MANCHESTER 1824

North Africa Research Group

New constraints on source to sink systems of NW Africa:

Provenance of the Mesozoic sandstones of the EAB

Emmanuel **Roquette**, Stefan Schröder, Tim Luber, Shane Tyrrell, Jonathan Redfern

18th September 2019


Essaouira Agadir Basin (EAB)
Sierra Morena Mountains
Sierra Nevada Mountains
Gulf of Cádiz
Alboran Sea
Algiers
Tunis
Gulf of Tunisia
Er Rif
Rabat
Moyen Atlas
Atlas Mountains
Madeira
Haut Atlas Mountains
Morocco
Anti-Atlas Mountains
Isla de la Palma
Lanzarote
Tenerife
Fuerteventura
Gran Canaria
Hamada Du Draa Desert
Algeria
Erg Iguidi Desert
Erg Chech Desert
Western Sahara
© 2018 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
US Dept of State Geographer
870 km
200 km

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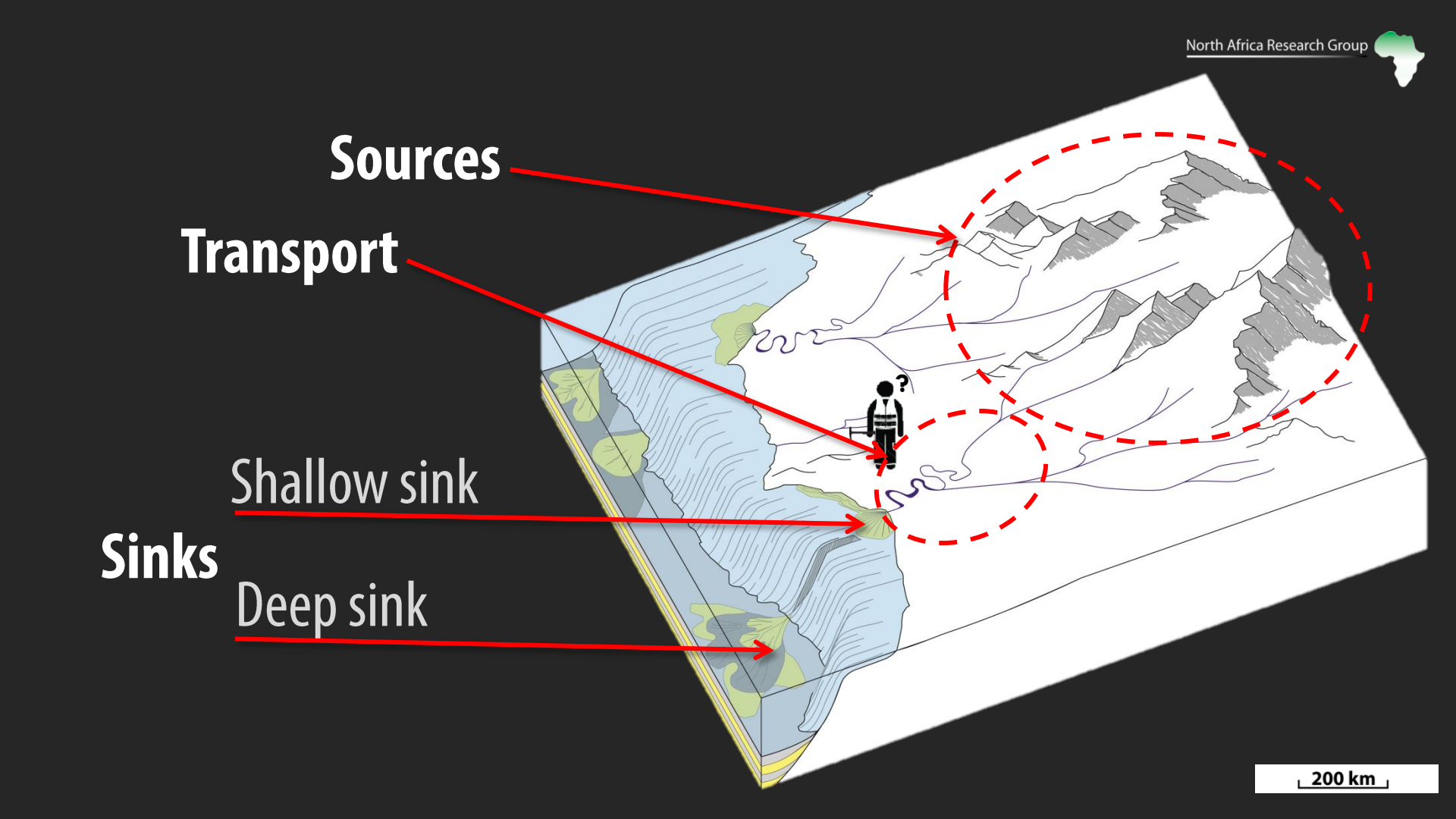

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I • Sink

(quick) Introduction to the EAB

Introduction – Tectonostratigraphic Framework

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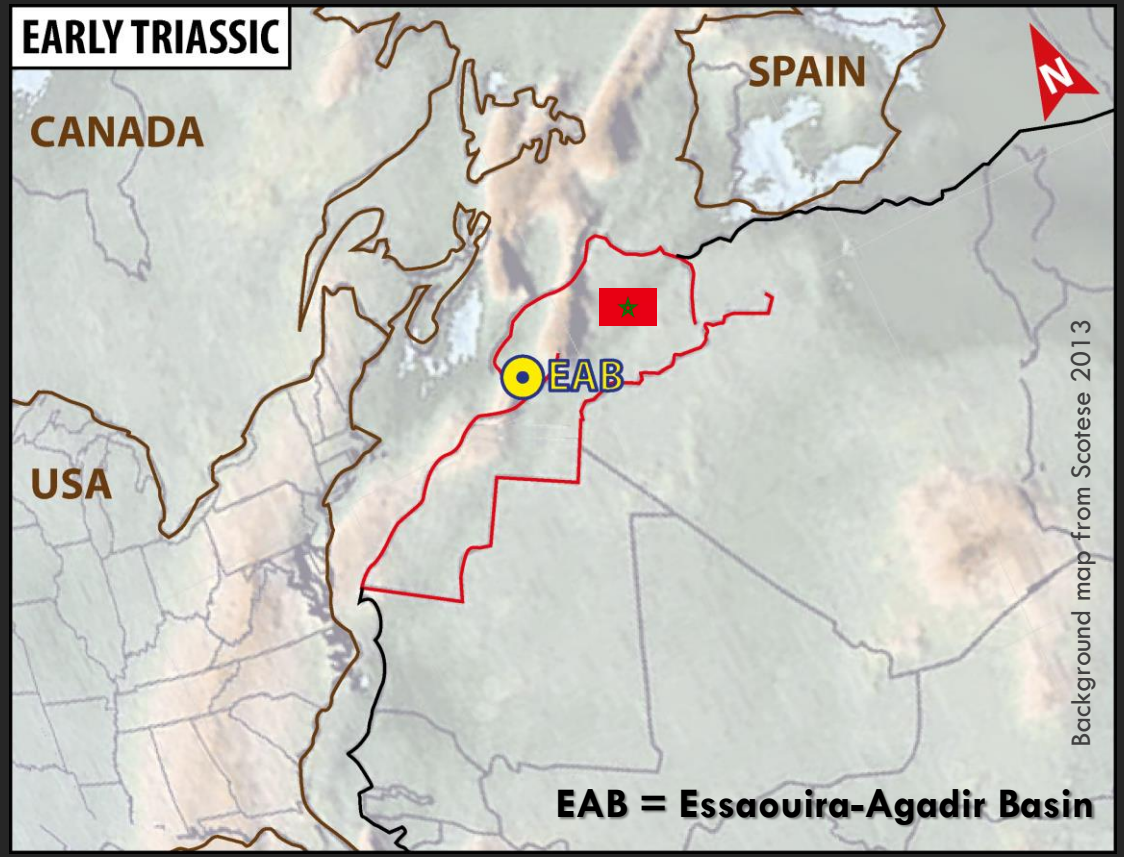

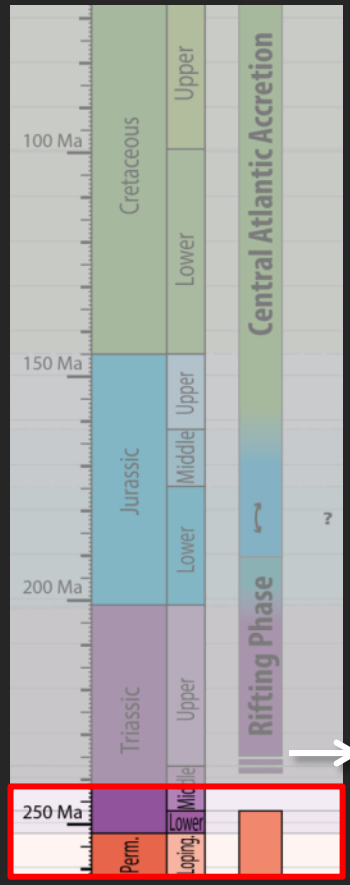

→ Rifting onset

Latest Hercynian magmatic events in Morocco

Introduction – Tectonostratigraphic Framework

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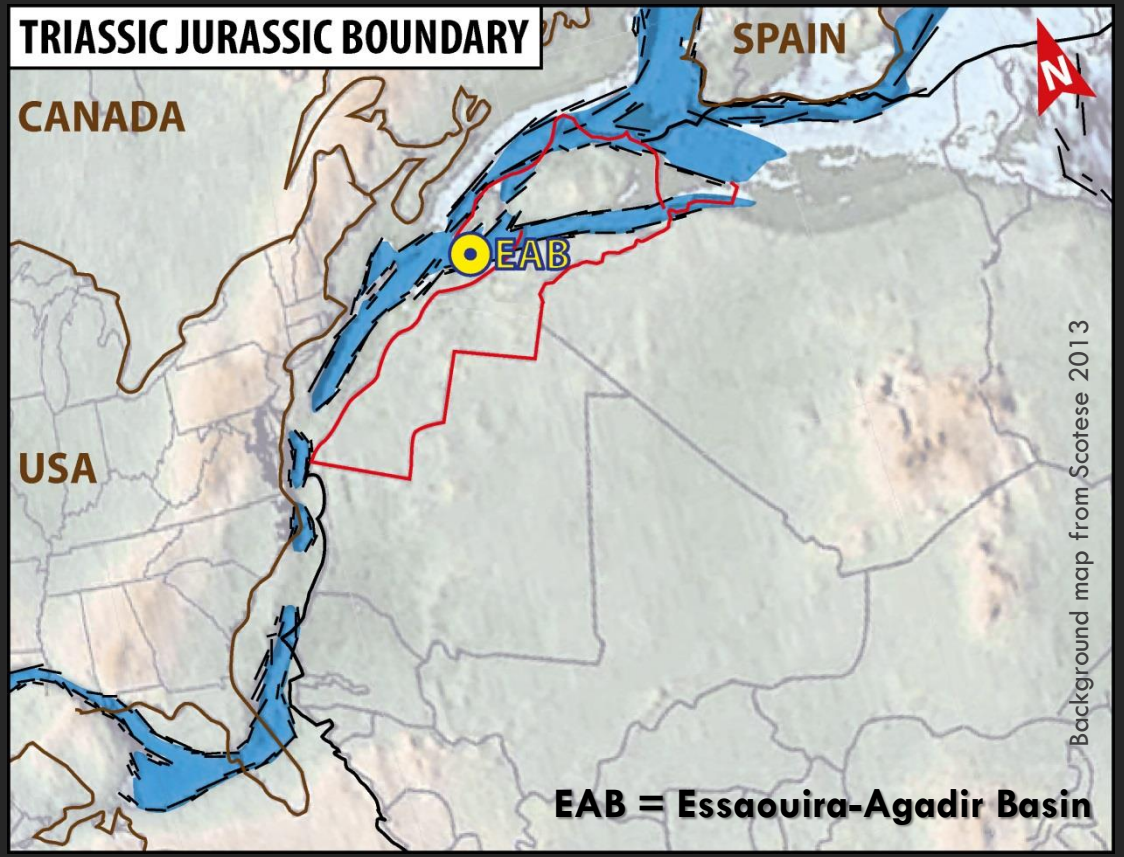
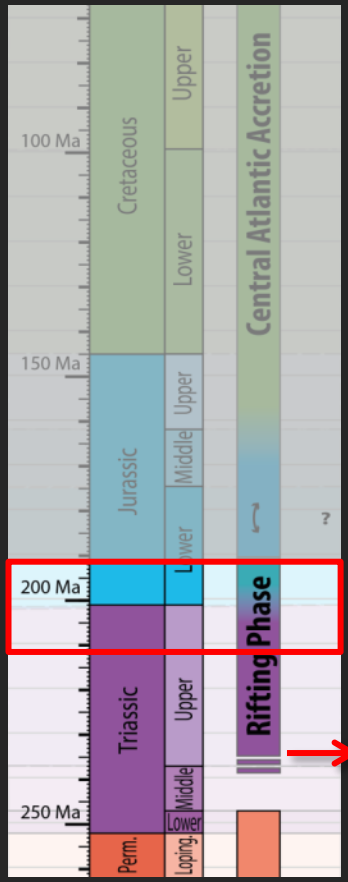




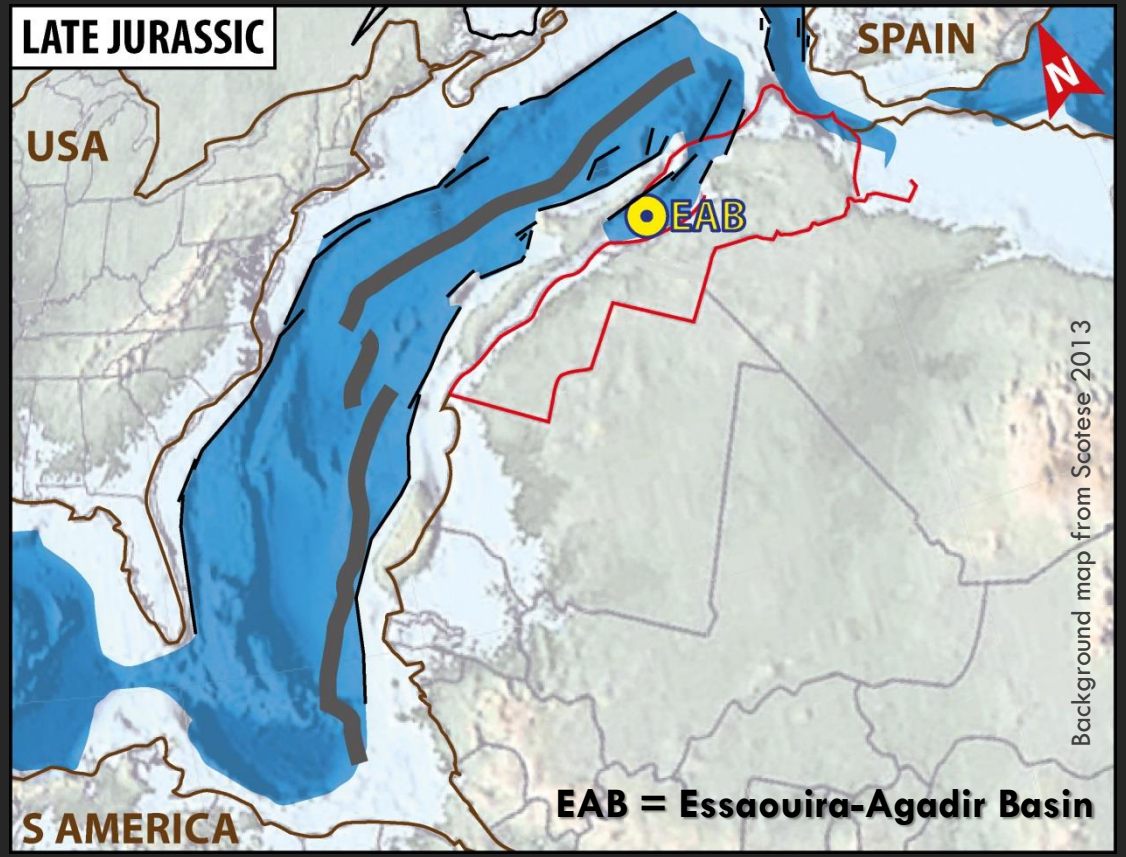
Earliest oceanic crust

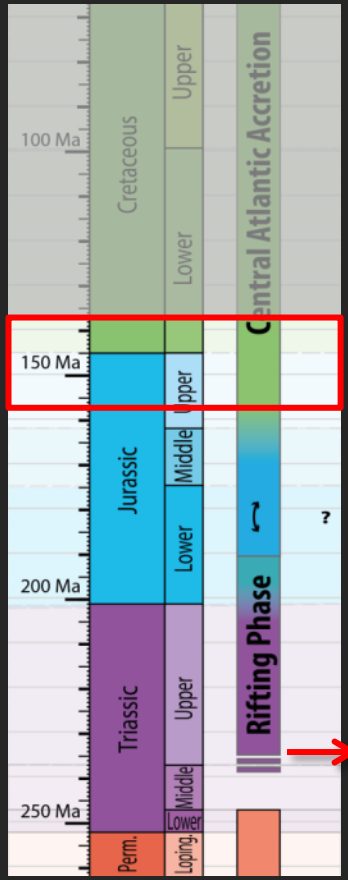
Rifting climax

Rifting onset

Latest Hercynian magmatic events in Morocco

Introduction – Tectonostratigraphic Framework





Earliest oceanic crust

Rifting climax

Rifting onset

Latest Hercynian magmatic events in Morocco

Introduction – Tectonostratigraphic Framework

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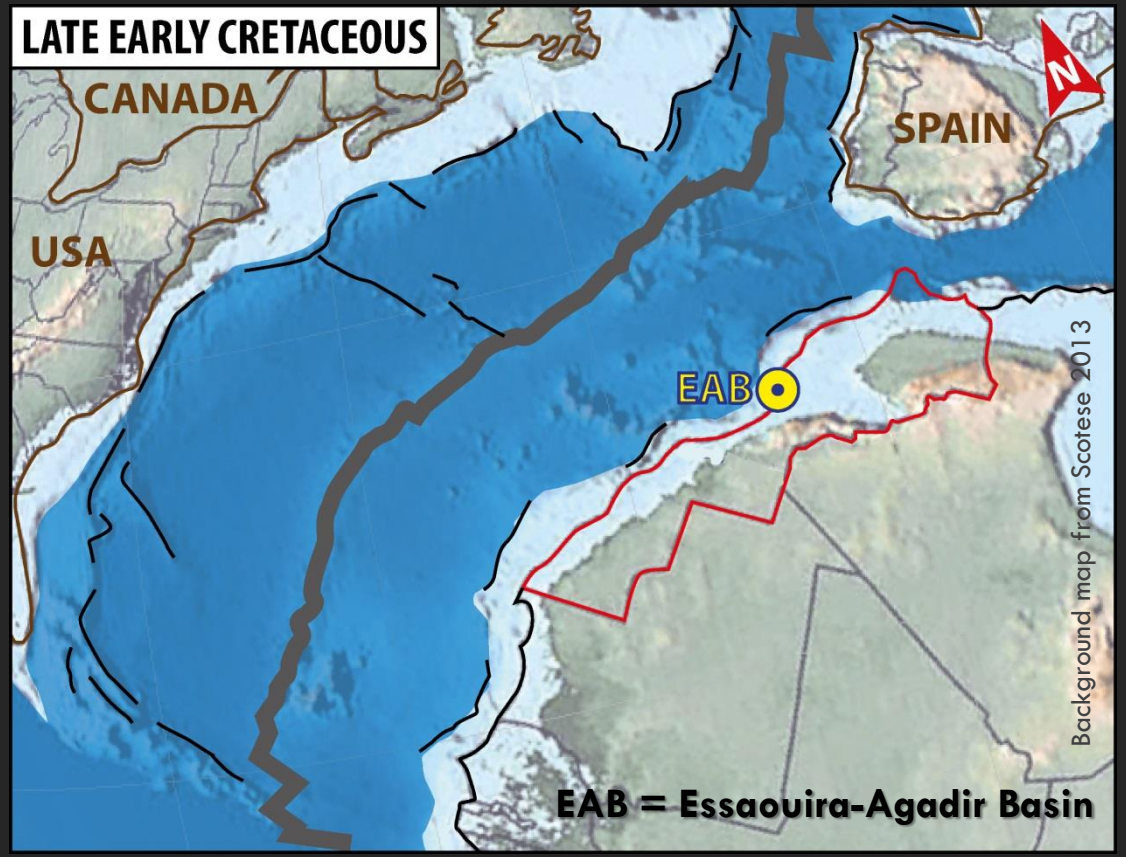
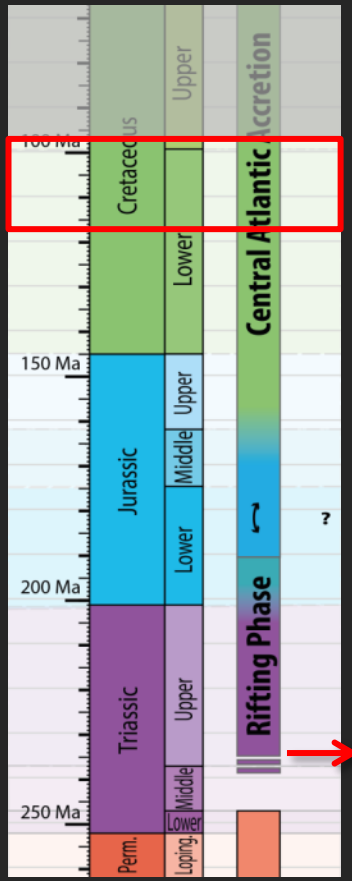




Mud dominated **shelfal** succession truncated by **shoreface** to **fluvial** sandstones.

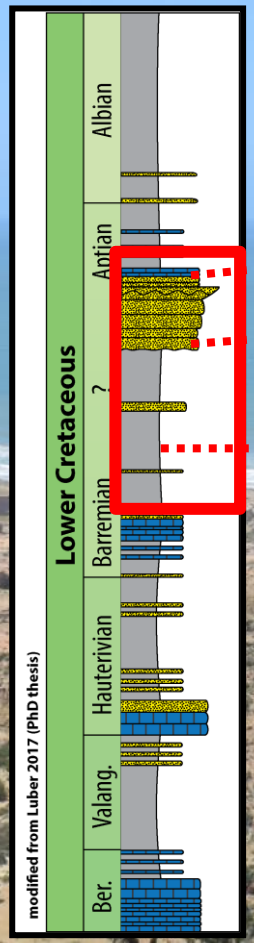
Earliest oceanic crust

Rifting climax

Rifting onset

Latest Hercynian magmatic events in Morocco

Introduction – Tectonostratigraphic Framework



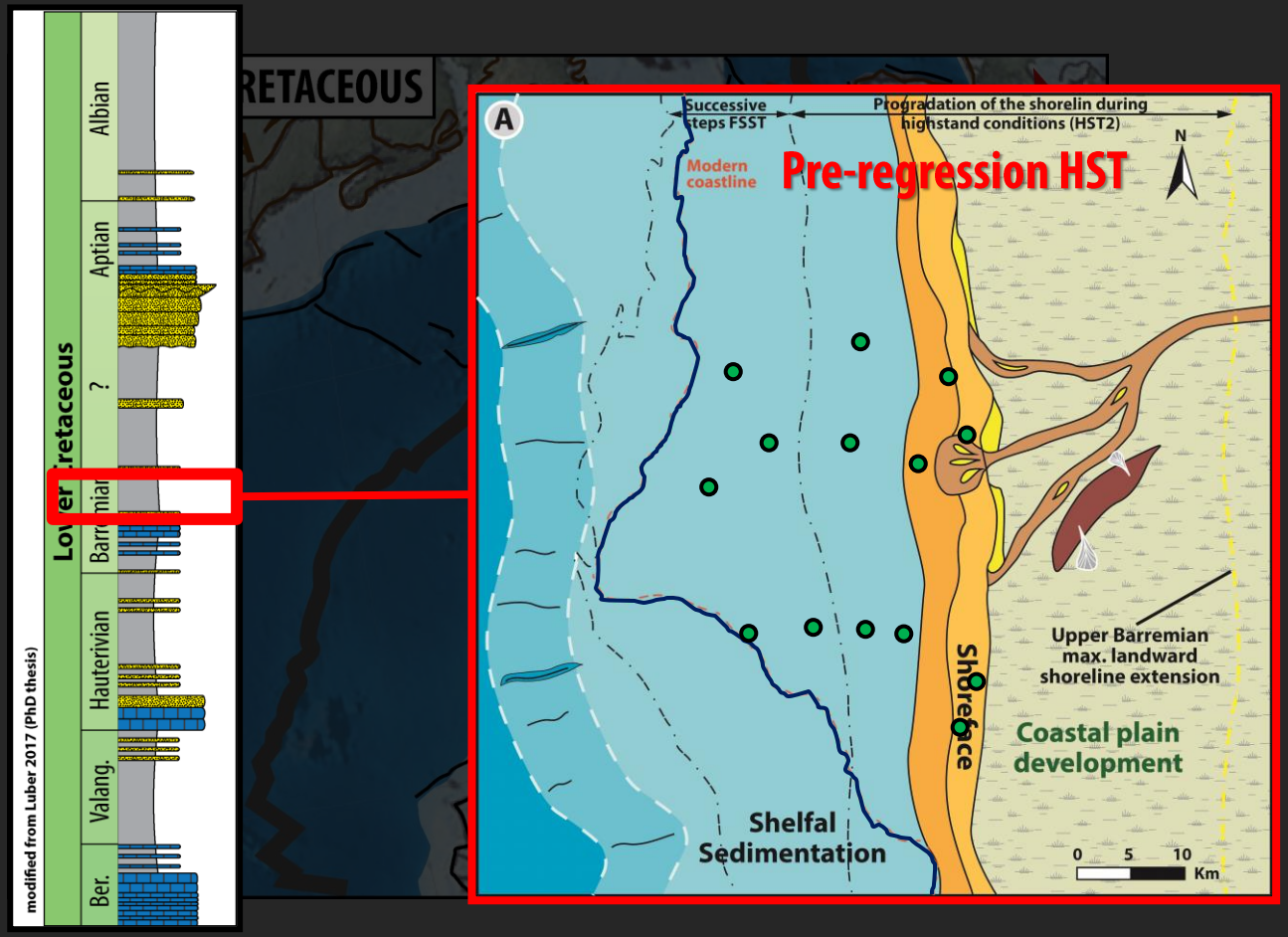
TST

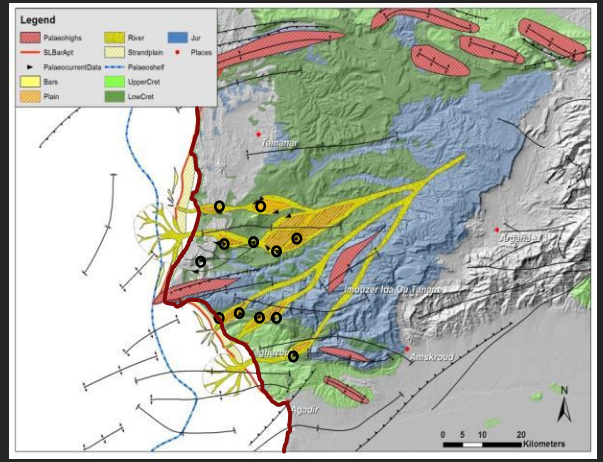
Max Regression

LST

HST

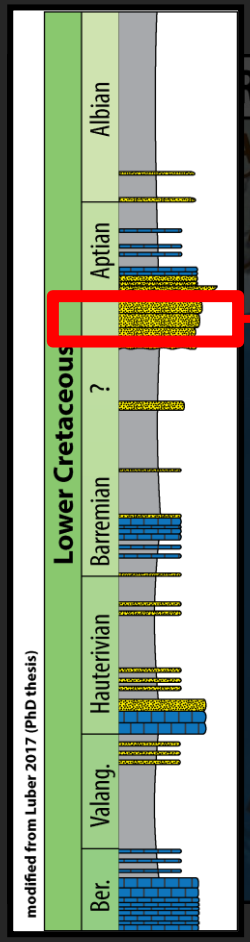
SINK: Essaouira Agadir Basin

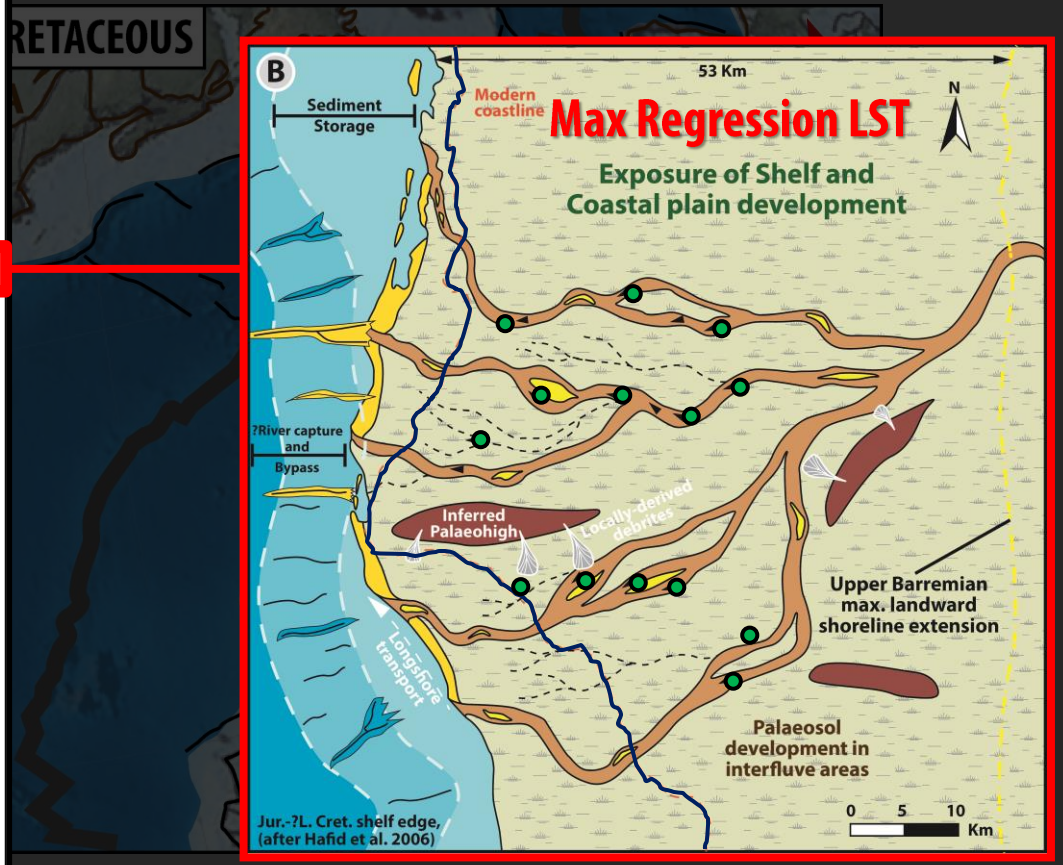


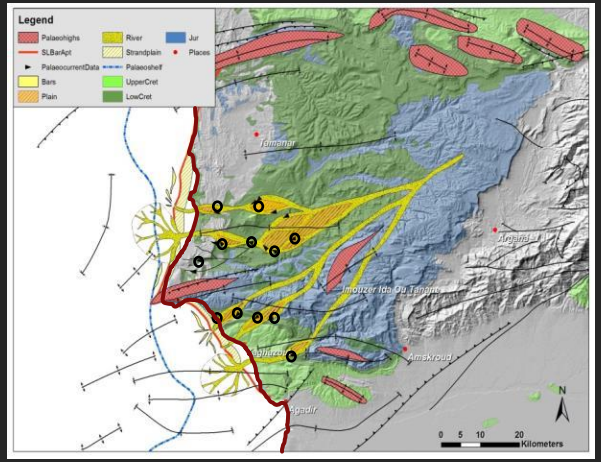


Luber 2017 (PhD Thesis)

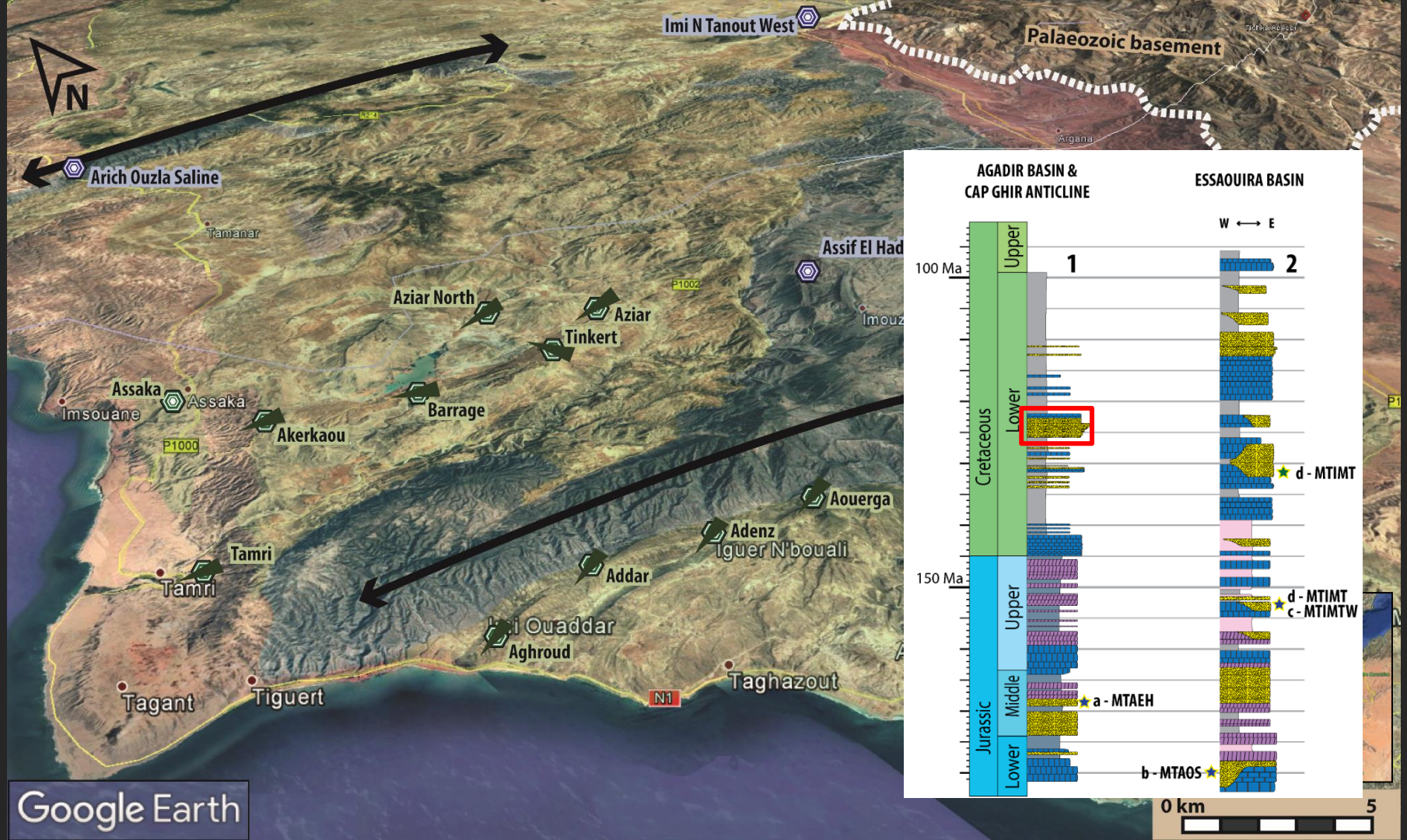
Introduction – Tectonostratigraphic Frame





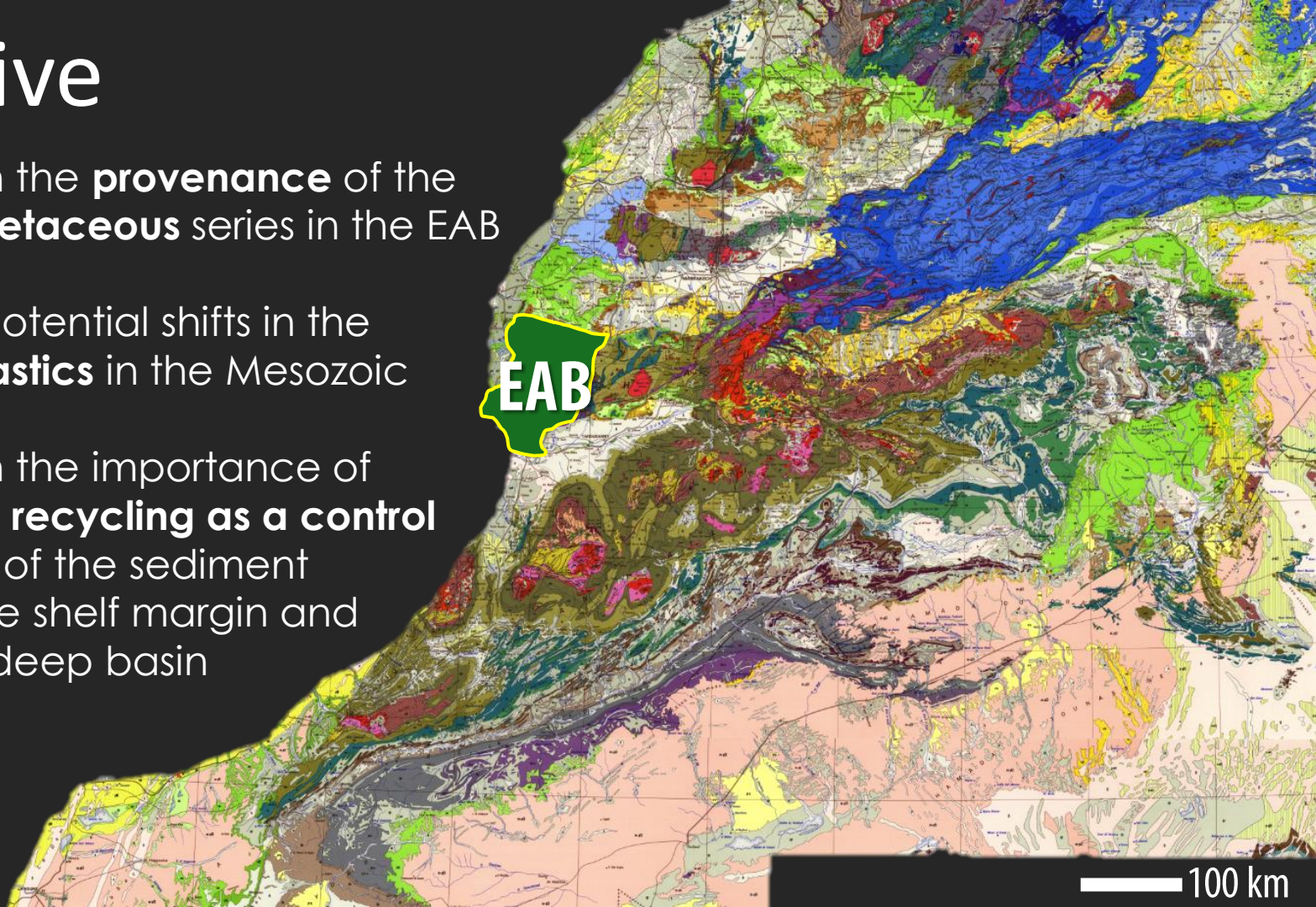


Luber 2017 (PhD Thesis)


Imi N Tanout West
Palaeozoic basement
Arich Ouzla Saline
Tamanar
Assif El Had
Aziar North
Aziar
Tinkert
Assaka
Assaka
Imsouane
Barrage
Akerkaou
P1000
P1002
Aouerga
Adenz
Iguer N'bouali
Addar
Tamri
Tamri
Aghroud
Tagant
Tiguert
Taghazout
N1
Argana
AGADIR BASIN &
CAP GHIR ANTICLINE
ESSAOUIRA BASIN
W ⟷ E
100 Ma
150 Ma
Cretaceous
Upper
Lower
Jurassic
Upper
Middle
Lower
1
2
d - MTIMT
d - MTIMT
c - MTIMTW
a - MTAEH
b - MTAOS
0 km
5
Google Earth

Objective

- Constrain the **provenance** of the **Jurassic to Cretaceous** series in the EAB
- Identify potential shifts in the **sources** of **clastics** in the Mesozoic
- Constrain the importance of **transport** and **recycling as a control on character** of the sediment brought to the shelf margin and delivered to deep basin



II • SOURCES

What were the terranes available to erosion

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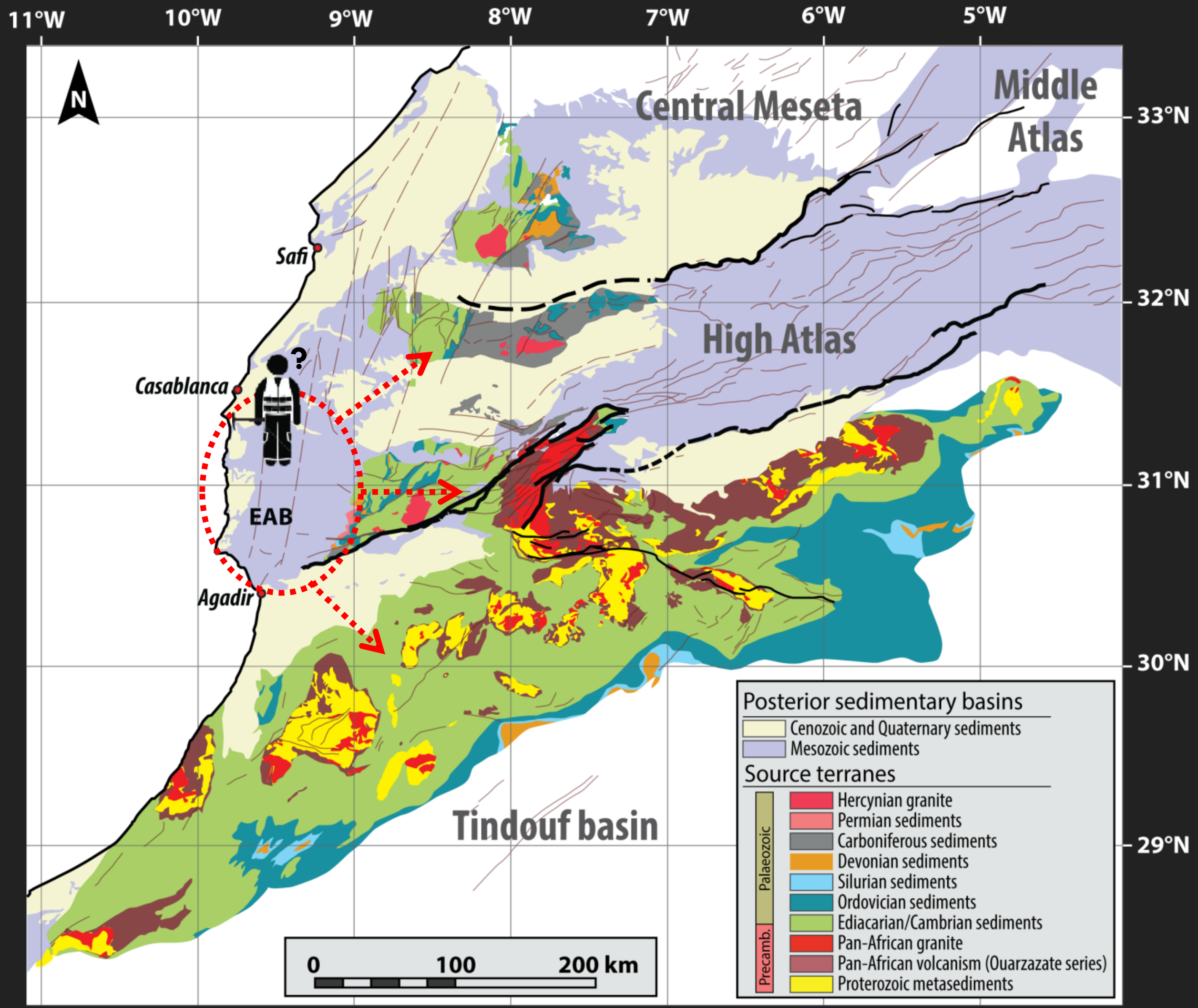
Provenance =
Correlation of detrital signals
(Rock fragments populations,
Isotopic fingerprints,
heavy mineral content)
with potential source domains



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What to correlate sedimentary fingerprints

(Rock fragments populations,
Isotopic fingerprints,
heavy mineral content)

with ?

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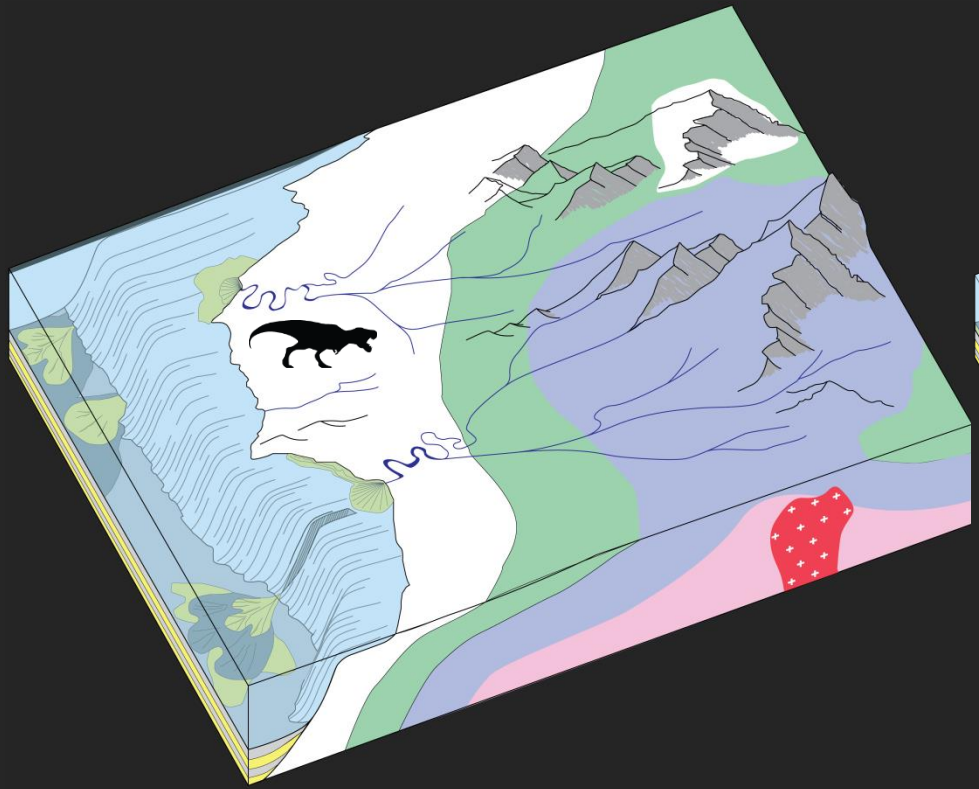
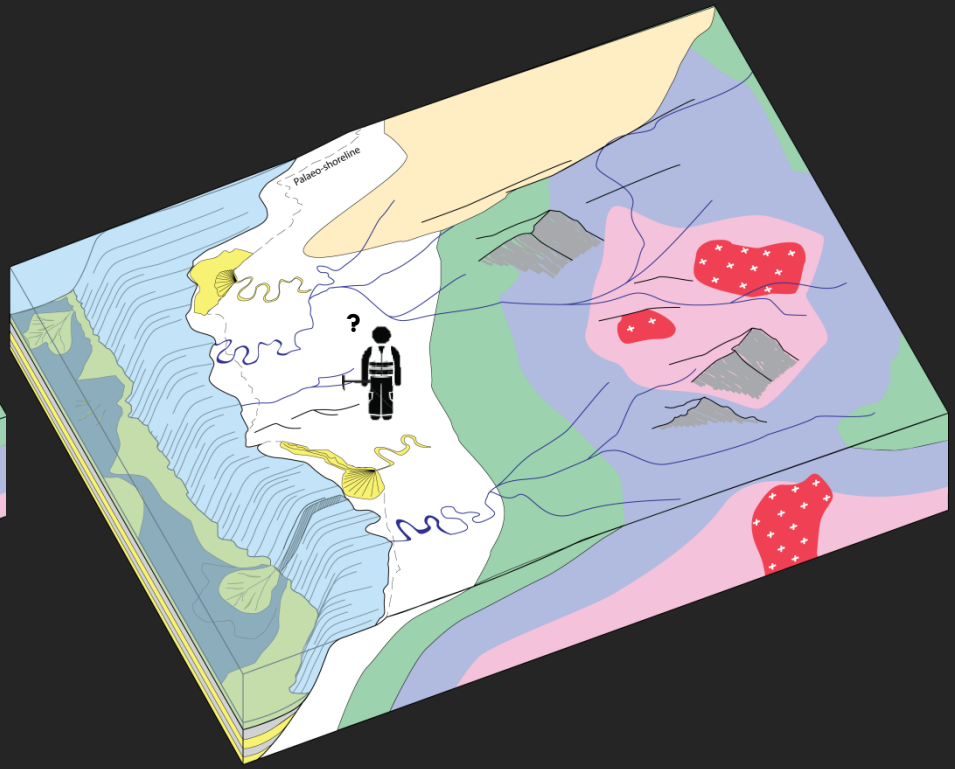
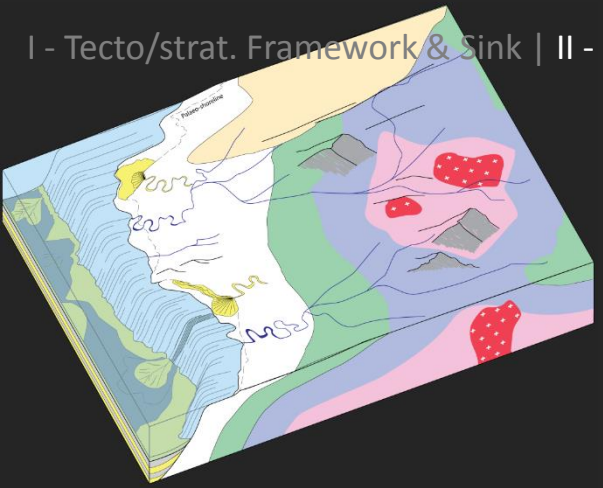
Geology then ≠ Geology Now

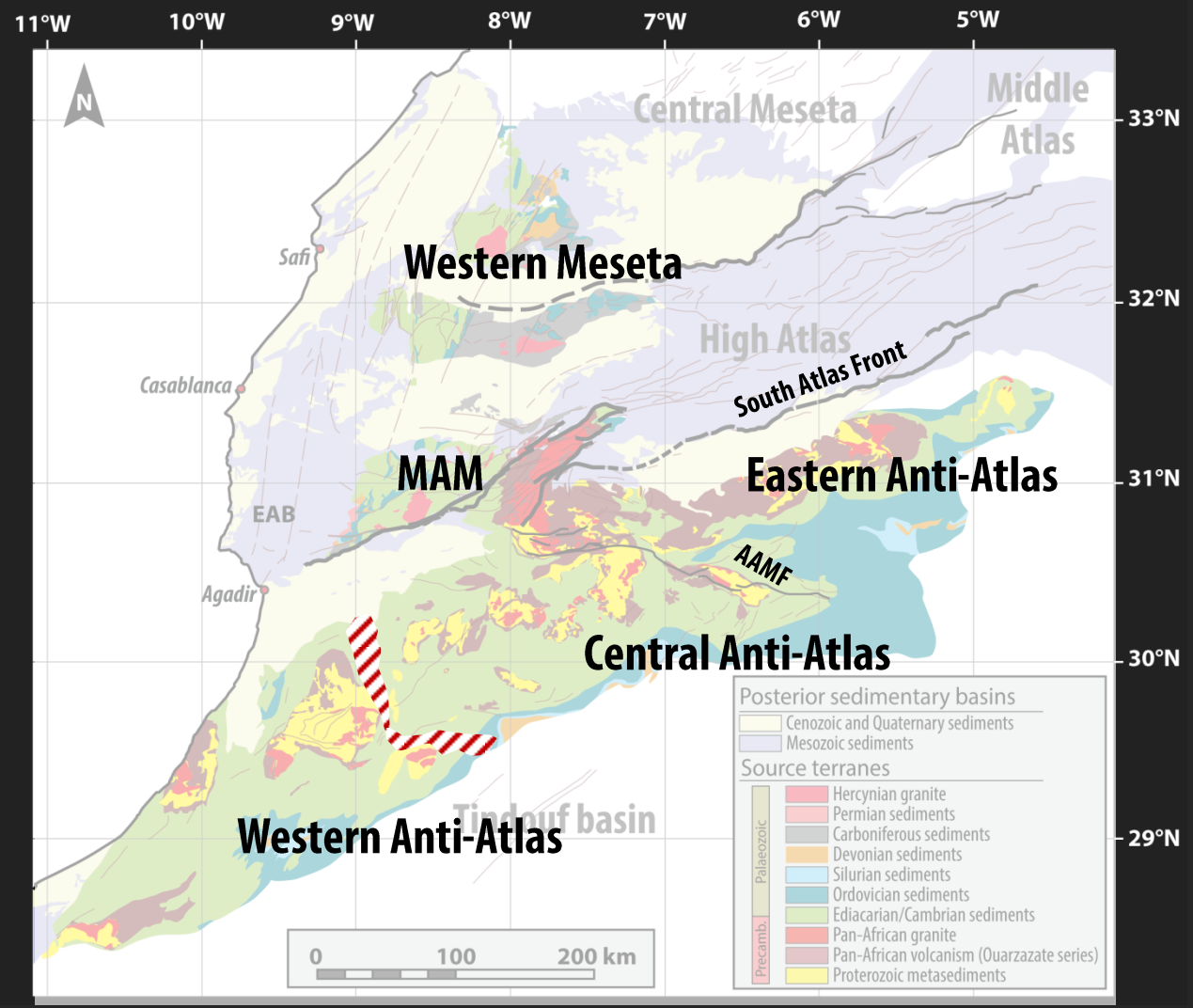






Essaouira Agadir Basin (EAB)

200 km



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8°W 7°W 6°W 5°W

33°N 32°N 31°N 30°N 29°N

Central Meseta

Middle Atlas

Western Meseta

High Atlas

South Atlas Front

Casablanca

MAM

Eastern Anti-Atlas

EAB

AAMF

Agadir

Central Anti-Atlas

Tindouf basin

Western Anti-Atlas

0 100 200 km

Posterior sedimentary basins

Cenozoic and Quaternary sediments

Mesozoic sediments

Source terranes

Palaeozoic

Precamb.

Hercynian granite

Permian sediments

Carboniferous sediments

Devonian sediments

Silurian sediments

Ordovician sediments

Ediacarian/Cambrian sediments

Pan-African granite

Pan-African volcanism (Ouarzazate series)

Proterozoic metasediments

LTT Synthesis from
Charton 2018 (PhD Thesis)

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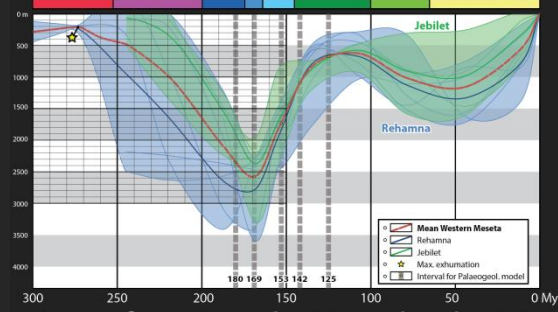
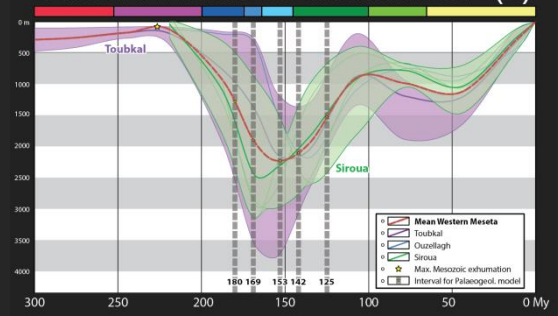
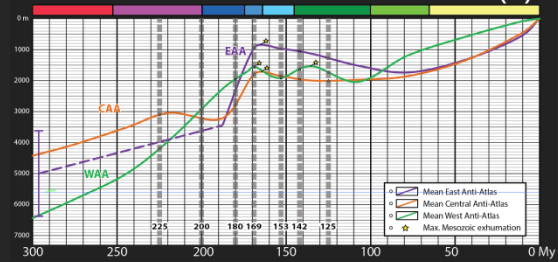
Western Meseta (b)



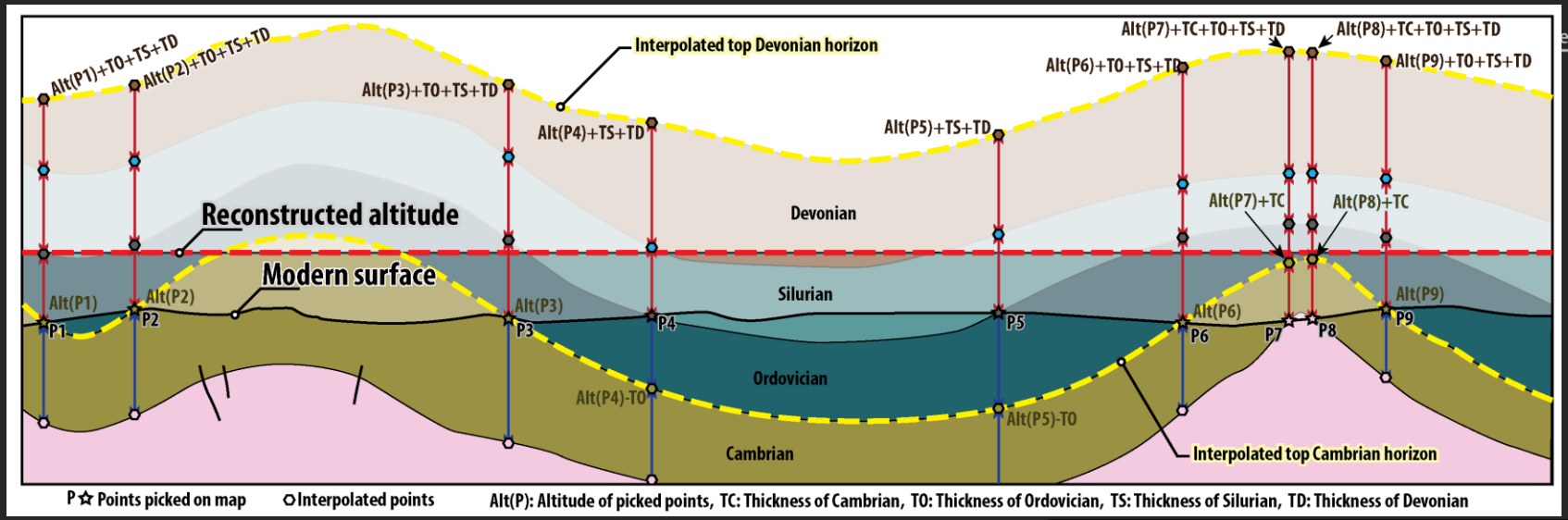
Massif Ancien de Marrakech (a)



Anti-Atlas (c)



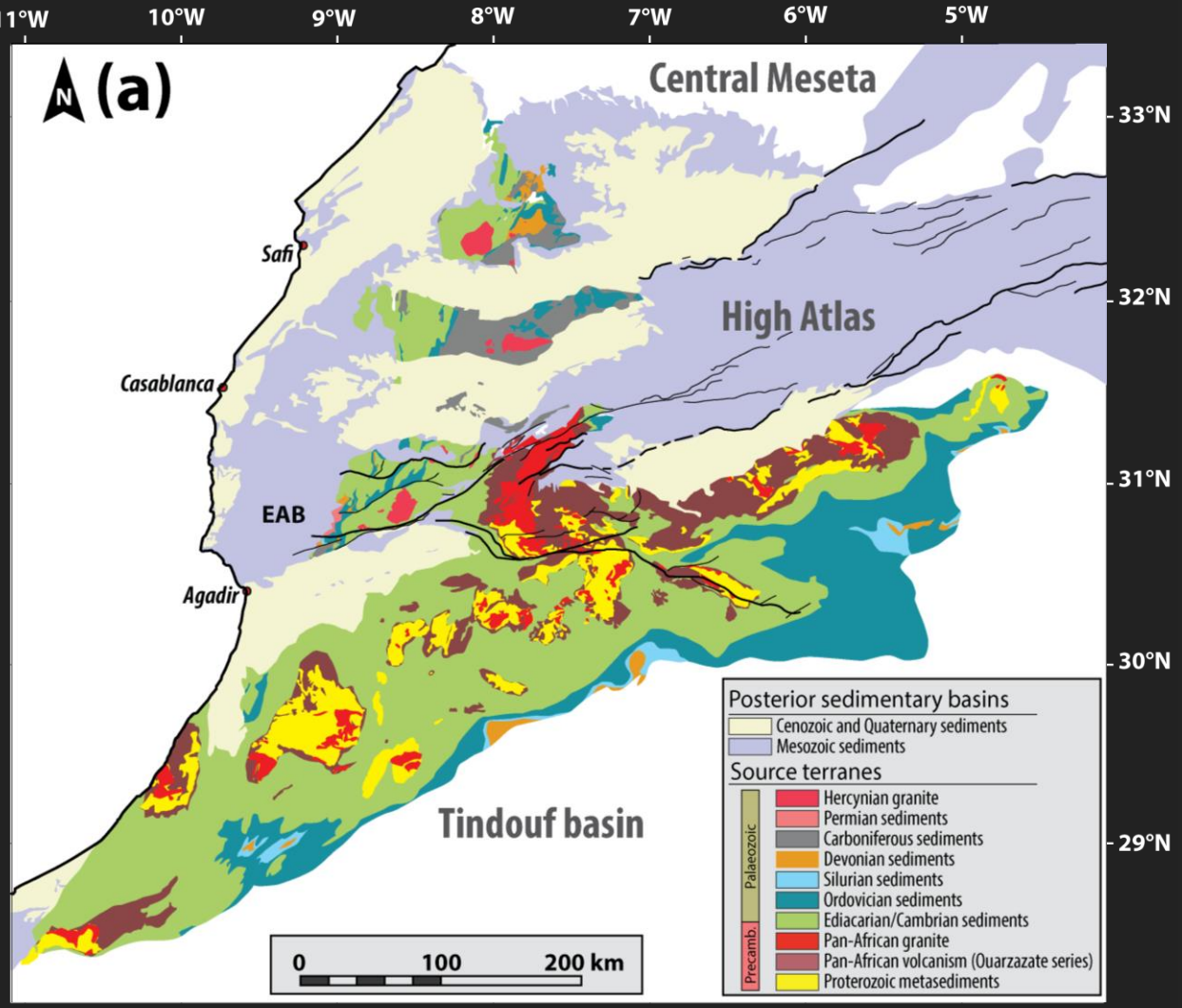
Step 1
Basement
(Pre-Hercynian terranes)
reconstruction



Basement modelling

Methods :

- Picking horizons
- Interpolation of horizons
- Intersect interpolated horizons with denudation map



Basement modelling

Methods :

- Denudation map
- Picking horizons
- Interpolation of horizons
- **Intersect interpolated horizons with denudation map**

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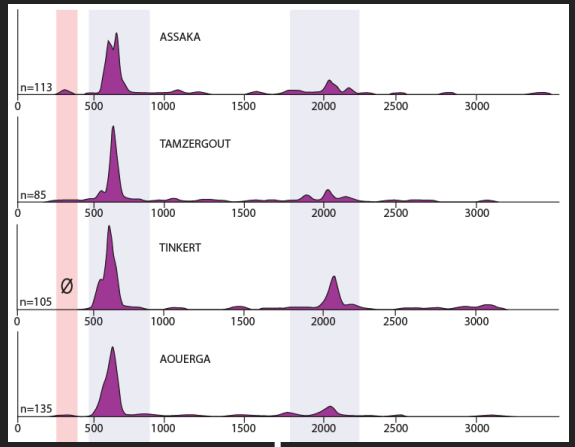
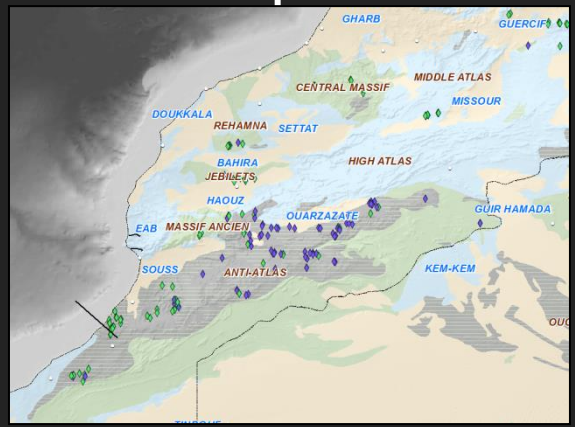
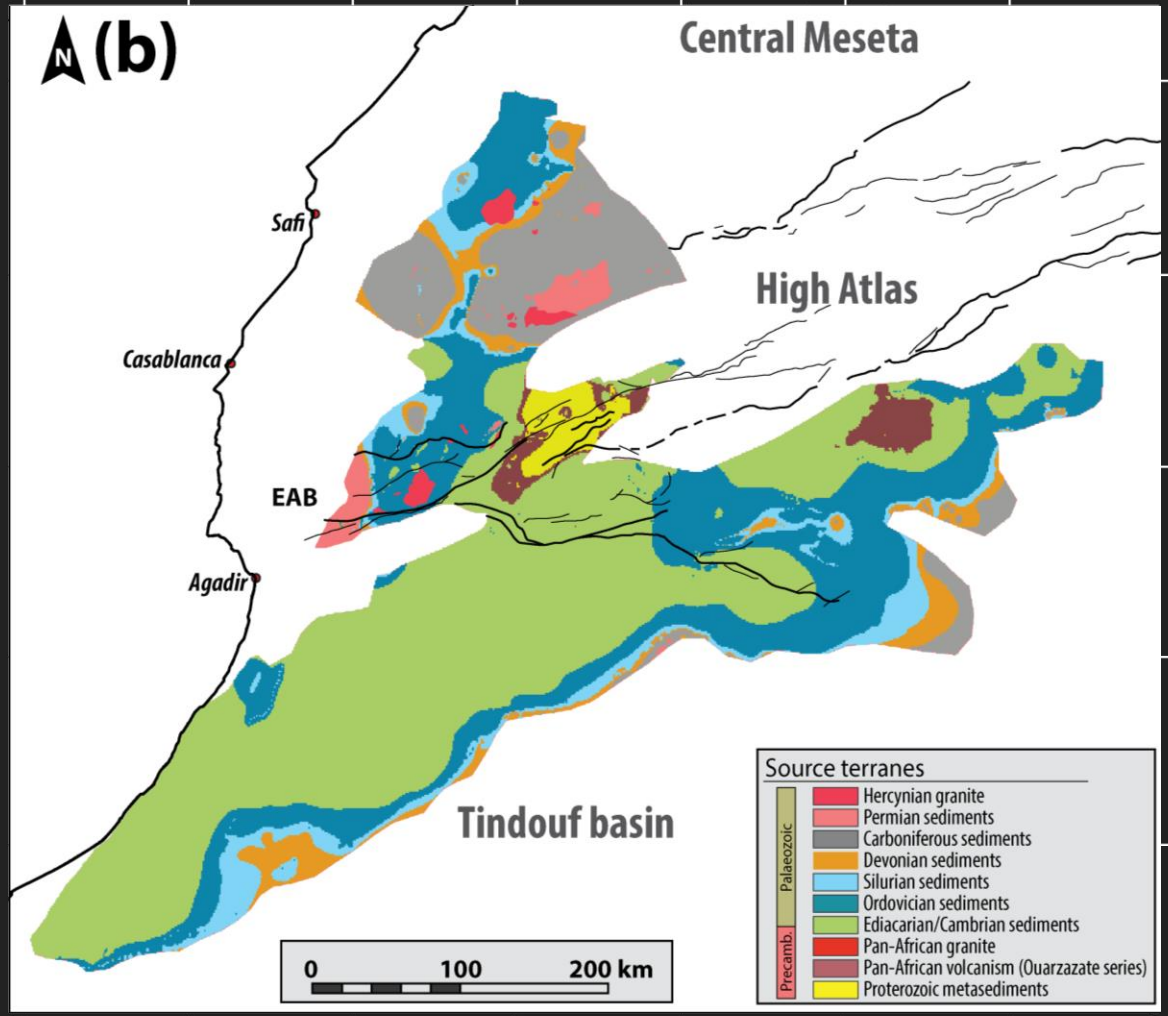
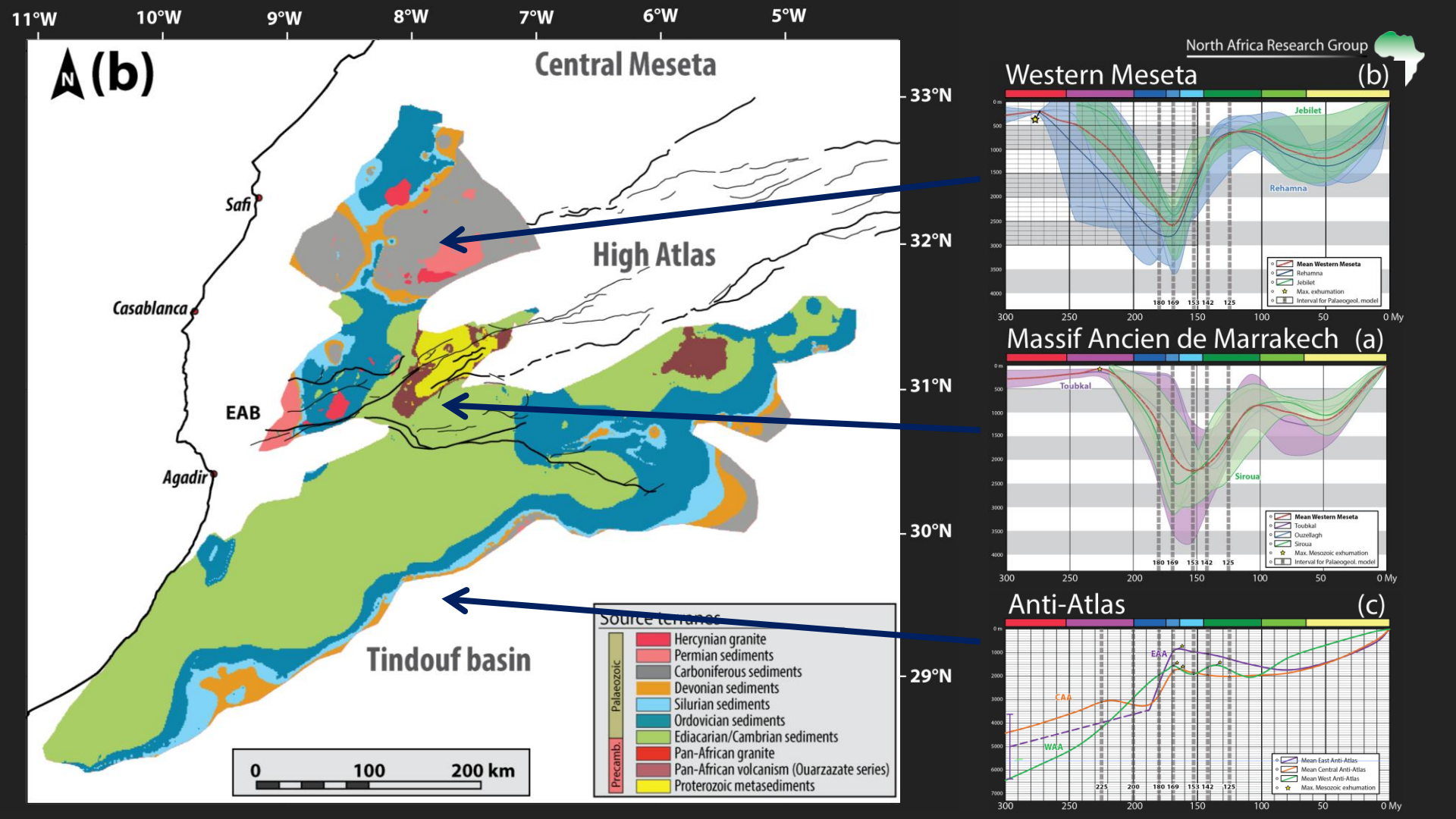
Basement modelling







Step 2
Mesozoic basins reconstruction


11°W
10°W
9°W
8°W
7°W
6°W
5°W
33°N
32°N
31°N
30°N
29°N
(b)
Central Meseta
High Atlas
Safi
Casablanca
EAB
Agadir
Tindouf basin
0
100
200 km
Source terranes
Palaeozoic
Precamb.
Hercynian granite
Permian sediments
Carboniferous sediments
Devonian sediments
Silurian sediments
Ordovician sediments
Ediacarian/Cambrian sediments
Pan-African granite
Pan-African volcanism (Ouarzazate series)
Proterozoic metasediments
North Africa Research Group
Western Meseta (b)
Jebilet
Rehamna
Mean Western Meseta
Rehamna
Jebilet
Max. exhumation
Interval for Palaeogeol. model
180 169 153 142 125
300 250 200 150 100 50 0 My
Massif Ancien de Marrakech (a)
Toubkal
Siroua
Mean Western Meseta
Toubkal
Ouzellagh
Siroua
Max. Mesozoic exhumation
Interval for Palaeogeol. model
180 169 153 142 125
300 250 200 150 100 50 0 My
Anti-Atlas (c)
EAA
CAA
WAA
Mean East Anti-Atlas
Mean Central Anti-Atlas
Mean West Anti-Atlas
Max. Mesozoic exhumation
225 200 180 169 153 142 125
300 250 200 150 100 50 0 My

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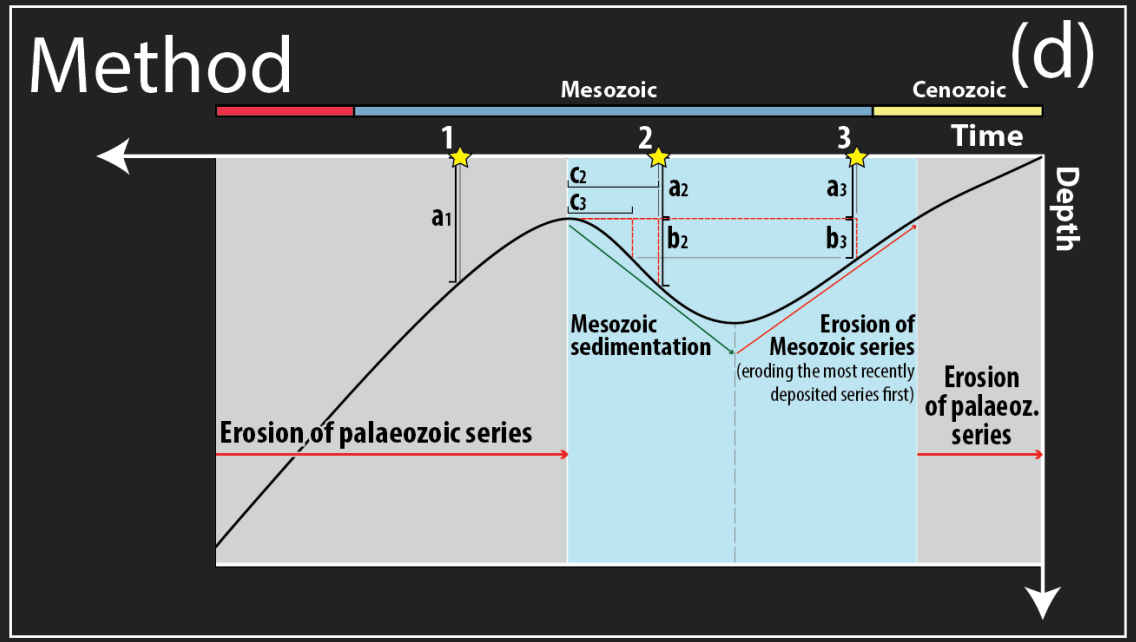

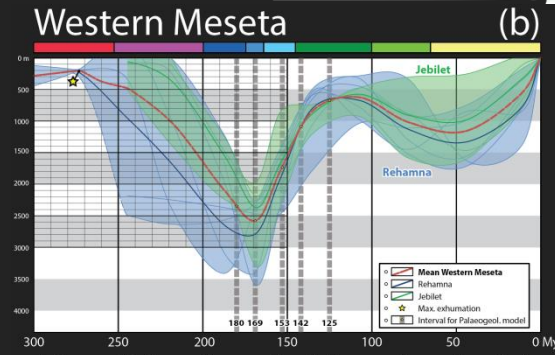

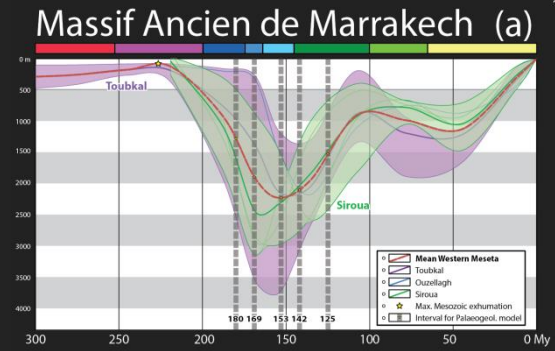

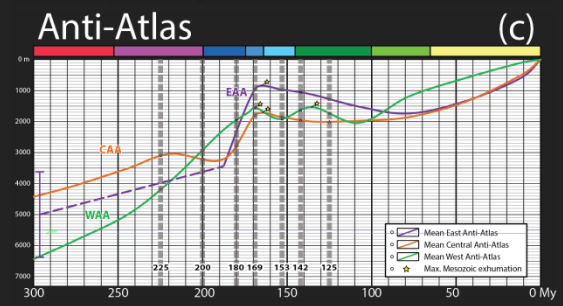

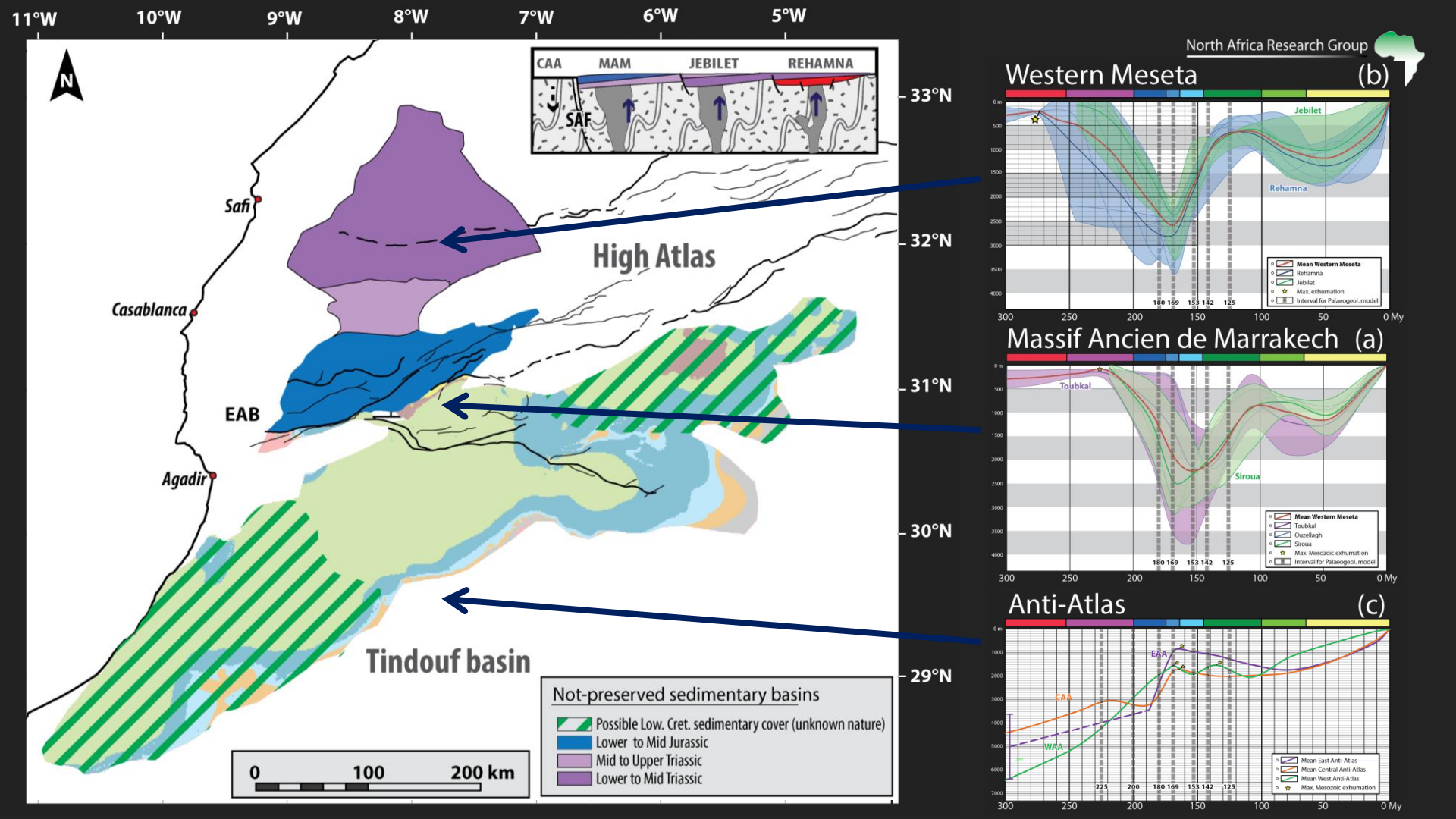
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High Atlas
EAB
Tindouf basin
0
100
200 km
Not-preserved sedimentary basins
Possible Low. Cret. sedimentary cover (unknown nature)
Lower to Mid Jurassic
Mid to Upper Triassic
Lower to Mid Triassic
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Western Meseta (b)
Jebilet
Rehamna
Mean Western Meseta
Rehamna
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Max. exhumation
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180 169 153 142 125
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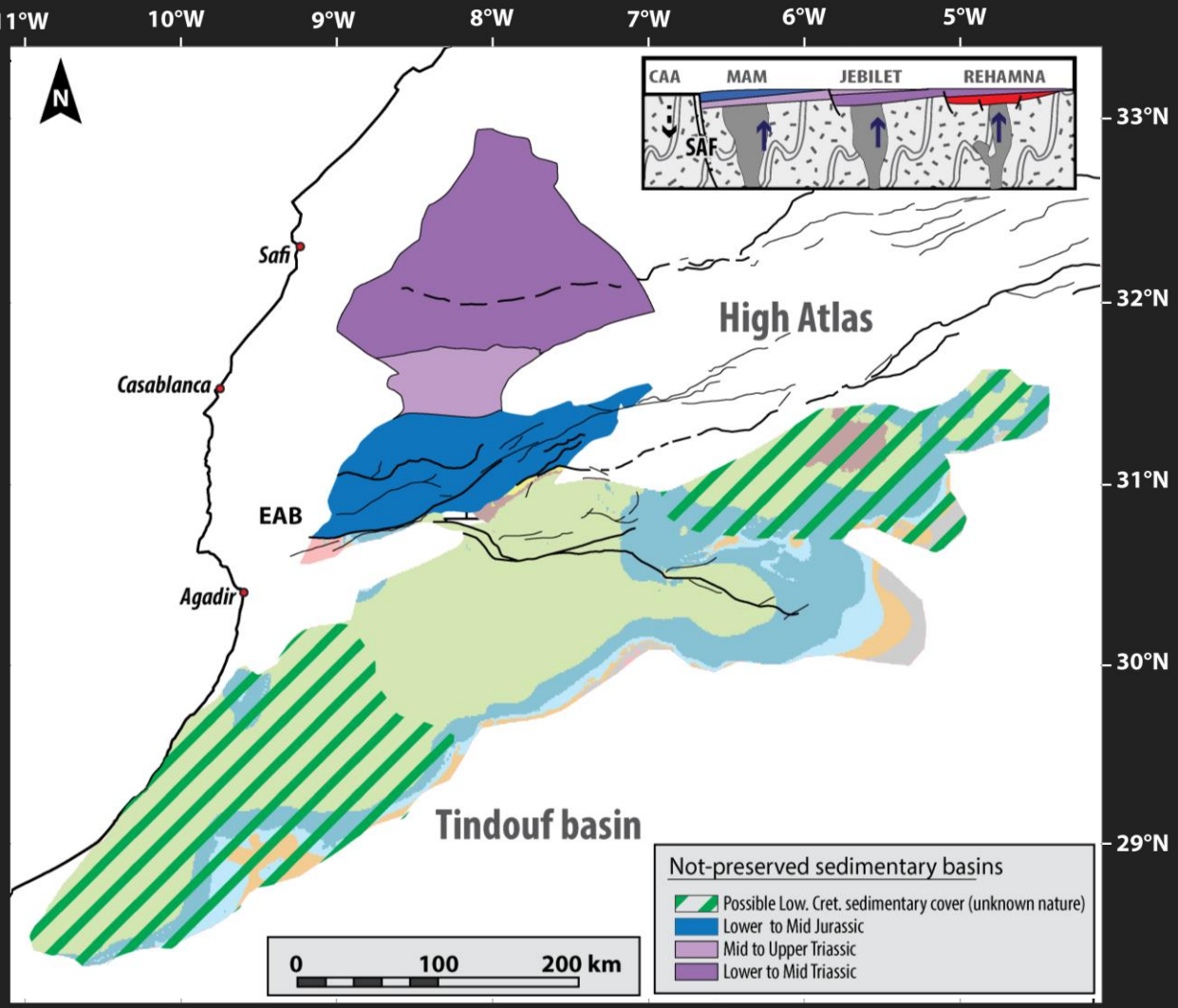
Anti-Atlas (c)
EAA
CAA
WAA
Mean East Anti-Atlas
Mean Central Anti-Atlas
Mean West Anti-Atlas
Max. Mesozoic exhumation
225 200 180 169 153 142 125
300 250 200 150 100 50 0 My

Step 3
Lithology attribution
and
reservoir potentials


11°W
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5°W
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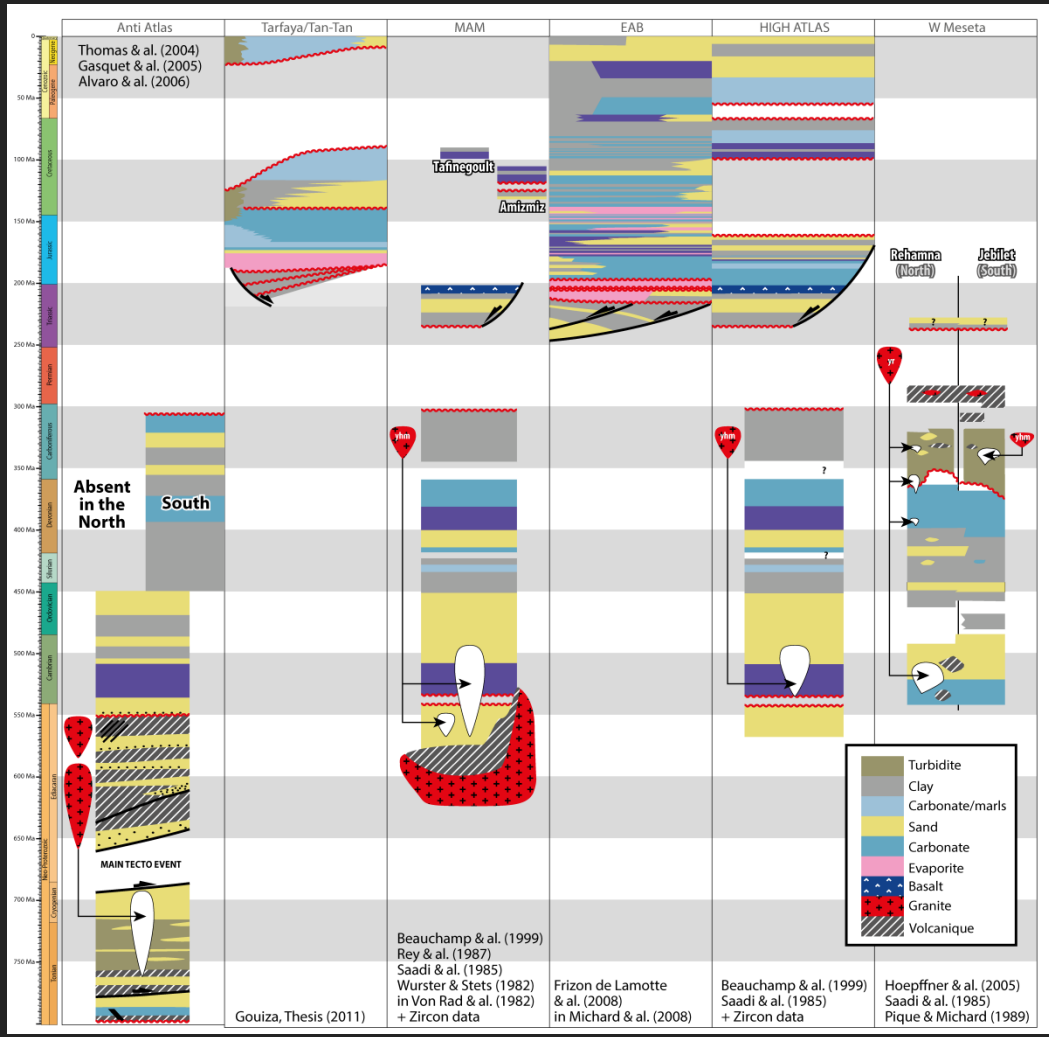
Not-preserved sedimentary basins
Possible Low. Cret. sedimentary cover (unknown nature)
Lower to Mid Jurassic
Mid to Upper Triassic
Lower to Mid Triassic



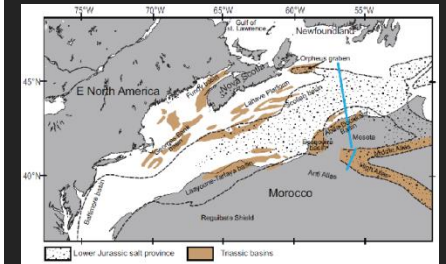


Figure 2.1: *Map of the Central Atlantic domain, showing the correlation between the main Triassic basins just prior to continental breakup (Labails, 2007; Le Roy, 1997; Sahabi et al., 2004). The blue line across NW Morocco indicates the trace of the constructed Doukkala–High Atlas transect (2.3).*

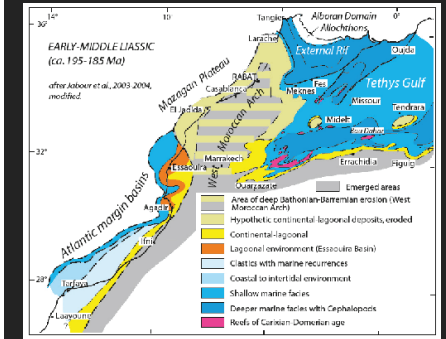
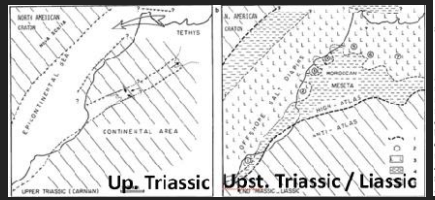
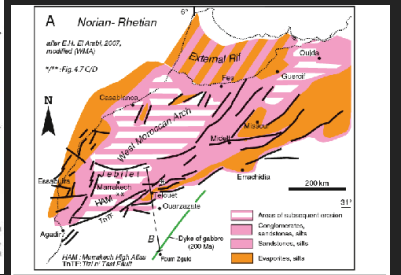


Fig. 4.4 *Paleogeographic map for the Liassic epoch, after Jabour et al. (2003–2004), modified. The most important modification concern the West Moroccan Arch, which is no longer regarded as a Liassic emergent land, but as a shallow platform eroded during the late Middle Jurassic–Early Cretaceous interval (Ghorbal et al., 2007; Saddiqi et al., 2008)*





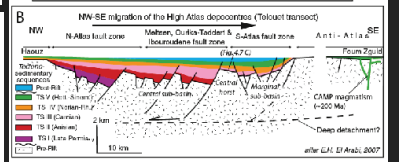


Fig. 4.7 *(continued)*

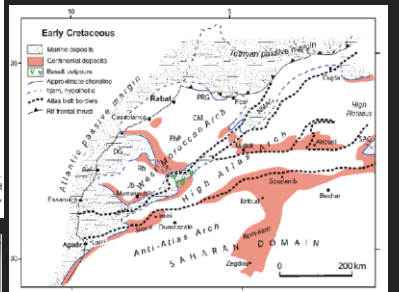
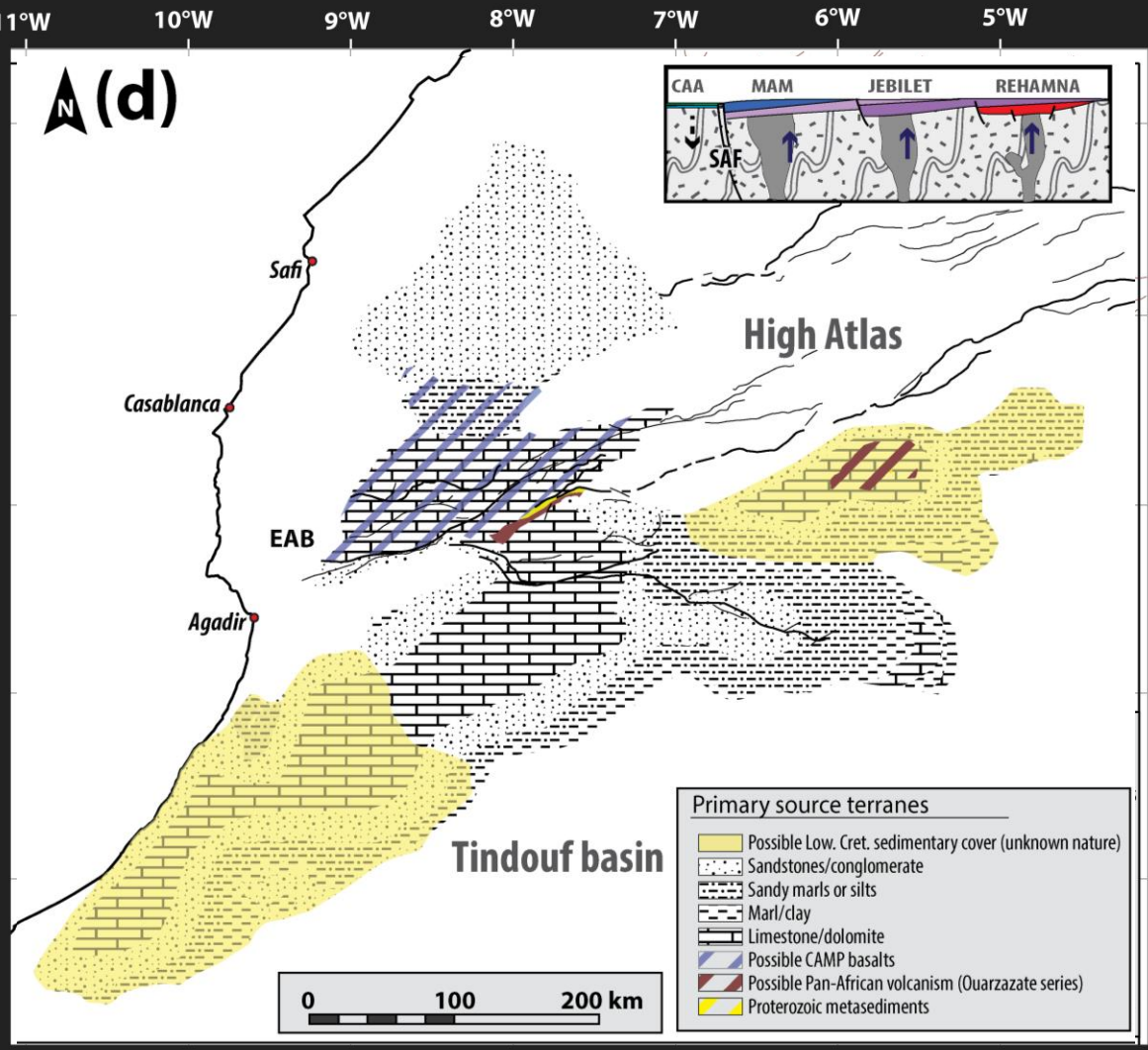


Fig. 4.17 *Generalized paleogeography of northern Morocco during the Early Cretaceous, unrestored for tectonic displacements, after Faure-Muret & Choubert (1971), modified. The Atlantic and Tethyan gulfs (western and north-eastern transgressions, respectively) are shown at their maximum extension, i.e. during the Aptian. Notice that Early Cretaceous continental formations occur beneath the marine deposits in the internal parts of the gulfs (cf. the thick Barremian red beds from Ouanzizarhi, Fig. 4.13). White areas correspond either to Early Cretaceous highlands devoid of red beds prior to the Cenomanian-Turonian transgression (e.g. Central Massifs, or to subsequently eroded areas (e.g. Central High Atlas). CM: Central Massif; DG: Doukkala Gulf; Jb: Jebilet; NHAG: North High Atlas Gulf; NMAG: North Middle Atlas Gulf (Gulf of Boulemane in Fig. 4.16); PhP: Phosphate Plateau; PRG: Preriff Ridge Gulf; Rh: Rehamna; SAG: Saharan Atlas Gulf*

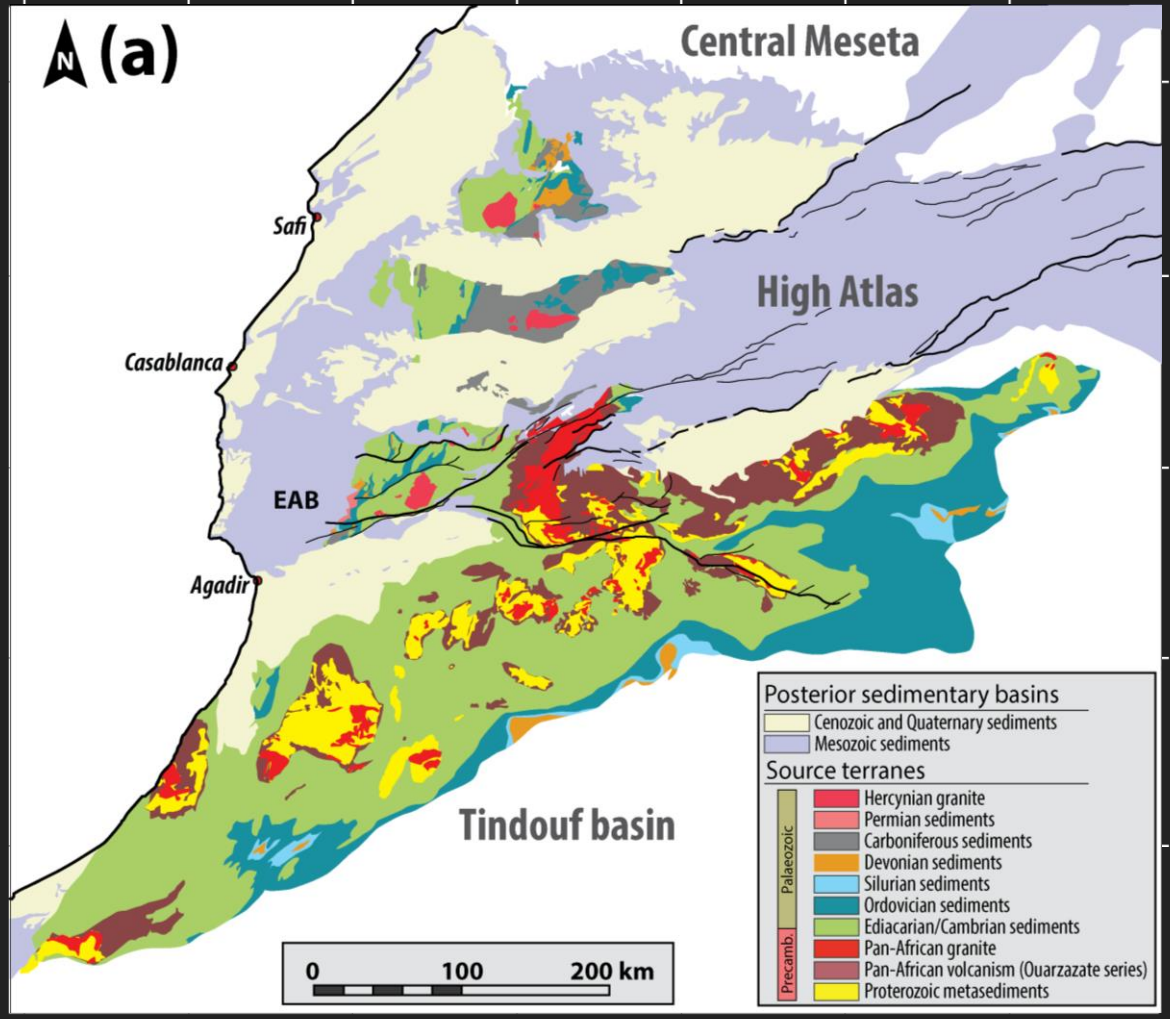


Modelling Cretaceous geology

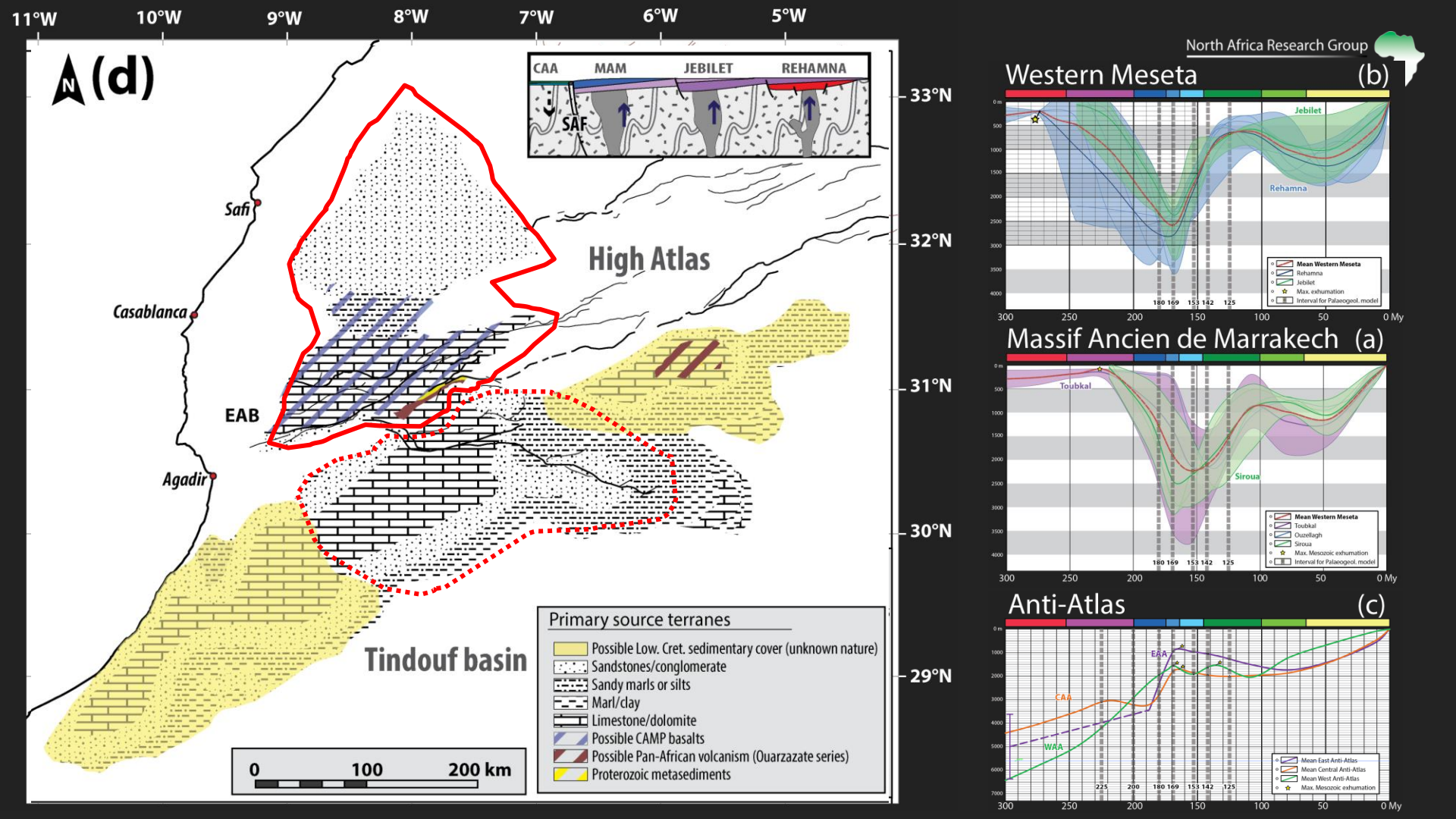
Model of cropping out lithologies at paleo altitude (at 125 My)
Layer 1: Basement
Layer 2: Mesozoic cover

↓

Based on subsidence data, GDE maps and preserved basins


(a)
N
Central Meseta
High Atlas
Tindouf basin
EAB
Safi
Casablanca
Agadir
11°W
10°W
9°W
8°W
7°W
6°W
5°W
33°N
32°N
31°N
30°N
29°N
0
100
200 km
Posterior sedimentary basins
Cenozoic and Quaternary sediments
Mesozoic sediments
Source terranes
Palaeozoic
Precamb.
Hercynian granite
Permian sediments
Carboniferous sediments
Devonian sediments
Silurian sediments
Ordovician sediments
Ediacarian/Cambrian sediments
Pan-African granite
Pan-African volcanism (Ouarzazate series)
Proterozoic metasediments

Step 4
Uplifting/subsiding domains


11°W
10°W
9°W
8°W
7°W
6°W
5°W
33°N
32°N
31°N
30°N
29°N
(d)
CAA
MAM
JEBILET
REHAMNA
SAF
Safi
Casablanca
Agadir
High Atlas
EAB
Tindouf basin
0
100
200 km
Primary source terranes
Possible Low. Cret. sedimentary cover (unknown nature)
Sandstones/conglomerate
Sandy marls or silts
Marl/clay
Limestone/dolomite
Possible CAMP basalts
Possible Pan-African volcanism (Ouarzazate series)
Proterozoic metasediments
North Africa Research Group
Western Meseta (b)
Jebilet
Rehamna
Mean Western Meseta
Rehamna
Jebilet
Max. exhumation
Interval for Palaeogeol. model
180 169 153 142 125
300 250 200 150 100 50 0 My
Massif Ancien de Marrakech (a)
Toubkal
Siroua
Mean Western Meseta
Toubkal
Ouzellagh
Siroua
Max. Mesozoic exhumation
Interval for Palaeogeol. model
180 169 153 142 125
300 250 200 150 100 50 0 My
Anti-Atlas (c)
EAA
CAA
WAA
Mean East Anti-Atlas
Mean Central Anti-Atlas
Mean West Anti-Atlas
Max. Mesozoic exhumation
225 200 180 169 153 142 125
300 250 200 150 100 50 0 My

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III • Sources to Sink

Fingerprints correlations

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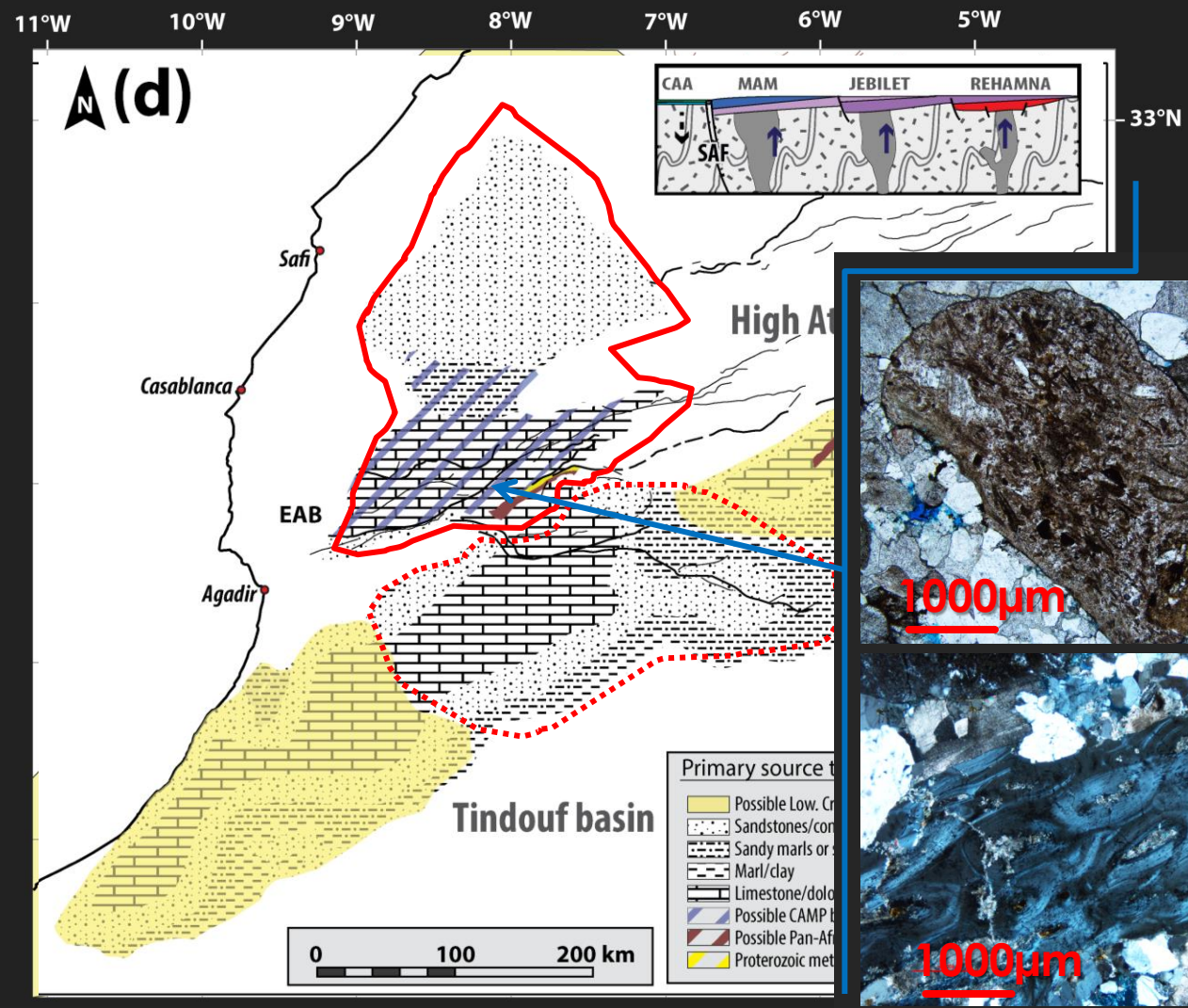
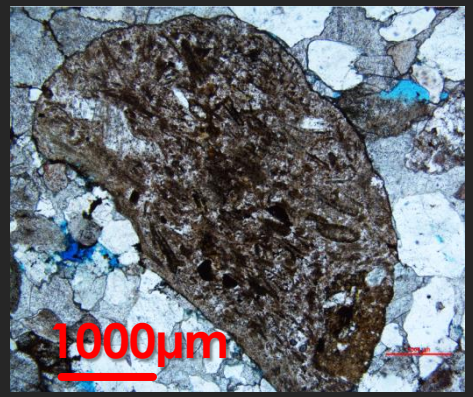
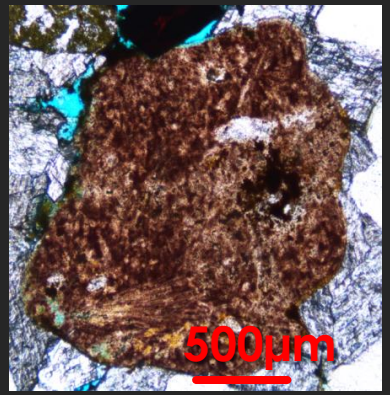


High prob. uplifting

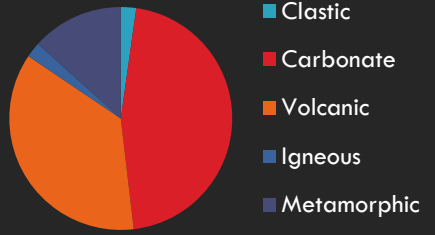
Possibly uplifting

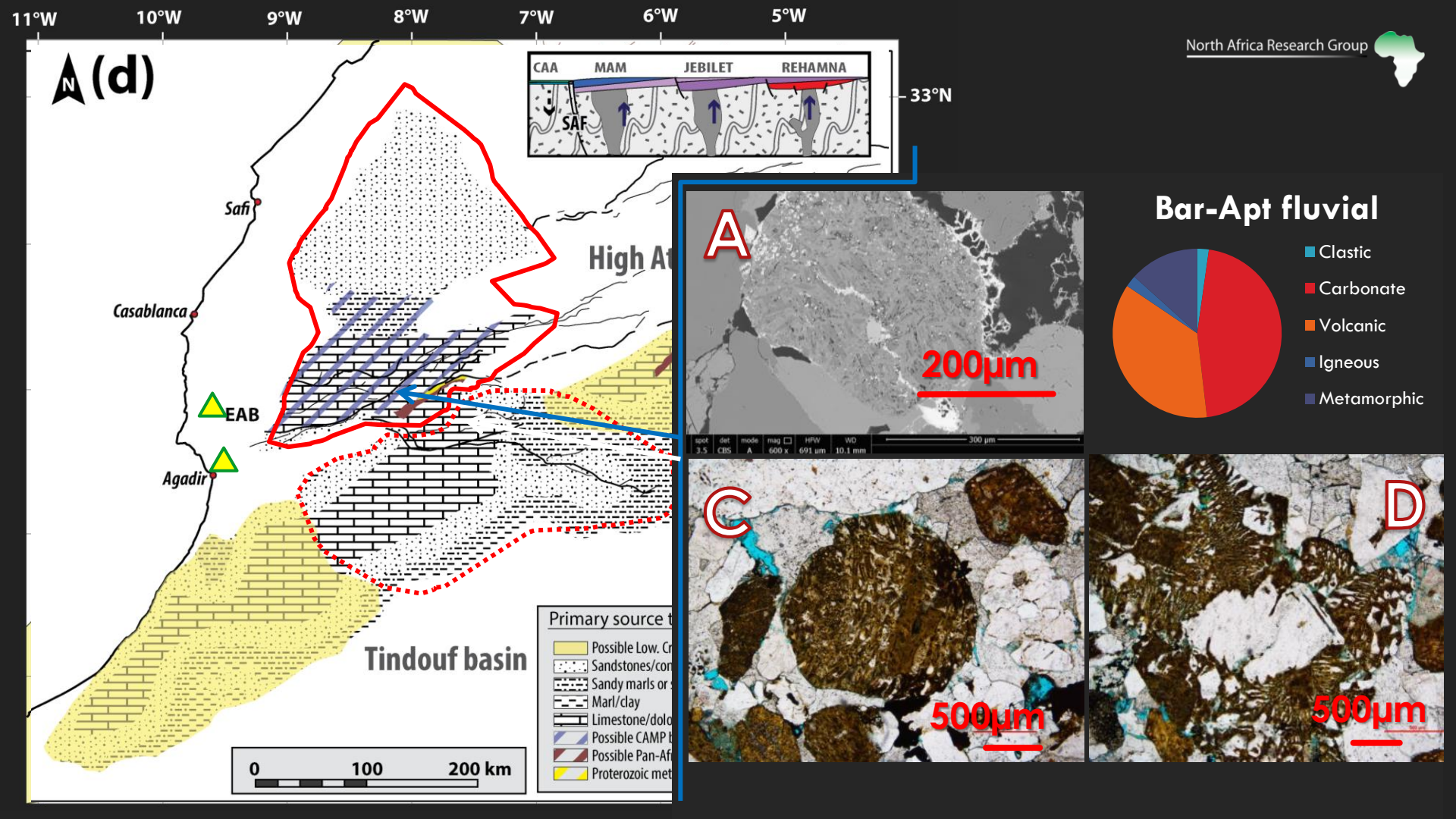




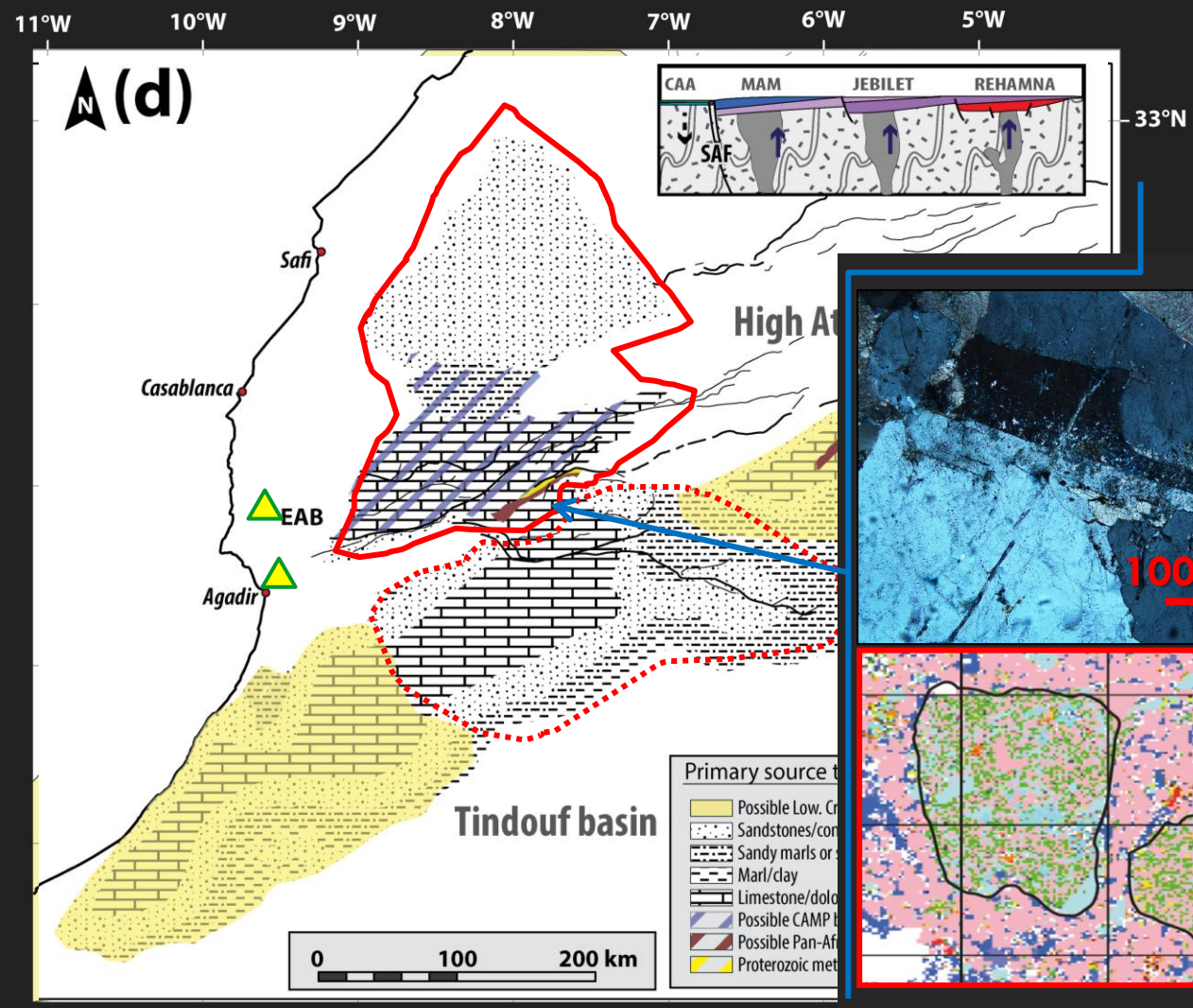
Carbonate clasts

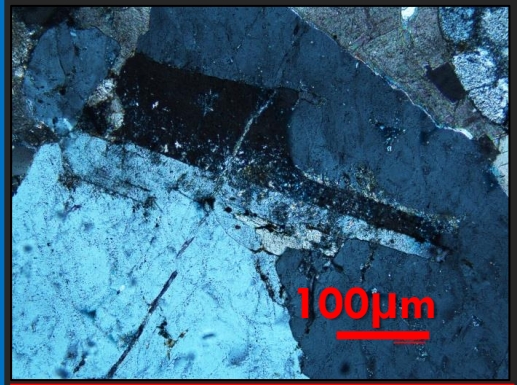
Bar-Apt fluvial

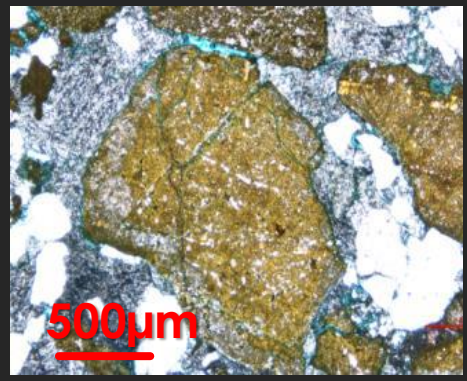


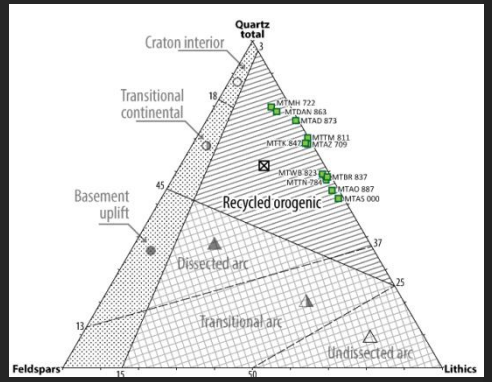

11°W
10°W
9°W
8°W
7°W
6°W
5°W
33°N
(d)
CAA
MAM
JEBILET
REHAMNA
SAF
Safi
Casablanca
EAB
Agadir
High At
Tindouf basin
Primary source t
Possible Low. Cr
Sandstones/con
Sandy marls or
Marl/clay
Limestone/dolo
Possible CAMP
Possible Pan-Af
Proterozoic met
0
100
200 km
North Africa Research Group
A
200µm
Bar-Apt fluvial
Clastic
Carbonate
Volcanic
Igneous
Metamorphic
C
500µm
D
500µm

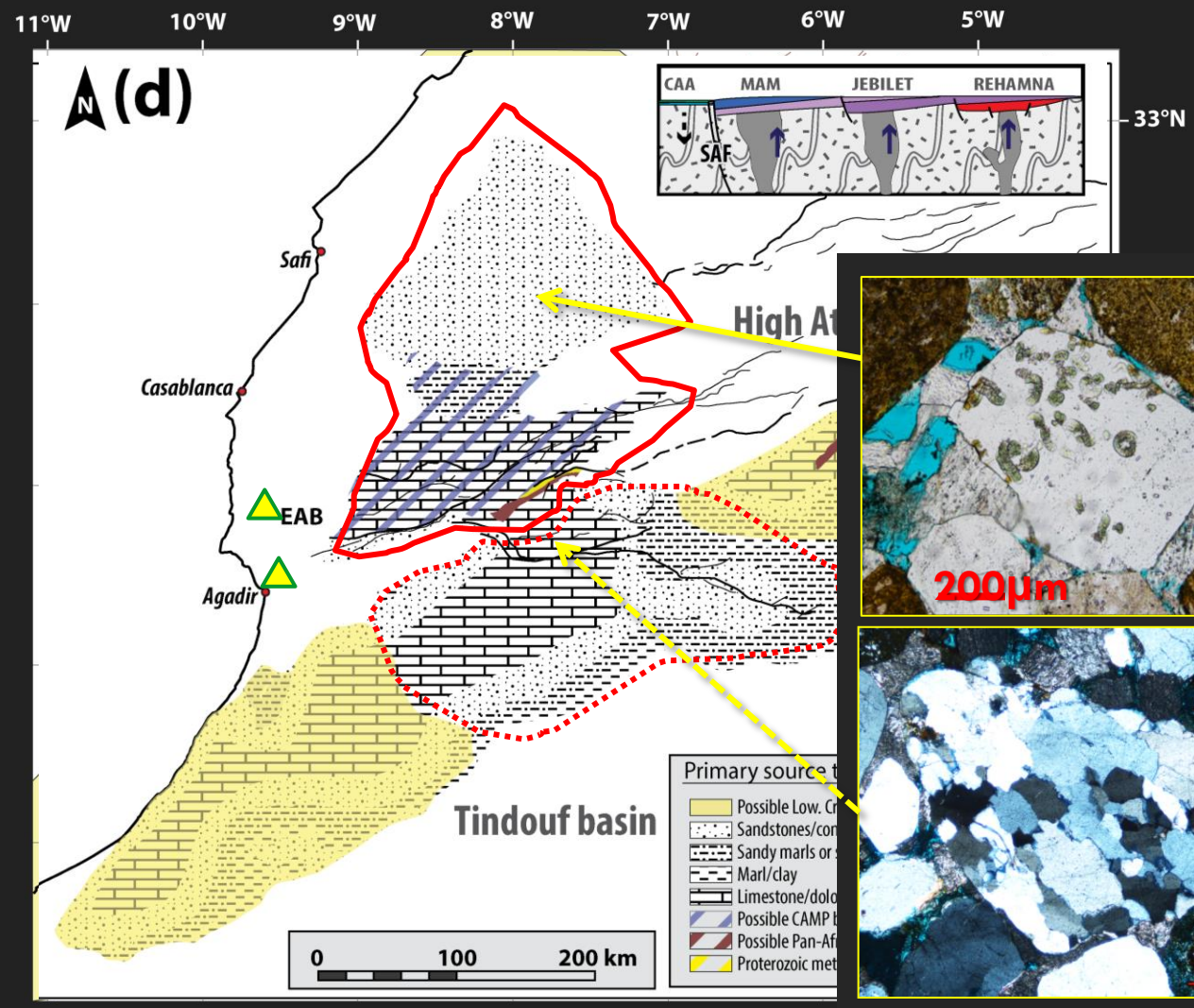
Feldspars (1st degree indicators) very rares

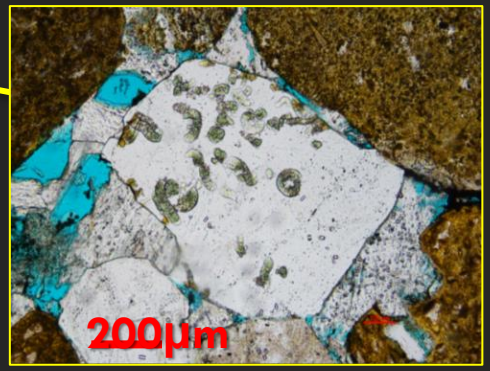


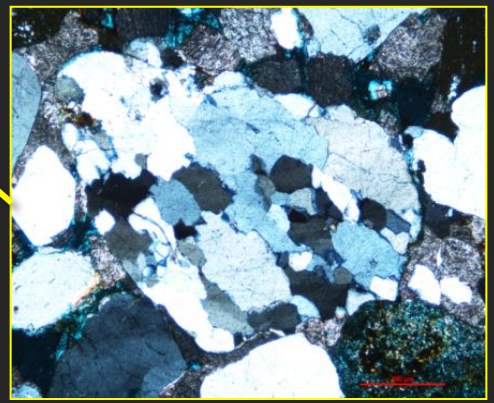


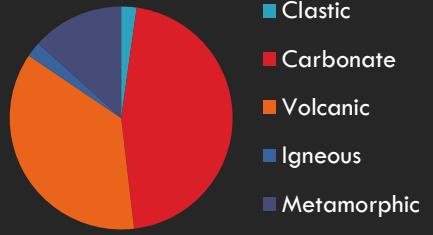




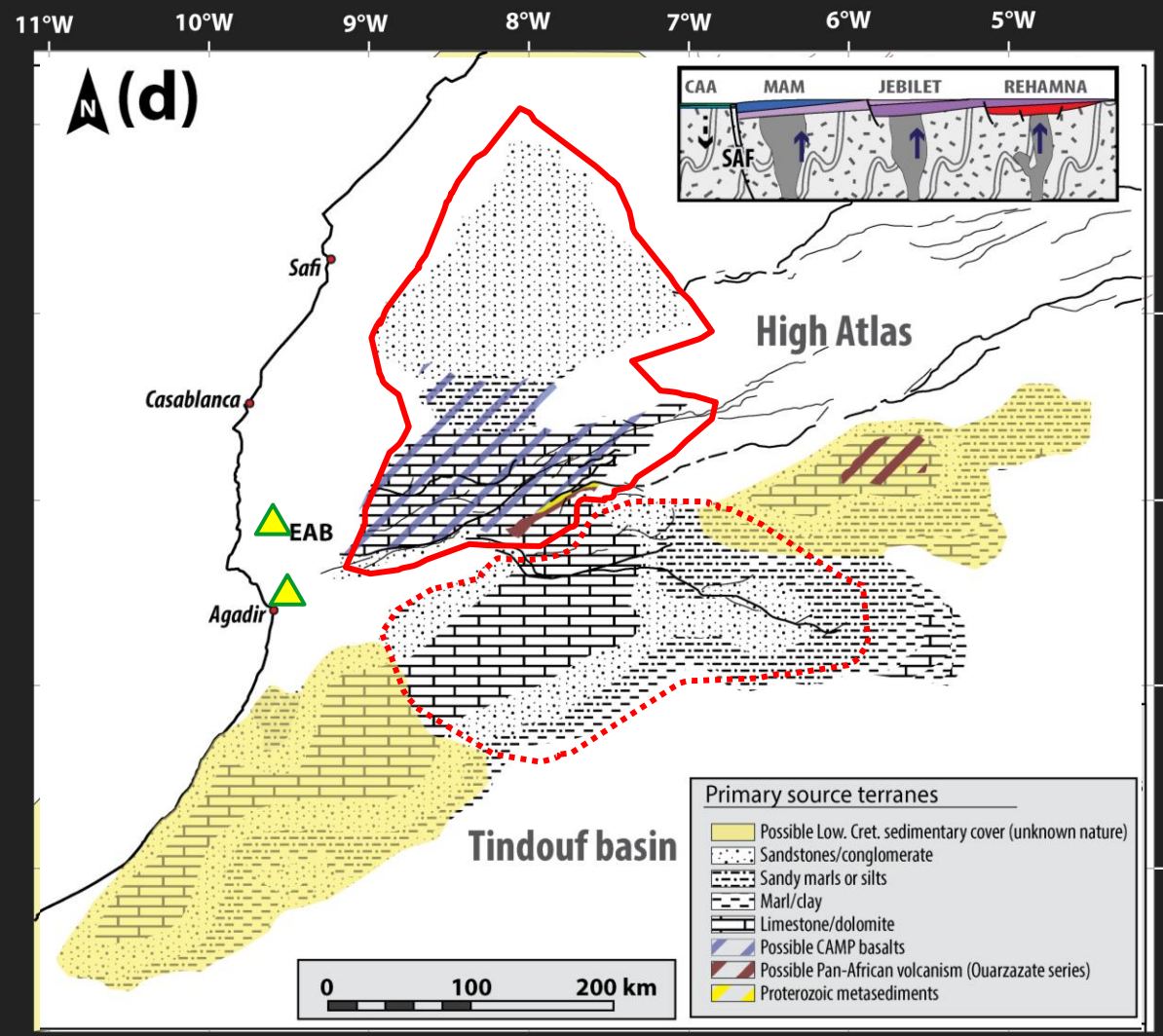








Vermicular chlorite (hydrothermal metamorphism)
Granitic clasts (MAM or recycled)


11°W
10°W
9°W
8°W
7°W
6°W
5°W
(d)
N
CAA
MAM
JEBILET
REHAMNA
SAF
Safi
Casablanca
EAB
Agadir
High Atlas
Tindouf basin
30°N
29°N
0
100
200 km
Primary source terranes
Possible Low. Cret. sedimentary cover (unknown nature)
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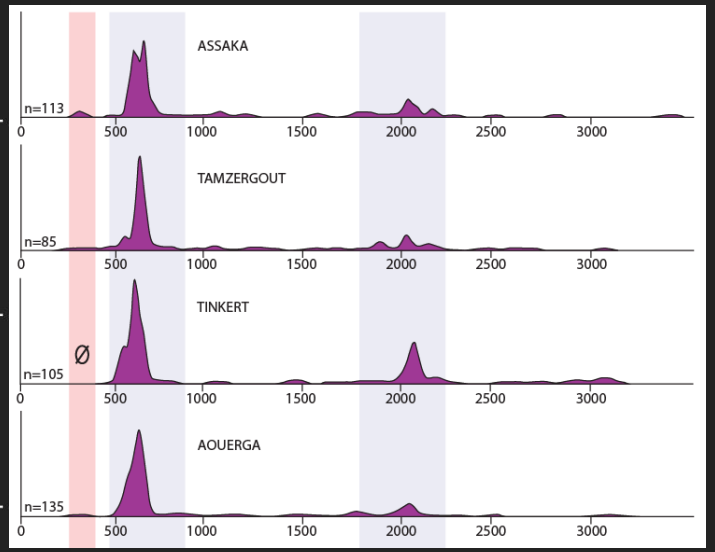
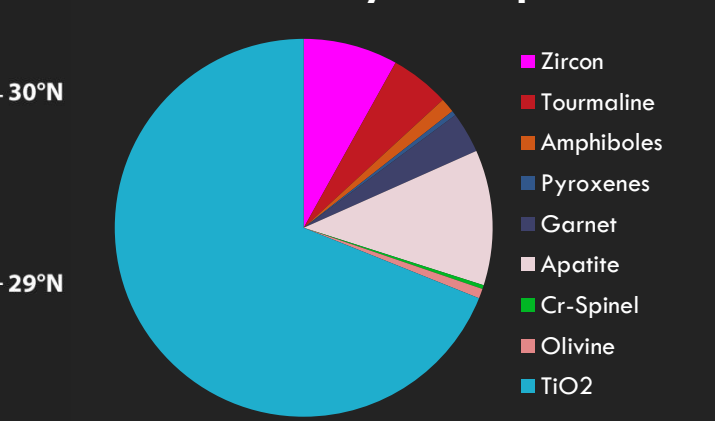
Sandy marls or silts
Marl/clay
Limestone/dolomite
Possible CAMP basalts
Possible Pan-African volcanism (Ouarzazate series)
Proterozoic metasediments


ASSAKA
n=113
TAMZERGOUT
n=85
TINKERT
n=105
Ø
AOUERGA
n=135
0
500
1000
1500
2000
2500
3000


125 My Bar-Apt
Zircon
Tourmaline
Amphiboles
Pyroxenes
Garnet
Apatite
Cr-Spinel
Olivine
TiO2

Summary

- Sources of sediments likely from **MAM and Western Meseta** during the Bar-Apt. regression,
- Palaeogeological maps correlate with the **sediment grade** delivered to the fluvial system
- Very high degree of **recycling** throughout the Mesozoic observable in TS, HM and detrital zircons

Future work

- Integrate error margins to model to have ranges of possibility
- Assess reservoir potentials for time intervals throughout Mesozoic
- Publications planned:
  - Model
  - Source to sink correlations
  - NARG Provenance paper

When doing provenance remember :

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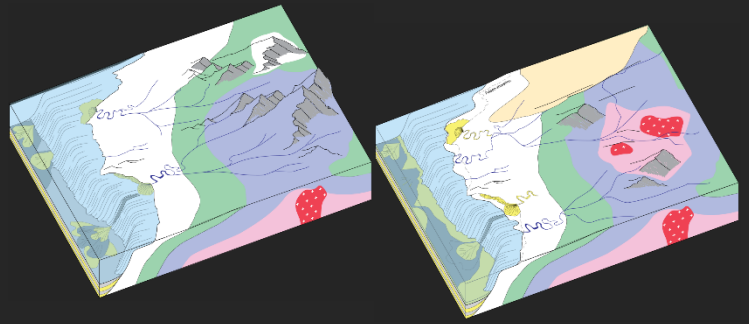
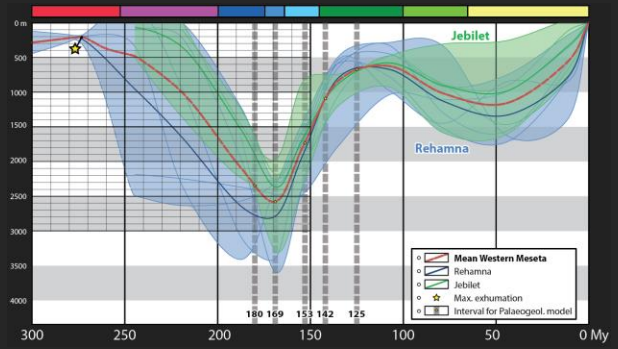
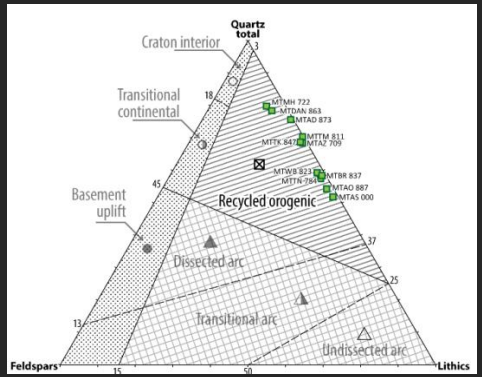
1) GEOLOGICAL MAPS CHANGE





2) USE ALL AVAILABLE LTT

3) RECYCLING IS ALWAYS HAPPENING



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