Plate tectonic processes in the South Atlantic Ocean: Do we need deep mantle plumes?

J. Derek Fairhead
School of Earth & Environment (Earth Sciences), University of Leeds, Leeds LS2 9JT, UK, and GETECH, University of Leeds, Leeds LS2 9JT, UK
Marjorie Wilson
School of Earth & Environment (Earth Sciences), University of Leeds, Leeds LS2 9JT, UK

ABSTRACT
Areas of volcanic over-production within the oceanic crust, such as linear chains of oceanic islands and seamounts, have traditionally been explained in terms of mantle plumes. For the South Atlantic Ocean, however, it appears that processes operating at the mid-ocean ridge may provide the dominant control. A model is proposed based on satellite-derived free air gravity and Global Positioning System (GPS) plate motion data, combined with extensive knowledge of the tectonic processes that have operated in the adjacent continents of Africa and South America. During the Central and South Atlantic opening, differential motion between plate segments was principally absorbed within the Caribbean and an extensive "passive" Mesozoic-Cenozoic rift system in West and Central Africa. In the African rift basins, changes in stratigraphy directly relate to changes in the state of stress in the African plate, brought about by changes in plate motions to accommodate plate interaction elsewhere on Earth (e.g., India-Eurasia and Africa-Europe collisions). These major plate interactions are clearly seen in the fabric of the Atlantic oceanic crust as changes in flowline directions, indicating relative plate motions. We propose that changes in the internal stress of the plates trigger changes in Mid-Atlantic Ridge (MAR) magmatic processes that cause excess volcanism on a range of scales from small-scale V-shaped volcanic trails, centered on the ridge axis, to large-scale aseismic ridges (e.g., Walvis Ridge, Rio Grande Rise). We suggest that the Walvis Ridge developed as a result of periodic stress release along shear/wrench/extensional deformation zones that penetrated short distances into the plate from the contemporaneous MAR axis. During the formation of such large-scale features, the state of stress in the adjacent plates may be different; stresses can be low in one plate (explaining, e.g., the lack of a conjugate of the St. Helena Seamounts–Cameroon Volcanic Line) or different (explaining, e.g., the asymmetry of the Walvis Ridge and Rio Grande Rise).