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The interaction and linkage of extension fractures and normal faults in the Koa'e Fault System, Hawaii.

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We use the exceptionally well exposed Koa'e fault system on the south flank of Kilauea Volcano on Big Island, Hawaii, to investigate the relationship between normal faults and associated extension fractures and folds at, or close to the free surface. The Koa'e represents an incipient rift zone that links the South West and East rifts, accommodating <1% extension at surface, and which is driven by gravitational spreading of the volcanic flank. The observed deformation has occurred since the last resurfacing event (400-700 years ago), hence the Koa'e represents an ideal area to study the early stages of fault and extension fracture development in a narrow, active rift. Structures in a 3 km2 area of the Koa'e were mapped remotely using high-resolution satellite imagery and aerial LiDAR-derived datasets. Structural maps were then ground-truthed during intensive structural field mapping, using dGPS to constrain fracture distributions to sub-metre precision and accuracy.

Field mapping has revealed a network of subvertical, segmented normal faults, en echelon extension fractures and monoclinal flexures. Two dominant trends in fault and extension fracture orientation were recorded: (1) an ENE-WSW (080°) trend that parallels the main Koa'e and East Rift axis and displays a dominant NNW-SSE opening direction, and (2) an ESE-WNW (110°) trend of fractures and faults that form a hard linkage between the main 080° bounding faults with opening directions across the 110° fractures are dominantly NE-SW. Analysis of displacement gradients along en-echelon fracture sets can provide evidence for mechanical interaction between individual segments. Some aperture (displacement) versus length profiles show strong asymmetry and high displacement gradients towards fracture tips, possibly reflecting tip interaction and displacement transfer between neighbouring extension fractures. However, other profiles appear to be more symmetric, with little evidence for increased displacement gradients at fault tips, despite the close spatial proximity between neighbouring fractures. Additionally, some hook-shaped interactions have been observed, but straight, underlapping and overlapping fracture traces are more common. Previous mechanical analyses suggest straight crack paths are typical of fracture propagation where the remote differential stress ($\Delta\sigma = \sigma x - \sigma y$; where σx and σy are the remote stresses parallel and normal to the crack traces, respectively) is positive. These results suggest that the fractures associated with the Koa'e fault system developed due to a differential stress with significant crack-parallel compression.

The growth of faults from depth is commonly associated with the formation of extension fractures as the tip line approaches the free surface. We show that these structures develop as complex networks of en echelon extension fractures. The details of these networks can provide important information on how en echelon faults and their secondary structures may interact and evolve into larger fault systems.