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Seismic anisotropy and rifting in Africa

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The rifting of continents and eventual formation of ocean basins is a fundamental component of plate tectonics, yet the mechanism for break-up is poorly understood. The East Africa Rift system (EARS) is an ideal place to study this process as it captures the initiation of a rift in the south through to incipient oceanic spreading in north-eastern Ethiopia. Measurements of seismic anisotropy can be used to test models of rifting. Here we summarise observations of anisotropy beneath the EARS from local and teleseismic body-waves and azimuthal variations in surface-wave velocities. Special attention is given to the Ethiopian part of the rift where the recent EAGLE project has provided a detailed image of anisotropy in the portion of Ethiopian Rift that spans the transition from continental rifting to incipient oceanic spreading. Analyses of regional surface-waves show sub-lithospheric fast shear-waves coherently oriented in a north-eastward direction from southern Kenya to the Red Sea. This parallels the trend of the deeper African superswell, which originates at the core-mantle boundary beneath southern Africa and rises towards the base of the lithosphere beneath Afar. The pattern of anisotropy is more variable at depths shallower than 150 km. Analyses of splitting in teleseismic phases (SKS) and local shear-waves within the rift valley consistently show rift-parallel orientations. The magnitude of the splitting correlates with the amount of magmatism and the orientation of the shear-waves aligns with magmatic segmentation along the rift valley. Analysis of surface wave propagation across the rift valley confirms that anisotropy in the uppermost 75 km is primarily due to melt alignment. Away from the rift valley the anisotropy agrees reasonably well with the pre-existing Pan-African lithospheric fabric. An exception is the region beneath the Ethiopian plateau, where the anisotropy is variable and may correspond to pre-existing fabric and ongoing melt migration processes. These observations support models of magma assisted rifting, rather than simple mechanical stretching. Upwellings, which

most probably originate from the larger superswell, thermally erode the lithosphere along sites of pre-existing weaknesses or topographic highs. Decompression leads to magmatism and dyke injection that weakens the lithosphere enough for rifting and the strain appears to be localised to plate boundaries, rather than wider zones of deformation.