Asymmetrical Sediment Input to Rift Margins*

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Abstract

The controls on the location of major sediment inputs to rift margins are investigated using source-to-sink analysis of modern drainage data into rifts of various ages. While the influence of pre-rift structures and asymmetry of rift-related tectonic structures is acknowledged, we also highlight the importance of pre-existing drainage direction on the distribution of sediment into rift settings. Capture of catchments during syn-rift times forms large drainage basins and river systems that are able to maintain erosion through evolving rift topography. This is observed to result in asymmetry depending on the orientation of the rift axis to the pre-existing drainage. Other factors such as structural asymmetry, regional lithological and climatic variations also play a role.

Given that the locations of major sediment inputs to rift basins are very stable over time, understanding the asymmetries of rift margins is important in establishing both rift and drift-related sediment input histories. In particular, we suggest that the asymmetrical nature of sediment input to rifts is common and cannot be explained entirely by tectonic factors. The major exploration implication is for the delivery of sand into rift basins and eventually passive margins.

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Asymmetric sediment input to rift margins

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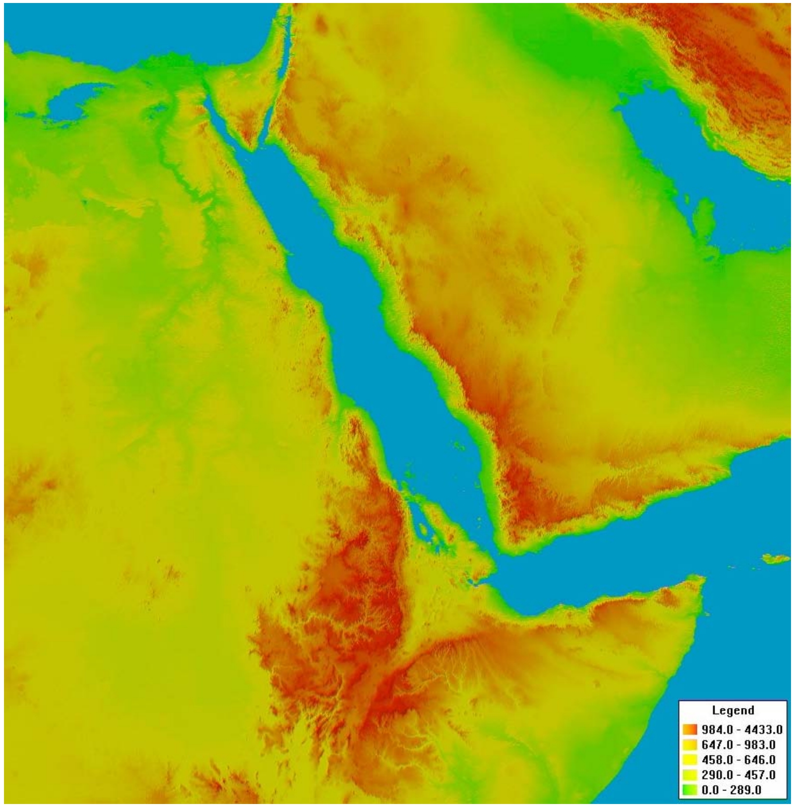
Introduction

- Major clastic and carbonate reservoirs are be controlled by location of large fluvial entry points
- Interaction between fault linkage and drainage well studied over 10’s km scale.

What about regional sediment input?

- Approach : use drainage analysis of modern rift systems to understand controls on major drainage inputs to rifted margins



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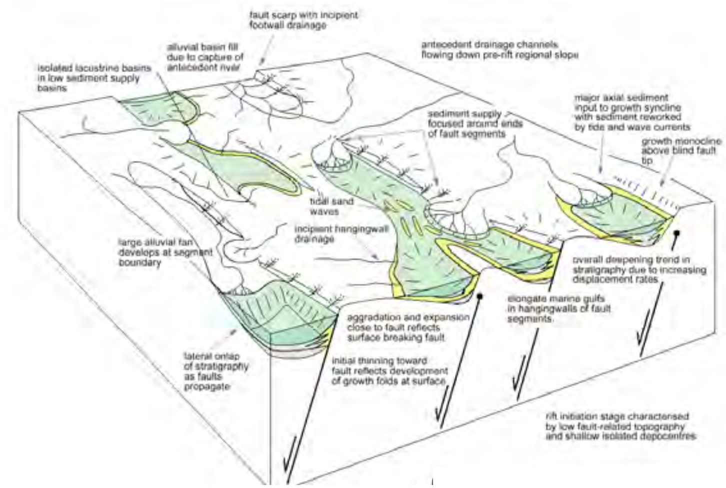
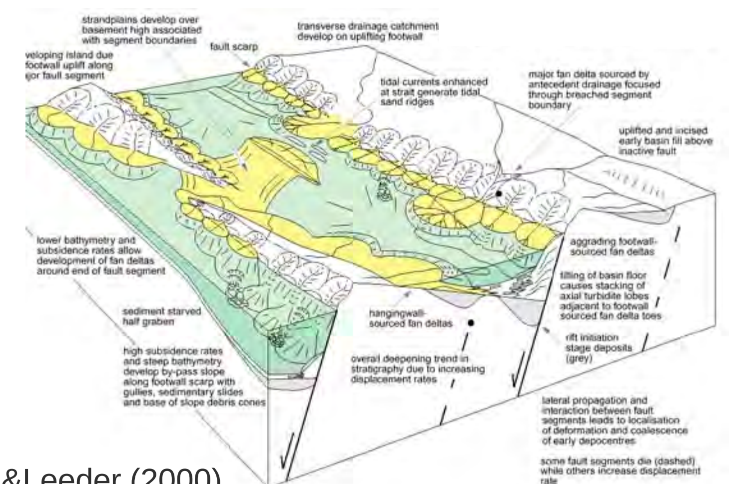
Summary of existing factors that affect rift drainage

- Sediment supply from
  - Small rift shoulder / footwall drainage
  - Large interior drainage
- Rift transfer zones are commonly sites of large drainage outlets
- Transfer zones occur where
  - fault segments overlap
  - basement lineaments intersect rifting
  - rift orientation changes direction
- Sediment delivery locally affected by lithology





Gawthorpe&Leeder (2000)

Regional sediment input

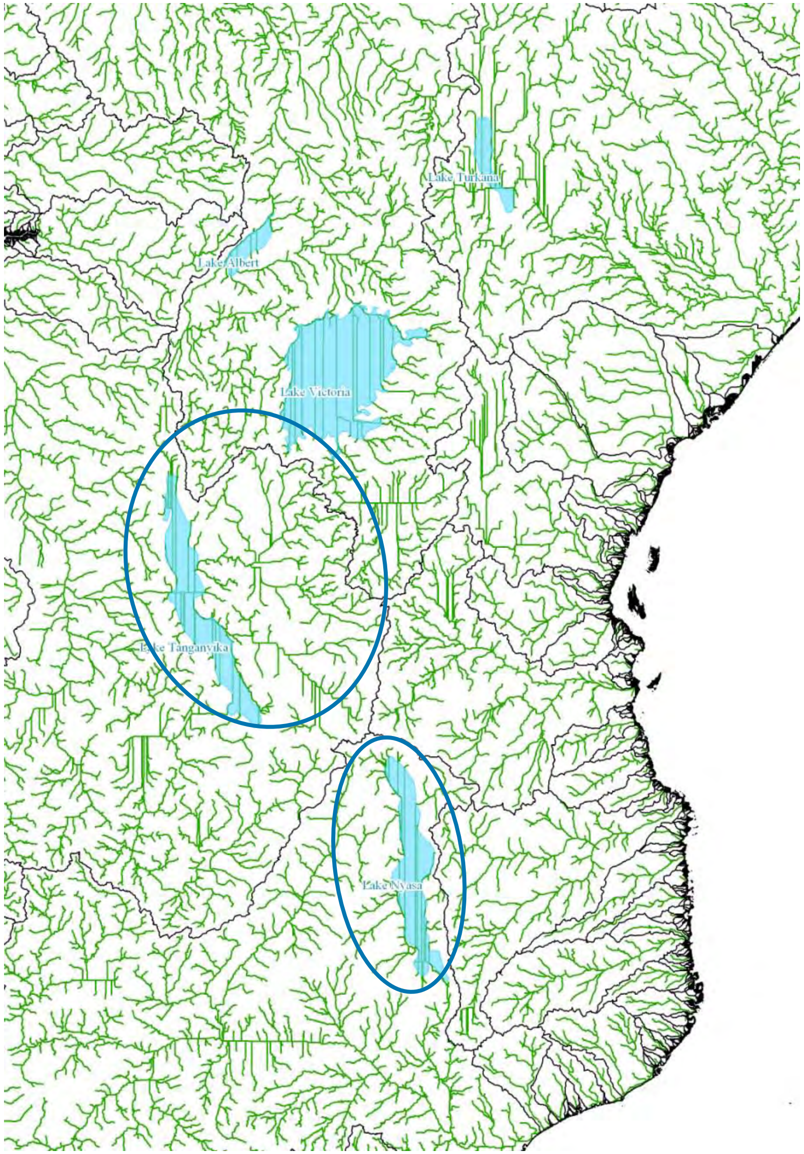
- Role of pre-rift drainage
- Regional sediment supply
  - Direction of pre-rift drainage controls where the main sediment feeder originates

- Lake Baikal – major delta system on SE coast
  - original river continues to the NW

Example - East Africa

- Drainage into Lakes Tanganyika and Malawi show asymmetry
- Lake Malawi
  - Larger drainage basins to the west

- The asymmetry in drainage basin size will determine asymmetry in sediment input (Hovius, 1998; Syvitski + Milliman, 2007)



Lake Malawi drainage evolution

- 1. pre-rift drainage west-to-east
- 2. development of rift valley and lake and capture of western half of original drainage
- 3. development of short, steep drainage to the east

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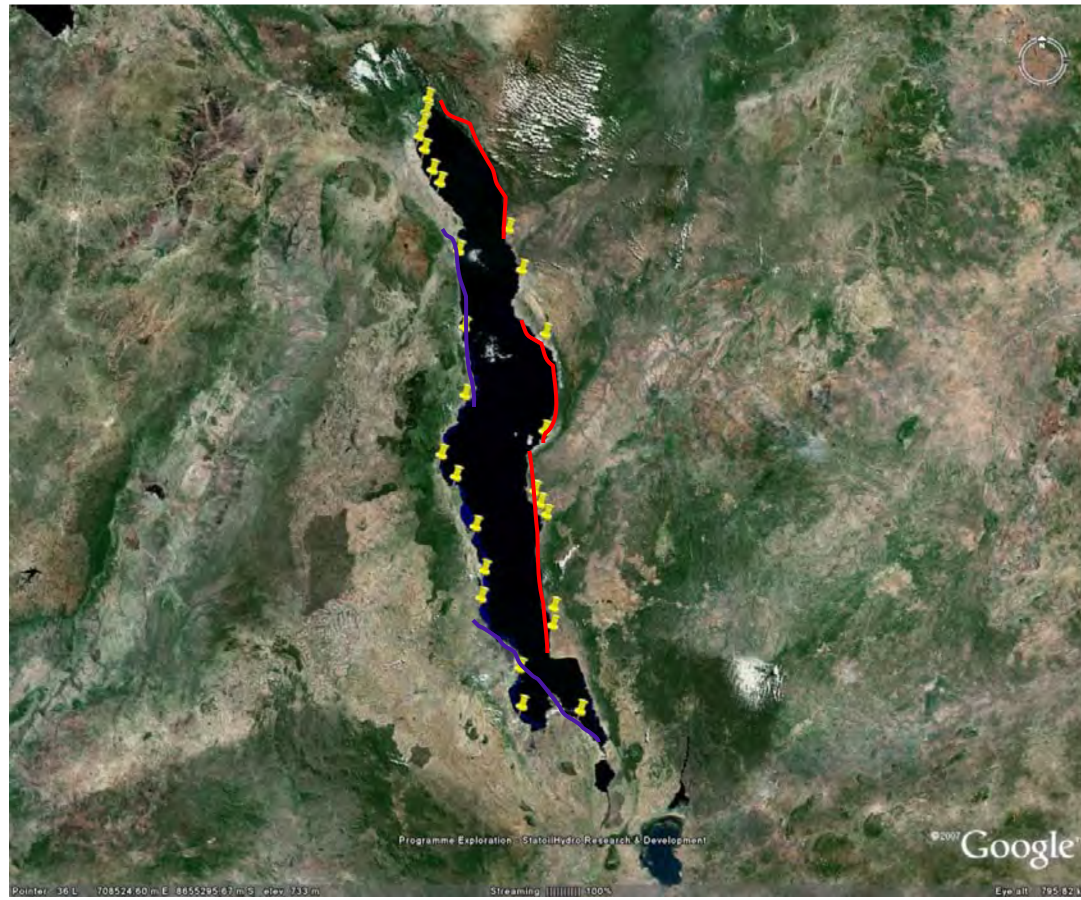
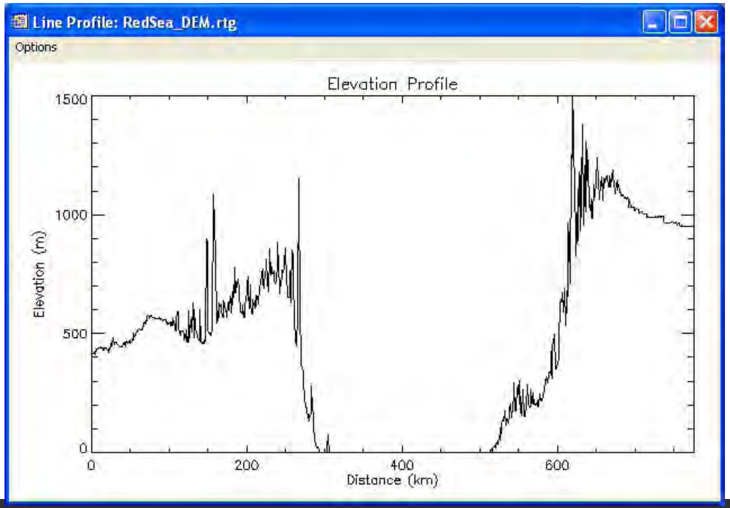
Deltas in Lake Malawi

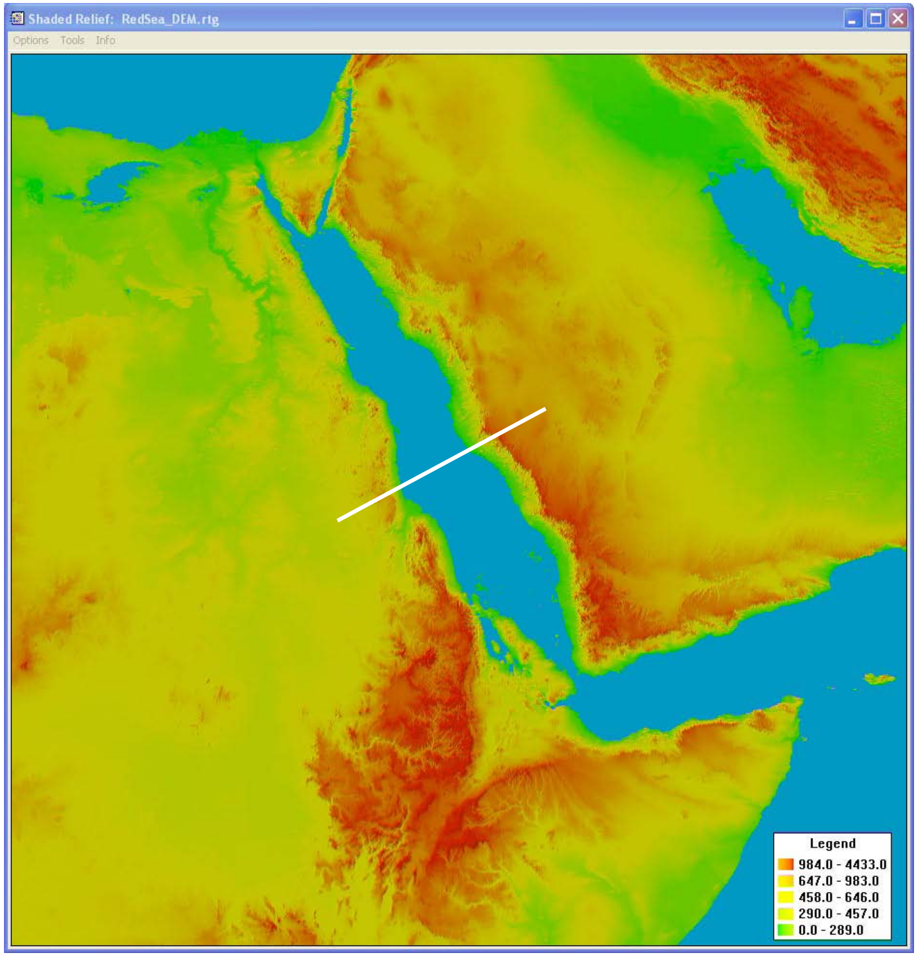
- Delta locations show asymmetry (more western-derived deltas than eastern-derived deltas)
- Delta asymmetry not controlled by dip domain of local fault blocks



Case Study : Red Sea

- Plume-related volcanism : 31-25 Ma
- Diachronous rift initiation : 28-24 Ma
- Rift shoulder uplift : 20 Ma
- Onset of seafloor spreading : 5 Ma
- Rift shoulder present on both margins

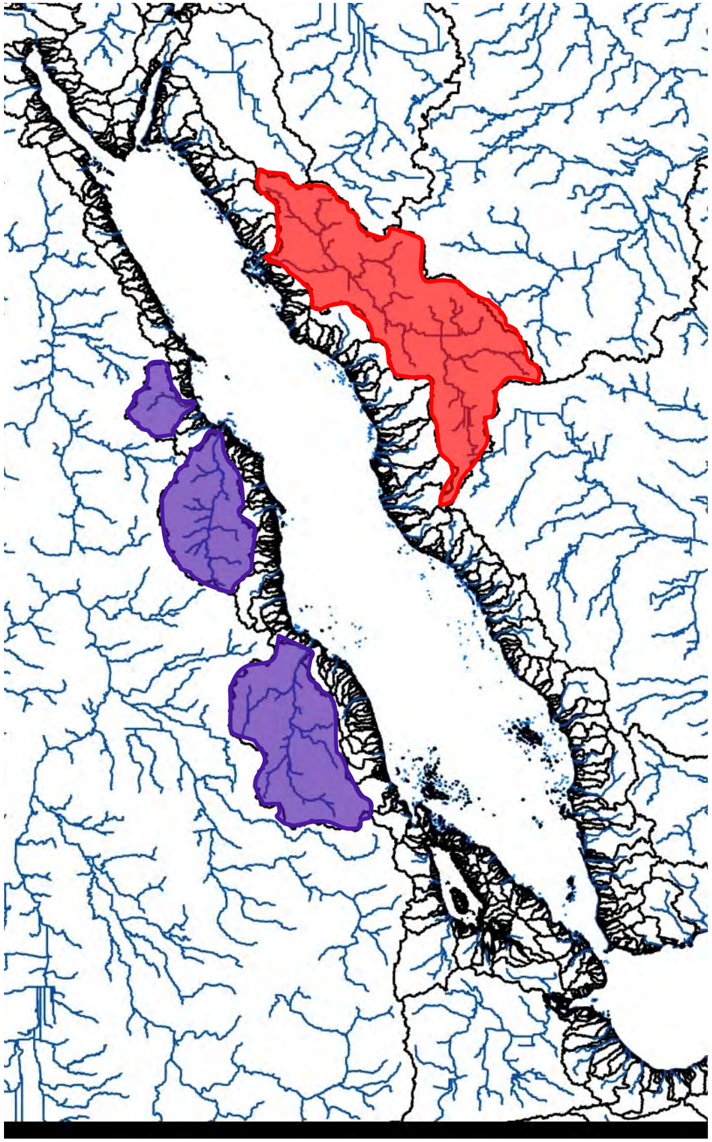




Red Sea drainage

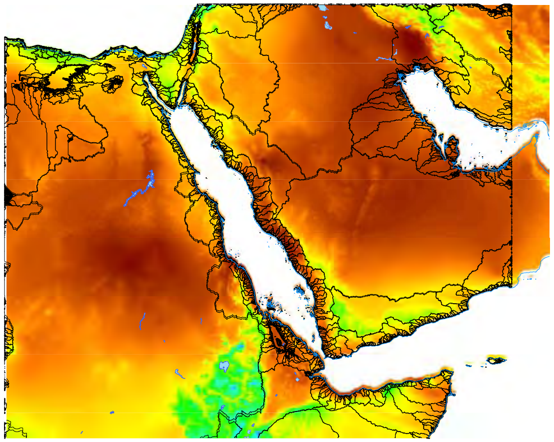
- Drainage into Red Sea is
  - mostly steep, rift shoulder drainages
  - some larger basins draining behind the rift shoulder

- Large drainage basins are asymmetric and major control post-salt depocentres. What controls asymmetry?

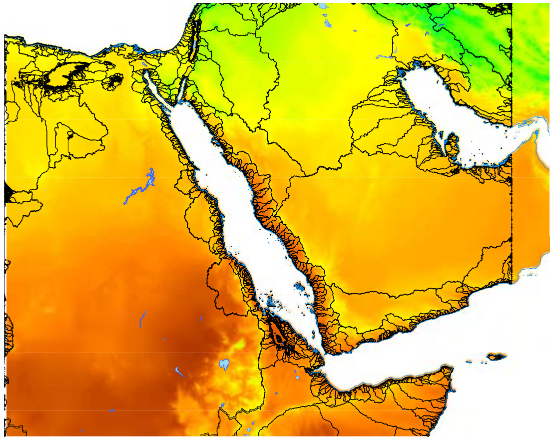


Red Sea drainage + temperature

- June temp has range of:
  - 25-40 deg C (Arabia)
  - 20-35 deg C (Africa)
- December temp has range of :
  - 10-25 deg C (Arabia)
  - 15-25 deg C (Africa)



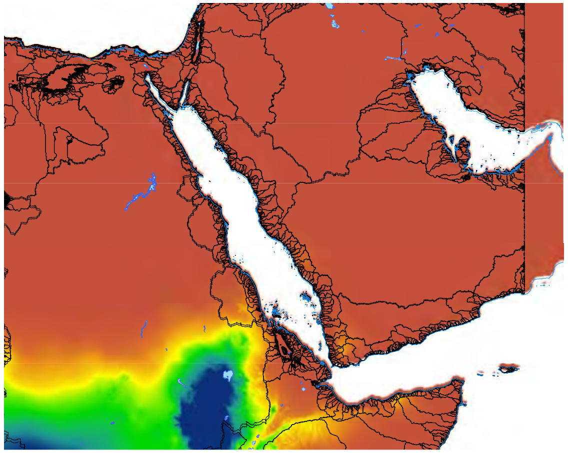
June



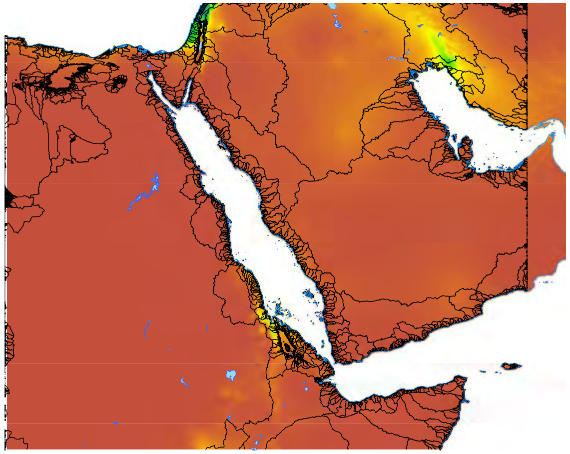
December

Red Sea drainage + precipitation

- June - 0mm precip mostly. Up to 50mm in the south
- December precip shows ~10mm on both sides of the margin
- Very little asymmetry in climate over the majority of the Red Sea margin



June

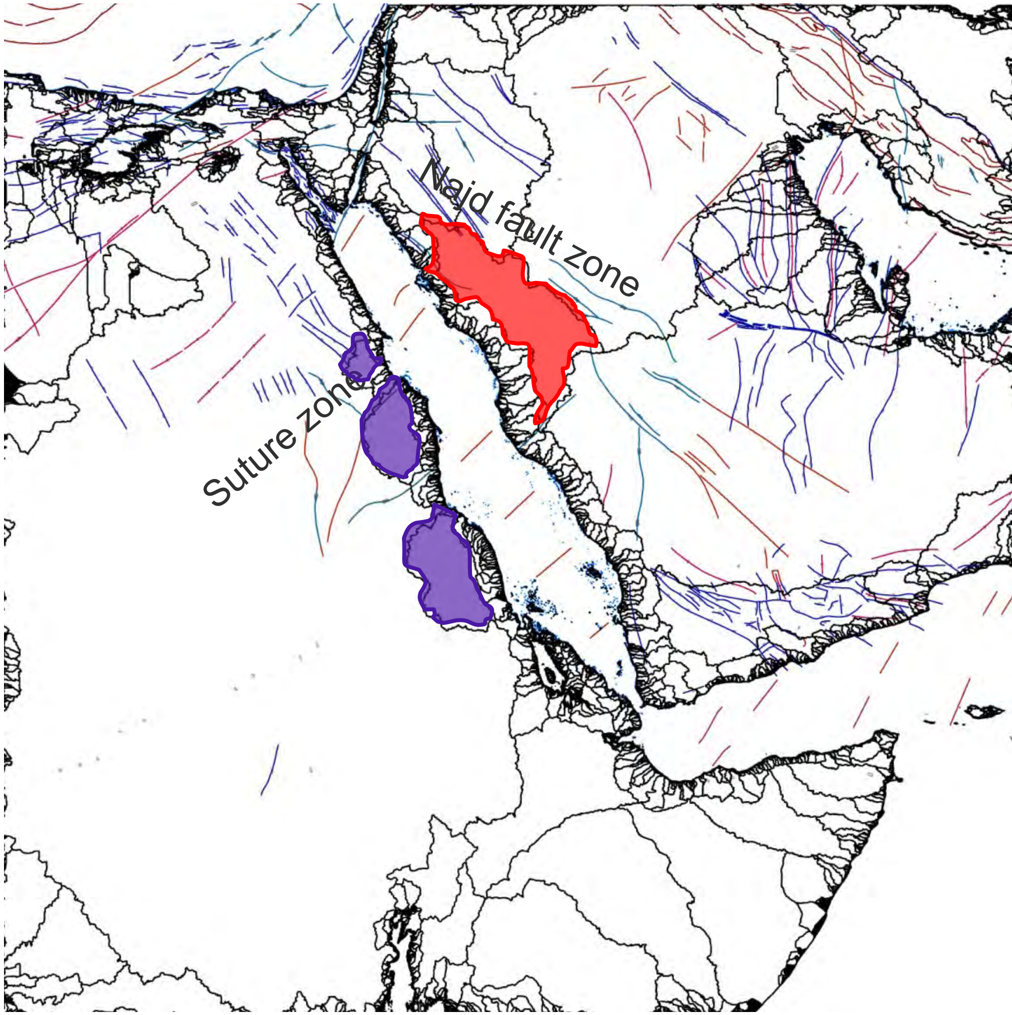


December

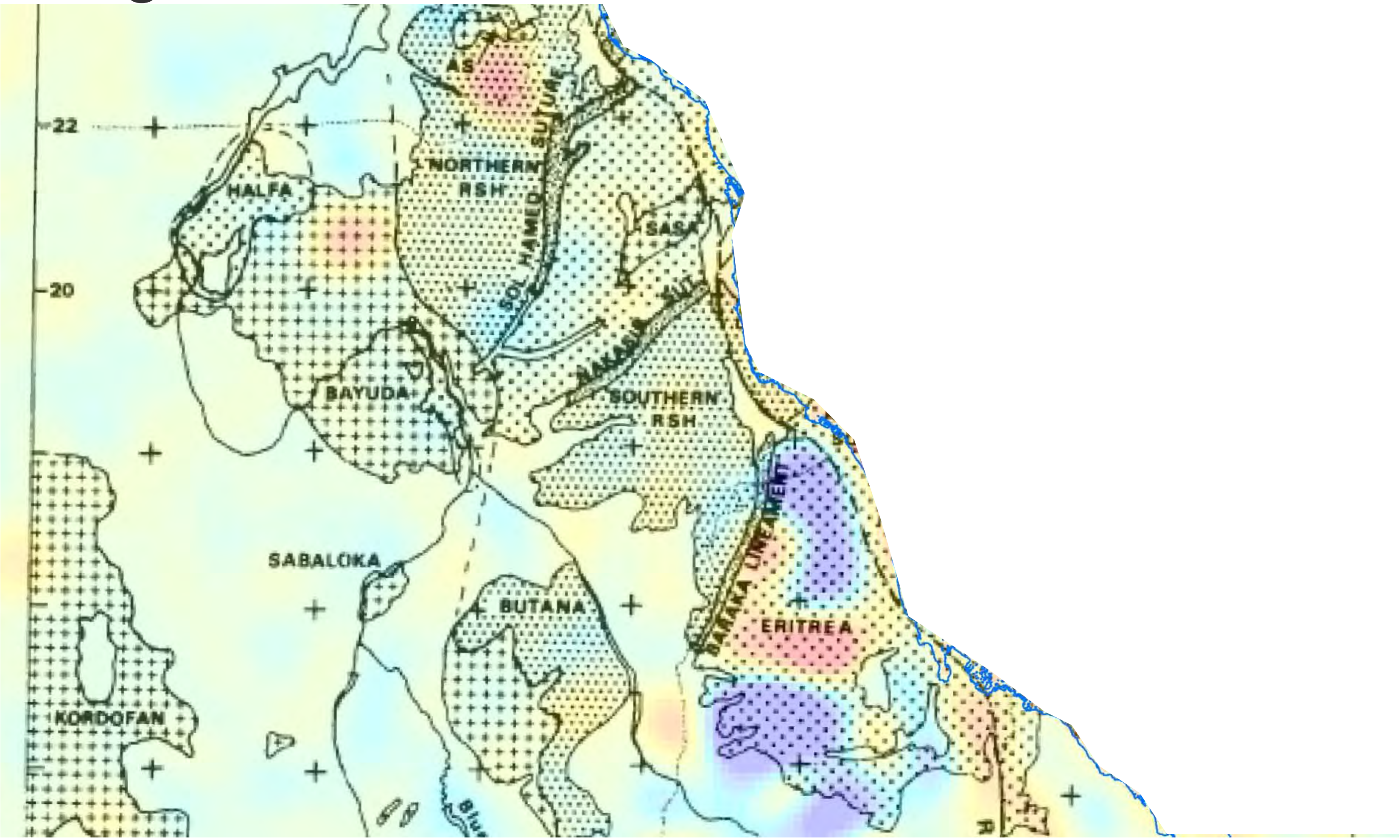
Red Sea drainage + structure

- Global structure dataset indicates some structural lineaments coincide with drainage basin outlets

- Bedrock maps show bedrock lithology has no major control over large drainage basin locations

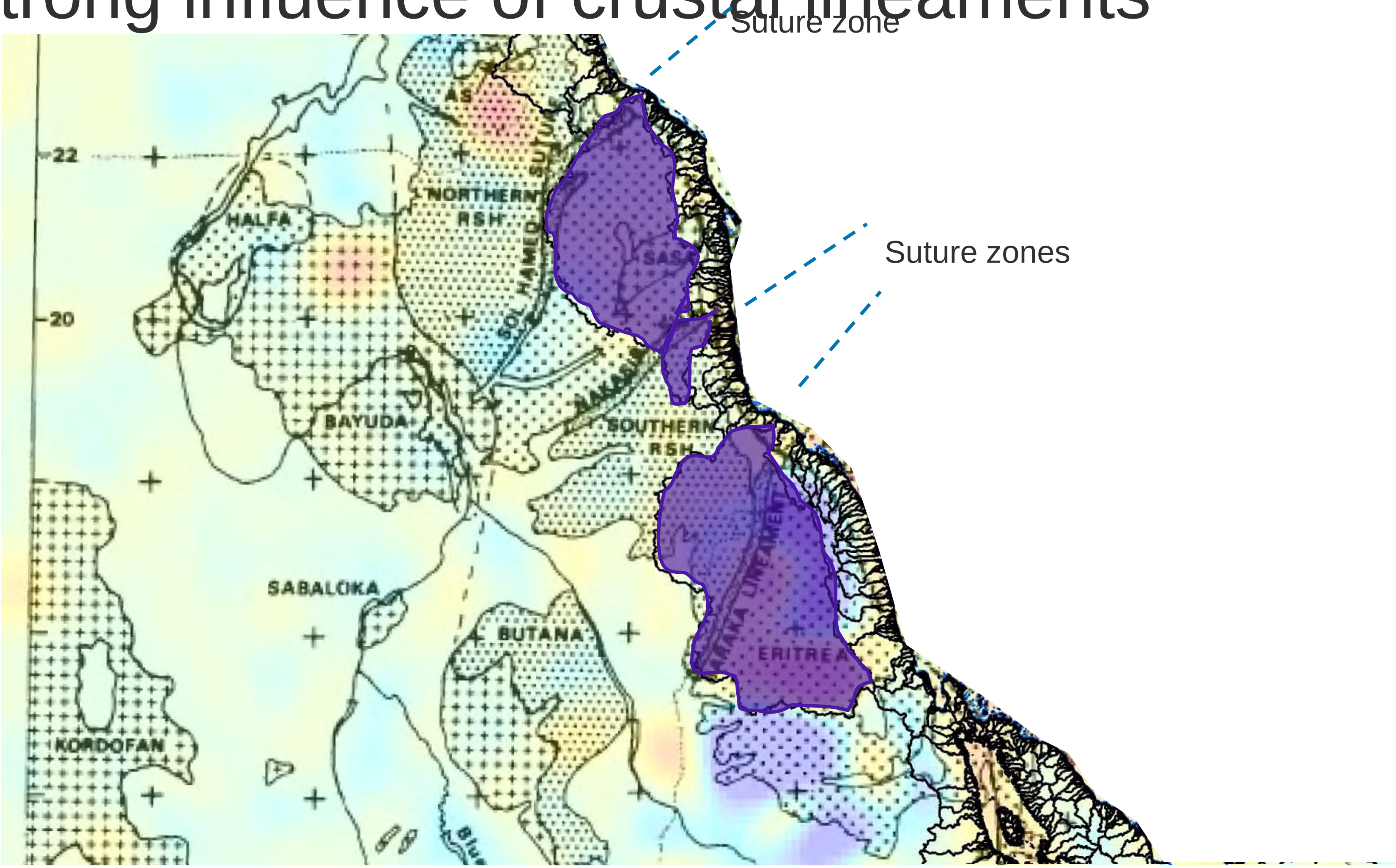


Strong influence of crustal lineaments



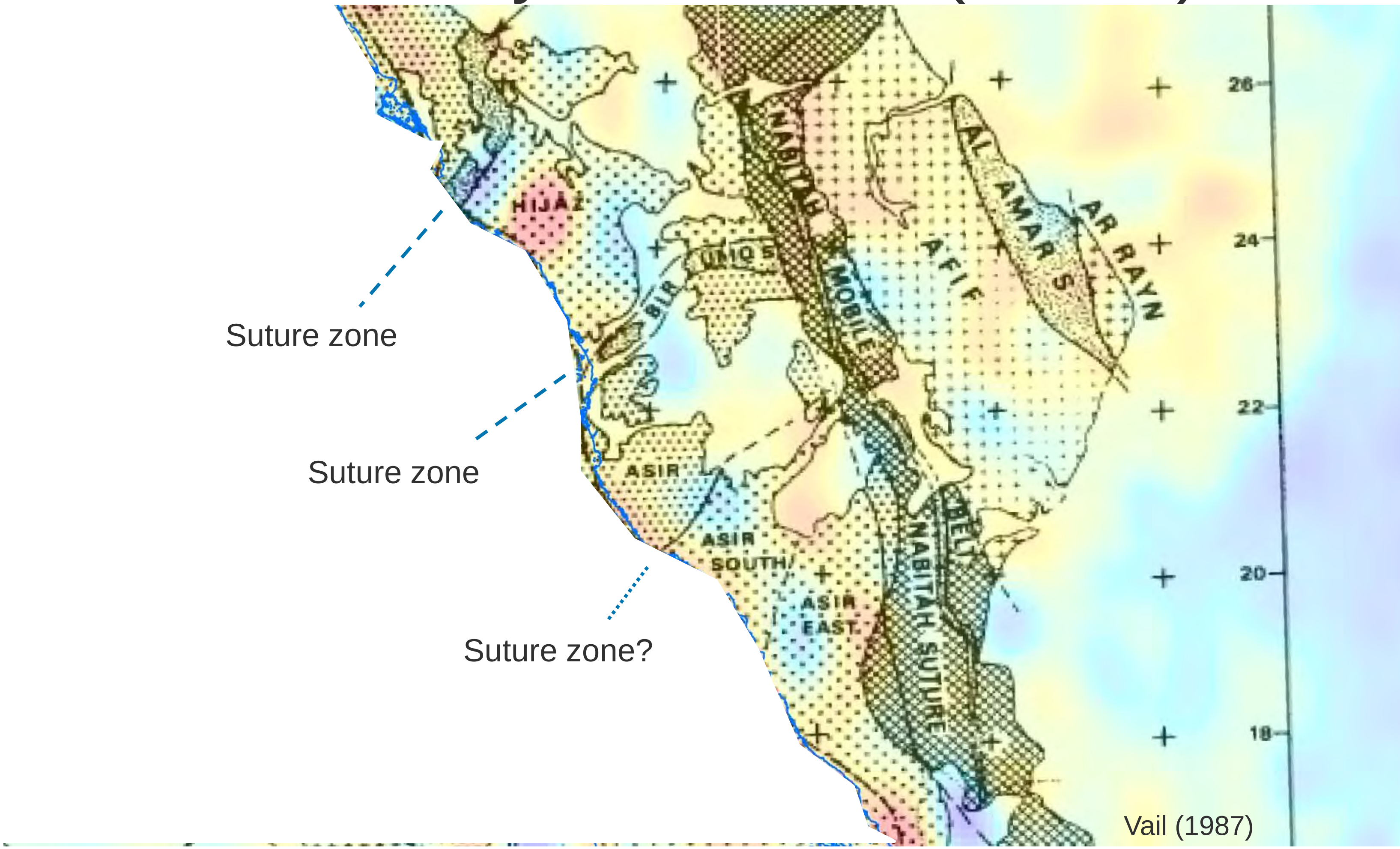
Vail (1987)

Strong influence of crustal lineaments



Vail (1987)

Weak influence by lineaments (Arabia)



Vail (1987)

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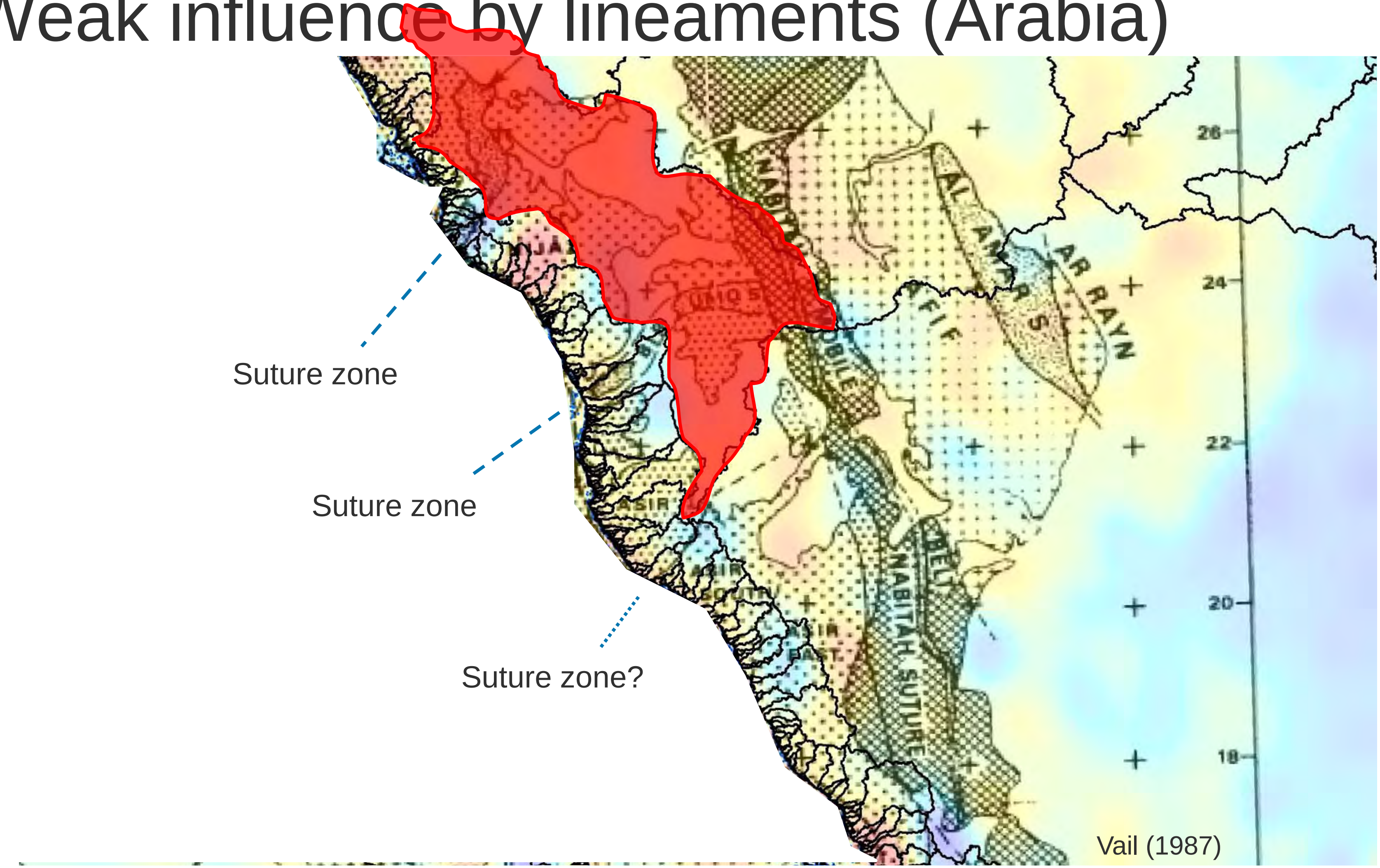
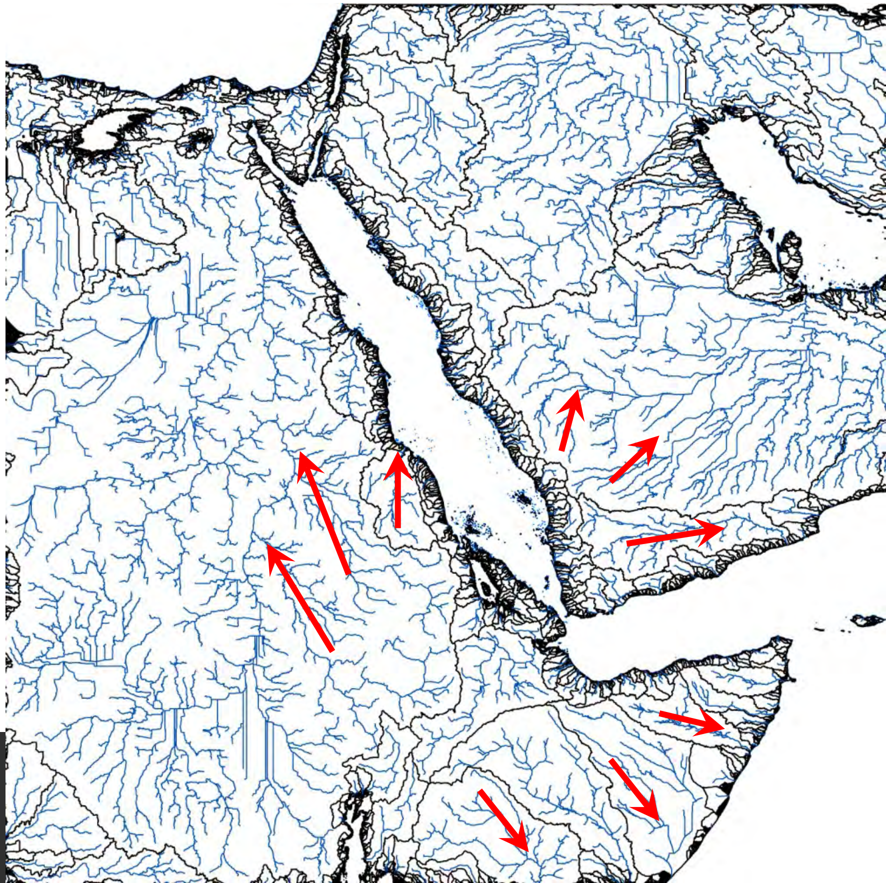


Vail (1987)

What are the causes of drainage asymmetry

- Bedrock lithology and climate not sigificant here
- Basement lineaments are present on both margins. Strong control of drainage on African margin, not on Arabian. Why?



- Modern drainage has a radial pattern
- Influence of plume-influenced

  pre-rift drainage?

Model for pre-rift control on major basins

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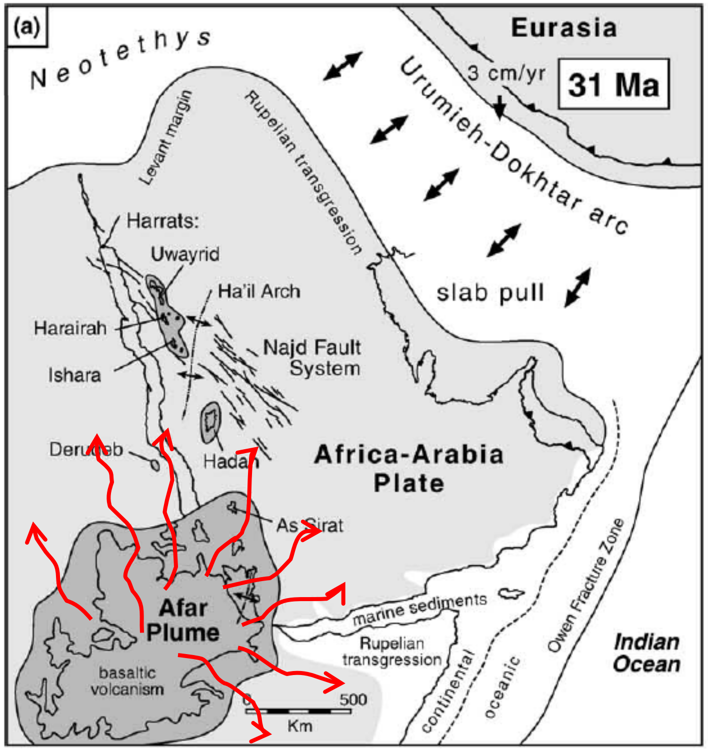
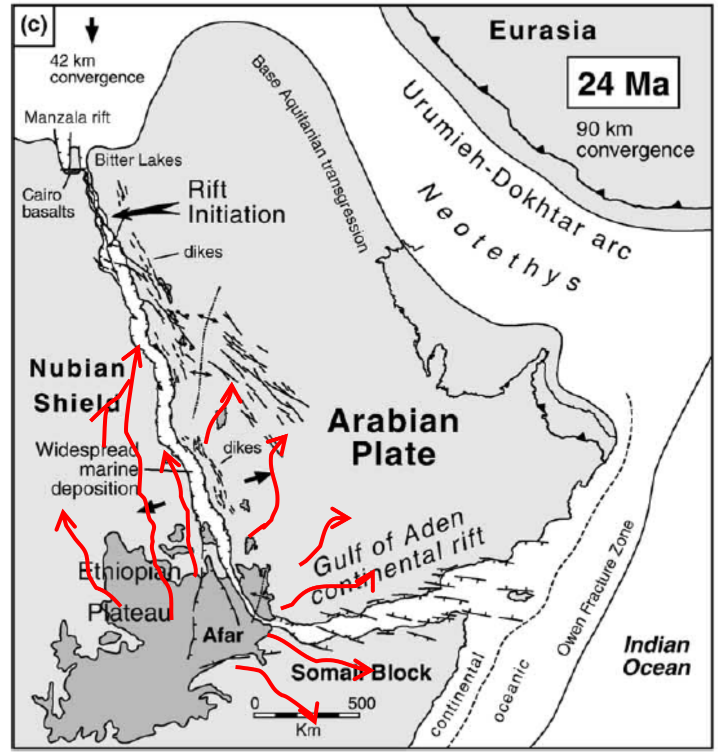


Plume uplift + volcanism

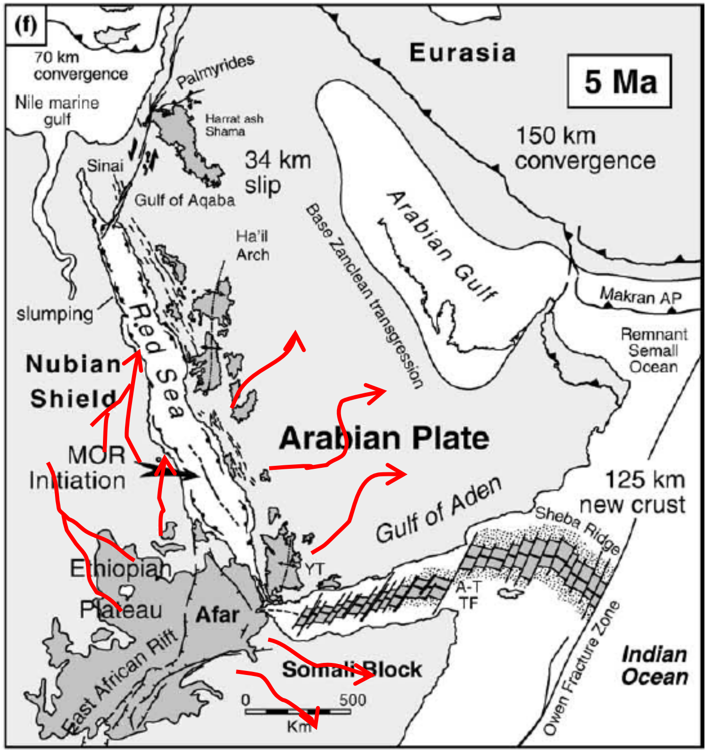


Rift initiation + onset of rift shoulder uplift

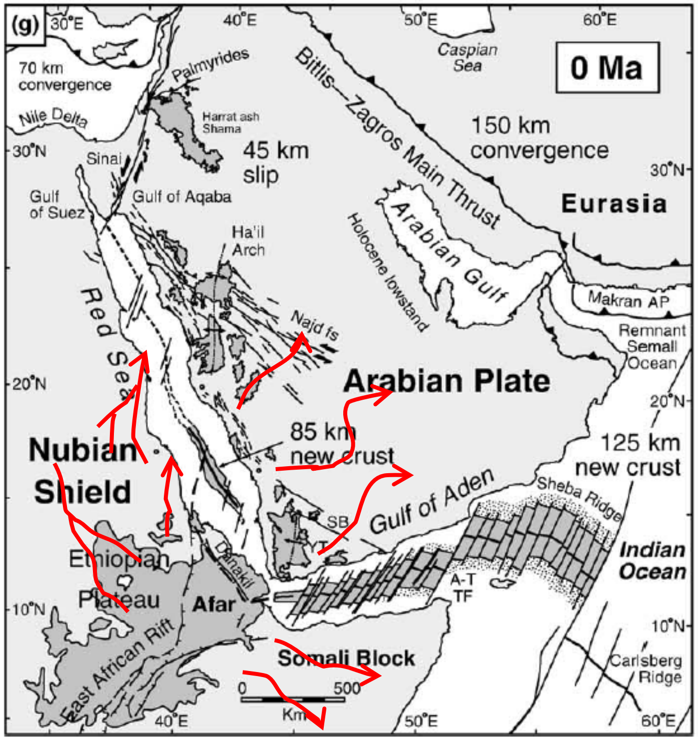
SEGMENTATION OF DRAINAGE BASINS ON AFRICAN MARGIN

Base figures from Bosworth (2005)

Model for pre-rift control on major basins



Onset of seafloor spreading



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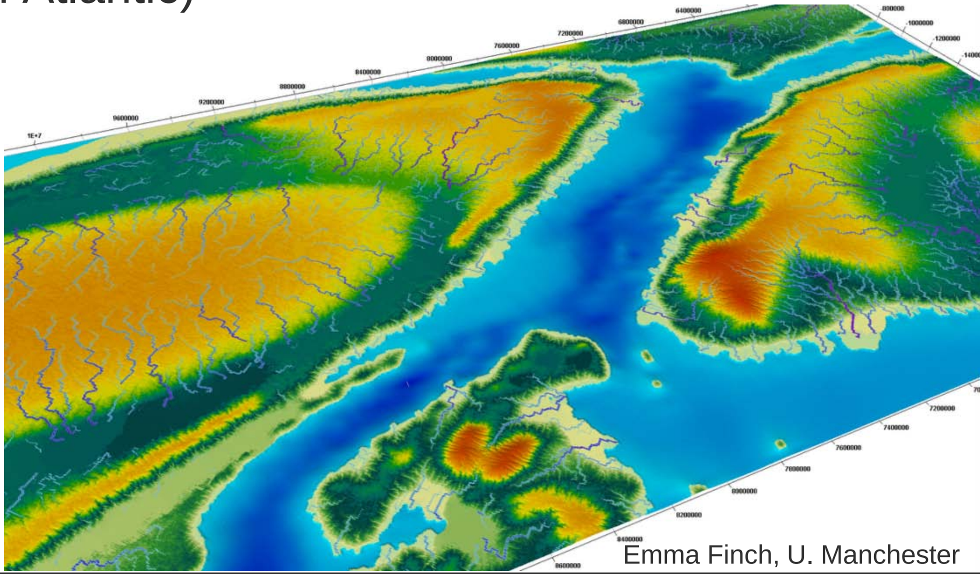
Relevance for frontier exploration

- Pre-rift topography associated with plume uplift / dynamic topography sets up long-term drainage asymmetry

- Exploration of conjugate basins should take account of asymmetry in sediment supply (ie North Atlantic)

- Further work based requires modelling drainage response to rift-shoulder uplift



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