The structure of the Central-Eastern External Rif (Morocco); Poly-phased deformation and role of the under-thrusting of the North-West African paleo-margin

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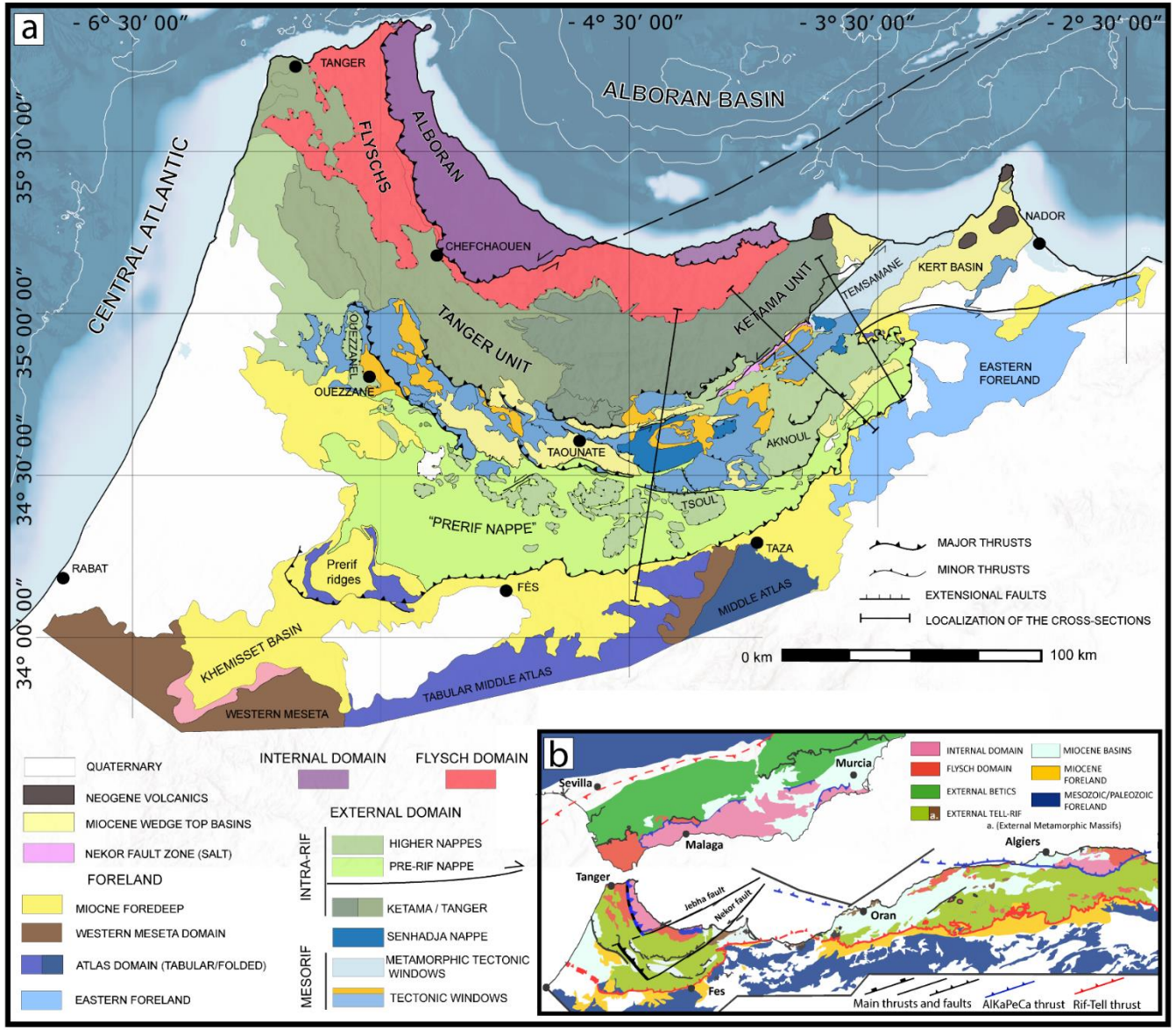
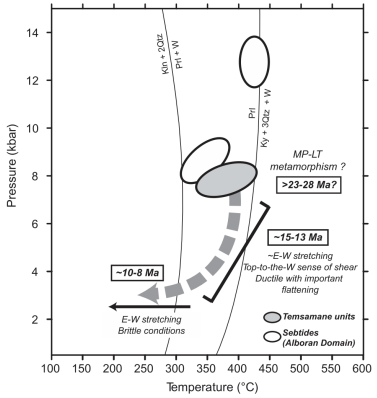
INTRODUCTION AND OBJECTIVES

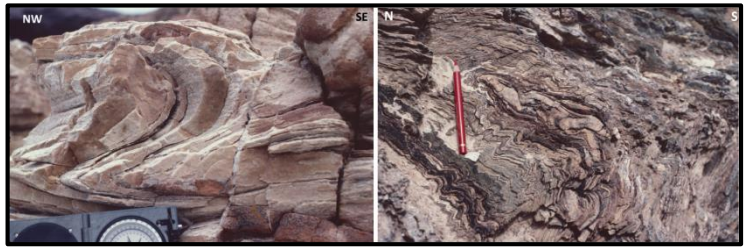
Characterize the Cenozoic compressional processes in the External Rif



- **Repartition and significance of the pre-Miocene contractional deformation.**

- **Integrate the MP-LT metamorphism at the scale of North-West Africa.**



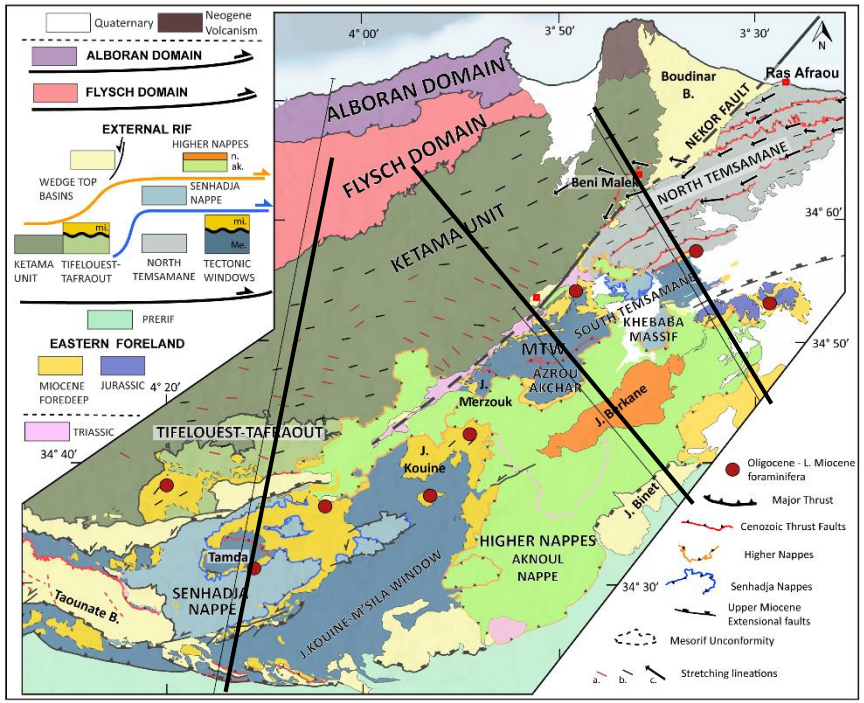


Monie et al., 1984; Negro et al., 2007

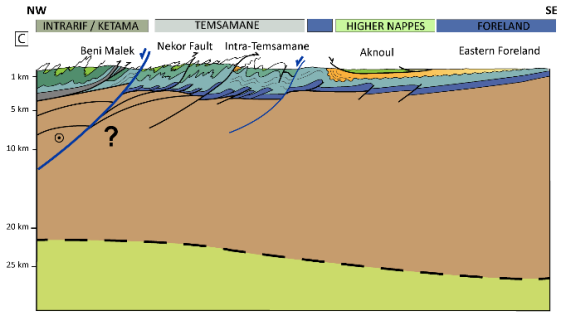
- **Origin and transport mechanisms of large allochthonous thrust-sheets, emplaced during the Middle-Upper Miocene**

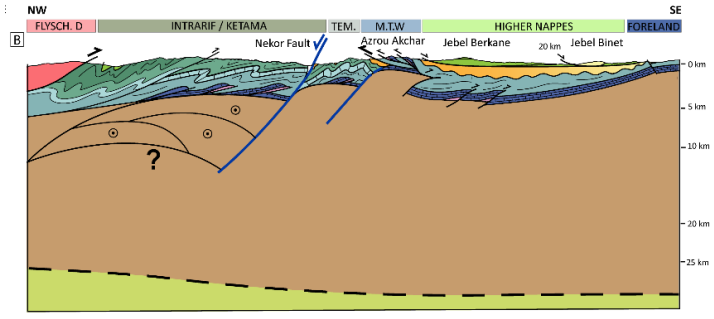
METHODOLOGY

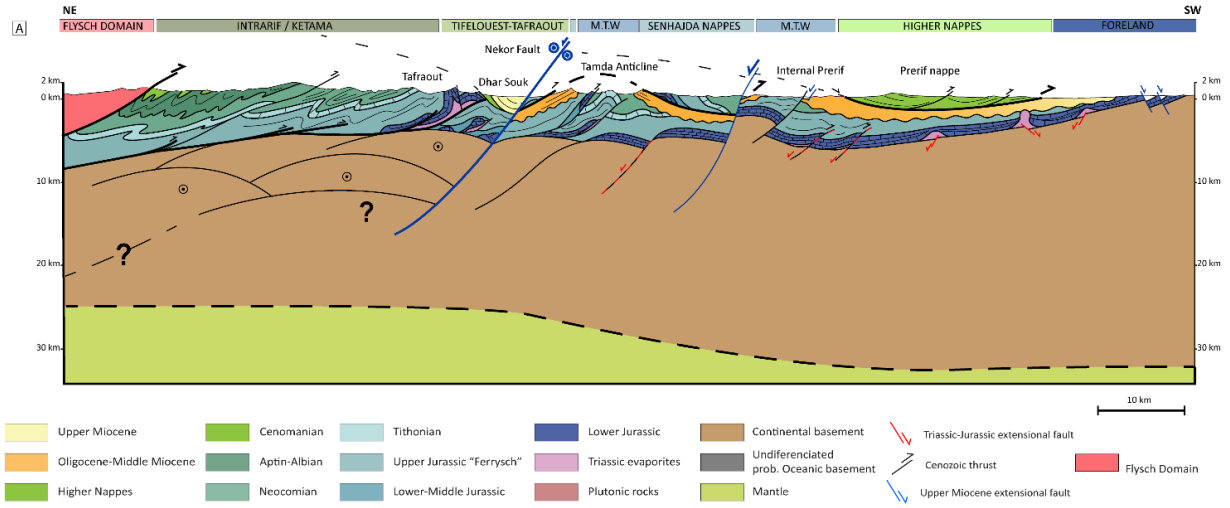
New geological and structural maps



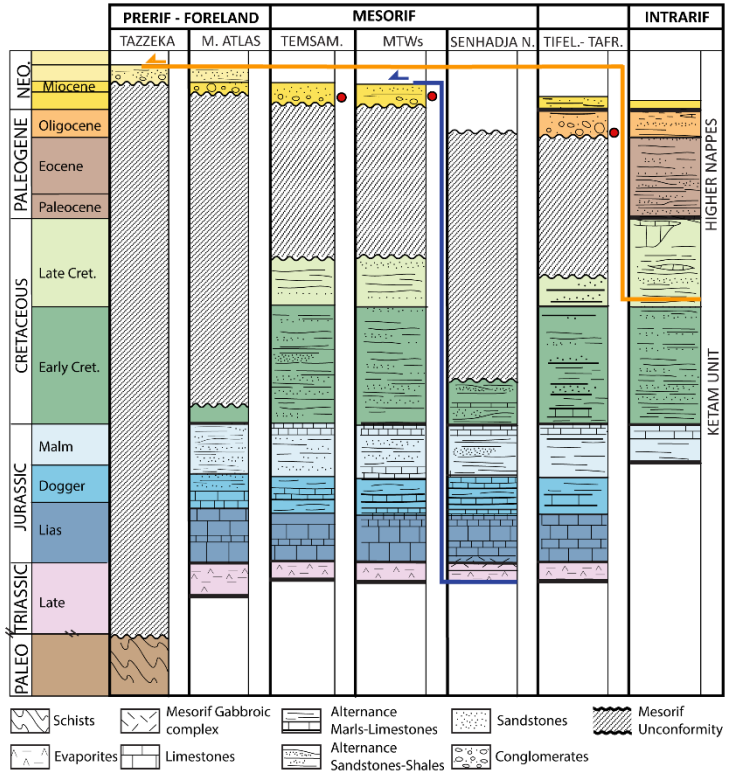
New geological cross-sections



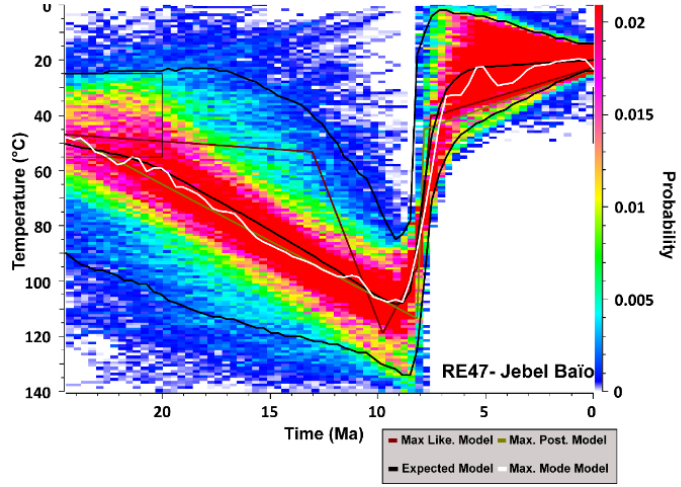




Study of the External Rif stratigraphy



Thermochronological analysis

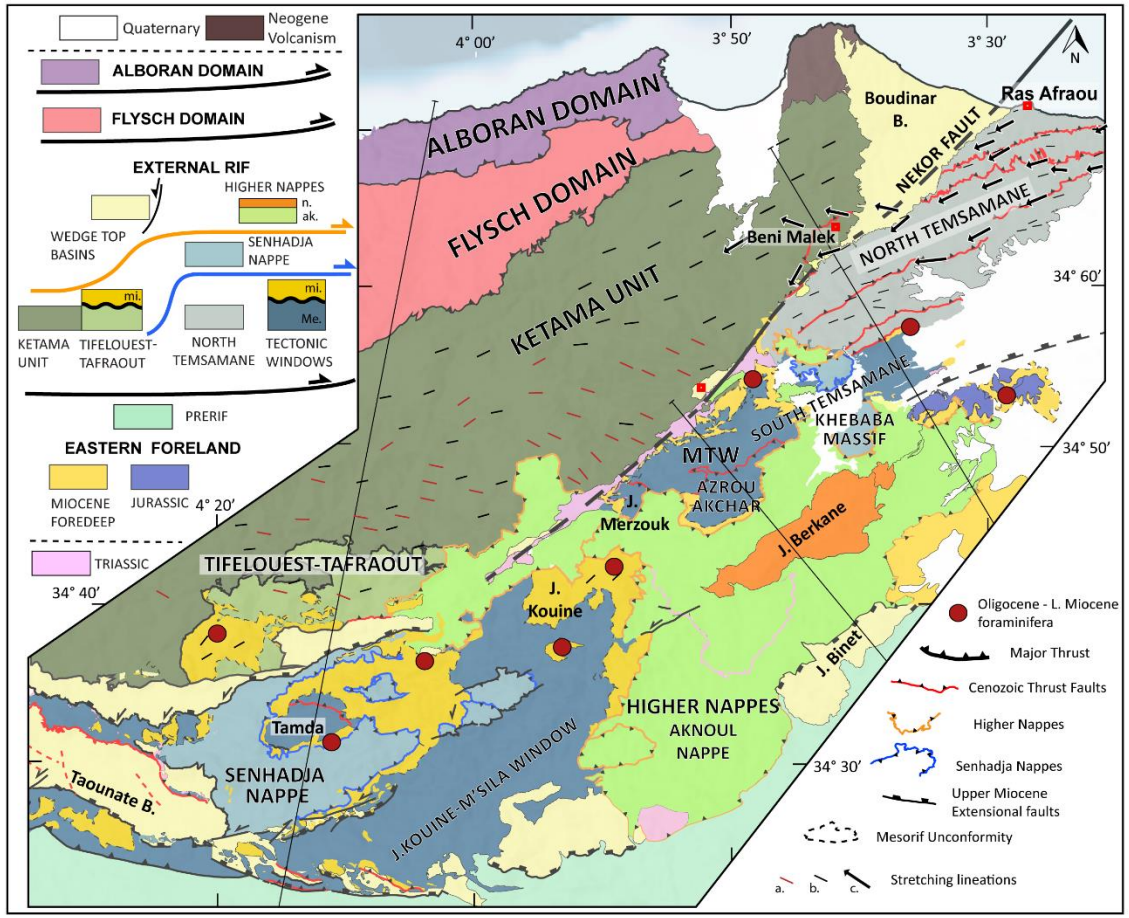


THE STRUCTURE OF THE CENTRAL-EASTERN EXTERNAL RIF

Study of 2 structural domains of the External Rif

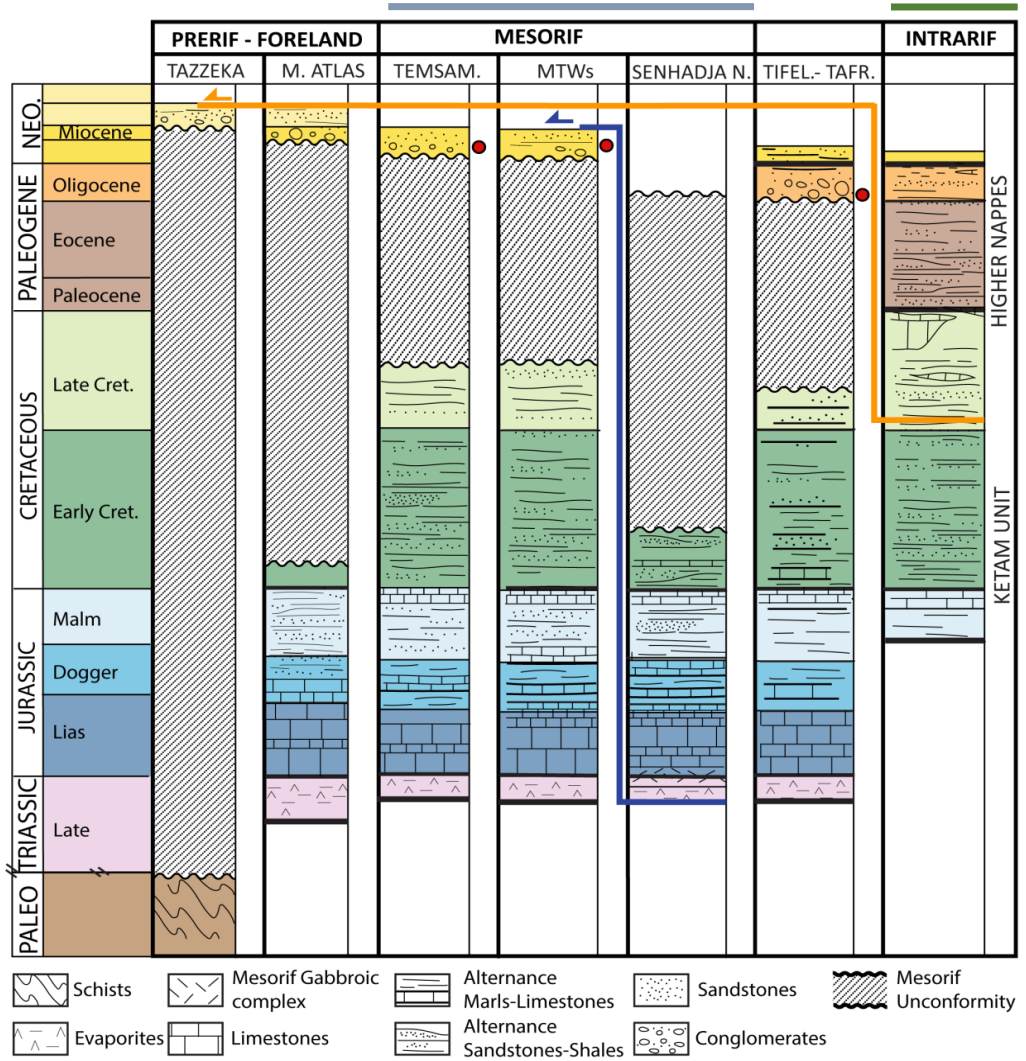
1. MESORIF

- Non-Metamorphic Mesorif Tectonic Windows
- Metamorphic Mesorif Tectonic Windows (Temsamane)
- Senhadja Nappes

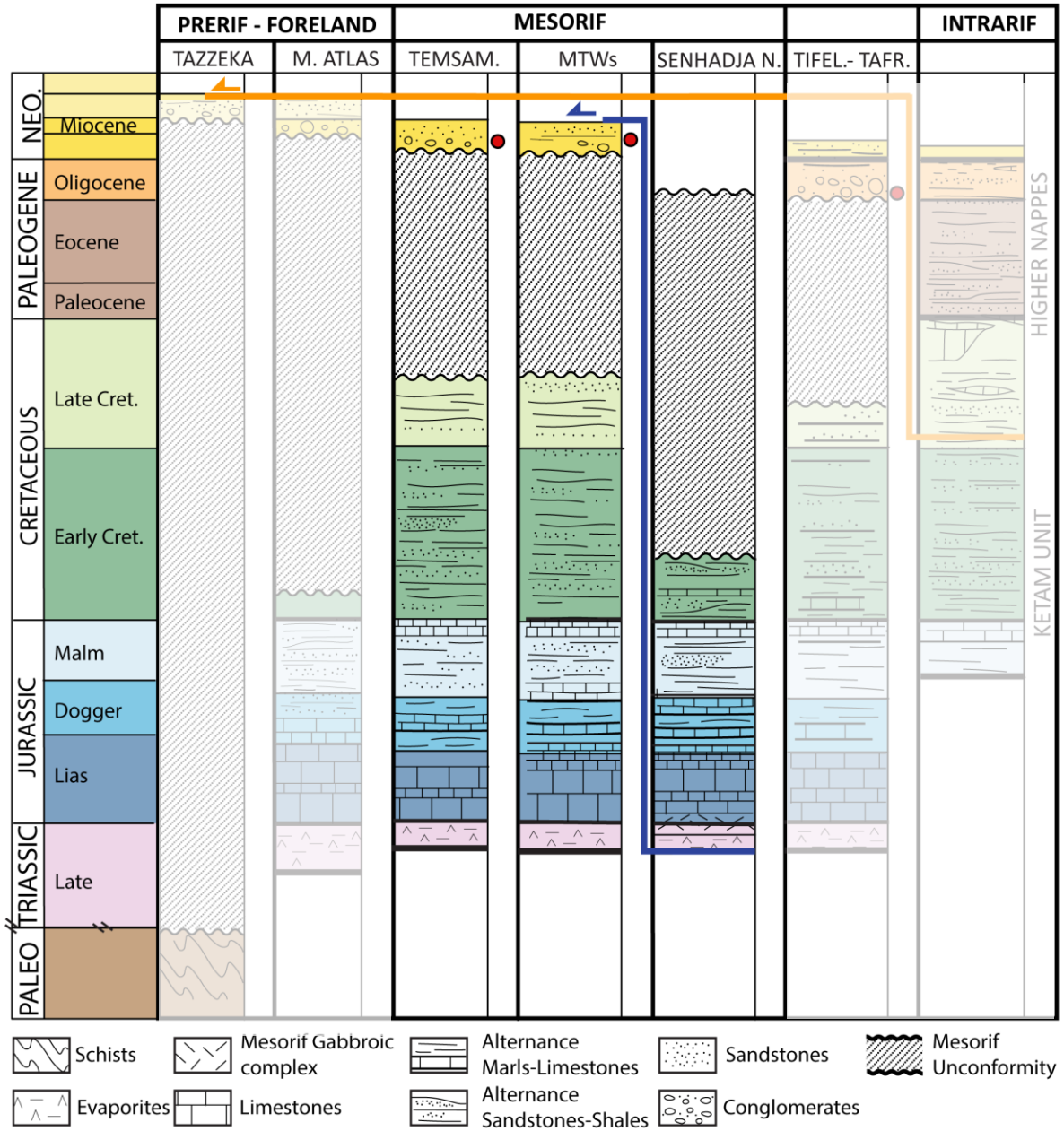


2. INTRARIF

- Higher Nappes



THE MESORIF



Comprises two structural units:

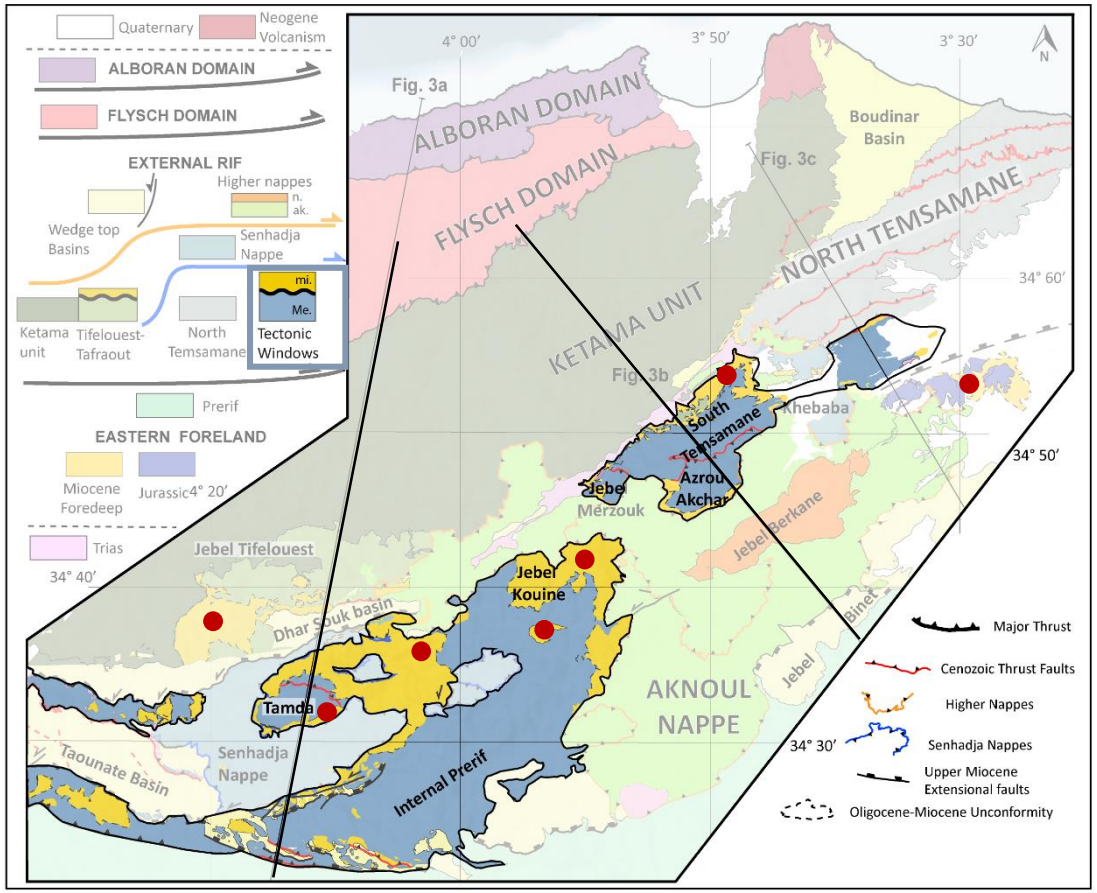
The Mesorif Tectonic Windows (MTW) and the Senhadja Nappe

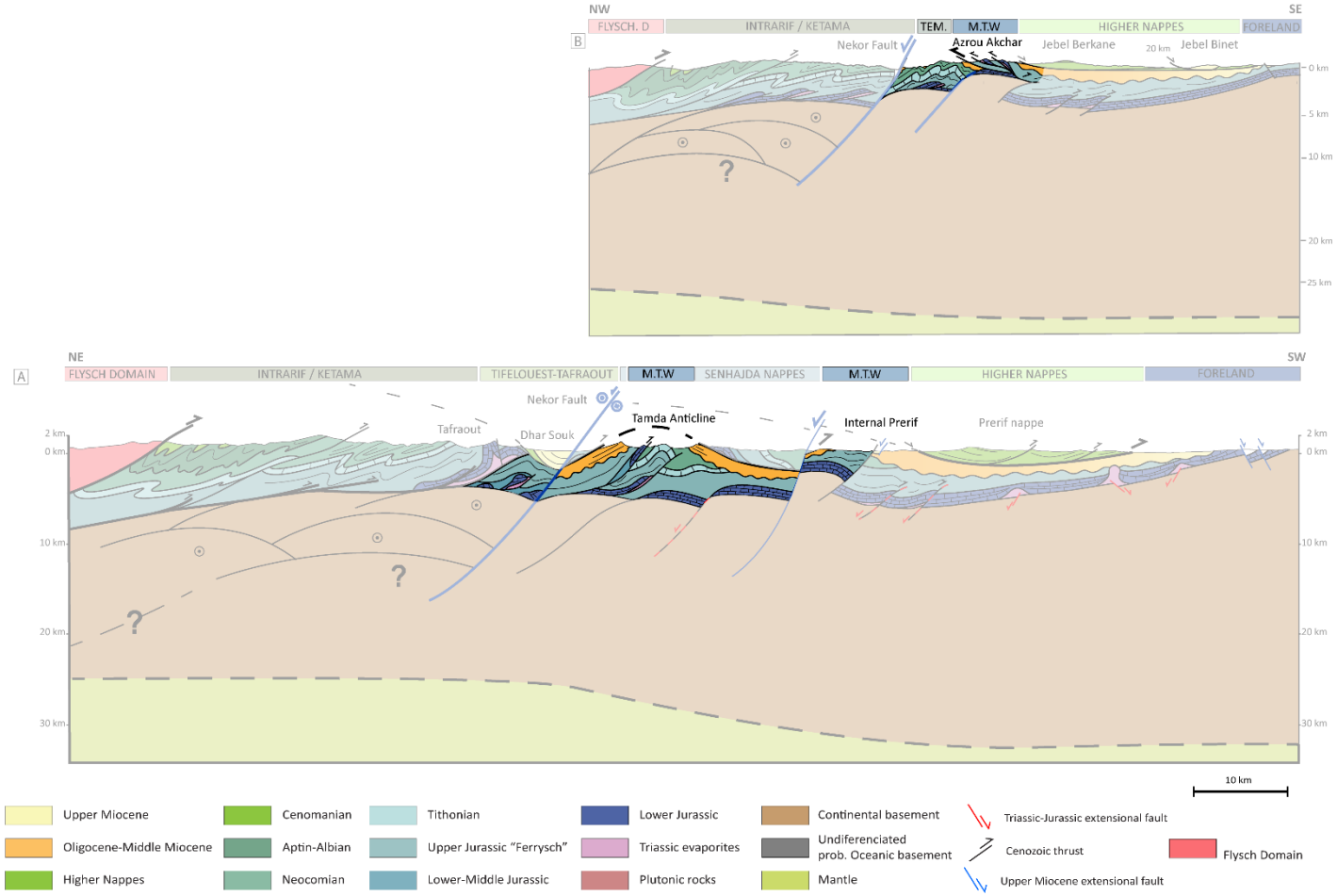
1- The Mesorif Tectonic Windows (MTW) crop out below large tectonic nappes.

1.1- The Temsamane window displays MP-LT Metamorphism (Subduction-related).

2- The Senhadja Nappe: an allochthon nappe emplaced on top of the Mesorif Tectonic Windows.

THE MESORIF: NON-METAMORPHIC MESORIF TECTONIC WINDOWS

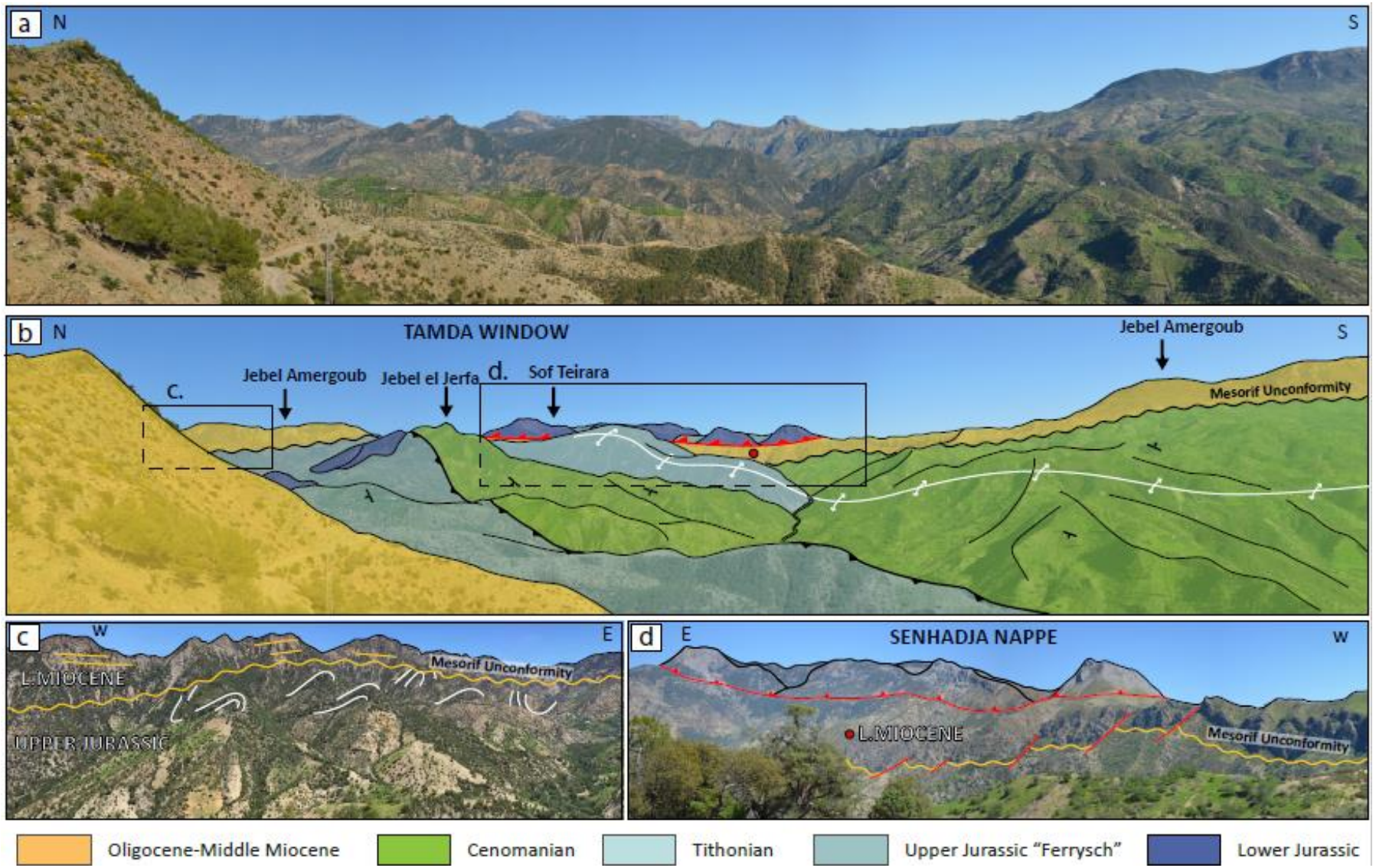




- ***Oligocene? to Lower Miocene Foraminifera***

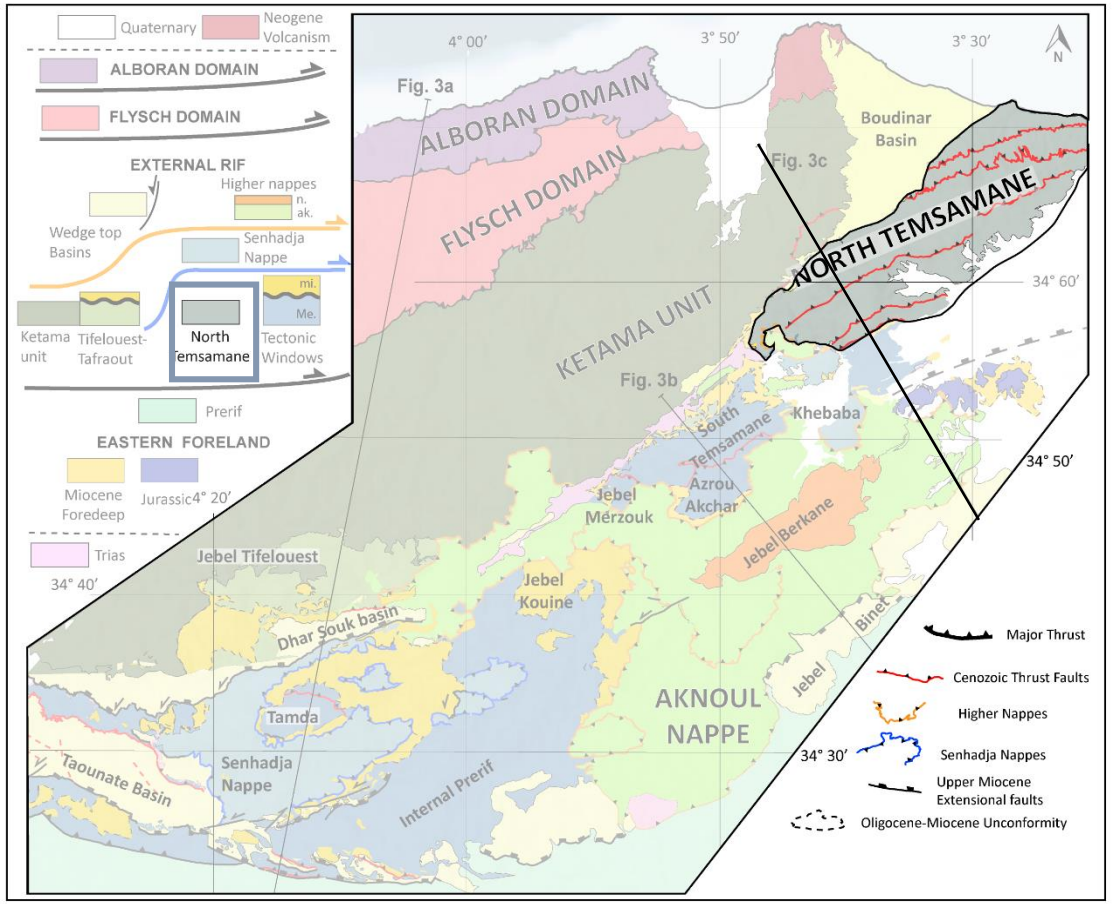
- Sub-autochthon units cropping out below large allochthon nappes.
- Oligocene- Miocene sediments unconformably deposited on top.
- Characteristic Mesozoic stratigraphy from the Upper Triassic to Upper Cretaceous.

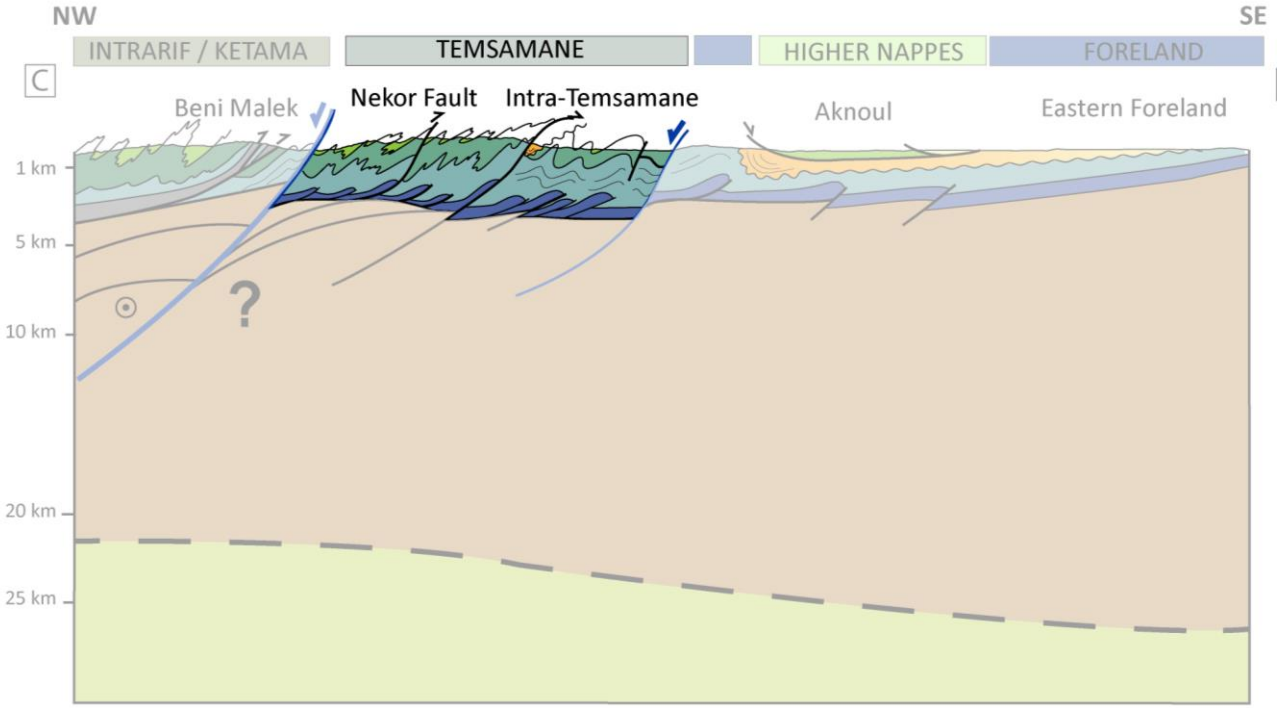
THE MESORIF: NON-METAMORPHIC MESORIF TECTONIC WINDOWS



- Occurrence of a deformed Mesozoic sequence, overlaid by Oligocene-Miocene sediments forming a major unconformity.
- Evidence of a Pre-Miocene deformation.

THE MESORIF: METAMORPHIC MESORIF TECTONIC WINDOWS (TEMSAMANE)

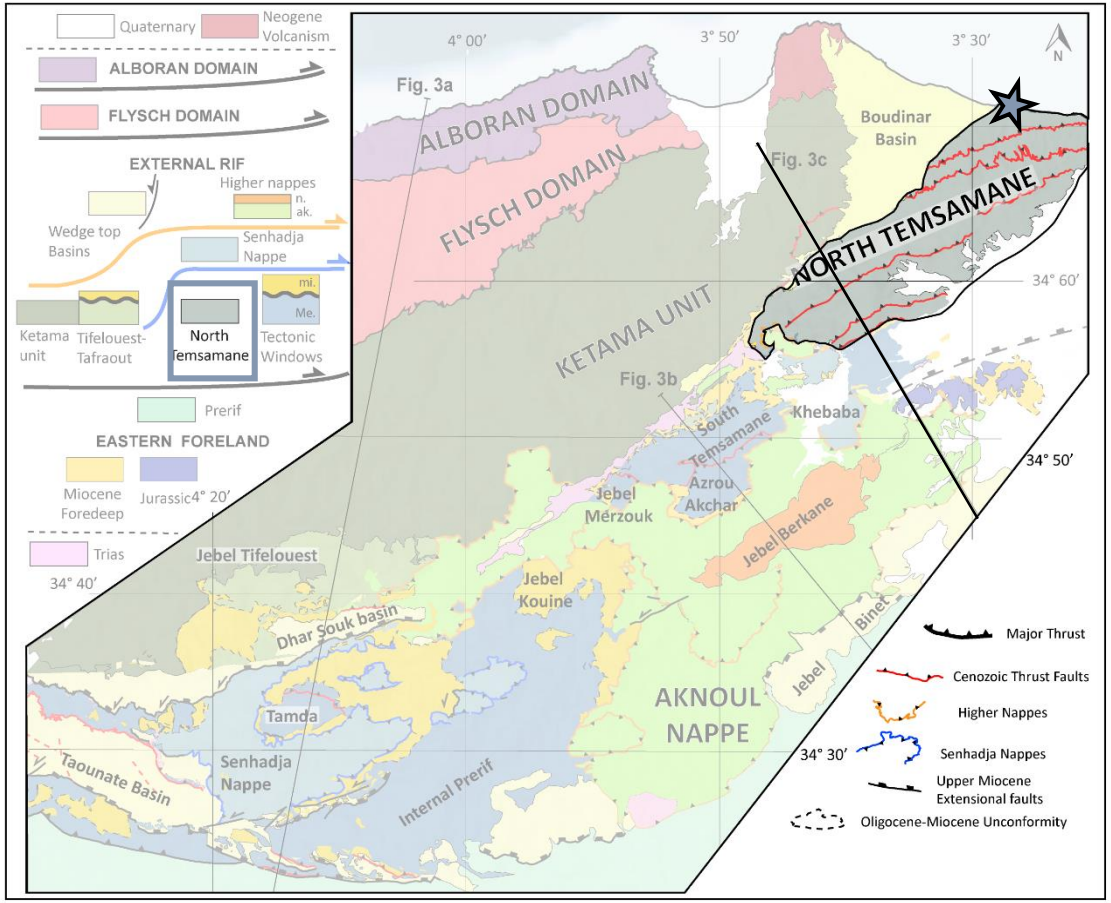


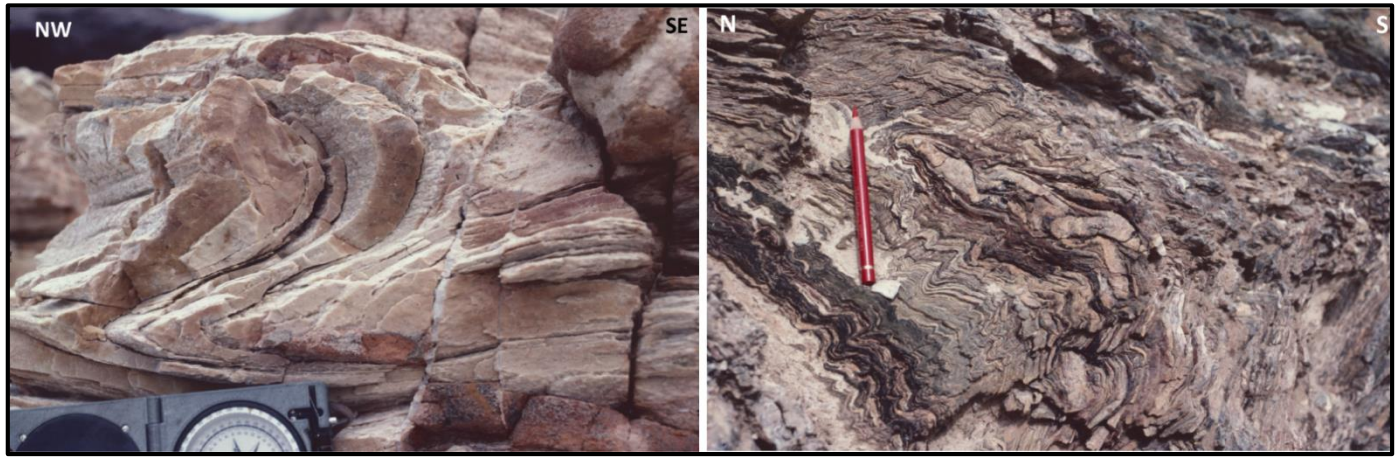


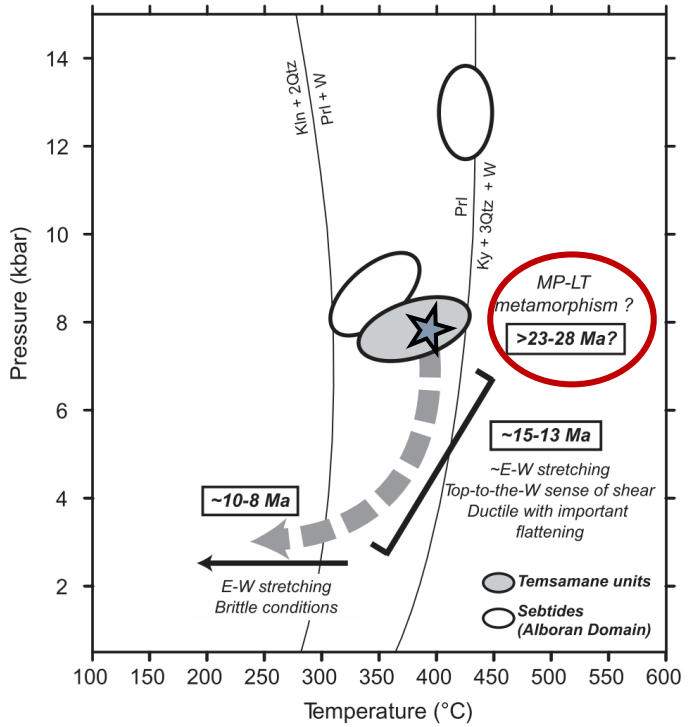
The Temsamane Unit is a particular Tectonic Window presenting:

- Fold and thrust stack characterized by asymmetric south verging folds.
- Similar Mesozoic sequence to MTW's and it also preserves the Oligocene-Miocene unconformity.
- It belongs to the Mesorif Tectonic Window, therefore it crops out below large allochthon nappes.

THE MESORIF: METAMORPHIC MESORIF TECTONIC WINDOWS (TEMSAMANE)







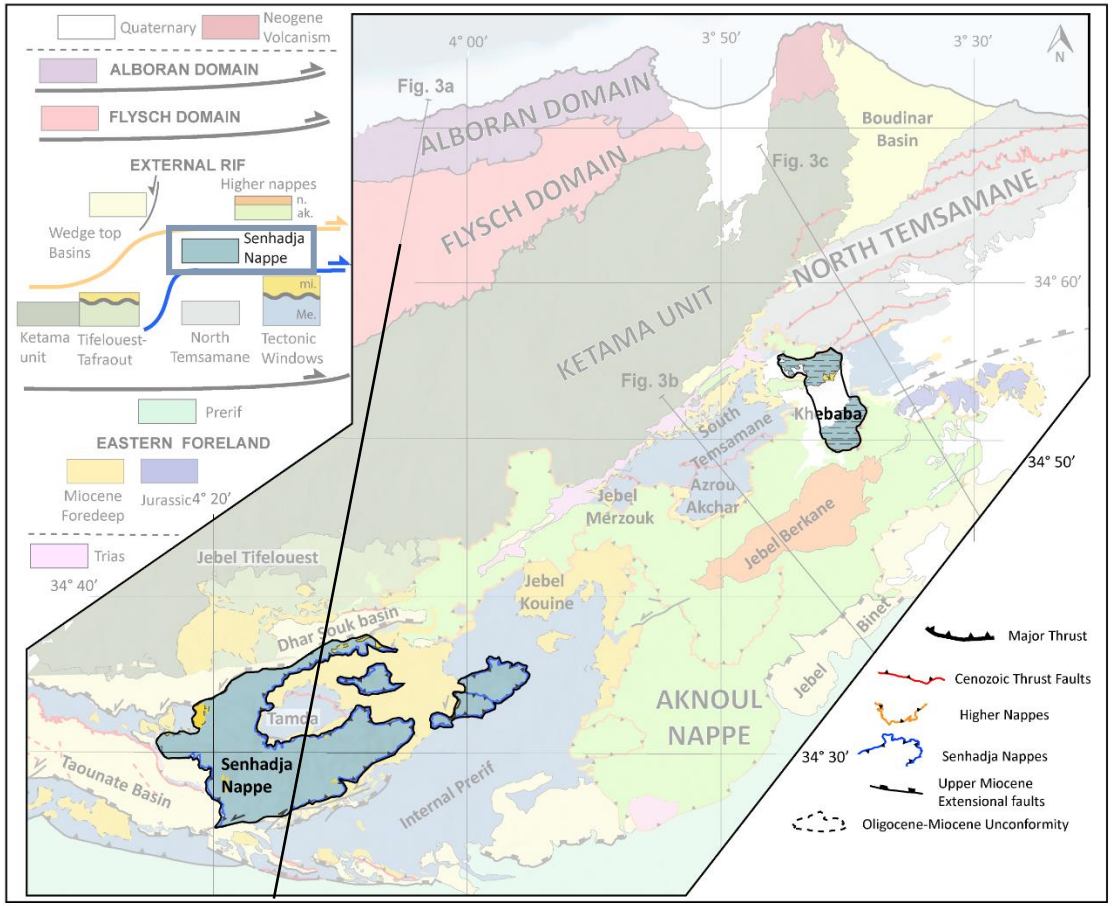
Monie et al., 1984; Negro et al., 2007

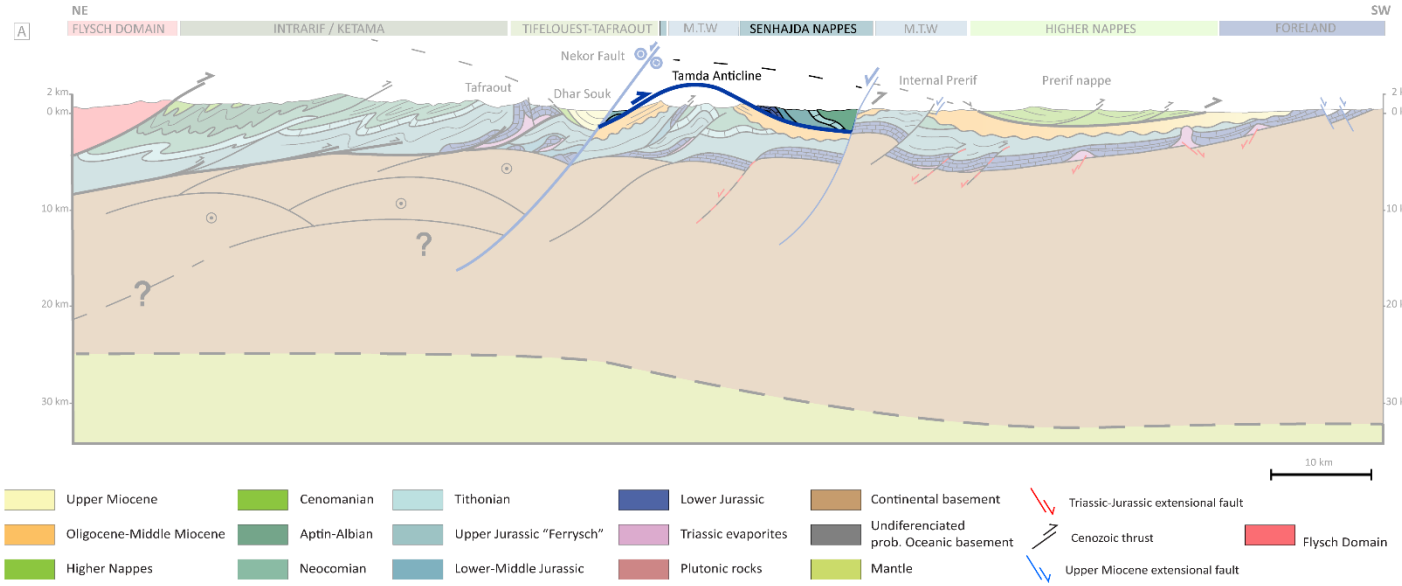
- This unit records MP-LT metamorphism (7–9 kbar and 330–430 °C).

- In the Ras Afraou, the Temsamane Unit metamorphic gradient indicates the occurrence of a former underthrusting zone.

- Peak of metamorphism dated 40Ar–39Ar at **28 Ma**, or older.

THE MESORIF: THE SENHADJA NAPPES

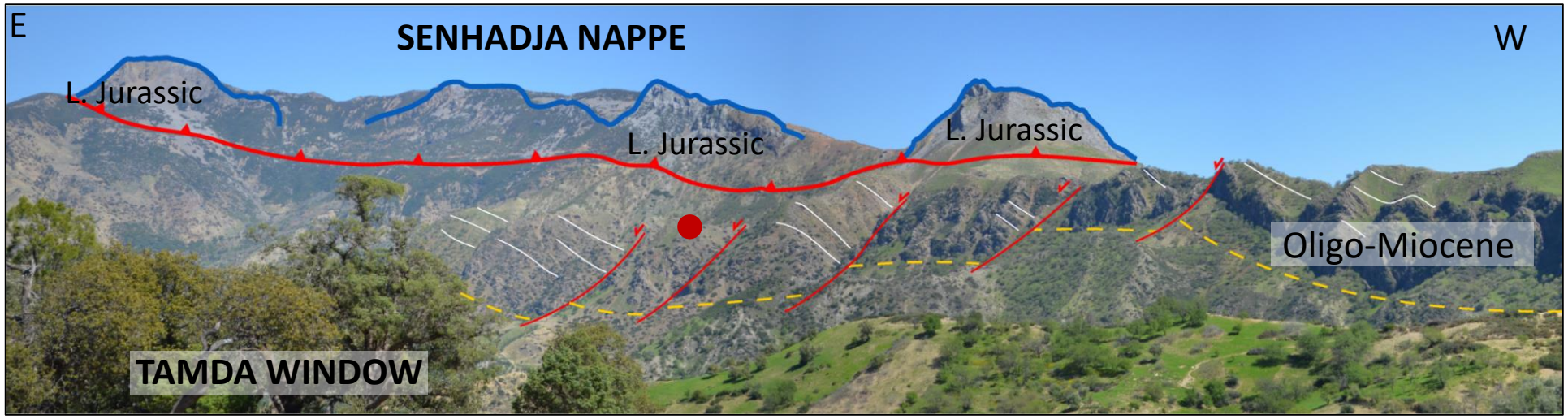


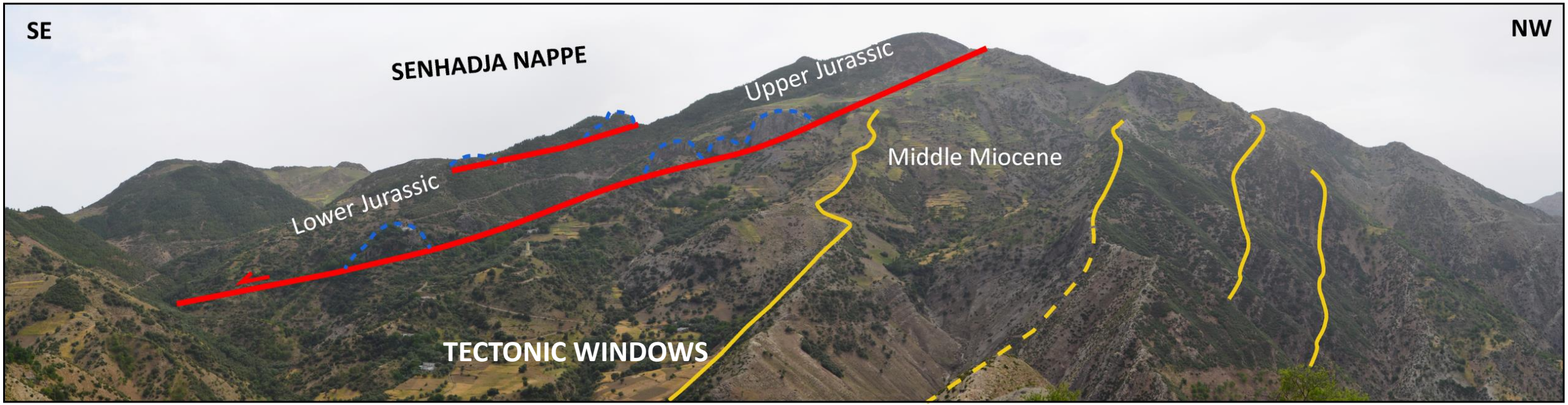


- Allochthon nappes emplaced on top of the Mesorif Tectonic Windows during the Early Miocene through a major thrust fault.
- Overlaid by the Higher Nappes, emplaced afterwards during the Upper Miocene.

- Initial position of the Senhadja Nappes root is the Nekor Fault Zone, between the Intrarif and the Mesorif Tectonic Windows.
- Share the Mesozoic stratigraphy with the Mesorif Tectonic Windows and completely different from the Intrarif and Flysch Domain.

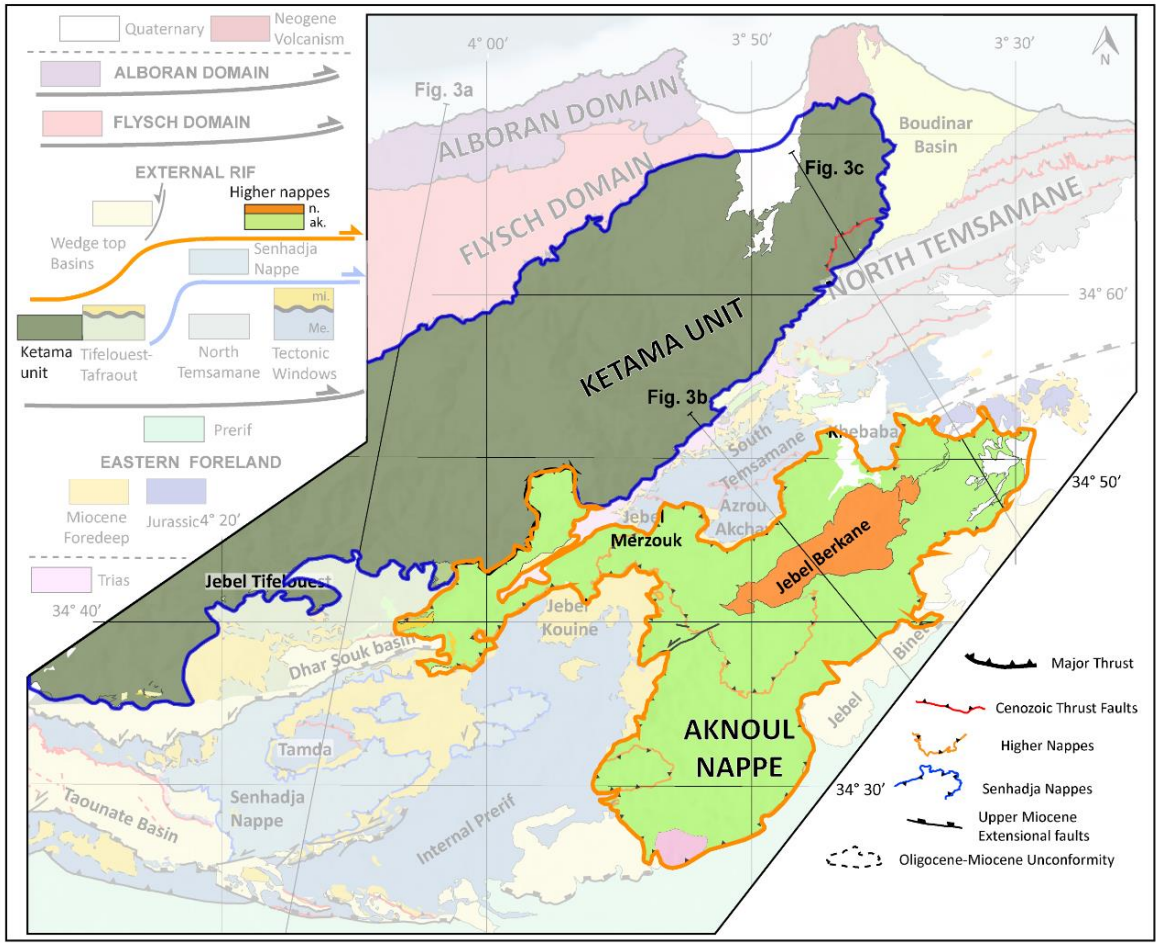
THE MESORIF: THE SENHADJA NAPPES

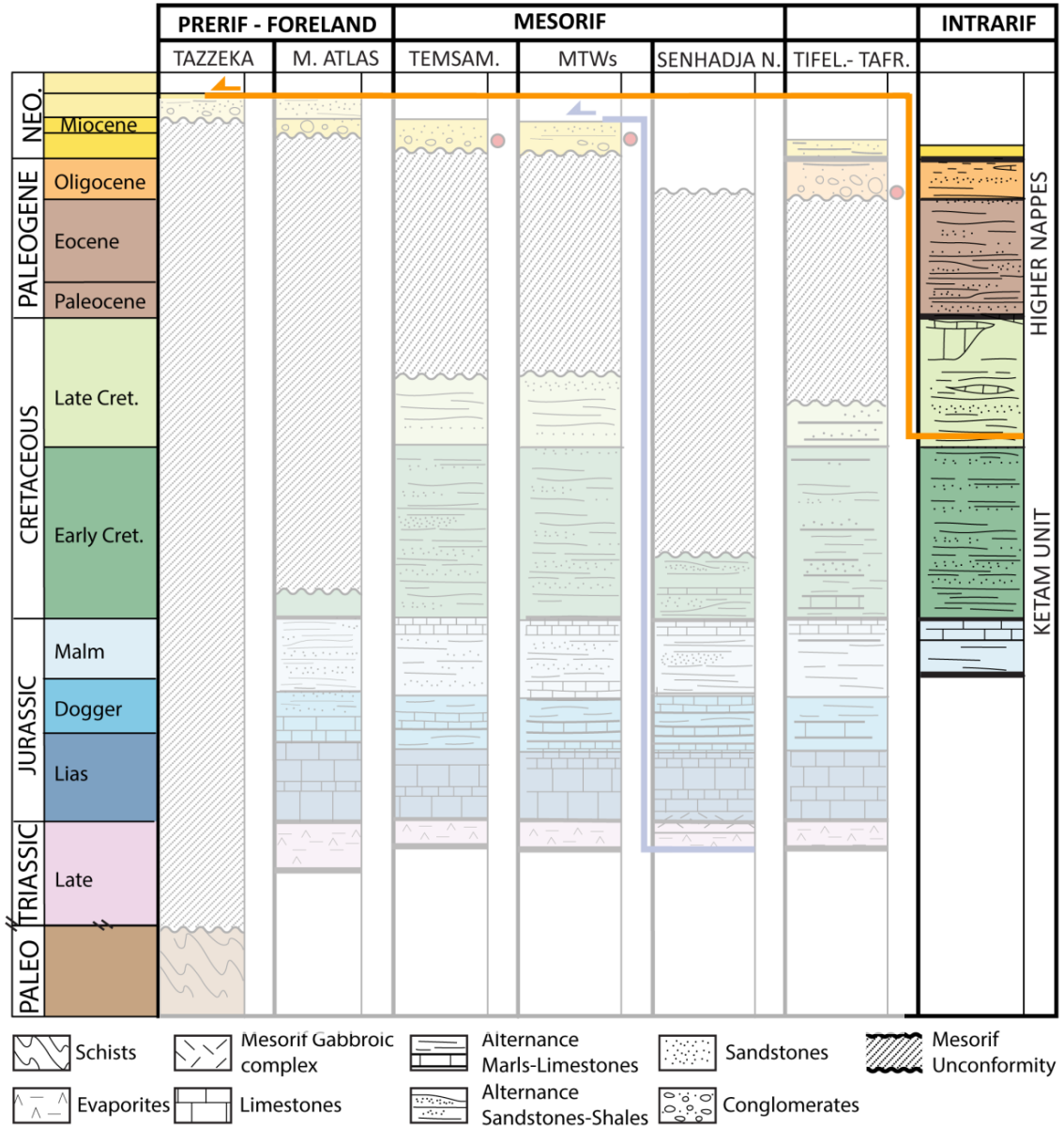




INTRARIF: KETAMA UNIT AND THE HIGHER NAPPES

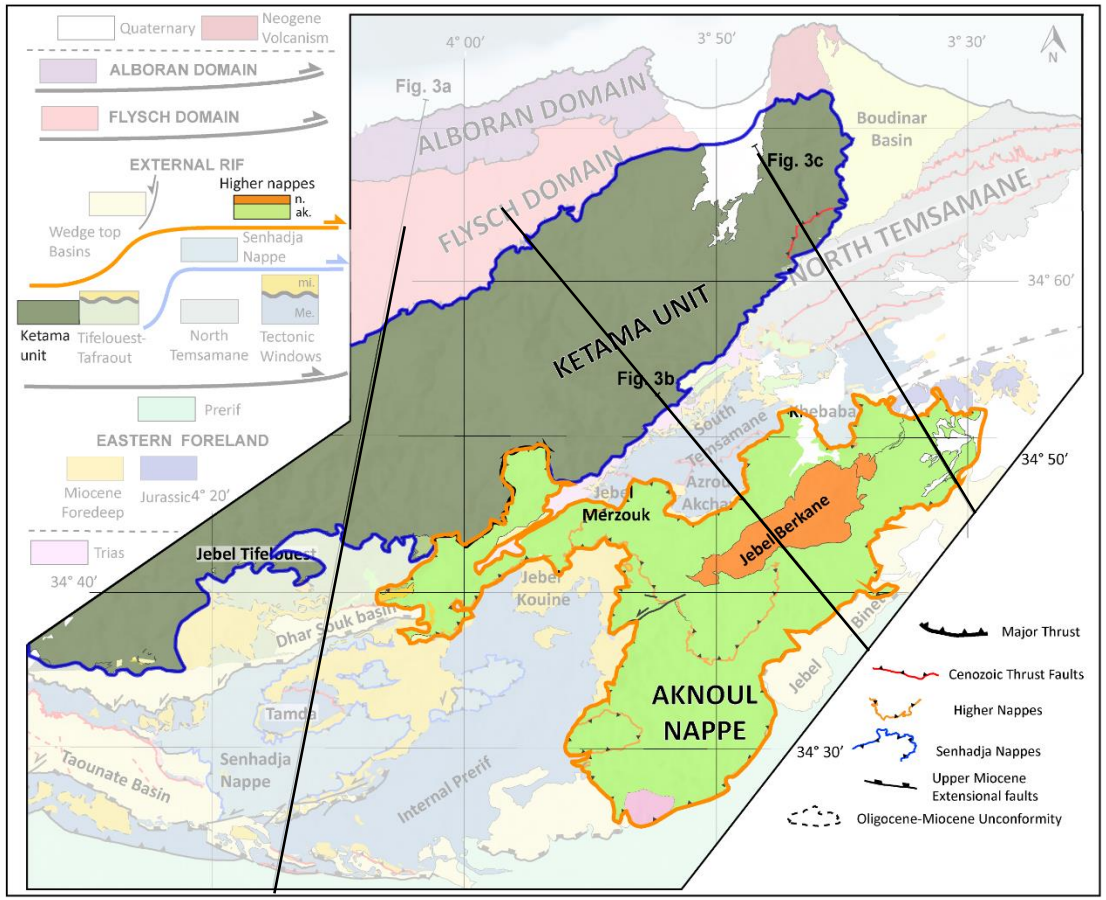
The Intrarif comprises two structural units: The Ketama Unit and the Higher Nappes

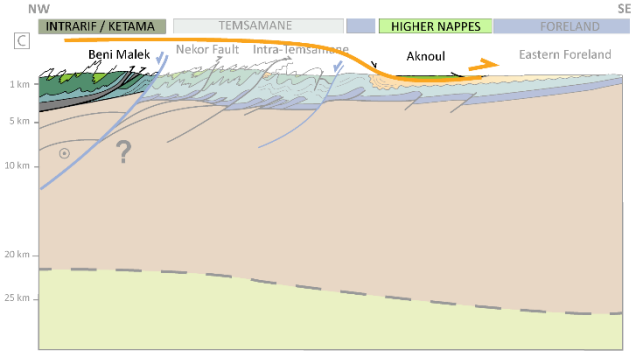


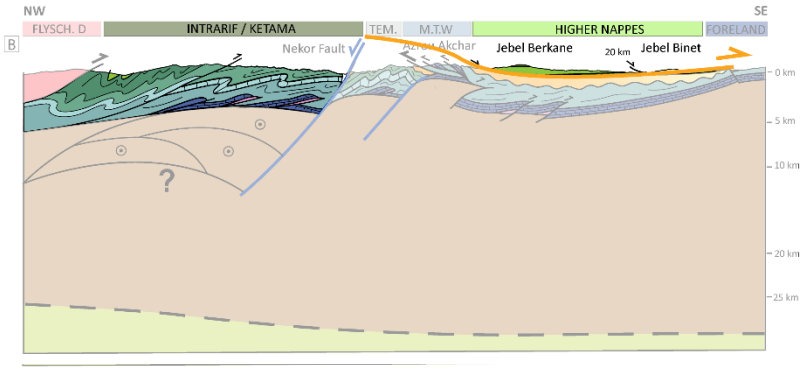


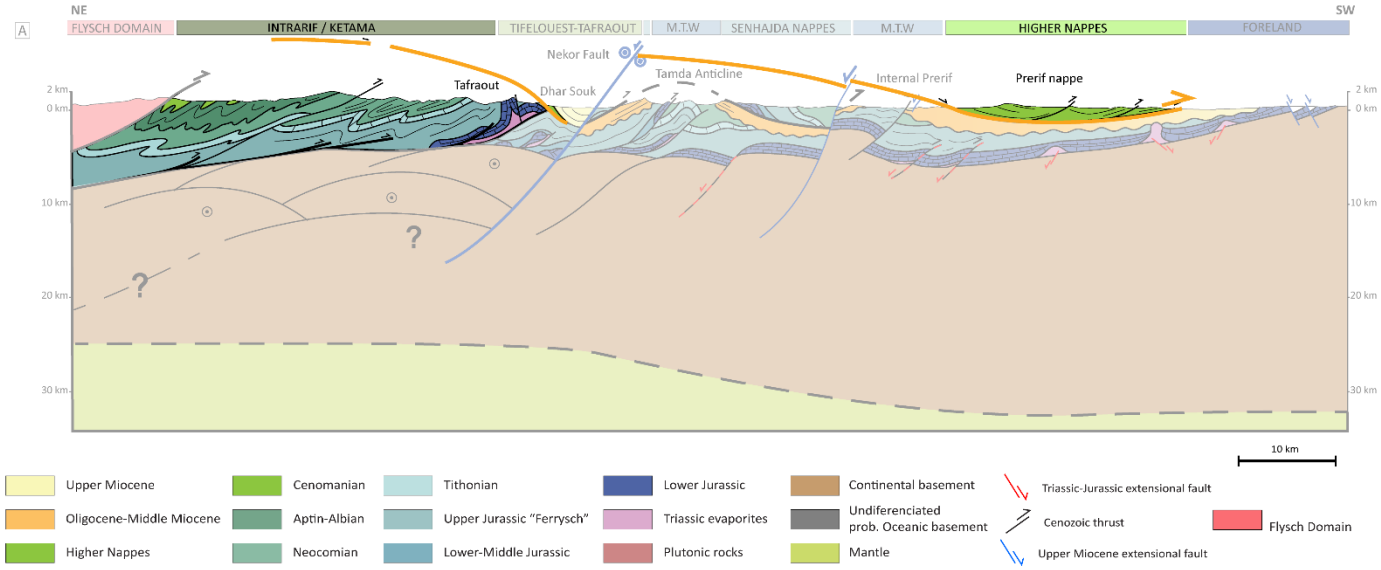
- Structurally higher elements of the External Rif nappe stack.
- Absence of the Oligo-Miocene unconformity observed in the Mesorif.

INTRARIF: KETAMA UNIT AND THE HIGHER NAPPES



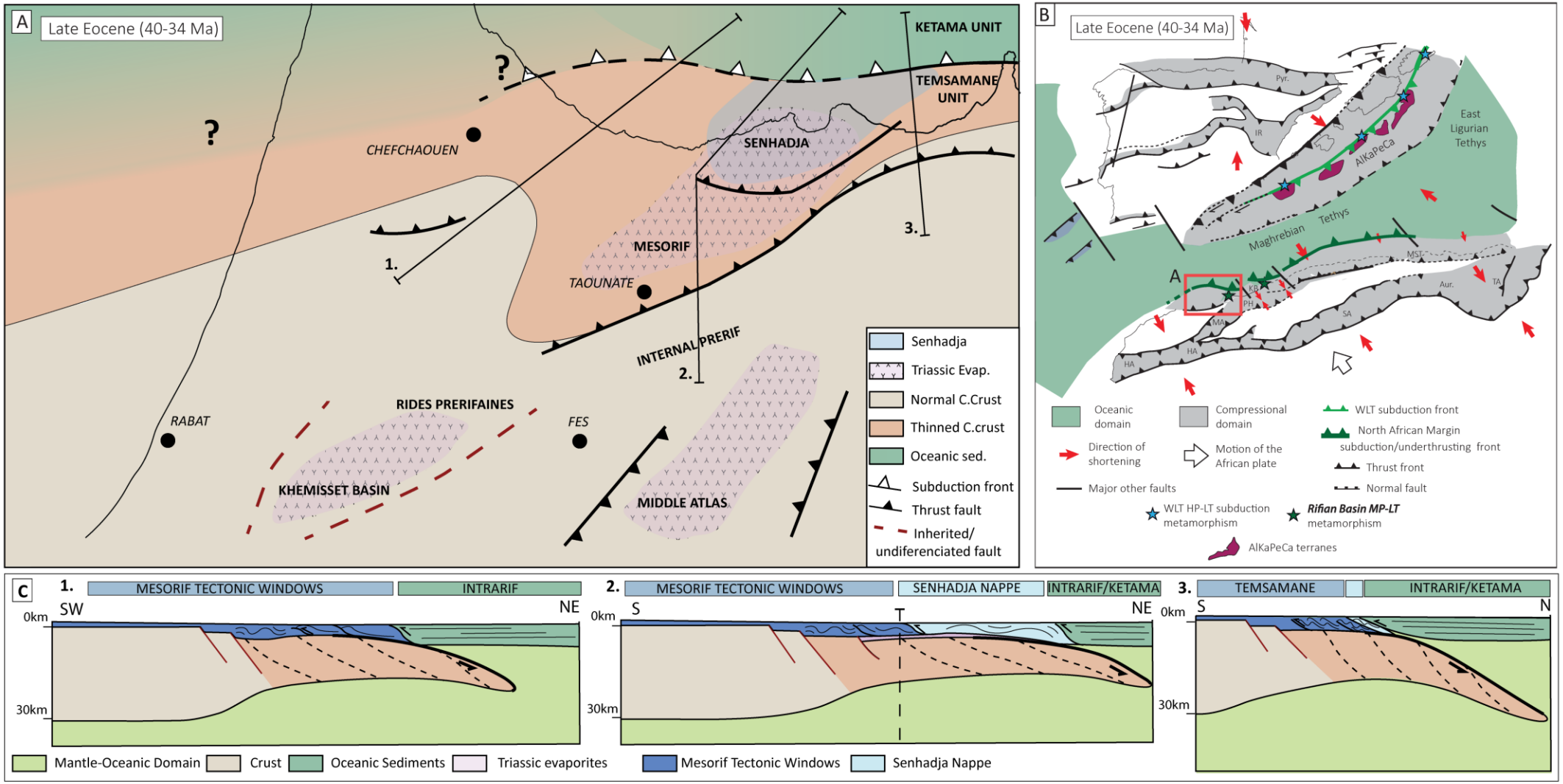






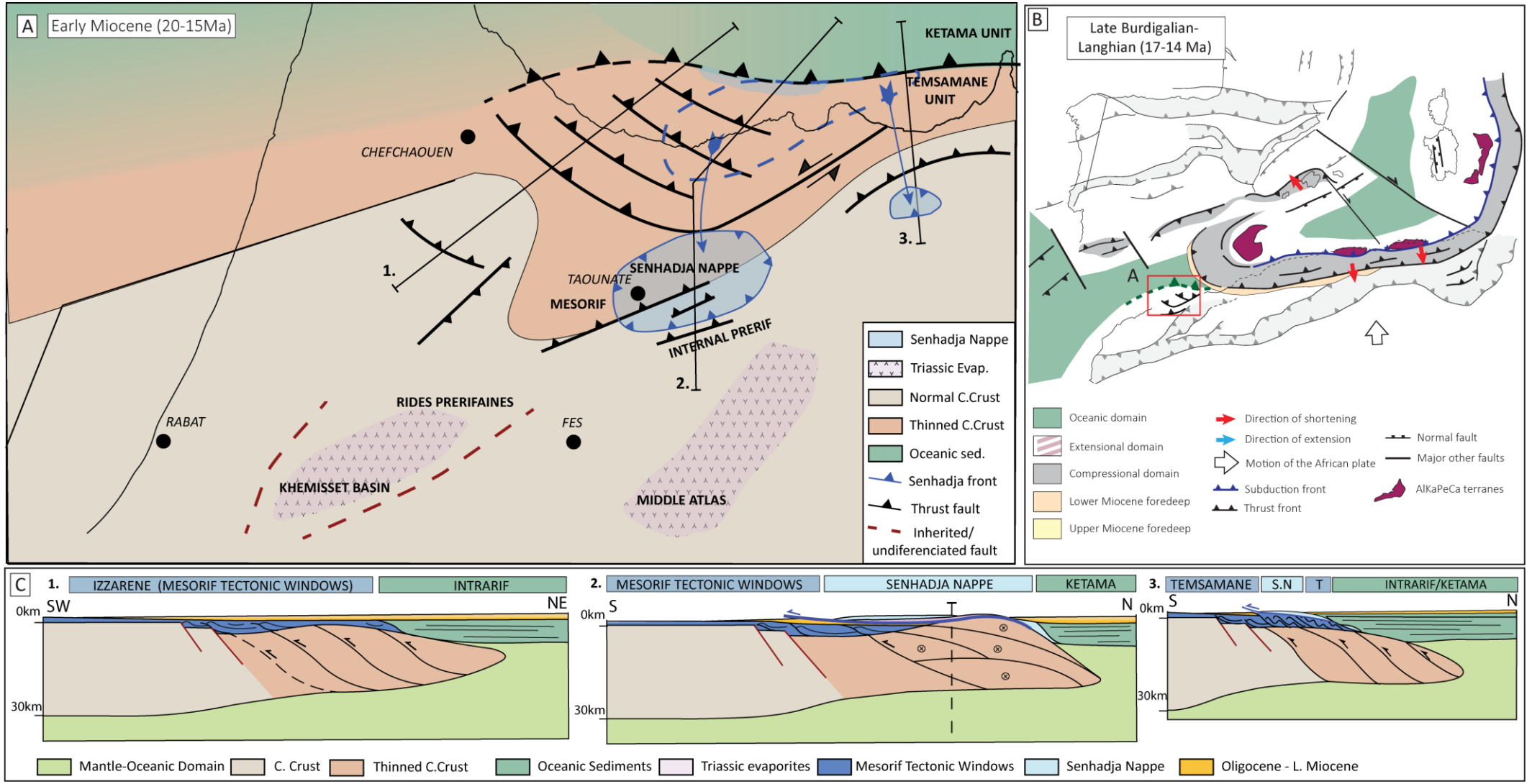
- Corresponds to deep sea basin sediments covering the Maghrebian Tethys.
- Ketama Unit has been folded and foliated during the Upper Miocene.
- The Higher Nappes are large allochthon nappes corresponding to the coverture of the Ketama Unit, detached by gravitational processes.

UPDATED PRE-MIOCENE GEODYNAMIC EVOLUTION



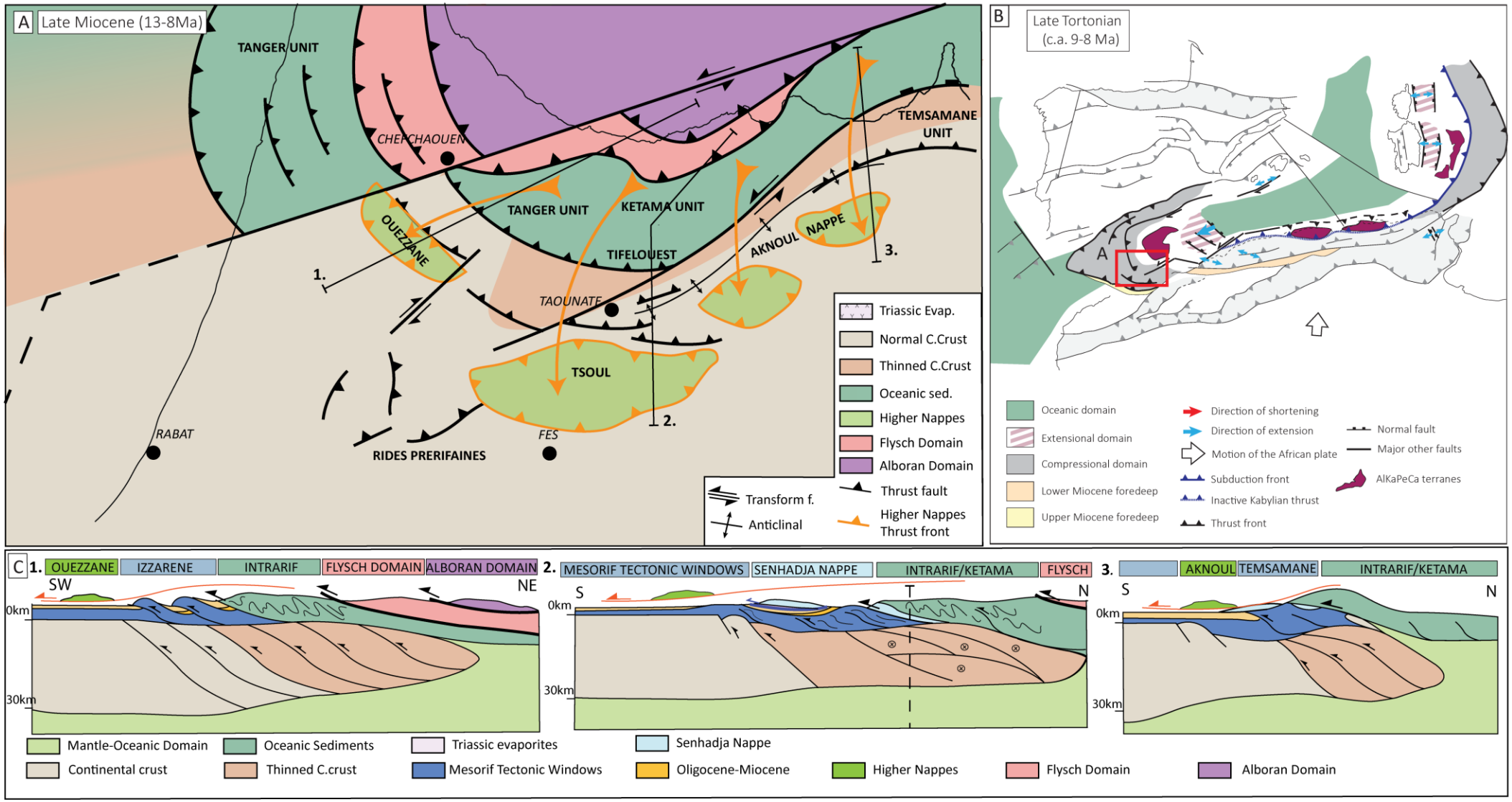
- Early deformation observed below the Oligo-Miocene unconformity in the Mesorif Tectonic Windows.
- Peak of (MP-LT) metamorphism in the Temsamane Unit at possibly 28 Ma, or earlier.
- Presence of an under-thrusting of the continental crust below the Oceanic Domain of the Intrarif.
- Absence of deformation in the “oceanic” domain of the Intrarif.

UPDATED EARLY MIOCENE GEODYNAMIC EVOLUTION



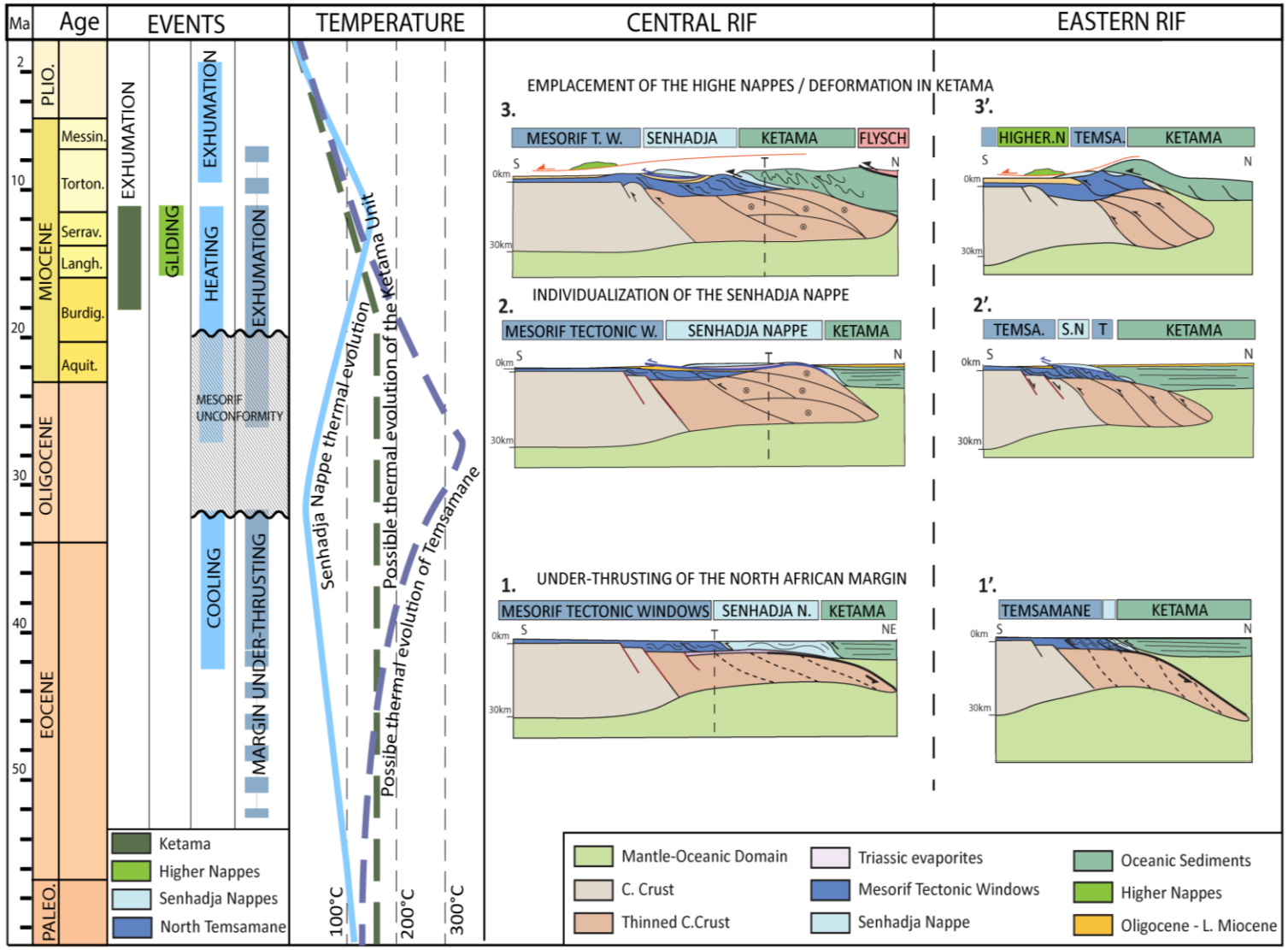
- Stop of the subduction zone and stacking of the continental crust at depth.
- Individualization of the Senhadja Nappe, gliding towards the south due to the important slope generated during the stacking.

UPDATED LATE-MIOCENE GEODYNAMIC EVOLUTION



- Subduction of the Maghrebian Tethys below the Internal (or Alboran) Domain.
- Exhumation of Temsamane and imbrication of the Intrarif (Ketama Unit).
- Detachment and emplacement of the Higher Nappes.

CONCLUSIONS



Late Miocene

- Exhumation of the Temsamane and Ketama Units.
- Emplacement of the gravitationally driven Higher Nappes.

Lower Miocene

- Transition from a subduction to a stacking at depth of the continental crust.
- Individualization and emplacement of the Senhadja Nappe.

Complex pre-Miocene contractional deformation

- Under-thrusting of the North African margin below the Maghrebian Tethys.
- MP-LT metamorphic gradient in the Temsamane Units.
- Oligocene-Miocene Unconformity in the Mesorif.
- Continuous sedimentation in the Intrarif.