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Could the mantle have caused subsidence of the Congo Basin?

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ABSTRACT

The Congo Basin is characterised by a near-circular shape, a pronounced negative free-air gravity anomaly, and a subsidence history that is slow and long-lived. The basin is often considered as an intracratonic basin, implying an unknown formation mechanism. However, the Congo Basin probably initiated by Precambrian rifting and the larger part of its older subsidence history could be explained by post-rift thermal relaxation. The uppermost layer of Mesozoic to Cenozoic sedimentary rocks in the basin appears discontinuous in its evolution and several studies have proposed that these rocks were deposited in response to a process in the mantle. We have examined gravity data and seismic tomographic models to evaluate the role of the sub-crustal mantle in the more recent evolution phase of the Congo Basin. Using seismic tomographic models of the upper mantle and lithospheric thickness models, we show that the Congo Basin is underlain by a thick lithosphere and that the basin boundary likely coincides with the boundary of the Congo Craton. We have reduced the EGM2008 free-air gravity field by correcting for topography and sediments. We find that the observed negative gravity anomaly is mainly due to the sedimentary units in the basin. The reduced gravity field has slightly negative to positive anomalies over the basin, depending on the densities assigned to the sedimentary rock package. We have analysed thirteen whole-mantle and five upper-mantle tomographic models and show that they do not provide supporting evidence that the sub-lithospheric mantle played a primary role in the more recent subsidence of the Congo Basin. We speculate that deposition of the Mesozoic–Cenozoic rocks could have raised the surface elevation of the Congo Basin to the present average level of ~400 m above sea-level and that the last subsidence phase could be a consequence of the sediment load rather than the cause.

1. Introduction

The Congo Basin (located in the Democratic Republic of Congo in Central Africa) is often cited as a classic example of an intracratonic sedimentary basin: it is an almost circular depression (Fig. 1a) with negative free-air gravity anomalies (Fig. 1b, d), which experienced slow subsidence over long periods of time. The upper layer of Mesozoic–Cenozoic sedimentary rocks was deposited during little tectonic activity and several studies have proposed that the subsidence that created the accommodation space for these sediments may be linked to processes below the crust (Crosby et al., 2010; Downey and Gurnis, 2009; Forte et al., 2010; Hartley and Allen, 1994). This inspired us to examine gravity data and seismic tomographic models to evaluate the role of mantle processes in causing subsidence of the Congo Basin.

The present-day Congo Basin is surrounded by topographically higher areas: the rift flanks of the Central African Rift to the north, the East African Rift to the east, the South African (Kalahari) Plateau to the south, and the Mayombe Mountains to the west. Earthquake focal mechanisms indicate a state of compressive stress, which previous studies have linked to the "background" stress field of the African plate caused by the oceanic spreading centres surrounding it or to the effect of a dynamically driven topography contrast between the basin and the East African and South African plateaus (Ayele, 2002; Craig et al., 2011; Delvaux and Barth, 2010). Unfortunately, detailed information on the basin fill is limited; only four deep wells were drilled in the Congo Basin (Samba, Dekese, Mbandaka-1 and Gilson-1, Fig. 1a) and most of the 1970s Esso/Texaco seismic survey is not publicly available. A description and interpretation of some of these data is in Daly et al. (1992), Kadima et al. (2011a) and Lawrence and Makazu (1988). The basin contains up to 9 km of sedimentary rocks of Precambrian to Tertiary age (Fig. 2b). The basin is thought to have been initiated by

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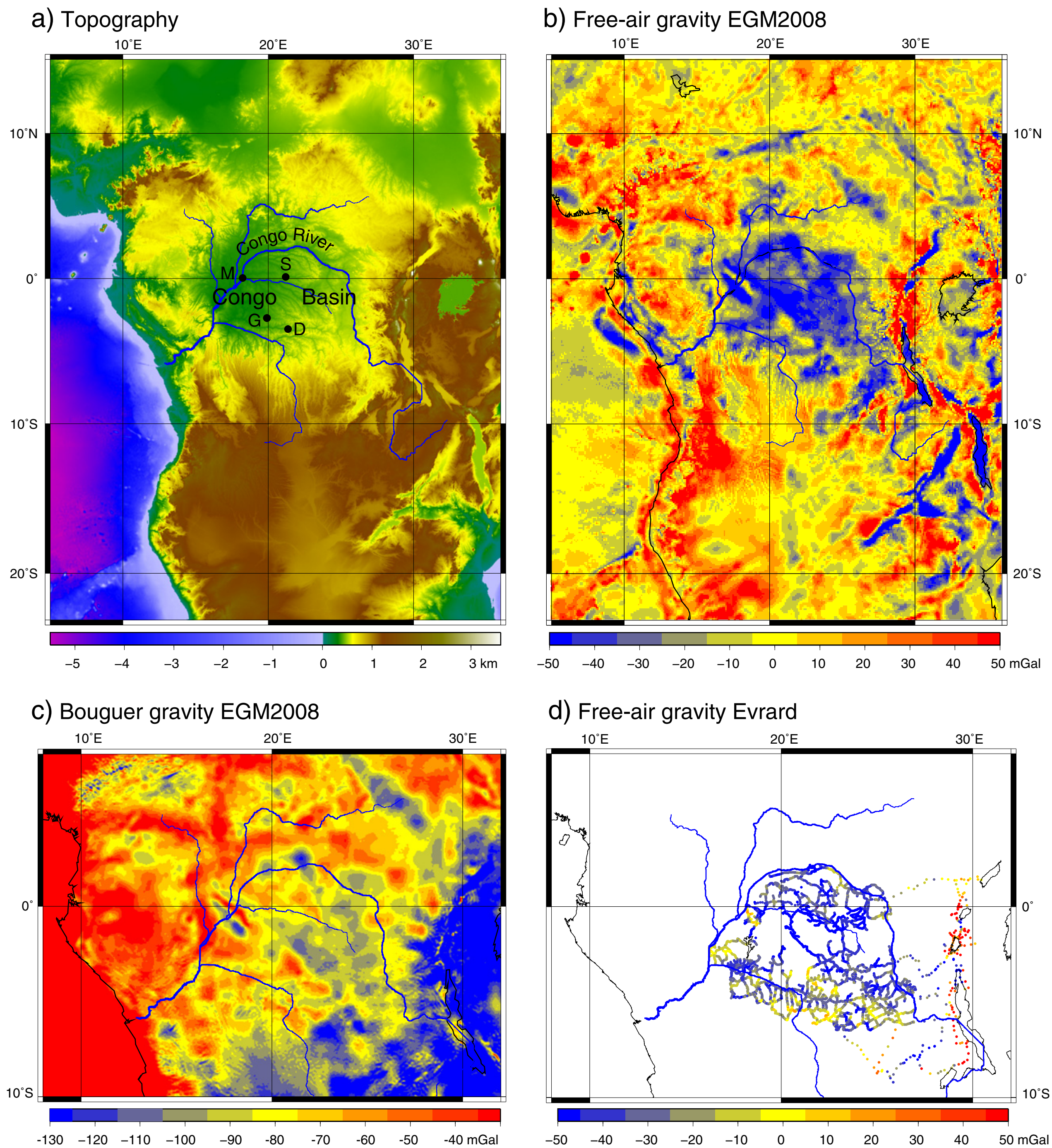

Fig. 1. a) Topography of the Congo Basin (ETOPO1 (Amante and Eakins, 2009)), with the location of the four deep wells (S = Samba, D = Dekese, G = Gilson-1, M = Mbandaka-1). b) Free-air gravity anomaly (EGM2008 (Pavlis et al., 2008)). c) Bouguer gravity anomaly computed from EGM2008 using a 2670 kg m^{-3} density correction. d) Free-air gravity anomaly from Evrard et al. (1960).

Neoproterozoic extension and the older, pre-Cretaceous sediments were probably deposited during a long post-rift subsidence phase (Crosby et al., 2010; Daly et al., 1992; Kadima et al., 2011b; Lawrence and Makazu, 1988). The evolution of the basin was discontinuous and there is clear evidence for stratigraphic unconformities of Neoproterozoic, early Palaeozoic (Pan-African), and Permian–Triassic ("Hercynian") ages. The early Palaeozoic and Permian–Triassic episodes have been linked to NE–SW-oriented compressional deformation in the centre of the basin by Daly et al. (1992). However, the interpreted basement uplift (Kiri High) may be less pronounced than previously thought and the basement may instead be composed of salt-rich sediments (Kadima et al., 2011a). The two wells drilled by REMINA, Dekese (in 1956, 1856 m depth) and Samba (in 1955, 2038 m depth), mainly encountered sandstone, schists, and clay layers and did not reach basement (Cahen et al., 1959, 1960). The Mbandaka-1 (4350 m) and Gilson-1 (4665 m) wells were drilled by Esso Zaire in 1981 and reached Cambrian sedimentary units, but again not basement