BASEMENT-INVOLVED THRUSTING IN THE EASTERN CORDILLERA-SUBANDEAN TRANSITION ZONE, SOUTHERN BOLIVIA: EVIDENCE FROM CROSS-SECTION BALANCING AND GRAVIMETRIC DATA

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RESUMEN

Mediante la utilización de perfiles balanceados junto con modelado gravimétrico bidimensional se interpreta la existencia de "basamento cristalino" involucrado en los corrimientos que constituyen la zona de transición entre la Cordillera Oriental y las Sierras Subandinas del Sur de Bolivia, lo que permite acotar el acortamiento producido en las Sierras Subandinas y sector oriental de la Cordillera Oriental a unos 140 km.

KEY WORDS: Southern Bolivia, Crustal shortening, Balanced cross-sections, Gravimetrical data

INTRODUCTION

The exceptionally thick continental crust of the central Andes was initially believed to have been built mainly by addition of mantle-derived magmas from the subduction zone (e.g.James, 1971). Meanwhile, tectonic shortening is envisaged as the main process responsable for crustal thickening, probably with some minor magmatic contribution. Estimates of shortening during the Andean orogeny have been published by a number of authors (e.g. Allmendinger et al. 1983, Roeder 1988; Baby et al. 1989). However, attention has so far mainly focussed on the external part of the thrust belt at the eastern slope of the Andes (the Subandean Ranges). This contribution deals with a cross-section at 21°15 S which includes the internal belt (the eastern part of the Eastern Cordillera) where basement becomes involved into thrusting. Especially, gravimetrical data are shown to constrain the structural interpretation and, consequently, shortening values.

GEOLOGICAL SETTING

In southern Bolivia north of 21°45 S, the Eastern Andean thrust belt can be subdivided into three strike-parallel belts. These are, from east to west: (1) The Subandean Ranges, which form a classical thrust belt. Its basal décollement is not located at the top of crystalline basement, but lies within the sedimentary cover in a Silurian shale unit. Outcropping rocks range from Devonian to Neogene in age. Andean-age shortening which started in the late Miocene is on the order of 80-100 km. (2) A tightly folded and thrust transition zone, made up mainly of Silurian and Devonian rocks. No units younger than Triassic are preserved. (3) The Eastern Cordillera proper, with Ordovician to Precambrian rocks surfacing in a large anticlinorium. Cretaceous sediments unconformably overlying the folded and foliated Ordovician document a pre-Cretaceous orogenic event.

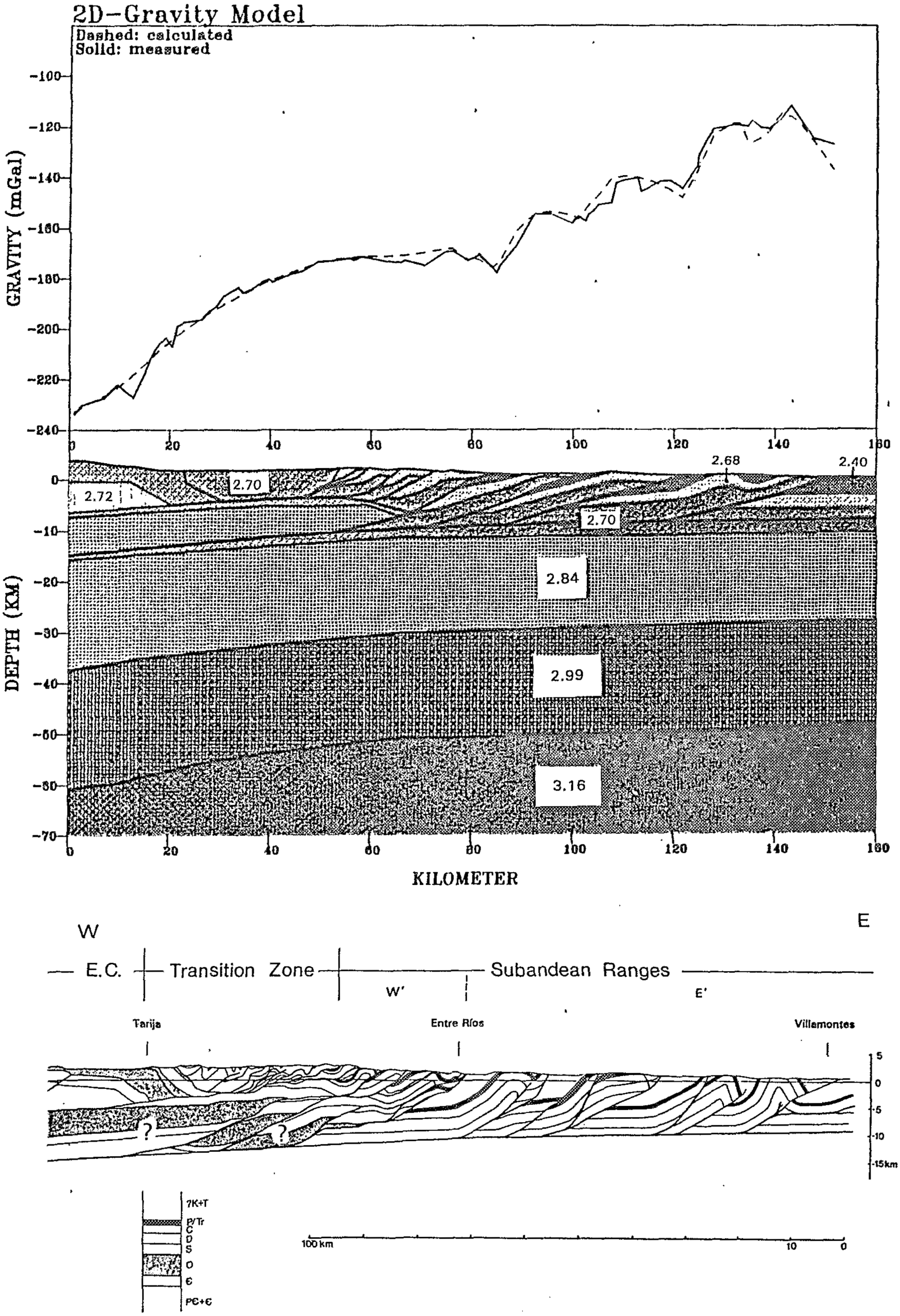
Gravimetric Data

Gravimetric data measured by the Bolivian Instituto Geográfico Militar (IGM 1974) were tied to the IGSN 71 point in La Paz, Bolivia (Strunk 1990). Correction for topographic effects was based on the digital elevation model of Isacks (1988) and detailed topographic maps of the IGM, using the algorithm by Ehrismann & Lettau (1971). In calculating the Bouguer anomaly, a reduction density of 2.67 g/cm^3 was used with sea level as reference datum. For the 2D gravimetric modeling we used an interactive computer program based on the algorithm by Won & Bevis (1987) developed by the gravity working group at the FU Berlin.

Balanced Cross-Section And Gravimetric Interpretation

The thin-skinned tectonic style of the Subandean Ranges is evidenced by the existence of a gently west-dipping "regional" which can be traced from the foreland throughout the Subandean Ranges up to the westernmost ocurrences of Neogene strata. In the transition zone, the elevations of stratigraphic horizons in the synclines again define a subhorizontal regional level, thus suggesting the existence of a shallow décollement at the base of the structures. This surface, however, is raised by almost 10 km relative to the basal décollement of the Subandean Ranges. On the other hand, the undeformed sub-décollement section (the "basement") of the Subandean Ranges from which the post-Ordovician sedimentary cover has been sheared off and thrust eastward must extend westward under the whole of the transition zone, as can be estimated from the shortening documented in the Subandean Ranges. The space between this "bottom" and the basal décollement of the transition zone might be filled by a thick thrust sheet involving the basement (Ordovician to Precambrian) or, alternatively, by imbrications of the same Silurian to Neogene sequence that builds up the Subandean Ranges. Cross-sections based on either assumption give shortening values about twice as high in the latter case (>300 km vs. ca. 140 km).
Gravimetric data in the Subandean Ranges show several small highs and lows which correlate with Paleozoic sediments in the cores of fold-thrust structures and the thick low-density Neogene sediments of their backlimbs, respectively (Fig. 1). In contrast, the transition zone coincides with a marked gravity high of longer wavelength. In the Bouguer residual gravity field, this feature stands out as a positive anomaly of more than +10 mGal. Hence, the latter of the two structural models considered above which predicts an accumulation of low-density sedimentary rocks in the subsurface of the transition zone can be discarded. "Basement" rocks appear to be present in buried thrust sheets immediately west of the western limit of the Subanden Ranges, although the easternmost outcrops of these rocks lie some 50 km further west. Detailed modelling of the gravity curve furthermore suggests that the basement of the transition zone is lithologically quite different from the basement exposed in the Eastern Cordillera farther west and south (Puncoviscana Fm. in northwestern Argentina), and possibly comprises intermediate to basic crystalline rocks. We can only speculate on the exact nature and origin of these rocks, which could be more basic equivalents of the mid-Cambrian Cañaní granitoids of northwestern Argentina but which might as well be much younger. (The latest magmatic events of the region are the effusion of the Mesozoic Entre Ríos Basalt of uncertain age and the intrusion of a granitoid pluton in the Eastern Cordillera close to the Argentine border at the (?) Jurassic-Cretaceous boundary).

Fig. 1: Above: 2D-Gravity model of a cross-section through the Subandean Ranges, Transition Zone and eastern margin of the Eastern Cordillera at 21°15 S. Numbers are densities in g/cm^3. Boundary between 2.99 and 3.16 corresponds to Moho as derived from refraction seismic data (Baldzuhn 1993).
Below: Balanced cross-section. Surface geology of the Subandean Ranges according to unpublished data from YPFB. Deep imbricates of the transition zone are shown with a thick Lower Palaeozoic sedimentary sequence as would be estimated from surface geology, but should contain high density material according to gravity data.


2D-Gravity Model
Dashed: calculated
Solid: measured
GRAVITY (mGal)
-100
-120
-140
-160
-180
-200
-220
-240
0
20
40
60
80
100
120
140
160
2.68
2.40
2.72
2.70
2.70
2.84
2.99
3.16
DEPTH (KM)
0
-10
-20
-30
-40
-50
-60
-70
KILOMETER
W
E
E.C.
Transition Zone
Subandean Ranges
W'
E'
Tarija
Entre Ríos
Villamontes
5
0
-5
-10
-15km
?
?
?K+T
P/Tr
C
D
S
O
Є
PЄ+Є
100 km
10
0

CONCLUSIONS

Gravimetrical data demonstrate that basement rocks become involved into thrusting immediately west of the Subandean Ranges. This limits the shortening value that can be deduced from balanced sections for the region from the undeformed foreland to the eastern part of the Eastern Cordillera to about 140 km. As these account for only about half of the shortening required to thicken the Andean crust to its present state, considerable shortening should have occured in areas farther west where extensive thrusting is often not evident at first sight. Besides the southern Altiplano., for which substantial shortening has been described (Baby et al. 1990), these regions may include the western part of the eastern Cordillera as well as areas which are now covered by Neogene to Recent volcanics.

REFERENCES

ALLMENDINGER, R.W., RAMOS, V.A., JORDAN, T. E., PALMA, M. & ISACKS, B.L. (1983): Paleogeography and Andean structural geometry, Northwest Argentina.- Tectonics, **2** (1), 1-16.

BABY, P., HERAIL, G., LOPEZ, J.M., OLLER, J., PAREJA, J., SEMPERE, T. & TUFIÑO D (1989): Structure de la Zone Subandine de Bolivie: influence de la géométrie des séries sédimentaires antéorogéniques sur la propagation des chevauchements.- C. R. Acad. Sci. Paris, **309**, Série II: 1717-1722

BABY, P., T. SEMPERE, J. OLLER, L. BARRIOS, G. HERAIL, R. MAROCCO (1990): Un bassin en compression d'âge oligo-miocène dans le sud de l'Altiplano bolivien.-C.R. Acad. Sci. Paris, **311**, Série II: 341-347.

BALDZUHN, S. (1993): Tiefenseismische Untersuchungen in der Ostkordillere und im Subandin Südboliviens. Diplomarbeit FU Berlin, unpublished.

EHRISMANN, W. & LETTAU, O (1971): Topographische Reduktion von Scweremessungen in der näheren und weiteren Stationsumgebung mit Digitalrechnern.- Arch. Met. Geoph. Biokl., Ser. A, 20, 383-396.

Instituto Geográfico Militar (IGM) de Bolivia (1974): Mediciones gravimétricas en Bolivia.- Departamento Geofísico, 165 p., La Paz, Bolivia.

ISACKS, B.L. (1988): Uplift of the Central Andean Plateau and Bending of the Bolivian Orocline.- J. Geophys. Res., **93** (B4), 3211-3231.

JAMES, D.E. (1971): Plate Tectonic Model for the Evolution of the Central Andes.- Geological Society of America Bulletin, **82**, 3325-3346.

ROEDER, D.(1988): Andean-age structure of Eastern Cordillera (Province of La Paz, Bolivia).-Tectonics, 7 (1), 23-39.

STRUNK, S. (1990): Analyse und Interpretation des Schwerefeldes des aktiven Kontinentalrandes der zentralen Anden (20°-26°S).-Berl. geowiss. Abh., (B), **17**, 1-135.

WON, I.J. & BEVIS, M. (1987): Computing the gravitational and magnetic anomalies due to a polygon: algorithms and FORTRAN subroutines.- Geophysics, **52** (2), 232-238.