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Identifying deformation styles and causes at two deforming volcanoes of the Central Main Ethiopian Rift with seismic anisotropy

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The Main Ethiopian Rift (MER) has undergone extension since ∼8 Ma, and whilst large border faults were active until later stages, since then (2 Ma) seemingly most extension has been via the Wonji Fault Belt (WFB), a series of en-echelon faults perpendicular to current spreading, which possibly focus around magmatic centres. Two such centres are Corbetti and Aluto volcanoes in the central MER. They have shown significant (>5 cm) uplift and subsidence for at least five years, probably erupted in the Holocene, and are geothermal sites. They are presumed therefore to play an active rôle in present-day extension along the rift, via magma injection and brittle deformation; yet a detailed physical explanation of their behaviour remains elusive. We report results from a recent combined seismic–geodetic study (ARGOS) of these areas, focussing on the seismic anisotropy revealed.

We confirm that both volcanoes are seismically active, with events located beneath the edifice having mean local magnitude $\overline{m_L} = 1.0$. Beneath Aluto, there are two main clusters of activity: (1) at depths 5–10 km below sea level (bsl), and (2) between -2 and 0 km bsl. Focal mechanisms show predominantly normal faulting on fault planes striking north-northeast (NNE), and event locations cluster along a similar trend. The identification of the WFB in this region is debated, but we show that only the deepest (5–15 km) events occur along the northeast-trending faults with outcropping to the east. Shear wave splitting of over 5 % is present, and appears to be confined to the top 5 km, since little depth dependence is shown. Fast shear wave orientations have again a NNE trend. These lines of evidence indicate that current seismic deformation, and aligned structures in the top few km, act in response to the current stress field, and not pre-existing features. Any magmatic emplacement occurring above 15 km is likely not as dykes, as these would create large seismic anisotropy at these depths which is not shown. Little evidence for a ‘mushy’, aseismic zone is found where geodetic studies have suggested a magma chamber is present. Hydrothermal processes may be responsible for much of the edifice loading, and we observe a positive correlation between rainfall and seismicity.

At Corbetti, a completely different pattern emerges. Anisotropy is largest (up to 0.3 s) within the caldera, and weak outside. Fast shear waves are oriented northwest (NW), strongly oblique to Wonji or border faults, but parallel to a cross-rift structure, the Wendo Genet scarp, whose surface expression ends east of the caldera. Deep (20 km) earthquakes are located on this feature using the Corbetti and Aluto seismic arrays alongside Addis Ababa University stations. Intriguingly, shear wave splitting patterns are totally different for a few ray paths which avoid the Wendo Genet fault, indicating that away from this zone of deformation, the usual, rift-parallel faulting behaviour again holds sway. In this instance, the presence of anisotropy strong enough to overprint the background trend may require the alignment of fluids, and possibly melt. We suggest that this is evidence of a nascent transform zone within the rift.