Did the Taconic Appalachians continue into southern South America?

Luis H. Dalla Salda
Centro de Investigaciones Geologicas, Universidad Nacional de La Plata, Calle 1, no. 644, 1900 La Plata, Argentina
Ian W. D. Dalziel
Institute for Geophysics, University of Texas, 8701 Mopac Boulevard, Austin, Texas 79759
Carlos A. Cingolani
Ricardo Varela
Centro de Investigaciones Geologicas, Universidad Nacional de La Plata, Calle 1, no. 644, 1900 La Plata, Argentina

ABSTRACT

The Appalachian Mountains, now terminating abruptly at the Gulf of Mexico coastal plain, may have formerly continued into southern South America. Rocks forming the basement of the Argentine Andes can be interpreted as remnants of an early Paleozoic orogen, the Famatinian belt, not unlike the Taconic Appalachians. Both orogens are bordered to the west (present coordinates) by lower Paleozoic carbonate platforms bearing the Olenellid trilobite fauna that is characteristic of Laurentia. Paleomagnetic and geologic data indicate that they could have formed as one continuous mountain chain, possibly extending into Antarctica, during Ordovician closure of an ocean basin ("southern" Iapetus) between Laurentia and Gondwana. The Taconic and Famatinian segments of the chain may have been truncated during Late Ordovician separation of Laurentia and Gondwana along the preexisting (late Neoproterozoic to Cambrian) rift system that initiated formation of the Ouachita embayment and the southern margin of North America.

SOUTHERN TERMINATION OF THE APPALACHIANS

The Appalachian mountain belt extends along the eastern seaboard of the North American Precambrian craton for more than 4000 km, from Newfoundland to Georgia (Fig. 1), where it is covered by Mesozoic and Cenozoic sedimentary strata of the Gulf of Mexico coastal plain. The mobile belt originated with a late Neoproterozoic to earliest Cambrian rift event that predated development of a Cambrian carbonate platform (Hoffman, 1989; Hatcher et al., 1989). Three main phases of regional dynamothermal metamorphism and granitic plutonism have long been recognized in the Appalachians: the Ordovician Taconic orogeny, the Devonian Acadian orogeny, and the late Paleozoic Alleghanian orogeny (Rodgers, 1970; Hatcher, 1989). The Alleghanian orogeny resulted from final collision of Laurentia with northwestern Africa, and it is best developed in the southern and central Appalachians. The effects of this collision are also recognizable in the Ouachita embayment (Fig. 1), which was not affected by the earlier compressional events (Hatcher et al., 1989). The Taconic belt, well developed immediately north of the coastal plain, is sharply truncated there. This constitutes a major problem of North American tectonics that has seldom been addressed.

SOUTH AMERICAN CONNECTION?

Reconstruction of Pangea prior to sea-floor spreading by using marine magnetic anomalies and fracture zones leaves no doubt that northwestern Africa must have collided with southeastern Laurentia in the terminal Alleghanian event of Appalachian orogenesis (Klitgord and Schouten, 1986). Southern Georgia, southern Alabama, and Florida are underlain by former African continental crust (Hatcher et al., 1989), detached during opening of the central Atlantic Ocean during the Mesozoic. Hence, following Wilson (1966), most geoscientists have assumed that northwestern Africa also formed the conjugate margin to eastern Laurentia during late Neoproterozoic rifting (e.g., see Hatcher, 1989). There is, however, no direct evidence of the juxtaposition of northwest Africa and southeastern Laurentia prior to the late Paleozoic.

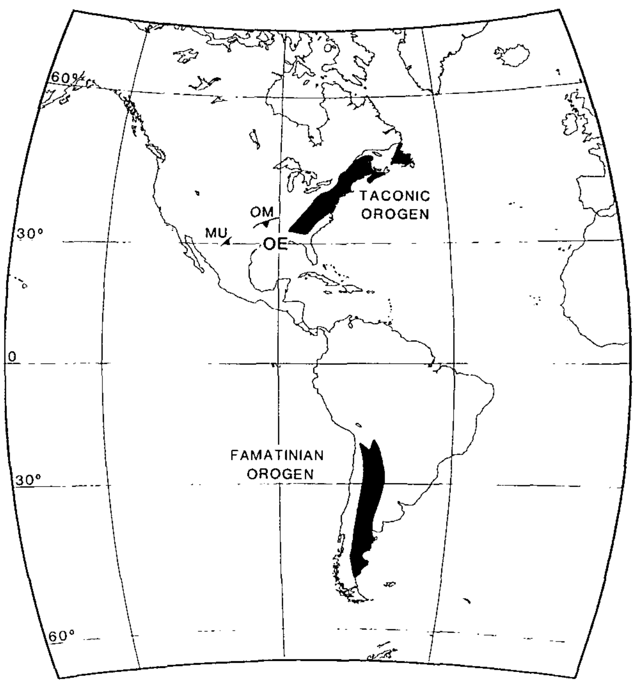

Figure 1. Present-day location of Taconic and Famatinian orogens. Barbed lines indicate late Paleozoic fold-thrust belt of Ouachita embayment (OE) exposed in Ouachita Mountains (OM) and Marathon uplift (MU).

A surprising similarity between the early Paleozoic stratigraphy and fauna of the northwestern Argentine Precordillera and those of eastern Laurentia has been recognized for some time (Borrello, 1971; Ross, 1975). It has been interpreted mostly in terms of the orogen-parallel displacement of tectonic slivers ("terranes") between the ancestral North American and South American continents (e.g., Ramos et al., 1986; Mena and Selles, 1989; Keppie, 1991). North America is usually positioned opposite northwestern Africa, as in most reconstructions based on paleomagnetic data (e.g., Trench et al., 1991). The suggestion of Moores (1991) that the Pacific margins of Laurentia and East Antarctica–Australia were juxtaposed in the late Neoproterozoic has opened up a fresh approach to pre-Mesozoic continental reconstruction. Amplifying Moores's hypothesis, Dalziel (1991) suggested that Laurentia could have originated between East Antarctica–Australia and South America, the Pacific Ocean basin having opened between Laurentia and East Antarctica–Australia during amalgamation of Gondwana, a thesis also developed by Hoffman (1991). Using paleomagnetic data to test the validity of this hypothesis, Dalziel presented a series of reconstructions demonstrating that Laurentia could have moved clockwise around Gondwana during the early to middle Paleozoic from a position near Antarctica. The reconstruction for 500 Ma (Dalziel, 1991, Fig. 2; also see Fig. 2), differing from more conventional ones (e.g., see Scotese and McKerrow, 1990) only in the paleomagnetically uncontrolled paleolongitudes selected, raises the possibility of an Ordovician collision between the eastern margin of Laurentia and the western margin of South America (present coordinates).

Dalla Salda et al. (1990) presented a collisional model to explain the evolution of upper Precambrian to middle Paleozoic rocks of the pre-Andean basement in southwestern South America that constitute the Famatinian orogen. Coupled with Dalziel's reconstruction for 500 Ma, this has led to the hypothesis of an Ordovician collisional event between Laurentia and the South American segment of Gondwana in order to explain both the Taconic event in the Appalachian orogen and the Famatinian event in southern South America (Dalla Salda et al., 1992). We suggest that the Famatinian orogen could represent the former continuation of the Taconic Appalachians, and that the Olenellid-bearing lower Paleozoic carbonate platform in southwestern South America is not a far-traveled terrane, but rather a fragment of Laurentia detached from the Ouachita embayment following Taconic-Famatinian collision with Gondwana.

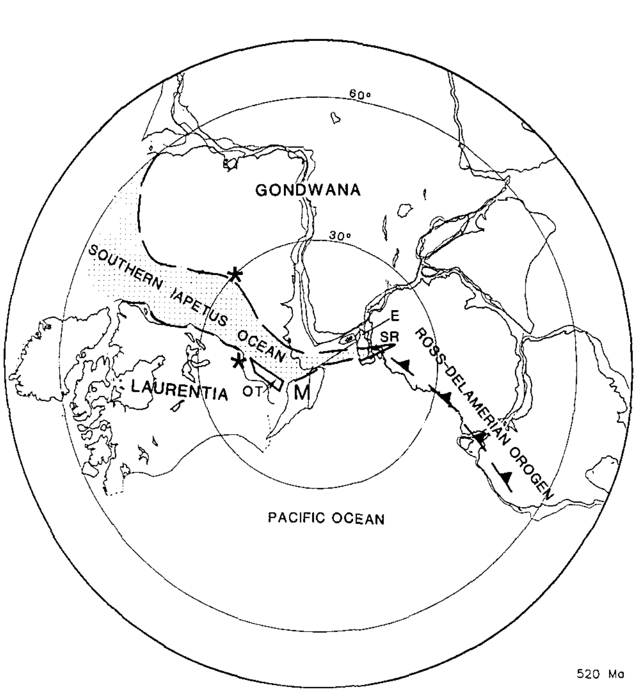

Figure 2. Reconstruction for Cambrian (ca. 520 Ma) showing "southern" Iapetus Ocean between Laurentia and Gondwana. North Africa was located over south pole in Early Ordovician time (see Dalziel, 1991, Fig. 2), and 30° and 60° small circles are shown here for scale only. Asterisks indicate truncated ends of Taconic and Famatinian belts (see Fig. 1), which are interpreted to have been coincident at time of Ordovician Laurentian-Gondwana collision (see Fig. 3) suggested by Dalla Salda et al. (1992). Occidentalia terrane of South America (OT) is restored to its proposed original location in Ouachita embayment of Laurentia; Mexico (M) is shown in its present-day position with reference to North American craton. E—Ellsworth-Whitmore mountains block (restored as in Dalziel and Grunow, 1992); SR—Shackleton Range of East Antarctica.

FAMATINIAN OROGEN

The pre-Andean basement of the entire southern part of South America is generally interpreted as a complex collage of cratonic blocks assembled between late Precambrian and late Paleozoic time (e.g., Ramos, 1988). On the eastern side of the high Andes in northwestern Argentina between lat 22° and 35°S, the basement is comparatively well exposed in the Pampean Ranges. In this region upper Precambrian and lower Paleozoic rocks along the rifted western edge of the Gondwana craton show the effects of intense polyphase ductile deformation, high-grade metamorphism, and syntectonic emplacement of peraluminous to metaluminous granitoids. Rb-Sr and K-Ar geochronometry indicate that the peak of this tectonic activity was reached during the Ordovician (480–460 Ma; Willner and Miller, 1982; Rapela et al., 1989). Following Aceñolaza and Toselli (1976), this is referred to as the Famatinian orogeny. The main metamorphism and syntectonic granitoid emplacement in the Taconic Appalachians and the Famatinian orogen were therefore broadly synchronous, the peak having been ca. 460 Ma in the Appalachians (Hatcher, 1972; Laird, 1988; Drake et al., 1989; Tucker and Robinson, 1990).

In the Precordillera of northwestern Argentina the Famatinian orogen is bounded to the west by a Cambrian marine platform characterized by the Ollenelid trilobite fauna of the North American "Pacific" realm (Walcott, 1889). The platform carbonates to the west of the Taconic orogen can be seen to rest directly on basement rocks of the continental cratonic nucleus (Hatcher et al., 1989), but in South America the base of the platform sequence is not exposed. However, outcrops of Precambrian crust along the western side of the Famatinian belt have been interpreted by Dalla Salda et al. (1991) to represent a long, narrow sliver of continental crust incorporating the Precordilleran carbonate platform, the Occidentalia terrane (Fig. 3). There is evidence of latest Precambrian to earliest Cambrian rifting prior to the spread of platform carbonates in the Early Cambrian (Bond et al., 1984; Rankin et al., 1989; Coira et al., 1990). Few reliable radiometric dates are available for the basement of the Occidentalia terrane, but there are several indications that it is broadly "Grenvillian" (1.3–1.0 Ga). The formation of continental crust in the northern Chilean Andes apparently started in the Mesoproterozoic (Baeza and Pichowiak, 1988). An Rb-Sr age of 1027 ±59 Ma has been obtained from a basement inlier in the westernmost Famatinian orogen (Varela and Dalla Salda, 1992), and a Grenvillian age for the basement of the Occidentalia terrane is also suggested by the presence of zircons yielding U-Pb ages of ca. 1.1 Ga in lower Paleozoic strata of the Precordillera (Loske, 1992).

The carbonates of the Precordillera that developed during the Cambrian and Early Ordovician were overwhelmed by sedimentation of black shales in interior basins during Arenigian-Llanvirnian time (Baldis et al., 1984). This is directly comparable to the Appalachians (Rodgers, 1970; Hatcher, 1989). Along the western margin of the Precordilleran platform, however, a marginal rift basin developed during Llandeilian-Caradocian time. Cuerda et al. (1985) considered the western Precordillera to represent part of a continental slope, and Ramos et al. (1986) interpreted it as a rifted continental margin with an ocean to the west. Superficially, this polarity seems to be the opposite to that of the western platform of the Taconic orogen. However, the early Paleozoic platform of the southern Appalachians deepened cratonward into the Reelfoot–Rough Creek–Rome trough rift system (Lowe, 1985; Arbenz, 1989; Fig. 3), and the eastern boundaries of both platforms are tectonically remobilized. Thus, direct correlation of the Precordilleran terrane with the Laurentian carbonate platform immediately to the west of the Taconic belt seems feasible; both are flanked by a developing mobile belt to the east and by a subsiding basin to the west.

Deformation, metamorphism, and the emplacement of granitoids that can be ascribed to the Famatinian orogeny have been recognized as far south as the North Patagonian and Deseado massifs (Dalla Salda et al., 1991; Fig. 3). Both the Taconic and Famatinian belts have a well-defined structural fabric and corresponding metamorphic zonation (Hall and Roberts, 1988; Dalla Salda et al., 1991). In both the Appalachians and the Famatinian belt, thrust planes affected the lower crust and upper mantle (Haworth et al., 1988; Dalla Salda et al., 1991). The dominant vergence in the Taconic orogen is westward, toward the craton, although easterly vergence at an early stage has been recognized (Hatcher et al., 1989). In the Famatinian orogen there is evidence of thrusting to both the east and the west; west-verging structures predominate in several zones (e.g., Baldis

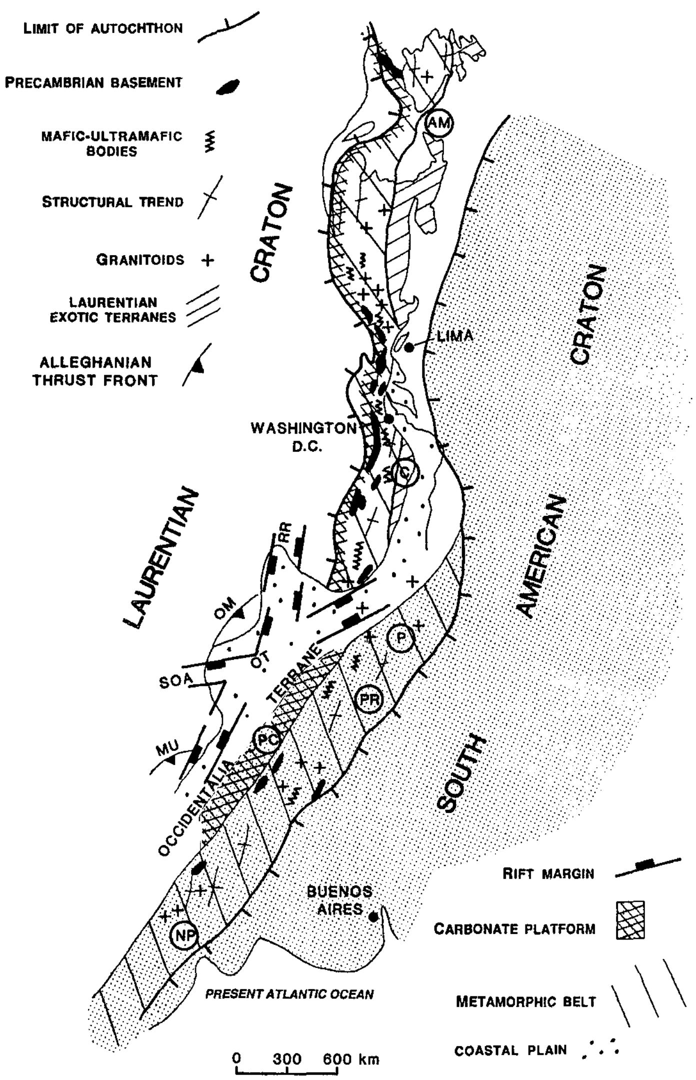

Figure 3. Reconstruction of Taconic-Famatinian orogenic belt as proposed for Middle Ordovician. Laurentia: AM—Avalon-Meguma terrane; C—Carolina terrane; MU—Marathon uplift; OM—Ouachita fold belt; OT—Ouachita trough; RR—Reelfoot rift; SOA—South Oklahoma aulacogen. South America: NP—North Patagonia massif; P—Puna; PC—Precordilleran belt; PR—Pampean Ranges.

et al., 1990). The relative age of east- and west-vergent structures is uncertain. There are narrow belts of deformed mafic to ultramafic rocks of late Precambrian to early Paleozoic age in both orogens (Hess, 1955; Rodgers, 1970; Drake et al., 1989; Dalla Salda et al., 1991).

TECTONIC DEVELOPMENT

There are uncertainties surrounding an intercontinental synthesis of the type presented herein. This is particularly true of two orogens that have histories as long and complex as those of the Appalachian and Andean belts subsequent to the Ordovician, and more so when one continent has been studied much more than the other. We attempt here to present a brief summary of the shared tectonic evolution that we envisage for the late Neoproterozoic to early Paleozoic margins of the Laurentian and South American continents.

Eastern Laurentia apparently remained close to South America during amalgamation of Gondwana and the opening of the Pacific Ocean basin, and the timing of suturing within Gondwana indicates that this must have taken place prior to the Cambrian (Dalziel, 1992). Rifting and seafloor spreading that generated the southern part of the Iapetus ocean basin between Laurentia and South America appear to have begun during the late Neoproterozoic or earliest Cambrian (Bond et al., 1984; Rankin et al., 1989; Dalla Salda et al., 1992) (Fig. 2). Following Dalla Salda et al. (1992), we suggest that collision between Laurentia and the South American segment of Gondwana during Ordovician time followed the opening of the "southern" Iapetus and was the main cause of the Taconic and Famatinian orogenies. Doubtless this would have been a process involving island arc–continent interaction and numerous other complexities such as those envisaged by the many workers who have studied the Taconic orogen. It would explain the presence of terranes of Gondwana affinities within the Appalachians (Hatcher et al., 1989; Fig. 3). In Figure 3 we show the two continents in positions such that the Taconic Appalachians continue into the Famatinian belt. The Famatinian belt can be traced as far south as Patagonia (Dalla Salda et al., 1992), and it is interesting that a basin at a high angle to the Transantarctic margin, and along strike from the Famatinian belt in our reconstruction, was inverted during the Ordovician in the Shackleton Range of Antarctica (Buggisch et al., 1990). Our suggestion that this deformation may have taken place at the extremity of Iapetus is tentative, because the Scotia arc–Weddell Sea area is a zone of extreme Mesozoic-Cenozoic tectonic complexity (Dalziel, 1989; Grunow et al., 1991).

With regard to the rift system that separated the Taconic and Famatinian parts of the mountain chain, we suggest that in South America it is represented partly by the western margin of the Precordilleran terrane. However, the northern termination of the Famatinian belt is obscured by the Mesozoic-Cenozoic Andean overprint. We suggest that in Laurentia the rift can be identified by the abrupt termination of the Taconic fold and thrust belt. The suture between the North American craton and the Tallahassee-Suwannee terrane, underlying the Florida peninsula (Horton et al., 1984), and the related Ouachita-Marathon deformation, are clearly the result of final collision of Laurentia with northwestern Africa during the late Paleozoic amalgamation of Pangea (Klitgord and Schouten, 1986; Hatcher et al., 1989). The abrupt offset in the Paleozoic margin of eastern Laurentia between the southern Appalachians and the Ouachitas is usually ascribed to an original offset in the Iapetus spreading ridge (Thomas, 1989). However, Lowe (1985, 1989) and Arbenz (1989) argued that the lower Paleozoic sediments in the Ouachita embayment may have been deposited in a narrow rift system, and that the real margin of the continent lay to the southeast, outboard of a microcontinent that was a continuation of the main Appalachian trend. We therefore suggest that the ancestral Gulf of Mexico margin originated with post–Taconic-Famatinian rifting of Laurentia from Gondwana along the lines of weakness represented by a preexisting (latest Precambrian) rift systems (Figs. 1 and 3). In this scenario the Precordilleran carbonate platform is the one distinctly Laurentian part of the continental fragment (the Occidentalia terrane of Dalla Salda et al. [1991, 1992]) that lay on the South American side of the final rift. Thus, the "oceanic" basin recognized by Ramos et al. (1986) to the west of the Precordilleran terrane in southern South America, on the basis of lower Paleozoic sedimentary facies and ophiolitic fragments, may have been the developing Ouachita embayment.

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