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Modification of continental crust during rifting: geophysical images and petrologic models of mafic intrusions in the Etendeka Province of Namibia

Robert Trumbull & Klaus Bauer

GeoForschungsZentrum Potsdam, Am Telegraphenberg, D-14473 Potsdam, Germany; Emails: bobby@gfz-potsdam.de,, *klaus@gfz-potsdam.de*

Central volcanic complexes in continental rifts stand out both in elevation and compositional diversity from the more voluminous but monotonous effusive lava sequences. This diversity of magma types in central complexes is both a challenge of understanding how they formed and assembled, and an opportunity because of the chance to isolate end-member compositions that are otherwise obscured or hopelessly mixed together in the more voluminous flood volcanism. The ideal case is where central volcanoes exist alongside flood basalts and where erosion has dissected most of the volcanic edifices to expose the internal plumbing system. This is the situation in the Etendeka province, NW Namibia, where some 20 ring complexes that formed during Gondwana breakup in the Early Cretaceous are exposed at the subvolcanic level. The complexes have generally good access and the arid climate ensures excellent exposure. They present a literal cross-section of the kinds of magmas associated with continental rifting worldwide, with carbonatites, silica-undersaturated and oversaturated peralkaline rocks, gabbro-anorthosites as well as peraluminous crustal granites. The exposures are at the subvolcanic level but their deeper structures can in some cases be inferred by combining geophysical data with petrologic evidence of magma sources and storage depths.

The most complete geophysical image is available from the Messum complex (132 Ma), which consists of concentric ring intrusions of gabbro-anorthosite, hybridized granodiorite and quartz syenite, and late nepheline-syenites associated with basanite-tephrite dikes. A joint interpretation of seismic reflection, refraction and potential field data that satisfies geologic and petrologic constraints indicates an intruded volume beneath Messum with an overall cylindrical form that must include an integrated average of 30 vol.-% gabbroic material. Seismic reflection data indicate that magma is dispersed in a network of intrusions with sub-km dime! nsions. Petrologic data from Messum and several of the felsic complexes (Brandberg, Erongo, Etaneno) require large bodies of mafic magma at depth, partly as a heat source for crustal melting and partly as a direct component of the exposed igneous rocks. This is confirmed by aeromagnetic and gravity anomaly interpretations, which reinforce the concept of semi-cylindrical root zones permeated by magmas more mafic than those currently exposed.