

An introduction to geology of the Precordillera, Western Argentina

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Introduction

The Precordillera of Western Argentina (See figure 1 for location) constitute a typical "thin-skinned" high level thrust-and-fold belt, which was formed during the Andean (Tertiary) crustal shortening, where mostly E-directed imbrications are combined with folding and involve a pile of Cambrian to Tertiary sediments. The thrust belt is detached above a main décollement within the Ordovician to Lower Devonian strata. To the East it is bounded by a back thrust zone directed westwards, meanwhile to the West it is bounded by a tectonic valley alignment trending N-S, separating from the adjacent Cordillera Frontal (Figure 2). On the other side no Precambrian basement rocks are exposed in the Argentine Precordillera, it being probably that the basement is composed of metamorphic rocks which can be inferred from xenoliths found in Tertiary volcanic rocks, which indicate a Grenville-age, ~ 1100 Ma, which allow a strong relationship between Precordillera and Appalachian basements, and so, to consider the Precordillera as a continental fragment rifted from Laurentia (Astini *et al.*, 1995). Indeed, Dalla Salda *et al.* (1993) propose that the Laurentian origin of Precordillera is because the Taconian Gondwana-Laurentia collision, which resulted the Occidental Terra, trending along the Andes from the Northern Chile to Patagonia, and the related Famatinian orogen.

In agreement with the new hypothesis concerned to the origin of the Precordillera as allochthonous terrane accreted to Gondwana during the Lower Paleozoic (Figure 3), it became necessary to introduce the name of "Cuyania" for a terrane continental fragment which include either the classical Precordillera as well as the Bloque de San Rafael, to the south in the province of Mendoza, and the San Jorge Limestones, outcropping in the province of La Pampa, within of the Sierras Pampeanas structural setting. On the other side, the Precordillera is considered as an autochthonous Gondwanic fragment (Baldis *et al.*, 1989; Aceñolaza and Toselli, 1999a; Aceñolaza *et al.*, 1999b) displaced by simple transcurrent mechanics; from a hypothetical intermediate sector between South America, Africa and Antarctica (Aceñolaza and Toselli, 1999a; Aceñolaza *et al.*, 1999b).

Structural and stratigraphic features

From a structural viewpoint, three morpho-structural units can be recognized in the Precordillera, which are distinguished between them, on the basis of their different stratigraphic composition and structural styles: The Eastern Precordillera, defined by Ortiz y Zambrano (1981), the Central Precordillera, defined by Baldis and Chebli (1969) and, the Western Precordillera defined by Baldis *et al.* (1982) (Figure 2). The Eastern Precordillera is stratigraphically characterized by a thick carbonate platform sequence, Cambrian to earlier Ordovician in age, distributed mainly at the Villicum, Zonda and Pedernal ranges. This sequence comprises, from the base upwards, the La Laja Formation (Lower to Middle Cambrian), the Zonda Formation (Middle Cambrian), the La Flecha Formation (Middle-Upper Cambrian), the

La Silla Formation (Upper Cambrian?-Lowermost Ordovician) and the San Juan Formation (Arengian to Early Llanvirnian). The boundary between them it is conformably everywhere. At the top, the San Juan Formation show an erosional surface (harground). This sequence is also, widely distributed in the Central Precordillera, changing to deep-sea clastic facies towards the Western Precordillera. In the Northern part of the Central Precordillera, a Cambrian sequence outcrops, including red clastic unit with interbedded evaporites of the Lower Cambrian, dolostone and limestone of the Middle and Upper Cambrian, succeed by Lower Ordovician limestone, Middle Ordovician shale, and Middle and Upper Ordovician synorogenic clastic-wedge rocks that reflect an eastern orogenic source.

At the Villicum range, the Cambrian-Earlier Ordovician carbonate sequence is followed by a thick siliciclastic marine sequence, ranging from Lower Llanvirnian to Upper Silurian (Peralta,1993), which includes from the base upwards, graptolitic black shales of .the Gualcamayo Formation (Lower Llanvirnian), succeed by Caradocian shelf deposits including graptolites of the *N. gracilis* Zone, bounded by an erosional surface marking the beginning of the Late Ashgillian glacial event, involving glacial-marine diamictite (pebbly mudstones), succeed by siltstones containing brachiopods of the *Hirnantia* Fauna, trilobites of the *Dalmanitina* Fauna, indeed *Normalograptus perraultus*. This succession is capped by oolitic ironstone bearing palynomorphs, interbedded with graptolitic shales, indicating Lower Llandoveryan age. A conspicuous erosional surface at the top of the Llandoveryan deposits point the beginning of a typical sedimentary mélangé, including olistostromes deposits and calcareous olistolith (Peralta,1993). Anywhere in Precordillera, the upper part of the San Juan Formation and the Gualcamayo Formation contains K-bentonite levels interbedded, which indicate the explosive volcanic event related to Famatina magmatic arch.

Carboniferous and Permian deposits are well distributed mainly in the Central Precordillera, where they show a develop of continental, glacial-marine and marine facies, changing westwards to predominately marine, glacial-marine and scarce continental facies, in the Western Precordillera. There, the Carboniferous marine strata contains brachiopods of the *Levipustula laevis* Zone, while in the Carboniferous-Permian boundary the *Cancriella* Zone occurs. At the Eastern Precordillera, Carboniferous deposits occurs on the western flank of the Zonda and Pederal ranges, however, up to date, Permian strata has not been recorded in the Eastern Precordillera.

For a large part of the Mesozoic, the Precordillera acted as a positive area and provided the source of sediments in the extensive basins that developed on its margins. During the Triassic, two main sedimentary basin, coinciding with the present valleys of Barreal-Uspallata and BermejoMendoza, were developed, involving typical lake and river sedimentation, related to basaltic rocks, and environments suitable for the spread of the classical *Dicroidium* flora and large numbers of reptiles. In this way, Mesozoic rocks are poorly represented in the Argentine Precordillera, despite this, they are mainly distributed in the Western Precordillera, predominantly in lacustrine facies containing abundant plant remains. On the other side, Triassic fossiliferous deposits, continental in origin, occurs at the Morado hill, southern end of the Mogna range, where a reptile fauna has been found. The main Triassic basins located in Uspallata-Potrerrillos valley, in province of Mendoza were suitable for the creation of coal, bitumen, oil and gas. In general the Triassic deposit show a typical "taphrogenic" vertical arrangement, forming thinning-upward sequences.

The absence of Jurassic and Cretaceous sediments in the Precordillera indicates that this region was elevated during this time, serving as a source area for the Beremejo and Uspallata basins, located out of the Precordillera; the former to the western, and the second one to the eastern of Precordillera. The new active margin was located to the west, corresponding to the present-day trench of the Andean Cordillera, and closely related to the magmatic and tectonic activity of the Cordillera Principal of San Juan and Mendoza (Baldis *et al.*, 1984).

In general sense, the Tertiary continental sequence of the Precordillera are composed mainly of alluvial deposits, whereas lacustrine, including bentonites beds, and eolian sediments, although to a small-scale, are present too. Anywhere Tertiary deposits outcrops in Precordillera, they show a typical orogenic arrangement forming coarsening-thickening upward sequences, in a foreland tectonic setting. In the Eastern Precordillera, the Tertiary deposits display everywhere, but they predominate in the north part, at the Mogna (= Mógica) range, mean-while, small Tertiary basins occurs sparsely in the Central Precordillera. On the other side, Tertiary sediments are abundant in Western Precordillera, particularly between that and Cordillera Frontal. Extensive Tertiary (Miocene) volcanic rocks outcrops mainly on the eastern margin of the Central Precordillera. Here, the volcanic rocks including xenoliths of crystalline basement rocks, which have ages of ~ 1100 Ma, and are geochemically like the basement of the Llano uplift on the Texas promontory of Laurentia (Thomas and Astini, 1996).

The Precordillera Terrane concept

In agree with the concept outlined by Coney, Jones and Monger (1980) a Terrane is characterized by "internal homogeneity and continuity of stratigraphic, tectonic style and history" and boundaries that are "fundamental discontinuities in stratigraphy that cannot be explained easily by conventional facies changes or unconformities". According this definition the Precordillera is a distinctive terrane which can be recognized mainly on the basis of its key stratigraphic composition, involving biostratigraphic, sedimentary and magmatic events, and its boundaries with the adjacent geologic regions, are abrupt (Ramos *et al.*, 1986).

Recent geochemistry and petrologic studies demonstrates that the metamorphic rocks distributed close of the Eastern boundary of the Precordillera, in Western Pampeanas ranges, are ~ 1100 My in age, likewise those of the basement of the Bloque de San Rafael and the San Jorge Limestones at the La Pampa Province. This allow to establish a close relationship with the Grenvillian rock basements of the Appalachian orogeny, in Laurentia. This data suggest that, at least during the Cambrian time, Precordillera Terrane was a Laurentian fragment. According with the Terrane concept, the present Precordillera, plus the Bloque de San Rafael and San Jorge Limestones, integrate a only geological entity so-called Precordillera Terrane or Cuyania Terrane.

There is not fundamental doubt that the Precordillera is an exotic terrane, but some questions are still open, such as the time of collision with the Gondwana margin, and the just place whence Precordillera was derived. Indeed, the recognition of allochthonous rocks, so-called "The Calingasta Allochthon" (Nullo and Stephens, 1996), in the Western Precordillera, surrounded by autochthonous Middle to Upper Ordovician sedimentary deposits, has been interpreted as a Taconic tie between eastern North America and western South America further confirms the linkage of these continents in the early Paleozoic and places additional constraints on the geographic juxtaposition of these continents.

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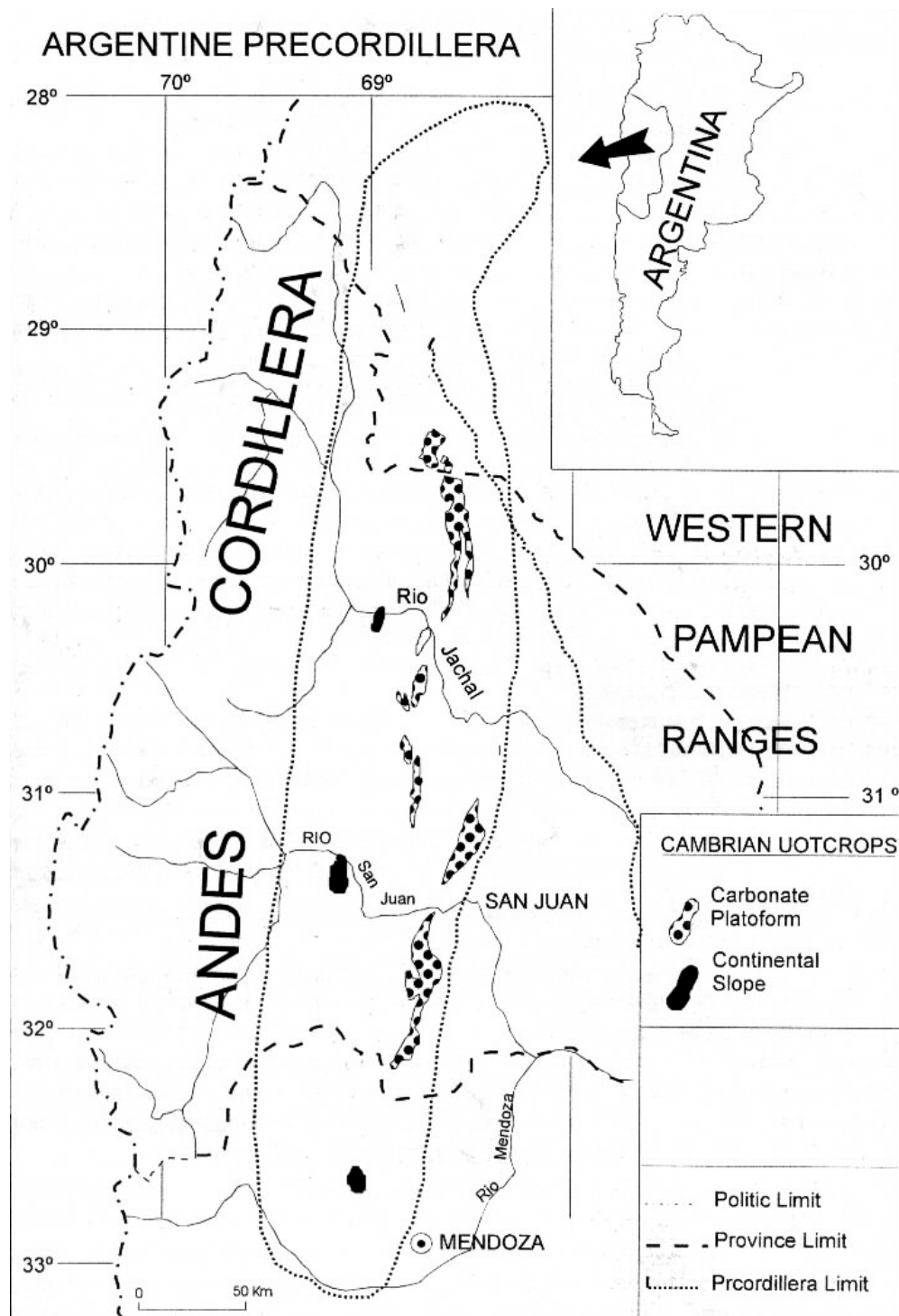
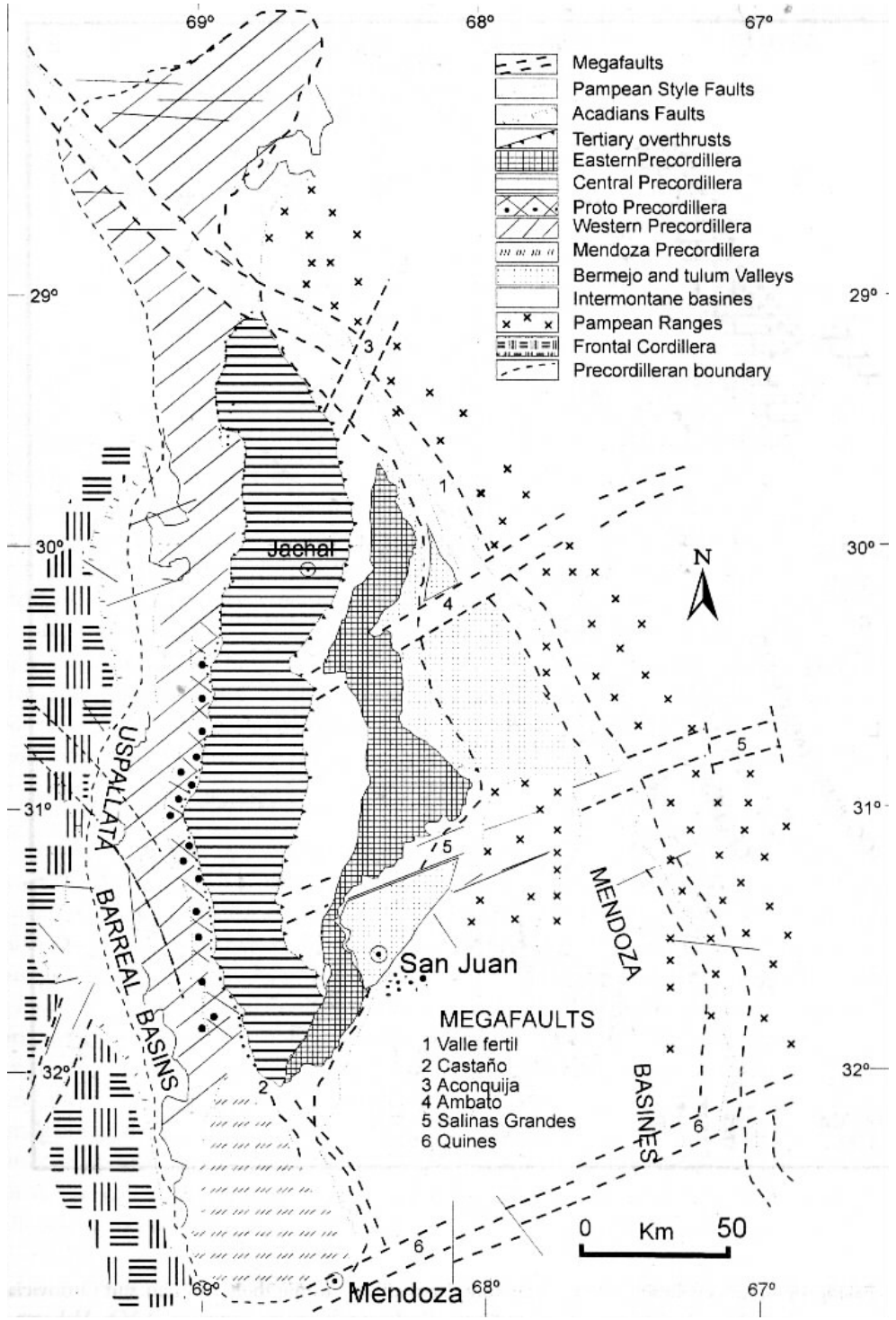
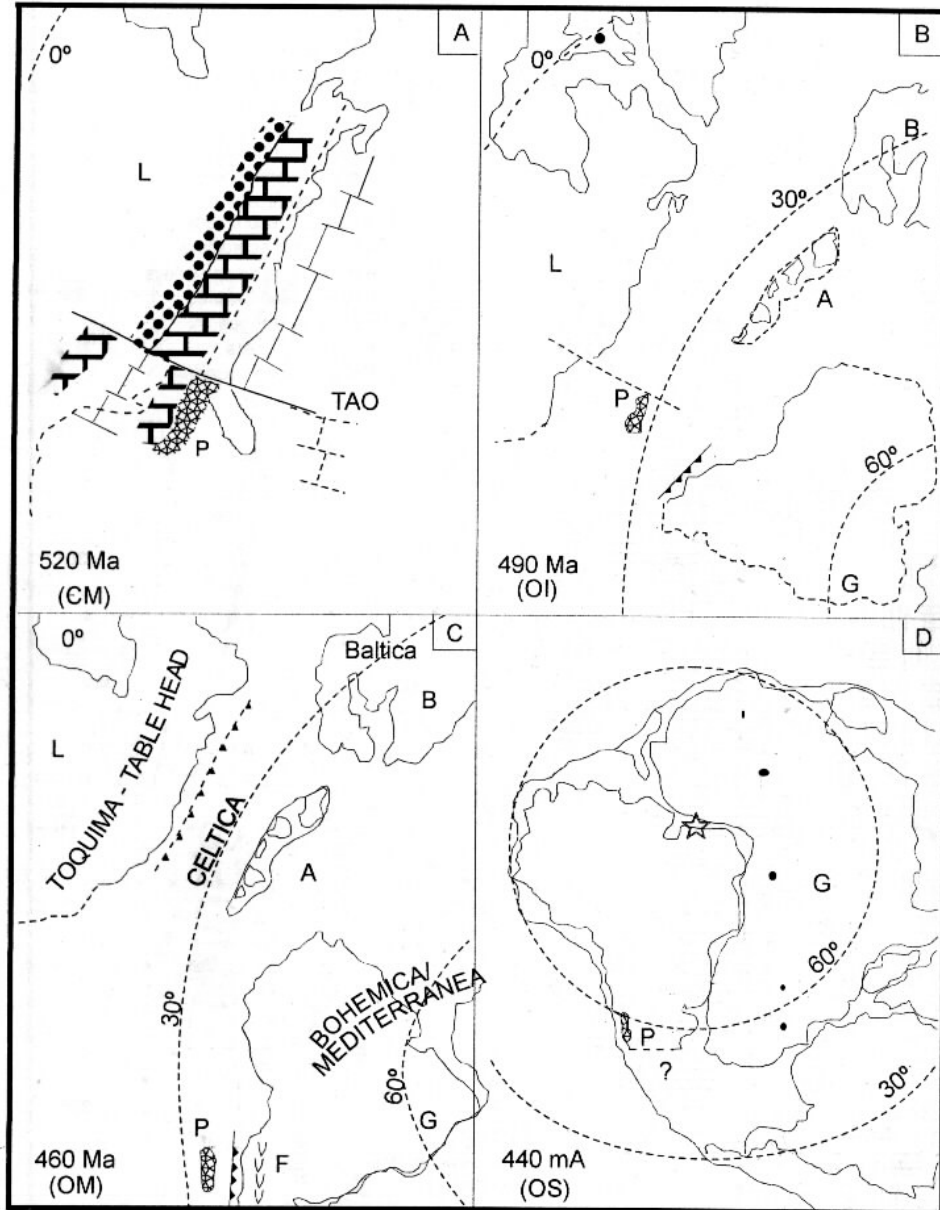


Fig 1. Geographical and geological setting of Cambrian outcrops of the Argentina Precordillera (From Bordonaro and Liñan, 1994).





ig. 3: Paleogeographic evolution of the Argentine Precordillera during the Cambrian and Ordovician. L: Laurentia, B: Baltica, A: Avalonia, G: Gondwana, P: Precordillera, F: Famatina, TAO: Alabama-Oklahoma transform-fault. (Modified from Astini *et al.*, 1996).