

Hydrogeochemical mechanisms driving the occurrence of elevated fluoride contents in crystalline aquifers in Benin, Western Africa

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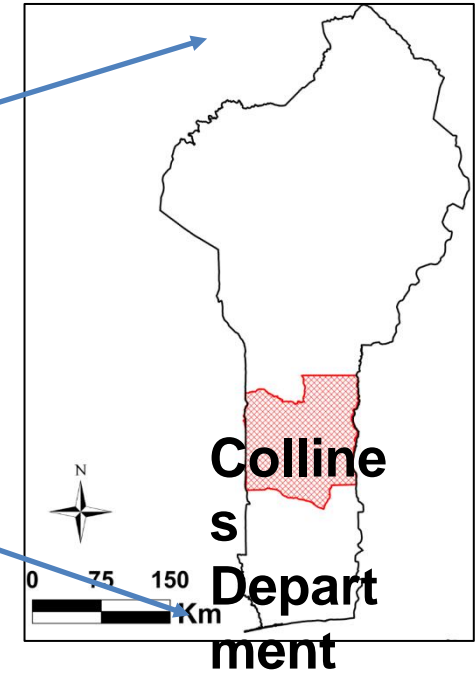
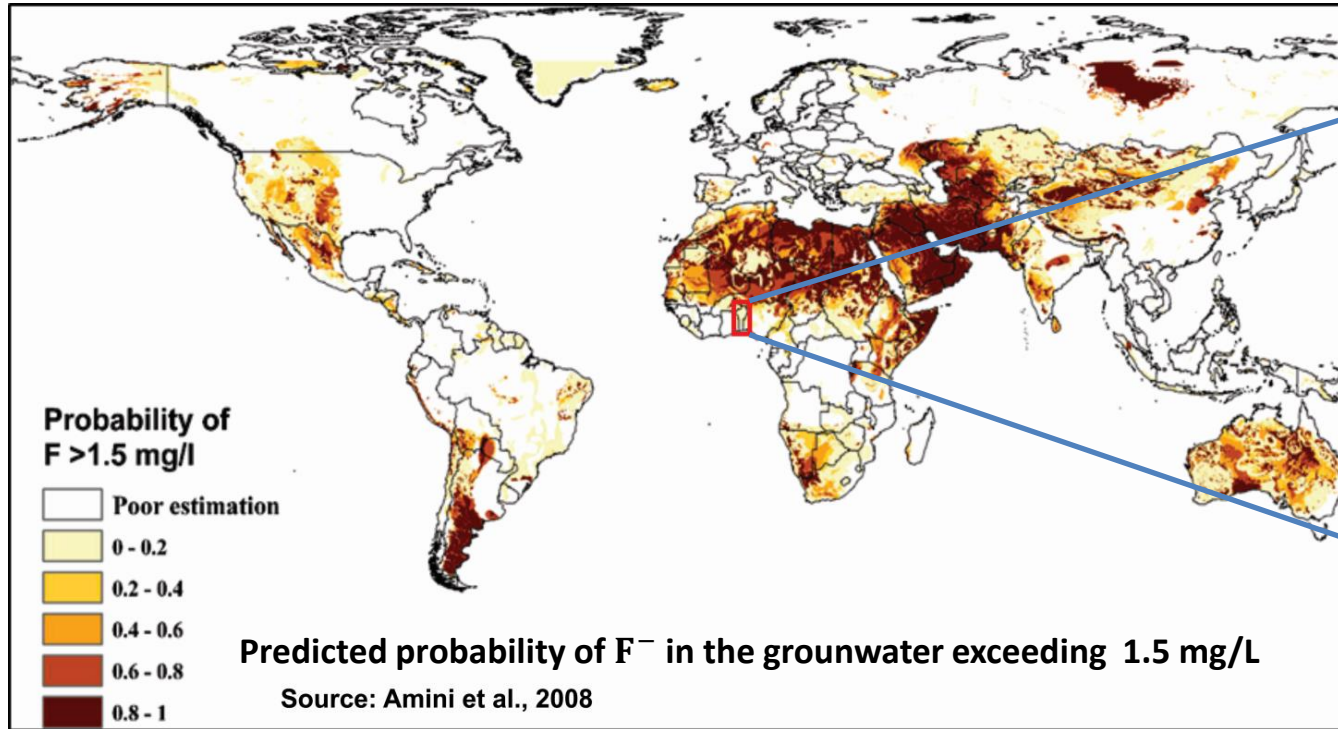
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Laboratoire
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Appliquée



Background



Health effects of fluoride (F^-)

- $F^- < 0.6$ mg/l in water
→ Dental decay
- $F^- > 1.5$ mg/l in water
→ Dental or skeletal fluorosis

Guideline for F^- value in drinking water (WHO): 0.6 - 1.5 mg/l

- Benin is concerned with a probability of 0.2 to 0.4
- The Collines Department is the most affected part of the country

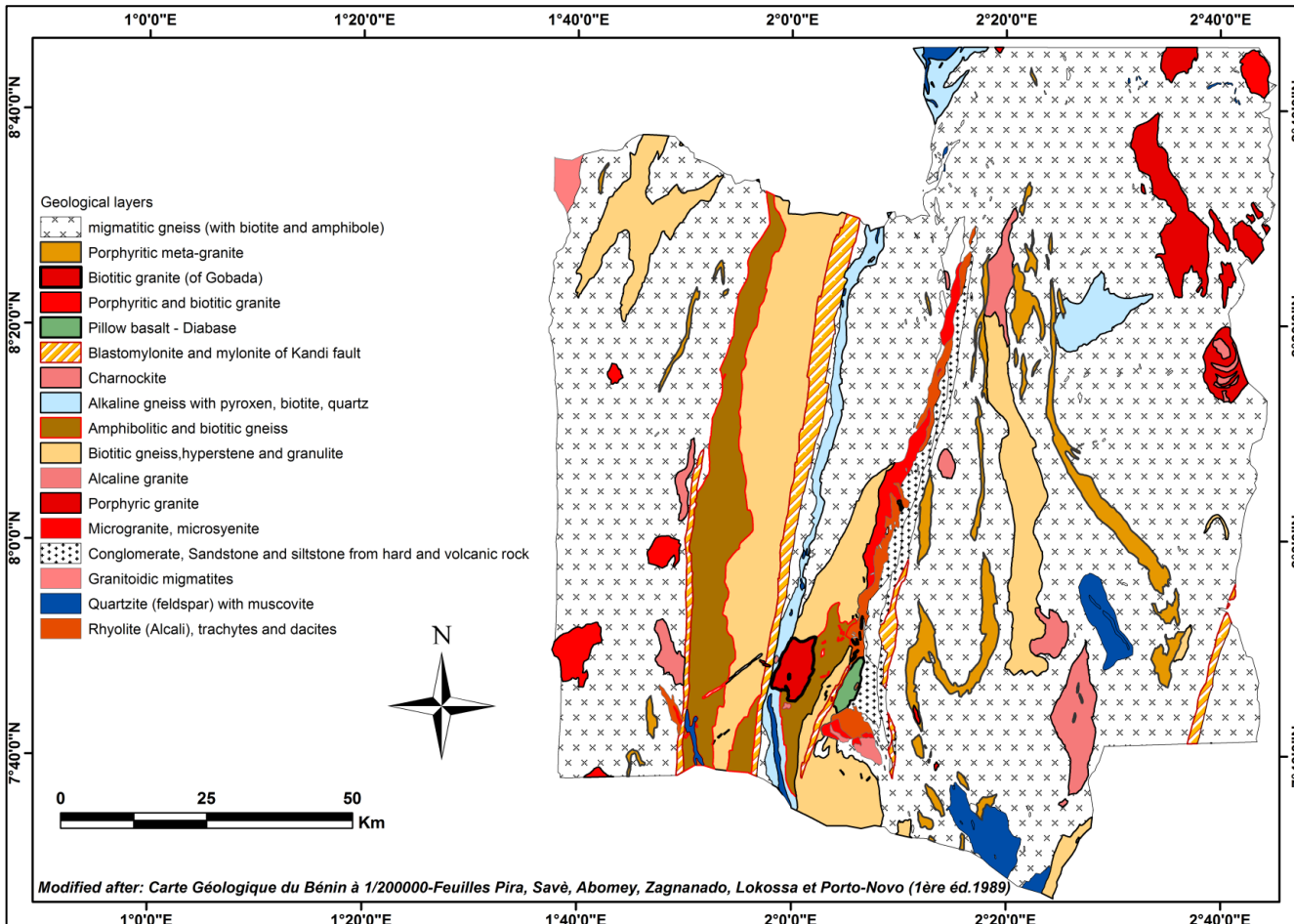
Objectives of the study

Fluoride groundwater contamination in Benin is well documented but not really investigated

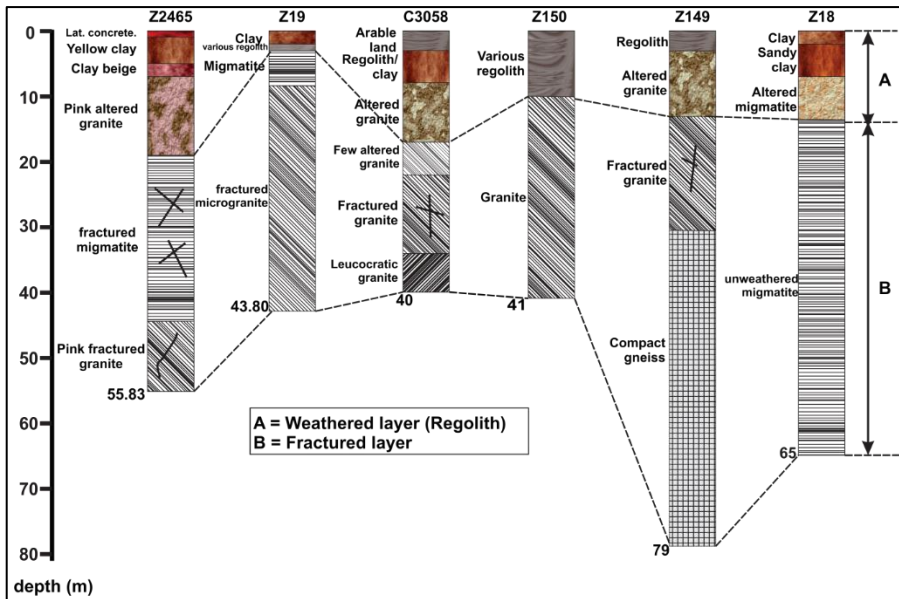
- Describe the general hydrogeochemical processes governing groundwater mineralization in the area of interest
- Identify the origin and geochemical processes controlling the high fluoride concentrations observed in groundwater (natural versus anthropogenic impacts?)
- Investigate on fluoride-bearing rocks and minerals

Geological and hydrogeological contexts

- Mainly precambrian crystalline rocks consisting of **migmatite, gneiss and granite**
- Peneplain with scattered inselbergs and plateaux

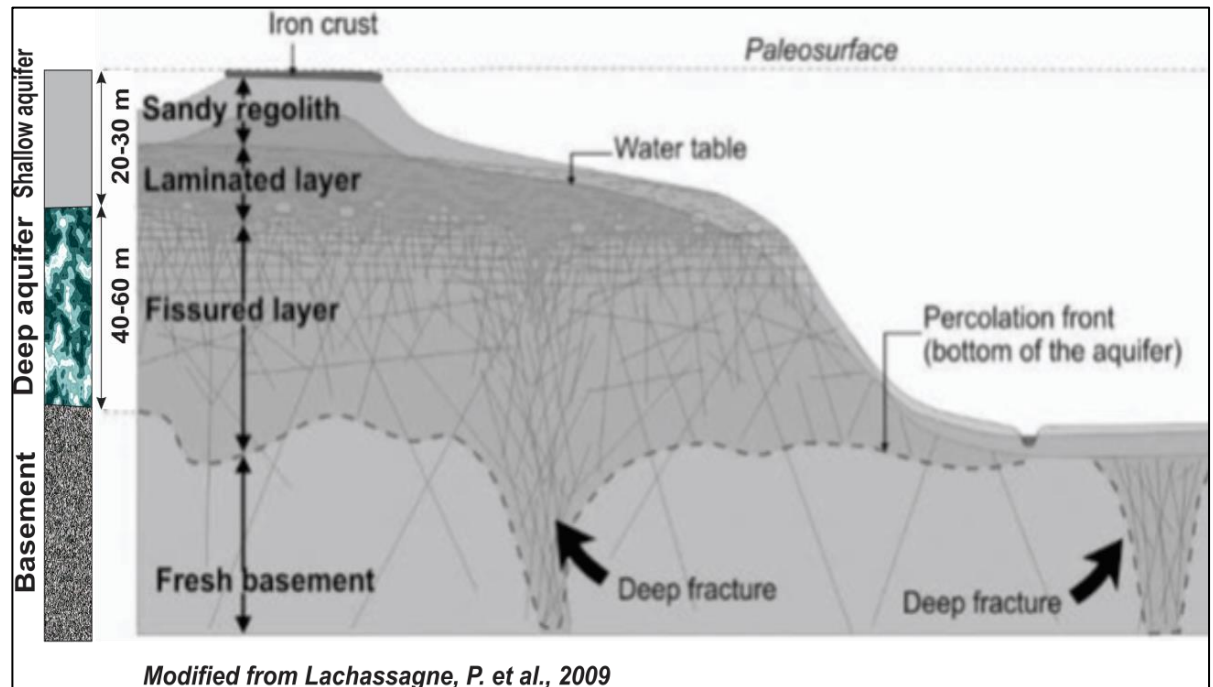


Geological and hydrogeological contexts



Schematic sections of boreholes from the study area

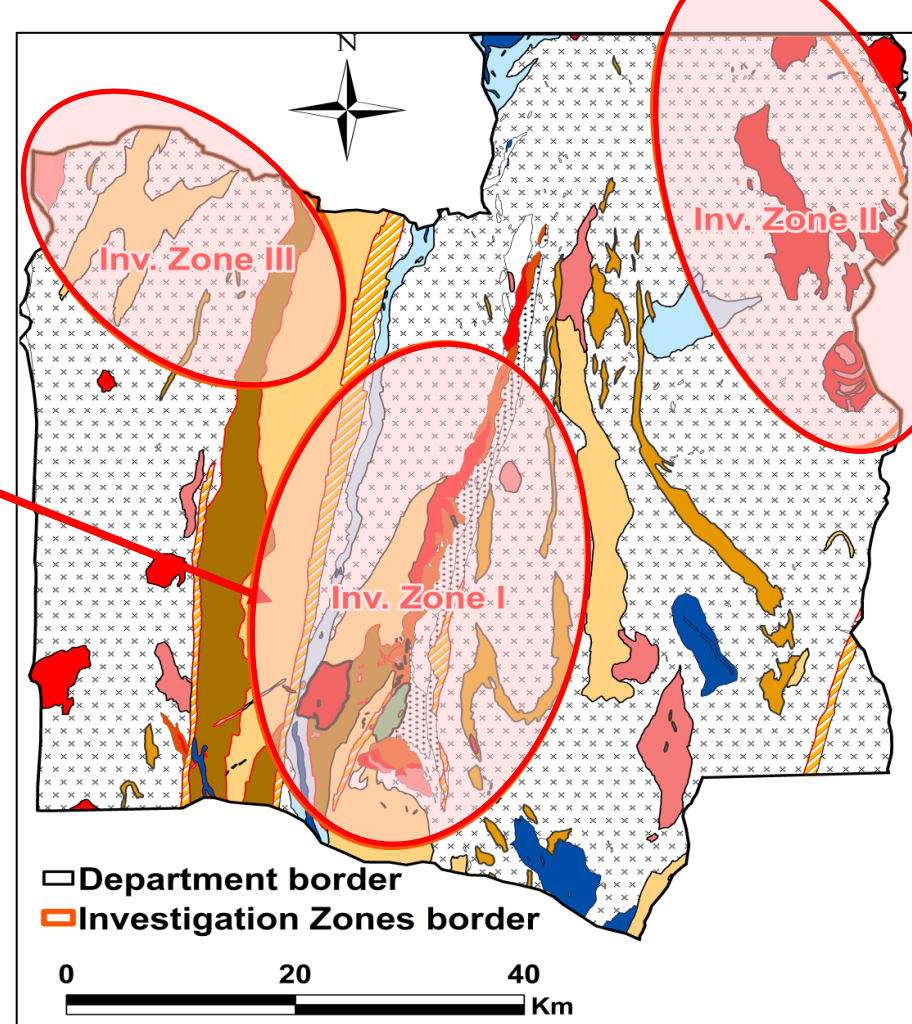
Aquifers consist of classical bi-layered systems as encountered in hard crystalline rock areas: **Shallow (upper)** and **Deep (underlying)** aquifers



Modified from Lachassagne, P. et al., 2009

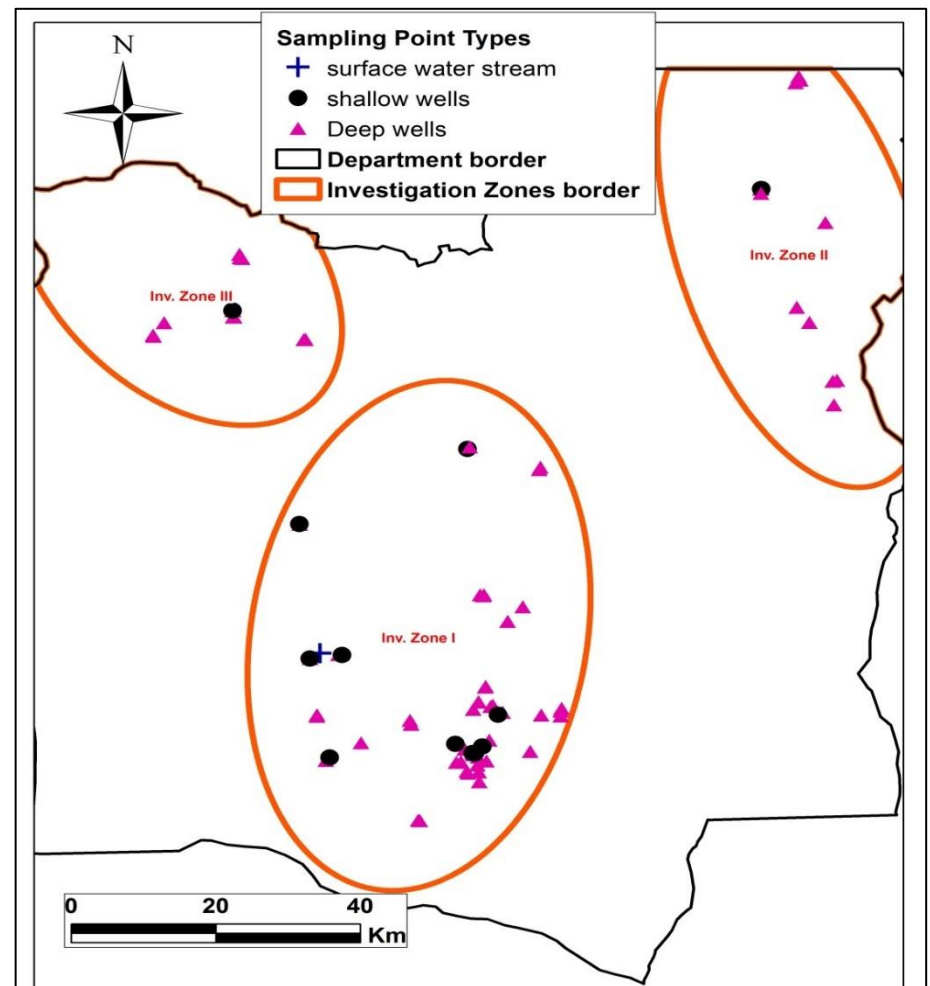
Methodology

- Sampling mainly in the Southern part of the region where dental fluorosis is more acute
- Few samples also in the North-eastern and the North-western

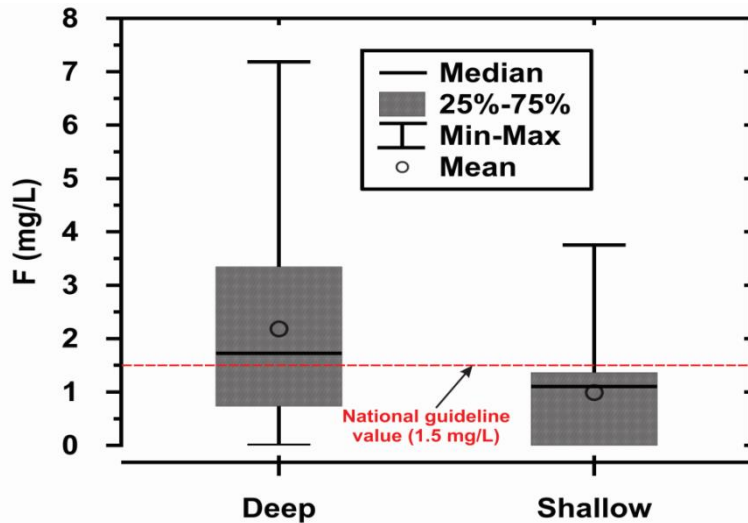
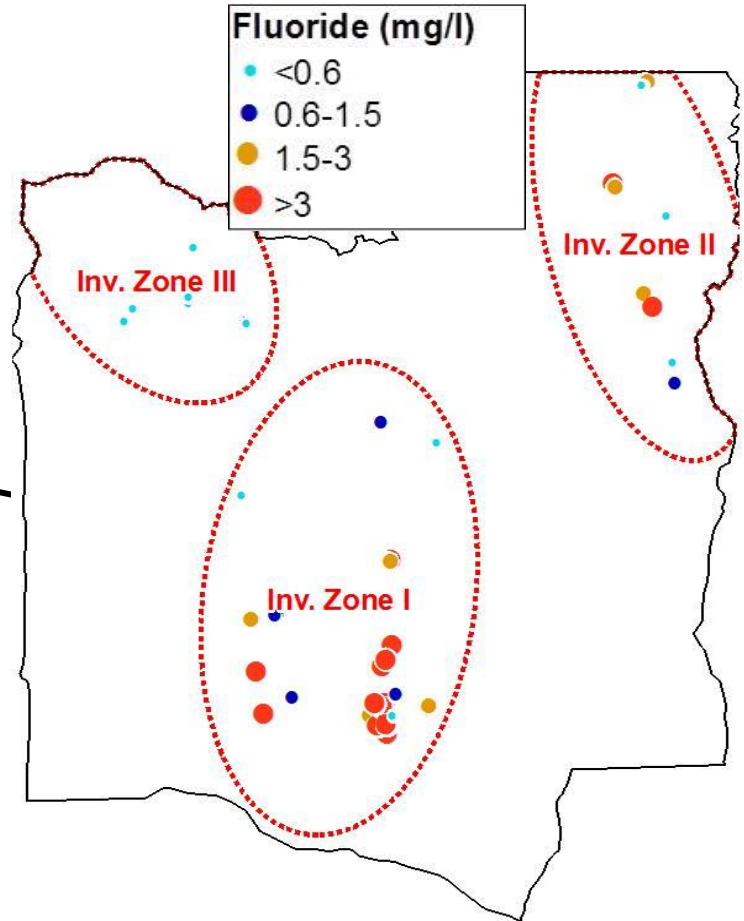
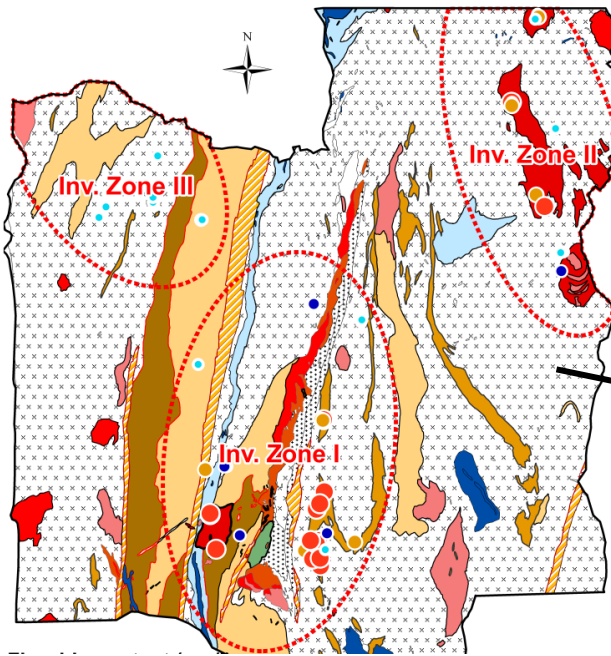


Methodology

- Water samples collected from **83 locations**, during two field campaigns (respectively in high and low groundwater levels) from both
 - the shallow aquifer
 - the deep aquifer
- **Analyzed parameters**
 - **Majors:** Ca^{++} , Mg^{++} , Na^+ , K^+ , HCO_3^- , CO_3^{--} , SO_4^{--} , Cl^- , NO_3^- , SiO_2
 - **Minors:** F^- , Fe^{3+} , Mn^{++} , NH_4^+ , H_2PO_4^- , Br^- , NO_2^-
- geochemical approaches and multivariate statistics for data exploring



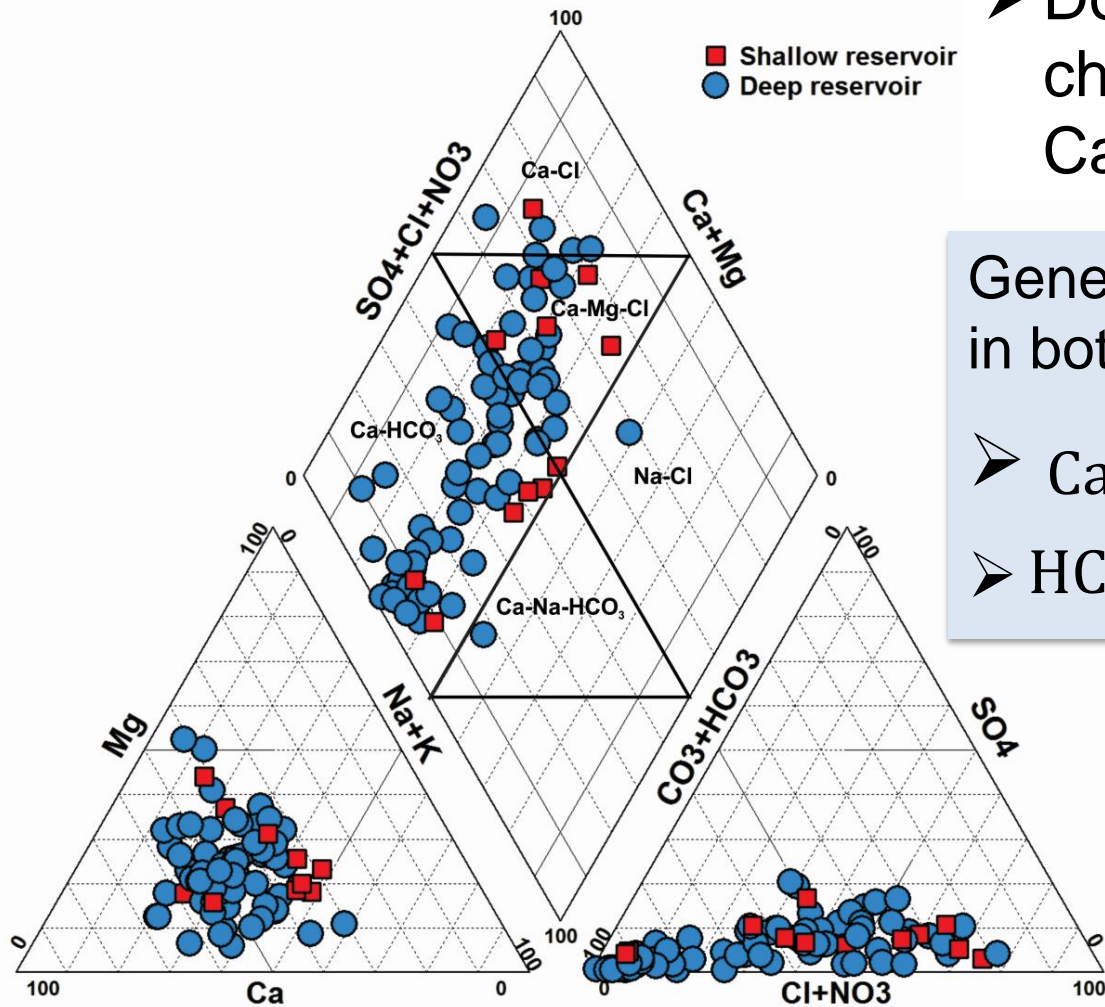
Spatial distribution of fluoride in groundwater



- More than 50% of samples from southern part have F^- contents exceeding the guideline value (1.5 mg/L)
- Higher content of F^- in deep reservoir

Groundwater chemical facies in the area

Piper Diagramme (Piper 1944)

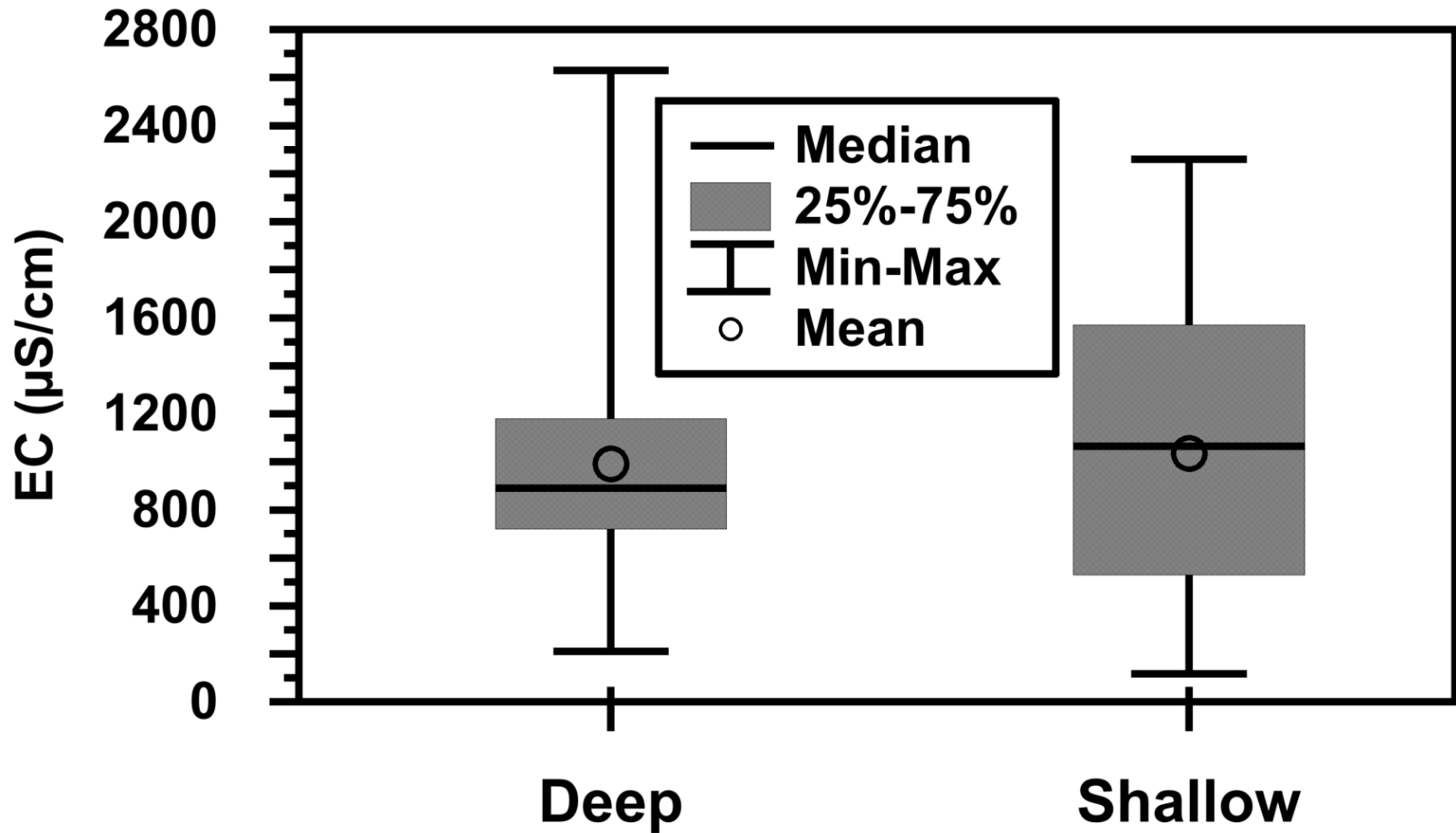


- Dominance of Ca-HCO_3 chemical type, followed by Ca-Mg-Cl Type

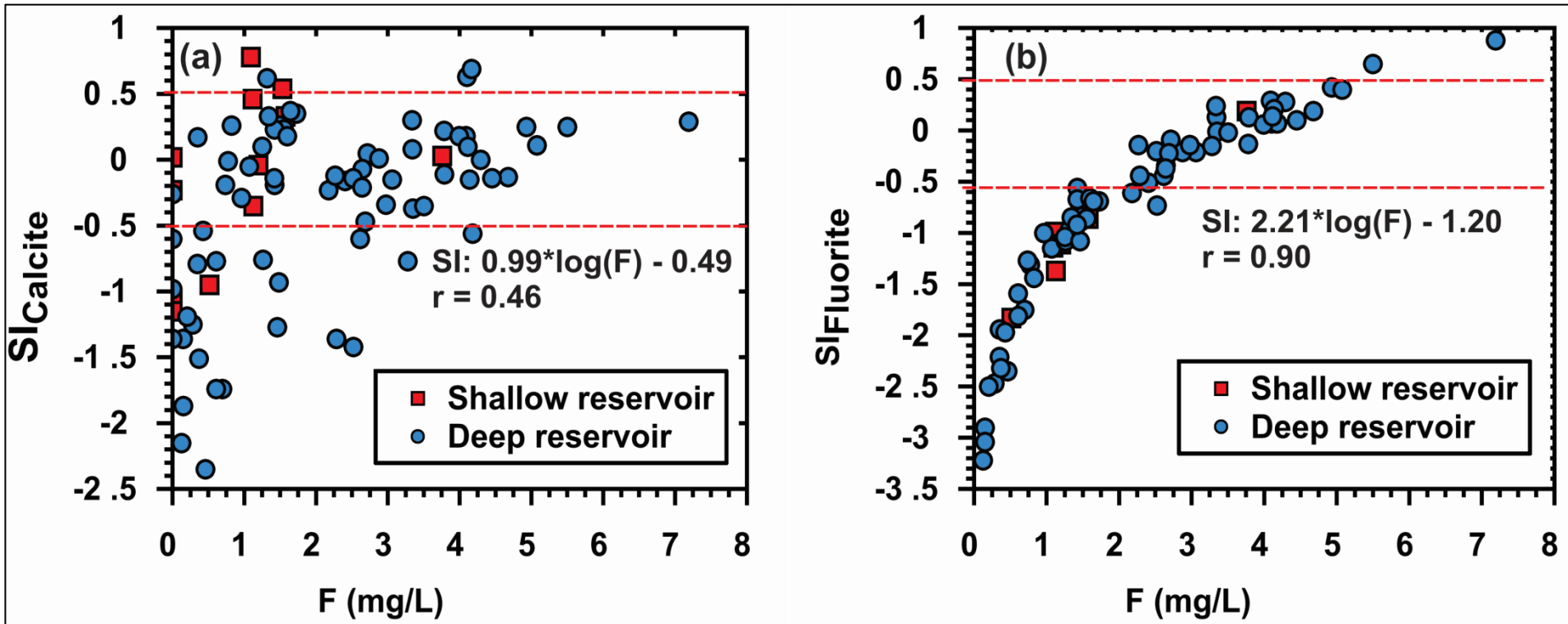
General abundance order (meq/L) in both reservoirs:

- $\text{Ca}^{2+} > \text{Na}^+ > \text{Mg}^{2+} > \text{K}^+$
- $\text{HCO}_3^- > \text{Cl}^- > \text{NO}_3^- > \text{SO}_4^{2-}$

Shallow reservoir more mineralized than the Deep reservoir



Saturation indices for calcite and fluorite and influence on fluoride mobilization in groundwater



- Relationship between fluoride content and SI Calcite and SI fluorite
- Earlier saturation of water with respect to calcite in shallow reservoir
→ favorable conditions for fluoride mobilization

Principal Components Analysis

3 clusters (poles):

- P1: External inputs / high mineralization
- P2: Water-rock interactions
- P3: ions exchange indicators

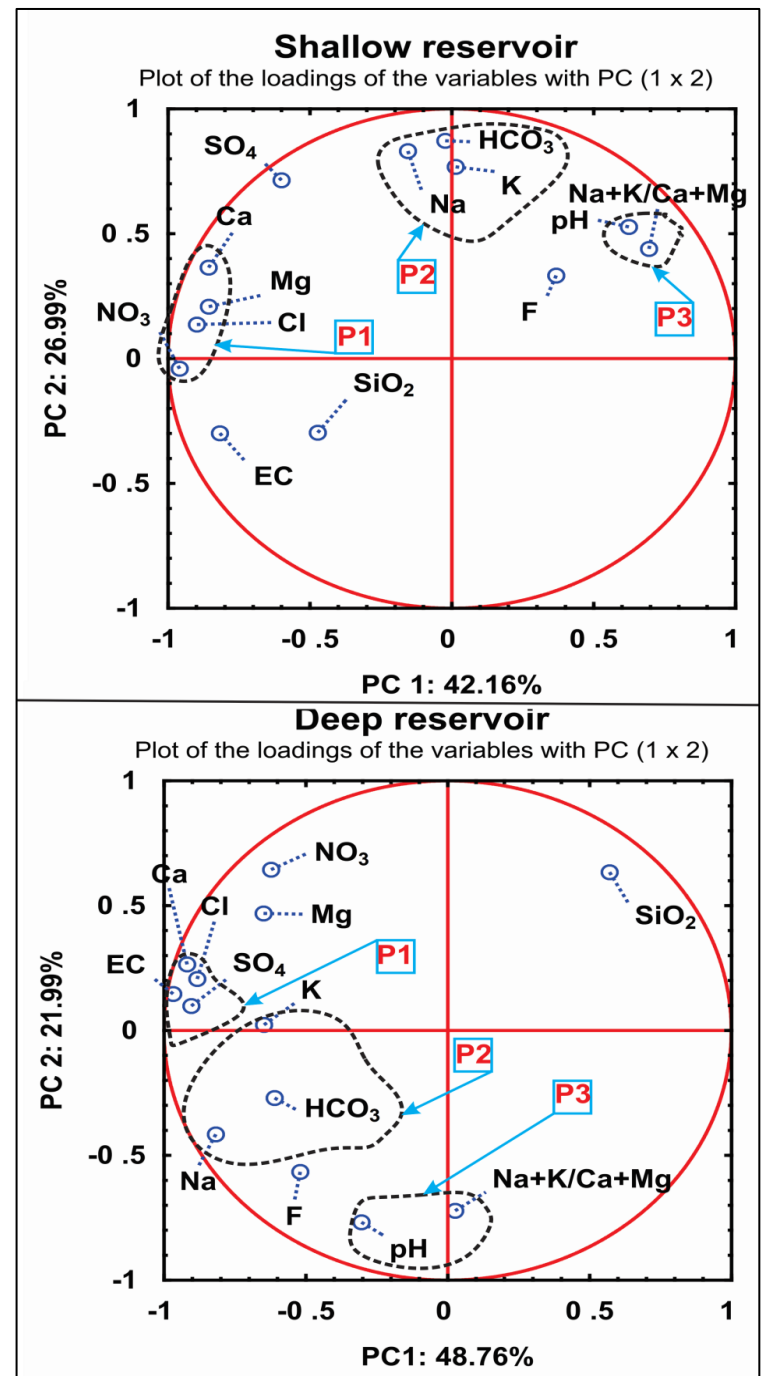
➤ Shallow reservoir:

Evidence of anthropogenic influence

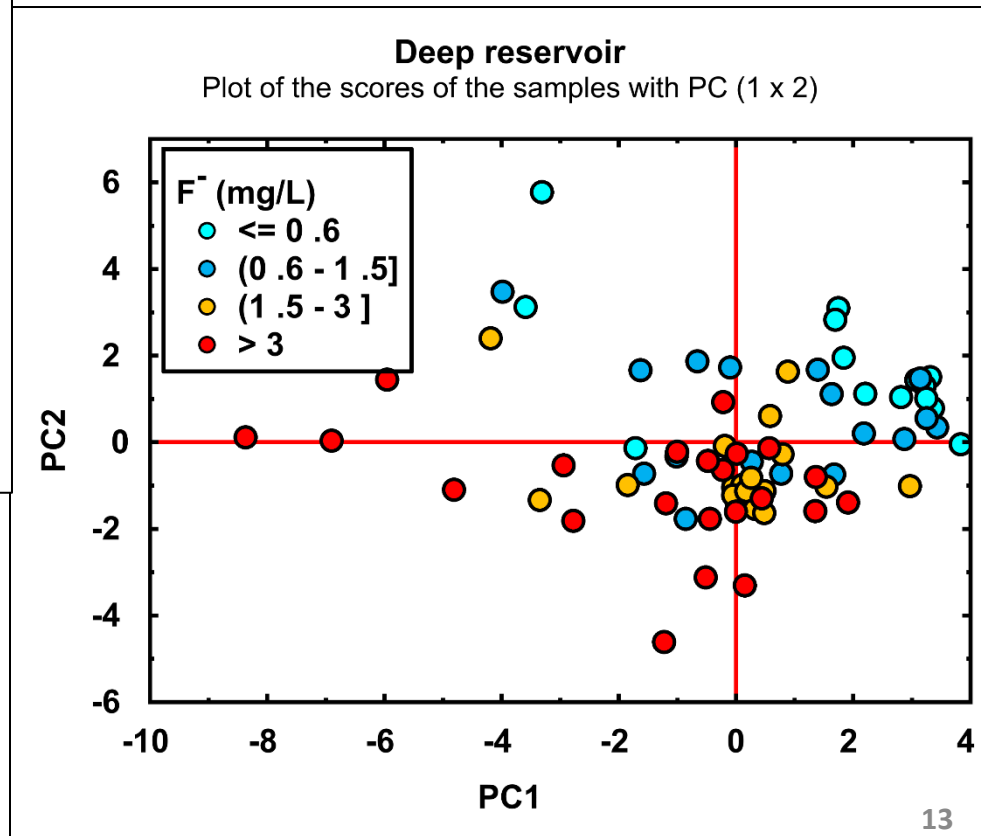
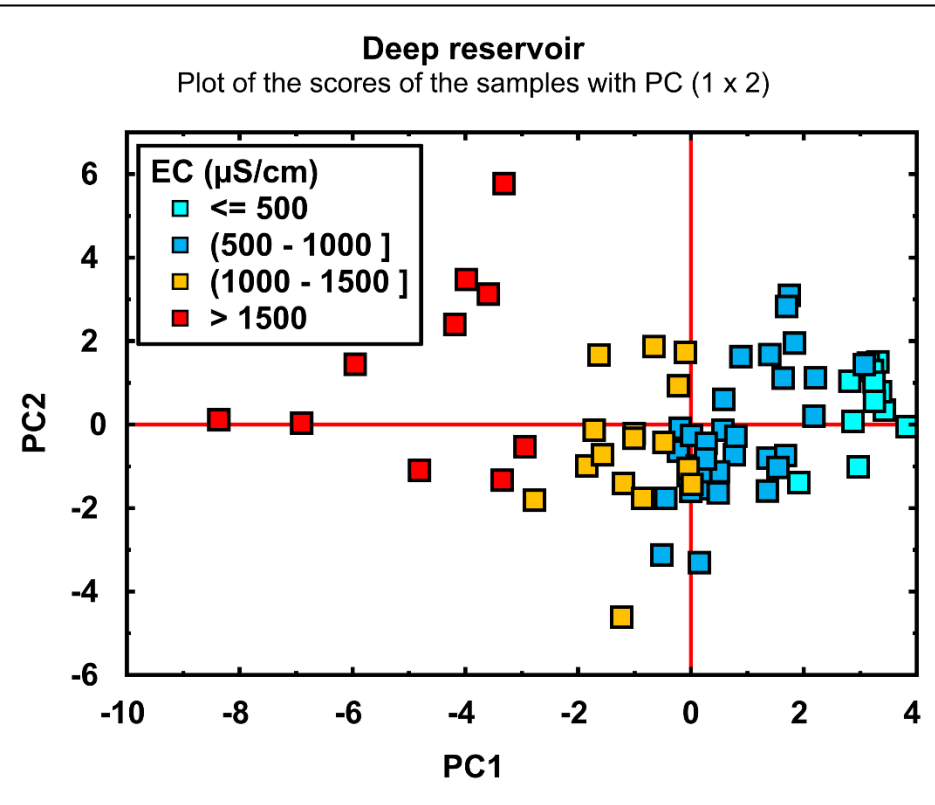
➤ Deep reservoir:

➤ Fluoride is more linked to water-rock-interaction indicators (Pole2), mainly hydrolysis of K and F rich minerals as micas, amphibole,

➤ Ions exchanges may also be involved in fluoride level rising both in shallow and deep reservoir.



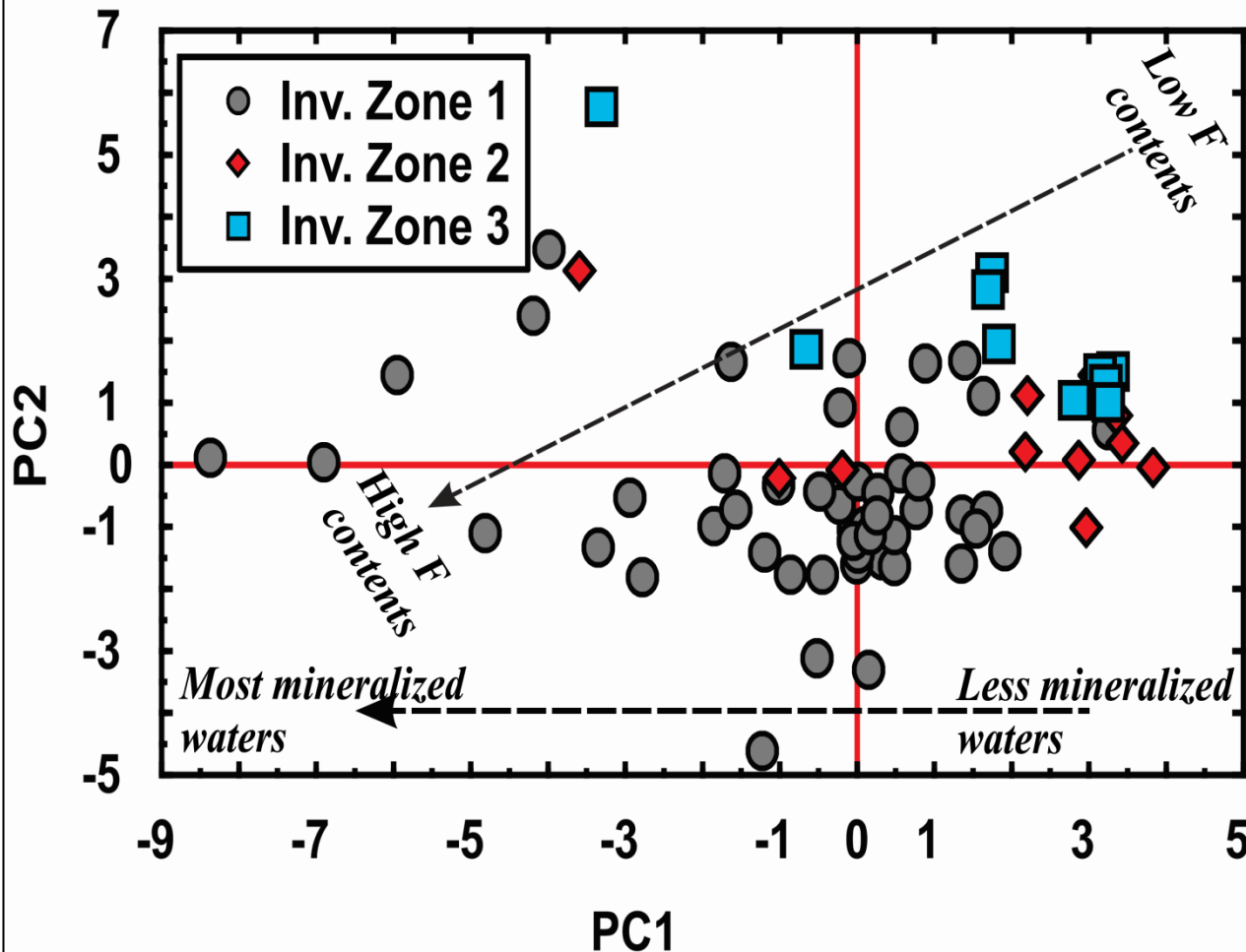
Principal Components Analysis: Plot of individuals (for the deep reservoir)



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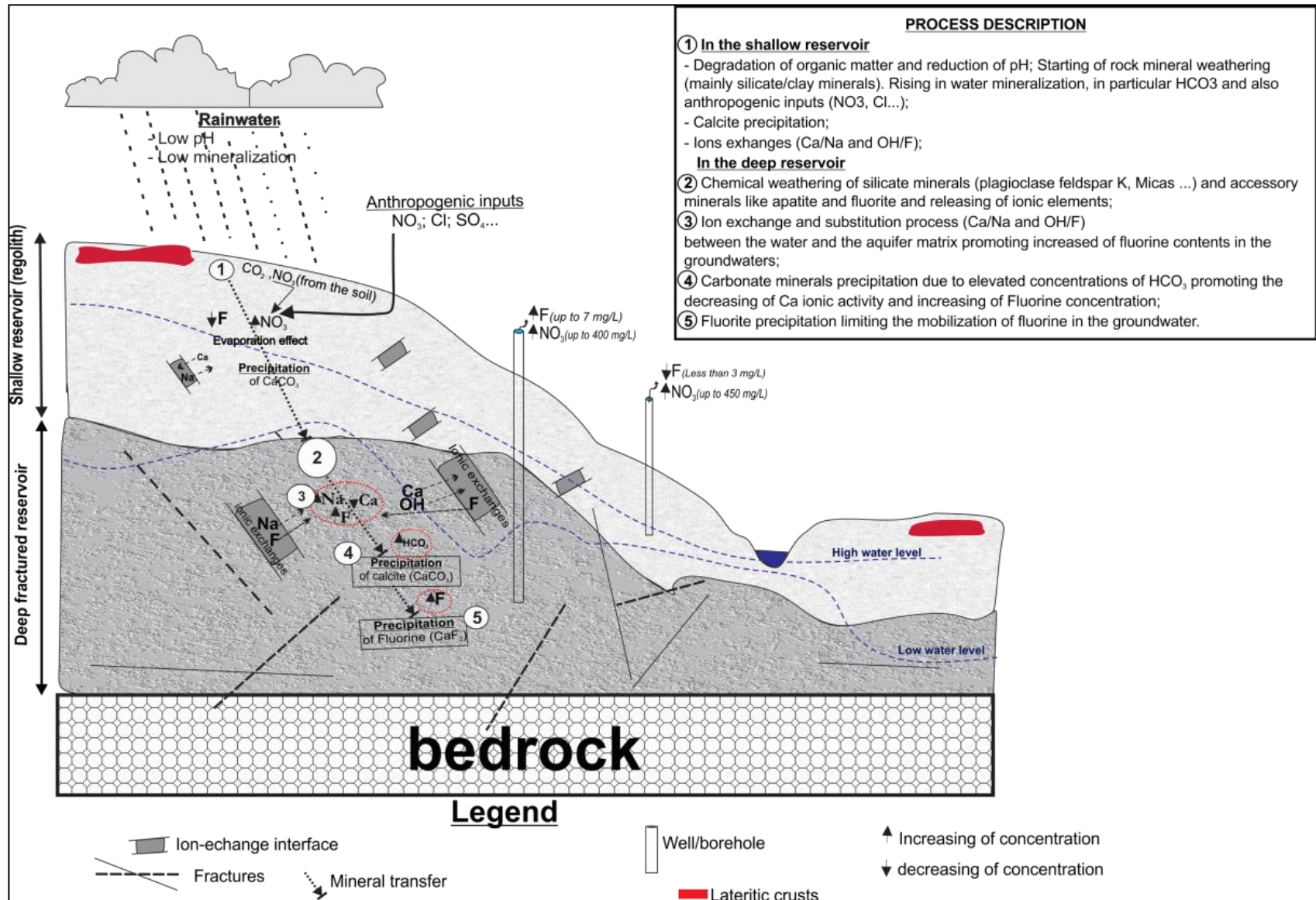
Deep reservoir

Plot of the scores of the samples with PC (1 x 2)



Regionalization of fluoride content in water → underlying geology plays important role in fluoride distribution

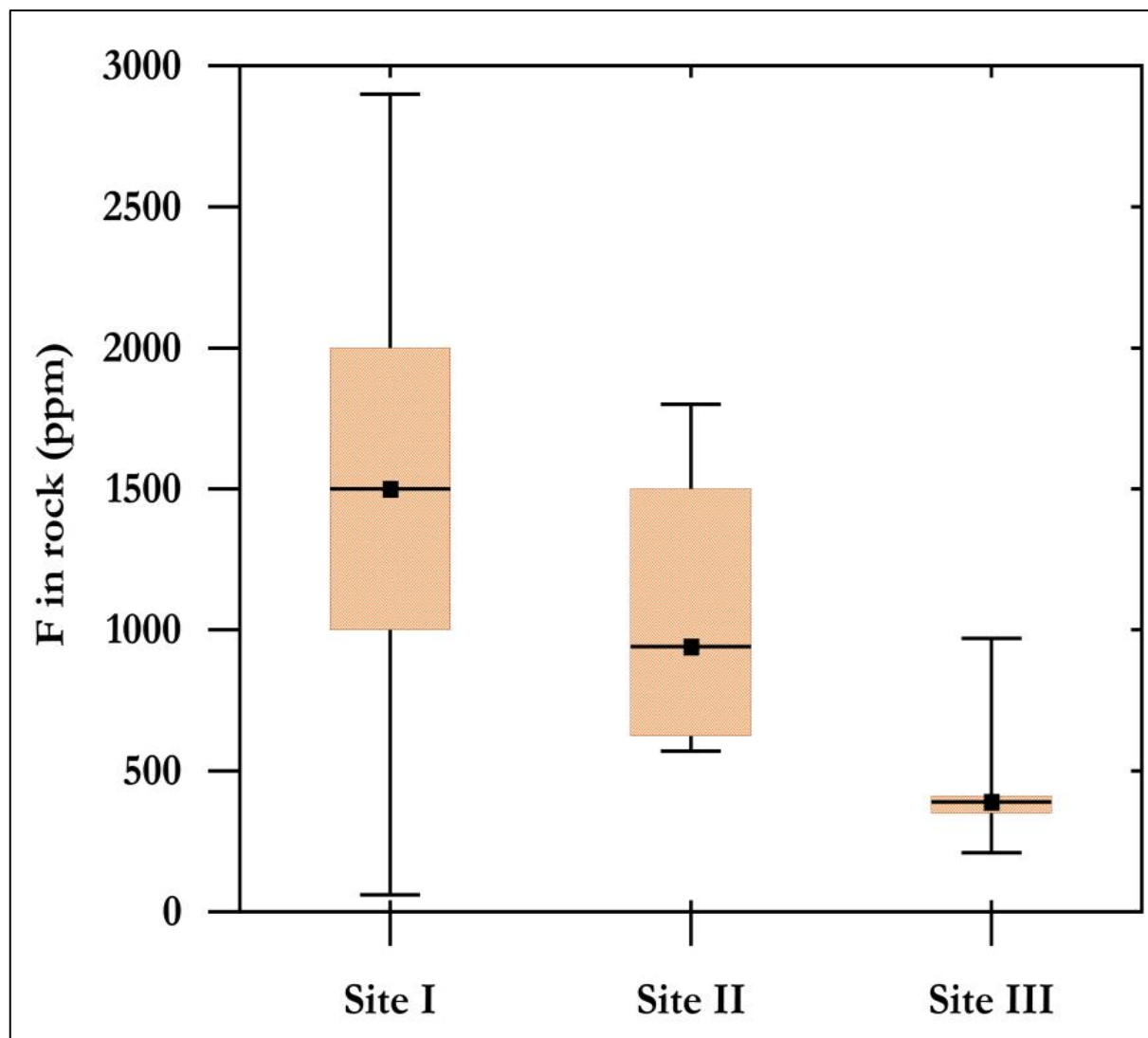
Conceptual model of fluoride mobilization in groundwater in the area



Ongoing work: F-bearing rocks and minerals

Preliminary investigations on petrography, mineralogy and geochemistry

More fluorine content in rock where fluoride content is high in groundwater

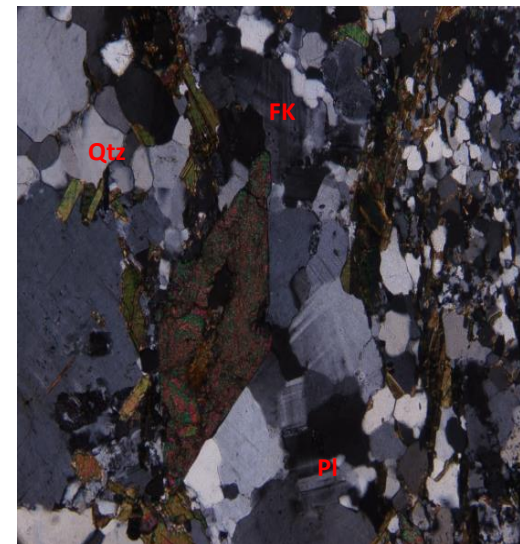
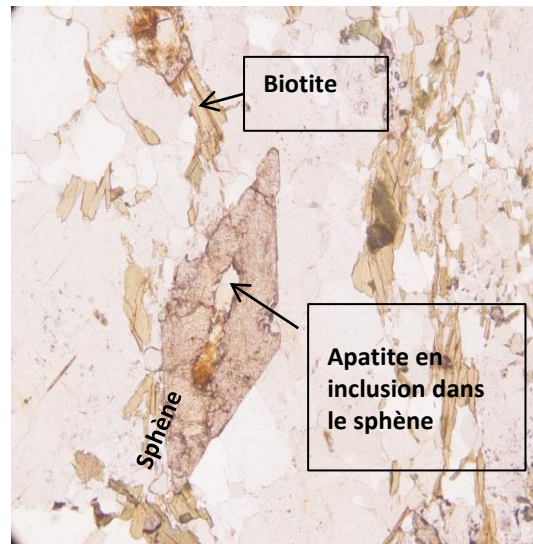
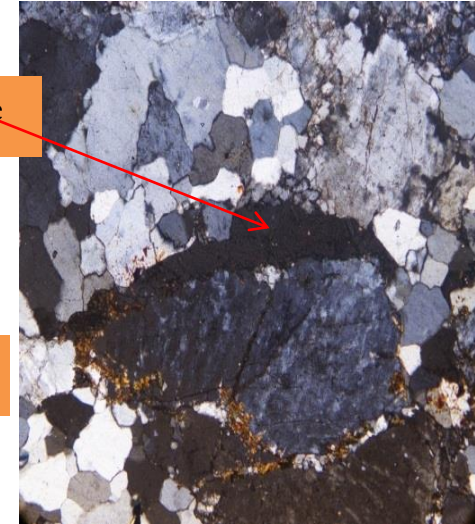
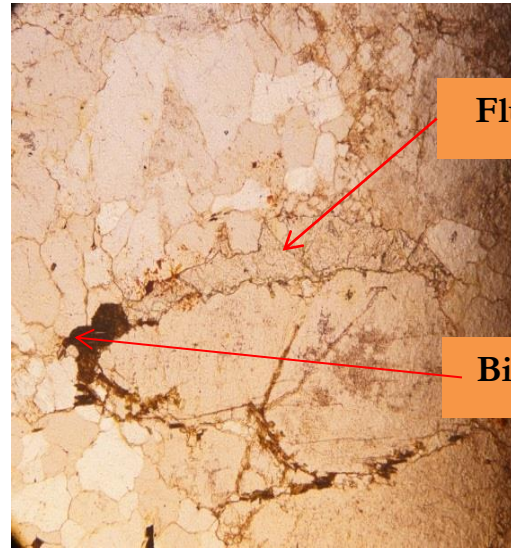
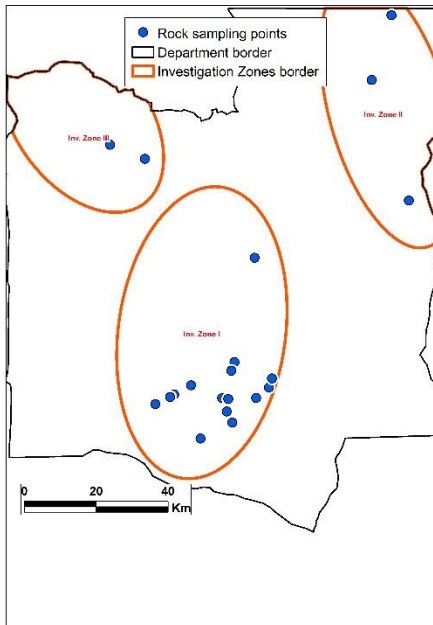


Ongoing work: F-bearing rocks and minerals

Preliminary investigations on petrography, mineralogy and geochemistry

Presence of fluorine rich-mineral as

- fluorite
- biotite,
- apatite,
- muscovite,
- titanite (sphene)
- chlorite



Synthesis

- Discrimination of fluoride origin in the groundwater, **mainly from natural sources (water-rock interactions)** even if external inputs influence the global water mineralization
- Investigations are going on to **identify main fluorine compounds in rock-aquifer** and also main conceptual of fluoride mobilization in groundwater
- Complementary investigations on **impacts of effluent waters on groundwater resources** in populated areas (stable isotopes) and link with ongoing hydrochemical processes?

Acknowledgement



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