Testing the impact of contrasting fault growth models on syn-rift stratigraphy using forward stratigraphic modelling.

Eoin O'Donnell[1,2], Peter Haughton[1,2], Lawrence Amy[1,2], Conrad Childs [1,3], Cedric Griffiths [4]

1 Irish Centre for Research in Applied Geoscience, University College Dublin.
2 UCD School of Earth Sciences, University College Dublin.
3 Fault Analysis Group, School of Earth Sciences, University College Dublin.
4 Curtin University, Perth, Australia.

1. Introduction

Intrabasinal transfer zones or relays are potentially important entry points for drainage systems to extensional basins (Figure 1).

Relays may form and evolve in two ways - **isolated** fault segments can lengthen to overlap and link, or the faults may overlap from an early stage forming a **constant length** fault system on which displacement accrues without an increase in length (Figure 2).

Forward stratigraphic modelling of the alternative fault relay models using SedSim has been undertaken to examine the stratigraphic consequences of the different styles of relay evolution.

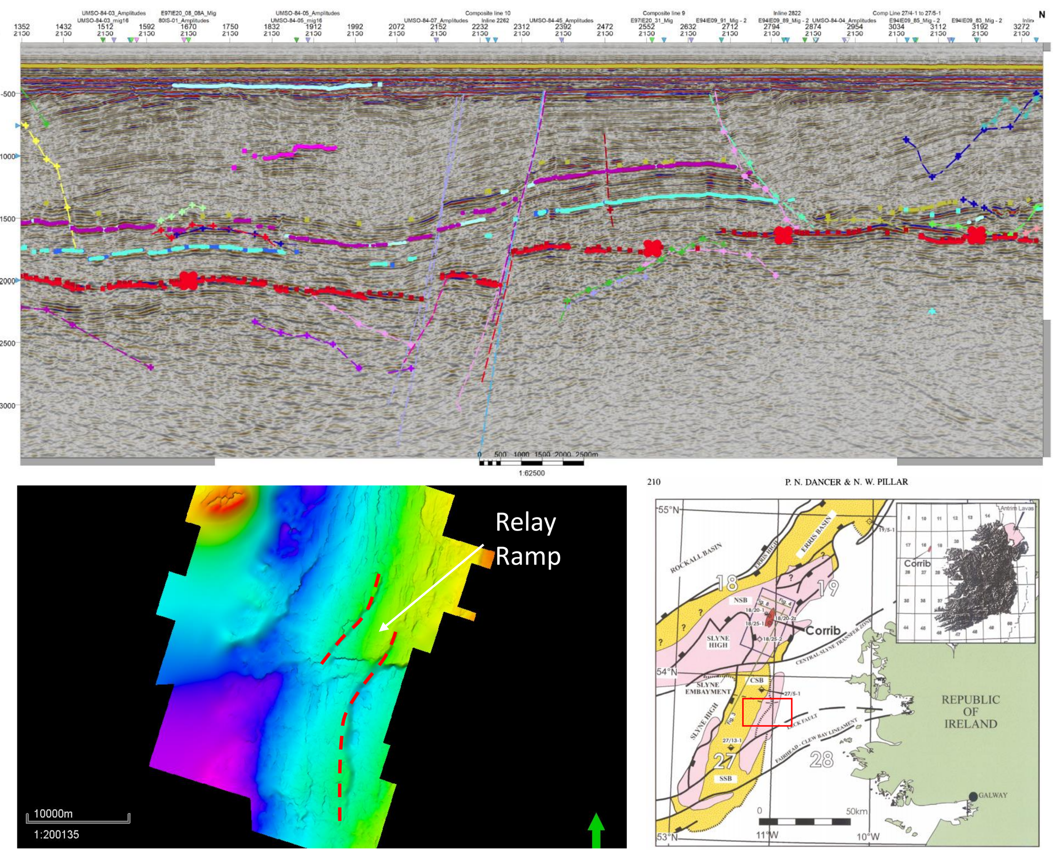
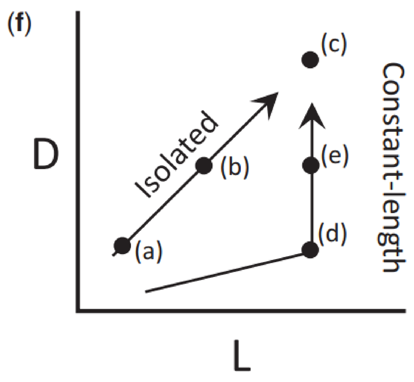
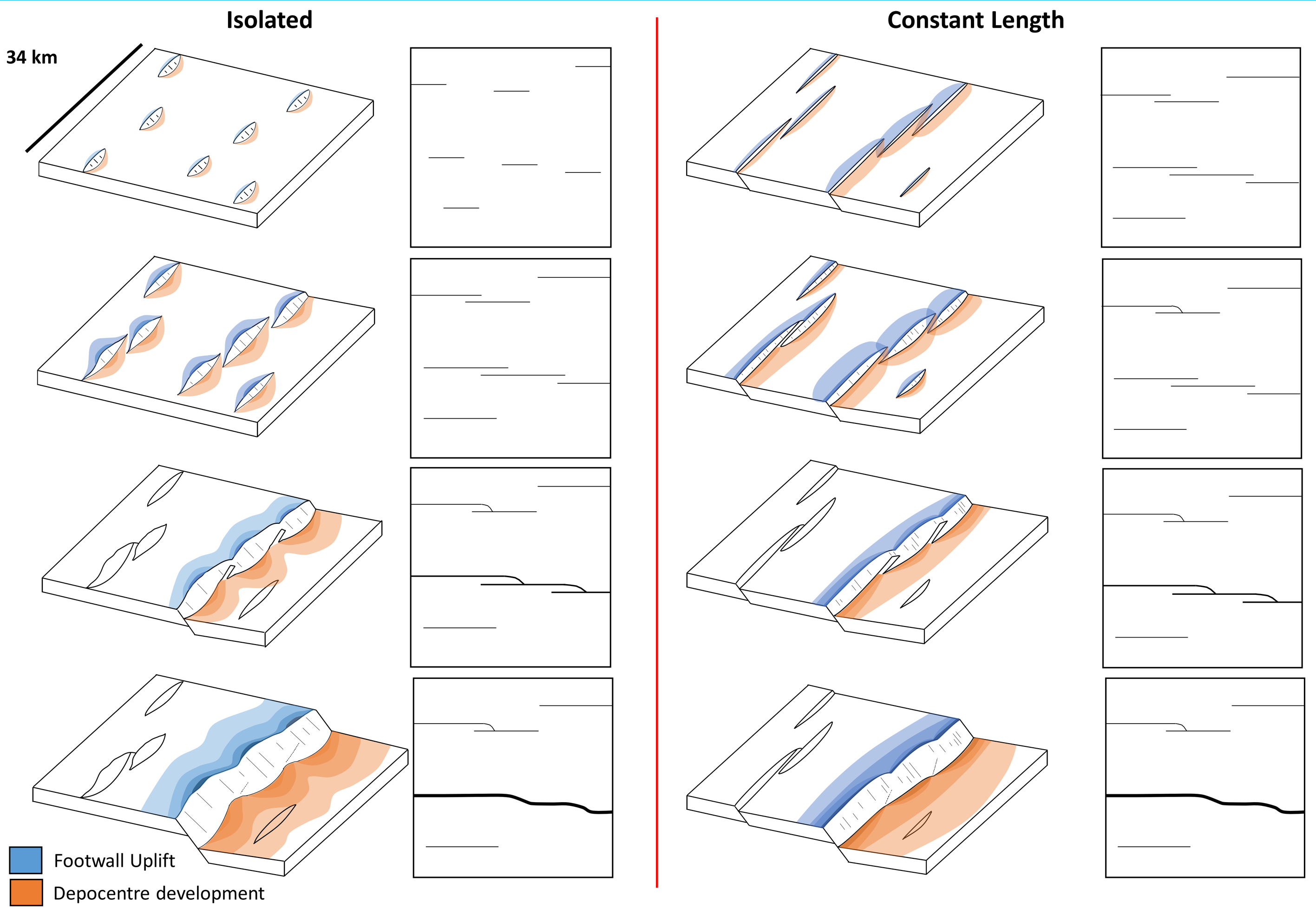


Figure 1. Seismic section from Slyne Basin Offshore Ireland displaying an interpreted surface offset by a relay ramp. Seismic courtesy of the Petroleum Affairs Division and cross section and interpretation provided by O'Sullivan, C. (HC4.2PhD2).

*Figure 2. Alternative models for relay evolution. The **Isolated** model envisages that the segments of a fault array originate as a series of isolated faults. As extension proceeds these faults systematically increase in both length and displacement until they interact and form a relay. In the **Constant length** model, fault length is established rapidly with relay zones forming between fault segments under low strain. Subsequent fault growth is achieved by an increase in fault displacement with minimal change in fault length (Walsh et. al, 2002)*



Childs et. al, 2017



2. Forward Stratigraphic Modelling

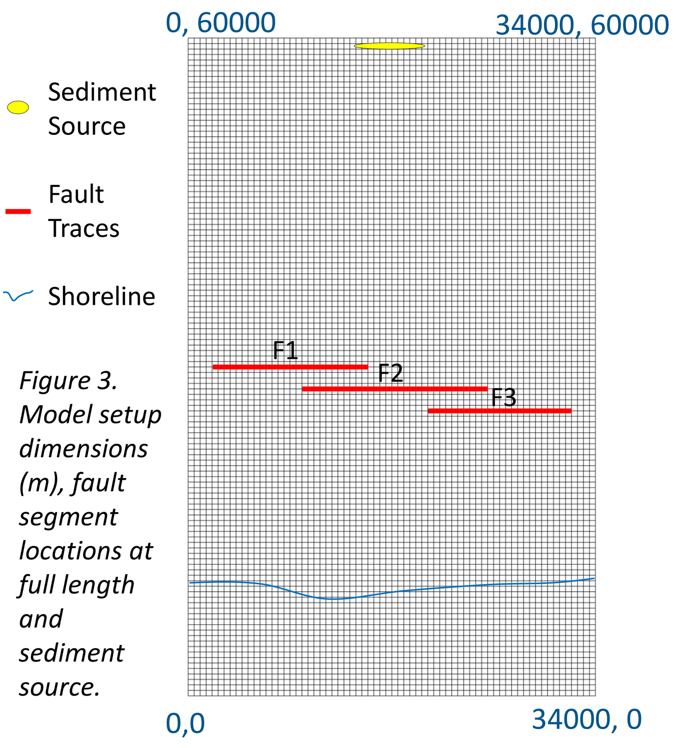


Figure 3. Model setup dimensions (m), fault segment locations at full length and sediment source.

Three fault segments exist in the model. The **isolated** faults initiate as 5 km long segments and increase in length until achieving their final length of 15 km.

The **constant length** faults achieve a length of 13 km in the first 1 Myr and accrue only 2 km of length before reaching their final length of 15 km.

The faults undergo a maximum displacement rate of 0.5 mm/yr

Breaching occurs when the displacement on the fault is ¼ the fault overlap distance.

Sediment is released into the system at a constant rate for 10 Myr . The tectonic input then deforms this surface for a further 5 Myr.

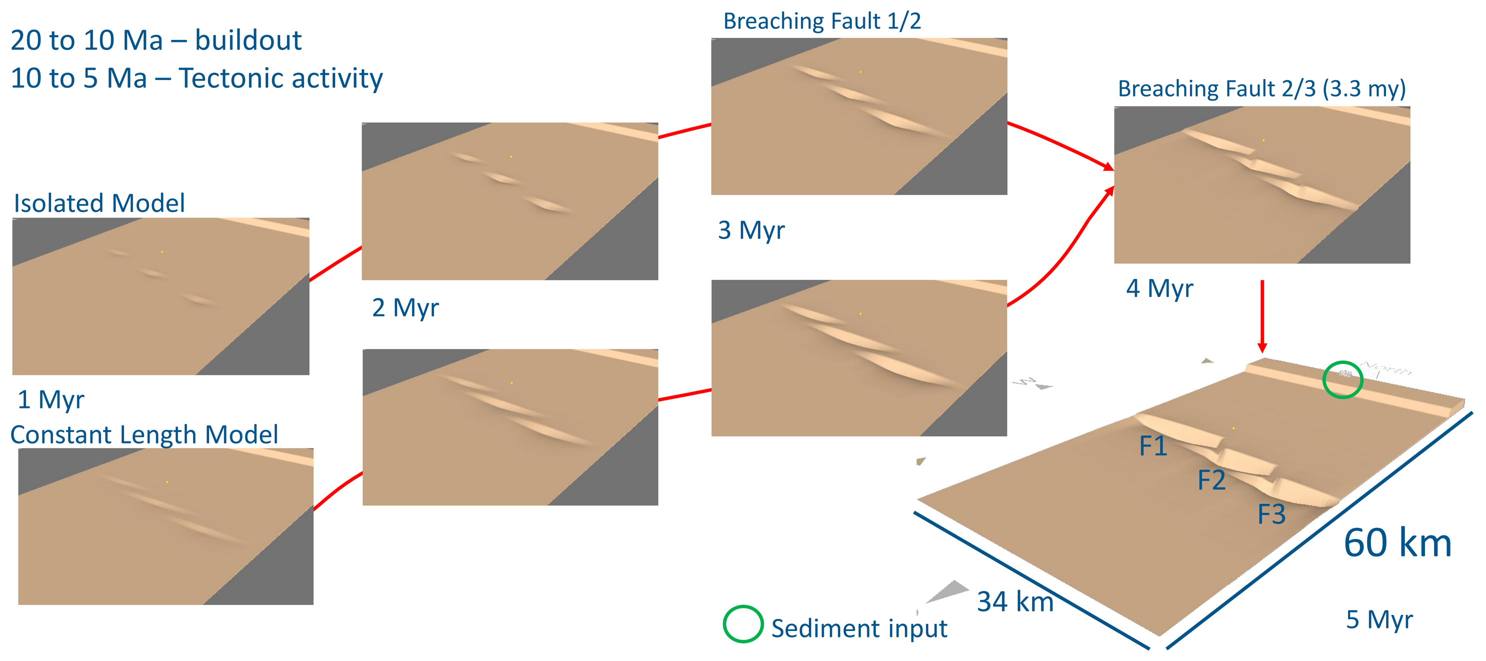


Figure 4. Tectonic input reflecting the two growth models being tested. Three fault segments evolve by the Isolated or Constant Model. Their individual fields of deformation are allowed to interact and produce relay ramps between segments until breaching occurs between 3 and 3.3 Myr.

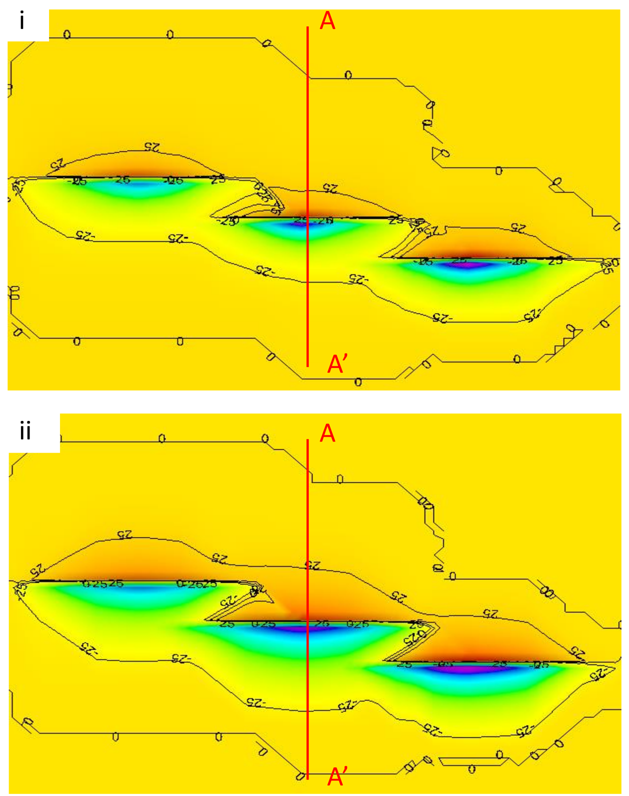


*Figure 5. Deformation fields associated with the three fault segments at 3 Ma. Lows between the fault segments persist in the **Isolated** model **(i)** and the hanging well depocentres are poorly connected. In the **Constant length** model **(ii)**, the depocentres are better connected and the area of footwall uplift spans all three segments.*

3. Modelling Results

Model results for the initial 3 million years of fault-controlled deposition, until relay breaching are shown in Figures 7 & 8 for (i) the **Isolated** model and (ii) **Constant length** model. Base level and sediment input (conc. 0.1 kg/m3) remained constant for the duration of the experiments. One set of experiments (Figure 7) used a constant water discharge of 10 m^3/s and a second set (Figure 8), a discharge of 50 m^3/s. The cross sections depict the input displacement (solid lines) and the observed output surface elevations (dashed lines) for the footwall and hangingwall immediately adjacent to the fault traces, and thickness maps (m) indicating deposition of coarse material (green) and erosion of sediment in red.

Sediment pathways, as highlighted by red erosional channels, are predominantly directed around the tips of the fault array in the **constant length** model at both discharge values (Figure 7B,D,F & Figure 8B,D,F). Trenching of flow across the footwall along the length of the faults also occurs and is more common in the higher discharge experiment and fed coarse transverse fans in the hangingwall (Figure 8D,F). Significant erosion of the footwall is also highlighted in the cross sections of Figure 8. ii. at 3 Myr.

In the **isolated model** the channels flow both around the fault tips and across the overlapping zone between the fault segments, making use of the topographic low that persists here. Major sediment entry points are thus seen via the relay ramps (Figure 7C,E & Figure 8C,E) up until breaching. This is highlighted by the deposition of coarse material at the base of the relay ramps as well as the erosion of fault tips in the vicinity of the ramps (Figure 7E & Figure 8C,E). Analogous incision at fault overlap zones during isolated fault growth has been reported by Kairanov et al. (2019) in the Lower Cretaceous of the Barents Sea.(Figure 9).

The depositional extent of coarse material (in green) also highlights the greater areal and volumetric extent of the depocentres that develop in the constant length model (Figure 8B) in comparison to the isolated model (Figure 8A) the extents of which are confined by the isolated geometry of the fault segments and their associated depocentres.

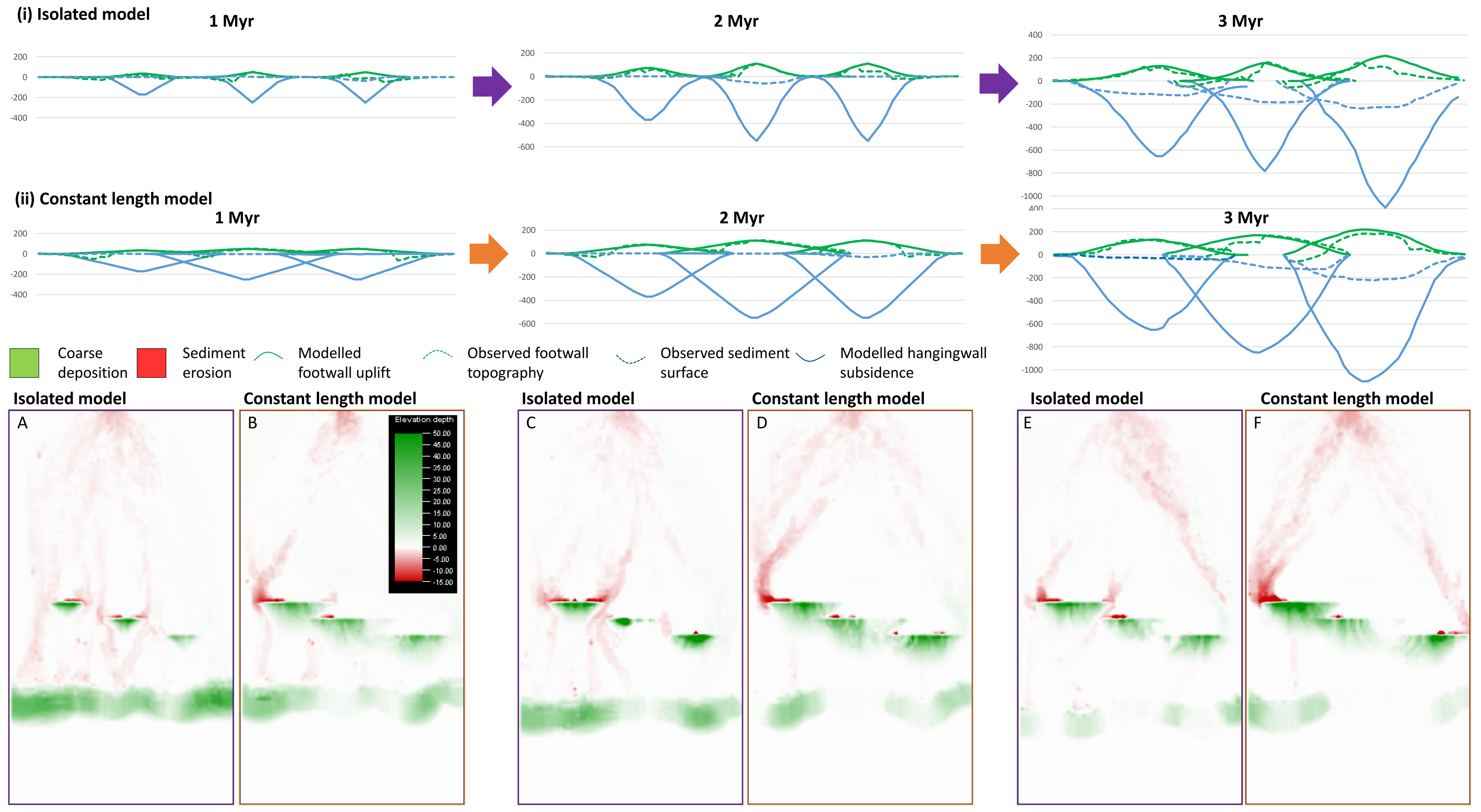


Figure 7. Isolated and Constant length model results with a sediment source discharge of 10 m3/s.

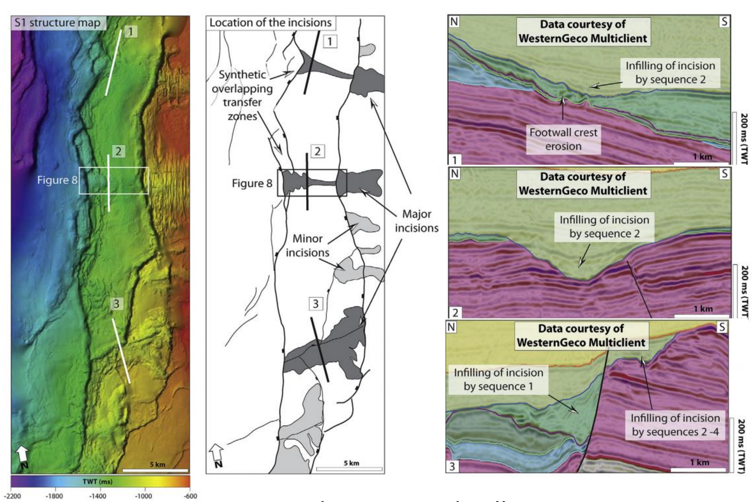


Figure 9. Structure map and interpreted valley incisions (Kairanov, 2019).

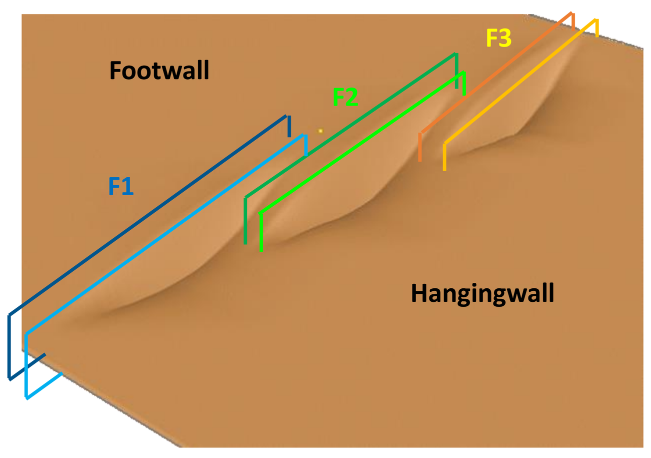


Figure 10. Cross section locations.

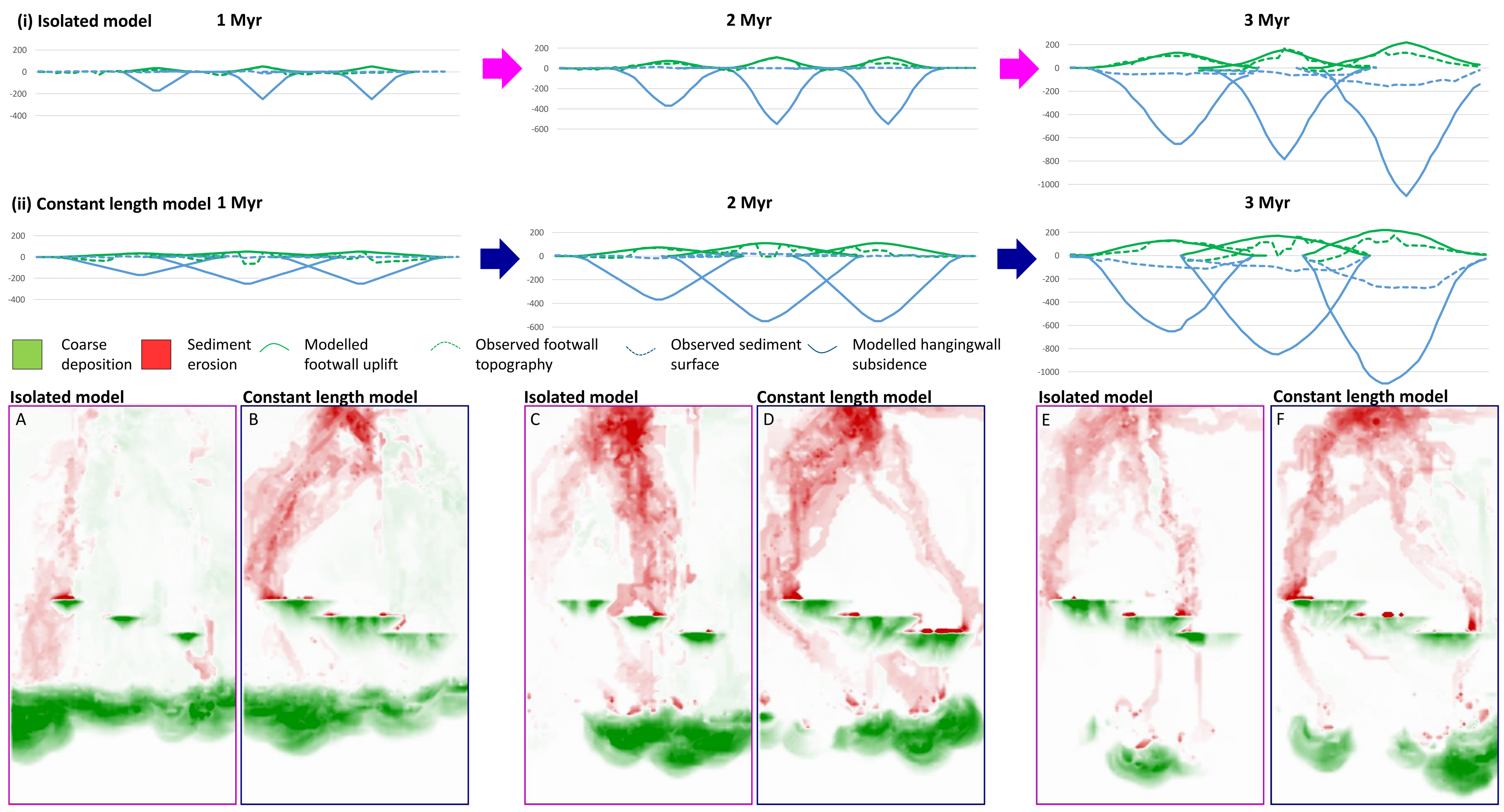


Figure 8. Isolated and Constant length model results with a sediment source discharge of 50 m3/s..

4. Conclusions and Future Work

1. The fault growth model has an impact on the sediment entry points in an array of overlapping fault segments with relay ramps.
   a) The Isolated model promotes the use of relay ramps
   b) The Constant length model shows flow dominantly as around the outer fault tips and transversely
2. The location of the coarse material is reflected by the dominant sediment entry point
   a) Fans of coarse material seen at the foot of relay ramps in the Isolated model
   b) In the Constant length model the greatest thickness of coarse material is seen at the outer fault tips and associated with trenching across the footwall.
3. The trapping efficiency is greatly increased in growth by the constant length model due to the areal extent and connection of the depocentres from early in growth history.
4. This modelling experiment examined footwall sources feeding the fault controlled depocentre, future work will investigate the sediment sources on the hangingwall.

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