Interaction between Faults and Igneous Intrusions in Sedimentary Basins: Insights from 3D Seismic Reflection Data*

Craig Magee[1], Christopher A. Jackson[1], and Nick Schofield[2]

Search and Discovery Article #41114 (2013)**
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Abstract

Normal faults and igneous intrusion complexes can individually influence sedimentary basin evolution and petroleum system development through compartmentalisation, trap formation and the generation of hydrocarbon migration pathways. Whilst our understanding of fault and intrusive systems continues to improve separately, few studies have considered the interaction of the two and the potential impacts on petroleum system development. Here, we present 3D seismic reflection interpretations detailing the relationship between saucer-shaped sills and faults within the Exmouth sub-basin located offshore NW Australia. Transgressive sill segments are frequently observed to preferentially exploit specific pre-existing faults, potentially forming localised seals. Furthermore, mound-shaped structures, interpreted to represent hydrothermal vents, are often developed above the upper tips of the faults that are intruded by the sills. We consider how the fault-seal potential, which is related to fault throw and the physical properties of the faulted lithologies, controls the styles of both intrusive magmatic and extrusive hydrothermal products. This study demonstrates the complex interactions that may occur between normal fault arrays and igneous systems, and highlights how fluid migration pathways and hydrocarbon traps may be modified in petroliferous basins.

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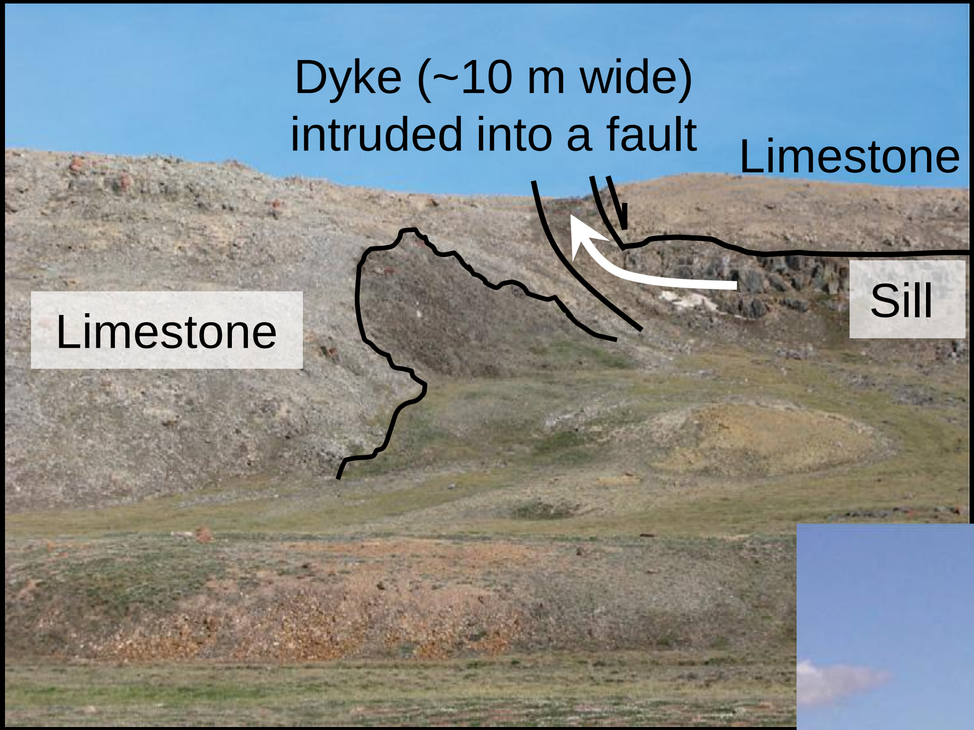
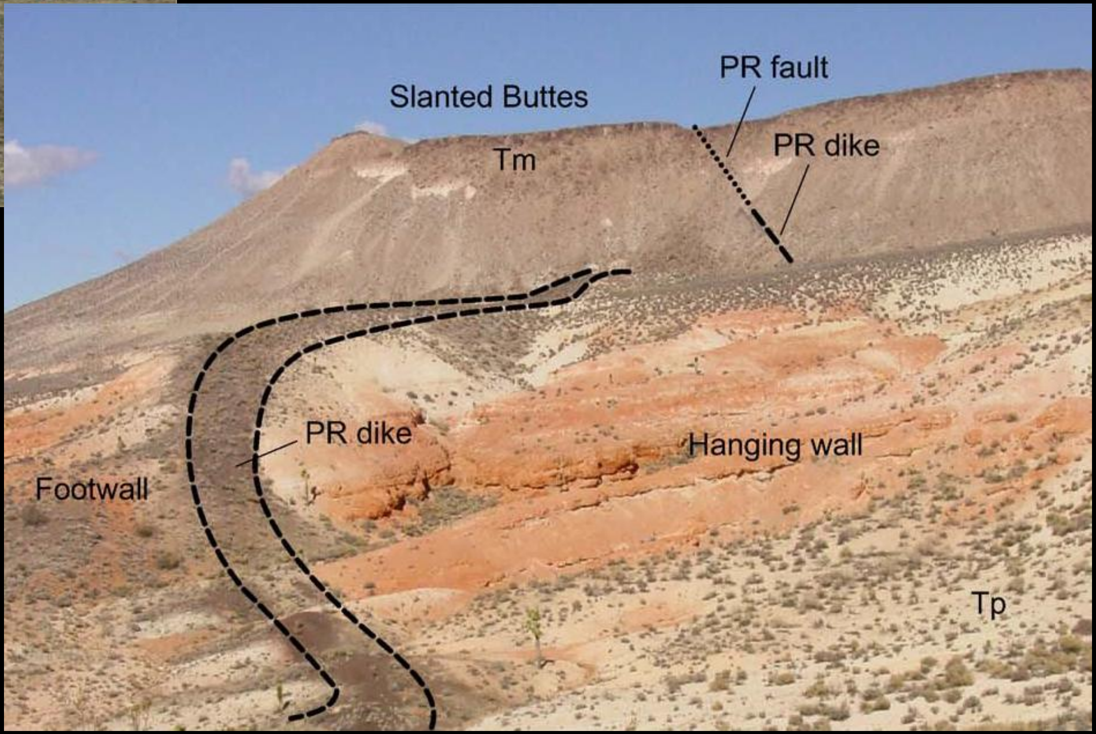
Data: Australian Government Geoscience Australia

Software: Schlumberger

Intrusion-Fault Relationships: Field



Franklin Sills (Canada) – modified from Bédard et al. (2012)



Paiute Ridge dykes (Nevada, USA) Valentine & Krogh (2006)

Intrusion-Fault Relationships: Seismic

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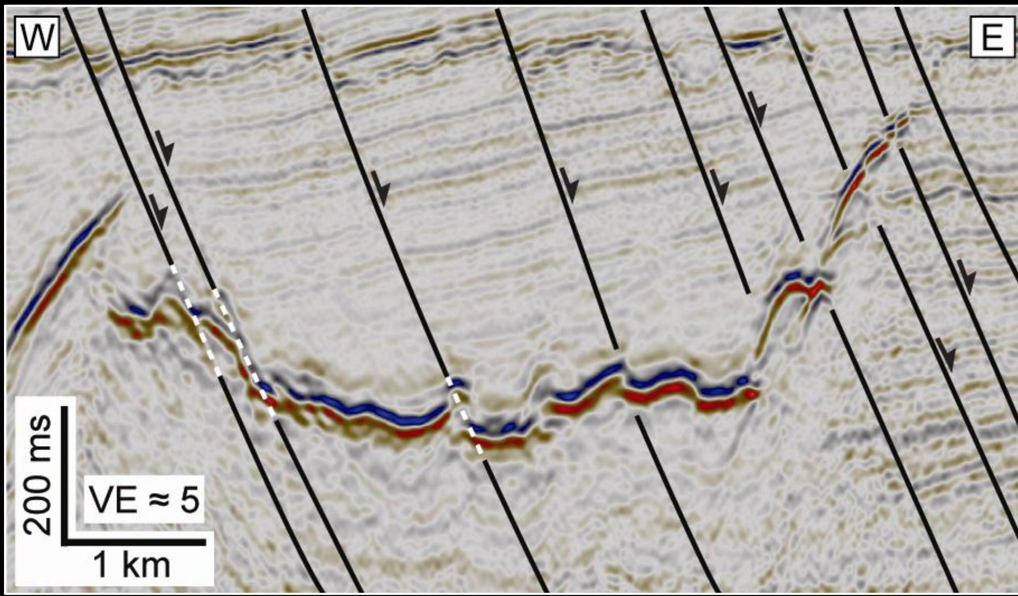
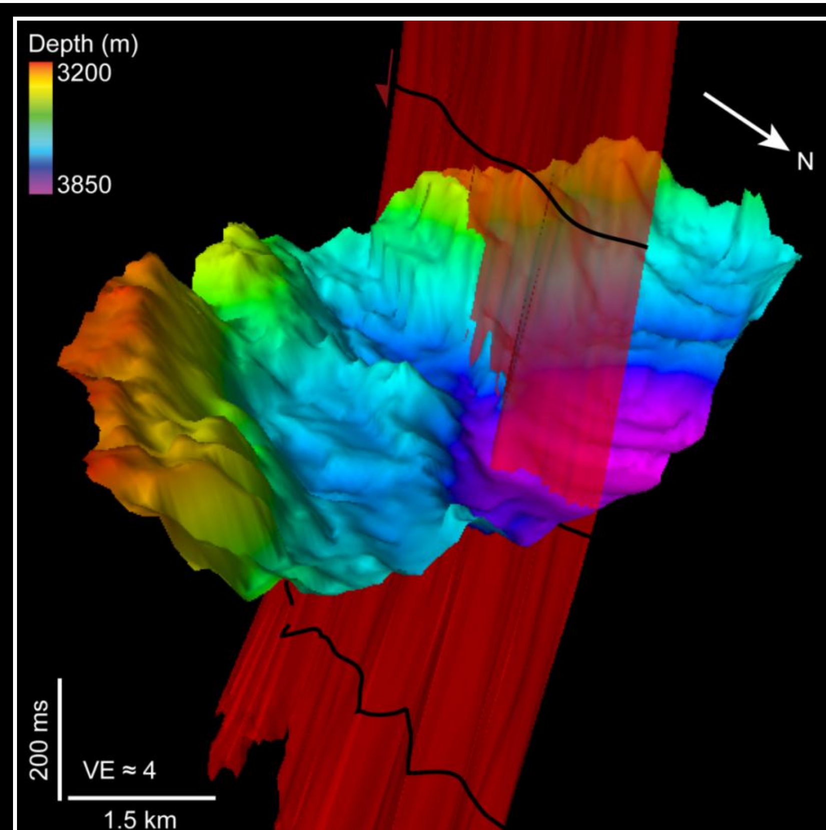
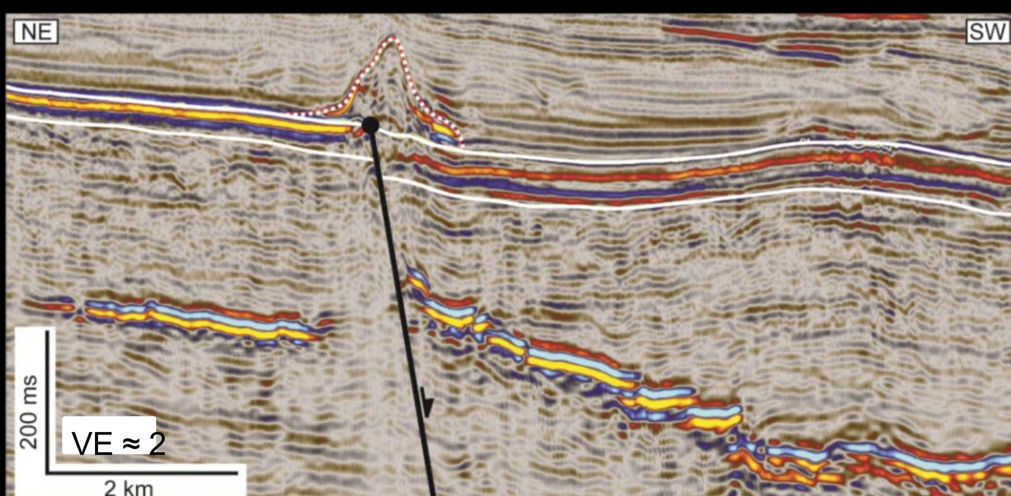
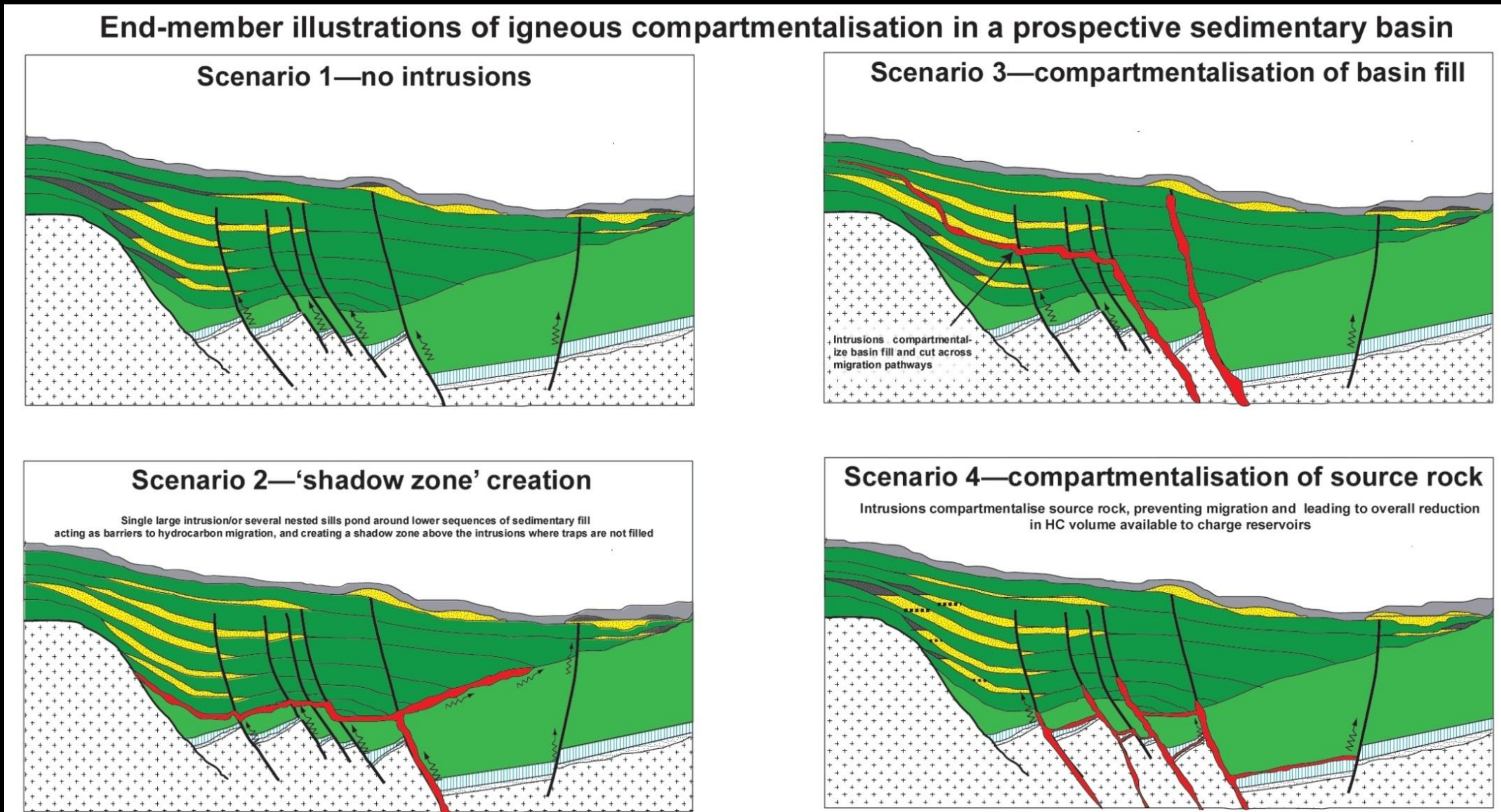


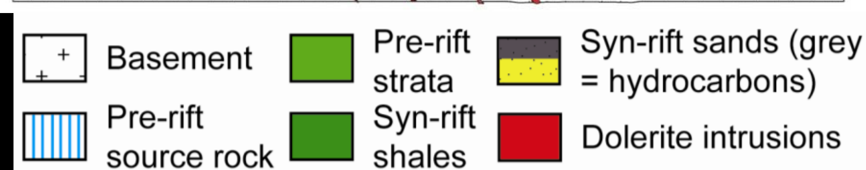




Bight Basin (southern Australia) - Jackson (2012)

Impact of Fault-controlled Intrusion on Petroleum Systems

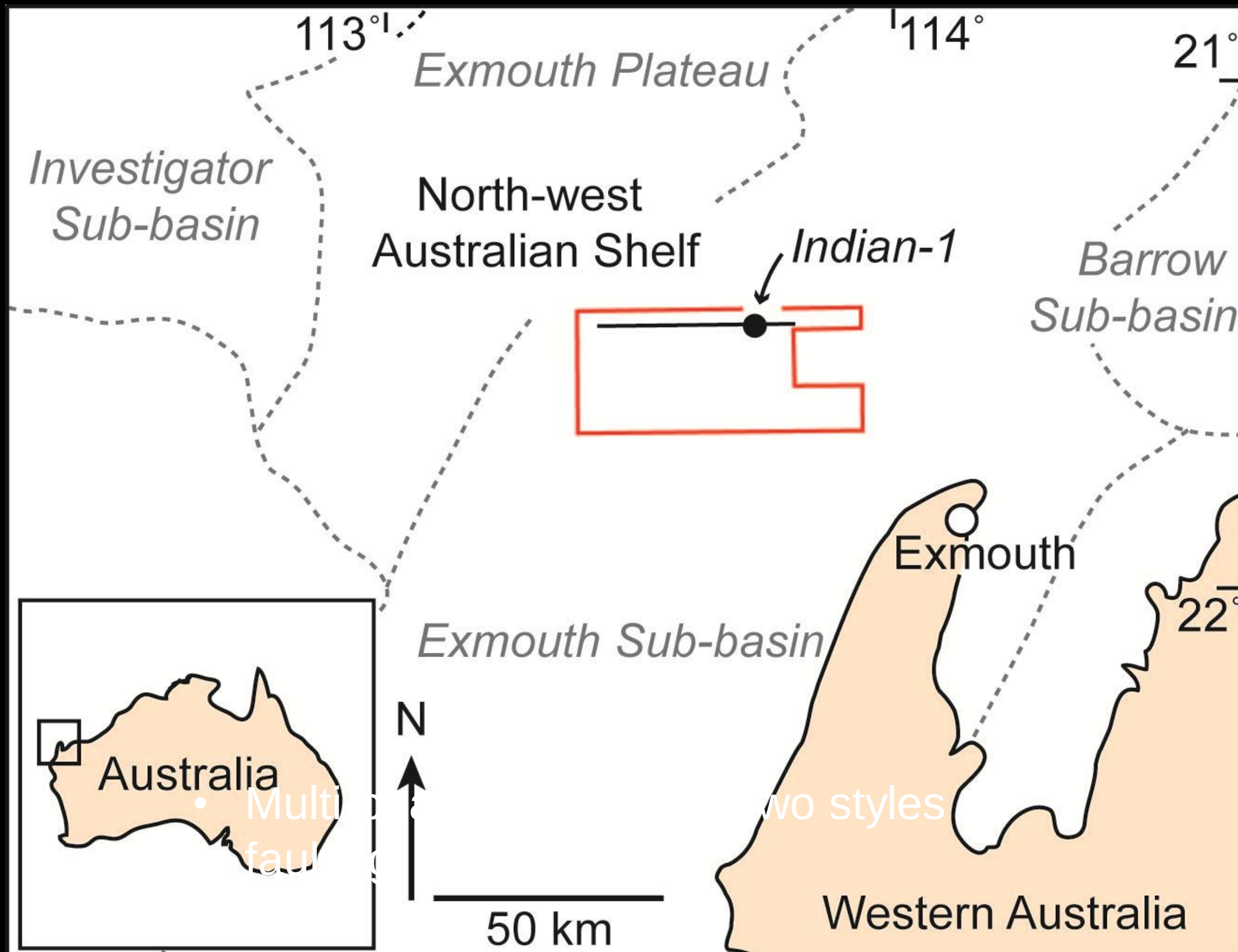




To test these hypotheses we need to understand what controls the location and mechanisms of intrusions along faults.

modified from Holford et al. (2012)

Exmouth Sub-basin (NW Australia)



- At least two phases of igneous activity

Exmouth Sub-basin (NW Australia)

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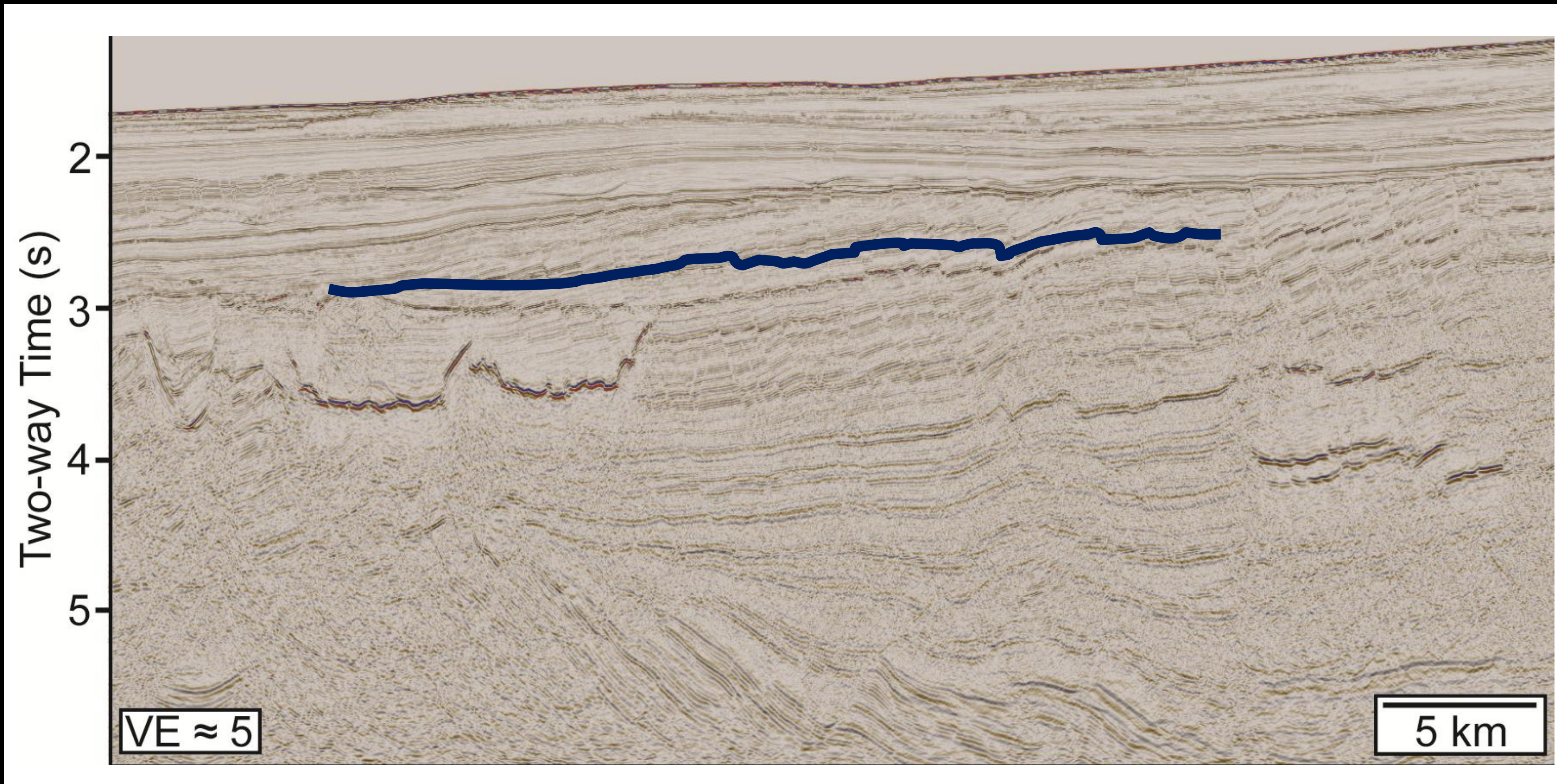

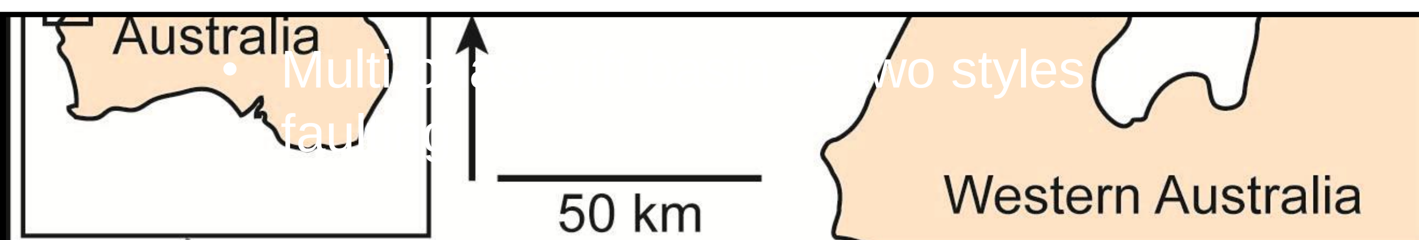

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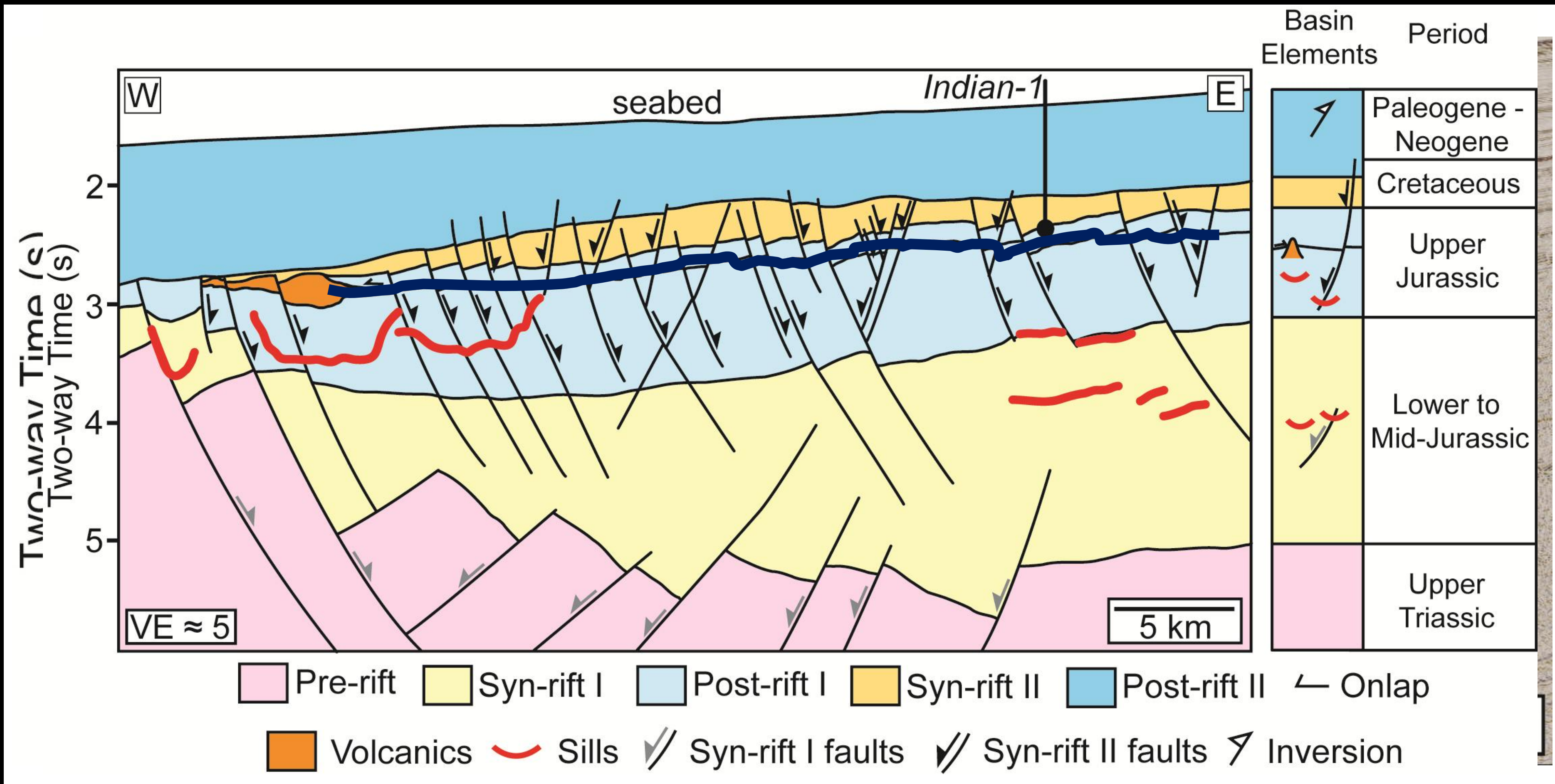

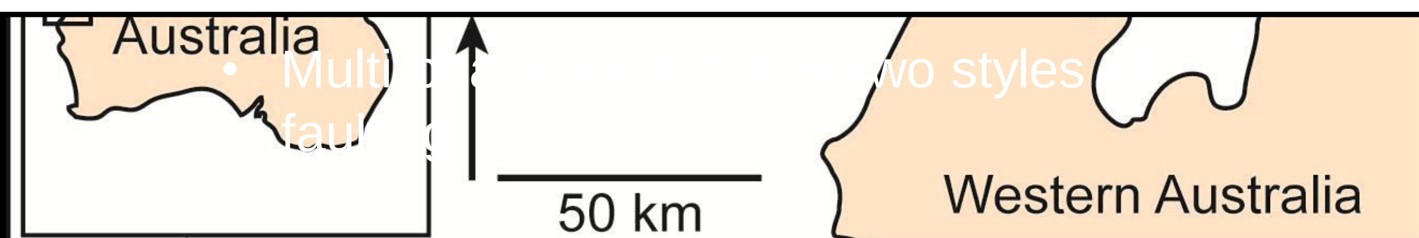

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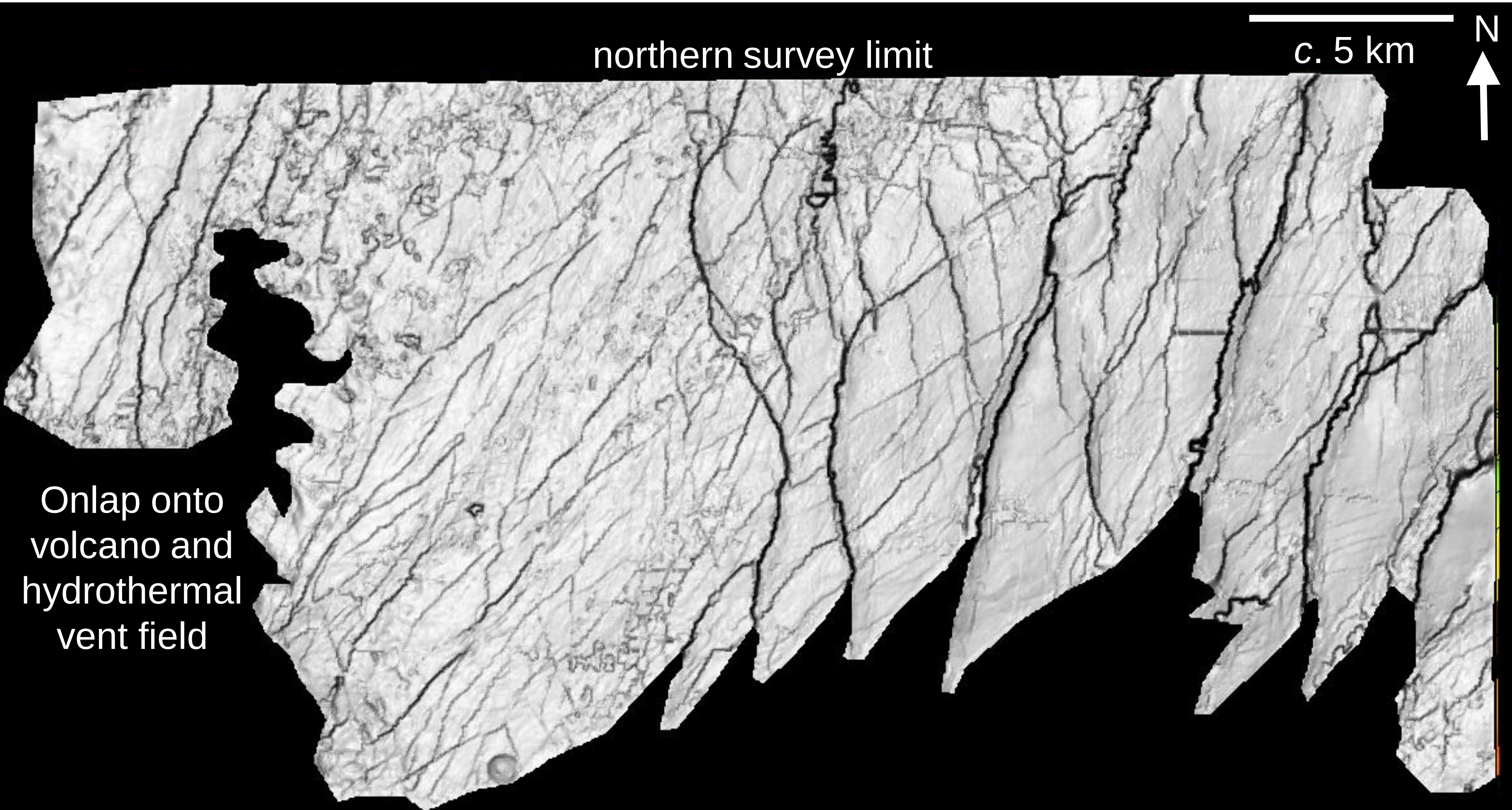
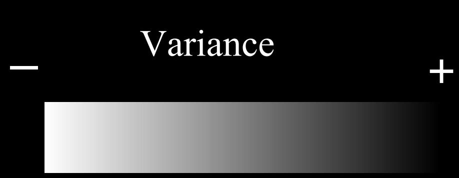
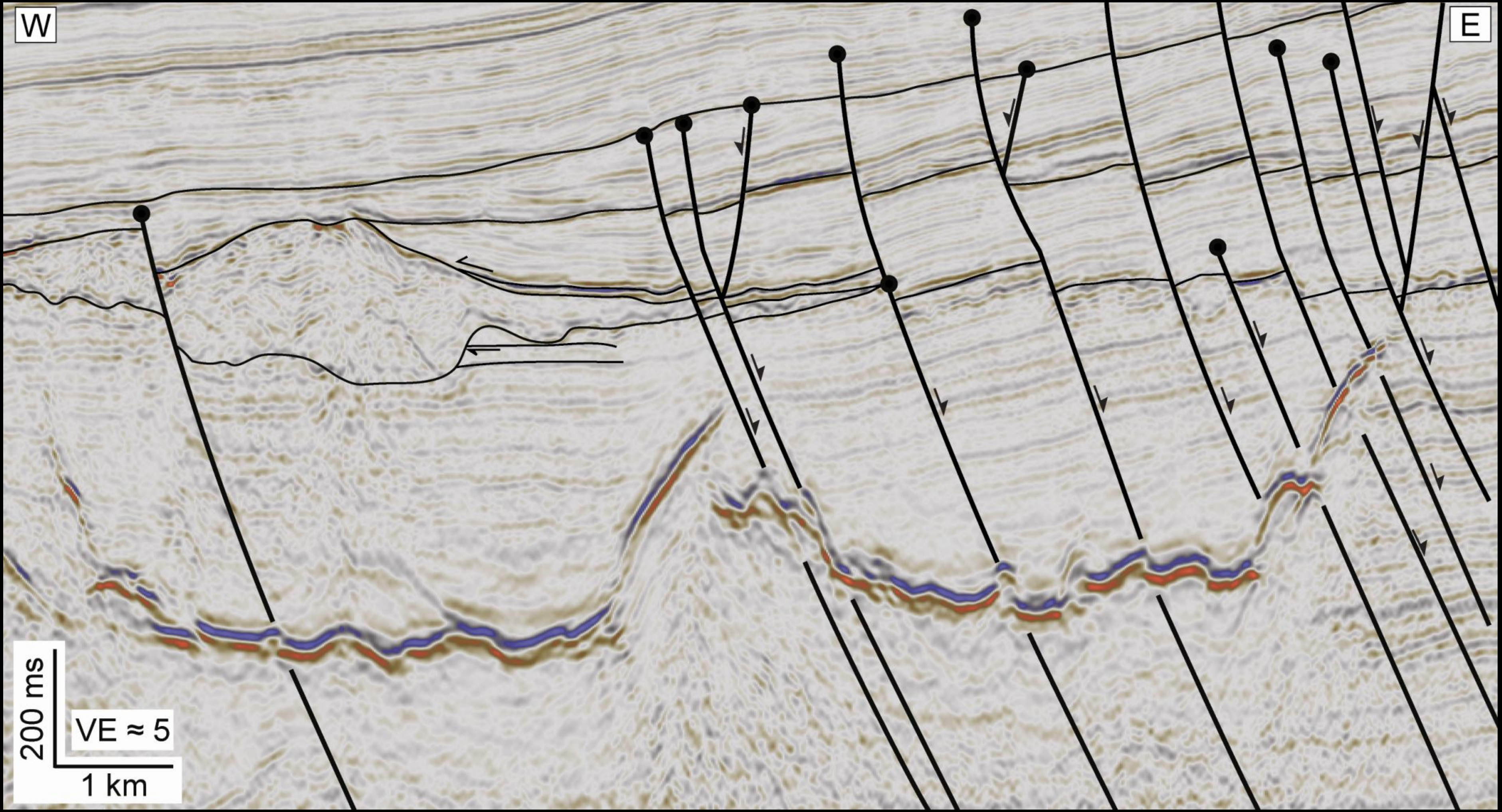
Structural Template





- ~N-S trending faults have large throws and extend into Lower Jurassic successions
- Denser network of NE-SW (some NW-SE) trending faults restricted to Upper Jurassic and Berriasian

Seismic Expression of Igneous Bodies



- Volcano truncates Kimmeridgian strata and onlapped by the Tithonian Dingo Claystone (source rock)
- Volcano displaced by Berriasian faults that controlled thickness of Macedon Sandstone (reservoir)
- Succession capped by the Muderong Shale (seal)
- Step in the intrusion does not fault displacement at shallower level; many sills not offset by faults

Seismic Expression of Igneous Bodies

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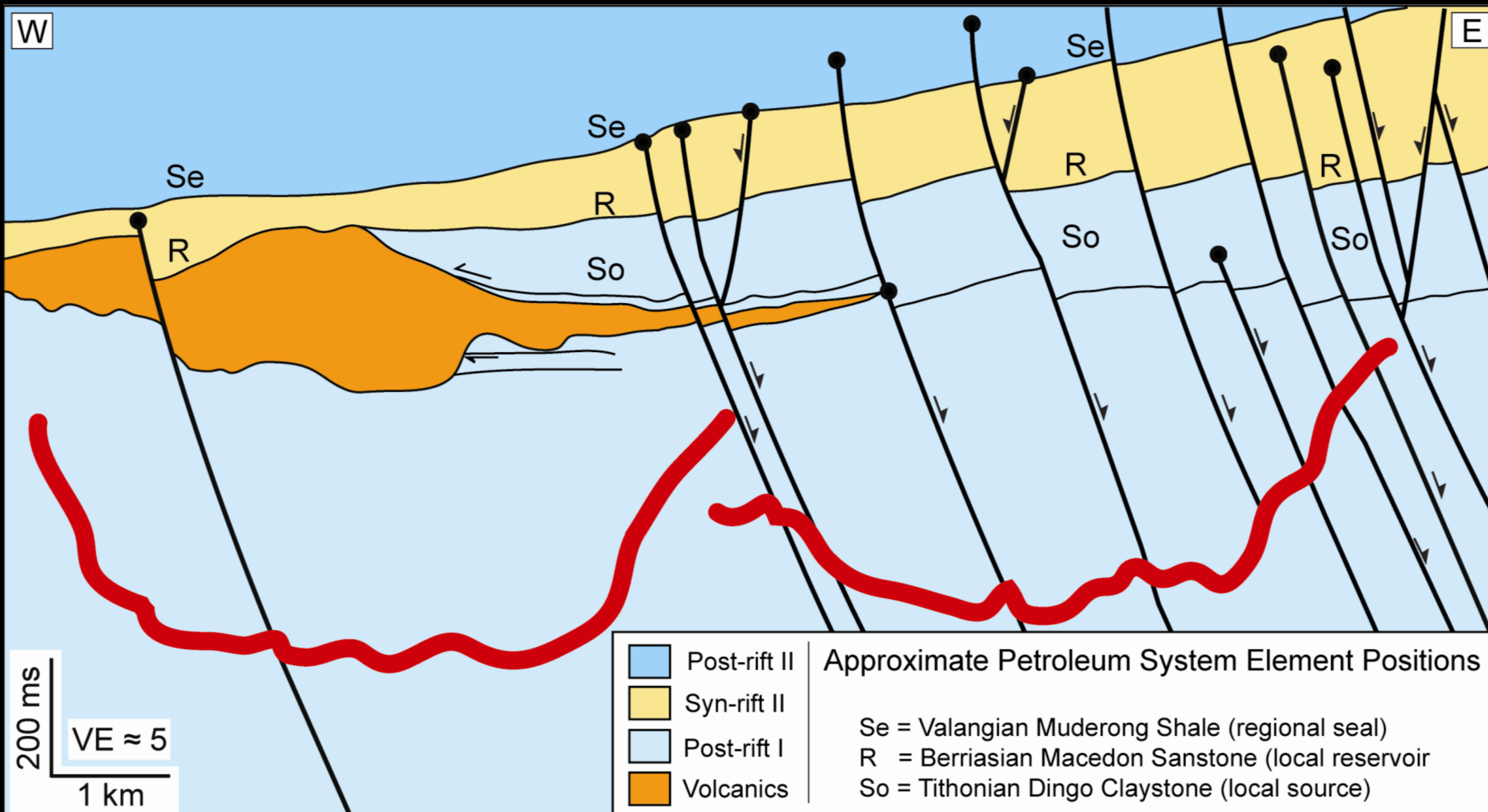

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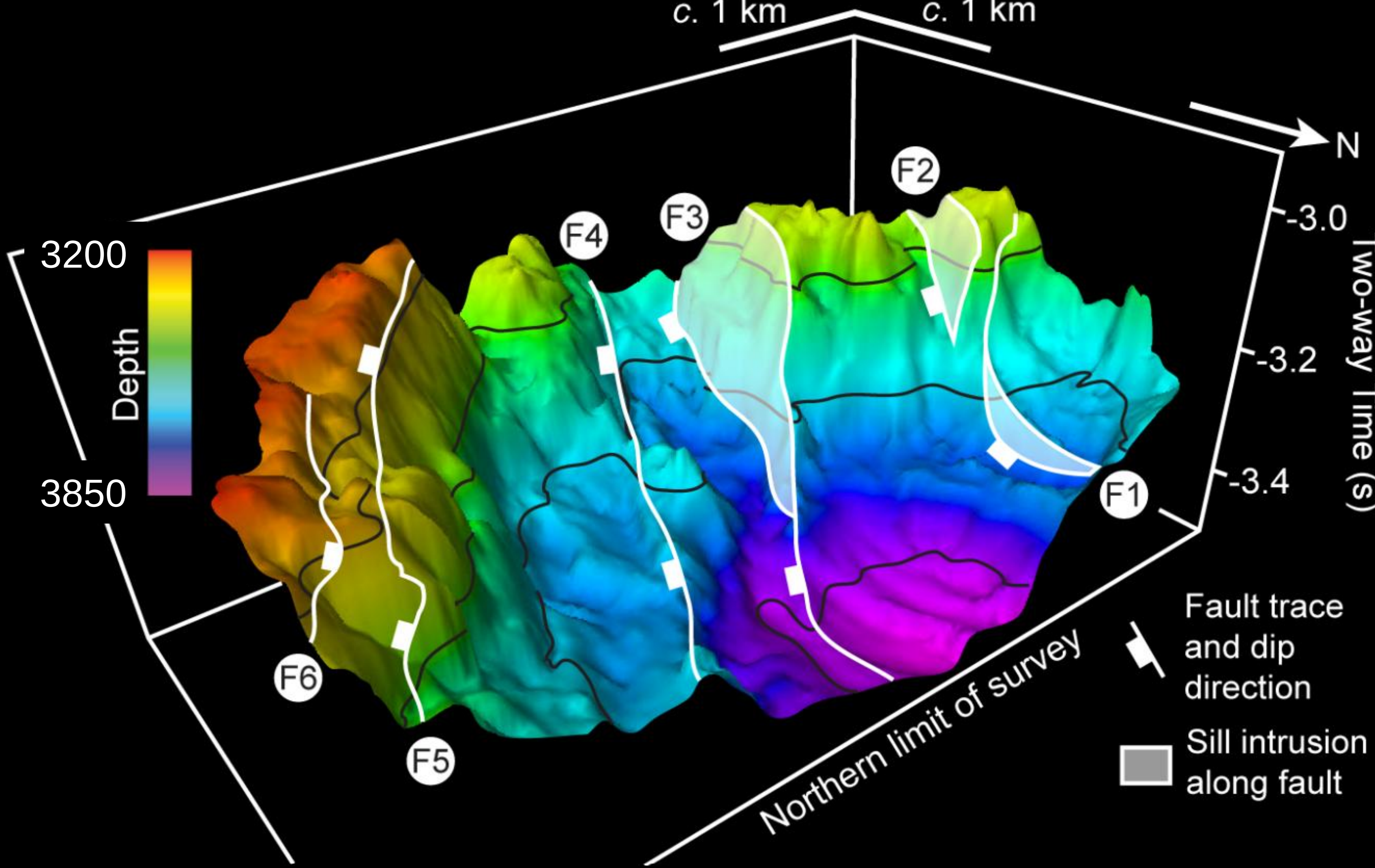
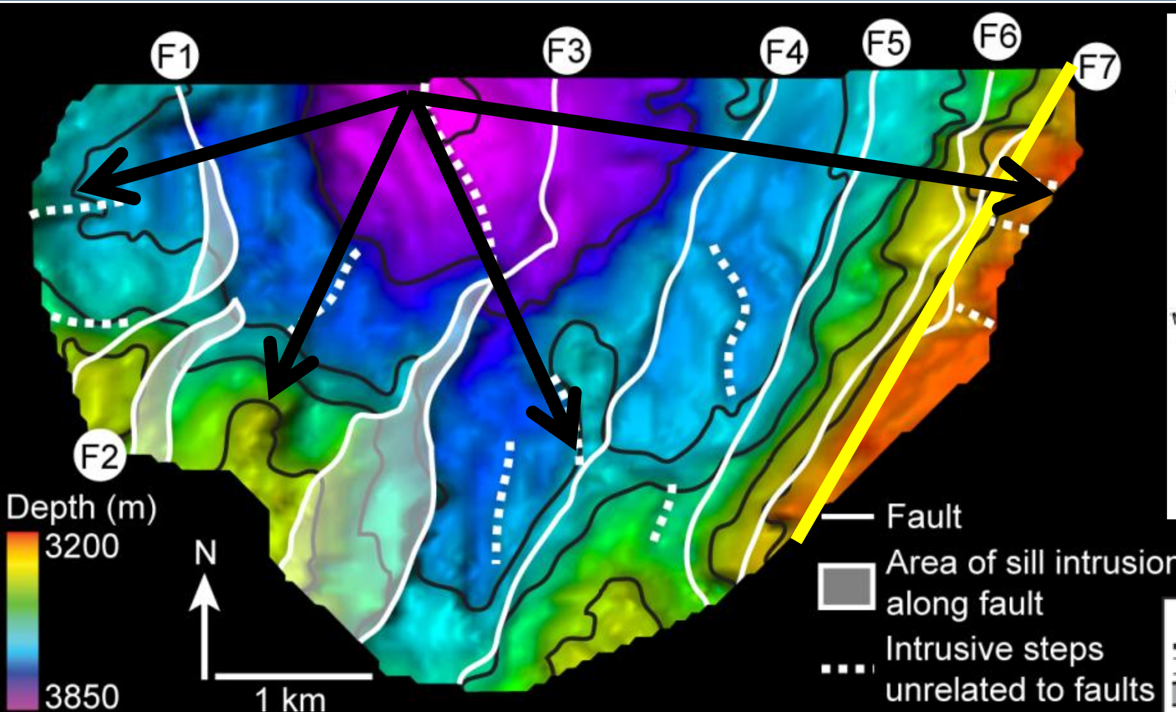
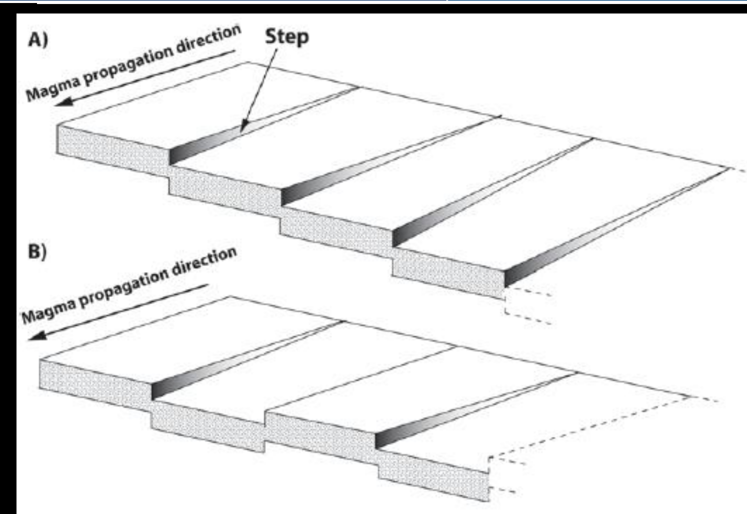
Sill Morphology

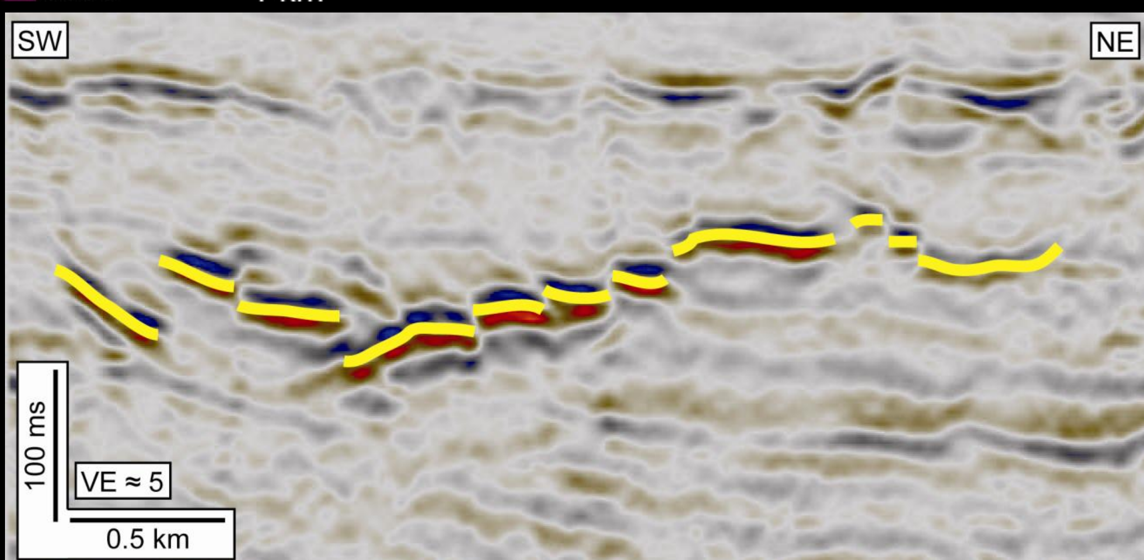


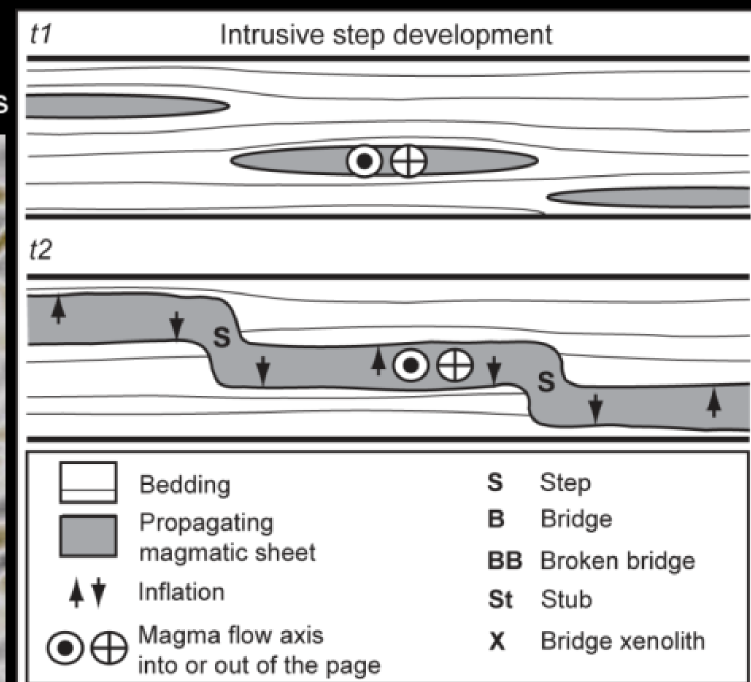
Magma Flow Directions



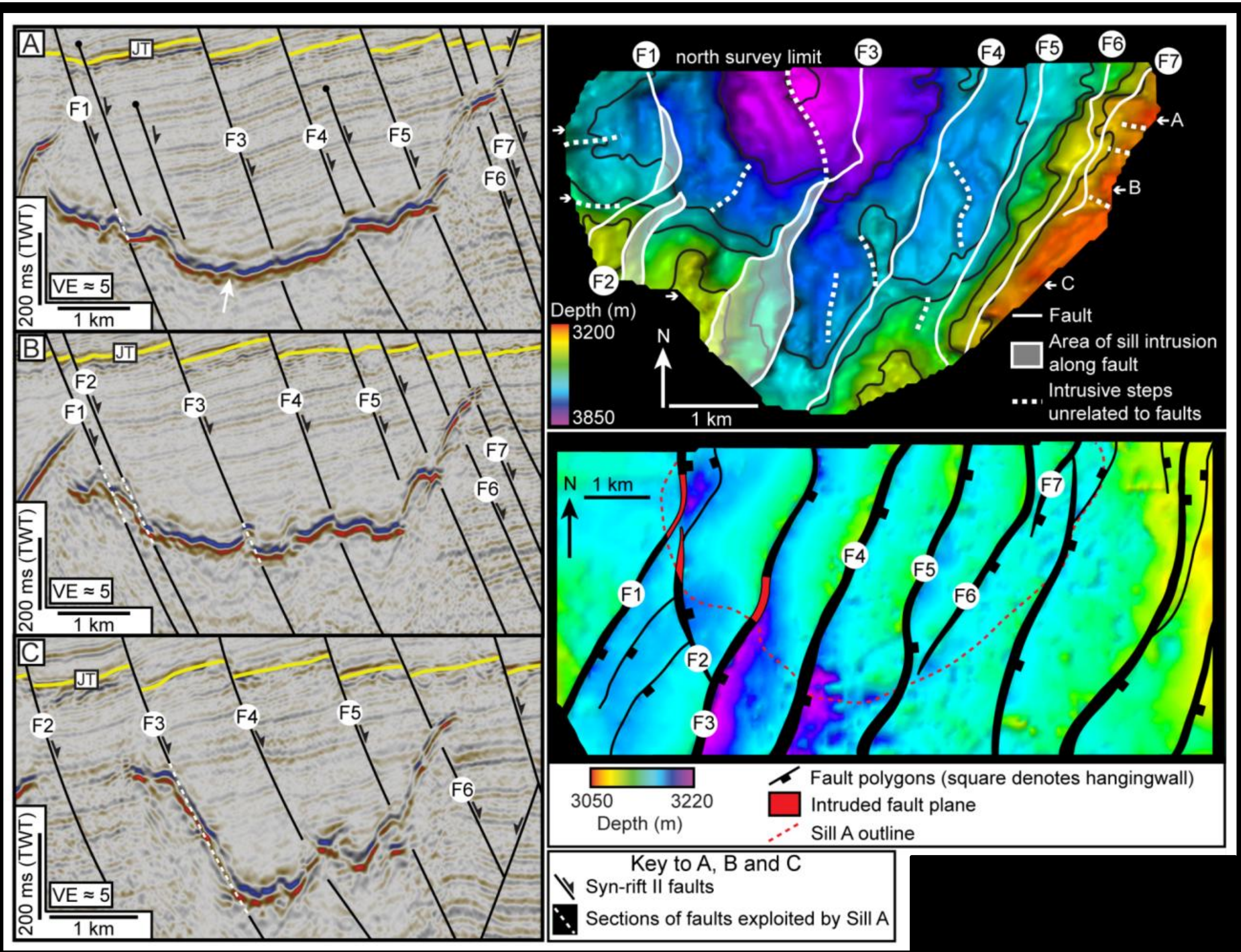


Schofield et al. (2012)

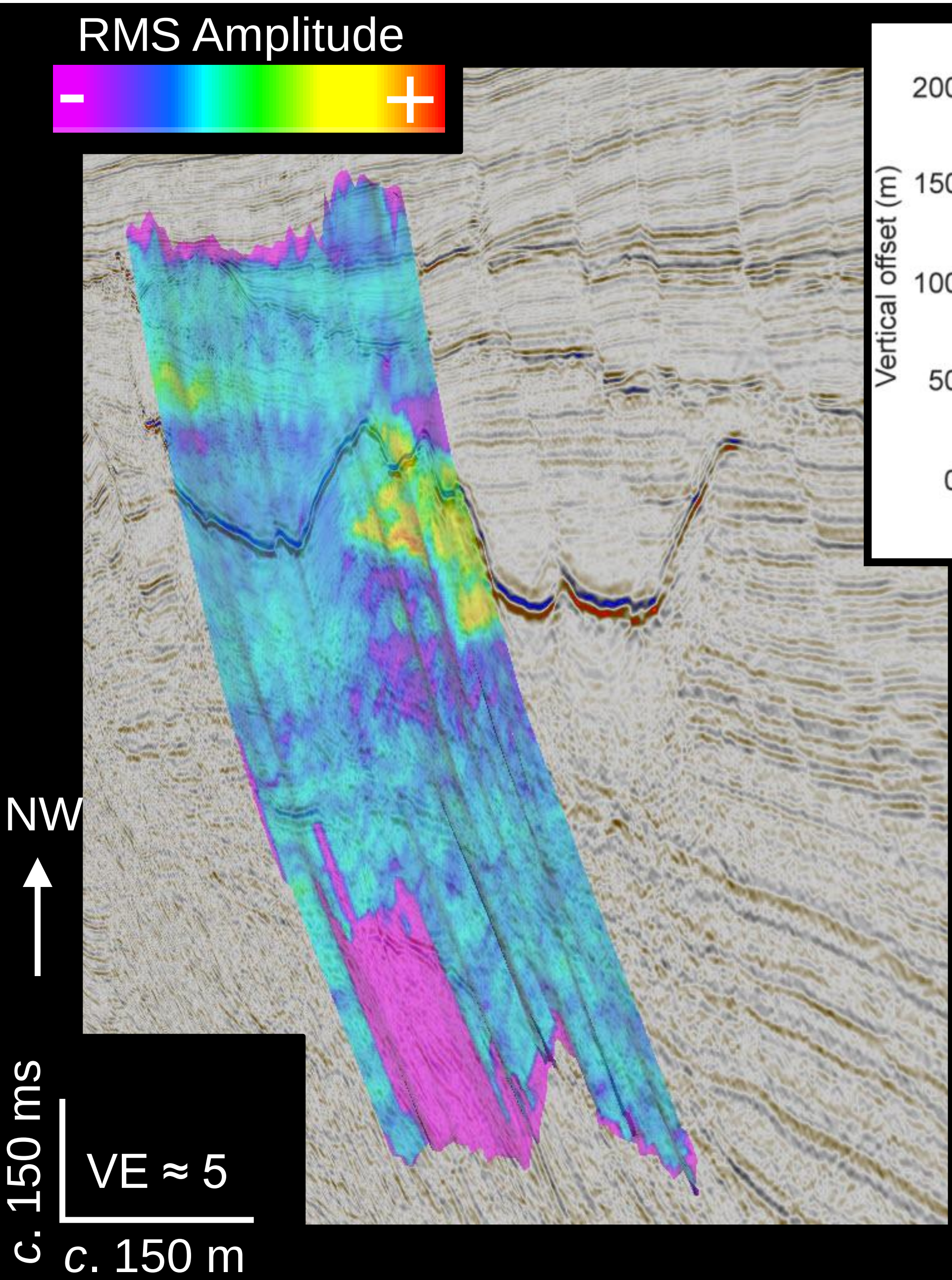


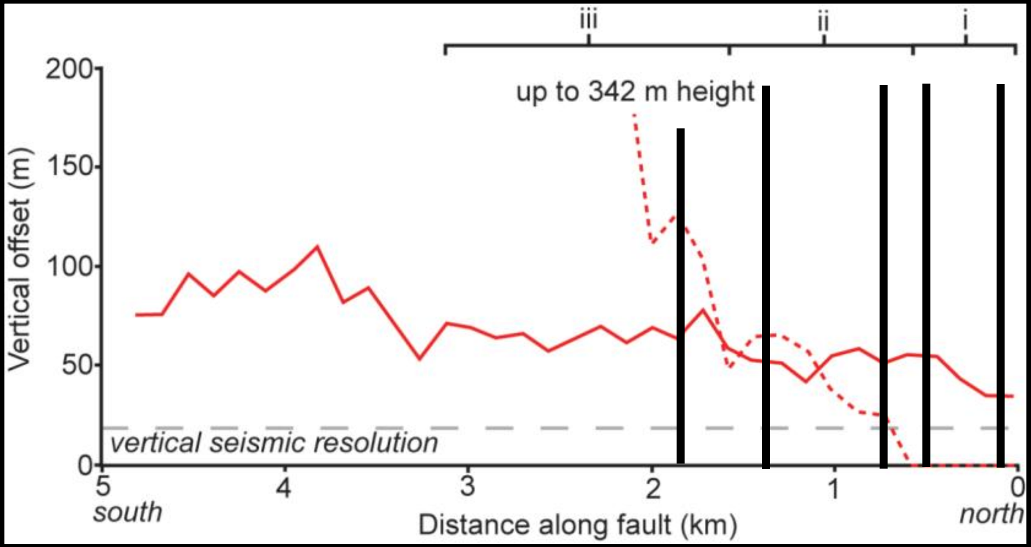


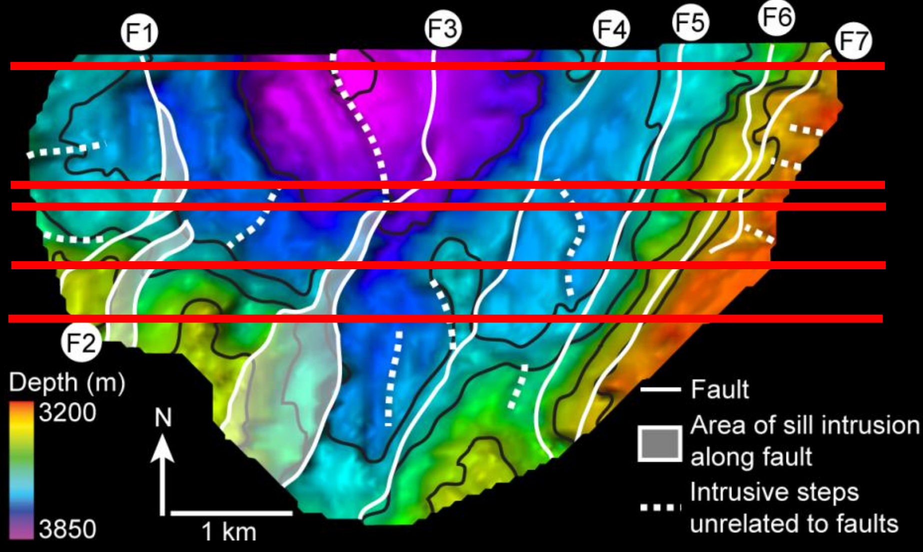
Fault / Sill Interactions



Fault Influence on Sill Emplacement







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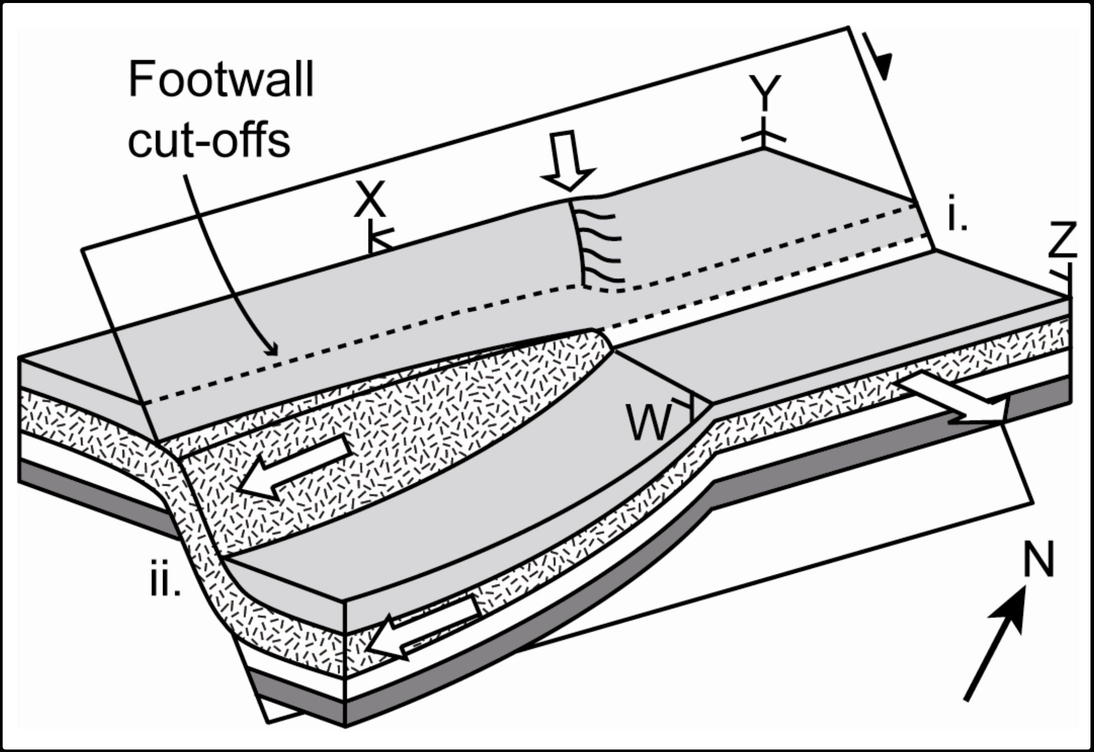

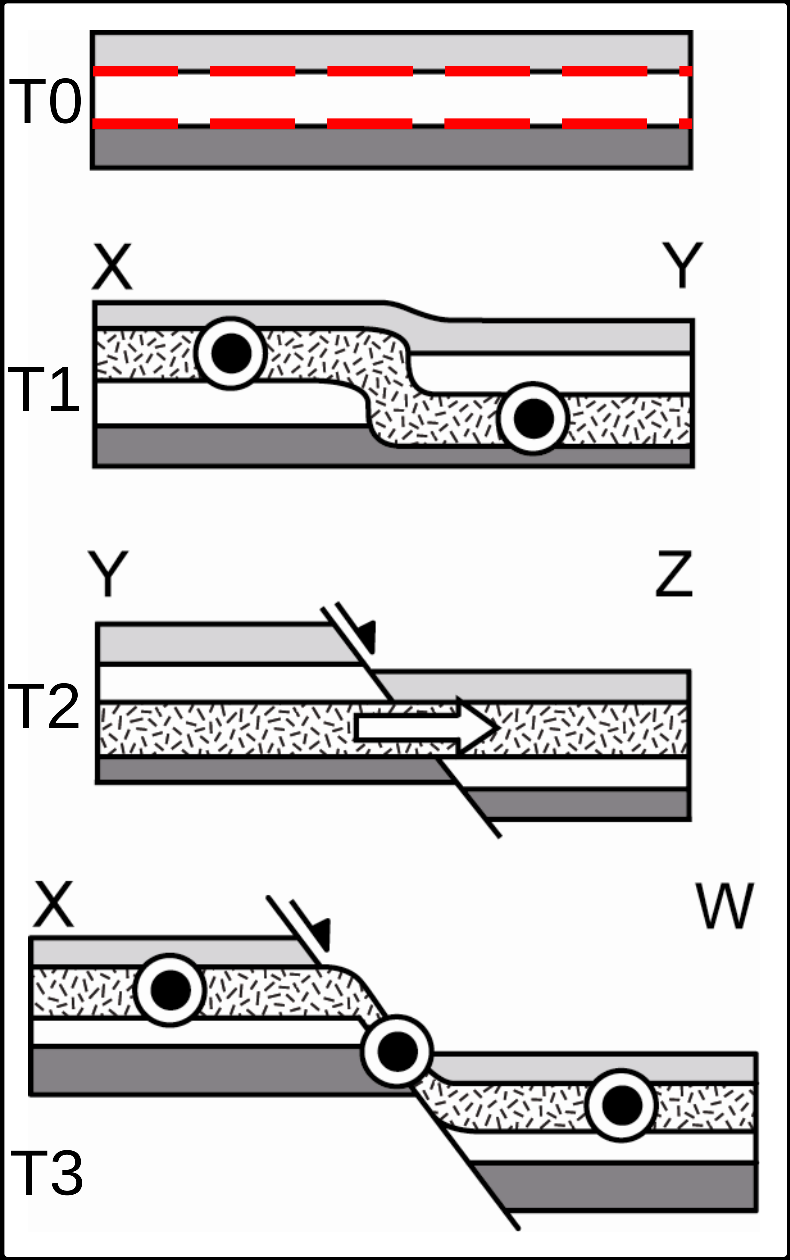

T0 – pre-intrusion stratigraphy

T1 – sill intrusion and step development

T2 – juxtaposition of preferentially intruded horizons across pre-existing fault

T3 – step developed along fault

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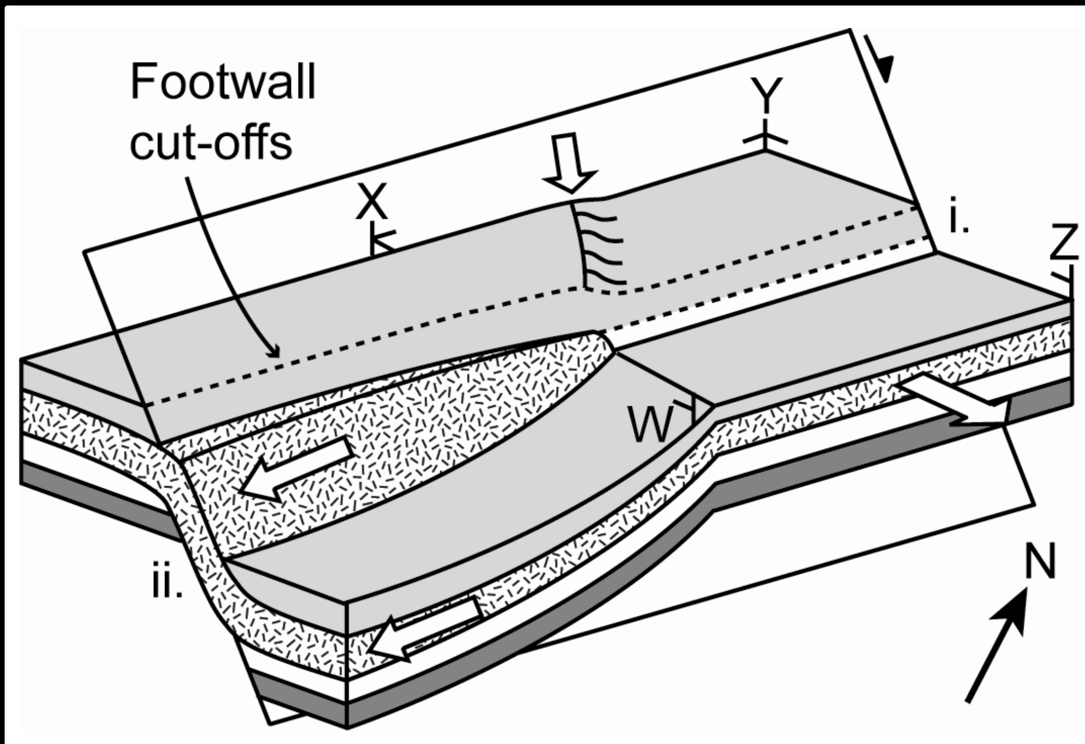

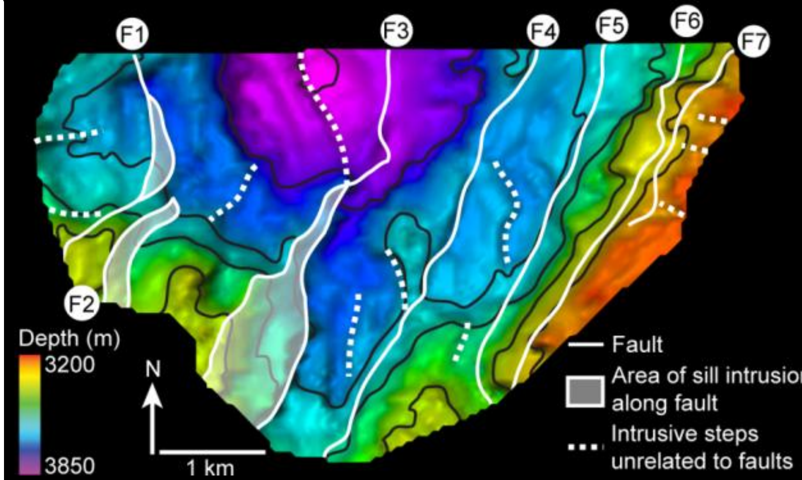

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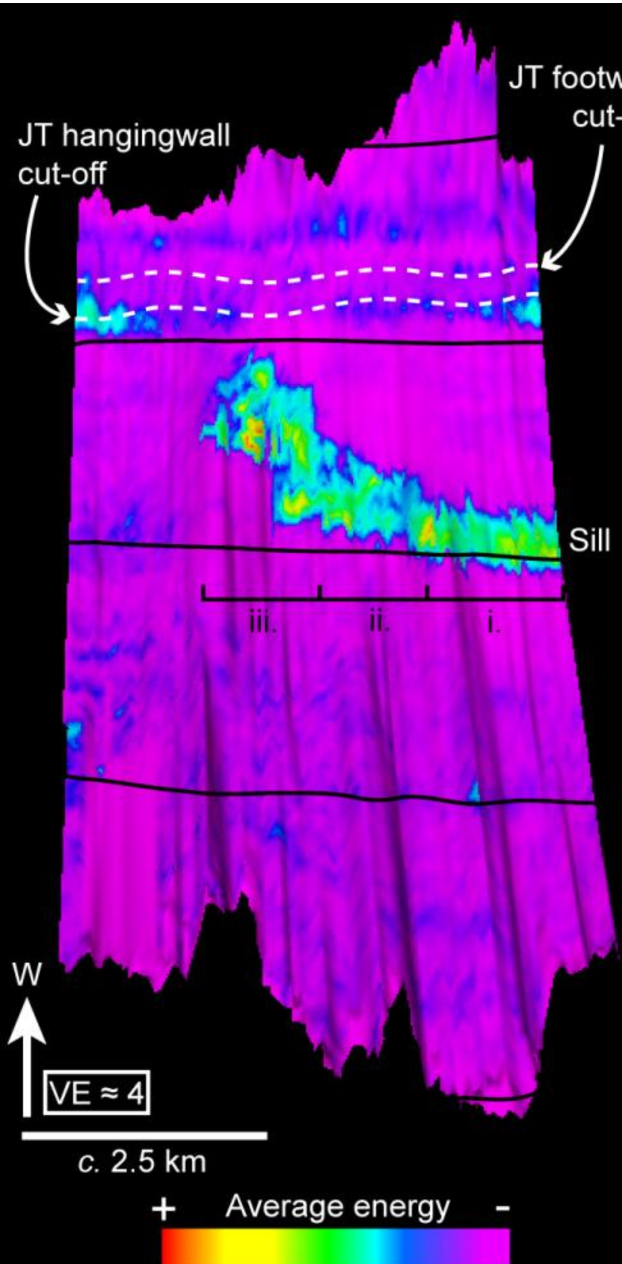

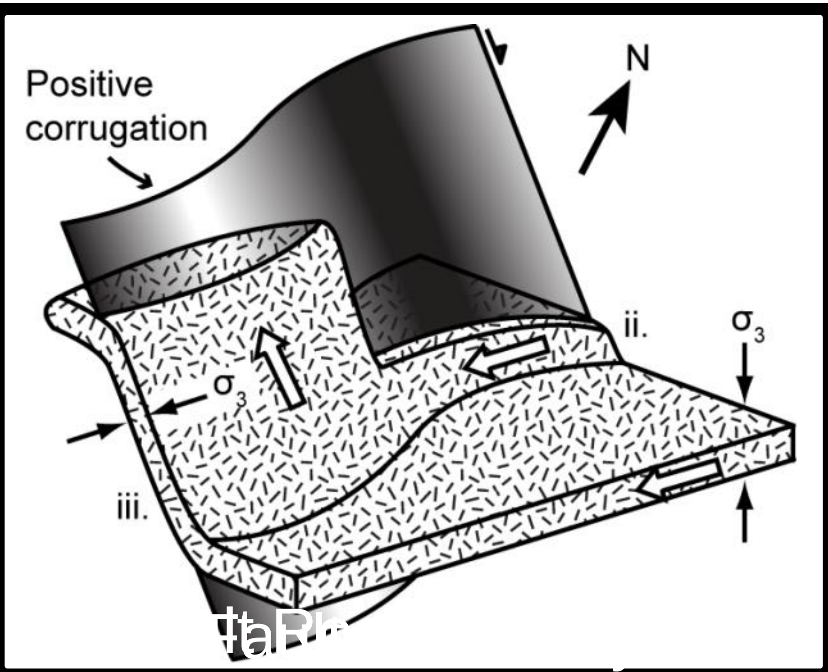

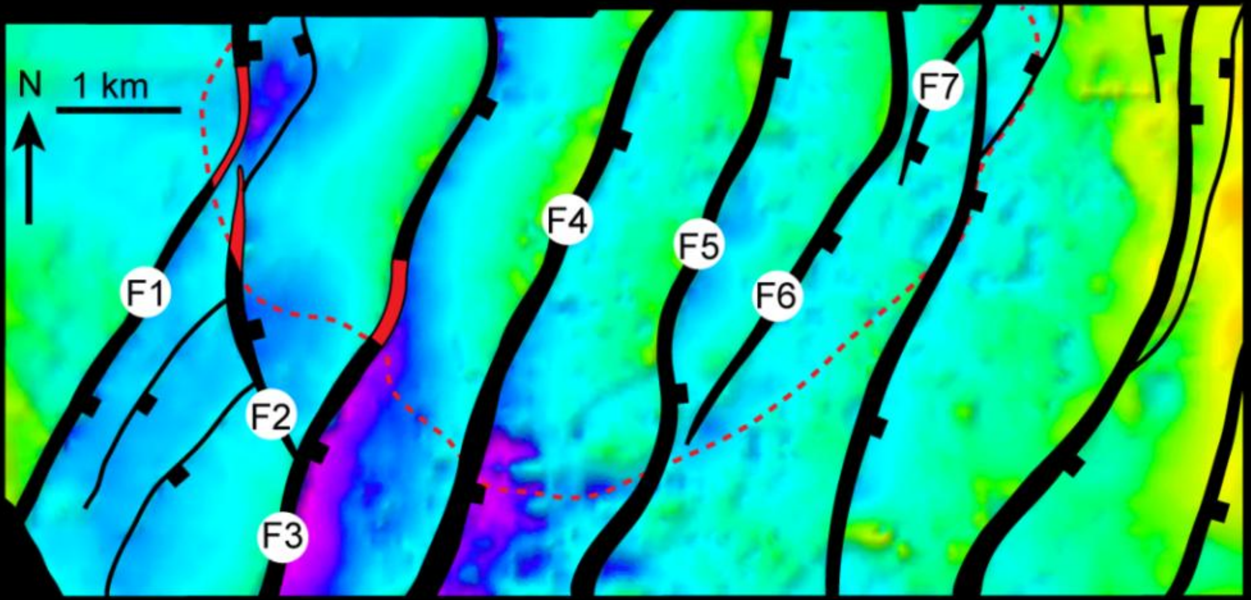

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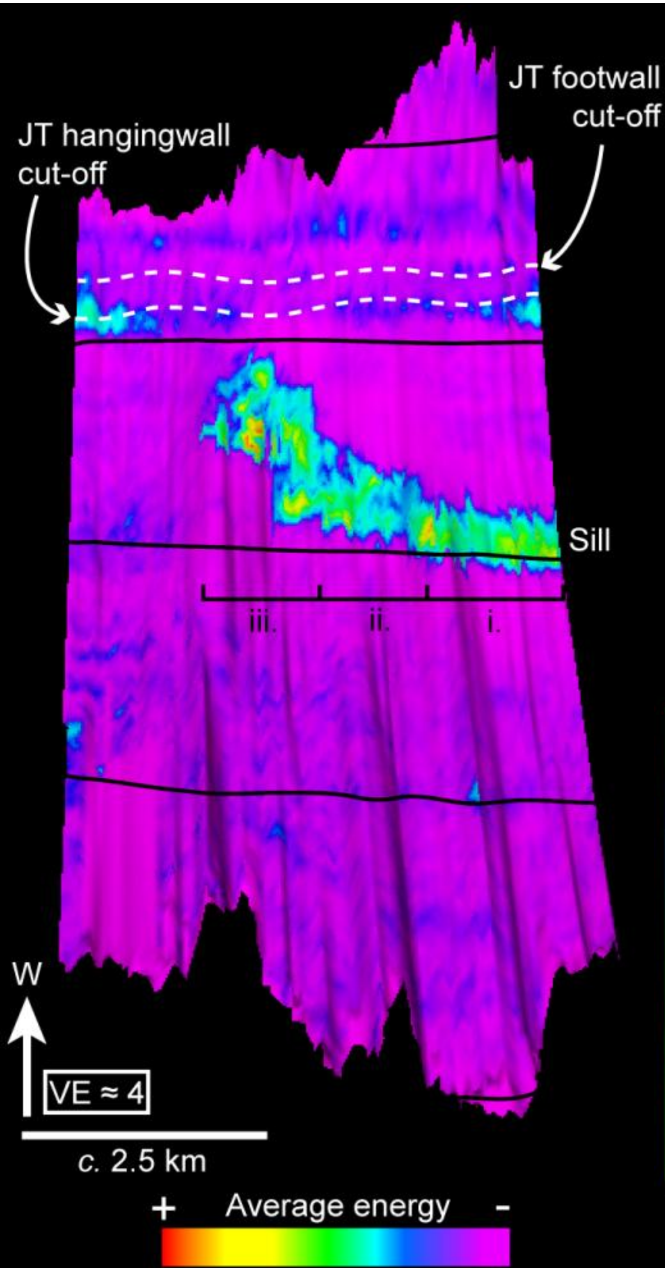
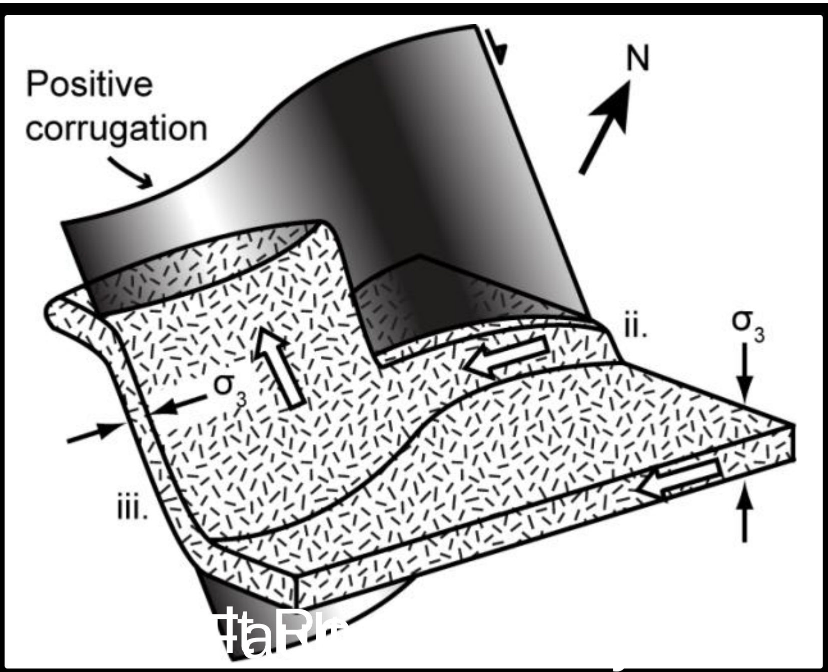
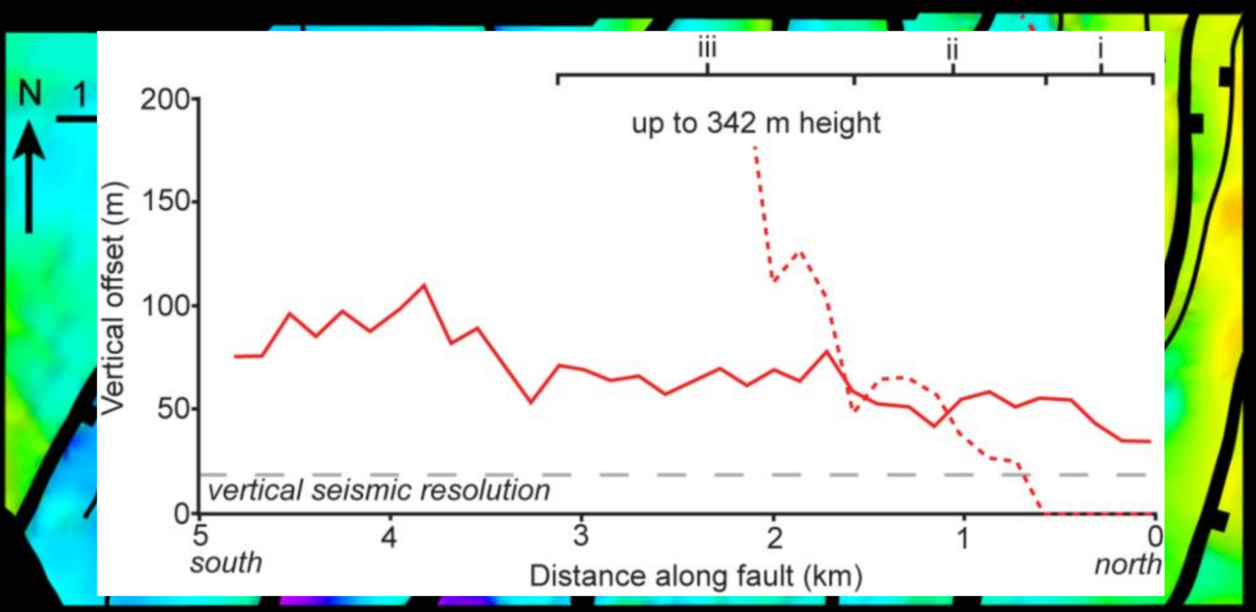
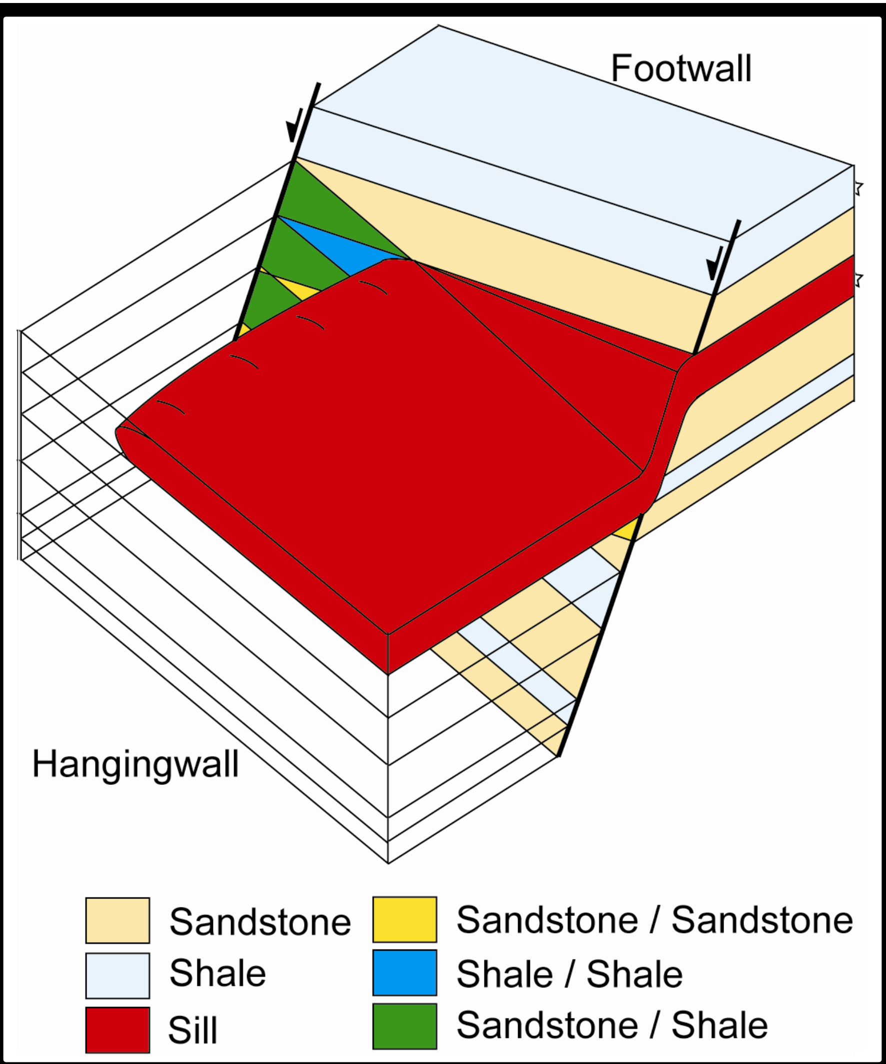






Igneous Intrusion and Fault Seal Potential



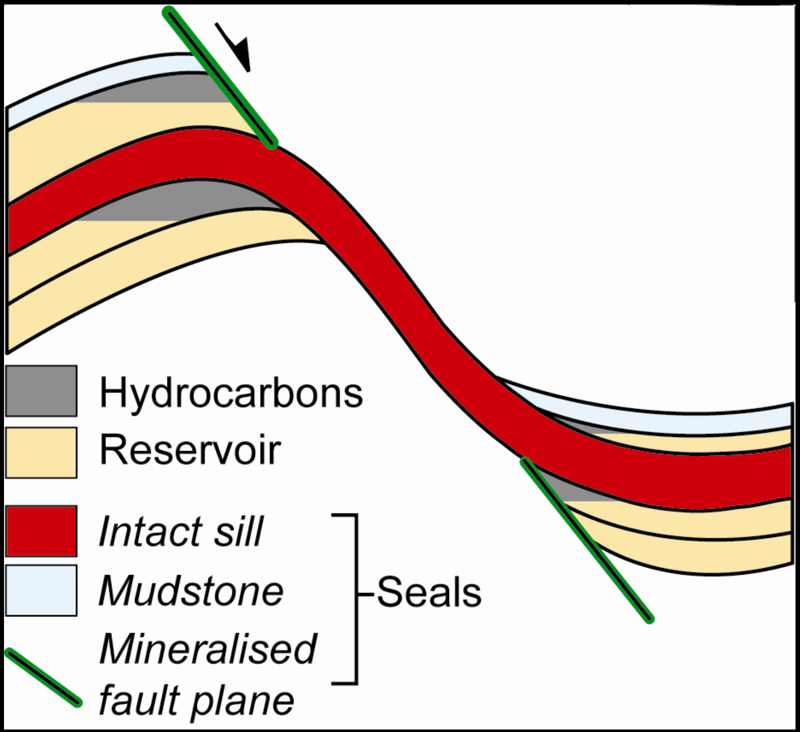
modified from Clarke et al. (2005)

Mechanisms of fault-seal generation:

1/ Bed juxtaposition

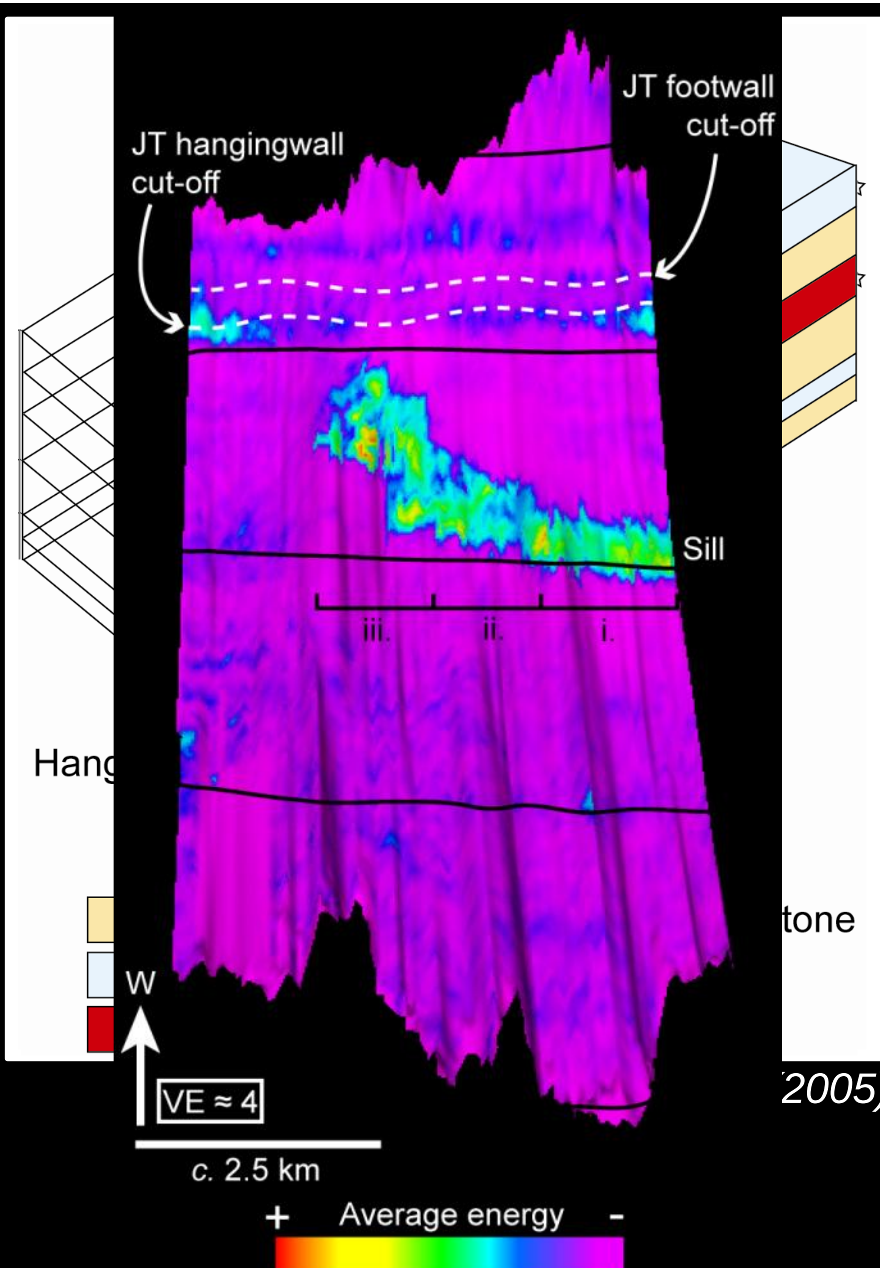
2/ Fault rock processes (e.g. Shale smear)

3/ Intrusion and crystallisation of magma



after Færseth (2006)

Igneous Intrusion and Fault Seal Potential



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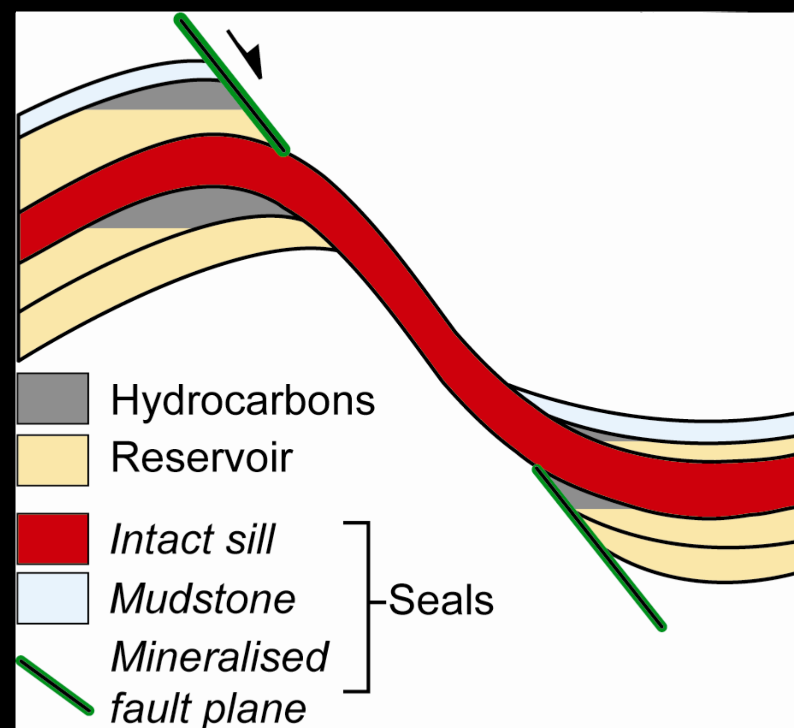

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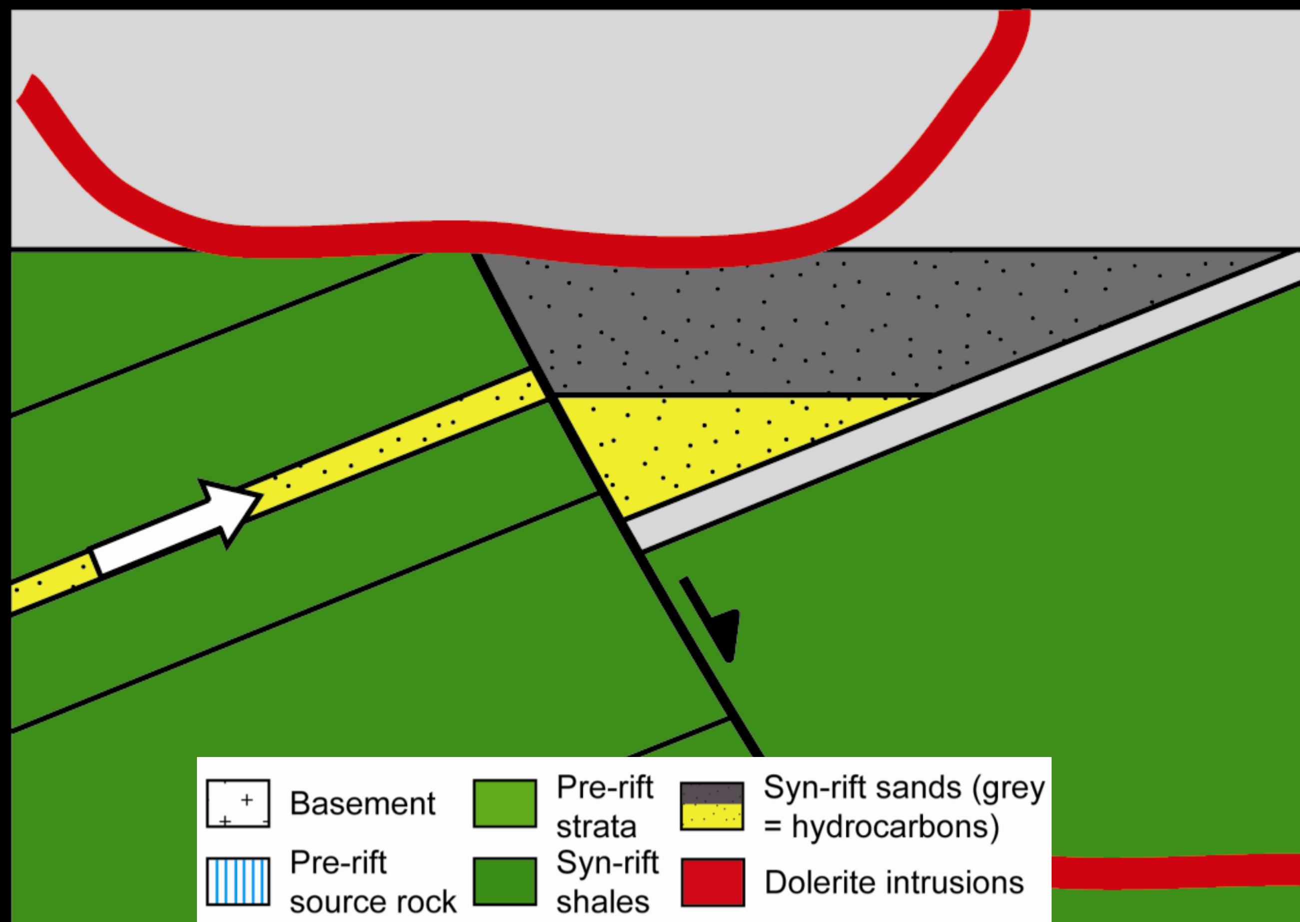
Intrusion-induced Compartmentalization



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- Intrusions may affect vertical and lateral migration pathways
- Impact on lateral connectivity reduced because intrusion is likely to be focused at specific fault segments

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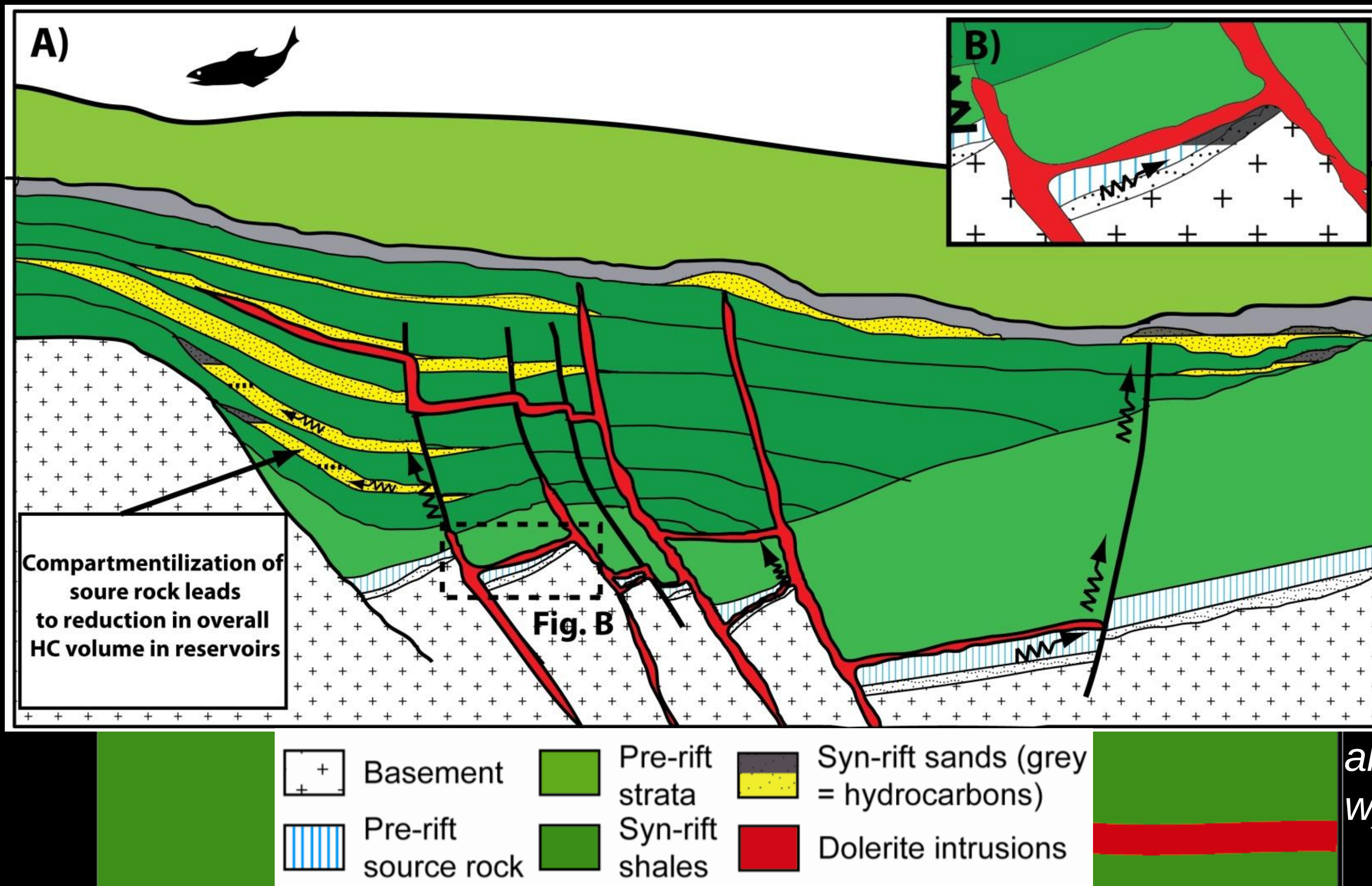

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Conclusions

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- Faults can provide low-permeability magma conduits
- Intrusions exploit laterally restricted fault segments (e.g., convex-into-the-footwall corrugations)
- Magma emplacement and intrusion geometry controlled by stress-field variations and fault rock lithology
- Intrusion and fault interactions may affect:
  - Fault seal potential
  - Hydrocarbon migration
  - Hydrothermal systems
  - Location of volcanic vents