Conjugate relay zones and transfer of displacement between faults of opposed dip

Conrad Childs, Rob Worthington, John J. Walsh, Vincent Roche & Conor O'Sullivan

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Conjugate relay zones: geometry of displacement transfer between opposed-dipping normal faults

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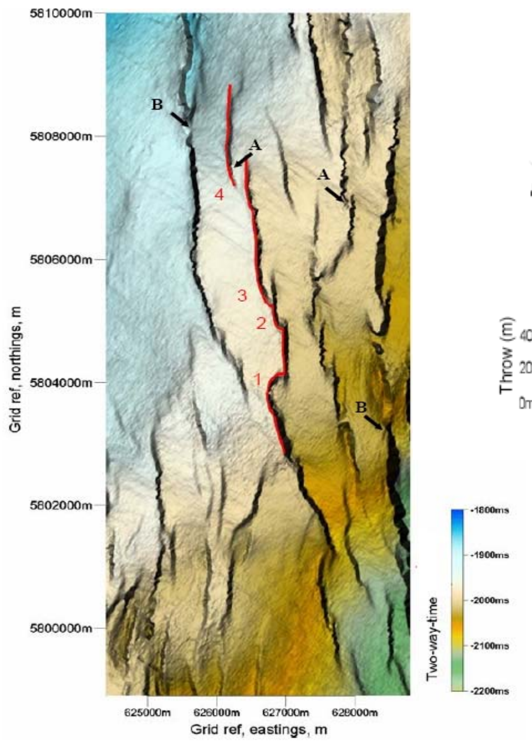
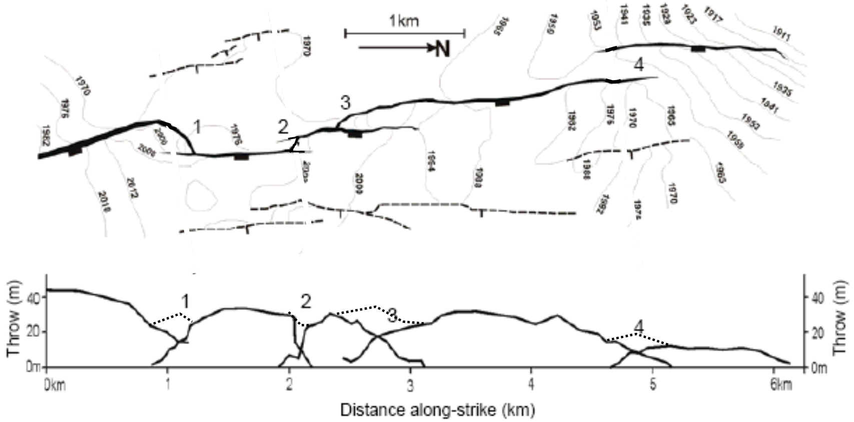




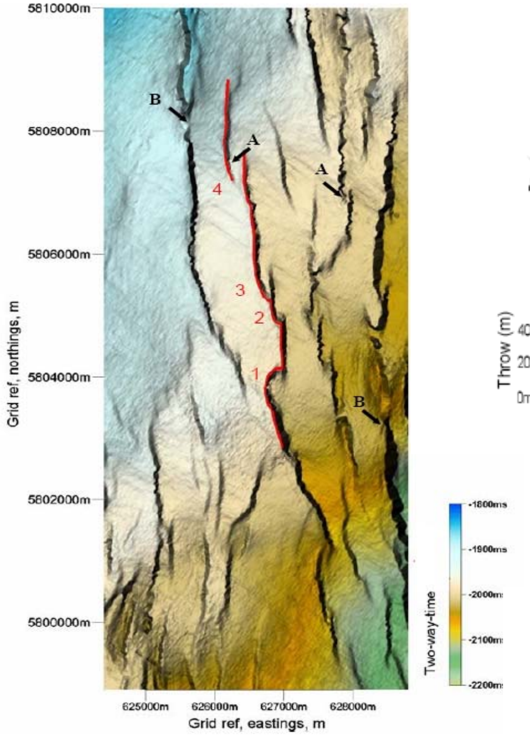
Worthington 2006

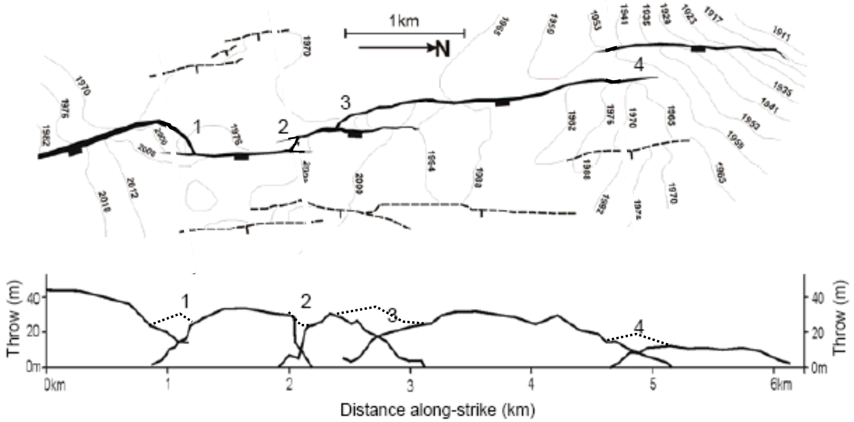
Introduction

Faults comprise segmented arrays

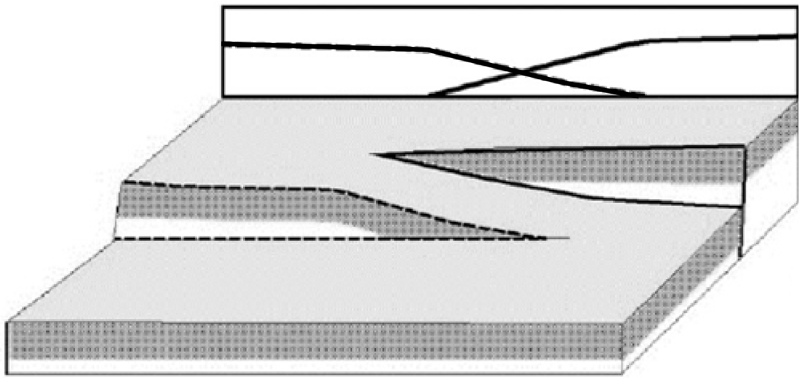
The summed displacement resembles the displacement distribution on a single fault

Geometric coherence (Walsh and Watterson, 1991)



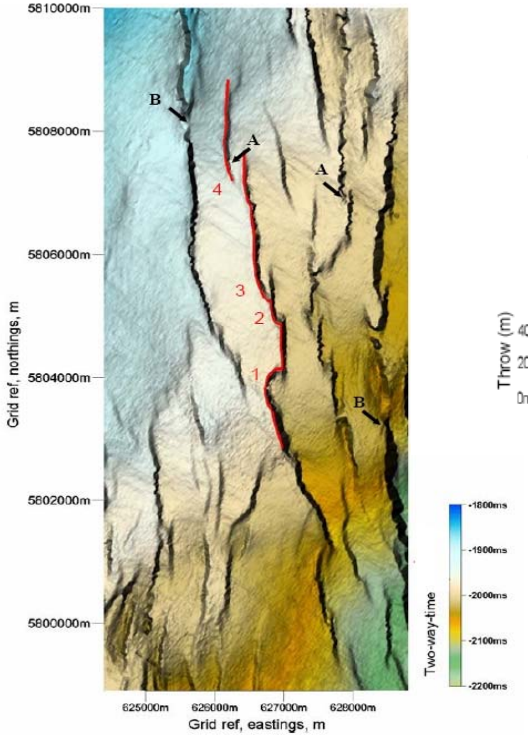


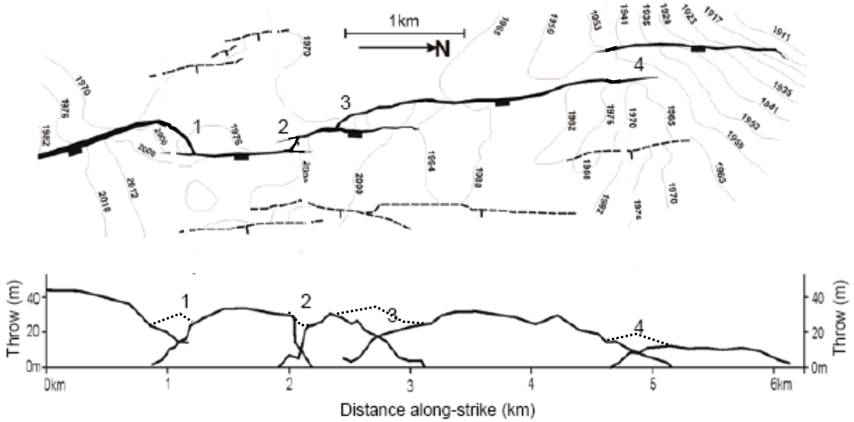
Worthington 2006



Introduction

Displacement is transferred between adjacent segments across relay zones or relay ramps



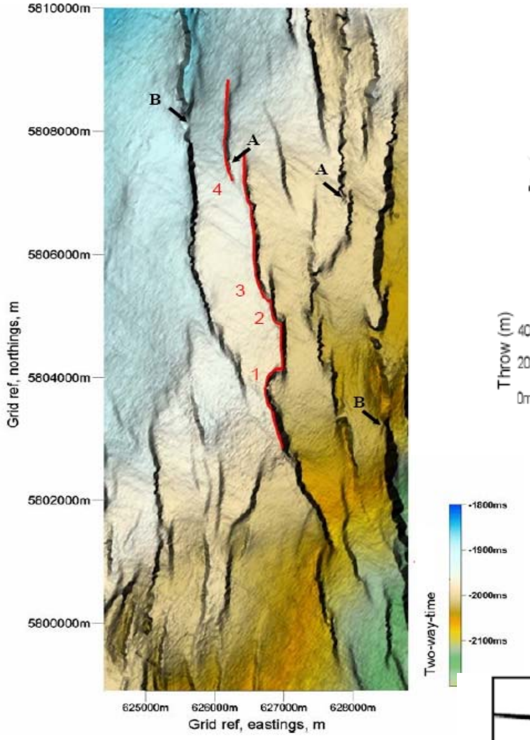


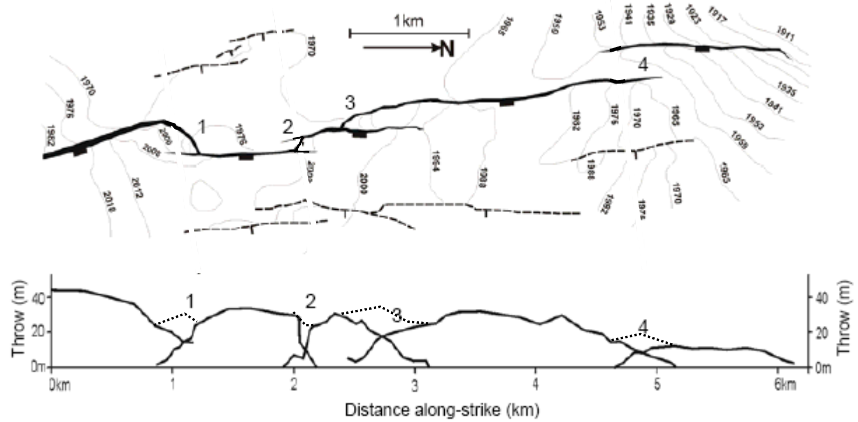
Worthington 2006

Kilve, Somerset

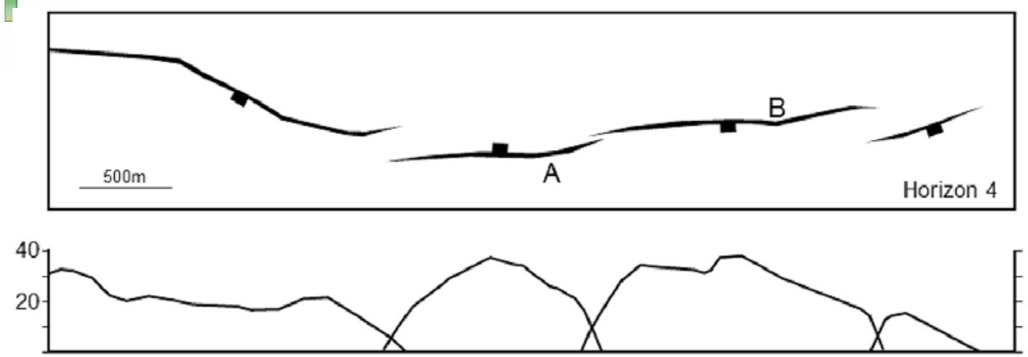
Introduction

Displacement is transferred between adjacent segments across relay zones or relay ramps





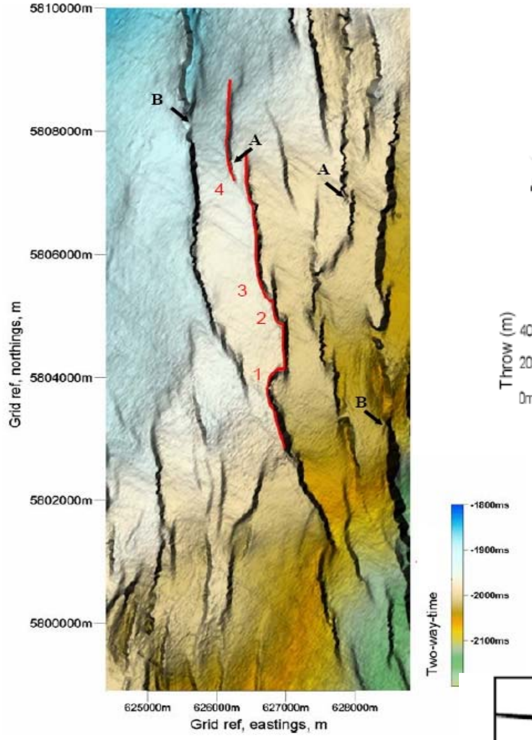
Worthington 2006

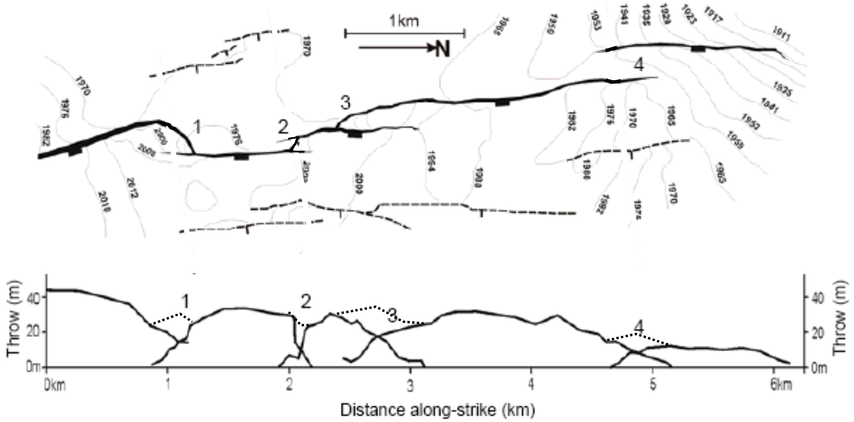


Introduction

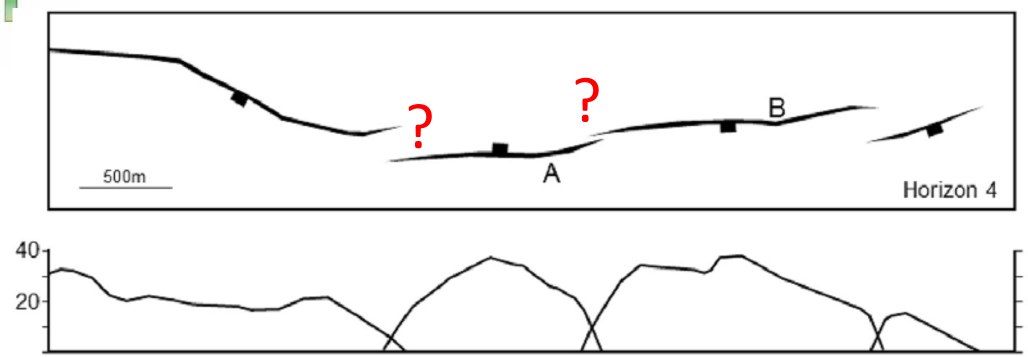
Sometimes segments within a fault array dip in the ‘wrong’ direction

Boundaries between segments are referred to as **conjugate relay zones**





Worthington 2006



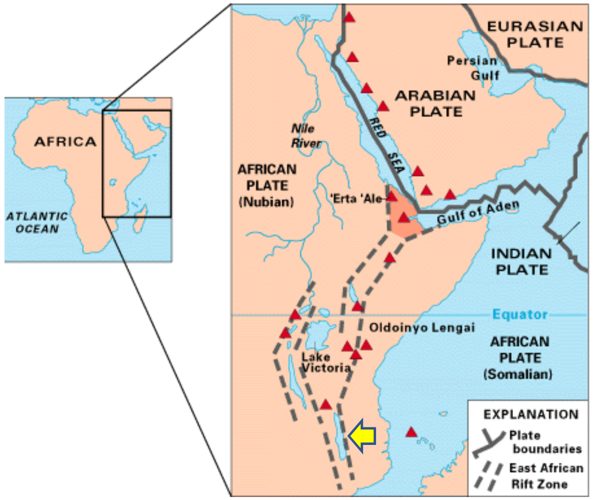
Introduction

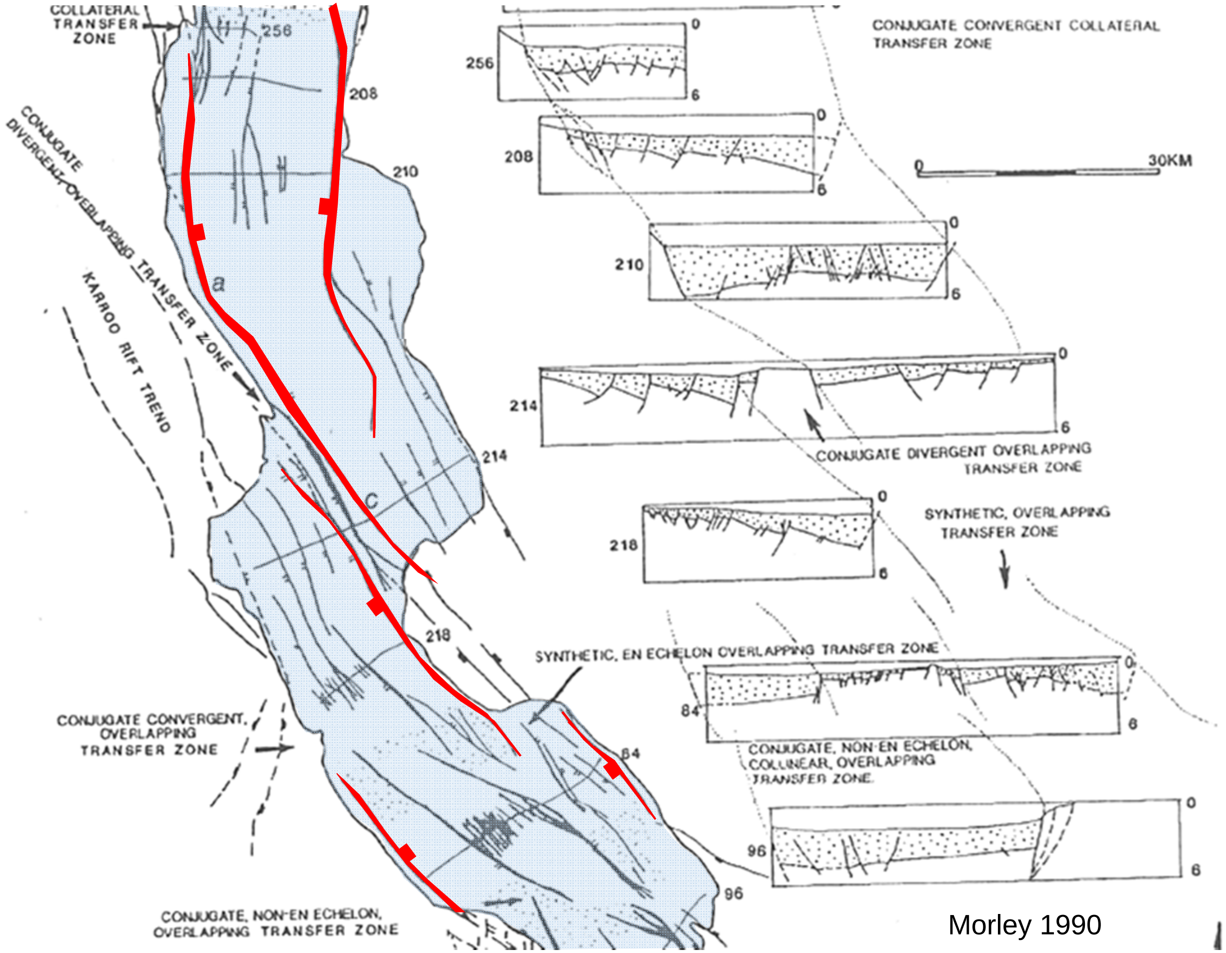
Sometimes segments within a fault array dip in the ‘wrong’ direction

Boundaries between segments are referred to as conjugate relay zones

What do these segment boundaries look like and how is displacement transferred across them?

Lake Malawi – accommodation zones

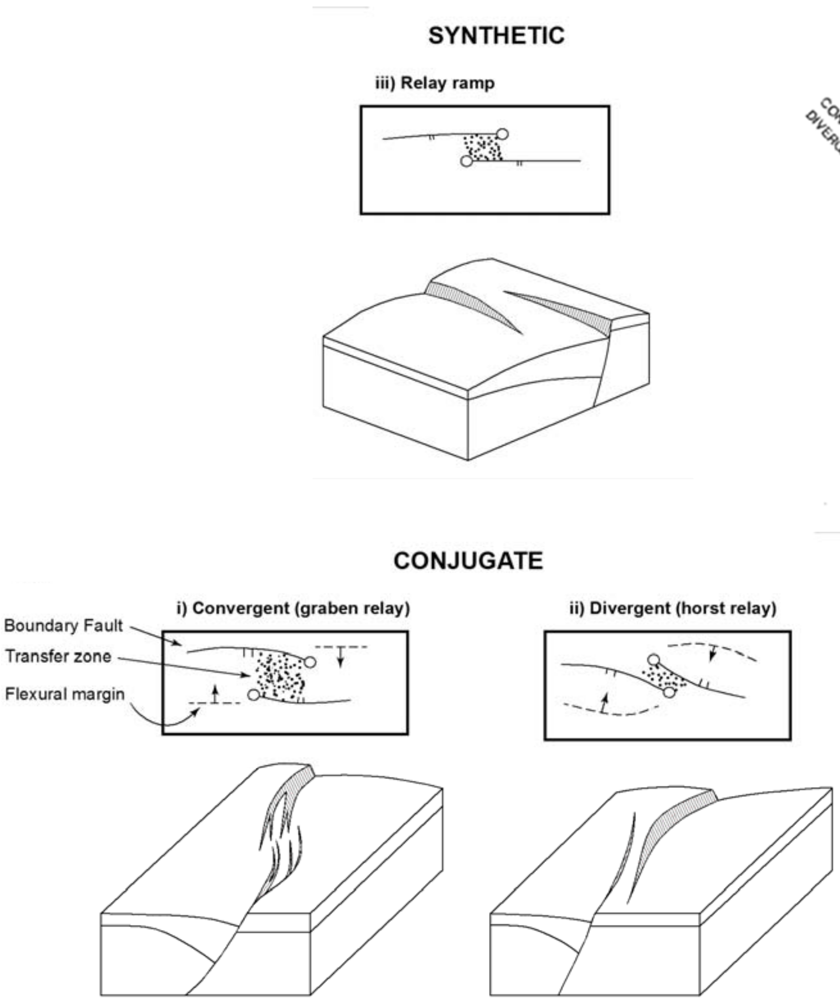


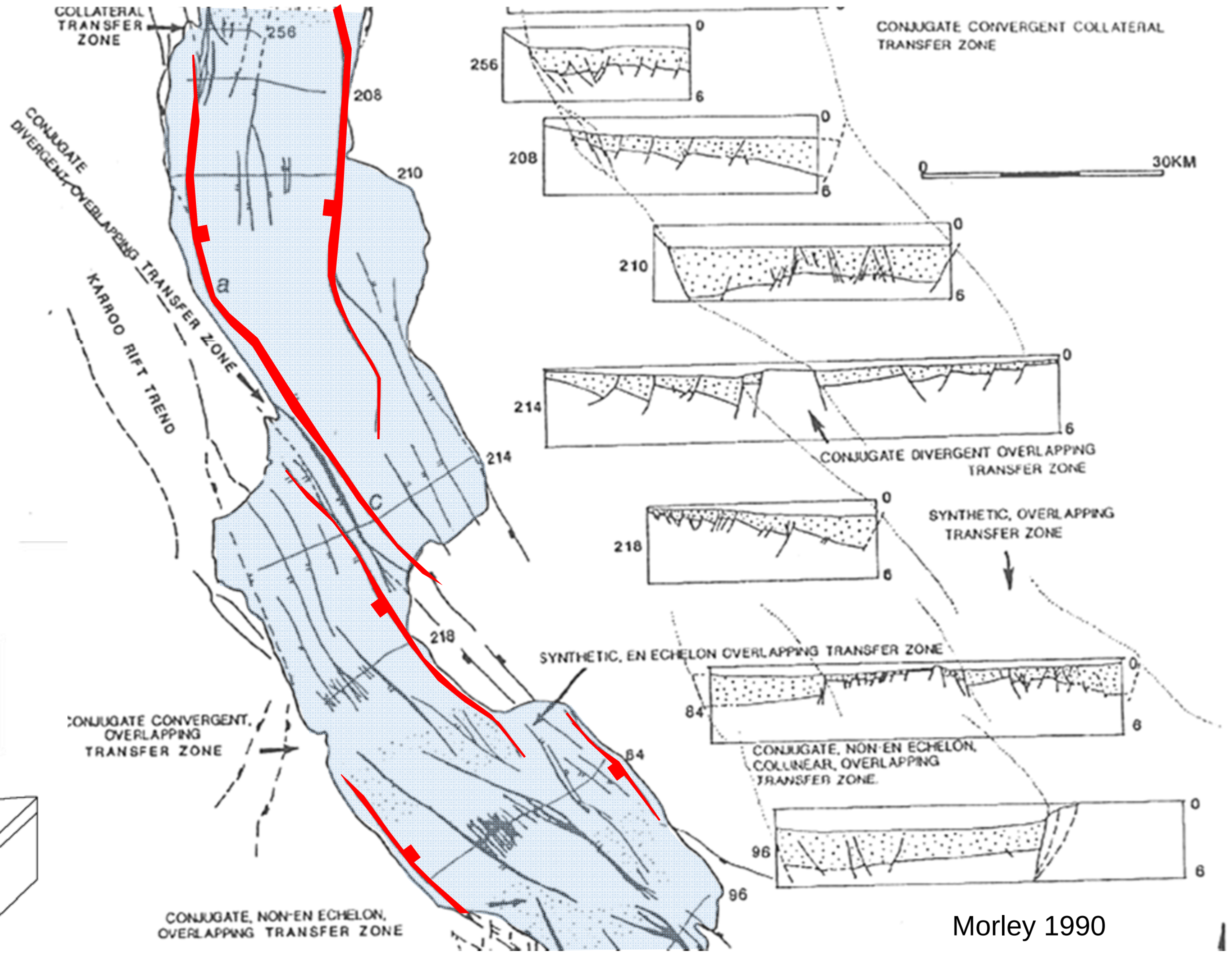


Morley 1990

The answer to these questions may be relevant to accommodation zones between basin-bounding faults

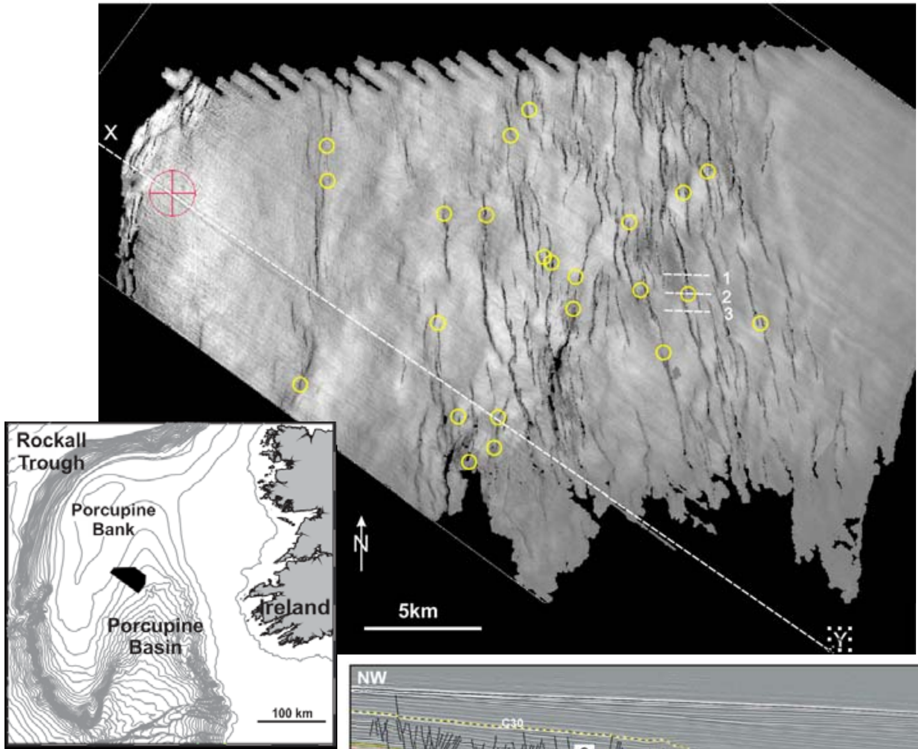
Lake Malawi – accommodation zones





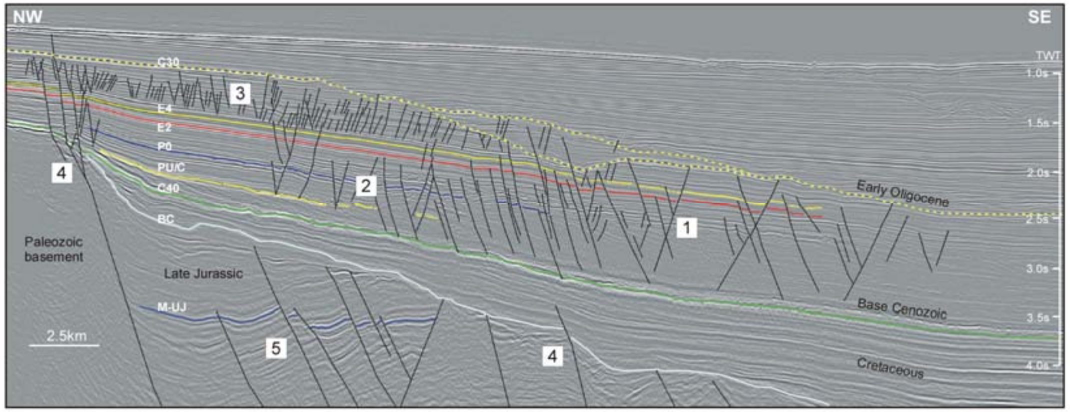
Morley 1990

Porcupine Basin



Mid Eocene surface (E4)
– *coherency attribute*

○ Conjugate relay zones



Worthington 2006

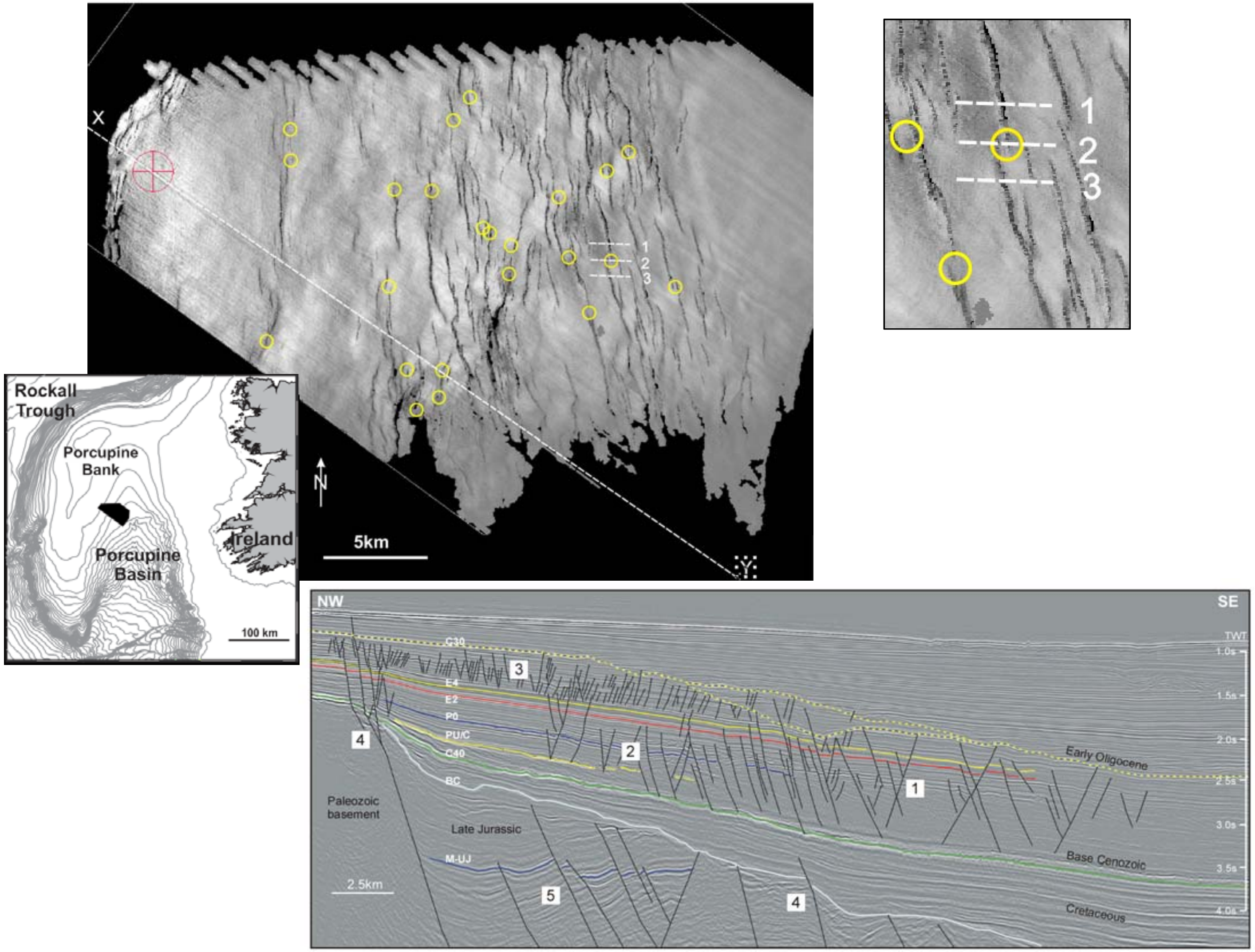
Layerbound normal fault system (1) within mud-dominated post-rift sequence

Cenozoic gravity driven fault system

Good quality seismic data

~N-S strike and up to 85 m throw

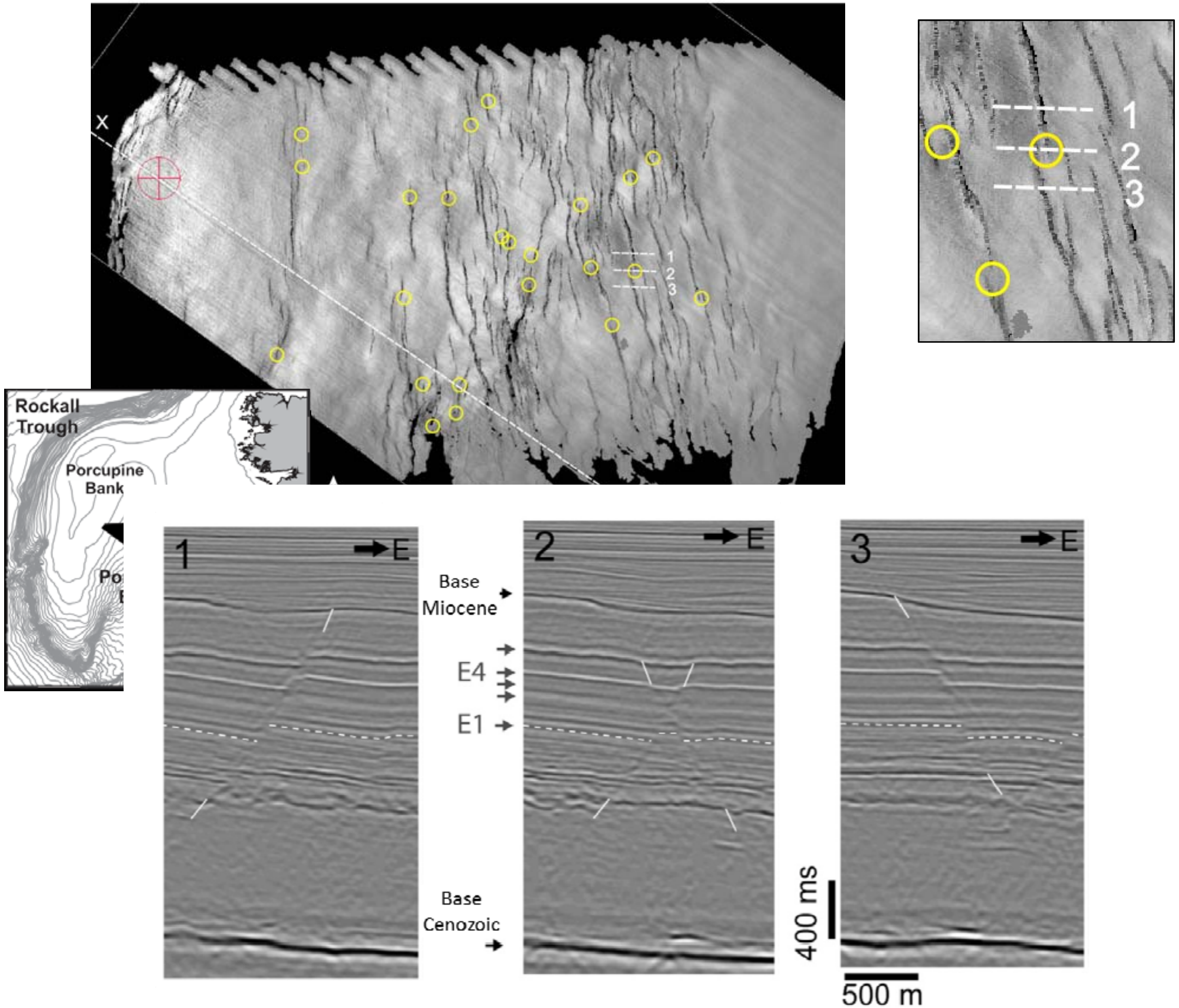
Roughly equal number of east- and west-dipping faults



Worthington 2006

Porcupine Basin

Detailed geometry of a typical conjugate relay zone



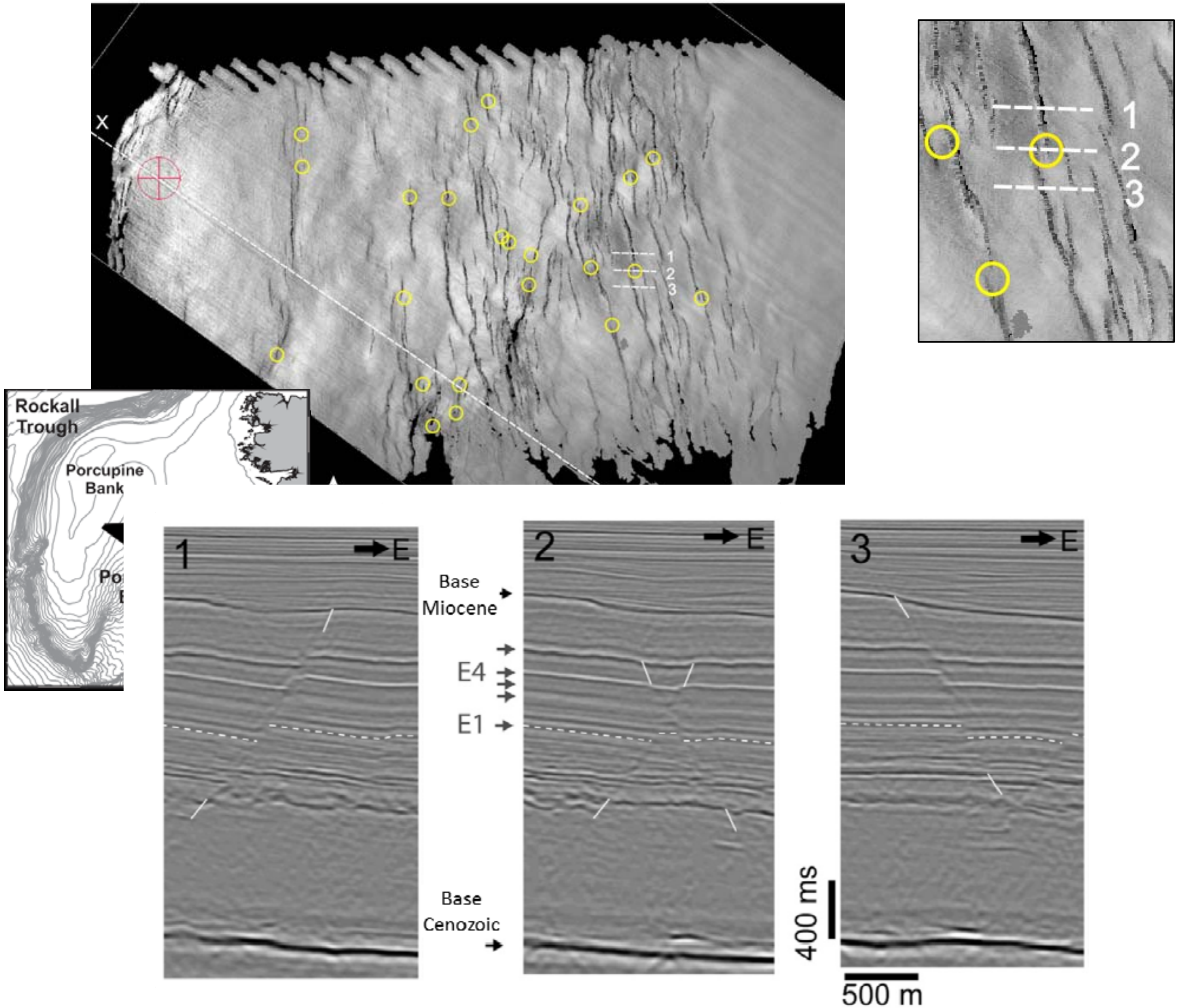
Porcupine Basin

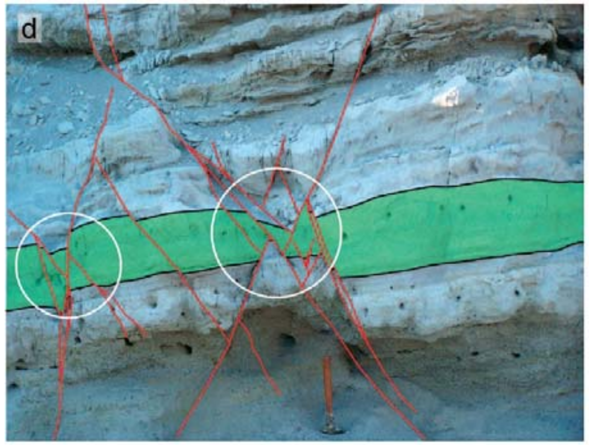
Seismic sections across a representative conjugate relay zone

The two opposed dipping faults intersect where they overlap one another

Porcupine Basin

Mutual cross-cutting faults at the line of intersection (not talking about this).

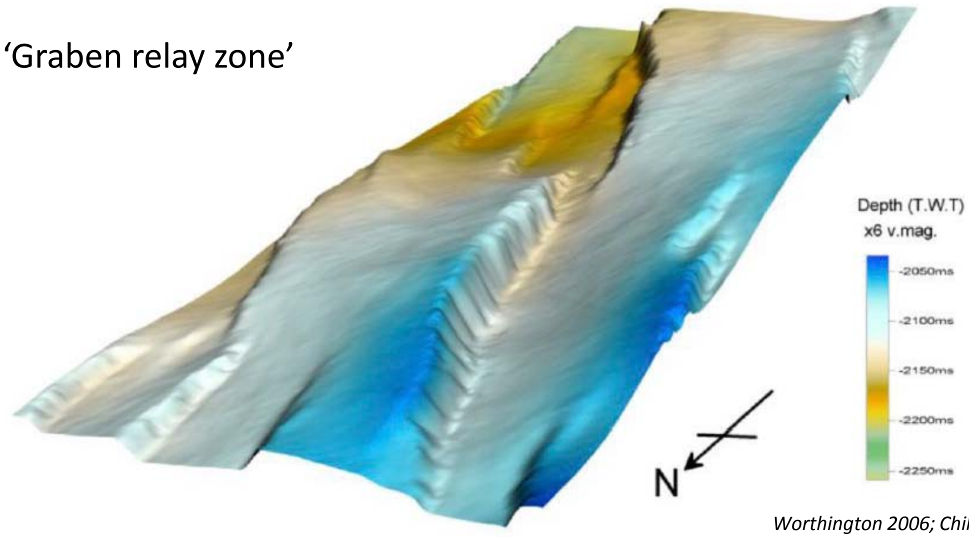




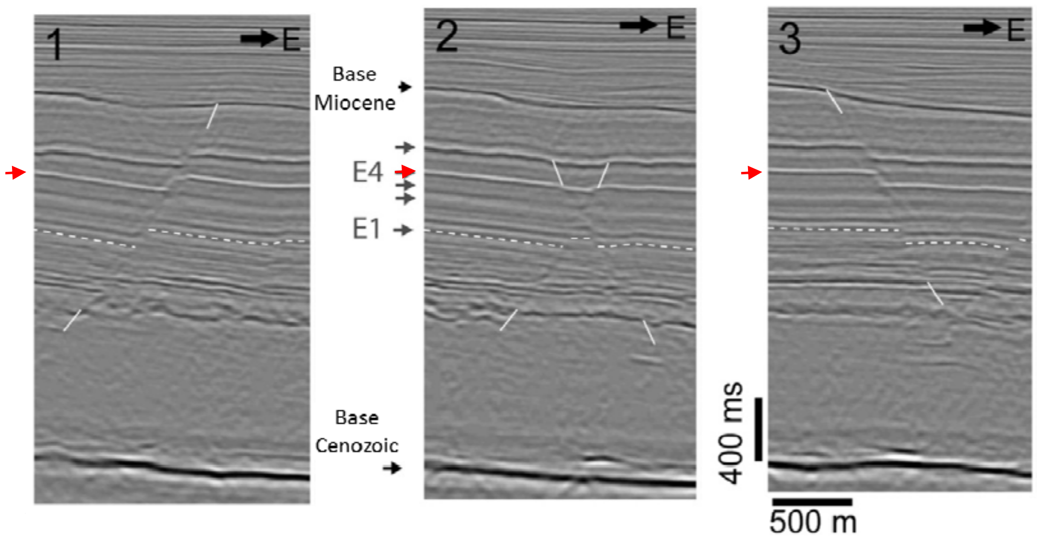
Ferrill et al. 2009

Porcupine Basin

‘Graben relay zone’



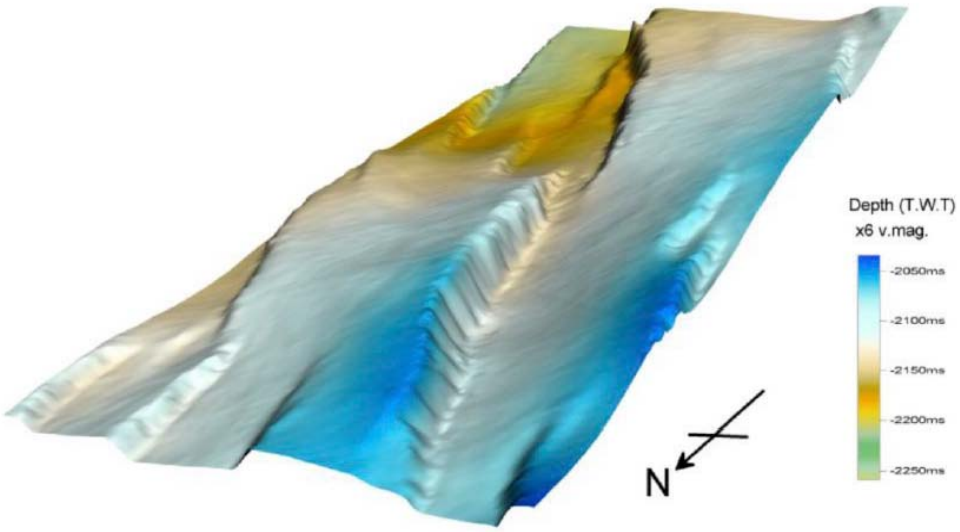
Worthington 2006; Childs et al. 2019

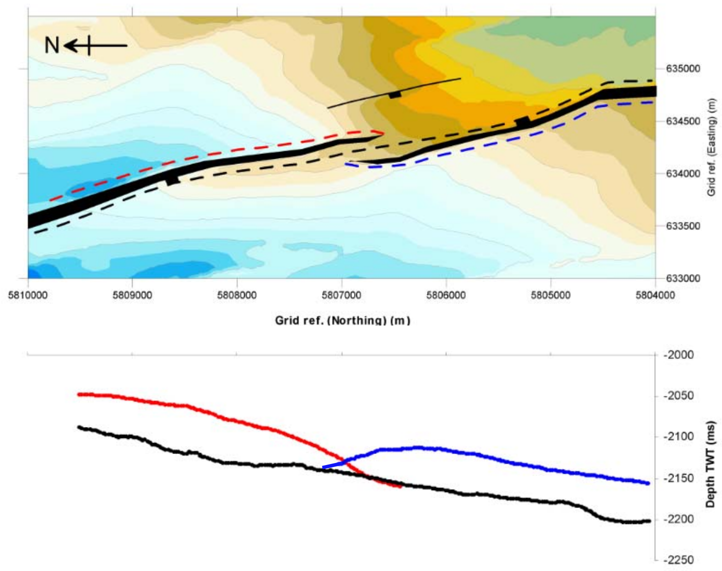


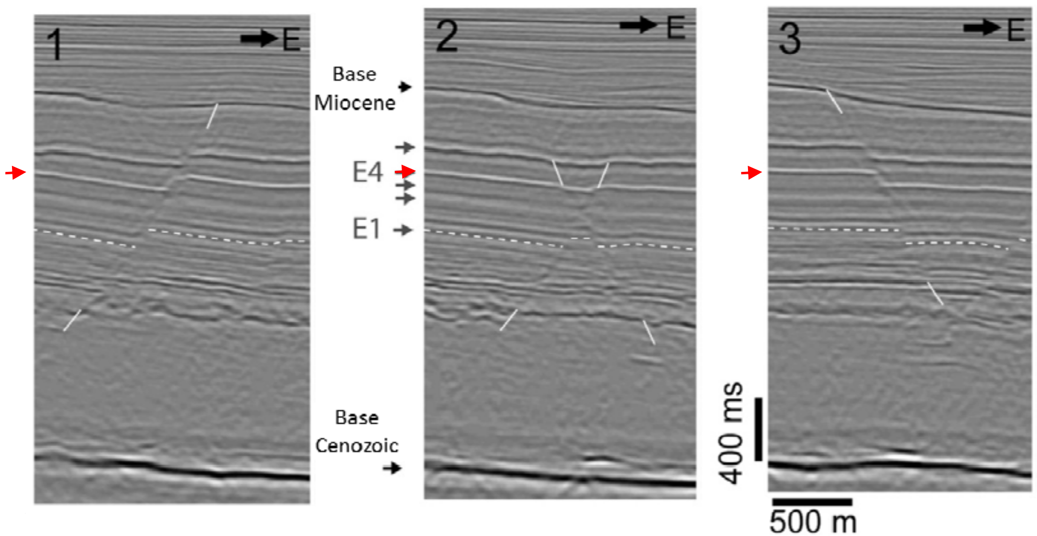
Seismic sections across a representative conjugate relay zone

Above the line of intersection the faults form a graben in cross-section

Porcupine Basin



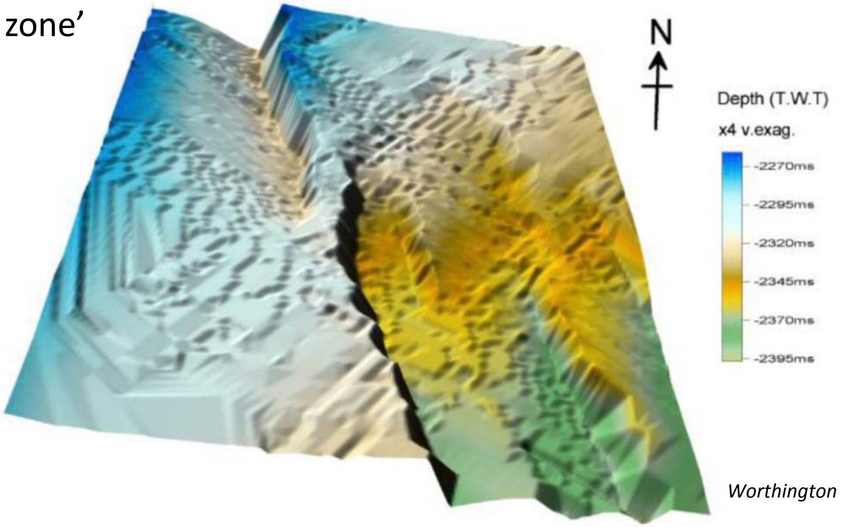




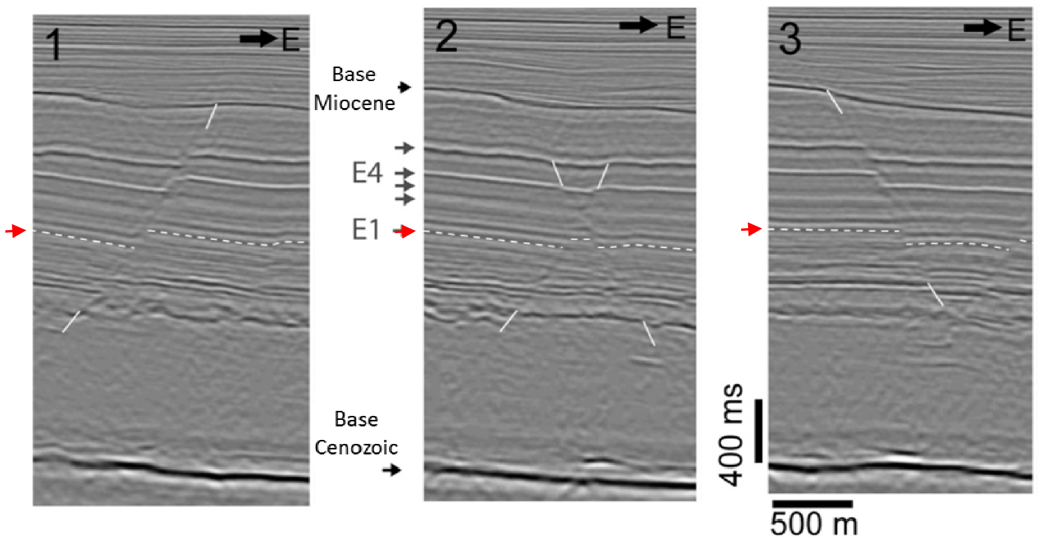
Flat topography between the opposed dipping faults. Displacement changes accommodated by change in footwall elevation.

Porcupine Basin

‘Horst relay zone’



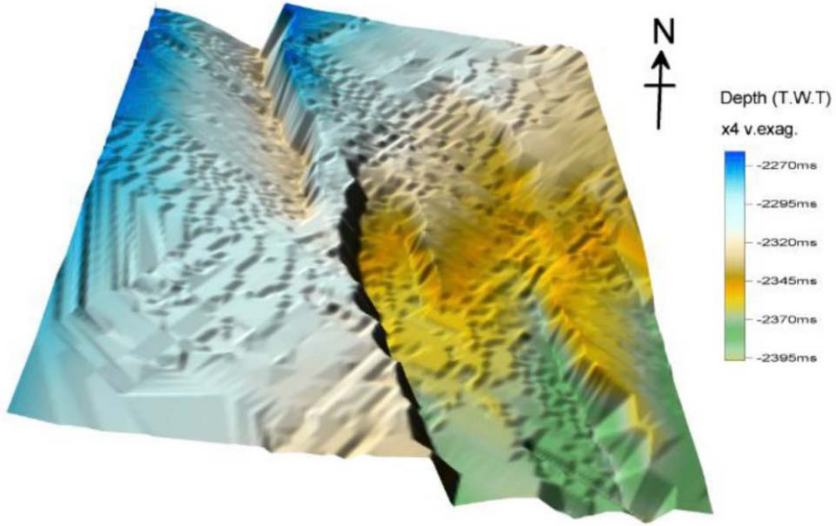
Worthington 2006; Childs et al. 2019

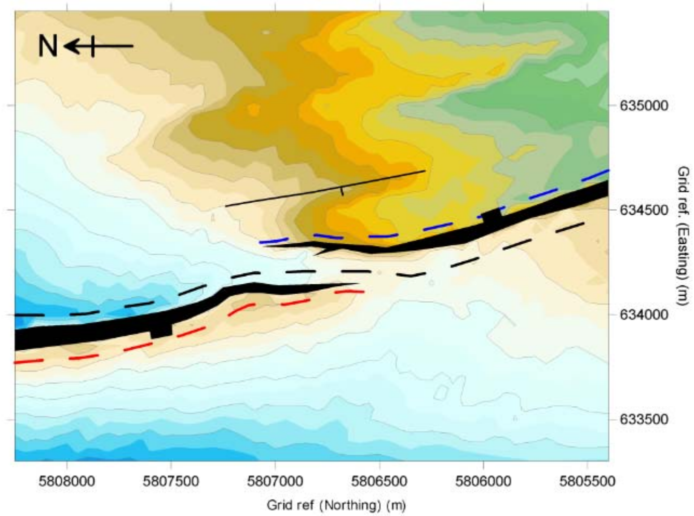


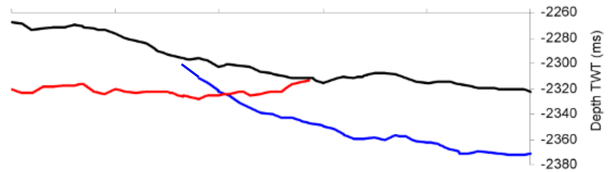
Seismic sections across a representative conjugate relay zone

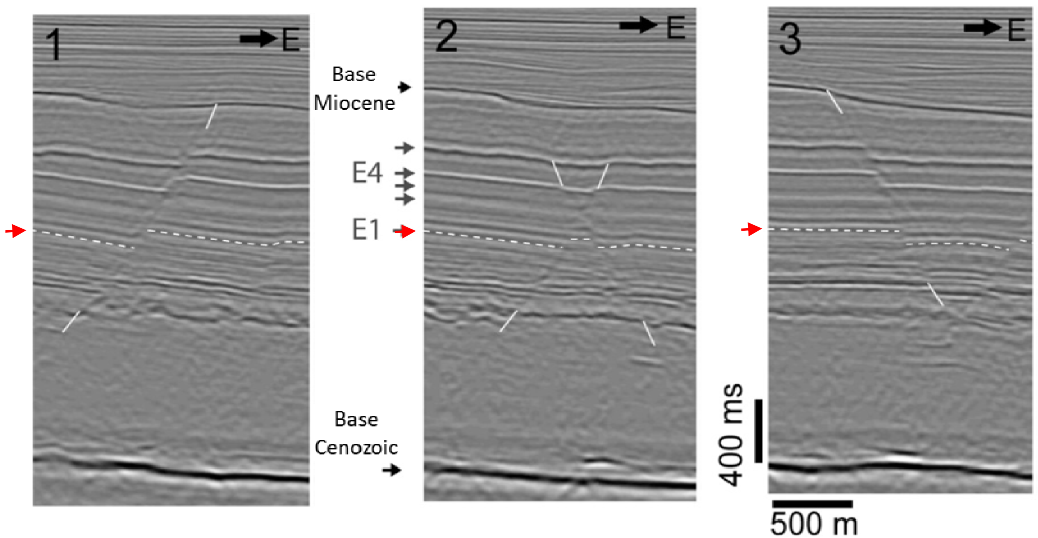
Below the line of intersection the faults form a horst in cross-section

Porcupine Basin





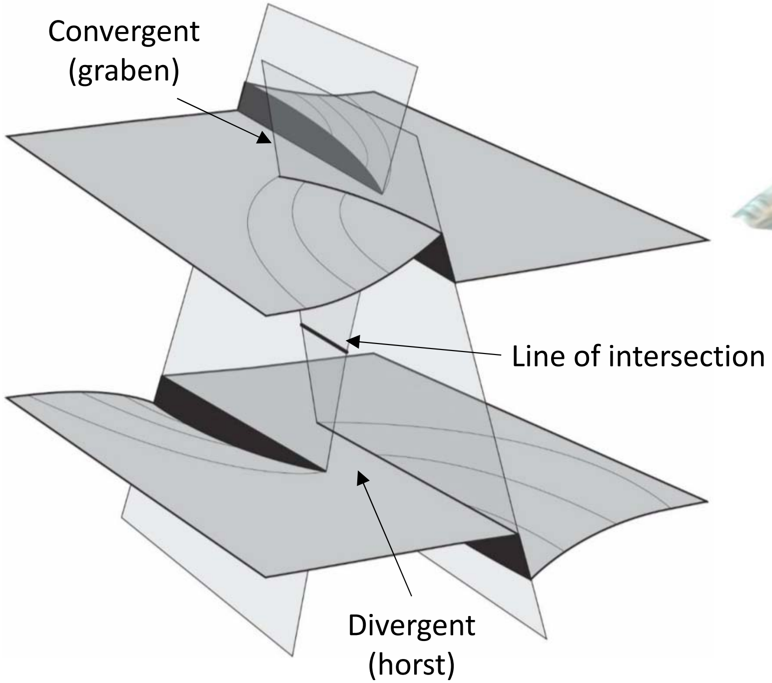




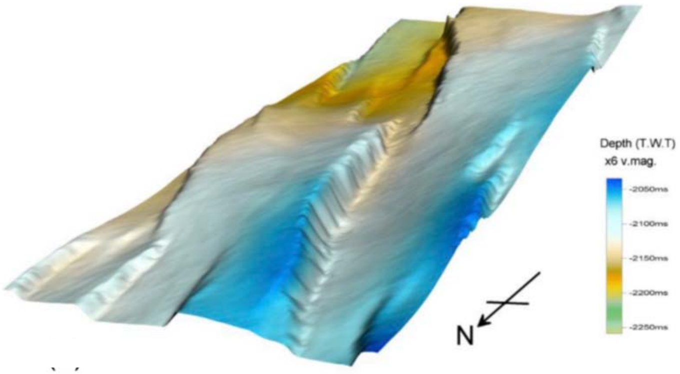
Flat topography between the opposed dipping faults.
Displacement changes accommodated by change in hanging-wall elevation.

3D geometry

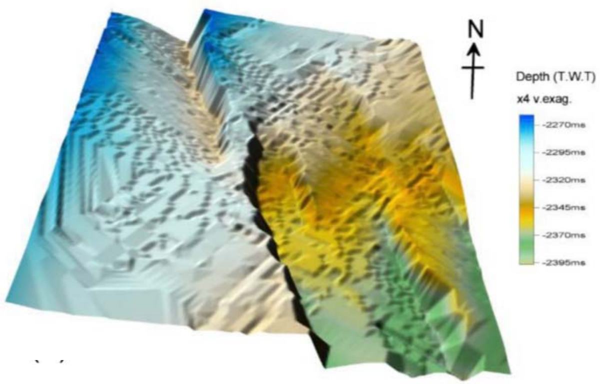
Conjugate relay zone geometry changes across the line of intersection between the faults.



Convergent (graben)

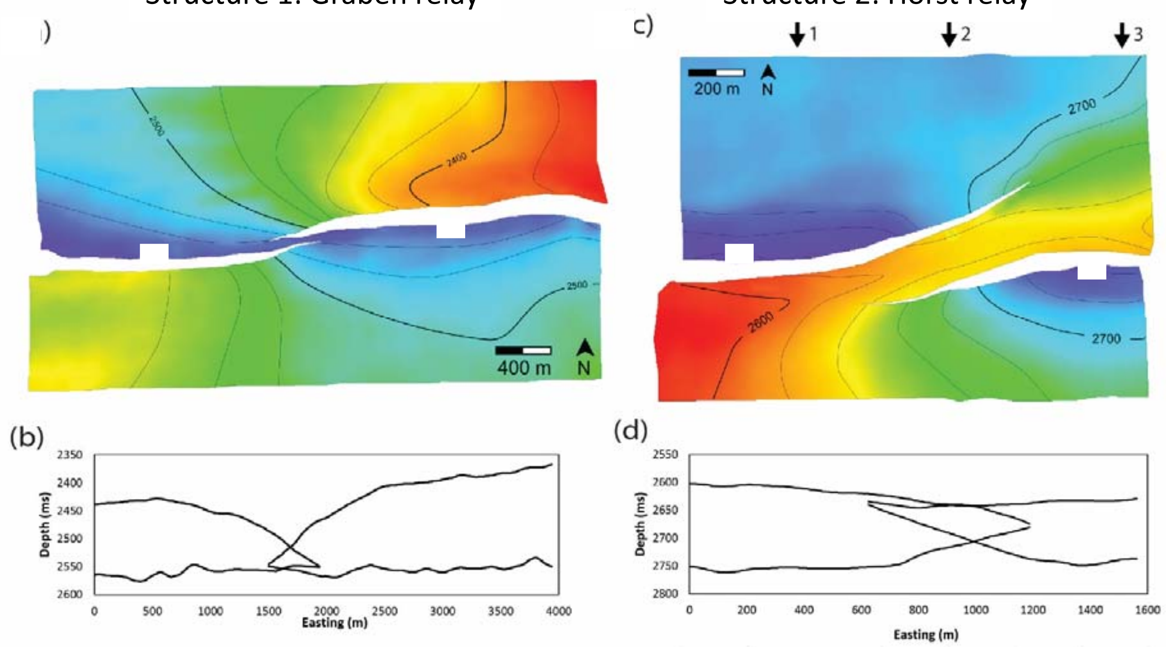


Divergent (horst)



Structure 1: Graben relay

Structure 2: Horst relay



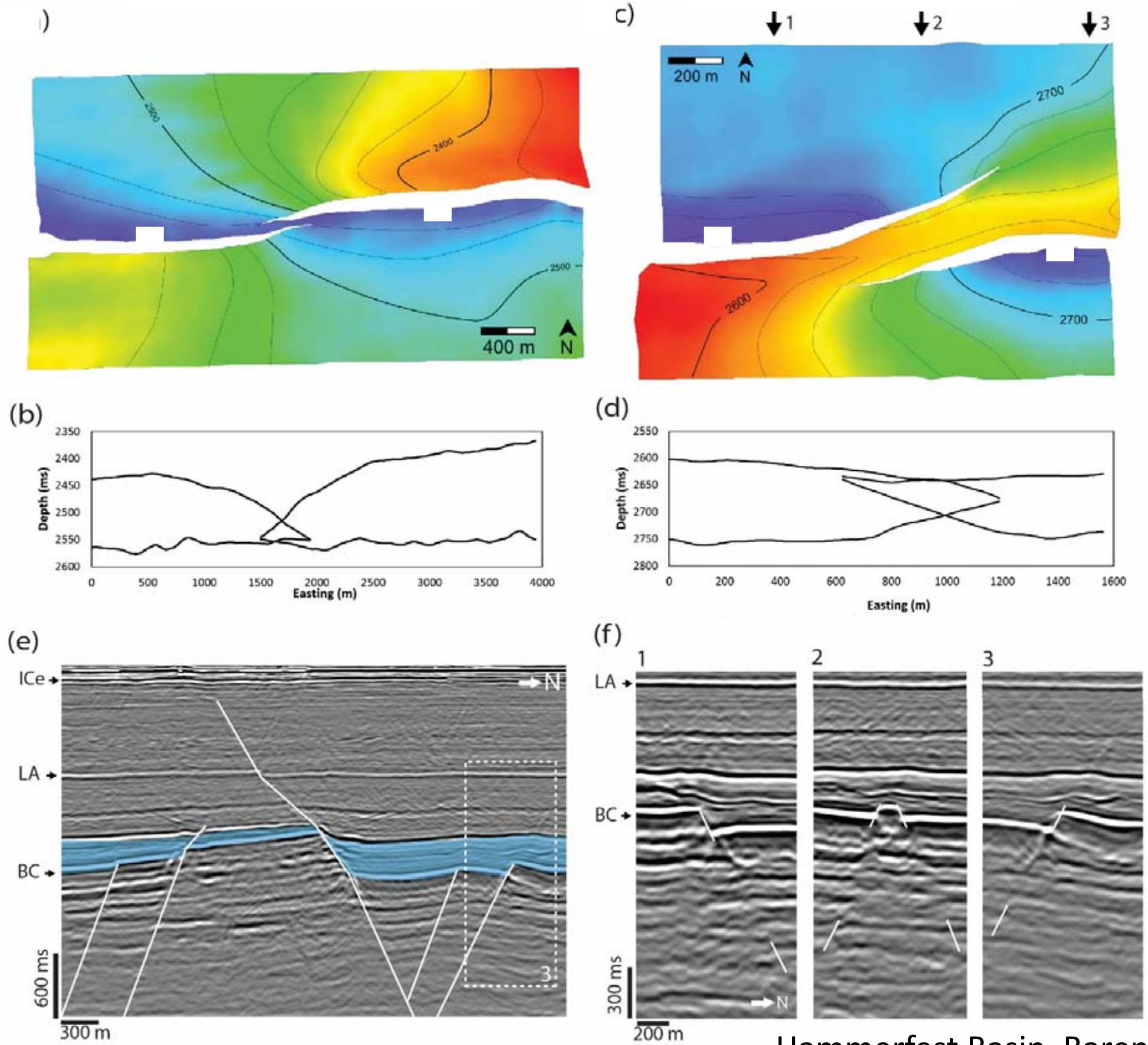
Hammerfest Basin, Barents Sea

Conjugate relay zones in other areas

Similar characteristics are observed on tectonically driven normal faults with up to 300m throw

Structure 1: Graben relay

Structure 2: Horst relay

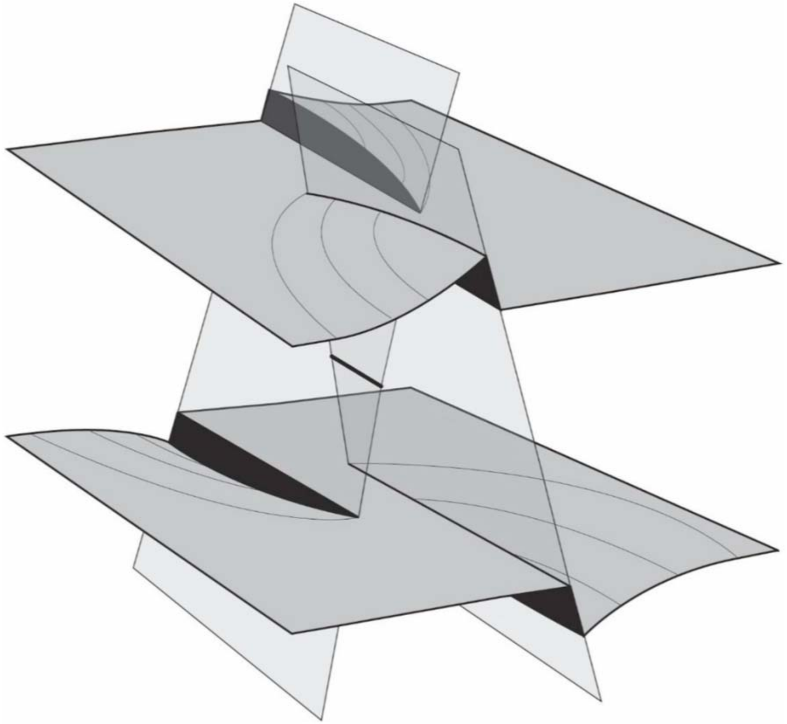


Hammerfest Basin, Barents Sea

Conjugate relay zones in other areas

Similar characteristics are observed on tectonically driven normal faults with up to 300m throw

Interaction occurs even when overlapping faults do not intersect one another

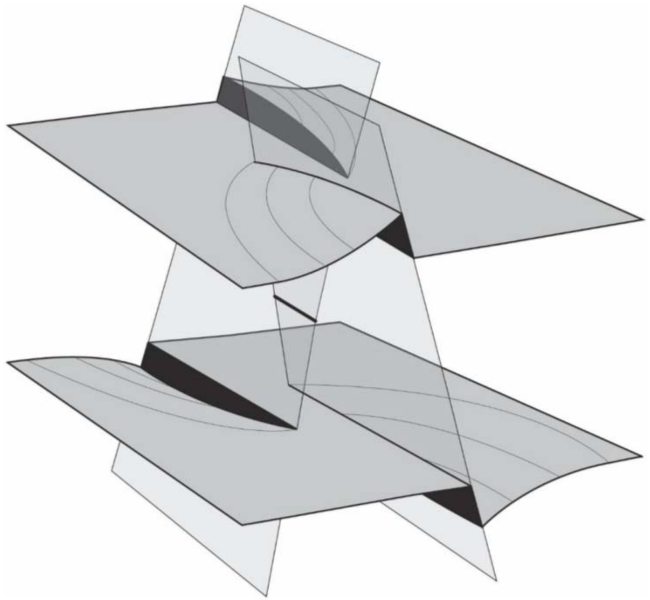


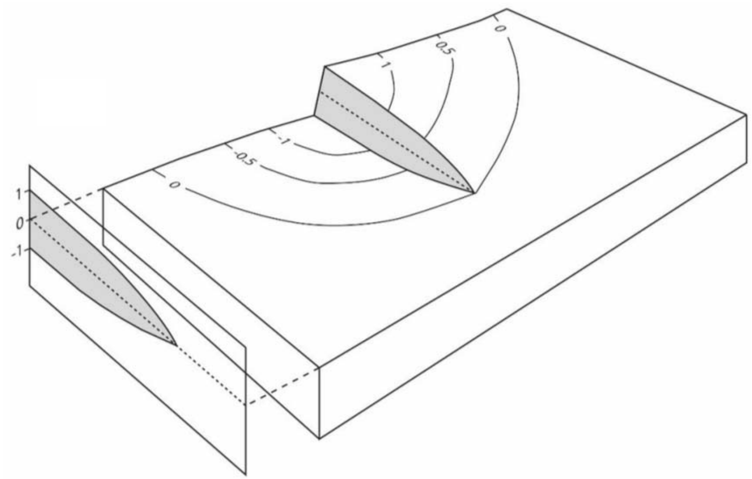
Horizon geometry – general pattern

High bed dips and large elevation changes outside the area of overlap

Flat horizons within the area of overlap between faults

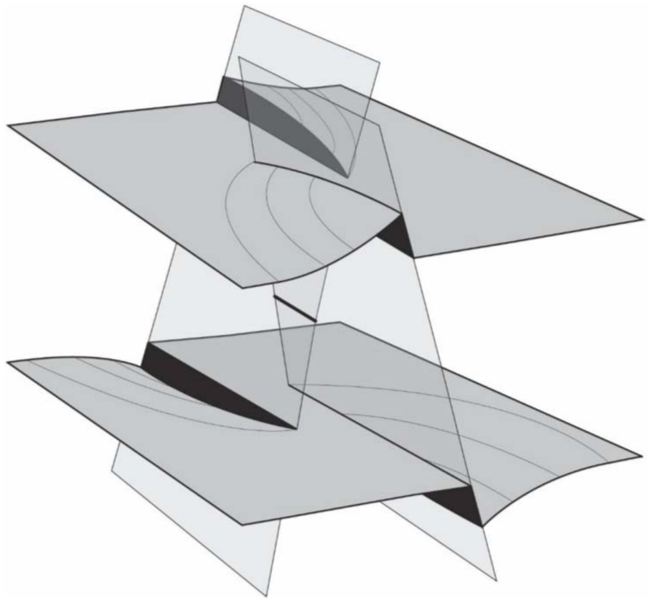
Switch in subsidence/ uplift pattern across the line of fault intersection

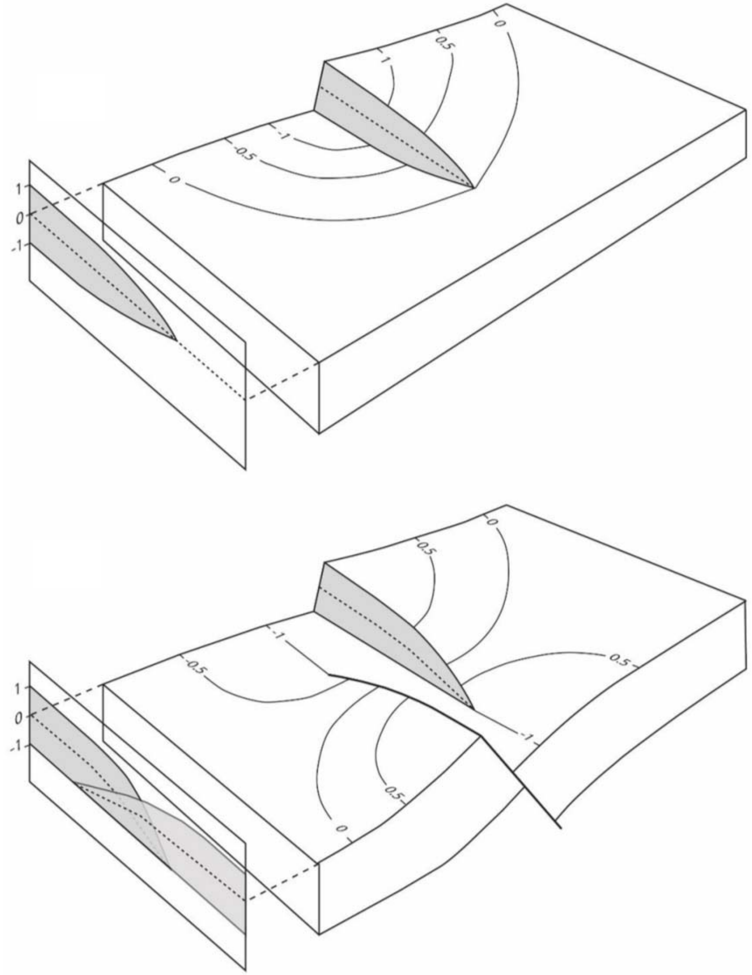




Horizon geometry – explanation

A single fault has symmetrical footwall uplift and hanging-wall subsidence



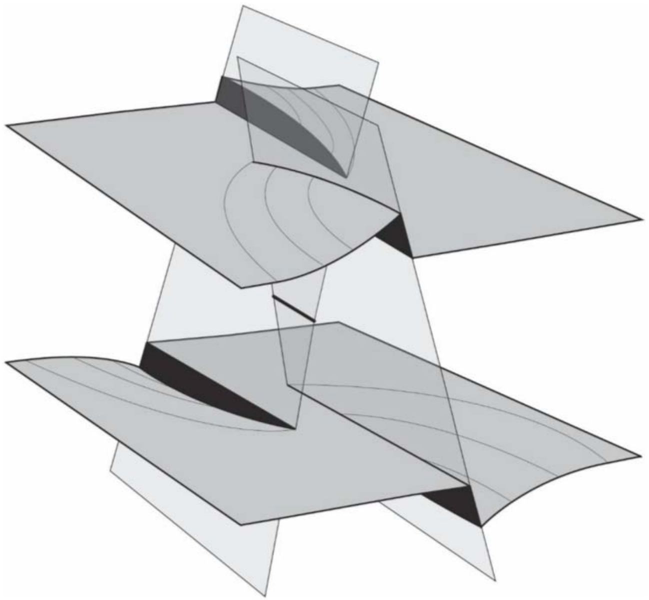


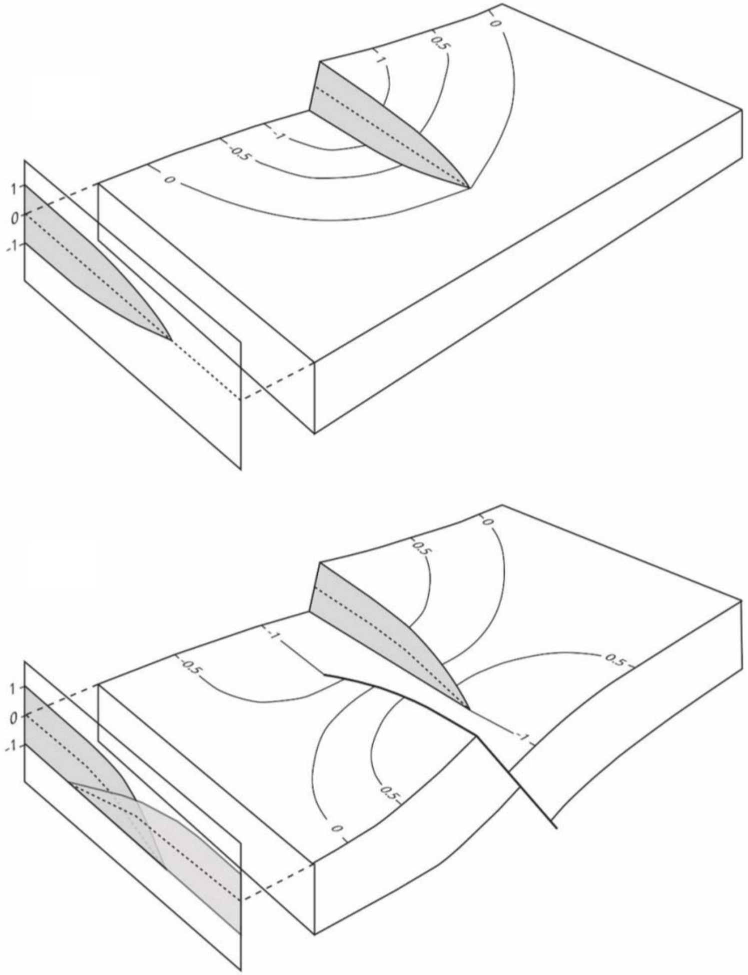
Horizon geometry – explanation

A single fault has symmetrical footwall uplift and hanging-wall subsidence

A second fault of similar size with opposed dip deforms the first fault to enhance footwall topography and reduce hanging wall topography.

Therefore mutual hanging wall is flat.



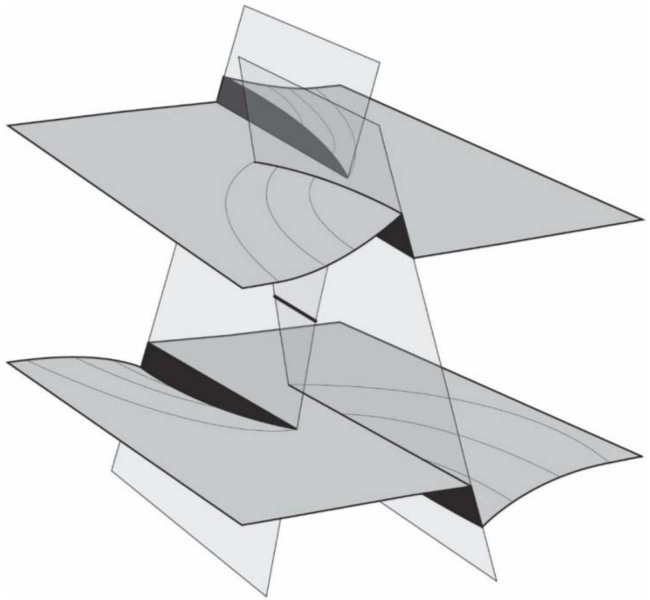


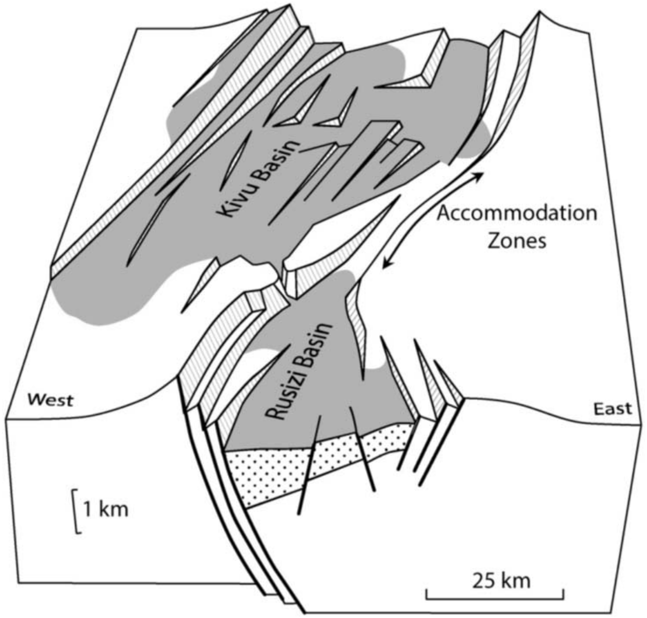
Horizon geometry – explanation

The same rationale can be used for horizon geometry beneath the line of intersection.

Horizon geometry is explained by a superposition of fault deformation fields.

Accommodation of strain



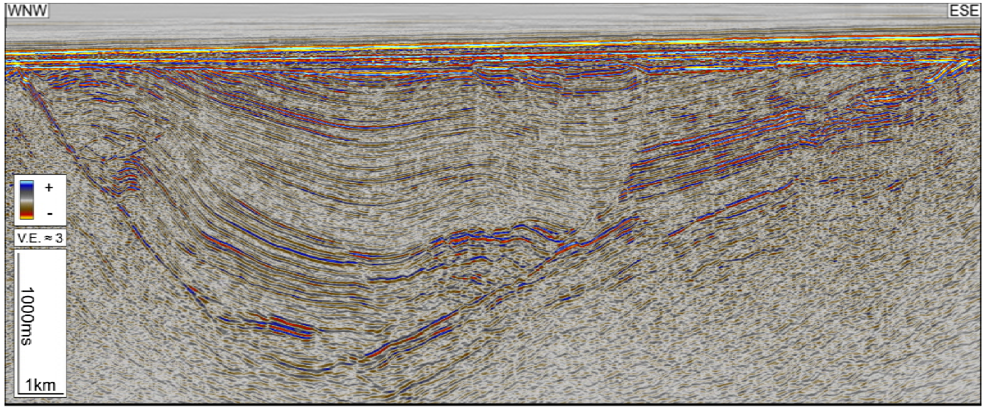


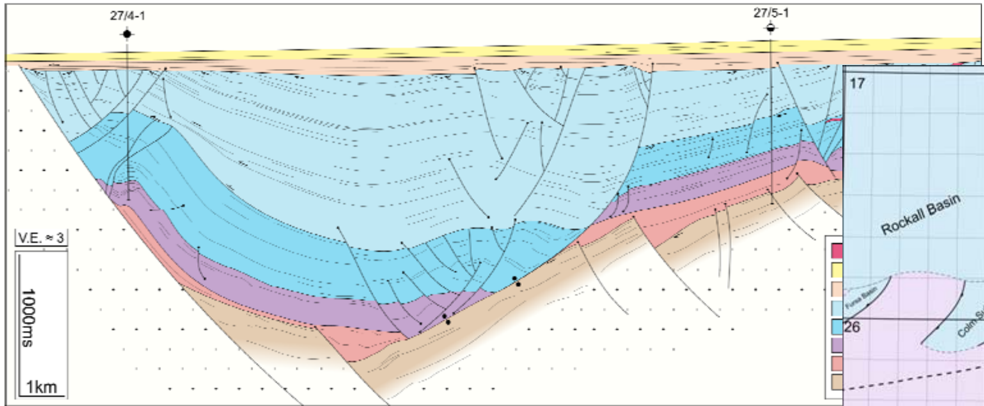
East African Rift
Ebinger 1989; Faulds & Varga 1998

Horst relay zone

Similar geometries to those mapped for 'small' faults are also recognized at accommodation zones between basin-bounding faults

Slyne Basin


WNW
ESE
+
-
V.E. ≈ 3
1000ms
1km


27/4-1
27/5-1
V.E. ≈ 3
1000ms
1km


17
18
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26
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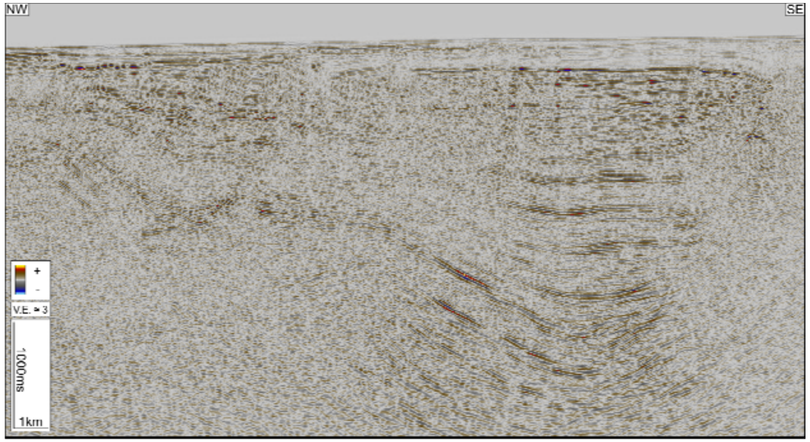
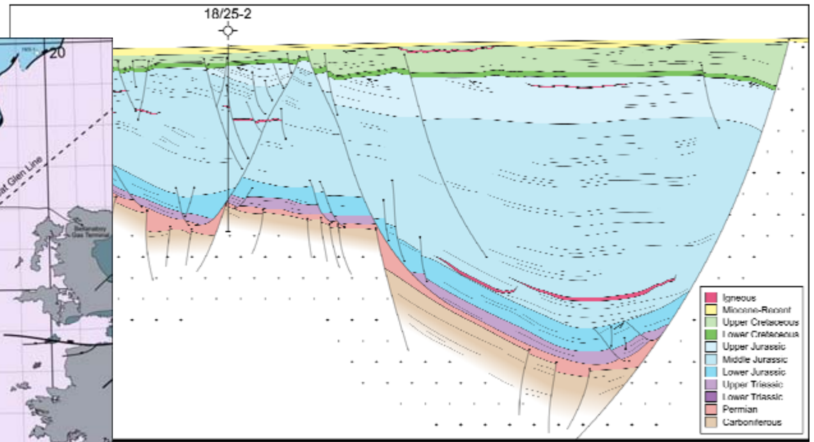
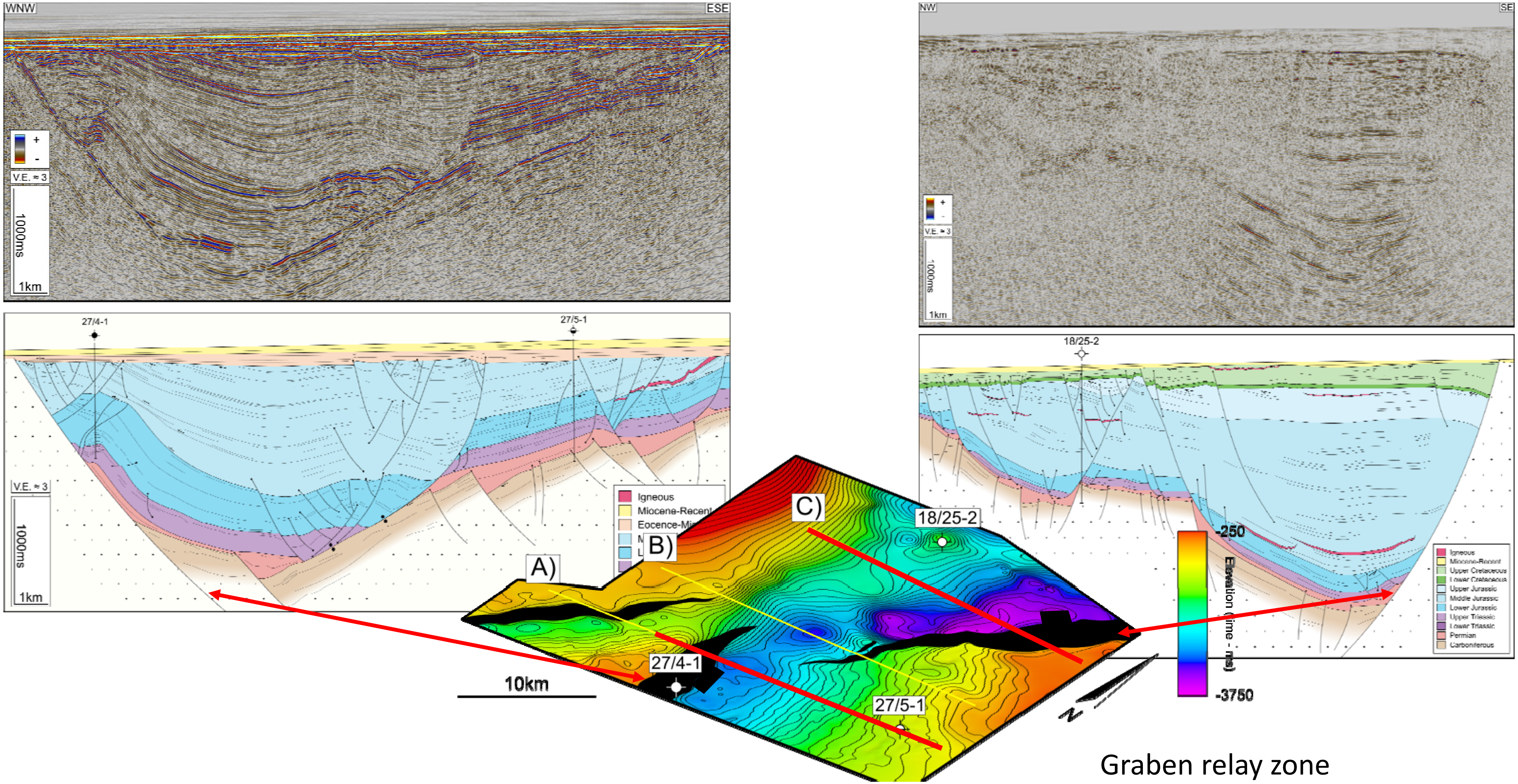
28
35
36
37
38
Rockall Basin
Erris Basin
North Slyne
Corrib
Great Glen Line
Slyne High
CSTZ
Colm Sub-Basin
Central Slyne
HB-CB Line?
Porcupine High
Irish Mainland Shelf
South Slyne
SU-AG Line
Porcupine Basin
Clare Basin


NW
SE
+
-
V.E. ≈ 3
1000ms
1km


18/25-2
Igneous
Miocene-Recent
Upper Cretaceous
Lower Cretaceous
Upper Jurassic
Middle Jurassic
Lower Jurassic
Upper Triassic
Lower Triassic
Permian
Carboniferous

Slyne Basin



Graben relay zone

Conclusions

Characteristic horizon geometries are associated with transfer of displacement between opposed dipping faults.

Horizon geometries can be explained as superposition of the deformation fields of contemporaneous faults with relatively low displacements (< 300 m).

May also account for displacement distributions and topographic expression at conjugate accommodation zones between basin-bounding faults.

Opposed dipping faults can interact with one another without intersecting.