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Research paper

Reconstruction of the southwestern African continental margin by backward modeling

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ABSTRACT

As the evolution of the southwestern African passive continental margin and in particular, the vertical movements in this area are still a matter of debate, this study aims to quantify the past vertical movements by reconstructing the paleobathymetric evolution of the southwestern African margin during the post-rift phase. To quantify the vertical movements, inferred from paleobathymetries, different subsidence components that have affected the passive continental margin are calculated and interpreted with respect to the generating processes.

Our investigation takes advantage of information on the present-day sedimentary thicknesses and the crustal configuration along the SW African margin. By using this detailed information and modeling backward in time we attempt to separate different subsidence components such as the load induced subsidence and the thermal subsidence for different time intervals during the post-rift phase. Calculating the amounts of each subsidence component and subtracting them from the present-day configuration yields paleobathymetries which are interpreted with respect to the evolution of the southwestern African passive margin.

These restored paleobathymetries for different time steps during the post-rift phase indicate spatial and temporal variations of vertical movements including phases of seafloor uplift. As a result, our investigation allows to give minimum estimates of the vertical movements that have occurred during the post-rift phase. In addition to predominant subsidence, about 1000 m of seafloor uplift are deduced for the northern and southern parts of the SW African margin. Quantifying the amounts of vertical movements cannot finally clarify the generating processes behind these movements but the timing and magnitude of seafloor uplift indicate a deep mantle mechanism.

1. Introduction

The southwestern African continental margin, located in the South Atlantic Ocean, includes three major basins: the Walvis Basin, Lüderitz Basin and Orange Basin (Fig. 1). It extends from north to south for about 1650 km, being limited by the Walvis Ridge in the north and the Agulhas Falkland Fracture Zone further south. The formation and evolution of the margin is structurally related to the opening of the Atlantic ocean, which can be traced back to the continental separation of the Gondwana supercontinent during Late Jurassic-Early Cretaceous times (e.g. Broad et al., 2006; Nürnberg and Müller, 1991). During the last decade, an increasing number of studies have focused on the southwestern African continental margin with the aim of improving the current understanding of the processes responsible for its tectonic evolution and their relevance for the formation and maturation of hydrocarbon resources. A non-exhaustive list comprises: (1) seismic investigations (e.g. Bauer et al., 2000; Bauer et al., 2003; Fernàndez et al., 2010; Gladczenko et al., 1998; Hartwig et al., 2012; Koopmann et al., 2013; Kuhlmann et al., 2010; Weigelt and Uenzelmann-Neben, 2007), (2) potential field modeling (Hirsch et al., 2007, 2009; Maystrenko et al., 2013; Stewart et al.,

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2000), (3) dating of vertical movements by sequence stratigraphy and geochemical dating methods (Broad et al., 2006; Brown et al., 1995; Holtar and Forsberg, 2000; Kuhlmann et al., 2011; Light et al., 1993; McMillan, 2003; Paton et al., 2007; Trumbull et al., 2007), (4) kinematic analysis (Will and Frimmel, 2013) or (5) a combination of several techniques (e.g.: Hirsch et al., 2010; Paton et al., 2008).

The sedimentary basins of the SW African continental margin store the archive of the margin history. The goal of our study is to use this archive as a starting point for investigating the margins evolution during the post-rift phase (the last 125 Ma) by a modeling approach backward through time. Therefore, we use information on the present-day structural configuration along the SW African margin between the coast and the continent–ocean boundary after Maystrenko et al. (2013).

Our backward modeling approach considers individual subsidence components such as the load induced subsidence and the thermal subsidence. The amount of load induced subsidence is calculated with a multi 1D "backstripping" approach while we calculate the amount of thermal subsidence after the uniform stretching model of McKenzie (1978). These subsidence components are then subtracted from the present-day bathymetry in order to reconstruct paleobathymetries. An in-house software (GeoModellingSystem (GMS), developed at the Helmholtz Centre Potsdam (GFZ); Scheck and Bayer, 1999) is used to assist our modeling of the subsidence evolution of the continental margin.

In particular, our approach differs from the established "backstripping" in that we do not prescribe a certain paleo-water depth but restore the latter.

Worth mentioning is that we do not prescribe any tectonic component in addition to cooling of a stretched lithosphere within the reconstruction, nor uplift events as proposed by e.g. Colli et al. (2014) or Séranne and Anka (2005). Nevertheless, we are able to estimate the magnitude of vertical movements by analyzing the reconstructed paleobathymetries. The resulting paleobathymetries help to understand the first-order margin evolution in terms of subsidence and seafloor uplift. We discuss the implications of these results with respect to previously published information on paleobathymetries and derive conclusions for the processes responsible for this evolution.

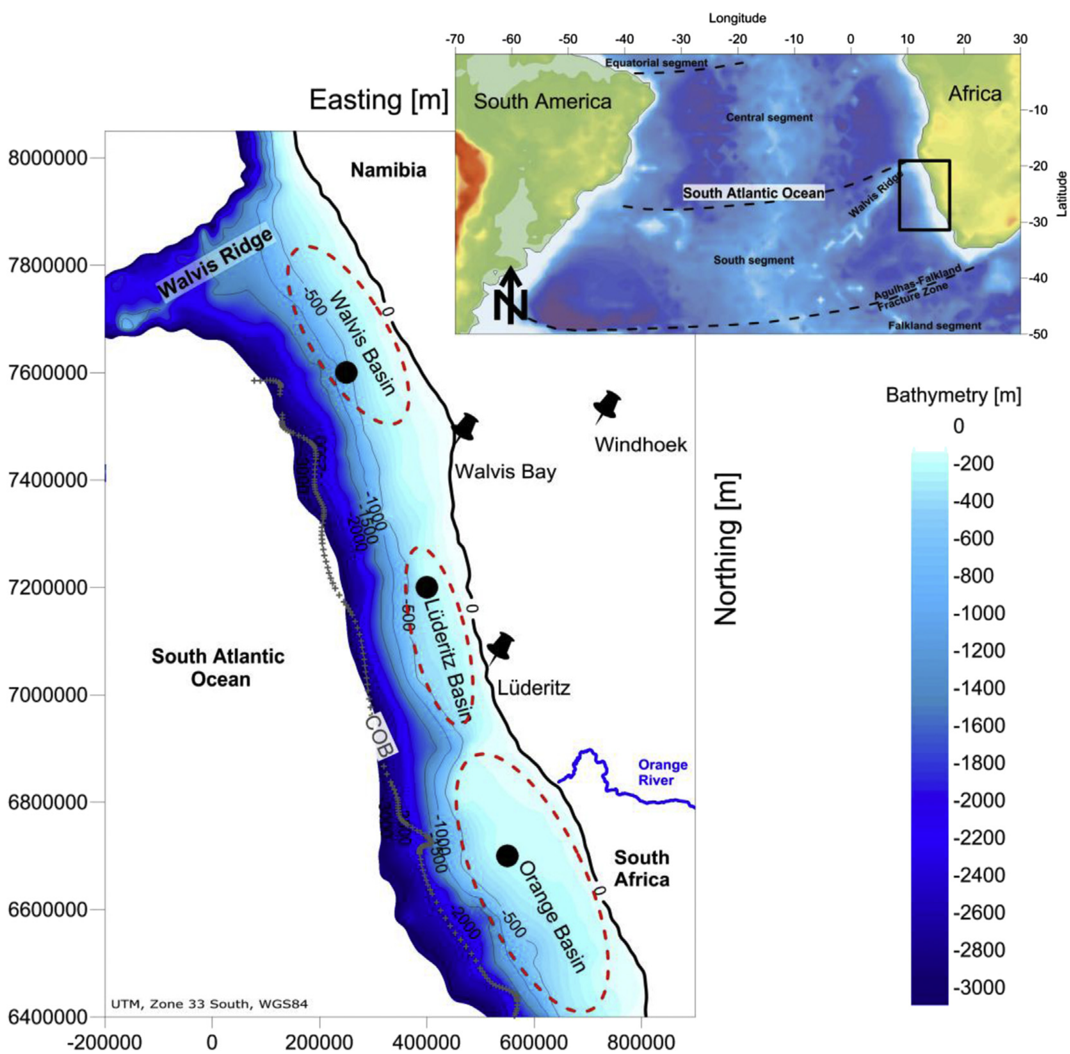

Fig. 1. Overview of the research area, the continental margin of southwestern Africa (bathymetry after IOC, IHO and BODC, 2003). The red ellipses show the location of the sedimentary basins. The gray dotted line indicates the continent–ocean boundary (COB; after Pawlowski, 2008). The black solid points mark the location of synthetic wells used in Fig. 6. Coordinate system is UTM [m], zone 33 south (WGS 84). Inset: Overview of the South Atlantic Ocean with location of the research area (black box) in geographical coordinates. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)