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North Africa Research Group
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Assessing the provenance and contribution of local vs regional drainage systems for the Upper Triassic fluvial deposits, High Atlas, Morocco

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The North African Triassic
and
The TAGI play

Field and Core Analysis

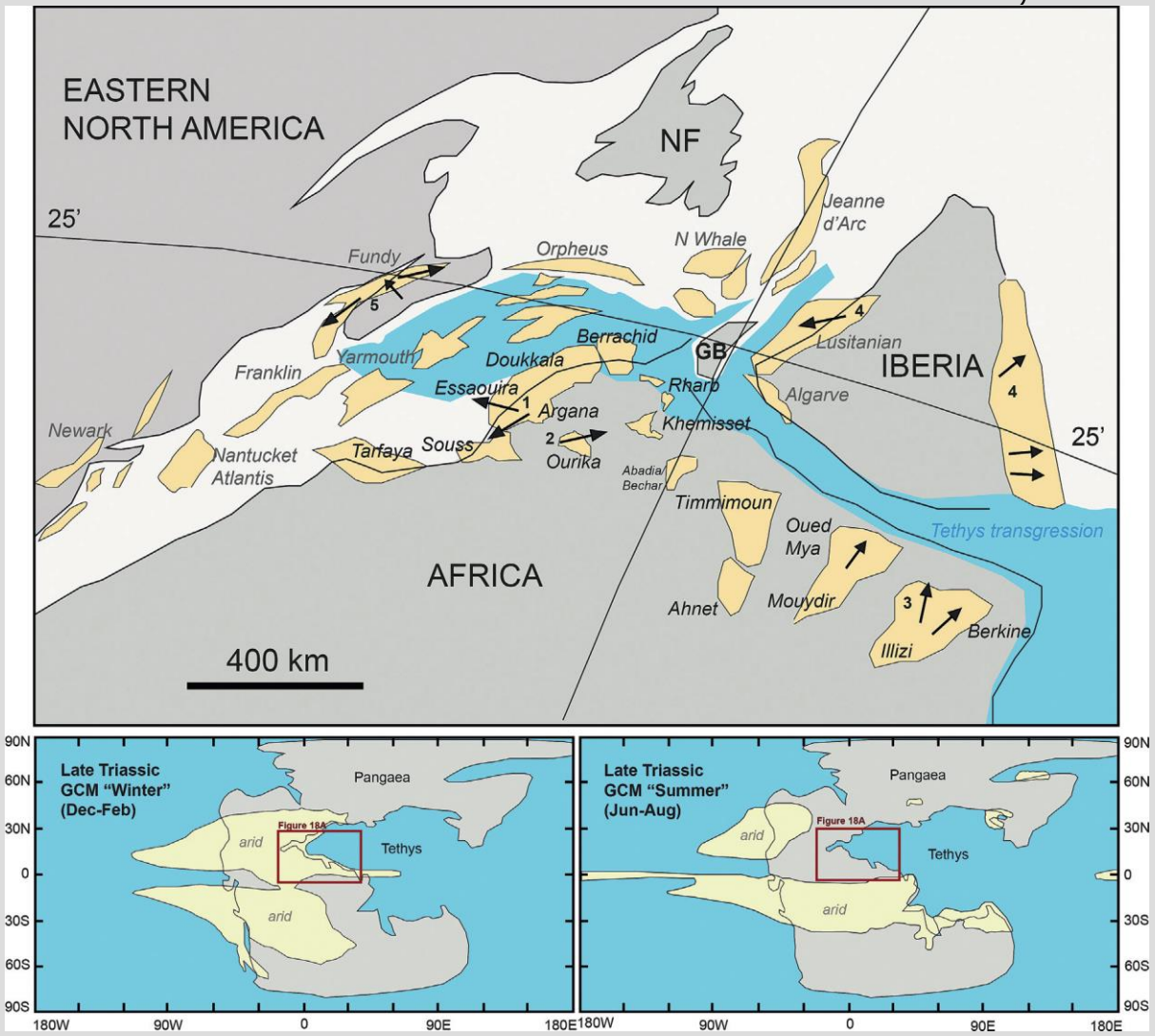
Provenance Study

Paleogeographic and
Reservoir Models

Conclusions and Future Work

Triassic Basins Overview

Mader and Redfern, 2011

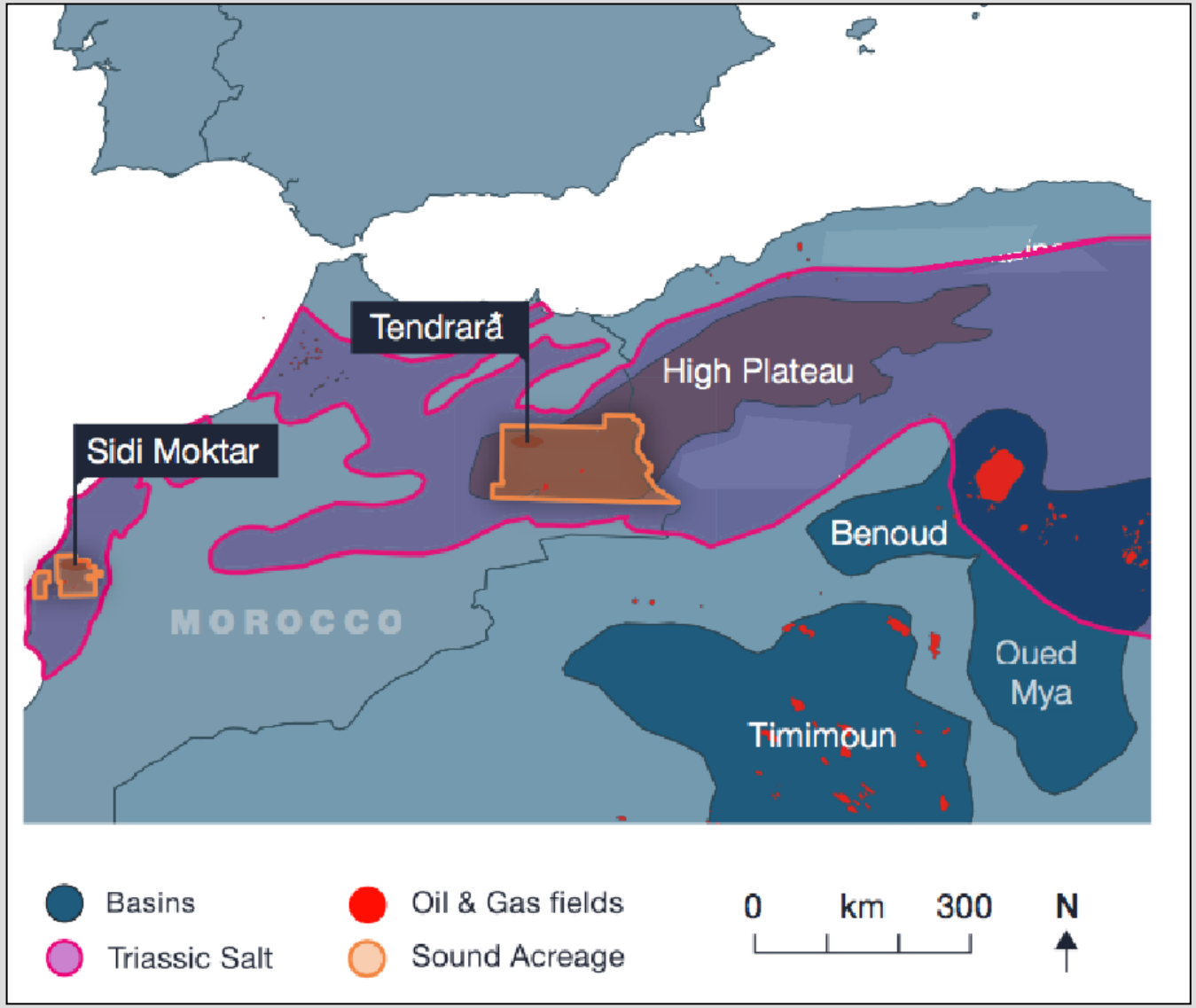


- Formed during rifting associated with the break up of Pangea
- North African Triassic basins located at similar latitude, similar paleo-environmental conditions.
- Continental, with increasing marine influence through time
- Rifted basins, evolving from early syn-rift to late rift

The TAGI Play

- Triassic petroleum play present across North Africa
- Continental sediments deposited within rift basins upon Hercynian Basement
- Silurian or Devonian source rock
- Triassic evaporites provide a regional seal
- Structural traps

The TAGI Play Morocco



Essaouira Basin

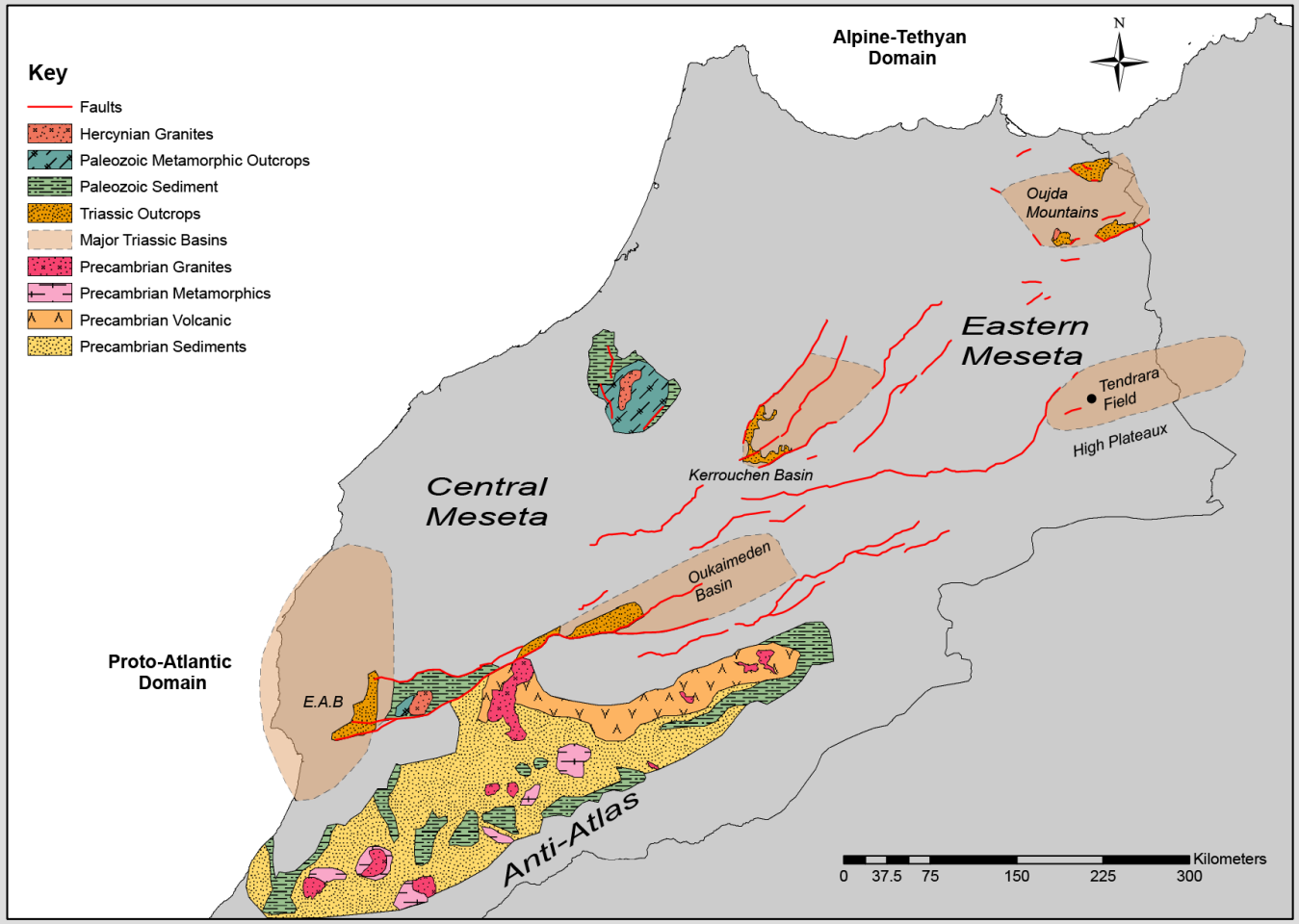
- Producing Meskala Field – gas condensate
- Exploration ongoing

High Plateau

- Tendrara gas discovery, being commercialized

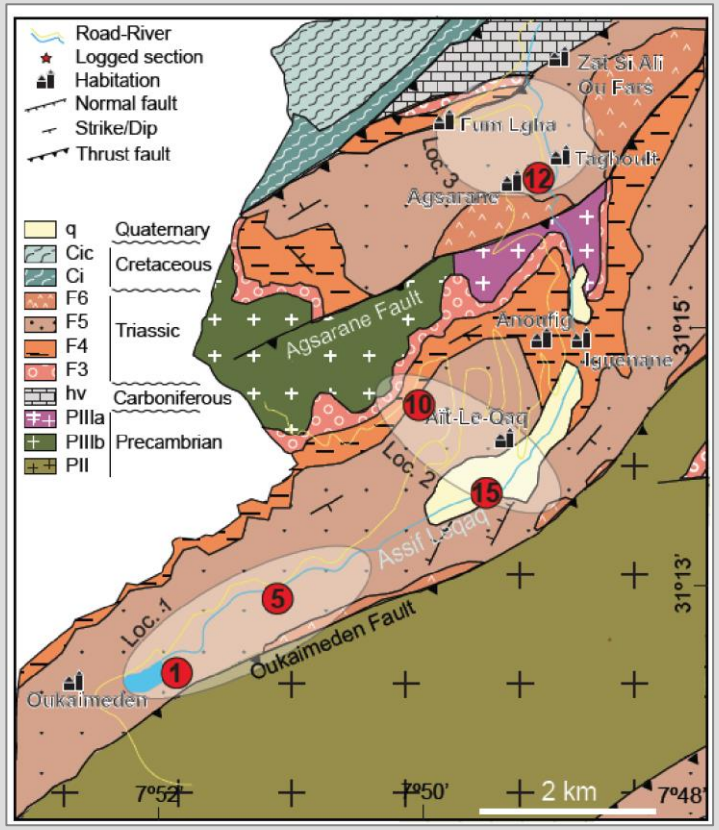
1. The North African Triassic and the TAGI play

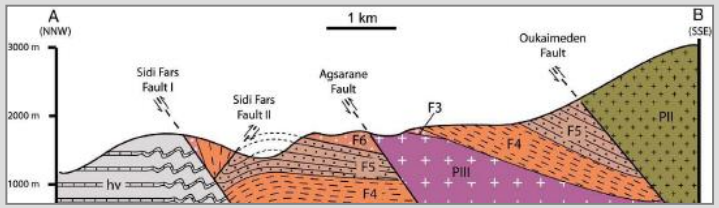
Key Questions

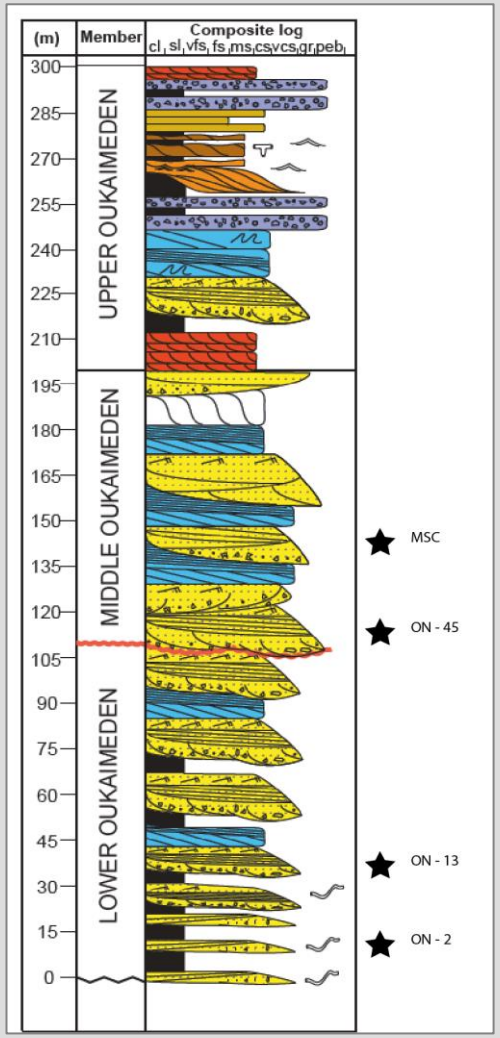


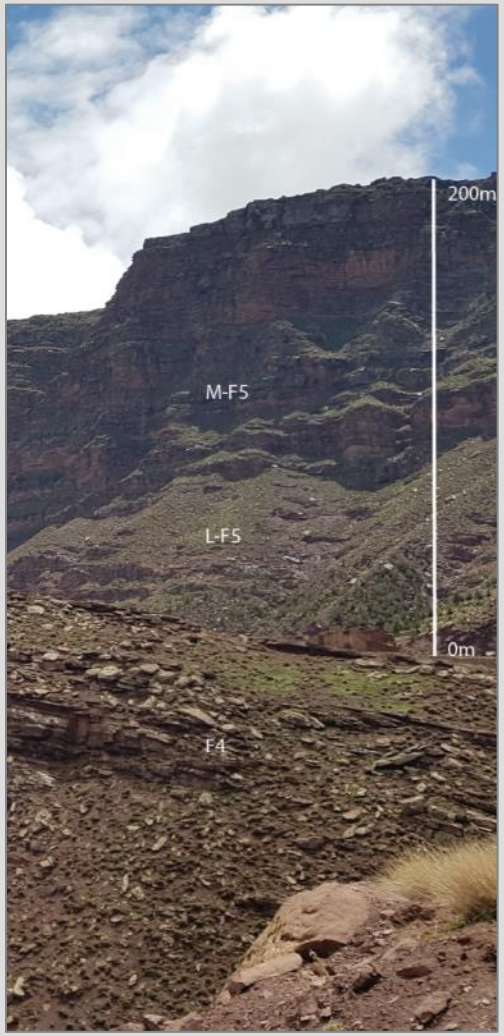
- Can provenance data be used to predict reservoir distribution and quality?
- Did a regional drainage network link the Moroccan Triassic Rift Basins and how far did it extend?
- Can local and regional drainage networks be identified by using provenance data?

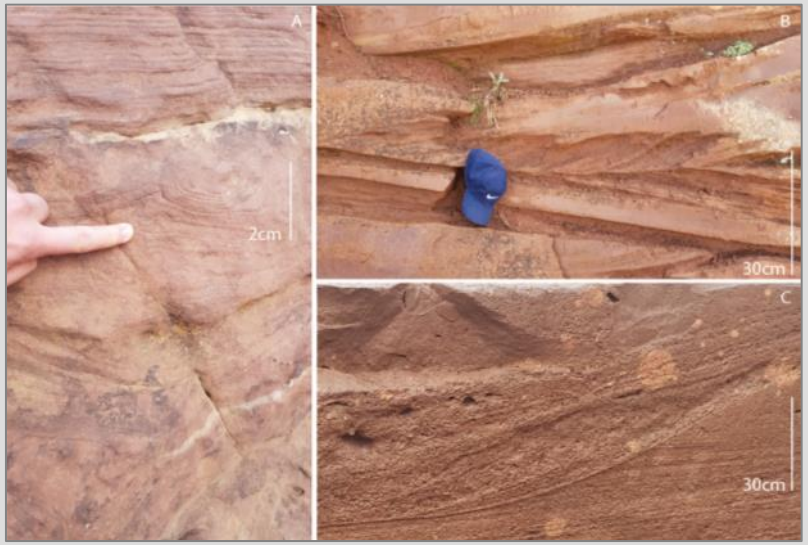
The Oukaimeden Basin











Map, cross section and log from (Fabuel-Perez *et al.* 2009)

The Kerrouchen Basin

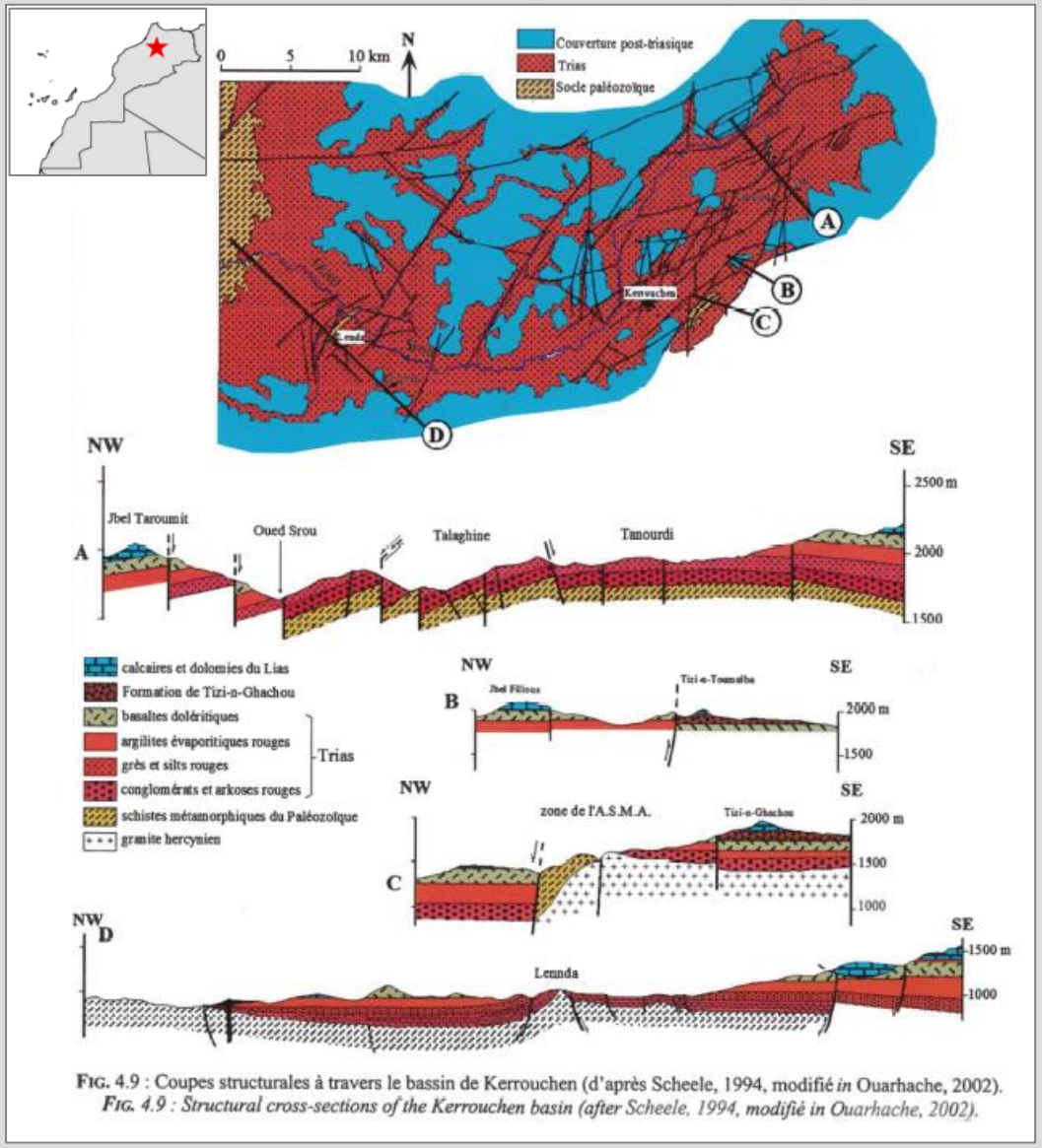
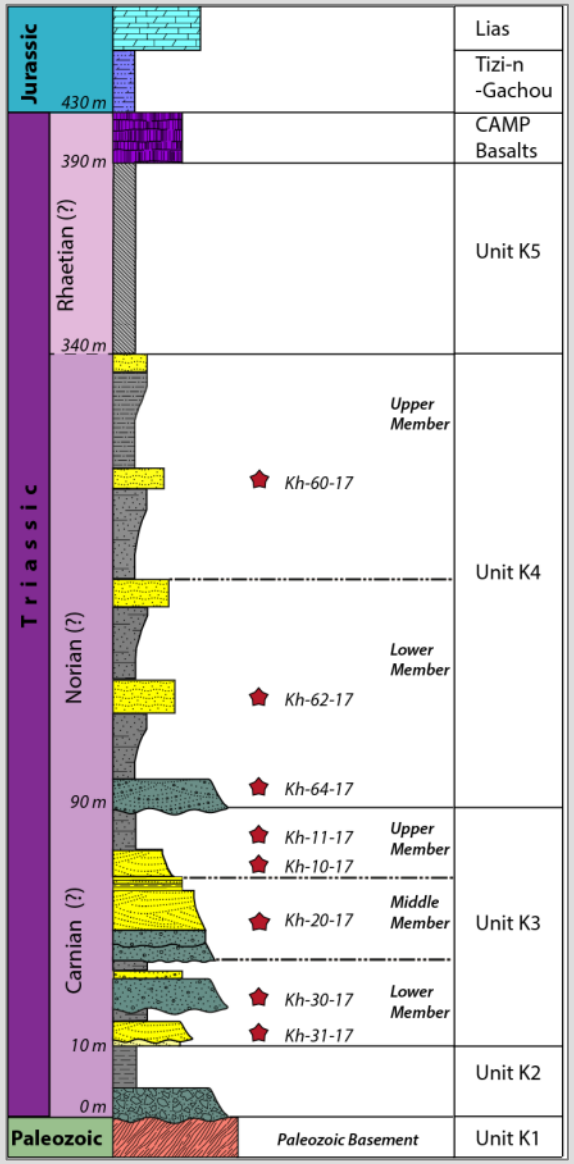
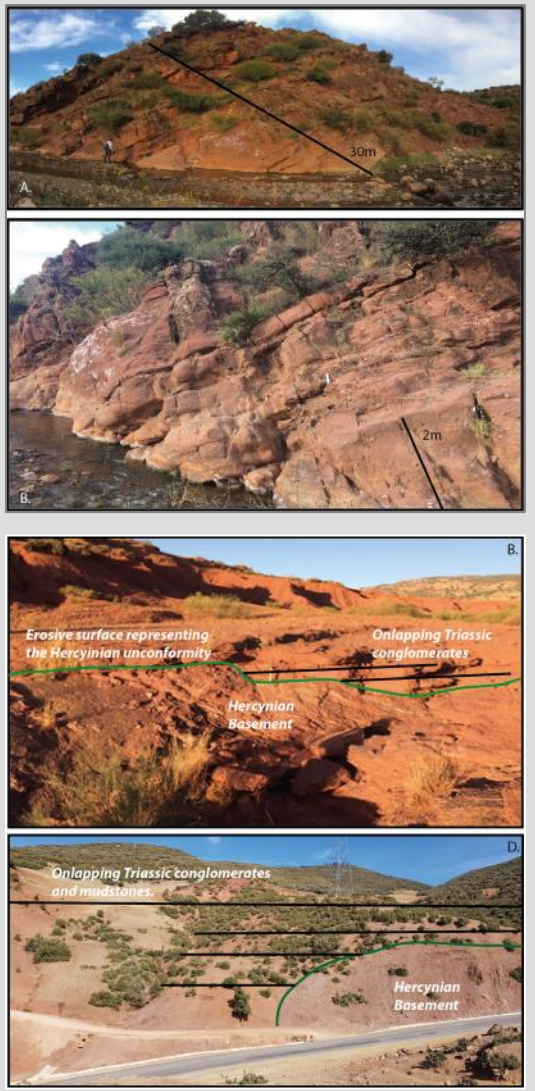
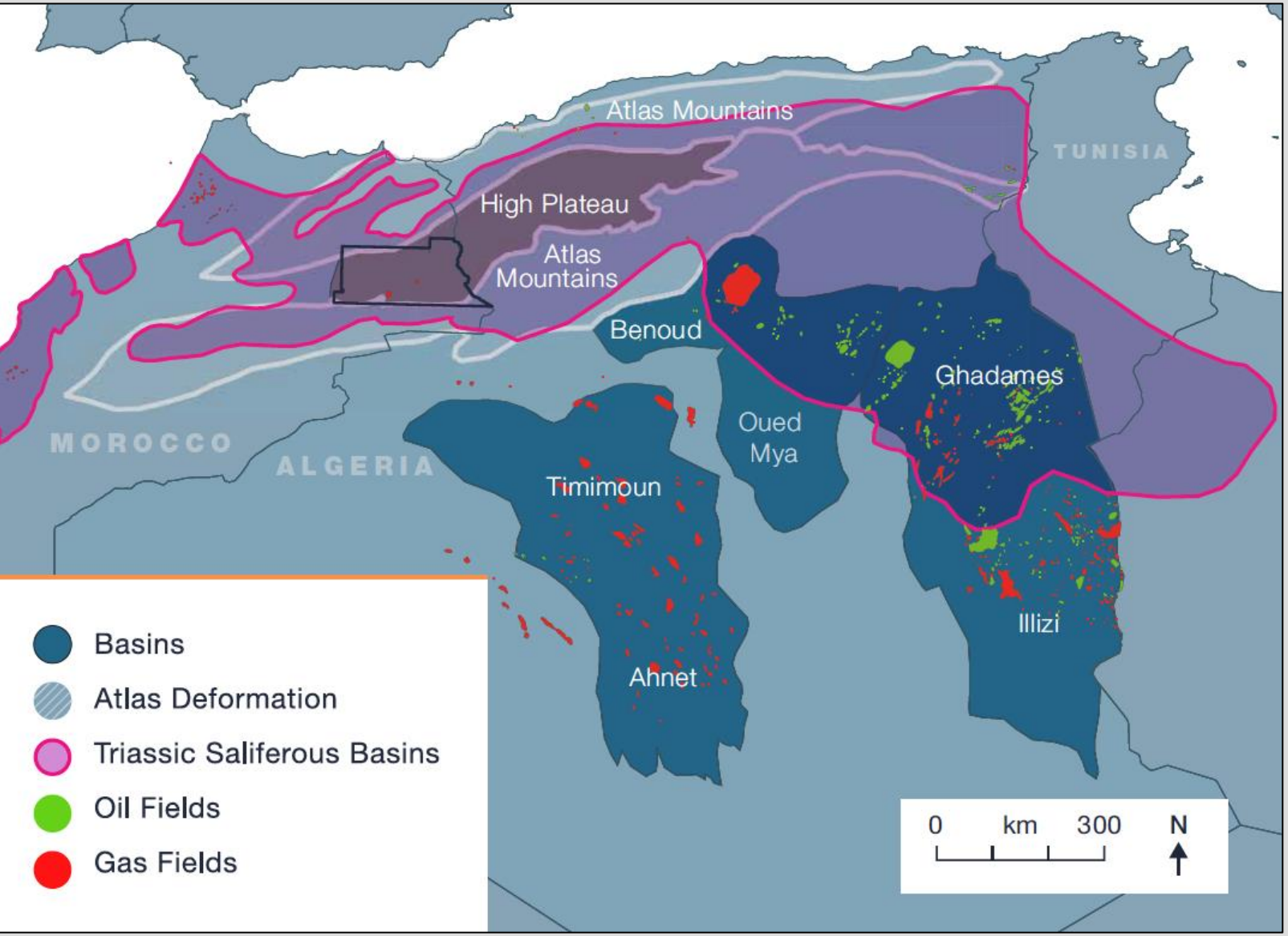


FIG. 4.9 : Coupes structurales à travers le bassin de Kerrouchen (d'après Scheele, 1994, modifié *in* Ouarhache, 2002).
FIG. 4.9 : Structural cross-sections of the Kerrouchen basin (after Scheele, 1994, modifié in Ouarhache, 2002).

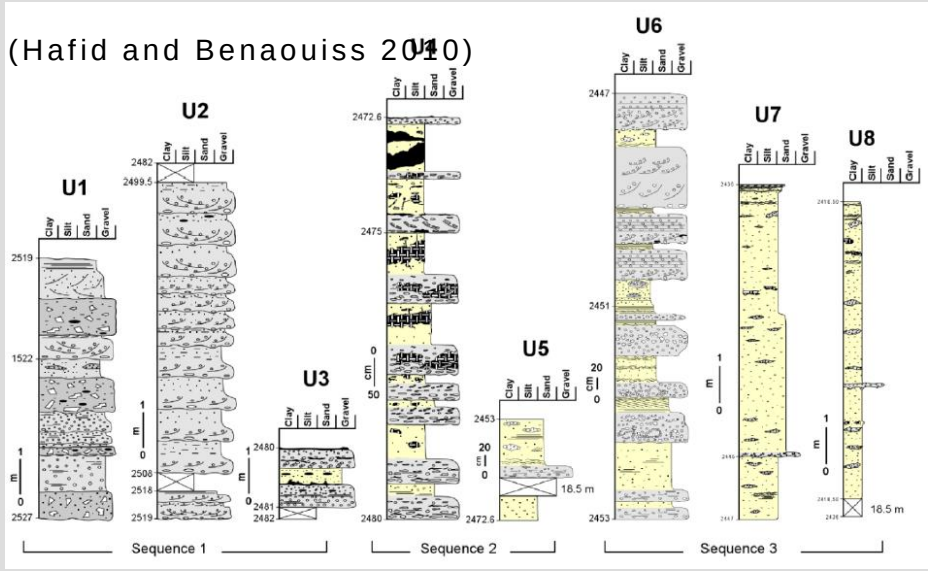




The Tendrara Field

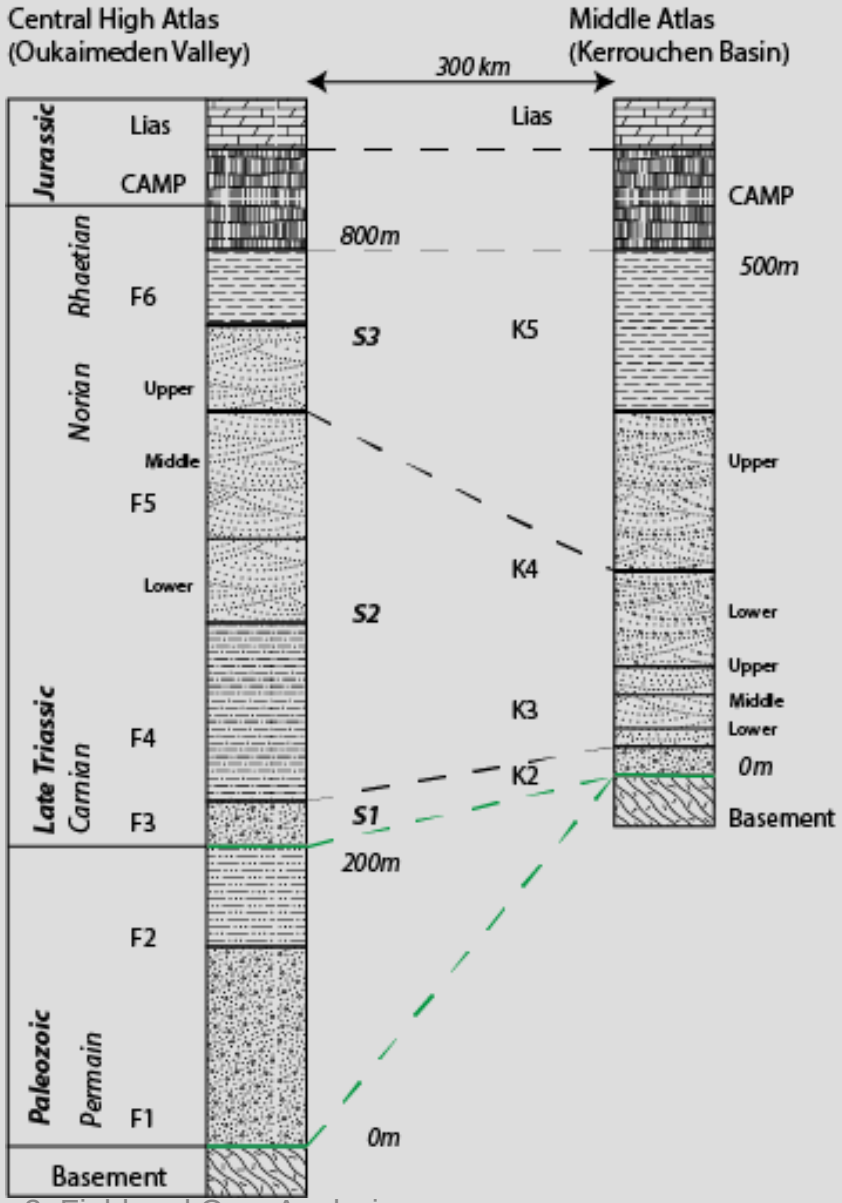


(Hafid and Benaouiss 2010)



- Sound Energy provided access to the TE-6 and TE-8 wells, including core, thin sections and well log data
- Lithofacies associations and depositional sequences identified in the Triassic of Tendrara basin, similar to Kerrouchen lithofacies

Regional Correlation



S1 ***Early syn-rift sequence***
S2 ***Middle syn - rift sequence***
S3 ***Late syn-rift sequence***

Key
Regional unconformity surfaces
Correlatable surfaces
Not to scale

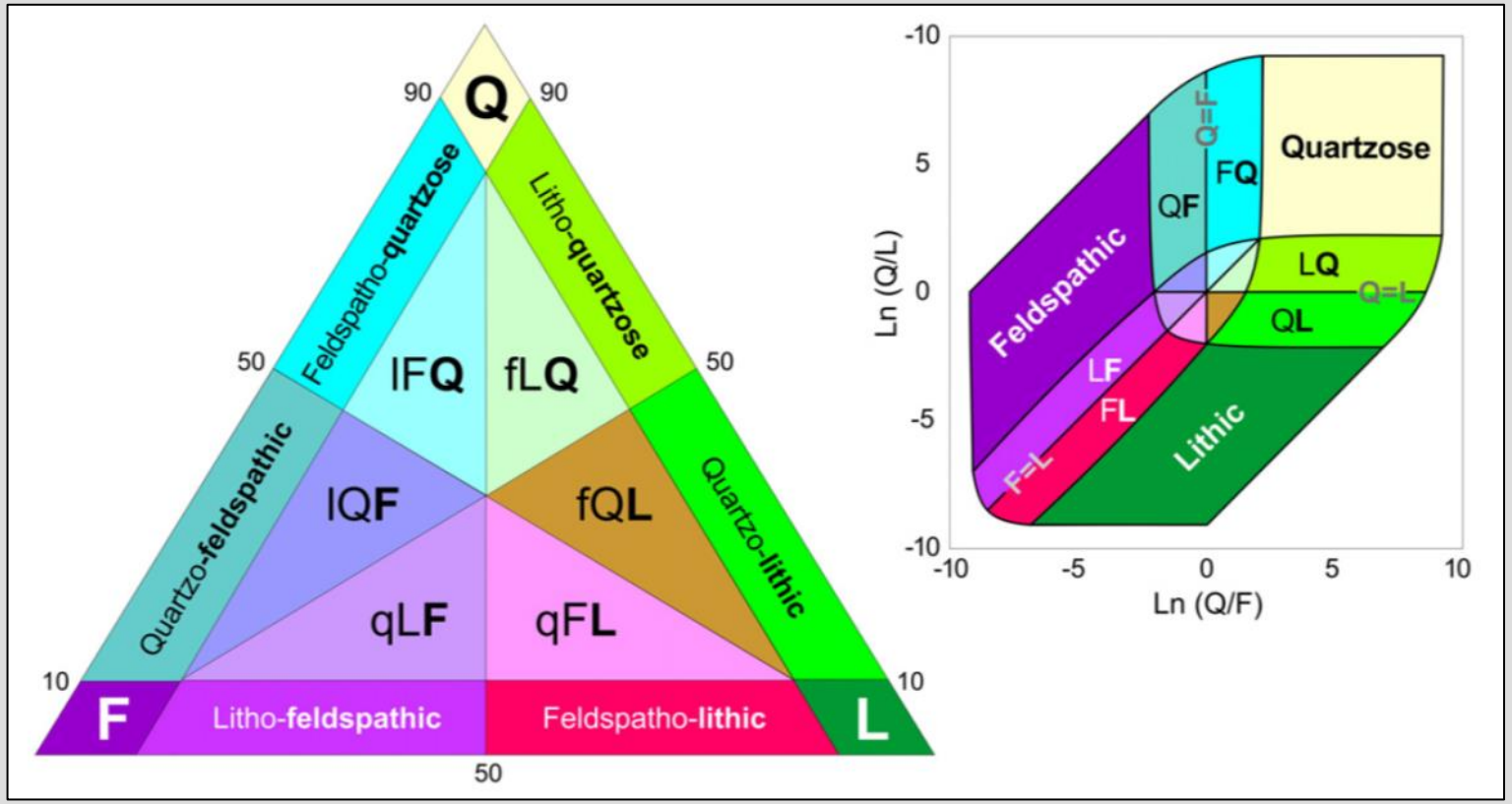
(Fabuel-Perez et.al. 2009, Lorenz 1976, 1988, Ouarhace et.al. 2002, 2012, Ouijidi et.al. 2002)

Key

- Dolomitic Limestone
- Theolitic Basalts
- Interbedded Sandstone - Shales
- Sandstone
- Shale
- Conglomerate
- Paleozoic Basement

- Based on recognition of early, middle and late syn-rift packages
- Provenance study focused on the middle syn-rift, S2

Methodology

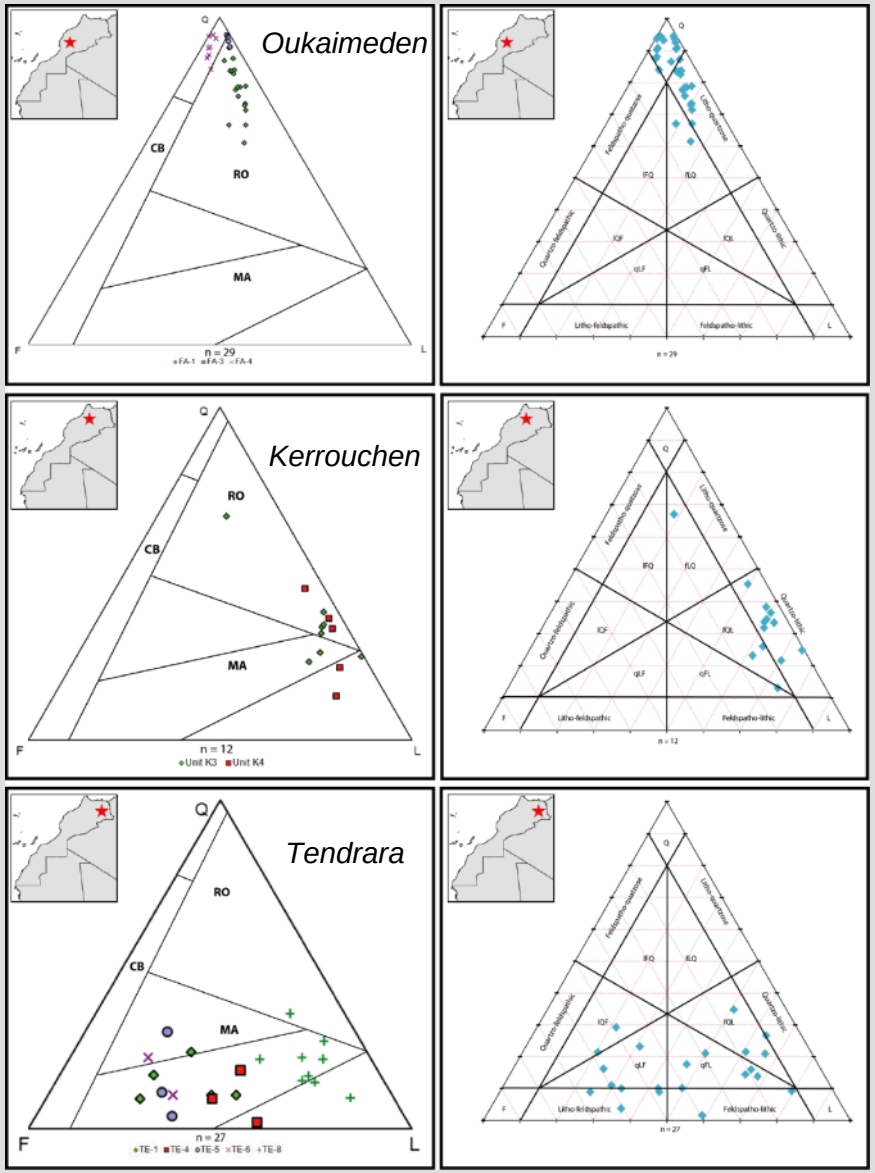


'Detrital framework grains present a ***proxy for the lithological components and variations in the source region'*** *(Garzanti 2016)*

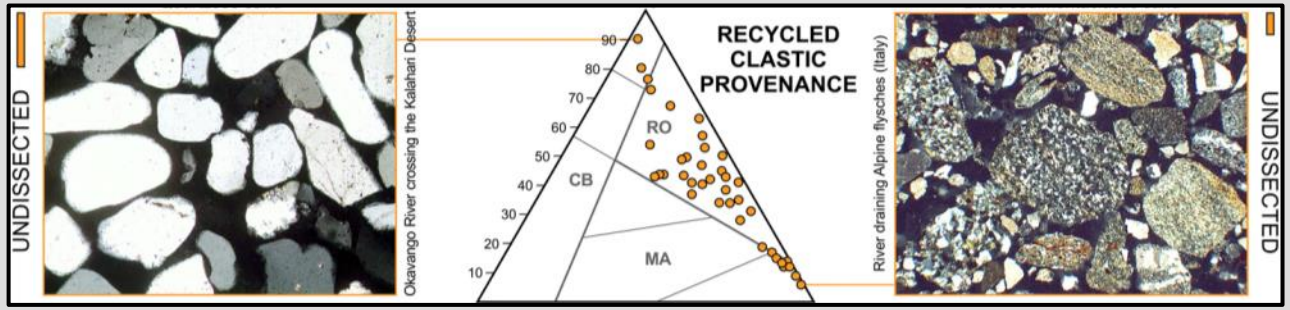
Thin sections analysed
12 Kerrouchen Basin
27 Tendrara Field,
29 Oukaimeden Basin

16 samples were selected for HM analysis

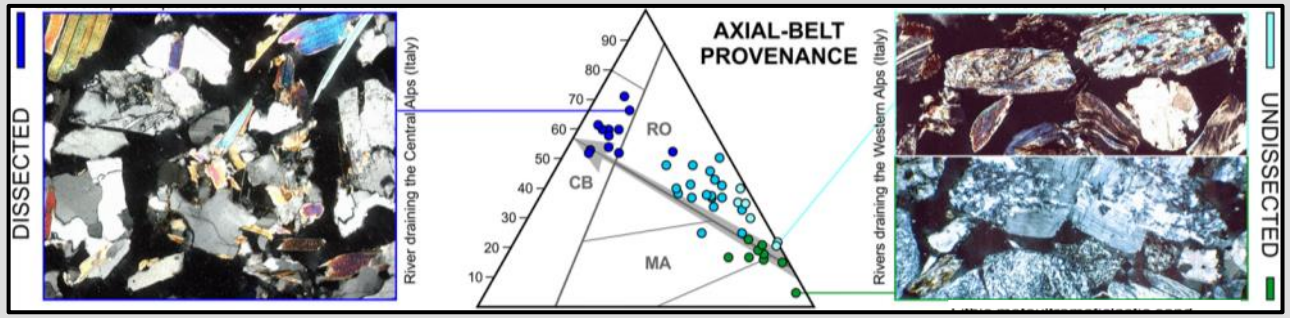
Petrographic Analysis



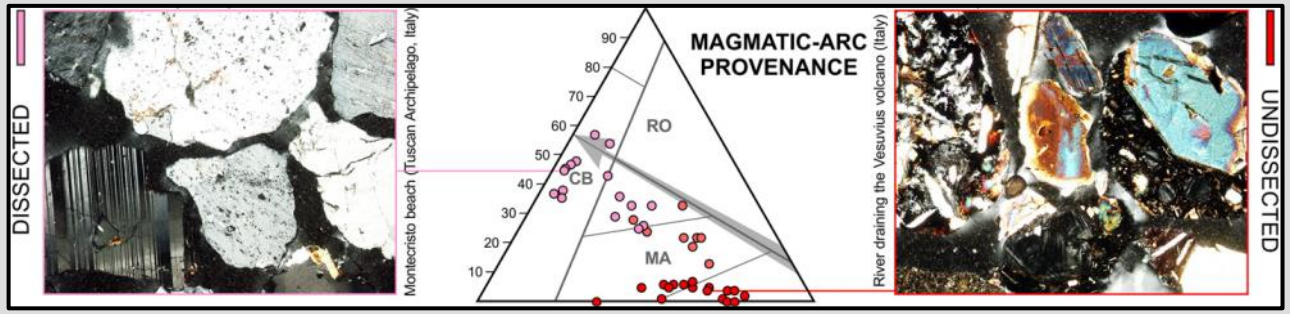
Quartzose sedimentaclastic sands



Quartzo-lithic-volcaniclastic sands

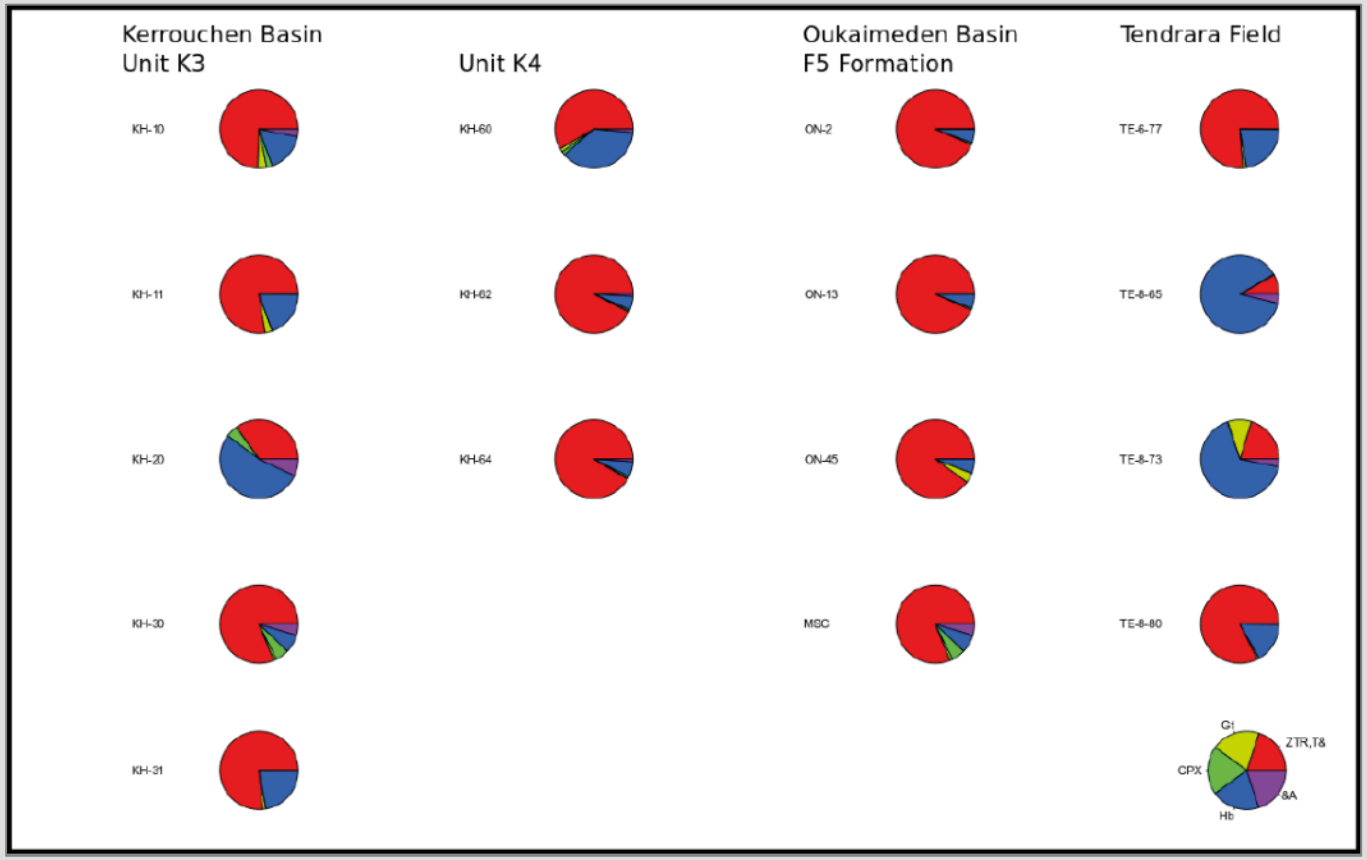


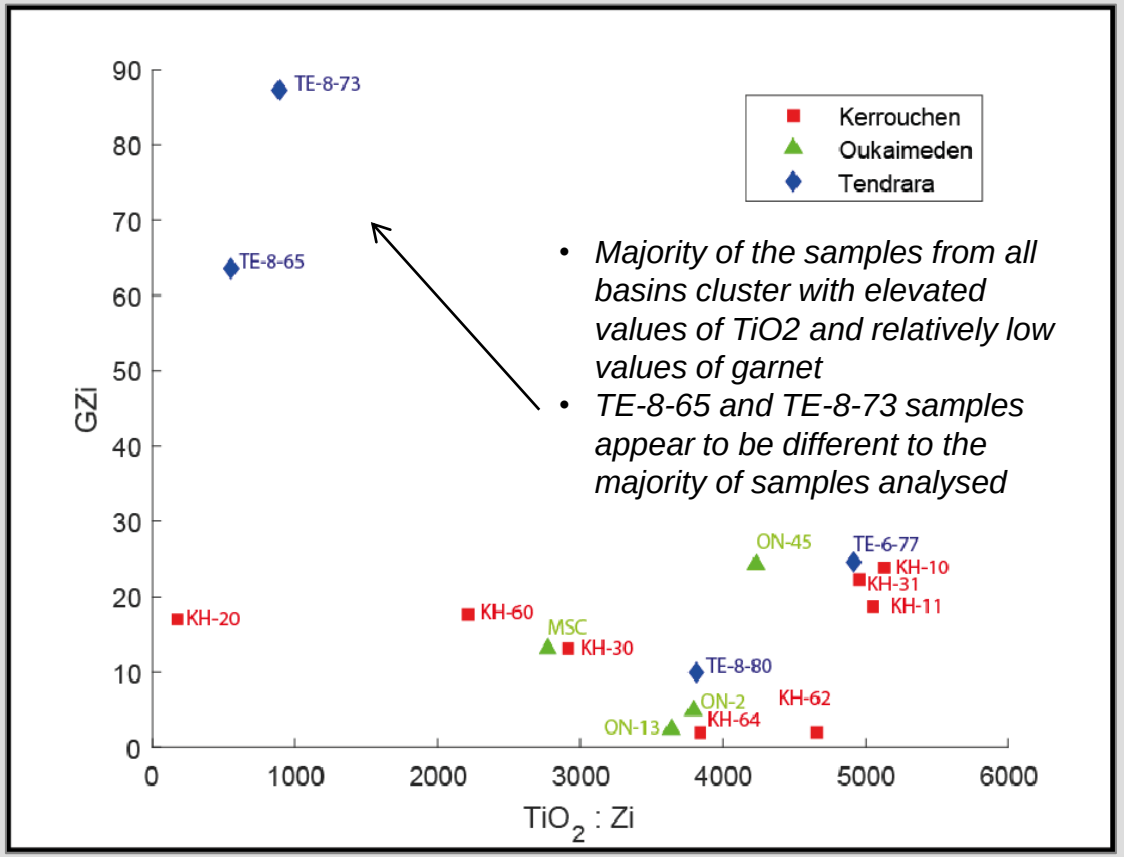
Quartzo-lithic-feldspathic plutoniclastic sands



(Garzanti 2016)

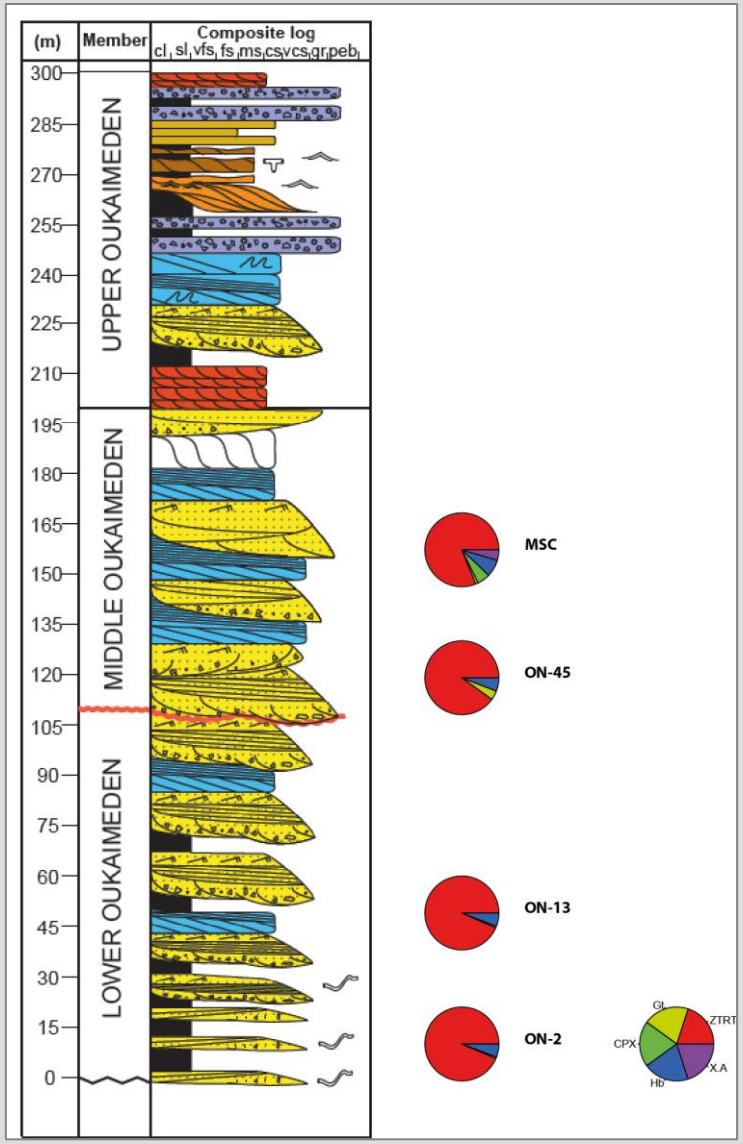
Heavy Mineral Results

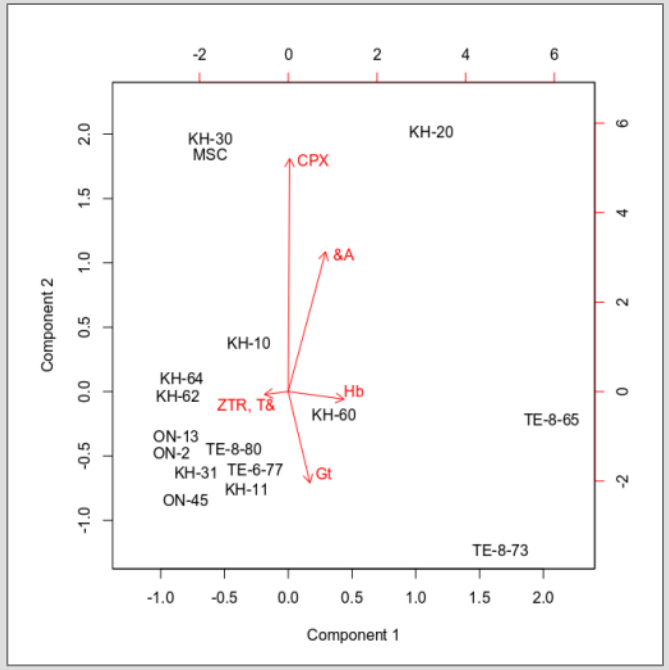


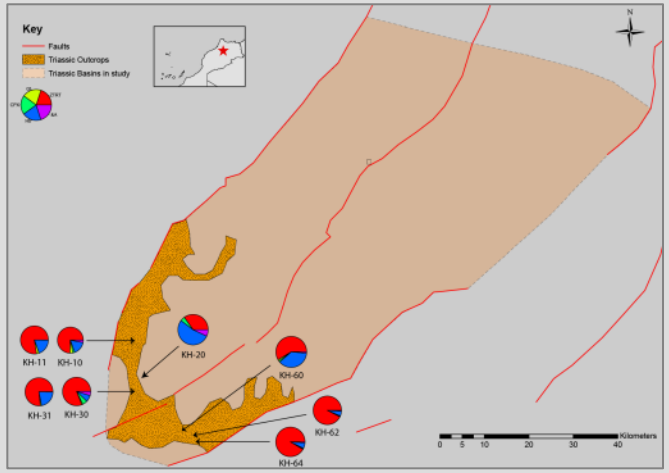


- Majority of samples are dominated by Zrn, Tur, Rt and other titanium minerals such as apatite, with secondary hornblende.
- KH-20, TE-8-65 and TE-8-73 samples dominated by hornblende. Erosion through the sedimentary and felsic cover in the middle Triassic before erosion into underlying mafic units in the late Triassic

Heavy Mineral Analysis

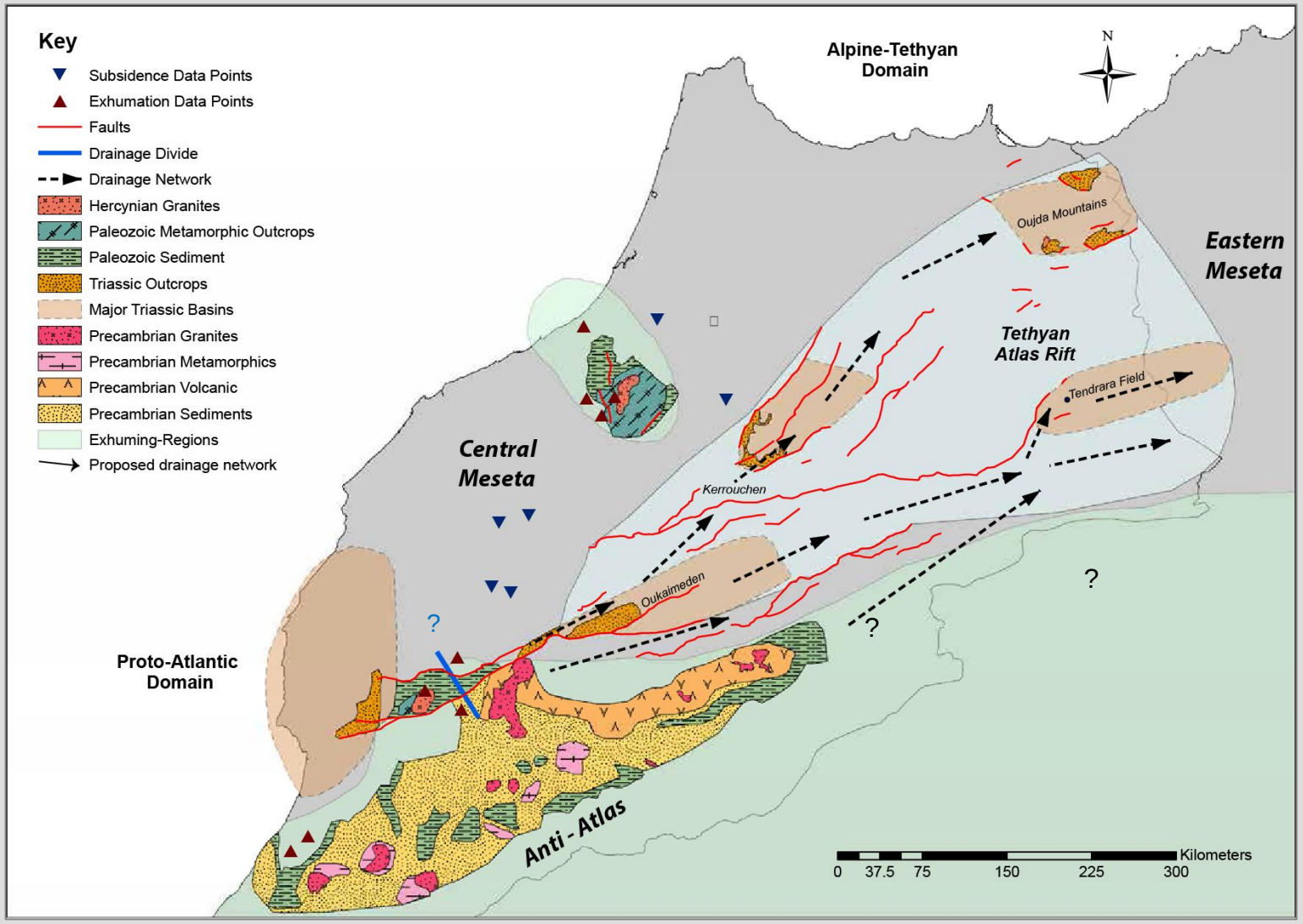






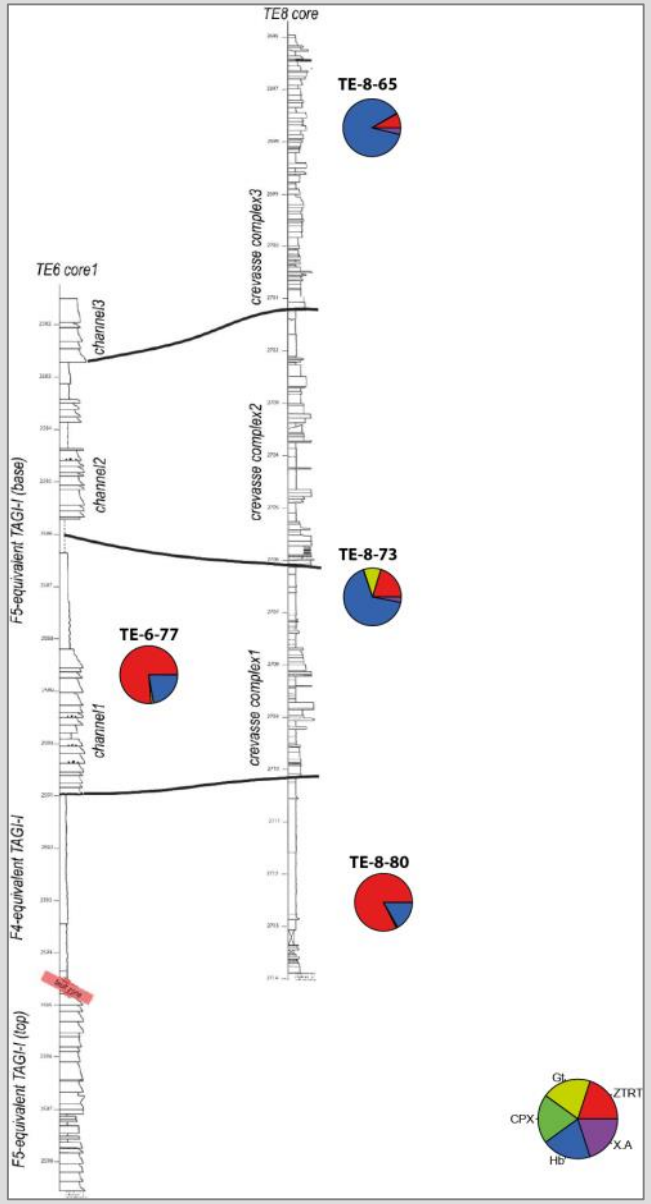
- Two main populations, 2 minor populations
- Stratigraphic trend is for more mafic heavy minerals in younger sediment
- Spatial trend is for more mafic heavy minerals in axial settings

Paleogeographic Model

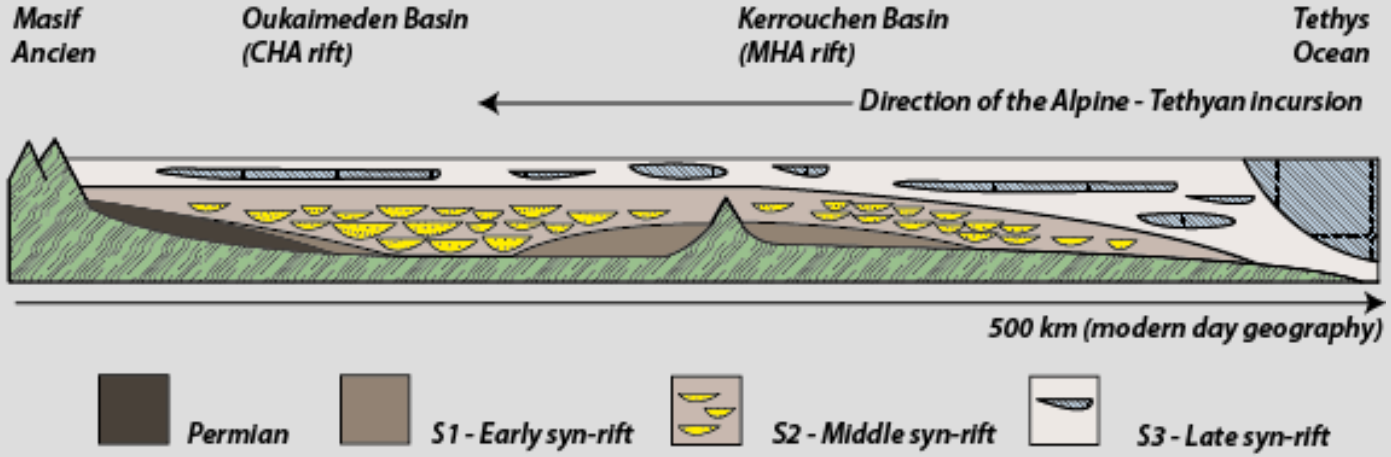


- 2 major populations, 2 minor populations
- Stratigraphic trend is for more mafic heavy minerals in younger sediment
- Spatial trend is for more mafic heavy minerals in axial settings
- Unroofing trend?

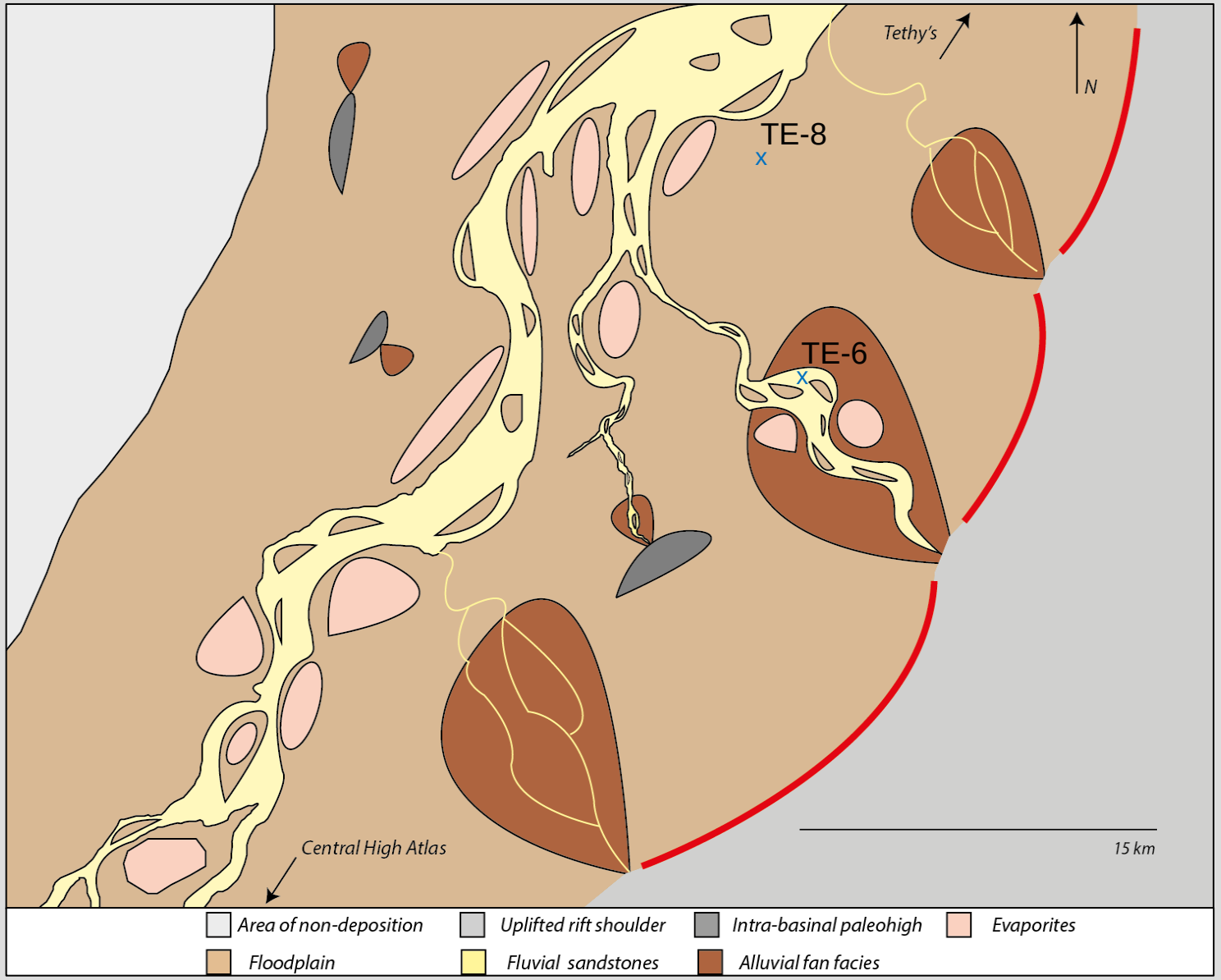
Reservoir Implications



- Correlation tool
- Low extent of burial diagenesis
- Overbank facies of regionally significant fluvial system cored by TE-8
- Lower quality reservoir in wells TE-1 to TE-6



Reservoir Implications



- TE-8 facies interpreted as crevasse channel facies
- Fluvial reservoirs orientated sub-parallel to structural trend
- Minor fluvial reservoirs within marginal alluvial-fluvial systems

Preliminary Conclusions

1. Kerrouchen Basin - outcrop analogue for the High Plateau/Tendrara
2. Probable axial system recognised during the Triassic, orientated parallel to the major rift structures
3. Significant input from lateral drainage off faulted highs
4. Complex reservoir distribution, variable quality
5. TE-1 to TE-6 wells encountered a local alluvial-fluvial system based on both the provenance and facies analysis
6. TE-8 drilled into reservoirs with a different style and provenance, potentially the distal equivalent of an axial system

Future Work – Aims

- Understand the extent of the Triassic Rift Fluvial Systems and reconstruct the paleogeography of the Moroccan Triassic to map out the TAGI play
- Did the Massif Ancien prevent the Western *(Argana)* and Eastern *(Oukaimeden)* High Atlas Rift Basins from linking, and how far North did this drainage divide extend?
- Link variations in provenance to variations in reservoir quality in the TAGI play

Objectives

- Improved understanding of the distribution of Triassic sediments across Morocco
- Improve understanding controls on basin development and depositional system evolution
- Develop workflow for using provenance data as a tool in exploration and development
- GDE Maps for the TAGI play across Morroco

Phase 1: Understanding the depositional systems

- Mapping and additional field analysis of the Kerrouchen Basin
- Fluvial System Modelling with Professor Martinius, TU Delft
- Integrating subsurface and field data with samples collected by previous workers into a regional stratigraphic framework
- Extensive sampling of outcrop and cores for high resolution integrated provenance study

Phase 2: Provenance Analysis

- Source rock density study to identify likely source regions for HM and geochronological analysis
- Varietal heavy mineral study utilising Raman Spectroscopy sand body correlation
- Detrital zircon geochronology of source and sink samples
- Detrital Apatite or K-Feldspar dating to identify the reworked signal
- Integrated source to sink analysis combining the multiple datasets
- Develop workflow for using provenance as an exploration and development tool

Future Projects

- Algeria
- Offshore sub-salt
- Additional uplift modelling for the Eastern Meseta
- Integrated stratigraphic framework

Sponsors

Special thanks to Sound Energy for access to core from the Tendrara field and to Jason Canning, Sound Energy, for the helpful discussions.

References

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