

Geogenic groundwater pollution in volcanic rock aquifer systems on the eastern, western and northern flanks of Mount Meru, Tanzania – special reference to fluoride

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Introduction

- Arusha volcanic region in northern Tanzania
 - Water shortage
 - **Surface water** – very high F^- conc.
 - **Groundwater** – source of drinking water
 - ❖ Very poor quality – high F^- conc.
 - ❖ Natural contamination
 - **Dental and skeletal fluorosis**

(Ghiglieri et al., 2012; Mckenzie et al., 2010).



Location of Mount Meru in Arusha region, Tanzania.
(Source: modified after Wikimedia; commons.wikimedia.org)

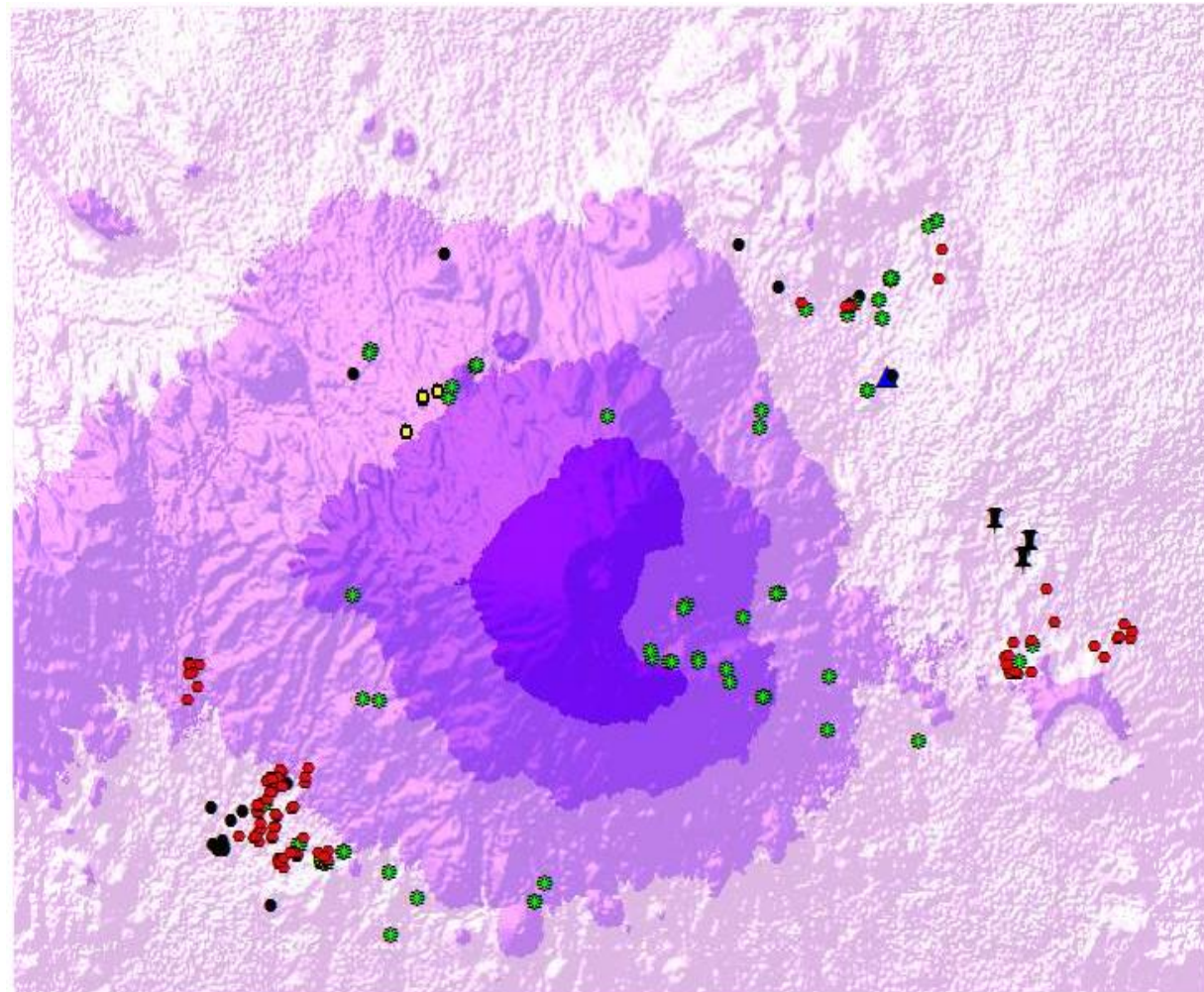
Methods

- Two field campaigns;
 - 9th July – 26th September 2017
 - 11th March – 23rd September 2018

- **182 water points;**
 - **178 groundwater points**
 - **4 surface water points**

- Groundwater points;
 - 96 hand-dug wells
 - 61 springs
 - 17 boreholes
 - 4 tap water points(from remote springs).

- Surface water points;
 - 3 lakes
 - 1 river



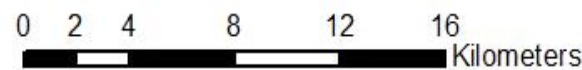
Legend

- Well
- Spring
- Borehole
- Tap water point
- Lake
- River

Value

- 1,112 - 1,608
- 1,609 - 2,118
- 2,119 - 2,909
- 2,910 - 4,532

10/9/2019

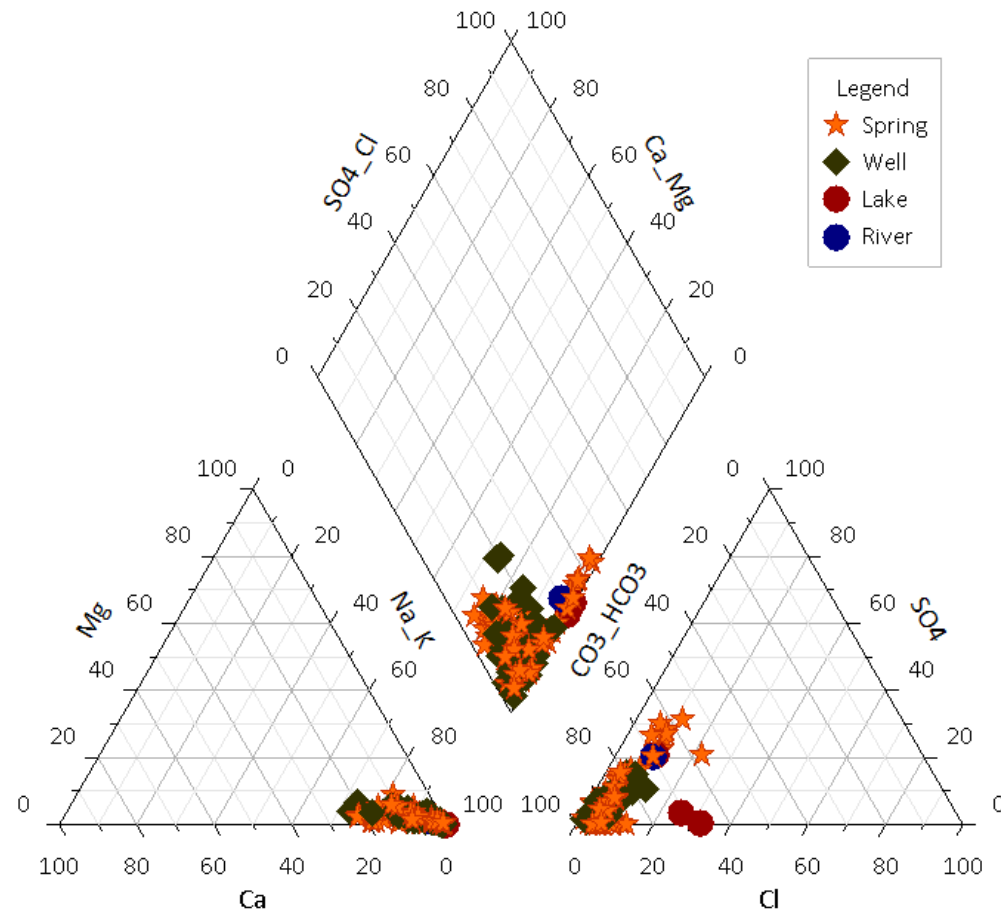


Methods

- Water samples;
 - **163 water samples** – 118 water points
 - ❖ **159** groundwater samples
 - **61** hand-dug wells, **53** springs
 - ❖ **4** surface water samples
 - **3** lakes, **1** river
- Water chemical analysis;
 - Laboratory for Applied Geology and Hydrogeology, Ghent University

Results and Discussion

- Laboratory analytical results;
 - **Sodium (Na^+)** and **bicarbonate (HCO_3^-)** are the dominant ions
 - **NaHCO_3** type water



Results and Discussion

- Laboratory analytical results;

➤ High values of F^- were recorded

- ❖ In 159 groundwater samples;

- Values range: **0.147 – 553 mg/l**

- Average value = **26.6 mg/l**

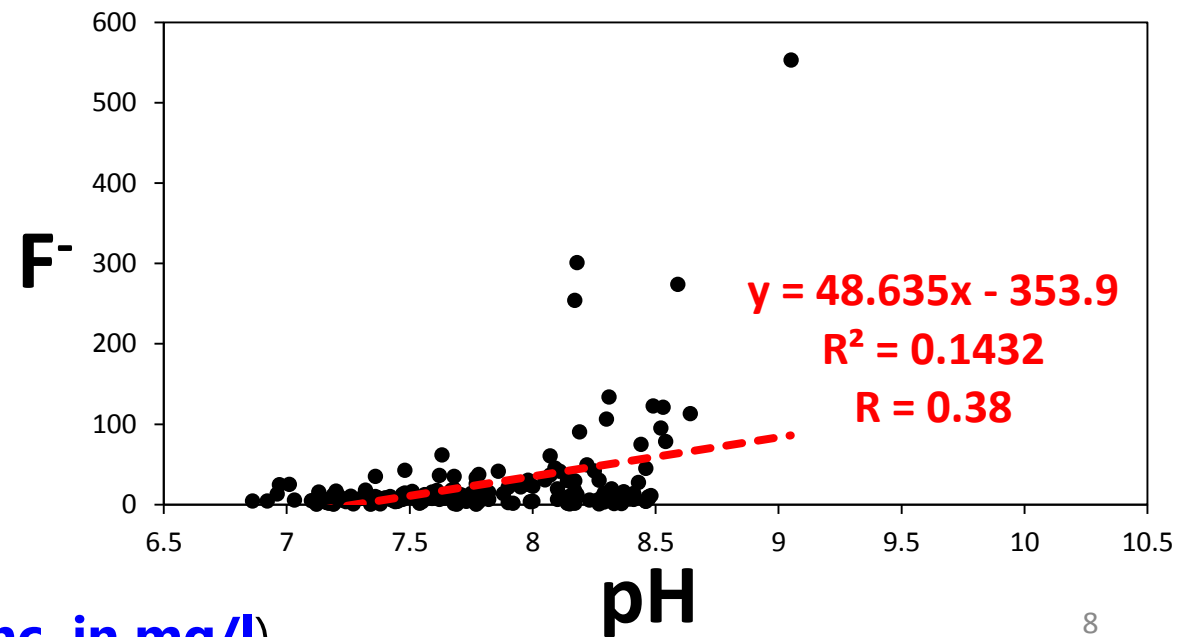
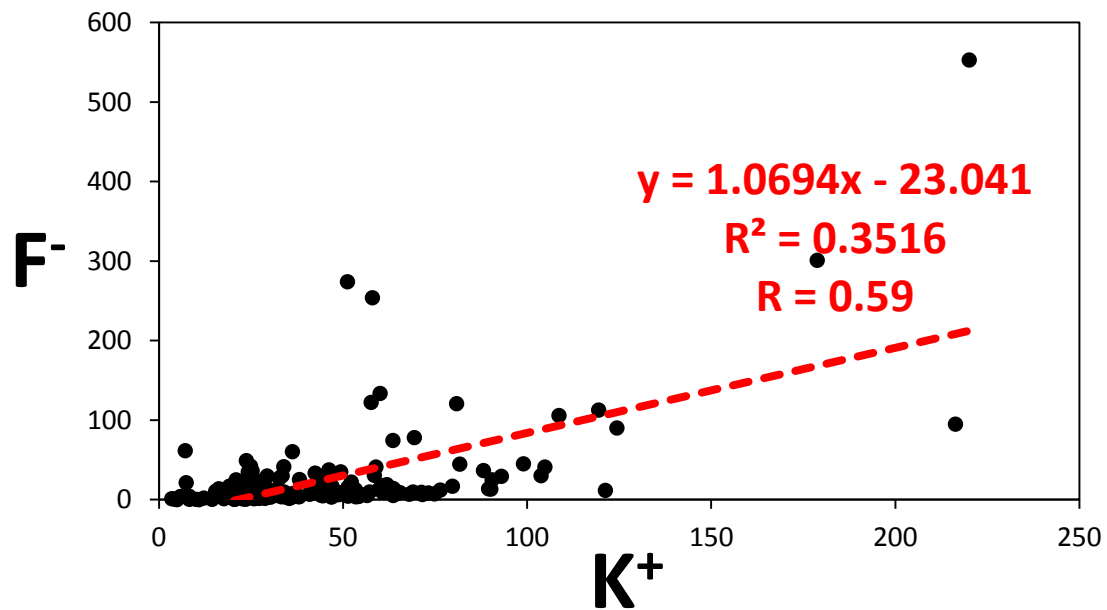
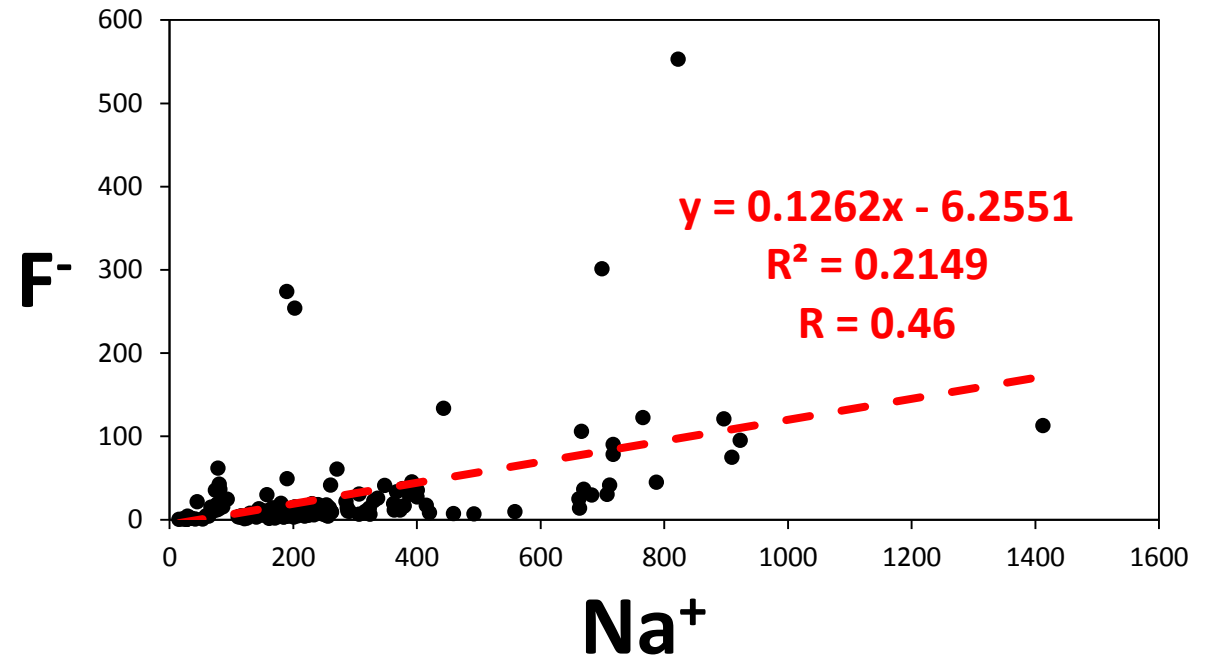
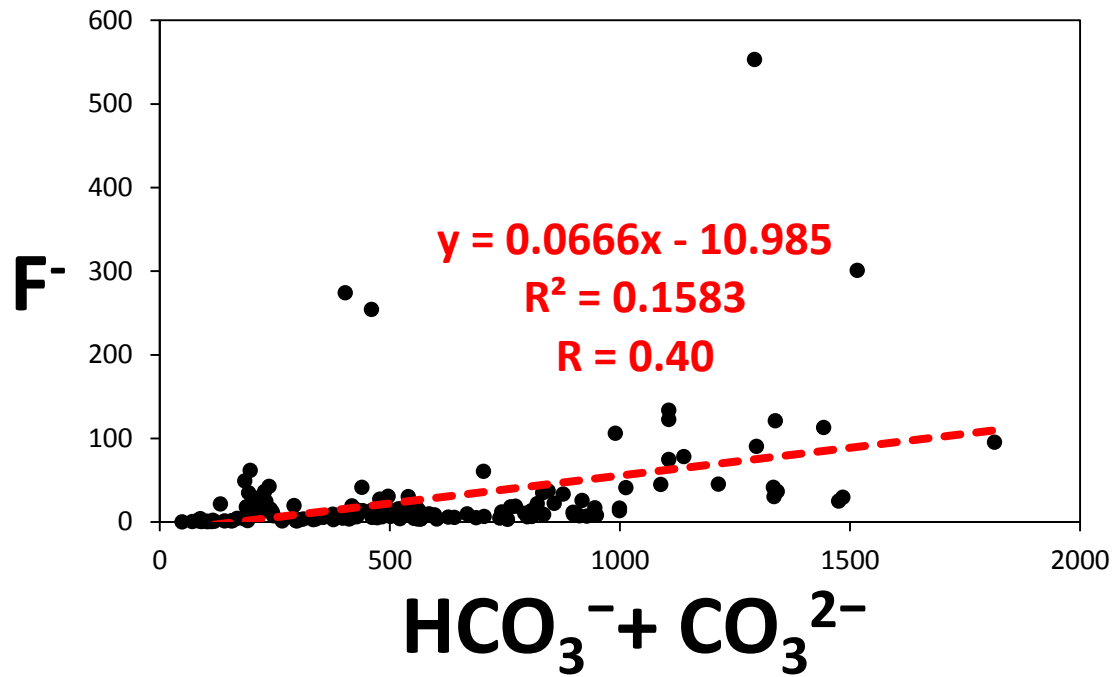
- ❖ In 4 surface water samples;

- Values range: **143.6 – 1004 mg/l**

- Average value = **588.2 mg/l**

Results and Discussion

- Laboratory analytical results;
 - F⁻ concentrations;
 - In **159** groundwater samples;
 - **91% (144 samples)** – above 1.5 mg/l (WHO limit for drinking water)
 - 9% (15 samples) – below the limit
 - ❖ Springs at higher elevations on N-E flank of Mount Meru
 - ❖ Recharge area within Arusha National Park



Results and Discussion

- Laboratory analytical results;
 - F⁻ concentrations in groundwater;

Table 3. Pearson correlation coefficients for HCO₃⁻ + CO₃²⁻, Na⁺, K⁺, pH, Ca²⁺ on fluoride.

$\alpha = 0.05$; *r*- correlation coefficients; *n*-number

	r	n	p-value
HCO ₃ ⁻ + CO ₃ ²⁻	0.40	158	2.07E-07
Na ⁺	0.46	158	7.59E-10
K ⁺	0.59	158	1.80E-16
pH	0.38	158	6.16E-10
Ca ²⁺	- 0.18	158	0.026827

- Significant **positive correlations** of F⁻ with HCO₃⁻ + CO₃²⁻, Na⁺, K⁺ and pH
 - ❖ **Weathering of silicate minerals**
- Significant **negative correlation** of F⁻ with Ca²⁺
 - ❖ **Dissolution of fluorite (CaF₂)**
 - ❖ **Calcite precipitation**
 - ❖ **Low/or absence of Ca²⁺**

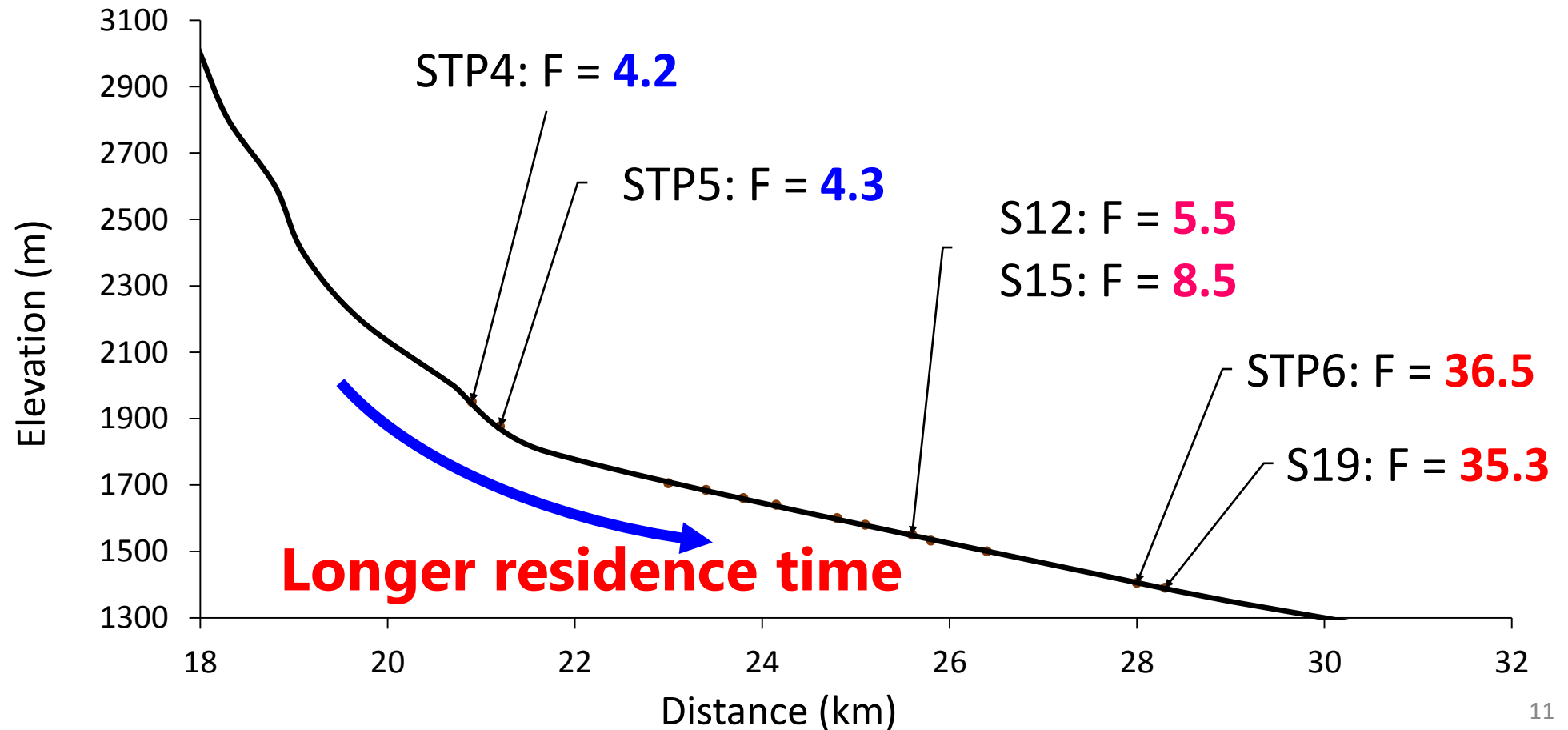
Results and Discussion

- Laboratory analytical results;
 - F:Cl ratio (by meq/l)
 - ☐ F:Cl < 0.10 – F⁻ from the atmosphere. (Kilham and Hecky, 1973)
 - ☐ Ratio > 0.10 – F⁻ from chemical weathering
 - 99% (157 samples) – F:Cl > 0.10
 - 1% (2 samples) – F:Cl < 0.10
 - ☐ Springs in the recharge area.
- Chemical weathering**

Results and Discussion

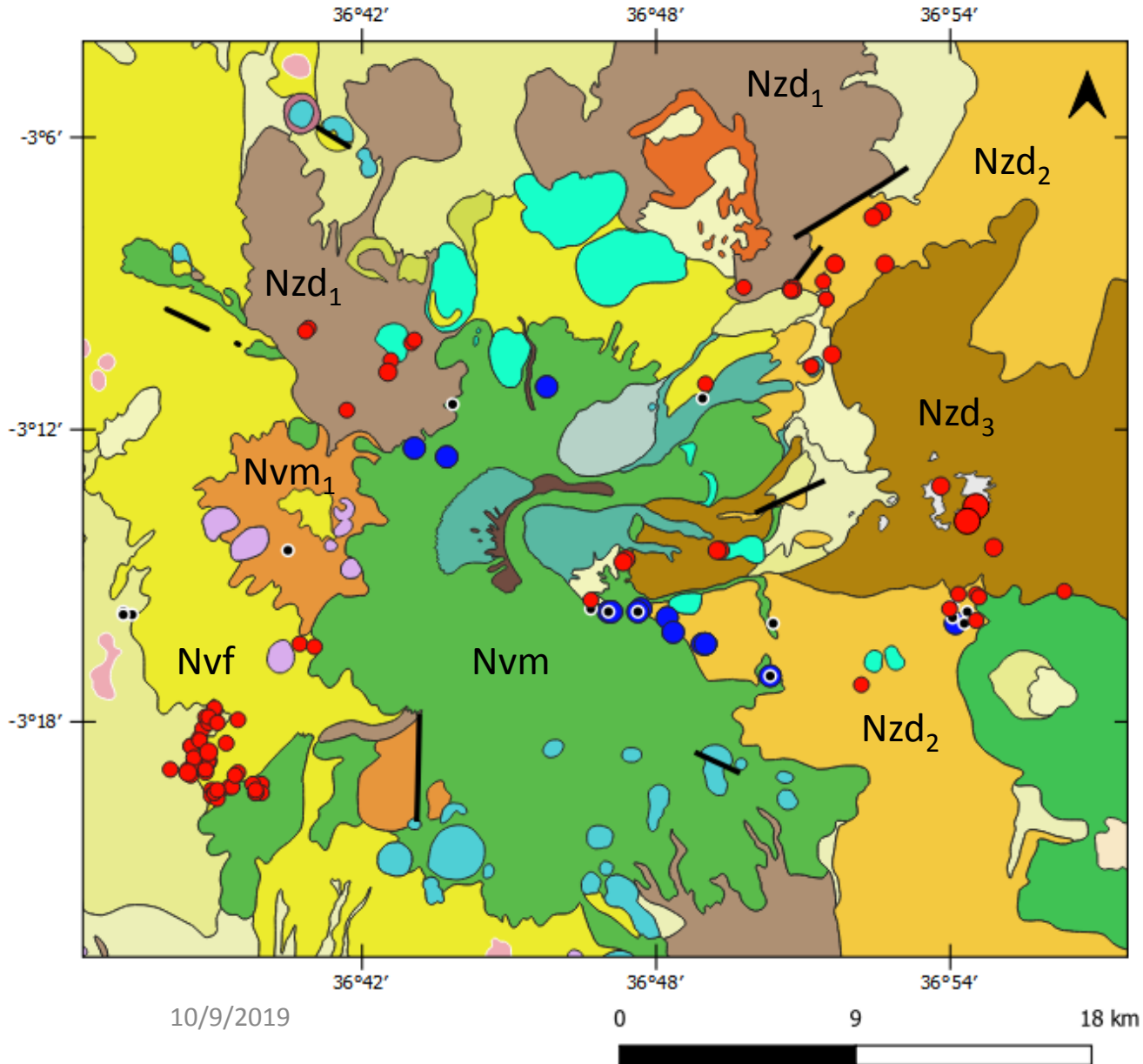
- Laboratory analytical results;
 - North-eastern flank of Mount Meru

❖ **F⁻ (mg/l) increase with a decrease in elevation**



Results and Discussion

• F⁻ conc. vs Geology



• Higher F⁻

➤ Lahars (DADs) - Nzd₁, Nzd₂, Nzd₃

➤ Mantling ash - Nvf

• Lower F⁻

➤ Pyroclastics with nephelinitic + phonolitic lavas - Nvm

➤ Nephelinite lavas and breccias - Nvm₁

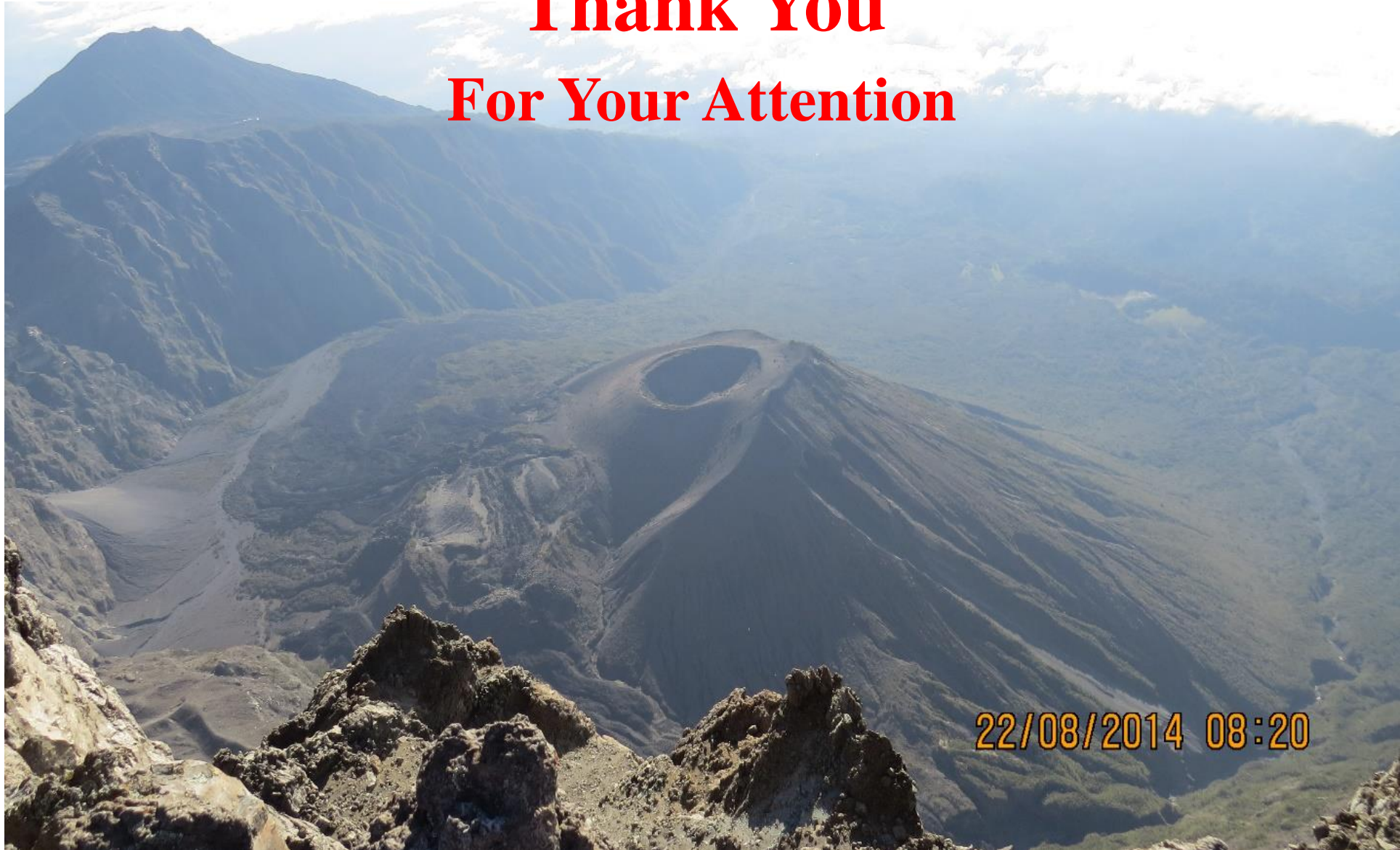
Fluoride concentrations

- F : ≤ 1.5 mg/l
- 1.5 < F ≤ 4.0 mg/l
- 4.0 < F ≤ 50 mg/l
- 50 < F ≤ 305 mg/l
- 305 < F ≤ 1005 mg/l

Conclusion

- Chemical evolution of groundwater;
 - **Weathering and dissolution of silicate minerals**
 - ❖ **Chemical weathering of Na-K-feldspars**
 - **Dissolution of fluorite (CaF₂) and calcite precipitation**
- Factors controlling F⁻ concentrations in groundwater;
 - **Long residence time**
 - **Nature of the geological formations (degree of weathering)**

**Thank You
For Your Attention**



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