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Structure of the Gabon Margin from integrated seismic reflection and gravity data

Stéphanie Dupré *, Sierd Cloetingh, Giovanni Bertotti

Tectonics and Structural Geology Department, Faculty of Earth and Life Sciences, Vrije Universiteit, de Boelelaan 1085, 1081 HV Amsterdam, The Netherlands

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ABSTRACT

In the South Gabon Basin, deep multi-channel seismic reflection and gravity modeling analysis have shed light on key features of the structure of the margin. The thinned continental crust beneath the Gabon Margin appears to be composed of two distinct layers, separated by a clear, strong and more or less continuous reflector running in the 7–10 s TWT window. The lower crust is characterized by a higher density, intermediate between the lower values of the upper crust and the denser values of the mantle. The lower crust is irregularly shaped and presents lateral thickness variations along the direction of thinning and along the coast. In the offshore thinned continental domain, the lower and upper crust form a 20–25 km thick body. Crustal thicknesses point to a relatively sharp and narrow transition, along a few tens of kilometers, between the unthinned and the thinned continental crust. The high density layer identified offshore Gabon presents similar characteristics in density, geometry and spatial distribution, as the underplated magmatic bodies observed along volcanic margins, e.g. along the South Atlantic Namibia Margin or the North Atlantic Vøring Margin. Although this lower crustal body could possibly represent ultra mafic serpentinized rocks or high grade metamorphic crustal rocks, we suggest that it could be composed of mafic rocks. Magmas resulting from partial melting during rifting may underplate the crust and/or be intruded in the lower crust through a system of dykes and sills. In this view, the present-day crustal thicknesses along rifted margins, characterized by magmatic underplating and/or intrusion, are not representative of the thinning that the crust experienced during rifting. Results of this study point to relatively shallow sedimentary basins along the South Gabon Margin. The deepest offshore depocenters located under the westernmost side of the continental platform appear to be associated with the deepest syn-rift basins These basins seem to extend along 20 to 40 km in the ~NE–SW direction with a present-day average thickness of 7.3 km. Offshore Gabon, whereas the crustal thinning appears significant, the syn-rift deposit are not thick. We suggest that the area was anomalously uplifted during the rifting phase, due to an elevated thermal lithospheric gradient. The conclusions derived from our seismic and gravity analysis are consistent with the implications such a thermal anomaly would have on the tectonic evolution of a rifted margin with 1) an underplated high density lower crustal layer, 2) shallow depth syn-rift basins associated with a relatively thin crust and subsequently 3) elevated recorded subsidence rates in the initial post-rift stages.

1. Introduction

Over the last decades, scientific interest in West Africa has risen due to discoveries of large petroleum provinces, largely in deep water parts of continent-margin basins. Joint efforts from Industry and Academy have led to a better accessibility to the data and to an increase of scientific publications and knowledge. However, the offshore sedimentary basins of the tropical domain (Angola, Gabon, Brazil) are characterized by massive evaporite deposits that considerably perturb the seismic, the most powerful tool to image sedimentary and crustal structures in deep marine environments. Despite a good reflection seismic image of the post-salt sedimentary sequence (Dupré et al., 2007), characteristics of the pre-salt sequence, which mainly includes the syn-rift sequence and the basement, are poorly known and are subject to large interpretational uncertainties. As a direct consequence, fundamental questions regarding rifting kinematics and controlling processes require further investigation. The purpose of this study is to determine the deep geometry of the margin with special attention to depth of the sedimentary basins and to lateral variation in crustal thickness. Offshore Gabon, 2D deep reflection seismic and well data provided by Western Geco and Norsk Hydro have been analyzed together with satellite gravity data from Sandwell & Smith (1997). Gravity modeling was conducted to constrain the structure of the Gabon Margin. The new picture of the margin's structure highlights key aspects of rifting processes and related margin's formation.

* Corresponding address at: Currently at IFREMER, Géosciences Marines, Plouzané, France. Tel.: +33 2 98 22 47 09; fax: +33 2 98 22 45 09.
E-mail address: stephanie.dupre@ifremer.fr (S. Dupré).

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2. Geological setting

In Late Jurassic time (~150–140 Ma), continental rifting began between South America and Africa and led to the opening of the South Atlantic and to the formation of the West and Central Africa Rift System (Binks & Fairhead, 1992; Davison, 1999; Kampunzu & Popoff, 1991; Nürnberg & Müller, 1991; Teisserenc & Villemin, 1990). Crustal separation and onset of oceanic spreading took place ~133 Myr ago (magnetic anomaly M11) in the Cape Basin of South Africa and propagated northward to the Gulf of Guinea (Binks & Fairhead, 1992; Davison, 1999; Kampunzu & Popoff, 1991; Nürnberg & Müller, 1991; Teisserenc & Villemin, 1990; Uchupi & Emery, 1991). Three successive domains (austral, tropical and equatorial), delimited by inherited Gondwanian mega-discontinuities, characterize the South Atlantic (Popoff, 1988). Complete separation between the South American and African continents occurred in Late Albian–Cenomanian times with the opening of the Equatorial Atlantic Ocean. Rifting opened Africa's new margins to marine sedimentation, initially in narrow epicontinental seas, later in deep ocean basins (Fig. 1). Major basins around Africa were filled with great thicknesses of Cretaceous and Cenozoic marine sediments.

The Gabon Basin is located at the limit of two old cratons which have been stable since ~2 Ga, the Sao Francisco Craton in Brazil and the Congo Craton in Africa (Castro, 1987; Reyre, 1984). In this region, two main rift axes developed, the Gabon-Sergipe-Alagoas (GSA) trend and the Recôncavo-Tucano-Jatobá (TTJ) trend. While the RTJ trend evolved as a failed rift arm, the GSA trend indicated a transitional evolution between the rift and drift stage (de Matos, 1992). Along the Gabon Margin, onset of rifting started in Neocomian–Berriasian times, ~144 Ma, based on dating of the oldest rift sediments corresponding most exclusively to fluviatile basal sandstones (Guiraud & Maurin, 1991; Reyre, 1984; Teisserenc & Villemin, 1990). In Cabinda (Fig. 2), a volcanic layer found on top of the pre-rift sequence has been dated at 140 Ma ± 5 Myr, corresponding to the Jurassic–Cretaceous boundary (Brice et al., 1982). The end of rifting has been dated and associated with the magnetic anomaly M0 at ~118.5 Ma (Guiraud & Maurin, 1991; Teisserenc & Villemin, 1990). Based on these ages, rifting duration can be approximated to 25 Myr.

The west African rifted margin is divided into two main domains by the oceanic Walvis Ridge (Fig. 1). South of the ridge, a volcanic margin extends from South Africa to Namibia (i.e. Walvis, Ludentz, Orange and Le Cap basins), and is characterized by seaward dipping reflectors (Gladczenko et al., 1997). The region north of the Walvis Ridge stretching from Angola to Cameroon is characterized by post-rift evaporites forming the South Atlantic Salt Basin (Mocamedes, Kwanza, Lower Congo, North and South Gabon, and Douala basins). The deposition of these sediments over such a large area, 250 km wide and 2000 km along strike (Jackson et al., 2000), was made possible by favorable climatic conditions and by restriction of the water circulation imposed by the Walvis Ridge (Dingle, 1999). The Gabon Margin is segmented by major normal faults parallel to the present-day coastline and by NE–SW trending strike-slip faults defining zones with partly different tectonic and stratigraphic histories (Teisserenc & Villemin, 1990). The N'Komi fracture zone divides the Atlantic Basin into the North Sub-Basin and the South Sub-Basin (Fig. 2). North of Gabon, approaching the Equatorial domain, the west African margin acquires a more transform character (Mascle & Blarez, 1987; Meyers et al., 1996).

The Phanerozoic evolution of the African plate has been characterized by diachronous uplift and/or rifting and magmatism since the Cambrian, and accompanying fragmentation of Gondwanaland from Carboniferous time to present (Kampunzu & Popoff, 1991). The oldest pre-rift sediments along the Gabon Margin are found in the north, in the Interior Basin, which is separated from the offshore Atlantic Basin by the Lambaréné Horst (Fig. 2). According to Teisserenc & Villemin (1990), they consist of Late Carboniferous to Triassic–Jurassic fluviatile

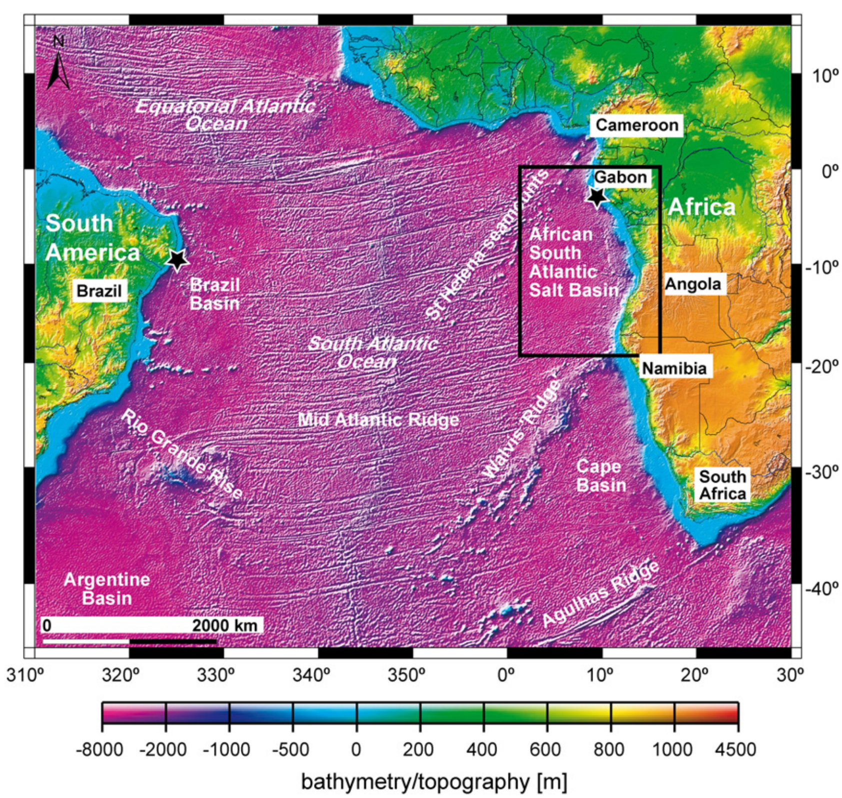

Fig. 1. South Atlantic Ocean shaded morphology map derived from satellite bathymetry data (Smith & Sandwell, 1997). Black stars stand for the studied area offshore Gabon and the Sergipe-Alagoas conjugate basins along the Brazil Margin.