ANOMALOUS UPPER MANTLE BENEATH THE CENTRAL ANDES. ISOSTASY AND ANDEAN UPLIFT.

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Resúmen: Tres modelos corticales con manto superior "normal" y anómalo en dos secciones gravimétricas (22° S y 25° S) de los Andes Centrales, fueron comparados. Se analiza la elección de uno u otro para evaluar tanto el equilibrio isostático como el levantamiento andino.

Key Words: Central Andes, anomalous mantle, isostasy, andean uplift.

Introduction:

It have been pointed out that below the Central Andes it could exist : (1) significant heating on the lithospheric mantle (Froideveaux - Isacks, 1984; Introcaso - Pacino, 1988; Introcaso, 1988) and (2) cooling produced by the Nazca Plate subduction beneath the continental lithosphere (Grow - Bowin, 1975; Introcaso - Pacino, 1988). We analize two effects : the one on the gravity and the one on the Andean uplift. Both of them would produce density anomalies from (1) and (2). From (1), we would have lesser gravity and uplift ϵ_{c_i}; from (2), it would be high gravity and subsidence ϵ_{e_i}. Our study involves two gravity sections located on 22° and 25° South latitude, with Bouguer anomalies of more than − 400 mGal.

Isostatic compensation. Uplift mechanisms.

In order to analize the relationship between the upper mantle masses anomalies, the isostatic equilibrium and the Andean elevation, we study the compensation by calculating isostatic anomalies in three levels : (a) at the maximun crustal depth, with compensating root $(\Delta R_i)_a = 6.675\ h_t$, where h_t is the topographic elevation. In this case we assume the Bouguer anomaly $(AB)_a$ as totally originated by the crustal root; (b) at 140 km deep, at the bottom of the thermal lithosphere. So, the thickness of the crustal root $(\Delta R_i)_b$ would be diminished in 8.25 ϵ_{c_i} respect to $(\Delta R_i)_a$ and the Bouguer anomaly $(AB)_b$ would involve the thermal root and the crustal thickness, now diminished; (c) at 400 km deep (involving the subducted Nazca Plate). In this case, according to our model, the oceanic plate effect would demand to diminish the crustal thickness defined in (a) in 8.25 ($\varepsilon_{c_i} - \varepsilon_{e_i}$). So, the Bouguer anomaly $(AB)_c$ would be compensed by the following effects : modificated crustal root, thermal root and subducted Nazca Plate. We must note that ε_{c_i} and ε_{e_i} effects, if they exist toghether, could be partially cancelled.

The three models present perfect masses balance, but at different depths. Because of this, the addition of the gravimetric effects that originates the compensating masses, is different in each one of them. Nevertheless, by comparing (a) and (b), for example, we show that these differences are not significant. In fact, if we think that the real model is (b), but we do not know the masses distribution below the sea level, it is usual to work with a classical model (like (a)) to evaluate isostasy. The gravity results show that, in general terms, the isostatic equilibrium was reached. In this case, the choice between (a) or (b) models is not critical for evaluating isostasy. But it is critical to find out the crustal characteristcs and to explain the Central Andean elevations. So, model (a) explains the uplift by: crustal shortening (S_h) or magmatic crustal addition (M_a), or by a combination of both mechanisms ($S_h + M_a$). In model (b), the isostatic compensation of the Andean masses is reached from a thermal lithospheric root and a crustal thickening produced by S_h or M_a or ($S_h + M_a$). Fig. 1 partially shows one of the two gravity sections analized from (a) and (b) models: the one located on 25° South latitude. Fig. 1 A shows the topographic elevation h_t, the crustal roots $(\Delta R)_a$ and $(\Delta R)_b$ and the thermal root $(\Delta R)_t$. Fig. 1 B shows the Bouguer anomalies $(AB)_a$ and $(AB)_b$. Fig. 1 C shows the isostatic anomalies $(AI)_a$ and $(AI)_b$.

From $(AB)_a$ gravity inversion, we found a maximun crustal root of 32 km, while $(AB)_b$ presents a maximun crustal root of 28 km. This crustal root was obtained from $(AB)_b$ gravity inversion with: $(AB)_b = (AB)_a + C_t$ where C_t is the thermal gravity correction.

We have calculated the isostatic anomalies $(AI)_a$ that correspond to the (a) model, with an isostatic correction $(CI)_a$ obtained from $(\Delta R)_a = 6.675\ h_t$. The isostatic anomalies $(AB)_b$ that correspond to the (b) model were calculated starting from $(\Delta R)_b = 6.675\ h_t - 8.25\ \varepsilon_{c_i}$. Now, the density excess produced by the crustal root diminishes in 5.29 km ($= 8.25\ \varepsilon_{c_i}$) so balancing the density deficit originated by the thermal root. So, $(8.25 \times \varepsilon_{c_i}) \times 0.4 = 70.6422 \times 0.03$ or, in other words, the Andean masses are compensated at a depth of 140 km , by means of a combination of the crustal root (now diminished) and the thermal lithospheric root. Then, below h_t we have: $h_t \times \sigma' = (\Delta R)_b \times (\sigma_m - \sigma_c) + (\frac{L}{2} + \varepsilon_{c_i}) \times (\sigma_m - \sigma'_m)$. All densities and thickness of this expression can be found in Fig. 1.

Anyone of the models, (a) or (b) defines the isostatical condition. Nevertheless, the seismic results of the Germany Group (mentioned by Strunk, 1990) point out that the crustal thickness is consistent with the thickness found in (b).

Let's return now to model (c). Here, the Andean masses are balanced from a combination of crustal thickness (S_h or M_a or ($S_h + M_a$), thermal lithospheric root (R_T) and vertical contraction (C_V) related to the subducted Nazca Plate.

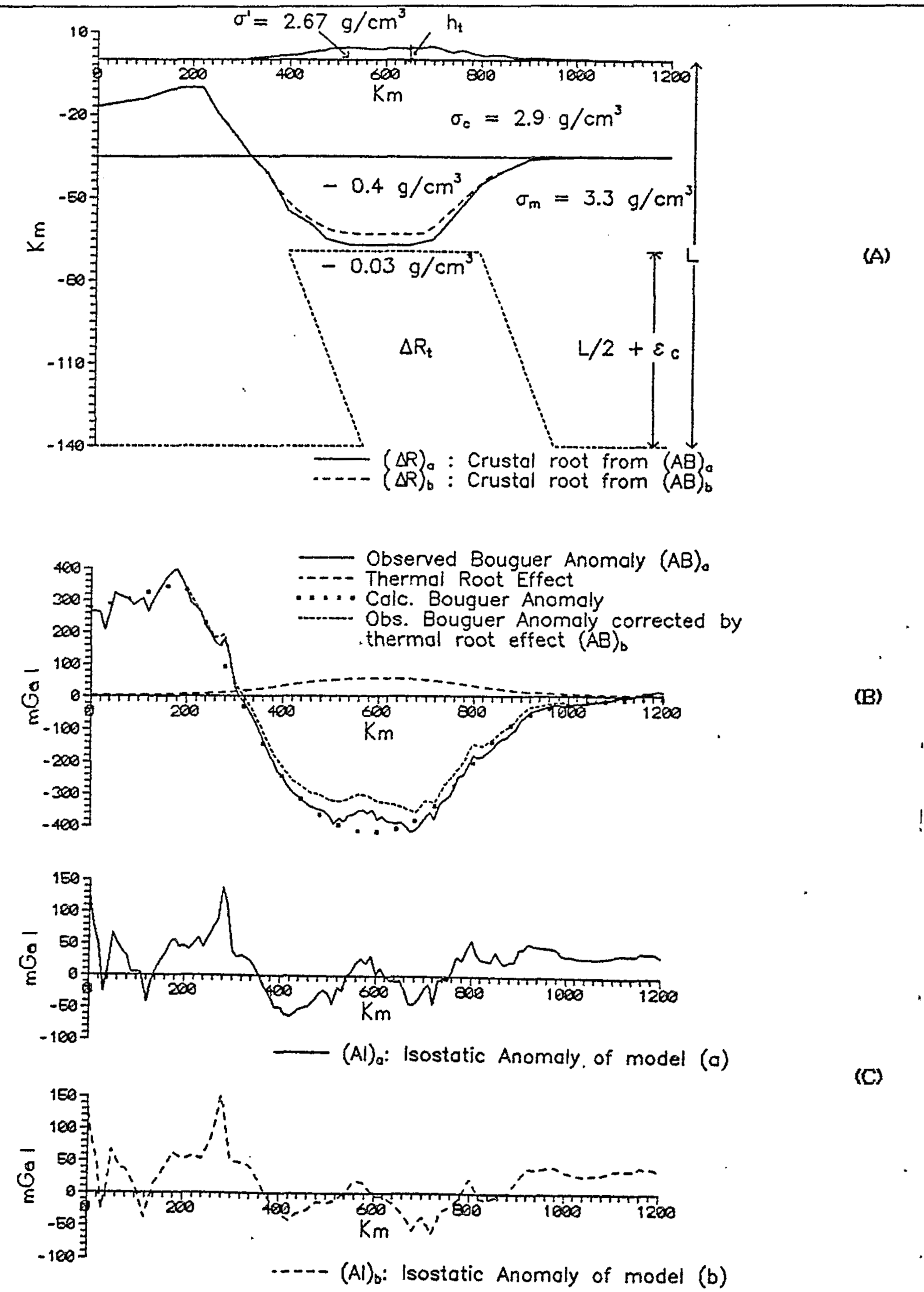

Fig. 1. **(A)** : Andean crust on 25° South latitude. $(\Delta R)_a$ root corresponds to model (a) with "normal" upper mantle. $(\Delta R)_b$ and $(\Delta R)_t$ roots correspond to model (b) with heating in the lower middle part of the thermal lithosphere. **(B)** : Observed Bouguer anomaly $(AB)_a$ with maximun amplitude of more than −400 mGal below the andean axis, and Bouguer anomaly $(AB)_b$ corrected by heating effect C_t (maximun C_t values: + 60 mGal). **(C)** : Isostatic anomalies $(AI)_a$ and $(AI)_b$ calculated from models (a) and (b) respectively.

Conclusions

Different crustal thicknesses from gravimetrical inversions made from $(AB)_a$, $(AB)_b$ or $(AB)_c$ have been found. In particular, we can see this in Fig. 1 for (a) and (b) models. Nevertheless, the isostatic anomalies $(AI)_a$ and $(AI)_b$ are consistent between themselves.

The choice among (a), (b) or (c) defines the posibilities for the different mechanisms to exist. This choice must be done trying to find the model whose crustal thickness could be consistent with the seismic results. In the 25° South latitude section, model (b) is probable.

This work, in its whole version, analizes the posibilities of (a), (b) and (c) models to explain the Central Andes uplift.

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References

Froideveaux, C. and Isacks, B., 1984. The mechanical state of the lithosphere in the Altiplano-Puna segment of the Andes. Earth Planet. Sci. Lett., 71: 305-314.

Grow, J. A. and Bowin, C. O., 1975. Evidence for high-density crust and mantle beneath the Chile trench due to the descending lithosphere. J. Geophys. Res., 80(11): 1449-1458.

Introcaso, A. and Pacino, M. C., 1988. Gravity Andean model associated with subduction near 24°25' South latitude. Rev. Geofis., 44: 29-44.

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

Strunk, S., 1990. Analyse und Interpretation des Schwerefeldes des aktiven Kontinentalrades der zentral Anden (20°- 26°S). Berliner Geowissenschaftliche Abhandlungen. Freie Universität Berlin : 1-135.