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

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ABSTRACT

Paleontologic and stratigraphic evidence points to the early Paleozoic Precordilleran terrane of western Argentina as being the conjugate rift pair of the Appalachians. Stratigraphic similarities of the Cambrian and early Arenig carbonate series and very strong affinities among trilobite, conodont, and brachiopod faunas show their close relationship. The most probable provenance areas are the Appalachian-Ouachita rifted margin and the Newfoundland Appalachians, although the former fits better with geometric and drifting paths suggested by faunal affinities. Increasing Celtic and Baltic brachiopod genera and divergent stratigraphy since the Arenig indicate the drifting of the Precordilleran terrane. Collisional foredeeps developed on collapsed former platform carbonates as flexural subsidence progressed. The collision of the Precordillera with western Gondwana occurred during the mid-Llanvirn to Llandeilo. A magmatic arc related to eastward subduction (present coordinates) was active in the Famatina Range east of the Precordillera. This region of Celtic affinity shows faunal exchange with the Precordilleran terrane since the late Arenig and may represent accreted intra-Iapetus volcanic island-arc complexes. The rifting and drifting stages are consistent with paleoclimatic and paleomagnetic data that show the migration of the Precordilleran terrane from periequatorial to peripolar latitudes between the Cambrian and latest Ordovician.

The deep ocean to the west of the Precordillera started to close by the Late Ordovician with the eastward drift of the Chilenian terrane. Absence of volcanic or pyroclastic arc-derived rocks in the Precordillera indicate west-dipping subduction. As Chilenia approached the continental margin, a new forebulge was established on the former collided Precordilleran terrane, developing an erosional unconformity in central Precordillera (Talacasto-Tambolar arch).

A Gondwanic signature was fully developed by the Middle Silurian when the Malvinokaffric *Clarkeia* Fauna flourished. Before then, the Late Ordovician glacial record and associated *Hirnantia* Fauna were the first clear tie to Gondwana. During the Silurian the marginal basin behaved as a foreland, with lithosphere rheology and eustasy governing the sequence stratigraphy. Wrench faulting along its eastern boundary displaced the Precordillera toward the south. Continued shortening during closure with the Chilenian terrane in the mid-Devonian produced thrust loading of the basin and generated a thick graywacke succession. Final accretion of Chilenia (Late Devonian) generated a regional angular unconformity between the lower and upper Paleozoic. New eastward subduction was initiated west of the accreted Chilenian terrane during the Late Permian–Triassic as indicated by the Choiyoi volcanic complex, which presently outcrops in the Frontal Cordillera.

INTRODUCTION

Numerous allochthonous terranes have collided against the Gondwana margin during the Paleozoic (Ben Avraham et al., 1981; Jordan and Gardeweg, 1989; Mpodozis and Ramos, 1989). In particular, the Precordilleran basin of western Argentina is considered to have had a somewhat controversial collisional history (compare Ramos et al., 1986; Keppie, 1991; Baldis, 1990; González Bonorino and González Bonorino, 1991; Loske, 1992, 1993).

Since the proposal of Bond et al. (1984), wherein the early Paleozoic carbonate platform of the Argentine Precordillera was considered to be attached to the Appalachian margin on the basis of their similar tectonic subsidence histories, several authors have discussed the tectonic evolution and paleogeography of this region. This paper uses new stratigraphic and faunal evidence derived from the Precordillera and surrounding geologic provinces to support the hypothesis of its origin as a conjugate rift pair of the Laurentian margin, allowing a revaluation of the early and middle Paleozoic history of the Precordilleran basin.

Ramos et al. (1986) first recognized the stratigraphic similarities between the New England Appalachians and the Argentine Precordillera, suggesting their adjacent position during the early Paleozoic. These authors also recognized two different terranes in the geodynamic history of the Precordilleran mountain belt during the Paleozoic: the Precordilleran and the Chilenian terranes. Dalziel (1991, 1992a, 1992b) and Moores (1991) have recently outlined a paleogeographic model in which the eastern Laurentian and proto-Andean margins are interpreted as being conjugate. Later papers by Dalla Salda et al. (1992a, 1992b) went even further, suggesting a Late Ordovician collision between South America and Laurentia to explain both the Taconic orogeny in the Appalachians and the Famatinian orogeny in Precordillera. In a later version, Dalziel et al. (1994) modified the collision timing to Middle Ordovician (Caradocian), suggesting a fast drifting between Laurentia and Gondwana to explain the Late Ordovician Gondwanic glacial deposits in the Precordillera.

Dalla Salda et al. (1992a, 1992b) suggested that the early Paleozoic metamorphic

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event and associated igneous rocks of the Famatinian belt resulted from the collision between Occidentalia (a sliver of Laurentia) and Gondwana. Hence, the carbonate platform of the Precordillera represents the southward continuation of the pre-Taconian Appalachians, which was disrupted during the early drifting stage of Laurentia. According to this hypothesis, the oceanic basin recognized by Ramos et al. (1986) to the west of the Precordilleran terrane represents a later interior rift basin or a back-arc basin (Loske, 1992). Paleontological data presented by Benedetto (1985) and Herrera and Benedetto (1991), however, do not support continuity of the South American and Laurentian margins. Neuman and Harper (1992) stated that, although the location of the Precordilleran terrane during the Early Ordovician remains unknown, it could be a fragment detached from the eastern Laurentian margin during its travel along the west side of South America, as was suggested by Dalziel (1991).

On the basis of brachiopod faunas, Benedetto (1993) suggested two alternative models consistent with the paleontological data: the Precordillera could either (1) have been a microcontinent that rifted from eastern Laurentia in the Late Proterozoic or Early Cambrian and moved from low to high latitudes during the Ordovician, or (2) have developed on the Gondwana continental margin and was the supercontinent that drifted intact away from eastern Laurentia. In the former, the Precordilleran terrane would have collided with Gondwana during the Middle Ordovician prior to Late Devonian accretion of the Chilenian terrane suggested by Ramos et al. (1984, 1986).

The purpose of this paper is to present a new model for the rifting, drifting, and collision of the Precordillera with the Gondwana margin that fits the most recent stratigraphic and paleontologic data (e.g., Benedetto and Astini, 1993; Astini and Benedetto, 1993; Vaccari, 1994). Several lines of evidence presented here indicate that the Precordilleran terrane and the eastern North American margins were not adjacent but represent a conjugate rift pair (opposite polarities) as originally suggested by Bond et al. (1984), and that the most probable pre-rift location was opposite to the Ouachita rifted margin. According to our evidence, both the Precordilleran and Chilenian terranes were accreted to Gondwana during the early Paleozoic (cf. Ramos et al., 1984, 1986), with the latter being responsible for the general paleogeographic rearrangement of the basin after the Devonian. Prior to the collision of the Precordilleran terrane, accretion of island-arc complexes (Famatina terrane) probably took place. An alternative plate tectonic interpretation for the accretion of Chilenian and the existing Grenvillian rocks to the east of Precordillera (western Sierras Pampeanas) is also discussed.

GEOLOGICAL SETTING AND BOUNDARIES OF THE PRECORDILLERA

The Precordillera is a thin-skinned thrust belt that forms the "foothills" of the Andean mountain belt between lat 29°S and 33°S (Fig. 1). Its main characteristic is the thick succession of lower Paleozoic rocks and the absence of volcanic or pyroclastic deposits, except for Ordovician pillow lavas and mafic-ultramafic sills located along the western edge of the belt (western tectofacies sensu Astini, 1988, 1991a).

Four to six major west-dipping Cenozoic thrusts account for 65%–70% of the total Andean shortening in the Precordillera (90–95 km according to Allmendinger et al., 1990). According to morphostructural and stratigraphic features, it can be divided into western, central, and eastern Precordillera (Ortiz and Zambrano, 1981) (Figs. 2 and 3). Complete summaries of the Paleozoic stratigraphy of the Precordilleran basin were presented in Baldis et al. (1982, 1984) and Ramos et al. (1986). The Cambro–Ordovician limestones serve as décollements for most of the major thrusts (Baldis and Chebli, 1969). Crystalline basement rocks are nowhere exposed in the Precordillera, so that the nature of its basement is virtually unknown, although xenoliths of metamorphic rocks in the Miocene andesites (Leveratto, 1968; Ramos et al., 1986) were recently interpreted by Abbruzzi et al. (1993) as basement rocks of Grenville affinity.

The intense Neogene to Quaternary deformation in the Precordillera is superposed on the older Famatinian orogenic cycle (Aceñolaza and Toselli, 1976), which includes the Ocloyic and Chanic orogenic events. Evidence for the Ocloyic orogeny (Late Ordovician) is mainly sedimentological and appears toward either the eastern or the western margins of the Precordillera. In the central Precordillera, this event was responsible for the erosional unconformity between Ordovician and Silurian units (Rolleri 1947; Astini, 1991a, 1992a). The Chanic orogeny (Late Devonian) was particularly important in developing a mountain belt that changed the paleogeography of the basin ("Proto-Precordillera" of Amos and Rolleri, 1965; Rolleri and Baldis, 1967). Scattered Early Carboniferous intrusive bodies with a wide compositional range (granitic to basaltic) have been mapped in the western Precordillera and in the adjacent Frontal Cordillera (Caminos et al., 1982; Ribba et al., 1988; Sessarego et al., 1990), and have been considered either as a Chanic (360–350 Ma) postorogenic magmatism (Llambías and Caminos, 1987; Sessarego et al., 1990) or as an early Hercynian magmatic arc related to convergence of the Arequipa massif and Gondwana (López Gamundí and Rossello, 1993). Late Carboniferous and Permian strata everywhere unconformably overlie deformed lower Paleozoic rocks.

To the north, the Precordilleran platform carbonates overlap in latitude with the early Paleozoic metasedimentary and sedimentary rocks and volcanics of the Famatina Range (Fig. 1). To the east, the Bermejo Basin, an 8-km-wide alluvial valley, hides the apparent boundary between the Sierras Pampeanas (Valle Fértil–Pie de Palo Ranges) and the Precordillera (Fig. 1). The relationships between the Precordillera and the Famatina Range, as well as with the Sierras Pampeanas basement, have been poorly understood. To the west, the Uspallata-Calingasta-Iglesia Valley separates the Precordillera from the Frontal Range (Fig. 1). Neogene and early Quaternary deposits fill in this valley, which was recently interpreted as an Andean piggyback basin (Beer et al., 1990). According to Ramos et al., (1984, 1986), this Cenozoic basin overlaps the boundary between the Chilenian and Precordilleran terranes. The southern extension of the Precordillera is rather unknown because of the regional plunge in that direction and Mesozoic cover, but scattered Ordovician limestones crop out as far as lat 35°S, ~180 km south of Mendoza (Baldis and Blasco, 1973). Limestone outcrops in La Pampa Province (some 600 km south) can also be related to the Precordilleran terrane.

PROS AND CONS OF SUSPECT TERRANES IN THE PRECORDILLERA

Data supporting the hypothesis of allochthonous terranes are based mainly on (1) the lack of continuity of stratigraphic units in western Argentina; (2) the existence of an intensely deformed zone between the east-

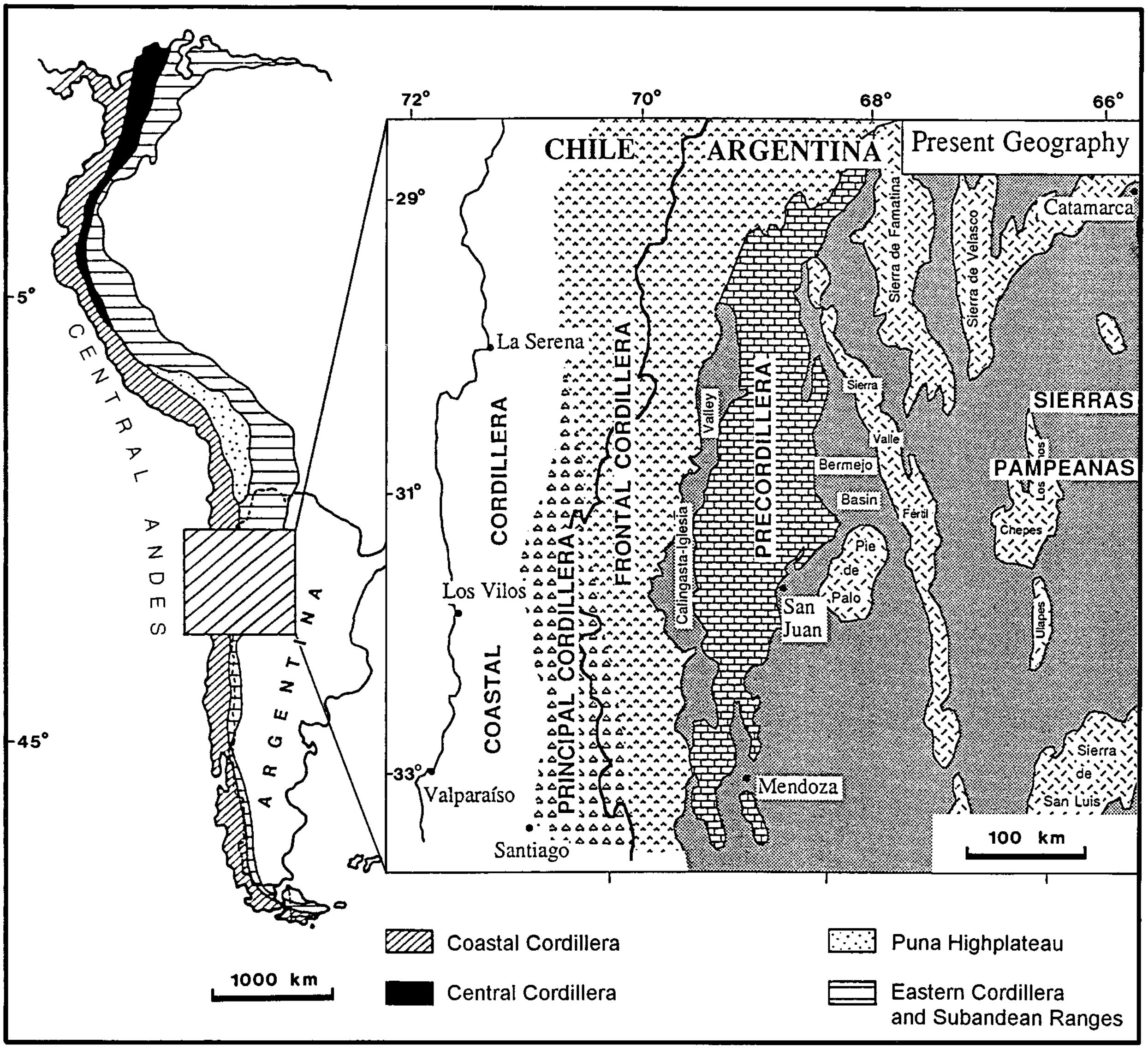


Figure 1. Major geologic and physiographic subdivisions of the Andes of South America (after Gansser, 1975) and morphotectonic elements of the central Andes between lat. 28°30′S and 33°30′S (after Jordan et al., 1983; Ramos et al., 1986).

ern Precordillera and the Pampeanas crystalline basement (eastern boundary of the Precordilleran basin), interpreted as a mélange and related to a continental fracture zone; (3) the existence of Paleozoic plutonism far inside the Sierras Pampeanas; (4) the existence of oceanic basalts and ultramafic rocks and related deep marine sedimentary rocks located along the western boundary of the Precordilleran basin; (5) tectonic features such as west-verging folds along the western border of the Precordillera interpreted as inherited accretionary prism structures related to east-dipping subduction; and (6) the presence of metamorphic-igneous basement west of the Precordillera (Frontal Cordillera and main Cordillera).

To evaluate these factors, their discrimination in space and time is necessary. The first three were taken as evidence of the allochthonous nature of the Precordilleran terrane, while the last three favor the existence of the Chilenian terrane. In addition to these, scarce paleomagnetic data support the allochthonous nature of both terranes (Mena and Selles Martínez, 1989; Rapalini and Tarling, 1993).

The idea of Ramos et al. (1986) concerning the existence of the two different terranes was based mainly on the truncation of the thick Cambrian to Lower Ordovician carbonate bank of the central and eastern Precordillera toward the north and south, and the existence of mafic and ultramafic rocks interfingered with Caradocian turbidites and hemipelagites along the western boundary of the Precordillera. The former has been known for a long time (Keidel, 1912; Harrington and Leanza, 1957; Borrello, 1971) and was probably the most important element supporting the allochthonous nature of the Precordillera, because the warm climate indicated by the lithologic and faunal assemblages contrasts with the rest of Gondwana.

The north-south–trending sedimentary mélange/olistostrome that bounds the Pre-

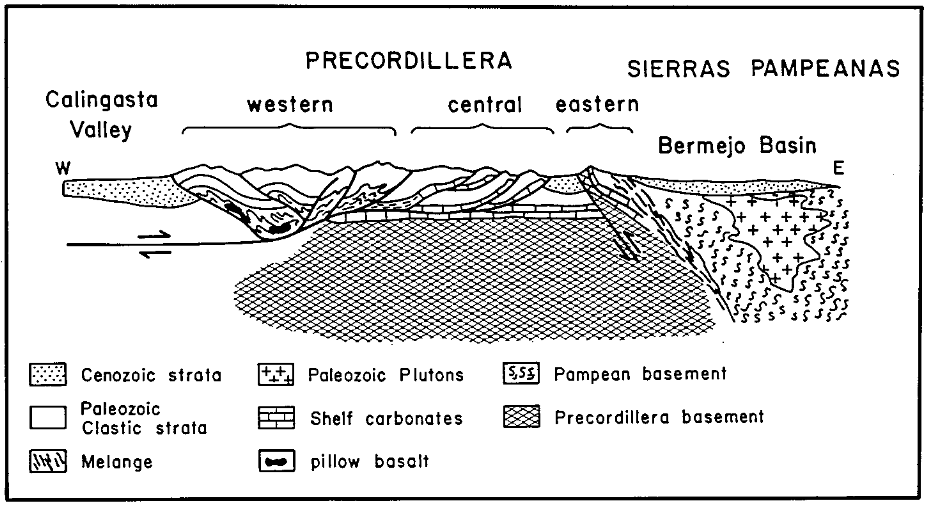


Figure 2. Schematic cross section of the Precordillera showing its three main structural belts and inferred contact zone between the Precordilleran and the Pampean basements. Not to scale (after Ramos et al., 1986).

cordillera to the east was interpreted as a shear zone indicative of a major fault that developed between the Precordilleran and Pampeanas terranes (Ramos et al., 1986). Afterward, it was interpreted as evidence of displacement of the Precordilleran terrane (Ramos, 1988b; Aceñolaza and Toselli, 1988; Baldis et al., 1989), which was considered to come from far south (dextral movement). In contrast, Amos (1954), González Bonorino (1975), and González Bonorino and González Bonorino (1991) interpreted the olistostrome as being entirely sedimentary in origin, related to normal faulting along a passive margin. Recently, von Gosen (1992) related the olistostrome to an old east-dipping fracture zone, although he remarked that no detailed fabric studies existed to provide evidence as to the real nature and sense of movement of this fracture zone.

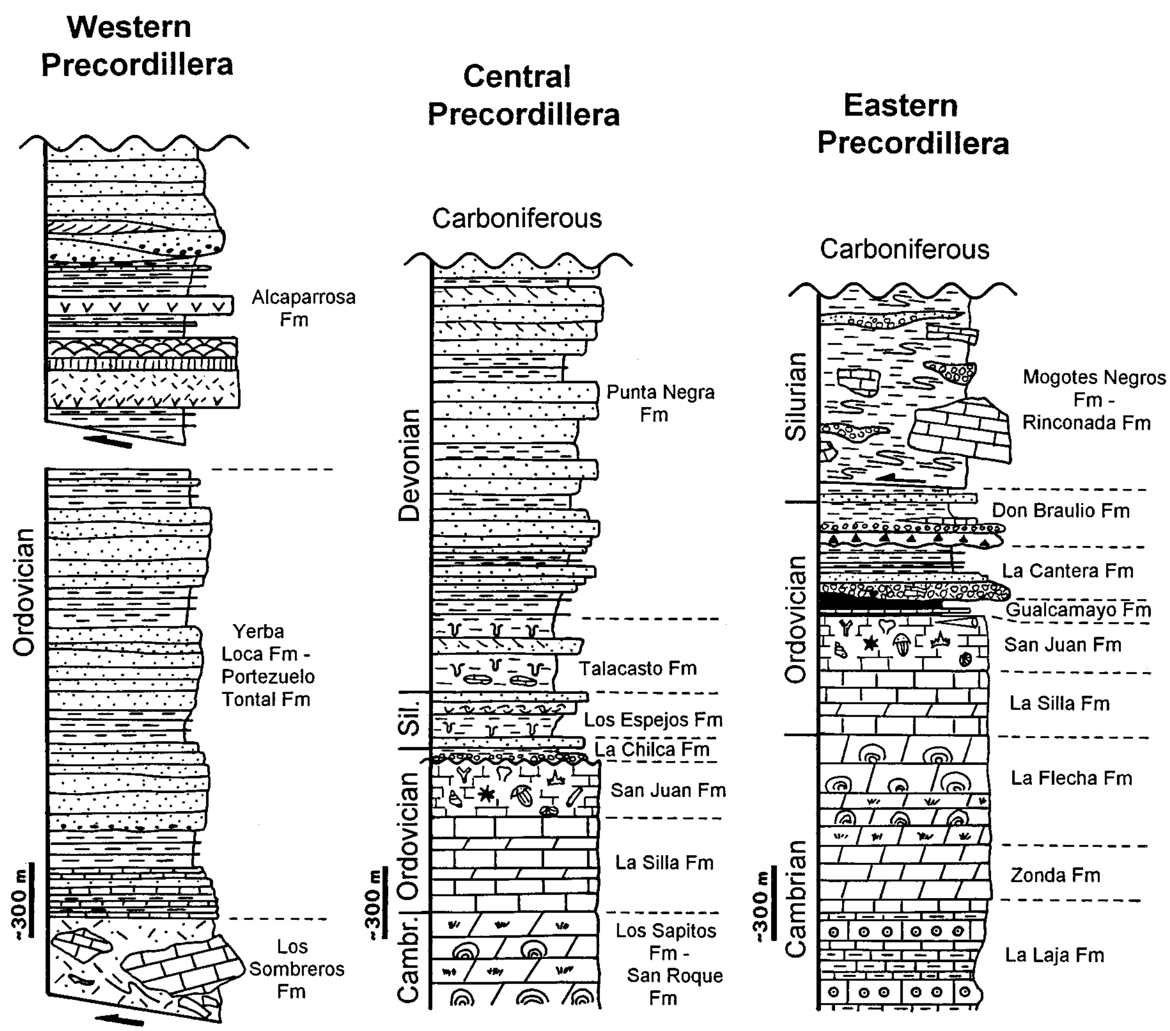


Figure 3. Detailed stratigraphic columns from the eastern, central, and western Precordilleran belts at lat. 31°30′S (see cross section in Fig. 2) (modified from Astini, 1991a).

The granitic plutonism present in the Sierras Pampeanas was interpreted by Ramos et al. (1984, 1986) as a deeply dissected magmatic arc and retroarc magmatic association related to eastward subduction, under the western margin of Gondwana, of oceanic slabs carrying the allochthonous terranes. In later papers Ramos (1988b, 1989) assigned the apparently within-plate plutonism of the eastern Pampeanas belt to a slightly older magmatic arc developed as a result of Late Proterozoic–early Paleozoic westward subduction to its eastern boundary. Recent petrologic studies (Rapela et al., 1990, 1992) suggest that the G2 granitoids in the Sierras Pampeanas are related to a lower Paleozoic eastward subduction. These arc granitoids could be related to the Precordilleran terrane subduction, but they have no relationship to the Chilenian terrane (Rapela et al., 1990, 1992; Dalla Salda et al., 1992a). This strengthens the hypothesis of eastward subduction of the Precordilleran terrane and weakens the idea of eastward subduction of Chilenia under Precordillera and Sierras Pampeanas. Moreover, this is probably the main reason for the presence of Early Ordovician volcanics in Famatina and their absence in the lower Paleozoic of the Precordillera, which was a major uncertainty in the previous models.

The mafic and ultramafic sills and pillow lavas, in concordance with the stratification (Cortelezzi et al., 1982; Kay et al., 1984; Haller and Ramos 1984), were interpreted as abnormal ocean-ridge basalts (Ramos et al., 1986) and were taken as evidence of closure of an ocean that separated the Precordilleran and Chilenian terranes. These rocks have been alternatively assigned to an interior rift basin (Dalla Salda et al., 1992a), to back-arc basin lava flows (Loske, 1992), and to magmatic injection due to passive margin extensional thinning (González Bonorino and González Bonorino, 1991). The primary results presented by Kay et al. (1984) suggest that any of these may be plausible alternatives, although they concluded that these rocks are most probably mid-ocean-ridge basalts.

The westward vergence of some turbidite packages with interlayered basic rocks along the western boundary of the Precordillera was interpreted by Ramos et al. (1984) as the remnant structural style of the original accretionary prisms built on the forearc region of the proto-Precordillera and related to eastward subduction of the Chilenian terrane. Astini (1991a) showed that the westward vergence is only local and that in various other localities there is an opposite vergence of the same rocks (see also Cucchi, 1972; von Gosen, 1992). The local vergence to the west may also be explained by later backthrusting. The presence of continental basement west of the Precordillera was an important reason to infer the existence of the Chilenian terrane (Ramos et al., 1986).

Various authors (Caminos, 1979a; Caminos et al., 1982; Hervé et al., 1981; Ribba et al., 1988; Nasi et al., 1990) proved the existence of basement rocks in the Frontal Cordillera, although, as González Bonorino and González Bonorino (1991) pointed out, the presence of basement rocks does not necessarily imply long-distance transport. The latter consider the possibility that Chilenia was a rifted part of Gondwana (see also Loske, 1992; Dalla Salda et al., 1992a), which separated during the Lower Ordovician and closed later during the Chanic orogeny. Astini (1991a) argued against the rift idea based on the absence of symmetry (e.g., no evidence of limestone outcrops to the west of the Precordillera). In terms of age of metamorphism (Silurian), these basement rocks are far too young to have been the basement for the Precordilleran limestones. The older ages of Frontal Cordilleran basement indicate metamorphism at 500 Ma (Caminos et al., 1979, 1982), when the Precordilleran carbonate platform was developing. This indicates a major structural boundary between the Precordillera and Frontal Cordillera and suggests the latter is allochthonous.

Recently reinterpreted paleomagnetic data from the Late Ordovician Alcaparrosa Formation (western Precordillera) support the allochthonous nature of the Precordillera (Mena and Selles Martínez, 1989). These data, obtained from mafic pillow lavas, show an anomalous positioning with respect to other Gondwanic paleopoles and an affinity with Laurentian paleopoles (Morel and Irving, 1978; Van der Voo, 1981). According to Vilas and Valencio (1978), these data provided evidence supporting a rapid apparent polar wandering path for Gondwana during the Middle Ordovician; but according to Mena and Selles Martínez (1989), they represent the drifting stage of the Precordilleran terrane, which was separated from the rest of Gondwana. Moreover, paleontological evidence indicates that the Precordilleran terrane was either facing or adjacent to Laurentia during the Cambrian and Lower Ordovician.

New preliminary data from the Cambrian and Lower Ordovician limestones of the eastern Precordillera also show paleomagnetic poles displaced northward from the main population of Cambrian–Ordovician poles of Gondwana (Rapalini and Tarling, 1993), but these data are still unreliable. It is interesting to note that the paleopole of the Lower Ordovician Suri Formation of the Famatina Range, which shows Celtic affinities, was positioned midway between the Precordilleran terrane–Laurentia and the rest of Gondwana (Vilas, 1981, *in* Mena and Selles Martínez, 1989).

Due to the paucity of paleomagnetic data supporting the wandering paths of the Precordilleran and Chilenian terranes, the biogeographic and stratigraphic data are presently the more compelling evidence.

BIOGEOGRAPHIC AFFINITIES

Trilobites

The close affinity of the Cambrian trilobites of the Precordillera with those of Laurentia was previously pointed out by Poulsen (1958) and Borrello (1965, 1971), but current detailed comparisons show an even closer correlation between the Precordillera and the Appalachians than previously recognized (Vaccari, 1994). For the Early Cambrian, typical Laurentian olenellids, including *Olenellus*, *Fremontella*, *Bristolia*, and *Arcuolenellus*, have been identified. Recently, Vaccari and Bordonaro (1993) described new species of *Sombrerella* and *Prozacanthoides* derived from resedimented carbonate blocks of the Los Sombreros Formation in the western Precordillera (Fig. 3). The only other record of these genera is restricted to the Early Cambrian of Sonora (Mexico) and New York. The Middle Cambrian faunas show strong affinities to the platform faunas of Laurentia.

In the restricted facies of the La Flecha (Upper Cambrian, Figs. 3 and 4), the trilobite genera are all endemic to Laurentia. The following genera were found in the lower part of the section (*Crepicephalus* Zone, Dresbachian): *Crepicephalus*, *Coosella*, *Coosina*, *Lonchocephalus*, *Welleraspis*, *Kingstonia*, *Komaspidella*, *Pemphigaspis*, and *Madarocephalus*. The faunal affinities between Precordilleran *Crepicephalus* Zone trilobites and those of Laurentia (Fig. 5) show a higher correlation with the central and southern Appalachians (Fig. 6). The Appalachian species *Madarocephalus laetus* Resser, *Komaspidella laevis* Rasetti, and *Dytremacephalus strictus* Rasetti were also identified in the Precordilleran carbonates. In the upper peritidal cycles of the La

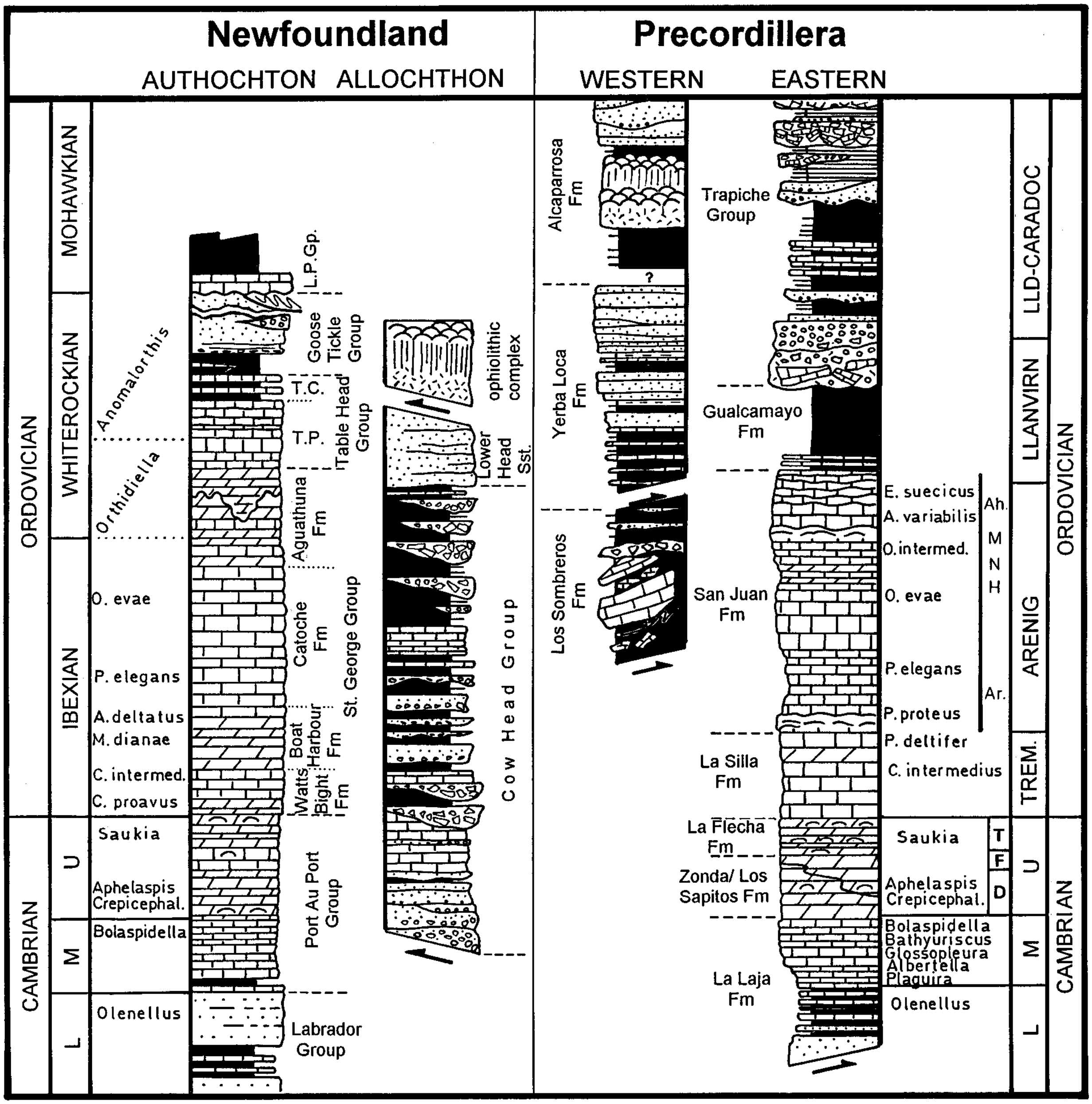


Figure 4. Detailed comparison of the lowermost Paleozoic stratigraphy of the Newfoundland Appalachians and the Argentine Precordillera. See text for explanation. In Precordillera, Ar., H., N., M., and Ah. are as in Figure 7. Not to scale.

Flecha Formation (Fig. 3), several species of *Plethopeltis* and *Stenopilus convergens* (Raymond) were found. *Plethopeltis obtusus* Rasetti was recovered from the basal levels of the La Silla Formation (Lower Ordovician; Figs. 3 and 4). Apparently trilobite affinities with Laurentia, and particularly with the central and southern Appalachians, were very strong until the Late Cambrian.

The lower levels of the San Juan Formation (uppermost Tremadoc–lower Arenig) have yielded two genera of bathyurids (*Peltabellia* and *Uromystrum*) associated with a new species of the cosmopolitan *Leiostegium* (Vaccari, 1994). The bathyurids are related to a warm-water periequatorial province (Whittington, 1966; Whittington and Hughes, 1973). Although *Peltabellia* has been recognized in Laurentia as well as in Siberia and North China (Zhou and Fortey, 1986), *Uromystrum* has only been recognized in Laurentia.

The Arenig–early Llanvirn trilobite faunas of the San Juan Formation are characterized by a mixture of endemic genera (*Arancibia* [Bathyuridae] and *Waisfeldaspis* [Scutellidae]), Laurentian genera (*Ectenonotus* and *Hibbertia*), Baltic genera (*Platillaenus*), and pandemic genera (*Annamitella*, *Ampyx*, *Illaenus*, *Carolinites*, and *Basilicus* [*Basiliella*]). This fact indicates an important separation between Laurentia and the Precordillera beginning in the Lower–Middle Ordovician (Vacarri, 1994). This permits the development of partially endemic faunas and also indicates an incipient faunal con-

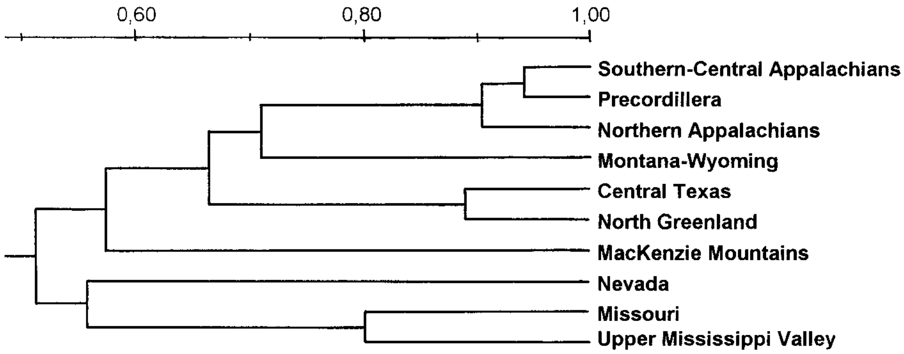


Figure 5. Q mode dendrogram showing biogeographic affinities between the Precordillera of western Argentina and the Laurentian North American localities based on trilobites from the *Crepicephalus* Zone (Dresbachian, Late Cambrian). Note that the correlation is higher with the south-central Appalachians than with the northern Appalachians (Vaccari, 1994).

nection with other continental blocks such as Baltica. In the Llanvirn Gualcamayo Formation and younger units of the Precordillera, only trilobite genera of wide geographic distribution have been recognized.

Brachiopods

Benedetto (1985) and Herrera and Benedetto (1991) demonstrated that the brachiopods of the San Juan Limestone (early Arenig–early Llanvirn) constitute mixed assemblages, containing a significant proportion of Toquima–Table Head genera (Ross and Ingham, 1970; Neuman and Harper, 1992) associated with several Celtic and Baltic elements. Herrera and Benedetto (1991) show that 90% of the *Archaeorthis* Zone (early Ibexian) genera are also present

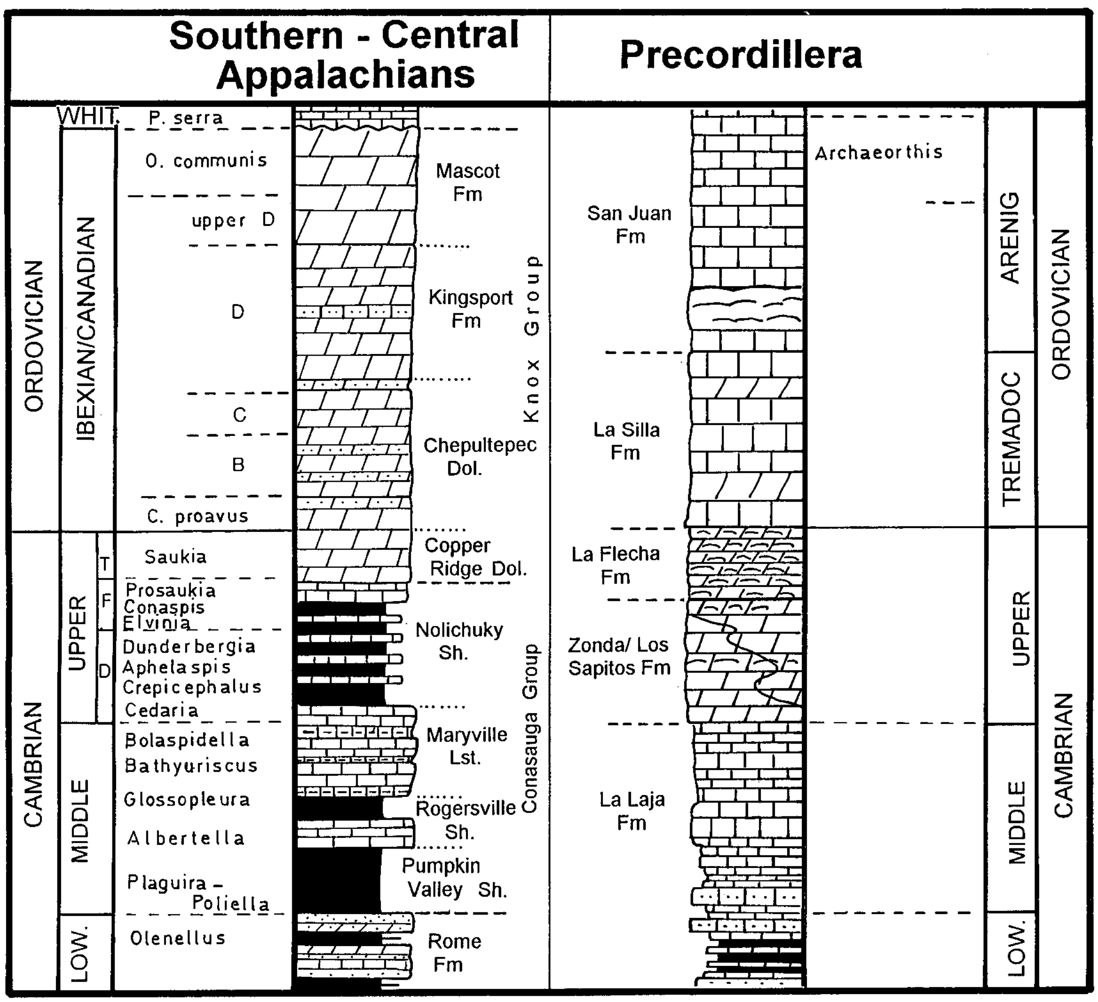


Figure 6. Detailed comparison of the lowermost Paleozoic stratigraphy of the south-central Appalachians and the Argentine Precordillera. See text for explanation. B, C, and D are the North America conodont zones according to Ethington and Clark (1971). For Precordilleran zonation see Figure 4. Not to scale.

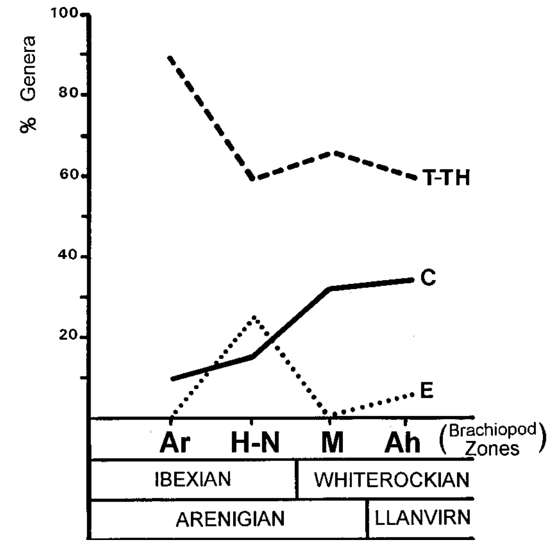


Figure 7. Variations in the biogeographic affinities of the Lower Ordovician brachiopod faunas of the San Juan Alloformation (San Juan Formation in the broadest sense). T-TH = Toquima–Table Head Province, C = Celtic Province, E = endemic genera, Ar = *Archaeorthis* Zone, H = *Huacoella* Zone, N = *Niquivilia* Zone, M = *Monorthis* Zone, Ah = *Ahtiella* Zone (after Benedetto, 1993).

in North America (Fig. 7), whereas in the *Huacoella* and *Niquivilia* Zones (late Ibexian) endemic constituents and at least two Celtic genera appear. The overlying biozone is characterized by the first occurrence of *Leptella* (*Petroria*) and by the widespread occurrence of *Monorthis*, which has been recognized only in Wales (a typical Celtic locality) and in the Famatina Range of Argentina (Suri Formation) (Benedetto, 1994). The former characterizes the *Orthidiella* Zone (lower Whiterockian) according to Ross et al. (1991).

Finally, in the *Ahtiella* Zone (lower Llanvirn) some genera belonging to the Toquima–Table Head province (from the *Orthidiella* Zone), such as *Camerella* and *Idiostrophia*, are mixed with several (~35%) typical Celtic and Baltic genera (e.g., *Ahtiella*, *Platystrophia*, *Productorthis*, *Inversella*, and *Rugostrophia*). On the basis of this association, the Precordillera was recently included by Neuman and Harper (1992) as a Celtic locality. These authors suggest that the Celtic province developed in high- to mid-latitude perigondwanic regions. Because the Celtic genera have never been recorded from North American Ordovician sequences (excluding the volcaniclastic rocks of central Newfoundland, Maine, and New Brunswick, which have been interpreted as the accretioning of intra-Iapetus volcanic island arcs), paleontological evidence does not support continuity of the South American and Laurentian margins.

The increasing amount of Celtic genera from early Arenig to early Llanvirn may reflect an expansion of the southern Iapetus ocean with a gradual drifting of the Precordillera from Laurentia and increasing connections with the Iapetus volcanic island arcs (e.g., central Newfoundland–New Brunswick). During the drifting stage, the Precordillera was accessible to faunal migration from the Laurentian and the Avalonian-Baltic continents and the intra-Iapetus island arcs.

The affinities between the Arenig faunas from the Suri Formation outcropping in the Famatina Range and those of the Precordillera were discussed by Vaccari et al. (1993), Vaccari and Waisfeld (1994), Benedetto (1994), and Albanesi and Vaccari (1994). The common genera *Paralenorthis*, *Tritoechia*, *Skenidioides*, and *Monorthis* (Benedetto, 1995) among the brachiopods and the trilobite *Annamitella* (Vaccari, 1993) suggest an important connection between these regions during the late Arenig. Each region, however, had a sufficiently endemic content to suggest that they remained separate. It seems that the individuality of the Precordilleran and Famatinian faunas rests largely on the fact that the former are associated with carbonate facies, while the latter are contained in volcaniclastic deposits. It is important to note that, although the Famatina has some linkage with the Precordilleran terrane, during the Arenig the connection of Famatinian assemblages was much stronger with the basins of northwestern Argentina. Common faunas of these basins are the Gondwanic trilobites *Famatinolithus*, *Pliomeridius*, *Merlinia*, and *Neseuretus*, and the brachiopod *Incorthis*, a Bohemian element recognized also in Bolivia (Havlicek and Branisa, 1980) and Morocco (Mergl, 1988).

The Llandeilo and Caradoc brachiopod fauna of the Precordillera seems to confirm the persistence of Baltic elements. Such is the case of *Oanduporella* from the Las Plantas Formation, which has only been recognized before in the Irish and Estonian Caradoc series (Harper et al., 1985). The Hirnantian fauna of the Precordillera (Benedetto, 1986; Sánchez et al., 1991b; Astini and Benedetto, 1992) belongs to the Kosov province (Rong and Harper, 1988), which is characteristic of cold perigondwanic seas, compared to the Edgewood province, which developed in the warm waters surrounding Laurentia. A definite Gondwana signature of the Precordilleran fauna was attained during the Silurian when the *Clarkeia* fauna expanded throughout the region (Cocks, 1972; Berry and Boucot, 1972; Benedetto et al., 1992a; Sánchez and Benedetto, 1993).

Conodonts

Precordilleran conodont faunas have also confirmed the correlation of the Precordillera with Laurentia (Lehnert and Keller, 1994). During the Ordovician they indicate a clear temperature trend on a generic level, which agrees with the lithological indicators of a general cooling toward Late Ordovician. According to Lehnert and Keller (1994), the Tremadoc faunas show significant affinities with the warm-water associations of the U.S. Midcontinent province, while during the Arenig they begin showing affinities to the North Atlantic realm, both temperate and cold-water groups. A short warming in the upper Arenig (e.g., *Parapanderodus*) during the sedimentation of the San Juan Formation can be related to the general shallowing indicated by the development of stromatoporoid reefs and associated grainstone facies. Later, during the Llanvirn–Llandeilo, cold-water North Atlantic realm (Miller, 1984; Bergström, 1990; Bagnoli and Stouge, 1991) affinities were developed (Lehnert and Keller, 1994).

STRATIGRAPHIC COMPARISONS

The previously published comparisons between the stratigraphy of the Precordillera and the Appalachians lack up-to-date sedimentological information. Even those suggested by Ramos et al. (1986) and Dalla Salda et al. (1992a, 1992b) contain little data on stratigraphic thickness, geometric relationships, and paleoenvironmental interpretations of the lower Paleozoic sedimentary sequences outcropping in the Precordillera and adjacent areas. While Ramos et al. (1986) compared the Precordilleran terrane with the northern Appalachians, Dalla Salda et al. (1992a, 1992b) compared it with Appalachian-Ouachita rifted margin of southeastern North America (Thomas, 1991).

When the Cambrian and Ordovician successions of the Precordillera are compared with the northern (Fig. 4) and southern Appalachians (Fig. 6), some important similarities are apparent. The Precordilleran stratigraphy has been summarized by Benedetto (1993), taking into account several recent studies (Astini 1991a; Benedetto and Vaccari 1992; Sánchez et al., 1993; Keller et al., in press and references therein). For the northern Appalachians, the synthesis of James et al. (1989), Stenzel et al. (1990), Knight et al. (1991), and papers cited therein were considered. The stratigraphy of the southern and central Appalachians has been synthesized from various papers, including Walker (1985), Read (1988, 1989), Thomas (1991), and references therein.

The Precordillera and the Northern Appalachians

In the northern Appalachians the Lower Cambrian succession starts with red fluvial and strandline sandstones, conglomerates, and siltstones that cover the crystalline Grenvillian basement. In the Precordillera similar facies are not exposed—neither is its basement—but Astini and Vaccari (in press) have recently reported the first outcrops of red siltstones and shales interlayered with evaporites and dolomites representing marginal marine sabkhas underlying the Lower Cambrian. These might be interpreted as initial rift sequences. Alternating limestones, shales, and siltstones of the Early to Middle Cambrian Forteau Formation (Labrador Group) are similar to the La Laja Formation (Borrello, 1962; Bordonaro, 1980; Keller and Bordonaro, in press).

The peritidal limestones and dolostones of the Newfoundland Port-au-Port Group are equivalents of the Zonda Formation and the lower part of the La Flecha Formation biolaminated intertidal dolomites (Bordonaro, 1980) from the Precordillera. The Upper Cambrian Berry Head Formation (higher unit of the Port-au-Port Group) and the Watts Bight Formation (basal unit of the St. George Group) are similar to the La Flecha Formation (Baldis et al., 1981) and partially correlate with the lowermost La Silla Formation (sensu Keller et al., in press). The first is represented by rich true stromatolitic (LLH-SH, sensu Logan et al., 1964) and trombolitic, highly dolomitized and chalcedonized facies that conform to small-scale stacked shallowing-upward intertidal cycles (Cañas, 1986; Keller et al., 1989). The La Silla Formation (which includes the Cambro–Ordovician boundary) is instead a random, mostly thick-bedded, dark gray to bluish, calcareous unit with minor biolaminated dolomite, which contains evidence of a restricted subtidal platform environment (Keller et al., in press) and can be readily correlated with the Boat Harbour Formation on the basis of both lithologic and faunal content. Characteristic conodonts from the U.S. Midcontinent Fauna D of Ethington and Clark (1971), such as *Glyptoconus quatraplicatus* Branson and Mehl, are present in both formations (Stouge, 1982, *in* Knight and James, 1987; Keller et al., in press).

The dramatic change into widespread muddy fossiliferous carbonates identifiable throughout western Newfoundland (i.e., the Catoche Formation) is represented in the Precordillera by the lower section of the late Tremadoc–early Arenig San Juan Formation (Hünicken, 1985, 1989; Lehnert, 1993; Keller et al., in press), composed of open-shelf subtidal limestones, thin- to medium-bedded burrowed skeletal wackestones, and packstones with thin intercalations of coarse-grained storm deposits and widespread metazoan buildups (sponges, receptaculitid *Calathium*, *Girvanella*, and microbial structures) associated with grainstones (Carrera, 1991; Cañas and Keller, 1993; Cañas and Carrera, 1993). Onlap was extensive during this time, representing probably the highest stand of sea level in the Early Ordovician (cf. Barnes, 1984; James et al., 1989). By then, the Precordilleran platform, as well as the Newfoundland Appalachians, had many of the attributes of an epeiric sea (sensu Shaw, 1964).

The regressive facies of the Aguathuna Formation are equivalent to the massive limestones with scarce fauna of the middle section of the San Juan Formation, which comprise the *Monorthis* Zone (Herrera and Benedetto, 1991) and are capped by stromatoporoid and sponge-algal-stromatoporoid reefs typical of very shallow warm water (Cañas and Keller, 1993). The microcrystalline peritidal dolostones and minor limestones are partially equivalent to the Beekmantown/Pinesburg Station/Ontelaunee/Bellefonte dolomites of the central Appalachians reentrants and are represented by a major gap both in Newfoundland, between the St. George Group and the Table Head Group, and in the southern Appalachians, between the Ibexian Knox Group/Kingsport-Mazcot sequence and the Lenoir Limestone. The upper stylo-nodular wackestones and packstones containing characteristic platform faunas in the San Juan Formation (*Ahtiella* zone; Herrera and Benedetto, 1991) can be litho-correlated with the Table Point Formation, although it is slightly out of phase (basal unit of the Whiterock Table Head Group).

The San Juan Formation is covered by north-south diachronous late Arenig–lower Llanvirn alternating black shales and platy-ribbon limestones (lower member of the Gualcamayo Formation; Astini, 1986, 1995b), or by homogeneous graptolitic black shales (middle and upper members of the Gualcamayo Formation; Astini, 1995b). These can be respectively correlated with the Table Cove and the Black Cove Formations, which in a revised stratigraphy of the Table Head Group (Stenzel et al., 1990) are laterally related, although they belong to different groups (Table Head and Goose Tickle Groups, respectively). Like the Table Cove Formation, the lower member of the Gualcamayo Formation was deposited on a gently dipping carbonate slope under increasing water depth, and its lateral thickness variations reflect differential subsidence rates of different platform blocks and hence the longevity of shallow-water carbonate sources. The black shales overlie the San Juan Formation along a widespread hardground (sensu Kendall and Schlager, 1981), which can be interpreted as a drowned unconformity.

After the Middle Ordovician (late Arenig–early Llanvirn), the lithostratigraphic similarities between the Precordillera and Newfoundland start phasing out. This gradual chronostratigraphic divergence is represented by the Goose Tickle and Long Point Groups, which are considered to be part of the autochthonous successions in the Newfoundland Appalachians, and their counterparts the Trapiche Group of the northern Precordillera and the La Cantera and Rinconada Formations of the eastern margin (Fig. 3). This chronostratigraphic phase difference documents an evolving divergence between Precordilleran and Newfoundland histories.

The Upper Ordovician stratigraphy of the Precordillera is capped by different, mainly siliciclastic units grouped into alloformations (Astini, 1991a, 1993a), bounded by erosional or nondepositional hiatuses. These units gradually increase their differences upward with those outcropping in the Appalachians. Resedimented deep-water facies equivalents of the Middle to Upper Cambrian–Lower Ordovician carbonates partly outcrop in the western Precordillera (western tectofacies of Astini, 1991a, 1992b; Fig. 3), which implies an opposite polarity than the one found in the Appalachians. Most of the time-equivalent parautochthonous telescoped succession is composed of slates, breccias, and carbonate olistostromes (Cuerda et al., 1986; Banchig and Bordonaro, 1990; Benedetto and Vaccari, 1992) contained in the Ordovician Los Sombreros Formation (Fig. 4).

The Precordillera and the Southern and Central Appalachians

Although with slight facies changes, the correlation of the Precordillera with the southern and central Appalachians reveals remarkable similarities not only in the sedimentary units but also in their thickness and faunal assemblages (Fig. 6). The fine-grained continental and transitional red beds found in the north of the Precordillera (Astini and Vaccari, in press) are considered correlatives of the Chilhowee succession, which represents in North America the transition from rift-fill to passive margin deposits (Thomas, 1991). The passive margin strata are represented by the overlying Cambrian and Lower Ordovician rocks, which in Laurentia constitute the craton-wide transgressive Sauk sequence of Sloss (1963), composed from bottom to top by the Shady Dolomite, the Rome Formation, the Conasauga Group, and the Knox Group.

The Shady Dolomite, not well represented in the Precordillera, could be correlated with Early Cambrian peritidal dolomites in the northern Precordillera (Cañas, 1988; Vaccari, 1988). The southeastern facies changes of the Rome Formation are similar to the lower levels of the La Laja Formation with abundant tidal and subtidal deposits. As implicitly suggested by Thomas (1991), there might be a basal diachroneity into the rifted terrane (our Precordilleran terrane), which would explain the facies changes and the later development of typical passive margin sequences as compared with the southern and central Appalachians. The Conasauga carbonates grade westward into clastic facies in the Appalachians. In the Precordilleran terrane, the lateral equivalents of the Conasauga are the La Laja, Zonda, and the lower part of the La Flecha Formations ("Los Sapitos Formation"). The last includes the Dresbachian trilobite faunas described above. These are closely correlated with the ones recovered from the Upper Cambrian Nolichucky Shale and Maynardville Limestones.

The uppermost Cambrian unit in the Precordillera is represented by the La Flecha Formation, which is correlated with the lower Knox Copper Ridge Dolomite. *Plethopeltis obtusus* (Rasetti) (*Saukia* Zone, *Saukiella serotina* Subzone–*Missisquoia depressa* Subzone) (Ludvigsen, 1982) was recovered from the autochthonous lower levels of the La Silla Formation, marking the Cambro–Ordovician boundary in the Precordillera (Vaccari, 1994). This unit might be correlated with the basal upper Knox Chepultepec Dolomite in the Appalachians. In the middle and upper parts, *Cordylodus intermedius* Zone elements are assigned to Ethington and Clark (1971) Faunas B and C of the U.S. Midcontinent (Keller et al., in press), which correlate with the Appalachian Chepultepec-Stonehenge limestones. The uppermost La Silla Formation and the San Juan limestones, which contain Faunas D and E, correlate with the late Canadian upper Knox Kingsport and Mascot Formations, truncated by the Knox unconformity. The *Oepikodus communis* level of the Mascot Dolomite correlates with the Arenig *Archaeorthis* Precordilleran zone.

Discussion

By their stratigraphy the Appalachians can be fairly well correlated with the Cambrian and Early Ordovician successions of the Precordillera, with greater or lesser detail depending on whether the section being considered is in a salient or recess on the continental margin. The paleontological evidence, however, makes some difference because the Cambrian trilobites have a better affinity with the southern and central Appalachians, and brachiopods show a better affinity with the northern Appalachian Toquima–Table Head province. In turn, the conodonts may be correlated with the U.S. Midcontinent province for Late Cambrian–Early Ordovician times and with the North Atlantic realm from then on, as the climate cools down (Lehnert and Keller, 1994). The data are compatible, as we show later, with the rifting of Precordillera from the Early Cambrian Ouachita continental margin, because it explains better the trilobite faunal exchange during the Middle and Late Cambrian. This is permitted by a narrower separation between the southern Appalachians and the Precordilleran terrane than the one needed between the Precordilleran terrane relative to the northern Appalachians, if we assume normal spreading rates. During the Arenig the drifting stage increased the endemic and Celtic benthic faunas. The drifting toward higher latitudes is consistent with the variations from the U.S. Midcontinent to North Atlantic realm conodont affinities.

Interesting geometric comparisons can also be drawn if we consider the probable southern continuation of the Precordillera in southeastern Mendoza and La Pampa Provinces (as mentioned later; Fig. 8). If we compare the sizes of the Precordilleran terrane and the Ouachita drifted terrane (Fig. 6 in Thomas, 1991) both are ~1000 km long, which is surprisingly coincident. The southern wedging out of the Precordilleran carbonate bank might be explained by the apparent regional basal diachronism toward the south suggested by Thomas (1991), wherein the La Pampa outcrops and the subsurface limestones recognized in Mendoza are analogs of the widely extended San Juan Alloformation (Astini, 1991a).

SEDIMENTATION, TECTONISM AND SEA-LEVEL CHANGES IN THE PRECORDILLERA

Taking into account the tectono-stratigraphic nature and position of the Ordovician and lower Paleozoic successions of the Precordilleran basin, Astini (1991a, 1992b) subdivided the outcrops into eastern and western tectofacies (Fig. 9). The eastern domain, subject to higher structural level deformation and characterized by relatively shallow marine sedimentation, was divided using a sequence stratigraphic approach (Astini, 1991a, 1993a). This allowed a better comprehension of its evolution than within the western tectofacies, where low-grade metamorphism, scarce fauna, and thorough deformation restrict the possibilities for detailed analysis.

In the eastern tectofacies, the demise of the carbonate platform occurred near the Arenig/Llanvirn boundary, which has been correlated by Astini et al. (1988) with a worldwide sea-level rise. The north-south diachroneity (Hünicken, 1985; Hünicken and Ortega, 1987) of the drowned surface,

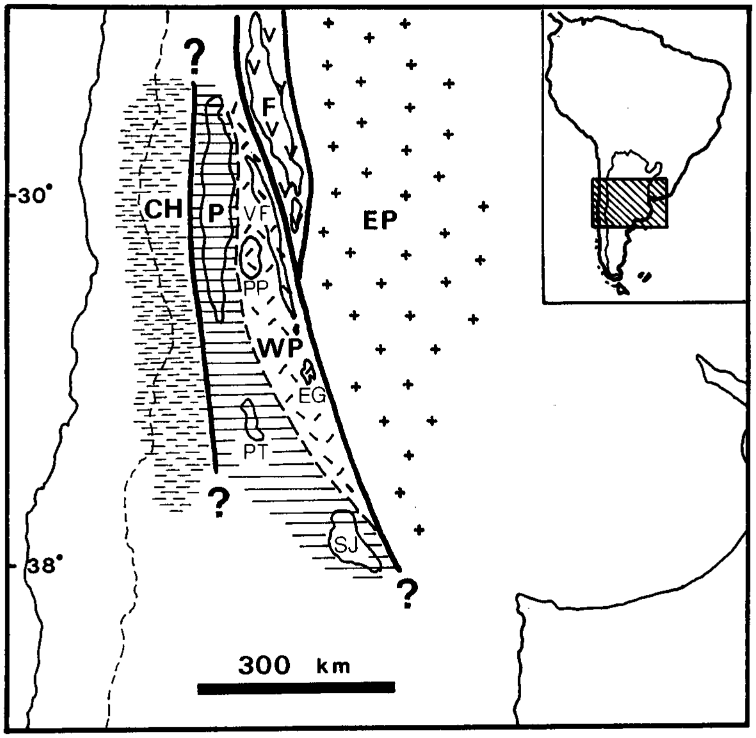


Figure 8. Non-palinspastic terranes map of west-central Argentina as the more plausible hypothesis described in the text. EP = Pampeanas terrane (eastern Pampeanas ranges), F = Famatina terrane, P = Precordilleran terrane, CH = Chilenian terrane, WP = Grenville basement of Precordilleran terrane (western Pampeanas ranges), VF = Valle Fértil Range, PP = Pie de Palo Range, EG = El Gigante Range, PT = Ponón Trehué limestones, SJ = San Jorge limestones.

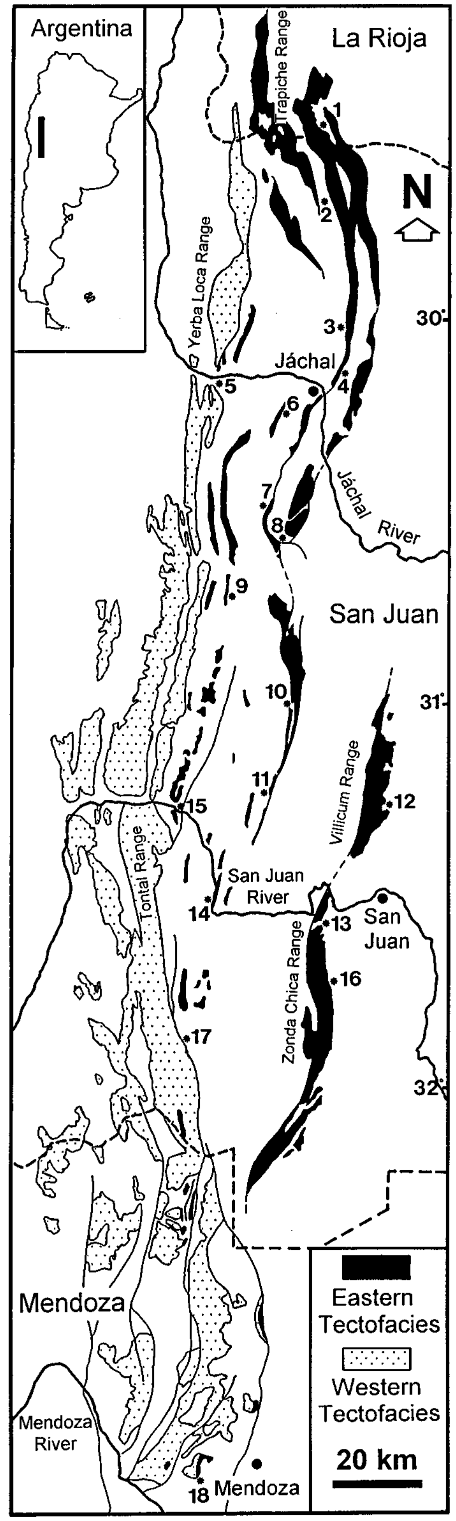


Figure 9. Tectofacies subdivision for the Ordovician System of the Precordillera (after Astini, 1991a). 1 = Guandacol area, 2 = Gualcamayo River, 3 = Cerro Potrerillo, 4 = La Paila Creek, 5 = Los Túneles, 6 = Las Aguaditas Creek, 7 = Las Chacritas Creek, 8 = Cerro la Chilca, 9 = Gualilán, 10 = Talacasto Gorge, 11 = La Deheza Creek, 12 = Villicum Range, 13 = Zonda Creek, 14 = Tambolar path, 15 = Pachaco, 16 = Rinconada, 17 = Los Sombreros, 18 = San Isidro Creek.

however, suggests that the drowning unconformity (sensu Schlager, 1989) might have a tectonic origin (Astini, 1994; Sánchez et al., in press). Discussions of similar phenomena in the Appalachians were provided by Bradley (1989), Stenzel et al. (1990), Diecchio (1991), and Knight et al. (1991), among others. Tectonic subsidence started during the early Arenig in the northeastern region (Guandacol subbasin) (Figs. 9 and 10) and extended later to the rest of the eastern border (e.g., the Rinconada trough) south of the Jáchal River. Thickness variations of the anoxic graptolitic black shales (Gualcamayo Alloformation) suggest that variable subsidence affected different parts of the basin (Fig. 10). Downwarping of a region, which had shortly before been a shallow carbonate platform, suggests that the deepening could have been related to initial collapse of the carbonate platform, corresponding to initiation of active subsidence due to thrust loading forming a foreland basin (toward the northeast of Guandacol; Fig. 11). The distribution and ages of the Gualcamayo black shales in the Precordilleran basin (Figs. 4 and 10) can be explained by lithospheric flexure models (Jacobi, 1981; Quinlan and Beaumont, 1984; Tankard, 1986; Ettensohn, 1991). This tectonism, which significantly affected the topographic expression of the platform since the late Arenig–early Llanvirn, can be related to the first stages of the Guandacol orogenic phase.

During the Llanvirn, particularly toward the eastern border, flysch-like clastic rocks (e.g., Rinconada Formation lower member, and Las Vacas and La Cantera Conglomerates) started to develop, reflecting the inception of deep troughs (Fig. 11) where subsidence occurred at a greater rate than sediment accumulation. The pronounced

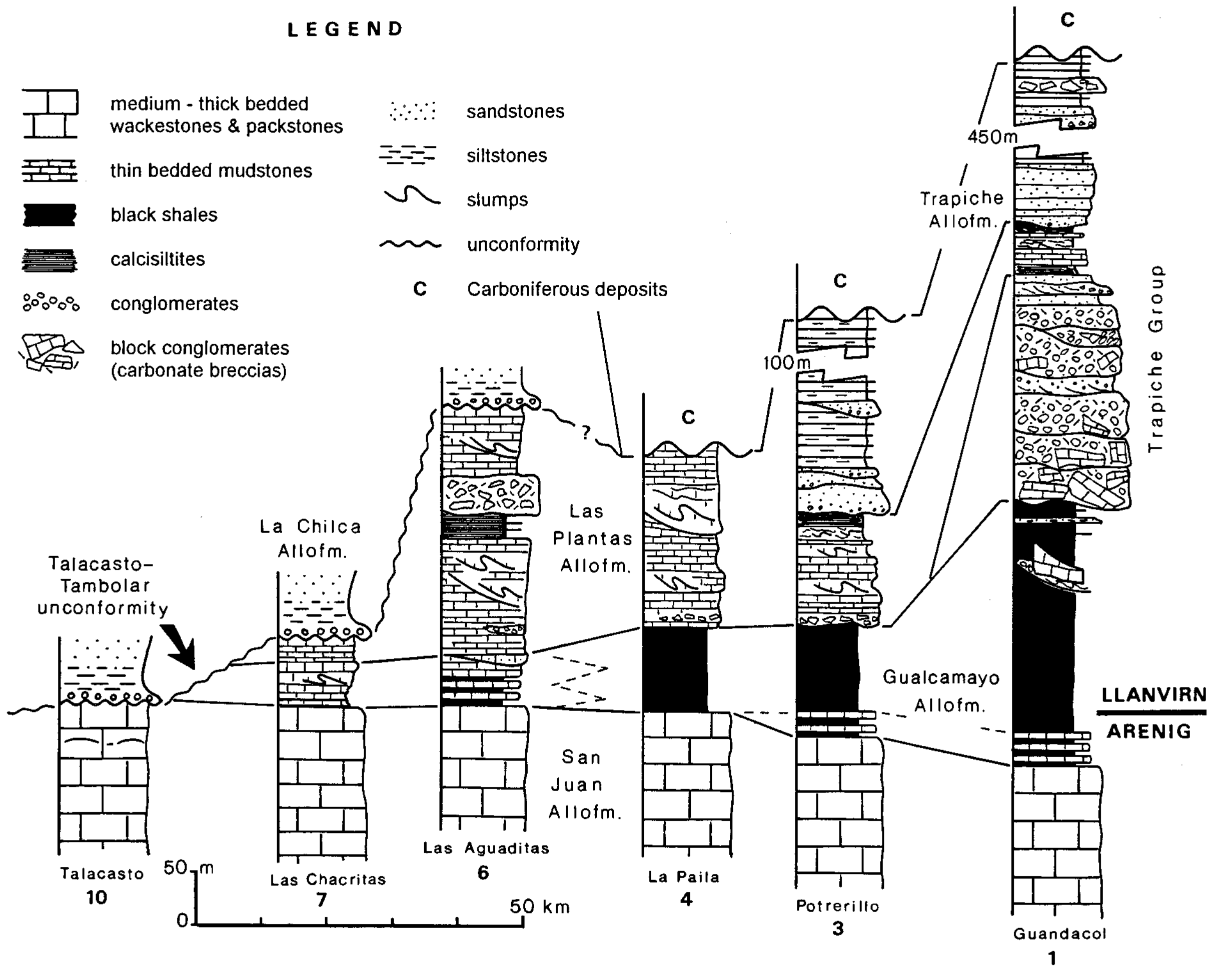


Figure 10. Stratigraphic correlation of several measured Lower to Middle Ordovician sections through the central-northern Precordillera, showing the diachronous development of the Gualcamayo Alloformation black shales and its lateral lime-muddy equivalents as the platform starts converging, changing from a passive to a peripheral foreland. The Arenig–Llanvirn boundary is shown as horizontal. The columns are aligned northeast-southwest on a palinspastically restored map and their location numbers are shown in Figure 9. Column 1 is the type area for the Gualcamayo, Las Plantas, and Trapiche Alloformations. Note the major sedimentary thickness toward the northeast, the lateral facies changes to carbonate deposits toward the southwest, and the northern reaches of the Talacasto-Tambolar unconformity in the south.

topographic relief, reflecting Paleozoic block faulting, is indicated by rapid lateral and vertical facies variations and thickness changes. The deposition of >1000 m of olistostromes with huge blocks of Ordovician limestones (Fig. 10) strongly suggests a block-faulted landscape toward the eastern border of the Precordilleran terrane. We interpret this rapidly subsiding stage (Guandacol orogenic phase) as related to loading of the peripheral foreland by westward moving thrusts, with the coarse clastic rocks being shed from the thrusted front and the block-faulted platform, as suggested by paleocurrent data and conglomerate composition (Astini, 1991a).

Toward the western border of the Precordilleran terrane, the carbonate fabric was reestablished after a short break during the late Arenig–early Llanvirn. There, the black shales of the Gualcamayo Alloformation grade into platy mudstones with abundant slumped horizons and debris flows, which indicate slope environments represented by the Las Aguaditas Formation (Keller et al., 1993; Astini, 1995c). This unit, included in the Las Plantas Alloformation (Fig. 10), outcrops in the central-north region of the eastern tectofacies (Las Chacritas–Las Aguaditas) and is sharply truncated to the south by an upper Ordovician diachronous unconformity (see below). Its age may reach the Caradocian, being a lateral equivalent of easternmost siliciclastic successions.

Of special paleogeographic interest is the Don Braulio Alloformation (Fig. 12) because of its glacial nature. This unit is related to the glaciation that partially covered Gondwana during the Late Ordovician Hirnantian stage, and it can be traced through northwest Argentina and Bolivia (Peralta and Carter, 1990; Buggisch and Astini, 1993; Astini, 1993b). This fact confirms a definite Gondwanic affinity of the Precordilleran terrane by Late Ordovician time.

A significant stratigraphic element is the regional diachronous unconformity, which has a maximum gap in the central Precordillera (Fig. 12). Its geometry reflects an upwarping of the central Precordillera between the Middle and Late Ordovician (Astini 1991a, 1992a, 1992b). Delineation of this unconformity has led to a coherent explanation of the post-Guandacol diastro-

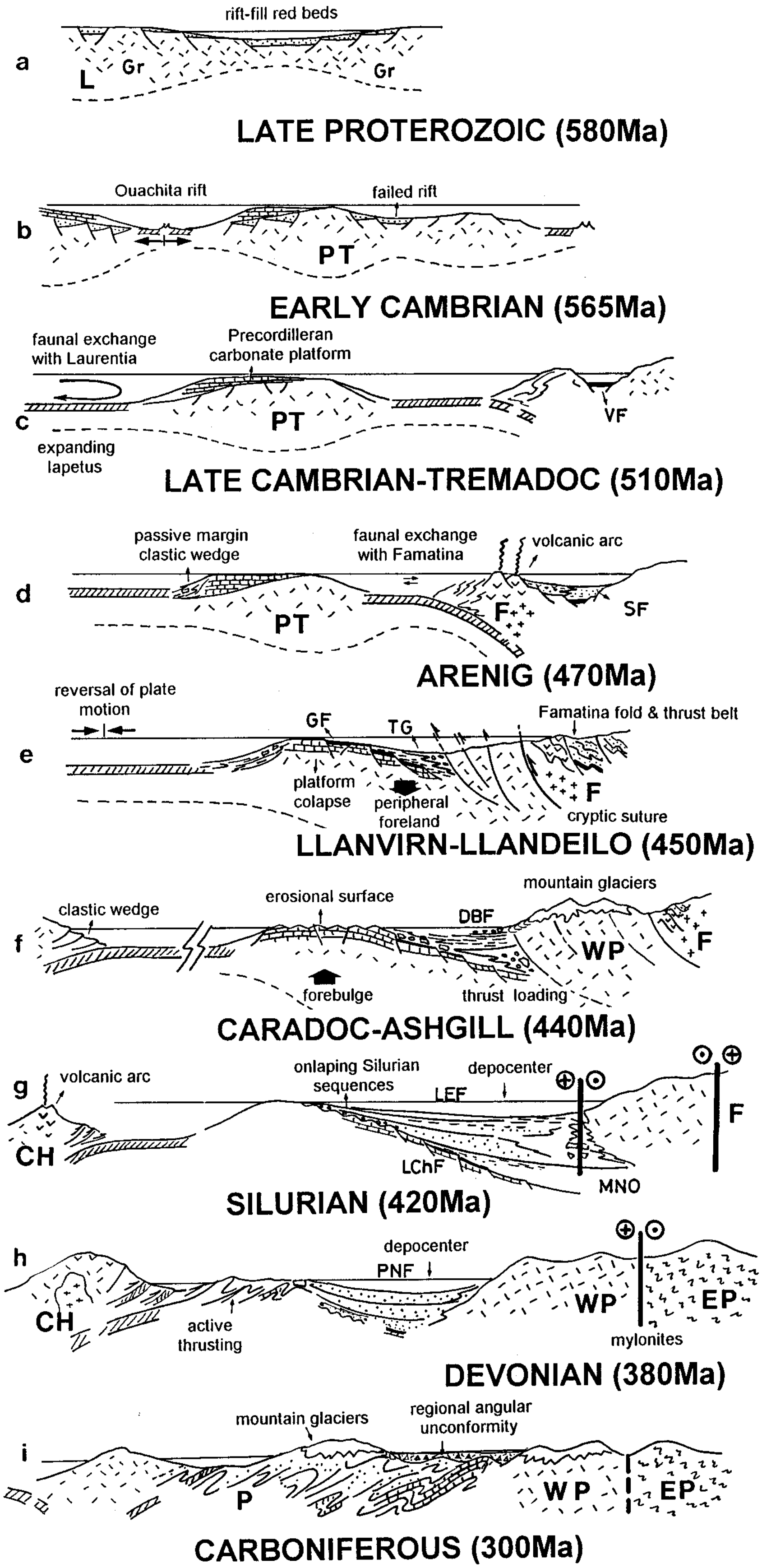


Figure 11. Schematic cross sections (not to scale) showing the geodynamic model in which the Argentine Precordillera evolves from a passive margin toward a rifted, drifted, and collided terrane during the early Paleozoic. (a) Initial rifting and opening of the southern Iapetus. (b) Opening of the Ouachita rift and failed rift to the right. Development of passive margin sequences: (c) Precordillera drifting and faunal exchange with Laurentia; (d) continuous drifting and faunal exchange with Celtic and Baltic Provinces and the Famatina volcanic-arc region; (e) collision with Famatina with generation of a peripheral foreland with collapse of the previous carbonate bank. Faulting of the Grenville basement and shortening led to differentiation of the Precordilleran sedimentary successions from its basement (later converted into the western Pampeanas ranges), (f) forebulging, and erosion in central Precordillera. Late Ordovician glacial sediments were derived from western Pampeanas. (g) Approximation of the Chilenian terrane, including an active magmatic arc; transcurrent faulting to the eastern border. Silurian sequences onlapping the former dome. (h) Active thrusting due to western approximation of Chilenia and generation of deep Devonian graywacke depocenters covering shallow Silurian deposits. (i) Final collisional stage wherein the lower Paleozoic is folded and covered later by glacial Carboniferous deposits. See text for more details. Gr = Grenville basement, L = Laurentia, P = Precordilleran terrane, F = Famatina, EP = eastern Pampeanas, WP = western Pampeanas, CH = Chilenian terrane, VF = Volcancito Formation, SF = Suri Formation, GF = Gualcamayo Formation, TG = Trapiche Group, DBF = Don Braulio Formation, LChF = La Chilca Formation, LEF = Los Espejos Formation, MNO = Mogotes Negros olistostrome, PNF = Punta Negra Formation.

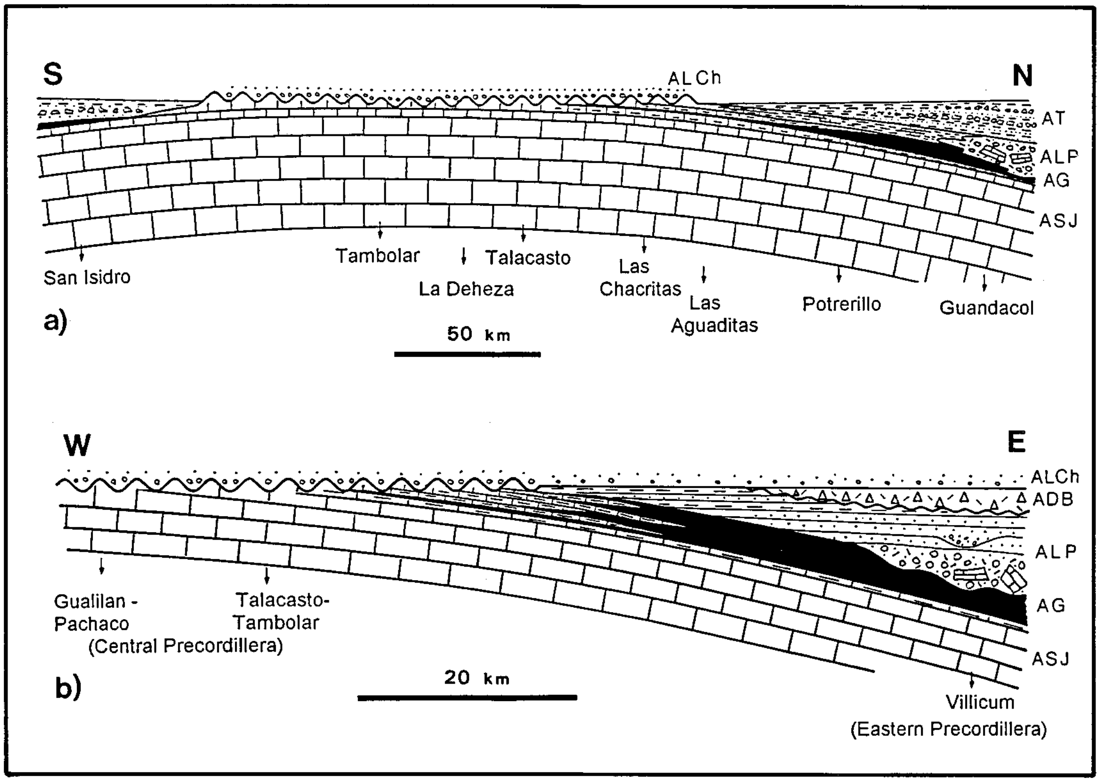


Figure 12. Cross sections along (a) and across (b) the Precordilleran Ordovician System, showing the regional Upper Ordovician unconformity developed by forebulging and erosion of previous Lower Ordovician successions (modified from Astini, 1992a, 1992b).

phism that epeirogenically affected the Precordillera (Furque and Cuerda, 1979, 1982) during the early Famatinian orogeny (Late Ordovician–Early Silurian). The maximum gap spans the Early–Middle Ordovician (middle Arenig) to Early–Middle Silurian (Ludlow) and is represented in what we call the Talacasto-Tambolar arch in the central Precordillera (see Figs. 3 and 12). It has a lesser extent toward the south, north, and east, where it only comprises the Middle–Late Ordovician (late Caradoc and early Ashgill). The diachronism of Upper Ordovician and Silurian siliciclastic sequences onlapping the Lower and Middle Ordovician deposits in the central Precordillera and the thick turbidite successions with interlayered carbonate megabreccias synchronous with the unconformity development to the south and north indicate regional doming in the central Precordillera while high subsidence troughs were active in both extremes (Fig. 12a). This was interpreted by Astini (1992a) as a peripheral bulge (cf. Jacobi, 1981; Shanmugam and Lash, 1982) related to the early stages of a foreland developed along a colliding irregular continental margin (Quinlan and Beaumont, 1984; Flemings and Jordan, 1990). The model is analogous to those shown in Dewey and Kidd (1974), Lash (1988, 1989), and Ettensohn (1991) for the Appalachians, wherein the promontories are involved first in the collisional effects, while the reentrants continue to function as depocenters. The important time gap involved in the Talacasto-Tambolar arch is probably related to combined effects of erosion and amalgamation with the previous forebulge active during the collision of the Precordilleran terrane with Gondwana.

New data on the Silurian (Benedetto et al., 1985, 1992b; Sánchez et al., 1991a, 1993; Astini and Piovano, 1992) and Devonian (Astini, 1990a, 1990b, 1991b; Herrera, 1991) of the Precordillera permit a better understanding of the depositional history of this basin, which can be compared with a foreland infill (Benedetto et al., 1985; Astini 1991b, 1992b; Sánchez et al., 1993), wherein the sequence arrangement is related to lithosphere rheology and eustasy. The thicknesses of the Late Ordovician to Devonian packages demonstrate that the foreland depocenters were east of the Precordilleran basin, between the eroded Famatinian collisional belt and the peripheral bulge.

Recently, González Bonorino and González Bonorino (1991) completed the tectonic subsidence curve proposed by Bond et al. (1984) for the lower Paleozoic carbonate successions of the Precordillera. According to this curve (Fig. 13), after the rifting stage that began ca. 555 Ma (Lower Cambrian), thermal subsidence typical of a passive margin (low gradient segment of the curve) lasted until the Middle Ordovician (450 Ma). After, a period of basin rearrangement during the Late Ordovician produced uplifting and erosion in the central Precordillera between the Jáchal and the San Juan Rivers (lat. 30°30′S–32°S; Fig. 9), before the deposition of the La Chilca Alloformation (Fig. 12). This is interpreted as the transition from a passive margin to a peripheral foreland, with the uplifted Talacasto-Tambolar arch representing the flexural forebulge. Coeval sedimentation was active north of the Jáchal River, south of the San Juan River, and in the Eastern Precordillera (Fig. 12), wherein coarse turbidite associations were deposited.

The curve of González Bonorino and González Bonorino (1991) (Fig. 13) is only valid for lat 30°15′S where the erosive unconformity, involving the Late Ordovician, developed between units gathered into the Las Plantas Alloformation (Las Aguaditas

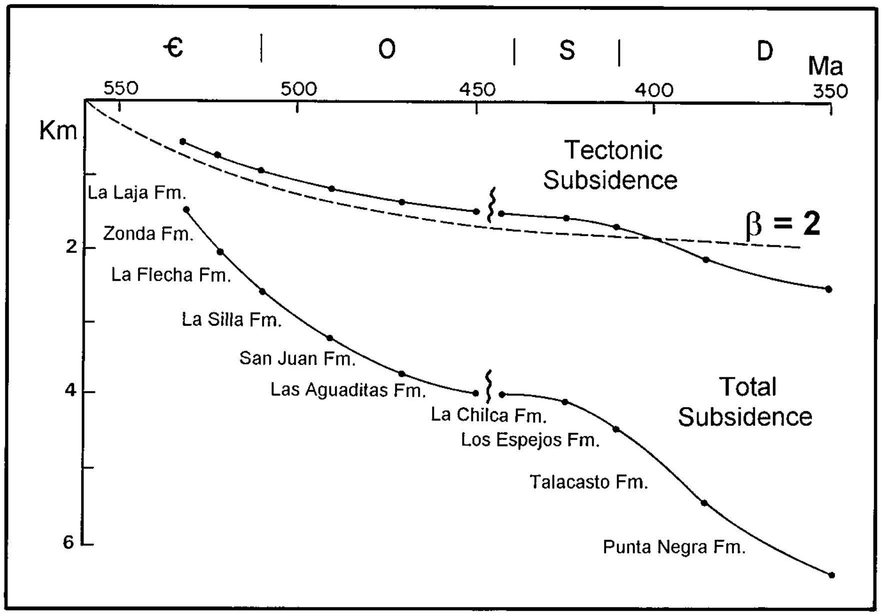


Figure 13. Tectonic subsidence and total subsidence curves for the lower Paleozoic successions of the Precordilleran basin at lat. 30°15′S. Note the unconformity at 450 Ma. The lithostratigraphy is given in the bottom curve (modified from González Bonorino and González Bonorino, 1991). For discussion see text.

Formation) and the La Chilca Alloformation (La Chilca Formation; Fig. 13). Due to the absence of evidence for the unconformity being controlled by a sea-level drop, the tectonic subsidence curve should be corrected to show the advent of upward crustal flexure, which was not considered by them. The thickness of the Trapiche Alloformation (Middle–Late Ordovician) at both ends of the arch, and particularly in the north (Fig. 12a), indicate high rates of sedimentation and accommodation, patterns that clearly show a developing foreland. High subsidence rates (Fig. 13) and space availability during the Silurian and Devonian coupled with the recurrent stacking of shallow marine successions typical of forelands (Swift et al., 1985, 1987). The increasing subsidence due to tectonic loading to the west (present coordinates) generated toward the Middle Devonian enough space to deposit the thick turbidite succession of the Punta Negra Formation (González Bonorino and Middleton, 1976; Astini, 1990b).

By this complicated lithostratigraphic scheme—abundance of coarse clastic rocks and strong variations in thickness and lateral extent—pure eustatics may be ruled out as causes of unconformities and sharp facies changes, particularly since the Early–Middle Ordovician. Before that, stacked carbonate sequences characterize a passive margin (Baldis et al., 1982; Baldis and Bordonaro, 1985; Bond et al., 1984) wherein eustatic sea-level changes were the main architectural influence.

Along the western border of the basin (western tectofacies), the Los Sombreros Formation crops out in the Yerba Loca and Tontal Ranges. This unit, mainly of Arenig–lower Llanvirn age (Ortega et al., 1991; Benedetto and Vaccari, 1992), consists of shales and turbidites with several horizons of olistostromes containing calcareous exotic blocks >100 m long of mixed Cambrian–Early Ordovician ages (Benedetto and Vaccari, 1992; Lehnert, 1994). The succession represents a steep shelf edge to deep marine slope environment developed west of the Precordilleran carbonate bank, which was uplifted during the early Guandacol orogenic phase. Its nature suggests an approximate positioning on the boundary between thick continental crust and attenuated continental crust, and provided that remnants of oceanic crust outcrop in the westernmost Precordillera. Olistolith age and lithology indicate provenance from the carbonate platform, and the regional extent of the olistostromes along the entire length of the carbonate bank margin suggests that seismicity related to the Precordilleran terrane collision was the most probable mechanism to trigger the detachment and mobilization of blocks on the steepened slope. Interestingly, the Cambrian blocks are themselves composed of slope carbonates, indicating they are derived from earlier slope deposits.

Llanvirn to mid-Caradocian thick turbiditic, siliciclastic successions, affected by low metamorphism (Baldis et al., 1982; Ramos et al., 1986; von Gosen 1992), overlay the Los Sombreros coarse clastic rocks. Based on their petrography, Astini (1991a; see also Spalletti et al., 1989) recognized a basement provenance dominated by low-grade metamorphic rocks with minor volcanic fragments. Astini (1991a) inferred that its provenance could not have been from the east (Gondwana basement), because the succession developed synchronously with the deposition of black shales and carbonates in the central and eastern Precordillera, which required low rates of clastic influx. He recognized, however, (see also Ortega et al., 1991) that in its initial stages the clastic wedge had some provenance from the east, although the sediments were arranged with longitudinal (north-south) paleocurrents. Afterward, the longitudinal patterns dominated and a probable western provenance, coming from the Chilenian terrane or some southern continuation of the Arequipa allochthon, provided the siliciclastic detritus. The longitudinal paleocurrents pattern, high sedimentation rate, general coarsening and thickening upward trend, and interfingered pillow lavas suggest a trench setting and convergence (Ramos et al., 1984; Astini 1991a). The interfingering of pillow lavas first with pelagites and then (in progressively younger strata) with coarser sandstones indicates the progressive approach of an oceanic ridge toward the trench. Few outcrops of Silurian and Devonian strata have been found in western Precordillera.

The pressure-temperature-time paths of the low-grade metamorphic western tectofacies (Fig. 9) can be interpreted in terms of mass balance of a deforming orogen (cf. Jamieson and Beaumont, 1988). Astini (1991a, 1992b) suggested that a steady-state exhumation could have affected the western Precordillera during the Devonian (Chanic) deformation that ended the Famatinian orogeny. According to this idea, the abrupt changes in the décollement depths between the central and the western Precordillera (boundary between the eastern and western tectofacies), highlighted by Allmendinger et al. (1990) and von Gosen (1992), could be related to the buttress ramp inherited from the rifted passive margin of Laurentia. This is also marked by the increasing Bouguer gravity gradient to the west (Introcaso et al., 1992), which appears to be coincident with the marked topographic change between the western and eastern tectofacies. The inherited relief apparently exerted a fundamental control on the location of the uplifts during convergence and successive compressive tectonics.

CRITICAL EVIDENCE ON FAMATINA AND WESTERN PAMPEANAS

The thick Arenigian successions in the Famatina Range and in northwestern Argentina are composed of shallow marine siliciclastic sequences. In addition, the Famatina Range successions contain abundant concordant subaqueous tuffs, pyroclastic rocks, and volcanic debris (Mángano and Buatois, 1990). Recent petrologic evidence from the Famatina Range (Aceñolaza and Toselli, 1988; Mannheim and Miller, 1992) are particularly significant in demonstrating the existence of an Ordovician volcanic arc between the Gondwana basement and the Precordilleran belt. Toselli et al. (1990) concluded, using geochemical trends of immobile elements, that the volcanic suites outcropping in northwest Famatina are derived from active continental margin volcanism, although Mannheim (1993) determined that this was the first stage of an oceanic volcanic arc. The granitic plutonism in the Famatina Range (Toselli et al., 1991, 1993) would represent the dissected volcanic arc complex. According to Saal (1993), in its southern continuation (the Paganzo Range), these granites have Late Ordovician radiometric ages. On the basis of its geology and the Celtic affinities of brachiopod faunas, the Famatina Range can be considered a probable remnant of the intra-Iapetus island arcs accreted as a different terrane (cf. Aceñolaza et al., 1990) to the proto-Gondwana margin prior to the formation of the Precordillera.

Reprocessed deep seismic reflection data (Cominguez and Ramos, 1991) across the western Sierras Pampeanas and Precordilleran boundary seem to be consistent with an allochthonous origin for the Precordillera and a subduction zone dipping to the east. Von Gosen (1992) distinguished, in the eastern Precordillera, west-directed duplex structures within the Ordovician limestones that contain inherited pre-Carboniferous thrusting, which might be related to the accretion of the Precordilleran terrane. He also pointed out the existence of widespread Devonian low-grade metamorphism accompanied by intense folding affecting the Ordovician and Silurian rocks in the western Precordillera. This deformation might be related to Chilenian accretion.

Based on different lines of evidence, Dalla Salda et al. (1992a), Loske (1992), and McDonough et al. (1993) suggested a broad Grenville age for the western Sierras Pampeanas of central Argentina. These new data have precipitated a debate related to the idea of a connection between Laurentia and proto-Gondwana, with the Grenville orogen the most suitable event to place both continents next to each other (Dalziel, 1992b; Dalla Salda et al., 1992b; Ramos et al., 1993). According to our data, and taking into account the partial interposition of the western Pampeanas between Precordillera and Famatina (see Fig. 1), it is much simpler to consider the western Pampeanas (Umango, Maz, Pie de Palo, Valle Fertil, La Huerta, and El Gigante Ranges; Fig. 8) part of the Proterozoic Laurentian basement that originally rifted together with Precordillera and, as a whole, collided against Famatina and the eastern Pampeanas (Pampia terrane of Ramos et al., 1993) during the Ordovician. In this case, the suture should be located east of the Valle Fertil Range (Fig. 8), which is surprisingly well aligned with basement outcrops in the El Gigante Range in the San Luis Province (Gardini, 1993) and in the southwestern part of La Pampa Province.

This leaves enigmatic Ordovician limestones (Sarmiento and Heredia, 1983; Hünicken, 1989) to the west. These are also recorded in the subsurface of the Cacheuta-Alvear subbasins (Rolleri and Fernández Garrasino, 1979; Criado Roque, 1979) in the southeast part of Mendoza. Moreover, the basement of the Ponón Trehué limestones series of Mendoza was correlated with the Grenvillian Pie de Palo basement (Criado Roque and Ibánez, 1979). Thus, the Precordilleran terrane would extend its southern boundary to northern Patagonia, yielding a length of almost 1000 km. In our hypothesis the hidden apparent disruption between the Precordilleran and western Sierras Pampeanas basements (Fielding and Jordan, 1988; Cominguez and Ramos, 1991; Smalley et al., 1993) can be interpreted as the extinct mid-ocean ridge of Thomas (1991, Fig. 4B). Recent studies on Grenville xenoliths in Miocene volcanic rocks from central Precordillera (Abbruzzi et al., 1993) reveal no obvious dissimilarities between Precordilleran and Pie de Palo (western Pampeanas) basements, which is in agreement with this hypothesis. On the other hand, the Rinconada–Mogotes Negros olistostrome would represent inherited passive margin normal faults reactivated and inverted during the collision of the Precordilleran terrane. This hypothesis would explain the abundant mafic cobble and boulder conglomerates deposited in the eastern Precordillera during the Middle and Late Ordovician, with provenances from the western Pampeanas basement, wherein basic-rock complexes are abundant (Villar, 1975; Caminos, 1979b).

EVOLUTION OF THE PRECORDILLERA: A GEODYNAMIC MODEL

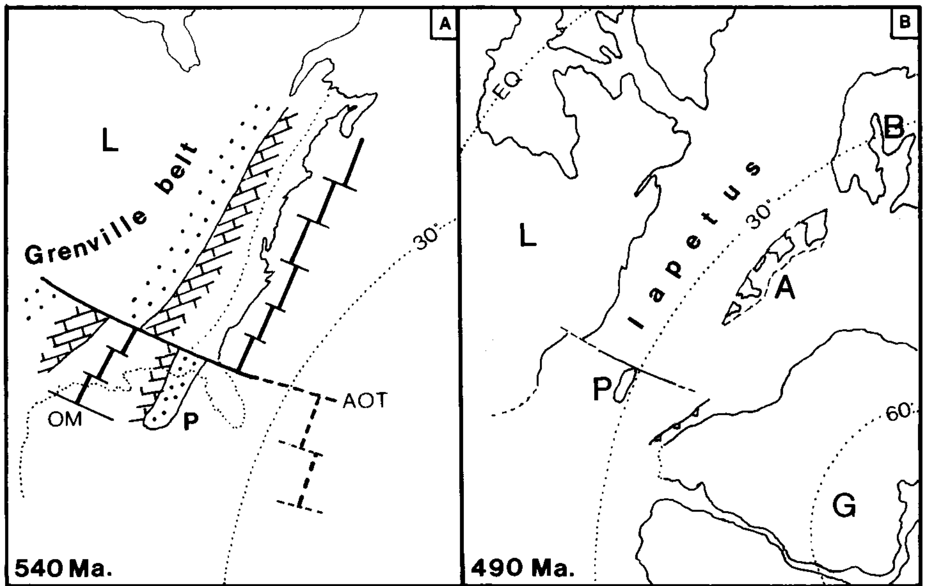
According to the data presented above, there is enough evidence in the Argentine Precordillera to support a collisional history due to consecutive accretion of the Precordilleran and Chilenian terranes to the early Paleozoic western Gondwana margin (Figs. 11 and 14).

Late Proterozoic–Early Cambrian

The rifting and opening of the Iapetus ocean at ca. 550–570 Ma (Hatcher, 1989) produced the passive continental margin of the Precordilleran terrane, which drifted away from Laurentia (Figs. 11a, 11b, and 14a). The most suitable site from which to derive the Precordillera is the Ouachita rifted margin of southeastern North America. Polarity trends in the Precordilleran terrane are opposite to those in the Appalachians, and both developed on Grenvillian basement. Although confirmed rift-related rocks have not been found in the northeastern Precordillera, a succession of red beds and evaporites seems to transitionally underlie the Early Cambrian open-marine limestones and fine-clastic alternations, which could be correlated to the syn-rift deposits (Fig. 11a). Strong trilobite affinities indicate that an incipient ocean may have separated both margins. This is interpreted as the Ouachita rift, which began to open in the Early Cambrian, according to Thomas (1991).

Middle–Late Cambrian

Carbonate deposition was continuous throughout the Cambrian in the Precordillera, reflecting a general transgressive period related to post-rift thermal subsidence (Bond et al., 1984) as well as eustatic sea-level rise (Vail et al., 1977). The Middle Cambrian successions are mainly subtidal,



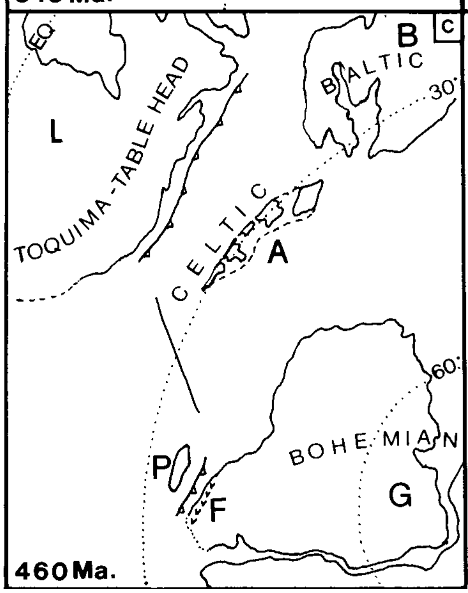


Figure 14. (A) Paleogeographic reconstruction for the Middle Cambrian with the initial rifting stage (modified from Thomas, 1991). (B) The drifting stage during the Early Ordovician (490 Ma) (modified from Dalziel, 1992a, 1992b). (C) The collision (460 Ma) of the Precordilleran terrane with the western Gondwana margin during Middle Ordovician, showing location of brachiopod biogeographic provinces. L = Laurentia, P = Precordilleran terrane, AOT = Alabama-Oklahoma transform, OM = Ouachita mid-ocean ridge, B = Baltica, A = Avalon, G = Gondwana, F = Famatina, EQ = equator.

while the Late Cambrian is composed of intertidal dolostone. Thorough trilobite exchange with the southern Appalachians is suggested based on the high affinities of faunas during this period (Fig. 11c).

Tremadoc

Tidal flat carbonates (La Flecha Formation) were followed by a predominantly calcareous mid-shelf sequence (La Silla Formation) deposited during the Tremadoc–early Arenig. This deepening correlates with a global sea-level rise suggested by James et al. (1989), which is reflected in the rest of the Gondwana margin by a widespread transgressive clastic sequence (Santa Victoria Group of northwest Argentina). In the Famatina region (toward the northeast, actual coordinates), the black shales of the Volcancito Formation were deposited in an ensialic back-arc basin related to the inception of a Late Cambrian east-dipping subduction zone (Fig. 11c). A similar geodynamic scenario was proposed by Bahlburg and Breitkreuz (1991) to explain the origin of the Puna and Cordillera Oriental basins of northwest Argentina.

Arenig

Brachiopod and conodont affinity variation supports the drifting of Precordillera during the Arenig (Fig. 14b). Some 80 m.y. after the break-up, the Precordilleran terrane was ~2500–3000 km southeast of the Laurentian margin, and a narrow ocean separated it from Gondwana (Fig. 11d). East of the subduction zone, an extensive volcanic-arc system had developed in the Famatina Range (Toselli et al., 1990). Shallow marine fossiliferous shale, sandstone, and layers of volcaniclastic materials (Suri Formation) filled the Famatina back-arc basin. Brachiopods with Celtic affinities indicate for the first time a faunal connection between the Famatina and the Precordilleran terrane carbonate platform. By the end of this stage, the close proximity to Gondwana initiated subsidence in the northeastern reaches of the Precordilleran terrane, which was transformed into a peripheral foredeep. Abrupt shallowing (San Juan Formation) and diachronous black shale deposition (Gualcamayo Alloformation) reflect the passage of the carbonate platform across a forebulge.

Along the open-sea facing margin (western tectofacies), a thick slope-to-basin coarse clastic wedge started to build to the west of the swell, which limited the starved foreland to the east. The succession contains abundant resedimented Cambrian slope carbonates, which indicate the former existence of bank margin deposits toward the west.

Llanvirn–Llandeilo

Continued eastward subduction resulted in the closing and deformation of the Famatina back-arc basin (early stage of collision), giving rise to the Guandacol orogenic event (Fig. 11e). Accretion of the Precordilleran terrane to Gondwana occurred during the Llanvirn (Fig. 14c). Extensive black shale unconformably covered the carbonate platform in a starved peripheral foreland during the early Llanvirn, causing the demise of the Precordilleran carbonate platform by the combined effects of tectonic and eustatic drowning. Major subsidence driven by west-verging thrust loading affected the eastern border of the Precordillera, where deep-water sediments were deposited directly on shallow-water limestones. Rapid lateral facies changes and wildflysch (i.e., Rinconada Formation) suggest that block-faulted structures (cf. Bradley and Kidd, 1991) accompanied the subsidence of the Precordilleran collisional foredeep.

Prominent diachronous conglomerates (i.e., La Cantera and Las Vacas Formations) filled small basins in the eastern tectofacies, suggesting active motion of normal faults during the Llandeilo–lower Caradoc related to post-collisional relaxation. This explains their problematic composition, mainly derived from basic and intermediate igneous rocks coming from the east (Astini, 1991a). Alternatively, the coarse-grained sedimentation could have been derived from sinistral wrench faulting due to oblique collision, which might have started to displace the Precordilleran terrane to the south toward its present position.

The exact location of the suture zone remains uncertain. The possibilities include either the boundary between the eastern Precordillera and the western Sierras Pampeanas or the eastern border of the western Sierras Pampeanas, considering in the latter the western Sierras Pampeanas as part of the Grenville Precordilleran terrane basement.

After the Precordilleran terrane collision occurred, new westward subduction began to systematically reduce the width of the ocean basin west of the Precordilleran terrane.

Caradoc–Ashgill

The approaching Chilenian terrane developed an eastward polarity, giving rise to a new foreland basin whose peripheral bulge caused upwarping and erosion in the central Precordillera (present coordinates). This gave rise to the regional unconformity developed diachronously during the Late Ordovician (Fig. 11f). The large gap in the Tambolar-Talacasto arch represents merging of the two forebulge unconformities and overlapping of the Arenig–Llanvirn and the Late Ordovician upwarping stages. These are interpreted, respectively, as the product of initial accretion of the Precordilleran and Chilenian terranes but, alternatively, may be related to initial and final forebulging episodes related to the Precordilleran collision.

Thick carbonate megabreccias (Trapiche Alloformation) were shifted from the arch into local rapid-subsidence depocenters localized to the south and north, making evident active cannibalization of exposed Lower and Middle Ordovician strata at the promontory.

In the westernmost part of the Precordillera, the clastic wedge was fed from basement rocks and lesser amount of volcanics (probably derived from the Chilenian terrane), progressively interfingered with pillow lavas during the Caradoc (i.e., Alcaparrosa Formation). The thickening-upward pattern indicates progressively greater proximity of the oceanic ridge to the trench and the eventual subduction.

During the late Ashgill (Hirnantian), eastern-derived glacial sediments, similar to those recorded in the sub-Andean ranges of northern Argentina and Bolivia, were deposited along the eastern margin of the Precordillera. These represent a straight-forward tie to Gondwana.

Silurian

Silurian and Devonian siliciclastic sequences are characterized mainly by fine-grained shelf deposits and are mostly confined to the east side of the later forebulge (eastern tectofacies). The Lower Silurian successions onlap the Tambolar-Talacasto arch (Fig. 11g) to the west. On the easternmost border of the Precordilleran basin, the wildflysch of Llandovery and Wenlock age (Mogotes Negros–Rinconada Formations) represent stages of collisional relaxation, although they also have been considered a probable north-south trend shear zone that displaced the Precordillera (Ramos et al., 1986).

The general stacking pattern of the Silurian successions and their predominantly shallow-marine nature suggest a foreland depositional environment where the cyclical facies arrangement was controlled by eustasy or by the lithospheric relaxation of the foreland.

Devonian

Cyclic patterns of shallow-marine sequences went on developing with progressive increments in the sedimentation rate. Increasing depth and final shallowing upward (Cuerda et al., 1990; Astini, 1990b) occurred toward the early and late Middle Devonian, represented by the Punta Negra Formation (Fig. 11h). This indicates the final stages of active thrust loading (deepening) and subsequent quiescence (emerging).

During the Late Devonian, the lower Paleozoic was folded and shortened during the Chanic diastrophism, which closed the Famatinian orogenic cycle (Fig. 11i). Carboniferous strata cover the lower Paleozoic succession in angular unconformity. This is regarded, as originally suggested by Ramos et al. (1984, 1986), as the final accretion of the Chilenian terrane with Precordillera.

CONCLUSIONS

The data presented herein agree in general with the hypothesis of two allochthonous terranes accreted to Gondwana during the early Paleozoic at the latitude of the Argentine Precordillera, as suggested originally by Ramos et al. (1986). In light of new sedimentologic, stratigraphic, and paleontologic data, the collisional history of the Precordillera and its paleogeography can be delineated (Fig. 11). The rift-drift stage of the Precordillera began in the Early Cambrian, when it was rifted from the Laurentian margin, probably from a position in or near the southern Appalachians (Fig. 14a). The Precordilleran terrane was accreted to Gondwana during the Early Ordovician (Arenig–Llanvirn), developing the volcanic arc of the Famatina Range due to eastward subduction. For the first time, it is suggested that the western Pampeanas could have been part of the Precordilleran terrane. At that time, extensive diachronous basinal black shale covered the carbonate platform in response to a combined sea-level rise and thrust loading subsidence related to the collision (Guandacolic orogeny). The approach of the Chilenian terrane during the Late Ordovician produced a peripheral bulge-related unconformity, which merged in the central Precordillera with the older (Guandacolic) unconformity. The Silurian and Devonian systems are mainly stack-up shallow-marine systems with cyclicity patterns influenced by the foreland subsidence history. The Chanic diastrophism (late Famatinian orogeny) due to final accretion of the Chilenian terrane, closed the early Paleozoic evolution in the Precordilleran basin by telescoping the successions. A regional angular unconformity underlies the upper Paleozoic rocks, which cover the lower Paleozoic everywhere. By the late Paleozoic a flip initiated new east-dipping subduction under the western margin of Chilenia.

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REFERENCES CITED

Abbruzzi, J., Kay, S. M., and Bickford, M. E., 1993, Implications for the nature of the Precordilleran basement from Precambrian xenoliths in Miocene volcanic rocks, San Juan Province, Argentina: Mendoza, 12° Congreso Geológico Argentino and 2° Congreso de Exploración de Hidrocarburos, v. 3, p. 331–339.

Aceñolaza, G. F., and Toselli, A. J., 1976, Consideraciones estratigráficas y tectónicas sobre el Paleozoico Inferior del Noroeste Argentino: Caracas, Venezuela, 2° Congreso Latinoamericano de Geología, v. 2, p. 755–763.
Aceñolaza, G. F., and Toselli, A. J., 1988, El Sistema de Famatina: Su interpretación como orógeno de margen activo: Santiago de Chile, 5° Congreso Geológico Chileno, v. 1, p. 55–67.
Aceñolaza, G. F., Miller, H., and Toselli, A. J., 1990, Zonas miloníticas de sectores orientales al Sistema del Famatina, Argentina: San Juan, 10° Congreso Geológico Argentino, v. 2, p. 289–292.
Albanesi, G. L., and Vaccari, N. E., 1994, Conodontes del Arenig en la Formación Suri, Sistema del Famatina, Argentina: Revista Española de Micropaleontología, v. 26, p. 125–146.
Allmendinger, R. W., Figueroa, D., Snyder, D., Beer, J., Mpodozis, C., and Isacks, B. L., 1990, Foreland shortening and crustal balancing in the Andes at 30° S latitude: Tectonics, v. 9, p. 789–809.
Amos, A., 1954, Estructura de las formaciones paleozoicas de La Rinconada, pie oriental de la Sierra Chica de Zonda (San Juan): Revista de la Asociación Geológica Argentina, v. 9, p. 5–38.
Amos, A., and Rolleri, E. O., 1965, El Carbónico marino en el valle de Calingasta-Uspallata (San Juan–Mendoza): Boletín de Informaciones Petroleras, v. 368, p. 1–21.
Astini, R. A., 1986, Análisis petrológico, litofacial y estratigráfico de las unidades clásticas ordovícicas en el área de Guandacol, Norte de la Precordillera y sus implicancias en la evolución paleogeográfica de la cuenca [Degree thesis]: Córdoba, Argentina, Universidad Nacional de Córdoba, 68 p.
Astini, R. A., 1988, Yerba Loca Formation, an Ordovician clastic wedge in western Argentina: Newfoundland, Canada, 5th International Symposium on the Ordovician System, Abstracts, p. 3.
Astini, R. A., 1990a, Cuerpos de arena en la Formación Talacasto, Plataforma fangosa del Devónico precordillerano, Provincia de San Juan: San Juan, 3° Reunión Argentina de Sedimentología, p. 13–18.
Astini, R. A., 1990b, Formación Punta Negra: ¿un abanico submarino o un complejo deltaico de plataforma?: San Juan, 3° Reunión Argentina de Sedimentología, p. 19–24.
Astini, R. A., 1991a, Paleoambientes sedimentarios y secuencias depositacionales del Ordovícico clástico de la Precordillera Argentina [Ph.D. thesis]: Córdoba, Argentina, Universidad Nacional de Córdoba, 851 p.
Astini, R. A., 1991b, Sedimentología de la Formación Talacasto: Plataforma fangosa del Devónico precordillerano, Provincia de San Juan: Revista de la Asociación Geológica Argentina, v. 46, p. 277–294.
Astini, R. A., 1992a, Origin and implications of a lower Paleozoic (Late Ordovician to Early Silurian) unconformity on the Precordillera basin of Western Argentina, *in* Thiry, M., ed., Paleoweathering records and paleosurfaces "Landscape reconstruction": La Plata, Argentina, 2nd International Meeting, Project 317 (IGCP), Abstracts, p. 6–7.
Astini, R. A., 1992b, Tectofacies ordovícicas y evolución de la cuenca eopaleozoica de la Precordillera Argentina: Estudios Geológicos, v. 48, p. 315–327.
Astini, R. A., 1993a, Secuencias depositacionales y niveles del mar en el sistema Ordovícico de la Precordillera Argentina: Boletín de la Real Sociedad Española de Ciencias Naturales (Geología), v. 88, p. 113–126.
Astini, R. A., 1993b, Facies glacigénicas del Ordovícico tardío (Hirnantiano) de la Precordillera Argentina: Boletín de la Real Sociedad Española de Historia Natural (Geología), v. 88, p. 137–149.
Astini, R. A., 1994, Sucesiones calcáreo-silicoclásticas coetáneas del Ordovícico inferior de la Precordillera y su significado en la evolución de la cuenca: Tucumán, 5° Reunión Argentina de Sedimentología, p. 113–118.
Astini, R. A., 1995a, Geología e interpretación de la Formación Gualcamayo en su localidad clásica (suroeste de Guandacol y Cordón de Perico-Potrerillo), Precordillera septentrional: Buenos Aires, Revista de la Asociación Geológica Argentina, v. 49 (in press).
Astini, R. A., 1995b, Paleoambientes y análisis secuencial de las unidades de pelitas negras (Aloformación Gualcamayo) que suprayace a las sucesiones carbonáticas Eo-Ordovícicas en la Precordillera Argentina: Buenos Aires, Revista de la Asociación Geológica Argentina, v. 49 (in press).
Astini, R. A., 1995c, Sedimentología de la Formación Las Aguaditas (talud carbonático) y evolución de la cuenca precordillerana durante el ordovícico medio: Buenos Aires, Revista de la Asociación Geológica Argentina, v. 49 (in press).
Astini, R. A., and Benedetto, J. L., 1992, El Ashgilliano tardío (Hirnantiano) del Cerro La Chilca, Precordillera de San Juan, Argentina: Ameghiniana, v. 29, p. 249–264.
Astini, R. A., and Benedetto, J. L., 1993, Paleozoic evolution of the Argentine Precordillera as a rifted, drifted and collided terrane: Geological Society of America Abstracts with Programs, v. 25, p. A232.
Astini, R. A., and Piovano, E. L., 1992, Facies de plataforma terrígena del Silúrico de la Precordillera sanjuanina: Revista de la Asociación Geológica Argentina, v. 47, p. 99–110.
Astini, R. A., Cañas, F. L., and Benedetto, J. L., 1988, The Ordovician in the Precordillera Basin, western Argentina: Newfoundland, Canada, 5th International Symposium on the Ordovician System, Abstracts, p. 4.
Bagnoli, G., and Stouge, S., 1991, Paleogeographic distribution of Arenigian (Lower Ordovician) conodonts: Rio de Janeiro, Anais da Academia Brasileira de Ciências, v. 63, p. 171–183.
Baldis, B. A., 1989, Autochthony of South American Eo-Paleozoic platforms: Washington D.C., 28th International Geological Congress, Abstracts, v. 1, p. 77–78.
Baldis, B. A., and Blasco, G., 1973, Trilobites ordovícicos de Ponon Trehué, Sierra Pintada de San Rafael, provincia de Mendoza: Ameghiniana, v. 10, p. 72–88.
Baldis, B. A., and Bordonaro, O., 1985, Variaciones de facies en la cuenca Cámbrica de la Precordillera Argentina y su relación con la génesis del borde continental: Bogotá, Colombia, 9° Congreso Latinoamericano de Geología, p. 31–42.
Baldis, B. A., and Chebly, G., 1969, Estructura profunda del área central de la Precordillera sanjuanina: 4º Jornadas Geológicas Argentinas, v. 1, p. 47–66.
Baldis, B. A., Beresi, M. S., Bordonaro, O., and Uliarte, E., 1981, Estromatolitos, trombolitos y formas afines en el límite Cámbrico–Ordovícicodel oeste argentino: Porto Alegre, Brazil, 2° Congreso Latinoamericano de Paleontología, v. 1, p. 19–30.
Baldis, B. A., Beresi, M. S., Bordonaro, O., and Vaca, A., 1982, Síntesis evolutiva de la Precordillera de Argentina: Buenos Aires, Argentina, 5° Congreso Latinamericano de Geología, v. 4, p. 399–445.
Baldis, B. A., Beresi, M. S., Bordonaro, O., and Vaca, A., 1984, The Argentine Precordillera as a key to the Andean structure: Episodes, v. 17, p. 14–19.
Baldis, B. A., Peralta, S., and Villegas, R., 1989, Esquematizaciones de una posible transcurrencia del terreno de Precordillera como fragmento continental procedente de áreas pampeano-bonaerenses: Tucumán, Argentina, Instituto Superior de Correlación Geológica, v. 5, p. 81–100.
Bahlburg, H., and Breitkreuz, C., 1991, Paleozoic evolution of active margin basins in the southern central Andes (northwestern Argentina and northern Chile): Journal of South American Earth Sciences, v. 4, p. 171–188.
Banchig, A. L., and Bordonaro, O. L., 1990, Nuevos afloramientos del talud continental cámbrico en la Sierra del Tontal, San Juan, Argentina: San Juan, 11° Congreso Geológico Argentino, v. 2, p. 49–52.
Barnes, C. R., 1984, Early Ordovician eustatic events in Canada, *in* Bruton, D. L., ed., Aspects of the Ordovician System: Paleontological Contribution University of Oslo, Universitetsforlaget, v. 295, p. 51–63.
Beaumont, C., Keen, C. E., and Boutiller, R., 1982, A comparison of foreland and rift margin sedimentary basins: Philosophical Transactions of the Royal Society London, Series A, v. 305, p. 295–317.
Beer, J. A., Allmendinger, R. W., Figueroa, D. A., and Jordan, T. E., 1990, Seismic stratigraphy of a Neogene piggy-back basin, Argentina: American Association of Petroleum Geologists Bulletin, v. 74, p. 1183–1202.
Ben-Avraham, Z., Nur, A., Jones, D., and Cox, A., 1981, Continental accretion: From oceanic plateaus to allochthonous terranes: Science, v. 213, p. 47–54.
Benedetto, J. L., 1985, Early Ordovician brachiopods of Argentine Precordillera and their paleogeographic significance: Brest, France, 1st International Congress on Brachiopods, Abstracts, p. 14.
Benedetto, J. L., 1986, The first typical Hirnantia fauna from South America (San Juan Province, Argentine Precordillera), *in* Racheboeuf, P. R., and Emig, C. C., eds., Les brachiopodes fossiles et actuels: Biostratigraphie du Paléozoique, v. 4, p. 439–447.
Benedetto, J. L., 1993, La hipótesis de la aloctonía de la Precordillera Argentina: Un test estratigráfico y biogeográfico: Mendoza, 12° Congreso Geológico Argentino, v. 3, p. 375–384.
Benedetto, J. L., 1994, Braquiópodos ordovícicos (Arenigiano) de la Formación Suri en la región del río Chaschuil, Sistema de Famatina, Argentina: Ameghiniana, v. 31, p. 221–238.
Benedetto, J. L., and Astini, R. A., 1983, A collisional model for the early Paleozoic stratigraphic evolution of the Argentine Precordillera: Oxford, United Kingdom, 2nd International Symposium on Andean Geodynamics, Abstracts, p. 13–15.
Benedetto, J. L., and Vaccari, N. E., 1992, Significado estratigráfico y tectónico de los complejos de bloques cambro–ordovícicos resedimentados de la Precordillera Occidental, Argentina: Estudios Geológicos, v. 48, p. 305–313.
Benedetto, J. L., Herrera, Z., and Sánchez, T., 1985, Paleoambiente de sedimentación de la Formación Los Espejos y su significado en la interpretación de la cuenca silúrica de la Precordillera Argentina: San Juan, Argentina, Reunión de Comunicaciones Paleontológicas, p. 61–63.
Benedetto, J. L., Racheboeuf, P., Herrera, Z., Brussa, E., and Toro, B., 1992a, Brachiopodes et biostratigraphie de la Formation Los Espejos, Silurien–Eodevonien de la Precordillère argentine: Geobios, v. 25, p. 599–637.
Benedetto, J. L., Sánchez, T. M., and Brussa, E. D., 1992b, Las cuencas silúricas de América Latina, *in* Gutierrez Marco, J. G., et al., eds., Paleozoico inferior de Ibero América: Madrid, Spain, Universidad de Extremadura, p. 119–144.
Bergstrom, S. M., 1990, Relations between conodont provincialism and the changing palaeogeography during the early Paleozoic, *in* McKerrow, W. S., and Scotese, C. R., eds., Palaeozoic palaeogeography and biogeography: Geological Society of London Memoir 12, p. 129–137.
Berry, W. B., and Boucot, A. J., 1972, Correlation of the South American Silurian rocks: Boulder, Colorado, Geological Society of America Special Paper 133, p. 1–59.
Bond, G. C., Nickeson, P. A., and Kominz, M., 1984, Breakup of a supercontinent between 625 Ma and 555 Ma: New evidence and implications for continental histories: Earth and Planetary Science Letters, v. 70, p. 325–345.
Bordonaro, O., 1980, El Cámbrico de la Quebrada de Zonda: Asociación Geológica Argentina Revista, v. 35, p. 26–40.
Borrello, A. V., 1962, Caliza La Laja (Cámbrico Medio de San Juan): La Plata, Argentina, Noticias y Comunicaciones de Investigaciones Científicas, v. 2, p. 3–8.
Borrello, A. V., 1965, Sobre el desarrollo bioestratigráfico del Cámbrico de la Precordillera: Tucumán, Argentina, Universidad de Tucumán, Acta Geológica Lilloana, v. 7, p. 1–39.
Borrello, A. V., 1971, The Cambrian of South America, *in* Holland, C. H., ed., Cambrian of the New World: New York, Wiley-Interscience, p. 385–438.
Bradley, D. C., 1989, Taconic plate kinematics as revealed by foredeep stratigraphy, Appalachian orogen: Tectonics, v. 8, p. 1037–1049.
Bradley, D. C., and Kidd, W. S. F., 1991, Flexural extension of the upper continental crust in collisional foredeeps: Geological Society of America Bulletin, v. 103, p. 1416–1438.
Buggisch, W., and Astini, R. A., 1993, The Late Ordovician ice age: New evidence from the Argentine Precordillera, *in* Findlay, R. H., et al., eds., Gondwana Eight, Assembly evolution and dispersal: Rotterdam, Netherlands, Balkema, p. 439–447.
Caminos, R., 1979a, Cordillera frontal: Córdoba, Academia Nacional de Ciencias Córdoba, 2° Simposio de Geología Regional Argentina, v. 1, p. 394–453.
Caminos, R., 1979b, Sierras Pampeanas Noroccidentales, Salta, Tucumán, Catamarca, La Rioja y San Juan: Córdoba, Academia Nacional de Ciencias Córdoba, 2° Simposio de Geología Regional Argentina, v. 1, p. 291–295.
Caminos, R., Cingolani, C. A., Hervé, F., and Linares, E., 1982, Geochronology of the pre-Andean metamorphism and magmatism in the Andean Cordillera between latitudes 30° and 36° S: Earth Science Review, v. 3, p. 333–352.
Cañas, F. L., 1986, Análisis de las facies carbonáticas de la formación Los Sapitos (Cámbrico?–Tremadociano) en la Qda. del Río Guandacol, La Rioja: San Juan, Argentina, 1° Jornadas de Geología de Precordillera, p. 271–276.
Cañas, F. L., 1988, Facies perimareales del Cámbrico Inferior en el área de Guandacol (La Rioja): Buenos Aires, 2° Reunión Argentina de Sedimentología, v. 1, p. 46–50.
Cañas, F. L., and Carrera, M., 1993, Early Ordovician sponges-algal reef mound of the Precordillera basin, western Argentina: Erlangen, Germany, Facies, v. 29, p. 169–178.
Cañas, F. L., and Keller, M., 1993, "Reefs" y "Reef Mounds" en la Formación San Juan (Precordillera sanjuanina, Argentina): Los Arrecifes más antiguos de Sudamérica: Boletín de la Real Sociedad Española de Historia Natural (Geologia), v. 88, p. 127–136.
Carrera, M., 1991, Los géneros *Selenoides* Owen y *Calathium* Billings en el Ordovícico de la Precordillera de San Juan, Argentina: Ameghiniana, v. 28, p. 375–380.
Cocks, L. R. M., 1972, The origin of the Silurian *Clarkeia* shelly fauna of South America, and its extension to west Africa: Palaeontology, v. 15, p. 623–630.
Cominguez, A. H., and Ramos, V. A., 1991, La estructura profunda entre Precordillera y Sierras Pampeanas de la Argentina: Evidencias de la sísmica de reflexión profunda: Revista Geológica de Chile, v. 18, p. 3–14.
Cortelezzi, C. R., Furque, G., and Pavlicevic, R. E., 1982, Estudio petrológico de las lavas almohadilladas del Caradociano de la zona de Rodeo, Departamento Iglesia, provincia de San Juan: Buenos Aires, Argentina, 5° Congreso Latinamericano de Geología, v. 2, p. 161–172.
Criado Roque, P., 1979, Subcuenca de Alvear: Córdoba, Argentina, Academia Nacional de Ciencias Córdoba, 2° Simposio de Geología Regional Argentina, v. 1, p. 811–836.
Criado Roque, P., and Ibáñez, G., 1979, Provincia Geológica San Rafaelino-Pampeana: Córdoba, Academia Nacional de Ciencias Córdoba, 2° Simposio de Geología Regional Argentina, v. 1, p. 837–869.
Cucchi, R. J., 1972, Geología y estructura de la Sierra de Cortaderas, San Juan—Mendoza, Republica Argentina: Revista de la Asociación Geológica Argentina, v. 27, p. 229–248.
Cuerda, A., Cingolani, C., Schauer, O., and Varela, R., 1986, Cámbrico y Ordovícico de la Precordillera de San Juan: Formación Los Sombreros, ampliación de su conocimiento bioestratigráfico: Mendoza, 4° Congreso Argentino de Paleontología y Bioestratigrafía, v. 1, p. 5–17.
Cuerda, A., Arrondo, O. G., Morel, E., and Spalletti, L. A., 1990, Procesos de continentalización en el Devónico de la Precordillera: Revista del Museo de La Plata, Nueva Serie (Geología), v. 10, p. 185–195.
Dalla Salda, L., Cingolani, C. A., and Varela, R., 1992a, Early Paleozoic belt of the Andes and southwestern South America: Result of Laurentia-Gondwana collision?: Geology, v. 20, p. 617–620.
Dalla Salda, L., Dalziel, I. W. D., Cingolani, C. A., and Varela, R., 1992b, Did the Taconic Appalachians continue into southern South America?: Geology, v. 20, p. 1059–1062.
Dalziel, I. W. D., 1991, Pacific margins of Laurentia and East Antarctica–Australia as a conjugate rift pair: Evidence and implications for an Eocambrian supercontinent: Geology, v. 19, p. 598–601.
Dalziel, I. W. D., 1992a, Antarctica; A tale of two supercontinents?: Annual Review of Earth and Planetary Sciences, v. 20, p. 501–526.
Dalziel, I. W. D., 1992b, On the organization of American plates in the Neoproterozoic and the breakout of Laurentia: GSA Today, v. 2, p. 237–241.

Dalziel, I. W. D, Dalla Salda, L. H., and Gahagan, L. M., 1994, Paleozoic Laurentia-Gondwana interaction and the origin of the Appalachian-Andean mountain system: Geological Society of America Bulletin, v. 106, p. 243–252.

Dewey, J. F., and Kidd, W. S. F., 1974, Continental collision in the Appalachian-Caledonian orogenic belt: Variations related to complete and incomplete suturing: Geology, v. 2, p. 543–546.

Diecchio, R. J., 1991, Taconian sedimentary basins of the Appalachians, *in* Barnes, C. R., and Williams, S. H., eds., Advances in Ordovician geology: Geological Survey of Canada Paper 90-9, p. 225–234.

Ethington, R. L., and Clark, D. L., 1971, Lower Ordovician conodonts in North America: Boulder, Colorado, Geological Society of America Memoir 127, p. 63–82.

Ettensohn, F. R., 1991, Flexural interpretation of relationships between Ordovician tectonism and stratigraphic sequences, central and southern Appalachians, *in* Barnes, C. R., and Williams, S. H., eds., Advances in Ordovician geology: Geological Survey of Canada Paper 90-9, p. 213–224.

Fielding, E. J., and Jordan, T. E., 1988, Active deformation at the boundary between the Precordillera and Sierras Pampeanas, Argentina, and comparison with ancient Rocky Mountain deformation, *in* Schmidt, C. J., and Perry, W. J., eds., Interactions of the Rocky Mountain foreland and the Cordilleran thrust belt: Boulder, Colorado, Geological Society of America Memoir 171, p. 143–163.

Flemings, P. B., and Jordan, T. E., 1990, Stratigraphic modeling of foreland basins: Interpreting thrust deformation and lithosphere reology: Geology, v. 18 p. 430–434.

Furque, G., and Cuerda, A., 1979, Precordillera de La Rioja, San Juan y Mendoza: Córdoba, Academia Nacional de Ciencias Córdoba, 2° Simposio de Geología Regional Argentina, v. 1, p. 455–522.

Furque, G., and Cuerda, A., 1982, Extensión y edad de los movimientos de la fase Guandacol en la Precordillera del Oeste Argentino: Buenos Aires, Argentina, 5° Congreso Geológico Latinoamericano, v. 1, p. 191–200.

Gansser, A., 1975, Facts and theories on the Andes: Journal of the Geological Society of London, v. 129, p. 93–131.

Gardini, C. E., 1993, La Estructura íntima del Basamento de la sierra de El Gigante, San Luis: Mendoza, 12° Congreso Geológico Argentino and 2° Congreso de Exploración de Hidrocarburos, v. 3, p. 1–10.

González Bonorino, G., 1975, Sedimentología de la Formación Punta Negra y algunas consideraciones sobre la geología regional de la Precordillera de San Juan y Mendoza: Revista de la Asociación Geológica Argentina, v. 30 p. 223–246.

González Bonorino, G., and González Bonorino, F., 1991, Precordillera de Cuyo y Cordillera Frontal en el Paleozoico Temprano: Terrenos "bajo sospecha" de ser autóctonos: Revista Geológica de Chile, v. 18, p. 97–107.

González Bonorino, G., and Middleton, G. V., 1976, A Devonian submarine fan in western Argentina: Journal of Sedimentary Petrology, v. 46, p. 56–69.

Gosen, W. von, 1992, Structural evolution of the Argentine Precordillera: The Río San Juan section: Journal of Structural Geology, v. 14, p. 643–667.

Haller, M. J., and Ramos, V., 1984, Las ofiolitas famatinianas (Eopaleozoico) de las Provincias de San Juan y Mendoza: San Carlos de Bariloche, 9° Congreso Geológico Argentino, v. 2, p. 66–83.

Harper, D. A. T., Mitchel, W. I., Owen, A. W., and Romano, M., 1985, Upper Ordovician brachiopods from the Clashford House Formation, near Herbertstown, Co. Mea2.6meretwreland: Bulletin of the British Museum of Natural History (Geology), v. 38, p. 87–305.

Harrington, H. J., and Leanza, A. F., 1957, Ordovician trilobites of Argentina: Lawrence, University of Kansas, Department of Geology, Special Publication 1, p. 1–259.

Hatcher, R. D., Jr., 1989, Tectonic synthesis of the U.S. Appalachians, *in* Hatcher, R. D., Jr., et al., eds., The Appalachian-Ouachita orogen in the United States: Boulder, Colorado, Geological Society of America, Geology of North America, v. F-2, p. 511–535.

Havlicek, V., and Branissa, L., 1980, Ordovician brachiopods of Bolivia (succession of assemblages, climate control, affinity to Anglo-French and Bohemian provinces): Rozpravy Ceskoslovenské Akademie Ved, v. 90, p. 1–54.

Herrera, Z. A., 1991, Taxonomía, bioestratigrafía y paleogeografía de los braquiópodos de la Formación Talacasto (Devónico) de la Precordillera argentina [Ph.D. thesis]: Córdoba, Argentina, University of Córdoba, 283 p.

Herrera, Z. A., and Benedetto, J. L., 1991, Early Ordovician brachiopod faunas of the Precordillera basin, Western Argentina: Biostratigraphy and Paleobiogeographical affinities, *in* McKinnon, D. I., et al., eds., Brachiopods through time: Rotterdam, Netherlands, Balkema, p. 283–301.

Hervé, F., Davidson, J., Godoy, E., Mpodozis, C., and Covacevich, V., 1981, The late Paleozoic in Chile: Stratigraphy, structure and possible tectonic framework: Academia Brasileira Ciencias Anais, v. 53, p. 361–373.

Hünicken, M. A., 1985, Lower Ordovician conodont biostratigraphy in Argentina: Córdoba, Argentina, Boletín de la Academia Nacional de Ciencias de Córdoba, v. 56, p. 309–322.

Hünicken, M. A., 1989, Some paleogeographical aspects of South American conodonts and related forms: Frankfurt, Germany, Courier Forschungsinstitut, Senckenberg, v. 117, p. 29–49.

Hünicken, M. A., and Ortega, G., 1987, Lower Llanvirn–lower Caradoc (Ordovician) conodonts and graptolites from the Argentine central Precordillera: Nottingham, United Kingdom, 4th European Conodont Symposium, p. 136–145.

Introcaso, A., Pacino, M. C., and Fraga, H., 1992, Gravity, isostasy and Andean crustal shortening between latitudes 30 and 35° S: Tectonophysics, v. 205, p. 31–48.

Jacobi, R. D., 1981, Peripheral bulge—A causal mechanism for the Lower/Middle Ordovician unconformity along the western margin of the northern Appalachians: Earth Planetary and Science Letters, v. 56, p. 245–251.

James, N. P., Stevens, R. K., Barnes, C. R., and Knight, I., 1989, Evolution of a lower Paleozoic continental margin carbonate platform, northern Canadian Appalachians, *in* Crevello, P. D., et al., eds., Controls on carbonate platform and basin development: Tulsa, Oklahoma, Society of Economic Paleontologists and Mineralogists Special Publication 44, p. 123–146.

Jamieson, R. A., and Beaumont, C., 1988, Orogeny and metamorphism: A model for deformation and pressure-temperature-time paths with application to the central and southern Appalachians: Tectonics, v. 7, p. 417–445.

Jordan, T. E., and Gardeweg, M. P., 1989, Tectonic evolution of the late Cenozoic central Andes (20°–33° S), *in* Ben-Avraham, Z., ed., Mesozoic and Cenozoic evolution of the Pacific margins: New York, Oxford University Press, p. 193–207.

Kay, S. M., Ramos, V. A., and Kay, R. W., 1984, Elementos mayoritarios y trazas de las vulcanitas ordovícicas de la Precordillera Occidental: Basaltos de rift oceánico temprano(?) próximos al margen continental: San Carlos de Bariloche, 9° Congreso Geológico Argentino, v. 2, p. 48–65.

Keidel, J., 1921, Observaciones geológicas en la Precordillera de San Juan y Mendoza: Anales del Ministerio de Agricultura, Sección Geología, Mineralogía y Minería, v. 15, p. 7–102.

Keller, M., and Bordonaro, O., in press, Cyclic carbonate platform evolution controlled by major regressive events: The Lower/Middle Cambrian La Laja Formation, western Argentina Precordillera: Journal of South American Earth Science.

Keller, M., Buggisch, W., and Bercowski, F., 1989, Facies and sedimentology of Upper Cambrian shallowing-upward cycles in the La Flecha Formation (Argentine Precordillera). Zentralblatt für Geologie und Paläontologie, v. 1, p. 999–1011.

Keller, M., Eberlein, S., and Lehnert, O., 1993, Sedimentology of Middle Ordovician carbonates in the Argentine Precordillera: Evidence of regional relative sea-level changes: Geologische Rundschau, v. 82, p. 362–377.

Keller, M., Cañas, F. L., Lehnert, O., and Vaccari, N. E., in press, The Upper Cambrian and Lower Ordovician of the Precordillera (western Argentina): Some stratigraphic reconsiderations: Newsletter on Stratigraphy.

Kendall, C. G. St. C., and Schlager, W., 1981, Carbonates and relative changes in sea-level: Marine Geology, v. 44, p. 181–212.

Keppie, J. D., 1989, Northern Appalachian terranes and their accretionary history, *in* Dallmeyer, R. D., ed., Terranes in the circum-Atlantic Paleozoic orogens: Boulder, Colorado, Geological Society of America Special Paper 230, p. 159–192.

Keppie, J. D., 1991, Avalon, an exotic Appalachian-Caledonide terrane of western South America provenance: Santiago, Chile, Comunicaciones, v. 42, p. 109–111.

Knight, I., and James, N. P., 1987, The stratigraphy of the Lower Ordovician St. George Group, western Newfoundland: The interaction between eustasy and tectonics: Canadian Journal of Earth Science, v. 24, p. 1927–1951.

Knight, I., James, N. P., and Lane, T. E., 1991, The Ordovician St. George unconformity, northern Appalachians: The relationship of plate convergence at the St. Lawrence Promontory to the Sauk/Tippecanoe sequence boundary: Geological Society of America Bulletin, v. 103, p. 1200–1225.

Lash, G. G., 1988, Along-strike variations in foreland basin evolution: Possible evidence for continental collision along an irregular margin: Basin Research, v. 1, p. 71–83.

Lash, G. G., 1989, Middle and Late Ordovician shelf activation and foredeep evolution, central Appalachian orogen, *in* Keith, B. D., ed., The Trenton Group (Upper Ordovician Series) of eastern North America. Deposition, diagenesis and petroleum: Tulsa, Oklahoma, American Association of Petroleum Geologists Studies in Geology, v. 29, p. 37–53.

Lehnert, O., 1993, Bioestratigrafía de los conodontes arenigianos de la Formación San Juan en la localidad de Niquivil (Precordillera sanjuanina, Argentina) y su correlación intercontinental: Revista Española de Paleontología, v. 8, p. 153–164.

Lehnert, O., 1994, A *Cordylodus proavus* fauna from west-central Argentina (Los Sombreros Fm., Sierra del Tontal, San Juan Province: Zentralblatt für Geologie und Paläontologie, v. 1, p. 245–261.

Lehnert, O., and Keller, M., 1994, The Conodont record of the Argentine Precordillera: Problems and possibilities: Zentralblatt für Geologie und Paläontologie. v. 1, p. 231–244.

Leveratto, M. A., 1968, Geología de la zona al oeste de Ullum y Zonda, borde oriental de la Precordillera de San Juan, eruptividad subvolcánica y estructura: Revista de la Asociación Geológica Argentina, v. 23, p. 129–157.

Logan, B. W., Rezak, R., and Ginsburg, R. N., 1964, Classification and environmental significance of algal stromatolites: Journal of Geology, v. 72, p. 68–83.

López Gamundí, O. R, and Rosello, E. A., 1993, Devonian–Carboniferous unconformity in Argentina and its relation to the Eo-Hercynian orogeny in southern South America: Geologische Rundschau, v. 82, p. 1065–1078.

Loske, W., 1992, The west-Argentinian Precordillera: A lower Paleozoic back arc basin?: Mérida, Mexico, Conferencia Internacional del Paleozoico inferior de Ibero-América, Abstracts, p. 96–97.

Loske, W., 1993, La Precordillera del Oeste Argentino: Una cuenca de back-arc en el Paleozoico: Mendoza, Argentina, 12° Congreso Geológico Argentino y 2° Congreso de Exploración de Hidrocarburos, v. 1, p. 5–13.

Llambías, E. J, and Caminos, R., 1987, El magmatismo Neopaleozoico de Argentina, *in* Archangelsky, S., ed., The Carboniferous System of Argentina: Córdoba, Argentina, Academia Nacional de Ciencias, Publicación Especial, p. 253–271.

Ludvigsen, R., 1982, Upper Cambrian and Lower Ordovician trilobite biostratigraphy of the Rabittkettle Formation, western District of Mackenzie: Royal Ontario Museum Contribution, Life Siences Division, v. 134, p. 1–188.

Mángano, M. G., and Buatois, L. A., 1990, Evolución paleoambiental del Ordovícico al sur del Río Chaschuil, noroeste de la Sierra de Narváez, Sistema de Famatina, Argentina: San Juan, 11° Congreso Geológico Argentino, v. 2, p. 227–234.

Mannheim, R., 1993, Génesis de las vulcanitas eopaleozoicas del sistema de Famatina, noroeste de Argentina: Mendoza, 12° Congreso Geológico Argentino and 2° Congreso de Exploración de Hidrocarburos, v. 4, p. 147–155.

Mannheim, R., and Miller, H., 1992, Sistema de Famatina, NW Argentina: acreción de un arco volcánico en el borde occidental del Gondwana en el Paleozoico Inferior: Mérida, Mexico, Conferencia Internacional del Paleozoico Inferior de Ibero-América, Abstracts, p. 102.

McDonough, M. R., Ramos, V. A., Isachsen, C. E., Bowring, S. A., and Vujovich, G. I., 1993, Edades preliminares de circones del basamento de la Sierra de Pie de Palo, Sierras Pampeanas Occidentales de San Juan: Sus implicancias para el supercontinente Proterozoico de Rodinia: Mendoza, 12° Congreso Geológico Argentino, v. 3, p. 340–342.

Mena, M., and Selles Martínez, J., 1989, Aloctonía de la Precordillera durante el Paleozoico Inferior: Evidencias paleomagnéticas, *in* Cingolani, C., ed., Reunión Transectas América del Sur: Mar del Plata, Chile, Universidad de Montevideo, p. 190–194.

Mergl, M., 1988, *Incorthis* (Orthida, Brachiopoda) from the Lower Ordovician (Arenig) of Morocco: Casopis pro Mineralogii a Geologii, v. 37, p. 199–202.

Miller, J. F., 1984, Cambrian and earliest Ordovician conodont evolution, biofacies and provincialism: Boulder, Colorado, Geological Society of America Special Paper 196, p. 43–68.

Morel, P., and Irving, E., 1978, Tentative paleocontinental maps for the early Phanerozoic and Proterozoic: Journal of Geology, v. 86, p. 535–561.

Moores, E. M., 1991, Southwest U.S.–East Antarctica (SWEAT) connection: A hypothesis: Geology, v. 19, p. 425–428.

Mpodozis, C., and Ramos, V. A., 1989, The Andes of Chile and Argentina, *in* Ericksen, G. E., et al., eds., Geology of the Andes and its relation to hydrocarbon and mineral resources: Houston, Texas, Circum-Pacific Council for Energy and Mineral Resources, Earth Science Series, v. 11, p. 59–90.

Mpodozis, C., Nasi, C., Moscoso, R., Cornejo, P., Maksaev, V., and Parada, M. A., 1985, The late Paleozoic–Early Triassic magmatic belt of the Chilean Frontal Range (28°–31° S): Igneous "stratigraphy" and tectonic setting: Santiago, Universidad de Chile, Comunicaciones, v. 35, p. 161–166.

Nasi, C., Moscoso, R., and Maksaev, V., 1990, Hoja Guanta. Región de Coquimbo: Servicio Nacional de Geología y Minería, Chile, Carta Geológica de Chile 67, 140 p.

Neuman, R. B., and Harper, D. A. T., 1992, Paleogeographic significance of Arenig–Llanvirn Toquima–Table Head and Celtic brachiopod assemblages, *in* Webby, B. D., and Lawrie, L., eds., Global perspectives on Ordovician geology: Rotterdam, Netherlands, Balkema, p. 241–254.

Ortega, G., Brussa, E., and Astini, R. A., 1991, Nuevos hallazgos de graptolitos en la Formación Yerba Loca y su implicancia estratigráfica (Precordillera de San Juan, Argentina): Ameghiniana, v. 28, p. 163–178.

Ortiz, A., and Zambrano, J. J., 1981, La provincia geológica Precordillera oriental: San Luis, 8° Congreso Geológico Argentino, v. 3, p. 59–74.

Peralta, S. H., and Carter, C., 1990, La Glaciación Gondwánica del Ordovícico tardío: Evidencias en fangolitas guijarrosas de la Precordillera de San Juan, Argentina: San Juan, 11° Congreso Geológico Argentino, v. 2, p. 181–185.

Poulsen, V., 1958, Contribution to the Middle Cambrian paleontology and stratigraphy of Argentina: Matematisk-fysiske Meddelelser, Det Kongelige Danske Videnskabernes Selskab, v. 31, p. 1–22.

Quinlan, G. M., and Beaumont, C., 1984, Appalachian thrusting, lithospheric flexure, and the Paleozoic stratigraphy of the eastern interior of North America: Canadian Journal of Earth Science, v. 21, p. 973–996.

Ramos, V. A., 1988a, The tectonics of the central Andes, 30° to 33° S latitude, *in* Clark, S., and Burchfiel, D., eds., Processes in continental lithospheric deformation: Boulder, Colorado, Geological Society of America Special Paper 218, p. 31–54.

Ramos, V. A., 1988b, Late Proterozoic–early Paleozoic of South America—A collisional history: Episodes, v. 11, p. 168–174.

Ramos, V. A., 1989, The birth of southern South America: American Scientist, v. 77, p. 444–450.

Ramos, V. A., Jordan, T. E., Allmendinger, R. W., Kay, S. M., Cortés, J. M., and Palma, M. A., 1984, Chilenia; un terreno alóctono en la evolución Paleozoica de los Andes Centrales: San Carlos de Bariloche, 9° Congreso Geológico Argentino, v. 2, p. 84–106.

Ramos, V. A., Jordan, T. E., Allmendinger, R. W., Mpodozis, C., Kay, S. M., Cortés, J. M., and Palma, M. A., 1986, Paleozoic terranes of the central Argentine Chilean Andes: Tectonics, v. 5, p. 855–880.
Ramos, V. A., Vujovich, G., Kay, S. M., and McDonough, M., 1993, La orogénesis de Grenville en las Sierras Pampeanas Occidentales: La Sierra de Pie de Palo y su integración al supercontinente Proterozoico: Mendoza, 12° Congreso Geológico Argentino, v. 3, p. 343–357.
Rapalini, A. E., and Tarling, D. H., 1993, Multiple magnetizations in the Cambrian Ordovician carbonate platform of the Argentine Precordillera and their tectonic implications: Tectonophysics, v. 227, p. 49–62.
Rapela, C. W., Toselli, A., Heaman, L., and Saavedra, J., 1990, Granite plutonism of the Sierras Pampeanas: An inner cordilleran Paleozoic arc in the southern Andes, *in* Kay, S. M., and Rapela, C. W., eds., Plutonism from Antarctica to Alaska: Boulder, Colorado, Geological Society of America Special Paper 241, p. 77–90.
Rapela, C. W., Coira, B., Toselli, A., and Saavedra, J., 1992, El magmatismo del Paleozoico Inferior en el sudoeste de Gondwana, *in* Gutiérrez Marco, J. L., et al., eds., Paleozoico Inferior de Ibero-América: Madrid, Spain, Universidad de Extremadura, p. 21–68.
Read, J. F., 1988. Evolution of Cambro–Ordovician passive margin, U.S. Appalachians, *in* Hatcher, R. D., Jr., et al., eds., The Appalachian-Ouachita orogen in the United States: Boulder, Colorado, Geological Society of America, Geology of North America, v. F-2, p. 42–57.
Read, J. F., 1989, Controls on evolution of Cambro–Ordovician passive margin U.S. Appalachians, *in* Crevello, P. D., et al., eds., Controls on carbonate platform and basin development: Tulsa, Oklahoma, Society of Economic Paleontologists and Mineralogists Special Publication 44, p. 147–165.
Ribba, L., Mpodozis, C., Hervé, F., Nasi, C., and Moscoso, R., 1988, El basamento del Valle del Transito, Cordillera de Vallenar: Eventos magmáticos y ´rficos y su relación con la evolución de los Andes chileno-argentinos: Revista Geológica de Chile, v. 15, p. 129–150.
Rolleri, E. O., 1947, Estudio geológico de la Quebrada de Talacastoy zonas adyacentes, Provincia deSan Juan [Ph.D. thesis]: La Plata, Argentina, University of La Plata, 258 p.
Rolleri, E. O., and Baldis, B., 1967, Paleogeographyand distribution of Carboniferous deposits in the Argentine Precordillera: Coloquio de la I.U.G.S.: La Estratigrafía del Gondwana: Ciencias de la Tierra, v. 2, p. 1005–1024.
Rolleri, E. O., and Fernández Garrasino, C. A., 1979, Comarca Septentrional de Mendoza: Córdoba, Academia Nacional de Ciencias Córdoba, 2° Simposio de Geología Regional Argentina, v. 1, p. 771–809.
Rong, Jia-Yu, and Harper, D. A., 1988, A global synthesis of the latest Ordovician Hirnantian brachiopod faunas: Transactions of the Royal Society of Edinburgh, Earth Sciences, v. 79, p. 383–402.
Ross, R. J., 1975, Early Paleozoic trilobites, sedimentary facies, lithospheric plates and ocean currents: Fossils & Strata, v. 4, p. 307–329.
Ross, R. J., Jr., and Ingham, J. K., 1970, Distribution of the Toquima–Table Head (Middle Ordovician Whiterock) faunal realm in the Northern Hemisphere: Geological Society of America Bulletin, v. 81, p. 393–408.
Ross, R. J., Jr., Ethington, R. L., and Mitchell, C. E., 1991, Stratotype of Ordovician Whiterock Series: Palaios, v. 6, p. 156–173.
Saal, A., 1993, El basamento cristalino de la Sierra de Paganzo, Provincia de La Rioja, Argentina, [Ph.D. thesis]: Córdoba, Argentina, University of Córdoba, 243 p.
Sánchez, M. T., and Benedetto, J. L., 1995, Distribución estratigráfica, paleoecologíaybiogeografı ´adel ge´nero *Clarkeia* en el SilúricoGondwa´nico, *in* Suárez Soruco, R., ed., Fósiles y facies de Bolivia—Volume 2: Invertebrados y Paleobotánica: Santa Cruz, Bolivia, Revista Técnica de YPFB, v. 13–14, p. 93–98.
Sánchez, M. T., Waisfeld, B., and Benedetto, J. L., 1991a, Lithofacies, taphonomy and benthic assemblages in the Silurian of western Argentina: A review of the Malvinokaffric realm communities: Journal of South American Earth Science, v. 4, p. 307–329.
Sánchez, M. T., Benedetto, J. L., and Brussa, E., 1991b, Late Ordovician stratigraphy, paleoecology and sea level changes in the Argentine Precordillera, *in* Barnes, C. R., and Williams, S. H., eds., Advances in Ordovician geology: Geological Survey of Canada Paper 90-9, p. 245–258.
Sánchez, M. T., Benedetto, J. L., and Astini, R. A., 1993, Eventos de recambio faunístico en las secuencias depositacionales del Paleozoico Temprano de la Precordillera argentina: Mendoza, 12° Congreso Geológico Argentino, v. 2, p. 281–288.
Sánchez, M. T.,Carrera,M., and Benedetto, J. L., inpress, Variaciones faunísticas en el techo de la Formación San Juan (Ordovícico temprano, Precordillera Argentina): Significado paleoambiental: Ameghiniana.
Sarmiento, G. N., and Heredia, S. E., 1983, Hallazgo de conodontes ordovícicos en la Formación San Jorge, Provincia de La Pampa, Argentina: Córdoba, Argentina, Academia Nacional de Ciencias, Reunión de Comunicaciones Paleontológicas, Abstracts.
Schlager, W., 1989, Drowning unconformities on carbonate platforms, *in* Crevello, P. D., et al., eds., Controls on carbonate platform and basin development: Tulsa, Oklahoma, Society of Economic Paleontologists and Mineralogists Special Publication 44, p. 15–25.
Sessarego, H. L., Amos, A. J., Texeira, W., Kawashinta, K., and Remesal, M. B., 1990, Diques Eocarbónicos en la Precordillera Occidental, margen oeste de las Sierras del Tigre, provincia de San Juan: Revista de la Asociación Geológica Argentina, v. 45, p. 98–106.
Shanmugam, G., and Lash, G. G., 1982, Analogous tectonic evolution of the Ordovician foredeeps, southern and central Appalachians: Geology, v. 10, p. 562–566.
Shaw, A. B., 1964, Time in stratigraphy: New York, McGraw-Hill, 365 p.
Sloss, L. L., 1963, Sequences in the cratonic interior of North America: Geological Society of America Bulletin, v. 74, p. 93–114.
Smalley, R., Jr., Pujol, J., Regnier, M., Chui, Jer-Ming, Chatelian, J. L., Isacks, B. L., Araujo, M., and Puebla, N., 1993, Basement seismicity beneath the Andean Precordillera thin-skinned thrust belt and implications for crustal and lithospheric behavior: Tectonics, v. 12, p. 63–76.
Spalletti, L. A., Cingolani, C. A., Varela, R., and Cuerda, A. J., 1989, Sediment gravity flow deposits of an Ordovician deep-sea fan system (western Precordillera, Argentina): Sedimentary Geology, v. 61, p. 287–301.
Stenzel, S. R., Knight, I., and James, N. P., 1990, Carbonate platform to foreland basin: Revised stratigraphy of the Table Head Group (Middle Ordovician), western Newfoundland: Canadian Journal of Earth Science, v. 27, p. 14–26.
Stockmal, G. S., Beaumont, C., and Boutilier, R., 1986, Geodynamic models of convergent margin tectonics: The transition from rifted margin to overthrust belt and the consequences for foreland basin development: American Association of Petroleum Geologists Bulletin, v. 70, p. 181–190.
Swift, D. P. L., Thorne, J. A., and Nummedal, D., 1985, Sequence stratigraphy in foreland basins: Inferences from the Cretaceous western interior: Houston, Texas, Offshore Technological Conference, Paper 4846, p. 47–54.
Swift, D. P. L., Hudelson, P. M., Brenner, R. L., and Thompson, P., 1987, Shelf construction in a foreland basin: Storm beds, shelf sandbodies, and shelf slope depositional sequences in the Upper Cretaceous Mesaverde Group, Book Cliffs, Utah: Sedimentology, v. 34, p. 423–452.
Tankard, A. J., 1986, On the depositional response to thrusting and lithospheric flexure: Examples from the Appalachians and Rocky Mountain basins, *in* Allen, P. A., and Homewood, P., eds., Foreland basins: Oxford, United Kingdom, Blackwell, International Association of Sedimentologists Special Publication, v. 8, p. 369–394.
Thomas, W. A., 1991, The Appalachian-Ouachita rifted margin of southeastern North America: Geological Society of America Bulletin, v. 103, p. 415–431.
Toselli, A. J., Saavedra, J., Pellitero, E., Rossi de Toselli, J., Aceñolaza, F. G., and Medina, M. E., 1990, Geoquímica y petrogénesis del volcanismo ordovícico de la Formación Las Planchadas, Sistema de Famatina: Revista de la Asociación Geológica Argentina, v. 45, p. 313–322.
Toselli, A. J., and nine others, 1991, El Paleozoico inferior del Sistema de Famatina, noroeste de Argentina: Viña del Mar, 6° Congreso Geológico Chileno, v. 1, p. 867–871.
Toselli, A. J., Rossi de Toselli, J. N., Pellitero, E., and Saavedra, J., 1993, El arco magmático granítico del Paleozoico inferior en el Sistema de Famatina, Argentina: Mendoza, 12° Congreso Geológico Argentino and 2° Congreso de Exploración de Hidrocarburo, v. 4, p. 7–15.
Vaccari, N. E., 1988, Primer hallazgo de trilobites del Cámbrico inferior en la Provincia de La Rioja (Precordillera Septentrional): Revista de la Asociación Geológica Argentina, v. 43, p. 558–561.
Vaccari, N. E., 1993, El género *Annamitella* Mansuy, 1920 (Trilobita, Leiostegiidae) en el Ordovícico de la Precordillera Argentina: Ameghiniana, v. 30, p. 395–405.
Vaccari, N. E., 1994, Las faunas de trilobites de las sucesiones carbonáticas del Cámbrico y Ordovícico temprano de la Precordillera Septentrional [Ph.D. thesis]: Córdoba, Argentina, Universidad Nacional de Córdoba, 271 p.
Vaccari, N. E., and Bordonaro, O., 1993, Trilobites en los olistolitos cámbricos de la Formación Los Sombreros (Ordovícico), Precordillera de San Juan, Argentina: Ameghiniana, v. 30, p. 383–393.
Vaccari, N. E., and Waisfeld, B. G., 1994, Nuevos trilobites de la Formacion Suri (Ordovícico temprano) en la región de Chaschuil, Provincia de Catamarca. Implicancias bioestratigráficas: Ameghiniana, v. 31, p. 73–86.
Vaccari, N. E., Benedetto, J. L., Waisfeld, B. G., and Sánchez, T. M., 1993, La fauna de *Neseuretus* en la Formación Suri (Oeste de Argentina): Edad y relaciones paleobiogeográficas: Madrid, Spain, Revista Española de Paleontología, v. 8, p. 185–190.
Vail, P. R., Mitchum, R. M., Jr., and Thompsom, S., III, 1977, Seismic stratigraphy and global changes of sea level, *in* Payton, C. E, ed., Seismic stratigraphy—Applications to hydrocarbon exploration: Tulsa, Oklahoma, American Association of Petroleum Geologists Memoir 26, p. 83–97.
Van Der Voo, R., 1981, Paleomagnetism of North America: A brief review, *in* McElhinny M., and Valencio, D., eds., Paleoreconstruction of the continents: Geodynamics Series, v. 2, p. 159–176.
Vilas, J. F., 1981, Paleomagnetism of South American rocks and the dynamic processes related with the fragmentation of western Gondwana, *in* McElhinny, M., and Valencio, D., eds., Paleoreconstruction of the continents: Geodynamics Series, v. 2, p. 106–114.
Vilas, J. F., and Valencio, D. A., 1978, Paleomagnetism and K-Ar age of the Upper Ordovician Alcaparrosa Formation, Argentina: Royal Astronomical SocienÀSuL.physical Journal, v. 55, p. 143–154.
Villar, L. M., 1975, Las fajas y otras manifestaciones ultrabásicas en la República Argentina y su significado metalogenético: Buenos Aires, Argentina, 2° Congreso Iberoamericano de Geología Económica, v. 3, p. 135–155.
Walker, K. R., ed., 1985, The geological history of the Thorn Hill Paleozoic section (Cambrian–Mississippian), eastern Tennessee: Knoxville, Tennessee, University of Tenneesse, Studies in Geology, Geological Society of America Southeastern Section Field Trip 6, 128 p.
Whittington, H. B., 1966, Phylogeny and distribution of Ordovician trilobites: Journal of Paleontology, v. 40, p. 696–737.
Whittington, H. B., and Hughes, C. G., 1973, Ordovician trilobite distribution and geography, *in* Organisms and continents through time: Palaeontological Society Special Paper 12, p. 235–240.
Zhou Zhi-Yi, and Fortey, R. A., 1986, Ordovician trilobites from north and northeast China: Stuttgart, Germany, Paläontographica (Abt. A), v. 192, p. 157–209.

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