Geophysical Research Abstracts, Vol. 9, 05677, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-05677

3D fault connectivity, curvature and segmentation due to oblique extension

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Existing failure criteria for rocks typically assume that fractures are planar and there is little available theory to explain the mechanics of fracture surfaces that are curved. This is at odds with field observations of naturally occurring fracture systems, in which individual surfaces are often observed to be significantly non-planar.

We use terrestrial laser scanning (ground-based LiDAR) to carry out detailed measurements of the 3D geometry of exposed fracture surfaces. The data provide unprecedented detail and allow spatial variation in various curvature parameters (such as normal, mean and Gaussian curvature) to be quantified. Recent laser- scanning work confirms the following qualitative observations previously made during field studies: many fractures are significantly curved; fracture curvature can include areas of cylindrical, elliptical and hyperbolic geometry (where Gaussian curvature is zero, positive and negative, respectively); fractures can curve repeatedly through the mean orientation, to give sinuous fault traces, in which the dip direction changes along the length of the fault.

Laser-scan data from an area of active oblique extension at Arkitsa in the Gulf of Evia, Greece, suggest that some areas of high curvature on fault planes can be caused when smaller slip patches coalesce to form larger fault panels. There is also evidence that the intersection of separate fracture patches can cause slip to be concentrated upon a curved composite surface that combines sections of both the individual intersecting patches, leaving relict sections of patch remaining in the hangingwall of the newly developed fault. However, some slip still clearly localises on these relict patches, causing disruption of the through-going fault plane in the region around the branch-line. Furthermore, the presence of multiple slickenline vectors on the exposed surface of the faults emphasises the 3D complexity of deformation in this region. We present a model in which non-plane strain is accommodated by slip on a number of possible combinations of fault patches, different permutations of which are linked at any given time. In this model, the main focus of slip can migrate by progressive dynamic re-linking of different configurations of fault panels. This process, active on a range of scales simultaneously, may be an effective way to accommodate complex oblique deformation on a regional scale, raising the possibility that it may not be favourable for all fault systems to progressively develop towards long, planar through-going structures.