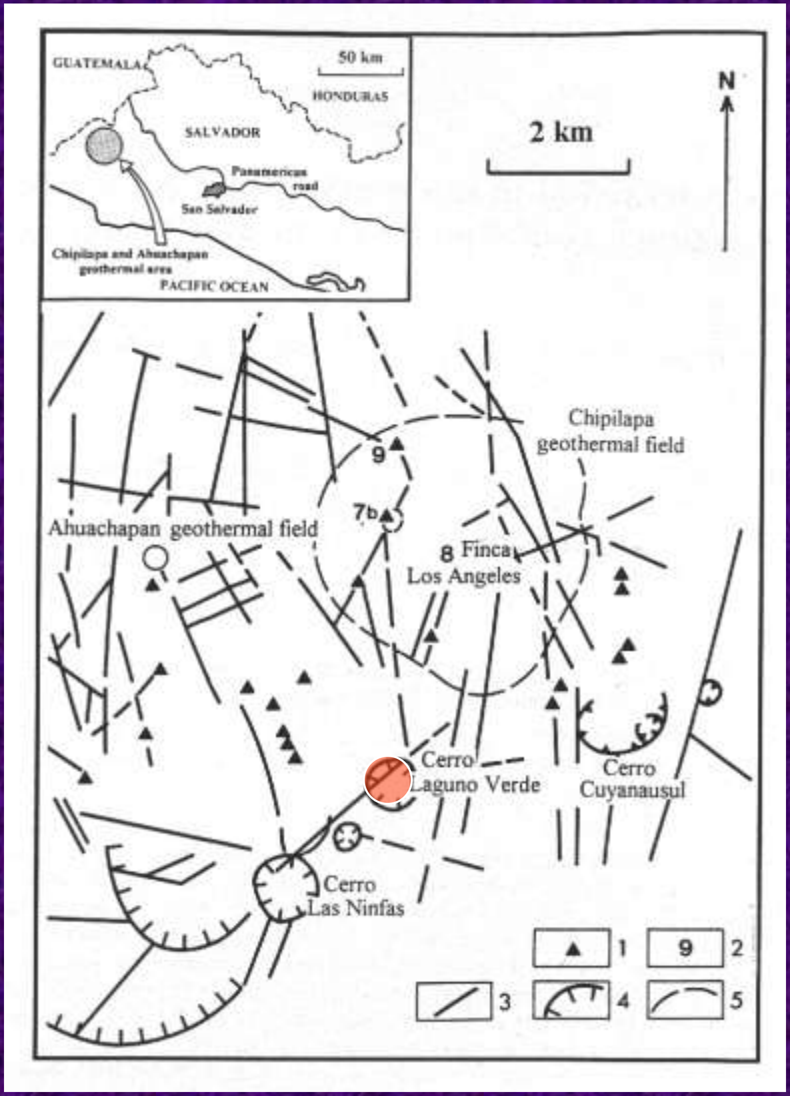
Summary

Clay minerals genesis and transformations, case study : Chipilapa high enthalpy geothermal system (Salvador)



Subduction of the Cocos under the Caraïbes one

Pliocene to Holocene formations

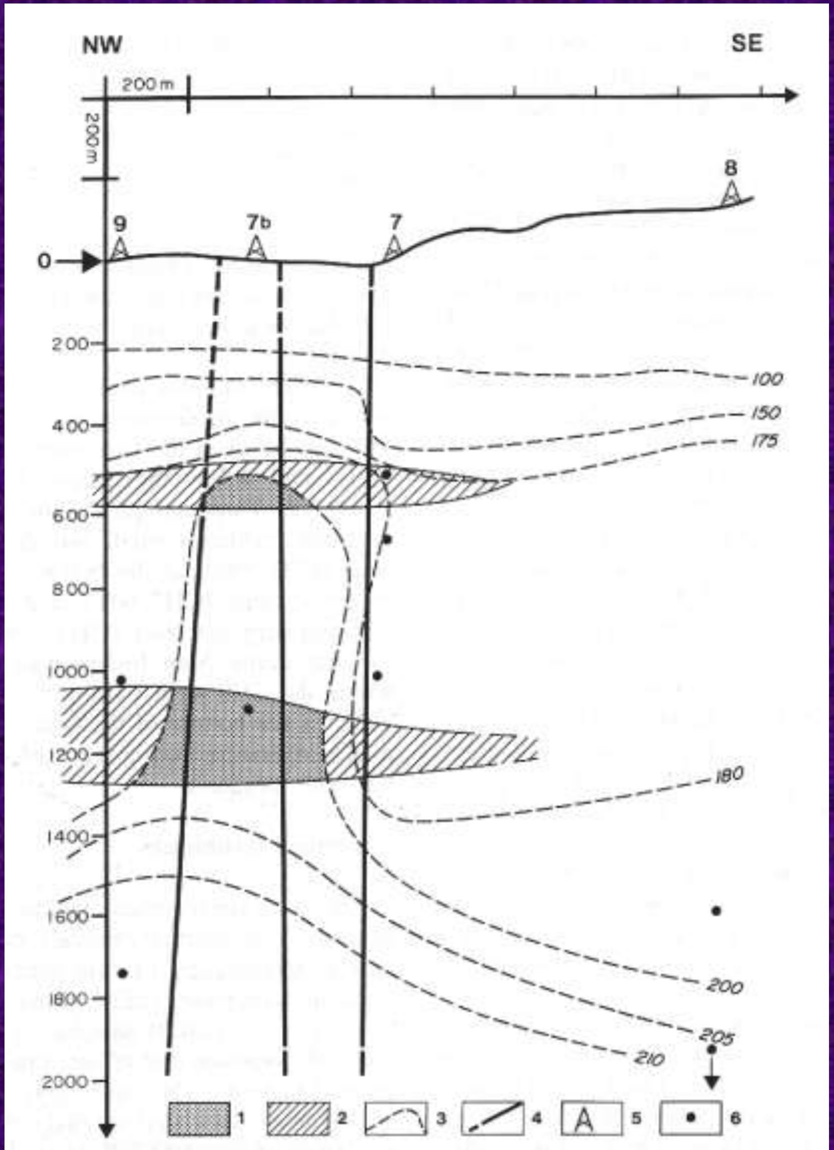
Dacitic to andesitic lavas and volcano-sedimentary formations

Young volcanism : 16 000 years

1 : hydrothermal manifestations

5 : limits of the geothermal area

Clay minerals genesis and transformations, case study : Chipilapa high enthalpy geothermal system (Salvador)



Fractured reservoir.

Fluids of meteoric origin

(T max : 250 °C)

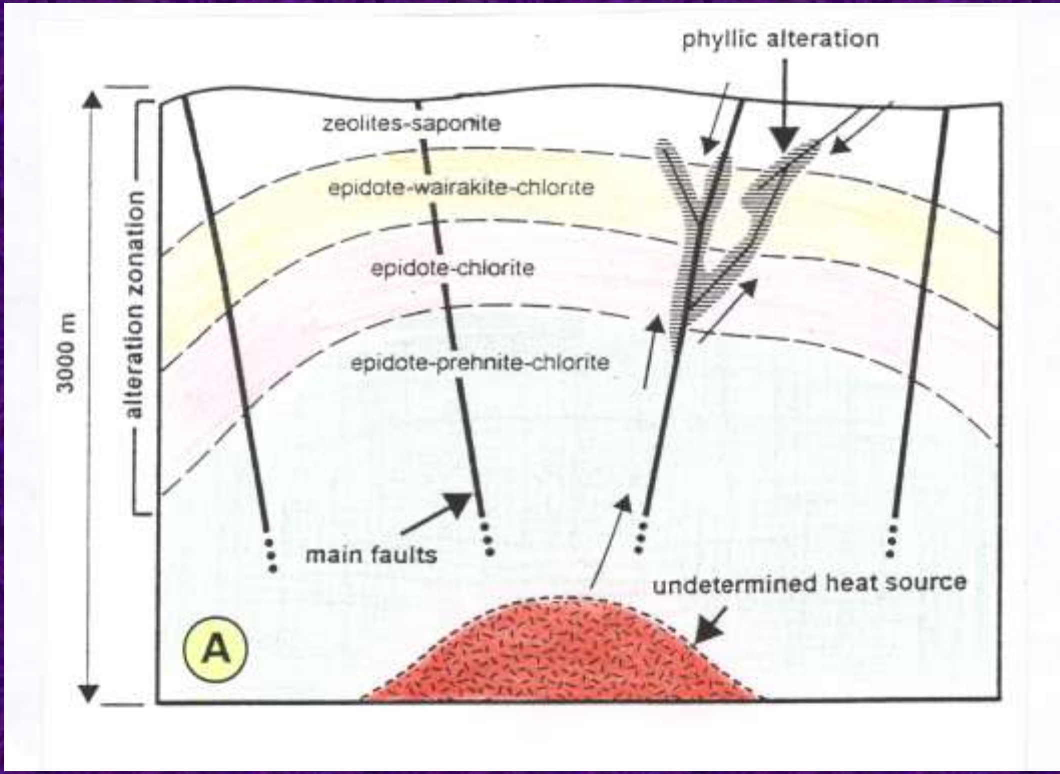
- Surficial zone : strongly argillized (impermeable level = cap rock limiting the thermal transfers)

- First reservoir (vapor dominated - 185°C)

- Non productive zone

- Deep reservoir (liquid dominated)

Stage 1



<u>Pervasive Alteration</u>

Selective and partial replacements

- Huge volume of rocks affected

- Low F/R, not faults controlled

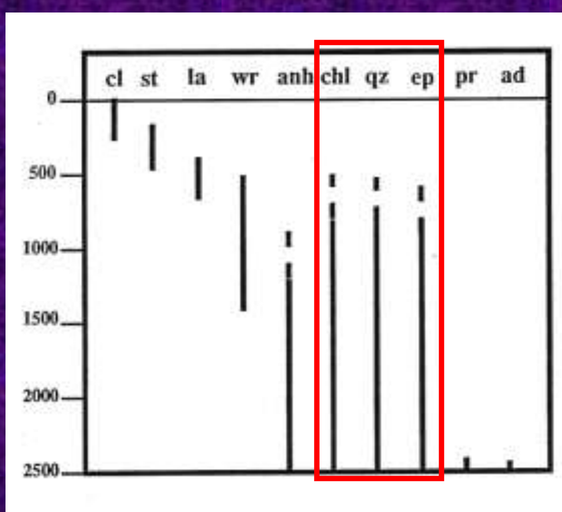
Stage 1

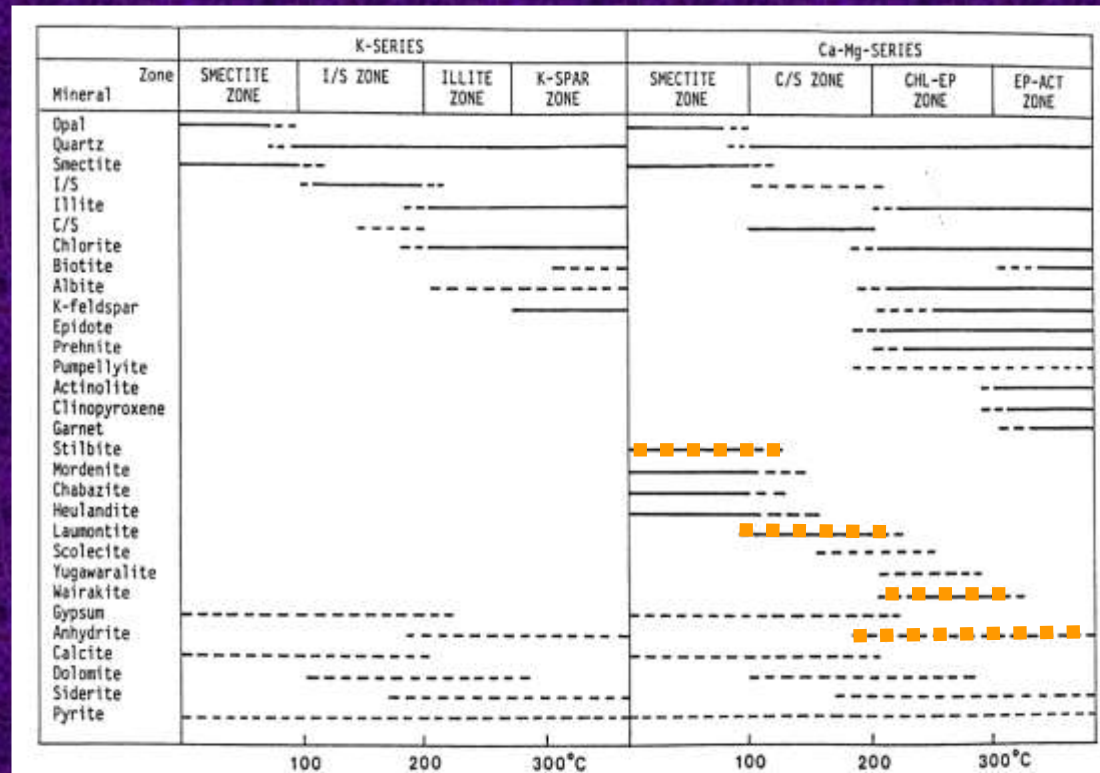
Propylitic Alteration

- Manifestation of a thermal anomaly

T : 100-300°C

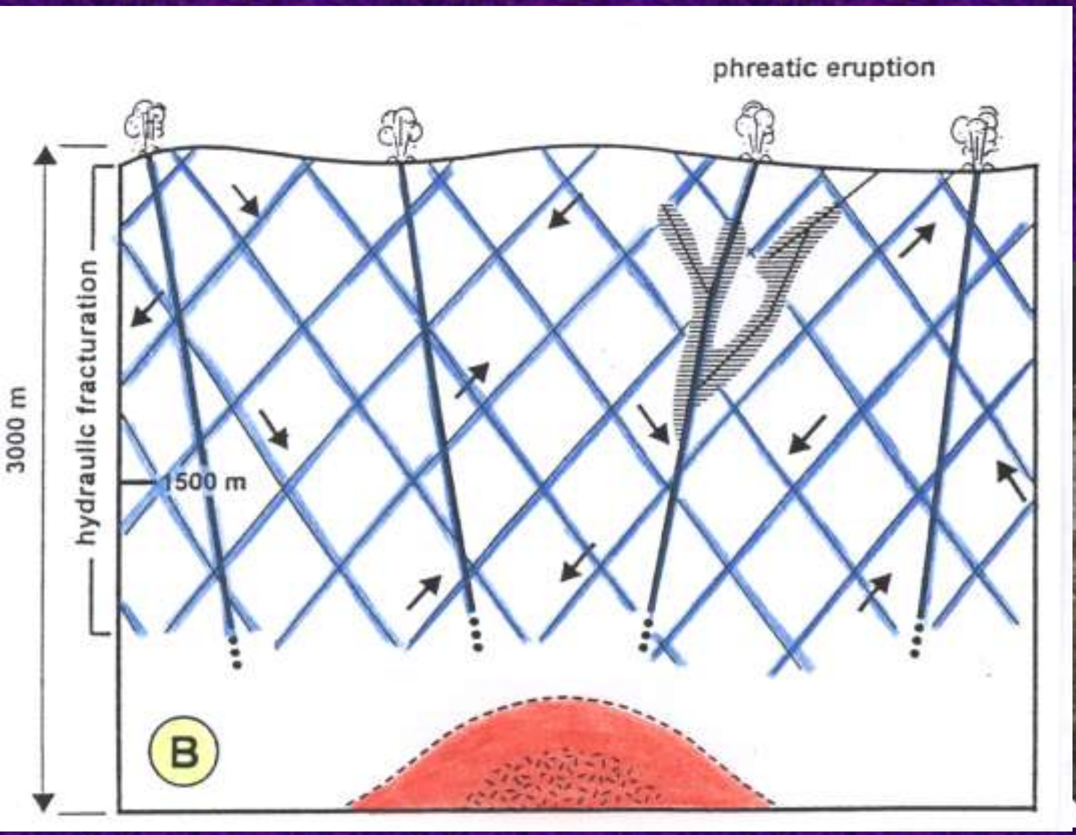
Zoning resulting from a paleogradient





Generalized summary of mineral assemblages observed in intermediate to alkaline types of alteration as a function of approximate temperature. *Solid* and *dashed* lines give an indication of the most common and rare occurrences, respectively. The temperature scale attached is approximate. *CHL-EP* chlorite-epidote zone, *EP-ACT* epidote-actinolite zone, *I/S* illite/smectite mixed layer mineral zone, *C/S* chlorite/smectite mixed layer mineral zone

Stage 2

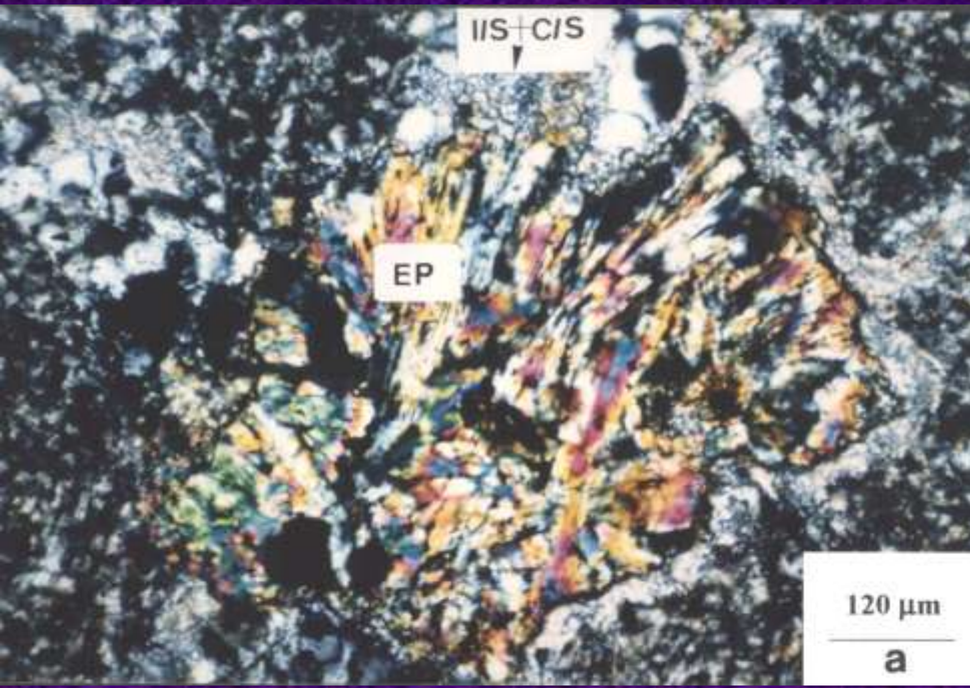


Alteration linked to a micro-fracturation network

(higher F/R)

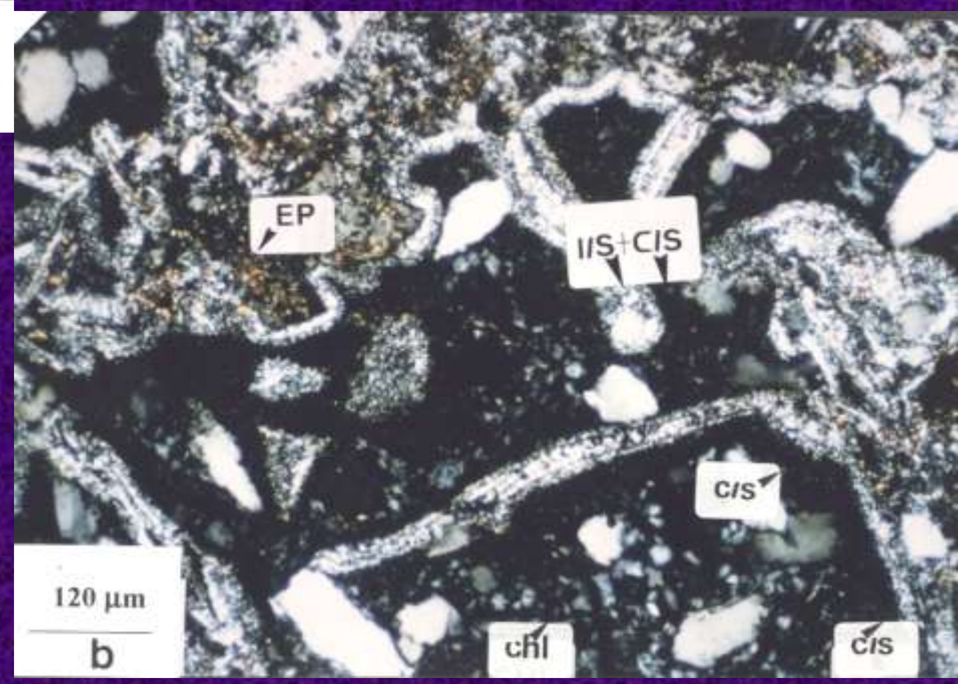
- Linked to the opening of the system

Stage 2



Hydrothermal paragenesis : clays - carbonates - hematite

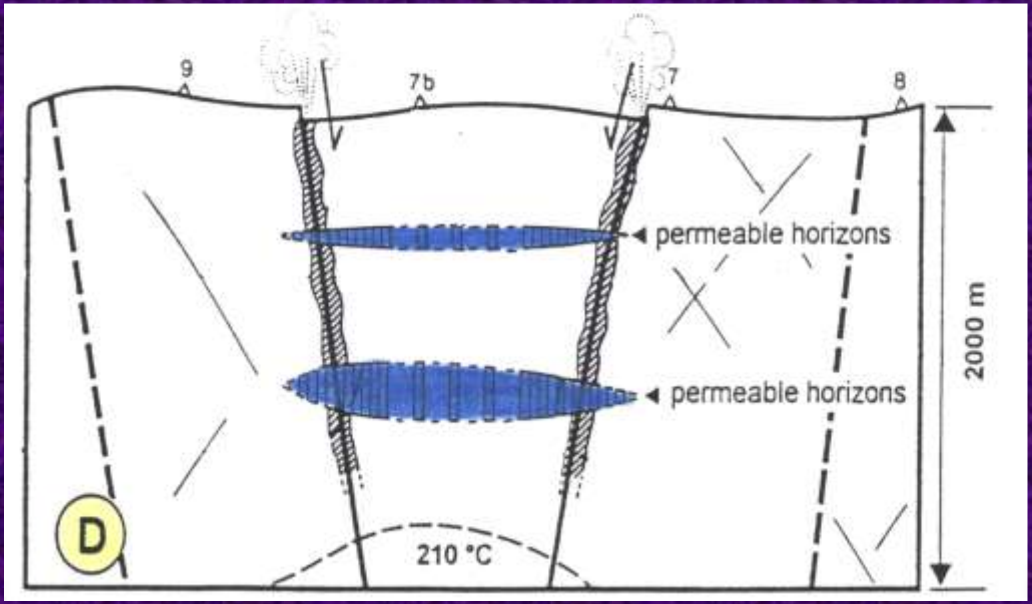
- No vertical zoning



-T : 230-250 °C all along the drill holes

-Fluids of meteoric origin evidence of boiling

Stage 3 : present activity



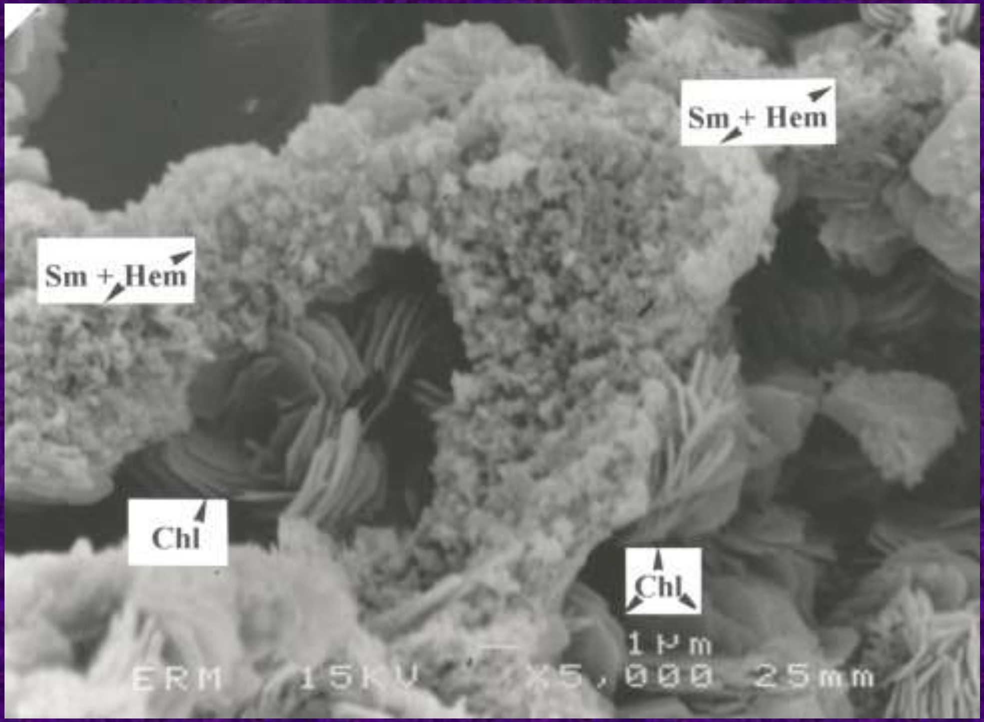
Stage 3 :

hydrothermal activity limited to the proximity of active faults network

Very similar to the Stage 2:

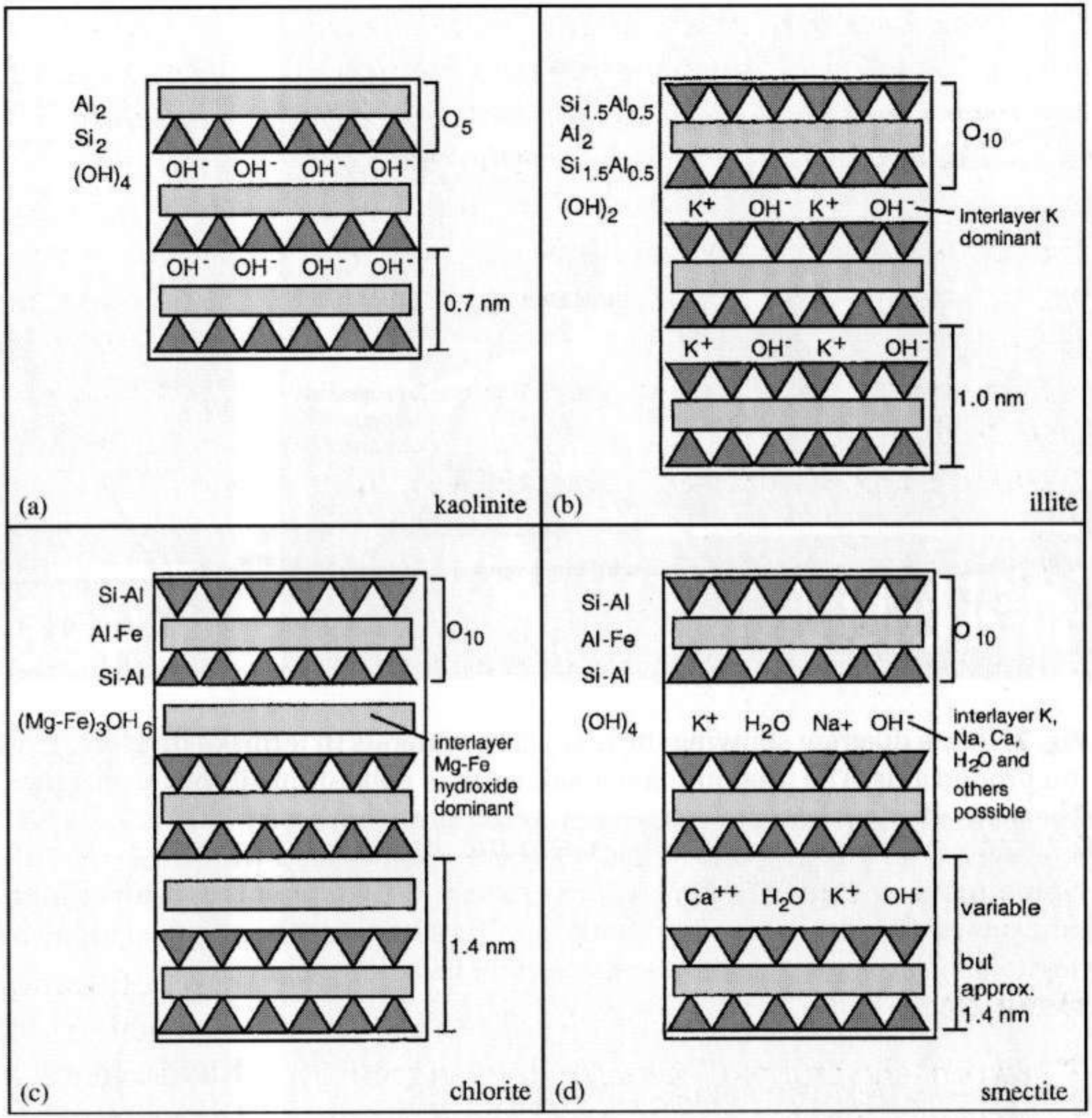
- Location controlled by fracturation …

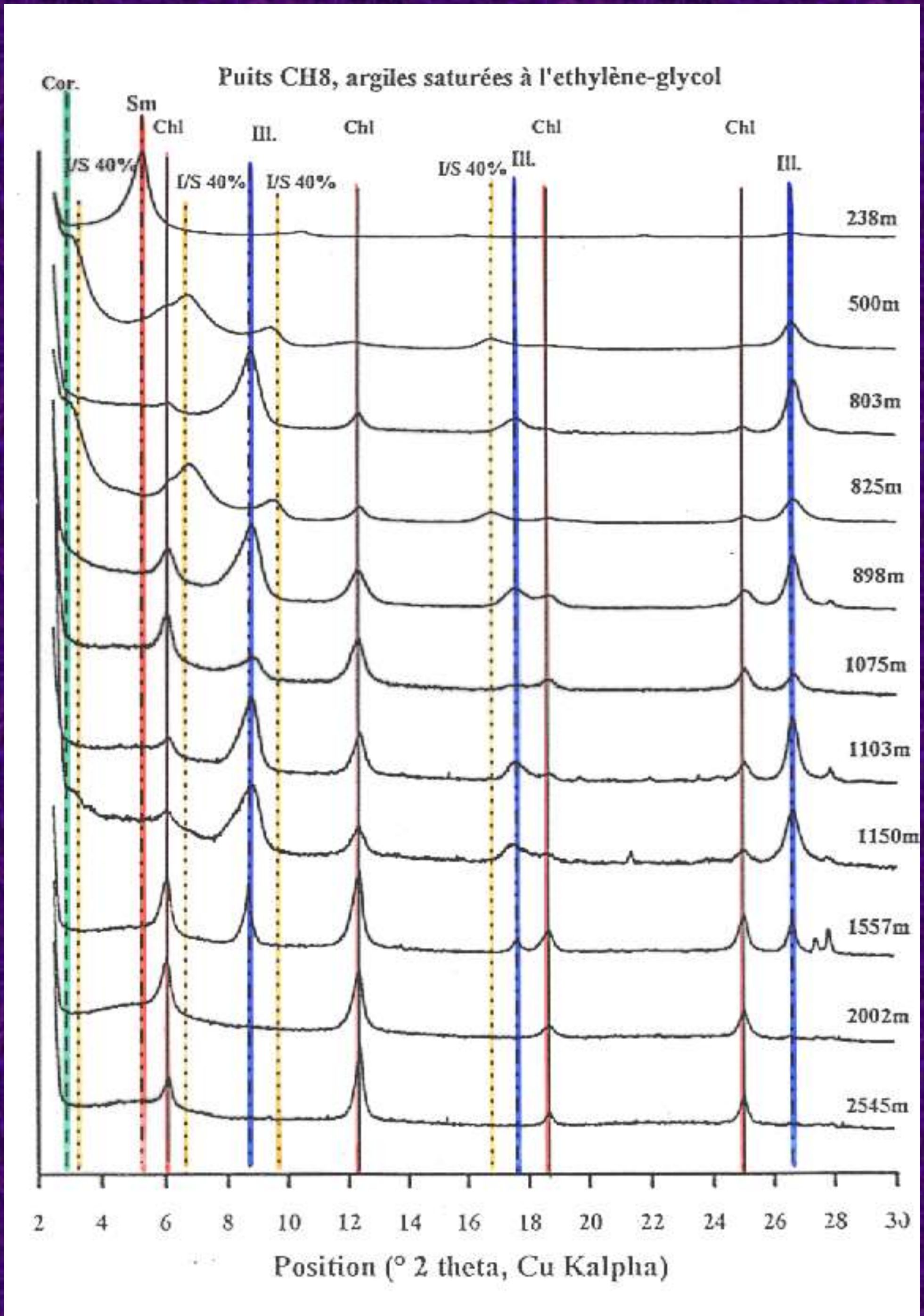
Stage 3



- Clays, carbonates, hematite
- T : ≈ 200°C
- Fluids of meteoric origin

Clay mineralogy



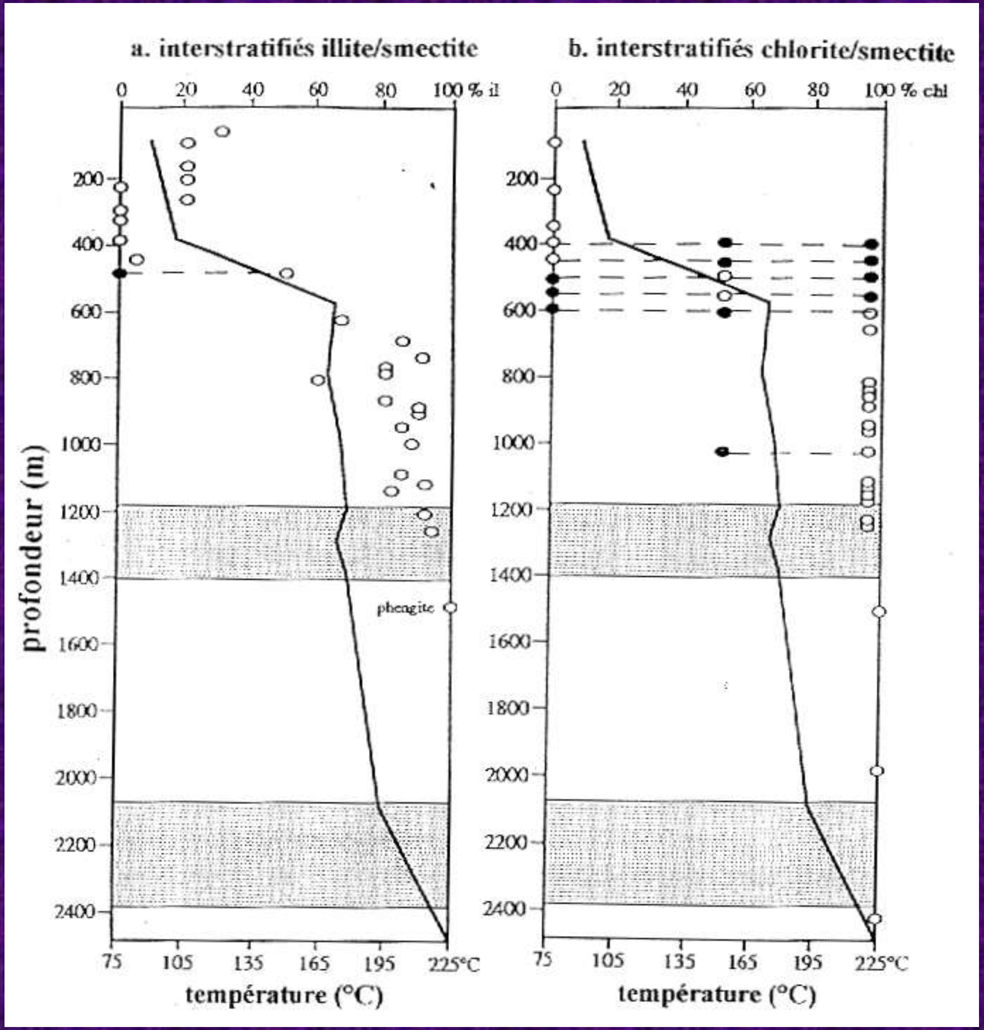


Clay mineralogy

Proportions of S/I et S/C function of the lithology

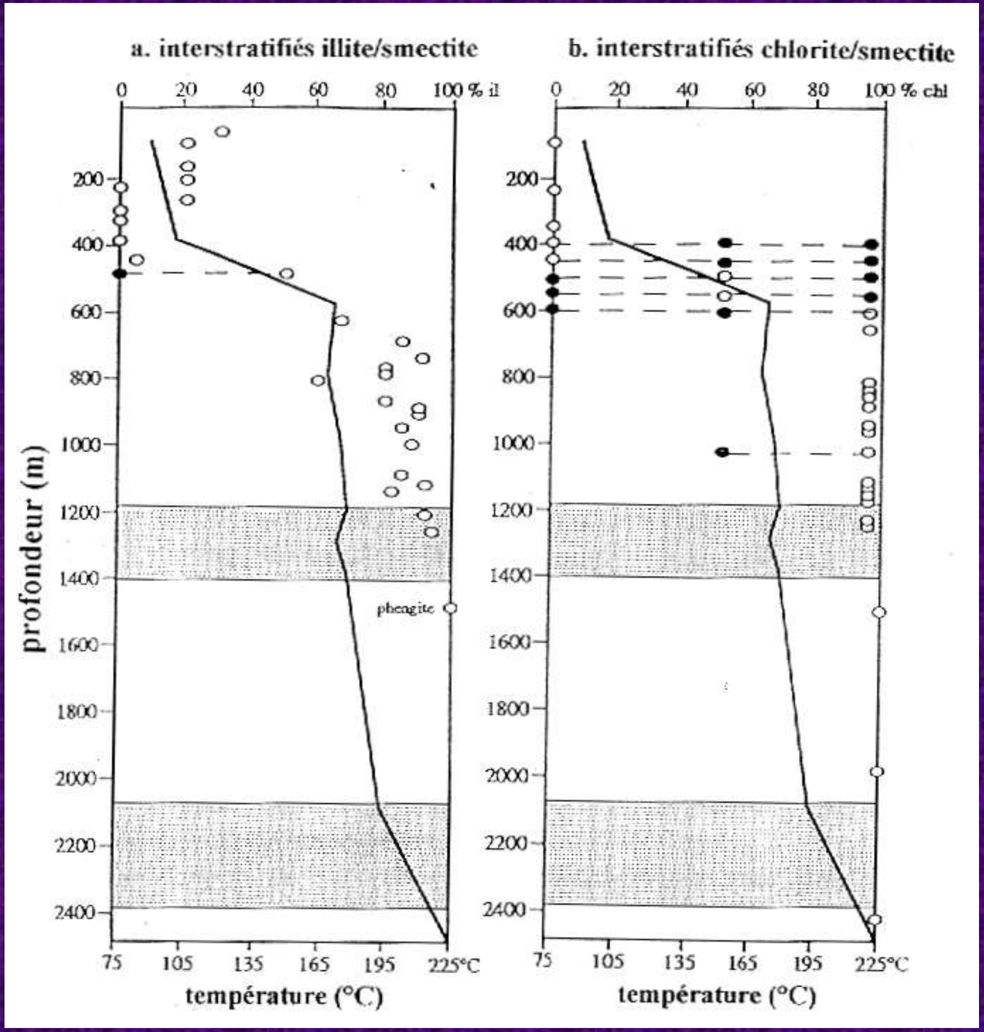
example of a non productive drill hole (CH8)

Clay mineralogy



example of a non productive well (CH8)

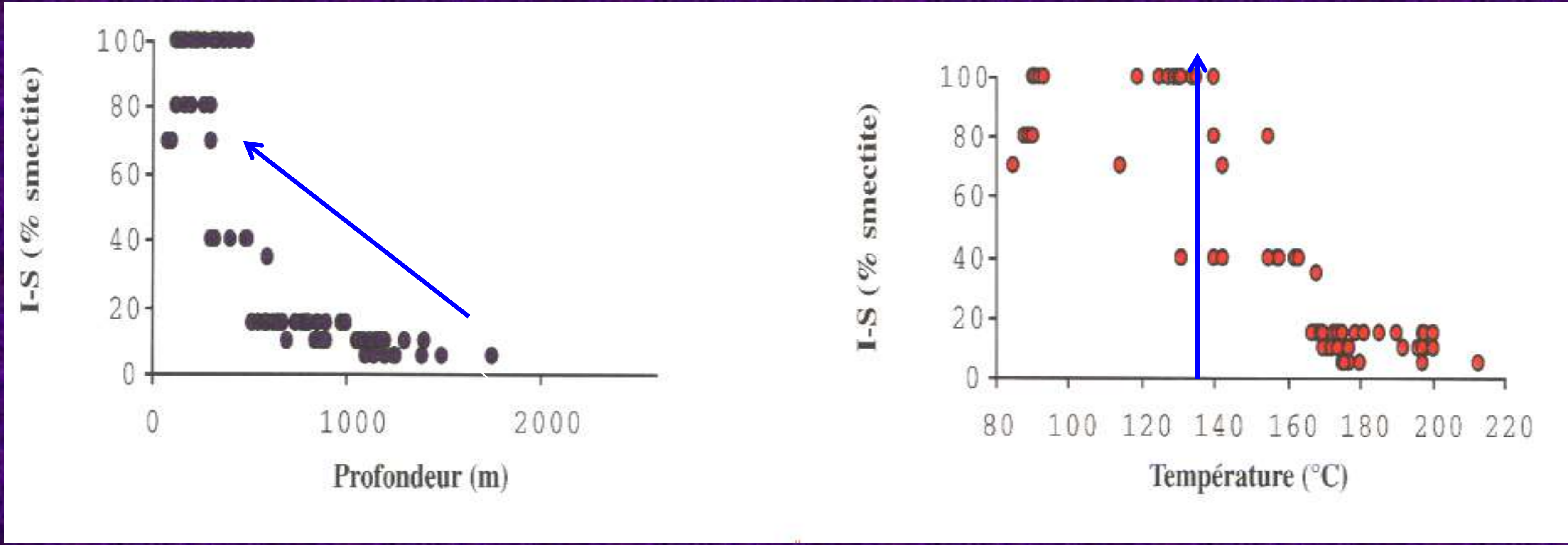
Clay mineralogy



- Decreasing of the smectite amount with depth
- Very sharp transition I/S R=0 - I/S R=1 reg. - I/S R=1
- = trioctahedral conversion series

example of a non productive well (CH8)

Clay mineralogy

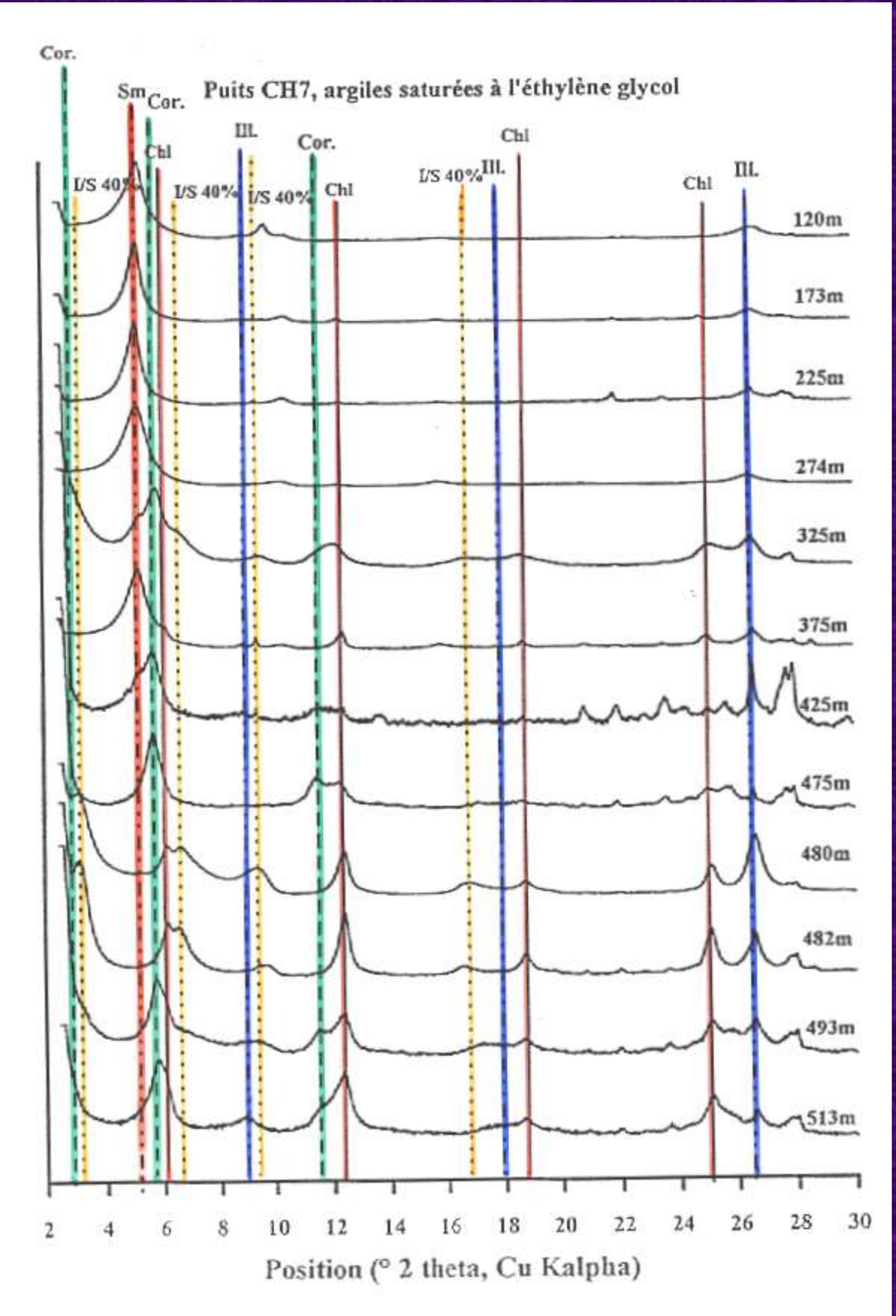


-Regular conversion series with depth ,

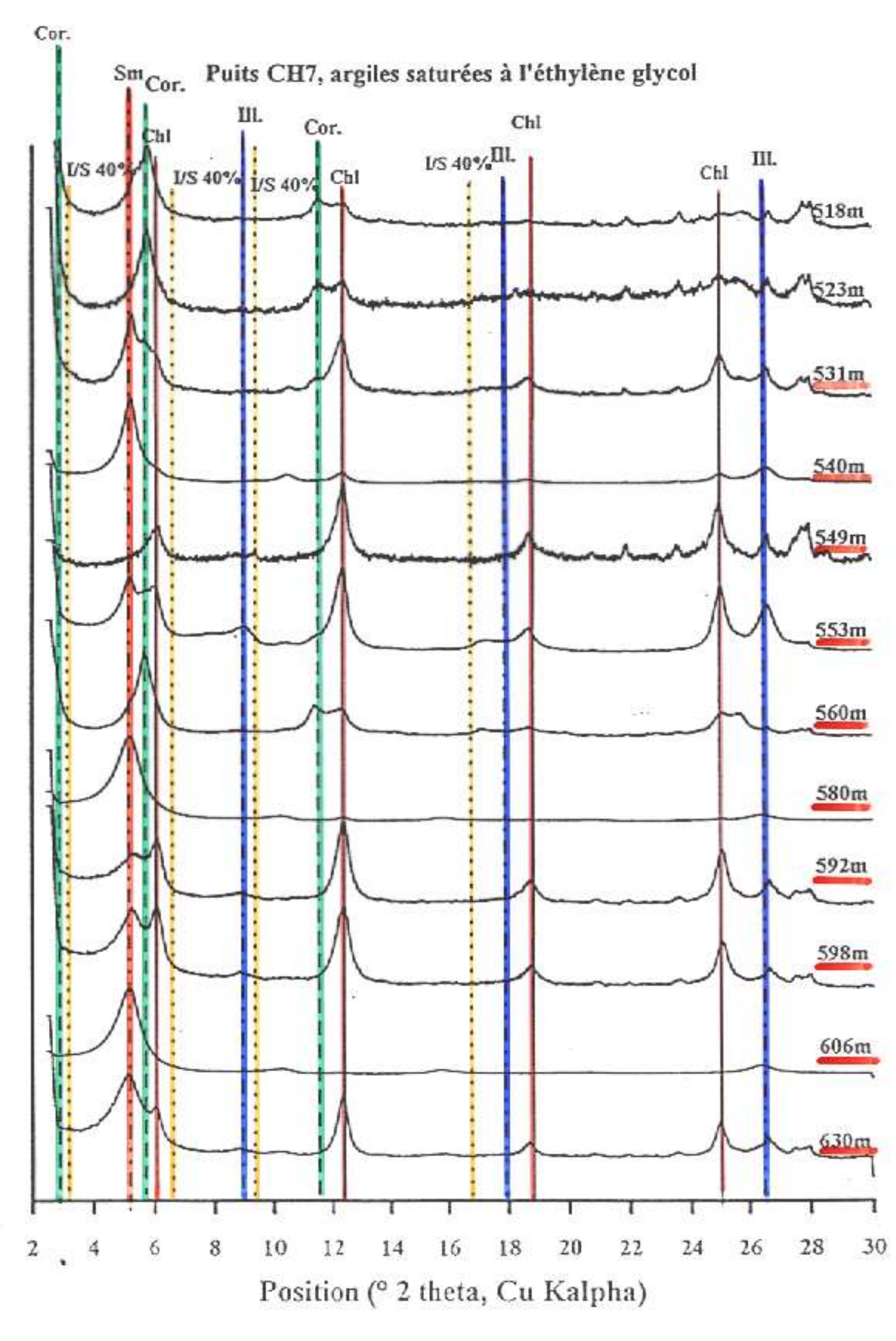
- Not linked to the measured thermal gradient !

example of a non productive well (CH8)

Clay mineralogy

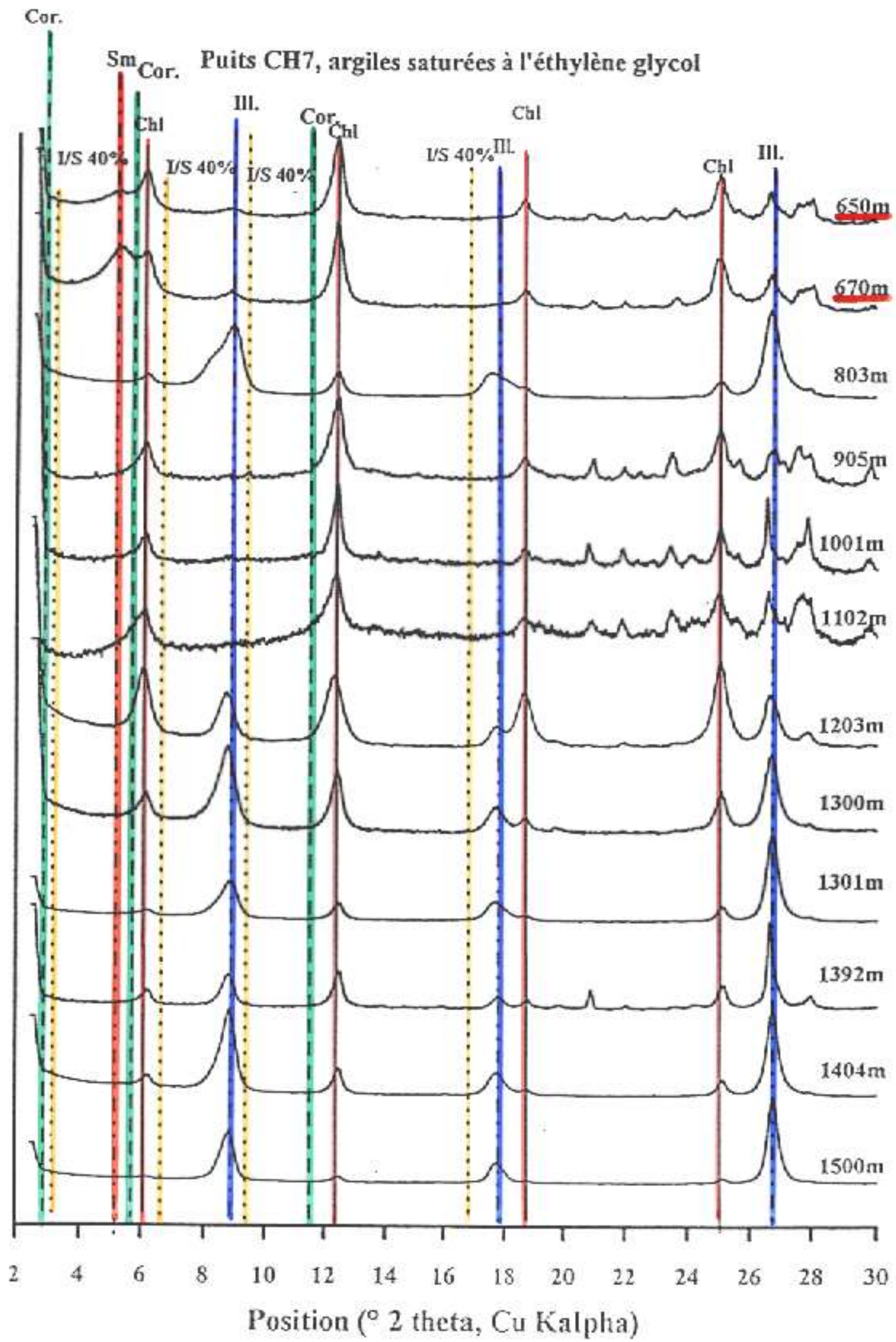


example of a productive well (CH7)



Clay mineralogy

example of a productive well
(CH7)

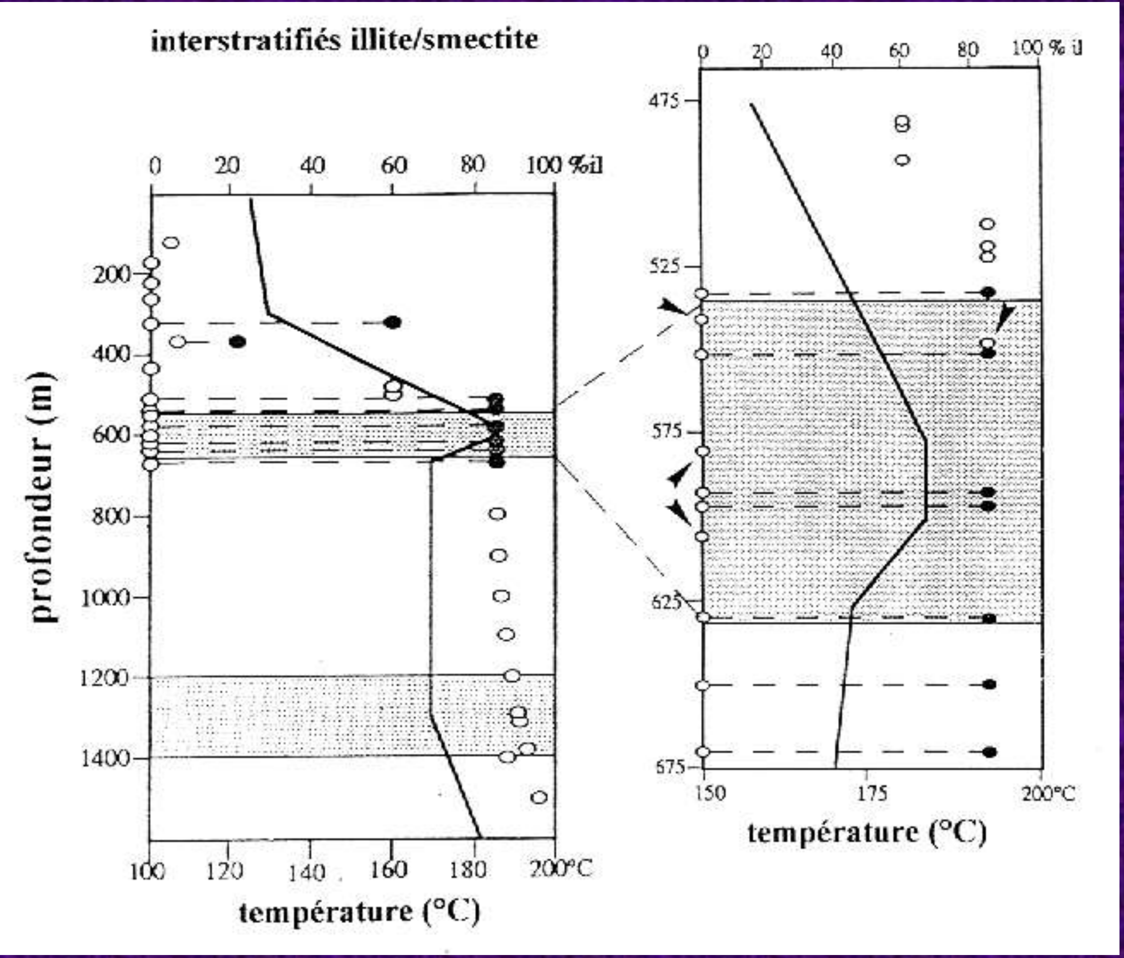


Clay mineralogy

example of a productive well (CH7)

Clay mineralogy

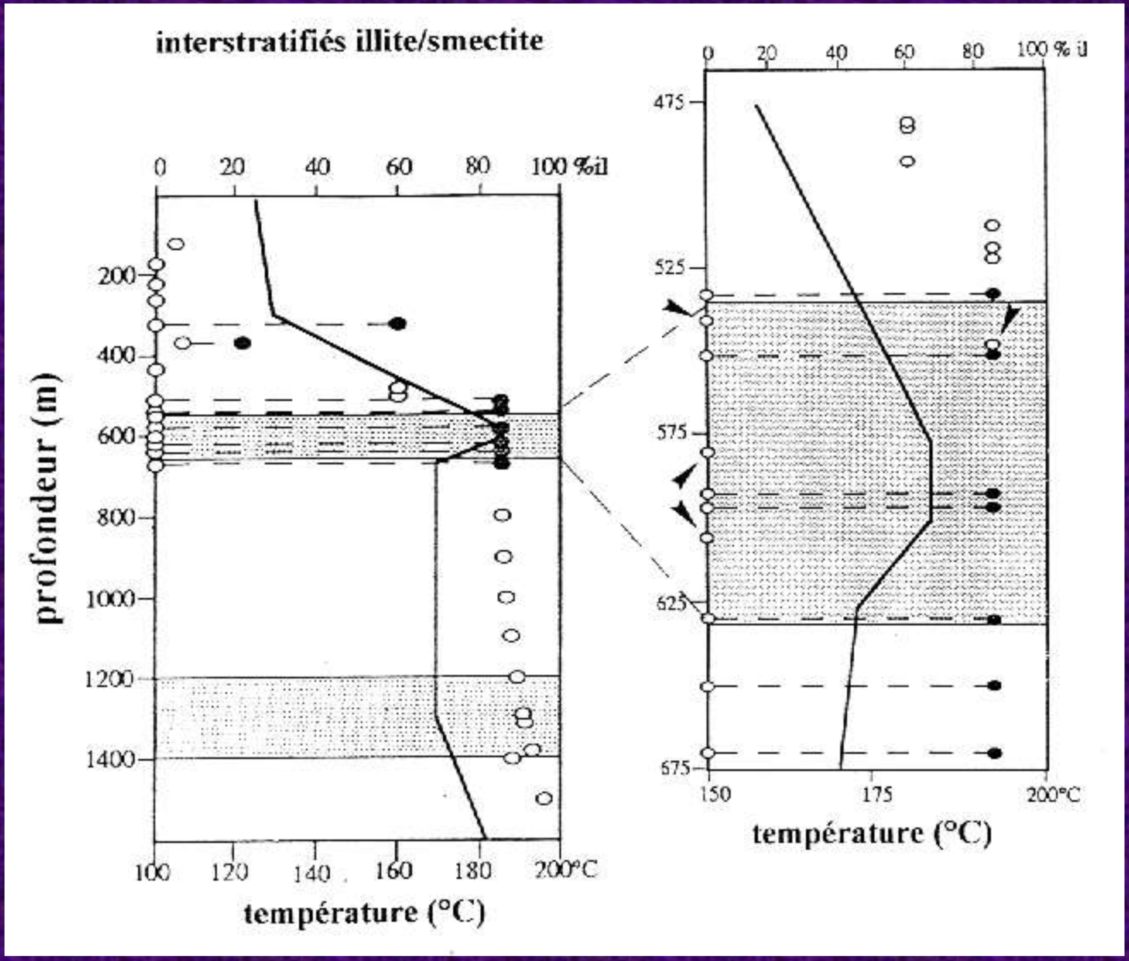
Dioctahedral conversion sequence



example of a productive well
(CH7)

Clay mineralogy

Dioctahedral conversion sequence



In zones of present day hydrothermal circulations :

- No regular evolution

- Anomalies close to or in the reservoirs

- ***Occurrence of HT smectites in reservoirs with boiling processes***

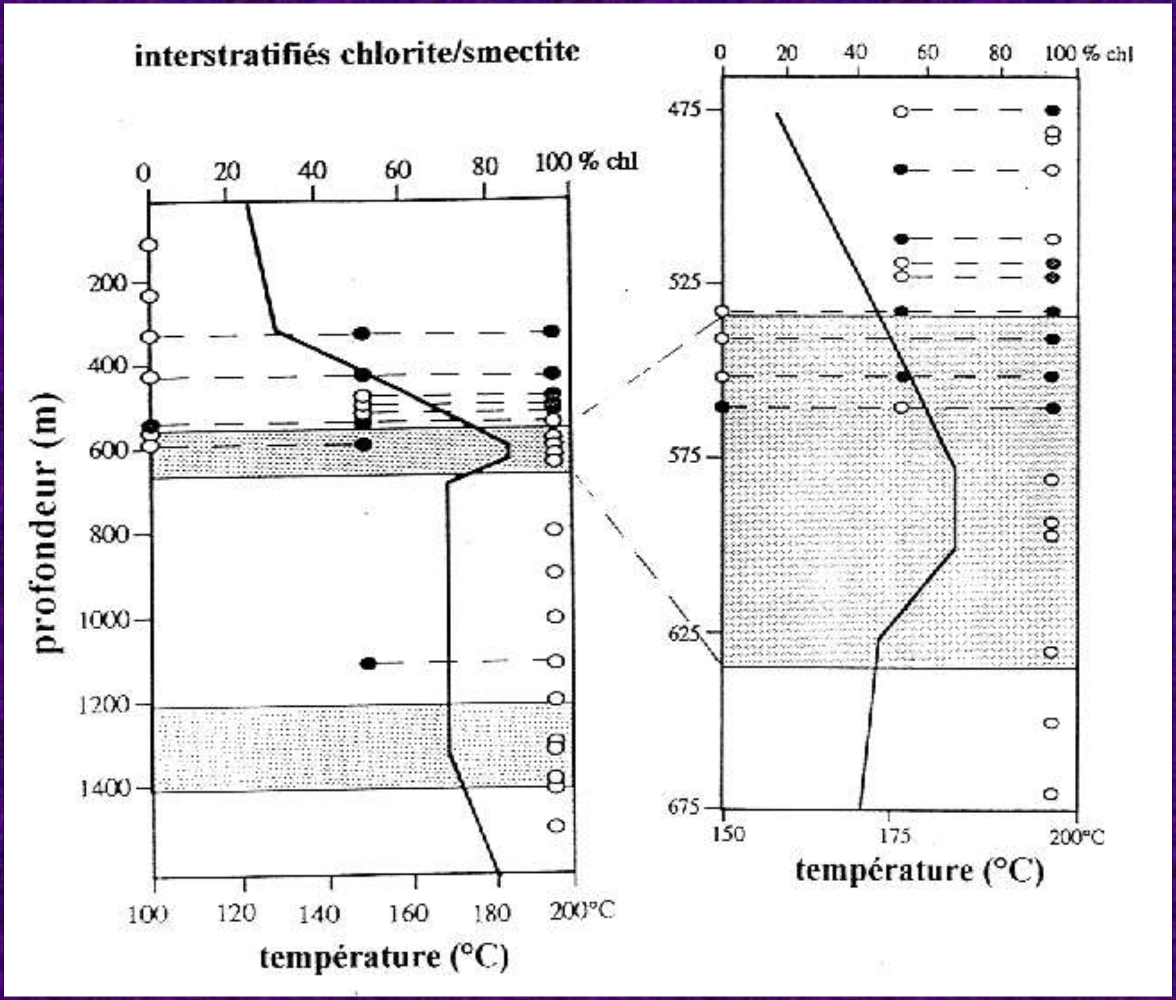
1st step of reaction

(present day formation)

example of a productive well (CH7)

Clay mineralogy

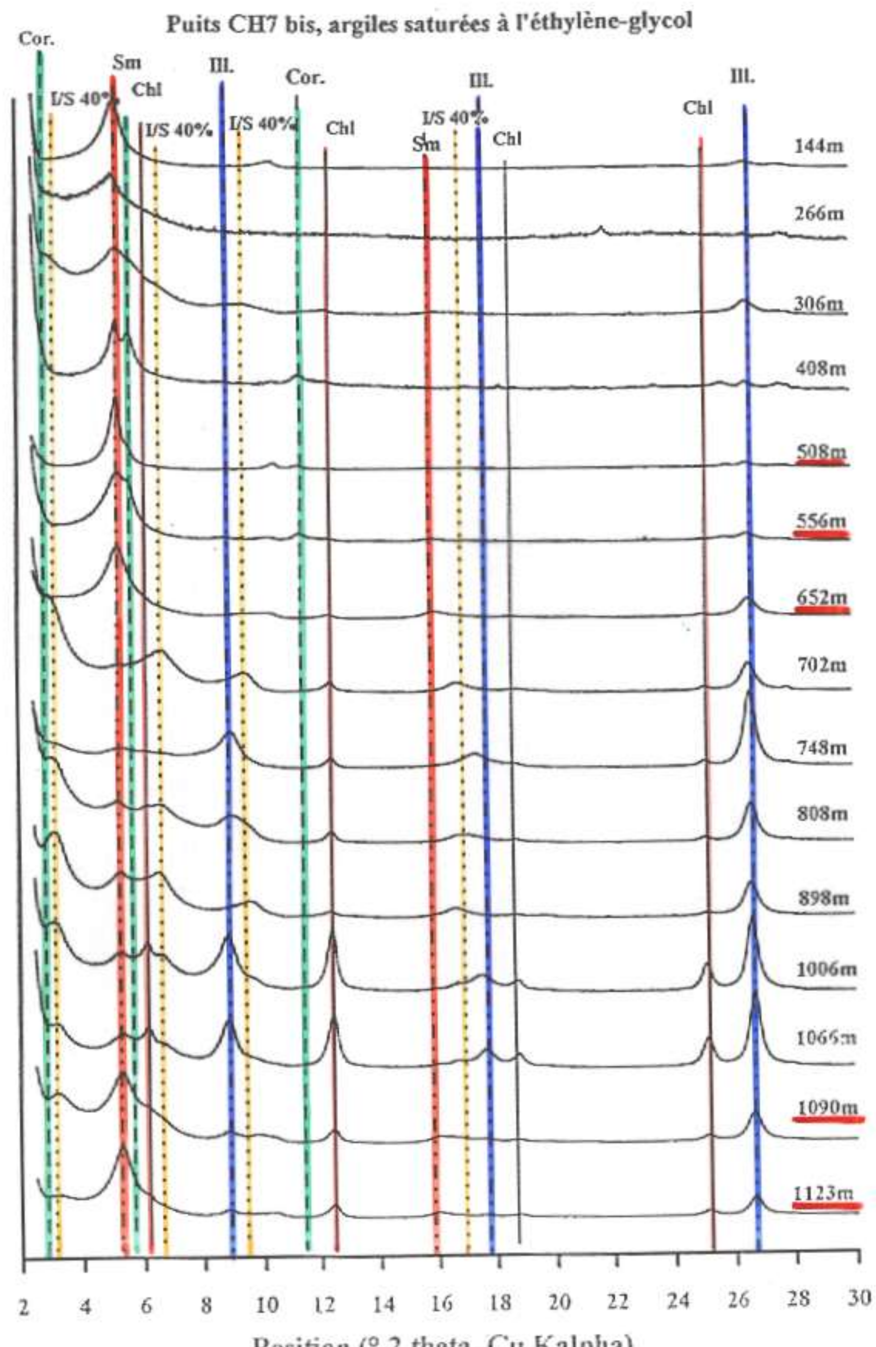
Trioctahedral conversion sequence



= dioctahedral conversion sequence

example of a productive well (CH7)

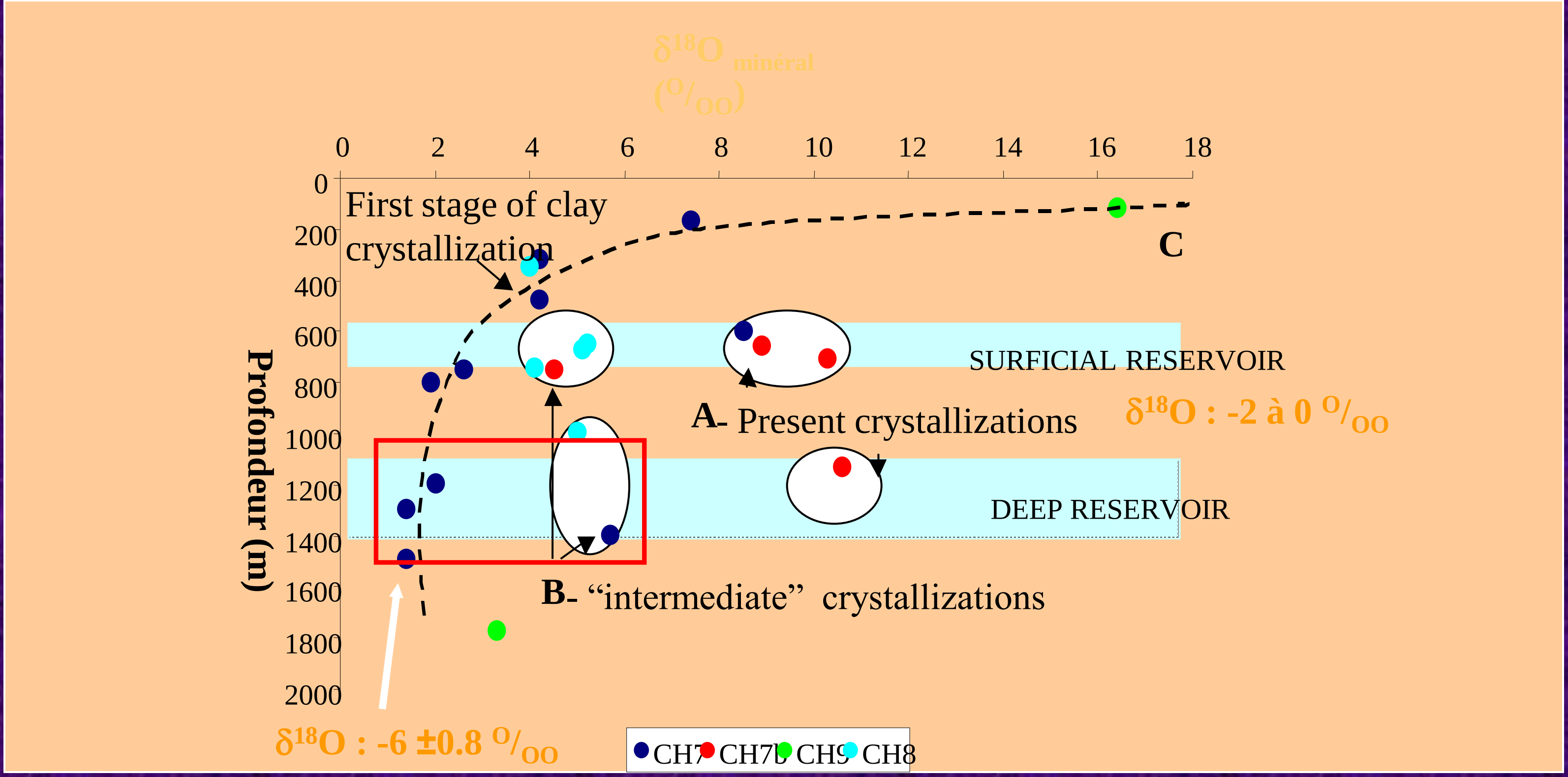
Clay mineralogy



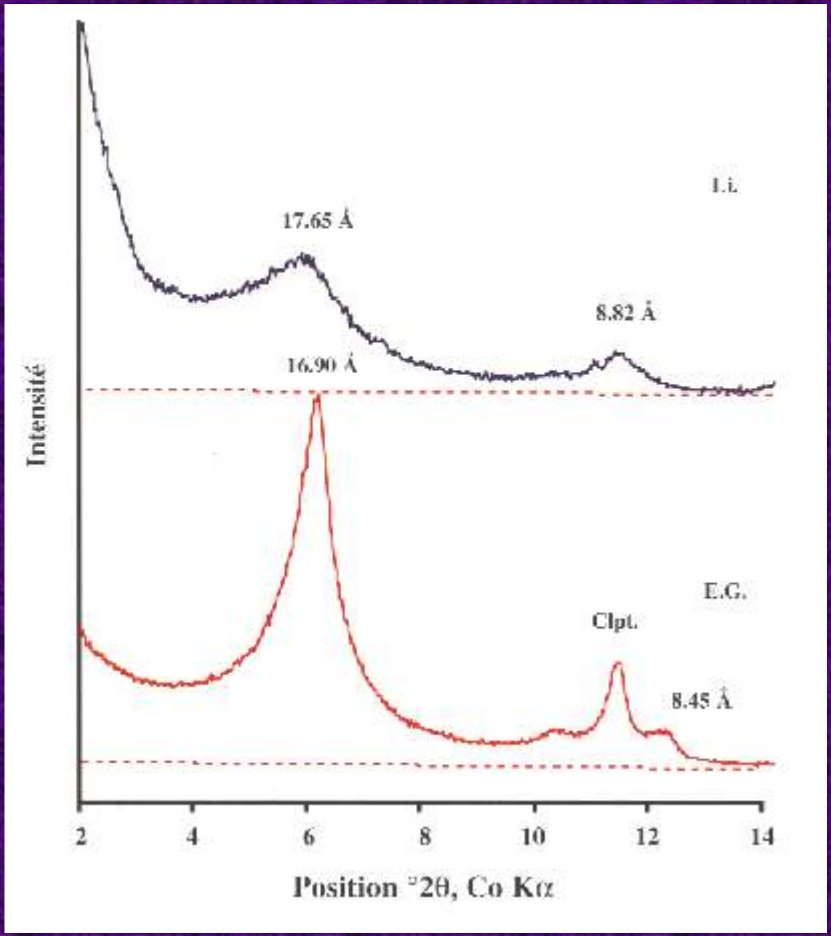
example of a productive well (CH7b)

Isotopic compositions

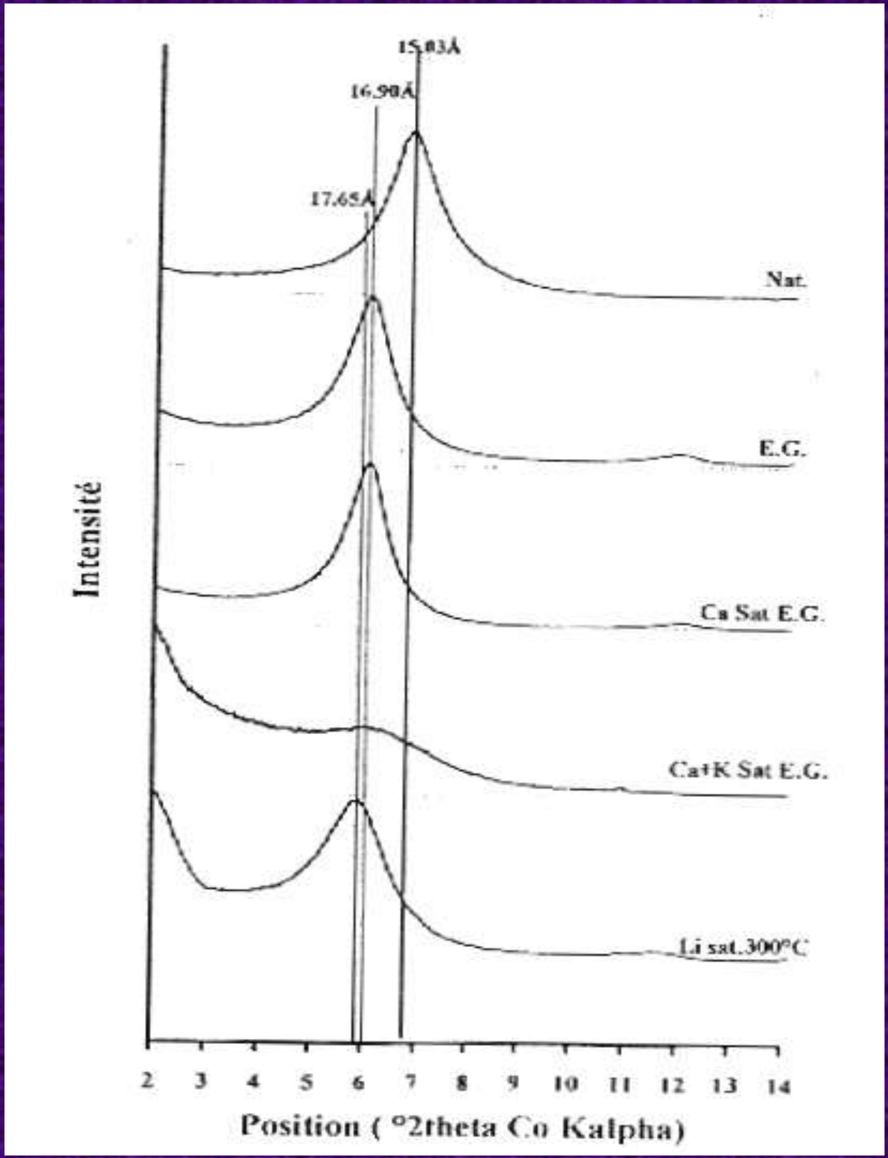
$\delta^{18}O_{I/S} - \delta^{18}O_{fl} = -4.19 + (2.58 - 0.16i)\ 10^6/T^2$ Savin et Lee 1988



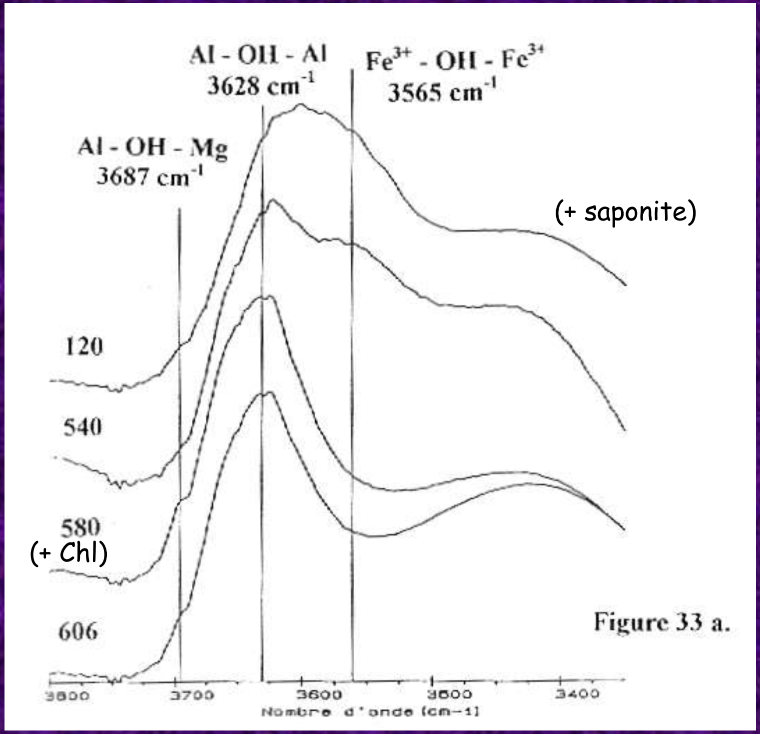
Clay mineralogy



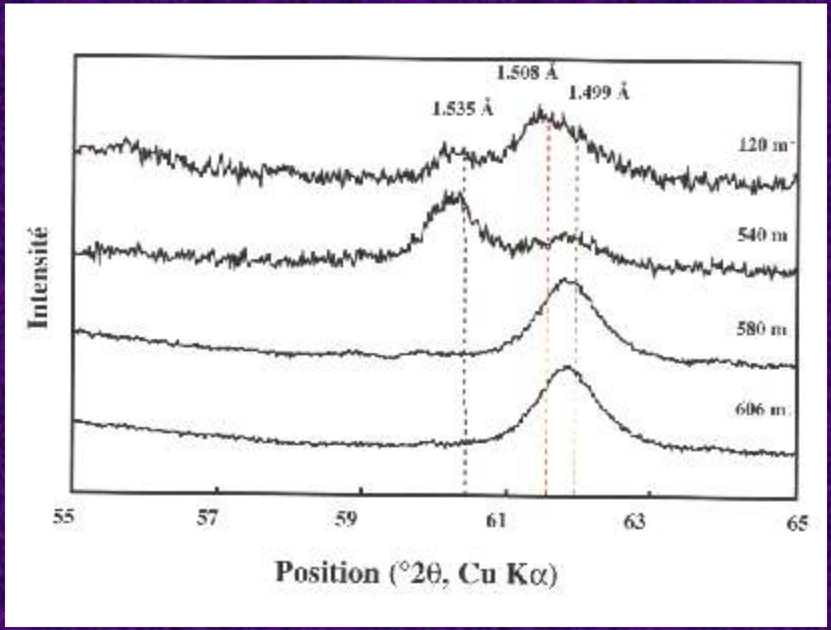
Properties of clays minerals
Present hydrothermal activity



Clay mineralogy



OH stretching region



Properties of clays minerals generated by the present day activity

Clay genesis : Chipilapa geothermal field (Salvador)

X.R.D.. :

- smectite of low cristallinity in reservoir zones
- In the reservoirs : mainly beidellite (± Fe)
- In surface: great heterogeneity of the smectitic material

Properties of clays minerals generated by the present day activity

d(A)	Position	Largeur	Intensité
10.89	8.116	0.79	2242
10.21	8.65	0.7	4000
9.75	9.065	0.526	5947

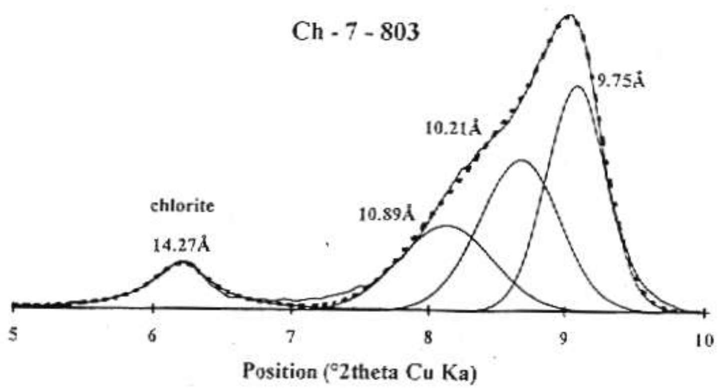
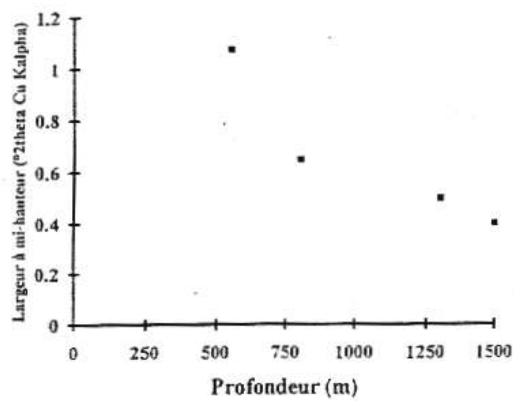
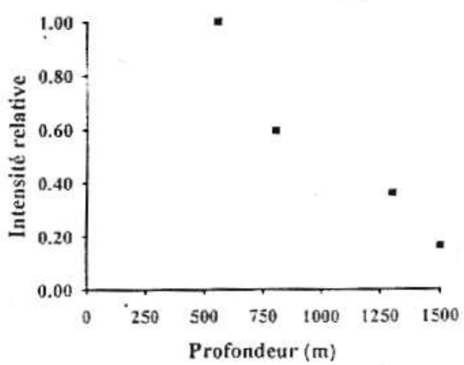


Fig. 24. Décomposition du domaine angulaire situé entre 5° et 10° 2Θ du diffractogramme de l'échantillon Ch - 7 - 803 après saturation à l'éthylène glycol.

a.

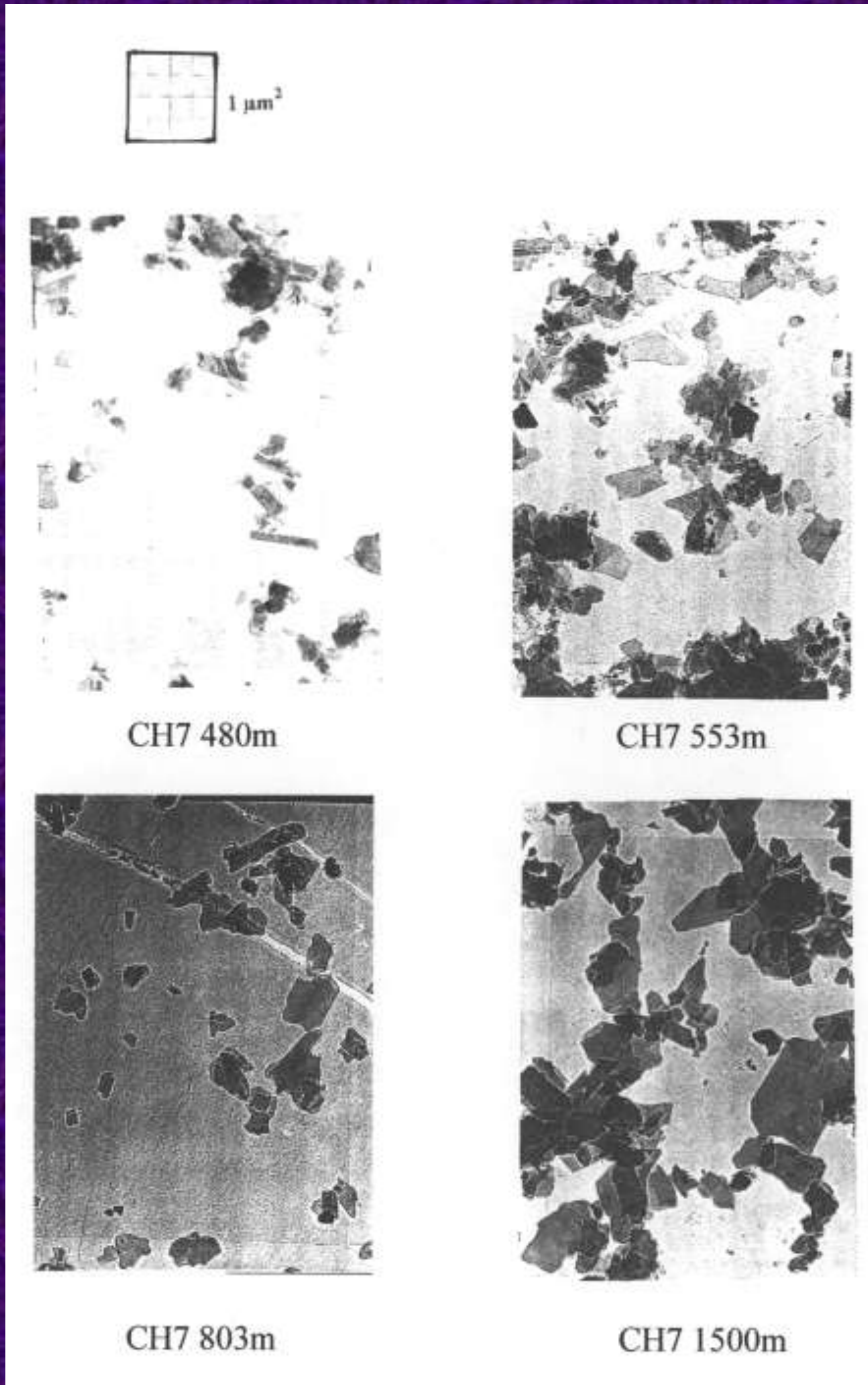


b.



Clay mineral transformations

Properties of clays minerals formed during the stage 2



Clay mineral transformations

Properties of clays minerals formed during the stage 2

Clay minerals transformations : Chipilapa geothermal field

X.R.D. :

- heterogeneity of the « illitic » material : illite + I/S
- Decreasing of the amount of expandable components with depth
- Progressive increasing of the amount and crystallinity of illite mineral

Crystal habit and size :

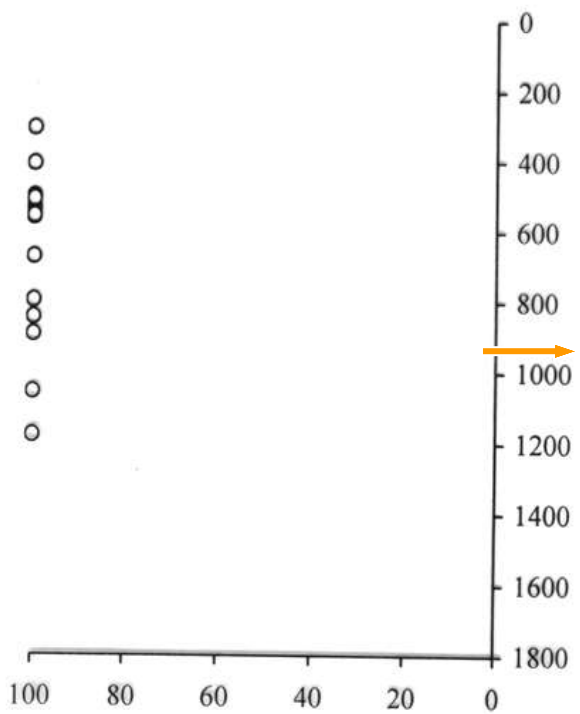
- laths → isometric habit
- Increasing of the thickness

Conversion series well established … but not correlated with the measured temperatures

Properties of clays minerals formed during the stage 2

Clay genesis and transformations : example of Chipilapa geothermal system (Salvador)

t = 0



By analogy with the present stage…

Massive crystallization of smectite following the opening of the system (t=0).

(FI : boiling, constant T all along the drill hole)

Properties of clays minerals formed during the stage 2

Clay genesis and transformations : example of Chipilapa geothermal system (Salvador)

smectites → sealing of the fracture network

↓

Conductive heat tranferts

↓

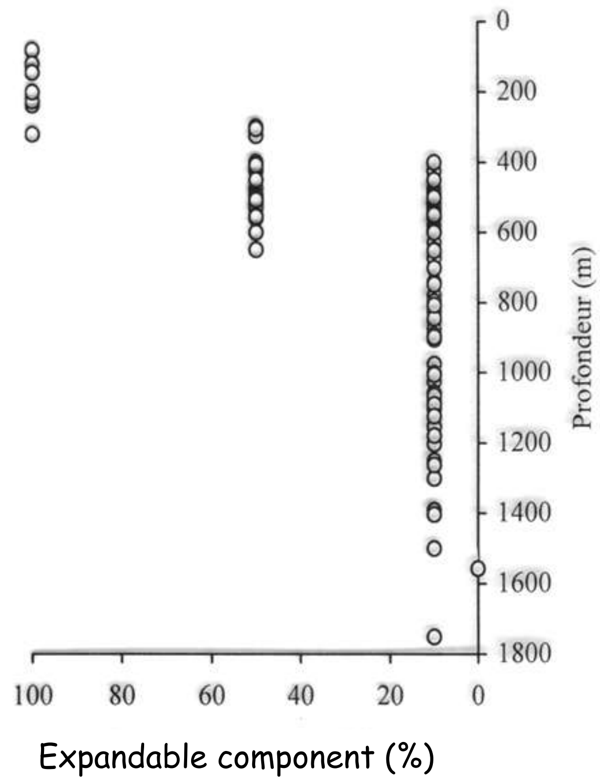
Regular thermal gradient with depth

This type of heat transfer probably predominate during the whole functioning of the system

↓

Recorded by the clay minerals

t = 16000 ans



Properties of clays minerals formed during the stage 2

<u>Clay genesis and transformations : example of Chipilapa geothermal system (Salvador)</u>

Implications on fossil hydrothermal systems…

- Clay minerals will record the post crystallization thermal history linked to the cooling of the magmatic intrusion

- Heat transfers are mainly conductive

⇓

Regular conversion series, even if clays are formed during polygenetic events.

Classical « zonings »

⇓

<u>The thermal gradient deduced from conversion series observed in fossil fields, by analogy with active systems, must not be considered as representative of a specific event but as the integration of the whole thermal and dynamic history of the system</u>

Clay genesis and transformations : example of Chipilapa geothermal system (Salvador)

To summarize…

1 – The crystal-genesis is controlled by the hydrodynamics. It coincides with the high instability periods of the system

2 – In these environments, hydrothermal smectites are not systematically indicators of low temperature alteration. They characterize zones with present day neogeneses

3 – According to their kinetic control, clays minerals occurring in geothermal systems reservoir cannot be used in most cases as geothermometers

4 – The reaction rate towards more stable phases is a function of the energy delivered to the system (time x temperature).

Argilogenèse et transformations argileuses

5 – Classicaly, zonings of clay paragenesis evidenced in fossil systems were considered as comtemporaneous of the nucleation process and all the clay assemblages observed in the drill holes were considered as resulting from a same crystallization stage

The study of the Chipilapa geothermal field :

Clay zonings appear with time