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Triassic Depositional Style, Provenance and the impact on Reservoir Distribution

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Research Themes

1. Triassic Depositional Systems
2. Local versus Regional Provenance Signals
3. Impact of depositional style and provenance on reservoir quality

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Research Theme 1:
Triassic Depositional Systems

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Background

Carnian

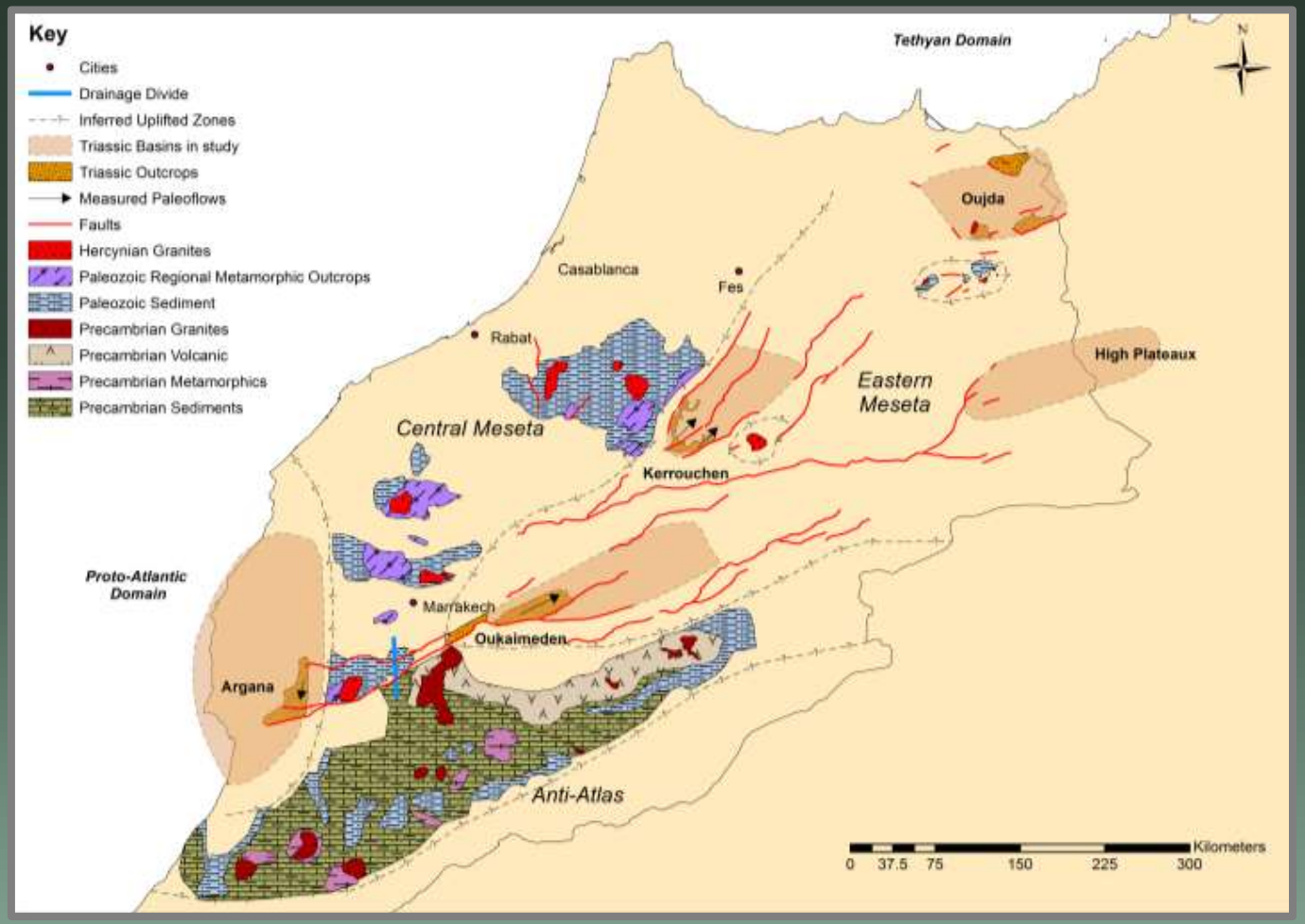
Norian

Early Jurassic

(Scotese, 2016)

Kerrouchen Basin

Location of Kerrouchen Basin in relation to the remnant Variscan chain and major Triassic basins of Morocco



Major Structures

- Several major faults trending NNE to ENE
- Lenda Anticline formed by reinversion of Variscan faults – Triassic intra-basinal high

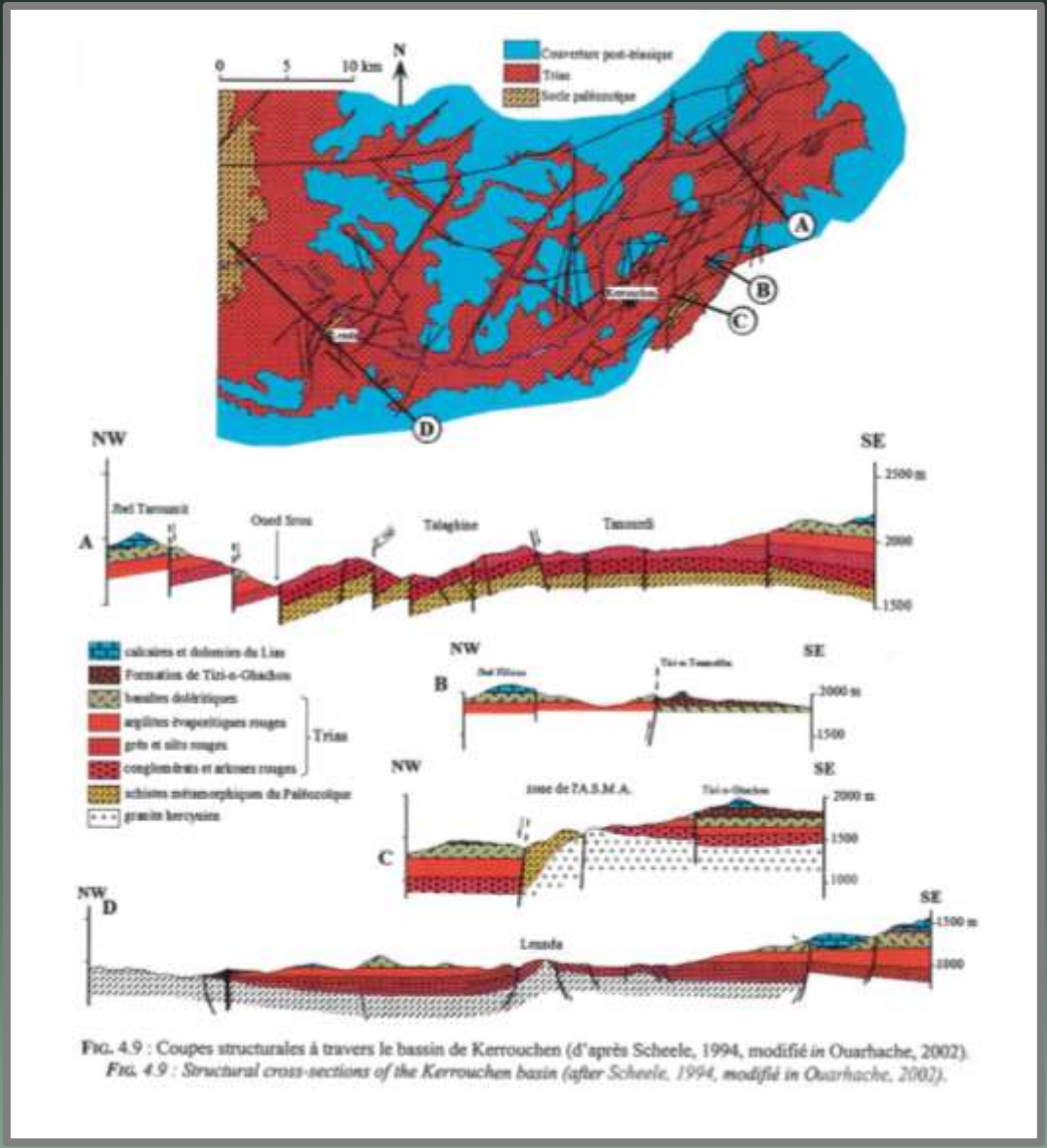


FIG. 4.9 : Coupes structurales à travers le bassin de Kerrouchen (d'après Scheele, 1994, modifié *in* Ouarhache, 2002).
FIG. 4.9 : Structural cross-sections of the Kerrouchen basin (after Scheele, 1994, modifié in Ouarhache, 2002).

Regional Tectono-Stratigraphy

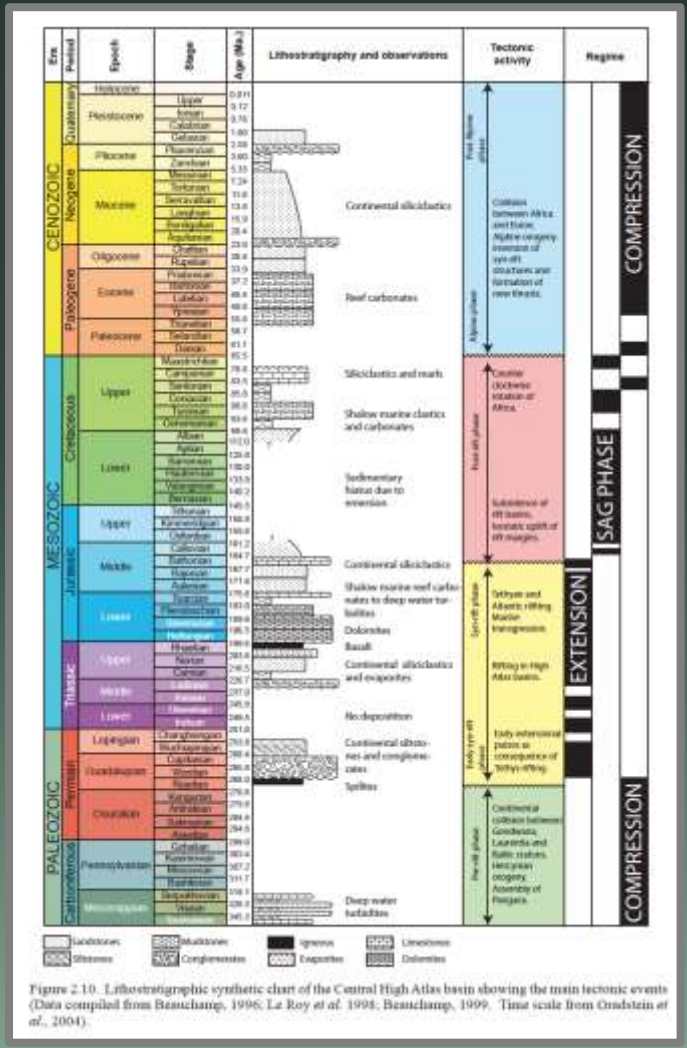
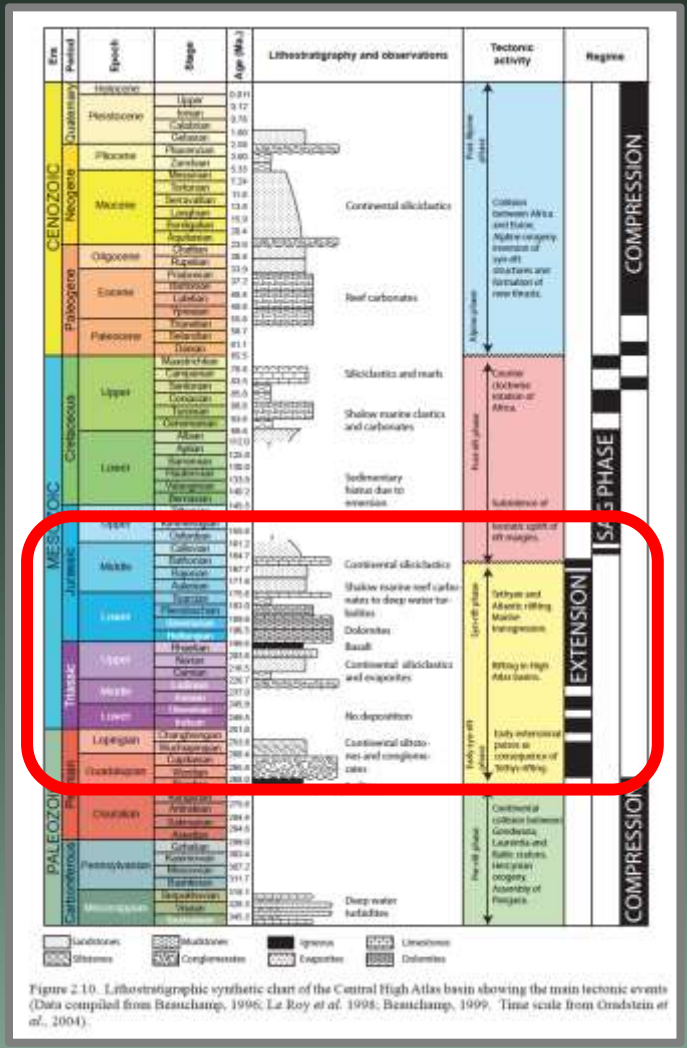


Figure 2.10. Lithostratigraphic synthetic chart of the Central High Atlas basin showing the main tectonic events (Data compiled from Beauchamp, 1996; Le Roy *et al.* 1998; Beauchamp, 1999. Time scale from Ordstein *et al.*, 2004).

- Triassic rifting due to the break up of Pangea
- Carnian to Rhaetian deposition of continental siliciclastic and evaporites
- CAMP Basalts mark the Triassic – Jurassic Boundary

(Fabuel-Perez, 2008, p.58)

Regional Tectono-Stratigraphy



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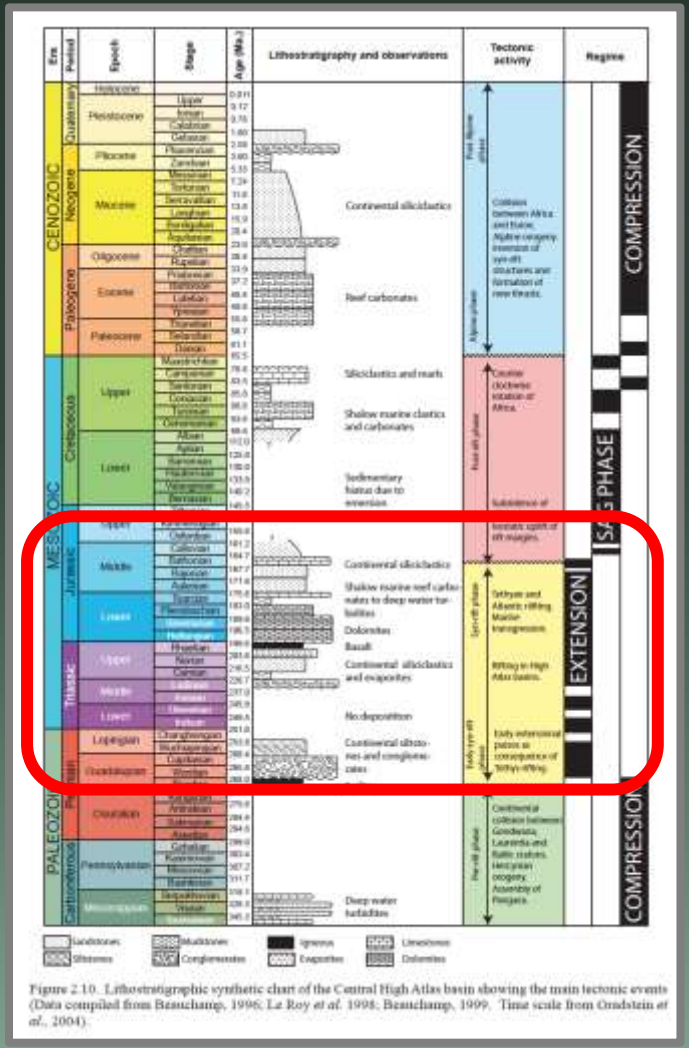
Regional Tectono-Stratigraphy



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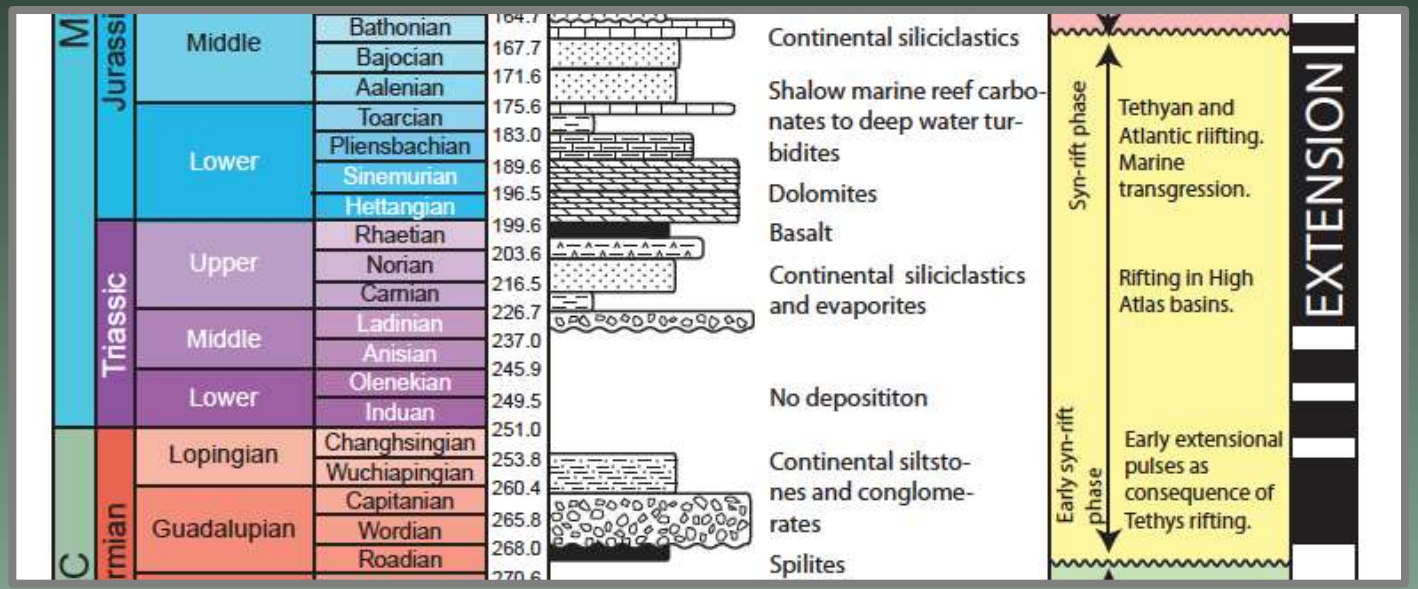
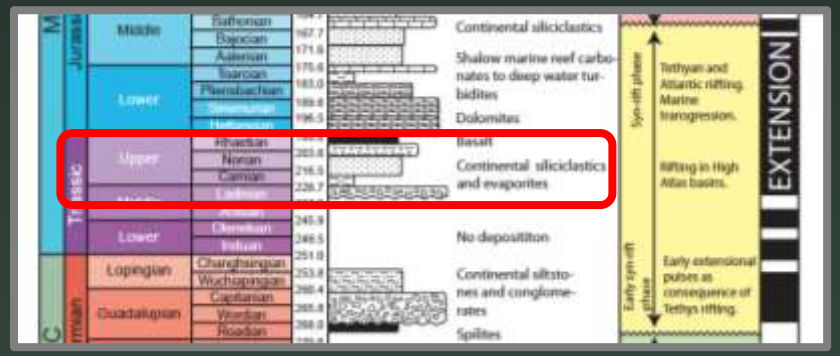
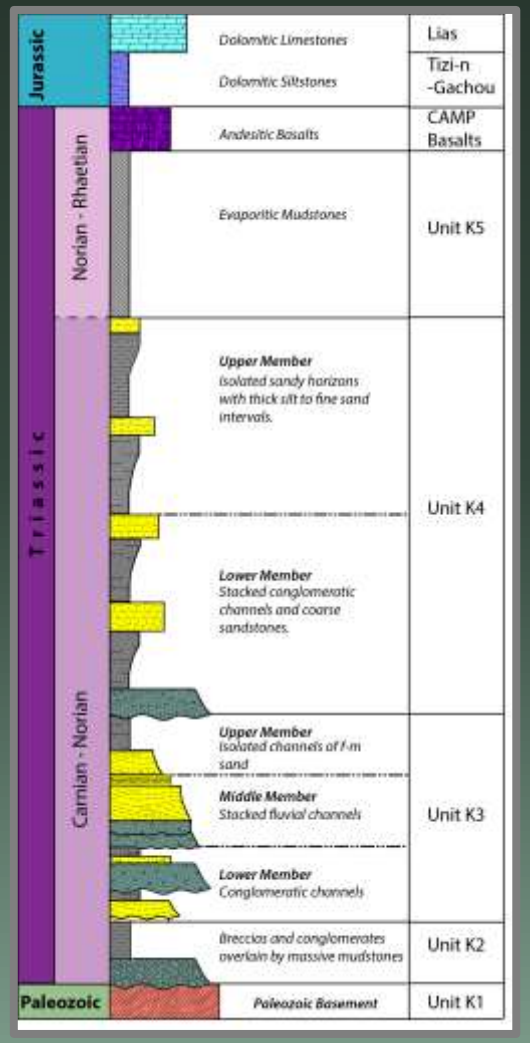


Stratigraphy of the Kerrouchen Basin



Three depositional systems within Triassic Kerrouchen Group

1. Transverse Alluvial System – K2
2. Axial fluvial system - K3
3. Transverse Alluvial - Fluvial System K4



(Modified from Lorenz 1976, Ouarhache 2012)

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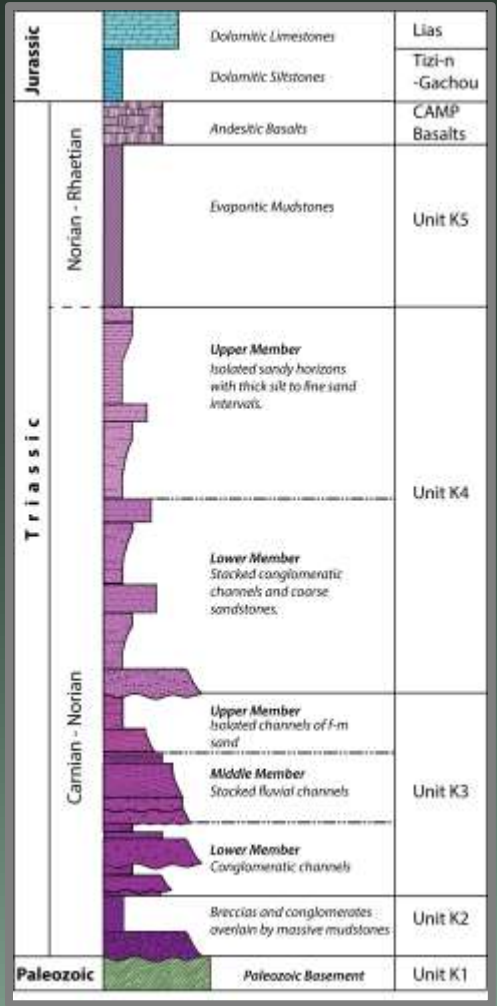
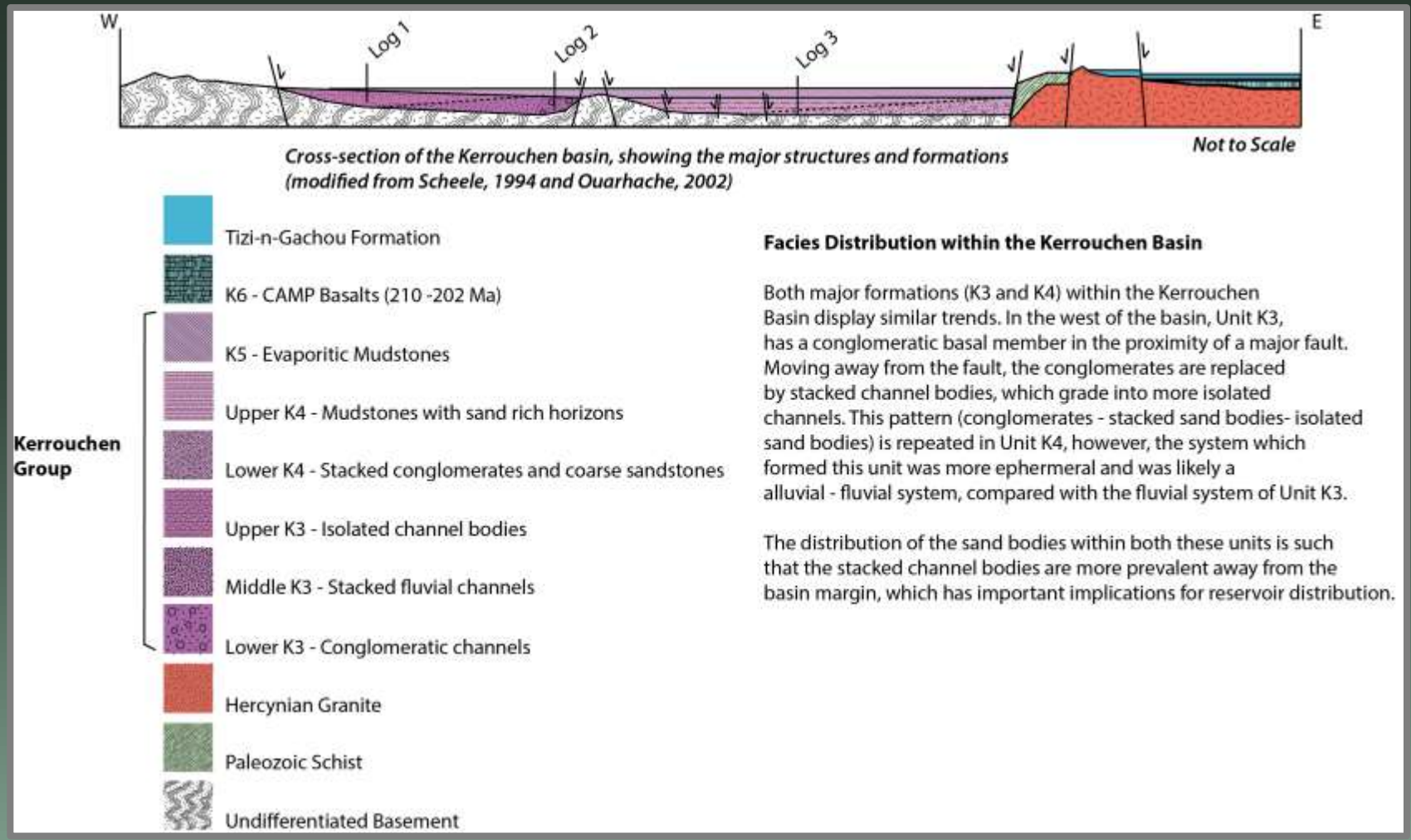
Kerrouchen Basin

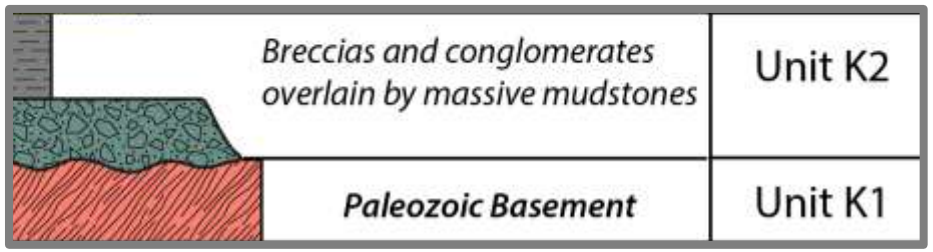




Facies Distribution within the Kerrouchen Basin

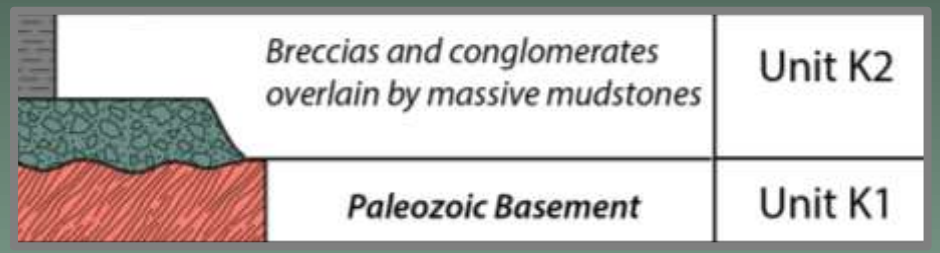
Both major formations (K3 and K4) within the Kerrouchen Basin display similar trends. In the west of the basin, Unit K3, has a conglomeratic basal member in the proximity of a major fault. Moving away from the fault, the conglomerates are replaced by stacked channel bodies, which grade into more isolated channels. This pattern (conglomerates - stacked sand bodies- isolated sand bodies) is repeated in Unit K4, however, the system which formed this unit was more ephermeral and was likely a alluvial - fluvial system, compared with the fluvial system of Unit K3.

The distribution of the sand bodies within both these units is such that the stacked channel bodies are more prevalent away from the basin margin, which has important implications for reservoir distribution.


Breccias and conglomerates overlain by massive mudstones
Unit K2
Paleozoic Basement
Unit K1

Transverse Alluvial System

- Breccias and Conglomerates onlapping and fringing paleohighs
- Grade rapidly to mudstones towards the basin centre
- Laterally discontinuous



Eastern basin margin

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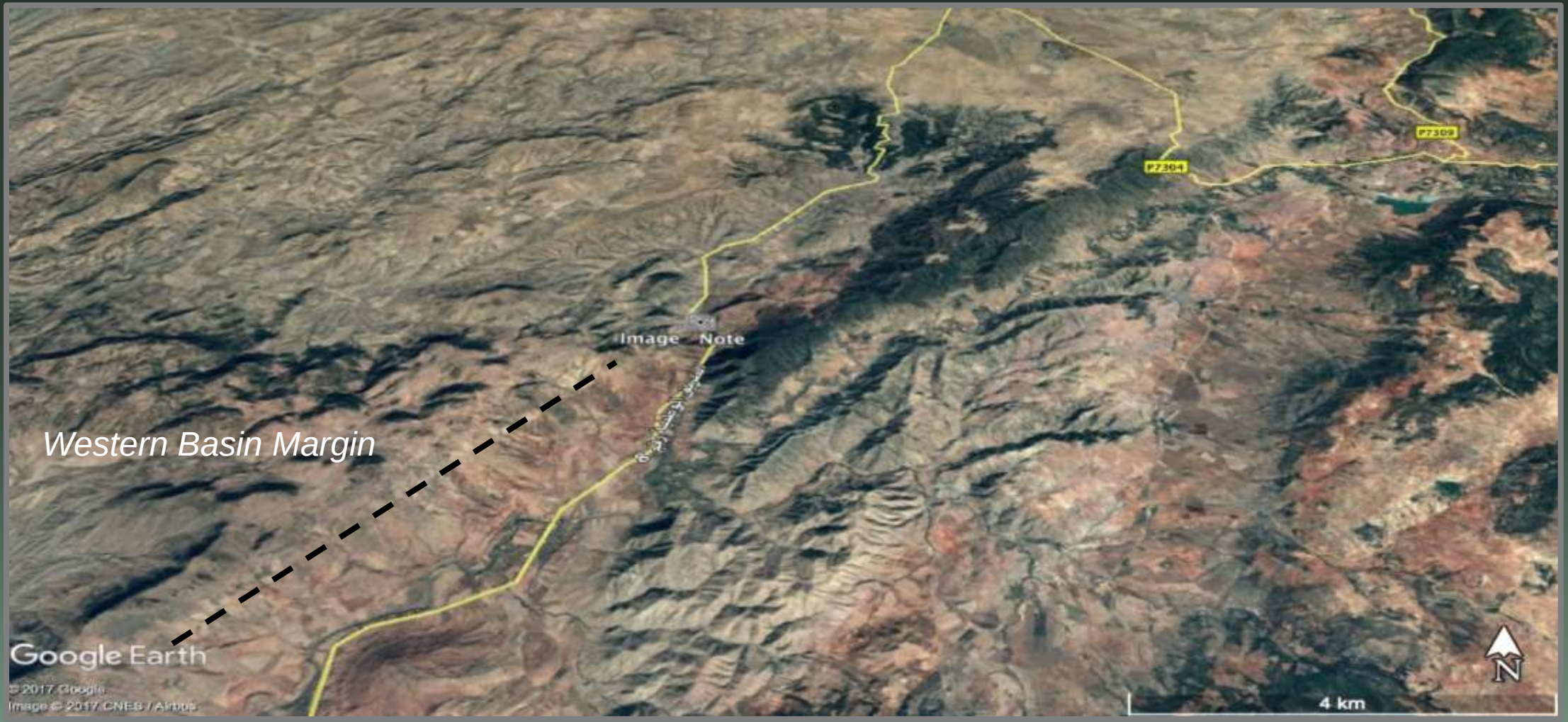


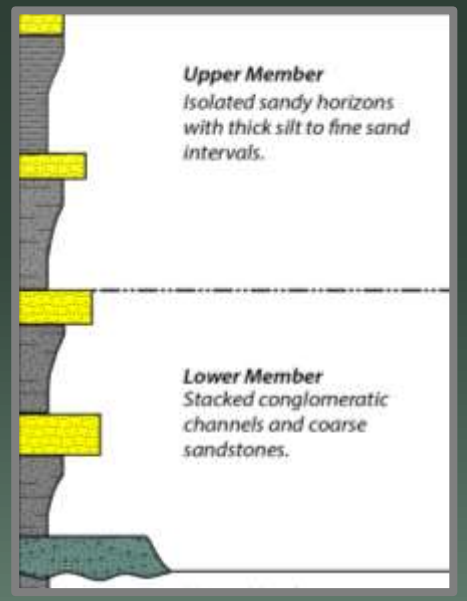
Research Theme 1: Triassic Depositional Systems

Western Basin Margin

Poorly sorted, massive conglomerates flowing from basin margins and paleohighs

Thinner conglomerates on intra-basinal paleohighs

Transverse Alluvial – Fluvial System



Unit K4

Alluvial-Fluvial Fan

Medial Alluvial-Fluvial Fan

Distal Alluvial-Fluvial Fan

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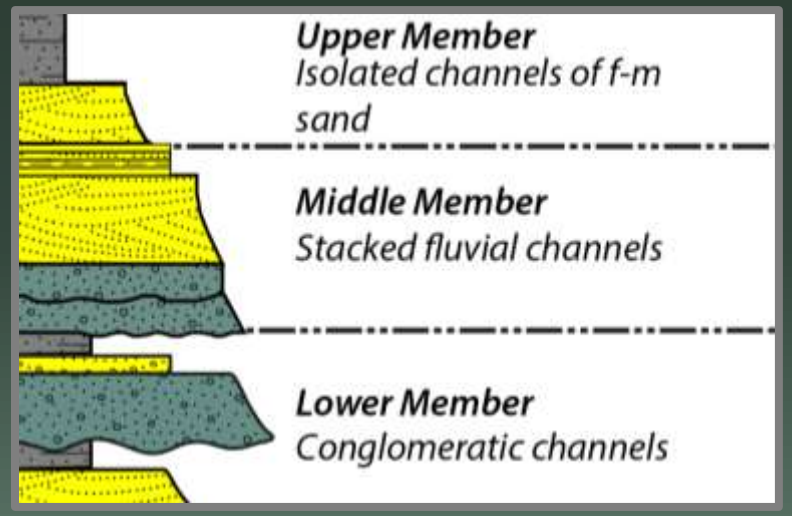
Axial Fluvial System



Upper Member

Middle Member

Lower Member

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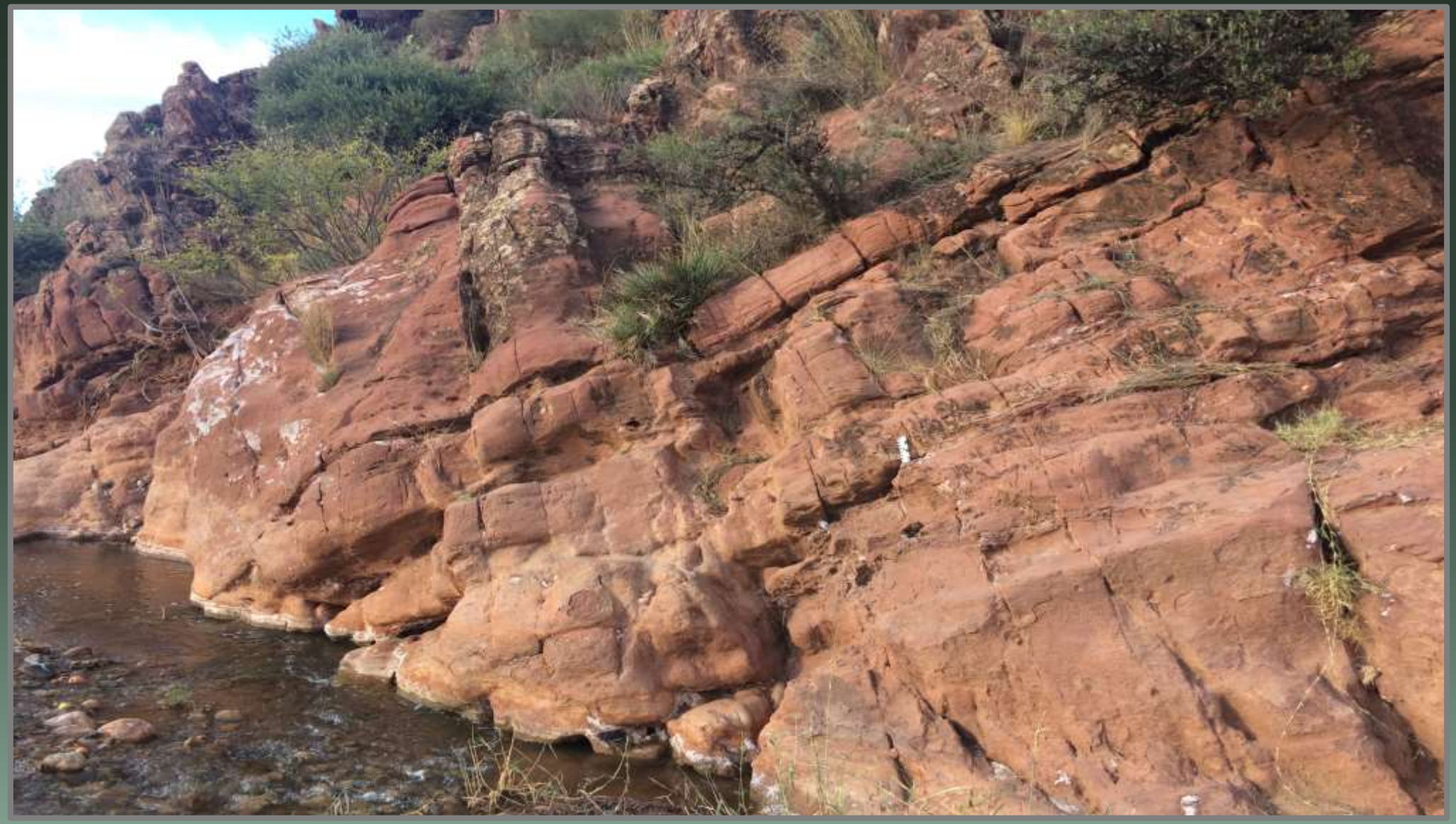


Paleoenvironmental Reconstruction

- Axial fluvial system developed in along basin axis, parallel to major structural trends
- Local input from fault controlled paleohighs
- Relay zones allowed for sediment bypass between the sub-basins
- Braided streams developed on the floodplain linking the alluvial-fluvial system with the axial fluvial system

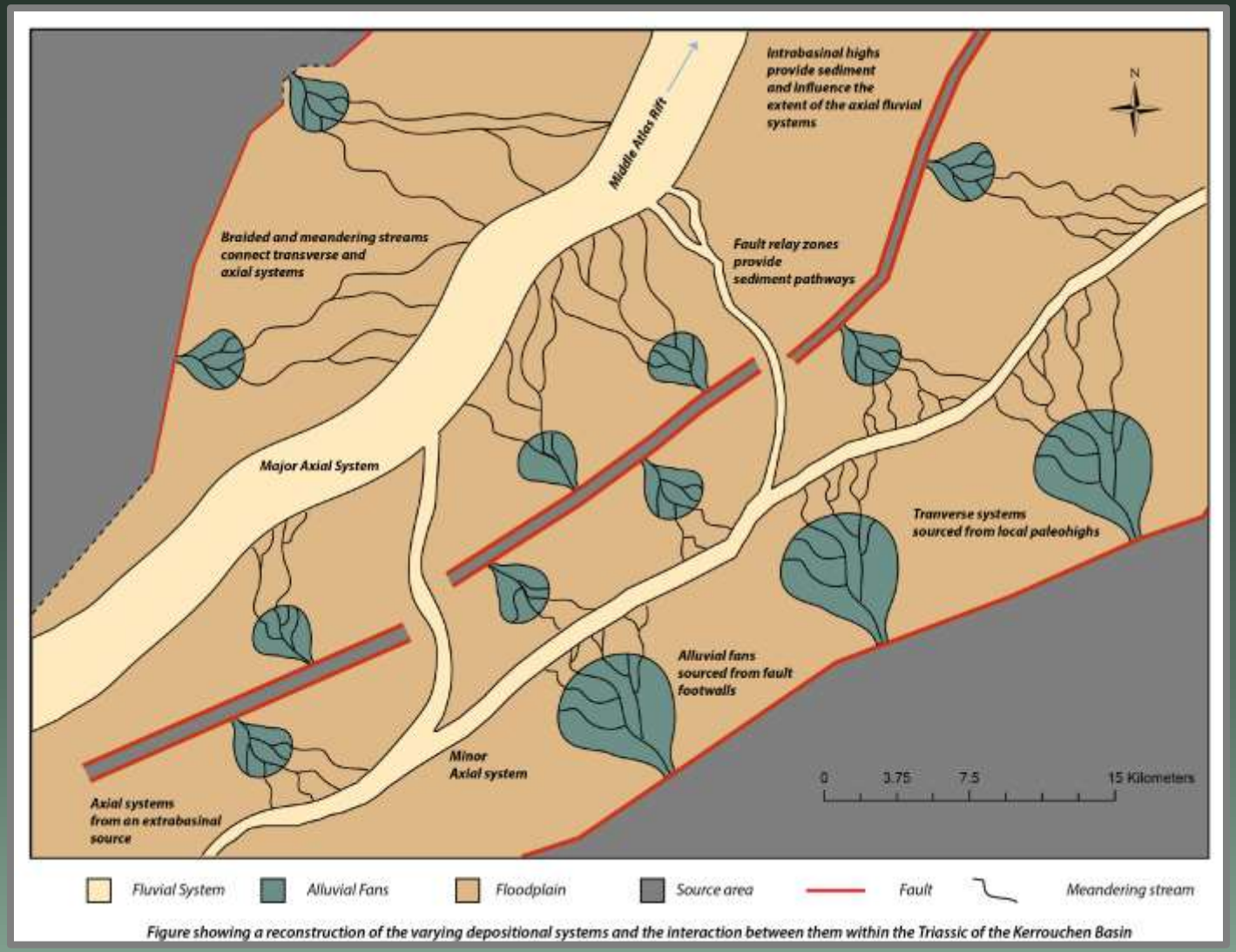
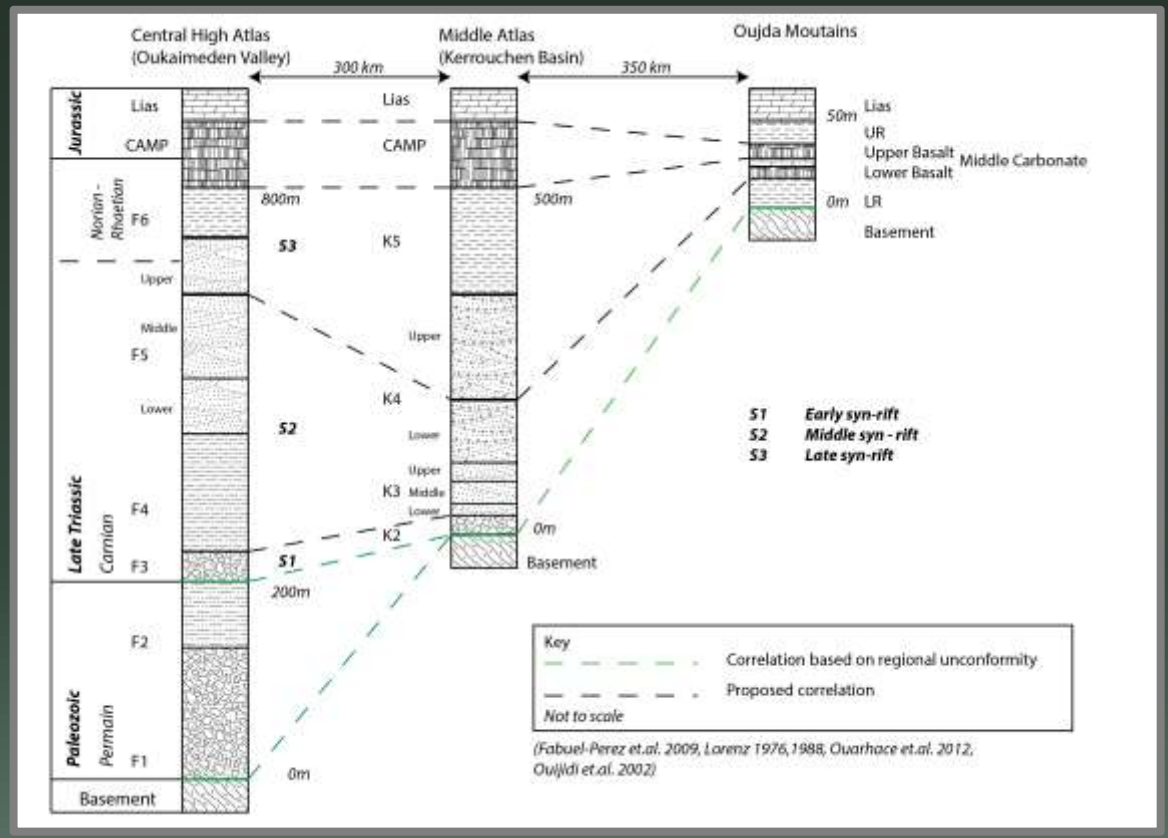
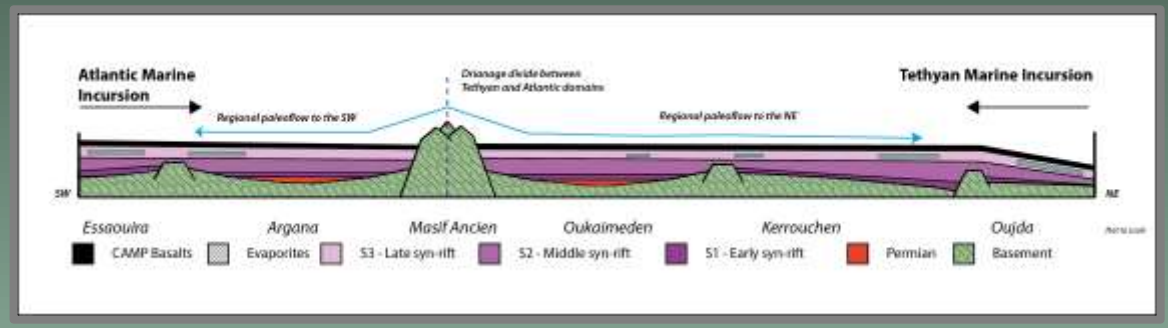


Figure showing a reconstruction of the varying depositional systems and the interaction between them within the Triassic of the Kerrouchen Basin

Timing of development of axial and transverse systems

- Earliest syn-rift is characterised by transverse depositional systems (Permian and S1)
- Middle syn-rift characterised by development of axial depositional systems (S2)
- Late syn-rift is characterised by deposition of regional evaporitic mudstone facies (S3), related to the onset of marine transgressions





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Key Questions

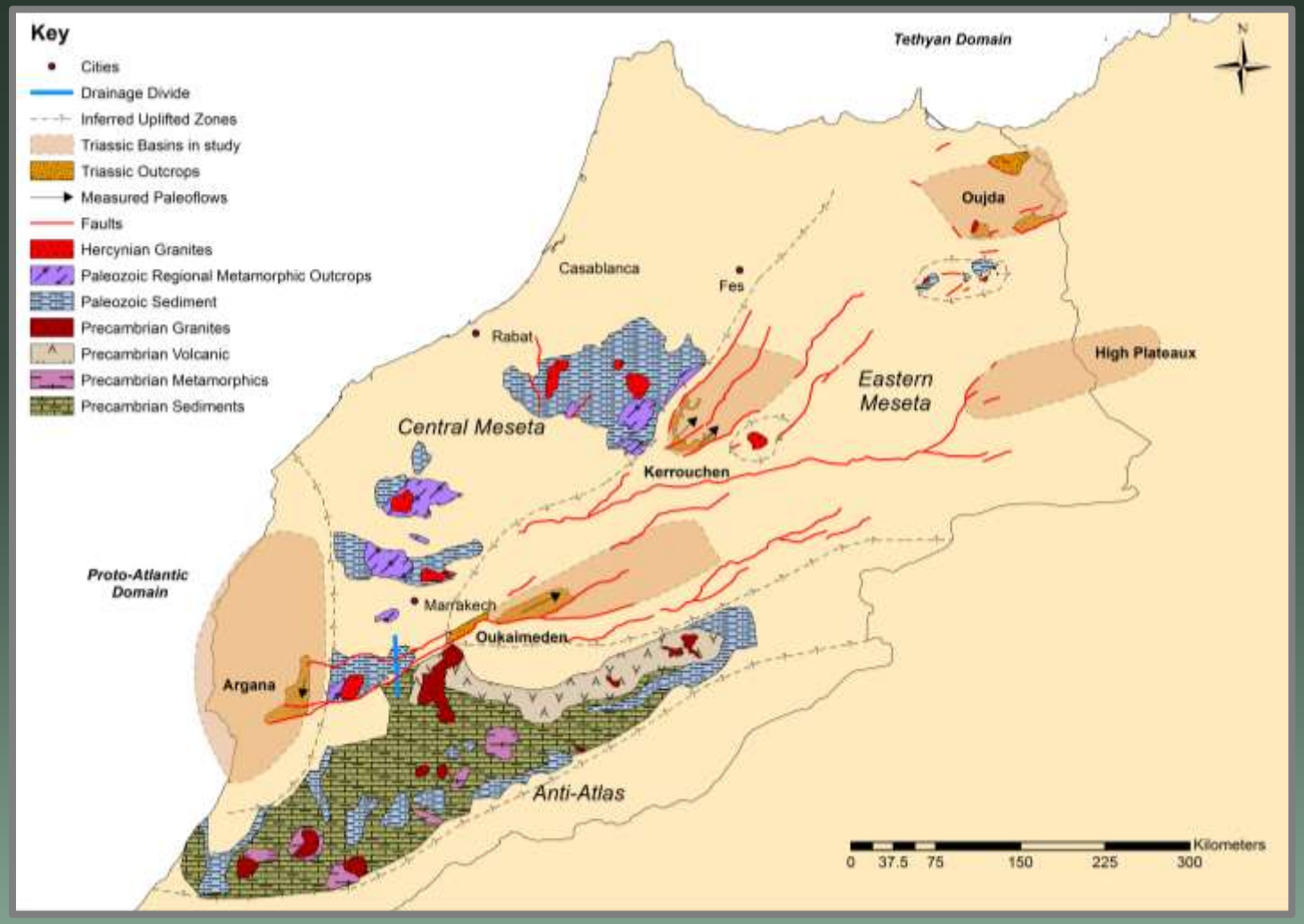
1. What are the controls on the development of the transverse systems?
2. How do the transverse and axial systems interact?
3. How far can these systems be mapped in outcrop?

Future Work

- Fieldwork in the Kerrouchen Basin to map out the axial and transverse systems.
- Log cores from the Middle and Central Atlas, Eastern Meseta.

Research Theme 2:
Local versus Regional Provenance Signals

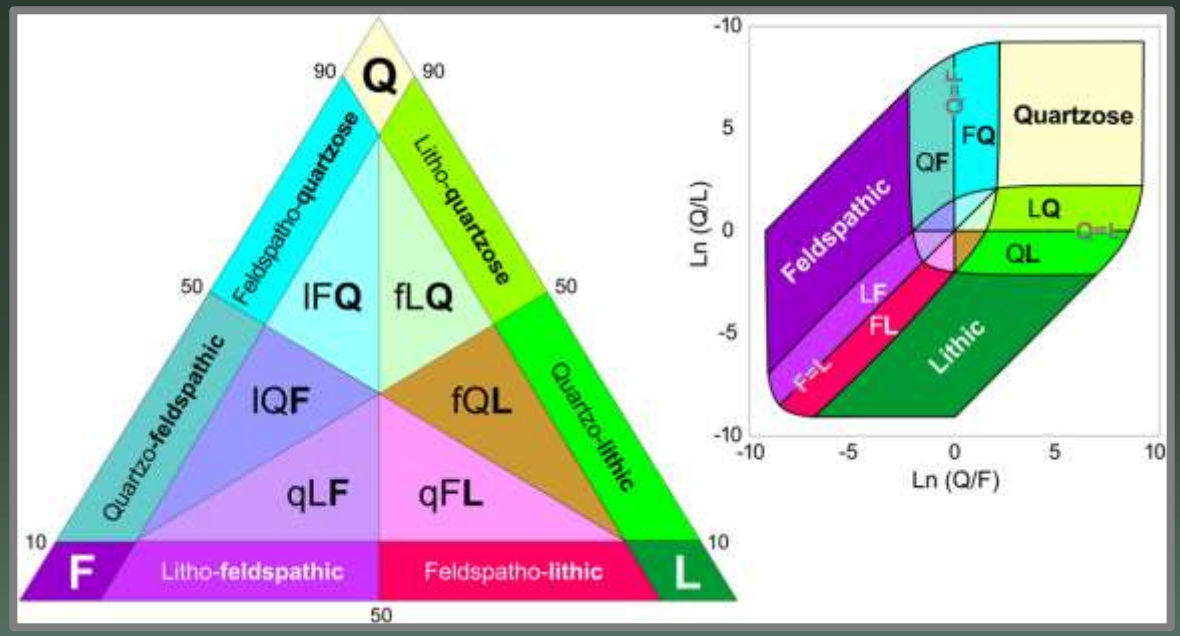
Paleoflow Data



- Distinct drainage divide between Tethyan and Atlantic domains
- Paleoflows run parallel to major structural trend, indicating presence of axial fluvial systems

Methodology

1. Point counting of detrital frameworks
2. Heavy Mineral Concentrations
3. Heavy Mineral Ratios



(Garzanti 2016)

*'detrital frameworks present a **proxy for the lithological components in the source region** so thus should be used to **indicate variations in the source region**. '*
(Garzanti 2016)

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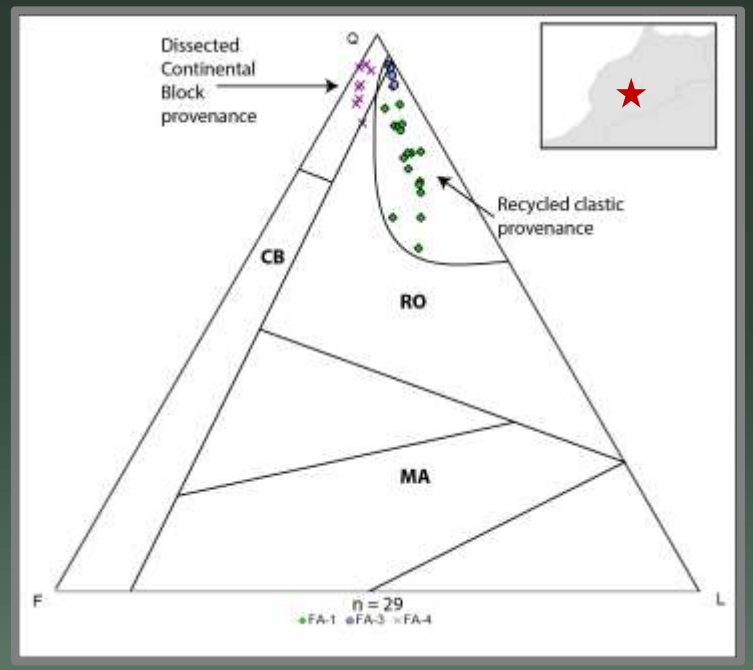
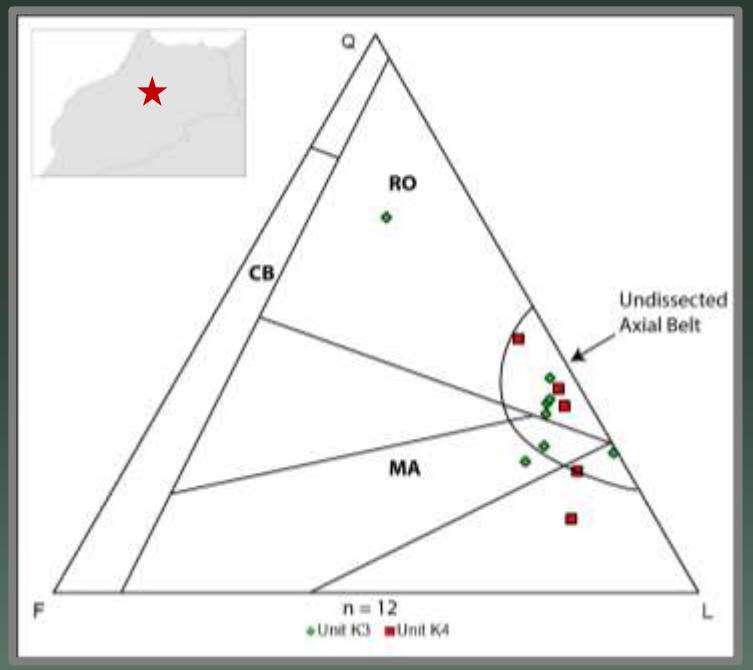
QFL Results

Oukaimeden



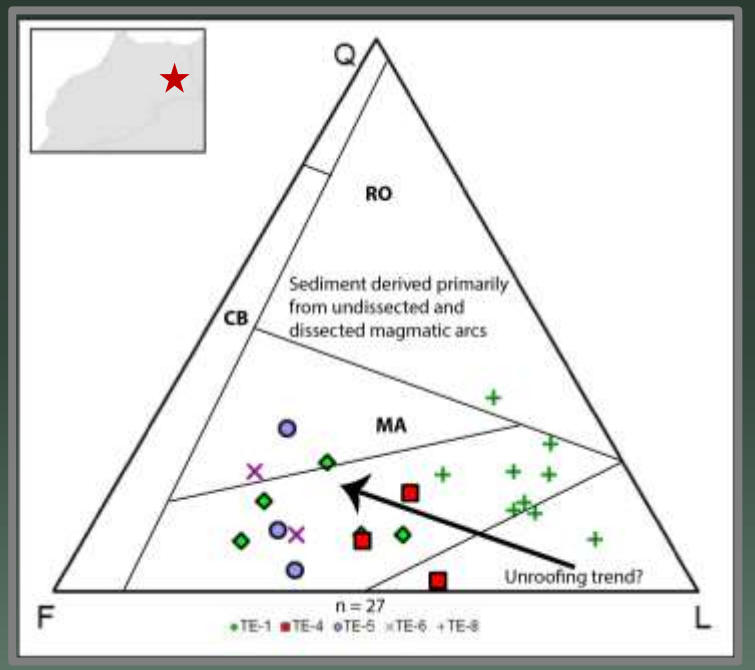
Lithic sedimenticlastic to quartzose sands

Kerrouchen



Quartzo-lithic metamorphiclastic sand

High Plateaux



Volcanoclastic to plutonoclastic sands

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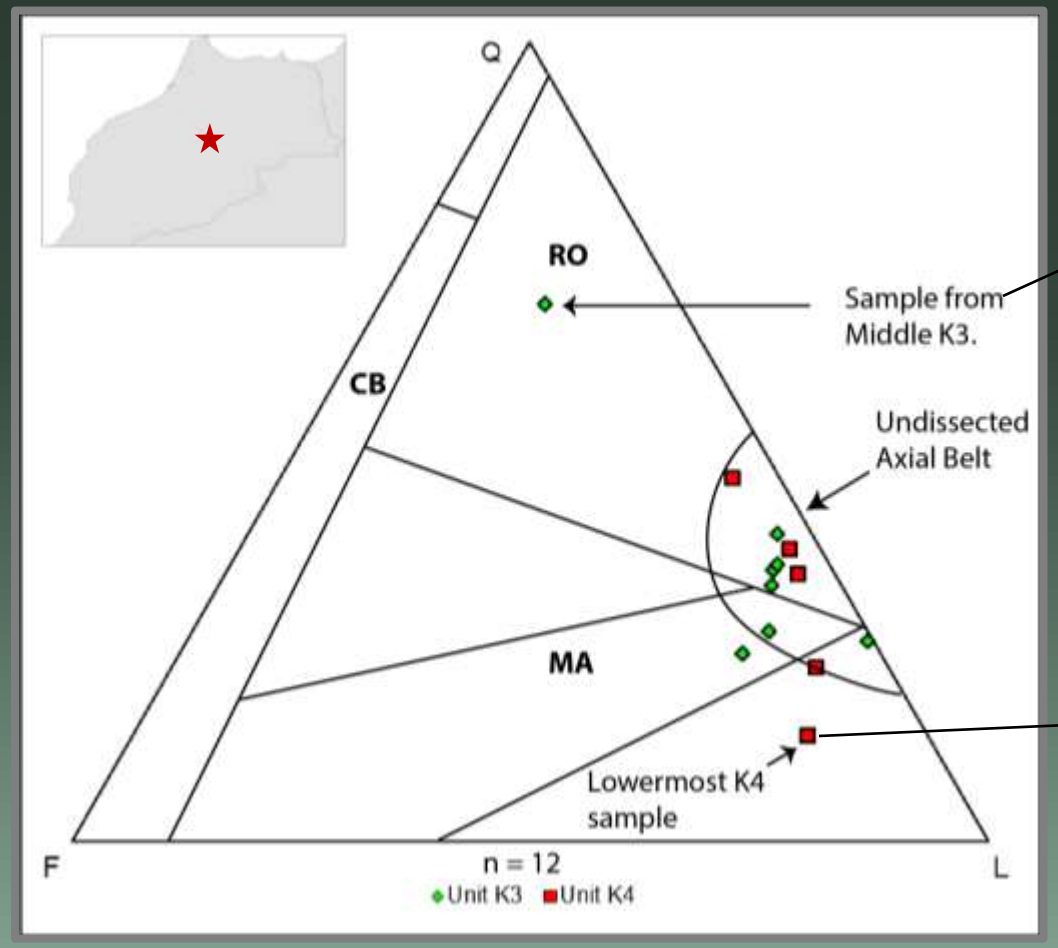
Variations in Axial vs Transverse

- Distinct signals recorded in axial and transverse systems

Kerrouchen



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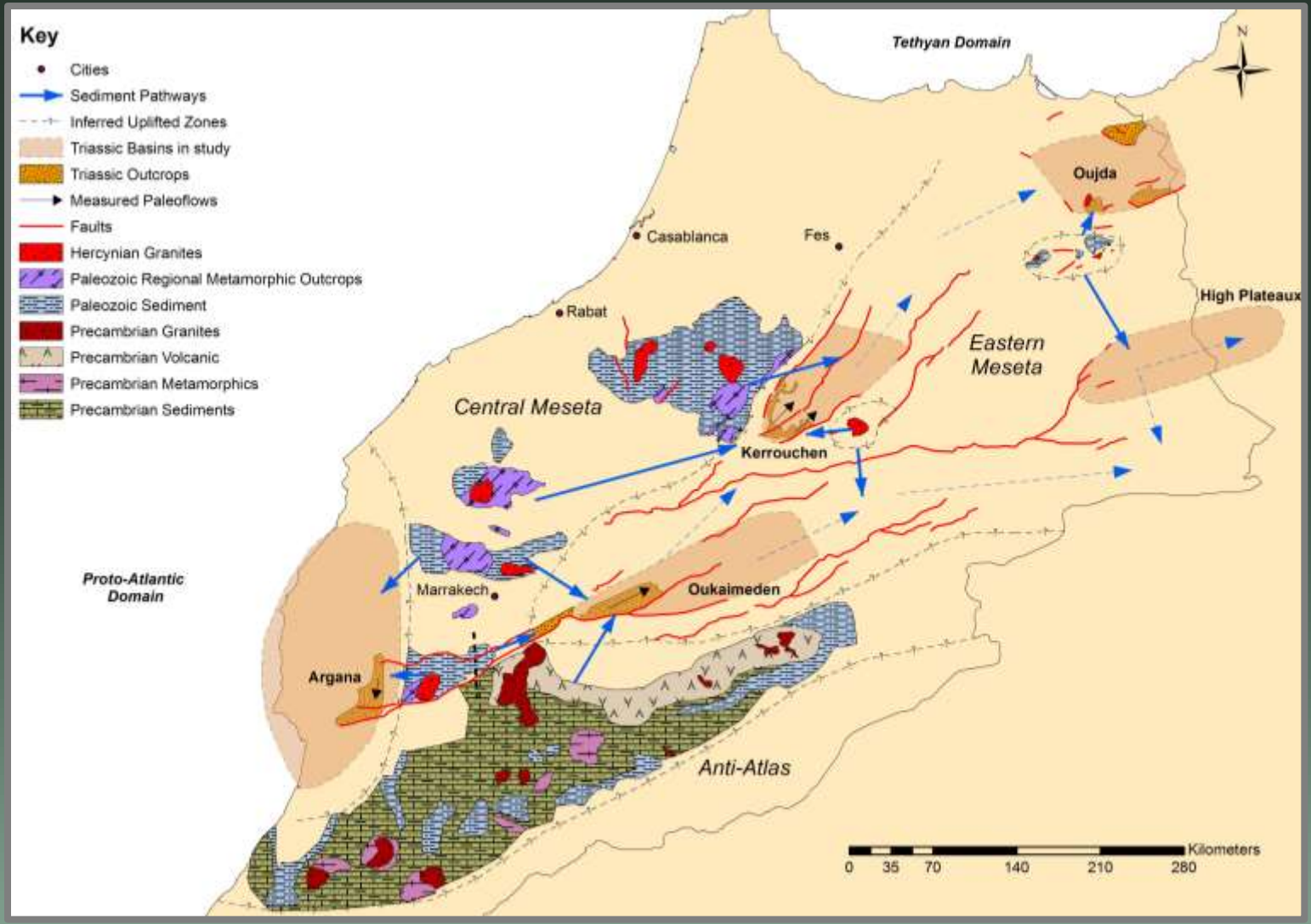
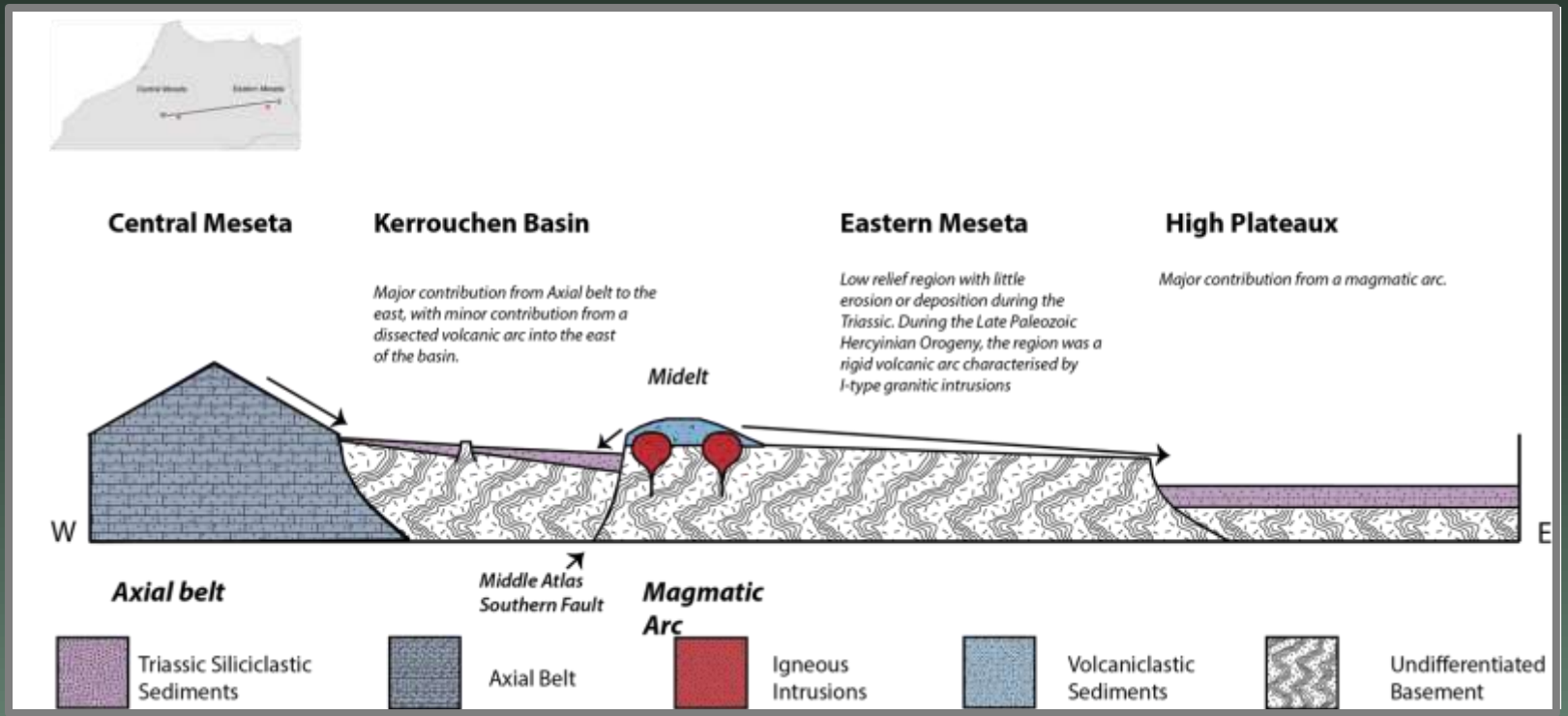
Provenance Model



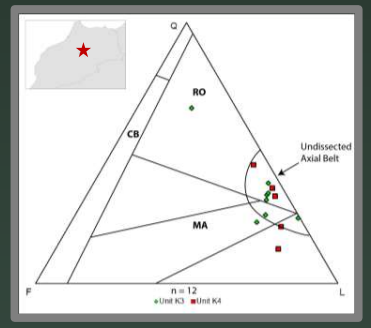
Questions

1. To what extent did faults prevent communication between the basins?
2. Does the addition of more sediment along the rift ‘overprint’ a regional HM signal?

Provenance Model



Kerrouchen



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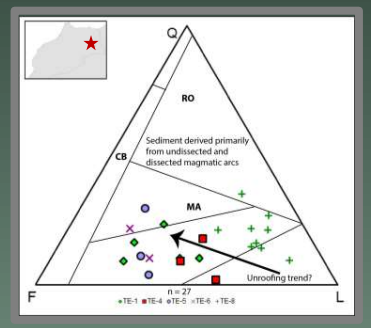


Key Questions

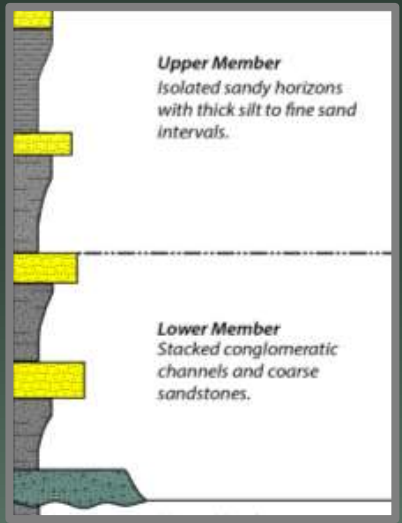
1. Do transverse and axial systems record local and regional signals respectively and to what extent do these signals mix?
2. Interconnected or isolated rift basins?
3. Can the HM data be used to correlate across basins?

Future Work

- HM study – indicate variations in provenance utilising HMC and HMR
- Geochronological work to constrain provenance

Research Theme 3
Impact of depositional style and provenance on reservoir quality

Reservoir Quality: Transverse Alluvial – Fluvial Systems



Analogue unit from the Kerrouchen Basin

Development of paleosols and pedogenic features

Alluvial – Fluvial transition coarse sand and sandy conglomerates

Thinner and finer sediment towards the basin centre

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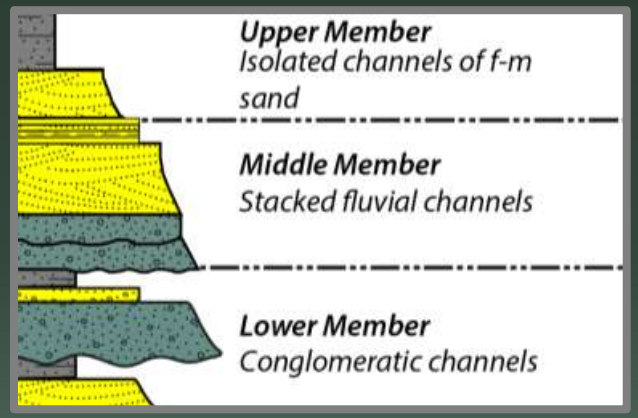
Reservoir Quality Axial Systems



Analogue unit from the Kerrouchen Basin

Stacked fluvial sands near basin axis

Isolated meandering channels towards basin margin

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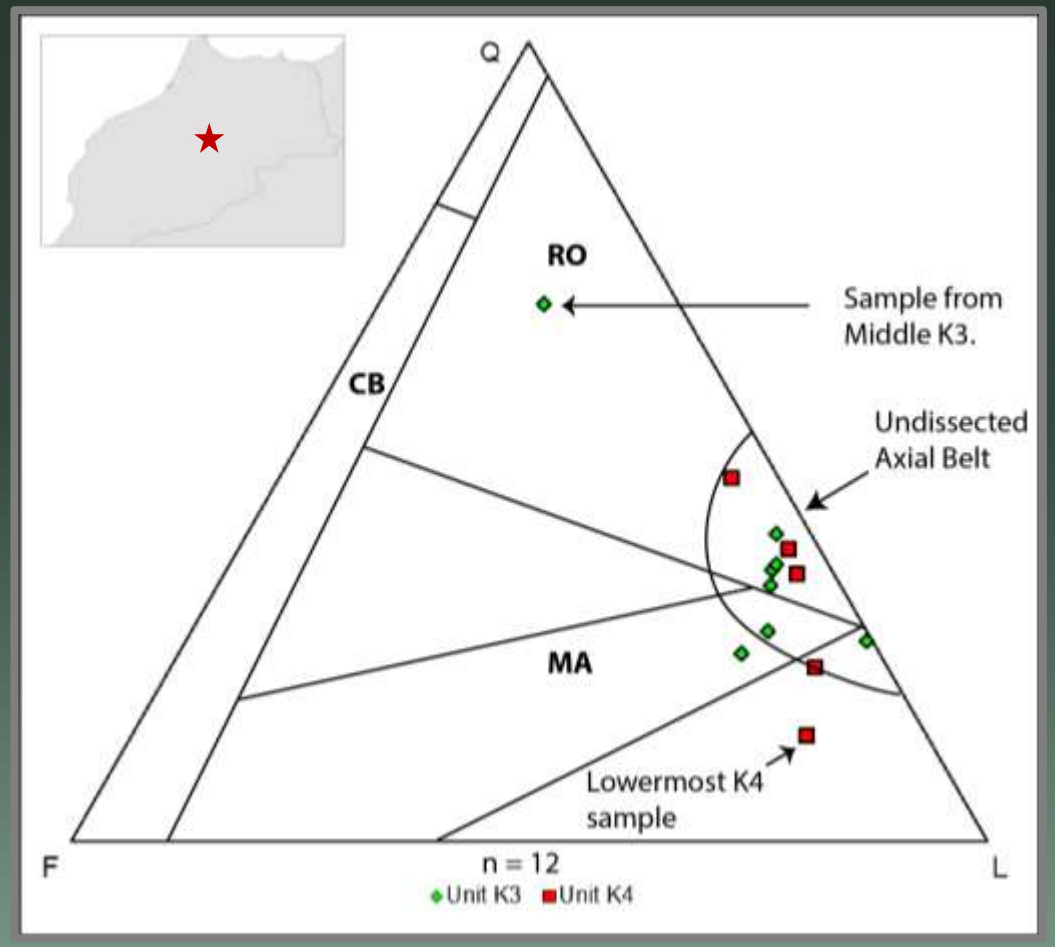
Provenance

- Local, intra-basinal signal, likely indicator of a transverse system
- Regional, extra-basinal signal indicates the presence of an axial system



Reservoir distribution model

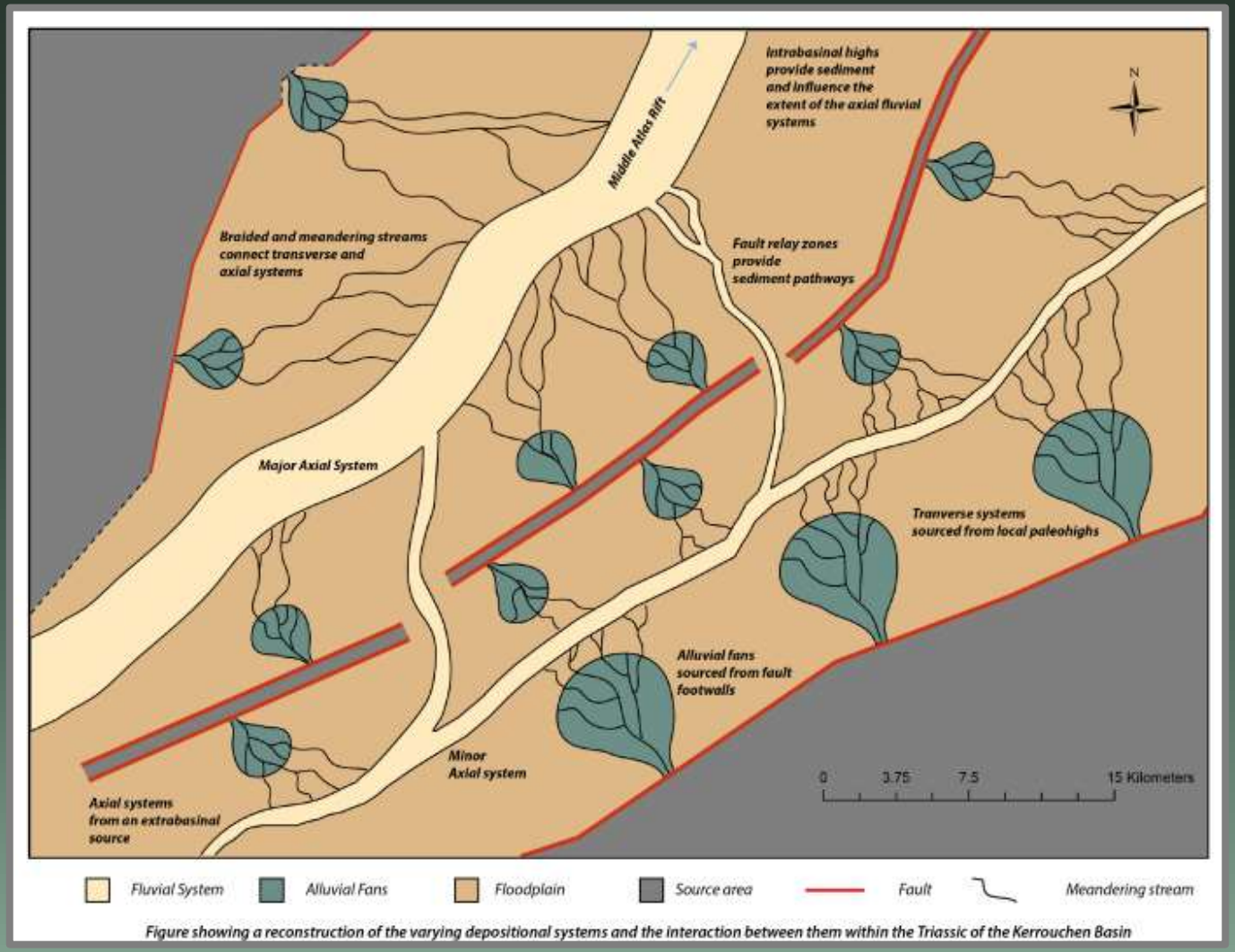
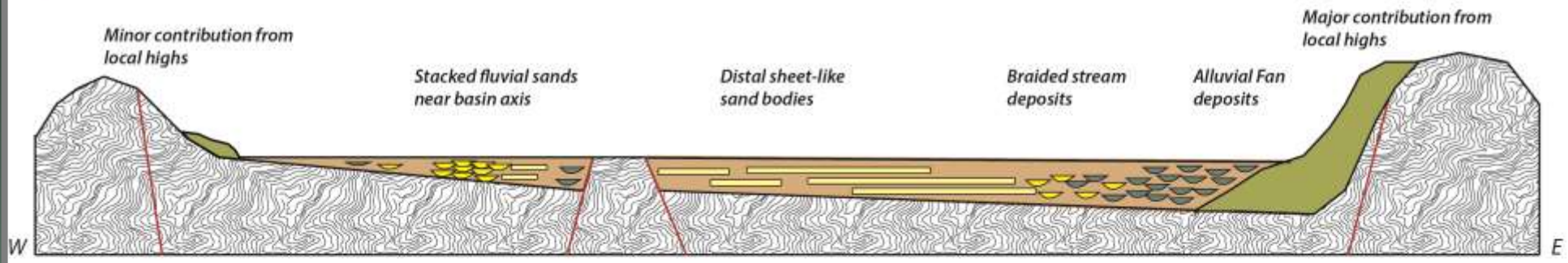


Figure showing a reconstruction of the varying depositional systems and the interaction between them within the Triassic of the Kerrouchen Basin

Research Theme 3: Impact of depositional style and provenance on reservoir quality

Cross-Section of the Kerrouchen Basin during deposition of K3 and K4 showing the implications for reservoir quality and distribution

Siltstones	*Floodplain deposits from fluvial and alluvial fan depositional systems*
Sheet like sands	*Deposited as overbank fines and as part of distal alluvial - fluvial fans*
Sand rich channels	*Depsoited by the axial fluvial system and as braided stream deposits at the alluvial-fluvial transition*
Conglomeratic channels	*Deposited by high energy fluvial and alluvial fan type systems*
Massive conglomerates	*High energy systems which provide local input into the basins.*
Basement	
Major faults	



Sub-basin domianted by regional depositional system

Intra-Basinal High

Sub-basin dominated by local depositional system sourced from local highs

In the Kerrouchen Basin, the thickest and most extensive sand bodies are found near the basin axis of both sub-basins, as a regional fluvial system with an extrabasinal source and a local fluvial system fed from an alluvial fan, would be most likely to develop near the basin centre away from the uplifted zones forming the basin margin. The basin margins are characterised by massive conglomerates and siltstones, deposited by alluvial fan type systems. Due to the ephermeral nature of alluvial fan deposition and the arid climate of the Triassic, pedogenic cementation is common within the basin margin conglomerates.
This has important implications for reservoir quality and distribution. Within the Kerrouchen Basin, the stacked fluvial sands of the western sub-basin are well sorted, medium to coarse sands with low cementation and high porosity, and would make a high quality reservoir. In contrast, the basin margin conglomerates are poorly sorted with extensive pedogenic cements (usually calcitic) which reduces the porosity, permeability and reservoir quality.

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Future Work

Masters *May – September 2018*

- HM study to identify local and regional signal

PhD *2019 onwards*

- Detailed mapping of the Kerrouchen Basin
- Geochronological Study
- Source to sink

Sponsors

With special thanks to

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