The Cambrian–Tremadocian units of the Santa Victoria Group (northwestern Argentina): a new correlation scheme

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Introduction

Detailed studies were carried out in Cambrian–Tremadocian successions of the Santa Victoria Group (late Upper Cambrian – early Upper Ordovician) exposed in the Argentine Eastern Cordillera. The resulting stratigraphic columns permit to analize some geological events concerning the early evolution of the Ordovician basin (Moya, 2003). In this opportunity, we present a correlation scheme based on the stratigraphic distribution of trilobites and graptolites coming from six areas of the Argentine Eastern Cordillera (Figures 1a–b and 2a–b). These areas were part of a wide marine shelf during the lower Paleozoic (Chaco Shelf), which embraced the Eastern Cordillera, Subandean Ranges and Chaco Plain. The Lipán Swell was an emergent to sub–emergent structure which divided the Chaco Shelf into an eastern part and a western part (horizontal and inclined lines respectively, Figure 2b). The stratigraphic columns here presented are based on individual sections in the western part of the region (La Quesera, Pascha and Angosto del Moreno) and to the integration of several profiles of the eastern part (Lesser and Mojotoro Ranges, Tilcara–Huacalera area in the eastern flank of the Quebrada de Humahuaca) (Figures 2 and 3). We defined seven stratigraphic intervals characterized by distinct fossil assemblages. Four of these stratigraphic intervals correspond to transgression–regression cycles, which are limited at bottom and top by sedimentary discontinuities that we tentatively compared to regressive events recorded in other regions (Cooper, 1999: References and comentaries): LREE (Lange Range Eustatic Event), ARE 1 and ARE 2 (multiple event, Acerocare Regressive Event), BMEE (Black Mountain Eustatic Event). On the other hand, we recognized two aditional regressive events: KRE (Kainella Regressive Event) and NORE (Notopeltis Regressive Event), as they are recorded inside the *Kainella meridionalis* and *Notopeltis orthometopa* zones. The data used correspond to those obtained by the authors in field work, without having yet incorporated the valuable and abundant information from other sources.

Evidences and discussions

Interval I. Interval I is limited by the LREE and ARE 1 events. It includes a transgression–regression cycle. The colonization begins with *Parabolina (Neoparabolina) frequens argentina* (Kayser), to which then *Parabolinella argentinensis* Kobayashi, *Angelina hyeronimi* (Kayser) and *Ciceragnostus iruyensis* (Kayser) are associated. At Tilcara–Huacalera area *Beltella ulrichi* (Kayser) is found and at Angosto del Moreno *Leiostegium douglasi* (Harrington), *Plicatolina scalpta* Harrington and Leanza, *Micragnostus* sp. aff. *M. tilcuyensis* (Kayser), *M. vilonii* Harrington and Leanza and *M. hoeki* Kobayashi occur. At the remaining profiles, this interval is not represented through fossiliferous levels. At Angosto del Moreno this interval contains conodonts from the *Hirsutodontus hirsutus* Subzone (*Cordylodus proavus* Zone, Upper Cambrian) (Moya *et al.*, this symposium).

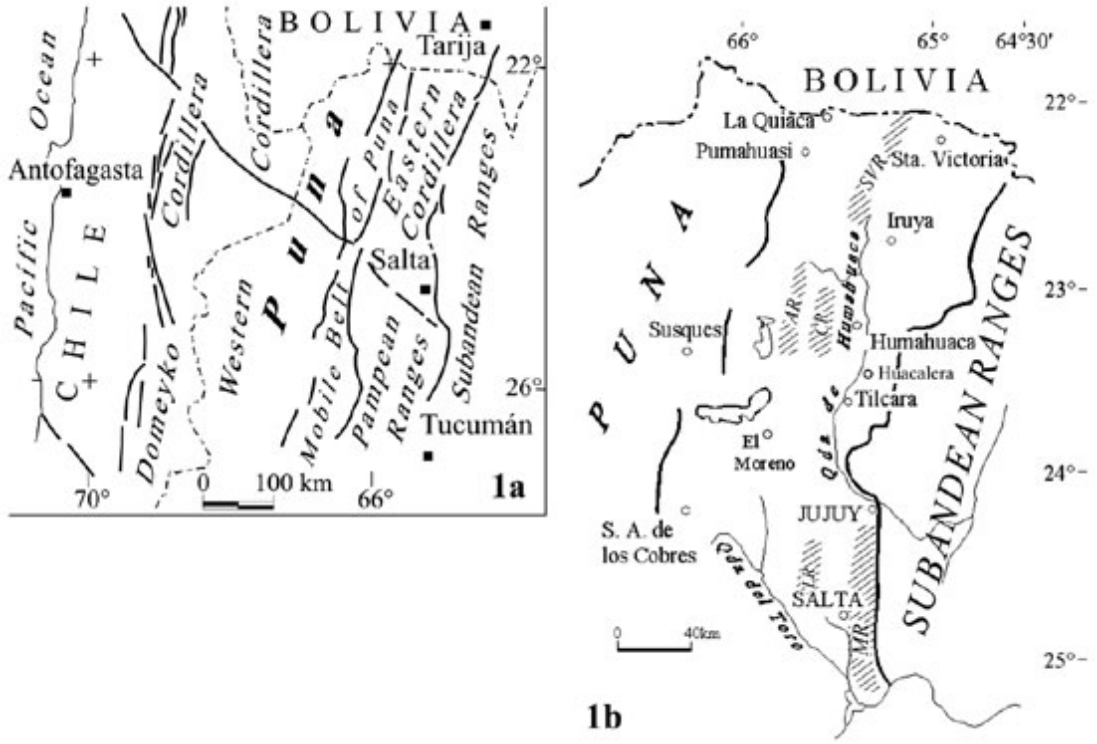

Figure 1. a. Geological Provinces of the Northern Argentinian Andes. **b.** Geographical map of the Argentine Eastern Cordillera: SVR, Santa Victoria Range. AG, Aguilar Range. CR, Cajas Range, MR, Mojotoro Range. LR, Lesser Range.

Interval II. Interval II is limited by the ARE 1 and ARE 2 events. It includes a transgression–regression cycle, in wich the Cambrian–Ordovician boundary would be recorded. This interval is registered in all the analized sections and with it an instability stage that produced a quick subsidence in Mojotoro, Lesser and Pascha begins. During this lapse, the appearance of *Rhabdinopora flabelliformis* (Eichwald), with subspecies in revision, and *Jujuyaspis keideli* Kobayashi was recorded, both of them very important to define the base of the Ordovician System. *R. flabelliformis* sspp. are together with *P.(N.) frequens* at Aguilar and with *J. keideli* at Lesser and Mojotoro Ranges and Tilcara–Huacalera area. Among the new trilobites that accompany *P. (N.) frequens* we mention *P. scalpta* in Tilcara–Huacalera area; *Leptoplastides marianus* (Hoek), *B. ulrichi*, *Conophrys erquensis* Kobayashi and *Parabolinella coelatifrons* Harrington and Leanza at Angosto del Moreno and, finally *P. argentinensis* and *P. coelatifrons* at Pascha. At Lesser and Mojotoro Ranges *P. (N.) frequens* has not been recongnized whereas *J. keideli* in association with *P. argentinensis*, is registered. At Mojotoro Range, besides, *J. keideli* is accompanied by *Apatokephalus exiguus* Harrington and Leanza, *Bienvilla shinetonensis* (Raw), *Niobina taurina* Harrington and Leanza, *P. coelatifrons*, *Geragnostus maurii* Harrington and Leanza and *G. nesossi* Harrington and Leanza.

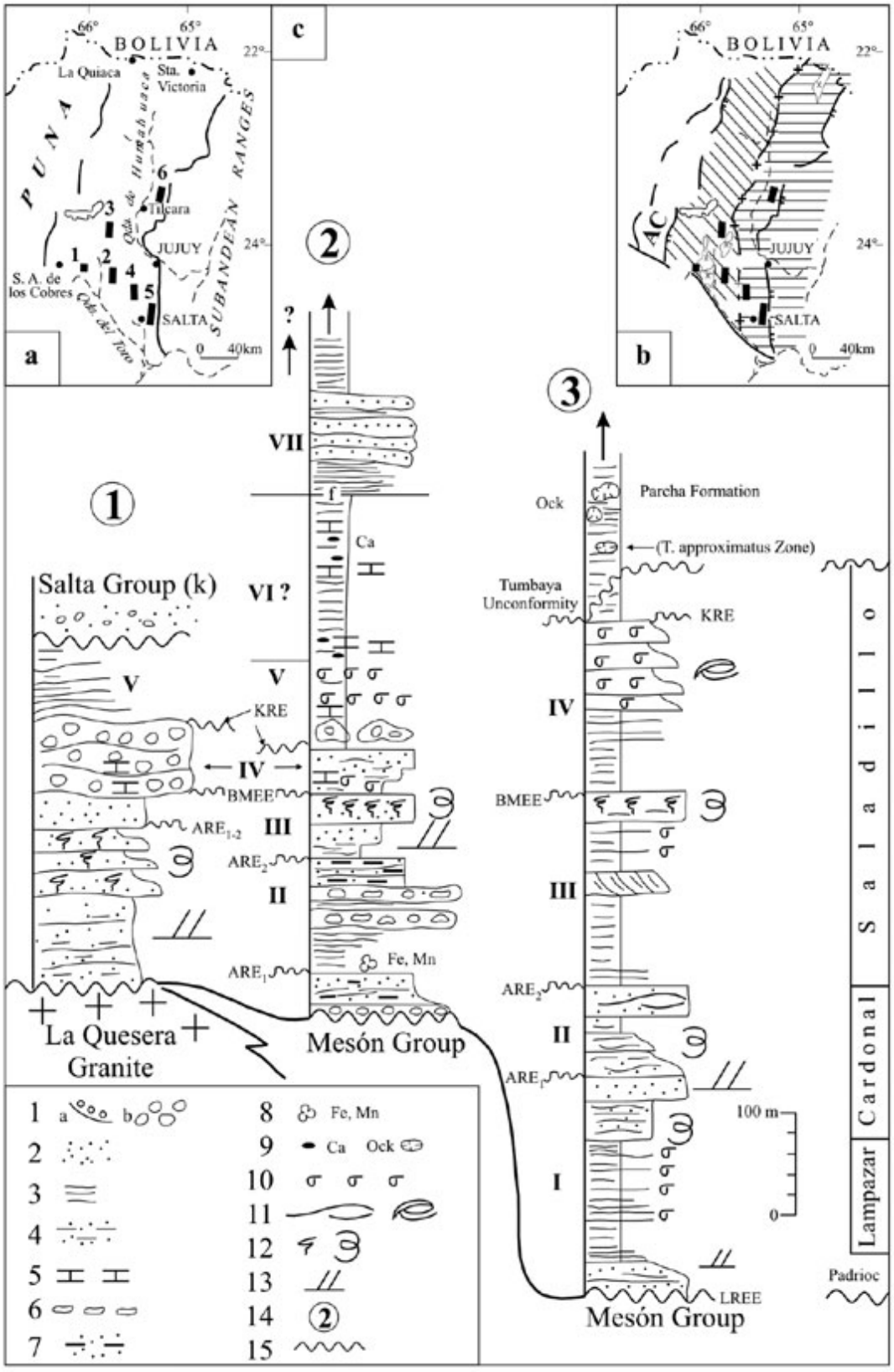

Figure 2. A. Location map of the stratigraphic columns (1–6). **B.** Paleogeographic sketch of the Ordovician Chaco Shelf: Western part (inclined lines), columns 1, 2, 3 (Figure 2c). Eastern part (horizontal lines), columns 4, 5, 6 (Figure 3). **C.** References of the Stratigraphic columns: 1a, Fluvial conglomerate 1b, Fluvial–coastal marine conglomerate. 2, Sandstone. 3, Shale. 4, Shale and sandstone. 5, Calcareous mudstone. 6, Gravity flows (beds and blocks). 7, Mudflakes. 8, Fe–Mn nodules. 9, Concretions with calcareous and iron oxide nucleous. 10, Coquina. 11, Storm succession and storm beds. 12. Bioturbation, trace fossils abundant. 13, Cross–beds. 14, Stratigraphic columns: La Quesera (1), Pascha (2), Angosto del Moreno (3). 15, Unconformity.

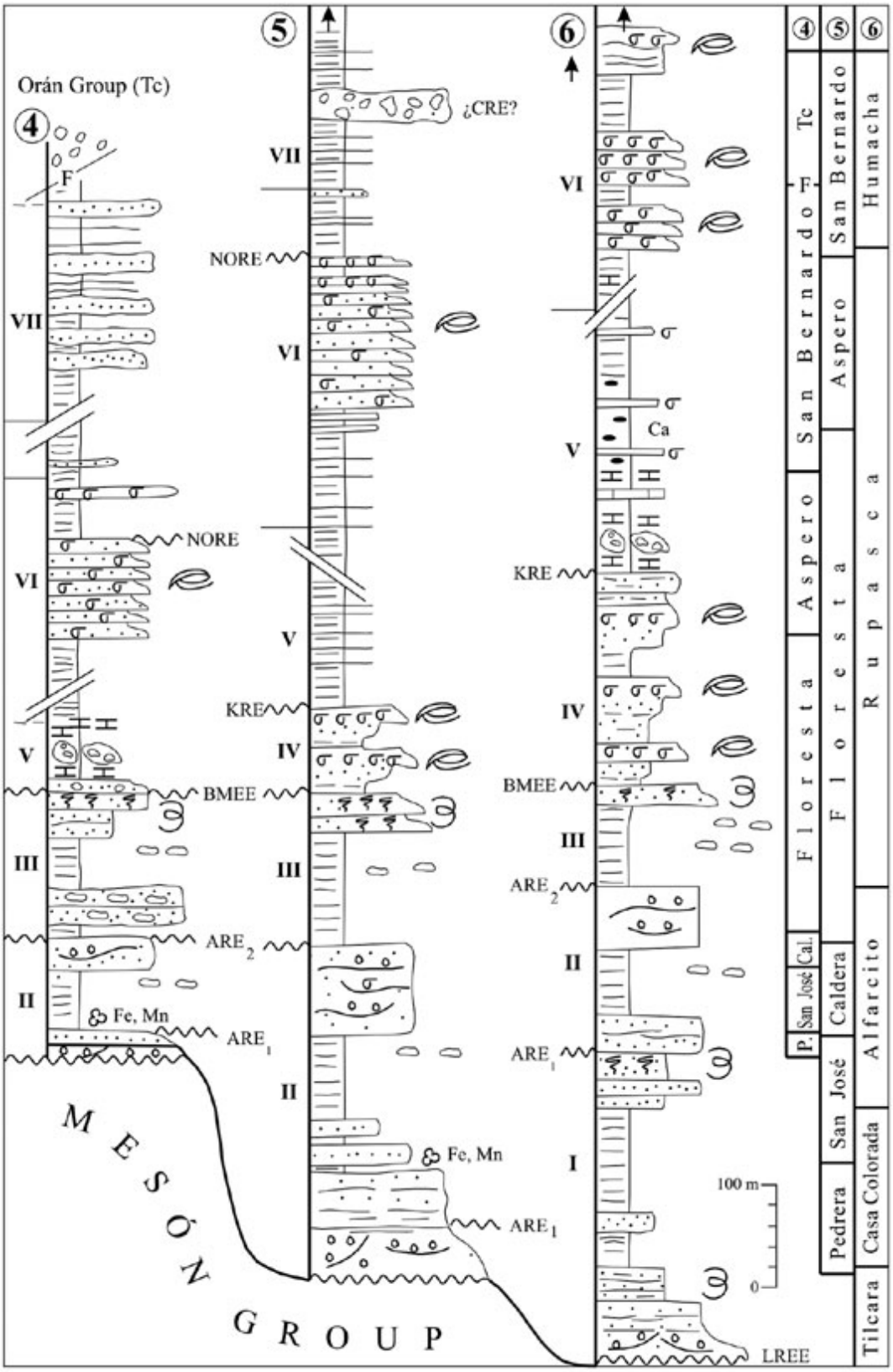

Figure 3. Stratigraphic columns: Lesser Range (4), Mojotoro Range (5), and Tilcara–Huacalera area (6, Quebrada de Humahuaca).

Interval III. This interval is limited by the ARE 2 and BMEE events. It is represented by a succession of fossiliferous shales that culminate with bioturbated sandstones (BMEE). In this interval, the appearance of *Anisograptus* spp. (of *A. matanensis* and *A. delicatulus* group) is registred, assemblage reaches a higher diversity with *Angelina kayseri* Harrington and Leanza, *Onychopyge branisi* Suárez Soruco, *Pseudokainella conica* (Kobayashi), *Rossaspis rossi* (Harrington and Leanza), *Saltaspis* sp., *Pseudorhaptagnostus (Machairagnostus) tmetus* (Harrington and Leanza), *Leiagnostus turgidulus* Harrington and Leanza and several species of others agnostoids.

Interval IV. Interval IV is limited by the BMEE event and a relative sea–level fall herein identified in the *Kainella Regressive Event* (KRE), since it is recorded inside the *Kainella meridionalis* Zone. The trilobites are represented, among others, by *K. meridionalis, Pseudokainella lata* (Kobayashi), *L. marianus, P. argentinensis, Conophrys spp.*, *M. neumanni* Harrington and Leanza, *A. hyeronimi* and *R. rossi.* This fossil assemblage is contained in mudstones, calcareous sandstones and coquinas that prograde over outer shelf shales. The calcareous coquina facies has a wide distribution in the Eastern Cordillera, thus becoming a real regional stratigraphic guide. At Mojotoro Range and Angosto del Moreno, the graptolites are represented by *Anisograptus matanensis* Ruedemann, *Callograptus (Pseudocallograptus) salteri* Hall and *Rhabdinopora flabelliformis* sspp.

Interval V. Interval V includes the pelitic succession which develops over the KRE event. Among the graptolites, *Bryograptus* sp. aff. *B. kjerulfi* Lapworth together with *Anisograptus* sp. characterize this interval and were found in La Quesera, Mojotoro Range, Pascha and Angosto del Moreno. The mentioned species are first associated with constituents of the *K. meridionalis* Zone and then with trilobites of the *Bienvillia tetragonalis–Conophrys minutula* Zone in the rest of the interval. This implies that during the recording of *B.* sp. aff. *B. kjerulfi* an important faunistic change took place, from a dominant ptychoparid assemblage, mainly olenids, to another of more numerous asaphid populations. The trilobite assemblage in this interval is characterized by the dominant presence of *Asaphellus catamarcensis* Kobayashi and *P. argentinensis*, together with *B. tetragonalis* (Harrington) and *Parabolinella triatrhroides* Harrington. This fossil assemblage is well represented in Tilcara–Huacalera area, Lesser and Mojotoro Ranges, La Quesera and Pascha.

Interval VI. Interval VI is represented by a succession of shales that underlies another one composed by quartzose sandstones and coquinas. The shales, together with those of the Interval V make up a continuous sedimentary succession, but they differ from the latter in the presence of trilobites from the youngest stage of the *B. tetragonalis – C. minutula* Zone, like *P. triarhroides*, *Apatokephalus tibicen* Prybil and Vanek and *Pharostomina trapezoidalis* (Harrington). This fossil assemblage is recorded in Pascha, Tilcara–Huacalera area and Mojotoro Range; in the latter area the trilobites coexist with *Adelograptus* nov. sp. (of *A. tenellus* group). On the other hand, the quartzose sandstones and coquina succession represent a relative sea–level fall, herein identified as *Notopeltis Regressive Event* (NORE), as it is recorded inside the *Notopeltis orthometopa* Zone. It is quite possible that the NORE may correspond to the *Ceratopyge Regressive Event* (CRE), because *Ceratopyge forficuloides* Harrington and Leanza is often associated with *Notopeltis orthometopa* (Harrington), without tresspassing the homonymous zone. The sandstone and coquina facies is only represented on the eastern flank of the Eastern Cordillera; its fossil record includes *N. orthometopa, Basiliella carinata* Harrington, *Bienvillia rectifrons* (Harrington) and *C. forficuloides*, sometimes associated to *P. triarhroides, Asaphellus jujuanus* Harrington and *A. catamarcensis*. Due to the pronounced shallowing, the upper levels show a clearly impoverished assemblage integrated almost exclusively by the index species or by *Dolerasaphus laevis* Harrington and Leanza.

Interval VII. This interval corresponds to the late upper Tremadocian beds accumulated during the beginning of the transgression occurring after the NORE event. The succession is composed of fine shales and fine–grained wackes which paleontological content demostrates a great magnitude faunistic change, recorded in Pascha, Lesser and Mojotoro Ranges. The most typical trilobites are *Kayseraspis asaphelloides* Harrington, *Kayseraspis brackebuschi* (Kayser), *Bienvillia parchaensis* (Harrington and Leanza) and the ubiquitous *Thysanopyge argentina* Kayser. In Mojotoro Range, the oldest forms of this trilobite assemblage coexist with *Aorograptus victoriae* Hall, *Paradelograptus* spp., *Kiaerograptus* spp. and *Paratemnograptus isolatus* Williams and Stevens, among others (Monteros and Moya, this symposium). At Lesser and Pascha, the trilobite assemblage is associate with a slightly younger graptofauna composed by *Araneograptus murrayi* (Hall) and *Paradelograptus* spp.

Conclusions

The Cambrian–Ordovician boundary is not documented in the first transgressive episode of the Santa Victoria Group (Interval I), as traditionally considered by different authors. The correlation scheme here presented points out that the Cambrian–Ordovician boundary should be investigated inside the Interval II that, among other, contains *Jujuyaspis keideli* and *Rhabdinopora flabelliformis*.

It is necessary to revise the nomenclature of the lithostratigraphic units that integrate Intervals I and II of the Santa Victoria Group. Different lithostratigraphic bodies are identified with the same name in typical areas of the Argentine Eastern Cordillera such as Pascha, Cajas Range and Angosto del Moreno. Thus, the "Lampazar

Formation" in the Cajas Range and in the Angosto del Moreno area corresponds to the Interval I, as long as, the "Lampazar Formation" in Pascha corresponds to the Interval II.

The Interval I is well developed in the center and north of the Argentine Eastern Cordillera (Angosto del Moreno, Cajas Range, Tilcara-Huacalera and Santa Victoria areas). However, Interval I is just represented by thin bodies of sandstone and conglomerate in the near areas to the basin borders (La Quesera and Mojotoro Range) and in the flanks of the Lipán Swell (Pascha area and Lesser Range) (Figures 2 and 3).

The areas undergoing erosion and/or non deposition during the Interval I (Lesser and Mojotoro Ranges and Pascha area) collapsed at the beginning of the Ordovician (Interval II) and they received sedimentation starting from this time.

The transgression–regression cycles represented in Intervals III and IV are well documented in all the Chaco Shelf.

The lowerTremadocian – upper Tremadocian boundary is reported in the lower section of Interval V (FAD of *Bryograptus* sp. aff. *B. kjerulfi*). In the western part of the Chaco Shelf, the Tumbaya Unconformity truncates different levels of Interval V; the upper Tremadocian deposits are poorly preserved and frequently, the Arenigian records overlies lower Tremadocian calcareous sandstones and coquinas with *Kainella meridionalis* Zone fossil assemblage.

The Tremadocian-Arenigian boundary has to be analyzed inside the Interval VII in the Pascha area, Mojotoro and Lesser Ranges.

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