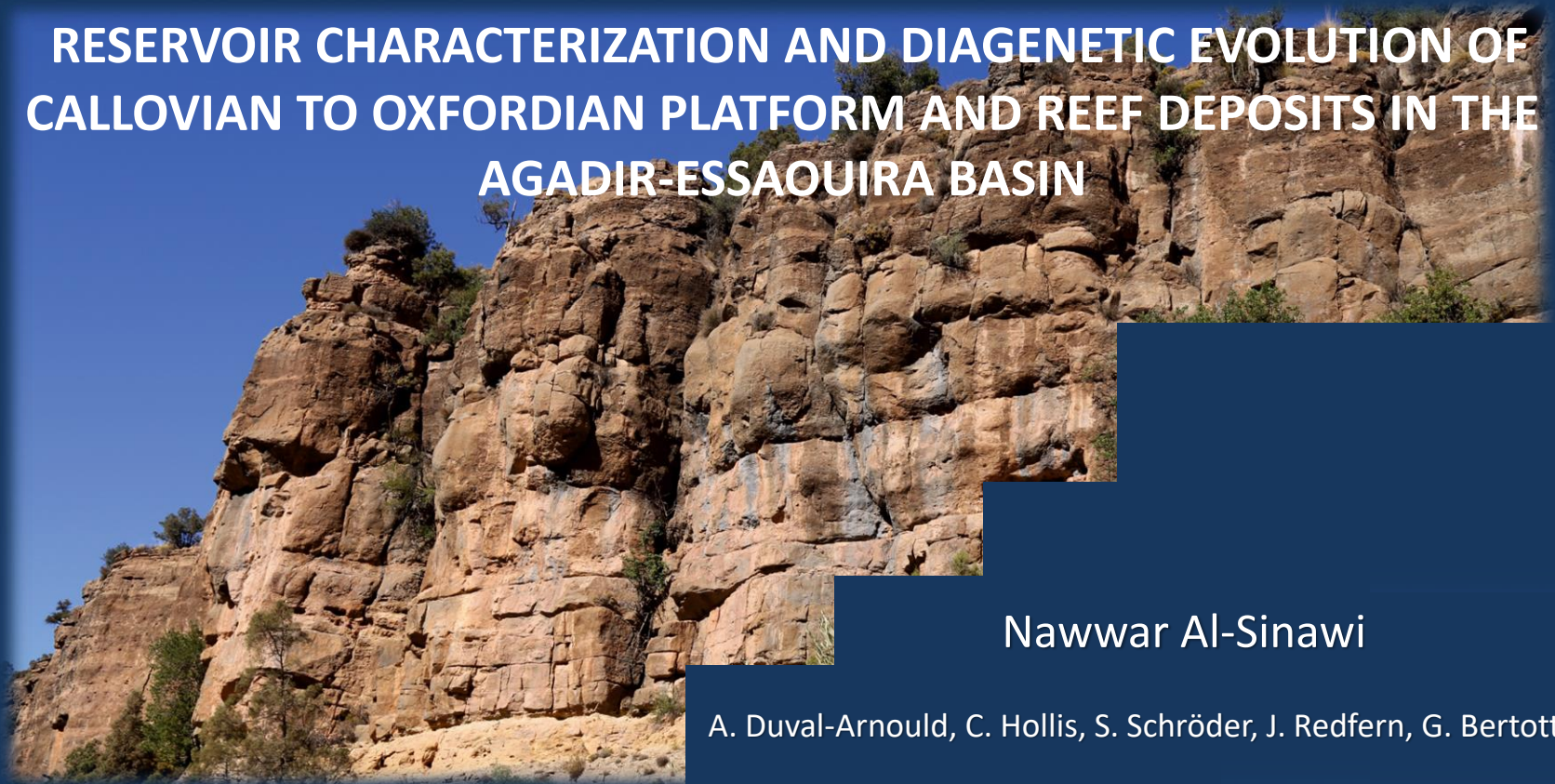


# RESERVOIR CHARACTERIZATION AND DIAGENETIC EVOLUTION OF CALLOVIAN TO OXFORDIAN PLATFORM AND REEF DEPOSITS IN THE AGADIR-ESSAOUIRA BASIN

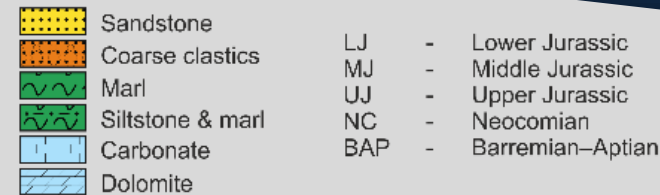


Nawwar Al-Sinawi

A. Duval-Arnould, C. Hollis, S. Schröder, J. Redfern, G. Bertotti

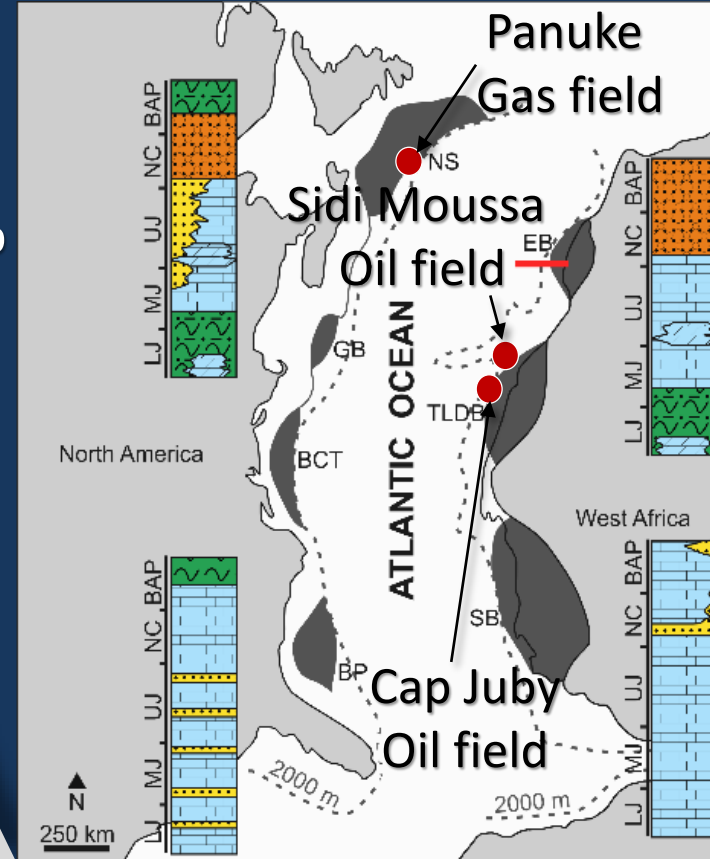
# AIMS AND OBJECTIVES

- Determine dolomite distribution, controls & origin
- Assess dolomitization impact on reservoir quality
- Log & map the dolomite, asses its stratal relationship
- Describe petrographically and geochemically

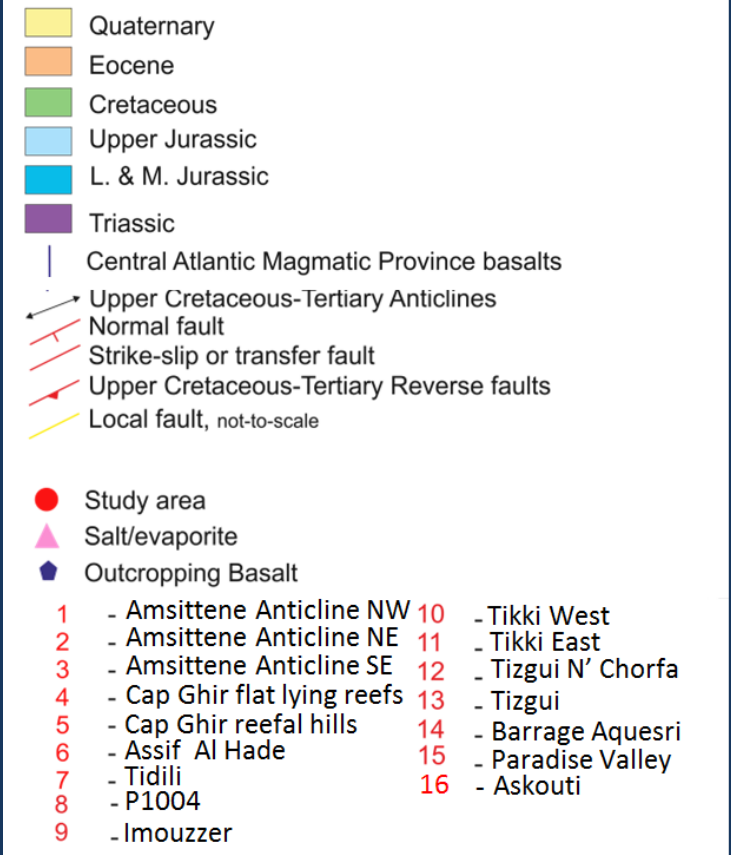
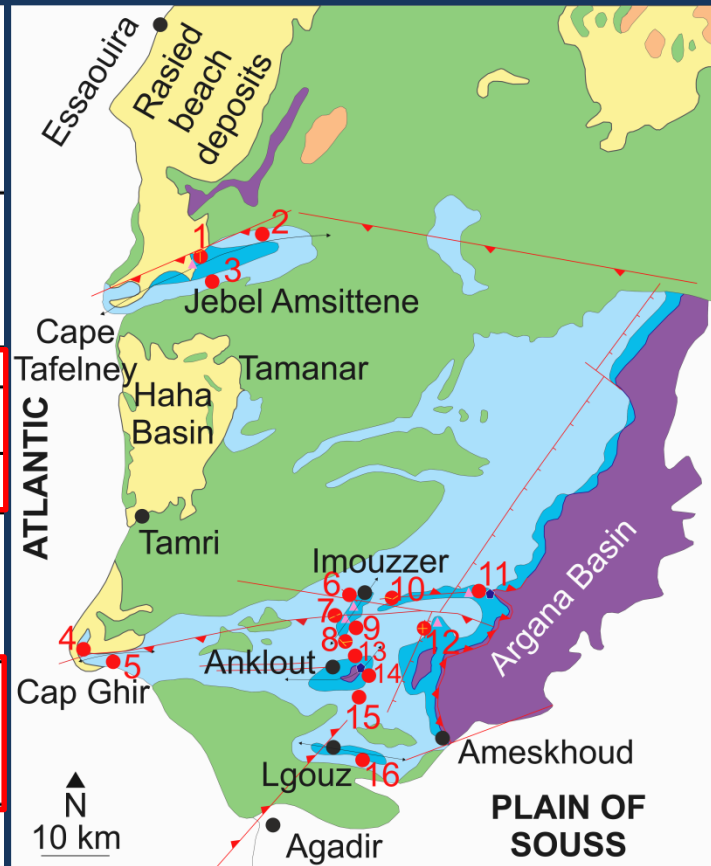
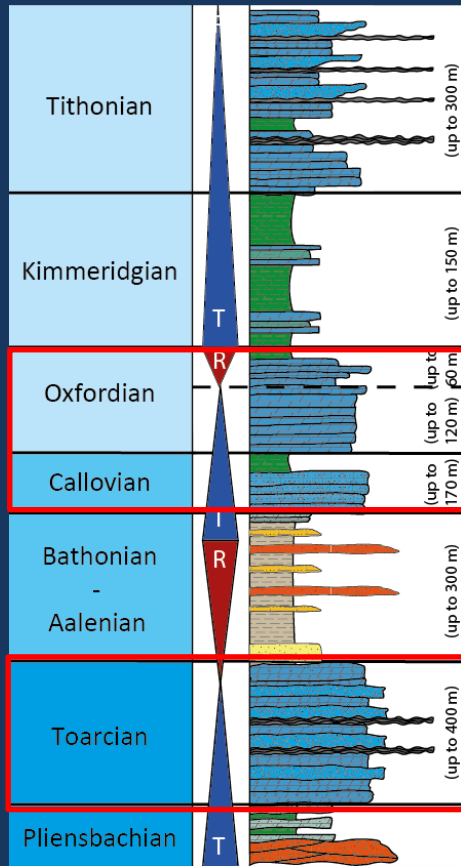


- |      |   |                               |
|------|---|-------------------------------|
| BP   | - | Blake Plateau                 |
| BCT  | - | Baltimore Canyon trough       |
| GB   | - | Georges Bank                  |
| NS   | - | Nova Scotia                   |
| EB   | - | Essaouira Basin               |
| SB   | - | Senegal Basin                 |
| TLDB | - | Tarfaya Laayoune Dakhla Basin |

Central Atlantic Basins  
(modified after Leprêtre et al. 2017)



# ESSAOUIRA – AGADIR BASIN

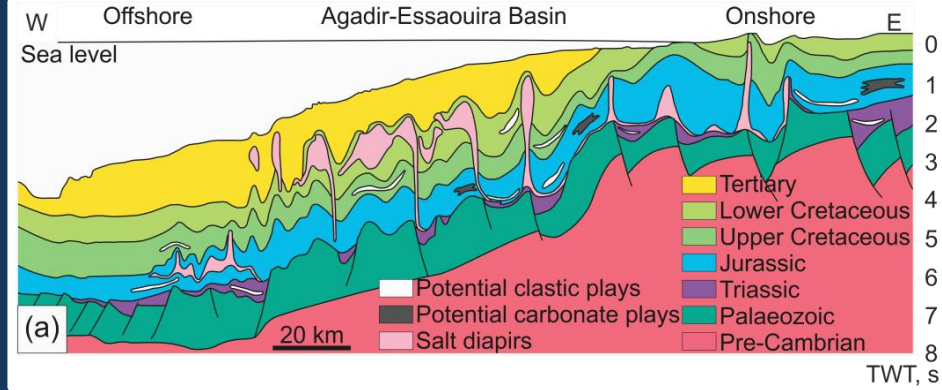
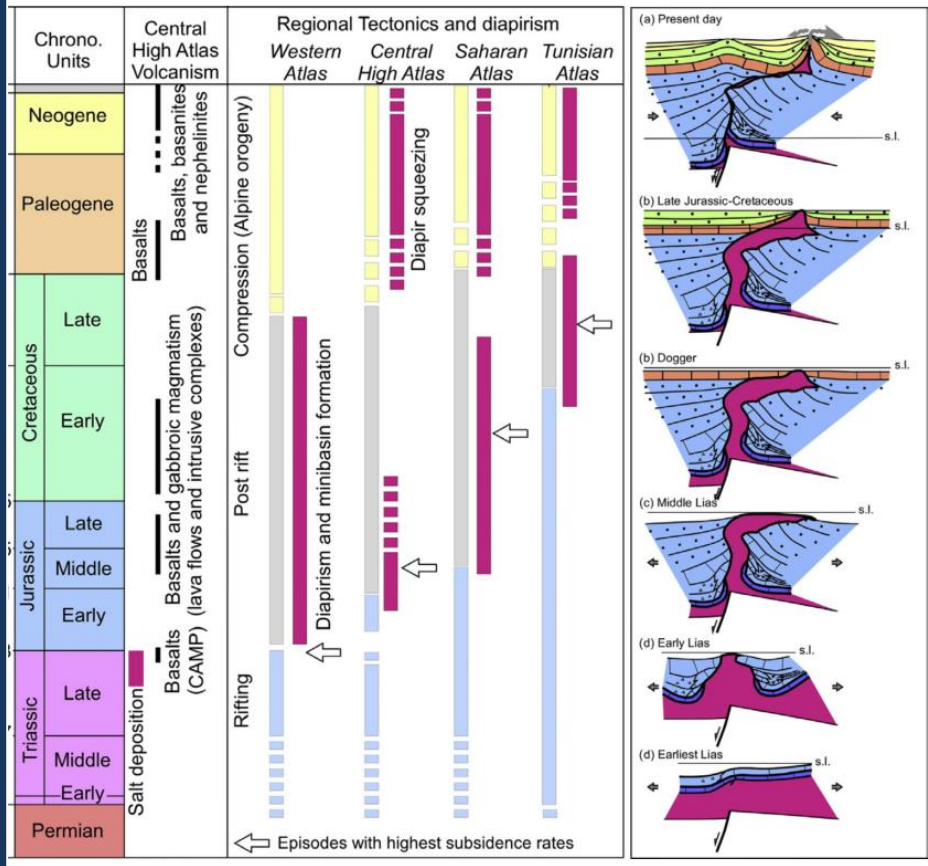


Modified after Ager (1974a), Mustaphi et al. (1997), Zuhlke et al. (2004), Hafid et al. (2006) and Frizon de Lamotte et al. (2008)

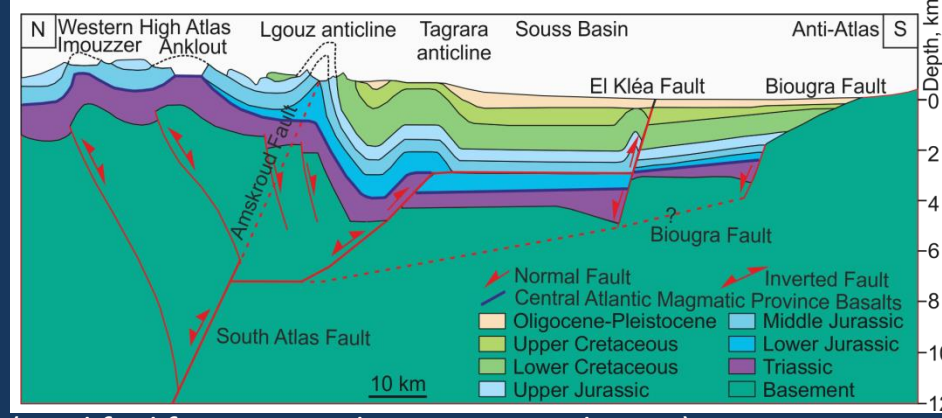
# ESSAOUIRA – AGADIR BASIN



From Vergés, et al. (2017)



(modified from Tari et al. 2013)

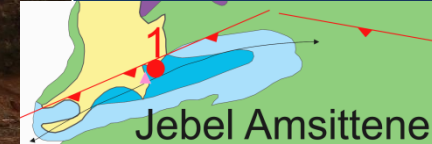


(modified from Frizon de Lamotte et al. 2008)

# SINEMURIAN DOLOMITIZATION

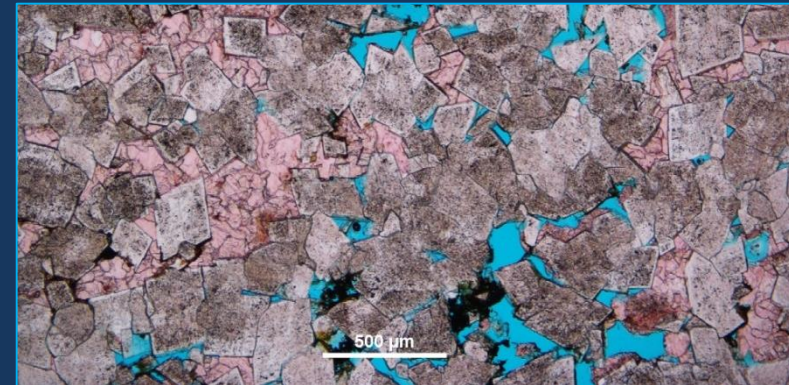
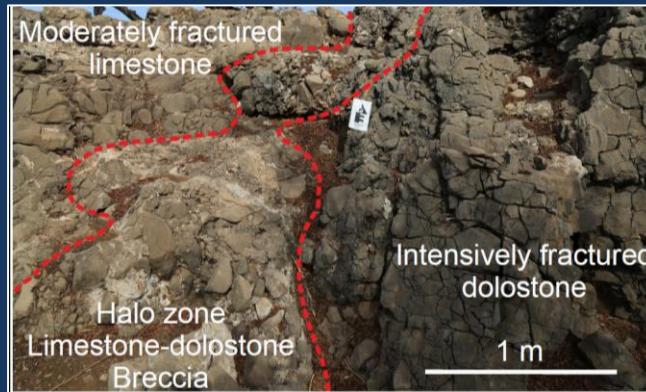


## NW Jebel Amsittene



## Stratabound dol.:

- Oolitic WST
- MST
- Peloidal PST



# TOARCIAN DOLOMITIZATION

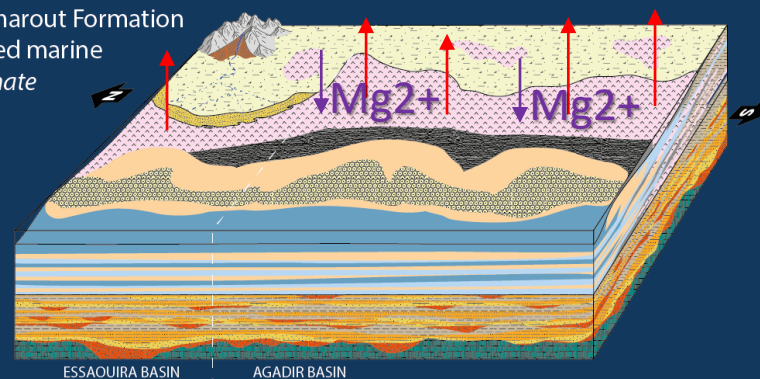


Barrage Aquesri



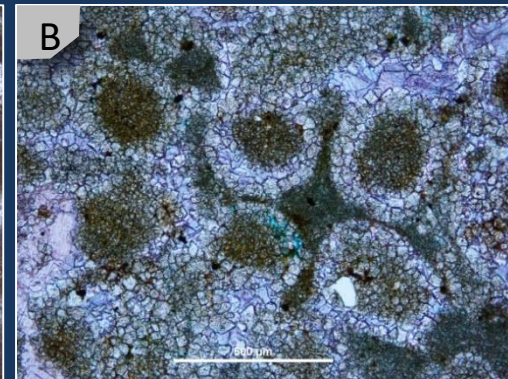
B2 - Tamarout Formation  
Restricted marine  
Arid climate

Seawater evaporation

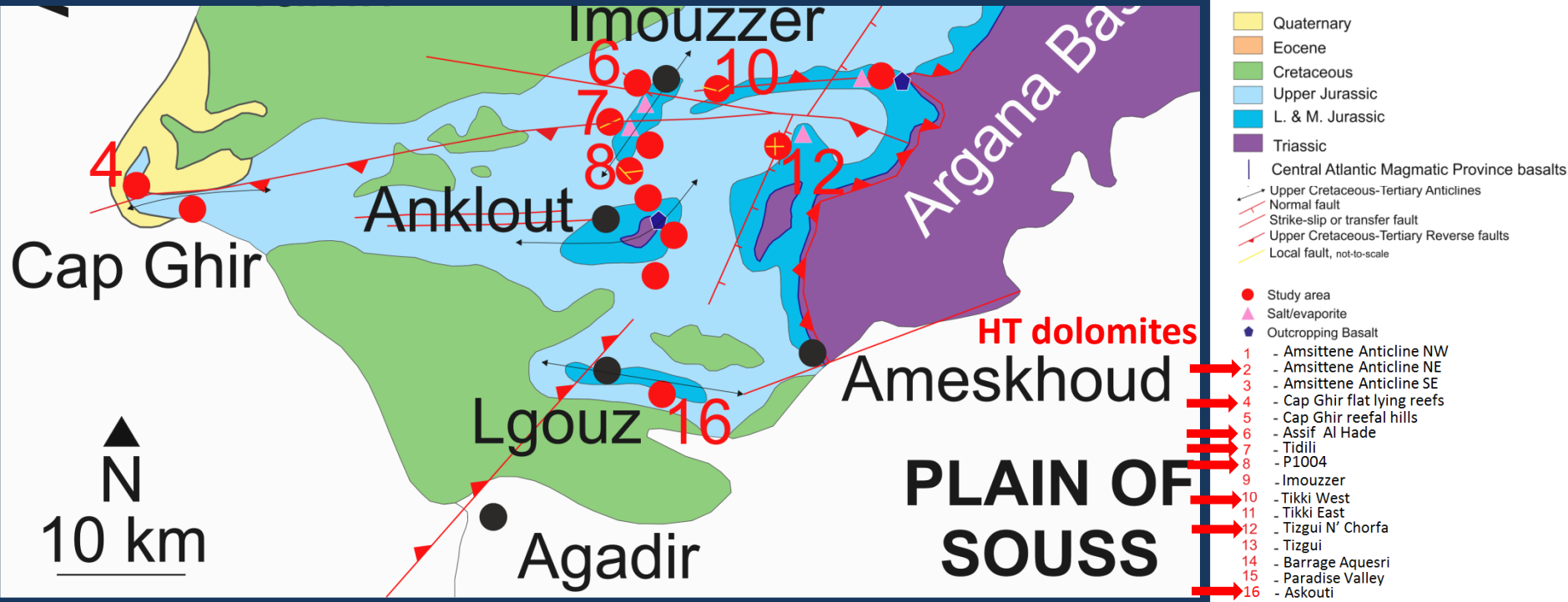


Stratabound dolostones:

- MST
- Oolitic and peloidal W/PST
- Oolitic GST
- Stromatolites



# BASIN SCALE STRUCTURAL OVERVIEW



*Modified after Ager (1974a), Mustaphi et al. (1997), Zuhlke et al. (2004), Hafid et al. (2006) and Frizon de Lamotte et al. (2008)*

# HYDROTHERMAL DOLOMITIZATION



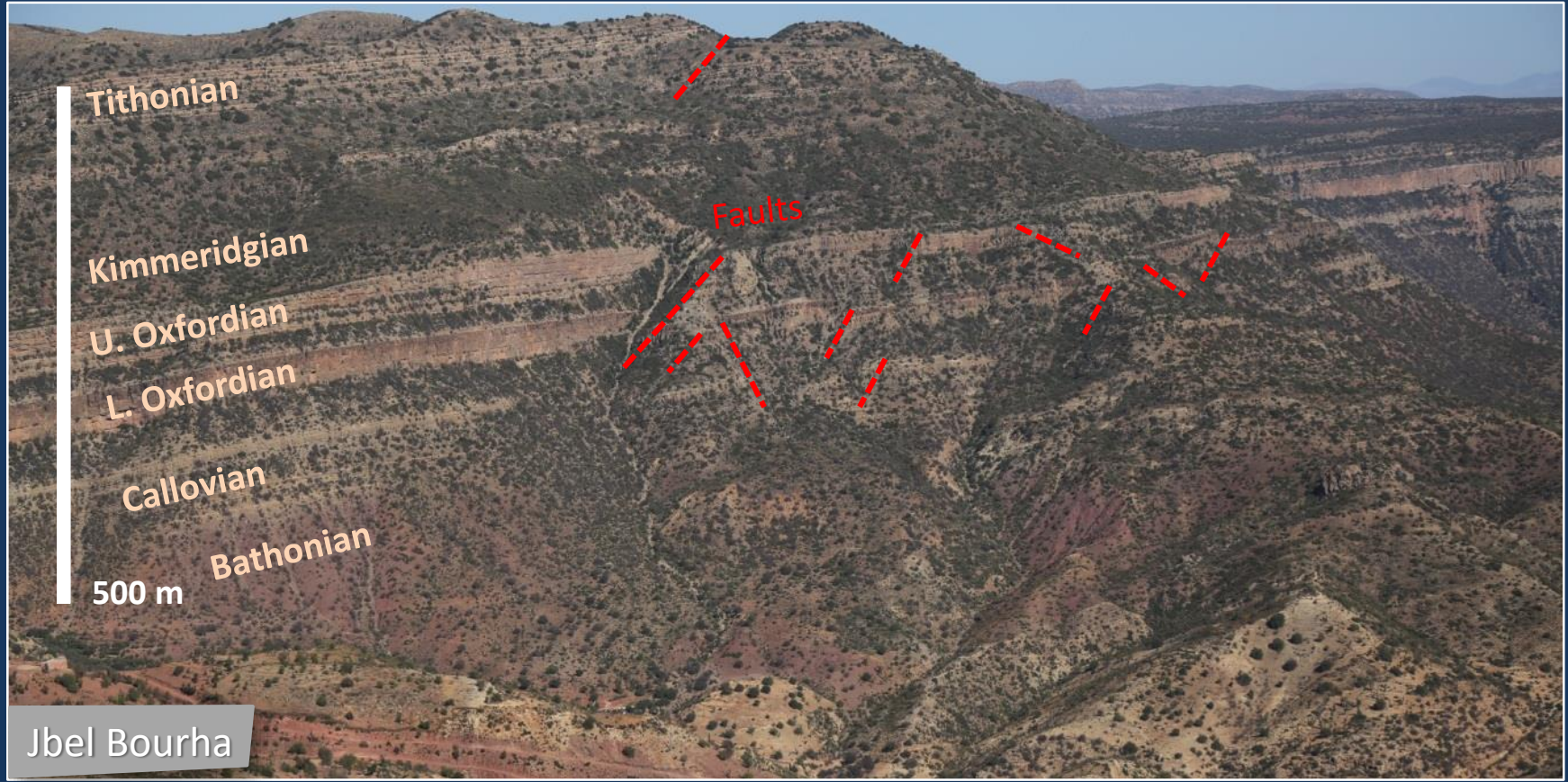
Fault controlled dolomitization occurring under burial conditions, normally at shallower depths, by highly saline fluids with T and P higher than the host limestone.

- Apparent unified model for HTD is often presented, however the reliability is still disputed
- Complete spectrum in terms of shape, size, fluid sources and mechanisms, with some occurring as multi-phase events
- Debate over fluids, source of fluid, Mg<sup>2+</sup> or dolomitization process



*Davies & Smith (2006)*

# OUTCROP SCALE STRUCTURAL OVERVIEW



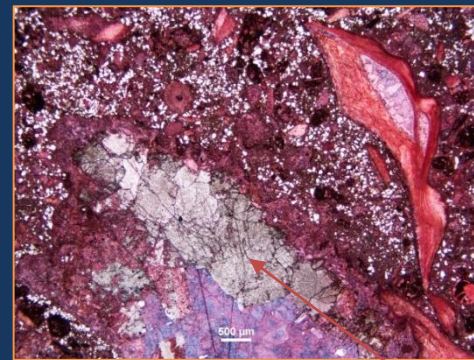
Jbel Bourha

# CALLOVIAN DOLOMITIZATION



UNIT I: Oolitic shoals and bioclastic ramp deposits

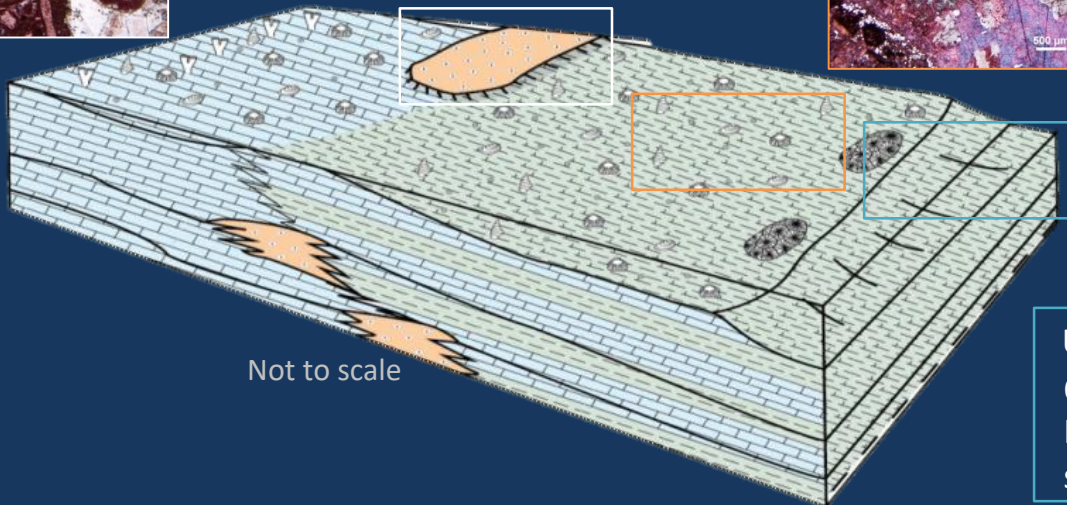
Anhedral dolomite cemented fractures



UNIT II: Marls and brachiopod rich FST

Open platform: outer ramp

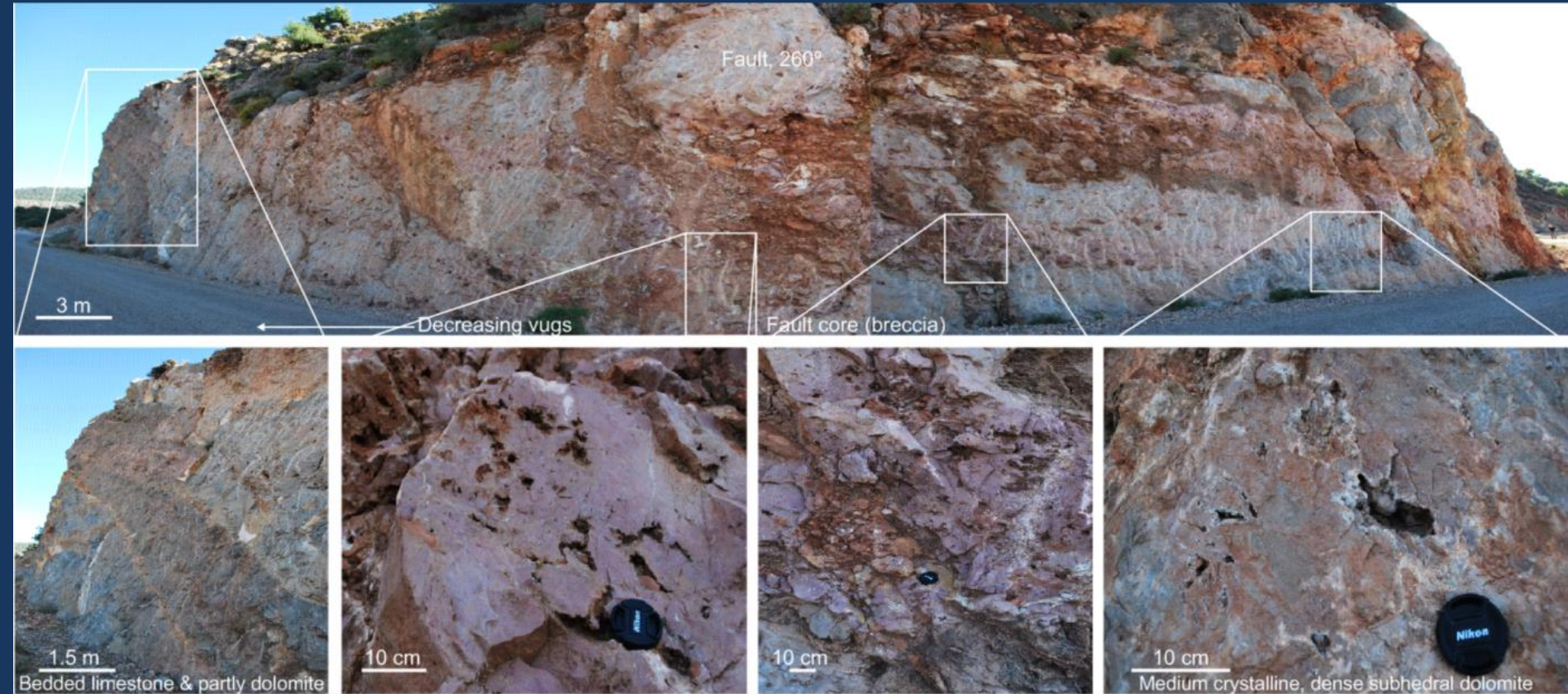
Selective replacement saddle dolomite (Fault controlled)



Not to scale

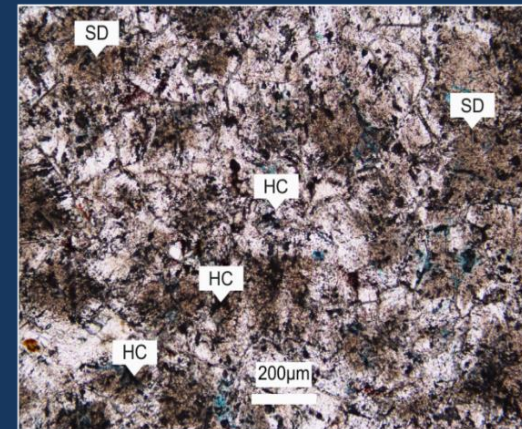
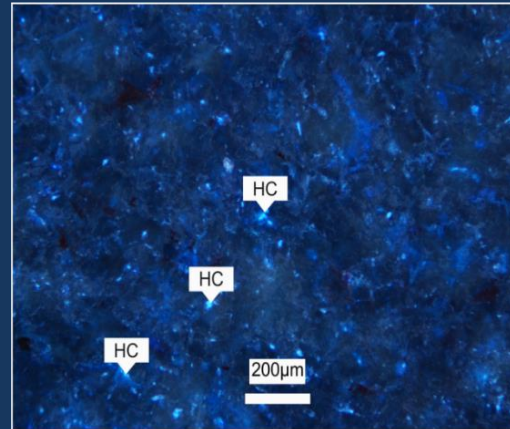
UNIT III: Marls  
Outer ramp / slope  
Matrix partly replaced by scattered dolomites

# OXFORDIAN DOLOMITIZATION



- Fault controlled dolomite is contemporaneous with HC
- Reefal unit- highly variable in pore size & connectivity
- Dedolomitization occluded primary porosity

- Argana (E)-Imouzzer (W) fault zone is 10s m thick
- Sub-vertical dolomite/ calcite veins
- Fault zone rocks are intensively dolomitized

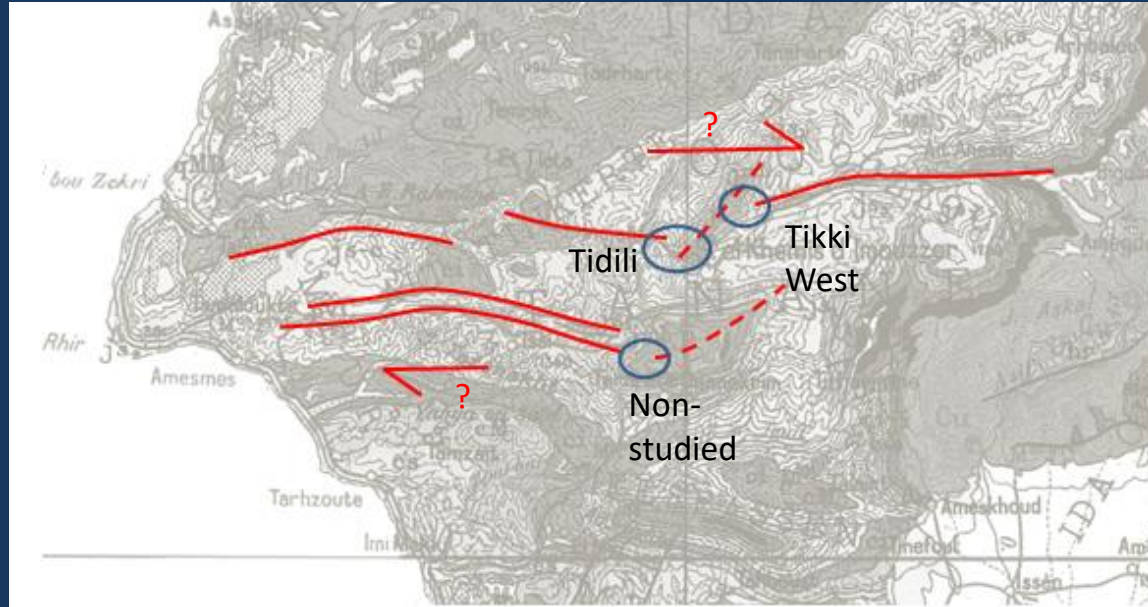


- Anhedral-saddle dolomite crystals
- Dolomitizing fluid flow along H. permeable layers

# HYDROTHERMAL DOLOMITIZATION



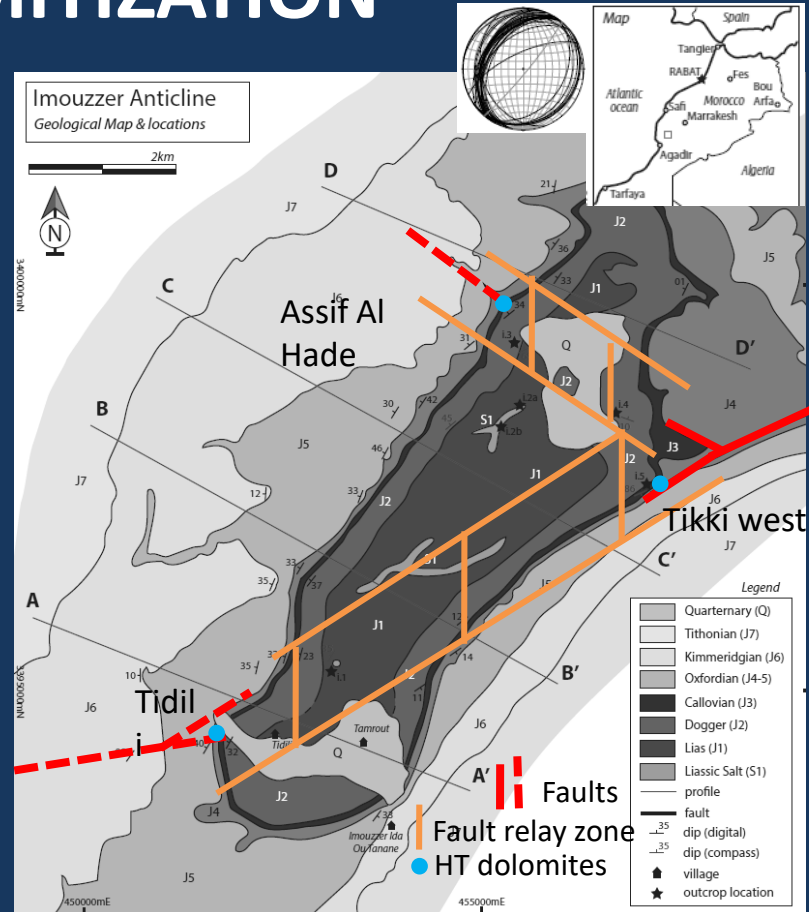
- The Imouzzer anticline: E-W trending faults
- Faults cut through Upper Jurassic to Lower Cretaceous layers
- Faults do not cross the Imouzzer anticline (neither the Anklout anticline further to the S).
- The faults seem to end at the NE-ward and SW-ward terminations of the Imouzzer anticline



# HYDROTHERMAL DOLOMITIZATION



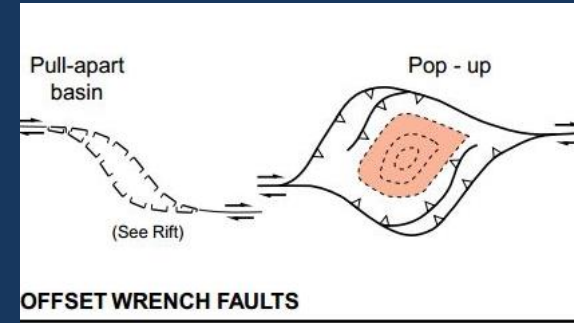
- The anticline becomes more open and eventually disappears both towards the NE and the SW.
- The proto-Imouzzer anticline started developing in Late Jurassic time, documented by coeval layers which thin from the flanks towards the hinge of the anticline (sedimentary).
- A series of reefs have used the topographically higher position of the anticline hinge.
- Jurassic folding (Q) could be related to tectonics, diapirism or to an interaction between the two.
- The largest part of folding is obviously of Alpine age.



Geological Map of Imouzzer Anticline showing outcropping HT dolomites (After Kluge, 2018)

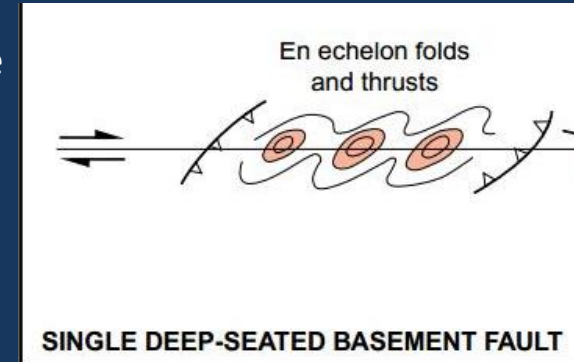
## Proposed model:

- The Imouzzer anticline is a contractional structure developed as a constraining bend or pop-up associated with dextral strike slip movements along the E-W trending faults
- Strike slip system acted as a conduit for the HT fluids.



## Imouzzer anticline and E-W faults:

- The association between the two is the only possible way to explain the fact that the faults cut in older layers in the Argana valley but do not do this in the Imouzzer anticline.
- The displacement of the fault must therefore be taken over by the anticline and transferred to the southern E-W trending fault.



# OXFORDIAN DOLOMITIZATION



- Offshore Canada
- Well: Encana Margaree F-70
- Area: Scotian Shelf
- Field: Deep Panuke
- Facies: Sponges and coral reefs
- Depositional environment: Forereef slope

- Highly dolomitized, fossil ghosts
- Coarse saddle dolomites cementing moulds
- Intense horizontal stylolites
- Dolomite cemented fractures.

Saddle dolomite



# DOLOMITIZATION

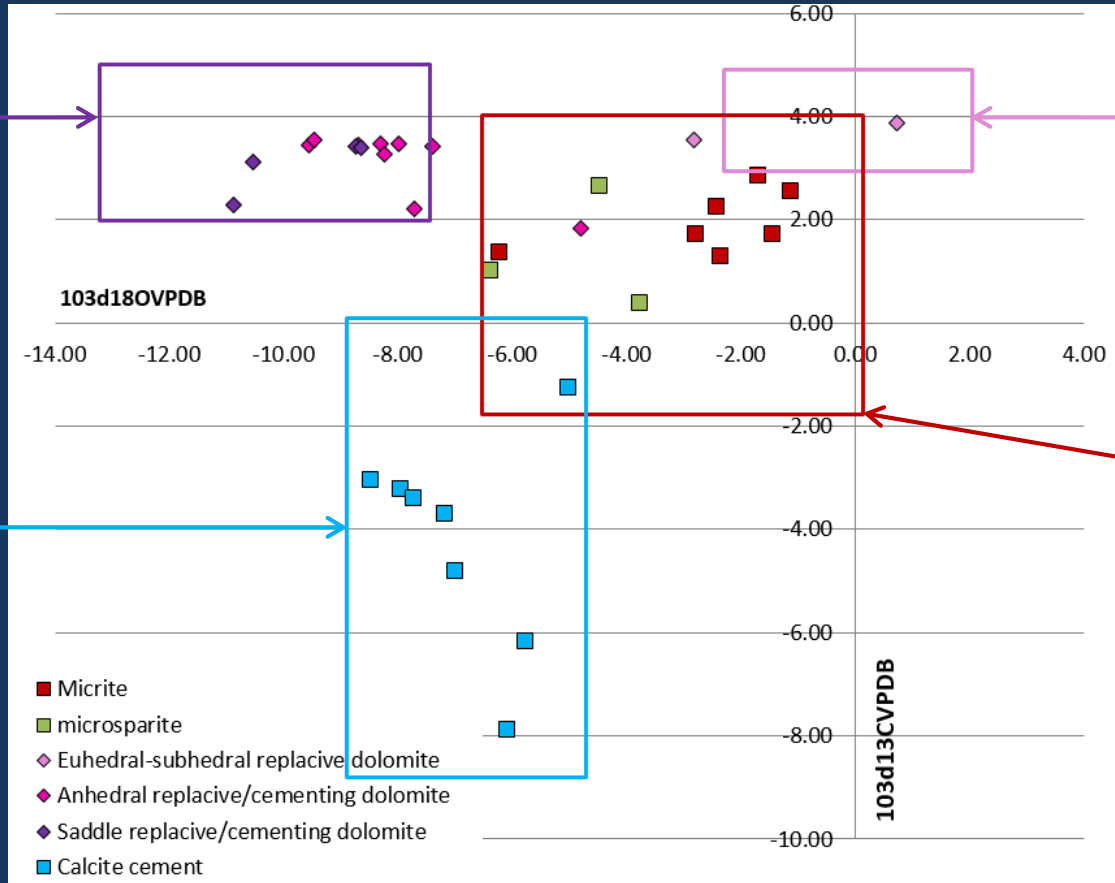


Deep burial  
High temp. dol  
Sellwood et al. (1989)

Sabkha/ marine  
hypersaline lagoon dol.  
Moore et al. (1988)

Includes calcitized dol.  
Non-luminescent  
Meteoric water  
Associated with kerogen?  
Related to uplift/  
subaerial exposure  
J.D. Martín-Martín et al.  
(2015)

Jurassic marine  
carbonate material  
Brand & Morrison (1987)



# RESERVOIR QUALITY

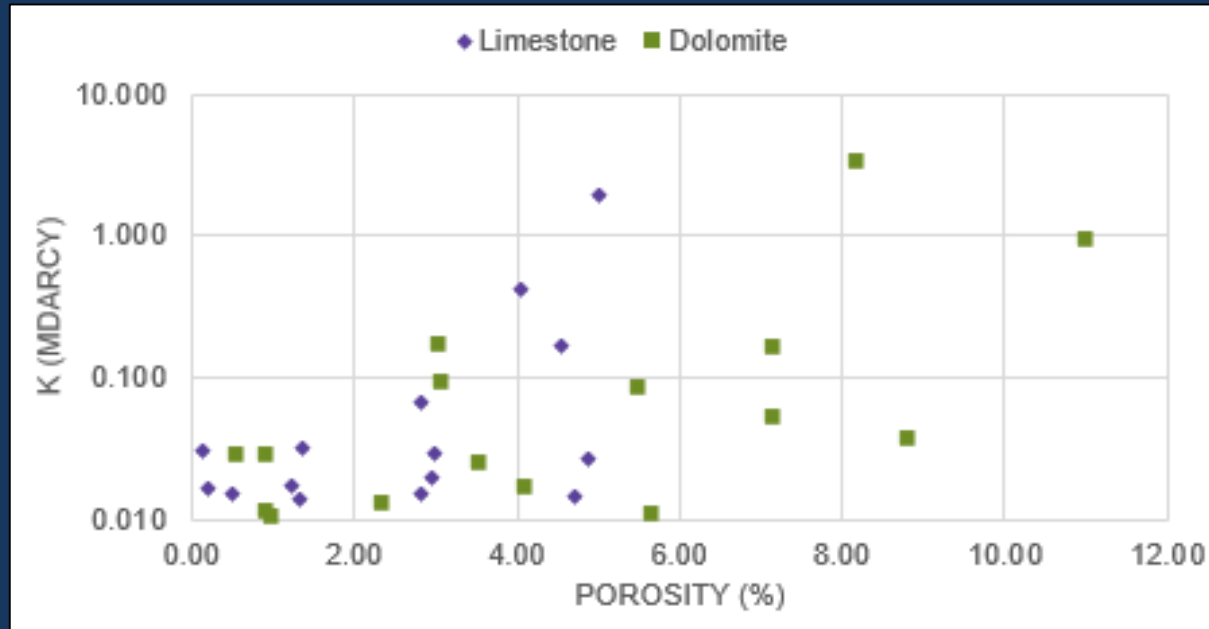
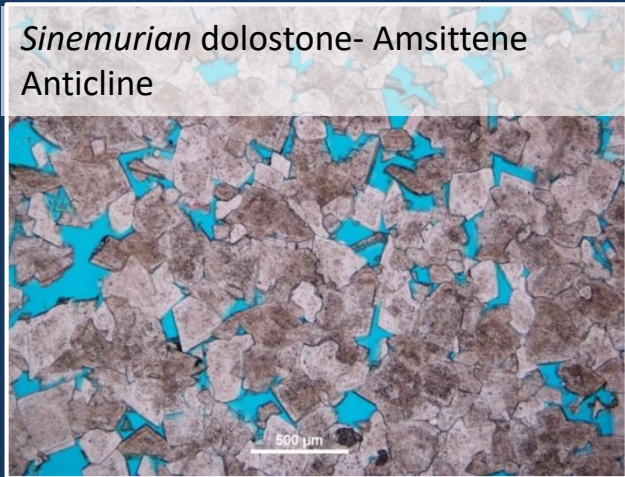


## Jurassic dolomitized facies:

- Mudstones
- Ooidal WST/PST
- Ooidal-Peloidal GST
- Skeletal PKST-GST/ FST-RST (abnd.)
- Coral reefs (abundant)
- Cross-bedded sandy carbonates

## Jurassic carbonates mean porosity:

- Limestone = 3%
- Dolostone = 4.75%



# CONCLUSIONS



- Lower Jurassic dolostones are stratabound and laterally extensive
- Middle- Upper Jurassic dolostones are stratabound and non-stratabound, occur in close vicinity to faults
- Euhedral- anhedral *Toarcian* dolomites sourced from seawater reflux?
- Anhedral- saddle *Callovian-Oxfordian* dolomites originated from **HT fluids** through **faults**
- Fabric destructive dolomites are **contemporaneous with Hydrocarbon**
- Dolomitization **enhanced porosity** of parent limestone
- Calcitization **occluded** original porosity created during dolomitization

THANK YOU FOR THE SUPPORT:

North Africa Research Group



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Petroleum Development Oman

bp



woodside



TOTAL



REPSOL

Special thanks :

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OFFICE NATIONAL DES HYDROCARBURES ET DES MINES