminifers and arthropods, as well as a variety of plants, including algae, land plants, and abundant palynomorphs, have been discovered.

Despite the occurrence of fossils throughout the entire section ranging from the upper Anisian to the upper Ladinian, land plant remains have not received any scholarly attention, and no detailed study has been conducted since publication of the works of Sordelli (Sordelli 1879, 1896).

With regard to Mesozoic paleobotany, Switzerland is famous for a single site, i.e. the Carnian floras of Neuewelt near Basel (e.g. Heer 1865; Leuthardt 1901, 1903, 1904; Kräusel & Leschik 1955, 1959; Kräusel & Schaarschmidt 1966). Only a few other Triassic plant fossil localities have been described from Switzerland to date (Leuthardt 1915). Ladinian plant fossils, including shoots of *Voltzia* and silicified wood (*Araucarioxy-*

1   Museo Cantonale di Storia Naturale, Viale Cattaneo 4, 6900 Lugano, Switzerland and Université de Lausanne, Institut de Géologie et Paléontologie, Anthropole, 1015 Lausanne, Switzerland. E-mail: rudolf.stockar@ti.ch
2   Naturmuseum Südtirol, Bindergasse 1, 39100 Bolzano, Italy. E-mail: Evelyn.Kustatscher@naturmuseum.it
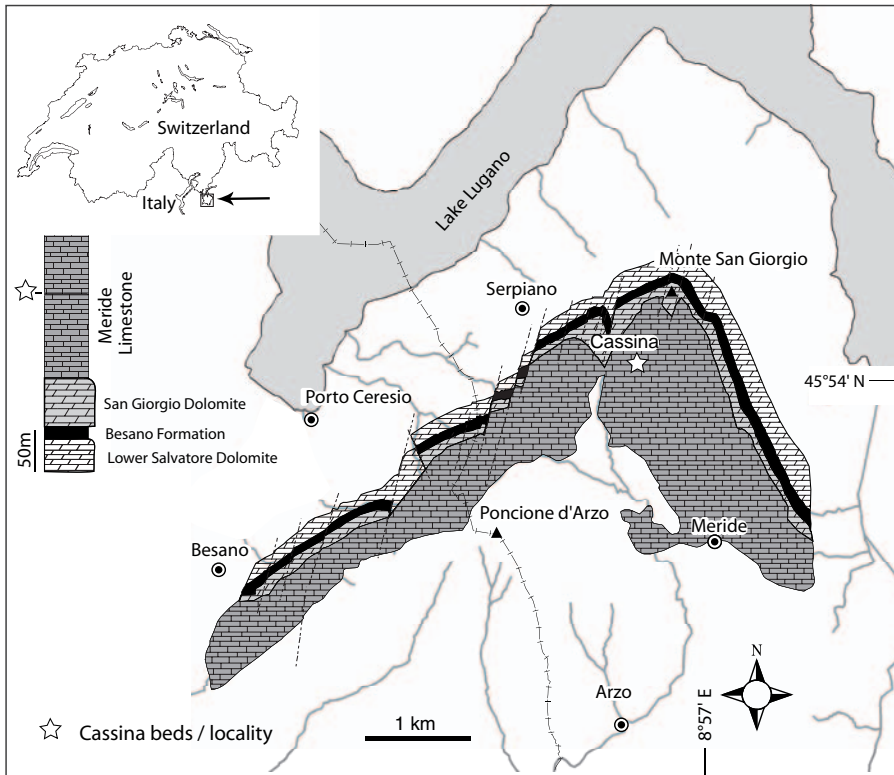
Fig. 1 - Map of the Monte San Giorgio area showing the Middle Triassic carbonate sequence and the excavation site (after Stockar 2010).

*lon*), are known from the Austroalpine Prosanto Formation in eastern Switzerland (Furrer 1995a, pp. 682-683; Grauvogel-Stamm et al. 2003).

In 2006, a new excavation in the Cassina beds fossiliferous horizon (Fig. 1) was launched by the Museo Cantonale di Storia Naturale (MCSN), Lugano. The fossiliferous horizon was first discovered in 1933 by colleagues of the University of Zurich, who also conducted several subsequent excavations in 1937, from 1971 to 1973, and again in 1975 (see Stockar 2010 for a review). All these field campaigns primarily focused on the vertebrate fossils. The aim of the new and ongoing excavation is to carefully re-document the level in order to provide a better characterization of the basin. Land plant remains occur within the recovered oryctocenosis, thus providing first insights into the structure and composition of the vegetation of the area.
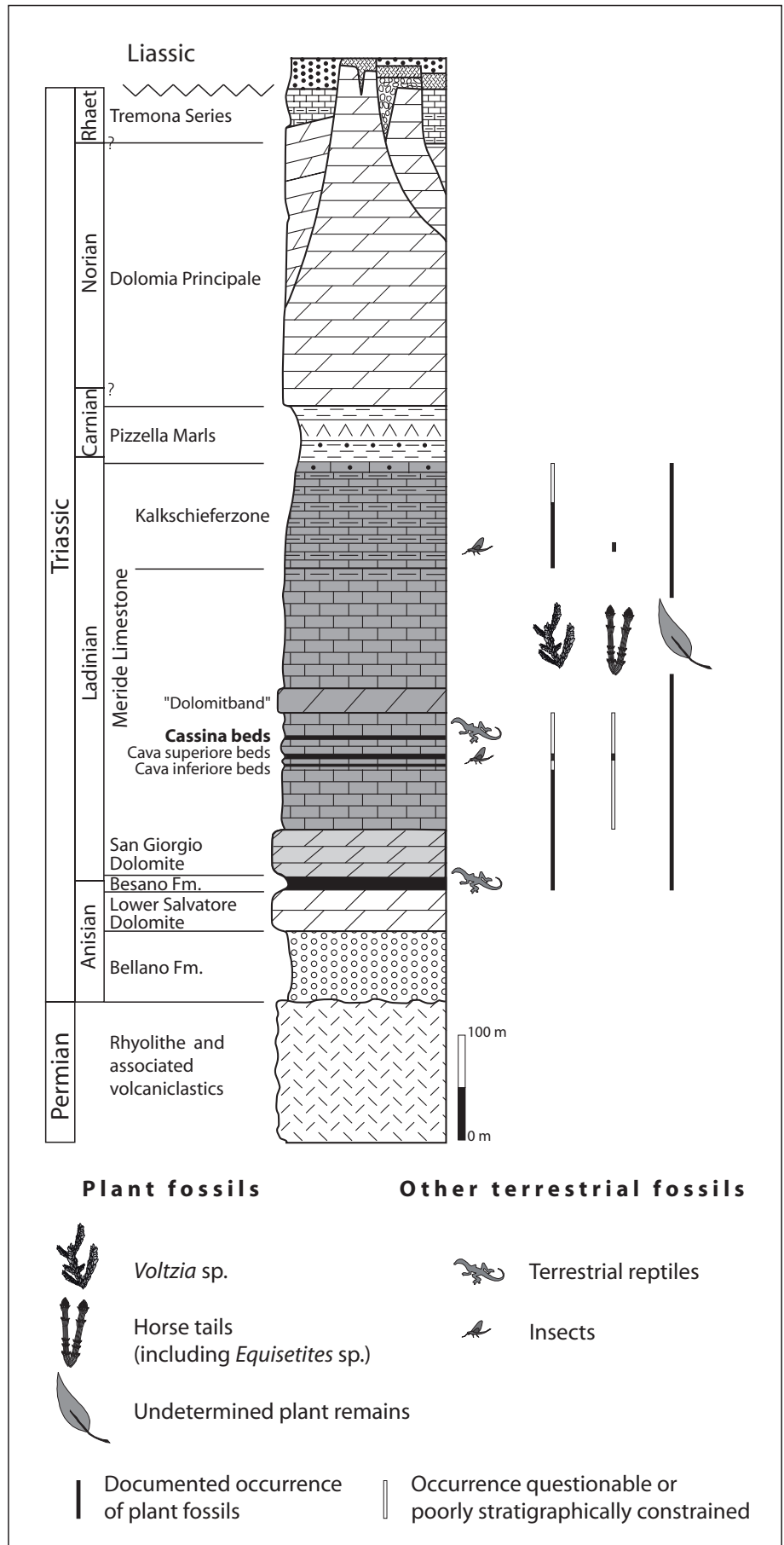
**Geological setting**

The Middle Triassic succession at Monte San Giorgio (Figs. 1-2) starts with a fluvio-deltaic sequence dated as late Anisian (Bellano Formation, Illyrian; Sommaruga et al. 1997) that overlies a Permian volcanic succession. The upper Anisian sediments indicate a progressive transgression of a shallow epicontinental sea and the related growth of carbonate platforms (Salvatore Dolomite; Zorn 1971) north of a land area buried today under the Po Plain (Picotti et al. 2007). During

the latest Anisian and Ladinian, shallow-water sedimentation continued in the north, whereas the formation of a 30-100 m deep and 10 to 20 km wide intraplatform basin with restricted circulation in the Monte San Giorgio area (Bernasconi 1994; Furrer 1995b) resulted in the deposition of the Besano Formation, San Giorgio Dolomite and Meride Limestone.

The Besano Formation ("Grenzbitumenzone"; Frauenfelder 1916) is an up to 16 m thick alternation of black shales and dolomites containing the Anisian-Ladinian boundary in its uppermost part (Brack & Rieber 1993; Brack et al. 2005). A volcanic ash layer lying a few metres below this boundary yielded an U-Pb minimum age of 241.2 ± 0.8 Ma (Mundil et al. 1996). The Besano Formation yielded most of the spectacular vertebrate fossils (reptiles and fishes), together with important index fossils such as ammonoids and daonellids, and in upward direction it grades into the 60 m thick San Giorgio Dolomite. The overlying 400 to 600 m thick Meride Limestone (Furrer 1995b) begins with the Lower Meride Limestone, 90 m (Wirz 1945) to 150 m thick (Furrer 1995b). This deposit contains three vertebrate fossil beds (i.e. the Cava inferiore, Cava superiore and Cassina beds), each with a different vertebrate assemblage (Sander 1989; Bürgin 1999). The fossiliferous beds consist of finely laminated limestones with intercalated volcanic ash layers.

The top of the Lower Meride Limestone is defined by a dolomite bed ("Dolomitband"; Frauenfelder 1916), reaching a thickness of about 30 m (Wirz 1945).

Fig. 2 - Synopsis of the Triassic plant fossils from the Monte San Giorgio area, plotted on the stratigraphic section in Furrer (1995b, modified). Data from different authors (see text). Other fossils of terrestrial provenance are also indicated.



Liassic

| Triassic | Rhaet | Tremona Series |
| | Norian | Dolomia Principale |
| | Carnian | Pizzella Marls |
| | Ladinian | Kalkschieferzone |
| | | Meride Limestone |
| | | "Dolomitband" |
| | | **Cassina beds** |
| | | Cava superiore beds |
| | | Cava inferiore beds |
| | | San Giorgio Dolomite |
| | Anisian | Besano Fm. |
| | | Lower Salvatore Dolomite |
| | | Bellano Fm. |
| Permian | | Rhyolithe and associated volcaniclastics |

100 m

0 m

**P l a n t   f o s s i l s**

*Voltzia* sp.

Horse tails (including *Equisetites* sp.)

Undetermined plant remains

Documented occurrence of plant fossils

**O t h e r   t e r r e s t r i a l   f o s s i l s**

Terrestrial reptiles

Insects

Occurrence questionable or poorly stratigraphically constrained

The overlying Upper Meride Limestone shows alternating well-bedded limestones and marlstones with an increasing clay content towards the top where strong seasonal variations of salinity and water level, together with the influence from a nearby elevated area, are recognizable. The uppermost part comprises the so-called "Kalkschieferzone", 120 m thick, which yielded peculiar fish faunas, crustaceans and arthropods (e.g. Furrer 1995b; Krzeminski & Lombardo 2001; Lombardo 2002; Lombardo & Tintori 2004; Tintori & Lombardo 2007), and represents the late evolution of the intraplatform basin, followed by the Carnian regressive phase (Pizzella Marls).

**The terrestrial macroflora from Monte San Giorgio (including Cassina beds): state of the art**

Terrestrial plant remains occur throughout the Middle Triassic carbonate sequence (Fig. 2) that was deposited within the subtropical zone at a palaeolatitude of around 18°N (Brack et al. 1999) under (mega)-monsoonal climatic conditions (Mutti & Weissert 1995).

Sordelli (1879) gave the first report of *Voltzia* remains from the Besano region that likely were discovered from the Besano Formation. According to this author, the fossil flora is entirely composed of conifers, whereas cycads, ferns, and lycopods are missing. Peyer (1944, p. 80) later reported "*Araucaria*-like" conifer shoots (likely also belonging to the voltzialean conifers) from both the Besano Formation and the Lower Meride Limestone, from where he also noted rare occurrences of horsetails. Moreover, this author reported unidentified plant fragments from both the Lower Meride Limestone and the Kalkschieferzone. Rieber (1973, p. 673) and Kuhn-Schnyder (1974, pp. 98-99, fig. 78) noted the presence of *Voltzia*-like plant fossils in the Besano Formation, the San Giorgio Dolomite and the uppermost Kalkschieferzone (probably referring to the work of Wirz 1945, see below). Kuhn-Schnyder (1974, fig. 78) and Felber (2005, fig. 95) illustrated a well-preserved conifer shoot from the Besano Formation, housed at the Paleontological Museum of the University of Zurich; the counterpart of this specimen, identified as *Voltzia* sp., is kept today in the museum of Meride. According to Pinna & Teruzzi (1991, p. 50) and Bernasconi (1994, p. 29), plant fossils from the Besano Formation constitute a monotypic *Voltzia* assemblage. This assemblage would be suggestive of a vegetation dominated by conifers (Pinna & Teruzzi 1991, p. 51). The presence of a hinterland setting is also confirmed by the occurrence of terrestrial reptiles such as *Ticinosuchus* and *Macrocnemus* in the black shales of the Besano Formation. According to Furrer (1995b, p.

835), the Kalkschieferzone contains *Voltzia* remains only in the lower and middle part, whereas other, unidentified plant remains are rare (lower part) to scarce (middle and upper part of the sequence). However, these conclusions were based exclusively on three small excavations carried out in 1994 in the Val Mara section and on the review of Wirz's original data and samples from the same locality (Wirz 1945, see below). Furrer (2001, pp. 6-7) also reported rare findings of *Equisetites* (a stem fragment was already figured in Furrer 1999, fig. 21) from the Cava superiore beds and rare coalified wood fragments from the Cava inferiore beds (both levels belonging to the Lower Meride Limestone). Felber (2005, fig. 145) illustrated a small slab containing a shoot fragment ascribed to *Voltzia* along with a small plant fragment attributed by the same author to the horsetails. According to our observations, this specimen comes from the lower Kalkschieferzone and belongs to the Wirz collection. Schatz (2005, p. 100) mentions *Voltzia* sp. shoots from the lowermost part of Meride Limestone between the San Giorgio Dolomite and the Cava inferiore beds.

Excavations conducted by the University of Milan (UNIMI) in the lower Kalkschieferzone in 1997-2003 yielded many new plant remains, sometimes quite well-preserved. Although a detailed study of this material, stored at the Museo Cantonale di Storia Naturale (Lugano), has not yet been completed, a preliminary evaluation suggests that a more diversified flora lived in this area during the Ladinian than was previously reported from the Kalkschieferzone.

It is worth mentioning that Wirz (1945, pp. 39-40), in his monograph on the Meride Limestone, reported the occurrence of plant remains at different levels within the Monte San Giorgio section. He regarded plant fossils, usually badly preserved *Voltzia* fragments, as frequent in the Besano Formation, San Giorgio Dolomite and uppermost Kalkschieferzone (but see above Furrer 1995b). In addition, he stated that unidentified plant remains occur widely throughout the Meride Limestone, with the exception of the middle part of the Upper Meride Limestone (Wirz 1945, p. 78). With regard to the Cassina beds, this author mentioned the presence of plant fossils in a 3.6 m thick interval referred to as VS 221-192, but did not give any further details. Wirz's section refers to a different locality (Val Serrata), and thus it is very difficult to correlate his data with the results from our excavation. Nevertheless, despite the absence of vertebrate remains from the above-mentioned level, it is clear that this level lies only a few meters below the Dolomitband. Moreover, it contains a comparable foraminiferal assemblage (Wirz 1945; Stockar 2010). Accordingly, the level VS 221-192 of Wirz probably was very close to

Fig. 3 - Detailed lithological succession of the upper part of the Cassina beds (after Stockar 2010), showing occurrences of plant fossils.
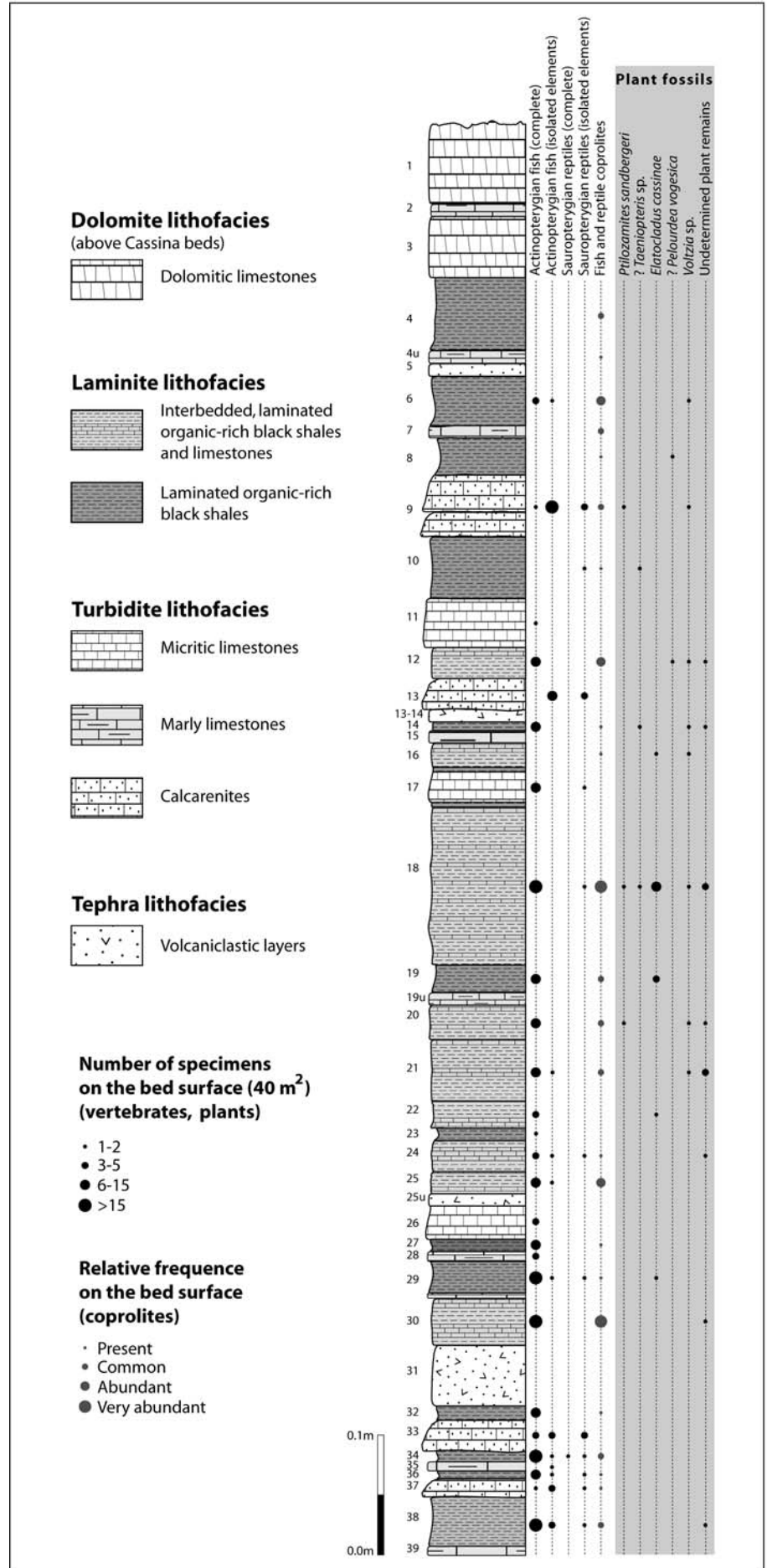
the horizon yielding the plant fossils described in this paper.

## Material and methods

The excavation site is located to the south of the summit of Monte San Giorgio, quite close to the outcrop where the Cassina beds were originally discovered. In the new locality (Stockar 2010), the Cassina beds occur as an almost 3 m thick interval that predominantly consists of interbedded finely laminated, organic-rich shales and limestones (laminite lithofacies) with intercalated thicker limestone (turbidite lithofacies) and volcaniclastic layers derived from volcanic ash fall (tephra lithofacies).

The sequence grades upwards into the thick-bedded dolomitic limestones and dolostones belonging to the "Dolomitband".

To date, the upper third of the succession (Fig. 3) has been excavated bed by bed on a surface of approximately 40 m², and has yielded a well-preserved vertebrate fauna mainly composed of fishes; the large predatory actinopterygian *Saurichthys* appears to be dominant in this fauna. Reptiles appear to be rare in the upper part of the Cassina beds, and the only articulated skeleton has been identified as a small representative of the genus *Neusticosaurus*.

The Cassina beds are traditionally regarded as early Ladinian in age (e.g. Hellmann & Lippolt 1981; Rieppel 1998; O'Keefe et al. 1999), but reliable index fossils such as ammonoids and conodonts have not been reported from this horizon. However, Scheuring (1978) mentioned the occurrence of *Echinitosporites iliacoides*, a palynomorph that, according to data from the Seceda core (Buchenstein Fm), is limited to the late Ladinian *P. archelaus* zone (Hochuli & Roghi 2002; see also Stockar 2010 for a review of the available biostratigraphic data).

The macroflora occurs throughout the excavated section, but the remains are fragmentarily preserved. Most fragments are small and display not much more than short leaf segments or single leaves; only a few almost entire shoots have been recovered. Cuticles could only be obtained from very few specimens.

Preservation closely depends on the lithofacies. The turbidite lithofacies contains exclusively small and poorly-preserved plant fragments, sometimes as coaly compressions. Thicker volcaniclastic layers (up to 5 cm) belonging to the tephra lithofacies do not contain plants. The laminite lithofacies contains larger and better preserved plant fossils. Nevertheless, in comparison to the vertebrates, which usually occur as articulated skeletons within the laminite lithofacies, the plant remains are fragmented, and are generally poorly preserved.

The specimens have been mechanically prepared under a dissecting microscope. If possible, the simple dégagement technique (Fairon-Demaret et al. 1999) using sharp preparation needles and a rubber air bulb was preferred over other, more destructive preparation tools such as vibrotools; in some cases, however, nature and thickness of the embedding matrix made the use of vibrotools necessary. If possible, cuticle preparations were made by maceration of small leaf fragments in Schulze's reagent (KClO$_3$ and 30% HNO$_3$) and subsequent neutralization in 5% ammonia. Cuticles were mounted on microscope slides in glycerine jelly or Gurr Aquamount and examined under transmitted light and UV-epifluorescence using a microscope equipped with a high-pressure mercury burner, DM400 dichroic mirror, 330-385 nm excitation filter and 420 nm barrier filter.

The fossils, including all figured specimens and cuticle slides, are housed at the Museo Cantonale di Storia Naturale, Lugano, under accession code "MCSN" followed by a number; specimens occurring on the same slab are identified by different capital letters following the catalogue number.

## Systematic palaeontology

Division **Pteridospermatophyta**

Order **indet.**

Family indet.

Genus *Ptilozamites* Nathorst, 1878

### *Ptilozamites sandbergeri* (Schenk) Kustatscher et Van Konijnenburg-van Cittert, 2007

Fig. 4A-C

**Selected synonymy** (for details, refer to Kustatscher & Van Konijnenburg-van Cittert, 2007):
1858 *Pterophyllum minus* Brongniart - Bronn, pp. 56-57, pl. 9, fig. 2.
1866-7 *Pterophyllum sandbergeri* Schenk - pp. 17-18, pl. 1, fig. 9.
2000 *Ptilozamites heeri* Nathorst - Wachtler & Van Konijnenburg-van Cittert, p. 108, pl. 2, fig. 2-9.
2005 *Ptilozamites heeri* Nathorst - Kustatscher & Van Konijnenburg-van Cittert, pp. 35-36.
2007 *Ptilozamites sandbergeri* (Schenk) - Kustatscher & Van Konijnenburg-van Cittert, pp. 82-84, fig. 4 A-J.

**Material:** MCSN8026, MCSN8034, MCSN8040A.

**Description.** Several specimens that are variable in size and shape, representing either a basal portion of a leaf (155 x 25 mm; MCSN8034; Fig. 4A) or several apical pinnae (38 x 18 mm; MCSN8040A; Fig. 4B). Leaves were at least 200 mm long, having an up to 40 mm long petiole with a slightly enlarged base. The rachis is about 4 mm wide at the base, but gradually decreases in width to slightly above 1 mm at the apex. The angular to sub-quadrate pinnae with a broad, slightly enlarged base and rounded apex are small in proximal portions of the leaf (4-5 x 5-6.5 mm), but increase distally in size (13-15 x 8-14 mm). Apically the pinnae decrease again in size (MCSN8040A; Fig. 4B). The veins arise perpendicularly from the rachis and run parallel to each other; no vein-free margin has been observed, probably due to the preservation of the fragments. The cuticle is thick, with irregularly distributed, rectangular epidermal cells of 24-38 x 15-22 μm (Fig. 4C). So far no stomata complex has been observed.

**Discussion.** Although the vein-free marginal rim and vein density per cm cannot be determined, the specimens from Monte San Giorgio fall within the morphological variability of *Ptilozamites sandbergeri*. Unfortunately, the cuticle is poorly preserved. It is thick, but the cutinizations of the anticlinal cell walls of the isodiametric epidermal cells are almost completely lost (probably due to taphonomy). As a result, no details on the stomata and their distribution can be given. Under epifluorescence microscopy the remains of the anticlinal wall became at least partially visible.
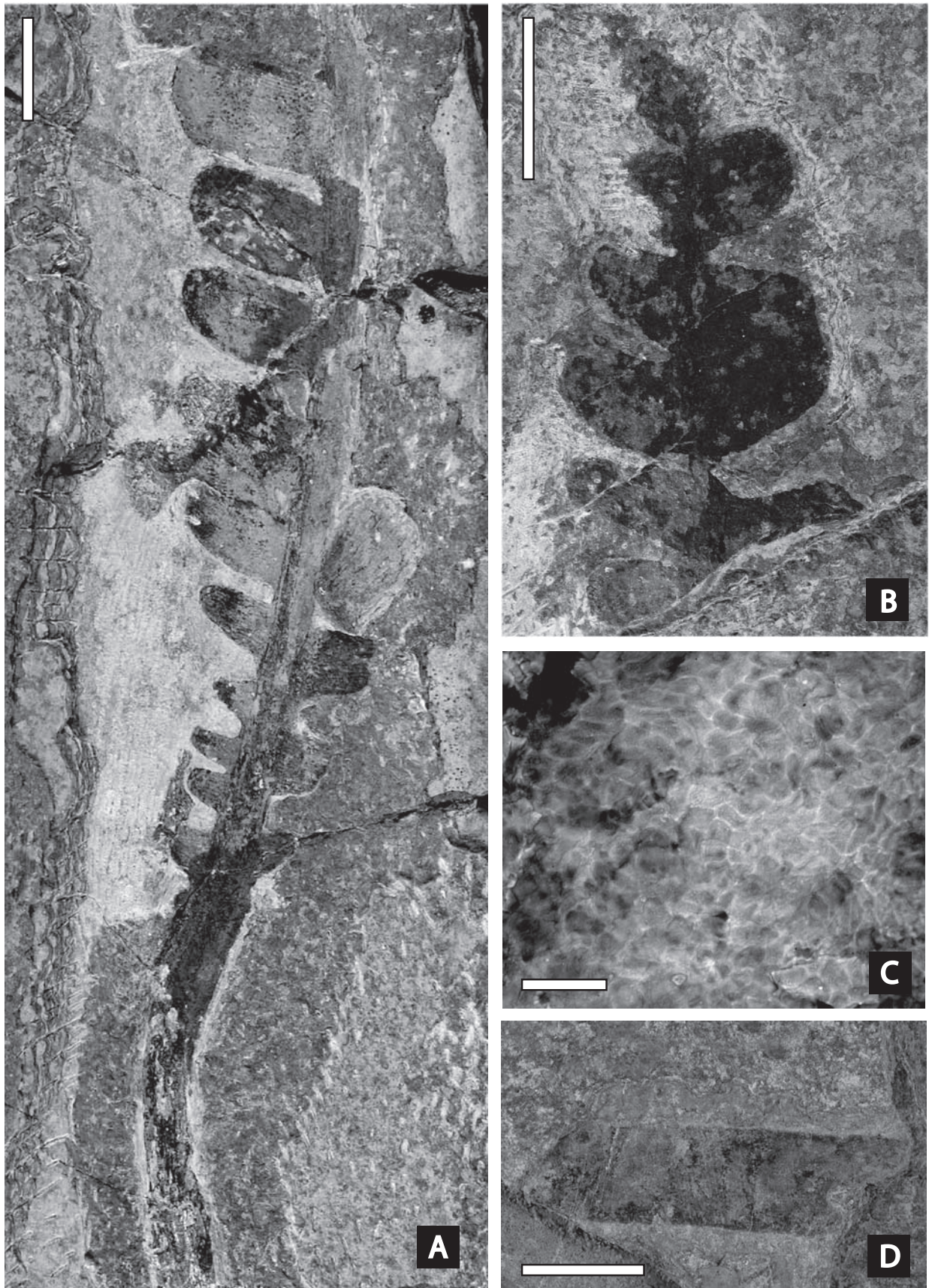
Fig. 4 - A) *Ptilozamites sandbergeri* (Schenk) Kustatscher et Van Konijnenburg-van Cittert, 2007, proximal leaf portion with petiole (MCSN8034); B) *Ptilozamites sandbergeri* (Schenk) Kustatscher et Van Konijnenburg-van Cittert, 2007, distal leaf fragment, pinnae are inserted almost oppositely (MCSN8040A); C) *Ptilozamites sandbergeri* (Schenk) Kustatscher et Van Konijnenburg-van Cittert, 2007, cuticle showing irregularly distributed epidermal cells (MCSN8040A). Incident UV fluorescence; D) ?*Taeniopteris* sp. (MCSN8021). Scale bar is 1 cm (4A, 4B, 4D) and 100 µm (4C).

*Ptilozamites* likely was a shrubby plant, although no detailed reconstruction is available for this genus (Kustatscher & Van Konijnenburg-van Cittert 2005, p. 41, fig. 5; Kustatscher et al. 2010, fig. 2).

**Distribution.** ?Upper Anisian of the Dolomites (N-Italy; Kustatscher & Van Konijnenburg-van Cittert 2007), Ladinian of Monte San Giorgio (Switzerland; this paper), upper Ladinian of the Dolomites (N-Italy) and Carnian of Raibl and Dogna (Julian Alps, N-Italy; Kustatscher & Van Konijnenburg-van Cittert 2007).

Division **Cycadophyta**

Order **Cycadales**

**?Taeniopteris** sp.

Fig. 4D

**Material**: MCSN8021, MCSN8024, MCSN8027.

**Description.** A few of the plant remains might represent cycadophyte foliage (e.g. MCSN8021; Fig. 4D) based on the strap-like appearance and delicate venation.

**Discussion.** Preservation of the material renders assignment to any species or genus impossible. However, the overall shape of the fossils and the venation pattern are reminiscent of cycadalean leaves belonging to the undivided cycadophyte morphogenus *Taeniopteris*, and resemble *Bjuvia* leaf fragments, described from the Middle Triassic of the Dolomites (Wachtler & Van Konijnenburg-van Cittert, 2000; Broglio Loriga et al. 2002; Kustatscher 2004; Kustatscher et al. 2004).

Division **Coniferophyta**

Genus *Elatocladus* Halle, 1913 emend. Harris, 1979

**Elatocladus cassinae** n. sp.

Fig. 5A-D, Fig. 6

**Derivatio nominis**: named after the fossiliferous level (Cassina beds) from which the specimens have been discovered.

**Holotype**: MCSN8045A, Fig. 5A.

**Locus typicus**: Monte San Giorgio (Switzerland).

**Stratum typicum**: Cassina beds, bed 19, Ladinian, Middle Triassic.

**Diagnosis**: Unbranched shoots with leaves arranged in loose helix; leaves dorsi-ventrally flattened, coriaceous, linear, with a rounded apex, and a constricted base; leaves become shorter towards the apex and base of the shoot. Leaves up to 30 mm long and 2.5-3 mm wide. Numerous veins (6-8) per leaf.

**Material**: MCSN8019, MCSN8022, MCSN8030, MCSN8036, MCSN8037, MCSN8038, MCSN8039, MCSN8040B, MCSN8041, MCSN8042, MCSN8043, MCSN8045A, MCSN8045B, MCSN8057, MCSN8066, MCSN8068.

**Repository**: Museo Cantonale di Storia Naturale, Lugano (Switzerland).

**Description.** This taxon is abundant in the flora. Shoots are up to 165 mm long and 40 mm wide (e.g. MCSN8045A, MCSN8039; Fig. 5A, B). The axis is proximally up to 3.5 mm broad, but decreases to 1 mm wide at the tip. The leaves are arranged in a loose helix (due to the compression of the shoots during fossilization, the leaves sometimes appear to be inserted almost oppositely or suboppositely). Leaves are up to 30 mm long and 2.5-3 mm wide, have a rounded tip, a constricted base, and decrease in length both toward the tip and base (length around 8-12 mm). The leaves are coriaceous and probably were vascularized by 6-8 veins (e.g. MCSN8030; Fig. 5C). Branching has not been observed among the shoot fragments.

In young shoots the axis is still very short, with leaves inserted in a dense helix. The leaves in these shoots are ~12 mm long and 2 mm wide (more apically about 3.5 x 1 mm) and have a smoothed tip (e.g. MCSN8043; Fig. 5D). Sometimes isolated leaves occur on the bedding planes. Specimen MCSN8040B (Fig. 6) shows a tectonically induced step-like dislocation, a feature that is typical for many other fossils from this locality.

**Discussion.** Unfortunately the cuticle is poorly preserved. The cuticle is thick, almost amorph. The anticlinal walls of the epidermal cells are only partly preserved. Stomatal apertures have sometimes been observed, but they never show enough detail for a description. As a result, cuticles do not provide any information that can be used for comparisons with other taxa.

The morphogenus *Elatocladus* has been established by Halle (1913) for sterile conifer shoots with elongated leaves inserted spirally or bilaterally. Later, Harris (1969, 1979) restricted the genus to shoots with helically or oppositely arranged and dorsiventrally flattened, single-veined leaves diverging from the axis, although the original species described by Halle shows dimorphic leaves, perhaps characterized by a delicate midrib. Nonetheless, the genus has lately been widely used for conifer shoots with spirally arranged leaves that diverge from the axis and are vascularized by one to several veins. Thus, as long as the genus is not redefined, we feel confident to accommodate our plant fossils in *Elatocladus* based on the morphological similarities with other well-known Triassic species of this genus. Our material cannot be assigned to *Podozamites* Braun, 1843, even if the leaves show more than a single midvein, because the leaves are inserted spirally and not oppositely as in *Podozamites*, and the scale-leaves at the base of the axis are missing.

*Elatocladus* was widely distributed during the Jurassic and Cretaceous, but has also been reported from the Upper Triassic, e.g. *Elatocladus australis* Frenguelli, 1944 from the Triassic of Argentina, *E. wanneri* Bock, 1969 from the Triassic of America, *E. denticulatus* Pal, 1913 and *E. raoi* Pal, 1913 from the Triassic of India, *E.*
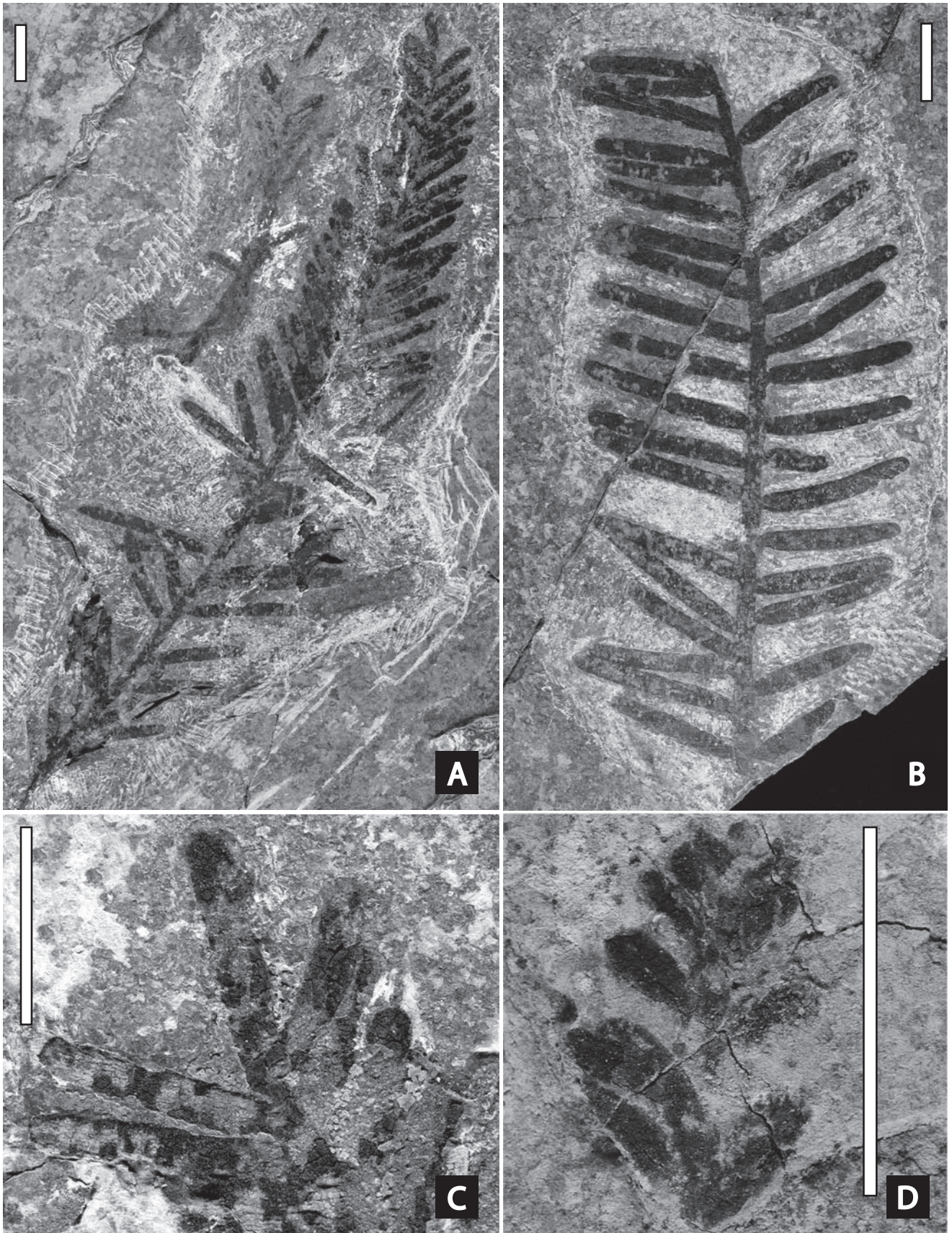
Fig. 5 - *Elatocladus cassinae* n. sp. A) holotype (MCSN8045A); B) leaves in helical arrangement (MCSN8039); C) distal shoot fragment with leaves showing 6-8 veins (MCSN8030); D) fragment of a young shoot with densely spaced leaves (MCSN8043). Scale bar is 1 cm.

Fig. 6    - *Elatocladus cassinae* n. sp. Shoot with tectonically-induced dislocation (MCSN8040B). Scale bar is 1 cm.

*carolinensis* (Emmons) Weber, 1997 from the Upper Triassic of Mexico, *E. porensis* Passoni et Van Konijnenburg-van Cittert, 2003 from the Carnian of the Bergamasc Alps (N-Italy), *E. prynadae* Shorokhova et Volynet, 2006 and *E. elegantus* Volynet et Shorokhova, 2006 from the Norian of Southern Primorye (Volynets et al. 2006, 2008).

*Elatocladus schimperi* (Nathorst) Seward, 1919, according to Seward (1919) from the Rhaetian of Skåne (Sweden), has recently been dated as Hettangian (Christian Pott, pers. comm. 2010). Harris (1935) described at least 18 species of *Elatocladus* from the Rhaetian-Liassic of Greenland. According to Mihai Popa (http://mepopa.com/gspecies.htm) only some of these taxa actually are from Rhaetian sediments, i.e. *Elatocaldus eurystomus* Harris, 1935, *E. molopicus* Harris, 1935, *E. nitidus* Harris, 1935, *E. perforatus* Harris, 1935, *E. physetus* Harris, 1935, *E. polystictus* Harris, 1935, *E. punctatus*

Harris, 1935, *E. stenostomus* Harris, 1935. The only other Middle Triassic *Elatocladus* specimen has been described from the Dolomites, but could only be identified to the genus level (Wachtler & Van Konijnenburg-van Cittert 2000).

**Comparisons.** *Elatocladus* sp. from the Ladinian (Middle Triassic) of the Dolomites (Wachtler & Van Konijnenburg-van Cittert 2000, p. 113, pl. 6, fig. 3) differs from *E. cassinae* in having more lanceolate leaves with a obtuse tip and a thinner, finer texture, maybe due to preservation. Moreover, the leaves of the specimen from the Dolomites are inserted in a much more compact helix than in the specimens from Monte San Giorgio. *Elatocladus porensis* Passoni et Van Konijnenburg-van Cittert, 2003 is characterized by much smaller leaves (15-30 (max. 50) x 0.5-2 mm) with only a single vein each leaf and a straight to slightly widened base. *Elatocladus prynadae* Shorokhova et Volynet, 2006 and *E. elegantus* Volynet et Shorokhova, 2006 differ from the Swiss material in the larger size of the leaves, the greater distance between two leaves, and the rounded leaf tip. In *Elatocladus wanneri* Bock, 1969 the leaves are much longer (although the width is the same) and the surface is covered by 4-5 ridges that are fused at the base, while *Elatocladus cassinae* leaves are vascularized by 6-8 delicate veins. Svanidze et al. (2000) mentions *Elatocladus laxus* (Phillips) Harris, 1979 from the Upper Triassic of Western Georgia; however, the lack of a description and illustrations of the specimens renders a comparison impossible. *Elatocladus denticulatus* Pal, 1913 differs from *Elatocladus cassinae* in having branched shoots and leaves with a denticulate margin. Leaves of *Elatocladus raoi* Pal, 1913 are smaller (20 x 1-1.5 mm), and possess a wide leaf base and single midvein. *Elatocladus carolinensis* (Emmons) Weber 1997 as figured in Weber (1997, pl. 1, fig. 5) seems to be closest to the Swiss material. According to Ward (1900, p. 298, pl. 42, fig. 4) the original specimen of Emmons shows linear (around 7 cm long, 3 cm wide) leaves that are alternately attached to the axis with an angle of 40° and have distinct veins and a narrow base. The latter species is characterized by having significantly larger leaves, inserted at a more acute angle than in *Elatocladus cassinae*. *Elatocladus australis* Frenguelli, 1944 differs from *E. cassinae* in having smaller leaves (5-6 x 0.75 mm) with only one vein.

The diagnosis of the Greenland species is based on cuticular analyses. Since our material did not yield well-preserved cuticles we are unable to compare with the Greenland taxa. Nevertheless, the leaves described by Harris (1935, pp. 61-78) are much narrower than those of *Elatocladus cassinae* (*E. perforatus* Harris, 1935: 1 mm broad; *E. stenostomus* Harris, 1935: 0.6 mm; *E. punctatus* Harris, 1935: 1.4 mm; *E. nitidus* Harris, 1935: 1-1.5 mm; *E. molopicus* Harris, 1935: 2 mm; *E. polystictus* Harris,

1935: < 1 mm broad; *E. physetus* Harris, 1935: 1.5 mm; *Elatocaldus eurystomus* Harris, 1935: 0.8 mm).

Genus *?Pelourdea* Seward, 1917

**?Pelourdea vogesiaca** (Schimper et Mougeot, 1844) Seward, 1917

Fig. 7A

**Material**: MCSN8033, MCSN8035.

**Description**. Two leaf fragments were provisionally assigned to *Pelourdea vogesiaca*. The leaf base (MCSN8033; Fig. 7A) shows the typical thickening with the curved attachment area, as well as the strong parallel veins (10 per cm). Also the other leaf fragment shows the typical venation, but it is twisted.

**Discussion**. The specimens represent leaf fragments only, but the coarse venation suggests that they belong to the shrubby conifer *Pelourdea vogesiaca*. The strap-like structure with longitudinal venation resem-
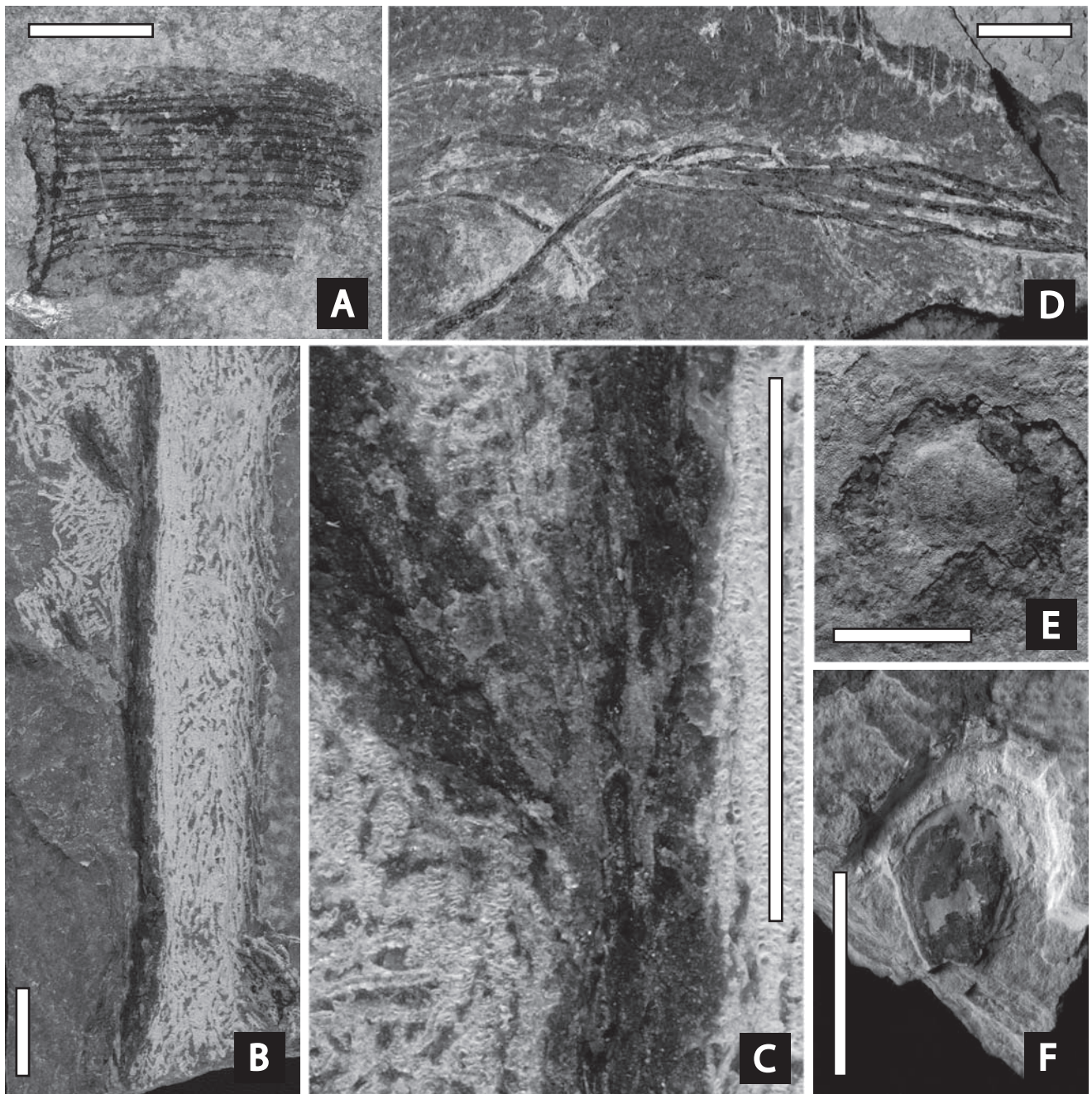


Fig. 7     - A) *?Pelourdea vogesiaca* (Schimper et Mougeout, 1844) Seward, 1917, leaf base with attachment area and prominent parallel veins (MCSN8033); B) *Voltzia* sp., shoot fragment with densely spaced leaves (MCSN8020); C) *Voltzia* sp., detail of the shoot fragment of Fig. 7B with leaf attachment and thick cuticle (MCSN8020); D) small, strap-like elements of unknown affinity (MCSN8029); E) female conifer scale (MCSN8071); F) unidentified seed (MCSN8058). Scale bar is 1 cm.

bles also badly-preserved equisetalean stems but no node structure has been observed so far. The apically slightly reducing width of the remains suggests the attribution to the genus *Pelourdea*. Only more complete fragments will permit a final determination.

**Distribution**. *Pelourdea vogesiaca* is known from the Anisian of the Vosges (France), and the Ladinian of the Dolomites (N-Italy) the Carnian of Raibl (Julian Alps, N-Italy) and the Bergamasc Alps (N-Italy) (Schimper & Mougeot 1844; Kustatscher et al. 2004, p. 65; Passoni & Van Konijnenburg-van Cittert 2003, p. 322-323) and the Ladinian of Monte San Giorgio (Switzerland; this paper).

Order **Voltziales**

Family Voltziaceae

Genus *Voltzia* Brongniart, 1828

**Voltzia** sp.

Fig. 7B, C

**Material**: MCSN8020, MCSN8023, MCSN8025, MCSN8031, MCSN8046, MCSN8047, MCSN8048, MCSN8050, MCSN8052, MCSN8054, MCSN8060, MCSN8063, MCSN8067.

**Description**. Various shoot fragments were assigned to this taxon. The fragments are short, up to 10 cm long and 20 mm wide (e.g. MCSN8020, MCSN8023; Fig. 7B, C); only few show branching (e.g. MCSN8020, Fig. 7C). The leaves are densely inserted around the axis that is about 1-5 mm thick. Leaves are falcate, 4-10 mm long and 1-2 mm wide.

**Discussion**. The preservation of the material, including the cuticle, precludes a more specific assignment. *Voltzia* remains have been reported from different levels of the Monte San Giorgio sequence, but have not yet explicitly been recorded for the Cassina beds.

**Indet.**

Fig. 7 D-F

Some of the plant remains from our locality have not yet been identified. These remains include small, strap-like elements, up to 10 cm long and 1-2 mm wide (e.g. MCSN8029, MCSN8051; Fig. 7D), scales (e.g. MCSN8071; Fig. 7E), and putative seeds (MCSN8058; Fig. 7F), 8 mm long and 6 mm wide. The strap-like elements could perhaps represent some *Neocalamites*-type of leaves. In this case, they would be longer than any so far described *Neocalamites* leaves from the Middle Triassic of the Alpine area. However, as long as they are not found attached to any stem, this theory cannot be proven.

## Discussion and conclusions

The patchy distribution of plant remains within the sediment mirrors a pulsating input from an elevated area (terrestrial area or islands) covered with vegetation. The exact paleogeographic location of this elevated area remains unknown. The presence of plant fossils in the Middle Triassic of Monte San Giorgio, occasionally together with terrestrial reptiles (*Ticinosuchus ferox*, *Macrocnemus bassanii*), has repeatedly been used as an indicator for the existence of small islands or a larger terrestrial area in the vicinity (e.g. Kuhn-Schnyder 1974, p. 102; Furrer 1995b, p. 845). The exact location of this terrestrial area, however, still remains controversial to date (e.g. Pinna & Teruzzi 1991, p. 51). Some authors have suggested that these areas were close nearby based on the completeness of the terrestrial reptile skeletons (e.g. Bernasconi 1994, p. 29; Kuhn-Schnyder 1974; p. 102; Pinna & Teruzzi 1991, p. 51).

The plant remains described in this paper mainly occur within the laminite lithofacies that is characterized by organic-rich black shales and limestones reflecting a microrhytmic pattern of irregular wavy dark and bright laminae. This lithofacies records a continuous background sedimentation under restricted conditions on the bottom of a basin below wave base, adjacent to a shallow-water platform and with limited connection to the open sea. Indications of bioturbation and physical reworking are absent. The systematic measuring of azimuthal orientation of fossils on bedding plane surfaces does not document any unimodal displacement of plant fragments, and thus probably rules out the existence of stronger, persistent bottom current action.

Unlike the marine vertebrate fossils from the Cassina beds, usually complete, articulated (or, if partially disarticulated, with dispersed body parts in spatial proximity to the rest of the skeleton; Stockar 2010) and excellently preserved up to the finest details (Renesto & Stockar 2009), the plant remains are poorly preserved and severely fragmented. Unlike the vertebrates, which reached the sea bottom as complete corpses soon after death, and thus underwent decomposition on the seafloor, the plants probably became deposited on the seafloor in an already advanced state of decay. According to Spicer (1989, p.109), leaves may float for weeks before becoming water-logged and sinking. In addition, watermass stratification, as inferable from the sediment features (Stockar 2010), tends to confine circulation to the surface waters and favours the offshore transport of buoyant terrestrial components (Tyson 1995, p. 455). On the other hand, plant fragments can have been blown into the basin during occasional storm events. This would also explain the low amount of plant remains and their differences in size (shoot fragments, leaf fragments, isolated conifer leaves,

seeds). These plant fragments could have floated for some time on the water before becoming water-logged and sink to the bottom of the sea. Also the missing anticlinal walls could be related to a partial decomposition of the plant remains before the burial event.

The flora is dominated by conifers (*Elatocladus, Voltzia* and ?*Pelourdea*), followed by pteridosperms with thick cuticles (*Ptilozamites*). Thick cuticles may be indicative of an arid place of growth, but in this case may rather be a result of the selection of taxa with thick and resistant cuticles during an extended pre-depositional transport. As a consequence, the preservation patterns (size, fragmentation, floral composition) of the plant fossils may suggest a relatively distant place of growth. If this interpretation is accurate, the plants may have grown on far-away islands, belonging to the platform system surrounding the basin or along the elevated southwestern border of the Meride Limestone basin (see fig. 2 in Picotti et al. 2007).

The absence of fossil evidence of terrestrial animals in the excavated section adds support to the hypothesis that at that time plants grew far away from the place of deposition. Although a specimen of the protorosaur *Macrocnemus* has been reported from Cassina beds (Peyer 1937), no indication on the exact occurrence of this fossil within the sequence is available (Heinz Furrer, pers. comm. 2010). Also insects have not been reported from the studied horizons, whereas they occur in the Cava superiore beds (Furrer 2003) and, more abundantly, also in the Kalkschieferzone (Krzeminski & Lombardo 2001) where, together with better preserved plant remains, they represent more persuasive evidence for a nearby place of growth.

Until recently, knowledge about the macroflora from Monte San Giorgio was limited to rare horsetail stems and a few conifer shoots (and possibly cones) attributed to the genus *Voltzia*. The new collection consists of at least five taxa, most of which represent shrubby or arborescent conifers (*Elatocladus cassinae* n. sp., ?*Pelourdea vogesiaca, Voltzia* sp.), but also a shrubby seed fern (*Ptilozamites sandbergeri*) and putative cycad remains (?*Taeniopteris* sp.) have been discovered, together with unidentified leaf fragments, scales and other remains.

Notwithstanding the poor quality of the fossils, our study of the macroflora from the newly opened excavation indicates that a more diverse flora than previously thought grew around the Monte San Giorgio area during the Ladinian. Further studies of fossiliferous deposits in the area may provide additional and better preserved specimens, which may make it possible to more fully assess the structure and composition of the vegetation of the Ladinian ecosystems within this UNESCO paleontological site.

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