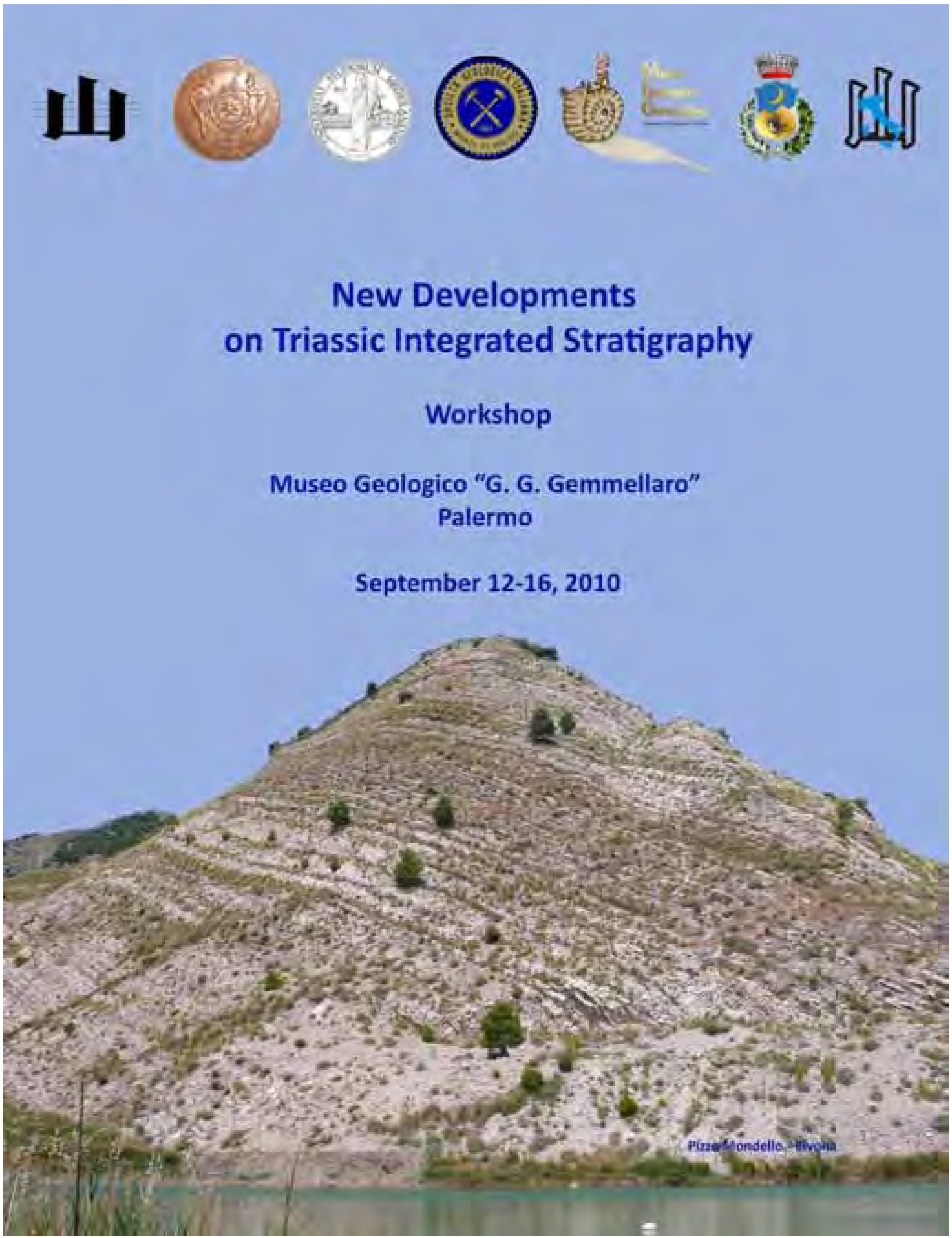
ALBERTIANA

Excursion Field Guide and Abstract Volume



New Developments
on Triassic Integrated Stratigraphy

Workshop

Museo Geologico "G. G. Gemmellaro"
Palermo

September 12-16, 2010

39

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Contents

Excursion guide

The primary aim of ALBERTIANA is to promote the interdisciplinary collaboration and understanding among members of the I.U.G.S. Subcommission on Triassic stratigraphy. Within this scope ALBERTIANA serves as the newsletter for the announcement of general information and as a platform for discussion of developments in the field of Triassic stratigraphy. ALBERTIANA is available as PDF at the STS website. Please send your manuscript to albertiana2010@gmail.com .

Cover: The Pizzo Mondello section.

"New Developments on Triassic Integrated Stratigraphy "

Organizing Committee

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Patronage

Società Geologica Italiana
Società Paleontologica Italiana
Commissione Italiana di Stratigrafia.

Co-sponsors

Subcommission on Triassic Stratigraphy (ICS)
Università degli Studi di Milano
Università degli Studi di Palermo
Università degli Studi di Palermo, Dipartimento di Geologia e Geodesia
Museo Geologico "G.G. Gemmellaro"
MIUR-PRIN 2008 Project "Upper Triassic integrated stratigraphy: GSSP and auxiliary sections in Italy"
Comune di Bivona.

Workshop Program

September 12, Sunday

from 19,00 registration.

19,30 Ice Breaker party.

September 13, Monday

9,00-9,20, Opening ceremony

Session 1. *Western Tethys stratigraphy, dedicated to the memory of the late Giovanni Viel (1944-2009)* .

9,20-9,30 Farabegoli E. — Dedication to Giovanni Viel.

9,30-9,50 Farabegoli E. — Anisian lithostratigraphy of the Dolomites: a 40-years-long debate.

9,55-10,15 Binda M., Berra F. and Jadoul F. — Calcare Rosso: key witness of the Ladinian carbonate platform exposure (Pegherolo Massif, Southern Alps).

10,20-10,40 Balini M., Nicora A. & Larghi C. — Biochronostratigraphic revision of the Wengen Formation (Ladinian-earliest Carnian) in the central Southern Alps.

10,45-11,05 Gianolla P., Mietto P., Rigo M., Roghi G. & De Zanche V. — Carnian-Norian paleogeography in the eastern Southern Alps.

11,10-11,30 *Coffee break*

11,30-11,50 Martin-Rojas I., Somma R., Delgado F., Estévez A., Iannace A., Perrone V. & Zamparelli V. — Sequence stratigraphy analysis of Triassic carbonate platform. An example from the Betic Cordillera Internal Zone (Spain).

11,55-12,15 Somma R., Martin-Rojas I., Zamparelli V., Delgado F., Estévez A., Iannace A., & Perrone V.— Significance of Ladinian foraminifer-rich guide levels in the Betic Internal Zone (Spain).

12,30-14,30 *Lunch*

14,30-14,50 Gale L. — Upper Triassic sedimentation of the Slovenian Basin (eastern Southern Alps, Slovenia) and its foraminiferal assemblage.

14,55-15,15 Cacciatore M. S., Di Stefano P., Zarcone G.— Carbonate Platform-Basin Transition in SW Sicily. Implications for the paleogeographic reconstruction of the Central Mediterranean area.

Session 2. *Biostratigraphy, integrated stratigraphy and Triassic scales*

15,20-15,40 Bachmann G. H. & SPBA Triassic Working Group—Triassic Stratigraphy and Facies of the Southern Permian Basin Area (England to Poland).

15,45-16,10 Farabegoli E. & Perri M.C. — The end-Permian mass extinction.

16,15-16,30 *Coffee break*

16,30-18,00 *Poster session*

Balini M., Krystyn L., Levera M. & Tripodo A.— Late Carnian-Early Norian ammonoids from the GSSP candidate section Pizzo Mondello (Sicani mountain, Sicily).

Bertinelli A. & Giordano N. — Radiolarian assemblages from the Norian GSSP candidate Pizzo Mondello section (Sicani Mountains, Sicily).

Cacciatore M.S., Todaro S., Zarcone G. & Di Stefano P. — *Triasina hantkeni* limestones from Sicily.

Golding M.L., Zonneveld J.-P., Orchard M.J., Mortensen J.K. & Ferri F.— Lower and Middle Triassic Stratigraphy of the Western Canada Basin and Implications for Timing of Terrane Accretion.

Levera M. & McRoberts C.A. — *Halobiid* bivalves as a tool for high resolution correlation between Carnian-Norian successions in Tethys and Panthalassa: a potential datum for a base-Norian GSSP.

Preto N., Rigo M., , Agnini C., Guaiumi C. , Borello S. & Westphal H. — Triassic and Jurassic calcareous nannofossils of the Pizzo Mondello section: potential for biostratigraphy.

Rigo M., Preto N., Boscaini N., Cognolato A., Franceschi M., Guaiumi C. & Osti G. — Stratigraphy of the Carnian – Norian Carcari con Selce in the Lagonegro Basin (Southern Apennines) and correlation with the Sicani Basin.

Tripodo A., Balini M. & D'Arpa C. — The revision of *Pinacoceras* (Ammonoidea, Upper triassic) of the Gemmellaro Collection.

Zarcone G. Cacciatore M.S., Todaro S., & Di Stefano P. — End Triassic karstification of a south Tethyan carbonate platform: the genesis of the "Libeccio Antico" a famous Baroque dimension stone.

September 14, Tuesday

Session 2. Biostratigraphy, integrated stratigraphy and Triassic scales.

9,00-9,20 Kozur H.W. & Bachmann G.H. — Correlation of the predominantly continental Upper Triassic of the Germanic Basin with the Tethyan scale.

9,25-9,45 McRoberts C. — Paleoecological controls on Triassic flat clam biochronology.

9,50-10,10 Kozur H.W. & Weems R.E — The conchostracan zonation of the Upper Triassic and basal Jurassic. Age of the CAMP volcanics in the Newark Supergroup.

10,15-10,40 *Coffee break*

Session 3. Towards the definition of the GSSP of the Norian stage.

10,40-11,00 Guaiumi C., Preto N. & Westphal H. — Origin of Upper Triassic deep water carbonate at Pizzo Mondello (Sicily).

11,05-11,25 Levera M.— An overview of the Sicilian halobiids from the Carnian-Norian boundary interval through the Pizzo Mondello fauna: useful proxies for the Norian GSSP.

11,30-11,50 Balini M., Bertinelli M.A., Di Stefano P., Guaiumi C. , Levera M., Mazza M., Muttoni G., Nicora A., Preto N., Rigo M., Krystyn L. & McRoberts C. — Bio-chronostratigraphic calibration of the Upper Carnian-Lower Norian magnetostratigraphic scale at Pizzo Mondello (Sicani Mountains, Sicily).

11,55-12,15 Mazza M., Cau A. & Rigo M.— Application of numerical cladistic analyses to the Carnian-Norian conodonts: a new approach for phylogenetic interpretations.

12,30-14,30 *Lunch*

14,30-14,50 Krystyn L.— Long distance marine biotic correlation events around the Carnian-Norian boundary: choice of Halobia austriaca as the defining boundary marker

14,55-15,15 Zonneveld J.P., Orchard M.J. , Beatty T.W., McRoberts C.A. & Williford K.H. — Stratigraphic architecture of Upper Triassic strata in the Williston Lake area, northeastern British Columbia: Implications for the Carnian-Norian GSSP.

15,20-15,40 Orchard M.J. — An exceptional conodont succession from the Carnian-Norian boundary of the Western Canada Sedimentary Basin, northeastern British Columbia.

15,45-16,05 Orchard M.J. & Carter E. S. —The Carnian-Norian boundary in Haida Gwaii: preliminary observations on the conodont faunas and their calibration with radiolarians.

16,10-16,30 *Coffee break*

16,30-18,00 Business Meeting of the STS

Evening: Social Dinner (Please contact the workshop desk for information).

Field excursion
The Triassic of western Sicily

September 15, Wednesday, Day 1 of the excursion

8,30 Meeting point Museo Gemmellaro.

8.45 Departure by bus.

Carnian to Lower Jurassic successions from the Panormide Platform and Imerese Basin (Palermo Mountains). The following outcrops will be visited:

- Cozzo di Lupo, the Late Triassic shelf-edge of the Panormide Carbonate Platform;
- Billiemi quarry, synsedimentary tectonics along the

Panormide Carbonate Platform margins;

- Cozzo Paparina, Carnian deposits (Mufara Formation) with megabreccia intercalations;

Monte Genuardo, tectonic retreat of a segment of the Triassic paleomargin of the Saccense carbonate platform around the T/J boundary.

Field leaders: Di Stefano P., Cacciatore M. S., Scopelliti G. and Zarcone G.

Dinner and overnight: Convento dei Cappuccini (Bivona).

September 16, Thursday, Day 2 of the excursion

Carnian to Rhaetian succession of the Sicanian Basin at Pizzo Mondello.

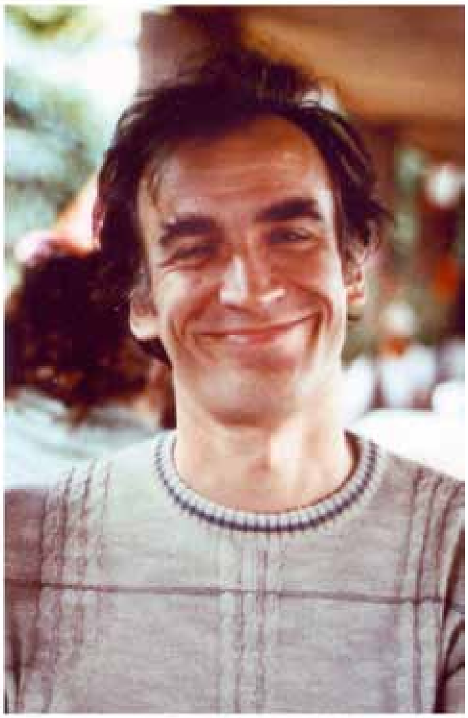
Four intervals will be visited: the Late Carnian-Early Norian, that is of great interest for the definition of the C/N boundary, the Middle Norian, the Late Norian and the Rheatian.

On the way to Palermo, panoramic views of some other successions of the “cherty limestone” will be observed.

Field leaders: Balini M., Bertinelli A., Guaiumi C., Levera M., Mazza M., Muttoni G., Nicora A. , Preto N. and Rigo M.

Arrival in Palermo in mid-late afternoon (approximately 18.00).

Dedication to Giovanni Viel (1944-2009)



Giovanni Viel was one of the young participants to the "Reinassance" of the investigations on the Triassic of the Southern Alps in the 1970s, as member of the Bologna school.

He was student of Raimondo Selli and Giulio Pisa and got the graduation in 1971, with a thesis on the geology of the Zoldo Valley between Pelmo and Civetta. After the graduation he worked in the Dolomites for about 10 years with Giulio Pisa and Enzo Farabegoli and directly contributed to a number of very important papers dealing with stratigraphic, paleogeographic and paleotectonic evolution of the Triassic of eastern Dolomites and Cadore.

His most cited paper is the revision of the lithostratigraphy of the Buchenstein and Wengen successions in the Dolomites and Cadore, published in 1979. This very innovative paper was based on extremely detailed sedimentologic and stratigraphic investigations in several key-areas that lead him to suggest a complete revision of the lithostratigraphic evolution of the succession that in the XIX century provided the basis for the proposal of the Ladinian Stage.

At the beginning of the 1980s Giovanni left the scientific research to work as professional engineering geologist, but in 2008 he came back to his first love and started again a research cooperation with E. Farabegoli on their old geologic passion. He passed away on September 19, 2009.

List of publications

Viel G. 1971. Geologia dell'alta valle zoldana fra il Pelmo ed il Civetta (Belluno). Tesi di Laurea inedita. Università di Bologna.

Rossi P.L., **Viel G.**, Simboli G. 1977. Significato paleogeografico e magmatico-Tettonico della serie Vulcanica Vulcano-Clastica Ladinica superiore nell'Area del Monte Civetta. Boll. Soc. geol. It., 433-458.

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Brusca C., Gaetani M., Jadoul F. & **Viel, G.** 1981. Paleogeografia Ladino-Carnica e metallogenesi del Sudalpino. Mem. Soc. Geol. It., 22: 65-82.

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Brusca C., Gaetani M., Jadoul F. & **Viel G.** 1982. I giacimenti Pb-Zn del Permo Trias nelle Alpi Meridionali e nelle Apuane. Relazione Finale Contratto C.R.E.S.T. 092.79.7 MPPI. Samim-Pertusola, 4.23-4.70 Roma.

Broglio Loriga, C., Conti, M.A., Farabegoli, E., Fontana, N., Mariotti, N., Massari, U., Neri, C., Nicosia, U., Pasini, M., Perri, M.C., Pittau, P., Posenato, R., Venturini, C. & **Viel G.** 1986. Upper Permian sequence and P/T Boundary in the area between Carnia and the Adige valley. In: Field

Conference on Permian and Permian-Triassic boundary in the South- Alpine segment of theWestern Tethys, and additional regional reports; 4– 12 July 1986, Brescia, Field guide-book, Italian IGCP project 203 group (ed.). Societa` Geologica Italiana, Brescia; 23–28.

Brusca C., Farabegoli E. & **Viel, G.** 2010. Le mineralizzazioni Pb-Zn nel quadro paleogeografico del Trias delle Dolomiti orientali. Ipotesi genetiche. Geo-archeologia*,* 1: 59114.

Excursion Guide

Introduction

The aim of the field trip is to offer an up-to-date outline of the stratigraphy and sedimentology of the Upper Triassic carbonate platform-basin systems of western Sicily.

During the first day some examples will be shown that offer the opportunity to discuss facies architecture and sedimentary dynamics of the south Tethyan carbonate platforms, the effects of the extensional tectonics along the Norian-Rhaetian margins, the pre-Carnian stratigraphy of the Panormide domain revealed by the elements of a Carnian megabreccia, the paleogeographic relationships during the Triassic among platform and basin-derived thrust sheets from the Maghrebian fold and thrust belt. The second day discussion will be regarding the Carnian-Rhaetian stratigraphy of the deep-water succession of cherty limestones exposed at Pizzo Mondello near Bivona in the Sicani Mountains, one of the best sections for the definition of the GSSP of the Norian Stage (Fig.1).

The description and illustrations of some stops were already published in previous guidebooks which are quoted along the text.

This excursion is in part possible thanks to the generous support of the Comune di Bivona.

Figure 1: Excursion itinerary: First day September 15 - Stops 1-4. Second day September 16 - Stop 5.

Geological framework of Sicily and the Triassic-Jurassic stratigraphic evolution

P. Di Stefano, M. S. Cacciatore, G. Zarcone

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1. Geological setting

Sicily is a segment of the Neogene Apenninic-Maghrebian fold and thrust belt (Fig. 2). The north is bounded by the Tyrrhenian Basin, an extensional area subject to crustal thinning since Tortonian times (Malinverno & Ryan, 1986; Rehault et al.,1987). Southward the Sicilian chain is bounded by the Plio-Pleistocene foredeep, a narrow furrow from Gela to Catania, and by the less deformed African foreland represented by the Sicily Channel and the Hyblean Plateau (Grasso & Reuther, 1988; Reuther, 1989). To the East the Hyblean Plateau is transitional to the Ionian basin through the Malta Escarpment.

In particular the Sicilian fold and thrust belt can be differentiated in: I) an European Kabilo-Calabride element, that crops out in the Peloritani Mountains, II) a Sicilide element of Alpine Tethyan affinity, well exposed in the Nebrodi Mountains, and III) an E-W trending Maghrebian element.

The latter consists of Meso-Cenozoic thrust imbricates that are well exposed in western Sicily and in central-northern Sicily (Madonie Mountains) while in central- southern Sicily they are covered by a large allocthonous complex of mostly Miocene and Pliocene sediments known as the Gela Nappe (Argnani, 1989; Grasso et al., 1991).

The Meso-Cenozoic thrust imbricates forming the Maghrebian element were deposited in extensional, mostly carbonate, sedimentary basins located along the African continental margin during Late Paleozoic and Mesozoic times (Di Stefano, 1988, 1990; Catalano et al., 1991). During Late Oligocene the area experienced the tectonic inversion of these basins from extensional to compressional (Catalano & D'Argenio, 1982a). These processes resulted in the development of new basins associated to a change of the sedimentary regime from carbonate to siliciclastics (e.g. Numidian Basin, Giunta, 1985).

On the basis of their Triassic to Eocene stratigraphic architecture, the thrust sheets that belong to the Sicilian Maghrebids are classically differentiated into groups that correspond to former paleogeographic zones (Catalano & D'Argenio, 1982a) (Fig. 3). The Trapanese and Saccense structural units are characterized by thick Triassic and Lower Jurassic carbonate platform strata, followed

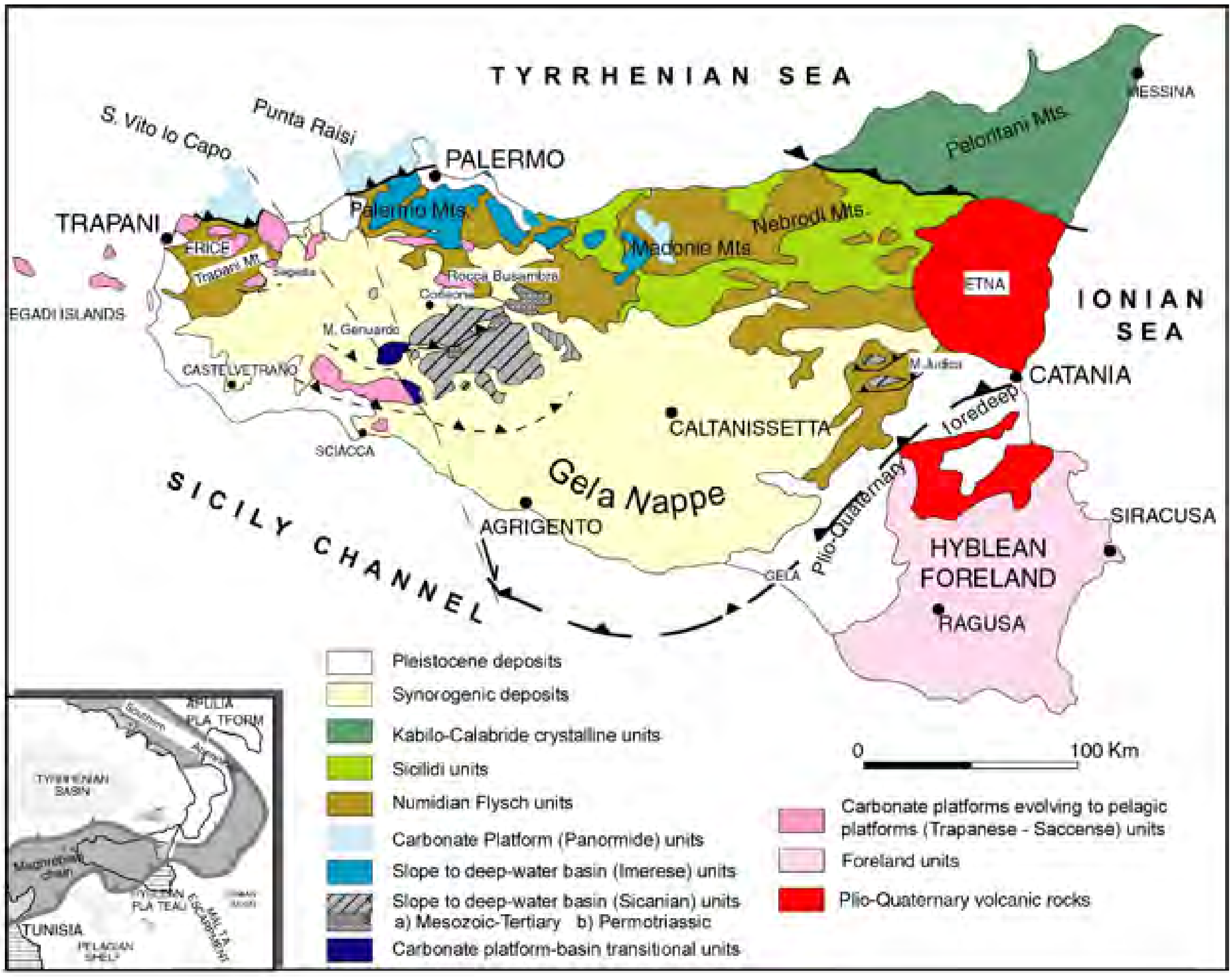

Figure 2: Structural sketch of Sicily (mod. after AA.VV., 1990, Structural model of Italy, sheet n. 6).

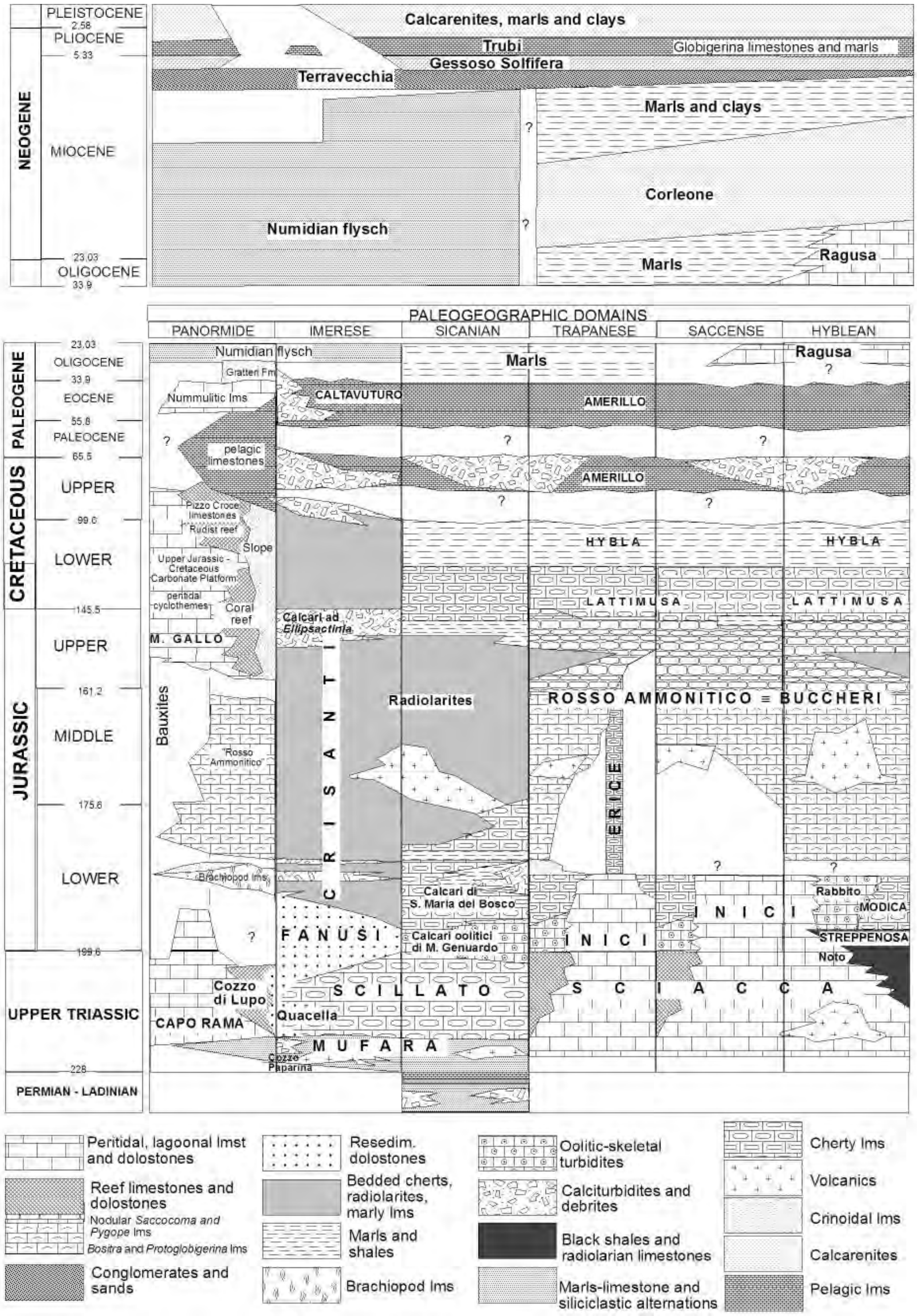

Figure 3: Lithostratigraphy of western and southern Sicily (Mod. from Di Stefano, 2002).

by pelagites and deeper water sediments. A similar stratigraphic architecture can be found in the subsurface of the Hyblean foreland (Patacca et al., 1979, Antonelli et al., 1991).The Panormide units (Ogniben, 1960) consist of Triassic to Eocene carbonate platform sediments separated by major unconformities, discontinuous levels of Jurassic pelagites and/or bauxites. The Imerese and Sicanian units consist of Triassic to Oligocene deep-water marls and cherty limestones with repeated intercalations of platform-derived clastic-carbonates and of Jurassic radiolarites and pillow lavas (Catalano & D'Argenio, 1982a, Di Stefano et al., 1996).

Several authors have pointed out that the collisional processes were controlled by pre-existing differences in physiography and crustal thickness among the paleogeographic sectors involved in the orogenic accretion (Speranza et al., 2000; Nigro & Renda, 2002; Di Stefano et al., 2008). Owing to the complex tectono-stratigraphic mosaic of the area, the paleogeographic reconstruction of the Central Mediterranean sector during Late Paleozoic and Mesozoic times is still debated. Main questions arise about the timing of the individuation and opening of the Ionian Tethys and

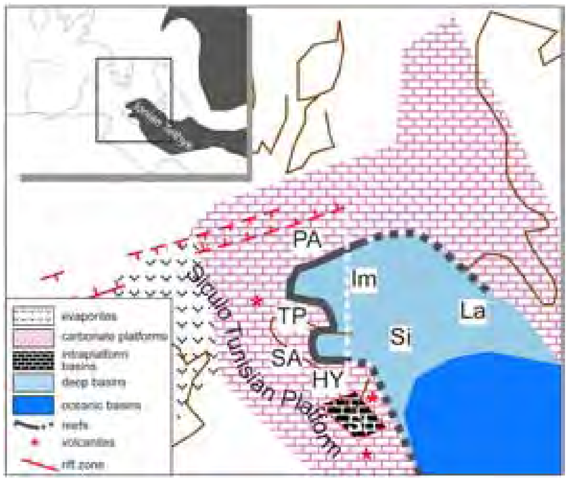

Figure 4: Palaeogeographic reconstruction of the central Mediterranean area which shows the main sedimentary domains of Sicily during Late Triassic times. Carbonate platforms: PA Panormide; TP Trapanese, SA Saccense, Hy Hyblean; Deep-water basins: IM Imerese, SI Sicanian, LA Lagonegro; Intraplatform basins: ST Streppenosa (mod. from Zarcone & Di Stefano, 2008). The white dotted line indicates the trace of the palinspastic section of Fig. 5.

the presence of a continental connection between Africa and Adria (Ziegler, 1988; Dercourt et al., 1993; Stampfli & Borel, 2002; Rosenbaum et al., 2004; Finetti, 2005; among others).

An attempt to reconstruct of the different paleogeographic zones of Sicily during Late Triassic times is given in Fig 4. In this reconstruction (Turco et al., 2007, Zarcone & Di Stefano, 2008) the Panormide Platform is considered as a crustal element connected to Adria, via the Apennine Platform that will be isolated during Jurassic times by the opening of the Alpine Tethys. The Trapanese, Saccense and Hyblean carbonate platforms are considered to be part of the rifted continental margin of Africa, while the Imerese and Sicanian basins (and the northernmost Lagonegro Basin), are the western termination, on a thinned continental crust, of the Ionian Tethys already individuated during Permian times. Fig 5 shows a schematic palinspastic section with a tentative interpretation of the pre-Norian sedimentary substrate of the Upper Triassic carbonate platform-basin systems of Sicily.

2. Triassic and Jurassic evolution of the Carbonate Systems from Sicily

2.1. Triassic

The Triassic carbonate platforms of Sicily and the adjacent deep water basins have been extensively studied during the past four decades (Patacca et al., 1979; Catalano and D'Argenio, 1982a; Antonelli et al., 1991; Catalano et al., 1996; Di Stefano et al., 1996). A scheme of the Triassic-Jurassic stratigraphy of the different paleogeographic domains is given in Fig. 3.

Thick peritidal successions of Norian-Simenurian age are well known in the subsurface of the foreland areas of south-eastern Sicily (Hyblean plateau and Sicily Channel), where they reach a thickness of more than 4000 m (Patacca et al., 1979; Antonelli et al., 1991) and are the most important reservoir of the Sicilian petroleum system (Sciacca and Inici Formations, Fig. 3). To the East they are bounded by the Malta escarpment, while to the west they extend to the deformed foreland areas in the Sciacca zone (south-western Sicily). In addition, the Triassic-Lower Jurassic peritidal limestones characterize the structural units of the chain from Corleone to Trapani and the Egadi Islands (Fig. 6). In this latter area the Triassic platform is locally transitional to evaporitic (sabkha) facies (Abate et al., 1982). Different sectors of this wide carbonate platform known as the Hyblean-Pelagian Domain (Nigro and Renda, 1999) can be differentiated on the basis of their sedimentary features, and are locally known as the Hyblean, Saccense and Trapanese domains (Catalano and D'Argenio, 1982a).

Based on stratigraphic relationships (e.g. the presence in some Trapanese-*type* successions of Panormide derived resedimented calcarenites, calcirudites and megabreccias of Late Jurassic and Cretaceous ages), the Panormide platform (Ogniben, 1960) is considered as the northern prosecution of the wide carbonate shelf, partly adjacent to, and continuous with, the Trapanese domain and further to the west to the African shelf (Fig. 5). Thrust sheets that are derived from this domain crop out in north-western Sicily from the San Vito Lo Capo Peninsula to the Palermo and Madonie Mountains. The eastward prosecution of this domain is known by exploration wells in the subsurface of the Nebrodi Mountains (Maragone and Bellafontana wells, Bianchi et al., 1987).

Di Stefano et al. (1996) have named the Triassic zone that included the Hyblean, Saccense, Trapanese and Panormide domains as the Siculo-Tunisian carbonate platform. Facies distribution indicates that this platform was characterized by a huge peritidal-lagoonal area subject to periodical sub aerial exposures. It was transitional to extensive sponge reefs rimming the platform and, in turn, to a deep water domain known as the Sicanian Basins. The slope and peribasinal areas lying between the Panormide sector and the Sicanian Basin characterized the Imerese Domain, a paleogeographic zone deeply influenced by the adjacent Meso-Cenozoic platform (Fig. 5).

Besides the global biotic crisis around the T/J boundary, the latest stages of the Upper Triassic carbonate sedimentation seems to have been controlled by a late Rhaetian sea level fall. This is supported by a sharp discontinuity surface overprinted by karstic dissolution on top of the Triassic strata.

The sedimentary dynamics was also influenced by tectonic activity. The Siculo-Tunisian platform was progressively dissected by NW-SE and SW-NE striking faults, which are also well seen in the foreland zones of the Hyblean plateau and offshore in the Sicily Channel (Antonelli et al., 1991). As a consequence several intraplatform basins were created (Catalano and D'Argenio, 1982b) totally or partly surrounded by wide and still productive carbonate shelves. Timing of the opening of these basins is bracketed

Figure 5: Schematic palinspastic section across the main sedimentary domains of Sicily during Late Triassic times.

between Late Norian and the Pliensbachian.

Extensional/transtensional tectonics was also active along the transitional zones of the former Triassic platform/basin system, inducing tectonic retreat of the platform margins, margin collapses and, in some cases, uplift and erosion.

2.2. Early Jurassic

During Hettangian and Sinemurian times, carbonate platform sedimentation continued across large faulted blocks of the Siculo-Tunisian Platform, resulting in a several hundred metres thick unit of peritidal and lagoonal limestones (Inici Formation). The platform margins were dominated by oolitic/skeletal sand wedges, often prograding onto the adjacent peribasinal areas. In distal sectors of the Sicanian basin radiolarian cherty limestones and marls were deposited. Contemporaneously, black shales and calcareous turbidites were deposited in the Streppenosa basin (Streppenosa Formation).

In the Panormide domain the Upper Triassic carbonate platform was uplifted and eroded during the Late Rhaetian or earliest Hettangian as suggested by a deep erosional truncation overprinted by paleokarsts in the Madonie and Palermo Mountains. As a consequence large volumes of clastic carbonates were accumulated in the adjacent Imerese basin (Scandone et al., 1972), giving rise to dolomitic aprons up to 500 m thick (Fanusi Formation). The uplift and erosion of the Panormide could have been related to the rifting in the Alpine Tethys, which produced the isostatic rebound of the rift shoulder (Zarcone, 2008; Zarcone and Di Stefano, 2008).

An early drowning of sectors of the Late Triassic platform margin are recorded also by the Monte Genuardo succession (central-western Sicily), where Hettangian to Sinemurian carbonate aprons made of oolitic-skeletal limestones overlie tilted blocks of shallow water dolostones.

During Late Hettangian or Early Sinemurian a sector of the Trapanese domain, located between the Monte Kumeta and Rocca Busambra zones, sunk and became the site of deposition of radiolarian cherty limestones and black shales. The existence of this basin (Marineo Basin, Catalano and D'Argenio, 1982b) is documented by subsurface data (Marineo well), although its areal extension is still poorly constrained.

During Pliensbachian times the termination of the still productive carbonate platforms is recorded (Jenkyns, 1970). The age of the topmost deposits of the Inici formation is generally dated as latest Sinemurian (Gugeberger, 1936; Arkell, 1956; Giacometti & Ronchi, 2000). A Pliensbachian age for the Inici top is reported from Monte Erice and "Rocca chi Parra" (Wendt, 1969). In some structural highs (e.g. Monte Kumeta) an anomalous benthic production occurred during early Pliensbachian (Di Stefano et al., 2002a).

The termination of the carbonate platforms caused the cessation of oolitic-skeletal shedding and a drop of sedimentation rates in the peribasinal areas.

Tectonic motions are documented by a first generation of neptunian dykes filled by crinoidal limestones (Wendt, 1971) and huge volumes of *in situ* breccias along major faults. Uplift and erosion of Inici strata are well documented in the Sciacca area, where listric faults predating the pelagic sedimentation produced block rotations associated with deep erosional truncations (e.g. Monzealese quarry, Di Stefano et al., 2002b). In the Trapanese domain a sub aerial exposure of the Inici top is documented at Rocca Busambra. In some structural highs the productivity change during the Pliensbachian is marked by the presence of crinoidal and brachiopod limestones (e.g. Monte Kumeta). Part of these deposits were emplaced as calciturbidites into the adjacent basins. Although tectonic activity was intense in this time interval, the drastic drop in carbonate productivity was perhaps related to eutrophic conditions that have recently been documented in other Tethyan regions like the Apennines (Morettini et al., 2002; Galluzzo & Santantonio, 2002).

By Toarcian times the former Triassic Siculo-Tunisian platform had turned into a complex mosaic of basins and swells connected by escarpments, on which the deposition of normal, condensed and composite pelagic facies associations (sensu Santantonio, 1993) took place. These pelagic sediments are informally indicated as Rosso Ammonitico (Catalano et al., 1981) and are equivalent to the Buccheri Formation of the Hyblean domain (Patacca et al., 1979).

Over most of the structural highs, thick ferromanganese crusts formed and Toarcian to lower Bajocian ammonitic limestones were only preserved in sparse metre- or centimetre-scale depressions and neptunian dykes.

The Imerese and Sicanian basins recorded the progressive switching from carbonate to siliceous sedimentation.

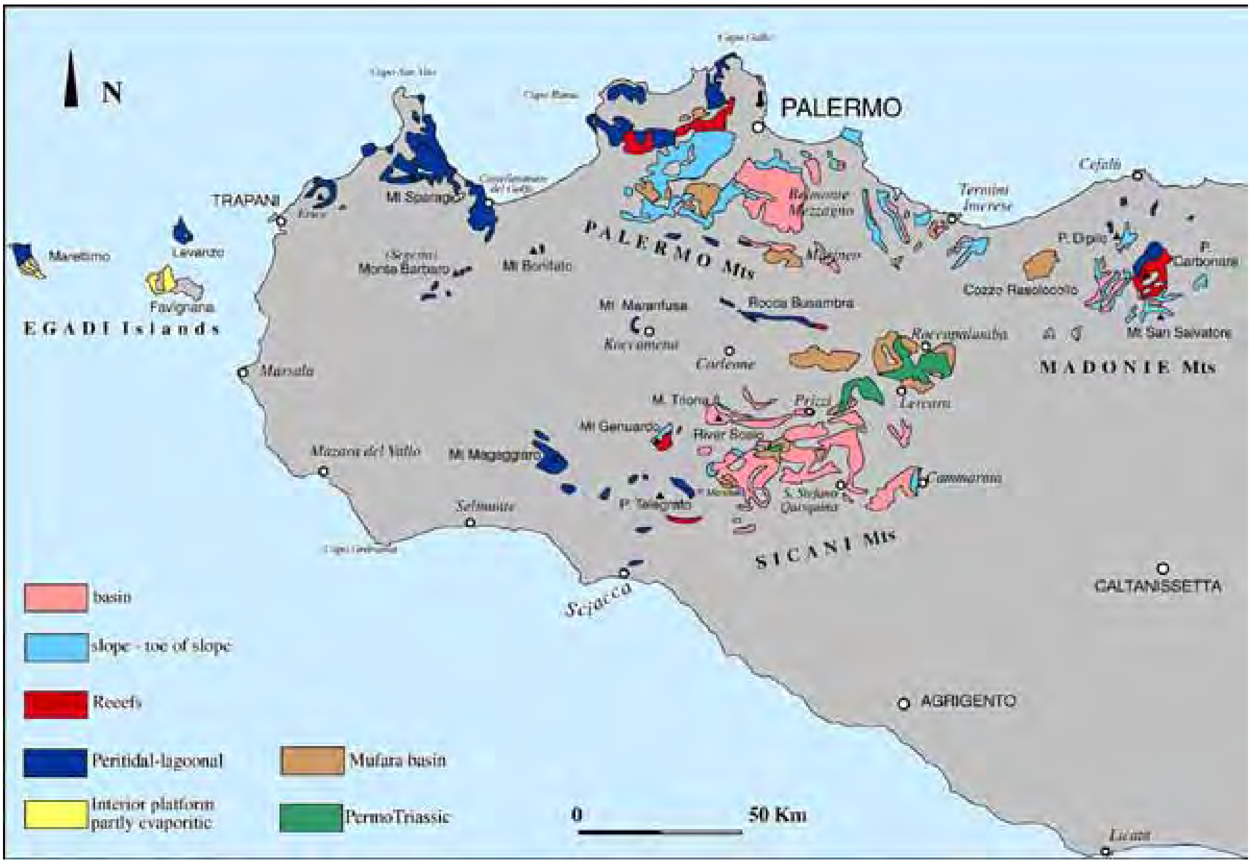

Figure 6: Present-day distribution of the Upper Triassic-lowermost Jurassic facies from Western Sicily. The main outcrops of the Mufara Formation and of the Permian-Ladinian complex are also indicated (from Di Stefano & Gullo, 1997).

Locally an imprinting of the Early Toarcian anoxic event (Jenkyns and Clayton, 1986) was recorded, as described by Parisi et al. (2001) in the Piana degli Albanesi succession.

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Facies architecture of the Upper Triassic margin from the Panormide Carbonate Platform: the Cozzo di Lupo section

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The aim of Stop 1 is to observe the lateral facies variations from megalodont limestones to sponge limestones along a continuous natural section of the Triassic Panormide shelf edge.

The Upper Triassic successions from the Panormide Carbonate Platform are well exposed in the Palermo Mountains (Fig. 1.1). In this area, two major thrust sheets that are derived from the Neogene contraction of the Panormide domain have been recognized (Catalano et al., 1979). They consist of Upper Triassic to Eocene strata, mostly shallow-water carbonates, unconformably covered by the Oligocene–Miocene Numidian Flysch. Southward, these thrust sheets are emplaced in turn on the Imerese structural units that are characterized by deeper-water Meso–Cenozoic carbonates and cherts.

In the Palermo Mountains, the palinspastic restoration of the Panormide-derived thrust sheets coupled with the distribution of the Triassic facies allow the identification of an inner zone of the carbonate platform, dominated by shallowing-upward peritidal cycles, and a marginal zone characterized by lagoonal cycles laterally transitional to the reef complex (namely the Cozzo di Lupo unit).

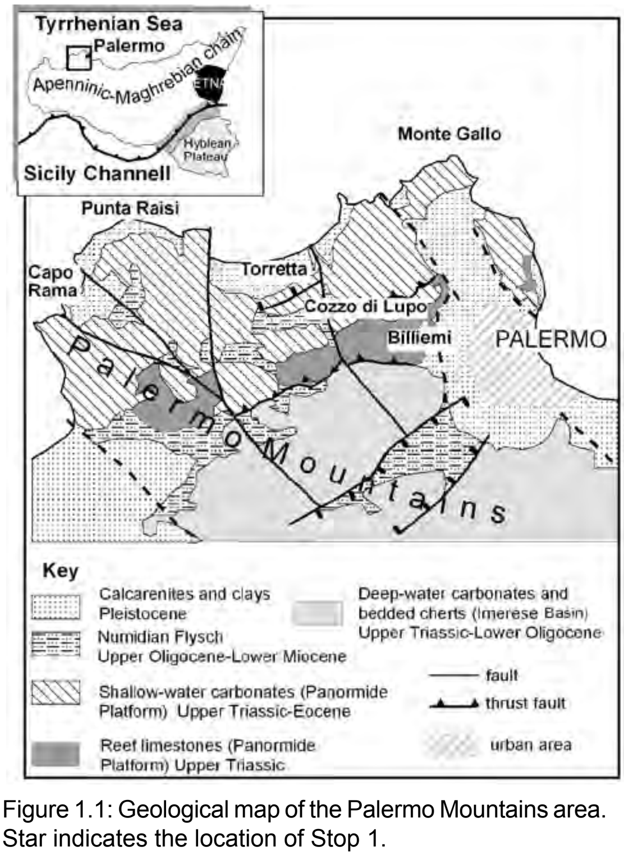

Figure 1.1: Geological map of the Palermo Mountains area. Star indicates the location of Stop 1.

The best exposures of the peritidal successions corresponding to interior areas of the platform crop out at Capo Rama near Terrasini. Here 200-300 m of shallowing upward cycles can be observed (Fig. 1.2). Each individual cycle, about 1.5-2 m thick, is formed by a sub-tidal facies consisting of megalodont-bearing grainstone-packstone, followed by an intertidal stromatolitic facies and by a supratidal facies which consists of loferitic breccias (*Ciclotemi di Capo Rama*, Catalano et al., 1974). The attribution of these deposits to the upper Norian is supported by megalodonts, dasycladalean algae and foraminifers as well as some ammonoids that occur in storm layers (*Rhabdoceras suessi* zone).

The marginal zones of the Panormide CP are well exposed at Cozzo di Lupo, near the village of Torretta (Fig. 1.1). In this locality a Dachstein-type sponge reef and its transition to the lagoonal megalodont and coralgal limestones can be laterally followed along a 3 km continuous section created by a road-cut closely parallel to the bedding.

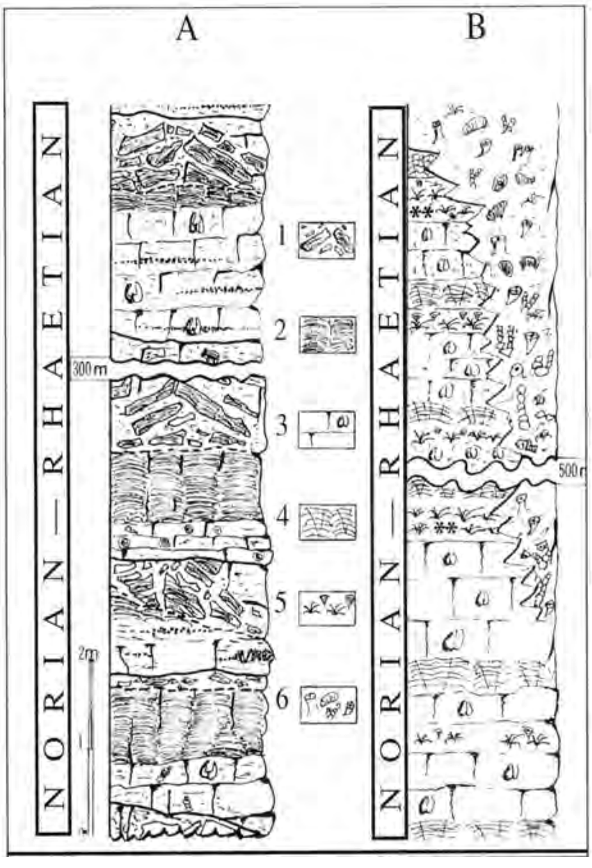

Figure 1.2: Facies-cycles in the carbonate platform deposits from the Palermo Mountains. A) peritidal-cyclothems (Capo Rama, after Catalano et al., 1974). B) outer lagoon cycles transitional to reef deposits (Cozzo di Lupo). 1) stromatolitic and loferitic breccias; 2) stromatolitic boundstone; 3) algal-megalodont grainstone-packstone; 4) Porostromate Cyanophycean bafflestone; 5) coral boundstone; 6) sponge-chetetid boundstone.

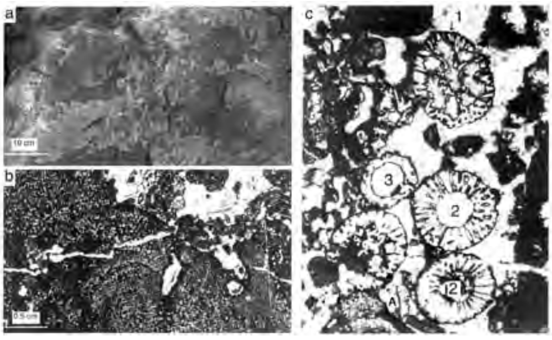

Figure 1.3: Calcareous algae of the outer lagoon environment of Cozzo di Lupo: outcrop view (a) and microphotograph (b) of the "Porostromata" algae bafflestone; c) dasycladalean grainstone, a common microfacies in the megalodont limestones 1) *Heteroporella micropora* Di Stefano & Senowbari-Daryan; 2) *Diplopora tubispora* Ott; 3) *Diplopora borzai* Bystricky. In association fragments of Porostromate Cyanophyceans x 13 ca.

The reef facies consist of hundred metres thick massive limestones and, locally, of dolostones with calcareous sponges (both Inozoans and Sphinctozoans), chetetids and subordinate corals (Senowbari-Daryan et al., 1982); their paleontological and sedimentological characters are comparable with those of the Upper Triassic reefs of the Tethyan realm (Flugel, 1981, 2002; Di Stefano et al., 1990).

Upward the reef limestones are truncated by an erosional surface with karstic overprint, sealed by deeper water brachiopod-bearing packstones and ammonitic wackestones of Pliensbachian to Oxfordian age (Di Stefano, 2002). Swarms of neptunian dykes cross-cut the reef limestones. They are filled up by coarse breccias or fine-grained, varicoloured limestones of Jurassic age (Voros et al., 1986).

Stop 1.1 - Outer lagoon limestones

In this outcrop thick beds of Megalodont limestones that alternate to coral and algal boundstone can be observed, giving rise to metre-scale facies cycles.

We interpret these cycles as due to high-frequency sea-level fluctuations in an outer lagoon environment. Cycles are less regular than those recorded by peritidal successions. The most common elementary cycle is characterized by a transgressive unit consisting of megalodont grainstone (20-150 cm) resting upon an erosional surface, usually with a basal lag. It is followed upward by a carpet of corals (20-50 cm thick) pointing to a deepening upward trend. Corals are mostly *Retiophyllia paraclatrata* Roniewicz and *Astreomorpha confusa* (Winkler). Corals are capped in turn by a regressive unit consisting of skeletal grainstone-packstone and/or algal bafflestones (Fig. 1.3) formed by Porostromate Cyanophyceans (*Cayeuxia* sp., *Orthonella* sp., *Zonotrichites* sp.) associated to ramose So1enoporae. This last lithofacies is commonly truncated upward by an erosional surface.

The skeletal grains in the megalodont limestone and in the coral boundstone consist almost exclusively of calcareous algae such as dasycladales, represented by highly diverse *Diplopora* and *Heteroporella* species and by nodular thalli of Cyanophyceans and Solenoporaceans (Fig. 1.3 c). They are associated to rare benthic foraminifers (*Alpinophragmium* sp., *Aulotortus* sp., *Glomospira* sp., *Triasina oberhauseri*). The remarkable dasycladacean content seems to be a peculiar character of sediments that have been deposited in back reef zones close to the central reef area (Senowbari-Daryan & Schäfer, 1982).

Moreover these well sorted sediments, depleted in micrite, point to high energy condition in this zone of the back reef lagoon. Thus the sponge reefs did not provide an efficient barrier to mitigate the wave energy.

Stop 1.2 -Reef limestones

Along the road cut, the transition from the back reef lagoon to the reef complex zone is pointed by the lateral facies variation from megalodont limestones to sponge-chetetid boundstones (Fig. 1.4). The reef deposits, namely massive dolomitized limestones, are mainly characterized by sponge-chaetetid boundstone (Fig. 1.5). Also sponge rudstones can be observed in places. A highly diverse assemblage of calcareous sponges, among which the sphinctozoans *Amblysiphonella, Paravesicocaulis, Cryptocoelia, Panormida*, act as primary framebuilders of these reef limestones. They are associated with abundant chetetids, *Cheilosporites tirolensis* Whàner and rare corals (*Montlivaltia* sp. and *Thamnasteria* sp.), as well as hydrozoans. The framebuilding organisms are frequently coated by several generations of encrusting organisms (sponges, foraminifers) and by algal-microbial crusts of "Spongiostromata" type (Fig. 1.5c).The intrabiolithitic cavities are filled either by a fine grained packstone/grainstone with abundant reef-dwelling foraminifers such as *Cucurbita* sp., *Foliotortus* sp., and *Galeanella spp.* or by wackestone/ mudstone with algae and microproblematics.These latter

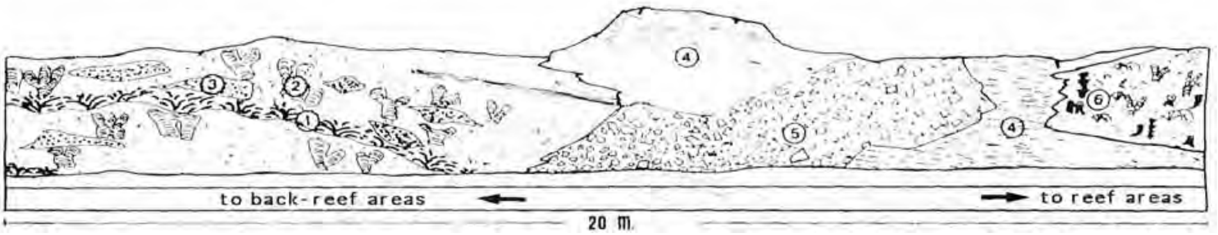

Figure 1.4: Cozzo di Lupo. Detail of the transitional zone between back-reef and reef deposits (from Abate et al., 1982). Coral boundstones (1) alternate in the back-reef area to algal bafflestone (2) and to skeletal grainstone-packstone (3). These facies are laterally transitional to skeletal grainstone-rudstone with calcareous sponges (4-5) and to sponge boundstone (6) representing the central reef area.

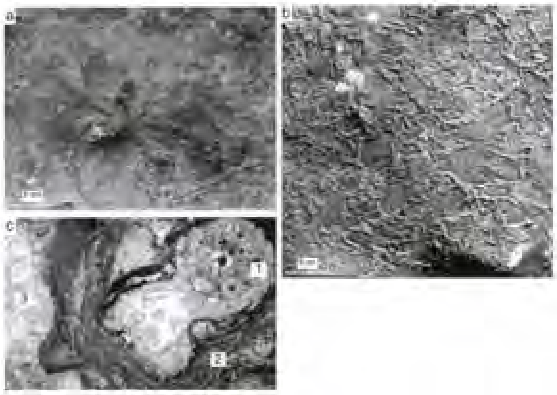

Figure 1.5: Upper Triassic sponge boundstone of Cozzo di Lupo: a) and b) well developed radiaxial fibrous cements (in relief) encrusting the primary framebuilding organisms (mostly sponges); c) detail of a common microfacies, consisting of inozoan sponges (1) coated by algal-microbial crusts (2) and by fibrous cements (3), x15.

sediments indicate more protected or deeper zones of the reef. In places the intra- and interbiolithitic cavities are coated by thick crusts of radiaxial fibrous calcite (Fig. 1.5b). These diagenetic structures indicate high energy sectors of the reef.

Later diagenetic overprint in the reef limestones are represented by small dissolution cavities filled up with reddish vadose silt. They are related to the subsequent subaerial exposure of the platform at the turn of the T/J boundary.

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The Billiemi breccia: the record of Rhaetian/lowermost Jurassic brittle deformations along the Panormide shelf edge

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The aim of Stop 2 is to vist the Billiemi quarries west of the Palermo plain and discuss the sedimentological and geochemical features of a famous dimension stone, the *Pietra di Billiemi*, that records the effects of the brittle deformation of an Upper Triassic reef margin at the turn of Rhaetian-earliest Jurassic times.

The Upper Triassic Dachstein-type sponge reefs from the Palermo Mountains crop out in a large NW-SE belt from Giardinello, via Cozzo di Lupo, to Monte Gibilforni (Fig. 2.1).

In the Monte Gibilforni area (Fig. 2.1) the brecciation of the reef limestones increases and these limestones grade to a massive breccia (Fig. 2.2.). This limestone breccia, known as *Pietra di Billiemi*, has been quarried since Roman times, being widely employed as dimension stone. The massive mesostructure of the rock has permitted monolithic blocks to be quarried and worked for material utilised in several monumental and religious buildings mainly in Palermo city (1).

The *Pietra di Billiemi* is a grey, coarse-grained and clast-supported limestone breccia mainly formed by metre-sized to centimetre-sized, angular platform-derived fragments and differently coloured matrices. Matrices consist of dark grey to black, or white or pale blue or red and yellow silt-sized mudstone (Fig. 2.3). The breccia clasts are mostly Upper Triassic sponge-chetetid boundstone/rudstone consisting of facies and microfacies types well comparable to the adjacent Cozzo di Lupo reef limestones as described in the Stop 1.

Recent sedimentological and geochemical studies support a major role of extentional/ transtensional tectonics at the turn of the Rhaetian/Lower Jurassic times as trigger mechanism for the formation of the Billiemi breccia and provide interesting information about the biotic and environmental conditions during its formation (Scopelliti et al., 2009).

In particular, the matrix is characterized by the absence of biogenic components and by variable mineralogy and geochemistry. Petrographic features and strontium isotope values indicate that the most important and earliest fillings of the breccia consist of black matrix and white matrix temporally referable to Hettangian-Sinemurian times.

The dominant matrix is a dark grey to black locally laminated calcilutite mainly consisting of silt-grained calcite with abundant pyrite present both as finely dispersed crystals (< 10 µm on average) and framboids. Pyrite also is concentrated along low-amplitude microstylolites. In these zones of pressure solution, it is possible to observe localized micrite envelopes. Turner et al. (2000) and Riding (2000) showed a similar microfabric, typically formed by an irregular sponge-like network of micrite (clotted micrite), suggesting a microbial origin. In the absence of substantial proportions of total organic carbon (TOC < 0.1%), the presence of abundant, finely dispersed pyrite crystals is thought to be responsible for the black colour of this matrix.

Considering i) the lateral relationships with the reef limestones, ii) the fitted fabric observed as common texture of the breccia and iii) the presence of a fine-grained infilled matrix, the Billiemi breccia can be interpreted as a lithodemic unit consisting of *in situ* breccias (Fig. 2.4).

Clotted micrite, carbonate fluorapatite and the abundant pyrite, in addition to relatively high contents of redox-sensitive elements (V, Ni, Zn, S), are consistent with deposition in anoxic conditions that favoured microbial mediation for authigenic carbonate (calcite and dolomite) precipitation in the matrix. As a whole, the Billiemi breccia can be considered a product of brittle deformation of a Tethyan carbonate platform edge around the Triassic/Jurassic boundary, formed when the drowned platform edge was covered by hemipelagic mudstones recording the anoxic conditions existing during Early Jurassic times (Fig. 2.4).

The Billiemi breccia can be observed in different quarries at the foot of Monte Gibilformi, near Palermo. In detail at "Petrazzi" quarry, today disused, the *Pietra di Billiemi* is exposed with the typical aspect characterized by grey-coloured, coarse-grained, and clast-supported limestone breccia mainly consisting of metre-to-centimetre-sized, angular platform fragments. Grey-to-black matrix, characterizing a particularly appreciated variety of the *Pietra di Billiemi*, known as "occhio di pernice" ("partridge eye", is not here widespread. This peculiar variety is today difficult to find. It was quarried at the "Generale Impianti", quarry today exploited only for the extraction of inert material. Finally, at "Bordonaro" quarry only the upper portion (not visitable for safety reasons) is today exploited for the extraction of limestone breccia blocks (Fig. 2.5).

(1) The oldest quarries of the *Pietra di Billiemi* became productive at the end of the XVI century AD, when the Porta Felice (the last gate of Palermo open towards the sea) was built. Successively, because of the good physical-

mechanical properties (high durability, low porosity, high compressive strength) and the massive mesostructure of the rock mass, it was possible to carve monolithic basins for the monumental fountains. In the same way monolithic columns, more than seven metres high, was utilized in several monuments and religious buildings of wide historic and artistic interest. In the Baroque epoch it was used like a "marble", employing it for structural highly aesthetic elements in the architecture and for the road paving of the old town of Palermo. More recently, this stone has been largely used for civil buildings and one of the last public works carried out in Palermo, the "Palazzo di Giustizia", has won the "Marble Architectural Awards Italy 2000" in Carrara. The *Pietra di Billiemi* has been exported to several foreign countries (i.e., Arabic Emirates, Hong Kong, etc.) being also employed for restoration in the Cathedral of Munich (Germany), together with another Sicilian dimension stone, the *Rosso di Castellammare*.

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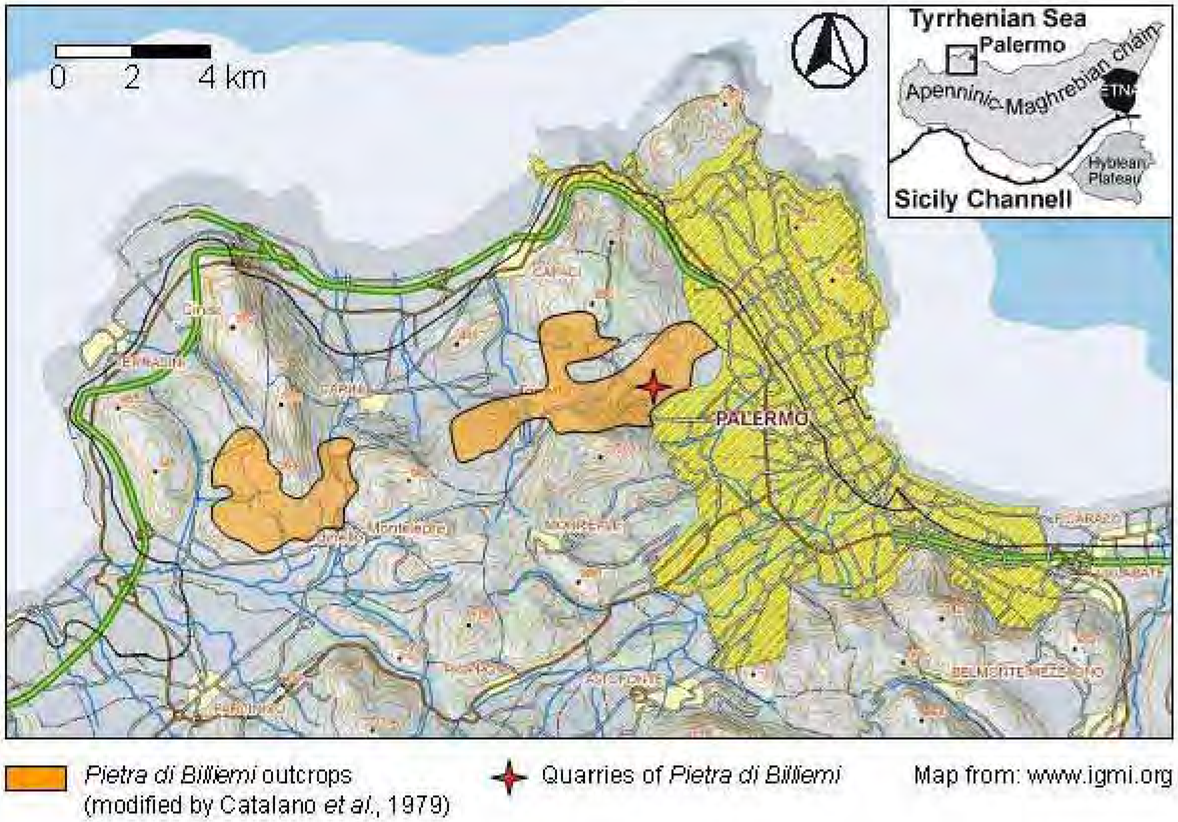

Map from: www.igmi.org

Figure 2.1: Distribution of the Pietra di Billiemi outcrops. Star indicates the location of the quarries.

Figure 2.2: Common facies of the Billiemi breccia, showing fitted fabric consisting of angular clasts of Upper Triassic sponge boundstone/rudstone and a black calcilutite matrix. Coin diametre = 25 mm.

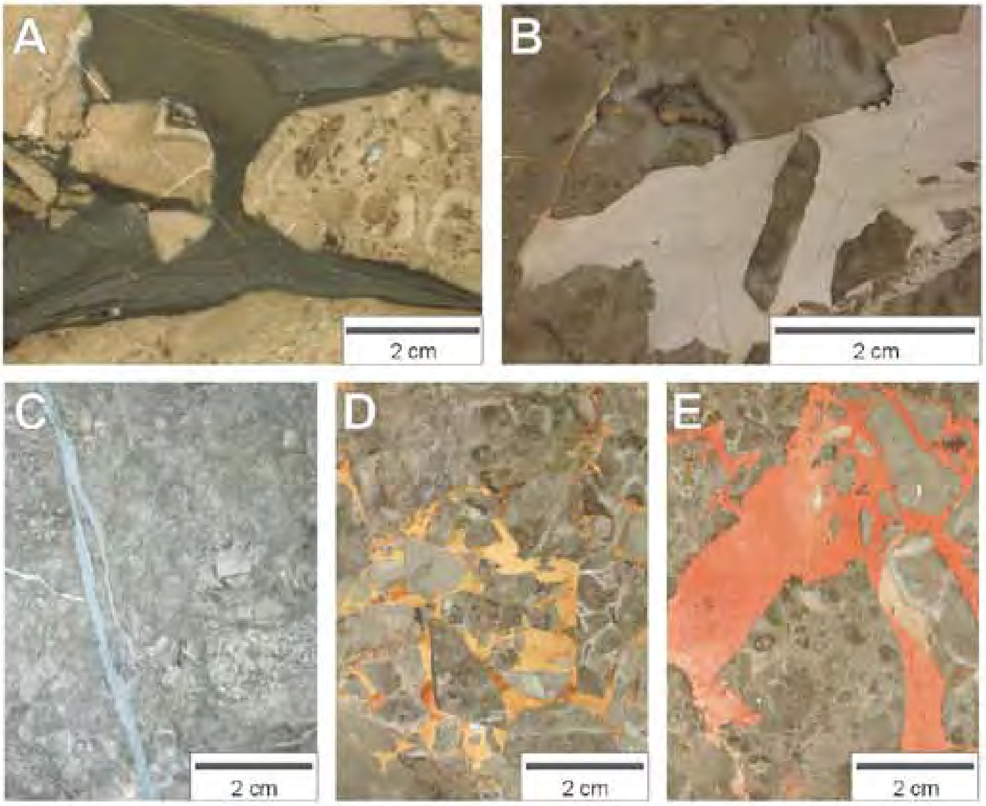

Figure 2.3: Texture of the Billiemi Breccia from Monte Gibilforni: limestones grade to a massive clast-supported breccia formed by large, angular and commonly fitted fragments, surrounded by a fine grained and varicoloured matrix.

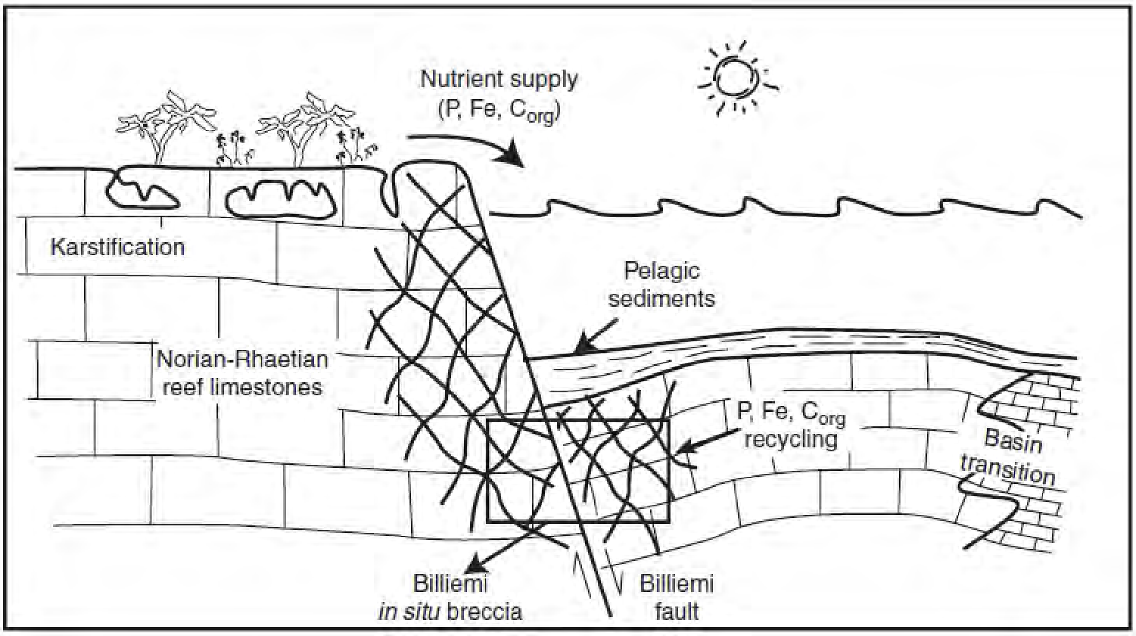

Figure 2.4: Summary reconstruction of the Billiemi breccia origin during Hettangian/Sinemurian times.

Figure 2.5: Panoramic view of the Bordonaro quarry.

Evidence of Middle Triassic to Carnian shallow-water limestones from megabreccia intercalations in the Carnian Mufara Formation: Cozzo Paparina (Altofonte)

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The aim of Stop 3 (Fig. 1) is to show an example of base-of-slope clastic carbonates that are intercalated in the Mufara Formation. They indicate the presence of source areas floored by Middle Triassic to lower Carnian carbonate platform successions.

The Mufara Formation outcrops in several localities of

Western Sicily. It was originally described as varicoloured clays and marls with thin intercalations of dolomitic limestones. The reference section is at Monte Mufara in the Madonie Mountains (Schmidt di Friedberg, 1962). This unit occurs at the base of the thrust sheets that are derived from the Imerese and Sicanian deep-water paleogeographic zones. Owing to Neogene compressive tectonics the true thickness of this formation is very difficult to estimate but probably does not exceed some hundred metres. It is largely accepted that the Mufara Formation acted as a major detachment level during the Maghrebian orogeny. In some areas (e.g. Sosio, Lercara) it occurs in tectonic complex associated to Permian – Ladinian "broken formations" (Lercara complex *Auct.*).

The Mufara Formation consists of deep-water marl-limestone alternations with intercalations of intra and extrabasinal clastic carbonates and basaltic pillow lavas. A siliciclastic input is reported by Mascle (1979) in some areas of the Mufara basin. According to Di Stefano & Gullo (1997) the siliciclastic fraction in the Mufara basin increases towards the present north as observable in the Termini Imerese (Cozzo Pideri) and in the Cozzo Rasolocollo areas where the Mufara beds consist of siliciclastic turbidites showing Tb-Te Bouma divisions. They alternate with thin *Halobia*-bearing limestones yelding well-preserved conodont faunas pertaining to the *Gladigondolella tethydis* Zone (*sensu* Kozur, 1989) of Julian age. The occurrence in these turbidites of policrystalline quartz, muscovite and feldspars, among other siliciclastic components, points to a provenance of the clastic material from a Kabilo-Peloritani-related source area.

Blackish marls showing an organic-carbon concentration and abundant pyrite are observed in some sections. They indicate episodes of deposition beneath dominantly anoxic bottom water (Bellanca et al., 1995).

The age of the Mufara Formation is considered to be Carnian. An Early Carnian age from the Mufara beds in the Marineo region was established by Zia (1956) on the finding of *Trachyceras aon* (Münster). Lentini (1974) refers the lowermost Carnian strata from the Monte Scalpello area to the *aonoides* Zone. Mascle (1979) assigned the Mufara Fm. of Monti Sicani to the Carnian, and he did not exclude a Ladinian age for its base.

Cafiero and De Capoa Bonardi's (1982) investigations mainly concerned the macrofossil *Halobia*. However, recognition of an ostracod-rich fauna with *Mockella muelleri* Bunza and Kozur, permitted a Julian age to be assigned to the clayey-calcarenitic deposits.

On the basis of conodonts, foraminifers and pollens, Martini et al. (1991) have reported a late Tuvalian age from several Mufara successions in Northern Sicily. Di Stefano & Gullo (1997) reconstructed a biostratigraphy, based on well preserved conodont associations from many sections in western and central Sicily. They indicated Julian and Tuvalian ages for the Mufara deposits and pointed out a diachronous transition to the overlying cherty limestone succession in Tuvalian times. Di Stefano et al. (1998) reported a Julian age for the small outcrop of Mufara Fm. at Monte Altesinella (Central Sicily) on the base of conodons indicating the *Gladigondolella tethydis* zone (sensu Kozur, 1989).

Buratti and Carrillat (2002) and Carillat & Martini (2009) recognized four distinct palynomorph associations ranging in age from late Ladinian/early Carnian to late Carnian age for the Mufara Formation.

Cozzo Paparina

The Mufara Formation outcrops in a large area between Giacalone and Altofonte in the southern Palermo Mountains (Fig. 3.1). It occurs at the base of the the Imerese succession as shown in the schematic section of Fig. 3.2. In this area the Mufara formation shows alternations of thin-bedded calcilutites and yellowish-brownish marls. The fossil content consists of radiolarians, halobids, conodonts, calcispheres. Small outcrops of altered basaltic pillow lavas are also present (Catalano et al., 1979). In some levels ichnofossils are abundant and point to an intense bioturbation of the sediment. Conodont samples from the marl/calcilutite alternations at Cozzo Paparina yielded a conodont assemblage with *Gladigondolella tethydis* (Huckriede) and *Paragondolella polygnathiformis* (Budurov & Stefanov) indicating a Julian age. Downsection the Julian age is also supported by the finding of *Badiotites eryx* (Münster) in calcilutite beds (Mietto, Preto & Rigo, *pers. com.*). In this locality, as in many others sections of the Mufara formation in Sicily, repeated intercalations of coarse clastic-carbonates occur between the calcilutite-marls alternations (Figg. 3.3 and 3.4). Their paleontological content was studied by Senowbari-Daryan & Abate (1986) and Senowbari-Daryan & Di Stefano (2001).

More recently Carillat & Martini (2009) described at Cozzo Paparina a section of 20 m of mainly yellow marls, silty marls intercalated by marly limestones. The authors indicate an upper Tuvalian age for this section.

The clastic beds of the Cozzo Paparina section dip to ENE of about 40°. The geometry of the sedimentary body is obscured in places by tectonic deformations and recent landslides.

Several metres to decametre-scale megabeds are present up-section. They mainly consist of clast-supported extrabasinal elements (Fig. 3.5). Their total thickness is of about 230 m. Lithoclasts in these megabeds are either angular or relatively well rounded and their size varies between mm to dm scales. A fining upward trend can be recognized in some megabeds. The matrix varies from yellowish marls to wackestones with radiolarian and "filaments". The clastic material was most probably emplaced at the toe-of-slope by debris flows, but we do not exclude that some coarse, unsorted, breccias upsection, could have been emplaced by rockfalls. Moreover, finer grained beds that consist of shallow-water skeletal grains (e.g. "*Tubiphytes*" and foraminifers) alternating to hemipelagic wackestone, can be interpreted as calciturbidites. The presence of lime-mud intraclasts with radiolarians indicates partial erosion and subsequent incorporation of semi-indurated background sediment into a fast turbidity current. In some cases these beds shows a channel filling geometry (Fig. 3.6).

In the coarse grained beds the extraclasts exhibit different facies types as well as different ages. Reef and lagoonal facies are the common constituents. According to Senowbari-Daryan & Abate (1986) among the platform-derived elements three main facies have been differentiated: i) reef facies; ii) lagoonal facies (this is represented by two distinct facies types: "Cayeuxia" bindstone and dasycladalean grainstone); iii) pisolite facies.

The reef facies is characterized by *boundstone* to *bindstone* dominated by sponges and "*Tubiphytes*". The lagoonal facies is characterized by "*Cayeuxia*" bindstone and dasycladalean grainstone. The dasycladalean grainstone contains the abundant species *Diplopora annulatissima* Pia (Fig. 3.7/1,3), in association to *Teutloporella peniculiformis* Ott (Fig. 3.7/2,4) and ?*Physoporella lotharingica* (Benecke).

This assemblage is typical of lagoonal facies of late Anisian to early Ladinian and probably also

Late Ladinian ages.

The association of these dasycladales, which also occurs in the Ladinian, with *Zornia obscura*, an organism not known from the Anisian, suggests that the dasycladalean-bearing boulders from Cozzo Paparina are most probably early Ladinian in age. The age of the "Cayeuxia" boundstone as well as of the pisolithic facies is not established (Fig. 3.8/1,2). More rare elements consist of yellowish marly limestones with *Meandrospira dinarica* Kochansky-Devide & Pantic (Fig. 3.8/3), a well known species in the Anisian of the Tethyan domain (Rettori, 1995).

Among the clastic elements pebbles of wackestones with "filaments" and radiolaria are also present (Fig. 3.8/5-6). The microfacies of these elements are well comparable with the matrix of the breccia of the calcilutites that are present at the base of the clastic beds, thus reflecting a possible cannibalization of the slope sediments.

The source area of the reworked extrabasinal clastics is unknown, as shallow-water carbonate successions of Anisian-Ladianian ages do not crop out in Sicily. The Imerese succession that develops up-section shows a continuous input of clastic carbonates that were derived from the Panormide Platform. In particular the Rhaetian and Jurassic formations (Fanusi and Crisanti formations) consist totally or partly by Panormide-derived intra- and extrabasinal clastic carbonates.

For this reason we believe that the source area of the Cozzo Paparina megabreccia was the Panormide zone (Di Stefano, 1990, 1996) and, as consequence, that the well known Upper Triassic to Eocene succession of the Panormide Platform was developed on a Middle Triassic to Carnian sedimentary substrate that was detached during the Maghrebian orogeny.

In Fig. 3.9 an already published depositional model for the Mufara Formation based on several sections from western Sicily (e.g. Cozzo Paparina, Belmonte Mezzagno, Marineo, Altesinella, Roccapalumba, Portella del Paradiso, among others) takes into consideration the presence of a large amount of carbonate extraclasts spanning ?Anisian to Early Carnian ages (Di Stefano et al. 1998). They are intercalated at different stratigraphic levels in the Mufara sediments.

Contrary to recent interpretations, the emplacement in the Mufara basin of large amounts of megabreccias and finer grained skeletal turbidites intercalated to hemipelagic wackestones with radiolarian and filaments is here interpreted as typical of slope-apron settings. The genesis of megabreccia aprons cannibalized from the upper slope can be consequence of relative sea level falls (Spence & Tucker, 1997). The intrabasinal skeletal grains in all the

Figure 3.1: Location of the Cozzo Paparina locality.

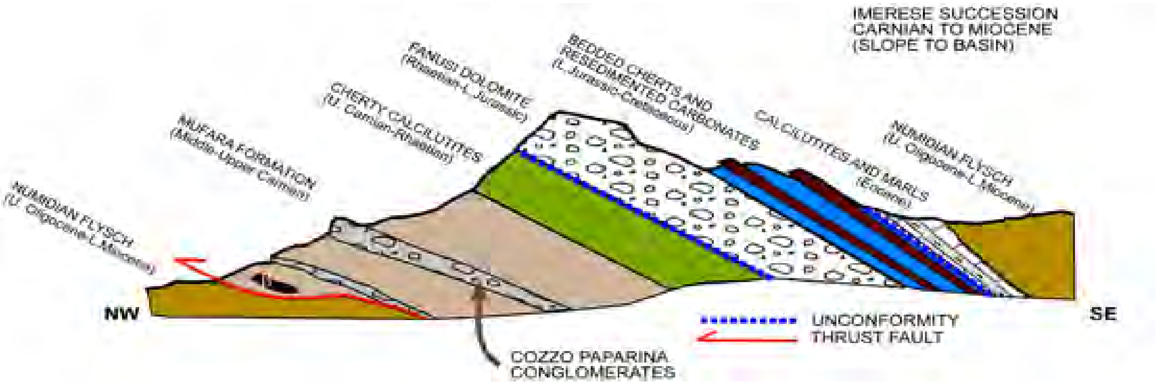

Figure 3.2: Schematic cross-section (not to scale) across the Imerese succession in the southern Palermo Mountains showing the main lithostratigraphic units.

sections could have been feed by buildups which developed downslope. We do not exclude also the effects of extensional tectonic movements associated to submarine basalt flows as possible trigger mechanism for the collapse of Anisian - Ladinian limestones along fault escarpments affecting the hinge zone between the Panormide Paltform and the Imerese Basin.

Most of the studied sections containing extraclast (e.g. Monte Altesinella, Belmonte Mezzagno, Marineo) can be dated as old as Julian (Di Stefano & Gullo, 1997; Di Stefano et al., 1998) on the base of conodont assemblages indicating the *Gladigondolella tethydis* zone (Kozur, 1989). These sections match the Car 2 sequence (Hardenbol et al., 1998).

An account of the different biostratigraphic evaluations of the Cozzo Paparina section, in order to evaluate its chronostratigraphic attribution, we are developing detailed biostratigraphic studies.

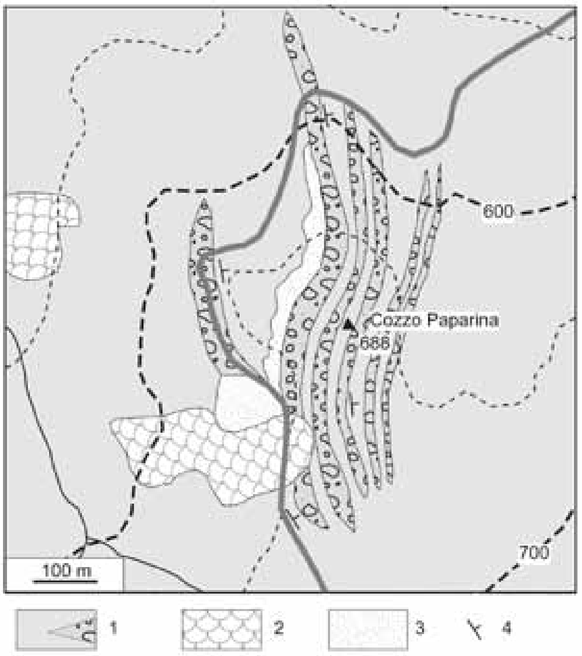

Figure 3.3: Geological map of Cozzo Paparina: 1 – Calcilutites, marls and megabreccia intercalations; 2) landslides; 3) debris.

Figure 3.4: Panoramic view of the Cozzo Paparina megabreccia

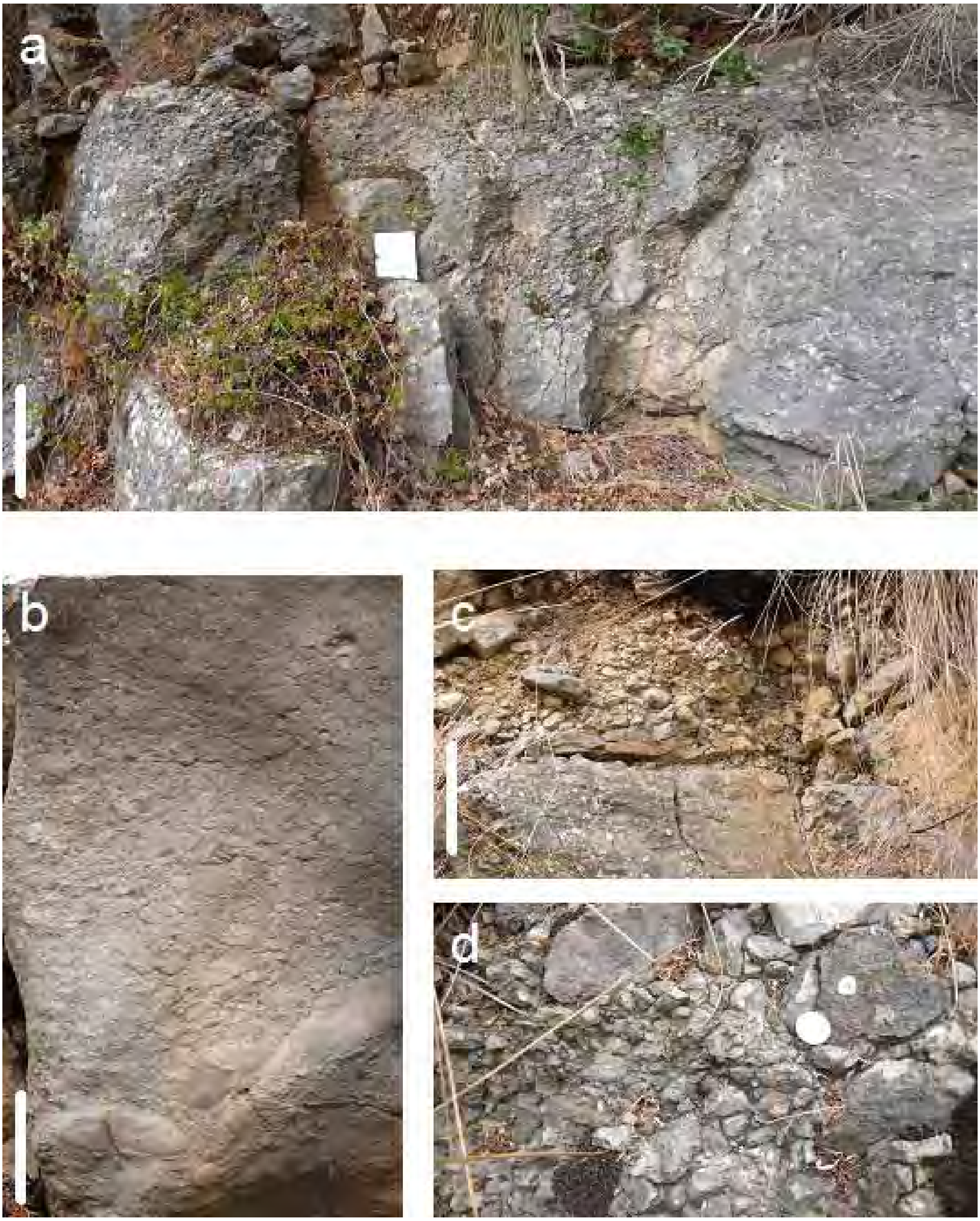

Figure 3.5: Details of the clastic beds from Cozzo Paparina: a) a poorly sorted, graded bed consisting of angular to rounded extraclasts of different origin: Sponge boudstone, “*Tubiphytes*” boundstone and laminated calcilutites are common. The scarce matrix consists of brown marls. Scale bar = 50 cm; b) Clast-supported and graded breccia, showing large elements at the base. Scale bar = 15 cm; c) Contact surface between two clastic beds, showing an intercalation of brownish-gray calcilutites (background sedimentation). Scale bar = 30 cm; d) large rounded extraclasts mixed to smaller angular elements. Coin diametre about 2,5 cm.

Figure 3.6: Fine-grained calciturbidites displaying channell-filling geometries in the uppermost zone of a megabed, passing upward, by a sharp contact, to a coarse mega-breccia.

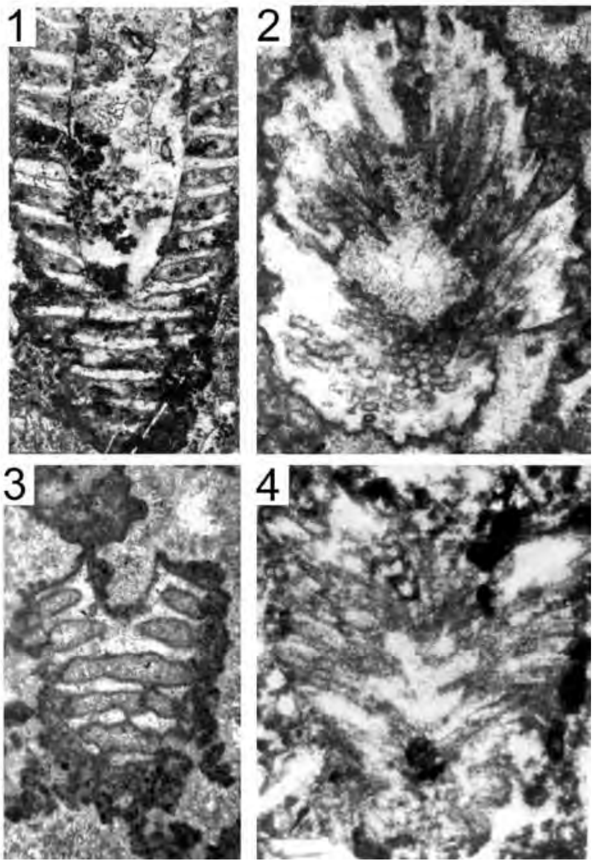

Figure 3.7: Dasycladalean algae from the Cozzo Paparina magabreccia: 1,3, *Diplopora annulatissima* Pia; 2, 4, *Teutloporella peniculiformis* Ott.

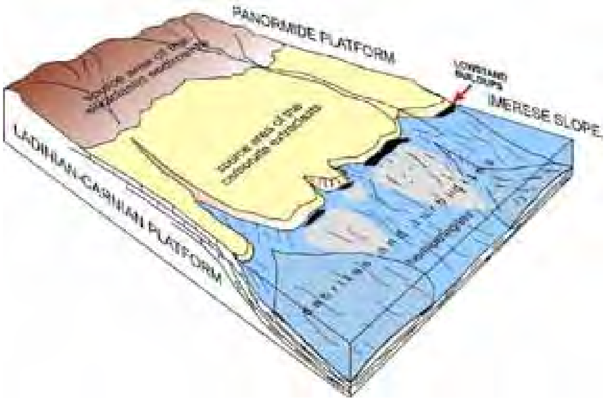

Figure 3.9: A schematic model for the carbonate aprons of the Mufara basin (slightly mod. by Di Stefano et al., 1998).

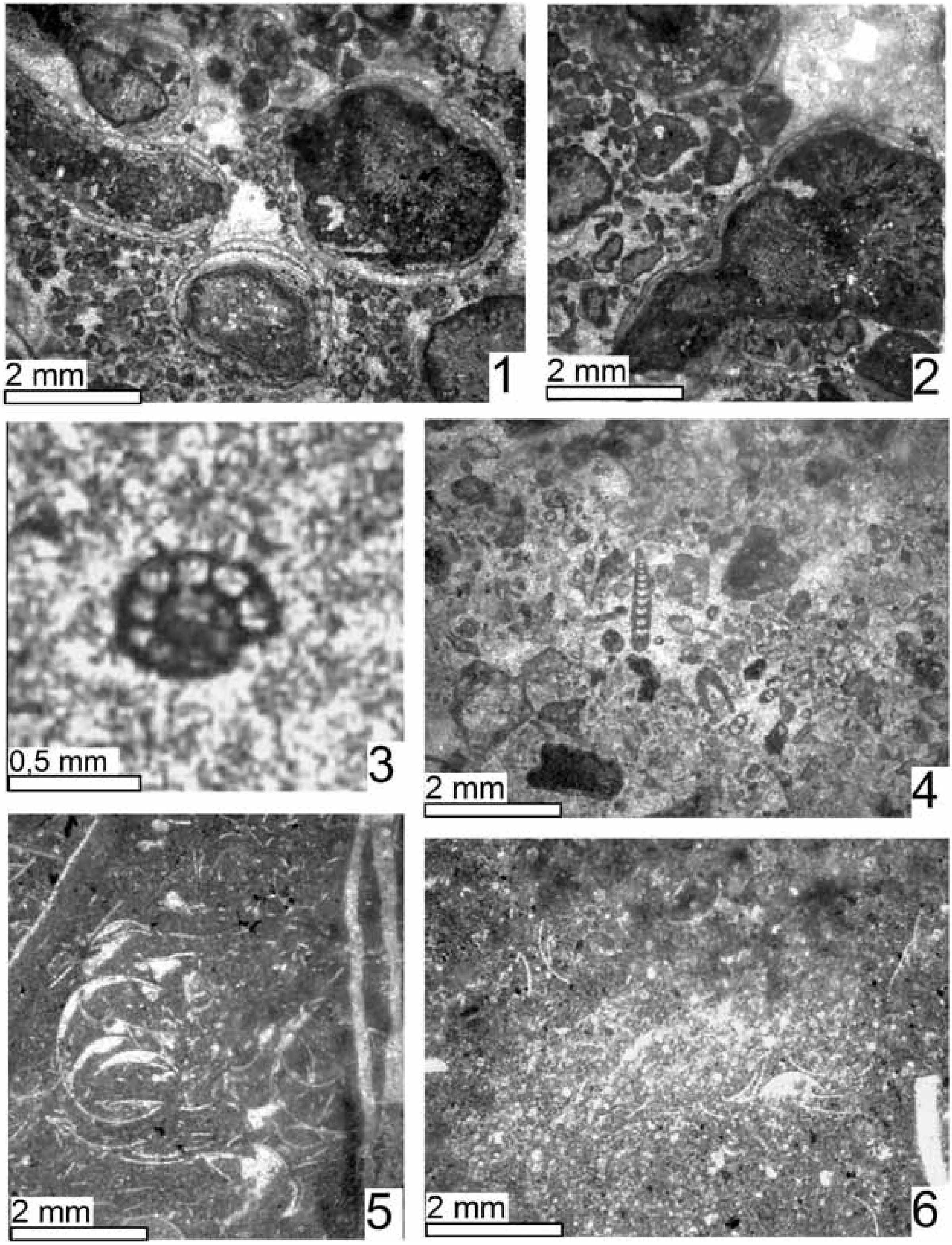

Figure 3.8: Microfacies from the Cozzo Paparina megabreccia: 1, 2 Pisolite facies. Nuclei prevalently formed by Porostromata algae ("*Cayeuxia*" type); 3 *Meandrosprira dinarica* Kochansky-Devidè & Pantic; 4 Grainstone with algal fragments, "*Tubiphytes*" and *Endotebanella* sp. 5, 6 Wackestone/packstone with halobids, calcispheres and radiolarians. Shelter porosity is present.

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Tectonic retreat of a segment of the Triassic paleomargin of the Saccense Carbonate Platform around the T/J boundary: the seismic-scale section of Monte Genuardo

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The aim of this panoramic stop is to show a large-scale natural section of the Upper Triassic-Lower Jurassic drowning sequence along the eastern slopes of the mountain and to discuss the tectonic retreat of a segment of the Triassic paleomargin of the Saccense carbonate platform around the T/J boundary. Moreover the paleogeographic relationships with the adjacent Sicanian basinal thrust sheets will be discussed in the light of recent structural and stratigraphic data collected for a PhD Thesis (Cacciatore) and the realization of the 1:50.000 Geologic Sheet N° 619 (National Geological Cartography – CARG project).

The Monte Genuardo succession is peculiar in western Sicily as it records the early drowning of a Late Triassic carbonate platform margin, and its conversion to a slope-to-peribasinal area connected to the Sicanian Basin, as a response to extensional tectonics around the Rhaetian-Hettangian boundary (Di Stefano & Gullo, 1987).

Monte Genuardo, near Sciacca, represents one of the tectonic units which are embricated in the external zone of the Maghrebian Chain in western Sicily (Figs. 2 and 4.1).

The sedimentary sequence consists of a thick (~1500 m) Upper Triassic to Neogene succession of carbonates and siliciclastics (Mascle, 1979; Di Stefano & Gullo, 1987). At the base of the succession, a thick interval of platform dolostones of Late Triassic age is exposed.

They are overlain through an angular unconformity by Jurassic-Lower Cretaceous slope to basinal deposits, consisting of resedimented oolitic calcarenites, crinoidal limestones, radiolarian cherty limestones with thick basalt layers, radiolarites, siliceous limestones and marls, calpionellid limestones and *Aptychus* marls (Fig. 4.2). Upper Cretaceous-Eocene megabreccia-bearing *Scaglia* and Oligocene-Miocene marls and calcarenites follow. They are covered by terrigenous molasse-type deposits, gypsum, marls and gypsarenites of late Tortonian-Messinian age.

Upwards the succession is capped by *Globigerina* marls (Trubi) and clays and calcarenites of Pliocene and Pleistocene ages.

The Monte Genuardo unit crops out as a polyphasically deformed, south-verging ramp-anticline (Fig. 4.1). The southern limb, overturned in places, is displaced by minor thrusts and in turn overthrusts Miocene and Lower Pliocene covers of the Pizzo Telegrafo unit, a more external structural unit belonging to the Saccense Domain (Di Stefano & Vitale, 1993, 1994).

Based on its Mesozoic stratigraphy and on its relationships with the adjacent structural units, the Monte Genuardo unit has been considered as a part of the northern margin of

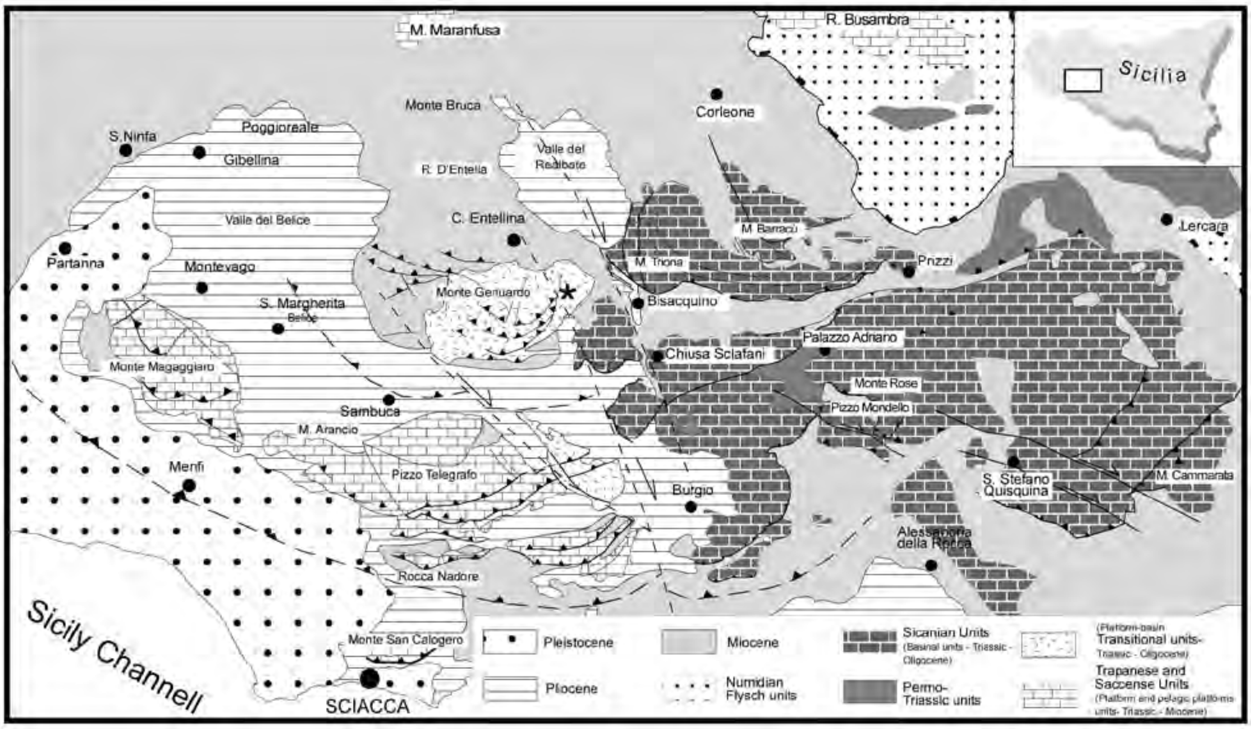

Figure 4.1: Structural map of the Sciacca-Monti Sicani area showing the surface relationships between the platform-derived thrust sheets, the “transitional” (shelf edge) thrust sheets and the deep water (Sicanian) thrust sheets .

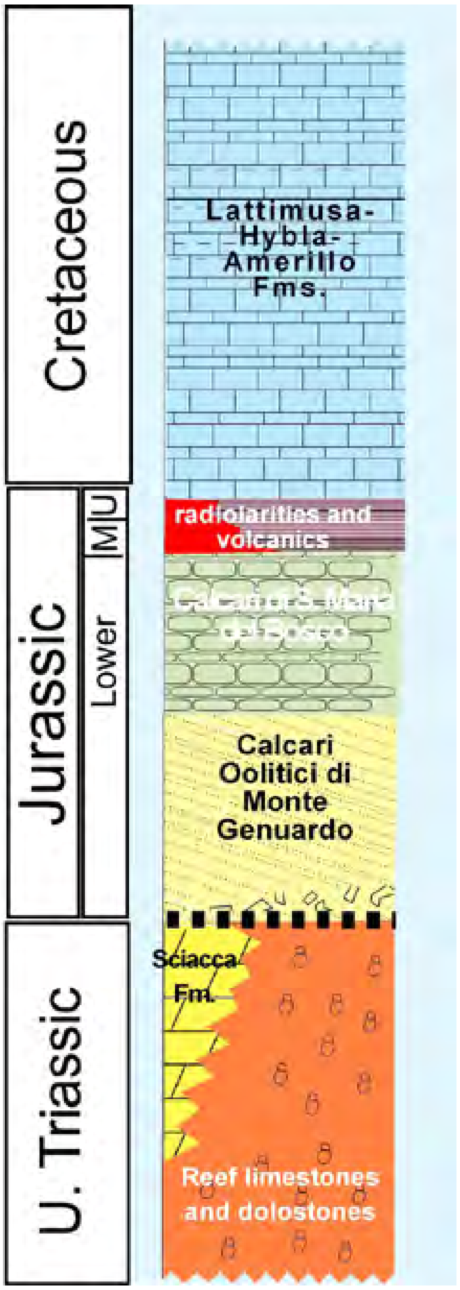

Figure 4.2: Stratigraphical column of the Mesozoic succession from Monte Genuardo.

the wide Triassic platform domain (Fig. 4) of the Sciacca area (Saccense Domain), adjacent to the Sicanian Basin (Di Stefano & Gullo, 1987).

A natural cross-section of the Upper Triassic-Lower Jurassic succession is exposed along a north-south oriented fault escarpment, bounding the eastern sector of Monte Genuardo (Fig. 4.3). The most stiking features observed here are:

1) The angular unconformity between the Upper Triassic platform strata and the overlying Early Jurassic deposits.

2) The large-scale stratal patterns of the oolitic skeletal turbidites above the unconformity, interpreted as a carbonate apron fed by off-platform shedding.

3) The upward transition of the oolitic wedge to radiolarian cherty limestones (Calcari di S. Maria del Bosco), indicating the shut down of the oolitic supply in the Carixian due to the drowning of the adjacent platform.

The lower part of the section consists of thick-bedded, peritidal dolostones of Late Triassic age (Sciacca Fm.).

Westwards, the peritidal facies is replaced by reef dolostones, whose thickness in outcrop ranges from a few tens of metres up to 200 m. The dominant facies in the reef dolostones is a sponge boundstone and skeletal rudstone, as described by Di Stefano et al., (1990). Calcareous sponges such as *Peronidella* sp., *Cystotalamia* sp., *Follicatena irregularis* Senowbari Daryan & Schafer, *Cryptocoelia* sp., *Panormida* sp., *Cheilosporites tirolensis* Wähner, associated with chaetetids and rare corals occur as primary framebuilding organisms. Encrusting sponges, hydrozoans and spongiostromata crusts are also frequent. The filling of the intrabiolithitic cavities consists of peloidal pack/grainstones with foraminifers like *Galeanella panticae* Zaninetti And Bronnimann and *Altinerina meridionalis* Zaninetti, Ciarapica, Decrouez & Miconnet. The sponge boundstones are interpreted as central reef area deposits, while the rudstones represent the reef detritus characterizing the reef flank and fore-reef zones. The microfacies recognized correspond in general to those of the Late Triassic reef complexes of the Alpine-Mediterranean region (Flügel, 1981) and show striking sedimentological and palaeontological similarities with those of the coeval reefs of the Panormide carbonate platform (Abate et al., 1977; Senowbari-Daryan et al., 1982; Di Stefano et al., 1990). The presence of reef deposits confirms the palaeogeographical location of the Monte Genuardo unit in a marginal sector of the Siculo-Tunisian Triassic platform.

The platform strata are truncated at an angle of about 10° by a deep and irregular erosional surface. Along the surface small dissolution cavities are filled with reddish silt and could be related to subaerial exposure. Upwards, a succession up to 100 m thick of lowermost Jurassic resedimented oolitic calcarenites with thin radiolarian cherty calcilutite interbeds follows (Fig. 4.4).

This unit, named the Calcari Oolitici di Monte Genuardo by Di Stefano & Vitale (1993), consists of grainstones with partly micritized ooids, botryoidal lumps and grapestones along with an abundant skeletal fraction consisting of foraminifers (textularids, lituolids, valvulinids and miliolids), brachiopods, molluscs and echinoderms (Fig. 4.4). Calcareous algae such as *Thaumatoporella parvovesiculifera* (Raineri), “*Cayeuxia*” spp. and dasycladalean fragments are also common. Bed thickness range from 3 up to 40 cm and normal grading and parallel lamination are common (Fig. 4.4). The calcilutite interbeds, up to 3 cm thick, are mudstone/wackestone with radiolarians, sponge spicules, foraminifers (*Lenticulina* sp., *Spirillina* sp.) and rare crinoid ossicles. “Chips” of radiolarian wackestone are frequently concentrated at the base of the calcarenite beds. In places coarse debrite beds containing Upper Triassic, reef-derived extraclasts occur. Large scale offlap geometries and the orientation of some channel-filling

Figure 4.3: Panoramic view of the eastern cliff of Monte Genuardo.

calcarenite beds in the lower zone indicate a roughly northeastward progradation of the oolitic-skeletal limestone. In the lowermost beds the coeval presence of *Siphovalvulina gibraltarensis* Boudagher-Fadel, Rose, Bosence & Lord, *Thaumatoporella parvovesiculifera* (Raineri) and *Aeolisaccus dunningtoni* Elliot supports a Hettangian age, moreover the *Palaeodasycladus mediterraneus* (Pia), found in the uppermost beds, proves the Sinemurian age for this unit (Cacciatore, 2009).

According to Di Stefano & Gullo (1987) the facies associations are typical of slope apron settings (Mullins & Cook, 1986). The oolitic-skeletal shedding implies the presence of an adjacent, healthy carbonate platform (i.e. Inici Formation). The offplatform transport of loose carbonate mud and sand originated at a carbonate edge was triggered most probably by currents initiated by storms, giving rise to alternations of sand sheets and periplatform ooze. Several recent and ancient examples suggest the progradation of carbonate platforms is related to an excess of carbonate production during sea-level highstands (Droxler & Schlager, 1985). No direct relationships with the inferred productive carbonate platform are observable at Monte Genuardo, but examples of large-scale progradation of Lower Jurassic carbonate platforms are well known from the subsurface of the Hyblean plateau in eastern Sicily (Rabbito Fm., Antonelli et al., 1991). Towards the top this unit grades into radiolarian cherty calcilutites known as the Calcari di Santa Maria del Bosco.

Discussion

Recent data coming from the eastermost termination of the Pizzo Telegrafo unit, about 10 km southeastward of Monte Genuardo (Fig. 4.1), indicate the presence of an Upper Triassic *Dachstein*-type reef (e.g. Cozzo Pagano, Cozzo Gelso sections) transitional to thick Upper Triassic peritidal deposits of the Saccense Platform that extend westward and southward in the Sicily Channel (Antonelli et al., 1991). As shown in Fig. 4.1, both the Pizzo Telegrafo and the Monte Genuardo units came into contact eastward with the deep-water Sicanian thrust sheets, along a slightly arched NNW–SSE trending front. The stratigraphy of the Sicanian thrust imbricates consists of Permian to Miocene deep water sediments (Catalano et al., 1991). Carbonate slope-aprons of latest Triassic-Early Jurassic age that mostly consist of Upper Triassic reef-derived clastics indicate that these thrust sheets were adjacent to the carbonate

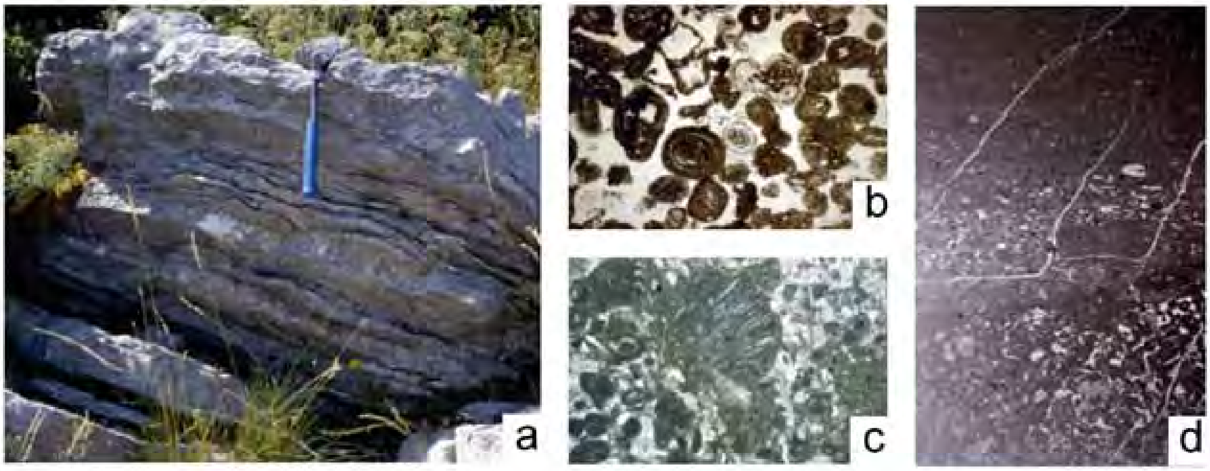

Figure 4.4: Calari Oolitici di Monte Genuardo (Hettangian to lower Pliensbachian): a) alternations of thin-bedded radiolarian wackestone and oolitic-skeletal grainstone; b) grainstone with micritized ooids and *Thaumatoporella* fragments; c) Grainstone with algae, “*Cayeuxia*” spp. d) microfacies transition between skeletal packstone and radiolarian wackestone.

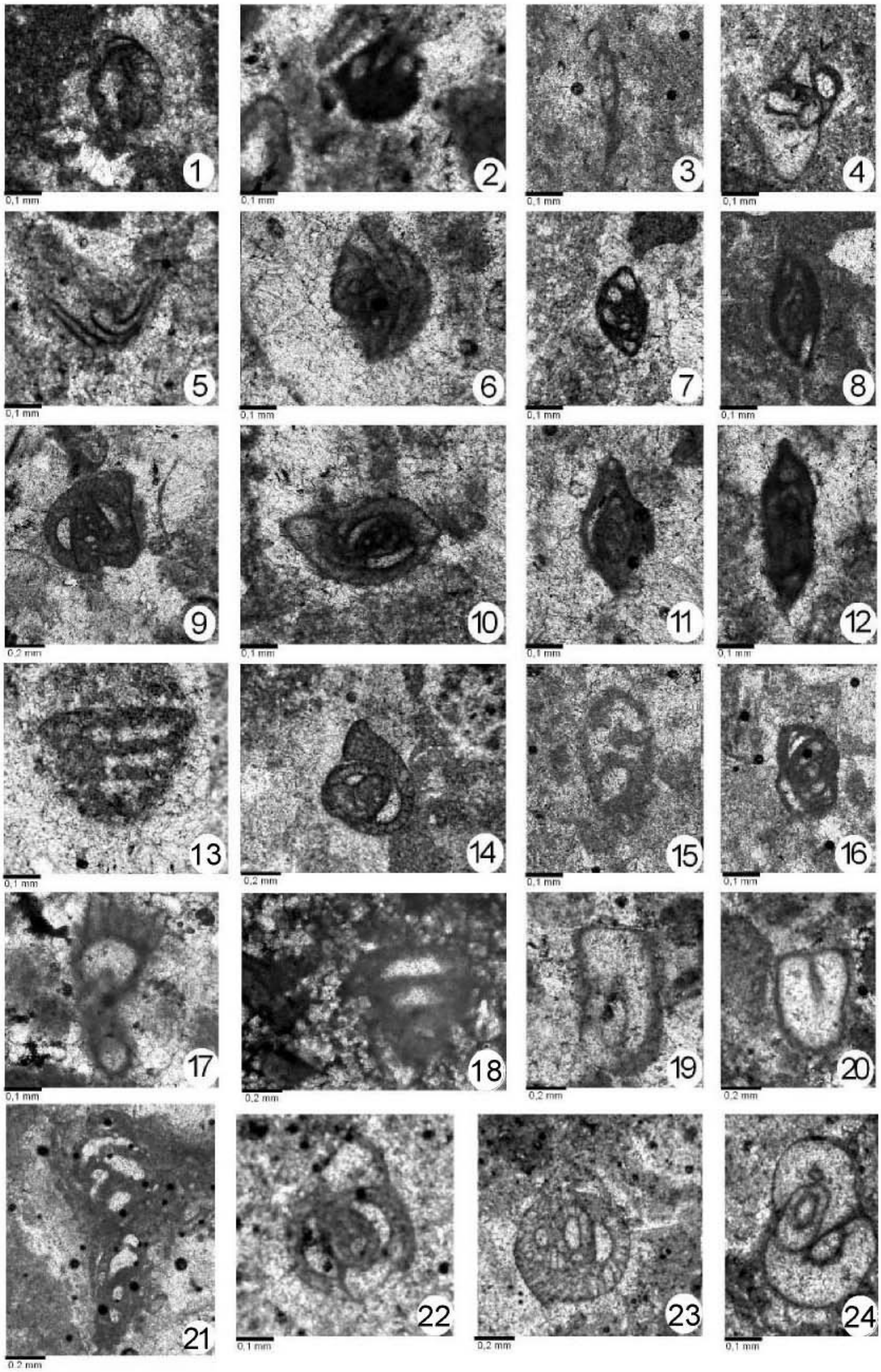

Figure 4.5: Upper Triassic reef-dwelling foraminifers from the Campofiorito carbonate aprons: 1) *Siphonophera pilleri* Senowbari-Daryan s.C.76; 2) *Altinerina meridionalis* Zaninetti, Ciarapica, Decrouez & Miconnet s.C77; 3) *Planiinvoluta*? sp. s.C76; 4) *Orthotrinacria expansa* ? (Zaninetti, Altiner, Dager & Ducret) s.C81; 5, 6) *Foliotortus spinosus* Piller & Senowbari-Daryan s.C77; 7, 8) *Sigmoilina* sp. s.C81-C76; 9, 14) *Galeanella panticae* Zaninetti & Bronnimann s.C77-C81; 10) *Galeanella* sp. s.C77; 11, 12, 16) *Ophthalmidium* sp. s.C77- C76; 13) *Kaeveria flüegeli* (Zaninetti, Altiner, Dager & Ducret) s.C73a; 15) Lituolidae s.C76; 17) *Siculocosta battagliensis* (Senowbari-Daryan) s.C79; 18) *Palaeolituonella* sp. s.C7b; 19) *Costifera* sp. s.C79; 20) *Costifera cylindrica* Senowbari-Daryan c.79; 21) Agglutinated foraminifer s.C4; 22, 24) *Galeanella* sp. s.C71-C69; 23) *Galeanella lucana* Miconnet, Ciarapica & Zaninetti s.C71 (from Cacciatore et al., 2006).

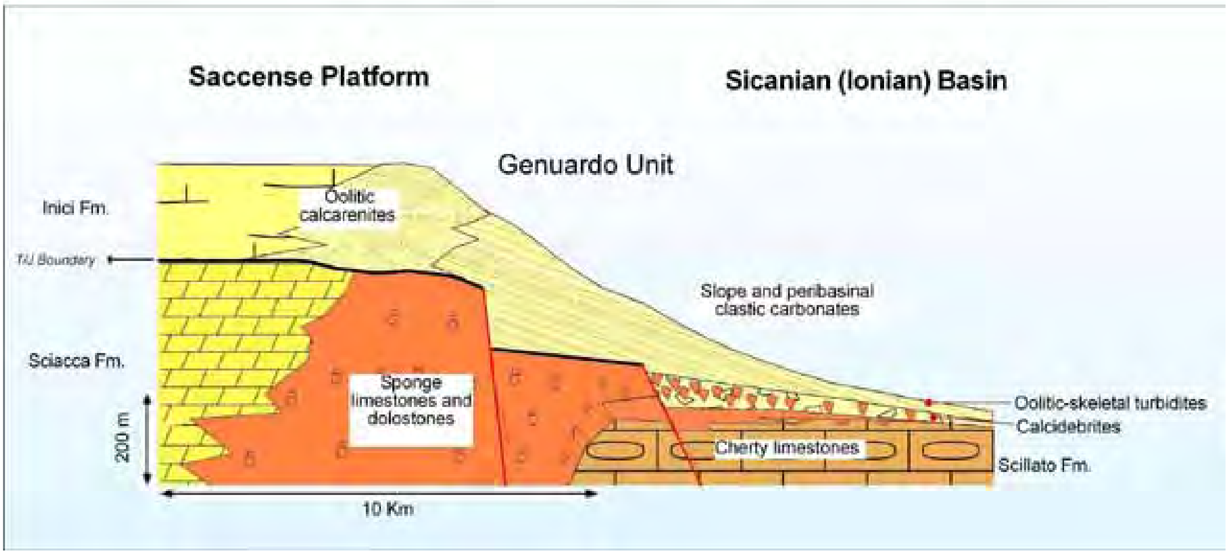

Figure 4.6: Reconstruction of the stratigraphic scheme of the Upper Triassic-Lower Jurassic sediments, across the Sciacca-Monti Sicani platform-basin transition (from Cacciatore, 2009).

shelf-edge (Di Stefano et al., 1996).

The facies composition of these aprons has been recently described by Cacciatore et al., (2006) from the Campofiorito structural unit, near Corleone (Fig. 4.5).

In spite of the lateral displacements, the Upper Triassic–Lower Jurassic facies distribution across the shelf and deepwater thrust imbricates represents thus a fundamental constraint on assuming their original contiguity (Fig. 4.6). The distribution of the Upper Triassic reef limestones at Monte Genuardo and Pizzo Telegrafo points to the presence of a Triassic shelf margin roughly oriented NW-SE. A complex Meso-Cenozoic sedimentary dynamics of this shelf margin has been traced on the base of several outcrop sections. Multiple erosional or stepped discontinuity surfaces, swarms of neptunian dykes associated with volcanics and megabreccias account for a Jurassic transtensional activity and a Late Cretaceous basin inversion. During the Neogene, oblique thrusting associated with rightlateral transpression and clockwise rotations resulted in the stack imbricate schematically depicted in Fig. 4.7. In the Sicanian thrust sheets, the presence of thin tectonic imbricates made of Permian and Triassic deep-water sediments could suggest that the Triassic paleomargin is an inherited structure from the Permian rifting. The orientation of this paleomargin is nearly parallel to the Malta Escarpment, the origin of which is still controversial (Argnani & Bonazzi, 2005, and ref. therein). According to Di Stefano et al. (2008) the stratigraphic dataset, coupled to previous structural interpretations, suggests that the reconstructed shelf to deep-water transition in the Sciacca-Monti Sicani area can be considered as a deformed segment of the rifted southern passive margin of the Permo-Triassic Ionian Tethys.

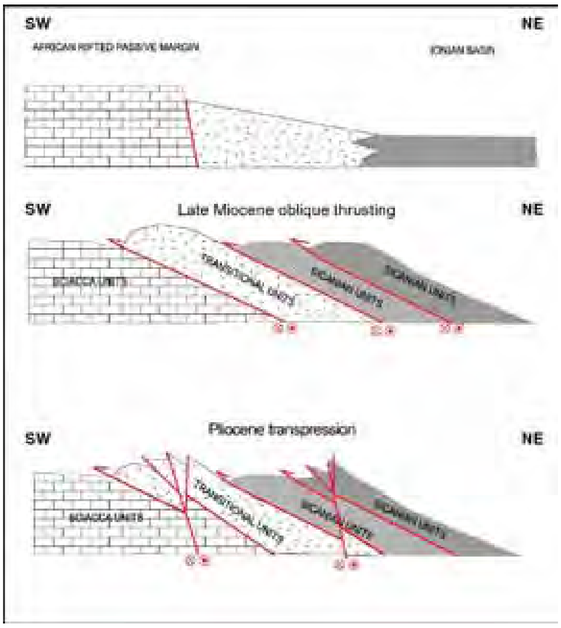

Figure 4.7: Schematic cartoon showing the pre- and post-deformative setting of the reconstructed platform-basin transition from the Sciacca area (from Di Stefano et al., 2008).

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THE LATE CARNIAN-RHAETIAN SUCCESSION AT PIZZO MONDELLO (SICANI MOUNTAINS)

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Introduction

The aim of the second day of the excursion is to visit the Pizzo Mondello section in the Sicani Mountains (Western Sicily, Italy; Fig. 1), one of the most continuous, well preserved and easily accessible Upper Triassic pelagic-hemipelagic successions in the Tethyan realm.

The well exposed succession shows high sedimentation rates of the order of 20-30 m/m.y (Muttoni *et al*., 2004), mostly uniform facies, a rich paleontologic record combined with paleomagnetic and stable isotope records which make this section one of the most suitable candidates for the definition of the GSSP of the Norian stage.

Pizzo Mondello is a relatively new section, which was described for the first time in the mid 1990's (Bellanca *et al*., 1995; Gullo, 1996), and it is close to other Carnian-Norian sections rather well known from the literature on halobiids and conodonts since the 1970's, as Monte Triona, Monte Cammarata, Capo Grosso and the Prizzi area (Montanari & Renda, 1976; Cafiero & De Capoa Bonardi, 1982; De Capoa Bonardi, 1984).

The Pizzo Mondello section has been included among the best sections for the definition of the GSSP of the Norian stage especially after the papers by Muttoni *et al*. (2001, 2004), providing an Upper Carnian to Rhaetian magnetostratigraphic scale calibrated with stable isotope variations and conodont bio-chronostratigraphy of Gullo (1996), with some additional conodont samples. In the last 4 years the part of the section spanning from the Upper Carnian to the Lower Norian has been totally re-studied bed-by-bed from a biostratigraphic point of view by means of high resolution in order to provide the best bio-chronostratigraphic ammonoid, halobiid, conodont and radiolarian calibration of the magnetostratigraphic scale. More recently also the Middle Norian to the Rhaetian parts of the succession have been resampled for conodonts.

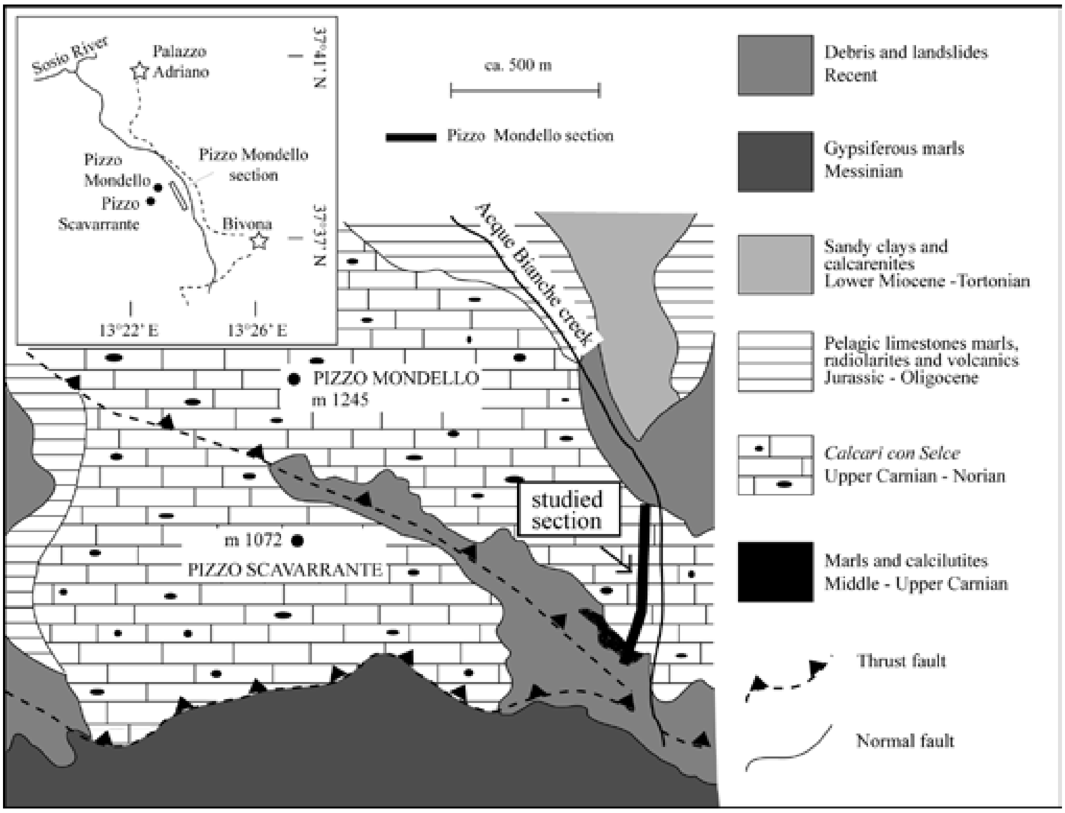

Figure 5.1 - Geological map of the Pizzo Mondello area (Sicani Mountains, Sicily) with location of the studied section (modified after Muttoni et al., 2004).

Figure 5.2 - Location of the 4 stops at Pizzo Mondello section (from Google Earth).

The stratigraphic section

The section is located in the lower part of the Pizzo Mondello tectonic unit, consisting of 1200 m of pelagic to hemipelagic carbonates, radiolarites and marls of Mesozoic to Cenozoic age overthrust onto a thick allochthonous complex of Neogene mudstones and evaporites of the Gela Nappe (Bellanca *et al*., 1993; Bellanca *et al*., 1995; Guaiumi *et al*., 2007 and references therein) (Fig. 5.1). Despite its position relatively close to a thrust, the Triassic succession exposed on the southern and eastern slope of the Pizzo Mondello and along the Acque Bianche creek (Fig. 5.1 and 5.2) is undisturbed.

The Triassic part of the Pizzo Mondello tectonic unit is divided into two lithostratigraphic units (Fig. 5.3). The lower 430 m of evenly bedded to nodular *Halobia*-bearing cherty calcilutites belongs to Cherty Limestone (*Halobia Limestone* and *Calcari con selce Auctorum*; equivalent to Scillato Formation, Schmidt di Friedberg, 1960), which ranges from Upper Carnian to Upper Norian. This thick succession of pelagic-hemipelagic limestones is overlain by 20 m of Portella Gebbia Limestone (*sensu* Gullo, 1996), consisting of lower to middle Rhaetian calcilutites and marls. Jurassic sediments locally discomformably overlain the Portella Gebbia Limestone (Gullo, 1996; Guaiumi *et al*., 2007).

The interval of interest for the definition of the Carnian-Norian boundary that has been studied in detail in the last 4 years (Guaiumi *et al*., 2007; Nicora *et al*., 2007, Balini *et al*., 2008) is the lower 143 meters of the Cherty Limestone (interval II of Muttoni *et al*. 2001, 2004), below the *Slump breccia* (interval III). The excursion (Figs. 5.2, 5.3 and 5.4) will start from the base of the Cherty Limestone to the *Slump breccia* level (Stop 5.1), then will move to the Middle-Upper Norian (Stops 5.2 and 5.3), and finally will reach the Rhaetian (Stop 5.4).

Sampling

The high-resolution and multistratigraphic sampling of the section is documented by the complex labelling of the samples (i.e., Fig. 5.3). The acronym PM refers to the first sampling for magnetostratigraphy and conodonts by Muttoni (in Muttoni *et al*., 2001, 2004). The section was re-sampled for conodonts by Nicora & Rigo in Spring 2006 (labels NA), then in Winter 2008 and again in Autumn 2008 (Nicora, Rigo and Mazza, labels NA and FNP). These samplings were more detailed than the previous PM, in the way that the interval PM0-58 of Muttoni (in Muttoni *et al*., 2004) is equivalent to NA0-71. The samples FNP were taken by Guaiumi for microfacies analysis in 2007. This sampling was very dense, then these labels have been used also for several halobiid samples and for some of the ammonoids. The halobiid and ammonoid samplings required several weeks of field work in Spring 2007 (Balini and Levera), Winter 2008 (Levera), Spring 2008 (Balini and Levera) and Autumn 2008 (Balini, Levera and Mazza). For some of the halobiids also the label NA and PM have been used, while the label PMAM refers only to some of the ammonoids.

Many samples taken and processed for conodonts provided rich and well preserved radiolarian assemblages. The first radiolarians samplings were made by Dumitrica and Hun-

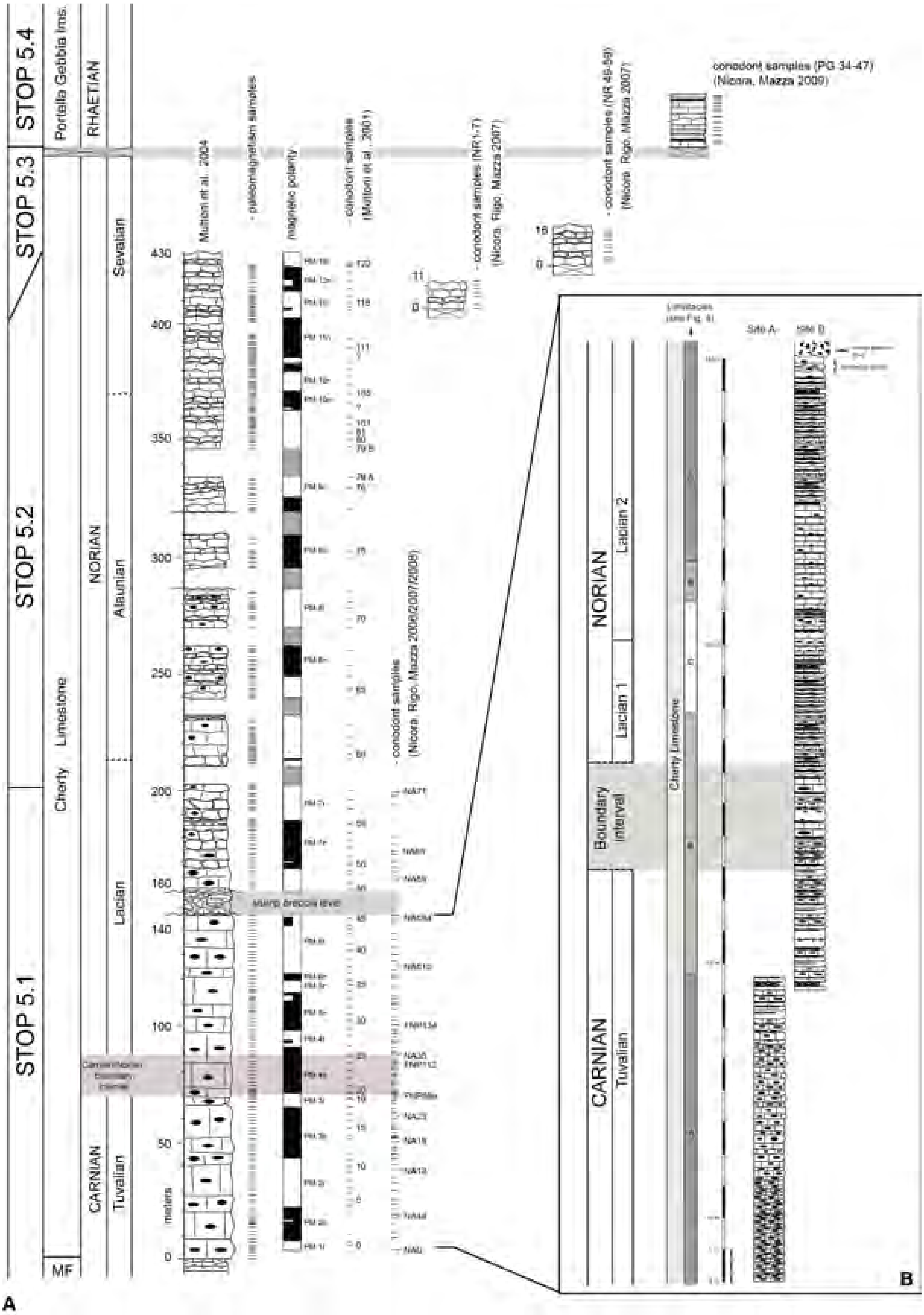

Figure 5.3 - Lithostratigraphic log of the Pizzo Mondello composite section visited at the 4 stops.
A. The first segment (0-430 m) is from Muttoni et al. 2004, while the uppermost three segments have been sampled and studied by Nicora, Rigo and Mazza from 2007 to 2010. MF: Mufara Formation. B. Lithofacies and detailed log of the Upper Carnian-Lower Norian part of the succession. The conodont, ammonoid, halobiid data of this interval are shown in Fig. 5.6, while the conodont distribution of the overall section is illustrated in Fig. 5.7. The base of the detailed log (m 0) is not exactly equivalent to the base of Muttoni et al. log.

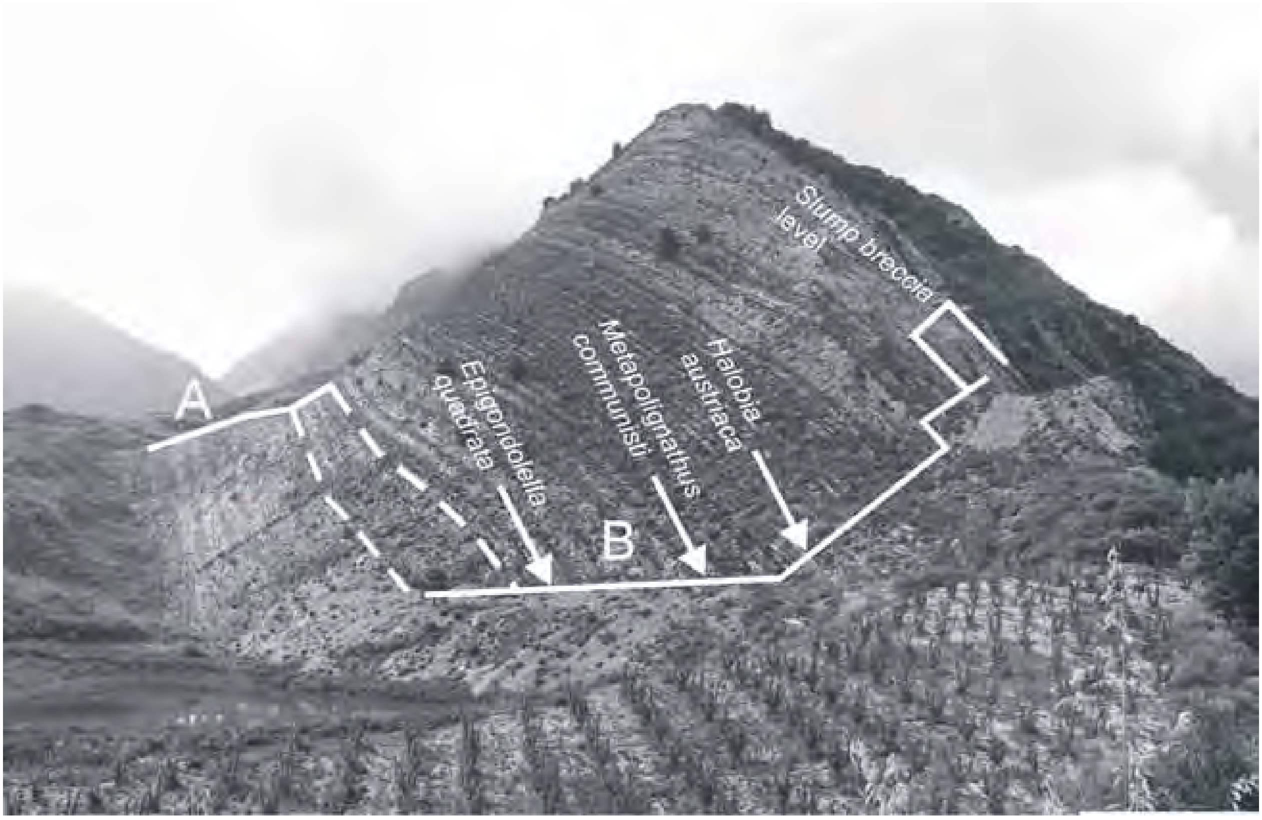

Figure 5.4 - The lower part of the Pizzo Mondello section, from the base of the Cherty Limestone to the Slump breccia level, showing the position of three of the possible markers for the base of the Norian. The best exposure of the lowermost part of the Cherty Limestone is along segment A, while segment B provides the easiest access to the exposure of the Carnian-Norian boundary interval.

gerbuhler during 2006 and 2007 (label A). New radiolarian samples were taken by Bertinelli and Rigo in February 2008 (label AM) to integrate the previous samplings.

Magnetostratigraphy

In the last 10 years, Pizzo Mondello section has become a world reference for the marine Upper Triassic, because of the unusual combination of a rather high consistent sedimentation rate, primary magnetization, stable isotope record and rich conodont content. All these features were well documented in integrated studies by Muttoni *et al.* (2001 and 2004), that followed preliminary papers by Bellanca *et al.* (1995) and Gullo (1996).

The really special feature of Pizzo Mondello is the continuous and undisturbed record spanning from the Late Carnian to the Rhaetian. This section has been considered an ideal reference for the calibration of less continuous sections, such as those in the Hallstatt facies, or for the correlations and dating of the astrochronological scale defined in the Newark basin (e.g., Krystyn *et al.*, 2002; Channel *et al.*, 2003; Muttoni *et al.*, 2004; for a complete discussion see Hounslow and Muttoni, 2010).

At Pizzo Mondello (Fig. 5.3) an overall sequence of 27 polarity intervals, labeled from magnetozone PM1 to PM12n, has been established starting from the base of the Cherty Limestone (Late Carnian) to the Portella Gebbia limestone (Rhaetian). Each magnetozone is subdivided into a lower predominantly normal and an upper predominantly reverse portion, in which submagnetozones can be embedded.

Stop 5.1

At "La Cava" locality, an abandoned quarry on the southern slope of the Pizzo Mondello mountain, the Upper Carnian-Lower Norian portion of the Cherty Limestone is extremely well exposed (Fig. 5.4). The 143 m thick interval from the base of the section to the *Slump breccia*, encompassing the Carnian/Norian boundary interval, and the next 40.8 m overlying the *Slump breccia* were investigated for sedimentological (microfacies), biostratigraphic (conodonts, ammonoids, halobiids, radiolarians), magnetostratigraphic and stable isotope variation studies. Two segments in part overlapping have been sampled (Fig. 5.4). The first segment, accessible from the entrance of the new active quarry, covers the first 80 m of the Cherty Limestone, from the lower boundary with the underlying Mufara Formation. This unit however is not very well exposed. The second segment, about 200 m from the first, overlaps the last 30 m the first segment, and covers the rest of the lower 143 m of the Cherty Limestone. Calibration of the two segments has been achieved tracing the beds.

Sedimentology

This sedimentological study identified three facies in the first 143 m of Pizzo Mondello section (Fig. 5.5):

Facies A: well-bedded, dm-thick, whitish calcilutites with blackbrown cherty nodules concentrated in the interlayers.

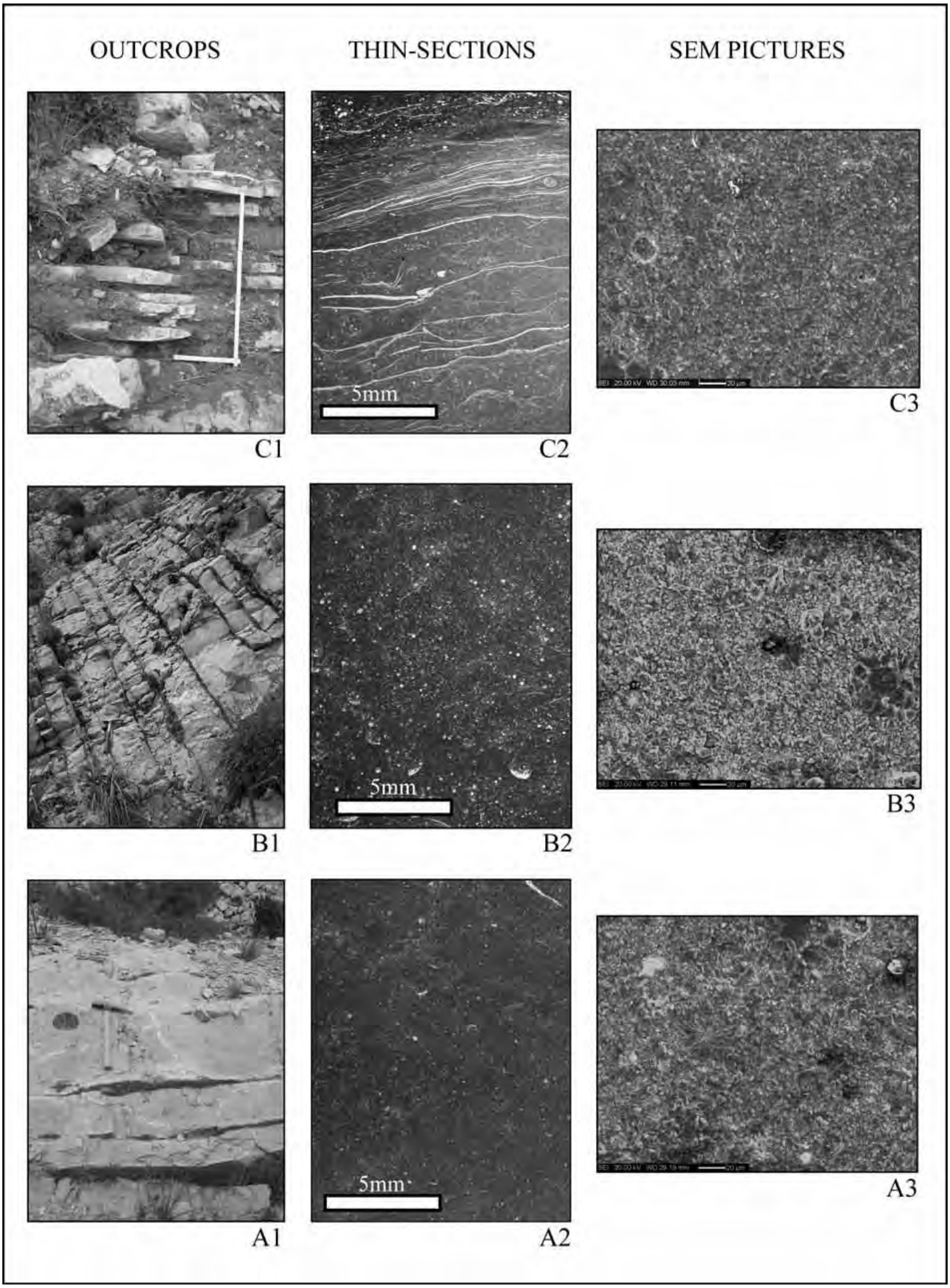

Figure 5.5 - Main lithofacies of the Upper Carnian-Lower Norian part of Pizzo Mondello section (from Nicora et al., 2007). A1) facies A in outcrop (m 15 ca.) A2) wackestone with radiolarian moulds and thin-shelled bivalves, sample FNP 11 (m 29), facies A. A3) calcispheres and fine calcite crystals, sample FNP 11 (m 29), facies A. B1) facies B in outcrop (m 47 ca.) B2) wackestone with abundant radiolarian moulds and thin-shelled bivalves, sample 110 (m 51), facies B, thin section. B3) calcispheres are abundant also in facies B; note radiolarian mould filled with large calcite crystals to the right, diameter 50 µm ca. (sample FNP 126, m 62). C1) facies C in outcrop, m 78 ca. C2) concentration of densely packed thin-shelled bivalves (Halobia sp.) of facies C in thin section (m 80). C3) abundant calcispheres in sample FNP 145 (m 74), facies C, as seen at SEM.

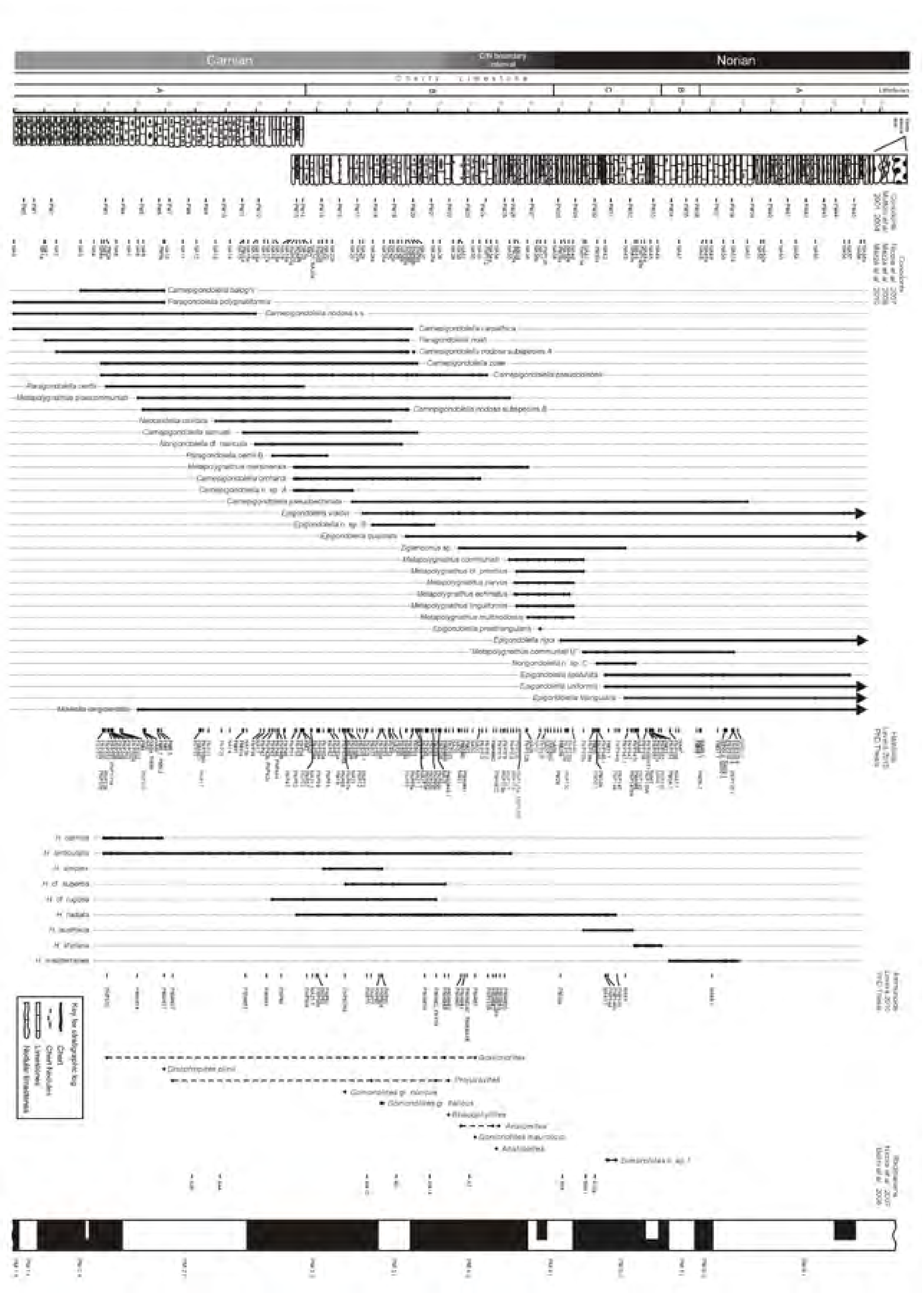

Figure 5.6 - Detailed stratigraphic log of the lower 143 meters of the Pizzo Mondello section, showing the distribution of lithofacies, conodonts, halobiids, ammonoids, radiolarian samples and magnetostratigraphy.

Calcilutite layers are composed mostly of micrite, with thin-shelled bivalves (halobiids), radiolarians, ammonoids, foraminifers and calcispheres; bioturbation and laminations are rare. Bivalve coquinas also occur. The interlayers are composed of mm-thick brownish clays, which are rarely laminated.

Facies B: similar to facies A, but layers are nodular, up to 1 m thick, and characterized by stylolitic joints. Thin-shelled bivalves, calcispheres and coquinas are more abundant. Bioturbation and laminations are common.

Facies C: calcilutite layers are even more nodular than in facies B but generally thinner (8-15 cm), and always laminated. Thin-shelled bivalves and calcispheres are extremely common. Silicified coquinas are very abundant. Cm- to dm-scale interlayers, composed of brown-black dolomitized clay-marls, are more common than in all other facies. This facies is rich in black chert, occurring in 5-7 cm thick beds.

These three facies alternate in an A-B-C-B-A sequence (Guaiumi *et al.,* 2007; Nicora *et al.*, 2007; Figs. 5.3 and 5.6) and have been interpreted as the result of a combination of oscillations in the carbonate sediment supply from surrounding carbonate platforms, varying dissolution rates at the bottom of the sea, and different autochthonous carbonate productivity, i.e., benthic thin-shelled bivalves and calcispheres, regarded as pelagic in origin (according to Bellanca *et al*., 1993, 1995; Guaiumi *et al*., 2007; Nicora *et al*., 2007).

Chemostratigraphy

The first stable isotope ($\delta^{13}C$ and $\delta^{18}O$) analyses of the Pizzo Mondello succession were provided by Bellanca *et al.* (1995), who presented the $\delta^{13}C$ and $\delta^{18}O$ curves for the lowermost part (Carnian) of the section. Muttoni *et al.* (2004) complemented these data, reporting the $\delta^{13}C$ and $\delta^{18}O$ curves for the whole Cherty Limestone succession (Muttoni *et al*., 2004, fig. 3; Fig. 3). A 1.2 per mil shift of $\delta^{13}C$ was reported from the upper part of the magnetozone PM4n, in correspondence to sample PM24 (Muttoni *et al*., 2004, fig. 3; Fig. 3). In 2009 a new detailed sampling campaign was conducted on the carbonate bulk of the first 143 meters of the section, below the *Slump breccia*. The new analyses show the same positive shift of the $\delta^{13}C$ curve observed by Muttoni *et al.* (2004), but at a slightly higher level (closer to sample PM25) than the one reported by Muttoni *et al.* (2004).

As already noticed by Richoz *et al.* (2008), this shift does not appear in other coeval stratigraphic sections but, having been reproduced independently in two separate analyses, it suggests a local perturbation. Furthermore, since the $\delta^{13}C$ values co-vary with the conodont population, they may reflect a local signal related to transient paleogeographical or paleoenvironmental conditions in the Sicano basin (see Mazza *et al*., 2010 for details).

Oxygen isotopes, instead, do not appear to record abrupt changes in the studied interval, but only a slight trend from lower $\delta^{18}O$ values at the base of the section towards higher $\delta^{18}O$ values near the *Slump breccia*.

Ammonoids

Among the macrofossils, no doubts the ammonoids are rarer than the halobiids. However, due to their importance to provide a high resolution chronostratigraphic constraint of the succession, a wide part of the outcrop has been checked in order to detect as many specimens visible on the surface as possible. Some specimens, however, have been found during the bed-by-bed sampling for halobiids.

The ammonoids are mostly documented in three intervals (Balini *et al*., this volume; Fig. 5.6): from 15 to 25 meters from the base of the Cherty Limestone, then from 50 to about 82 meters and from 99 to 103 meters. Most of the collected specimens belongs to the “trachyostraca” and allow a chronostratigraphic attribution of the first two intervals to the Upper Carnian, while the third can be referred to the first zone of the Lower Norian, following the ammonoid standard scale of Krystyn (in Krystyn *et al*., 2002).

The first interval is at least in part attributed to the *Discotropites plinii* Subzone, the last but one subzone of *Anatropites spinosus* Zone of the uppermost Carnian, by occurrence of the index species, accompanied also by early *Gonionotites*. The second interval is more fossiliferous and yields mostly *Gonionotites*, *Projuvavites*, “*Anatomites*”, together with some “leiostraca”. This interval is attributed to the latest subzone of the Upper Carnian, by the occurrence of *Gonionotites* gr. *italicus* and of one *Anatropites*, that was found on top of the interval. After about 18 m without any ammonoids, the Lower Norian *Guembelites jandianus* Zone is documented by *Dimorphites* very close to *D.* n. sp. 1 of Krystyn (1980). It is worth nothing that this still undescribed species is typical of the first subzone of the *G. jandianus* Zone.

Halobiids

Halobiids have been found from 162 stratigraphic levels of the lower 143 m of the Cherty Limestone (Levera, this volume; Fig. 5.6; Pl. 1). The specimens are abundant in almost all of the samples, and they generally show a good preservation, often tridimensional, with very limited compaction of the shells. A peculiar preservation is typical of the set of beds between samples FNP 150 and FNP 156, where *Halobia* specimens are preserved as thin siliceous films packed on bed or laminas’ surfaces. The summary of the available data is illustrated by Levera (this volume).

Upper Carnian (Tuvalian)

From level FNP 337 (Fig. 5.6), about 15 metres from the base of the section, to level FNP 118, at about 83 metres, the succession is dominated by a typical Tuvalian (Upper Carnian) fauna, mainly characterized by the dominance of *Halobia carnica* Gruber and *H. lenticularis* (Gemmellaro), with a minor occurrence of *H. superba* Mojsisovics, *H.* cf. *rugosa* and *H. simplex* Gemmellaro.

The FO of *Halobia radiata*, marker species for the upper Tuvalian (Tuvalian 3 *sensu* Krystyn *et al.,* 2002) throughout the Tethys, is recorded in level FNP 52. Its LO is about

3 metres below the FO of *H. styriaca*.

The specimens of *Halobia radiata* occurring in the lower portion of this species' range are mostly small forms, probably representing juveniles to sub-adults stages. Adult specimens of *Halobia radiata*, equal to the *Halobia radiata hyatti* (Kittl) sub-species, occur at Pizzo Mondello in levels FNP 103 and PMAM 42 (between 73 and 79 metres from the base of the section), and PM 31.1 (at about 98 metres from the base of the section, thus belonging to the following interval).

Carnian/Norian boundary interval

From level FNP 118 to level FNP 135a (about 94 meters from the base of the section) the succession is dominated by *Halobia radiata*. In facts, *Halobia lenticularis* disappears at level FNP 118, marking the lower limit of the Carnian/Norian boundary interval, as identified on the basis of bivalves.

Lower Norian (Lacian)

Since the base of the Norian Stage has yet to be defined, and a bioevent marking this boundary is still being debated, the FO of *Halobia austriaca* Mojsisovics (at level FNP 135a) is here considered as marker for the upper limit of the Carnian/Norian boundary interval based on halobiids.

At Pizzo Mondello, *Halobia austriaca* belongs to the Early Norian *Guembelites jandianus* Zone (Lacian 1). This datum is based on the occurrence, within the range of *H. austriaca* (in the levels FNP 145 and FNP 147; see Fig. 5.6), of *Dimorphites* close to *D.* n. sp. 1 of Krystyn (1980), which is the marker for the lower part of the *G. jandianus* Zone according to Krystyn & Gallet (2002).

From level FNP 147c to level FNP 155 (between 102.5 and 105 metres from the base of the section), the succession is characterized by the mass occurrence of specimens belonging to the species *Halobia styriaca*, restricted in stratigraphic range between the intervals of *H. austriaca* and *H. mediterranea* Gemmellaro.

From level PM 34.1 to level NA 51.1 (from 108 to 120.2 metres from the base of the section), the section is characterized by the occurrence of *Halobia mediterranea*, a species never found in North America. At Pizzo Mondello, the FO of *H. mediterranea*, less than 0.5 metres above the LO of *H. styriaca*, marks the base of the Lacian 2 in the Tethyan realm (Krystyn *et al.*, 2002).

Conodonts

A total number of 105 conodont samples have been taken from the base of the Cherty Limestone to the *Slump breccia*, with additional 10 samples collected above this level (Figs. 5.3, 5.6, 5.7). The portion of the section re-sampled (samples from NA0 to NA71) corresponds to the PM0-PM58 interval of Muttoni *et al.* (2004). Conodonts are abundant in almost all the samples collected and they show an average CAI (Colour Alteration Index) value of 1, indicating none or insignificant thermal alteration (Epstein *et al.*, 1977). Some data have been already published (Mazza *et al.*, 2010), while phylogeny is abstracted in Mazza *et al.* (this volume).

Upper Carnian (Tuvalian)

From sample NA0 (1.70 m below PM0), at the base of the section, to sample NA26b (1.87 m below PM20), the succession is dominated by a typical Tuvalian (Upper Carnian) conodont fauna (Pl. 2), characterized by the association of mainly two genera, *Paragondolella* and *Carnepigondolella*, with less abundant representatives of genus *Metapolygnathus*.

-The first conodont species occurring at the bottom of the section are *Paragondolella polygnathiformis*, *Paragondolella noah*, *Carnepigondolella nodosa sensu* Hayashi (1968) (i.e. *C. nodosa* ss.) and *Carnepigondolella nodosa* subspecies A, *Carnepigondolella carpathica* and *Carnepigondolella baloghi*. This association indicates a middle/upper Tuvalian age.

-From sample NA4a (0.70 m below PM3) to sample NA12 (1.30 m above PM8) the succession is already surely upper Tuvalian in age for the occurrence in this interval of a typical upper Tuvalian conodont association: *Carnepigondolella zoae*, *Carnepigondolella pseudodiebeli*, *Paragondolella oertlii*, the new species *Metapolygnathus praecommunisti* (Mazza *et al.*, in press) and *Carnepigondolella nodosa* subspecies B. *Carnepigondolella baloghi* and *Paragondolella polygnathiformis* disappear in this interval.

-From sample NA13 (1.60 m above PM9) to NA19 (1.30 m below PM13) the succession is characterized by the occurrence of the conodont association composed by *Neocavitella cavitata*, *Carnepigondolella samueli*, *Norigondolella* cf. *navicula* and *Paragondolella oertlii* B. This last species is a new morphotype of *Paragondolella oertlii*, identified from sample NA18 (2.35 m above PM12) to sample PM15b (Mazza, 2010; PhD thesis). This form is notable for its short range, confined to the late Tuvalian. In this interval *Carnepigondolella nodosa* ss. disappears. *Norigondolella* cf. *navicula*, much smaller than the true Norigondolellae, has been recovered from surely Upper Carnian strata also in other two Tethyan sections: the Pignola 2 (southern Italy, Lagonegro basin) (Rigo *et al.*, 2007) and the Feuerkogel (Austria, Northern Tethys) (Krystyn, 1980) sections, demonstrating that it is not an endemic species exclusive of Pizzo Mondello, but it is spread in the entire Tethys.

-The interval from sample FNP51a (~PM13) to NA23 (0.80 m below PM17) corresponds to the stratigraphical range of *Carnepigondolella* n. *sp.* A. In this interval the FADs of *Carnepigondolella orchardi* and *Metapolygnathus mersinensis* also occur, while both the morphotypes of *Paragondolella oertlii* disappear.

-The interval from sample NA23 to NA26b is characterized by the first occurrences of *Carnepigondolella pseudoechinata*, *Epigondolella vialovi* and *Epigondolella* nova *sp.* B, while *Neocavitella cavitata* and *Norigondolella* cf. *navicula* have here their last occurrence. The association of *Carnepigondolella orchardi*, *Epigondolella vialovi* and *Epigondolella* nova *sp.* B, which are transitional species to the much more evolved Norian Epigondolellae, indicates a uppermost Tuvalian age for this portion of the section.

CNB interval

The CNB boundary interval is established on the base of the FADs of the conodont species considered at present as the two possible primary biomarkers for the definition of the base of the Norian, which has still to be defined: the FAD of *Epigondolella quadrata* at its base (sample FNP88a = 1.19 m below PM20) and the FAD of *Metapolygnathus echinatus*, coinciding with the FAD of *Metapolygnathus communisti*, at its top (sample NA35 = 0.60 m below PM26). The FAD of *Epigondolella quadrata* is the biomarker proposed for the Tethys (Moix *et al*., 2007; Nicora *et al*., 2007; Noyan & Kozur, 2007; Balini *et al*., 2008; Celarc & Kolar-Jurkovšek, 2008; Mazza *et al*., 2010), while *Metapolygnathus echinatus* is the North American candidate (McRoberts, 2007; Orchard, 2007; Orchard, 2009).

From sample FNP88a to NA35 the succession is dominated by the genus *Epigondolella*, historically considered as a wholly Norian conodont genus (Orchard, 1991b; Krystyn *et al*, 2002; Kozur, 2003; Noyan & Kozur, 2007; Celarc & Kolar-Jurkovšek, 2008). In this interval *Epigondolella quadrata* occurs and *Epigondolella vialovi* is very abundant. The specimens of *Epigondolella quadrata* occurring in this interval are mostly primitive forms, smaller and less advanced than the holotype from Pardonet Hill, Canada (Orchard, 1991b; Pl. 3.5), which seems to be a very advanced specimen. Nevertheless, these two forms have the same morphological characters that allow the assignment of both of them to *Epigondolella quadrata*: the centrally located pit, the bifurcated keel end, the weak microreticulation on the platform margins, the high denticles on the lateral platform margins, the stepped lateral profile of the lower platform and the peculiar accessory node placed in the middle of the squared and flat posterior platform. The *Epigondolella quadrata* closer to the holotype first occurs in this interval in sample FNP112 (0.10 m above PM24). Between samples FNP88 and FNP90, in correspondence to the *Epigondolella quadrata* FAD (sample FNP88a), almost all the Carnepigondolellae extinguish, except for *Carnepigondolella pseudodiebeli* and *Carnepigondolella orchardi* which disappear around sample FNP112, where advanced *Epigondolella quadrata* first occurs, and *Carnepigondolella pseudoechinata*, which ranges up in the section. Also *Metapolygnathus praecommunisti* disappears in this interval.

On the basis of biostratigraphical and geochemical data (see Mazza *et al*., 2010), and considering its capability as a worldwide correlation tool, the FAD of *Epigondolella quadrata* appears to be the most suitable conodont bioevent to mark the base of the Norian, since it is worldwide spread and its evolution is not triggered by any ecological perturbation (Mazza *et al*., 2010). The North American candidate, *Metapolygnathus echinatus*, even if it seems to be present in the Tethys, it is rarer and its first occurrence at Pizzo Mondello coincides with a positive shift of the δC13 isotopic curve (see Mazza *et al*., 2010) and a mass occurrence of almost all the Metapolygnathids. It is thus possible that the Neotethyan occurrence of this species may be facies controlled and, thus, not very suitable for global correlation. All the possible marker events for the definition of the CN boundary are however under examination by the Subcommission on Triassic Startigraphy.

Lower Norian (Lacian)

-From sample NA35 (0.60 m below PM26) to FNP134 (1.30 m above PM29), the succession is characterized by the mass occurrence of species of the *Metapolygnathus communisti* group (Pl. 3). The association is composed by *Metapolygnathus communisti*, *Metapolygnathus multinodosus*, *Metapolygnathus parvus*, *Metapolygnathus linguiformis*, *Metapolygnathus echinatus* and *Metapolygnathus* cf. *primitius.* The North American morphotype of *Metapolygnathus echinatus* (Orchard, 2007) was identified but the specimens are rare. Also true *Metapolygnathus parvus* is very rare, and most of the specimens collected are seemingly juvenile growth stages of *Metapolygnathus communisti*. At sample PM28 *Epigondolella rigoi* first occurs and at sample NA37 (1.40 m above PM27) the presence of *Epigondolella praetriangularis* is recorded, although the latter species is very rare and occurs only in this sample. Before sample FNP134 all the Metapolygnathids definitely disappear.

-From sample FNP134 to NA51b (0.06 m above PM38), the section is dominated by the association "*Metapolygnathus communisti* B"- *Norigondolella* n. *sp*. C, which occurrence is limited to this interval, together with *Epigondolella spatulata*, *Epigondolella uniformis* and *Epigondolella triangularis*. *Epigondolella quadrata*, *Epigondolella rigoi* and *Epigondolella vialovi* are still very common in this interval. This association can be referred to lower Lacian (Orchard, 1991a,b; Krystyn & Gallet, 2002; Channell *et al*., 2003; Kozur, 2003).

-From sample NA51 (0.80 m below PM39) to PM58 (1.30 m above NA71) the conodont association is composed exclusively of *Epigondolella quadrata*, *Epigondolella vialovi*, *Epigondolella rigoi*, *Epigondolella uniformis* and *Epigondolella triangularis*. *Epigondolella spatulata* disappears before the *Slump breccia* level and, above it, is substituted by a similar but less ornamented form, here named *Epigondolella* cf. *spatulata* (between samples NA59-NA62). *Carnepigondolella pseudoechinata* has its last occurrence at the beginning of this interval (sample NA51), *Epigondolella uniformis* and *Epigondolella vialovi* at its end (samples NA66 and NA69 respectively).

Radiolarians

In the 30 m thick Carnian/Norian boundary interval the first Early Norian radiolarian assemblage occurs about 4 m above the FAD of *Epigondolella quadrata* Orchard and about 14 m below the FAD of *Metapolygnatus communisti* Hayashi. This radiolarian assemblage is referable to Early Norian for the presence of *Braginastrum curvatus* Tekin, *Capnuchosphaera deweveri* Kozur & Mostler, *Capnuchosphaera tricornis* De Wever, *Kahlerosphaera norica* Kozur & Mock, *Mostlericyrtium sitepesiforme* Tekin,

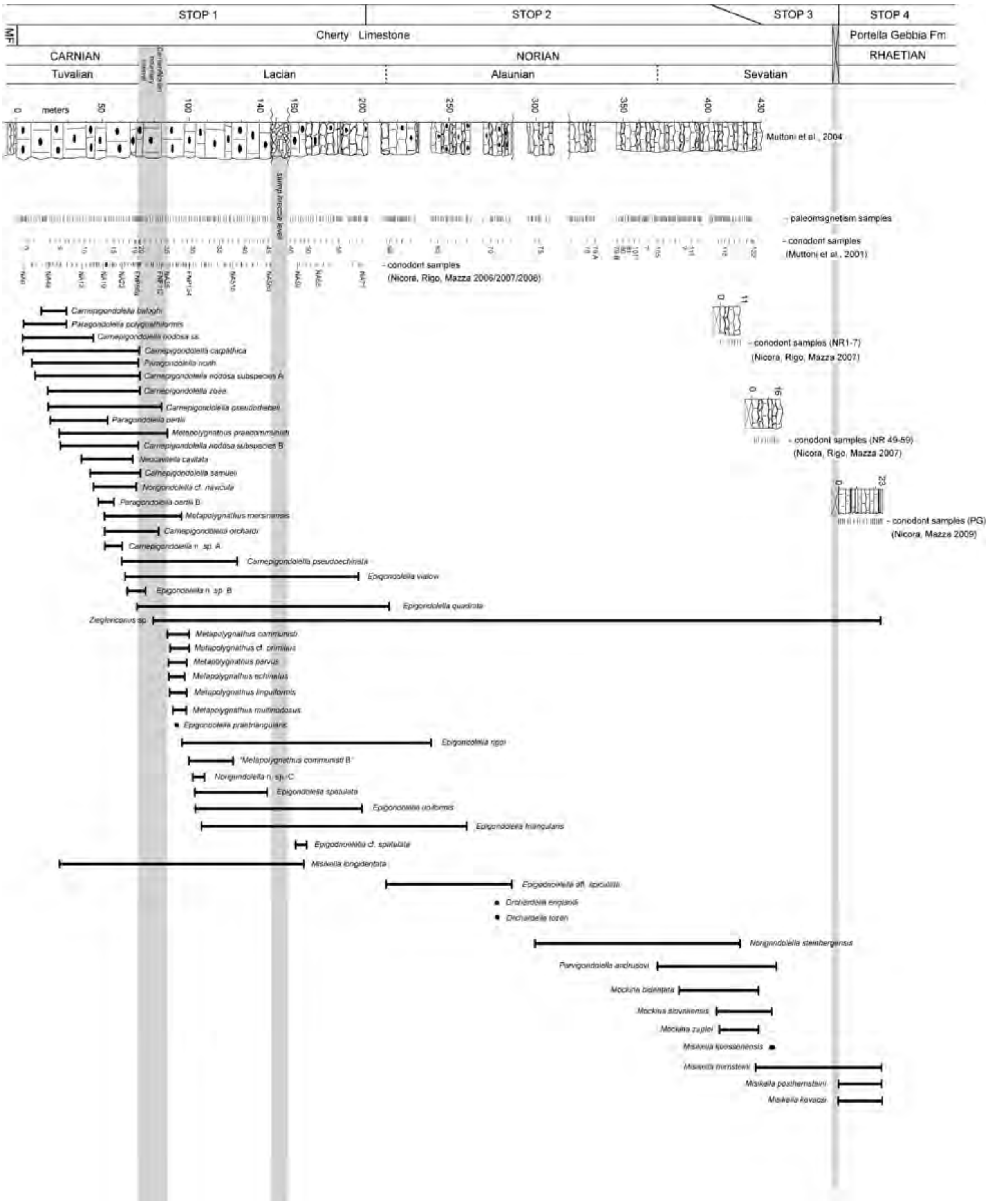

Figure 5.7 - Stratigraphic log of the entire Pizzo Mondello section, from Upper Carnian to Rhaetian (modified after Muttoni et al., 2004), with the ranges of all the conodont species.

Podobursa akayi Tekin and *Xiphothecaella longa* Kozur & Mock. Two new Late Carnian - Early Norian genera *Blechschmidtia* and *Tjerkium* Dumitrica and Hungerbuhler (2007) are present in the above radiolarian assemblage. New radiolarian assemblages from 30 m thick Carnian/Norian boundary interval are still in progress to contribute for the definition of the new stratigraphic ranges. In the middle-upper portion of the Cherty Limestone succession, radiolarian fauna is present in different samples but specimens are often poorly preserved. The Rhaetian interval, represented by the Portella Gebbia limestone, yields a typical Rhaetian radiolarian assemblage with *Globolaxtorum* and *Livarella* genera.

Stop 5.2

Higher up, the middle-upper portion of the Cherty Limestone succession crops out along the Acque Bianche creek mostly covered by vegetation (sample PM59 to PM122). Only conodonts have been studied (Pl. 4).

Middle Norian (Alaunian)

-From sample PM59 to PM64 the conodont association is characterized by *Epigondolella quadrata*, *Epigondolella rigoi* and *Epigondolella* aff. *spiculata*, which marks the beginning of the Alaunian (Kozur, 2003). In this interval *Epigondolella quadrata* and *Epigondolella rigoi* have their last occurrence.

-From sample PM68 to PM79A a typical middle Norian association is present, being composed of *Epigondolella triangularis*, *Epigondolella englandi*, *Epigondolella* aff. *spiculata*, *Orchardella tozeri* and *Norigondolella steinbergensis* (Orchard, 1991a,b; Kozur, 2003).

Upper Norian (Sevatian)

-From sample PM104 to PM122 the section is Sevatian in age for the occurrence of the following conodont association (sensu Kozur and Mock, 1991): *Mockina bidentata*, *Parvigondolella andrusovi* and *Epigondolella slovakensis*. *Norigondolella steinbergensis* also occurs.

Stop 5.3

The upper part of the Cherty Limestone succession (uppermost Norian), above the last sample (PM122) collected by Muttoni *et al*., (2001), have been logged and sampled in two separate sites on the eastern slope of the Pizzo Mondello mountain, in the Acque Bianche creek. The two sections are correlated to the main log of the Pizzo Mondello section on the base of the conodont fauna. Some stratigraphical gap between the two sections is possible (Fig. 5.3, 5.7). Only conodonts have been studied (Pl. 4).

Upper Norian (Sevatian)

The two non continuous sections, located in the upper portion of Pizzo Mondello section along the Acque Bianche creek (e.g. Muttoni *et al*., 2004; Fig. 5.3, 5.7), are characterized by a similar conodont association represented by *Mockina bidentata*, *Mockina zapfei, Parvigondolella andrusovi* and *Epigondolella slovakensis* (NR 1-7), several *Misikella hernsteini* and *Misikella koessenensis* only in the uppermost part of the section (NR 8-9 and NR 49-59). This conodont association suggests a Sevatian age (e.g Kozur and Mock, 1991, Rigo *et al*., 2005; Reggiani *et al*, 2005; Giordano *et al*., 2010) for the uppermost portion of the Cherty Limestone.

Stop 5.4

The Rhaetian interval is represented by the Portella Gebbia limestone of the Pizzo Mondello section, located at the Contrada Torcitore locality, about 50 m above the Acqua Bianche creek (Fig. 5.2, 5.3, 5.7). Only conodonts have been studied (Pl. 4).

From its outcropping base, the Portella Gebbia limestone yields a typical Rhaetian conodont fauna, consisting in *Misikella posthernsteini*, *Misikella kovacsi* along with few specimens of *Misikella koessenensis* (Bertinelli *et al*., 2005; Bazzucchi *et al*., 2005; Giordano *et al*., 2010; Muttoni *et al*., 2010). Towards the top (PG 41), *Misikella ultima* also occurs.

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Plate 1

Fig. 1: ***Halobia carnica*** **Gruber, 1977**: right valve, sample FNP 336-1
Fig. 2: ***Halobia carnica*** **Gruber, 1977**: right valve, sample FNP 331-4
Fig. 3: ***Halobia lenticularis*** **(Gemmellaro, 1882)**: right valve, sample PMAM 42-17
Fig. 4: ***Halobia lenticularis*** **(Gemmellaro, 1882)**: right valve, sample PMAM 42-44
Fig. 5: ***Halobia superba*** **Mojsisovics, 1874**: left valve, sample NA 23-5
Fig. 6: ***Halobia radiata*** **Gemmellaro, 1882**: left valve, sample PMAM 42-13
Fig. 7: ***Halobia radiata*** **Gemmellaro, 1882**: right valve, sample PMAM 42-29
Fig. 8: ***Halobia radiata*** **Gemmellaro, 1882**: left valve, sample PMAM 42-61
Fig. 9: ***Halobia styriaca*** **(Mojsisovics, 1874)**: left valve, sample NA 45-1
Fig. 10: ***Halobia styriaca*** **(Mojsisovics, 1874)**: left valve, sample FNP 151.1-5
Fig. 11: ***Halobia styriaca*** **(Mojsisovics, 1874)**: left valve, sample FNP 151.1-6
Fig. 12: ***Halobia styriaca*** **(Mojsisovics, 1874)**: right valve, sample FNP 151.4-1
Fig. 13: ***Halobia mediterranea*** **Gemmellaro, 1882**: left valve, sample FNP 170.2-1
Fig. 14: ***Halobia mediterranea*** **Gemmellaro, 1882**: left valve, sample FNP 170.2-3
Fig. 15: ***Halobia*** **cf.** ***rugosa***: right valve, sample AM 1-1, 1.5x
Fig. 16: ***Halobia*** **cf.** ***rugosa***: right valve, sample FNP 88a-26, 1.5x
Fig. 17: ***Halobia simplex*** **Gemmellaro, 1882**: right valve, sample FNP 62-1
Fig. 18: ***Halobia austriaca*** **Mojsisovics, 1874**: right valve, sample FNP 147bis-5
Fig. 19: ***Halobia austriaca*** **Mojsisovics, 1874**: left valve, sample FNP 147-14
Fig. 20: ***Halobia austriaca*** **Mojsisovics, 1874**: left valve, sample FNP 147-4
Fig. 21: ***Halobia radiata*** **Gemmellaro, 1882**: right valve, sample PMAM 42-11
Fig. 22: ***Halobia*** **cf.** ***rugosa***: left valve, sample FNP 42b-1, 1.5x

Scale bar is 1 cm. All the specimens are from Pizzo Mondello.

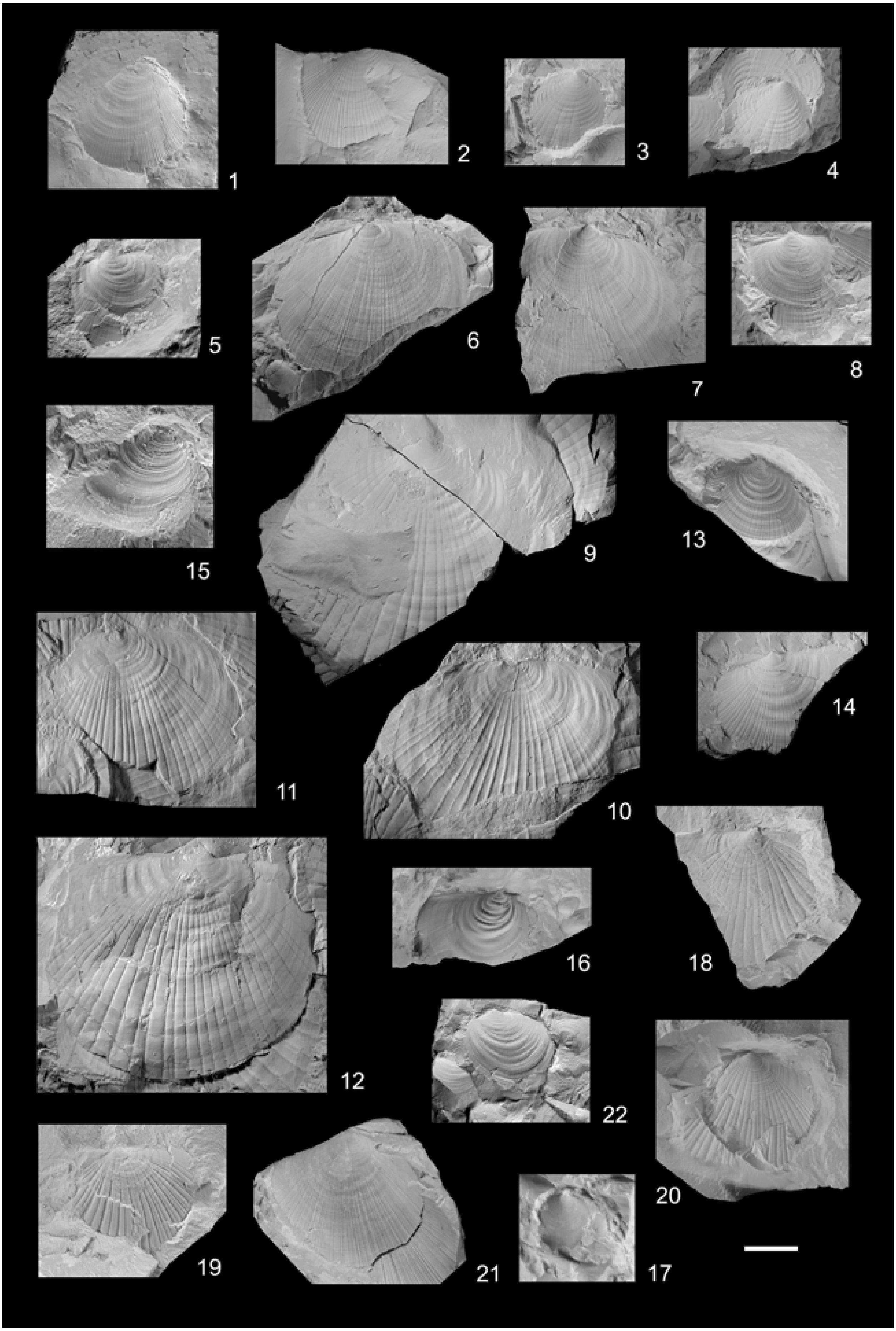
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Plate 2

Fig. 1: ***Paragondolella noah*** **(Hayashi, 1968)**: mature growth stage, sample NA2.
Fig. 2: ***Carnepigondolella nodosa*** subspecies **A**: mature growth stage, sample PM3a.
Fig. 3: ***Carnepigondolella nodosa*** subspecies **B**: extremely mature growth stage, sample NA9 (FO).
Fig. 4: ***Carnepigondolella*** n. sp. **A**. Holotype, mature growth stage, sample FNP52.
Fig. 5: ***Carnepigondolella carpathica*** **(Mock, 1979)**: mature growth stage, sample NA4.
Fig. 6: ***Carnepigondolella pseudoechinata*** **(Kozur, 1990):** adult growth stage, samples NA25.
Fig. 7: ***Carnepigondolella zoae*** **(Orchard, 1991)**: mature growth stage, sample PM19.
Fig. 8: ***Neocavitella cavitata*** **Sudar & Budurov, 1979**: mature growth stage, sample NA15.
Fig. 9: ***Misikella longidentata*** **Kozur & Mock, 1974**: samples NA9.
Fig. 10: ***Zieglericonus*** **sp:** sample NA27.
Fig. 11: ***Norigondolella*** cf. ***navicula****:* adult growth stage, sample NA16 (FO).
Fig. 12: ***Carnepigondolella pseudodiebeli*** **(Kozur, 1972)**: advanced specimen, mature growth stage, sample NA24.
Fig. 13: ***Carnepigondolella samueli*** **(Orchard, 1991)**: mature growth stage, sample NA24.

Scale bars are 200 µm. All the specimens are from Pizzo Mondello
a=upper view; b=lateral view; c=lower view


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Plate 3

Fig. 1: ***Metapolygnathus praecommunisti*** **Mazza, Rigo & Nicora (in press):** holotype, adult growth stage, sample NA12.
Fig. **2:** ***Metapolygnathus mersinensis*** **Kozur and Moix, 2007**: mature growth stages, sample FNP53.
Fig. 3: ***Carnepigondolella orchardi*** **(Kozur, 2003)**: adult growth stage, sample NA53.
Fig. **4:** ***Epigondolella*** n. sp. ***A***: holotype, sample NA25. Fig. 15: extremely mature growth stage, sample NA27.
Fig. 5: ***Epigondolella quadrata*** **Orchard, 1991**: stratigraphically lower form (i. e. primitive) (FAD), mature growth stage, sample FNP88a.
Fig. 6: ***Epigondolella vialovi*** **(Burij, 1989):** morphotype with the typical small notch in the middle of the posterior margin, mature growth stage, sample FNP112.
Fig. 7: ***Epigondolella quadrata*** **Orchard, 1991**: stratigraphically higher (i. e. advanced) form, mature growth stage, sample FNP112.
Fig. 8: ***Epigondolella rigoi*** **Kozur, 2007**: mature growth stage, sample PM28 (FAD).
Fig. 9: ***Metapolygnathus*** cf. ***primitius***: sub-mature growth stages, sample NA39.
Fig. 10: ***Metapolygnathus communisti*** **Hayashi, 1968**: mature growth stages, sample PM29.
Fig. 11: ***Metapolygnathus echinatus*** **(Hayashi, 1968)**: North American morphotype, mature growth stage, sample NA39.
Fig. 12: ***Metapolygnathus parvus*** **Kozur**: adult growth stage, sample NA37.

Scale bars are 200 µm. All the specimens are from Pizzo Mondello
a=upper view; b=lateral view; c=lower view

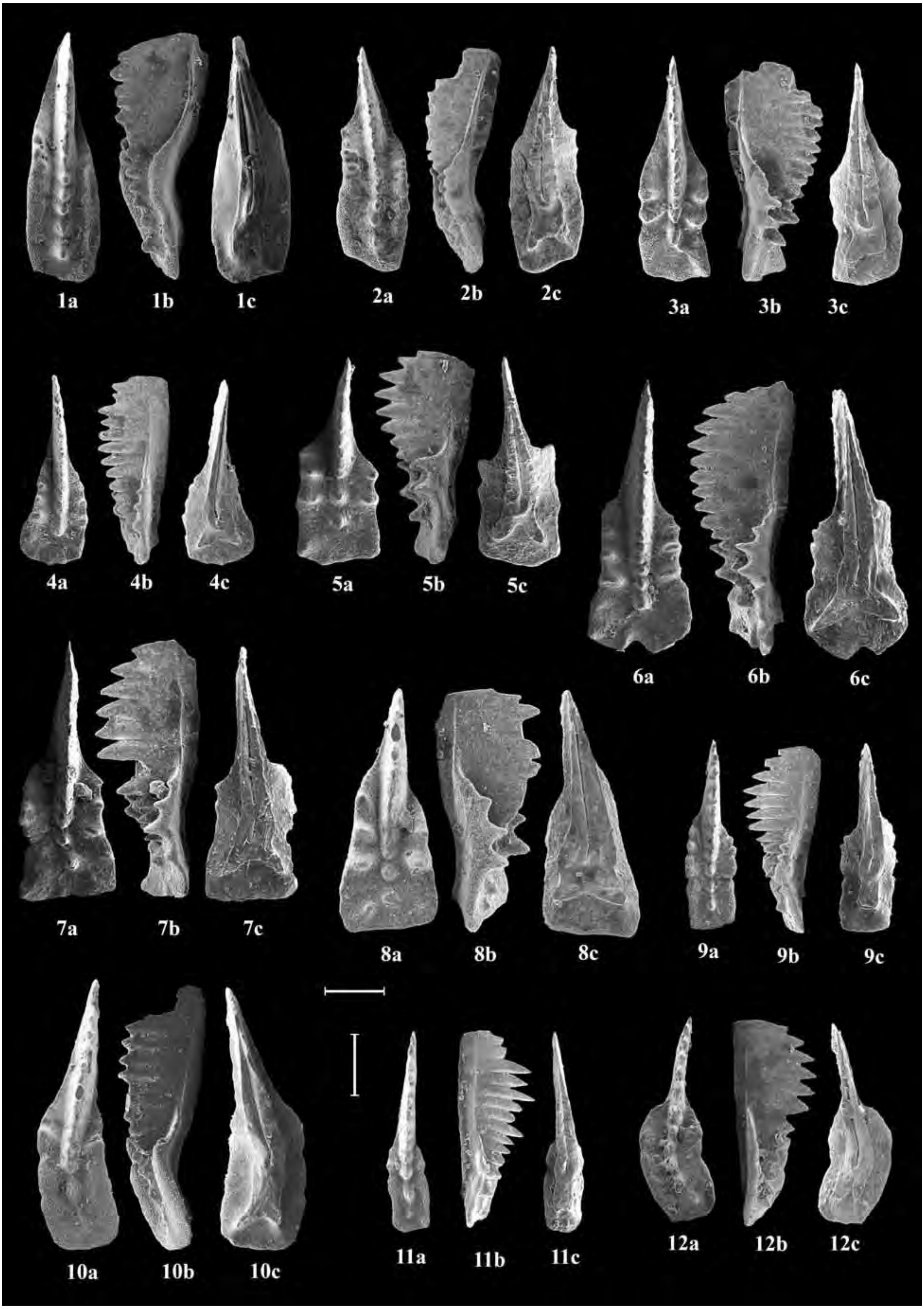
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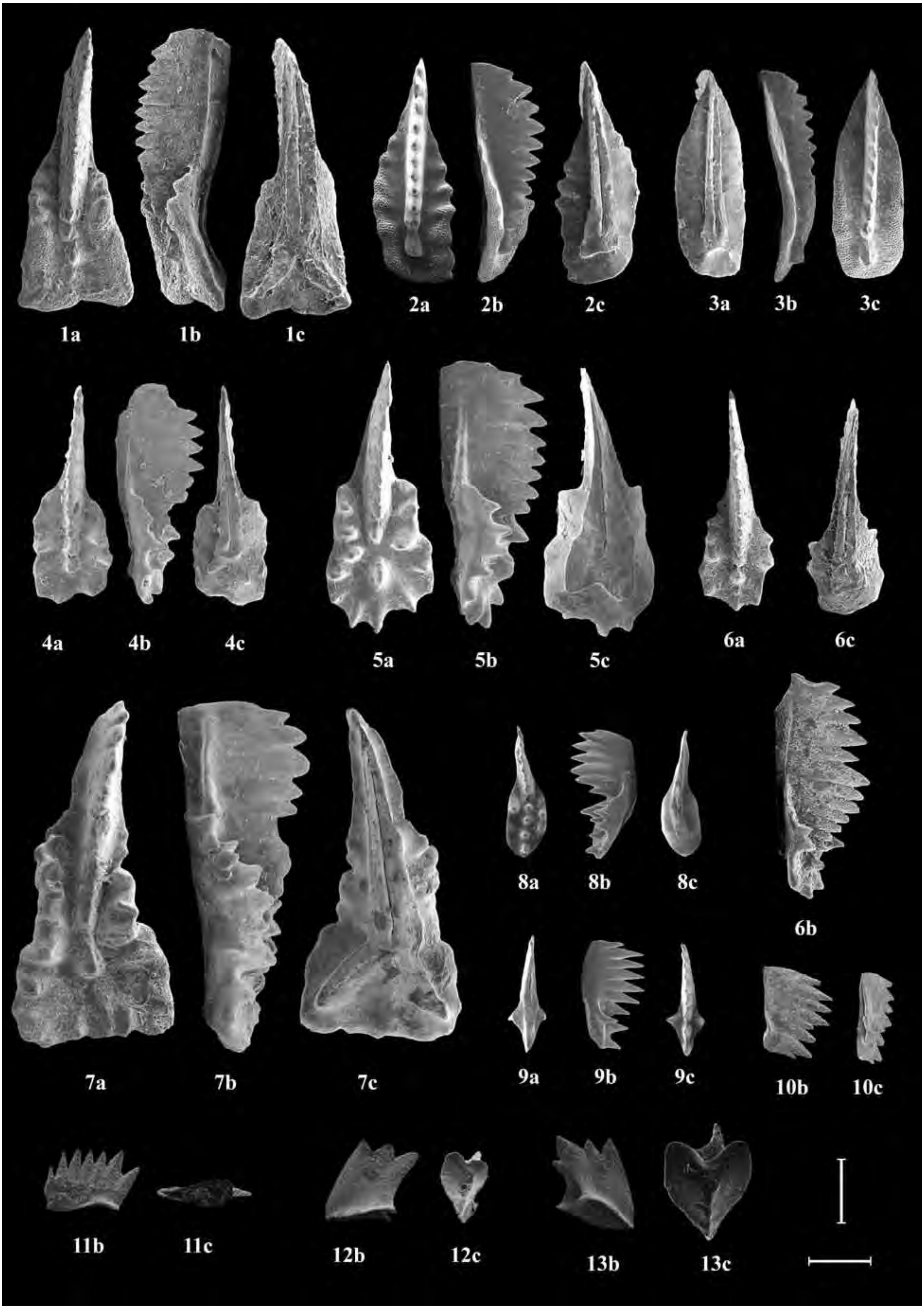
Plate 4

Fig. 1: ***Metapolygnathus linguiformis*** **Hayashi, 1968**: mature growth stage, sample NA39.
Fig. 2: **"*Metapolygnathus communisti* B" Krystyn, 1980**: mature growth stage, sample PM30a.
Fig. 3: ***Norigondolella*** n. sp. **A**: mature growth stage, sample NA43.
Fig. 4: ***Epigondolella praetriangularis*** **Kozur & Moix, 2007**: mature growth stages, sample NA37.
Fig. 5: ***Epigondolella uniformis*** **(Orchard, 1991)**: mature growth stage, sample NA42.
Fig. 6: ***Epigondolella spatulata*** **(Hayashi, 1968)**: mature growth stage, sample NA48.
Fig. 7: ***Epigondolella triangularis*** **(Budurov, 1972)**: mature growth stage, sample NA68.
Fig. 8: ***Mockina slovakensis*** **(Kozur)**: mature growth stage, sample NR5.
Fig. 9: ***Mockina bidentata*** **(Mosher):** mature growth stage, sample NR1.
Fig. 10: ***Parvigondolella andrusovi*** **Kozur and Mock**: mature growth stage, sample NR1.
Fig. 11: ***Misikella hernsteini*** **(Mostler)**: mature growth stage, sample NR59.
Fig. 12: ***Misikella posthernsteini*** **Kozur & Mock**: mature growth stage, sample PG34.
Fig. 13: ***Misikella ultima*** **Kozur & Mock**: mature growth stage, sample PG41.

Scale bars are 200 µm. All the specimens are from Pizzo Mondello
a=upper view; b=lateral view; c=lower view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Abstracts of the international workshop on "New developments on Triassic integrated stratigraphy"

Oral presentations

Triassic Stratigraphy and Facies of the Southern Permian Basin Area (England to Poland)

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The new "Petroleum Geological Atlas of the Southern Permian Basin Area" (SPBA; Doornenbal & Stevenson 2010) reviews the palaeogeographic and tectonic evolution and hydrocarbon potential of each stratigraphic interval in the Southern Permian Basin (or Central European Basin) including the United Kingdom, Belgium, the Netherlands, Denmark, Germany and Poland between latitudes 50°30'N and 56°N and longitudes 1°45'W and 22°E.

Lithostratigraphic and chronostratigraphic correlation between each country in tectonostratigraphic charts has been one of the most challenging aspects of the Atlas. The Triassic correlation is shown in Fig. 1 (Bachmann *et al.* 2010). The classic tripartite succession of Germany is also referred to as the "Germanic Triassic", and its depositional area as the "Germanic Basin". The Germanic Triassic is now ranked as a lithostratigraphic supergroup consisting of three groups, the Buntsandstein, Muschelkalk and Keuper, each of which is divided into three subgroups (e.g. Lower, Middle and Upper Buntsandstein), which in turn consist of formations, most of which are subdivided into members. Recently, the German Stratigraphic Commission (2002) replaced many of the mostly ill-defined and sometimes confusing traditional German Triassic formation names with a simplified formal nomenclature (e.g. the name "Unterer Gipskeuper" was replaced by Grabfeld Formation). In Fig. 1 the former names are given in brackets.

As the classic tripartite German lithostratigraphic scheme is valid for large parts of the basin, it is used as a reference to which other schemes, from eastern England to Poland, are related in the correlation chart. The Triassic chapter of the Atlas is also subdivided according to the German lithostratigraphy (e.g. Buntsandstein Group and equivalents). Depth and isopach maps are given for each group as well as facies and isopach maps for most subgroups. However, in most cases the lithostratigraphic boundaries and names differ for historical reasons or because of facies changes. It is important to note that some lithostratigraphic units, despite having the same name, may have different lithostratigraphic ranks and ranges in different countries. Several intra-Triassic unconformities are present that are especially obvious on swells or towards the basin margins. Substantial hiatuses are associated with the unconformities, especially in the Upper Triassic.

Correlation of the German lithostratigraphy with the Tethyan Triassic stages and substages is well established using ammonoid, bivalve, crinoid, conodont, conchostracan, palynological and magnetostratigraphical data (e.g., Bachmann and Kozur 2004, Kozur and Bachmann 2008 and 2010, this volume). Thus, the German Triassic succession is again used as a reference in Fig. 1. So far there are no radiometric age data from Triassic successions in the basin but the newest and most reliable age data were imported for the numerical calibration of the stage and substage boundaries. Attempts to improve the numerical ages by astronomical calibration were also considered. The Germanic Triassic is especially appropriate for such calibration as it has a well-developed cyclicity, both at outcrop and in well logs. The cycles are not all Milankovitch Cycles, but many of them seem to be well pronounced ~100 ka eccentricity cycles and ~20 ka precession cycles.

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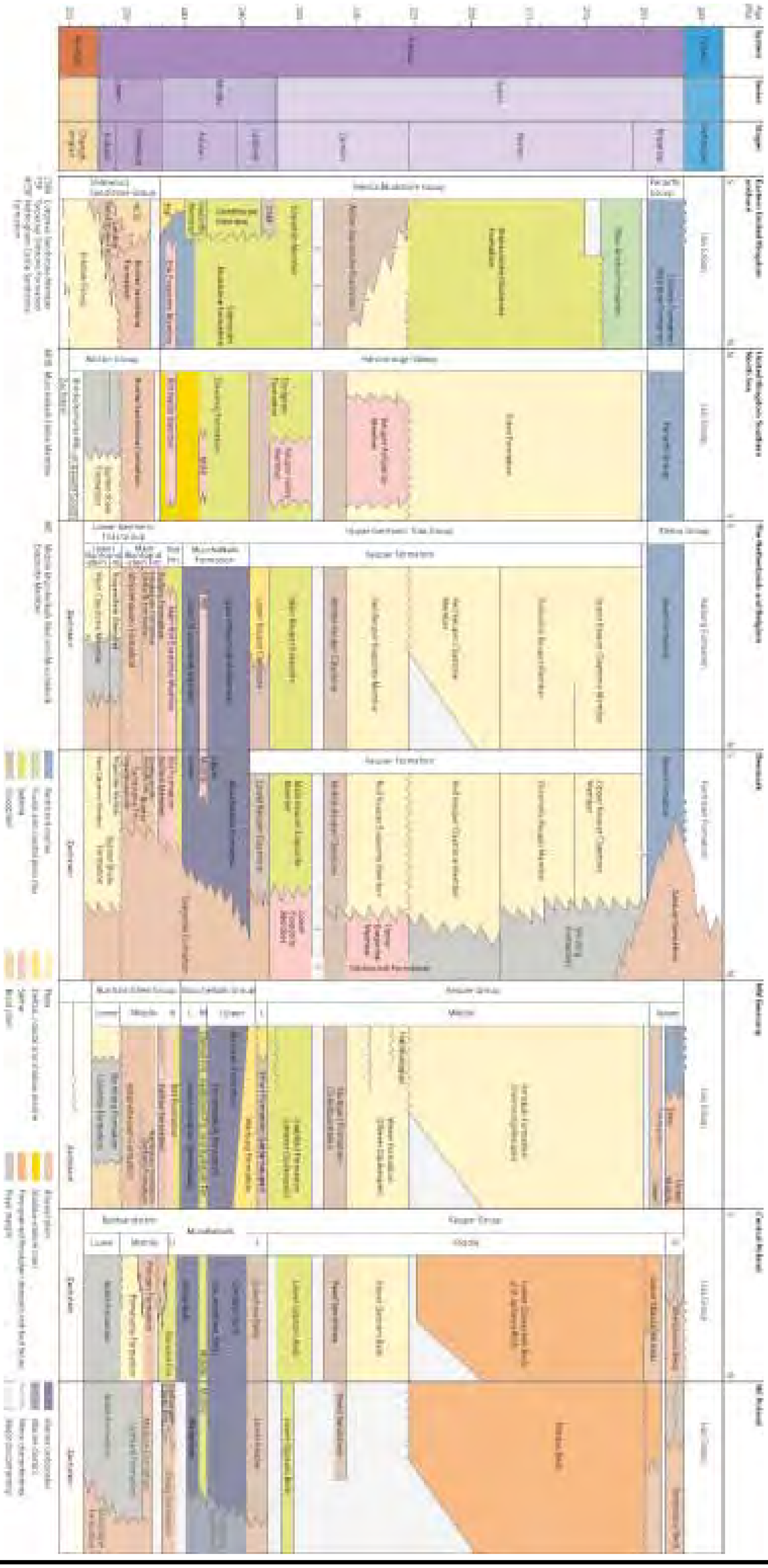
Figure 1 (next page): Triassic correlation chart. After Bachmann *et al.* (2010), modified.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United Kingdom Southern North Sea
The Netherlands and Belgium
Denmark
NW Germany
Central Poland
NE Poland
Lias Group
Penarth Group
Keuper Formation
Zechstein

Bio-chronostratigraphic calibration of the Upper Carnian-Lower Norian magnetostratigraphic scale at Pizzo Mondello (Sicani Mountains, Sicily)

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Pizzo Mondello section is known since 15 years because of the continuous Late Triassic pelagic record of great significance for the establishment of an integrated chronostratigraphy of the Late Triassic (Gullo *et al.* 1996; Muttoni *et al.* 2001, 2004).

During the last 4 years, Pizzo Mondello section has been studied in detail to provide a new and high resolution integrated bio-chronostratigraphy for the calibration of the magnetostratigraphy and chemostratigraphy proposed by Muttoni *et al.* (2001, 2004), and now it is one of the GSSP candidates for the definition of the base of the Norian.

The lowest 143 m of the Cherty Limestone, straddling the C/N boundary have been studied in detail. The preliminary data of the ongoing research have been presented in all the meetings of the STS from Albuquerque 2007 and here we summarize the final results.

The key correlation to the standard marine Triassic Scale is provided by the ammonoids. They are relatively rare, however the available collections document the Upper Carnian *Discotropites plinii* and *Gonionotites italicus* Subzones, from meter 15 to meter 80 from the base of the section. The following 15 meters are poor in ammonoids, while higher up the lower part of the Lower Norian *Guembelites jandianus* Zone is documented by *Dimorphites* cf. n. sp.1 of Krystyn, 1980.

Conodonts are very abundant and have a great potential as practical tool for global correlations. The abundance of specimens at Pizzo Mondello gave the opportunity to point out clear relationships among the five most widespread Upper Camian/Lower Norian conodont genera (*Paragondolella*, *Carnepigondolella*, *Metapolygnathus*, *Epigondolella* and *Norigondolella*) and to identify trends of the generic turnovers (Mazza *et al.* 2010). The two biomarkers so far proposed as possible marker events for the GSSP were the FAD of *E. quadrata* (sample FNP88A) and the FAD of *M. communisti* (sample NA35). However, the FAD of *E. quadrata* occurs within the *Gonionotites italicus* Subzone, while the FAD of *M. communisti* is on its top.

Halobiids are extremely common in the Cherty Limestone and they have also a great potential for large scale correlations. Nine species of *Halobia* have been recognized: *Halobia carnica*, *H. lenticularis*, *H. simplex*, *H. superba*, *H.* cf. *rugosa*, *H. radiata*, *H. austriaca*, *H. styriaca* and *H. mediterranea*. The best possible marker for the base of the Norian is the first occurrence of *Halobia austriaca*, that is recorded in the middle of the interval between the record of the *Gonionotites italicus* Subzone and the *Guembelites jandianus* Zone.

Radiolarians were found in few samples but with high diversity assemblages. In the upper *Gonionotites italicus* Subzone to the *Guembelites jandianus* Zone there is an overlap of species previously considered Late Carnian with species usually regarded as Early Norian. About 4 m above the FAD of *E. quadrata*, in the *Gonionotites italicus* Subzone, the first assemblage with *Capnuchosphaera deweveri* Kozur & Mostler, *Capnuchosphaera tricornis* De Wever, *Kahlerosphaera norica* Kozur & Mock and *Xiphothecaella longa* Kozur & Mock, usually referred to Early Norian, occurs.

These integrated bio-chronostratigraphic studies lead to identify some possible GSSP marker events especially on conodonts and halobiids, which occur in the upper part of magnetozone PM 4n, within PM 4r and in the lower part of PM 5n.

Possibly the most suitable magnetostratigraphic event to recognize the basal Norian is the base of magnetozone PM 5n, as already suggested by Krystyn et al. 2002 and Muttoni et al. 2004.

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Bio-chronostratigraphic revision of the Wengen Formation (Ladinian-earliest Carnian) in the central Southern Alps

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The Ladinian carbonate buildups are particularly well represented in Southern Alps, where they developed as a number of isolated platforms (Esino Limestone and Schlern/Sciliar Formation) separated by intraplatform basins with volcanoclastic-dominated sedimentation (Wengen Formation) or carbonate-dominated sedimentation (Perledo-Varenna Limestone). The traditional dating of many of these buildups was mostly based on lithostratigraphic correlations instead of bio-chronostratigraphy, because the occurrence of age-diagnostic fossils (e.g., ammonoids) is limited to very few platforms and it is also scattered.

Here we present new bio-chronostratigraphic data on the Wengen Formation from a selected area of central Southern Alps, i.e., the eastern Lombardy between Scalve and Giudicarie Valleys. Five new sections have been selected: Cima Verde (north face of Presolana, BG), Corna S. Fermo (Pizzo Camino, BG), Monte Colombine (Caffaro Valley, BS), Monte Corona and Malga Le Pozze (Bondone Valley, TN*)*. The studied successions were all deposited in a basin to platform transition setting, where the Wengen Formation is overlain by the prograding of the Esino Limestone. The data from these sections complement earlier data (Balini *et al.* 2000) from successions deposited in distal setting with respect to the carbonate platforms, and the detailed bio-chronostratigraphic study by Mietto et al. (2008) on the Wengen Formation of the Dolomites.

In all the new sections the successions the Wengen Formation is up to 200 m thick and is overlain by at least 400 m of carbonate facies traditionally attributed to the Esino Limestone. After detailed bed-by-bed sampling of the studied sections, the most significant bio-chronostratigraphic data are:

1) *Daonella lommeli* is common in the lowermost part of the Wengen Formation in almost all sections.
2) The ammonoids are scattered, but in all the studied sections *Frankites*, genus typical of the Upper Ladinian *Frankites regoledanus* Zone to the lowermost part of the Lower Carnian *Daxatina canadenis* Zone, occurs in the middle part of the Wengen Fm.
3) The genus *Trachyceras*, whose first occurrence is recorded in the lower part of the Lower Carnian *Daxatina canadensis* Zone, has been found in the

uppermost Wengen Fm. at Corna S. Fermo.

4) The FO of *Paragondolella polygnathiformis*, that is one of the proxies for the base of Carnian, has been detected in the uppermost Wengen Fm. or in the transitional facies to the Esino Limestone in all the studied sections.

These new data question the traditional paleogeographic reconstruction of eastern Lombardy during Late Ladinian to Early Carnian. The main points which are modified are the following:

1) The Wengen-Esino transition is attributed to the earliest Carnian, and the facies of the Esino Limestone usually referred to the Ladinian are instead Carnian in age.
2) The "Esino Limestone" of eastern Lombardy is not coeval with the facies of the Esino Limestone in the type area of Esino Lario (Grigna) and Brembana Valley, but it documents a platform coeval with the Carnian Breno Formation.
3) The development of an earliest Carnian platform is also documented by the deposition of the Pratotondo Limestone in a basinal setting. The age of this unit is well constrained by the F.O. of *P. polygnathiformis* located in its lowermost part.

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The Calcare Rosso: key witness of the Ladinian carbonate platform exposure (Pegherolo Massif, Southern Alps)

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Close to the Ladinian-Carnian boundary, a major sea level drop leads to exposure of the flat-topped, prograding Esino Lmst. carbonate platform in the Central Southern Alps. The geometry of the platform (with flat top and steep slopes) favoured a different recording of the subaerial exposure on the platform top and on the reef-upper slope area. The subaerial exposure reduced the size and efficienty of the carbonate factory, as observed in other coeval carbonate platforms in the Lombardy Basin (Berra, 2007).

The reduced accommodation at the top of progradational platform led to the deposition of the thin (from a few to a 60m) regressive unit of the Calcare Rosso. This unit attests a detailed evidence of the sedimentological effects of sea level fall in the platform interior, reef and upper slope, documenting the reaction of a carbonate factory to a major environmental change.

The thickness changes in the Calcare Rosso reflect the existence of higher-subsidence sectors, where the thickness reaches 45-60m), whereas it thins laterally above the inner platform facies of the Esino Lmst., where it is substituted by the residual facies.

Slightly irregular surfaces with evidence of dissolution mark the transition between the massive facies of the reef-upper slope (Esino Lmst. platform) and the bedded peritidal-supratidal limestones of the Calcare Rosso. From this surfaces, sedimentary dykes filled with reddish and marly limestones are cut into the underlying facies.

Typical facies consists of cycles of peritidal limestone rich in cements (up to 80% of the whole rock), with m-scale tepee (Assereto and Folk,1977; Mutti, 1992) capped by terra rossa paleosoils and red marls. The facies organization indicates multiple event of subaerial exposures and superimposed diagenetic deformations. Locally, mainly in the upper part, dm-thick layers of red and green shales (probably tuffaceous) intercalate, possibly showing a nearby volcanic activity. In the Central Southern Alps, the deposition of up to 50 m of ialoclastic breccias occur in the southernmost outcrops of the Calcare Rosso (Val Seriana), documenting a locally important syndepositional volcanic activity.

Above the inner platform facies of the Esino Lmst., the thickness of the Calcare Rosso is reduced to 0,5-5m. This unit is represented by lenses of amalgamated breccias layers with grey to reddish matrix and angular to slightly rounded centimetric calcareous clasts. Locally, breccias layers are separated by bedded limestone or tuffaceous horizons.

The irregular lenses of breccias evolve laterally to peritidal limestone, suggesting an origin due to karst collapses, which generate chaotic to mosaic breccias and cave filling with chips, slabs and blocks. The relations between these deposits and an upper karst system with pit caves filled by monogenetic crackle to mosaic breccias developed in the Carnian Breno Fm. is not clear.

The facies distribution of the Calcare Rosso indicates a tight relationships between facies of the underlying platform (Esino Lmst.) and its thickness and facies association. In detail, the facies distribution points to a different creation of accommodation space on the top of the Esino Lmst. carbonate platform, which can be ascribed to syn-depositional tectonics, differential subsidence or volcanic activity, which possibly played different role in different part of the carbonate platform.

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Carbonate Platform-Basin Transition in SW Sicily. Implications for the paleogeographic reconstruction of the Central Mediterranean area

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A Triassic/Jurassic carbonate platform to basin transition, nearly orthogonal to the main direction of the Tertiary thrust propagation, has been recently revealed by the carbonate facies analysis from the Apenninic-Maghrebian Fold and Thrust Belt in the Sciacca – Monti Sicani area (SW Sicily).

Based on their stratigraphic successions two main types of thrust sheets can be differentiated in this area i) platform-derived structural units (known as Saccense or Sciacca units) which consists of thick Triassic and lower Jurassic peritidal successions and Jurassic to Cretaceous pelagites; ii) deep-water basin-derived structural units (Sicanian units), mostly formed by cherty limestones of Triassic to Eocene age. These units came into contact along a NW–SE trending alignment. Between platform and basin-derived units some thrust sheets that show a transitional evolution from Late Triassic sponge reef, to deeper water slope calciturbidites of Early Jurassic age outcrop (i.e. the Monte Genuardo unit).

Nevertheless the Tertiary compressive deformations the facies distribution from Triassic and Lower Jurassic strata in all these units is consistent with their paleogeographic contiguity. Moreover the correlation of the Upper Triassic and Lower Jurassic facies sequences in all the studied units allow us to reconstruct the depositional dynamics along the margin of the Saccense Platform and the adjacent Sicanian Basin at the turn of T/J boundary.

The shelf edge of the Saccense platform records the evolution from an Upper Triassic Dachstein-type reef to a Bahamian-type sandy margin during Early Jurassic times, as consequence of the T/J biotic crisis. Large slope-aprons in adjacent deep-water successions consist of reef-derived carbonate breccias and by oolitic-skeletal turbidites. Middle Jurassic pelagic sediments seal the carbonate system.

A complex Meso-Cenozoic sedimentary evolution of the shelf margin has been traced on the base of several outcrop sections. Multiple erosional or stepped discontinuity surfaces, swarms of neptunian dykes associated with volcanics and megabreccias account for a Jurassic transtensional activity and a Late Cretaceous basin inversion along the shelf edge. During the Neogene, oblique thrusting along the paleomargin, coupled to right-lateral transpression and clockwise rotations, resulted in a complex stack imbricate. The imbrication of thin tectonic slices of Permian deep-water sediments in the orogenic wedge (e.g. Portella Rossa, near Burgio) suggests that the Triassic paleomargin is a Late Paleozoic inherited structure. The orientation of this paleomargin is nearly parallel to the NW–SE margin of the Streppenosa Basin in the Hyblean region and to the Malta Escarpment.

Anisian lithostratigraphy of the Dolomites: a 40-years-long debate

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In Italian geologic maps of the Dolomites at 1:100.000 scale printed before the Second World War, the Anisian terrains are represented usually as: *ai- Anisico inferiore, as- Anisico superiore e medio, and an- Anisico indifferenziato*. The first to recognise the complex architecture of the Anisian terrains cropping out in the Braies area was Pia (1937). He mapped many rapid lateral changes of facies from continental to carbonate-terrigenous lagoon, to reef and basin sediments; Pia's geologic mapping is considered the first demonstration of Walther's Law. This stratigraphic framework was improved but substantially confirmed by Bechstädt and Brandner (1970); they affirmed the existence of three continental conglomerates in the Untere-, Mittlere and Obere Peresschichten and, moreover, mapped three major reef-like carbonate units, the Unterersarldolomite, Hauptdiploporenkalk and Oberer Sarldolomit, plus a minor one, the Algenwellenkalk. Farabegoli *et al.* (1977) and Assereto *et al.* (1977) re-named the continental conglomerate of the Obere Peresschichten as the Richthofen Conglomerate, and the Oberer Sarldolomit as the Contrin Fmn. Pisa *et al.* (1979) named the Dolomia del Serla superiore the Algenwellenkalk plus the Hauptdiploporenkalk p.p., both units being overlain by the basinal Dont Fmn or, locally, by the Mt. Bivera Fmn. Anisian tectonics was unanimously considered dominant in controlling the shape of the Dolomites basin and the distribution of facies.

By contrast, De Zanche *et al.* (1993) interpreted the Middle Triassic architecture of the Dolomites in terms of sequence stratigraphy controlled by sea-level changes driven by climate change. They proposed a lithostratigraphic nomenclature based partly on a few historical units, partly on revised units, and partly on new units (named and unnamed).

In some cases, the new nomenclature do not match with the old, generating contradictions that appear today in the sheets of the new 1:50.000 Geological Map of Italy.

In this paper some major discordances in the Anisian lithostratigraphy of the Dolomites are pointed out. A solution minimizing some of the problems with the geologic maps is presented.

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The end-Permian mass extinction

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The debate on the causes of the end-Permian extinction is shifting from simple one-parameter cause to a multi-parameter cause in which each factor combined to disrupt the global equilibrium of Late Permian life. Analysis of many stratigraphic sections across the Permian–Triassic Boundary in the Dolomites (Italy) has allowed identification of three transgressive-regressive depositional cycles, their timing, and possible causal relationships with four mass-mortality events which constitute the end-Permian extinction event in western Palaeotethys. The duration of each cycle ranges from less than 20 millennia to ca. 100 ky; the magnitude of the sea level changes ranged between 5 and 15 m. Each mass-mortality event affecting the shallow marine environments of western Palaeotethys corresponded to a regressive phase on millennial scale.

We hypothesize that few local palaeo-environmental factors concurred to modulate in space and time the intensity and duration of the mortality events. The increasing warmth was of primary importance in controlling the mortality-trail. We interpret the cause of the mass-mortality events as a composite top-down type mechanism, with acid-rains events in conjunction bringing about devastation of "Permian-type" biota in continental and subsequently shallow marine environments, these taking place during millennial periods of cooling and regression of the Bellerophon Gulf. The ultimate causal factor was, very probably, volcano-derived large-scale atmospheric perturbations.

Upper Triassic sedimentation of the Slovenian Basin (eastern Southern Alps, Slovenia) and its foraminiferal assemblage

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The majority of the Slovenian territory tectonically belongs to the eastern Southern Alps and the northern Dinarides (Placer, 1999). This area was situated on the southern passive continental margin of the Meliata ocean during the Middle and Late Triassic, and the Piedmont-Ligurian ocean from the Late Triassic/Early Jurassic to the end of Cretaceous. The palaeogeographic reconstruction comprises two shallow-water carbonate platforms and an intermediate deep-sea basin. The Julian Carbonate Platform (Julian High since the Pliensbachian) and the Slovenian Basin are nowadays preserved mostly in the Julian and the Tolmin Nappes of the Southern Alps respectively, whilst remains of the Dinaric Carbonate Platform form most of the Dinarides (Buser, 1986).

The Triassic succession of the Slovenian Basin in the Tolmin Nappe consists of the Carnian Amphiclina beds and the Norian-Rhaetian Bača Dolomite. The latter in the northernmost part of the basin vertically and laterally passes into the Upper Norian-Rhaetian Slatnik Formation.

The Mt.Slatnik section (Julian Alps, W Slovenia), situated in the Tolmin Nappe, comprises the Bača Dolomite, the Slatnik Formation and the Lower Jurassic Krikov Formation. The Mt.Slatnik section is the only section where primary sedimentary features of the Bača Dolomite can be observed due to incomplete dolomitization. Furthermore, a rich foraminiferal assemblage has been retrieved from the Bača Dolomite and the Slatnik Formation. The Norian-Rhaetian boundary has been placed here in the lower part of the Slatnik Formation on the basis of conodonts of the *Parvigondolella andrusovi-Misikella hernsteini* conodont zone by Rožič et al. (2009). The Triassic-Jurassic boundary has been placed in the package of thin-bedded limestones in the upper part of the Slatnik Formation, based on the correlation with the Mt.Kobla section, where conodonts disappear slightly below this horizon (Rožič *et al.*, 2009).

The Bača Dolomite comprises mud- and clast-supported slump breccias with laminated intraclasts and chert fragments, bedded and massive dolomites, bedded, often amalgamated limestones with partial Bouma sequences and rare marlstones. Chert nodules are locally abundant (Gale, in press). The Slatnik Formation differs from the underlying Bača Dolomite in the absence of dolomitization and in containing generally more coarser-grained beds, including boulder breccias with corals and cipit boulders. Sedimentation of both units took place on the inner apron, outer apron and basin plain via hemipelagic settling and carbonate gravity flows. Three "retrogressive-progressive" 3^rd^ order cycles have been recognized during the Norian-Rhaetian interval.

Foraminiferal assemblage points at the presence of a reef on a margin of the Julian Carbonate Platform. 42 genera and 63 species of foraminifers were determined. The Norian age of the Bača Dolomite has been confirmed on the basis of co-occurence of ?*Endotriada tyrrhenica, Endotriadella alpina, Endotebanella bicamerata, Ophthalmidium exiguum*, ?*Turriglomina magna* and *Pseudonodosaria obconica* with ?*Duotaxis birmanica*, *Sigmoilina? schaeferae*, *Galeanella panticae* and ?*Variostoma crassum*. *Duostomina multangulata* and *Variostoma catilliforme*, described from the Norian strata, were also found. The Norian age for the dasyclad algae *Probolocuspis espahkensis* is confirmed. The Norian-Rhaetian boundary is marked by the first occurrence datum of *Involutina* ex gr. *I. liassica* in the lower part of the Slatnik Formation. *Ornatoconus turris* was found slightly above this datum, and the Rhaetian age is further confirmed by the co-occurrence of both mentioned species with *Trocholina crassa*, *Triasina oberhauseri*, *?Aulotortus tumidus* and other Upper Triassic foraminifers. The Triassic-Jurassic boundary has been placed at the last occurrence datum of duostominids, a few meters below the package of thin-bedded mudstones in the upper part of the Slatnik Formation. The Lower Jurassic *Siphovalvulina colomi* was found in the overlying Krikov Formation 20m higher, above the dolomitized and tectonized part of the section.

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Carnian-Norian paleogeography in the eastern Southern Alps

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A detailed analysis of Upper Triassic basinal successions from Eastern Cadore, Carnia and Julian Alps allows us the reconstruction of the paleogeography of this important sector of the Southern Alps. The presence of Tuvalian basinal facies at the toe of slope of a prograding carbonate platforms in the Santo Stefano di Cadore area (cfr. Geyer, 1900) and the correlation with similar succession in the Julian Alps (Gianolla *et al*., 2003) testifying the presence of a distinct branch of the Slovenian Basin (cfr. Buser, 1987) here called Tarvisio Basin. At present it appears to be very narrow and E-W lengthened, owing to the strong tectonic shortening.

The Tarvisio Basin delimited the northern margin of the wide peritidal platform Dolomia Principale. This margin was composed by a serpulid-dominated reef in association with corals, microbialites and marine phreatic cements and was connected to the basin by sigmoidal clinoforms, dipping to NNE at about 30°-35°, consisting of breccias and calcarenites interfingering with dark limestones of the Carnitza Formation (middle-upper Tuvalian). The onset of inner platform is represented by an alternation of aphanitic dolomites and marls (Monticello Fm., cfr. Carulli *et al*., 1998), later replaced by the typical peritidal cycles of the Dolomia Principale. The progradation of the platform-basin system towards NNE seems to have been very quick. Near the Italian-Slovenian border (Portella/Törl), east of Cave del Predil/Raibl and in the Santo Stefano di Cadore sections, the middle and upper Tuvalian (Subbullatus and Anatropites Zones) is documented by ammonoids, conodonts and palynomorphs (Geyer, 1900; Lieberman, 1978; De Zanche *et al*., 2000). Eastward (Vrata Valley, Slovenia) the timing and the evolution of the platform/basin system is recorded by the progradation of the Dachstein Reef platform onto the Martuljek platy limestones bearing Tuvalian- lower Lacian ammonoids and conodonts (Ramovs, 1986; Schlaf *et al*., 1997; Celarc and Kolar-Jurkovšek, 2008).

During Early Norian, most of the Tarvisio Basin seems to have been filled by the quick progradation of the shallow water platform. Since then, the existence of the upper Triassic basinal facies (Bača Fm) north to the Julian Alps (Rožič et al., 2009) is only documented in the southern Karawanken, where a completely basinal section, extended from upper Carnian to Jurassic, is recorded (Schlaf, 1996). This succession shows the first evidence of the proximity of a prograding platform after Lacian age. Abundant platform deriving breccias and megaturbidites appeared in the middle-upper Norian (cfr. Schlaf, 1996, Schlaf *et al*., 1997). This is the same age commonly assigned to the intraplatform basins, tectonically controlled, set within the Dolomia Principale that are called Dolomia di Forni in Julian Alps, Aralalta Group in the Bergamasc Alps, Seefeld (Austria) and Rezi Dolomite Fms (Hungary) (cfr. Rigo *et al*., 2007; Rožič *et al*., 2009). Recently, a possible passageway between the Dolomia di Forni basins and the open sea represented by the Slovenian Basin have been identified in the disaerobic to anoxic Rio Resartico unit that yielded an useful monospecific conodont fauna consisting of *Mockina slovakensis* (Rigo *et al*., 2007). This fauna is exactly alike to that collected from intraplatform basins of Dolomia di Forni, Seefeld and Rezi Dolomite Fms.

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Origin of Upper Triassic deep water carbonate at Pizzo Mondello (Sicily)

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Thick successions of deep water carbonates formed in the Tethys during the Upper Triassic, and are represented mostly by a cherty limestones facies association that crop out in Southern Apennines, Sicily, Tarvisio and the Dinarids. Most of these deep water limestones are older than the explosion of calcareous nannoplankton, and their formation is thus problematic: either these cherty limestones testify for the contribution of some unknown calcareous nannofossil earlier than previously thought or, rather, they are periplatform deposits, mostly constituted by carbonate mud exported from nearby platforms.

The composition of Late Carnian – Early Norian limestones from Pizzo Mondello, Sicily, was evaluated in order to quantify the contribution of different components to the net accumulation of deep water carbonates. Major constituents have been found to be fine carbonate matrix or micrite, calcareous nannofossils (orthopithonellid calcispheres), thin shelled bivalves and radiolarians. Foraminifers and ammonoids are also present. Calcareous nannofossils and radiolarians are pelagic, thin shelled bivalves testify for deep water benthic production of carbonate, while the provenance of micrite is uncertain.

The nature of nannofossils and micrite was investigated by Scanning Electron Microscopy (SEM). Calcispheres are nearly spherical with a diameter of some tens of microns, and exhibit a syntaxial overgrowth of calcite that makes their determination difficult. A few specimens are better preserved and are tentatively attributed to orthopithonellids. Micrite is mixed, mostly constituted by small ($< 5\ \mu m$) crystals with some larger pitted crystals. This indicates a prevailing calcite precursor, as also suggested by low Sr contents (Bellanca *et al*., 1995).

The relative abundance of major components was evaluated via point counting on thin sections. The sediment is composed on average by micrite (45%), radiolarians (25%), nannofossils (18%) and thin shelled bivalves (6%), with minor components accounting for the remaining 6%. Thus, the sediment of Pizzo Mondello contains a significant portion of true pelagic carbonate. Nearly half of the sediment (nannofossils, calcitized radiolarians and thin-shelled bivalves) derives from pelagic or autochthonous deep-water sources.

The stratigraphic interval between m 89 and 107, that overlaps with the Carnian-Norian boundary interval, is characterized by abundant shales and chert beds. It is also distinctive in terms of composition: nannofossils become more abundant (ca. 29 %), mostly at the expense of micrite (39 %). The increase of insoluble sediment (clays and chert) near the Carnian-Norian boundary interval is interpreted as an episode of increased carbonate dissolution, similar to one observed at the lower / upper Carnian boundary in cherty limestones of the Lagonegro Basin (Rigo *et al*., 2007), but weaker in intensity: at Pizzo Mondello, the CCD did not rise above sea floor. Calcareous nannofossils, being originally composed of low-Mg calcite, are relatively resistant to dissolution and were thus concentrated.

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Correlation of the predominantly continental Upper Triassic of the Germanic Basin with the Tethyan scale

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Traditional lithostratigraphic correlations within the dominantly continental Germanic Upper Triassic are generally correct, but some problems exist in the marginal facies, particularly in SW Germany. There, for instance, the lower Rhaetian Malschenberg Sandstein is not contemporaneous with, but instead is younger than, the Sevatian Stubensandstein 4 of the Löwenstein area (Kozur and Weems, 2010). Therefore, even the part of the Trossingen Formation (Knollenmergel, with the famous *Plateosaurus* fauna) that is younger than the Stubensandstein 4 still is Sevatian in age.

Some marine or marine-influenced brackish intercalations occur within the continental Germanic Upper Triassic that allow a good correlation with the international Tethyan marine scale. Fig. 1 shows the Upper Triassic Tethyan ammonoid and conodont zonations including the original three-fold subdivision of the Carnian into Cordevolian, Julian and Tuvalian substages. The Cordevolian is characterized in all stratigraphically important fossil groups by a mixture of Carnian and Ladinian elements, e.g. among ammonoids the Carnian *Trachyceras* appears, and occurs together with *Frankites* which persists from the Ladinian, among pelagic bivalves the Carnian *Halobia* occurs together with Ladinian species of the Middle Triassic *Daonella*, among conodonts the Carnian *Paragondolella polygnathiformis* and *P. noah* occur together with the Ladinian genus *Budurovignathus*, among radiolarians Carnian and younger saturnalids occur together with Ladinian types of oertlispongids. In the Julian, in all of these faunal groups, the Ladinian forms are no longer present. The persistence of Ladinian faunal elements and dasycladaceans was the reason why the Cordevolian was previously partly assigned to the Ladinian, against the original definition. Even in recent papers, before the Carnian base was defined by the base of the *Daxatina canadensis* Zone, that zone usually was assigned to the Ladinian. The Norian base is not yet fixed. Most suitable is the base of the *E. quadrata* Zone, though another possibility is the base of the *E. orchardi-N. navicula* Zone or the contemporaneous base of the *M. primitius* Zone of the southern Tethys (Neotethys).

The excellent definition of the Carnian base at the base of the *Daxatina canadensis* Zone in the GSSP at Stuores

Wiesen by Broglio Loriga et al. (1999) allows a good correlation with the Germanic Triassic. The sporomorphs *Patinasporites densus* Leschik and *Vallasporites ignacii* Leschik begin at the GSSP close to the base of the Carnian. These species begin in the Germanic Basin close to the base of the Estherienschichten of the upper Grabfeld Formation (Fig. 2) together with the conchostracan species *Laxitextella multireticulata* (Reible); the appearance of these taxa defines the base of the Carnian in the Germanic Basin. *L. multireticulata* is also common in the basal Newark Supergroup of eastern USA (Kozur and Weems, 2007). Brackish beds in the basal Stuttgart Formation of northern Germany contain a rich euryhaline marine ostracod fauna with *Simeonella alpina* Bunza and Kozur, which is also common in the upper Julian of Hungary and the Alps. The inverse estuarine-marine Dolomie de Beaumont immediately above the Schilfsandstein in the southwestern Germanic Basin contains a marine bivalve fauna with *Costatoria vestita* (Alberti), indicating a position close to the Julian-Tuvalian boundary. The euryhaline marine ostracod *Simeonella nostorica* Monostori, common in the Lehrberg Beds, characterizes the lower Tuvalian in Hungary and the Alps. A distinct change in sporomorph associations occurs in the Mainhardt Formation and equivalents, characterized by the FOD of *Granuloperculatipollis rudis* Venkatachala and Góczán and *Classopollis meyeriana* (Klaus) de Jersey, Zhang and Grant-Mackie (Orlowska-Zwolinska, 1983, Heunisch, 2005, Schulz and Heunisch, 2005). In the Alps, this association begins in the upper Tuvalian within the Opponitz Beds (Roghi et al., 2010). A monospecific *Palaeolimnadia schwanbergensis* conchostracan fauna characterizes the basal Arnstadt Formation. It also occurs in the Newark Basin (Warford Member, lower Passaic Formation) together with the oldest *Aetosaurus*, a Norian vertebrate index genus. Most of the lower Arnstadt Formation is characterized by a conchostracan fauna with *Euestheria buravashi* Kobayashi, also known from the lower Norian of Thailand (Kobayashi, 1954, 1975). The large *Shipingia hebaozhaiensis* Shen, found in the upper part of the middle Arnstadt Formation, is an important middle Norian guide form that also occurs from the USA to China, where it can be correlated with marine middle Norian. The likewise very large *S. olseni* Kozur and Weems characterizes the Sevatian. At the Norian-Rhaetian boundary all large conchostracans disappear and the Rhaetian conchostracan fauna consists only of small forms, like *Gregoriusella polonica* Kozur and Weems and *Euestheria brodieana* (Jones). The upper Rhaetian contains a monospecific *E. brodieana* fauna. Around the base of the Hettangian, *Bulbilimnadia killianorum* Kozur and Weems appears. The traditional basal Hettangian beds in the Germanic Basin are the transgressive Psilonotum Beds [(*Psiloceras psilonotum* (Quenstadt) is probably a junior synonym of *P. sampsoni* (Portlock)] of the *P. planorbis* Zone, but these actually are younger than the Hettangian base, which lies somewhat above the reddish Levallois Clays within the upper Triletes beds. The reddish Levallois Clays appear to correspond to the similarly reddish Schattwald Beds of the Northern Alps.

Ma	Stage/Substage		Ammonoid Zone/Subzone		Conodont Zone/Subzone	
201.5	Low. Hettangian		Psiloceras spelae		Neohindeodella detrei	
	RHAETIAN	Upper Rhaetian	Chor. marshi	Choristoceras marshi	Misikella ultima	
				Choristoceras ammonitiforme	Misikella posthernsteini	Misikella koessenensis
		Lower Rhaetian	"Chor." haueri	Vandaites stuerzenbaumi		
				"Choristoceras" haueri		Misikella hernsteini-Misikella posthernsteini
			Paracochloceras suessi			
206	NORIAN	Sevatian	Metasibirites spinescens		Mis. hernsteini-Parv. andrusovi	
			Sagenites quinquepunctatus		Mockina bidentata	
		Alaunian	Halorites macer		Mockina postera	
			Himavatites hogarti		Mockina ? spiculata	
			Cyrtopleurites bicrenatus		Mockina medionorica	
		Early Norian ("Lacian")	Juvavites magnus		Epigondolella triangularis-Norigondolella hallstattensis	
			Malayites paulckei		Epigondolella rigoi	
225+3 222			Guembelites jandianus		Epigondolella quadrata	
					E. orchardi-N. navicula	M. primitius
	CARNIAN	Tuvalian	Anatropites spinosus		Carnepigondolella pseudodiebeli	
230.91			Tropites subbullatus		Carnepigondolella zoae	
					Paragondolella carpathica	
			Tropites dilleri		P. postinclinata-P. noah	
		Julian	Austrotrachyceras austriacum		Gladigondolella tethydis-Paragondolella noah	
			Trachyceras aonoides			
		Cordevolian	Trachyceras aon		Budurovignathus diebeli-Paragondolella polygnathiformis	
237			Daxatina canadensis			

Fig. 1

Figure 1: Tethyan Upper Triassic ammonoid and conodont zonation. Modified after Bachmann and Kozur (2004); Moix et al. (2007) and Balini et al. (2010).

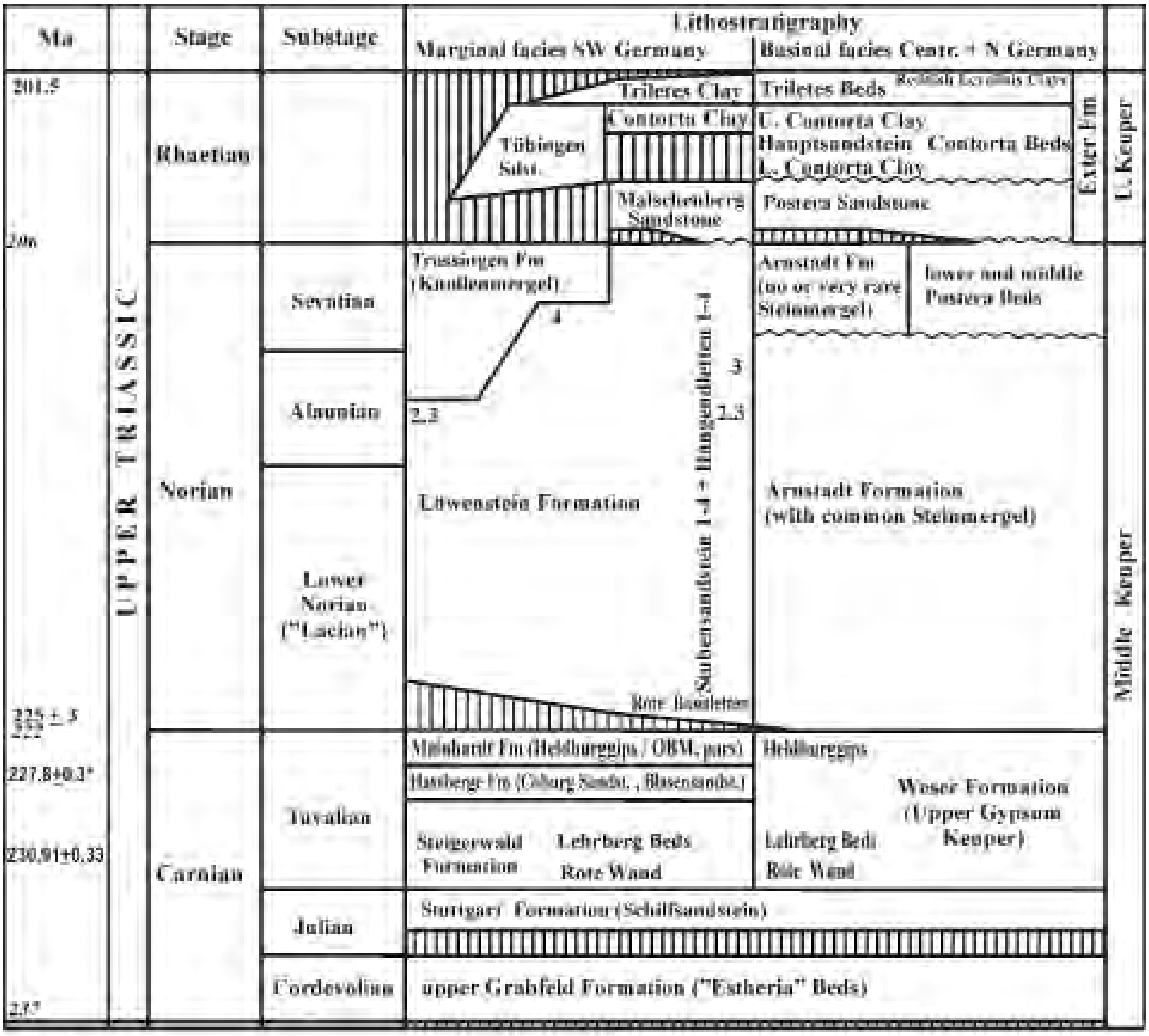

Fig. 2

Figure 2: Lithostratigraphic subdivisions of the Germanic Upper Triassic and their correlation with the international marine timescale and numeric ages. Slightly modified after Kozur & Weems (2010). Date with an asterisk mark (*) is ^{40}Ar/^{39}Ar data from the Adamanian of Ishigualasto, Argentina (Rodgers et al., 1993). 230.91±0.33 Ma date after Furin et al. (2006). 225±3 Ma after Gehrels et al. (1986, 1987). The 201.5 Ma for the Triassic-Jurassic boundary is based on a biostratigraphic re-dating (Kozur & Weems, 2007) as latest Rhaetian of radiometric data from the lower lava flow of the CMP volcanics in the Newark Supergroup, and on radiometric data from a well-dated Rhaetian-Hettangian boundary section in Peru by Schaltegger et al. (2008). Calculated numeric ages are in italic script. 2.3, 3, 4 = Stratigraphic position of the Stubensandstein subdivisions designated as Stubensandstein 2.3, Stubensandstein 3 and Stubensandstein 4. OBM = Obere Bunte Mergel: U = Upper; L = Lower.

The conchostracan zonation of the Upper Triassic and basal Jurassic. Age of the CAMP volcanics in the Newark Supergroup

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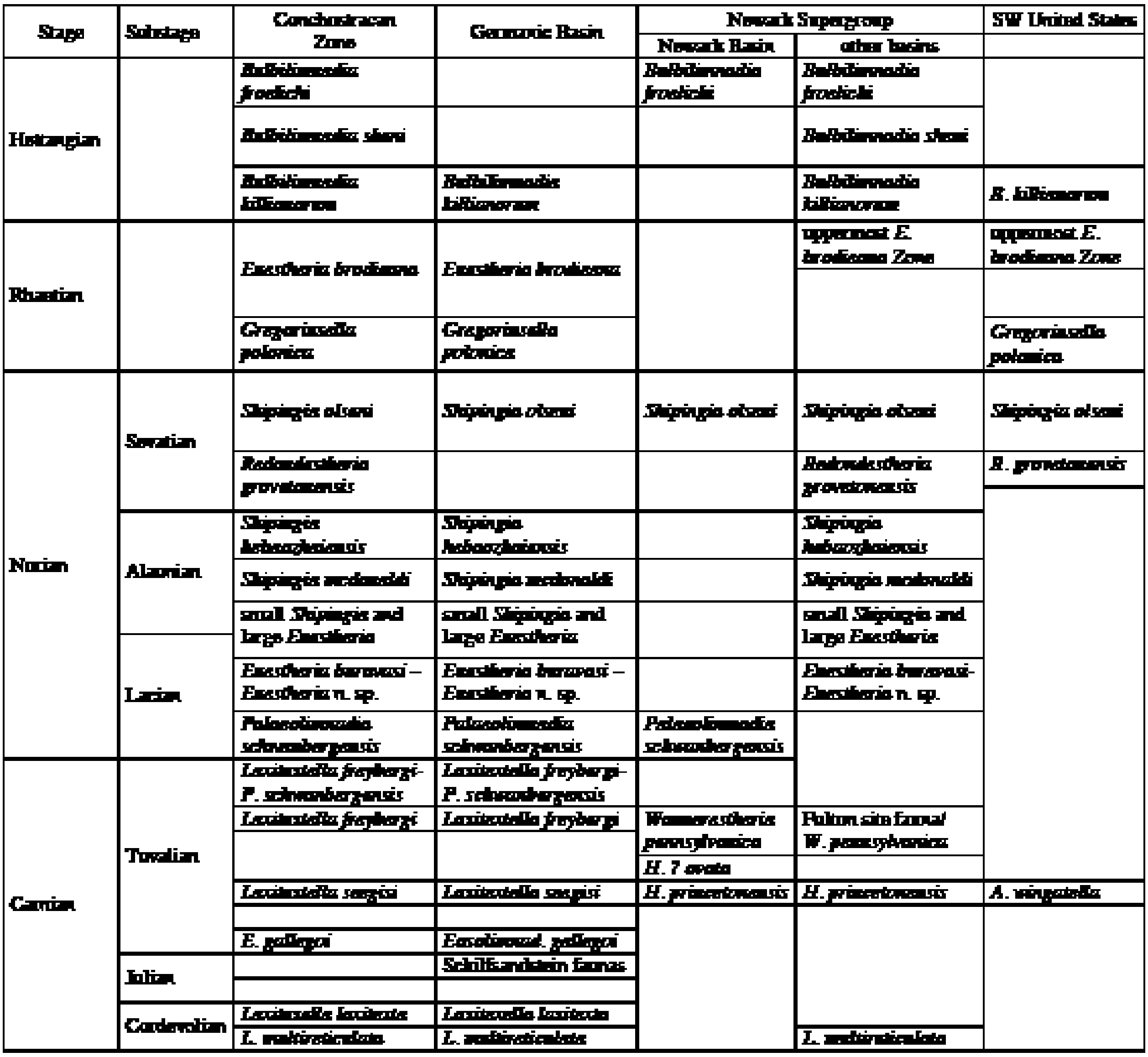
Conchostracans or clam shrimp (Order Conchostraca Sars) are Arthropoda of the Class Branchiopoda Latreille. Their short, laterally compressed bodies are enclosed in a chitinous carapace consisting of two lateral valves that are in Triassic forms 2-12.5 mm long. As the animal grows it enlarges its carapace by adding bands of new shell material (growth bands) that are separated from the adjacent growth bands by a narrow line (growth line). Conchostracan shells of the suborder Spinicaudata Linder, to which all Triassic conchostracans belong, have a very small to large umbonal area without growth lines and a generally (much) larger part with growth lines. The umbonal area is smooth, punctate or reticulate and may bear one, rarely two or three, often elongate nodes. The space between the growth lines is smooth, punctate, reticulate or has radial lirae or anastomozing lirae. Vertical radial ribs may be present on the carapace and these may bear nodes or short spines. The desiccation- and often freeze-resistant eggs can be dispersed widely by wind. Thus conchostracans may have a huge geographic distribution. A frequently wide distribution and short stratigraphic range of some species, and presence of these same species in markedly different climatic zones, makes them excellent guide fossils in continental deposits. The stratigraphic resolution of Triassic conchostracans is about as high as that of pelagic Triassic conodonts. The main habitats of living and fossil conchostracans are temporary alkaline inland ponds and small temporary freshwater lakes. They also can occur in flood-plain pools, coastal flood plains, coastal salt flats and, in the case of some species, in brackish water estuarine facies or in deltaic plains with variable salt content (Webb, 1979; Kozur and Weems, 2010). In deposits formed in very shallow marine environments with variable salt content, conchostracans can be present on some bedding planes or in some intervals. Therefore, the potential of conchostracans for correlation of marine and continental beds is high.

The Lower and partly also Middle Triassic conchostracan zonation and its correlation with the marine scale are well established. In the Upper Triassic, a lot of taxonomic work is yet to be done. There is only a preliminary zonation (Fig. 1, from Kozur and Weems, 2010), and its detailed correlation with the marine scale is only partly known. The preliminary zones will remain, some restricted in scope, but in the final zonation there will be more zones due both to splitting some longer zones and by adding new zones between existing preliminary zones. For these new zones, index species are yet to be described. Despite the wide geographic distribution of most species, in the Norian a slight endemism can be observed. The Sevatian *Redondestheria* is only known from North America and *Acadiestheriella* Kozur & Weems is only known from the Sevatian of the Fundy Basin. This latter very restricted occurrence may not be caused by endemism but rather may be due to insufficient knowledge of Norian conchostracans.

Best studied within the Upper Triassic conchostracan zonation and best correlated with the marine scale are the Cordevolian and Sevatian to early Hettangian conchostracan faunas. Within these stratigraphic intervals the most significant results for the correlation of the continental Upper Triassic were obtained. The oldest conchostracan faunas from the Newark Supergroup, except in the Fundy Basin, are lower Cordevolian faunas of the *Laxitextella multireticulata* Zone and include its index species (Kozur and Weems, 2007, 2010). Only in the Fundy Basin of SE Canada are Middle Triassic beds present, as has been known for some time (Lower Economy beds, Baird and Olsen, 1983). Because these beds are considerably older than any other beds usually included in the Newark Supergroup, generally they have been excluded from the definition of the Newark Supergroup (e.g. Weems and Olsen, 1997). However, the lower Wolfville Formation of the Fundy Basin, always placed in the Newark Supergroup s.s., also ranges down to the late Ladinian (Longobardian) *Euestheria minuta* Zone (Kozur and Weems, 2010). Based on conchostracans, the Carnian-Norian boundary in the Newark Basin lies at the base of the Warford Member of the lower Passaic Formation, where it also has been drawn based on vertebrates (FAD of *Aetosaurus*). Conchostracans, vertebrates, and sporomorphs all place the Norian base at about this level, but palaeomagnetic correlations have placed this boundary much lower, within the Stockton Formation; this cannot be corroborated by conchostracan faunas or any other biostratigraphic data. The CAMP volcanics of the upper Newark Supergroup have been long regarded as entirely Jurassic (e.g. Kent and Olsen, 2000), but Kozur and Weems (2005, 2007, 2010) found immediately below and above the first lava flow a late Rhaetian monospecific *Euestheria brodieana* fauna, succeeded by conchostracan faunas of the early Hettangian *Bulbilimnadia killianorum* and *B. sheni* zones in the middle and upper part of the beds between the first and second lava flow. This indicates that the first lava flow is latest Rhaetian in age, and only the younger lava flows belong to the Hettangian. A similar result was published by Cirilli et al. (2009), who found Rhaetian sporomorphs below and above the North Mountain basalt of the Fundy Basin, which correlates with the first lava flow of the Newark Supergroup in other basins. A strong change in the sporomorph association at the former Triassic-Jurassic boundary in the Newark Basin (one precession cycle below the first lava flow) according to the conchostracan fauna marks a climatic change between the late Norian (Sevatian) *Shipingia olseni* Zone with very big conchostracans below this level and the Rhaetian *E. brodieana* Zone with exclusively very small conchostracans above this level.



Stage	Substage	Conchostracan Zone	Germanic Basin	Newark Supergroup		SW United States
				Newark Basin	other basins	
Hettangian		*Bulbilimnadia froelichi*		*Bulbilimnadia froelichi*	*Bulbilimnadia froelichi*	
		Bulbilimnadia sheni			*Bulbilimnadia sheni*	
		Bulbilimnadia killianorum	*Bulbilimnadia killianorum*		*Bulbilimnadia killianorum*	*B. killianorum*
Rhaetian		*Euestheria brodieana*	*Euestheria brodieana*		uppermost *E. brodieana* Zone	uppermost *E. brodieana* Zone
		Gregoriusella polonica	*Gregoriusella polonica*			*Gregoriusella polonica*
Norian	Sevatian	*Shipingia olseni*	*Shipingia olseni*	*Shipingia olseni*	*Shipingia olseni*	*Shipingia olseni*
		Redondestheria grovetonensis			*Redondestheria grovetonensis*	*R. grovetonensis*
	Alaunian	*Shipingia hebaozhaiensis*	*Shipingia hebaozhaiensis*		*Shipingia hebaozhaiensis*	
		Shipingia mcdonaldi	*Shipingia mcdonaldi*		*Shipingia mcdonaldi*	
		small *Shipingia* and large *Euestheria*	small *Shipingia* and large *Euestheria*		small *Shipingia* and large *Euestheria*	
	Lacian	*Euestheria buravasi* – *Euestheria* n. sp.	*Euestheria buravasi* – *Euestheria* n. sp.		*Euestheria buravasi*-*Euestheria* n. sp.	
		Palaeolimnadia schwanbergensis	*Palaeolimnadia schwanbergensis*	*Palaeolimnadia schwanbergensis*		
Carnian	Tuvalian	*Laxitextella freybergi*-*P. schwanbergensis*	*Laxitextella freybergi*–*P. schwanbergensis*			
		Laxitextella freybergi	*Laxitextella freybergi*	*Wannerestheria pennsylvanica*	Fulton site fauna/ *W. pennsylvanica*	
				H. ? ovata		
		Laxitextella seegisi	*Laxitextella seegisi*	*H. princetonensis*	*H. princetonensis*	*A. wingatella*
		E. gallegoi	*Eosolimnad. gallegoi*			
	Julian		Schilfsandstein faunas			
	Cordevolian	*Laxitextella laxitexta*	*Laxitextella laxitexta*			
		L. multireticulata	*L. multireticulata*		*L. multireticulata*	

Figure 1

Figure 1: Conchostracan zones of the Upper Triassic and Hettangian

Long distance marine biotic correlation events around the Carnian-Norian boundary: choice of *Halobia austriaca* as the defining boundary marker

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The Carnian-Norian boundary of present use has been defined by ammonoids in North America between the *Klamathites macrolobatus* and the *Stikinoceras kerri* Zones (Tozer, 1967). The same boundary is recognized in the Tethys placed there between the *Anatropites spinosus* and the *Guembelites jandianus* Zones (Krystyn, 1980). Characteristic latest Carnian genera in N.A. and the Tethys are *Euisculites, Thsibites, Hadrothisbites, Microtropites* and *Margarijuvavites*, replaced in the basal Norian by the distinct juvavitid genera *Dimorphites* and *Guembelites*. The sirenitid *Pterosirenites* is an important member auf the Canadian *kerri* Zone and allows a cross-correlation with the Boreal Realm where the base of the Norian is defined by the *Pterosirenites obruchevi* Zone. As this boundary reflects the strong faunistic changes observed between Carnian and Norian ammonoids and can in marine sediments be globally correlated, any new definition should follow it as closely as possible.

Other important Triassic fossil groups for high-resolution biochronology with interregional to global correlation potential are represented by pelagic bivalves (halobiids) and conodonts. The latter show, according to the most recent data, considerable provincialism during the C-N boundary interval with no clear correlations between North America and the Tethys. Species seem either to be endemic (*Metapolygnathus primitius* for N. A., *M. communisti* for the Tethys) or show distinctly differing ranges in the two regions (e.g. *Metapolygnathus echinatus*, *Epigondolella quadrata*) according to Orchard (2007) and Mazza et al. (2010). Another widely distributed form, *Norigondolella navicula*, misses a direct forerunner and its appearance is thought to be facially controlled since it does not occur in the GSSP candidate Pizzo Mondello (Mazza et al., 2010). A very distinct boundary marker seems the appearance of *Halobia* austriaca, which is dated to the base of the *jandianus* Zone in Austria by Krystyn (1980) and to that of the coeval *kerri* Zone of the GSSP candidate Black Bear Ridge in Canada by McRoberts (2007). Moreover, the FO of *Halobia austriaca* can be traced widely throughout the Tethys (Krystyn & Gallet, 2002) and, as the species occurs also in the Boreal and Notal Realms (Bychkov et al., 1976, Campell, 1994), it would allow a worldwide recognition of the CNB in marine environments.

The *austriaca* event is further strengthened by the timely coincidence with the LO of *Halobia radiata* in the Tethyan Hallstatt facies (Krystyn & Gallet, 2002) and in Canada (McRoberts, 2007). Only in Pizzo Mondello, *Halobia radiata* is mentioned to range into the basal Norian (Mazza et al., 2010) but these records have yet to be figured and are highly questioned here. Across the C-N boundary interval *H. radiata, H. austriaca* and *H. styriaca* constitute a sequence of short successive ranges in many areas of the Tethys and could therefore provide a firm basis for long distance correlations within the C-N boundary interval in generally ammonoid free but *Halobia*-bearing rocks (Krystyn et al., 2002).Other conodont proxies for the "*austriaca* boundary" are the widespread appearance of *Norigondolella navicula* and the closely following LO of the conodont genus *Metapolygnathus* s.str. (i.e. *M. communisti* group, including *M. echinatus*), two dates recognizable in North America (Orchard, 2007) as well as the Tethyan Hallstatt facies (Krystyn & Gallet, 2002). Magnetostratigraphically, the *austriaca* event is also very close to the base of the normal chron PM 5n of Muttoni et al. (2001) or UT 13n sensu Hounslow & Muttoni (2010), a chron widely recognized in Tethyan sections as proxy for the CNB (Krystyn & Gallet, 2002).

From all that I highly recommend considering the ***autriaca* event** as the **primary marker for the future CNB** due to the *highest correlation potential of all discussed biotic events*.

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An overview of the Sicilian halobiids from the Carnian-Norian boundary interval through the Pizzo Mondello fauna: useful proxies for the Norian GSSP

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The Late Triassic was a time of important biotic changes, especially around the Carnian/Norian boundary, and a global reference (GSSP) for the base of the Norian is still needed. In this view, the Pizzo Mondello section (Western Sicily, Italy) was proposed as a candidate for the base-Norian GSSP by Muttoni *et al.* (2001, 2004), and soon became one of the world references for the Late Carnian-Early Norian.

With the aim of providing macropaleontologic support to the GSSP proposal, the first 143 metres of the Cherty Limestone (Muttoni *et al.* 2001, 2004; Guaiumi *et al.* 2007) succession were sampled with a bed-by-bed criterion for ammonoids and halobiids during five field trips between spring 2007 and autumn 2009. The macrofossils include a total of 1107 halobiid specimens from 162 levels, which were classified and the best preserved individuals were processed for biometric analysis.

The study of the influence of taphonomy on the fossil record allowed the recognition three types of shell-lags: type (A) is characterised by single tri-dimensional valves mostly in convex-up orientation, type (B) by single or (possibly) articulated valves reduced to thin films and type (C) by small specimens dispersed in the rock matrix. This data were used to evaluate the occurrence of possible gaps in the fossiliferous sequence, which is considered to be reasonably complete.

In the Pizzo Mondello section, nine *Halobia* species occur (in stratigraphic order): *Halobia carnica*, *H. lenticularis*, *H. simplex*, *H. superba*, *H.* cf. *rugosa*, *H. radiata*, *H. austriaca*, *H. styriaca* and *H. mediterranea*. These forms from Pizzo Mondello were then compared with various collections world-wide, and especially from of Sicily, Lucania, Austria and North America to provide a revision of their systematics.

Because the ammonoids are not so frequent in the section, as well as in other coeval sections world-wide, the bivalves play a key role as correlation tools towards other macrofossils-rich sections. In fact, *Halobia* species have always been considered useful biostratigraphic markers, having ranges well calibrated with those of the ammonoids both in the Tethys and in North America, as well as a resolution comparable with that of ammonoids in terms of duration of the biozones.

The Pizzo Mondello section can be subdivided into 6 halobiid zones, which were used to propose a bio-chronostratigraphic interpretation of the succession. In this section, the first appearance of *Halobia carnica* marks the Tuvalian 2 substage (Late Carnian) and the genus ranges up at least to the Lacian 2 substage (Lower Norian).

Some halobiid marker events can be traced throughout all the Sicanian Basin. In facts, the most important species for the definition of the C/N boundary interval are *Halobia austriaca* and *H. styriaca*, and the levels bearing these two species can be recognised clearly at Pizzo Mondello as well as at Monte Cammarata and Monte Triona, two of the classic localities of this area.

Through the comparison of the faunas from Pizzo Mondello and those from Austria, Lucania (Southern Italy), Greece, Montenegro, and North America, a revision of the world-wide correlations based on *Halobia* species was achieved. The two species *Halobia austriaca* and *H. styriaca* result to be the best markers for world-wide correlations, especially the first one, occurring both in the Tethys and in North America at the base of this stage (Krystyn and Gallet, 2002; McRoberts, 2007).

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Sequence stratigraphy analysis of Triassic carbonate platform. An example from the Betic Cordillera Internal Zone (Spain)

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The studied Triassic succession belongs to the Alpujarride Complex of the Betic Cordillera Internal Zone (Spain). This succession, analysed in the Sierra de Gador (Gador-Turon unit), consists of a Meta-detrital fm (Mdf, Anisian) and a Meta-carbonate fm (Mcf). The Mdf is formed by a lower, middle and upper member. The Mcf is sub-divisible in six members (Ladinian-Carnian; from base to top): (1) marly-calcareous-dolomitic member, (2) dolomitic member, (3) fossiliferous calcareous-marly member, (4) cherty calcareous member, (5) mineralized calcareous-dolomitic member, and (6) marly-calcareous member. Each member is sub-divided in intervals. We attempted a sequence stratigraphic characterization of these deposits, based on stratigraphic and sedimentological features. Three depositional sequences (DS) have been identified, namely, DS1 in the Mdf, and DS2-DS3 in the Mcf.

The siliciclastic sediments of the lower member of the Mdf deposited in peri-continental environments. These sediments upwards grade to shallow marine carbonate deposits belonging to the middle member. According to that, we hypothesise that the lower member represents the LST (Low stand Systems Tract), the middle member represents the TST (Transgressive Systems Tract). Carbonates evolve to peri-continental siliciclastic sediments belonging to the upper member. We interpret the upper member as the HST (High stand Systems Tract) of DS1. The carbonate sediments of the Mcf deposited from the inner ramp (member 1 lower interval), to the middle-proximal outer ramp (member 1 middle-upper intervals and member 2), up to the distal part of the outer ramp (member 3 lower interval). According to that, we hypothesise that member 1 to member 3 lower interval represent the TST of DS2. The overlying carbonates show an evolution from the outer ramp (member 3 middle interval) to the middle-inner ramp (member 3 upper interval). We interpret this progradational stacking as the HST of DS2. The carbonate sediments of member 4 lower interval deposited from the middle to distal outer ramp. Consequently, this interval record a deepening-upwards trend. According to that, we hypothesise that member 4 lower interval represents the TST of DS3. A general shallowing-upwards tendency is recorded from member 4 middle interval (proximal outer-middle ramp) to the top of member 5 (deposited in tidal environments above fair weather base level). Consequently, we hypothesize that this tendency corresponds to the HST of DS3. In member 5, four parasequences have been recognized. We interpret them as related to tectonics-induced subsidence, because just in this part of the Triassic succession the occurrence of a strong syn-sedimentary extensional tectonics has recently been demonstrated (Martin-Rojas *et al*., 2009).

The sequences identified correlate with those recognized in other sectors of the Alpujarride domain the Germanic- and Alpine -type Triassic.

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Application of numerical cladistic analyses to the Carnian-Norian conodonts: a new approach for phylogenetic interpretations

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The high intraspecific variability of conodonts in the upper Carnian-lower Norian interval and the proliferation of numerous species in this relatively short stratigraphical time generated many problems in the understanding of the Late Triassic conodonts phylogeny, systematic and taxonomy. The abundance of synonymies *per* species and the absence of an established phylogenetic model contribute to increase the issues concerning the conodonts systematic. Unfortunately, being natural assemblages of the Late Triassic conodont apparatuses still unknown, a multielement approach to the problem would just introduce more biases instead of solutions. The application of cladistic methods to the platform elements, instead, may provide an extremely valid methodology in the understanding of their evolutionary relationships. Platforms are in fact the most abundant conodont elements and they have well observable evolutionary patterns and, thus, they can be considered as the primary basis for the interpretation of the Late Triassic conodont phylogeny.

We applied numerical cladistic analysis to the species belonging to the five most widespread Late Triassic genera (*Paragondolella*, *Carnepigondolella*, *Metapolygnathus*, *Epigondolella* and *Norigondolella*) from the Pizzo Mondello section (Sicani Mountains, Western Sicily, Italy), GSSP candidate for the Norian (Mazza *et al*., 2010 and references therein). This section provides several advantages for these kind of taxonomic and cladistic studies on conodonts: the section is a continuous succession of pelagic carbonate sediments (*Calcari con selce* or *Halobia Limestone auctorum*; Cherty Limestone, Muttoni *et al.* 2001, 2004; Guaiumi *et al.* 2007), characterized by uniform facies, high sedimentation rates and, more important, it has a rich conodont record which is representative of faunas spread in the entire Tethys.

A taxon-character data matrix describing the distribution of 68 characters among 2 outgroup and 32 ingroup taxa was thus compiled and processed using PAUP* 4.1.

The analyses confirmed the validity of a series of evolutionary trends among the platform elements, evidenced the most important morphological characters for their classification and led to a reinterpretation of the phylogenetic position of the genera considered: *Metapolygnathus* and *Epigondolella* resulted the only two monophyletic groups and, thus, true phylogenetic genera; *Paragondolella* a polyphyletic assemblage of basal members of the ingroup; *Norigondolella* a paraphyletic series of taxa bracketed by *Paragondolella* and *Carnepigondolella* a paraphyletic group including all conodonts more derived than *Paragondolella* and *Norigondolella* but outside the *Metapolygnathus* and *Epigondolella* clades.

These results show the potentiality of applying cladistic methods also to parataxonomic taxa. Parsimoniously grouping by synapomorphies (shared derived characters) provides a more informative classification than using simple similarities (phenetics). A cladogram, in fact, describing more of the character state changes than a phenogram, gives a higher information content and provides a more natural classification.

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Paleoecological controls on Triassic flat clam biochronology

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The biochronologic significance and correlation potential of the Triassic flat clams *Claraia*, *Peribositria*, *Enteropleura*, *Daonella*, *Halobia*, *Eomonotis*, and *Monotis* is demonstrated at regional and global scales. Their biochronologic and paleogeographic utility is likely a result of a combination of their unique paleoautecology in combination with a genetic propensity for rapid evolutionary and turnover rates in a high-stress regime. Their evolutionary paleoecology can, in the absence of modern analogs or genetic information, be inferred from morphological adaptations, their unique facies occurrence, and analogous yet anecdotal similarities from other non-pelagic bivalves.

Most Triassic flat clams were likely either freely resting or reclining without byssal attachment (e.g. *Peribositria*, *Enteropleura*, *Daonella* and *Halobia*) or attached with a feeble or weakly functioning byssus (e.g. *Claraia*, *Eomonotis*, and *Monotis*). Although occurring across a spectrum of accumulation modes, many (but not all) of these bivalves occur within episodic monospecific or paucispecific shell accumulations. Triassic flat clam accumulations may be associated with a demonstrable pelagic fauna including ammonoids, radiolarians, conodonts and globochaets. Many of these shelly accumulations are clearly a result of significant biostratinomic processes, yet the most informative shell beds are those that represent occasional or episodic census assemblages (= life assemblages) or within-habitat time-averaged assemblages (= neighborhood assemblages). Shell beds vary considerably in thickness (some achieving thickness of several meters or more), their accumulation suggest density independence. These shell beds show a rapid increase in population numbers until saturation occurs and can extend for 10s and perhaps 100s of meters laterally. The abrupt upper surface of shell accumulations likely represents a mass mortality event due to reduction in one or more limiting factors or introduction of lethal pathogen.

Major constraints in the occurrence of marine bivalves are bathymetry, turbidity, availability of substrate, temperature, dissolved oxygen, and nutrition. Given that Triassic flat clams occur in a broad spectrum of marine environments mostly in relatively open marine settings at variable water depths, temperature and salinity levels are likely relatively constant and not likely significant inhibitors to their distribution or occurrence. Adaptations to dysaerobic environments alone cannot explain all mass occurrence (and mass mortality) of Triassic flat clams as they also occur in fully oxygenated marine settings (e.g.

pelagic Hallstatt-type or cherty limestone facies). The nature of Triassic flat clam shell beds suggest an ephemeral or episodic factor (or factors) that might be associated with productivity driven variability in organic oxidization leading to decreased dissolved oxygen and/or toxicity due to phytoplankton blooms. Episodic oxygen depletions (dead zones) and the effects produced by harmful algal blooms (usually *dinoflagellates* and/or cyanobacteria that produce toxic pathogens) are a major source of mass mortality of modern macrobenthos and could explain the unique occurrence modes of Triassic flat clams.

Triassic flat clams likely comprise opportunistic populations that have the ability to rapidly colonize and dominate stressed open marine environments. Once colonization occurs, the flat clam population dominates the substrate to the exclusion of other benthic organisms. (dominance of the incumbent). This dominance may continue even if detrimental conditions become favorable. Following a mass mortality event (due to oxygen depletion, toxicity, or some other factor), subsequent migration/colonization can commence once stressed is reduced resulting in episodic replacement of flat clam populations of similar or different taxa.

Evolutionary/turnover rates of marine taxa are strongly correlated with habitats of high environmental stress and rapid fluctuations in environmental conditions tend to favor eurytopic species with high genetic diversity. Although near shore environments are often more associated with high-stress regimes, one would predict that similar evolutionary rates would be expected high-frequency changes in open-ocean environments subject to episodic stress. These flat clam populations likely exhibited low resistance to environmental perturbations but are resilient in that being able to recover quickly.

An exceptional conodont succession from the Carnian-Norian boundary of the Western Canada Sedimentary Basin, northeastern British Columbia

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Abundant and diverse conodonts from the Carnian-Norian boundary (CNB) of northeastern British Columbia (NE BC) record remarkable progressive morphogenesis documented in a ~85 m stratigraphic succession. Several new groups, formerly combined by this author as '*Metapolygnathus*', are differentiated on the basis of platform outline, lateral profile, and ornamentation; within each group, taxa show evolutionary trends involving a reducing platform, anterior migration of platform constriction, increased parapet or node development on the anterior platform margins, and/or anterior migration of the pit. New genera are proposed for some of these groups and a case is made for abandoning much of the present nomenclature, which is compromised by missing stratigraphic context and/or woefully inadequate definition.

Eight conodont faunas are recognized spanning mostly the Macrolobatus and Kerri ammonoid zones: the oldest three are based on changes in *Carniepigondolella*, the next four on progressive changes in several lineages including '*Metapolygnathus' primitius*, and the youngest on *Epigondolella quadrata* sensu stricto.

Fauna 1 (beds P-1: ~46 m) is characterized by *Carniepigondolella samueli* and related species and by relatively unornamented metapolygnathids exhibiting various platform shapes but lateral profiles that are flat or anteriorly down-curved. Most of these specimens have short free blades and a posteriorly located pit, although specimens of one uncommon group have a medial pit.

Fauna 2 (beds 1c-2a: 3.5 m) is marked by elements with longer free blades and reduced platforms in both *Carniepigondolella* and in smooth 'metapolygnathids'. The latter also exhibit the beginning of an important trend in elevated and noded anterior platform margins. A group of slender 'metapolygnathids' have a marked platform constriction in the posterior 1/3 of the platform.

Fauna 3 (beds 3-4: 1.5 m) comprises *Carniepigondolella* elements that show the culmination of the trend in reduced platforms with the appearance of several forms, including some that resemble the diminutive forms such as *Metapolygnathus echinatus* and *M. pseudoechinatus*. Strongly noded (not denticulated) 'metapolygnathids' appear and some also exhibit anterior migration of the pit.

Fauna 4 (beds 5-13: 7 m) is marked by the appearance of the '*Metapolygnathus' primitius* stock with subgroups having very narrow, expanded, quadrate, and pointed posterior platforms. Other groups have a more anteriorly located platform constriction, and others have raised anterior platform margins.

Fauna 5 (beds 13a-17: 7 m) includes '*M.' primitius* s. s. and similar forms, including some questionably included in *Orchardella*. Several groups show an anterior shift in the pit position, and one has the platform divided into two equal halves by a medial constriction. Curved, linguiform, and pointed groups are differentiated, some with nodose anterior platform margins and others with remarkable, sometimes pointed anterior parapets.

Fauna 6 (beds 17a-17c: 1 m) occurs in a narrow interval just before the preferred boundary level and marks a latest Carnian speciation event leading successively to forms with quadrate platform and medial pits, forms with very high parapets, and forms with both very narrow or very expanded posterior platforms.

Fauna 7 (beds 18a-18h: 1.2 m) includes new nodose forms including those close to '*Epigondolella' orchardi* and the first typical examples of the *Metapolygnathus parvus*. In particular, bed 18h marks the appearance of abundant *parvus* group representatives, and the last occurrence of many typical Carnian taxa. This fauna immediately precedes the turnover event.

Fauna 8 (beds 20-31: ~18 m) is distinguished from all the older faunas by the virtual absence of typically Carnian smooth 'metapolygnathids'. The *parvus* group remains common in bed 20 but is much less so above, where *Metapolygnathus communisti* and parapet-bearing species are also rare. *Norigondolella navicula* appears suddenly in bed 25 and continues through bed 31.

Fauna 9 (bed 32- up) is marked by the appearance of *Epigondolella quadrata* sensu stricto and similar forms. No smooth metapolygnathids have been recovered from this fauna, which passes up-section both here and in several others sections nearby into the *E. triangularis* fauna.

The Carnian-Norian boundary in Haida Gwaii: preliminary observations on the conodont faunas and their calibration with radiolarians

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Conodonts and radiolarians co-occur in the Late Triassic Kunga Group of Haida Gwaii (formerly Queen Charlotte Islands), part of the allochthonous Wrangel terrane that was accreted to western North America subsequent to its formation in more southerly latitudes. Revision of the Carnian-Norian boundary (CNB) conodont succession in the Pardonet Formation of northeast British Columbia (NE BC) prompted a reappraisal of the Kunga conodont faunas, which have elements in common with those from both the former region and with Eurasian Tethys. For example, many important CNB elements of the *primitius* and *parvus-echinatus* groups are common to both the Kunga Group and Pardonet Formation, whereas some other taxa such as the Tethyan *Neocavitella* occur only in Haida Gwaii.

Several sections on Haida Gwaii contribute valuable information on the association of conodonts and radiolarians around the CNB. Chief amongst these are Sadler Point, Frederick Island, Shields Bay, Huxley Island, Kunga Island, and Kunghit Island. In particular, at Sadler Point a succession that begins low in the Upper Carnian (Dilleri ammonoid Zone) ranges up through the Lower Norian *Epigondolella quadrata* Zone and embraces the CNB, which can be recognized by both the succession of conodonts and by the conodont faunal turnover recognized in the Pardonet Formation (Orchard, 2007, fig. 5). Many of the morphospecies newly differentiated in NE BC are recognized in the Kunga Group, as are the intervals characterized by the *samueli*, *"pseudoechinatus", primitius*, *orchardi,* and *quadrata* indices.

Amongst radiolarian species, the boundary interval is marked by the incoming at several levels of new species, most of which generally have been considered as either uppermost Carnian/lowermost Norian or lower Norian in the past (Blome, 1984; Tekin, 1999; Carter & Orchard, 2000; Bragin, 2007). Detailed sampling at Sadler Point produced two successive radiolarian faunas separated by about 3 m. The older one is characterized by *Braginastrum curvatus* Tekin, *Catoma geometrica* Blome, *Icrioma deweveri* (Tekin), *I. tetrancistrum* De Wever, *Kahlerosphaera kermerensis adentta* Tekin, *Bulbocyrtium insolitum* Blome group, *Mostlericyrtium sitepesiformis* Tekin, *Pachus* *longinqus* Blome, *Spinosiocapsa*? *yazgani* Tekin, *Trilatus praerobustus* Sugiyama and *Xipha nodosa* Sugiyama. Some of these taxa can be shown to occur earlier elsewhere on Haida Gwaii (e.g. Kunga Island, Shields Island), but their upper range is not yet established. Associated conodonts generally indicate a latest Carnian age.

The younger radiolarian fauna appears concurrently with the distinctive *Metapolygnathus parvus* group conodont fauna at Sadler Point and also on Frederick Island; also present in these collections are the conodonts *'Epigondolella' orchardi* and *Norigondolella* sp. Notable among the radiolarians are *Capnodoce crystallina* Pessagno, *Icrioma cruciformis* Tekin, *Loffa mulleri* Pessagno, *Paleosaturnalis izeensis* Blome, *Corum carinatus* (Tekin), *Hetalum parvis* (Tekin) and *Veghia sulovensis* Kozur & Mock. Together, these two succeeding faunal levels indicate that the transition from a typically Upper Carnian to Lower Norian radiolarian fauna takes place over a very short distance. Comparison with radiolarians reported from Pizzo Mondello (Nicora *et al*., 2007) suggests that this CNB succession of radiolarians in Haida Gwaii is probably older than the Norian fauna from Pizzo Mondello.

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Significance of Ladinian foraminifer-rich guide levels in the Betic Internal Zone (Spain)

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The Betic Cordillera is divided into three structural zones: the External, Flysch, and Internal Zones. The External Zone consists of units deriving from deformation of a palaeogeographic domain localized on the southern end of the Iberian plate. The Triassic successions of this domain, characterized by Germanic facies, are formed by thick continental and coastal deposits, with interbedded thin shallow marine carbonates. The Internal Zone is formed by three stacked tectonic complexes (from top to base: Malaguide, Alpujarride, and Nevado-Filabride Complexes). This Zone, made up of Palaeozoic and Meso-Cenozoic rocks, derives from deformation of a palaeogeographic domain interposed between the Iberian and the African plates, known as Mesomediterranean realm. The Mesomediterranean Triassic deposits, characterized by Alpine-type facies, comprise continental clastic deposits and over 1 km-thick shallow marine carbonates. The aim of this research is to interpret significance of *foraminifer-rich guide levels* found in the Triassic succession of the Internal Zone (Alpujarride C., Gador-Turon unit). This succession is made up of a Meta-detrital fm (Anisian) and of a Meta-carbonate fm formed by six members (mb; Ladinian-Carnian). Particularly, this succession (over 1500 m-thick) can be subdivided in three depositional sequences (DS): namely, DS1 in the Meta-detrital fm, and DS2-DS3 in the Meta-carbonate fm. *Foraminifer-rich guide levels* are two, each one about 7 m-thick, and localized at the top of mb 1. These levels are formed by decimetre beds of limestones with bioclastic packstone texture. They are comprised between marls, at the base, and dolostones, at the top, defining a shallowing upwards cycle. Particularly, the foraminifer-rich limestones show high-energy structures. Foraminifers are reworked and tractive parallel lamination is particularly developed.

These characteristic features indicate a deposition in the middle-outer ramp. Foraminifers consist of great size Involutinids. Among these benthic foraminifers, we found *Lamelliconus* gr. *biconvexus–ventroplanus* and *Lamelliconus cordevolicus* (Oberhauser). These taxa are considered as originating from the northern sectors of the Tethys. Their chrono-stratigraphic range extends from Ladinian to Carnian. Notwithstanding, the abundance and the size of these foraminifers are consistent with a Ladinian age. According to a sequence stratigraphic point of view, the *foraminifer-rich guide levels* found in mb 1 deposited in the context of a transgressive system tract (DS2) in which the maximum flooding surface lies in the carbonates of mb 3. Analogous beds, only 10 cm-thick, have been found in the *Muschelkalk* of the External Betic Zone (Pérez-López *et al.*, 2005). According to these latter, these foraminifer-rich limestones mark a l. Ladinian maximum flooding surface. Particularly, this maximum flooding surface should depend on a transgression responsible for the ingression (and proliferation) of these Tethyan foraminifers in the Germanic domain. In conclusion, differently from the *Muschelkalk* of the External Zone, the *foraminifer-rich guide levels* of mb 1 here studied and found in the Internal Betic Zone, do not testify the maximum flooding surface but a stage of a transgressive phase that will reach its maximum later, during deposition of mb 3 (l.-?m. Ladinian). This time-delay in reaching the transgressive maximum has important palaeogeographic implications. According to the palaeogeographic models of the western Neo-Tethys, in the Betic basin, the Germanic Triassic deposits of the External Zone and the Alpine deposits of the Internal Zone were parallel arranged and NE-SW stretched. The Betic Germanic deposits were located NW with respect to the Alpine ones of the Internal Zone. The first Ladinian maximum transgression occurred in different times in the two different Betic basins. It was early Ladinian in the *Muschelkalk* and more recent, presumably m. Ladinian, in the studied Alpine carbonates. Consequently, the different ages of the transgression should indicate that the sense of movement of the transgression wave probably was towards S.

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Stratigraphic architecture of Upper Triassic strata in the Williston Lake area, northeastern British Columbia: Implications for the Carnian-Norian GSSP

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Carnian and Norian strata in northeastern British Columbia, Canada are represented by the Charlie Lake, Baldonnel, Ludington and Pardonet formations. At Williston Lake, these sites comprise a complex, mixed siliciclastic-carbonate, westward deepening succession deposited in a distally steepened carbonate ramp setting on the northwestern margin of the Pangaea supercontinent. These strata comprise several transgressive-regressive cycles within a single large-scale, overall deepening upwards trend that spanned the entire Carnian & Norian in the study area. With the exception of the Charlie Lake Formation, these units are highly fossiliferous (Zonneveld and Orchard, 2002; Zonneveld et al., 2010). Most significantly conodont, ammonoid & bivalve collections from these strata have provided a template & framework for global biostratigraphic correlation (McRoberts, 2007; Orchard, 2007).

On the eastern margin of the study area continental and marginal marine strata of the Charlie Lake Formation grade upwards through shallow marine (proximal to medial ramp) strata of the Baldonnel Formation which are overlain by offshore (distal ramp) strata of the Pardonet Formation (Zonneveld and Orchard, 2010). Sites on the western margin of the study area consist of offshore (medial to distal ramp) strata of the Ludington Formation conformably overlain by offshore distal ramp) strata of the Pardonet Formation. A north-south-oriented ‘hingeline’ separates the shallow marine Baldonnel Formation from the deeper marine Ludington Formation. Regional isopach mapping & stratigraphic correlations show that several Carnian depositional units thicken considerably across this line supporting the interpretation that it represents the presence of a growth fault-bound western sub-basin. The presence of moderate-scale, olistolith-bearing debris flow deposits (debrites) as well as small-scale slumps/slides in the Ludington Formation adjacent to the inferred scarp margin support the interpretation that this scarp was active during the Upper Triassic.

The Carnian-Norian boundary interval is particularly well represented at Williston Lake. In eastern locales, such as East Carbon Creek and McLay Spur, the Carnian-Norian boundary occurs within bioclastic packstone and grainstone beds of the uppermost Baldonnel Formation (Zonneveld and Orchard, 2002). Further to the west, at Pardonet Hill, Juvavites Cove and Black Bear Ridge, the Carnian-Norian boundary occurs within heterolithic carbonate strata of the lower Pardonet Formation.

Black Bear Ridge, a candidate locality for the base-Norian Global Boundary Stratotype Section and Point (GSSP) occurs on the western side of the hingeline within the depositional sub-basin (Orchard et al., 2001; Orchard 2007; Zonneveld et al., 2010). The Black Bear Ridge section is apparently continuous, with no evidence for either subaerial exposure or submarine erosion. The absence of erosional scours in the study interval confirms emplacement of these strata well below both fair-weather and storm wave base. Evidence for continuous & relatively rapid sedimentation through the C-N boundary interval at this locality as well as minimal alteration by tectonic disturbances & lack of metamorphism make this locality an excellent GSSP candidate.

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Poster presentations:

Late Carnian-Early Norian ammonoids from the GSSP candidate section Pizzo Mondello (Sicani Mountains, Sicily)

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The Cherty Limestone of Western Sicily is known since the XIX century for the rich record of Carnian to Norian pelagic bivalves (halobiids) and ammonoids, which were monographed by Gemmellaro (1882, 1904). Since Gemmellaro's time, the knowledge on halobiids has been improved mostly by De Capoa (Cafiero & De Capoa Bonardi, 1982; De Capoa Bonardi, 1984), while no new data has been published for the ammonoids. Gemmellaro's collection, consisting of 780 specimens classified into 230 taxa, has come from several localities, but without stratigraphic control on the fossil-bearing levels. For this reason Gemmellaro's collection has never been taken into account for the refinement of the Upper Triassic chronostratigraphic scale, despite of the very good quality of the specimens.

Here we present the results of very dense bed-by-bed sampling carried out on the GSSP candidate section Pizzo Mondello within the last 4 years, in the framework of an integrated bio-chronostratigraphic research aimed to support the magnetostratigraphic scale provided by Muttoni et al. (2001, 2004).

Though ammonoids are relatively rare in the section, the possibility to follow the beds along strike for longer distance allowed us to collect about one hundred specimens in situ from the Carnian-Norian boundary interval. About 2/3 of them are of small to very small size, but the remaining specimens are large and complete enough for a classification at least at a generic level. *Gonionotites*, *Projuvavites*, "*Anatomites*", *Dimorphites* are the most frequent genera together with Arcestidae, and more rare *Discotropites*, *Anatropites* and Phylloceratina. The relatively abundant "trachyostracaean" ammonoids document the *Discotropites plinii* and the *Gonionotites italicus* Subzones of the latest Carnian *Anatropites spinosus* Zone and the *Guembelites jandianus* Zone of the earliest Norian.

The *D. plinii* Subzone is recognized in the lower part of the section by the occurrence of the index species, together with some early *Gonionotites*. The *G. italicus* Subzone is characterized by *Gonionotites* gr. of *italicus*, *G. maurolicoi*, *Projuvavites*, "*Anatomites*" and a single *Anatropites*. *Gonionotites* is especially frequent in this zone that is recognized between about 50 to about 82m from the base of the section, with the single *Anatropites* found nearly on top of this interval.

After about 18 m without ammonoids *Dimorphites* has been found, with several small specimens from at least 3 levels. Comparison of these specimens with a large collection of *Dimorphites* n. sp. 1 of Krystyn (1980) and *D. selectus* from Feuerkogel lead to refer by *confronta* the Pizzo Mondello specimens to *Dimorphites* n. sp. 1. This identification suggests the attribution of this interval to the first subzone of the *Gumbelites jandianus* Zone, the first zone of the Norian Stage. Moreover, these specimens are also very close to *Dimorphites pardonetiensis* sensu Tozer, 1994, pl. 114, fig. 1, allowing thereby a cross-correlation of this interval with Subzone 1 of the basalmost Norian *Stikinoceras kerri* Zone of British Columbia (Canada).

The new data, although based on relatively sparse ammonoids, provide a high resolution calibration for the conodont and halobiid bioevents, as well as for the magnetostratigraphic scale. New investigations at two other fossil-rich sites in the surroundings of Santo Stefano Quisquina and Castronuovo di Sicilia are in progress, in order to test and to integrate the ammonoid record at Pizzo Mondello.

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Radiolarian assemblages from the Norian GSSP candidate Pizzo Mondello section (Sicani Mountains, Sicily)

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Pizzo Mondello section (Sicani Mountains, Western Sicily) is one of the best localities in the world for the definition of the Carnian/Norian boundary and presents a combination of features to be candidate as GSSP section for the base of the Norian. The exposed succession is made of 450 m thick pelagic-hemipelagic limestones (*Calcari con selce* or *Halobia limestone Auctt.*). The *Calcari con selce* of Pizzo Mondello were divided by Muttoni *et al.* (2001, 2004) in four lithozones. The Carnian/Norian boundary interval occurs into the lower part of the section (140 m thick, lithozones I and II), consisting of well bedded white to yellow calcilutites, with black chert nodules. Pizzo Mondello section is well known for the different analysis carried out in the past: primary magnetostratigraphic record and stable isotope variations (Muttoni *et al.*, 2001, 2004), lithological and sedimentological investigations (Guaiumi *et al.*, 2007, Nicora *et al.,* 2007) and biostratigraphic calibration integrating conodonts, ammonoids, pelagic bivalves and radiolarians, still in progress. In the 140 m thick lower part of the section the Carnian/Norian boundary interval is 30 m thick and lies magnetozones PM4n and PM4r as well the positive shift of $\delta^{13}C$. Conodonts are the most promising tool for the definition of the base of the Norian and two major events were identified with the FAD of *Epigondolella quadrata* Orchard and the FAD of *Metapolygnatus communisti* Hayashi (Nicora *et al.*, 2007, Balini *et al.,* 2008, Mazza *et al.*, 2010). Conodont biostratigraphy and taxonomy around the Carnian/Norian boundary is rather problematic because of the apparent provincialism of most of the conodont species (Kozur, 2003; Mazza and Rigo, 2008). An additional tool for global correlations is represented by radiolarians, found in several samples with rich and diversified assemblages. Radiolarian assemblages permit to improve the biostratigraphic resolution of the Carnian and Norian stages, and allow to discriminate between the two proposed FAD for the base of the Norian.

In the 30 m thick Carnian/Norian boundary interval the first Early Norian radiolarian assemblage occurs about 4 m above the FAD of *Epigondolella quadrata* Orchard and about 14 m below the FAD of *Metapolygnatus communisti* Hayashi. This radiolarian assemblage is referable to Early Norian for the presence of *Blechschmidtia raridenticulata*

(Kozur & Mock), *Braginastrum curvatus* Tekin, *Capnuchosphaera constricta* Kozur & Mock*, Capnuchosphaera concava* De Wever*, Capnuchosphaera deweveri* Kozur & Mostler*, Capnuchosphaera theloides* De Wever, *Capnuchosphaera tricornis* De Wever, *Kahlerosphaera kemerensis adentatus* Tekin, *Kahlerosphaera norica* Kozur & Mock, *Mostlericyrtium sitepesiforme* Tekin, *Paronaella norica* Kozur & Mostler*, Podobursa akayi* Tekin, *Spinopoulpus noricus* Kozur & Mostler, *Spongotortilispinus tortilis* Kozur & Mostler and *Xiphothecaella longa* (Kozur & Mock). New radiolarian assemblages from 30 m thick Carnian/Norian boundary interval are still in progress to contribute for the definition of the new stratigraphic ranges.

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Triasina hantkeni limestones from Western Sicily

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Lagoonal limestones with Triasina hantkeni Majzon are described from Upper Triassic carbonate platform successions cropping out in western Sicily.

These facies were recognized in two different thrust sheets of the Maghrebian chain:

a) At Monte Sparagio near the San Vito Lo Capo peninsula (northwestern Sicily), a structural unit which is regarded as belonging to the Panormide Carbonate Platform. In this unit the Mesozoic stratigraphic succession consists of Upper Triassic to Lower Jurassic peritidal cyclothems followed by Rosso Ammonitico pelagics and uppermost Jurassic to Cretaceous slope limestones. The base of the outcropping succession consists of whitish-grey dolomitized limestones of Late Triassic age that can be ascribed to the Sciacca Formation. Peritidal facies, namely megalodont limestones, stromatolitic limestones and green marls, are cyclically arranged along the succession. The uppermost zone of these limestones shows the common occurrence of Triasina hantkeni, a benthic foraminifer that is abundant in Rhaetian neritic beds from the Tethyan realm. Triasina hantkeni is present in lagoonal sediments, consisting of thick-bedded whitish packstone/grainstone with dasycladacean algae, other benthic foraminifera, thick-shelled bivalves and oncoids (Di Stefano et al., 2009). They occasionally alternate to coral carpets (*Rhaetiophyllia*-type);

b) At Pizzo Telegrafo, in the Sciacca area (southwestern Sicily). In this locality a platform-derived structural unit which belongs to the so called Saccense units outcrops. The most basal beds exposed in this unit consist of peritidal-lagoonal cycles (Sciacca Fm.) that laterally are transitional to well preserved Upper Triassic, *Dachstein*-type, reef limestones. A Rhaetian terminal complex, with chaetetid-dominated boundstones associated to Triasina hantkeni, characterizes the topmost zone of the reef limestones. The development of this terminal complex is probably related to the end-Triassic biotic crisis.

A sharp discontinuity surface on top of the Triasina hantkeni beds is overprinted in places by karstic dissolution in both sectors. It is interpreted as an evidence of a late Rhaetian sea-level fall locally amplified by the platform uplift (Monte Sparagio). The subsequent aggradation of peritidal cycles indicates the recovery of the carbonate productivity coupled to a sea-level rise during Hettangian times.

The absence of *Triasina hantkeni* limestone beds in the eastern sector of the Panormide carbonate platform is probably due to a deeper, tectonically enhanced, erosional truncation (Zarcone *et al., this volume*).

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Lower and Middle Triassic Stratigraphy of the Western Canada Basin and Implications for Timing of Terrane Accretion

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The Western Canada Sedimentary Basin (WCSB) stretches from the Yukon in the north, down through British Columbia and Alberta to the border with the USA, where sedimentation is continuous into the Laramide Basin. It contains rocks of Mississippian age through to Jurassic. The Triassic part of the sequence has been well studied due to the large volumes of natural gas contained within these rocks. The majority of this gas is found in the subsurface Montney and Doig formations (Griesbachian to Ladinian), which have been most completely described in Alberta. In an effort to encourage petroleum exploration to the west in BC, stratigraphic studies are being carried out on the surface equivalents to the Montney and Doig formations, namely the Grayling, Toad and Liard formations. Collection of conodont and ammonite samples, as well as gamma ray measurements from surface sections in north-eastern BC, allow for correlation with rocks in the subsurface and elsewhere in the WCSB. This will lead to an improved understanding of sedimentation in the basin during the Lower and Middle Triassic. This is an important time period for western Canada, as it contains the first evidence for the accretion of pericratonic terranes to the ancestral margin of North America. Sedimentary provenance studies combined with the new stratigraphical correlations in the WCSB will allow the timing of this event in BC to be more tightly constrained.

Halobiid bivalves as a tool for high resolution correlation between Carnian-Norian successions in Tethys and Panthalassa: a potential datum for a base-Norian GSSP

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The Carnian/Norian boundary interval remains to be defined by the Subcommission on Triassic Stratigraphy and has seen significant research activity over the last years, especially on the two GSSP candidates: the west-Tethyan section at Pizzo Mondello (Sicily, Italy) and the east Panthalassan section at Black Bear Ridge (B.C., Canada). Significant progress has been made in understanding bio-chronological markers by the two workgroups. Ammonoids are often considered as the primary tools for bio-chronological studies and worldwide correlations, but other taxa (especially conodonts and radiolarians) and magneto- and chemo- stratigraphic events can provide useful datums. Both the Pizzo Mondello and Black Bear Ridge sections have a rich conodont record and a rich halobiid record, but are somewhat lacking in ammonoids. Stable isotope chemostratigraphy is not fully advanced to provide meaningful correlations and magnetostratigraphy is only available for Pizzo Mondello. We suggest halobiid bivalves as one of the best tools of correlating the C/N boundary successions, and as a possible GSSP defining datum. Many *Halobia* species are widely distributed and exhibit high speciation rates, with a resolution comparable with that of ammonoids in terms of duration of the biozones. Although often hampered by preservation/taphonomic issues and a poor understanding of intrapopulational morphological variation, sufficient data on key species have been collected to allow precise correlation of more than one bioevent within the C/N interval between the west-Tethyan and eastern Panthalassic realms.

In the Pizzo Mondello section, nine *Halobia* species occur (from base to top): *Halobia carnica*, *H. lenticularis*, *H. simplex*, *H. superba*, *H. septentrionalis (= H.* cf. *rugosa* of Levera, 2010), *H. radiata*, *H. austriaca*, *H. styriaca* and *H. mediterranea* (Levera, this volume). Most, if not all, of these taxa and their succession are repeatable throughout much of the western-Tethys, especially in Austria, Lucania (Southern Italy), Greece and Montenegro. The halobiid sequence at Black Bear Ridge includes, from base to top, six species: *Halobia septentrionalis*, *H. ornatissima*, *H. radiata*, *H. selwyni, H. austriaca*, and *H. cordillerana*. Likewise, most of these Canadian taxa provide strong correlations across eastern Panthalassa (including the tectonostratigraphic terranes of western North America) and especially throughout far-eastern Russia.

Within the C/N interval, there are several species common to both Pizzo Mondello and Black Bear Ridge which offer potential for global correlation and may provide a potential datum of the base-Norian GSSP. At Pizzo Mondello, the C/N interval closely corresponds to the first occurrence of *Halobia austrica, H. styriaca,* and *H. beyrichi* and species of the same group best represented in low palaeolatitudes with notable occurrences in the western and eastern Tethys and eastern Panthalassa. While *H. styriaca* is common in the western and eastern Tethys and western Panthalassa, it has not yet been reported in western North America. Similarly, *Halobia beyrichi*, which is only known from a few occurrences in the terranes of British Columbia, is not known to occur in craton-bound strata such as at Black Bear Ridge. *Halobia austrica*, on the other hand, is a taxon that is most wide-spread, occurring in the tropical western and eastern Tethys, throughout Indonesia and the western Panthalassa, the Boreal of northeastern Russia and throughout the North American Cordillera.

At both Pizzo Mondello and Black Bear Ridge, first appearance of *Halobia austriaca* is closely associated with a turnover in conodont faunas. At Pizzo Mondello, this datum is about 1 meter above the T3 event of Mazza *et al.* (2010) which marks the mass disappearance of most *Metapolygnathus* species, with the exception of "*Metapolygnathus communisti* B", appearing at this level. At Black Bear Ridge, the FAD corresponds precisely with a turnover to a *Metapolygnathus echinatus* dominated conodont fauna (see Orchard, 2007).

We underline therefore the role of *Halobia austriaca* first appearance datum as the best proxy of the base of the

Norian stage in world-wide correlations.

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Triassic and Jurassic calcareous nannofossils of the Pizzo Mondello section: potential for biostratigraphy

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Pizzo Mondello is a ca. 500 m long pelagic-hemipelagic succession cropping out in Sicily. The section mostly consists of a nodular cherty limestones facies association of upper Carnian to upper Norian age, with the uppermost portion, believed to be Rhaetian (Gullo, 1996), represented by plane-bedded limestones of the Portella Gebbia formation. Due to exceptional exposure conditions, richness of fossil content and low thermal maturity that allowed the preservation of magnetic polarity inversions and carbon isotopes, this section was proposed as GSSP for the Norian stage (Muttoni et al., 2004; Mazza et al., 2010).

The calcareous nannofossil content of limestones was studied with Scanning Electron Microscopy (SEM) in two portions of the Pizzo Mondello section, one within "La Cava" that encompasses all proposed horizons for the base of the Norian, and one within the Portella Gebbia formation in the uppermost part of the section.

Calcareous nannofossil assemblages of the first portion displays a low diversity, being constituted exclusively by cf. *Thoracopshaera* calcispheres, that may constitute up to 40% of the sediment.

Species richness increases in the upper portion, where calcareous nannofossils are constituted both by "calcispheres" (cf. Allaby and Allaby, 1990) of uncertain taxonomic affinity and coccoliths. Initially, samples are dominated by *Prinsiosphaera*, a nannolith of unknown taxonomic affinity. Rare calcareous dinoflagellate cysts (*Thoracosphaera geometrica*) and coccoliths are present in few samples. Uppermost samples are still dominated by "calcispheres" comparable to *Thoracosphaera*, but also yield a variety of coccoliths.

Conodont biostratigraphy was used to date the occurrence of the different calcareous nannoplancton taxa. Cf. *Thoracosphaera* of the lower portion are thus dated to the late Carnian to early Norian, while samples dominated by *Prinsiosphaera*, with rare *Thoracosphaera* and coccoliths are Rhaetian. The calcareous nannofossil assemblage of the uppermost samples, along with the absence of conodonts, point to a Jurassic age for the uppermost Portella Gebbia formation at Pizzo Mondello.

In conclusion, the uppermost part of the Pizzo Mondello section is Jurassic, i.e., younger than previously thought. Calcareous nannofossils are present from the base of section and exhibit a significant taxonomic diversity, thus providing an auxiliary biostratigraphic tool especially for the Rhaetian - Jurassic interval.

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Stratigraphy of the Carnian – Norian Calcari con Selce in the Lagonegro Basin (Southern Apennines) and correlation with the Sicani Basin

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The Upper Triassic Calcari con Selce Formation, cropping out in the southern Apennines (S Italy), consists of 400 m of micritic limestones, often nodular, with chert lists and nodules organized in dm to m beds, intercalated with mm (rarely centimetric) marly horizons. Within this formation, three intervals characterized by higher siliciclastic component have been recognized:

1) the green clay-radiolaritic horizon (Rigo *et al*., 2007), previously known as "livello argilloso ad *Halobia superba*" (e.g. Scandone, 1967), Julian/Tuvalian (lower/upper Carnian);

2) a interval of some tens of meters of limestones and brown shales, with abundant chert beds, Carnian/Norian;

3) the ca. 3 m thick red shale horizon (Rigo *et al*., 2005), Sevatian (upper Norian) in age.

All these intervals are characterized by micritic limestones or marly limstones with bivalves, radiolarians and conodonts alternated with shales (green, brown or red) having thicknesses of 50 cm or more. These intervals are also associated to an increase of calciturbidites, constituted of echinoderm fragments, isolated thin-shelled bivalves and reworked, partially lithified intraclasts of the Calcari con Selce Fm.

In particular, the second terrigenous interval is characterized by a basal portion consisting of bioturbated limestones with little chert intercalated and m-thick brown clayey horizons ("Giglio del Cavaliere" facies), followed by a thick portion of nodular cherty limestones overlaid by an alternation of abundant calciturbidites or marly limestones with chert and 50-cm-thick shale horizons ("Gianni Grieco" facies). Above, the normal cherty limestones sedimentation resumes. Conodont biostratigraphy allows a preliminary correlation with Pizzo Mondello in the Sicani Basin. Thus, the Giglio del Cavaliere facies might be correlated to Tuvalian facies A of Pizzo Mondello section for the presence of *Metapolygnathus praecommunisti* and *Paragondolella polygnathiformis*, and the Gianni Grieco facies to Lacian facies C of Pizzo Mondello because of the joint occurrences of *Epigondolella rigoi* and *Metapolygnathus parvus* (see Mazza *et al.*, 2010).

The Carnian green clay-radiolaritic horizon and the Sevatian red siliciclastic interval are useful lithostratigraphic markers recognizable throughout the Lagonegro Basin and have been used as guide horizons to evaluate the lateral continuity of contiguous limestone beds. The green clay-radiolaritic horizon has been logged in 4 sections (Pignola 2, Mt. Armizzone, Pezza la Quagliara, San Michele), presently separated by up to 50 km - but Tertiary thrusts occur between the sections. Above the green clay-radiolaritic horizon, single carbonate beds or banks with the same stratigraphic position and common characteristics are recognizable in all sections. The thickness of these limestone beds may vary, but the shale interlayers and cherty beds are identical, thus, the carbonate beds have been correlated.

The stratigraphic interval comprising the Sevatian red shale horizon has been acquired in two sections separated by 7 km, Monte Buccaglione and Monte Cugnone, with a terrestrial LIDAR. LIDARs produce high resolution and high accuracy 3D representations of outcrops, stored as point-clouds. A regular sequence of limestone beds and shale interlayers, distinguished because of their different reflectance, has been recorded below the red shale horizon, and the thickness of single carbonate banks resulted identical within the instrumental resolution.

Calcareous beds or banks thus can be correlated at the basinal scale. This implies that the Lagonegro Basin is characterized by laterally continuous carbonate sedimentation, most probably controlled by allocyclic factors. There is thus potential for a cyclostratigraphic study of the Carnian – Norian succession of the Lagonegro Basin.

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The revision of *Pinacoceras* (Ammonoidea, Upper Triassic) of the Gemmellaro Collection

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The Triassic ammonoids described by G.G. Gemmellaro constitute one of the most important collections housed in the homonymous museum of Palermo University. This collection is composed of 780 specimens attributed to 49 genera that are further divided in 230 taxa of which 166 have been erected by Gemmellaro. The collection was done between the end of 1800 and the first years of 1900 by Gemmellaro or his co-workers. All the ammonoids of this collection have been described in the monograph "*I cefalopodi del Trias Superiore della regione occidentale della Sicilia*" (Gemmellaro, 1904). This monograph provides the final report of the taxonomic and stratigraphic studies performed by Gemmellaro on the Triassic cephalopoda.

Since the beginning of the XX no studies on Upper Triassic ammonoids from Sicily have been carried out, while the taxonomy and biostratigraphy of coeval faunas have been notably improved in other Tethyan areas and North America. As a consequence the original taxonomy by Gemmellaro was no more up to date, and his collection needs a deep systematic revision. Two years ago we started a project aiming at this revision and we present here a first contribution on the genus *Pinacoceras*.

The type species of this genus is *Pinacoceras metternichi* (Hauer, 1846). It was established by Mojsisovics, 1873 on specimens from Hallstatt (Northern Alps, Austria), and it includes 34 species divided into 6 groups. For a long time *Pinacoceras* has been considered a "basket" containing a wide variety of species. Some authors have tried to provide a more refined taxonomy of the genus, by separating some groups as independent genera like *Eupinacoceras*, *Parapinacoceras*, *Placites* (see Arkell et al. 1957).

Gemmellaro originally described 4 species of *Pinacoceras*, but actually only 3 of them are documented in the Gemmellaro collection: *P. zitteli* Gemmellaro, 1904, *P. suessi* Gemmellaro, 1904, *P. haueri* Gemmellaro, 1904.

The type specimens of these 3 species have been re-described and, as a result, we suggest to include *Pinacoceras suessi* into *Eupinacoceras* Spath, 1951 for the characteristic sutural line.

The remaining Sicilian species show some different features from *Pinacoceras* s.s. (i.e., the group of *P. metternichi*), such as the Uw/D parameter and the more simple sutural line. The cronostratigraphic distribution is different too, in fact *P. metternichi* (Krystyn, 2008) is referred to the Upper Norian-Lower Rhaetian stage while the Gemmellaro species probably came from Carnian beds. For all of these reasons most probably *P. zitteli* and *P. haueri*, represent a separate group of *Pinacoceras*.

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End Triassic karstification of a south Tethyan carbonate platform: the genesis of the "Libeccio Antico" a famous Baroque dimension stone

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The S.Vito Lo Capo Peninsula is the most important area for the extraction of dimension and ornamental stones in Sicily (Bellanca and La Farina, 1962). This area is known as the Custonaci (marble) district. At present the most quarried stone is the "Perlato di Sicilia" a rudist limestone breccia of Cretaceous age. Triassic and Jurassic limestones were also quarried and a famous polichrome limestone known as the *Libeccio Antico* was appreciated mostly during the Baroque age (Montana and Gagliardo, 1998). This ornamental stone offers a good example to discuss the evolution of the Panormide Carbonate Platform around the Triassic/Jurassic boundary. The old quarries of *Libeccio Antico* are located along the northern slope of Monte

Sparagio, an E-W trending ridge that extends for about 15 km from the locality of Scopello to the village of Custonaci.

Monte Sparagio is regarded as a structural unit belonging to the Panormide domain (Abate *et al.*, 1991). The stratigraphic succession of Monte Sparagio consists of Upper Triassic-Lower Jurassic shallow-water limestones, Middle and Upper Jurassic ammonitic limestones, uppermost Jurassic-Lower Cretaceous *Ellipsactinia* limestones, Cretaceous rudist breccias with intercalations of volcanites, Oligo-Miocene calcarenites and clays (Giunta and Liguori, 1972).

Recent studies allow a better definition of the facies sequences and stratigraphy of the Triassic and Lower Jurassic.

The base of the outcropping succession consists of about 450 m of parallel bedded, whitish-grey, dolomitized limestones of Late Triassic age that can be ascribed to the Sciacca Formation. Peritidal facies, namely megalodont limestones, stromatolitic limestones and green marls, are cyclically arranged along the succession. The uppermost zone of these limestones shows the common occurrence of *Triasina hantkeni* MAJZON (Di Stefano *et al.*, 2009). These beds are marked by the presence of an intense network of paleokarstic cavities filled up with polychrome silts, as observable at Contrada Cocuccio quarry. Worth noting is that the quarries of Libeccio antico are aligned in a relatively narrow stratigraphic interval that correspond to the topmost zone of the Triassic succession. A discontinuity surface (paraconformity) overprinted by karstic dissolution, separate the Triassic strata from the Lower Jurassic ones. This change is marked by the disappearence of large Megalodonts, and of *Triasina hantkeni* and the presence of *Aeolisaccus* sp. and of valvulinids associated to *Thaumatoporella parvovesiculifera* (RAINERI). The facies organization of the Lower Jurassic strata is similar to the Triassic ones. Metre-scale peritidal cyclothems develop upsection for a total thickness of about 200 m (Inici Formation).

The paleokarstic overprint of the peritidal cycles is partly due to the periodical emersion of the carbonate platform during the cycle formation but mainly related to a discontinuity surface on top of the Triassic strata. Dissolution cavities filled with polychome silts or collapsed breccias develop from this surface downwards. A well exposed metre-scale cavity filled-up by laminated red silt can be observed along the quarry walls. Moreover a network of stratal to oblique neptunian dykes filled up by pink to gray marine sediments related to the Rosso Ammonitico and to the *Ellipsactinia* limestones crosscut all the previous structures. The karstification of the platform top may be related to the end-Triassic sea level fall (Hallam, 1997). However the deep karstic system, speak in favour of a tectonic uplift of the Panormide Platform around the T/J boundary as already suggested by Zarcone & Di Stefano (2008, 2010) to explain the deep erosion of the Upper Triassic strata in the Palermo and Madonie Mountains. The regional uplift of the Panormide Carbonate Platform, at this time, could be interpreted as the isostatic response to the rifting in the adjacent Alpine Tethis, which has fragmented the wide Triassic carbonate realm surrounding the Ionian Tethys.

In conclusion the Libeccio Antico polichrome ornamental stone appear to have been originated by the karstification of the peritidal cycles of the Panormide Carbonate Platform close to the T/J boundary and by the later (Jurassic) overprinting of neptunian dykes.

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From: Salvador, A. (ed.), 1994. International Stratigraphic Guide. Second Edition. International Commission on Stratigraphic Classification of IUGS International Commission on Stratigraphy. IUGS/GSA, Boulder, Co, p. 66.

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