The Northern Namibian Margin: Crustal Structure and Post-Breakup Evolution*

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Abstract

The passive margins display several patterns resulting from a complex coupling between local effects and global processes. Several studies have been done on continental or on oceanic domains and at the surface. However, few of them integrate the two domains with a crustal and a mantle scale. We propose such an approach for the northern Namibian margin.

The Namibian margin belongs to the southern African margins that limit the high African plateau. Its eastern side displays a high topography with an average elevation around 1200 m. A coastal scarp that reaches locally 2200 m borders this high plateau from the coastal plain and offshore domain. This scarp is discontinuous and disappears when the Damara Belt crosses the coast. Thus, the transition between the high plateau and the deep part of the margin displays various patterns poorly constrained. We analyse this transition through a crustal cross-section based on data synthesis and field trips.

The reconstruction of the onshore evolution indicates a denudation of 5 km since 130 Ma, including 3 km during the Cenozoic. It allows us to propose a landscape at the end of the breakup. The land erosion is compared to the sedimentary record: it displays a maximum of sediment transfer during the upper Createaceous with two main depositional centers. One is located on the upper part of the margin where it exists with landward-tilted blocks, and the second one is above the transition between ocean and continent seaward-tilted blocks. These two depositional centers accommodated differential subsidence between upper and lower domains of the margin that are controlled by deep structures of the margin. The correlation between geomorphic markers located onshore and offshore suggests that the margin underwent a large-scale flexure after rifting. The origin of this flexure is debated, however it strongly constrained sediment transport.

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THE NORTHERN NAMIBIAN MARGIN : CRUSTAL STRUCTURE AND POST BREAKUP EVOLUTION

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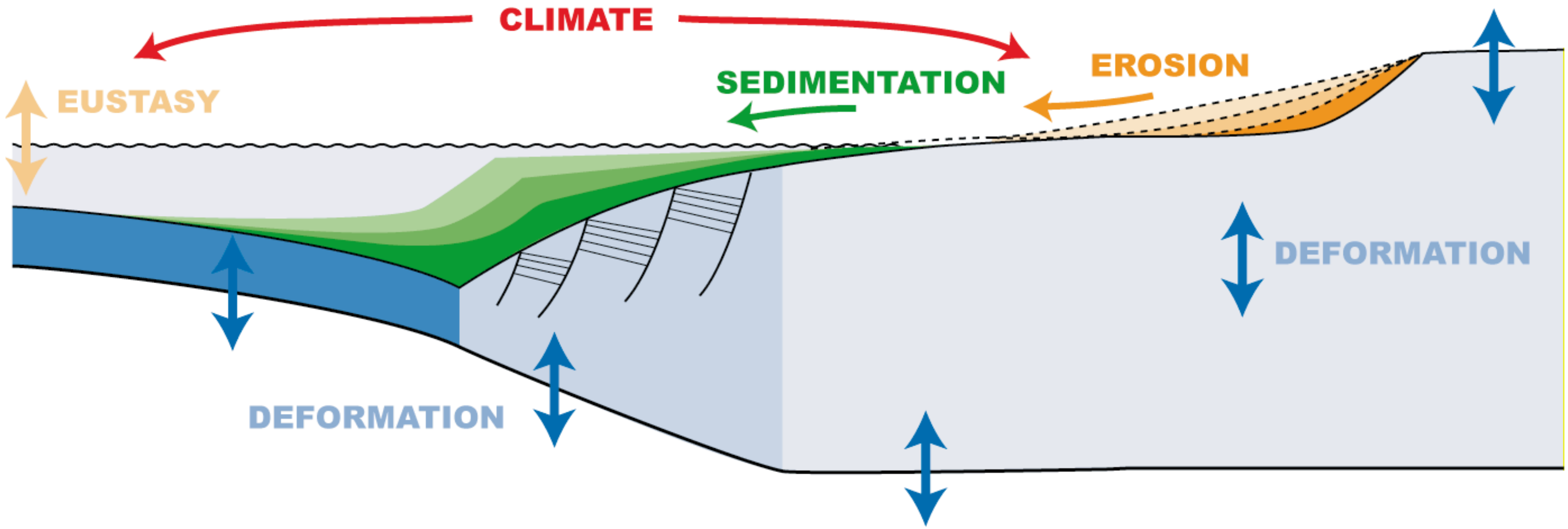
WHY STUDY PASSIVE MARGIN?



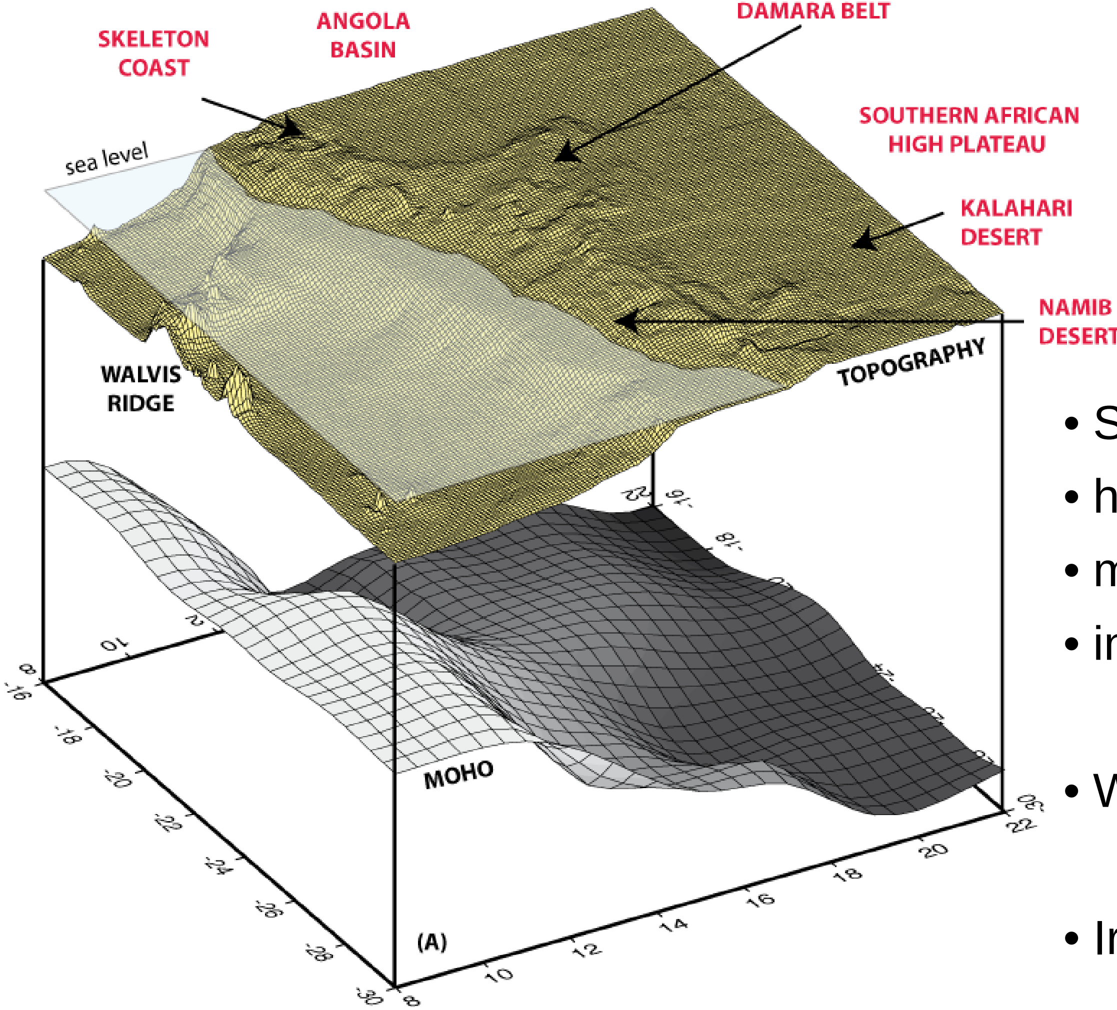
Transition between continent and ocean
Material transfer from eroded/weathered domain to depositional domain

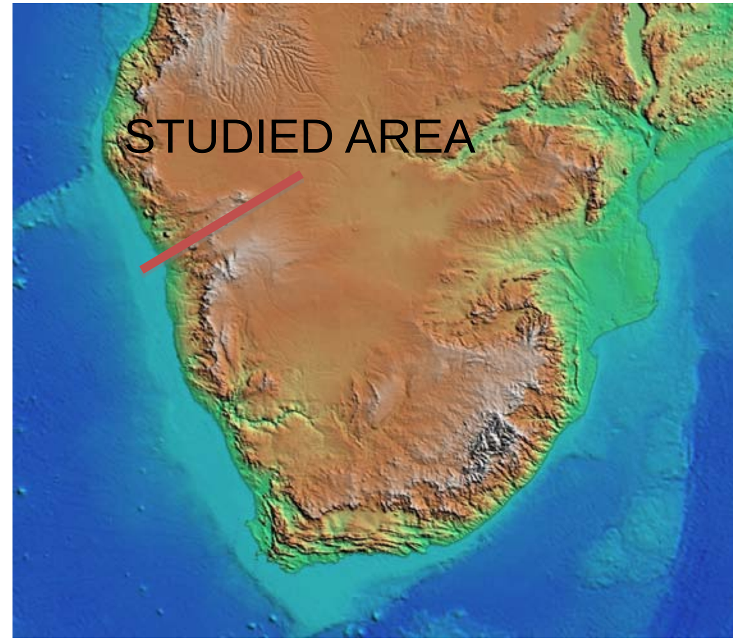
Mass transfer controlled by mantle dynamics, lithospheric deformation, regional climate and eustasy

Couplings between internal and external processes that involve geosphere, hydrosphere, atmosphere and biosphere

MORPHOLOGY OF THE MARGIN

Fish River canyon





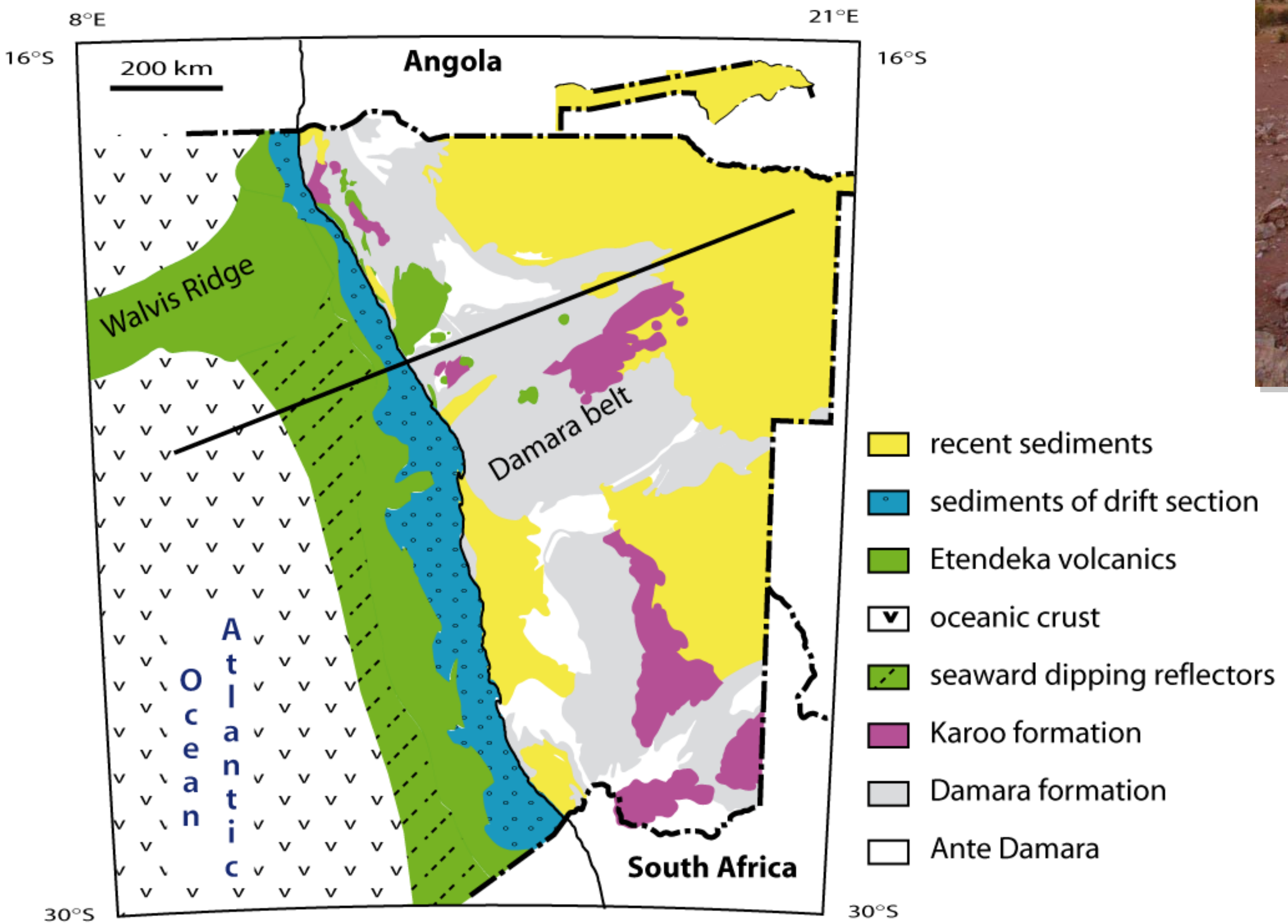
- South African plateau: 1100-1500 m
- high relief close the coast (scarps)
- more or less wide coastal plain
- influence of the Damara basement

- Walvis ridge: topographic high at sea

- Irregular Moho depth

GEOLOGICAL SETTING OF NAMIBIA

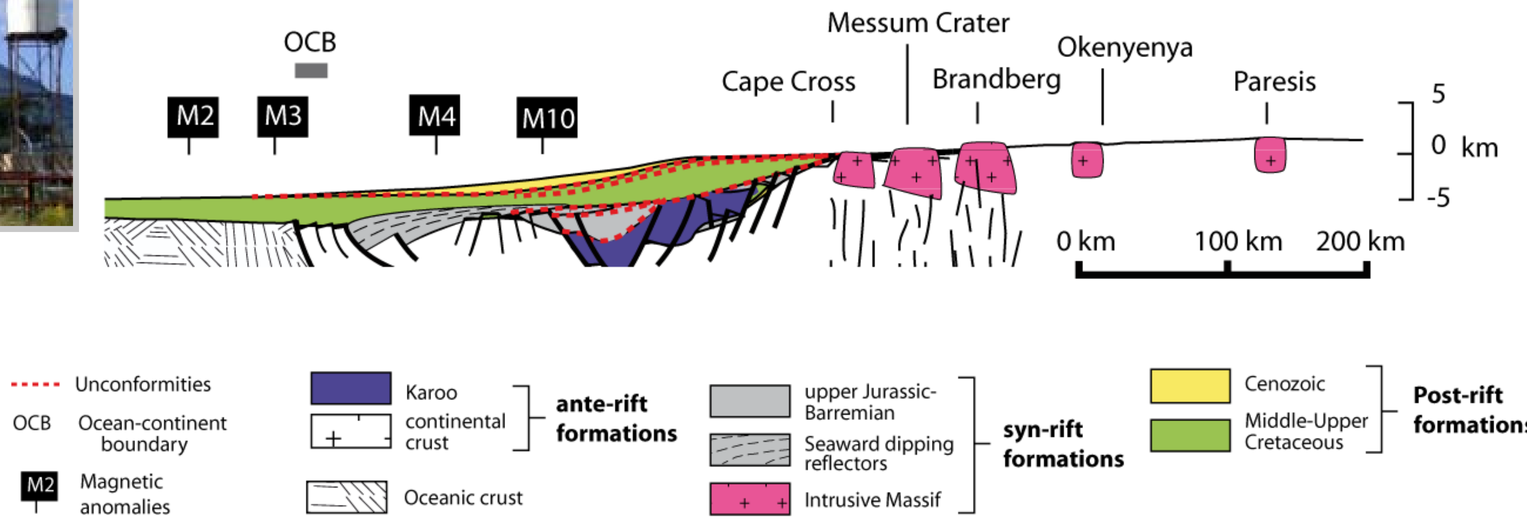
- Important erosion of the continental domain during the Meso-Cenozoic
- Wide outcrops of Damara basement
- Offshore: large sediment deposits during the Meso-Cenozoic



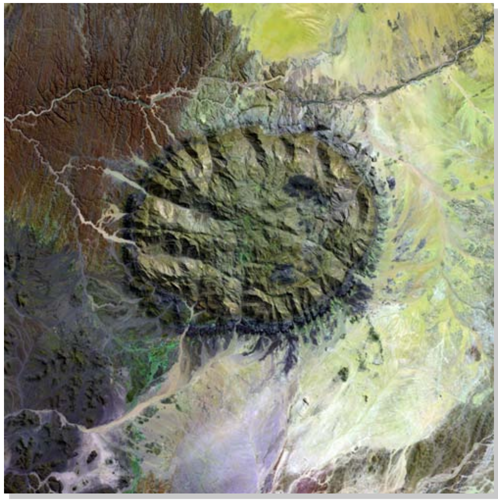
Dyke in Damara formation

MESO-CENOZOIC EVOLUTION

Etjo sandstone (Jurassic)



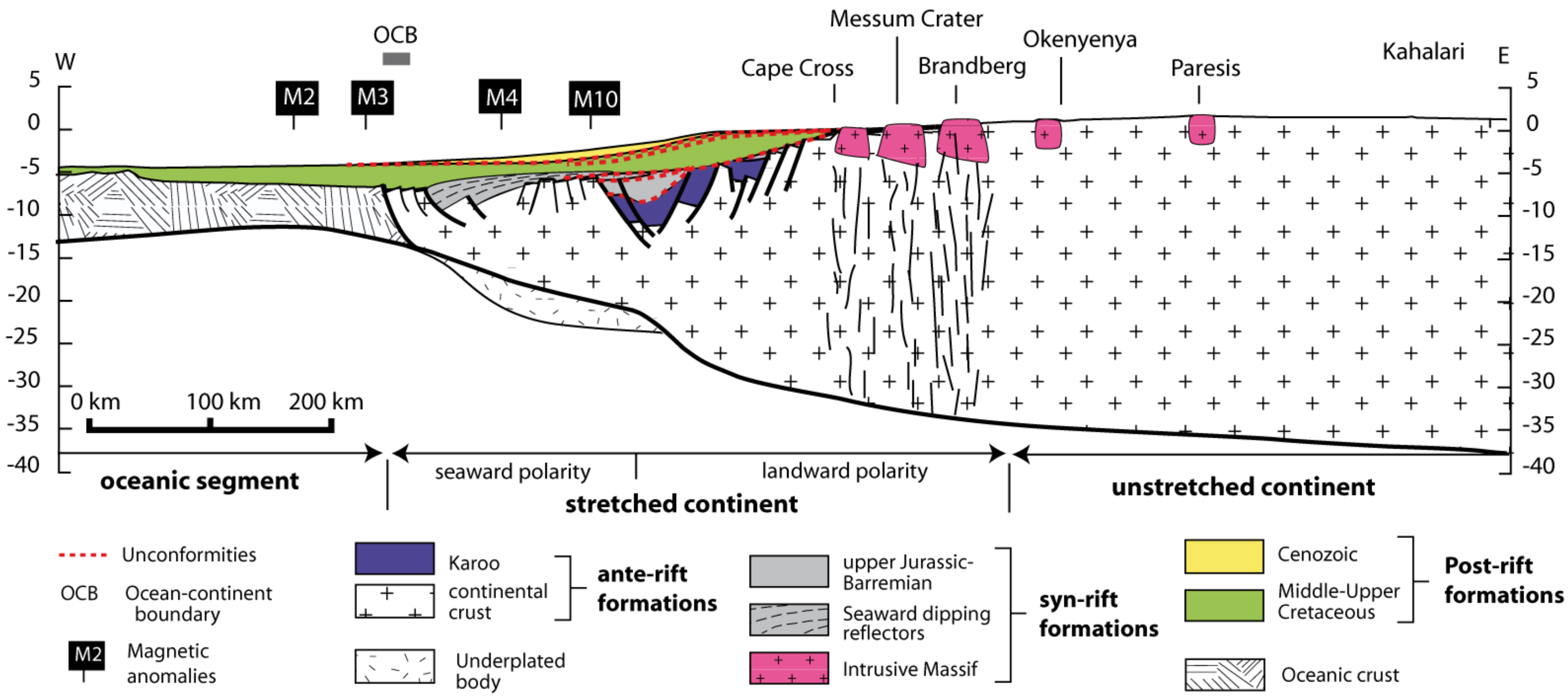
- Jurassic Karoo rift
- Lower cretaceous rift (Berriasian)
- Etendeka magmatism during Lower cretaceous volcanism (137-132 Ma), then magmatism (130-123 Ma)
- Oceanic spreading (± 123 Ma)
- Margin subsidence with marine deposits (Aptian ±117 Ma)
- Continental erosion since Hauterivian: ± 5km from AFT



Brandberg intrusion

→ *6-10 Ma offset of margin subsidence*

CRUSTAL SECTION



- Moho shape: gentle slope from 37 to 30 km, a step of 8 km

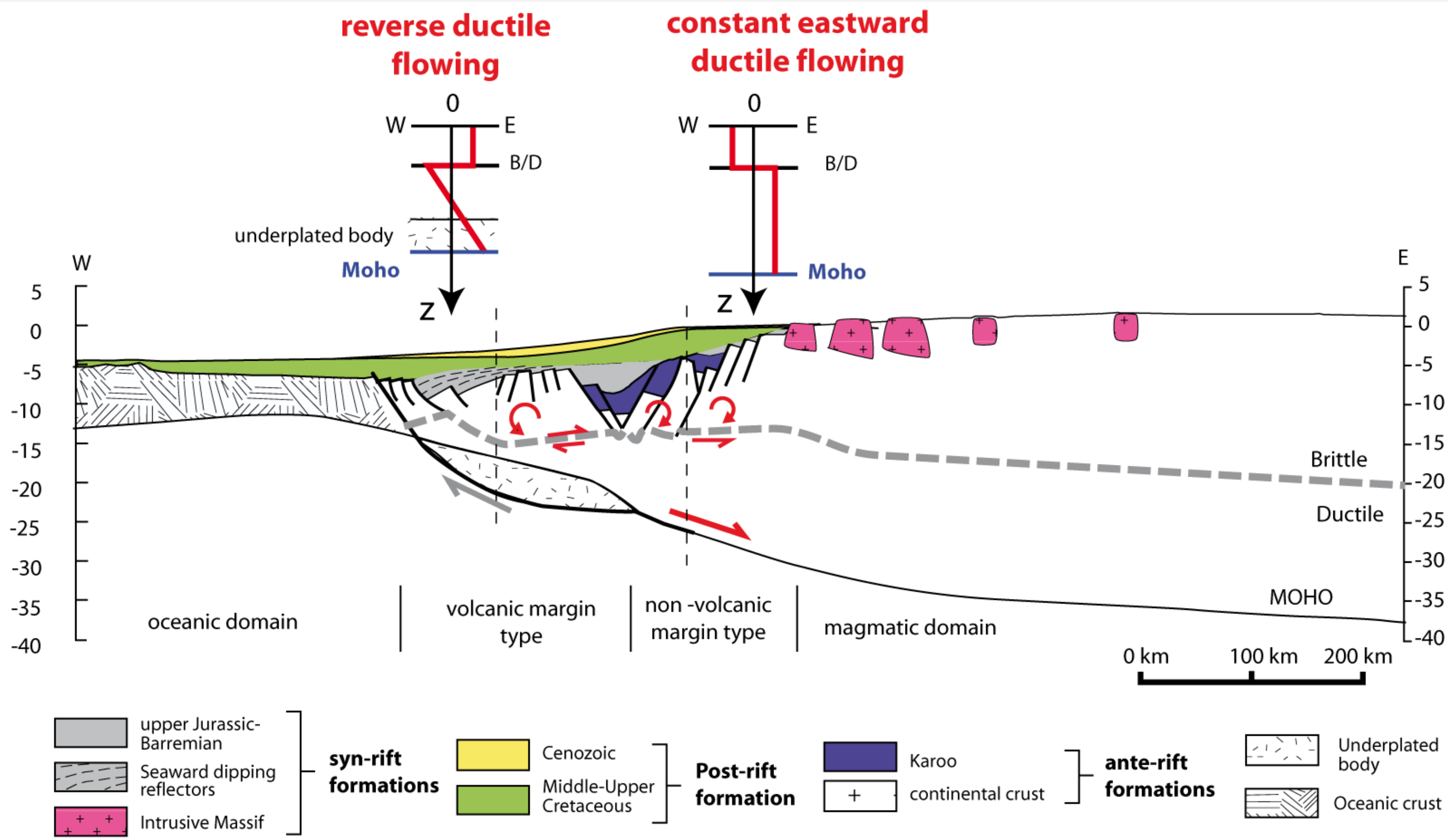
→ *first crustal thinning during Karoo event*

- Deep through above the Karoo rift

→ *Karoo rift influences cretaceous evolution*

- Underplated body below the lower part of the margin
- Rifting structure with landward tilted blocks and seaward tilted blocks

RIFTING MECHANICS

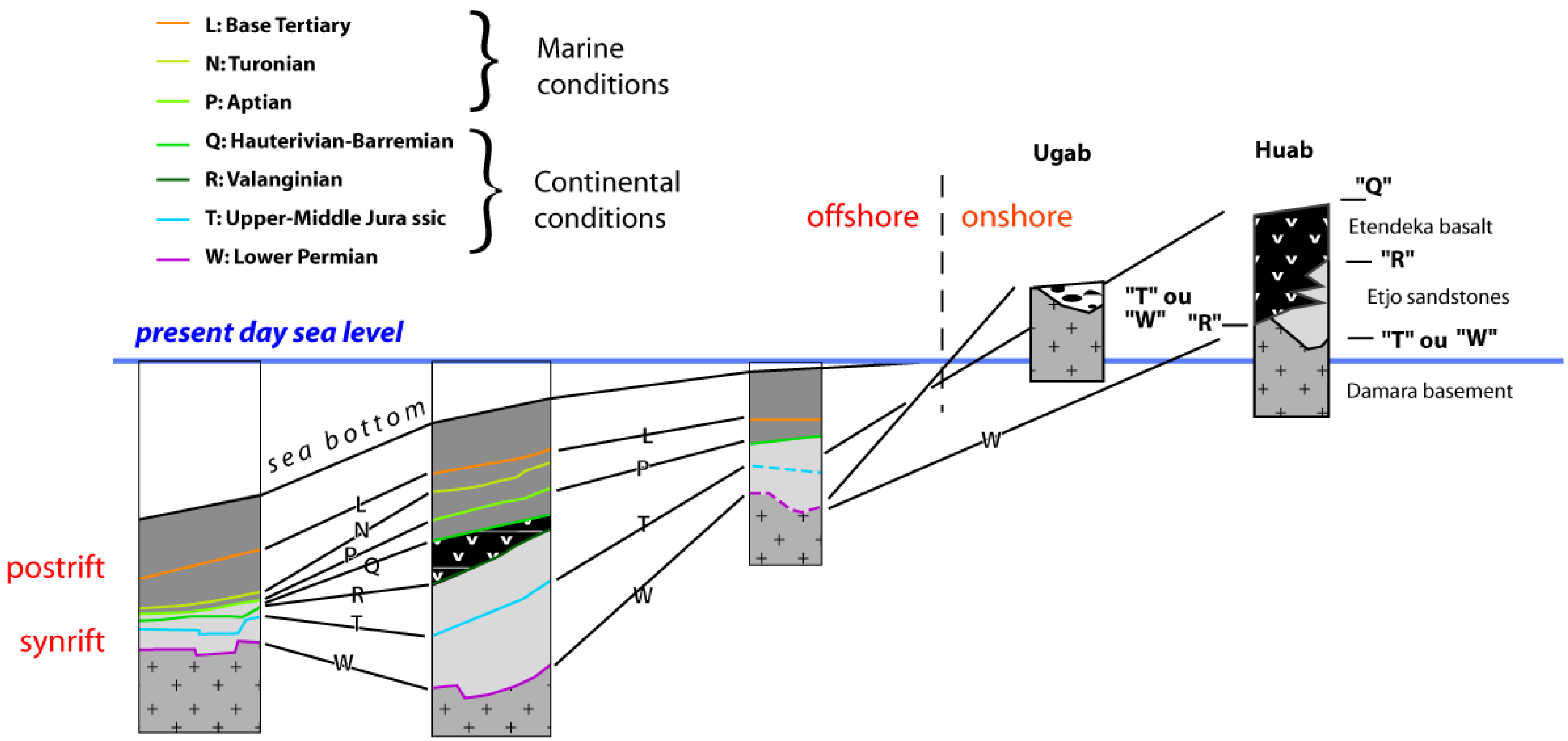


Flowing pattern of ductile crust deduced from Brun (1999)

Different crustal dynamics between upper and lower part of the margin.

→ *Deep ductile crust with complex flowing pattern.*

LAND TO SEA CORRELATION

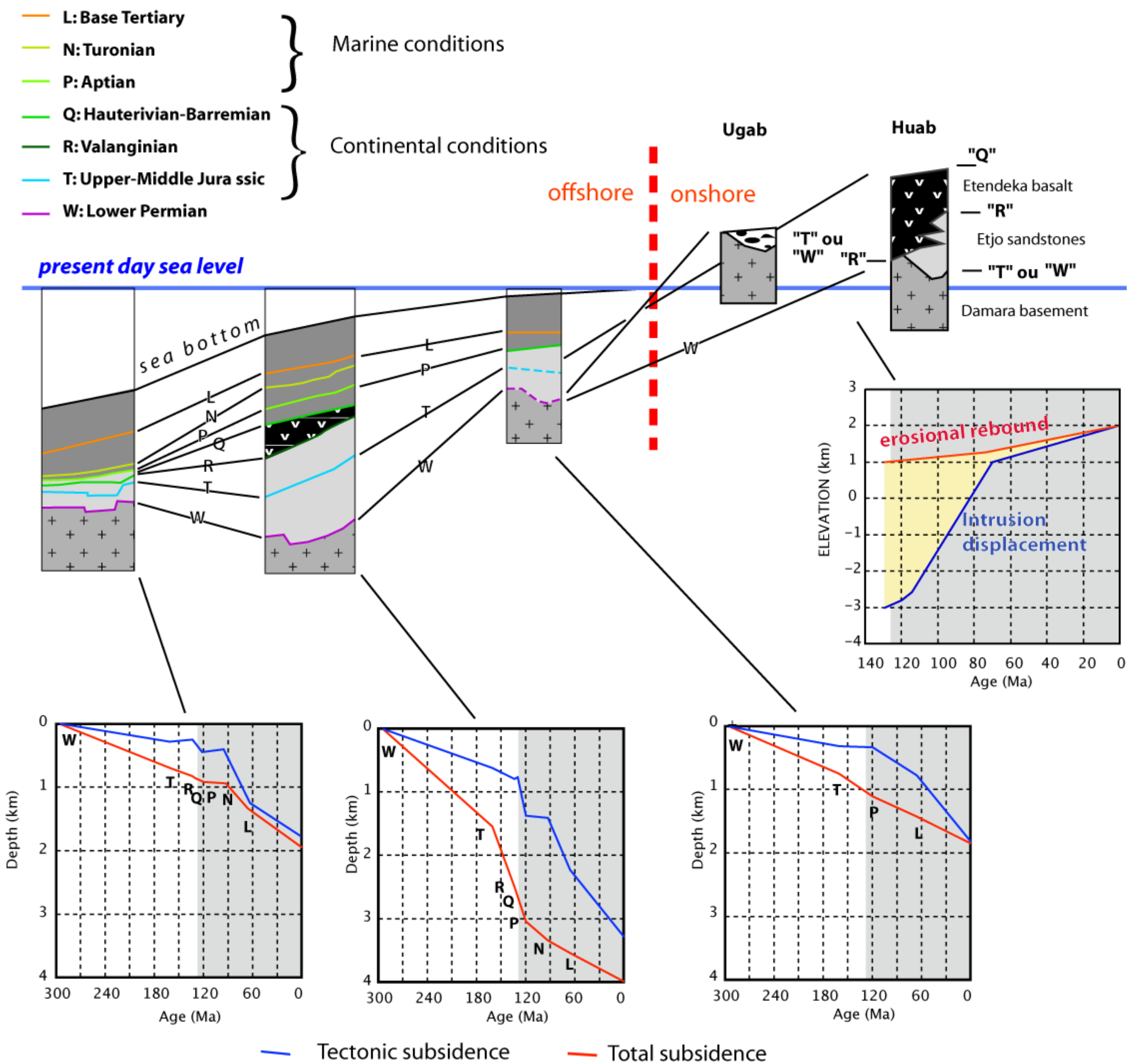


- Onshore: erosional sequence after the breakup with eolian deposits
- Offshore: - Middle part of the margin with thicker synrift sequence
  - Postrift sequence more or less homogeneous.

➡ *Subsidence variations strike on margin and with time*

- No continuity between SDRs and land volcanism: *erosion or two volcanic episodes?*

VERTICAL MOTION ESTIMATIONS



Onshore:

- Erosional rebound
- Depth of intrusion

Offshore:

Subsidence curves

- Variable subsidence strike on margin
- Offset of the fast subsidence:

after the breakup on the lower part and in the upper cretaceous in the upper part

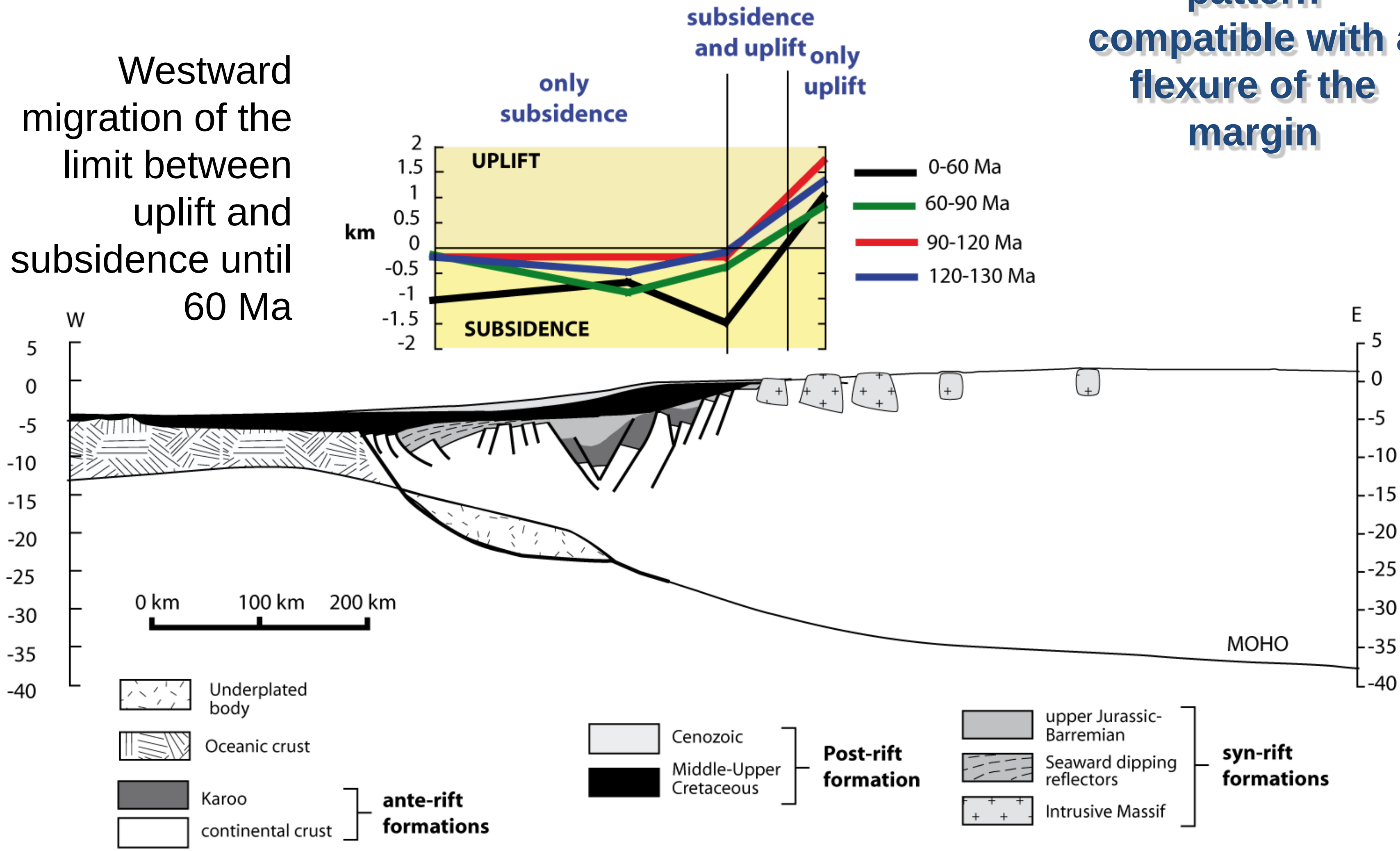
(sag phase)

VERTICAL MOTIONS STRIKE ON MARGIN

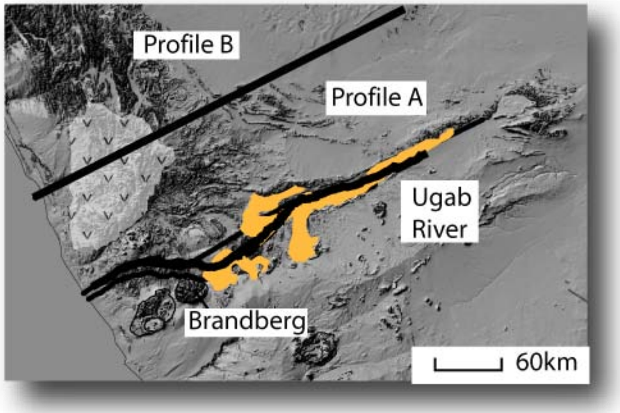
3 domains with different vertical motions

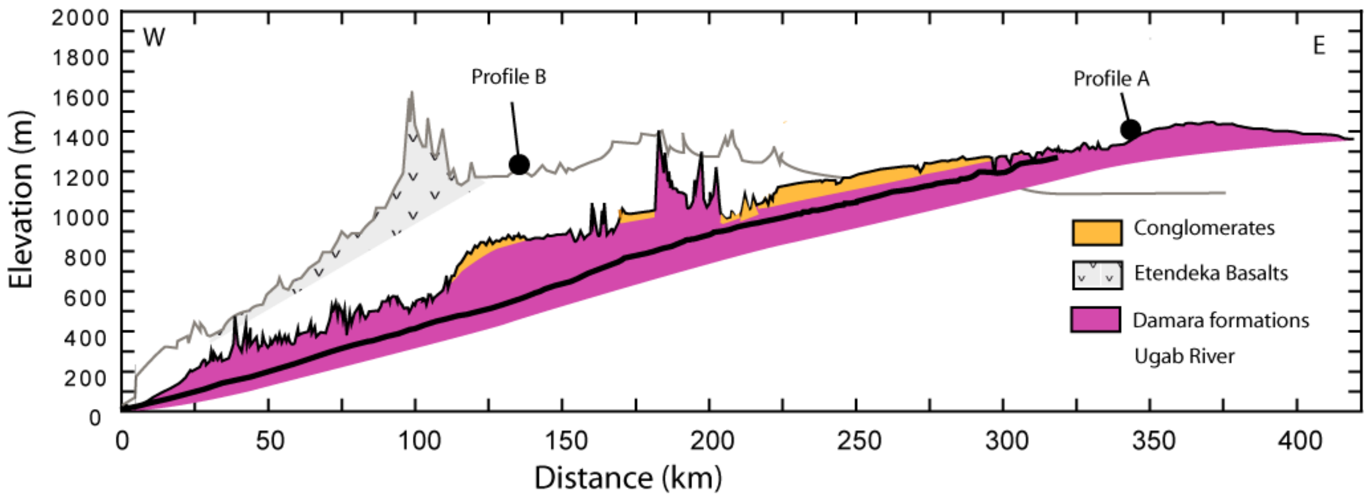
Displacement pattern compatible with a flexure of the margin

Westward migration of the limit between uplift and subsidence until 60 Ma



TOPOGRAPHIC SECTION OF UGAB RIVER





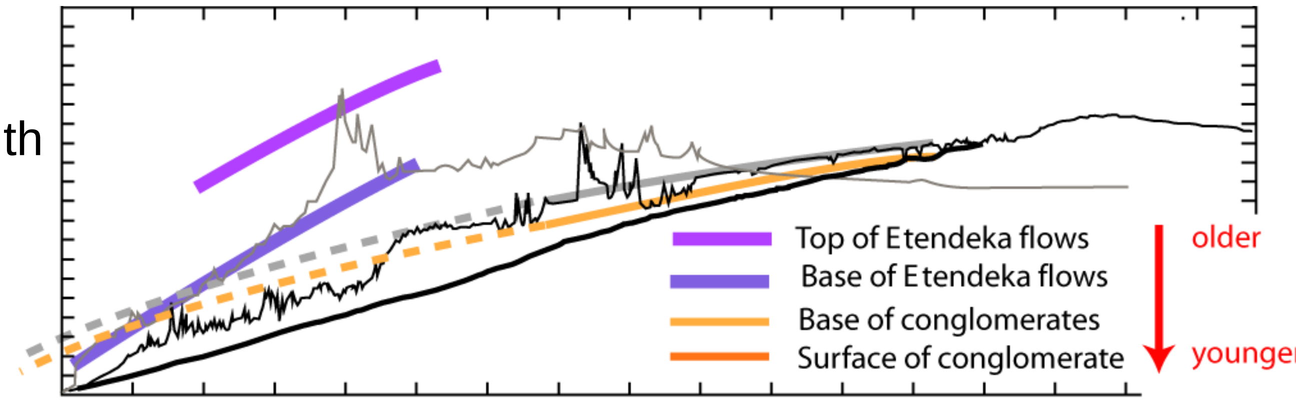
Markers of the deformation:

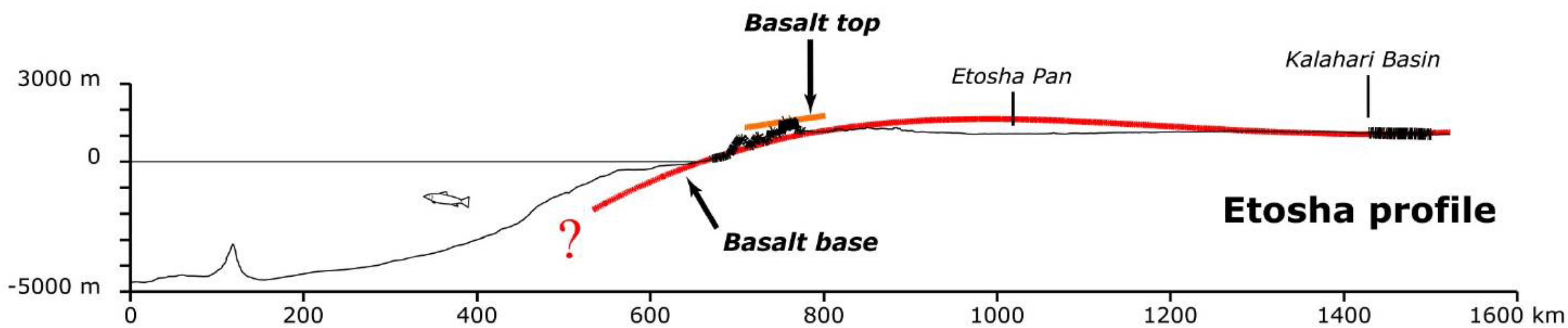
- Base and top of the lava flows
- Base of cenozoic conglomerate
- Present-day surface of conglomerate

FLEXURE IN CONTINENTAL DOMAIN

The markers display a bending toward sea.

This bending decreases with the age of the markers:
High for basalt and low for conglomerate





By integrating basalts in Kalahari basin, wide flexure

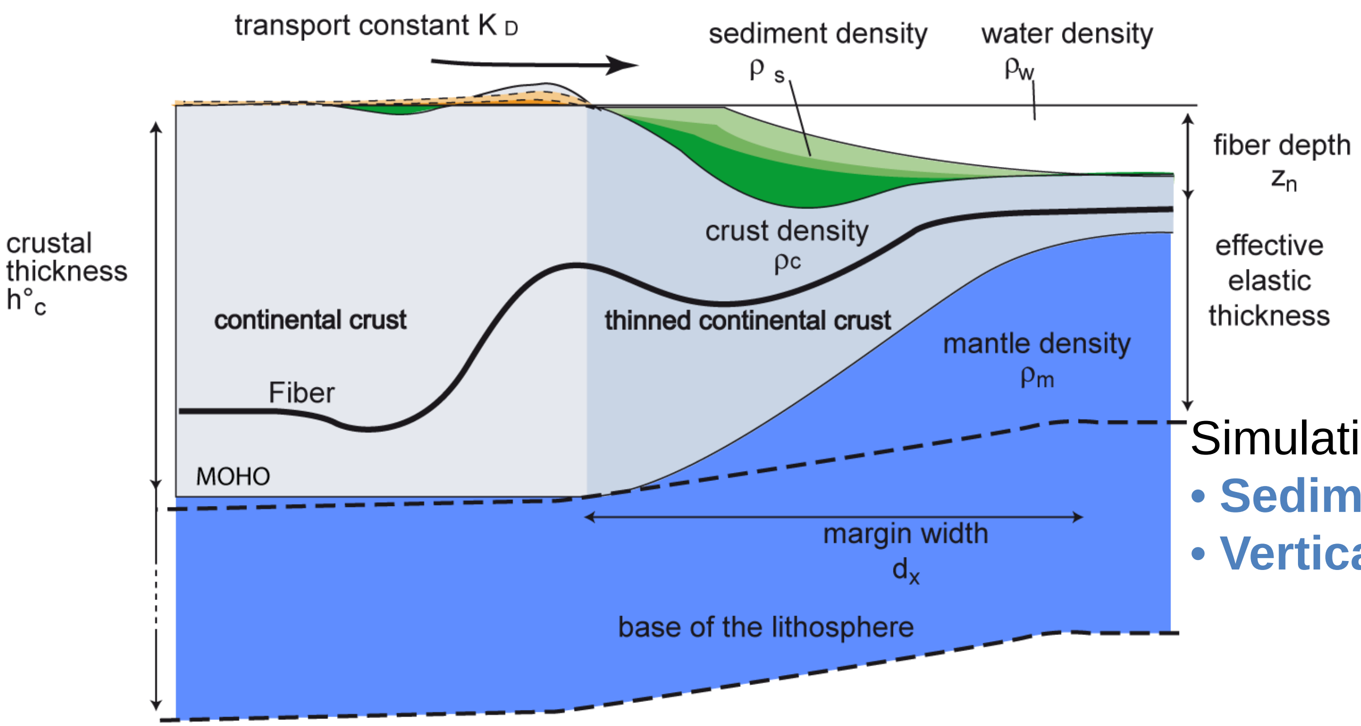
The continental domain was affected by a flexure during the Meso-Cenozoic time that is compatible with displacement pattern of the oceanic domain

DIRECT MODELLING

Numerical modelling of evolution of a passive margin after the continental breakup.

Physical processes involved: thermal adjustment, flexure, isostasic response

Material transfer from continent to sea: diffuse solution

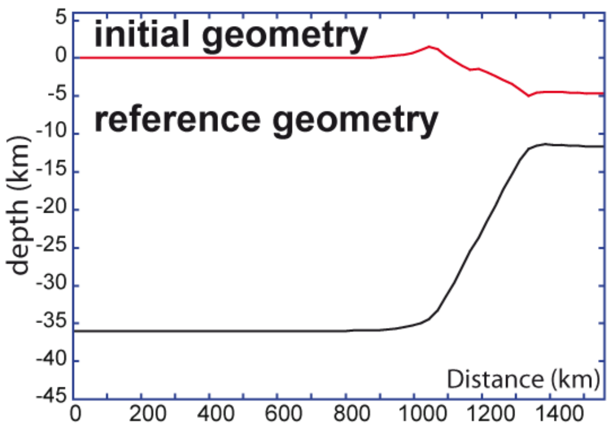


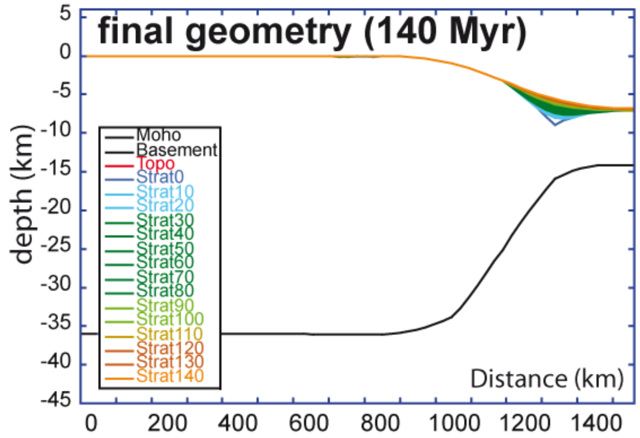
Simulation of:

- **Sedimentary organisation**
- **Vertical motions**

POSTER: F. Deschamps, J. Braun, O. Dauteuil, D. Rouby*, C. Robin, F. Guillocheau:
3-D Numerical Modelling of the Dynamic of the Relief of African Passive Margins
(Poster theme 2)

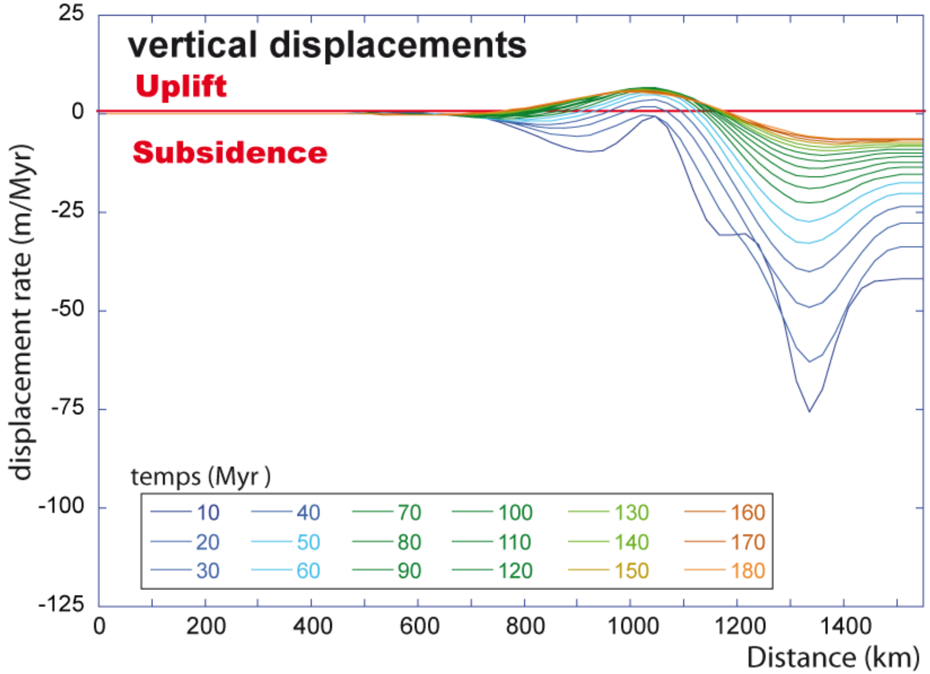
RESULTS





At the end of experience:

- two deposit centres separated by eroded area
- large trough
- no more relief

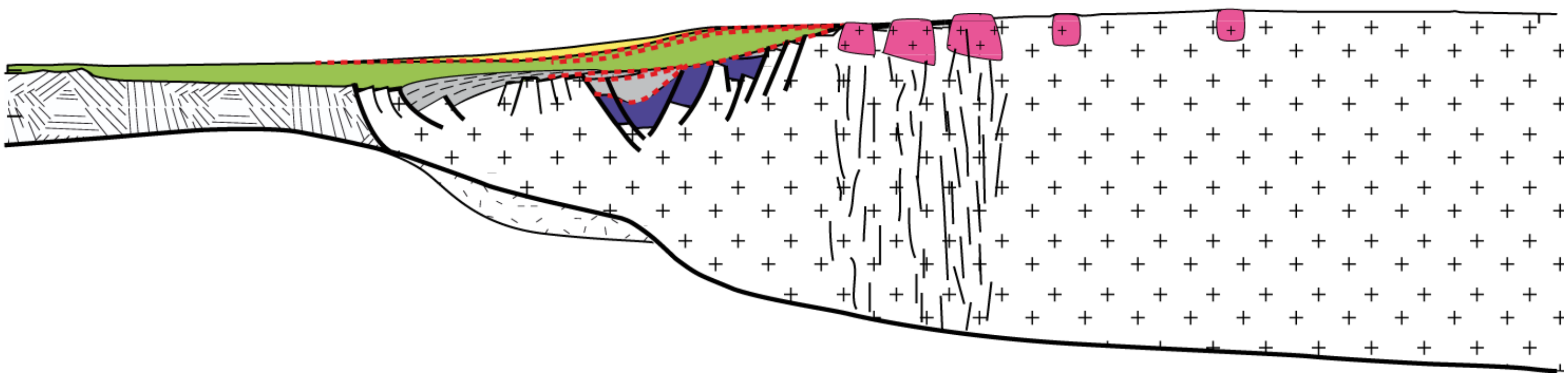


Complex displacement pattern.

- decrease of displacement rate in time
- strike on margin : Alternation of uplifted and downlifted zones
- zone with alternation of behaviour in time.

CONCLUSIONS

- Preexisting structure (Karoo rift) controlled the sediment accumulation during the Cretaceous
- Complex pattern of vertical motions induced by a crustal flexure after the continental breakup.
- Deep marine conditions and subsidence occur some Ma after the breakup. A quiet period exits after the breakup (Sag phase)



To understand a passive margin evolution, we have to integrate a large domain that starts largely inside the continent and ends close to the oceanic ridge.

References

Brun, J.P., 1999, Narrow rifts versus wide rifts; inferences for the mechanics of rifting from laboratory experiements, *in* Response to the Earth's lithosphere to extension: Philosophical Transactions Royal Society Mathematical Physical and Engineering Sciences, v. 357/1753, p. 695-712.

Deschamps, F., J. Braun, O. Dauteuil, D. Rouby, C. Robin, and F. Guillocheau, 2008, 3-D numerical modelling of the dynamic of the relief of African passive margins: Implications for sedimentary systems and surface transfers: Poster presentation, AAPG International Conference and Exhibition, Cape Town, South Africa, October 26-29, Search and Discovery http://www.searchanddiscovery.com/abstracts/html/2008/intl_capetown/abstracts/464680.htm