

AN EMERGING THERMO-CHRONOMETER FOR CARBONATE ROCKS : $\Delta_{47}/(U-Pb)$

A case study from the Middle Jurassic reservoirs
of the Paris basin

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Supervision team :

IFP Energies Nouvelles

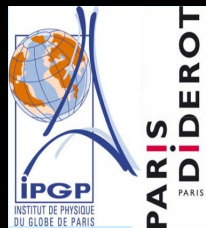
Marta Gasparini

Virgile Rouchon

IPGP, Sorbonne Paris Cité

Magali Bonifacie

Magali Ader



THERMAL HISTORY CHARACTERIZATION

identify the timing of dominant episodes of heating and cooling

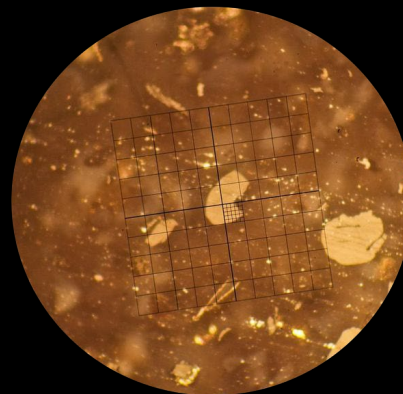
quantify the paleotemperatures through time

characterise the mechanisms of heating and cooling

MAIN THERMAL
INDICATORS



Vitrinite reflectance



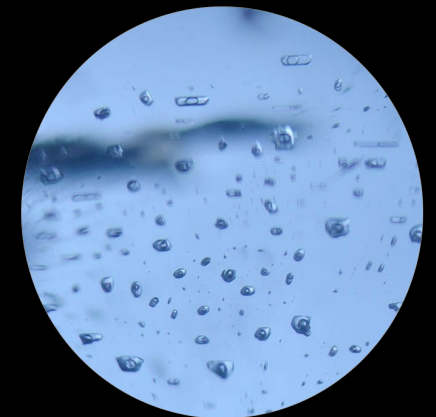
Ro% of continental OM

*Apatite fission
track analyses*



Apatite in sandstone

*Fluid inclusions
studies*



FI in silica/carbonate minerals



AN EMERGING THERMO-CHRONOMETER FOR CARBONATE-BEARING ROCKS ?

RECENT ANALYTICAL DEVELOPMENTS IN CARBONATE GEOCHEMISTRY

1. Carbonate clumped isotope geothermometry (Δ_{47})
2. in-situ U/Pb dating of carbonates (LA-ICPMS)

PROBLEMATICS OF THIS STUDY:

- 1) Does the coupling of Δ_{47} *and* *U-Pb* provides a direct determination of burial paleotemperature and timing of paleo-thermal episodes reached by an individual carbonate rock?
- 2) Are these tools usefull to identify, quantify and characterize an entire heating and/or cooling history of buried carbonate sequences in sedimentary basins?

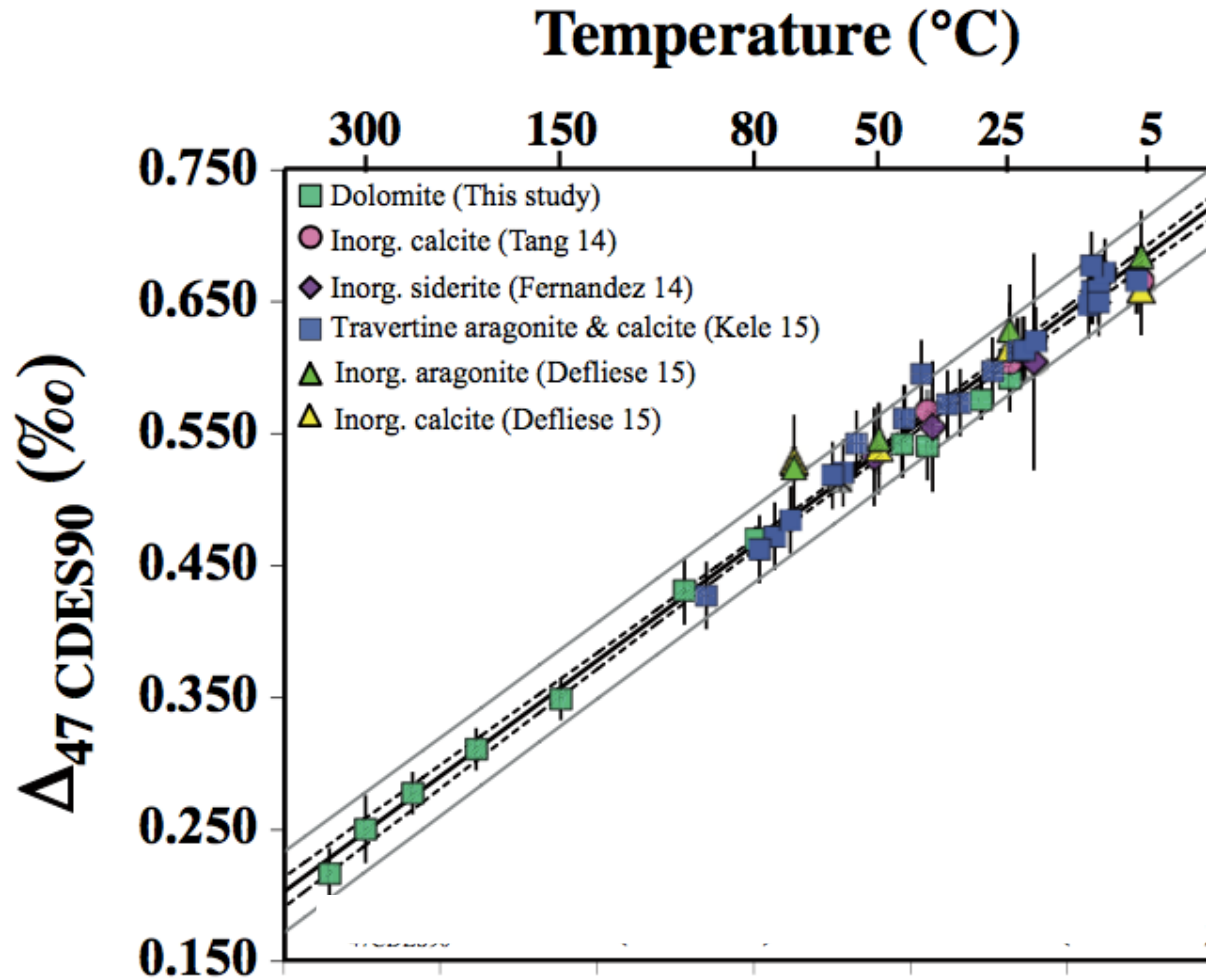


CLUMPED ISOTOPES (Δ_{47}) – THEORETICAL PRINCIPLES

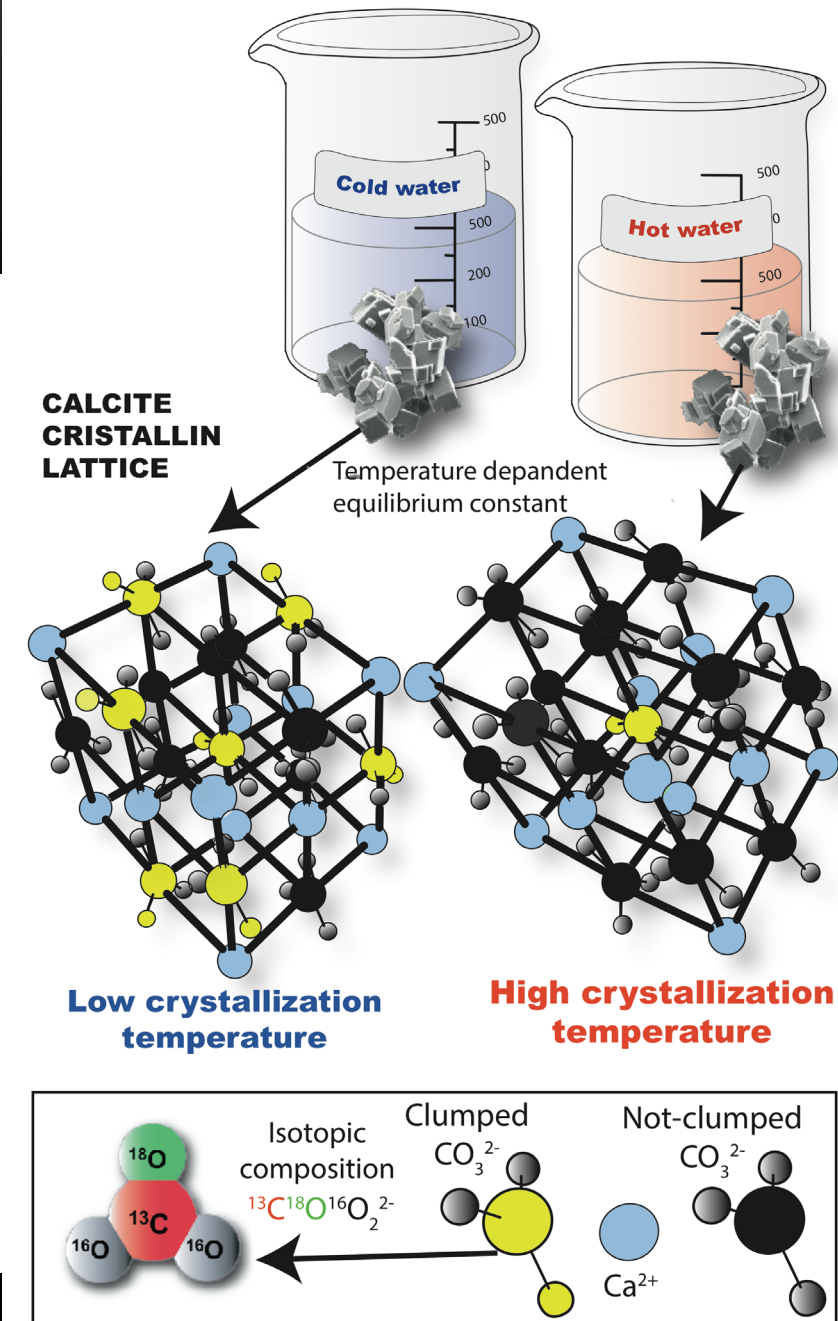
Applicable to all carbonate mineralogies: Calcite, aragonite, dolomite

COVER THE
RANGE OF
TEMPERATURES
RELEVANT FOR
DIAGENETIC
PROCESSES
(0-300° C)

Bonifacie et al.
2017
(GCA)

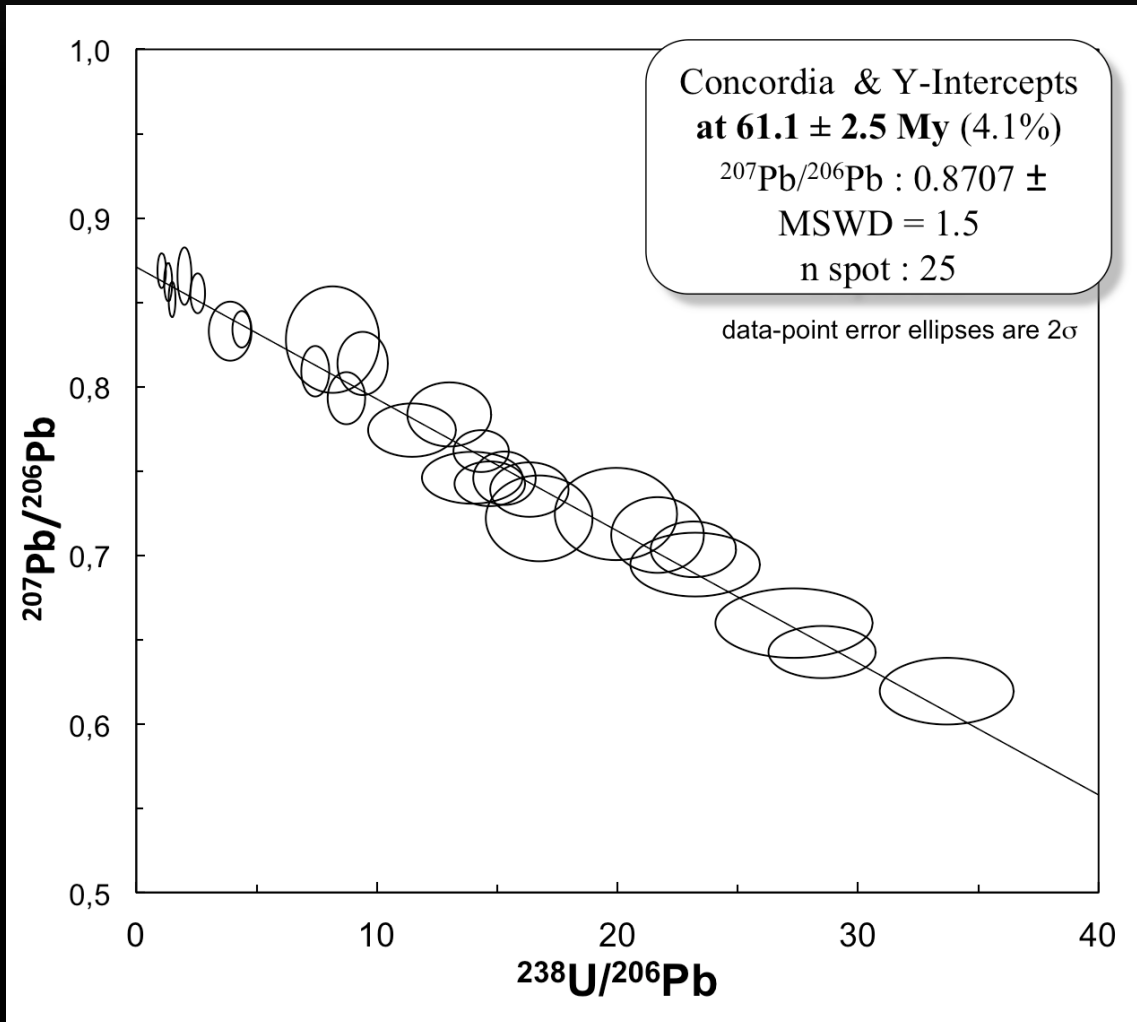


Mangenot et al. 2017 (Chemical Geology)

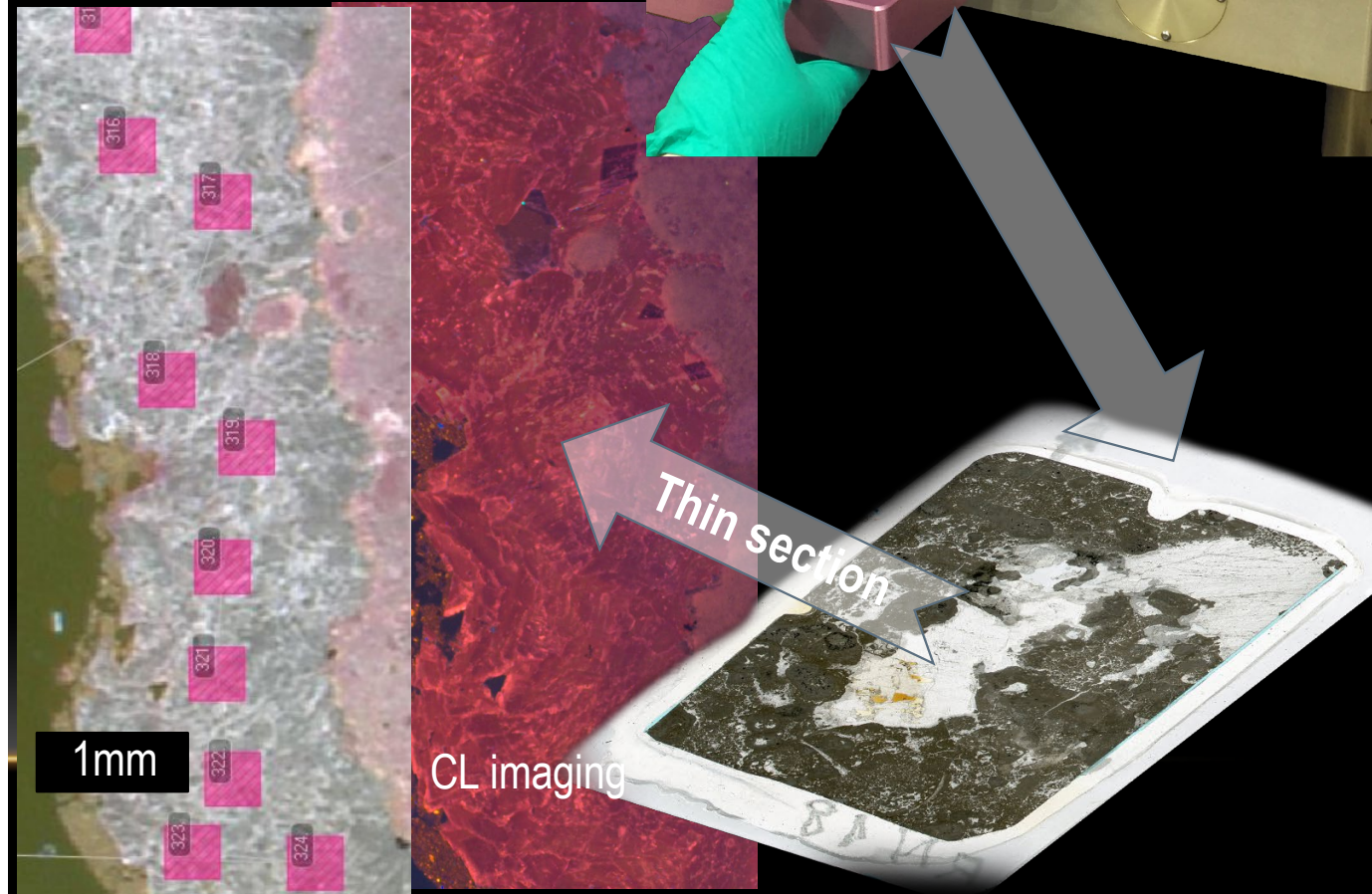


U-PB DATING– IN-SITU ANALYSES

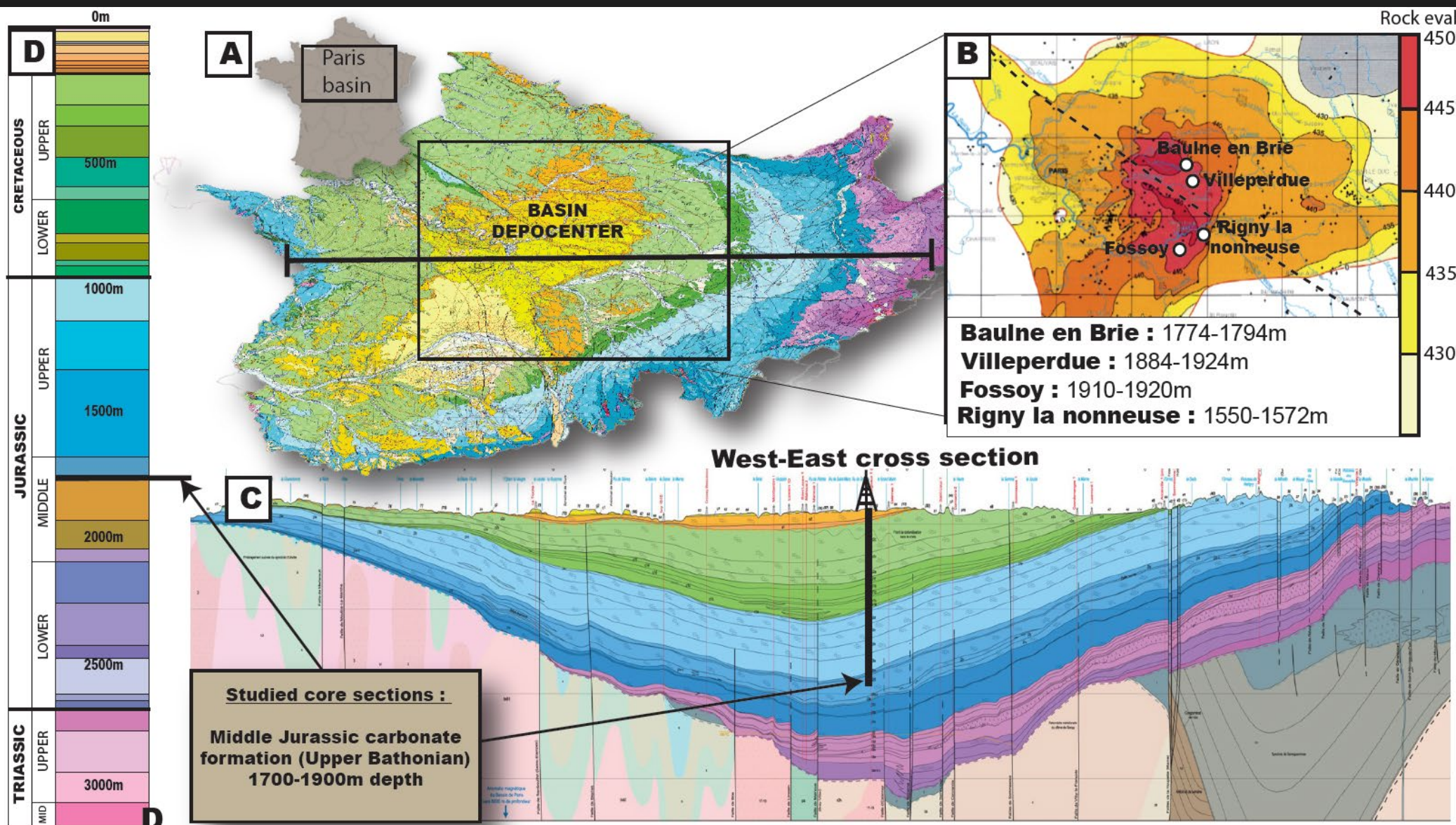
Small Scale isochron measured on a calcite cement (61My $\pm$ 2.5)



Cathodoluminescence
imaging = selection of
homogeneous carbonate
phases prior to analyse



SAMPLING STRATEGY AT THE BASIN SCALE



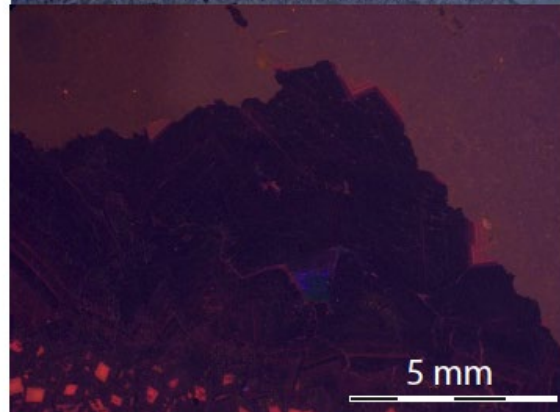
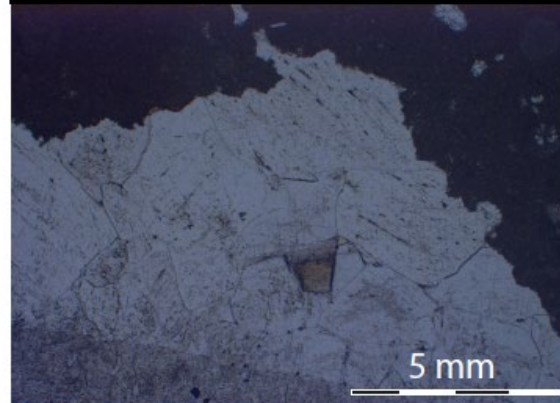
Mangenot et al. 2018
Sedimentology

C) Cal1 cement (BEB12)



Cal1 macroscopic view

D) Dol 1- saddle (FOS1610)



Dol1 macroscopic view

Porosity

Cal2

Dol2

Dol1

Cal1

Micrite

Bioclast

A complete cementation history in a single rock sample

Medical CT imaging

3cm

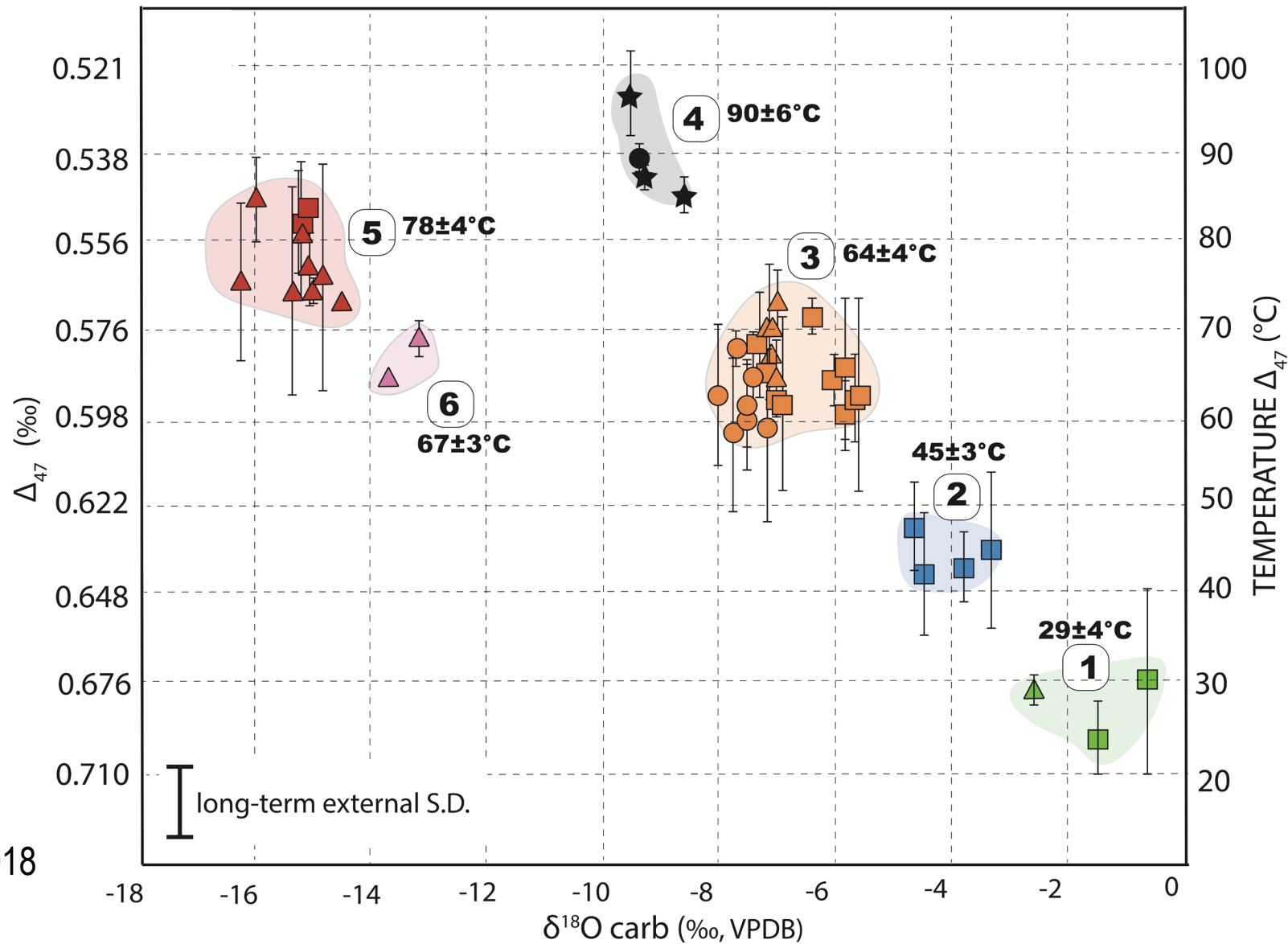
CLUMPED ISOTOPE THERMOMETRY

Carbonates

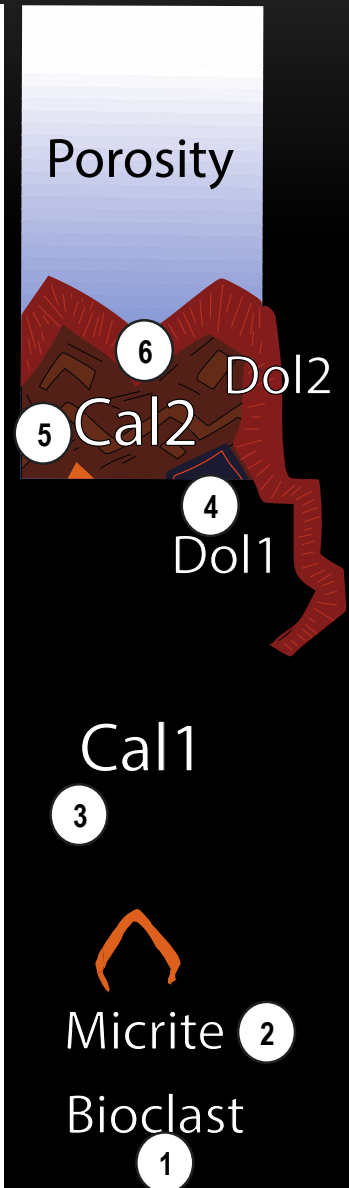
- 6 Dol2
- 5 Cal2
- 4 Dol1
- 3 Cal1
- 2 Micrites
- 1 Bioclasts

Sampled cores

- Baulne en Brie
- Rigny la Nonneuse
- Villeperdue
- Fossoy



Mangenot et al. 2018
(Sedimentology)



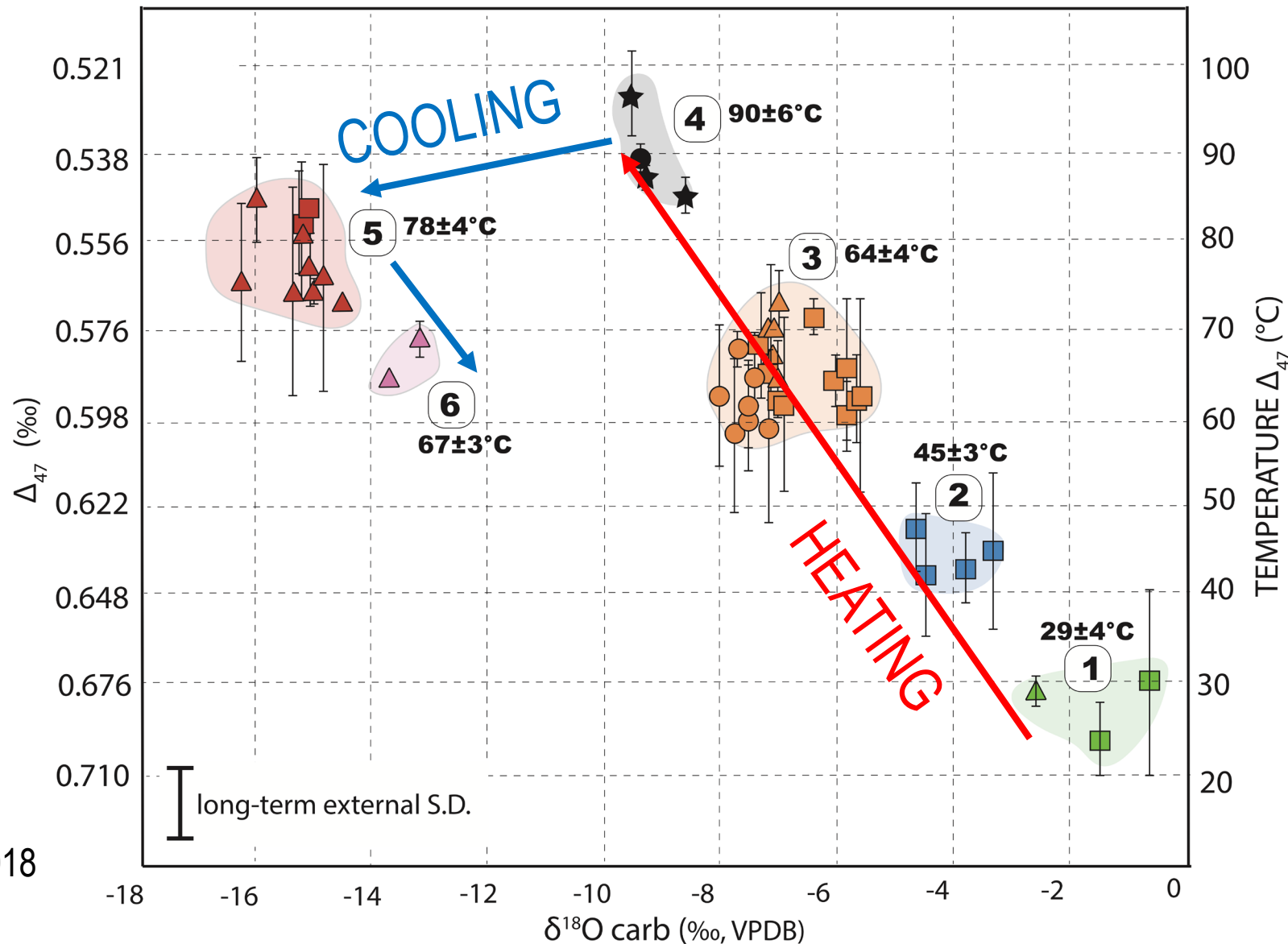
CLUMPED ISOTOPE THERMOMETRY

Carbonates

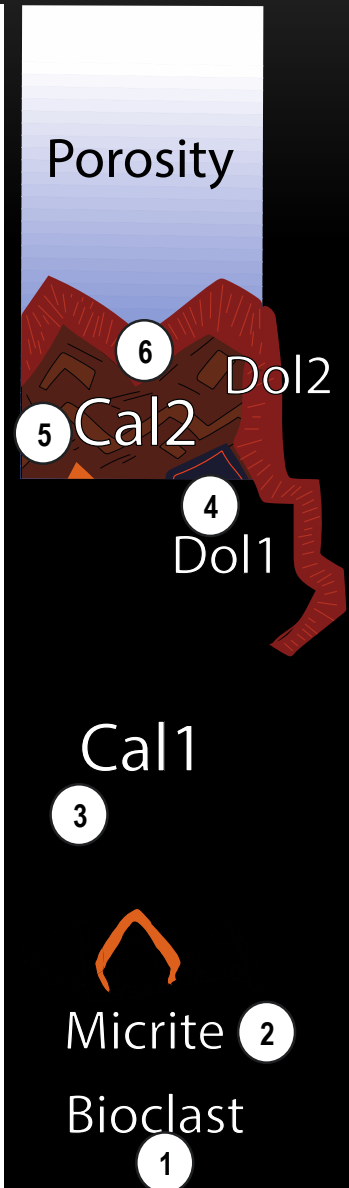
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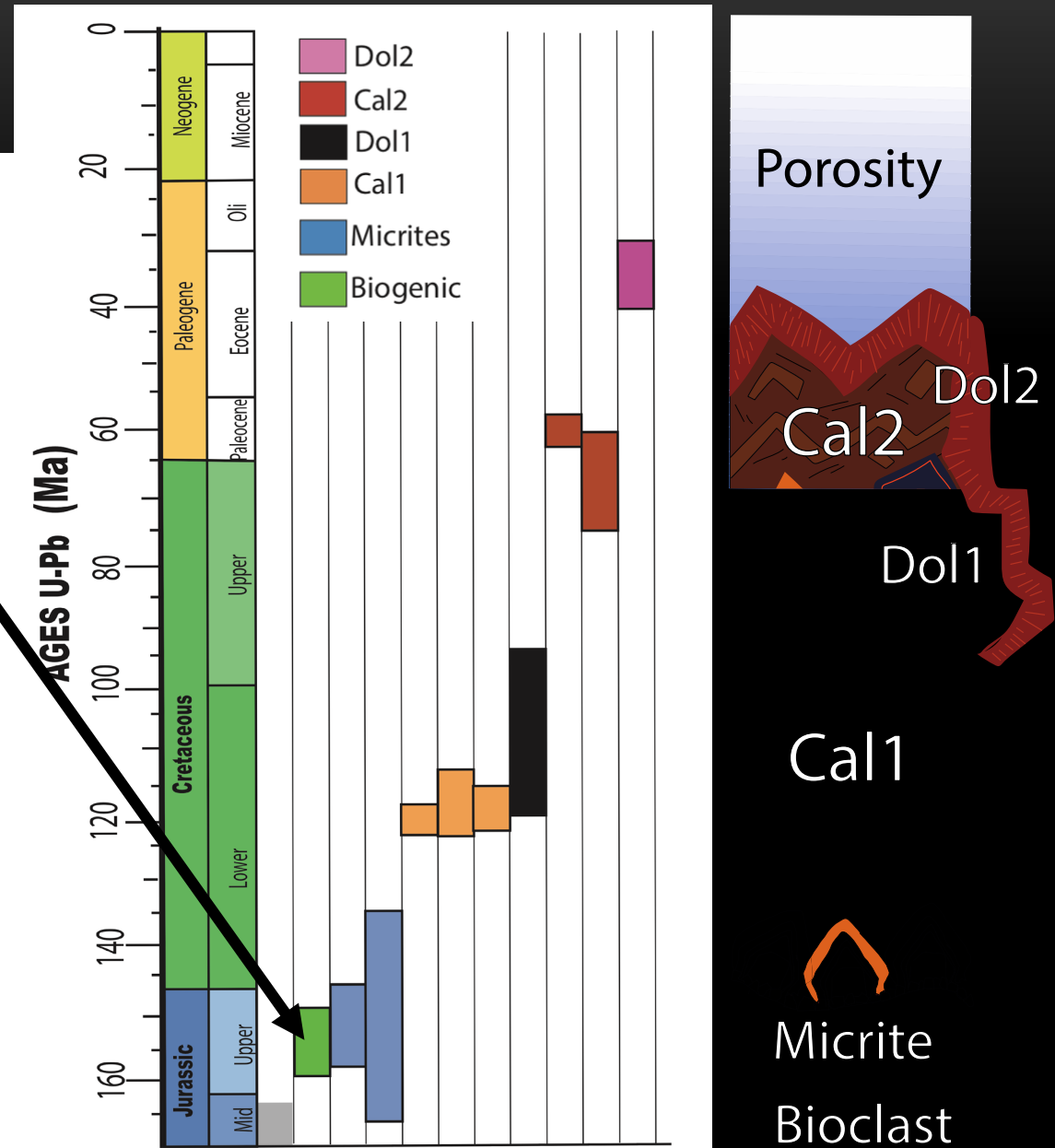
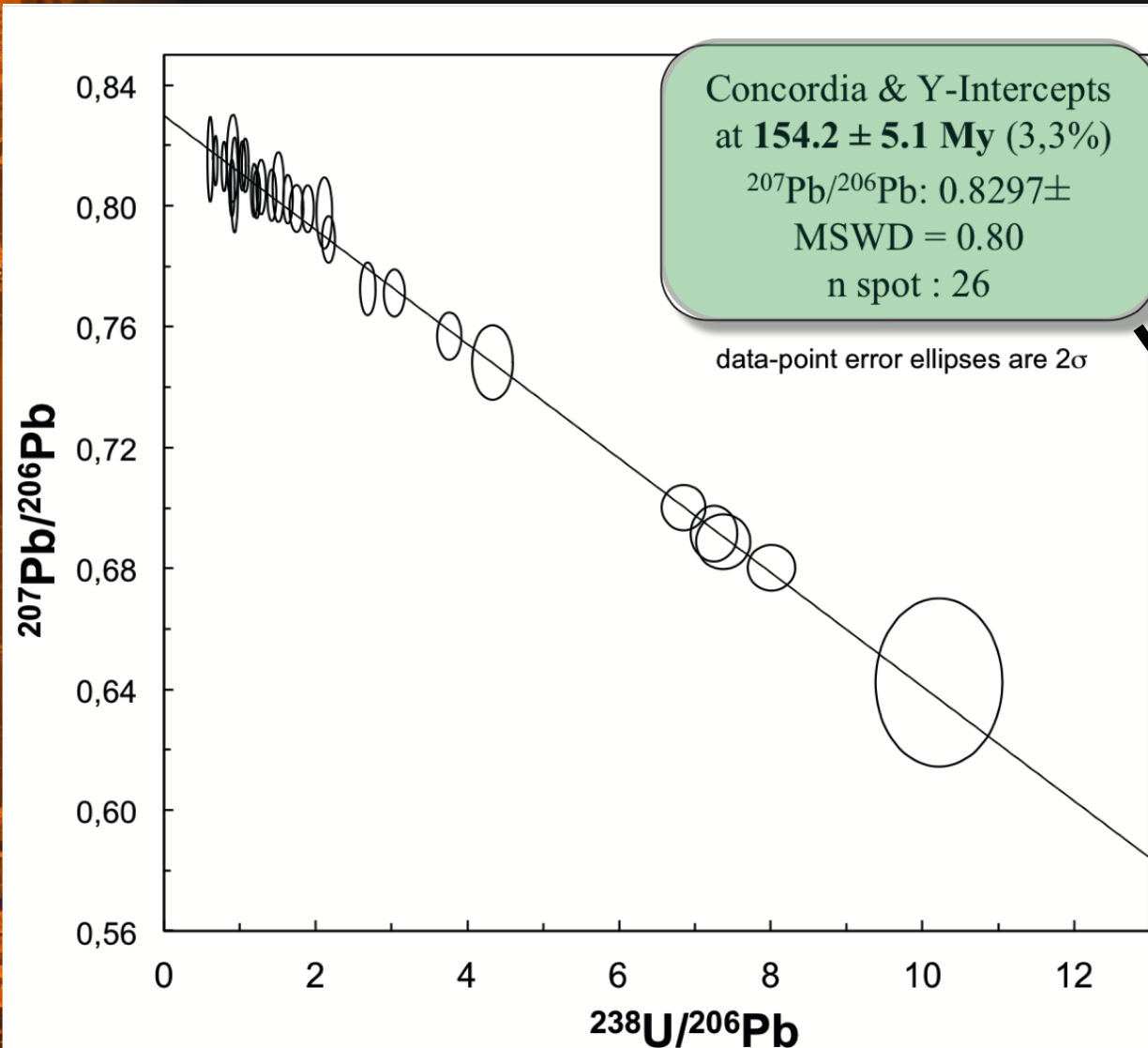
- Baulne en Brie
- Rigny la Nonneuse
- Villeperdue
- Fossoy



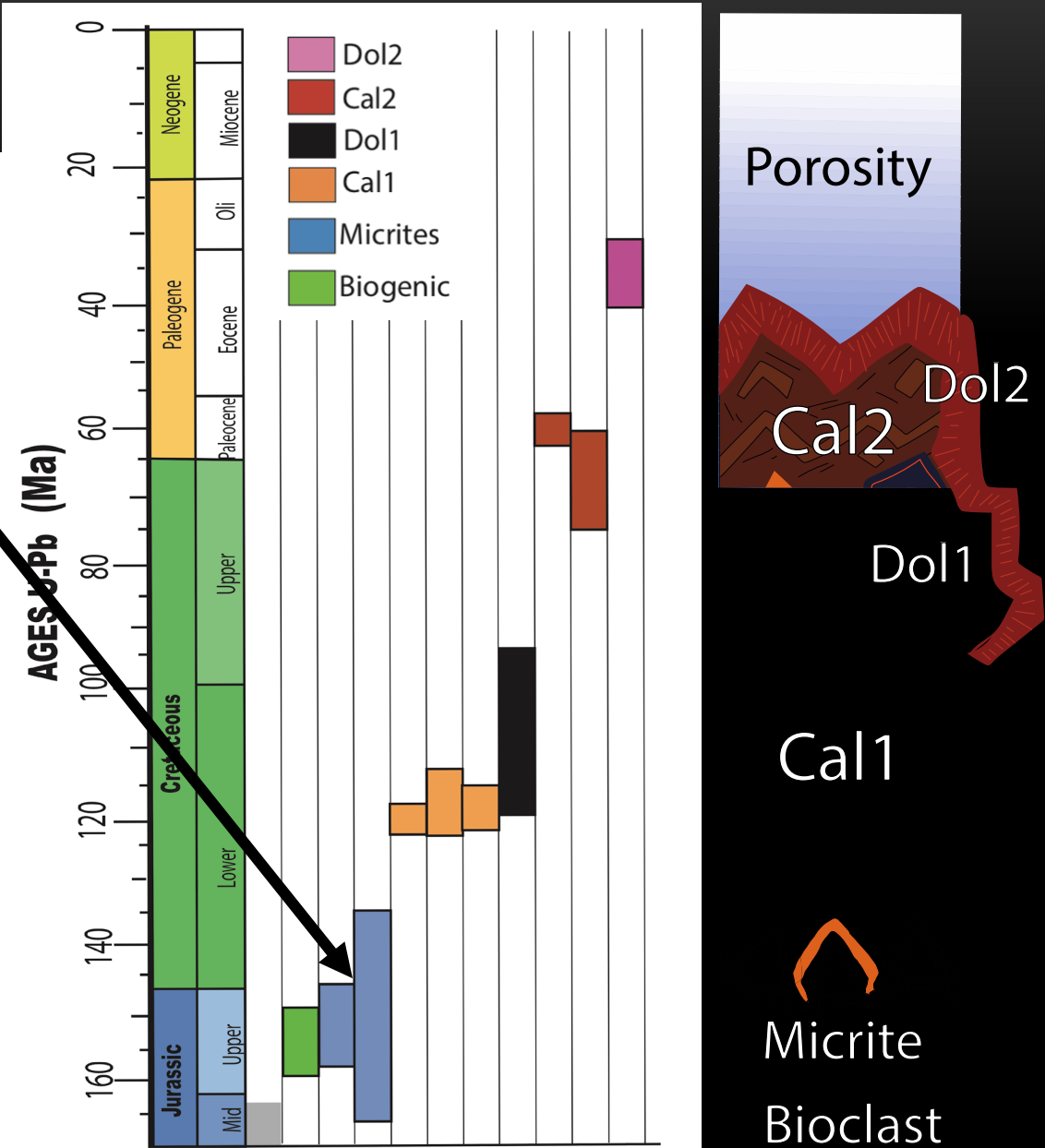
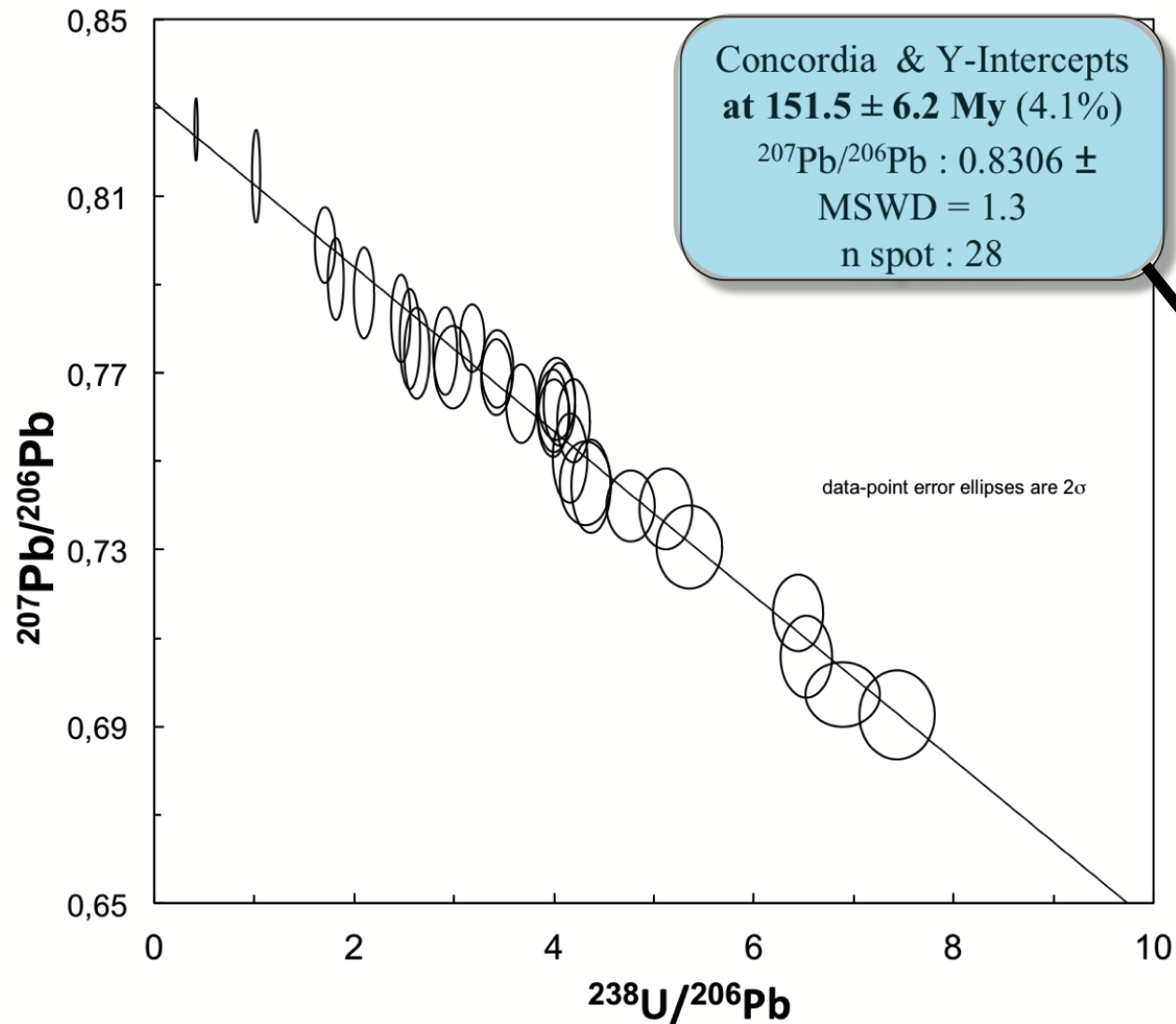
Mangenot et al. 2018
(Sedimentology)



LASER ABLATION U-PB DATING



LASER ABLATION U-PB DATING



Porosity

Dol2
Cal2

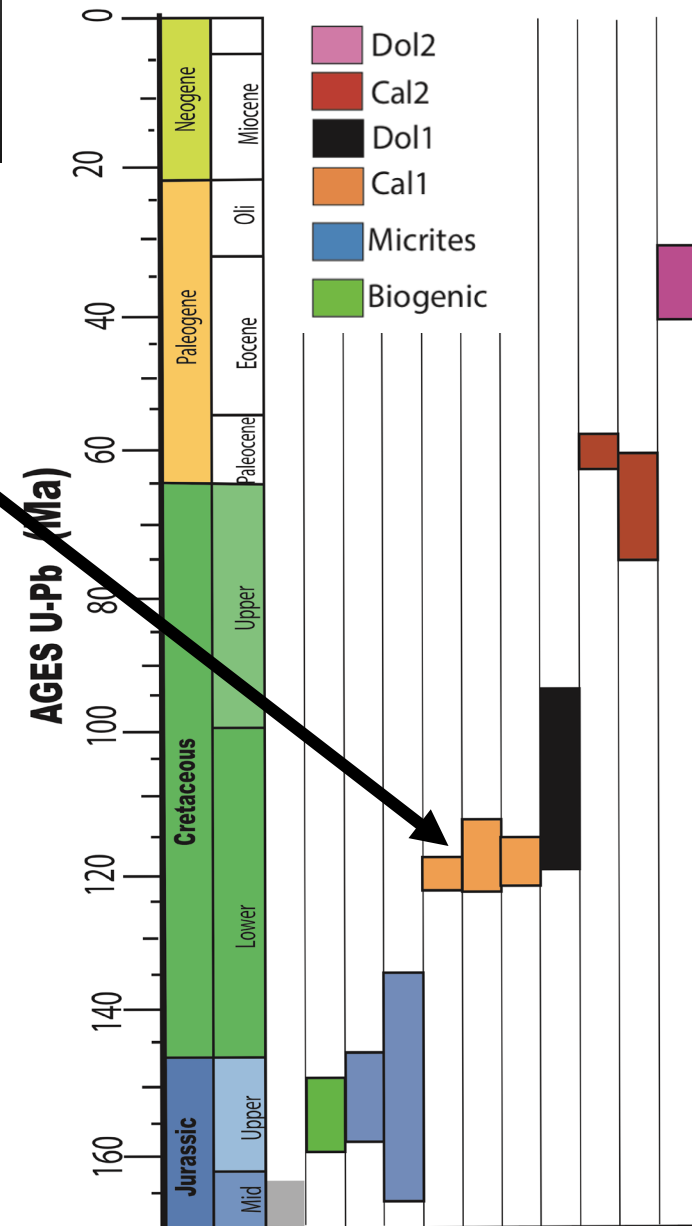
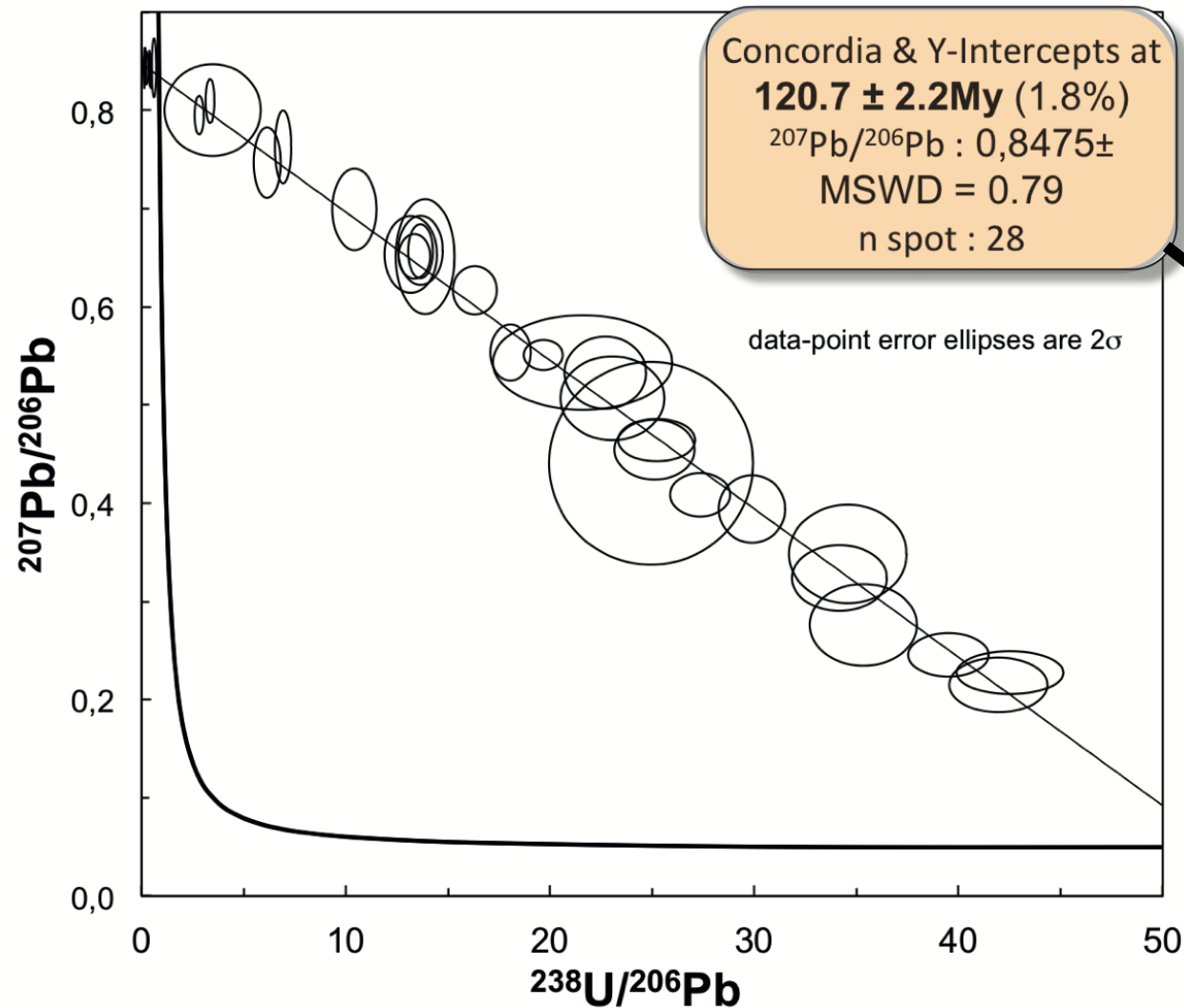
Dol1

Cal1

Micrite

Bioclast

LASER ABLATION U-PB DATING



Porosity

Dol2
Cal2

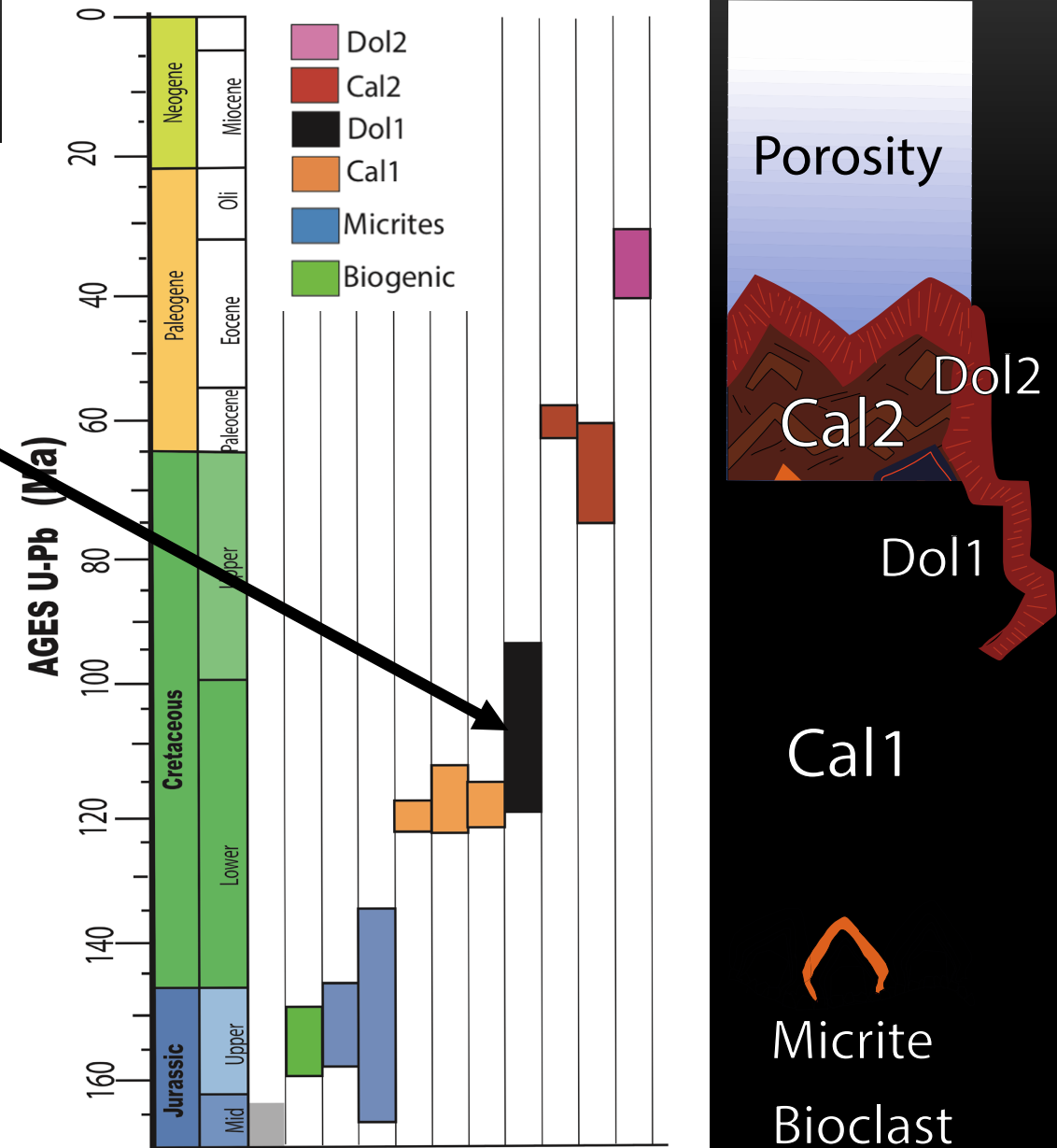
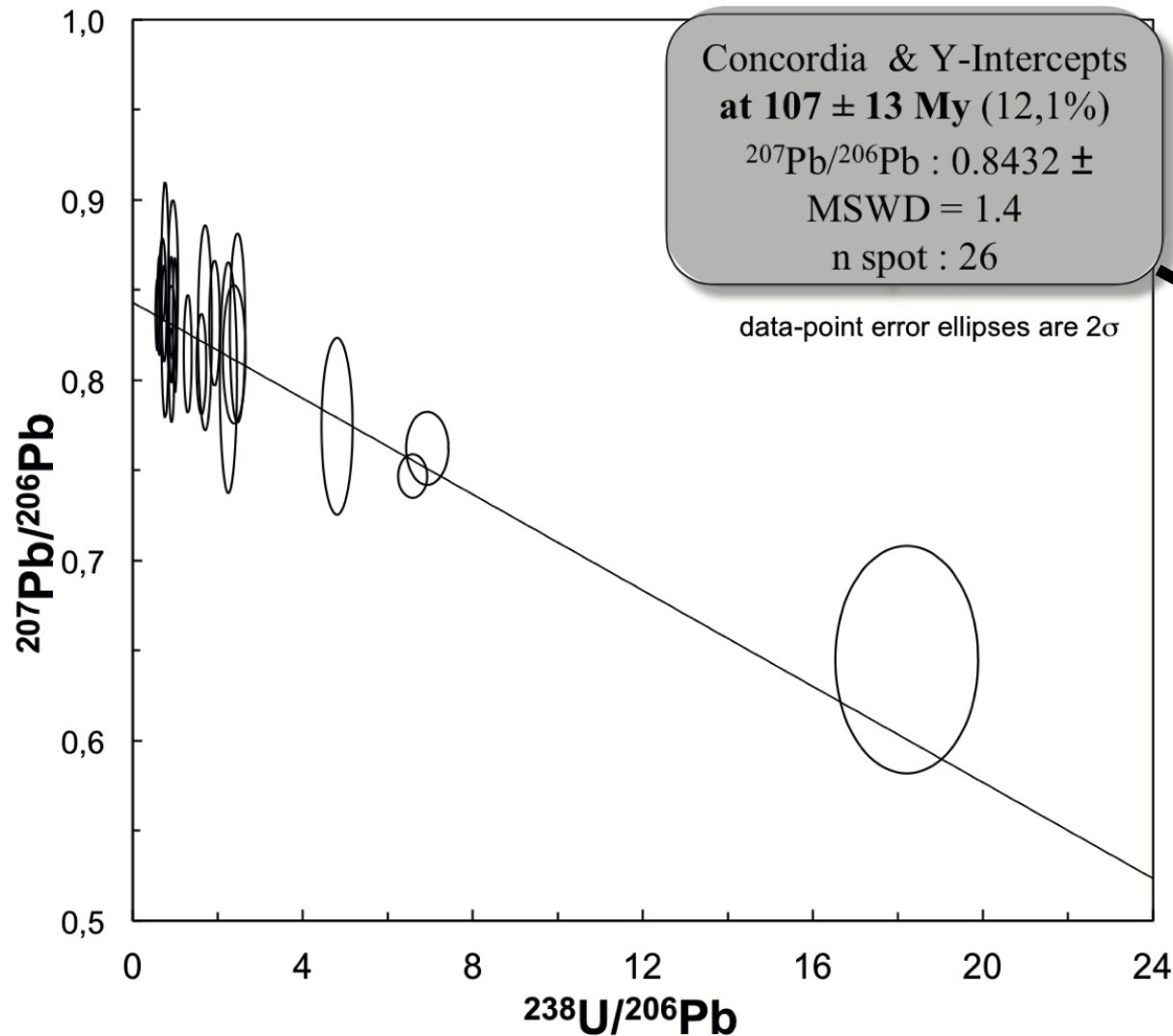
Dol1

Cal1

Micrite

Bioclast

LASER ABLATION U-Pb DATING



Porosity

Dol2

Cal2

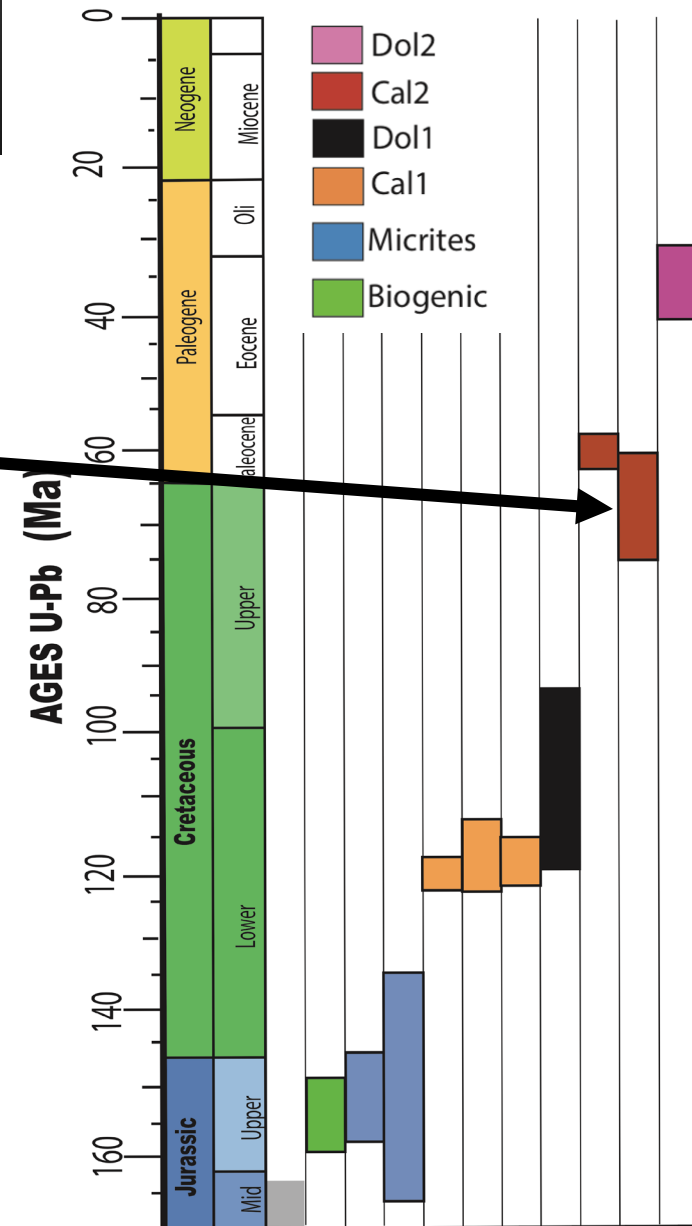
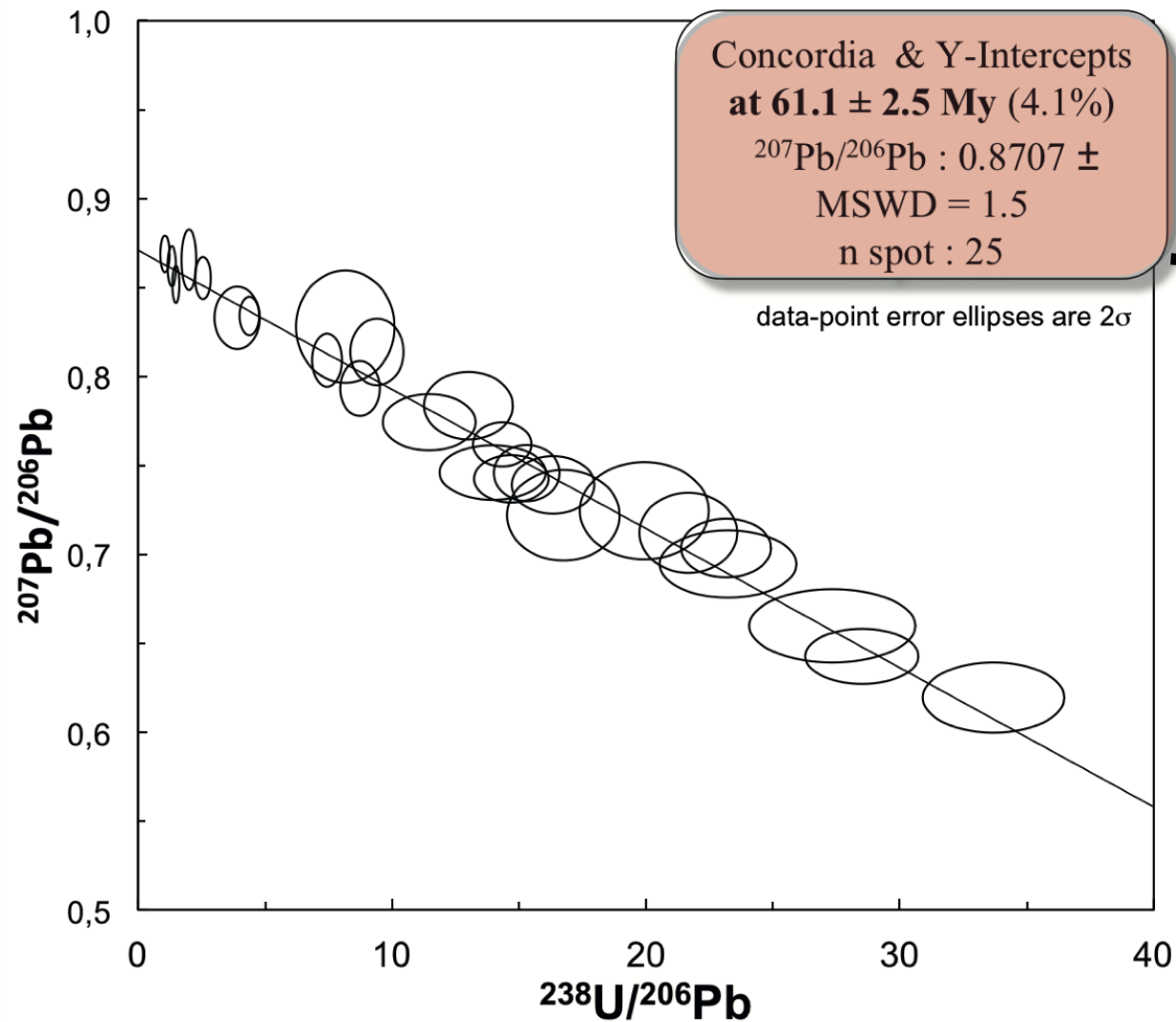
Dol1

Cal1

Micrite

Bioclast

LASER ABLATION U-PB DATING



Porosity

Dol2
Cal2

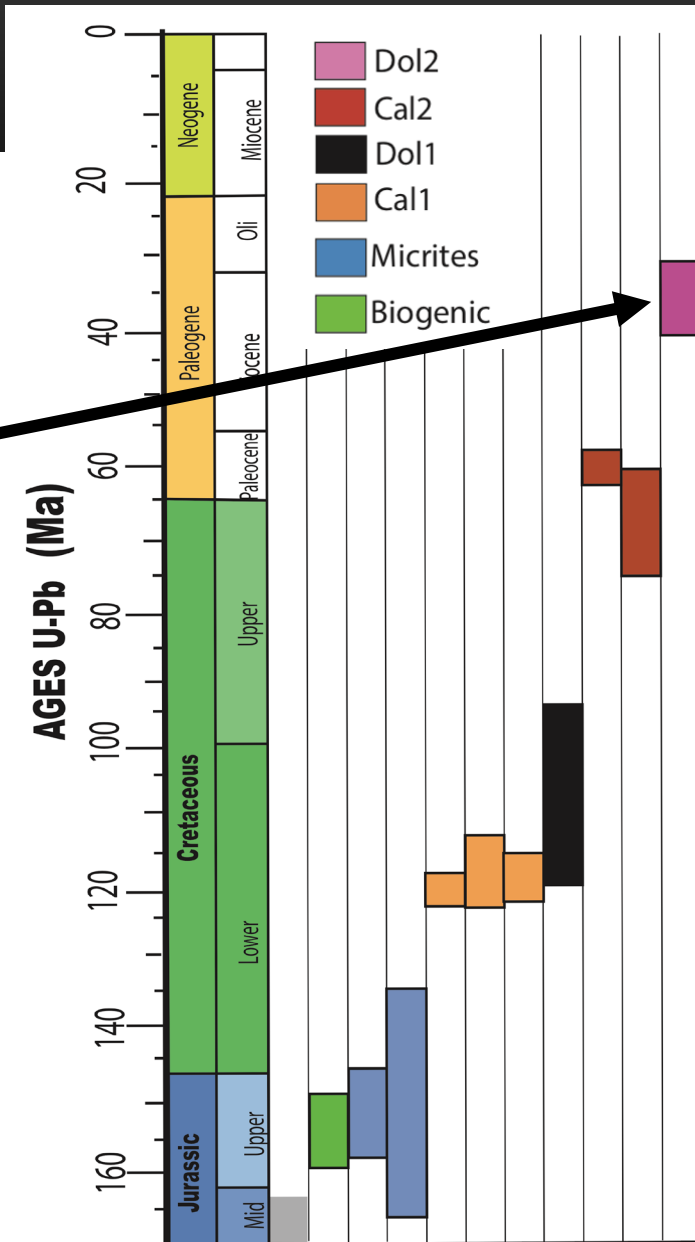
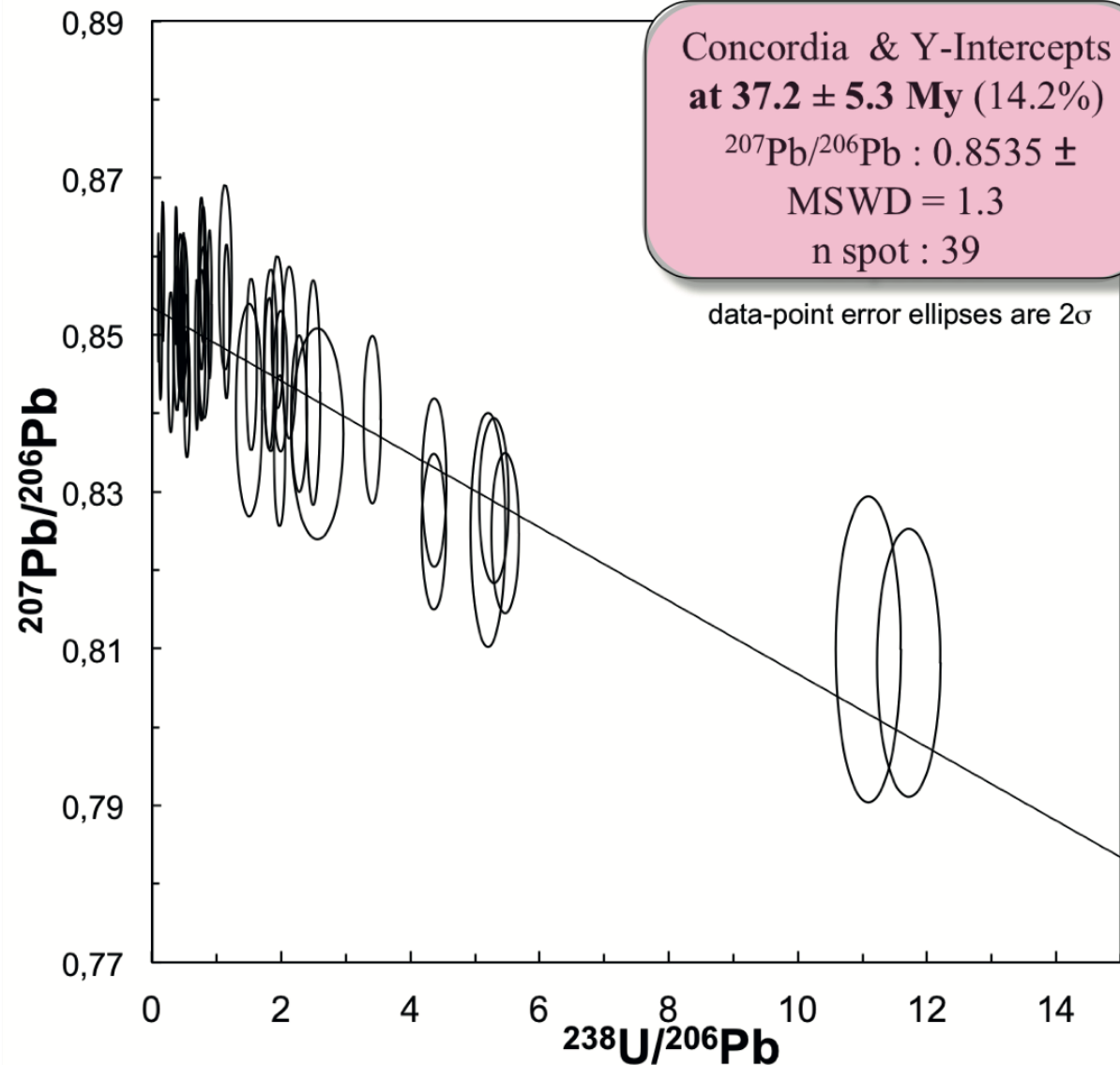
Dol1

Cal1

Micrite

Bioclast

LASER ABLATION U-PB DATING



THERMAL HISTORY OF THE CARBONATE RESERVOIRS

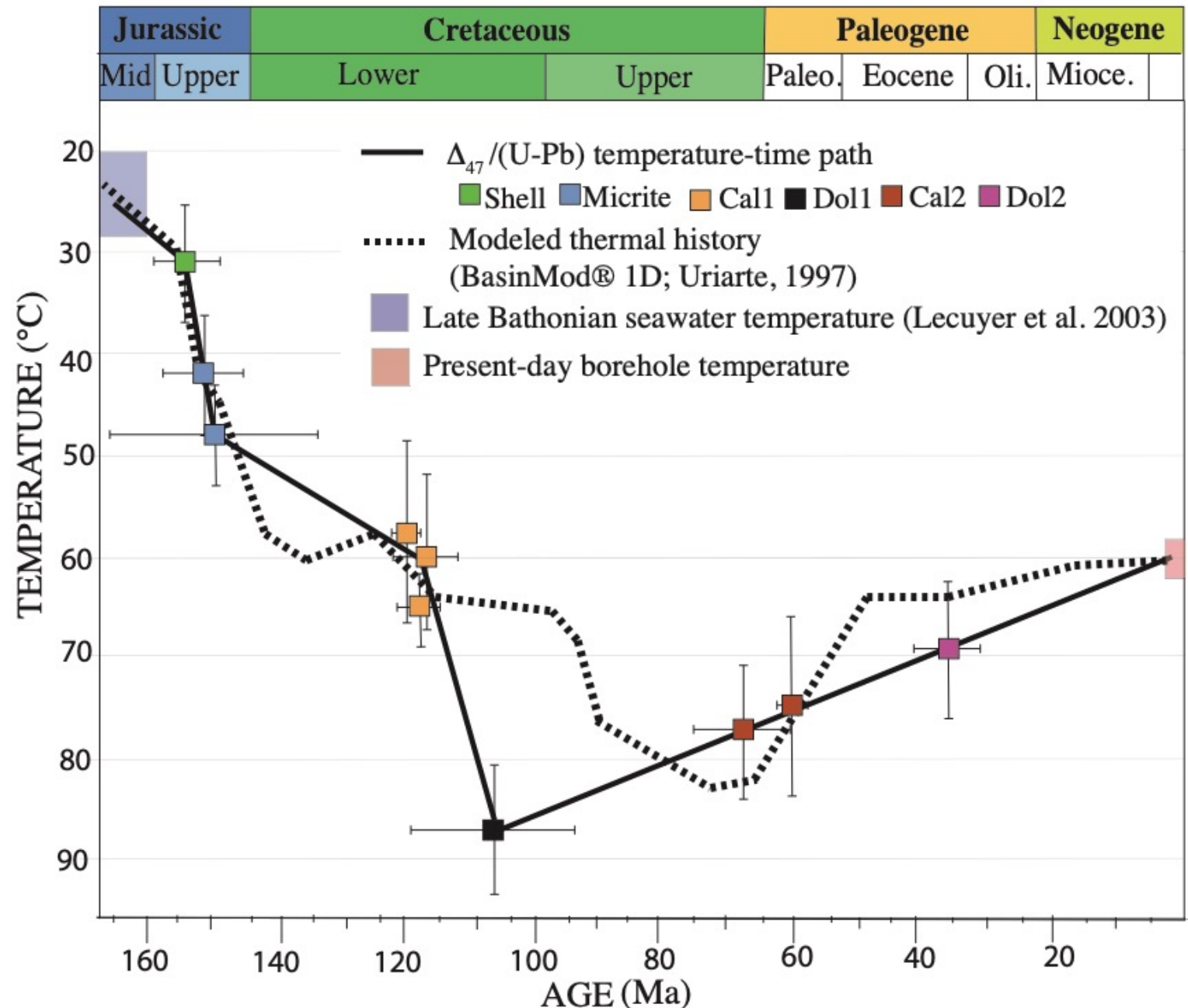


Very good agreement between vitrinite reflectance and Δ_{47} -U-Pb thermal histories

Δ_{47} -U/Pb thermo-chronometer allows to:

- (1) identify heating and cooling history
- (2) quantify paleotemperatures through time
- (3) Detect hydrothermal activity

Mangenot et al. 2018. Geology (in rev)



GENERAL CONCLUSIONS

TAKE HOME MESSAGE

Clumped isotope paleothermometry can be paired with direct radiogenic dating (U/Pb) in carbonate to obtain a more accurate and detailed record of the thermal history of sedimentary basins

- (1) Improvement of thermal history characterization of the Paris Basin
- (2) Calibration of the paragenetic sequence both in time (U/Pb) and temperature (Δ_{47})
- (3) Determination of a detailed fluid-flows history in time and space

MAIN
RESULTS
OF MY
PhD

A NEW THERMOCHRONOMETER IS EMERGING
FOR STUDYING CARBONATE BEARING ROCKS



Δ_{47}
U-Pb



Société Géologique de France
Des géologues au service de la société

A big thanks to the SGF !

This study would not have been possible without the collaboration of a large team of scientists coming from different universities and research institute.

Thanks to all of you !

M. Gasparrini



V. Rouchon



IFPEN

M. Bonifacie



M. Ader



IPGP.

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Université Paris-Sud