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The interaction between antecedent drainage networks and normal fault propagation

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Research on landscape evolution around normal fault arrays has helped further understanding of the spatial and temporal evolution of sediment supply and drainage network development in evolving footwall uplands. Detailed analysis of specific well-constrained catchments and sequence stratigraphy of depositional systems have stressed the importance of fully understanding the complex interactions between relative sea-level, sediment supply and tectonics when attempting to deconvolve the signals from a long since eroded hinterland. Analysis and interpretation of coupled catchment-deposition systems, however, still tends to focus on individual channels within a fault system assuming that the channel has been fixed through time to feed a specific location in the basin. Knowledge of the controls and feedbacks at larger scales is still required.

A three-dimensional numerical model of erosion and clastic sedimentation is applied to investigate the effect of displacement on a normal fault to the distribution of sediment in an extensional basin and the modifications that varying fault activity exerts on an antecedent drainage network. Material is eroded from the hinterland through a stream-power incision law and deposited in the basin using a modified diffusion algorithm. An initial topography is generated to steady state. It comprises approximately 10 major basinward channels and is perturbed by the introduction of a propagating 15 km long normal fault. Experiments are implemented for 2Myr where the fault experiences differing displacement rates (1.0m/kyr - 2.0m/kyr), propagation rates, location and activity within the 2Myr to demonstrate the influence of the propagation of an isolated normal fault on drainage capture, network re-organisation, sediment routing and deposition.

Faster displacement rates cause footwall-derived deltas to be cut-off more rapidly from the hinterland source area. Drainage networks are re-organised such that sediment is transported around the fault tips into axially sourced deltas. Sediment can continue to be deposited in the hanging wall at the fault centre, but this material has not been sourced directly from the adjacent footwall, even though the stratigraphic architecture might suggest it. Drainage networks are modified by drainage reversals in the antecedent channels, and the development of areas of abandoned/trapped drainage are common. Changes in sediment supply due to network re-organisation are also reflected in the basin stratigraphy, with rapid back-stepping of deltas when the source is diverted elsewhere in the basin. Later incision and headward erosion of the footwall channels may cause re-capture of earlier channels, while network re-organisation causes depositional in-filling of earlier channels. The drainage divide shifts basinward as fault displacement rate increases, resulting in smaller footwall-derived deltas. The length of time a fault is active is also key in interpreting results from basin stratigraphy, where fault death can rapidly alter drainage networks and deposition locations. The location of the fault within the pre-existing drainage network exerts a control on the likelihood of channels to incise the rising footwall.

These models show that antecedent drainage networks and fault displacement history represent important controls on the along-strike variability of stratigraphy associated with displacement on normal faults. Furthermore, the history of sediment routing may be more complex than the most straightforward interpretation of the stratigraphy.