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Gravity anomalies, Magmatism, and the Segmentation of Passive Margins

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The free-air gravity "edge effect" anomaly associated with passive continental margins is one of the most distinctive features of the marine gravity field. Early studies attributed the edge effect to the transition between thick continental crust and thin oceanic crust. While thinning of the crust during continental break-up is a major contributor, it is now recognized that geological processes such as flood basalt extrusion, magmatic underplating, and sediment loading modify the edge effect. In this paper, simple models are presented for the free-air, and hence isostatic, gravity anomalies expected at rifted passive margins that are dominated by magmatism. We show that flood basalt extrusion and magmatic underplating are associated with distinct isostatic anomaly patterns, examples of which are clearly seen in the satellite-derived gravity anomaly field. Offshore southeast Greenland there is an isostatic anomaly "high" that is flanked on its landward side by a "low". We interpret this anomaly pattern as the consequence of flood basalt loading close to break-up and the subsequent rotation of the flexed surfaces following on-going subsidence and thinning of the crust. Similar anomaly patterns exist offshore North and South Carolina and Georgia, along the southern East Coast, USA margin. Offshore Namibia, in contrast, the isostatic anomaly is dominated by a "low" that is flanked by asymmetric "highs". We interpret this pattern as the result of mantle melting and the rise of bouyant material that ponds below and flexes upwards the overlying crust. These inferences on the role of magmatism at rifted margins are in accord with the results of 3-D combined backstripping and gravity modeling that take into account sediment loading and with observations of the structure of the crust derived from seismic refraction data. Unlike the latter, however, which is limited to a few across-strike "transects", the isostatic anomaly has the potential to determine the extent of magmatism along-strike rifted margins. Offshore southeast Greenland and the southern East Coast, USA margin, for example, the isostatic anomaly high is strongly linear, extending for a few hundreds of km along-strike. In contrast, offshore Namibia, the same anomaly is dominated by isolated lows which resemble the "bulls-eye" mantle Bouguer anomalies that have been observed along-strike some mid-oceanic ridge crests. These observations of the isostatic anomaly pattern suggest differences in the pattern of magma emplacement at volcanic rifted margins. At some margins magmatic material appears to be channelled along great distances whilst in others it is focussed in a few isolated centres. The cause of these differences is an important question to address in the future, especially as it impacts the along-strike prospectivity of rifted margins which may, otherwise, have had a similar thermal and mechanical evolution.