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THE PUFELS/BULLA ROAD SECTION: DECIPHERING ENVIRONMENTAL CHANGES ACROSS THE PERMIAN-TRIASSIC BOUNDARY TO THE OLENEKIAN BY INTEGRATED LITHO-, MAGNETO- AND ISOTOPE STRATIGRAPHY. A FIELD TRIP GUIDE.

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With 11 figures

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Topographical map: Carta topografica/Topographische Wanderkarte 1:25.000, Val Gardena/Gröden – Alpe Siusi/Seiser Alm, Bl. 5, Tabacco
Geologic map: Geologische Karte der Westlichen Dolomiten/Carta geologica delle Dolomiti Occidentali 1:25.000. – Autonome Provinz Bozen-Südtirol/Provincia Autonoma di Bolzano-Alto Adige, Amt für Geologie & Baustoffprüfung/Ufficio Geologia e Prove Materiali, Kardaun/Cardano, Bozen/Bolzano, 2007.

Route (see also Figs. 1, 2)

From Bozen/Bolzano 1 hour bus drive to Seis/Siusi, Kastelruth/Castelrotto (both on top of a thick Permian volcanic sequence ("Bozen-Quarzporphyr", Etschtaler Vulkanit-Gruppe/Gruppo vulcanico Atesino) and Panider Sattel/Passo Pinei (Gardena/Gröden–Fm.), bifurcation to Pufels/Bulla. Several stops along the Pufels/Bulla section, which is well exposed along the abandoned road to Pufels/Bulla.

Aim of the excursion

The Pufels/Bulla section offers an excellent opportunity to study the Permian-Triassic boundary (PTB) and the Lower Triassic Werfen facies and stratigraphy in a nearly continuous section from the PTB to the Induan/Olenekian boundary (IOB) located within the Campill Member. In this guidebook we present for the first time the complete section with the exact position of the samples taken for palaeomagnetic analysis (see Scholger et al., 2000) and for carbon isotope analysis (see Horacek et al., 2007a), together with the interpretation of 3rd and 4th order cycles. In addition, dissimilarities in the lithostratigraphic subdivisions of the Werfen Formation by different research groups are shown for clearness. Until now, there do exist only few sections in the world where integrated stratigraphy has been carried out in such a detail at the PTB and within the Lower Triassic. On the basis of this key-section at Pufels/Bulla we want to stimulate the discussion on questions of the "system earth", i.e. genetically related correlations of lithofacies, sea-level changes, anoxia and stable carbon and sulphur isotope curves. Magnetostratigraphy enables a direct comparison with continental sedimentary sequences of the German Zechstein and Buntsandstein to understand sequence stratigraphy, cycles and regional climatic influences.

General remarks

The Permian-Triassic sequence is embedded within two major tectono-sedimentary cycles situated on top of Variscan crystalline basement. The cycles are: (1) the > 2000 m thick "Athesian Volcanic Group"

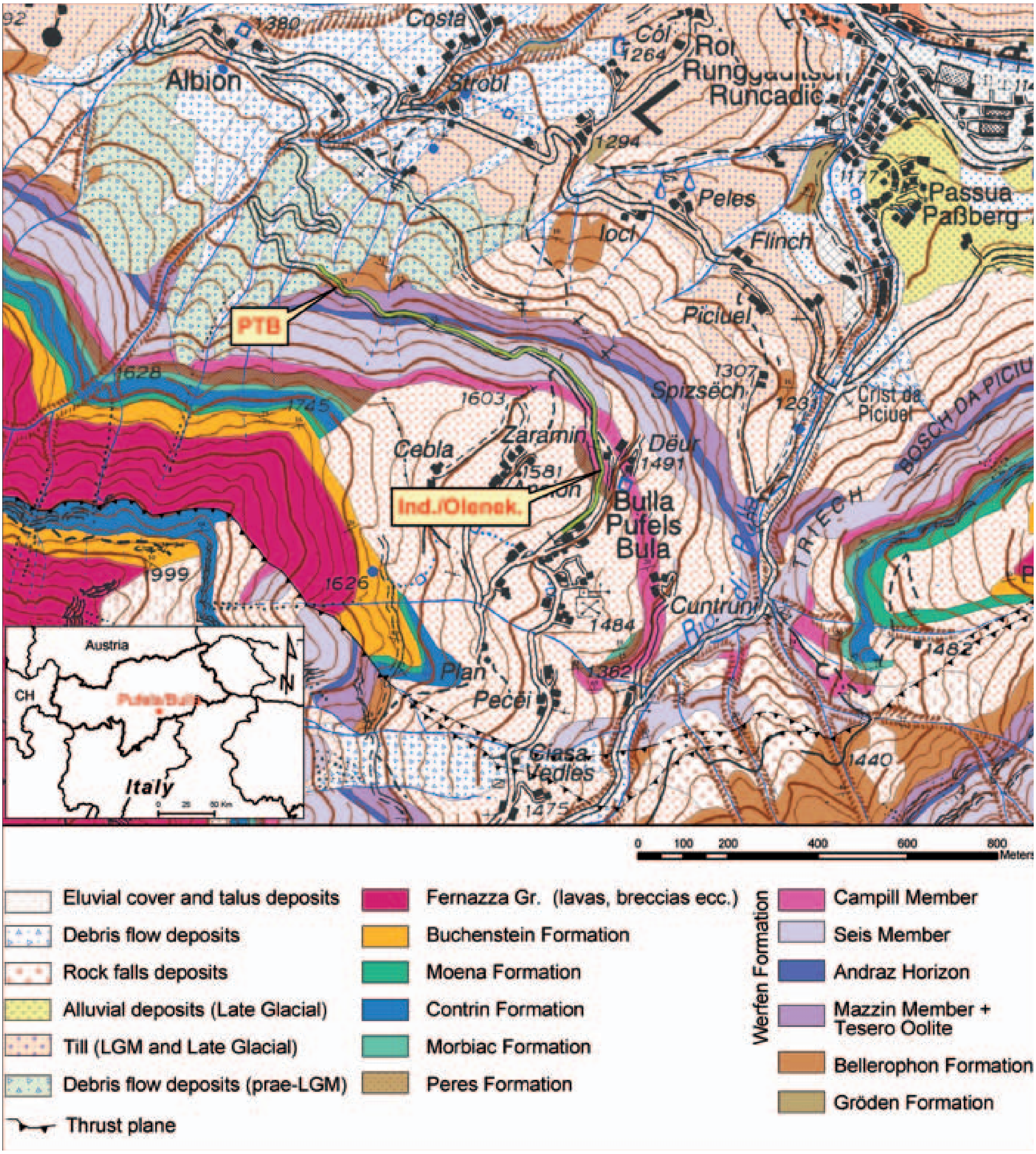


Fig. 1: Geologic map with excursion route (red-yellow) along the old road to Pufels/Bulla. PTB = Permian-Triassic Boundary. Geologic map after "Geologische Karte der Westlichen Dolomiten 1:25.000".- Autonome Provinz Bozen – Südtirol, Amt für Geologie & Baustoffprüfung, Bozen/Kardaun, 2007.

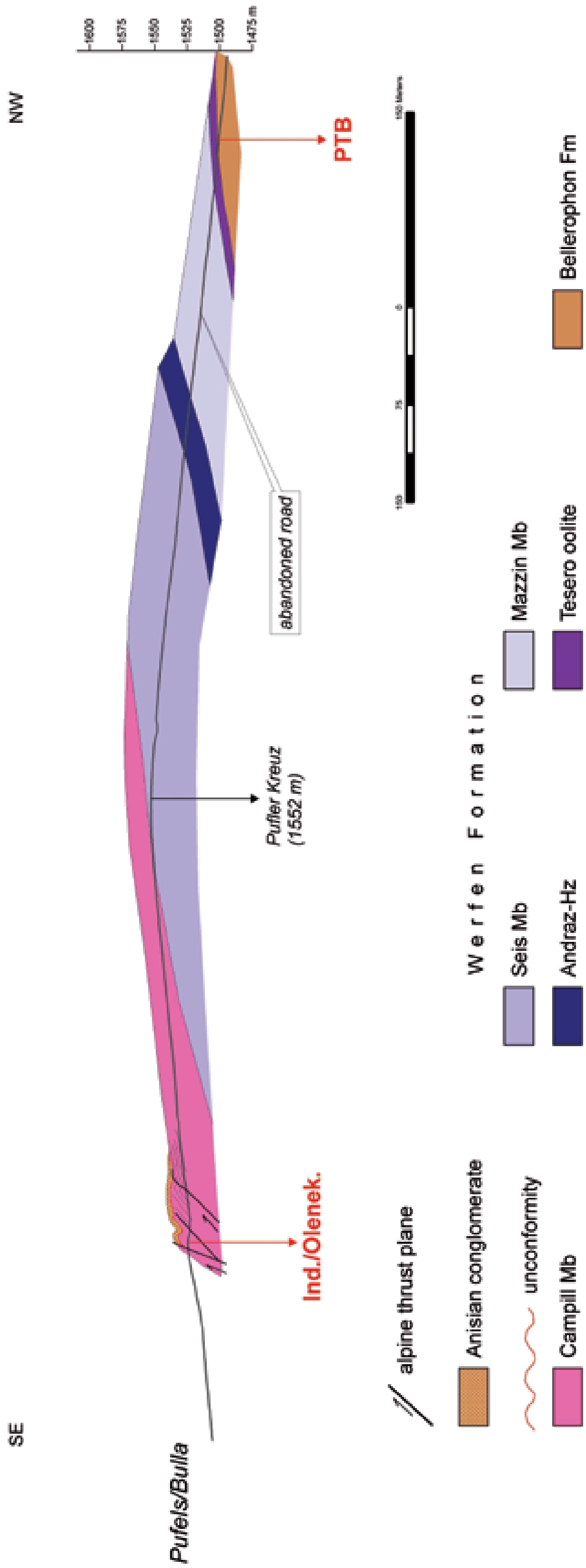


Fig. 2: Section through the Werfen Formation along the abandoned road to Pufels/Bulla. The top of the section shows ramp folds, which can be restored bed by bed. Upper Anisian conglomerates, which record upper Anisian uplift and erosion, overlie unconformably the lower part of the Campill Member.

of Lower Permian age, separated by a regional unconformity from, (2) a transgressional continental to marine sedimentary sequence, spanning the Upper Permian to Lower Anisian. Volcanic rocks of the first cycle infill intramontane basins and halfgrabens that developed during a pronounced extensional tectonic period related to the rifting of the Neotethys. Fluvial red sandstones of the Gardena/Gröden Formation interfinger eastward of the Etsch/Adige Valley with evaporites and shallow marine carbonates of the Bellerophon Formation stacked in several cycles representing 3rd order sequences within a general westward prograding sedimentary wedge. The overlying Werfen Formation is a strongly varying sequence of mixed terrigenous siliciclastic and carbonatic lithofacies, organized in T/R-cycles of different order and frequency. These 3rd order depositional sequences (see De Zanche et al., 1993, Gianolla et al., 1998) are composed of 4th order cycles of storm layers (thickening or thinning upward) and may have been orbitally forced. For detailed descriptions of lithology and biostratigraphy see Broglio Loriga et al. (1983).

The Pufels/Bulla section is well known for findings of conodonts constraining the Upper Permian, PTB and Lower Triassic succession as well as its excellent outcrop quality. Investigations on lithostratigraphy and biostratigraphy have been carried out by Mostler (1982), Perri (1991) and Farabegoli & Perri (1998). Integrated studies of lithostratigraphy, magnetostratigraphy and chemostratigraphy have been carried out by Scholger et al. (2000), Korte & Kozur (2005), Korte et al. (2005), Farabegoli et al. (2007) and Horacek et al. (2007a). A comprehensive review is given by Posenato (2008).

Lithostratigraphy and depositional environment

The shallow marine sediments of the topmost Bellerophon Fm and Werfen Fm were deposited on a very gentle, NW – SE extending ramp with a coastal plain environment of the upper Gröden Fm in the West and a shallow marine, mid and outer ramp environment of the Bellerophon Fm in the East. The PTB mass extinction of carbonate producing organisms prevented the evolution of a rimmed shelf area for the whole Lower Triassic. After the exceptionally long lasting recovery period of reefal buildups in the whole Tethys area, the first appearance of reef building organisms was found in the lower Middle Triassic nearby in the Olang/Valdaora Dolomites (Bechstädt & Brandner, 1970).

The lack of reefal buildups and binding organisms may have caused the extreme mobility of loose carbonate and siliciclastic sediment piles, which have been removed repeatedly by storm-dominated high energy events. This generated a storm-dominated stratification pattern that characterises the specific Werfen facies. Applying the concept of proximality of storm effects (Aigner, 1985), i. e. the basinward decrease of storm-waves and storm-induced currents, we tried to interpret relative sea level changes from the stratigraphic record. Proximal and distal tempestite layers are arranged in shallowing-upward cycles (parasequences) but also in deepening-upward cycles depending on their position within the depositional sequences (see Fig. 3, 10). However, numbers of cycles and cycle stacking patterns vary from section to section according to the different ramp morphology. Thus the main control seems to be the ratio between accommodation space and sediment supply, which follows the variable position of the baselevel (see baselevel concept from Wheeler, 1964). Variations of the baselevel determine the geometry of progradational, aggradational and retrogradational stacking patterns of the cycles. The baselevel, however, does not automatically correspond to sea level. Therefore until now it was not possible to proof true eustatic sea level changes within the Lower Triassic.

Reviewing the published data of magnetostratigraphy and chemostratigraphy, calibrated with bio-chronostratigraphy, Posenato (2008) made an attempt to put also radiometric ages for the Lower Triassic of the western Dolomites. Assuming that the duration from PTB to IOB is roughly 1.3 Ma, the total sediment thickness of 200 m in the Pufels section translates into a sedimentation rate of 1 m/6.500 a, uncorrected for compaction. This rather high sedimentation rate suggests a high frequency of storm events (hurricanes), which stresses the exceptional environmental conditions during this period indicating the lack of dense vegetation in the hinterland.

Since the 19th century there have been attempts to subdivide the Werfen beds into mapable lithostratigraphic units: (1) in a first step, Wissmannn, 1841 (lit. cit. in Posenato, 2008) made a simple subdivision according to the grey and red colours of the interbedded marls in Seiser Schichten and Campiler Schichten. (2) Modern research in sedimentology and biostratigraphy by Bosellini (1968), Broglio Loriga et al. (1983, 1990) and others enabled a division of the

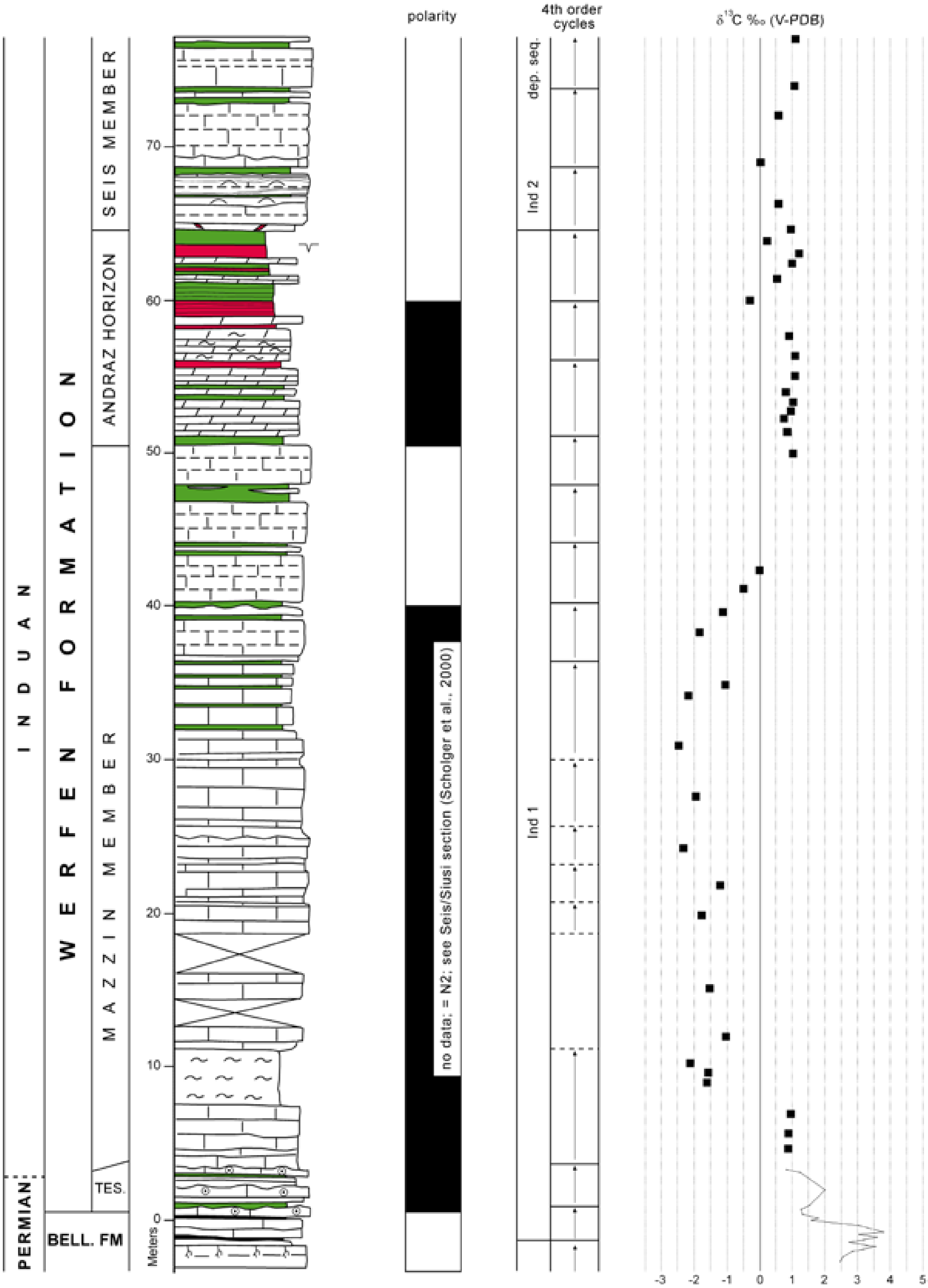


Fig. 3: Pufels/Bulla road section with correlations based on lithostratigraphy, magnetic polarity (Scholger et al., 2000 and completed for the Andraz Member), sequence stratigraphy and δ^{3}C curve (Horacek et al., 2007a). We revised the definition of sequences and renamed them according to the new terms of the stages to avoid confusion with the terms of the sequences interpreted by De Zanche et al. (1993). For legend see Fig. 10.

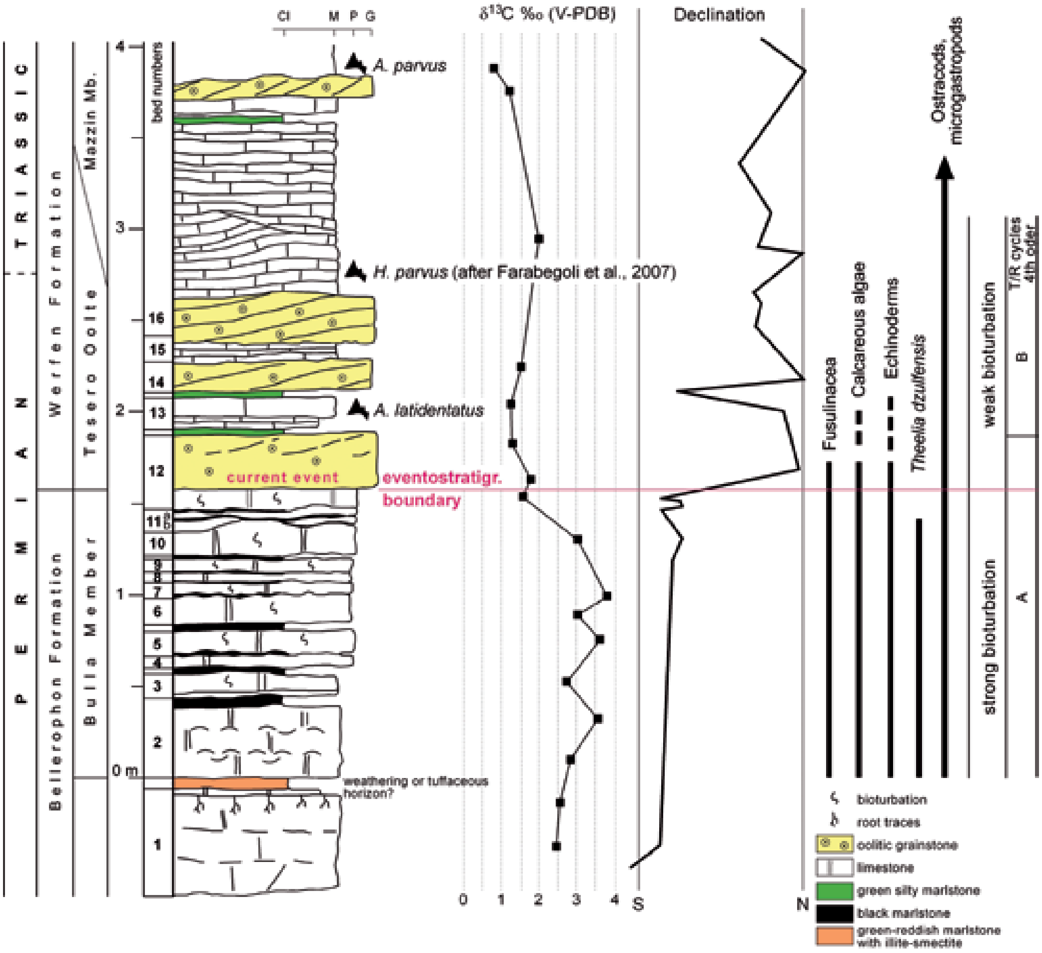


Fig. 4: Detailed section of the PTB along the abandoned road to Pufels/Bulla with litho-, bio-, chemo- and magnetostratigraphy. Conodonts and position of the PTB after Mostler (1982) and Farabegoli et al. (2007), magnetic declination after Scholger et al. (2000), selected microfossils (det. W. Resch, Univ. Innsbruck, 1988, unpubl.).

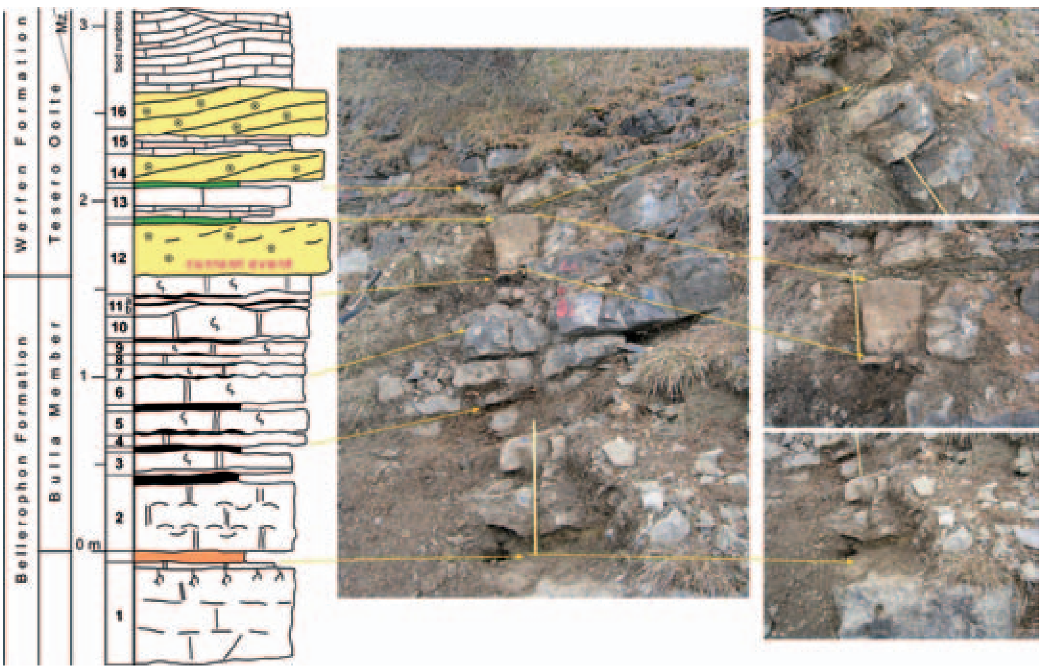


Fig. 5: PTB section of Pufels/Bulla in the outcrop. For legend see Fig. 4. (Mz. = Mazzin Member).

Werfen Formation – still an informal unit – into 9 members (Tesero, Mazzin, Andraz, Siusi/Seis, Gastropodenoolith, Campil, Val Badia, Cencenighe, San Lucano) which correspond pro parte to depositional sequences (De Zanche et al., 1993). In general, the Werfen Formation is characterized by subtidal sediments, but intra- to supratidal horizons with evaporitic intercalations are present within the Andraz, Gastropodenoolith, the base of Val Badia, Cencenighe and San Lucano members.

The historical lithostratigraphic units "Seiser Schichten" and "Campiler Schichten" are now considered members (Siusi/Seis Mb ("Siusi" is the Italian translation of the German name of the village Seis) and Campill Mb) but with different handling of the lower and upper boundaries depending on research groups. This mismatch of lithostratigraphic definitions has been ignored by some authors especially from outside of Italy with all the consequences of wrong and confusing correlations of biostratigraphy, magneto- and chemostratigraphy (for further information see the review of Posenato, 2008).

Due to relative sea-level changes, facies belts are shifting on the gentle ramp in time and space, with the consequence that lithologies are arranged in cycles and therefore are repetitive. In such a situation it is rather obvious, that members as lithostratigraphic units are shifting in time, too. Thus the defined boundaries of the members are not always isochronous. More stratigraphic studies, which are independent of local facies developments, such as magnetostratigraphy and chemostratigraphy, are needed for more clearness and correlation.

Practicality for field mapping: detailed lithostratigraphic divisions are important for 3-D understanding of palaeogeography, but also for the resolution of tectonic structures. By mapping large areas in the eastern and western Dolomites we had always the problem of the correct determination of the "Gastropodenoolith Member", particularly in areas with isolated outcrops or tectonic disturbances. This unit is characterised by a high lateral variability in facies and thickness (Broglio Loriga et al., 1990) with storm layers of oolitic grainstones with microgastropods and occasionally intraformational conglomerates ("Kokensches Konglomerat"). As these lithotypes occur in different positions in the Seis/Siusi and Campill Mbs, the boundaries of the "Gastropodenoolith Member" have been defined differently depending on authors (see Fig. 10). For geologic mapping in the field we found a practicable solution in defining the lower boundary of the Campill Mb with the appearance of the first observable sandstone- or calcareous sandstone layers (unit D on top of the Siusi Mb defined by Broglio Loriga et al., 1990). This terrigenous input marks a distinct break in the sedimentary development of the Werfen Formation and has a very wide palaeogeographical distribution. The stronger clastic input in the overall marine Werfen Fm is genetically correlatable with the boundaries between Unterer/Oberer Alpiner Buntsandstein in the Austroalpine (Krainer, 1987) and Lower/Middle Buntsandstein of Central Germany (Szurlies et al., 2003). The term "Gastropodenoolith" will be used only as remarkable facies type but not as an individual lithostratigraphic unit (see Geological map of the Western Dolomites, 2007).

The Pufels/Bulla road section exposes the whole sequence from the PTB to the supposed IOB, i. e. uppermost Bellerophon Fm and Werfen Fm with Tesero Mb, Mazzin Mb, Andraz Mb, Seis Mb and lower Campill Mb. Younger members of the Werfen Fm are lacking in this area due to block tilting and erosion during the Upper Anisian.

Bellerophon Fm: the outcrop at the starting point of the section shows only the top of the formation with gray calcareous dolomite mudstones, with vertical open tubes, interpreted as root traces. The dolomites belong to the top of the "Ostracod and peritidal dolomite unit" described by Farabogoli et al. (2007). It is covered by 4 cm thick orange to green coloured marls, which represent probably a hiatus interpreted as a sequence boundary. The sequence "Ind 1" starts with a package of dm bedded, grey to dark grey fossiliferous packstones that are intercalated with irregular cm thick layers of black carbonaceous marlstones. Bedding planes are wavy due to strong bioturbation (Figs. 4, 5). The 155 cm thick package is termed Bulla Mb (Farabegoli et al., 2007) which is identical with cycle A in Brandner, 1988.

Werfen Fm: The Werfen Fm starts with the Tesero Oolite Mb within bed number 12 of the detailed section (Figs. 4, 5). Fossiliferous packstones are overlain with a sharp contact by well washed, fossiliferous grainstones, 4 to 5 cm thick (Fig. 6), grading to grainstones with superficial ooids (5 cm) and cross bedded oolites (20 cm) on the top of the beds. The detailed description of this important environmental change was made possible by sampling the whole 40 cm thick bed for the preparation of a continuous polished slab and 5 large thin sections. In contrast to the black carbonaceous marlstone layers of the Bulla Member, centimeter intercalations in the Tesero Oolite Member are composed of greenish terrigenous silty marlstones.

With the Tesero Oolite, at the base of the Lower Triassic Werfen Formation, we see a fast westward shift of the shoreline for several tens of kilometres with a typical onlap configuration, i. e. transgression and not regression as described from several areas in the world. Topmost Bellerophon Formation (cycle A in Brandner, 1988; Bulla Member sensu Farabegoli et al., 2007) and the Tesero Oolite record severe environmental changes at the eventostratigraphic boundary of the PTB including profound biotic extinctions, which coincide more or less with the well known negative carbon isotope excursion (Fig. 4). The eventostratigraphic boundary of the PTB is situated ca. 1.3 m below the FAD of the conodont *Hindeodus parvus*, that defines the base of the Triassic (see Mostler, 1982 and Fig. 3 in Farabegoli et al., 2007).

The transition from fossiliferous packstones of the Bellerophon Fm to the barren grainstones of the Tesero Oolite is characterized in detail by a stepwise increase in the hydrodynamic energy (see bed 12, Figs. 4-5 and "current event" of Brandner, 1988; see Figs. 8, 9). The steps are recorded in three 4-5 cm thick storm layers without a significant unconformity or indication of subaerial exposure that was proposed by Farabegoli et al. (2007). Petrographic evidence suggests friable-cemented firm grounds on the sea floor. Borings of bioturbation show only poorly defined walls (Fig. 6). The uneven surface of the firm ground shows only little erosion by storm waves. There is no evidence for vadose diagenesis. For a different interpretation see Farabegoli et al. (2007).

On the contrary, ooids are not leached (such as the oomoldic porosity of the Miami Oolite) but have nuclei of calcite crystals and sparry calcite cortices encrusted by micritic laminae. Calcite crystals show borings of endolithic algal filaments underlining their primary precipitation on the sea floor (Fig.7). Further investigations are needed to proof the primary low-magnesium calcite precipitation on the Permian-Triassic sea floor. The known factors controlling the precipitation of calcium, i. e. low Mg/Ca ratios and faster growth rates (Chuodens-Sánchez & González, 2009), would shed an interesting light to the assumed unusual seawater chemistry at the PTB.

Some ooids contain coatings of finely dispersed pyrite, but pyrite is also common in intergranular positions (in agreement with Wignall & Hallam, 1992). Enhanced oxygen depletion in the surface water may have been caused by global warming and ocean heating (Shaffer et al., 2009). This points to an increase in alkalinity within a reducing, subtidal environment. The drop of the carbon isotope curve correlating with the Tesero Oolite may indicate an increase of isotopically depleted bicarbonate ions in seawater caused by the activity of sulphate reducing bacteria in a stratified ocean (Tethys as a "giant Black Sea", see Korte et al., 2004, Horacek et al., 2007b). An increase in the amount of HCO^{3-} forces precipitation of calcite on the sea bottom. Carbonate seafloor crusts and fans and special types of oolites and oncolites are widespread in different levels of the Lower Triassic and are often connected to perturbations of the carbon isotope curve (Pruss et al., 2006, Horacek et al., 2007a, b).

Synchronously to the pronounced increasing hydrodynamic energy in the shallow water environment at the eventostratigraphic boundary of the PTB, an increase of humidity and freshwater discharge is documented at the beginning of the continental Buntsandstein facies. This is proved by magnetostratigraphic correlation of the Pufels/Bulla section and sections of the continental facies realm of the German Triassic (Szurlies et al., 2003, Hug & Gaupp, 2006).

Mazzin Member

The contact of the Tesero Oolite to the Mazzin Member is transitional; some beds of Tesero Oolite are intercalated within dm-bedded, nearly unfossiliferous grey limestones (structurless mudstones, sometimes microbial structures). The oolite intercalations are interpreted as sand waves or sheets of ooid sand accumulating in a mid to outer ramp position. They are fed by about 10 meter thick sand bars which are preserved in the depositional environment as a barrier island in the section of Tramin/Termeno, about 40 km west of Pufels (Fig. 8). The repea-

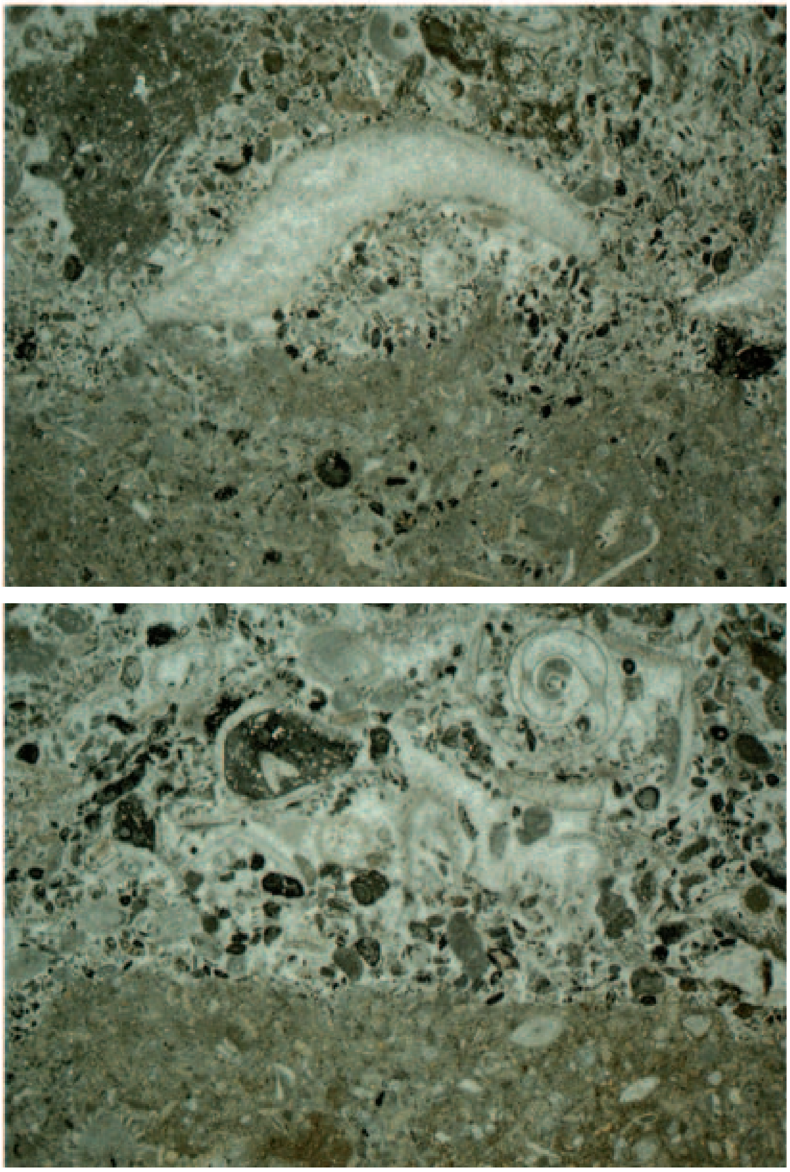


Fig. 6: Two thin-section photomicrographs (x 3) of the eventostratigraphic boundary (bed 12) in the uppermost Bellerophon Formation in the lateral continuation. In both sections we see a variably sharp contact between a fossiliferous packstone to a grainstone along a firm ground. An increase of hydrodynamic energy is documented by outwash of mud and reworking of intraclastic grains. In the section above, the same contact is less sharp than in the section below, borings of bioturbation which cross the contact show typical features of "friable" cemented firm ground. Only a part of the grains is reworked (e. g. fusulinids). Contrary to Farabegoli et al. (2007) we do not see evidence for subaerial exposure.

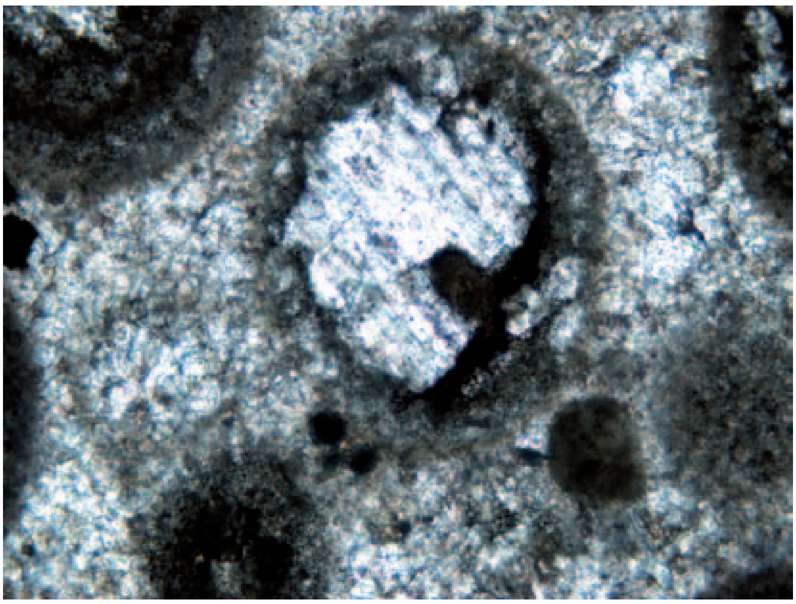


Fig. 7: Thin-section photomicrograph of a single ooid grain (diameter 0.6 mm) of the Tesero Oolite (type "crystalline oolite"). Borings of endolithic algae on the surface of the calcite crystal in the nucleus prove the primary precipitation of calcite on the sea floor. Note also pyrite crystals (black squares) in the pore space.

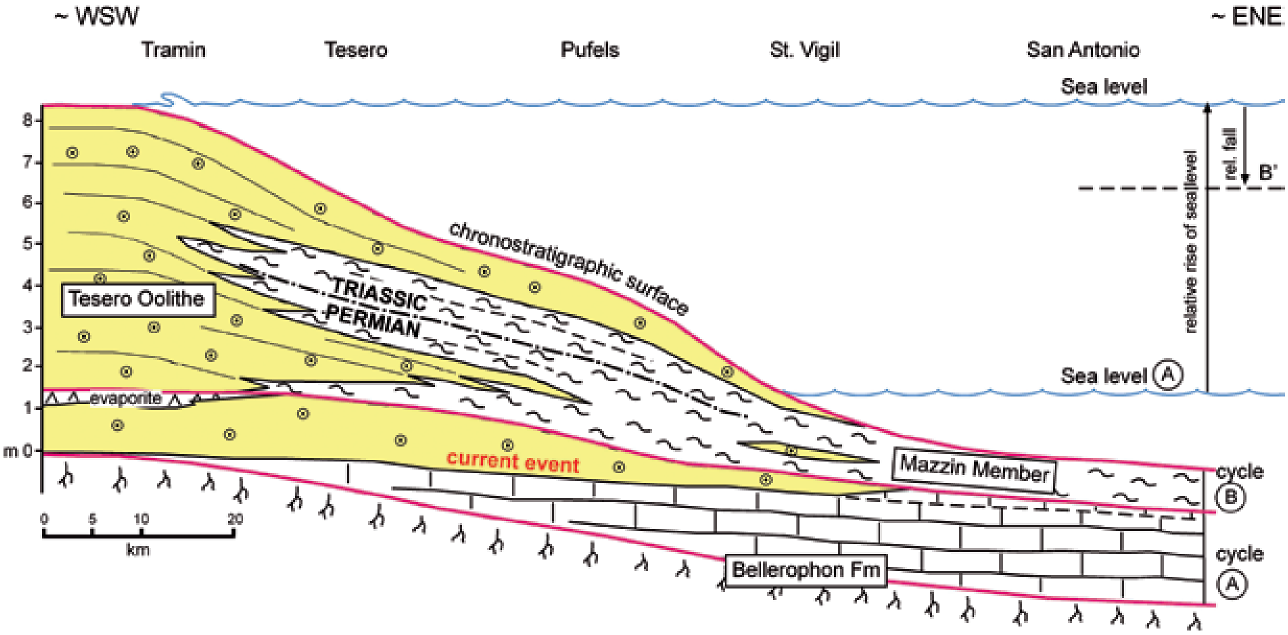


Fig. 8: Palaeogeographic cross section at the end of cycle B, based on correlation of parasequences of several detailed sections in inner to outer ramp position. The alignment of the cross section is in WSW – ENE direction from western to eastern Dolomites (redrawn after Brandner, 1988).

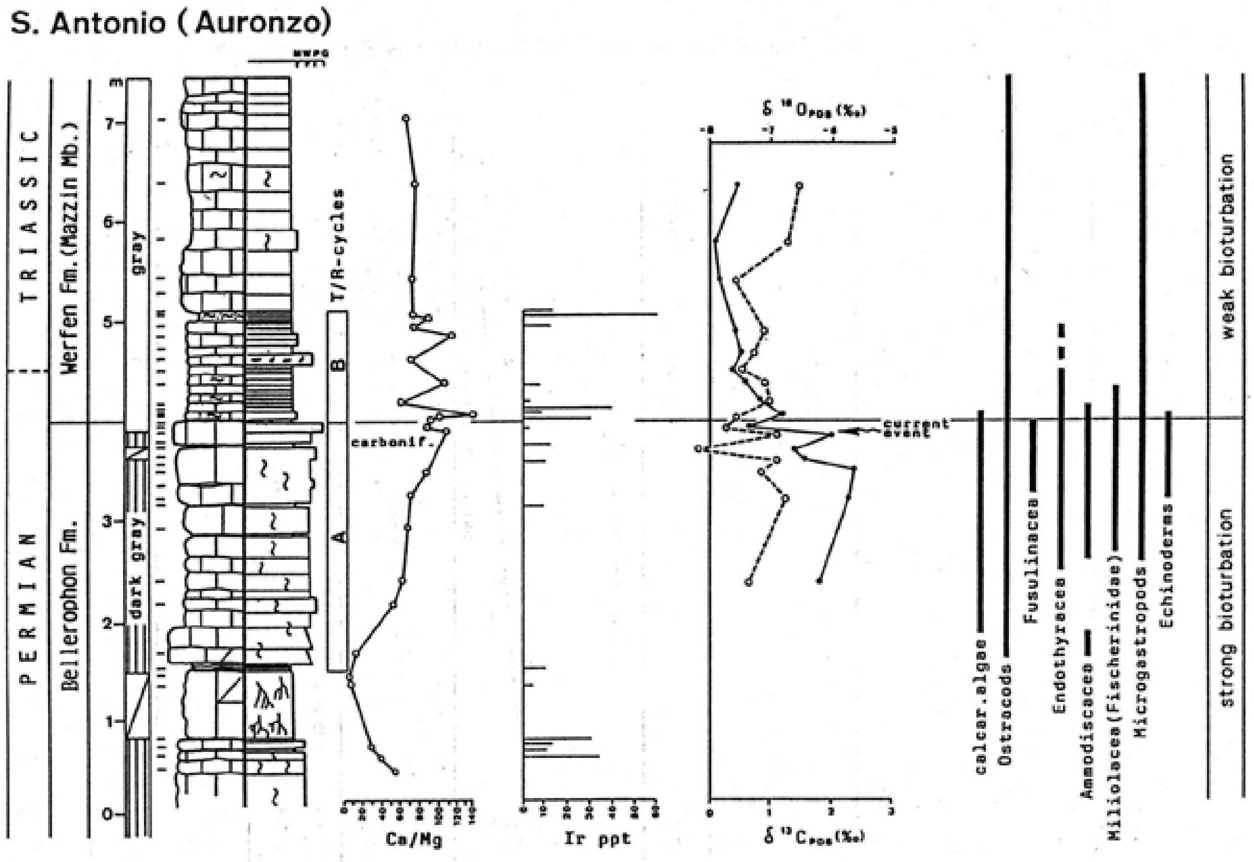


Fig. 9: PTB-section without Tesero Oolite for comparison (from Brandner, 1988). The San Antonio section was measured along a road-cut near the village Auronzo, east of Cortina d'Ampezzo, eastern Dolomites.

ted migration of oolitic sand to the shelf area may have been controlled by cyclic sea level lowstands and storm dominated transport. Oolitic grainstone layers disappear upward in the section, emphasizing the transgressive trend of the depositional sequence.

A very characteristic lithotype in the middle part of the section are "streaked" mudstones: beds of grey limestones or marly limestones with low content of silty quartz and micas with mm- to cm thick planar laminae of graded bioclastic packstones (mostly ostracods). They are interpreted as distal storm layers. Streaked mudstones alternate with structurless, bioturbated mudstones generating meter-scaled symmetrical cycles. Mudstones with strong bioturbation correspond to the time-equivalent vermicular limestones in Iranian sections (e. g. Horacek et al., 2007), or the Lower Anisian "Wurstelkalke" in the Austroalpine.

The upper part of the section shows an increase of terrigenous input. Meter-scale cycles with thickening storm layers of bioclastic packstones are capped by greenish marlstones suggesting a shallowing-up trend (Fig. 3). The development culminates in the predominance of multicoloured laminated siltstone with wave ripples and mud crack structures on top of the depositional sequence (Ind 1).

Andraz Member

The peritidal unit consists of a cyclic alternation of marly-silty dolomites, locally cellular, laminated silty marls and siltstones of a typical mud flat facies locally associated with evaporitic layers. As there is no clear interruption in the sequence, we propagate a progradation of the coastal tidal flat facies rather than a distinct drop of the sea level.

New artificial outcrops of the Andraz Member (this unit is usually completely covered) along the abandoned road and during the construction of the gallery of the new road to Pufels enabled the measurement of a detailed section and sampling for the analyses of magnetostratigraphy and carbon isotopes.

Seis/Siusi Member

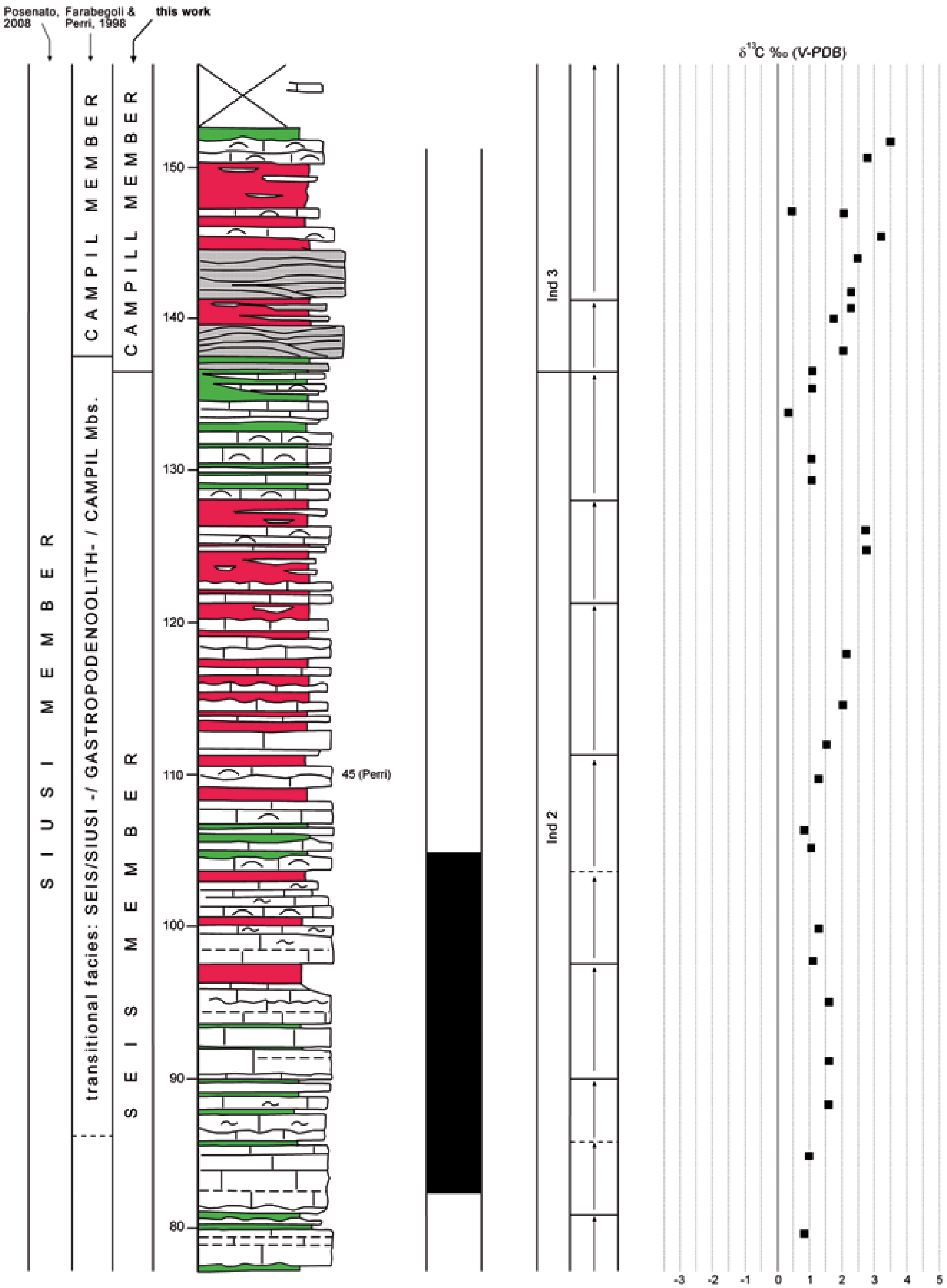
The Seis Member overlies the Andraz Member with a well preserved erosional unconformity which is interpreted as SB at the base of the depositional sequence Ind 2. The sequence starts with a transgressional package of well bedded tempestites characterized by rip up clasts (flat pebbles), microgastropods and glauconite.

The Seis Member is a sequence of interbedded limestones and silty marlstones of greenish colour in the lower and reddish in the upper part (Figs. 3, 10). The ubiquitous content of terrigenous quartz and micas, always in the same silt grain size, reveal an air blown silt transport from the hinterland in the west. Limestone beds show textures typical for tempestites. In general they consist of graded litho- and bioclastic packstones and wackestones (often shell tempestites) with bed thickness ranging between centimetres and few decimetres. The base of the beds is mostly sharp and erosional; scours and gutter casts are present. Wave-ripples with wavelengths up to 100 cm are common often causing a lenticular shape of the beds, and hummocky cross stratification at the base of the rippled beds.

A special lithotype is the "Gastropodenoolith" (a term defined by German authors). Individual tempestite beds consist of reddish grainstones and packstones with oolites and microgastropodes (often with internal sediments or ferroan dolomite spar fillings and glauconite which do not correspond to the matrix of the packstones). "Kokensches Konglomerat", another old term used by German authors, is a flat pebble conglomerate. Both lithologies are handled as "leading faciestypes" for the Gastropod Oolite Member. Unfortunately both types are to be found in the lower and upper part of the Seis Member as well as in the Campill Member, complicating the definition of the Gastropod Oolite Member (see above).

Tempestite proximality (thick-bedded tempestites are more proximal (= shallower) than thinner bedded tempestites (= deeper)) enables the grouping of beds in thicking- or thinning upward cycles on the scale of few meters. The lithofacies comprise both the upper shoreface and the offshore environment. Hummocky cross stratification and gutter casts indicate the lower shoreface facies and offshore facies of a high-energy type of coast.

The onset of reddish marlstone in the upper part of the member signalizes a better oxidation of the sea bottom, which may be a consequence of a lower sedimentation rate or better circulation of bottom water. Reddish marlstones in the upper part of the Seis Member are present in the western and eastern Dolomites, but their isochronous onset is not proved. Toward the boundary with the Campill Member the predominance of offshore facies in the cycles shifts



Posenato, 2008
Farabegoli & Perri, 1998
this work
CAMPIL MEMBER
CAMPILL MEMBER
SIUSI MEMBER
transitional facies: SEIS/SIUSI -/ GASTROPODENOOLITH- / CAMPIL Mbs.
SEIS MEMBER
150
140
130
120
110
100
90
80
45 (Perri)
Ind 3
Ind 2
δ13C ‰ (V-PDB)
-3
-2
-1
0
1
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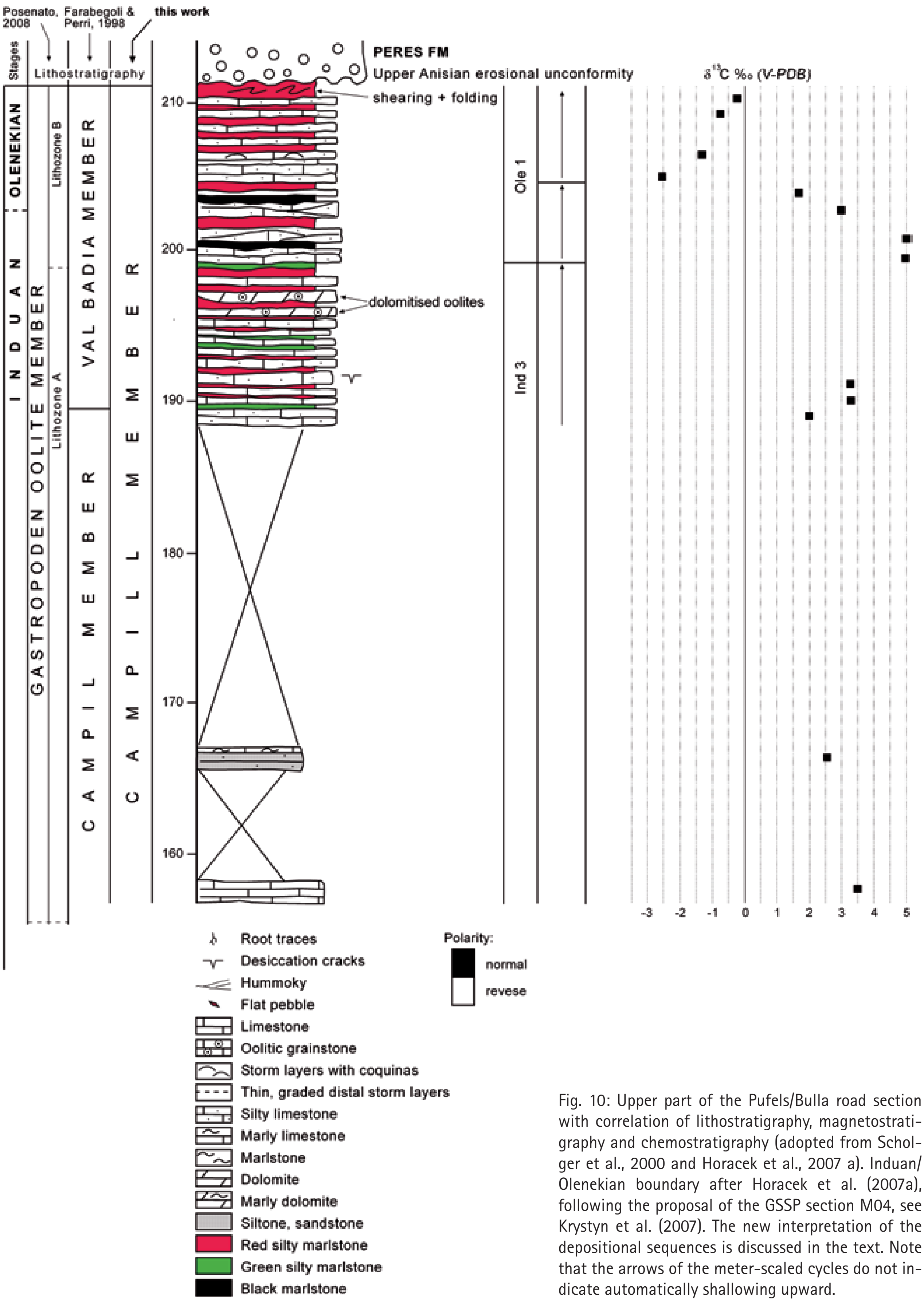

Fig. 10: Upper part of the Pufels/Bulla road section with correlation of lithostratigraphy, magnetostratigraphy and chemostratigraphy (adopted from Scholger et al., 2000 and Horacek et al., 2007 a). Induan/Olenekian boundary after Horacek et al. (2007a), following the proposal of the GSSP section M04, see Krystyn et al. (2007). The new interpretation of the depositional sequences is discussed in the text. Note that the arrows of the meter-scaled cycles do not indicate automatically shallowing upward.

Fig. 11: Lower part of the Campill Member with thinning upward cycles of tempestite beds. Road cut of the abandoned road to Pufels/Bulla. Scale: 2 meters. Photo courtesy of Lois Lammerhuber, Vienna.

once more to the shoreface facies with thickening of shell tempestites and scour fillings.

Biostratigraphic remarks: The Seis/Siusi Member in the Dolomites is known for the abundance of *Claraia* specimens defining the *Claraia* Zone. The subzones with *C. wangi-griesbachi, C. clarai* and *C. aurita* occur in the upper Mazzin, lower and upper Seis members (Broglio Loriga et al., 1990, Posenato, 2008). In the Pufels/Bulla sections several findings of *Claraia* specimens have been documented by Mostler (1982).

Campill Member

The start of the Campill Member is defined here with the first distinct occurrence of quartz/mica sandstones. Half meter- to meter-thick calcareous sandstone beds with hummocky cross stratification and a remarkable glauconite accumulation represent the transgressive phase of the sequence Ind 3. The beds grade to thinner bedded storm layers (bioclastic shell tempestites) forming thinning upward cycles on the scale of several meters (Figs. 10, 11). U-shaped burrows interpreted as *Diplocraterium* burrows, microripples and wrinkle structures are remarkable sedimentary structures in this part of the section. Most typical are "Kinneyia" structures, mm-scale winding ridges resembling small-scale interference ripples. After Porada & Bouougri (2007) they formed underneath microbial mats and are usually preserved on flat upper surfaces of siltstone or sandstone beds.

Further on, from ca. 152 m to 186 m the road section is mostly covered. The next outcrops at the top of the section show some folding and ramp folds, but exact balancing of the stratigraphy by retrodeformation is possible.

The last 20 meters of the section (Fig. 10) are important for two reasons: (1) we recognize a prominent change in the facies development from peritidal to subtidal offshore environment, and (2) this change is accompanied by a strong negative shift of the carbon isotope curve which is correlatable to the proposed GSSP section of the Induan-Olenekian Boundary in Mud (Spiti, Himalaya) (Krystyn et al., 2007). Peritidal cycles are made up by greenish to reddish silty and sandy marls with wave ripples and mud cracks alternating with dm-bedded silty bioclastic limestones and few yellowish oolitic dolomites and marly dolomites. Posenato (2008) termed this unit "lithozone A" of the Gastropod Oolite Mb in the definition of Broglio Loriga et al. (1990). Two thinning upward cycles with some dm thick amalgamated hummocky cross-stratified silty limestone beds at their base represent the transgressive phase of sequence "Ole 1" (accepting the strong negative carbon isotope excursion as a proxy for the IOB). The background sedimentation is still composed by red silty and sandy marlstones. Rare dark gray to black laminated marlstones may indicate short intervals of decreasing oxygen at the sea bottom.

The road section ends with the upper Anisian erosional unconformity on top of the lower part of the Campill Member. Upper Anisian Conglomerates (Voltago-/Richthofen Conglomerate) directly overlie red siltstones, sandstones and silty marls.

Conclusions

The lithostratigraphic and sedimentologic study has enabled the identification of meter-scale transgressive-regressive cycles (parasequences) in peritidal to subtidal depositional environments. Associations of the parasequences constitute in varying stacking patterns four depositional sequences, which may have regional significance. This is proven by careful study of integrated stratigraphy of several sections in the Dolomites and Iran (Horacek et al., 2007 a, b). It evidences that the main excursions of the carbon isotope curve are clearly correlated to sequence stratigraphic boundaries: (1) transgressive systems tract (TST) of sequence Ind 1, (2) TST of Ole 1 (see also Krystyn et al., 2007) and (3) the TST at the base of the Val Badia Member (not preserved in the Pufels section). This would imply that the profound changes in the global carbon cycle in the Lower Triassic are forced by eustatic sea level changes. The TSTs of the sequences Ind 2 and Ind 3 are not clearly mirrored by the carbon isotope curve at Pufels, and a general trend is not obvious.

Only in the passage of more terrigenous input, i. e. at the base of the Campill Member, irregularities in the trend of the carbon isotope curve are noticed. More conspicuous is a negative shift in the Iranian sections (Horacek et al. 2007). On the other hand, the regional importance of the terrigenous input signal is evidenced by the magnetostratigraphic correlation with the continental facies of the German Triassic. Equivalent to the terrigenous Campill event in the Southalpine and the Upper Buntsandstein in the Austroalpine, the Volpriehausen Formation at the base of the Middle Buntsandstein starts with the first basin-wide influx of coarse grained sands (Szurlies, 2004). These distinct breaks in the sedimentation style indicate a climate change to a more humid environment with increased rainfall and continental runoff.

Acknowledgments

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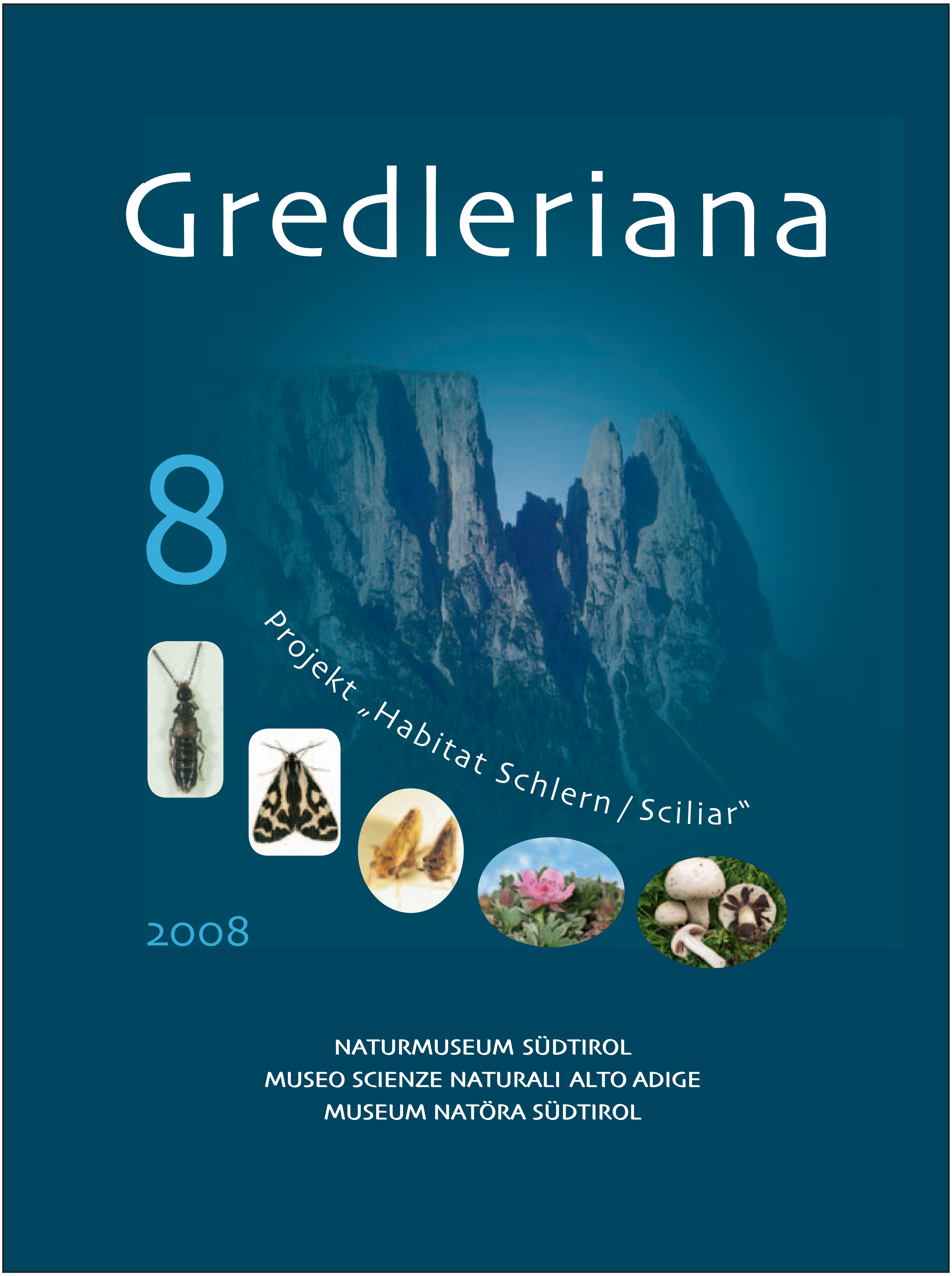
Errata Corrige

Errata corrige to Geo.Alp, Vol. 5, p. 121-137, 2008
Preliminary report on a new vertebrate track and flora site from Piz da Peres (Anisian – Illyrian): Olang Dolomites, Northern Italy

The original manuscript unfortunately contains the following errors that could not be corrected prior to publication.
On page 126, Plate 3, Fig. 3 shows *Neuropteridium voltzii,* Plate 3, Fig. 2 shows *Scolopendrites* sp., Plate 3, Fig. 4 shows ?*Botrychium* sp., Plate 4, Figs. 5-6 show *Voltzia recubariensis.*
The author list submitted originally read Michael Wachtler, Rossana Todesco and Marco Avanzini. Marco Avanzini as coordinator of the research deeply regrets that he changed the sequence of authors and that there was an insertion of another co-author without giving prior information to all authors.

Leider kam es nach Abgabe des Originalmanuskriptes zu einigen bedauerlichen Fehlern, welche nicht mehr vor Drucklegung korrigiert werden konnten.
Seite 126: Tafel 3, Fig. 3 zeigt *Neuropteridium voltzii,* Tafel 3, Fig. 2 zeigt *Scolopendrites* sp., Tafel 3, Fig. 4 zeigt ?*Botrychium* sp. *Voltzia recubariensis* wurde auf Tafel 4, Fig. 5-6 abgebildet.
Die ursprüngliche Autorenliste bestand aus Michael Wachtler, Rossana Todesco, Marco Avanzini. Marco Avanzini als Koordinator des Forschungsprojektes bedauert, dass er die Autorenreihenfolge geändert und einen weiteren Autor aufgenommen hat, ohne die anderen Autoren zu informieren.



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