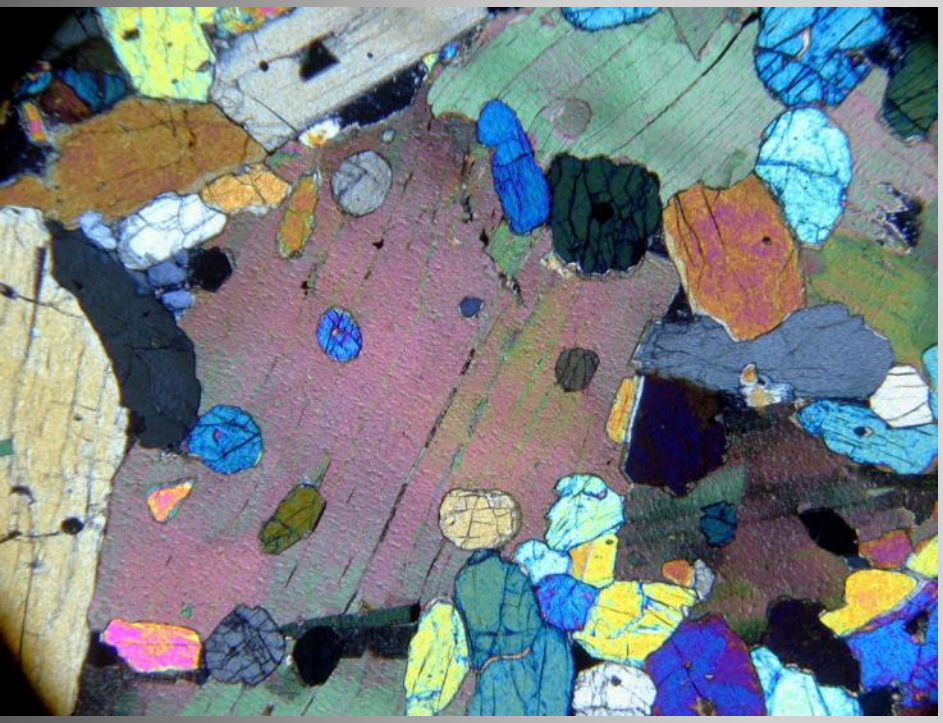
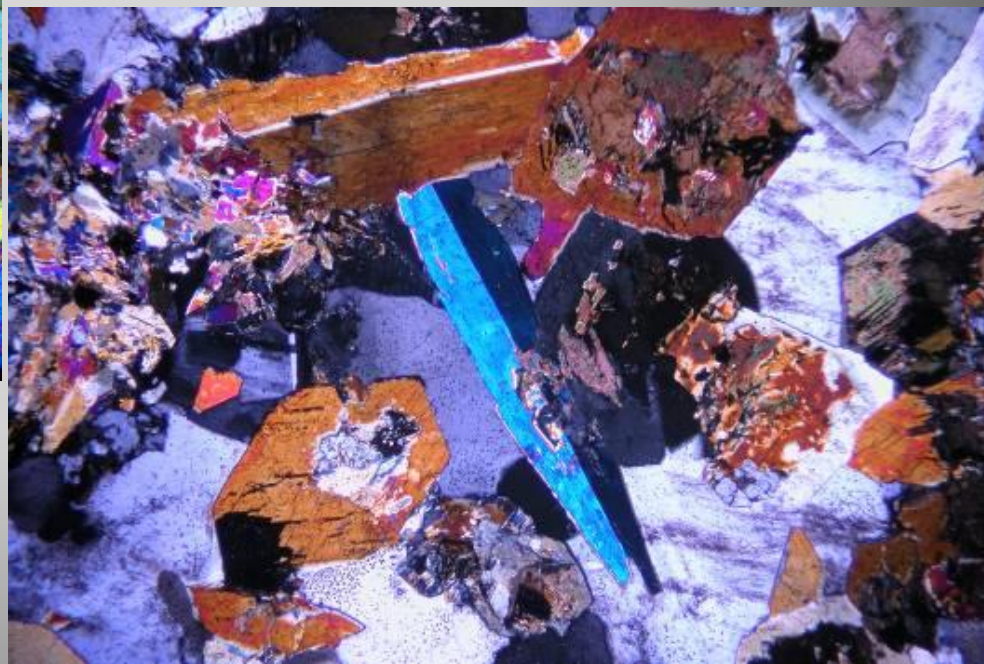
Géodynamique et matériaux





Gilles CHAZOT

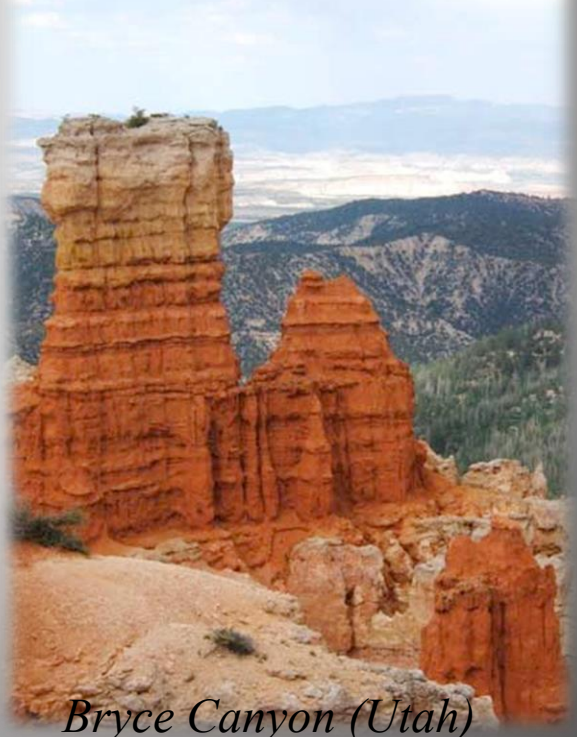
IUEM

02.98.49.87.59

Les roches sédimentaires

Mont Aiguille (26)

Ammonite Bérriasien, Quaix en Ch. (38)



Bryce Canyon (Utah)

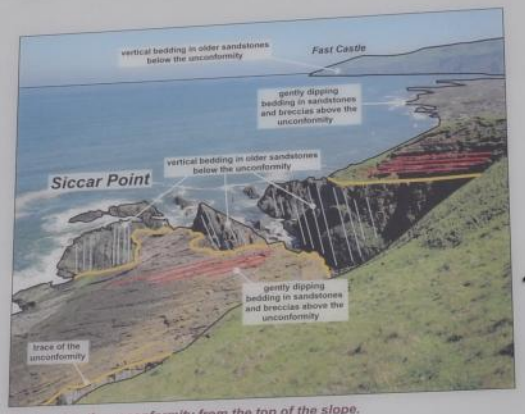
SICCAR POINT

James Hutton (1726 – 1797) known as the founding father of geology was a man of genius. Whilst farming nearby he indulged in his passion for geology. The rocks here at Siccar Point were the defining proof for his revolutionary Theory of the Earth. Most people at this time thought the world no older than a few thousand years. Hutton realised that earth processes are cyclical and that geological time is virtually unlimited. What we see today is very much how he would have seen it over 200 years ago (but a moment in geological time!).

SAFETY WARNING

The slope down to the unconformity is steep and dangerous. Please proceed with care at your own risk along the field boundary to your right. You do not need to go down to the shore to observe what these photographs illustrate.

A close-up of the unconformity from the shore



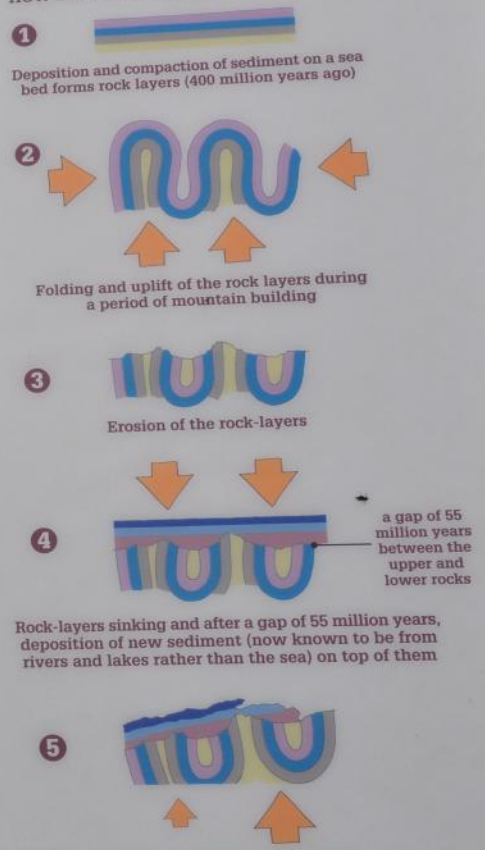
A view onto the unconformity from the top of the slope.

The yellow lines mark the time gap between the underlying vertical rock-layers (greyish in colour and called 'Greywackes') and the overlying gently dipping rock-layers (reddish in colour and called 'Old Red Sandstone and Conglomerates'). The gap represents 55 million years.

During this time the underlying rocks formed from layers of sediment deposited on the floor of an ancient ocean, had been folded, uplifted and eroded. This produced an uneven land surface onto which the overlying rocks were then deposited as sand and gravel. The irregular surface between the vertical and the gently dipping rock-layers is known as an unconformity.

"Having taken boat at Dunglass Burn, we set out to explore the coast", writes James Hutton of his trip down the Berwickshire coast with his friends John Playfair and James Hall from nearby Dunglass, to find the proof for his theory…and this they did. *"At Siccar Point"*, he wrote *"… we found a beautiful picture of this junction washed bare by the sea"*. John Playfair, deeply moved by the significance of what they observed wrote later *"The mind seemed to grow giddy by looking so far into the abyss of time"*.

HOW THE UNCONFORMITY WAS FORMED



To find out more about Hutton AND THE TRAIL take a trip to the James Hutton Exhibition located at the Reiver Country Farm shop in Auchencrow.

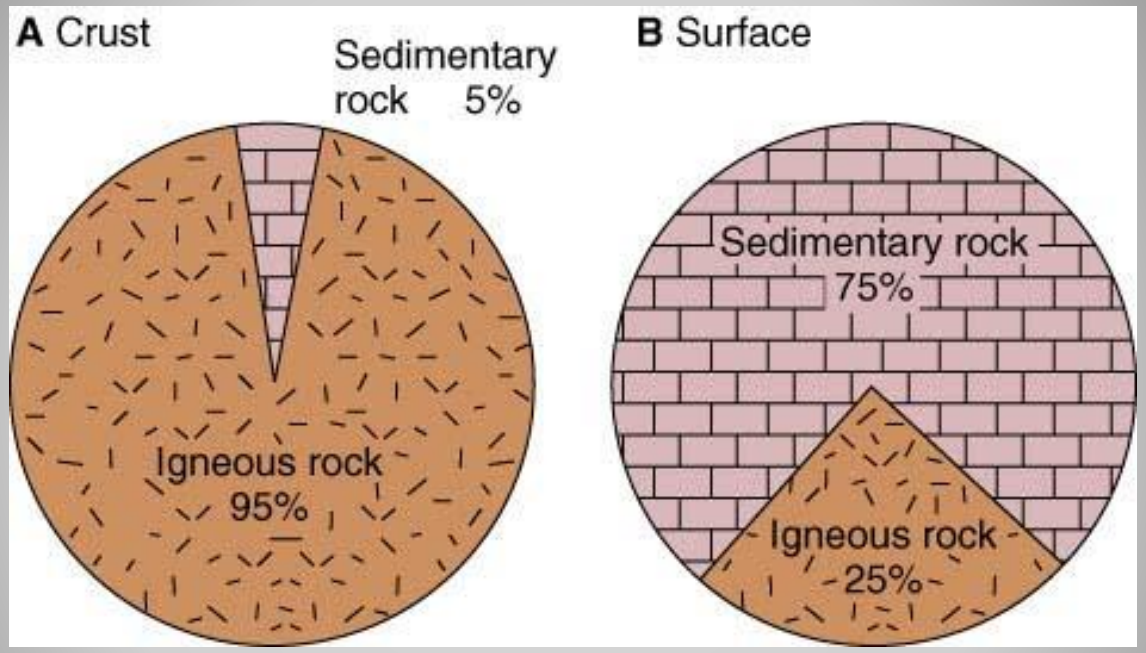
This project was initiated by BFRS and implemented in partnership with farmers on whose land this trail occurs and with public and private funding. www.bfrs.org

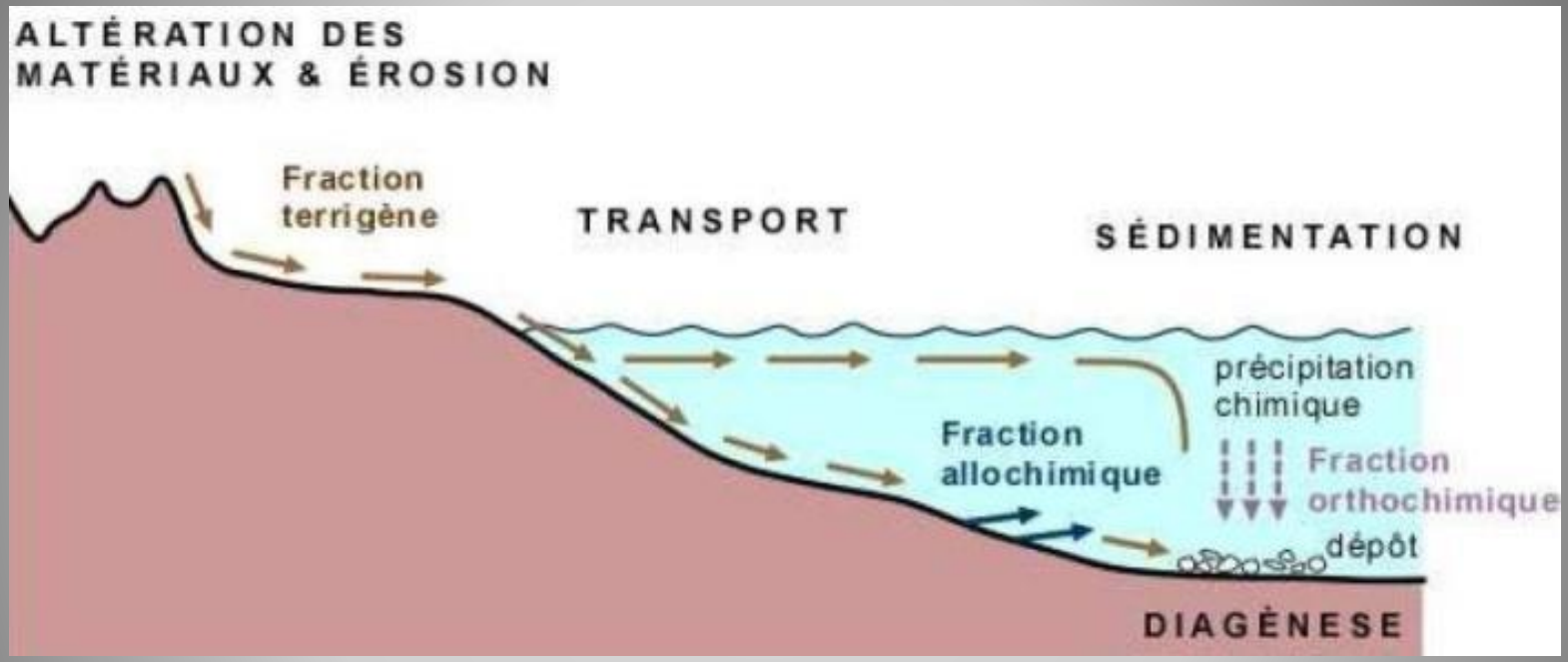
PROJECT PART-FINANCED BY THE EUROPEAN UNION

SCOTTISH NATURAL HERITAGE

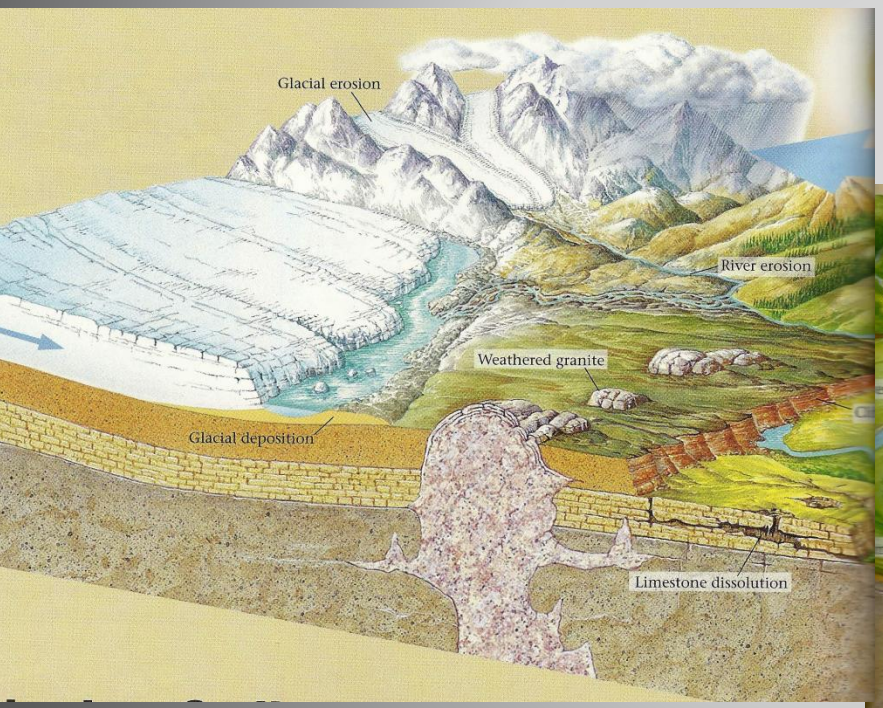
British Geological Survey

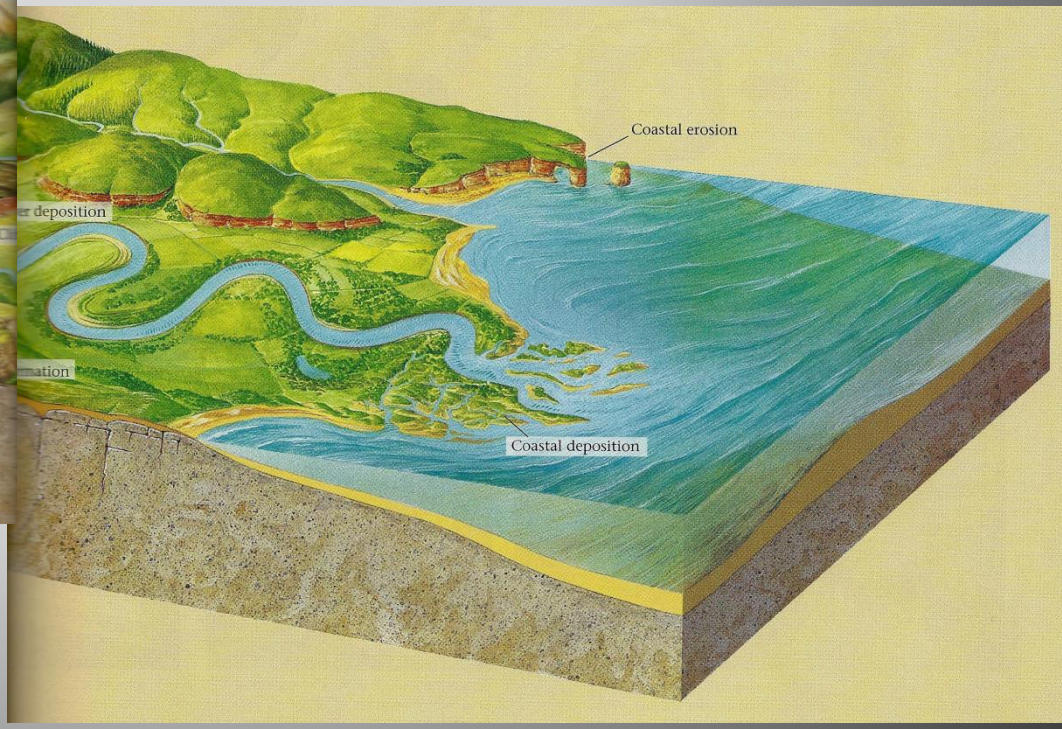
UKRIGS

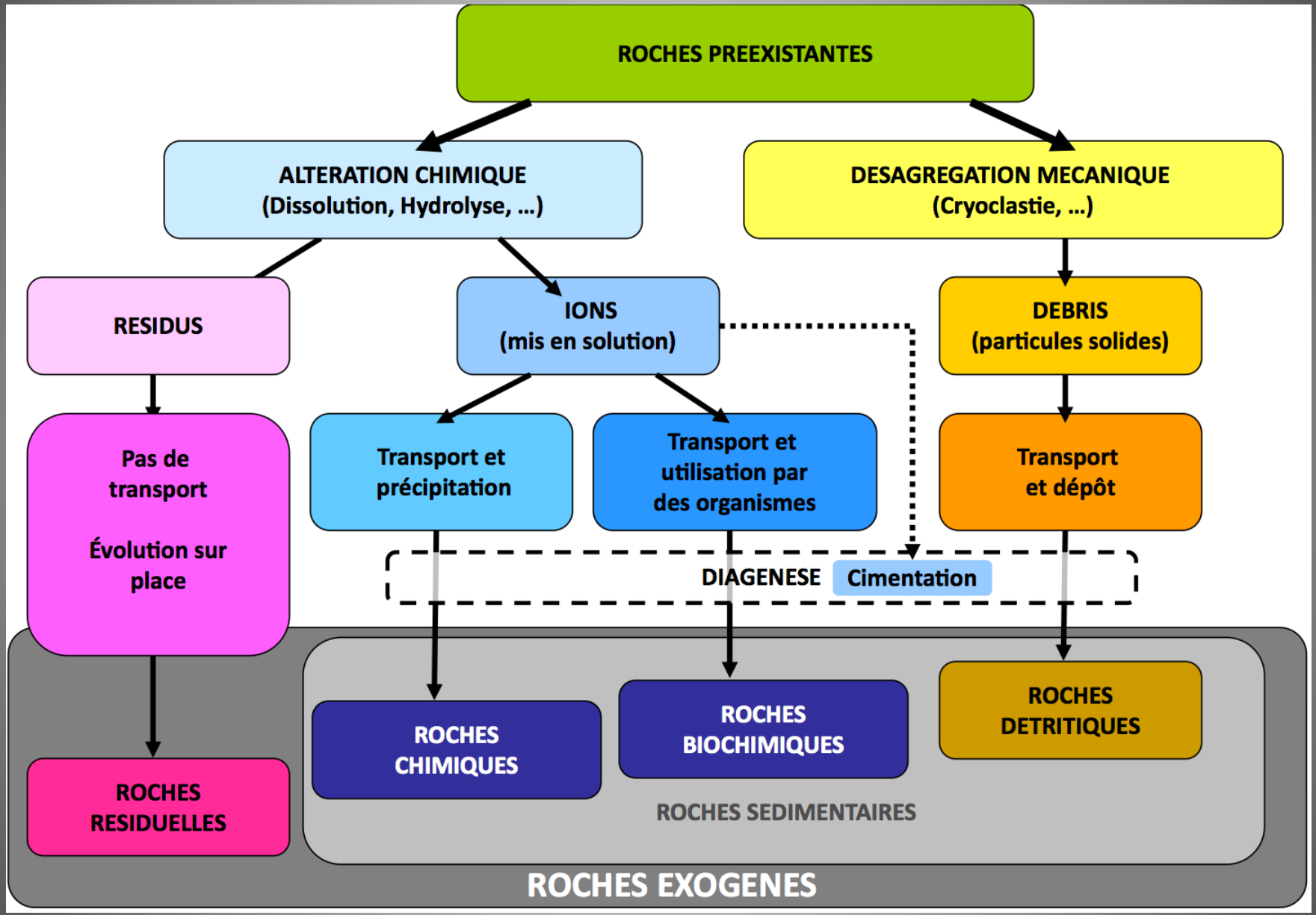

A Crust
Sedimentary rock 5%
Igneous rock 95%
B Surface
Sedimentary rock 75%
Igneous rock 25%

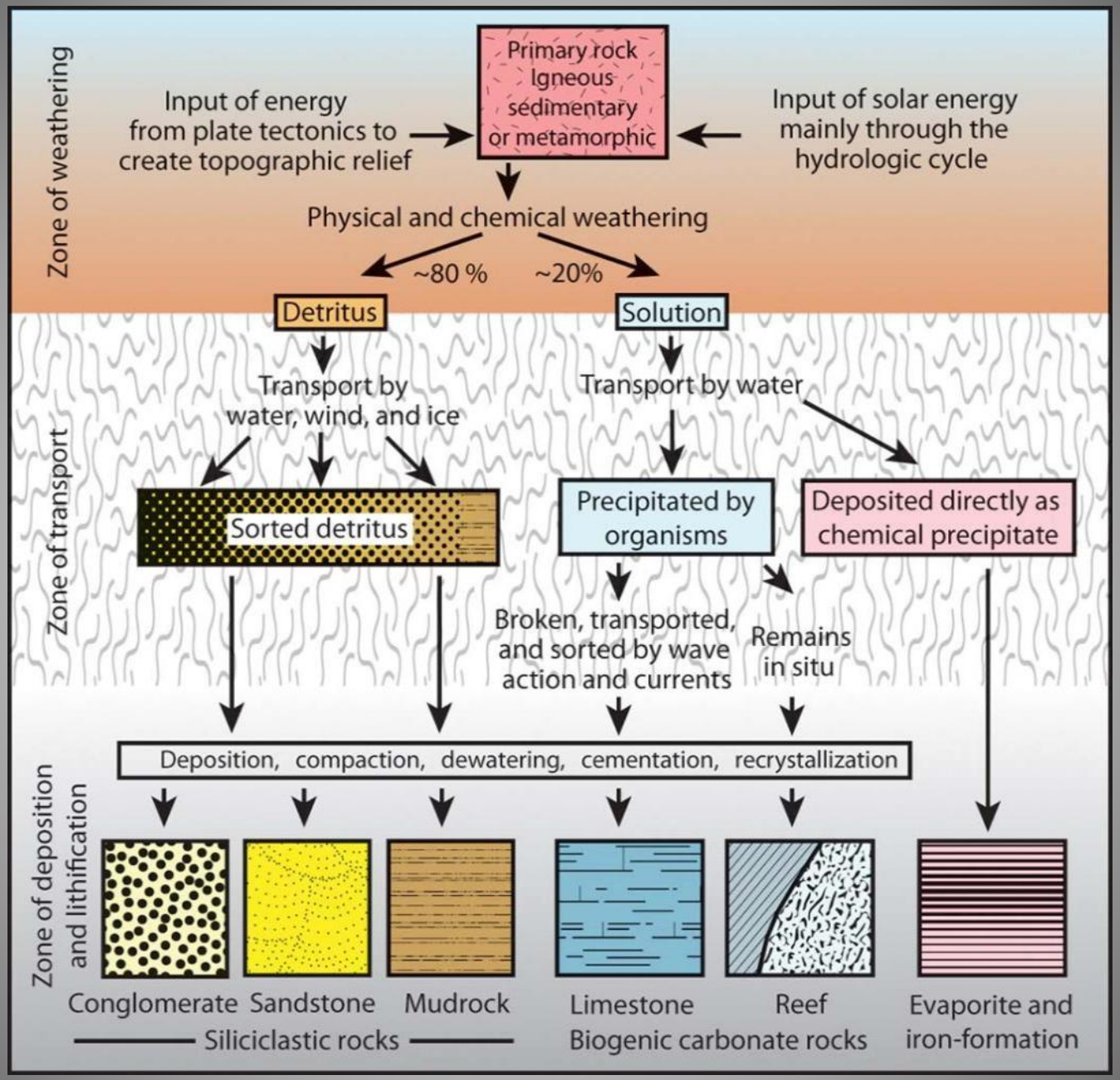

ALTÉRATION DES
MATÉRIAUX & ÉROSION
Fraction
terrigène
TRANSPORT
SÉDIMENTATION
précipitation
chimique
Fraction
allochimique
Fraction
orthochimique
dépôt
DIAGÈNESE

Erosion, transport, sédimentation





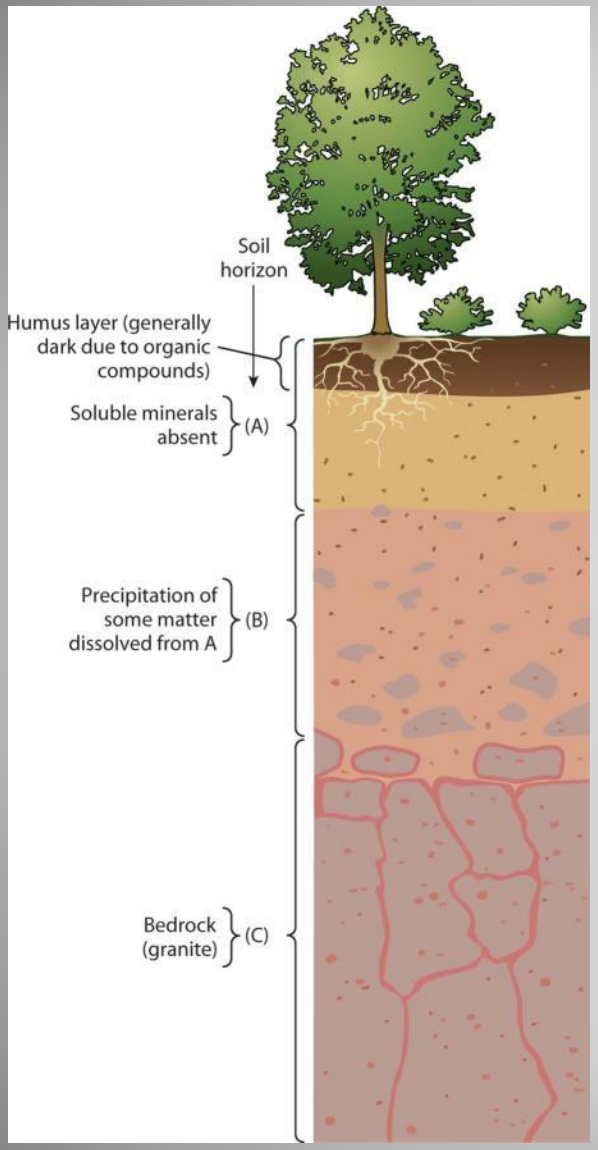

ROCHES PREEXISTANTES
ALTERATION CHIMIQUE
(Dissolution, Hydrolyse, …)
DESAGREGATION MECANIQUE
(Cryoclastie, …)
RESIDUS
IONS
(mis en solution)
DEBRIS
(particules solides)
Pas de transport
Évolution sur place
Transport et précipitation
Transport et utilisation par des organismes
Transport et dépôt
DIAGENESE
Cimentation
ROCHES RESIDUELLES
ROCHES CHIMIQUES
ROCHES BIOCHIMIQUES
ROCHES DETRITIQUES
ROCHES SEDIMENTAIRES
ROCHES EXOGENES


Zone of weathering
Primary rock
Igneous
sedimentary
or metamorphic
Input of energy
from plate tectonics to
create topographic relief
Input of solar energy
mainly through the
hydrologic cycle
Physical and chemical weathering
~80 %
~20%
Detritus
Solution
Zone of transport
Transport by
water, wind, and ice
Transport by water
Sorted detritus
Precipitated by
organisms
Deposited directly as
chemical precipitate
Broken, transported,
and sorted by wave
action and currents
Remains
in situ
Deposition, compaction, dewatering, cementation, recrystallization
Zone of deposition
and lithification
Conglomerate
Sandstone
Mudrock
Limestone
Reef
Evaporite and
iron-formation
Siliciclastic rocks
Biogenic carbonate rocks

Tout commence par altération / érosion…

Profil d'altération, parc de la Rivière Bleue (N.C.)

Erosion

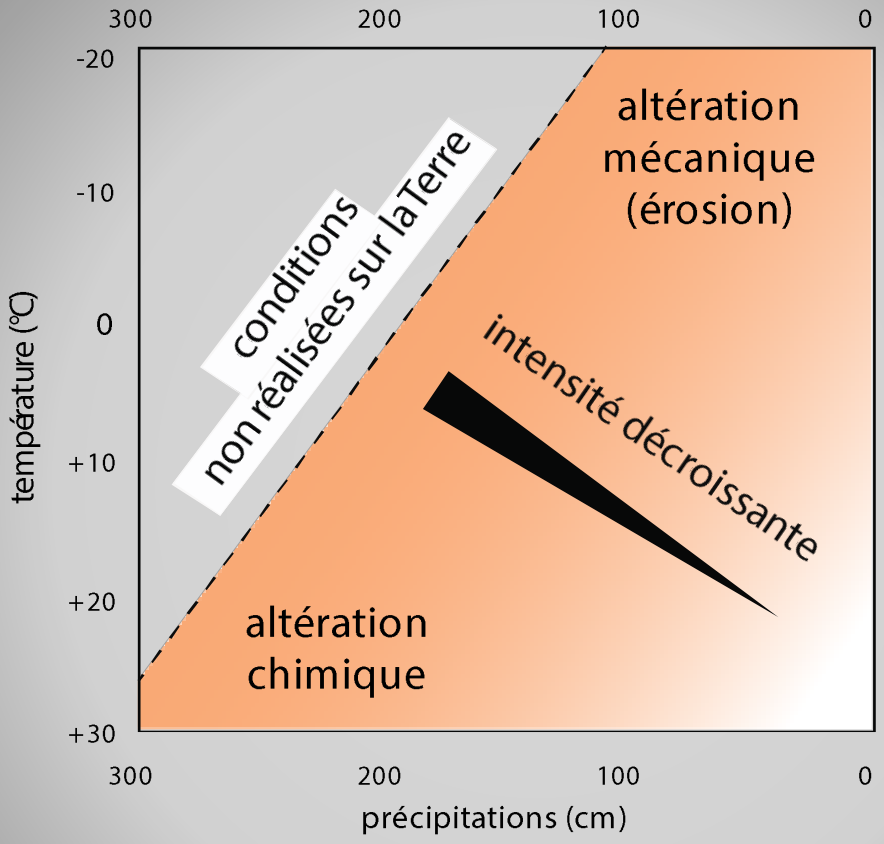


Arène granitique sur l'Île Callot

Altération chimique (hydrolyse)

$2KAlSi_3O_8 + 2CO_2 + 11H_2O \rightarrow Al_2Si_2O_5(OH)_4 + 2K^+ + 2HCO_3^- + 4H_4SiO_4$

Feldspath Eau de pluie Kaolinite Ion K Ion bicarbonate Acide silicique



Type et l'intensité des altérations

La dissolution et l'hydrolyse sont les deux processus principaux de l'altération chimique. Oxydation et hydratation/déshydration jouent un rôle plus mineur.

La **dissolution** est la décomposition totale d'un minéral, c'est par exemple le cas de la calcite ou de l'aragonite :

$$CaCO_3 + CO_2 + H_2O \rightarrow Ca^{2+} + 2HCO_3^-$$

L'**hydrolyse** est la décomposition incomplète conduisant à un minéral résiduel :

$$2NaAlSi_3O_8 + 2CO_2 + 11H_2O$$

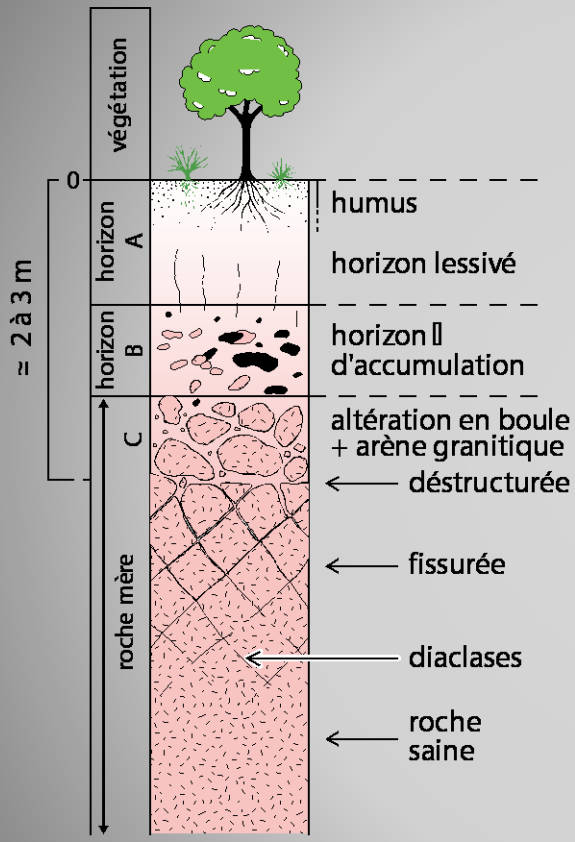
Albite

$$\downarrow$$

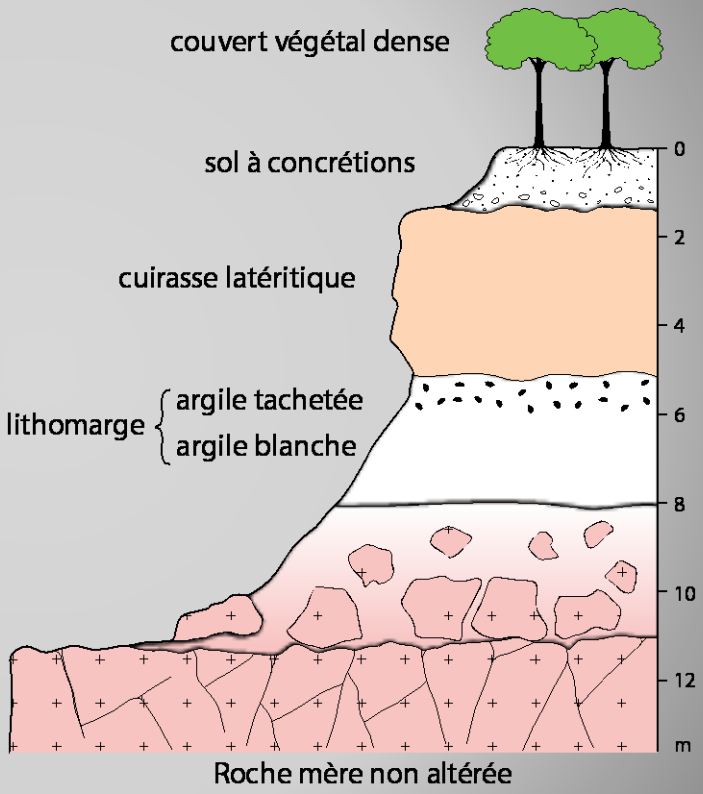
$$Si_2O_5Al_2(OH)_4 + 2Na^+ + 2HCO_3^- + 4H_4SiO_4$$

kaolinite acide silicique

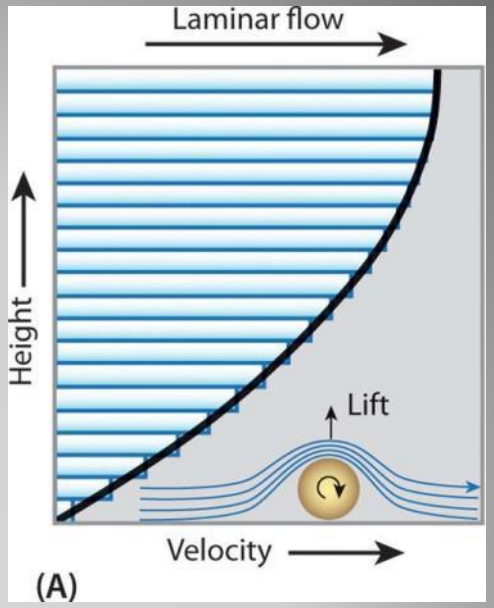
Région tempérée

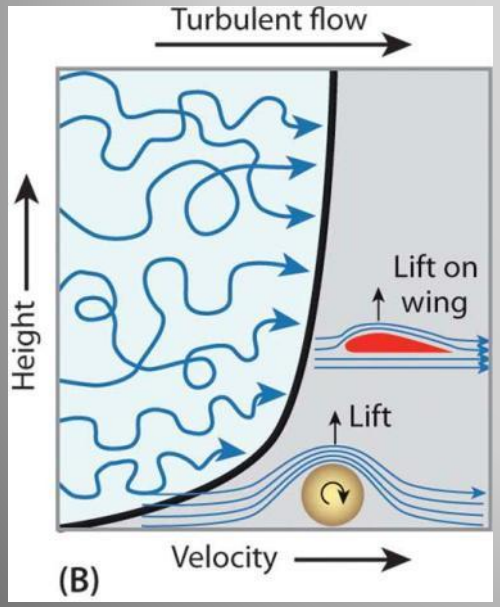


Région tropicale humide

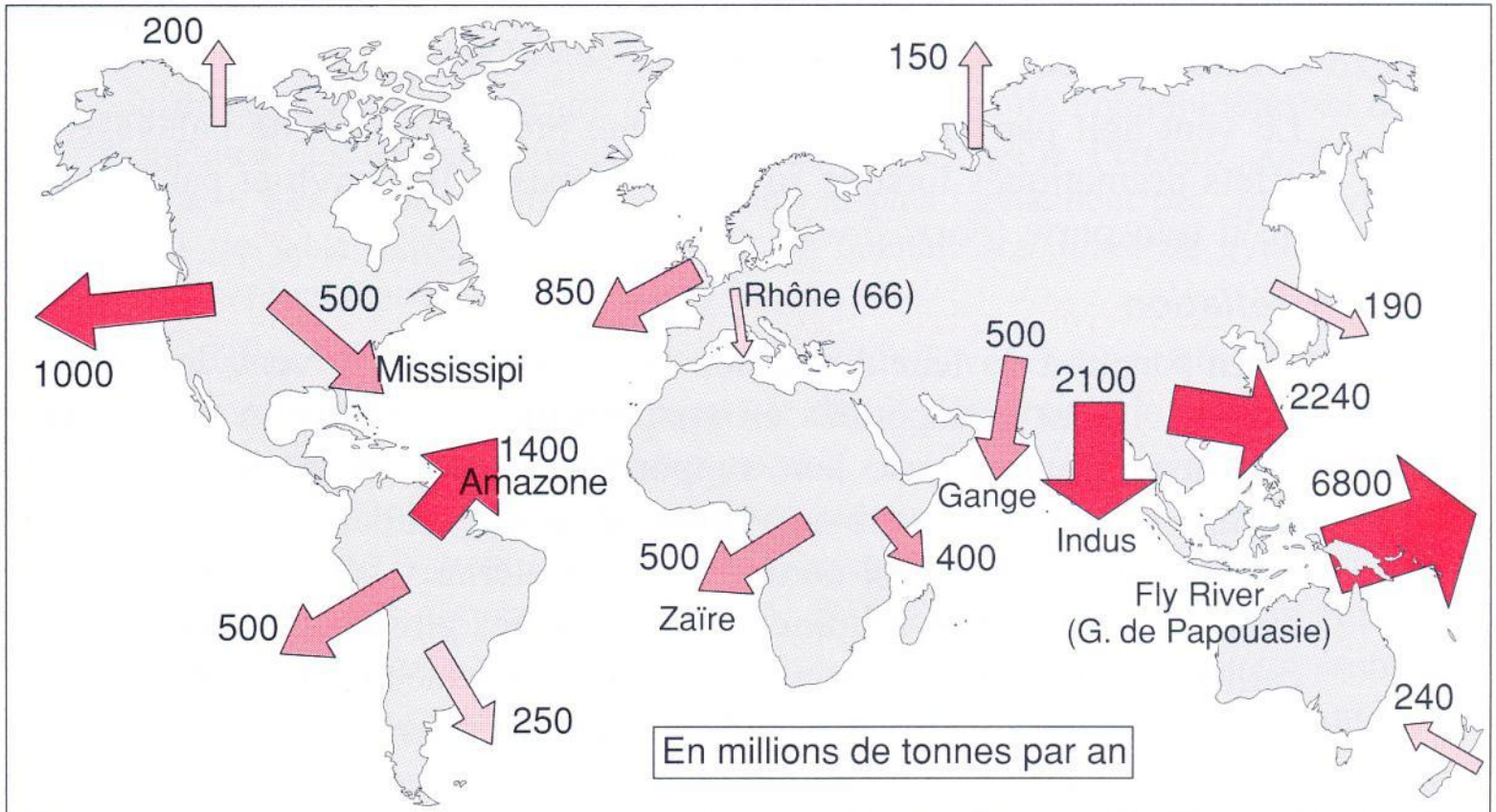


Transport

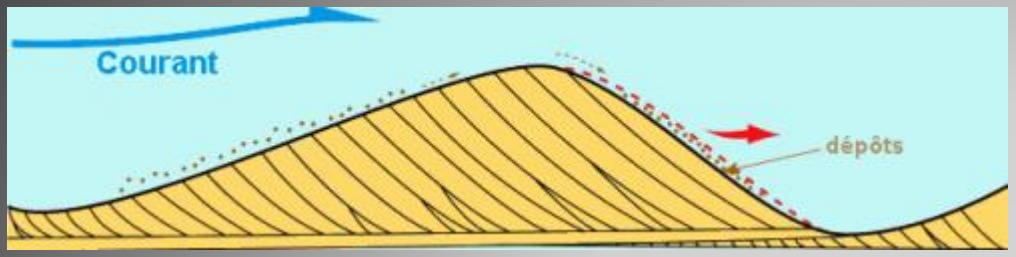

Laminar flow
Height
Lift
Velocity
(A)

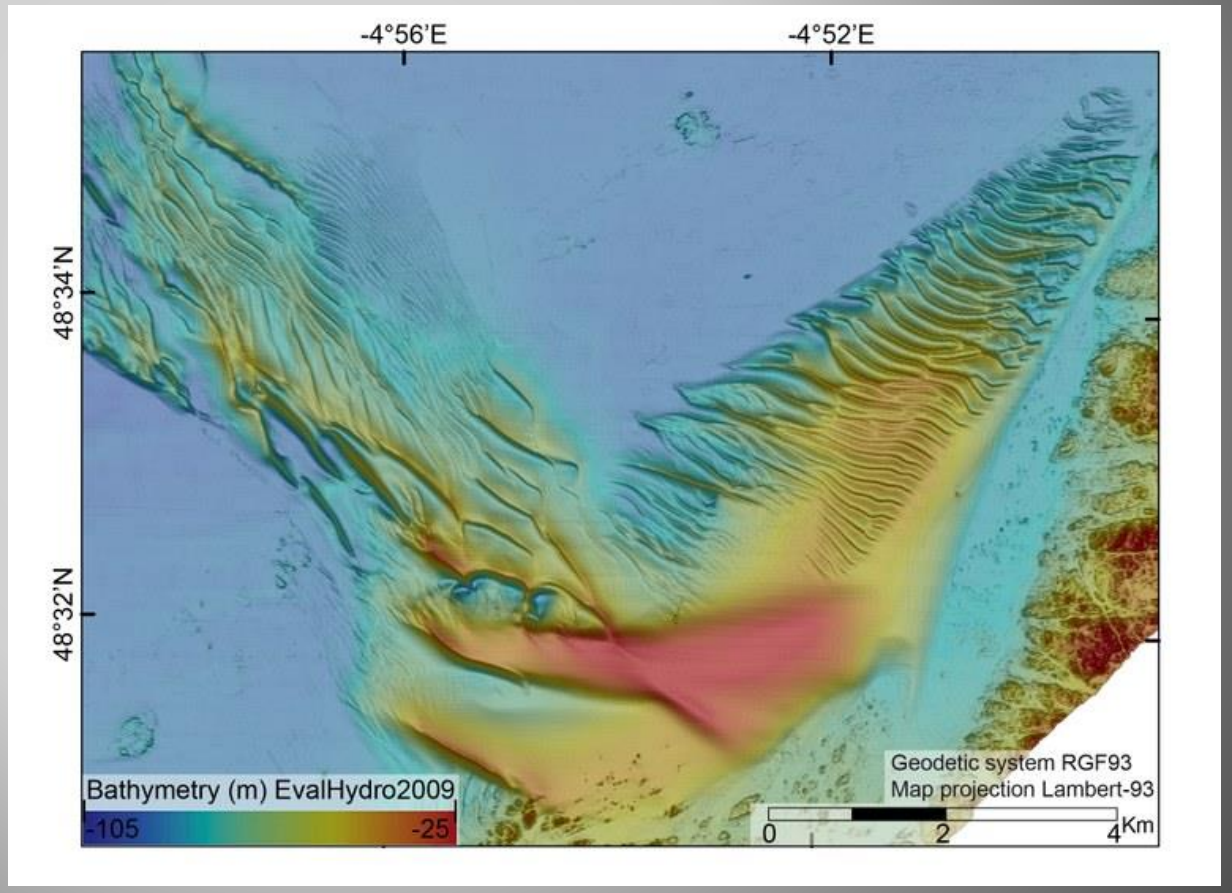

Turbulent flow
Height
Lift on wing
Lift
Velocity
(B)


USGS
science for a changing world
NASA
0
10
20 Miles
N



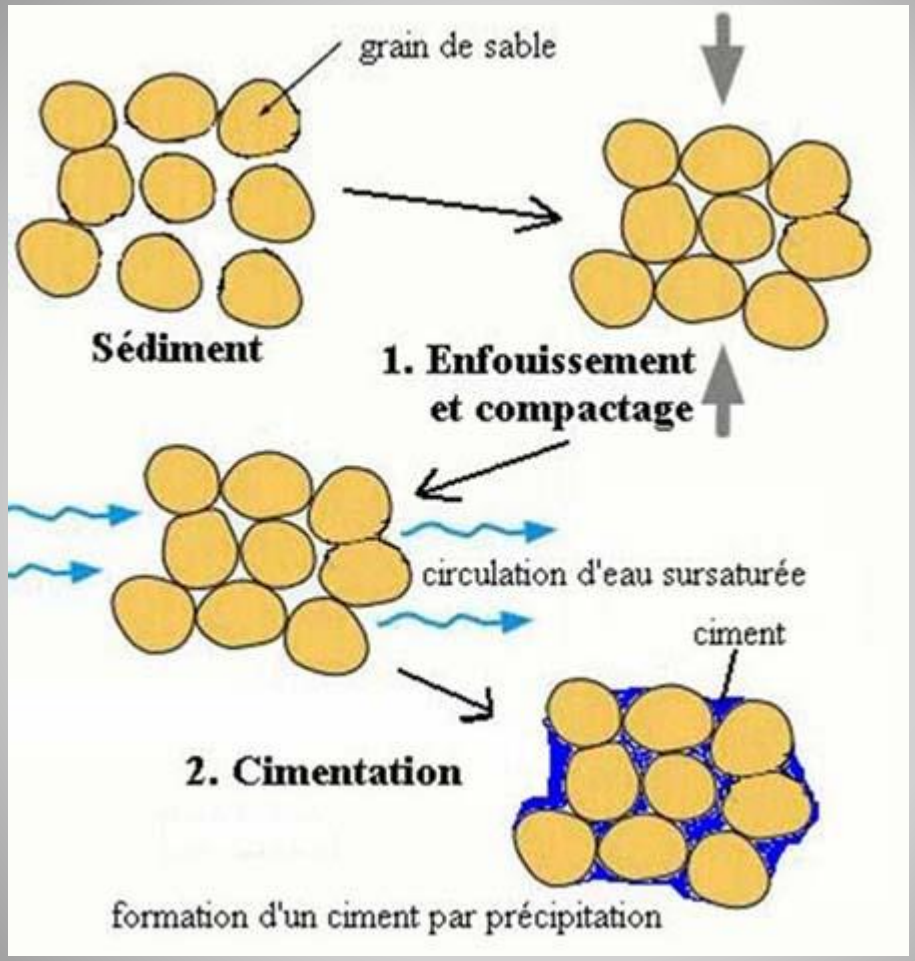
Décharge de charges solides par les fleuves. Total : 18,3 milliards de tonnes/an

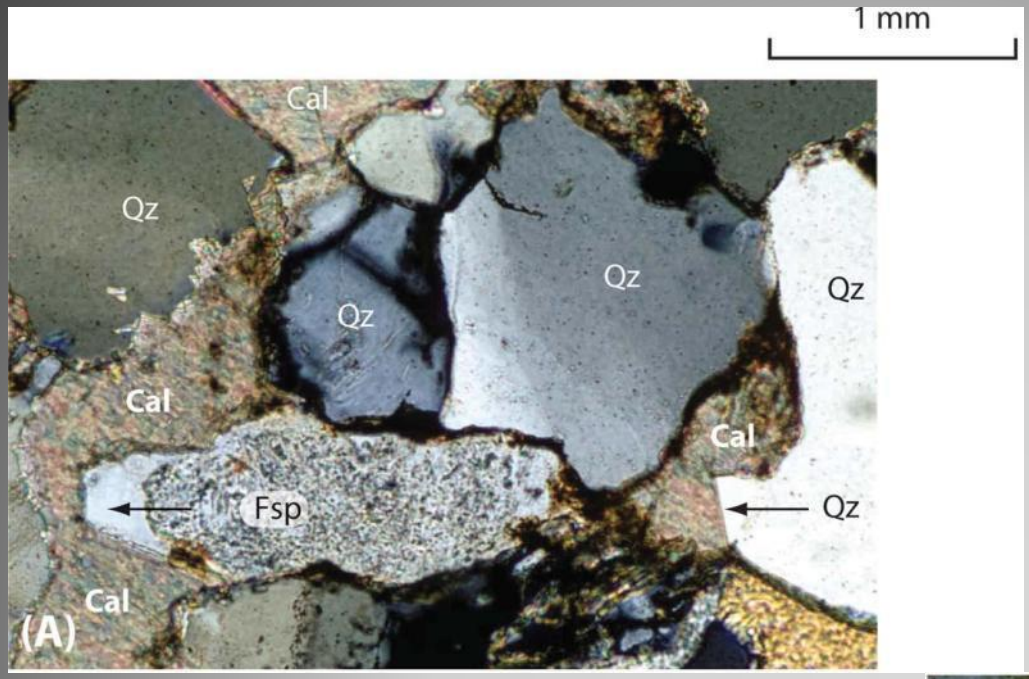

Courant
dépôts

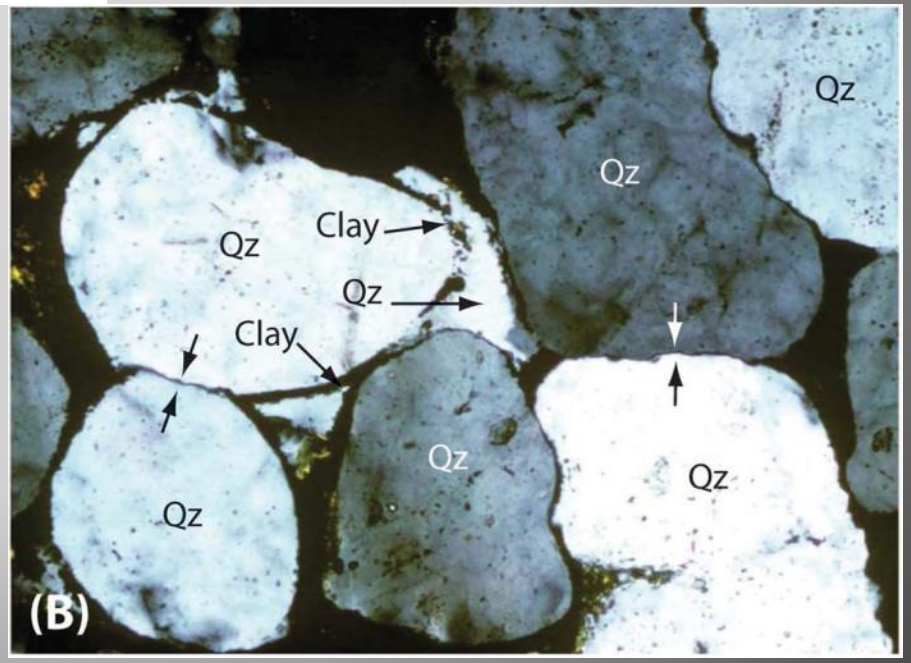

-4°56'E
-4°52'E
48°34'N
48°32'N
Bathymetry (m) EvalHydro2009
-105
-25
Geodetic system RGF93
Map projection Lambert-93
0
2
4Km

Sédimentation

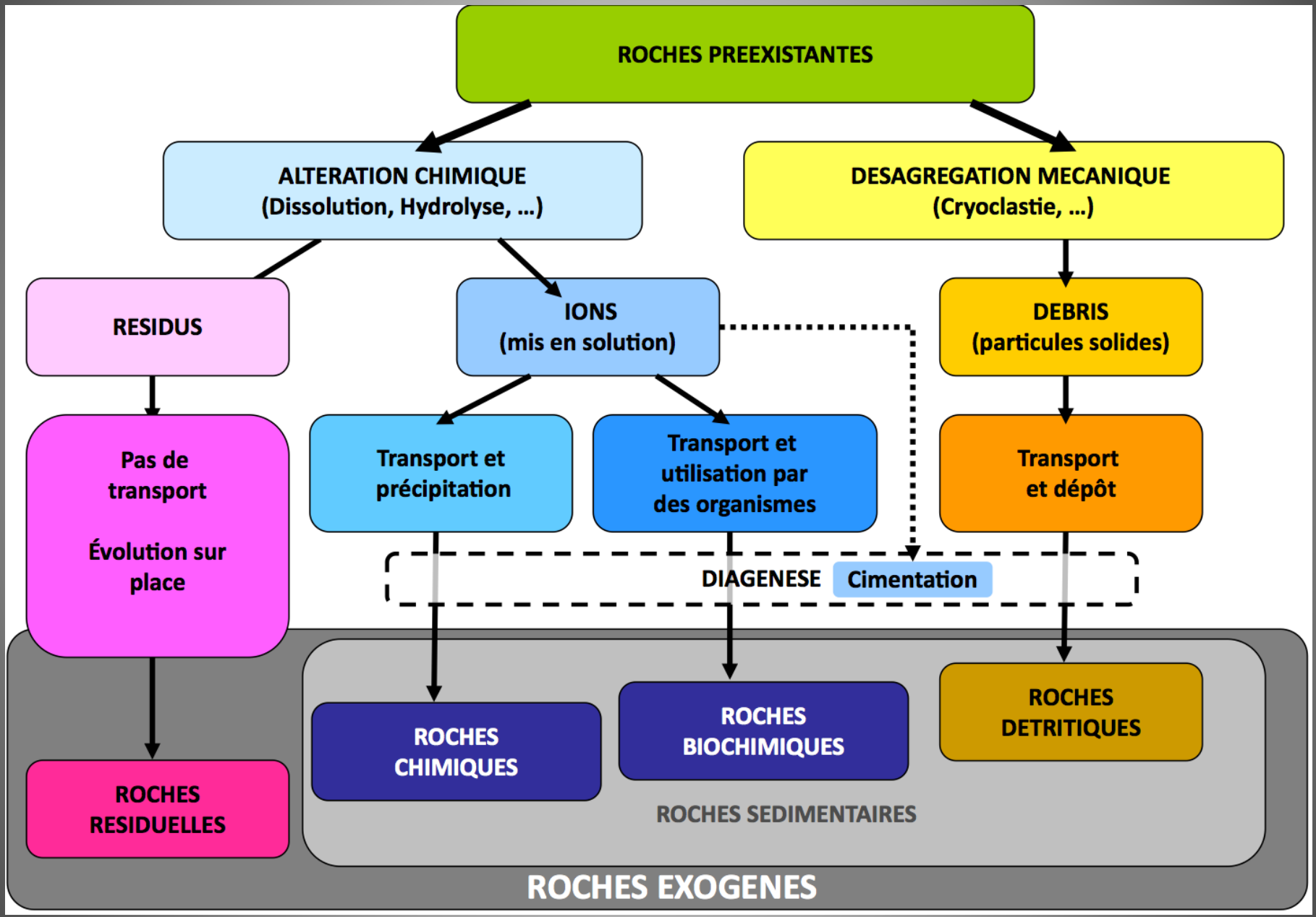
Diagenèse


grain de sable
Sédiment
1. Enfouissement
et compactage
circulation d'eau sursaturée
ciment
2. Cimentation
formation d'un ciment par précipitation


1 mm
Cal
Qz
Qz
Qz
Qz
Cal
Cal
Fsp
Qz
Cal
(A)


Qz
Qz
Clay
Qz
Qz
Clay
Qz
Qz
Qz
(B)

- 1/ Nomenclature
- 2/ Géodynamique
- 3/ Roches sédimentaires et l’homme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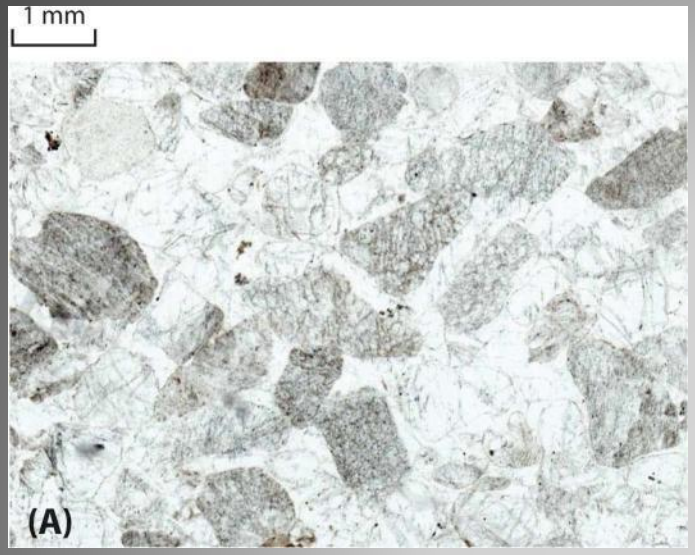
CHIMIQUES
ROCHES
BIOCHIMIQUES
ROCHES
DETRITIQUES
ROCHES SEDIMENTAIRES
ROCHES EXOGENES

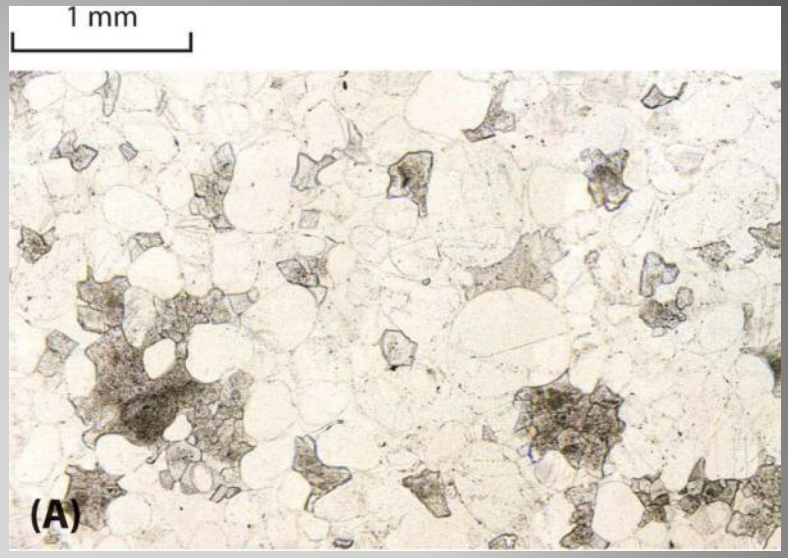
- Roches sédimentaires détritiques
- R.sedimentaires résiduelles
- R.sédimentaires chimiques
- R.sédimentaires évaporitiques
- R.sédimentaires carbonées

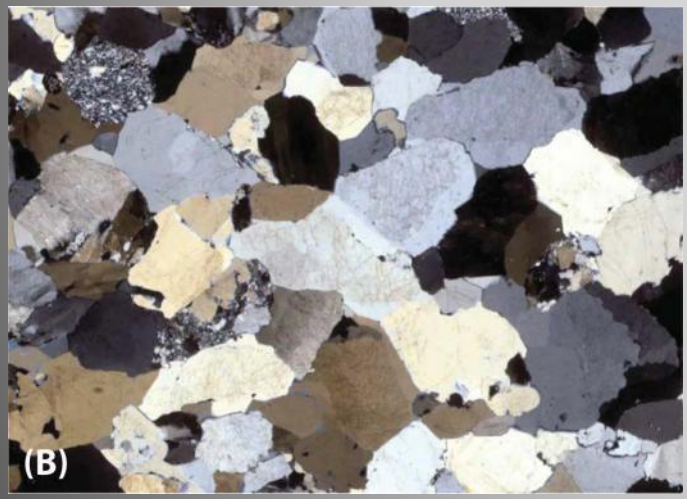
- Constitués par l’accumulation de débris d’autres roches !

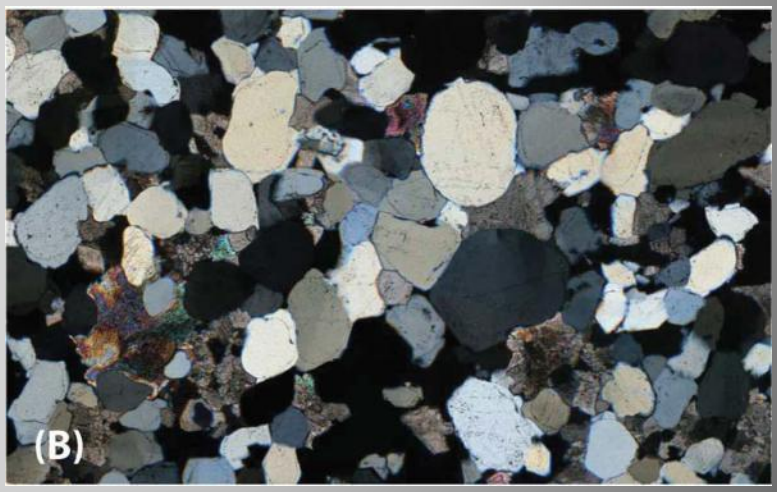
Taille des particules (mm)	Classes granulométriques	Eléments	Sédiments non consolidés	Sédiments consolidés
256	RUDITES	BLOCS		
		GALETS, CAILLOUX	CAILLOUTIS	CONGLOMERAT
16				
2		GRAVIERS	GRAVIERS, GRAVES	MICROCONGLOMERAT
1	ARENITES	très grossiers		
0,50		GRAINS I grossiers		ARENITE
0,25		DE I moyens	SABLE	"GRES"
0,125		SABLE I fins		
0,063		très fins		
0,050	LUTITES	PARTICULES SILTEUSES	SILT	SILTITE
				"PELITE"
0,002		ARGILES	ARGILE	ARGILITE

Grès







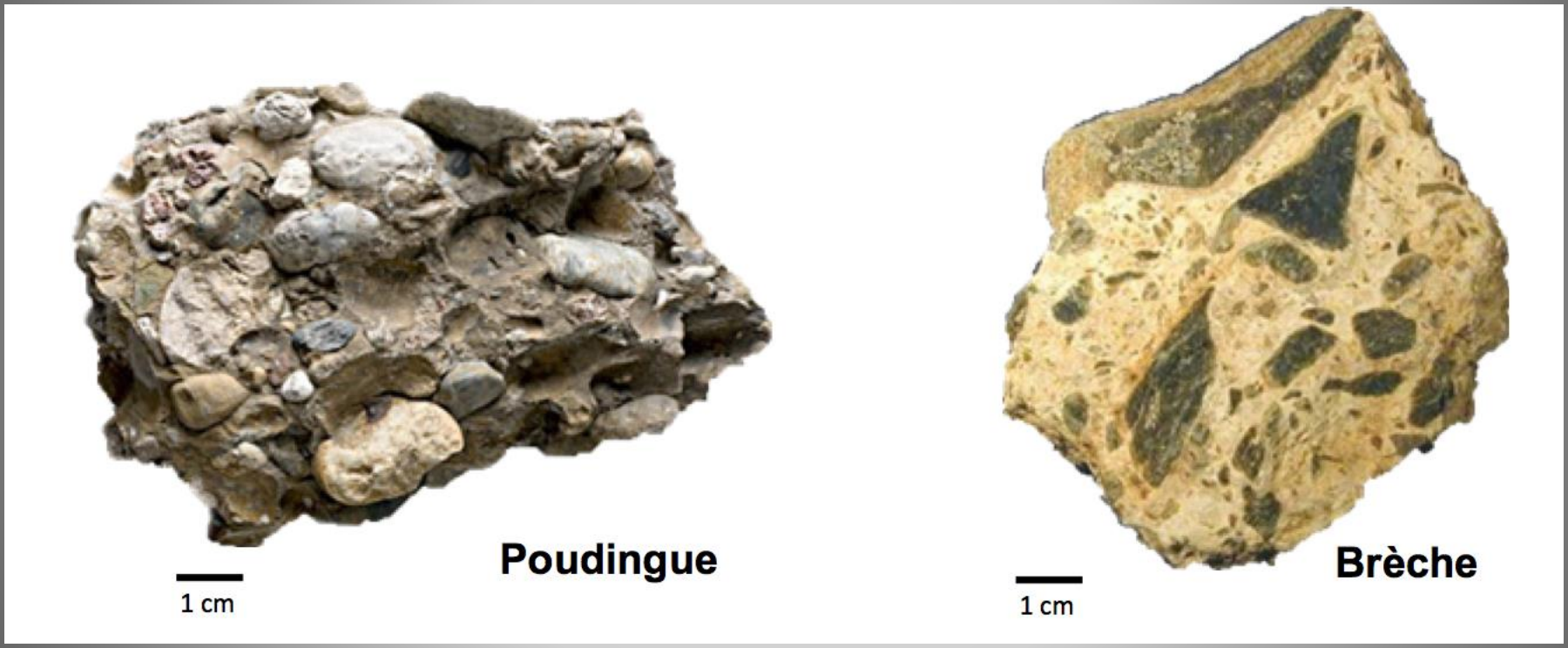


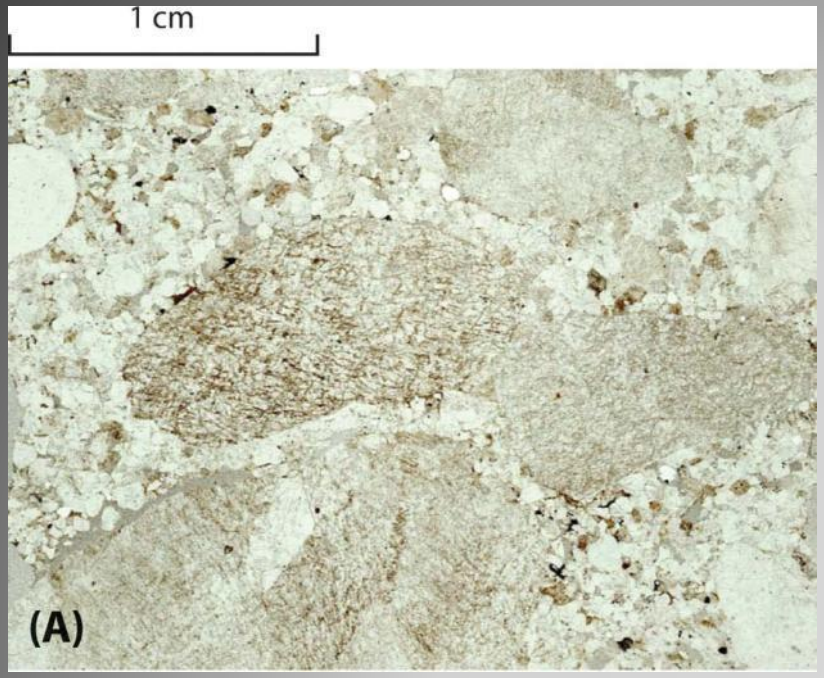
Ciment siliceux

Ciment calcaire

Monument Valley, Arizona

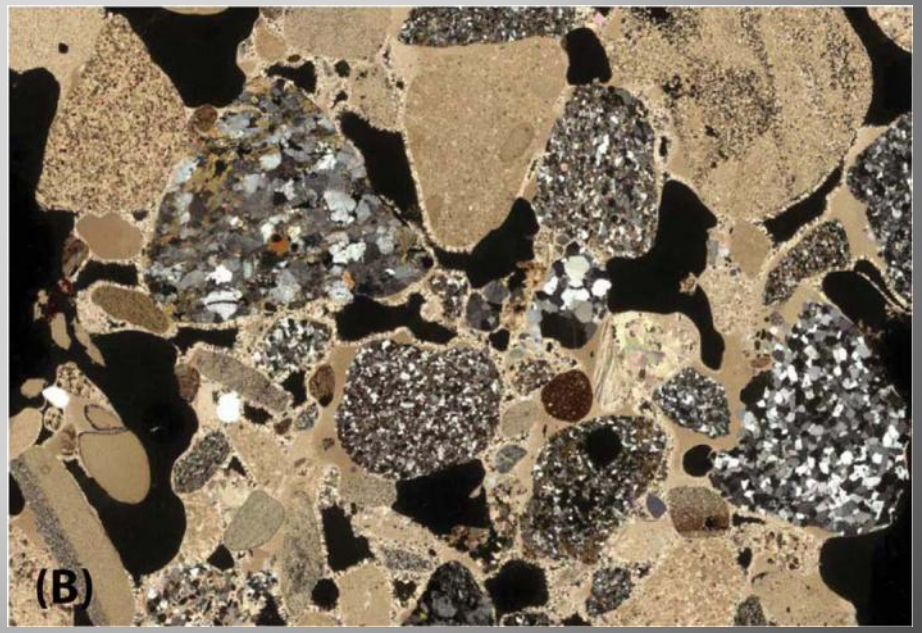
Conglomérats

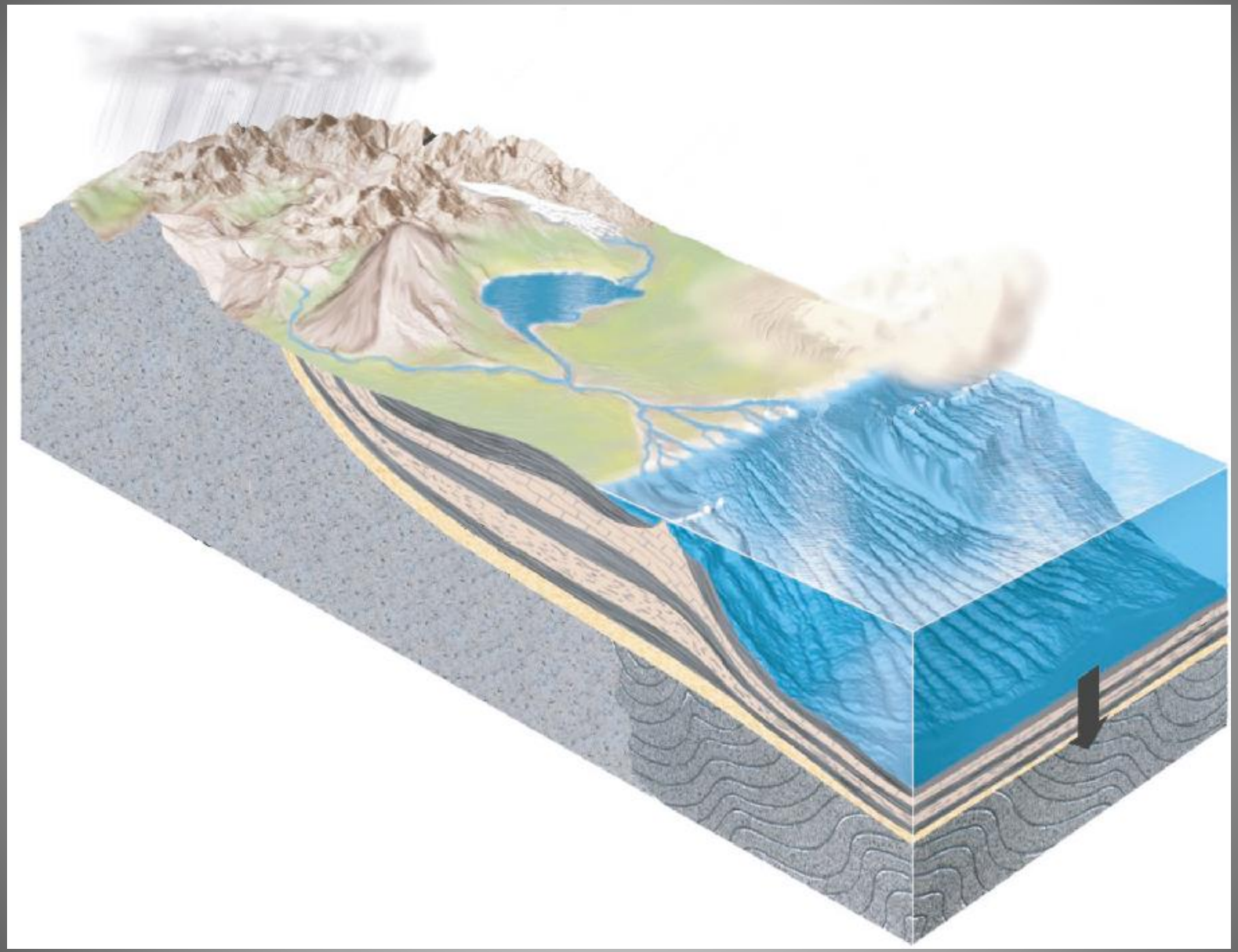


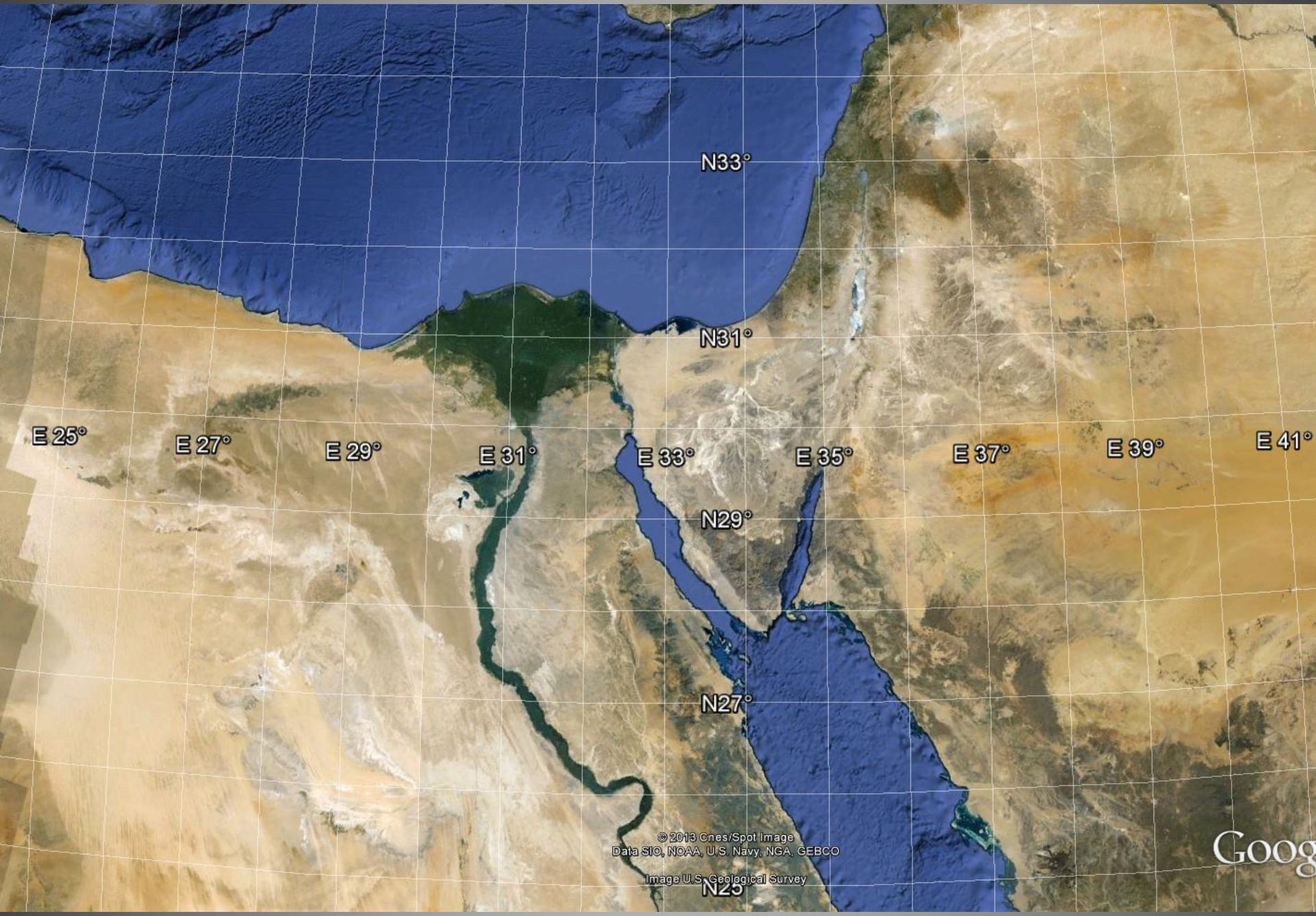


Conglomérat

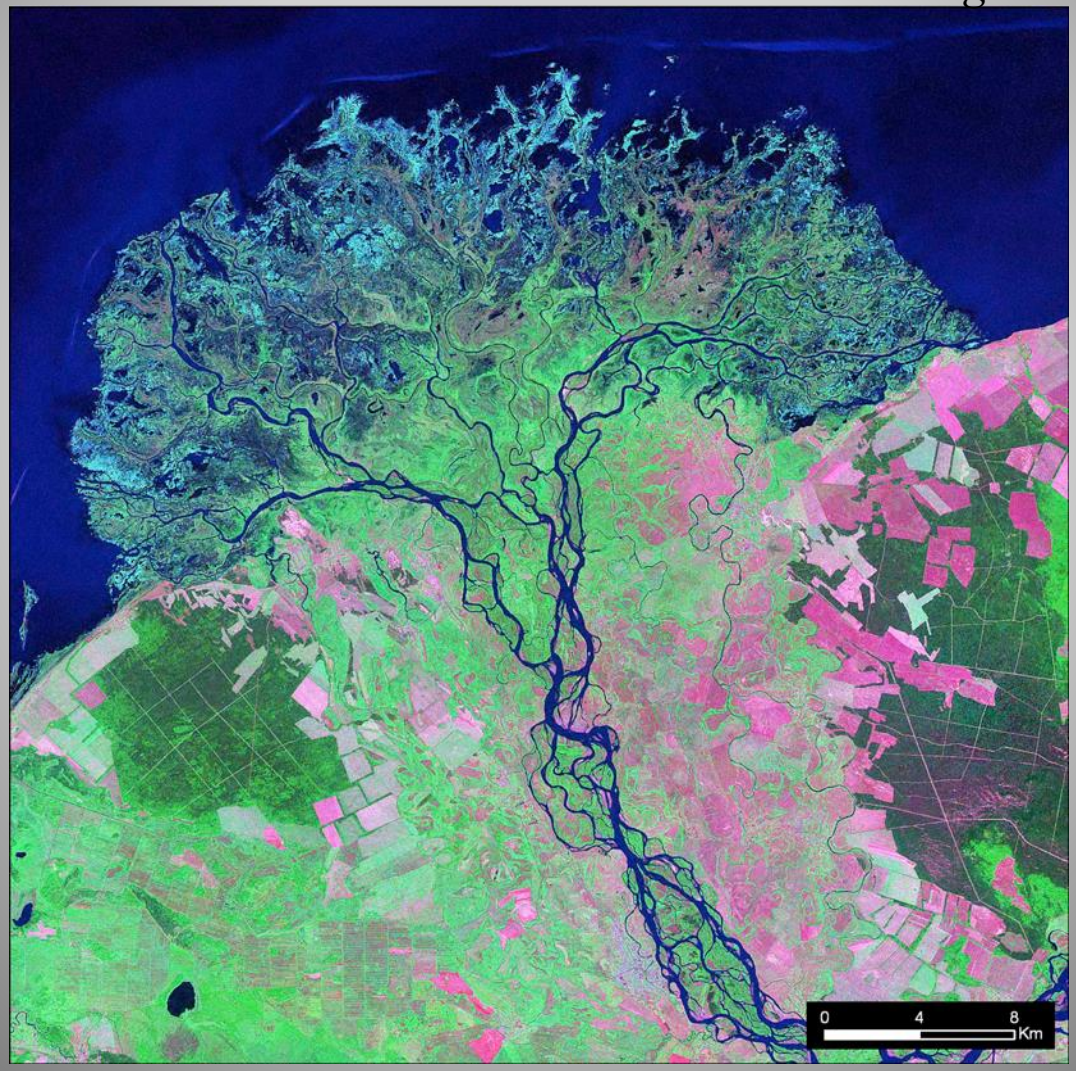
Conglomérat



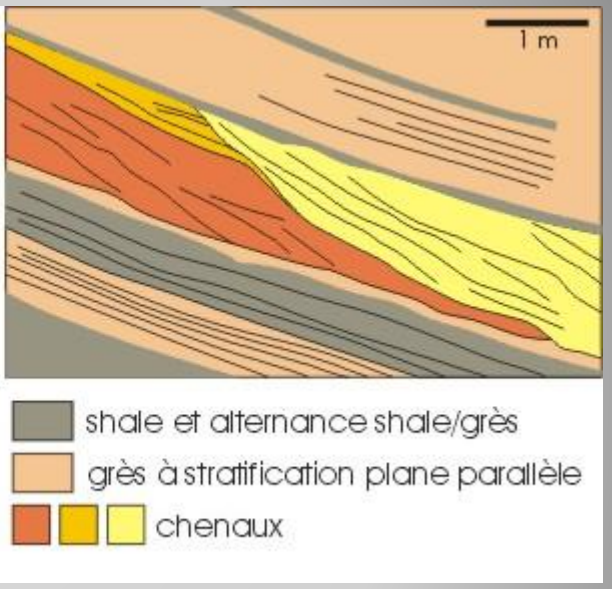



N33°
N31°
N29°
N27°
N25°
E 25°
E 27°
E 29°
E 31°
E 33°
E 35°
E 37°
E 39°
E 41°
© 2013 Cnes/Spot Image
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image U.S. Geological Survey

Lac Baikal
Selenge River

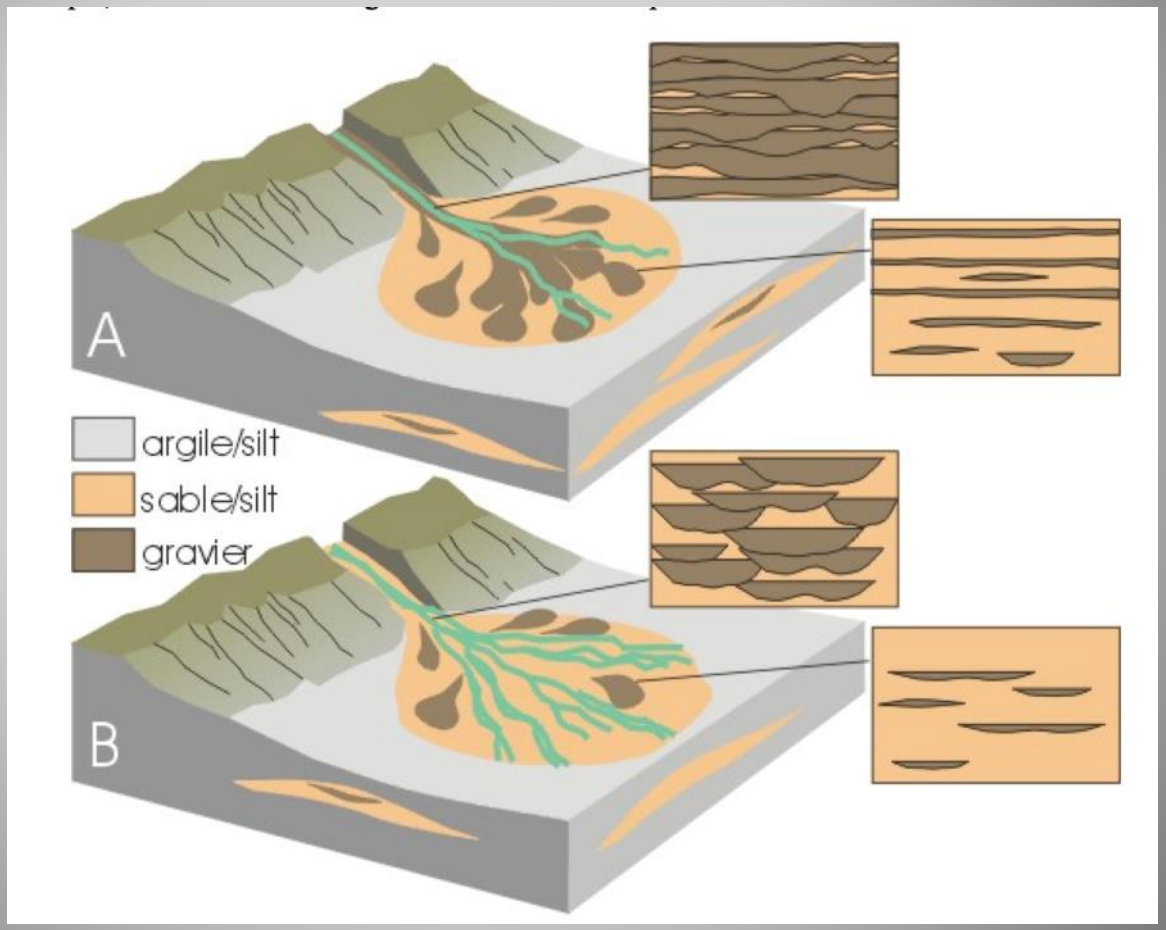


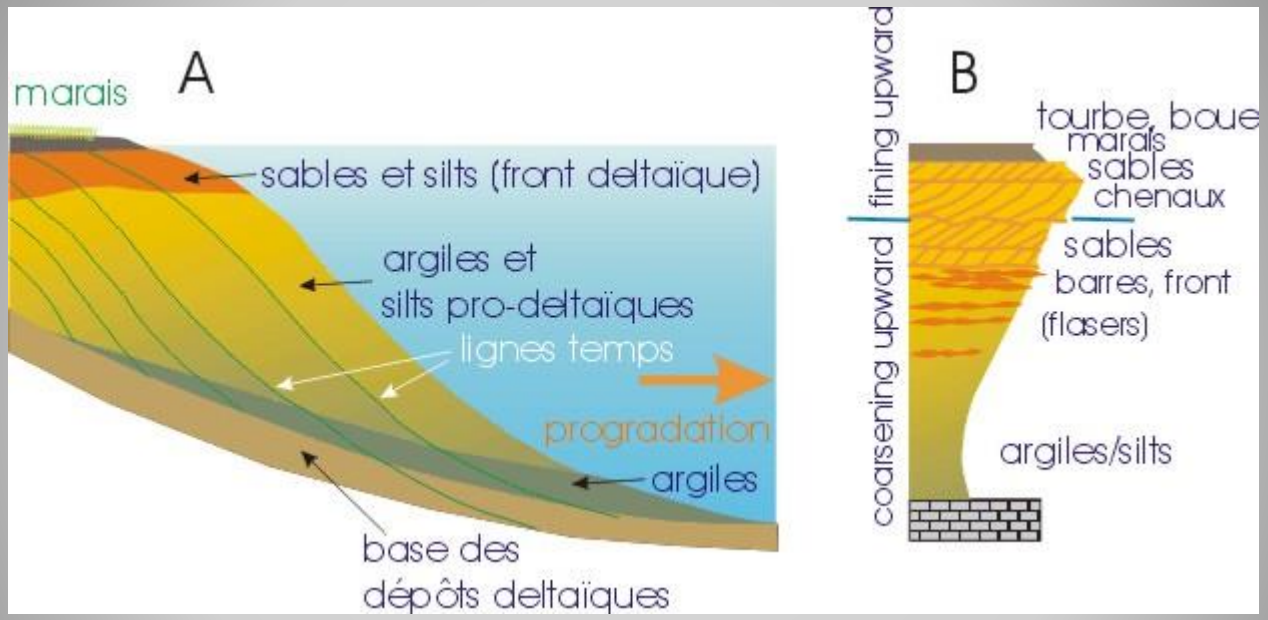
Photographie : Pierre Thomas


1 m
shale et alternance shale/grès
grès à stratification plane parallèle
chenaux

Canyonland N.P., Utah

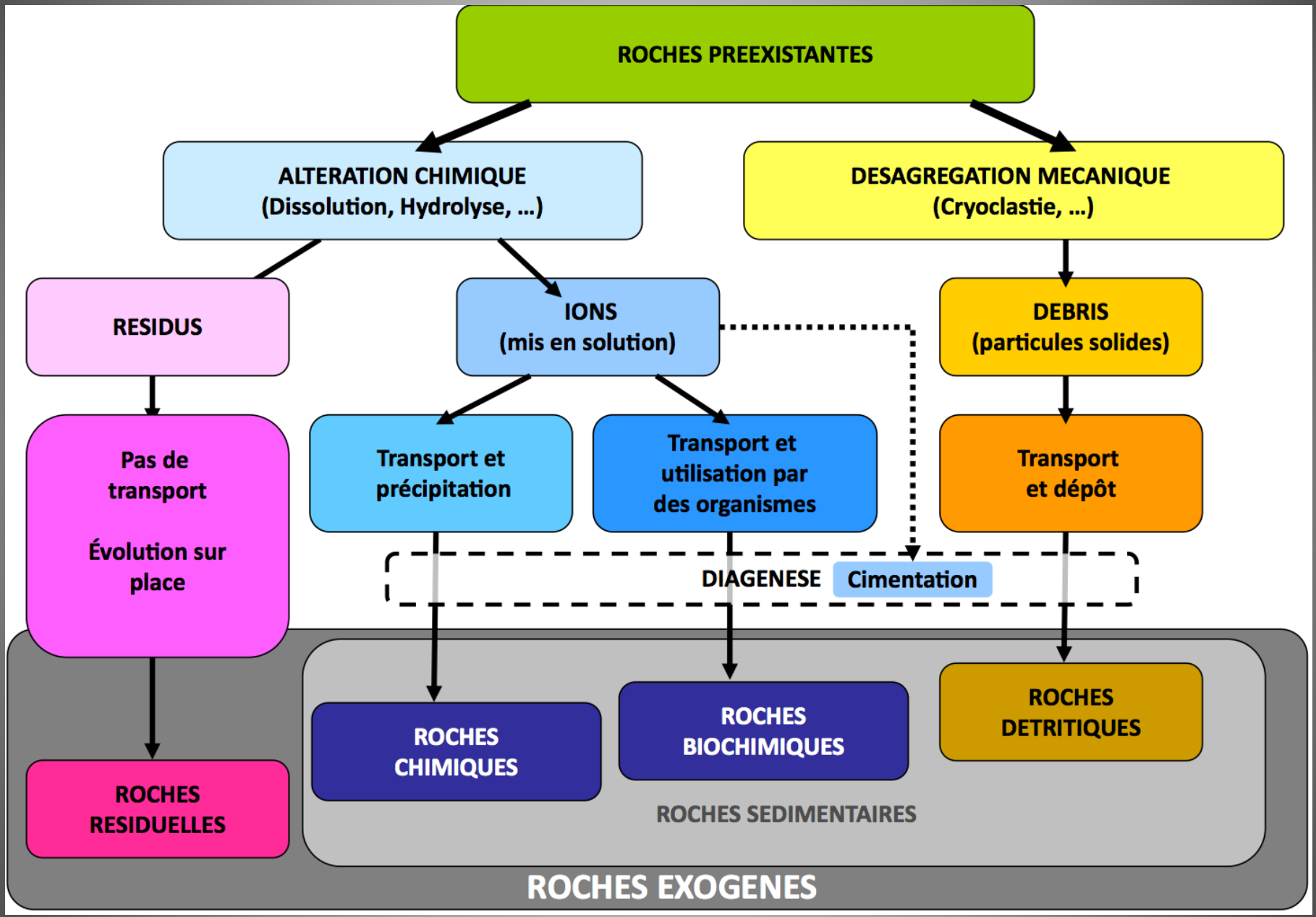
Litages entrecroisés
Cônes aluvionnaires




A
marais
sables et silts (front deltaïque)
argiles et
silts pro-deltaïques
lignes temps
progradation
argiles
base des
dépôts deltaïques
B
coarsening upward
fining upward
tourbe, boue
marais
sables
chenaux
sables
barres, front
(flasers)
argiles/silts

Nasa: mission Curiosity 2012-2013

- Roches sédimentaires détritiques
- R.sedimentaires résiduelles
- R.sédimentaires chimiques
- R.sédimentaires évaporitiques
- R.sédimentaires carbonées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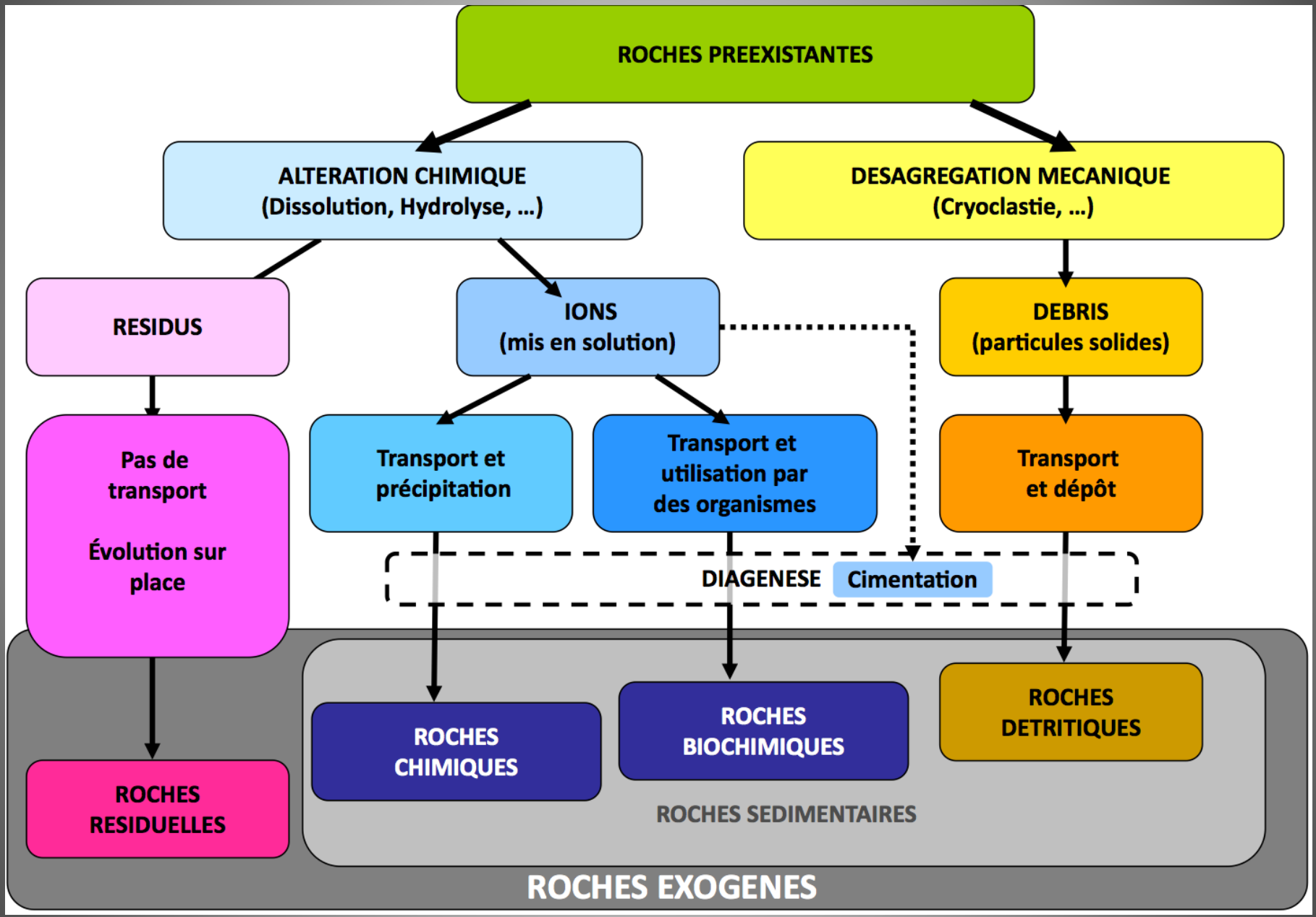
CHIMIQUES
ROCHES
BIOCHIMIQUES
ROCHES
DETRITIQUES
ROCHES SEDIMENTAIRES
ROCHES EXOGENES

Ce qui reste après altération ! Profils de latérites, bauxites, arènes… L2 !

- Roches sédimentaires détritiques
- R.sedimentaires résiduelles
- R.sédimentaires chimiques
- R.sédimentaires évaporitiques
- R.sédimentaires carbonées


ROCHES PREEXISTANTES
ALTERATION CHIMIQUE
(Dissolution, Hydrolyse, …)
DESAGREGATION MECANIQUE
(Cryoclastie, …)
RESIDUS
IONS
(mis en solution)
DEBRIS
(particules solides)
Pas de
transport
Évolution sur
place
Transport et
précipitation
Transport et
utilisation par
des organismes
Transport
et dépôt
DIAGENESE
Cimentation
ROCHES
RESIDUELLES
ROCHES
CHIMIQUES
ROCHES
BIOCHIMIQUES
ROCHES
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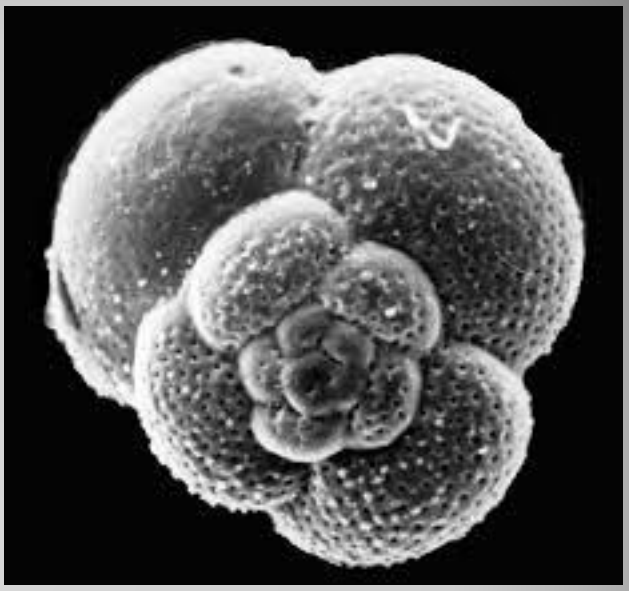
silex

- $CaCO_3$
- SiO_2

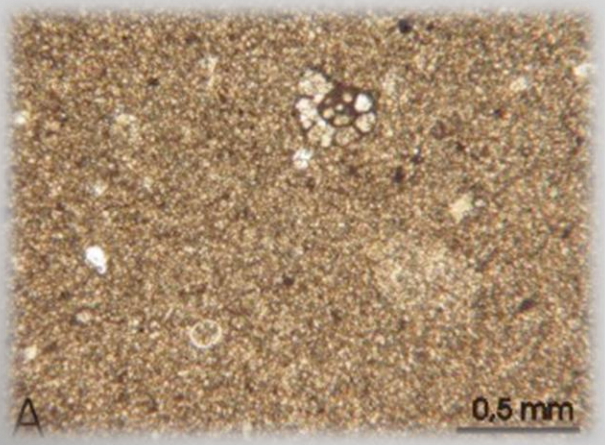


- **$CaCO_3$ sédiments calcaires**

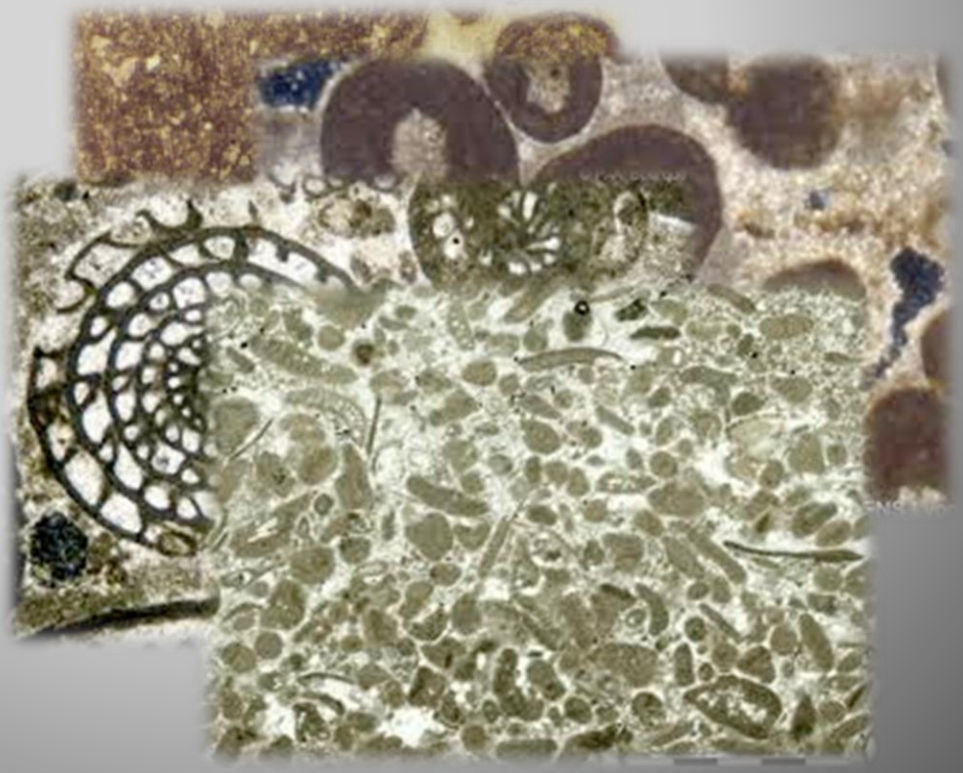
- Deux classifications basées sur l'aspect au microscope : Folk et Dunham
- On distingue grains ou ***allochems***
- Et ciment ou ***orthochems***

- Les orthochems peuvent être :
- Sparite

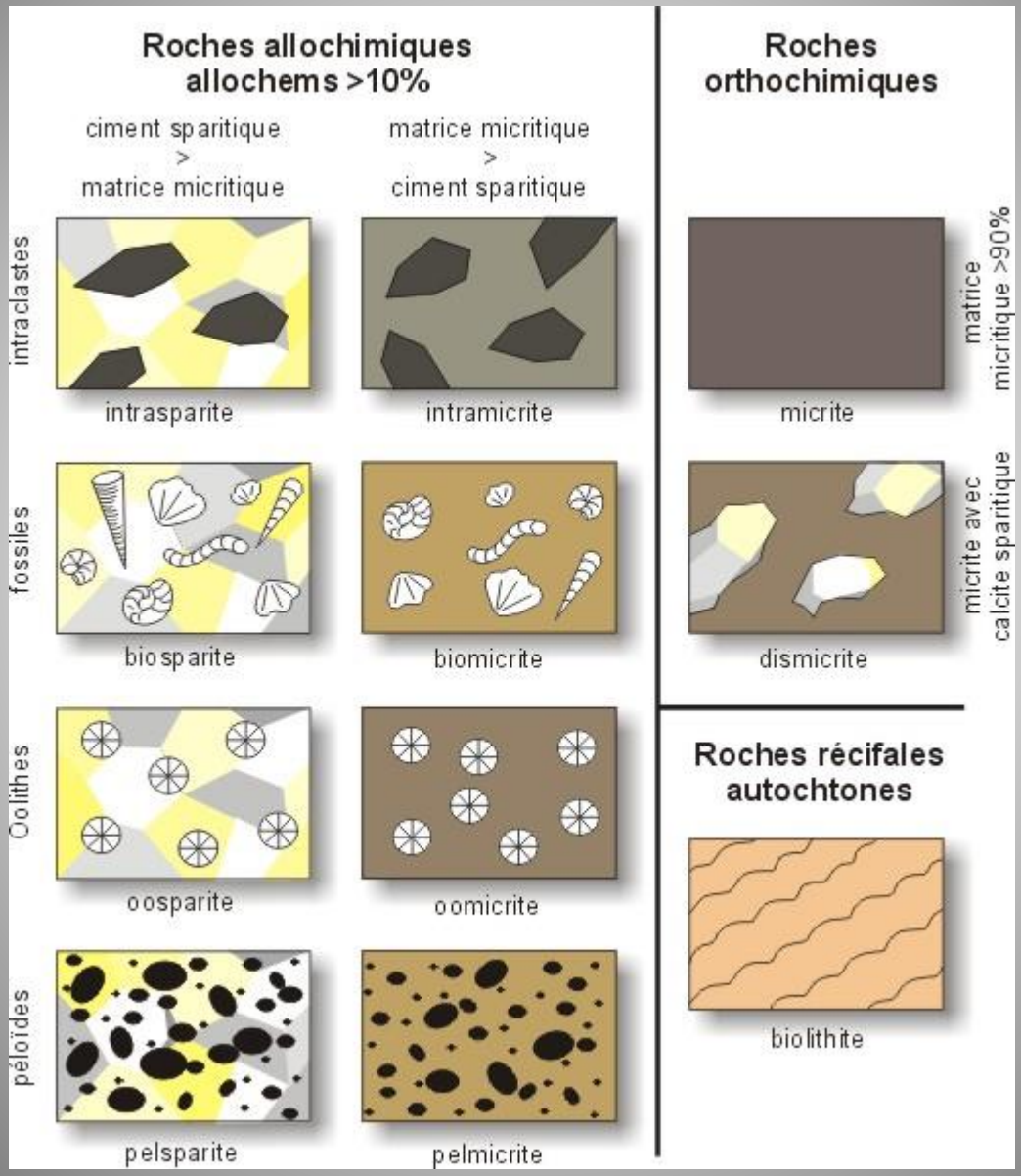
- micrite



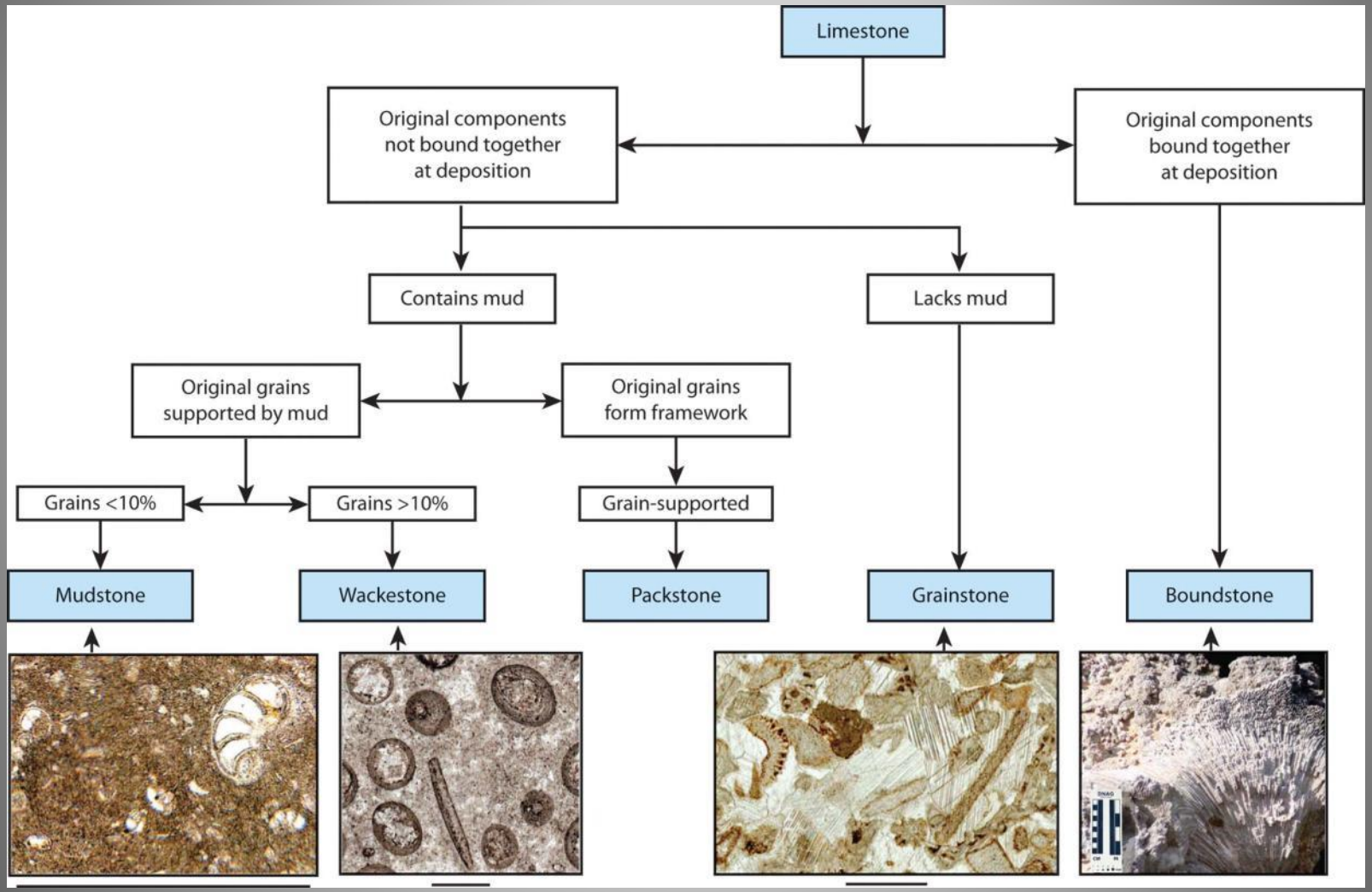
- Les allochems peuvent être :
- Fragments de sédiments « intraclasts »
- Oolites
- Microfossiles
- pellets



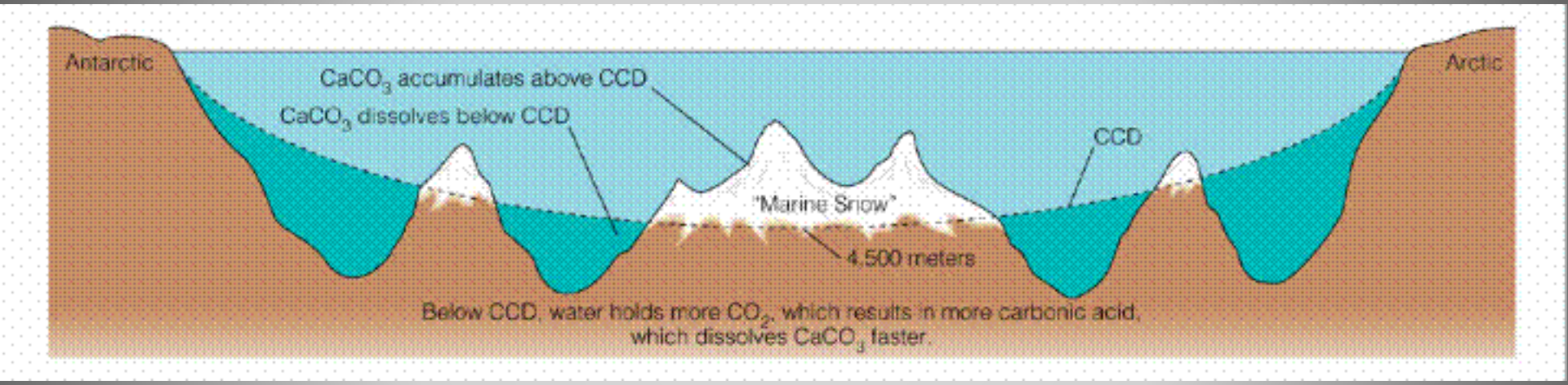
Classification de Folk



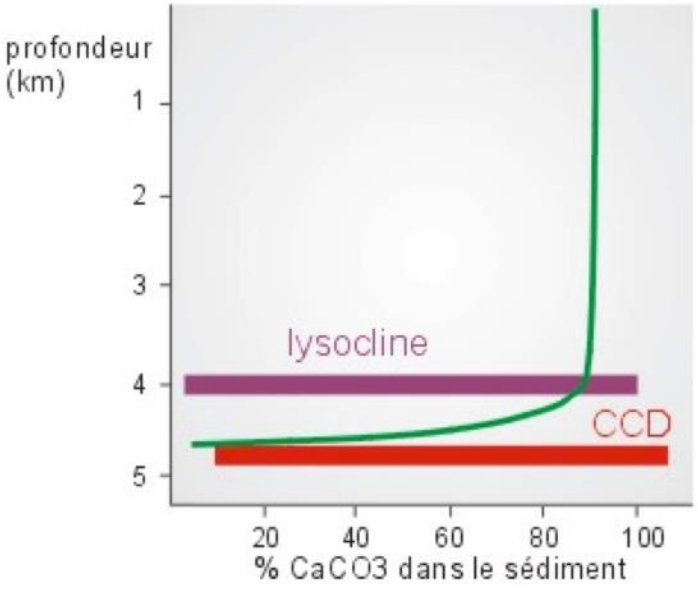
Classification de Dunham



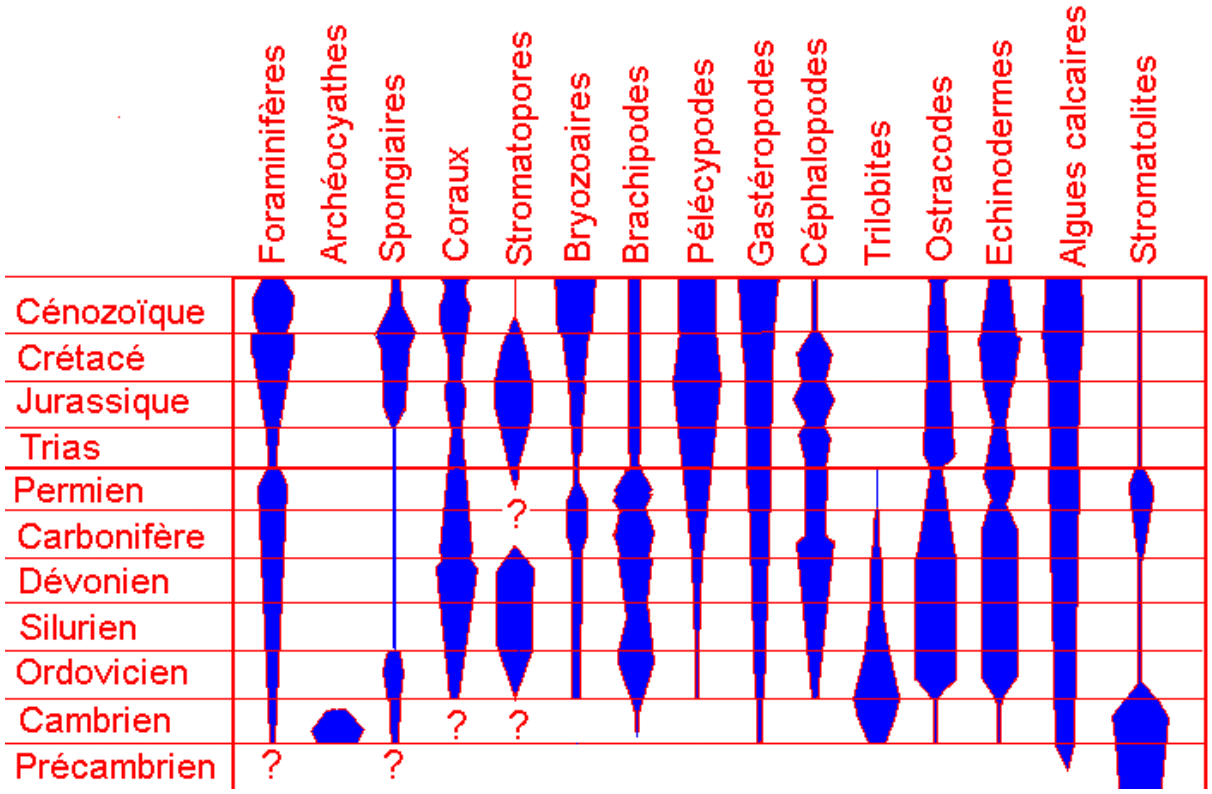
La limite de compensation des carbonates…

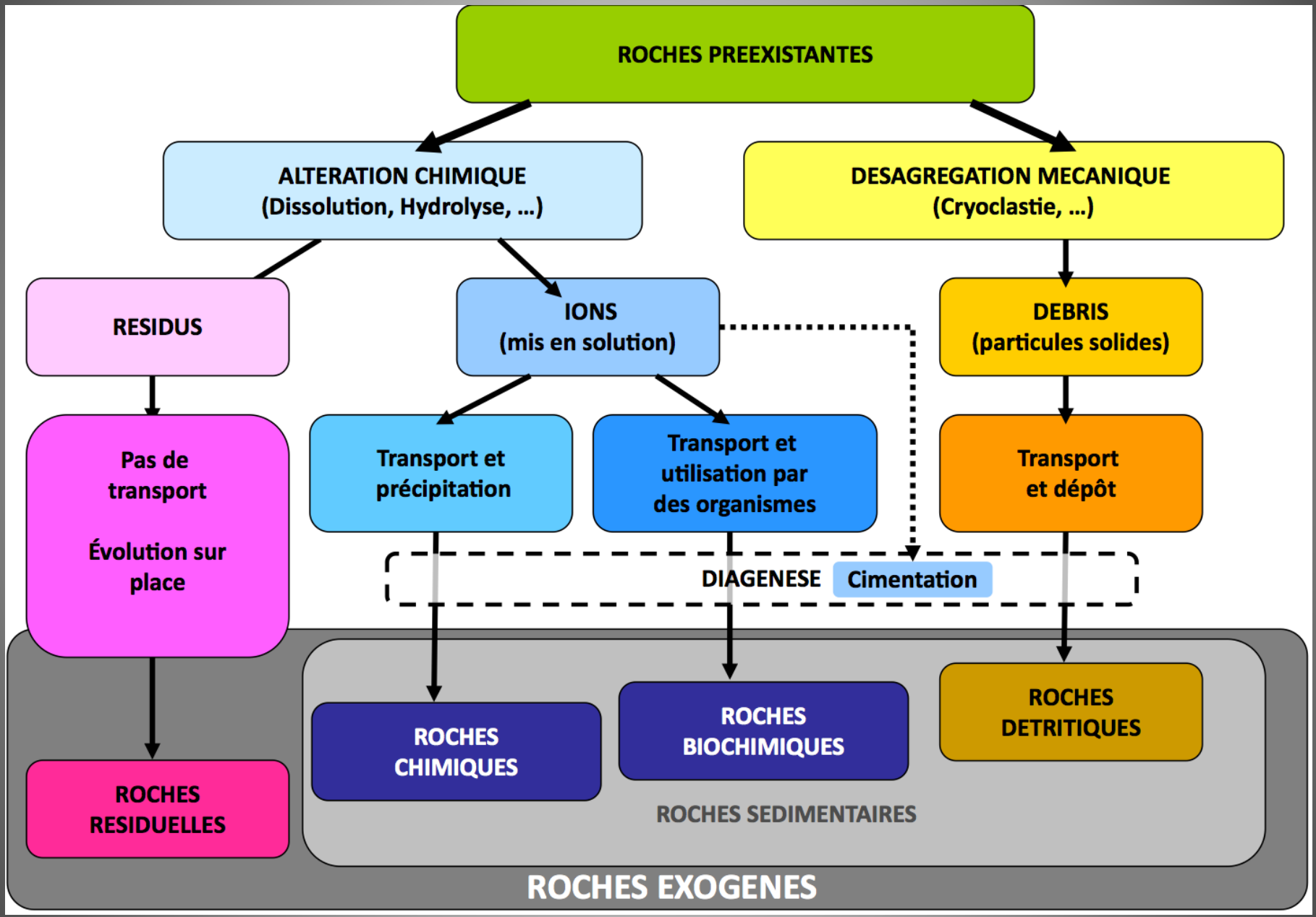


profondeur CCD en km



Calcaire et dolomie: la dolomitisation


Foraminifères
Archéocyathes
Spongiaires
Coraux
Stromatopores
Bryozoaires
Brachipodes
Pélécypodes
Gastéropodes
Céphalopodes
Trilobites
Ostracodes
Echinodermes
Algues calcaires
Stromatolites
Cénozoïque
Crétacé
Jurassique
Trias
Permien
Carbonifère
Dévonien
Silurien
Ordovicien
Cambrien
Précambrien
?
?
?
?
?
?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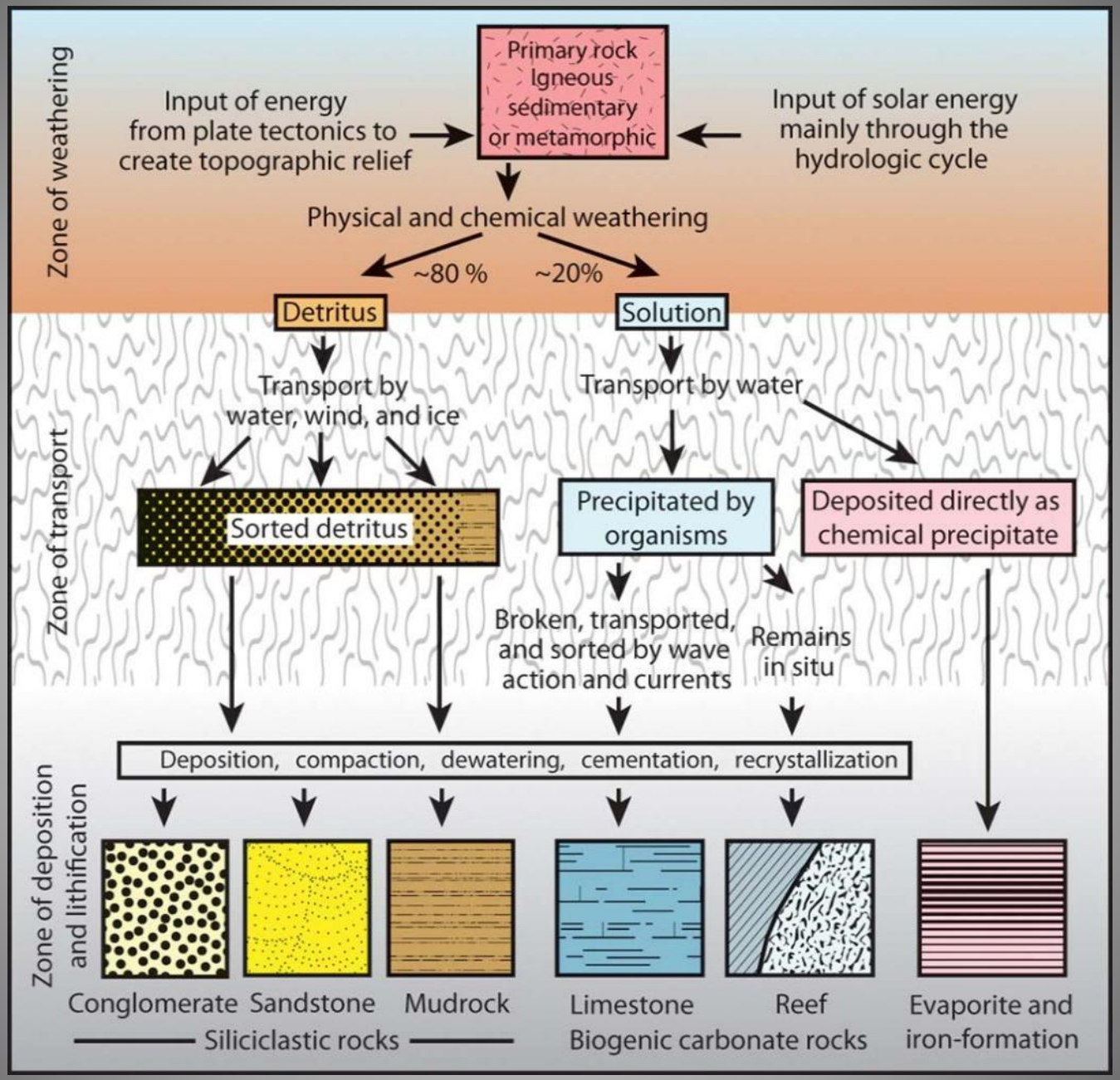
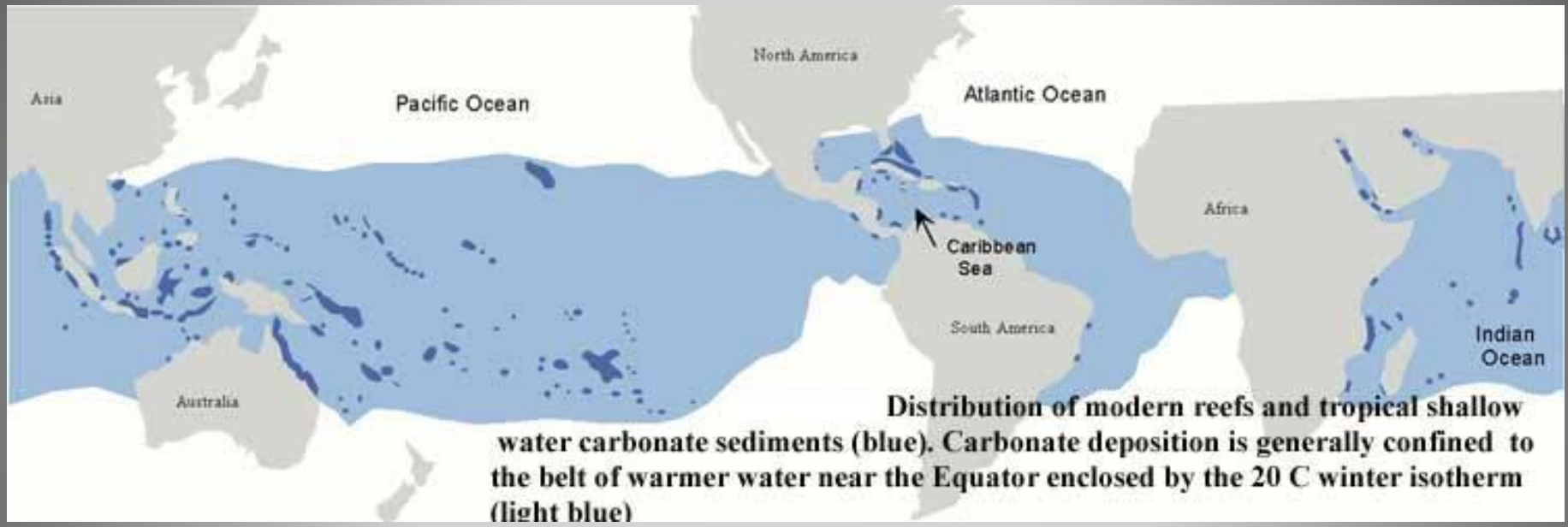
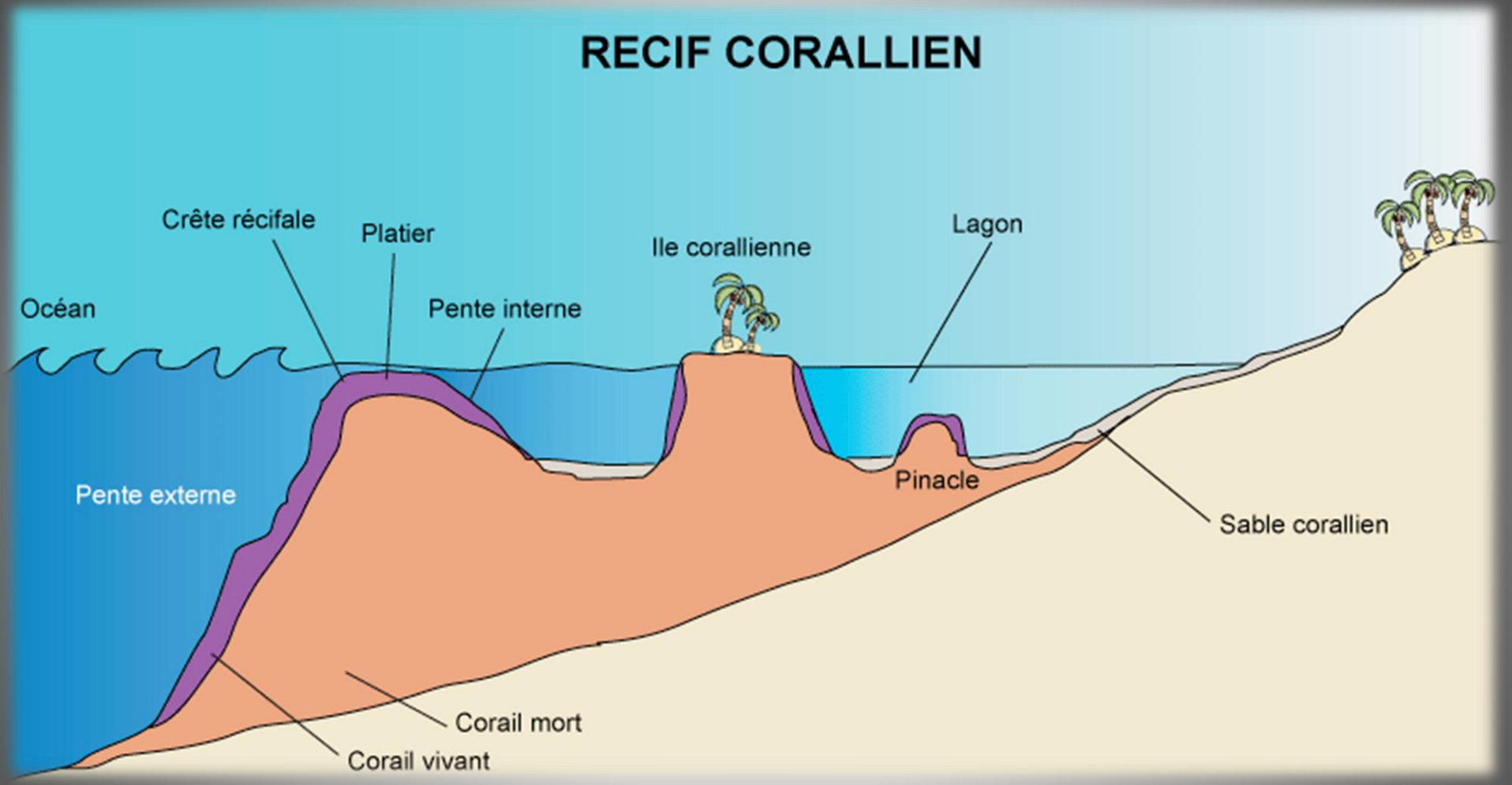
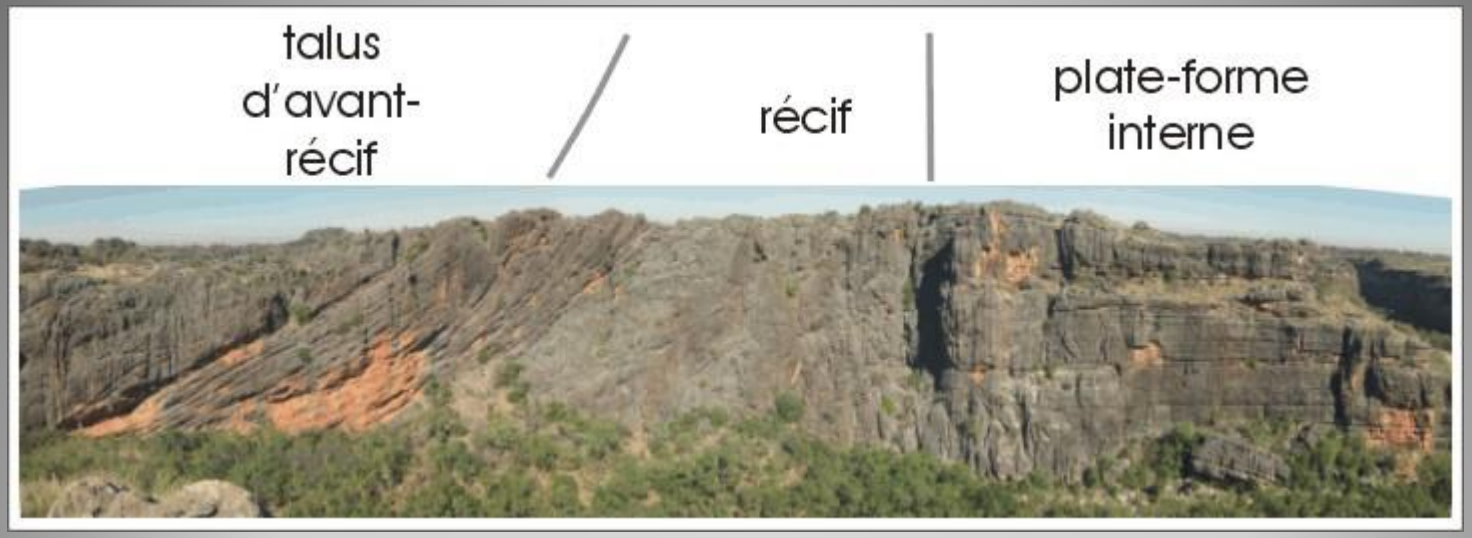

Zone of weathering
Primary rock
Igneous
sedimentary
or metamorphic
Input of energy
from plate tectonics to
create topographic relief
Input of solar energy
mainly through the
hydrologic cycle
Physical and chemical weathering
~80 %
~20%
Detritus
Solution
Zone of transport
Transport by
water, wind, and ice
Transport by water
Sorted detritus
Precipitated by
organisms
Deposited directly as
chemical precipitate
Broken, transported,
and sorted by wave
action and currents
Remains
in situ
Deposition, compaction, dewatering, cementation, recrystallization
Zone of deposition
and lithification
Conglomerate
Sandstone
Mudrock
Limestone
Reef
Evaporite and
iron-formation
Siliciclastic rocks
Biogenic carbonate rocks



Distribution of modern reefs and tropical shallow water carbonate sediments (blue). Carbonate deposition is generally confined to the belt of warmer water near the Equator enclosed by the 20 C winter isotherm (light blue)


© Gilles Chazot


RECIF CORALLIEN
Crête récifale
Platier
Ile corallienne
Lagon
Océan
Pente interne
Pente externe
Pinacle
Sable corallien
Corail mort
Corail vivant



1 bassin	2 plate-forme profonde	3 base de talus	4 talus avant-récif	5 récif	6 arrière-récif shoals	7 plate-forme interne	8 plate-forme restreinte	9 sebkha saline
"SMF" 1, 2, 3	2, 8, 9 10	2, 3, 4	4, 5, 6	7, 11, 12	11, 12 13 14, 15	8, 9, 10 16, 17 18	16-19 21-24	20, 23

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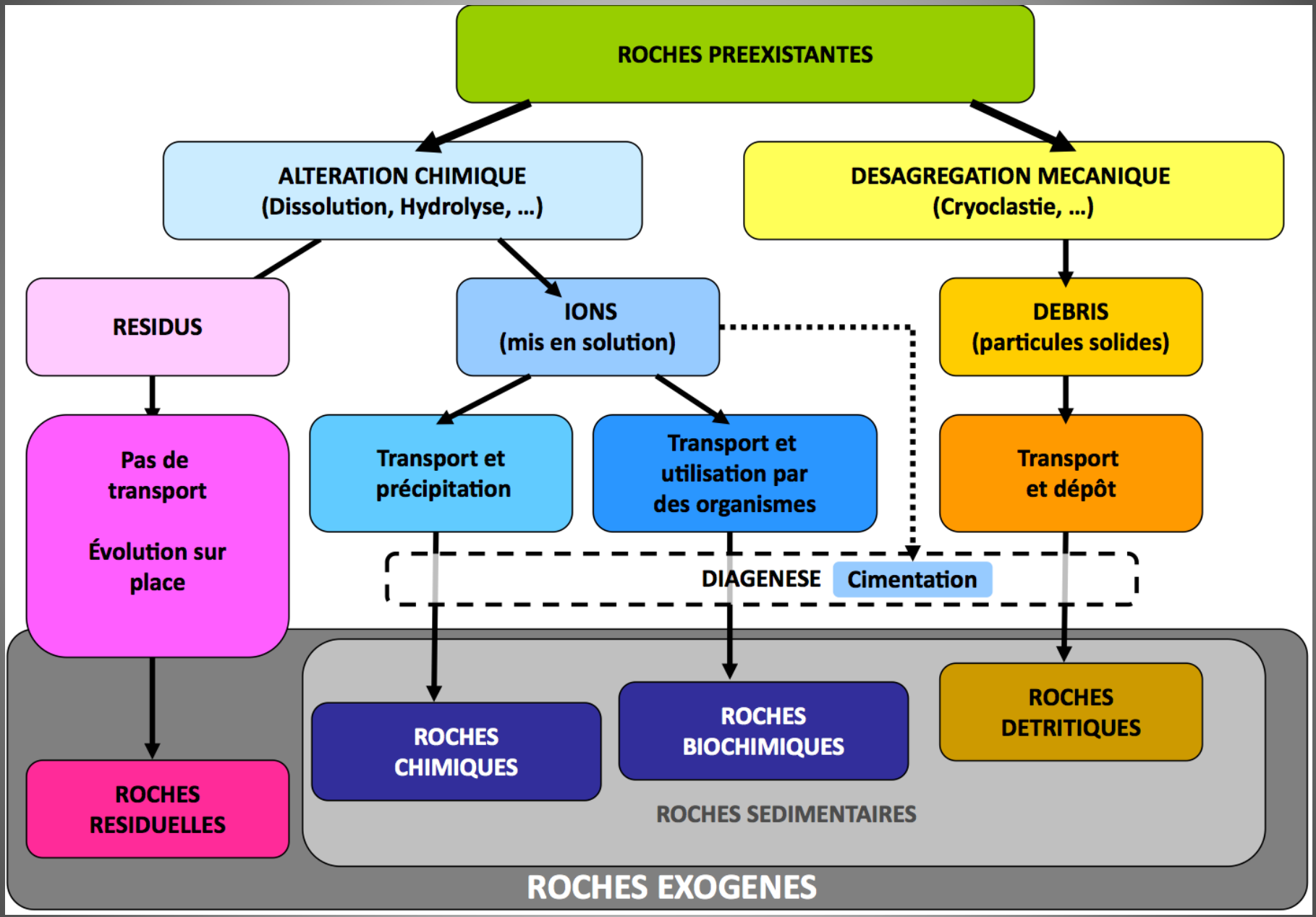
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ROCHES SEDIMENTAIRES
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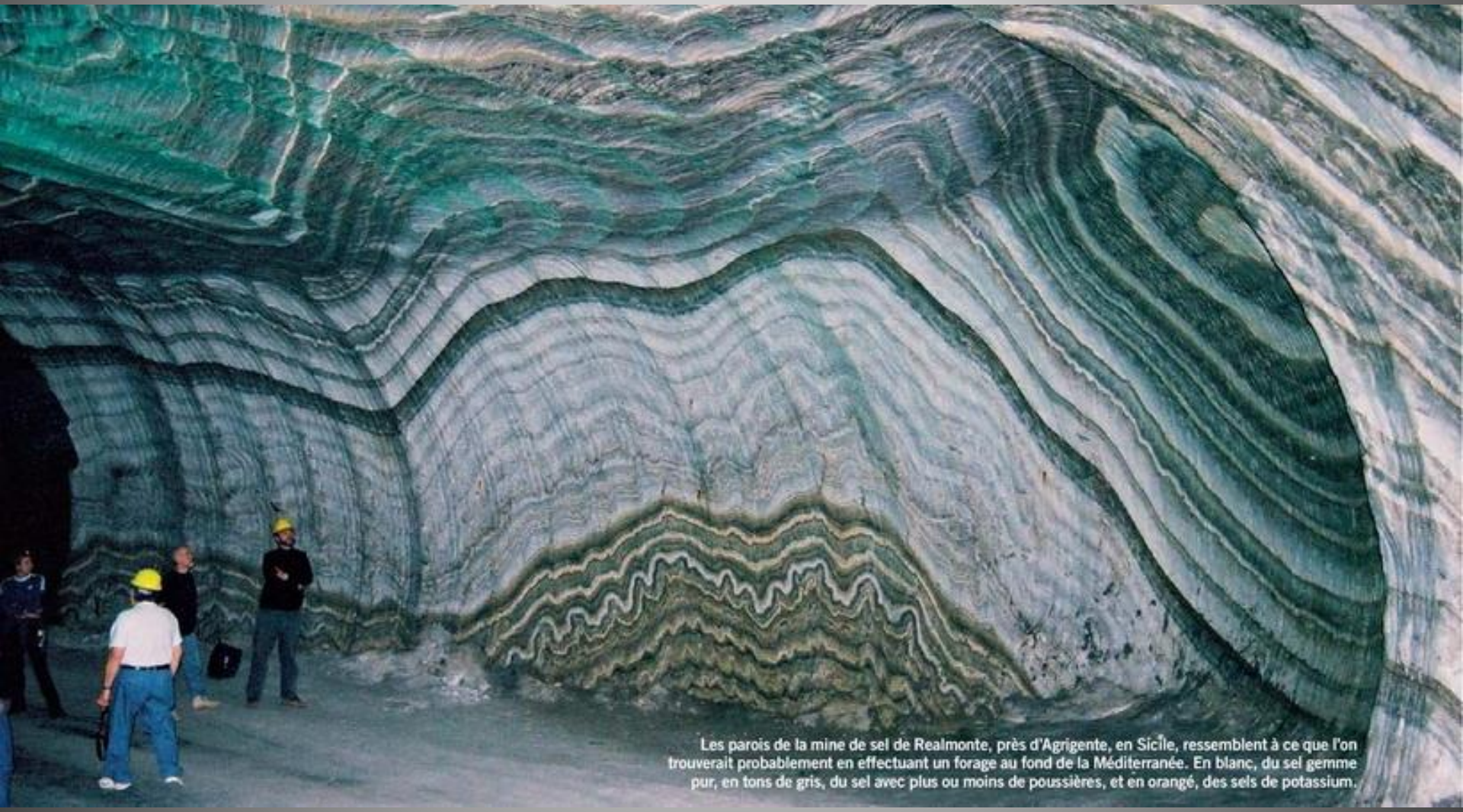
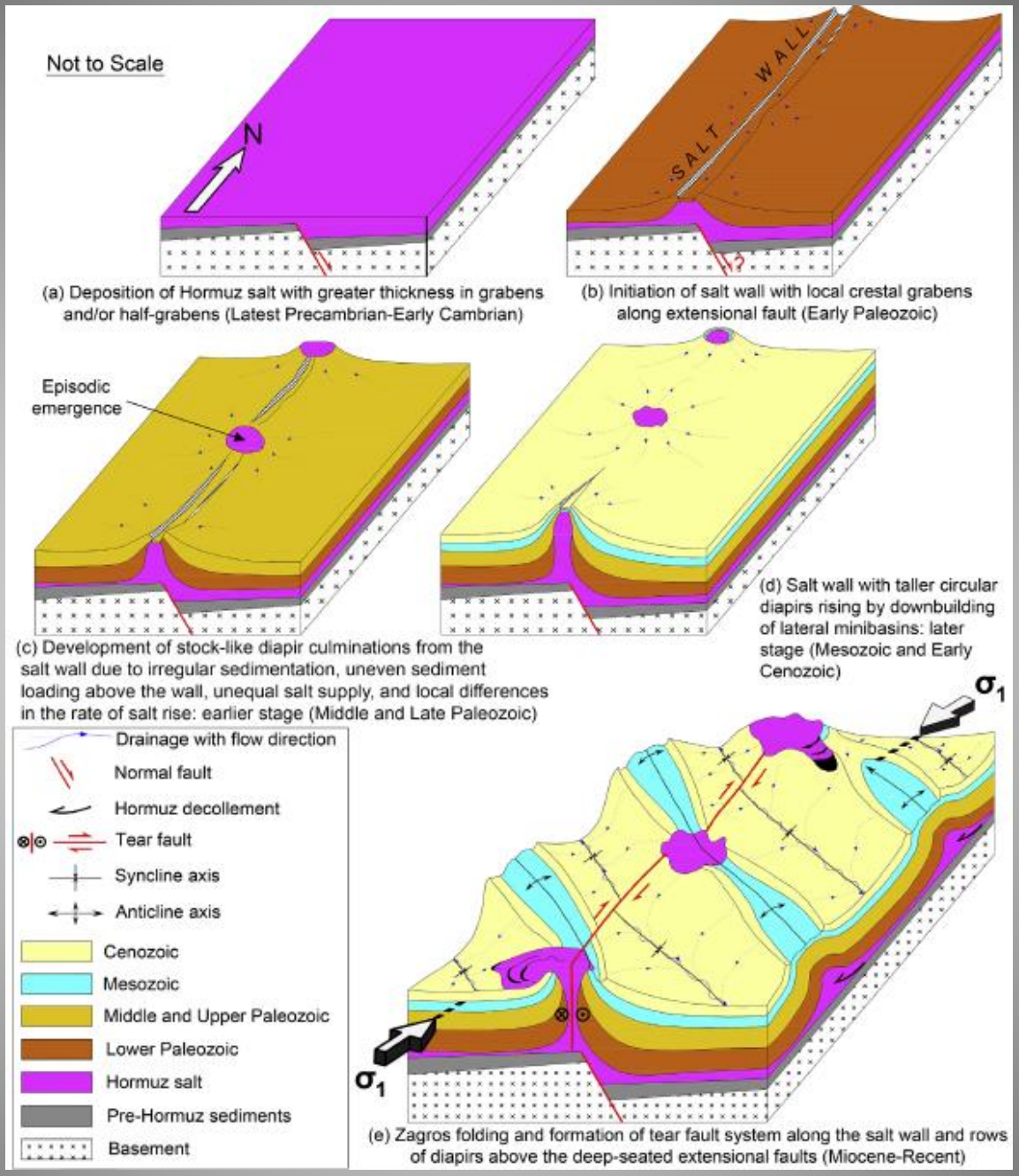
- NaCl le plus souvent, mais aussi $CaSO_4$ (H_2O), KCl etc…



Les parois de la mine de sel de Realmonte, près d'Agrigente, en Sicile, ressemblent à ce que l'on trouverait probablement en effectuant un forage au fond de la Méditerranée. En blanc, du sel gemme pur, en tons de gris, du sel avec plus ou moins de poussières, et en orangé, des sels de potassium.


163
S 17 120


18.3 km
Image © 2020 CNES / Airbus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2020 Maxar Technologies
Image © 2020 Maxar Technologies
Google Earth



Jahani et al., 2017

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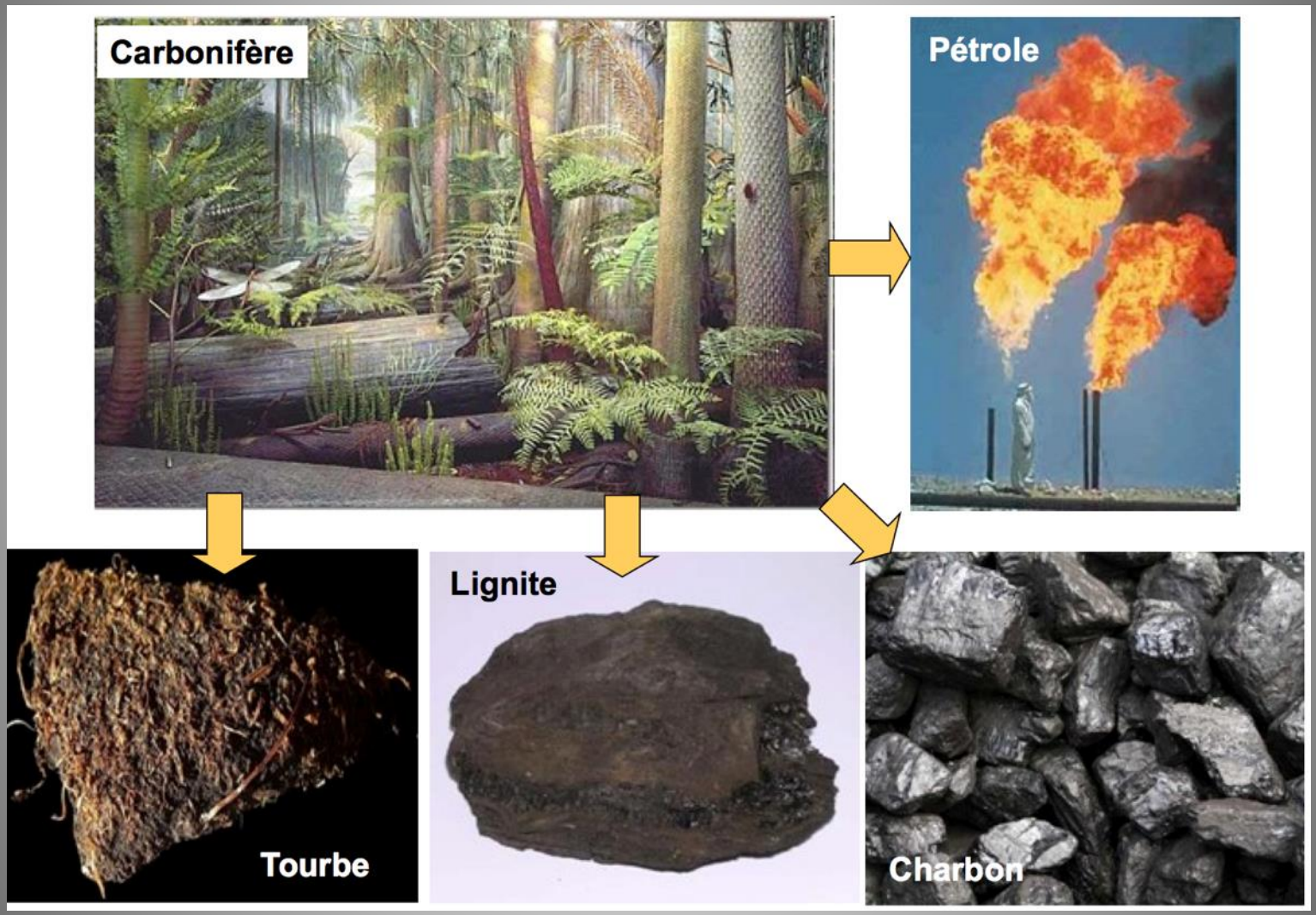
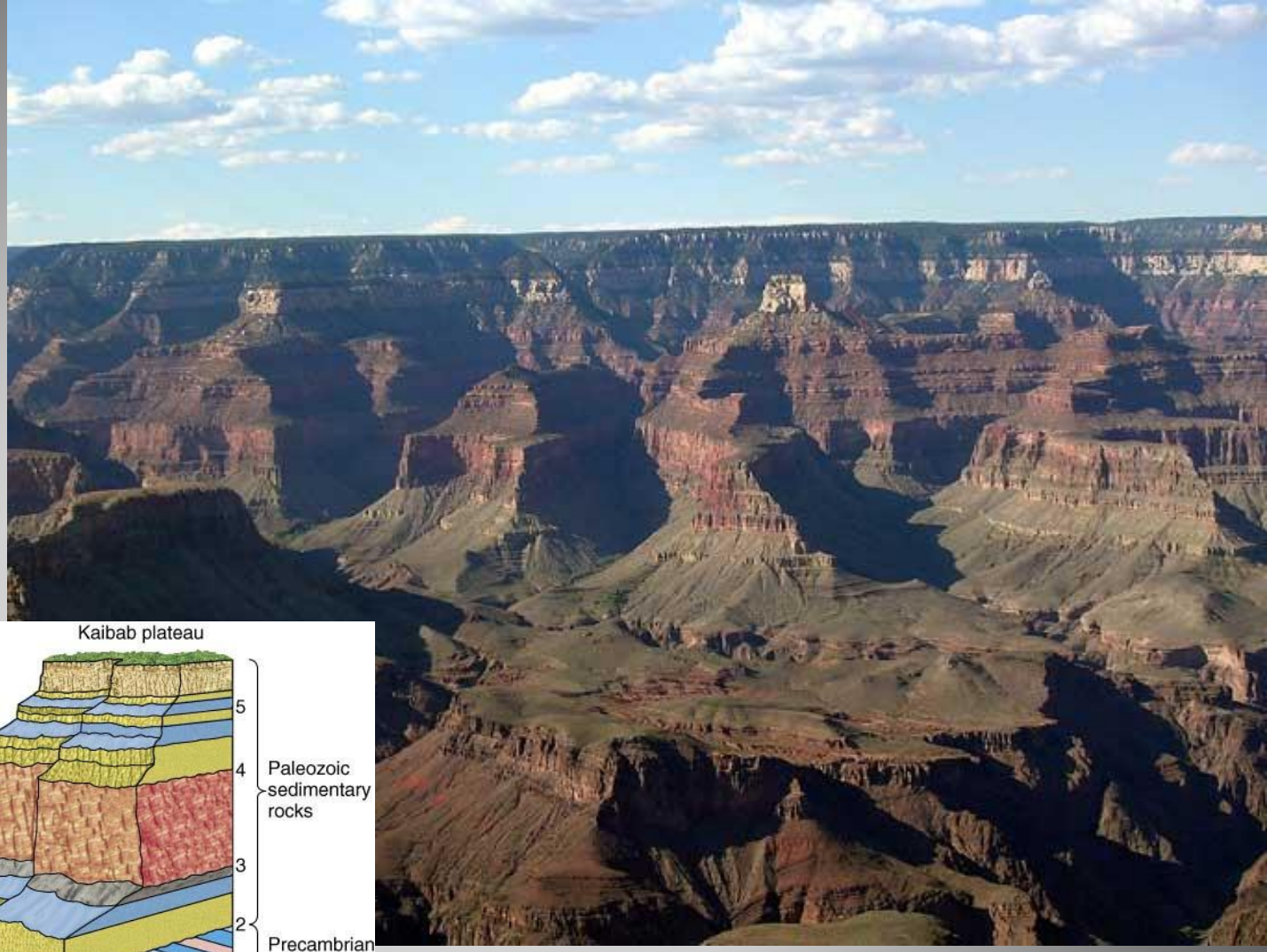
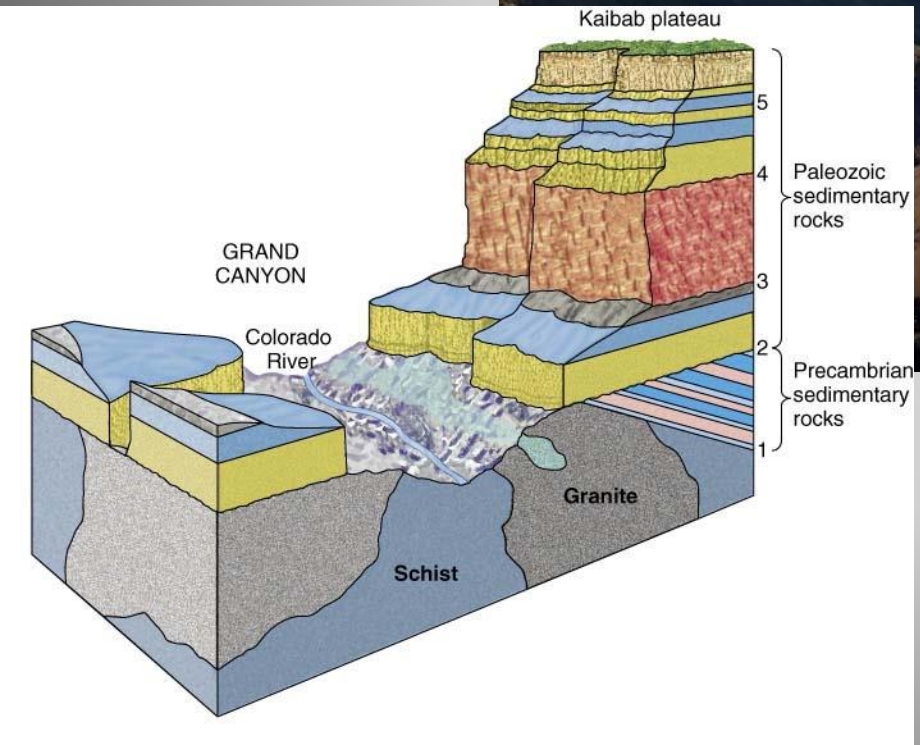
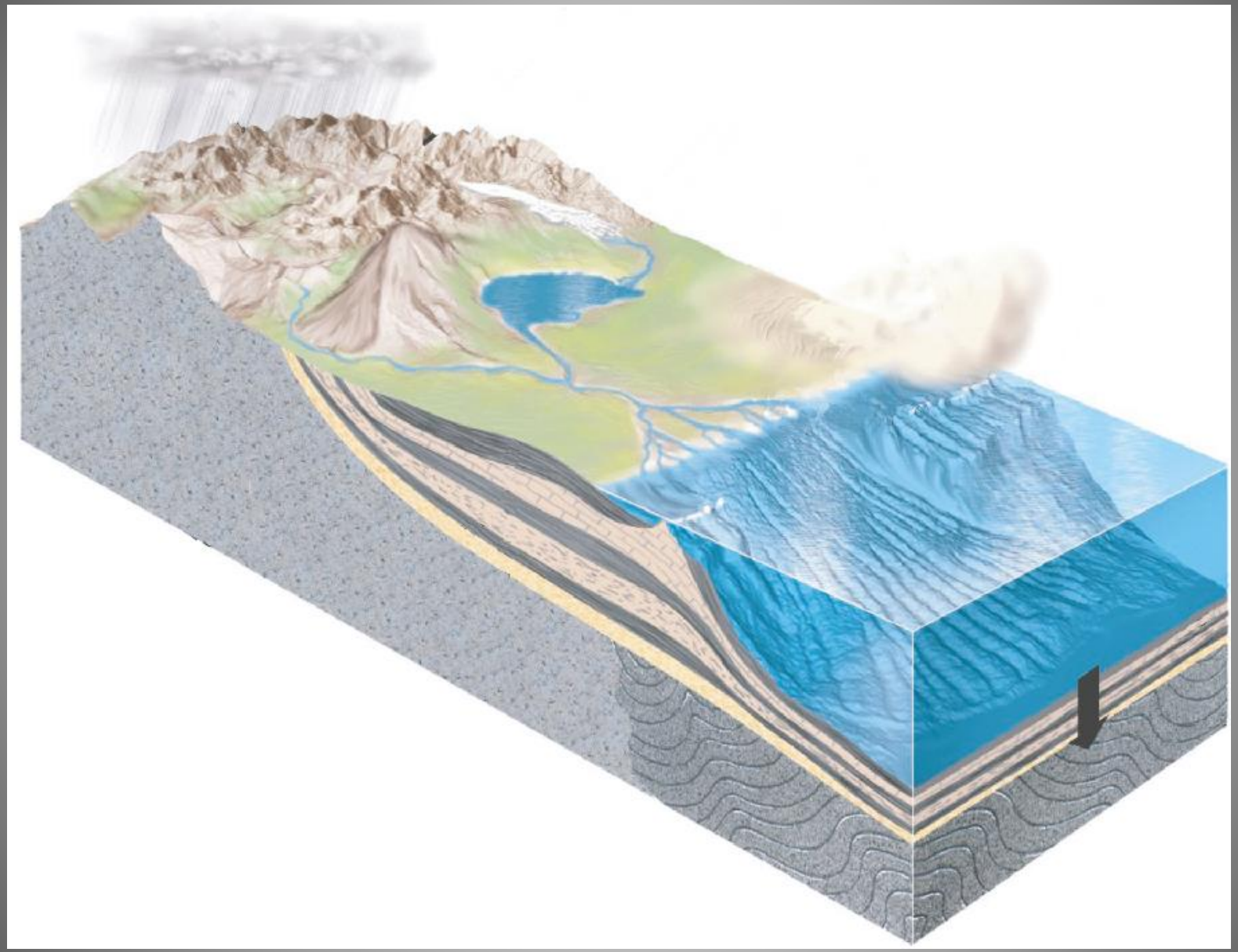

Carbonifère
Pétrole
Tourbe
Lignite
Charbon

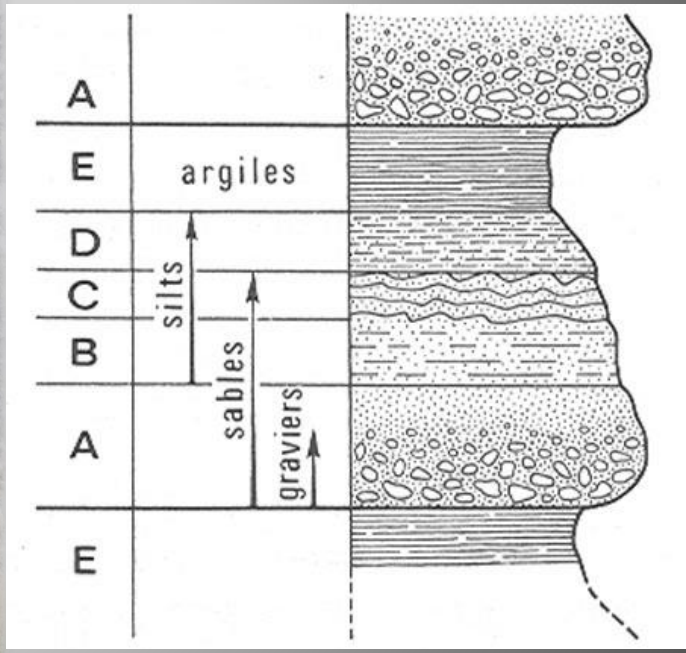
Sédimentation



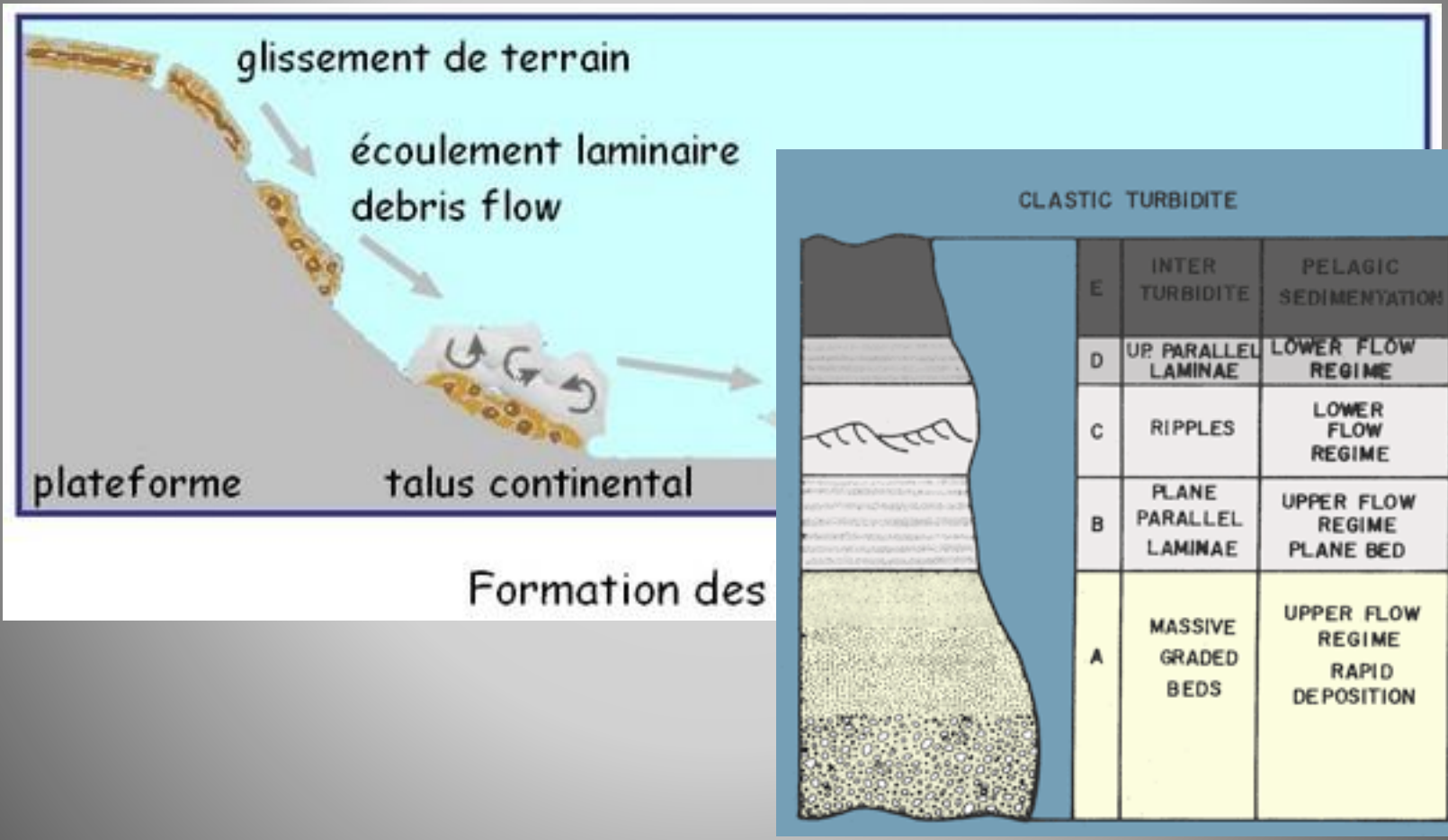




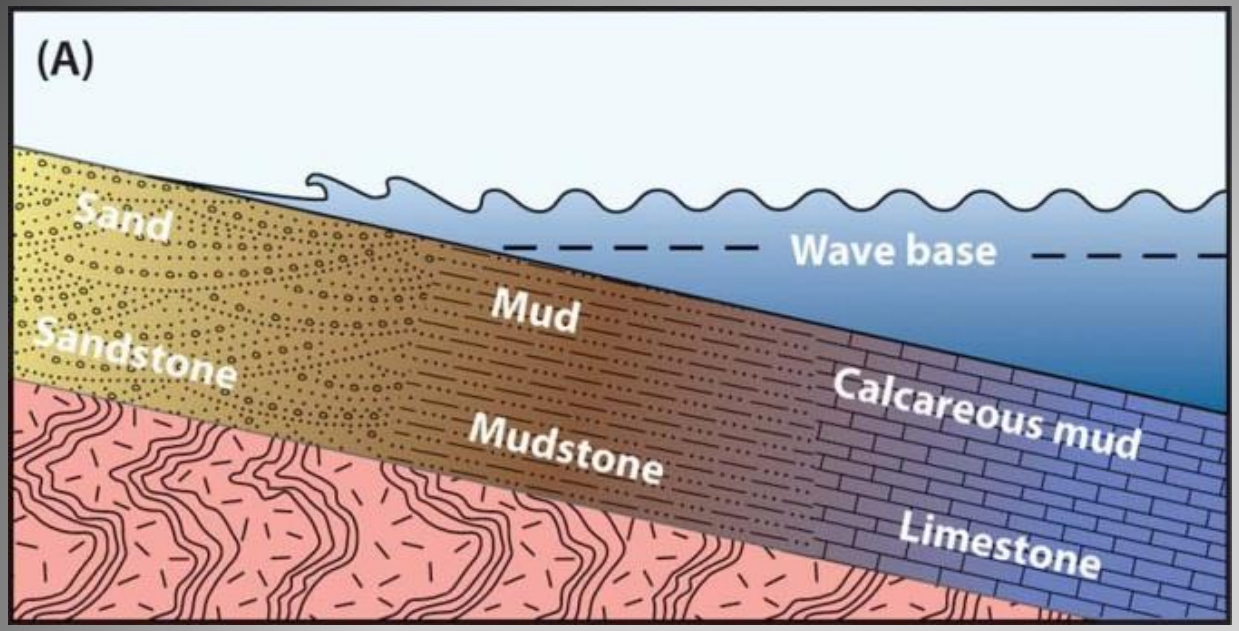
Granoclassements:

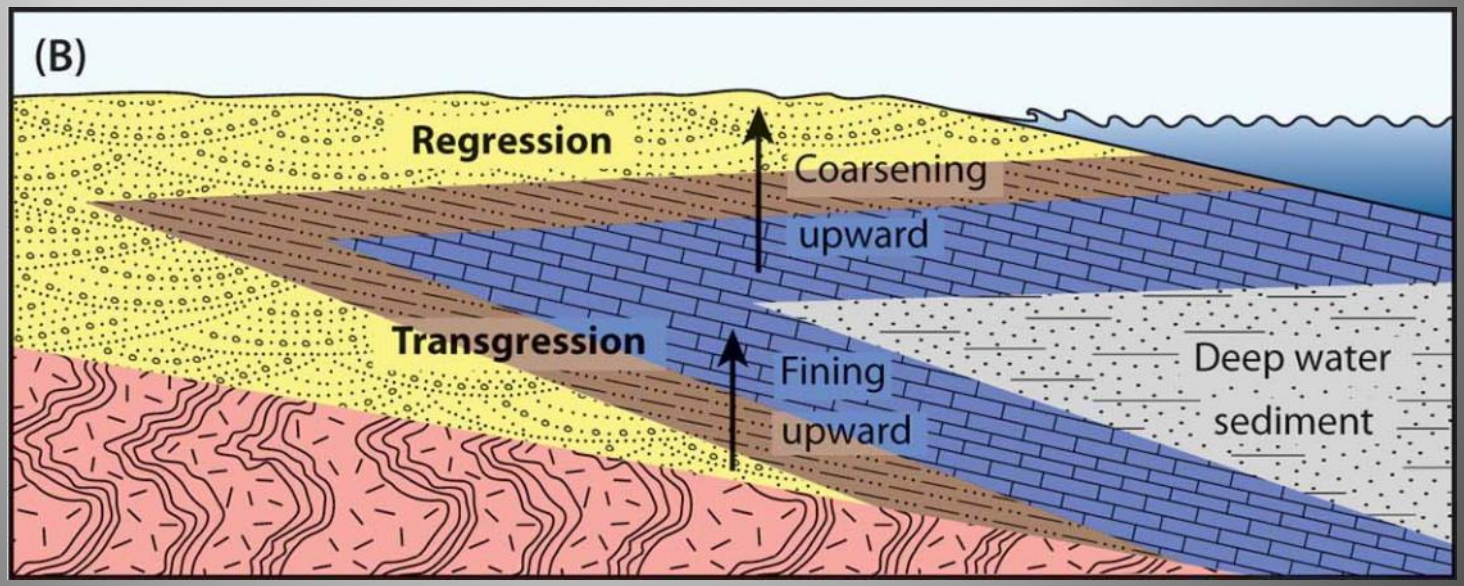


Granoclassements:

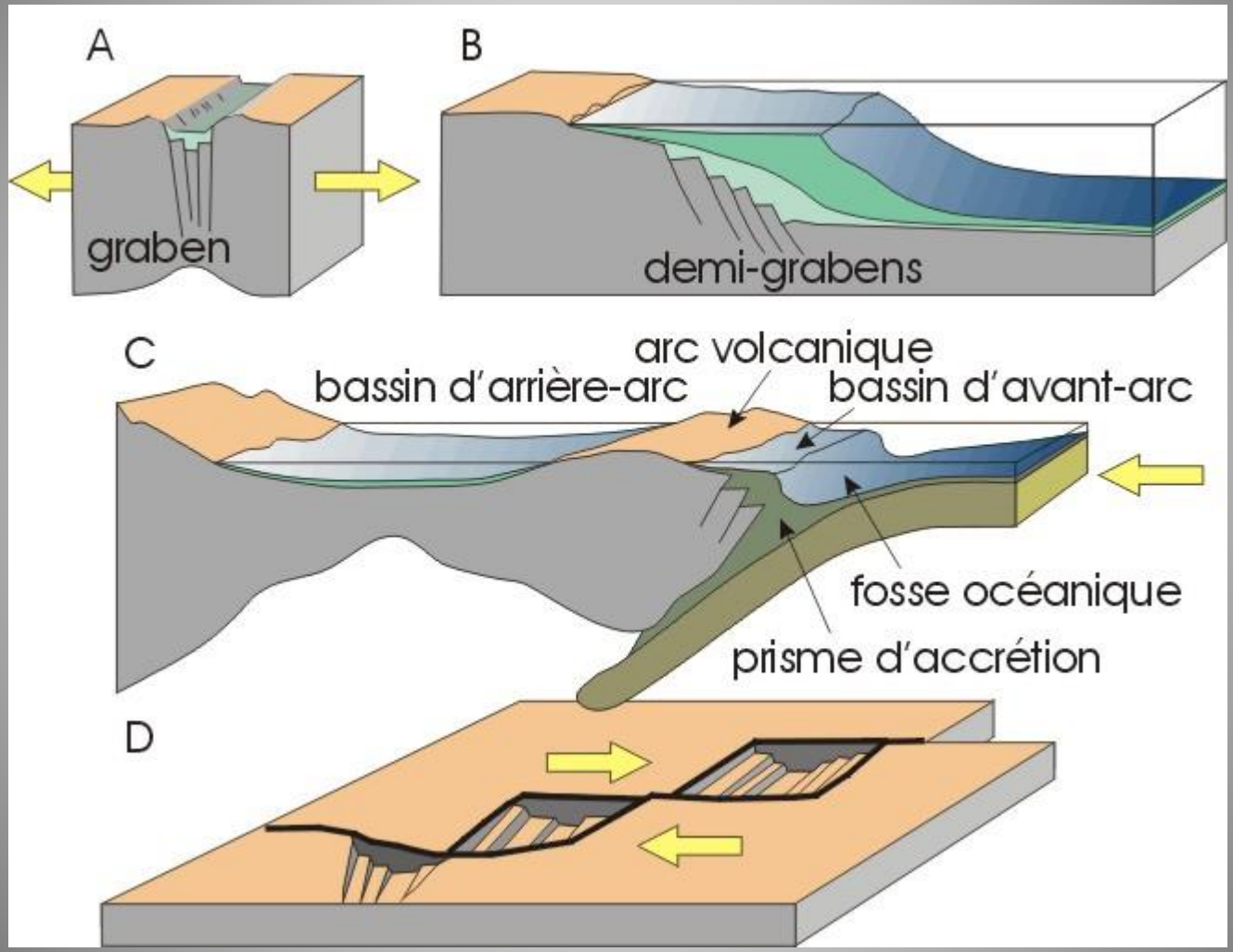


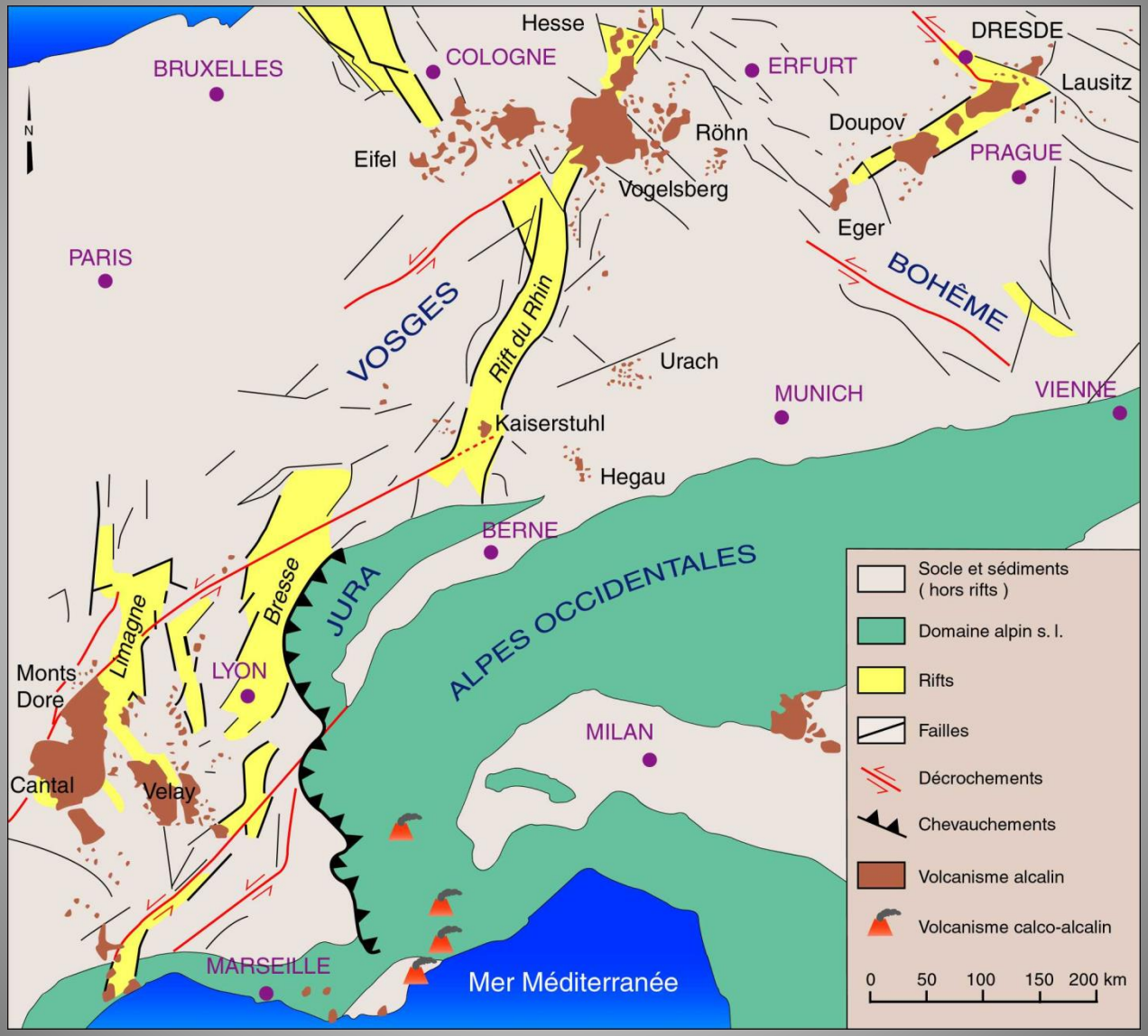
Tri granulométrique

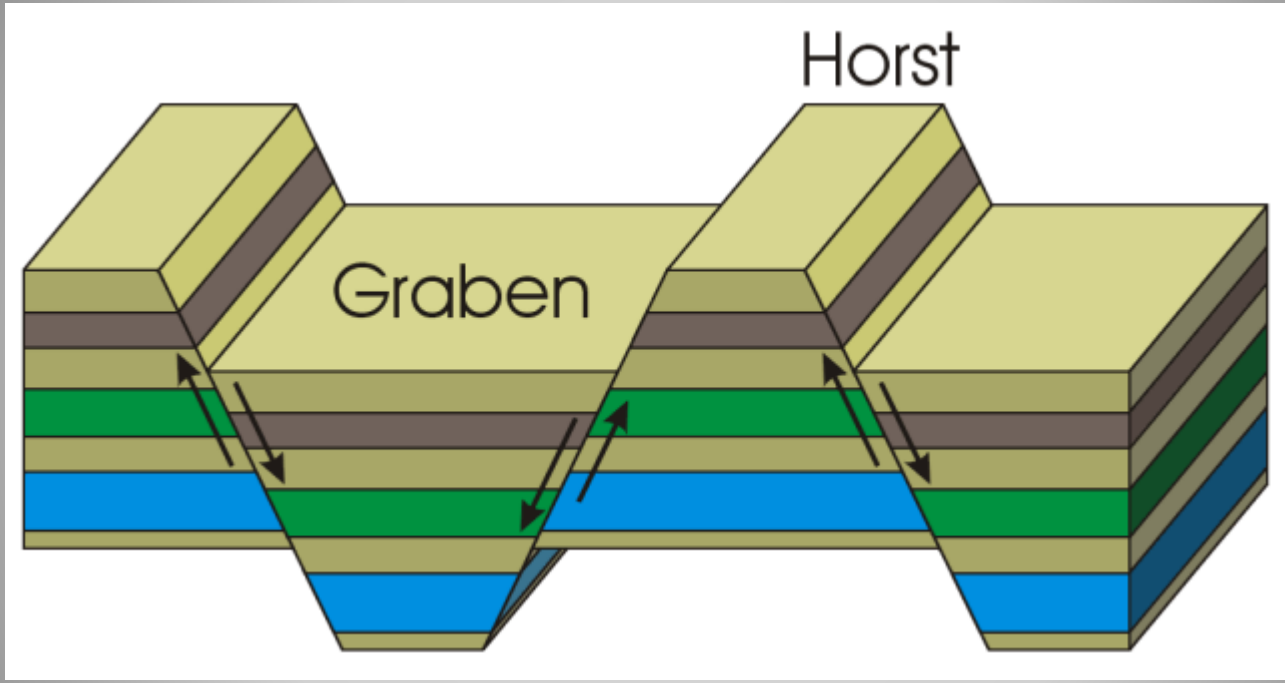


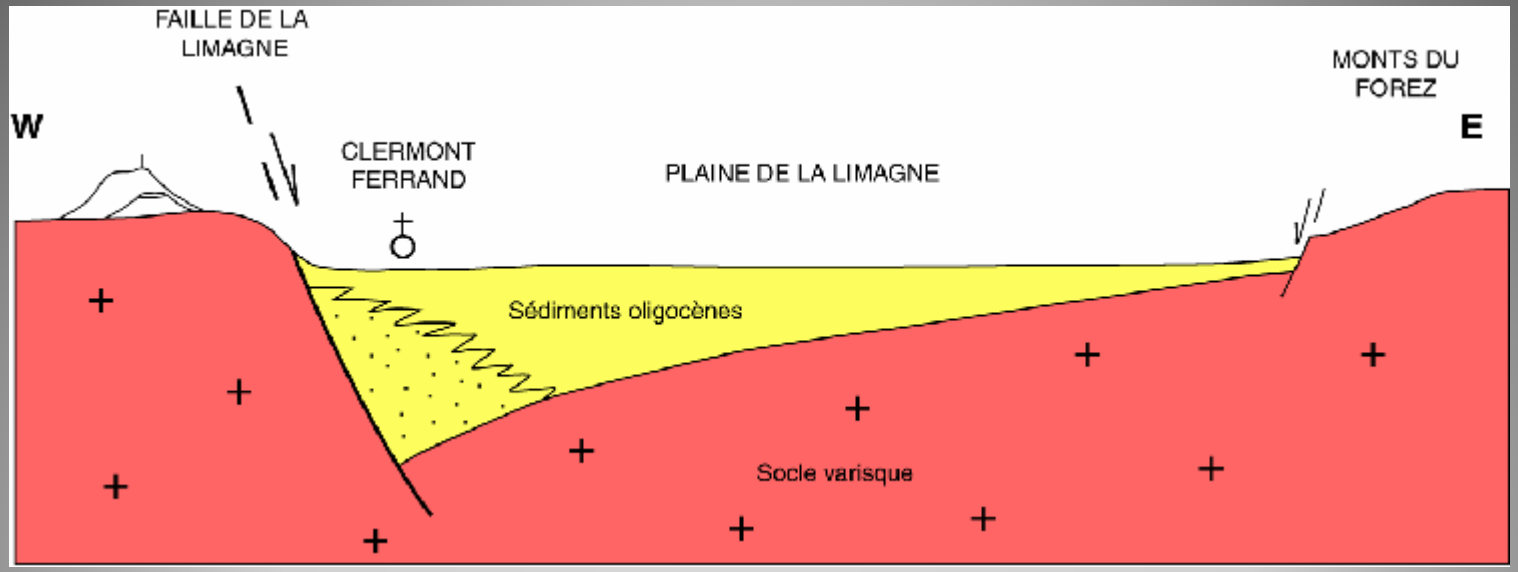


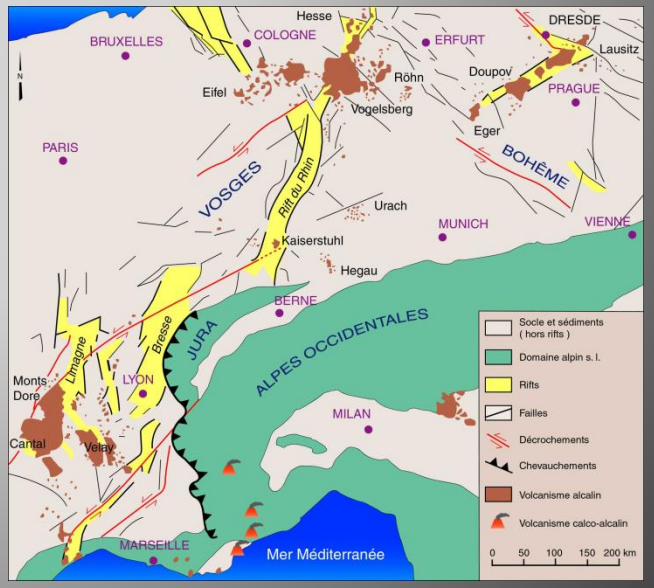

Barr. inf.
bioclastique
s0
Barr. inf.
bioclastique
Di
s0
s0
Barr. inf. marno-calc.
Barr. inf. marno-calc.
Hauterivien


A
graben
B
demi-grabens
C
arc volcanique
bassin d'arrière-arc
bassin d'avant-arc
fosse océanique
prisme d'accrétion
D


Hesse
DRESDE
BRUXELLES
COLOGNE
ERFURT
Lausitz
Doupov
Röhn
Eifel
PRAGUE
Vogelsberg
Eger
PARIS
BOHÊME
VOSGES
Rift du Rhin
Urach
MUNICH
VIENNE
Kaiserstuhl
Hegau
BERNE
JURA
Bresse
Limagne
ALPES OCCIDENTALES
Monts Dore
LYON
MILAN
Cantal
Velay
MARSEILLE
Mer Méditerranée
N
Socle et sédiments (hors rifts)
Domaine alpin s. l.
Rifts
Failles
Décrochements
Chevauchements
Volcanisme alcalin
Volcanisme calco-alcalin
0 50 100 150 200 km


Horst
Graben


FAILLE DE LA LIMAGNE
W
CLERMONT FERRAND
PLAINE DE LA LIMAGNE
MONTS DU FOREZ
E
Sédiments oligocènes
Socle varisque


Hesse
BRUXELLES
COLOGNE
ERFURT
DRESDE
Lausitz
Eifel
Röhn
Doupov
PRAGUE
Vogelsberg
Eger
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Failles
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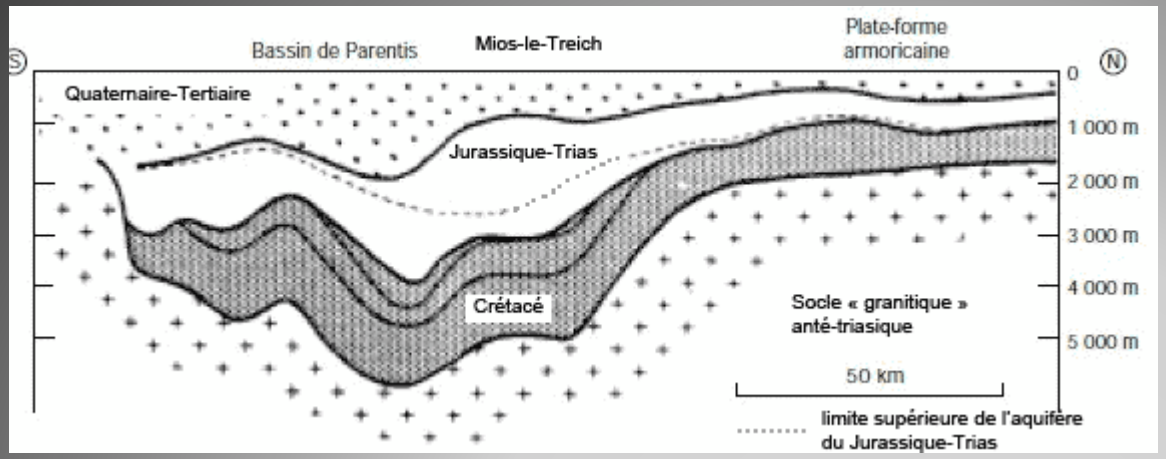
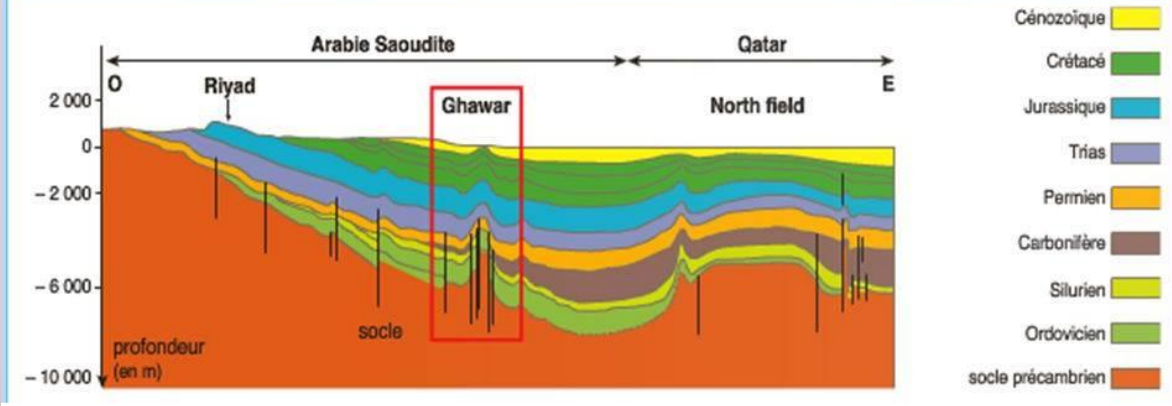
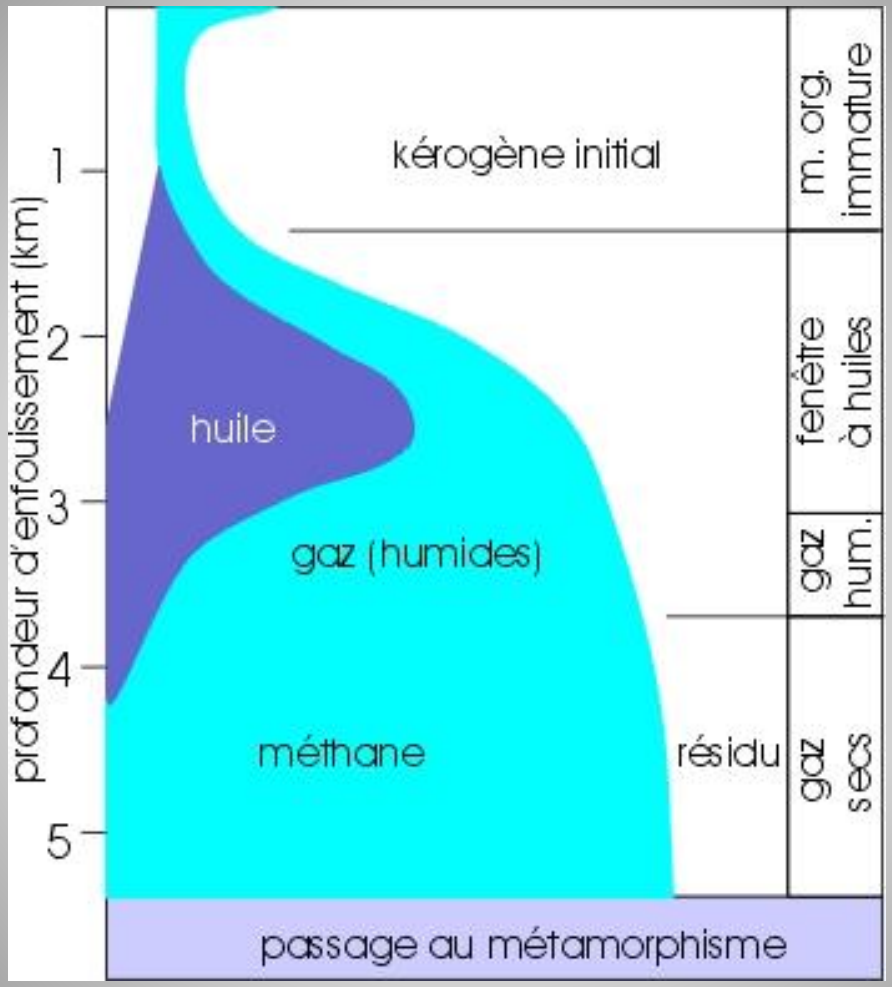
Chevauchements
Volcanisme alcalin
Volcanisme calco-alcalin
0 50 100 150 200 km

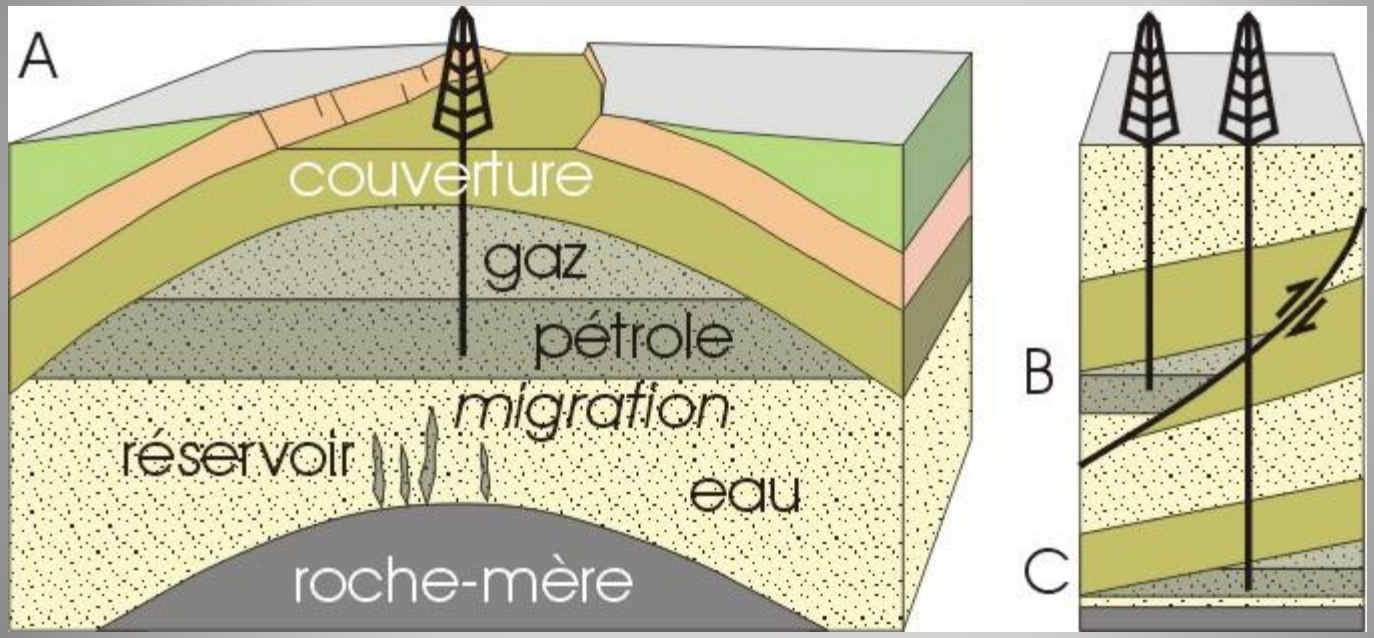


BASSIN SEDIMENTAIRE



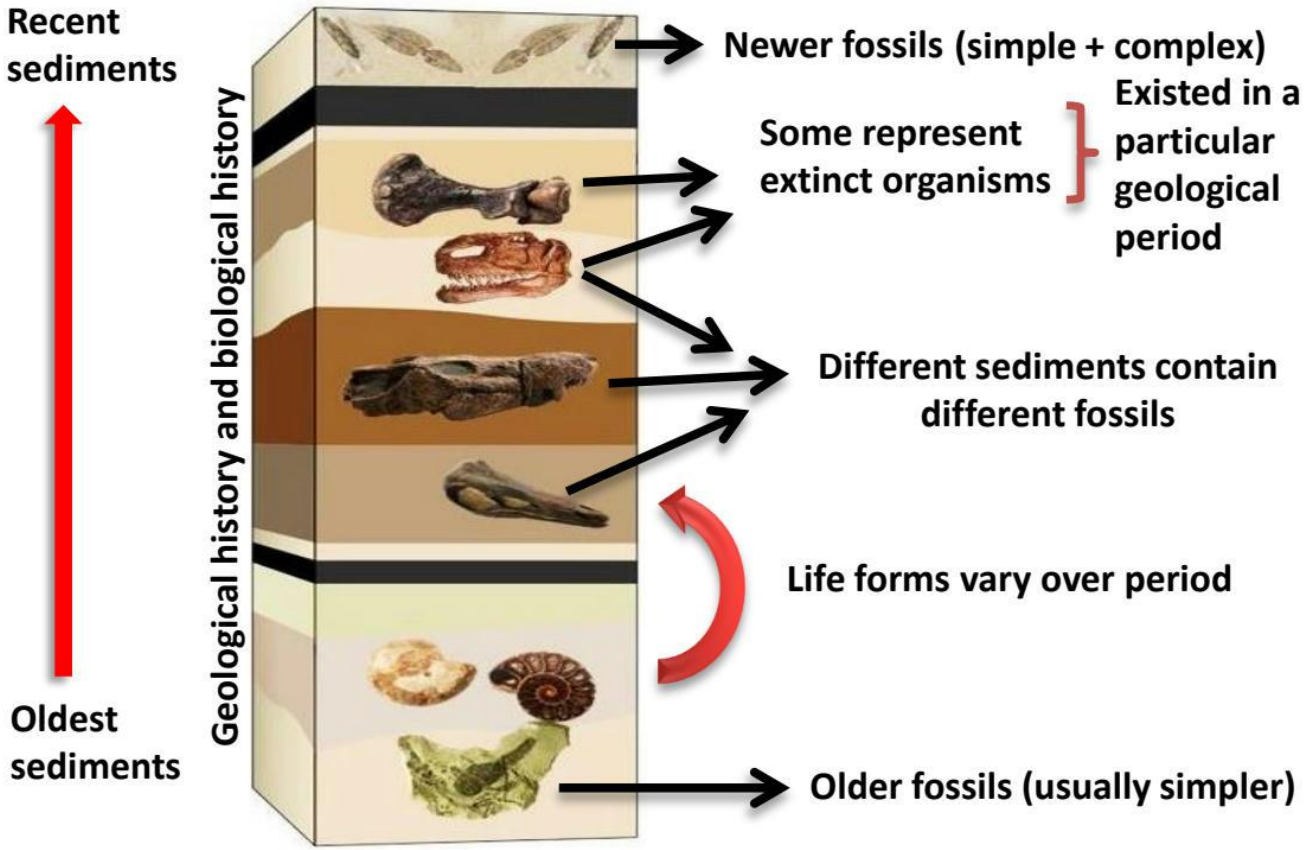
- Portion de la croûte terrestre déprimée tectoniquement, une dépression en forme de cuvette évasée due à un affaissement lent et progressif (subsidence), où se sont empilés pendant une longue période (10 à 100 Ma.) et sur une grande épaisseur des sédiments variés, marins ou continentaux, subhorizontaux ou faiblement déformés.


profondeur d'enfouissement (km)
1
2
3
4
5
kérogène initial
huile
gaz (humides)
méthane
résidu
passage au métamorphisme
m. org. immature
fenêtre à huiles
gaz hum.
gaz secs

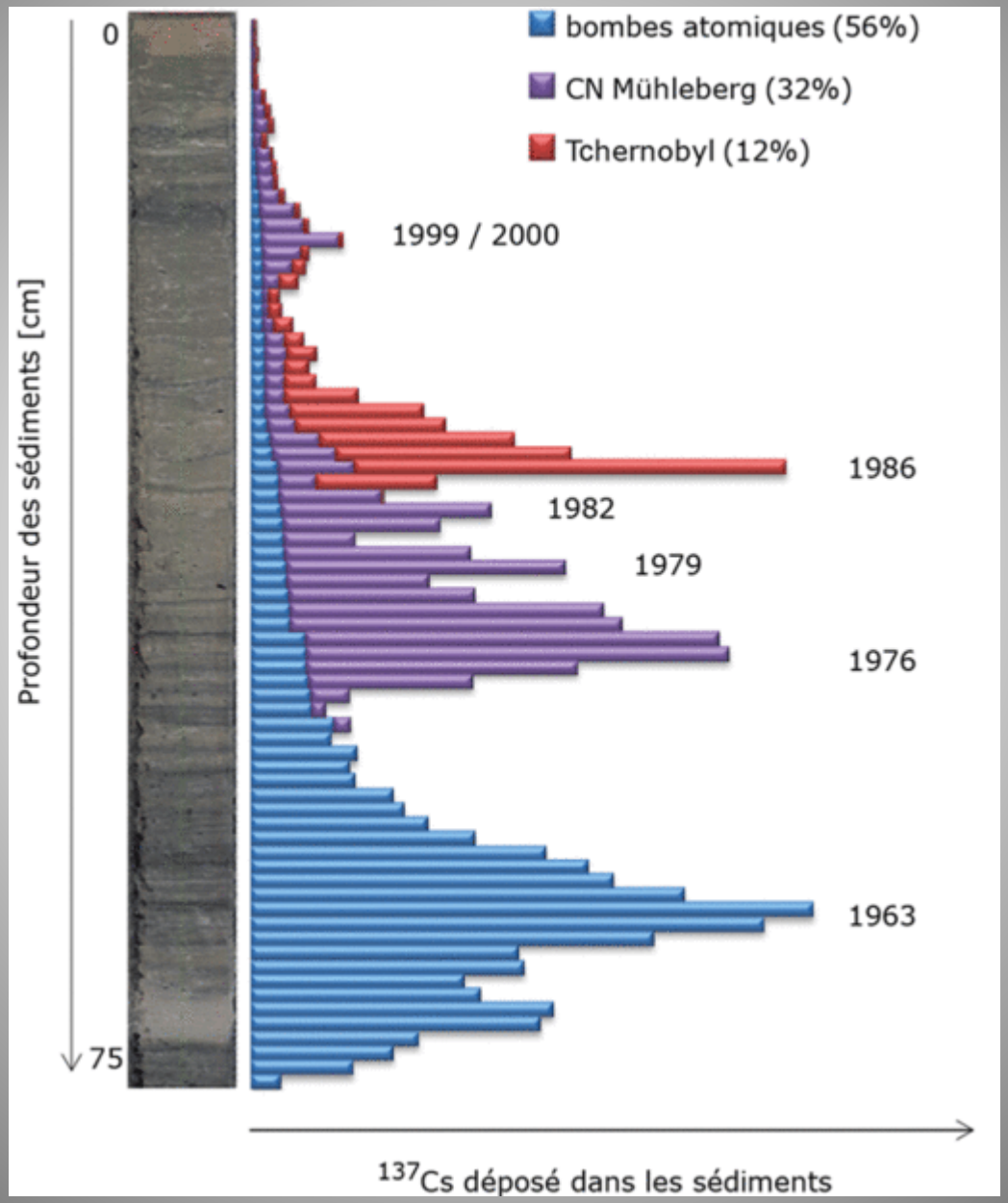

A
couverture
gaz
pétrole
migration
réservoir
eau
roche-mère
B
C

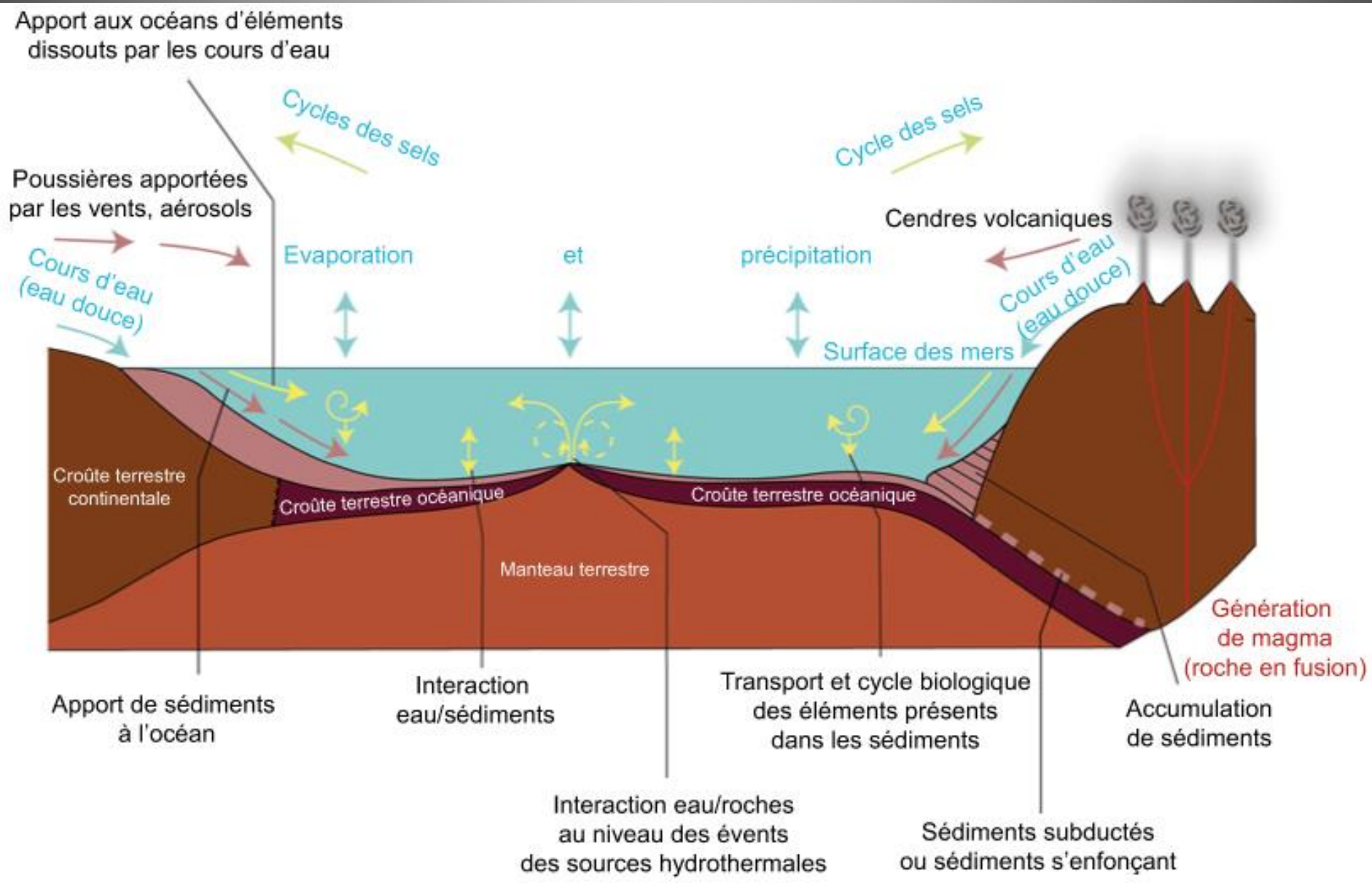
Autres utilisations des roches sédimentaires

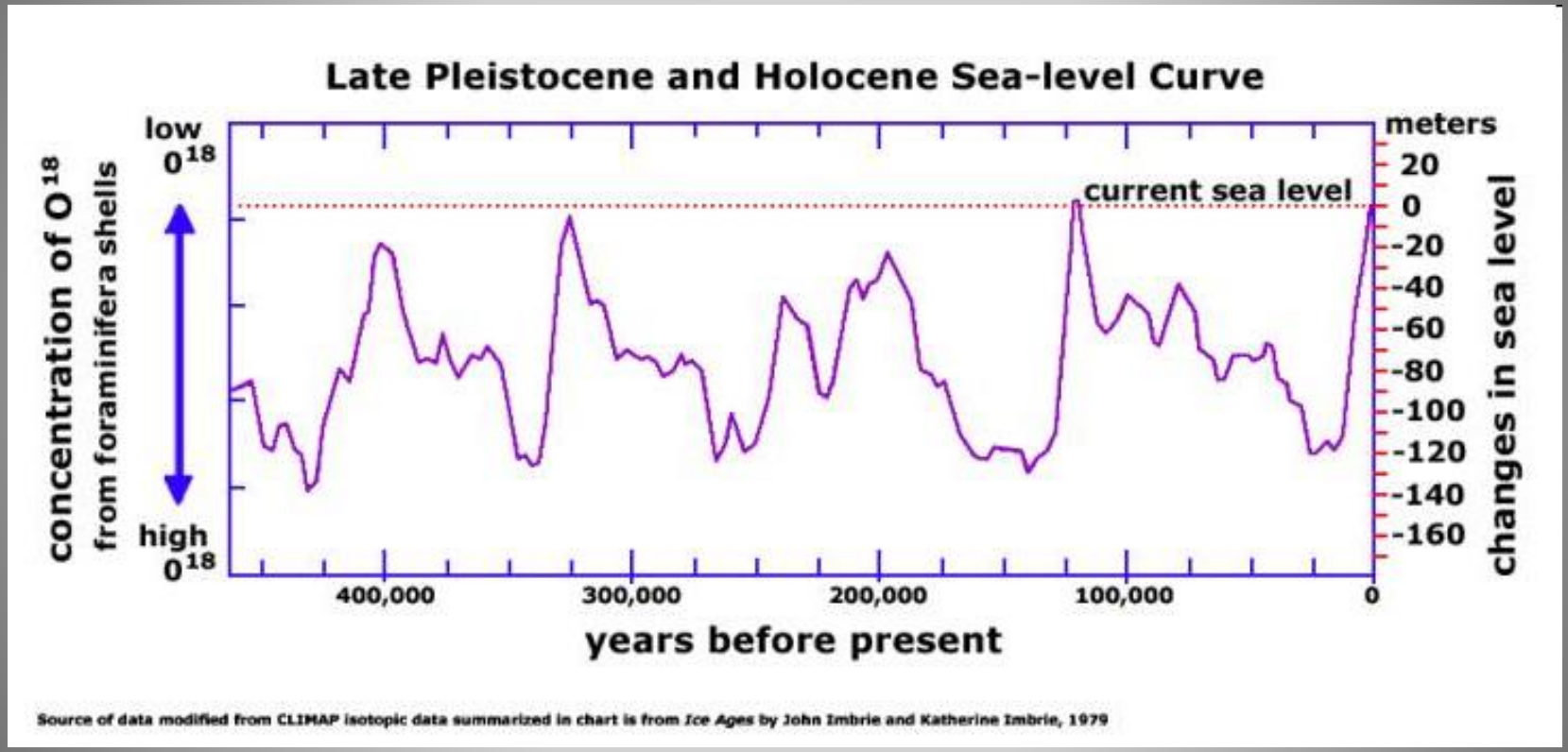
(1) Palaeontological evidences



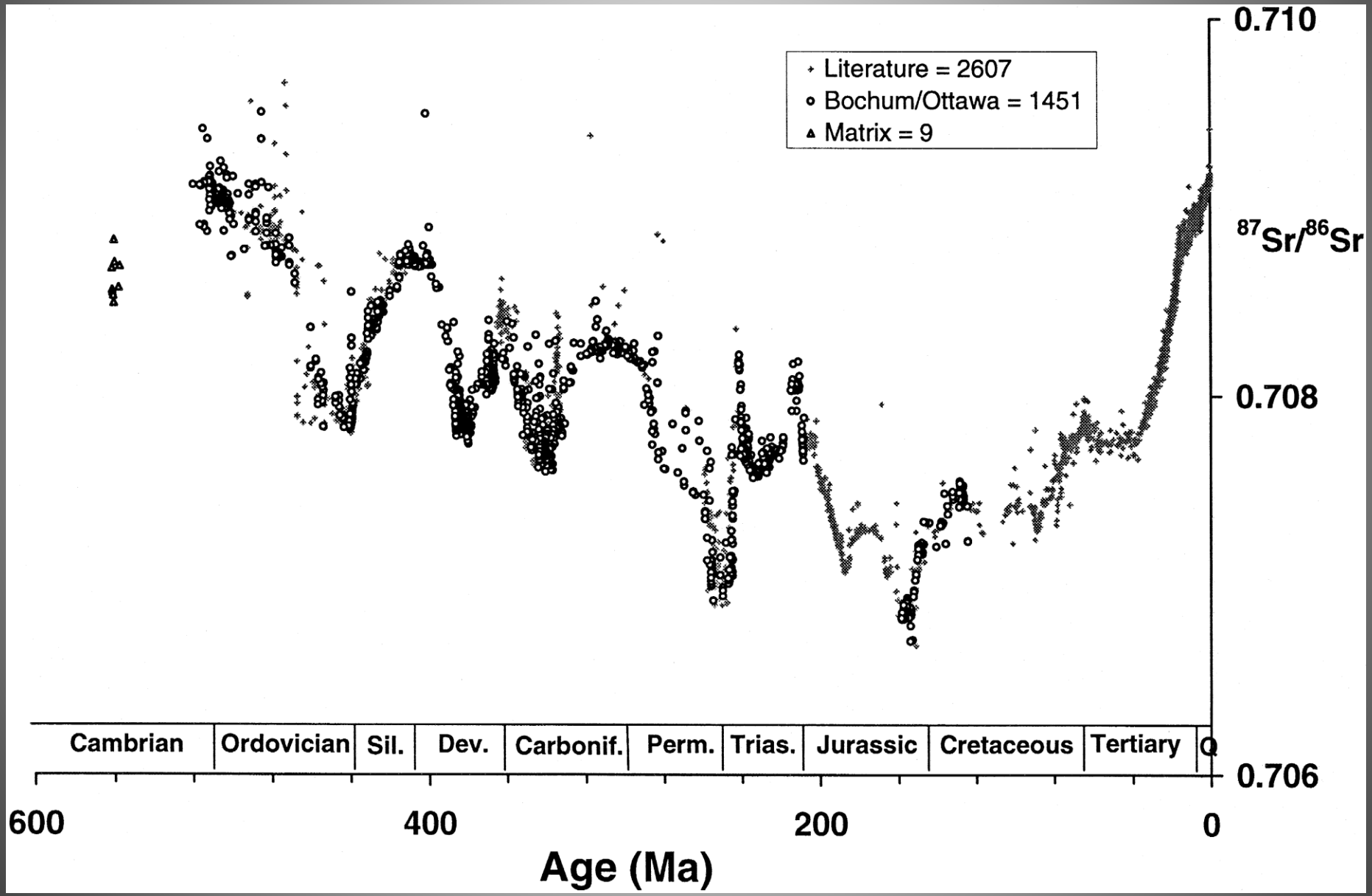
Sédiments d'un lac suisse, près d'une centrale nucléaire

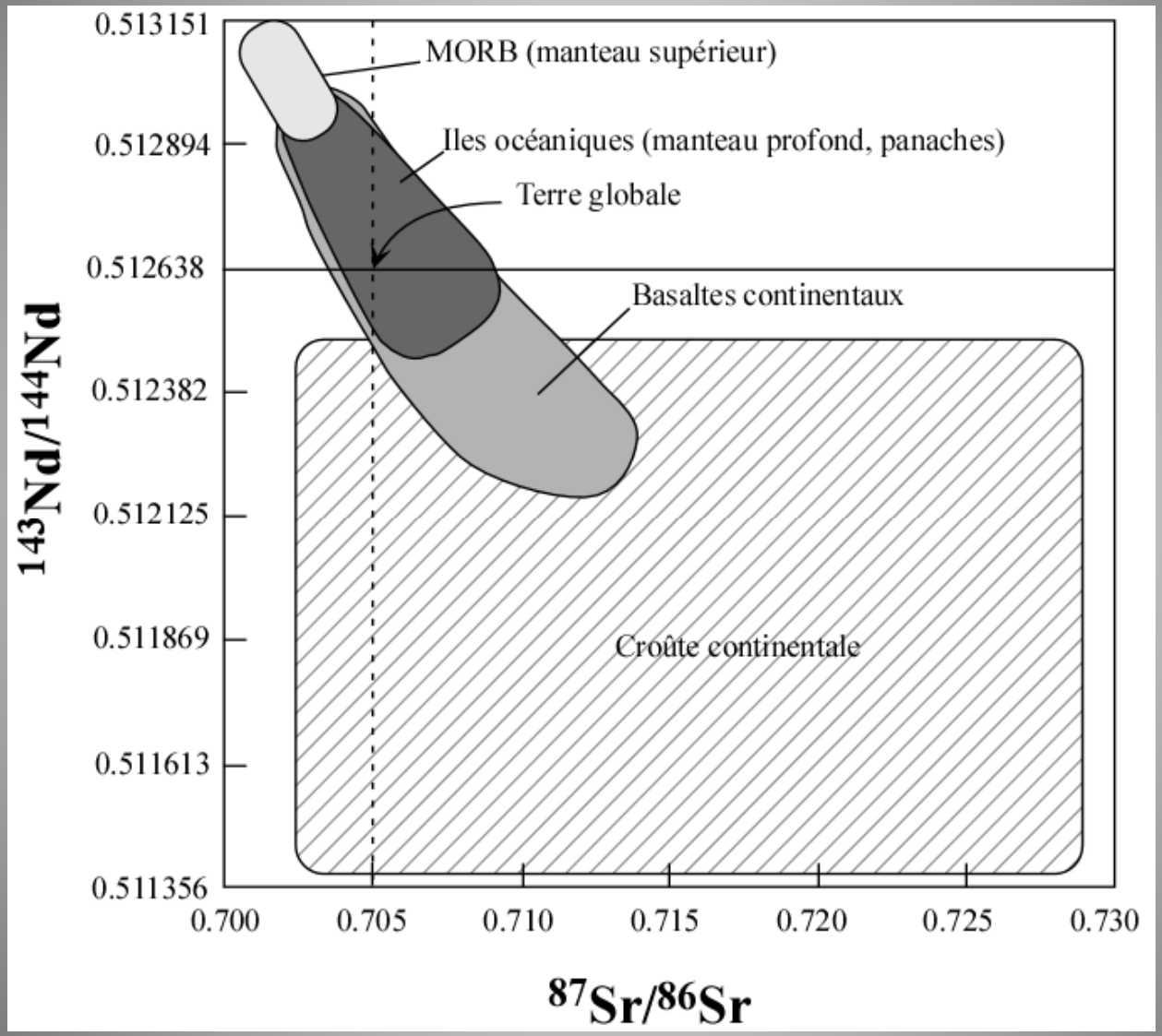



Apport aux océans d'éléments dissouts par les cours d'eau
Cycles des sels
Cycle des sels
Poussières apportées par les vents, aérosols
Cendres volcaniques
Cours d'eau (eau douce)
Evaporation
et
précipitation
Cours d'eau (eau douce)
Surface des mers
Croûte terrestre continentale
Croûte terrestre océanique
Croûte terrestre océanique
Manteau terrestre
Génération de magma (roche en fusion)
Apport de sédiments à l'océan
Interaction eau/sédiments
Transport et cycle biologique des éléments présents dans les sédiments
Accumulation de sédiments
Interaction eau/roches au niveau des évents des sources hydrothermales
Sédiments subductés ou sédiments s'enfonçant


Late Pleistocene and Holocene Sea-level Curve
concentration of O18 from foraminifera shells
low O18
high O18
current sea level
meters
20
0
-20
-40
-60
-80
-100
-120
-140
-160
changes in sea level
400,000
300,000
200,000
100,000
0
years before present
Source of data modified from CLIMAP isotopic data summarized in chart is from Ice Ages by John Imbrie and Katherine Imbrie, 1979

Composition isotopique des océans déterminée à partir de brachiopodes, de bélemnites et de conodontes




0.513151
0.512894
0.512638
0.512382
0.512125
0.511869
0.511613
0.511356
143Nd/144Nd
0.700
0.705
0.710
0.715
0.720
0.725
0.730
87Sr/86Sr
MORB (manteau supérieur)
Iles océaniques (manteau profond, panaches)
Terre globale
Basaltes continentaux
Croûte continentale