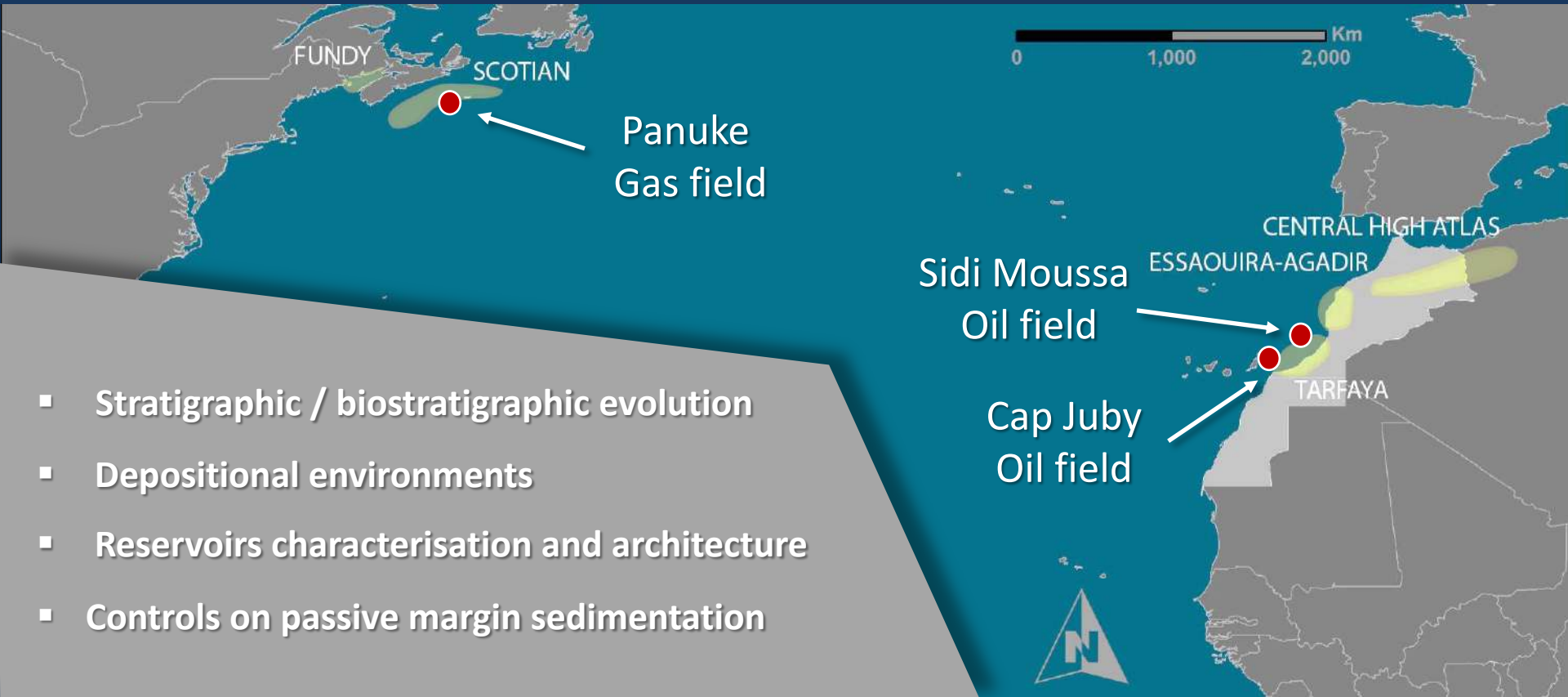




Controls on stratigraphic development
of shelf margin carbonates:
Jurassic Atlantic margin
Essaouira-Agadir Basin
Western Morocco



CONJUGATE ATLANTIC BASINS



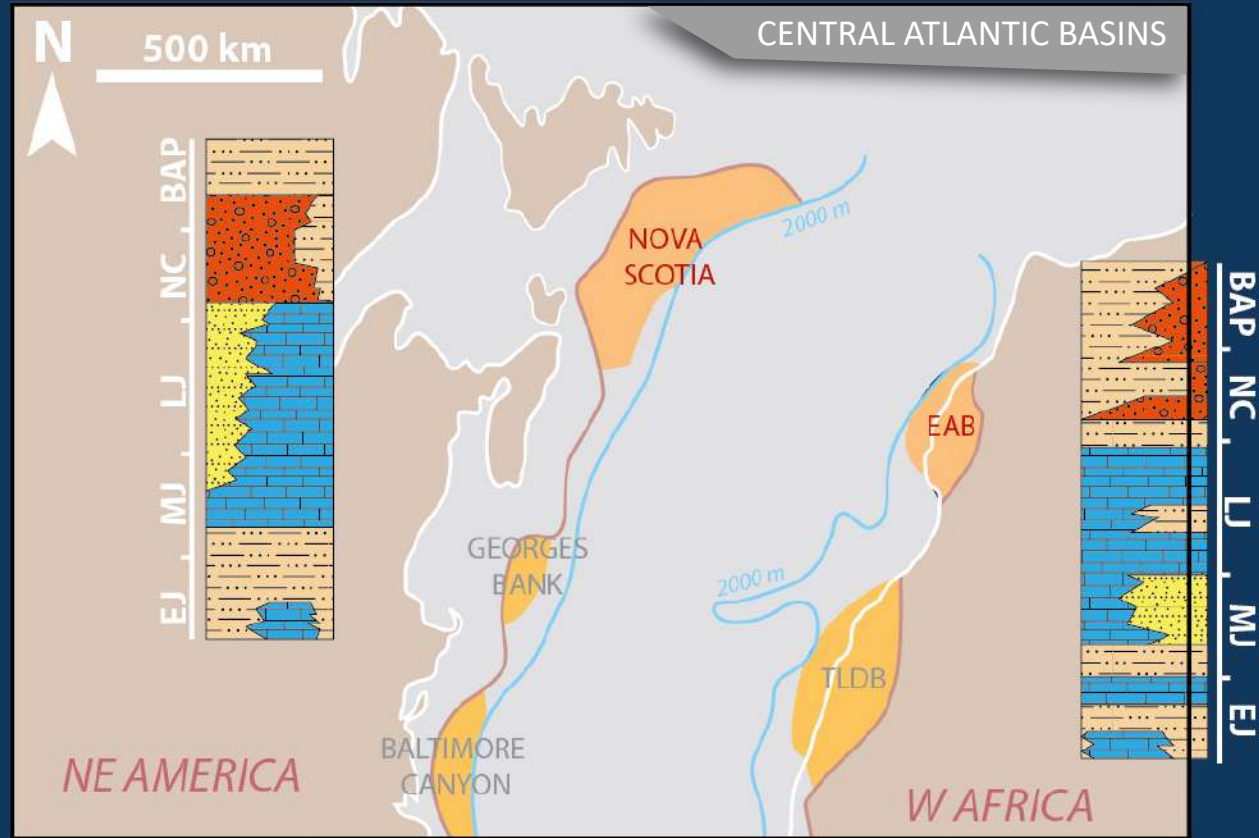
Comparison of **Middle Jurassic to Aptian** stratigraphic record of Central Atlantic Ocean conjugate passive margins

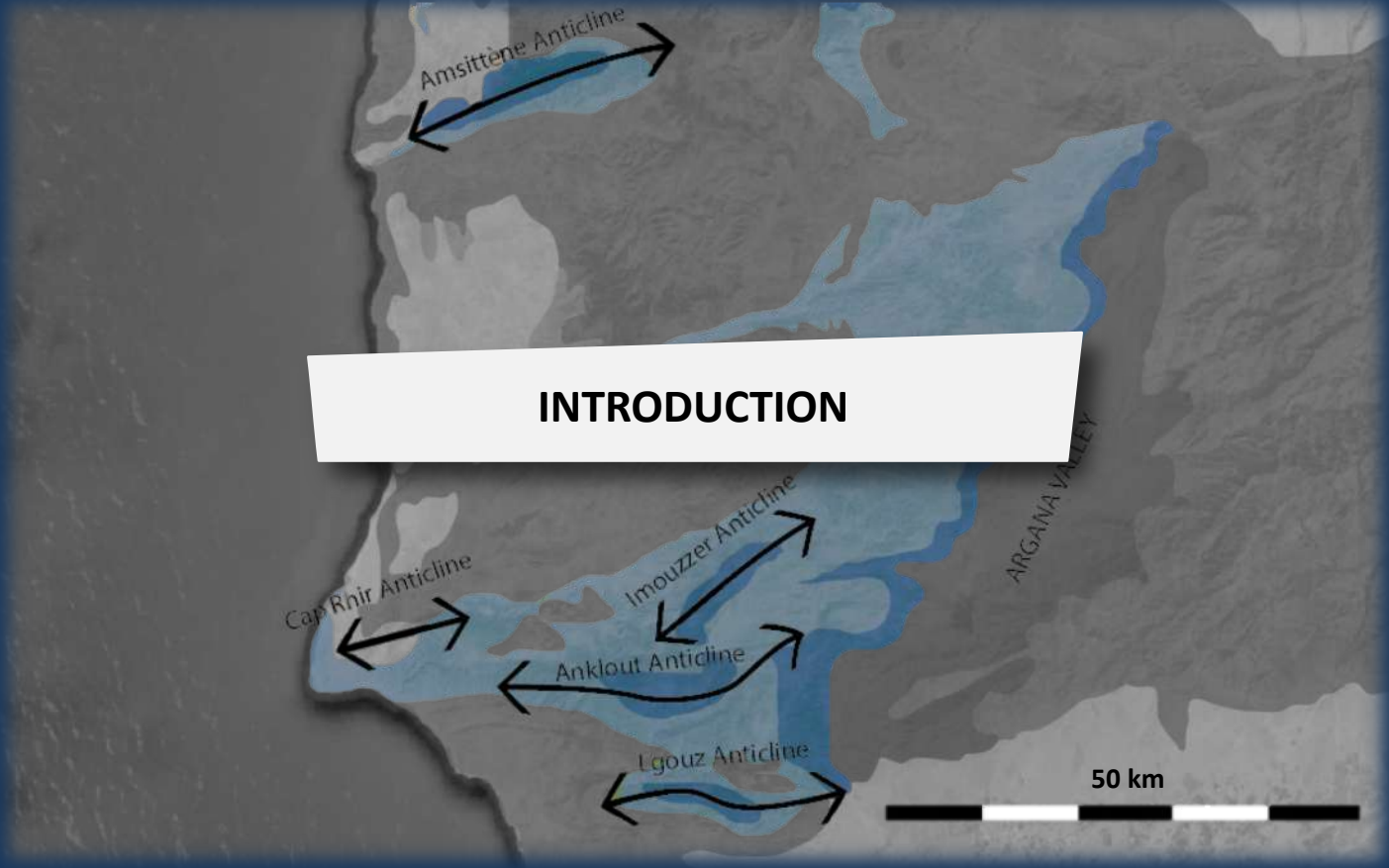
Jurassic:

- Stable carbonate platform
- Replaced by siliciclastic deposition during the Cretaceous

➤ Potential **reservoir**

*Modified after
Leprêtre et al, 2017*





EAB STRATIGRAPHY



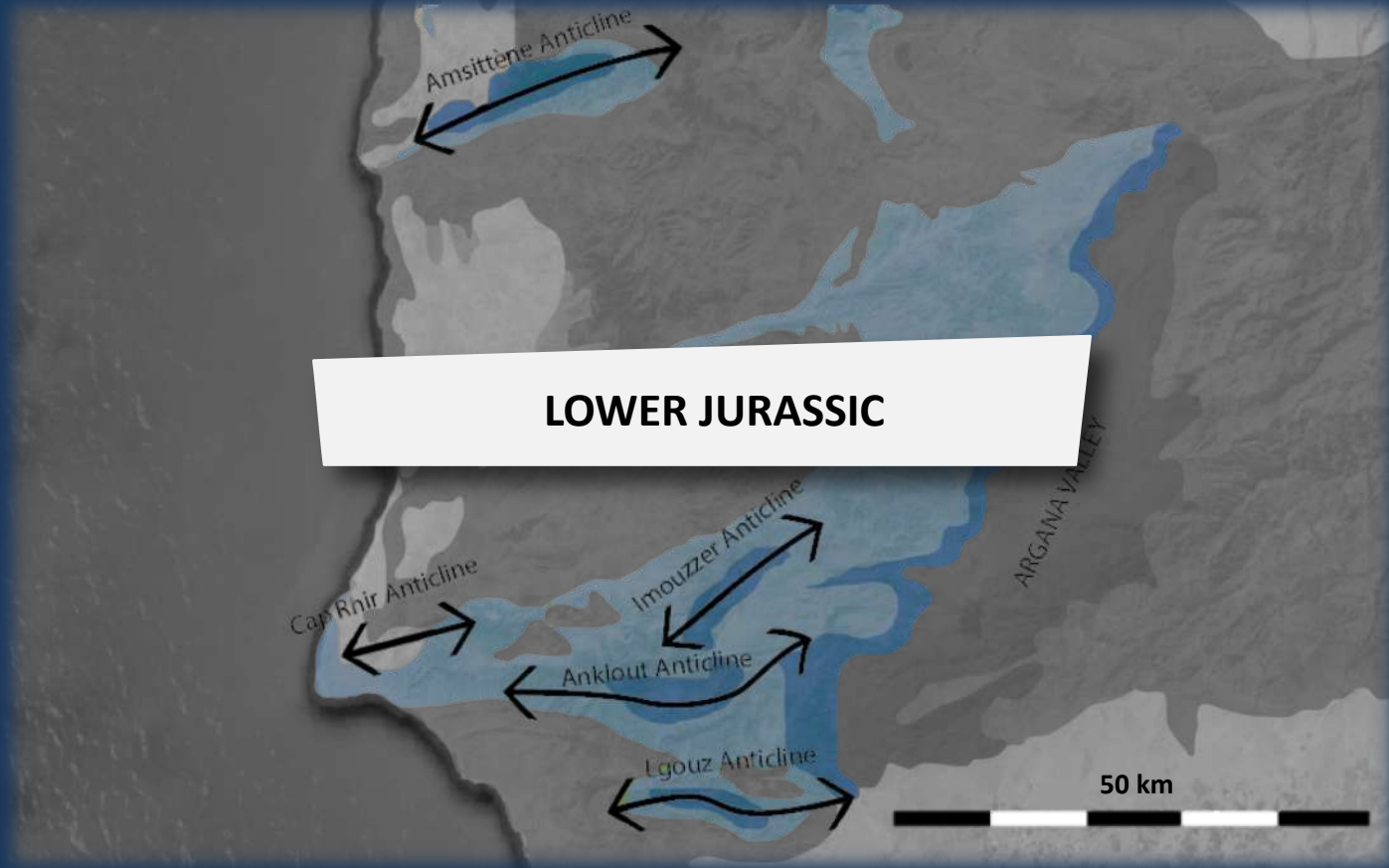
Ages	Simplified Section	Formations Name	Environments	Dominant Facies	Reservoir potential	Seal potential	Bests Seals and reservoirs
UPPER		TISMEROURA FORMATION	Internal ramp (up to 300 m)	Dolomite	Medium		
		IMOUZZER FORMATION	Lagoon / Emerged proximal ? (up to 150 m)	Red marls		Good	→ MARLS
		IGGUI EL-BEHAR FORMATION	Sabkha Shallow marine (up to 120 m)	MST - PST		Medium	
		LALLA OUJJA FORMATION	Coral build-ups (up to 60 m)	BST - Dolomite	Good		→ CORALS
MIDDLE		OUNAMANE FORMATION	Outer ramp Inner ramp carbonates (up to 170 m)	Marls PST - RST	Good	Good	→ MARLS → OOLITES
		AMESKHOUD FORMATION	Alluvial plain Intertidal siliciclastic (up to 300 m)	Clay - Silt - SST		Medium	
		TAMAROUT FORMATION	Supratidal Intertidal Subtidal (up to 400 m)	GST - Dolomite	Good		→ OOLITES
		AMSITTÈNE FORMATION	Alluvial fan Coastal plain (up to 50 m)	Conglomerates	Medium		
		ARICH OUZLA FORMATION	Open ramp (outer) Open ramp (middle) (up to 150 m)	GST - Dolomite	Good		→ DOL. OOLITES
LOWER							

Reservoirs:

- Good
- Medium

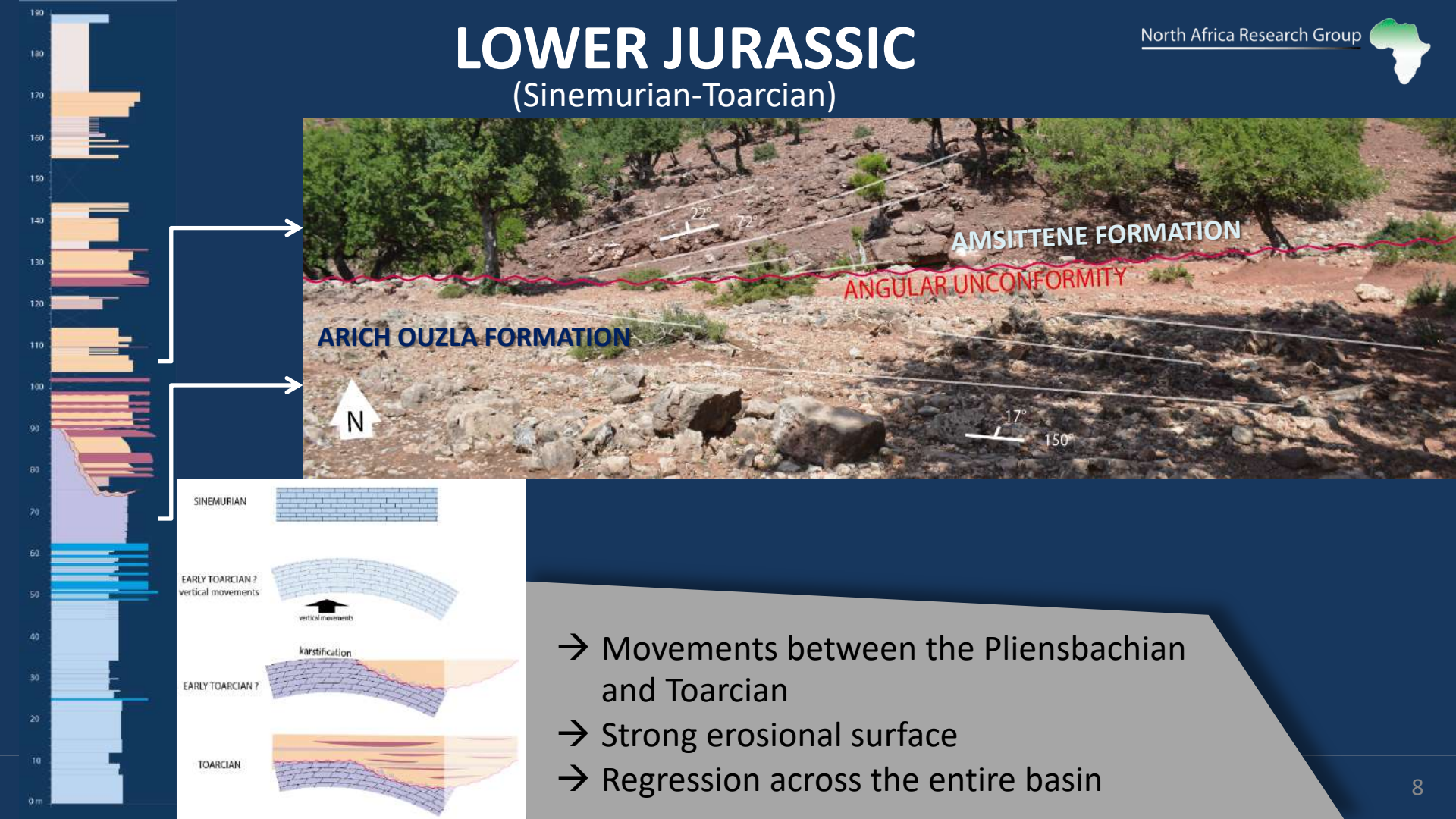
Seals:

- Good
- Medium



LOWER JURASSIC

LOWER JURASSIC (Sinemurian-Toarcian)

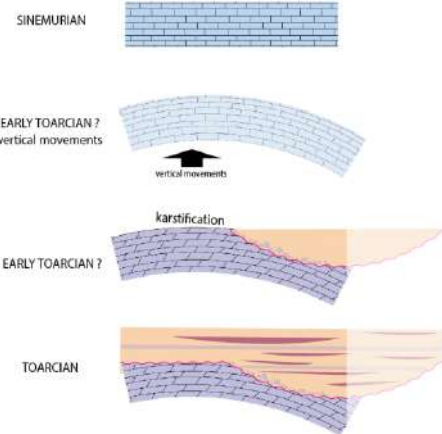


ARICH OUZLA FORMATION

AMSITTENE FORMATION

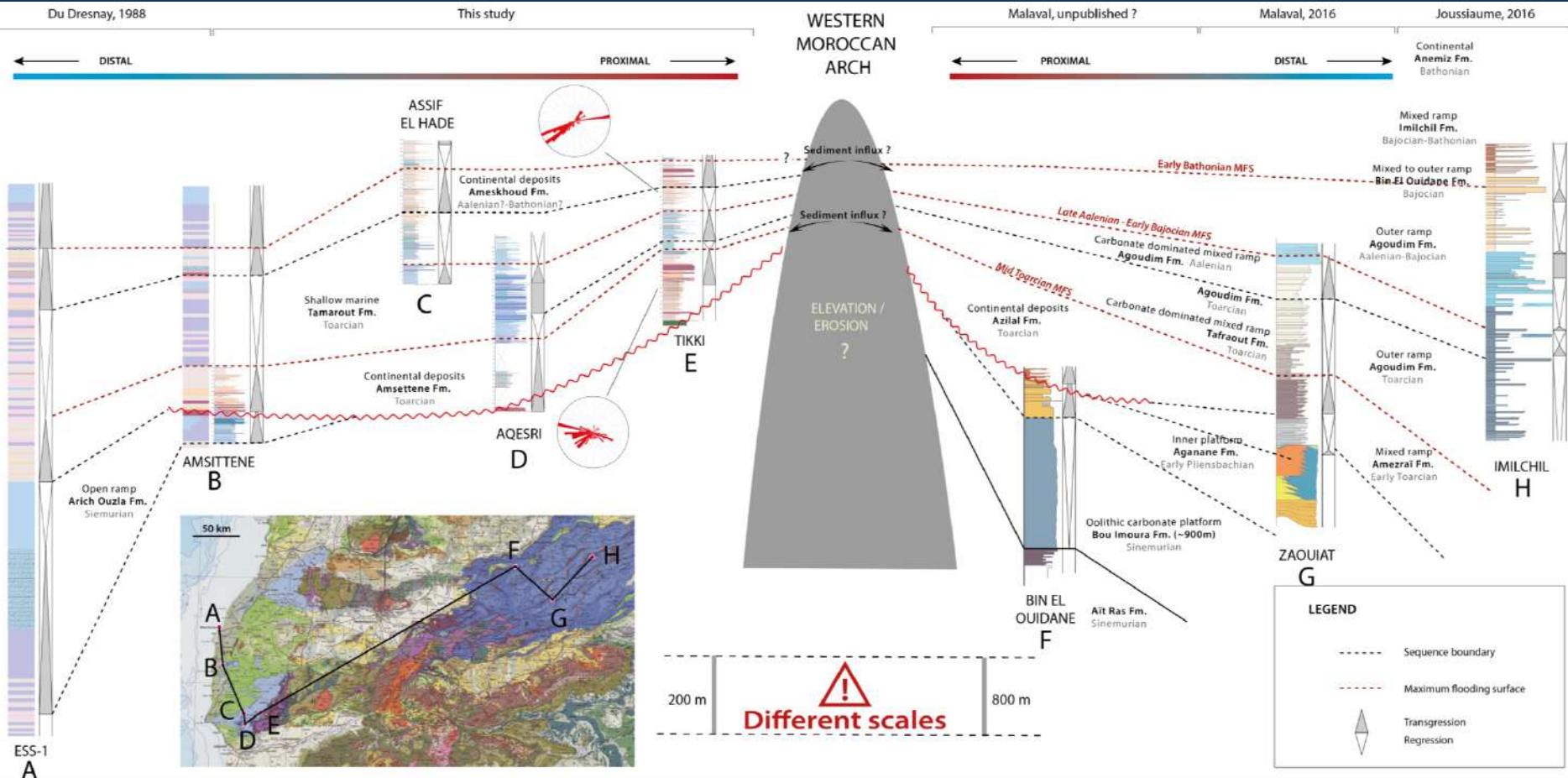
ANGULAR UNCONFORMITY

N



- Movements between the Pliensbachian and Toarcian
- Strong erosional surface
- Regression across the entire basin

COMPARISON CENTRAL HIGH ATLAS



TOARCIAN PLATFORM



Aqesri barrage outcrop



Toarcian Palaeomap
From Scotese, 2011

Sedimentary structures



PST/GST Elements

Elements %
↑



Peritidal cycles :

- Oolitic GST
- Oolitic an peloidal W/PST
- Gypsum levels
- Dissolution breccias
- Stromatolites

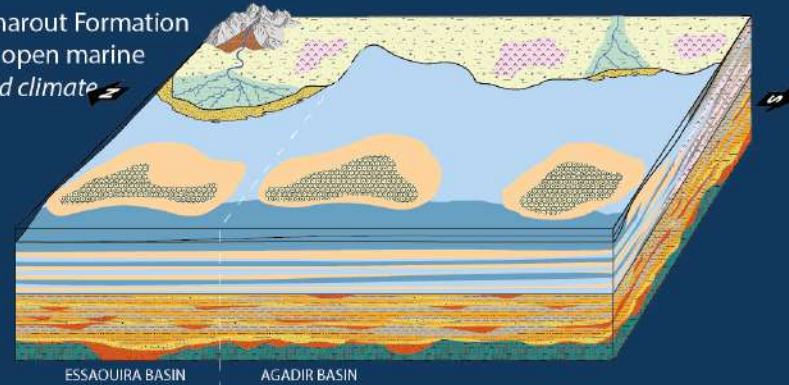
DEPOSITIONAL ENVIRONMENTS



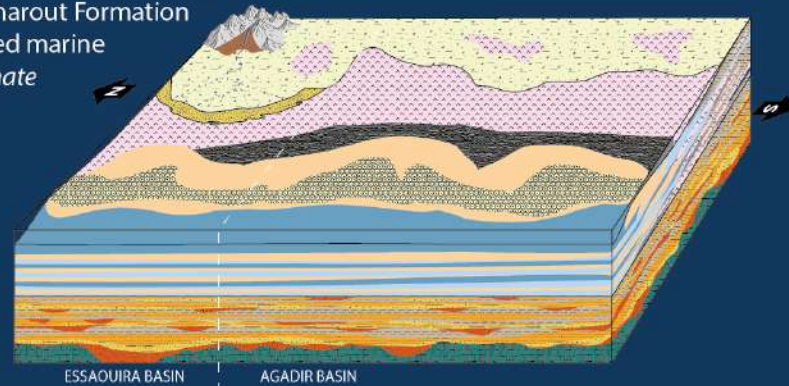
A - Amsittene Formation
Continental deposits

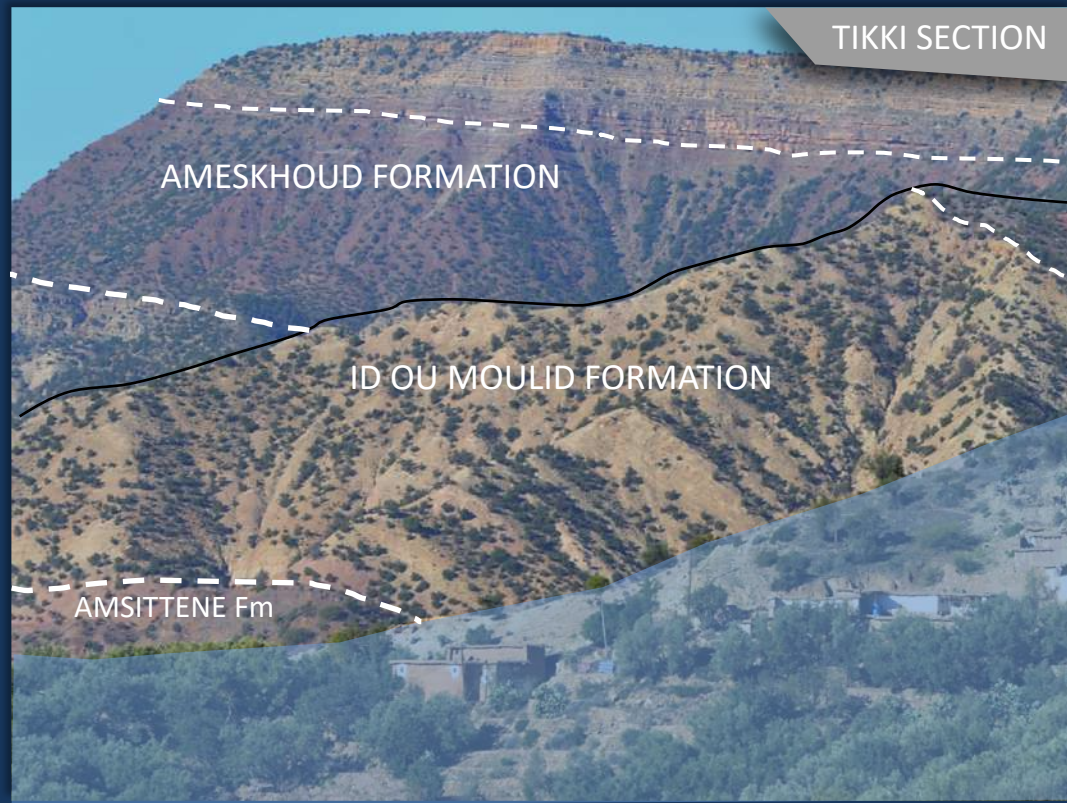
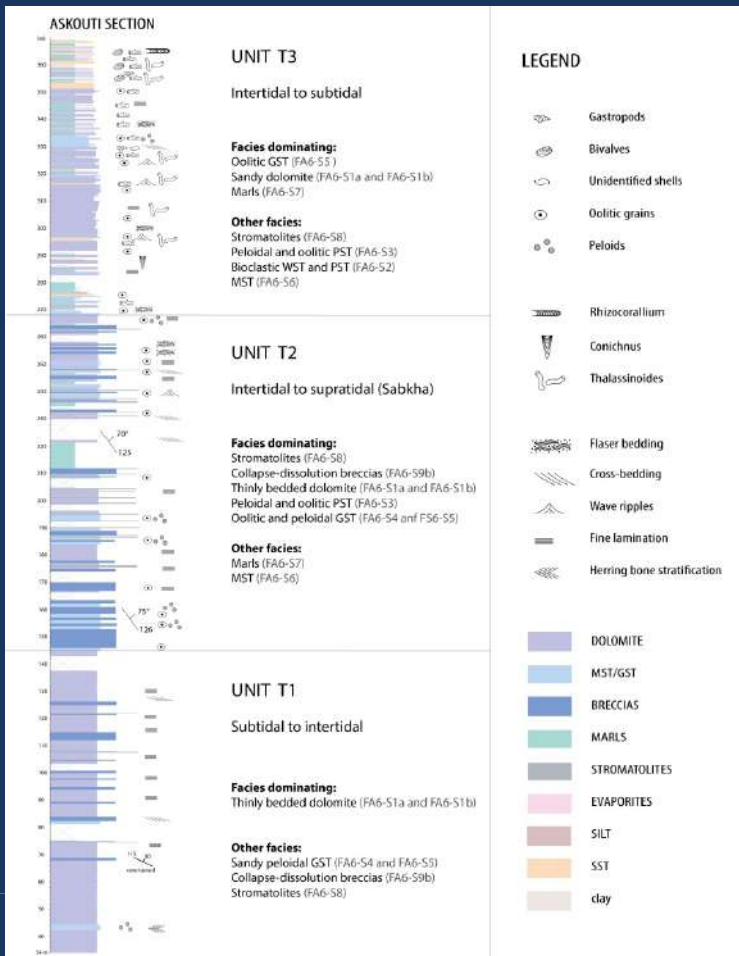


B1 - Tamarout Formation
Shallow open marine
Semi-arid climate



B2 - Tamarout Formation
Restricted marine
Arid climate



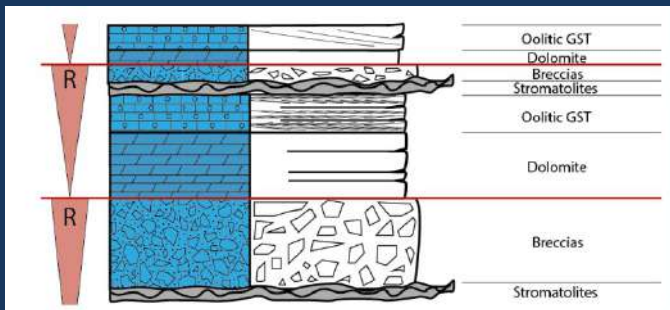


LOWER JURASSIC



UNIT 2

Intertidal to
Supratidal cycles



Oolitic GST



Stromatolites



UNIT 3

Subtidal deposits
Oolitic GST



Cross-bedded Oolite



Quartz gr. and ooids Xlamina

*Apparition of dark,
Kerogenic horizons,
presence of wood
fragments*



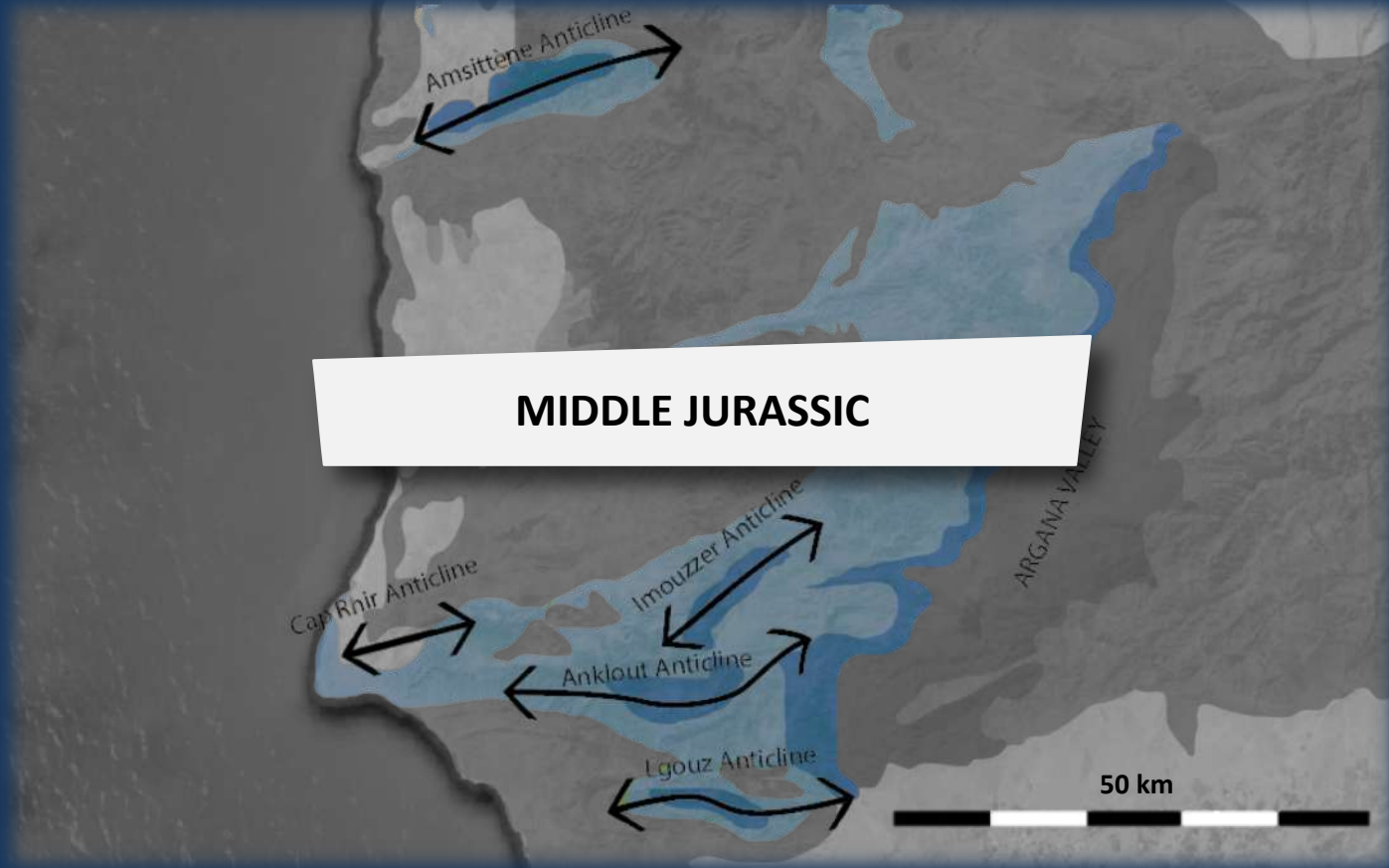
Evaporites



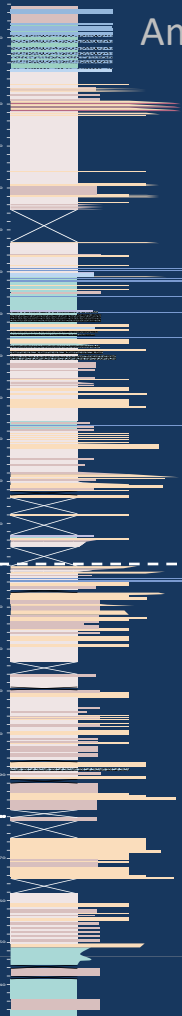
Dissolution breccias



→ Best potential reservoir unit



MIDDLE JURASSIC



Red mudstones



Roots traces



Dolomite horizons



Red sandstones



Wave ripples



Tidal channels

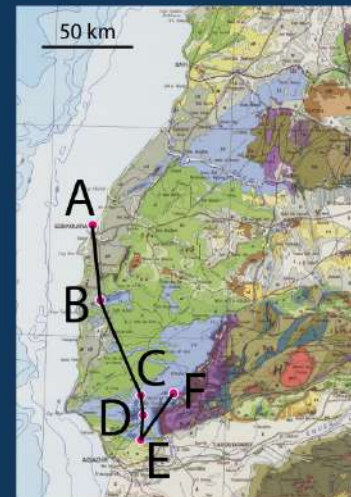
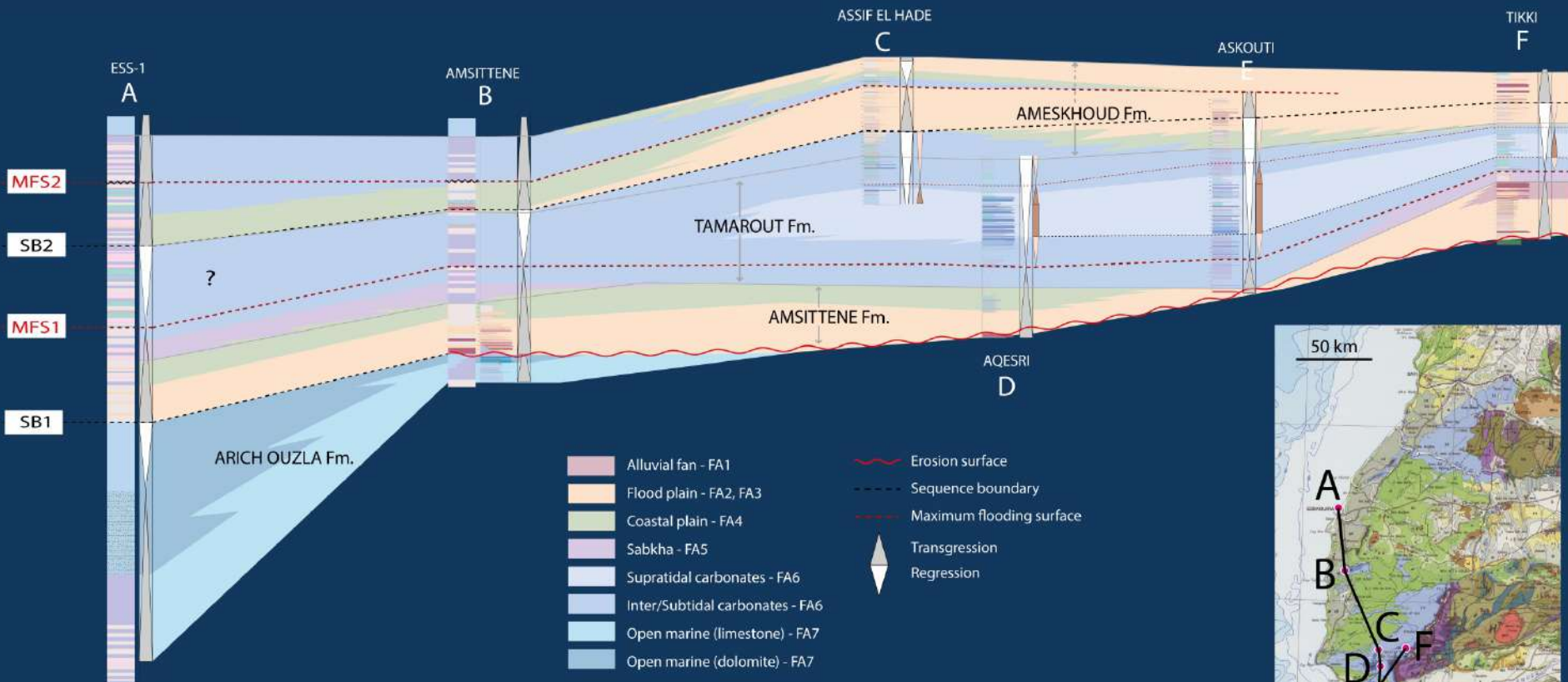
TERRESTRIAL

MARINE

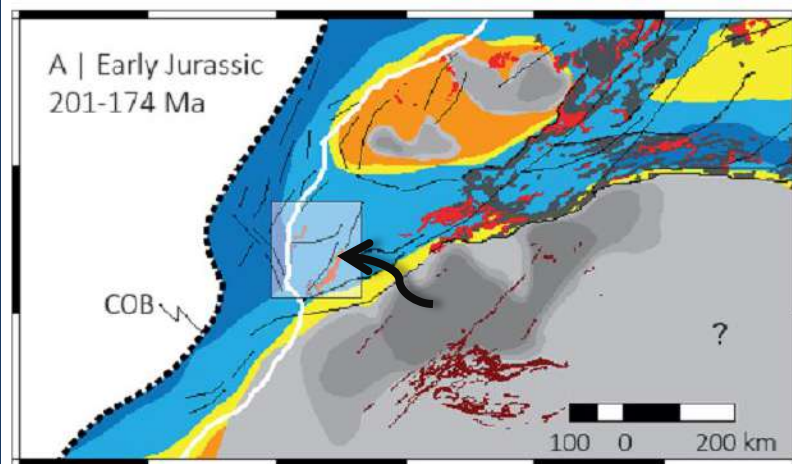
LOWER AND MIDDLE JURASSIC



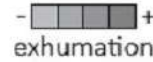
TIKKI
F



SILICICLASTICS



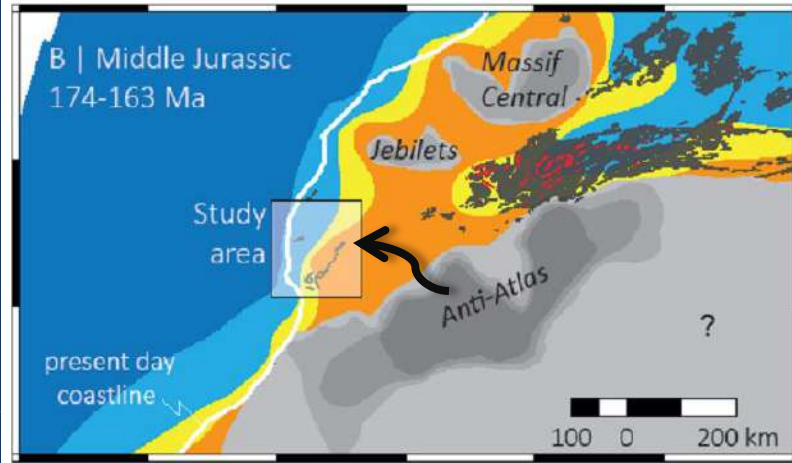
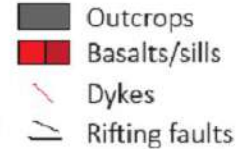
Source area
(after Charton, 2018)



Environments
(after Charton, 2018)



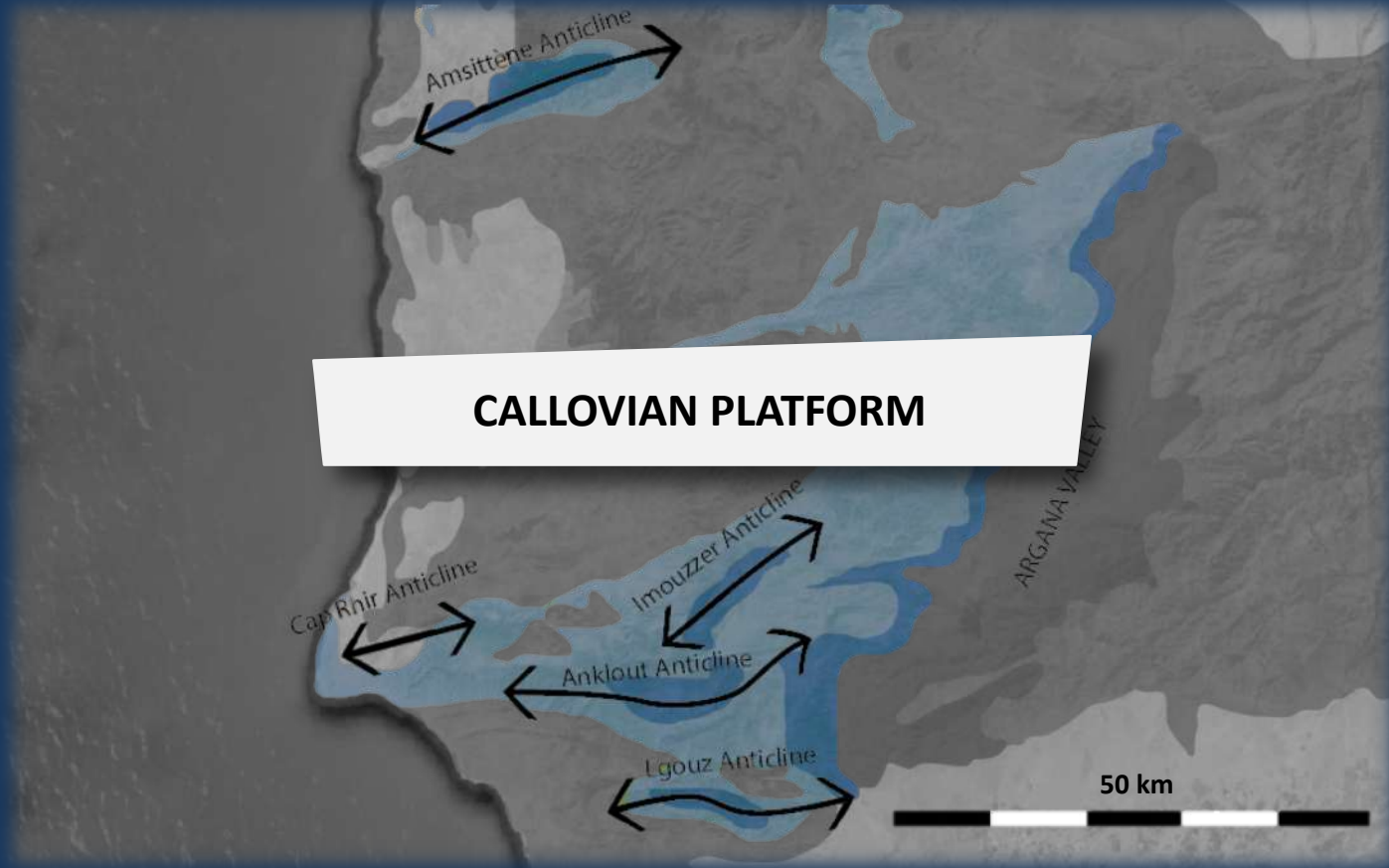
Geological map
(after Hollard et al., 1985)



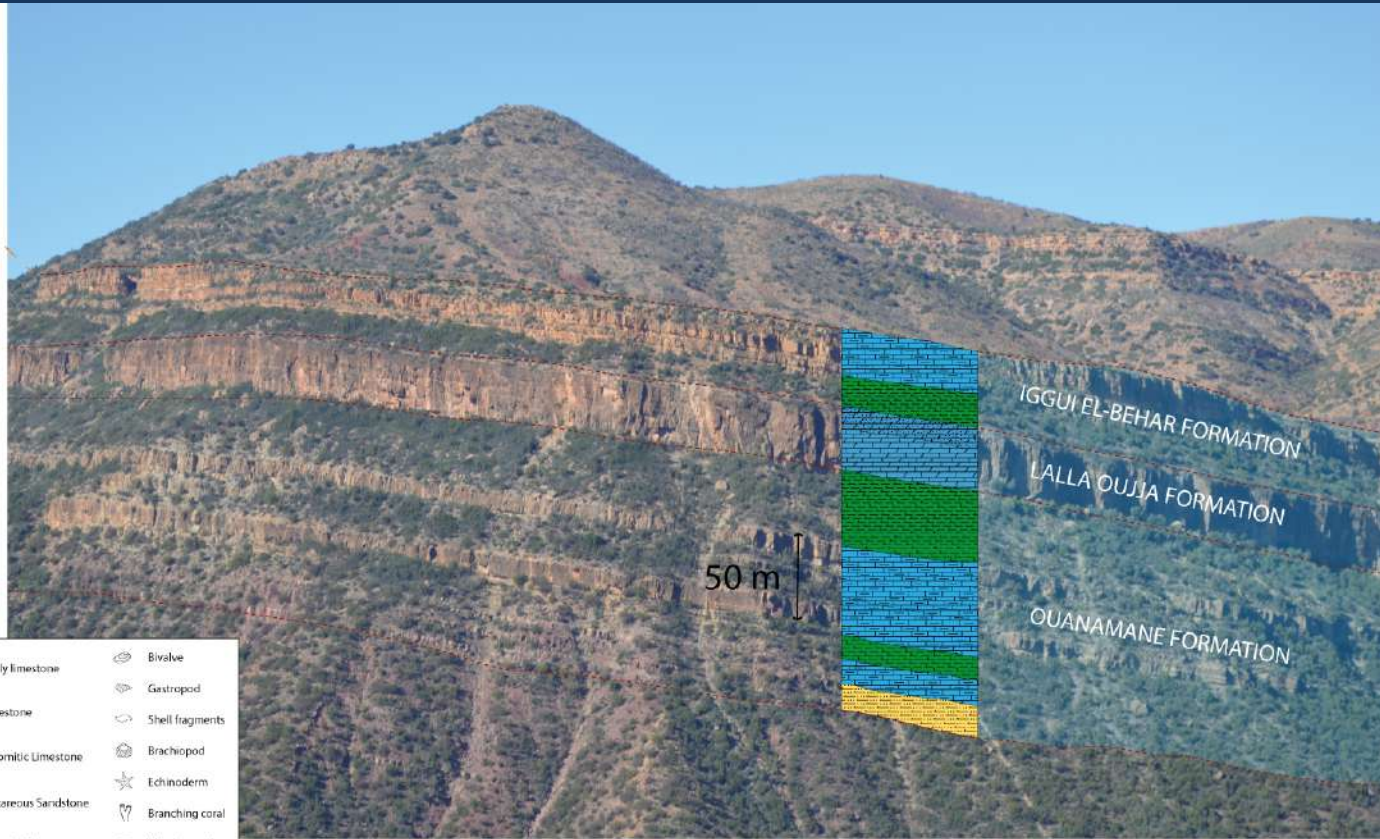
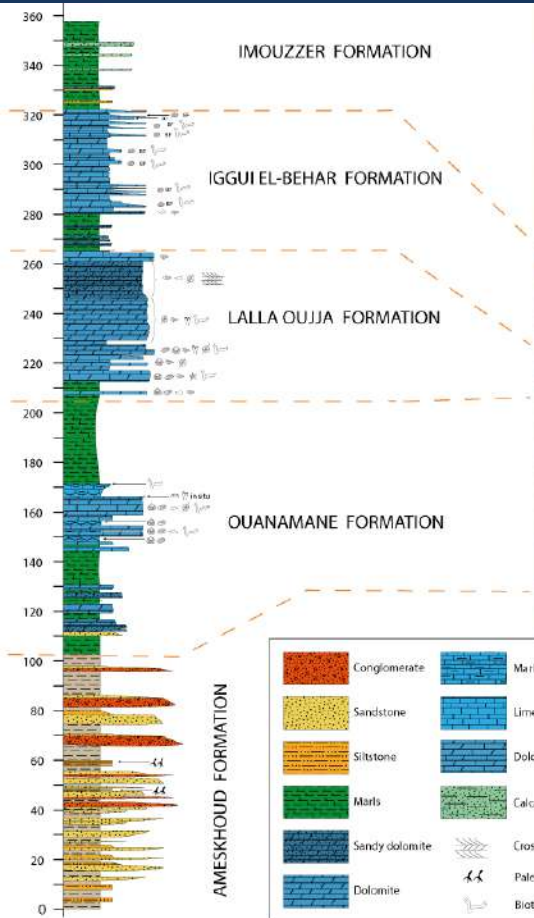
Lower and Middle Jurassic:

- Strong exhumation of the Central Anti-Atlas
- Smaller exhumation of the Massif Central and Jebilet
- General SE-NW proximal-distal orientation


Siliciclastics provenance very likely from the Central Anti-Atlas



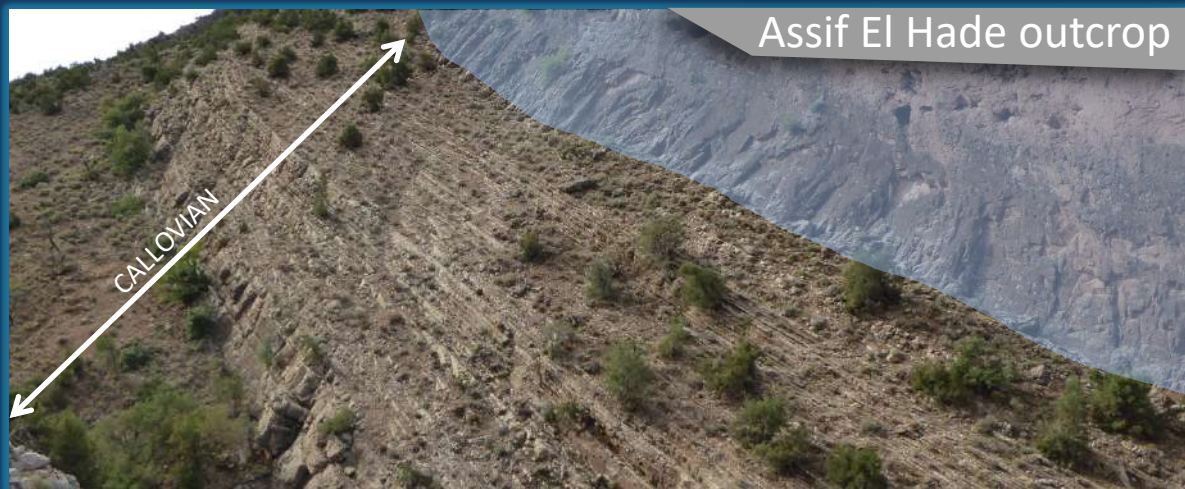
STRATIGRAPHIC OVERVIEW



	Conglomerate		Marly limestone		Bivalve
	Sandstone		Limestone		Gastropod
	Siltstone		Dolomitic limestone		Shell fragments
	Marls		Calcareous sandstone		Brachiopod
	Sandy dolomite		Cross bedding		Echinoderm
	Dolomite		Paleosol		Branching coral
			Bioturbation		Massive coral
					Solitary coral
					Coral fragments

 Dolomitic limestones
  Marly limestones
  Sandy dolomite
  Marls
  Calcareous siltstone

CALLOVIAN PLATFORM



Aalenian-Callovian
Palaeomap
From Scotese, 2011

Open platform:

- Oolitic GST
- Brachiopod rich marls
- FST and RST
- Firm and Hard Ground
- General transgression

Alternation Marls /  rich FST

PST/FST
Elements

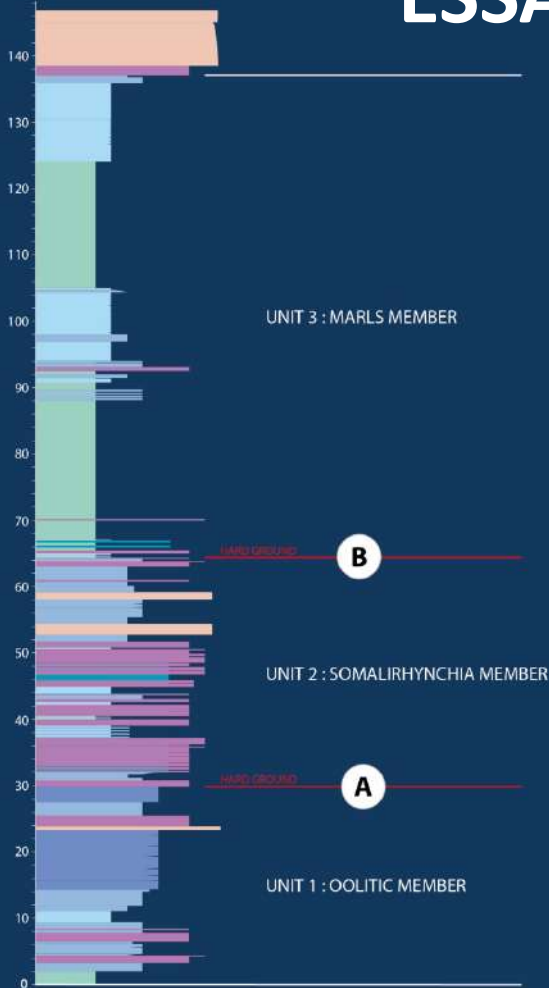
Elements %
↑



ESSAOUIRA – AGADIR BASIN



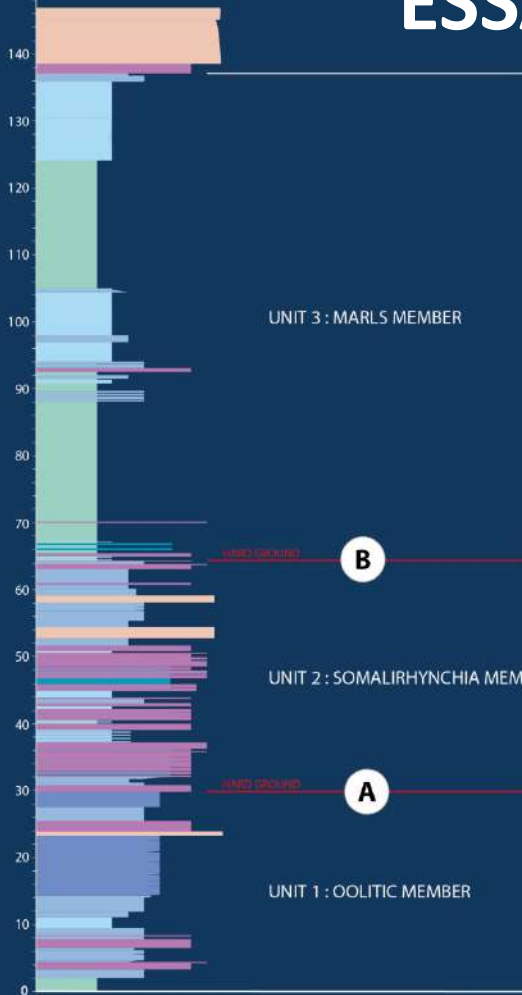
TIZGUIT SECTION



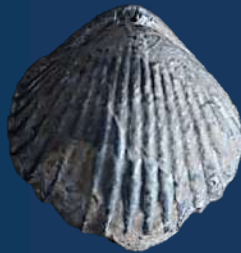
ESSAOUIRA – AGADIR BASIN



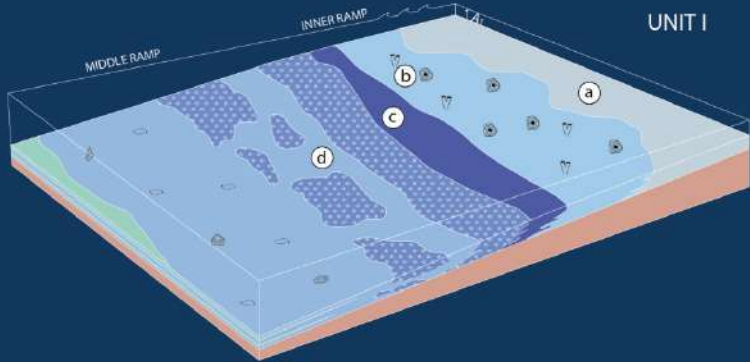
TIZGUIT SECTION



transgression

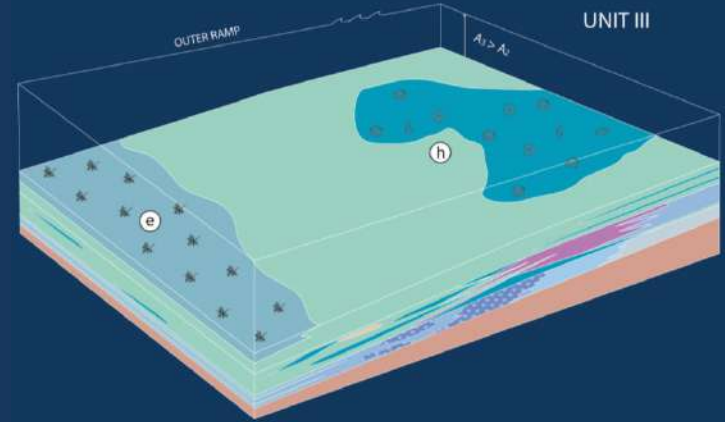


DEPOSITIONAL ENVIRONMENTS

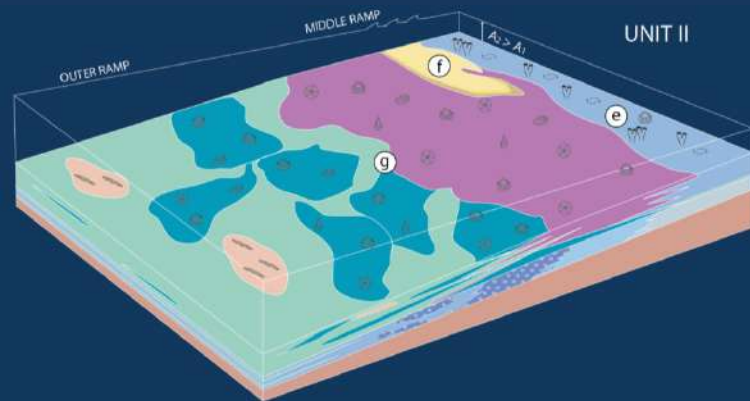


UNIT I

- Silty/sandy limestone
- WST/PST and oncoidal FST with patch-reefs
- Coraline RST and Oolitic /Bioclastic GST
- Oolitic and Bioclastic GST
- Bioclastic WST/PST locally FST



UNIT III

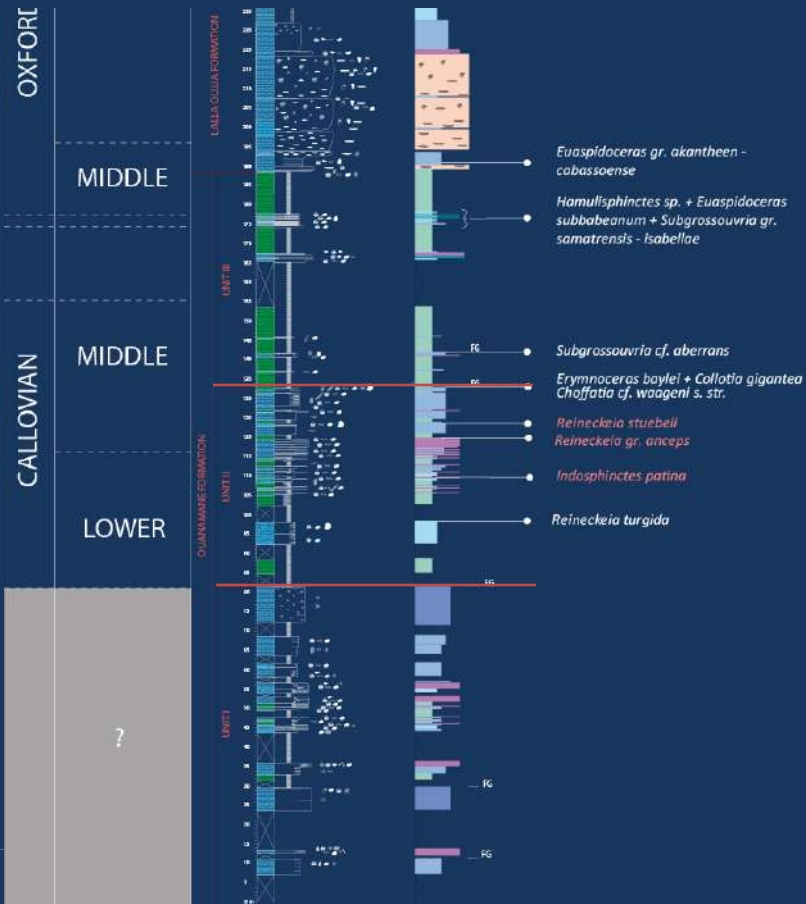


UNIT II

- Bioclastic WST/PST with patch-reefs
- Carbonate sandstone and sandy carbonates
- Brachiopod-rich FST and RST
- Brachiopod-rich marly FST and RST
- Marls
- Platy-coral Boundstones

- Chondrites trace-fossil
- Gastropods
- Echinoderms
- Corals
- Oncoids
- Bivalves
- Brachiopods
- Bioclasts
- Brachiopod-rich marly FST and RST
- Marls
- Marly MST

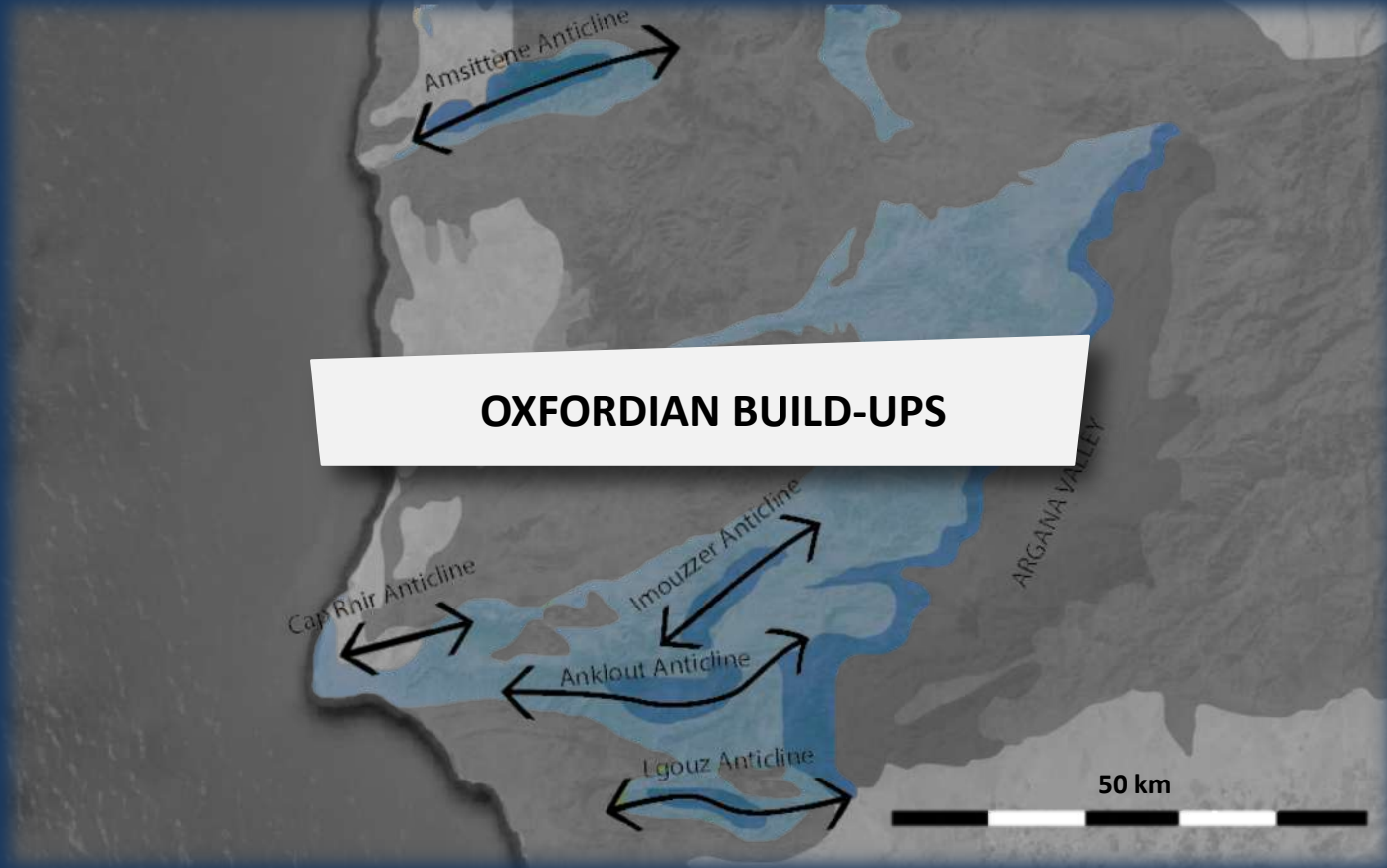
BIOSTRATIGRAPHY



STAGES		ZONES	Subzones	EAB RECORD	
OXFORDIAN	UPPER	PLANULA		LALLA OUIJJA FORMATION	
		BIMAMMATUM			
	MIDDLE	BIFURCATUS			
		TRANSVERSARIUM			
		PLICATILIS			
	LOWER	CORDATUM			
MARIAE					
CALLOVIAN	UPPER	LAMBERTI	Lamberti	<ul style="list-style-type: none"> • <i>Euspidoceras subbabeanum</i> 	
			Poculum		
	ATHLETA	Collotiformis	<ul style="list-style-type: none"> • <i>Pseudopeltoceras (= Hamulisphinctes) / Subgrossouvria cf. gr. samatrensis - isabellae</i> 		
		Trezeense			
		Rota			
	MIDDLE	CORONATUM	Leuthardti		<ul style="list-style-type: none"> • <i>Reineckeia sp. juv. gr. reissi / Subgrossouvria cf. aberrans</i> • <i>Collotia cf. gigantea / Choffatia waageni / Erymnoceras baylei / Reineckeia cf. rugosa / Choffatia cf. waageni / Rehmannia (Loczyceras)</i>
			Baylei		
			Tyranniformis		
	LOWER	ANCEPS	Stuebeli		<ul style="list-style-type: none"> • <i>Reineckeia gr. anceps / Choffatia gr. subbalinensis / Reineckeia stuebeli / Rehmania (Loczyceras) gr. richei</i> • <i>Reineckeia (Reineckeia) cf. turgida / Indosphinctes aff. choffati / Indosphinctes patina</i>
			Patina		
Michalskii					
GRACILIS		Voultensis			
		Grossouvria			
		Pracequense			
BULLATUS		?			
				OUANAMANE FORMATION	

CORRELATIONS

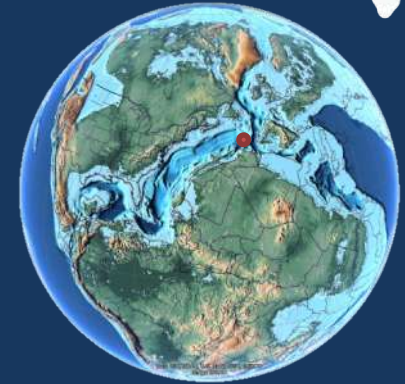




OXFORDIAN BUILD-UPS

OXFORDIAN BIOSTROMES

Tidili outcrop



Oxfordian-Kimmeridgian
Palaeomap
From Scotese, 2011

Evolution of coral
associations

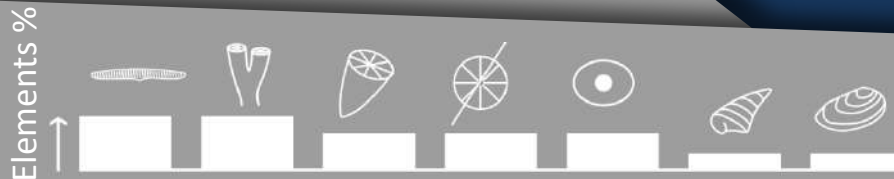


Prograding
Clinoforms

Rimmed platform:

- Coral reefs
- MST / PST / BST
- Diachronism
- Shallowing upward

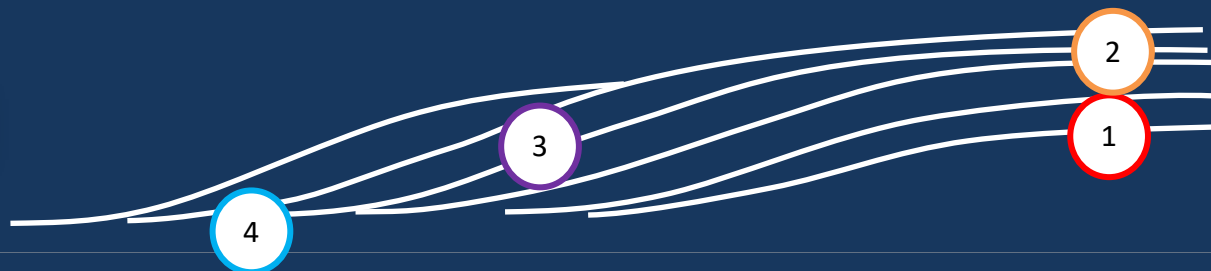
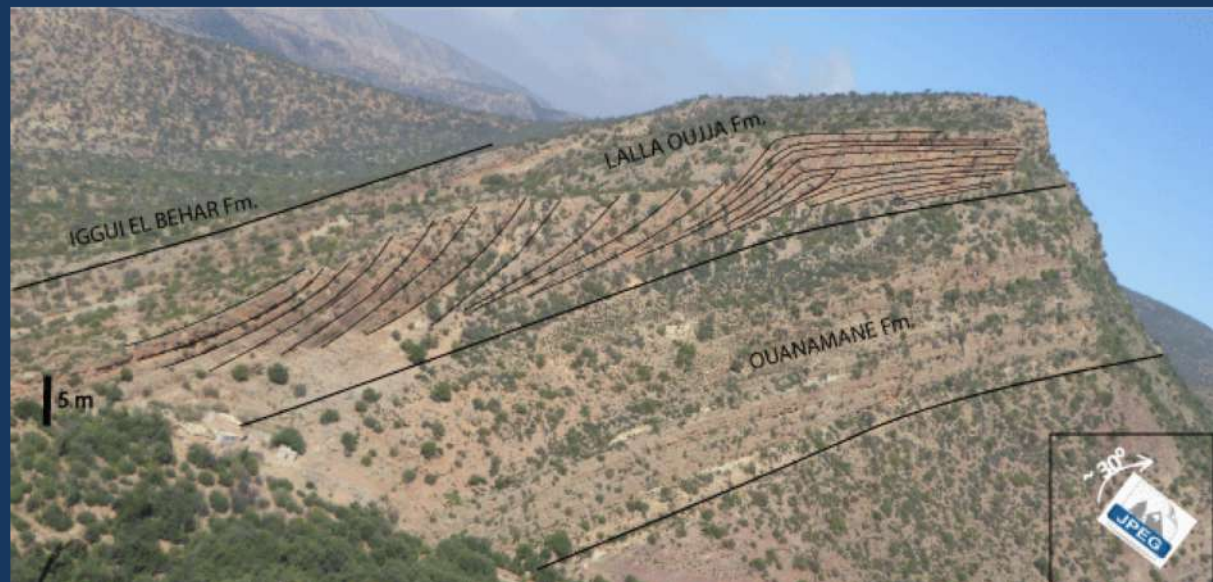
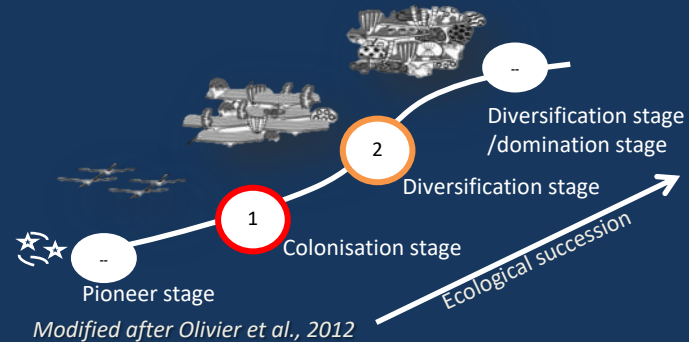
BST/FST
Elements



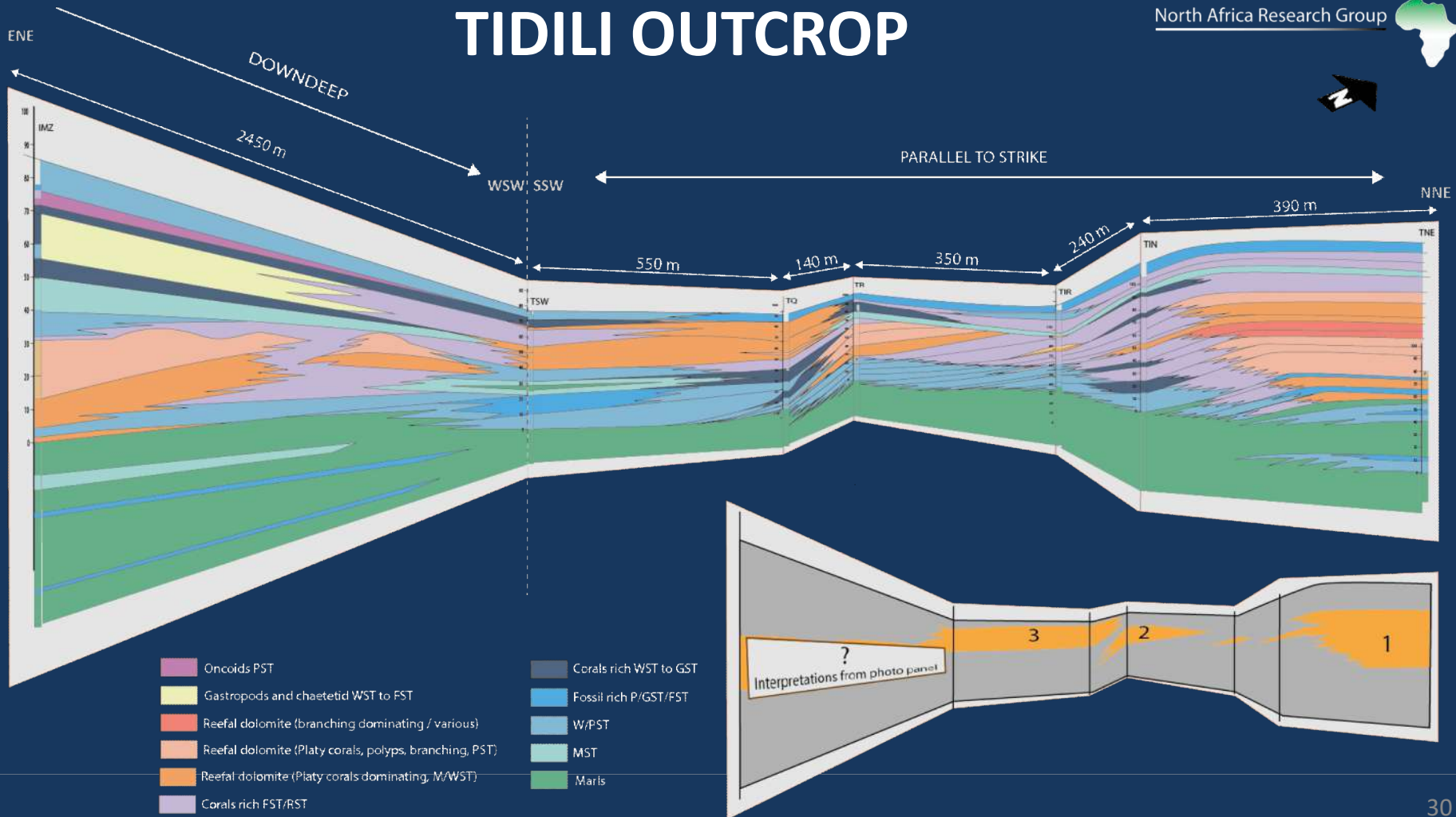
TIDILI OUTCROP



OXFORDIAN REEF ECOLOGICAL SUCCESSION



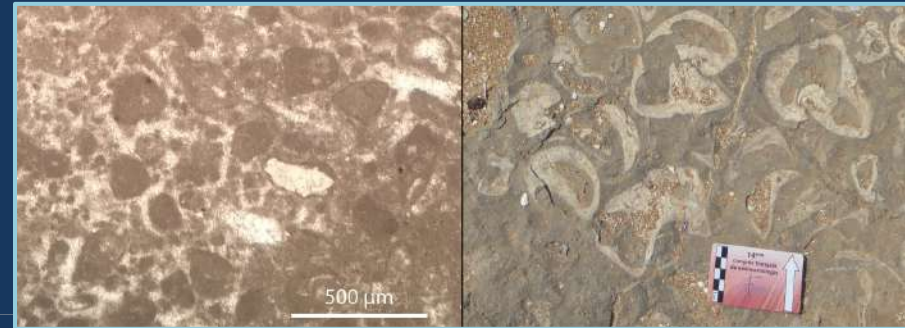
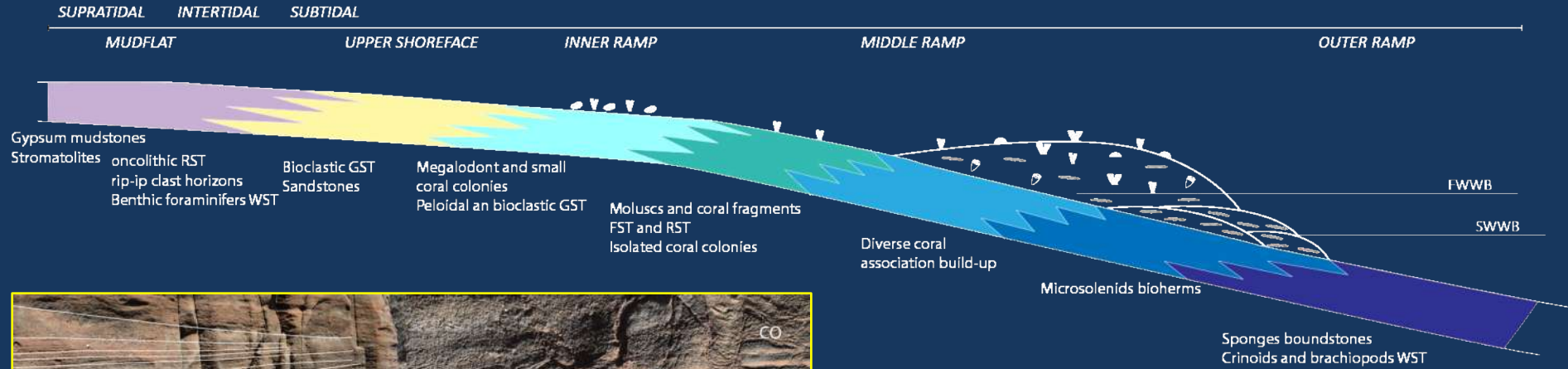
TIDILI OUTCROP



OXFORDIAN BIOSTROMS



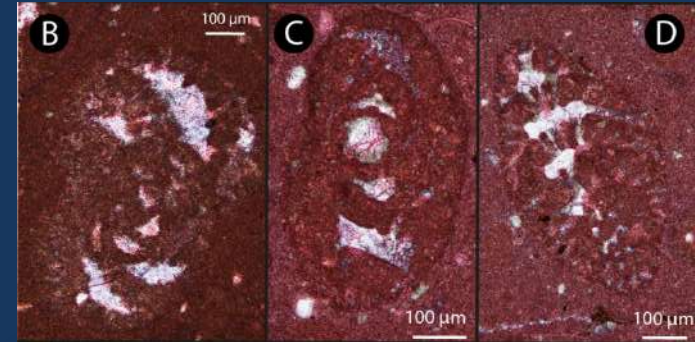
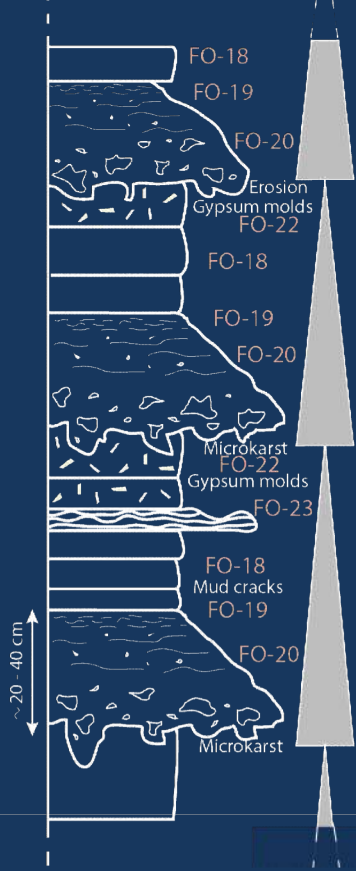
DEPOSITIONAL ENVIRONMENT



IGGUI EL-BEHAR FORMATION



Peritidal / supratidal cycles

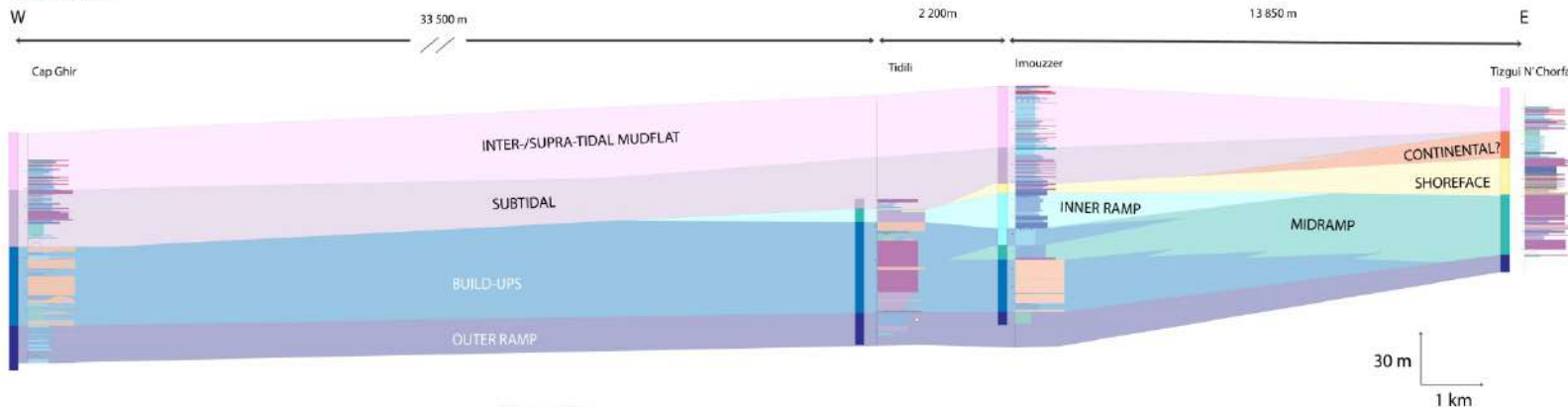


Pseudocyclamina and Alveosepta

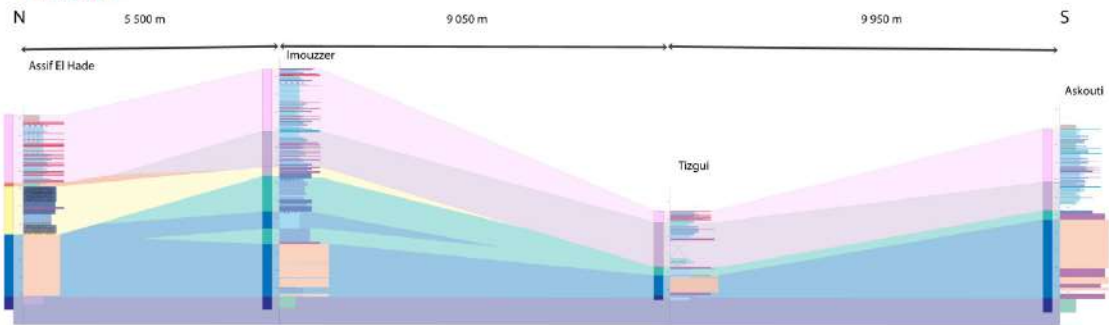
CALLOVIAN - OXFORDIAN



Transect A :



Transect B :



BOUNDSTONES



FLOATSTONES



GRAINSTONES



MUDSTONES



MARLS



RIP UP CLASTS HORIZON



DOLOMITE



WACKSTONES/PACKSTONES

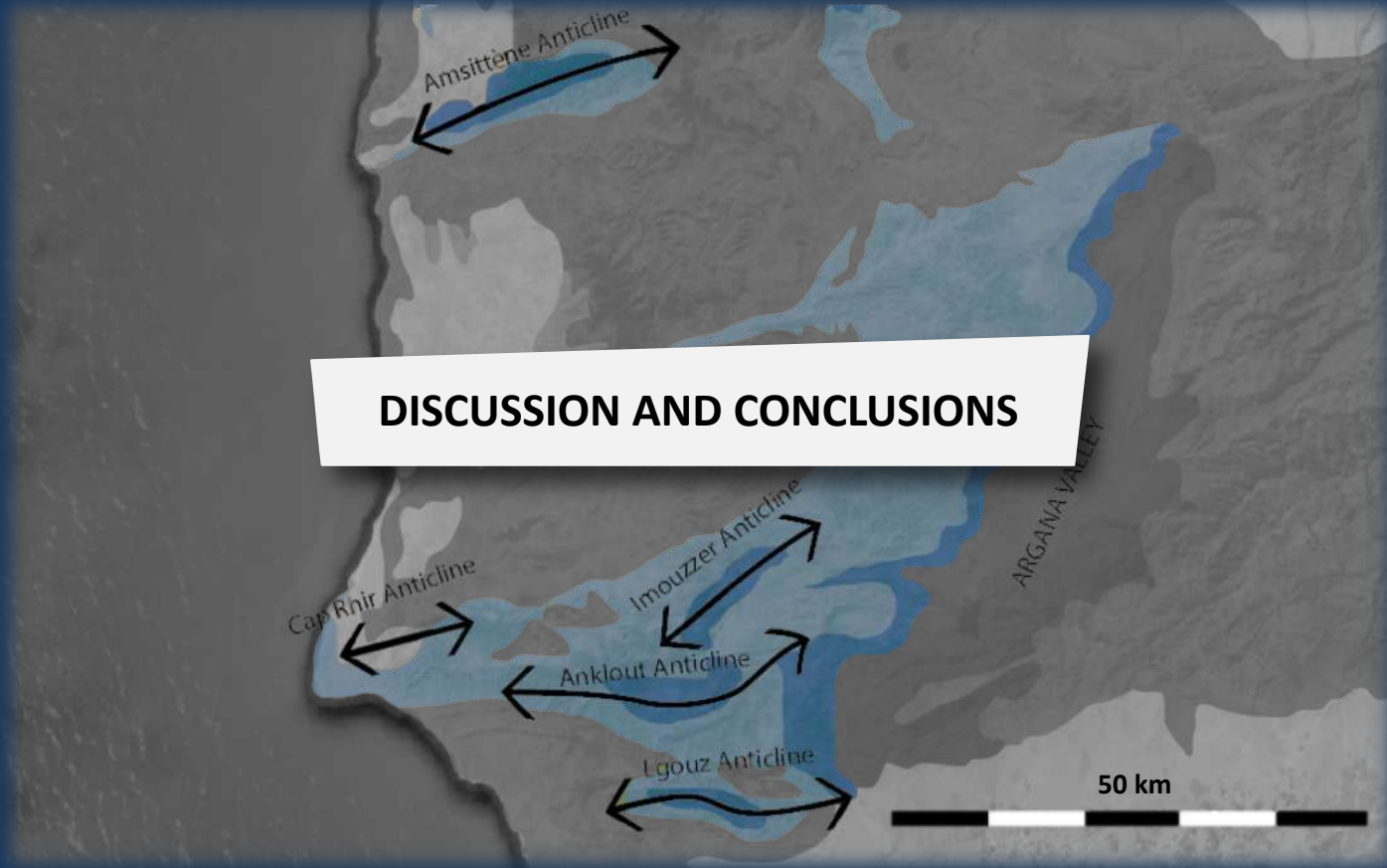


MARLY FLOATSTONES



SANDY CARBONATES





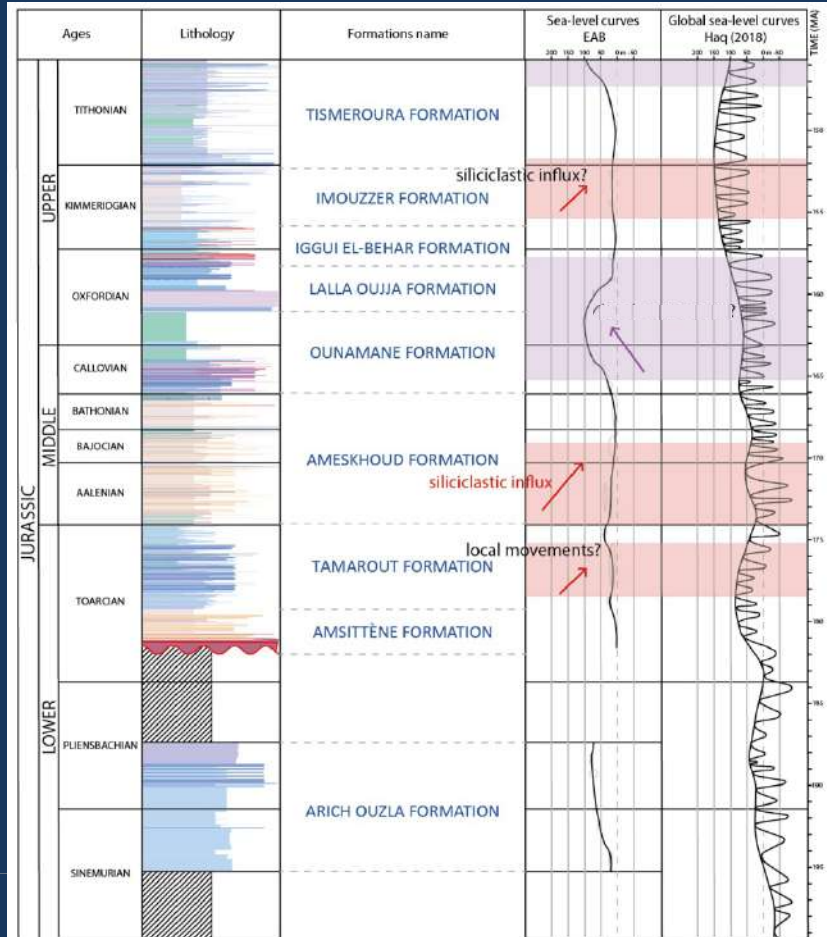
DISCUSSION AND CONCLUSIONS

COMPARISON NOVA SCOTIA



SCOTIAN BASIN			ESSAOUIRA-AGADIR BASIN			SUBSTAGES	STAGES
FORMATION	MEMBER	LITHOLOGY	LITHOLOGY	MEMBER	FORMATION		
ABENAKI	BACCARO			---	IGGUI EL BEHAR	UPPER	OXFORDIAN
	---	---	---	---	LALLA OUJJA	MIDDLE	
	MISAINÉ			MARLS	---	?	
	---	---	---	---	OUANAMANE	UPPER	CALLOVIAN
	SCATARIE			SOMALIRHYNCHIA	---	MIDDLE	
	---	---	---	OOLITE	---	LOWER	

STRATIGRAPHIC CONTROLS

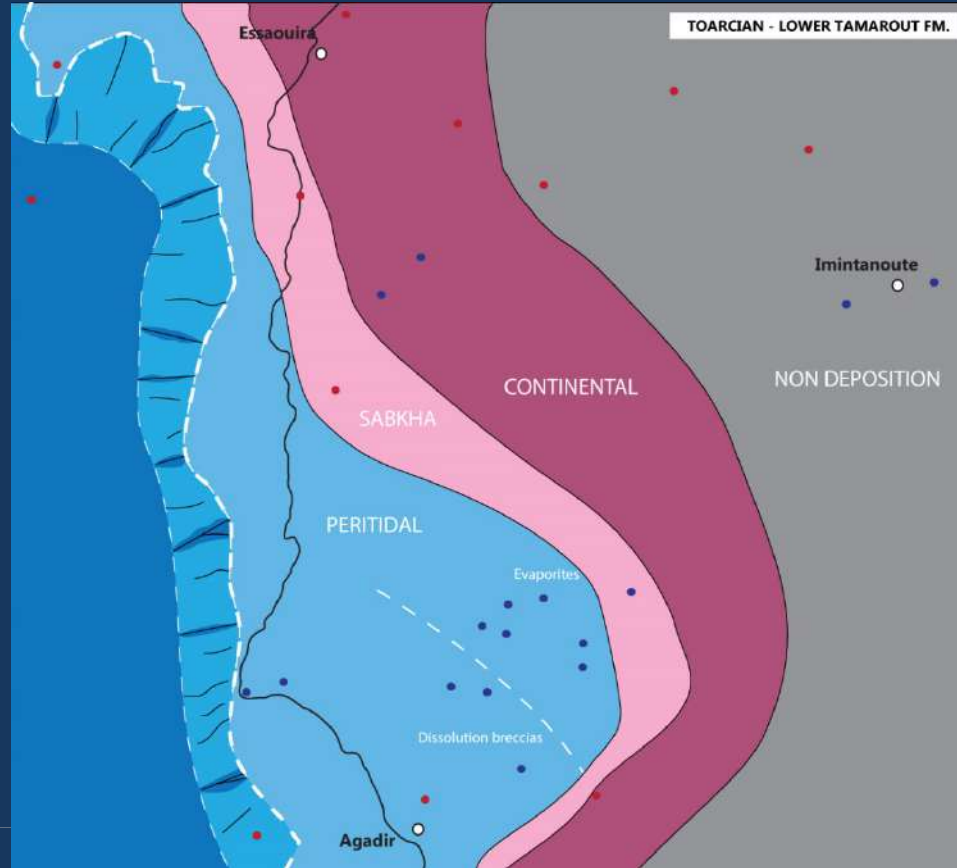


LESSER SILICICLASTIC INFLUX
MESETTA ? MOVEMENTS

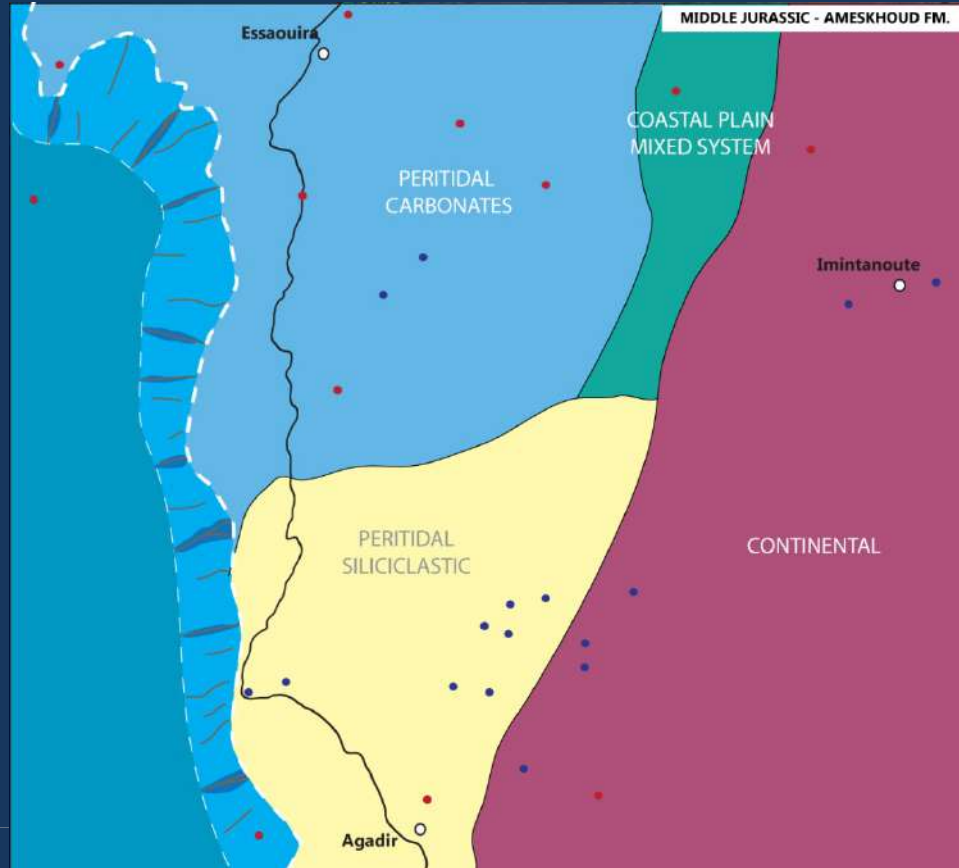
ENVIRONMENTAL CHANGES -
MICROSOLENIDS

STRONG SILICICLASTIC INFLUX
ANTI-ATLAS MOVEMENTS

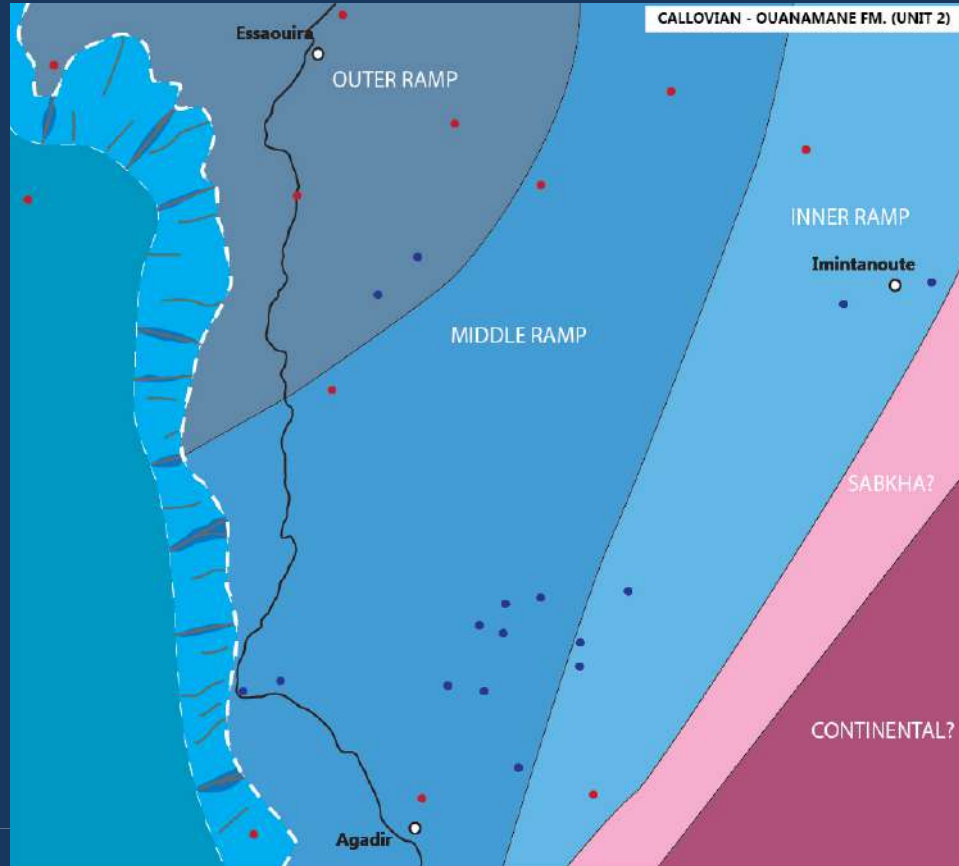
TOARCIAN



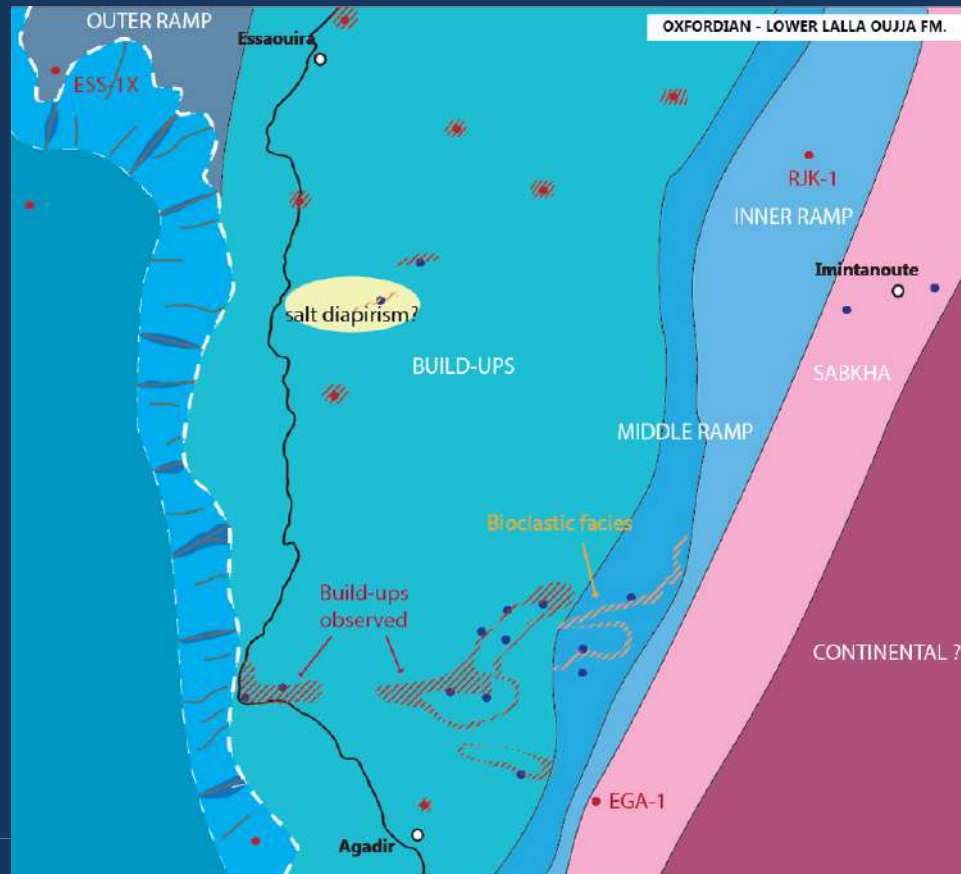
MIDDLE JURASSIC



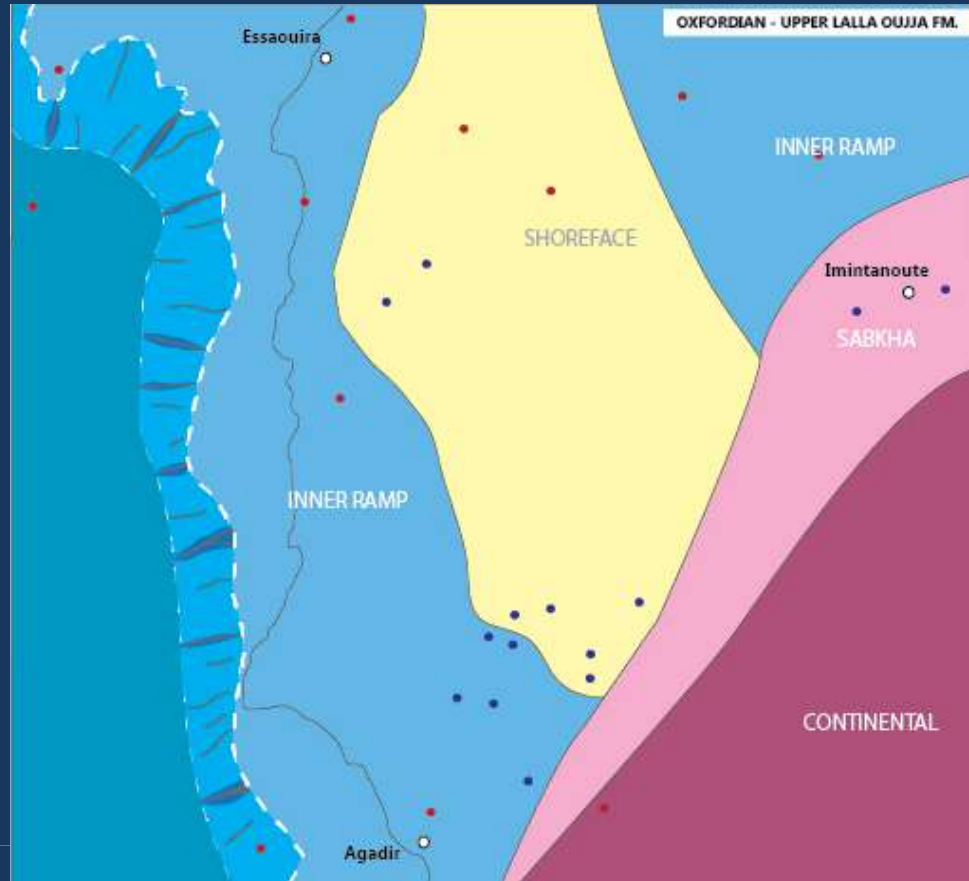
CALLOVIAN



OXFORDIAN



OXFORDIAN 2



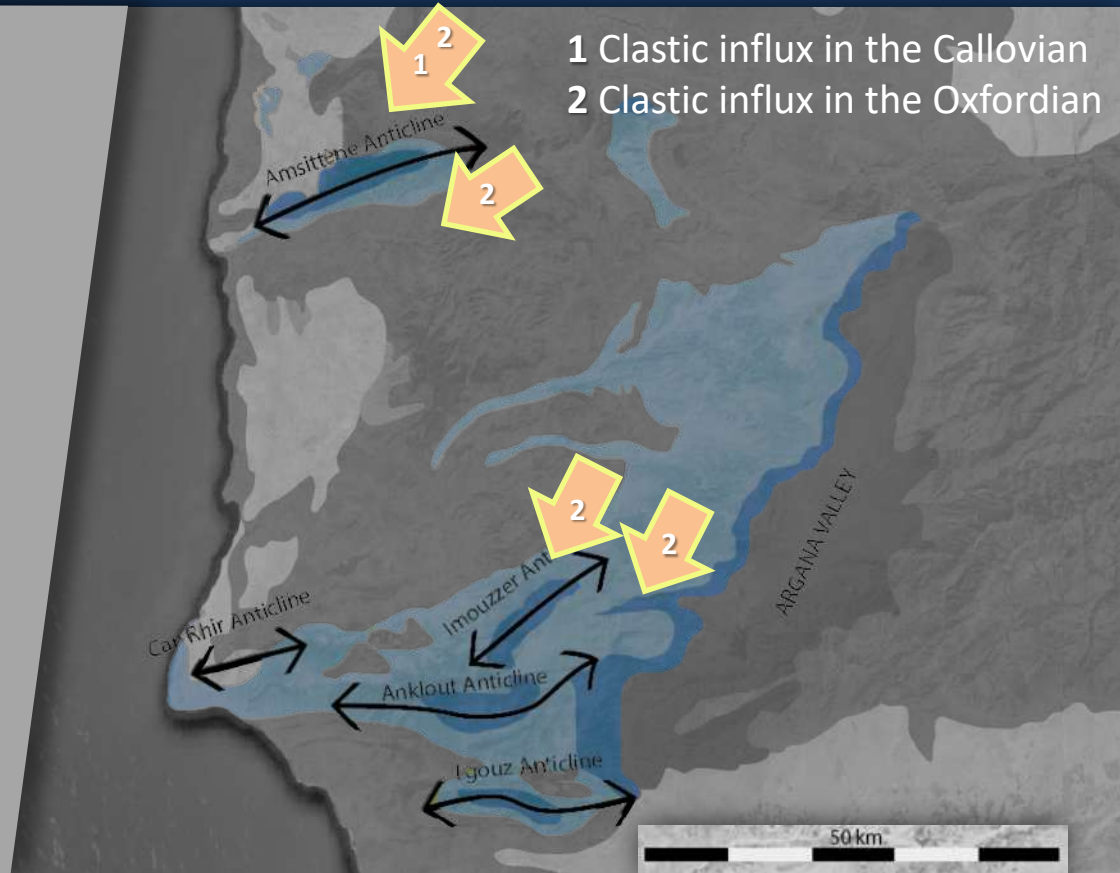


SILICI-CLASTIC INFLUX

Influence on the platform development :

- Reduces species diversity
- Increase the water turbidity
- Favours branching corals over flat corals
- Suppresses coral growth

Shoreface and beach deposits with siliciclastic influx from the North



CONCLUSIONS

▪ Biotratigraphy

- Age of the Ouanamane and Lalla Oujja Fm. refined (Lower Callovian – Middle Oxfordian)
- **Condensation / hiatus** (Central and Western Europe equivalent)

▪ Basin stratigraphy

- Toarcian **major erosion and siliciclastics** sedimentation linked to **hinterland movements**
- Extensive **shallow marine platform** during Toarcian
- Middle J. **siliciclastic regression** in the south of the basin linked to **hinterland movements**
- Callovian carbonate **ramp deposits** evolution to outer ramp marls followed by “deep” **microsolenids build-ups** growing locally to diversified coral colonies
- Major **regression** across the basin during the **Upper Oxfordian**

▪ Central Atlantic Margin

- Comparison with the **Scotian Basin**: very similar stratigraphy
- Better understanding of the controls of **Jurassic platforms along the margin**

Exploration implications

Potential **reservoir** levels identified:

- **Oolites** (Toarcian – Callovian)
- Coral Build-ups (Middle Oxf.)
- Middle Jurassic siliciclastics (S)
- Upper Jurassic **siliciclastics** (N)

Potential **source-rock** levels:

- Toarcian (weak)
- Kimmeridgian/Tithonian (to be studied)

Good extensive **Callovian seal**
Localised **Kimmeridgian seal**



- 1) Refining *Ammonites* biostratigraphy
- 2) *Siliciclastic influx* variations and provenance (Mid J. and Oxfordian)
- 3) Extend paleogeography further North (Carbonates evolution and variations)
- 4) Constraining *Kimmeridgian* and *Tithonian* source-rock potential
- 5) Refining stratigraphy and palaeoenvironments using *Charophytes* (Comparison with Portugal species)

THANK TO OUR SPONSORS :



TOTAL

REPSOL

bp



equinor



Special thanks :

