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Revised middle Triassic stratigraphy of the Swiss Prealps based on conodonts and correlation to the Briançonnais (Western Alps)

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Abstract The Triassic in the "Médianes rigides" Nappe of the Swiss Prealps, belonging to the Briançonnais realm of the Western Alps, consists of a several hundred meters thick carbonate succession. At the localities Wiriehorn and Rothorn, 650 m above sequence base, the *Costatoria goldfussi* limestone, a remarkable coquina and widespread transgressive marker bed, yields the key conodont *Sephardiella truempyi* (HIRSCH), a proxy for the Curionii - lower Gredleri ammonoid Zones (Early Ladinian). This new discovery has deep implications on the age of the different Triassic formations in the Swiss Prealps and for its correlation with other tectonic units. The newly established Pralet Formation in the Swiss Prealps comprises the Balmi Member with the Lower Ladinian *Costatoria goldfussi* limestone at its base, followed by the dolomitic breccias of the Ladinian Erpilles Member. Below the *S. truempyi* level, both the mighty platform carbonate sequence of the Wiriehorn Formation in the Swiss Prealps, and of the coeval Champcella Formation in the Brianconnais realm, are reassigned here to the Late Anisian. In our revised correlation, the *Costatoria goldfussi* limestone corresponds to the main flooding surface (MFS) of the large marine transgression that correlates biostratigraphically the now well dated Upper Muschelkalk transgression in Provence, Sardinia and Spain with the basal Ladinian type locality at Bagolino in the Southern Alps.

Keywords Carbonate platform · Anisian · Ladinian · *Costatoria goldfussi* limestone · Large marine transgression

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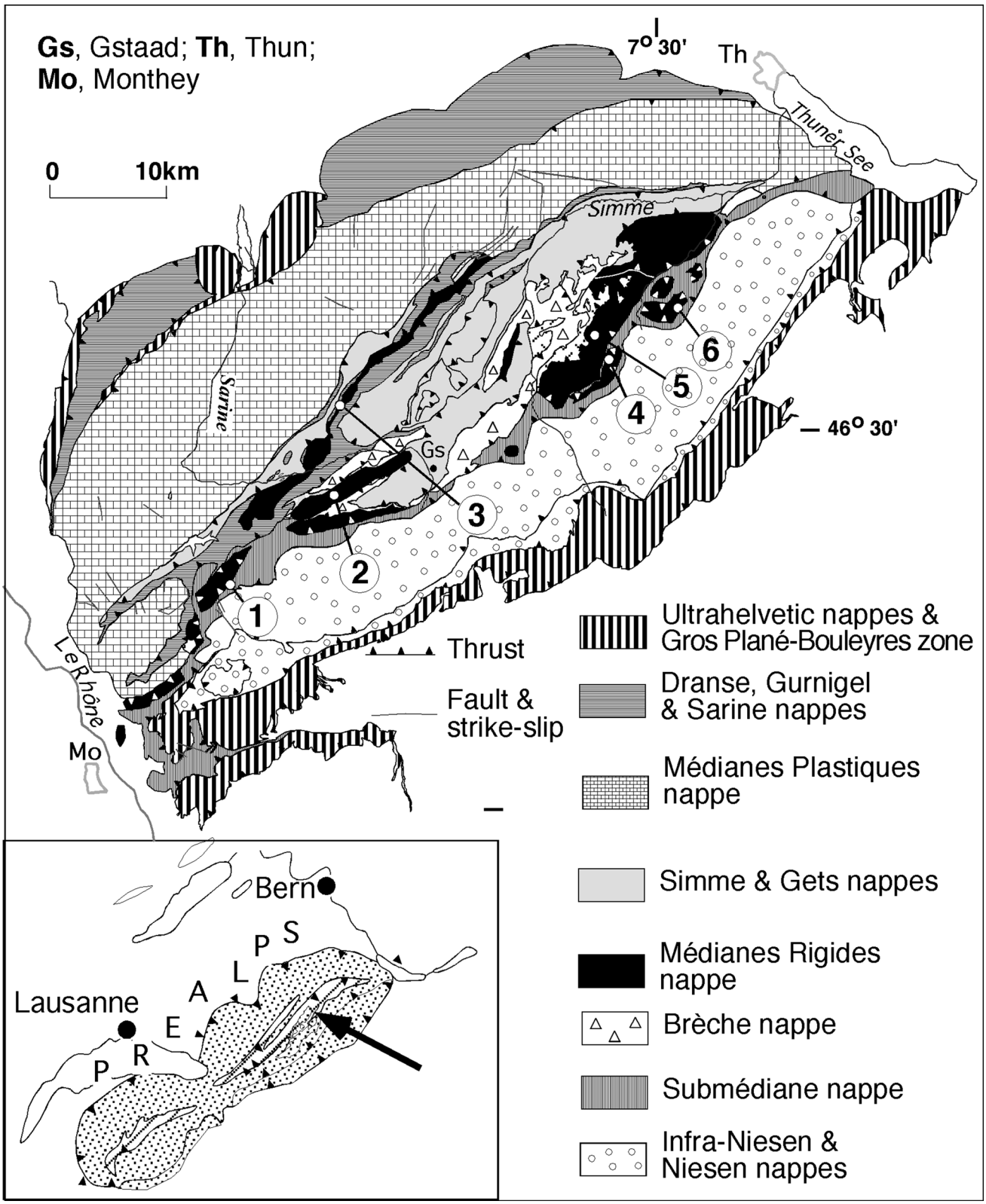
1 Introduction

It is a century ago that Alphonse Jeannet (1912–1913), in his impressive "Monographie géologique des Tours d'Aï", described in detail the Middle Triassic stratigraphy of the Swiss "Préalpes Médianes" along the West bank of the Rhône Valley near Aigle. He herein proposed the stratigraphic correlation of the Triassic exposures with those that were already known at that time from more internal zones of the Alps. Also, while studying the NE of the Prealps, Jeannet and Rabowski (1912) found for the first time the level with the bivalve *Myophoria goldfussi* at the top of their Middle Triassic "écaille du Twiriehorn" (=Wiriehorn thrust sheet, 6 in Fig. 1). Almost half a century later, Ellenberger (1950), restudying Jeannet's collections, discovered the close affinity between the Triassic sections in the Swiss Prealps with those of the Briançonnais (Western Alps).

1.1 Geological frame of the Swiss Prealps (Fig. 1)

The Swiss Prealps represent a stack of nappes that was thrusted from the south over the Molasse foreland and


Gs, Gstaad; Th, Thun;
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Le Rhône
Mo
Thrust
Fault & strike-slip
Ultrahelvetic nappes & Gros Plané-Bouleyres zone
Dranse, Gurnigel & Sarine nappes
Médianes Plastiques nappe
Simme & Gets nappes
Médianes Rigides nappe
Brèche nappe
Submédiane nappe
Infra-Niesen & Niesen nappes
Bern
Lausanne
PENNIQUE

◀**Fig. 1** Simplified geological map of the Prealps thrust sheet of Western Switzerland with the position of the studied sections that belong to the Middle Triassic units of the "Préalpes médianes rigides" tectonic unit (modified, after Bill 1998). *1* Mont d'Or section studied by Botteron (1961). *2* Rocher Plat section, type locality of the new Pralet Formation. *3* Rocher de Raye section, locality of the new Erpilles Member. *4* Wildgrimmi section, type-locality of the Wildgrimmi Member and reference section for the Wiriehorn Formation. *5* Seehorn section studied by Genge (1958). *6* Wiriehorn section, type locality for the Wiriehorn Formation, the Bodeflue Member and the Balmi Member

Ultrahelvetic domains of the Alpine belt. From NW to SE they consist of:

- The External nappes Dranse and Gurnigel, Médianes Plastiques, Simme and Gets;
- The Internal nappes of "Préalpes médianes Rigides" and "Brèche nappe" that are themselves thrusted over the Wildflysch of the "Zone Submédiane" and Niesen nappes (Fig. 1).

The "Préalpes médianes", both "Plastiques" and "Rigides", are a Triassic domain in Western Switzerland, belonging to the exotic Briançonnais micro-plate that collided with the southern European margin since Late Cretaceous times.

The reinvestigated Middle Triassic sediments occur only in the internal "Préalpes médianes Rigides" (Fig. 1).

1.2 Previous research in the Middle Triassic carbonate succession of the the Swiss Prealps (Fig. 2)

Since the earlier work of Pia (1912), Dasycladacean calcareous algae became very useful to the biochronology of Triassic shallow water carbonate platforms. In his synthesis on the Triassic of the Briançonnais, Ellenberger (1958) subdivided the Middle Triassic carbonate platform using three superposed Dasycladacean associations:

- Early Anisian: *Oligoporella* association, (=*Anisoporella occidentalis* Botteron, 1961);
- Middle-Late Anisian: *Physoporella praelpina* and *Diplopora annulatissima* association;
- Ladinian: *Diplopora uniserialis* and *Diplopora lotharingica* association.

At the top of the Dasycladacean sequence, the *Myophoria (=Costatoria) goldfussi* level appears. This was correlated by Ellenberger (1958) with the well-known Goldfussi-coquina in the Germanic Lettenkohle (basal Keuper), and considered Late Ladinian to Early Carnian.

In the Prealps, the biochronology of Ellenberger (1950) was followed by Genge (1958) and Botteron (1961) for the Middle Triassic carbonate succession. Two decades later, in their synthesis of the Western Alpine Triassic, Baud and Mégard-Galli (1975) and Mégard-Galli and Baud (1977) still used the same time scheme, but subdivided the Middle Triassic carbonate succession in three cycles (I to III) that correspond to the following three units (Figs. 2, 3, 4):

1. the Anisian St. Triphon Formation (CI);
2. the Early Ladinian Champcella/Wiriehorn Formation (CII);
3. the Late Ladinian-Early Carnian "couches à *C. goldfussi*" (CIII).

2 Triassic lithostratigraphy of the Swiss Prealps

The Briançonnais-type Triassic deposits in the Swiss Prealps reach a maximum thickness of about 1100 m (Fig. 3). The Lower Triassic consists of mature quartz-arenite. The Middle Triassic is built up of three transgressive–regressive (T-R) cycles of rapidly succeeding shallow marine carbonates of cyclic nature. The Upper Triassic sediments, made of evaporites, are topped by a shallow marine, partly dolomitic carbonate platform.

The three Middle Triassic cycles correspond to lithological units that start and end under emersive environmental conditions. The first author successfully applied this scheme during the geological mapping campaigns of the Middle Triassic in the Swiss Prealps (Baud in Lombard et al. 1975, Baud, in Furrer et al. 1993; and see Online Resource 1).

Some formations and members have been previously named after respective type localities in the Prealps or the Briançonnais (Baud and Mégard-Galli 1975; Mégard-Galli and Baud 1977; Baud 1984, 1987). The type localities and sections of the new formal units, proposed here for the Prealps (Fig. 3), are described in the Online Resources 1, 2, Figs. a, c and e, and 3, Fig. g).

These three Middle Triassic cycles, established by Baud and Mégard-Galli (1975) correspond to 3rd order T-R eustatic cycles, as in Courel et al. 1998 and in Franz et al. 2015.

2.1 Cycle CI: "Formation de Saint-Triphon"

The St-Triphon Formation (Baud 1984, 1987), corresponding to the first cycle, is characterized by shallow-water limestone that yields the dasycladacean *Physoporella prealpina,* and *Diplopora annulatissima* association. The discovery of the ammonoid *Beyrichites cadoricus* in the upper part of the St-Triphon Formation (Baud 1984, 1987) provides a Middle Anisian age constraint (Monnet et al. 2008). The same age was previously attributed to the first conodont finding in the Prealps, presumably "*Gondolella"*

?mombergensis (Baud et al. 1968) The presence of ammonoids and conodonts in this very shallow sequence point to a transgressive peak in the upper part of the Formation, which could correspond to the Middle Anisian Balatonicus ammonoid Zone (Fig. 4).

2.2 Cycle CII: "Formation du Wiriehorn" (alias Champcella; Online Resources 1 and 2)

The Wiriehorn Formation (Baud and Mégard-Galli 1975; Baud, in Furrer et al. 1993; Online Resources 1 and 2 for a description) represents the mightiest Briançonnais Middle Triassic carbonate cycle (between 250 to 330 m) and is built up by a set of restricted upwards-shallowing carbonate para-sequences, 20 to 50 m thick (banded limestone = Wildgrimmi Member, Online Resource 2, Figs. b and c), capped by a 20–80 m thick peritidal regressive dolostone ("Dolomies claires" = Bodeflue Member, Online Resource 2, Fig. d and e) ending with mud-cracks dolostone beds. The Wiriehorn Formation is equivalent with the "Formation de Champcella" in the Briançonnais (Mégard-Galli and Baud 1977; Online Resource 1). The revised age proposed herein for this interval is Late Anisian (see Chap. 3).

2.3 Cycle CIII: "Formation du Pralet " (Online Resources 1 and 3)

Mégard-Galli and Baud (1977) having not provided a formation name for this cycle, we propose herein the Pralet Formation for the Prealps. This "Formation du Pralet" overlies conformably the Wiriehorn Formation.

It encompasses two members: the new Balmi and Erpilles Members. Transgressive from the bottom, the Balmi Member (Online Resources 1 and 3) starts with light coloured dolo-grainstone, followed by the large transgressive unit of the "Couches à *Costatoria goldfussi*" that represents the peak of the transgression (MFS). It ends with the sudden appearance of crinoidal limestone, with a brown dolomite at its top.

The second member, the Erpillles Member, starts with terrigenous yellowish clay (mudstone). This sudden terrigenous input was previously interpreted as the base of a new cycle (Cycle IVa, Mégard-Galli and Baud 1977). But it is at present interpreted as the continuation of the high-stand deposit of Cycle III that consists of the thick, partly brecciated, dolomite of the Erpilles Member. We propose a Ladinian age for the Pralet Formation time interval, with the Balmi Member being Early Ladinian (Fig. 3 and Online Resources 1, 2 and 3 for further details).

2.4 The three Upper Triassic cycles (Fig. 3)

Cycle CIV corresponds to the "Complexe de Clot-la-Cime" in the Briançonnais s.str. (description by Mégard-

Fig. 3 New composite section of the Triassic units of the Western Swiss Prealps ("Médianes plastiques and Médianes rigides"). In *red*, the position of the studied "*goldfussi*" unit. *mfs* main flooding surface. Numerical age according to the Triassic time chart, in Ogg et al. (2016)

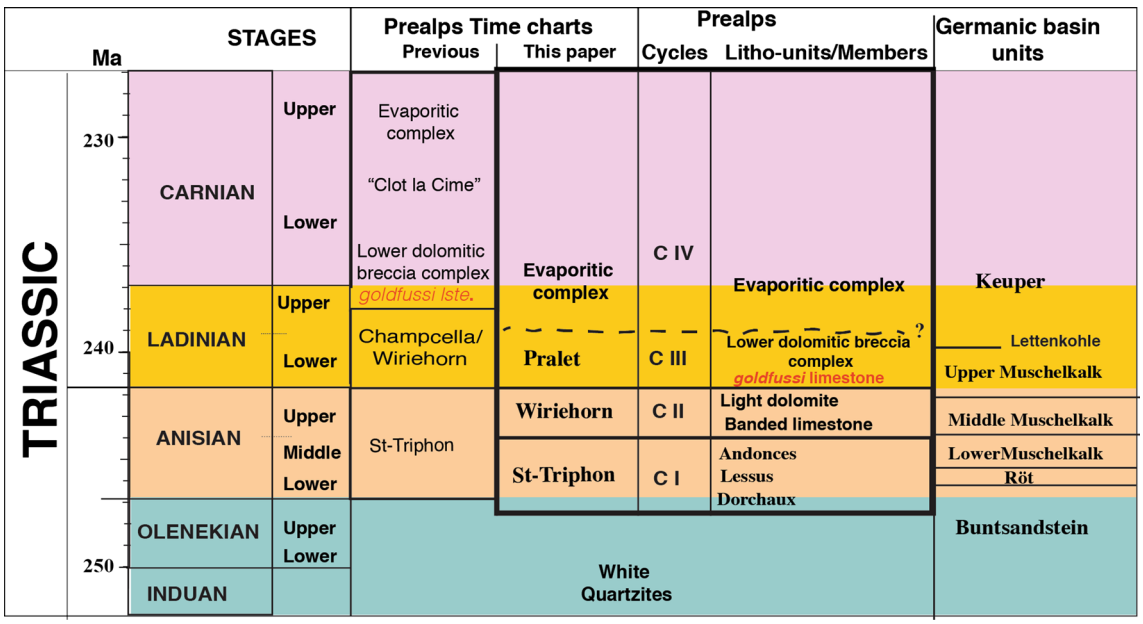
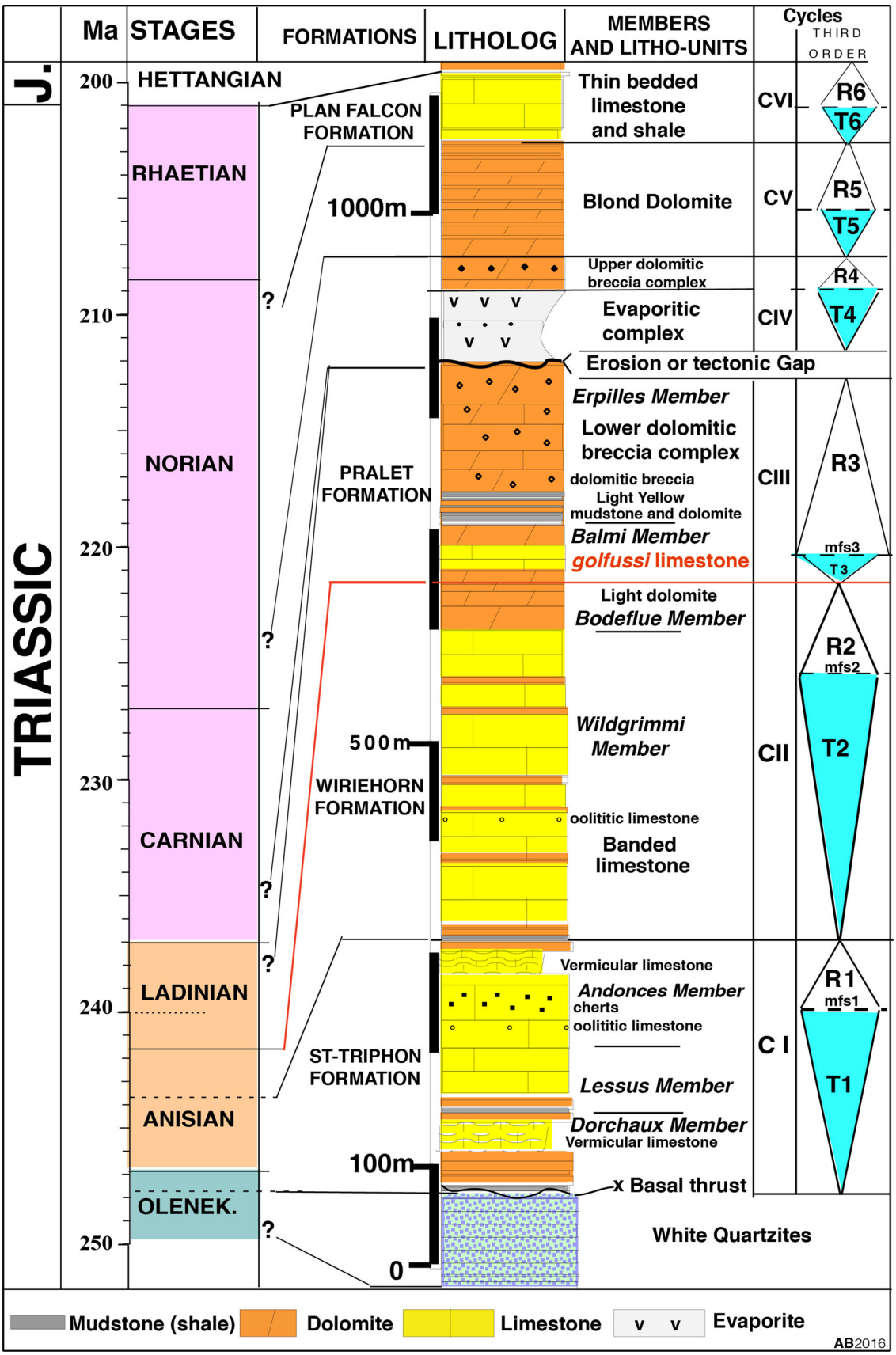


Fig. 2 Stratigraphic chart showing the previous (ref. in the text) and the revised age attribution of the lithological units of the Swiss Prealps and the Briançonnais and their comparison with the Germanic basin units according to Franz et al. (2015)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FORMATIONS
LITHOLOG
MEMBERS AND LITHO-UNITS
Cycles
THIRD ORDER
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TRIASSIC
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HETTANGIAN
RHAETIAN
NORIAN
CARNIAN
LADINIAN
ANISIAN
OLENEK.
PLAN FALCON FORMATION
1000m
PRALET FORMATION
500m
WIRIEHORN FORMATION
ST-TRIPHON FORMATION
100m
0
Thin bedded limestone and shale
Blond Dolomite
Upper dolomitic breccia complex
Evaporitic complex
Erosion or tectonic Gap
Erpilles Member
Lower dolomitic breccia complex
dolomitic breccia
Light Yellow mudstone and dolomite
Balmi Member
golfussi limestone
Light dolomite
Bodeflue Member
Wildgrimmi Member
oolititic limestone
Banded limestone
Vermicular limestone
Andonces Member
cherts
oolititic limestone
Lessus Member
Dorchaux Member
Vermicular limestone
x Basal thrust
White Quartzites
CVI
CV
CIV
CIII
CII
C I
R6
T6
R5
T5
R4
T4
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mfs3
T3
R2
mfs2
T2
R1
mfs1
T1
Mudstone (shale)
Dolomite
Limestone
Evaporite
AB2016

Galli 1972; Mégard-Galli and Faure 1988) where it comprises two evaporitic complexes (anhydrite and gypsum), whereas only one is present in the Prealps, with detrital *Equisetum* shale and sandstone followed by an upper brecciated dolomite complex, partly Carnian in age according to Mégard-Galli and Faure (1988).

The Cycle CV is made of medium bedded blond dolomite that is correlated with the Norian "Hauptdolomit" of the Eastern and Southern Alps (Jeannet 1912).

The Cycle CVI (Plan Falcon Formation) is marked by the large transgression of the *Rhaetavicula* limestone (bivalve coquina) characterizing the Rhaetian stage (Jeannet 1912).

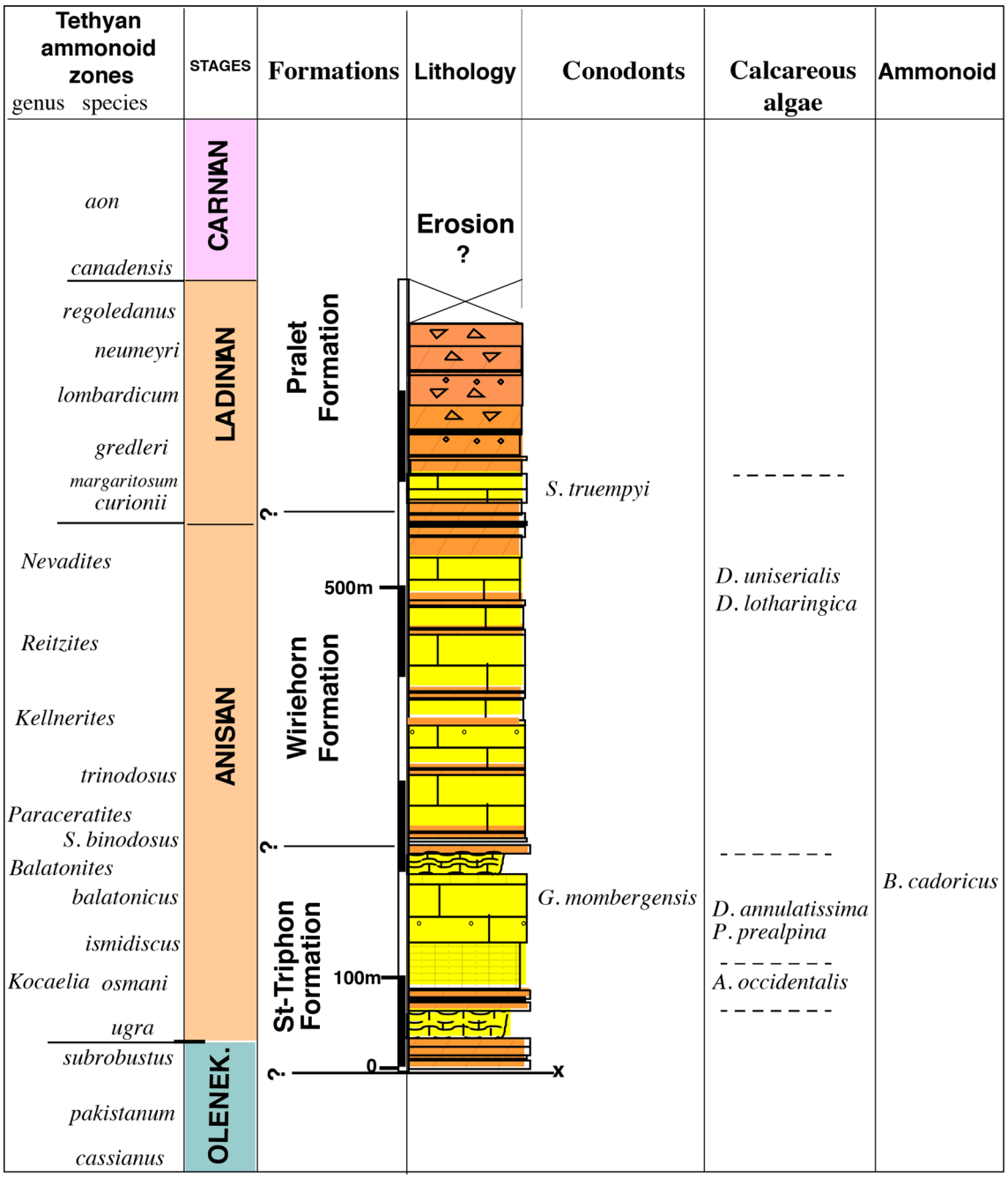


Fig. 4 New composite section of the Middle Triassic of the "Préalpes medianes Rigides" thrust sheet, with the position of conodonts, of calcareous algae and of ammonoid occurences. Age not in scale and caption in Fig. 3. Tethyan ammonoid zones modified from Balini et al. (2010)

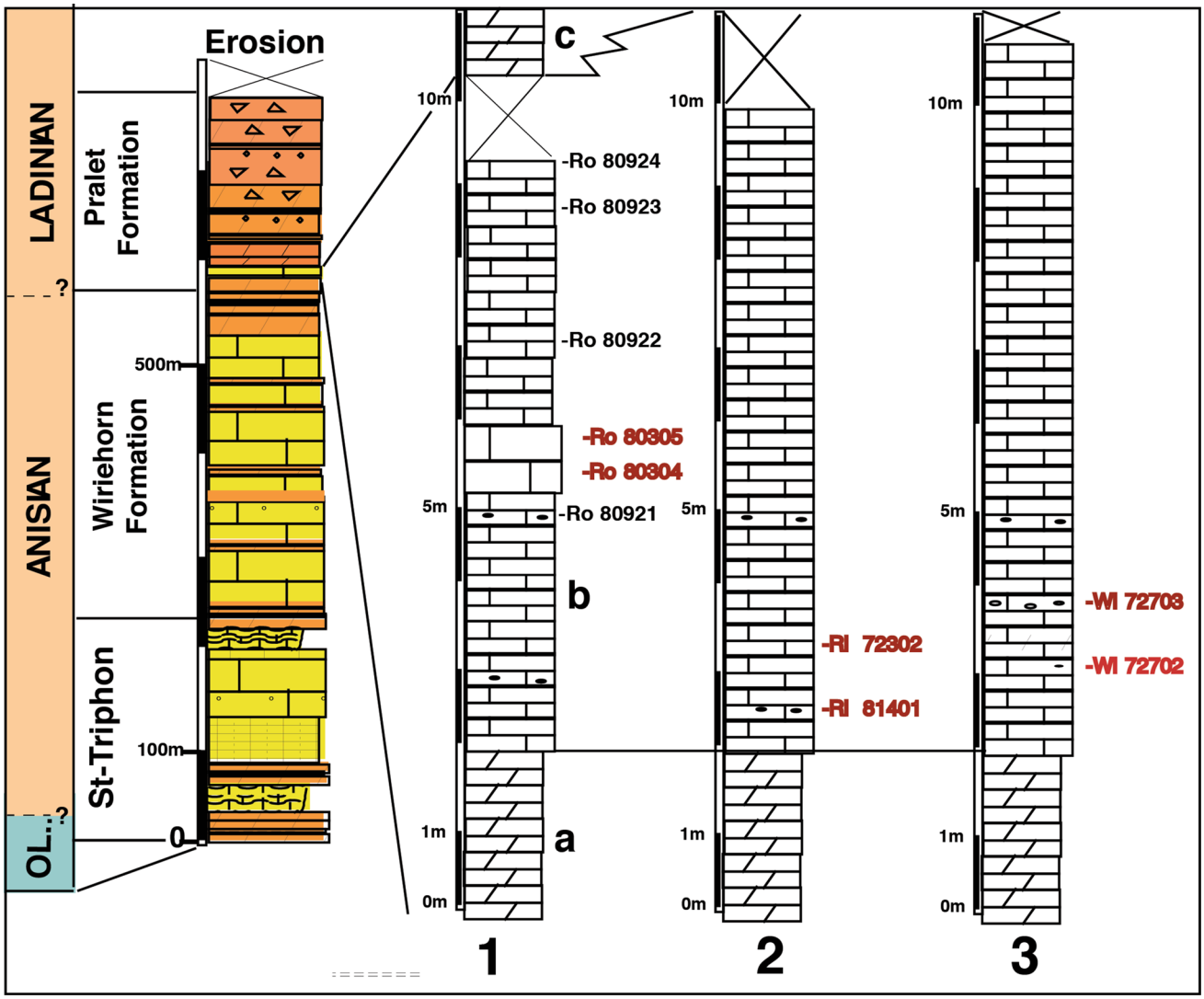


Fig. 5 Position of the samples within the Balmi Member from three sections of the Wiriehorn–Rothorn thrust sheet (Online resources 1 and 2). Conodont samples in red. Stratigraphic columns: *1* Rothorn, "Lyss Hütte" section, coordinate: 46°33′9.96″N 7°27′45.67″E; *2* Riprechtifluh, road section, coord.: 46°35′7.00″N 7°30′3.36″E; *3* Wiriehorn, Balmi section, coord. 46°35′8.50″N/7°31′36.49″E. Levels: *a* top of the "Dolomies claires" unit; *b C. goldfussi* Limestone unit; *c* base of the "Dolomie brune" unit. Caption in Fig. 3

3 The Prealps "Couches à *Costatoria goldfussi*": new conodont age constraint for the Balmi Member of the Pralet Formation (Fig. 3)

The "Couches à *Costatoria goldfussi*" form the bulk of the Balmi Member of the Pralet Formation in the Prealps (Fig. 3). Corresponding to the transgressive lower part of cycle CIII, it overlies undisturbed the Wiriehorn Formation (Champcella in the Briançonnais). These *Costatoria goldfussi* marker beds can be followed all the way down to the Mediterranean coast (Mégard-Galli and Baud 1977). It is most often dolomitized in the Western Alps.

In the Seehorn section (Fig. 6), just north of the Rothorn thrust sheet, Genge (1958) described and illustrated *Myophoria goldfussi*, as well as Pectinids, Cyprinids, Dentalids and Aviculids. He also mentioned crinoids with *Encrinus liliiformis* and a *Solenopora* algae.

Its faunal content in the Vanoise area of the French Alps has been described and illustrated by Ellenberger (1958). Among the bivalves, this author proposed the use of *Myophoria goldfussi* var. *alpina* as a marker. Bivalves comprise smooth Myophorids, *Pachycardia* and *Trigonodus*. Among gastropods figures *Omphaloptycha* (or *Geinitzia*) cf. *escheri*.

Dolomitized "Couches à *Costatoria goldfussi*" are present in most of the Swiss Prealps "Préalpes médianes Rigides" thrust sheets (Botteron 1961; Genge 1958), but in the Eastern part of these Prealps they show rare but interesting limestone outcrops (Diemtigtal, sections 1, 2 and 3 in Figs. 5, 6). There, in-between dolomitic layers, the

Fig. 6 E–W Google Earth view-3D in the SSW direction of the upper part of the Diemtigtal Valley. Geographic situation of the three sections 1, 2, 3 placed on Fig. 5. Coordinate in Fig. 5 caption. Seehorn is the Genge (1958) locality (5 in Fig. 1)

5–10 m thick *Costatoria goldfussi* interval represents a level of lime-wackestone with some cherts in the lower part (Fig. 5), capped by crinoidal lime-packstone.

During our quest in these uppermost limestone of the Wiriehorn-Rothorn Middle Triassic thrust sheet, we were lucky to find the key conodont *Sephardiella truempyi* that is a proxy for the Early Ladinian *curionii* zone (Brack et al. 2005). Previously, this limestone was correlated with Upper Ladinian to Lower Carnian units of the Germanic Triassic. The new finding and description (see below) of the conodont *Sephardiella truempyi* within these "Couches à *Costatoria goldfussi*" from the top of the Rothorn section (1, in Figs. 5 and 6: Online Resources 1 and 2 Fig. c) and of the Twiriehorn (Wiriehorn) section (3, in Figs. 5, 6; Online Resources 1 and 2 Fig. e) provide an Early Ladinian age as discussed below and in the Chap. 5. All the productive samples are coming from these upper limestone beds and among all the extracted conodonts, those originated from a singular thick bed of the "Lyss Hütte" section (1 in Fig. 5, Fig. 7, red star; Online Resource 2, Figs. b and c) are illustrated in the Fig. 8.

Consequently, this *Costatoria goldfussi* limestone level near the top of the first thick carbonate succession of the Briançonnais realm, is of Early Ladinian age. The overlying monogenic and synsedimentary dolomitic breccia still contains *Costatoria goldfussi* shells (Genge 1958) and represents the Erpilles Member of the Pralet Formation (Online Resources 1 and 3). This unit is now to be considered of Ladinian age instead of Carnian, as it was assumed in earlier publications (Fig. 2: previous and this paper charts).

Remark: As a result of the establishment of the Global Stratotype Section and Point (GSSP) at the onset of the Curionii ammonoid Zone in the Bagolino section by Brack et al. (2005), the Anisian–Ladinian boundary was shifted upwards by up to three ammonoid zones. Getting younger, the Upper Anisian part of the Briançonnais includes now the Wiriehorn (Champcella) Formation. This formation, held previously for Lower Ladinian on the base of the *Diplopora uniserialis* and *Diplopora lotharingica* dasycladacean association (Mégard-Galli and Baud 1977; Baud 1984, 1987), is at present fully comprised within the Upper Anisian (Figs. 2, 3, 4, this paper). This new age attribution is apparently also in agreement with the revised Dasycladacean stratigraphy of Granier and Grgasović (2000).

4 The conodonts

Sephardiella truempyi (HIRSCH 1971) is characterized by acuminate platform elements with an amygdaloid or ellipsoid basal cavity (Fig. 8). It belongs to the subfamily

Fig. 7 Outcrop view of the *Costatoria goldfussi* limestone, "Lyss Hütte" section of the Rothorn thrust sheet (Locality 1 in Figs. 5, 6). The *red star* shows the conodont finding bed, about 60 cm thick (scale = hammer on the *right of the star*)

Sephardiellinae of the Family Gondolellidae (Plasencia et al. 2007) that is also characterized by acuminate platform elements with an amygdaloid or ellipsoid basal cavity (Fig. 8). First classified as *Gladigondolella*, for its acuminate shape, but possessing a gondolellid multielement apparatus, the species *truempyi* was subsequently referred to the genera *Epigondolella* Mosher 1968, *Carinella* Budurov 1973, *Budurovignathus* Kozur 1989 and *Sephardiella* March et al. 1990, validated in the first revision by Sudar (1989). The species *Sephardiella truempyi* has smooth platforms devoid of any nodes or denticles. The conodont fauna from the "Préalpes médianes Rigides", found in the "Lyss Hütte" section of Locality 1, Rothorn (Figs. 5, 6, 7; Online Resource 2 Figs. b and c), samples Ro 80304, Ro 80305, consists of relatively small specimens (varying between 0.2–0.5 mm) which all correspond to the original diagnosis of *S. truempyi* (See Fig. 8).

Specimens of *S. truempyi*, have also been found in the samples Ri 72302 and Ri 81401 of the Riprechtifluh, road section (locality 2 in Figs. 5, 6) and in the sample Wi 72702 of the Wiriehorn section (locality 3 in Figs. 5, 6; Online Resource 2, Figs. d and e). Together with the extracted conodonts, a great amount of fish remains and teeth are expected to be studied in a near future.

5 Age of *Sephardiella truempyi*

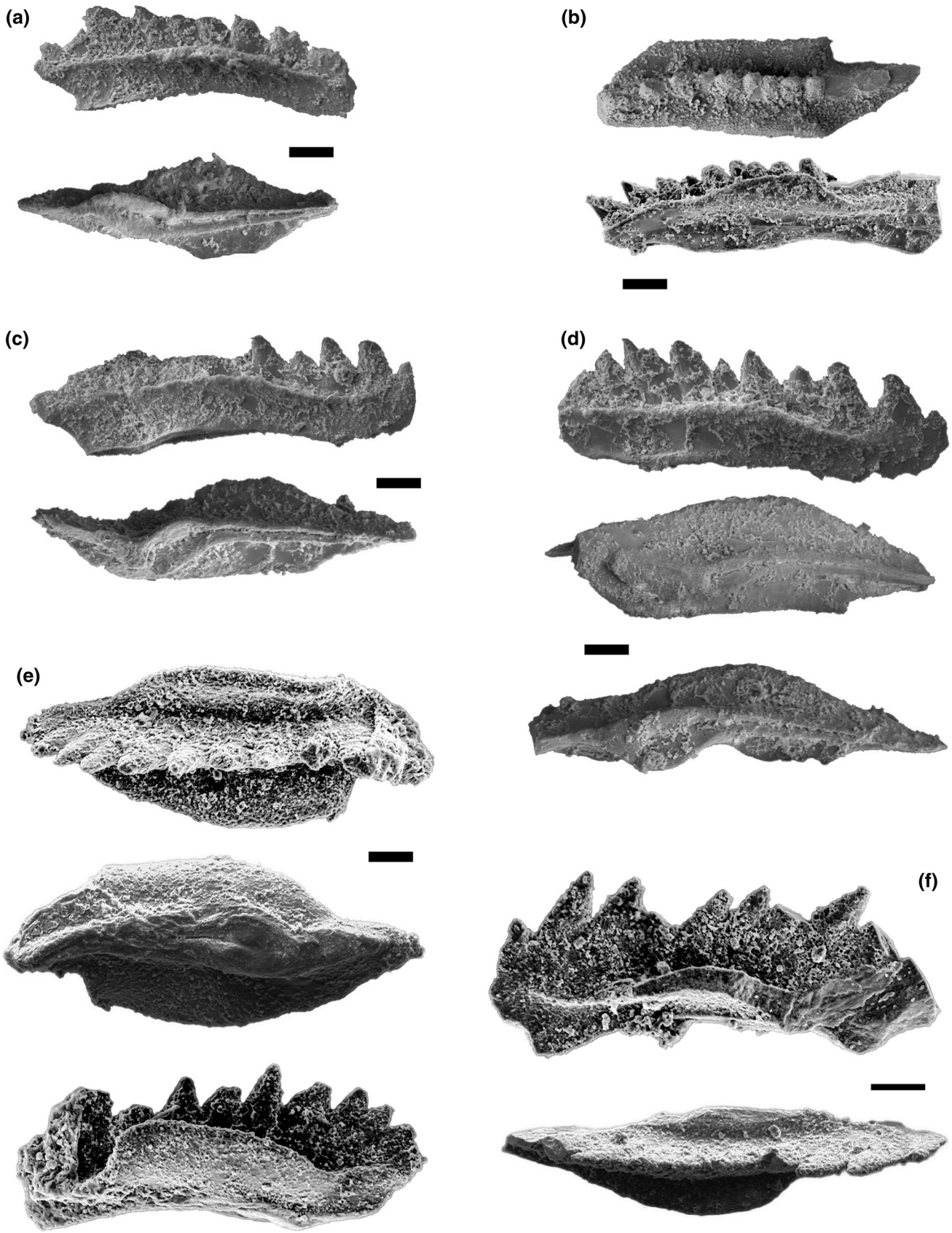
Sephardiella truempyi is present in the Buchenstein Formation of the Southern Alpine Bagolino section, the GSSP of the Ladinian stage, defined at the base of the ammonoid *Eoprotrachyceras curionii* Zone (Nicora and Brack 1995; Brack et al. 1999, 2005). At Bagolino, the conodont *S. truempyi* is found in a level that is 2.7 m above the base of the Curionii Zone and 2 m below the Margaritosum ammonoid Zone, in the Northern Grigna section near Lecco (Nicora and Rusconi 2007) and at Belvedere (Colle S. Lucia) in a level that falls into the upper Curionii ammonoid Zone (Muttoni et al. 2004, Figs. 6, 7). These authors report that between the upper Curionii Zone and basal portion of the Gredleri Zone (240–239 Ma), an abrupt decrease in specific variability occurs, characterized by the substitution of the relatively abundant *Paragondolella* and *Neogondolella* association of the previous *secedensis*—basal *curionii* ammonoid interval (241–240 Ma), with an association of fewer species, such as *Paragondolella praehungarica, P. gabriellae* and *Sephardiella truempyi.*

The current Southern Alpine *S. truempyi* range would correspond to the middle portion of the Curionii Zone up to the basal part of the Gredleri ammonoid Zone. These two zones define the "Fassanian" substage of the Ladinian (Brack et al. 2005; Hochuli et al. 2015) that can be considered as the closest approximation of the original historical range of the "Fassanian" (=Buchenstein Beds).

At Felsöörs (Balaton), the FAD of the diagnostic *S. truempyi* postdates *Paragondolella praehungarica,* while it predates the FAD of *Eoprotrachyceras* (Vörös et al. 2003).

In the Northwestern Sardinia, *S. truempyi* is most abundant, and is considered by Bagnoli et al. (1985), Brocard (1991) and Carrillat et al. (1999) as indicative of the upper Curionii ammonoid Zone (now Early Ladinian). For Kovacs and Kozur (1980), it is the index conodont of the Truempyi-range-Zone.

At Alós de Balaguer in the Catalonian Pyrenees, Plasencia (2009) and Plasencia et al. (2015) found *S. truempyi* together with *Pseudofurnishius murcianus* van den Boogaard (1966) in the "Grey Limestone" unit. The


(a)
(b)
(c)
(d)
(e)
(f)

◀**Fig. 8** P1 elements of *Sephardiella truempyi* (Hirsch) from the Rothorn section. Sample 80304 and 80305, 3 and 4 m above base of Pralet Fm, respectively (Lower Ladinian, Swiss Prealps). *All bars* = 0.05 mm (=50 μm). **a** Right element, sample Ro80304, specimen K99II_10. Inner and lower views. Note the amygdaloid basal cavity. **b** Left element, sample Ro80304, specimen K99II_25. Upper, inner and lower views. **c** Right element, sample Ro80304, specimen K99II_59. Outer and lower views. **d** Left element, sample Ro80304, specimen K99II_65. Outer and lower views. **e** Left element, sample Ro80305, specimen Ro-80-305-04. Upper, lower and outer views. **f** Right element, sample Ro80305, specimen Ro-80-305-08. Inner and Lower views

FAD of the latter lies within the Early Ladinian ammonoid *Eoprotrachyceras curionii ramonensis* Zone at Ramon in Israel and at Calasparra in S.E. Spain (Hirsch 1972). Pérez Valera (2016) confirmed this ammonoid to correspond to the S. Alpine *E. curionii* species after careful comparisons.

6 Palaeogeographic significance of the "Couches à *Costatoria goldfussi*"

The *Costatoria goldfussi* level that characterises the Balmi Member, of the lower part of the Pralet Formation in the Swiss Prealps yields *S. truempyi* that can thus be correlated with a portion of the lower Ladinian (Fassanian).

In the Germanic basin, *C. goldfussi* occurs in the Nodosus ammonoid Zone, which is also Early Ladinian (Fassanian, Brack, written comm.). The rare occurrence of *S. truempyi*, just above the "Cycloides Bank" of the Meissner Formation, has been claimed (Kozur and Bachmann 2005), a statement that we were unable to verify. But this "Cycloides Bank" interval corresponds to the Lower Buchenstein Beds just above the latest Anisian Nevadites ammonoid Zone, with a maximum basin depth according to Brack et al. (1999).

Recorded within the Briançonnais realm all along the Western Alps from the Central Swiss Prealps to Franco-Italian maritime Alps, the "Couches à *Costatoria goldfussi*" are well known in the Triassic of the Provence area (Southern France), where it corresponds to the Formation III or F of the Provence Upper Muschelkalk (Caron 1967; Brocard 1991). It is interesting to note that *S. truempyi* occurs in levels with *C. goldfussi* in both Provence and Sardinia. It concern the "La Bastide de la Blanque" section, North of Toulon (Provence, SE France, Hirsch 1971) and the "Monte San Giusta", "Punta del Lavatoio" and "Cala Poglina" sections of NW Sardinia (Carrillat et al. 1999; Posenato et al. 2002).

Franz et al. (2015), in their palaeogeographical overview of the Upper Muschelkalk wrote: "the latest Illyrian MFS is also suggested in Provence and Northwest Sardinia where nodular limestones and bioturbated limestones (partly with dasycladaceans) are superimposed by bioclastic limestones with the index conodont *S. truempyi* corresponding to the Curionii Zone". This correlates with the Early Ladinian age assignment of the Upper Muschelkalk transgression in Provence that is based on the finding of *Ceratites {Cycloceratites}* cf. *laevigatus* by Urlichs (1997), and confirmed by Durand et al. (2011).

Correlative levels with *Costatoria goldfussi* have also been described from the Muschelkalk of Spain (Escudero-Mozo et al. 2015): during the Anisian–Ladinian transition, a marine transgressive peak, well dated with the *curionii* ammonoid fauna, onlaps over Variscan foreland (Pérez Valera 2016). It corresponds to the maximum extent of the Triassic basins in the Southern Alps and the migration of ammonoid fauna from the Neotethyan domain to peripheral seas (Gianolla et al. 1998; Brack et al. 1999).

Costatoria goldfussi rich beds have been found in the first marine transgressive "dolomie capucin" belonging to the basal sedimentary cover of the Variscan Massif, South of the Belledone Massif of the Western Alps (Mégard-Galli oral communication).

S. truempyi is reported at Tarasci (Turkey) by Chen et al. (2015), in co-occurrence, among others, with the ammonoid *Israelites*, Late Ladinian in their view, but Early Ladinian according to Assereto and Monod (1974) and to Pérez Valera (2016).

Finally, *S. truempyi* is not restricted to the Western Tethys and adjacent shallow Triassic seas, but is found in SW China, where, at Guangdao, North flank of the Great bank of Guizhou, Nanpanjiang Basin, this proxy pinpoints the base of the Ladinian stage (Lehrmann et al. 2015).

7 Conclusions

The appearance in the Prealps of the conodont *Sephardiella truempyi* is linked with the large marine transgression along the western Tethys during the Anisian–Ladinian transition (Franz et al. 2015), well dated by the *curionii* ammonoid fauna in Spain (Minorca and Betic Range, Pérez Valera 2016) and also corresponding with the first marine transgression over the external Variscan basement shown by Courel et al. (1998) and by Escudero-Mozo et al. (2015).

In the Swiss Prealps, the finding of *Sephardiella truempyi* attributes the "Couches à *Costatoria goldfussi*" to the Early Ladinian. These "Couches à *Costatoria goldfussi"* define the Balmi Member transgression that is the base of the newly proposed Pralet Formation. The level of *Costatoria goldfussi* extends along the entire Briançonnais realm. The Pralet Formation in the Prealps, corresponds to

the Middle Triassic 3rd order T-R Cycle III that is older than the Clos-la-Cime Formation in the Briançonnais.

The "Couches à *Costatoria goldfussi*" of the Balmi Member that was formerly assigned to the Upper Ladinian to Lower Carnian, is now of Early Ladinian age.

The Wiriehorn Formation in the Prealps and the coeval Champcella Formation in the Brianconnais, both formerly held for Ladinian in age, must now be assigned a Late Anisian age. They represent the thickest carbonate platform units in the Prealps and Briançonnais.

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