Chronology of Leaking Events and Sealing Processes in Fractured Reservoir: A Natural Example in Utah (USA)*

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Abstract

A multidisciplinary work on complex fluids, migrating from deep reservoirs to the surface in faulted zones, has been led in order to investigate and quantify the episodic opening and sealing of faults above a natural hydrocarbon reservoir and an aquifer locally CO_2 enriched, in Green River area, Utah. It is well known that fluids flow through faults, but it is also demonstrated that fault zones may act as impermeable barriers. We consider here that active faults can successively open and close paths for fluids. In the studied example, these cycles are recorded close to the surface by observation of the fluid paths and travertine precipitation.

Several methods have been used to investigate the correlation between complex fluid sources and migration processes through reservoirs and faults, and finally with surface precipitation. Field and petrographic work reveal the complexity of travertine structures. Two main types of travertine precipitation have been found: 1) travertine built on surface, and 2) cross-cutting veins, each of them characterized by different crystallisation modes and processes. The link with the evolution of flow rates variation through the fault has been investigated.

Stable isotope δ18O, δ13, cathodoluminescence and fluoX-mapping studies of a young travertine located close to a current source, show a certain periodicity of circulation along the fault itself. The circulation cycles recorded in the precipitations evidenced different

exotic fluid sources and the evolution of migrating paths through time. Recurrence and duration characteristic times may be evaluated with paleomagnetic tools. In the case of the young travertine, the time-mineralization for the deposition of a 10 m-thick travertine seems to be very short: less than 1000 years. However, data from an older travertine had recorded two magnetic inversions during its formation (indicating age of more than 760 ky). These data are going to be calibrated with absolute radiogenic dating (U/Th).

We conclude that a chronology of leaking episodic events and sealing processes along active faults can be evidenced. Understanding these mechanisms are essential to calibrate transfer models at the reservoir scale.

Selected Reference

Hilgers, C., D. Koehn, P.D. Bons, and J.L. Urai, 2001, Development of crystal morphology during unitaxial growth in a progressively widening vein: II. Numerical stimulations of the evolution of antitaxial fibrous veins: Journal of Structural Geology, v. 23/6-7, p. 873-885.

Chronology of Leaking Events and Sealing Processes in Fractured Reservoirs

Natural analogue:
Colorado Pateau

How faults' transfer properties evolve?
through time and space

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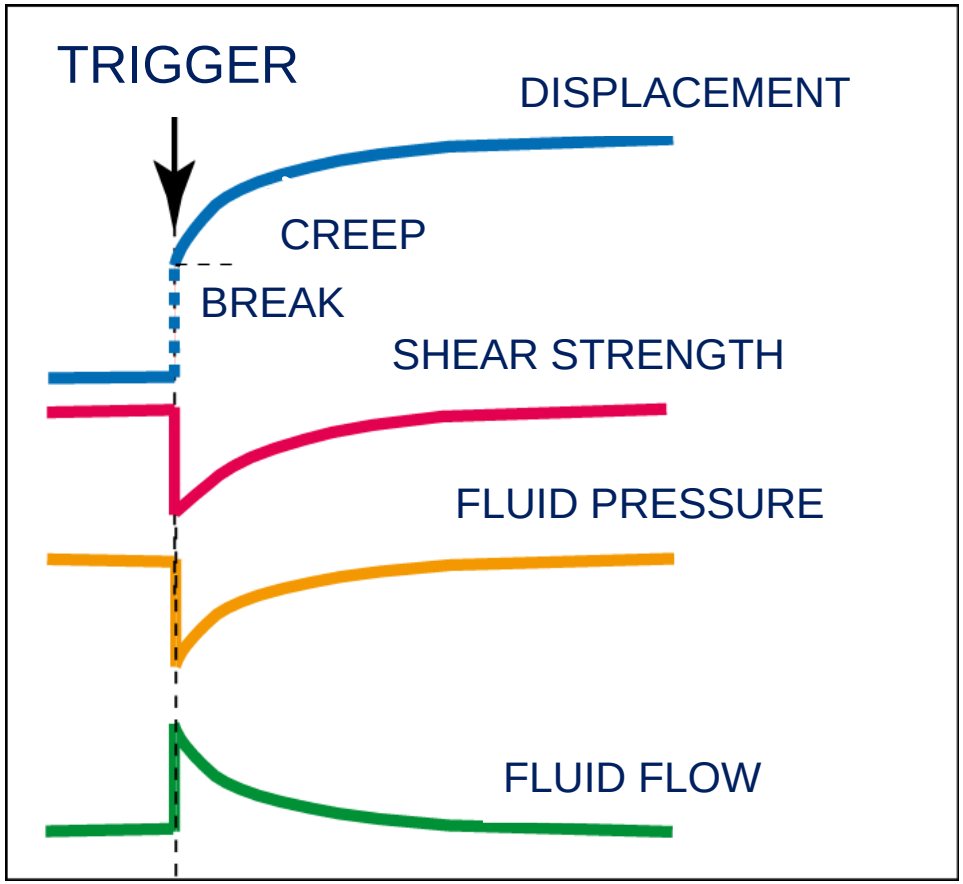
Working partners : D. Blamart (LSCE), C. Aubourg (Pau University) & J. Faure, A. Battani J.Schmitz, O. Vincke (IFP *Energies nouvelles*)

Introduction
Transfer properties evolution in the faults

FAULT = **PATH**



Gratier & Gueydan, 2007

OPENED

CLOSED

earthquakes, overpressures in the reservoirs, Localized dissolutions

Progressive sealing

Introduction
Transfer properties evolution in the faults

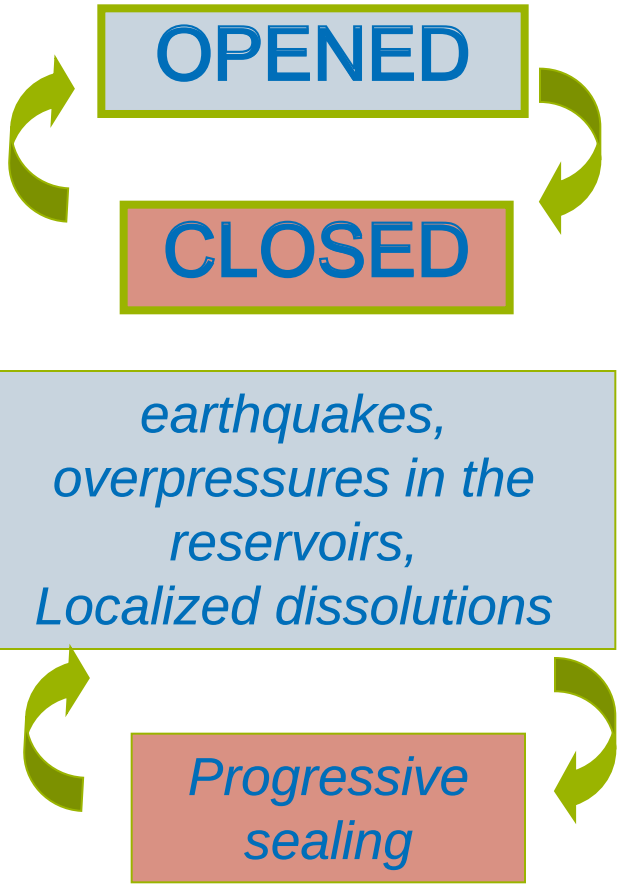
FAULT = **PATH**

1) Faults' network architecture
- Field description & measurements

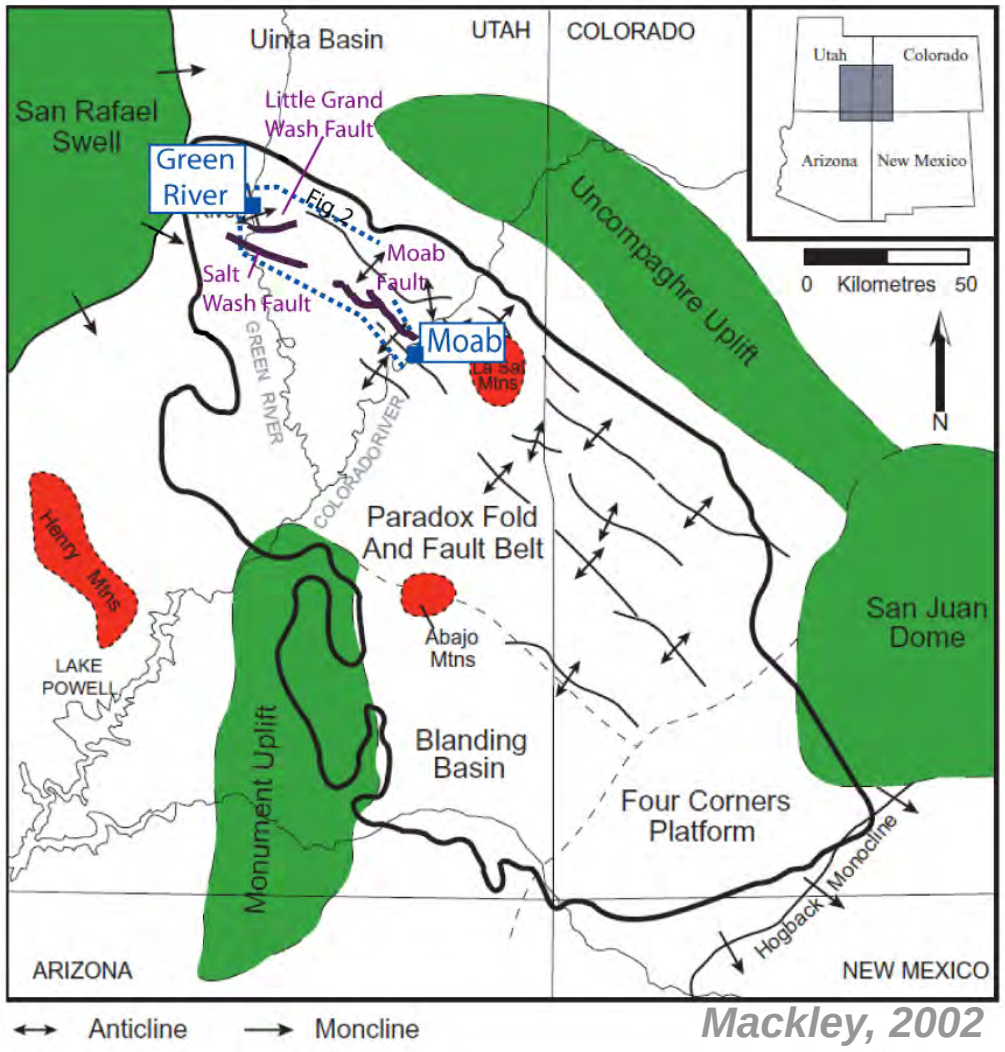
2) Fluids migration & precipitation processes
- From field to thin section scale

3) Fluids' nature and origin
- Petrology, $\delta^{18}O$ $\delta^{13}C$ stable isotopes

4) Characteristic time-laps of faults' circulation and sealing
- Paleomagnetic & radiogenic dating



Location : NW Colorado Plateau, Utah



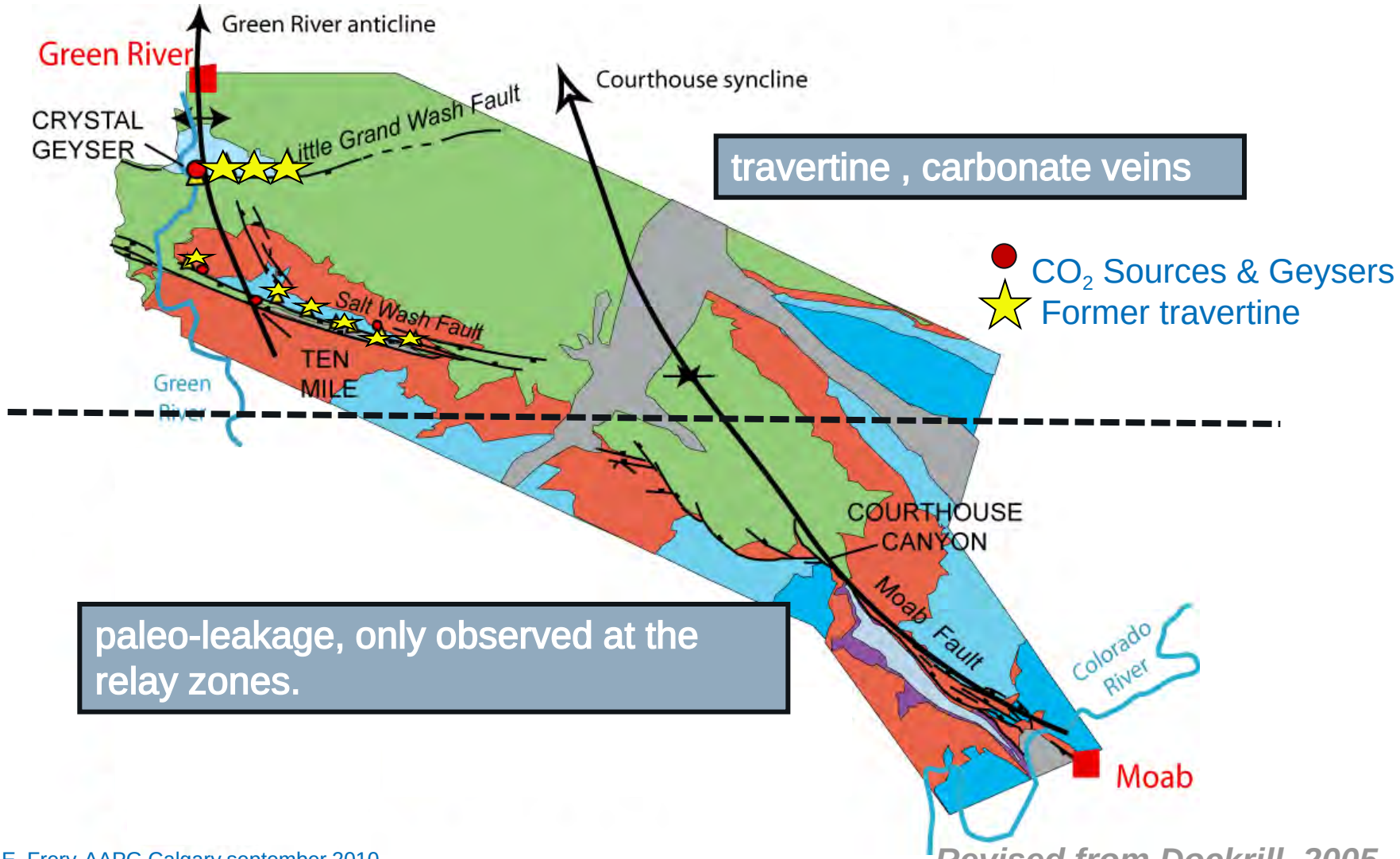
Mackley, 2002

Studied area

North : GREEN RIVER
South : MOAB

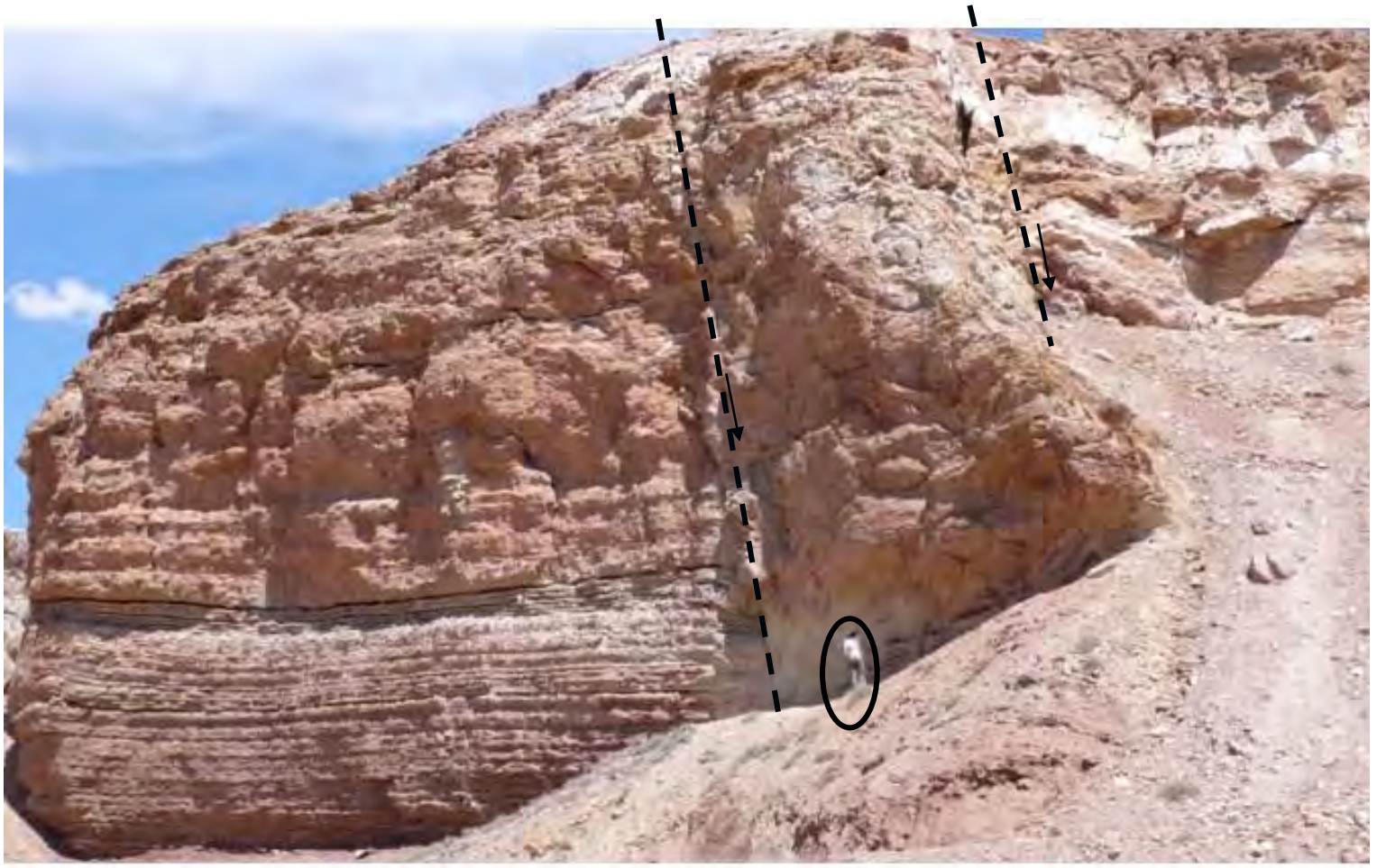
- Paradox basin
- 3 faults:
  - Little Grand Wash (LGW)
  - Salt Wash (SW)
  - Moab (M)

Location : NW Colorado Plateau, Utah

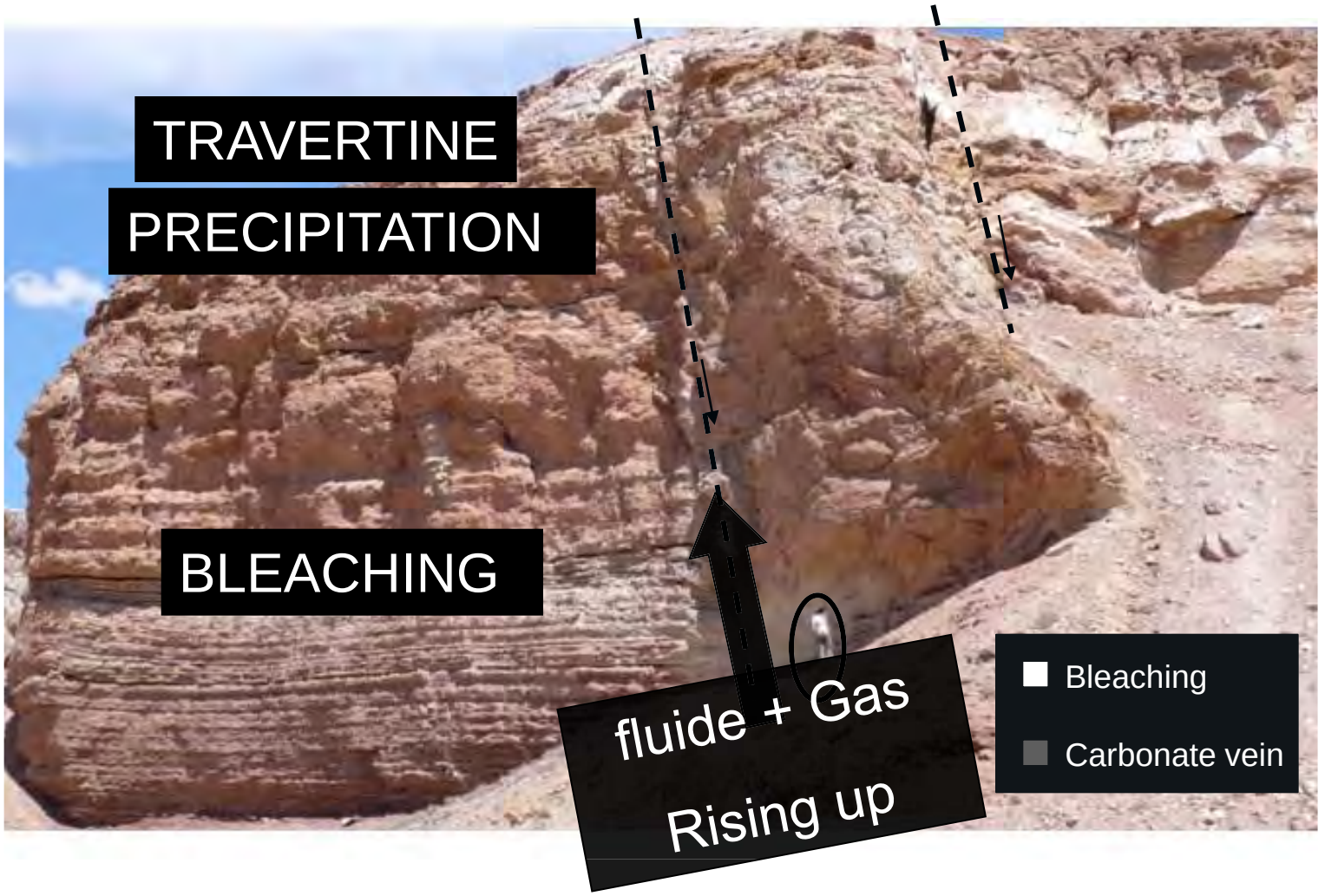


Revised from Dockrill, 2005

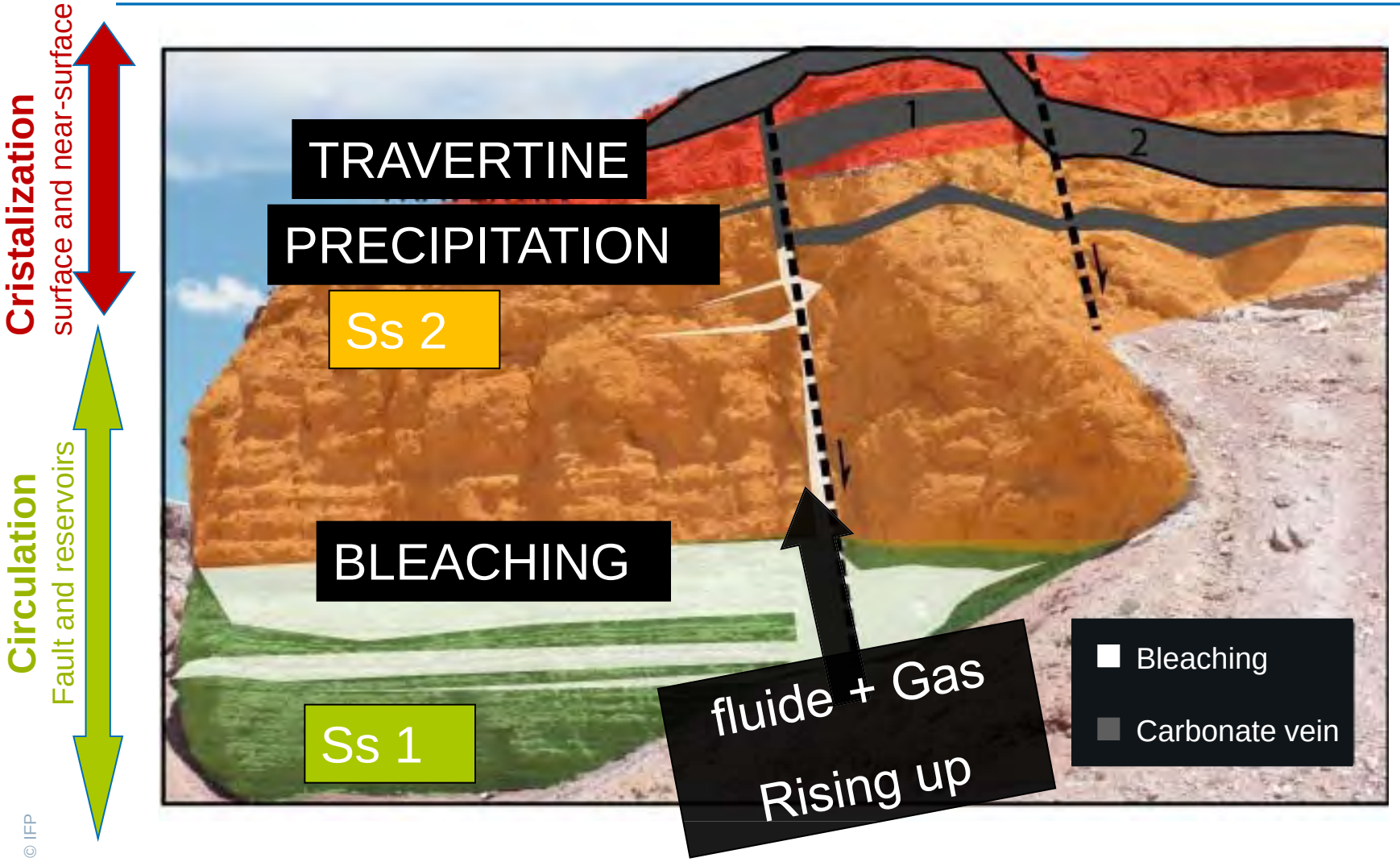
Architecture of an acid fluid rise up through a fault

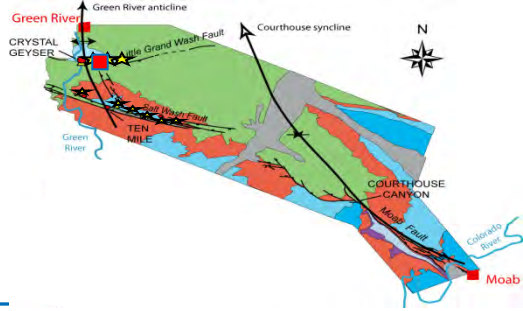


Architecture of an acid fluid rise up through a fault

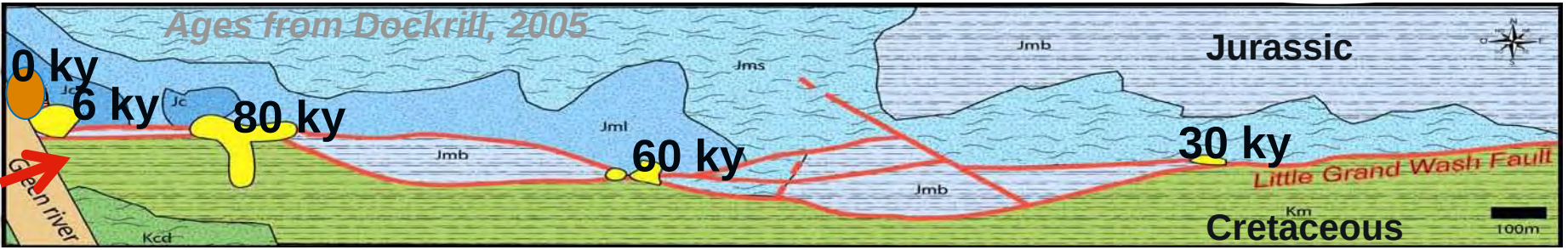


Architecture of an acid fluid rise up through a fault

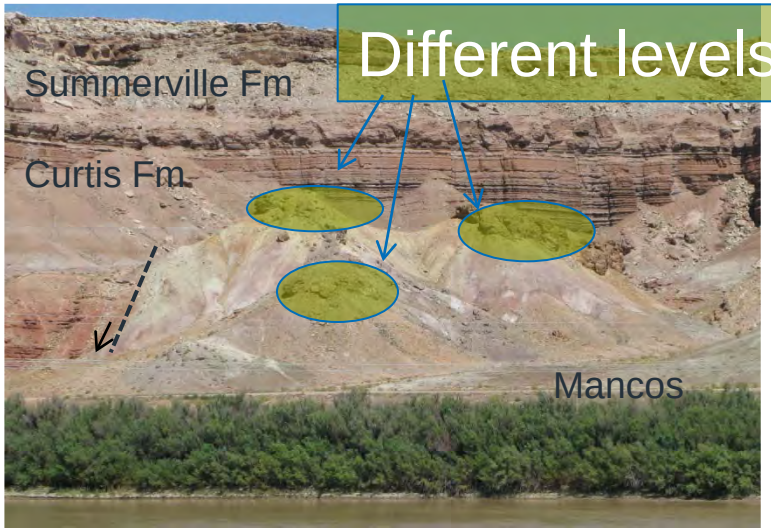




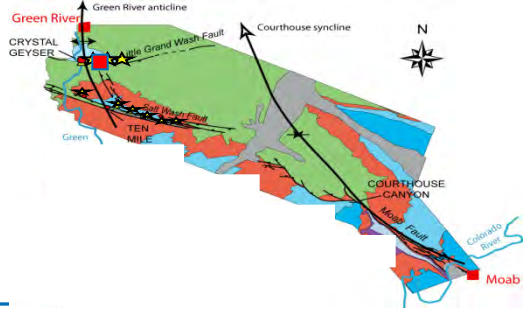
Little Grand Wash Fault



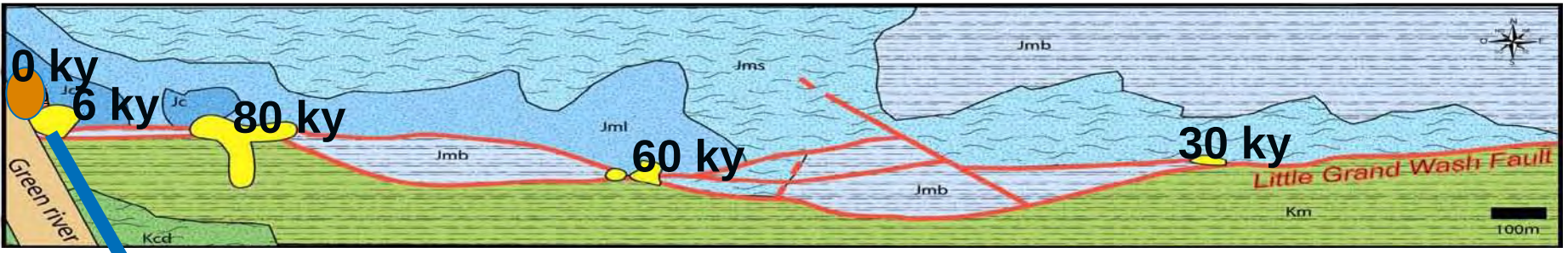
Nature of gas
99,28% CO2



Episodic circulation through time and space along the fault



Little Grand Wash Fault



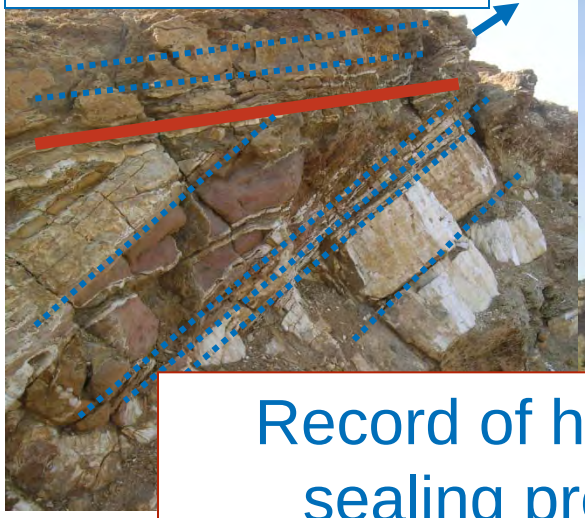
Former travertine

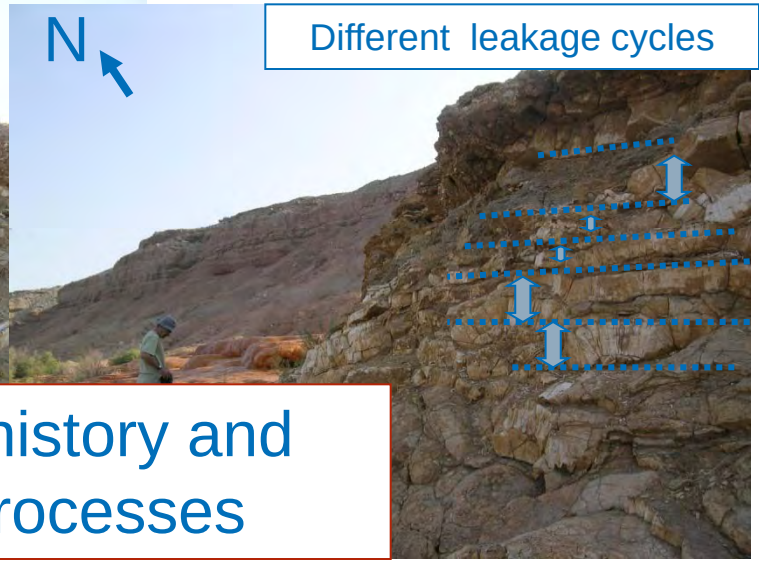
Angular unconformity

S

N

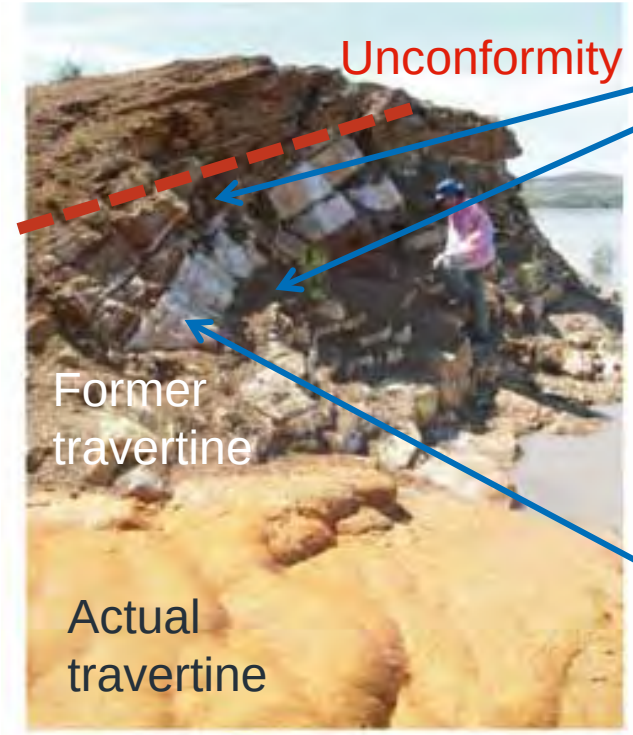
Different leakage cycles



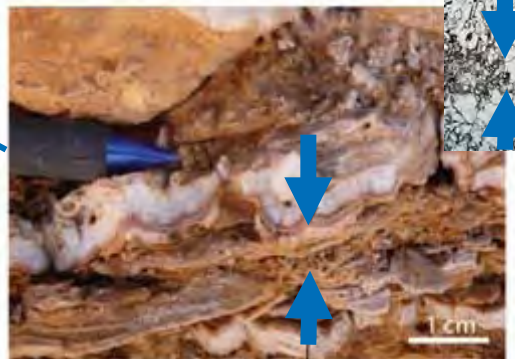


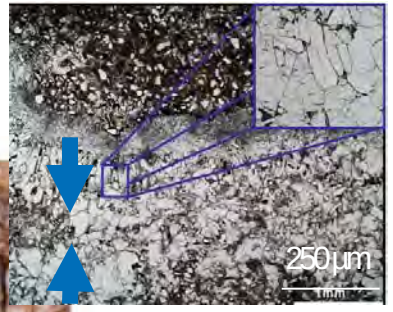
Record of history and sealing processes

1) Set up processes?



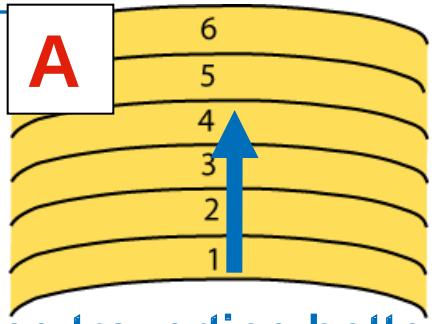
surface travertine bottom up by successive precipitation



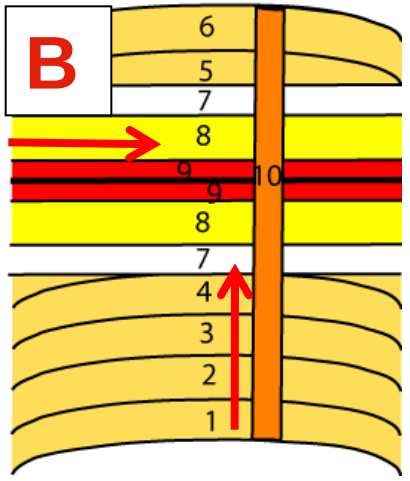


veins centripetal growth

1) Set up processes?



surface travertine bottom up by successive precipitation

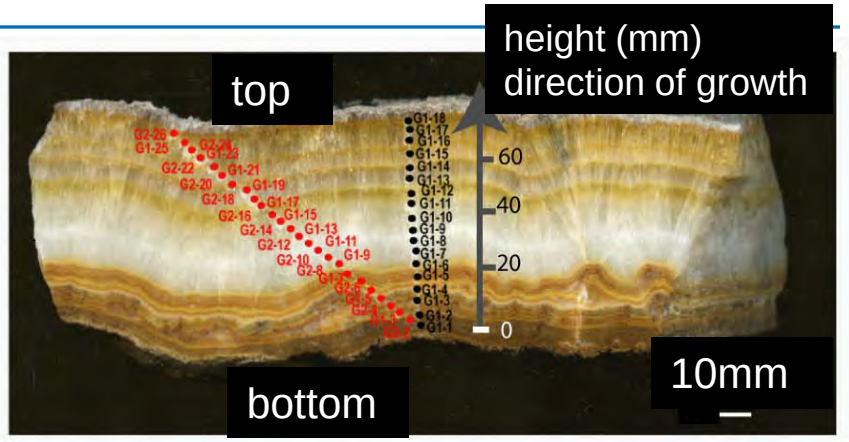


veins centripetal growth

The travertine is a complex structure which records different kind of events related to different thermodynamic status at depth

2) Fluid and CO2 sources?

δ18Ow(SMOW) and δ13Cw(PDB) isotopic study



Ratio
delta 18O(SMOW) / delta 13C(PDB)

0,515
0,51
0,505
0,5
0,495
0,49
0,485
0,48

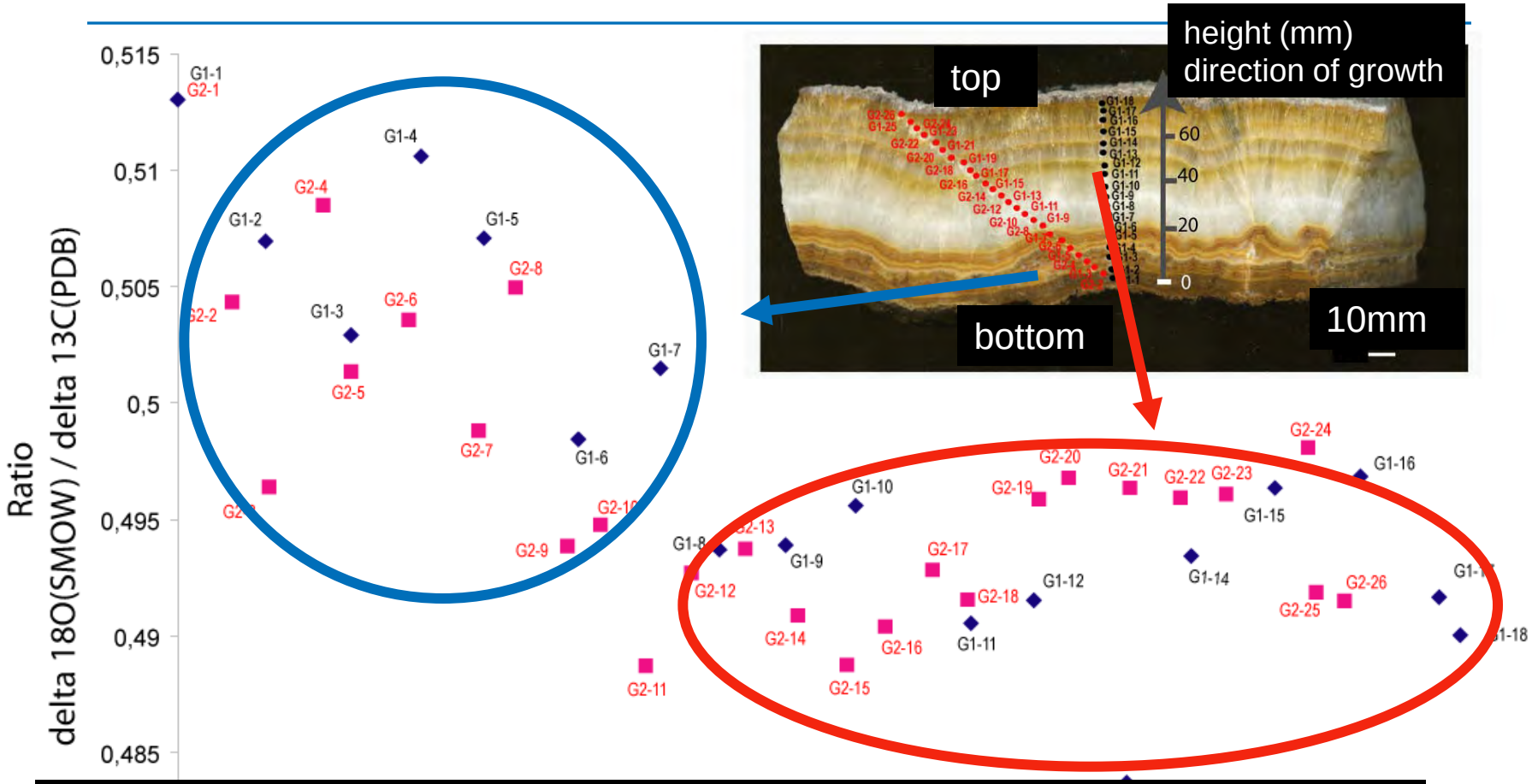
0
10
20
30
40
50
60
70
80

Height (mm)

G1-1 G2-1 G1-4 G2-4 G1-2 G1-5 G2-8 G2-2 G2-6 G1-3 G1-7 G2-5 G2-7 G1-6 G2-3 G2-10 G2-9 G1-8 G2-13 G1-9 G1-10 G2-12 G2-14 G2-16 G2-11 G2-15 G2-17 G2-18 G1-11 G1-12 G1-13 G2-19 G2-20 G2-21 G2-22 G2-23 G2-24 G1-16 G1-15 G1-14 G2-25 G2-26 G1-17 G1-18

2) Fluid and CO2 sources?

δ18Ow(SMOW) and δ13Cw(PDB) isotopic study



Record of the paleo-fluid circulation signatures

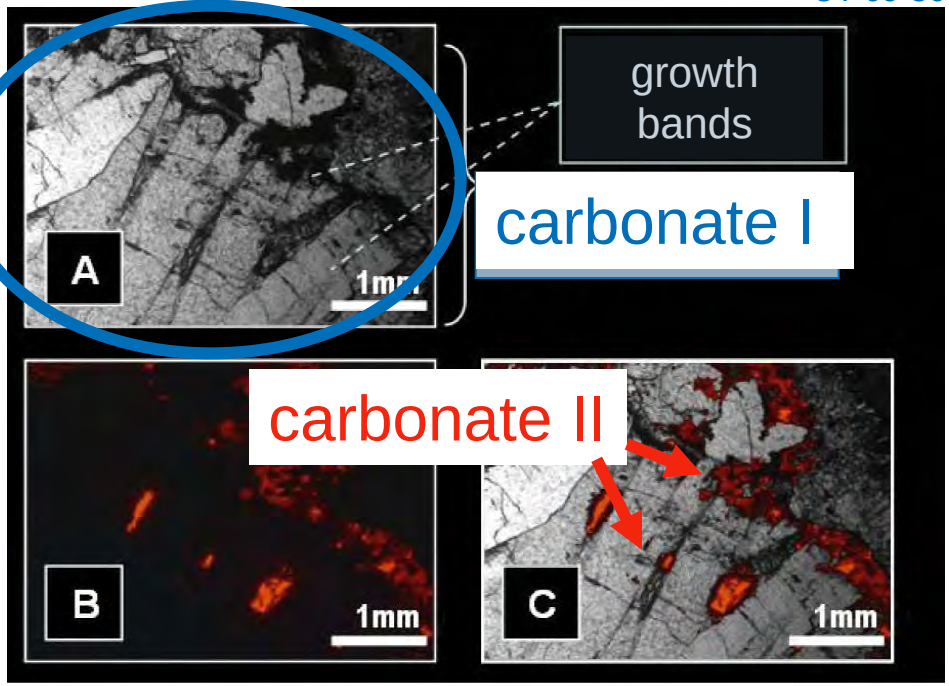
2 mineralization episodes: associated with different sources?

2) Fluid and CO2 sources?

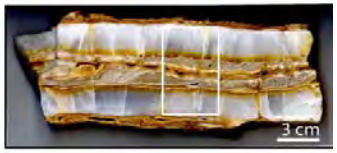
petrographic study

Cathodoluminescence

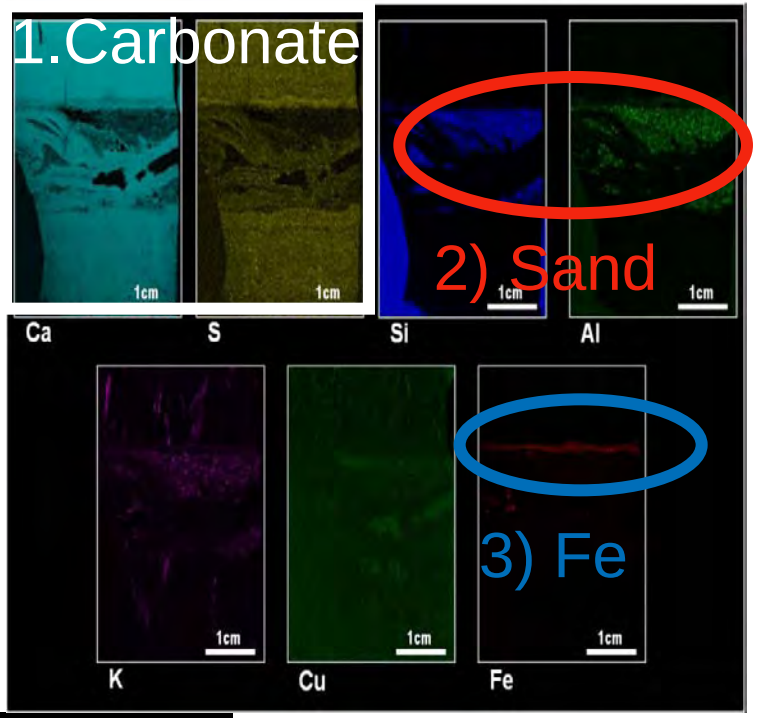
UT-09-36



Fluo X mapping



UT-09-41

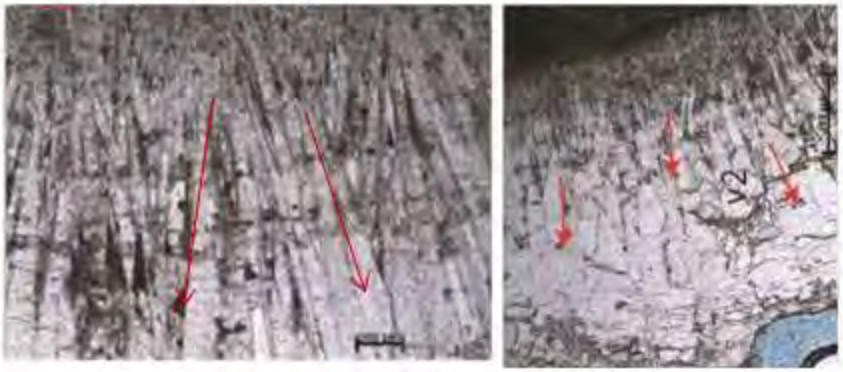


Several episodes with different signatures

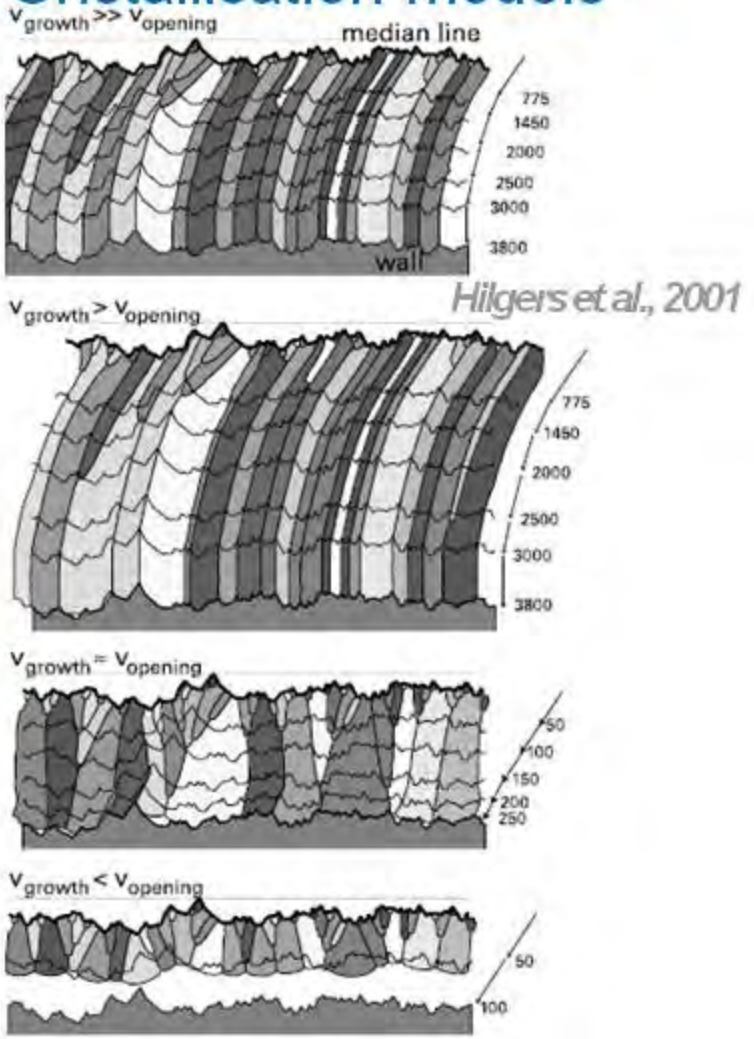
2) Fractures opening processes?

Vgrowth of the minerals versus Vopening of the fracture

Thin sections

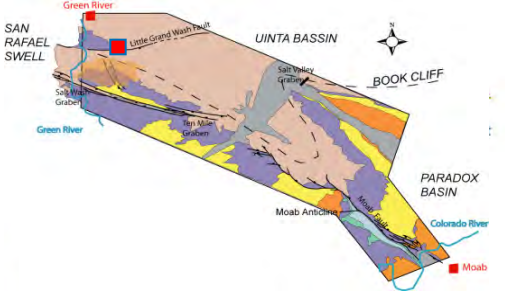


Cristallisation models

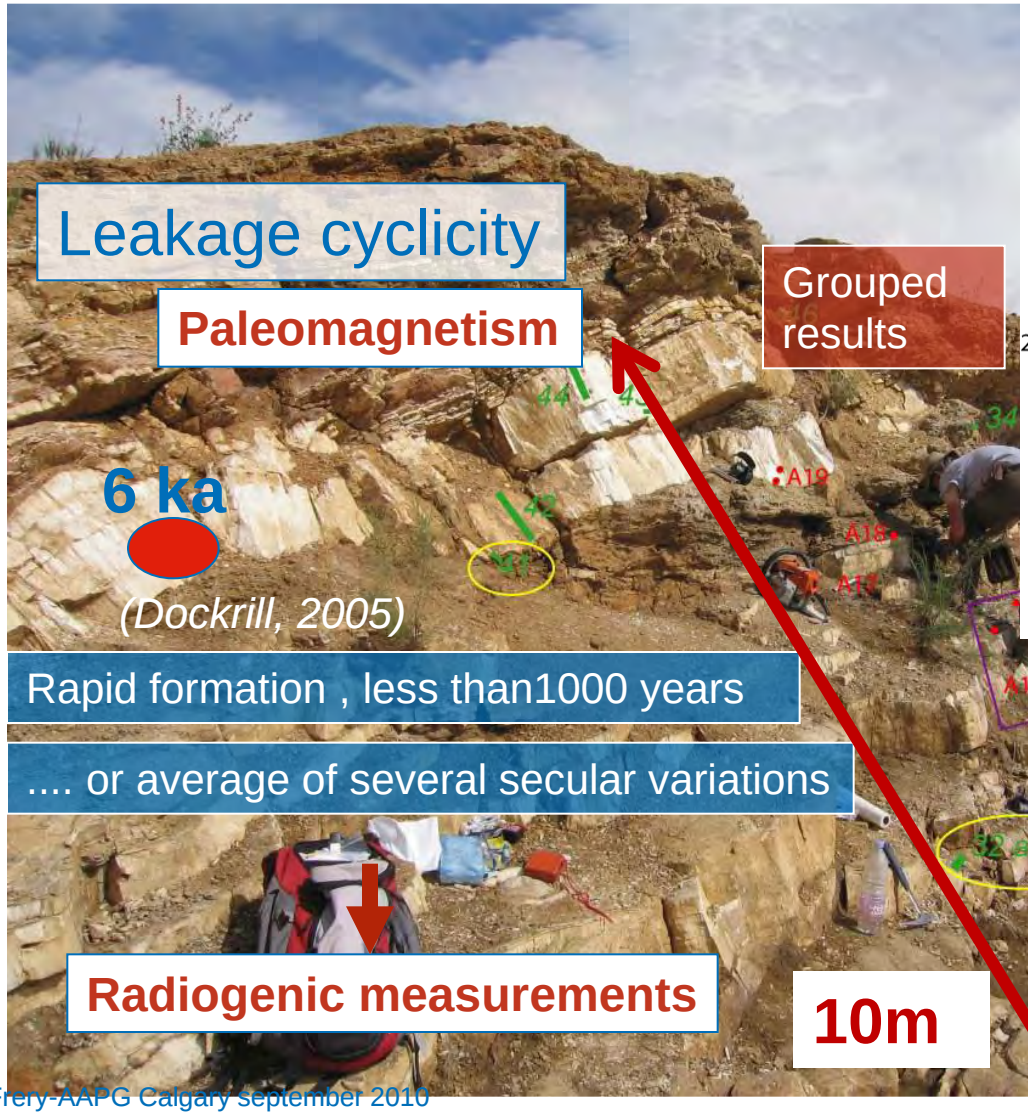


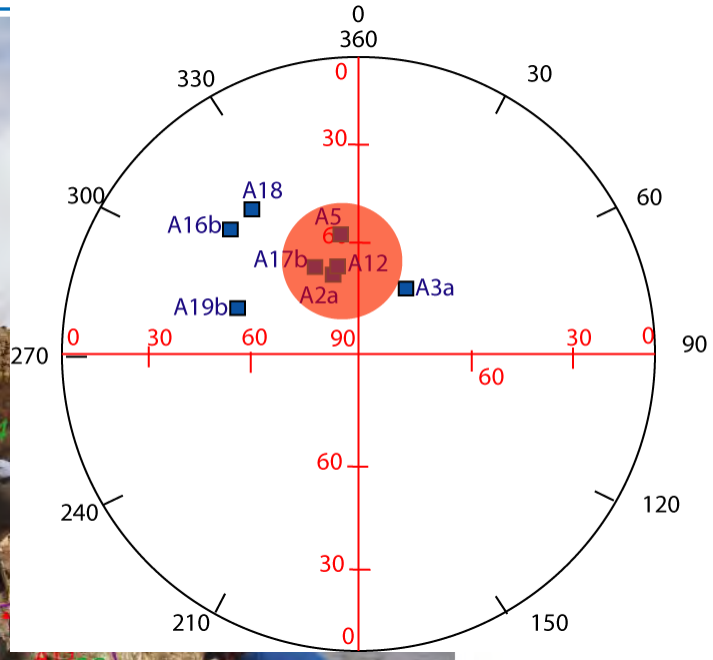
The shapes of the minerals is a great help to understand the opening/cristalization processes

Sealing time laps?



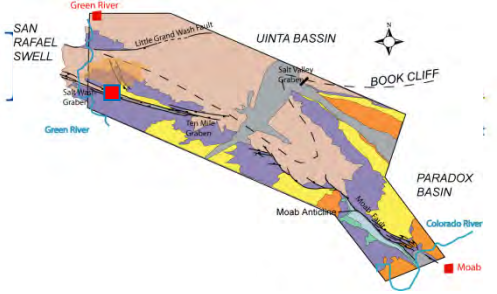
Relative dating





Sealing time laps?

Another example: Salt Wash Fault travertine



N

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Former Travertine

Entrada Fm

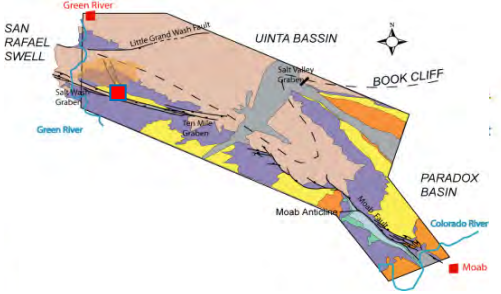
Breccia

Carbonate veins

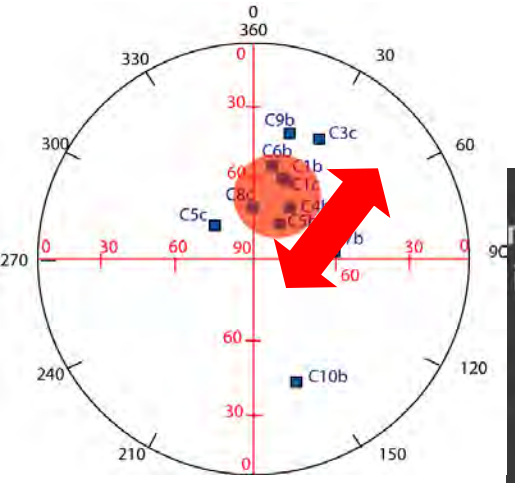
Cedar Mountain Fm

Salt Wash Fault

Sealing time laps?

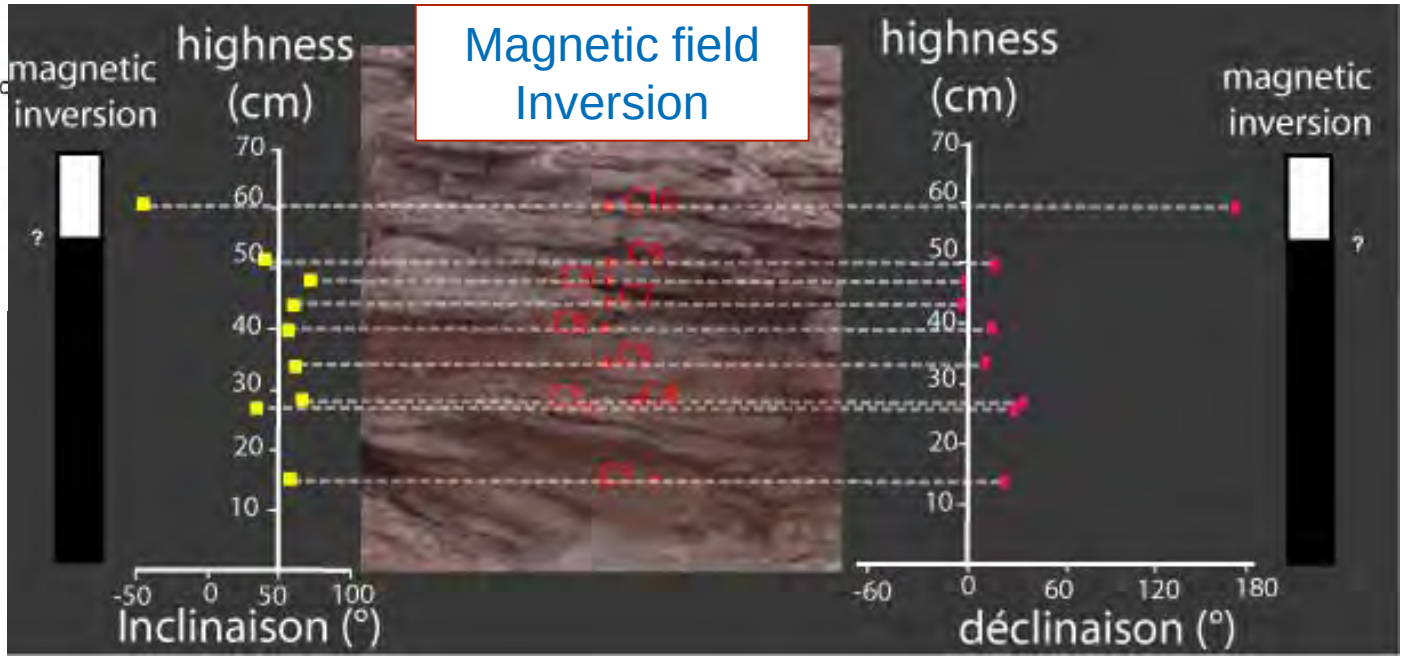


Paleomagnetic dating



Several secular variations?

travertin age **> 760 ky**



Formation time-laps> several thousand years

Next : radiogenic dating to calibrate the results

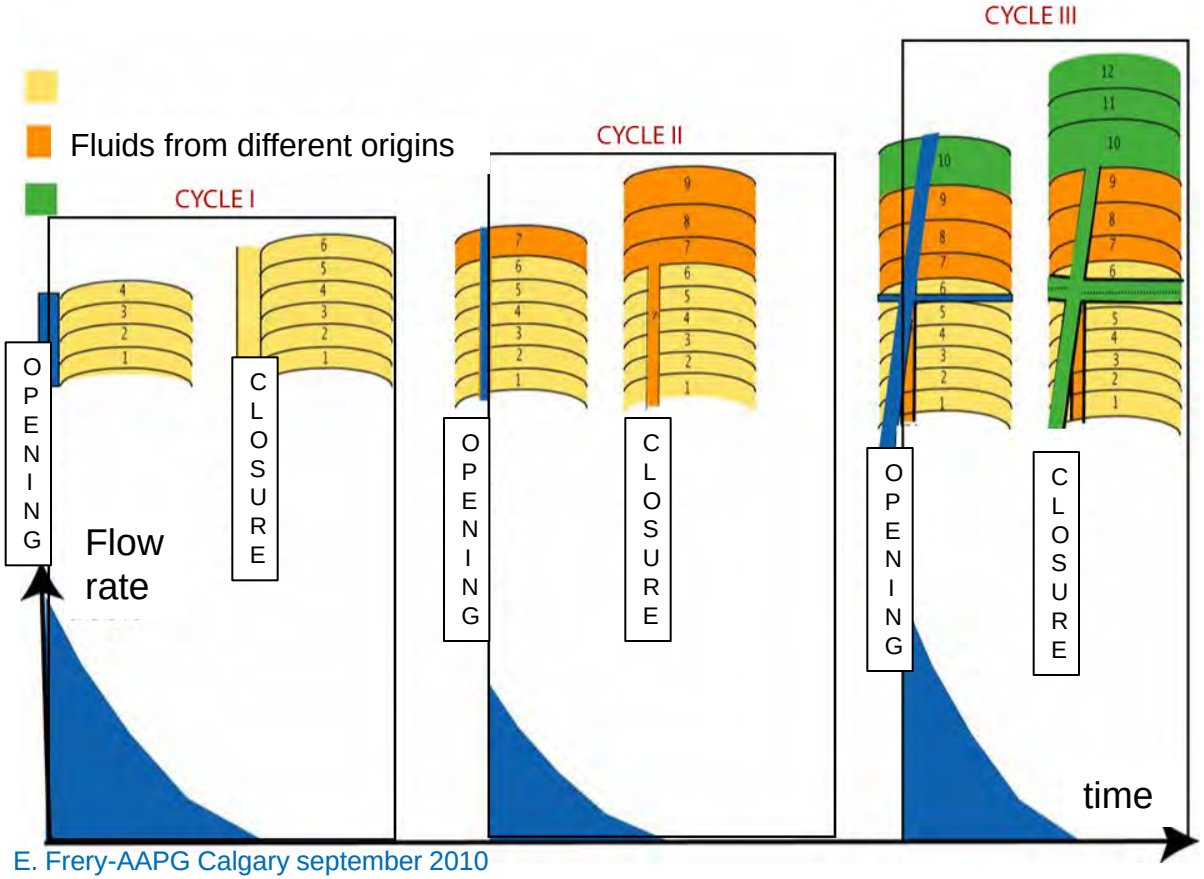
Summary of the study coupled

- Several precipitation cycles of fluids coming from different sources, different thicknesses and frequencies.
- Calibration of episodes and recurrence time
  - LGW fault's studied travertine -10 m - building up in probably less than 1000 years: major leakage episode took a short period
  - SW fault'studied travertine - 70 cm - building up in thousands of years, and registration of a magnetic field inversion (> 740My): Episode of a low leakage rate over a long period or several leakages spaced in time at the same place.
  - ➡ two different time-laps of sealing events

Conclusion
Link between the evolution of transfer properties in the fault and the surface precipitations

- **Architecture / Source / Processes / Time-laps**

⇨ **identification of circulation periodicity along the fault.**



Precipitation grown up

=

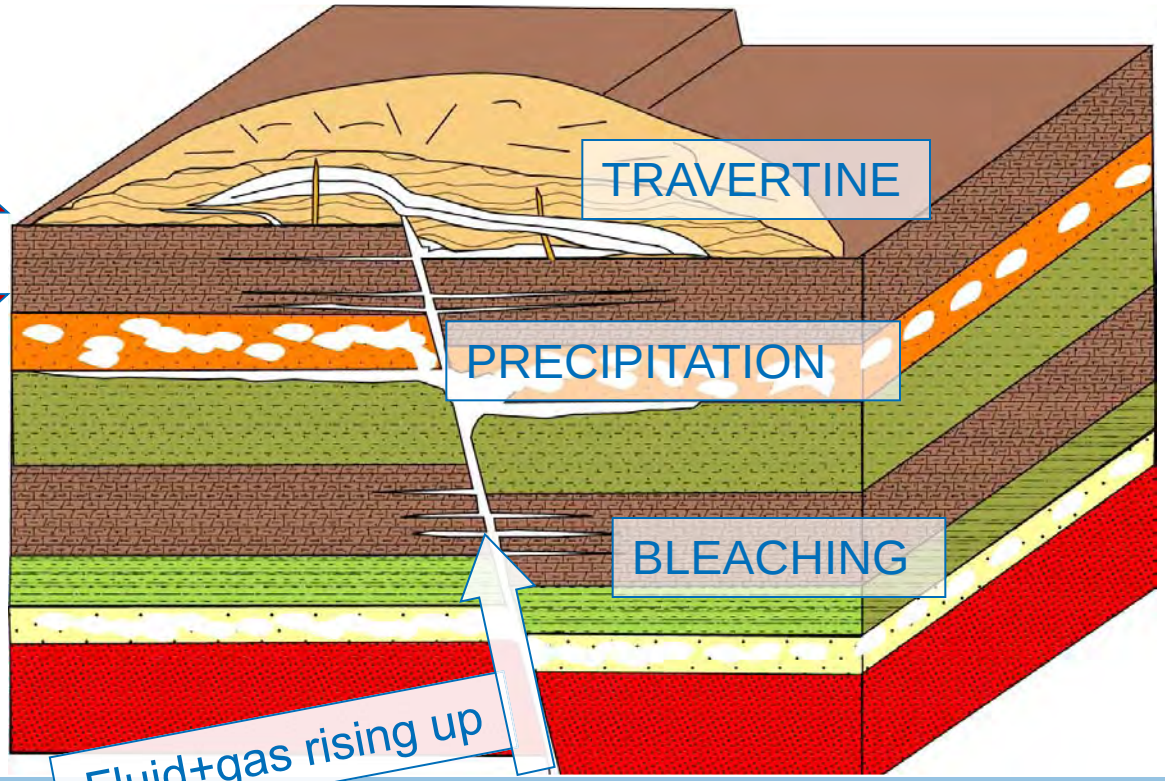
fonction : fluid flow, set up mode

- **Surface travertine:** lower and continuous flow rate
- **veins :** stronger flow rate

Final aim

Cristalization surface and near-surface

Circulation Fault and reservoirs



Arxim /Coores
And
Themis Flow

Modeling and characterization

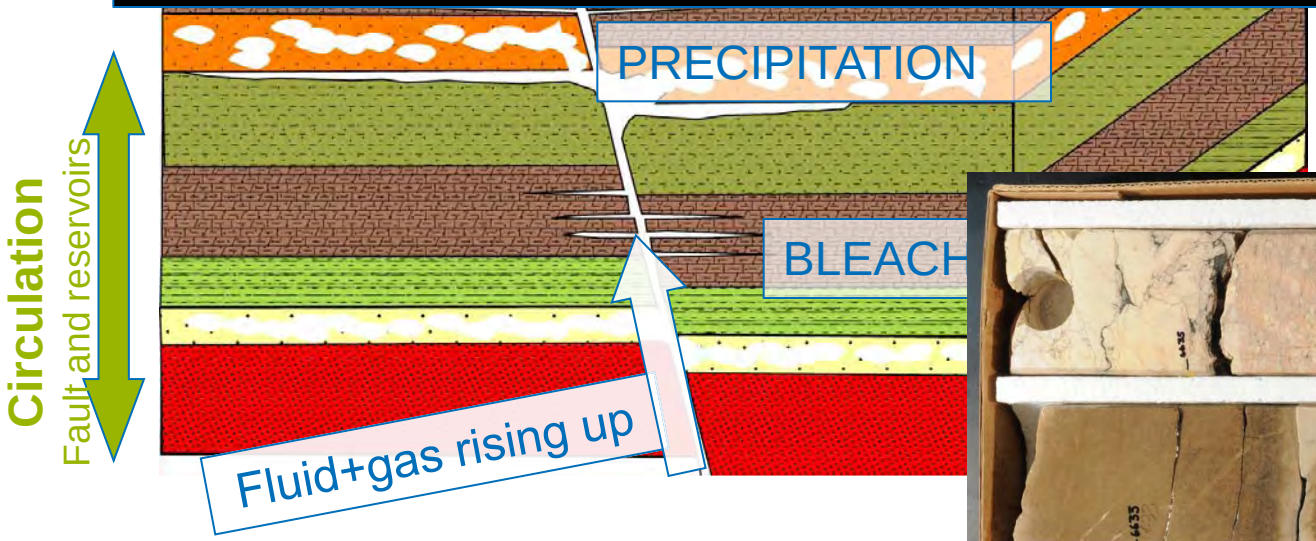
Of transfert properties (permeability) evolution through time and space

in a fractured zone

Perspective

Investigate the fluid flow and diagenetic history, deeper into the sedimentary pile

Cores study



Well cores example Wolverine federal #17.3