Early Paleozoic orogenic belt of the Andes in southwestern South America: Result of Laurentia-Gondwana collision?

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ABSTRACT

The late Precambrian to early Paleozoic age rock units of the Pampean ranges, the Puna, and the North Patagonian massif of southwestern South America constitute the Famatinian orogenic belt. They are interpreted as an Ordovician collisional belt between the Occidentalia terrane and the Gondwana craton. They include mafic and ultramafic belts of Neoproterozoic to early Paleozoic age. An intense tectonothermal event resulted from the collision; syntectonic granitoids represent crustal melting. In that collision syntectonic to late-tectonic foreland basins developed. The recently proposed juxtaposition of Laurentia and East Antarctica-Australia in the Neoproterozoic raises the possibility that Laurentia and western South America were close together in the early Paleozoic, and therefore that the Famatinian belt resulted from Laurentia-Gondwana collision. Occidentalia, which is bordered by a Cambrian carbonate platform similar to that of eastern North America, may be a sliver detached from Laurentia during Late Ordovician time.

BACKGROUND

East of the Andean cordillera in southwestern South America, there is a mobile belt of rocks of late Precambrian to early to middle Paleozoic age along the western boundary of the Gondwana craton and separated from the Pacific margin of South America by the Occidentalia terrane, which also represents an ancient continental sliver. The belt is called the Famatinian orogen (Fig. 1).

The eastern craton, which assembled and stabilized during the late Precambrian, is covered by the Paleozoic Chaco-Parana sedimentary basin; a set of faults marks its western boundary. Major marine basins such as the Balcarce, Sierra de la Ventana, and Sierra Grande developed on the Rio de la Plata cratonic region to the south during and after the Famatinian orogeny. The Occidentalia terrane is underlain by Precambrian rocks unaffected, or only slightly affected, by Paleozoic deformation; thus, they differ markedly from the rocks of the Famatinian orogen. Another difference is the fact that Paleozoic granitoids are scarce. Exposures of the Occidentalia terrane are aligned along the western side of the Famatinian orogen from Arequipa, in southern Peru, to Patagonia (Fig. 1). Most of Occidentalia integrates the Arequipa-Belen-Antofalla, Mejillones, and Chilenia allochthonous continental blocks, the Precordillera terrane, and the western belt of Pampeanas terrane described by Ramos et al. (1986). Here we propose that these continental blocks and terranes are part of a sliver of eastern Laurentia, detached from it following collision with Gondwana in Ordovician time.

The eastern side of the basement of the Occidentalia terrane is partly covered by a Cambrian to Early Ordovician carbonate bank and by Ordovician to Devonian foreland sedimentary strata. Ramos et al. (1986) emphasized an oceanic basin to the west of the Precordilleran belt during Cambrian to Early Ordovician time; we propose that open sea faced the eastern Precordillera during that time. The Middle to Upper Ordovician deep-sea sedimentary rocks of the western Precordillera, and the Late Ordovician age ophiolites emplaced in it, suggest an interior rift basin. These rocks led to the orthodox model of an early Paleozoic ocean west of the Precordilleran belt.

Continent-continent collision has been invoked to explain the early Paleozoic age rocks of southwestern South America (e.g., Coira et al., 1982; Allmendinger et al., 1982; Ramos, 1988; Dalla Salda et al., 1991a, 1991b). A similar collisional model has been proposed for the mid-Paleozoic evolution of Andean Colombia, where an allochthonous Precambrian terrane exists west of a mobile belt with Cambrian to Silurian granitoids (Forero Suarez, 1990). Correlation of the Famatinian belt with the early Paleozoic age rocks of the intervening Peruvian-Bolivian Andes would imply that this collisional episode, though in Colombia assigned to Late Silurian to Early Devonian time, could have been of a continental scale.

Dalziel (1991) has advanced the hypothesis of a Neoproterozoic supercontinent in which the proto-Appalachian margin of Laurentia and the proto-Andean margin of Gondwana were conjugate (see also Bond et al., 1984). In this model Laurentia and South America were still closely juxtaposed in the Ordovician (Fig. 2). Here we propose the hypothesis that direct Laurentia-Gondwana collision could have been the principal cause of the Famatinian tectonic event (540–330 Ma; Aceñolaza and Toselli, 1976).

FAMATINIAN OROGEN

The basement of the Precordilleran belt (not exposed) in northwestern Argentina, which borders the Famatinian orogen to the west (Fig. 1), is covered by an early Paleozoic age carbonate platform that contains trilobites (*Olenellidae*) similar to those of eastern North America (see e.g., Bond et al., 1984; Ramos et al., 1986). The trilobite, conodont, and graptolite chronozones suggest that this platform was developing while granitoids were being emplaced along the western margin of the Gondwana craton in South America. The so-called G1 granitoids of the Famatinian orogen are pretectonic. They are dated as 580–540 Ma, have low $^{87}Sr/^{86}Sr$ initial ratios and tholeiitic affinities (Jezek et al., 1987; Rapela et al., 1990), and are interpreted to be precollisional and subduction related (e.g., the Cachi trondhjemites in the Pampean ranges; Gallisky and Miller, 1989).

During the Ordovician Famatinian tectonothermal climax (460–480 Ma) the crust was thickened by shortening, undergoing low- to medium-pressure, high-temperature metamorphism, resulting in migmatization and syntectonic granites (G2 granitoids; Rapela et al., 1990; Dalla Salda, 1991a, 1991b). The main deformational phase is characterized by north-northwest–trending tight to recumbent folds with a dominantly westward vergence, and mylonitic shear zones associated with overthrusting. Overall, the Famatinian orogen is characterized by a complex polyphase deformational structural style in which interference patterns and distinctive changes of structural domains are common (Dalla Salda, 1987). Different crustal levels were juxtaposed by thrusting and transcurrent faulting in the Puna (Allmendinger et al., 1982), the Pampean ranges (Toselli et al., 1989), and the North Patagonian massif (Dalla Salda et al., 1991a). Large-scale megafractures, some of which affected the lower crust and upper mantle, are present in the Famatinian orogen, trending both parallel or oblique to the strike. Narrow thrust belts described from Aconquija in the central Pampean ranges (Toselli et al., 1989) contain slices of the upper mantle and lower crust. Omarini et al. (1989) have pointed out that the lithosphere in northwestern Argentina comprises two contrasting zones: a western zone with a

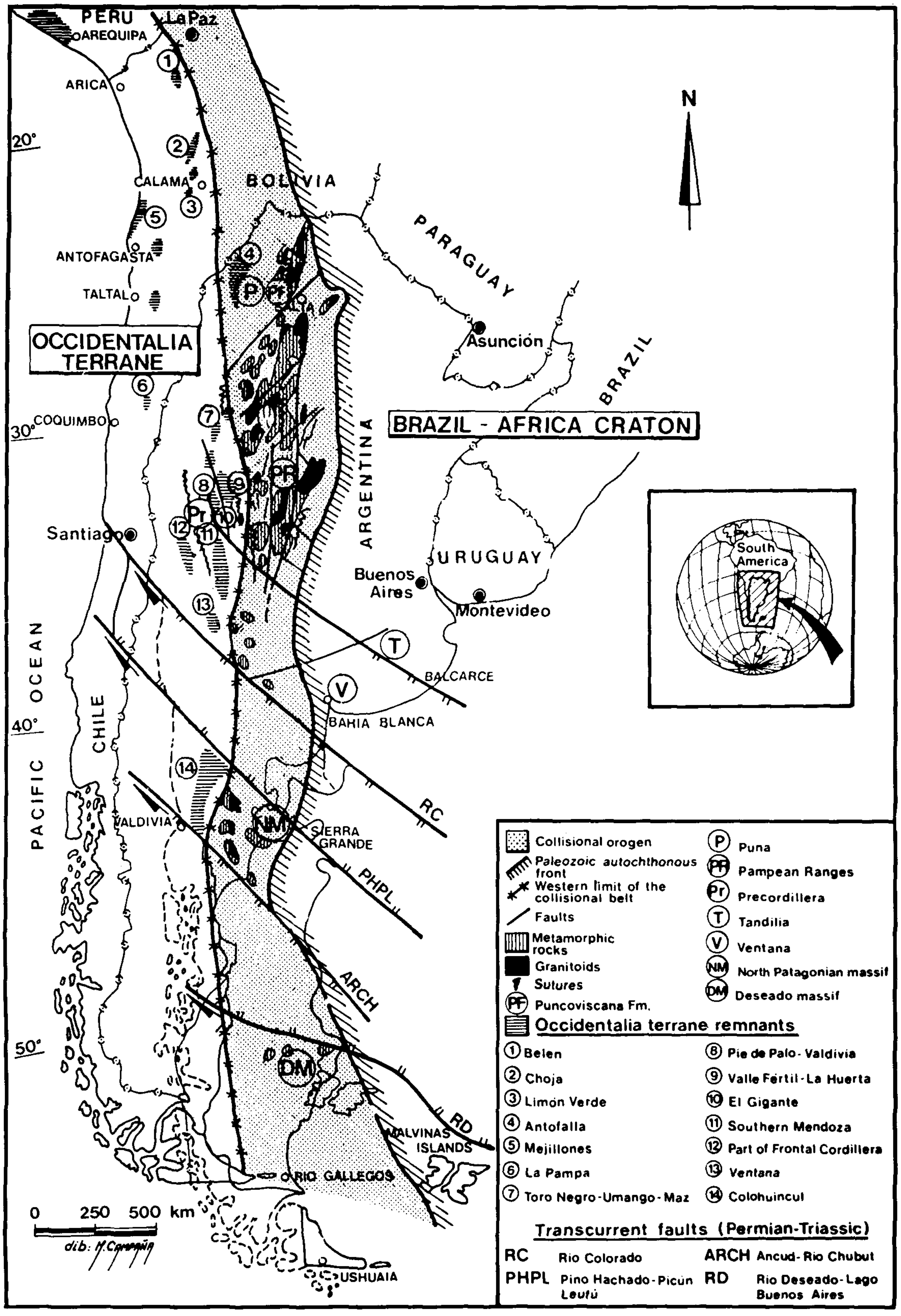

Figure 1. Early Paleozoic collisional orogenic belt (Famatinian orogen), showing geologic features referred to in text. Most megafractures in orogen are collisional, but some postdate collision (e.g., Permian-Triassic transcurrent system that offsets continuity of Famatinian orogenic belt).

thick and complex crust, and a Phanerozoic platform to the east of Salta city (Fig. 1).

Narrow, and usually short, lenticular deformed mafic and ultramafic rocks, dated as 800–400 Ma, representing remnants of ocean floor, lower crust, and upper mantle, define discontinuous sutures within the Famatinian orogen. They occur, for example at Pie de Palo, Valle Fertil, Virorco–Las Aguilas, Maz, Ancasti, and Fiambala in the Pampean ranges and in the Precordilleran belt (Fig. 1). The late Ordovician Precordilleran belt has been interpreted as an early stage of an oceanic rift, a transitional ridge segment, a back-arc basin, or some poorly defined setting in a fore-arc region (Ramos et al., 1986). We relate it to the rift-drift transition during Gondwana-Laurentia postcollision break-up.

Alkalic mafic volcanic rocks of the Puncoviscana Formation, an upper Precambrian to Lower Cambrian supracrustal unit of the northwestern Pampean ranges located along the western margin of the Gondwana craton, are interpreted as relicts of an intracontinental rifting, oceanic rift, or ocean floor (Coira et al., 1990). These rocks are here included as representing the rifting stage that predated the Neoproterozoic supercontinent break-up.

The granitoids of the Famatinian orogen may also indicate a continental collision orogenic environment: Cambrian subduction-related pretectonic, Ordovician syntectonic, and Silurian to Devonian late to postorogenic bodies. The granitic activity ends with subalkalic to alkalic lower Carboniferous rocks (Rapela et al., 1990). S-type rocks are usually associated with migmatitic areas. Damm and Pichowiak (1981) classified the Paleozoic plutons of northern Chile as S-type and suggested that their genesis was related to crustal thickening resulting from continental collision. The initial $^{87}Sr/^{86}Sr$ ratios within the Famatinian orogen are low (~0.704) in pretectonic rocks interpreted as subduction related, and mostly higher than 0.706 (some 0.710–0.715) in those associated with the collisional episode. As usual in collisional settings, volcanic rocks are scarce.

A low- to intermediate-pressure, high-temperature metamorphism characterizes most of the rocks in the Famatinian orogen. Migmatitic rocks with cordierite and andalusite have been described in the Pampean ranges (e.g., Willner, 1990). Higher pressure conditions are apparent locally, although some of these reflect unequilibrated precollisional events. Granulite facies rocks dated at ca. 900 Ma have been recorded at Sierra Chica in the southern Pampean ranges. Hence, as in the case of the Himalayas, many of the metamorphic rocks resulted from the reactivation and regeneration of older complexes.

Late-tectonic structures in the Famatinian orogen, as well as retrograde and contact metamorphism, were related to emplacement of late-tectonic and posttectonic granitoids in partially unstable crust.

LAURENTIA AND SOUTH AMERICA

The presence in the Precordilleran belt of northwest Argentina of early Paleozoic fossils similar to those in North America has been known for some time (see, e.g., Bond et al., 1984). This has mainly been interpreted to mean that the belt represents an exotic terrane accreted to the South American margin prior to the Mesozoic-Cenozoic Andean orogeny (Ramos et al., 1986). However, paleomagnetic data indicate that Laurentia could have been close to the proto-Andean margin of South America in the early Paleozoic (Fig. 2). The collisional nature of the Famatinian belt and the North American affinities of the fauna contained in the Cambrian carbonate platform along its western border therefore strongly suggest that direct Laurentia-Gondwana interaction was responsible for the Famatinian tectonic event during the Ordovician. Separation of Laurentia and South America is interpreted here to have followed the Early to Middle Ordovician regional metamorphism in the Famatinian belt. Pre-Silurian unconformities in both the Appalachian belt (Hatcher, 1989) and the Precordilleran belt of South America may reflect this event. Comparison of the lithostratigraphy and fauna of the carbonate platforms in the Precordilleran belt of southwestern South America and along the eastern

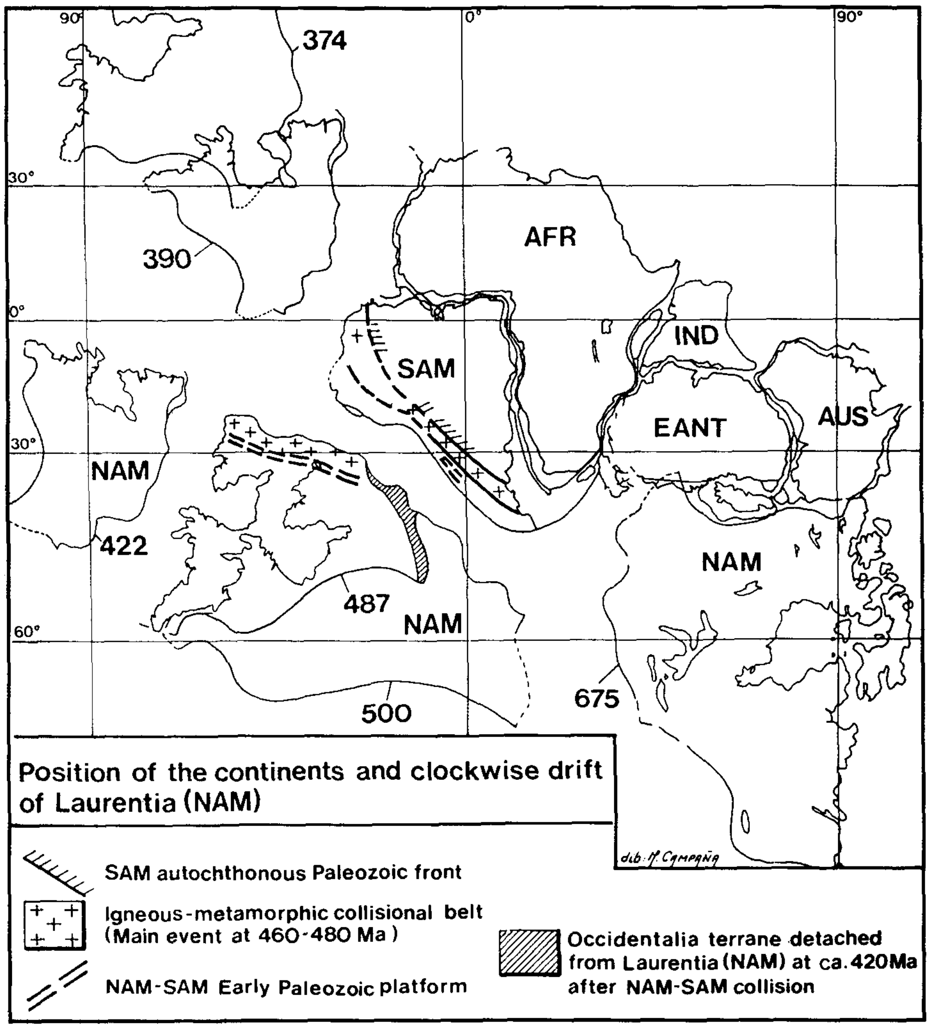

Figure 2. Position of North America (NAM) and South America (SAM) during late Precambrian-Paleozoic time (Dalziel, 1991). Present-day Africa (AFR) is fixed, and Gondwana is assembled according to sea-floor spreading data; relative positions of Gondwana and Laurentia are determined from paleomagnetic data. Occidentalia terrane is shown as possible sliver of Laurentia detached after collision. Diachroneity of events along North America–South America collisional front is probable. IND = India, EANT = East Antarctica, AUS = Australia.

margin of North America may reveal the exact provenance of the Occidentalia terrane.

CONCLUSIONS

The late Precambrian to mid-Paleozoic tectonic evolution of the Famatinian orogen and related sedimentary basins of southwestern South America is believed to have resulted from continent-continent collision. We suggest that the continent colliding with Gondwana was Laurentia. The history of the Famatinian orogen began during a latest Precambrian extensional event that can be related to the opening of southern Iapetus. The eastern trailing edge of Laurentia, on which a Cambrian to Early Ordovician carbonate bank formed, drifted away from South America. A subduction regime was established along the Gondwana craton margin during the Cambrian. Subsequently, a convergent regime between the Laurentia and Gondwana cratons resulted in Iapetus closure and, finally, Laurentia-Gondwana collision. The collision reached a climax during the Ordovician (ca. 460–480 Ma), producing a collisional orogenic belt with high-grade metamorphism, granitization, and mafic-ultramafic rock belts reflecting the suture. Subsequently, granitic plutons were emplaced (during the Silurian and Devonian) in an epizonal environment, and syncollisional to postcollisional foreland sedimentary basins evolved.

Taking into account the possible extension of the Paleozoic orogenic belt of southwestern South America into the Peruvian-Bolivian Andes and collisional aspects of the mid-Paleozoic belt in Colombia, the Famatinian tectonic event could be part of a diachronous continent-scale orogenic belt. The possibility that the Occidentalia terrane represents a continental sliver rifted from eastern North America following collision with South America offers new insights into the geotectonic evolution of both continents.

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