The early Paleozoic evolution of the Argentine Precordillera as a Laurentian rifted, drifted, and collided terrane: A geodynamic model: Discussion and Reply

Discussion

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In their interesting comparison of the early Paleozoic biostratigraphy of the Precordillera of northwest Argentina with that of the Laurentian craton, Astini et al. (1995) reached the same basic conclusion as did we and our colleagues (Dalla Salda et al., 1992a, 1992b; Dalziel et al., 1994). We all agree on the Appalachian affinities of the Precordilleran terrane and that the Ouachita embayment is the most likely point of origin. We also agree that the Precordillera docked against the Gondwana craton in mid-Ordovician time. This is in contrast to Torsvik et al. (1995), who suggested a Devonian transfer from Laurentia to South America, a timing incompatible with the Upper Ordovician glacial deposits of the Precordillera as well as with the timing of Famatinian orogenesis (Dalziel, 1993; Dalziel et al., 1994).

We disagree, however, with two aspects of the "geodynamic model" put forward by Astini et al. (1995). First, following Thomas (1991) they suggested that the Precordillera was initially separated from the Laurentian craton by a "Ouachita mid-ocean ridge" near the Precambrian-Cambrian boundary (ca. 540 Ma), at the same time as along the Appalachian margin as a whole (Astini et al., 1995, Fig. 14A). Yet sedimentologic and thermal subsidence studies indicate that rift-drift transition in the Ouachita embayment was later than along the Appalachian margin proper (cf. subsidence curves 15 and 18 in Bond and Kominz, 1991). Astini et al. also stated (p. 268) that "polarity trends in the Precordilleran terrane are opposite to those of the Appalachians," thereby ignoring the presence of the latest Precambrian to early Paleozoic Rome-Reelfoot rift system west of the Appalachians (see Dalla Salda et al., 1992, Fig. 3). We contend that the Precordillera was not separated from the Laurentian craton by an active spreading ridge until after collision with Gondwana in the mid-Ordovician.

The second point concerns the relative positions of Laurentia and Gondwana during the Ordovician Period as the Precordillera approached South America. The whole point of the model put forward by Dalla Salda et al. (1992a, 1992b) and amplified by Dalziel et al. (1994) is that the paleomagnetic data allow either the traditional separation of Laurentia and present-day northwest Africa by an ocean 4500 km in width (the "archetypal paleogeographic scenario" of Torsvik et al., 1995, p. 284 and Figs. 11a–11c) or else, as demonstrated by Dalziel (1991, Fig. 2), a "tight fit" of the proto-Appalachian margin of Laurentia and the proto-Andean margin of South America (the "alternative paleogeographic approach" of Torsvik et al., 1995, p. 284 and Figs. 11d–11f). It is not clear what control Astini et al. used in the reconstruction of their Fig. 14, which illustrates their model. They neglected to state the projection and the paleomagnetic pole or poles used. The small circles of latitude shown look like those for Laurentia, but, as demonstrated by both Figure 3 of Dalziel et al. (1994) and Figure 11 of Torsvik et al. (1995), existing paleomagnetic data for mid-Ordovician times do not permit placement of the central part of the Appalachian margin opposite the Peruvian margin of South America, separated by 3000 km of oceanic lithosphere, as in Astini et al., Fig. 14C. This point is supported by new data from Antarctica (Grunow, 1995).

Thus, either Laurentia and northwest Argentina were far more widely separated in the mid-Ordovician than is depicted in the model of Astini et al. (1995), or else they were much closer. If they were in the "archetypal" position, it would have been impossible for the Precordillera to have separated from Laurentia and converged on the proto-Andean margin of Gondwana in the time interval permitted by the analysis of Astini et al., below the uniformitarian Mesozoic-Cenozoic plate tectonics "speed limit." For the reasons stated in Dalla Salda et al. (1992a, 1992b) and Dalziel et al. (1994), we suggest that the two continents collided and subsequently separated along the lines of the pre-existing Ouachita embayment fault system, leaving the Precordillera as an exotic terrane within South America prior to the docking of Chilenia. In this scenario the Precordillera is a tracer, like the Cambrian-Ordovician platform deposits of the Hebridean craton in northwest Scotland (Dalziel, 1993), testifying to the former tectonic interaction of two now widely separated continents.

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Reply

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We welcome discussion by Dalziel and Dalla Salda on our recent paper in the Bulletin and hope that it clarifies some confused issues related to our Argentine Precordillera rifting and drifting hypothesis.

In their discussion, Dalziel and Dalla Salda pointed out that we both reached the same basic conclusion on the Appalachian affinities of the Precordillera and also agreed on a mid-Ordovician docking of the Precordillera against Gondwana, although they modified the timing from their previous papers. These are two very general conclusions that have been previously suggested since the breakup hypothesis of Bond et al. (1984). Until recently, there was no firm geologic evidence in favor of this hypothesis, and, due to the absence of paleomagnetic data coming from the Precordilleran terrane, any reconstruction of Precordilleran history had to account for geological observations. Our thoughts are based not only on biostratigraphy and biogeography, but also on basic sedimentology, stratigraphy, and geology of the Precordillera and surrounding regions (Astini et al., 1995). Despite the above remarked similarities, there is a fundamental difference between our models. In Dalla Salda et al. (1992a, 1992b, 1993), Dalziel (1992, 1993), and Dalziel et al. (1994), the Precordillera is considered part of an extensive continental sliver (the Occidentalia terrane) and believed to represent the western foreland of an early Paleozoic collisional orogen (the Famatinian belt), whereas in our paper the Precordillera is considered an uppermost Cambrian to lowermost Ordovician Appalachian derived terrane. In Dalla Salda and Dalziel's view, the Precordilleran carbonate bank would be part of the interior of the Laurentian craton, rifted from the Ouachitan embayment after the collision with South America (western Gondwana margin) during the Taconic-Ocloyic orogeny. For this reason, Dalziel (1993) considered the Precordillera as a tectonic tracer of one of the several continent-continent collisions between Laurentia and Gondwana in Laurentia's journey along the proto-Andean margin. Conversely, we visualize the Precordillera as an independent microcontinent, and, if accepting the SWEAT hypothesis, it should have rifted and departed Laurentia after the late Neoproterozoic supercontinent breakup. For this reason, in our view the Precordillera should not be considered as a tectonic tracer, but as a block exotic to South America. The strongest evidence for considering the Precordillera as an independent block comes from the faunal endemism developed in the Precordillera since the Early Ordovician and its connections with the intra-Iapetus Celtic Province and Baltic Province during the same period of time (Herrera and Benedetto, 1991; Benedetto, 1993; Astini et al., 1995; Benedetto et al., 1995; Vaccari, 1995; Baldis, 1995), as well as from the apparently different wandering paths of the Precordillera, Gondwana, and Laurentia based on lithological indicators of climate (Astini, 1995a).

With respect to the first aspect questioned by Dalziel and Dalla Salda, we are well aware of the differences in timing between the older Blue Ridge rift/mid-Iapetus ridge (rifting ends at earliest Cambrian) and that of the younger Ouachita rift (rifting ends at middle Late Cambrian) depicted by Thomas (1989, 1991). In our Figures 11a and 11b we attempted to show the westward shift in crustal extension (transferred along the Alabama-Oklahoma transform) that occurred during the Early Cambrian, which initiated Ouachitan rifting and the subsequent separation of the Precordilleran terrane in the Late Cambrian. The strong similarities between the recently discovered Lower Cambrian evaporite-clastic-carbonate successions in the Argentine Precordillera (Astini and Vaccari, in press) and those in the subsurface of the southern Appalachians (Raymond, 1991), and in the Birmingham graben (Thomas, 1991), suggest a shared evolution along the rifted margin of the Ouachita embayment, from where the Precordillera originated at an asymmetric (conjugate-pair) rift. The Rome–Rough Creek–Mississippi Valley graben system constitutes the northern extension of the Ouachita rift, which failed to open a new ocean (Thomas, 1991). The polarity of the Argentine Precordillera present coordinates is opposite to that of the Ouachita rifted margin, as well as that generally developed in the Appalachians, but the rift stratigraphy resembles that preserved in the Rome–Rough Creek–Mississippi Valley–Birmingham graben system, suggesting its proximity and relative position toward the southeast. The existence of Middle Cambrian outer-shelf carbonate blocks in the western tectofacies of the Precordilleran terrane (Vaccari and Bordonaro, 1993; Benedetto and Vaccari, 1992; Astini, 1992) is compelling evidence that slope facies had developed by then in the Precordillera, clearly indicating separation. According to trilobite cluster analysis (Vaccari, 1994), however, separation of the Precordillera and the southern Appalachians was not complete until the Late Cambrian, when an effective barrier prevented fluent exchange of benthic faunas between the Argentine Precordillera and Laurentia. This evidence shows that the Precordillera separated from Laurentia during Late Cambrian time, much before the suggested collision with Gondwana, and not later, as suggested by Dalziel et al. (1994).

Surprisingly, the first sentence of the second point raised by Dalziel and Dalla Salda supports our suggestion for the independence of the Precordillera when considering its approach to South America. Neither of the two basic coincidences outlined at the beginning of Dalziel and Dalla Salda's comment favors, either the traditional or the alternative (see Torsvik et al., 1995) paleogeographic scenarios in absence of new paleomagnetic data. By contrast, the only published Precordilleran paleomagnetic data (Rapalini and Tarling, 1993) suggest that the Precordillera had an intermediate position between the 4500 km that separated Laurentia and present-day northwest Africa in the archetypal scenario, and the tight fit (less than 500 km) of the proto-Appalachian and the proto-Andean margins in the alternative one. We do not disregard Moores's (1991) and Dalziel's (1991) SWEAT hypothesis, although the "details of the timing of rifting and drifting and of the exact original configuration of the continents remain to be worked out," as cited by both authors in a discussion with Boucot (1992; Moores and Dalziel, 1992). For this reason, we slightly modified the traditional scenario, which fits better with our paleobiogeographic data (see also Herrera and Benedetto, 1991) and has stronger geological support (Huff et al., 1995; Wright et al., 1995; Williams and Harper, 1995; van der Pluijm et al., in press). Nonetheless, our model was basically constructed as independent of adopting one or the other polar wandering path for the intervening continents. We appreciate Dalziel and Dalla Salda's highlighting of the apparent mistake in our Figure 14. Unfortunately, we do not have PLATES software and do not know Grunow's (in press) paper, but we feel that paleogeographic maps should be done on a much larger database than that coming from paleomagnetism. For this reason, we did not use the term *paleomagnetic reconstruction* but *paleogeographic reconstruction.*

In regards to the spreading rate objected to by Dalziel and Dalla Salda, even considering the archetypal position and assuming a 10 cm/yr drifting rate, it would be enough to cover the distance traveled by the Precordillera to converge on the proto-Andean margin of Gondwana during the time interval 510–465 Ma (approximately Early Ordovician). This is far below the uniformitarian Mesozoic-Cenozoic plate tectonics "speed limit" and considerably lower than that assumed by Meert et al. (1993, 1994) and also indicated by Dalziel et al. (1994) for the Vendian–Early Cambrian interval.

In view of the Dalziel and Dalla Salda model, in which the Precordillera remained attached to Laurentia until its separation from Gondwana, it is difficult to explain the paleobiogeographic development of the Precordillera, particularly the endemism developed during the Early Ordovician (during its travel) and the presence of Baltic and Celtic intra-Iapetus brachiopods. It is difficult to explain several well-founded observations related to the approach of the Precordillera to Gondwana, such as the diachronous foundering of the carbonate bank indicating the development of a collisional foredeep (Astini, 1995b) and the recent discovery of early Llanvirn K-bentonites (Kolata et al., 1995) related to its collision, in which the Famatinan ranges seem to be the counterpart Preliminary work by Huff et al. (1995) indicates that these are not related to Appalachian bentonites and confirms that the Precordillera must have departed Laurentia before the Middle Ordovician. We are not certain that the alternative paleomagnetic reconstruction does not violate faunal, climatic, and structural data (cf. Dalziel et al., 1994). In fact, the first two factors do not support this hypothesis, but do support the behavior of the Precordillera as an independent drifting terrane for at least the Early Ordovician. The somewhat colder-water faunas and climate-sensitive facies of the Middle Ordovician rocks in the Precordillera contrast with warmer-water faunas and facies in the Appalachians, suggesting also the existence of a large separation between the Precordillera and Laurentia at that time.

The point we tried to make in our paper is that the Precordillera initiated rifting during the Early Cambrian, separated from Laurentia during the latest Cambrian, and would have drifted during the Early Ordovician, allowing the development of an increasing endemic fauna during the Early-Middle Ordovician before its accretion to Gondwana. This was the intended contribution of our paper, in addition to certain details about where and how the rifting, drifting, and collision would have happened.

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