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A HISTORY OF PROTEROZOIC TERRANES IN SOUTHERN SOUTH AMERICA: FROM RODINIA TO GONDWANA

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Abstract

The role played by Paleoproterozoic cratons in southern South America from the Mesoproterozoic to the Early Cambrian is reconsidered here. This period involved protracted continental amalgamation that led to formation of the supercontinent Rodinia, followed by Neoproterozoic continental break-up, with the consequent opening of Clymene and Iapetus oceans, and finally continental re-assembly as Gondwana through complex oblique collisions in the late Neoproterozoic to Early Cambrian. The evidence for this is based mainly on a combination of precise U-Pb SHRMP dating and radiogenic isotope data for igneous and metamorphic rocks from a large area extending from the Rio de la Plata craton in the east to the Argentine Precordillera in the west and as far north as Arequipa in Peru. Our interpretation of the paleogeographical and geodynamic evolution invokes a hypothetical Paleoproterozoic block (MARA) embracing basement ultimately older than 1.7 Ga in the Western Sierras Pampeanas (Argentina), the Arequipa block (Peru) the Rio Apa block (Brazil), and probably also the Paraguaia block (Bolivia).

Introduction

The role of southern South American cratons in Rodinia reconstructions, particularly those of Amazonia and Rio de la Plata, is a long-debated issue (Hoffman, 1991; Dalziel, 1997; Weil et al., 1998; Omarini et al., 1999; Loewy et al., 2003; Li et al., 2008; Trindade et al., 2006; Cordani et al., 2010; Santosh et al., 2009, among others). The debate was stimulated by the ideas that 1) Eastern Laurentia was juxtaposed to Amazonia and the Rio de la Plata craton in Rodinia at ca. 1 Ga as a result of Grenvillian orogeny, and that 2) Laurentia rifted away to its present position in the northern hemisphere (present coordinates) in the late Neoproterozoic, accompanied by opening of the Iapetus Ocean and the final amalgamation of West Gondwana (Hoffman, 1991; Dalziel, 1997 and references therein). However, the models derived from these studies took only minor account of the relatively small outcrops with Paleoproterozoic basement south of Amazonia and west of the Rio de la Plata craton. The wealth of data now available from detrital zircon ages and crystallization ages of many igneous rocks has transformed this situation. These outcrops are scattered over a very large region (Fig. 1), with an extensive cover of Mesozoic to Cenozoic sedimentary rocks, which hinders correlation between them. The Paleoproterozoic rocks crop out as inliers within the Andean belt (e.g., the Arequipa block in Peru; Loewy et al., 2004, and references therein; Casquet et al., 2010), in the Andean foreland (Sierra de Maz in the Western Sierras Pampeanas of central Argentina; Casquet et al., 2006, 2008a) and in the stable mainland far from the Andean active margin (e.g., Rio Apa and Paraguá in southern Brazil; Cordani et al., 2010) (Fig. 1). Other occurrences may be hidden farther south in Argentine Patagonia. In consequence, the role of these outcrops in Rodinia reconstructions has been largely underestimated, hindering understanding of the role played by cratons in the Neoproterozoic-to-Early Paleozoic evolution of southern South America after the break-up of Rodinia.

The presence of a pre-Grenvillian continental mass called Pampia has been suggested (Ramos,1988; Ramos & Vujovich, 1993), initially as a block embracing most of the present Sierras Pampeanas realm, with a late Neoproterozoic turbidite basin (the Puncoviscana Formation) along the western passive margin that eventually collided with the Arequipa-Antofalla block. This view was largely retained by Ramos et al. (2010) in a recent review of Pampia.

Based largely on our own work since the 1990s in the pre-Andean basement, we proposed (Casquet et al., 2009) that by the end of the Paleoproterozoic the basement outcrops referred to above, i.e., Arequipa, Rio Apa and Maz, constituted a single larger continental mass (the MARA craton, Fig. 1). Part of this craton was involved in Mesoproterozoic orogenies along its northern and western margins that led first to its accretion to Amazonia at ca. 1.3 Ga or earlier, and then amalgamation with Laurentia between ca 1.3 and 1.0 Ga. The latter event involved accretion of juvenile arcs and continental collision with reworking of older continental crust. After Rodinia break-up the larger continental mass embracing MARA + Laurentia + Amazonia (and probably other still unconstrained cratons) underwent protracted Neoproterozoic rifting, as exemplified by A-type granite and carbonatite-syenite intrusions. Opening of an oceanic basin was eventually followed by oblique collision with some West Gondwana cratons (including Rio de la Plata and Kalahari) to produce the Pampean-Paraguay-Araguaia orogeny. This process was coeval with rifting-drifting of Laurentia and the opening of the Iapetus Ocean along the western margin of the large continental mass and represents the final stage in the formation of SW Gondwana. We provide here a detailed account of this evolution.

1. The Paleoproterozoic MARA craton

In the Western Sierras Pampeanas of Argentina, the Maz terrane (comprising the sierras of Maz and Espinal) (Fig. 1) consists of a metamorphic Andean-type magmatic arc (1.33 – 1.26 Ga) and older metasedimentary rocks. (Casquet et al., 2006, Rapela et al., 2010). The latter contain detrital zircons older than 1.7 Ga and have Nd model ages of between 1.7 and 2.6 Ga and very radiogenic Pb, from which we infer that the protoliths were probably cover to a Paleoproterozoic basement older than 1.7 Ga (Casquet et al., 2008a). The Maz terrane was further reworked in the Ordovician and Silurian by the Famatinian orogeny (Casquet et al., 2005).

The Arequipa Massif in southern Peru (Cobbing and Pitcher, 1972) (Fig. 1) consists for the most part of Paleoproterozoic metasedimentary rocks and orthogneisses that record orogenic events (magmatism, sedimentation and metamorphism) between ca. 1.79 and 2.1 Ga (Loewy et al., 2004; Casquet et al., 2010). These rocks underwent intense Grenville-age (*sensu* Rivers, 2008) metamorphism between 1.04 and 0.84 Ga (Martignole and Martelat, 2003; Loewy et al., 2004; Casquet et al., 2010 and references therein). UHT metamorphism first recorded in the Arequipa Massif by Martignole and Martelat (2003) remains of disputed age, either Paleoproterozoic or Grenvillian (Martignole and Martelat, 2003; Casquet et al., 2010). Mixing of Paleoproterozoic and juvenile Grenvillian sources was recognized farther south in northern Chile and Argentina (Loewy et al., 2004), lending support to the idea of a continuous basement of Paleoproterozoic age under this part of the Central Andes, corresponding to the northern part of the Arequipa-Antofalla craton of Ramos (1988). A link between the Maz terrane and the northern part of the Arequipa-Antofalla craton was first established by Casquet et al. (2008a) on the basis of detrital zircon evidence and Pb and Nd isotope compositions.

Finally the Rio Apa block, south of present-day Amazonia (Fig. 1), consists of a suite of Paleoproterozoic orthogneisses recording igneous events at 1.95 Ga, 1.84 Ga, and between 1.72 and 1.77 Ga, as well as medium- to high-grade metamorphism of ca.1.7 Ga (Cordani et al., 2010). The Rio Apa block was overprinted by a thermal event at ca. 1.3 Ga (Cordani et al., 2010) coincident with the San Ignacio orogeny along the southern margin of Amazonia (Böger et al., 2005; Cordani and Teixeira, 2007).

The three cratonic outcrop areas referred to above, although separated by hundreds of kilometres, show evidence of common geological processes evidenced by U-Pb geochronology and similar Nd model ages (Fig. 2). This leads to the idea that all three formed part of a common continental mass before the onset of the Mesoproterozoic orogenies. We call this craton MARA (after **M**az - **A**requipa - **R**io **A**pa), consisting of rocks formed between 1.7 and 2.1 Ga and with Nd residence ages (T_{DM}) between 1.7 and 2.6 Ga (Casquet et al., 2009).

2. The Mesoproterozoic Evolution of the Mara Craton

No evidence has so far been recognized in any of the three Paleoproterozoic outcrops for significant igneous or metamorphic activity between ca. 1.3 and 1.6 Ga, although they experienced constrasting igneous and metamorphic events in the second half of the Mesoproterozoic (Fig. 3).

The Maz terrane records an Andean-type magmatic arc (1.33 – 1.26 Ga) and intermediate P/T amphibolite to granulite facies metamorphism between 1.23 and 1.17 Ga followed by emplacement of AMCG complexes at 1.07-1.09 Ga (Casquet et al., 2005, 2006; Rapela et al., 2010). Moreover in the nearby Sierra de Pie de Palo, and in minor outcrops south of it (Fig. 1), a late Mesoproterozoic juvenile arc/back-arc oceanic complex has been identified (the Pie de Palo Complex) that records protracted subduction between ca. 1.24 and 1.03 Ga (Kay et al., 1996; Vujovich et al., 2004; Rapela et al., 2010). The Pie de Palo Complex is the basement of the enigmatic, supposedly Laurentia-derived, Precordillera terrane (Thomas and Astini, 1996; for a review see Ramos, 2004): alternatively the terrane might have been para-autocthonous (Aceñolaza and Toselli, 2000; Galindo et al., 2004; Finney, 2007). In any hypothesis, docking of this terrane to the margin of Gondwana occurred in the mid-Ordovician during the Famatinian orogeny (Ramos et al., 1998; Ramos, 2004; Casquet et al., 2001; Galindo et al., 2004). Overlying the Pie de Palo Complex is an imbricate thrust system that reworked basement consisting of late Mesoproterozoic orthogneisses and metasedimentary rocks overlain by a Neoproterozoic sedimentary cover (Casquet et al., 2001; Mulcahy et al., 2011). This basement underwent pre-Famatinian metamorphism under conditions close to those of the Maz terrane, to which it is probably equivalent (Casquet et al., 2001). Orogenic activity between ca 1.3 and 1.0 Ga in the Maz terrane and the Pie de Palo Complex can be interpreted as resulting from the approach and eventual collision of the MARA craton (and the juxtaposed Amazonia) with Laurentia to produce the middle to late Mesoproterozoic orogenic belt that fringes Amazonia on the west, with outcrops as far north as Colombia (Cardona et al., 2010, and references therein) (Fig. 1). Paleomagnetic data for ca. 1.2 Ga are compatible with this interpretation (Tohver et al., 2004). The relative positions of the oceanic Pie de Palo Complex and the continental Maz terrane in the Mesoproterozoic orogen are difficult to retrieve because of Famatinian oblique thrusting in Sierra de Pie de Palo and protracted post-Paleozoic activity along the Bermejo-Desaguadero fault that separates the block containing the Sierra de Pie de Palo and the Argentine Precordillera from that containing the sierras of Maz and Espinal (Fig. 1).

The Rio Apa block underwent a strong thermal episode at ca. 1.3 Ga with temperatures above 300ºC, which affected the entire region (Cordani et al., 2010). This corresponds to the San Ignacio orogeny (1.34–1.32 Ga; Böger et al., 2005), the main belt of which developed farther north, along southern Amazonia (Fig. 1), and is one of several 1.56–1.3 Ga orogenic belts constituting the Rondonia-San Ignacio province of southern Amazonia (Bettencourt et al., 2010, and references therein). The lack of evidence in the Rio Apa block for the late Mesoproterozoic Sunsás orogeny s.l. (1.20–1.07 Ga; Cordani and Teixeira, 2007; Böger et al., 2005) suggests that it - and consequently the MARA craton - was accreted to the southern Amazonia margin during the San Ignacio orogeny, and was a mainly stable region in late Mesoproterozoic times. Deformation associated with the Sunsás orogeny, long considered the main representative of the Grenville orogeny in southern South America, occurred farther north along branched transcurrent belts and pull-apart basins (Fig. 1) involving local metamorphism and granitic magmatism (for a review see Teixeira et al., 2010). The Paraguá block of Eastern Bolivia (Fig. 1) also has Paleoproterozoic basement older than ca. 1.7 Ga (Böger et al., 2005) that was accreted to SW Amazonia during the San Ignacio orogeny (Bettencourt et al., 2010) and could thus also have been part of MARA.

The history of the Arequipa massif differs in that it shows evidence for true Grenville-age (*sensu* Rivers, 2008) low-P high-T regional metamorphism between ca 1.04 and 0.85 Ga, younger than in the Maz terrane and Rio Apa block (Loewy et al., 2004; Casquet et al., 2010). The massif was probably an inlier in the middle to late Mesoproterozoic orogenic belt that only underwent late-orogenic metamorphism. However its pre-orogenic location and the geodynamic setting of metamorphism remain uncertain. With respect to location Dalziel (1992, 1994) and Sadowsky and Bettencourt (1996, and references therein) proposed that the Arequipa massif was the tip of a promontory of NE Laurentia. Subsequently Loewy et al. (2004) suggested that the Arequipa massif and its southward extension may have been part of a larger craton in collision with Amazonia. With respect to metamorphism an extensional setting in the Grenvillian hinterland has been hypothesized on the grounds that extension was widespread over southern Amazonia at this time (equivalent to the Rigolet event of the Grenville orogeny; Casquet et al., 2010). Significantly, accretion of MARA to Amazonia during the San Ignacio orogeny would explain the input of detrital zircons with ages between 1.2 and 1.6 Ga to the late Mesoproterozoic Atico basin in Arequipa, for which no local sources have been recognized (Casquet et al., 2010). Amalgamation of Laurentia and the MARA craton (with Amazonia) in the Mesoproterozoic at ca. 1.2 Ga (Tohver et al., 2002) was an important contribution to the formation of Rodinia.

3. Neoproterozoic to Early Paleozoic evolution

The Neoproterozoic to Early Paleozoic history is summarized focusing on evidence from the Sierras Pampeanas of Argentina.

3.1 Rifting events and the Clymene Ocean

Protracted rifting of Rodinia took place throughout the Neoproterozoic. Two early aborted rifting events, at ca. 840 and 760 Ma, are represented by A-type granitoids in Sierra de Maz and Sierra de Pie de Palo, bearing zircons with juvenile Hf and O isotopic signatures (Baldo et al., 2006; Colombo et al., 2009; Rapela et al., 2011). Further rifting occurred at ca. 570 Ma (Ediacaran), represented by a carbonatite-nepheline syenite complex in the Sierra de Maz (Casquet et al., 2008b). We suggest that this latter event probably initiated opening of the Clymene Ocean (Fig. 4). This ocean was named by Trindade et al. (2006), who argued on the basis of paleomagnetism for such a late Neoproterozoic ocean between Amazonia + Laurentia on the one hand and West Gondwana cratons, such as Rio de la Plata and Kalahari, on the other. As an alternative to the Pampia model of Ramos (1988) and Ramos et al. (2010), we envisage that MARA was attached to the former continental mass and that the closure of this ocean led to the Pampean orogeny (Casquet et al., 2009). 570 Ma is just within error of the Sm-Nd age of 647± 77 Ma for alleged Pampean ophiolite relics (whole-rock errorchron with MSWD = 7.6), obtained by Escayola et al. (2007).

3.2 The Difunta Correa Sedimentary Sequence

Further evidence for the Clymene Ocean comes from the Sr-isotope composition of platform carbonates of the Difunta Correa Sequence, which was deposited on the Paleoproterozoic and Mesoproterozoic basement of the Western Sierras Pampeanas in the late Neoproterozoic (Varela et al., 2001; Galindo et al., 2004; Rapela et al., 2005; Murra et al., 2011). From comparison with the Sr-isotope composition of seawater through time, Galindo et al. (2004) deduced a maximum age of 580 Ma (Ediacaran) for the sequence in Sierra de Pie de Palo. This accords with the similar findings of Varela et al. (2001) for equivalent carbonate cover in Sierra de Umango (Western Sierras Pampeanas) and of Murra et al. (2011) for marbles from Sierra de Ancasti (Eastern Sierras Pampeanas). Similar Ediacaran shallow-marine carbonates that were post-glacial with respect to the Marinoan (ca. 635 Ma) and Gaskiers (ca. 580 Ma) events are recorded elsewhere in southern South America (Misi et al., 2007). This evidence for extensive carbonate platforms at ca. 580 Ma is compatible with the existence of the Clymene Ocean during Ediacaran time (Fig. 4).

3.3 The Puncoviscana Formation

The Puncoviscana Formation (Turner, 1960) is a thick, mainly siliciclastic partly turbiditic, succession (Ježek, 1990; Omarini et al., 1999, Zimmermann, 2005 and references therein) that crops out in northern Argentina and allegedly throughout most of the eastern Sierras Pampeanas (e.g., Schwartz and Gromet, 2004; Rapela et al., 2007). It has been the subject of much controversy in terms of its age and tectonic setting of sedimentation. The formation is important in that it shows the main evidence for the Early Cambrian Pampean orogeny, in the form of penetrative deformation and metamorphism, the grade of the latter increasing from the Puna and Sierras Orientales in the north (very low- to low-grade) to the Sierras de Córdoba in the south (high-grade). The formation was also host to the Pampean plutonic arc in the south, formed between ca. 550 and 530 Ma (Rapela et al., 1998; Schwartz et al., 2008; Iannizzotto et al., 2011). The term Puncoviscana Formation in the literature embraces sedimentary rocks probably older, coeval and younger than the Pampean magmatic arc with the only constraint that they are older than the unconformably overlying Middle to late Cambrian Meson Group (e.g., Omarini et al., 1999; Adams et al., 2008, 2011; Escayola et al., 2011, and references therein). We restrict our treatment here to that part of the siliciclastic succession that hosts the magmatic arc in the south, which is of relevance to the early history of the Puncoviscana sedimentary basin. This southern tract is mainly pelitic and contains characteristic detrital zircons populations with major peaks at 1100–960 Ma and 680–570Ma and lacks grains derived from the nearby Rio de la Plata craton (2.02–2.26 Ga) (Schwartz and Gromet, 2004; Escayola et al., 2007; Rapela et al., 2007). Sedimentation here took place on the eastern margin of the Clymene Ocean between ca. 570 Ma (the approximate age of the youngest detrital zircons) and ca. 530 Ma (Fig. 4); the older age being coincident with that of the anorogenic carbonatite-syenite event referred to above. The paleogeographical position was probably distant from the Rio de la

Plata craton, to which the Puncoviscana Formation basement became juxtaposed through right-lateral displacement during Pampean subduction and collision (Schwartz and Gromet, 2004; Rapela et al., 2007; Verdecchia et al., 2011). However, the sedimentary setting of this tract of the Puncoviscana Formation remains uncertain; a fore-arc basin was suggested Rapela et al. (2007) but a passive margin setting for the older part of the tract can not be discounted.

4. The Pampean orogeny and the amalgamation of SW Gondwana

Subduction started in the Late Neoproterozoic or Early Cambrian along the eastern margin of the Clymene Ocean, giving rise to the Pampean orogeny. An I-type Andean-type magmatic arc developed between ca. 550 and 530 Ma (Rapela et al., 1998; Schwartz et al., 2008; Iannizzotto et al., 2011) (Fig. 4). At the same time Laurentia rifted away from MARA + Amazonia in the west (present coordinates), resulting in opening of the Iapetus Ocean (Dalziel, 1997) and with development of passive margin sedimentary sequences well preserved along the Appalachian margin of Laurentia and in the Precordillera terrane of western Argentina (e.g., Astini et al., 1995; Thomas and Astini, 1996). Final closure of the Clymene Ocean occurred between 530 and 520 Ma as implied by the ages of intermediate P/T Barrovian-type collisional metamorphism and coeval S-type plutonism (Rapela et al., 1998; Rapela et al., 2002; Otamendi et al., 2009) (Fig. 4).

At the start of the Pampean orogeny (ca. 550 Ma) the Paleoproterozoic and Mesoproterozoic basement of the Western Sierras Pampeanas was part of a large but ephemeral continental mass rifted from Laurentia (Rapela et al., 2007; Casquet et al., 2009), consisting of MARA together with Amazonia (Fig. 4). The Western Sierras Pampeanas probably formed the southern tail of this landmass (Rapela et al., 2007). Participation of the Pie de Palo complex in this new continental assemblage cannot be ruled out in the hypothesis of a para-autochthonous Precordillera terrane (Galindo et al., 2004; Finney, 2007).

The Pampean orogeny involved oblique closure of the Clymene Ocean between MARA + Amazonia and other West Gondwana cratons (Rio de la Plata, Kalahari,…), ultimate collision of these continental masses bringing to an end the formation of Gondwana (Trindade et al., 2006; Rapela et al., 2007). We suggest that these collisions were responsible for the formation of a continuous mobile belt embracing the Pampean orogen in the south and the Paraguay and Araguaia belts further north (Fig. 1), all of which have igneous, metamorphic and structural features in common (Rapela et al., 2007; Moura et al., 2008; McGee et al., 2011, Bandeira et al., 2011). Moreover, no evidence of Cambrian orogeny has yet been convincingly demonstrated for the western margin of Amazonia (e.g., Chew et al., 2007). Consequently, this orogenic belt was probably part of the Terra Australis orogen of Cawood (2005), although the South American tract that we describe here follows a different trend along eastern Amazonia (Fig. 3). The Trans-Brasiliano lineament of Cordani et al. (2003) (Fig. 1) is interpreted as a late Pampean mega-fault equivalent to the Córdoba Fault (e.g., Rapela et al., 2007) (Fig. 4) responsible for the final assembly of eastern South America continental masses before Pangea. On the other hand the western margin of MARA + Amazonia (now part of Gondwana) facing the Iapetus Ocean remained passive until the Early Ordovician when it evolved into an Andean-type orogeny that persisted throughout the Paleozoic and the Mesozoic, evolving into the present Andean margin of South America.

5. Conclusions

Southern South America contains an outstanding record of Rodinia formation, further supercontinent break-up in the Neoproterozoic and final re-assembly of continental blocks in SW Gondwana in the Early Cambrian. We suggest here that several minor Paleoproterozoic blocks, such as the Maz terrane in the Western Sierras Pampeanas, the Arequipa block including its southern extension, and the Rio Apa block, at least, formed a major continental mass, i.e., the MARA craton, which collided with Amazonia at ca. 1.3 Ga. The resulting continent further amalgamated to Laurentia during middle and late Mesoproterozoic orogenies as part of Rodinia formation. Protracted break-up of Rodinia took place in the Neoproterozoic as recorded by episodic anorogenic magmatism and eventual opening of the Clymene Ocean in Ediacaran times. Post-glacial platform carbonates formed in this ocean followed by deposition of the largely turbiditic Puncoviscana Formation along the eastern margin in late Ediacaran to Early Cambrian times. Eastward right-lateral subduction led to closure of the Clymene Ocean coeval with Laurentia drifting away to the west to open the Iapetus Ocean. The proto-Andean margin formed at this time and remained passive till the start of the Andean-type Famatinian orogeny in the Early Ordovician. Final closure of the Clymene Ocean led to oblique collision of the large continental mass formed by MARA+Amazonia with other West Gondwana cratons (Kalahari, Rio de la Plata..) to produce the transpressional Pampean-Paraguay-Araguai orogenic belt in the Early Cambrian, and brought to an end the assembly of SW Gondwana.

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Figure Captions

Figure. 1: Sketch map of South America showing Paleoproterozoic to Archean cratons and the middle-to-late Mesoproterozoic, and Neoproterozoic to Early Cambrian orogenic belts. The MARA craton reached its present position after right-lateral oblique accretion to the Rio de la Plata craton during the Pampean orogeny and further displacement along the Córdoba fault. Outcrops in red are Paleoproterozoic and Mesoproterozoic outcrops referred to in the text. DBF: Desaguadero-Bermejo Fault; CF: Córdoba Fault.

Figure 2: The Paleoproterozoic record in the three outcrops forming the hypothetical MARA craton. Data from Casquet et al. (2008a, 2010) and Cordani et al. (2010).

Figure 3: Middle-to-late Mesoproterozoic evolution of the MARA craton. From Rapela et al. (2010), Casquet et al. (2010) and Cordani et al. (2010)

Figure. 4: 3-D diagrams showing geotectonic evolution during the Neoproterozoic and the Early Cambrian that led to the Pampean orogeny and final amalgamation of MARA to Gondwana. See text for explanation. The figure highlights the role played by the opening of the Clymene Ocean in the late Neoproterozoic and its subsequent closure in the Early Cambrian coeval with drifting of Laurentia in the west *en route* to the northern hemisphere

Figure 1

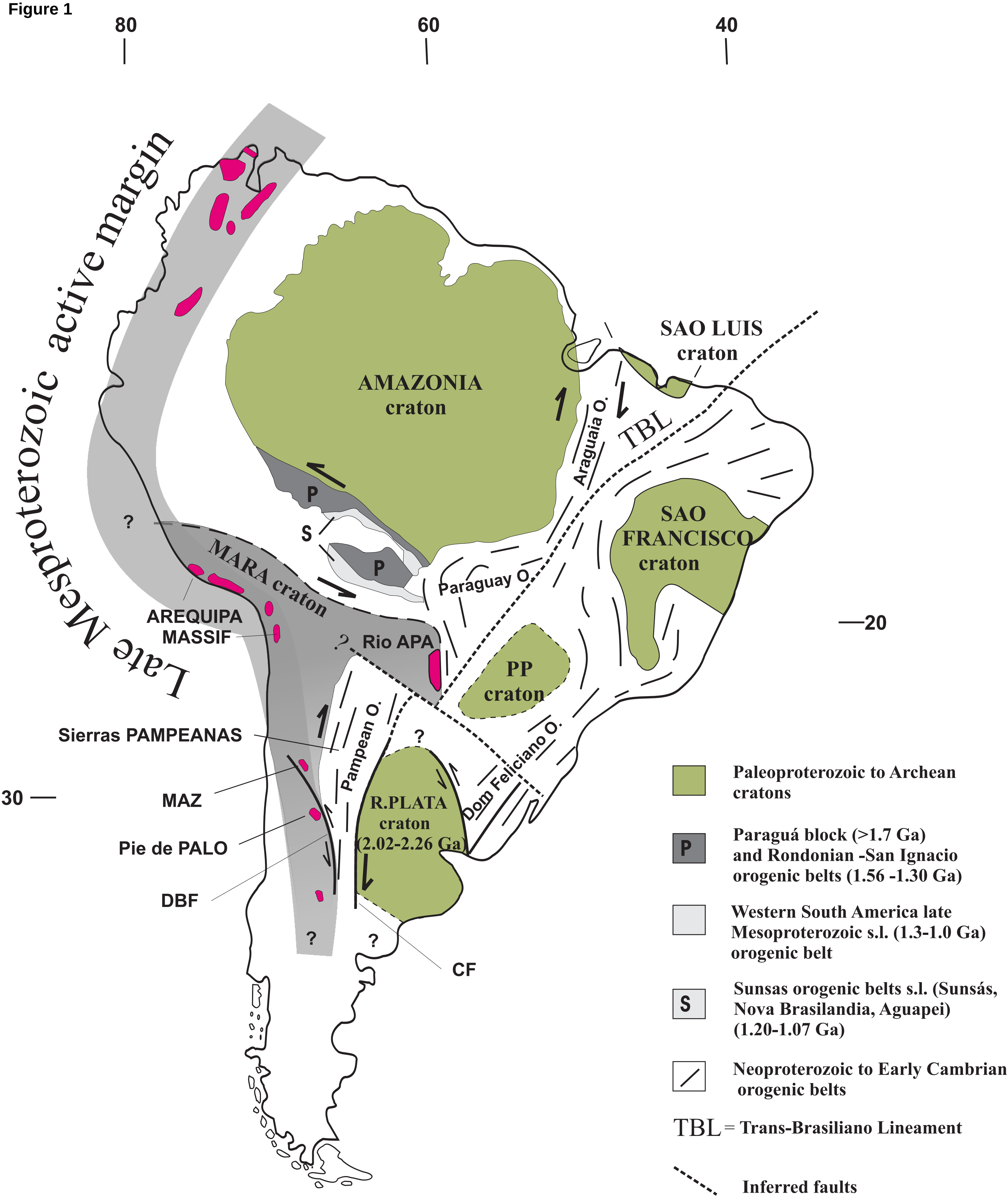

Figure 1

Figure 2

COMPARATIVE EVOLUTION OF PALEOPROTEROZOIC BLOCKS

	AREQUIPA		RIO APA		MAZ TERRANE	
U-Pb Geochronology					**1.3 - 1.7 Ga**	*Sedimentation on Paleoproterozoic basement*
	1.7 - 1.79 Ga	*Late felsic magmatism*	**1.72 - 1.76 Ga**	*Granite magmatism & regional metamorphism*	**1.7 Ga**	*Magmatism (inferred from detrital zircons in metasediments)*
	~1.87 Ga	*UHT metamorphism*				
		Sedimentation			**1.9 Ga**	
	1.9 - 2.1 Ga	*Magmatism (inferred from detrital zircons in metasediments)*	**1.94 - 1.83 Ga**	*Granite magmatism*		
Nd model ages (TDM)	**1.9 - 2.5 Ga**		**1.9 - 2.5 Ga**		**1.7 - 2.6 Ga**	

Figure 2

Figure 3

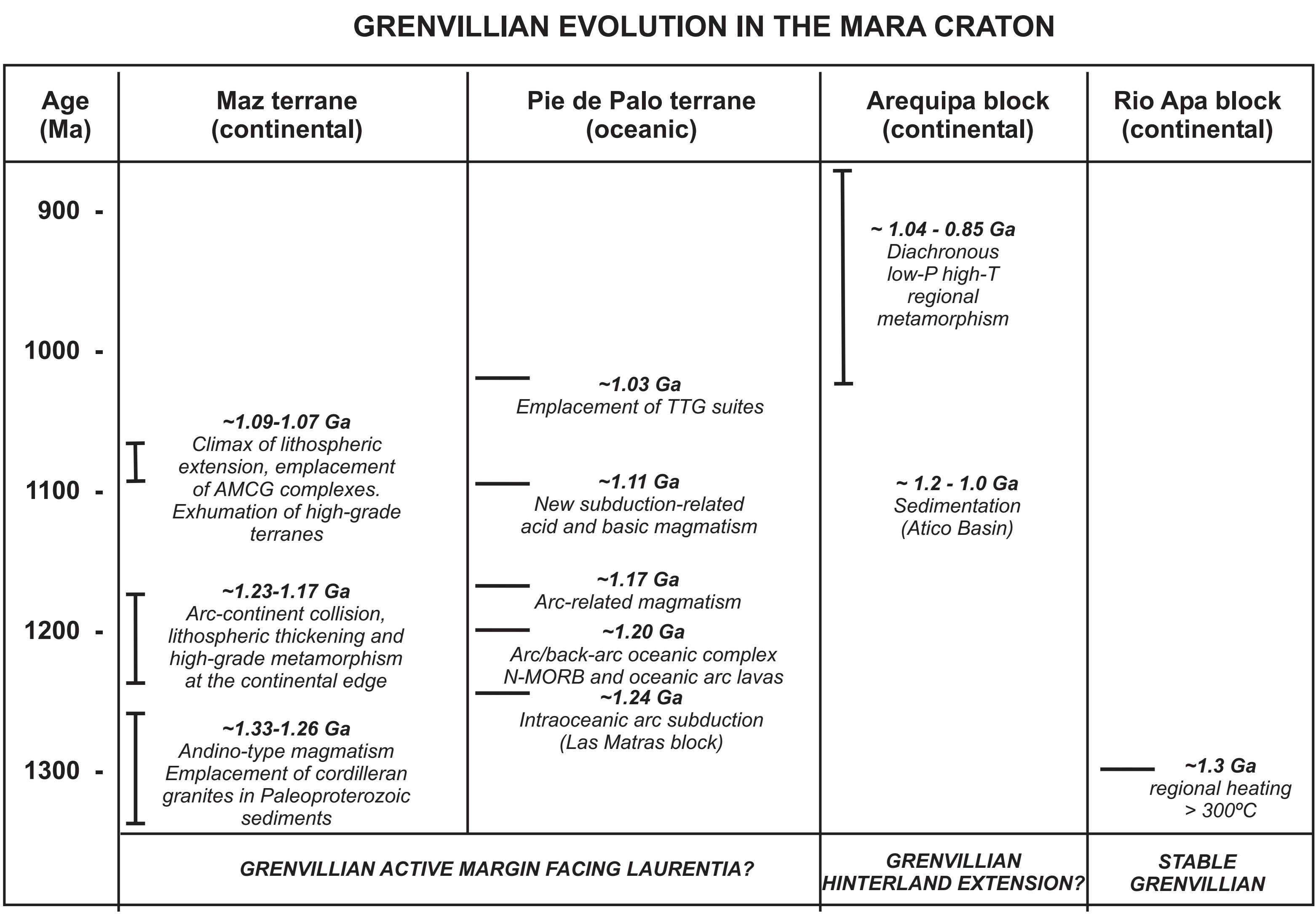

Figure 3

Figure 4

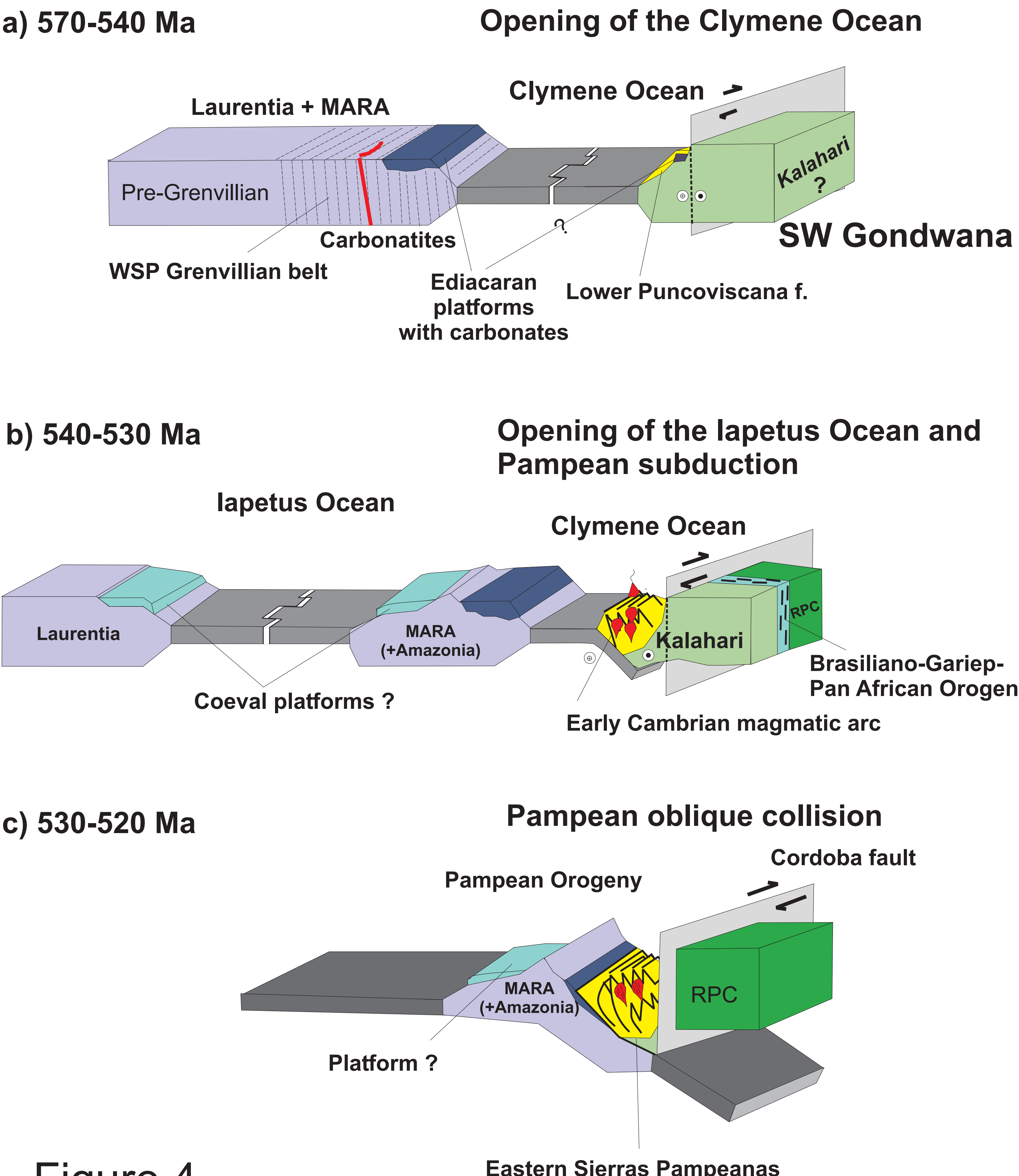

Figure 4