



# ESTABLISHING AN INTEGRATED STRATIGRAPHIC FRAMEWORK FOR THE EARLIEST CRETACEOUS INTERVAL OF THE MOROCCO ATLANTIC MARGIN

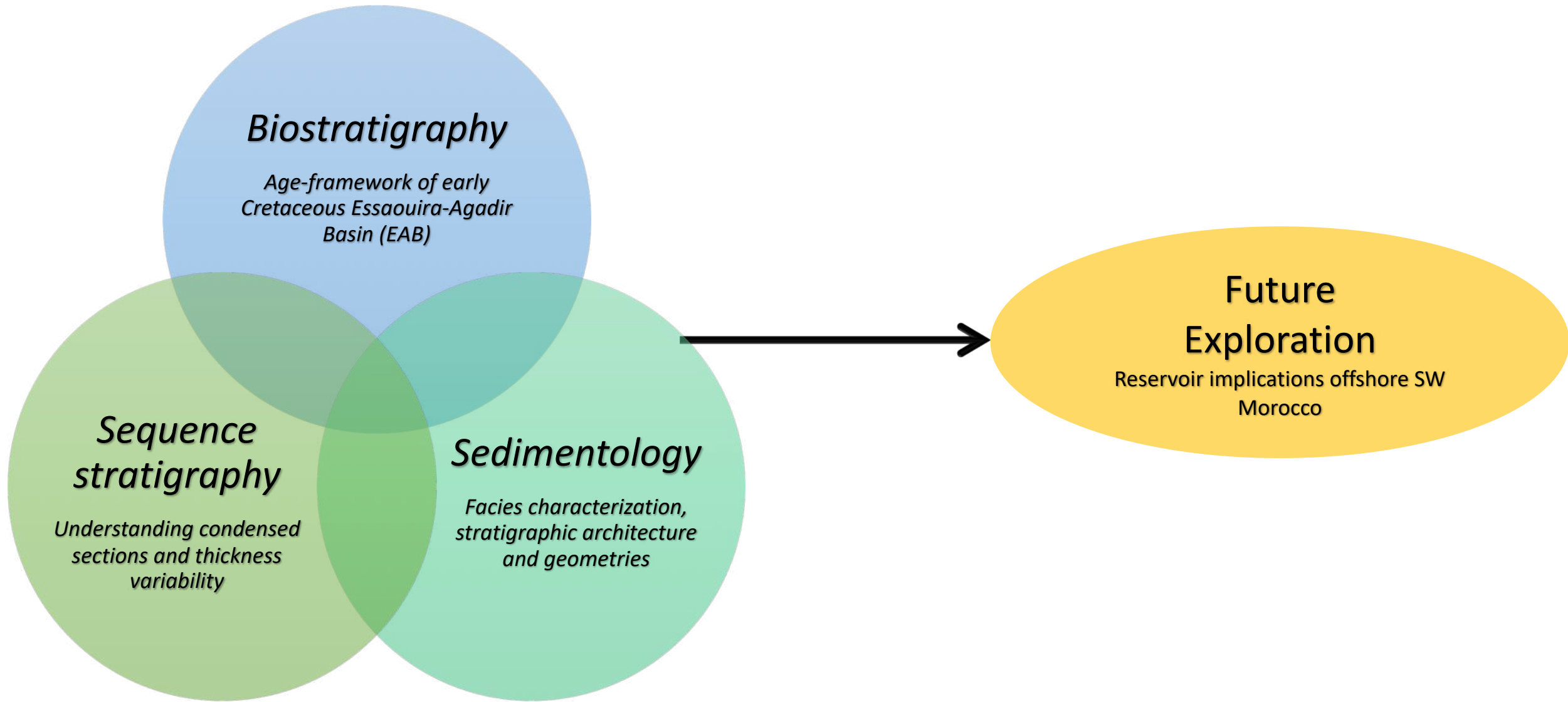
NARG STEERING MEETING SEPTEMBER 2019

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- **Project Rationale**
- **Project Aims**
- **Regional Context**
- **Initial Biostratigraphic Framework**
- **The Middle Berriasian Unconformity – a global scale hiatus?**
- **Thickness Variation Controls**
- **Key Outcomes**
- **Future Work**
- **Q&A**

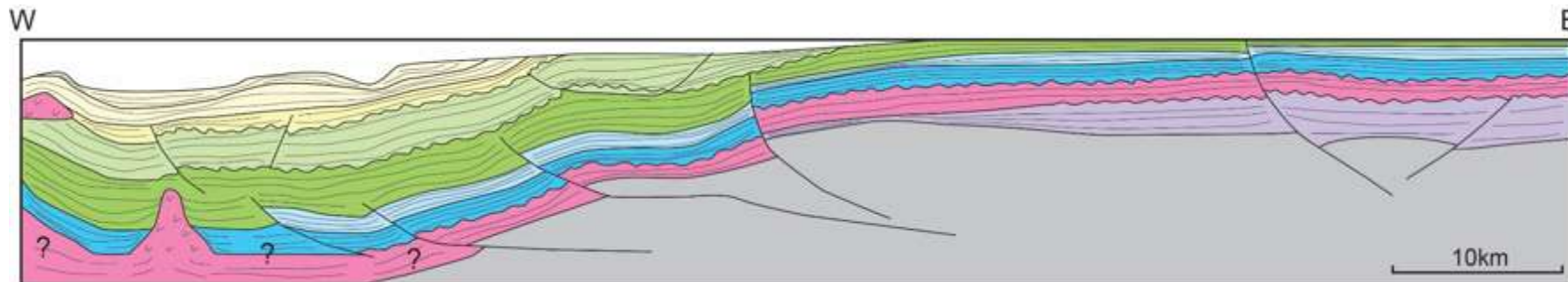
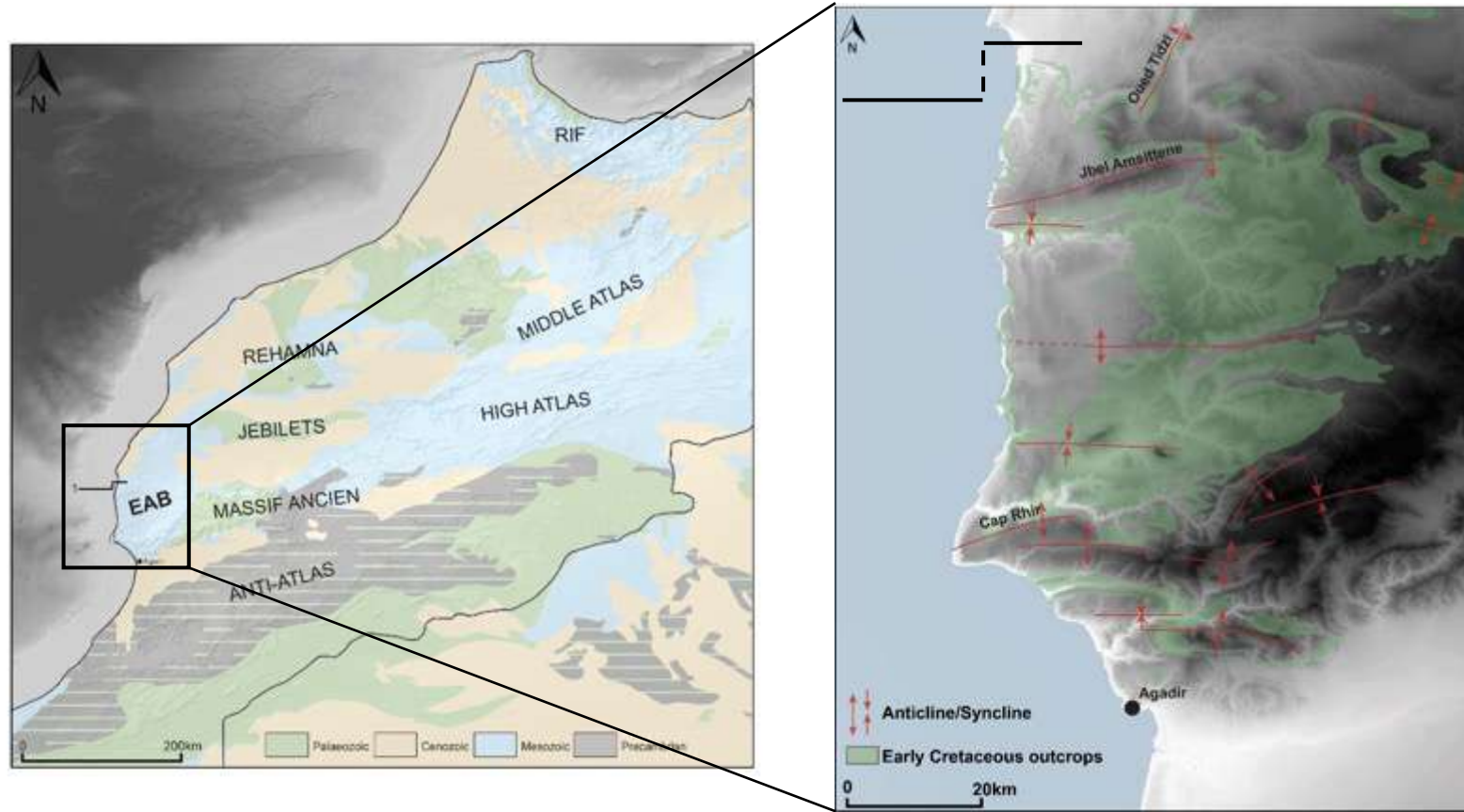
# PROJECT RATIONALE





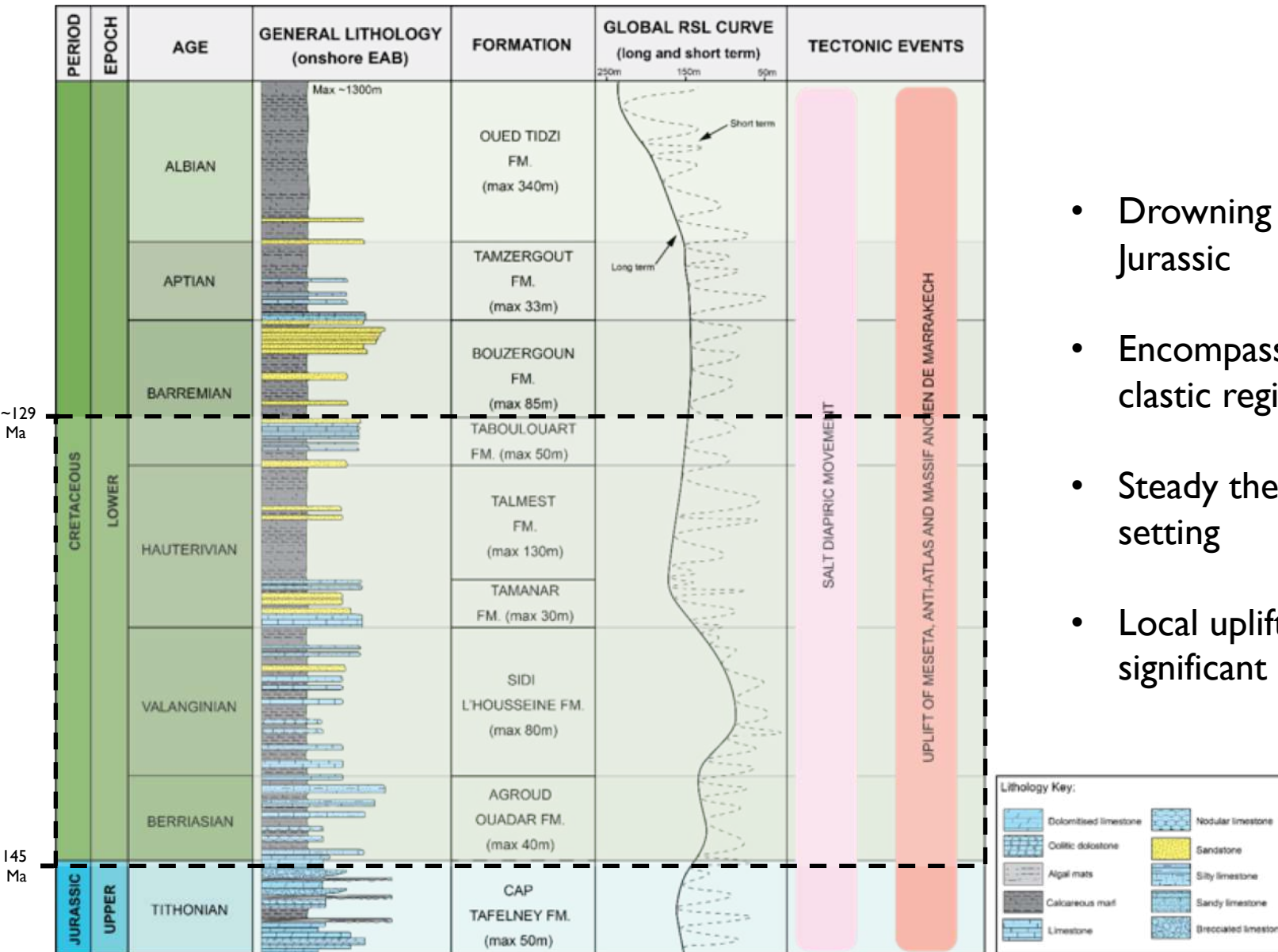
1. Establish a high-resolution biostratigraphic framework for the earliest Cretaceous Essaouira-Agadir Basin
2. Improve understanding of the controlling factors on condensed sections/hiatus intervals in passive margins
3. Develop a robust stratigraphic framework on a regional-scale

# REGIONAL GEOLOGICAL CONTEXT



(Modified from Hafid, 2006)

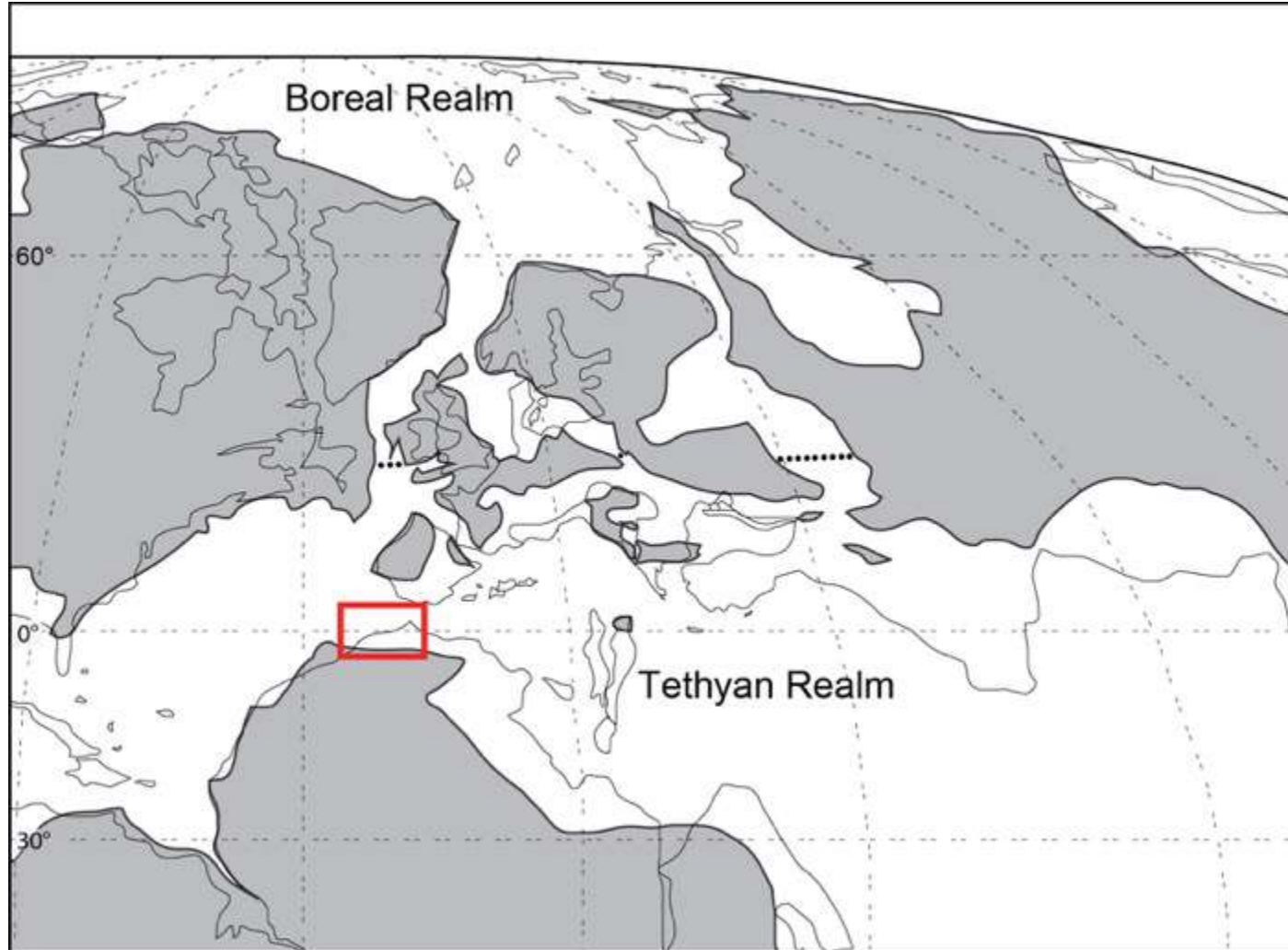
# REGIONAL GEOLOGICAL CONTEXT



- Drowning of major carbonate shelf at end of Jurassic
- Encompasses transition between a carbonate-clastic regime
- Steady thermal subsidence in passive margin setting
- Local uplift of ancient highs resulted in significant periods of clastic input basinward

(Stratigraphy and tectonic events based on recent NARG studies. RSL curve from Haq, 2014.)

# PALAEOGEOGRAPHICAL CONTEXT

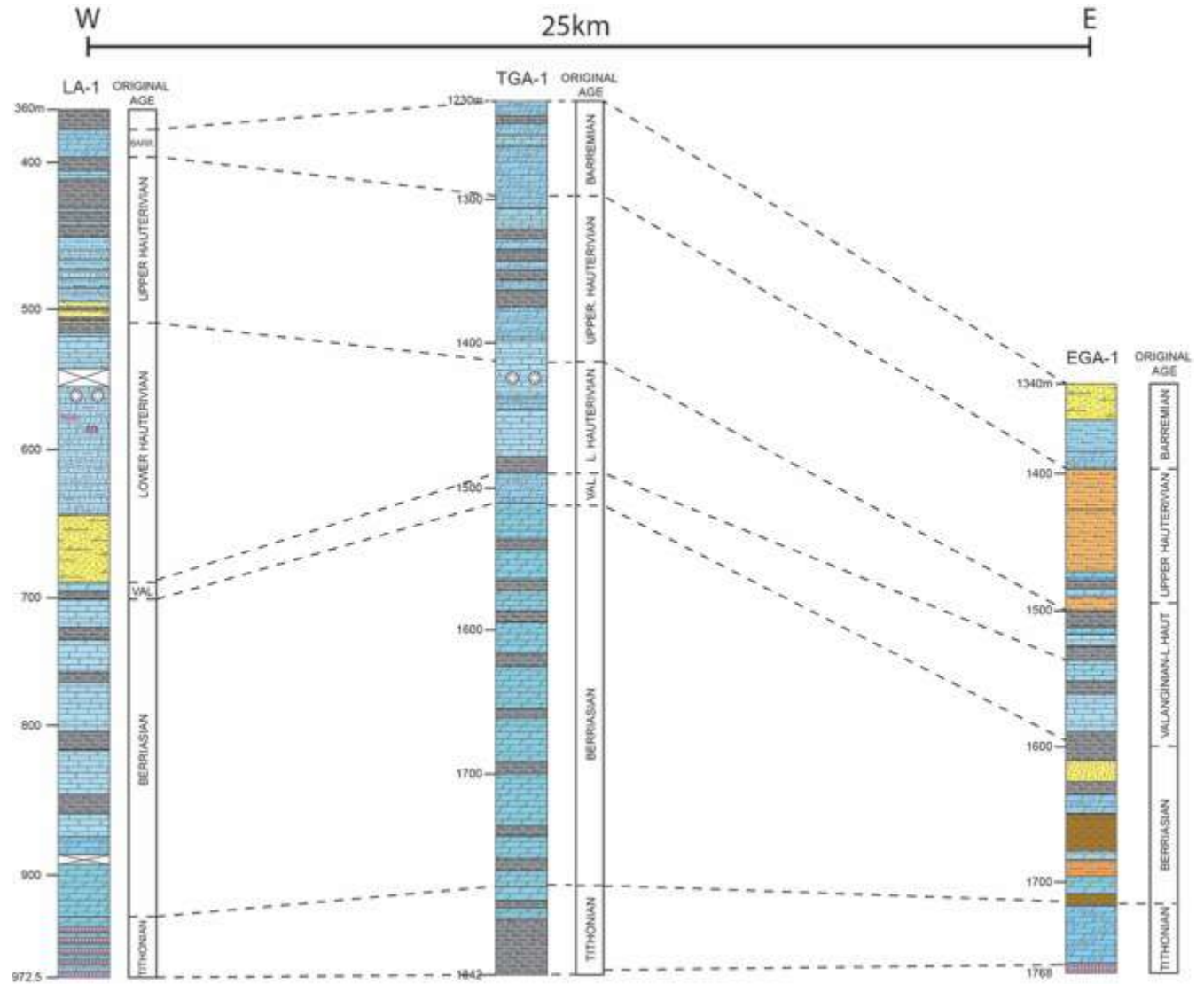


(Modified from Mutterlose, 2008)

		Standard Western Mediterranean Zonation Hoedmaecker & Rawson (2000)			Proposed Moroccan Atlantic Atlas Zonation (Ettachfni, 2004)	
		ZONES	SUBZONES	HORIZONS	ZONES	HORIZONS
HAUTERIVIAN	UPPER	<i>P. angulicostata auctorum</i>	<i>P. catuloi</i>		<i>P. ohmi</i>	<i>P. ohmi</i>
		<i>B. balearis</i>	<i>P. angulicostata auct.</i>		<i>C. balearis</i>	<i>C. balearis</i>
	<i>P. ligatus</i>			<i>P. ligatus</i>		
	<i>S. sayni</i>		<i>C. cruasense</i>	<i>S. sayni</i>		
	LOWER	<i>L. nodosoplicatum</i>		<i>O. (O.) variegatus</i>	<i>L. nodosoplicatum</i>	<i>L. claveli</i> <i>L. nodosoplicatum</i>
VALANGINIAN	UPPER	<i>C. loryi</i>	<i>O. (J.) veneti</i> <i>C. loryi</i>		<i>C. loryi ?</i>	
		<i>A. radiatus</i>		<i>B. castellanensis</i>	<i>A. radiatus</i>	<i>L. buxtorfi</i> <i>B. castellanensis</i>
		<i>T. calidiscus</i>		<i>T. calidiscus</i>	<i>N. calidiscus</i>	<i>N. calidiscus</i>
	LOWER	<i>H. trinodosum</i>	<i>O. (O.) nicklesi</i> <i>C. furcillata</i> <i>N. peregrinus</i>		<i>H. trinodosum</i>	<i>C. furcillata</i> <i>O. (O.) nicklesi</i> <i>N. peregrinus</i>
		<i>S. verrucosum</i>	<i>K. pronicostatum</i> <i>S. verrucosum</i>		<i>S. verrucosum</i>	<i>S. verrucosum</i>
BERRIASIAN	UPPER	<i>B. campylotoxus</i>			<i>K. biallense</i>	
		<i>T. pertransiens</i>			<i>B. campylotoxus</i>	
	LOWER	<i>T. otopeta</i>			<i>N. aff. subtenis</i> <i>N. tremolcus</i>	
MIDDLE	UPPER	<i>F. boissieri</i>	<i>T. spilensis</i> <i>B. picteti</i> <i>M. paramimounum</i>		<i>F. boissieri</i>	<i>T. spilensis</i>
		<i>T. occitanica</i>	<i>D. dalmasi</i> <i>B. privasensis</i> <i>T. subapina</i>		<i>T. occitanica</i>	<i>T. subapina</i>
	LOWER	<i>B. jacobi</i>			<i>B. jacobi</i>	

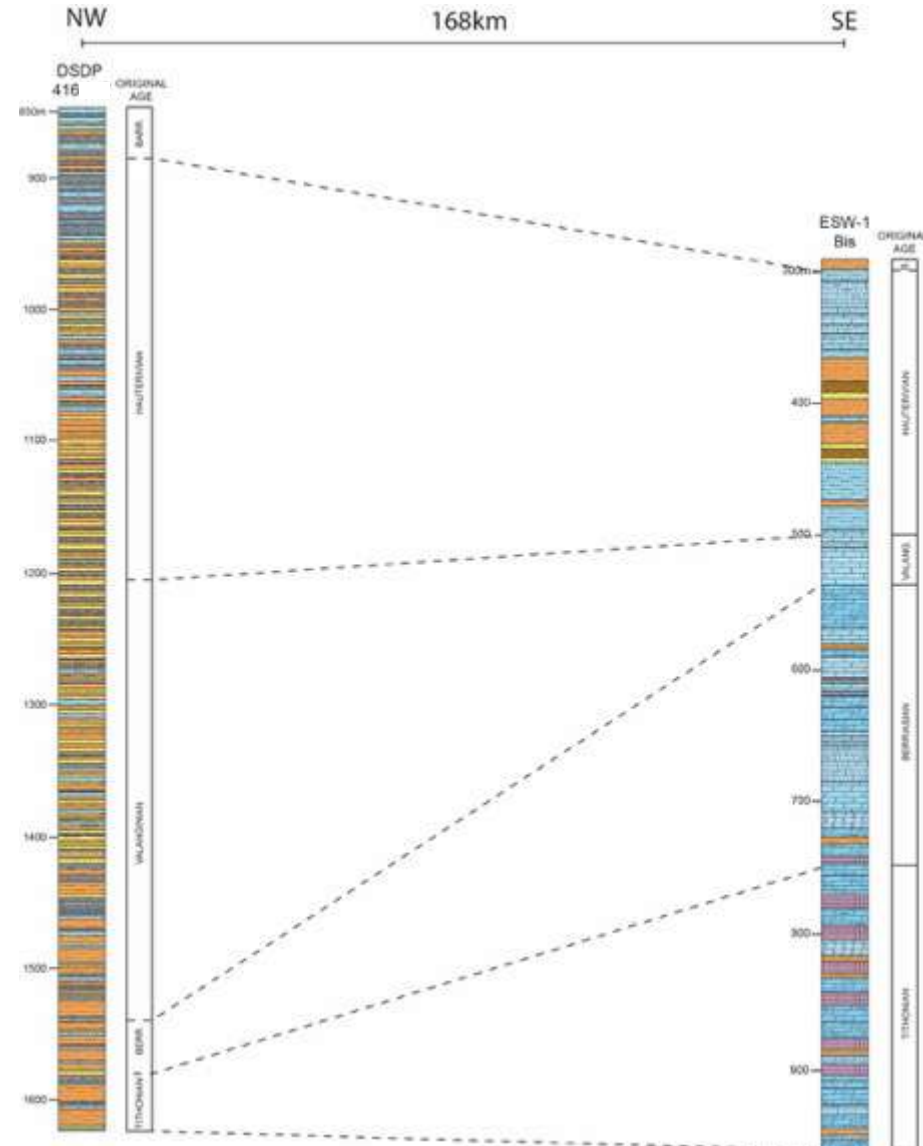
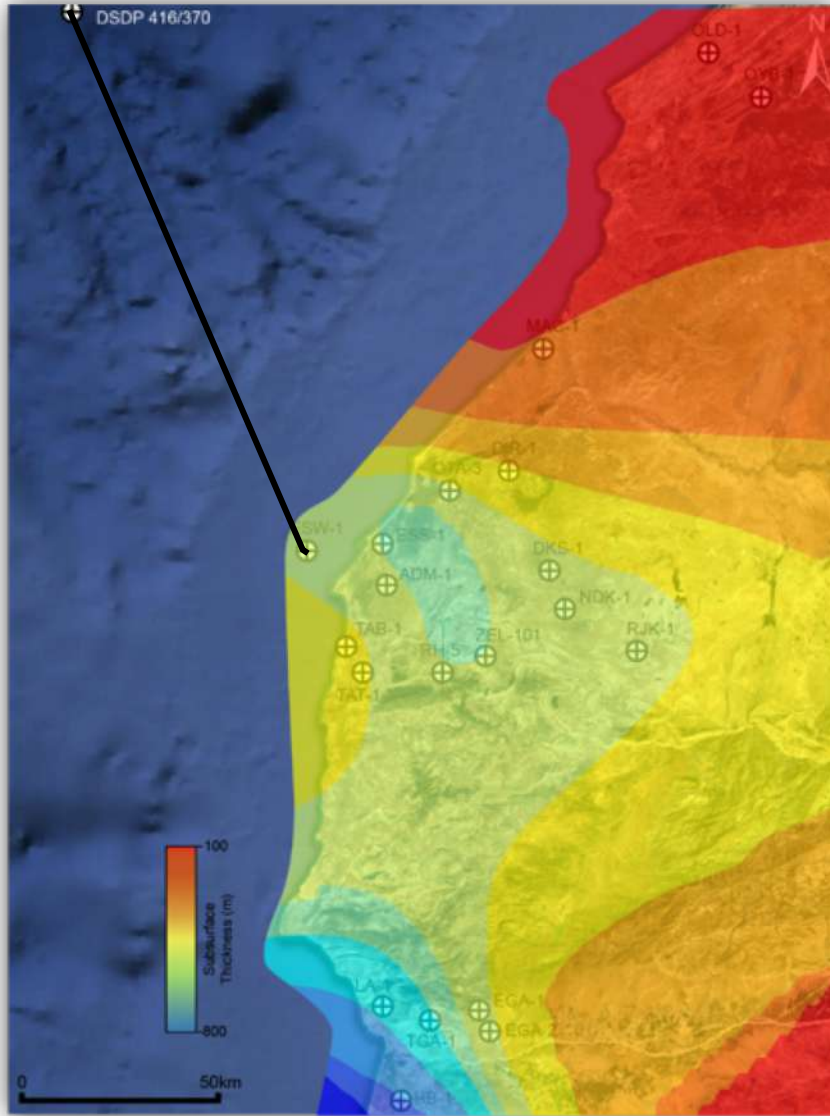
(Digitised from Ettachfni, 2004)

# REGIONAL CONTEXT– SUBSURFACE DATA





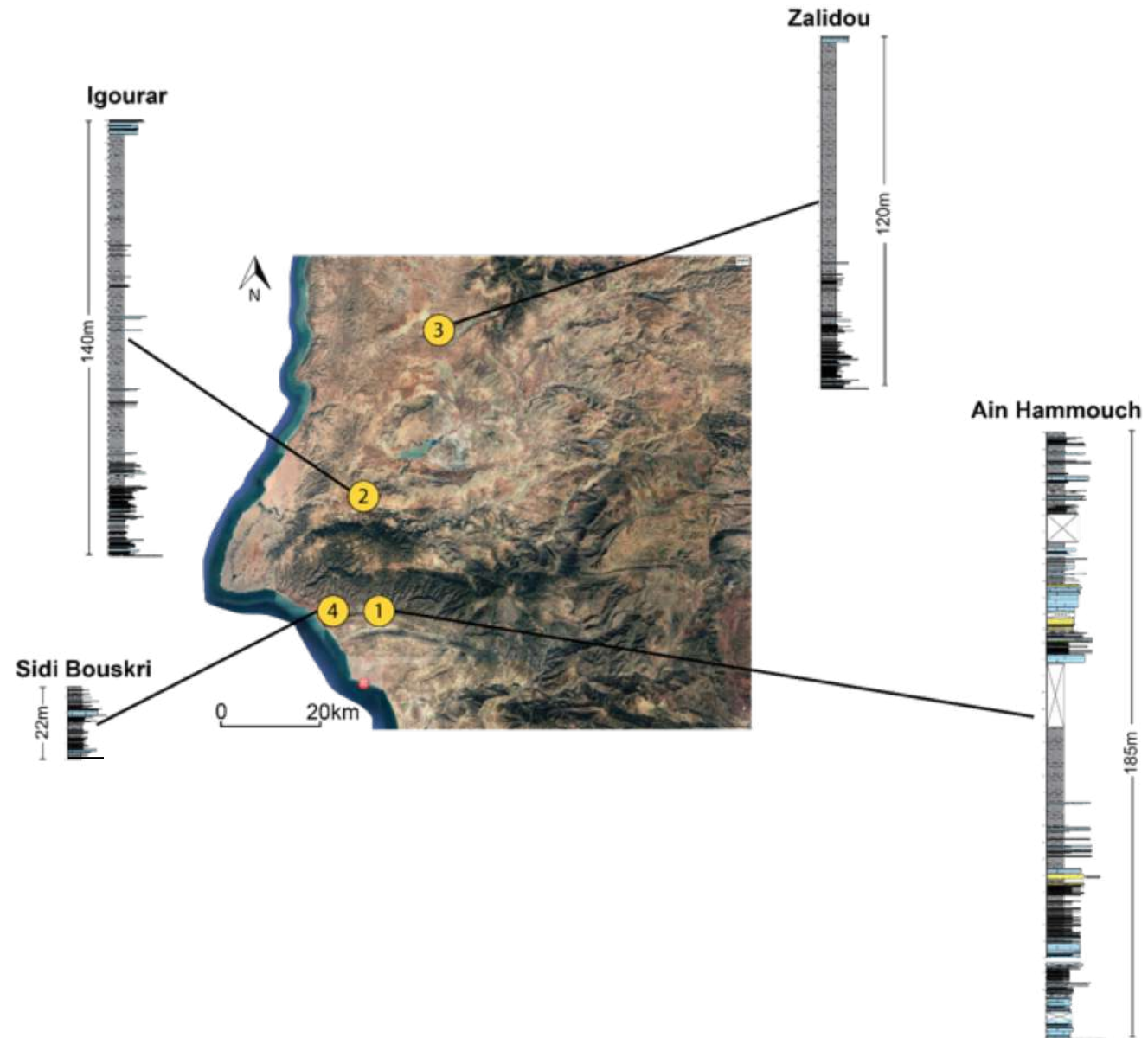
# REGIONAL CONTEXT– SUBSURFACE DATA



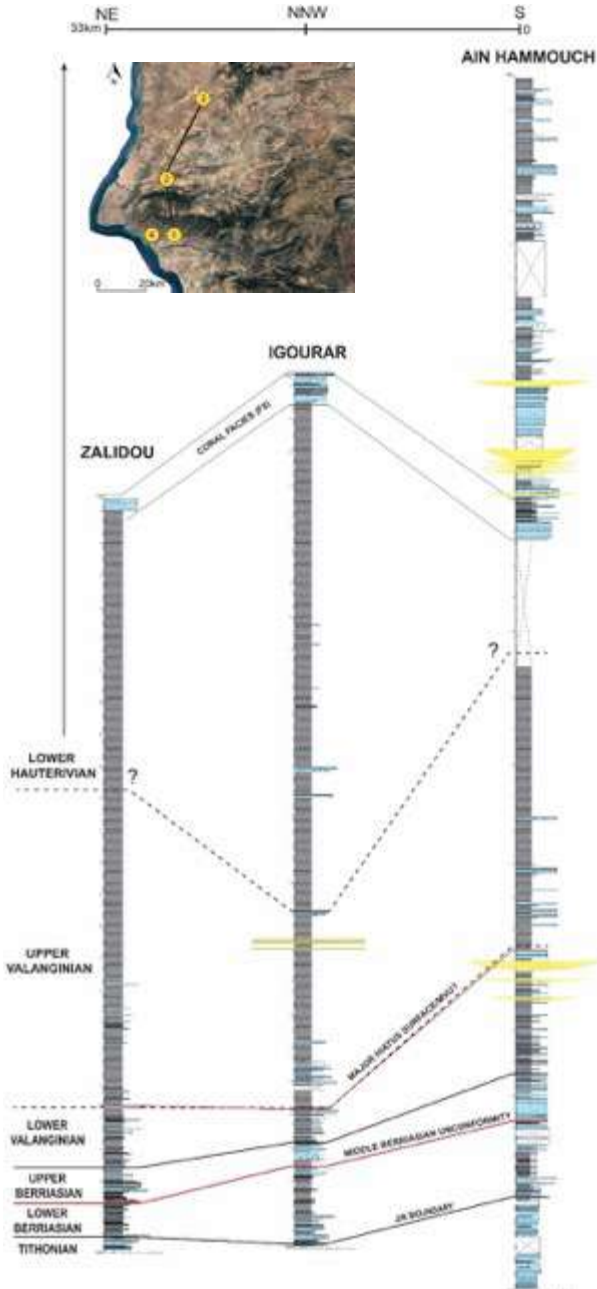
# FIELD WORK – STUDIED SECTIONS



- Sedimentary logs made at high-resolution, bed-by-bed scale
- Sampled thoroughly for ammonites, calpionellids and calcareous nanofossils and hand specimens for facies analysis



# INITIAL BIOSTRATIGRAPHIC FRAMEWORK



**Zalidou**

- Revised age framework using ammonites, calpionellids and calcareous nannofossils
- 3 key reference sections for the EAB

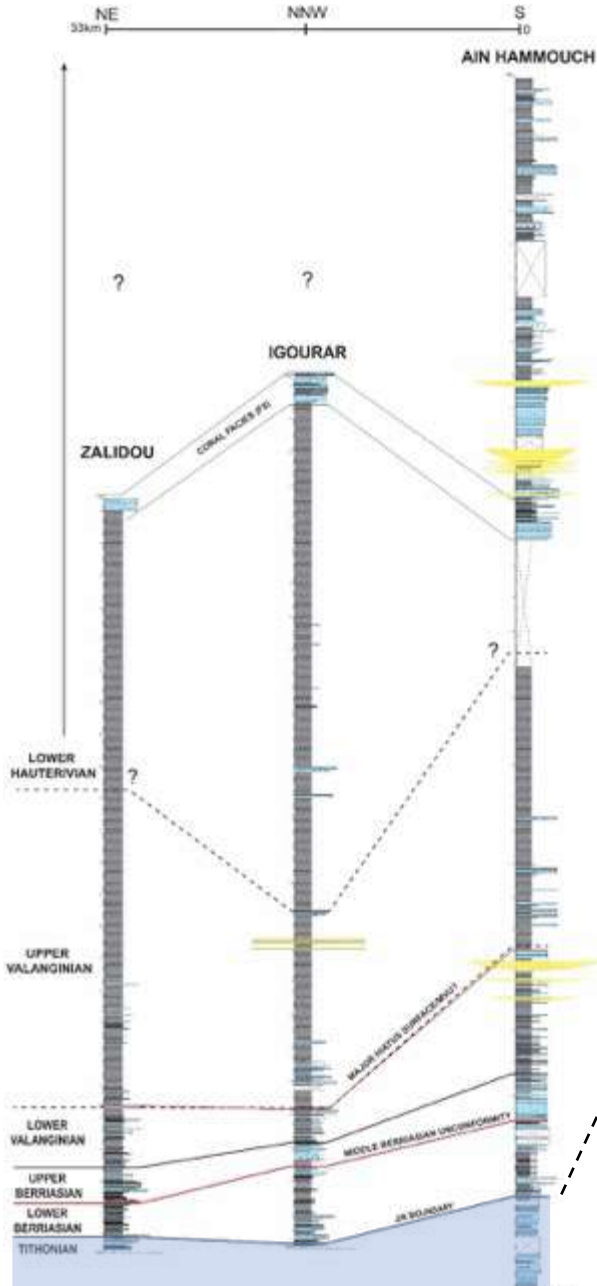


**Igourar**



**Ain Hammouch**

# CAP TAFELNEY FM – TITHONIAN- LOWER BERR.



- **J/K boundary** identified using calpionellids, shifted slightly up
- Regional hiatus surface/hard ground lies below suggested new boundary

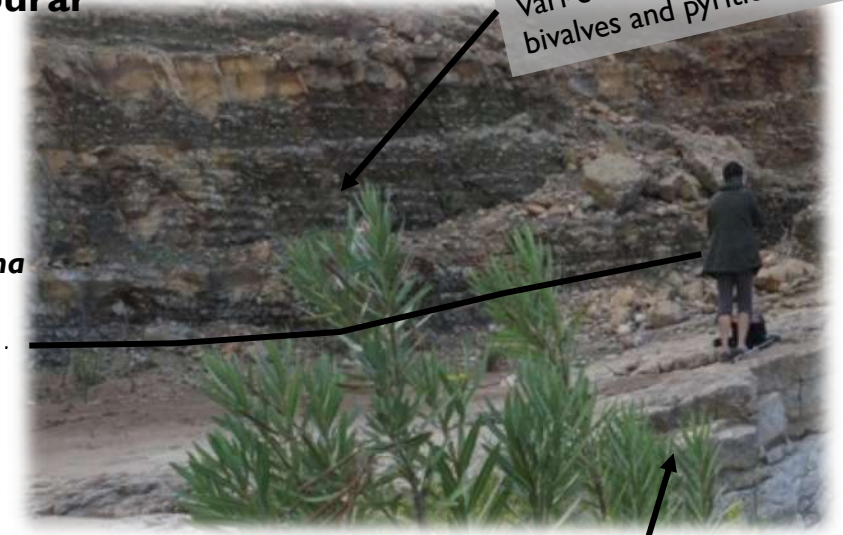
**Ain Hammouch**



**Nodular-bedded Ist (F3):**  
WST, brach + bivalve-rich



**Igourar**



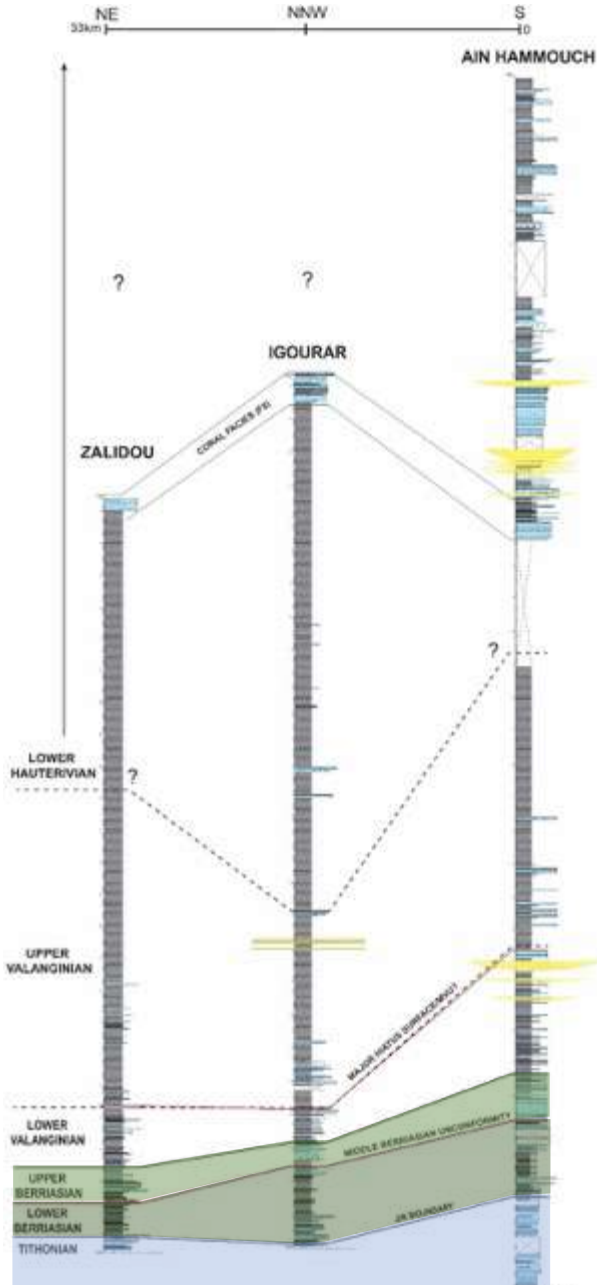
**Marlstone (F2):**  
Vari-coloured, small brachs,  
bivalves and pyritic nodules

*C. alpina*  
*C. parvula*

**Massive crystalline limestone (F1):**  
Algal mats, highly cemented



# AGROUD OUADAR FM – UPPER BERRIASIAN

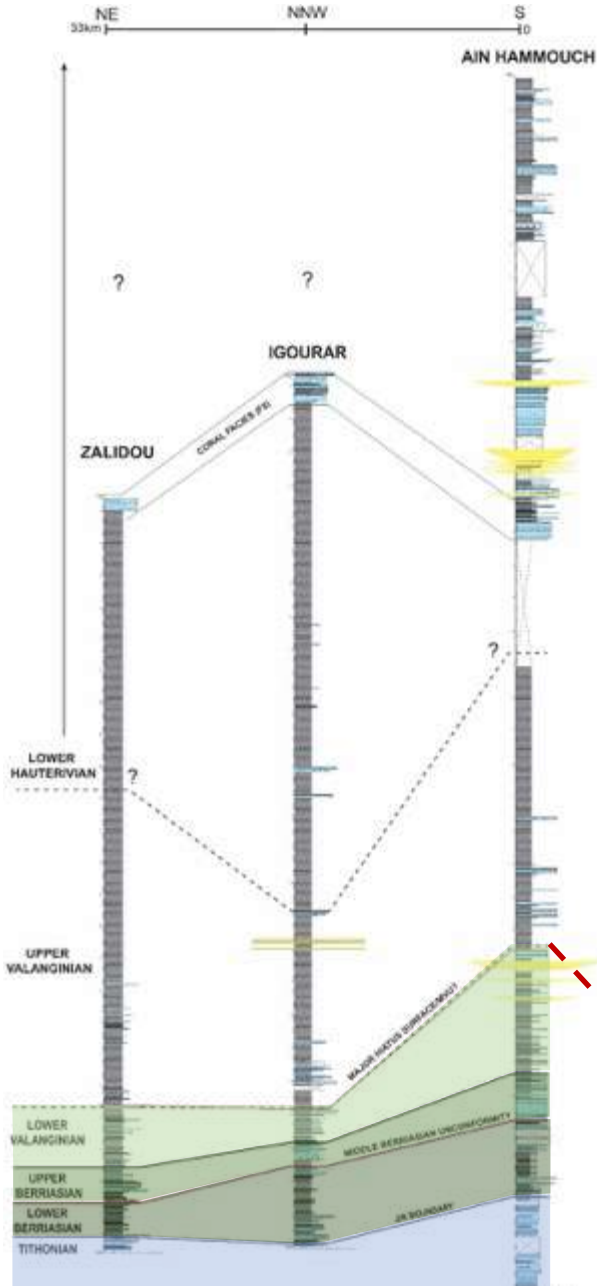


- Bioclastic limestones (F4) interbedded with marls (F2) Rich ammonite assemblage
- Good ammonite and nanofossil-rich facies for biostrat dating

Ain Hammouch



# SIDI L'HOUSSEINE FM – LOWER VALANGINIAN



- Notable calcareous sands at AH, non-existent at northern sections
- Index species of Verrucosum zone missing throughout southern EAB, possibly linked to a **major time gap/hiatus between Lower and Upper Valanginian?**

## AH

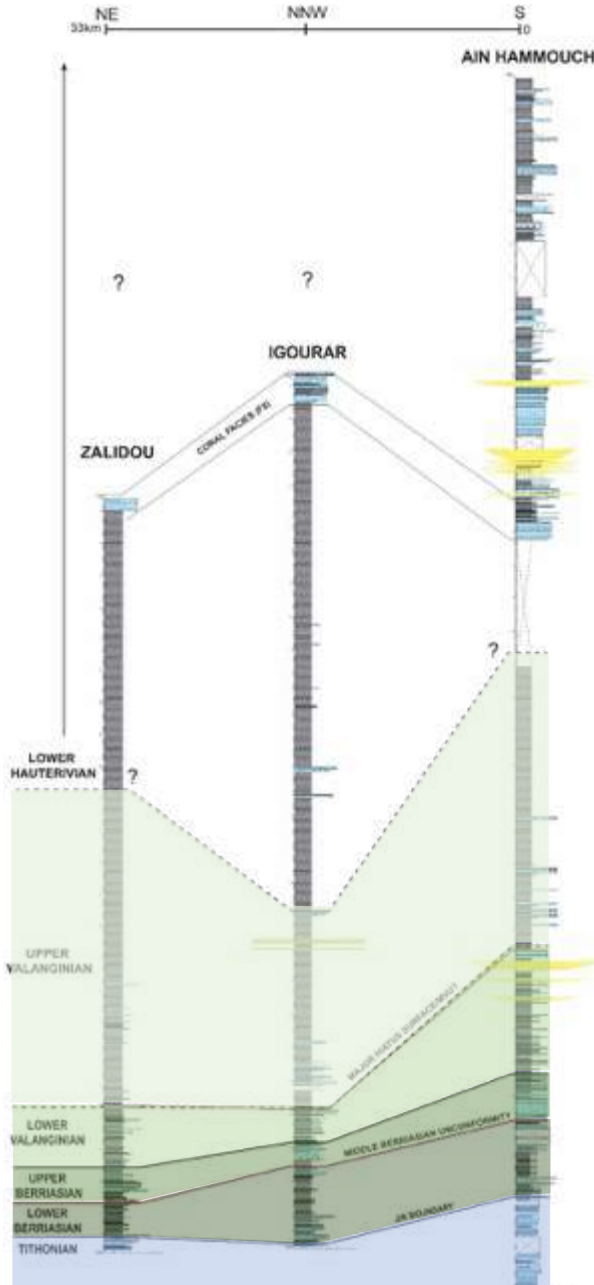


**Shoreface Sand (F6):** L: vf-f, planar to X-bedding. R: erosive, rippled base (palaeoflow 280°NW)

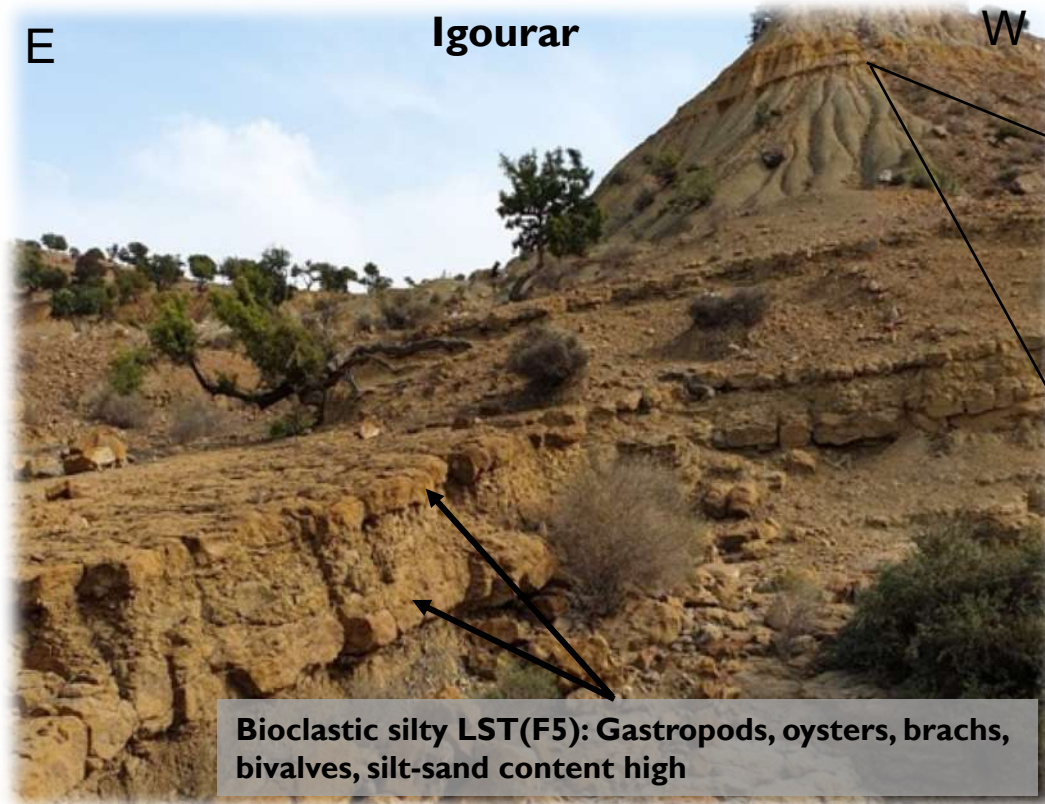
## Zalidou



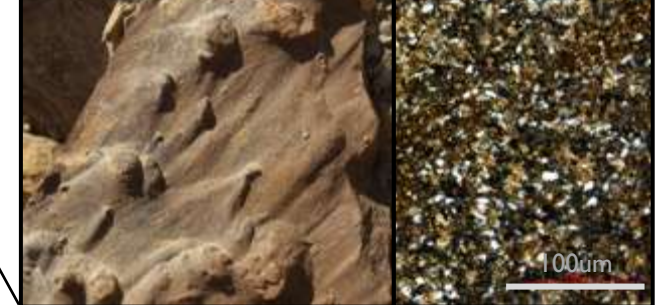
# SIDI L'HOUSSEINE FM – UPPER VALANGINIAN



- Increased clastic content in both bioclastic limestones and marls and discovery of turbidite system indicates clear sediment influx towards basin
- Thickening of marl intervals expresses increasing subsidence/deepening

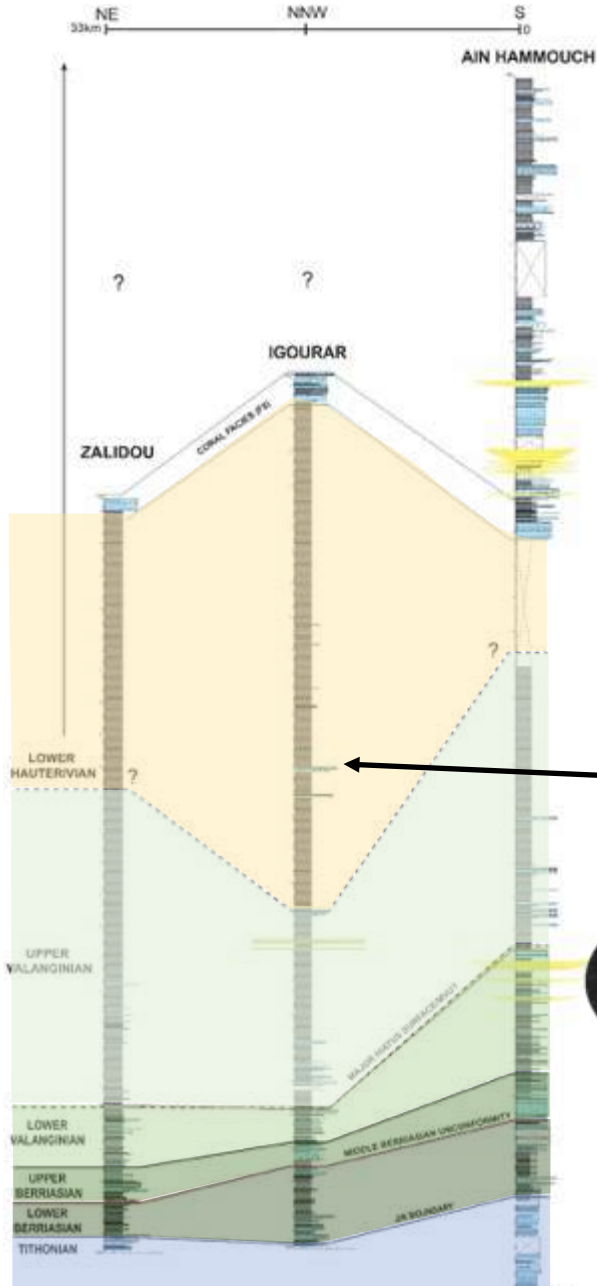


**Calci-clastic turbidite (F7):** L: flute marks on erosive base, palaeoflow 275°NW. R: crystalline mixed calc and quartz (XP)

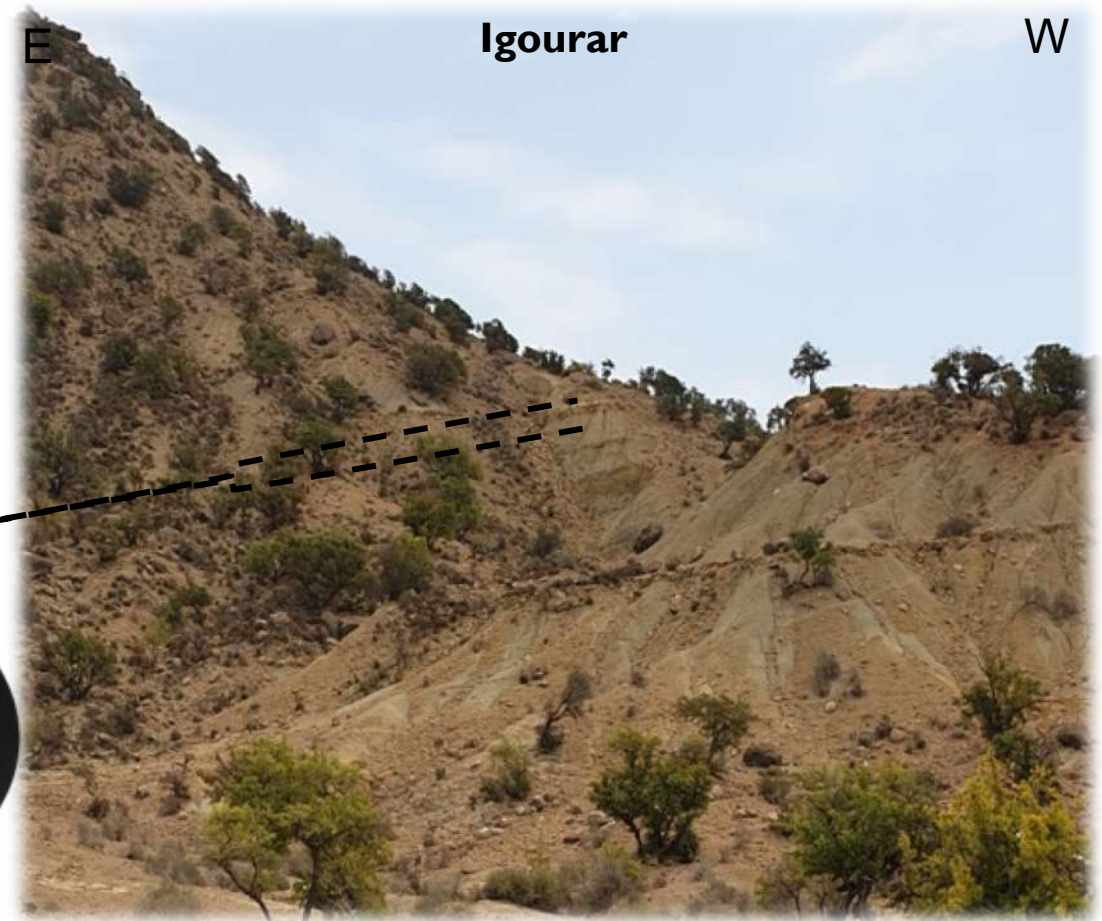


**Bioclastic silty LST (F5):** Gastropods, oysters, brachs, bivalves, silt-sand content high

# SIDI L'HOUSSEINE FM– UPPER VAL.-LOWER HAUT.



- Val/Haut boundary better constrained, introducing new zone for Morocco  
**“*Acanthodiscus marocanus*”**
- Difficult to tie exact boundary in Zal and IG due to poor outcrop
- Thick marl-dominated upper succession



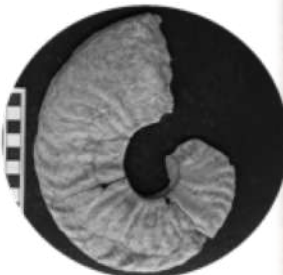
**3 new species of ammonite discovered**



*Acanthodiscus marocanus* sp. nov.

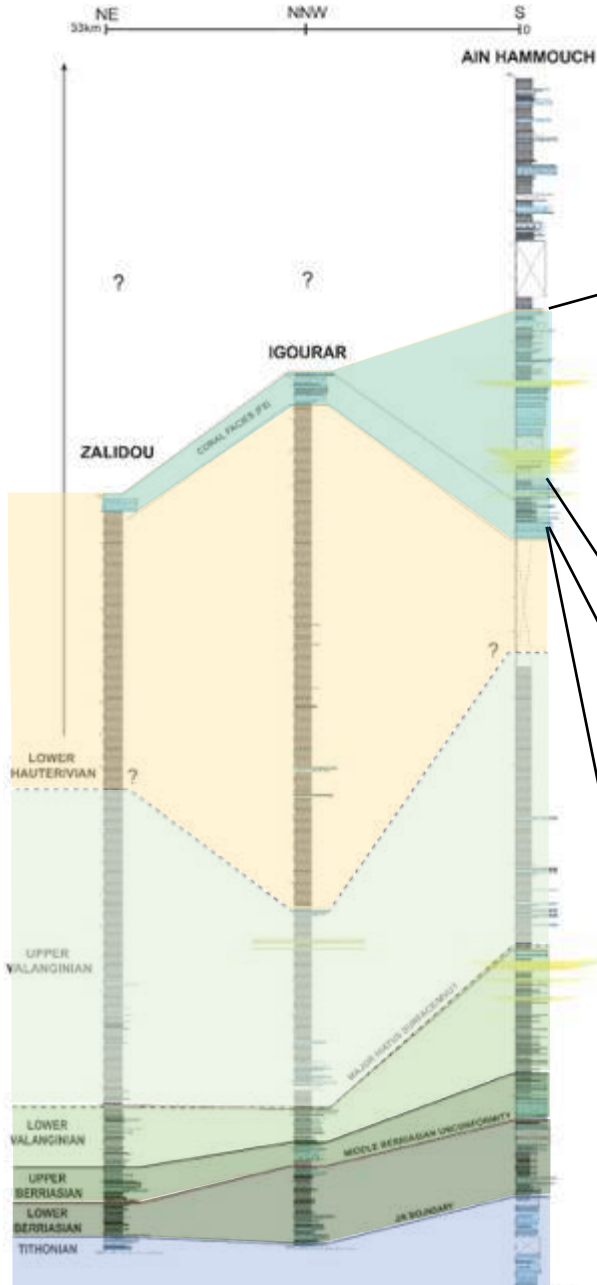


*Leopoldia nargi* sp. nov.

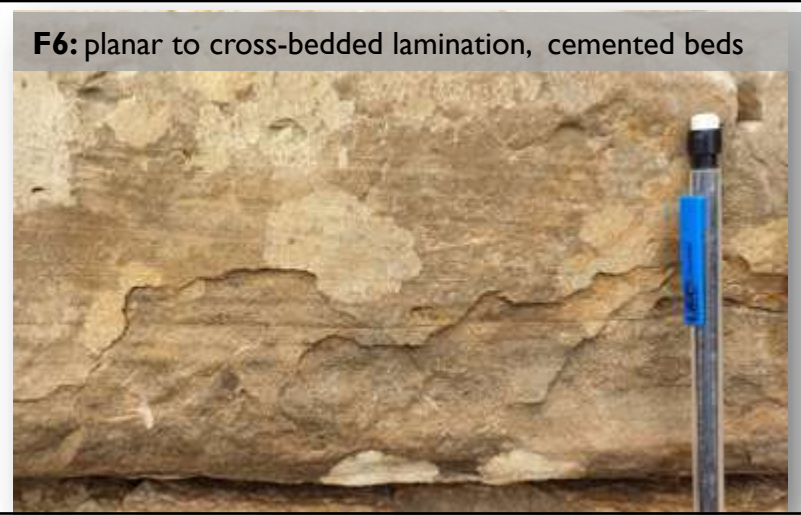


*Oosterella masrouri* sp. nov.

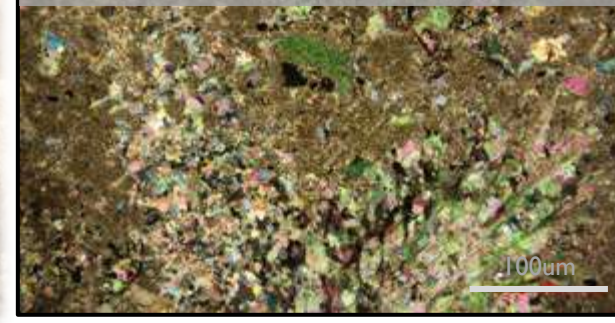
# TAMANAR FM – LOWER HAUTERIVIAN



- Coral-rich, massive limestone beds, interbedded with thin sands and oyster-rich beds, extends into thick sands and coarsening up bioclastic beds commonly with hard-ground tops



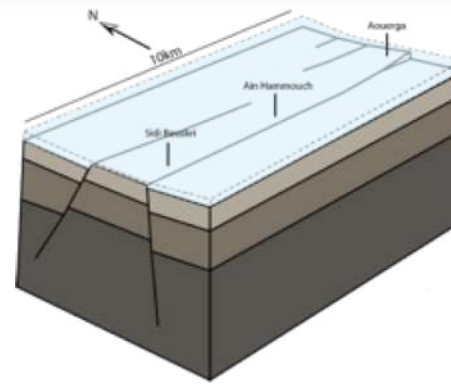
**Coral-rich LST (F8):** Calcified bryozoan (coral) fragment, microcrystalline background (XP light)



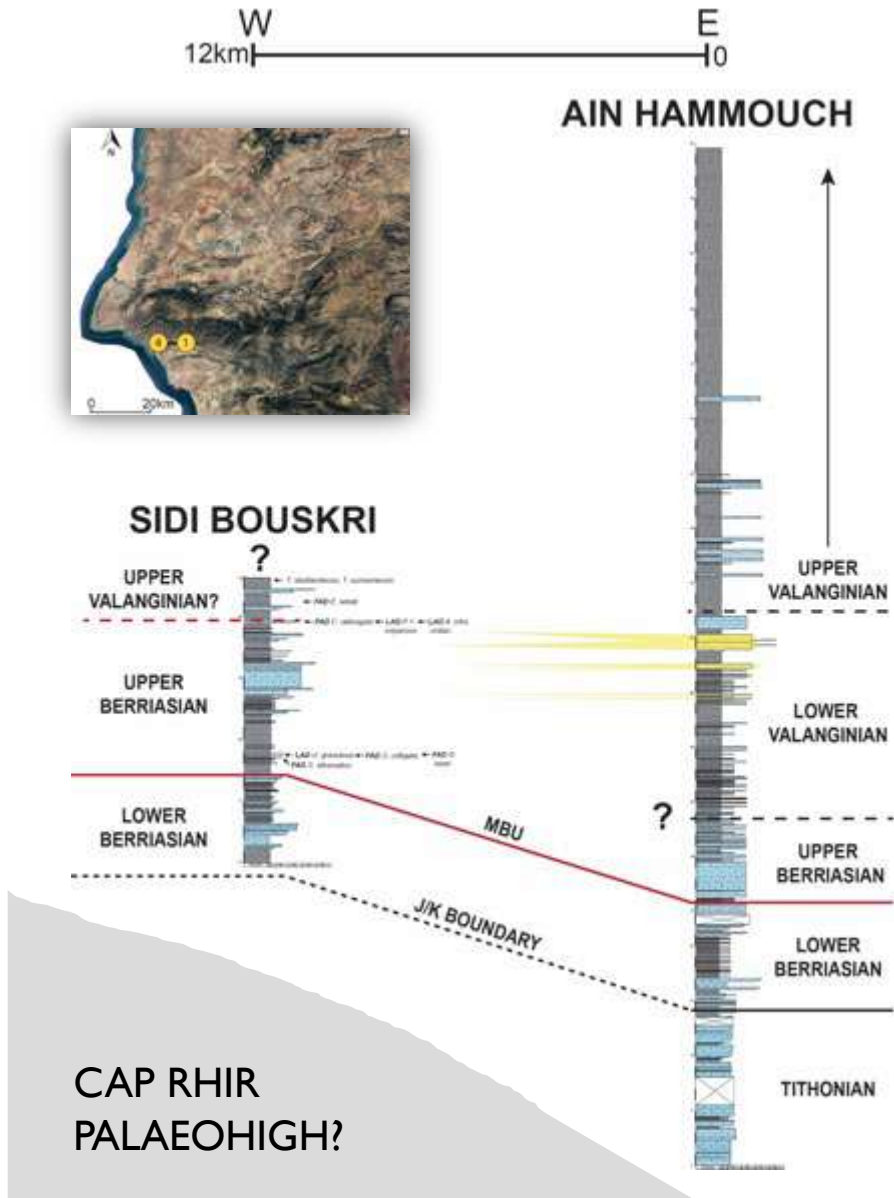
# W-E CORRELATION



- Drastic thickness reduction over short distance
- Several major hiatus surfaces recorded
- No strata recorded above lowest UVal



- Topographic disparities resulting in differential subsidence or RSL changes or mixed cause?

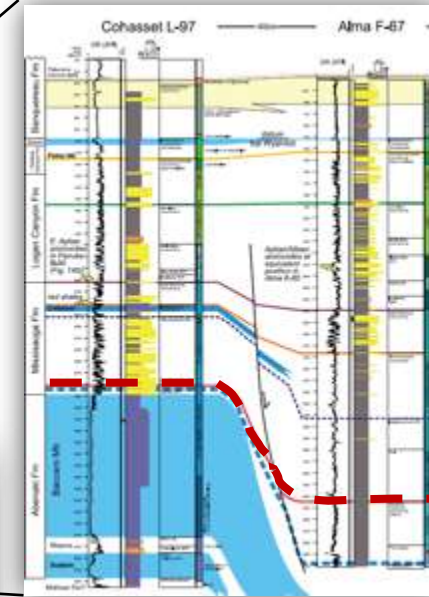




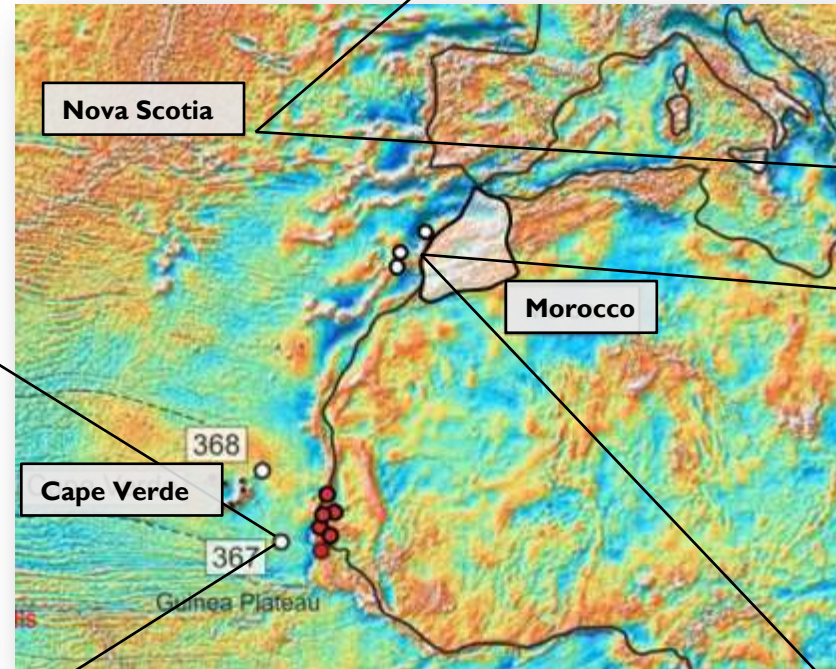
# MIDDLE BERRIASIAN UNCONFORMITY – A GLOBAL SCALE HIATUS?



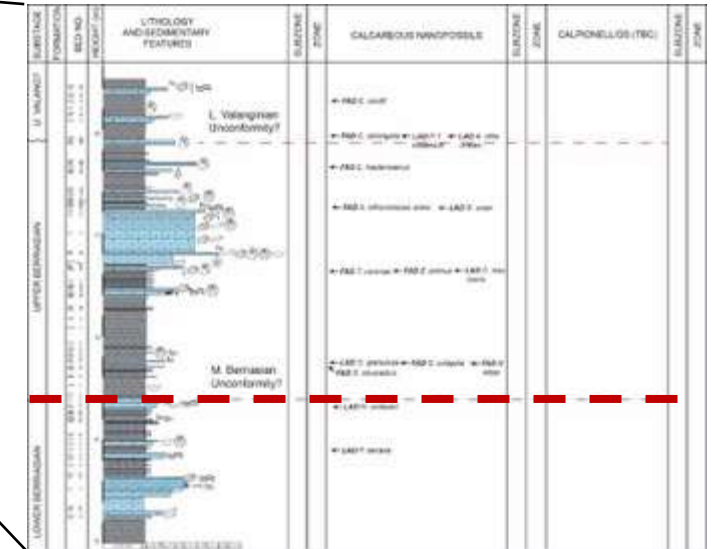
- MBU may be part of a global event, identified on the Scotian margin, Weston et al, 2012), Cape Verde Basin DSDP Site 367 (NARG re-evaluation) and the Base Cretaceous Unconformity in the North Atlantic



(Weston et al, 2012)



(Left and middle images - Casson, NARG, 2019)



(This study)



## ***1. Integrated biostratigraphic framework – New J/K Boundary candidate in Morocco and shift in boundary, new framework separating the NW African and Tethyan faunal realms***

- Complete logging and sampling of L. Haut to L. Barremian for biostratigraphy and plug in gaps of J/K to L. Haut (Spring 2019)
- Log sections further inland to build depositional model and understand facies changes

## ***2. Controls on hiatus formation in passive margins – implications for subsurface correlations, understanding of time gaps***

- Complete biostratigraphic framework
- Categorise hard grounds in field, microfacies and carbonate geochemical analyses

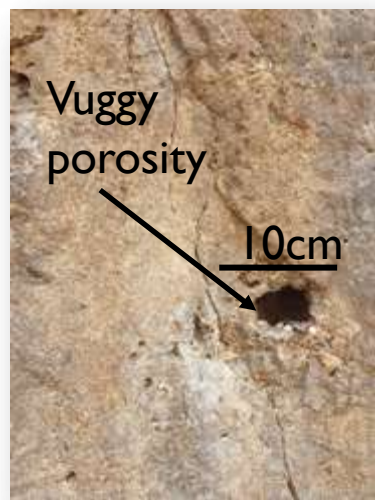
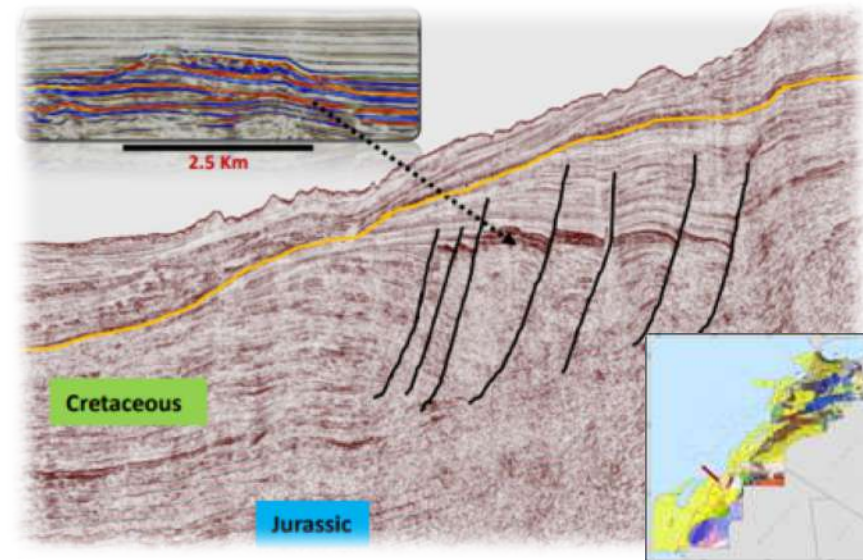
## ***3. Hauterivian reef architecture and geometry– potential reservoir facies along NW African margin***

- Dedicated field season to map, log and characterise outcrops (October 2019)
- Assess porosity-permeability with hand-specimen petrophysical analyses
- Key facies and microfacies (inc. thin-section analysis)

# FUTURE WORK – HAUTERIVIAN REEF STUDY



Reservoir potential on shallow margin?



- Mapping geometry, morphology, vertical and lateral facies changes at key outcrop
- Samples to be analysed for poro-perm, thin section for cementation/diagenesis
- Compare to seismic expression offshore Tarfaya and Boujdour



1. *Establish a high-resolution biostratigraphic framework for the earliest Cretaceous EAB*

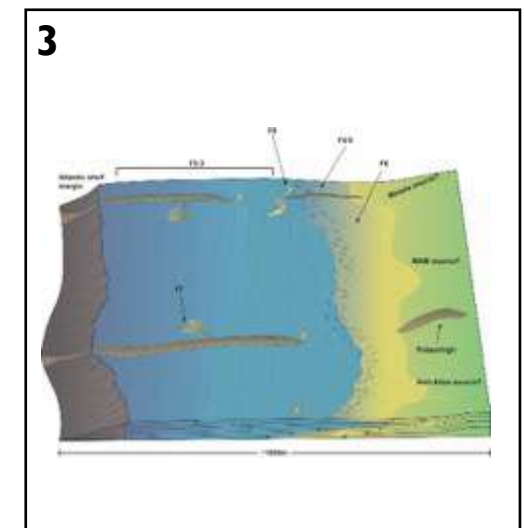
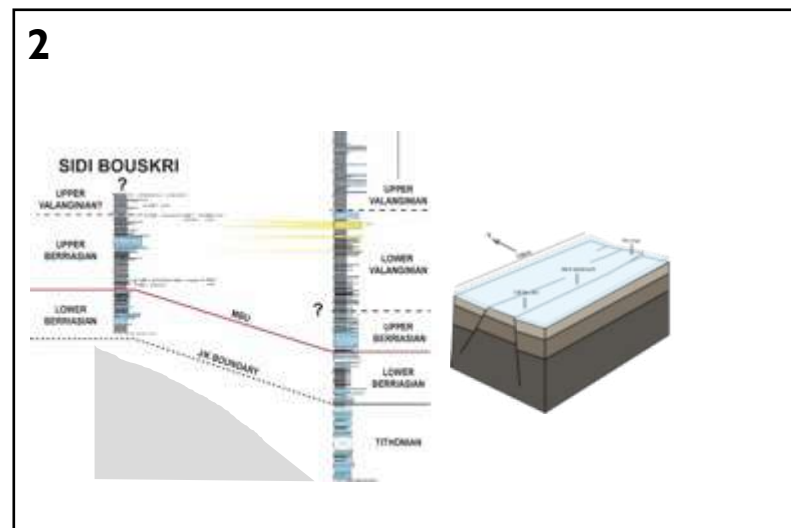
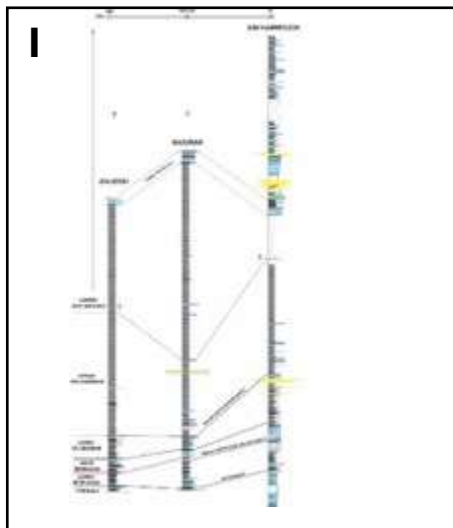
➤ **Strong foundation built for the high-resolution framework, clear faunal differences to Tethyan realm identified inc. new ammonite species**

2. *Improve understanding of the controlling factors on condensed sections/hiatus intervals in passive margin*

➤ **Key unconformities recognized e.g. Middle Berriasian Unconformity, thickness variations may be linked to inherited Jurassic structure**

3. *Develop a robust stratigraphic framework on a basin-scale*

➤ **Identified significant timing of sediments offshore, depositional model in progress**



# THANKS TO ALL OUR SPONSORS



With additional thanks to Luc, Mohsine, Mousa, Max, Paul and Tim for their help in the field and to Elsa for her professional photography of the ammonite collection

# QUESTIONS?



1. *Establish a high-resolution biostratigraphic framework for the earliest Cretaceous EAB*

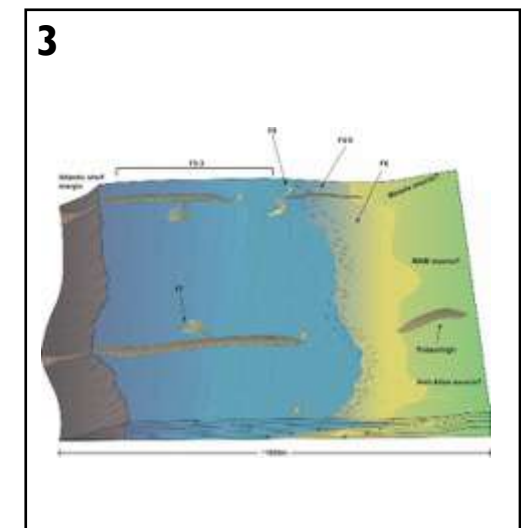
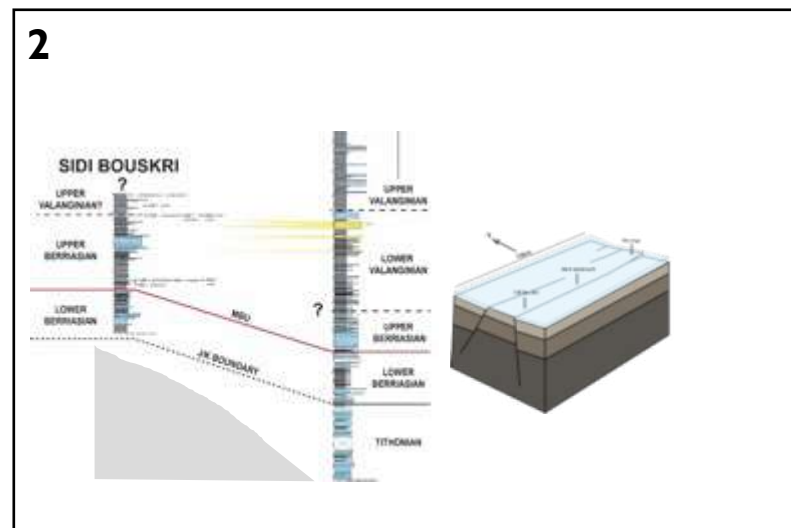
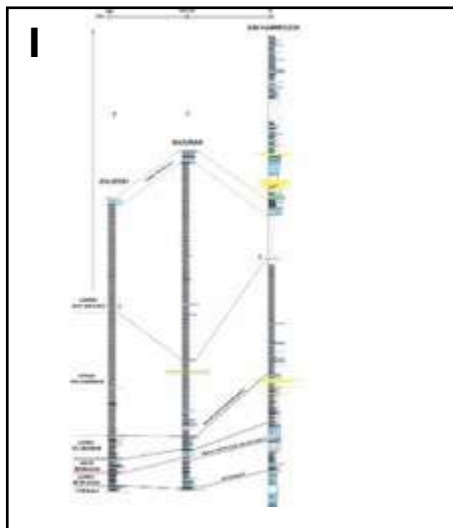
➤ **Strong foundation built for the high-resolution biostratigraphic framework**

2. *Improve understanding of the controlling factors on condensed sections/hiatus intervals in passive margin*

➤ **Key unconformities recognized e.g. Middle Berriasian Unconformity, thickness variations may be linked to hiatuses and local palaeotopographic variations**

3. *Develop a robust stratigraphic framework on a basin-scale*

➤ **Identified significant timing of sediments into basin, developed facies model**

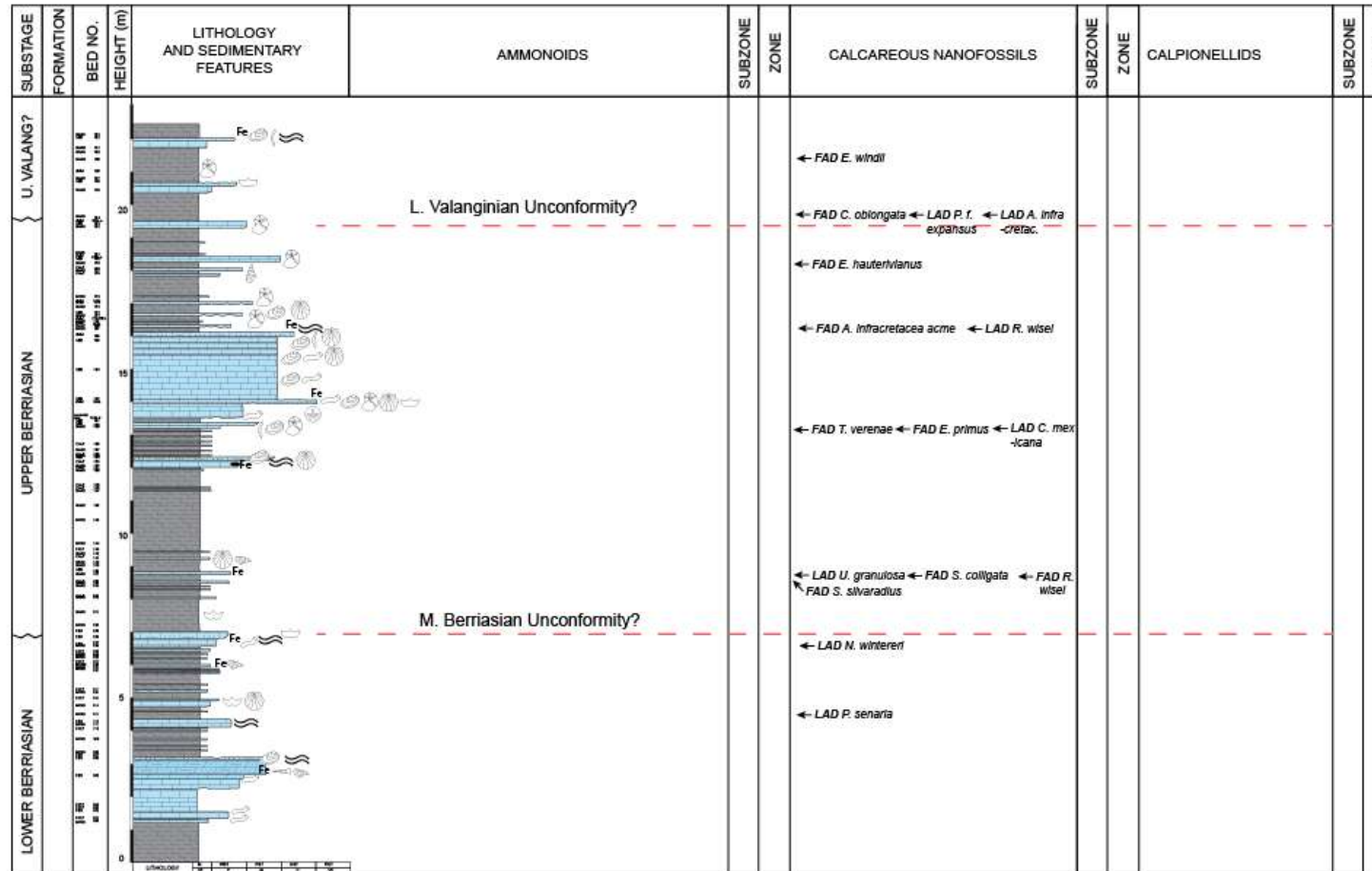


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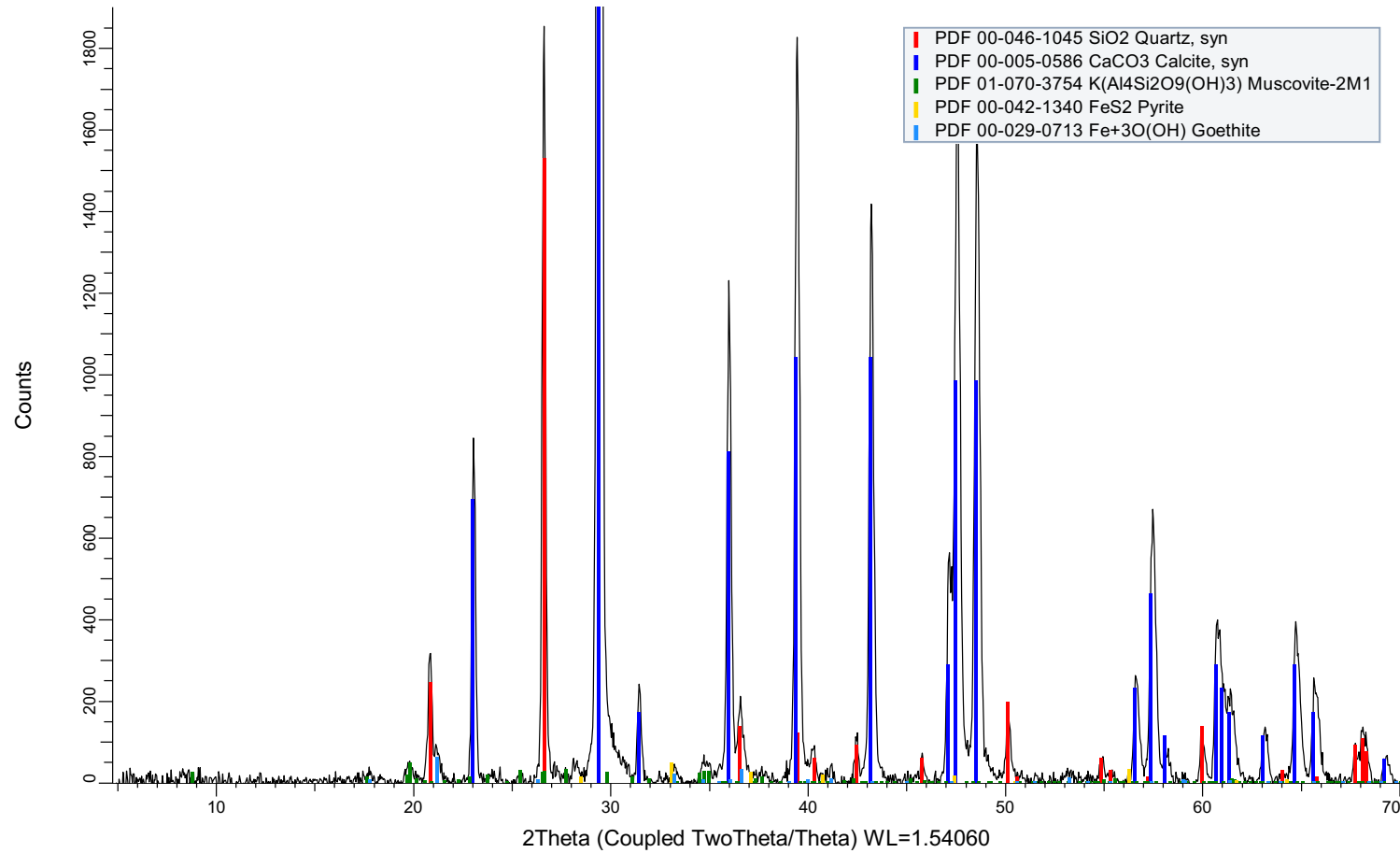
## SB biostrat







## Hard Ground Geochem:



## Igourar Sand:

