Geodynamic evolution and tectonostratigraphic terranes of northwestern Argentina and northern Chile

Heinrich Bahlburg* *Geologisch-Paläontologisches Institut, Ruprecht-Karls-Universität, Im Neuenheimer Feld 234, 69120 Heidelberg, Germany*

Francisco Hervé *Departamento de Geología, Universidad de Chile, Casilla 13518, Correo 21, Santiago, Chile*

ABSTRACT

In Ordovician time, Gondwana in the area of northwestern Argentina and northern Chile had a west-facing active margin. The evolution of this margin culminated in the Oclóyic orogeny at the end of Ordovician time. This orogeny was caused by the collision of the allochthonous Arequipa-Antofalla terrane with this margin. The early Paleozoic evolution of northwestern Argentina and northern Chile contrasts markedly with the accretionary history of central Argentina and central Chile, where the Precordillera and Chilenia terranes docked in the Late Ordovician and Late Devonian periods, respectively. An inspection of the available stratigraphic and geochronological data on sedimentary, volcanic, and plutonic units of the southern Central Andes of northern Chile and northwestern Argentina reveals a lull in magmatic and metamorphic activity lasting for ~100 m.y., from Early Silurian to early Late Carboniferous time. This is interpreted as corresponding to a tectonic scenario in which the present Andean margin was a passive margin of Gondwana. This passive margin developed in response to the rifting off of a part of the Arequipa-Antofalla terrane; the present location of this block is unknown. Late Carboniferous time marks the renewed onset of subduction, initiating the Andean plate tectonic setting still prevalent today. Recently proposed models explain the Late Ordovician orogeny by the collision of Laurentia with western South America during Laurentia's clockwise motion around South America and away from its position in the Neoproterozoic supercontinent. In its present form, this hypothesis is difficult to reconcile with the Paleozoic tectonostratigraphic evolution of the southern Central Andean region.

*Present address: Geologisch-Paläontologisches Institut, Westfälische Wilhelms-Universität, Corrensstrasse 24, D-48149 Münster, Germany. E-mail: bahlbur@uni-muenster.de

INTRODUCTION

Recently proposed paleotectonic reconstructions of Neoproterozoic and early Paleozoic time suggest that the Laurentian craton was located close to Antarctica and South America at these times (Dalziel, 1991; Moores, 1991; Hoffman, 1991). The clockwise movement of Laurentia around South America during early Paleozoic time is interpreted to have resulted in repeated plate tectonic interaction of the two continents (Dalziel et al., 1994). Furthermore, Dalla Salda et al. (1992a) and Dalziel et al. (1994) proposed that the early Paleozoic Famatinian orogenic belt of the Andes in southwestern South America, and the Late Ordovician–Early Silurian Oclóyic orogen within the Famatinian belt, may have originated jointly with the Taconic orogenic belt from the collision of eastern Laurentia and southwestern South America, during the latter part of Ordovician time (Fig. 1). Accordingly, the Late Ordovician rifting off of Laurentia after the Taconic orogenic pulse is thought to have left behind the Precambrian Arequipa massif in southern Peru, related basement units in northern Chile, and probably the western part of northwestern Argentina (Figs. 2 and 3). The recognition of tectonostratigraphic terranes in central Argentina and central Chile (Ramos et al., 1986) has invited the tentative extrapolation of this accretionary history to the regions farther north in northwestern Argentina, northern Chile, southern Bolivia, and southern Peru (Ramos, 1988). However, in this contribution we suggest a significantly different accretionary history of the southern Central Andes that is based on our own work and a compilation of the available information on Paleozoic stratigraphy and the radiometric ages of magmatic and metamorphic events of northern Chile and northwestern Argentina (Figs. 2, 3, and 4). With regard to the radiometric ages in particular, one should bear in mind that the Paleozoic rocks of the central Andes are not as well and systematically studied as the Appalachian mountain range, for example, or many other more accessible orogens. Some data compiled in Table 1 should therefore be considered preliminary. In the interpretation of stratigraphic and radiometric data we used the time scale of Harland et al. (1989). We apply the data to evaluate earlier models of terrane accretion in the southern Central Andes (e.g., Dalziel and Forsythe, 1985; Ramos et al., 1986; Hervé et al., 1987; Ramos, 1988; Bahlburg and Breitkreuz, 1991; Forsythe et al., 1993) and the hypothesis of Dalziel et al. (1994), and propose a new terrane map for the region.

PALEOZOIC RECORD

Figure 4 synthesizes the available data on sedimentary, magmatic, and metamorphic events in

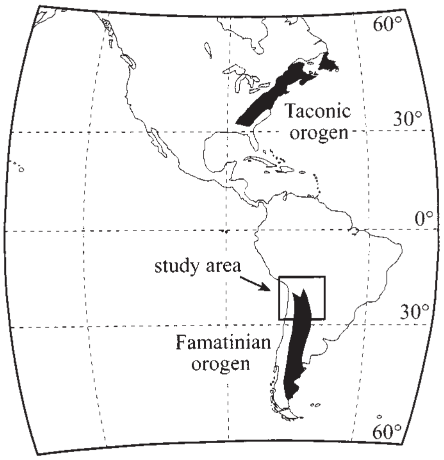

Figure 1. Present-day location of the Taconic and Famatinian orogens, and the study area in the southern Central Andes (adapted from Dalla Salda et al., 1992a).

GSA Bulletin; July 1997; v. 109; no. 7; p. 869–884; 12 figures; 1 table.

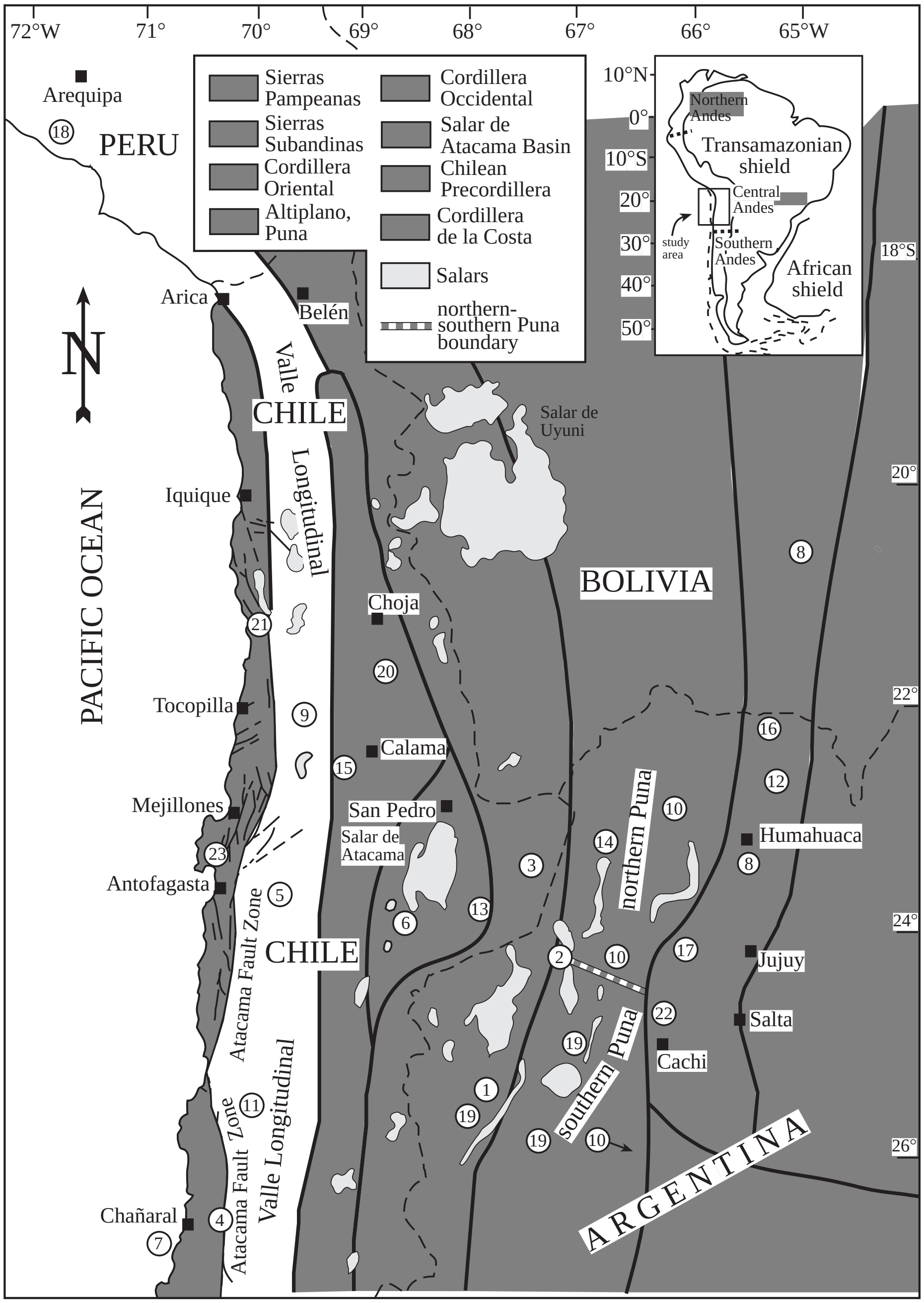

Figure 2. Distribution and areal extent of morphostructural units in the southern Central Andes. Numbers refer to outcrops indicated on the map of Figure 3 and are included here for orientation purposes only.

northern Chile and northwestern Argentina. It illustrates that magmatic and metamorphic activity occurred mainly in the Ordovician and Late Carboniferous–Permian periods. These peaks of activity are separated from each other by a period of tectonic, magmatic, and metamorphic quiescence ranging from Early Silurian to early Late Carboniferous time. The Paleozoic evolution is presented according to this temporal three-fold division into Cambrian-Ordovician, Silurian to Early Carboniferous, and Late Carboniferous–Permian time.

Evolution During Cambrian and Ordovician Time

The oldest and easternmost stratigraphic unit considered here is represented in the Cordillera Oriental of northwestern Argentina (Fig. 2) by the metaturbidites of the Puncoviscana Formation and equivalents of variable metamorphic grade (Figs. 2, 3, and 4). It acquired its first metamorphic overprint in the Early Cambrian Pampean orogeny (Willner et al., 1987; Mon and Hongn, 1996). In the Cordillera Oriental and Sierras Pampeanas (Figs. 2, 3, and 4), these rocks were intruded in Middle Cambrian time by the post-tectonic peraluminous Santa Rosa de Tastil and Cañaní granitoids (Figs. 3, 4, and Table 1; Bachmann et al., 1987; Damm et al., 1990).

The Puncoviscana Formation and the Middle Cambrian plutons are overlain in the Cordillera Oriental with an angular unconformity by the shallow marine, partly tidally influenced quartz-sandstones and shales of the Late Cambrian Mesón Group (Figs. 3 and 4). The Mesón Group has a minimum thickness of 1000 m and was deposited on a -west-facing marine platform (Kumpa and Sanchez, 1988) interpreted to be part of an epeiric sea east of the continental margin (Sanchez and Salfity, 1990; Gohrbrandt, 1992). With an erosional unconformity (Fig. 4, Irúyica event, Turner and Méndez, 1979), the Mesón Group is overstepped to the east and west by the sandstones and shales of the Early Ordovician Santa Victoria Group (Figs. 3 and 4) which received sediment mainly from the east. The thickness of the Santa Victoria Group is estimated as approximately 4500 m (Turner, 1960; Moya, 1988).

In Early Ordovician time, (Tremadocian and Arenigian), a magmatic arc was farther to the west in the western Puna region and south of the Salar de Atacama in northern Chile (Fig. 2). It led to the formation of basaltic to andesitic lavas of volcanic arc geochemical affinity, and associated volcaniclastic apron deposits of approximately 3500 m thickness (Las Vicuñas and Aguada de la Perdíz formations, Complejo Ígneo-Sedimentario del Cordón de Lila (Figs. 3 and 4; Koukharsky et al., 1988; Niemeyer, 1989; Breitkreuz et al., 1989; Bahlburg, 1990; Moya et al., 1993). Graptolites and trilobites present in clastic intercalations date the volcanic rocks as Tremadocian and Arenigian (e.g., Garcia et al., 1962; Coira and Nullo, 1987; Bahlburg et al., 1990; Moya et al., 1993). Cogenetic calc-alkaline intrusive activity is recorded in the Choschas granodiorite (502 ± 7 Ma) in the Complejo Ígneo-Sedimentario del Cordón de Lila in northern Chile and in Archibarca granite (485 ± 15 Ma) in the western reaches of the southern Puna (Figs. 3, 4, and Table 1; Mpodozis et al., 1983; Palma et al., 1986; Niemeyer, 1989; Rapela et al., 1992). Crustal extension in the region of the Faja Eruptiva de la Puna Oriental farther to the east in the northern Puna (Figs. 2 and 3) is indicated by minor volumes of basaltic pillow lavas and sills of within-plate geochemical affinity (Coira and Koukharsky, 1991).

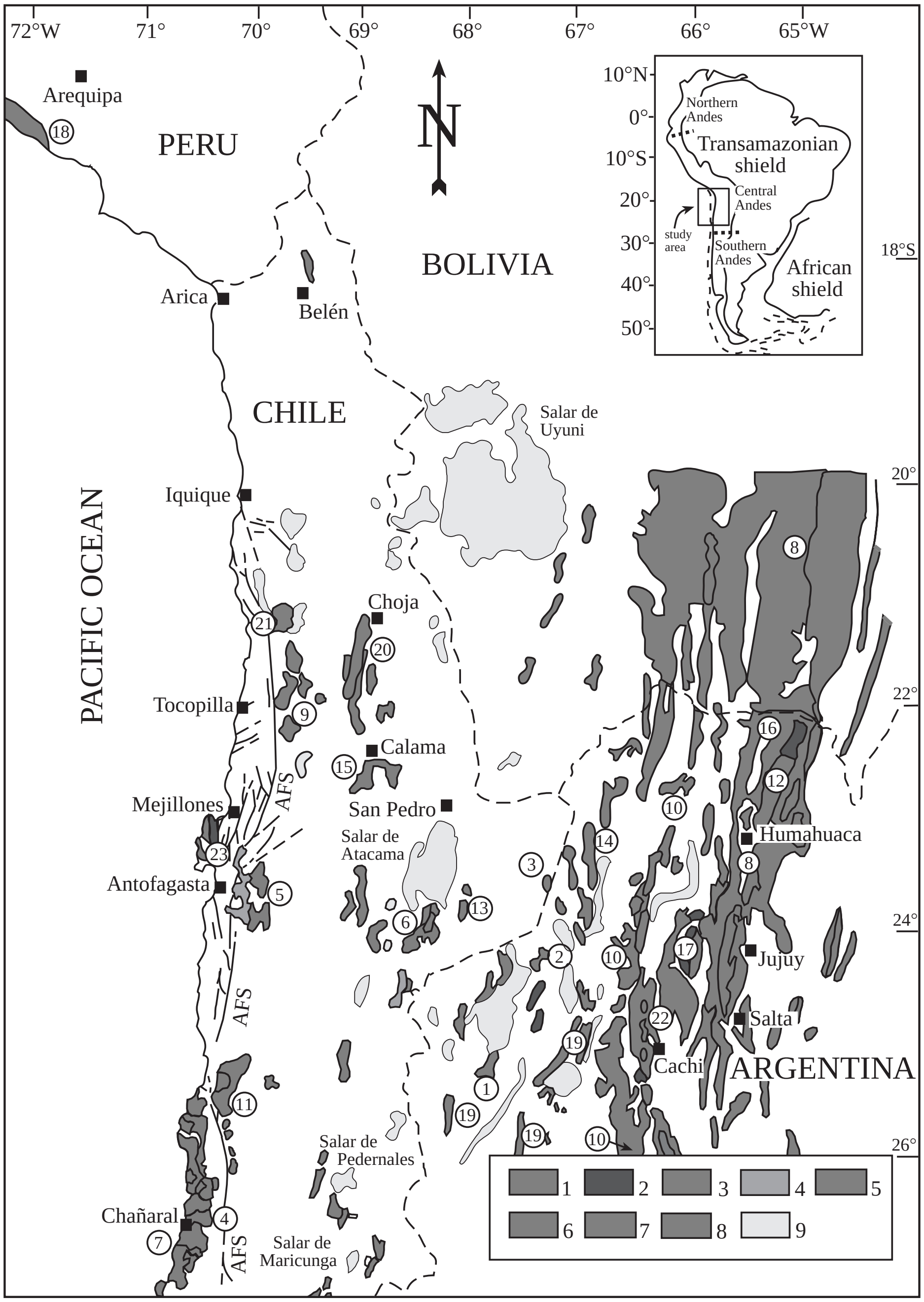

Figure 3. Outcrop map of Paleozoic units in northwestern Argentina and northern Chile, modified from Reutter et al. (1994). Key: 1: Precambrian to early Paleozoic sedimentary and metamorphic rocks; 2: Precambrian to Cambrian plutonic rocks; 3: early Paleozoic plutonic rocks; 4: plutonic rocks of unspecified Paleozoic age; 5: late Paleozoic plutonic rocks; 6: Precambrian and Cambrian sedimentary rocks; 7: early Paleozoic (Cambrian to Silurian) sedimentary and volcanic rocks; 8: late Paleozoic (Devonian to Permian-Triassic) sedimentary and volcanic rocks; 9: salars. Circled numbers, lithological units and localities: 1: Archibarca granite; 2: Las Vicuñas, Arizaro, and Cerro Oscuro formations; Salar del Rincón Formation and ill-defined, unnamed Devonian beds; 3: Aguada de la Perdíz Formation; 4: Albayay Superunit; 5: Cerros de Cuevitas and Sierra del Tigre formations; 6: Complejo Ígneo Sedimentario del Cordón de Lila, Cordón de Lila and Zorritas Formation; 7: Chañaral Melange; 8: Cordillera Oriental; 9: El Toco Formation and Bellavista pluton; 10: Faja Eruptiva de la Puna Oriental; 11: Las Tórtolas Formation; 12: Puncoviscana Formation; 13: Peine Group; 14: Puna Turbidite complex; 15: Sierra Limón Verde complex; 16: Santa Victoria and Mesón groups; 17: Santa Rosa de Tastil granite; 18: Arequipa massif; 19: Ordovician ophiolites associated with the Ordovician sedimentary rocks; 20: Sierra de Moreno; 21: Río Loa canyon; 22: Cordillera Oriental trondhjemites, 23: Mejillonia basement rocks, Mejillones peninsula.

Coira et al. (1982) and Rapela et al. (1992) interpreted calc-alkaline dacites and granites of the Faja Eruptiva de la Puna Oriental as a magmatic arc of a second east-dipping subduction zone in the central region of the northern Puna which developed after the first magmatic event connected to extension. Geochemical data for both basic and silicic rocks, however, indicate that their formation was more probably related to extension (Hanning, 1987). Furthermore, the siliciclastic successions of the Santa Victoria Group in the Cordillera Oriental to the east of the Faja Eruptiva de la Puna Oriental do not contain evidence of syndepositional magmatism. Transgressive and regressive facies patterns reflect global sea-level changes during Early Ordovician time and indicate the absence of tectonic disturbances (Moya, 1988) that would be expected in the proximity of an arc. The major regression which occurred in early Middle Ordovician time (Llanvirnian) was connected to tectonic activity in the western reaches of the Puna basin (Fig. 5) and close to the western arc.

Tectonic subsidence rates increased at the beginning of the Middle Ordovician in the western Puna basin from about 65 m/m.y. to about 600 m/m.y., thus marking the change from basin evolution driven by extension to the inception of a foreland basin (Allen et al., 1986; Bahlburg, 1991b). Patterns of subsidence and facies distribution are compatible with the emplacement of supracrustal loads of 8000 m thickness on the western margin of the basin (Bahlburg and Furlong, 1996). This was accompanied on the eastern side of the basin by the emergence of the siliciclastic platform of the Santa Victoria Group in the Cordillera Oriental (Figs. 2, 3, and 5) during the early Llanvirnian Guandacol event (Fig. 4; Salfity et al., 1984), due to the development of a periph-

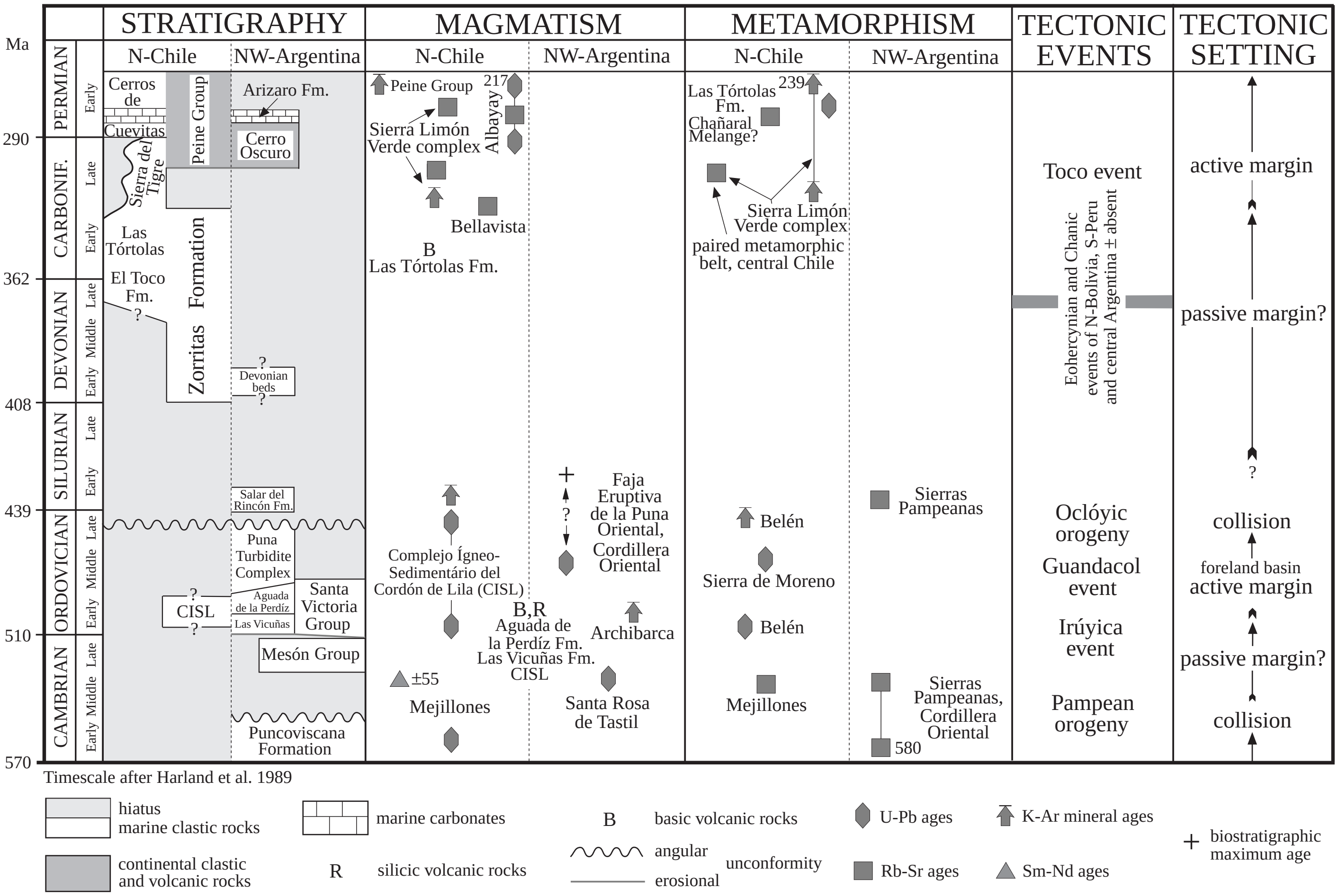

Figure 4. Synopsis of stratigraphy, magmatism, metamorphism, and tectonic events in northwestern Argentina and northern Chile, and their geodynamic interpretation. Relative geographic west-east distribution of sedimentary units is indicated in the stratigraphy column by a respective left- or right-centered position of a given unit. The data points in the columns on magmatism and metamorphism either mark discrete lithological units, or a group of genetically related units here represented by the mention of a characteristic member of the respective group. CISL: Complejo Ígneo Sedimentario del Cordón de Lila. For locations, see Figures 2 and 3. In the two columns on the righthand side of the diagram, (1) peaks of tectonic activity are marked in the tectonic events column, differentiated according to minor (events) and major (orogenies) intensity, and (2) the tectonic setting column notes our interpretation of the overall plate tectonic setting of the units and processes marked in the other columns of the figure. The time scale used is the one by Harland et al. (1989). For references see text.

eral bulge in response to load emplacement on the basin's western side (Fig. 6). In response to this loading event, the approximately 3500-m-thick volcaniclastic Puna Turbidite complex formed in the Puna basin between the arc and the emerging Cordillera Oriental region (Figs. 2, 3, and 5).

Peridotites, including wehrlites and serpentinites, are preserved only in the southern Puna as tectonic thrust slices within the biostratigraphically dated Ordovician successions of turbidites (Figs. 2 and 3; Argañaraz et al., 1973; Allmendinger et al., 1983; Kay et al., 1984; Zappettini et al., 1994). The sedimentary rocks contain intercalated basaltic flows and pillow lavas, and silicic volcaniclastic rocks (U. Zimmermann, 1996, personal commun.). Minor volumes of gabbro intruded into all units prior to the main phase of Late Ordovician deformation. The wehrlites have e-type mid-ocean ridge basalt (MORB) geochemical features and are interpreted as part of a dismembered ophiolite sequence (Blasco et al., 1996).

The mafic-ultramafic assemblages have not been dated. They were considered to be Ordovician ophiolites by Allmendinger et al. (1983), Forsythe et al. (1993), and Blasco et al. (1996), whereas structural data indicate a pre-Ordovician and most likely Precambrian age (Mon and Hongn, 1991). We agree with the assumption of an Ordovician age for the ultramafic assemblages because (1) eastward subduction beneath the region of the Cordillera Oriental east of the southern Puna during the Ordovician seems to be indicated by the Ordovician trondhjemite plutons in the Cordillera Oriental (Figs. 2, 3, and 7; Galliski et al., 1990; Rapela et al., 1992; Ramos and Vujovich, 1995); (2) they appear to be always associated with the Ordovician deposits; and (3) Precambrian rocks are generally very scarce in the Puna.

The Late Cambrian and Ordovician units in northern Chile, the Puna, and the Cordillera Oriental were folded in Ashgillian time during the Oclóyic orogeny (Fig. 4; Turner and Méndez, 1979; Monaldi and Boso, 1987). In the Puna, this tectonic event led to an upright to west-verging fold pattern (e.g., Mon and Hongn, 1987); folds verge to the east only along the western margin of the Puna (Moya et al., 1993). Folding was accompanied by the intrusion of peraluminous granitoids, which are syntectonic and post-tectonic, in eastern northern Chile, the eastern Puna and the

TABLE 1. REPRESENTATIVE RADIOMETRIC DATA OF LITHOSTRATIGRAPHIC UNITS

Unit	Lithology	Age (Ma)	Method	Reference
Southern Peru, Arequipa Massif				
Mollendo	Granulite	1198 +6/–4	U-Pb, Z	Wasteneys et al. (1995)
		1900	U-Pb^{ui}, Z	
	Granulite	970 ± 23	U-Pb, Z	
		1900	U-Pb^{ui}, Z	
	Granulite	1910 ± 36	U-Pb^{ui}, Z	Dalmayrac et al. (1977)
		720 ± 29	U-Pb, Z	
	Granulite	1811 ± 39	Rb-Sr, WR	Cobbing et al. (1977)
	Granulite	1918 ± 33	Rb-Sr, WR	Shackleton et al. (1979)
Atico igneous complex	Granite	440 ± 7	Rb-Sr, WR	Shackleton et al. (1979)
San Nicolas batholith	Diorite, granodiorite	392 ± 22	Rb-Sr, WR	Shackleton et al. (1979)
San Nicolas batholith	San Juan granodiorite	388 +13/–18	U-Pb, Z	Mukasa and Henry (1990)
		989 +114/–126	U-Pb^{ui}, Z	
	Lomitas granodiorite	425 ± 4	U-Pb, Z	
		1604 +60/–62	U-Pb^{ui}, Z	
Southern Bolivia				
Berenguela	Augen gneiss clasts	1171 ± 20	U-Pb^{ui}, Z	Tosdal et al. (1994)
		1158 ± 12	U-Pb^{ui}, Z	
	Migmatitic gneiss	1098 ± 48	U-Pb^{ui}, Z	
San Andres borehole	Metagranite	1050 ± 100	Rb-Sr	Lehmann (1978)
		530 ± 30	K-Ar	
Northern Chile				
Belén	Orthogneiss	507 ± 48	U-Pb, Z	Basei et al. (1996)
Sierra de Moreno	Migmatite	1213 +28/–25	U-Pb, Z	Damm et al. (1990)
	Orthogneiss	466 +8/–7	U-Pb, Z	Damm et al. (1990)
Complejo Ígneo-Sedimentário del Cordón de Lila	Choschas granodiorite	502 ± 7	U-Pb, Z	Damm et al. (1990)
	Tucúcaro granite	450 +12/–11	U-Pb, Z	Damm et al. (1990)
	Tucúcaro granite	441 ± 8	Rb-Sr, WR	Mpodozis et al. (1983)
	Cerro Lila diorite	434 ± 2	U-Pb, Z	Damm et al. (1990)
	Pingo Pingo granodiorite	429 ± 11	K-Ar, Hbl, Bi	Mpodozis et al. (1983)
Sierra Limón Verde complex	Gneiss	309 ± 5	Rb-Sr, WR	Hervé et al. (1985)
	Gneiss	276 ± 6	U-Pb, Z	Damm et al. (1990)
	Amphibolite, mica schist	312–218	K-Ar, Hbl, Mu, Bi	Hervé et al. (1985)
	Amphibolite	300 ± 20	Rb-Sr, WR	Cordani et al. (1988)
	Granodiorite	298 ± 1.5	U-Pb, Z	Damm et al. (1990)
		777 +36/–35	U-Pb^{ui}, Z	
	Granodiorite	293 ± 11	K-Ar, Bi	Hervé et al. (1985)
	Granodiorite	267 ± 6	K-Ar, Bi	Hervé et al. (1985)
	Granite	276 ± 24	Rb-Sr, Wr	Cordani et al. (1988)
Bellavista	Granite	318	K-Ar	Maksaev and Marinovic (1980)
Albayay Superunit	Granite	292 ± 14	U-Pb, Z	Berg et al. (1983)
	Cerro del Vetado granite	236 ± 3	Rb-Sr, WR	Brook et al. (1986)
	Granite	217 ± 12	U-Pb, Z	Berg and Baumann (1985)
Puna	Doña Ines Chica granodiorite	270 ± 10	Rb-Sr, WR	Brook et al. (1986)
	Corral del Alhambre granodiorite	248 ± 2	Rb-Sr, WR	Brook et al. (1986)
	Montandon granodiorite	275 ± 6	K-Ar, Bi	Brook et al. (1986)
Las Tórtolas Formation	Turbidite shale	280 ± 15	Rb-Sr, WR	Brook et al. (1986)
Peine Group	Ignimbrite	268 ± 6	K-Ar, ?	Gardeweg (1988)
	Crystal tuff	278 ± 8	K-Ar, Bi	Breitkreuz and Zeil (1994) and references therein
	Granitoids	305–202	U-Pb, Rb-Sr, K-Ar	
Northwestern Argentina				
Puncoviscana Formation	Slates	565 ± 7	K-Ar, WR	Adams et al. (1990)
	Mica schists	535 ± 6	K-Ar, WR	
Santa Rosa de Tastil	Monzogranite	536 ± 7	U-Pb, Z	Bachmann et al. (1987)
Puna	Archibarca granite	485 ± 15	K-Ar, Bi	Palma et al. (1986)
	Faja Eruptiva de la Puna granites	476–467 ± 1	U-Pb, M	Lork and Bahlburg (1993)
	Faja Eruptiva de la Puna granite	471 ± 12	Rb-Sr, WR	Omarini et al. (1984)

Note: WR—whole rock age; Bi—biotite mineral age; Hbl—hornblende mineral age; Mu—muscovite mineral age; Z—zircon mineral age; M—monazite; U-Pb^{ui}—upper intercept.

Cordillera Oriental (Figs. 2, 3, and 4; Table 1; Mpodozis et al., 1983; Rapela et al., 1992). The magmatic rocks of the Faja Eruptiva de la Puna Oriental were deformed by sinistral, subvertical shear zones (Bahlburg, 1990). Interpretation of intrusive activity in the Faja Eruptiva de la Puna Oriental (Fig. 3) is complicated by a discrepancy of radiometric and biostratigraphic age data. Rb-Sr whole-rock and U-Pb monazite ages date the crystallization of the intrusives at between 476 and 467 ± 1 Ma (Fig. 4, and Table 1; Middle Ordovician; Omarini et al., 1984; Lork and Bahlburg, 1993). However, in the northern Puna the intrusives, including one of the dated granites, intruded folded graptolite-bearing sedimentary rocks of Late Ordovician age (Fig. 4; Bahlburg et al., 1990). Regional metamorphism affected basement units in northern Chile during the Late Ordovician (Sierra de Moreno, Belén, Figs. 3, 4, and Table 1; Hervé et al., 1987; Damm et al., 1990). A retrograde metamorphic overprint of some Ordovician intrusives in the Sierras Pampeanas of northwestern Argentina is tentatively assigned to the Silurian (Figs. 2, and 4; C. W. Rapela, 1996, personal commun.).

Geodynamic Interpretation. The shallow-marine quartz-arenites and shales of the Cambrian

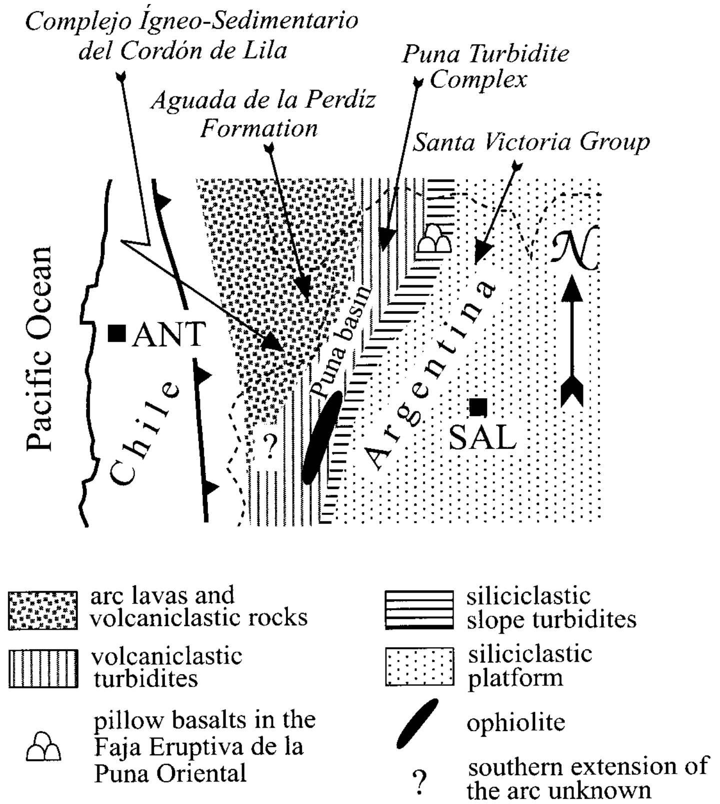

Figure 5. Palinspastically unrestored Early and Middle Ordovician paleogeography of the Puna basin and westwardly adjacent arc in northwestern Argentina and northern Chile.

Mesón Group were deposited on a slowly subsiding platform on the eastern margin of an extensional basin (Gohrbrandt, 1992). Because there is no Late Cambrian record of (1) magmatic or metamorphic activity in this region and (2) a western basin margin, it is unclear whether these units reflect the development of a short-lived passive margin (about 20 m.y.) or of a back-arc margin at the cratonward side of the basin (Figs. 6 and 7).

During Early Ordovician time, the Puna basin and the siliciclastic platform of the Santa Victoria Group were in a back-arc position relative to the magmatic arc in the western Puna and in northern Chile (Figs. 6 and 7). In the northern Puna, the loading event on the western basin margin marks the change from an extensional to a foreland basin setting in Middle Ordovician time. The beginning of eastward thrusting of the westwardlying arc over the Puna basin, probably during the Guandacol event (Fig. 4), resulted in eastverging folds at the western basin margin (Fig. 6; Moya et al., 1993). In contrast to the northern Puna (Fig. 6), back-arc extension was more pronounced in the southern Puna (Fig. 7; Forsythe et al., 1993) because ophiolites of inferred Ordovician age are restricted to this area. Closure of the southern part of the Puna basin led to the establishment of an east-dipping subduction zone near the Puna–Cordillera Oriental border, as indicated by the trondhjemites in the Cordillera Oriental (Figs. 2, 3, and 7). During later stages of shortening in the Oclóyic orogeny, the Cordillera Oriental is inferred to have been thrust westward over the eastern edge of the Puna, thus producing eastdipping thrusts and the prominent west-verging fold pattern in this region (Figs. 6 and 7; Mon and Hongn, 1996).

Silurian to Early Carboniferous Evolution

In the Puna, the Oclóyic orogeny resulted in an angular unconformity between the Ordovician rocks and coarse-grained, quartz-rich continental and intertidal to shallow subtidal lower shoreface deposits of the Salar del Rincón Formation of early Llandoverian age (Figs. 3 and 4; Isaacson et al., 1976; Benedetto and Sanchez, 1990). The Salar del Rincón Formation represents the only evidence of marine deposition in this region during Silurian time. From Early Silurian time until the early Late Carboniferous period (approximately 100 m.y.), there is no evidence in the region of igneous or metamorphic activity (Fig. 4). Although the number of available radiometric age data of a specific stratigraphic unit or time interval does not necessarily represent a measure of the intensity or geographical extent of the dated event, we do not consider the about 100 m.y. gap in the northern Chilean and northwestern Argentinian record an artifact because a number of geochronological studies defined this gap (Table 1; Mpodozis et al., 1983; Berg et al., 1983; Hervé et al., 1985; Brook et al., 1986; Damm et al., 1990; Breitkreuz and Zeil, 1994).

At the beginning of Devonian time, marine deposition shifted westward to northern Chile. The approximately 2700-m-thick Zorritas Formation (Figs. 2, 3, and 4; Davidson et al., 1981; Bahlburg and Breitkreuz, 1991, and references therein) is exposed in large outcrops to the south of the Salar de Atacama (Fig. 3). In the Cordón de Lila (Fig. 3), Early Devonian shore-face deposits of the Zorritas Formation transgress a soil horizon formed on the Late Ordovician Tucúcaro pluton. Considerable denudation is thus indicated for Silurian time. The biostratigraphical record, although incomplete, allows for the stratigraphic correlation of units and depositional events recorded in the Zorritas Formation (Cecioni, 1982; Isaacson et al., 1985; Breitkreuz, 1986; Isaacson and Sablock, 1989; Bahlburg and Breitkreuz, 1993). Beds of Emsian-Eifelian or Givetian age contain a mixed brachiopod fauna consisting of elements pertaining to either the warmer water Eastern Americas Realm or the colder water Malvinokaffric Realm, a situation also present in coeval beds overlying the Arequipa Massif in southern Peru (Isaacson and Sablock, 1989; Boucot et al., 1980, 1995).

The Zorritas Formation records alternating intertidal and shallow subtidal quartz-rich siliciclastic deposition throughout Devonian and Early Carboniferous time. Subsidence rates, averaging 18 m/m.y. (Bahlburg, 1991a), are thus in the range of typical values of passive margins and interior basins (e.g., Bond et al., 1984; Angevine et al., 1990). Subsidence appears to have been balanced by detrital input. Paleocurrent indicators document derivation of the detritus from eastern sources. This marine record ends with an erosional unconformity, which is overlain by the continental volcanic-sedimentary successions of the Peine Group (Fig. 4). The age spanned by the unconformity is uncertain. Available stratigraphic evidence indicates its age to be close to the Early to Late Carboniferous boundary and extending into Late Carboniferous time (Osorio and Rivano, 1985; Bahlburg and Breitkreuz, 1991; Breitkreuz et al., 1992).

From Late Devonian time to the end of Carboniferous time, quartz-rich turbidite sedimentation took place farther west in the northern Chilean Cordillera de la Costa (Fig. 2). These rocks are grouped into the Las Tórtolas, El Toco and Sierra del Tigre formations (Figs. 3, 4, and 8; Ulricksen, 1979; Harrington, 1961; Niemeyer et

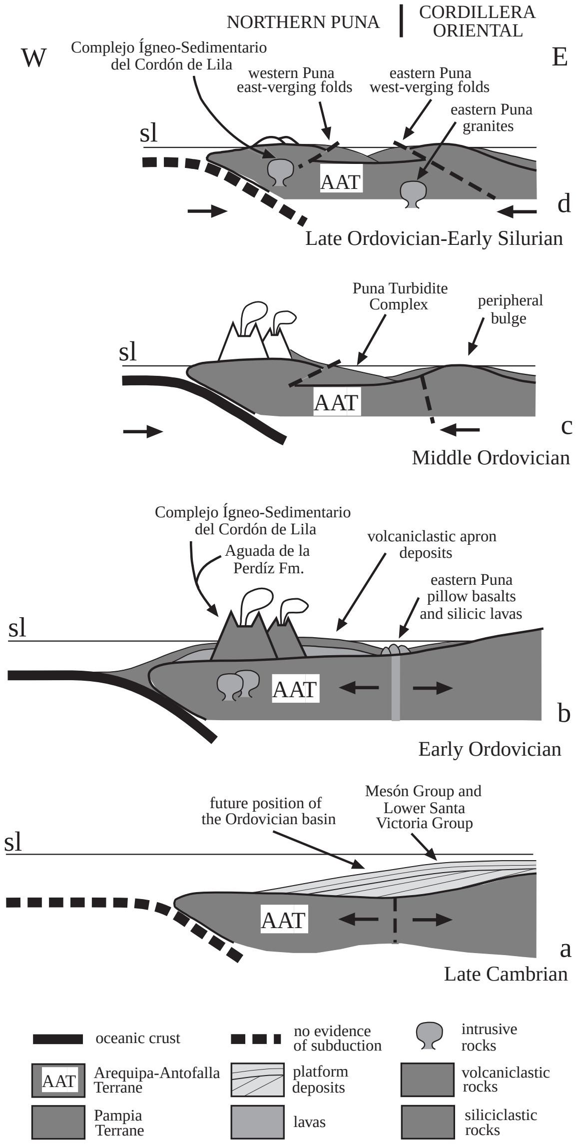

Figure 6. Schematic cross sections outlining the evolution of the northern Puna of northwestern Argentina and northern Chile during Late Cambrian and Ordovician time. sl—sea level.

al., 1985). The stratigraphic ages of these formations are indicated by sparse fossils, including plant remains, conodonts, brachiopods, and pelecypods (Maksaev and Marinovic, 1980; Bahlburg, 1987; Niemeyer et al., 1985). Sedimentologically, the turbidite units represent locally anchored and aggradational turbidite systems typical of some extensional basins (Macdonald, 1986; Bahlburg and Breitkreuz, 1993). Paleocurrent data document axial transport to the south and subordinately to the north, as well as transport toward the southeast and southwest. These data indicate that detritus was not only derived from eastern sources, but also from an unknown source in the west (Bahlburg and Breitkreuz, 1993). The contemporary shelf and the positive area of the Oclóyic orogen were located to the east (Fig. 8). Isaacson (1975) showed that the Devonian deposits of Bolivia were almost entirely shed from a western source. This source has been interpreted as a western and southern extension of the Arequipa basement massif of southern Peru, or as being connected to a "mysterious" Pacific continent (e.g., Dalmayrac et al., 1980; Fig. 8). The present location of this western source region is unknown.

Only the Las Tórtolas Formation contains minor amounts of subvolcanic and extrusive basic rocks, and andesitic and dacitic tuffs. Their geochemical features characterize this magmatism as having tholeiitic or alkaline within-plate affinities (Bell, 1982; Breitkreuz et al., 1989). In view of the absence of outcrops of oceanic crust and the presence of quartz-rich mica schists, migmatites, and rare intermediate orthogneisses underlying the El Toco Formation (Lucassen et al., 1994), these within-plate magmatic rocks are interpreted to have been erupted through continental crust.

Around the Devonian-Carboniferous boundary, the Chanic and Eohercynian orogenies affected the regions of central Argentina and southern Peru and northern Bolivia, respectively (Fig. 4; Dalmayrac et al., 1980; Coira et al., 1982). No related unconformity or deformation was observed in the Zorritas Formation or the turbidite units.

Geodynamic Interpretation. We conclude that in Silurian to Early Carboniferous time no subduction took place at this part of the proto-Andean margin (Figs. 8 and 9a). Although flat-angle subduction would be a fitting scenario to explain the absence of magmatism during this time span, we consider it unlikely in view of the lack of strong deformation connected to such a setting. The recent central Chilean margin is a well-studied example of a modern flat-angle subduction setting that caused the formation of a mountain range as high as 7 km by the thin-skinned stacking of several thrust sheets (e.g., Mpodozis and Ramos, 1990). No comparable tectonic activity is documented in the mid-Paleozoic rocks of northern Chile or northwestern Argentina. Together with the absence of magmatism and metamorphic events, the depositional patterns of the clastic units and the subsidence evolution of the margin make it likely that this region evolved in a passive margin setting during Devonian and Early Carboniferous time.

Late Carboniferous to Permian Evolution

In the Late Carboniferous period, turbidite deposition continued in the Cordillera de la Costa in the Sierra del Tigre and the Las Tórtolas Formations (Figs. 2, 3, and 4; Niemeyer et al., 1985). The turbidite units were increasingly affected by synsedimentary deformation, slumps, and the disintegration of rocks into dismembered formations of variable thickness. Synsedimentary deformation was followed by tectonic folding in the Late Carboniferous Toco tectonic event (Fig. 4; Bahlburg and Breitkreuz, 1991). The combination of synsedimentary and tectonic deformation led in the Las Tórtolas Formation to the formation of the approximately 3-km-thick Chañaral melange, which is interpreted as an accretionary prism (Bell, 1982, 1987). The Toco tectonic event affected only the turbidite units in the Cordillera de la Costa, the strata of the Zorritas Formation farther to the east were only tilted by block rotations during Permian or Triassic time. Fold axes in the turbidite units strike north-south and less commonly northwest-southeast; folds have a prominent vergence to the west (Miller, 1970a; Bell, 1987). In the Sierra del Tigre Formation, the turbidites are unconformably overlain by the Early Permian limestones and clastic rocks of the Cerros de Cuevitas Formation, which contain shallow-marine brachiopods (Figs. 4 and 9b; Niemeyer et al., 1985; H. Niemeyer, 1996, personal commun.).

Toward the end of Late Carboniferous time, intrusive and extrusive calc-alkaline magmatism occurred throughout northern Chile (Bellavista pluton, Albayay superunit and equivalents in northern Chile, Peine Group, and Sierra Limón Verde complex; Figs. 2, 3, 4, 10, and Table 1). The latest Carboniferous radiometric ages of the Albayay superunit (292 Ma and younger, Table 1) establish the younger limit of the Toco folding event, because some of these plutons intrude the folded turbidite units and the Chañaral melange. Magmatism was accompanied by the deposition of thick volcaniclastic successions in the area surrounding the Salar de Atacama (Peine Group, Figs. 3, 4, 9b, and Table 1). The volcaniclastic deposits interfinger to the east and west with the marine carbonates of the Cerros de Cuevitas and Arizaro formations, respectively (Figs. 3, 4, and 10). The geochemical features characterize the plutons and the volcanic rocks as having originated in an arc setting (Davidson et al., 1985; Brook et al., 1986; Brown, 1990; Breitkreuz, 1991). There is coeval regional high-pressure metamorphism in the gneisses, schists, and amphibolites of the Sierra Limón Verde complex (Figs. 3 and 4, and Table 1; Hervé et al., 1985; Cordani et al., 1988; Damm et al., 1990; Lucassen et al., 1996). Hervé et al. (1985) interpreted these metamorphic rocks as representing a deep structural level of a convergent margin accretionary complex.

The age of deformation that resulted in the Chañaral melange accretionary prism is crucial in piecing together the geodynamic evolution of the northern Chilean margin in Late Carboniferous time. Its exact stratigraphic position in the late Paleozoic assemblage of northern Chile is poorly defined, because the formation of the melange has not yet been radiometrically dated. However, an indication of the age of this event may be given by the 280 Ma Rb-Sr whole-rock age of the low-grade regional metamorphism which homogenized the isotope systems in the Las Tórtolas Formation and the Chañaral melange (Figs. 3 and 4, and Table 1; Brook et al., 1986). This age in turn falls in the range of the radiometric ages of metamorphism of the deeper part of the accretionary prism in Sierra Limón Verde complex (Figs. 3 and 4; and Table 1). We therefore interpret that these data, and especially the age of metamorphism of the Las Tórtolas Formation, indirectly also date the Chañaral melange as Late Carboniferous (Chañaral melange?, Fig. 4).

Geodynamic Interpretation. The passive margin stage during Silurian through early Late Carboniferous time came to an end when subduction began in the Late Carboniferous period (Fig. 9). Arc-related magmatism and metamorphism commenced and the turbidite units of the Cordillera de la Costa were deformed and partly metamorphosed when the accretionary wedge of

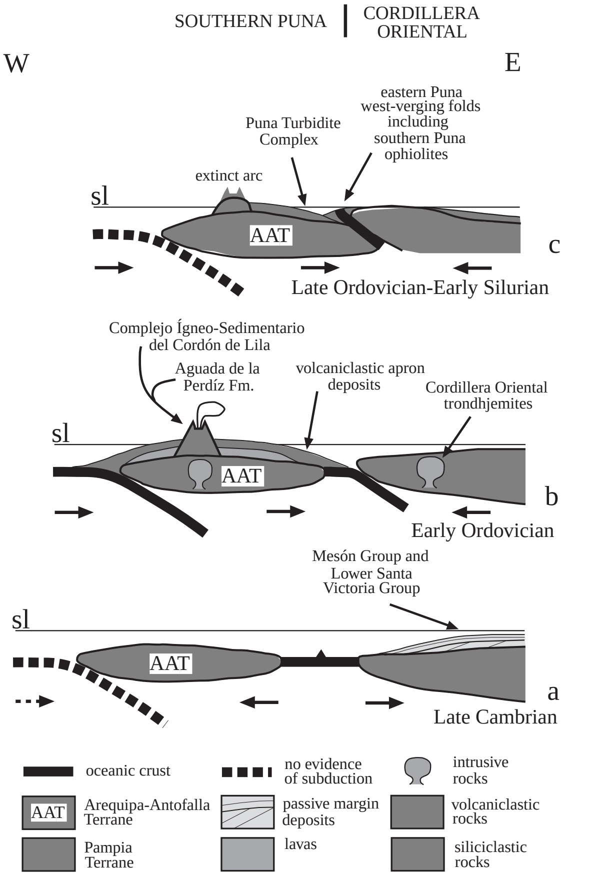

Figure 7. Schematic cross sections outlining the evolution of the southern Puna of northwestern Argentina and northern Chile during Late Cambrian and Ordovician time. sl—sea level; modified from Rapela et al. (1992), Forsythe et al. (1993), and Ramos and Vujovich (1995). These sections are hypothetical, because the Cordillera Oriental east of the southern Puna lacks any record of Late Cambrian and Ordovician deposits.

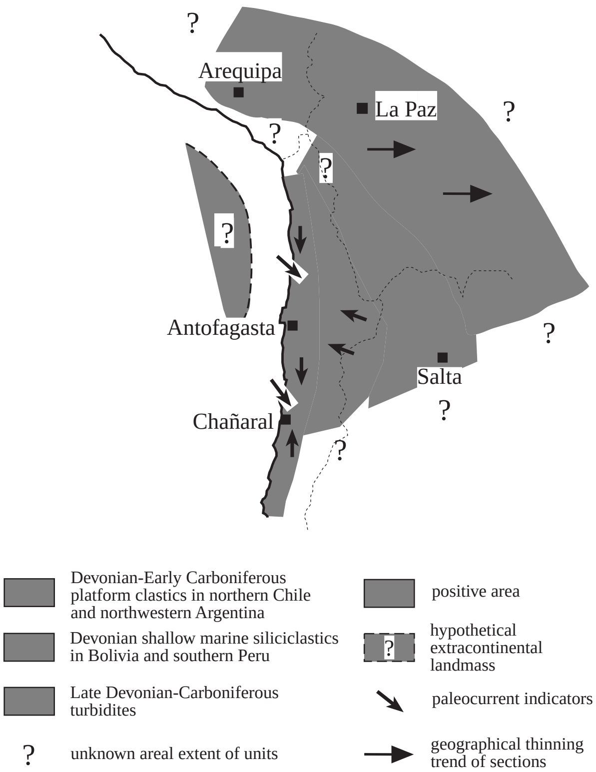

Figure 8. Palinspastically unrestored Late Devonian and Early Carboniferous paleogeography of the southern Central Andes (based on Padula et al., 1967; Isaacson, 1975; Dalmayrac et al., 1980; Bahlburg and Breitkreuz, 1993).

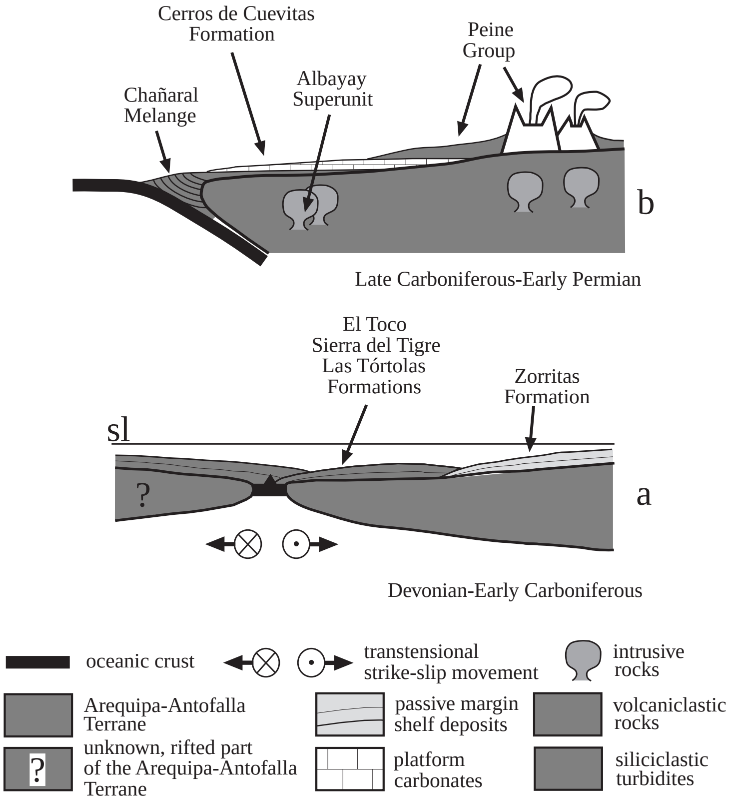

Figure 9. Schematic cross section outlining the evolution of northern Chile during (a) Devonian and Early Carboniferous time; and (b) Late Carboniferous and Early Permian time.

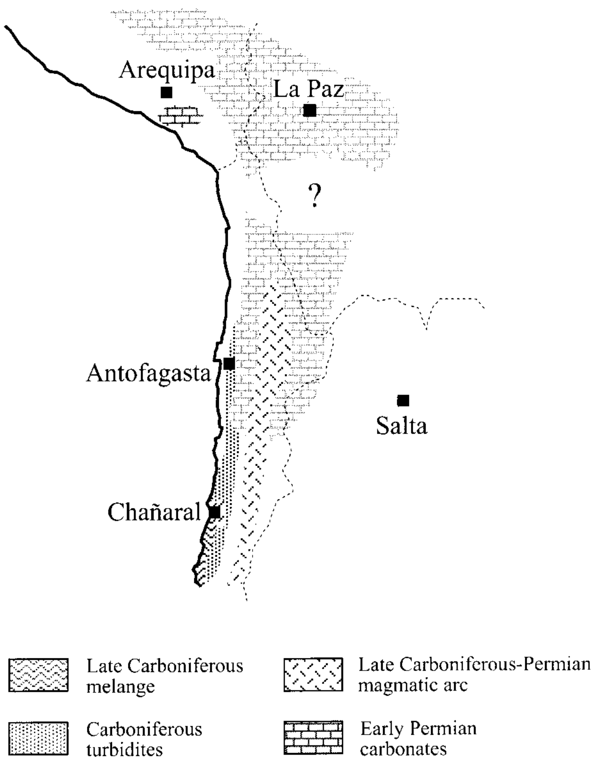

Figure 10. Palinspastically unrestored Late Carboniferous and Early Permian paleogeography of the southern Central Andes (based on Hervé et al., 1987; Breitkreuz et al., 1988; Kay et al., 1989; Sempéré, 1995).

the Chañaral melange and the Sierra Limón Verde complex formed. We interpret the unconformity that separates the turbiditic Sierra del Tigre Formation from the shallow-marine carbonates of the Cerros de Cuevitas Formation (Fig. 4) as documenting the growth of the accretionary wedge from deeper marine to shallow marine environments. At the same time, the clastic shelf of the Zorritas Formation was incorporated into the evolving arc of the Peine Group intrusive and volcanic rocks (Figs. 9b and 10).

TECTONOSTRATIGRAPHIC TERRANES OF NORTHWESTERN ARGENTINA AND NORTHERN CHILE

After the first discussion of tectonostratigraphic terranes of northwestern Argentina and northern Chile by Dalziel and Forsythe (1985), terrane analysis was significantly furthered by the publication of the first simplified terrane map by Ramos (1988; Fig. 11). The terrane distribution shown in this map as applied to northwestern Argentina and northern Chile was strongly influenced by the recognition of two allochthonous terranes that docked to central Argentina during the Paleozoic. (1) The Precordillera terrane, which later was recognized to form part of the larger composite Cuyania-Precordillera Terrane, accreted to Argentina at the end of Ordovician time (Figs. 11 and 12; Ramos et al., 1986, 1993; Astini et al., 1996). (2) The Chilenia terrane docked during Late Devonian time (Fig. 11; Ramos et al., 1986). The Cuyania block of the Cuyania-Precordillera terrane (Fig. 12) consists of low-, medium-, and high-grade metamorphic rocks that were metamorphosed between ca. 900 and 1100 Ma - (McDonough et al., 1993). These rocks are considered to be an equivalent of the basement underlying the Precordillera block, which, on the basis of zircon and whole-rock Nd-Pb isotopic evidence, is interpreted to have originated in the Grenville belt of eastern Laurentia (Abbruzzi et al., 1993; Kay et al., 1996; Astini et al., 1996). The Precordillera block of the Cuyania-Precordillera terrane (Figs. 11 and 12) is of particular significance because it bears a very pronounced lithostratigraphic and biostratigraphic resemblance in its Cambrian and Early Ordovician carbonate successions to the southern Appalachians (Bond et al., 1984; Ramos et al., 1986; Astini et al., 1995). It is recognized as a sliver of the Appalachians and the mode of transfer to South America is intensively debated (e.g., Bond et al., 1984; Ramos et al., 1986, 1993; Dalla Salda et al., 1992a; Dalziel et al., 1994, 1996; Astini et al., 1995, 1996).

The Chilenia terrane is largely obscured by late Paleozoic and younger magmatism and metamorphism (Ramos et al., 1986; Mpodozis and Kay, 1992). It includes a basement that indi-

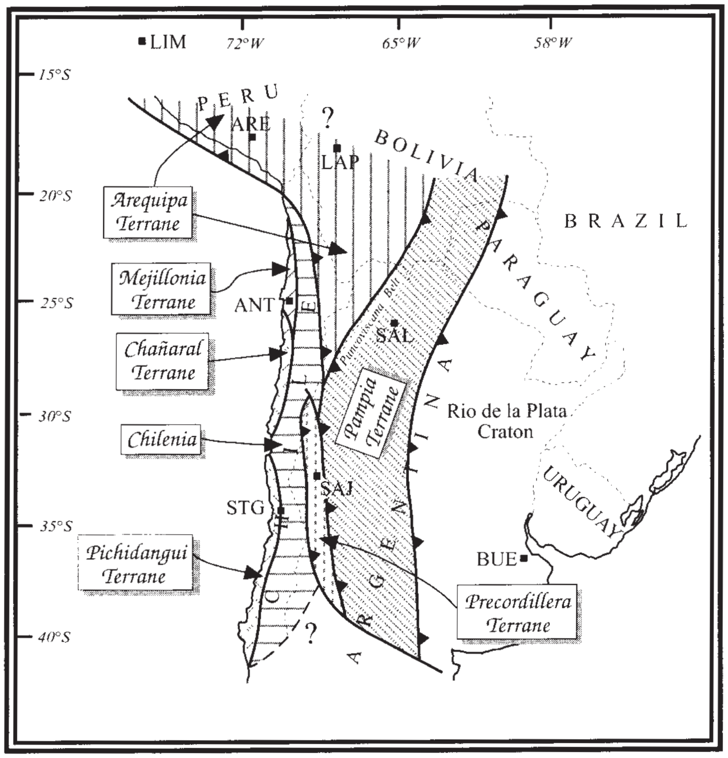

Figure 11. Terrane map of southern South America, redrawn from Ramos (1988), slightly modified after Ramos et al. (1993). ANT—Antofagasta; ARE—Arequipa; BUE—Buenos Aires; LAP—La Paz; SAJ—San Juan; SAL—Salta; STG—Santiago de Chile.

cates metamorphism ca. 500 Ma and 415 Ma (Caminos et al., 1979; Ribba et al., 1988), overlain by Silurian limestones (Ramos, 1994). It is suspect because the origin of this tectonostratigraphic terrane is unknown. In his map, Ramos (1988) extended the Chilenia terrane into western northern Chile and up to the Chilean-Peruvian frontier in the region of the Arica bend of the modern Andes, and suggested that it may represent the basement of a large part of the region.

Arequipa-Antofalla Terrane

A crucial piece in the reconstruction of the Paleozoic terrane assemblage of the Central Andes is the Arequipa-Antofalla terrane (Figs. 11 and 12). In southern Peru, the Arequipa massif (Fig. 3) comprises early Paleozoic granitoids and granulite units, which yielded radiometric zircon ages of metamorphism at 1198 +6/–4 Ma and 970 ± 23 Ma, with upper intercepts ca. 1900 Ma (Table 1; Wasteneys et al., 1995). These upper intercept ages coincide with U-Pb upper intercept and Rb-Sr whole rock ages of 1910 ± 36 Ma and 1918 ± 33 Ma, respectively (Dalmayrac et al., 1977; Shackleton et al., 1979; Table 1), and were interpreted as the Early Proterozoic age of the protoliths by Wasteneys et al. (1995). Early Paleozoic plutons of the Arequipa massif and metamorphic rocks in southern Bolivia yielded U-Pb upper intercept and Rb-Sr whole-rock ages of between ca. 1604 and ca. 1000 Ma (Mukasa and Henry, 1990; Tosdal et al., 1994; Lehmann, 1978; Table 1). This temporal range is in northern Chile and is represented by a U-Pb zircon age of 1213 +28/–25 Ma of migmatites in the Sierra de Moreno (Fig. 3 and Table 1; Damm et al., 1990). Accordingly, these regions are included in the Arequipa-Antofalla terrane (Figs. 11 and 12; Ramos, 1988). A preliminary Rb-Sr isochron by Pacci et al. (1980) from the Esquistos de Belén in northern Chile (Fig. 1) indicating an age of 1000 Ma is not considered here. A recalculation of these data by Damm et al. (1990) pointed to an age of 495 Ma. U-Pb zircon dating by Basei et al. (1996) yielded an age of 507 ± 48 Ma (Table 1). Also included with the Arequipa-Antofalla terrane are undated metamorphic assemblages in the western part of the Río Loa Canyon in the Cordillera de la Costa (Fig. 3, no. 21; Lucassen et al., 1994) and west of the Salar de Antofalla in the southern Puna of northwestern Argentina (Figs. 2 and 3; Ramos, 1988; Palma, 1990; Tosdal et al., 1994). The combination of Early and Middle Proterozoic radiometric ages in the Arequipa-Antofalla terrane represents a unique feature in the Andes. Because of the similarity of the Proterozoic age distribution in the Arequipa massif and the Makkovik-Ketilidian belt and the Trans-Labrador batholith in northeastern Laurentia, Wasteneys et al. (1995) envisaged the Arequipa massif as part of the Arequipa-Antofalla terrane, to represent an exotic terrane that originated in the Labrador-Greenland promontory of Laurentia (Dalziel et al., 1994; Litherland et al., 1989). According to Tosdal et al. (1994), however, Pb isotopic data link the Arequipa-Antofalla terrane to the Amazon craton. Paleomagnetic data suggest that the Arequipa-Antofalla terrane was already located close to its present position in Late Proterozoic time and that it has been transferred to its present parautochthonous position during the Oclóyic orogeny (Forsythe et al., 1993).

Pb-isotopic data on Cenozoic arc lavas and ores, and their host rocks in northern Chile, northwestern Argentina, and southern Bolivia, hint at a broad subdivision of the modern Andean crust into several crustal domains of different age and composition (Aitcheson et al., 1995). For example, between lat 20° and 21°S (Figs. 3 and 12), Cenozoic magmatism sampled Proterozoic nonradiogenic crust to the north of about 20°S, and Paleozoic radiogenic crust to the south of 21°S (Wörner et al., 1994). However, the middle Proterozoic basement outcrops in the Sierra de Moreno extend southward to 22°S (Fig. 3 and Table 1), suggesting that the distribution of crustal domains may be more complicated. Furthermore, still unpublished U-Pb zircon ages reveal an inherited Middle Proterozoic component in Permian granitoids in regions even farther to the south in northern Chile (C. Mpodozis, 1995, personal commun.). This implies that part of the Proterozoic crust, of which the data of Aitcheson et al. (1995) show no evidence, was still present in this region in Permian time. However, the available isotopic data indicate that the Arequipa-Antofalla terrane does not represent a homogenous crustal block, but potentially a collage of several distinct basement domains (Aitcheson et al., 1995; Kay et al., 1996) that possibly assembled before ca. 1000 Ma (Table 1) and prior to the docking of the composite terrane to this margin. Accordingly, a broad subdivision of the Arequipa-Antofalla terrane into two blocks may be possible: an Early and Middle Proterozoic Arequipa block in the north, and a Late Proterozoic and early Paleozoic Antofalla block in the south (Fig. 12).

Paleozoic Terranes and the Geodynamic Evolution of Northwestern Argentina and Northern Chile

Late Cambrian and Ordovician. After the Pampean orogeny in Middle Cambrian time, the basement units of the Pampia terrane, including

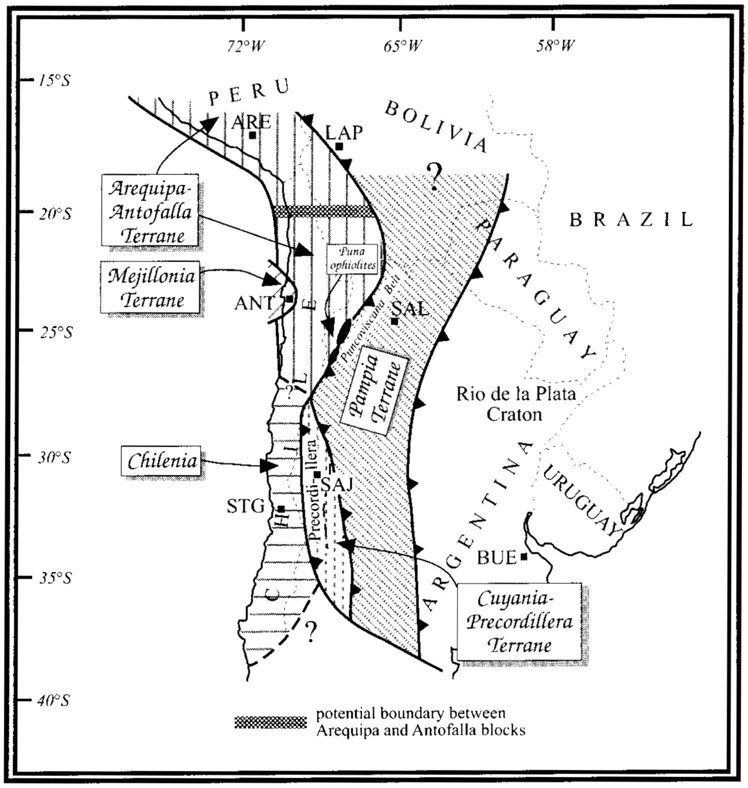

Figure 12. Revised terrane map for northwestern Argentina and northern Chile, this paper, and the Cuyania-Precordillera terrane according to Astini et al. (1996). For abbreviations, see Figure 11. The real extent of the Mejillonia terrane is exaggerated.

the outcrop belt of the Puncoviscana Formation, formed part of the South American autochthon (Ramos, 1988). The Late Cambrian Mesón Group basin formed by extension along the western margin of the Pampia terrane. The tectonic setting of this basin is unclear, because its evolution was not accompanied by related magmatism. Although some authors interpret it as a pericratonal basin bordered in the west by an emerged region (Salfity et al., 1975; Gohrbrandt, 1992), we are unaware of any direct evidence supporting the presence of this western basin margin. However, circumstantial evidence may be supplied from the Ordovician evolution.

Extension of the Mesón basin continued in Early Ordovician time, as indicated by the increase in areal extent of the Ordovician siliciclastic platform of the Santa Victoria Group (Figs. 5 and 6). This increase cannot be interpreted as being simply the result of a rising global sea level because it occurred partly during times of low sea level (Sanchez, 1994). By the beginning of the Early Ordovician, east-dipping subduction (present coordinates) had started and a magmatic arc became active along the border region between Argentina and Chile on the western side of the Ordovician back-arc basin. Geochemical data indicate that the arc had a sialic foundation (Koukharsky et al., 1988; Breitkreuz et al., 1989). This may be taken as indication that the arc rested on the potential western margin of the Early Cambrian Mesón basin represented by the Arequipa-Antofalla terrane.

Forsythe et al. (1993) presented paleomagnetic evidence that the Arequipa-Antofalla terrane rifted off of the Pampia terrane in the Late Cambrian by clockwise rotation around a Euler pole located approximately in northern Peru. Subsequently a marginal basin opened, accommodating the Mesón Group and the Ordovician units. This basin is interpreted to have progressively widened southward, leading to the extrusion of some pillow basalts and dacites in the eastern reaches of the northern Puna (Faja Eruptiva de la Puna Oriental, Figs. 5 and 6) and the generation of ophiolitic crust in the southern Puna (Fig. 7). The Oclóyic orogeny is interpreted as marking the resuturing of the Arequipa-Antofalla terrane to the Pampia terrane after a drift reversal that took place during Ordovician time (Forsythe et al., 1993; Ramos et al., 1993). We interpret that this drift reversal took place at the beginning of the Ordovician period, as may be documented by the onset of arc magmatism in the western Puna. The increase in tectonic subsidence rates during the Arenig has been related to the progressive construction of the arc edifice (Bahlburg and Furlong, 1996) and the subsequent eastward thrusting of the arc during the Guandacol event. During this convergent regime, the erosional debris of the arc fed the tectonically controlled deposition of the Puna Turbidite complex (Figs. 6 and 7; Bahlburg, 1991b). The main deformation of the basin fill occurred in the Late Ordovician Oclóyic orogeny. Syntectonic and post-tectonic plutons intruded in the Faja Eruptiva de la Puna Oriental and between 450 and 429 Ma in the Complejo Ígneo Sedimentário del Cordón de Lila (Table 1, Figs. 6 and 7).

The ophiolite suture between the Pampeanas and Arequipa-Antofalla terranes does not extend into the northern Puna. Scarce occurrences of trondhjemites and associated plutons east of the southern Puna in the Cordillera Oriental (Galliski et al., 1990; Rapela et al., 1992) are interpreted as the product of this basin's closure by east-dipping subduction (Ramos and Vujovich, 1995). According to Niemeyer (1989), the principal Ordovician subduction zone was located west of the Complejo Ígneo-Sedimentario del Cordón de Lila in northern Chile (Figs. 3, 6, and 7). The boundaries of the Arequipa-Antofalla terrane are poorly defined. In the map of Ramos (1988), the western border of the Arequipa-Antofalla terrane, i.e., the border between the Arequipa and the Chilenia terranes as well as the subduction zone of Niemeyer (1989), is inferred to extend almost due north (present coordinates) across northern Chile. The sialic basement of the remainder of northern Chile therefore is suggested to have accreted in Late Devonian time as a part of the Chilenia terrane (Ramos, 1988). We find this difficult to reconcile with the Devonian stratigraphic record and the lack of tectonic, magmatic, or metamorphic evidence of this accretion event (Fig. 4). The structural relationships can be resolved by the assumption that the Ordovician subduction zone was located still farther to the west in the present-day Pacific Ocean. In this case, almost all of northern Chile and the western reaches of the Puna pertain to the Arequipa-Antofalla terrane (Fig. 12). The terrane boundary between the Pampia and Arequipa-Antofalla terranes is accordingly represented by the ophiolite suture in the southern Argentinian Puna and its northward continuation in the Faja Eruptiva de la Puna Oriental in the northern Puna (Figs. 3, 5, and 12).

We conclude that the Chilenia terrane does not extend into northwestern Argentina and northern Chile. Furthermore, the absence of Silurian limestones equivalent to those of Chilenia indicates a marked climatic, biogeographic, and paleogeographic distance between this terrane and northwestern Argentina and northern Chile at this time. On the basis of the regional distribution of the discussed lithostratigraphic units, we assume the actual terrane boundary between the Arequipa-Antofalla and Chilenia terranes to be located farther to the south in northern Chile, approximately at lat 27°30′S (Fig. 12; and V. A. Ramos, 1995, personal commun.). This is in good agreement with the inference of basement provinces based on Pb isotope data (Tosdal et al., 1994).

Postulated Laurentia Connection. According to the hypothesis of repeated Laurentia-Gondwana interaction early in the Paleozoic era, Laurentia is suggested to have collided with central Argentina during Middle Ordovician time, thus leading to the formation of a continuous Oclóyic-Taconic mountain belt, and transferring the Precordillera terrane as part of the Occidentalia terrane of Dalla Salda et al. (1992b) to Argentina (Dalla Salda et al., 1992a; Dalziel et al., 1994). On the basis of similar radiometric age distributions and types of metamorphism, Dalziel et al. (1994) also assumed that the Arequipa-Antofalla terrane was part of the Grenville belt of Laurentia. By Late Ordovician time, Laurentia had to have been separated from South America by a significant distance and was positioned at low latitudes (Scotese and McKerrow, 1990). Eastern Laurentia lacks any record of the Late Ordovician glaciation, the deposits of which are well developed in Argentina (Long, 1994; Peralta and Carter, 1990; Turner, 1960). Furthermore, collisional tectonics occurred in northwestern Argentina during the Ashgill (Oclóyic orogeny, e.g., Turner and Méndez, 1979; Monaldi and Boso, 1987). If a part of Laurentia collided with this margin as late as Ashgill time, evidence of the glacial episode that occurred concomitantly with the Oclóyic orogeny should be present in the Taconic orogen. As we understand the literature, this evidence has not been found (e.g., Drake et al., 1989). It may be possible to postulate that the Arequipa-Antofalla terrane was transferred as a separate entity from Laurentia to South America, when Laurentia had separated from central Argentina after Middle Ordovician time and prior to the Oclóyic orogeny, thus explaining the different timing of tectonic events in central and northwestern Argentina. However, this is difficult to reconcile with the timing of basin opening as well as the lack of remnants of oceanic crust in the northern Puna. Although the mentioned inconsistencies of the proposed Laurentia connection are currently difficult to reconcile with this hypothesis, we do not want to rule it out unequivocally.

Silurian to Permian. After the Late Ordovician collision event, denudation of the Oclóyic orogenic belt in Silurian time preceded the formation of a west-facing siliciclastic platform-turbidite basin pair by the beginning of Devonian time (Zorritas, El Toco, Las Tórtolas, and Sierra del Tigre formations, Figs. 4, 8, and 9a). Patterns of facies and subsidence, together with the absence of magmatism indicate a passive margin setting at least during Devonian to Early Carboniferous time, and probably extending back into Silurian time. A comparable evolution was indicated for this margin in southern Chile by Fortey et al. (1992). The present location of that part of the Arequipa-Antofalla terrane that must have rifted off of this margin during the Silurian is unknown. The lack of synrift deposits may be explained by the fact that denudation of the Oclóyic orogen during Silurian time had exposed the Late Ordovician to Early Silurian granitoids by the beginning of Devonian time when the basal Devonian deposits transgressed the plutons.

Dating back to Burckhardt (1902), the literature contains a variety of indications of and arguments for the existence of a mythical "Pacific continent" in Paleozoic time (e.g., Steinmann, 1923; Miller, 1970b; Isaacson, 1975; Dalmayrac et al., 1980; Bahlburg, 1993). Data of direct implication to the northern Chilean situation include (1) the westward derivation of the thick Devonian clastic successions of Bolivia (Isaacson, 1975), (2) the presence of eastward-directed paleocurrents in the Devonian and Early Carboniferous turbidite units of northern Chile (Bahlburg and Breitkreuz, 1993), and (3) the joint occurrence of Malvinokaffric brachiopods with those of eastern Laurentia derivation in Middle Devonian beds of the Zorritas Formation (Fig. 2), and in coeval beds overlying the Arequipa massif in southern Peru (Figs. 1 and 8; Boucot et al., 1980, 1995). These data were taken by Dalziel et al. (1994) to suggest that during Paleozoic time Laurentia drifted northward along the proto-Andean margin in a clockwise fashion to its Permian Pangea position, and intermittently collided with southern South America in Middle Ordovician time and with northern South America in Devonian time (Kent and Van der Voo, 1990; Restrepo-Pace, 1992). In interpreting the Devonian evolution of northern Chile, this hypothesis offers an explanation for the formation of the northern Chilean passive margin. This passive margin would have formed when Laurentia rifted off of this part of South America after the Oclóyic orogeny, taking a part of the Arequipa-Antofalla terrane with it. According to the radiometric age distribution of this terrane, the missing part must therefore be located within the Laurentian Grenville belt (Wasteneys et al., 1995; Dalziel et al., 1994), awaiting identification.

In view of the inconsistencies of this hypothesis as applied to the data from Ordovician time, it is unlikely that Laurentia collided with South America in Ordovician time. It is equally speculative to interpret the formation of the northern Chilean passive margin in Silurian-Devonian time within the framework of this hypothesis. However, the previously stated observations made in various independent studies, e.g., sediment derivation from unknown western sources located in the present Pacific Ocean, remain to be explained. In conclusion, we interpret the Devonian to Early Carboniferous passive margin in northern Chile to have formed by rifting away of a western part of the Arequipa-Antofalla terrane (Fig. 9a). The persistence of the western sediment source during the entire Devonian period and in early Late Carboniferous time suggests that the rifted terrane moved northward in a transtensional fashion along the margin. In the wake of this terrane moving northward, subduction of Pacific crust started along the Chilean margin during Late Carboniferous time (Fig. 9). On the western margin of Chilenia in southern Chile, it led (1) to the formation of an accretionary prism and associated subduction zone metamorphism (Fig. 4) and (2) to accretionary, intrusive, and metamorphic events recorded at several localities in central Chile (Hervé et al., 1974, 1984; Thiele and Hervé, 1984; Ribba et al., 1988, Mpodozis and Kay, 1990, 1992; Pankhurst et al., 1992). In northern Chile, the onset of subduction produced (3) the accretionary complex of the Chañaral melange and the Sierra Limón Verde complex, as well as (4) the magmatic arc of the Peine Group and Albayay superunit and equivalents (Figs. 3, 4, and 9b, and Table 1).

Mpodozis and Kay (1990, 1992) invoked the oblique collision of the suspect Equis terrane with this margin during Early Permian time to explain patterns of magma genesis and compressional deformation (San Rafael tectonic phase) in the late Paleozoic arc between lat 28° and 31°S. The lack of any physical evidence of this terrane is explained by the assumption of its removal (i) by processes of tectonic erosion common along this margin during the Mesozoic and Cenozoic (von Huene and Scholl, 1991), or (ii) by longitudinal northward displacement along the margin in the Mesozoic. According to Breitkreuz and Zeil (1994), the Peine Group of northern Chile and its associated plutons (Peine Group and Albayay superunit, Fig. 9b) do not show the pertinent features observed by Mpodozis and Kay (1990, 1992) with regard to the Equis terrane farther to the south. The Peine Group, including the coeval plutons, is interpreted as representing a magmatic arc, including an arc graben basin.

In contrast to the Andean regions farther to the south in Argentina and Chile, the Early Permian San Rafael shortening event is not recorded in northern Chile. This contrasting tectonic evolution lends further support to our inference of an early Paleozoic strike-slip terrane boundary between lat 27° and 28°S (Fig. 8) which also may have influenced the post-Paleozoic evolution of this margin. We conclude that the Equis terrane did not extend into northern Chile.

Post-Paleozoic Terrane Movements

Strike-slip faulting has been cited as having been important in shaping the post-Paleozoic Andean margin. On the basis of preliminary paleomagnetic data, Forsythe et al. (1987) identified the Pichidangui displaced terrane as occupying the coastal region of central Chile (Fig. 11). It comprises late Paleozoic and Triassic fore-arc clastic rocks and is interpreted to have been displaced dextrally northward along the strike of the margin by approximately 15° of latitude after Late Triassic time, reaching its new position by Middle to Late Jurassic time. This would constrain the longitudinal displacement to Early Jurassic time. On the basis of this interpretation, Ramos (1988) classed the mid-Paleozoic turbidite units of the north Chilean Cordillera de la Costa (Figs. 2, 3, and 8), including the Chañaral melange (Fig. 4), as the displaced Chañaral terrane (Fig. 11) which he assumed to have been displaced jointly with the Pichidangui terrane. In this case the Atacama fault zone (Figs. 2 and 3), which partly limits the turbidite units to the east, was taken as the terrane boundary. However, geochronologic and paleomagnetic data of both terranes do not support the proposed allochthon (Beck et al., 1991; Brown et al., 1991, 1993). The Atacama fault zone acted as a sinistral shear zone accommodating about 100 km of displacement from Jurassic to Tertiary time (Hervé, 1987; Scheuber and Andriessen, 1990; Brown et al., 1993). For Jurassic time, this coincides with oceanic plate reconstructions indicating subduction toward the southeast (present coordinates; Larson and Pitman, 1972; Zonenshayn et al., 1984). We therefore based our interpretation of the north Chilean situation (Figs. 8, 9, and 12) on the assumption of an autochthonous relationship between the Zorritas Formation and the turbidite units in the Cordillera de la Costa. Nonetheless, deposits of the slope connecting shelf and turbidite basin have not yet been identified.

The last terrane to be discussed is the Mejillonia terrane (Ramos, 1988; Figs. 11 and 12) which occupies the northern and central part of the small Mejillones Peninsula north of Antofagasta (Figs. 2 and 3). Very little is known about this unit. It comprises two formations of schists, gneisses, and amphibolites that were intruded by a late kinematic granodiorite pluton (Baeza and Pichowiak, 1988). Sparse radiometric data fall into two clusters at 560 to 520 Ma and 200 to 108 Ma (Fig. 4; Díaz et al., 1985; Baeza and Pichowiak, 1988; Damm et al., 1990; Pichowiak, 1994). The older cluster is taken to reflect a Cambrian magmatic and metamorphic event, whereas the younger cluster indicates a thermal event, concentrated in Jurassic time, that was at least partly connected to Jurassic arc magmatism (Pichowiak, 1994). The Mejillones peninsula has a faulted contact to the mainland along the western branch of the Atacama fault zone (Fig. 2) and lies westward of the outcrop belt of the mid-Paleozoic turbidite units and oceanward of the Jurassic magmatic arc, both of which are located in the Cordillera de la Costa (Fig. 2). The Mejillonia terrane is interpreted as an allochthonous Late Proterozoic to Cambrian basement terrane that docked to the Chilean margin in Jurassic time (Ramos, 1988; Damm et al., 1990). To the east of Antofagasta, in the region of the Salar de Navidad, a granodiorite pluton outcrop gave a U-Pb zircon age of 582 ± 4 Ma (Damm et al., 1990). Other recorded radiometric ages of the southern Central Andes are either significantly older or younger than this age and the older age cluster of the Mejillones Peninsula (Table 1). The significance of the Mejillonia terrane within the south-central Andean terrane collage is still unclear, but it is probable that this terrane represents (1) either a displaced parautochthonous part of the Arequipa-Antofalla terrane, which in Jurassic time formed part of the fore-arc basement of the respective arc, or (2) a reaccreted remnant of the unknown block which rifted off of this margin in the Silurian (Fig. 9a). It may have been emplaced in its present structural and geographic position by Jurassic sinistral strike-slip movements along the Atacama fault zone connected to oblique subduction (Brown et al., 1993; Scheuber and Andriessen, 1990).

CONCLUSIONS

Our terrane analysis of the southern central Andes of northwestern Argentina and northern Chile resulted in the identification of only a single Paleozoic allochthonous to parautochthonous terrane, the Arequipa-Antofalla terrane, which docked to its present position at the early Paleozoic margin of South America in Late Ordovician time. A new western margin of the Arequipa-Antofalla terrane formed probably during Silurian time, when a passive margin developed in the region of northern Chile by an extensional event that rifted off a part of the Arequipa-Antofalla terrane. The eventual paleogeographic destination of this rifted part is unknown but, according to Dalziel et al. (1994), it may be found in northeastern Laurentia. The passive margin stage in northern Chile lasted approximately 100 m.y., from Early Silurian to early Late Carboniferous time, a span marked by the absence of active margin magmatism and tectonics (Fig. 4). During Late Carboniferous time, a new convergent plate boundary was established at the formerly passive margin. It is evidenced by widespread arc magmatism and related metamorphic and tectonic events, melange formation, and contemporaneous volcaniclastic sedimentation. Post-Paleozoic margin-parallel and sinistral strike-slip movements probably led to the emplacement of the parautochthonous displaced Mejillonia terrane in Jurassic time. Neither the Cambrian-Ordovician Precordillera terrane nor the Silurian–Late Devonian Chilenia terrane of central Argentina and central Chile (Ramos et al., 1986) extend into the northern reaches of the respective countries.

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REFERENCES CITED

Abbruzzi, J., Mahlburg Kay, S., and Bickford, M. E., 1993, Implications for the nature of the Precordilleran basement from the geochemistry and age of Precambrian xenoliths in Miocene volcanic rocks, San Juan Province, Argentina: XII Congreso Geológico Argentino y II Congreso de Exploración de Hidrocarburos Actas, no. III, p. 331–339.

Adams, C., Miller, H., and Toselli, A. J., 1990, Nuevas edades de metamorphismo por el método K-Ar de la formación Puncoviscana y equivalentes, NW de Argentina, *in* Aceñolaza, F. G., Miller, H., and Toselli, A. J., eds., El ciclo Pampeano en el Noroeste Argentino: Correlación Geológica, no. 4, p. 209–219.

Aitcheson, S. J., and eight others, 1995, Pb isotopes define basement domains of the Altiplano, Central Andes: Geology, v. 23, p. 555–558.

Allen, P. A., Homewood, P., and Williams, G. D., 1986, Foreland basins: An introduction, *in* Allen, P. A., and Homewood, P., eds., Foreland basins: International Association of Sedimentologists Special Publication 8, p. 3–12.

Allmendinger, R. W., Ramos, V. A., Jordan, T. E., Palma, M., and Isacks, B. L., 1983, Paleogeography and Andean structural geometry, northwest Argentina: Tectonics, v. 2, p. 1–16.

Angevine, C. L., Heller, P. L., and Paola, C., 1990, Quantitative sedimentary basin modeling: American Association of Petroleum Geologists Continuing Education Course Note Series, v. 32, p. 1–133.

Argañaraz, R., Viramonte, J., and Salazar, L., 1973, Sobre el hallazgo de serpentinitas en la Puna Argentina: V Congreso Geológico Argentino Actas, no. 1, p. 23–32.

Astini, R. A., Benedetto, J. L., and Vaccari, N. E., 1995, The early Paleozoic evolution of the Argentine Precordillera as rifted, drifted and collided terrane: A geodynamic model: Geological Society of America Bulletin, v. 107, p. 253–273.

Astini, R. A., Ramos, V. A., Benedetto, J. L., Vaccari, N. E., and Cañas, F. L., 1996, La Precordillera: un terreno exotico a Gondwana: XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos Actas, no. V, p. 293–324.

Bachmann, G., Grauert, B., Kramm, U., Lork, A., and Miller, H., 1987, El magmatismo del Cambrico Medio/Cambrico Superior en el basamento del noroeste argentino: Investigaciónes isotópicas y geochronológicas sobre los granitoides de los complejos intrusivos de Santa Rosa de Tastil y Cañani: X Congreso Geológico Argentino Actas, no. 4, p. 125–127.

Baeza, L., and Pichowiak, S., 1988, Ancient crystalline basement provinces in the North Chilean Central Andes: Relics of continental crust development since the Mid-Proterozoic, *in* Bahlburg, H., Breitkreuz, C., and Giese P., eds., The southern Central Andes: Contributions to structure and evolution of an active continental margin: Heidelberg, Germany, Springer Lecture Notes in Earth Science, v. 17, p. 3–24.

Bahlburg, H., 1987, Sedimentology, petrology and geotectonic significance of the Paleozoic flysch in the Coastal Cordillera of northern Chile: Neues Jahrbuch für Geologie und Paläontologie Monatshefte, v. 1987, p. 527–559.

Bahlburg, H., 1990, The Ordovician basin in the Puna of NW Argentina and N Chile: Geodynamic evolution from back-arc to foreland basin: Geotektonische Forschungen, v. 75, p. 1–107.

Bahlburg, H., 1991a, Die geodynamische Entwicklung mariner Sedimentbecken am paläozoischen Kontinentalrand von Gondwanaland im Bereich der südlichen Zentralanden (NW-Argentinien, N-Chile): Zeitschrift der Deutschen Geologischen Gesellschaft, v. 142, p. 131–148.

Bahlburg, H., 1991b, The Ordovician back-arc to foreland successor basin in the Argentinian-Chilean Puna: Tectonosedimentary trends and sea-level changes, *in* Macdonald, D. I. W., ed., Sedimentation, tectonics, and eustasy: International Association of Sedimentologists Special Publication 12, p. 465–484.

Bahlburg, H., 1993, Hypothetical southeast Pacific continent revisited: New evidence from the middle Paleozoic basins of northern Chile: Geology, v. 21, p. 909–912.

Bahlburg, H., and Breitkreuz, C., 1991, The evolution of marginal basins in the southern Central Andes of Argentina and Chile during the Paleozoic: Journal of South American Earth Sciences, v. 4, p. 171–188.

Bahlburg, H., and Breitkreuz, C., 1993, Differential response of a Devonian-Carboniferous platform–Deeper basin system to sea-level change and tectonics, N. Chilean Andes: Basin Research, v. 5, p. 21–40.

Bahlburg, H., and Furlong, K. P., 1996, Lithospheric modeling of the Ordovician foreland basin in the Puna of NW Argentina: On the influence of arc loading on foreland basin formation: Tectonophysics, v. 259, p. 245–258.

Bahlburg, H., Breitkreuz, C., Maletz, J., Moya, M. C., and Salfity, J. A., 1990, The Ordovician sedimentary rocks in the northern Puna of Argentina and Chile: New stratigraphical data based on graptolites: Newsletters on Stratigraphy, v. 23, p. 69–89.

Basei, M. A., Charrier, R., and Hervé, F., 1996, New ages (U-Pb, Rb-Sr, K-Ar) from supposed pre-Cambrian units in northern Chile: Third International Symposium on Andean geodynamics, Collection Colloques et Séminaires, p. 763–766.

Beck, M. E., Garcia, A., Burmester, R. F., Munizaga, F., Hervé, F., and Drake, R. E., 1991, Paleomagnetism and geochronology of late Paleozoic granitic rocks from the Lake District of southern Chile: Implications for accretionary tectonics: Geology, v. 19, p. 332–335.

Bell, C. M., 1982, The lower Paleozoic metasedimentary basement of the Coastal Ranges of Chile between 25°30′ and 27°S: Revista Geológica de Chile, no. 17, p. 21–29.

Bell, C. M., 1987, The origin of the Upper Paleozoic Chañaral mélange of N Chile: Journal, Geological Society [London], v. 144, p. 599–610.

Benedetto, J. L., and Sanchez, T. M., 1990, Fauna y edad del estratotipo Salar del Rincón (Eopaleozoico, Puna Argentina): Ameghiniana, no. 27, p. 317–326.

Berg, K., and Baumann, A., 1985, Plutonic and metasedimentary rocks from the Coastal Range of northern Chile: Rb-Sr and U-Pb isotopic systematics: Earth and Planetary Science Letters, v. 75, p. 101–115.

Berg, K., Breitkreuz, C., Damm, K.-W., Pichowiak, S., and Zeil, W., 1983, The north-Chilean Coast Range: An example for the development of an active continental margin: Geologische Rundschau, v. 72, p. 715–731.

Blasco, G., Villar, L., and Zappettini, E. O., 1996, El complejo ofiolítico desmembrado de la Puna argentina, Provincias de Jujuy, Salta y Catamarca: XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos Actas, no. III, p. 653–667.

Bond, G. C., Nickeson, P. A., and Kominz, M. A., 1984, Breakup of a supercontinent between 625 and 555 Ma: New evidence and implications for continental histories: Earth and Planetary Science Letters, v. 70, p. 325–345.

Boucot, A. J., Isaacson, P. E., and Laubacher, G., 1980, An Early Devonian, Eastern Americas faunule from the coast of southern Peru: Journal of Paleontology, v. 54, p. 359–365.

Boucot, A. J., Bahlburg, H., Breitkreuz, C., Isaacson, P. E., Niemeyer, H., and Urzúa, F., 1995, Devonian brachiopods from northern Chile: Journal of Paleontology, v. 69, p. 257–263.

Breitkreuz, C., 1986, Das Paläozoikum in den Kordilleren Nordchiles (21°–25°S): Geotektonische Forschungen, v. 70, p. 1–88.

Breitkreuz, C., 1991, Fluvio-lacustrine sedimentation and volcanism in a Late Carboniferous tensional intra-arc basin, N Chile: Sedimentary Geology, v. 74, p. 173–187.

Breitkreuz, C., and Zeil, W., 1994, The Late Carboniferous to Triassic volcanic belt in northern Chile, *in* Reutter, K.-J., Scheuber, E., and Wigger, P., eds., Tectonics of the southern Central Andes: Structure and evolution of an active continental margin: Heidelberg, Germany, Springer Verlag, p. 277–292.

Breitkreuz, C., Bahlburg, H., and Zeil, W., 1988, The middle to late Paleozoic evolution of north Chile: Geotectonic implications, *in* Bahlburg, H., Breitkreuz, C., and Giese P., eds., The southern Central Andes: Contributions to structure and evolution of an active continental margin: Lecture Notes in Earth Sciences, v. 17, p. 87–101.

Breitkreuz, C., Bahlburg, H., Delakowitz, B., and Pichowiak, S., 1989, Volcanic events in the Paleozoic central Andes: Journal of South American Earth Sciences, v. 2, p. 171–189.

Breitkreuz, C., Helmdach, F., Kohring, R., and Mosbrugger, V., 1992, Late Carboniferous intra-arc sedimentary rocks in the North Chilean Andes: Stratigraphy, paleogeography and paleoclimate: Facies, v. 26, p. 67–80.

Brook, M., Pankhurst, R. J., Shepherd, T. J., and Spiro, B., 1986, Andchron. Andean geochronology and metallogenesis: Overseas Development Agency, Open File Report, p. 1–83.

Brown, M., 1990, Comparative geochemical interpretation of Permian-Triassic plutonic complexes of the Coastal Range and Altiplano (25°30′ to 26°30′S), northern Chile, *in* Harmon, R. S., and Rapela, C. W., eds., Andean magmatism and its tectonic setting: Geological Society of America Special Paper 265, p. 157–177.

Brown, M., Dallmeyer, R. D., Diatz, F., and Grocott, J., 1991, The role of the Atacama Fault System in the post–late Paleozoic of North Chile: Is it a terrane boundary?: Vth International Circumpacific Terrane Conference, Expanded Abstracts: Comunicaciones, no. 42, p. 30–34.

Brown, M., Diaz, F., and Grocott, J., 1993, Movement history and tectonic significance of the El Salado segment of the Atacama Fault System, northern Chile: Geological Society of America Bulletin, v. 105, p. 1165–1174.

Burckhardt, C., 1902, Traces géologiques d'un ancien continente Pacifique: Revista del Museo La Plata, no. 10, p. 179–192.

Caminos, R., Cordani, U. G., and Linares, E., 1979, Geología y geochronología de las rocas metamórficas y eruptivas de la Precordillera y Cordillera Frontal de Mendoza, República Argentina: 2° Congreso Geológico Chileno Actas, no. 1, p. F43–F61.

Cecioni, A., 1982, El Devónico inferior de la Formación Lila, Región de Antofagasta, Chile: 3° Congreso Geológico Chileno Actas, no. III, p. F160–F178.

Cobbing, E. J., Ozard, J. M., and Snelling, N. J., 1977, Reconnaissance geochronology of the crystalline basement rocks of the Coastal Cordillera of southern Peru: Geological Society of America Bulletin, v. 88, p. 241–246.

Coira, B., and Koukharsky, M., 1991, Lavas en almohadillas ordovícicas en el Cordón de Escaya, Puna Septentrional, Argentina: 6° Congreso Geológico Chileno Actas, no. 1/A5, p. 674–678.

Coira, B., and Nullo, F., 1987, Facies piroclasticas del vulcanismo Ordovícico (Arenigiano-Llanvirniano), Salina de Jama, Jujuy: X Congreso Geológico Argentino Actas, no. 4, p. 308–311.

Coira, B., Davidson, J., Mpodozis, C., and Ramos, V., 1982, Tectonic and magmatic evolution of the Andes of northern Argentina and Chile: Earth Science Reviews, v. 18, p. 303–332.

Cordani, U., Kawashita, K., Baeza, L., Díaz, M., and Evangelista, D., 1988, Geochronología de la Sierra de Limón Verde, Antofagasta, Chile: 5° Congreso Geológico Chileno Actas, no. 2, p. 63–74.

Dalla Salda, L., Dalziel, I. W. D., Cingolani, C., and Varela, R., 1992a, Did the Taconic Appalachians continue into southern South America?: Geology, v. 20, p. 1059–1062.

Dalla Salda, L., Cingolani, C., and Varela, R., 1992b, Early Paleozoic orogenic belt of the Andes in southwestern South America: Result of Laurentia-Gondwana collision?: Geology, v. 20, p. 617–620.

Dalmayrac, B., Lancelot, J. R., and Leyreloup, A., 1977, Two-billion-year granulites in the late Precambrian metamorphic basement along the southern Peruvian coast: Science v. 198, p. 49–51.

Dalmayrac, B., Laubacher, G., Marocco, R., Martinez, C., and Tomasi, P., 1980, La chaine hercynienne d'amerique du sud, structure et évolution d'un orogène intracratonique: Geologische Rundschau, v. 69, p. 1–21.

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., and Forsythe, R. D., 1985, Andean evolution and the terrane concept, *in* Howell, D. G., ed., Tectonostratigraphic terranes of the Circum-Pacific-Region: Circum-Pacific-Council for Energy and Mineral Resources Earth Science Series, v. 1, p. 565–581.

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.

Dalziel, I. W. D., Dalla Salda, L. H., Cingolani, C., and Palmer, P., 1996, The Argentine Precordillera: A Laurentian Terrane?: Penrose Conference Report: GSA Today, v. 6, p. 16–18.

Damm, K.-W., Pichowiak, S., Harmon, R. S., Todt, W., Kelley, S., Omarini, R., and Niemeyer, H., 1990, Pre-Mesozoic evolution of the Central Andes; the basement revisited, *in* Mahlburg Kay, S., and Rapela, C. W., eds., Plutonism from Antarctica to Alaska: Geological Society of America Special Paper 241, p. 101–126.

Davidson, J., Mpodozis, C., and Rivano, S., 1981, El Paleozoico de Sierra de Almeida, al oeste de Monturaqui, Alta Cordillera de Antofagasta, Chile: Revista Geológica de Chile, no. 12, p. 3–23.

Davidson, J., Ramirez, C. F., Gardeweg, M., Herve, M., Brook, M., and Pankhurst, R., 1985, Calderas del Paleozoico Superior-Triásico Superior y mineralización asociada en la Cordillera de Domeyko, Norte de Chile: Comunicaciones, no. 35, p. 53–57.

Díaz, M., Cordani, U. G., Kawashita, K., Baeza, L., Venegas, R., Hervé, F., and Munizaga, F., 1985, Preliminary radiometric ages from the Mejillones Peninsula, northern Chile: Comunicaciones, no. 35, p. 59–67.

Drake, A. A., Jr., Sinha, A. K., Laird, J., and Guy, R. E., 1989, The Taconic orogen, *in* Hatcher, R. D., Thomas, W. A., and Viele, G. W., eds., The Appalachian-Ouachita orogen in the United States: Boulder, Colorado, Geological Society of America, The geology of North America, v. F-2, p. 101–177.

Forsythe, R. D., Kent, D. V., Mpodozis, C., and Davidson, J., 1987, Paleomagnetism of Permian and Triassic rocks, Central Chilean Andes, *in* McKenzie, G. D., ed., Gondwana six: Structure, tectonics and geophysics: American Geophysical Union Geophysical Monograph 40, p. 241–252.

Forsythe, R. D., Davidson, J., Mpodozis, C., and Jesinkey, C., 1993, Lower Paleozoic relative motion of the Arequipa block and Gondwana: paleomagnetic evidence from Sierra de Almeida of northern Chile: Tectonics, v. 12, p. 219–236.

Fortey, R., Pankhurst, R. J., and Hervé, F., 1992, Devonian trilobites at Buill, Chile (42°S): Revista Geológica de Chile, no. 19, p. 133–144.

Galliski, M. A., Tosselli, A. J., and Saavedra, J., 1990, Petrology and geochemistry of the Cachi high-alumina trondhjemites, northwestern Argentina, *in* Mahlburg Kay, S., and Rapela, C. W., eds., Plutonism from Antarctica to Alaska: Geological Society of America Special Paper 241, p. 91–100.

Garcia, A. F., Perez D'Angelo, E., and Ceballos, S. E., 1962, El Ordovícico de Aguada de la Perdíz, Puna de Atacama, provincia de Antofagasta: Revista Mineralógica, v. 77, p. 52–61.

Gardeweg, M., 1988, Petrografía y geoquímica del complejo volcanico Tumisa, Altiplano de Antofagasta, Andes del Norte de Chile: 5° Congreso Geológico Chileno Actas, v. III, p. I183–I208.

Gohrbrandt, K. H. A., 1992, Paleozoic paleogeographic and depositional developments on the proto-Pacific margin of Gondwana: Their importance to hydrocarbon accumulation: Journal of South American Earth Sciences, v. 6, p. 267–287.

Hanning, M., 1987, The geochemistry of Ordovician volcanics from the Faja Eruptiva, Argentina: Implications for the tectonic setting [B.A. thesis]: Ithaca, New York, Cornell University, 44 p.

Harland, W. B., Armstrong, R. L., Cox, A. V., Craig, L. E., Smith, A. G., and Smith, D. G., 1989, A geologic time scale 1989: Cambridge, United Kingdom, Cambridge University Press, 263 p.

Harrington, H., 1961, Geology of parts of Antofagasta and Atacama provinces, northern Chile: American Association of Petroleum Geologists Bulletin, v. 45, p. 169–197.

Hervé, M., 1987, Movimiento sinistral en el Cretácico Inferior de la Zona de Falla Atacama al norte de Paposo (24°S): Revista Geológica de Chile, v. 31, p. 31–42.

Hervé, F., Munizaga, F., Godoy, E., and Aguirre, L., 1974, Late Paleozoic K/Ar ages from Pichilemu, Central Chile: Earth and Planetary Science Letters, v. 23, p. 261–264.

Hervé, F., Kawashita, K., Munizaga, F., and Bassei, M., 1984, Rb-Sr isotopic ages from late Paleozoic metamorphic rocks of central Chile: Geological Society [London] Journal, v. 141, p. 877–884.

Hervé, F., Munizaga, F., Marinovic, N., Hervé, M., Kawashita, K., Brook, M., and Snelling, N., 1985, Geocronología Rb-Sr y K-Ar del basamento cristalino de Sierra Limon Verde: 4° Congreso Geológico Chileno Actas, no. III, p. 235–253.

Hervé, F., Godoy, E., Parada, M. A., Ramos, V., Rapela, C., Mpodozis, C., and Davidson, J., 1987, A general view on the Chilean-Argentine Andes, with emphasis on their early history: American Geophysical Union Geodynamic Series, v. 18, p. 97–113.

Hoffman, P. F., 1991, Did the breakout of Laurentia turn Gondwanaland inside-out?: Science, v. 252, p. 1409–1412.

Isaacson, P. E., 1975, Evidence for a western extracontinental land source during the Devonian Period in the central Andes: Geological Society of America Bulletin, v. 86, p. 39–46.

Isaacson, P. E., and Sablock, P. E., 1989, Devonian System in Bolivia, Peru and northern Chile, *in* McMillan, N. J., Embry, A. F., and Glass, D. J., eds., Devonian of the world: Canadian Society of Petroleum Geologists Memoir 14, p. 719–728.

Isaacson, P. E., Antelo, B., and Boucot, A. J., 1976, Implications of a Llandovery (Early Silurian) brachiopod fauna from Salta province, Argentina: Journal of Paleontology, v. 50, p. 1103–1112.

Isaacson, P. E., Fisher, L., and Davidson, J., 1985, Devonian and Carboniferous stratigraphy of Sierra de Almeida northern Chile, preliminary results: Revista Geológica de Chile, no. 25-26, p. 113–121.

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: IX Congreso Geológico Argentino Actas, no. 2, p. 48–65.

Kay, S. M., Ramos, V. A., Mpodozis, C., and Sruoga, P., 1989, Late Paleozoic to Jurassic silicic magmatism at the Gondwana margin: Analogy to the Middle Proterozoic in North America?: Geology, v. 17, p. 324–328.

Kay, S. M., Orrell, S., and Abbruzzi, J. M., 1996, Zircon and whole rock Nd-Pb isotopic evidence for a Grenville age and Laurentian origin for the basement of the Precordillera terrane in Argentina: Journal of Geology, v. 104, p. 637–648.

Kent, D. V., and Van der Voo, R., 1990, Paleozoic palaeogeography from palaeomagmatism of the Atlantic-bordering continents, *in* McKerrow, W. S., and Scotese, C. R., eds., Palaeozoic palaeogeography and biogeography: Geological Society [London] Memoir 12, p. 49–56.

Koukharsky, M., Coira, B., Barber, E., and Hanning, M., 1988, Geoquímica de vulcanitas ordovícicas de la Puna (Argentina) y sus implicancias tectónicas: 5° Congreso Geológico Chileno Actas, no. 3, p. I137–I.

Kumpa, M., and Sanchez, M. C., 1988, Geology and sedimentology of the Cambrian Grupo Mesón (NW Argentina), *in* Bahlburg, H., Breitkreuz, C., and Giese P., eds., The southern Central Andes: Contributions to structure and evolution of an active continental margin: Heidelberg, Germany, Springer Lecture Notes in Earth Sciences, v. 17, p. 39–54.

Larson, R. L., and Pitman, W. C., III, 1972, World-wide correlation of Mesozoic magnetic anomalies, and its implications: Geological Society of America Bulletin, v. 83, p. 3645–3662.

Lehmann, B., 1978, A Precambrian core sample from the Altiplano/Bolivia: Geologische Rundschau, v. 67, p. 270–278.

Litherland, M., and 10 others, 1989, The Proterozoic of eastern Bolivia and its relationship to the Andean mobile belt: Precambrian Research, v. 43, p. 157–174.

Long, D. G. F., 1994, Non-glacial mixtites in the Paleozoic of eastern Laurentia: A key to terrane correlation with South America?: Second Circum-Atlantic Circum-Pacific Terrane Conference, Program and Abstracts, p. 23.

Lork, A., and Bahlburg, H., 1993, Precise U-Pb ages of monazites from the Faja Eruptiva de la Puna Oriental and the Cordillera Oriental, NW Argentina: XII Congreso Geológico Argentino y II Congreso de Exploración de Hidrocarburos Actas, no. IV, p. 1–6.

Lucassen, F., Laber, A., and Franz, G., 1994, Geology and petrology of metamorphic rocks from the Preandian basement of northern Chile, 18°–24°S. 7° Congreso Geológico Chileno Actas, no. I, p. 96–100.

Lucassen, F., Wilke, H. G., Viramonte, J., Beccio, R., Franz, G., Laber, A., Wemmer, K., and Vroon, P., 1996, The Paleozoic basement of the central Andes (18°–26°S): A metamorphic view: Third International Symposium on Andean Geodynamics, Collection Colloques et Séminaires, p. 779–782.

Macdonald, D. I. M., 1986, Proximal to distal sedimentological variation in a linear turbidite trough: Implications for the fan model: Sedimentology, v. 33, p. 243–259.

Maksaev, V., and Marinovic, N., 1980, Cuadrángulos Cerro de la Mica, Quillagua, Cerro Posada y Oficina Prosperidad, Región de Antofagasta; Carta Geológica de Chile; 1:50 000: Instituto de Investigaciones Geológicas de Chile, no. 45–48.

McDonough, M. R., Ramos, V. A., Jackson, C. E., Bowring, S. A., and Vujovic, G. I., 1993, Edades preliminares de la Sierra de Pie de Palo, Sierras Pampeanas Occidentales de Jan Juan: Sus implicancias para el supercontinente proterozoico de Rodinia: XII Congreso Geológico Argentino y II Congreso de Exploración de Hidrocarburos Actas, no. III, p. 340–342.

Miller, H., 1970a, Vergleichende Studien an prämesozoischen Gesteinen Chiles unter besonderer Berücksichtigung ihrer Kleintektonik: Geotektonische Forschungen, v. 36, p. 1–64.

Miller, H., 1970b, Das Problem des hypothetischen "Pazifischen Kontinentes" gesehen von der chilenischen Küste: Geologische Rundschau, v. 59, p. 927–938.

Mon, R., and Hongn, F., 1987, Estructura del Ordovícico de la Puna: Revista de la Asociación Geológica Argentina, no. 42, p. 31–38.

Mon, R., and Hongn, F., 1991, The structure of the Precambrian and lower Paleozoic basement of the Central Andes between 22° and 32°S. Lat.: Geologische Rundschau, v. 80, p. 745–758.

Mon, R., and Hongn, F., 1996, Estructura del basamento proterozoico y paleozoico inferior del norte argentino: Revista de la Asociación Geológica Argentina, v. 51, p. 3–14.

Monaldi, C. R., and Boso, M. A., 1987, Dalmatina (Dalmatina) subandina nov. sp. (Trilobita) en la Formación Zapla del norte argentino: IV Congreso Latinoamericano de Paleontología, no. 1, p. 149–157.

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

Moya, M. C., 1988, Lower Ordovician in the southern part of the Argentine Eastern Cordillera, *in* Bahlburg, H., Breitkreuz, C., and Giese P., eds., The southern Central Andes: Contributions to structure and evolution of an active continental margin: Heidelberg, Germany, Springer Lecture Notes in Earth Sciences, v. 17, p. 55–70.

Moya, M. C., Malanca, S., Hongn, F. D., and Bahlburg, H., 1993, El Tremadoc temprano en la Puna occidental argentina: XI Congreso Geológico Argentino y II Congreso de Exploración de Hidrocarburos Actas, no. II, p. 20–30.

Mpodozis, C., and Kay, S. M., 1990, Provincias magmáticas ácidas y evolución tectónica de Gondwana: Andes chilenos (28°–31°S): Revista Geológica de Chile, no. 17, p. 153–180.

Mpodozis, C., and Kay, S. M., 1992, Late Paleozoic to Triassic evolution of the Gondwana margin: Evidence from Chilean Frontal Cordillera batholiths: Geological Society of America Bulletin, v. 104, p. 999–1014.

Mpodozis, C., and Ramos, V. A., 1990, The Andes of Chile and Argentina, *in* Ericksen, G. E., Cañas Pinochet, M. T., and Reinemund, J. A., eds., Geology of the Andes and its relation to hydrocarbon and mineral resources: Circum Pacific Council for Energy and Mineral Resources Earth Science Series, v. 11, p. 59–90.

Mpodozis, C., Hervé, F., Davidson, J., and Rivano, S., 1983, Los granitoides de Cerros de Lila, manifestaciones de un episodio intrusivo y termal del Paleozoico inferior en los Andes del Norte de Chile: Revista Geológica de Chile, no. 18, p. 3–14.

Mukasa, S. B., and Henry, D. J., 1990, The San Nicolás batholith of coastal Peru: Early Palaeozoic continental arc or continental rift magmatism?: Geological Society [London] Journal, v. 147, p. 27–39.

Niemeyer, H., 1989, El complejo igneo-sedimentario del Cordón de Lila, región de Antofagasta: Significado tectónico: Revista Geológica de Chile, no. 16, p. 163–181.

Niemeyer, H., Urzúa, F., Aceñolaza, G., and Gonzalez, R., 1985, Progresos recientes en el conocimiento del Paleozoico de la región de Antofagasta: 4° Congreso Geológico Chileno Actas, no. 1, p. 410–438.

Omarini, R., Viramonte, J., Cordani, U., Salfity, J., and Kawashita, K., 1984, Estudio geochronológico Rb-Sr de la Faja Eruptiva de la Puna en el sector de San Antonio de los Cobres, Provincia de Salta: IX Congreso Geológico Argentino Actas, no. 3, p. 146–158.

Osorio, R., and Rivano, S., 1985, Parpaechitidae (Ostracoda) del Paleozoico Superior en la Formación Pular (Harrington, 1961), Quebrada de Pajonales, vertiente occidental de la Sierra de Almeida, Antofagasta: 4° Congreso Geológico Chileno Actas, no. I, p. 439–457.

Pacci, D., Hervé, F., Munizaga, F., Kawashita, K., and Cordani, U., 1980, Acerca de la edad Rb-Sr Precambrica de rocas de la Formación Esquistos de Belén, Departamento de Parinacota, Chile: Revista Geológica de Chile, no. 11, p. 43–50.

Padula, E., Rolleri, E. O., Mingramm, A. R. G., Criado Roque, P., Flores, M. A., and Baldis, B. A., 1967, Devonian of Argentina., *in* Oswald, D. H., ed., International Symposium on the Devonian System: Alberta Society of Petroleum Geologists Memoir 2, p. 165–199.

Palma, M. A., 1990, La evolución tectonica durante el Ciclo Famatiano, en el segmento Andino ubicado entre los 24° y 28° de latitud Sur: XI Congreso Geológico Argentino Actas, no. II, p. 343–346.

Palma, M. A., Parica, P. D., and Ramos, V. A., 1986, El granito de Archibarca: Su edad y significado tectonico, provincia de Catamarca: Revista de la Asociación Geológica Argentina, no. 41, p. 414–419.

Pankhurst, R. J., Hervé, F., Rojas, L., and Cembrano, J., 1992, Magmatism and tectonics in continental Chiloé, Chile (42°–42°30′S): Tectonophysics, v. 205, p. 283–294.

Peralta, S., and Carter, C., 1990, La glaciación gondwánica del Ordovícico tardío: evidencias en fangolitas guijarrosas de la precordillera de San Juan, Argentina: X Congreso Geológico Argentino Actas, no. II, p. 181–185.

Pichowiak, S., 1994, Early Jurassic to Early Cretaceous magmatism in the Coastal Cordillera and the Central Depression of North Chile, *in* Reutter, K.-J., Scheuber, E., and Wigger, P., eds., Tectonics of the southern Central Andes: Structure and evolution of an active continental margin, Heidelberg, Germany, Springer Verlag, p. 203–217.

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

Ramos, V. A., 1994, Terranes of southern Gondwanaland and their control in the Andean structure (30°–33°S Latitude), *in* Reutter, K.-J., Scheuber, E., and Wigger, P., eds., Tectonics of the southern Central Andes: Structure and evolution of an active continental margin: Heidelberg, Germany, Springer Verlag, p. 249–261.
Ramos, V. A., and Vujovich, G. I., 1995, New appraisal on the southwestern Gondwana terranes and their Laurentian affinities: Laurentian-Gondwanan connections before Pangea: IGCP Field Conference Project 376, Abstracts, p. 31–32.
Ramos, V. A., Jordan, T. E., Allmendinger, R. W., Mpodozis, C., Kay, S., Cortés, J. M., and Palma, M., 1986, Paleozoic terranes of the central Argentine-Chilean Andes: Tectonics, v. 5, p. 855–880.
Ramos, V. A., Vujovich, G., Mahlburg Kay, S., and McDonough, M., 1993, La orogenesis de Grenville en las Sierras Pampeanas occidentales: la Sierra Pie de Palo y su integración al supercontinente proterozóico: XII Congreso Geológico Argentino y II Congreso de Exploración de Hidrocarburos Actas, no. III, p. 343–358.
Rapela, C. W., Coira, B., Toselli, A., and Saavedra, J., 1992, The lower Paleozoic magmatism of southwestern Gondwana and the evolution of the Famatinian Orogen: International Geology Review, v. 34, p. 1081–1142.
Restrepo-Pace, P. A., 1992, Petrotectonic characterization of the Central Andean Terrane, Colombia: Journal of South American Earth Sciences, v. 5, p. 97–116.
Reutter, K.-J., Döbel, R., Bogdanic, T., and Kley, J., 1994, Geological map of the Central Andes between 20°S and 26°S, *in* Reutter, K.-J., Scheuber, E., and Wigger, P., eds., Tectonics of the southern Central Andes: structure and evolution of an active continental margin: Heidelberg, Germany, Springer Verlag, p. 1–333.
Ribba, L., Mpodozis, C., Hervé, F., Nasi, C., and Moscoso, R., 1988, El basamento del Valle Tránsito, Cordillera de Vallenar: Eventos magmáticos y metamórphicos y su relación con la evolución de los andes chileno-argentinos: Revista Geológica de Chile, no. 15, p. 126–149.
Salfity, J. A., Omarini, R. H., Baldis, B., and Gutierrez, W. J., 1975, Consideraciones sobre la evolución geológica del Precambrico y Paleozoico del norte Argentino: II Congreso Iberoamericano de Geología Económica, no. 4, p. 341–361.
Salfity, J. A., Malanca, S., Brandan, M. E., Monaldi, C. R., and Moya, C., 1984, La Fase Guandacol en el norte de la Argentina: IX Congreso Geológico Argentino Actas, no. 1, p. 555–567.
Sanchez, M. C., 1994, [Ph.D. thesis]: Salta, Argentina, Facultad de Ciencias Naturales, Universidad Nacional de Salta.
Sanchez, M. C., and Salfity, J. A., 1990, Litofacies del Grupo Mesón (Cámbrico) en el oeste del Valle de Lerma (Cordillera Oriental Argentina): X Congreso Geológico Argentino Actas, no. II, p. 129–132.
Scheuber, E., and Andriessen, P. A. M., 1990, The kinematic and geodynamic significance of the Atacama fault zone, northern Chile: Journal of Structural Geology, v. 12, p. 243–257.
Scotese, C. R., and McKerrow, W. S., 1990, Revised world maps and introduction, *in* McKerrow, W. S., and Scotese, C. R., eds., Palaeozoic palaeogeography and biogeography: Geological Society [London] Memoir 12, p. 1–21.
Sempéré, T., 1995, Phanerozoic evolution of Bolivia, *in* Tankard, A. J., Suarez-Soruco, S., and Welsink, H. J., Petroleum basins of South America: American Association of Petroleum Geologists Memoir 62, p. 207–230.
Shackleton, R. M., Ries, A. C., Coward, M. P., and Cobbold, P. R., 1979, Structure, metamorphism and geochronology of the Arequipa Massif of coastal Peru: Geological Society [London] Journal, v. 136, p. 195–214.
Steinmann, G., 1923, Umfang, Beziehungen und Besonderheiten der andinen Geosynklinale: Geologische Rundschau, v. 14, p. 69–82.
Thiele, R., and Hervé, F., 1984, Sedimentación and tectónica de antearco en los terrenos preandinos del Norte Chico, Chile: Revista Geológica de Chile, no. 22, p. 61–75.
Tosdal, R. M., Munizaga, F., Williams, W. C., and Bettencourt, J. S., 1994, Middle Proterozoic crystalline basement in the Central Andes, western Bolivia and northern Chile: A U-Pb and Pb isotopic perspective: 7° Congreso Geológico Chileno Actas, no. II, p. 1464–1467.
Turner, J. C. M., 1960, Estratigrafía de la Sierra de Santa Victoria y adyaciencias: Boletin de la Academía Nacional de Ciencias de Córdoba, no. 41, p. 163–196.
Turner, J. C. M., and Méndez, V., 1979, Puna, *in* Turner, J. C. M., ed., Geología Regional Argentina, Volume 1: Buenos Aires, Academía Nacional de Ciencias, Córdoba, y Editorial Librart, p. 13–56.
Ulriksen, C., 1979, Regional geology, geochronology and metallogeny of the Coastal Cordillera of Chile between 25°30′ and 26° south [M.S. thesis]: Halifax, Nova Scotia, Dalhousie University, 221 p.
von Huene, R., and Scholl, D. W., 1991, Observations at convergent margins concerning sediment subduction, subduction erosion, and growth of continental crust: Reviews of Geophysics, v. 29, p. 279–316.
Wasteneys, H. A., Clark, A. H., Ferrar, E., and Langridge, R. J., 1995, Grenvillian granulite facies metamorphism in the Arequipa massif, Peru: a Laurentia-Gondwana link: Earth and Planetary Science Letters, v. 132, p. 63–73.
Willner, A., Lottner, U., and Miller, H., 1987, Early Paleozoic structural development in the NW Argentine basement of the Andes and its implications for geodynamic reconstructions, *in* McKenzie, G. D., ed., Gondwana six: Structure, tectonics and geophysics: American Geophysical Union Monograph 40, p. 229–239.
Wörner, G., Moorbath, S., Horn, S., Entenmann, J., Harmon, R. S., Davidson, J. P., and Lopez-Escobar, L., 1994, Large- and fine-scale geochemical variations along the Andean arc of northern Chile (17.5°–22°S), *in* Reutter, K.-J., Scheuber, E., and Wigger, P., eds., Tectonics of the southern Central Andes: Structure and evolution of an active continental margin, Heidelberg, Germany, Springer Verlag, p. 77–92.
Zappettini, E. O., Blasco, G., and Villar, L. M., 1994, Geología del extremo sur del Salar de Pocitos, Provincia de Salta, República Argentina: 7° Congreso Geológico Chileno Actas, no. I, p. 220–224.
Zonenshayn, L. P., Savostin, L. A., and Sedov, A. P., 1984, Global paleogeodynamic reconstructions for the last 160 million years: Geotectonics, v. 18, p. 181–195.

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