# Changes in plate motions and their control on the subsidence of rifted basins in the African plate

Janssen, M.E.; Stephenson, R.A.; Cloetingh, S.A.P.L.

***published in***
Geoscientific research in Northeast Africa
1993

*Geoscientific Research in Northeast Africa, Thorweihe & Schandelmeier (eds)*
*© 1993 Balkema, Rotterdam, ISBN 90 5410 318 3*

# Changes in plate motions and their control on the subsidence of rifted basins in the African plate

M.E.Janssen, R.A.Stephenson & S.Cloetingh
*Institute of Earth Sciences, Vrije Universiteit, Amsterdam, Netherlands*

ABSTRACT: Backstripped tectonic subsidence curves of approximately 200 selected wells from marginal and intra-continental basins of the African plate are presented. A comparison of these data with the plate motions of the African plate from Late Jurassic until Recent supports a temporal and spatial correlation between phases of rapid subsidence and changes in plate motions and stress regime of the African plate.

## 1 TECTONIC SETTING

From the early Mesozoic until Recent, the African continent was generally in a state of extension. Plate tectonic reconstructions and sedimentary basin subsidence studies demonstrate this. Beginning with the initial break-up of Gondwana in the Permo-Triassic, this resulted in the formation of the present-day African continental margins and a series of intra-continental rift basins, located mainly on older (late Proterozoic) shear-zones. During this period several distinct episodes of rifting can be recognized. The first (phase 1) includes Karoo rifting in southeast Africa, from Late Carboniferous until Middle Jurassic (Lambiase, 1989; Cloetingh et al., 1992), as well as rifting along the present northwestern margin of Africa, from Middle Triassic until Middle Jurassic (Favre and Stampfli, 1992; Guiraud et al., 1992). The Karoo rifting is thought to result in the opening of the Indian Ocean. Crustal separation at the northwestern margin, between Africa and North America, began in the Middle Jurassic. The second phase of rifting (phase 2), Late Jurassic until the Early Aptian, resulted in the separation of South America from Africa. Crustal separation commenced in the south, in the Cape Basin, at ~130 Ma (Rabinowitz and LaBrecque, 1979) and propagated to the north, reaching the central Atlantic by ~119 Ma (Mascle et al., 1986). During this period, the NW-SE striking rift basins of the West and Central African Rift System (WCARS) developed (Genik, 1992; Guiraud and Maurin, 1992). From Early Aptian until Late Albian a third rifting event occurred (phase 3), resulting in the opening of the equatorial Atlantic (Guiraud et al., 1992). The basins of the WCARS deepened and E-W to ENE-WSW trending pull-apart basins developed. This rifting phase is followed by a Late Cretaceous subsidence phase, either due thermal subsidence (Guiraud et al., 1992), or to renewed rifting (Genik, 1992; McHargue et al., 1992). A fourth period of rifting (phase 4) started between Maastrichtian (Genik, 1992) and Paleocene (McHargue et al., 1992) and is probably related to rapid northward motion of India and very high spreading rates in the Indian Ocean (Bosellini, 1989). The fifth and youngest rifting event (phase 5) began in the Late Eocene and resulted in separation of Arabia and Africa and the opening of the Red Sea, Gulf of Aden and East African Rift System in the Neogene (Guiraud et al, 1992; Binks and Fairhead, 1992; Rosendahl et al., 1992). During the development of the African rift basins only two compressional events are clearly observed. The first occurred during the Santonian, synchronous with a rapid change in plate motion of the African plate related to the onset of the collision with the European plate. The second took place during the Eocene, contemporaneous with enhanced mountain-building activity in the African-European collision belt (Guiraud et al., 1992).

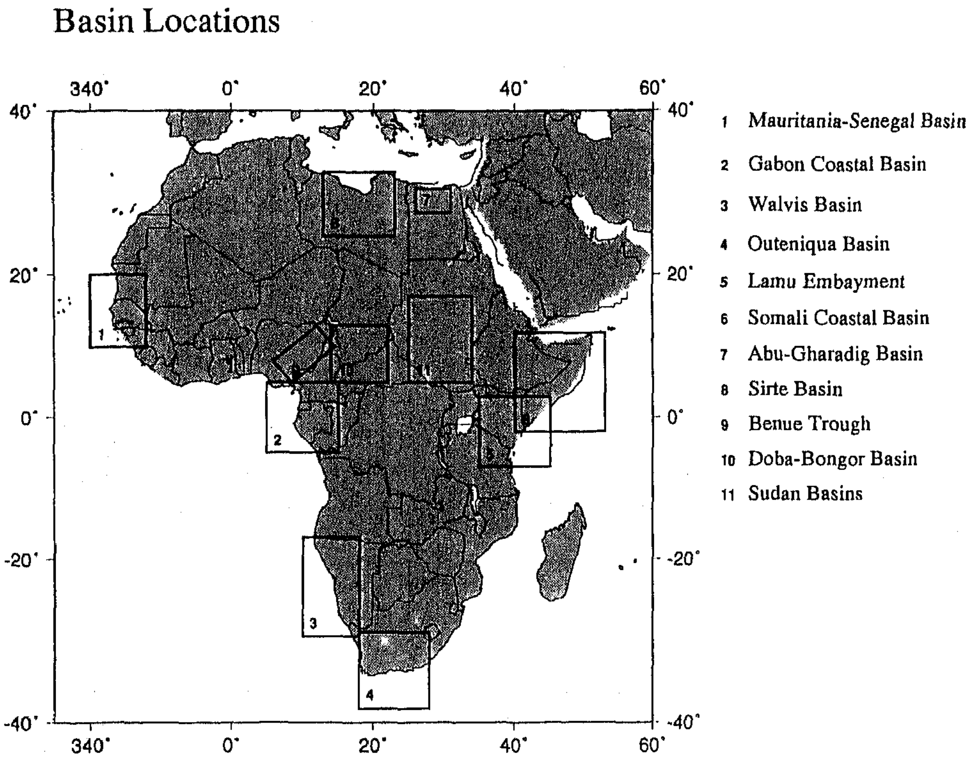


Figure 1. Approximate locations of the study areas.

## 2 RESULTS

In the present study, two-hundred wells from marginal as well as intra-continental rift basins (see Figure 1) have been backstripped to elucidate their Mesozoic and Tertiary tectonic histories. The results of the analysis show a generally consistent pattern of subsidence and uplift phases in all basins (see Figure 2). In general, the rapid subsidence phases in all basins correlate well with documented rifting phases at the margins of the African continent. Effects of Atlantic rifting (phases 2 and 3) are seen all over the African plate, with increased tectonic subsidence rates in all backstripped wells. These observations are consistent with far-field stress propagation in the lithosphere away from the plate boundaries (Cloetingh, 1992; Ziegler, 1992). Lateral changes in the magnitude of the subsidence perturbation could reflect the effect of stress attenuation as a function of distance of propagation (Ziegler, 1992), or be caused by variations in lithosphere rheology of the African plate due to different pre-rift tectonics histories. During Cenomanian-Turonian, however, a deviation occurs from the thermal subsidence phase that followed the Atlantic break-up. Instead of the expected decrease in tectonic subsidence rate most basins show an increase. Renewed rifting seems to occur as already suggested by Genik (1992) and McHargue et al. (1992), but no clear change in plate motions or stress regime, related to plate boundary reconfiguration, has been observed. The Paleogene rifting event (phase 4) is restricted to basins located at or near the eastern margin of the African continent. This event is not recorded in any of the other basins. During phase 5, most wells show an increase in tectonic subsidence rate. In basins at or near the eastern margin this subsidence event is clearly related to rifting in the Red Sea, Gulf of Aden and East African Rift System. Whether this relation also exist for basins that are located on other margins is not clear.

Tectonic subsidence

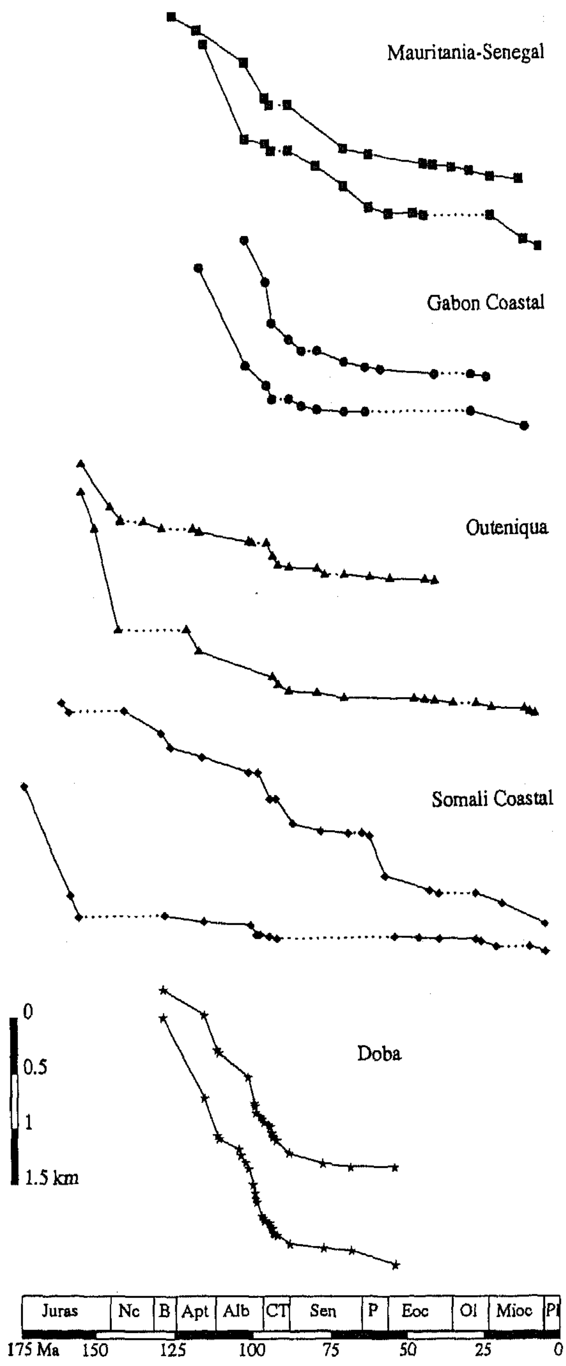


Figure 2. Tectonic subsidence curves from selected wells from five of the studied basins. (For location of the basins, see Figure 1)

## 3 CONCLUSIONS

Documented rifting phases along the proto- African continental margins are reflected in periods of rapid, or increased, subsidence in all studied basins. I addition, a number of periods of rapid subsidence phases can be observed which do not correlate well with documented changes in plate motions and stress regime of the African plate. At this stage it is not clear, whether this could be the result of limited data on paleo-stress changes in the African plate during these time slices.

## REFERENCES

Binks, R.M. & J.D. Fairhead 1992. A plate tectonic setting for Mesozoic rifts of West and Central Africa. *Tectonophysics* 213: 141-151.

Bosellini, A. 1989. The continental margins of Somalia: their structural evolution and sequence stratigraphy. *Mem. Sci. Geol.* 41: 373-458. Padova.

Cloetingh, S. 1992. Intraplate stress and sedimentary basin evolution. In G.C. Brown, C.J. Hawkesworth & C. Wilson (eds.) *Understanding the earth:* 415-434. Cambridge: Cambridge Univ. Press.

Cloetingh, S., A.C. Lankreijer, M. de Wit & I. Martinez 1992. Subsidence history analysis and forward modelling of the Cape and Karoo Supergroups. In M.J. de Wit & I.G.D. Randsome (eds.), *Inversion tectonics of the Cape fold belt, Karoo and Cretaceous basins of Southern Africa:* 239-248. Rotterdam: Balkema.

Favre, P. & G.M. Stampfli 1992. From rifting to passive margin: The example of the Red Sea, Central Atlantic and Alpine Tethys. *Tectonophysics* 215: 69-97.

Genik, G.J. 1992. Regional framework, structural and petroleum aspects of rift basins in Niger, Chad and the Central African Republic (C.A.R.). *Tectonophysics* 213: 169-185.

Guiraud, R., R.M. Binks, J.D. Fairhead & M. Wilson 1992. Chronology and geodynamic setting of Cretaceous-Cenozoic rifting in West and Central Africa. *Tectonophysics* 213: 227-234.

Guiraud, R. & J.C. Maurin 1992. Early Cretaceous rifts of Western and Central Africa: an overview. *Tectonophysics* 213: 153-168.

Lambiase, J.J. 1989. The framework of African rifting during the Phanerozoic. *J. Afr. Earth Sci.* 8: 183-190.

Mascle, J., M. Marinho & J. Wannesson 1986. The structure of the Guinean continental margin: implications for the connection between the Central and the South Atlantic Oceans. *Geol. Rundsch.* 75: 57-70.

McHargue, T.R., T.L. Heidrick & J. Livingstone 1992. Tectonostratigraphic development of the Interior Sudan Rifts, Central Africa. *Tectonophysics* 213: 187-202.

Rabinowitz, P.D. & J. Labrecque 1979. The Mesozoic South Atlantic and evolution of its continental margins. *J. Geophys. Res.* 84: 5973-6002.

Rosendahl, B.R., E. Kilembe & K. Kaczmarick 1992. Comparison of the Tanganyika, Malawi, Rukwa and Turkana rift zones from analyses of seismic reflection data. *Tectonophysics* 213: 235-256.

Ziegler, P.A. 1992. Plate tectonics, plate moving mechanisms and rifting. *Tectonophysics* 215: 9-34.