

Learning's on basement fracturing and weathering in rift-shoulder fault blocks; a reservoir analogue from the Sinai Suez Rift (Egypt)

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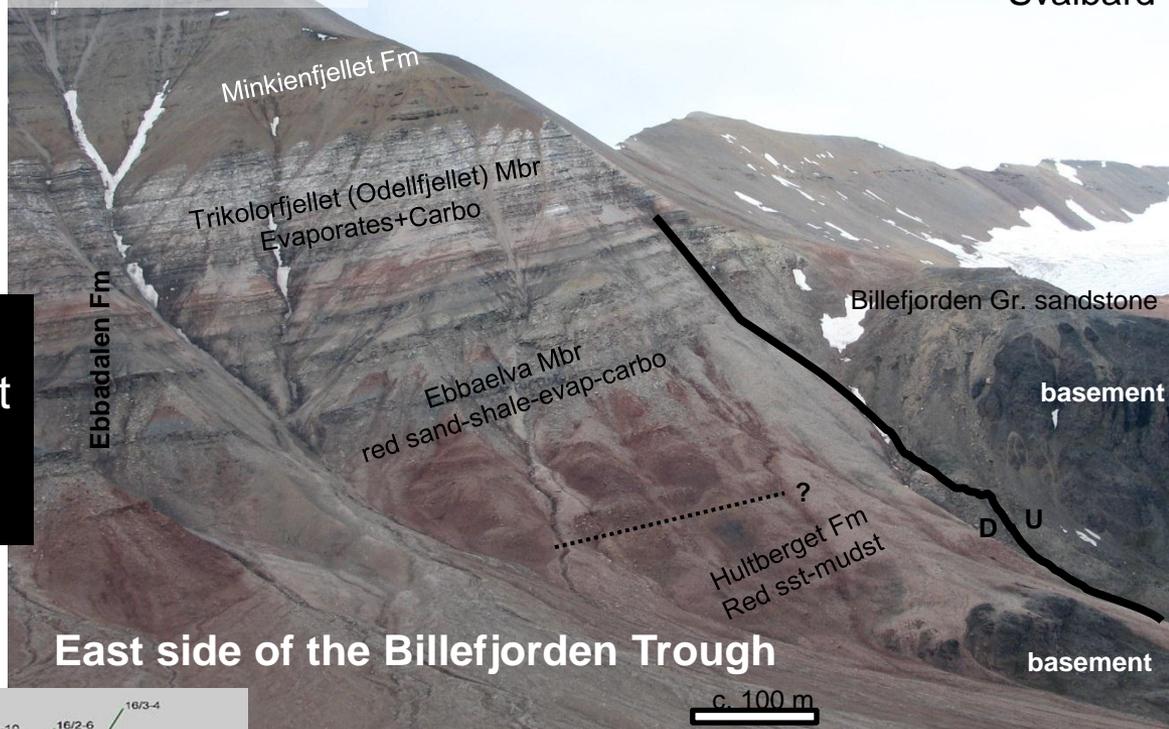
- 1) Regional setting
- 2) Basement fields in the Suez Rift
- 3) Basement lithologies
 - Main lithologies
 - Diagenesis and weathering products
- 4) Datasets
 - a) fracture systems in the basement
 - b) tropical to arid weathering profile on top basement
 - c) sedimentary deposits overlying basement
- 5) Summary and Conclusions

Before leaving the Norwegian shelf



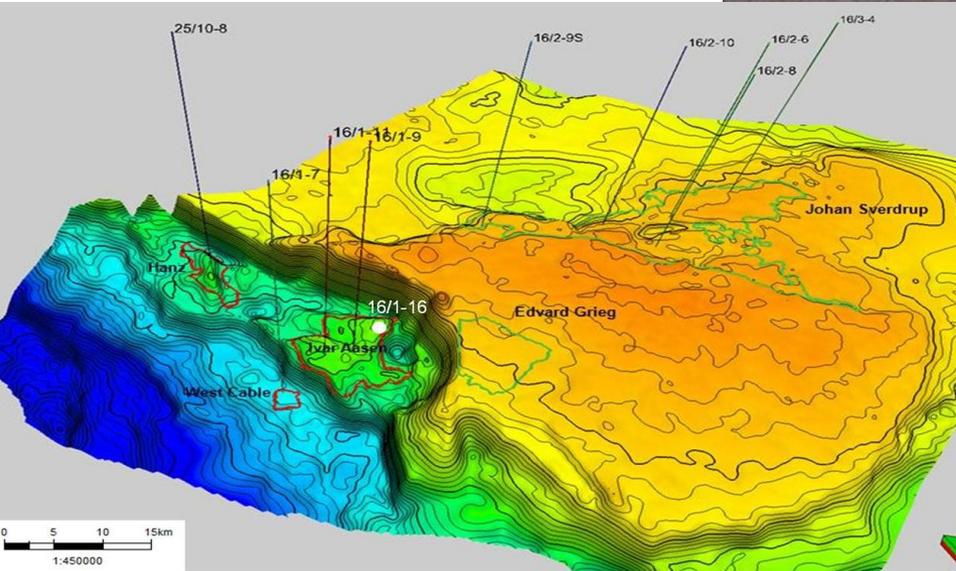
Basement offers a new HC play concept with significant learning potential

BARENTS SHELF ANALOUGE



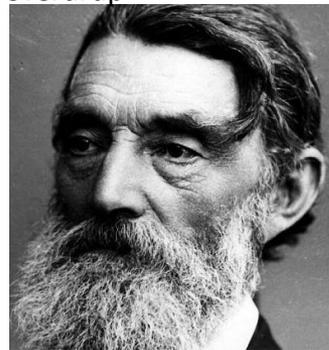
Basement in exhumed fault blocks, Carboniferous Billefjorden Trough, Svalbard

East side of the Billefjorden Trough

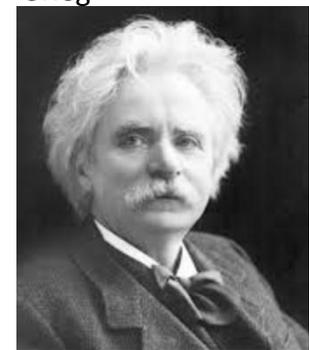


"old men, new knowledge"

Sverdrup



Grieg



Aasen

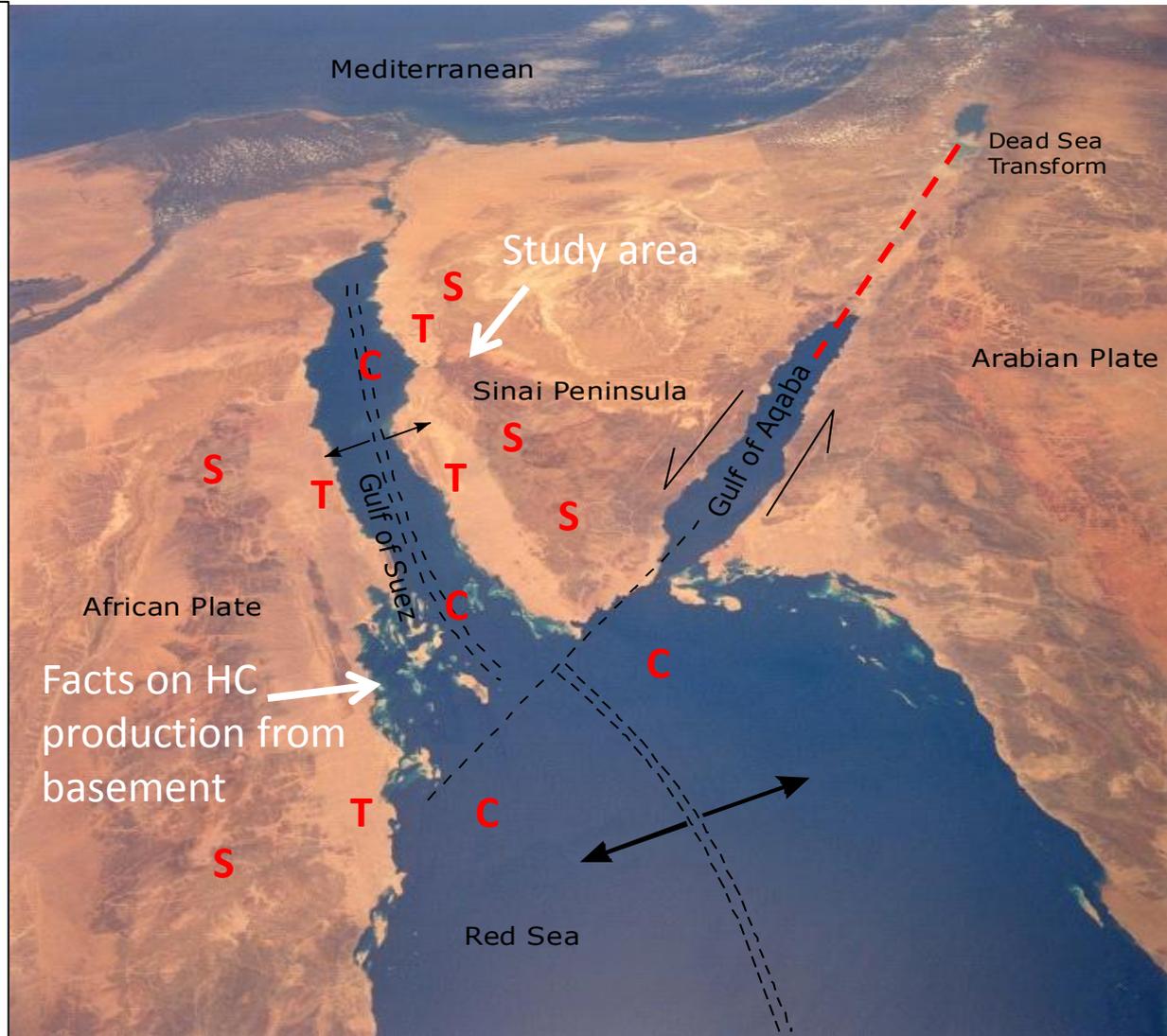
1) REGIONAL SETTING

Suez Rift

- Abandoned arm of Red Sea Rift
- Oligocene-Miocene rifting
- 4-6 km structural relief
- 70 HC fields
- 8 fields producing basement

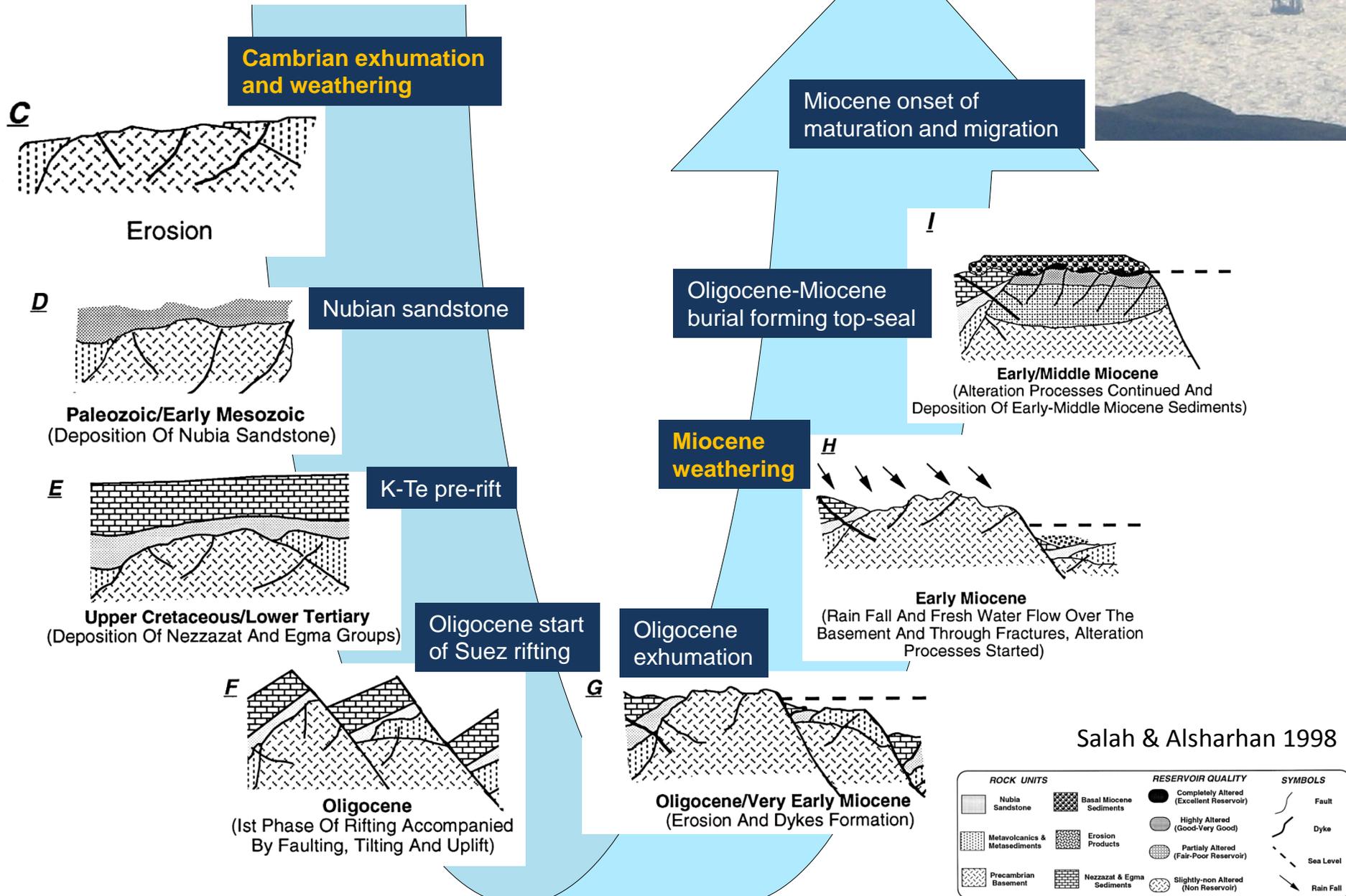
- Central rift (C)
- Rift terraces (T)
- Rift shoulder (S)

- ☐ Outstanding exposures



Satellite photo courtesy of NASA

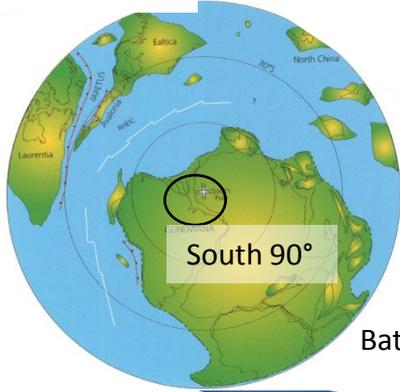
Suez rift development ...



Rift development

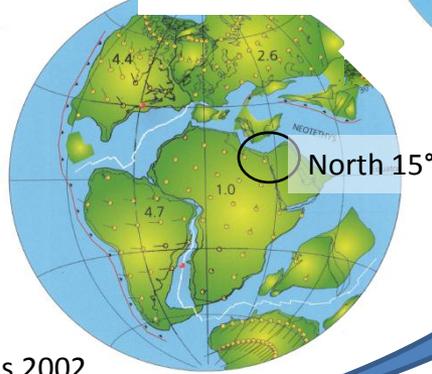
... geography and climate

Ordovician

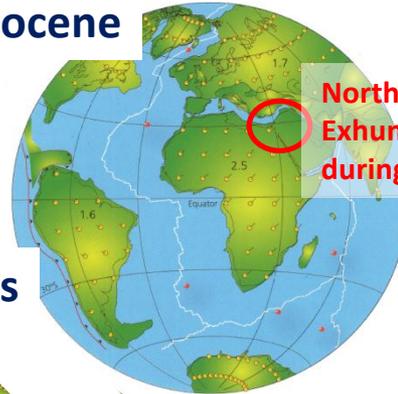


Batlas 2002

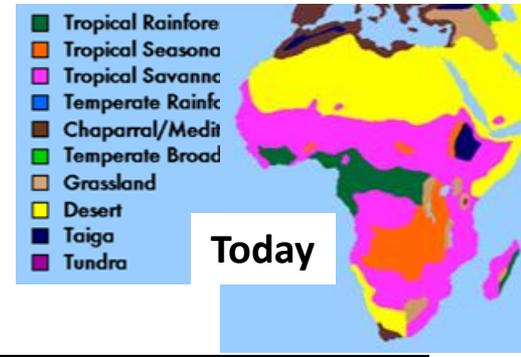
Cretaceous



Miocene



North 30°
Exhumation
during rifting

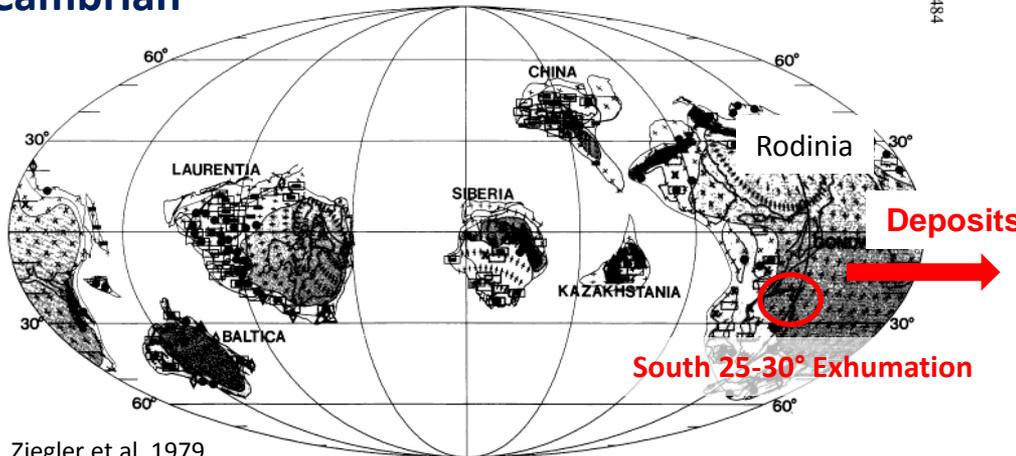


Tropical to Desert weathering system

Quartz Arenites;

- ✓ > 90% qtz, < 3% kaolinite
- ✓ 10-29% porosity
- ✓ 70-850 mD permeability

Cambrian



South 25-30° Exhumation

Ziegler et al. 1979

Figure 2 Middle late Cambrian (Franconian) paleogeographic reconstruction. Shading and symbols for Figures 2-8 as follows: dark grey = mountains, medium grey = lowlands, light grey = shallow shelves, white = deeper shelves and oceanic areas, solid triangles = andesitic volcanics, open triangles = plateau basalts, diamonds = ophiolites, dots = coarse clastics, dashes = fine clastics, boxes = carbonates, X's = evaporites, C's = coals, T's = tillites.

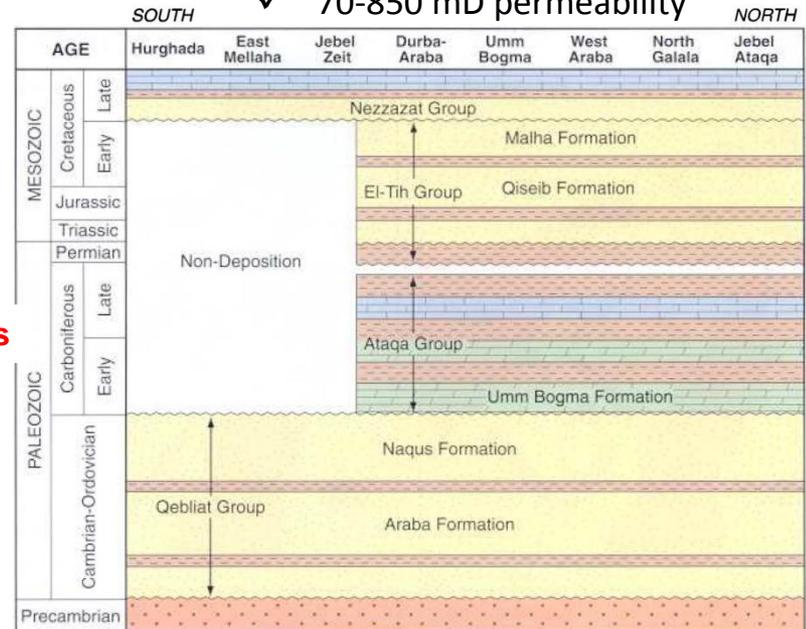


Figure 3: Distribution of the Nubian Sandstone units along the Gulf of Suez.

2) BASEMENT FIELDS

- 70 fields
- 8 fields producing from basement

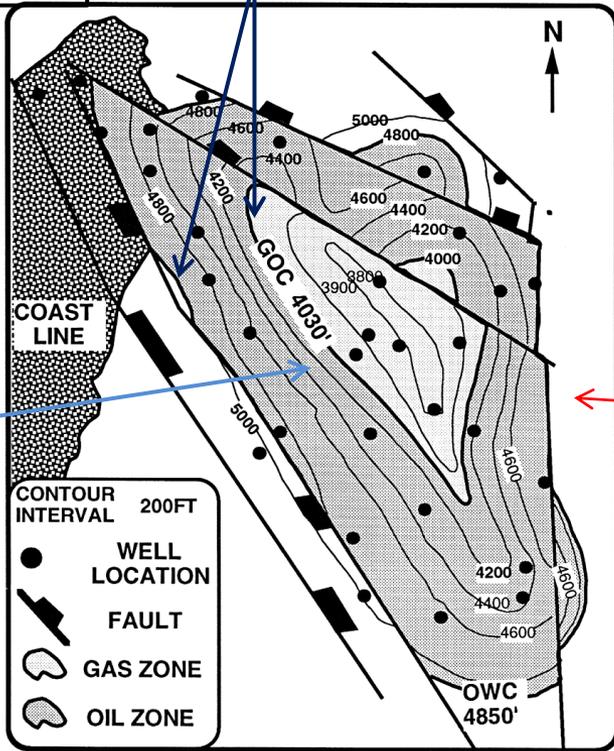
Basement horst reservoir, with major sealing faults

HC column height = 340m

- top res. - GOC ~ 70m
- GOC - OWC ~ 270m

Well production varies:

- ⇒ diagenetic effects
- ⇒ variable intensity of fracture network
- internal segmentation of plumbing system



Salah & Alsharhan 1998

ZEIT BAY OIL FIELD

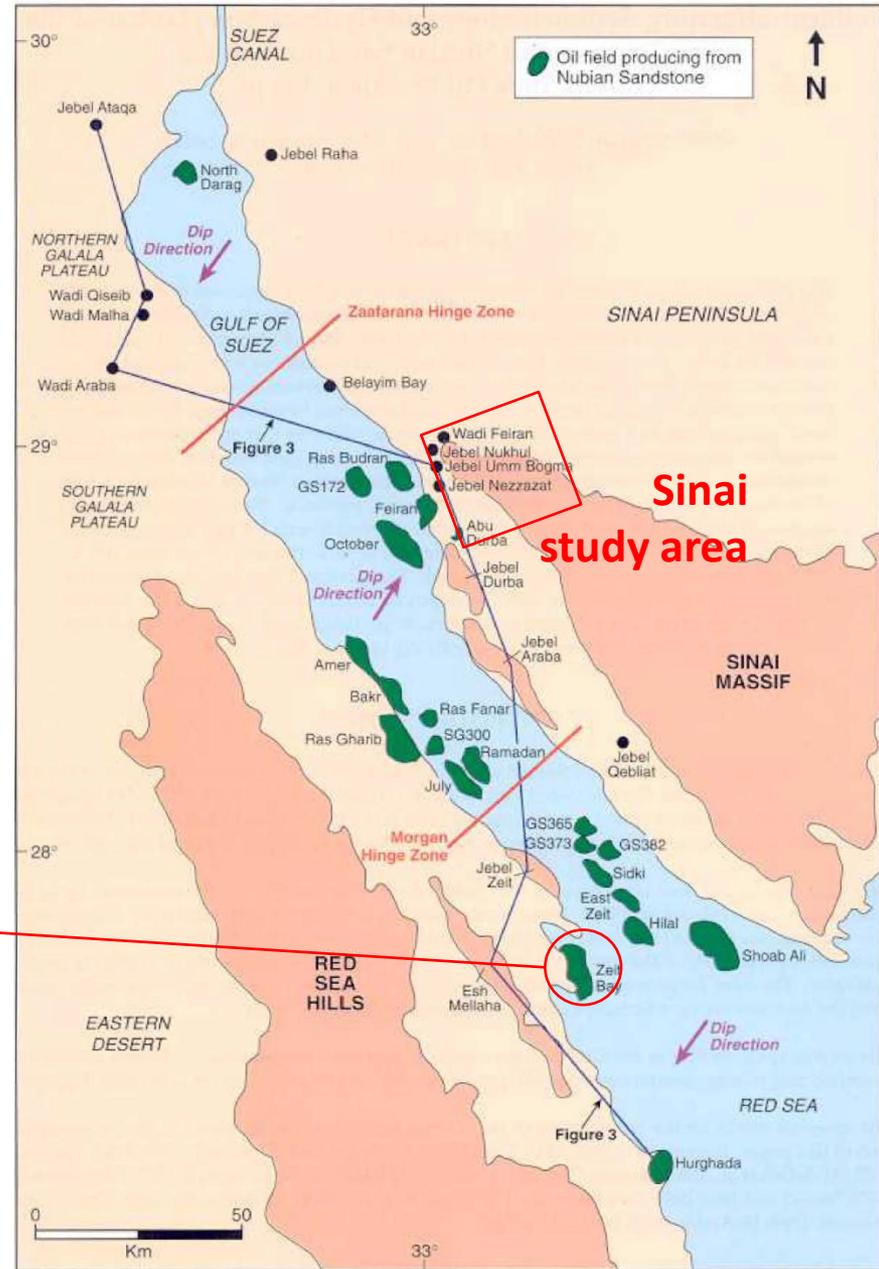


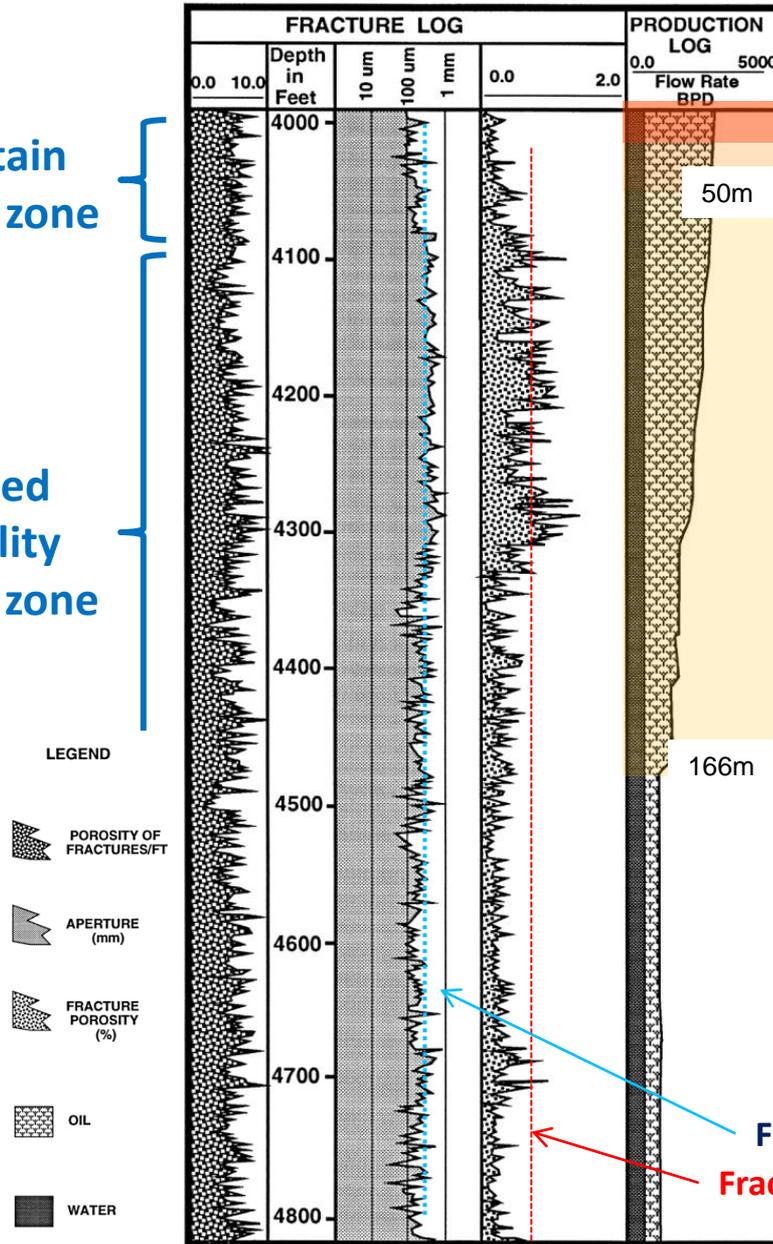
Figure 1: Nearly 20 of the more than 60 oil fields in the Gulf of Suez produce oil from the Nubian Sandstone.

Basement fields ... well log through basement section, Geisum Field

Deeper wells into basement encounter more good zones in the HC column

Certain pay zone

Varied quality pay zone



Certain Transition Top-basement weathering

Good production

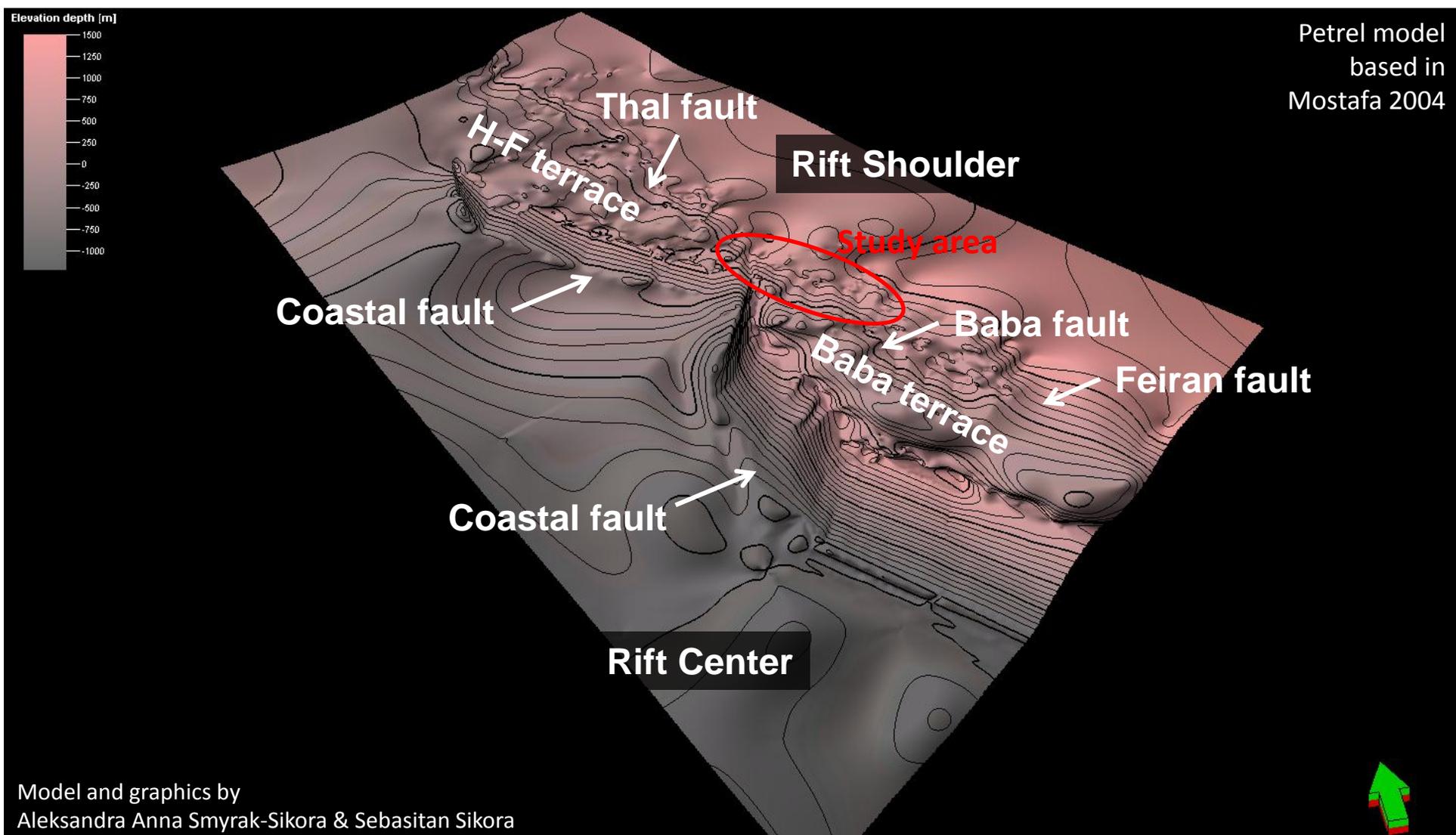
Mod.-Low production

Fracture aperture= 0,01-1 mm

Fracture Poro= 0,5-1,5%

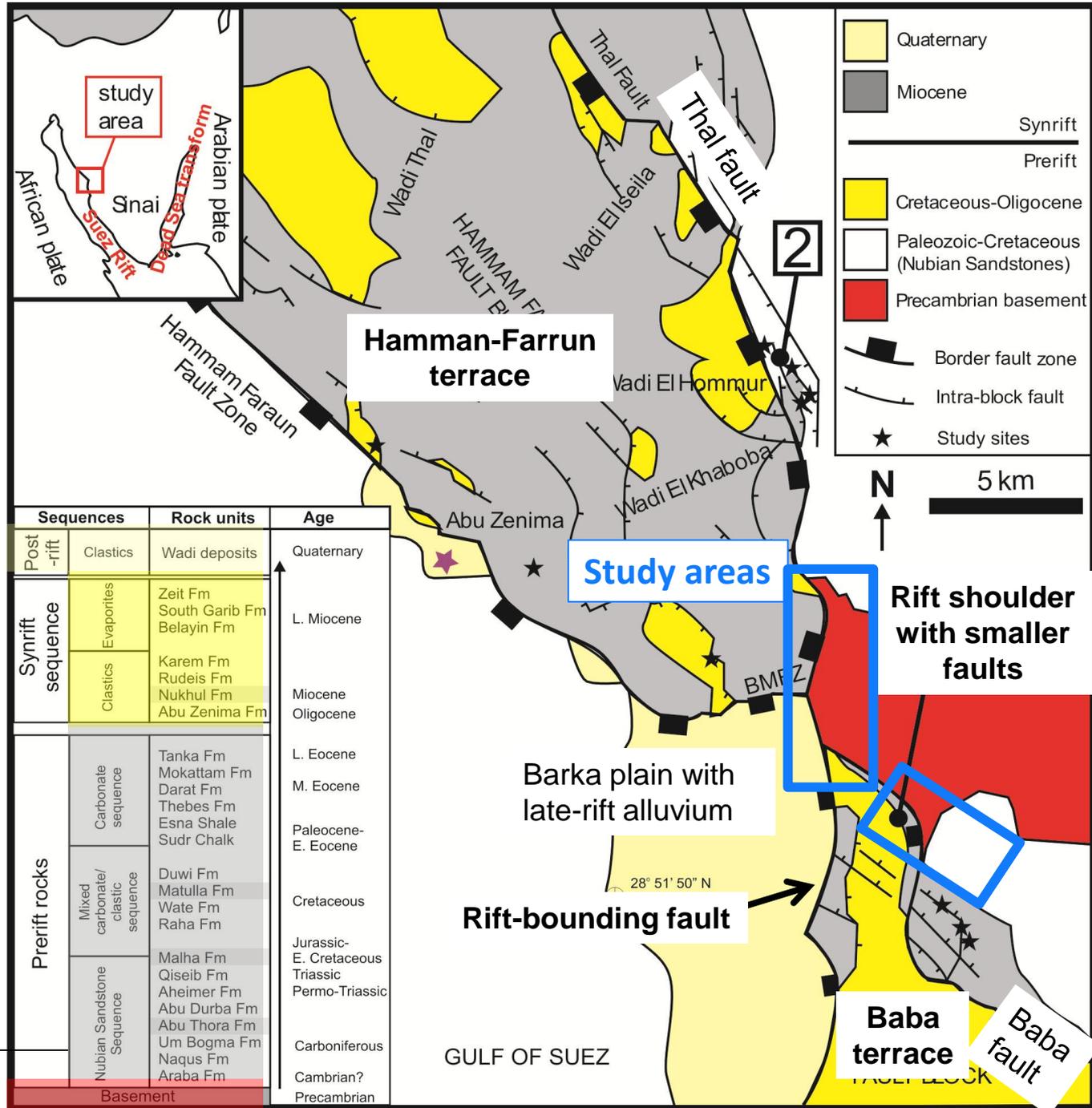
Study area onland Sinai:

Oblique view of top-basement contact of western Sinai rift, from center to shoulder ...



Location of study areas of Sinai

Excellent exposures are found in the rift shoulder, where uplifted basement is partly exhumed



Sequences		Rock units	Age	
Post-rift	Clastics	Wadi deposits	Quaternary	
Synrift sequence	Evaporites	Zeit Fm South Garib Fm Belayin Fm	L. Miocene	
	Clastics	Karem Fm Rudeis Fm Nukhul Fm Abu Zenima Fm	Miocene Oligocene	
Prerift rocks	Carbonate sequence	Tanka Fm Mokattam Fm Darat Fm Thebes Fm Esna Shale Sudr Chalk	L. Eocene M. Eocene Paleocene-E. Eocene	
		Mixed carbonate/clastic sequence	Duwi Fm Matulla Fm Wate Fm Raha Fm	Cretaceous
		Nubian Sandstone Sequence	Malha Fm Qiseib Fm Aheimer Fm Abu Durba Fm Abu Thora Fm Um Bogma Fm Naqus Fm Araba Fm	Jurassic-E. Cretaceous Triassic Permo-Triassic Carboniferous
	Basement		Cambrian? Precambrian	

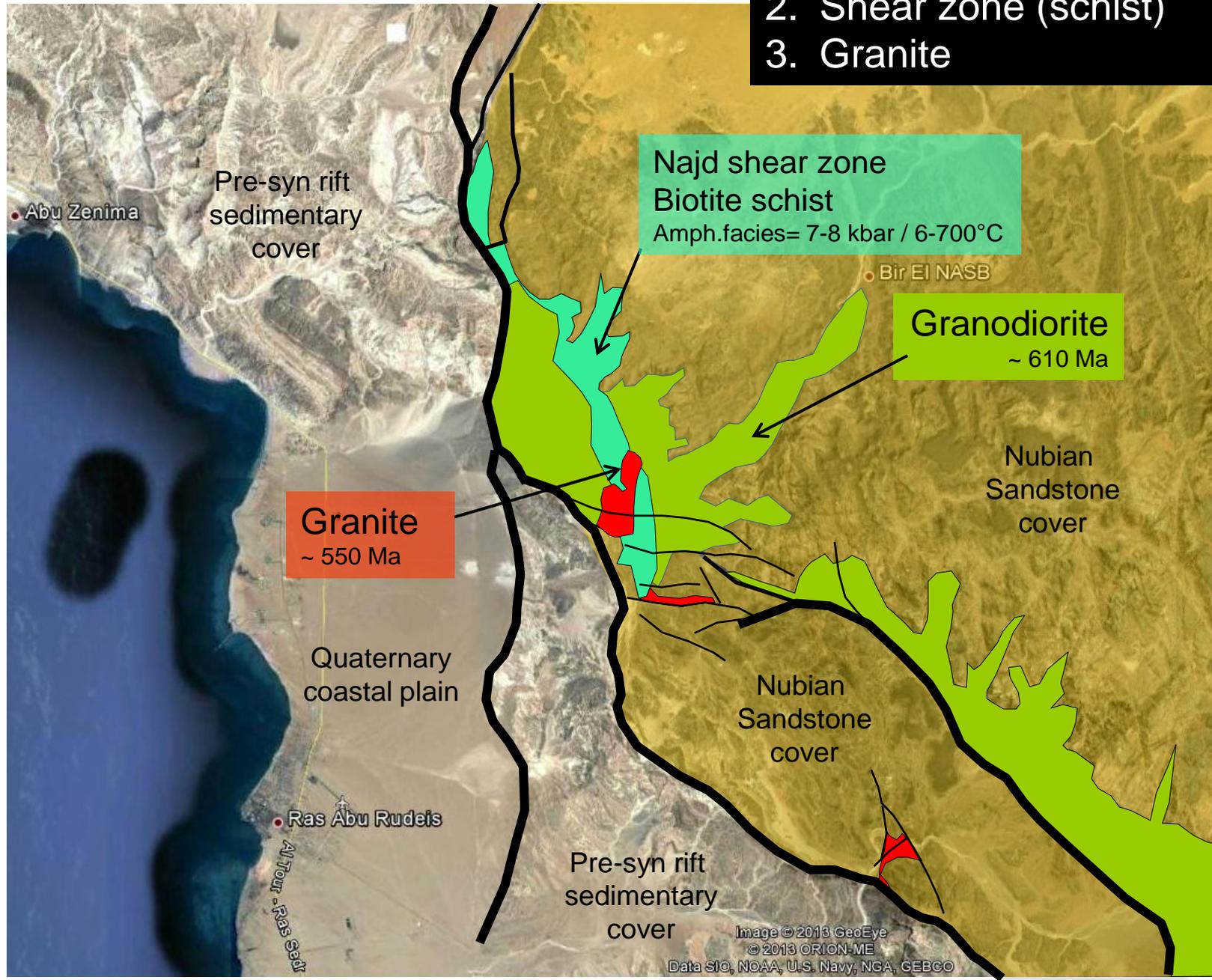
Section studied {

Oblique view into study area

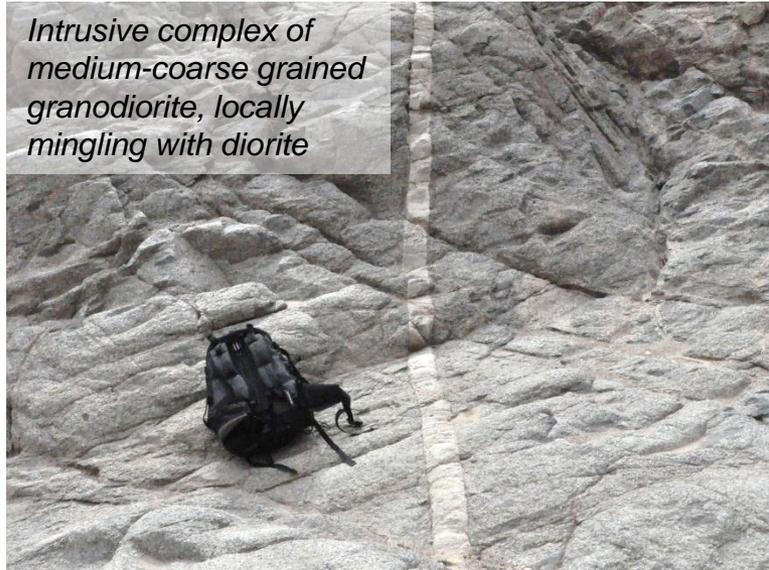


3) BASEMENT LITHOLOGIES

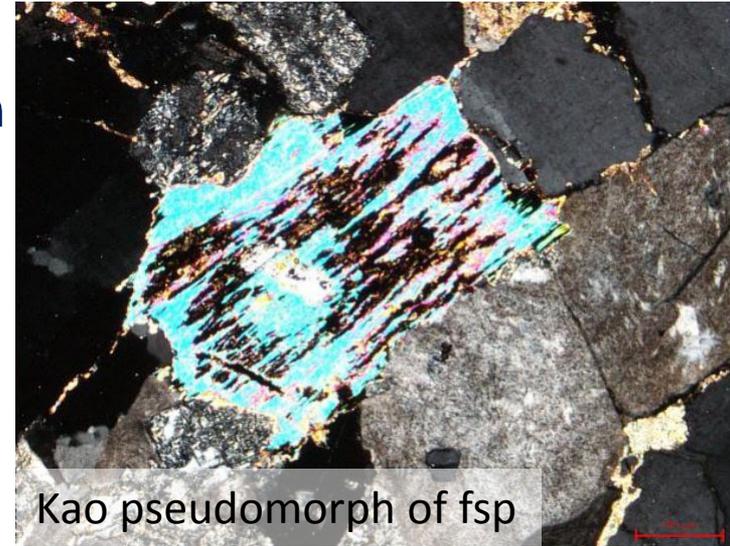
1. Granodiorite complex
2. Shear zone (schist)
3. Granite



Granitoides (Granodiorite and Granite) => weathered granitoides



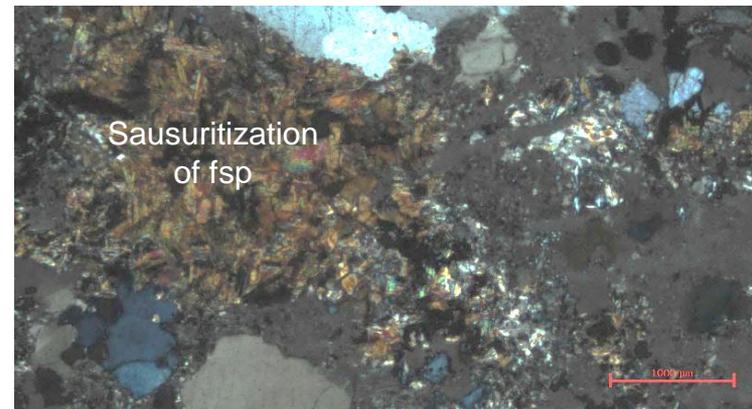
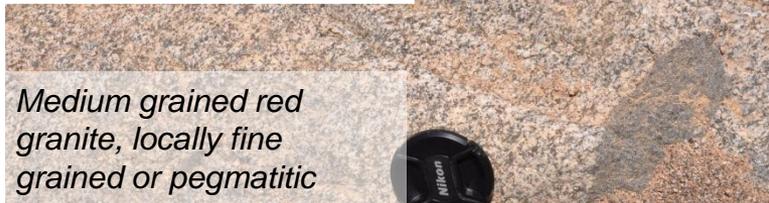
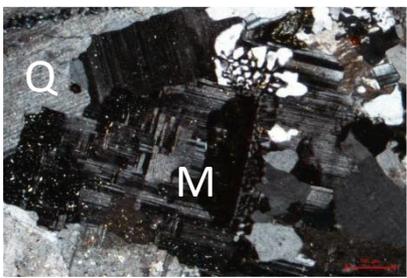
- **Outcrop**
- **thin-section**
- **XRD**



Intrusive complexes of medium-coarse grained granitoids
Qtz+Kfsp+albite+hbl+bio+white mica

Weathering

Breakdown of mafic minerals and fsp => Qtz+ kaolinite+ illite
± albite ± microcline ± bio ± white mica ± montmorillonite ± hematite ± dolomite ± gypsum ± halite

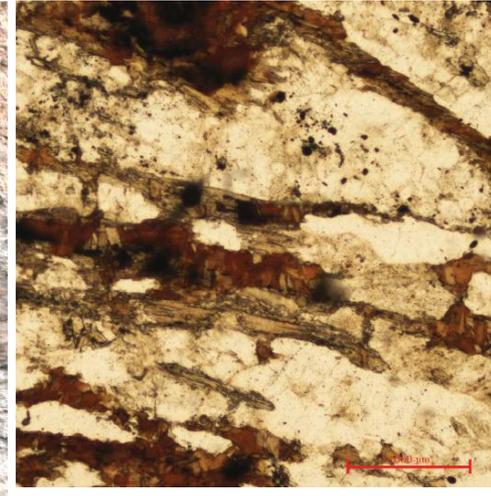
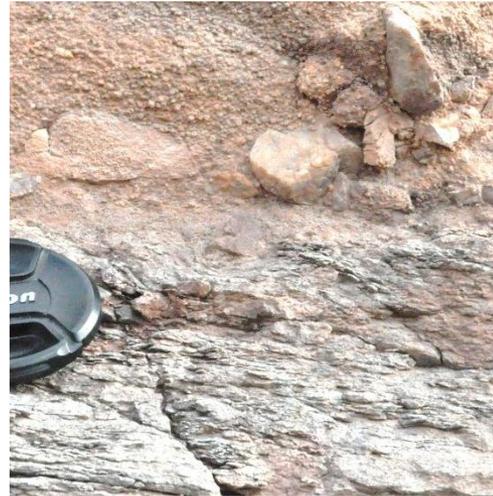


Biotite schist => weathered schist

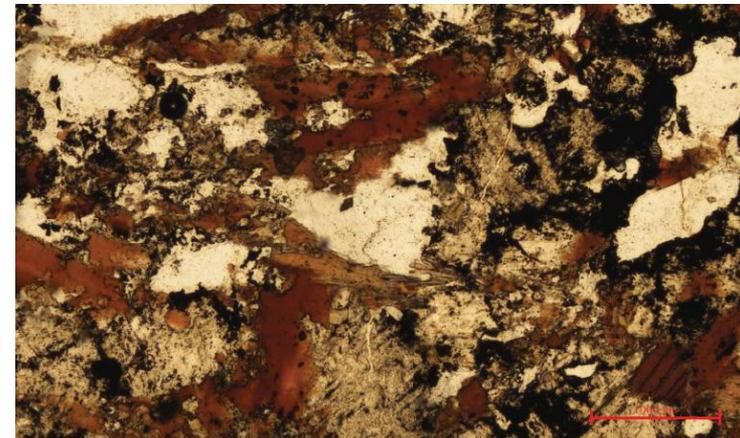
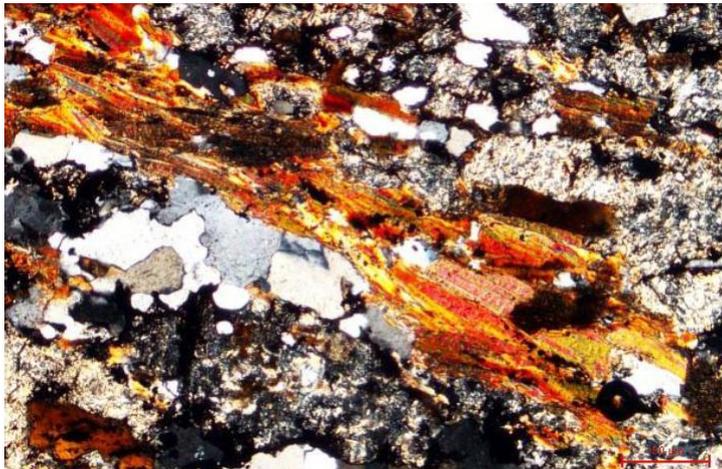
Ductile shear zone cutting intrusive complex



Fine-medium grained schist, showing transitions into lower strained granodiorite
Qtz+bio+albite±Kfsp±hbl schist

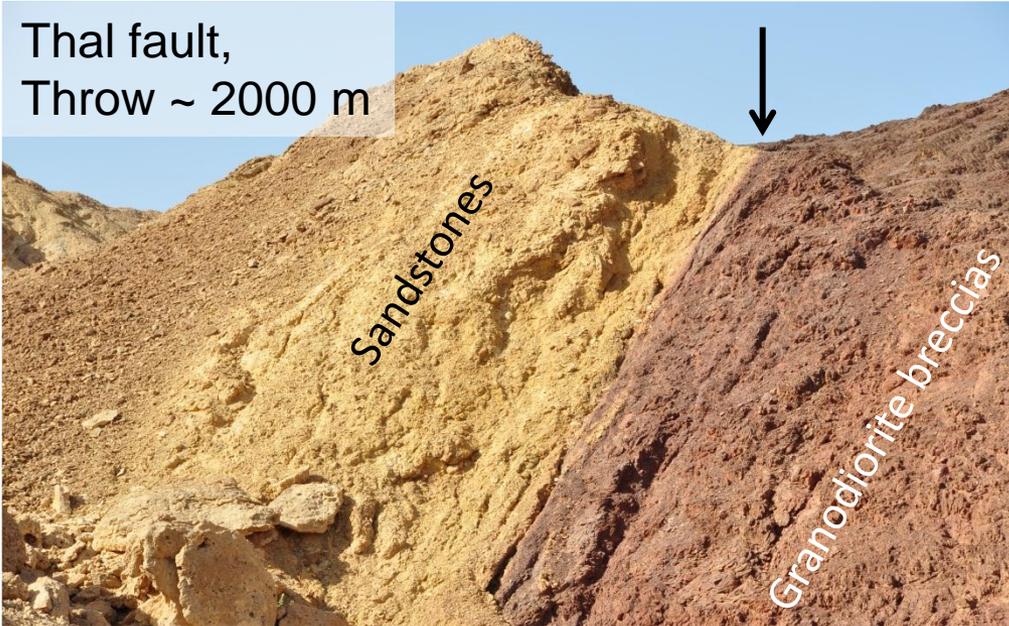


Breakdown of mafic minerals and fsp
Qtz+bio+kaolinite+illite
± albite ± montmorillonite ± hematite ± gypsum ± halite



Faults and fractures => weathering

Thal fault,
Throw ~ 2000 m



Fault rocks =
early cataclasites,
superimposed breccias and gouge

⇒ Qtz+ kaolinite+ illite+ fsp
± carbonate ± montmorillonite ±
hematite ± halite

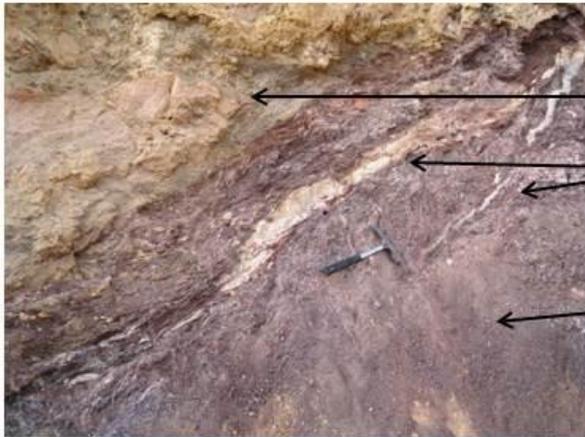
- Mafic-intermed. basement rocks
=> fractures mostly filled
- Granitoids
=> fractures mostly open



4) DATASETS a) fracture systems in the basement;

a1) Fault damage zones

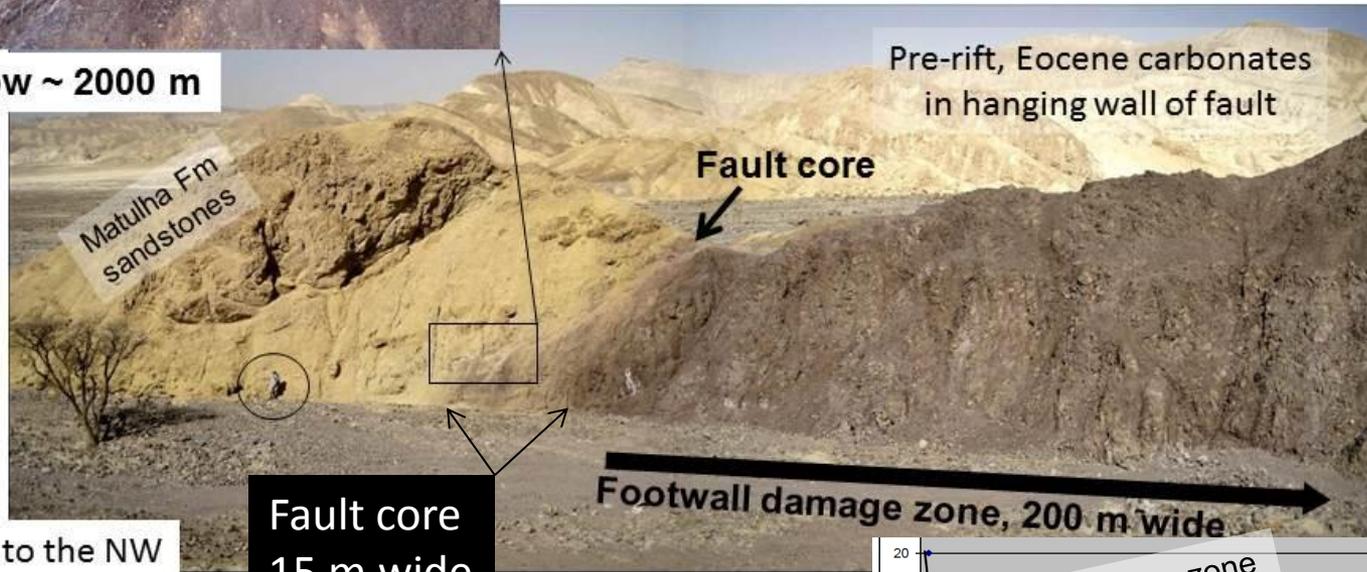
a2) background fracturing of shoulder



Throw ~ 2000 m

Thal fault

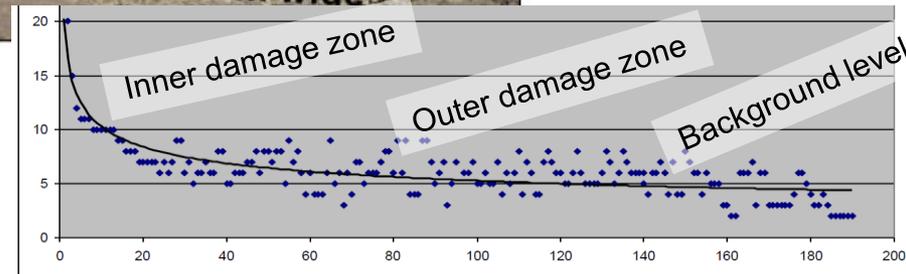
Border to rift shoulder
T > 2000m



View to the NW

Fault core
15 m wide

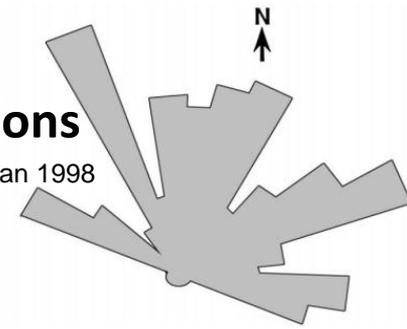
Fracture Intensity (f/m) per meter from fault



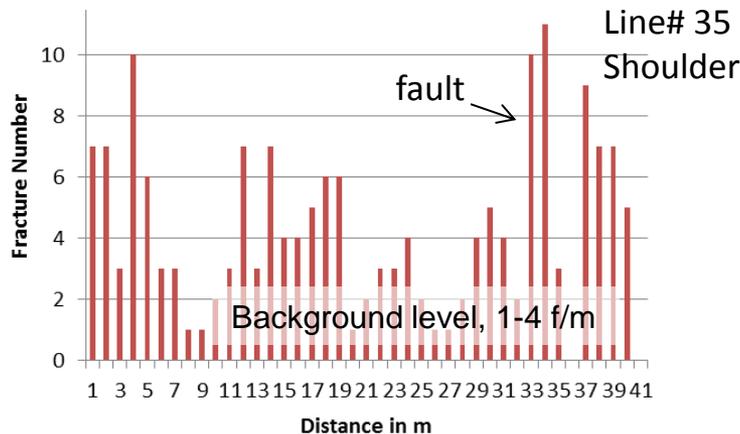
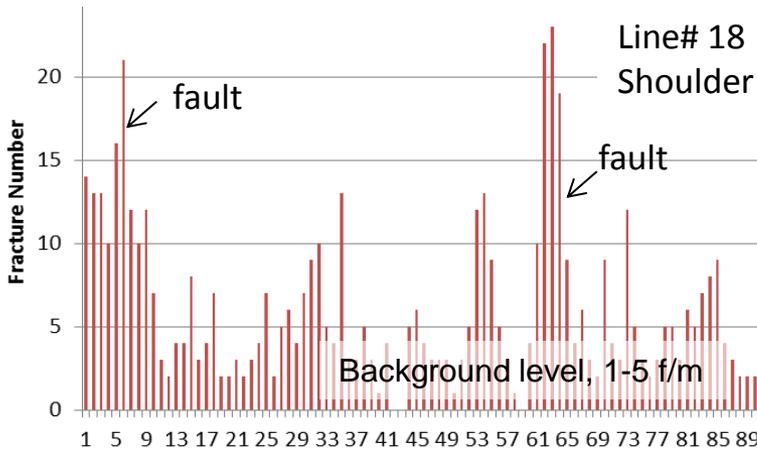
Scanlines recording of fracture system, N= 39

Fracture orientations

Salah & Alsharhan 1998



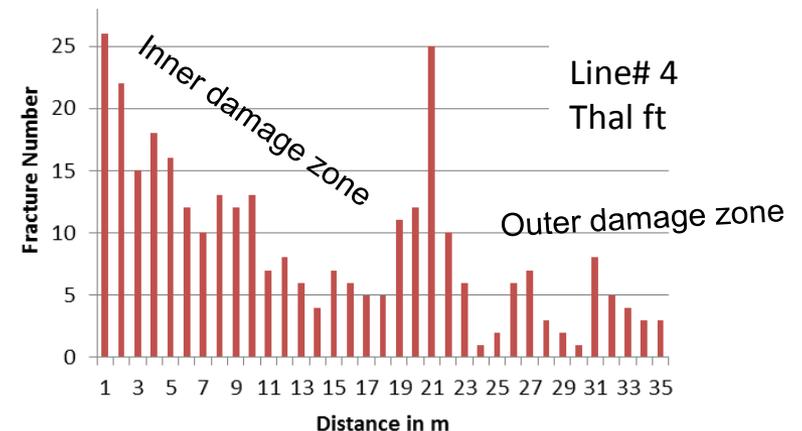
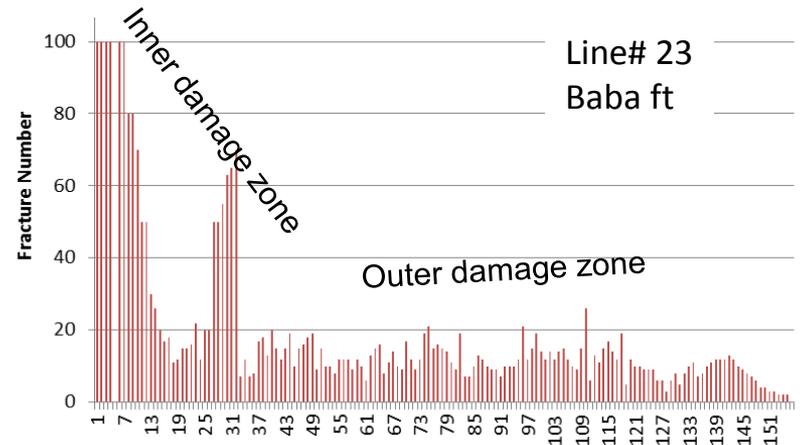
Rift shoulder with small faults



Background level = 1-4 f/m
Small fracture corridors = 3-10 m wide

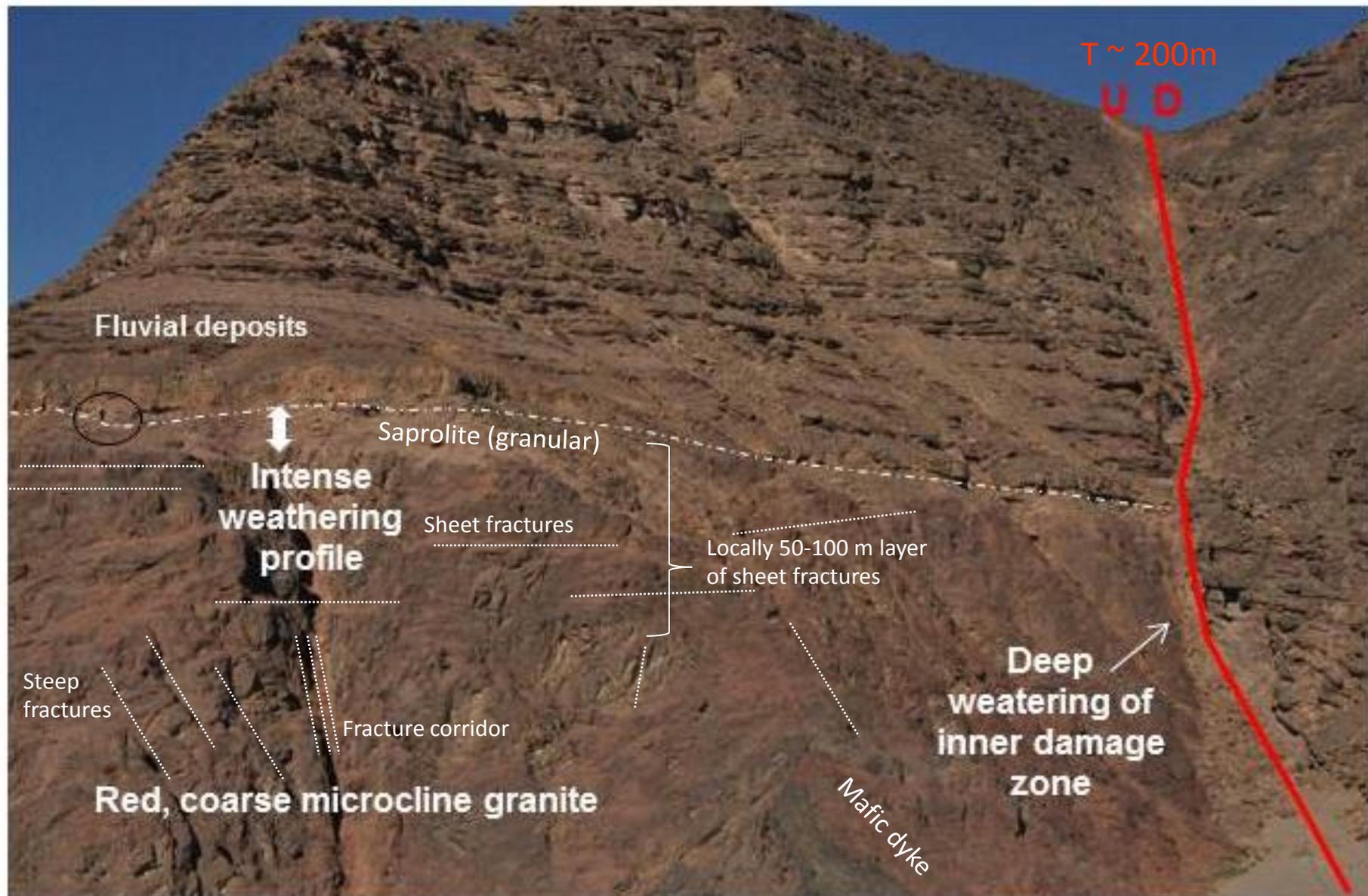
Large faults with FW damage zone

Fracture intensity per meter (f/m)



Inner damage zone = 20-35 m wide
Outer damage zone = 100-150 m wide

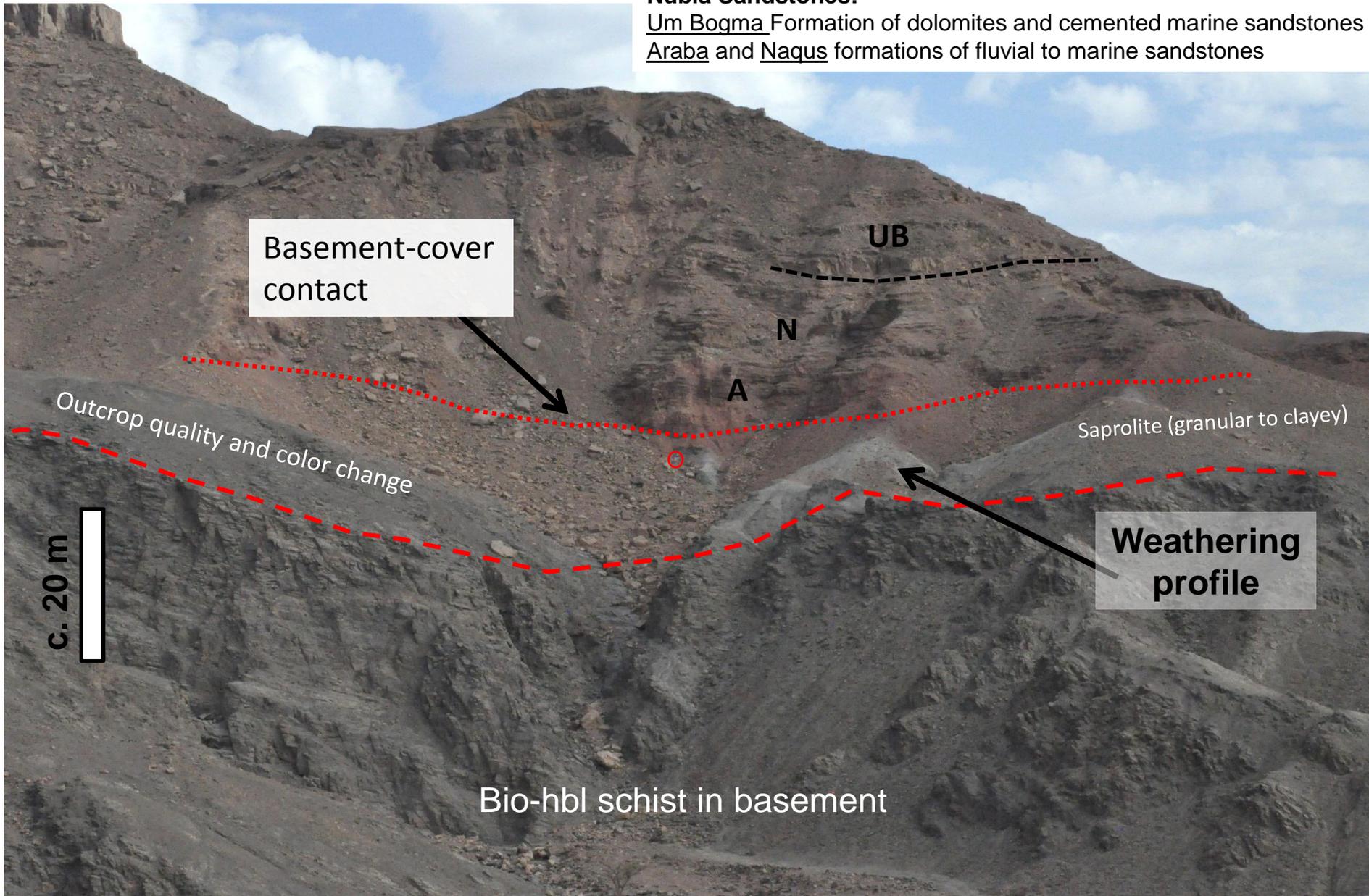
4b) tropical to arid weathering profile (saprolite) along top of basement, and along faults



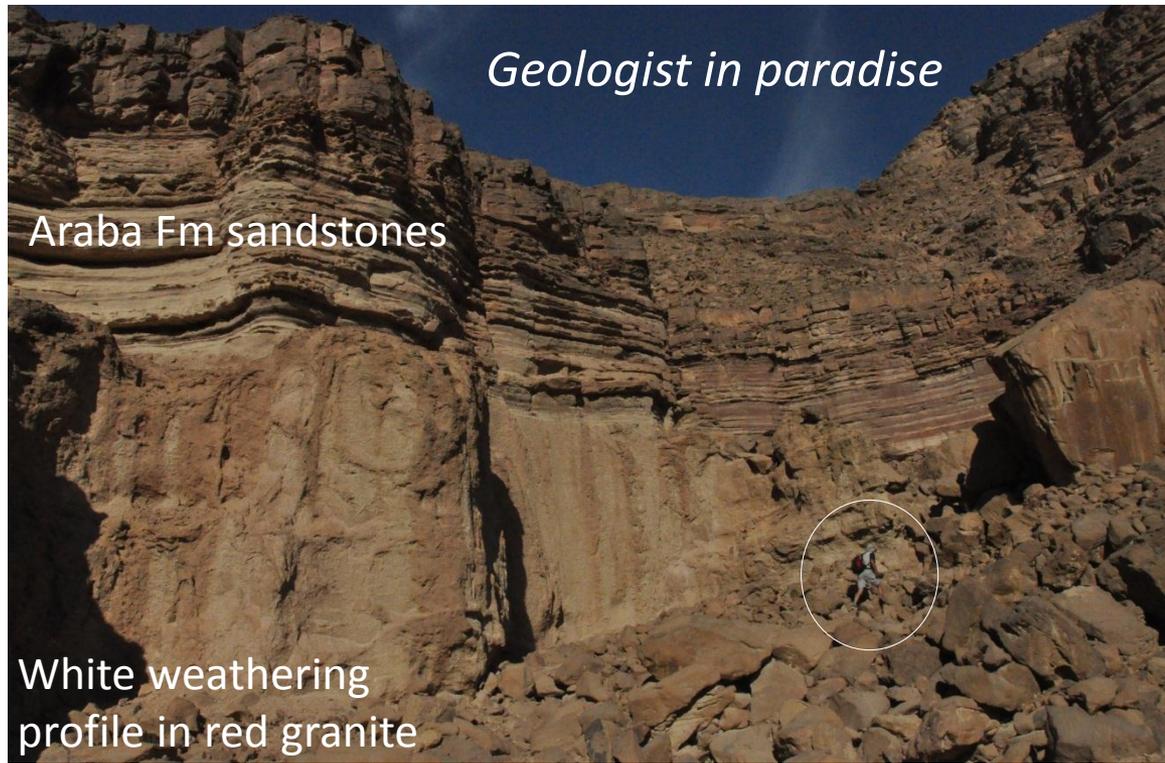
Weathering profile along top of basement

Nubia Sandstones:

Um Bogma Formation of dolomites and cemented marine sandstones
Araba and Naqus formations of fluvial to marine sandstones



Measuring thickness of weathering profiles ...



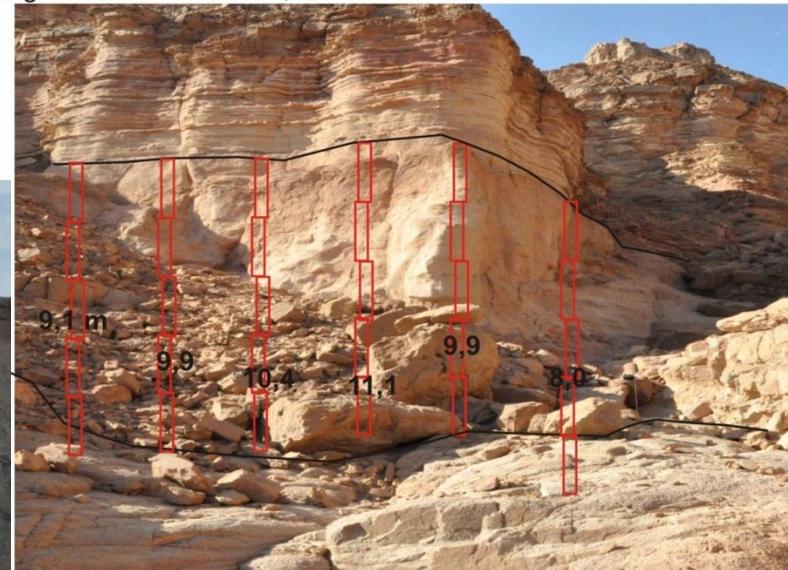
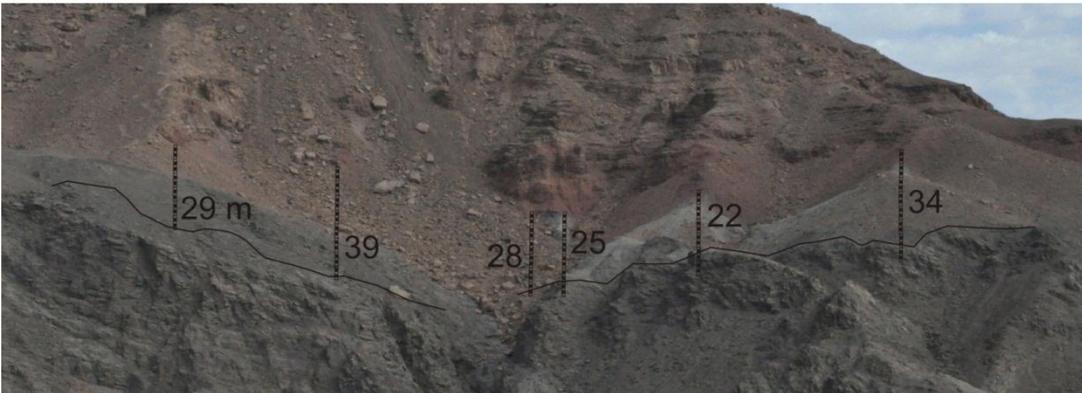
Geologist in paradise

Araba Fm sandstones

White weathering profile in red granite

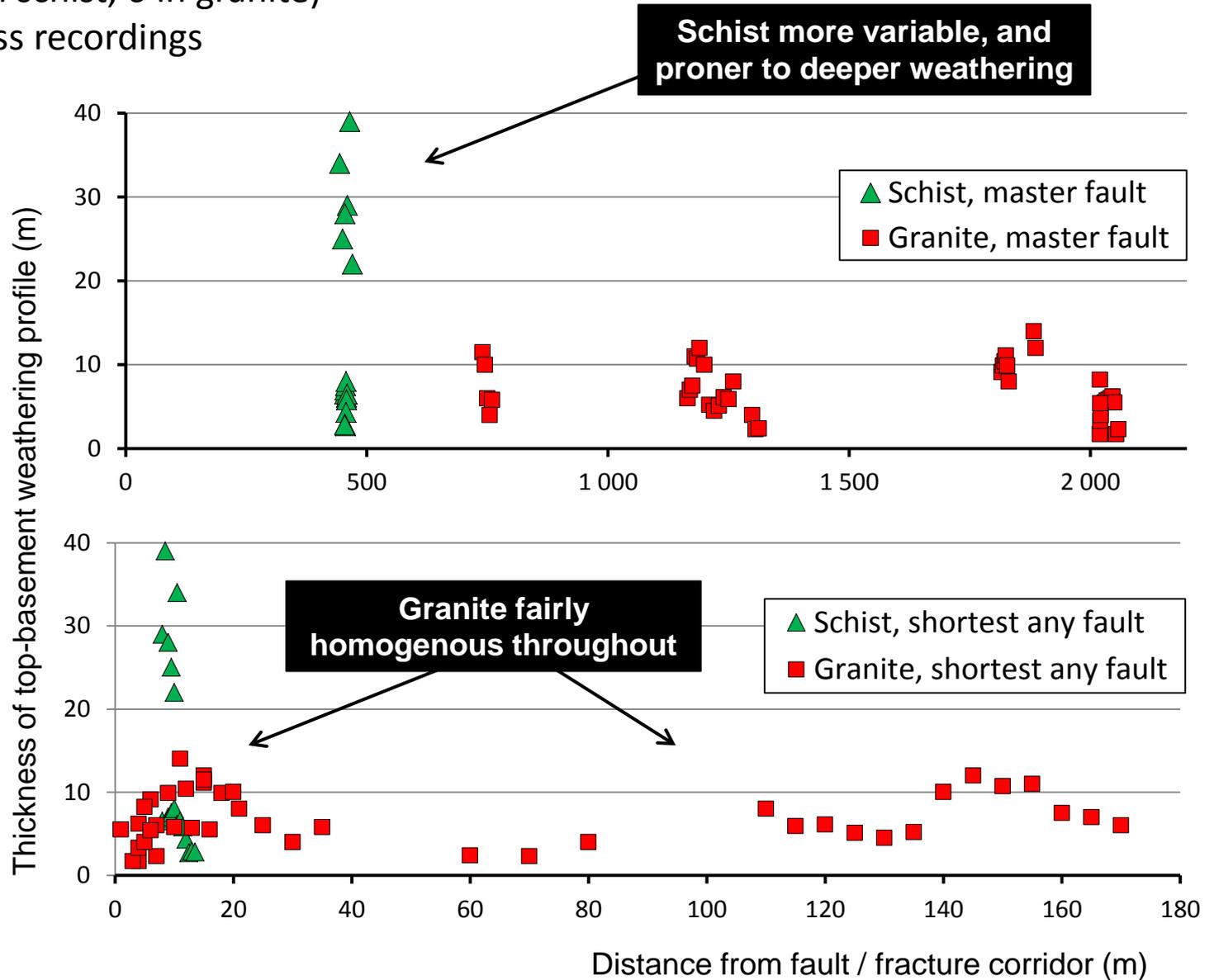
Wadi Baba, side valley, view to the N (sites BS1-6)
Red, coarse granite in rift shoulder, few small faults

Wadi Baba, view to the E (sites WB1-6)
Granodioritic schist, some small faults, ca 100 m into Fwall of Baba Ft



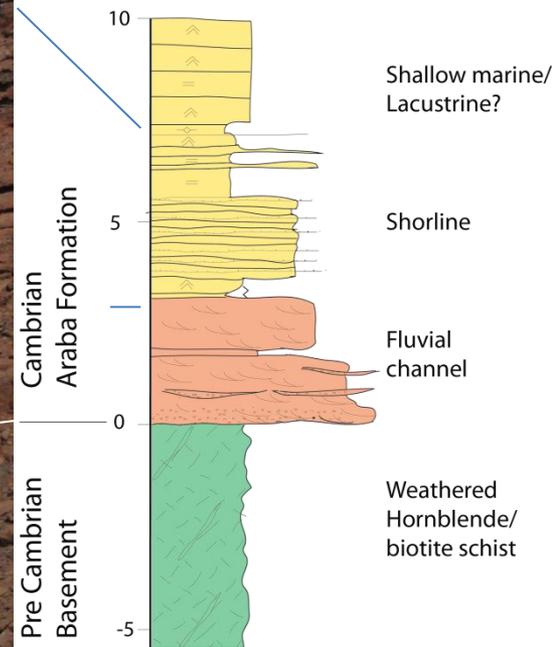
Top-basement weathering profile

- 9 sites (3 in schist, 6 in granite)
- 58 thickness recordings



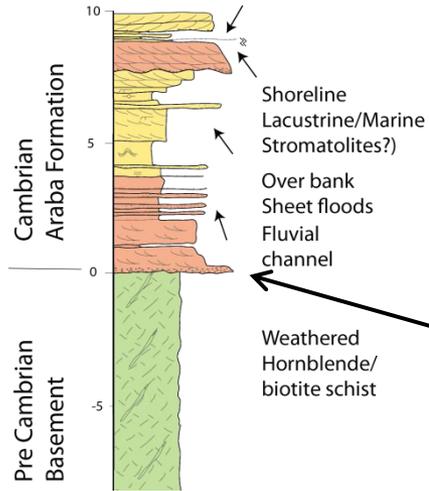
4c) Cambrian sandstones (Araba Formation) ... overlying basement.

Coarser grained alluvial red beds passing upward to red to yellowish finer grained marine or lacustrine shoreline deposits

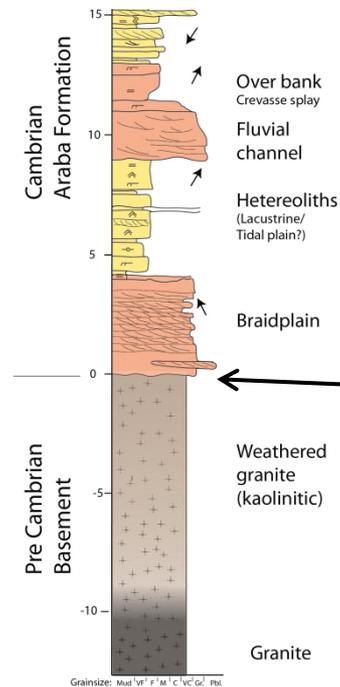


Sedimentary basement-cover transition

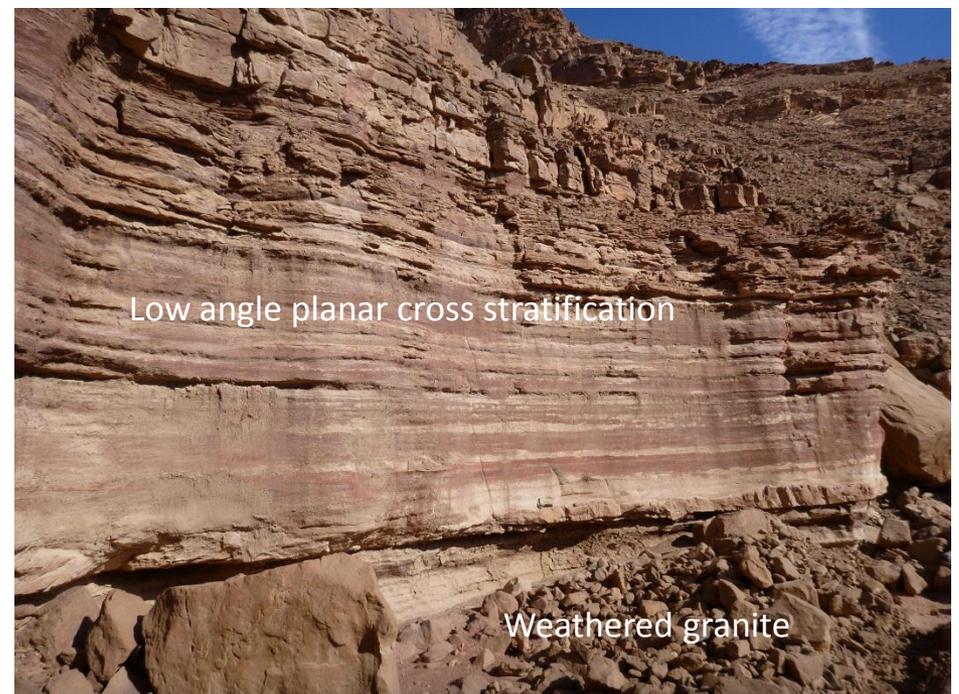
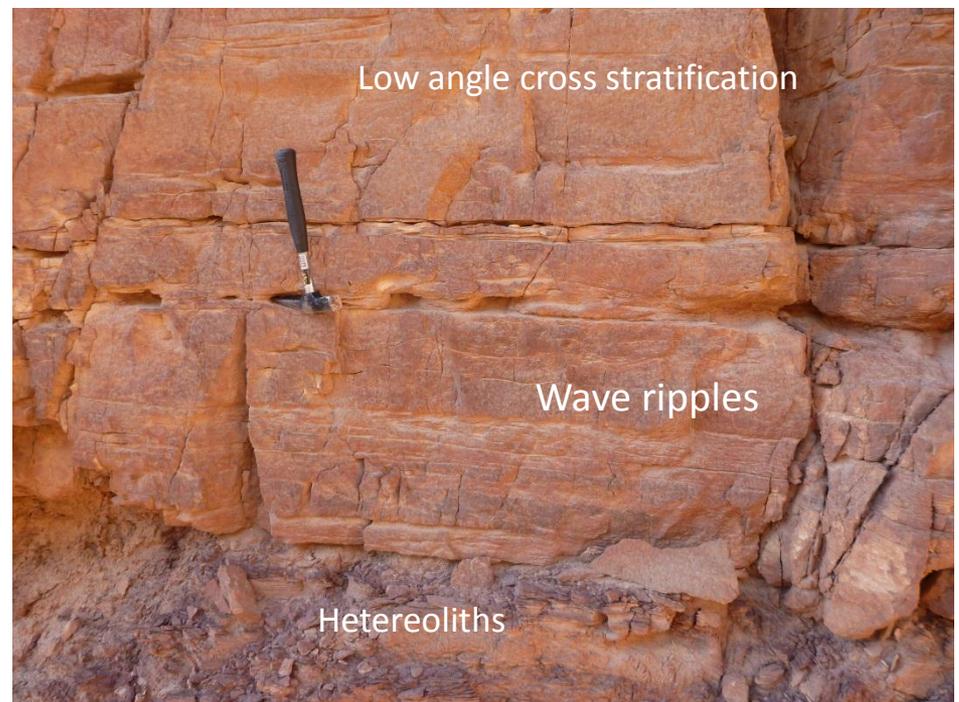
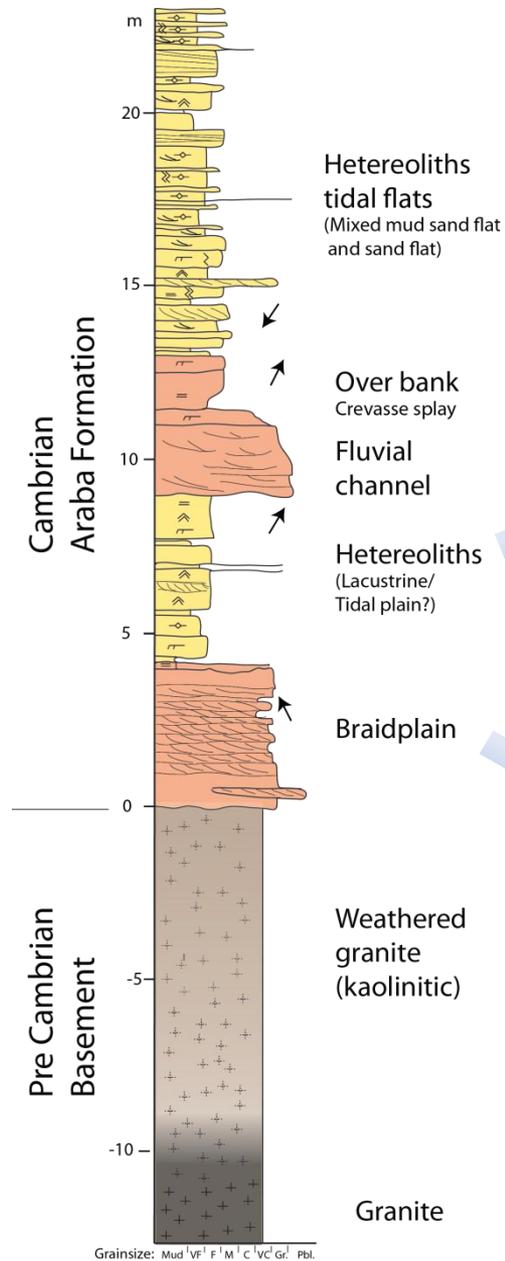
Wadi Baba village



Wadi Baba side valley



Cover sandstone facies



Cambrian mixed fluvial and tidal/shoreline facies as cover deposits

N

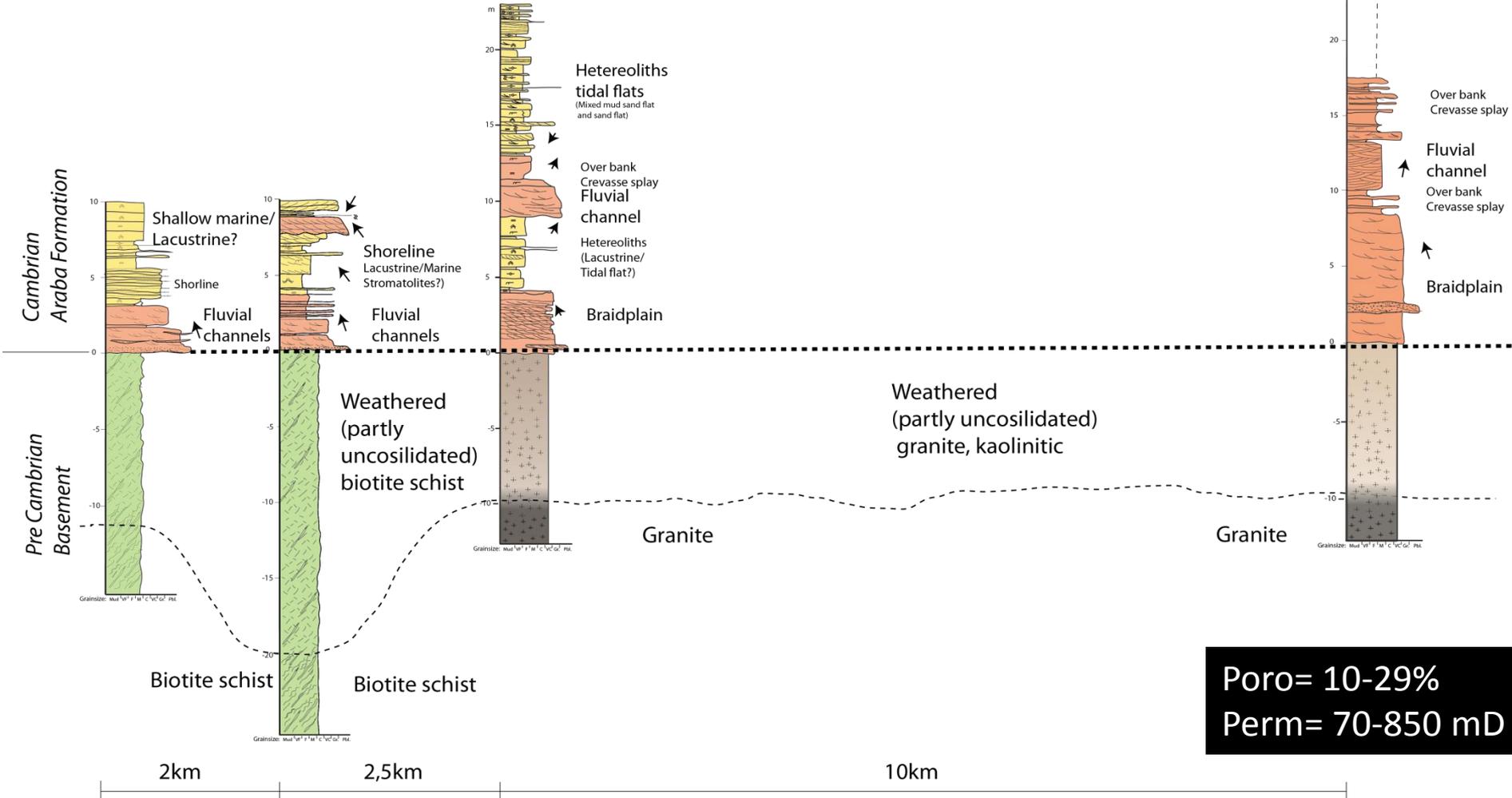
Distal ←

→ Proximal

Cont. => shallow marine succession

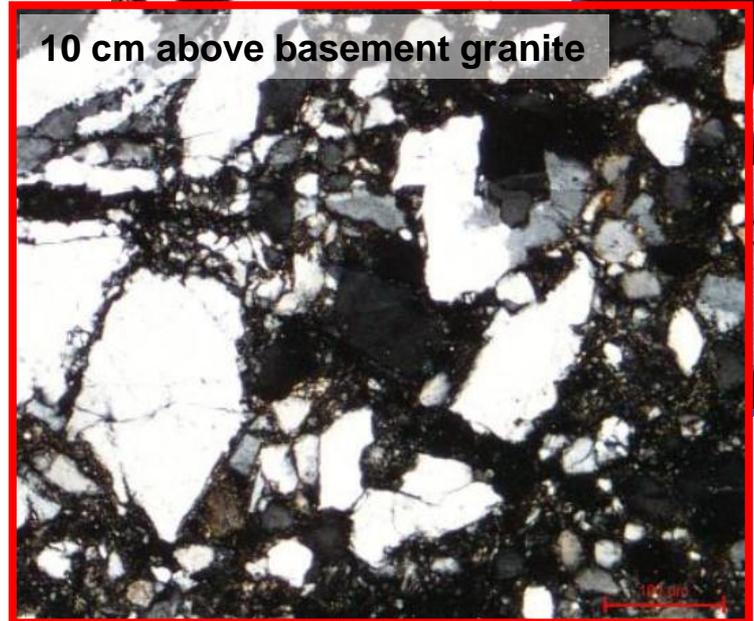
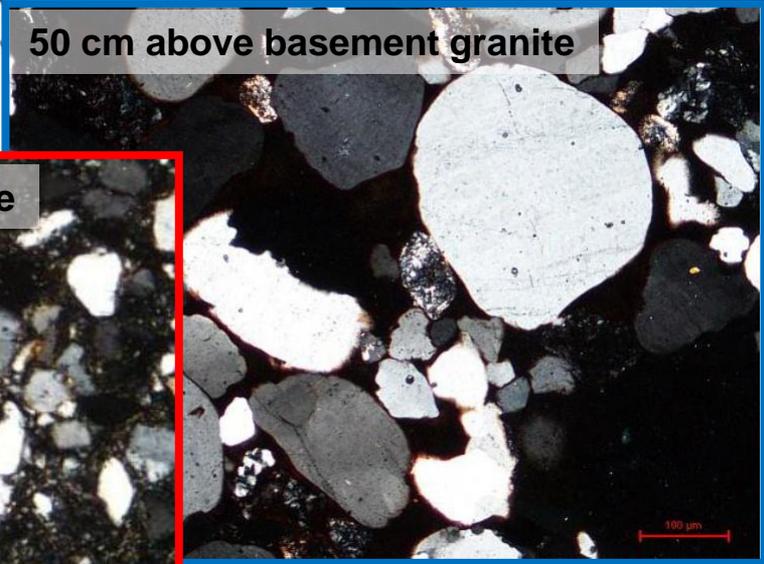
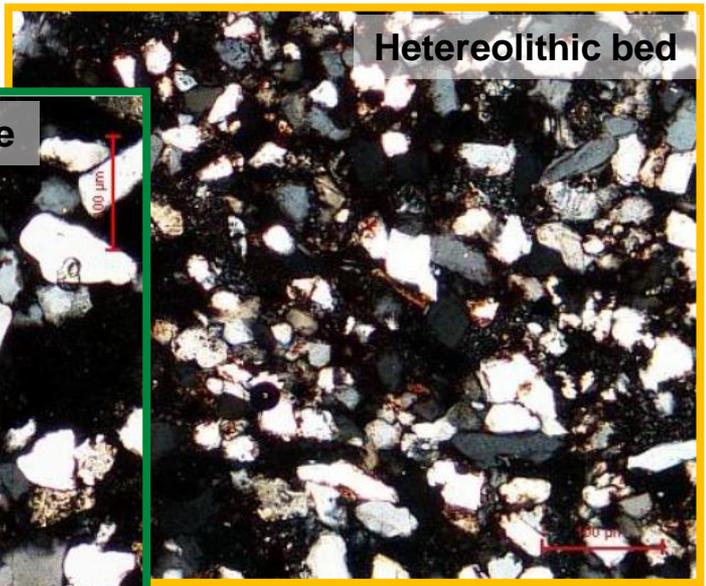
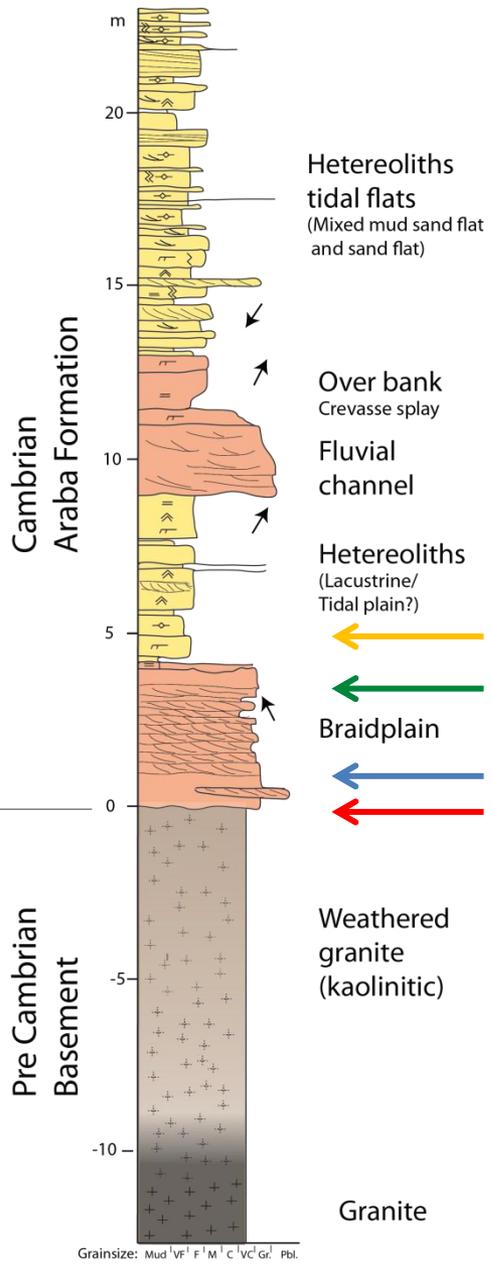
Continental succession

S



Poro= 10-29%
Perm= 70-850 mD

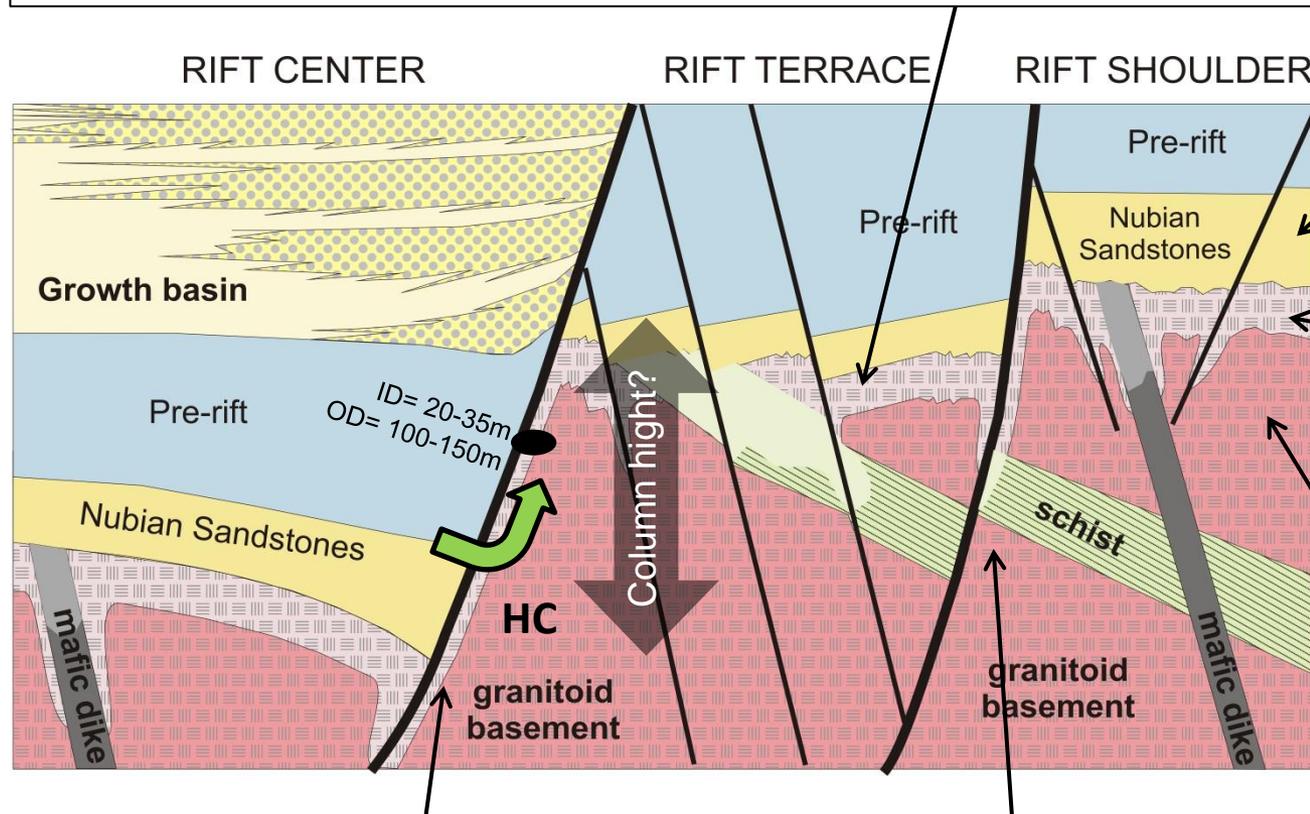
Sedimentary cover overlying basement – upward increased maturity of the sandstones



5) SUMMARY AND CONCLUSIONS (Suez case)

Note selective weathering and diagenesis of lithologies;

- Schist and mafic rocks with significant secondary mineralization
- Kaolinite (cement+clastic) and illite in weathering profile and partly in overlying sandstones



RESERVOIRS

Porous sandstone succession infilling basement relief

Porous (10-20%) and permeable 5-15 m thick weathering profile on-top felsic intrusives

Fractured basement reservoir with ~ 1-3% porosity

PLUMBING SYSTEM

Fault damage zones with open fractures in granitoids

Selective deep weathering, and corroded fracture system along faults

*Thank
you ...*

Adventdalen Snake Weasel Oil & Gas
Field Inspection
Abu Zenima, February 2012

