



# Microscopie électronique et carpologie

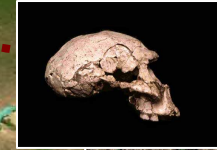
Application au plus vieux site archéologique d'Eurasie

**Erwan MESSAGER <sup>a,b</sup> et Brigitte DENIAUX <sup>b</sup>**

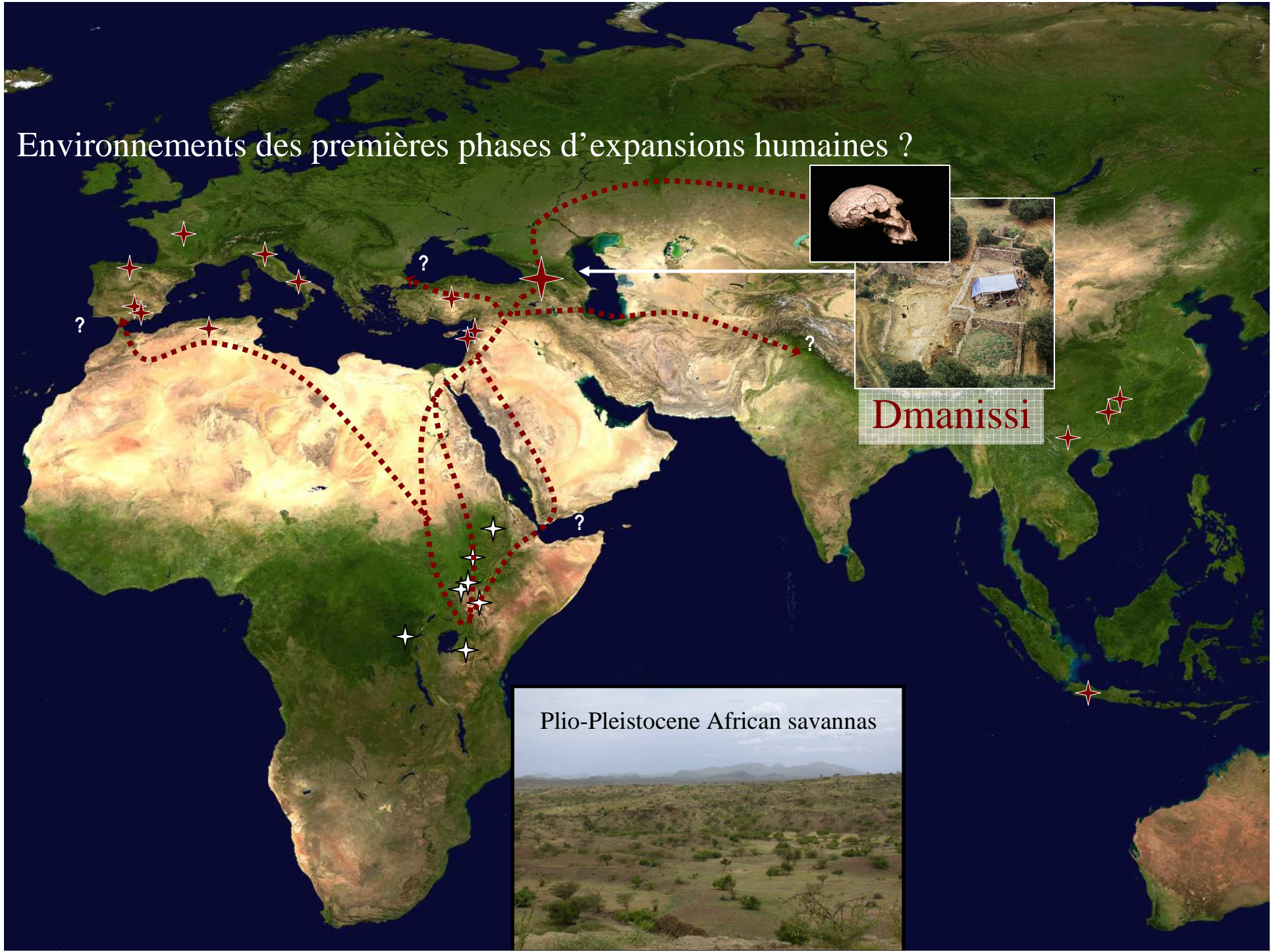
a. Maison de l'Archéologie et de l'Ethnologie, UMR 7041,  
ArscAn, 21, allée de l'Université, 92023 Nanterre

b. Département de Préhistoire du Muséum national d'Histoire  
naturelle, Paris, UMR 7194, 1, rue René Panhard, 75013 Paris /  
UMR 7194, Avenue Léon-Jean Grégory, 66720 Tautavel

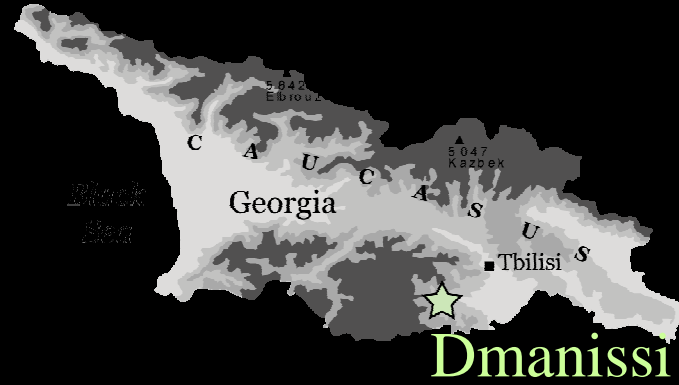
# Environnements des premières phases d'expansions humaines ?



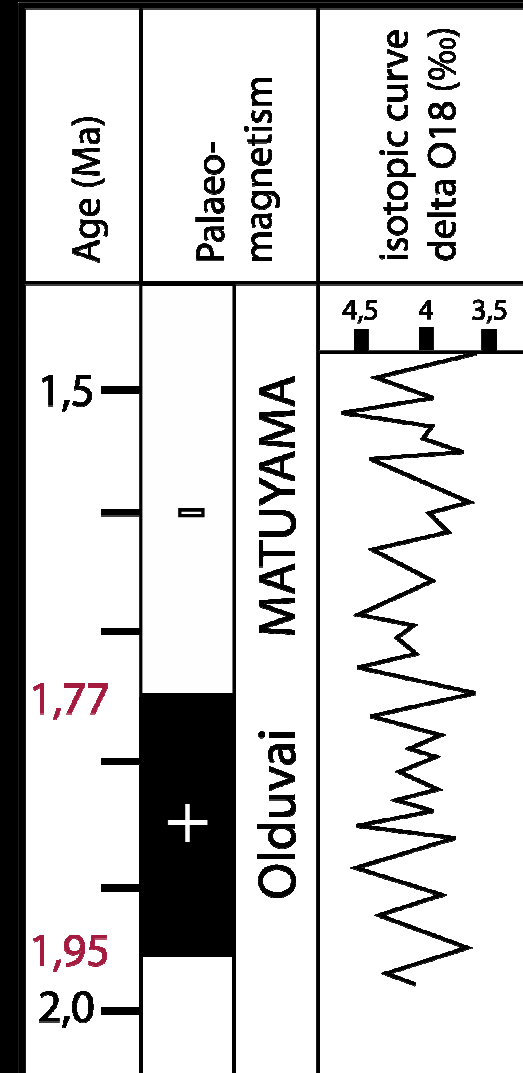
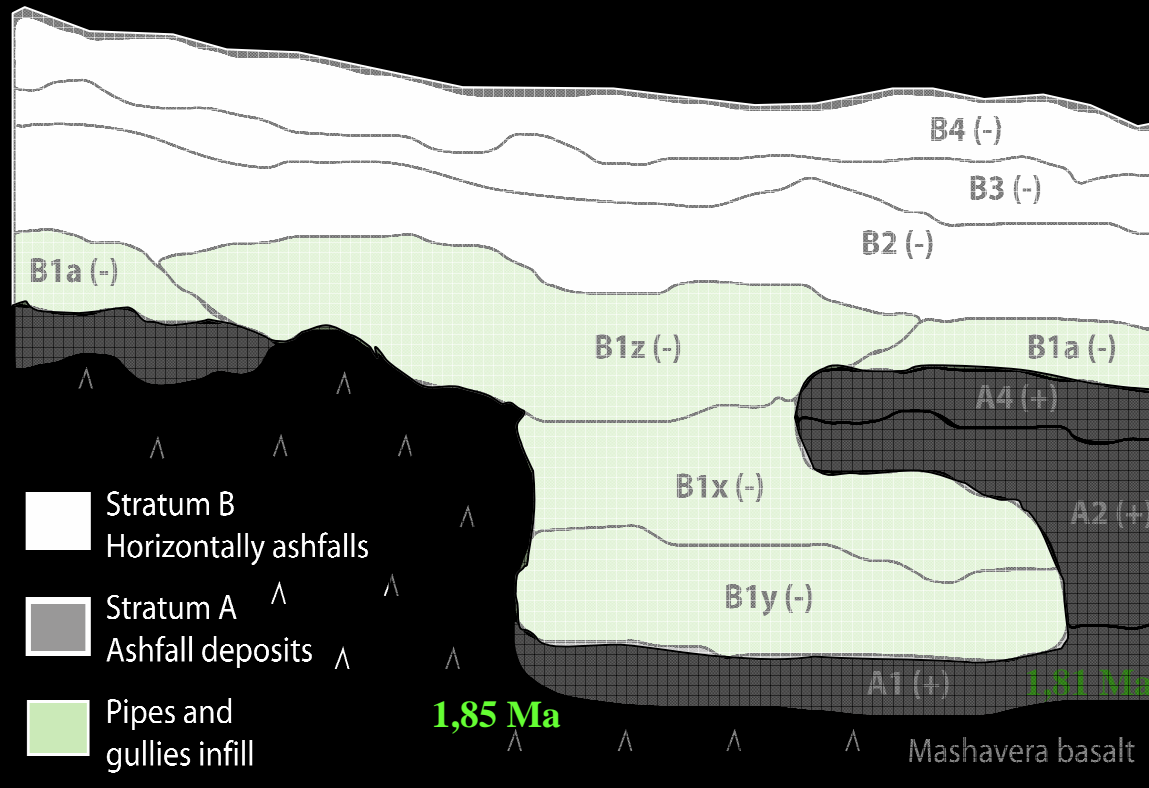
Dmanissi



# Fouilles à Dmanissi



# Stratigraphie et géochronologie



(Secteur 2, d'après R. Ferring, in Lordkipanidze *et al.*, 2007)

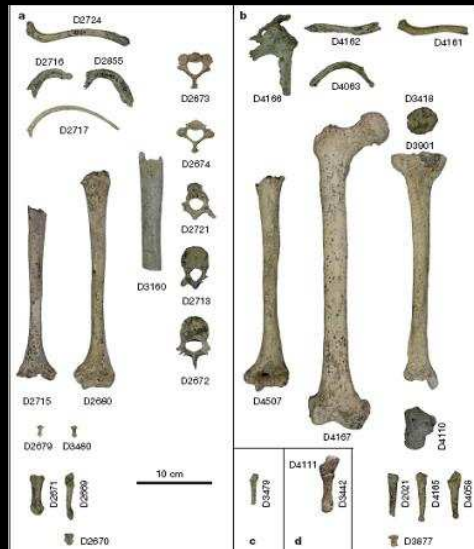
# Assemblage archéologique

## Restes humains



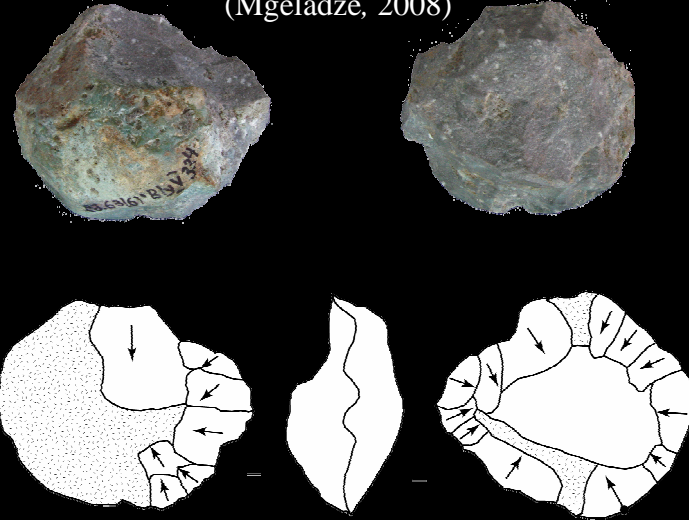
Georgian Centre  
of Prehistoric Research

5 crânes, 4 mandibules, plus de  
trente restes post-crâniens

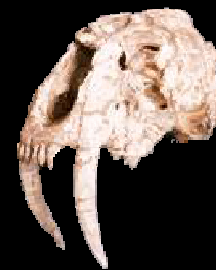


(Lordkipandze *et al.*, 2007)

## Outils taillés (Mgeladze, 2008)



## Restes paléontologiques



*Megantereon  
megantereon*



*Canis etruscus*

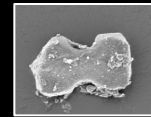
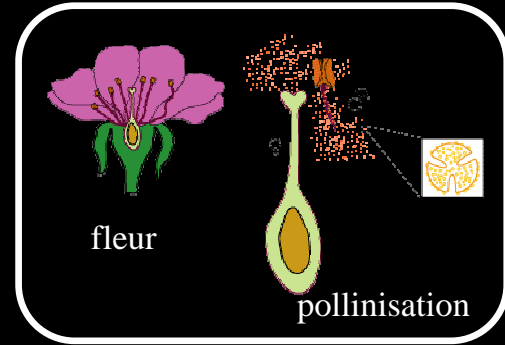


*Palaeotragus sp.*

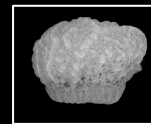
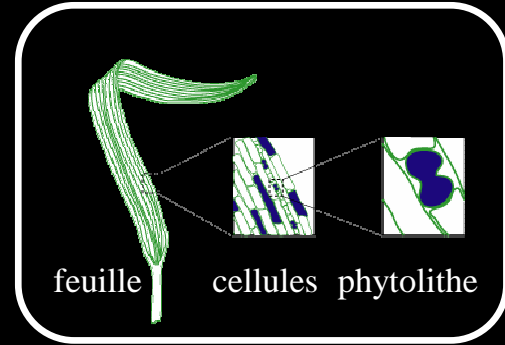
# Etudes paléobotaniques effectuées



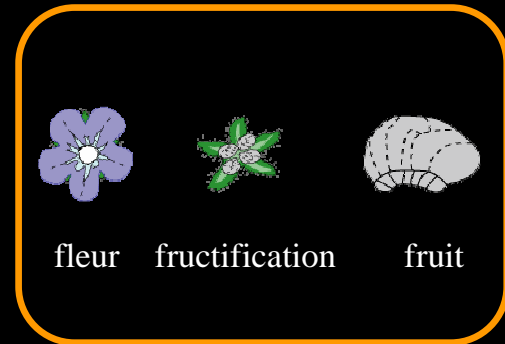
pollen








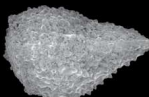
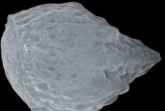

phytolithe



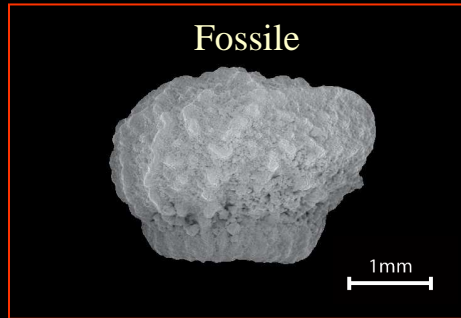
carpo-reste



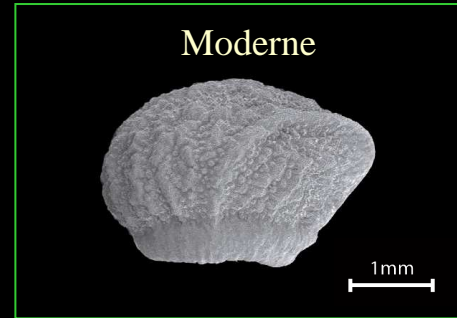
# Identification de l'assemblage complet

	<b>Désignation</b>	<b>Morphologie générale (échelle non respectée)</b>	<b>Fréquence</b>
1	Classe I		3
2	Classe II, morphotype 1		>200
3	Classe II, morphotype 2		316
4	Classe II, morphotype 3		2
5	Classe II, morphotype 4		2
6	Classe II, morphotype 5		2
7	Classe II, morphotype 6		9
8	Classe II, morphotype 7		1

# Protocole d'identification en microscopie électronique



ESEM  
Philips XL 30

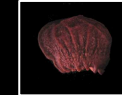


SEM  
JEOL JSM-840A

## Référence collection



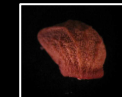
*Anchusa angustifolia*



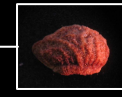
*Anchusa pulla*



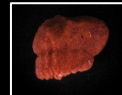
*Anchusa ochroleuca*



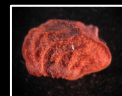
*Anchusa stylosa*



*Lycopsis orientalis*



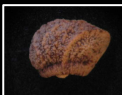
*Anchusa sartori*



*Nonea armena*



*Anchusa officinalis*



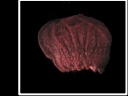
*Lycopsis erecta*

# Protocole d'identification en microscopie électronique

## Référence collection



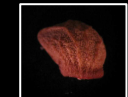
*Anchusa angustifolia*



*Anchusa pulla*



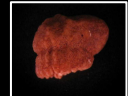
*Anchusa ochroleuca*



*Anchusa stylosa*



*Lycopsis orientalis*



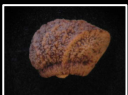
*Anchusa sartori*



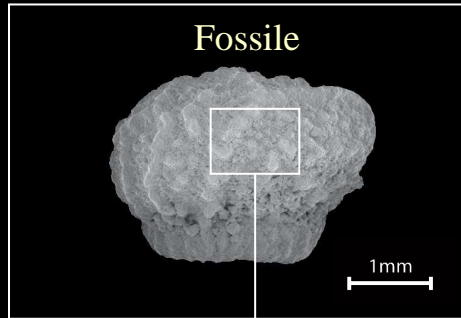
*Nonea armena*



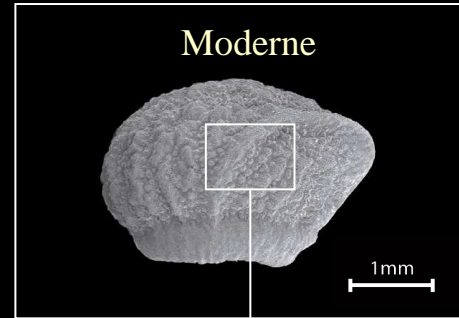
*Anchusa officinalis*



*Lycopsis erecta*



Fossile

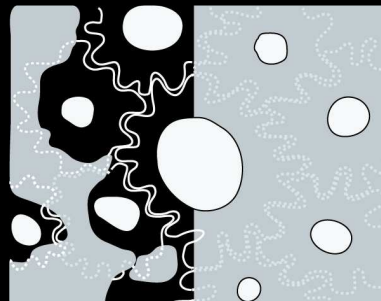


Moderne

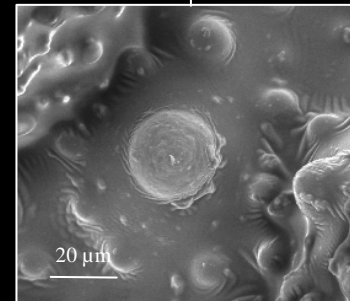
## Caractéristiques microscopiques



Fossile



Moderne



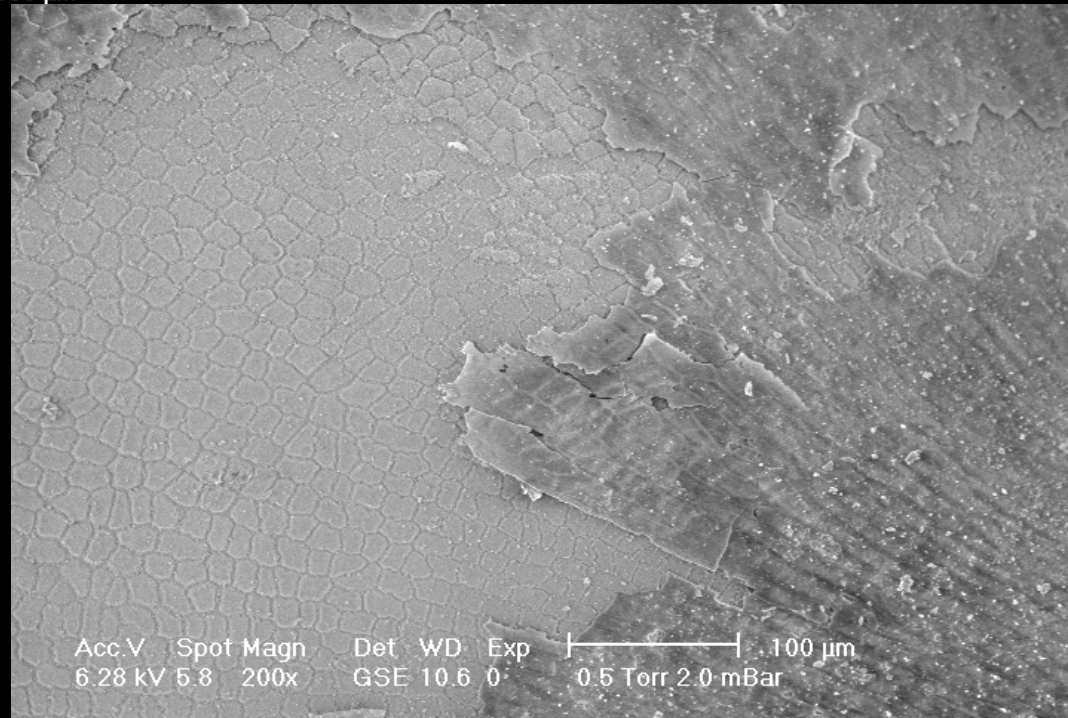
Images : Brigitte Deniaux , Gérard Mascarell et Erwan Messenger  
MEB environnemental du CERPT et MEB du MNHN

Exemple 1 : Fossile sans ornementation spécifique



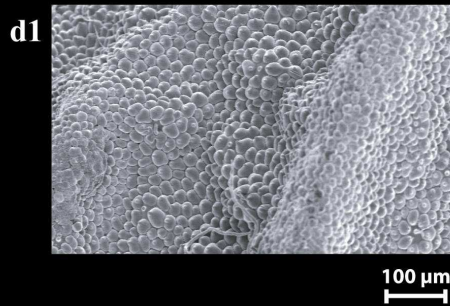
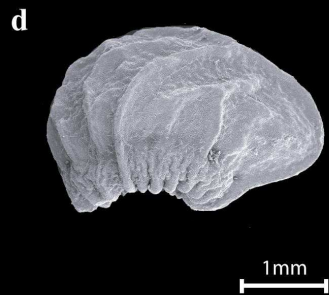
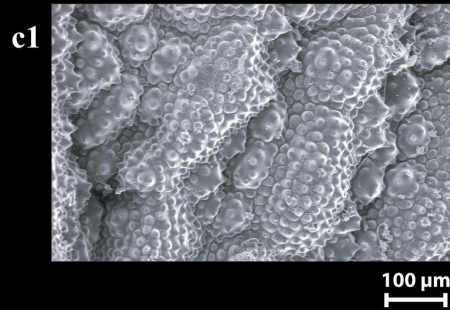
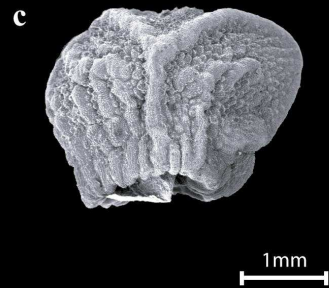
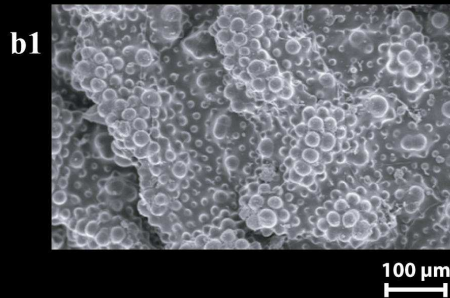
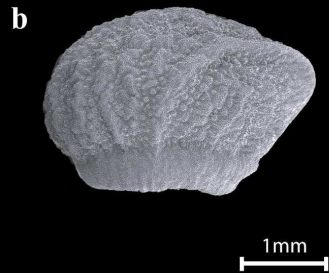
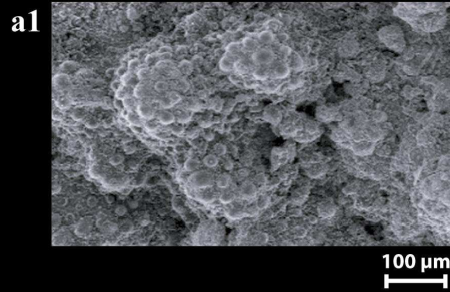
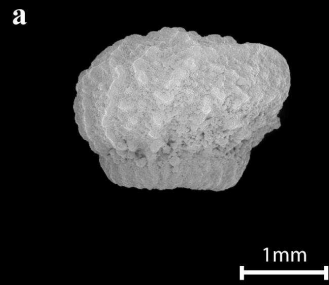
Identification au genre : *Myosotis*

Acc.V Spot Magn Det WD Exp |-----| 500 µm  
6.28 kV 5.6 60x GSE 10.6 0 0.5 Torr 2.0 mBar



Acc.V Spot Magn Det WD Exp |-----| 100 µm  
6.28 kV 5.8 200x GSE 10.6 0 0.5 Torr 2.0 mBar

Exemple n° 2 : Fossile avec une ornementation



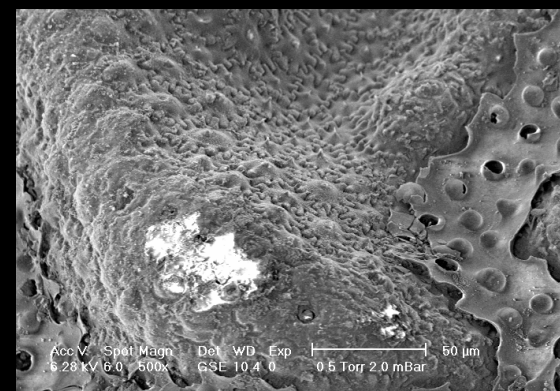
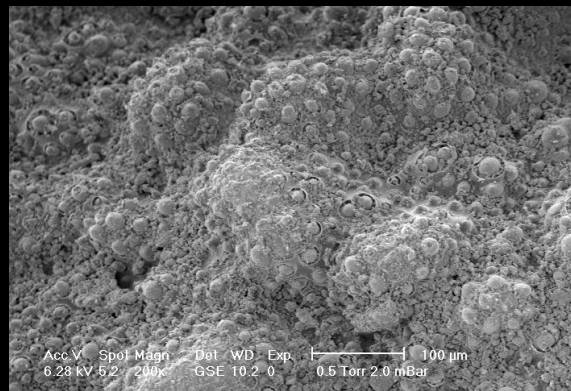
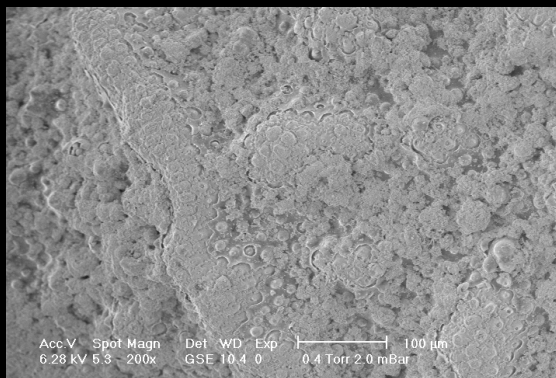
Fruit fossile

Genre *Lycopsis*

Genre *Anchusa*

Genre *Nonea*

# Exemple n° 2 : Recherche de caractéristiques sur l'ornementation de surface



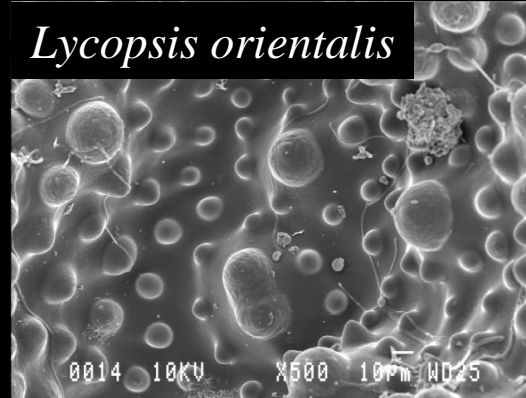
Images : ESEM

Exemple n° 2 : Comparaison avec les différentes espèces des genres *Anchusa* et *Lycopsis*

*Anchusa stylosa*



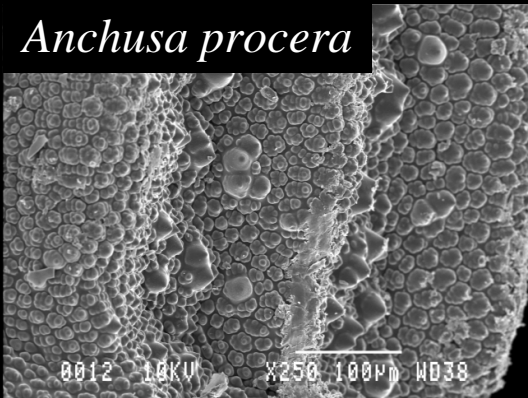
*Lycopsis orientalis*



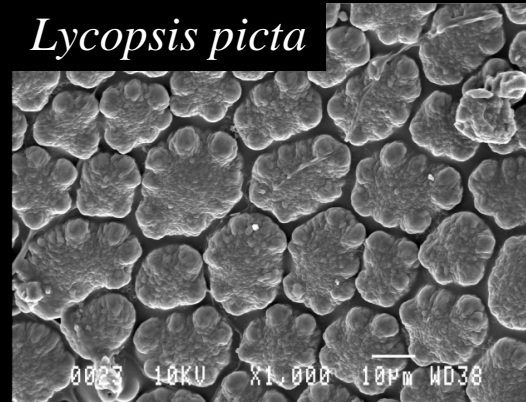
*Anchusa angustifolia*



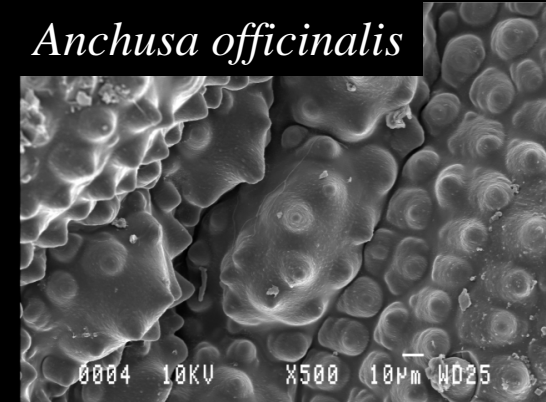
*Anchusa procera*



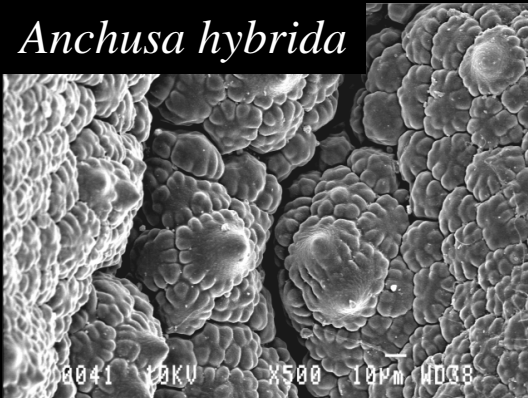
*Lycopsis picta*



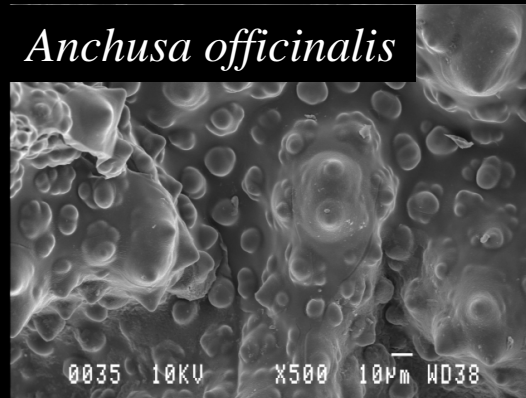
*Anchusa officinalis*



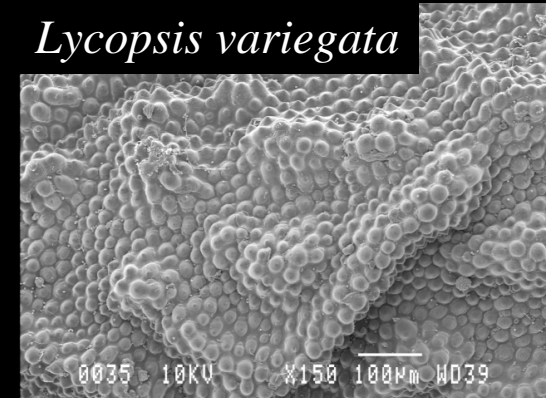
*Anchusa hybrida*



*Anchusa officinalis*



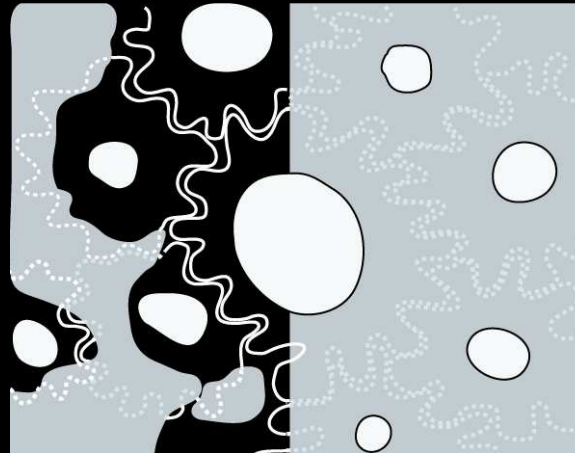
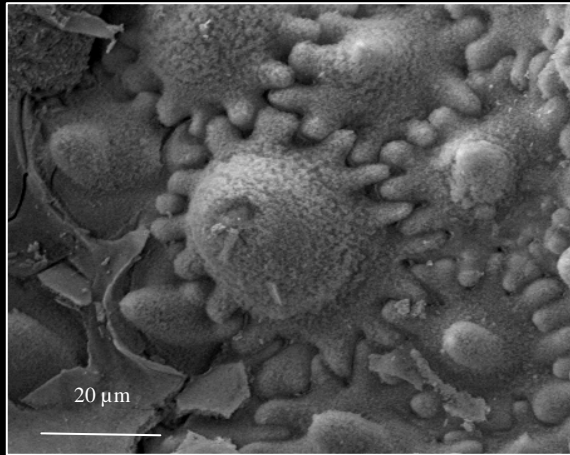
*Lycopsis variegata*



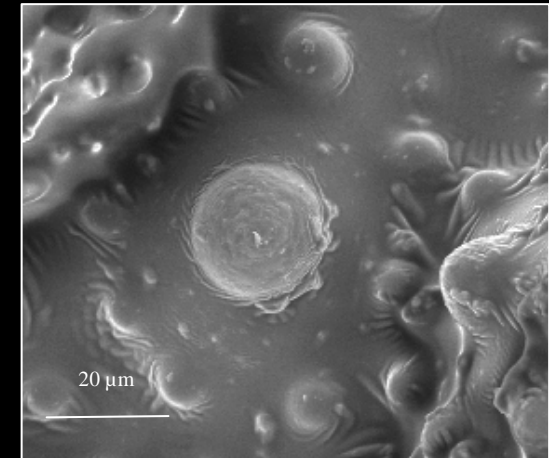
Images : SEM

## Exemple n° 2 : Comparaison à l'échelle cellulaire

Fossile



Spécimen de référence  
*Lycopsis orientalis*

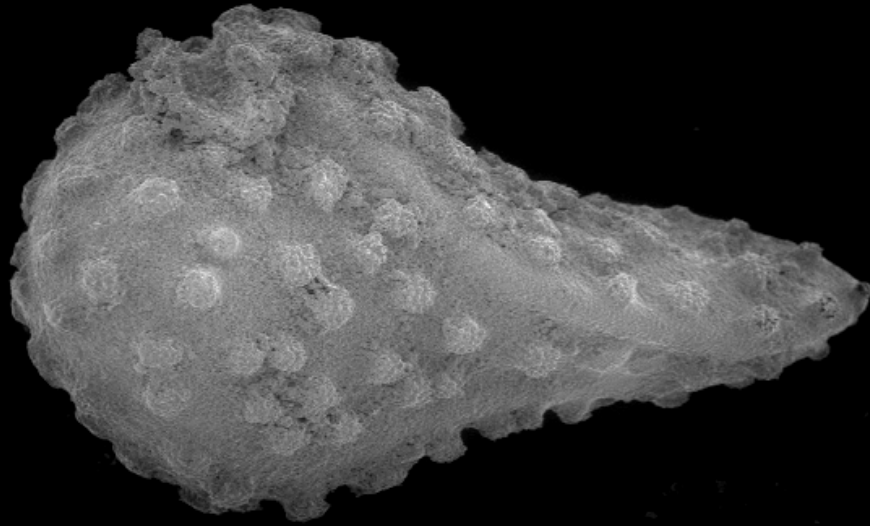


Images : ESEM et SEM

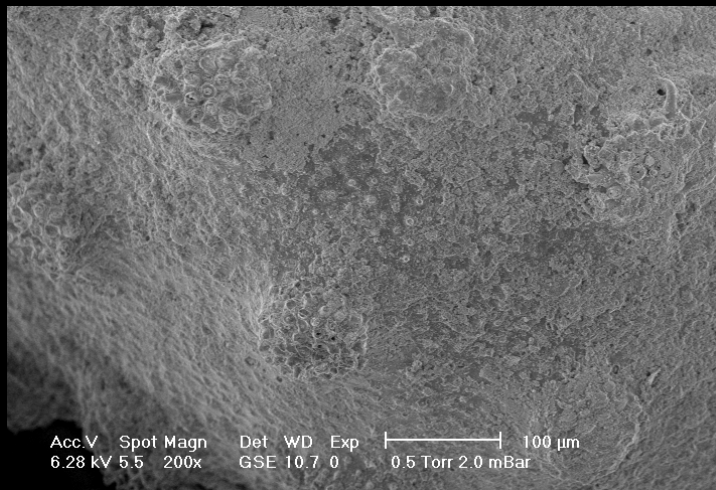
Identification au rang de l'espèce

➔ Gain considérable de précision sur l'écologie du fossile

# Exemple n° 3



Acc.V Spot Magn Det WD Exp |-----| 500 µm  
6.28 kV 5.5 40x GSE 10.9 0 0.5 Torr 2.0 mBar



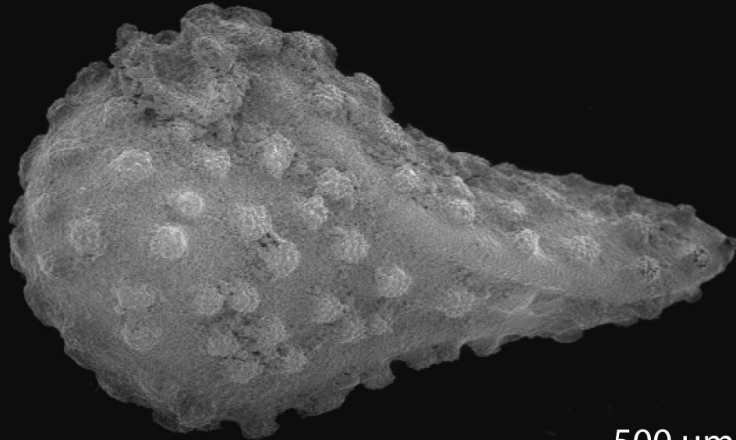
Acc.V Spot Magn Det WD Exp |-----| 100 µm  
6.28 kV 5.5 200x GSE 10.7 0 0.5 Torr 2.0 mBar



Acc.V Spot Magn Det WD Exp |-----| 20 µm  
6.28 kV 5.5 1000x GSE 10.6 0 0.5 Torr 2.0 mBar

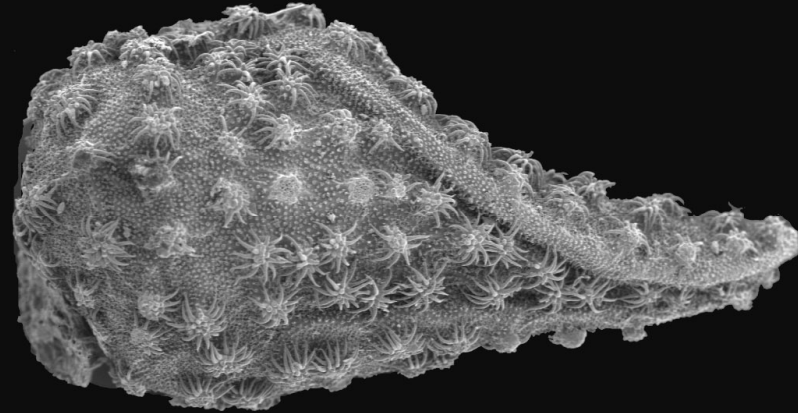
Exemple n° 3

**a**



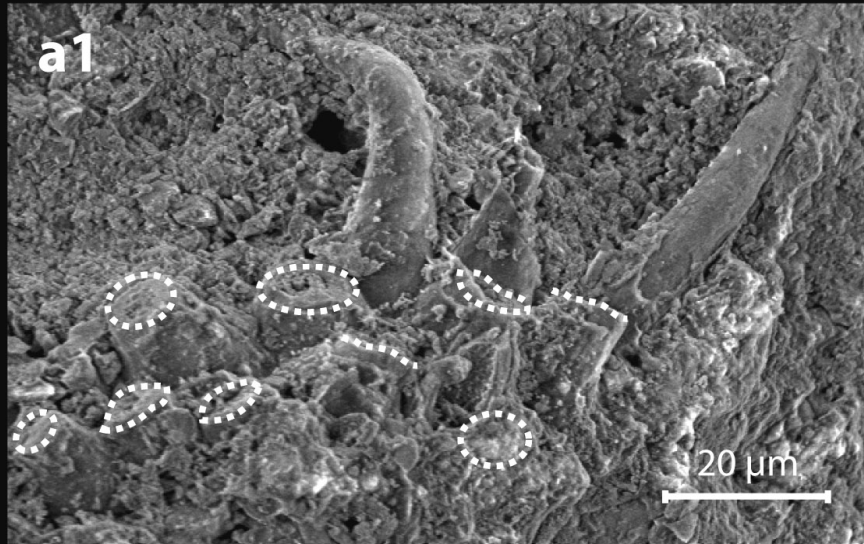
500  $\mu$ m

**b**



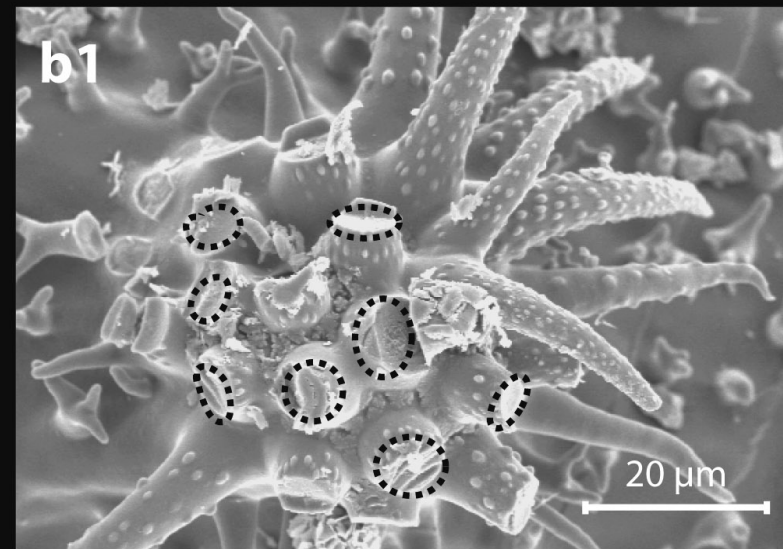
500  $\mu$ m

**a1**









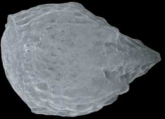

20  $\mu$ m

**b1**




20  $\mu$ m

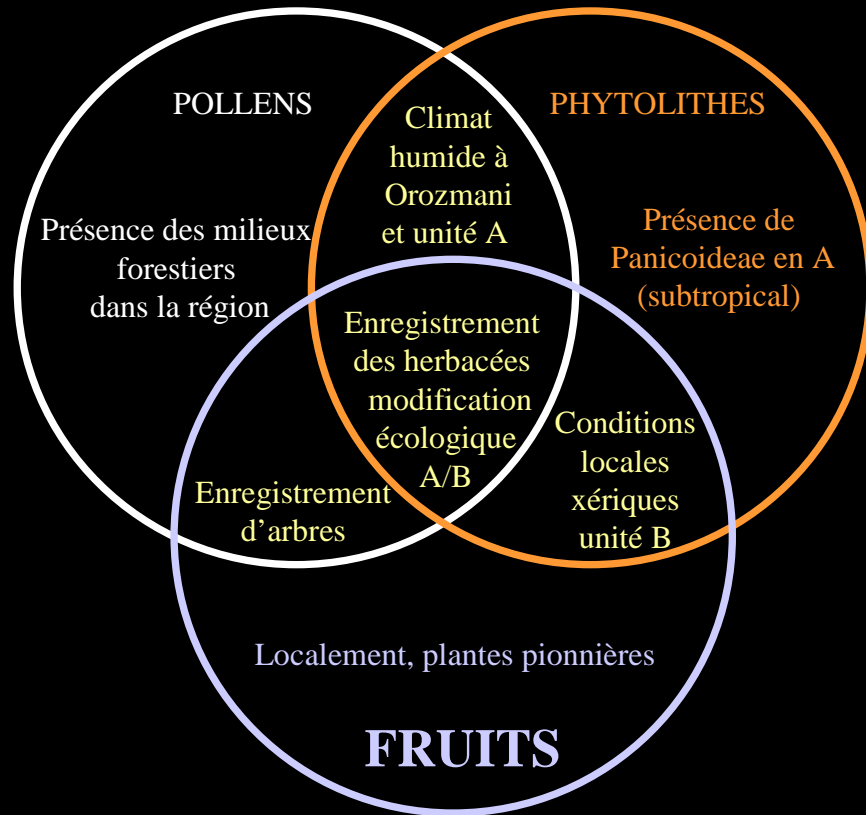
# Identification de l'assemblage complet

	<b>Désignation</b>	<b>Morphologie générale (échelle non respectée)</b>	<b>Fréquence</b>
1	Classe I		3
2	Classe II, morphotype 1		>200
3	Classe II, morphotype 2		316
4	Classe II, morphotype 3		2
5	Classe II, morphotype 4		2
6	Classe II, morphotype 5		2
7	Classe II, morphotype 6		9
8	Classe II, morphotype 7		1

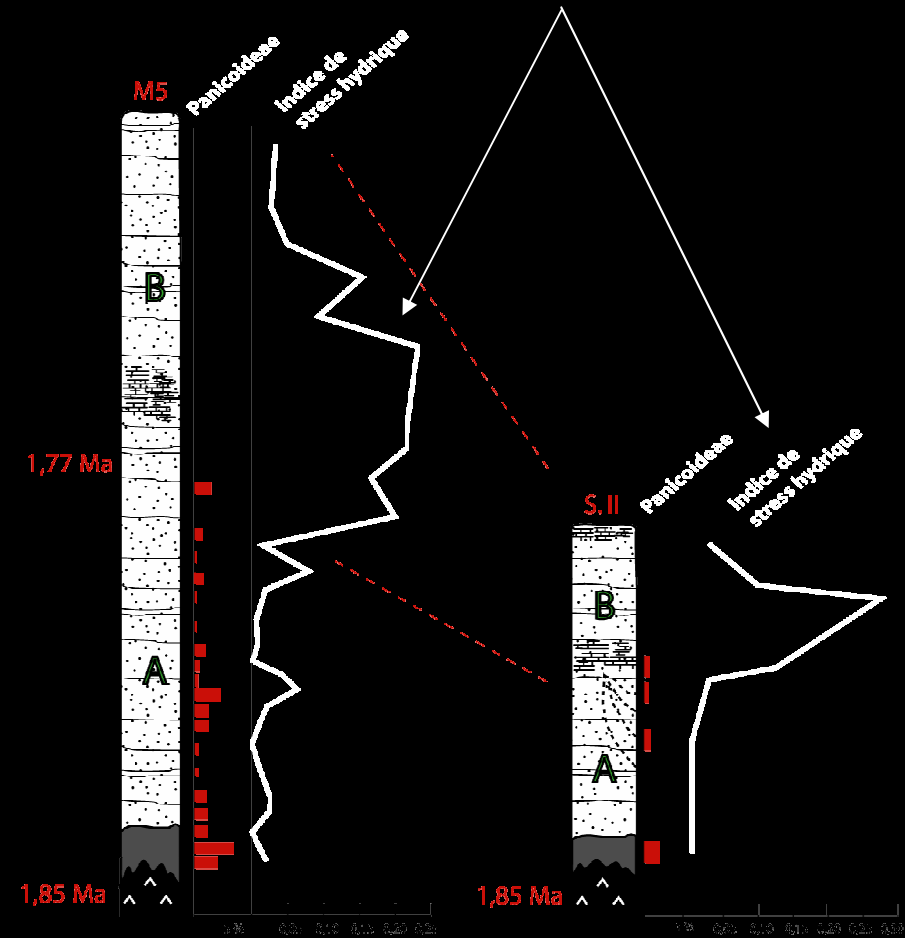
## Implications paléoécologiques

Désignation	Taxon déterminé	Fréquence
Classe I	<b>Petit arbre d'espaces semi-ouverts</b>	3
Classe II, morphotype 1	<i>Myosotis</i> sp.	>200
Classe II, morphotype 2	<b>Plantes pionnières à affinité xérique de milieux ouverts</b>	
Classe II, morphotype 3		
Classe II, morphotype 4		
Classe II, morphotype 5	<i>Lithospermum</i> sp.	2
Classe II, morphotype 6	Lithospermeae	9
Classe II, morphotype 7	<i>Onosma</i> sp.	1

# Conclusions sur l'environnement



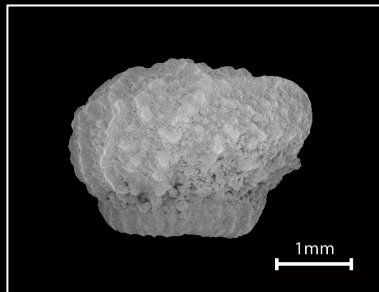
## Aridité indiquée par les phytolithes



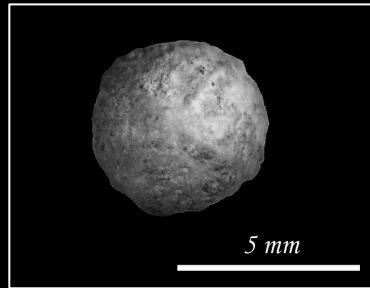
**Environnements à caractère aride**  
contemporain de la plus ancienne occupation humaine hors d'Afrique

Origine de la conservation dans un contexte sédimentaire minéral ?

Fossile



Fossile



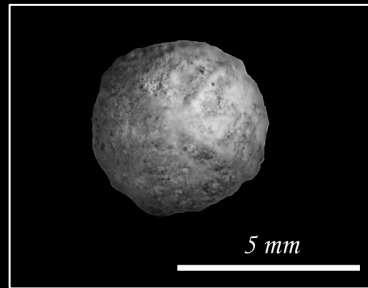
Minéralisation

Phosphatisation

Biominéralisation

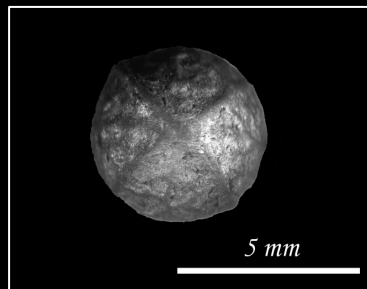
## 2 cas de carpo-restes minéralisés

Fossile

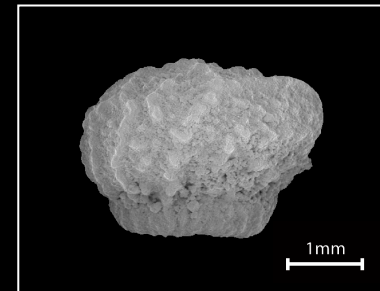


*Celtis* sp.

Moderne

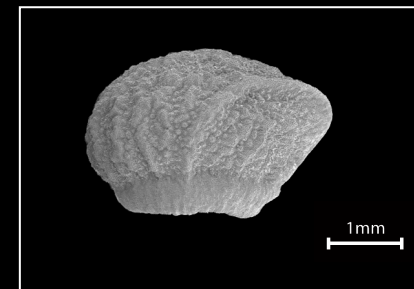


Fossile

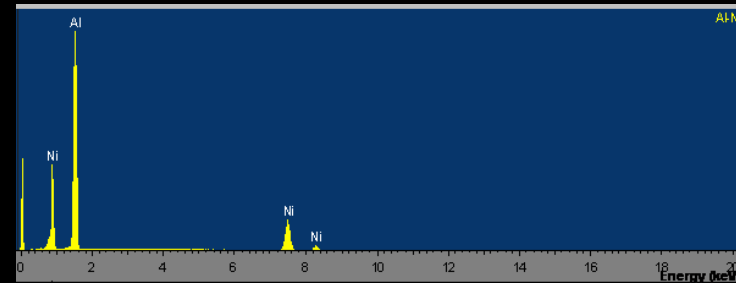
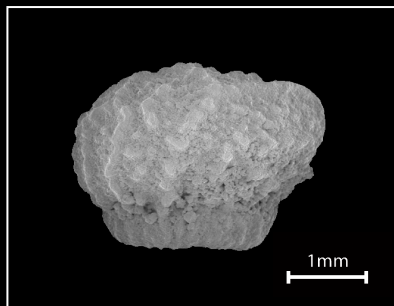


*Lycopsis* sp.

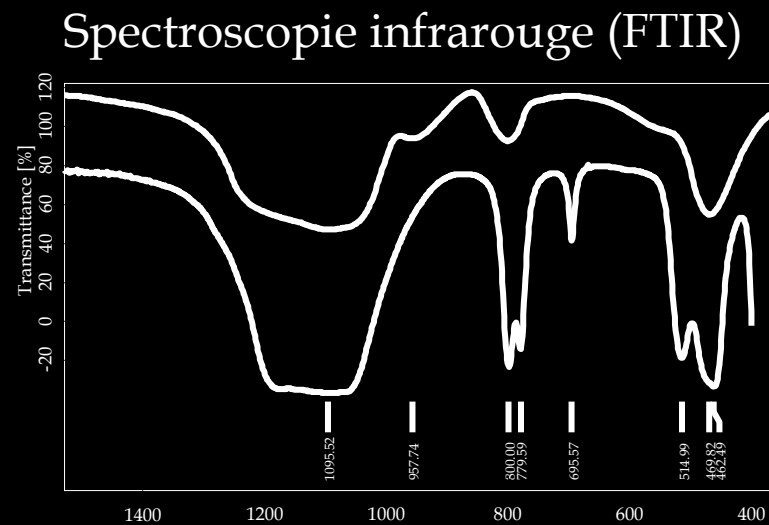
Moderne



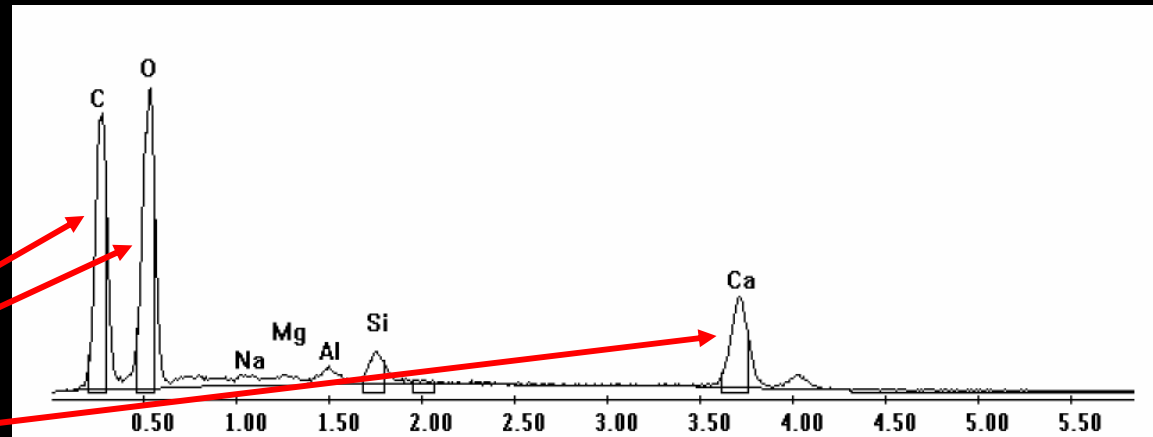
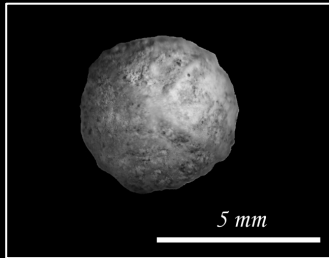
# Méthodes employées



Caractérisation (EDS-SEM)

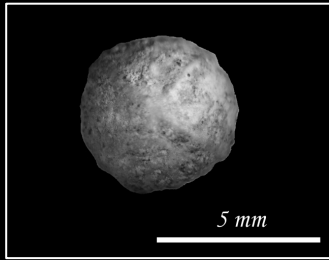


Spectroscopie infrarouge (FTIR)



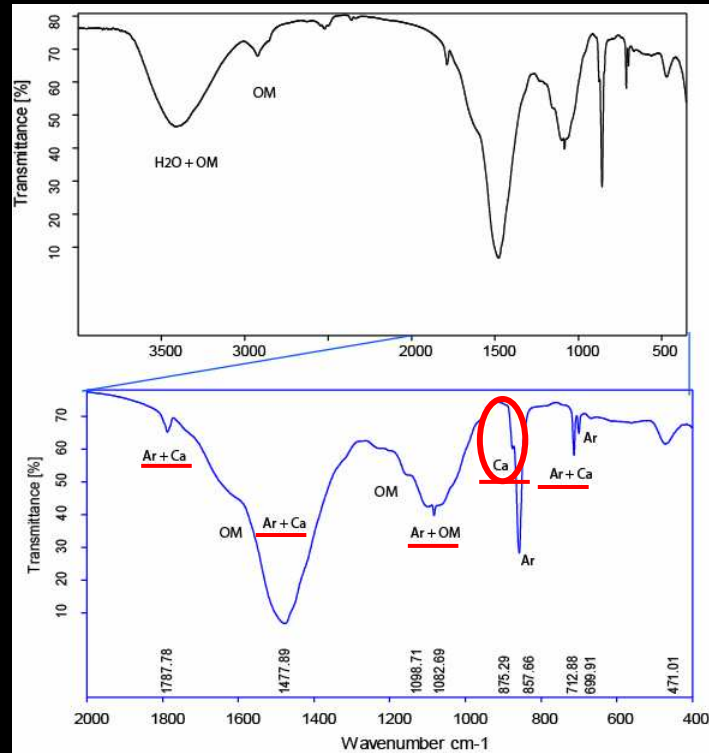
Hypothèse :  
Carbonates de calcium



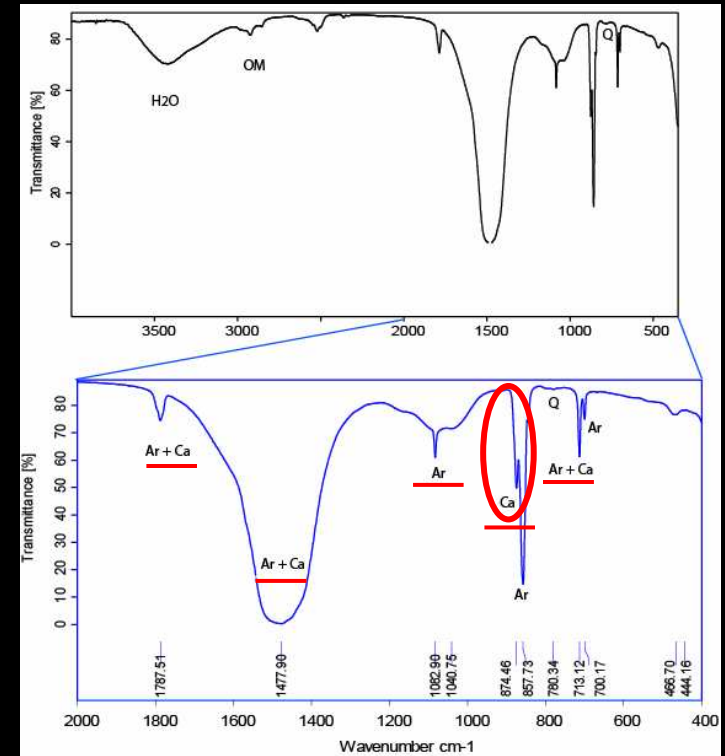


## Carbonates

### Moderne



### Fossile



Moderne

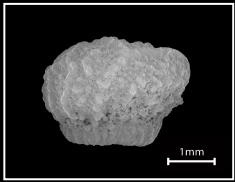
Fossile

Masse	0,75 mg	0,75 mg
Calcite	4 %	79 %
Aragonite	44 %	15 %

Résultats :

1. Carbonates biogéniques

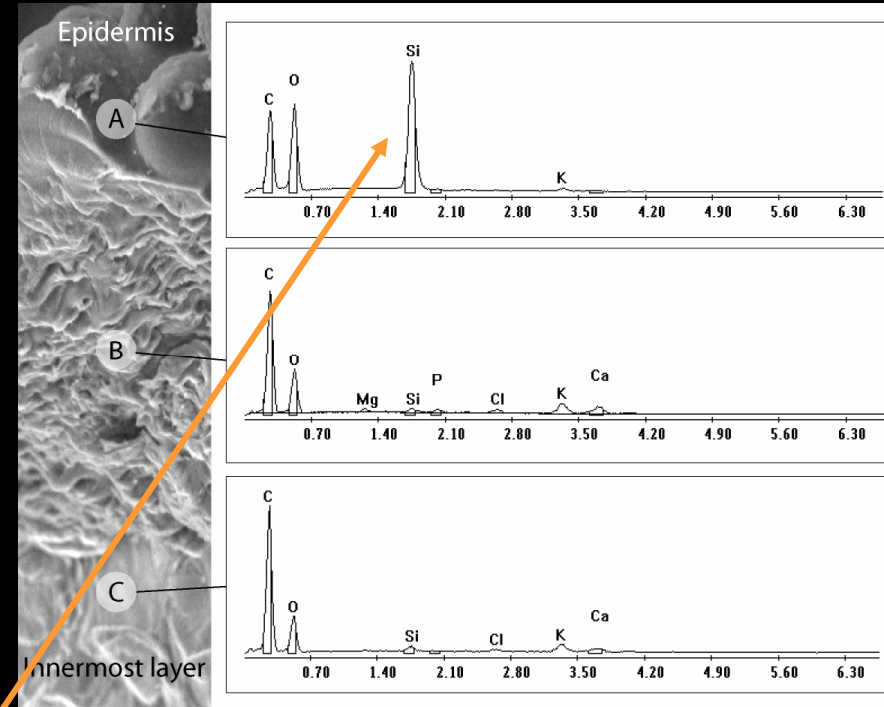
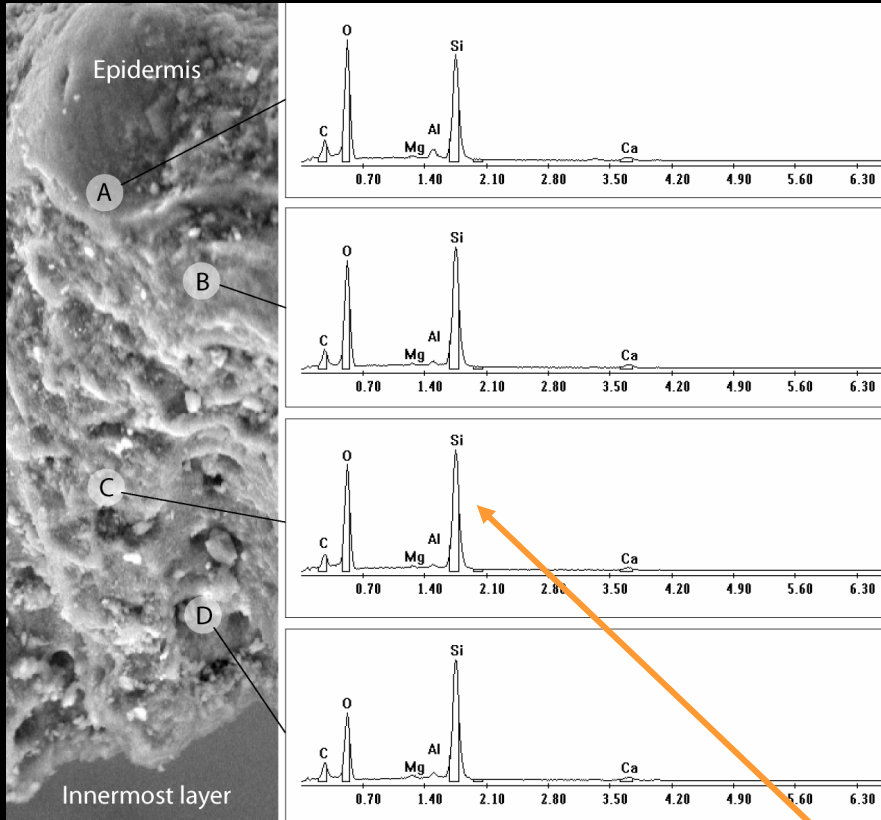
2. Transformation de l'aragonite en calcite lors de la fossilisation



Fossile

Moderne

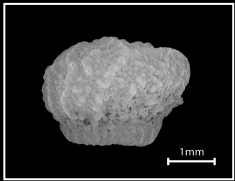
Coupe de l'enveloppe



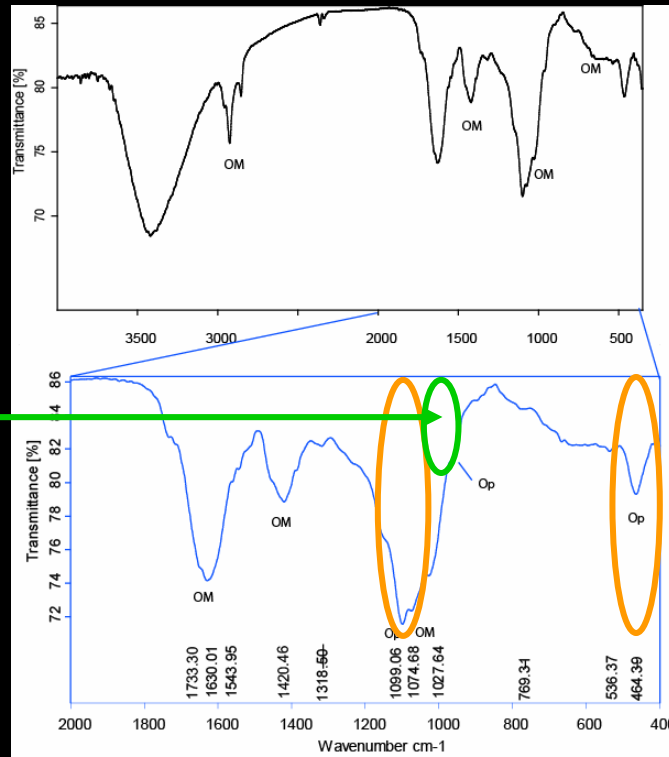
Présence de silice aussi bien dans le spécimen fossile que moderne

# Résultats : Analyses de *Lycopsis*

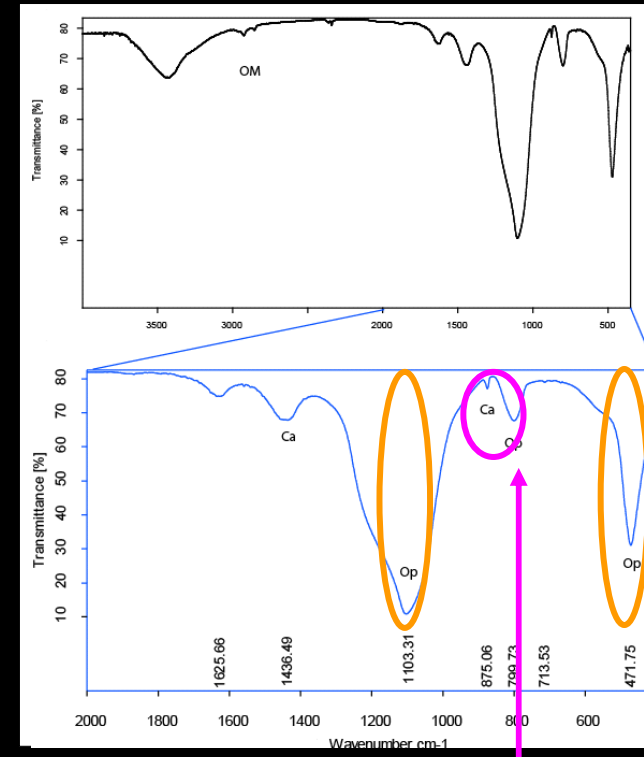
## Spectroscopie infrarouge



### Moderne



### Fossile



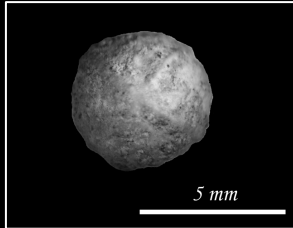
Résultat :

1. Opale de silice biogénique

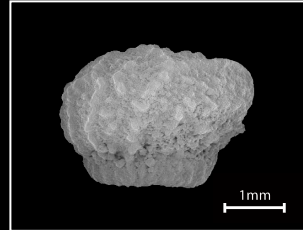
2. Structuration de la silice lors de la fossilisation

# Les processus impliqués et leurs conséquences

Fossile

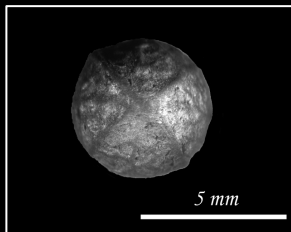


*Celtis sp.*



*Lycopsis sp.*

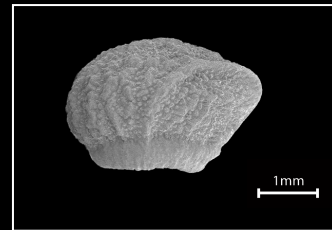
Moderne



Bio-minéralisation

- Carbonates

Diagenèse



Bio-minéralisation

- silice amorphe

Diagenèse

1. Les restes carpologiques sont bio-minéralisés

probabilité plus forte de préservation

2. Les structures minérales se modifient sous l'action de la diagenèse.

stabilisation de la structure minérale

très bonne conservation des structures

Pour un site aussi ancien, de presque 2 millions d'années,

### 1. Observations MEB

la végétation au moment de l'occupation humaine

### 2. Caractérisation EDS + Spectroscopie infrarouge

l'origine de la conservation des fossiles

## Remerciements

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