Source rock deposition in Morocco from Late Cenomanian to Early Turonian

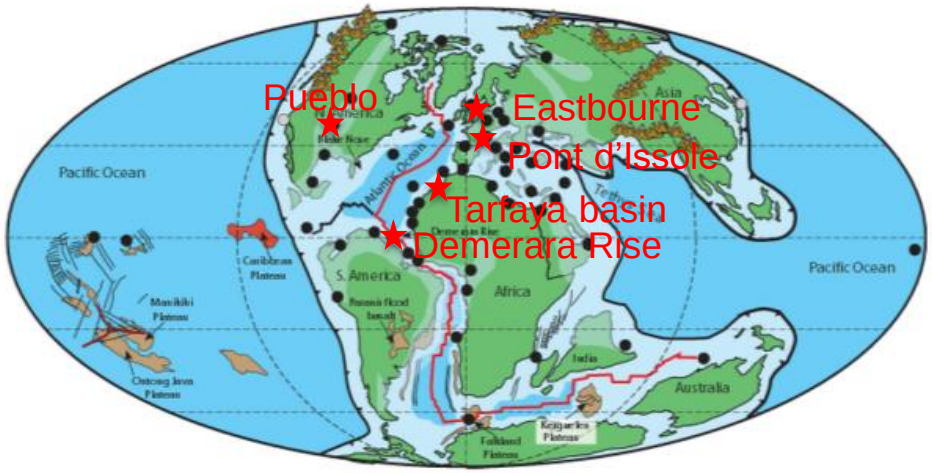
Jianpeng Wang

Supervisors: Prof. Jonathan Redfern
Prof. Kevin Taylor
Dr. Luc G. Bulot

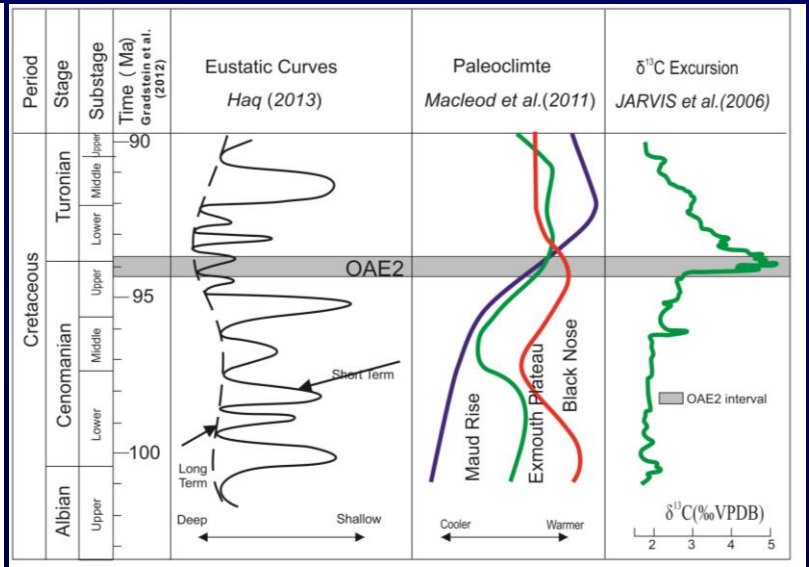
Introduction

OAE2

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



Distribution of black shales during OAE2



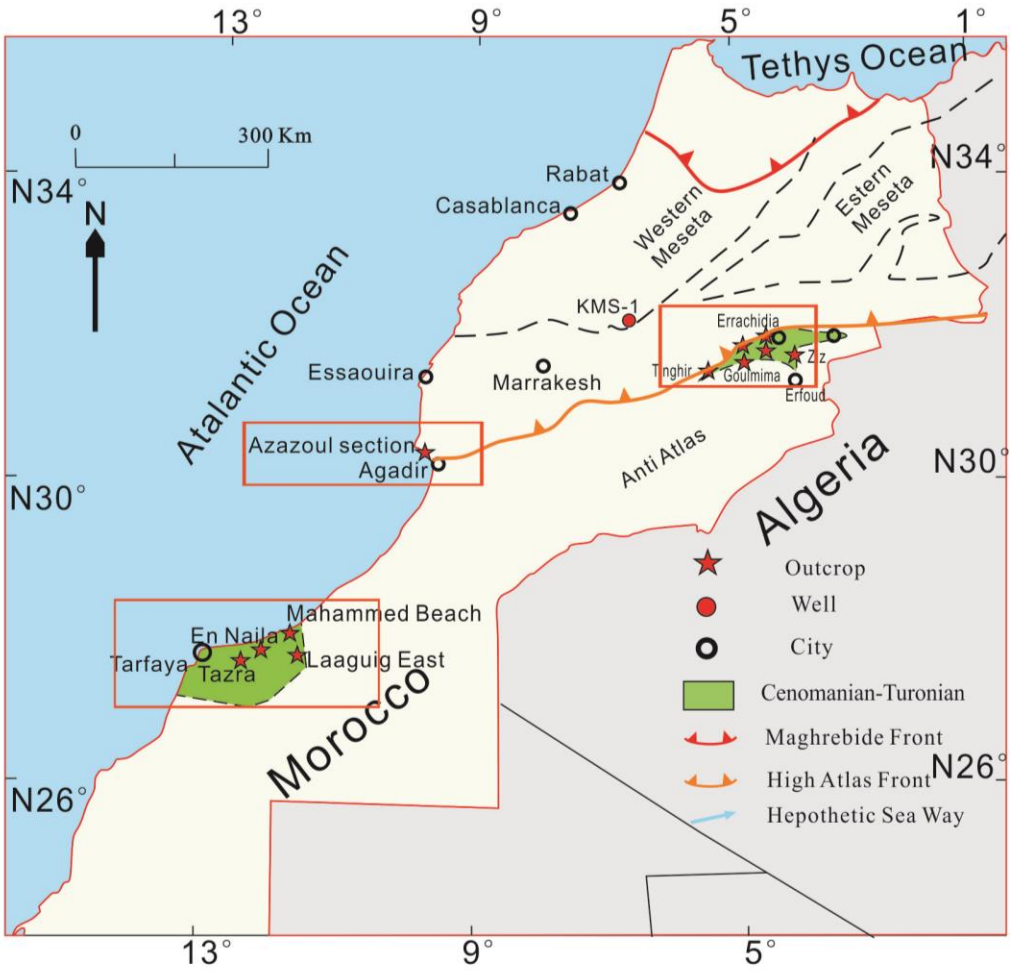
The characteristics of OAE2

Age: Late Cenomanian to Early Turonian Duration: < 1 Ma

Paleoclimate: Extremely warm climate and high sea level

Characteristics: OM-rich mudstones deposition and positive $\delta^{13}C$ excursion

Introduction



Location of studied Moroccan basins

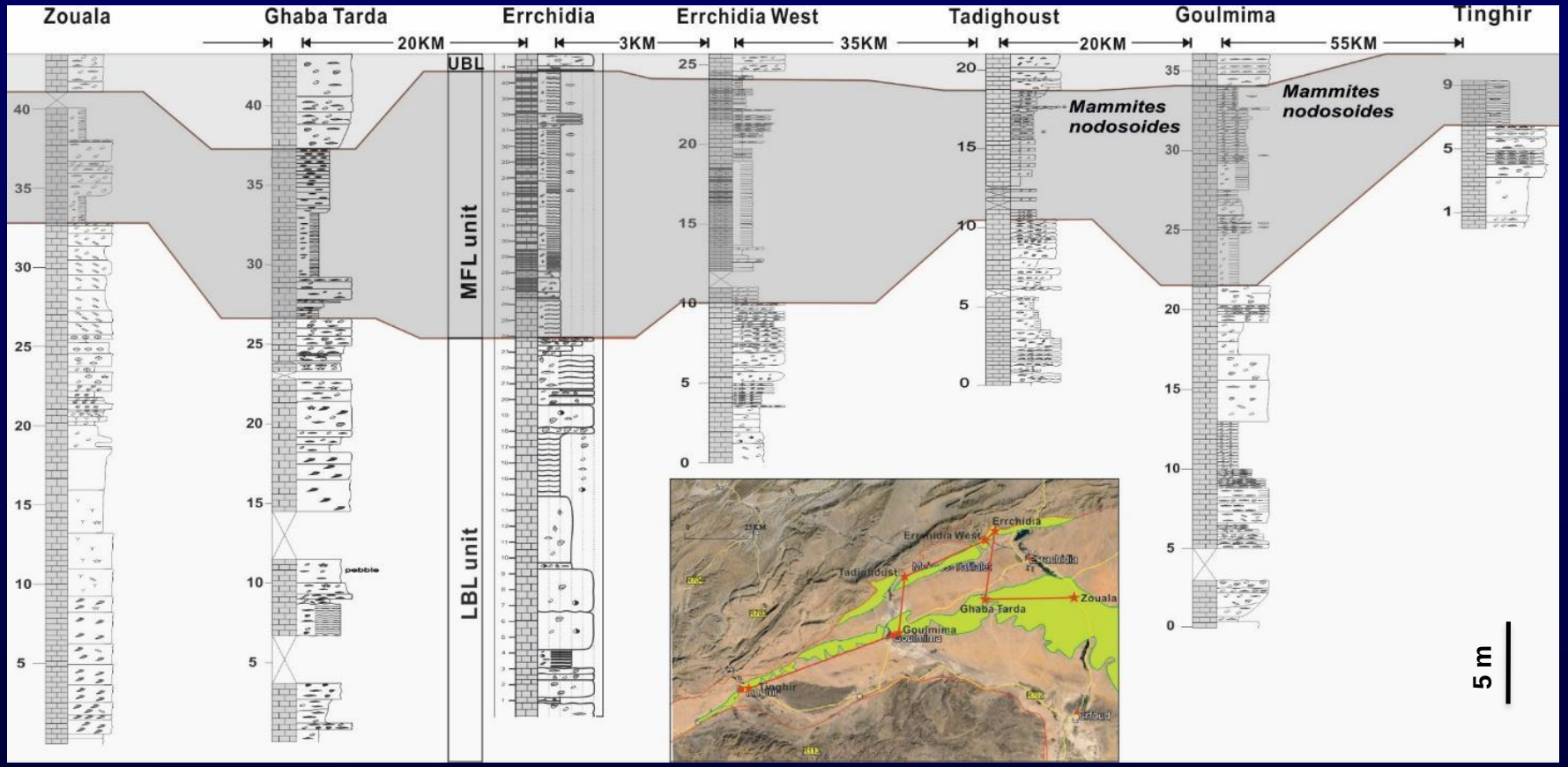
Aims:

- Identify the distribution and quality of C/T source rock
- Source rocks timing
- Controls on the source rocks
- Analogue for offshore basins

Studied basins:

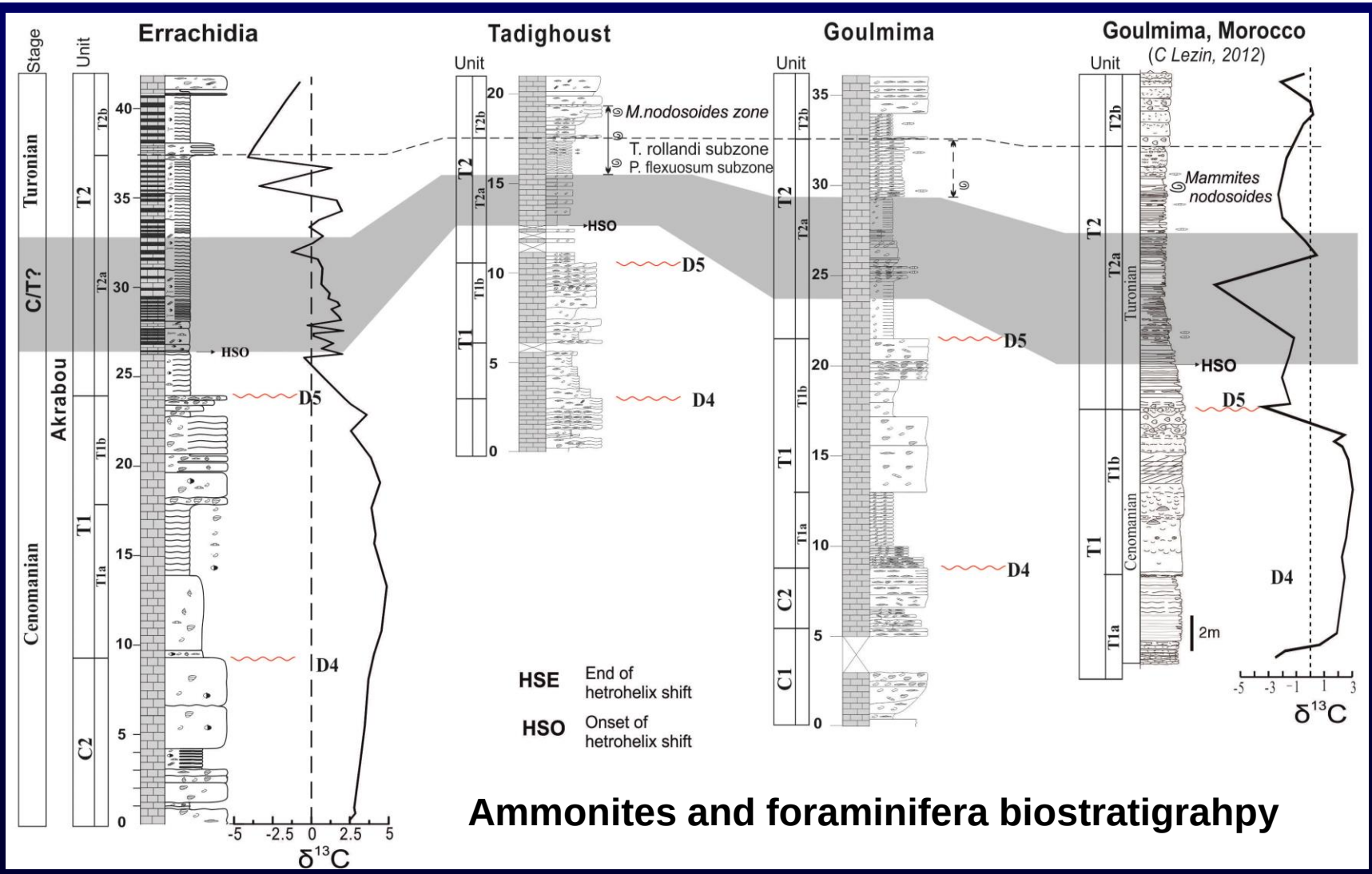
- **Errchidia-Goulmima Basin**
  -Tethys Ocean Influence
- **Agadir-Tarfaya basins**
  -Atlantic Ocean Influence

1. Errachidia-Goulmima Basin



Shallow carbonate platform deposition was controlled by Tethys Ocean
Black organic-rich mudstones were only recognized in the Errachidia area

1. Errachidia-Goulmima Basin

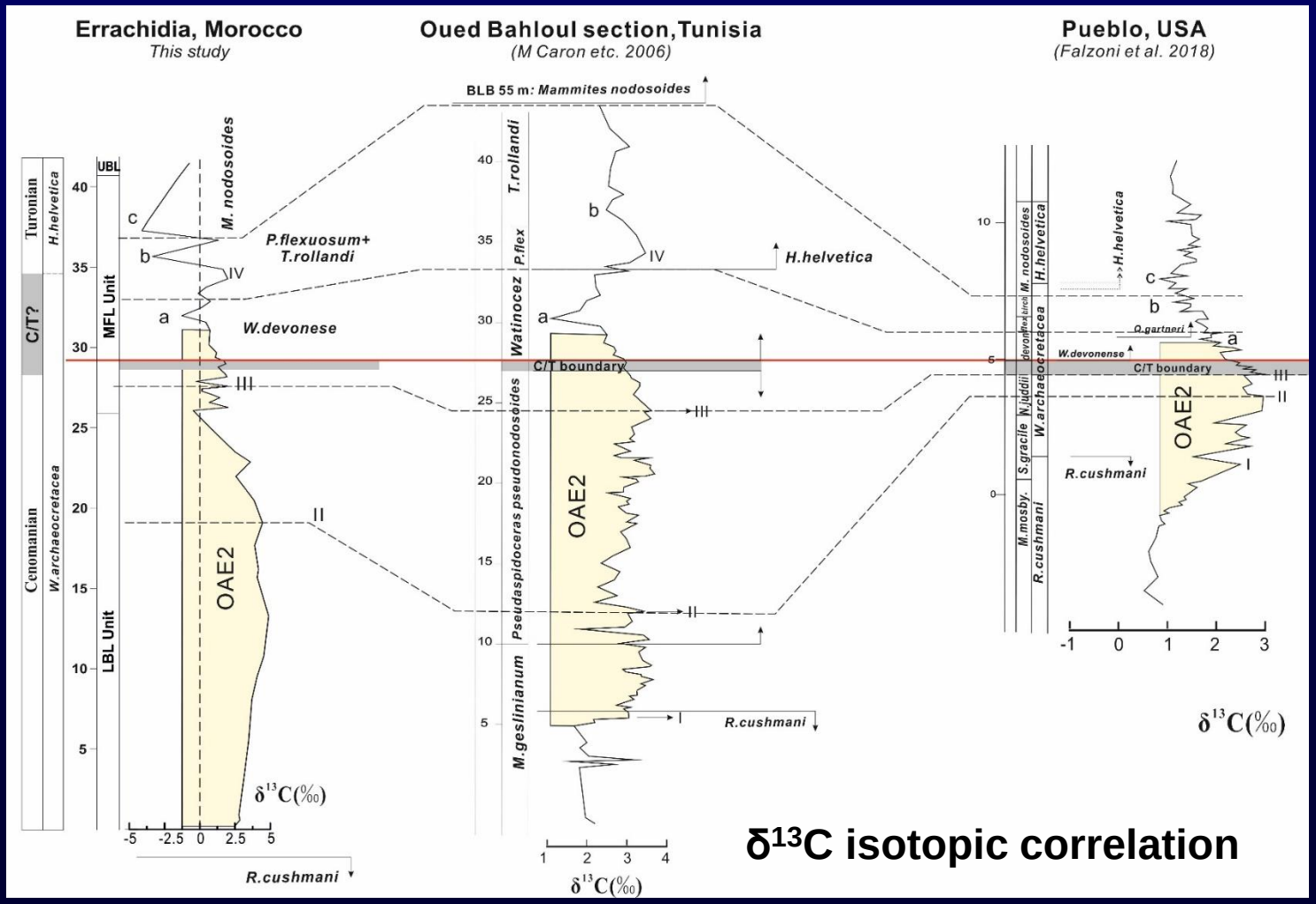


Ammonites and foraminifera biostratigrahpy

1. Errachidia-Goulmima Basin

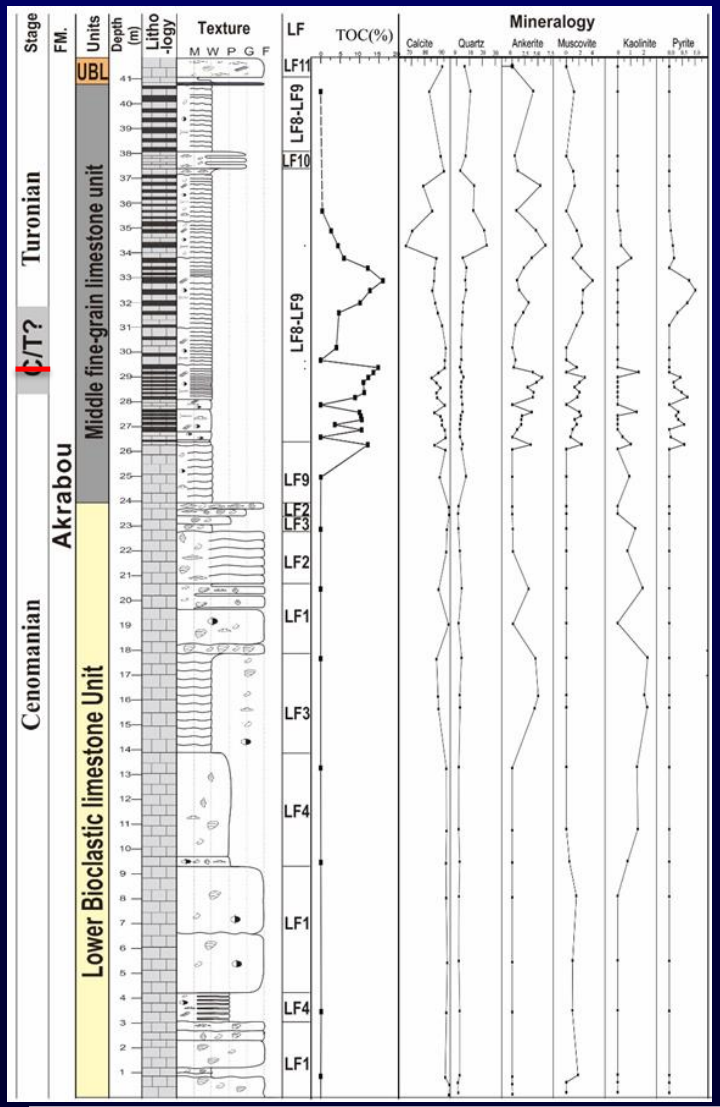
Errachidia

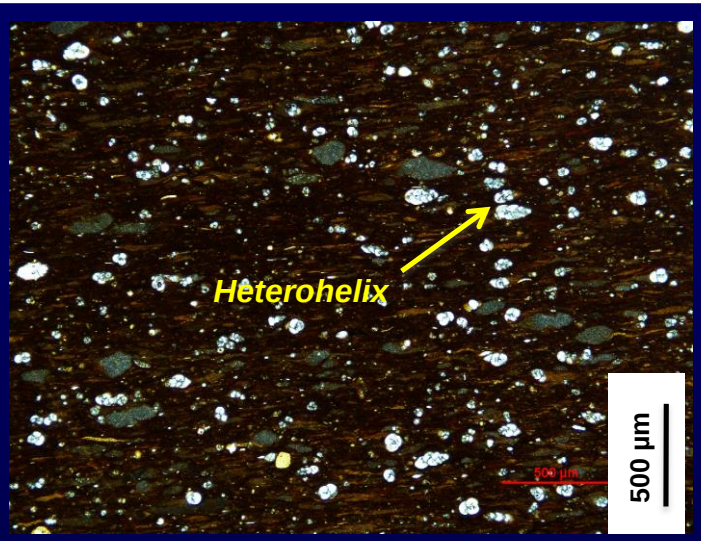
C/T boundary and OAE2 interval

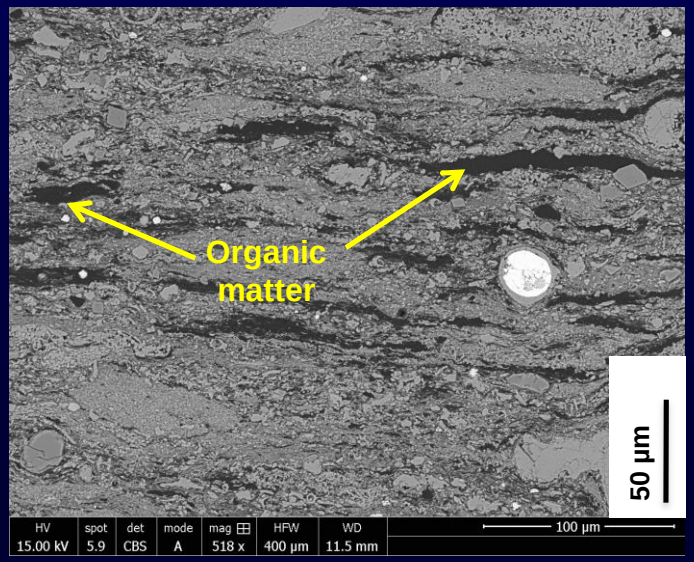


1. Errachidia-Goulmima Basin

Errachidia



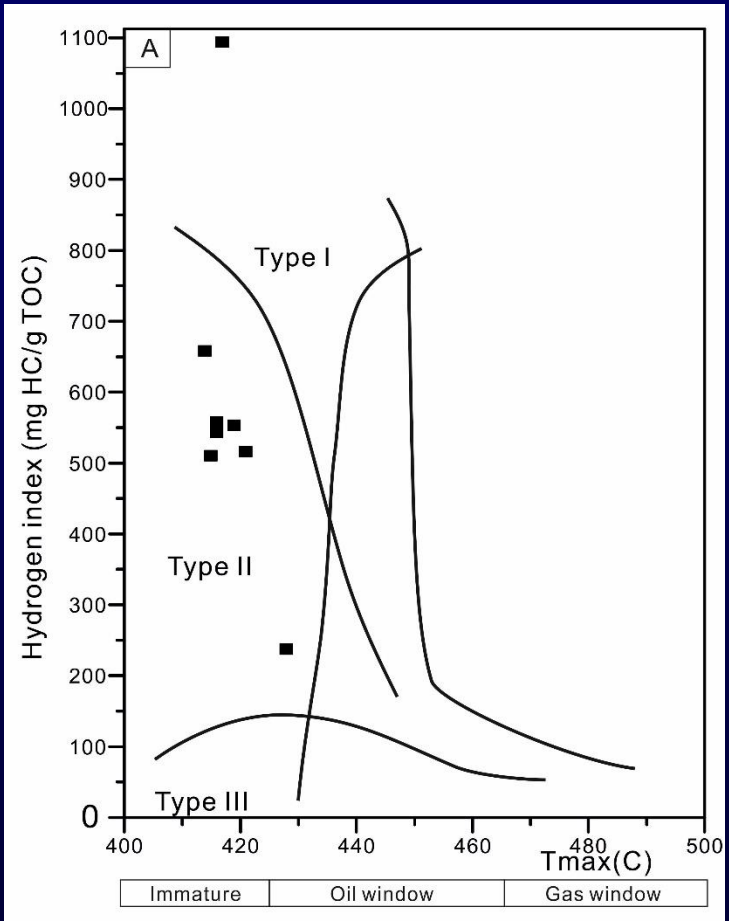


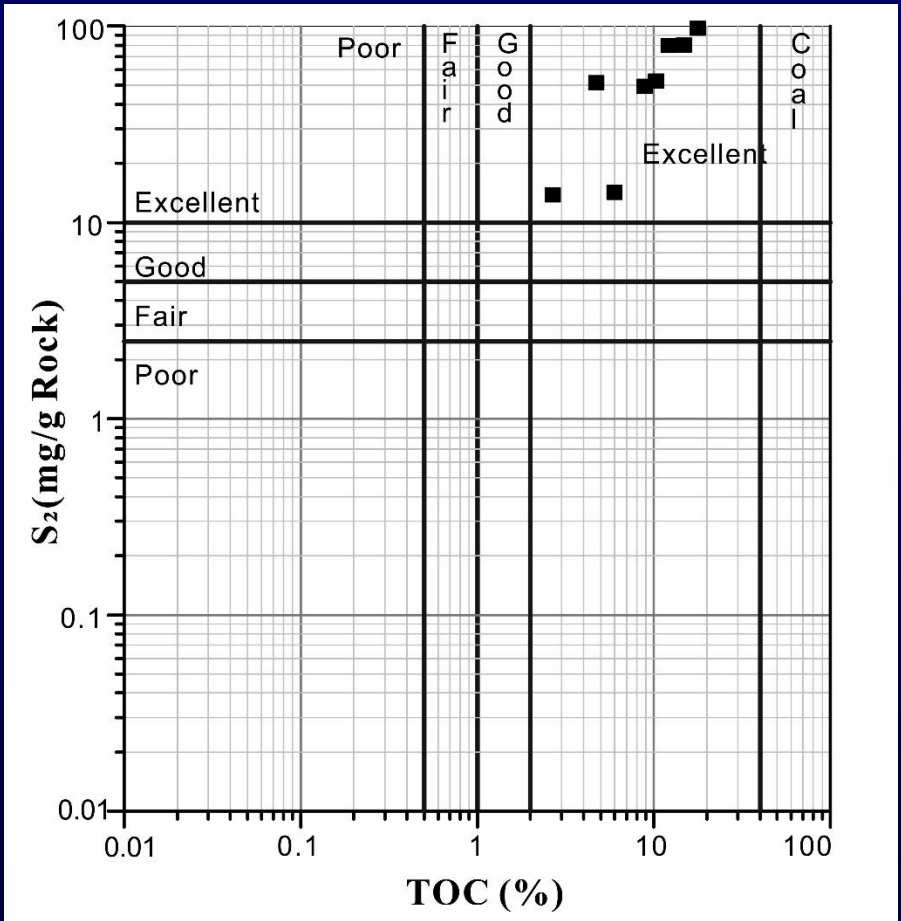


- Organic-rich mudstones/ organic-poor limestones bedding couplet
- Carbonate-rich
- Laminated
- Planktonic foraminifer rich
- TOC: average 9.3%, Maximum17.7%
- Low pyrite content

1. Errachidia-Goulmima Basin

Errachidia

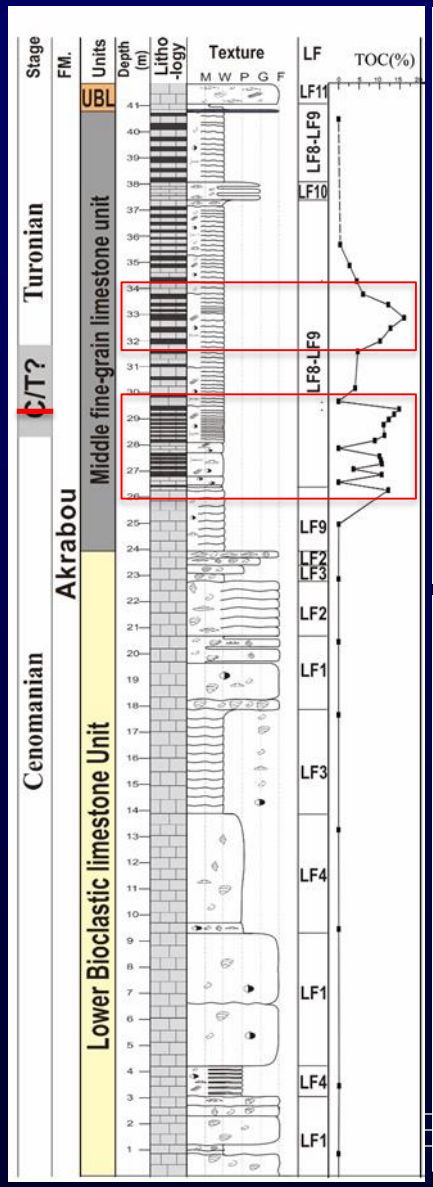


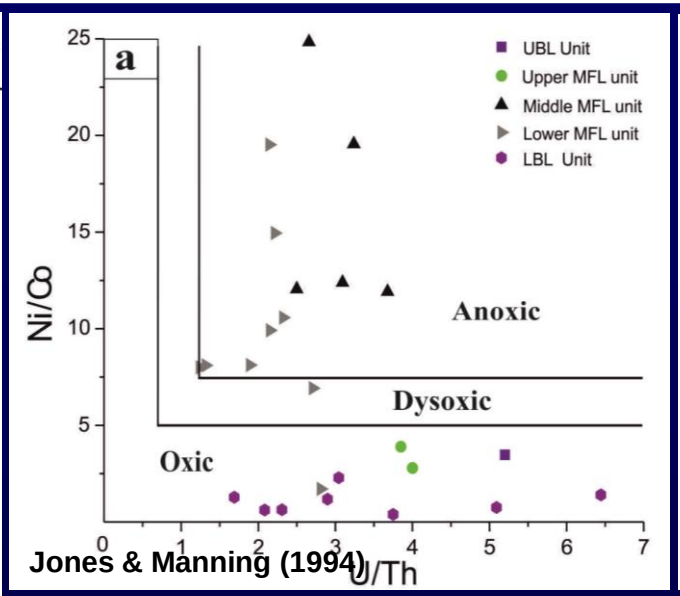


Dominant kerogen type II, high HI and TOC values
Excellent source rocks

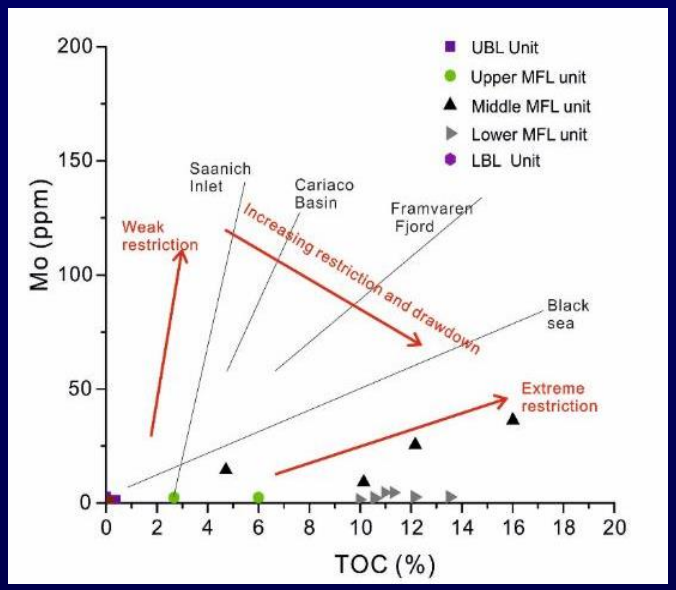
1. Errachidia-Goulmima Basin

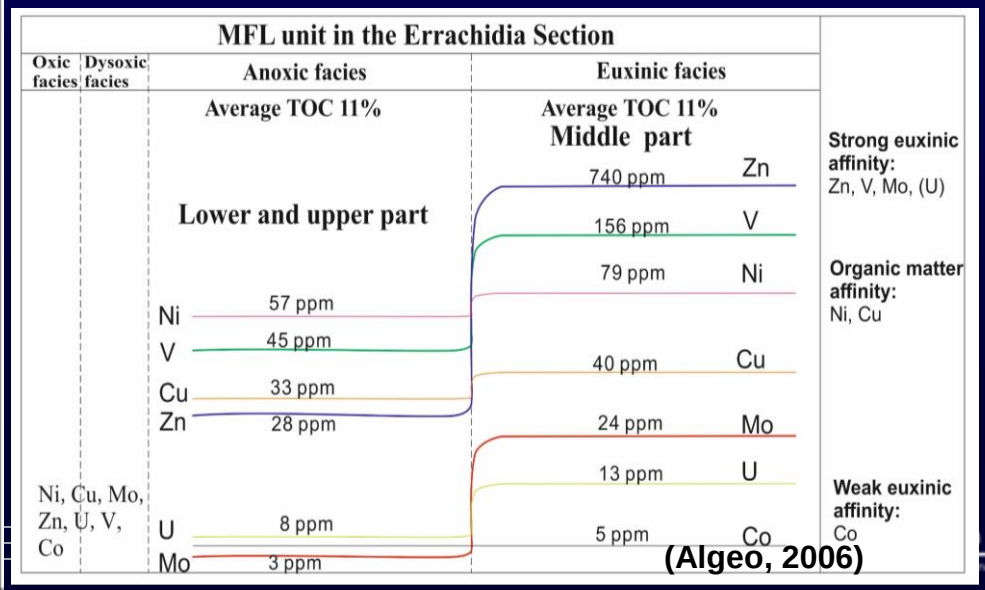
Errachidia





Jones & Manning (1994)





(Algeo, 2006)

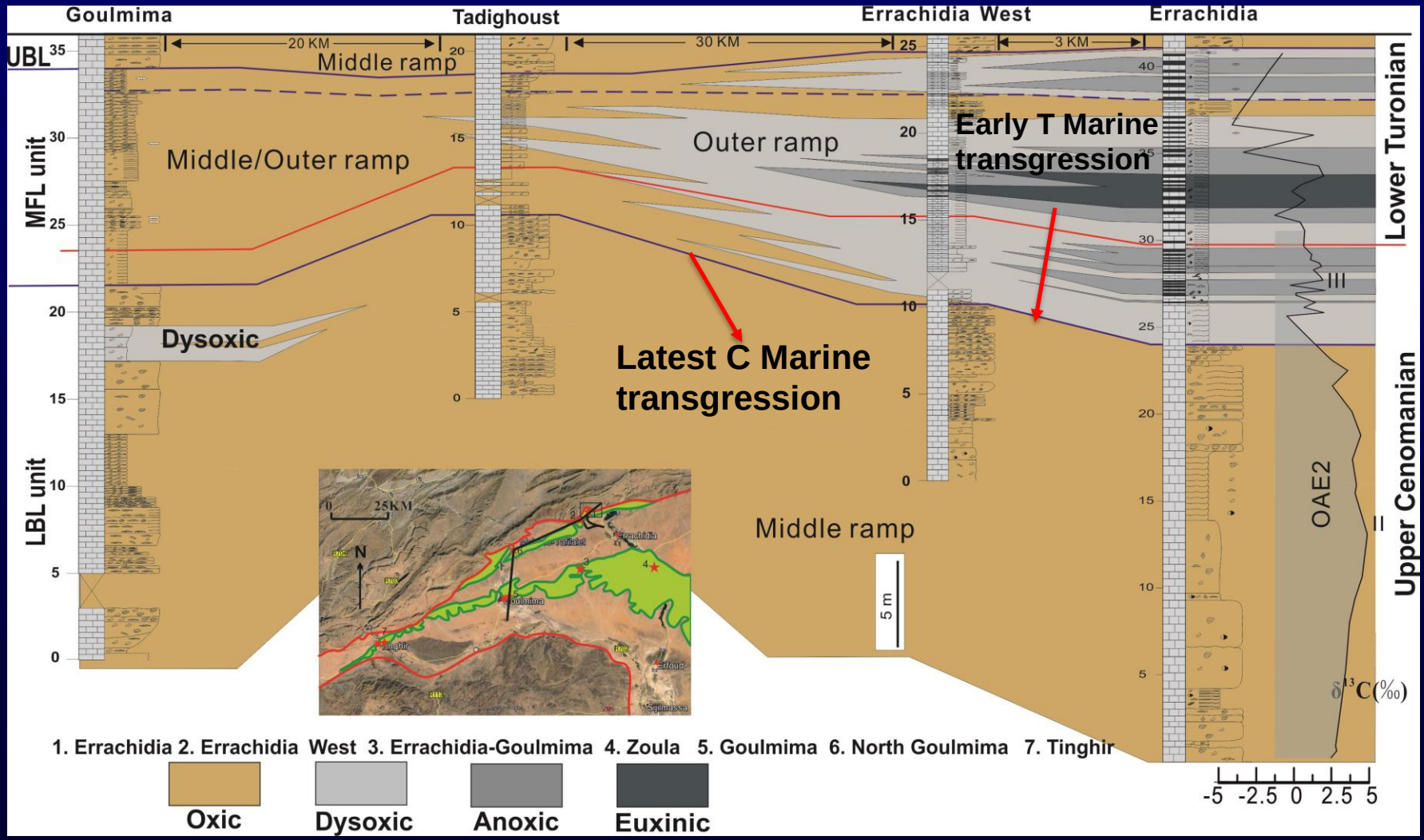
Extreme restricted condition

Anoxic/Euxinic bottom conditions

Africa Research Group

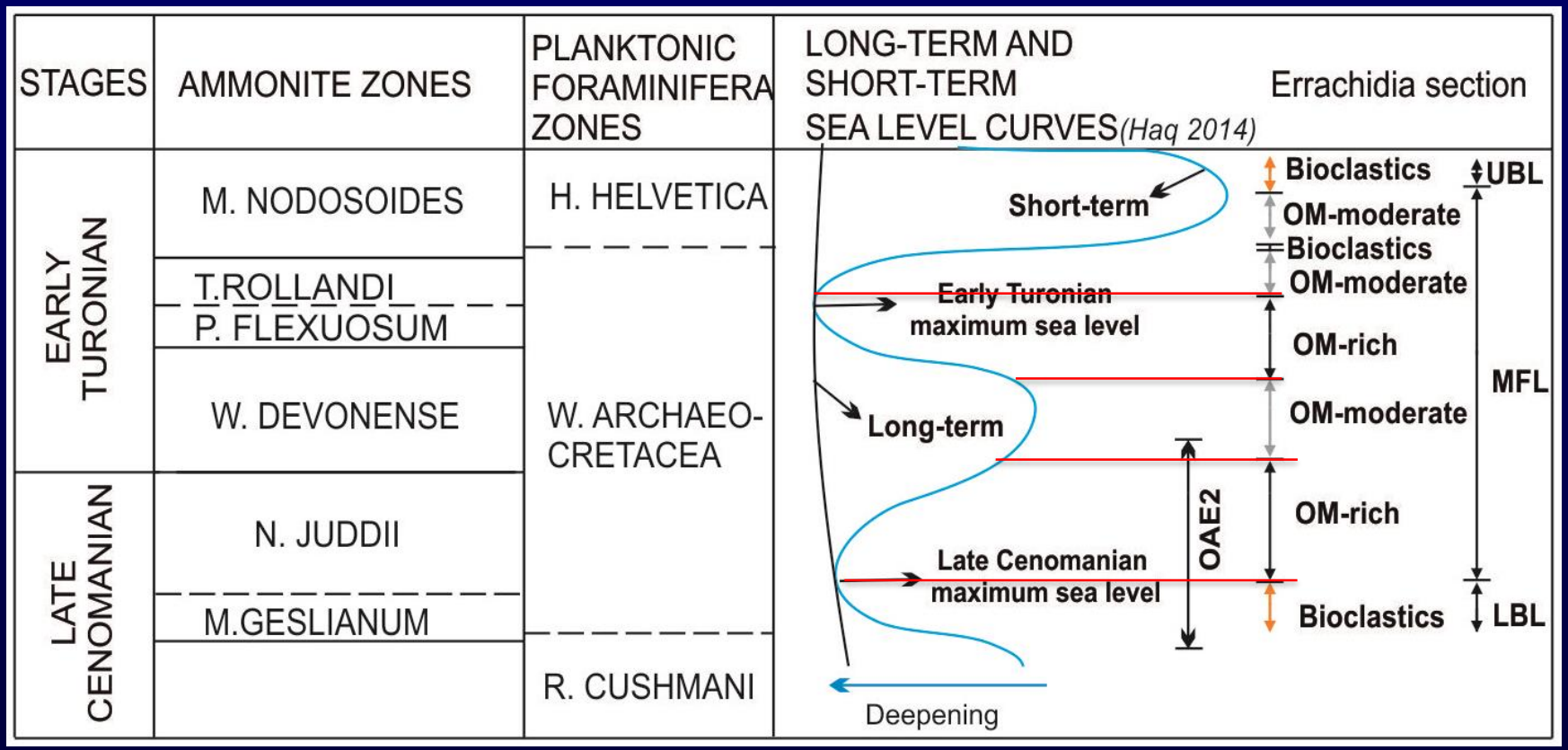
1. Errachidia-Goulmima Basin

Summary



1. Errachidia-Goulmima Basin

Summary



The organic-rich black mudstones interval correlate with eustatic cycles

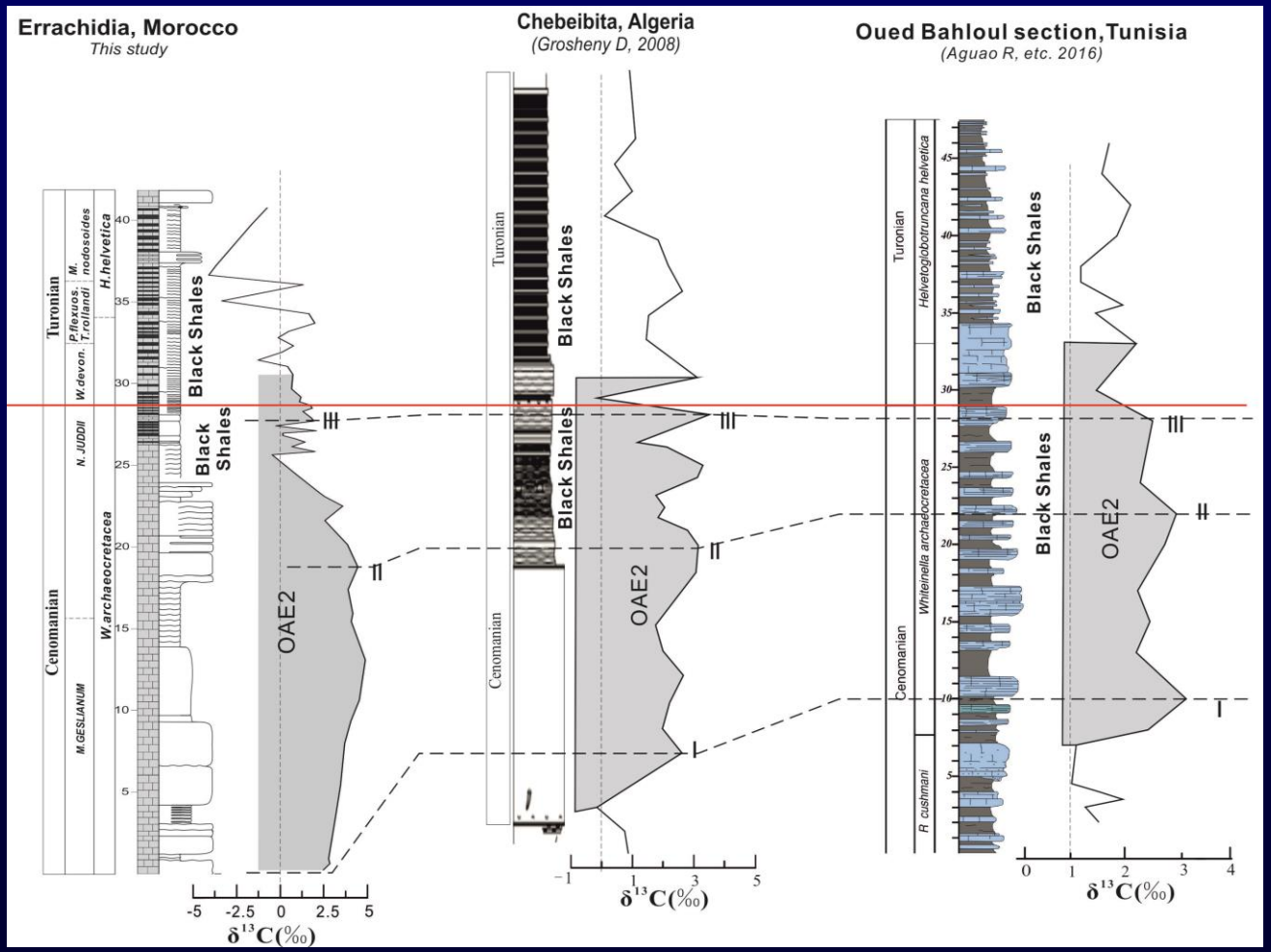
Late Cenomanian marine transgression: delay response, anoxic conditions

Early Turonian marine transgression: coeval, euxinic redox conditions

1. Errachidia-Goulmima Basin

Summary

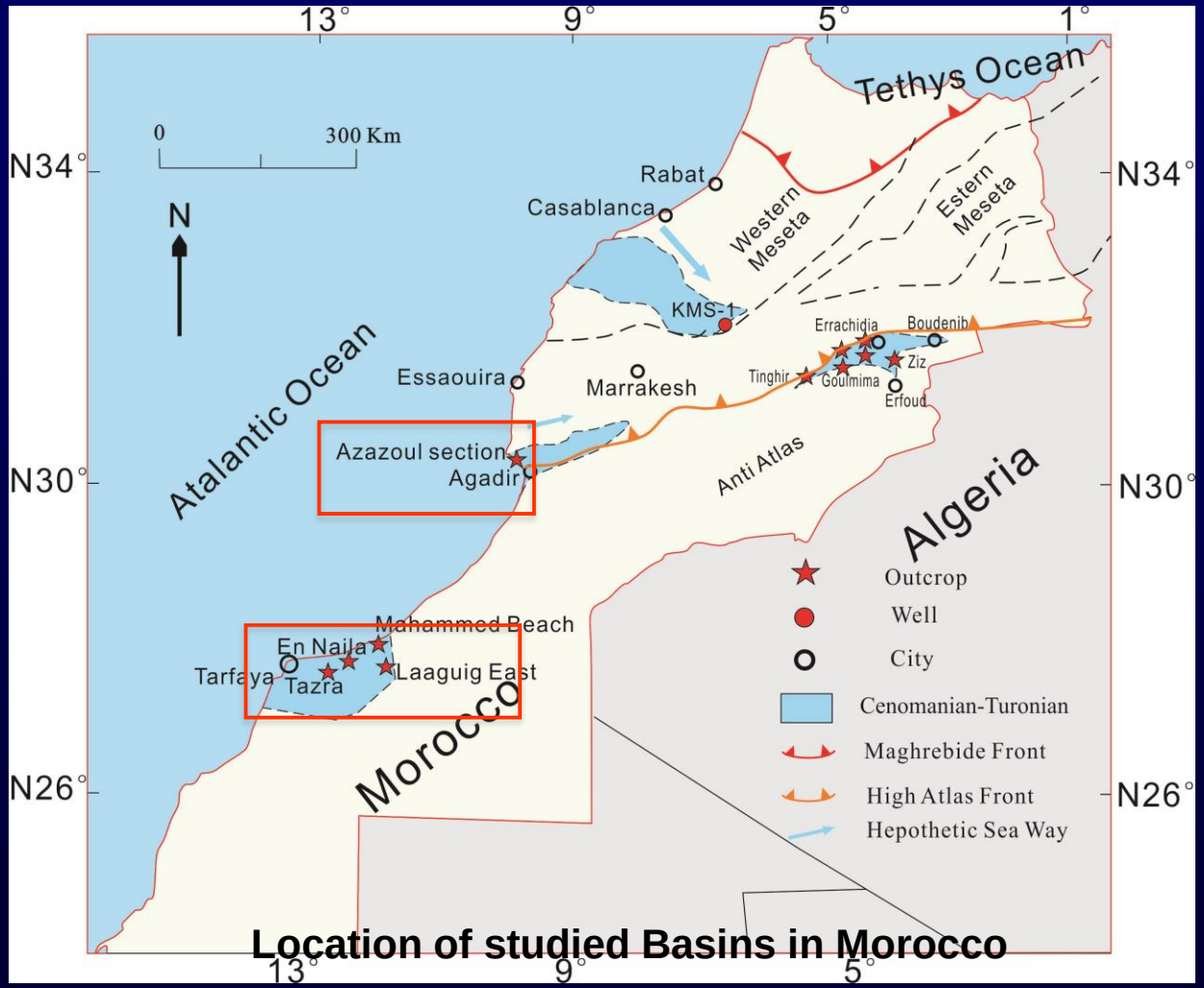
Regional correlation among Tethys influenced basins



OM-rich mudstones were developed in Upper OAE2 and Early Turonian interval, corresponding to the late Cenomanian and Early Turonian transgression

OM-rich mudstones were deposited in a strongly restricted marine environment with extremely low detrital influx, high productivity and anoxic/euxinic water conditions

2.Tarfaya and Agadir Basins



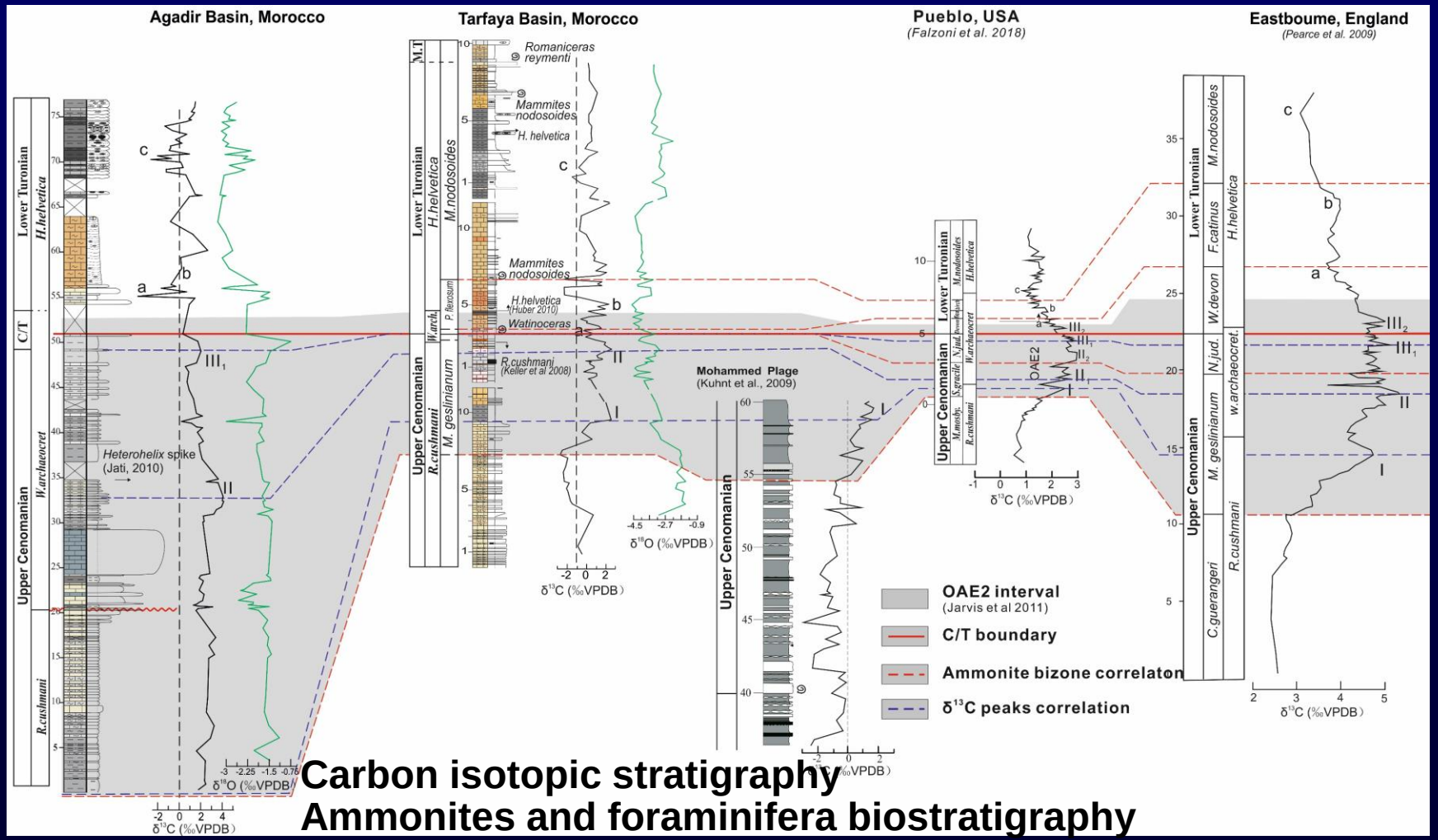
Location of studied Basins in Morocco

Atlantic ocean controlled basins:

Agadir Basin:
Azazoul section

Tarfaya Basin:
Laaguig East section
Tazra section
En Naila section

2.Tarfaya and Agadir Basins

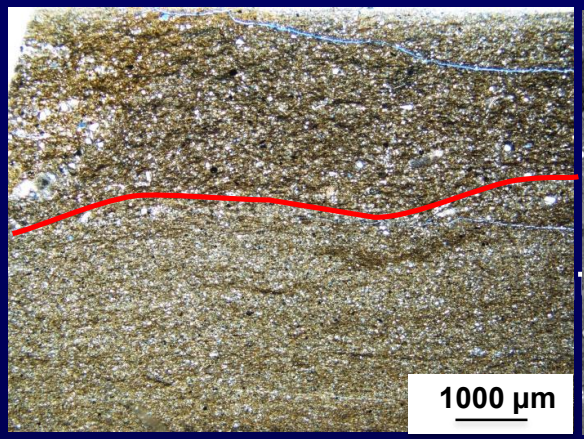


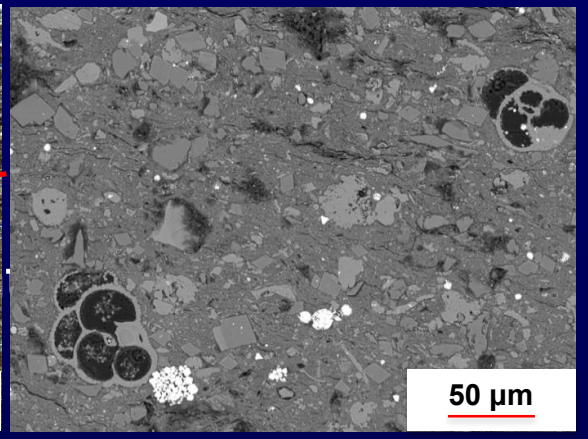
Carbon isotopic stratigraphy
Ammonites and foraminifera biostratigraphy

2.Tarfaya and Agadir Basins

OAE2

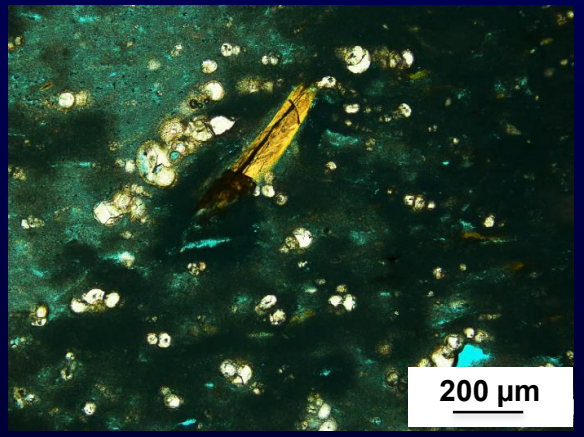
Agadir Basin

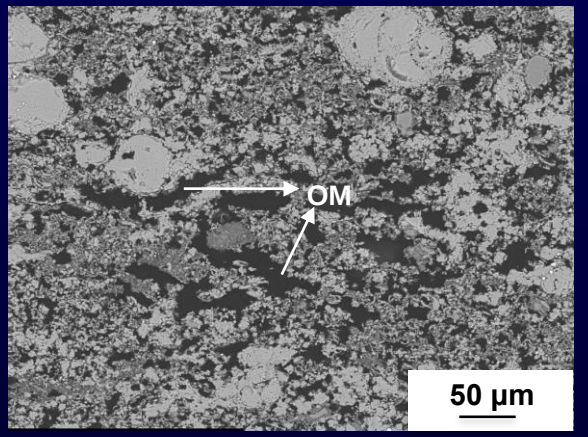




TOC values less than 1%, clay mineral-rich, organic matter in foraminifera tests

Tarfaya Basin



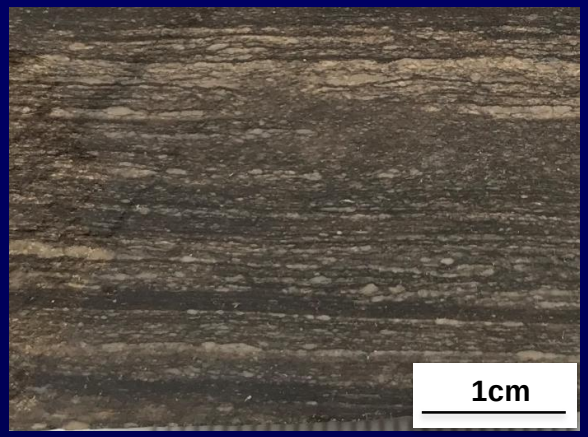


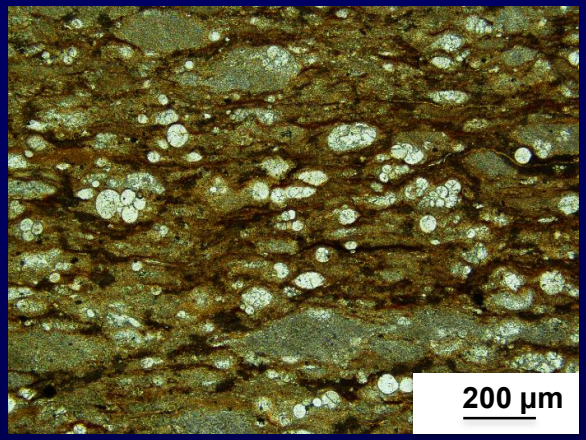
Weathered, carbonate-rich, abundant planktonic foraminifera and ‘organic matter '
TOC up to 12.5%, Kerogen II in the equivalent level of nearby sections

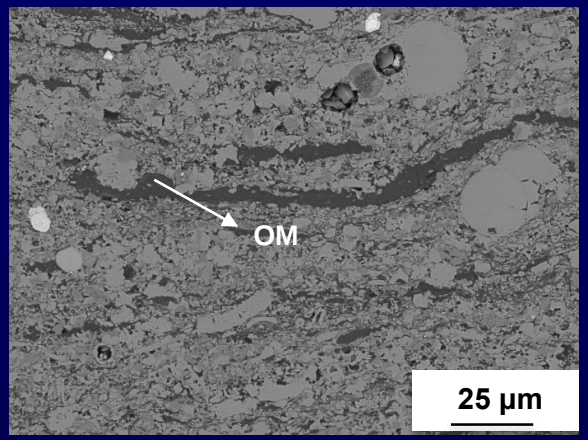
2.Tarfaya and Agadir Basins

Early Turonian

Agadir Basin

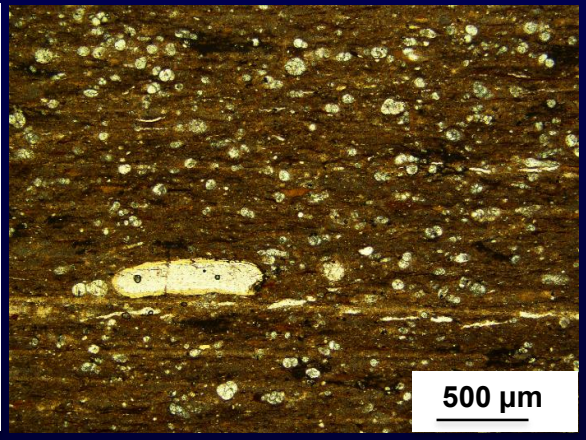


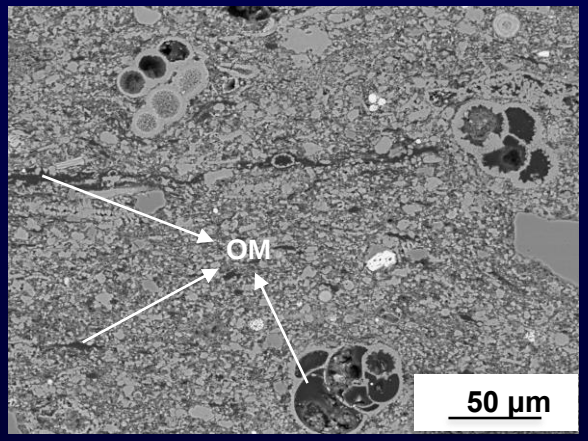




TOC up to 9.2%, average 2.5%. Calcite/quartz-rich. organic matter in the matrix

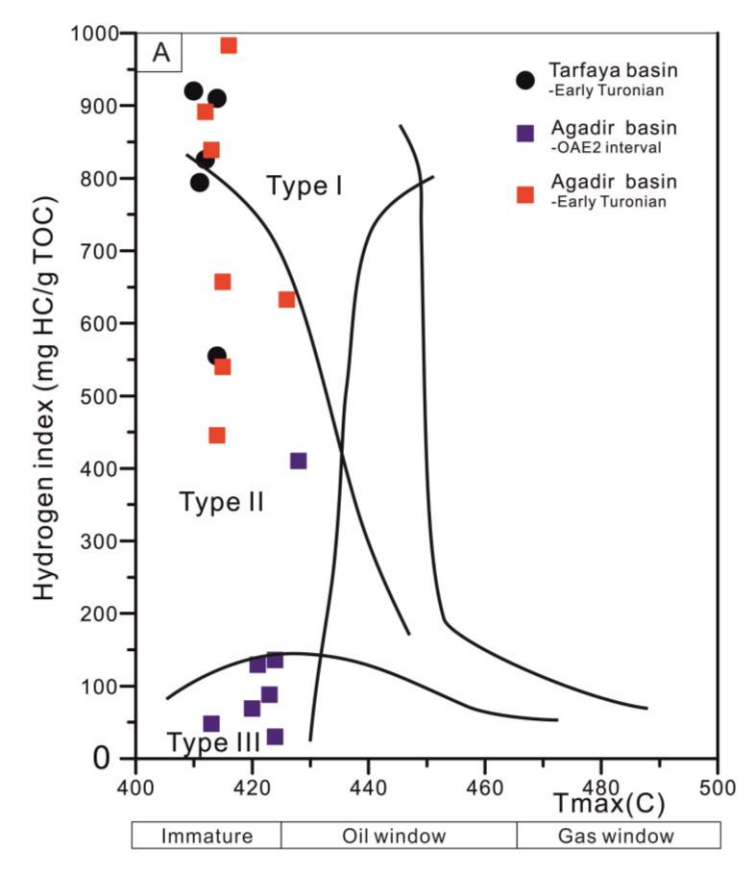
Tarfaya Basin

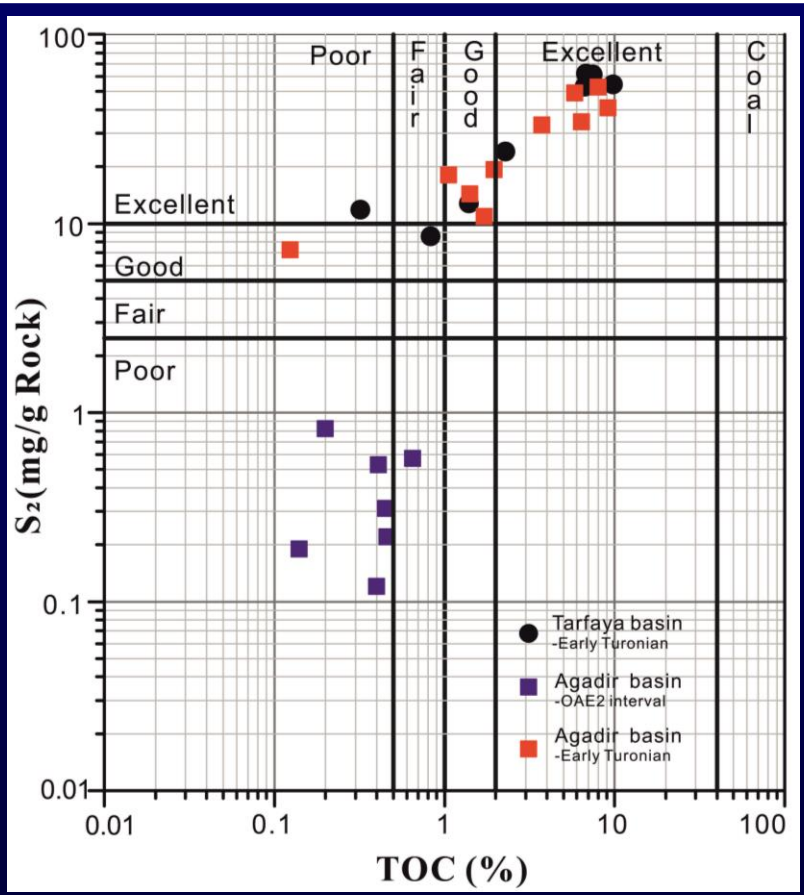




TOC up to 9.8%, average 3.5%. Carbonate-rich. organic matter in foraminifera test and matrix

2.Tarfaya and Agadir Basins

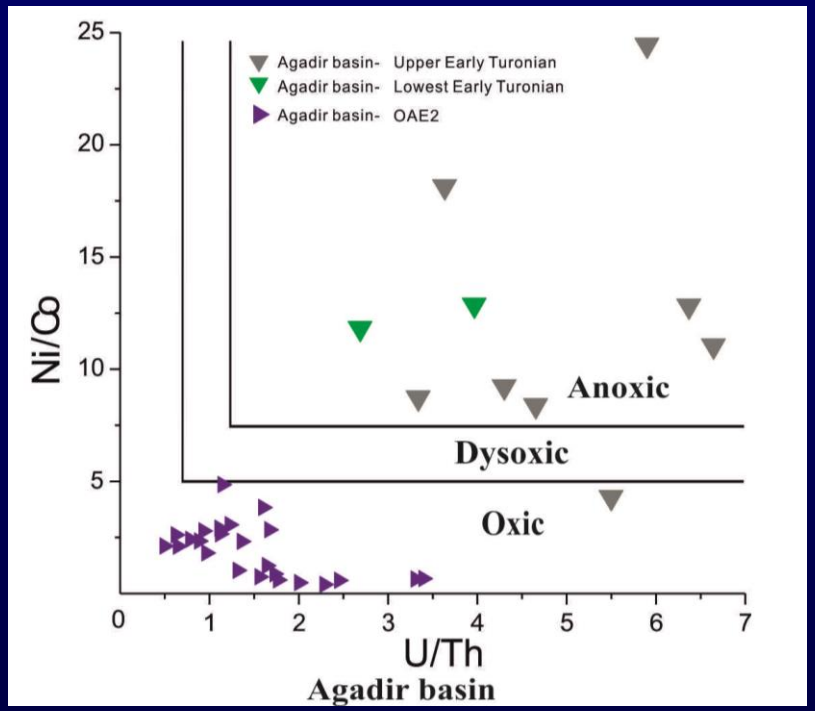


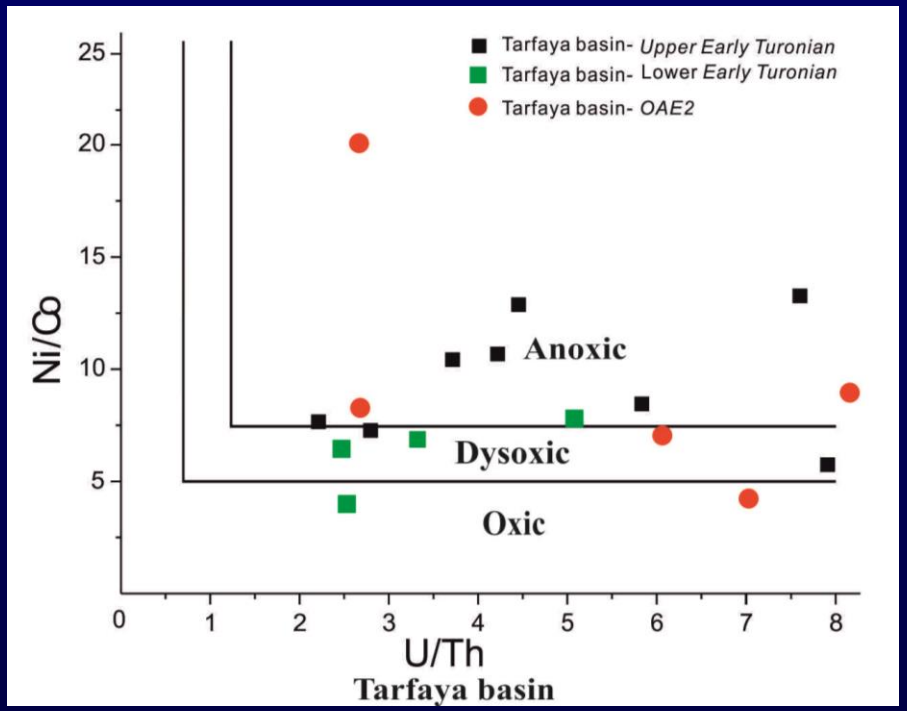


The OAE interval
- **Agadir Basin: dominant kerogen type III**
- **Tarfaya Basin: dominant kerogen type II (Wager et al, 2013)**

Early Turonian — **Mixture kerogen type I and II**

2.Tarfaya and Agadir Basins

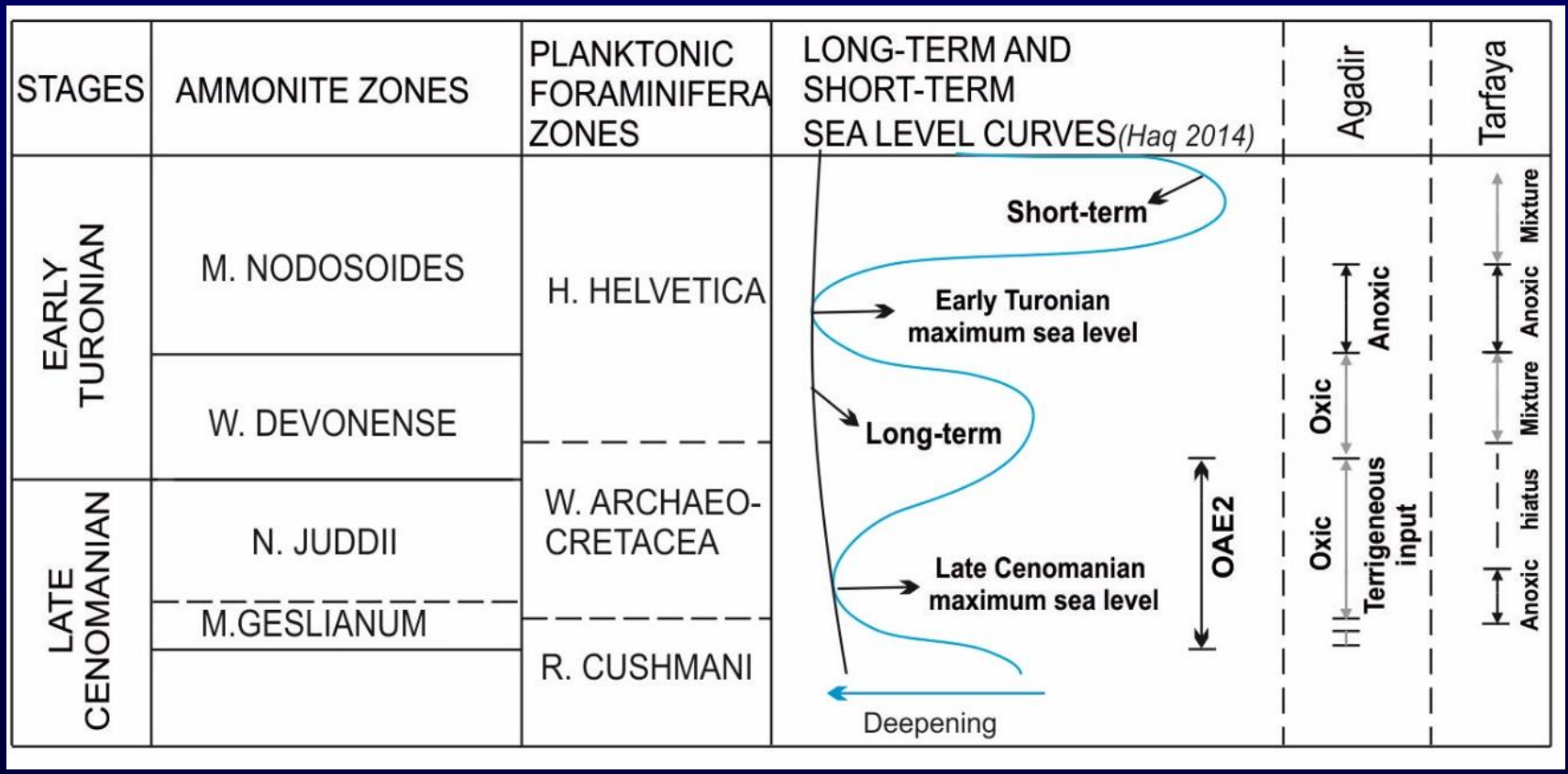




The OAE interval
- **Agadir Basin: Oxia**
- **Tarfaya Basin: Anoxia/dysoxia**

Early Turonian
- **Agadir Basin: Anoxia/dysoxia**
- **Tarfaya Basin: Anoxia/dysoxia**

2.Tarfaya and Agadir Basins



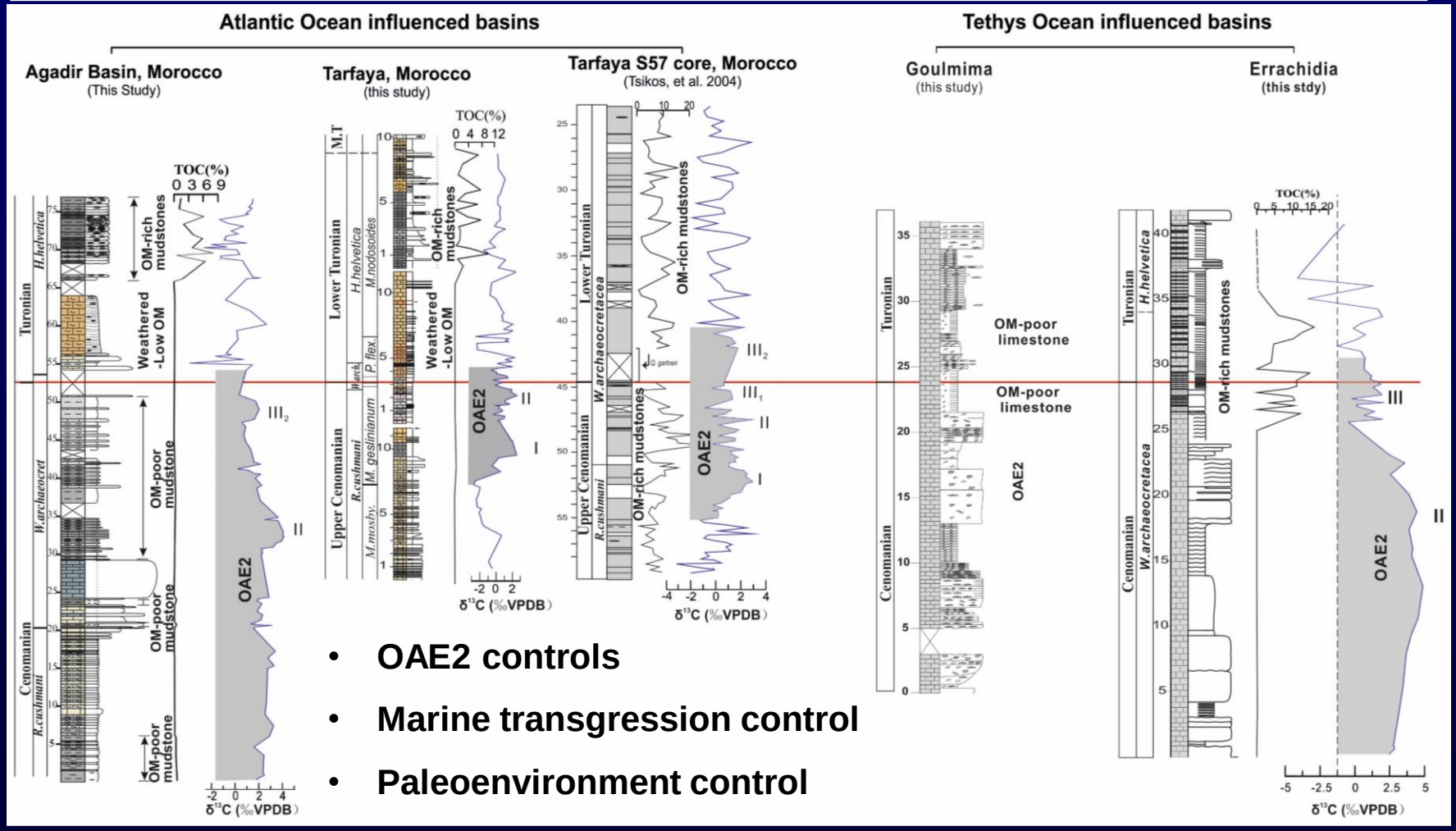
The organic-rich black mudstones interval correlate with eustatic cycles

2.Tarfaya and Agadir Basins

Locations	Wells /Oucrops	Age	Av.TOC (wt. %)	MAX TOC (%)	Kerogen Type	HI (mg HC/g TOC)	Tmax (℃)	Thickness (m)	Data Source
Tarfaya	En-Naila section	Post-OAE2	5.00	9.8	I/II	550-1050	409-414	6	This Study
	Mohammed plage	OAE2	9.6	12.5	II	230-770	410-419	6	(Kuhnt et al., 2009; Mort et al., 2008)
	Sondage-4 well	Post-OAE2	11.57	15.36	I/II	640-840	411	80	(Ghassal et al., 2016b)
		OAE2	8.00	15.44	I/II	600-880	412	15	
	SN°4	OAE2	9	20				>20	(Kuhnt et al., 2017)
	T85, T86,T87	C/T	1.5-16%	16.00	II	500–850	419–422	100-150	(Nzoussi-Mbassani et al., 2005; Nzoussi-Mbassani et al., 2003)
	S75	Post-OAE2	5.20	15.00	I/II	466-838	405-422	30	(Kolonic et al., 2002; Kuhnt et al., 2005)
		OAE2	7.20	17.00	I/II	500-800	410-420	25	
	S13	Post-OAE2	14	20.00	I/II	600-780	410-425	>16	(Kolonic et al., 2005; Prauss, 2012)
		OAE2	11	18.00	I/II	340-900	420-425	30	
	S57	Post-OAE2	8.00	14.00				20	(Dickson et al., 2016; Kraal et al., 2010; Tsikos et al., 2004)
		OAE2	10.00	26.00				15	
Agadir	Outcrop--Azazoul	Post-OAE2	3.00	9.2	II	445-980	412-426	10	This Study
		OAE2	0.50	0.60	III	30-160	420-428	35	
South of Tangier	Mauretanian (M69, M13, M39)	Early T	8.20	13.80	II	30-130	412-426		(Herbin et al., 1986)
		Late C		0.60	III	70-90	458		
Gibraltar Arch	Massylian (M12,M8, D96)	Early T	5.40	11.50	II	20-720	433-445	4	
		Late C	6.10	11.70	II/III			1	
Arba Ayach	Moroccan Rif	C/T		4.47	II/III	37-282	440		(Groune et al., 2013; Herbin et al., 1986)

- **OAE2 interval controls: organic-rich mudstones are distributed in the south deep marine environments, rarely developed or absent in the North Basins.**
- **Early Turonian transgression controls: Early Turonian interval is associated with a wider OM-rich mudstones distribution, but the south Moroccan has a thicker deposition than North Basins**

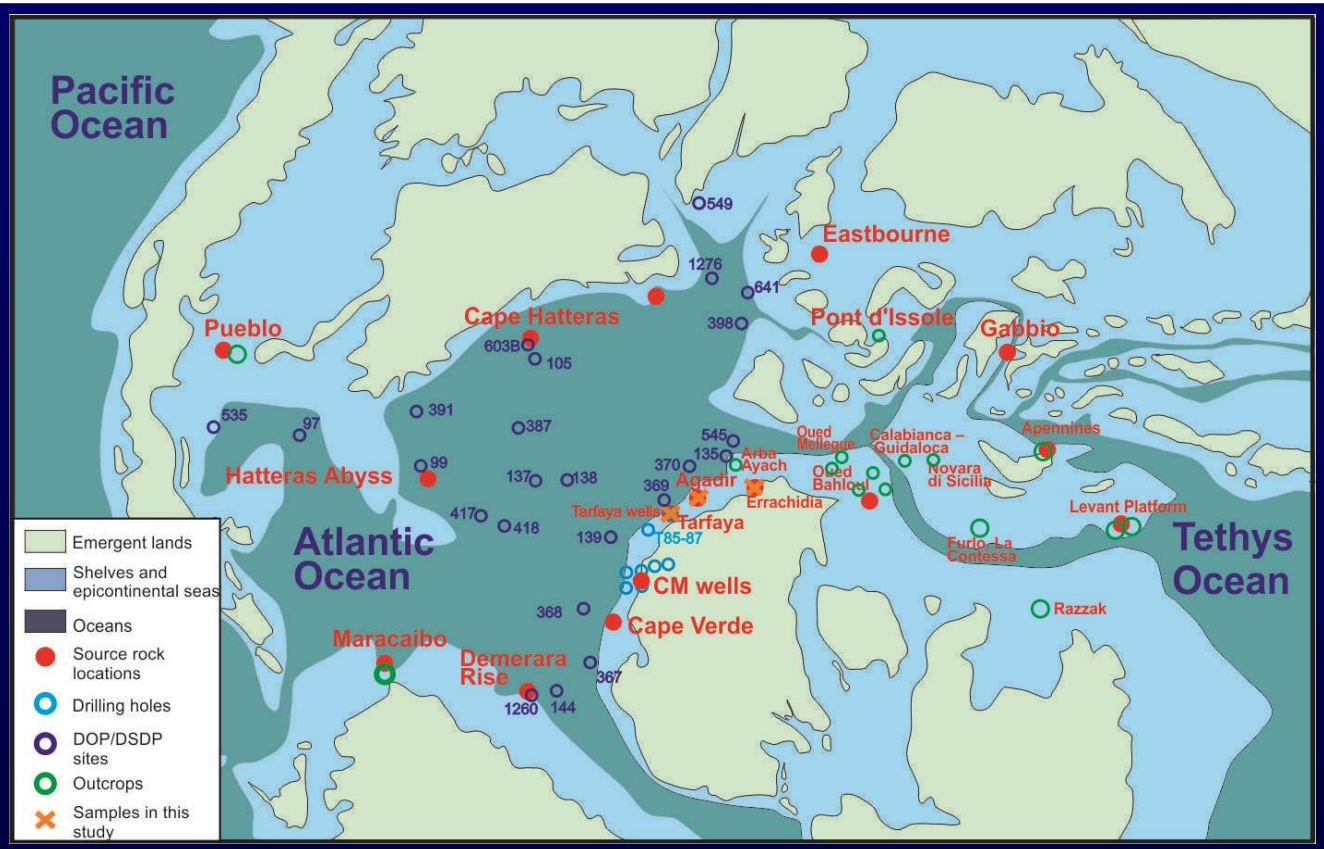
3. Moroccan Basins



- **OAE2 controls**
- **Marine transgression control**
- **Paleoenvironment control**

The Atlantic influenced Tarfaya Basin, with thick organic-rich deposition in both OAE2 and Early Turonian intervals, has the greatest hydrocarbon potential.

4. Atlantic Ocean and Tethys Ocean



- 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.

Conclusions

- In Atlantic influenced Basins, the OAE2 related organic-rich mudstones were mainly identified in the Tarfaya Basin with the deeper environments, while they are absent in the shallower marine environments in North Moroccan Basins. The Early Turonian Transgression facilitated a wider OM-rich mudstones deposition in most of the coastline basins.

- In Tethys influenced basin, the considerable organic carbon deposition was only identified in the Errachidia area during the Late Cenomanian/Early Turonian marine transgression, but not associated with the OAE2 closely. The marine transgression and special paleogeographical settings (extremely restricted marine conditions) lead to the OM-rich mudstones distribution locally.

- The organic-rich mudstones were developed within low detrital influx, high productivity and anoxic/euxinic water conditions.

- The distribution and quality of organic-rich mudstones in Moroccan Basins were controlled by the OAE2, marine transgression, and paleoenvironments during Late Cenomanian to Early Turonian.

- Much higher hydrocarbon potential in the Atlantic influenced Basins than the Tethys influenced Basins during Late Cenomanian/Early Turonian interval

Questions and Answers:

Thank you for your support:

Special Thanks:

ONHYM

المكتب الوطني للهيدروكاربورات و المعادن

OFFICE NATIONAL DES HYDROCARBURES ET DES MINES

Azazoul section, Morocco 23/05/2015