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Review of the geodynamic evolution of the SW margin of Gondwana preserved in the Central Andes of Argentina and Chile (28°-38° S latitude)

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A B S T R A C T

In the southwestern margin of Gondwana, preserved in the Argentinean-Chilean Andes (28-38° S latitude), three subduction events, Famatinian, Chanic and Gondwanan, took place from the Ordovician to the middle Permian. The first two culminate in collisional orogens in Middle Ordovician and Late Devonian times respectively, while the Gondwanan is a subduction-related orogen, developed in late Carboniferous-middle Permian times. This model is only valid for these latitudes, which coincide with the N and S limits of the Chi-Cu continental fragment (Chilenia + Cuyania subplates). Northern and southern limits of this continental fragment coincide with two major Andean lineaments, Valle Ancho and Huincul respectively.

Contents

1. Introduction

In recent years, a wealth of information on sedimentology, structure, magmatism and metamorphism of the Paleozoic basement of the Andes has been produced (see Heredia et al., 2016 and references therein). What is also remarkable is the progress in

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geochronology and in the knowledge of the environmental conditions and geotectonic context in which the Paleozoic deformation events took place. In this sense, the belonging of the southern part of South America to the southwestern margin of Gondwana in the Paleozoic has been long known and also that several terranes and continental fragments were accreted to this margin during this time (Fig. 1). The aim of this paper is to propose a new and synthetic geodynamic model for the late Neoproterozoic-Paleozoic basement of the Andean Cordillera between 28°-38° of S latitude. This model arises from the interpretation of previous data provided by numerous authors who have worked in the area in recent years and the results obtained by our research group (PaleoAndes Group). Thus, the PaleoAndes Group has published recently the works of Heredia et al. (2016, 2017) on the Paleozoic evolution of the Chilean-Argentinean Andes, which have been taken as a reference for the development of this article. In this way, a more precise Paleozoic geodynamic evolution of the named Cuyo Sector by these authors, located between 28 and 38°S, is presented here.

The Cuyo Sector of the Paleozoic basement of the Argentinean-Chilean Andes is constituted by four mountain ranges with a submeridian trend that, from W to E, are: Coastal Cordillera, High Cordillera (further divided into Principal and Frontal cordilleras) and Precordillera (Fig. 2). These ranges constitute morpho-tectonic units related to the Andean orogen, responsible for the current architecture of the Andes, mainly developed during the Cenozoic and strongly controlled by the Paleozoic structure.

During the late Neoproterozoic and the Paleozoic, the geodynamic evolution of this sector is related to the Famatinian, Chanic and Gondwanan orogenic cycles, developed in the former SW Gondwana margin (Fig. 3). These cycles culminate, respectively, in the Famatinian (Early Ordovician-Silurian), Chanic (Middle Devonian-early Carboniferous) and Gondwanan (late Carboniferous-middle Permian) orogenies. The two oldest ones preserve evidences of collisional and pre-collisional (subduction-related) events, produced during the accretion of two small continental fragments to the southwestern Gondwana margin. The most recent one resulted from the subduction of the proto-Pacific oceanic crust beneath this margin of Gondwana.

At the same latitudes of the Cuyo Sector was defined the Pampean cycle (Ramos, 1988). This cycle is related to the accretion of the Pampia terrane to Gondwana in Neoproterozoic-Cambrian times, but the rocks affected by this orogenic cycle outcrop outside the Andes (mainly in the Pampean ranges) so they have not been studied in this paper.

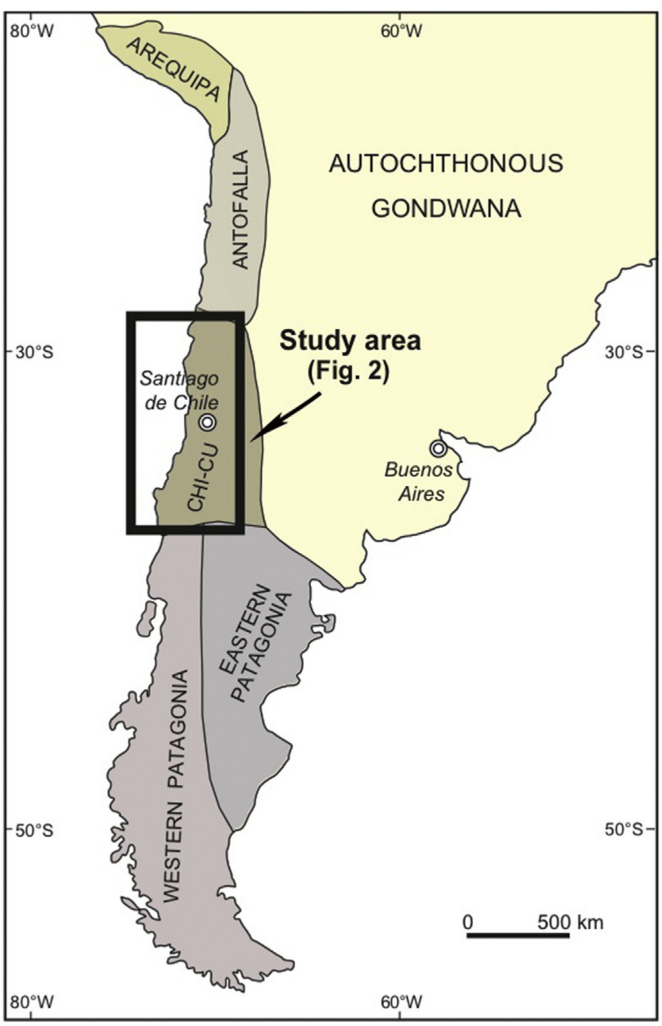

Fig. 1. Paleozoic terranes and continental fragments present in the Andes of southern South America and location of the study area shown in Fig. 2. Modified from Ramos (2009) and Heredia et al. (2017).

2. Geodynamic evolution

The geodynamic evolution described in this paper begins during the breakup of Rodinia, in the early Ediacaran period (López de Azarevich et al., 2009) of the Neoproterozoic (~630 Ma, age from Varela et al., 2011) with a rifting event (Davis et al., 2000) that took place within the Chi-Cu (**Chi**lenia + **Cu**yania) continental fragment (Figs. 3 and 4A). This extensional process resulted in the opening of an ocean (formation of oceanic crust) to ~575 Ma; age of the oldest ophiolitic rocks (Davis et al., 2000) in the southern part of the Chi-Cu continental fragment (Chanic ocean), which allowed the separation of two small continental blocks, the Chilenia and Cuyania subplates (Figs. 2 and 4A). These subplates, were previously defined as terranes by Ramos et al. (1986) and Ramos (1988, 2004), and their paleogeographic links and accretion to southwestern Gondwana have been the focus of intensive discussion. For some authors, Chilenia and Cuyania are fragments with Laurentian affinities that drifted towards Gondwana (Ramos, 1988; Dalla Salda et al., 1992; Davis et al., 1999, 2000; Thomas and Astini, 2003; Ramos, 2004; Naipauer et al., 2010; Thomas et al., 2015; and references therein), whereas others propose a parautochthonous origin respect to Gondwana (Aceñolaza et al., 2002; Finney et al., 2003; López and Gregori, 2004; González-Menéndez et al., 2013; and references therein). However, González-Menéndez et al. (2013) suggest that Chilenia and Cuyania are part of the same continental fragment, partially rifted in Ordovician times and only separated by an oceanic crust in the southern part. We have not done new studies to discern between an allochthonous or parautochthonous origin for the Cuyania continental fragment regarding Gondwana and therefore whether it is or not a terrane. We only provide new data to support the idea of González-Menéndez et al. (2013) that Chilenia and Cuyania are part of the same continental fragment: Chi-Cu.

The Chi-Cu continental fragment consists of a Grenvillian Mesoproterozoic basement (>1.0 Ga), that only outcrops in five localities of the study area (Varela et al., 2011). The westernmost outcrop of this Grenvillian basement belongs to the Chilenia subplate and is located in the present Frontal Cordillera (Las Yaretas gneiss) (Figs. 2 and 4A). The rest of the Grenvillian outcrops belong to the Cuyania subplate and they are located in the northern Precordillera (Río Bonete Metamorphic Complex and related rocks; BR, UR and ME in Fig. 2) and in their equivalent to the south, the San Rafael Block (Cerro de la Ventana formation; VP in Fig. 2). The Las Yaretas gneiss

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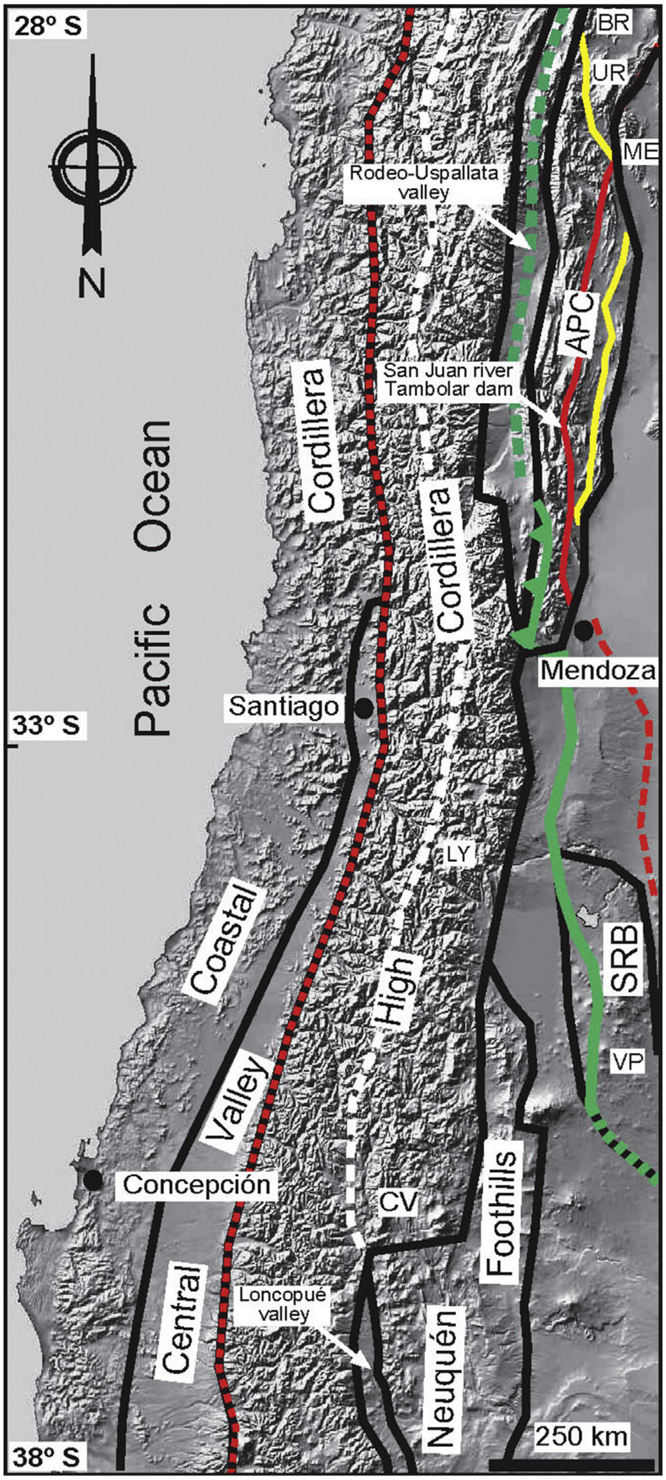

Fig. 2. Schematic map showing the location and distribution of the major morphotectonic units and the main Paleozoic tectonic features of the Andes at 28°-38° S latitude. SRB- San Rafael Block, APC- Andean Precordillera. CV- Cordillera del Viento. Main outcrops of the Mesoproterozoic basement: BR- Bonete river, UR- Umango range, ME- Maz and Espinal ranges. VP- Southern part of the San Rafael Block, LY- Las Yaretas. Dotted white line indicates the limit between the Main (to the W) and Frontal Cordilleras. Green lines show the approximate present location of the boundary between the two Chanic orogen branches. Dotted green line marks the location of the ancient rift axis in the unrifted Chi-Cu continental fragment (area without creation of oceanic crust). The solid green line marks the suture between Chilenia (to de W) and Cuyania subplates of the rifted Chi-Cu fragment. Solid green line with triangles marks the zone with preserved ophiolitic rocks. Yellow line shows the approximate location of the orogenic fronts of the Famatinian orogen and the red lines show the two fronts of the Chanic orogen. Base Map: NASA (SRTM). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

is covered by Carboniferous and Permian-Triassic rocks, while the Grenvillian outcrops of the Precordillera and San Rafael Block are covered by Pre-Andean Cambrian to lower Permian sedimentary rocks (Keller, 1999; Bordonaro, 1999; Baldis and Peralta, 1999; Azcuy et al., 1999; and references therein). This allows us to deduce that a large part of the Chilenia subplate remained emerged up to the Carboniferous (Fig. 4A and B), constituting the main source area for the pre-orogenic series of the Chanic cycle located on this subplate. However, a part of the pre-Carboniferous series could also have been eroded during the Chanic cordillera uplift in Late Devonian-early Carboniferous times (Fig. 3). The other emerged zone, located in Cuyania, represents the main source area for the sediments deposited in both Cuyanian margins in Ediacaran-Ordovician times, prior to the Famatinian orogeny that affected its western margin. In the northern part of the Chi-Cu continental fragment, the rifting process was aborted and the emerged areas remained separated by an epicontinental sea located above an extended and thinned continental crust (Kay et al., 1984; Alonso et al., 2008; González-Menéndez et al., 2013). The sedimentary series deposited on this thinned crust contains abundant basic igneous rocks, interbedded in the sedimentary series of Chilenia and Cuyania passive continental margins (Fig. 4A) (Kay et al., 1984; Keller, 1999; González-Menéndez et al., 2013; and references therein). In the Middle Ordovician, the eastern passive margin of Chi-Cu (Cuyania subplate) collided with Gondwana (western margin to the previously accreted Pampia terrane, Figs. 3 and 4A) resulting in the Famatinian orogen (Ramos, 1988) (Fig. 3), while the oceanic crust between Cuyania and Chilenia continued developing until the Silurian. The Famatinian orogenic belt shows a NNW trending and double vergence (Fig. 4B and C). The eastern branch of this orogen, developed in the Gondwana margin (Pampean ranges, east of the study area), preserves pre-collisional structures in its hinterland (Ramos, 2004) related to the Famatinian subduction event (~515-465 Ma, ages of the arc-related rocks; Figs. 3 and 4A) (Rapela et al., 2001). Meanwhile, the western branch of this orogen, developed on the Chi-Cu continental fragment (Cuyania subplate), is preserved in the Eastern Precordillera and especially in the northern part of the Precordillera (Figs. 2 and 4B), where west-vergent structures and Middle Ordovician-Silurian synorogenic sedimentary rocks (Fig. 3), deposited in a peripheral foreland basin, are present (Guandacol foreland basin, from Thomas and Astini, 2003). The eastern border of the northern Precordillera is located very close to the Famatinian suture (Fig. 2) and the deformation becomes ductile, allowing the development of pervasive cleavages and shear zones at the base of the thrusts. The presence of migmatites and synorogenic granitoids also indicates the location of this area in the hinterland of the narrower western branch of the Famatinian orogen. These ductile Famatinian thrusts involve the Grenvillian Mesoproterozoic basement of Cuyania, and were reactivated as brittle structures (reverse faults) during the most recent Gondwanan and Andean orogenies, promoting the uplift and exposure of this basement in large areas of the northeastern Precordillera ranges (BR, UR in Fig. 2).

In the Western Precordillera and in the San Rafael Block (Fig. 2), there is no evidence of Famatinian deformation, so that we interpret that the old western Famatinian foreland was located in these areas (Fig. 4D). The slight disconformity present at the base of the Silurian rocks in the Central and Western Precordillera could be interpreted as a response to the uplift of the Famatinian mountain chain (Fig. 4B), which triggered the sedimentation in the rift of the Chi-Cu continental fragment and, afterwards, in the western

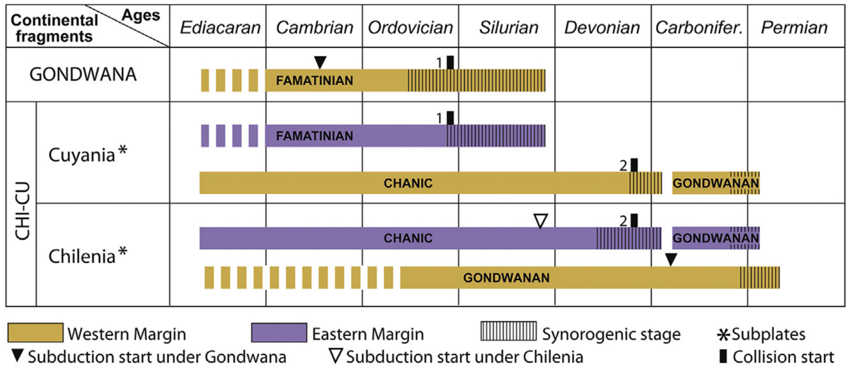

Fig. 3. Sketch showing the temporary extension of the late Neoproterozoic-Paleozoic orogenic cycles in the Cuyo Sector of the Argentinean-Chilean Andes. Continental fragments involved and main geodynamic events are also shown. (1) start of the Gondwana-Cuyania collision during the Famatinian orogeny, (2) start of the Gondwana-Chilenia collision during the Chanic orogeny. Based in Heredia et al. (2016).

passive margin of Cuyania. The Famatinian orogen also produced the burial of the emerged part of the Cuyania subplate, which was placed under the western Famatinian branch (Fig. 4B). The end of the Famatinian orogeny took place in the Silurian-Devonian boundary (~420 Ma, according to Mulcahy et al., 2011), when a subduction process started in the eastern margin of Chilenia (Fig. 3), which leads the closure of the Chanic ocean and the beginning of the Chanic cycle only developed in this Andean sector (Fig. 4C).

During the Devonian, the Chanic subduction resulted in an incipient magmatic arc (small spaced plutons) developed in the eastern margin of Chilenia (Fig. 4C), which includes, among others, the Pampa de los Avestruces granodiorite (Tickyj et al., 2009). This incipient magmatic arc, developed in Devonian times and before the Chanic collision (Late Devonian), implies a short subduction process and therefore a small Chanic ocean, probably related with a little-active mid-oceanic ridge. The effusive terms of this arc provide Devonian age zircons to the contemporaneous sedimentary rocks deposited on the southern Chilenia active margin. Detrital zircons of this age are absent in the sedimentary series of northern Chilenia, where this arc was not developed. In the Middle Devonian, large fragments of sedimentary and igneous rocks of the Chilenia margin and oceanic crust were subducted and deformed on high-pressure metamorphic conditions, as the Guarguaraz Complex (López and Gregori, 2004; López de Azarevich et al., 2009; Willner et al., 2011; García-Sansegundo et al., 2016). On the other hand, the existence of Lower Devonian I-type plutonic rocks deformed during their emplacement (Tickyj et al., 2009), points to the incipient development of a pre-collisional orogen (Fig. 3). Meanwhile, in the western passive margin of Cuyania (located in the present Precordillera), the pre-Chanic sedimentation was continuous (Fig. 3) until the Late Devonian (Keller, 1999; Alonso et al., 2008; Amenábar and Di Pasquo, 2008; and references therein), except for the aforementioned Silurian disconformity. In Late Devonian times, both the Chilenia-Cuyania collision and the inversion of the intracontinental basin of the Chi-Cu continental fragment in the northern part of the orogen, began. Deformation, metamorphism and magmatism were more intense towards the south, where the hinterland of this orogen is well developed (García-Sansegundo et al., 2014b). During the Chanic collisional orogeny, the emplacement of the high-pressure (HP) metamorphic rocks over the Chilenia margin took place (Guarguaraz Complex, Frontal Cordillera; GC in Fig. 4D). The eastern continental margin of Chilenia was also overthrusted Cuyania (Giambiagi et al., 2014; Farias et al., 2016), giving rise to a suture zone whose existence can be deduced in the Southern Precordillera by the presence of klippes of ophiolitic rocks (Davis et al., 2000) (Fig. 4D). Thin marine-continental synorogenic deposits crop out mainly in the Precordillera (Cuyania) (Heredia et al., 2012; Colombo et al., 2014), containing in their basal part abundant clasts of igneous rocks coming from the Chanic magmatic arc located in the Frontal Cordillera (Chilenia) (Gallastegui et al., 2014). The Chanic orogenic belt shows a double vergence, to the east in the eastern branch, developed on Cuyania, and to the west in the western one developed on Chilenia (Fig. 4D). To the east of the best-preserved eastern branch, in the undeformed foreland, located to the east of the Central Precordillera, the Devonian and Carboniferous series have been conformably deposited. Furthermore, in the middle part of the Central Precordillera (east of the Tambolar dam meridian, Fig. 2) no significant Pre-Gondwanan deformation (Chanic or Famatinian) can be observed (Figs. 2 and 4D). The hinterland of the western branch of the Chanic orogen are represented discontinuously in the High Cordillera, while in the Coastal Cordillera the pre-Carboniferous rocks do not show this deformation and are in stratigraphic continuity with the Carboniferous rocks (Charrier et al., 2015) (Fig. 3). This allows us to deduce that the foreland of the orogen must be placed in the western part of the High Cordillera, while the undeformed foreland could correspond to the Coastal Cordillera. Thus, the western front of the orogen could match the western edge of the High Cordillera (Figs. 1 and 4D). The Chanic orogenic belt is only recognized between 28° and 38° S (Cuyo Sector of the Paleozoic basement of the Andes); latitudes that represent the limits of the Chi-Cu continental fragment (Heredia et al., 2016, 2017). These limits coincide approximately with two Andean lineaments: the Valle Ancho (28° S) and the Huincul lineaments (38° S), defined by Ramos (1999) and Ploszkiewicz et al. (1984) respectively. According to Heredia et al. (2016) north of 28° S (Puna Sector) the Ocloyic orogeny develope (Late Ordovician-Late Devonian), while south of the 38°S (Patagonia Sector) took place the Gondwanan orogeny (Middle Devonian-early Permian).

The Chanic orogeny ends at the early Carboniferous (~340 Ma), with the beginning of a new subduction stage (the Gondwanan subduction; Hervé, 1988) developed in the western margin of Chilenia (Figs. 3, 4D and 4E). A rapid erosion of the Chanic orogen, related to an extensional event, occurred from this moment onward, while several isolated sedimentary basins with local depocenters were formed in the inner/eastern part of the new Gondwana margin. Volcano-sedimentary series were deposited in the initial infill stages of the pre-orogenic San Rafael and Paganzo basins (~337-326 Ma, ages of interbedded volcanic rocks), as observed in the Cordillera del Viento (CV in Fig. 2) (Hervé et al., 2013; Giacosa et al., 2014) and in the northern part of the

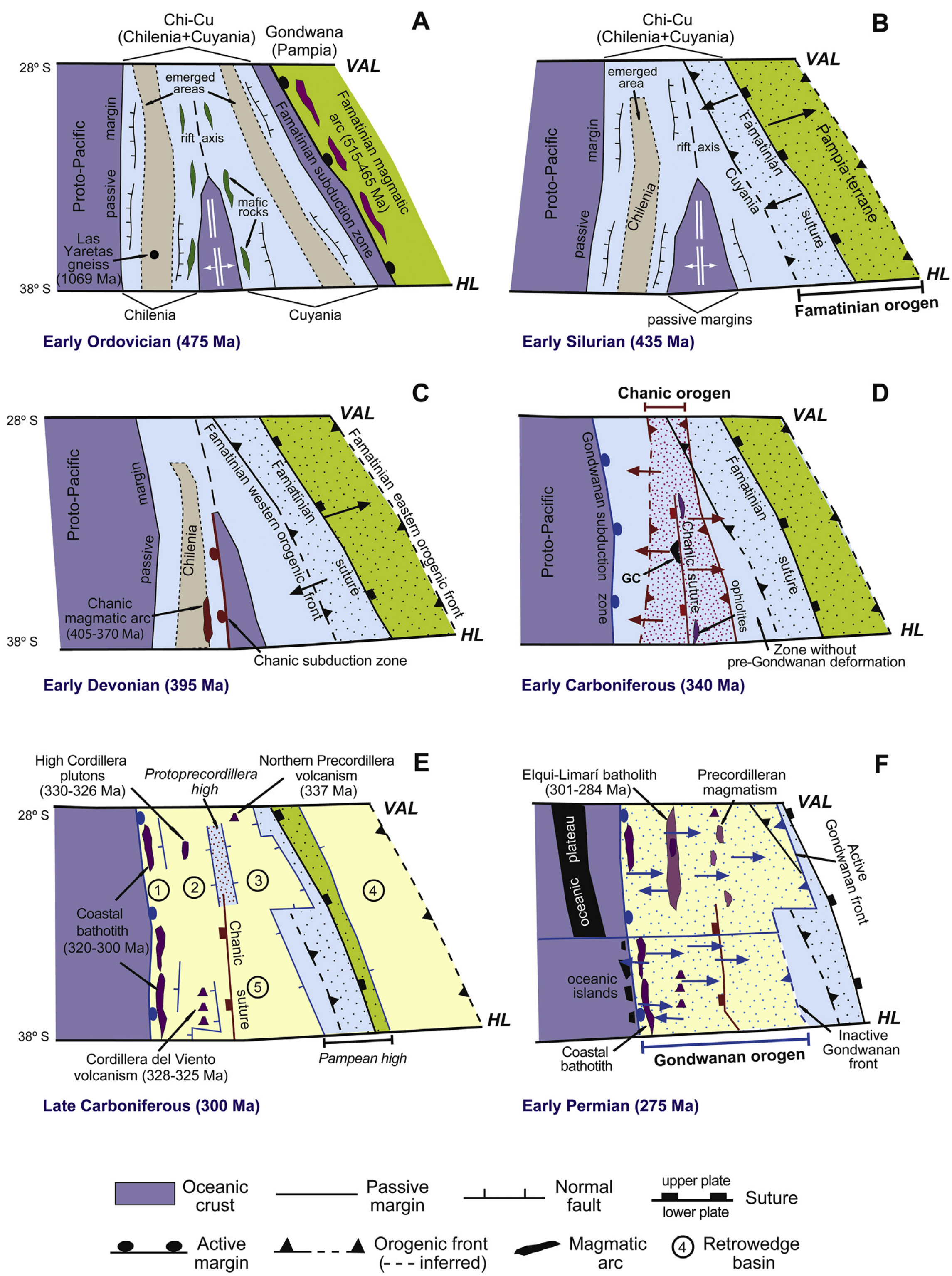

Fig. 4. Sketch showing the Paleozoic geodynamic evolution of the Andes and its foreland between 28° and 38°S latitude. Figure not-to-scale, the relative position of the different components is only shown. Lineaments: HL- Huincul, VAL- Valle Ancho. Retrowedge basins: 1-Arrayán, 2- Río Blanco, 3- Paganzo, 4- Chaco-Paraná, 5- San Rafael. The arrows point to the vergence of the main structures: Famatinian in black, Chanic in red and Gondwanan in blue. GC- high-pressure Guarguaraz Metamorphic Complex. Ages of igneous rocks from Rapela et al. (2001), Ramos (2004), Ramos and Folguera (2009), Varela et al. (2011), Hervé et al. (2014) and Sato et al. (2015). See text for explanation. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Precordillera (Astini et al., 2011) (Fig. 4D). The pre-orogenic Gondwanan magmatism is more common within the limits of the old Chanic orogen and it also includes some small plutons (~330-326 Ma), similar to those described by Hervé et al. (2014) and Sato et al. (2015) in the northern part of the eastern High Cordillera (Fig. 4E).

Afterward, during the late Carboniferous, the pre-orogenic basins expanded (Fig. 4E), while the volcanic contribution decreased (Giacosa et al., 2014). The lateral continuity of these retrowedge basins was occasionally interrupted by the formation of horsts (Limarino and Spalletti, 2006), like the Pampean high (remnant of the Famatinian orogen) or the Protoprecordillera high (remnant of the Chanic orogen according to Heredia et al., 2012), where the Carboniferous pre-orogenic deposits are very scarce (Fig. 4E). The Pampean high was the main detrital source at that time, with some little contributions from the Protoprecordillera (Spalletti et al., 2012).

The Gondwanan orogeny started in the late Carboniferous (~320 Ma) related to a mature subduction in the western margin of Chilenia (Fig. 3), after a long period of platformal sedimentation on this ancient passive margin during the Paleozoic (Charrier et al., 2007, 2015). The deformation associated with this orogen started close to the accretionary prism and coevally with the formation of the first Gondwanan magmatic arc (Coastal batholith), located in the current Coastal Cordillera (Figs. 2 and 4E) and intruded between 320 and 300 Ma (Deckart et al., 2014). This orogen shows a N trend, eastern vergence and narrow hinterland, as it is common in the Andean type orogens. Furthermore, to the south, the Gondwanan deformation was less intense, which resulted in a narrower orogenic belt (Fig. 4F). During the early Permian, the northern part of this orogen developed as a flat-slab subduction type (Ramos and Folguera, 2009), so that the deformation quickly migrated eastward. The magmatism migrated in the same direction and resulted in the calc-alkaline and peraluminous intrusive units (Hervé et al., 2014) of the Elqui-Limarí batholith (~301-284 Ma, according to Hervé et al., 2014) and reached the actual Precordillera (Ramos and Folguera, 2009 and references therein) (Fig. 4F). In the southern part of the Gondwanan orogen the flat-slab subduction did not occur. This fact is evidenced because (i) the southern orogenic front of the Gondwanan orogen did not migrate eastward and (ii) the deformation reached the Coastal batholith (Fig. 4F) in late Carboniferous times (~300 Ma) and this batholith remained inactive until the end of the orogeny in the early Permian (~280 Ma). This part of the Gondwanan orogen is likely related to the arrival of oceanic islands to the trench (Hyppolito et al., 2014), blocking the subduction and allowing the exhumation and the emplacement of the basal accretionary prism on the fore-arc basin. South of the Huincul lineament (Fig. 4), outside the studied sector and in the Patagonian Andes Sector, this orogen changed to a collisional type, as proposed by García-Sansegundo et al. (2009). Heredia et al. (2016) propose the collision of the Western Antarctica terrane for the origin of this collisional orogeny.

During the early-middle Permian, in the northern part of this Andean sector, the Gondwanan orogeny developed close to the trench, while in the rest of the study area the orogeny ended in the early Permian (~280 Ma) (Fig. 3), age of the first post-orogenic deposits and volcanic rocks of the lower Choiyoi Group (Rocha-Campos et al., 2011) as well as the coeval plutons in the Colangüil batholith (calc-alkaline Choiyoi of Sato et al (2015).,). The westwards migration of the Gondwanan magmatism and the deformation towards the trench could be related to the accretion of an oceanic plateau (Fig. 4F), which produces a steepening and finally the blocking of the subduction (García-Sansegundo et al., 2014a). In this context, remains of the Gondwanan basal accretionary prism and fragments of the subducted oceanic crust were exhumed and emplaced over the fore-arc basin, close to the volcanic arc. The rocks of the basal accretionary prism were strongly deformed under ductile/metamorphic conditions, in contrast to the fore-arc and the rest of the Gondwanan orogenic belt, deformed in brittle conditions (García-Sansegundo et al., 2014a). The exhumed basal prism, previously deformed under high-pressure metamorphic conditions inside the Gondwanan subduction zone (Willner et al., 2004), outcrop discontinuously in the Coastal Cordillera. These rocks, known as “Western Series” in the geological literature of the Chilean Andes (see Charrier et al., 2015 and references therein), represent the narrow hinterland of the Gondwanan orogen.

Synorogenic deposits related to the Gondwanan orogeny are preserved in the retroarc, located in the current Argentine Frontal Cordillera (Busquets et al., 2005) and Precordillera (Colombo et al., 2014) and also in the fore-arc, which outcrops in the Coastal Cordillera (Charrier et al., 2007). The Gondwanan synorogenic rocks rest both over the non-deformed pre-orogenic series as over the ancient extensional reliefs of the Protoprecordillera (Heredia et al., 2012). The retroarc foreland basin was filled by continental deposits with abundant interbedded volcanic rocks (Busquets et al., 2013) and retains the only preserved Carboniferous paleo-forest of South America (Césari et al., 2010, 2012). This basin was filled until the early Permian and migrated to the east together with the deformation. In the fore-arc, the synorogenic basin shows a marine character (Rivano and Sepúlveda, 1985) and goes up to the middle Permian in its northern part.

In the middle Permian (~265 Ma), the Gondwanan subduction ends and a new stage of low velocities subducting plate start (Rey et al., 2016). This low velocity subduction resulted in the formation of subsiding extensional continental basins that were filled with thick volcano-sedimentary successions of the upper Choiyoi Group (Permian-Triassic). Coeval calc-alkaline to transitional A-type granitic intrusions took place linked to this process, mainly represented in the Elqui-Limarí (Hervé et al., 2014) and Colangüil batholiths (Sato et al., 2015), which outcrop in the Chilean and Argentine Frontal Cordillera respectively. The Choiyoi rocks rest uncomformably over the Paleozoic and mark the beginning of the Andean cycle.

3. Conclusions

The geological evolution of the Andean basement between 28°-38° S latitude here proposed, is based on a set of structural, metamorphic, sedimentological, geochemical and geochronological data. These data allow us to reconstruct the geodynamic processes that took place during the Neoproterozoic and Paleozoic and to establish a new evolutionary model. This model explains the geodynamic evolution of the different margins of the Chi-Cu continental fragment during its accretion to Gondwana.

The major milestones of this evolutionary model are:

- The Chi-Cu continental fragment began to split into the Chilenia and Cuyania subplates in Ediacaran times. This rifting process allowed the development of an oceanic crust in the southern part of the Chi-Cu continental fragment until the Silurian.
- In the middle Ordovician, the collision of the Cuyania subplate with Gondwana, result in the Famatinian orogeny. At the same time, Chilenia was still separating from Cuyania. The western branch of the Famatinian orogen is preserved in the Eastern Precordillera, although is possible to recognize it in most of the northern end of the Precordillera, where the Famatinian suture is very close. Furthermore, in the hinterland of this branch of the Famatinian belt, mainly preserved in the eastern part of the northern Precordillera, the deformation involves the Grenvillian Mesoproterozoic basement.

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- In the earliest Devonian, the Famatinian orogen finished because the Chanic subduction began under the eastern margin of Chilenia, where a high-pressure (HP) metamorphic complex was developed in Middle Devonian times. This subduction led to the collision between the two Chi-Cu fragment subplates in Late Devonian-early Carboniferous times. The Chanic orogen is only present in this Andean sector and shows a good developed hinterland in its southern part, where Chilenia and Cuyania did get to become independent plates. In this southern part, the suture zone between the two subplates is preserved as ophiolitic klippes, emplaced over the Cuyanian margin (western Precordillera). The eastern branch of the Chanic orogen is preserved in the current Central and Western Precordillera as well as in the San Rafael Block. The western branch of the Famatinian orogen outcrops in the High Cordillera, where the Guargaraz HP Metamorphic Complex was emplaced over the margin of Chilenia (eastern Frontal Cordillera). In the last stages of the Chanic deformation, the western branch of the orogen overlapped the eastern one.
- During the Carboniferous, the proto-Pacific oceanic crust was subducted beneath the western margin of the Chi-Cu continental fragment, while extensive sedimentary basins (retro-wedge basins) grew in the continent.
- In the late Carboniferous the Gondwanan orogeny started, showing a different development in its northern and southern parts. This orogeny affected all the study area and had a non-collisional character (subduction-related orogen). In the northern part of the study area, the Gondwanan orogen was related to a flat-slab subduction that ended in early Permian times. This subduction produced the migration to the east of the magmatic arc and the deformation front, which reached beyond the Eastern Precordillera. At the end of this orogeny, in the middle Permian, took place the arrival of an oceanic relief to the trench, which produced the steepening and blocking of the subduction and the migration of the deformation close to the trench. In the southern part of the Gondwanan orogen, the flat-slab subduction did not occur. The magmatic activity of the arc ended in the late Carboniferous and remained inactive until the end of the orogeny in early Permian times. Moreover, the orogenic front did not advance as far as the northern part, so that at the same latitude the Gondwanan deformation is always less intense that in the southern part, where the Gondwanan orogeny is related to the arrival of several oceanic islands to the trench.
- The Gondwanan orogen allows the emplacement of the high-pressure metamorphic rocks of the basal accretionary prism on the fore-arc basin, close to the magmatic arc. These rocks form isolated outcrops in the Chilean Coastal Cordillera that constitute the narrow hinterland of this orogen.
- The north and south boundaries of the Chi-Cu continental fragment must correspond with the Valle Ancho and Huincul lineaments, respectively (VAL and HL in Fig. 4). To the south of the Huincul lineament, in the North Patagonian Cordillera, the Gondwanan orogeny has collisional characteristics.

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