

Variability of Cenomanian/Turonian source rocks in Moroccan basins: paleoenvironments and global organic carbon burial aspects

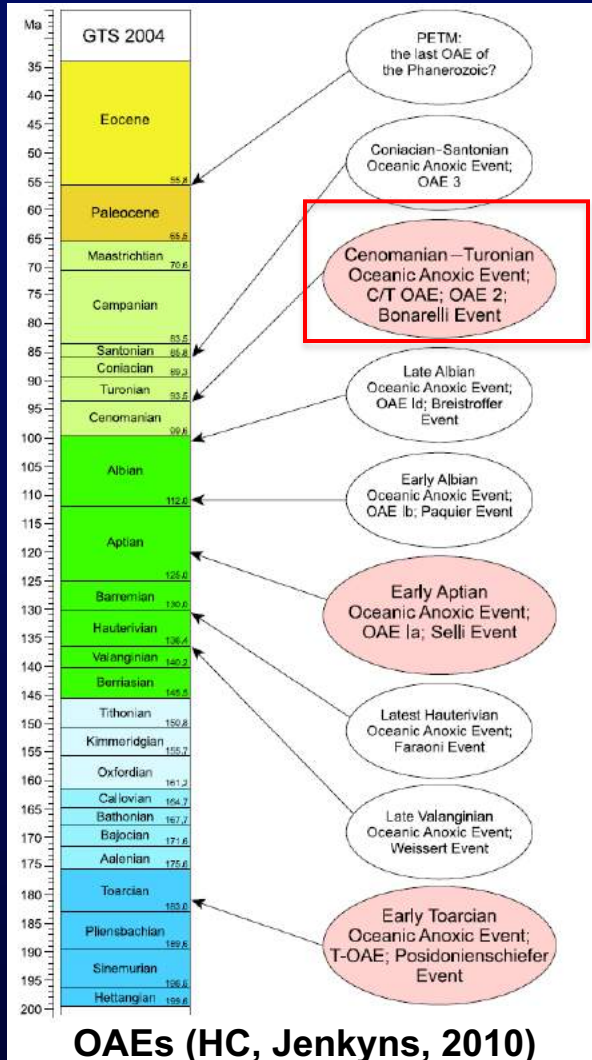
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Prof. Jonathan Redfern
Dr. Luc G. Bulot**



Introduction

OAE2



OM-rich mudstones were widely deposited during C/T Oceanic Anoxic Event (OAE2), an interval with increased organic carbon storage globally



- Black shale or OM rich sediment
- ★ Reference outcrops of OAE2 study

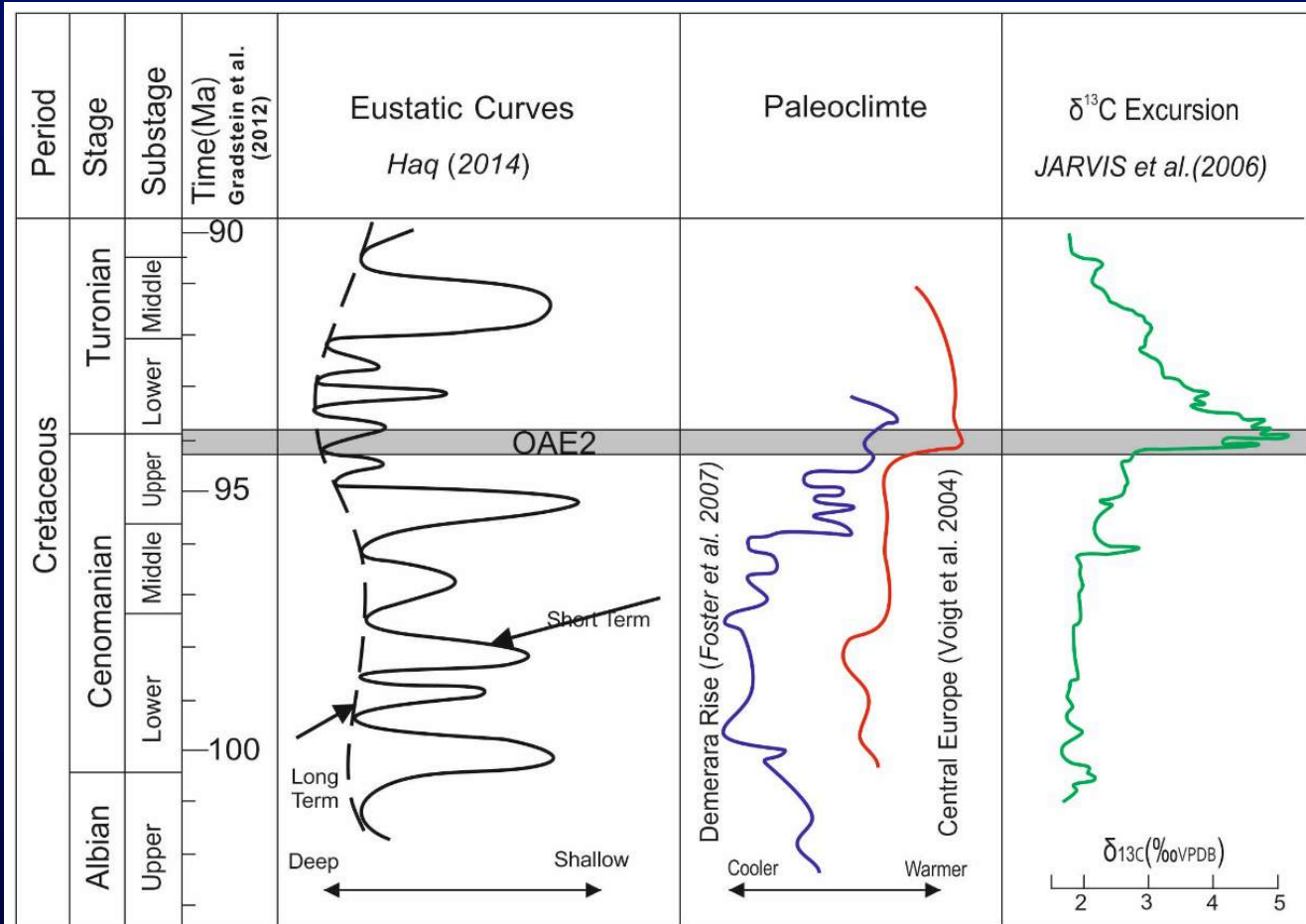
(Danielle, 2013)

Distribution of black shales during OAE2



Introduction

OAE2



The characteristics of OAE2

Age: Late

Cenomanian to
Early Turonian

Duration: < 1 Ma

Paleoenvironments:

Extremely warm
climate

High sea level

Characteristics:

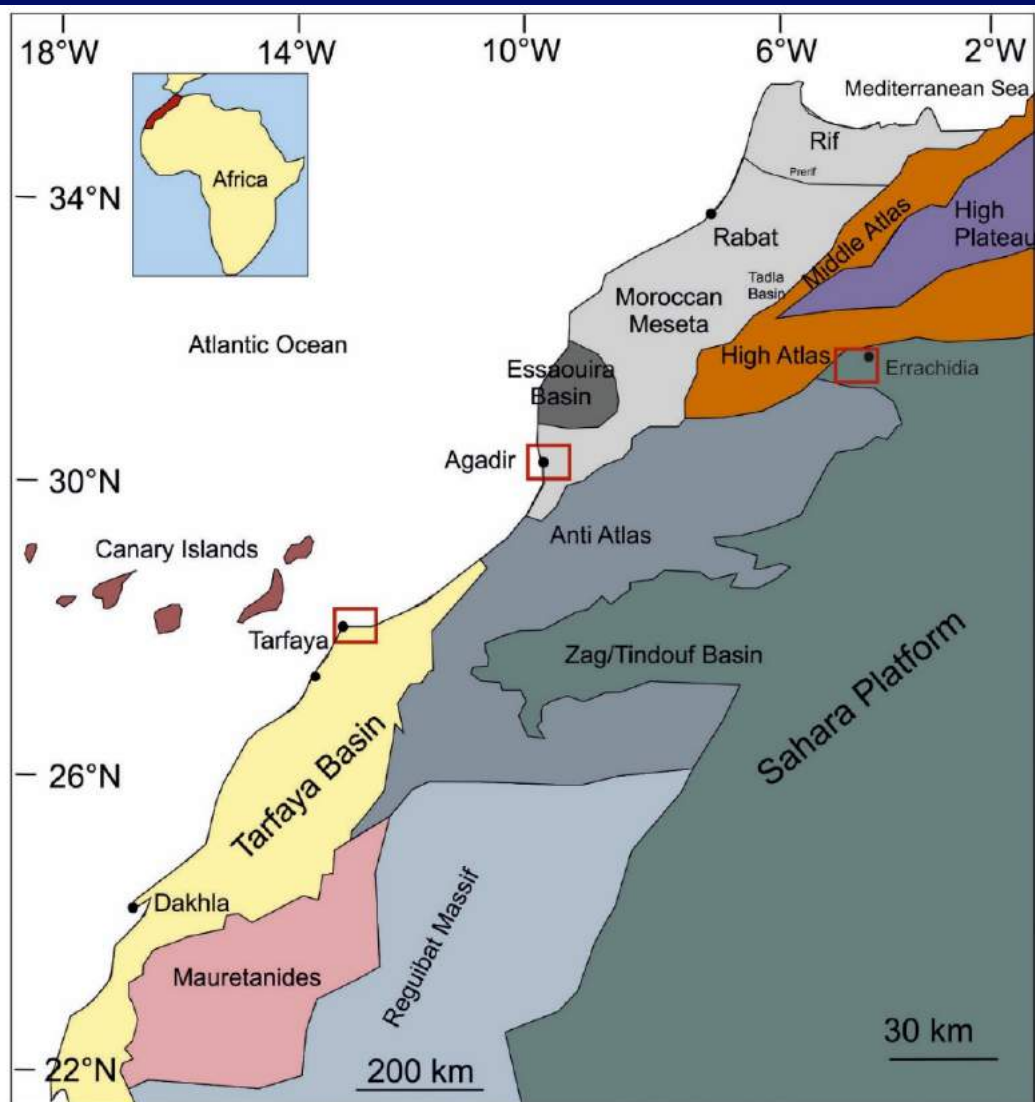
OM-rich sediments,
positive $\delta^{13}\text{C}$

excursion



Introduction

Moroccan Basins



Location of studied Moroccan basins

Aims:

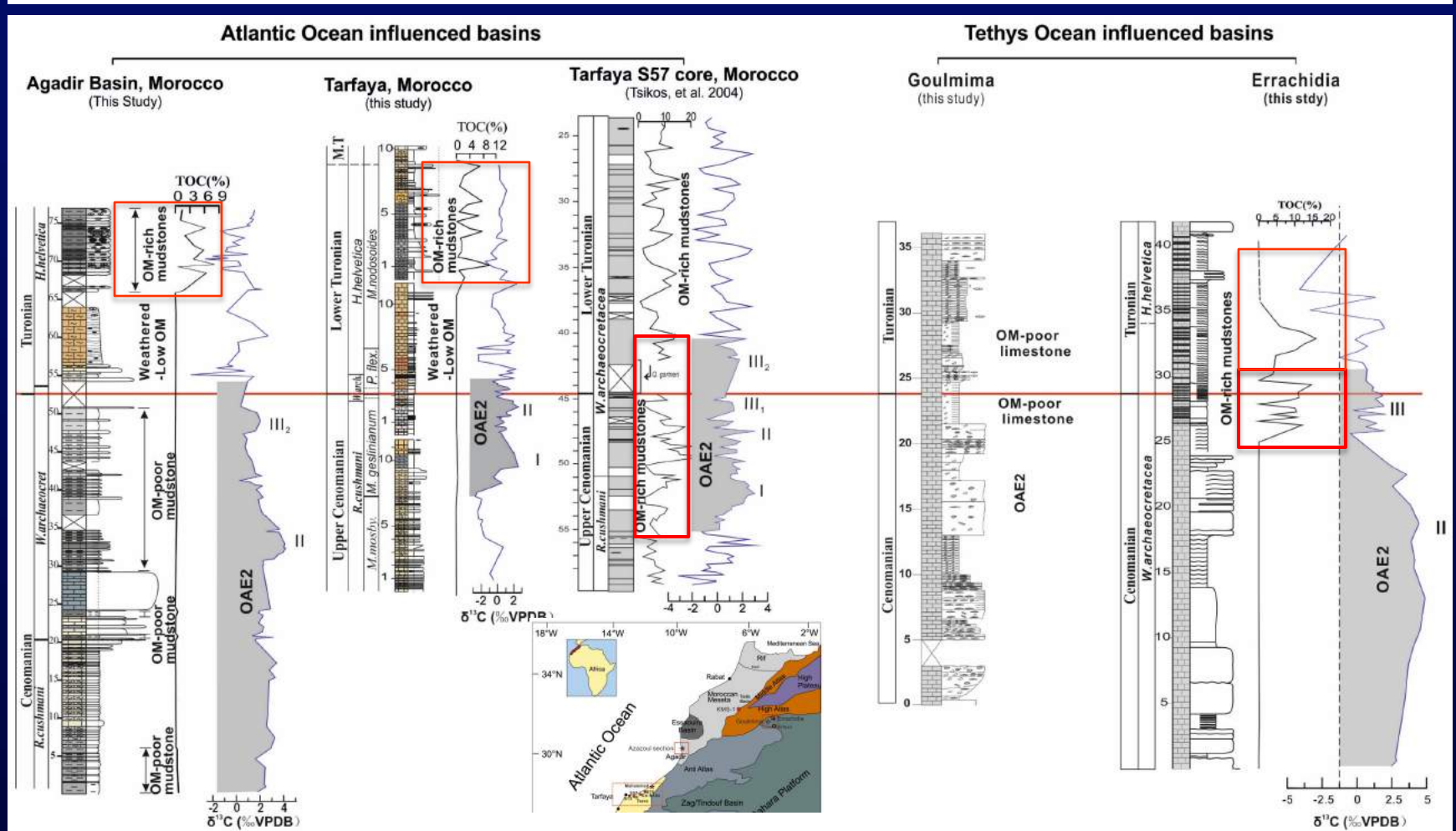
- Locate the C/T boundary more precisely
- Identify the distribution and quality of C/T source rock
- Reconstruct the paleoenvironment of source rocks and interbedded rocks across the OAE2 and post OAE2 interval
- Find out the controls of the source rocks deposition
- Compare the influences of Tethys and Atlantic oceans
- Analogue for offshore basins

Studied basins:

- Errchidia-Goulmima Basin -Tethys Ocean Influence
- Agadir-Tarfaya basins -Atlantic Ocean Influence

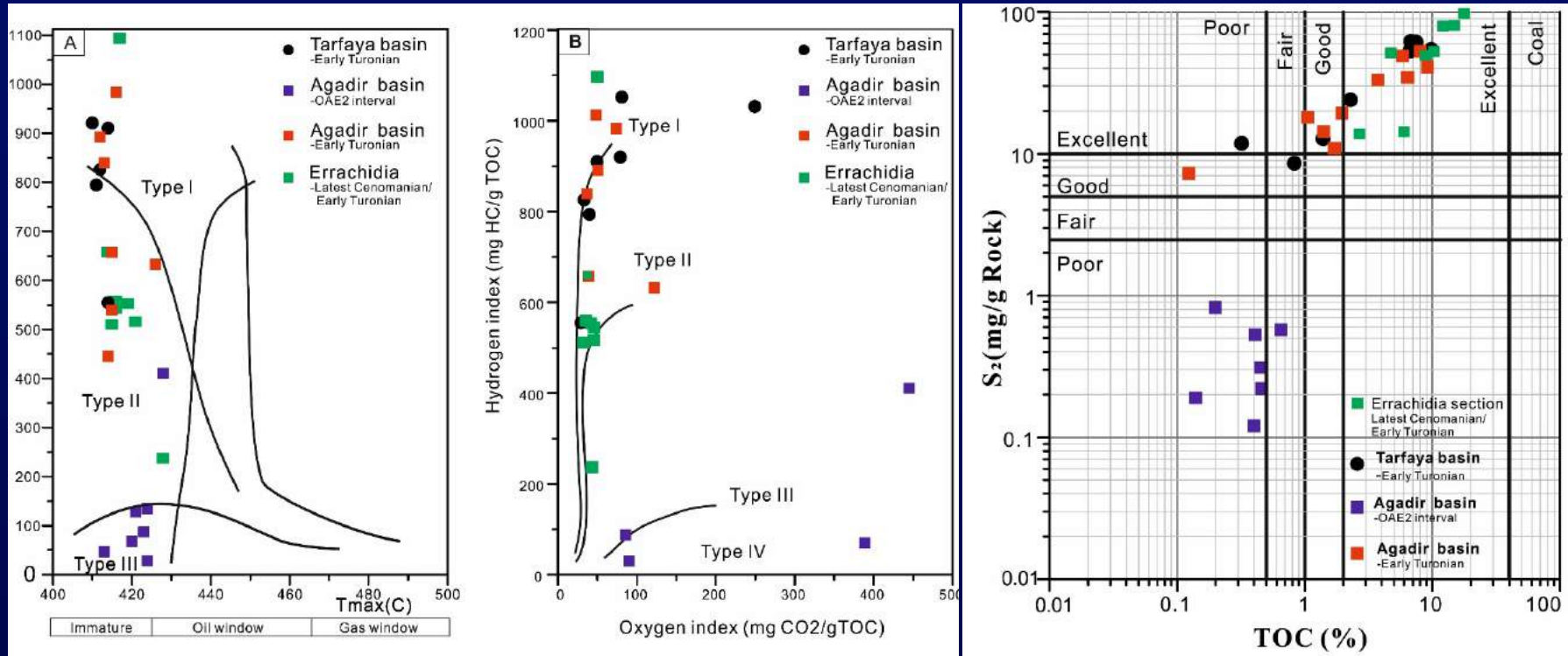


OM-rich mudstone distribution



- OAE2 associated OM-rich mudstones were widely developed in deeper Tarfaya basin, and locally developed in Errachidia basin.
- Early Turonian transgression related OM-rich mudstones are more geographical developed in Morocco.

Source rock quality



Latest C/ Earliest T
(The OAE2 interval)

Agadir Basin: dominant kerogen type III, **TOC < 0.5%**, 35 metres

Tarfaya Basin: dominant kerogen type II, **7% < average TOC < 11%**, up to 30 metres thick

Errachidia Basin: dominant kerogen type II, **average TOC 10.8%**, 2 to 3 metres thick

Agadir Basin: mixture kerogen type I and II, **TOC average 3%**, 10 metres thick

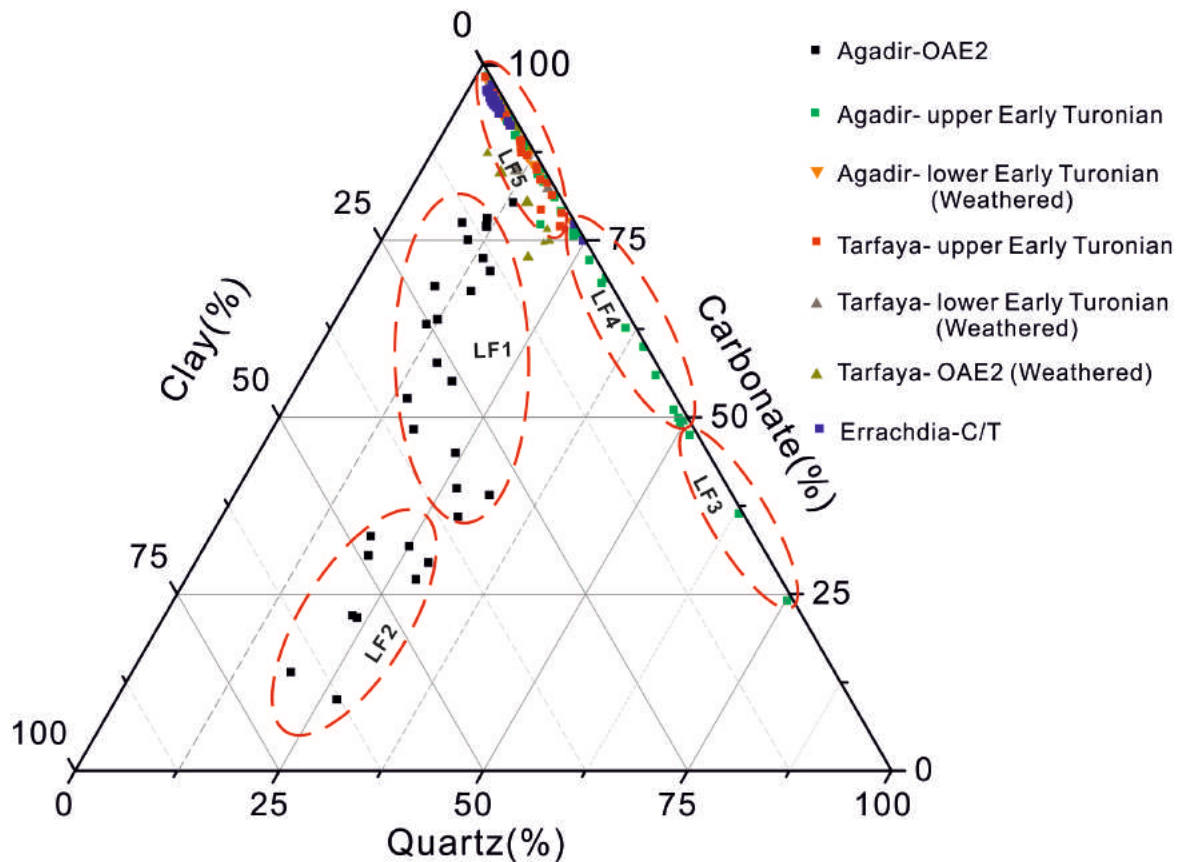
Early Turonian
(The Post-OAE2 interval)

Tarfaya Basin: dominant kerogen type II, **5% < average TOC < 14%**, up to 80 metres thick

Errachidia Basin: dominant kerogen type II, **average 8.3%**, 4 to 5 metres thick



Mudstones lithofacies



Five mudstone lithofacies were defined:

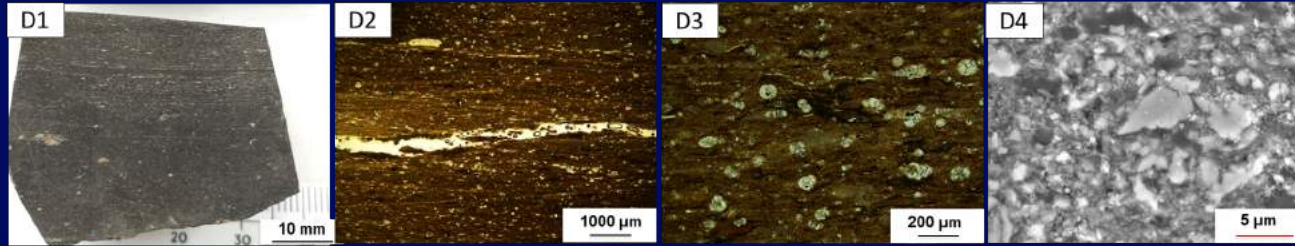
- **LF1:** calcareous-argillaceous mudstone
- **LF2:** argillaceous-siliceous mudstone
- **LF3:** siliceous-calcareous mudstone
- **LF4:** calcareous-siliceous mudstone
- **LF5:** calcareous mudstones

Ternary diagram illustrating the normalized mineralogical composition of C/T mudstones in Moroccan basins. Total quartz, carbonate (calcite, ankerite, dolomite, etc.) and total clay (e.g., kaolinite, ankerite, etc.)

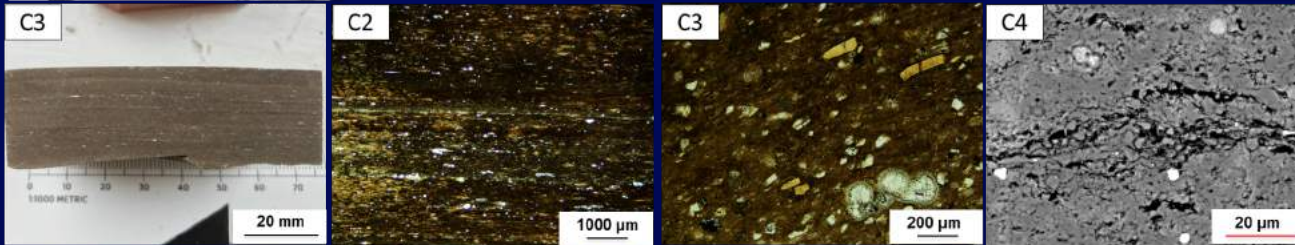


Mudstones lithofacies

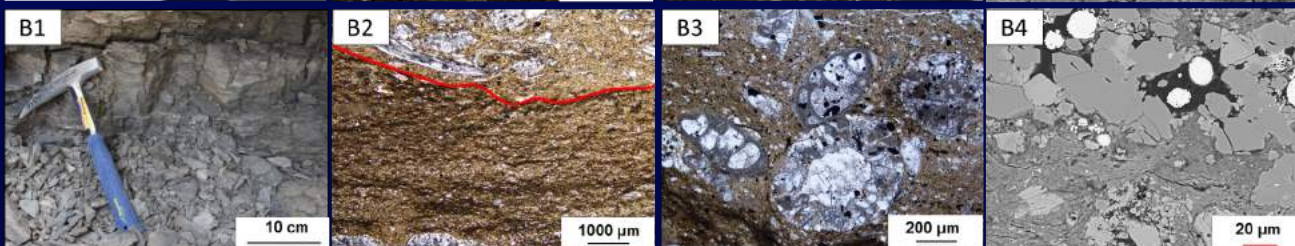
LF4:
Calcareous -
Siliceous
mudstone



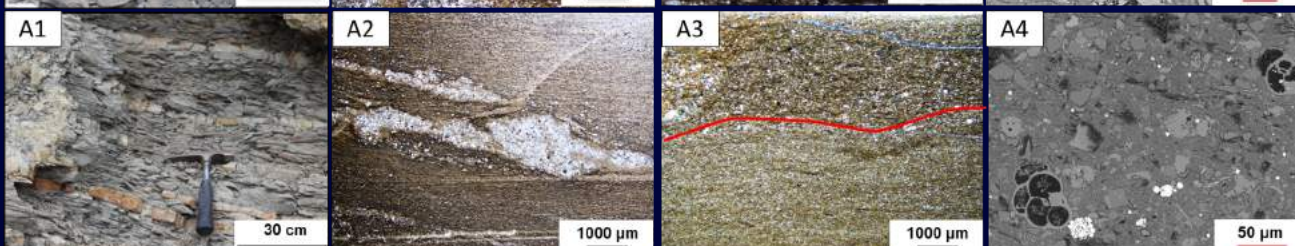
LF3:
Siliceous-
calcareous
mudstone



LF2:
Argillaceous-
siliceous
mudstone



LF1:
Calcareous
argillaceous
mudstone



Anoxia

Dysoxia

OXia

Early Turonian

OAE2

Agadir Basin



Mudstones lithofacies

LF5: Calcareous mudstones

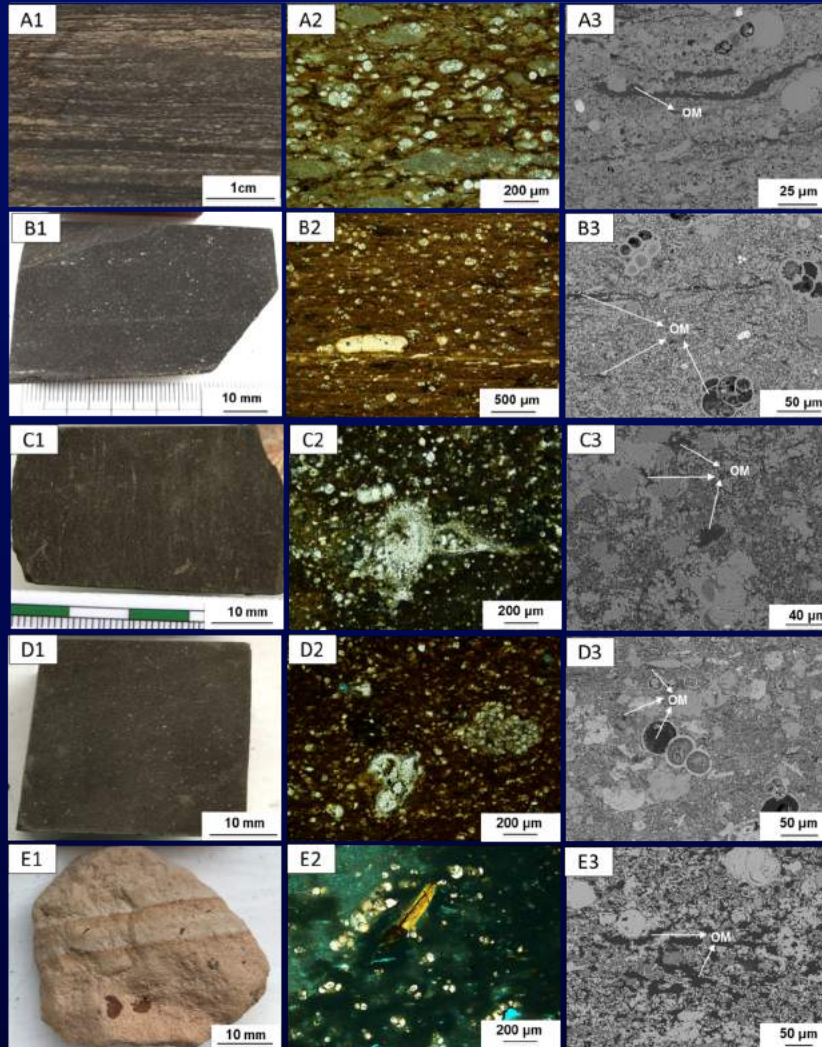
MF1: Dark grey/black weakly bioturbated calcareous mudstone

MF2: Black laminated calcareous mudstone

MF3: Dark grey strongly bioturbated calcareous mudstone

MF4: Dark grey weakly/moderately bioturbated black calcareous mudstone

MF5: Yellowish calcareous mudstone



Oxial/
Dysoxia

Anoxial/
Euxinia

Anoxial/
Euxinia

Anoxia

Anoxia

OAE2

Early Turonian

Agadir Basin

Tarfaya Basin

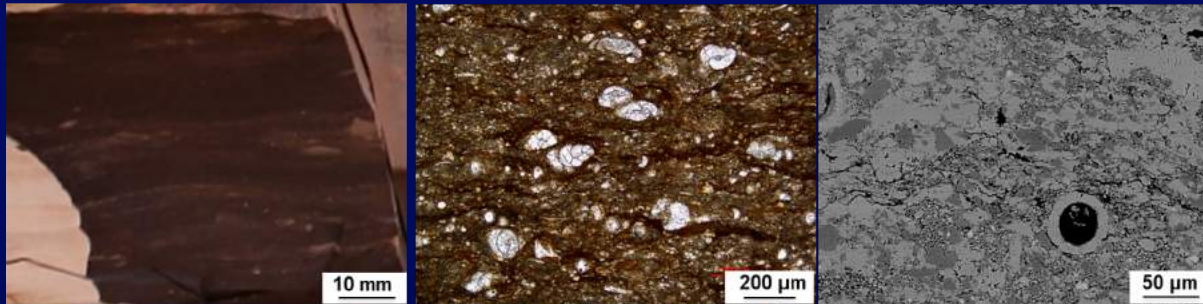
Tarfaya
Agadir



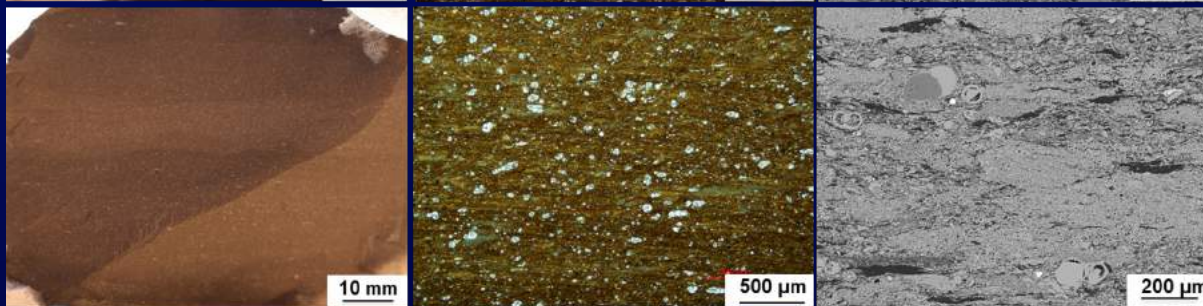
Mudstones lithofacies

LF5: Calcareous mudstones

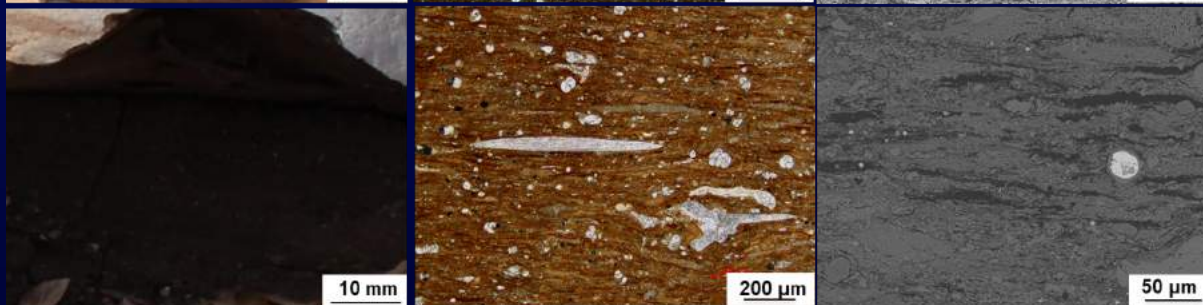
MF6: Black calcareous mudstones



MF7-1: Extremely black and laminated calcareous mudstone



MF7-2: Extremely black and laminated calcareous mudstone



Dysoxia

Euxinia

Anoxia

OAE2

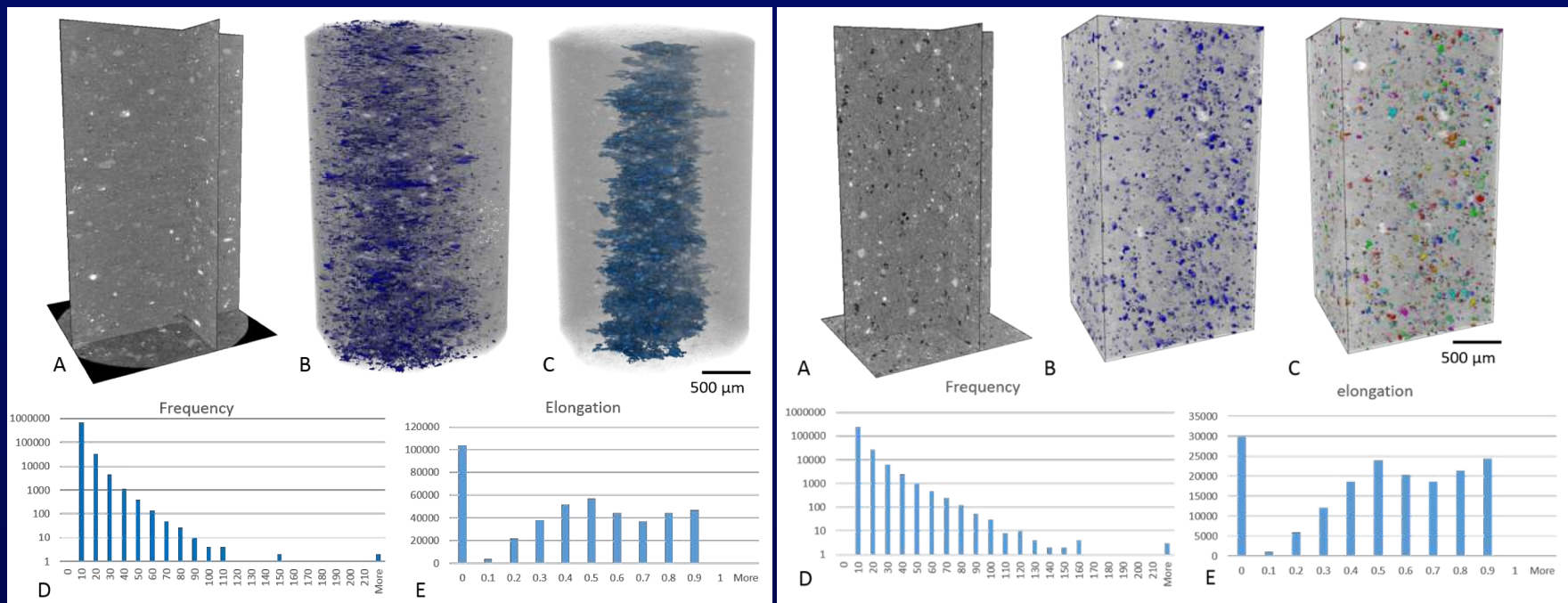
Early Turonian

Errachidia



Mudstones lithofacies

Organic matter distribution

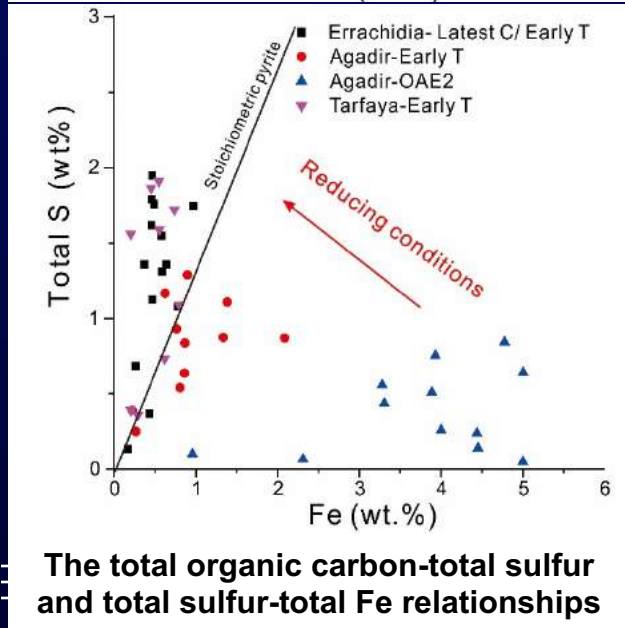
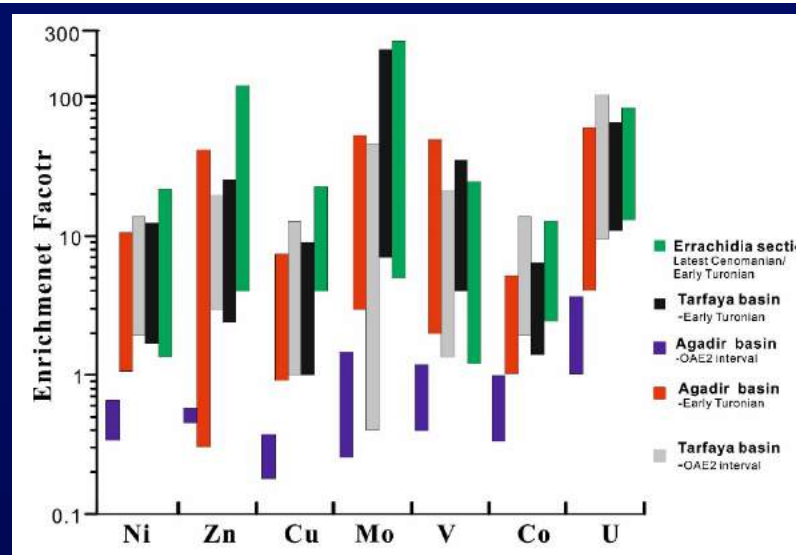
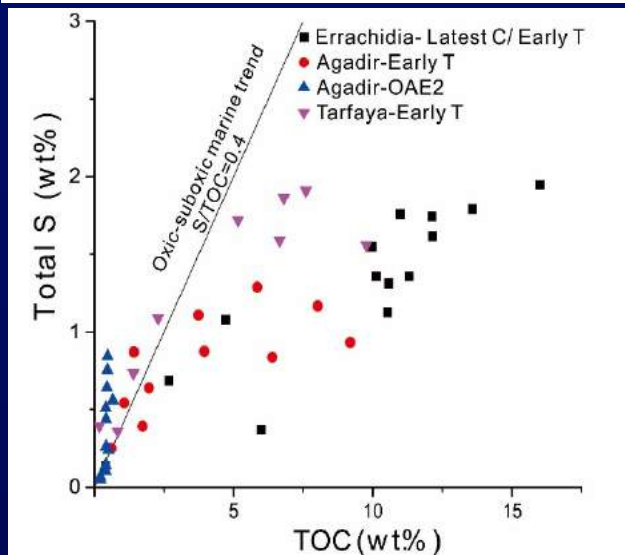


Two geometries of organic matter particles are recognized:

- (1) Elongated shapes in the matrix with good connectivity
- (2) Spherical shapes in the foraminifera tests with poor connectivity.



Inorganic geochemistry



The organic-rich mudstones developed in anoxic/euxinic water conditions, and associated with high S content and high S/Fe values
 OM-poor mudstone deposited in oxic/dysoxic water conditions, with much less S content and lower S/Fe values

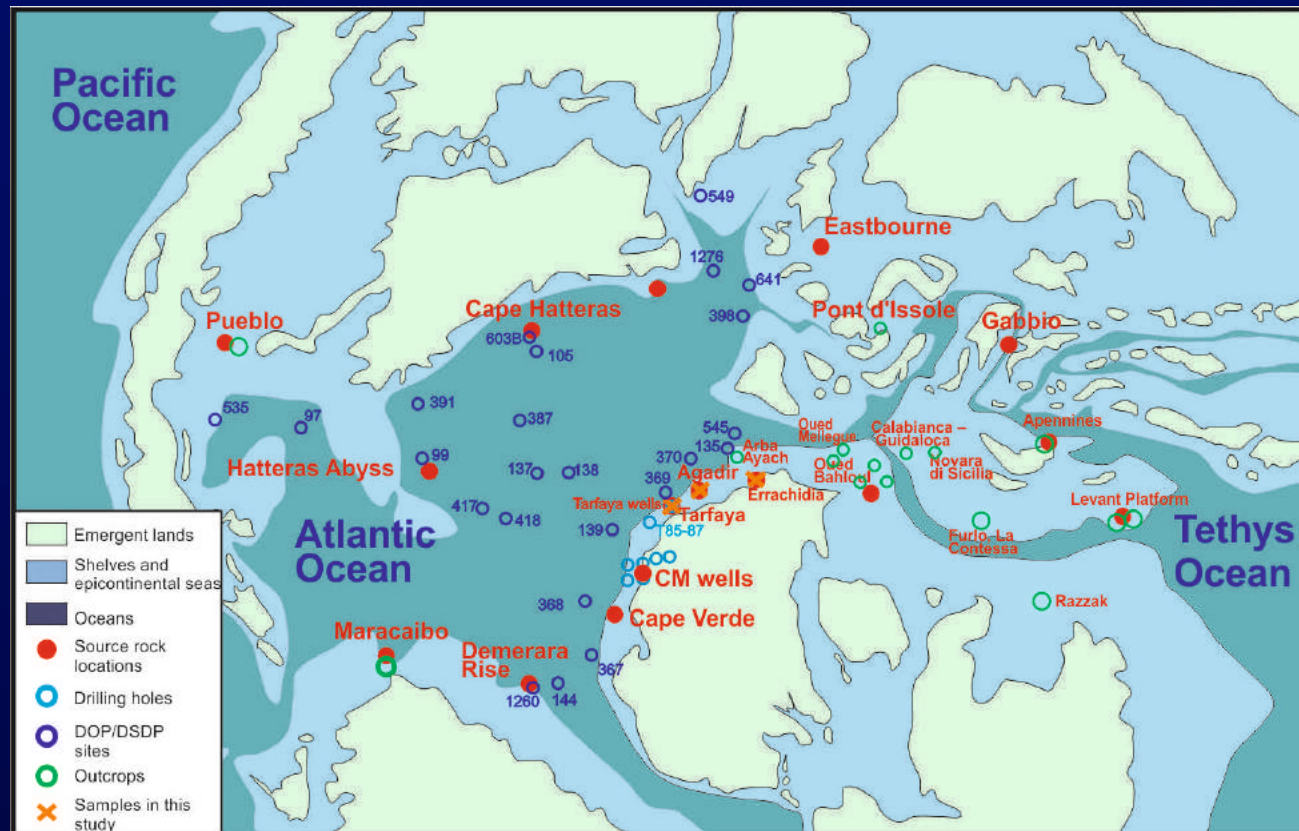
The C/T organic-rich mudstones in the Tethys influenced basin present a generally higher TE concentration than the Atlantic influenced basins

The total organic carbon-total sulfur and total sulfur-total Fe relationships

C/T source rock distribution globally

	Hole	Locations	Age	Av.TOC (%)	MAX TOC (%)	Kerogen Type	HI (mg HC/g TOC)	Tmax (°C)	Thickness (m)	Data Source
Atlantic Ocean	ODP 1257	Demerara Rise, Leg 207	Late C	7.60	13.60	II	453-704		44	(Erbacher et al., 2005; Forster et al., 2007; Meyers, 2006; Wagner et al., 2013)
	ODP site 1258		Early T	11.00	17.00	II	485-687	384-405	60	
			Late C	14.00	29.00					
	ODP site 1259A		Early T	17.00	36.00	II	528-763	387-404	50	
	ODP site 1260		Early T	7.00	15.00	II	110-722	375-414	90	
			Late C	10.00	22.00					
	ODP site 1261		Early T	7.00	14.00	II	352-805	392-413	87	
		Late C	10.00	29.00						
	Outcrop-Maracaibo	Venezuela	Early T	3.29	4.58		177-243	438-440		(Perez-Infante et al., 1996)
			Late C	3.98	5.82		152-276	437-443		
	DSDP144	French Guyana	Late C	7.00	9.00					(Kuypers et al., 2002)
	DSDP 367	Cape Verde Basin	Early T	18.00	30.00	II	600		49.6	(Herbin et al., 1986;
			C/T	24.90	34.20	I/II	477-655	396-411		Wagner et al., 2013)
			Late C	26.60	60.00					(Dickson et al., 2016)
Late C			16.00	46.00					(Kuypers et al., 2002)	
		C/T	10–40%	40.00	II	300–900		150	(Nzoussi-Mbassani et al., 2005)	
DSDP 105, 603B	Cap Hatteras	C/T	6.00	26.00		150-270			(Kuypers et al., 2004)	

C/T source rock distribution globally



- ❑ C/T source rocks are thicker and have higher TOC content in the Atlantic influenced basins than the Tethys influenced Basins.
- ❑ The Early Turonian interval is associated with a wider OM-rich mudstones distribution globally.



Conclusion

- **C/T OM-rich black mudstones are recognized in both the Atlantic Ocean and Tethys Ocean influenced basins in Morocco. They are not only associated with the OAE2 interval but also distributed during post-OAE2 interval over a wide area in Morocco.**
- **Five mudstones lithofacies are recognized during the C/T interval in these Moroccan basins based on the distributions, and organic matter is preferentially developed in parallel-laminated calcite-rich mudstones**
- **Organic matter particles were predominantly identified in the matrix and in foraminiferal tests. The former type is an elongated or irregular shape and well connected while the latter type is more dispersively distributed.**
- **The Atlantic influenced basin also presents a greater hydrocarbon potential than Tethys influenced basins, especially in deep marine environment with vertically continuously thick organic-rich beds from OAE2 interval to post-OAE2 interval.**



Questions and Answers:

Thanks my sponsors:



Special Thanks:

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Azazoul section, Morocco 23/05/2015