THE LITHOSPHERE STRUCTURE BENEATH THE BENUE TROUGH FROM MODELING GRAVITY FIELDS OF GOCE AND EGM08

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Introduction. Our work contributes to define the crustal properties in Central and West Africa, specifically below the Benue Trough, Nigeria (Fig. 1). The Benue Trough is the result of a sinistral tectonic movement along shear faults during the opening of the Atlantic Ocean (Binks and Fairhead, 1992). In response to this movement, in particular, there was the thinning of the lithosphere and the formation of a thick sedimentary basin. For this reason the Benue Trough and the Niger Delta, its terminal towards the Atlantic Ocean, are of broad interest due to the high hydrocarbon potential. Also the Cameroon line, immediately adjacent to the Benue Rift, is of broad interest due to the volcanic hazard. At the base of hydrocarbon prospection and evaluation of volcanic risk lies the good knowledge of the thickness and physical properties of crust and mantle lithosphere. In this work we have tried to apply the McKenzie model combined with other geophysical data available in bibliography, to the area of Benue Trough in order to get a better knowledge of the lithosphere structure. The McKenzie model describes the formation of a rift basin due to stretching of

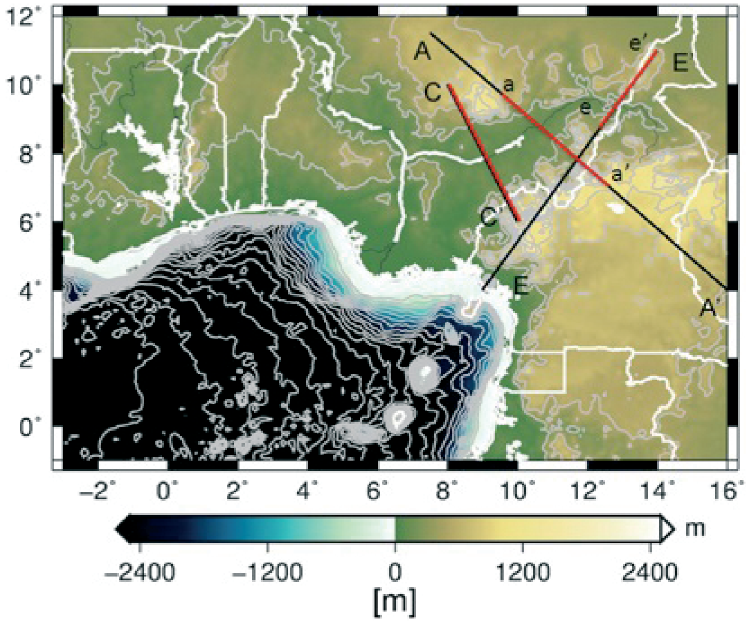

Fig. 1 - The area of study, Benue Trough, and the sections that were modeled.

lithosphere in two stages:

1. Synrift subsidence due to an isostatic response caused by the thinning of lithosphere and perturbation of the geothermal gradient;
2. Thermal subsidence, that is produced by the return of the geothermal gradient to the pre-stretched position.

In the Benue Trough, the first stage has been developed until the Santonian event (80 Ma) and consisted in the accumulation of a deep sequence of continental and marine deposits. At 80 Ma there was a change in the direction of stresses that resulted in a compressional event; hence the extension and the synrift phase ceased, but the basin continued to deepen in response to the thermal cooling of the lithosphere that caused a change in the lithospheric densities (Fairhead and Okereke, 1987). Hence, for these reasons, we have tried to apply the McKenzie model to this area.

Synthetic models derived from the McKenzie model. As already hinted the Benue Trough has been described as a possible application of the stretching models in previous studies (Fairhead

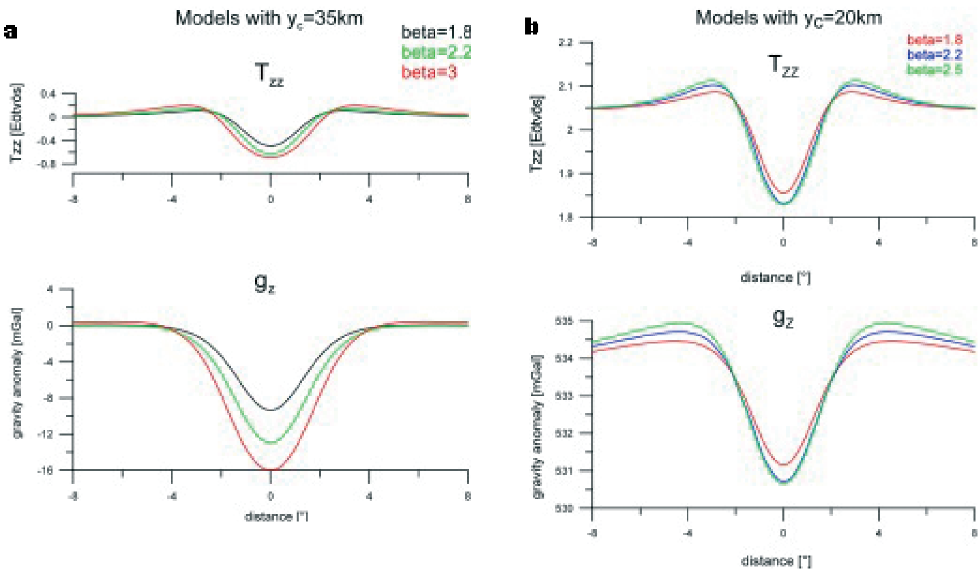

Fig. 2 - Gravity signals gz (gravity anomaly) and Tzz (vertical gravity gradient) derived from synthetic models, obtained varying the applied stretching (beta) and the initial crustal thickness. a) crustal thickness=35km b) crustal thickness=20 km.

and Okereke, 1987). With the McKenzie model we're able to calculate thickness of the basin, the thickness of stretched mantle and crust and all the densities, function of the average temperature. Introduction of the temperature dependency is an innovation with respect to existing studies. In order to achieve this objective, we verified and quantified the gravimetric signals of interest (vertical gradient component Tzz and gravity anomaly gz) at the height of GOCE orbit by the production of a series of synthetic models, In these models we varied the stretching applied to the lithosphere and the initial crustal thickness (in pre-stretched condition).

As can be observed, we have a good signal at the height of GOCE, with amplitude of over 4mGal. We also recognize a typical pattern of these geodynamic environments: it seems that model McKenzie predicts an important minimum that is bounded by a very low maximum. The amplitude of the minimum is not linearly dependent to the basin depth. This fact is evident in Fig. 2b, where the increase of the applied stretching factor, and as a consequence, the increase of basin's depth, are not underlined by a more negative gravity anomaly. Hence the amplitude of the signal could not be used to estimate correctly the basin's depth. We mark also that the Tzz component seems to be a good indicator of the basin margins, as is appreciated from the two maxima that bound the minimum.

Constraints and modeling of benue trough. In order to improve the knowledge of the structures in this area we rely on new gravity data derived from EGM08 (Pavlis et al., 2008) and GOCE (Migliaccio et al., 2010) Earth gravity potential models and evaluate the gravity anomalies and vertical gravity gradient anomalies constructing a lithosphere density model.

We used previously published data as constraints and tried to apply the McKenzie model. This model allows to

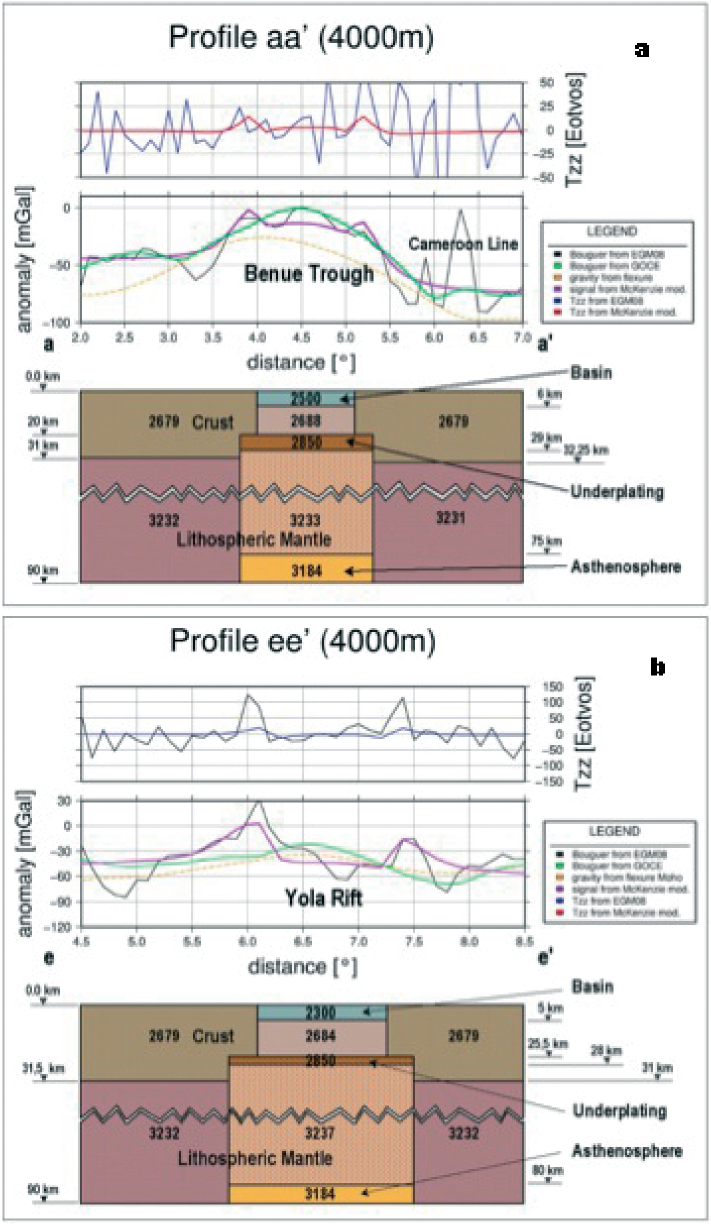

Fig. 3 - Results of modeling process on the section aa' (Fig. 3a) and ee' (Fig. 3b).

obtain the densities of the stretched lithosphere using the simple isostatic principle, and it also takes the particular thermal conditions of these areas (high heat flow) into account. Thickness of stretched and un-stretched crust is taken from the studies of Tokam et al. (2010) and Fairhead and Okereke (1987), the basin's depths from Kamguia et al. (2005) and Petters and Ekweozor (1982) and finally the boundary between lithosphere and asthenosphere from Fishwick (2010). Following the approach of McKenzie (1978) we calculated the densities of crust, mantle and asthenosphere from a linear relationship that links average temperatures to density. We evaluated the signals at the height of 4000m (Figs. 3a and 3b), because the level should be above the maximum topography, to allow consistent calculations of the terrain effect.

Results. We discovered that the Benue Trough is not a perfect application of the McKenzie model and it is associated with a wide area of sub-crustal thinning covered by a less extensive sedimentary basin. This first feature was explained by the application of a non-uniform stretching model with depth, instead of a uniform stretching, as the McKenzie model. As observed in the synthetic models, the uniform stretching model of McKenzie predicts a minimum bounded by two maxima; in Benue Trough instead we have a maximum with a small minimum super-imposed, that is better explained by the non-uniform stretching model. Moreover, in order to get a good fit of the gravity anomalies we have to introduce a low-density body (with respect to mantle density) beneath the stretched crust, another feature that is not included in the McKenzie model. The thickness of this body, interpreted as an underplated magmatic intrusion, seems to be not constant in the whole area: in the Benue Trough (profile aa') it is almost 10km thick, while in the Yola rift (the eastern arm of Benue, profile ee') it is thinner, about 3 km.

Finally we evaluate the stretching factors for Benue Trough and Yola rift and we find that the Benue Trough has been subjected to a higher stretching compared to its eastern arm. This characteristic could also explain the different volumes of magma found beneath these two zones: a smaller stretching value implies a reduced volume of magma, while an important stretching is underlined by greater magmatic activity.

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