Paleomagnetic determinations of vertical-axis tectonic rotations from Late Cretaceous and Paleocene strata of Bolivia

R. F. Butler
D. R. Richards } Department of Geosciences, University of Arizona, Tucson, Arizona 85721
T. Sempere 13 rue Geoffroy l'Angevin, 75004 Paris, France
L. G. Marshall Institute of Human Origins, 1288 9th Street, Berkeley, California 94710

ABSTRACT

Structural development of the Altiplano during the past 10 m.y. involved crustal thickening and enhanced curvature of the central Andes. Oroclinal bending of 30° explains reasonably the pattern of vertical-axis rotations observed from units with ages 10 to 30 Ma. New paleomagnetic data from Late Cretaceous through Paleocene strata of southeastern Peru and the Eastern Cordillera of Bolivia document rotations that are also counterclockwise on the north limb of the orocline and clockwise on the south limb. However, the rotations of units with ages 30 to 70 Ma are more variable; nearby areas have undergone differential vertical-axis rotations of up to 60°. These larger rotations that have affected 30–70 Ma units in the central Andes may represent (1) local rotations during late Oligocene to present orogeny, (2) local rotations during Eocene orogeny, and/or (3) oroclinal bending during Eocene orogeny.

INTRODUCTION

The development of the Altiplano continental plateau occurred predominantly during the past 10 m.y. through major crustal shortening and thickening of the central Andes region. In addition, oroclinal bending has enhanced the curvature of both the coastline and the Andes. More generally, the central Andes (10°–27°S), as expressed topographically by the broad areas of high elevation, geologically by the eastward-verging fold and thrust belt along the east part of the range, and by the thickened crust, are primarily the result of late Oligocene to present orogeny (Jordan et al., 1983; Jordan and Alonso, 1987; Sempere et al., 1990; Richards, 1995). The broad area of high elevation in the Altiplano and Eastern Cordillera suggests that shortening was greatest through central Bolivia, where the Andes are at their widest, with a decrease in the amount of shortening along the Andean strike both to the north and south (Isacks, 1988). Total shortening of the crustal section from the trench to the limit of the fold and thrust belt is estimated to be ≳320 km (Schmitz, 1994). A result of along-strike variation in shortening is oroclinal bending of the Andes (Isacks, 1988). We use orocline in the sense of Marshak (1988), where the strikes of segments of the mountain belt have changed through its development. In the terminology of Marshak (1988), the central Andes display an antitaxial bend. Paleomagnetic declination data can discern vertical-axis rotations, and regional coverage may distinguish if the process that caused the rotation was oroclinal bending or local structural effects (Bachtadse and Van der Voo, 1986; Eldredge et al., 1985; Schwartz and Van der Voo, 1983).

Heki et al. (1983) and Kono et al. (1985) provided the first paleomagnetic data indicating that counterclockwise vertical-axis rotation has affected central and southern Peru, and they suggested that oroclinal bending may have produced these rotations. May and Butler (1985) observed counterclockwise rotations in coastal areas of central Peru and suggested that crustal shortening and thickening in the central Andes was responsible. Recent analyses of the growing paleomagnetic data base from western South America indicate that in situ block rotations of the continental margin along with oroclinal bending are required to explain the pattern of vertical-axis rotations (Hartley et al., 1992; Roperch and Carlier, 1992; Beck et al., 1994). The paleomagnetic data of MacFadden et al. (1990) and those reported here provide determinations of vertical-axis rotations in the Altiplano of Peru and Eastern Cordillera of Bolivia. These data demonstrate that rotations are not simply restricted to continental margin areas of Chile and Peru, but involve inboard regions of the central Andes as well.

EXPERIMENTAL PROCEDURES AND DATA

We collected paleomagnetic samples for magnetostratigraphic analysis from the Maastrichtian to early Paleocene El Molino Formation at La Palca (lat 19.53°S, long 294.17°E); this 480 m section is a homoclinally tilted succession in the southeast edge of the Miraflores syncline. The Paleocene Santa Lucia Formation was collected at Tiupampa (18.0°S, 294.5°E) and at Sucusuma (18.08°S, 294.25°E), where sections of the formation are ~100 m thick. A stratigraphic succession ~400 m thick was collected for magnetostratigraphic analysis of the Maastrichtian and/or Paleocene Umayo Formation at Laguna Umayo (15.75°S, 289.85°E) near the northwest edge of Lake Titicaca in southeastern Peru. These sample locations are shown in Figure 1. Paleomagnetic samples were collected from each of 150 sedimentary horizons (= paleomagnetic sites)

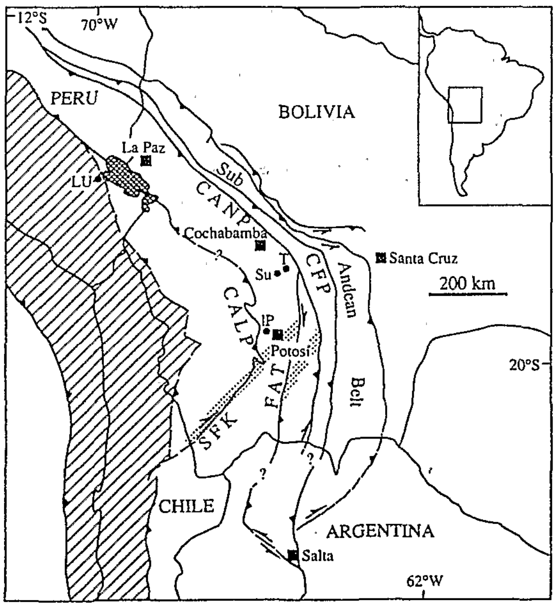

Figure 1. Structural sketch map of Neogene central Andes (simplified after Sempere, 1995) and localities mentioned in text. Diagonal rule = western Andean belt. Spanish abbreviations for faults: CANP = Main Andean thrust, CALP = Main Altiplano thrust, CFP = Main Frontal thrust, FAT = Aiquile-Tupiza fault, SFK = Khenayani fault system. Stipple = Khenayani-Turuchipa paleostructural corridor. Sampling locations: LU = Laguna Umayo; Su = Sucusuma; T = Tiupampa; IP = La Palca. Insert shows location of map (box) within South America.

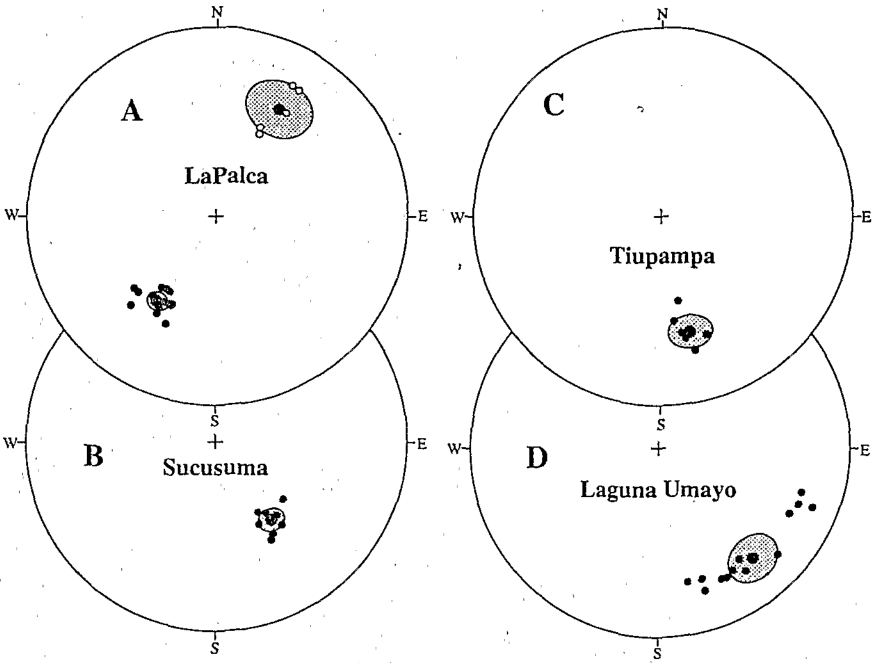

Figure 2. Equal-area projection of site-mean ChRM directions from (A) La Palca, (B) Sucusuma, (C) Tiupampa, and (D) Laguna Umayo used for tectonic analysis. Solid circles indicate directions in lower hemisphere of projection, and open circles indicate directions in upper hemisphere. Larger circles are mean directions of normal and reversed polarity groups of site-mean directions with surrounding 95% confidence limits indicated by stippled areas.

distributed among these four stratigraphic sections. Samples were collected from the finer-grained layers and are dominantly reddish claystones and siltstones.

Following sample preparation, all paleomagnetic specimens were stored, measured, and demagnetized in a magnetically shielded room with average field intensity <200 nT (nannotesla). All measurements of natural remanent magnetization (NRM) were done by using a two-axis cryogenic magnetometer (ScT C-102). Progressive thermal demagnetization employed from 8 to >16 temperature steps up to 680 °C. The magnetic field inside the thermal demagnetization furnace was <10 nT. Results of thermal demagnetization were analyzed by principal component analysis (Kirschvink, 1980). Magnetostratigraphic results and attendant geochronologic analyses will be presented elsewhere.

Because the original magnetostratigraphic objectives required that sampling be distributed stratigraphically, only three samples were collected from most of the paleomagnetic sites. Accordingly, stringent selection criteria have been applied before site-mean directions are accepted for the following tectonic analysis. Only characteristic components of NRM (ChRM) determined by results of ≥4 successive thermal demagnetization steps and with maximum angular deviation (MAD) ≤15° are considered reliable. For the majority of samples meeting this criterion, results from ≥6 thermal demagnetization temperatures usually yield line fits with MAD ≤10° and often yield MAD ≤5°. Only site-mean directions with 95% confidence limit (α_{95}), ≤20° are admitted for tectonic analysis. Paleomagnetic data from 13 sites at Laguna Umayo, 18 sites at La Palca, 8 sites at Sucusuma, and 7 sites at Tiupampa pass these criteria. Both normal and reversed polarity groups of site-mean ChRM directions are available from La Palca, and these directions yield a positive reversal test (class C of McFadden and McElhinny, 1990). Mean directions were computed for each of the four localities by using standard statistics (Fisher, 1953) applied to the site-mean directions and inverting the directions from normal polarity sites. These site-mean paleomagnetic directions are illustrated in Figure 2 and summarized in Table 1.

VERTICAL-AXIS ROTATIONS

Uncertainties in the South American reference paleomagnetic poles have produced difficulties in paleomagnetic analyses of regional tectonics (Beck, 1988). Macedo-Sánchez et al. (1992) have specifically discussed problems with South American Cenozoic reference paleomagnetic poles. We agree with their conclusion that "synthetic" Cenozoic reference poles rotated into South American coordinates provide better reference poles than those available from paleomagnetic studies of Cenozoic units from South America. For this analysis we have used the South American reference poles (with ages greater than 20 Ma) determined by Roperch and Carlier (1992), who rotated the synthetic apparent polar wander path of Besse and Courtillot (1991) into the South American framework. The analyses of vertical-axis rotation (R ± ΔR) employed the techniques of Beck (1980) and Demarest (1983). The results presented here greatly expand the available paleomagnetic data from Bolivia (Table 1).

Vertical-axis rotations inferred from paleomagnetic declinations are illustrated in Figures 3 and 4. Paleomagnetic results from units in the 10 to 30 Ma age range show a pattern of vertical-axis rotations consistent with simple oroclinal bending as the major cause (Figs. 3 and 4A). North of the orocli-

TABLE 1. VERTICAL-AXIS ROTATIONS INDICATED FROM PALEOMAGNETIC DATA

Rock Unit	Age (Ma)	N	Site location Lat (°S)	Site location Long (°E)	Observed direction I (°)	Observed direction D (°)	Observed direction α_{95} (°)	Reference pole Lat (°S)	Reference pole Long (°E)	Reference pole A_{95} (°)	Rotation $R \pm \Delta R$ (°) (°)	Ref.
Oligocene and Younger Units												
Ocros dykes	~10	32	13.5	286.0	32.1	165.2	5.2	86.9	273.5	3.0	−14.1 ± 5.5	1
Quebrada Honda	11–12	79	22.0	294.6	40.7	197.8	3.9	86.9	273.5	3.0	19.0 ± 4.9	2
Salla	21–24	58	17.2	292.3	37.4	173.4	5.4	80.5	287.3	2.7	−5.7 ± 6.0	2
Paciencia Group	24–27	9	22.8	291.6	27.0	200.0	13.5	80.5	287.3	2.7	20.8 ± 12.4	3
Calipuy Group	15–53	9	11.5	283.5	29.0	163.5	8.6	80.5	287.3	2.7	−15.8 ± 8.2	4
Eocene, Paleocene, and Late Cretaceous Units												
Purilactis Group	40–64	15	22.6	291.7	36.0	221.0	8.9	78.9	307.0	4.3	44.5 ± 9.7	3
Tiupampa	58–60	7	18.0	294.5	38.1	167.2	7.9	80.5	340.7	4.2	−5.3 ± 8.9	5
Laguna Umayo	~60	13	15.8	289.9	24.0	139.2	10.4	80.5	340.7	4.2	−32.9 ± 9.8	5
Sucusuma	59–61	8	18.1	294.3	47.3	144.6	4.7	80.5	340.7	4.2	−27.8 ± 6.7	5
La Palca	60–71	18	19.5	294.2	42.1	212.9	4.4	80.5	340.7	4.2	40.6 ± 6.0	5

Note: N = number of paleomagnetic sites; Lat = latitude; Long = longitude; I, D, α_{95} = inclination, declination, 95% confidence limit of mean direction, respectively; A_{95} = 95% confidence limit of reference pole; R = vertical-axis rotation of observed direction compared to expected direction; ΔR = 95% confidence limits on R; Ref. = reference number; 1 = Heki et al. (1983); 2 = MacFadden et al. (1990); 3 = Hartley et al. (1992); 4 = Macedo-Sánchez et al. (1992); 5 = this paper. The Miocene reference pole is the North American Miocene pole (87.4°N, 129.7°E, A_{95} = 3.0°; Hagstrum et al., 1987) rotated into South American coordinates by clockwise rotation of 1.86° about an Euler pole at 11.37°N, 53.08°E.

nal axis at ~18°S, these units indicate counterclockwise vertical-axis rotations of ~15°, whereas south of the oroclinal axis, slightly larger clockwise rotations of ~20° are indicated. Isacks (1988) preferred a model of oroclinal tectonics with decidedly asymmetric rotations (Fig. 3A). Admitting the scarcity of data, analysis of 10–30 Ma age units suggests that oroclinal bending may have been approximately symmetric; within confidence limits, these results can be explained by 15° counterclockwise rotation north of the orocline axis and 15° clockwise rotation south of the axis. Following the technique of Schwartz and Van der Voo (1983), Figure 3B illustrates the rotation of paleomagnetic declinations as a function of the strike of fold axes around the Bolivian orocline. If all deviations of paleomagnetic declination and bending of strike of the fold and thrust belt were due to oroclinal bending, the data on such a plot would fall along a line of unit slope. Linear regression of the data from 10–30 Ma age units yields a correlation coefficient of 0.91, indicating a good fit to an oroclinal bending model. The slope of 0.78 ± 0.15 is significantly less than 1.0, perhaps indicating that an initial curvature existed prior to the oroclinal bending, which has occurred since 10 Ma.

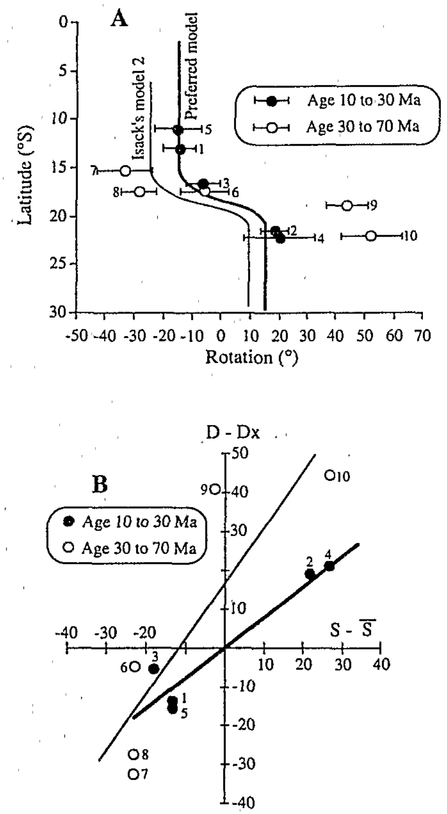

Figure 3. A. Vertical-axis rotation vs. latitude of sampling area. Negative rotations indicate counterclockwise rotation; positive rotations indicate clockwise rotation; error bars are 95% confidence limits. Solid circles are from units in 10–30 Ma age range; open circles are from units in 30–70 Ma age range. Curves are vertical-axis rotation models of Isacks (1988) and symmetric oroclinal bending model favored by present analysis. B. Declination deviation vs. strike deviation. Declination deviation is observed declination (D) minus expected declination (Dx). Strike deviation is average strike of fold axes within ~20 km of sampling location (S) minus assumed initial strike (S̄) of N22°W. Bold line is linear regression of data from units with ages 10–30 Ma and fine line is linear regression of data from units with ages 30–70 Ma. 1 = Ocros dikes; 9 = Quebrada Honda; 3 = Salla; 4 = Paciencia Group; 5 = Calipuy Group; 6 = Tiupampa; 7 = Laguna Umayo; 8 = Sucusuma; 9 = La Palca; 10 = Purilactis Group. References to paleomagnetic studies given in Table 1.

Although the number of areas studied and their geographic distribution are not large, it is evident from Figures 3 and 4 that Late Cretaceous and Paleogene units in Bolivia and northern Chile have undergone larger rotations than younger units. These rotations, which affected the 30–70 Ma units, are generally counterclockwise north of 18°S and clockwise farther to the south. Our data obtained from Maastrichtian-Paleocene strata in the Bolivian Eastern Cordillera show that the vertical-axis rotations of the La Palca and Sucusuma sections, which are currently separated by only ~150 km, differ by 68.4°. There is a difference of 22.5° in vertical-axis rotation between Sucusuma and Tiupampa, which are separated by <30 km in two adjacent thrust sheets. It is not possible for these differences in vertical-axis rotations over such short distances to result from simple oroclinal bending. Figure 3B shows that paleomagnetic declinations from 30–70 Ma units are not nearly so well described by oroclinal bending as are declinations from 10–30 Ma age units. Linear regression of the data from 30–70 Ma age units yields a correlation coefficient of 0.73 and a slope of 1.44 ± 0.50. The larger rotations that have affected 30–70 Ma units may represent (1) local rotations during late Oligocene to present orogeny, (2) local rotations during Eocene orogeny, and/or (3) oroclinal bending during Eocene orogeny.

DISCUSSION AND CONCLUSIONS

In Bolivia, oroclinal tectonics considerably shortened and displaced structural domains that are bounded by major fault zones and include pre-Andean structural heterogeneities (later reactivated) and numerous distinct Andean thrust sheets (Sempere et al., 1990, 1991). Because of their specific locations (Figs. 1 and 4), we suggest that some of the observed vertical-axis rotations were produced by block rotations of such crustal domains or thrust sheets, with dimensions of tens of kilometres, in relation to motions on nearby faults. At La Palca, the drag-fold shape in map view of the Miraflores syncline and the observed ~40° clockwise rotation appear to be due to right-lateral strike-slip faulting (probably during late Oligocene–Neogene) along the Khenayani-Turuchipa paleostructural corridor (Sempere et al., 1991). Hartley et al. (1992) observed a similar ~43° clockwise rotation in Paleo-

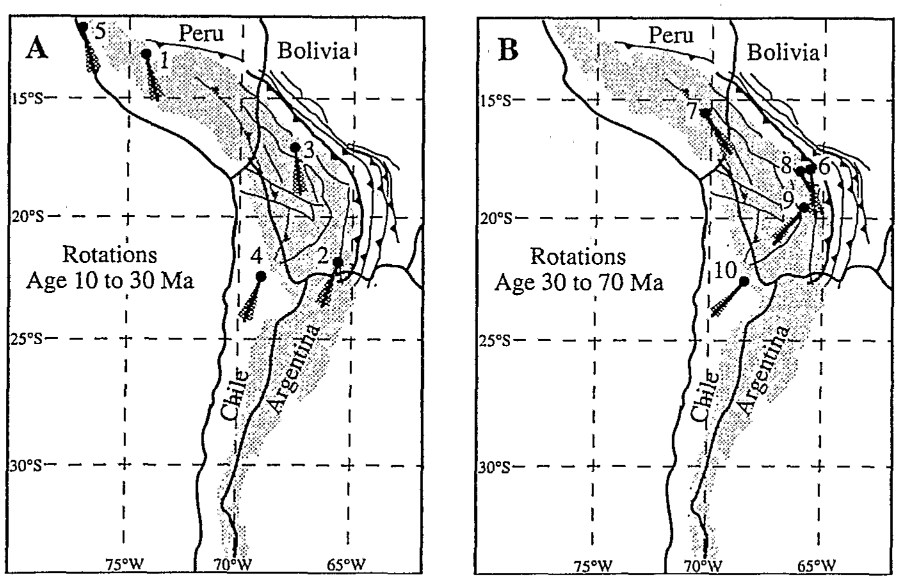

Figure 4. Vertical-axis rotations indicated by 10–30 Ma units (A) and 30–70 Ma units (B) of central Andes. Stippled region is Altiplano and Puna plateau area with elevation >3000 m. Solid circles show locations of paleomagnetic studies in Table 1; data points labeled as in Figure 3; black line pointing southward from each circle is mean paleomagnetic declination (computed in reversed-polarity format); expected direction is directly south; deviations of observed mean declinations from directly south indicate vertical-axis rotation of sampled area; patterned pie slices indicate 95% confidence limits on vertical-axis rotations. After Roperch and Carlier (1992).

cene-Eocene rocks of the Cerros de Purilactis syncline, just southeast of the Khenayani-Turuchipa paleostructural corridor in northern Chile; the syncline also shows a drag-fold shape in map view.

However, the above interpretation is not sufficient to explain why older strata have been regionally affected by larger rotations (Figs. 3 and 4). Recent field observations suggest that compressional deformation developed in Eocene time at least in the southern part of the Eastern Cordillera in Bolivia. The infilling of the Mondragón-Bolívar basin, which is located in the Eastern Cordillera and represents the foreland basin of the main Altiplano thrust system (Sempere et al., 1991), is now interpreted to be mainly Eocene in age and laterally onlaps deformed Cretaceous strata near Potosí. Major deformation that involved east-verging duplexes and large overthrusts northeast of Uyuni, previously interpreted as late Oligocene or younger (Baby et al., 1992), may have developed in the Eocene. Eocene thrusting is also indicated within the Eastern Cordillera of southern Bolivia by a thick early to middle Eocene proximal foreland basin section that contains large Maastrichtian clasts. A late Eocene tectonothermal event in the La Paz area suggests that Eocene tectonics also affected the Eastern Cordillera of northern Bolivia (Farrar et al., 1988). Collectively, these data from the Eastern Cordillera suggest that large-scale oroclinal tectonics might have started to develop as early as Eocene time, and may account, in part, for the larger rotations we observe in older strata.

Incipient oroclinal tectonics may have been active in the Eocene, earlier than the late Oligocene age previously assumed for the onset of oroclinal tectonics in Bolivia (Sempere et al., 1990). Differential rotations between adjacent thrust sheets have occurred, as in the case of Sucusuma and Tiupampa. Nearby major fault zones and preexisting crustal heterogeneities have had considerable influence, as at La Palca. Consequently, in all cases vertical-axis rotations must be analyzed in the local structural context before large-scale tectonic implications can be addressed. Paleomagnetic and geologic data are only now beginning to provide insights into the space and time heterogeneities and complexities of Cenozoic deformations within the central Andes.

ACKNOWLEDGMENTS

Supported by National Geographic Society grant 4810-92 and a grant from the University of Arizona International Program Development Fund. Logistical support was provided by ORSTOM (Institut Français de Recherche Scientifique pour le Developpement en Cooperation) and Yacimientos Petroliferos Fiscales Bolivianos (YPFB). We thank Bryan Backes, David Lindsay, Thurston Strom, and Rob Feyerharm for assistance with paleomagnetic laboratory analyses.

REFERENCES CITED

Baby, P., Sempere, T., Oller, J., and Hérail, G., 1992, Evidence for major shortening on the eastern edge of the Bolivian Altiplano: The Calazaya nappe: Tectonophysics, v. 205, p. 155–169.

Bachtadse, V., and Van der Voo, R., 1986, Paleomagnetic evidence for crustal and thin-skinned rotations in the European Hercynides: Geophysical Research Letters, v. 13, p. 161–164.

Beck, M. E., Jr., 1980, Paleomagnetic record of plate-margin tectonic processes along the western edge of North America: Journal of Geophysical Research, v. 85, p. 7115–7131.

Beck, M. E., Jr., 1988, Analysis of Late Jurassic–Recent paleomagnetic data from active plate margins of South America: Journal of South American Earth Sciences, v. 1, p. 39–52.

Beck, M. E., Jr., Burmester, R. F., Drake, R. E., and Riley, P. D., 1994, A tale of two continents: Some tectonic contrasts between the central Andes and the North American Cordillera, as illustrated by their paleomagnetic signatures: Tectonics, v. 13, p. 215–224.

Besse, J., and Courtillot, V., 1991, Revised and synthetic apparent polar wander paths of the African, Eurasian, North American and Indian plates, and true polar wander since 200 Ma: Journal of Geophysical Research, v. 96, p. 4029–4050.

Demarest, H. H., 1983, Error analysis of the determination of tectonic rotation from paleomagnetic data: Journal of Geophysical Research, v. 88, p. 4321–4328.

Eldredge, S., Bachtadse, V., and Van der Voo, R., 1985, Paleomagnetism and the orocline hypothesis: Earth and Planetary Science Letters, v. 119, p. 153–179.

Farrar, E., Clark, A. H., Kontak, D. J., and Archibald, D. A., 1988, Zongo–San Gabán zone: Eocene foreland boundary of the central Andean orogen, northwest Bolivia and southeast Peru: Geology, v. 16, p. 55–58.

Fisher, R. A., 1953, Dispersion on a sphere: Royal Society of London Proceedings, ser. A, v. 217, p. 295–305.

Hagstrum, J. T., Sawlan, M. G., Hausback, B. P., Smith, J. G., and Grommé, C. S., 1987, Miocene paleomagnetism and tectonic setting of the Baja California Peninsula, Mexico: Journal of Geophysical Research, v. 92, p. 2627–2639.

Hartley, A. J., Jolley, E. J., and Turner, P., 1992, Paleomagnetic evidence for rotation in the Precordillera of northern Chile: Structural constraints and implications for the evolution of the Andean forearc: Tectonophysics, v. 205, p. 49–64.

Heki, K., Hamano, Y., and Kono, M., 1983, Rotation of the Peruvian block from paleomagnetic studies in the central Andes: Nature, v. 305, p. 514–516.

Isacks, B. L., 1988, Uplift of the central Andean plateau and bending of the Bolivian orocline: Journal of Geophysical Research, v. 93, p. 3211–3231.

Jordan, T. E., and Alonso, R. N., 1987, Cenozoic stratigraphy and basin tectonics of the Andes Mountains, 20°–28° South latitude: American Association of Petroleum Geologists Bulletin, v. 71, p. 49–64.

Jordan, T. E., Isacks, B. L., Allmendinger, R. W., Brewer, J. A., Ramos, V. A., and Ando, C. J., 1983, Andean tectonics related to geometry of subducted Nazca plate: Geological Society of America Bulletin, v. 94, p. 341–361.

Kirschvink, J. L., 1980, The least-squares line and plane and the analysis of palaeomagnetie data: Royal Astronomical Society Geophysical Journal, v. 62, p. 699–718.

Kono, M., Heki, K., and Hamano, Y., 1985, Paleomagnetic study of the central Andes: Counterclockwise rotation of the Peruvian block: Journal of Geodynamics, v. 2, p. 193–209.

Macedo-Sánchez, O., Surmont, J., Kissel, C., Mitouard, P., and Laj, C., 1992, Late Cainozoic rotation of the Peruvian Western Cordillera and the uplift of the Central Andes: Tectonophysics, v. 205, p. 65–77.

MacFadden, B. J., Anaya, F., Perez, H., Naeser, C. W., Zeitler, P. K., and Campbell, K. E., 1990, Late Cenozoic paleomagnetism and chronology of Andean basins of Bolivia: Evidence for possible oroclinal bending: Journal of Geology, v. 94, p. 541–555.

Marshak, S., 1988, Kinematics of orocline and arc formation in thin-skinned orogens: Tectonics, v. 7, p. 73–86.

May, S. R., and Butler, R. F., 1985, Paleomagnetism of the Puente Piedra Formation, central Peru: Earth and Planetary Science Letters, v. 72, p. 205–218.

McFadden, P. L., and McElhinny, M. W., 1990, Classification of the reversal test in palaeomagnetism: Geophysical Journal International, v. 103, p. 725–729.

Richards, D. R., 1995, Terranes and tectonic evolution of the Andes: A regional synthesis [Ph.D. thesis]: Tucson, University of Arizona, 451 p.

Roperch, P., and Carlier, G., 1992, Paleomagnetism of Mesozoic rocks from the central Andes of southern Peru: Importance of rotations in the development of the Bolivian Orocline: Journal of Geophysical Research, v. 97, p. 17,233–17,249.

Schmitz, M., 1994, A balanced model of the southern central Andes: Tectonics, v. 13, p. 484–492.

Schwartz, S. Y., and Van der Voo, R., 1983, Paleomagnetic evaluation of the orocline hypothesis in the central and southern Appalachians: Geophysical Research Letters, v. 10, p. 505–508.

Sempere, T., 1995, Phanerozoic evolution of Bolivia and adjacent regions, *in* Tankard, A. J., et al., eds., Petroleum basins of South America: American Association of Petroleum Geologists Memoir G2 (in press).

Sempere, T., Hérail, G., Oller, J., and Bonhomme, M. G., 1990, Late Oligocene–early Miocene major tectonic crisis and related basins in Bolivia: Geology, v. 18, p. 946–949.

Sempere, T., Baby, P., Oller, J., and Hérail, G., 1991, La nappe de Calazaya: Une preuve de raccourcissements majeurs gouvernés par des éléments paléostructuraux dans les Andes boliviennes: Paris, Académie des Sciences Comptes Rendus, sér. II, v. 312, p. 77–83.

Manuscript received March 3, 1995
Revised manuscript received June 7, 1995
Manuscript accepted June 8, 1995

Printed in U.S.A.