

REGIONAL SYNTHESIS FOR AFRICA'S CONTINENTAL MARGINS

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Introduction

Africa's Atlantic margins received considerable attention throughout the last decade as the traditional hydrocarbon provinces such as the Arabian Gulf, the Gulf of Mexico and the North Sea reached a mature exploration and production phase. This attention by the oil industry also sparked renewed scientific interest in this area resulting in significant advances in our understanding of the processes that shaped the margins. However, most of the published findings concern relatively small areas either as a result of limited data coverage or because the geological processes were active in restricted areas. In this study, we utilize a continuous seismic reflection data set that reaches from the Straits of Gibraltar along the entire length of Africa's Atlantic seaboard to the Cape of Good Hope (Fig. 1) to summarize the recent literature, corroborate their findings, and, most importantly, to determine regional variations in the geology of the African Margin. The new data coverage allows in an unprecedented way to delineate regional margin features such as: 1) the difference between rifted and transform margin segments, 2) variations in sediment supply, 3) extent of halokinesis, 4) extent of volcanic margin development, and 5) the areas of sediment mobilization due to bottom currents and submarine slope stability.

Margin segments

On a first order analysis, the African Margins can be divided into the rifted margins off West Africa, the transform margins of the Gulf of Guinea, and the rifted margins off southwest Africa. In addition there are several second order transform margin segments offshore west and southwest Africa, e.g. the 70 km long segment of transform margin offshore Senegal, and short second order segments of rifted margins in the Gulf of Guinea, e.g. offshore Cote d'Ivoire. Most of the second order transform margin segments are covered by thick post-rift sediments and they are difficult to image. However, even in places where they are well imaged their horizontal extent is small compared to transform margin segments of other continental margins. This possibly indicates that most of the transform stresses in the plate tectonic context were accommodated by movement on the main Gulf of Guinea fracture zones, and that the residual stresses were probably partitioned along the margin as transtensional accommodation zones and relays split up on many small transform segments which is consistent with the large number of fracture zones in the oceanic domain (Davison, 1999; Meyers et al., 1996). Whereas

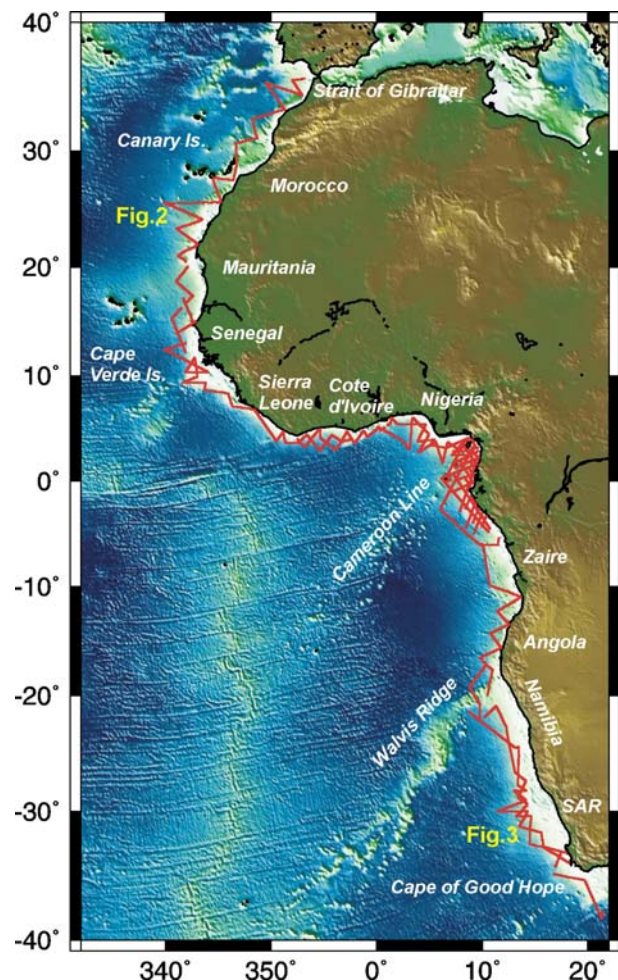


Fig 1: 2D multi-channel seismic data coverage (red lines) for the western continental margins of Africa used in this study. SAR, South African Republic.

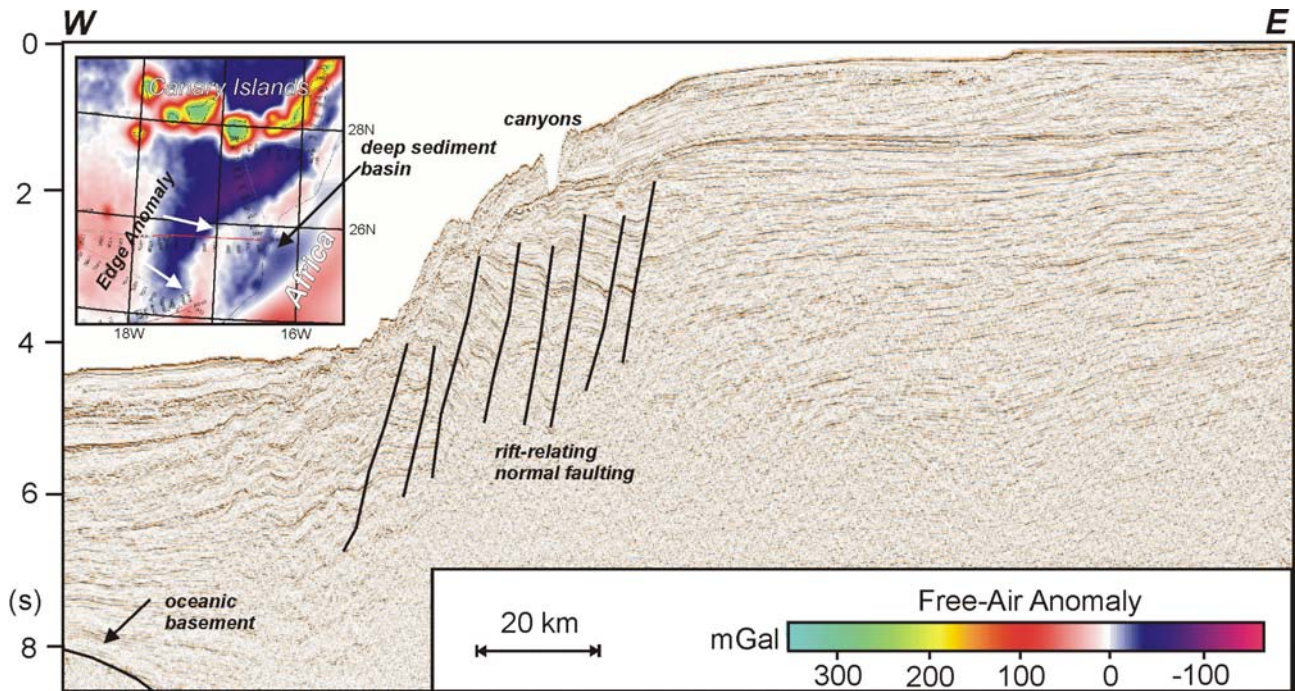


Fig. 2: Seismic data example for the thick sedimentary cover along the margins of southern Morocco and Mauritania. Inset: free-air gravity anomaly supporting the great sediment thickness.

numerous fracture zones interrupt the Mid-Atlantic Ridge, few of them, apart from those originating at the translational zone of the Gulf of Guinea, are more than tens of kilometres and mostly widely spaced. They occur on sections of ridge, which are opening orthogonally, as well as obliquely. They are a feature of thin oceanic crust and should not be “expected” at break-up.

Variations in sediment supply

Seismic and satellite derived free-air gravity anomaly data (Sandwell and Smith, 1997) constrain the major sediment depocentres off the African margins (Fig. 2). The new data show significant sediment thickness offshore Mauritania, Senegal, Nigeria, Cameroon, Zaire, and Angola indicating that the current river-fed delta systems have been the main depocentres since break-up. In some areas such as north of Senegal sediment thickness is considerable even without current river input. This could either be explained by margin parallel sediment transport by bottom currents or by nowadays-extinct river systems draining this part of the Saharan desert in former times.

Halokinesis

There are three major salt provinces off Africa's west coast: 1) on the margins offshore Morocco, 2) a minor province offshore Senegal and Liberia, and 3) the major salt province offshore Angola. Tari et al. (2003) concluded in a comparative study that the main similarity between these provinces is an extensional domain in the proximal basin areas and compression in the distal parts of the basin. Offshore Angola this trend is strongest leading to raft tectonics close to the shelf. These findings are fully supported by our study. The extent of these provinces indicates which margin segments remained as confined basins for a considerable time after breakup, becoming repeatedly flooded and emptied in order to generate sufficient amounts of evaporites.

Volcanic margin shaping

The only true volcanic passive margins west of Africa are the margins offshore Namibia and the South African Republic. These margin segments experienced large-scale volcanism during continental break-up due to the thermal anomaly in the upper mantle called the Tristan da Cunha hotspot

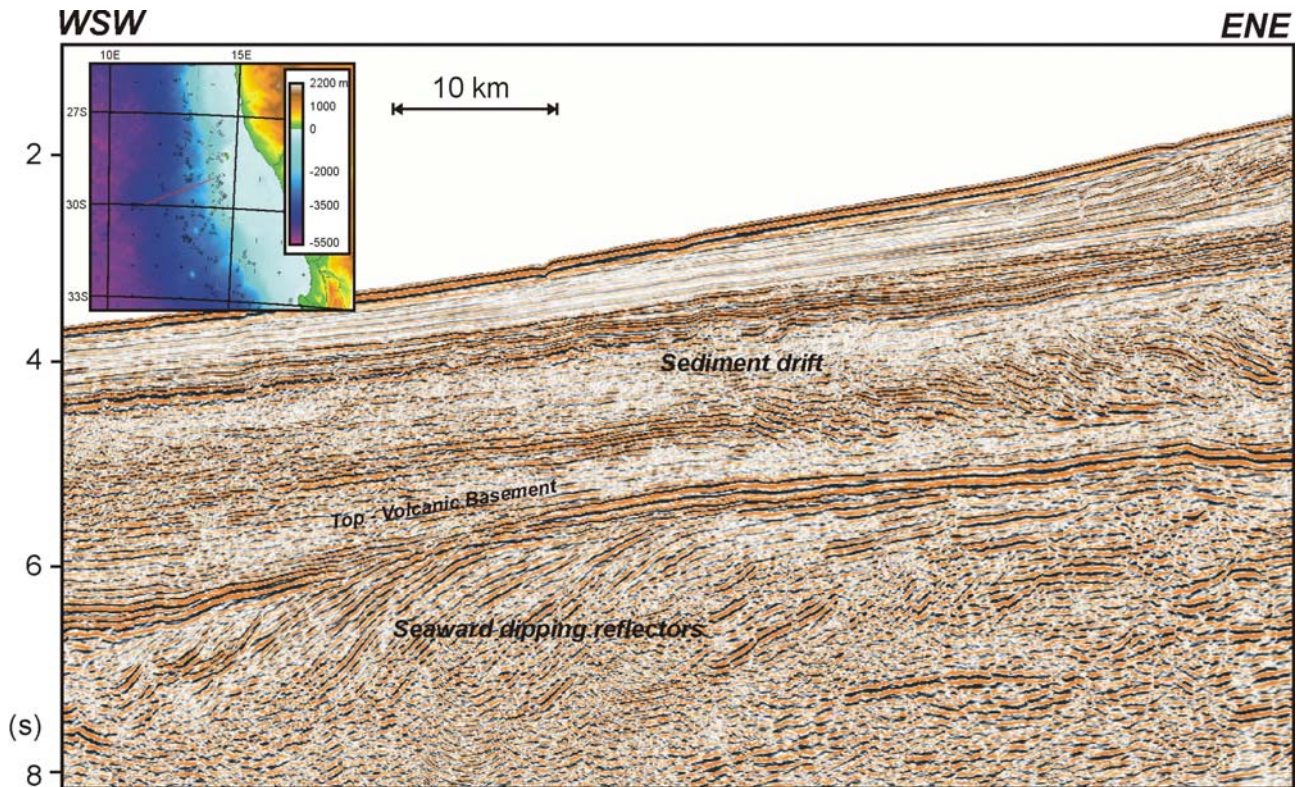


Fig. 3: Seismic example for the volcanic passive margins west of South Africa. Note, the thick sedimentary drift overlying seaward dipping reflector sequences.

(Gladchenko et al., 1999). The extrusive part of this volcanism is manifest as seaward dipping reflector sequences that reach from the Walvis Ridge south beyond Cape of Good Hope. During the drift phase the volcanism was confined to the Walvis Ridge. Seaward dipping reflector dip directions in the new data suggest that the eastern part of the Walvis Ridge subsided faster than the surrounding margins during break-up and early drift phase possibly as a result of magmatic crustal thickening and lithospheric weakening close to the hotspot. Apart from the volcanic margins southwest of Africa there are many areas west of Africa that also experienced volcanism, however, on a much smaller scale: around the Canary and Cape Verde hotspots near the Cameroon Line in the Gulf of Guinea and offshore Angola.

Sediment mobilization

Both constructive and destructive sediment transport processes are evident on the African margins. The most pronounced constructive processes were active west of South Africa, where the Benguela current or its predecessor deposited up to 300 m high and several hundred km long sediment drifts (Fig. 3). Similar but smaller features are also found south of the Canary Islands and offshore Sierra Leone.

On the other hand destructive processes mobilized large volumes of sediments during submarine slope failure. The areas that are most heavily affected by submarine mass wasting are offshore Mauritania, Senegal and South Africa, whereas large areas in between show no evidence for mass wasting at all. These sections of the margin, apparently unaffected by the large-scale failures are largely characterised by fan accumulations, where any original shelf has subsided and was covered with sediment.

Conclusions

This synthesis of existing literature with an extensive, previously unpublished 2D-seismic data set, and potential field data has allowed a comprehensive reassessment of the geological processes that shaped the continental margins west of Africa. Most observations can readily be explained by the interplay between plate tectonic setting, i.e. rifted or transform margin, the rifting rate which controlled the deposition or non-deposition of salt, the ambient mantle temperature and hence the amount of volcanism, and finally the drift phase sediment loading which is primarily controlled by the location of river systems as sediment sources.

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