# Previously Unrecognised Extensional Tectonics Exposed in the Barmer Basin, Northwest India*

**Andrew J. Bladon[1,2], Stuart M. Clarke[1], Stuart D. Burley[1,4], Hazel Beaumont[1], Nicholas Whiteley[3], V. Kothari[3], and P. Mohapatra[3]**

Search and Discovery Article #30426 (2015)**
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Editor' note: Please refer to related article by the first author and others, Search and Discovery Article #10593 (2014) (http://www.searchanddiscovery.com/documents/2014/10593bladon/ndx_bladon.pdf).


[1]Keele University, Keele, United Kingdom (andrew@mve.com)
[2]Midland Valley, Glasgow, United Kingdom
[3]Cairn India Limited, Gurgaon, India
[4]Murphy Oil Corporation Limited, Kuala Lumpur, Malaysia

## Abstract

Several giant oilfields were discovered in the Barmer Basin in 2004, predominantly situated within the crests of faulted blocks, and the basin is now an established oil- and gas-producing province (7.3 BBL of STOIIP, 200,000bopd production). However, the extent and geometry of many fault-blocks within the rift are controlled by poorly understood rift-oblique faults that are variably imaged throughout the subsurface. Here we present a study of Early Cretaceous sedimentology that accumulated prior to the main rifting event in the Barmer Basin, exposed along the eastern rift margin in the Sarnoo Hills, along with a detailed investigation of a rift-oblique fault network that is exposed nowhere else in the region. The findings provide critical insights into the structural evolution of the Barmer Basin and regional tectonic processes hitherto unrecognised. Lower Cretaceous sediments were deposited within an alluvial-plain fluvial system. The high proportion of floodplain mudstones and siltstones preserved within the fluvial succession and the lack of evidence for long-term floodplain stability, suggest aggradation of the floodplain, possibly due to rapid subsidence or a high sediment supply. Subsequent to deposition, brittle deformational structures accommodated northwest-southeast extension, highly oblique within the north-northwest-trending Barmer Basin and previously unrecognised in northwest India. Despite the pre-rift tectono-stratigraphical relationship between the sedimentary succession and the fault network exposed at outcrop, the sedimentology suggests deposition was triggered by the onset of rapid subsidence in

the Barmer region during the Early Cretaceous, and is likely a manifestation of the rift-oblique (≈ NW-SE) extensional tectonics exposed. The identification of Early Cretaceous, rift-oblique extension that pre-dated the main rifting event in the Barmer Basin during the Paleogene indicates that the present-day structural architecture of the Barmer Basin resulted from two, superimposed, non-coaxial extensional events and elucidates poorly understood rift-oblique faults interpreted in the subsurface throughout the rift. Integration of the findings with the currently understood regional tectonic framework suggests northwest-southeast-oriented Early Cretaceous extension is an intra-continental manifestation of transtension between the Greater Indian and Madagascan continents during Gondwana fragmentation.

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[1] Basin Dynamics Research Group | Keele University | Keele | Staffordshire | ST5 5BG | England.
[2] Midland Valley Exploration Limited | Floor 9 | 2 West Regent Street | Glasgow | G2 1RW.
[3] Cairn India Limited | 3rd Floor | Vipul Plaza | Suncity | Sector 54 | Gurgaon | 122 002 | India.
[4] Murphy Oil Corporation Limited | Level 29 | Petronas Twin Towers | KLCC | 50088 | Kuala Lumpur | Malaysia.

*andrew@mve.com

BASIN DYNAMICS RESEARCH GROUP
BDRG

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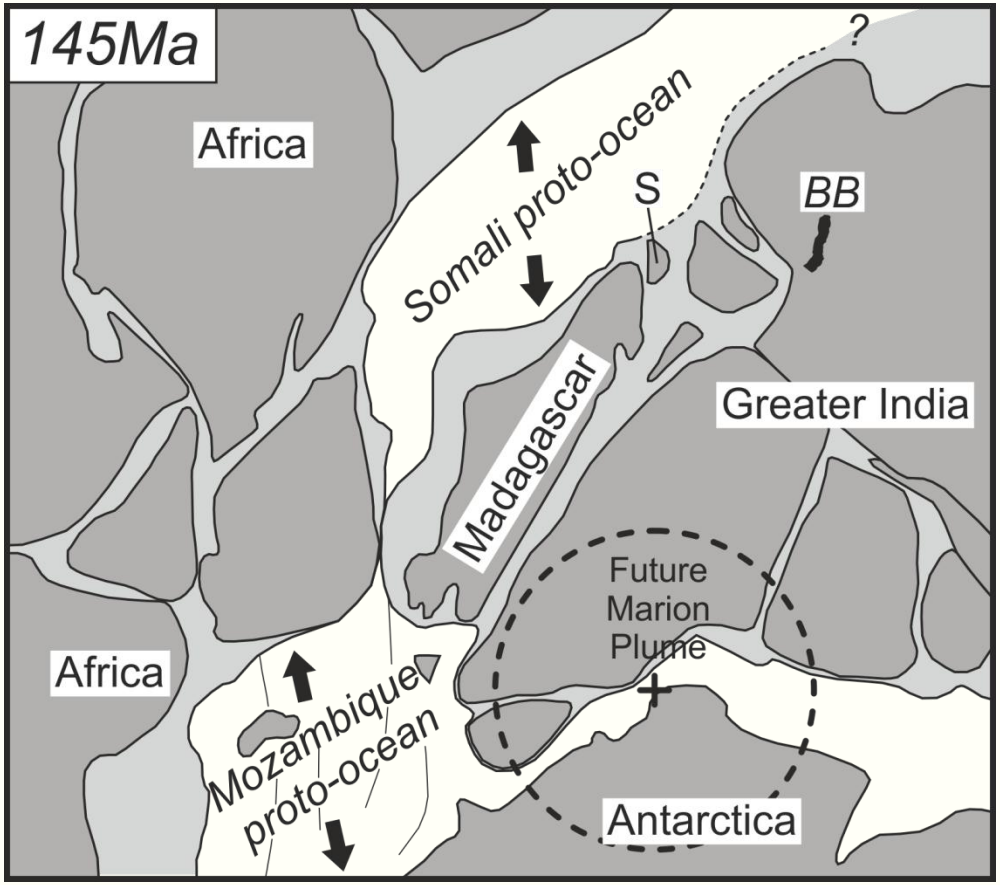
***Presentation is based on Bladon et al. 2015***

# Plate Tectonic Setting of Northwest India

Fragmentation of East Gondwana and isolation of Greater India

<u>145Ma:</u>

Separation of *African* and *Greater Indian-Madagascan-Antarctic-Australian* continents




***after Reeves 2014***

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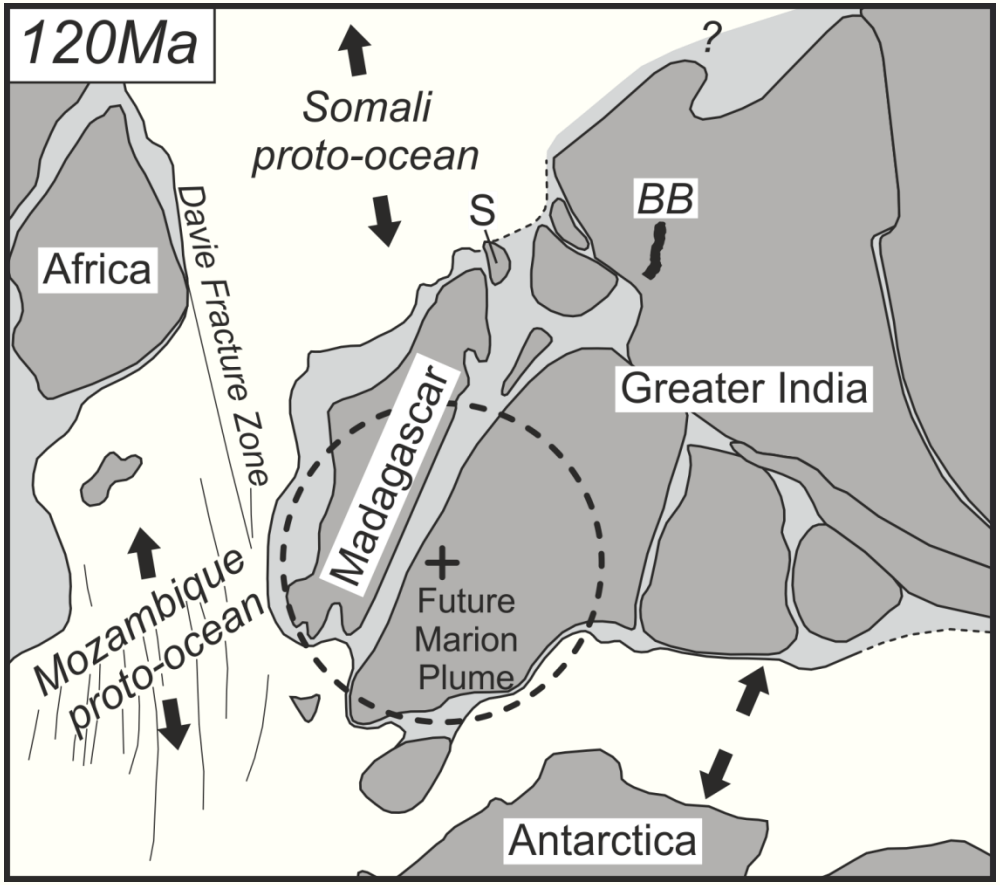
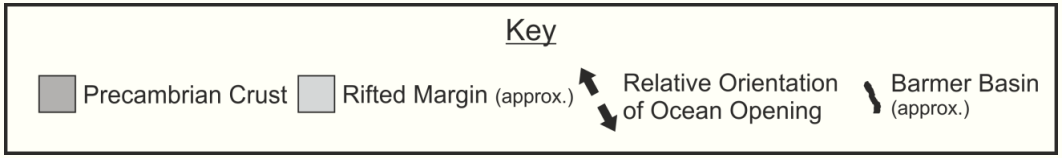



***after Reeves 2014***

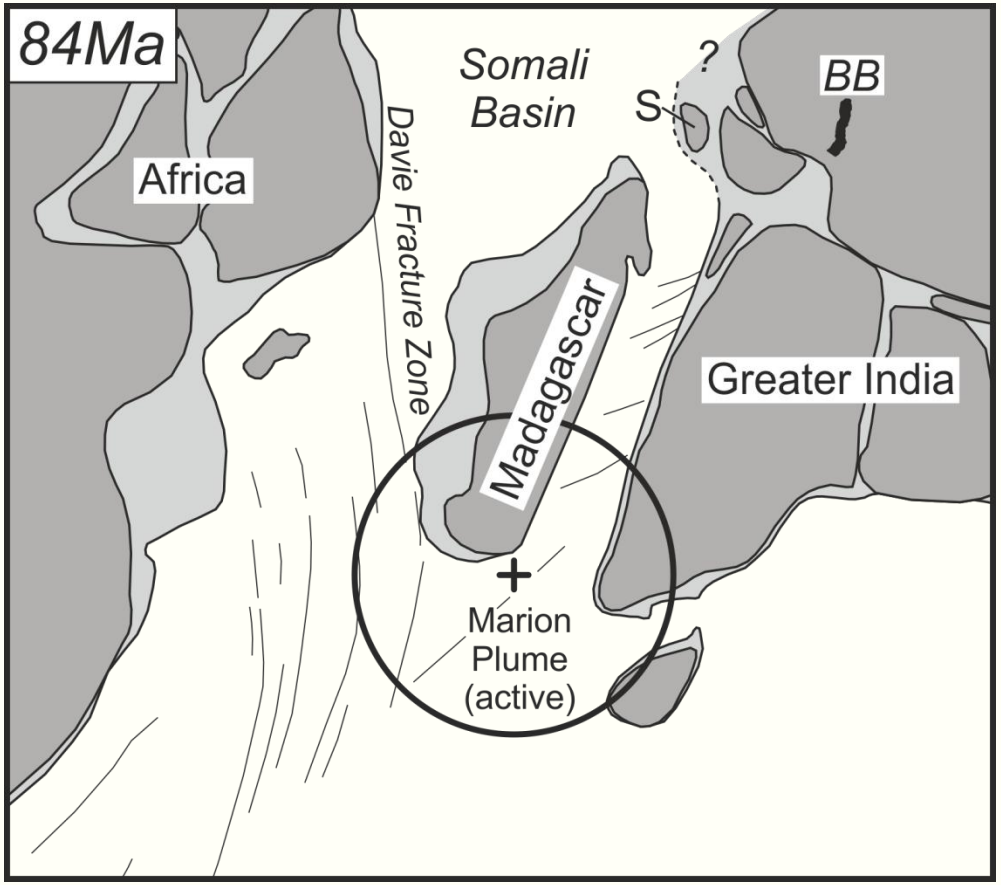
<u>120Ma:</u>

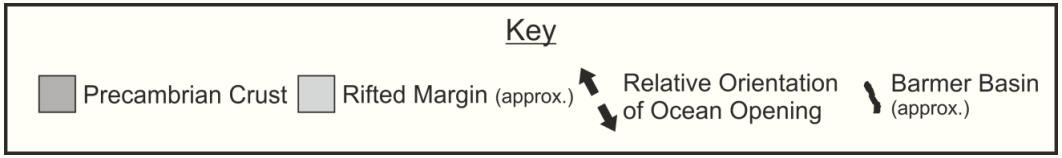
Separation of *Greater Indian-Madagascan* and *Antarctic-Australian* continents

[Transtension between Greater Indian and Madagascan continents (Bastia et al. 2010; Reeves 2014)]

# Plate Tectonic Setting of Northwest India

Fragmentation of East Gondwana and isolation of Greater India




***after Reeves 2014***

<u>84Ma:</u>

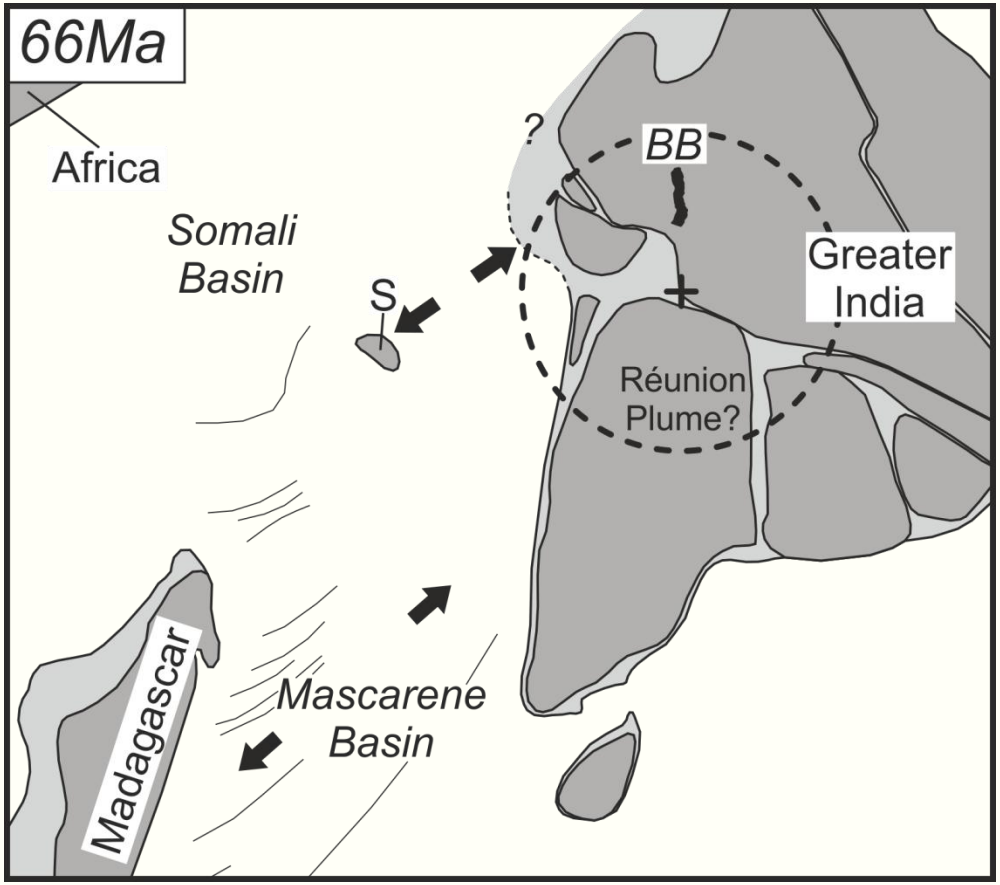
Separation of *Greater Indian* and *Madagascan* continents (Marion Plume)

# Plate Tectonic Setting of Northwest India

Fragmentation of East Gondwana and isolation of Greater India

<u>66Ma:</u>

Rifting of Seychelles microcontinent from *Greater Indian* continent (Reunion Plume?)



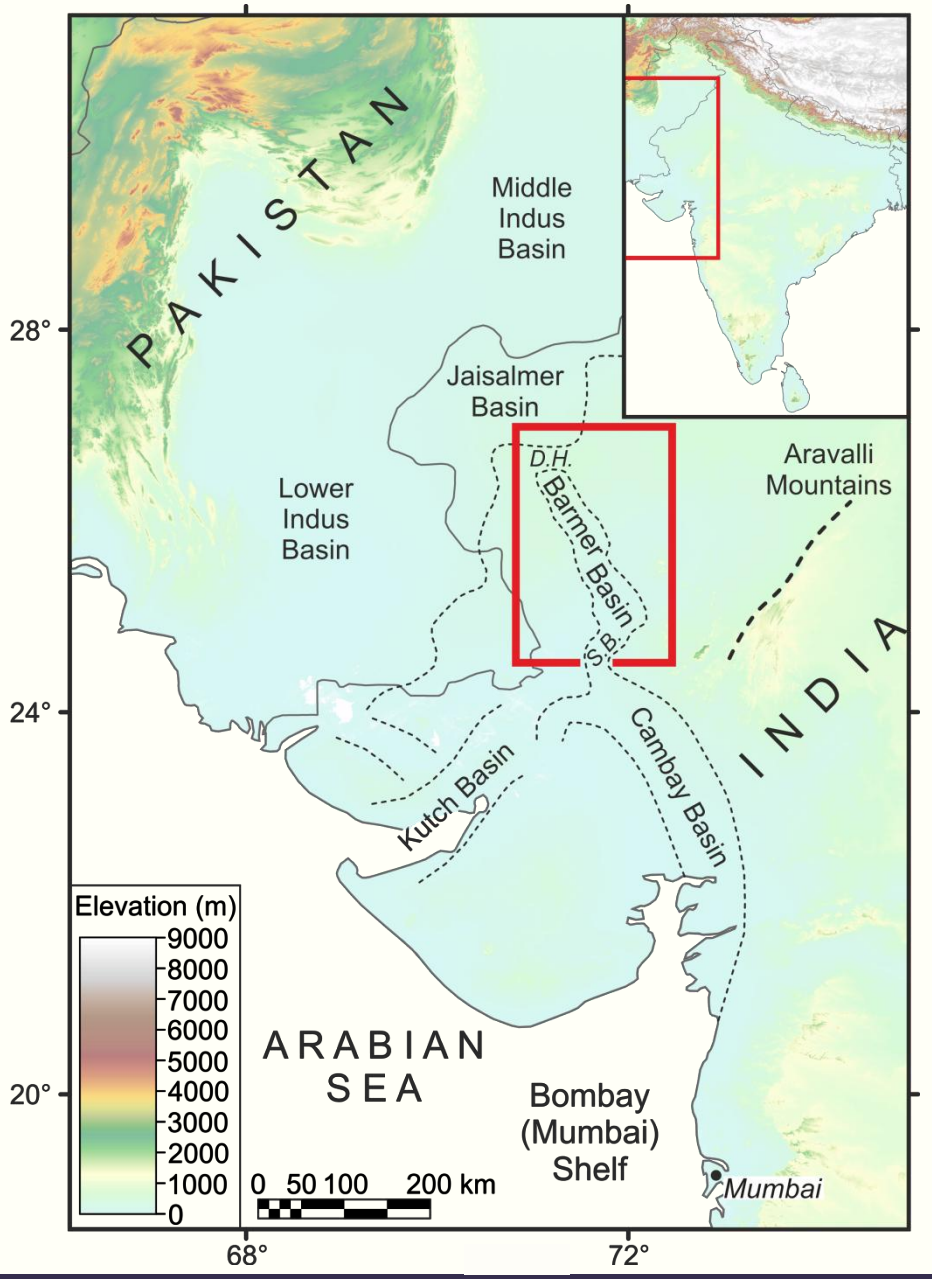

Key

Precambrian Crust | Rifted Margin (approx.) | Relative Orientation of Ocean Opening | Barmer Basin (approx.)

*after Reeves 2014*

# West Indian Rift System (WIRS)

- Kutch, Cambay, Narmada, and Barmer basins
- Main Phase of rifting occurred during the Paleogene Period
- Pre-Deccan sediments in Kutch and Narmada (Cambay?) basins

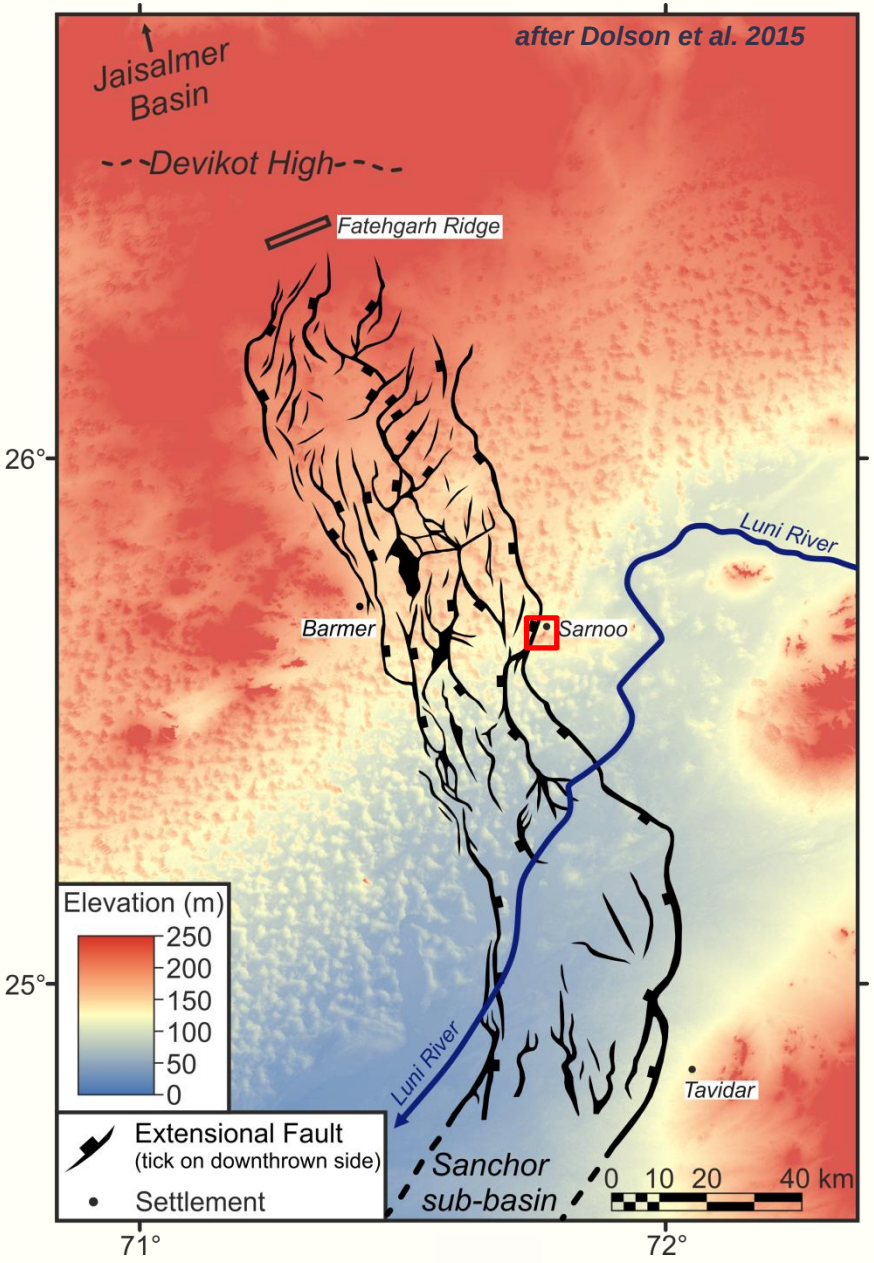


# Barmer Basin

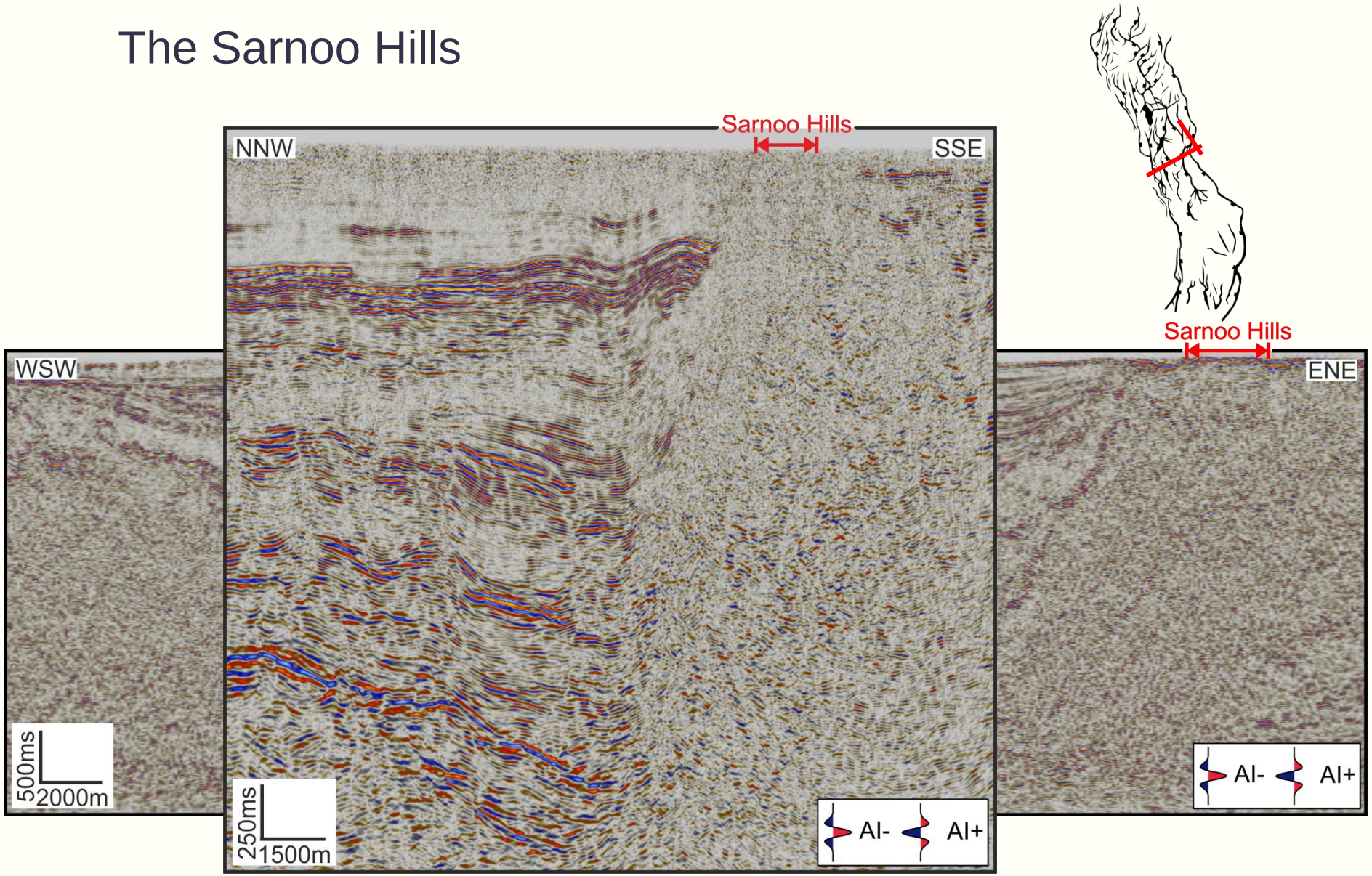
- Northernmost rift in the WIRS
- 200km long, <40km wide, <6km deep
- Main phase of subsidence was fault-controlled and occurred during the Paleogene Period
- Evolving rift-faults affected by pre-existing structures

# Rationale

Investigate a rift-oblique fault network exposed along the central eastern rift margin and place the findings within a regional context

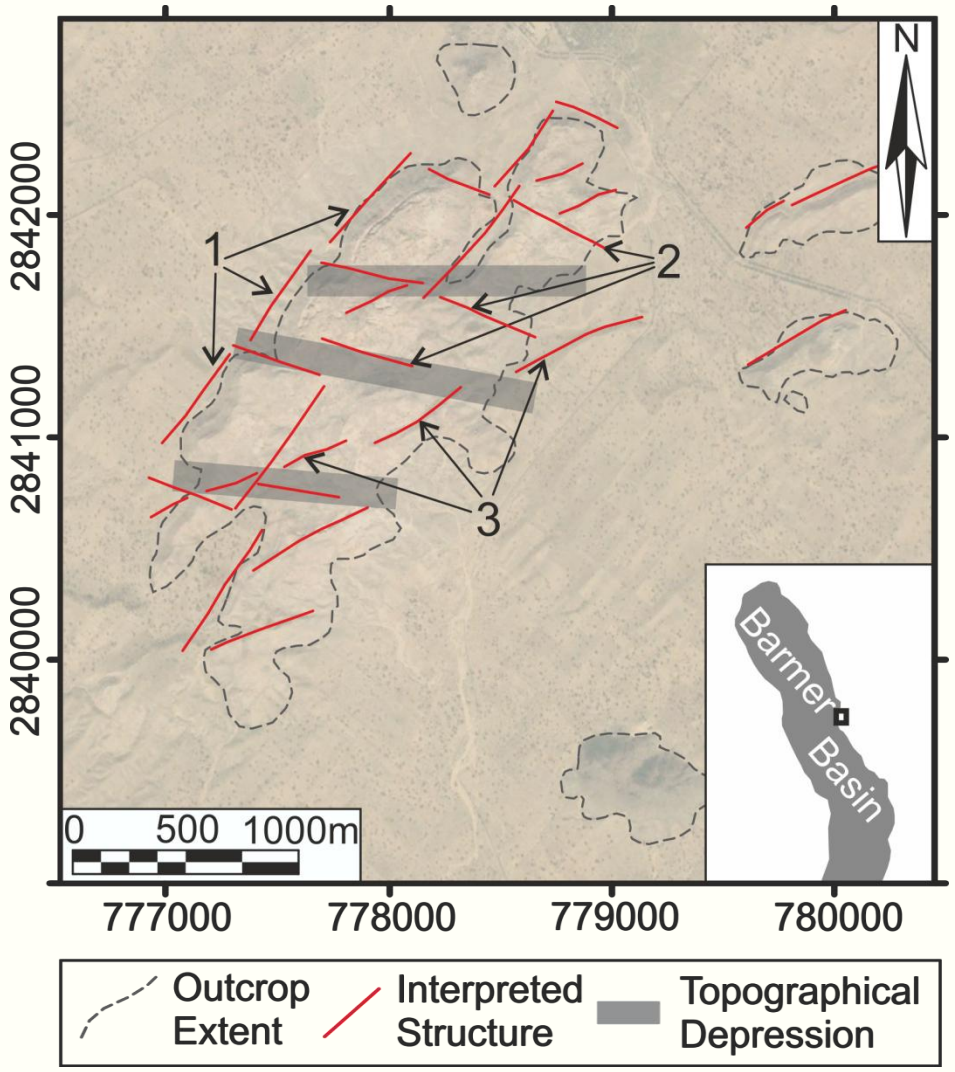


# The Sarnoo Hills

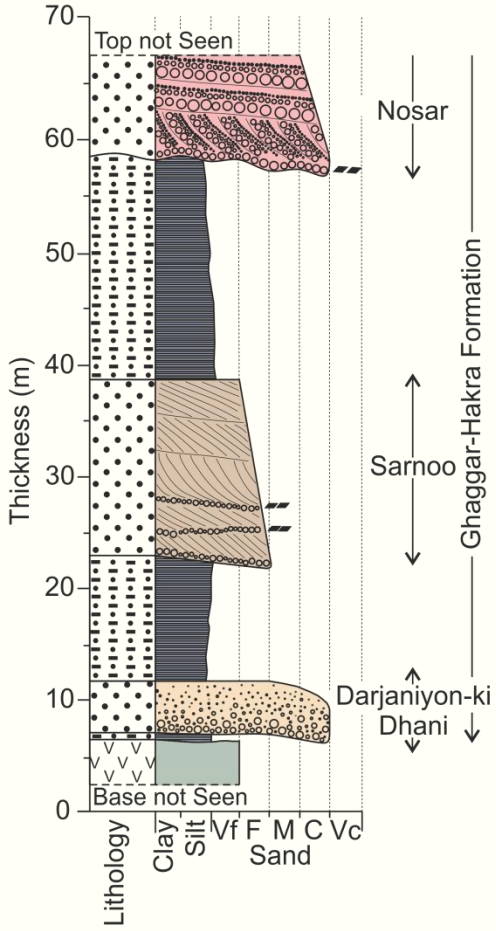


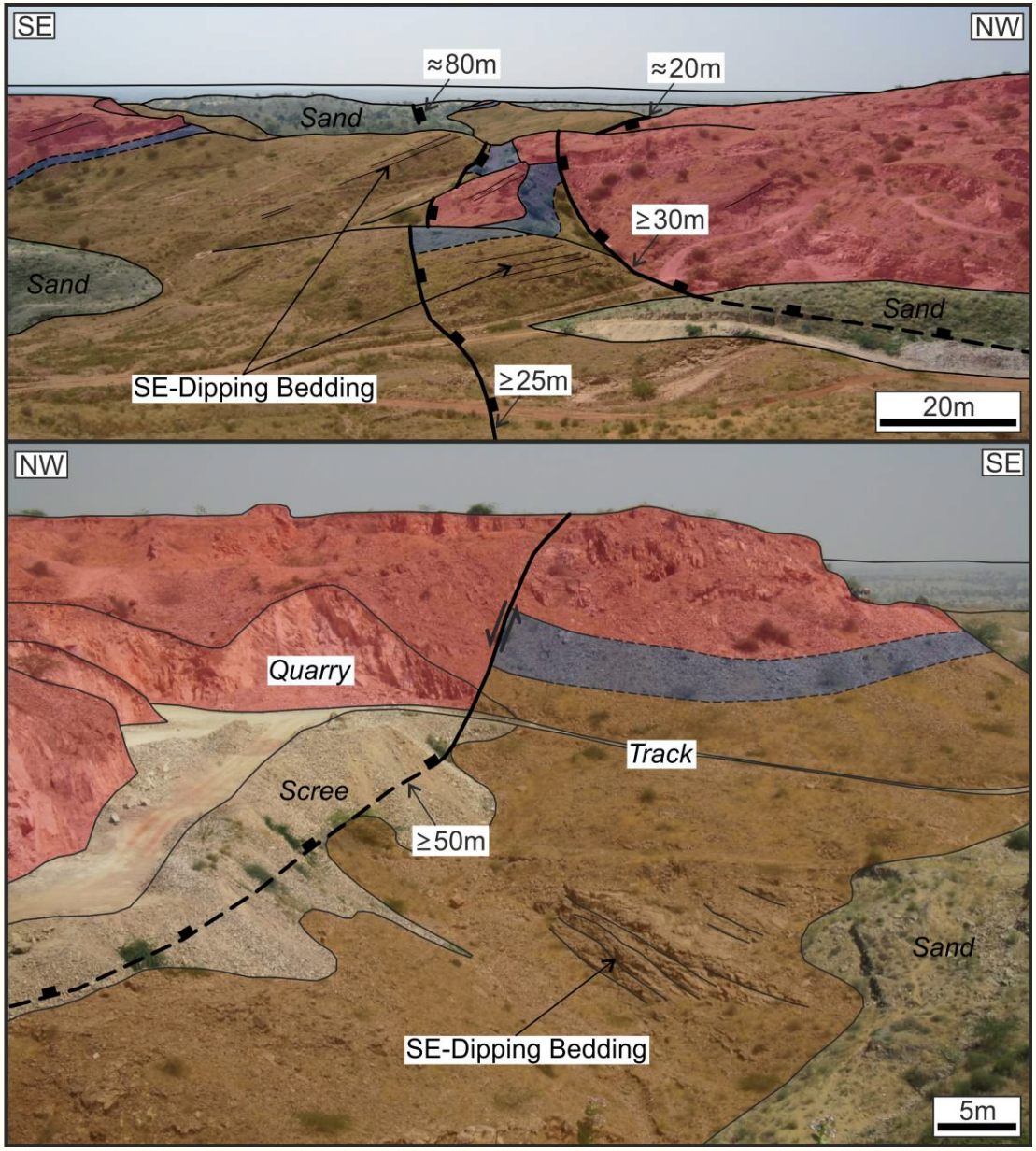
# The Sarnoo Hills

- Sporadic exposure
- Largest continuous exposure ≈ 2 km$^2$
- Three structural trends evident
  1. NE-SW
  2. E-W
  3. ENE-WSW

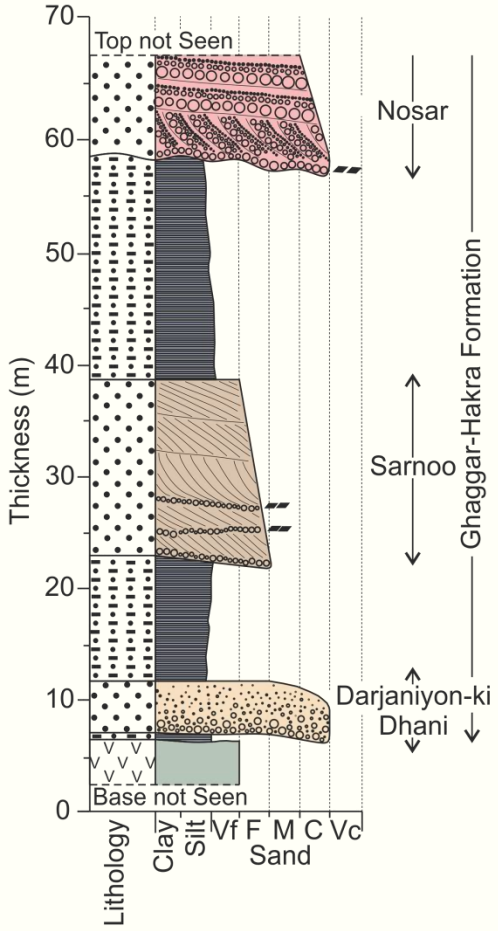


# NE-SW faults


Top not Seen
Base not Seen
Nosar
Sarnoo
Darjaniyon-ki Dhani
Ghaggar-Hakra Formation
Thickness (m)
70
60
50
40
30
20
10
0
Lithology
Clay
Silt
Vf F M C Vc
Sand


SE
NW
≈80m
≈20m
Sand
≥30m
Sand
Sand
SE-Dipping Bedding
≥25m
20m
NW
SE
Quarry
Track
Scree
≥50m
Sand
SE-Dipping Bedding
5m

# E-W faults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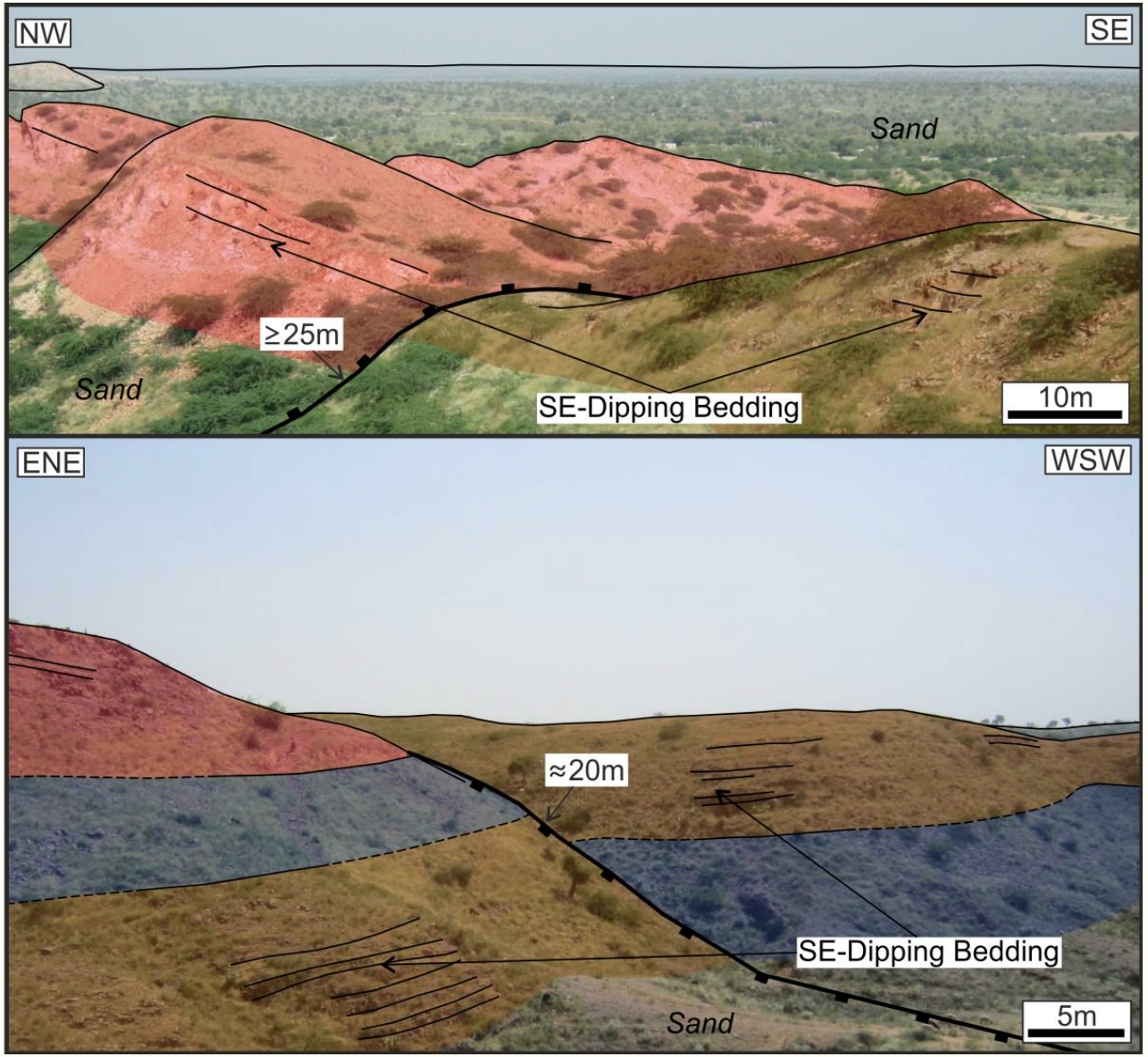
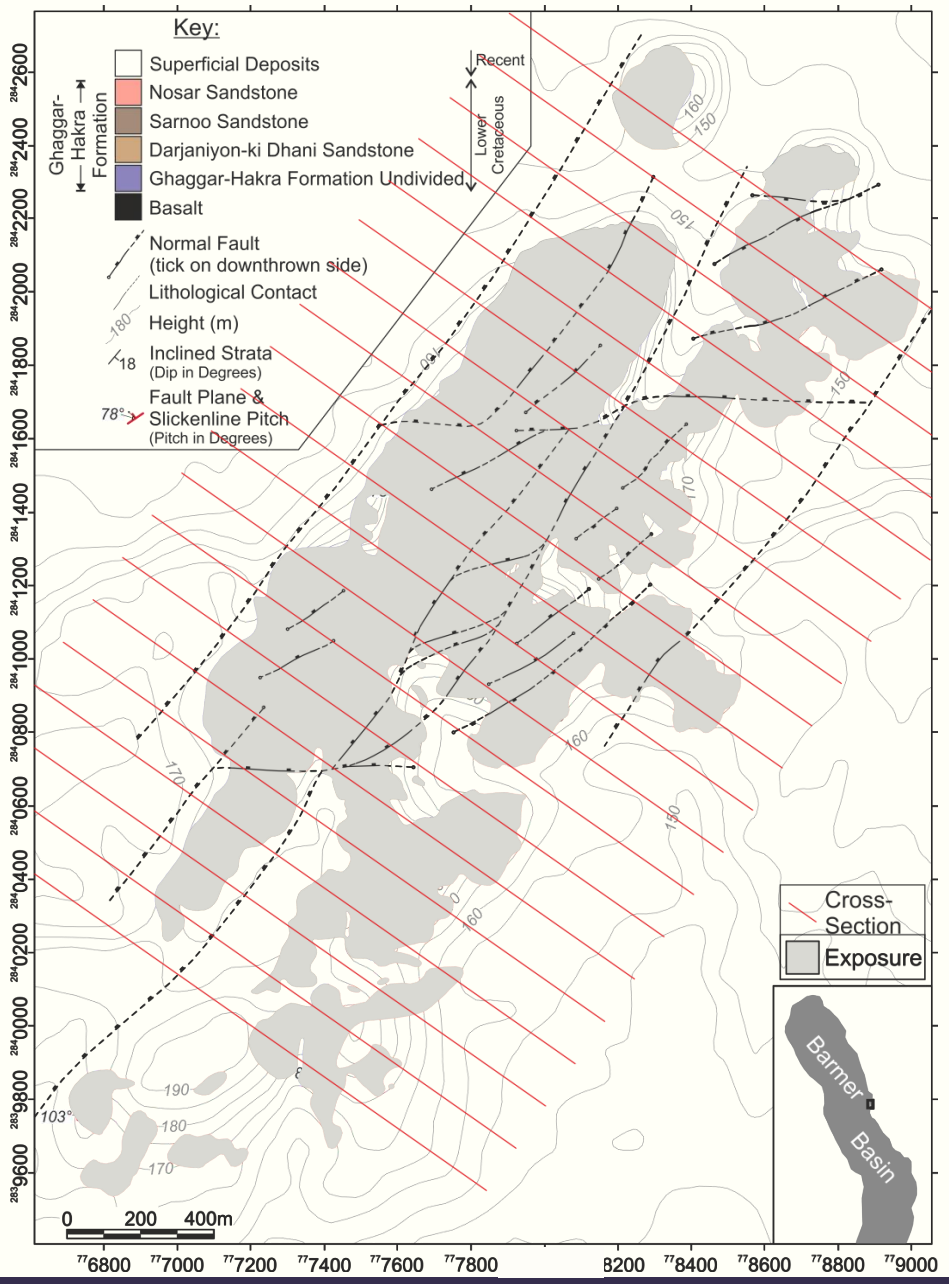
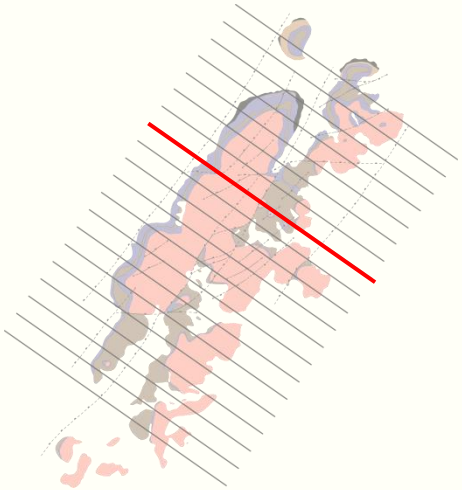

NW
SE
Sand
≥25m
Sand
SE-Dipping Bedding
10m
ENE
WSW
≈20m
SE-Dipping Bedding
Sand
5m

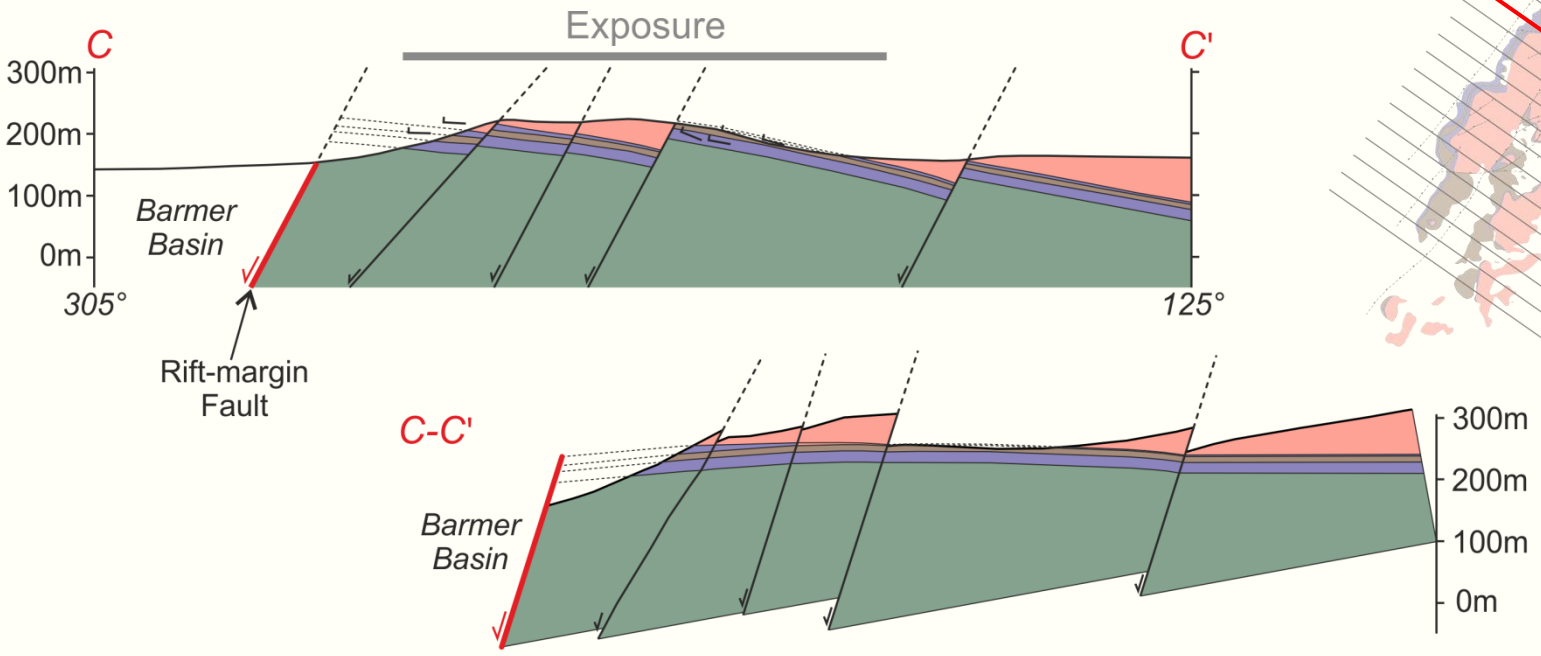
# The Sarnoo Hills

- Dominant SW-striking, NW-dipping faults
- Smaller-offset W-striking, N-dipping faults



# Cross-Sections









Ghaggar-Hakra Formation

- Nosar Sandstone
- Sarnoo Sandstone
- Darjaniyon-ki Dhani Sandstone
- Ghaggar-Hakra Formation Undivided
- Basalt

0 200 400m

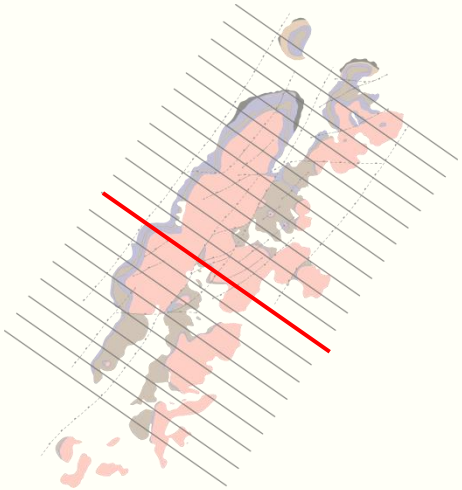
**Key**

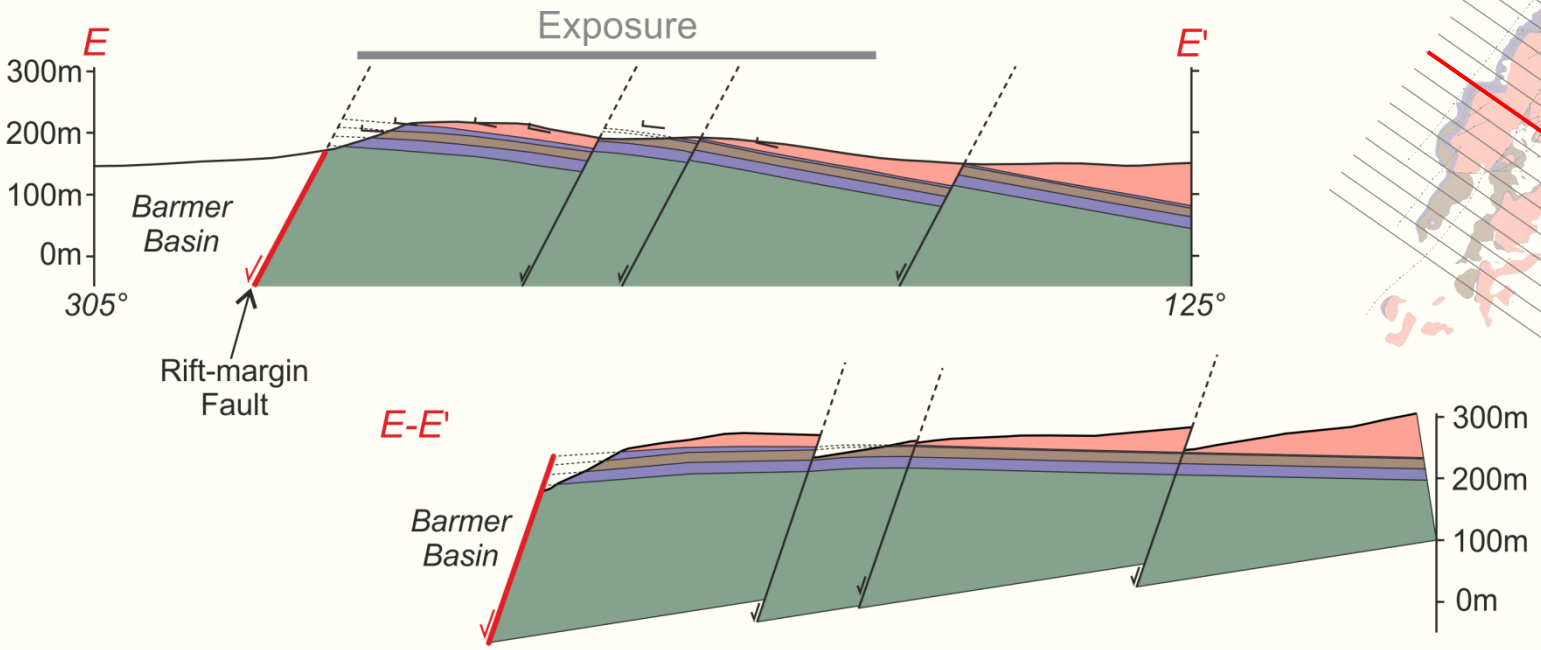
- Dipping Strata (dipping to the right)
- Fault (throwing down to the left)

***Cross-sections redrawn from Midland Valley's Move software package***

move™

# Cross-Sections



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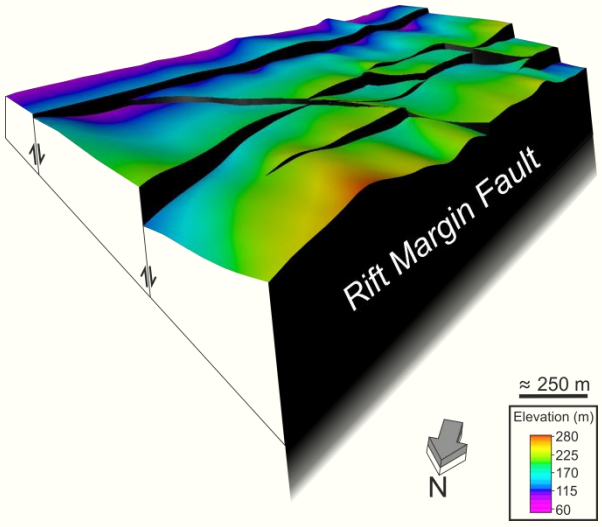
*Cross-sections redrawn from Midland Valley's Move software package*

move

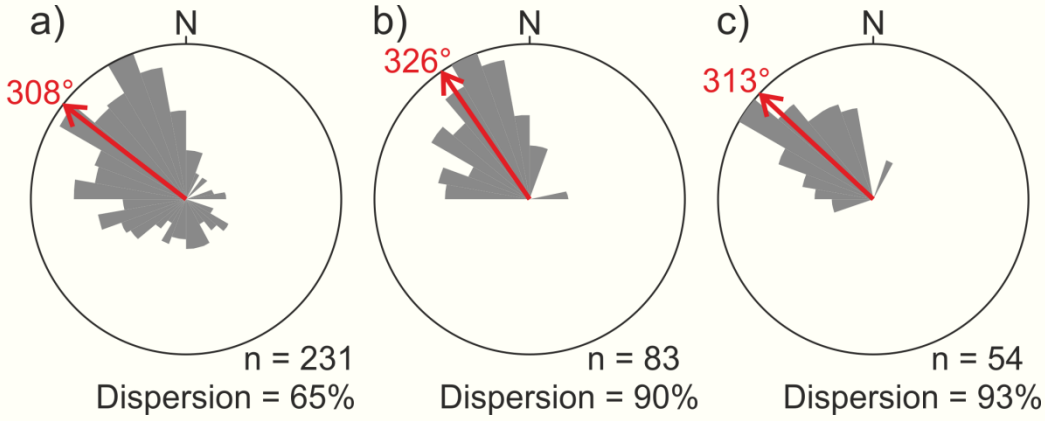
# 3D model

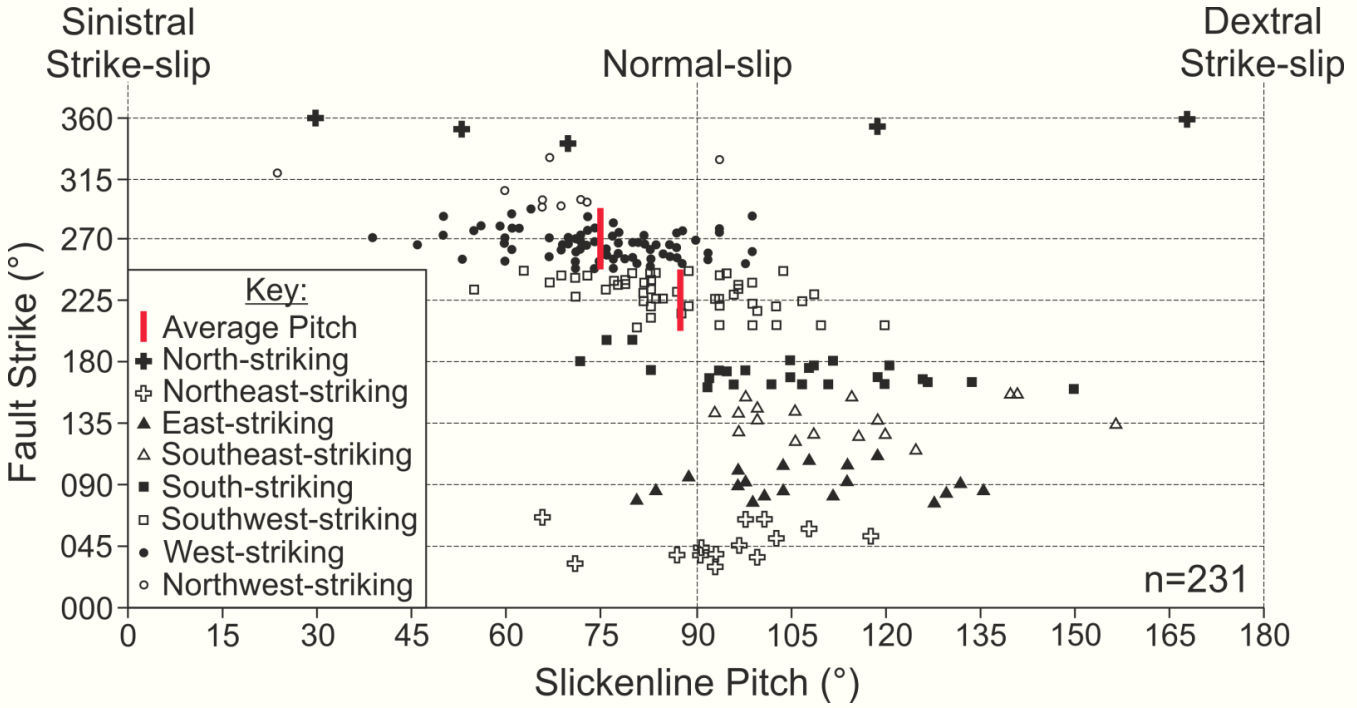
- 3D model constructed from structural framework
- Variable characteristics of W-striking faults



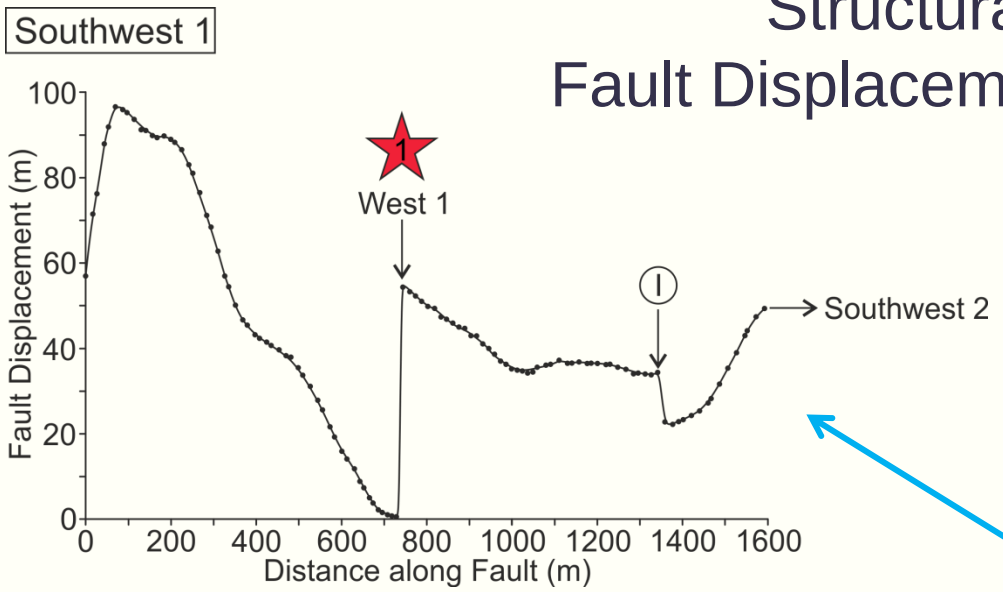
# Structural Analyses

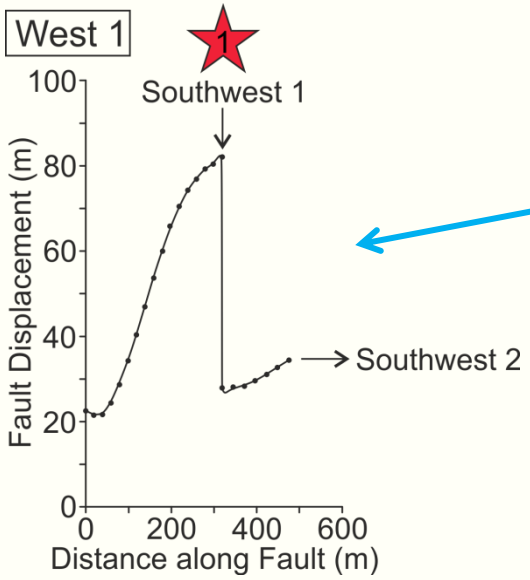
- Average slickenline trend varies between W- and SW-striking faults by 013°
- SW-striking faults accommodated pure normal slip
- W-striking faults deformed with a 15° component of sinistral oblique-slip

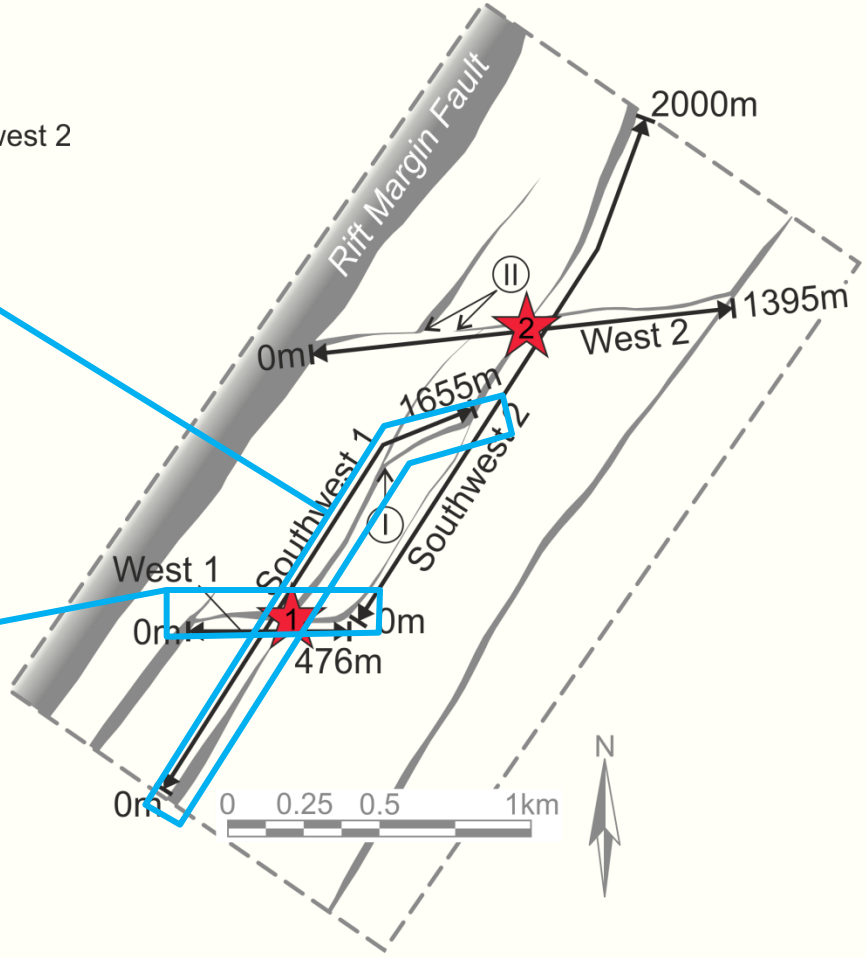


# Structural Analyses:
# Fault Displacement-Length Profiles



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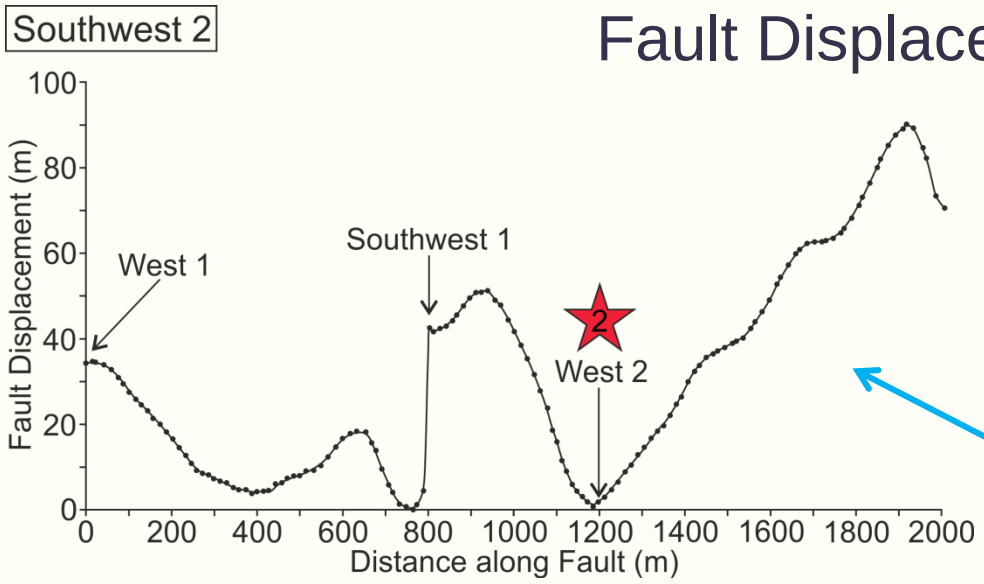
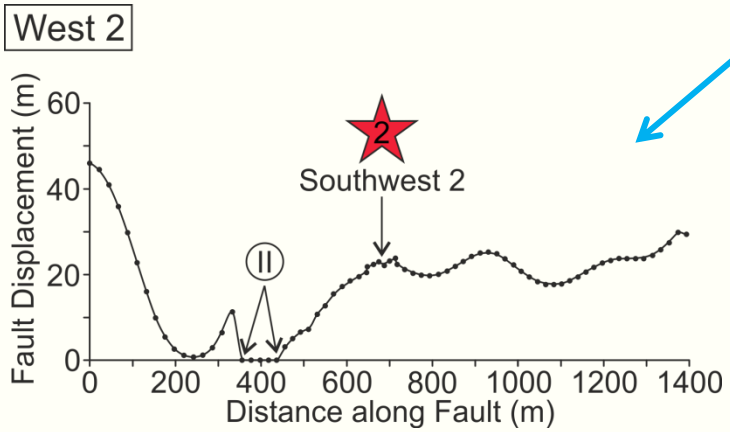
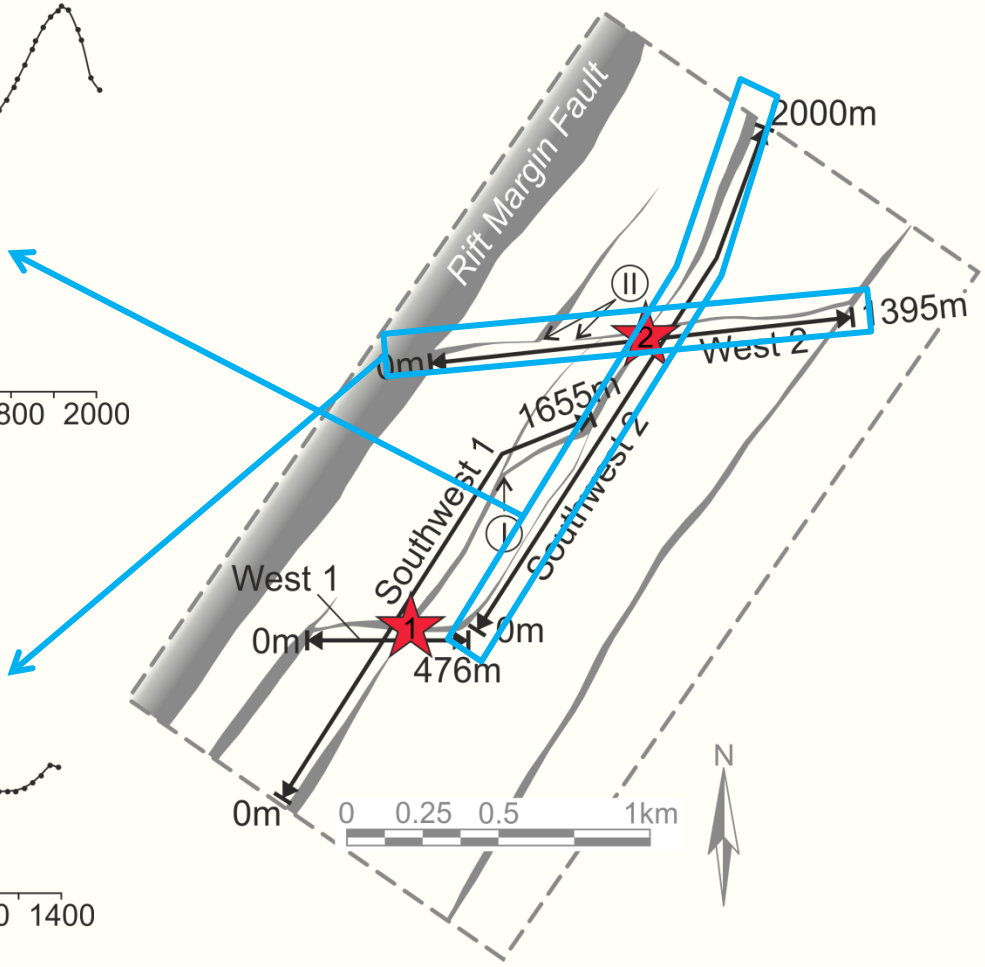
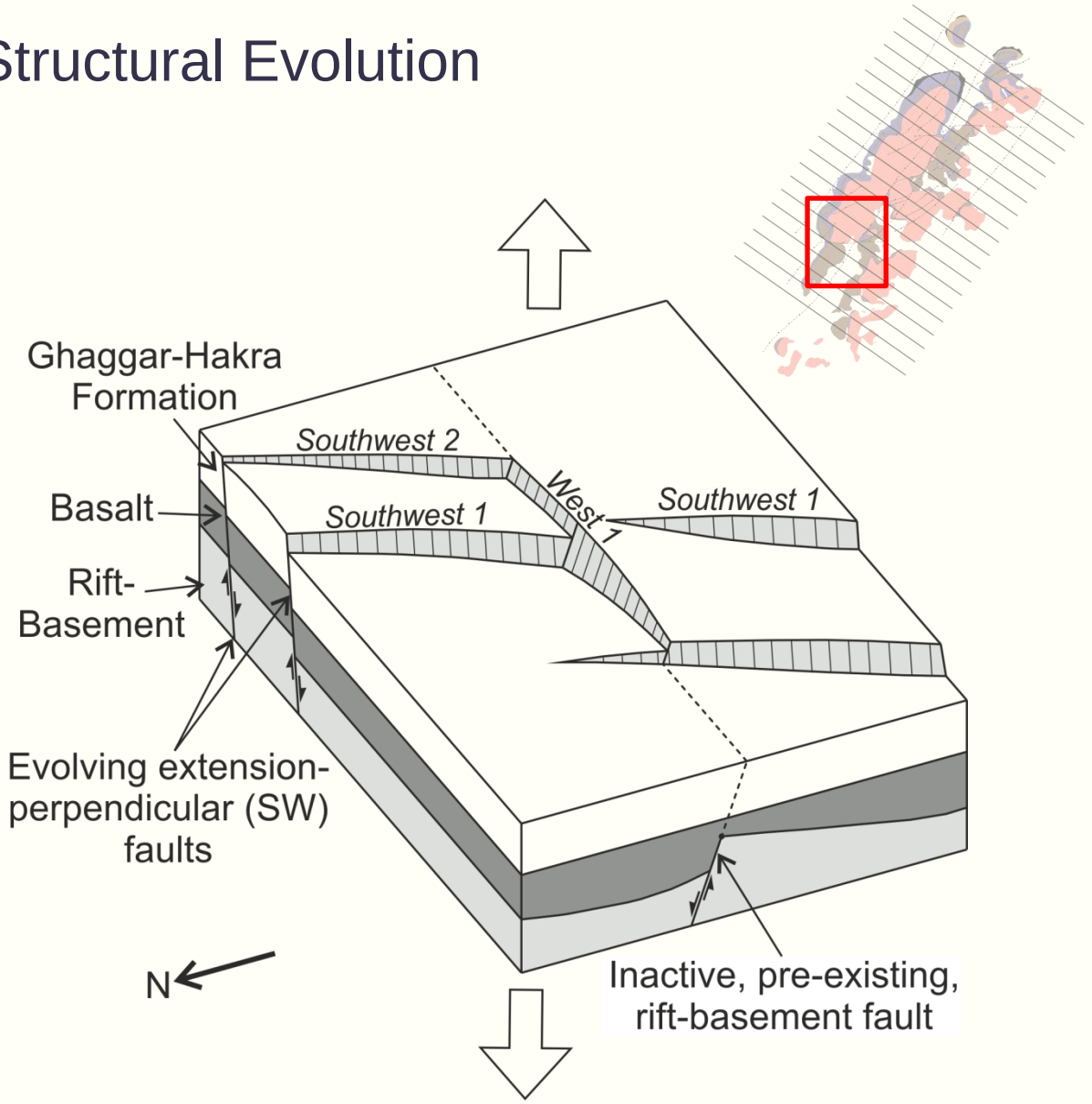


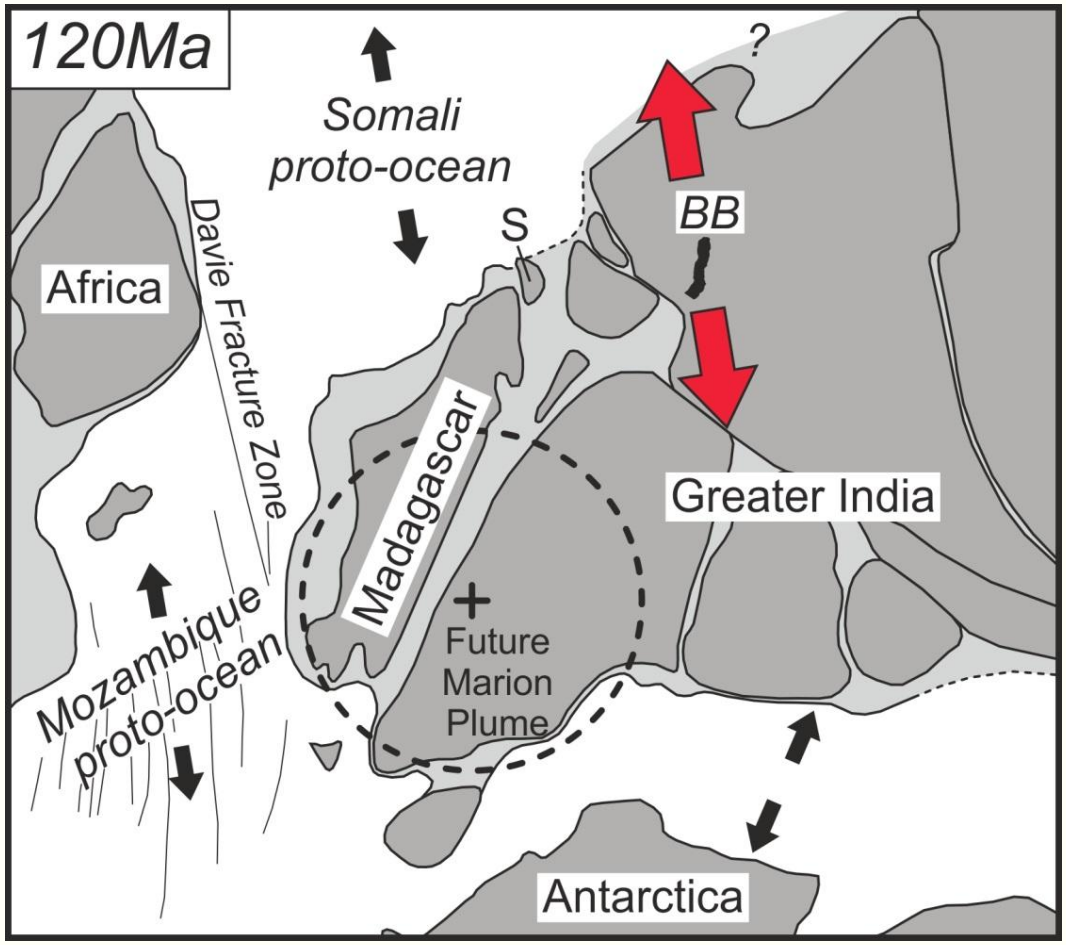
# Structural Evolution

- W-striking faults incorporated into evolving SW-striking fault systems
- Activity on W-striking faults restricted the evolution of SW-striking faults
- Juvenile fault network



# Regional Context: NW-SE Extension?

- NW-SE extension related to plate tectonic unrest associated with a period of mutual spreading to the N and S of the Greater Indian Continent (e.g. Bastia et al. 2010; Reeves 2014)
- NW Indian rifting pre-dates Deccan (Réunion Plume)?



# Summary

- The Sarnoo Hills fault network evolved during NW-SE extension and comprises W- and SW-striking faults.
- Pre-existing W-striking faults were incorporated into the evolving SW-striking fault systems.
- Evolution of the SW-striking fault systems was restricted by reactivated segments of pre-existing W-striking faults.
- NW-SE extension pre-dates NE-SW Paleogene rifting in the Barmer Basin, and may be associated with a period of mutual spreading to the N and S of the Greater Indian continent during the late Early Cretaceous Epoch.
- Rifting pre-dates Deccan?

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