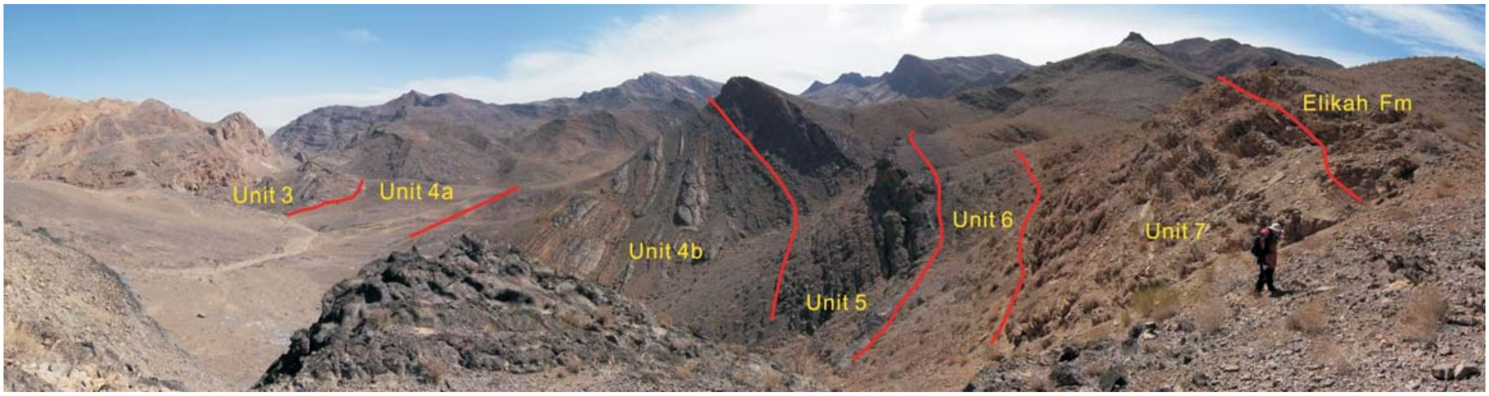
Permophiles

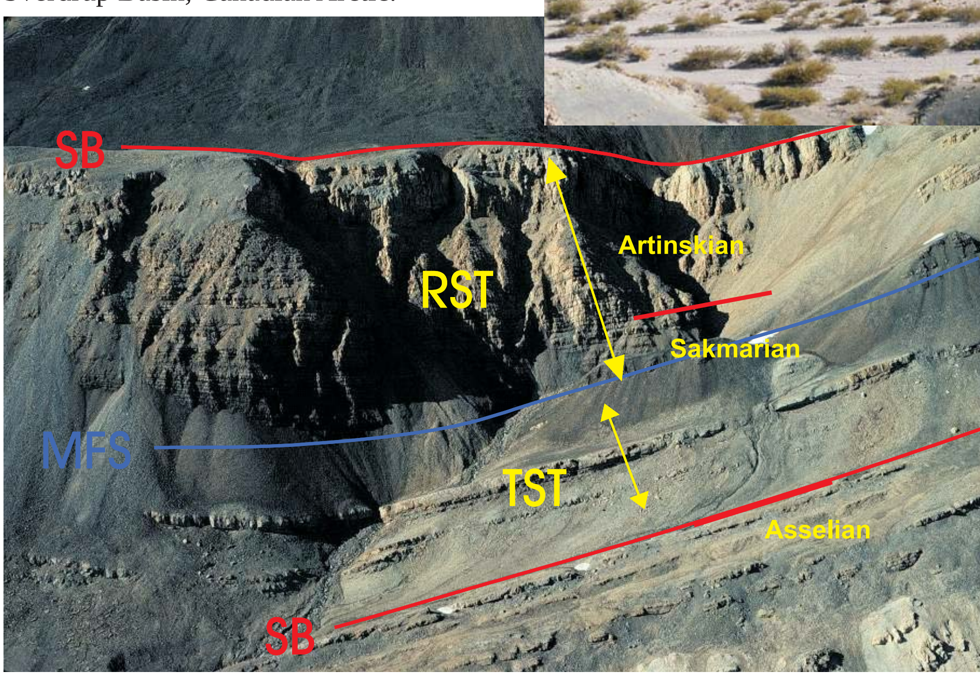
International Commission on Stratigraphy
International Union of Geological Sciences



The Upper Permian and Lower Triassic of Iran (p. 2).
Photo by Shuzhong Shen.

Right: The Lower Permian of Uspallata Hills. The major transgression marks the end of major Gondwana glaciation although some minor glacial deposits occur above. Photo by Charles Henderson. See Taboada et al. (p. 13).

Below: Notice the similarity in sequence stratigraphic signature with high-frequency cycles in Asselian and earliest Sakmarian and major 3rd order sequence above. Photo by Benoit Beauchamp from Ellesmere Island, Sverdrup Basin, Canadian Arctic.



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Contents

EXECUTIVE NOTES

Notes from the SPS Secretary

Shuzhong Shen

Introduction and thanks

This issue was planned to be edited by Charles and I in Calgary during the International Conodont Symposium (ICOS 2009). I attended ICOS 2009, but had to come back immediately after ICOS 2009 for an NSFC meeting in Beijing, and Charles was busy in guiding the post-symposium field excursion in the Rocky Mountains. So we didn't actually have time to sit together to edit Permophiles. I would thank Charles for organizing such a wonderful conodont symposium in Calgary. I enjoyed the sessions and the beautiful scenery in the Rocky Mountains. I would particularly thank Christine MacLean for typesetting this issue. Charles revised the English for all contributions. I would thank Arturo C. Taboada and his Argentine colleagues, G. Cassinis and his colleagues, Wang Yue, Zhang Yichun of the Nanjing Research Group for their contributions to this issue. I would like to use this opportunity to thank our Iranian colleagues for their excellent guiding and all of their kindness for the joint field excursion in central Iran (see a detailed report by Shuzhong Shen in this issue).

Previous and forthcoming SPS Meetings

An SPS business meeting was held immediately after the Session "Permian conodonts" on the 14th of July during ICOS 2009 in Calgary. SPS Chair Charles Henderson chaired the SPS business meeting. The former SPS Chair Bruce Wardlaw, SPS Vice-Chair Vladimir Davydov, SPS Secretary Shuzhong Shen joined in the business meeting. The other individuals in attendance included Markus Aretz, Mei Shilong, Qi Yuping, Carine Randon, Barry Richards, Tamra Schiappa, Mark Schmitz, Kate Tierney and Wang Xiangdong. SPS made some very important discussions. In the business meeting, Charles Henderson reported the conodont results based on the samples collected from the three Cisuralian (Sakmarian-base, Artinskian-base and Kungurian-base) GSSP candidates in southern Urals, Russia during the field excursion in southern Urals organized by Boris Chuvashov and Vladimir Davydov in 2007. I presented the carbon isotope data from the latest Carboniferous to the Early Artinskian of the Usolka, Dalny Tulkus and the Kondurovsky sections. Kate Tierney of Ohio State University presented a similar Early Permian curve based on sections in South China and USA. Mark Schmitz, earlier in the day, reported on the Sr-isotope curve from conodonts for the Cisuralian GSSP interval. Unfortunately, the conodont lineage to define the Sakmarian-base GSSP at the Kondurovsky section proposed by the Cisuralian Working Group was not fully recovered based on the samples Charles and I processed. In addition, samples were dominated by either juveniles-only or reworked specimens. Furthermore, Charles Henderson pointed out problems with respect to the FAD of *Sweetognathus merrilli* based on new material from Bolivia – it may appear much earlier in Bolivia compared to Russia. Furthermore, the only geochronologic ages for this interval in the region are from the Usolka section. According to Charles' conodont results, the Dalny Tulkus section as the candidate of Artinskian-base GSSP contains a better conodont succession, but analyses of geochemical samples indicates possible serious diagenetic issues. In addition, the boundary interval does not outcrop well and should be better exposed. The FAD sample of *Neostreptognathodus pnevi* at the base of Kungurian at the Mechetlino GSSP candidate section did not contain any conodonts. Thus, SPS considered that the Kondurovsky and the Mechetlino sections are probably no longer appropriate to serve as the Sakmarian-base and the Kungurian-base GSSP candidates respectively. It was discussed that a new search for a Kungurian-base GSSP candidate and that a new working group needs to be re-organized by SPS in near future. SPS also recognized that the Usolka section has good potential to define the Sakmarian-base GSSP because of the better conodont succession (particularly of *Streptognathodus*; *Sweetognathus* is exceptionally rare) and good geochronological constraints based on several ash beds dated by Mark Schmitz and his colleagues. The following course of action was decided by SPS:

1. Base-Sakmarian; Ask Cisuralian Working Group under the leadership of Boris Chuvashov and Valery Chernykh to consider shifting the GSSP section to Usolka and possibly to determine a new point within the *Streptognathodus* or *Mesogondolella* lineage and then proceed with a proposal as soon as possible afterward.
2. Base-Artinskian; Proceed with the GSSP proposal by the Cisuralian Working Group under the leadership of Boris Chuvashov by adding all new data, in particular the stable isotope data, conodont Sr-isotope data, and geochronologic ages.
3. Base-Kungurian; Form a new working group to consider a new GSSP section – probably using the same point as defined by the FAD of *N. pnevi*. Other levels could be considered and sections outside of Russia will be investigated. If no other sections are available then the new working group will reconsider Mechetlino.

It is evident that further work is necessary to establish the three remaining Permian GSSPs in the near future and SPS is fully committed to completing this process before the next IGC in 2012. SPS welcomes comments and suggestions for further work on the Early Permian GSSPs.

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This issue contains a few interesting field work reports. Our Argentine colleagues led by Arturo C. Taboada organized an excellent field trip in the Calingasta-Uspallata Subbasin (western Argentina) and Tepuel-Genoa Basin (Patagonia), Argentina between February 16 and March 2, 2009 (see detailed reports by Taboada *et al.* in this issue). The Nanjing Institute Group carried out a field trip in central Iran and collected more than 900 kg samples. Those samples will be very helpful to solve the Lopingian and Guadalupian correlation problems between South China and Iran. Wang Yue and her Russian collaborators provided a progress report of the Sino-Russian collaborative project supported by both NSFC and All Russian Fundamental Foundation. Zhang Yichun of the Nanjing Institute presented a report on the field trip in western Tibet, which is another gateway area to solve the Permian correlation between the Tethyan timescale defined mainly based on fusulinids and the international timescale based on conodonts. Giuseppe Cassinis and his colleagues provide a report of recent multidisciplinary studies, meetings and field excursions of the Upper Carboniferous to Triassic continental deposits cropping out in the Southern Alps, Tuscany and Sardinia. In addition, Aymon Baud announced a planned field trip for the Permian-Triassic boundary sections in Oman in February, 2010 (see announcement in this issue). Zhong Chen provides new information on XVII ICCP to be held in Perth in 2011 and on IGCP Project 572.

Future issues of Permophiles

The next issue of Permophiles is the 54th issue of Permophiles. Charles and I plan to edit Permophiles #54 in Nanjing during early 2010. We hope our colleagues in the Permian community can contribute papers, reports, comments and communications. The deadline for submission to Issue 54 is Friday December 18, 2009. Manuscripts and figures can be submitted via my email address (szshen@nigpas.ac.cn or shen_shuzhong@yahoo.com) as attachments or by our SPS website (http://www.nigpas.ac.cn/permian/web/index.asp). Please follow the format on page 3 of Issue 44 of Permophiles.

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Notes from the SPS Chair

Charles M. Henderson

Permophiles 53 is a substantial issue and consists of three parts. The first part is the regular issue of Permophiles, which contains several excellent reports and important announcements, including information on XVII ICCP in Perth, Australia (July 3-11, 2011) - add it to your calendars now! The second part is Supplement 1 that includes the Abstract volume for ICOS 2009 (International Conodont Symposium) held at the University of Calgary in July 2009. I thank Christine MacLean for her assistance in editing and producing all of Permophiles 53. The third part is the Fieldtrip Guidebook co-authored by Charles Henderson, Barry Richards and David Johnston that highlights the stratigraphy of the Southern Canadian Rocky Mountains. These three parts provide a wealth of information that will be of interest to more than just the Permian community.

During ICOS 2009 a SPS business meeting was held and reported in the Secretary's notes above. I am pleased to report that Bruce Wardlaw has agreed to Chair the new Base-Kungurian Working Group. I know there will be some that will disagree with the decisions made at the SPS meeting as reported above, but it is essential that the best GSSP candidates be found.

During an informal SPS Business Meeting at the Museo Paleontologico Egidio Feruglio at the end of the Argentina field excursion it was determined that more representation from "Gondwanan countries" was needed within SPS. To this effect, I am pleased to announce that Dr. Nestor R. Cuneo of the Museo Paleontologico Egidio Feruglio in Trelew Argentina has agreed to become a voting member and this is reflected in the list of voting members near the back of this issue (p. 72).

I am especially gratified to see the reports on the Gondwana succession in Argentina by Arturo Taboada *et al.* and on the continental succession in Europe by Giuseppe Cassinis *et al.* Information about these two successions have not appeared often in Permophiles although Prof. Cassinis has been very good about producing reports in recent issues. I would personally like to thank my Argentine hosts Arturo Taboada, Alejandra Pagani and Pablo Puerta. It was a memorable trip and a tremendous learning experience. We enjoyed fine wine, excellent barbeque meat (Pablo's asado) and the unbelievable night sky of Patagonia. Thank you so very much for inviting me and allowing me to take part – I will cherish those memories always. Professor Cassinis clearly demonstrates in his report that we can use the International Time Scale to a certain extent in the continental succession. The efforts of the Continental Working Group to continue to sort out these correlation problems is very important to SPS as they will allow the full understanding of events that shaped the Permian World both on the land and in the sea.

REPORTS

Report of the field trip of the Permian stratigraphy in central and eastern Iran

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Since the last century, the Permian System in Iran has been one of the most extensively-studied subjects (Iranian-Japanese-Research-Group, 1981; Kozur, 1975; Stepanov *et al.*, 1969; Taraz,

Figure 1. Chinese-Iranian Working Group at Hambast Valley, Abadeh, central Iran

1969; Taraz, 1971; Taraz, 1973; Taraz et al., 1981; Teichert et al., 1973). Recently, the end-Permian mass extinction and its environmental changes based on the Permian-Triassic boundary sections in Iran has progressively become the focus (Baud *et al*., 1996; Heydari *et al*., 2000; Heydari *et al*., 2003; Korte *et al*., 2004; Kozur, 2007; Richoz, 2006). However, biostratigraphic correlation of the Permian System between Iran and South China is still far from being satisfied. As we have known, Rostovtsev and Azaryan (1973) first proposed the Dorashamian Stage based the strata containing the ammonoids from the *Phisonites* Bed to the *Paratirolites* Bed in Azerbaijan and Iran and considered that the Changhsingian in South China is equivalent to the lower part of the Dorashamian. On the contrary, Zhao *et al*. (1981) and Sheng *et al*. (1984) studied the ammonoids and conodonts and stated that the ammonoids in the Dorashamian are correlative with those of the *Paratirolites-Shevyrevites* Subzone in the lower part of the Changhsingian in South China. These controversial viewpoints are still in hot debate after 30 years. The Lopingian (Late Permian) conodont biostratigraphy in Iran has been extensively discussed recently among the Permian community (Baud, 2008; Henderson *et al*., 2008; Shen, 2007; Sweet and Mei, 1999a; Sweet and Mei, 1999b). To refine the correlation of the Permian System between Iran and South China, joint fieldwork was undertaken in central Iran by an international research team organized by Shuzhong Shen of Nanjing Institute of Geology and Paleontology, China and Mohammad N. Gorgij of University of Sistan and Baluchestan,

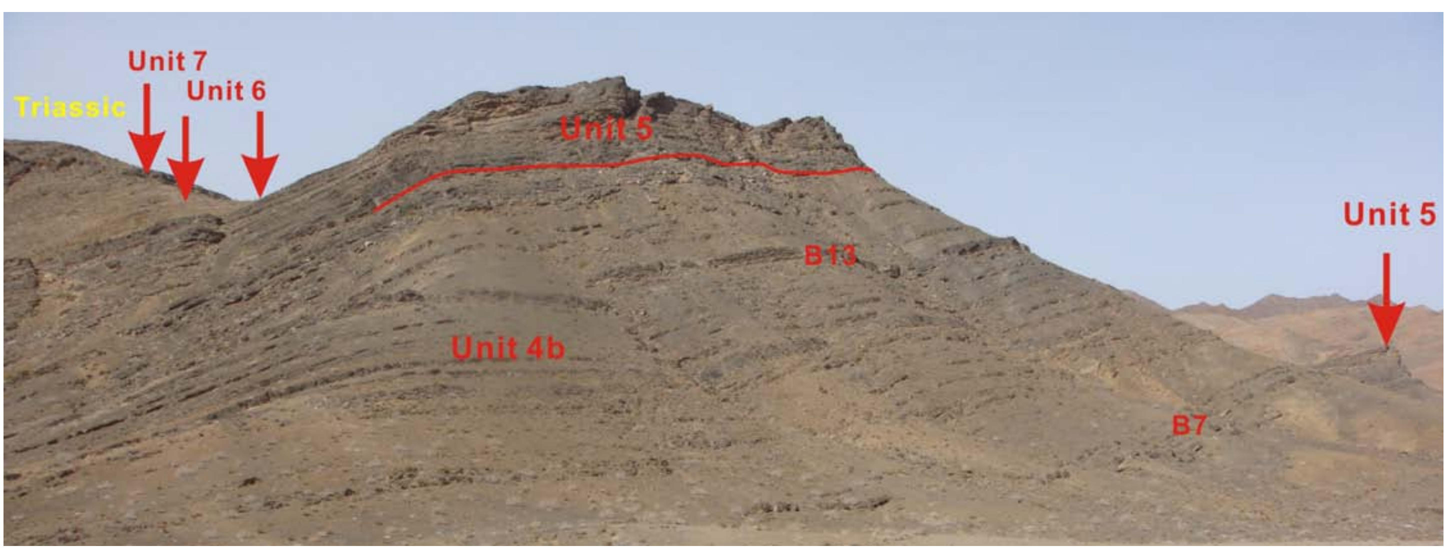

Figure 2. Permian-Triassic sequence at Abadeh Section C, Abadeh, central Iran.

Iran. Other members of the fieldwork team included Wei Wang, Yichun Zhang (Nanjing Institute of Geology and Paleontology) and Hamed Reza Khammar and Sayed Hojjatollah Tabatabaei (University of Sistan and Baluchestan) (Fig. 1). During the 17-day (March 2 to 18, 2009) excursion, we investigated the marine Permian sequence from the Middle Permian Surmaq Formation to the Lower Triassic Elikah Formation in the Hambast Valley, the Banirizeh (Chah-Baneh) section in the Abadeh area in Central Iran and the non-marine Permian-Triassic Halvan section in the Tabas area in Eastern Iran.

The Permian sequence in the Hambast Valley in the Abadeh area of Central Iran has been investigated in detail by the Iranian-Japanese Working Group (1981). It has been subdivided into the Surmaq Formation, the Abadeh Formation and the Hambast Formation in ascending order (Fig. 2). This excursion is actually a successive investigation of the Iranian-Chinese Working Group (1995) led by late Prof. Yugan Jin. During the 1995's excursion, very limited samples from the Hambast Formation of the Lopingian (Late Permian) were collected. During this field excursion, we have collected samples from the whole Permian sequence in the Hambast Valley. The Surmaq Formation is composed of dark thick-bedded limestone containing extremely abundant fusulinids including *Eopolydiexodina* in the lower, *Veeberkina* in the middle and *Chusenella abichi* in the upper part of the formation. The overlying Abadeh Formation consists of two units (Unit 4 and Unit 5) (Iranian-Japanese-Research-Group, 1981). Unit 4 is dominated by bioclastic limestone alternated with mudstone and calcareous mudstone and contains abundant benthic fossils such as foraminifers, bryozoans, crinoids and brachiopods. Unit 5 is dominated by dark thick-bedded bioclastic limestone containing abundant foraminifers and the fusulinid *Codonofusiella-Reichelina* fauna. The age of Unit 5 is still in different opinions (Iranian Chinese Research Group, 1995; Iranian Japanese Research Group, 1981; Kozur, 2004; Kozur, 2005; Taraz, 1969; Taraz, 1971). Unit 6 of the Hambast Formation consists of mudstone alternated with thin-medium bedded bioclastic limestone. The lower part of the unit contains abundant well-preserved brachiopods which is called the *Araxilevis* Bed. This unit is overlain by the reddish thin-bedded nodular limestone of Unit 7 containing abundant ammonoids and conodonts. The topmost 4 m of the Unit was named as the *Paratirolites* Bed by Stepanov *et al*. (1969) because it contains abundant *Paratirolites*. The Hambast Formation is successively overlain by the Elikah Formation. The basal part of the Elikah Formation contains a few distinct fan-like microbialite beds.

The Banirizeh (Chah-Baneh) section was introduced by Prof. Mehdi Yazdi of Swan University in Esfahan. The Permian sequence at this section is largely comparable with that at the Hambast Valley, but has a relatively thick Unit 7 and thinner Unit 6 of the Hambast Formation. Ammonoids are extremely abundant in Units 6 and 7 at this section. There is a volcanic intrusion at the Permian-Triassic boundary, which penetrates all of Unit 7, but seems to be truncated by the Lower Triassic thin-bedded limestone in the basal part of the Elikah Formation.

The Halvan section in the Tabas area in the eastern part of Iran is interesting. The whole Permian sequence is well exposed and composed of the Chili, Sartakht and Hermez formations in ascending order, which is overlain by the Lower Triassic Sorkh Shale Formation. The Chili Formation contains early Sakmarian to Artinskian fusulinids (Leven and Gorgij, 2008). The upper part of the Sartakht Formation is mainly composed of medium-bedded limestone, which is unconformably overlain by a bauxite bed in the basal part of the Hermez Formation. The Hermez Formation consists of thick-bedded dolostone with rare fossils. Between the Permian and Triassic, a unit of 24.1 m is very distinctive from the overlying and underlying units. This unit is composed of medium-grained quartzitic sandstone interbedded with a few thick laterite beds with rich hematite. The topmost part of this unit is a bauxite bed about 2 m thick. Mohammad N. Gorgij proposed a new name, the Rizi Formation, for this distinct lithologic unit. The Rizi Formation is overlain by thick brownish dolostone with microbialites apparently indicating the latest Changhsingian transgression.

During this excursion, we would like to thank our drivers (Barat Galavi, Kader Bazzi), for their long-distance drive and numerous help in transporting the samples from the sections to the vehicles. We would thank Dr. Yazdi who sent two students (Mehdi Ghaedi and Hassan Safdari) to guide the Banirizeh (Chah-Baneh) section. This work is supported by the National Science Foundation of China and the University of Sistan and Baluchestan, Iran.

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A Preliminary report of the fieldtrip on the Carboniferous-Permian sequences in the north and south of the Longmuco-Shuanghu suture zone, Northern Tibet in May and June, 2009

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The Paleo-tethys suture in the Permian marks the lost Ocean that existed between the South China and Peri-Gondwana blocks. The Changning-Menglian suture zone is widely accepted as the Paleo-tethys suture in western Yunnan province of China (Wopfner, 1996; Jin, 2002). However, the western extension of Changning-Menglian suture zone in Tibet was subjected to controversy for the past two decades. In recent years, the discoveries of Devonian radiolarian cherts (Zhu *et al*., 2006), Permian ophiolite (Zhai *et al*., 2004) and Triassic ecologite (Li *et al*., 2006) in the Longmuco-Shuanghu suture zone in central Tibet support that this suture is a Paleo-tethys suture equivalent to Changning-Menglian suture in Yunnan Province. The Qiangtang Block of Tibet was divided into North Qiangtang Block and South Qiangtang Block. The Carboniferous and Permian sequence in the north and south of the Longmuco-Shuanghu suture zone is far from understood. To investigate the Carboniferous and Permian sequence and faunas in the North Qiangtang Block and South Qiangtang Block, joint fieldwork was undertaken in Nyima and Shuanghu County of Tibet by a research team organized by Yichun Zhang from Nanjing Institute of Geology and Palaeontology and Qingguo Zhai from Institute of Geology, Chinese Academy of Geological Sciences. During this excursion (May 2 to June 7), we investigated the Carboniferous to Permian sequence in the North Qiangtang Block and Permian sequence in the South Qiangtang Block.

1. South Qiangtang Block

The Carboniferous-Permian sequence of the South Qiangtang Block was named Horpatso Series (Norin, 1946) and then was dismembered into Cameng, Zhanjin and Qudi formations in Duoma area of western Qiangtang Block (Liang *et al*., 1983). The Cameng and Zhanjin Formation were characterized by containing diamictites with typical dropstone structure (Figure 1A). The Zhanjin Formation was reported to be composed of sandstones and limestones in the Duoma area (Liang *et al*., 1983). However, they were strongly metamorphosed into slate, schist and marble in the Nyima area.

The Zhanjin Formation was overlain conformably by the Qudi Formation, which consists mostly of fine-grained sandstones and

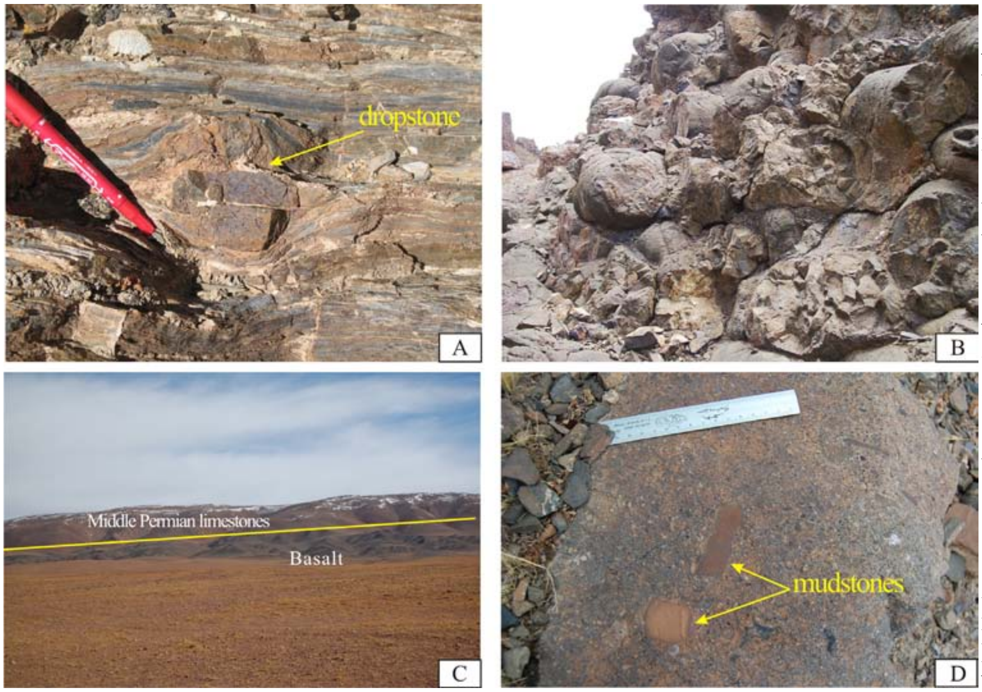

Fig.1. Permian sequence of the South Qiangtang Block.
A. dropstone structure from the diamictites of Zhanjin Formation; B. Middle Permian pillow basalt of Lugu Formation; C. seamount type deposition of Middle Permian Lugu Formation; D. volcaniclastic rock with abundant fusulinids in Lugu Formation.

mudstone of typical flysch deposits. Some bioclastic limestone with abundant fusulinids was discovered from the upper part of the Qudi Formation. Some debris of mudstone and basalt are discovered in the bioclastic limestone of the Qudi Formation (Figure 1D). Preliminary examination of the fusulinids proved the existence of *Pseudofusulina*, *Eoparafusulina* and *Chalaroschwagerina*, which indicate the Early Permian. The existence of basalt debris in the upper part of the Qudi Formation may indicate that the volcanic activity was active in the South Qiangtang Block during the Early Permian.

The Lugu Formation is the Middle Permian deposits of the South Qiangtang Block, which conformably overlies the Qudi Formation. The Lugu Formation is composed of limestones with basalt basement and interlayers. In the Jiaomuri hill, the basalt appeared as pillow basalt (Figure 1B). In the Chasang area, the Middle Permian limestones deposited on the basalt (Figure 1C), with some fusulinids such as *Parafusulina* and *Pseudodoliolina* discovered in the lower part of the limestones. The upper part of the Lugu Formation contains *Neoschwagerina*, *Verbeekina*, *Chusenella* and *Sumatrina*. The geochemistry of the basalt in Jiaomuri supported that the basalt formed near the midoceanic ridge and was a kind of seamount in the sea (Zhai *et al*., 2004, 2006).

2. North Qiangtang Block

Cheng *et al*. (2006, 2007) reported the discoveries of Late Carboniferous fusulinids in the Raggyorcaka area of North Qiangtang Block and set up the Walongshan Formation. This time, we restudied the Upper Carboniferous and Lower Permian sequences. The Walongshan Formation is composed of medium-bedded limestones containing abundant fusulinids and corals (Figure 2A). The fusulinids comprise *Fusulina*, *Fusulinella* and *Profusulinella* that indicate Moscovian age.

The Lower Permian sequence was named Changshehu Formation during the geological mapping in 2003. However, the Lower Permian sequence measured this time was composed of grey limestone same as the Walongshan Formation. That is, the Lower Permian sequence can not be differentiated from the Walongshan Formation by lithology alone. The fossils in the Lower Permian sequence comprise fusulinids and corals. The field examination of fusulinids confirmed the presence of *Triticites*, *Eoparafusulina* (Figure 2B) and *Robutoschwagerina* (Figure 2C).

The Middle Permian was named Xuyuanhe Formation in 2003. This formation is composed of massive grey limestone in the lower part and thin-bedded sandstone in the upper part. The fusulinids in the limestone comprise *Neoschwagerina* and *Verbeekina*.

The Upper Permian in the North Qiangtang area was named the Raggyorcaka Formation (Wen, 1979). The Raggyorcaka section was restudied this time. This section is a syncline structurally. The lower part of the Raggyorcaka Formation is composed of mudstone and shale with sandstone interlayers while the upper part of this Formation is composed of mudstones with limestone interlayers. Abundant fusulinids such as *Palaeofusulina sinensis*, *Palaeofusulina fusiformis*, *Reichelina* and other genera/species were discovered in the limestone interlayers (Figure 2D), which indicates Changhsingian stage. The uppermost part of the Raggyorcaka Formation was renamed as the Heitugou Formation (Chen *et al*., 2006). This formation was dominated by mudstone and sandstone with coal layers. Some plant fossils such as *Pecopteris* and *Gigantopteris* were reported from the section (Chen *et al*., 2006). The boundary between the Upper Permian Heitugou Formation and Lower Triassic Kanglu Formation can be recognized by the first presence of purple conglomerate. The transition from the uppermost Permian mudstone to the Lowermost Triassic conglomerate may indicate a transgressive trend of sea level.

3. Correlation of Carboniferous and Permian sequences

The discoveries of Moscovian *Fusulina* and *Fusulinella*, Late Carboniferous *Triticites* and Early Permian *Robutoschwagerina*, together with the similarity of lithology from Upper Carboniferous to Middle Permian imply that the North Qiangtang Block was under a warm and stable depositional circumstance. However, by contrast, the South Qiangtang Block was affected by cool water during Late Carboniferous to Early Permian, as recognized by diamictites and dropstone structure in the Chameng and Zhanjin formations. The first appearance of fusulinids in the South Qiangtang Block is marked by *Pseudofusulina*,

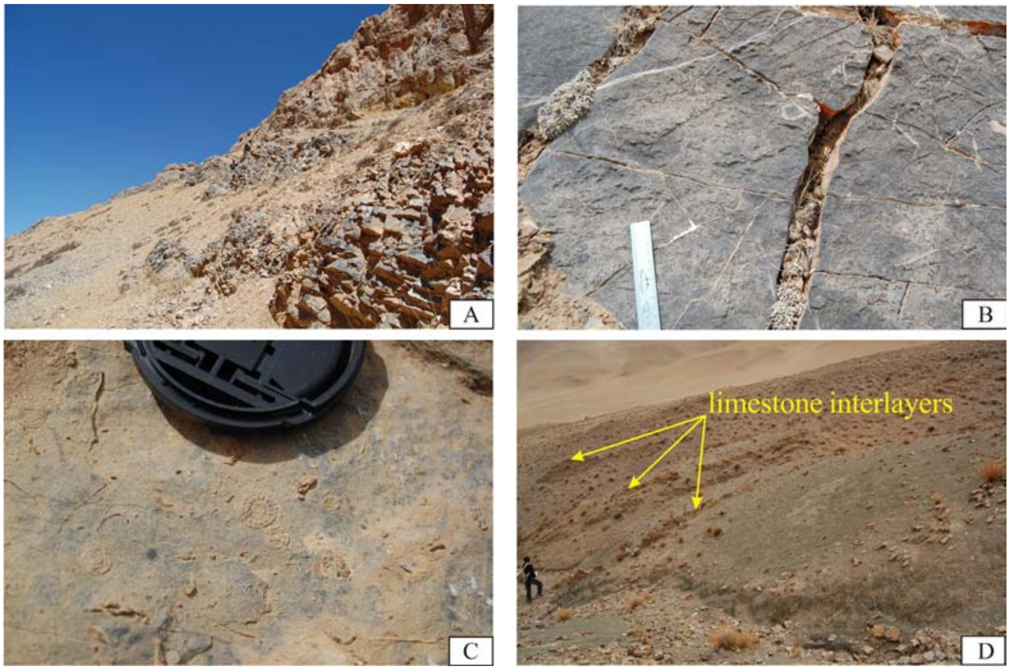

Fig.2. Permian sequence of the North Qiangtang Block.
A. the Upper Carboniferous sequence from the Changshehu area; B. Early Permian *Eoparafusulina*; C. Early Permian *Robutoschwagerina* fauna; D. Upper Permian Raggyorcaka Formation in the Raggyorcaka area.

Chalaroschwagerina in the Qudi Formation, which is correlative with the fauna in the Baoshan Block. It accounts for the interpretation that the South Qiangtang Block and the Baoshan Block may situate in the same latitude during the Early Permian.

The Middle Permian Xueyuanhe Formation of the North Qiangtang Block is a kind of typical platform deposit while the Lugu Formation of the South Qiangtang Block are the result of seamount type carbonate that deposited on basalt.

According to all data mentioned above, the Carboniferous and Permian sequences of the South Qiangtang Block are entirely different from those of the North Qiangtang Block. Thus, the Longmuco-Shuanghu suture zone between the North Qiangtang Block and the South Qiangtang Block is a Paleo-tethys suture resembling the Changning-Menglian suture zone in Yunnan Province that divides the South China and peri-Gondwanan blocks.

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Preliminary results from the joint Chinese-Russian Project on the Lopingian of the International Permian Standard and the Tatarian of the Regional East European Scale

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Sponsored bilaterally by the National Science Foundation of China (40711120374) and All Russian Fundamental Foundation (GREN # 06-05-39015 and RFFI # 09-05-01009), the joint Project of "Comparative investigation and correlation of the Late Permian (Lopingian and Tatarian) of China and Russia" has been executed since 2007. The main goal of the project was a comparative investigation and correlation of the uppermost deposits of the Upper Permian from South China and the Eastern European Region of Russia, as well as the detailed correlation of the Lopingian Series of the global scale elaborated for the normal-marine deposits of Equatorial climatic zone and the Tatarian Series of the East-European Regional Scale applicable for the dating and detailed partition of the deposits outside of the Tropical zone of sedimentation.

Participants from China are Drs. Shang Qinghua (vertebrates), Shen Shuzhong (brachiopods), Wang Wei (geochemistry) and Wang Xiangdong (corals). Participants from Russia include Drs. E. Leven (fusulinids), V. Golubev (tetrapods), A. Markov (dynamics of diversity of Phanerozoic biota). The co-leaders of the project are Drs. Wang Yue (China) and T. Grunt (Russia). The major results are described as follows.

1. Marine biostratigraphy (fusulinids, brachiopods and corals)

Among the invertebrates, the main attention is dedicated to fusulinids and brachiopods. Fusulinids are the principal group acceptable for compilation of global and Tethyan stratigraphic scales. The resulting monograph dedicated to the Upper Carboniferous and Permian of Western Tethys (fusulinids, stratigraphy, biogeography) pays special attention to the characterization of the final (Midian – Changhsingian) stages of their historical development compiled by E.Ja. Leven (in press) and by E.La Leven together with M.N. Gorgij (2007).

The characteristic assemblages for each stage and mostly for substages are elaborated. Those traced all over the territory from the Pamirs in the east to Spain and North Africa in the west. Common consistent patterns in the development of fusulinids are established. Three main peaks of diversity and abundance through the Late Carboniferous – Permian are established; these are: Moscovian, the Asselian – Sakmarian boundary and Midian. At the Midian/Wuchiapingian boundary (*i.e.*, the Guadalupian/Lopingian boundary of the International Scale) brief impoverishment of fusulinid assemblages are noticed. This supports the point of view of Chinese specialists that the well known biotic crisis at the Permian/Triassic boundary becomes only the last phase of extinction, which started at the beginning of the Lopingian. Chinese specialists connect this event with the beginning of the regression that exposed partrs of South China and adjacent territories at the end of the Guadalupian. The traces of this regression could be noticed in the series of sections in Afghanistan, North Pamirs and Transcaucasia. In some sections these traces are not visible, but the distinctive interchanging of the assemblages and their impoverishment are marked.

The phylogeny of the Late Permian boultoniids has been further discussed by Wang and Ueno (2009). The evolutionary lineage of *Dunbarula-Nanlingella-Paralingella-Dilatofusulina* was established. The genus *Palaeofusulina*, the dominant fossil for the Changhsingian, possibly represents a different origin fron *Nanlingella*. The newly identified genus *Dilatofusulina* has a paleogeographic distribution limited to the northern and southern margins of the Tethys Basin. Stratigraphically, it belongs to the *Palaeofusulina sinensis* Zone, which is well developed in the Paleo-Tethys.

The stratigraphic age of the genus *Palaeofusulina* has long been recognized as Changhsingian. Recent study discovered the earliest *Palaeofusulina* at the base of the Wuchiapingian at the Penglaitan section in South China, the GSSP section for the base-Wuchiapingian. Further studies will be applied to refine its taxonomy and stratigraphic range.

Based on two main orders of Permian Brachiopoda (Productida and Spiriferida), which are mostly characteristic in the basins of all climatic zones, 17 regional biostratigraphic zones were elaborated by T. Grunt (2007a). They have been traced all over the territory of Eastern Europe, and through the Barentz Shelf area.

The age of the Late Permian deposits in the basins of the

Laba and Belaja rivers in the North Caucasus was discussed. The presence of diverse and abundant marine fauna represented by brachiopods, fusulinids, small foraminifers and others typical for the northern shelves of Paleotethys points are Wuchiapingian (=Dzhutfian) rather than Changhsingian in age. The normal-marine fauna from the North Caucasus hardly could be Changhsingian because of the intensive general extinction of marine biota finalized in the context of the significant reduction of the Permian shelves at the beginning of the Changhsingian. However, the diversity of brachiopods within the Late Permian North Caucasian sections reaches more than 240 species belonging to various Orders, and the dimensions of populations were significant (Grunt, 2007b).

The evolution of articulate brachiopods belonging to the order Athyridida through the Guadalupian – Lopingian are discussed by T. Grunt and Shuzhong Shen (2007).

The rugose corals, specifically the systematic revision of *Waagenophyllum* and *Ipciphyllum* of the Upper Permian from southern Tibet have been made by Wang Xiangdong and others. With the constraints of the biostratigraphy of fusulinids as well as the conodonts, the coral reefs at the Gyanyima section might represent the latest Permian rugose coral reefs.

2. Terrestrial biostratigraphy

A new itemized tetrapod regional biostratigraphic scale composed of 10 zones as elaborated by Golubev (2007a) for the post-Kungurian deposits of East Europe, which is significant for regional correlation. In global aspect only two superzones corresponding to the Guadalupian (~Biarmian) and Lopingian (~Tatarian) are traced. The recent discovery of the new Viaznikovian Regional Stage (Lozovsky, Kukhtinov, 2007) and faunistic assemblage (Golubev and Sennikov, 2007a; 2007b; Kukhtinov *et al*., 2008;) in the uppermost part of Vjatskian Stage demonstrate that this rich and diverse assemblage contains floristic remains, bivalves, chonchostraca, ostracods, insects and tetrapods. It is characterized by “transitional” features between Permian and Triassic biota.

It was determined previously that there was a significant “break” at the Permian/Triassic boundary. The discovery of the Vjaznikovian demonstrates a gradual character of the Permian-Triassic boundary in the territory of the Russian Platform.

According to Chinese and Russian participants, continental deposits containing Pareasaurian Dicinocephalic tetrapod assemblage are present in the territory of Northwest China. V. Golubev suggested that in ecological and phylogenetic aspects, the Chinese fauna corresponds to the theriodontic fauna of the European Russia, which is characteristic for the Lopingian Series (*Scutosaurus* superzone). But, the composition of Chinese tetrapod fauna and the history of its development differ in some details from that of the Russian theriodontic fauna. In particular: *Lystrosaurus* and Dinocephalic tetrapods existed contemporary within the Chinese tetrapod communities at the end of the Permian; the lystrosaurids briefly replace dicynodontids over the Permian/Triassic boundary in Eastern Europe. This turnover represents the significant crisis within the terrestial tetrapod communities. The singularity of Chinese tetrapod fauna is probably related with, on one hand, the considerable geographic isolation, and on the other hand, the difference of climatic environments between the regions. In both regions, climate was warm, but it was seasonal in the European Russia. By contrast, it was humid in the territory of China (at least at the territory of Inner Mongolia). The Biotic crisis was gradual and stepwise both in the communities of China and South Africa. But, the same groups (pareiasaurids, gorgonopids, therocephalids, dicynodontids, lystrosaurids, tecodontids) arise and disappear in different regions at different stratigraphic levels. Endemic features and differentiation along this change in the different continents are gradual, continuous and mosaic, which gives evidence of some inner synecological reasons for this process (Golubev and Sennikov, 2007).

V. Golubev participated the geological excursion in Inner Mongolia in 2007 of the Permian – Carboniferous Congress.

Dr. Shang Qinghua has been working on the marine reptile in the Triassic. She demonstrated that the marine reptile appeared in the late Early Triassic in Anhui province may represent the earliest recovery of marine vertebrates after the end Permian extinction, and it was greatly developed in the Olenekian.

3. Geochemistry research

The geochemistry near the Guadalupian/Lopingian boundary has been studied in the upper Yangtze Region by Wang Wei and his colleagues (Wang *et al*., 2004). The carbon isotopic result shows a negative shift near the boundary, which is largely consistent with the ‘pre-Lopingian benthos crisis’.

4. Statistical analysis on the Late Permian diversity

The dynamics of diversity of Phanerozoic marine and continental biota at the level of species, genera and families was established. It demonstrated that the hyperbolic growth of diversity could be explained by non-linear positive second-order feedback between the diversity growth and community structure complexity just prior to the end-Permian mass extinction and that the Permian/Triassic crisis became critical in the development of marine Phanerozoic communities leading to acceleration of the rates of community evolution (Grinin *et al*., 2008).

Further investigations

Future work will include tracing the boundaries, including precise tracing of the lower boundary of the Lopingian within East-European sections (the possibility of determination of the Kiama/Illawara boundary within sections of South China) as well as determination of the lower boundary of the Lopingian within the “mixed” magnetostratigraphic zone of East European and Northern Germany sections.

Future work will also include precisly tracing the upper boundary of the Lopingian within East European sections. Correspondence of the Changhsingian International Stage to the Vjaznikovian Regional Stage (or Vjaznikovian Horizon) of the East European Regional Scale. The latter is characterized by “mixed” Permian/Triassic taxa within tetrapods, fishes, ostracods, flora and palynomorphs.

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International Field Workshop and Symposium Report: An approach to the Carboniferous-Early Permian Stratigraphy, Paleontology, Paleogeography and Paleoclimatology of the Calingasta-Uspallata Subbasin (western Argentina) and Tepuel-Genoa Basin (Patagonia), Argentina, February 16 - March 2, 2009.

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The Second International Symposium and Field Workshop of Gondwana was held in Argentina; it was organized as a second step, following the first International meeting held at Deakin University in Melbourne, Australia, in January 2008, inspired by Prof. Guang Shi (see report by Charles Henderson, Guang Shi and Roger Pierson in Permophiles 50, p. 9). On this occasion the Symposium was organized by Alejandra Pagani, Arturo Taboada and Pablo Puerta (in charge of the logistic organization of the fieldtrip), and colleagues from Australia, Canada, New Zealand and Russia were invited. Participants experienced the richly fossiliferous Upper Paleozoic outcrops and the beautiful Argentinean landscapes.

Two weeks of an International Field Workshop visiting Carboniferous and Early Permian sequences of western Argentina (Calingasta-Uspallata Subbasin) and Patagonia (Tepuel-Genoa Basin), and a final day symposium held at the Paleontological Egidio Feruglio Museum (MEF) in Trelew city, brought together a group of biostratigraphers and paleontologic experts. The event had financial and logistical support from the National Research Council of Argentina (CONICET) and the MEF, as well as ALUAR S.A. The aim of the meeting was to show some key stratigraphic sections, as well as faunal and floral assemblages, that characterize the Upper Paleozoic sequences of western and southern Argentina. This subject was in order to improve the knowledge of its potential biostratigraphic alignment with high paleolatitude Carboniferous-Permian sequences of Gondwana and the Arctic. The visitors were Roger Pierson and Guang Shi (Australia), Charles Henderson (Canada), Bruce Waterhouse (New Zealand), Alexander Biakov and Alexandr Klets (Russia) (Figure 1).

The participants met at Mendoza city on February 16, to start a two-week long field workshop; Alejandra Pagani, Arturo Taboada and Pablo Puerta drove almost 3000 kilometres. Before reaching the first stop at Barreal town in San Juan Province (located 200 km northwest from Mendoza city), a short detour was made to appreciate the Inca Bridge (a natural land bridge crossing the Mendoza River) and a striking view of the Aconcagua Mountain, the highest peak (almost 7000 m.a.s.l.) of the Americas. That afternoon we arrived at Barreal town where we checked into the Doña Pipa Bungalows for two nights. On the following days (February 17-18), we visited conspicuous units such as El Paso, Hoyada Verde and Pituil, cropping out in the Barreal Hill, just to the east of Barreal town. During the night of February 17, participants enjoyed a typical argentine "asado" (like a barbecue) cooked by Pablo Puerta and "irrigated" with regional red wines and beers. Besides the richly fossiliferous outcrops, participants were able to experience sunshine and oppressive heat during the days in the Precordillera.

The afternoon on February 18, under pouring rain, we arrived to Uspallata town (Mendoza Province) located 100 km south of Barreal, where we checked into the Uspallata Hotel for two nights. The following day the sun came out, warm weather returned, and the participants went to Uspallata Hill and the Paramillos de Uspallata area.

Early in the morning on February 20, the group started a two-day connecting trip to reach the Patagonian region in the southern part of the country. After 1700 km, through five Argentine provinces (Mendoza, La Pampa, Río Negro, Neuquen and Chubut), participants arrived at the small locality of Tecka in western Chubut late in the afternoon of February 21. In this village, Mr. Mariano Caffa and Daniel Menghini, from the MEF in Trelew, joined to the group with additional equipment to extend logistic support for the following three days.

On February 22, with a temperature lower than in the Precordillera but still sunny, we visited the base of the Tepuel Group at its type section in the Tepuel Hill. Landscape and outcrops were covered by a thin white layer of volcanic ash from the Chaitén volcano, that had erupted three days before. The volcano is located 200 km to the west near the Argentine-Chilean border, and the ash was brought by strong Pacific winds.

During February 23 and 24, the group camped in tents near the Tres Lagunas Post located in the Tres Lagunas Valley of the Tepuel Hill. In this place, participants could appreciate the upper section of the Tepuel Group, including the uppermost part of the Pampa de Tepuel Formation and the Mojón de Hierro Formation. The bright Milky Way and constellations such as the Southern Cross illuminated the nights; it was a beautiful dark blue sky compa-

Figure 1. Participants of field excursion. Participants are seating in front of glacial boulder pavement in Hoyada Verde Member, Barreal Hill. From left to right are: Charles Henderson, Guang Shi, Alejandra Pagani, Arturo Taboada, Alexandr Klets, Roger Pierson, Bruce Waterhouse and Alexander Biakov. Front row: Pablo Puerta.

rable to the Mongolian sky according to Guang Shi. Unforgettable funny stories of encounters with bears in the Arctic and Siberia by Charles Henderson and Alexander Klets, took place around a big bonfire under the Patagonian sky.

On February 25, we left the Tepuel Hill, Mariano Caffa and Daniel Menghini returned to Trelew, and the group visited the El Molle area where participants could appreciate good examples of glacial pavements. After El Molle outcrops, we went to the Gobernador Costa town and reached the southernmost outcrops of the Río Genoa Valley, where the uppermost stratigraphic sections could be examined during February 26 and 27, our last days of the field workshop.

All days in Patagonia showed wild life such as hares, gumps, choiques (native ostriches), grey foxes, "pilquines" (native rodent like a squirrel) and "piches" (native armadillo) and many others.

The last stretch of 500 km from Gobernador Costa city to Trelew city was done on February 28, with a short stop at the Ameghino Lake Dam, which is enclosed by volcanic deposits of Jurassic age. Paleontological collections housed in the Egidio Feruglio Paleontological Museum were examined by participants during the afternoon of March 1.

In the course of March 2 and last day of the meeting, each of the visitors, as well as Alejandra Pagani and Rubén Cúneo from the MEF and Arturo Taboada from the LIEB, presented contributions in twenty minutes presentations concerning their current research. After a welcome speech by the director of the MEF, Dr. Rubén Cúneo, Alexander Biakov (North-East Interdisciplinary Scientific Research Institute, Russian Academy of Sciences) discussed the similarities and differences of the lowermost Permian bivalve faunas of Patagonia and Northeast Asia. Rubén Cúneo highlighted the Early Permian flora of the Tepuel-Genoa basin as the most diverse in the whole Gondwana supercontinent, but with a floristic spectrum where ferns and conifers prevail over any other plant group including glossopterids. Charles Henderson (Department of Geoscience, University of Calgary) talked about the correlation of the Lower Permian Stages around the world, which would be representing an analogous time frame to the modern day that begins with a series of glacial and interglacial events and ends with a run-away greenhouse and major extinction event. Alexandr Klets (Siberian Federal University at Krasnoyarsk) with Ruslan Kutygin and Alexey Kazansky as co-authors, considered the question of Upper Paleozoic correlation between Siberia and Gondwana group of continents. Three large stages separated from each other by basic paleogeographic changes (Scheglov and Tylakh events) were recognized in Angaraland and analyzed for recognition of circum-continental correlation events. Roger Pierson (Deakin University) talked about the current knowledge of the Late Paleozoic Palynology of Victoria, Australia, for Gondwanan correlation. Guang Shi (Deakin University) with Arturo Taboada and Alexandr Klets as co-authors, explained Gondwana-Eurasian Permian biogeographic links and its implications for Permian global marine biogeography, inter-continental correlations and climate change. Arturo Taboada and Alejandra Pagani gave a brief advance of recently recognized new species of Cimmeriella Archbold and Hogeboom and Jakutoproductus Kaschirtzev in Patagonia and its stratigraphic meaning for the high paleolatitude correlations. Finally, Bruce Waterhouse proposed to reinforce a subsidiary time-scale or at least biozonation based on brachiopods and mollusks for the marine Early Permian (Cisuralian) of Gondwana.

The night of March 2, participants enjoyed a farewell dinner in a typical restaurant "Marcelino" in Rawson Port (approx. 20 km east from Trelew).

This field workshop had the privilege of a selected and outstanding group of invited biostratigraphers and paleontologic experts taking part. Nevertheless, insufficient available funds and limited logistic support did not allow us to have a greater number of local and international participants, as we would have had wished.

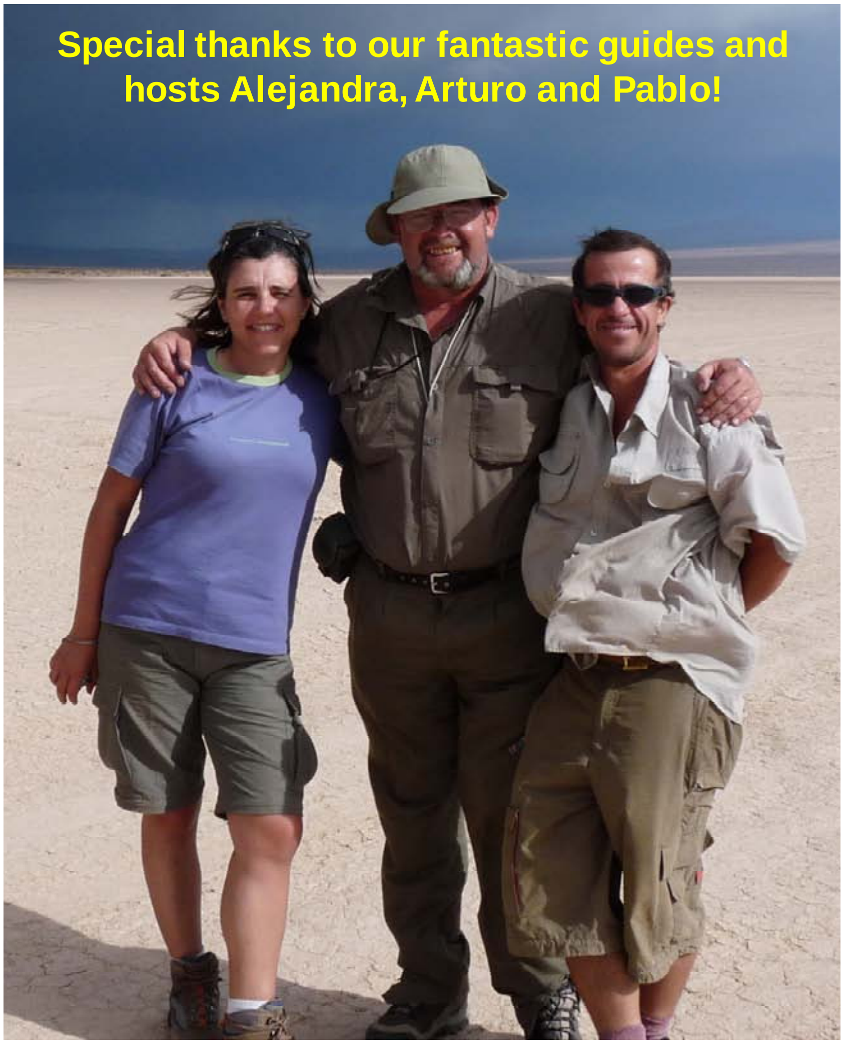

Figure 2. The authors of this report including Alejandra Pagani, Arturo Taboada, and Pablo Puerta north of Uspallata before the rain.

1969; Taraz, 1971; Taraz, 1973; Taraz *et al*., 1981; Teichert *et al*., 1973). Recently, the end-Permian mass extinction and its environ

An Approach to the Carboniferous-Early Permian Stratigraphy, Paleontology, Paleogeography And Paleoclimatology of the Calingasta-Uspallata Subbasin (Western Argentina) and Tepuel-Genoa Basin (Patagonia), Argentina: A Fieldguide

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The purpose of this contribution is to present to all Upper Paleozoic workers an adaptation of the fieldguide used in the "Second International Symposium and Field Workshop on the Carboniferous-Early Permian Stratigraphy, Paleontology, Paleogeography and Paleoclimatology of the Calingasta-Uspallata Subbasin (western Argentina) and Tepuel-Genoa Basin (Patagonia), Argentina". The symposium took place during February 16 and March 2, 2009 in Argentina.

General geological setting

During the Late Paleozoic, the Gondwana supercontinent plausibly reached its maximum expansion, with vast Upper Paleozoic basins of South America recorded along its southwestern margin constituting an important link in the reconstruction of Gondwana history. Following Limarino and Spalletti (2006), two major groups of Late Paleozoic basins, separated by a large, continuous upland area, are traditionally recognized in this part of South America (Figure 1): (1) intraplate basins located to the east and (2) basins along the active margin of Gondwana, almost entirely in the western (Andean) region. These two types of basins are separated by a large upland area. To the south, this positive feature is represented by the Somuncura Massif (northern Patagonia), which enlarges to the north to form the Pampean Arch, which remained a paleogeo-

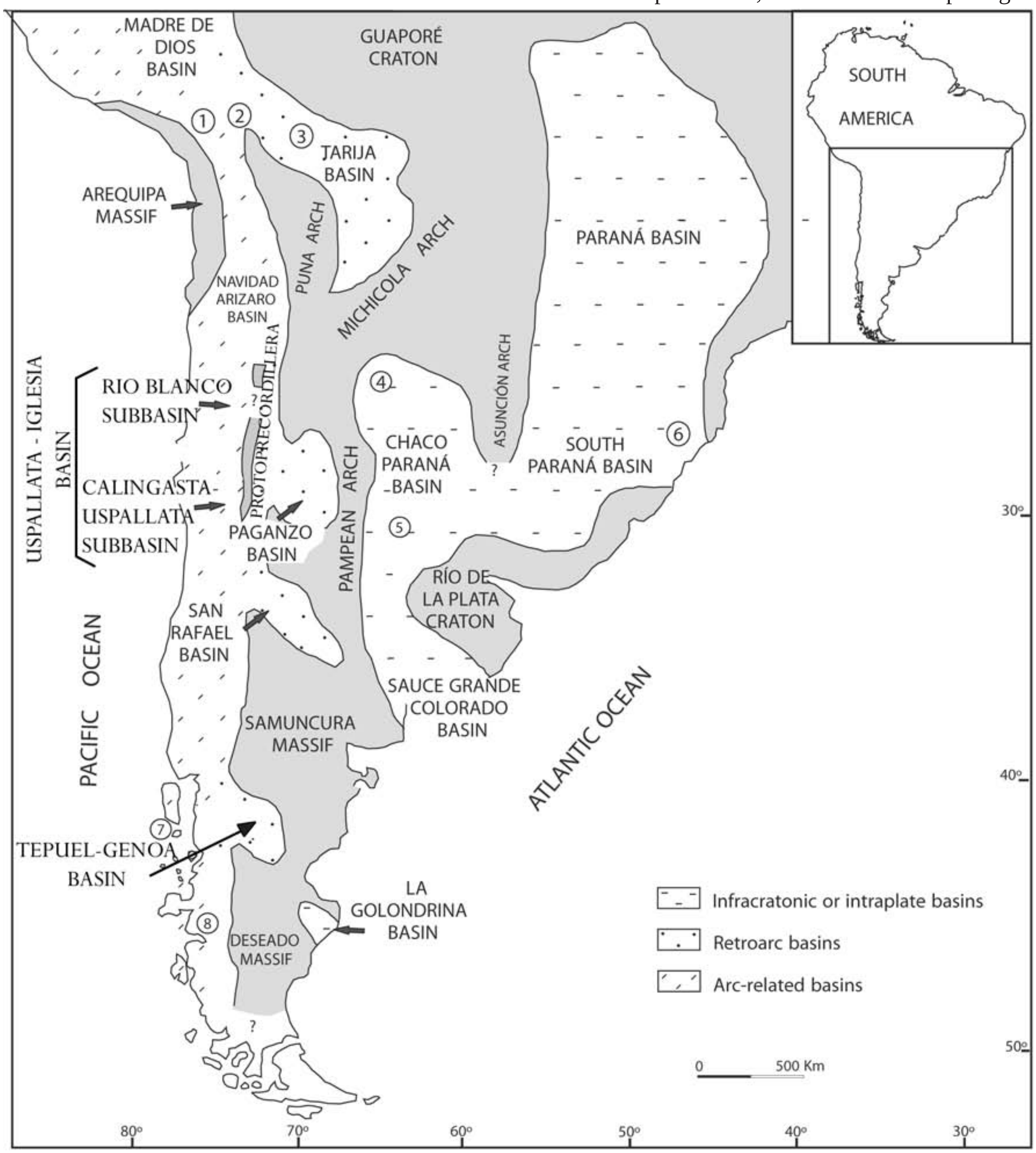

Figure 1. Major paleogeographic features of southern South America. (1) Altiplano of Peru´ and Bolivia, (2) Huarina fold-and-thrust belt, (3) Potosí low subsidence area, (4) Alhuapampa depocentre, (5) Las Breñas depocentre, (6) Perimbó fault zone, (7) Los Chonos, and (8) Bahía La Lancha. (modified from Limarino and Spalletti, 2006).

graphic highland during Late Paleozoic sedimentation. At about 24ºS, the Pampean Arch splits into two branches, the Puna Arch to the west and the Michicola Arch to the east, which is welded northward to the Guaporé Craton. Overall, intraplate basins are floored by continental or quasi-continental crust (*e.g.*, Guaporé, Brasiliano and Río de La Plata cratons). Likewise, the major part of the intraplate basins opened at the beginning of the Late Carboniferous. Therefore, Early Carboniferous rocks are missing or their occurrence is so limited that they have not been studied in depth. The main basins of the intraplate region are the Paraná, Chaco-Parana, Sauce Grande-Colorado, and La Golondrina. The Paraná Basin is the largest Upper Paleozoic basin of South America, covering approximately 1,700,000 km^2 (Milani and Zalán, 1999; Holz *et al*., 2000). It is bounded to the north by Precambrian crystalline rocks of the Brasiliano and Guaporé cratons and to the south by the Río de La Plata craton. The Asunción Arch separates the Paraná and Chaco-Paraná basins. According to paleogeographic reconstructions, two major depocentres, Alhuampa and Las Breñas are recognized in the Chaco-Paraná basin. Despite several facies changes among depocentres, the stratigraphic record of the Chaco-Paraná Basin can be correlated with the Paraná area in Brazil. To the south occurs a small group of outcrops and subsurface sequences known as the Sauce Grande-Colorado basin (López Gamundí *et al*., 1994; Andreis and Japas, 1996; Limarino *et al*., 1999; Chebli *et al*., 1999). Finally, in the Patagonian region, the La Golondrina basin represents the southernmost record of Late Paleozoic rocks in the cratonic area. This small basin, flanked and floored by Proterozoic metamorphic rocks and Paleozoic granitoids belonging to the so-called Deseado Massif (Leanza, 1958), shows a succession of fossil-rich latest Carboniferous-Early Permian deposits (Archangelsky *et al*., 1996).

In contrast with the intraplate area, the basins located along the western Gondwana margin are floored by different types of crustal rocks, from an Early-Middle Paleozoic oceanic and quasi-oceanic crust to Precambrian and Early Paleozoic granitic rocks. Moreover, the westernmost basins of southern South America exhibit a very complex tectonic history associated with widespread magmatic activity encompassing a large extensional episode along the active margin of Gondwana during the Permian and Early Triassic (Nasi *et al*., 1985; Breitkreuz *et al*., 1989; Kontak *et al*., 1990; Bahlburg and Breitkreuz, 1991; Llambiás, 1999). Subsidence rates were high, leading to the accumulation of several thousand metres of Late Paleozoic rocks. Despite their similar paleogeographic location and common features, they can be differentiated into arc-related (including fore- intra-, and backarc) and retroarc basins. The former encompass northwestern and central Chile, western Argentina, and west Patagonia, with intensive deformation during the Late Paleozoic, extensive magmatism, and in some cases metamorphism of Carboniferous sediments (Gohrbandt, 1992; Sempere, 1996; Jacobshagen *et al*., 2002; Thompson and Hervé, 2002). In contrast, retroarc basins suffered a minor degree of deformation, less magmatic activity characterized by basic lava flows, and a complete lack of metamorphism of Carboniferous deposits. The main retroarc basins are the eastern sector of the Madre de Dios, Tarija, Paganzo, and Tepuel-Genoa basins.

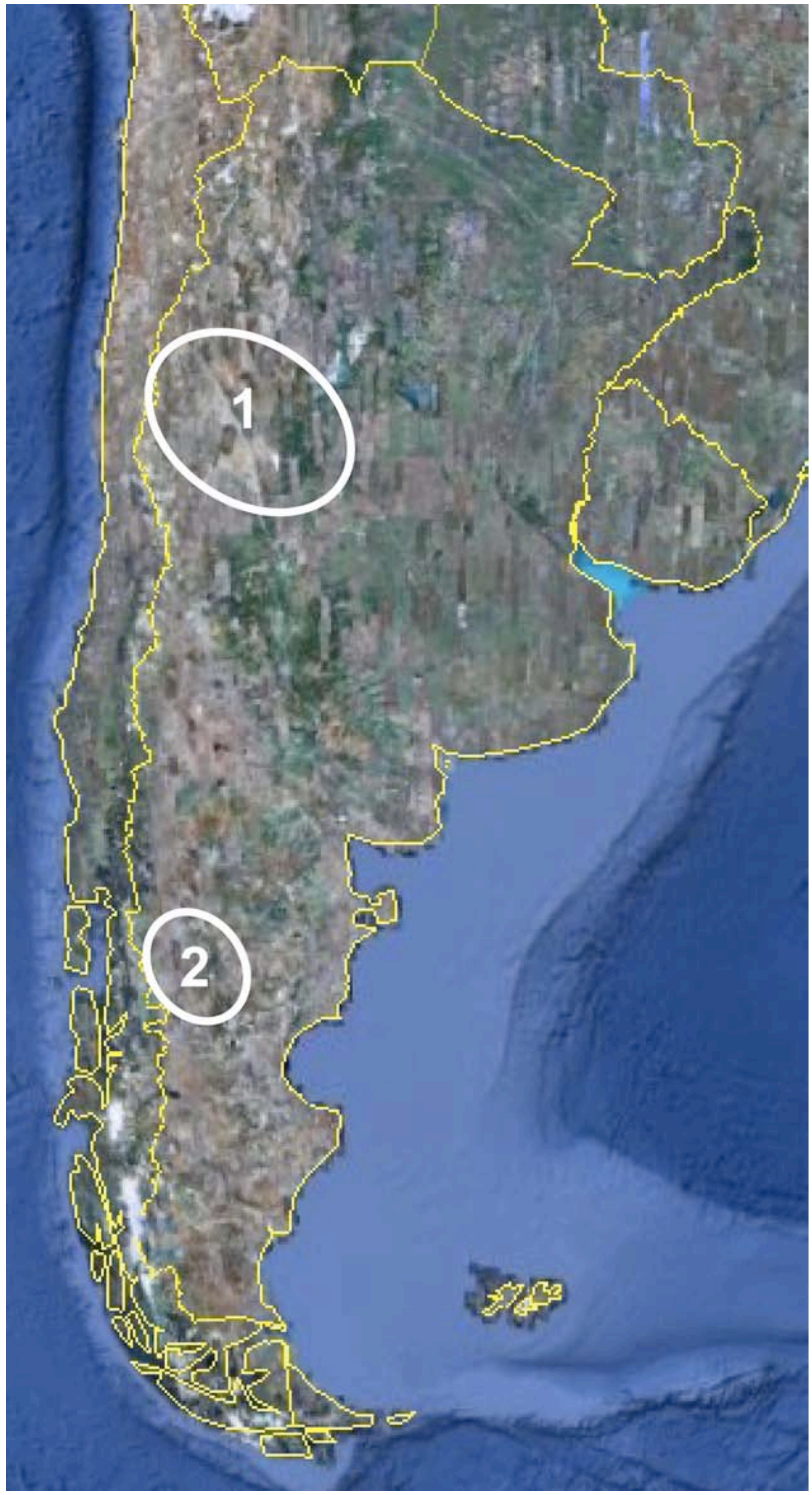

Figure 2. Google Earth image. 1. Calingasta-Uspallata Subbasin. 2. Tepuel-Genoa Basin.

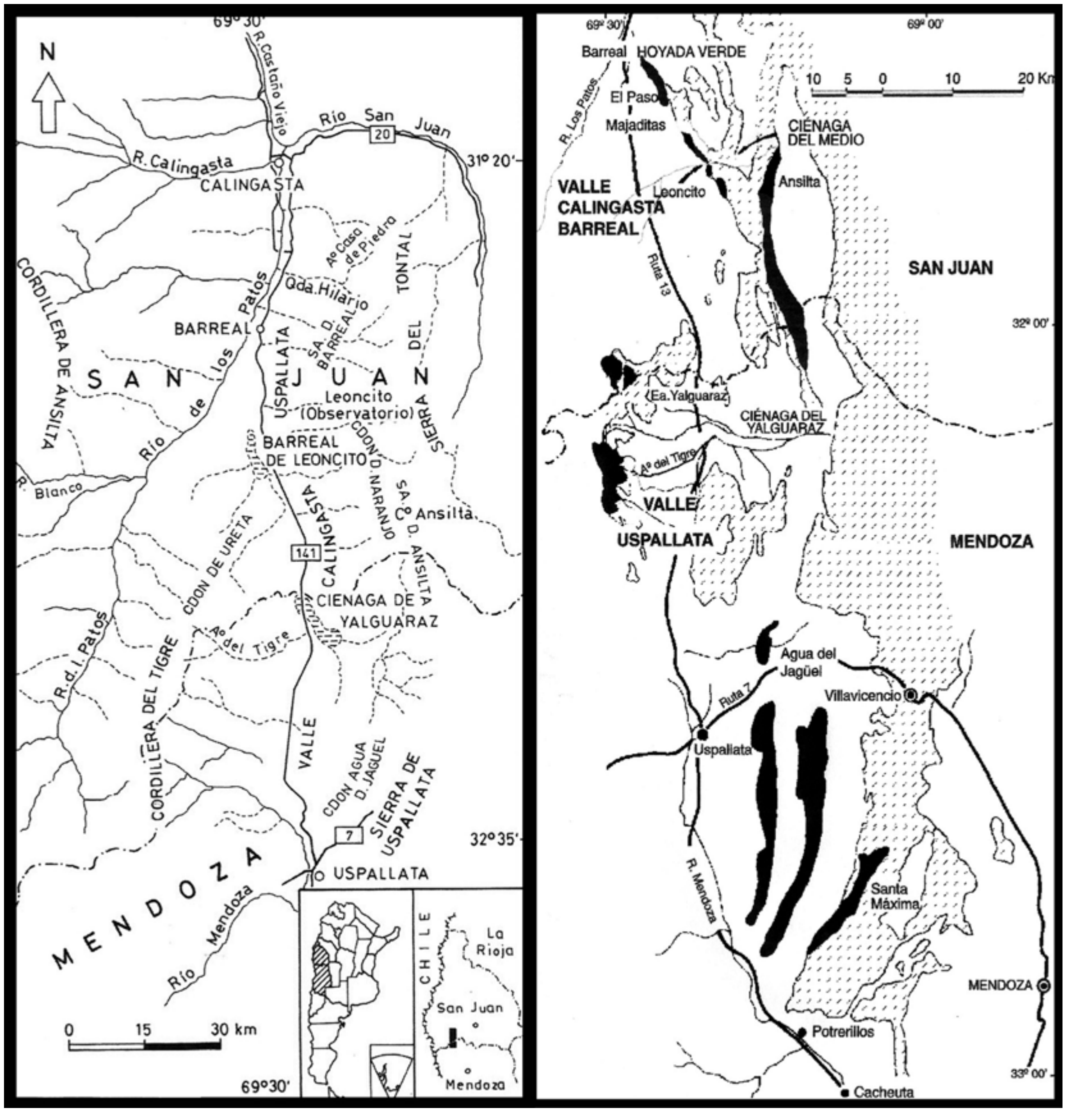

Figure 3. a: Calingasta-Uspallata Subbasin location map. b: Main Upper Paleozoic outcrops of the Barreal-Uspallata valley.

Arc-related basins include westernmost Madre de Dios, Navidad-Arizaro, Río Blanco, and Calingasta-Uspallata, as well as several dispersed Late Paleozoic outcrops in the central, coastal, and Patagonian regions of Chile. In one particular case, the San Rafael Basin can be divided in two sectors, with the western margin as an arc-related basin showing volcanic and volcaniclastic sedimentation and the eastern flank as a more stable retroarc environment.

Several Late Paleozoic sediments occur as disperse outcrops along the Andean Cordillera, longitudinal valley, and the coastal region of Chile (Thiele and Hervé, 1984; Rivano and Sepúlveda, 1983, 1985; Bell, 1987; Díaz Martínez *et al*., 2000). They likely are related with similar age sequences in northwest Argentina (Río Blanco and Calingasta-Uspallata), but the continuity of the outcrops is interrupted by a large volcanic

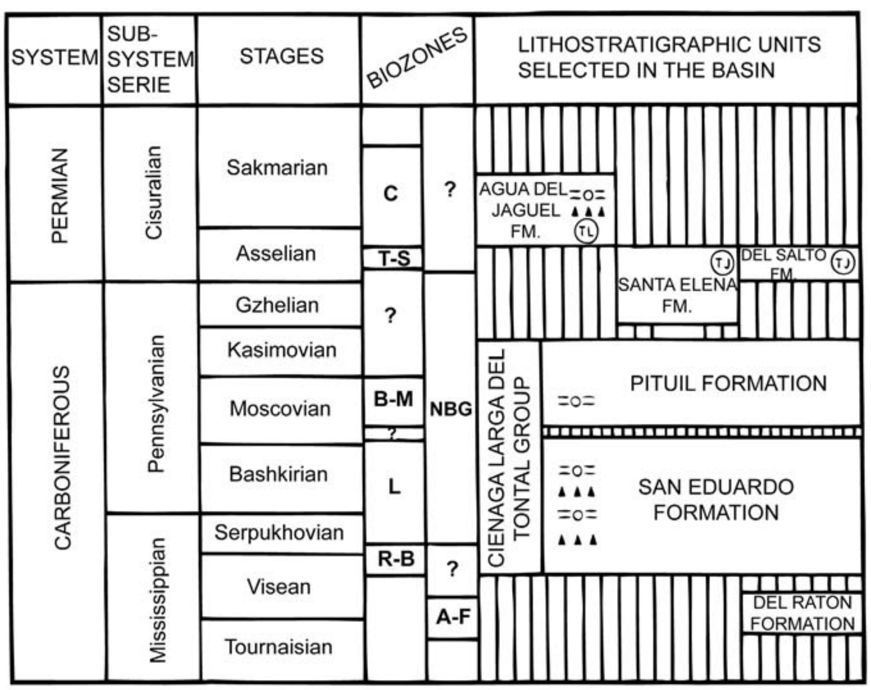

Figure 4. Scheme of stratigraphic correlation of selected Late Paleozoic units of the Calingasta-Uspallata subbasin, showing temporal and spatial distribution of different faunistic associations, lithostratigraphic units where they occur and recognized glacial episodes. Stages and stratigraphic units of higher hierarchy according to the International Stratigraphic Chart published by Gradstein *et al*. (2004). Formations without scale. A-F, *Archaeosigilaria-Frenguellia*; NBG, *Nothorhacopteris-Botrychiopsis-Gingophyllum*; R-B, *Rugosochonetes-Bulahdelia*; L, *Levipustula*; B-M, *Balakhonia-Maemia*; T-S, *Tivertonia-Streptorhynchus*; C, *Costatumulus*; ▲▲▲=O=, Diamictite and associated facies of Glacial episodes II and III; □□□□, San Eduardo epeirogenic phase (modified from Taboada, 2006).

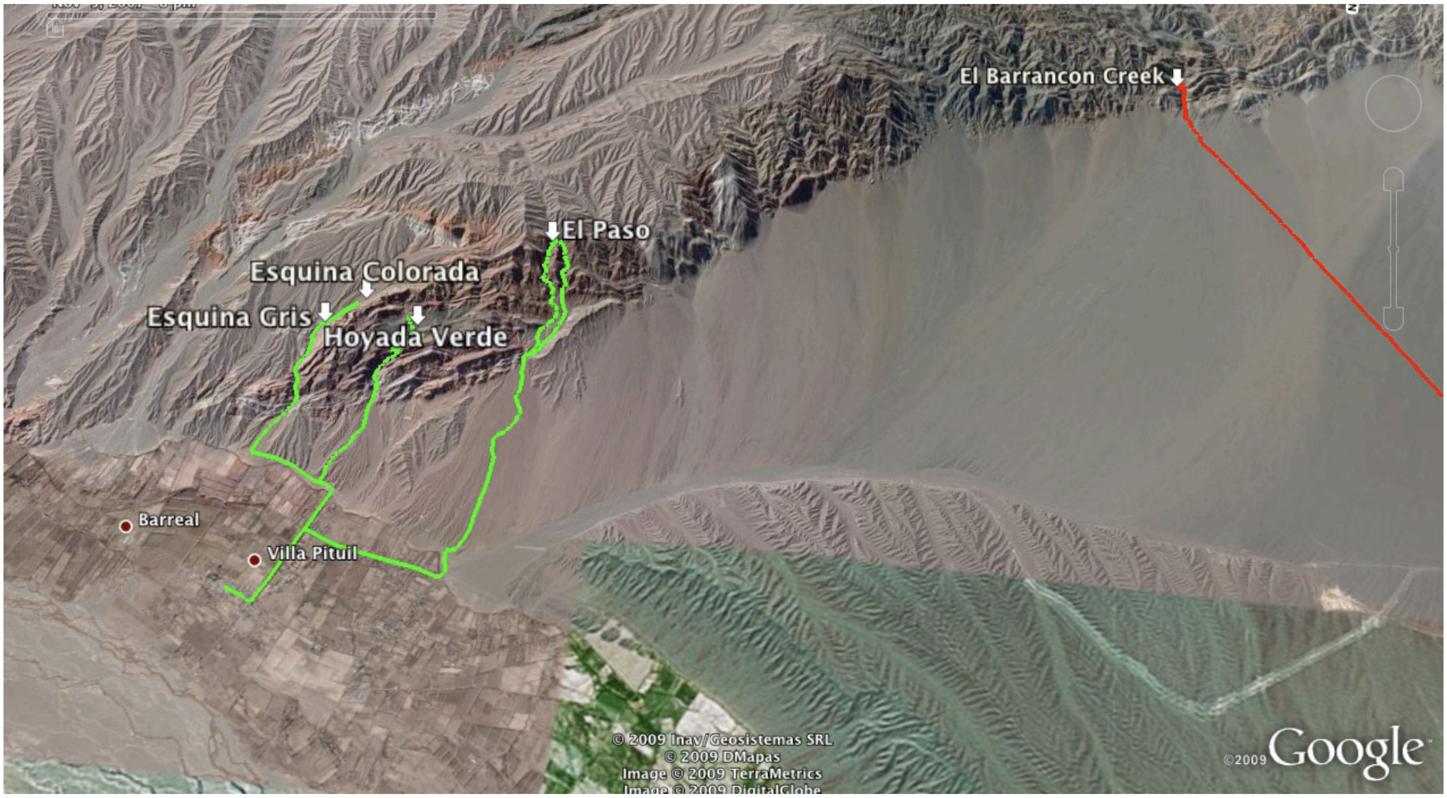

Figure 5. Sketch from Google Earth showing Stops 1 to 4.

Figure 6. Sketch from Google Earth showing Stops 5 and 6.

Figure 7. Sketch from Google Earth showing Stops 1 to 3. (Close-up of Figure 5)

chain developed during the Early Permian-Middle Triassic along the Andean Cordillera.

The so-called Protoprecordillera separates the western Río Blanco and Calingasta-Uspallata basins from the eastern Paganzo area (Salfity and Gorustovich, 1983; González Bonorino, 1991). The Paganzo basin shows an almost continuous sedimentary record from the latest Early Carboniferous to the Late Permian (Salfity and Gorustovich, 1983; Pérez *et al*., 1993; Limarino *et al*., 1996). The Río Blanco and Calingasta-Uspallata basins began to subside during the Early Carboniferous, and sedimentation was progressively replaced by volcanism by the latest Early Permian (Fernández Seveso *et al*., 1993; Limarino *et al*., 1996; Llambías, 1999). The Protoprecordillera was uplifted in the Late Devonian-Earliest Carboniferous and is basically composed of Late and Middle Paleozoic folded and faulted marine sediments. The Protoprecordillera is likely to continue toward the northeast, welded to the Puna Arch, which basically consists of deformed Lower-Middle Paleozoic sedimentary rocks (Salfity *et al*., 1975). In this way, the Protoprecordillera and Puna Arch may have acted as important structural elements separating the highly mobile arc-related basins from the retroarc basins. The Tarija Basin appears as a southerly embayment between the Puna Arch and Michicola-Guaporé Craton that grades northward into the eastern margin of the Madre de Dios Basin. Tarija exhibits a complete record from Early Carboniferous to Late Permian sediments (López Gamundi, 1986; Starck *et al*., 1993; Schulz *et al*., 1999). To the south, the paleogeography of the Late Carboniferous-Late Permian San Rafael basin is not well understood. In the northwest, the relation with the Calingasta-Uspallata basin has been clearly established by López Gamundi *et al*. (1994) but its relation to the southwestern sector of the Paganzo basin remains poorly known. The eastern extension of the San Rafael Basin has been considerably extended in recent years (Melchor, 1990; Azcuy and di Pasquo, 1999).

In the Patagonian region, the Tepuel-Genoa basin is flanked by the Somúncura and Deseado massifs, exhibiting a continuous sequence from the Early Carboniferous to the Early Permian (Andreis *et al*., 1987; Archangelsky *et al*., 1996; Limarino *et al*., 1999). This basin likely is related in the west to metamorphic rocks outcropping in the Cordillera de La Costa of Chile (Duhart *et al*., 2001). The belt of Late Paleozoic metamorphic rocks continues along the Patagonian Cordillera of Argentina and Chile toward the south to 48º30' (Riccardi, 1971; Godoy *et al*., 1984; Bell and Suárez, 2000).

Summarizing, Early Carboniferous times were marked by active tectonism in the basins located along the active margin of Gondwana and a lack of significant sedimentation in the rest of southern South America. Deposits of Early Pennsylvanian age occur throughout the analyzed region, with limited evidence of tectonism and magmatism and separated by unconformities from the Early Carboniferous successions. The Late Pennsylvanian-Early Cisuralian corresponds to the maximum extent of glacial accumulations in the cratonic region while fluvial deposits, interfingered with shallow marine sediments, generally prevailed in the basins of the active margin of Gondwana. The Late Cisuralian shows considerable contrast in the pattern of the western basins and those in the cratonic area. Whereas the former were locally

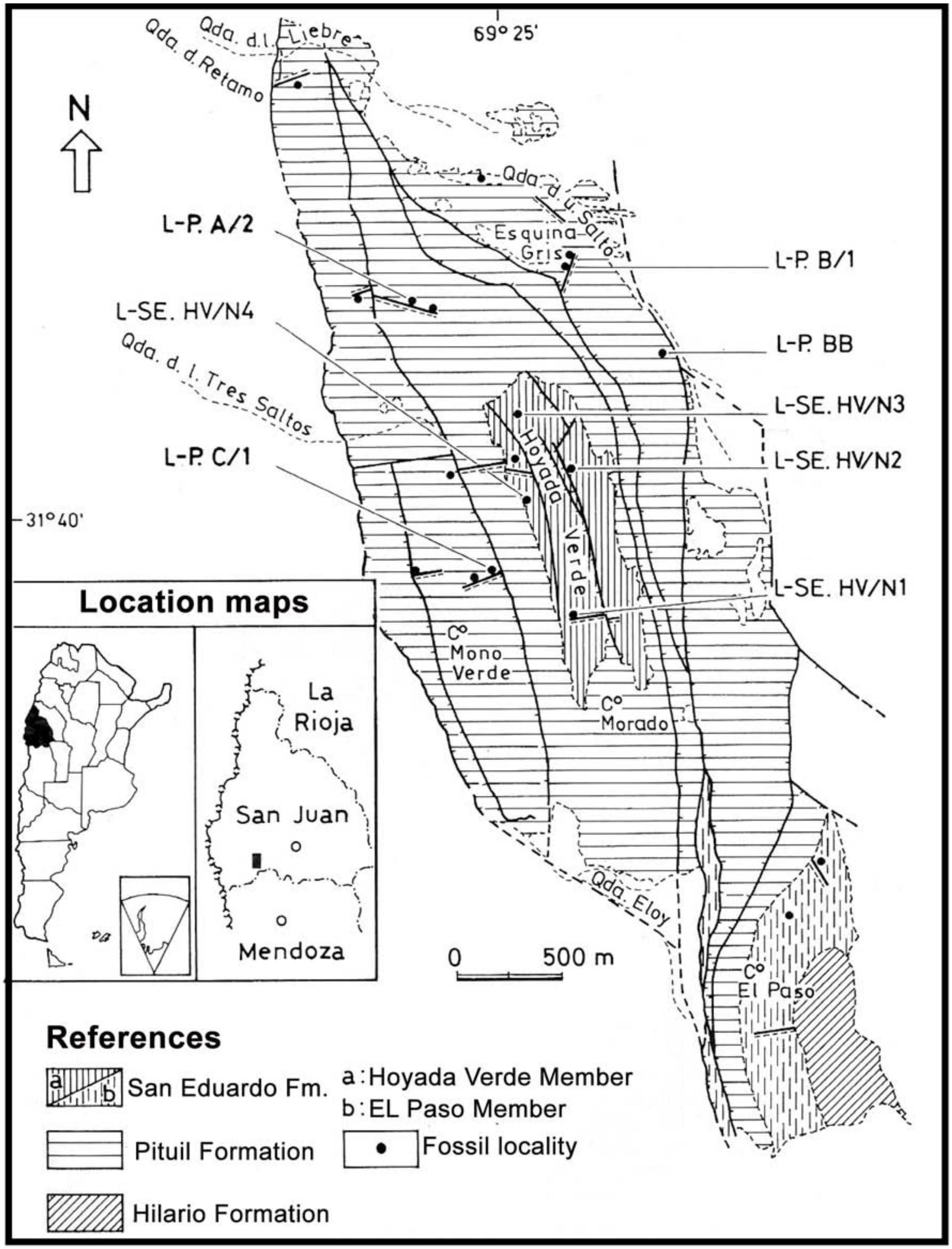

Figure 8. Geological map of the Paleozoic outcrops of the Barreal Hill (modified from Mésigos, 1953).

dominated by volcaniclastic sediments or marine deposits, including carbonate-terrigenous successions, in the cratonic area, transgressive-regressive cycles composed of shallow marine, deltaic, and fluvial siliciclastic deposits prevailed. The Middle-Late Permian elapsed with extensional tectonic conditions associated with the beginning of Gondwana break-up. Sedimentation continued with two contrasting patterns: widespread volcanism linked to volcaniclastic and fluvial-eolian sedimentation in the western region, and shallow marine, deltaic and fluvial deposition in the intraplate domain.

Calingasta-Uspallata Subbasin

The Calingasta-Uspallata Subbasin is the southern extension of the Río Blanco Subbasin, both constituting the narrow elongate arc-related Uspallata-Iglesia Basin, extended between 28º-34ºS, approximately (Figure 2). Upper Paleozoic deposits of the Calingasta-Uspallata Subbasin are recognized from the Calingasta village in the north to the Mendoza river in the south, and deposited mainly aligned in the east along the western flank of the Precordillera (Tontal, Cortaderas and Uspallata hills) and the Frontal Cordillera (Tigre, del Plata and Portillo hills) to the west (Figure 3). The Calingasta-Uspallata Subbasin presents an apparent complicated stratigraphy due in part to the strong tectonism that affected most of the Late Paleozoic deposits, now cropping out discontinuously. This circumstance has favoured a possible excessive number of lithostratigraphic units, some of them being poorly dated because of its nonexistent, insufficient or debatable fossil record. The stratigraphic scheme, and its stratigraphic correlation of selected Late Paleozoic units of the Calingasta-Uspallata Subbasin, shows temporal and spatial distribution of different faunistic/floristic associations, lithostratigraphic units where they occur and recognized glacial episodes (Figure 4). The key stratigraphic sections of Calingasta-Uspallata Subbasin were examined in five stops (Figures 5 and 6).

Stop 1. El Paso Member (Mésigos, 1953; nom. transl. González, 1993) of the San Eduardo Formation (Mésigos, 1953; nom. transl. González, 1993). Figure 7

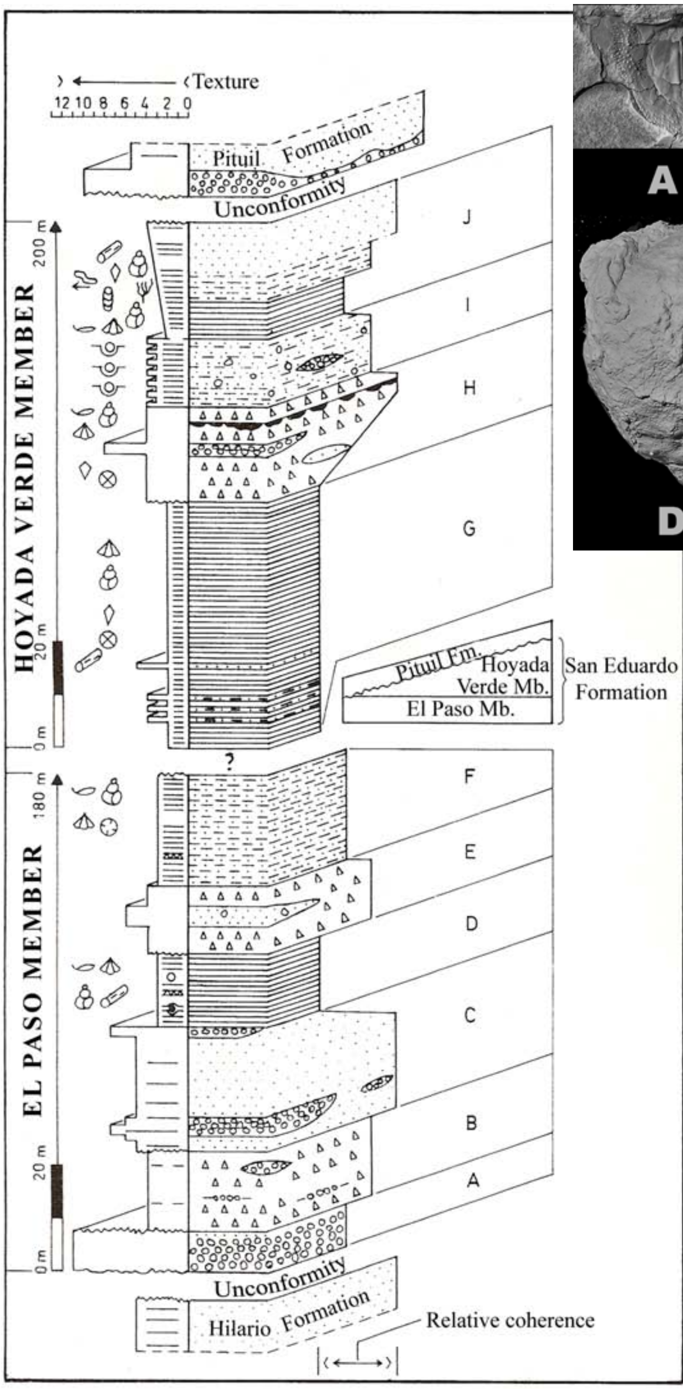

Figure 9. Stratigraphic section of the San Eduardo Formation at the Barreal Hill (modified from Taboada, 1997).

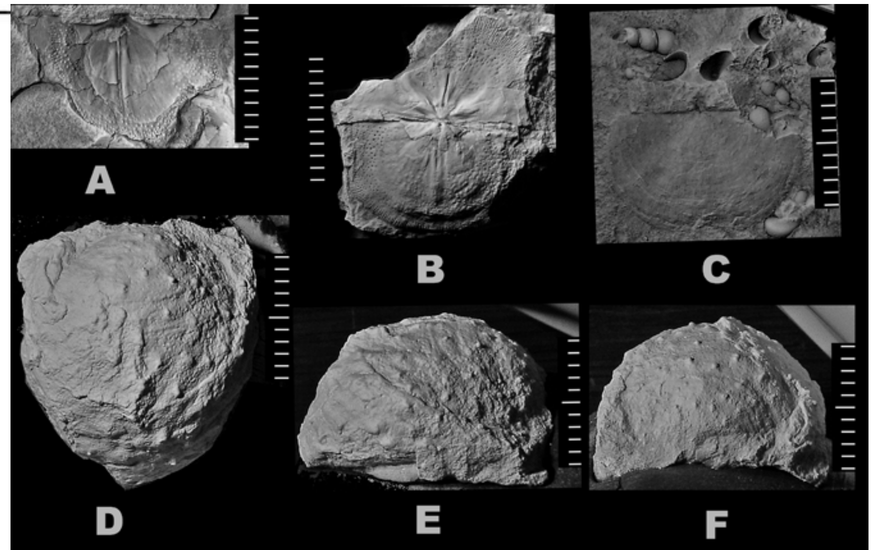

Figure 10. A-C, *Rugosochonetes gloucesterensis* (Cvancara) Taboada, 1989; A, FML-PI 1194-6, ventral valve internal mould; B, PIL 13539, dorsal and ventral internal moulds; C, PIL 13538, dorsal valve external impression and external and internal moulds of *Murchisonia* (*Murchisonia*) aff. *tatei* Elias? (Taboada, 1989). D-F, *Bulhadelia* cf. *myallensis* Roberts (Taboada, 1989), PIL 13550, ventral valve exterior in ventral, lateral and posterior views. (all specimens X 2. Scale bar = 10 mm.)

El Paso Member crops out in the southernmost part of the Barreal Hill (Figure 8), overlying the Hilario Formation (Ordovician) with an angular unconformity and underlying the Pituil Formation with an erosive and slightly angular (no more than 15º) contact. The El Paso Member reaches approximately 180 m of thickness (Mésigos, 1953; Taboada, 1997), and from the base to the top shows a glacial-marine sequence (Figure 9). It is constituted by massive conglomerate (A), matrix-supported conglomerate(diamictite) (B), stratified sandstone and conglomerate lenses (C), laminated shale with dropstones, siliceous concretions, sandstone lenses, cone-in-cone structures and invertebrate fossils, which occur within the shales and the concretions (D), massive matrix-supported conglomerate (diamictite) with pebbly sandstone and mudstone lenses (E), and laminate siltstone, siliceous concretions, cone-in-cone structures and invertebrate fossils (F). Taboada (1989), who described and listed a faunal assemblage constituted by brachiopods, mollusks (bivalves, gastropods and cephalopods), corals and bryozoans, provided the first report of a fossil record in the El Paso Member. The fauna has yielded the brachiopods *Rugosochonetes gloucesterensis* (Cvancara) and *Bulhadelia* cf. *myallensis* Roberts (Figure 10) (indistinguishable from the Australian specimens *sensu* Dr. John Roberts, pers. comm., Buenos Aires, 1991), as elements of biochronologic value. This allowed the recognition of the *Rugosochonetes-Bulahdelia* local biozone of late Viséan-early Namurian age, a biostratigraphic unit that would be preceding the incoming of the widespread slightly younger *Levipustula* fauna in western Argentina. Cisterna and Simanauskas (1999) and Simanauskas and Cisterna (2001), have concluded that the brachiopod faunas from the El Paso "Formation" would be within the latest Carboniferous-Early Permian range, provided a different interpretation of the fauna from the El Paso Member and additional fossil descriptions. On the other hand, others authors have considered the El Paso Member/Formation as partially or totally a lateral equivalent in regard of the Hoyada Verde Member/Formation (Amos and López Gamundi, 1982; López Gamundi and Martínez, 2003). Recently, an early Pennsylvanian age was suggested for the El Paso Member based on the first palynological record dominated by *Cristatisporites rolleri*, which can be also related with other associations from different localities of the

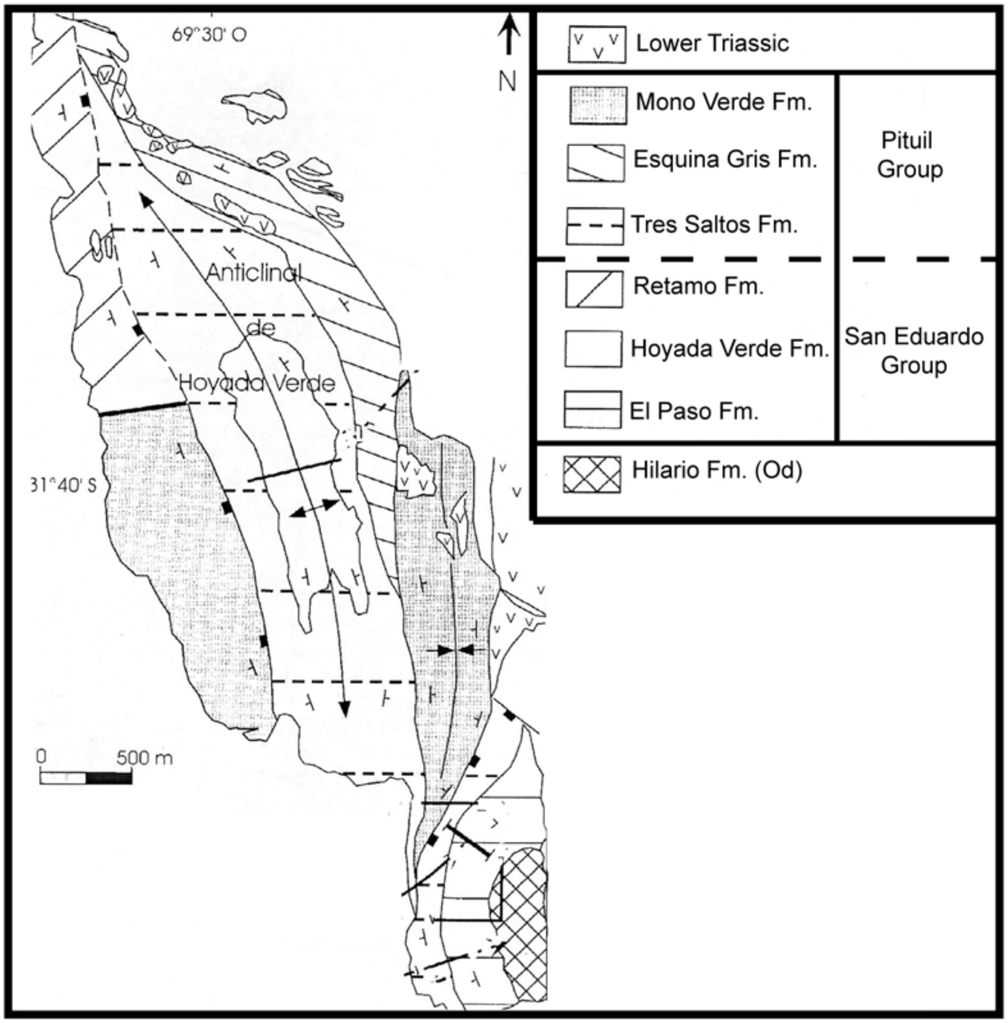

Figure 11. Hoyada Verde anticline map with stratigraphy following Mésigos (1953).

central western Argentinean basins included in the *Raistrickia densa-Convolutispora muriornata* Biozone (Vergel *et al*., 2008).

Stop 2.1. Hoyada Verde Member (Mésigos, 1953; nom. transl. González, 1993), and the Pituil Formation (Amos and Rolleri, 1965; nom. nov. for the Barreal Group of Mésigos, 1953; emend. Taboada, 1997) through the Tres Saltos creek at the western flank of the Barreal hill. Figure 7

The Hoyada Verde Member occupies the core of a major anticline with minor faults, forming a circle-like depressed topography, locally known as "Hoyada Verde" (≈ "green hole"). The base of the Hoyada Verde is unknown, but its stratigraphic continuity with the El Paso Member would be expected. These rocks are fringed by the Pituil Formation outcrops on the outer side of the anticline, with a regional erosive unconformity separating both units, due to epeirogenic movements between them (Taboada, 2001, 2004). A stratigraphic bias of almost all the Hoyada Verde Member can be appreciated toward the south of the Hoyada Verde and beyond. This erosive contact would be locally, with more or less angular character, caused by the younger orogenic diastrophic phase San Rafael of Sakmarian-Artinskian age (Taboada, 2004). Nevertheless, the nature of this contact was historically controversial and nowadays is still interpreted by different authors from an angular unconformity by orogenic diastrophic movements to a transitional passage of a continuous sequence. Recently, an erosive character (discontinuity with a hierarchy of second order) of the contact between the mentioned units is also indicated by López Gamundi and Martínez (2003) and Buatois and Limarino (2003). The Hoyada Verde Member exhibits 200 m of thickness (Cuerda, 1945, Mésigos, 1953;Taboada, 1997) of an exceptional well exposed glacial-marine sequence (Figure 9). From the base to the top of a compound profile shows: laminated shale with calcareous concretions, abundant glendonites (a cold water indicator), invertebrate fossils and floating trunks (G), matrix-supported conglomerate and pebbly mudstone (diamictite) with conglomerate lenses and siliceous concretions sometimes with invertebrate fossils, and a striated boulder pavement (González, 1981a) (H), stratified siltstone and sandstone with conglomerate lenses and dropstones (I), and laminated shale and limestone, parallel and cross-bedding stratified sandstone, with invertebrate fossils, glendonite, floating stems and bioturbation (J). More than fifty species have been recorded in the Hoyada Verde Member, which started with the contribution by Reed (in Du Toit, 1927) and later with descriptions/mentions by Cuerda (1945), Leanza (in Heim, 1945), Mésigos (1953), Amos *et al*. (1963), Amos and Rolleri (1965), Sabattini and Noirat (1969), Sabattini (1972, 1980a, 1980b), González (1985a), Taboada and Sabattini (1987), Taboada (1997) and Sterren (2003). The main described/illustrated invertebrates are: the bryozoans *Fenestella sanjuanensis, F. altispinosa* and *F. barrealensis* (Sabattini, 1972), the gastropods "*Peruvispira*" *australis* (Sabattini and Noirat, 1969), *Barrealispira mesigosi* and *Pthychomphalina striata* (Sowerby) (Taboada and Sabattini, 1987), the brachiopods *Spiriferellina octoplicata* Sowerby (Reed, 1927) and *Levipustula levis* Maxwell (See Simanauskas and Cisterna, 2001), the bivalves *Streblochondria sanjuanensis* and *S. stappenbecki* (Reed) (Reed, 1927, Sterren, 2003), and the annelids? *Sphenotallus stubblefieldi* (Schmidt and Teichmüller) (Taboada, 1997). Since the contribution by Amos *et al*. (1963), the *Levipustula* biozone has been recognized in the Hoyada Verde Member, in other units of the subbasin, as well as the La Capilla (at Las Cambachas place) and Leoncito formations. Later, elements of the *Levipustula*

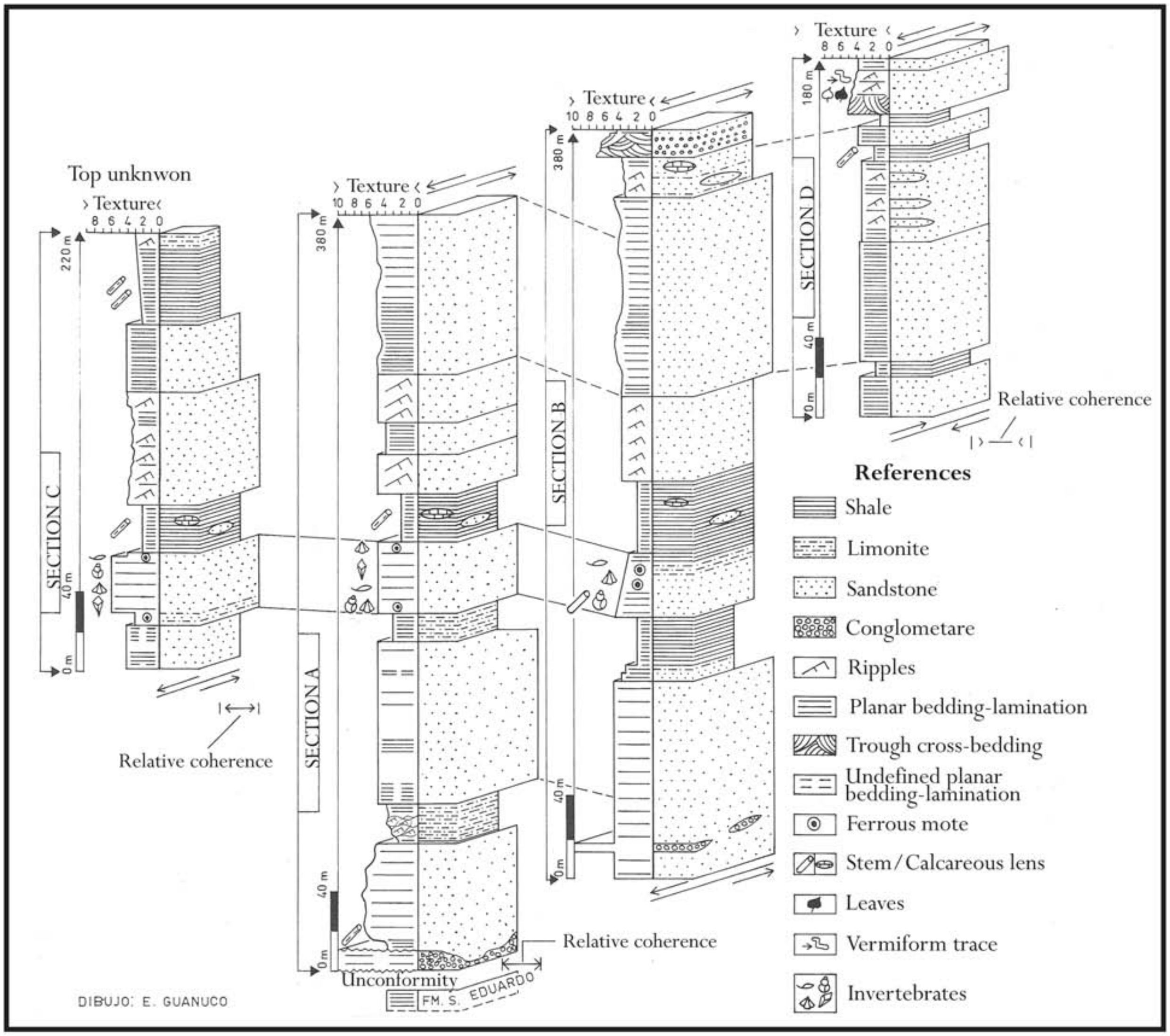

Figure 12. Composite columnar section of Pituil formation at the Barreal Hill. Sections A, B, C and D are equivalent to the Tres Saltos, Esquina Gris, Mono Verde and El Retamo "Formations" of Mésigos (1953) respectively (modified from Taboada, 1997)

fauna were reported from outcrops of La Capilla Formation at the Corral Village (González and Taboada, 1987) and Yalguaraz Formation at the Frontal Cordillera (Taboada and Cisterna, 1996). The Hoyada Verde Member exhibits the base and top of the *Levipustula* biozone in western Argentina (Taboada, 1990, 1997), which was recently discriminated yielding the nominated intraglacial and postglacial *Levipustula* faunas (Cisterna and Sterren, 2008), respectively. The Namurian postglacial transgression has been widely recognized also in the Rio Blanco subbasin and eastern Paganzo basin (Limarino *et al*., 2002). The age of the *Levipustula* biozone in western Argentina is currently estimated as Serpukhovian-Bashkirian, when glacial conditions prevailed in most Gondwanic regions.

Stop 2.2. The Pituil Formation (Amos and Rolleri, 1965; nom. nov. for the Barreal Group of Mésigos, 1953; emend. Taboada, 1997) through the Tres Saltos creek at the western flank of the Barreal hill. Figure 7

The Pituil Formation groups different sections cropping out at the Barreal Hill, which were formerly indicated as Tres Saltos, Mono Verde, Esquina Gris and El Retamo "formations" in the stratigraphic scheme by Mésigos (1953) (Figure 11). The identification of a common fossiliferous content together with lithostratigraphic similarities allowed interpreting these sections (Figure 12) as part of a single stratigraphic unit (Taboada, 1990, 1997). The minor transverse and meridian faults that affected the sequence have been indicated as tear faults and ridings linked to the folding mechanism (Milana and Banchig, 1997, López Gamundi and Martínez, 2003). The sequence of 450 m of maximum thickness (at the Barreal hill), starts with coarse sandstone, conglomerate and matrix-supported conglomerate (diamictite) above an erosive unconformity that indicate a relatively significant fall of sea level and the movement of shallower facies to the centre of the basin (López Gamundi and Martínez, 2003). The basal coarse filling (fluvial initial incision of Buatois and Limarino, 2003) is followed by a transgressive set of facies with a short interval of maximum flooding at the level with invertebrate fossils, also reflecting an intrabasinal expansion of depositional areas. *The Marginovatia-Maemia* (formerly *Balakhonia-Geniculifera*) biozone was defined

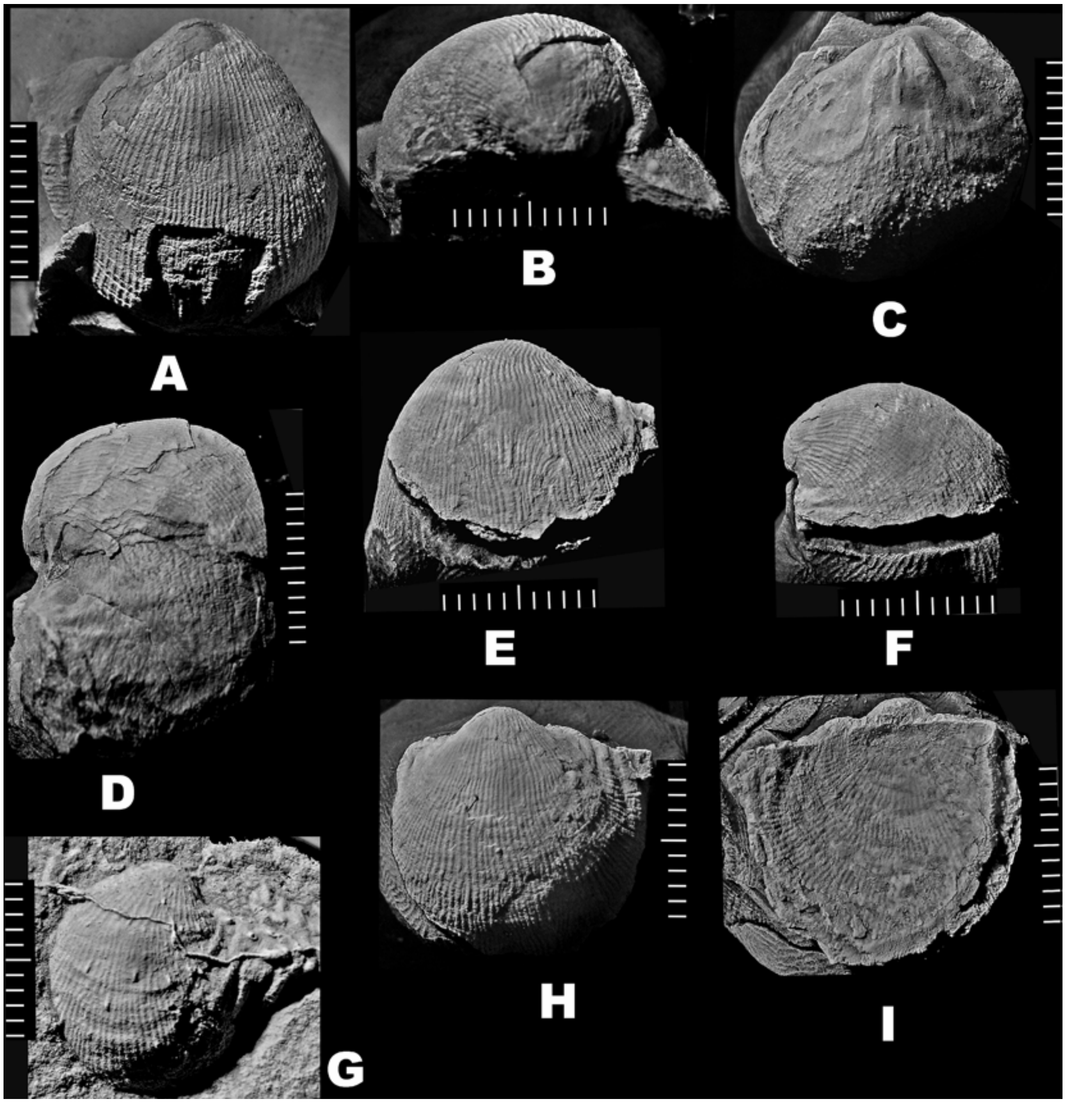

Figure13. A-I, *Marginovatia peregrina* (Taboada). A-B, FML-PI 552 (holotype), ventral valve in ventral and posterior views; C, FML-PI 551, ventral valve internal mould; D, FML-PI 561, ventral valve in lateral view; E-F, H-I, FML-PI 571, articulate specimen in anterior, lateral, ventral and dorsal views; G, FML-PI 569, latex cast of ventral valve exterior in ventro-lateral view. (All specimens x2; Scale bar = 10 mm.; FML-PII: Paleontological Institute Miguel Lillo Foundation, Tucumán, Argentina).

for this last stratigraphic interval and estimated to be of late Westphalian (Moscovian) age (Taboada, 1997). It is characterized by a faunal assemblage with *Neoplatyteichum barrealensis* (Reed), *Glabrocingulum (Stenozone?) argentinus* (Reed), *Straparollus (Euomphallus) subcircularis* (Mansuy), (Reed, 1927, Sabattini and Noirat, 1969, Taboada, 1989), *Aviculopecten barrealensis* (Reed) (Reed, 1927, Taboada, 1997, Sterren, 2003), *Nuculanella camachoi* (González), *Streblochondria* sp. and *Streblopteria* sp. (Sterren, 2003), *Reticularia notica* (Reed), *Leiorhynchus* sp. (Cisterna and Taboada, 1997), *Marginovatia peregrina* (Taboada) (Figure 13), *Maemia tenuiscostata* (Taboada) (Figure 14), *Neochonetes granulifer* (Owen), *Sphenotallus stubblefieldi* (Schmidt and Teichmüller) (Taboada, 1997, 2006), and others. These same levels were previously indicated by Amos and Rolleri (1965) as the type section of the supposed younger (Early Permian) *Cancrinella* cf. *farleyensis* (Etheridge and Dunn) (=*Linoproductus lineatus* Waagen of Reed, 1927) Zone, which was reassigned later to *Balakhonia peregrina* by Taboada (1997) and currently to *Marginovatia peregrina* (Taboada) (Taboada and Pagani, 2009). The *Marginovatia-Maemia* fauna was linked to a formidable climatic change in the region that brought mild environments to the setting (interglacial of González, 1990; paleoclimatic subphase IIIb of López Gamundi *et al*., 1992) after the disappearance of the previous glacial conditions, and joined to the *Levipustula* fauna in the Precordillera. On the other hand, Cisterna (in López Gamundi and Martínez, 2003) has also suggested an Early Permian age to sections correlated with the Pituil Formation at the Barreal Hill.

Stop 3. The Pituil Formation (Amos and Rolleri, 1965; nom. nov. for the Barreal Group of Mésigos, 1953; emend. Taboada, 1997) throughout the Un Salto creek, northeastern flank of the Barreal hill. Figure 7

The Pituil Formation exhibits three partial sections in contact by meridian faults throughout the Un Salto creek. The westernmost outcrops, previously referred as El Retamo “Formation”, have yielded macro- and microflora remains in the creek north of Un Salto Creek. From this last locality, Carrizo (1992) has reported *Nothorhacopteris argentinica* (Geinitz), *?Araucarioxylon* sp., *Caheniasaccites ovatus* Bose and Kar and *Protohaploxyplinus* cf. *P. perfectus* (Naumova ex Kara-Murza). The core of the middle section constitutes the northernmost part of the anticline of the Barreal Hill, with a section of the A/Tres Saltos “Formation” partially exposed. The eastern section shows a well exposed profile of a section of the B/Esquina Gris “Formation”, where historical fossiliferous localities are found. One of them is the Esquina Gris locality (“grey corner”), where Stappenbeck (1910) found the first invertebrate fossils of the Upper Paleozoic of Argentina. The other, is the Esquina Colorada locality (“red corner”), where probably Du Toit, guided by Keidel, collected samples later described by Reed (in Du Toit, 1927). These localities have provided most of the specimens described for the Pituil Formation and where

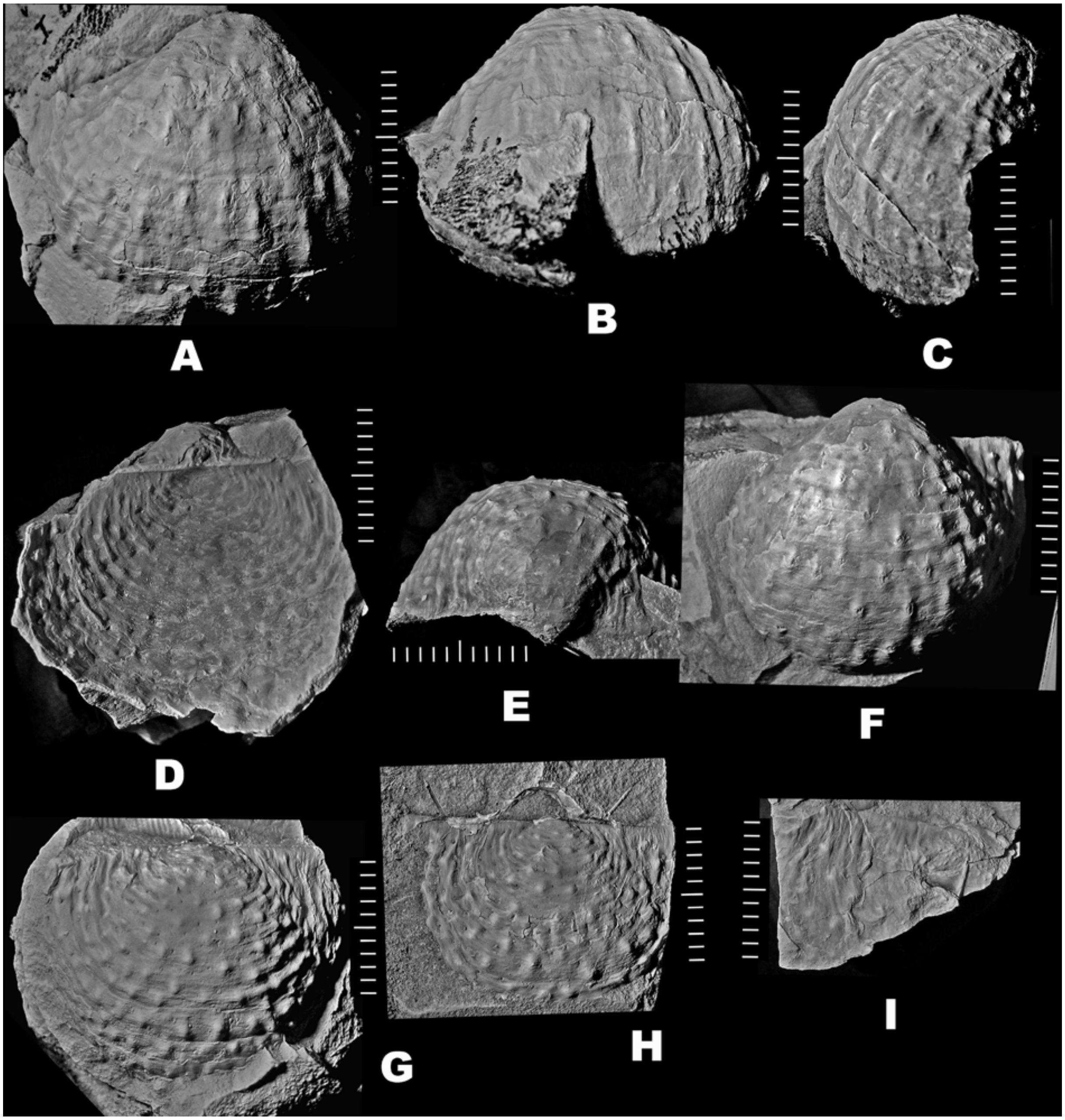

Figure 14. *Maemia tenuiscostata* (Taboada). A-C, FML-PI 1061 (holotype), ventral valve in ventral, anterior and lateral views; D, FML-PI 1062 (paratype), articulate specimen in dorsal view; E-F, FML-PI 1068 (paratype), ventral valve in posterior and ventral views; G, FML-PI 1076 (paratype), mould dorsal valve exterior; H, FML-PI 1074 (paratype), mould dorsal valve exterior of an articulate specimen showing cardinal spines; I, FML-PI 1066 (paratype), fragmentary dorsal valve interior. (All specimens x2; Scale bar = 10 mm.; FML-PI: Paleontological Institute Miguel Lillo Foundation, Tucumán, Argentina)

the *Marginovatia-Maemia* biozone is well represented (Figures 13 and 14).

Stop 4. The Majaditas Formation (Amos and Rolleri, 1965) at the El Barrancón creek, Del Naranjo hill. Figure 5

The Majaditas Formation with 650 m of thickness is exposed along the northwestern flank of the Del Naranjo hill, 15 km south of Barreal village (Figure 15). Its exposures are flanked to the south and north by discontinuous outcrops of Carboniferous deposits of similar age (San Eduardo/Pituil and Leoncito/Ansilta Formations, respectively). The unit has been subdivided into six informal members with nine facies identified (Figure 16) (López Gamundi, 2001): Basal member, Diamictitico member, Rojo I member, Areniscas and Pelitas moteadas member, Rojo II member and Superior member. The facies include:

Facies 1: deposits are confined to the basal part of the section (Basal member) consist of clast-supported conglomerate and subordinate coarse- to medium grained sandstone. Clasts in the basal conglomerate display flow-parallel long axis orientation, indicative of suspension rather than traction. The abundance of conglomerate and maximum clast size decreases up section. Overall, the basal third of the section shows a clear fining-upward trend. These deposits were deposited by high-density gravity flows and tractional flows in a coarse-grained delta (fan delta) setting.

Facies 2: deposits are massive pebbly mudstone intercalated within the facies 1 deposits. The exposures are limited and some of the clasts show striations. Based on contextual evidence, the pebbly mudstone may be interpreted as part of the spectrum of shallow gravity flows that dominate the basal part of the section.

Facies 3: is made up of laminated mudstone and interceded lenticular diamictite. Dropstones, indicative of ice-rafted material,

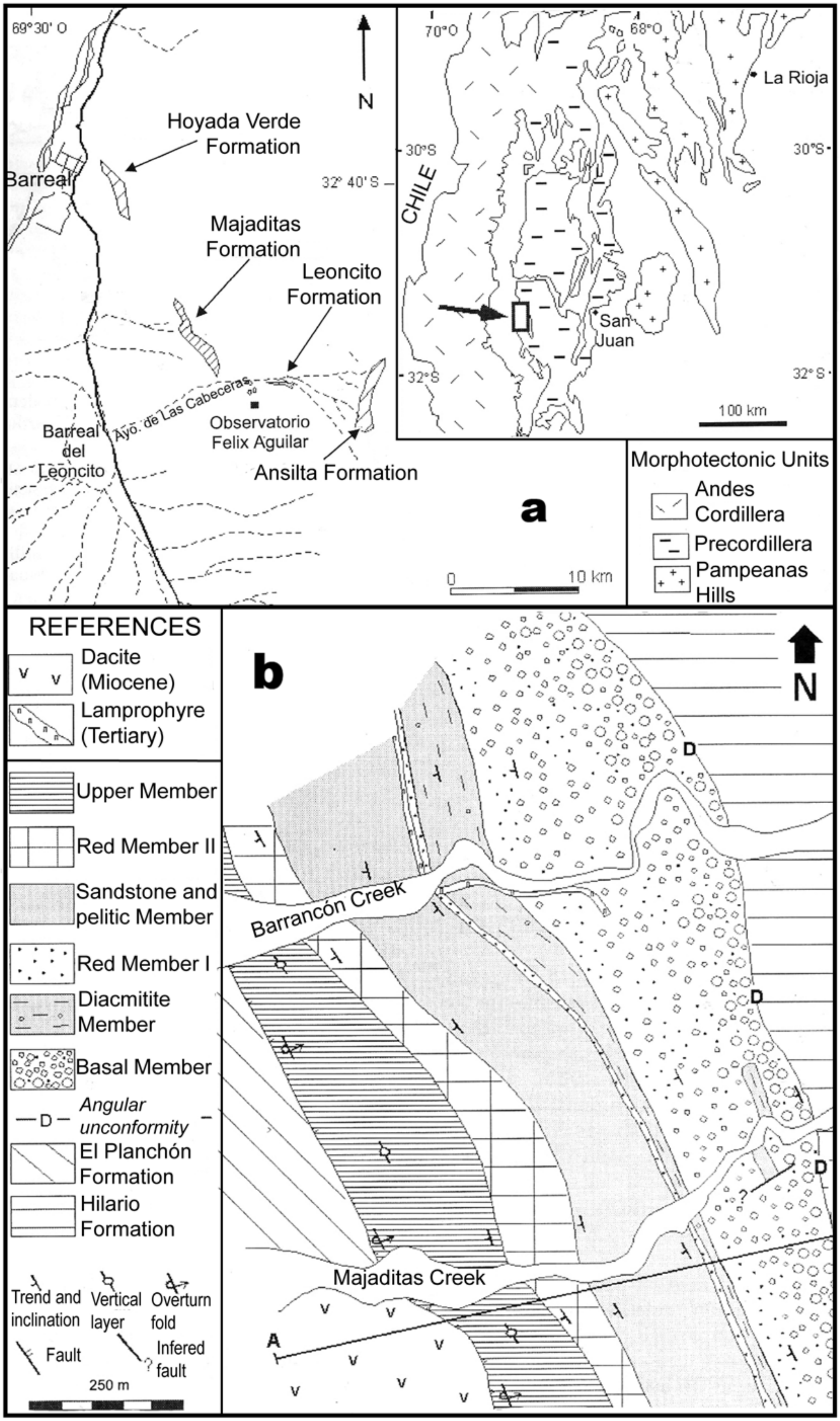

Figure 15. a: Location and generalized geological maps of the Majaditas Formation and other Carboniferous units exposed along de western flank of the Precordillera near the town of Barreal. b: Detailed geological map of the Majaditas Formation and its members between the Barrancón and Majaditas creeks. (modified from López Gamundi, 2001).

are present in the laminated mudstone. The lenticular bodies of diamictite show in some cases two distinct lithologies (pebbly mudstone and pebbly sandstone) with sharp contacts surrounded by variably deformed mudstone.

Facies 4: consists of thin bedded, low-density turbidites with complete Bouma cycles. These facies deposits were locally affected by centimetric to decametric scale soft-sediment deformation (slumps). Flute casts and tool marks indicate a southwesterly paleoflow.

Facies 5: deposits are dominated by well-sorted, coarse- to medium grained sandstone with 3D ripples and cross-bedding stacked into multistorey (5 to 20 m thick), channeled complexes.

Facies 6: is characterized by a heterolithic interbedding of fine-grained, current-ripple-laminated sandstone and subordinate mottled (bioturbed) mudstone.

The erosive surface between the Diamictitic member and the Rojo I member was considered equivalent with the unconformity interposed between the San Eduardo and Pituil formations and the former sections broadly correlated with the last units, respectively (López Gamundi, 2001; Taboada, 2004).The

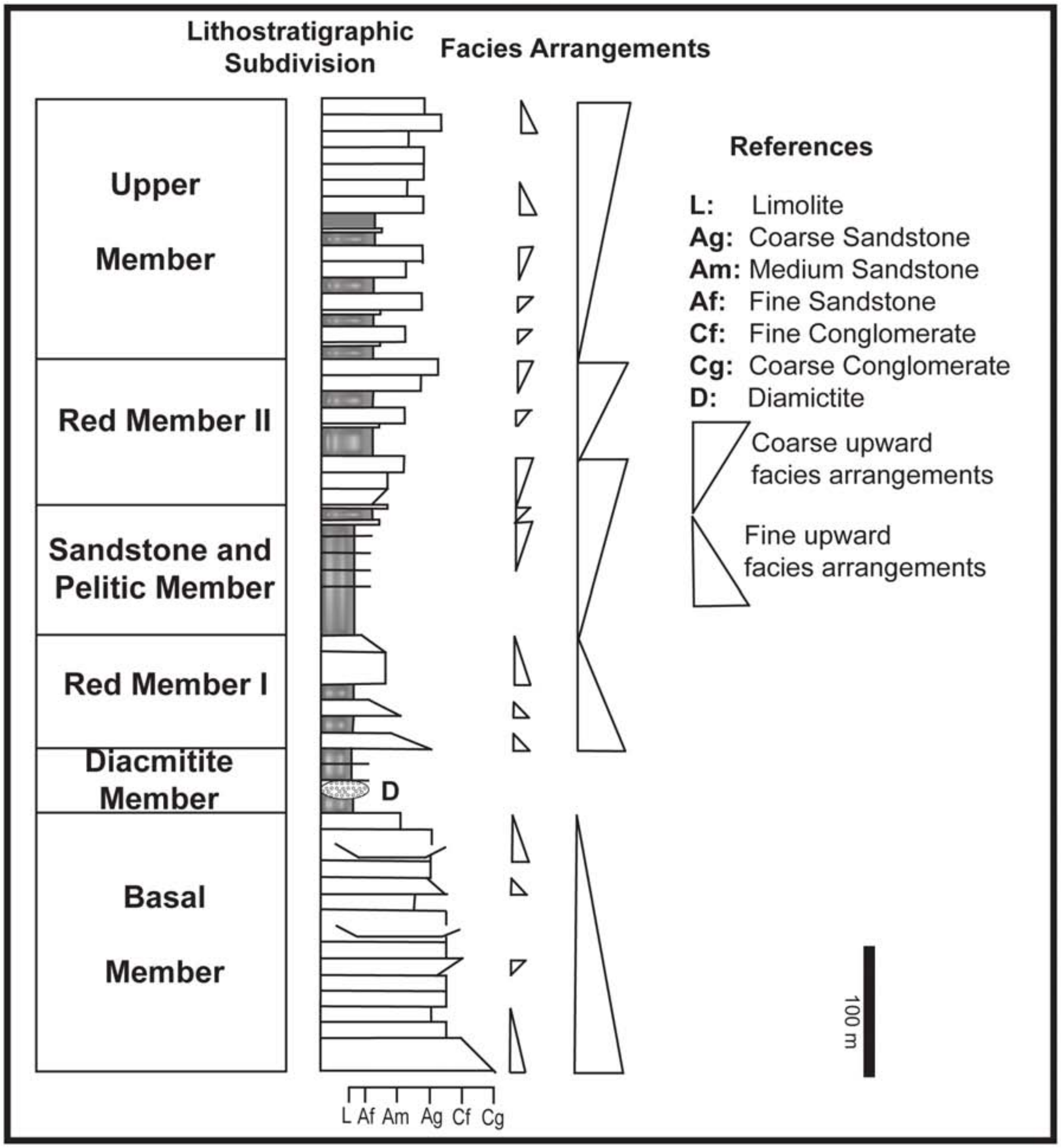

Figure 16. Schematic summary of facies associations, key correlation surfaces and fill stages identified in the Majaditas Formation. Note the retrogradational trend of fining upward successions (distributary channels) of member Rojo I (fill stage III) and progradational parasequence sets of upper half of Areniscas y Pelitas moteadas member and Rojo II member. (modified from López Gamundi, 2001).

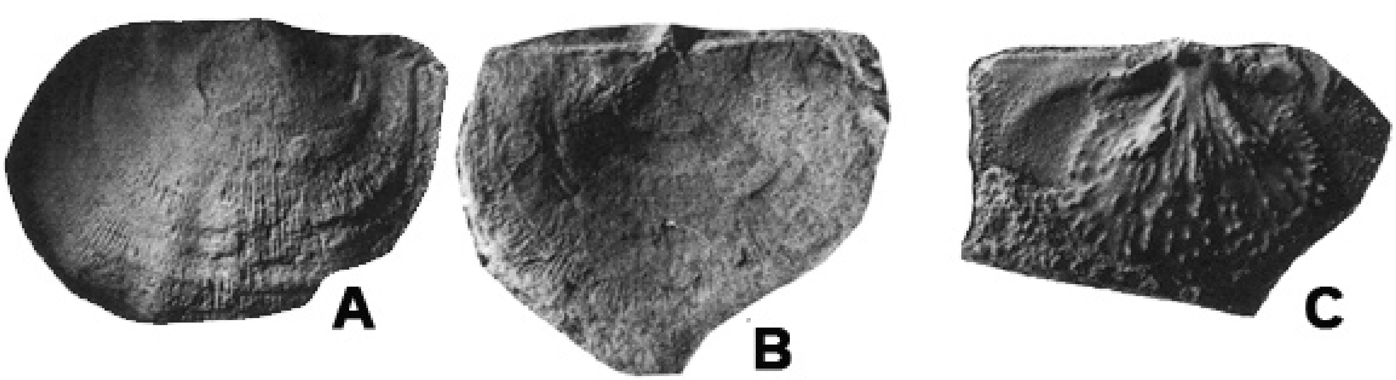

Figure 17. A-C. *Tivertonia jachalensis* (Amos). A, IPI 3960a x 6, exterior of partially decorticated ventral valve; B, IPI 390b x 5, exterior of partially decorticated dorsal valve; C, IPI 3980a x 7, interior of dorsal valve. (Modified from Taboada, 2006).

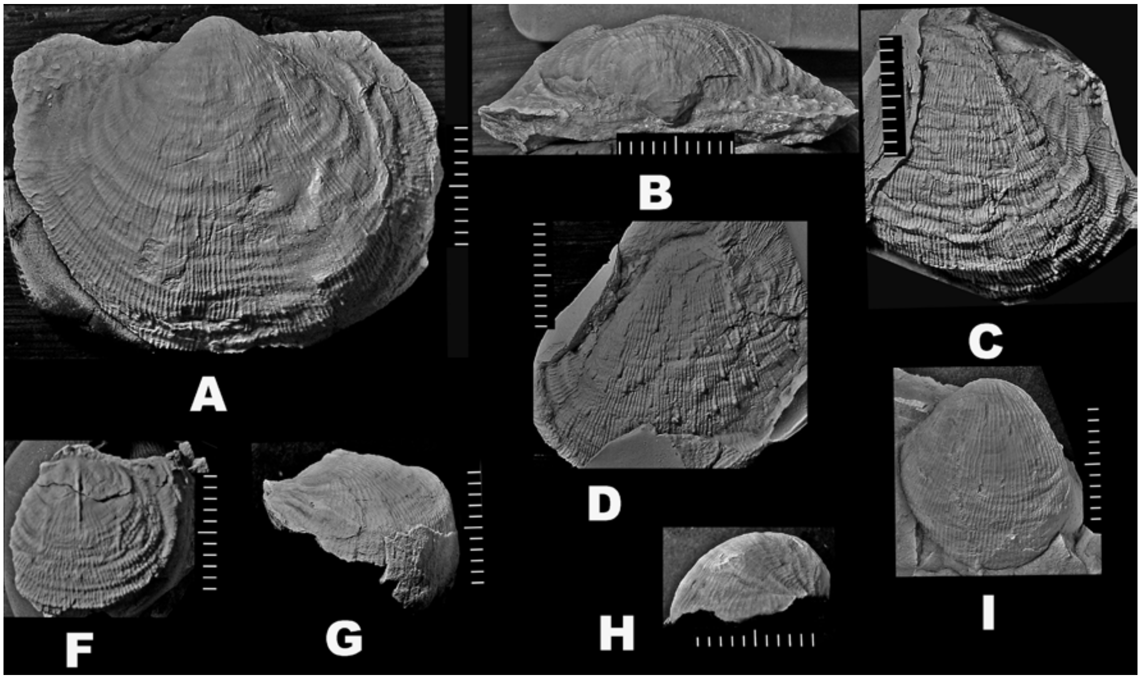

Figure 18. A-D, *Costatumulus amosi* Taboada, 1998. A-B, FML-PI 1311a (holotype), ventral valve in ventral and posterior views. C, FML-PI 1869 (paratype), latex mould ventral valve exterior. D, FML-PI 1871 (paratype), latex mould ventral valve exterior. F-I: *Coolkilella keideli* Taboada, 198. F, H, FML-PI 1842 (holotype), articulate specimen showing dorsal valve interior and ventral valve in lateral view. G, FML-PI 1833 (paratype), dorsal valve in lateral view. I, FML-PI 1845 (paratype), mould ventral valve interior in ventral view (all specimens x 1.5; scale bar: 10 mm.).

first mention of abundant fossils in the Majaditas Formation was provided by Taboada (1997) although most of them remain unpublished. Recently, González (2002a,b) has described the bivalves *Euchondria* sp., *Streblopteria?* sp., *Pleurophorella?* sp., *Myonia?* sp., *Vacunella?* sp., *Myofossa calingastensis* and *Burnettilina taboadai* (González) (Waterhouse, 2008). The gastropods *Auriptygma?* sp., *Mourlonia?* sp., *Murchisonia?* sp., *Neoplatyteichum barrealensis* (Reed), *Ptychomphalina striata* (Sowerby), *Ptychomphalina turgentis* Taboada, *Straparollus (Straparollus)* sp. and the brachiopods *Anopliidae indet, Beecheria* sp., *Gonzalezius naranjoensis* Taboada, *Martinia?* sp., *Reticularia* sp. indet, *Spirifer* sp., besides *Orchesteropus atavus* Frenguelli are identified in the Pituil Formation at the Barrancón creek (Taboada *et al*., 2008). All fossils known to this locality, including remains of the *Nothorhacopteis-Bothychiopsis-Gyngkophyllum* flora and genera of the Apiculati Infraturma (Vergel *et al*., 2000), come from the "Spotted Sandstone and Siltstone Member", which can be correlated with the widespread postglacial deposits of the IIIa paleoclimatic subphase or threshold of an interglacial event in western Argentina. In the Precordillera, this faunal association would be close to the top of the *Levipustula levis* Maxwell biozone or may be representing the first younger subsequent faunistic record (older than the *Marginovatia-Maemia* fauna) with an estimated late Bashkirian-early Moscovian age.

Stop 5. Santa Elena (Yrigoyen, 1967; emend. Taboada, 1998) and Agua del Jagüel (Harrington, 1971) formations, through the Uspallata Creek. Figure 6

Two different lithostratigraphic units can be distinguished along the Uspallata creek, one bearing the *Costatumulus* fauna and the other with the *Tivertonia-Streptorhynchus* and NBG faunal and floral assemblages, respectively. The last were recorded in the Santa Elena Formation, which was subdivided into two members, the older or Tramojo Member (Polansky, 1970; nom. transl. Taboada, 1998 - equivalent to Sections G and H of Dessanti and Rossi, 1950/Sections II, IIIa, IIIb, IIIc2 of Rodríguez, 1966) and the younger Jarillal Member (Polansky, 1970; nom. transl. Taboada, 1998). Both members are partial stratigraphic sections, each faulted at its base and top, and its stratigraphic arrangement was suggested by extrapolation with the similar faunal and floral association occurrences in the correlatable Río del Peñón Formation, in the Río Blanco subbasin to the north (Taboada, 1998). On the other hand, partial sections bearing *Costatumulus amosi* which crop out crossing the Uspallata Creek were correlated with the Agua del Jagüel Formation (Taboada, 1998), which has its type section a few km to the north of the creek. The Tramojo Member reaches 600 m of thickness of a sequence deposited mostly in a lacustrine fan delta (Freije, 2004). Plant fossil remains occur in several levels and belong to the macrofloral assemblage *Nothorhacopteris-Botrychiopsis-Gingophyllum* of Late Carboniferous age (Archangelsky and Archangelsky, 1987). The described flora includes *Paracalamites australis* Rigby, *Nothorhacopteris argentinica* (Geinitz), *Fedekurtzia argentina* Archangelsky and *Brotrychiopsis sp.* (Archangelsky and Archangelsky, 1987).

The Jarillal Member exhibits 650 m thickness, of a sequence mainly with shallow marine (lower half) and fluvial-lacustrine (upper half) environments (see Freije, 2004). The marine section has provided fossils of the *Tivertonia-Streptorhynchus* fauna (Taboada, 1997, 1998, 2006) of mid-late Asselian age (Archbold and Simanauskas, 2001; Archbold *et al*., 2004; Taboada, 2006). *Edmondia* sp., *Schizodus* sp., *Septosyringothyris keideli* (Harrington), *Costatumulus* sp., *Neospirifer* sp., *Streptorhynchus?* sp. and *Knightites (Cymatospira) montfortianus* (Norwood and Pratten) were listed and *Tivertonia jachalensis* (Amos) (Figure 17) was described (Taboada, 1998, 2006) for the marine section. The mollusks (bivalves *Myonia, Vacunella, Stutchburia, Schizodus, Atomodesma/Aphanaia, Streblochondria, Volsellina,*

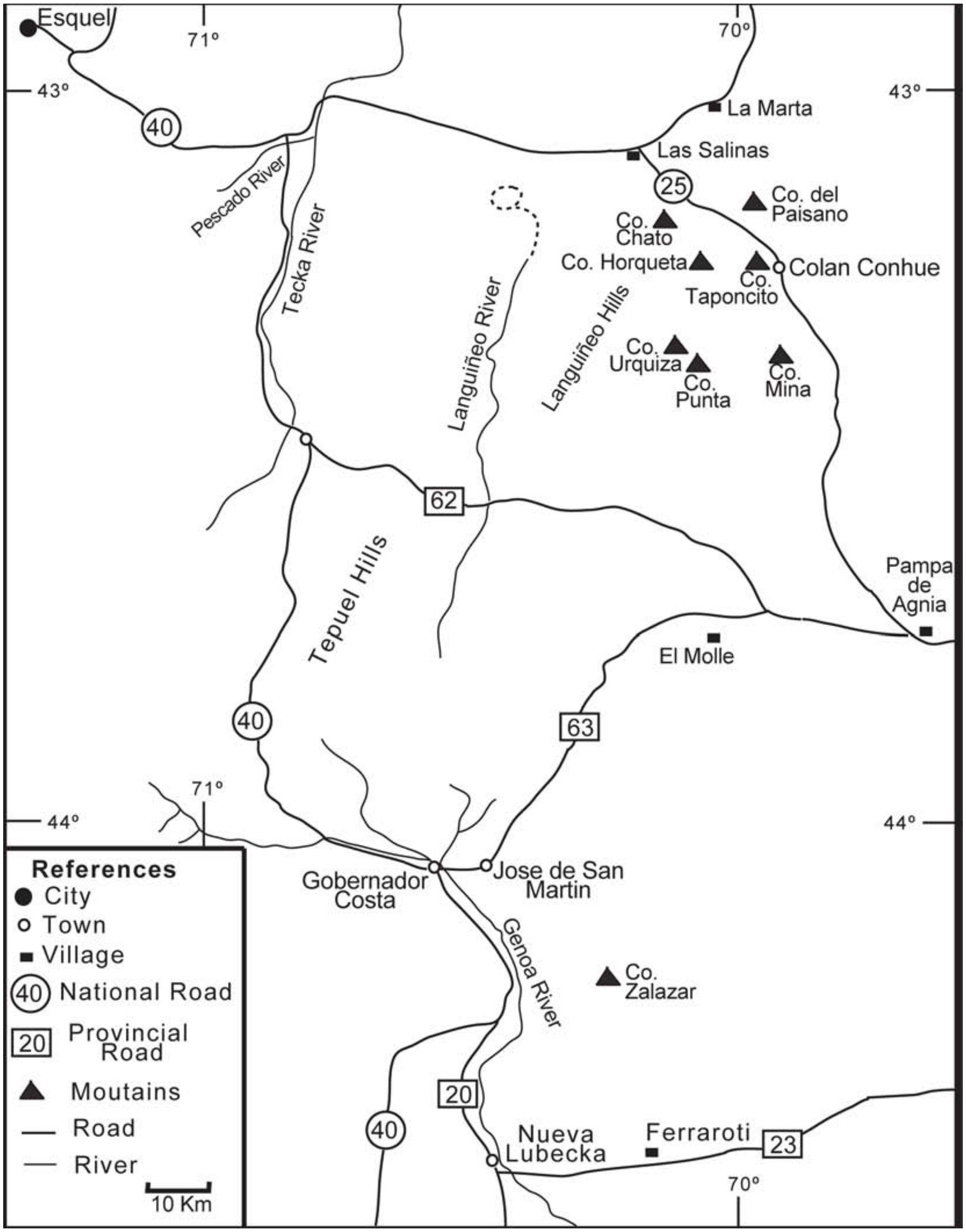

Figure 19. Tepuel-Genoa Basin map location.

Eurydesmid, and forms close to *Pyramus* and *Megadesmus*, and the gastropod *Peruvispira*) reported by Rocha Campos (1970) belong to this marine section of the Jarillal Member, although it comes from the Portezuelo de la Invernada locality, a few kilometres south of the Uspallata creek. The *Tivertonia-Streptorhynchus* fauna was linked to a large marine transgression that was able to surpass the highlands of the Protoprecordillera through a few inlets and allow migration of the fauna to the east (eastern Paganzo Basin). This fauna is also represented in the northern Río Blanco subbasin and in the southern San Rafael basin, establishing the most extensive Late Paleozoic marine transgression that covered western Argentina during the Late Paleozoic. On the other hand, eolian dunes were recognized in the uppermost levels of the Jarillal Member, being evidence of an arid paleoclimatic phase (Freije, 2002, 2004), which was regionally well represented (Limarino *et al*., 1993). Two partial sections cropping out at the Uspallata Hill were segregated from the Tramojo "Series" and correlated with the Agua del Jagüel Formation by its paleontological content (Taboada, 1998). The westernmost section was also previously referred to as Grupo occidental or J (Dessanti and Rossi, 1950) and Sección I (Rodríguez, 1966). It exhibits 280 m of a shallow marine sequence (see Freije, 2004) that could be broadly correlated with the upper part of the Agua del Jagüel Formation at its type locality. It has yielded a fauna characterized by the brachiopods *Costatumulus amosi* (formerly *Cancrinella* aff. *farleyensis* (Etheridge and Dunn) Archangelsky and Lech, 1987) and *Coolkilella keideli* (Taboada, 1998) (Figure 18). Also, Archangelsky and Lech (1987) previously reported *Crurithyris* aff. *roxoi* (Olivera), *Orbiculoidea* aff. *saltensis* Reed, *Orbiculoidea annae* Feruglio, *Lingula* sp., *Septosyringothyris* sp., *Chonetes?* sp., *Promytilus* sp., *Myonia* sp., *Cypricardinia sp.* and *Aviculopecten sp.* More recently, Archbold *et al*. (2005) described from this section the inarticulate brachiopods *Argentiella stapenbecki* and *Orbiculoidea sp.* The other section is a thin tectonic slice located a few km to the east, between outcrops of the Jarillal and Tramojo members. This section, previously mentioned as Section F (Dessanti and Rossi, 1950) or Section IIIc2 of the Tramojo "Series" (Rodríguez, 1966), bears the fossiliferous locality reported by Dessanti and Rossi (1950), which has provided specimens of *Costatumulus amosi*. This section of mudstone with small calcareous fossiliferous lenses, are interbedded to the north (Zorro creek) with glacial-marine diamictite (mainly mudstone with dropstones and matrix-supported conglomerate), which would be partially equivalent with the intermediate and lower sections of the Agua del Jagüel Formation at its type locality (Taboada, 1998).

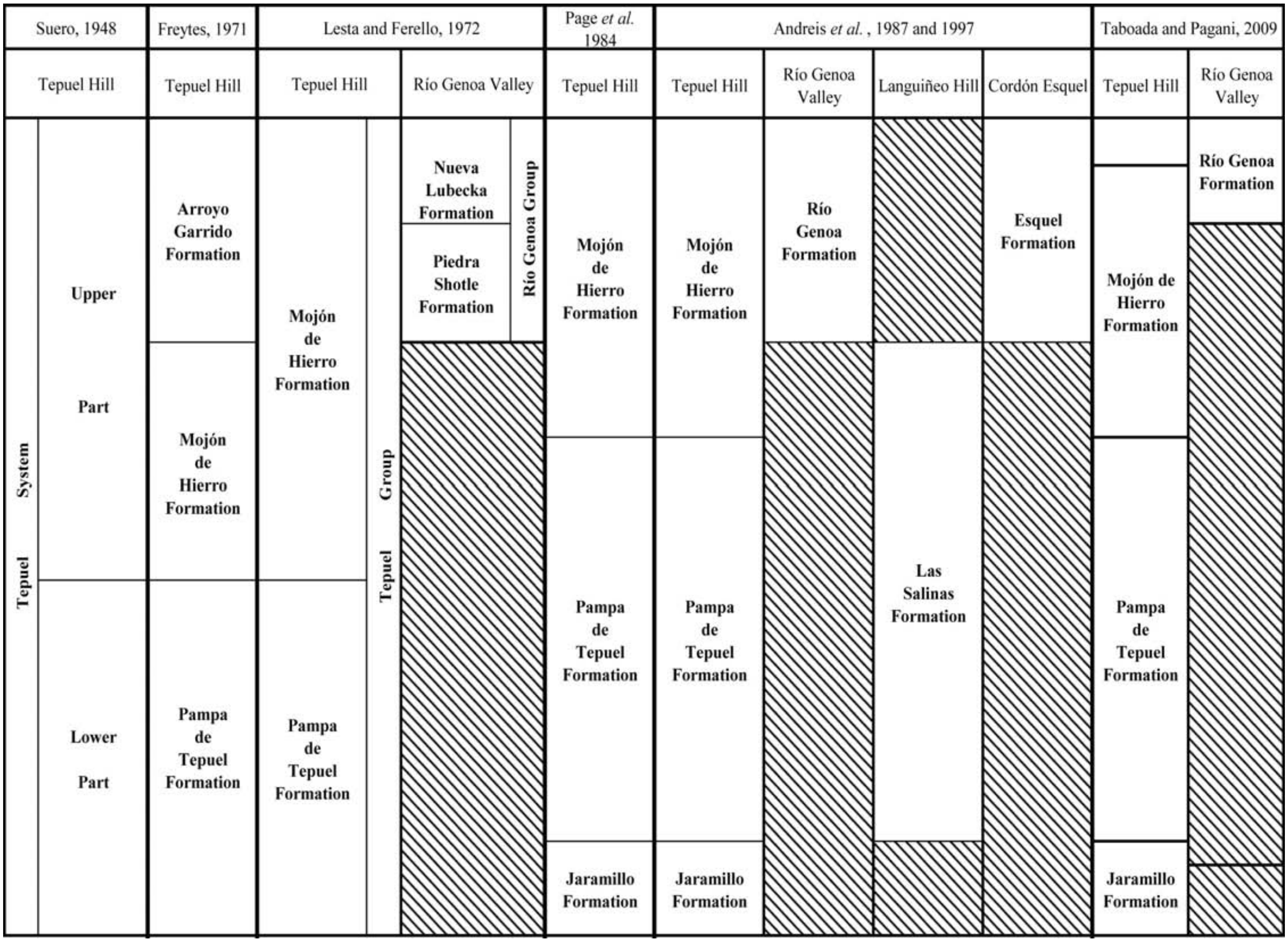

Figure 20. Different lithostratigraphic divisions for the Upper Paleozoic of the Tepuel-Genoa Basin.

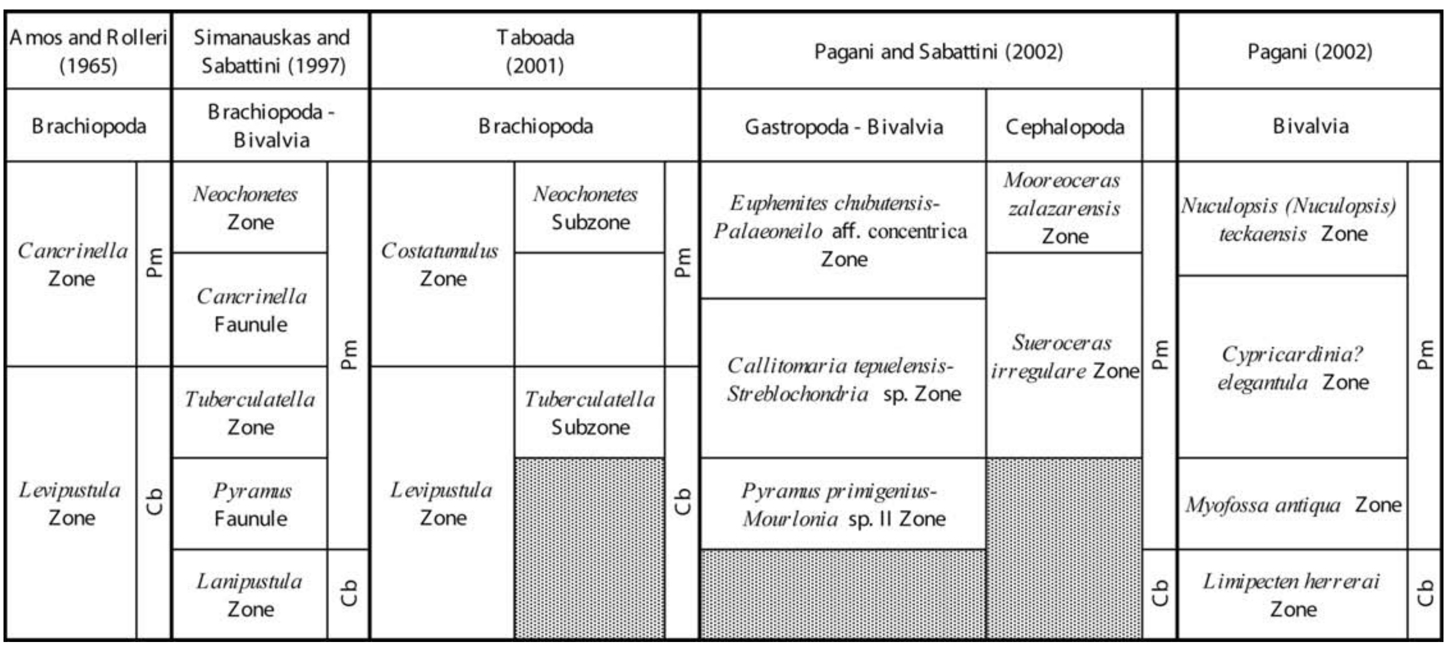

Figure 21. Diagram showing relations between biostratigraphic units proposed by different authors. (from Pagani and Sabattini, 2002 and Pagani, 2004).

Figure 22. Sketch from Google Earth showing Stops 7 to 9. 1, basal levels of Pampa de Tepuel Formation; 2, middle levels of Pampa de Tepuel Formation; 3, upper levels of Pampa de Tepuel Formation

Figure 23. Sketch from Google Earth showing Stop 11.

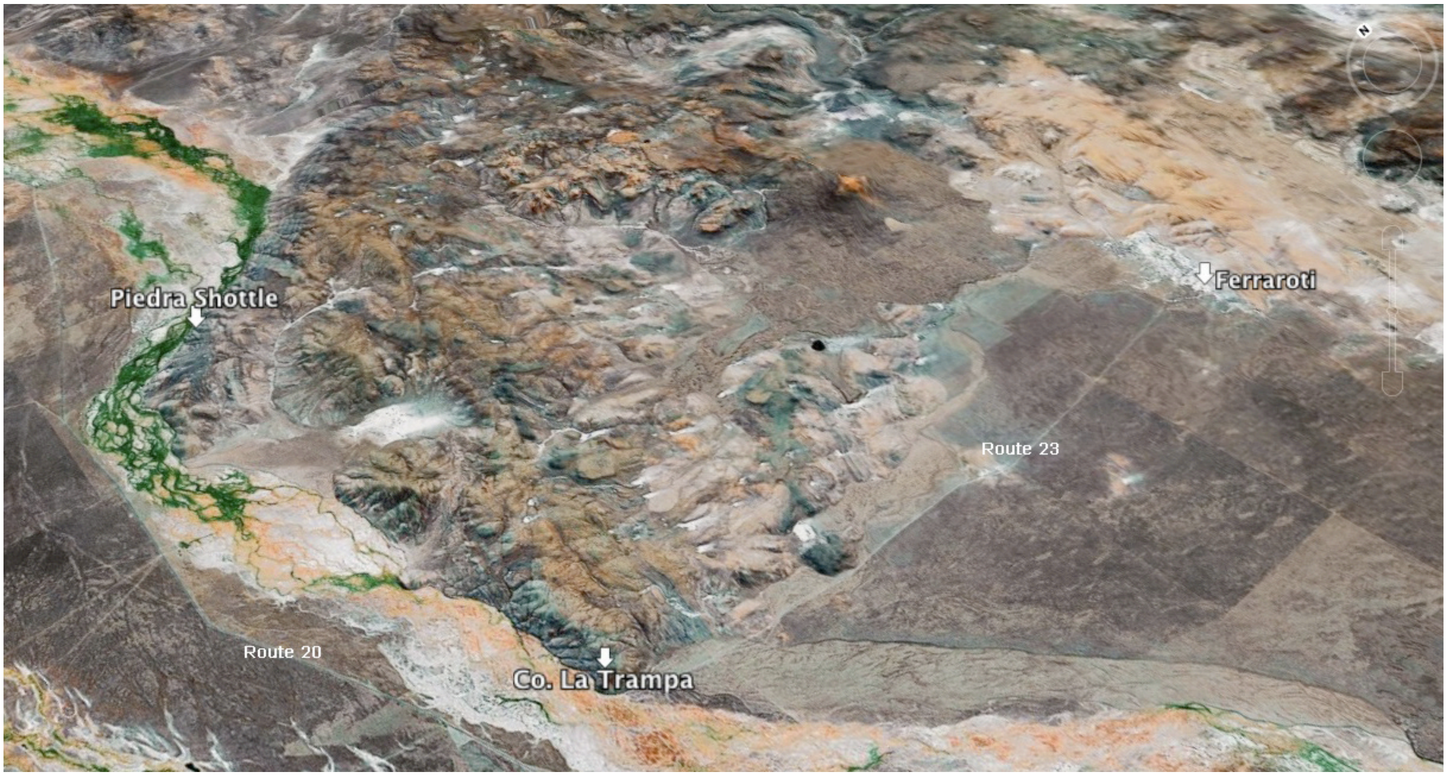

Figure 24. Sketch from Google Earth showing Stops 12 to 14.

Stop 6. The Agua del Jagüel Formation (Harrington, 1971) at the type locality, Paramillos de Uspallata. Figure 6

The Agua del Jagüel Formation exhibits a folded and faulted sequence at the creek, which would be reaching 840 m of thickness in a compound stratigraphic profile (See Taboada, 1984, 1997). Angular unconformities separate the Agua del Jagüel Formation from the underlying Ordovician Villavicencio Formation and the overlying Tigre "Group" (part of the "Choiyoi" Permian-Triassic widespread volcanic episode in western Argentina). The Agua del Jagüel Formation was previously correlated with the Pituil "Group" by Amos and Rolleri (1965) and later detached from the former by its different lithologic and paleontological content (Taboada, 1997, 1998). The sequence shows an intercalated glacial-marine section between mainly marine offshore facies of the lower and upper sections. These last sections enclose the *Costatumulus amosi* biozone and it has provided the bivalves *Oriocrassatella sanjuanina* González?, *Cypricardinia?* sp., *Sanguinolites* sp., *Schizodus* sp. and *Streblochondria?* sp. (González, 1982), the brachiopods *Histosyrinx jaguelensis* (Lech) (Lech, 1986, 1990; Lech and Raverta, 2005), *Costatumulus amosi* (formerly *Cancrinella* cf. *farleyensis* of Amos and Rolleri, 1965), *Coolkilella keideli* and *Tivertonia leanzai* (Taboada, 1998, 2006), among other figured and mentioned taxa. This *Costatumulus* faunal assemblage would be in biochronologic succeeding the *Tivertonia-Streptorhynchus* association, but is only recorded in a possible paleogeographically restricted embayment at the southernmost region of the Uspallata-Iglesia Basin (Taboada 2001, 2006). The marine transgression bearing the *Costatumulus amosi* fauna happened after a regressive non-marine stratigraphic interval (non marine upper section of the Jarillal Member) and is intercalated between the last biotic event and the preceding *Tivertonia-Streptorhynchus* faunal records. After that a transient colder paleoclimatic episode, recognized by the glacial-marine deposits stratigraphically enclosed by the *Costatumulus amosi* association, briefly interrupted the temperate paleoclimatic conditions established in the region since the Late Carboniferous. This transient Alpine type glacial episode (González 1981) would be contemporary with another lithologically similar glacial-marine deposit recorded in the upper section of the Mojón de Hierro Formation in Patagonia, which was estimated of likely Sakmarian age (Taboada 2001a, 2006, 2008; Taboada and Pagani, 2009). On the other hand, considerable disagreement exists in regard to the Agua del Jagüel Formation stratigraphy and biochronology. For some authors the base of the sequence starts with the glacial-marine section, which is considered contemporary with the Late Carboniferous glacial episode (López Gamundi and Martínez, 2003; Ciccioli *et al*., 2008). Also, Moscovian-Kasimovian (Lech, 2002) or latest Carboniferous-earliest Permian (Martínez *et al*., 2001) ages were suggested to the Agua del Jagüel Formation, including its correlation with El Paso Member of the San Eduardo Formation at the Barreal Hill (Simanauskas and Cisterna, 2001). These majority positions imply the rejection of transient Permian glacial conditions occurring in the "Pacific" (western) basins of Argentina, contrary to the almost isolated opinion sustained here.

Tepuel-Genoa Basin, Patagonia

The Tepuel-Genoa Basin (Figure 2) (Andreis *et al*., 1987) outcrops are located in central-western region of the Chubut province (central Patagonia) extending approximately between latitudes S42º50'-S44º40' and meridians W69º30'-W71º20 (Figure 19), but is also indicated underground to the south reaching the north-

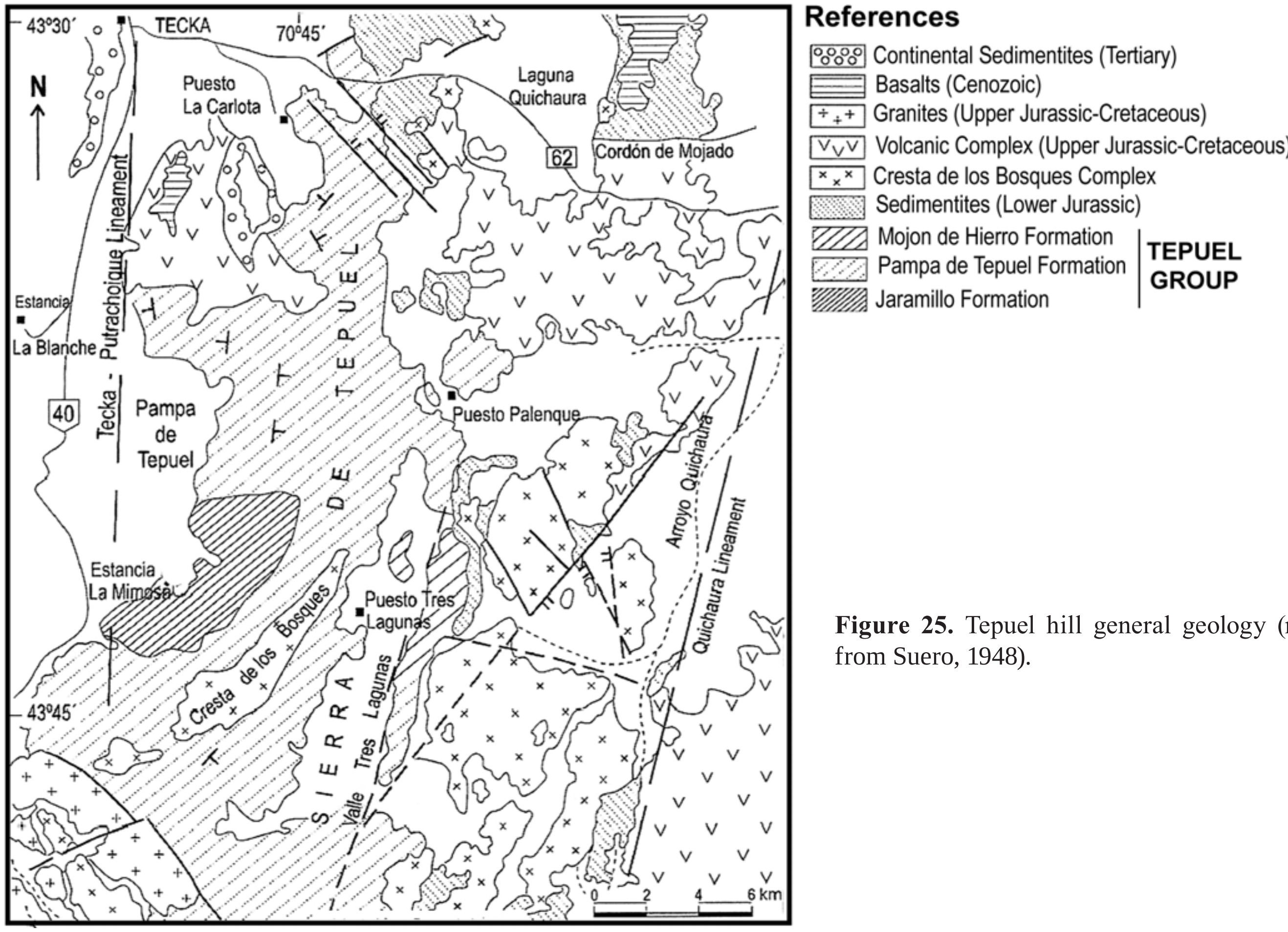

Figure 25. Tepuel hill general geology (modified from Suero, 1948).

western area of the Santa Cruz province. These deposits were originally described by Keidel (1922), Piátnitzky (1933, 1936) and Suero (1946, 1947), the last mentioned author (Suero, 1948, 1953) being the one who indicated its stratigraphic location in the Upper Paleozoic as the Tepuel "System". The current terminology was proposed by Page *et al.* (1984) following modern nomenclature rules, with a tripartite scheme, the Jaramillo, Pampa de Tepuel and the Mojón de Hierro formations of the Tepuel Group. Other formational names were proposed to partially equivalent sequences cropping out at Esquel city (Esquel and Valle Chico formations of Cucchi, 1980) and Languiñeo Hill (Las Salinas Formation of González, 1972). On the other hand, the outcrops of the southernmost Río Genoa Valley were divided into two units by Ugarte (1966), the lower Piedra Shottle Group and the upper Nueva Lubecka Group. Later, Lesta and Ferello (1972) downgraded these units to formational rank and joined both into the Río Genoa Group. More recently, Andreis *et al.* (1986) redefined this sequence as Río Genoa Formation, which was considered a lateral facies (deltaic complex) correlatable to the north with the Mojón de Hierro Formation. Also, Andreis and Cúneo (1989) recognized the uppermost stratigraphic sections belonging to a single and youngest unit, the Río Genoa Formation, but conformably overlying the Mojón de Hierro Formation at Lomas Chatas ("Upper Tepuel System" in Ugarte 1966). Finally, Taboada and Pagani (2009) have indicated that the previous equivalence of these formations must be rejected, on the grounds of biochronologic meaning and intrabasinal distribution of faunal assemblages, together with the stratigraphic arrangements of the Mojón de Hierro (with glacial-marine levels) and Rio Genoa Formations (without glacial-marine levels). Nevertheless, as Taboada and Pagani (2009) noted, until the precise boundary between the two units can be defined with accuracy, a possible relatively minor lateral interfingering between the uppermost levels of the Mojón de Hierro Formation and lowermost levels of the Río Genoa Formation (especially at the key sections of Arroyo Garrido and Lomas Chatas), can't be disregarded. Figure 20 shows stratigraphic units as proposed by different authors.

The first biozonation scheme proposed for the Tepuel-Genoa Basin was done by Amos and Rolleri (1965), who recognized two biostratigraphic units based on brachiopods described by Amos (1960): the *Levipustula levis* (Moscovian) and *Cancrinella* cf. *farleyensis* (Etheridge and Dunn) (Late Carboniferous) Biozones. These units were also extended 2000 km to the north, reaching the Calingasta-Uspallata Sub-basin in western Argentina (Precordillera) (Amos and Rolleri 1965). Afterward the ages of the biozones were adjusted by Amos *et al.* (1973), Sabattini (1978) and González (1981b, 1985b), with Namurian-Westphalian? and Early Permian (Asselian) ages suggested to the *Levipustula* and *Cancrinella* Zones, respectively. The Amos and Rolleri scheme for Patagonia was substantially modified and replaced by a new one with five zones/faunules, based on multivariate analysis grouping of the invertebrate faunal composition of the Tepuel-Genoa

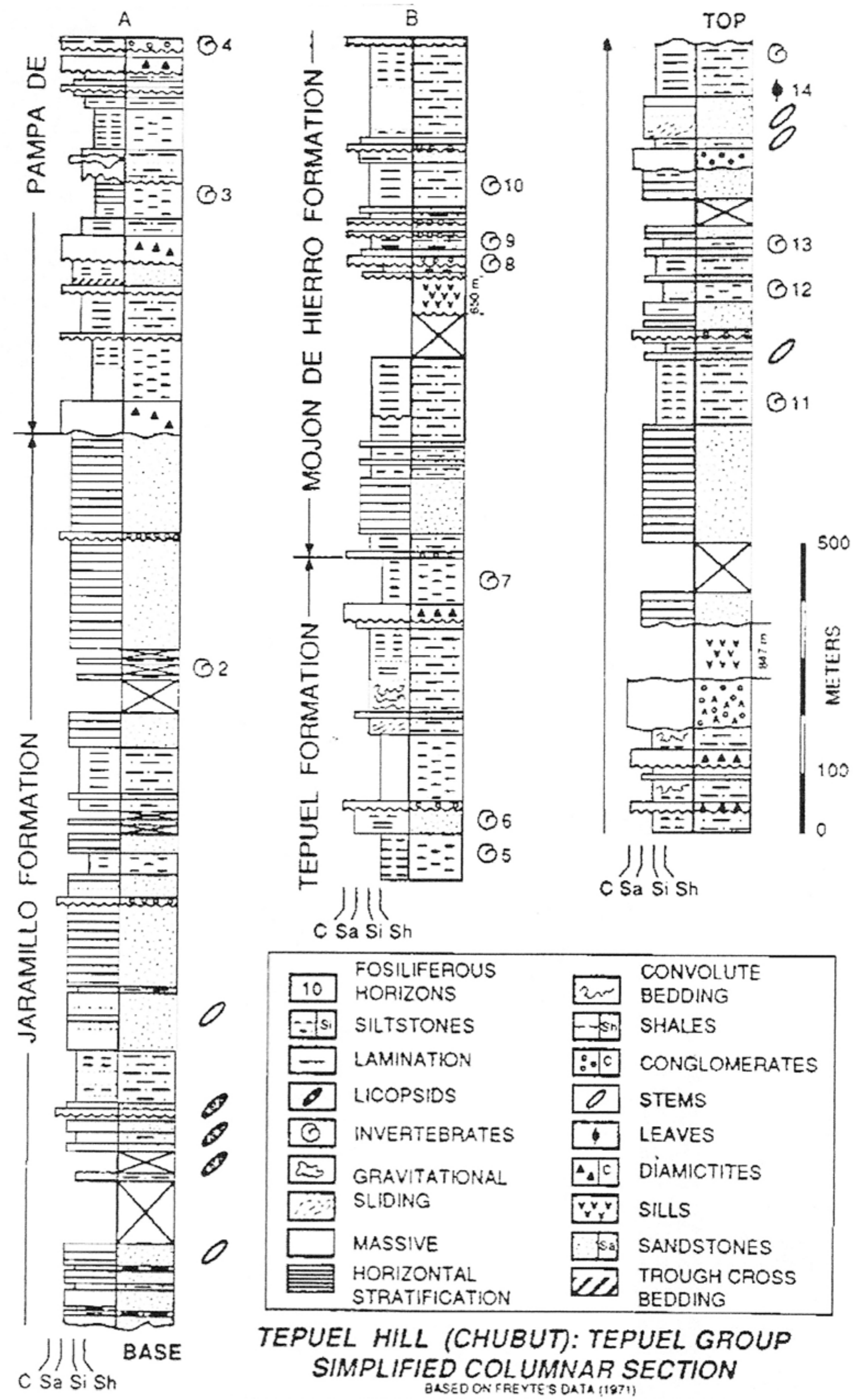

Figure 26. Tepuel Group simplified columnar sections at the named hill. (modified from Freytes, 1971).

Basin (Simanauskas and Sabattini 1997). These authors proposed the *Lanipustula* Zone (Namurian-Stephanian) (formerly *Levipustula levis* Zone of Amos and Rolleri 1965), *Pyramus* Faunule (Asselian), *Tuberculatella* Zone (Sakmarian), *Cancrinella* Faunule (formerly *Cancrinella* cfr. *farleyensis* (Etheridge and Dunn) Zone of Amos and Rolleri 1965) (Sakmarian-Artinskian) and *Neochonetes* Zone (Artinskian-Kungurian). Pagani and Sabattini (2002) also introduced two new biozone charts for the Tepuel-Genoa Basin, one of them based exclusively on gastropod and bivalve distribution, and another one based on cephalopod distribution. The *Mourlonia* sp. II-*Pyramus primigenius, Callitomaria tepuelensis-Streblochondria* sp. and *Euphemites chubutensis-Palaeoneilo* aff. *concentrica* Zones were assigned to gastropods and bivalves only. Another two cephalopod zones are: the *Sueroceras irregulare* and the *Mooreoceras zalazarensis* biozones. Pagani and Sabattini's biozones were dated as Lower Permian age (Cisuralian). Figure 21 shows a diagram with relations between biostratigraphic units proposed by different authors. Finally, updated faunal successions based on brachiopods were mentioned for the basin (Taboada *et al*., 2005; Taboada, 2008; Taboada and Pagani, 2009), but no additional biostratigraphic charts were proposed. The key stratigraphic sections of Tepuel-Genoa Basin are examined in eight stops (Figures 22, 23 and 24).

Stop 7. Jaramillo and Pampa de Tepuel Formations (Page et al., 1984), at the Tepuel hill. Figure 22

The Tepuel hill locality is the type section (Figure 25) of the group, where it attains the greatest thickness – up to 5000 m of mostly marine sediments (Figure 26). The base of Tepuel Group does not crop out in this area and is only observed in the Catreleo place, on the western side of Sierra de Agnia (Robbiano, 1971). The overlying sediment consists of Jurassic rocks in a pseudoconformable relationship

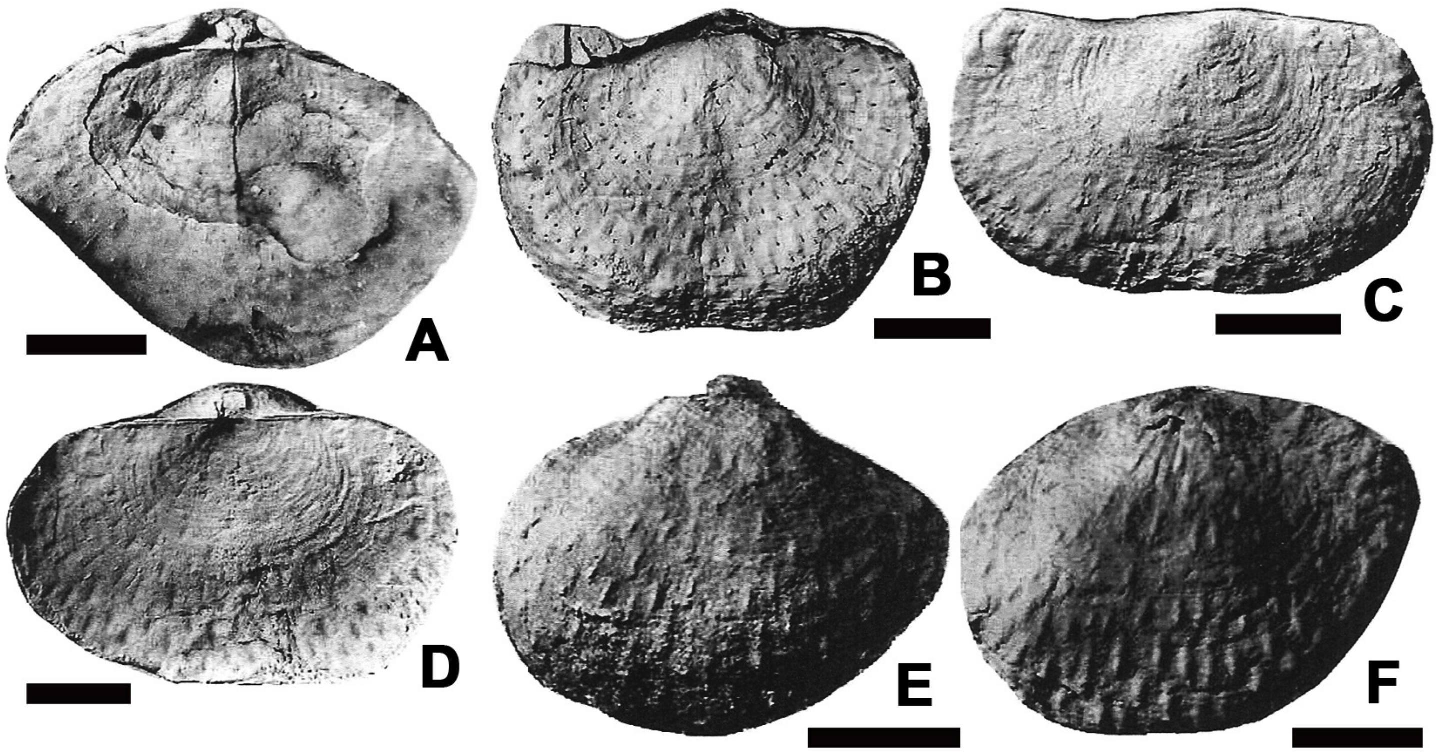

Figure 27. A-D, *Verchojania archboldi* Taboada (2008). A, LIEB-PI 1 (paratype), latex cast dorsal valve exterior showing cardinal process external view; B, LIEB-PI 3 (paratype), mould dorsal valve exterior in dorsal view; C-D, LIEB-PI 4 (paratype), articulate specimen in posterior and anterior views, dorsal valve external mould. K-S, Verchojania inacayali Taboada (2008). E, IPI 3988 (holotype), ventral valve exterior view; F, IPI 3989 (paratype), dorsal valve external mould. Scale bar: 10 mm. (Modified from Taboada, 2008).

(Suero, 1948).

The Jaramillo Formation is 1000 m thick and is made up of yellowish-grey to greenish-grey sandstone with a lesser amount of siltstone and diamictite. This unit represents the beginning of a transgressive cycle with the sediments deposited in a near shore environment. Its fossil content is rather poor with only a few brackish water mollusks (González, 1987) (and also inarticulate brachiopods), and plant remains such *Gylboaphytum argentinum* Carrizo and Azcuy (2006) and *Archaeosigillaria conferta* (Menéndez) Petriella and Arrondo (1978), that have been identified. The latter suggests a correlation with the *Archaeosigillaria-Lepidodendropsis* Zone from the Calingasta-Uspallata Subbasin, dated as Early Carboniferous.

The Pampa de Tepuel Formation overlies the Jaramillo Formation and may be 2900 m in thick. This unit is characterized by a variable lithologic composition represented by siltstone, sandstone and diamictite that contains several fossiliferous horizons with marine fauna. The genesis of this unit has been related to debris flows and turbiditic processes associated with submarine fans. It has also been argued that the submarine fan progradation was indirectly regulated by glacialgenic processes that occurred on the near continent. Nevertheless, a more direct glacial influence was indicated for this section (Gonzalez Bonorino *et al*., 1988; González Bonorino, 1992), which is recognized by records in associated glacial related facies, of striated pavement and dropstones in lowermost, middle and uppermost levels of the Pampa de Tepuel Formation (González *et al*., 1995, 2003; González and Glasser, 2008; Taboada and Pagani, 2009; unpublished data).

The fossil content of the Pampa de Tepuel Formation has been included in the *Lanipustula* (formerly *Levipustula* Zone) and *Tuberculatella* Biozones (Simanauskas and Sabattini, 1997), lately regarded as Bashkirian and early Late Pennsylvanian-Asselian (Taboada *et al*., 2005; Taboada, 2008), respectively. The bryozoans *Eliasopora australis, Fenestella tepuelensis, F. sueroi, F.* cf. *cerva* (Campbell), *F.* cf. *aspratilis* Basler, *Levifenestella chubutensis, Austropolypora neerkolensis* (Crockford), *Septatopora pustulosa* (Crockford), *S. freitesi, Penniretepora tenuissima, Rhombopora? bifurcata* (Campbell) (Sabattini, 1972), *Fistulamina frondescens* Crockford, *F. amosi* (Sabattini, 2002), the bivalves *Cosmomya* (Paleocosmomya) *chubutensis*, *Phestia tepuelensis* González (1969), *Nuculopsis (Nuculanella) camachoi* González (1972), *Sanguinolites freytesi, Myofossa antiqua, Leptodesma (Leiopteria) variabilis, Palaeoneilo amosi, Schizodus paucus* (González, 1977), *Orbiculopecten parma* González (1978), *Limipecten herrerai* Pagani (2006), *Striochondria sueroi* (González) (Waterhouse, 2008), the gastropod *Straparollus (Straparollus) perminutus* Sabattini (1995), the crinoid stem *Camptocrinus patagoniensis* Hlebszevitsch (2005) and the brachiopod *Lanipustula patagoniensis* Simanauskas (1996) (see Simanauskas, 1996), were described from the middle section of the unit (Complex B, level 8 of Suero, 1948 and the slightly higher Ft1-13 level of Freytes, 1971). "*Levipustula levis* Maxwell" was indicated for this level, but none of the specimens assigned to this species by Amos (1960) have been described from it. Nevertheless, traditionally this last

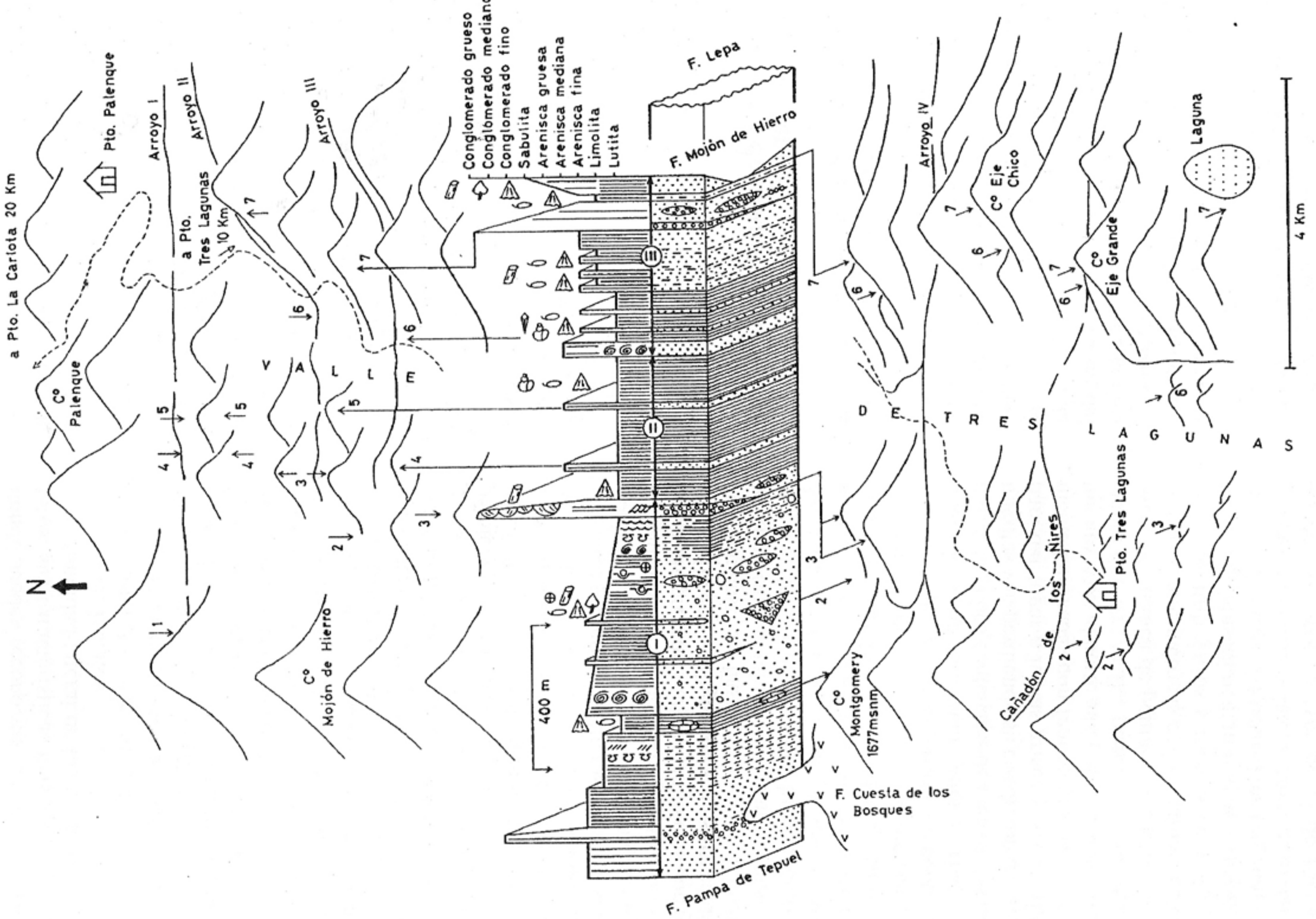

Figure 28. Sketch of the Tres Lagunas Valley showing location of fossiliferous localities and its stratigraphic position in a compound stratigraphic profile of the sequence. (from Taboada, 2001)

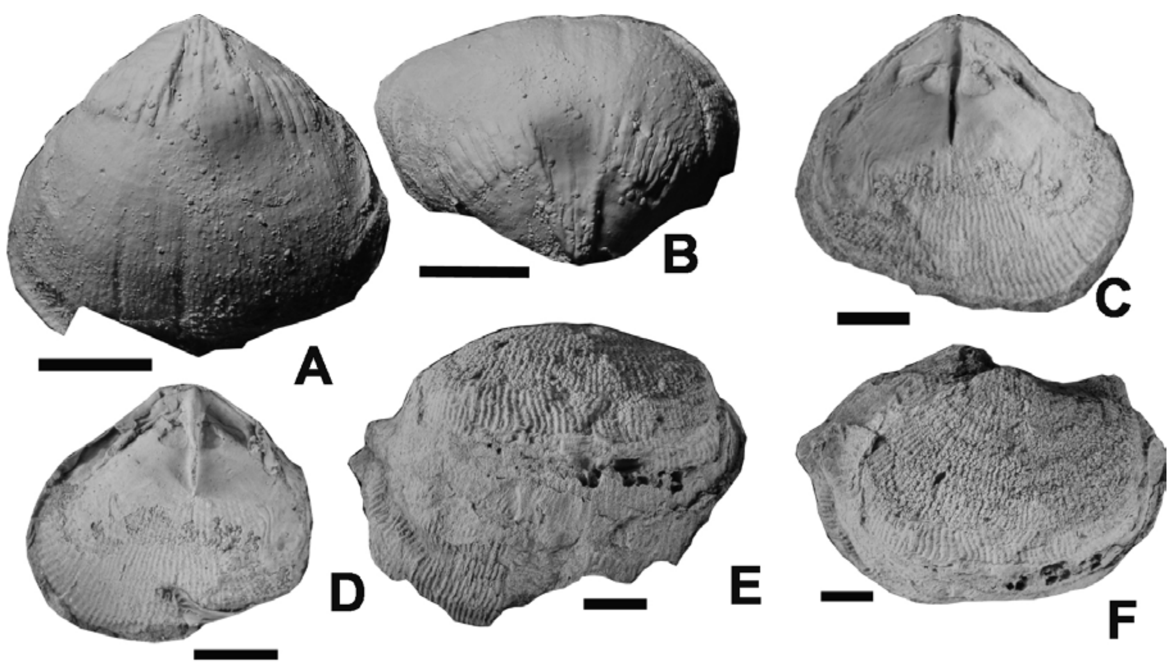

Figure 29. *Cimmeriella* sp. A-D, LIEB-PI 209 (holotype), composite internal mould in antero-ventral, ventral and dorsal views, and latex cast of dorsal valve interior.E-F, FML-PI 2565 (paratype), articulate specimen in anterior view showing ventral trail and dorsal valve external mould in ventral view. Scale bar = 5 mm.(Modified from Taboada and Pagani, 2009)

level had been considered as part of the formerly *Levipustula levis* “biozone” in Patagonia, until the Simanauskas’ description of his species *Lanipustula patagoniensis.*

The bivalves *Pyramus tehuelchis* and *P. primigenius* (González, 1972), were described from the level with *“Allorisma*” of Suero (1948), located stratigraphically 40 m above the former.

The gastropod *Peruvispira australis* Sabattini and Noirat (1969), the nautiloid *Sueroceras irregulare* Riccardi and Sabattini (1975) and the bivalve *Palaeoneilo gonzalezi* Pagani (2004), have been described from the level located “below” (to the west of) (Complex C, level 17 of Suero, 1948) the Jurassic Cresta de los Bosques Formation (gabbric complex intrusion)), 1000 m stratigraphically above the levels previously mentioned. Finally, the gastropod *Glabrocingulum (Stenozone)* sp. and the brachiopod *Verchojania archboldi* Taboada (2008) were described from levels located 500 m to the southwest of Tres Lagunas Post, where a faunal assemblage awaits description. This last level is the highest fossiliferous record in the Pampa de Tepuel Formation.

Stop 8. Pampa de Tepuel Formation at Puesto La Carlota. (Figure 22)

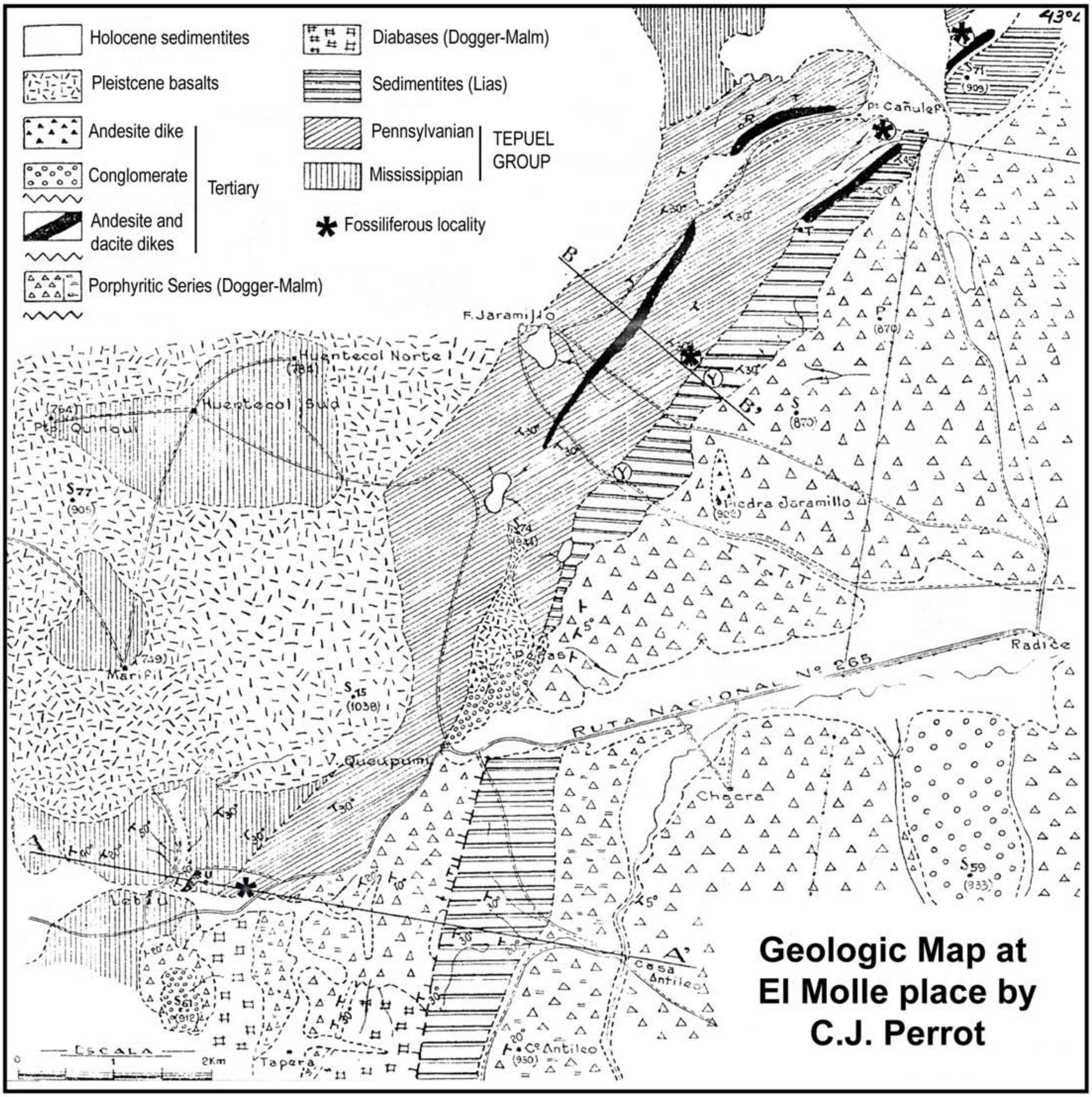

Figure 30. Geological map of the El Molle area. (modified from Perrot, 1960).

The key section at La Carlota Post is located 8 km to the southeast of Tecka town and crops out in a small area of 1 km^2 with 200 m of thickness. Suero (1948) has described four levels, (1) dark grey shale, (2) sandy shale with abundant crinoid remains, (3) fine pebbly sandstone with fossils, and (4) dark shale (with soft deformation) which yields fossiliferous concretions upward. The section has provided the first marine Upper Paleozoic fossil record of Patagonia, with a profuse paleontological content of brachiopods (Amos, 1958, 1960; Simanauskas 1996a; Taboada, 2008), bivalves (González, 1969, 1972, 1974, 2006; Pagani 2004a,b, 2005), bryozoans (Sabattini 1972, 1986), cnidarians (Mariñelarena, 1970; Sabattini and Hlebszevitsch 2004, 2005), gastropods (Sabattini and Noirat 1969; Sabattini 1978, 1995, 1997), echinoderms (Hlebszevitsch 2004, 2005, 2006), as well as scarce cephalopods (Closs 1967; Riccardi and Sabattini 1975; Sabattini *et al*. 2006) and trilobites (Miller and Garner 1953; Amos *et al*. 1960). Nevertheless, the faunal record should be clearly located to avoid possible confusion and controversy. *Levipustula levis* Maxwell and the named biozone have been associated with this locality since Amos' (1960) work, although those data were not accurate. Simanauskas (1996b) rejected the record of '*Levipustula*' at La Carlota Post, and the *Tuberculatella* faunal association and biozone were proposed later for the same locality (Simanauskas and Sabattini 1997) at the concretionary level (= level 4 of Suero 1948). More recently, specimens co-specific with those described by Amos (1960) as *Levipustula levis* Maxwell from La Carlota Post (level 3 of Suero 1948) were reassigned to *Verchojania inacayali* Taboada, 2008 (Figure 27). Consequently the boundary between level 3 and 4 at La Carlota locality is emphasized by changes in faunal composition and the appearance of the *Tuberculatella* fauna. Therefore, the base of the *Tuberculatella* biozone (at level 4 of the section) was estimated no older than early Late Pennsylvanian (Taboada, 2008).

With certainty, the gastropod *Straparollus (Straparollus) perminutus* Sabattini (1995), the bivalves *Cosmomya (Paleocosmomya) chubutensis*, *Phestia tepuelensis* González (1969), *Striochondria sueroi* (González) (Waterhouse, 2008), *Palaeoneilo gonzalezi* Pagani (2004) the bryozoans *Austrofenestella stroudensis*, *Austropolypora neerkolensis* (Sabattini, 1972) and the crinoid stem *Camptocrinus patagoniensis* Hlebszevitsch (2005), come

Figure 31. Glacial pavement in the upper section of the Pampa de Tepuel Formation at El Molle place, to the northeast of the Lefiú Post and 200m stratigraphically below levels bearing the invertebrate fauna with *Verchojania archboldi*. (from Taboada and Pagani, 2009).

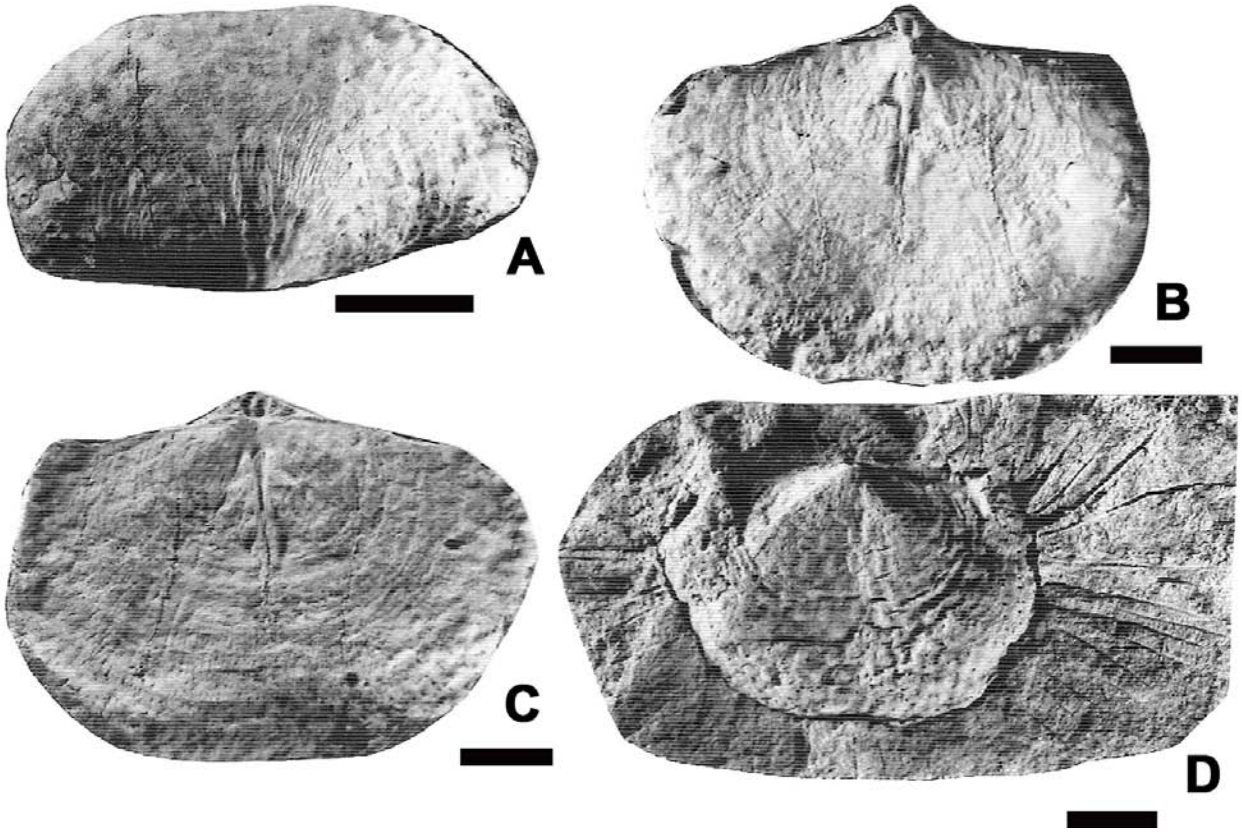

Figure 32. *Verchojania archboldi* Taboada. A-C, IPI 3834 (holotype), articulate specimen in ventral, tilted ventral and dorsal views; D, IPI 3828 (paratype), dorsal valve external mould, latex cast dorsal valve exterior. Scale bar = 10 mm (Modified from Taboada, 2008)

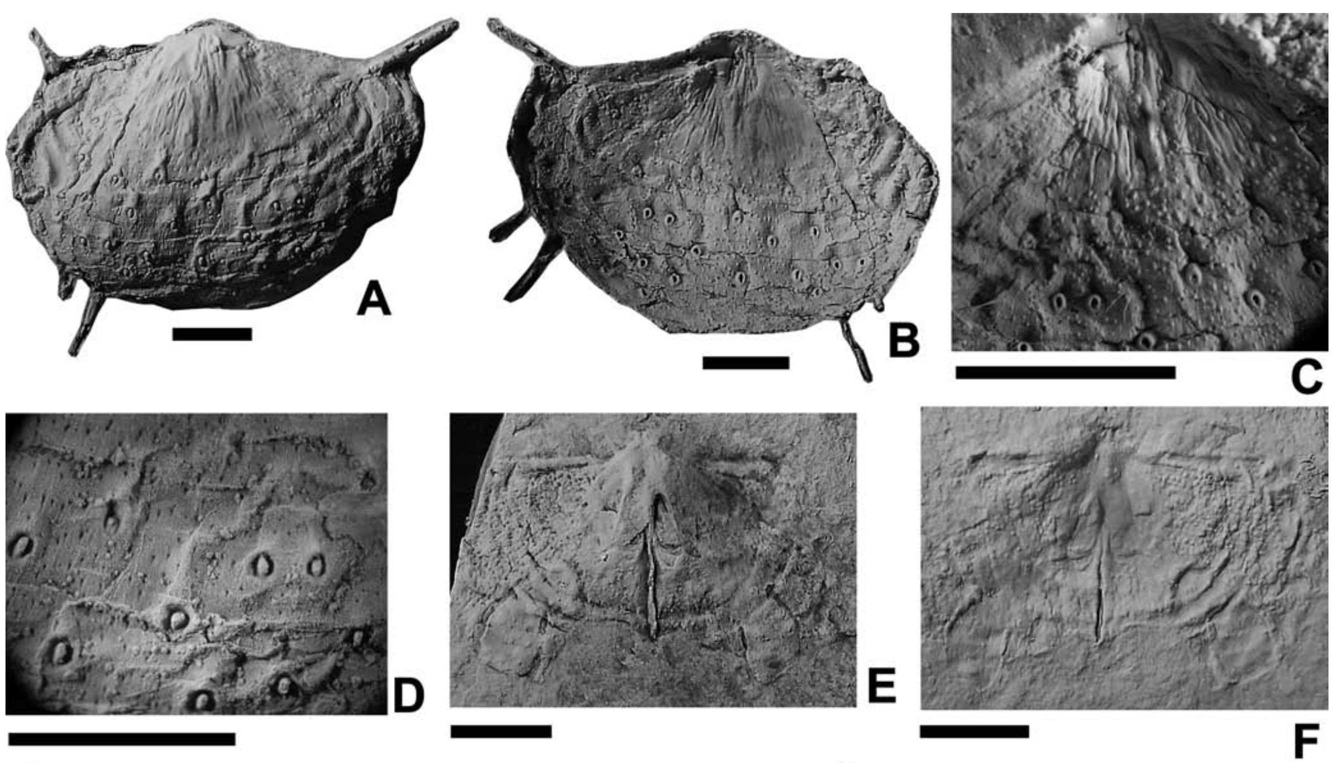

Figure 33. *Jakutoproductus* sp. Taboada and Pagani (2009), from Piedra Shottle and cerro La Trampa localities. A-D, MPEF-PI 1443 (holotype), ventral valve internal mould, latex cast ventral valve interior, ventral valve internal mould showing muscle scars, detail of ventral valve internal mould showing endospines and external spine bases. E-F, MPEF-PI 1214 (paratype), dorsal valve internal mould, latex cast dorsal valve interior. Scale bar= 5 mm (Modified from Taboada and Pagani, 2009)

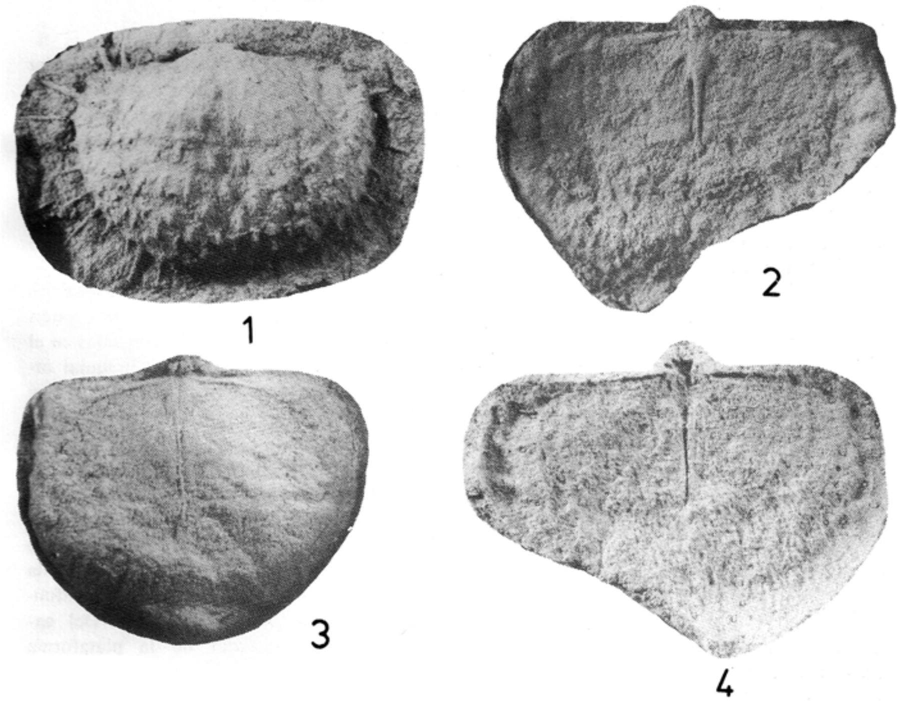

Figure 34. *Piatnitzkya borreloi* Taboada, 1993. (From Taboada, 1993).

from level 3 of the section at La Carlota Post. While, the gastropods *Callitomaria tepuelensis*, *Neoplatyteichum barrealensis* (Reed) (Sabattini and Noirat, 1969), *Cinclidonema sueroi* Sabattini (1997), the conularids *Paraconularia tepuelensis*, *P. acuminata*, *P. sueroi*, *P. pulcheria* (Mariñelarena, 1970), the nautiloid *Sueroceras irregulare* Riccardi and Sabattini (1975), the bivalves *Striochondria sueroi* (González) Waterhouse, 2008, *Cosmomya (Paleocosmomya) chubutensis*, *Nuculopsis (Nuculopsis) patagoniensis* González (1969), *Euchondria sabattiniae* González (1974), *Leptodesma (Leiopteria) variabilis* González (1977), *Cypricardinia? elegantula* Dickins (Pagani, 2006b) and the brachiopods "*Tuberculatella*" *laevicaudata* (Amos) (a species which would be classified in *Dyschrestia* Grant or more properly in another closely allied, possibly new, genus *sensu* Taboada, 2008) (see Simanauskas, 1996c) and *Amosia sueroi* (Simanauskas, 1996b, 1996c) come from level 4 of the same sequence.

Stop 9. Mojón de Hierro and Pampa the Tepuel Formations at Tres Lagunas valley, between Palenque and Tres Lagunas Posts. Figure 22

The Late Paleozoic of the Tres Lagunas valley (also known as Mojón de Hierro valley) reaches nearly 1600 m of thickness, constituting the upper third of the sequence of Tepuel (Figure 28). The upper section of the Pampa de Tepuel Formation and the Mojón de Hierro Formation (at its type locality) crop out in the valley and surrounding hills. The contact between these units is exceptionally exposed in the valley. The upper section of the Pampa de Tepuel Formation includes glacial-related deposits with marked lateral facies variation and a faunal assemblage with *Verchojania archboldi* Taboada (2008), which could be considered as part of the top of the *Tuberculatella* biozone (Taboada, 2008), estimated to be no younger than Asselian (Taboada *et al*. 2005, Taboada, 2008). The overlying Mojón de Hierro Formation is more than 900 m thick sequence of mainly marine deposits. Its lower half exhibits blue laminated shale and limestone with beds of coarse pinkish sandstone intercalated. It was interpreted as a postglacial sea level rise (López Gamundi, 1989, 1990), which would be synchronous with the major and widespread sea level rise in Gondwana during the progressive global climatic amelioration of the Late Asselian-Tastubian times (Dickins, 1985, 1996; Taboada 2001). The upper half of the unit contains a relatively diversified fauna with *Cimmeriella* (Taboada *et al*., 2005; Taboada and Pagani, 2009) (Figure 29) as a conspicuous element, associated with the brachiopods *Costatumulus sp.* (Amos 1960) (*Costatumulus* is represented by more than one species throughout the column, whose record starts in the lower section of the Mojón de Hierro Formation and reaches the uppermost levels of the Río Genoa Formation), *Spirelytha* sp. Taboada and Cisterna (1996), *Quinquenella* sp. (Amos) (Taboada and Shi, 2009), and other still undescribed brachiopods like *Brachythyrinella* cf. *occidentalis* Thomas, *Arctitetra* Whatfield, *Neochonetes* Norwood and Pratten, *etc*. Also, the gastropod *Peruvispira sueroi* Sabattini and Noirat (969), the bivalves *Cosmomya (Paleocosmomya) chubutensis* González (1969), *Palaeoneilo amos* González (1977), *Palaeoneilo gonzalezi* Pagani (2004a), *Phestia regularis* Pagani (2004b), *Striochondria sueroi* (González) (Waterhouse, 2008), *Streblopteria lagunensis* Pagani (2006), and the hyolithids *Hyolithes patagoniensis* Pagani *et al*. (2002), *Schizodus* sp., *Vacunella?* sp., *Edmondia* sp., *Phestia* sp., *Palaeoneilo* sp., *Modiolus* sp., *Parallelodon? quichaurensis*, *Heteropecten cortignasi*, *Etheripecten saraviae*, *Euchondria sabattiniae*, *Sueroa andreis*, *Praeundulomya moreli* González (2006), *Montorbicula montgomeryi* (González) (Waterhouse, 2008) and *Stutchburia* sp. among others, come from these levels. A late Sakmarian (Sterlitamakian) age was recently suggested for the levels bearing *Cimmeriella* in Patagonia (Taboada and Pagani, 2009). This age agrees with the *Glossopteris* flora occurrence (unpublished data) interbedded with levels bearing the *Cimmeriella* fauna, a few km south of Palenque Post.

Finally, glacial-related deposits with marked lateral facies variation occur in the uppermost levels of the Mojón de Hierro Formation, above the *Cimmeriella* fauna. These deposits represent the highest and youngest stratigraphic evidence of glacial influence in the Tepuel column, which has its best exposure to the south of the Tepuel hill, at the head of the Arroyo Garrido stream.

Stop 11. Pampa de Tepuel and Mojón de Hierro Formations at El Molle place.

At this locality, only the Pampa de Tepuel and Mojón de Hierro Formations are represented (Figure 30). The former corresponds to a 1200 m thick sequence consisting of polymictic conglomerate and diamictite, graded or massive sandstone and massive siltstone with dispersed quartz grains (Page *et al*., 1984). In the latter, intraformational folding due to gravitational sliding may

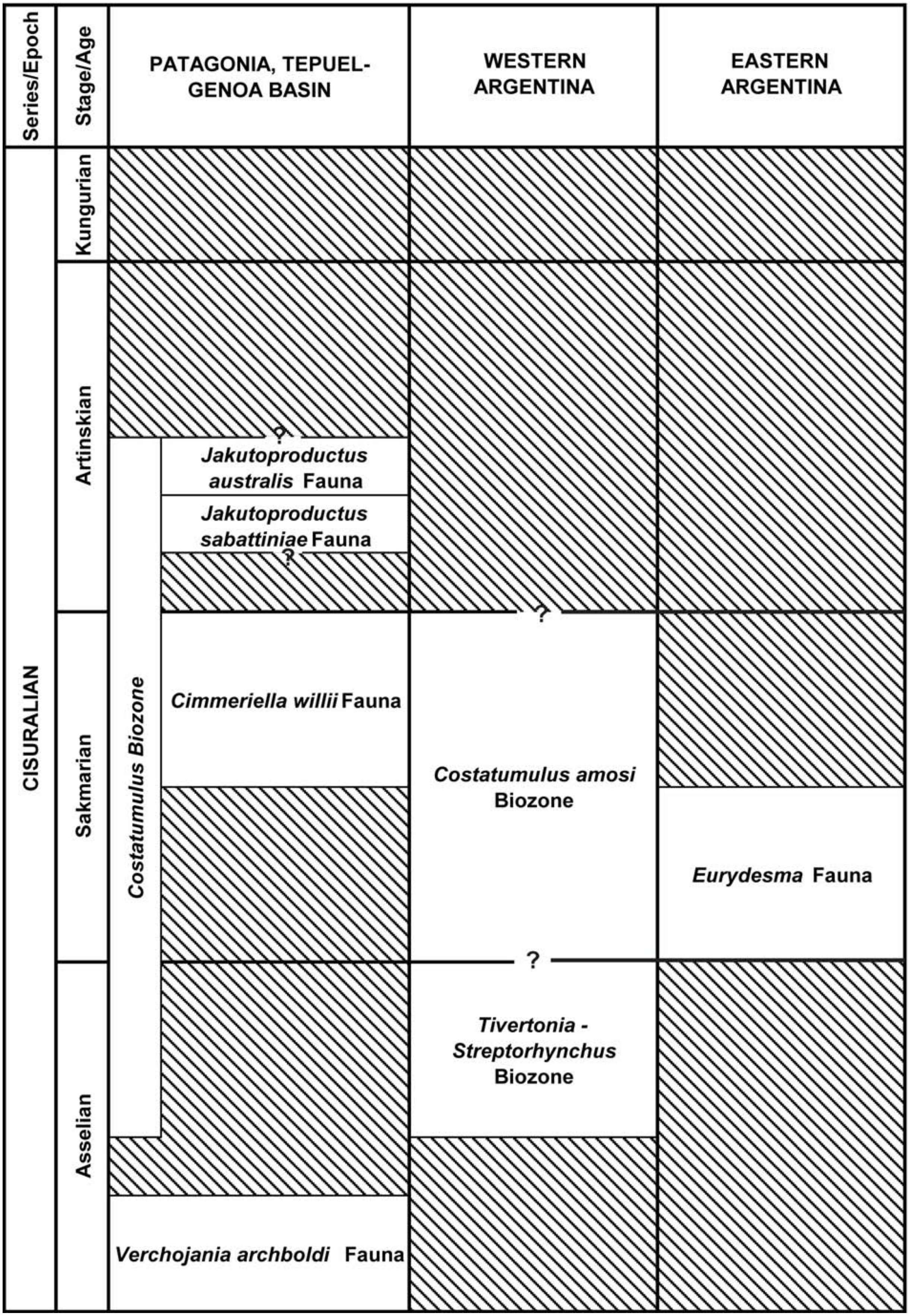

Figure 35. Cisuralian Biozones/faunal assemblages correlation chart between western Argentina (Uspallata-Iglesia Basin), eastern Argentina (Sauce Grande Basin) and Patagonia (Tepuel-Genoa Basin). (modified from Taboada and Pagani, 2009).

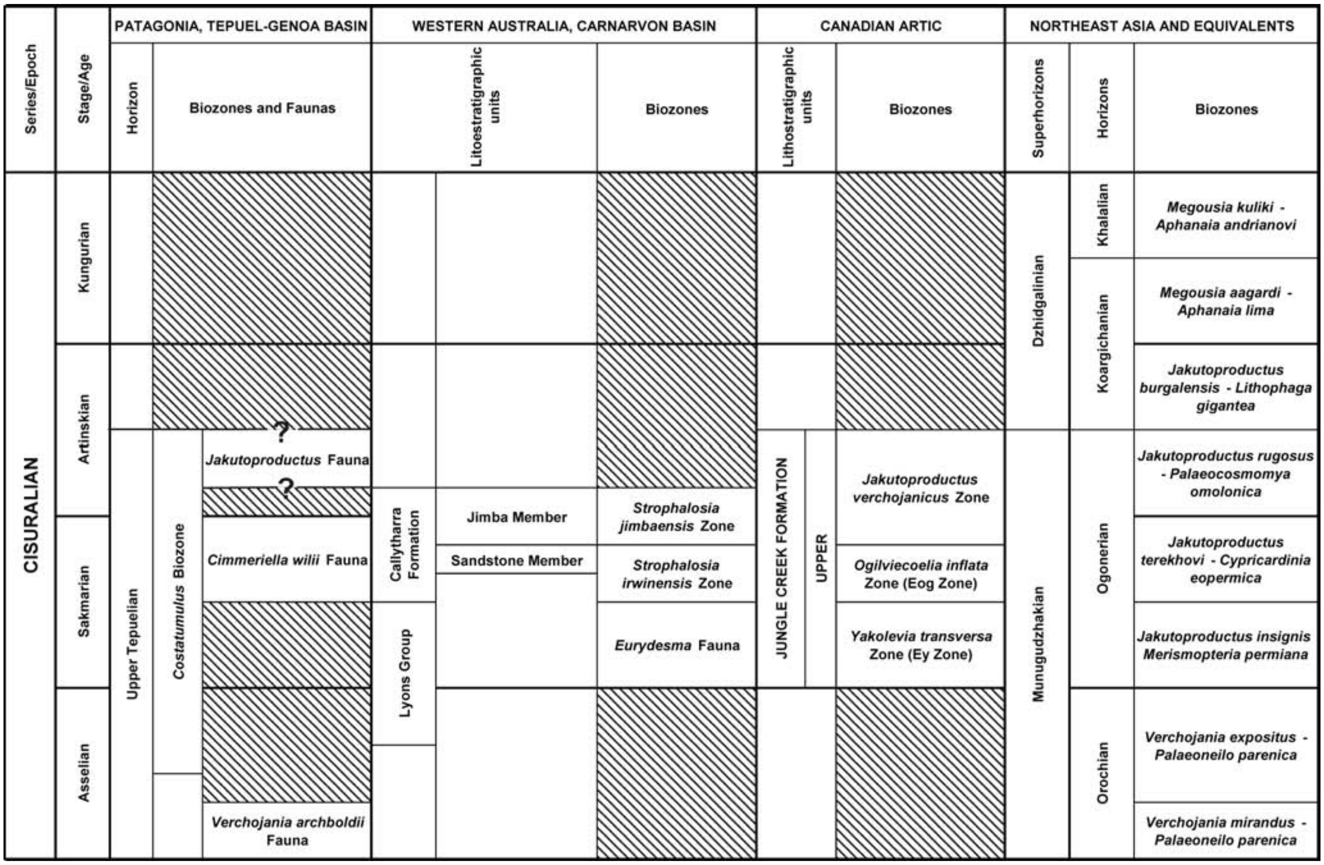

Figure 36. Transcontinental correlation chart of median to high paleolatitude sequences, based on the coupled V*erchojania-Jakutoproductus*, *Eurydesma-Cimmeriella* and *Cimmeriella-Jakutoproductus* faunal occurrences. (modified from Taboada and Pagani, 2009).

be present. The genesis of this formation was indicated as related to submarine fans with some possible glacigenic control (Page *et al*., 1984), but other contributions suggested a more direct glacial influence (González Bonorino (1992). It was recognized by glacial pavement documented (González *et al*., 2003; González and Glasser, 2008; Taboada and Pagani, 2009) (Figures 31) in two different levels throughout the Lefiú creek's profile. This sequence, probably represents the best example of the latest Carboniferous-Asselian glacial episode record in the western "Pacific" basins of Argentina (Taboada and Pagani, 2009) where *Verchojania archboldi* Taboada (2008) (Figure 32) and a small fauna association (undescribed "*Tuberculatella*", *Amosia* and *Paraconularia*), were recorded in a pebbly sandstone overlying tillite and blue laminated shale with dropstones of the uppermost Pampa de Tepuel Formation.

In the El Molle area, the uppermost Mojón de Hierro Formation (a partial section), reaches 600 m in thickness, and is composed of massive calcareous sandstone with some conglomeratic lenses, and greenish grey limestone with fossiliferous concretions bearing a diversified fauna of the *Costatumulus* biozone (probably younger levels than those with *Cimmeriella*). The nautilids *Sueroceras irregulare* Riccardi and Sabattini (1975), *Amosiceras reticulatum* Sabattini *et al*. (2006), the goniatitid *Wiedeyoceras argentinense* (Miller and Garner) (Riccardi and Sabattini (1975), the brachiopod *Leiorhynchus cuyana* (Amos) and the bivalve *Promitylus patagonicus* González (1975), were described from the levels cropping out near the Cañulef Post. The contact of this section with the older Pampa de Tepuel Formation, bearing the fossil assemblage with *Verchojania archboldi,* is not exposed in the area.

Stop 12. Mojón de Hierrro Formation at Garrido creek, southern Tepuel hill. Figure 23

This locality is nearly 30 km to the NNW of Gobernador Costa town, where a key section of 900 m in thickness allows connecting the stratigraphic column with the sequence cropping out throughout the Tres Lagunas valley. The section has deposits of shallow marine platforms that exhibit several fossiliferous levels and two regressive episodes bearing plant remains (Andreis and Cúneo, 1985). The section was previously indicated as the informal Arroyo Garrido Formation (Freytes, 1971) and later assigned to the uppermost part of the Mojón de Hierro Formation (Page *et al*., 1984). The marine levels have provided *Costatumulus* sp. (formerly *Cancrinella* cf. *farleyensis*) and the bivalves *Nuculopsis (Nuculopsis) patagoniensis* and C*osmomya (Paleocosmomya) chubutensis* González (1969), *Palaeoneilo amosi* González (1977), *Heteropecten argentinoensis* Pagani (2005), *Striochondria sueroi* (González) (Waterhouse, 2008) and *Streblopteria lagunensis* Pagani (2006). A tripartite glacial-marine succession of diamictite/shale/sandstone (200 m of maximum thickness) occurs intercalated between the precedent *Cimmeriella* fauna (in stratigraphic continuity after minor dislocation) and the younger assemblages. Some significant undescribed taxa such as *Costatumulus* sp., *Trigonotreta sp.* and *Kochiproductus* are present in levels just overlying the glacial-marine section. Stratigraphically above (nearly? 200 m) a regressive section bearing plant remains such as *Bumbudendron* sp., *Paracalamites australis* Rigby, *Botrychiopsis* sp., *Nothorhacopteris major*, and *Eusphenopteris* cf. *obtusiloba (Brongniart)* Novik, *Calymatotheca* sp., has been described by Cúneo (1990) and estimated to be of Late Carboniferous age. Also, *Asterotheca piatnitzky* Frenguelli, *Pecopteris* sp., *Sphenopteris* sp., *Glossopteris wilsoni* (Seward) Archangelsky, *Eucerospermun* cf. *nitens* Feruglio and *Cordaites sp.* of Early Permian age were reported from the uppermost levels of the sequence (Cúneo, 1990), near the Arroyo Garrido Post.

Stop 12, 13 and 14. Río Genoa Formation at Piedra Shottle (or Shotel), cerro La Trampa and Ferrarotti localities, Río Genoa valley. Figure 24

The Tepuel Group is represented in the Río Genoa valley by the youngest unit, the Río Genoa Formation (Andreis *et al*., 1986), which would be overlying the Mojón de Hierro Formation at the Lomas Chatas locality, but is probably contemporaneous. The Río Genoa Formation crops out through irregular patches mainly distributed along the left margin of the valley and is separated by faults. This unit represents several progradational events of a deltaic complex over shallow marine platforms (Cortiñas and Arbe, 1982; Andreis and Cúneo, 1989). A number of deltaic facies and subenvironments have been identified, including upper delta plain deposits, distributary channels, levees and open sea facies corresponding to prodelta and shallow marine platform deposits. Based on the distribution of facies and the cyclic characteristic of the sequence, a lobate delta model (see Andreis and Cúneo, 1989) with the corresponding constructive and abandonment phases, has been suggested for the Río Genoa Formation (Andreis and Cúneo, 1989). The age of this formation, based on faunistic and floristic evidence, is considered to be Early Permian.

The Río Genoa Formation contains the richest southern hemisphere Early Permian flora with more than 100 species identified to date. Even though the Glossopterids have been recorded from the plant assemblages, the most common plants groups are conifers and ferns. This floristic richness, and its stratigraphic variability, has been used to define detailed biostratigraphy (Archangelsky and Cúneo, 1984; Cúneo, 1987). The *Ferugliocladus* Superzone, characterized by the conifer of this name, is a biostratigraphic unit that includes all plant assemblages recorded from the Río Genoa Formation and the upper part of the Mojón de Hierro Formation. It has been divided into two formal zones. The lower *Nothorhacopteris chubutiana* Zone includes plant assemblages from the lower part of the Río Genoa Formation and is characterized by elements such as *Nothorhacopteris chubutiana, Sphenophyllum sp.* and *Corynepteris australis.* The upper assemblages are included in the *Ginkgoites eximia* Zone characterized by *Ginkgoites eximia, Genoites patagonica, Botrychiopsis valida, Polyspermophyllum sergii, etc.* The composition of the flora from Patagonia suggests a humid and warm temperate climatic regime for this part of western Gondwana during the Early Permian (Archangelsky and de la Sota, 1960; Cúneo, 1986, 1987; Cúneo and Andreis, 1983), although more probably after Sakmarian times.

Marine incursions in the delta complex have been recorded in several areas, including Piedra Shottle, cerro La Trampa and Ferrarotti localities (Figure 23); all of them with representatives of the brachiopod *Jakutoproductus Karshichev* (Simanauskas and Archbold, 2001; Taboada and Pagani, 2009) (Figure 33). A latest Sakmarian-early Artinskian age has been suggested for the section bearing faunas with this conspicuous element (Taboada and Pagani, 2009). Also, the nautilid *Amosiceras reticulatum* Sabattini *et al*. (2006) and the gastropods *Mourlonia cuneoi, Glabrocingulum?* sp., *Peruvispira sueroi* Sabattini and Noirat and *Strobeus* sp. have been described from the Piedra Shottle locality (Ferrari and Sabattini, 2008). Finally, four marine levels have been indicated in the Ferrarotti locality by Ugarte (1966), the two lowermost being the richest. They have provided, besides *Jakutoproductus*, the bivalves *Phestia tepuelensis, Cosmomya (Paleocosmomya) chubutensis* (González, 1969), *Euchondria sabattiniae* González (1974), *Phestia regularis* Pagani (2004b), *Heteropecten argentinoensis* Pagani (2005) and *Streblopteria lagunensis* Pagani (2006), the nautilid *Mooreoceras zalazarensis* Sabattini and Riccardi (1984), the gastropod *Euphemites chubutensis* Sabattini (1992) and the crinoid stem *Camptocrinus bezouglovae* Hlebszevitsch (2005). The third level bears *Piatnitzkya borreloi* Taboada (1993) (Figure 34) among undescribed *Rhynchopora* and bivalves. The fourth, and probably the highest marine level of the Rio Genoa Formation (and the Tepuel Group), has scarce fossils of undescribed species of *Costatumulus* and *Attenuatella*.

Recently, a chart (Figure 35) has been proposed showing Cisuralian Biozones/faunal assemblages correlation chart between western Argentina (Uspallata-Iglesia Basin), eastern Argentina (Sauce Grande Basin) and Patagonia (Tepuel-Genoa Basin). A second transcontinental correlation chart (Figure 36) of Early Permian median to high paleolatitude sequences is based on the coupled *Verchojania-Jakutoproductus, Eurydesma-Cimmeriella* and *Cimmeriella-Jakutoproductus* faunal occurrences (Taboada and Pagani, 2009).

Finally, an important subject in regard to understanding the evolution of biotic change, paleogeography and paleoclimatology of Patagonia is the hypothesis of Patagonia as an independent and exotic microcontinent from the rest of South America (see Ramos, 2008, and references therein). The arrival of plate tectonics triggered different hypotheses, some of them with fixed position interpretations that consider Patagonia as an autochthonous part of Gondwana, and others more mobilistic that postulate an allochthonous origin. After several decades, although some consensus exists among those hypotheses that postulate its allochthony, there is no agreement on its boundaries, subduction, accretion, and final amalgamation times to the Gondwana supercontinent. Aware that important uncertainties still remain, a new model has been recently proposed (Ramos, 2008) with two magmatic arcs: a western belt that was active from the Devonian to the mid-Carboniferous, and a northern one partially coeval that led to the collision of Patagonia against the southwestern margin of Gondwana during the Early Permian. It was hypothesized that the termination of the western magmatic arc activity was linked to the collision of the Antarctic Peninsula and associated terranes. The reconstruction of the plate tectonic history of Patagonia during the Paleozoic shows the existence of several episodes of fragmentation and rifting, convergence and accretion as well as renewed periods of rifting and reaccretion to the Gondwana margin. Those processes were intrinsic to the formation of the Terra Australis Orogen, controlled by the absolute motion of the Gondwana supercontinent and guided by successive global plate reorganizations (Ramos, 2008).

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Data and Hypotheses from Carboniferous to Triassic Continental Deposits of Italy, Based on the 1999-2006 Brescia and Siena Meetings

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Introduction

In recent years, a group of Italian geologists from the Pavia, Siena and Cagliari Universities, with the collaboration of foreign researchers, has carried out a great number of multidisciplinary studies on the Upper Carboniferous to Triassic continental deposits cropping out in the Southern Alps, Tuscany and Sardinia. In this short report, however, the authors point out some topics of wider interest, which were the objects of discussion during the international meetings at Brescia (1999) and Siena (2001, 2006), as well as during their field trips held respectively in Sardinia and the central-eastern South-Alpine segment (at the first meeting) in Tuscany and the southern France, between Provence and Languedoc (at the second one), and again between Provence and Tuscany, along with a two-day visit to the Permian and Lower Triassic succession of the Ligurian Alps (at the last meeting).

Southern Alps

Thin continental Carboniferous sedimentary sequences occur sparsely in the western Southern Alps (Fig. 1, first left column), such as in the Varesotto (Bèdero), Comasco (Alpe Logone), Canton Ticino (Manno, Val Colla) and nearby regions. Due to the lack of modern data, a detailed litho- and biostratigraphic revision to reconsider the chronologic positions with respect to previously published age attribution is required for a realistic correlation of these small but key outcrops with the rest of Europe. In this context, recall that the dating above the Upper Paleozoic successions, scattered over a wide area and strongly tectonized along remarkable structural lineaments, has been debated for a long time between Westphalian and Stephanian, as well as inside these regional stratigraphic units.

Venzo and Maglia (1947) related the Logone deposits, yielding *Calamites* spp., *Pecopteris plumosa*, *Linopteris neuropteroides*, *Lepidodendron weltheimi*, *L. aculeatum*, *L. majus*, abundant *Sigillariae* and other forms, to the middle Westphalian (C), whereas Jongmans (1950, 1960) pointed out in the Manno molasse (Lugano) the presence of *Linopteris neuropteroides*, *Pecopteridium*, *Sigillariaephyllum* and *Cordaites* cf. *borassifolius* as probably pertaining to a slightly older Westphalian age (B-C). Lastly, Pittau *et al.* (2008) also recognized in the same basal clastics that the palynoflora of Brezzo di Bèdero (near Luino, Lake Maggiore), consisting of 42 spore genera and 76 species, shows great affinities with those of Western Europe. The most abundant forms are trilete spores known to be characteristic of late Westphalian (?) and early Stephanian assemblages. They include the noteworthy presence of *Florinites* and subordinately *Wilsonites* species, few *Potonieisporites*, rare *Limitosporites* and *Vesicaspora*, and very rare *Latensina-Cordaitina* pollen. According to Pittau *et al.* (2008) this palynological suite would be indicative of a well-established lowland Cordaitean vegetation and well-settled pterophytic, pteridosperm and minor sphenophytic and lycophytic, hygrophytic plant communities.

According to our understanding, the Lower Permian Collio Basin is an intramontane continental basin caused by the late-Variscan tectonics in the central Southern Alps (Fig. 2). Its evolution was controlled by a transtensional geodynamic regime associated with calc-alkaline, intermediate and acidic magmatism.

During this period, the alluvial to lacustrine sedimentation was accompanied by episodic volcanism, manifested in different ways. In particular, immediately above the lower Collio Formation (Pian delle Baste member), a thin volcaniclastic body (Mt. Dasdana I Beds, according to Breitkreuz *et al*., 2001a; Fig. 2), crops out. Already interpreted as calc-alkaline rhyolitic lavas (Peyronel-Pagliani, 1965), this and other younger similar extrusive

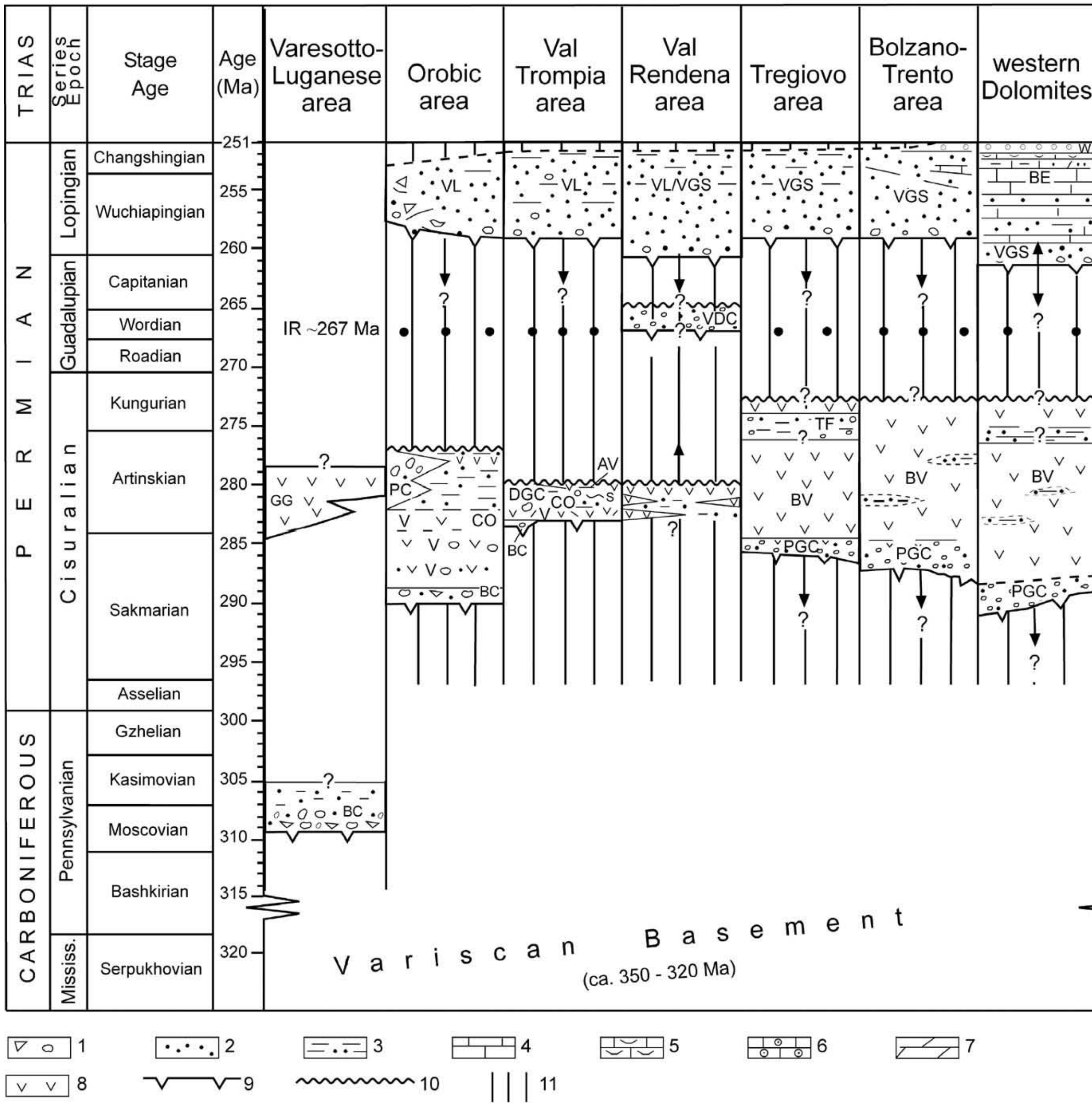

Fig. 1 – Selected and simplified Permian stratigraphic columns of central and eastern Southern Alps, from Lake Maggiore (W, Varesotto-Luganese) to the western Dolomites (E). Lithostratigraphic units (from bottom) – LOMBARDY-CANTON TICINO (Varese, Lugano, Orobic and Val Trompia areas): BC, basal conglomerate; V, undifferentiated volcanics; GG, Val Ganna granite; CO, Collio Formation; PC, Ponteranica Conglomerate; DGC, Dosso dei Galli Conglomerate (S, Pietra Simona Member); AV, Auccia Volcanics; VL, Verrucano Lombardo. TRENTINO-ALTO ADIGE (Val Rendeva, Tregiovo, Bolzano-Trento areas and western Dolomites): PGC, Ponte Gardena Conglomerate; BV, undifferentiated Bolzano (Bozen) volcanics; TF, Tregiovo Formation; VDC, Val Daone conglomerate; VL, Verrucano Lombardo; VGS, Val Gardena (Gröden) Sandstone; BE, Bellerophon Formation; W, Werfen Formation. In the above context, the succession of the Varesotto-Luganese area results strongly incomplete because of the great number of geometric lithological changes affecting the region, which prevent a careful stratigraphic reconstruction. In the related scheme, only the Westphalian–Stephanian "basal conglomerate" (BC) and the overlying shallow intrusive ("granophyre") known as "Ganna Granite" (GG) of 281.8±5 Ma, obtained by Schaltegger and Brack (2007) on zircon age, have been introduced. Lithology – (1) conglomerate and breccia; (2) sandstone and siltstone; (3) pelite, siltstone and marlstone; (4) limestone; (5) fossiliferous limestone; (6) oolitic limestone; (7) dolostone; (8) volcanic rocks. Other symbols – (9) unconformity; (10) erosional surface; (11) stratigraphic gap. Standard global chronostratigraphic scale from Gradstein *et al*., 2004a. Vertical distances are not time- or thickness-related.

bodies, used as key beds, are at least in part presently interpreted as sub-lacustrine volcaniclastic mass-flow deposits (Cassinis and Perotti, 1997; Breitkreuz *et al*., 2001a, b). East of Mt. Dasdana , along the Maniva-Croce Domini road, a section of the Dasdana I Beds is represented (base to top) by: (1) a light-grey, amalgamated coarse-sand to gravel crystal-rich massive subunit, including black pelite (lacustrine Collio rin-ups) and subordinate volcanic and metamorphic rocks, which resemble Bouma-a(b) divisions suggesting deposition from coarse-grained turbidity currents; and by (2) a greenish, well-bedded sandy-shaley more dilute turbiditic subunit with outsize porphyritic lava fragments (Breitkreuz *et al*., 2001b). On the whole, this succession can locally reach up to about 20 m in thickness.

Based on our research, these so-called "Dasdana Beds" originated from one or more igneous centres at the eastern part of the Collio Basin beyond the Caffaro Valley, near the Brescia-Trento border, and rapidly thin westward. In particular, the main source areas of this igneous activity were located along the ENE Val Trompia lineament, north of the Bagolino-Riccomassimo "knee-fold". Here, the subvolcanic bodies cut the crystalline basement as well as part of the overlying Lower Permian succession and flowed onto the basin floor from the Dosso del Bue lava dome (up to about 200 m thick).

According to some authors (Visscher *et al*., 2001), the age of the alluvial to lacustrine sediments of the Permian Orobic and Val Trompia (or Collio) basins, cropping out between central Lombardy and western Trentino (Figs. 1 and 2), cannot be inferred in detail from their known macro- and microfloral assemblages; only a general correlation with the German Rotliegend is possible so far. In contrast, the presence in both basins of a large number of tetrapod footprints, even though these are not always indicative of a well-defined chronological interval, seems compatible with an age referable at an interregional scale to the Early Permian. In particular, within the limits of the Orobic and Collio basins, these forms come from the middle–basal part of the first tectono-sedimentary megacycle.

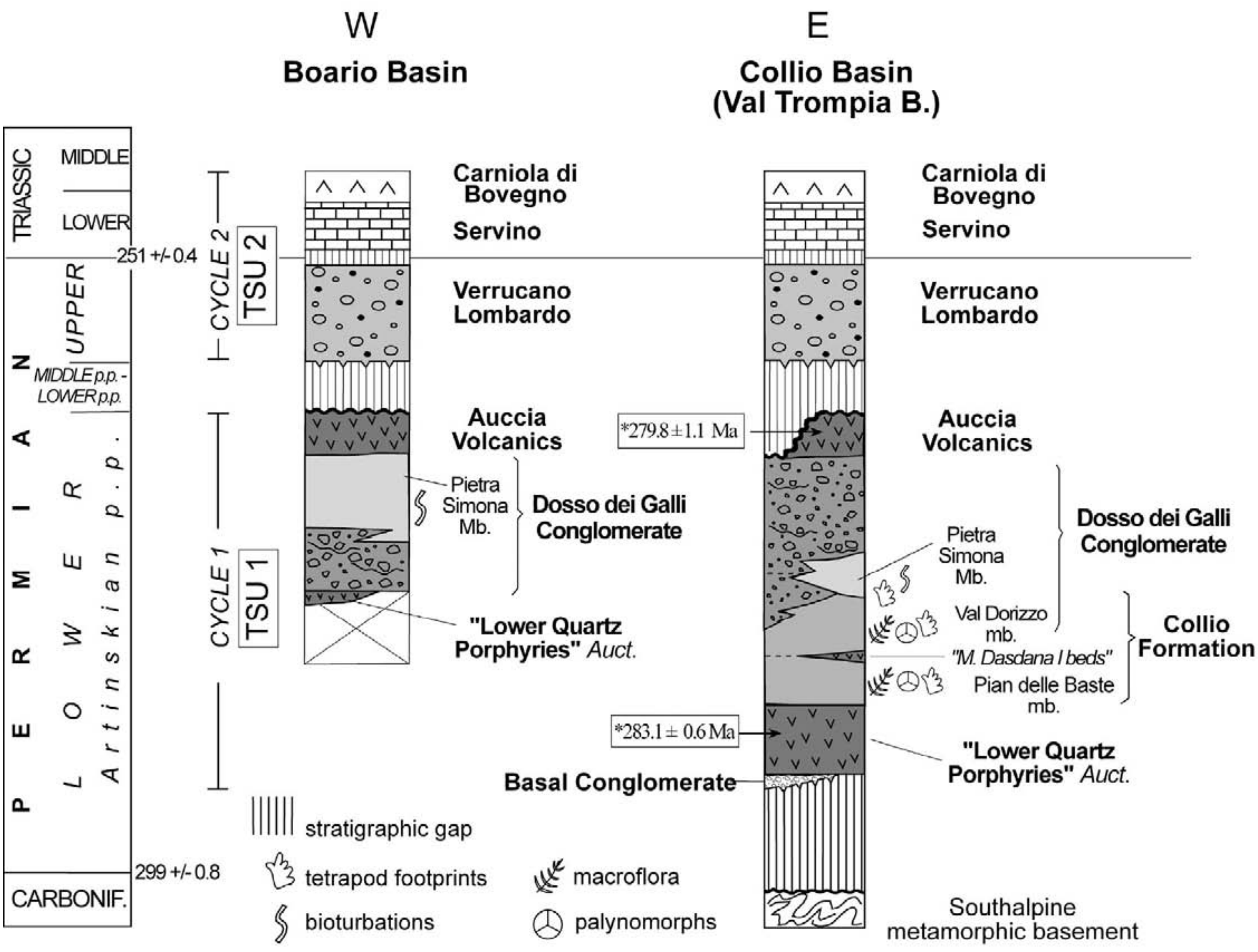

Fig. 2 – Synthetic stratigraphic columns in central Southern Alps, from the typical Lower Permian Collio Basin (E), in the Val Dasdana-Passo Maniva area, and the close small Boario Basin (W), in the lower Val Camonica. Vertical distances are not time- or thickness-related. Geologic time scale from Gradstein *et al.* (2004a).

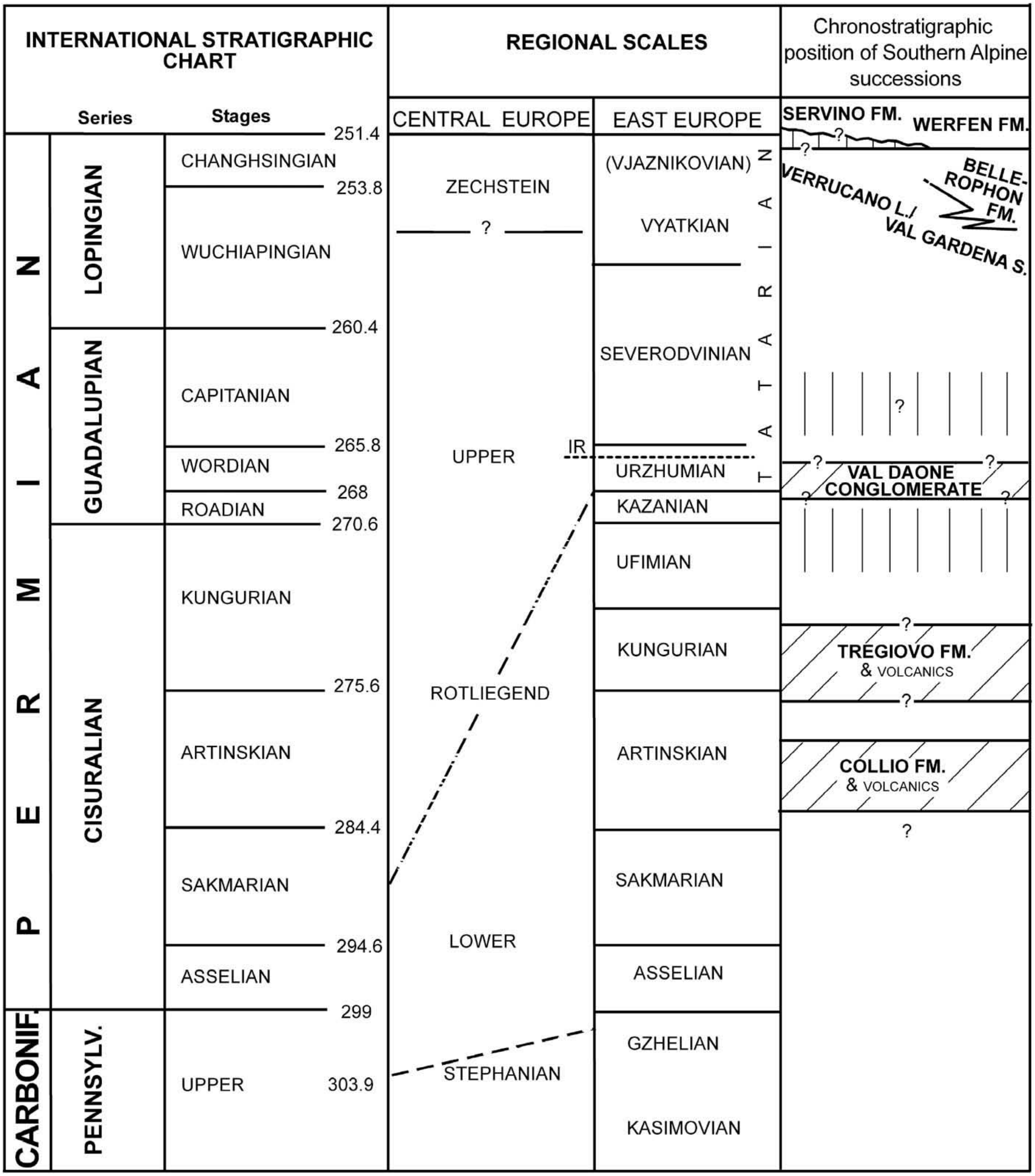

Fig. 3 – Tentative age-assessment of some well-known lithostratigraphic units (oblique lines) in the central Southern Alps, based on palynological research, radiometric data and regional correlation. Perpendicular lines: presumed stratigraphic gaps. Vertical distances are not time- or thickness-related. Geologic times scales from Menning, 1995 (Central Europe), Kotlyar and Propina-Nestell, 2005 (East-Europe), and Grandstein *et al*., 2004a (International Stratigraphic Chart).

Due to the poor and still imprecise stratigraphic significance of the fossil content, it follows that the only tools now suitable to date all or part of the above continental basins must be calibrated on careful radiometric analyses of volcanic rocks, generally derived from U-Pb zircon age. In this way, the Early Permian Collio Basin, which is generally constrained between the "lower rhyolite ignimbrites" (resting directly on the pre-Permian Variscan crystalline basement) and the "upper rhyolite ignimbrites" (known as Auccia Volcanics and unconformably overlain by the Verrucano Lombardo) has highlighted, for the above extrusive units, two distinct ages of 283.1 ± 0.6 and 279.8 ± 1.1 Ma respectively (Schaltegger and Brack, 2007). (Figs. 1 and 2). That is, some dates relate the whole examined succession to approximately the lower–middle Artinskian (according to the Gradstein *et al*. Time Scale, 2004a). From the very few available radiometric data, the Orobic Basin would seem to have originated earlier (Zr 288.4; Cadel *et al*., 1987), possibly during the Sakmarian and persisted, if compared with the typical Collio Basin, to relatively more recent times (278 ± 3 Ma?; in Cadel, 1986), but still pertaining to the Artinskian. (Fig. 1).

Northward, between Trentino and Alto Adige, the age of the Tregiovo Formation has also been discussed. From the paleontological research of recent decades (*e.g.* Remy and Remy, 1978; Kozur, 1980; Cassinis and Doubinger, 1992; Barth and Mohr, 1994; Pittau 1999a), the finding of abundant macro- and microfloral assemblages is in agreement with an age-assessment more recent than that of the Collio-type (Figs. 1 and 3). These generally span the late Artinskian and the Kungurian–Ufimian *p.p.* (both recently correlated in the report of the committee on the Permian System of Russia with the Kungurian of the Global Stratigraphic Scale 2004; Kotlyar and Pronina-Nestell, 2005; Fig. 3). However, Pittau considers that the top of the above unit could pertain to the Kazanian for the presence of *Lueckisporites virkkiae*, a pollen grain cited by Utting *et al.* (1997) in the lower part of that type-stage. In this context, again according to Pittau, a comparison with the microfloral assemblages of the overlying Val Gardena (Gröden) Sandstone shows remarkable differences in qualitative and quantitative composition, even though the suite affinity of the non-taeniate disaccate pollen and the presence of *Nuskoisporites dulhuntyi* is impressive. Pittau (1999a) asserted that the age of the upper part of the "Tregiovo" tends generally towards the Middle Permian rather than the Lower Permian.

In spite of the aforementioned controversial paleontological data and the respective chronostratigraphic interpretations, some Zr radiometric analyses of the rhyolitic tuffs of the Ora formation, which crops out in the Adige Valley on top of the Tregiovo deposits and closes the cycle of the Athesian Volcanic Group (AVC), indicate that they took place at about 277–274 Ma (Bargossi *et al*., 2004; Morelli *et al*., 2006; Schaltegger and Brack, 2007), *i.e.* around a late Artinskian to early Kungurian interval (Figs. 1 and 3).

In conclusion, the accurate use of isotopic methods in the continental domains provides a remarkable tool to solve some paleontological problems of uncertain age.

The geodynamic evolution of the central Southern Alps is marked, from Late Paleozoic to Mesozoic times, by significant igneous events. As in southern Paleoeurope, the Early Permian is characterized by a transtensional regime due to a dextral transform margin between Gondwana and Laurussia. The calc-alkaline, intermediate-to-acidic volcanics and alluvial-to-lacustrine deposits, which can be grouped into a lower tectonosedimentary cycle and infill fault-bounded pull-apart basins (like the Collio and other basins in the above-cited South-Alpine area), are accompanied by widespread granitoids and minor gabbros from asthenospheric upwelling and crustal contributions. From the Late Permian to Anisian, an extensional regime gave rise to a second tectonosedimentary cycle after a stratigraphic gap estimated at about 15–20 Ma. In this context, the volcanic activity stopped and was replaced by a progressive peneplanation of the region, generally evidenced firstly by the siliciclastic red beds of the Verrucano Lombardo/Val Gardena Sandstone, and later during the Early Triassic by the shallow-marine sediments of the Servino/Werfen Formations. The transition to epicontinental arc/back-arc environments, due to the northwestward subduction of Paleotethys between Anisian and Carnian times, was marked by the regression of the evaporitic Bovegno Carnieule. The new framework, already supported by some authors (Armienti *et al*., 2003; Corazzato and Groppelli, 2004), is in tune with plate reorganization and the opening eastward of the Meliata back-arc basin. In the Brescia province, during the Ladinian–Carnian, a new igneous cycle took place, mainly represented by (base to top): (1) fine-grained rhyolitic tuff ("pietra verde" *Auct.*) interbedded with nodular limestone; (2) large volumes of acidic high-K to shoshonitic subvolcanics and abundant extrusives; (3) high-K calc-alkaline to shoshonitic subaerial volcaniclastics. A marked geodynamic change, probably late Carnian in age, is suggested by transitional basaltic dykes (217 ± 3 Ma) and lavas. This rifting event predates the opening of the Neotethys Ocean.

Along the Giudicarie Belt (western Trentino), the large intra-Permian gap between the lower and upper tectonosedimentary cycles, which has been emphasized in recent years throughout the entire Southern Alps, is seemingly split by a well-developed alluvial clastic wedge known as the Val Daone Conglomerate (VDC) (Figs. 1 and 3). This unit consists dominantly of vein quartz and volcanic fragments, and reaches a maximum thickness of about 100–130 m. In the type-area, the VDC rests unconformably on the Lower Permian volcanic and fluviolacustrine deposits of the Collio Basin and paraconformably (?) below the fluvial red beds of the Verrucano Lombardo/Val Gardena Sandstone, both generally related to a Late Permian age (Figs. 1 and 3). The finding from Pittau *et al.* (2006) of a significant palynological assemblage, yielding *Lueckisporites virkkiae*, *Corisaccites* sp., *Crucisaccites* (closely resembling to *C. variosulcatus*, Djupina, 1971), as well as other forms, allows us to suggest that the discussed unit belongs to the Middle Permian, plausibly to the Wordian of the International Time Scale. To the south, in the Riccomassimo Valley, the unit directly overlies the Dosso dei Galli Conglomerate of the Collio Basin, which is reddish in colour and generally located at a lower position in the Lower Permian succession, but is Artinskian in age as based on correlation with the Zr radiometric data of the nearby Auccia ignimbrites.

East of Val d'Adige, notably in the western Dolomites (Fig. 1), the Val Gardena Sandstone (VGS) is locally rich in macro- and microflora, and tetrapod footprint assemblages. According to Visscher *et al.* (2001), through detailed comparative cuticle analyses in the Bletterbach area it was possible to recognize three distinctive species within the coniferous form-genus *Ortiseia* (Clement-Westerhof, 1984): *Ortiseia leonardii, O. visscheri* and *O. jonkeri*. Other dominant conifers are *Majonica*, *Dolomitia* and *Pseudovoltzia*, rather than *Walchia, Ulmannia* and *Woltzia* of the earlier literature. The most prominent pteridosperm fragments correspond to the species formerly known from the Zechstein Basin of NW Europe as *Callipteris martinsii*, now included in the natural genus *Peltaspermum* (*P. martinsii*; Poort and Kerp, 1990).

Palynological studies have been published by a large number of authors (Klaus, 1963; Clement-Westerhof *et al*., 1974; Italian IGCP-203 Group, 1986; Visscher and Brugman, 1988; Massari *et al*., 1988, 1994; Conti *et al*., 1997; Cirilli *et al*., 1998; *etc*.). The large quantity of pollen grains in the Bletterbach section first gave rise, according to Pittau (in Massari *et al*., 1988), to three informal associations: A) not defined by particular taxa; B) identified by the concurrent presence of *Protohaploxypinus microcorpus* and *Playfardiaspora crenulata*; and upwards, C) characterized by the occurrence of *Lunatisporites noviaulensis*, *Inaperturopollenites dolomiticus* n. sp. and *Lueckisporites* sp. However, this biostratigraphic scheme has not been extended to all the studied sections of the Val Gardena area, because of the unsatisfactory control of some taxa. Therefore, in a voluminous paper on the Upper Permian deposits of the Dolomites and Carnia (Massari *et al*., 1994), several sets of taxa, besides the presence-absence of *Protohaploxypinus microcorpus* and *Endasporites exareticulatus*, have been successfully used to correlate the lower and central parts of the succession (respectively corresponding to A and B associations of the Bletterbach section); in addition, other stratigraphically relevant taxa, such as *Lueckisporites parvus* and *Guttulapollinites* sp., have been used to identify the upper part of the succession (equivalent to the C association of the Bletterbach section).

In the Dolomite Alps, it is now generally agreed that the age of the fluvial Val Gardena Sandstone, which upwardly and laterally passes to the carbonate Bellerophon Formation, falls into the Late Permian (Figs 1 and 3). Tentative correlation to the marine scales was also proposed. For instance, a late Middle Permian (Capitanian?) age for the lowermost part of the succession (Fig. 1, last right column) and an Abadehian to Dorashamian age for the overlying part was suggested in previous papers (*e.g.* Conti *et al*., 1986; Massari et *al*., 1988), even though the striking similarities with the Zechstein microflora (Schaarschmidt, 1963; Dybová-Jachowicz, 1974; *etc*.) of Central and Northern Europe, the Hilton Plant Beds (Clarke, 1965) and Ireland (Visscher, 1971) were pointed out.

Recently, according again to Pittau (1999b), the updated palynological account of the Tatarian stage given by Koloda and Kanev (1996) allows a feasible correlation of the lower and middle part of the succession, namely below the *Lueckisporites parvus* and *Guttulapollenites* sp. appearances, with the Severodvinian Horizon of the type-area, or more reliably with the Vyatkian (Vyazniki) Horizon (upper Tatarian) (Fig. 3). The upper part of the Bletterbach succession, yielding *Lueckisporites parvus* and *Guttulapollenites* sp. other than a suite of disaccate alete pollen grains, does not seem to have comparable assemblages in the Tatarian, thus probably indicating a younger age.

Lastly Pittau (2001), in a paper aimed again at correlating the Mid–Upper Permian sporomorph complexes of the Southern Alps with the Tatarian complexes of the stratotype region, points out that a moderate taxonomic similarity, as well as different vegetation composition in the two regions, are indicated for the Urzhumsky Horizon (lower Tatarian). The occurrence of *Lunatisporites* and *Klausipollenites schaubergeri* pollen grains, and the smaller number of Costati, enhance the similarity between the Severodvinian Horizon and the Val Gardena Sandstone 1st cycle microfloras. Based on the presence of *Protohaploxypinus microcorpus* in the Vyatkian Horizon and the very high degree of taxonomic similarity between the assemblages, a correlation is proposed between the microfloras of this late Tatarian stage and those of the Val Gardena Sandstone and Bellerophon Formation 2nd and 3rd cycles. According again to Pittau (2001), the presence of *Lunatisporites noviaulensis* in the topmost levels of the Vyatkian Horizon, and the absence of *Lueckisporites parvus* from the Tatarian type-section, which is observed stratigraphically later in the Southern Alps, might suggest a very limited extent of the stratigraphic gap between Tatarian and Triassic, probably spanning only a part of the Dorashamian or Changshingian.

However, a recent paper of Kukhtinov *et al.* (2008) from the Permian–Triassic transition of the East European Platform points out for the first time a non-marine ostracod association pertaining to the "Vjaznikovian Horizon", which is considered coeval with the Changshingian Stage. This fauna consists of forms that are typical of the youngest horizons from the late Tatarian, as well as some species known from the Permian and (?) Triassic beds of Siberia. Thus, Vjaznikovian ostracods occupy the highest position in the Permian, at the transition with the Triassic. Their discovery and determination represents a very important contribution to non-marine Permian stratigraphy, because it shows that the Tatarian of the East European Platform is practically complete, with barely any gap at the Permian–Triassic boundary.

In contrast, this continuity of sedimentation between Permian and Triassic has been well documented previously in the eastern Southern Alps, where above the fluvial Val Gardena red beds follow firstly the marine Bellerophon Formation, with *Comelicania haueri* and *C. megalotis* beds at the top ascribed to the late Changshingian, and secondly, after some transitional beds (with *Orthothetina*, *Ombonia* and *Janiceps*), part of Tesero member of the Werfen Formation, of which the basal oolitic bank is overlain by marly interlayers yielding *Crurithyris* (Tesero and Bulla sections) and *Eumorphotis*-like bivalves (*e.g.* Sass de Putia section), both again related to late Changshingian times (Posenato, 2001). The overlying part of the Tesero Member, characterized by the appearance of the conodont *Hindeodus parvus* (Kozur and Pjatakova), marks the beginning of the basal Triassic (early Griesbachian). (Fig. 1, last right column).

Tetrapod footprint assemblages are very common and well known in the Bletterbach-Butterloch outcrops. According to Conti *et al*. (1999), typical Permian genera, such as *Ichniotherium* and *Hyloidichnus*, have been found in association with taxa displaying a clearly Triassic affinity. In fact, the whole ichnofauna is characterized by an extreme "modernity" in comparison with

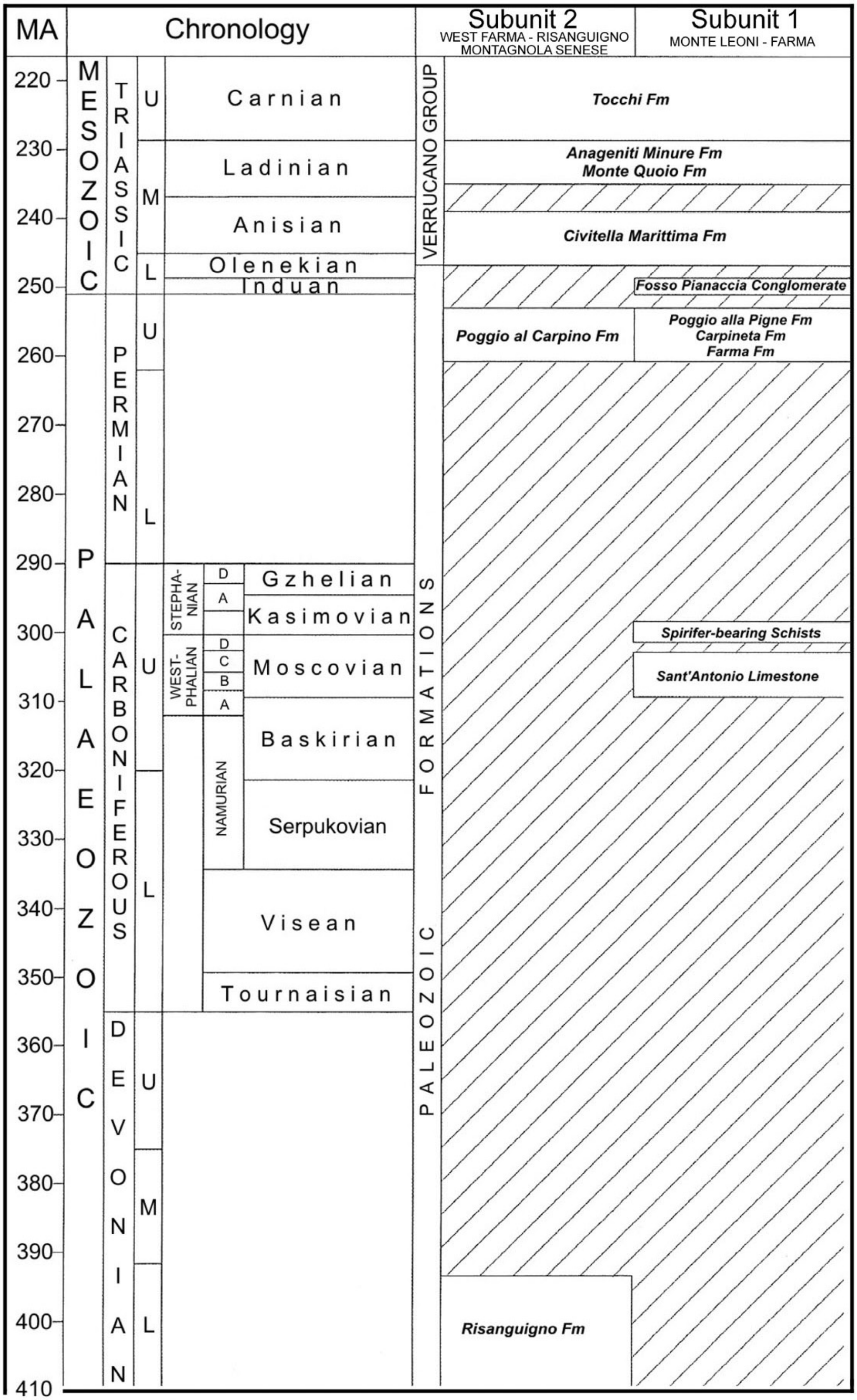

Fig. 4 – Chronostratigraphic table showing the relationships among the Paleozoic and Triassic formations of the Monticiano-Roccastrada Unit in Tuscany. Thickness is not to scale. Upper Carboniferous scale is after Cowie and Basset (1989); Permian scale after Menning (2001); Triassic scale after Gradstein *et al.* (2004b). Modified from Aldinucci *et al.* (2008a).

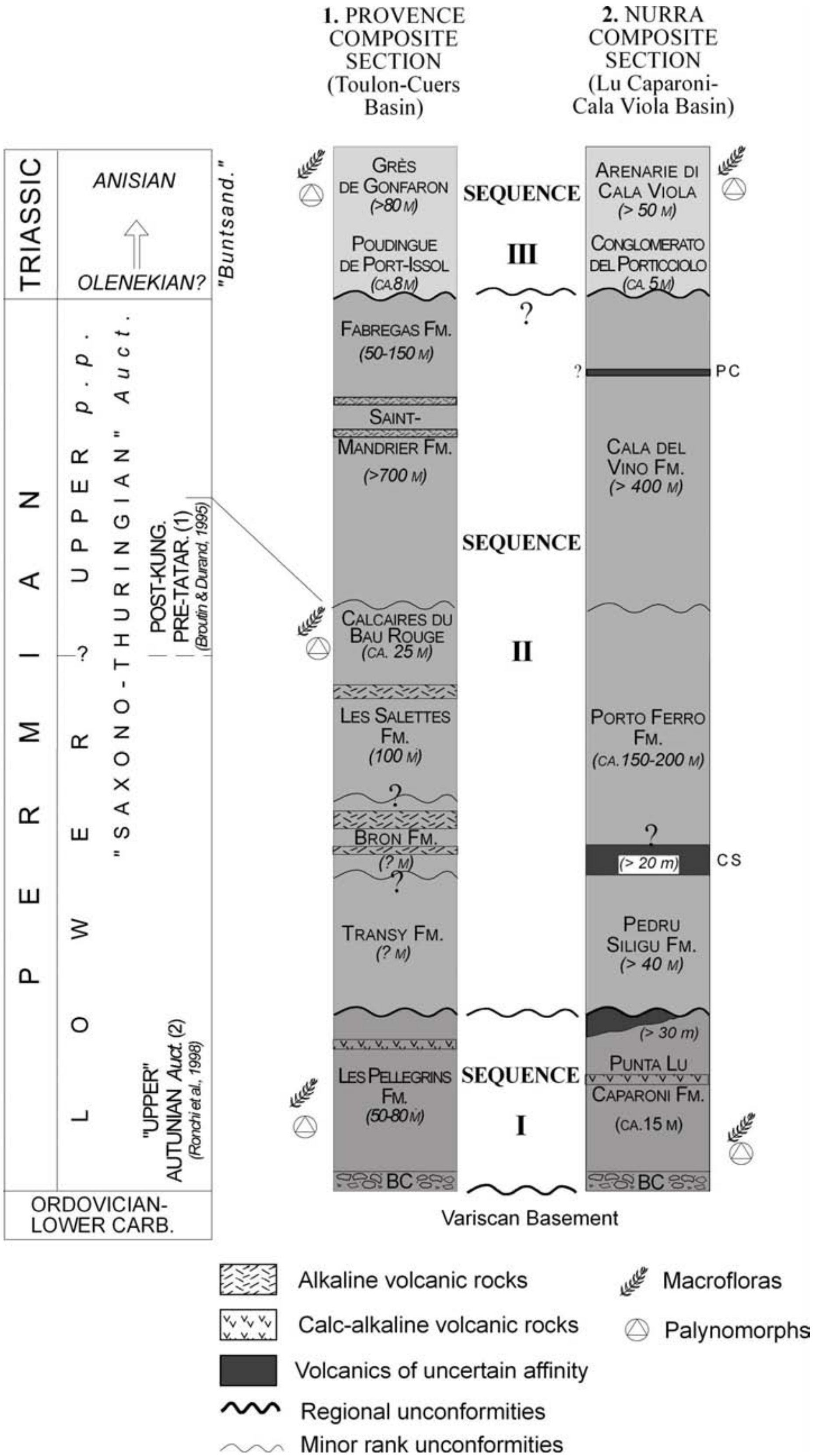

Fig. 5 – Schematic and composite logs of the Permian and Triassic sequences of Lu Caparoni-Cala Viola (Nurra) and Toulon-Cuers (Provence) basins. Stratigraphic sections are not to scale. In the time column, the dating (1) pertains to the Provence section (southeastern France), whereas (2) to the Nurra section (northwestern Sardinia). (After Cassinis *et al*., 2003).

the other known Permian faunas, as witnessed by the presence of *Rhynchosauroides* and *Dicynodontipus*, which are known elsewhere as typical Triassic ichnogenera. For this reason, the Bletterbach ichnofauna is really unique, and probably represents the youngest Permian assemblage known in the world. The most typical element of this ichnofauna is *Pachipes dolomiticus*, which is ubiquitous and can be regarded as a biochronologic marker.

The relative uniformity of the ichnofauna in the Bletterbach section suggests that the time interval represented by the Val Gardena and Bellerophon units may be rather short.

Tuscany

The continental stratigraphic record of the Pisan Mts. has not been affected substantially compared with that previously known (*e.g.* Rau and Tongiorgi, 1974). Present research has centred on the very abundant macrofloras essentially based on the famous De Stefani collection assembled since the nineteenth century from the San Lorenzo schists (?Westphalian D/Stephanian–Autunian). This assists in locating their provenance and other new sites in Valle del Guappero, with the aim to draw specialists' attention to better define their age, as yet scarcely calibrated, and to promote wider correlations in the Mediterranean region. This research has also allowed recognition for the first time in the lower part of the above lithostratigraphic unit of the presence of shallow-marine fossiliferous intercalations yielding bivalves, bryozoa, crinoids and dubious brachiopods. Therefore, these new findings induce some modifications to recent reconstructions of the Late Carboniferous paleogeography and paleoenvironment in the Northern Apennine.

The Asciano breccia, which unconformably rests beneath the Verrucano-type of the Mts Pisani, bearing basal rhyolitic lithoclasts not observed in previous units suggests, owing to interregional correlation, a general age-assessment likely related to the middle–upper part of the Lower Permian. Moreover, in this context, the Asciano breccia, which presumably represents a lateral equivalent of the Torri breccia in the nearby small Iano Basin and of the Dosso dei Galli Conglomerate (Artinskian) in the South-Alpine Collio Basin, could mark the onset of a widespread tectonic event. As already indicated, after a gap of as yet uncertain duration follows the Verrucano Group which, along with the overlying Mt. Serra quartzite formation, generally spanned

Middle Triassic–Carnian times.

As a consequence of the data, the post-Variscan Pisan stratigraphic record could be subdivided into three distinct tectonosedimentary cycles, marked in ascending order by the San Lorenzo schists, the Asciano breccia and the Verrucano group respectively, and separated by stratigraphic gaps of various importance.

Southward, in the Monticiano-Roccastrada tectonic Unit, the Carboniferous–Permian succession of the previous authors (*e.g.* Lazzarotto *et al*., 2003; Aldinucci *et al*., 2008a) has been progressively revised since 2000. The present stratigraphic scheme shows, after a long gap above the Devonian Risanguigno metamorphic basement of the Subunit 2 (Fig. 4), the Poggio al Carpino/Mt. Argentario sandstone formations both probably referable to Late Permian and/or Early Triassic times (Cirilli *et al*., 2002). These are unconformably capped everywhere by the Verrucano Group reaching from the top of the ?Olenekian (Civitella Marittima Formation.) as far as the Carnian (Mt. Quoio, Anageniti Minute and Tocchi formations, on the whole marked at the beginning by a gap). In the Subunit 1 (Fig. 4), which is geometrically the lowest and outermost, the Farma and Carpineta formations, in times past related to the Middle Carboniferous because of the presence of fusulinids, have been now attributed to Permian times, in agreement with the aforementioned stratigraphic order, on account of multidisciplinary investigations (Aldinucci *et al*., 2008b). In particular, the finding in the upper part of the Farma Formation of a large number of palynomorphs (such as *Lueckisporites virkkiae*, *Lunatisporites noviaulensis*, *Klausipollenites schaubergeri*, *etc*.), notably pertaining to the Middle–Upper Permian, have been decisive for settling the new age of the formation. Nevertheless, all the data gathered from careful sedimentologic and structural research in the same unit suggest that the fusulinids were affected by reworking processes. More evidence of this Tuscan age-appraisal could also be provided by the local occurrence, above the Farma and Carpineta formations, of the Poggio alle Pigne Formation (Fig. 4), a unit which was already related by Aldinucci *et al*. (2001) to Late Permian times, owing to the discovery at its summit of some brachiopods identified by Wardlaw (pers. comm.) with the genus *Tschernyschewia*.

As a consequence, the new age-assessment of the Farma Formation implies a very different paleogeographical scenario for this unit, as being deposited in the Middle–Late Permian mainly by unchannelled, relatively dense turbidity flows within an extensional (transtensional?) basin.

Sardinia

In SW Sardinia, generally based on the presence of macro- and microfloras, the S. Giorgio, Tuppa Niedda and Guardia Pisano continental remnants of mainly fluvial to lacustrine basins developed during Late Carboniferous/Early Permian times. Specifically, the first two successions are safely related to Stephanian, whereas the last one is dominated at the beginning by an early Asselian assemblage (a date also confirmed by a radiometric datum of 297 ± 5 Ma from an intercalated calc-alkaline acidic lava followed upwards by post-Asselian sediments of as-yet-uncertain age). These fossiliferous sequences allow us to establish useful correlations with the Permo–Carboniferous basins of other European and extra-European sectors, such as North Africa and the USA. For example, according to Pittau et *al*. (2002), in the last one the diagnosed palynomorphs yielding (base to top) *Crucisaccites*, *Luberisaccites*, *Gondwanopollis*, *Lueckisporites*, along with very abundant *Potonieisporites* and subordinate *Florinites* (1st ass.), are followed by a large number of species of *Potonieisporites*, *Limitisporites*, *Costapollenites*, *Vittatina* (2nd ass.), and then are successively mostly composed of Sphenophyte spores (3rd ass.). These suggest that the area now occupied by the Guardia Pisano succession would be positioned to the south at the beginning of the Permian, probably close to southern Spain and north Africa, thus possibly assuming the characteristics of a mixed Euro-Gondwanian flora, as already suggested by Broutin (1986) in this Mediterranean region. Only later, but still during the earliest Permian, did this area presumably drift northwards to reach the Sardinian-Corsican sector, in the stable part of southern France.

In the central and eastern intramontane basins of Sardinia (such as Escalaplano-Lake Mulargia, Perdasdefogu, Seui-Seulo, Montarbu), these would be characterized, as well as the Guardia Pisano Basin, by stratigraphic successions at least in part correlatable with the "Autunian" of the type-locality (Gzhelian–lower Sakmarian, *sensu* Broutin *et al*., 1999), cropping out NE of the French Massif Central, and affected by generally similar stratigraphic and structural aspects that have recently constrained Ronchi *et al*. (2008) to group them under the name of "Autuniano Sardo". Among the aforementioned basins, research on the Perdasdefogu Basin, which can be estimated as the most representative for the large amount of paleontologic and lithologic data investigated by Ronchi *et al*. (1998), led Broutin *et al*. (1996) to recognize that the macrofloral assemblage is strictly identifiable with that of the Surmoulin/Millery units attributed to "Upper Autunian" of the Autun Basin. Moreover, the finding of three branchiosaur species, of which the *locus typicus* is reported from the Rotliegend (upper Goldlauter Formation) of the Thuringian Forest, has enabled the correlation of the above fossil strata with the late Asselian of the global marine standard scale (Werneburg *et al*., 2007; Ronchi *et al*., 2008).

In NW Sardinia, the macro- and microfloral assemblages of the Punta Lu Caparoni formation is also comparable, according again to Broutin *et al*. (1996), to the "Upper Autunian" of the above-mentioned Millery sequence. Generally, from the large number of observations carried out in this area, the evolution of the Permian and Triassic continental record in Nurra shows strict affinities with that of the Toulon-Cuers Basin in southern Provence (Cassinis *et al*., 2003). (Fig. 5).

In summary, the research on the post-Variscan continental deposits of Sardinia has until now highlighted three main depositional sequences or tectonostratigraphic cycles, separated by unconformities of as-yet-uncertain duration (Cassinis and Ronchi, 2002; Ronchi *et al*., 2008). In Nurra, the first sequence extends above the metamorphic basement up to the "Autuniano Sardo" included (Fig. 5); the second spans the Pedru Siligu Formation and the *red beds* of the Porto Ferro and Cala del Vino formations, probably during Early to Late Permian times, but not better identified (Fig. 5); the third sequence, which coincides with the typical "Buntsandstein", comprises the Porticciolo conglomerate and the Cala Viola sandstones, that is a succession from the

Lower Triassic (Olenekian ?) as far as the Middle Triassic marine Muschelkalk (Fig. 5).

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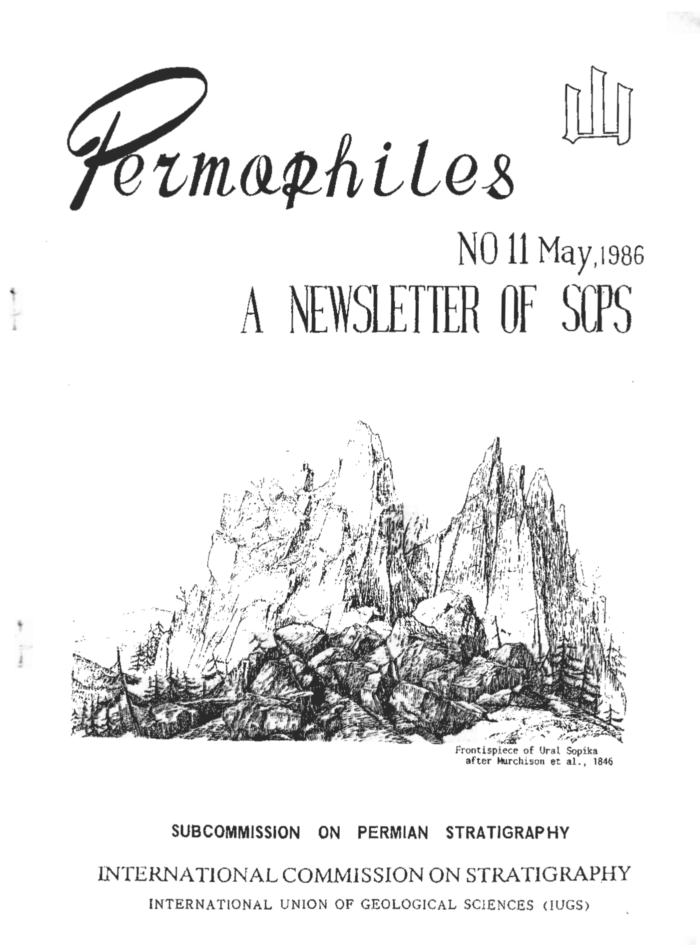

Cover of Permophiles #11 published in 1986 showing the frontispiece of Ural Sopika (after Muchison *et al*., 1846)

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Submission Deadline for Issue 54 is
Friday, December 18, 2009

ANNOUNCEMENTS

International Geological Correlation Program - UNESCO
IGCP 572: Recovery of ecosystems after the Permian-Triassic mass extinction

Third annual Fieldworkshop at GUtech, Muscat, Oman February 20-26, 2010
First circular

Scientific Committee for the Third IGCP 572 Fieldworkshop : Michaela Bernecker (GUtech, Muscat), Sylvie Crasquin (Paris), Alda Nicora (Milano), Aymon Baud (Lausanne), Charles Henderson (Calgary), Leopold Krystyn (Vienna) and Oliver Weidlich (Kassel).

Objectives

Much evidence indicates that many of Earth's ecosystems are under threat during the present day. This is nothing new, as Earth has suffered major extinction and upheaval on numerous occasions over the geological past, the most serious of which occurred during the Permian-Triassic transition. Of the major factors proposed to have caused the Permian-Triassic biotic crisis, including increased carbon dioxide concentrations, oceanic anoxia, hypercapnia, and rapid global warming, some are observed in the present day, and others are predicted for the near future. The Permian-Triassic rock and fossil records may thus record a natural experiment in global-scale ecosystem collapse that, if properly deciphered, could provide insights into the possible responses of modern ecosystems to present day climate and environmental change.

The field workshop aims to investigate the recovery of ecosystems following the end-Permian mass extinction through analyses of the rock and fossil records via studies of biostratigraphy, paleontology, paleoecology, sedimentology, geochemistry and biogeochemistry.

Potential participants : Members of the IGC 572 Program, Members of the Permian Subcommission on Stratigraphy, Members of the Triassic Subcommission on Stratigraphy, all interested Geoscientists from Middle-East and Oil Companies.

Schedule: February 20-26, 2010
The GuTech buiding, Muscat area, Oman

The topics of the one and half day conference at the Gutech, February 21 and 22, 2010, will address recovery patterns of various fossil groups; reconstruct global Permian-Early Triassic oceanic and climatic conditions; outline P/Tr ecosystem types; and correlate these types of data with a global stratigraphic framework. New data on Permian-Triassic transition in Oman will be presented.

Conference room and a meeting room for the organizing committee, meeting convenors fieldtrip leaders and IGCP officers will be provided by GUtech for the one day and half Conference.

Abstract submission deadline October 15, 2009

Tentative Costs of the 6 days fieldworkshop; 750 € (Conference fee at GUtech; 150 €)

The four and half days fieldworkshop excursion will offer to the participants the opportunity to visit the magnificent outcrops of the Oman Mountains, that provide unparalleled access **to the Permian-Triassic transition units along the Gondwana margin of the Tethys, from shallow carbonate platform, Tilted block margin, continental slope** and **abyssal plain deposits.**

Fieldtrip Organisation and Schedule:

Leaders: O. Weidlich, A. Baud, B. Beauchamp, L. Krystyn, A. Nicora, C. Henderson, S. Richoz, T. Aigner

The maximum number of participants to the fieldtrip will be 30

Duration: 4 1/2 days involved

Cost : The estimation of the cost of the fieldtrip is 600 € (4 1/2 days)

Tentative itinerary:

First Half Day, February 22: Permian-Triassic transition in Wadi May (Oliver Weidlich)

February 23: Permian-Triassic bloc in Wadi Wasit (A. Baud, L. Krystyn)

February 24: Permian-Triassic transition on Saiq Plateau (A. Baud, T. Aigner)

February 25: Permian-Triassic transition in deep water: the Buday'ah section (A. Baud, B. Beauchamp, L. Krystyn, A. Nicora, C. Henderson)

Permian-Triassic large outcrops on the Saiq Plateau, Oman Mountains, February 24 field day

February 26: Permian-Triassic transition in slope deposit: the Wadi Maqam section (Sumeini), (A. Baud, B. Beauchamp, L. Krystyn,. S. Richoz)

IGCP 572 Website: www.igcp572.segs.uwa.edu.au

GUtech Website: www.gutech.edu.om
Pre-registration will start in August, 2009

For further info contact Michaela Bernecker
michaela.bernecker@gutech.edu.om

Carboniferous/Permian GSSP Palynological Voucher Specimens Transferred.

Michael T. Dunn
Brandon K. McDonald
Department of Biological Sciences, Cameron University,
Lawton, OK 73505

As part of the continuing investigation of the Palynology of the Upper Pennsylvanian and Lower Permian, the palynological GSSP voucher specimens cited in:

Dunn, M. T. 2001. Palynology of the Carboniferous-Permian boundary stratotype, Aidaralash Creek, Kazakhstan. Review of Palaeobotany and Palynology, 116: 175-194

have been transferred from the Ohio University Paleobotanical Herbarium (OUPH) to the Cameron University Herbarium (CAMU) on permanent loan. Figured specimens are taken from 16, +20µm sieved slides and can be referenced from Table 1.

OUPH #	GSC#	MAB
13950	C4202-8	+26.0
13951	C4202-7	+15.82
13952	C4201-8	+7.4
13953	C4202-6	+5.8
13954	C4201-7	+4.2
13955	C4202-5	+2.4
13956	C4201-6	-0.4
13957	C4201-5	-1.1
13958	C4202-4	-1.6
13959	C4201-4	-2.6
13960	C4201-3	-5.1
13961	C4201-2	-7.1
13962	C4202-3	-9.1
13963	C4201-1	-10.6
13964	C4202-2	-14.2
13965	C4201-1	-24.2

Table 1. Correlation of specimen numbers from Dunn (2001). OUPH# = Ohio University Paleobotanical Herbarium number, GSC# = Geological Survey of Canada (Calgary) processing number, MAB = Metres Above Base of Permian GSSP.

In addition 16, -20µm sieved slides (OUPH13966-13981), 16, un-sieved slides (OUPPH13982-13997) and 8 Kerogen slides (OUPH13998-14005), are part of the transferred collections.

Please refer all correspondence regarding these specimens to:

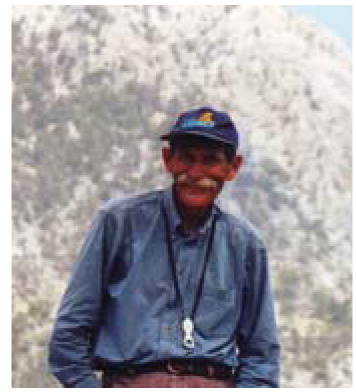
Michael T. Dunn, Curator
Cameron University Herbarium (CAMU)
Department of Biological Sciences
Cameron University
Lawton, Oklahoma 73505
Ph. 580-581-2287
michaeld@cameron.edu

CR2P
"Centre de Recherches sur la
Paléobiodiversité et les Paléoenvironnements"

2nd circular

In Memory of Pr. Jean Marcoux

Second IGCP 572
Annual field workshop
Antalya, Southern Turkey
2009 September 2nd – 6th



Organisers: Erdal Kosun, Sylvie Crasquin, Aymon Baud, Steve Kershaw, Sylvain Richoz

General information:

The field workshop aims to investigate the recovery of ecosystems following the end-Permian mass extinction through analyses of the rock and fossil records via studies of biostratigraphy, paleontology, paleoecology, sedimentology, geochemistry and biogeochemistry.

A one-day meeting is organized at the Engineering faculty Akdeniz University in Antalya. The field trip will be introduced by Aymon Baud. We propose to have open discussions and will address recovery patterns of various fossil groups; reconstruct global Permian-Early Triassic oceanic and climatic conditions; outline P/Tr ecosystem types; and correlate these types of data with a global stratigraphic framework. Different topics will be introduced by a short talk and will be followed by a casual discussion with participation of all of us. We propose here some topics. *All proposals are welcome!*

- Microbialites and depositional environments: general introduction by S. Kershaw
- Microbialites and depositional environments within the basal Triassic of Turkey : introduction by A. Baud
- Microbialites and associated fauna: introduction by S. Crasquin
- Recovery of benthic fauna: introduction by Z.Q. Chen

Other topics

- Recovery, competition between microbial and skeletal carbonate factories: introduction by A. Baud
- Influence of paleogeographic location on recovery
- Unconformities, subaerial exposures versus submarine dissolution.

The field workshop will give participants the possibility to visit the magnificent outcrops of the Taurus Mountains that provide unparalleled access to Permian to Triassic Tethyan platform carbonates. A unique opportunity will be offered to examine in detail the contact between end-Permian pre- and postextinction carbonates, the microbialite onset, the carbonate precipitates and the varied microbialite deposits with liliput microfauna. This fieldwork will be dedicated to the memory of Jean Marcoux, who studied and mapped in great detail the geology of the area and promoted Permian and Triassic studies.

Participants: Members of the IGCP 572 Program, Members of the Permian or Triassic Subcommissions on Stratigraphy, and all interested colleagues. The number of participants is limited to 20 due to safety reasons. The acceptance will be done in order of registration and payment.

Travel: Antalya is situated in the eastern Mediterranean, on the South Coast of Turkey. Its international airport is connected by direct flights from many European towns or with corresponding flights through Istanbul from European capitals or from overseas. Participants registered to the Ankara meeting before the fieldworkshop can book a flight on Sept. 2, from one of the 3 afternoon flights from Ankara to Antalya or take the night bus. Participants can make the 20-30 minutes journey from the Antalya airport to the Perla Mare Hotel (http://www.perlamarehotel.com/) by taxi.

Fieldtrip organization and schedule (departure and return in Antalya):

Sept. 2: evening: arrival of the participants at Antalya, Icebreak Party, overnight in Antalya Perla Mare Hotel (http://www.perlamarehotel.com/).

Sept. 3: meeting at Engineering Faculty of Akdeniz University in Antalya. Introduction to the fieldworkshop and open discussion on proposed topics (Permian-Triassic transition in Turkey, recent advances). End of afternoon, minibuses will take the participants to Gul Mountain hotel going up through Kemer and Kemer Gorge (1h30 drive). General overview of the regional geology. Overnight at Gul Mountain hotel.

Sept. 4: Fieldwork on Permian-Triassic transition with 5 stops at the Cürük Dag section. Back in the evening to Antalya, overnight Antalya Perla Mare Hotel (http://www.perlamarehotel.com/).

Sept. 5, departure to Alanya - Demirtaç, (2h30 drive) fieldwork on Permian-Triassic transition with 2 stops at the Demirtaç section in the afternoon. Overnight in Gazipaça (Selinus Beach Club Otel).

Sept. 6, fieldwork on Permian-Triassic transition with 2 stops at the Oznur Tepe section in the morning.

The afternoon the minibuses will bring back the participants to Antalya (Airport or hotel).

End of the fieldworkshop

Costs of the 4 days fieldworkshop: 550€ (departure and return to Antalya).

This includes transportations, accommodation, meals and guidebook from evening Sept. 2 to afternoon Sept. 6, 2009.

Travel from aboard to Antalya and drinks are not included!

Sending of samples: Due to the strict regulation for export samples outside of Turkey, a special permission has been requested and the sending of samples will be organized via Great Britain (1kg from Turkey to GB is around 5€ + cost from GB to your country). You have to pay for this before leaving Turkey.

Funding: Some funding for travel and conference expenses is available through IGCP. Please ask first your National IGCP Committee. If you still have some funding problems, send your request to Sylvie Crasquin (sylvie.crasquin@upmc.fr)

Registration before July 15, 2009: on website

http://sgfr.free.fr/seance/marcoux/pre-register-Fieldtrip.php

Please note the number of participants is limited to 20 (due to safety measures). The admissions will be done by order of registration and payment.

Please note: before July 15 that all refunds will include a 25% charge

No refund after

Payment before July 15:

Complete the form available on web site http://sgfr.free.fr/seance/marcoux/ or the attached form and send it back with your signature, to Société géologique de France

All the pre-registered participants will receive the final circular with all the useful information (hotel name and address, equipment, weather, *etc.*)

Contact: sylvie.crasquin@upmc.fr

IGCP 572 Website : http://www.igcp572.segs.uwa.edu.au/

In Memory of Pr. Jean Marcoux

Cimeride – Tethyside :

recent breakthroughs ICGP 572 Fieldwork, 2009 September 2nd– 06th

PAYMENT FORM

Name: First Name:

Address:

e-mail:

I shall be attending the IGCP 572 fieldworkshop in the Antalya area

Registration fees all included except drinks and travel to Antalya
before July 15, 2009 **550€**
(after July 15, 2009 650€)

Payment methods :

-Bank transfer : Fortis Banque Monge, IBAN : FR76 3048 8000 7700 0477 0089 806 SWIFT: BPARFRPP

-Personal cheque: only cheques in euros drawn on a French bank will be accepted (because of prohibitive bank charges on foreign cheques). Please make cheques to the order of: SGF-MARCOUX

-Postal money order to SGF-MARCOUX

-Credit Card: VISA or MASTERCARD. **Please fax or mail the form with your signature to SGF (address below):**

Name and first name of account holder:

Card number: |__|__|__|__|__| |__|__|__|__| |__|__|__|__| |__|__|__|__|

Expiry date: |__|__|__|__|

Secu rity number: : |__|__|__|__| |__|__|__| (back of the card)

I authorise SGF to charge my credit card for the amount of ______ euros

Don e: in date Signature:

Please send this form to the address below NOT LATER THAN July 15, 2009
Société géologique de France
77 rue Claude Bernard 75005
Paris, France
Phone : + 33 (0)1 43 31 77 35 Fax : +33 (0)1 45 35 79 10 e-mail : accueil@sgfr.org

XVII ICCP (July 3-7, 2011, Perth) conference excursion

Route 1: Upper Devonian to Permian of the Canning Basin, NW Australia: Gondwanan records of biotic development following the Late Devonian massextinctions and global icehouse-greenhouse climate changes

1. Introduction

The Canning Basin lies in the Kimberley region, NW Australia, some 2,300 km north of Perth. The basin is the largest sedimentarybasin in Western Australia covering an area of some 530,000 m^2. It is one of the few remaining areas in Australia which is under explored for petroleum to see magnificent fossil and geological records of the Devonian "Great Barrier Reef", Permo-Carboniferous glaciations and Permian extreme climates from icehouse to greenhouse, but also to enjoy colourful wildlife, spectacular landscapes and mysterious local indigenous cultures.

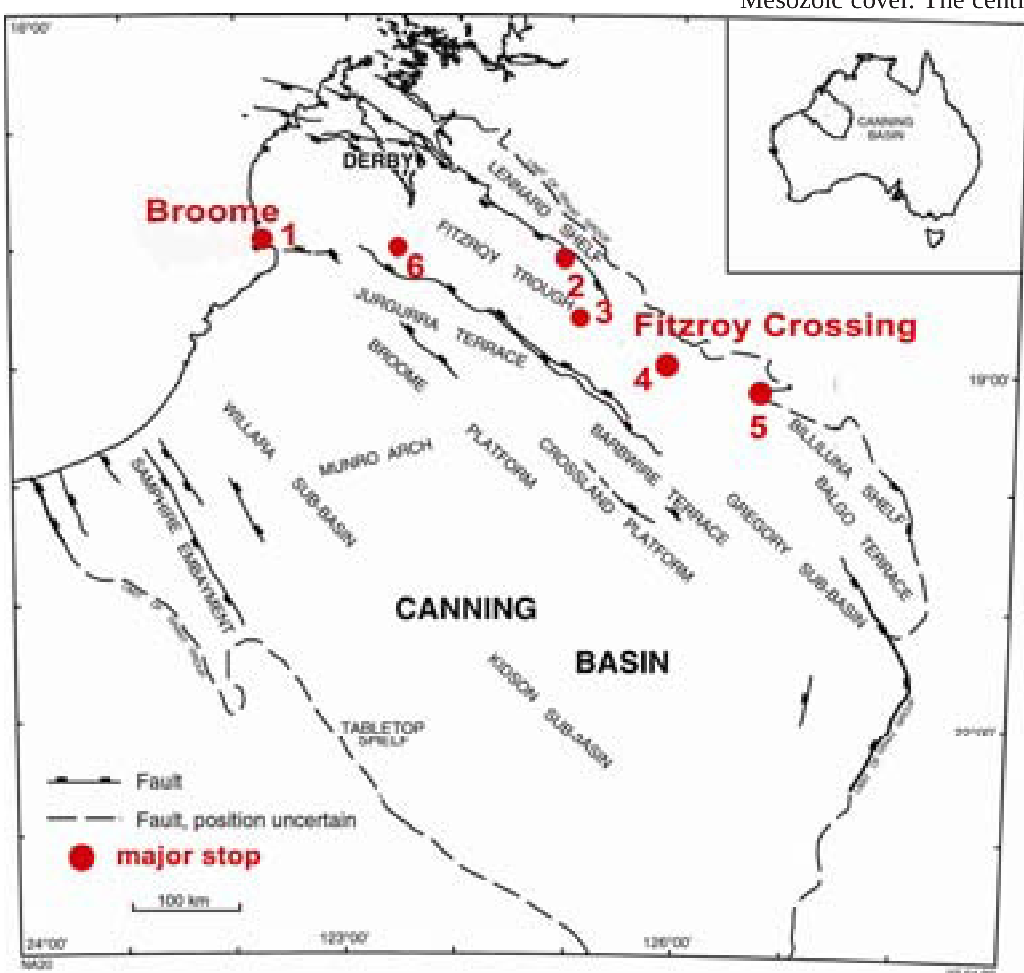


Fig. 1. Geographical map showing outline of the Canning Basin, NW Australia and major stops of the excursion.

The Canning Basin initially developed in the Early Paleozoic as an intracratonic sag between the Precambrian Pilbara and Kimberley Basins. The basin contains two major northwesterly trending troughs separated by a mid-basin arch, and marginal shelves. The northern trough is divided into the Fitzroy Trough and the Gregory Sub-basin, which are estimated to contain up to 15 km of predominantly Paleozoic rocks. The southern trough includes the Kidson and Willara Subbasins, in which there are thinner sedimentary successions (4–5 km thick) of predominantly

Ordovician to Silurian and Permian age, with extensive Mesozoic cover. The central arch is divided into the Broome and Crossland Platforms, and structural terraces step down from it into the troughs on either side. The subdivisions of the basin are based on presently expressed structural elements, although growth faulting initially developed some of these elements, and troughs developed and were active at different times during the basin's history. The succession in the basin consists of continental to marine-shelf, mixed carbonate and clastic sedimentary rocks. Major evaporitic basins were present in the Ordovician, with lesser such accumulations in the Silurian and Early Devonian. Significant tectonic events affected the basin in the Early Ordovician (extension and rapid subsidence), Early Devonian (compression and erosion), Late Devonian (extension and subsidence), Middle and Late Carboniferous – Permian (compression then subsidence), and Early Jurassic (transpressional uplift and erosion). The southern Canning

Basin is less intensely deformed than the northern part, the major fault block movements being absent in the south.

2. Pre-Late Devonian stratigraphy settings

The earliest Phanerozoic succession of the Canning Basin comprises the marine Ordovician deposits, which are present in subsurface sections in the southern part of the basin. These successions are assigned to the Nambeet, Acacia/Willara, Goldwyer, and Nita Formations (Begg, 1987; see also Fig. 2). From the Early Silurian to the Middle Devonian the southern Canning Basin was an evaporite-dominated barred marine basin. The Carribuddy Group of Silurian age comprising a thick halite-bearing sequence was deposited in the southern and eastern parts of the basin (Fig. 2). The Silurian-Devonian boundary is represented by a basin-wide unconformity. The late Early Devonian to Middle Devonian Tandalgoo Sandstone is a unit comprising eolian to fluvial sandstone. A regional unconfirmity separates the Middle Devonian and underlying strata from the overlying Late Devonian carbonate, which developed the massive platform and reefs in late stages of the Devonian.

3. Late Devonian-Carboniferous stratigraphy

Carbonate platform grew probably in latest Givetian or early-middle Frasian (Late Devonian). Massive carbonates forming the lower part of the Canning reef complex are assigned to the Pillaraor Napier Formation, while the mudstone-dominated successions occurring in the interplatform basins are usually referred to the Gogo Formation, which is well-known by the exceptionally preserved Gogo fish fauna. Ammonoids, brachiopods, conodonts and fish are rich in the reef complex and its equivalents in the basin. The reef complex is capped by the latest Famennian Fairfield Formation, which is characterized by shale or calcareous mudstone and yields abundant brachiopods, ammonoids and conodonts. A significant stratal gap is believed to be present between Fairfield Formation and overlying Laurel Formation in most areas of the basin (Fig. 2). However, the Devonian-Carboniferous boundary in Canning remains undefined due to lack of continuous boundary outcrop sections in the basin.

The Laurel Formation comprises calcareous mudstone and muddy limestone and was constrained as Tournaisian in age due to the presence of abundant brachiopods and conodonts (Roberts, 1971). The overlying Anderson Formation is poorly defined in

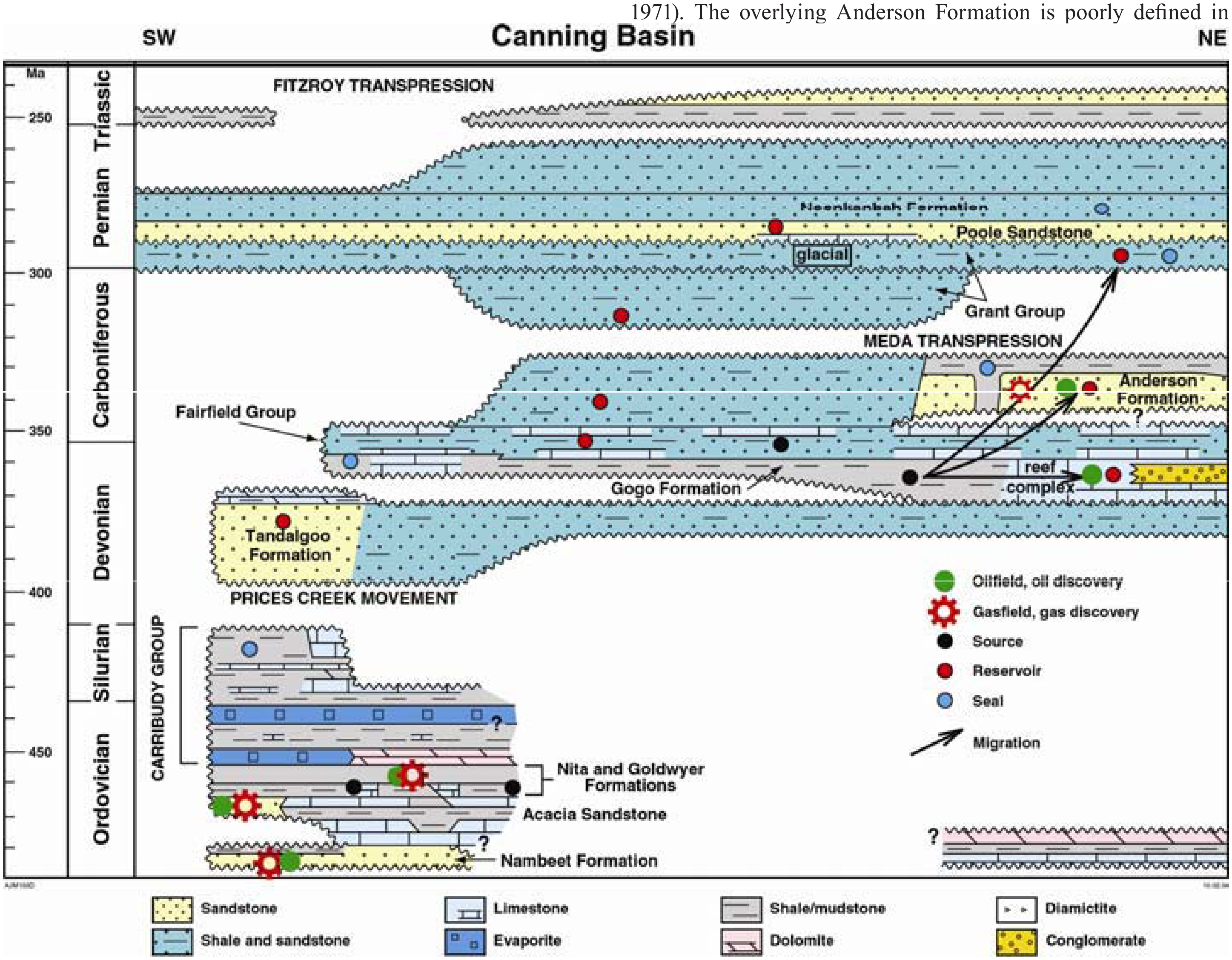


Fig. 2. Stratigraphy, development history and petroleum systems of the Canning Basin.

terms of lithology and age constraints. This unit is unfortunately only seen in drill cores and was collectively assigned to the Upper Carboniferous (Pennsylvanian) (*i.e*. Roberts, 1971). Later, Apak and Backhouse (1999) restricted the Anderson Formation to the lower part of the previous "Anderson Group". The presence of microfloral *Granulatisporites frustulentus* Assemblage suggests a Tournaisian age for the revised Anderson Formation. These authors have also proposed Reeves Formation to accommodate the largely sandstone succession below the revised Grant Group, previously known as the Lower Grant Group. The basal part of the Reeves Formation is believed to be the late Visean in age and the rest part of the formation extends to the latest Carboniferous in age (Apak and Backhouse, 1999). This unit yields *G. frustulentus, Grandispora maculosa, Spelaeotriletes ybertii, Diatomozonotriletes birkheadensis,* and *Deusilites tenuistriatus* micrfloral assemblages (Apak and Backhouse, 1999). However, the presence of mid- to upper Carboniferous Reeves Formation can only be confirmed with any certainty in 18 wells, of which 13 are in the Fitzroy Trough. The unit is up to 1250 m thick, dominantly fluvial in character, and was previously included in the glacial Grant Group. Nevertheless, there appears to be a significant break between these two units spanning the Asselian of the earliest Permian.

4. Permian stratigraphy

The lowest unit of the Permian is assigned to the Grant Group, which is equivalent to the Paterson Formation of the southern Canning Basin (Fig. 2). This unit is seen in most drill wells of the basin (up to 256 wells) and thus is widely distributed in the basin. The entire group appears to lie entirely within the Pseudoreticulatispora confluens microflora Zone of early-middle Sakmarian age. Lithologically, the Grant Group, up to 300-800 m thick, is subdivided into the Hoya, Calytrix and Clianthus Formations in an ascending order and represents the most rapid period of deposition in the basin. However, brachiopod faunal correlation suggests an Asselian to early Sakmarinan age for the Grant Group (Archbold, 1998).The debate as to the dominance of tectonic (Eyles and Eyles, 2000) versus glacial (Redfern and Williams, 2002) influences during deposition of this unit is not easily resolved (Mory *et al*., 2008). The overlying Poole Sandstone is a dominantly nearshore to deltaic unit of late Sakmarian to early Artinskian age restricted to the *P. pseudoreticulata* and *S. fusus* Zones (Apak and Backhouse, 1999), and is characterized by upward-coarsening cycles in the northwestern and central parts of the basin. These cycles grade eastwards into massive channel facies, probably denoting a stronger fluvial influence, thereby hindering differentiation from similar facies at the top of the Grant Group. The Nura Nura Member is locally exposed in the Fitzroy Trough and yields abundant macrofossils such as brachiopods and ammonoids, indicating the deglaciation sedimentation similar to the Callytharra Formation of the Carnarvon and Fossil Cliff Formation of the Perth Basin (Archbold, 1998).

The shale-dominated Artinskian–Kungurian Noonkanbah Formation represents the most marine part of the succession, and thus has attracted the most paleontological interest. The unit is up to 640 m thick, with the major depocentre coinciding with the Fitzroy Trough. Abundant fossils are yielded from this unit. The Liveringa Group comprises Lightjack Formation in the lower and the Condren Sandstone in the upper. Abundant brachiopod and bryozoans fossils are yielded from the Lightjack Formation, while the Condren Sandstone represents a period of fluviodeltaic

Fig. 3. A reef exposure at the Windjana Gorge (the "classic faces"). Horizontal reef platform (right), passes into steeply-digging reef-margin and reefal-slope facies (centre), and marginal-slope facies (at left). Cliff about 80 m high.

Fig. 4. Cave painting on the sandstone of the Lower Permian Grant Group.

deposition. The Liveringa Group is constained as the Roadian–Wuchiapingian in age. The entire unit suggests a regressive depositional cycle. The Hardman Formation comprising Kirkby Range Sandstone, Hicks Range Sandstone, and Cherrabun Members represents the Wuchiapingian deposition due to the presence of ammonoid *Cyclolobus persulcatus.* Brachiopods are extremely abundant and diverse in both the lower and upper parts of the formation, respectively. The Changhsingian marine deposits have not been found in the exposure and may be seen in the subsurface sections in the Fitzroy Trough of the basin.

5. Major stops

5.1. Stop 1: Broome, NW Australia

The field excursion starts and ends at the largest population centre, Broome, in the Kimberley region, which has an international airport. Broome is the outback oasis where the azure waters of the Indian Ocean laps salt white beaches and where ancient pindan cliffs dramatically change colour in the setting sun, going from pink to start red before your eyes. Broome has the beautiful Cable Beach, fragrant frangipani and lazy palm trees, tropical rainforest buildings. Broome is also the Pearling Capital of the world and is only one small part of what makes Australias North West one of the best destinations in the world.

Fig. 5. Lower Permian glacial sequence exposed at the roadside section, south of Fitzroy Crossing. A large granite boulder is shown at the left lower corner. The person at left of the picture as a scale.

5.2. Stop 2: Windjana Gorge: Devonian "Great Barrier Reef" and Famennian microbiliate reef

A semi continuous chain of Middle to Upper Devonian limestone reefs are exposed as a series of low ranges extending for 350 km along the northern Canning Basin. These exposures are the inferred remnant of a more extensive barrier reef system that rimmed much of the western and northern Kimberley. The reefs are world famous for there excellent preservation, exposure and spectacular scenery. The Windjana-Tunnel Creek Road passes through and runs along the reefs in a number of places. We will

Fig. 6. An example of the brachiopod-bryozoan community preserved in the Noonkanbah Formation.

have opportunity to examine the reef up-close at the Windjana Gorge. The reefs are composed of massive limestone, typically exhibiting karst topography. They rest on the Proterozoic basement. The main reef-builders were calcareous microbes (*i.e.* Renalcis spp.) and sponge-like stromatoporoids, with other organisms including corals, performing a minor role.

5.3. Stop 3: Roadside between the Windjana Gorge and Fitzroy Crossing: Fairfield and Laurel Formations

The back-reef facies calcareous mudstone and muddy limestone of the Fairfield Formation (late Famennian) and muddy limestone of the Laurel Formation of the Tournaisian are poorly exposed in area between the Reef and North Great Highway.

5.4. Stop 4: Fitzroy Crossing

Another major stop of the excursion is the Fitzroy Crossing, one of only two "towns" along the over 1000 km stretch of highway between Broome and Kununurra, NW Australia. The town owes its existence to the Fitzroy River and is a welcoming, pleasant little township with a mostly Aboriginal population. It is also the most famous Aboriginal culture centre in the Kimberly region. You can touch the deep of Aboriginal culture and ordinary life.

4.5. Stop 5: Roadside section, 100 km south of Fitzroy Crossing: Lower Permian Glacial succession

A Lower Permian glacial sequence section is located the south side of the Great North Highway, about 100 km south of the Fitzroy Crossing. At this site, the glacial succession rests on the Devonian limestone and is capped by the Poole Sandstone. The Grant Group comprises diamictite, conglomerate and sandstone (Fig. 5). Massive clast rich diamictite form the bulk of the formation and are distinctive because of a green/grey clast matrix. Granule- to boulder-sized clasts are common. Diamictite is characterized by a very poorly sorted framework with clast set in a matrix of green mudstone to siltstone. Boulders of granite and indurated sandstone sometimes display faceted, polished and superbly striated surfaces.

4.6. Stop 6: Liveringa Mountain: Lower Permian glaciation-deglaciation sequence

If time permits, we will visit the Liveringa Mountain section. Here, the glacial sequence of the Grant Group and the overlying deglaciation successions (Poole Sandstone, Noonkanbah Formation and Lightjack Formation) are well exposed. Macrofossils such as brachiopods, bryozoans, corals are extremely abundant throughout the entire section (Fig. 6).

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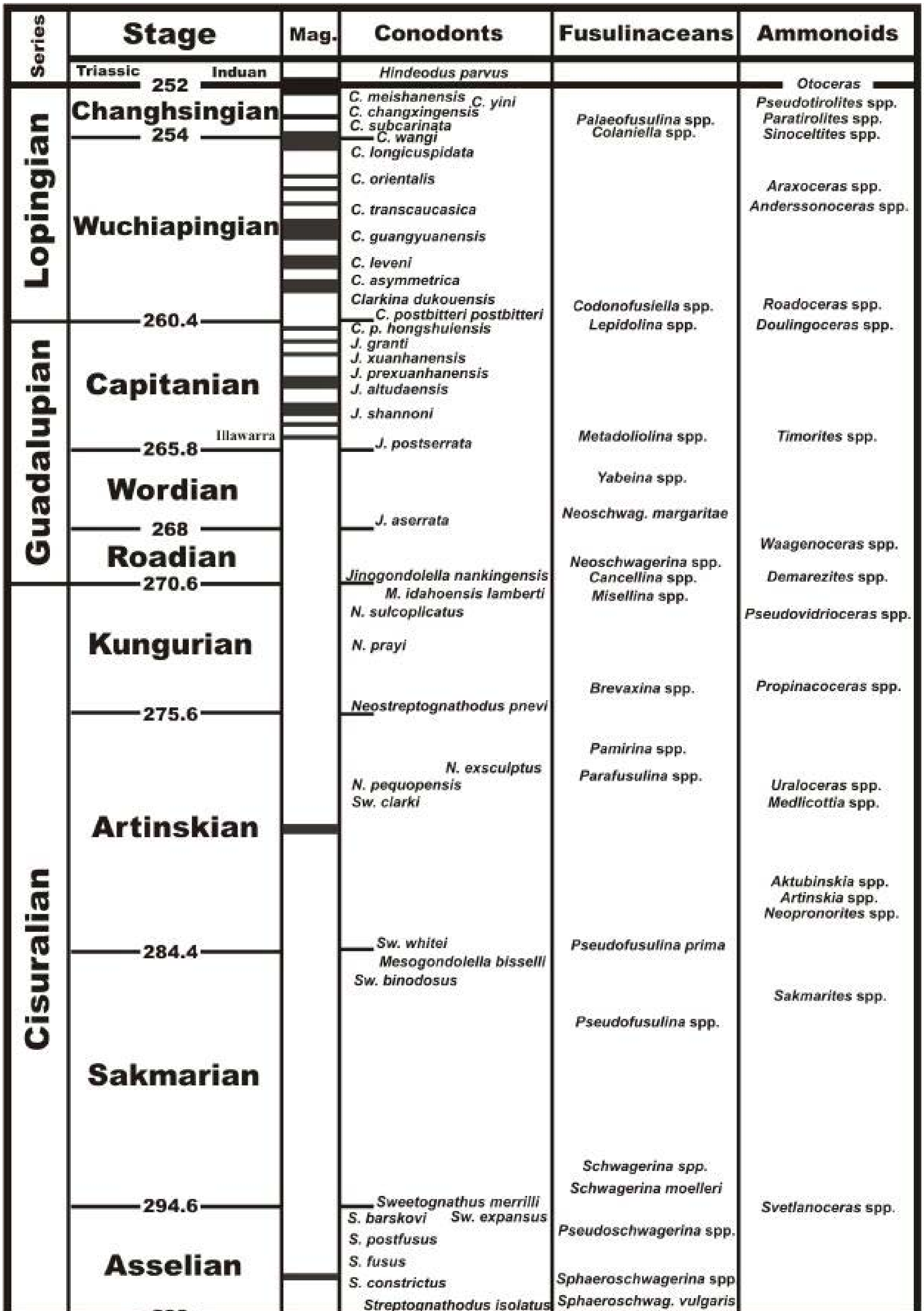

Permian Time Scale

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