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Causes and consequences of continental breakup in the South Atlantic: lessons learned from the SAMPLE program

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Since 2009 the SAMPLE program (www.spp-sample.de) provides a platform for research into the causes and effects of continental breakup and the evolution of passive margins. SAMPLE encompasses 28 projects from 13 German institutions and many international partnerships. The 6-year program will run through 2015. At the core of the program are observational studies that are interlinked by modelling projects examining the interplay of deep mantle dynamics, lithospheric stress fields, pre-rift fabric and melt-weaking on localizing rifting.

Geophysics teams collect and integrate existing data from wide-angle seismic profiles, reprocessed multichannel seismics, as well as gravity, magnetics and heat-flow studies to construct self-consistent lithospheric-scale 3-D models along the conjugate margins. Key interests are variations in margin architecture, distribution of magmatic features and the evolution of sedimentary basins (subsidence and thermal histories). An exciting new contribution of SAMPLE geophysics is a linked set of seismic, seismologic and magnetotelluric experiments along the Walvis Ridge, including onshore NW Namibia and the Tristan da Cunha hotspot. In the deep mantle, we examine evidence from global seismic tomography for dramatic low seismic-velocity regions near the core-mantle boundary beneath southern Africa and their implications for dynamics in the deep Earth and the thermo-chemical nature of plumes.

Petrologic studies focus on near-primary mantle melts represented by Mg-rich mafic dikes. Projects address the origin of magmas and crust-mantle interaction, and the environmental impact of mega-scale volcanism during breakup. Thermobarometry results from the African margin reveal a N-to-S decrease in mantle potential temperatures from 1520°C (N) to 1380° (S), which supports a thermal plume origin for excessive melt production in the north.

Thermochronology data from both conjugate margins reveal complex and puzzling patterns in the denudation history after breakup. Unexpected are the implied short time and spatial scales of topographic variations, which challenge conventional wisdom on how passive margins evolve. These variations in surface topography are critical observables for testing models of shallow vs. deep-mantle buoyancy effects.

Studies of sedimentary basins offshore complement the denudation studies and are linked with 3D lithospheric models of the margins. A group of projects examines structures, sedimentary sequences and thermal/subsidence histories of selected conjugate basins, and finds major asymmetries. Allied studies of hydrocarbon systems in the basins involve mapping present and paleo gas escape/sequestration features (mud volcanoes, pockmarks, gas chimneys) combined with 3D petroleum systems models.

Relating the offshore sedimentary record to lithospheric dynamics requires understanding effects of paleo-oceanography. Major changes in Atlantic circulation due to tectonic events and the geometry of the ocean basin are recorded in erosive and depositional features of offshore sediments. SAMPLE projects use high-resolution seismic data to map and date these features, and in a further step, to study the influence of paleo-ocean circulation on global climate using coupled atmosphere-ocean models.