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THE PARANÀ LARGE IGNEOUS MAGMATISM AT SURFACE AND LOWER CRUSTAL LEVELS

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A) GOAL

- Understand lithospheric structures under the Paraná basin.
- Calculate Bouguer residual using sediment gravity effect of known sediments.

B) GEOLOGICAL INTRODUCTION

The Paraná basin is a wide Paleozoic sedimentary basin with basalt flood volcanism (Lower Cretaceous). This basin belongs to a LIP (Large Igneous Province), and it represents a forerunner of the Southern Atlantic Ocean opening.

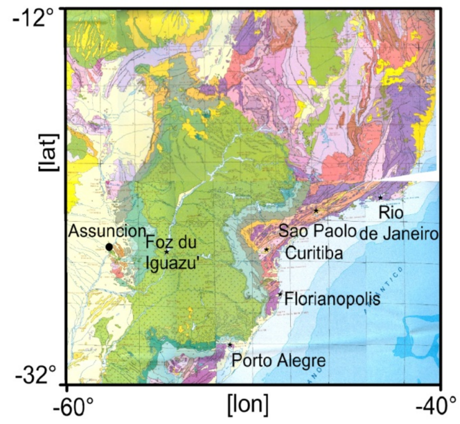

Fig. 1 - Geological map of studied area.

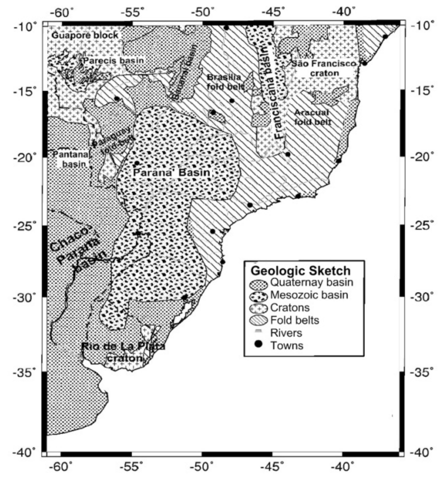

Fig. 2 - Geological sketch of studied area.

C) METHODOLOGY

- Gravity modeling using new data of GOCE satellite mission, with the integration of seismological data. GOCE data is useful to study wide area as intracratonic basin.
- We start modeling the sedimentary layers using: from bottom to surface:
- The first level belongs to Paleozoic sediments where density changes from 2400 to 2600 kg/m^3 and isopachs reach 3500 m (Silva and Vianna, 1982), digitized by Melfi et al. (1988).
- Second layer is composed by the basalt of Serra Geral Formation with a constant density of 2850 kg/m^3 (Marques et al., 1984) with a thickness of about 1500 m.
- The top layer is located only in the northern part of the basin, and corresponds to upper Cretaceous sediments of Bauru group. The latter is a small sedimentary basin of about 250 m thickness, with a constant density of 2200 kg/m^3 (Silva and Vianna, 1982).
- We use recent seismological (receiver function) data from South America (Feng et al., 2007, Lloyd et al., 2010) and newest model from Assumpção et al. (2012) to constrain crustal thickness.
- We calculate the Bouguer residual anomaly taking into account the effect of sediments and the seismological crustal root. In detail we test 2 contrast densities between crust and mantle: -0.3 and -0.5 Mg/m^3.

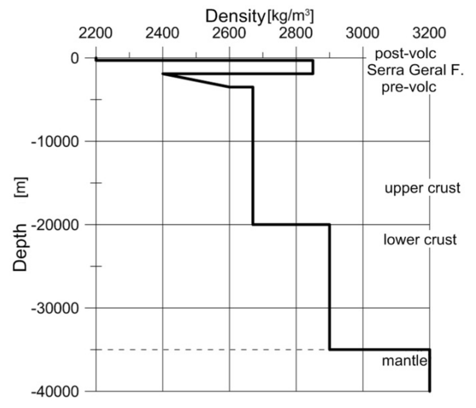

Fig. 3 - Density depth-profile variations, parameters used during modeling.

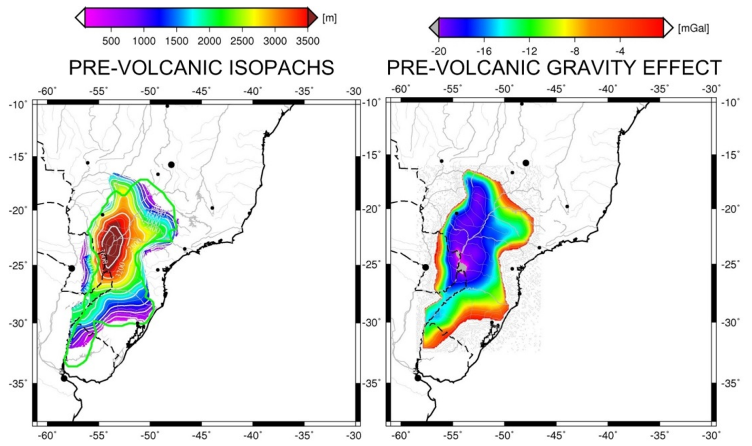

Fig. 4 - Pre-volcanic rocks: paleozoic sediments, left: isopachs of sediments (Melfi et al., 1988); right: gravity effect of sediments.

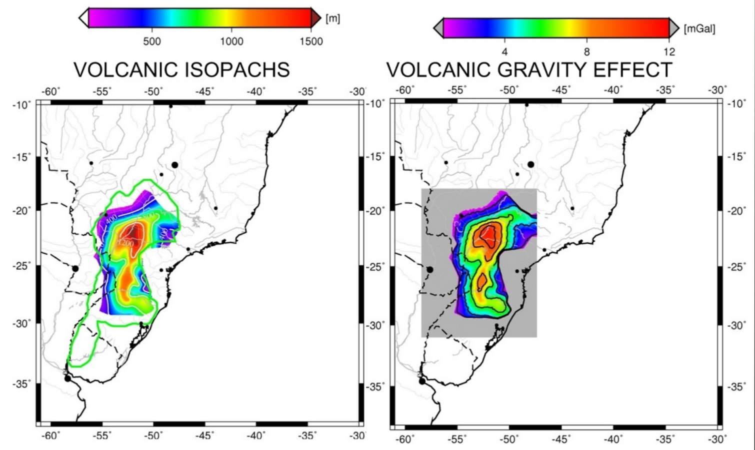

Fig. 5 - Volcanic rocks of Serra Geral formation: Early Createaceous, left: isopachs of Serra Geral (Silva and Vianna., 1982); right: gravity effect.

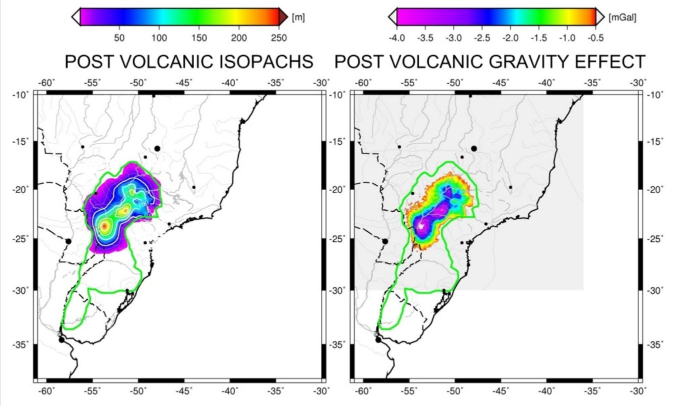

Fig. 6 - Post-volcanic rocks: Upper Cretaceous left: isopachs of sediment (database USP); right: gravity effect of sediments.

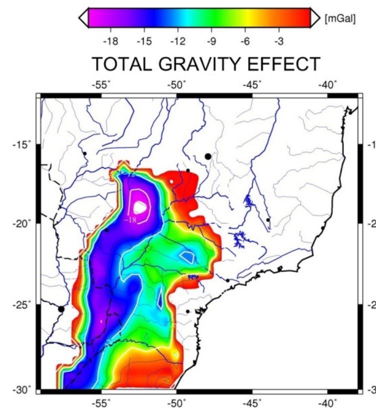

Fig. 7 - Total gravity effect of sediment layers under the Paraná basin.

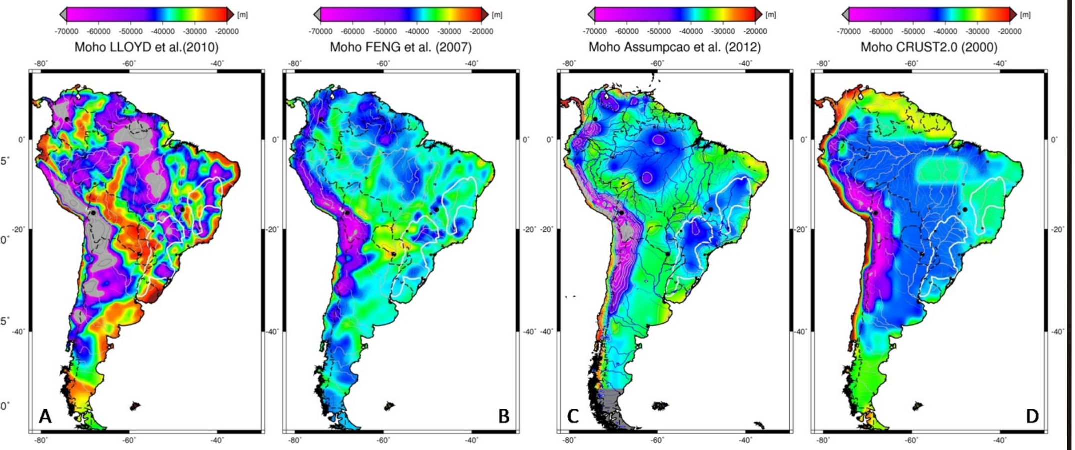

Fig. 8 - Seismic Moho for South America using, A: Lloyd et al. (2010); B: Feng et al. (2007); Crust2.0 (Laske et al., 2000) and Assumpção et al. (2012).

D) BOUGUER RESIDUAL FOR RECOVERY OF UNKNOWN MASS:

- We calculate Bouguer residual to recovery unknown mass: positive value identifies missing mass with high density respect to the normal crust, while negative anomaly value localizes missing mass with smaller density respect to normal crust.
- Seismological data off-shore and along southern part of Brazilian coastline are poor: therefore we do not analyze this sector (see white area on the Fig. 9, 10, 11).
- Fig. 9, 10, 11 show residual Bouguer corrected respectively for Feng, Lloyd and Assumpção Moho models: on the first rows (Figure A, B) the Bouguer is corrected only for the seismological root, testing 2 different densities between mantle and crust: left figure (Figure A) is :-0.5 Mg/m^3, right figure -0.3 Mg/m^3 (Figure B). On the second rows (Figure C, D) the residual is corrected also for gravity of known sediments.
- We find: residual Bouguer over the Amazon region and on the Argentinean sector is positive.
- Paraná region: positive anomaly found over Paraná region greater for Assumpção crustal model, smaller for Lloyd model. Positive signals over the basin: for Lloyd further north than for Feng.
- Effect of sediment is to increase residual. This consideration is important where the sediment gravity effect is not calculated, as for example under the Amazonian region (the positive value would be much bigger than present).
- Using Feng and Assumpção crustal model, the positive value is correlated with Paraná river.

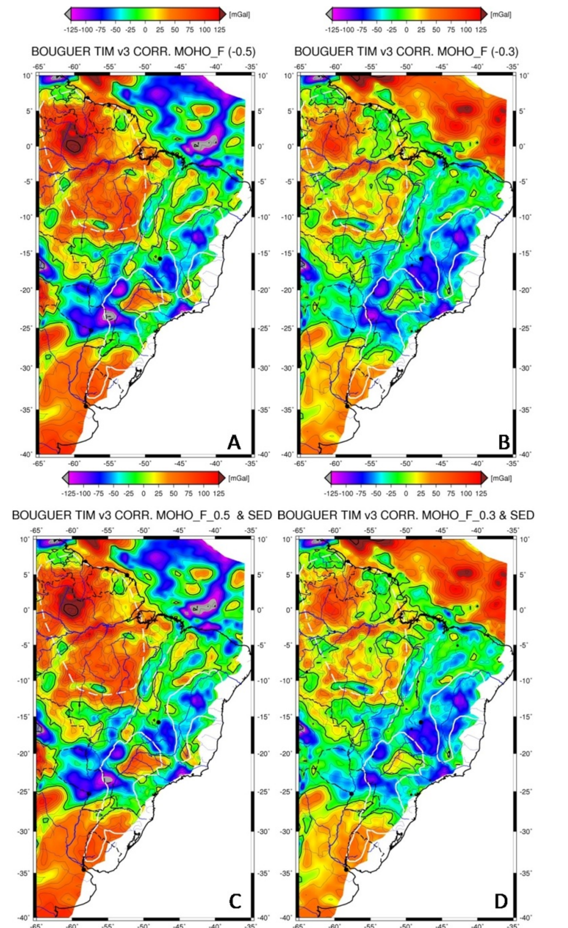

Fig. 9 - Residual Bouguer calculated with GOCE TIM v3 model and considering Feng et al. (2007) seismological crustal model, without sediment effect (first row) or with sediment effect : A) and C) using contrast density of -0.5 Mg/m^3, B) and D) using contrast density of -0.3 Mg/m^3.

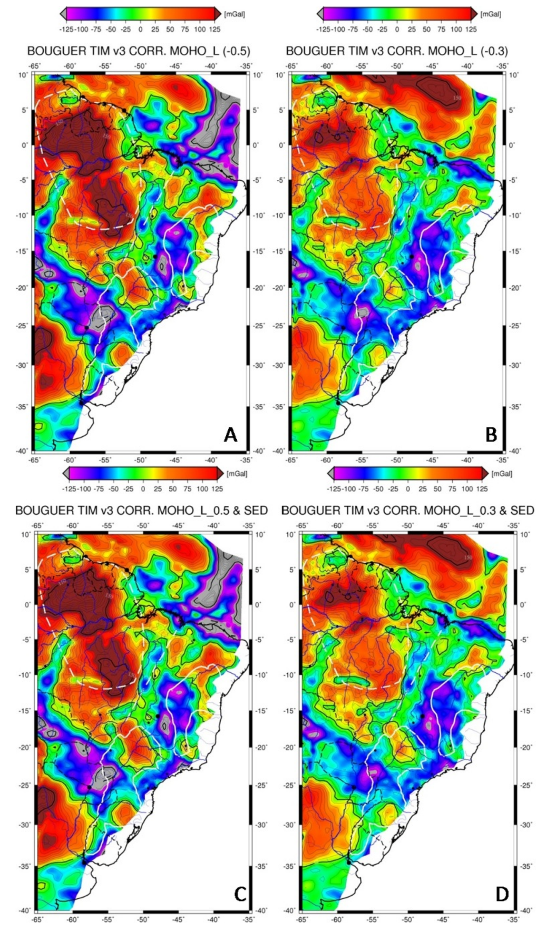

Fig. 10 - Residual Bouguer calculated with GOCE TIM v3 model and considering Lloyd et al. (2010) seismological crustal model, without sediment effet (first row) or with sediment effect : A) and C) using contrast density of -0.5 Mg/m^3, B) and D) using contrast density of -0.3 Mg/m^3.

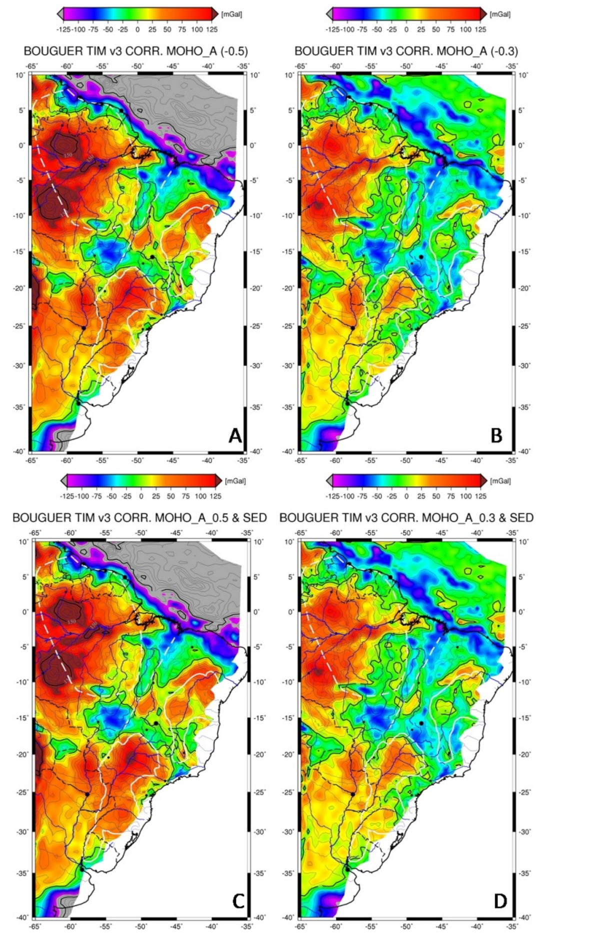

Fig. 11 - Residual Bouguer calculated with GOCE TIM v3 model and considering Assumpção et al. (2010) seismological crustal model, without sediment effet (first row) or with sediment effect: A) and C) using contrast density of -0.5 Mg/m^3, B) and D) using contrast density of -0.3 Mg/m^3.

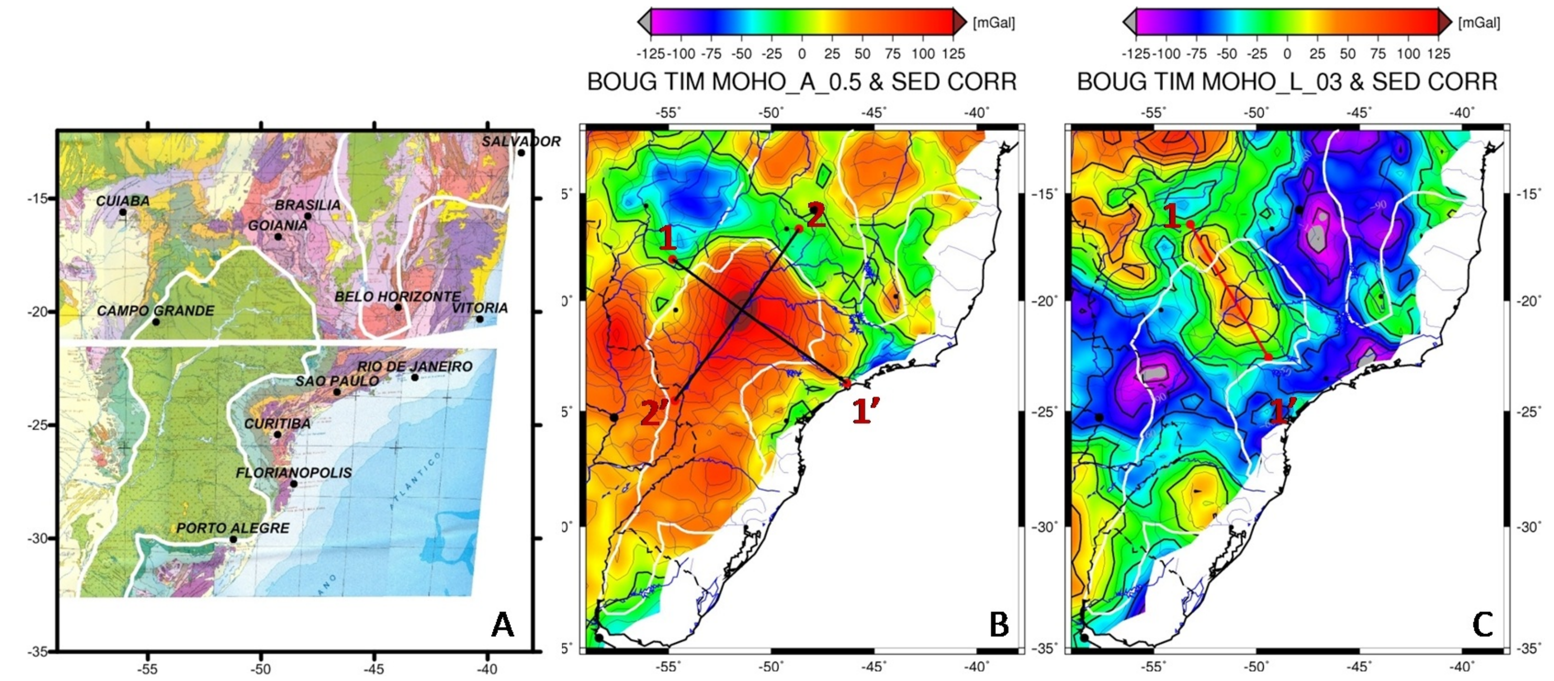

Fig. 12 - Focus on Paraná basin: A) geologic map (CPRM, 2000), B) Residual Bouguer using seismological Moho (Assumpção et al., 2012) considering a contrast density between crust and mantle of : -0.5 Mg/m^3 and using the correction of sediment gravity effect of known sediments, profile 1-1'(NE-SW) and 2-2'(NW-SE) crossing main anomaly residual; C) Residual Bouguer using seismological Moho (Lloyd et al., 2010) considering a contrast density between crust and mantle of : -0.3 Mg/m^3 and using the correction of sediment gravity effect of known sediments, profile 1-1'(NE-SW) crossing main anomaly residual.

E)UNDERPLATING BELOW PARANÀ BASIN:

The Bouguer residuals given by the models shown on Fig. 12 are used to detect the volume of unknown masses. The methodology proceeds with the solution of the inverse gravity problem of these fields. First of all the Bouguer anomaly is corrected for the effect of seismological Moho. In particular we adopt Assumpção and Lloyd Moho and a contrast density between crust and mantle of -0.5 and -0.3 Mg/m^3. We add to the crust a body with higher density respect to the normal crust. The volume of unknown masses is predicted by testing several cases:

1) The body reference depth is : 20, 30, 40 km.
2) The density contrast between supposed normal crust and anomalous mass is: 0.2, 0.3, 0.5, Mg/m^3 considering that 0.5 Mg/m^3 is a value almost impossible to recognize in the normal crust.

The unknown volume is approximated by a simple pattern of cut off cone, composed by 2 different radius (R>r), and 1 height (H) between r and R. The geometry changes according to adopted models. We analyzed it using several profiles shown in Fig. 12.

The increasing density contrast causes a decreasing layer thickness, while the increasing depth layer achieves an increasing thickness (Tab. 1, 2).

Example of density rocks: **Sedimentary** rocks: salt: 2.1 Mg/m^3, clay: 1.2-2.2 Mg/m^3, limestone: 2.3-2.7 Mg/m^3; **Intrusive** rocks: gabbro 2.8-3.1 Mg/m^3 , granite 2.5-2.8; **Hypoabyssal**: diabase 2.8-3.1 Mg/m^3; **Metamorphic** rocks: gneiss and schist: 2.5-2.9 Mg/m^3, amphibolite 2.8-3.2 Mg/m^3, eclogite 3.3-3.4 Mg/m^3.

Profile 1-1' Assumpção et al., (2012)

Depth [km]	0.2 [Mg/m^3]	0.3 [Mg/m^3]	0.5 [Mg/m^3]
20	13 km	8 km	5 km
30	14 km	8.5 km	5.3 km
40	15 km	9.5 km	5.5 km

Profile 2-2'

Depth [km]	0.2 [Mg/m^3]	0.3 [Mg/m^3]	0.5 [Mg/m^3]
20	13 km	9km	4 km
30	14 km	9.2 km	43 km
40	15 km	9.5 km	4.5 km

Profile 1-1' Lloyd et al., (2010) (small bell)

Depth [km]	0.2 [Mg/m^3]	0.3 [Mg/m^3]	0.5 [Mg/m^3]
20	5 km	4.6 km	2.2 km
30	7.5 km	5 km	2.8 km
40	8.5 km	6 km	3.4 km

Profile 1-1' (big bell)

Depth [km]	0.2 [Mg/m^3]	0.3 [Mg/m^3]	0.5 [Mg/m^3]
20	8.5 km	5 km	2.3 km
30	9 km	6 km	3.7 km
40	10 km	7 km	4.4 km

Table 1 - Height of cut-off cone derived by profile analysis for different models employed. Fig. 12 shows position of profiles.

Assumpção et al. (2012)

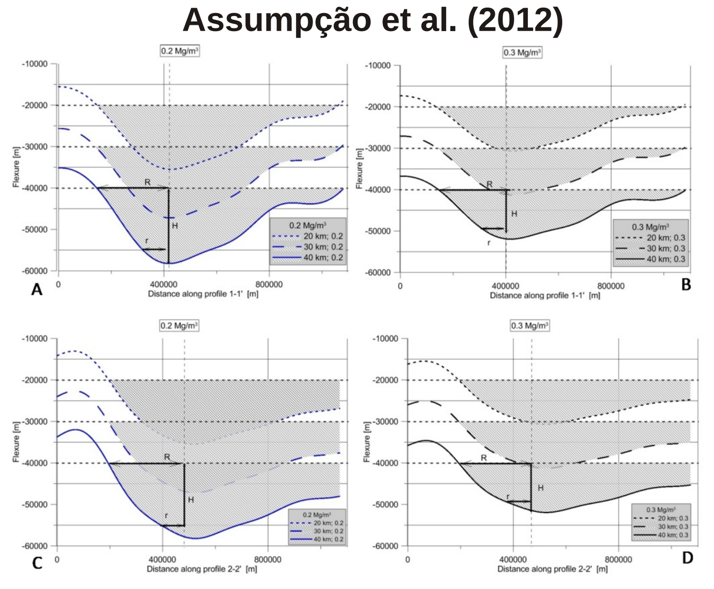

Fig. 13 - Underplating masses from Assumpção along profile 1-1' and 2-2', and geometry of cut-off cone, see Tab. 1, and Fig. 14.

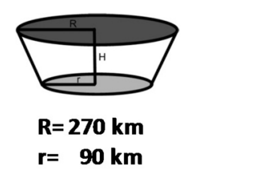

Fig. 14 - Simplified geometry for Assumpção crustal Moho. Cones for profile 1-1' and 2-2' are quite similar.

Cut off cone = $1/3\,\pi H\,(R^2 + r^2 + rR)$

SERRA GERAL FLOOD BASALT VOLUME	UNDERPLATING VOLUME		VOLUME	CONTRAST DENSITY [Mg/m^3] & DEPTH [km]
	Lloyd $\Delta\rho$=0.3 [Mg/m^3]	Assumpção $\Delta\rho$=0.5 [Mg/m^3]		
~0.46 X 10^6 km^3	1.28 X 10^6 km^3	1.66 X 10^6 km^3	MAX	0.2 & 40
	0.96 X 10^6 km^3	1.25 X 10^6 km^3	MEDIUM	
	0.65 X 10^6 km^3	0.88 X 10^6 km^3	MIN	0.3 & 20

Table 2 - Predicted volume for underplating models and flood basalts.

Lloyd et al. (2010)

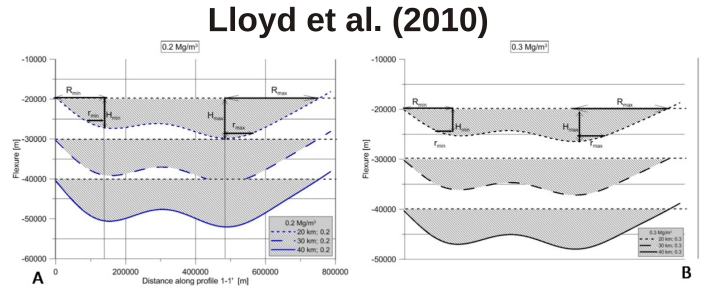

Fig. 15 - Underplating masses from Lloyd crustal Moho. Predicted geometry from inversion Moho along profile 1-1'. See Tab. 1 and Fig.16.

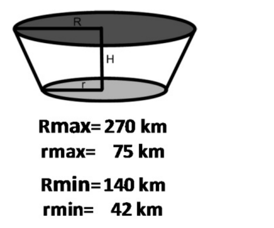

Fig. 16 - Simplified geometry for Lloyd crustal Moho. We can recognize 2 cones.

F) DISCUSSION AND CONCLUSION:

- Under the northern part of Paraná basin seismological crustal thickness is greater than 40 km, and it is much deeper than what would be predicted from gravity and isostasy (see Poster EGU2012- 5183). This would announce a densified body. If it is located at 40 km of depth with a density contrast between crust and mantle of 0.3 Mg/m^3, the thickness predicted (column height) is 9.5 km for Assumpção and 6-7 km for Lloyd model, while if contrast density is less than previous the thickness increases respectively from 8.5 to 15 km.
- We propose essentially two models that explain this mass as diabase dykes that were emplaced in the crust, demonstrating that flood basalt layer constitutes only a part of the melted material, the rest being emplaced in the crust. In the southern part of Parana the missing mass fits a petrologic model of Piccirillo et al. (1987) that predicts increased density intracrustal rocks, as shown by the melting process produced acid magmatism found on the southern part of Parana basin.

G) REFERENCES:

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