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Cenozoic convergence in western South America: Subduction of the Nazca, Farallon, and Aluk plates

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The Andean magmatic arc that parallels the western margin of South America was almost permanently active since at least the Early Jurassic, pointing out a long-lived subduction history. Determining the kinematics of the convergence in western South America requires summing up reconstructions through a circuit following constructive plate boundaries. The present discussion is based on reconstructions following the Nazca-Antarctica-Africa-South America plate-circuit for the 0-26 Ma time interval, and the Farallon-Pacific-West Antarctica-East Antarctica-Africa-South America circuit for the 28-68 Ma time interval. Reconstructions for earlier times are not possible because the lack of appropriate sea floor data in the Pacific basin. A paleomagnetic test strongly suggests that the older rotations derived from the latter plate-circuit successfully describe the relative motion of the Pacific plate respect to South America (Fig. 1). The main uncertainty in the set of Early Cenozoic reconstructions derives from the poor determination to full absence of oceanic anomalies older than ca 36-40 Ma in the Nazca plate. Then, estimates of relative motion between the Pacific and Farallon plates for these older times were usually carried out by assuming symmetric spreading (SS) in the Pacific-Farallon ridge (e.g. Pardo Casas and Molnar, 1987). Later identification of some Early Cenozoic magnetic anomalies close to the Chilean coast suggests that the SS assumption acceptably describes the Oligocene to middle Eocene Pacific-Farallon relative motions (Cande and Haxby, 1991). However, this approach brings to no subduction of the Farallon plate beneath most of the Chilean margin during the Paleocene. It is shown here that this scenario does not change substantially when considering the possibility of asymmetric spreading (AS) in the Farallon-Pacific rise. This suggests that another plate instead Farallon was subducted in southern South America during latest Cretaceous to Paleocene times. Below they are shown the main characteristics of the Cenozoic convergence between the Farallon (Nazca) and South American plates, and it is presented a brief discussion on the possibility of subduction of a third plate during the Paleocene. Ages were assigned according to the timescale of Cande and Kent (1995).

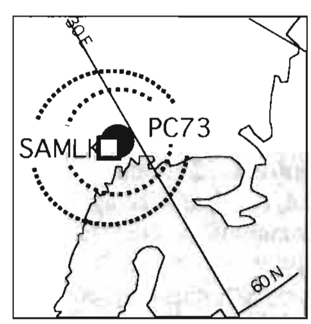

Figure 1:Tight fit between South American (SAMLK, Somoza and Tomlinson, 2002) and Pacific (PC73, Petronotis and Gordon, 1999) Late Cretaceous paleomagnetic poles when the former is transferred to Pacific plate coordinates.

The middle Eocene to present convergence history may be divided into two distinctive stages, the 26 Ma to present day interval and the 47 to 28 Ma interval, each one having a rather constant location of their Euler poles and a characteristic evolution of convergence rate. Figure 2 shows the latter as observed in a site at 22° S latitude (northern Chile). The parameters from the stages between 26 and 11 Ma given in Somoza (1998) are averaged into a single interval in Figure 2. This is in order to remark the main characteristics and the contrast with earlier times. The new information conducts to reconstructions that do not show major changes in convergence rate during middle Eocene-middle Oligocene times.

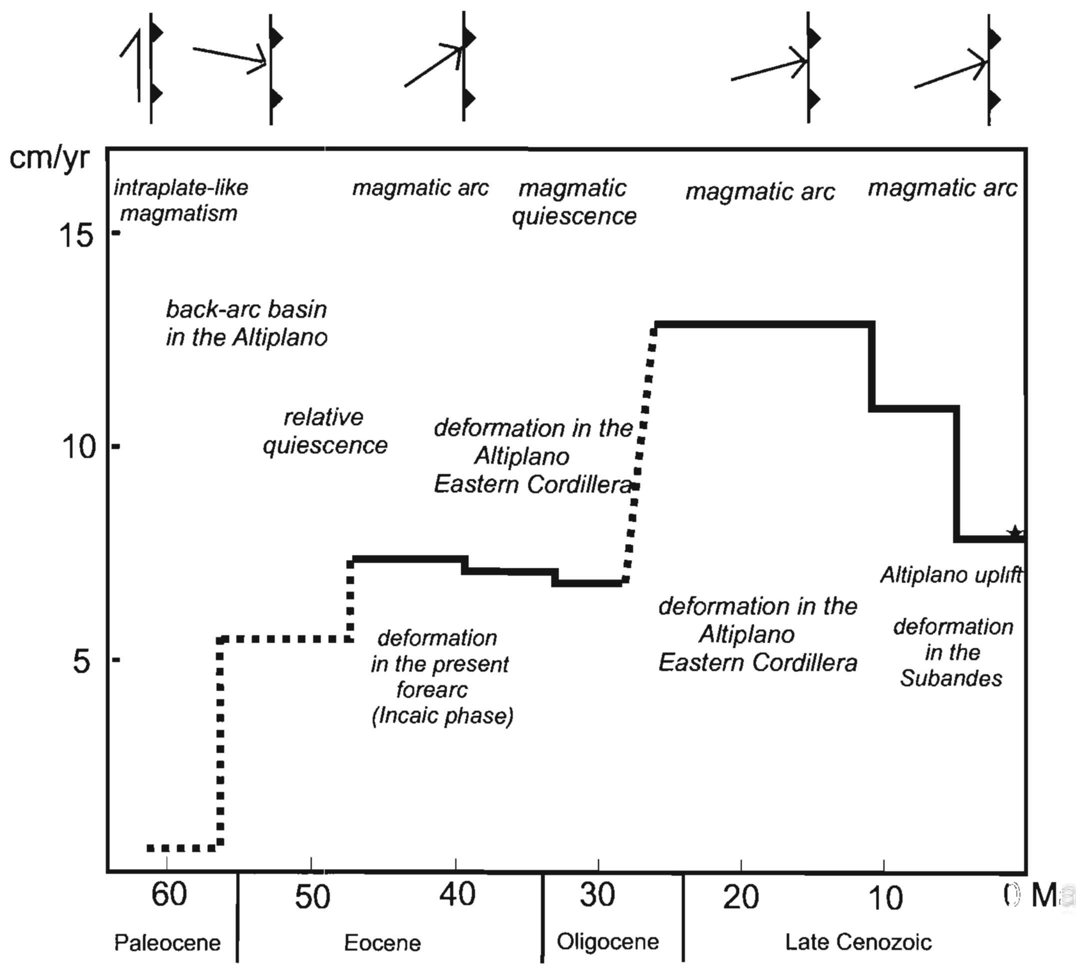

Figure 2. 22° South latitude, northern Chile. Average convergence rate for each of the intervals used to analyze plate kinematics in western South America, the older stages using the symmetric spreading assumption in the Pacific-Farallon rise. The path corresponding to the major change in convergence between ca 28 and 26 Ma is uncertain. Dotted lines in the older stages reflects the uncertainty derived from both changing convergence parameters and lack of data in the Nazca plate to fully check these changes (see main text for discussion). In the upper part of the diagram it is shown the local motion of the Nazca (Farallon) respect to a fixed South America for each time interval. The legends within the box point out the main characteristics of the Central Andean tectonic evolution, as observed at latitudes of northern Chile.

Figure 3a illustrates the rather constant direction of Farallon-South America convergence for the 47-28 Ma interval. Both the beginning and the end of this convergence stage are coeval with and likely related to major events such as the plate reorganization in the southeast Pacific during middle Eocene (Cande et al., 1982) and the break up of the Farallon plate in the late Oligocene.

The data suggest a more changing scenario from latest Cretaceous to early Eocene times (Fig. 3b, c). The 56-47 Ma reconstruction (SS in the Pacific-Farallon rise) points out a different convergence direction (Fig. 3b). The location of the corresponding stage pole does not allow subduction of the Farallon plate beneath southernmost

South America, suggesting that a different plate (likely the Aluk plate) was consumed there. An Eocene triple junction in southernmost South America could explain different characteristics of roughly coeval volcanic rocks in the region, with arc-like geochemical signatures north and intra-plate type basalts south of the probable position of the triple junction (Ramos and Key, 1992). Either or both ridge subduction and contrasting age of con-sumed oceanic lithosphere may have resulted in the development of slab windows in the region, as envisaged by Ramos and Kay (1992).

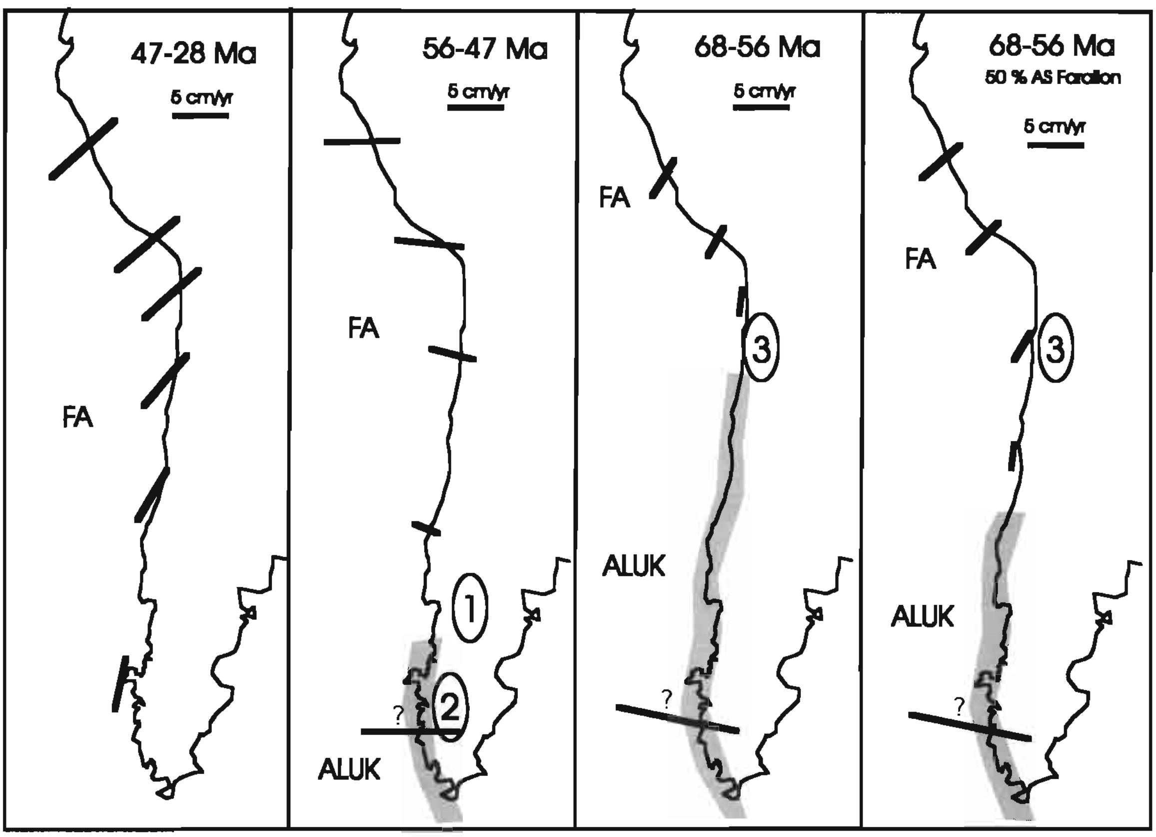

Figure 3. Direction of Farallon (FA)-South America convergence for each of the discussed intervals. a, b, and c after assuming symmetric spreading in the Pacific-Farallon rise, d considering 50% asymmetric spreading (favoring Farallon) in the same rise (see main text for discussion). Bars show convergence azimuth and rate according to scale. Shadow thick lines indicates regions where another plate (likely Aluk) instead Farallon would have been subducted. Speculated direction and rate of Aluk-southernmost South America convergence during the Paleocene is also shown. 1 indicates the region of arc-like Eocene volcanism in northern Paragonia (Rapela et al., 1988). 2 indicates the region of Eocene plateau basalts in southern Patagonia (e.g. Ramos and Kay, 1992). 3 indicates the region of Paleocene intraplate-like magmatism in northern Chile (Cornejo and Matthews, 2000). On the other hand, subduction related calk-alkaline magmas dominated in Perú during most of the time span considered in the figure (Soler and Bonhomme, 19902).

When considering SS in the Pacific-Farallon rise, the reconstructions suggest that the Farallon plate did not converge in most of the Chilean margin during latest Cretaceous – Paleocene times (Fig. 3c). Albeit a Farallon-South America plate boundary is permitted in northern Chile, the data suggest a highly oblique (to transcurrent) and very low relative motion there (Fig. 2, 3c). This scenario agrees with a rather extensional environment and the occurrence of intraplate-like volcanism during Paleocene (Cornejo and Matthews, 2000), further suggesting little influence of subduction in the magmas of northern Chile by those times.

The impact of asymmetric growth in the Pacific-Farallon pair on the Farallon-South America reconstructions could be estimated by assuming AS in the Pacific-Farallon ridge. The approach was achieved by arbitrarily adopting 30 and 50 % AS. Observations from the evolution of worldwide ridges (Müller et al., 1998) suggest that the higher of these values would be rather large for the timescale resolved by the reconstructions (ca 10 Myr.), then it would constitute a workable upper bound for the expected AS accumulated in a plate pair. If AS favored the Pacific plate (i.e. the Pacific grew faster than Farallon) the differences between the 68-56 Ma stage and younger times become even more dramatic. In contrast, 50% AS favoring the Farallon plate would support the possibility of a larger Farallon-South America plate boundary (Fig. 3d). Nevertheless, subduction of Farallon from central Chile southward is also questioned by this latter approach (Fig. 3d).

The above descriptions suggest that another plate instead Farallon was subducted beneath great part of Chile during the Paleocene. This independently supports the observations of Cande and Leslie (1986), who based on the plate boundary configuration in the southeast Pacific suggested that the Aluk plate could have been subducted in southern South America during the early Paleogene. Then, a southward moving triple junction environment, possibly alternating between trench-ridge-trench and trench-fault-trench types, would have migrated southward in the Chilean margin during the early Paleogene. Convergence would have been faster south of the triple junction. Poorly constrained estimates suggest a roughly E-W direction at a rate ~10 cm/yr in southernmost South America during Paleocene-early Eocene times (Fig. 3b, c).

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