Fault zone heterogeneity in carbonate successions: field examples from the Maghlaq Fault Zone, SW Malta

Chris Bonson, Conrad Childs & John Walsh

Fault Analysis Group, Department of Geology, University College Dublin, Ireland.
Email: fault@fag.ucd.ie

Knowledge of the structure and content of fault zones is a pre-requisite for the construction of fault zone models and for assessments of fluid capacity and flow behaviour within faulted sequences. In this paper, we summarise field observations of the Maghlaq Fault Zone in Malta which is characterised by localised complexities in fault zone architecture arising from the linkage of an array of fault segments.

The Maghlaq Fault is a >200m displacement, left-stepping, normal fault outcropping in coastal exposures of southwest Malta. The fault displaces Oligo-Miocene, pre- to syn-faulting carbonate sediments, that exhibit a range of deformation styles reflecting their state of lithification during deformation. We focus on the fault zone geometry and fault rocks of the footwall sequence of pre-faulting, and generally, massive limestones that were lithified prior to faulting. Though the footwall fault surface is usually relatively planar and coated with a mm-cm thick zone of fine-grained breccia and cataclasite, heterogeneities in fault zone structure and content are common and can be related to specific linkage-related structures.

Breached relay zones - Deformation within breached relay zones varies with the nature of the faulted sequence and tends to be more complex within massive rather than well-bedded carbonate sequences, because of the space problems associated with accommodating relay-related bed rotations. Ramp rotations predominantly accommodated by flexural slip within well-bedded sequences are instead accommodated by antithetic faults, synthetic faults and bed-parallel slip surfaces that combine to form a linked slip system within massive limestones. This ramp deformation gives rise to fault densities that are one to two orders of magnitude greater than background values.

Branch-lines - Progressive rotation of a relay ramp eventually leads to segment linkage and the formation of a branch-line, the plunge of which depends on the relative orientations of the intersecting faults, but is usually sub-vertical. Continued interaction between the intersecting faults, combined with the often very high strains localised within the intervening rock volume, results in the formation of anomalous thicknesses of coarse fault breccia.

Bends –Increasing displacements on faults that link along branch-lines give rise to an angular fault bend on the footwall fault. Where the axis of this bend is oblique to the fault slip vector the local slip direction swings into parallelism with the axis. In some circumstances this scenario is kinematically unfavourable and the fault bends are modified by abrasion of the footwall to form a cylindrical fault geometry, in which a constant slip direction can be maintained around the bend. Bends are therefore characterised by anomalously thick fault zones which are occupied by decametre-scale lenses of deformed footwall limestone.

The Maghlaq Fault Zone is characterised by increased brecciation and fracturing associated with the linkage of fault segments, along zones that tend to be elongate in the fault slip direction. These findings suggest that the evolution of segmented fault arrays within carbonate rocks, will tend to provide linear zones of enhanced vertical permeability at pre-existing segment boundaries.