# GRAVITY, ISOSTASY AND ANDEAN CRUSTAL SHORTENING BETWEEN 30°S AND 35°S LATITUDES

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Resumen

Cuatro secciones gravimétricas Andinas EW ubicadas en 30°S, 32°S, 33°S y 35°S revelan: (i) Aceptable equilibrio isostático (Airy); (ii) Que las probables reparticiones de masas heterogéneas subcorticales no presentan resultados gravimétricos observables; (iii) Modelos de acortamiento pueden justificar totalmente la formación de los Andes y de las Sierras Pampeanas.

Key words: gravity, isostasy, Andes and Sas. Pampeanas building.

## Introduction

Based on 12 gravimetric sections in east-west direction properly distributed upon the South American austral sector between 20°S and 44°S latitudes, and mostly extended from the Pacific Ocean to the Atlantic Ocean, gravity charts of Free Air anomalies, Bouguer anomalies and isostatic anomalies for Argentina-Chile were prepared.
Using gravimetric inversion of those sections, crustal models were prepared (Introcaso-Pacino, in prep.), and a chart of Moho for the Andes of Argentina-Chile was done based on those models. A chart of isostatic geoid for the Andes complete our study. Adding the following published charts: (i) the satellital geoid; (ii) the 3 Km contour Andean elevation; and (iii) the contours of depth to the central part of the Wadati-Benioff seismic zone, we have done a comparative analysis which we will later comment. From this general work, four gravimetric Andean sections located at 30°S, 32°S, 33°S and 35°S latitudes, allowed us to analize with more details the Andean structure's behaviour in this transitional zone, yet studied in a deeper way using seismological data, by the Instituto Sísmológico Zonda (I.S.Z.), the Instituto Nacional de Prevención Sísmica (INPRES) and by some researchers from Cornell's University, for example, between others, Smalley and Isacks (1987).
The analized segment goes across the Cordillera de la Costa, the Valle Central and the Cordillera de los Andes in Chile, and the Cordillera Principal and the Llanura Chaco-Pampeana in Argentina. The three northernmost sections also go across the Western Sierras Pampeanas.
These ranges, which are similar in many ways to the U.S.A. Laramide uplifts, show active compression at present, pointed out by many focal

mechanisms, by either altitude and gravity temporary changes, and by the recognition of reverse faulting fields. Studies of deep reflection also mark the listric character of the crustal faulting. Curiously, we have found significative positive gravity values over these ranges. The analized gravimetric sections from N to S present: extensions of about 3200 km, 2000 km, 1900 km, 1450 km; maximun dephts in the trench of 6400 m, 6200 m, 5900 m and 5475 m; maximun mean altitudes (and from measurement) over the Andean building of 5800 (4790)m, 4200 (2150)m, 4200 (3265)m and 3500 (2280)m respectively; maximun Free Air anom. of -175 mGal, -180 mGal, -193 mGal and -130 mGal over the trench, and maximun Bouguer anomalies of -340 mGal, -320 mGal, -300 mGal and -225 mGal over the Andean belt. (Introcaso, 1980; Pacino e Introcaso, 1988; Fraga e Introcaso, 1988).

Results. Brief discussion

A relationship between Bouguer anomalies and altitudes in 1° x 1° obtained for Argentina and the Andean belt, modifies the relationship defined 20 years ago with less values, and approximates the relationship in 1° x 1° obtained for U.S.A., being considered as in isostatic equilibrium.
There also exist a remarkable correlation between each of the following charts: topographic one, of Bouguer, of isostatic correction, of the Moho and the Geoid (which presents, because of its esence, a width bigger than the others). This correlation clearly indicates that, at least in a great part, there exist isostatic crustal compensation in the Airy System.
Apparently, a correlation between the slope chart of the Subducted Nazca Plate and the preceding charts, does not exist. Below 33°S latitude, and as we had already pointed out for the 24°S parallel (Introcaso y Pacino, 1988), the probable gravimetric effects (positive one for the subducted plate and negative one for the wedge of hot astenospheric materials, source of Quaternary volcanism), if they exist, could be mostly cancelled. Above 33°S latitude in the flatten subduction zone, we should consider almost only the probable positive effect of the plate looking for its compensation beneath the Oceanic Plate, since it is not reflected in the results, or we should think that the effect of the plate is not significative.
The most obvious conclusion is that the Bouguer anomaly, both in the studied sector and in the whole Argentina-Chile, is mainly controlled by Mohorovicic discontinuity.
The four gravimetric sections were regionalizated by the upwards-continuation method (Pacino e Introcaso, 1987). Studies of delay time anomalies in four east-west stations in Western Argentina, and of deep seismicity (crust and upper mantle in the Chilean sector, and intermedium crust in Argentina) complete the preparation of our models. The inversions allowed us to define antiroots beyond the Chile Trench and the bottom of the crust with the following maximun depths: 71 km at 30°S, 65.5 at 32°S, 65 at 33°S and 57 at 35°S. The crustal roots were involved in the Andean shortening models, as we will later see. Recently, shortenings of 40-45 km for the Cordillera Principal (Ramos, V. personal comunic.) and 95 km for the Precordillera (State Oil Argentine Company) were recognized.
With this modifications, the whole crustal shortening for the Argentine sector, including the Pampean segment would be of 150 to 160 km. Taking into account the Chilean sector, we ought to admit a probable crustal shortening of about 180-190 km for the total extension of the profile. For the Sierras Pampeanas, we have recently analized a compressional rotation lifting mechanism, which explains only in part the high gravity that was

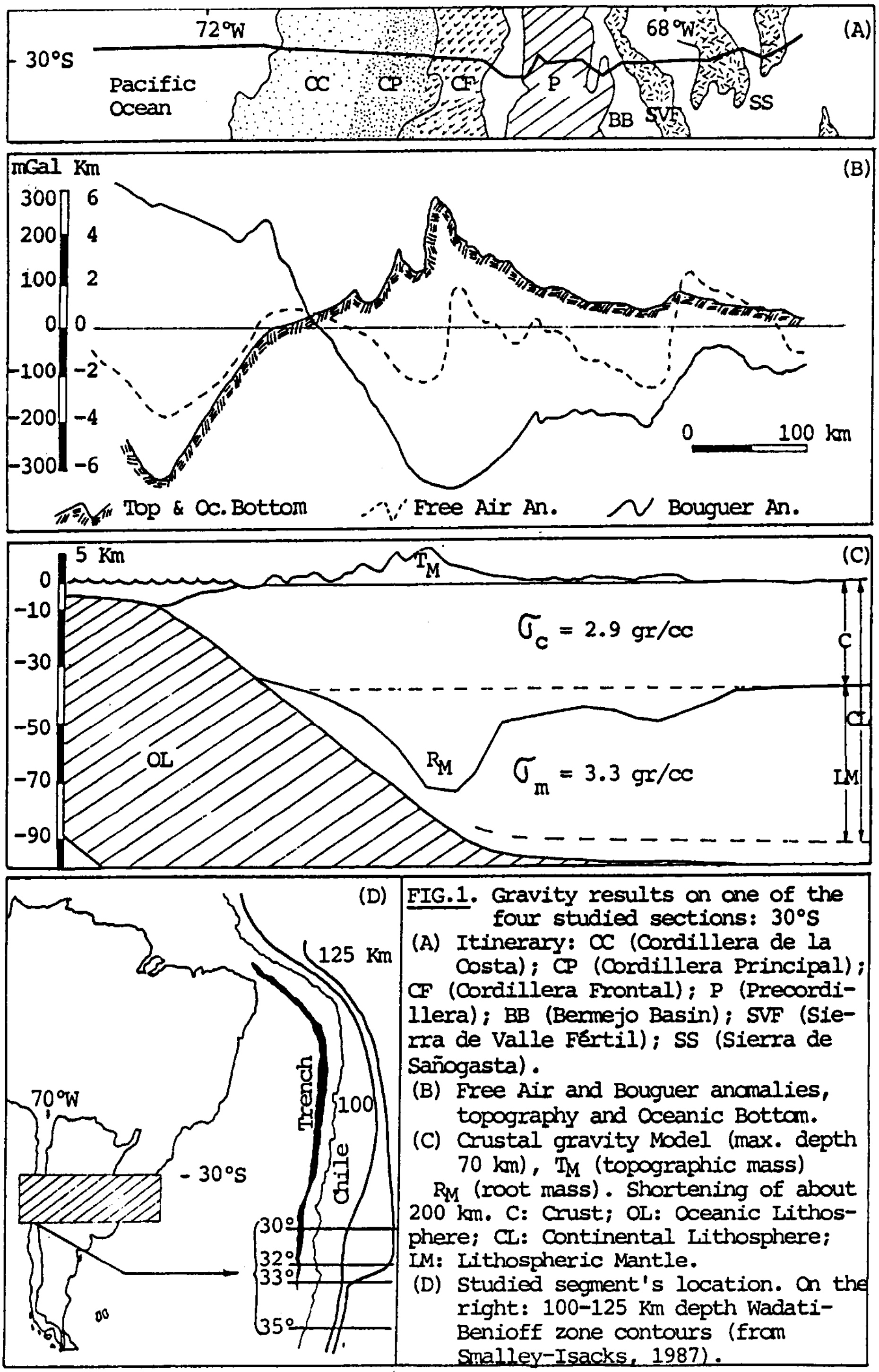


FIG.1. Gravity results on one of the four studied sections: 30°S
(A) Itinerary: CC (Cordillera de la Costa); CP (Cordillera Principal); CF (Cordillera Frontal); P (Precordillera); BB (Bermejo Basin); SVF (Sierra de Valle Fértil); SS (Sierra de Sañogasta).
(B) Free Air and Bouguer anomalies, topography and Oceanic Bottom.
(C) Crustal gravity Model (max. depth 70 km), $T_M$ (topographic mass) $R_M$ (root mass). Shortening of about 200 km. C: Crust; OL: Oceanic Lithosphere; CL: Continental Lithosphere; LM: Lithospheric Mantle.
(D) Studied segment's location. On the right: 100-125 Km depth Wadati-Benioff zone contours (from Smalley-Isacks, 1987).

observed. The other part could be due to dense anomalous masses, located at medium and upper crust.
With the crustal gravimetric models, we have evaluated the crustal root areas, which - added to the excedent masses respectively - allowed us to find rates of shortening of about 200 km, 180 km and 90 km for the 30°S, 32°S (and 33°S) and 35°S sections, consistent with the last studies, and to explain the whole Cenozoic building of the Andean Cordillera.
Magmatic intrusion could be a partial factor for the Andean building elevation. Numerical calculus revel a very little contribution during the Cenozoic. In fact, a reasonable magmatic intrusion of 900 to 1500 $km^2$, would make the crust (which is 200 km wide) thicker in 4,5- 7,5 km, justifying only a 10% to 20% of the actual Andean altitudes.

## Conclusions

Classical crustal models show: antiroots in the Chile Trench sector, significative crustal thickening with roots of 38 km (in 30°S), 32 km (in 32°S and 33°S) and 24 km (in 35°S) consistent with the topographic excesses (reasonable isostatic equilibrium in the Airy System). The addition of all the assumed subcrustal effects is not significatively reflected in the observed gravimetrical results.
Shortening models explain: (i) the Western Sierras Pampeanas building, by rotation and lifting through listric faults. This mechanism justifies only a little part of the high observed positive gravity anomalies. The rest can be explained by significative masses of high density, setted at the intermedium to upper crust; (ii) the studied Andean segment elevation (that involves crustal roots gravimetrically defined), with no need of considering other mechanisms as, for instance, magmatic intrusion.

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