Multi-level gas monitoring to understand the origin of transients

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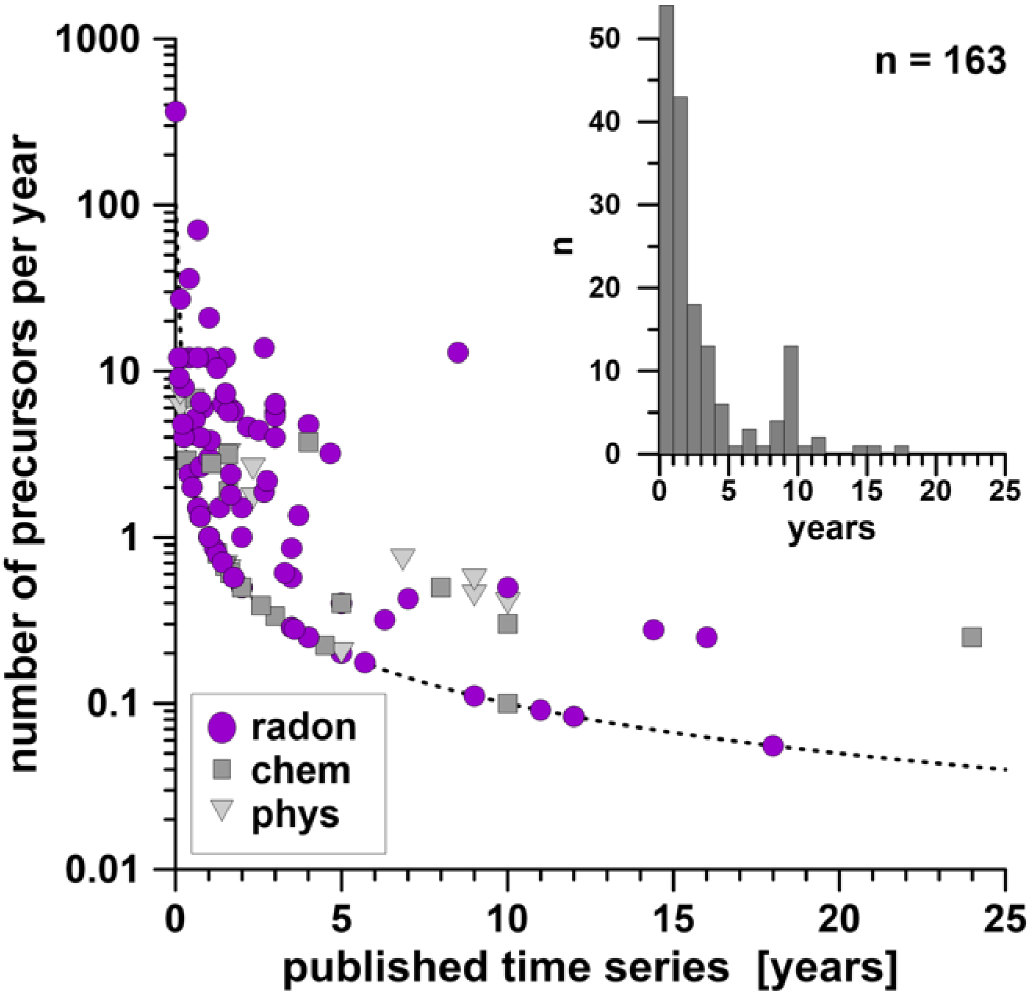
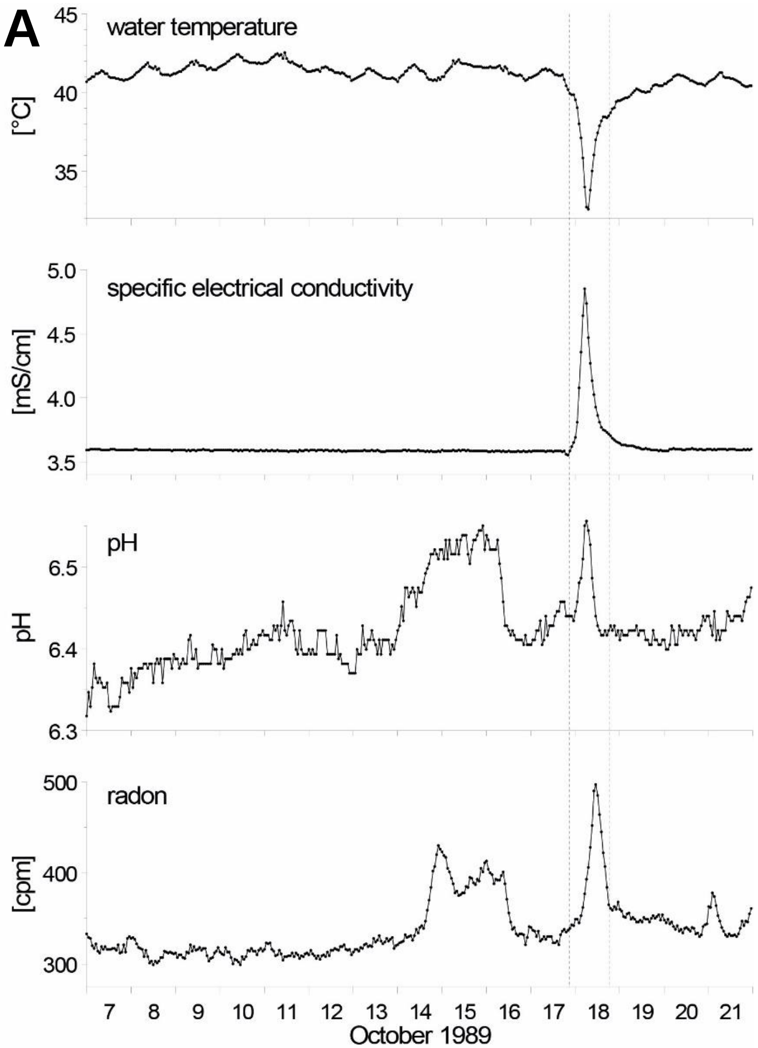
Motivation

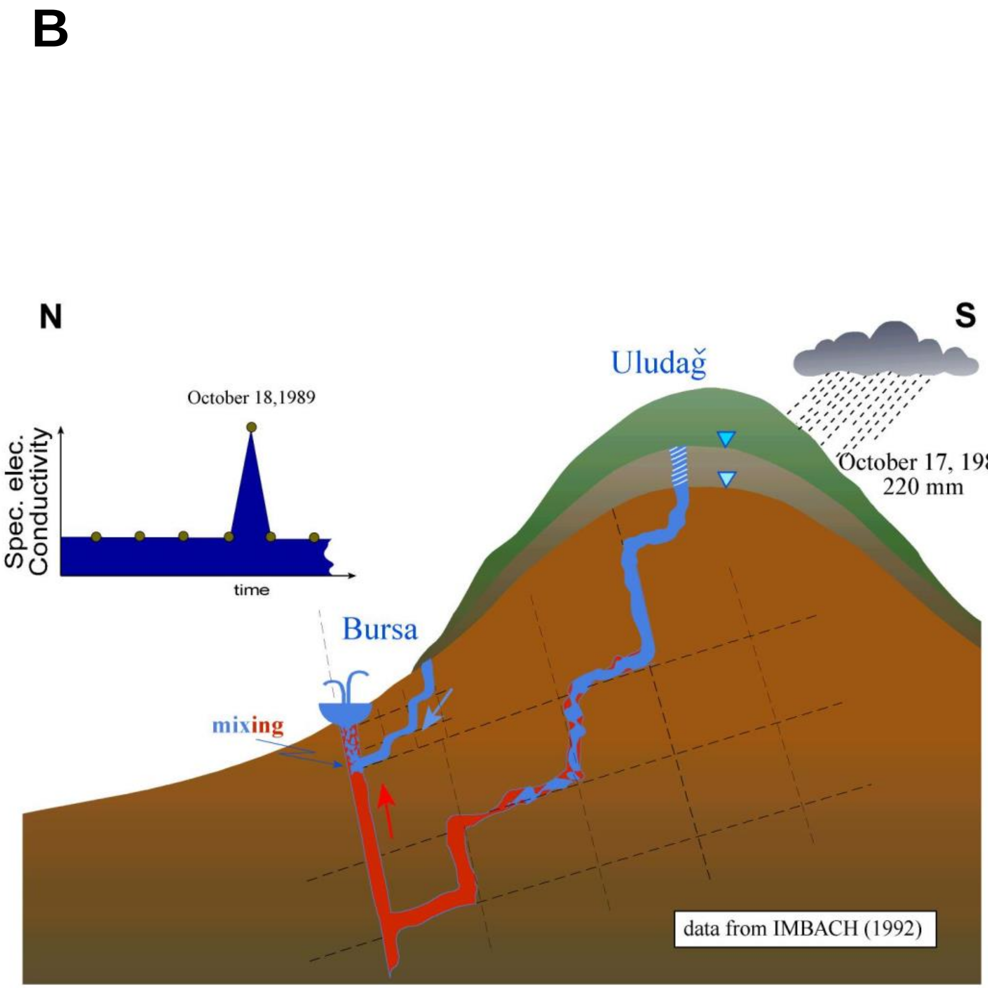


The number of earthquake precursors apparently is inversely correlated with the length of the published (!) timeseries – this might be an indication that some of the "precursors" are not related to the earthquake process. For an in-depth discussion see Woith (2015).

Updated dataset modified from:
Woith (2015) Eur. Phys. J. Spec. Top., 224, 611-627, 10.1140/epjst/e2015-02395-9

Motivation



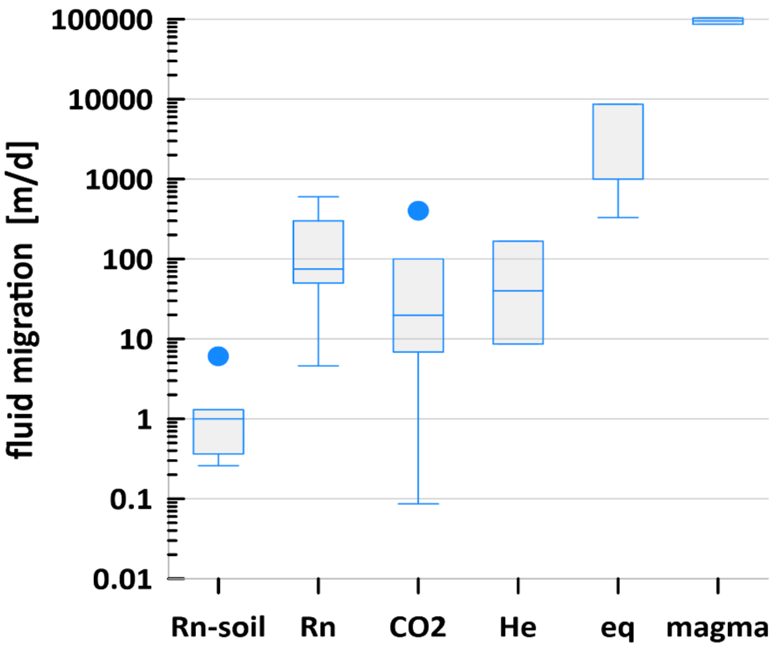


(A) Anomaly of physico-chemical parameters at Kuzuluk hot spring, NW Turkey (Woith, 1996); (B) Cross section of the Mt. Uludağ south of Bursa, about 130 km W of Kuzuluk, NW Turkey, modified from Imbach (1992). Both anomalies are likely rain-induced, but look strikingly similar to many published "seismo-tectonic" ones.

Motivation

<u>Objectives:</u>

1. How fast move fluids through the crust?
2. What causes short-term gas flow transients?
3. Are degassing sites connected?

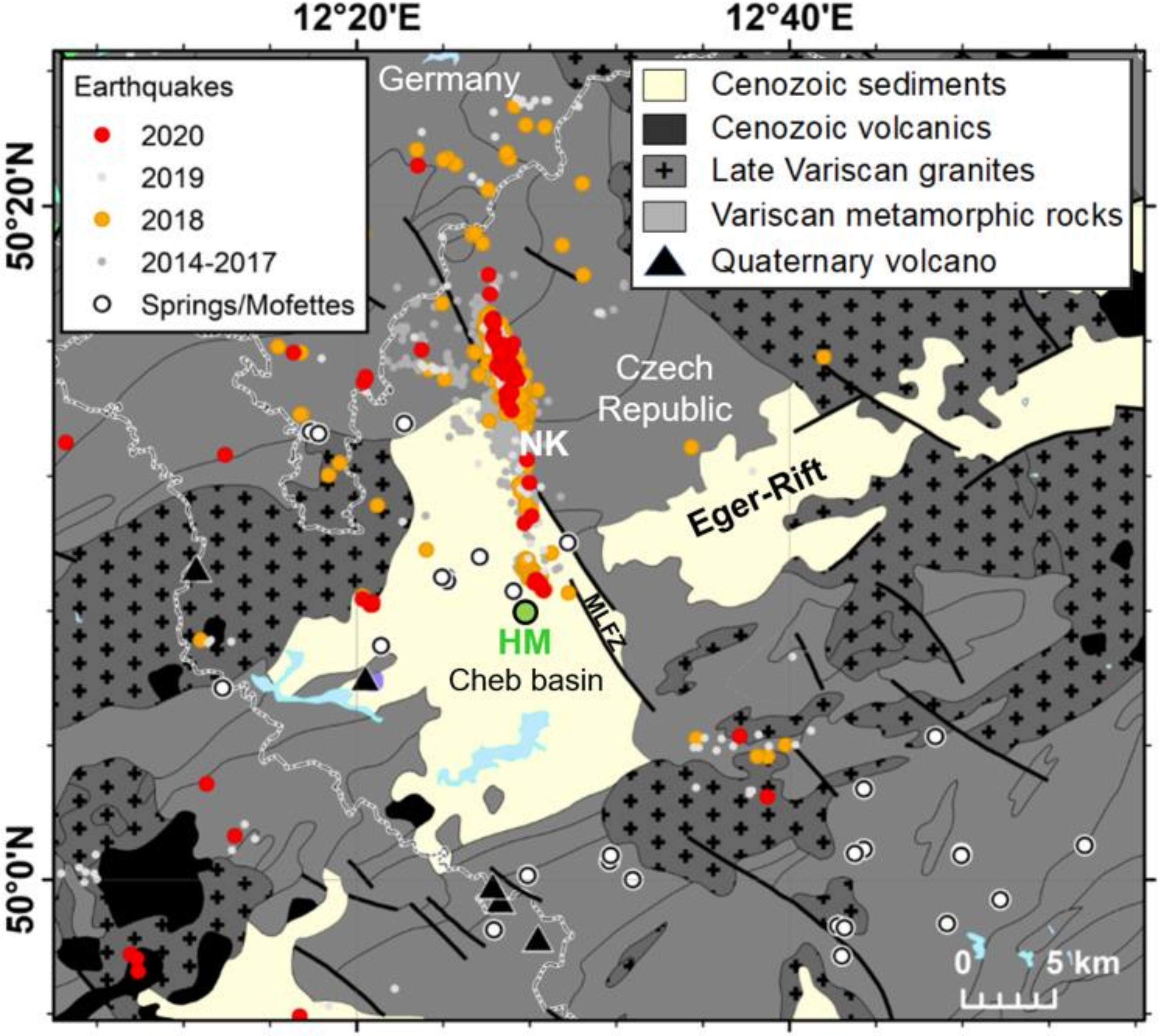


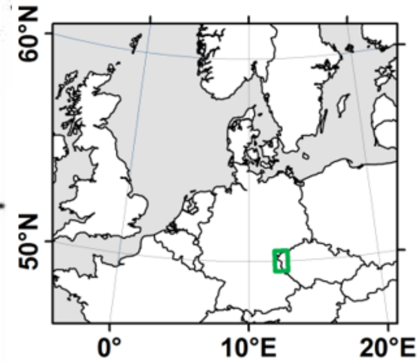
<u>Strategy:</u>

- continuous fluid monitoring at different depths
- repeated sampling on different faults

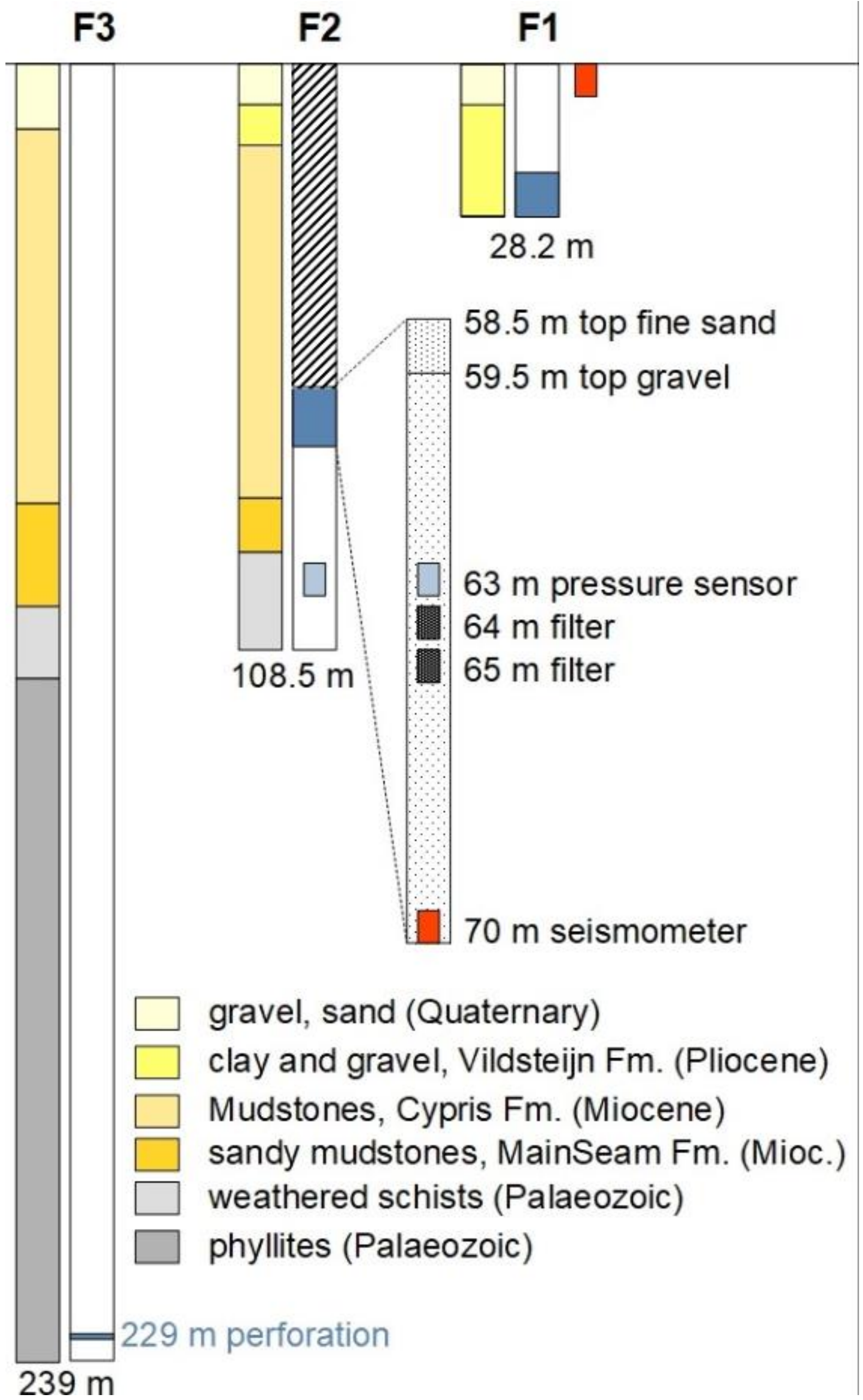
This work is a part of MoRe - “Mofette Research” – project which was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - 419880416

Keysite: Hartoušov mofette (HM)





multi-level monitoring set-up

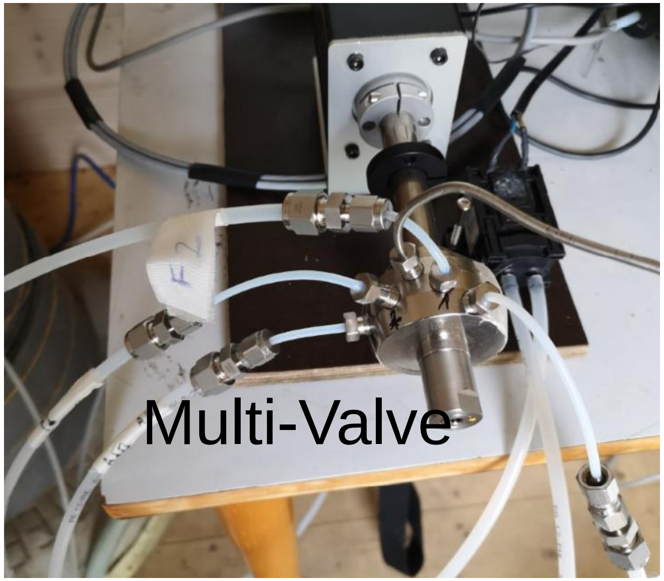


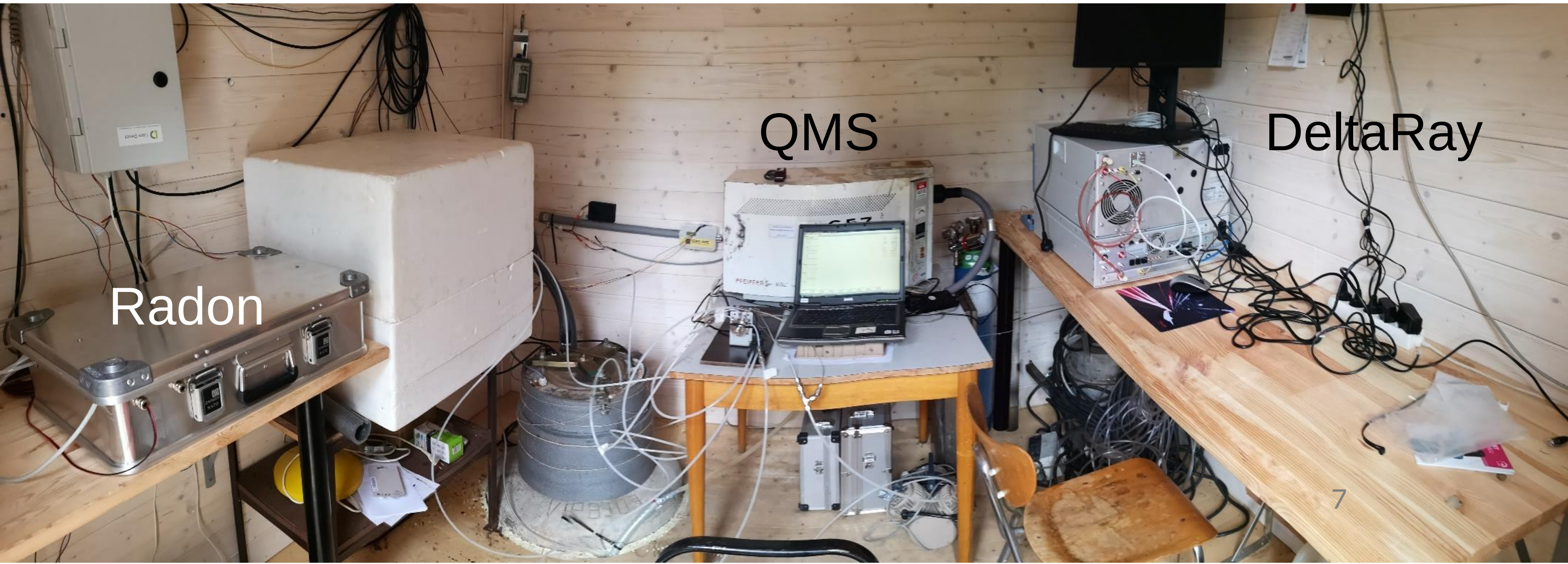
F1
- gas monitoring
- weather station (Vaisala WXT536)
- broadband seismometer (Trillium Compact 120")
- gas flow, water temperature and water level at 3 different depth levels + gas pressure in wellhead

see Fischer et al. (2020) Solid Earth, 11:983

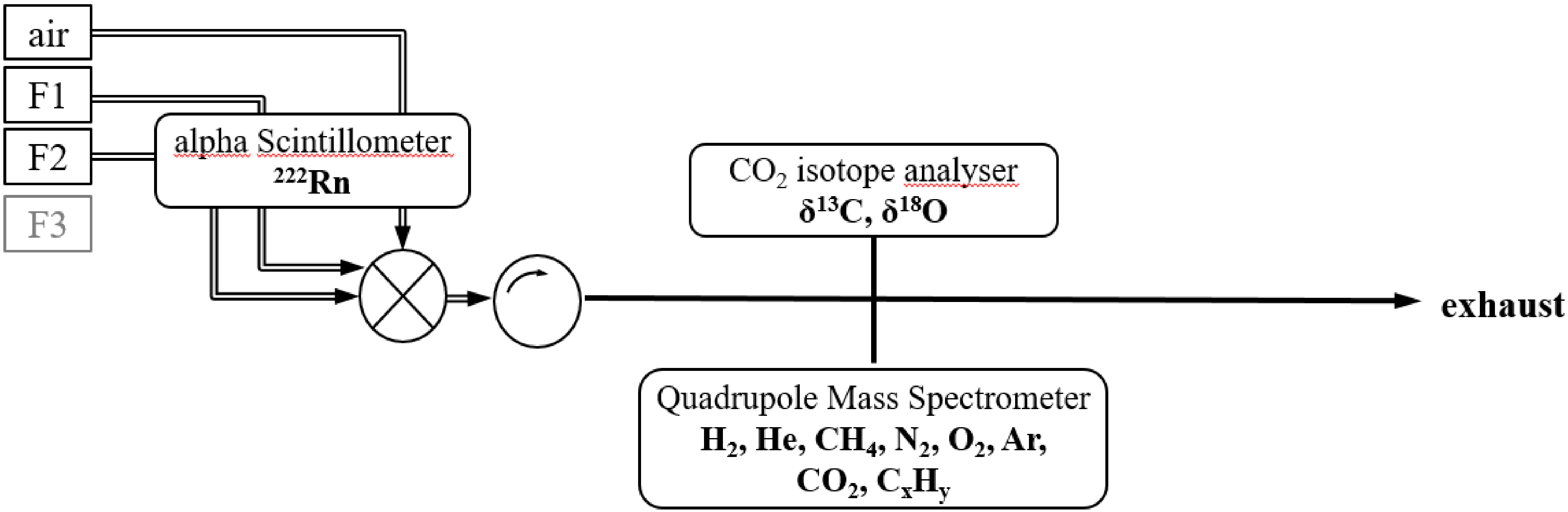
F2
- fluid pressure at 92 m and 63 m
- borehole seismometer (ASIR SiA) at 70 m

Gas monitoring equipment



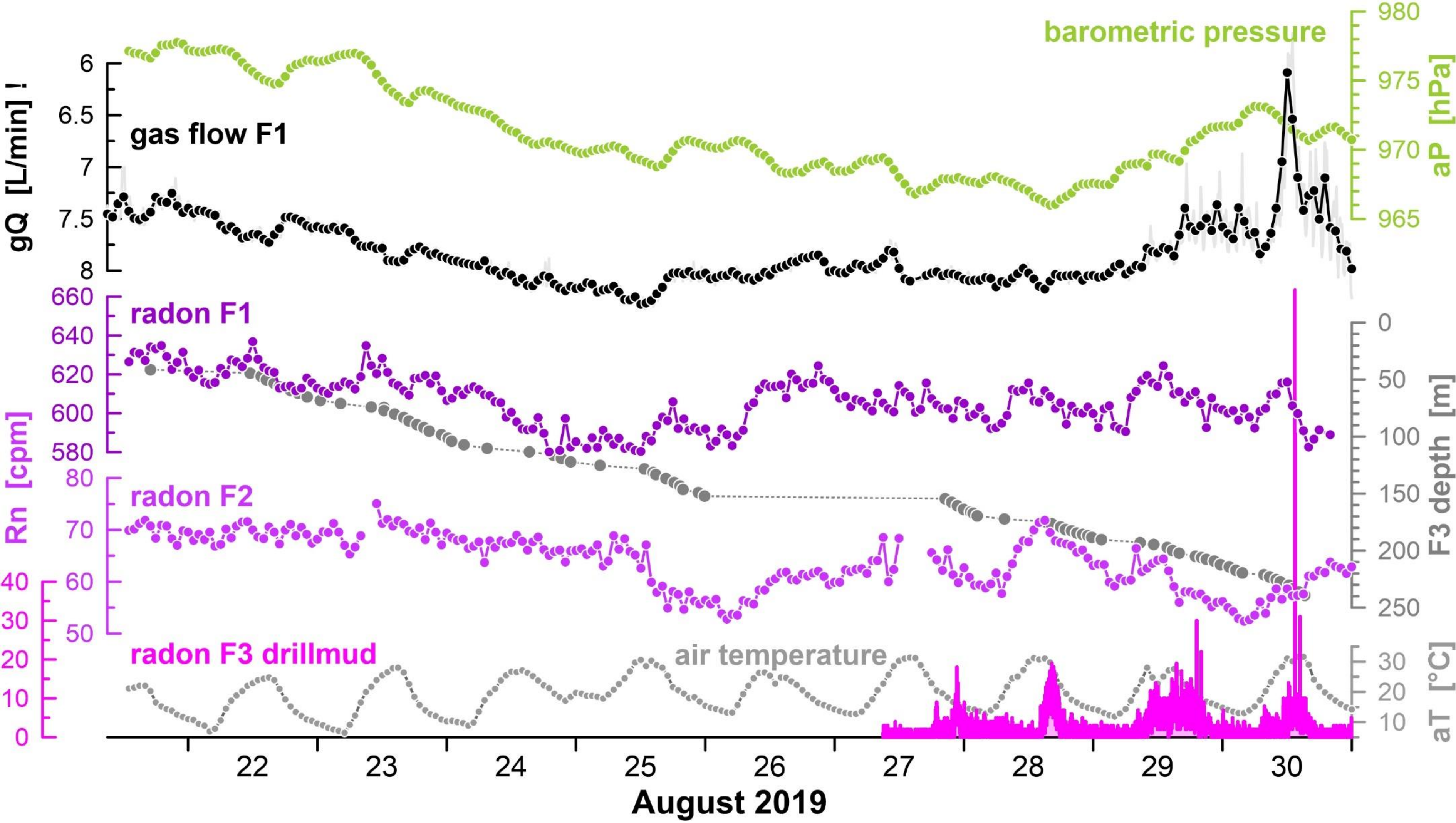


Gas monitoring equipment



F3 drilling 239.3 m

Fluid monitoring while drilling F3

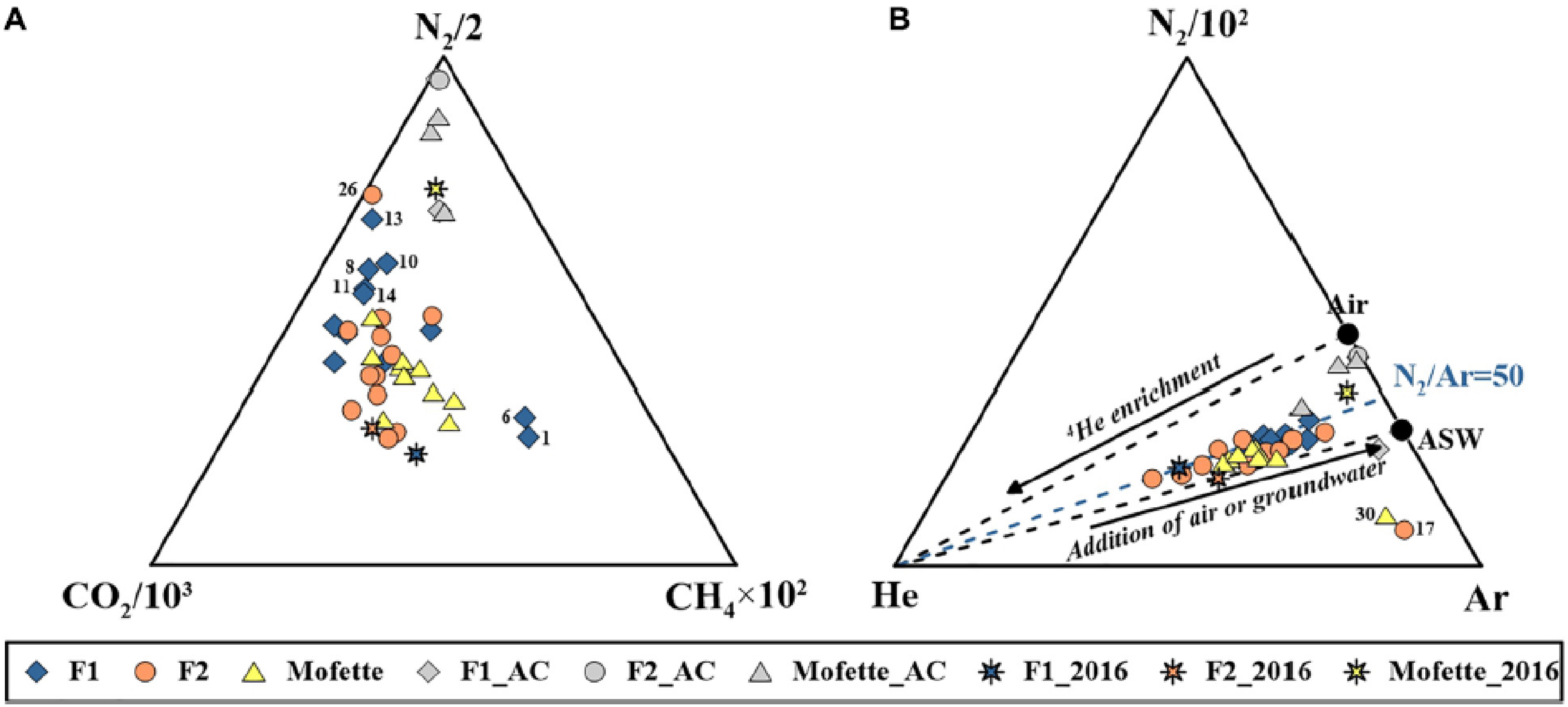


from: Woith *et al.* (2020) Front. Earth Sci. 8:585733. doi: 10.3389/feart.2020.585733

Fluid transients while drilling F3

- an excess of **Ar** for so far unknown reasons in two samples collected when the drilling of F3 arrived at 2 m and 41 m depth, respectively.
- perturbations at F1 on the **bubble fraction and the gas flow** when F3 was at a depth of ~38 m.
- fluid **pressure** transients in F2 lasting 2 days when F3 drill depth was between 110 and 125 m, i.e. when the first significant degassing of the cores was observed.
- the **highest CH_4** value (22.9 µmol/mol) during the drilling phase was observed in F1 when F3 drill depth was ~125 m.
- at a drill depth of ~230 m, a significant **decrease in the gas flow** occurred at F1 while the **radon** concentration in the drillmud showed its maximum. This coincided with a **conductivity increase** and a **decreased redox** potential at the natural mofette located about 90 m SSE of the drillsite, both indicating the admixture of a mineralized deep fluid component to the low-conductivity shallow water typically present at the Hartoušov mofette.
- **H_2** was always below detection limit, apart from one sample (0.27 µmol/mol) collected from F2 when the drilling reached its final depth.
- **higher He** (31.8 µmol/mol) concentrations were found in F2 samples at the end and after the F3 drilling, indicating CO_2 loss.
- the **lowest CH_4** value (0.5 µmol/mol) was found at F2 in the sample collected after the perforation of the F3 steel casing in January 2020.

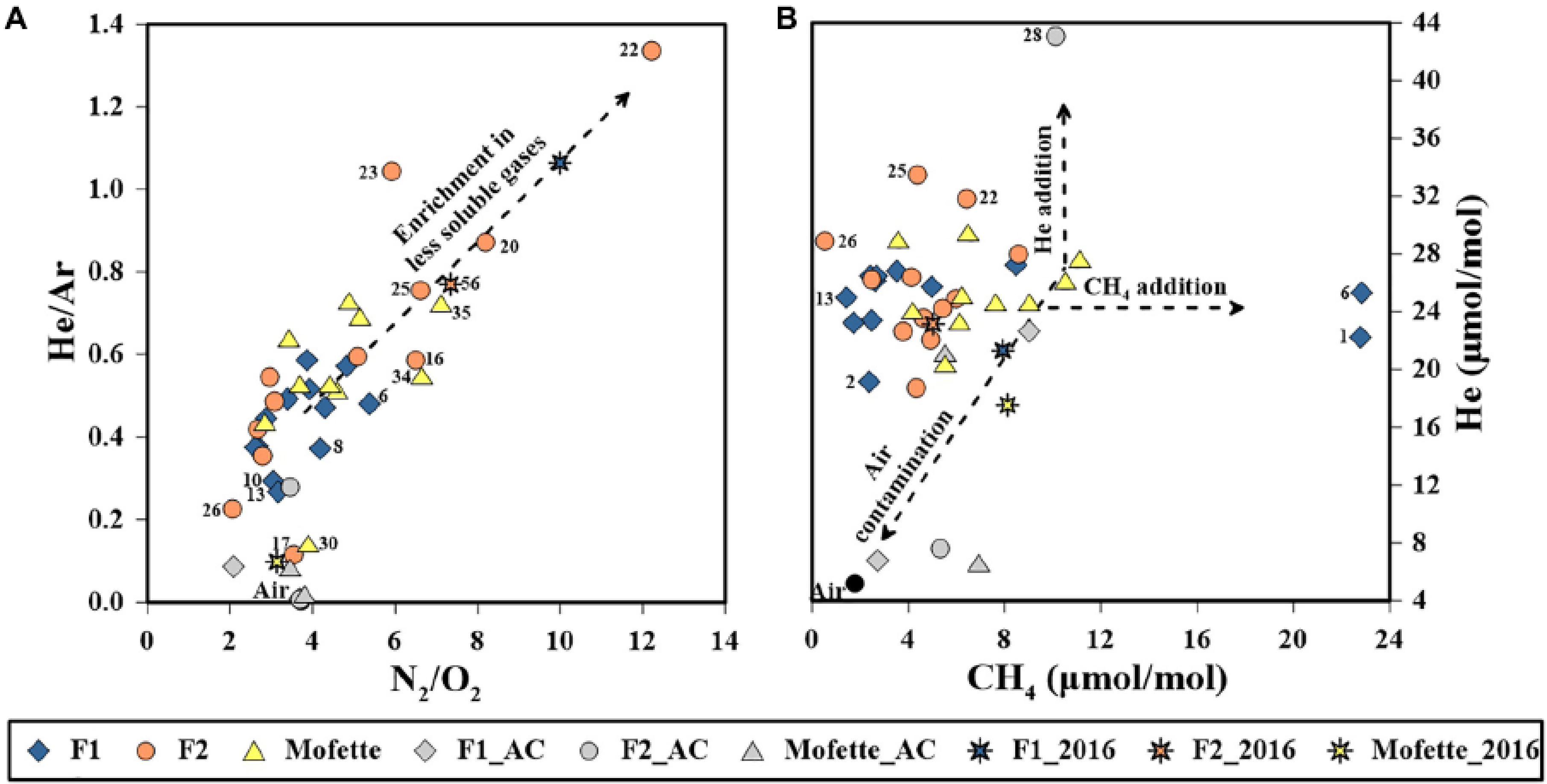
Hartoušov gas composition



(A) N_2-CO_2-CH_4 ternary diagram after Giggenbach et al. (1993) and **(B)** N_2-He-Ar ternary diagram after Giggenbach et al. (1983) of the gas emitted in the HMF. The abbreviation _AC stands for air contamination, while data of samples collected during 2016 are from Bräuer et al. (2018).

from:
Daskalopoulou et al. (2021) Front. Earth Sci. 9:615766. doi: 10.3389/feart.2021.615766

Hartoušov gas composition



Binary plots of (**A**) He/Ar vs. N_2/O_2 and (**B**) He vs. CH_4. Secondary processes are indicated with dashed arrows. The abbreviation _AC stands for air contamination, while data of samples collected during 2016 are from Bräuer et al. (2018).

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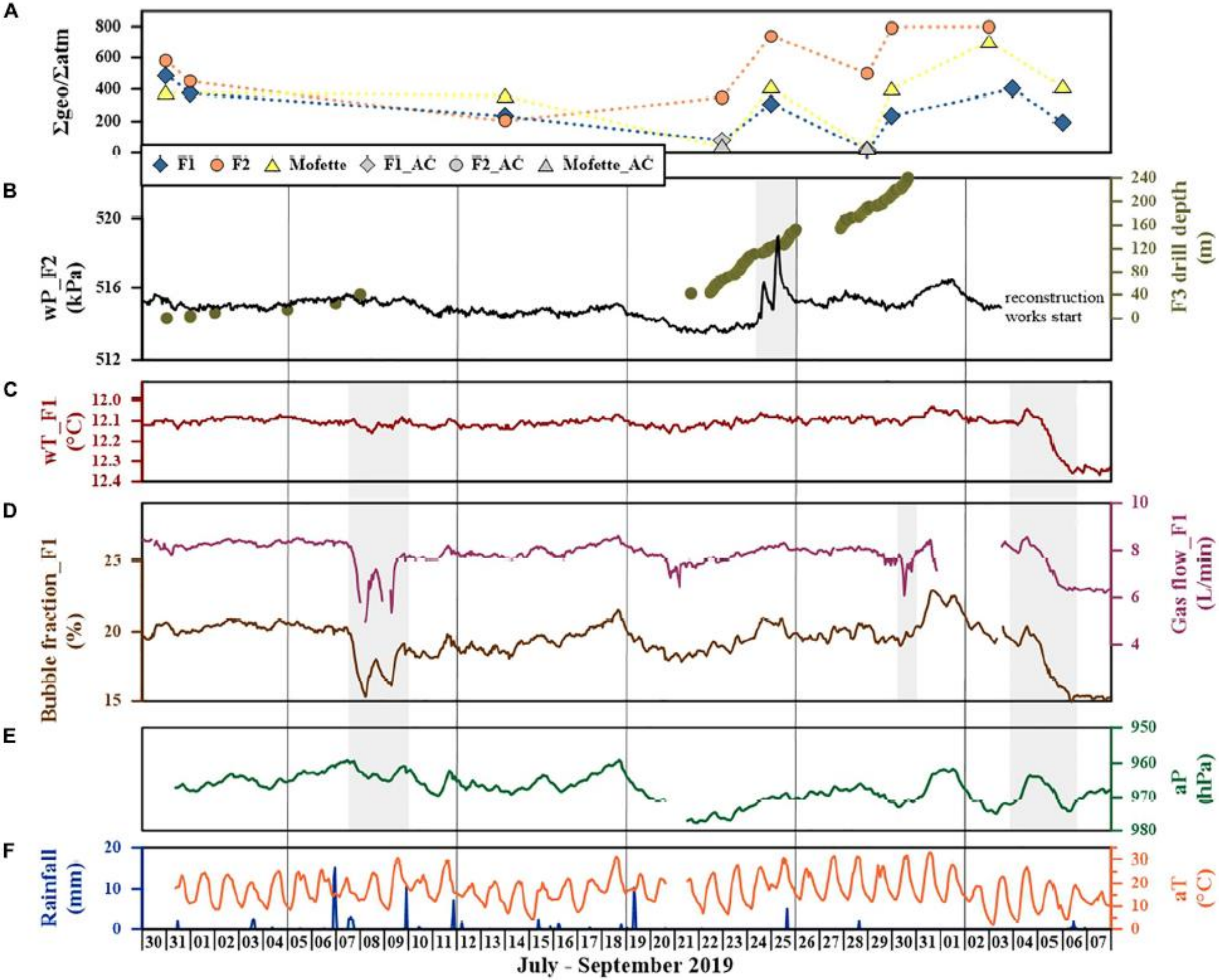
Hartoušov gas composition timeseries



Time series plot for the period 30 July-7 September 2019 showing (**A**) Σgeo/ Σ atm ratio in the two boreholes and the mofette, where Σgeo = CO_2+He+H_2+C_xH_y and Σatm = N_2+O_2+Ar, (**B**) the wellhead pressure (wP) of F2 and the drilling depth of F3 (Woith et al., 2020), (**C**) the water temperature (wT) in F1, (**D**) the calculated bubble fraction and the measured gas flow in F1, (**E**) the barometric pressure (aP) and (**F**) the meteorological conditions represented by the precipitation and the air temperature (aT). The axes of water temperature and barometric pressure are inverted. The vertical gray lines indicate the beginning of a new week, while the gray areas correspond to anomalies discussed in the text. Data of the gas flow and the temperature monitoring at Hartoušov are available at web.natur.cuni.cz/uhigug/carbonnet/en_index.html.

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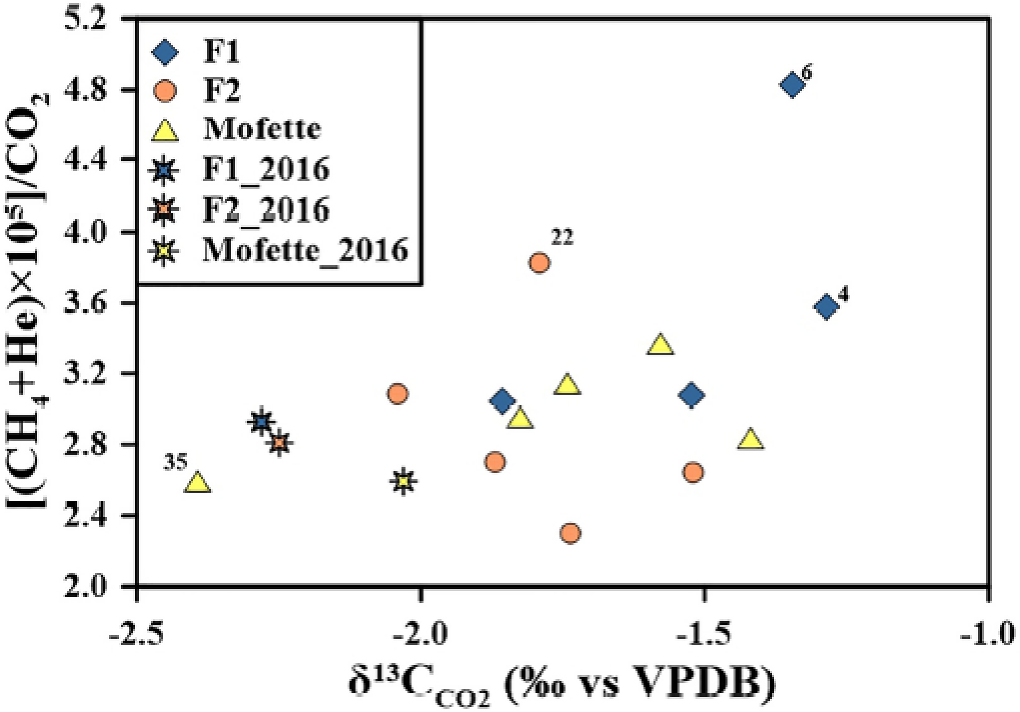
Hartoušov gas composition vs. $\delta^{13}C$



Binary plot of $(He+CH_4)/CO_2$ vs. $d^{13}C_{CO2}$ for the gases of Hartoušov. Data of samples collected during 2016 are from Bräuer et al. (2018).

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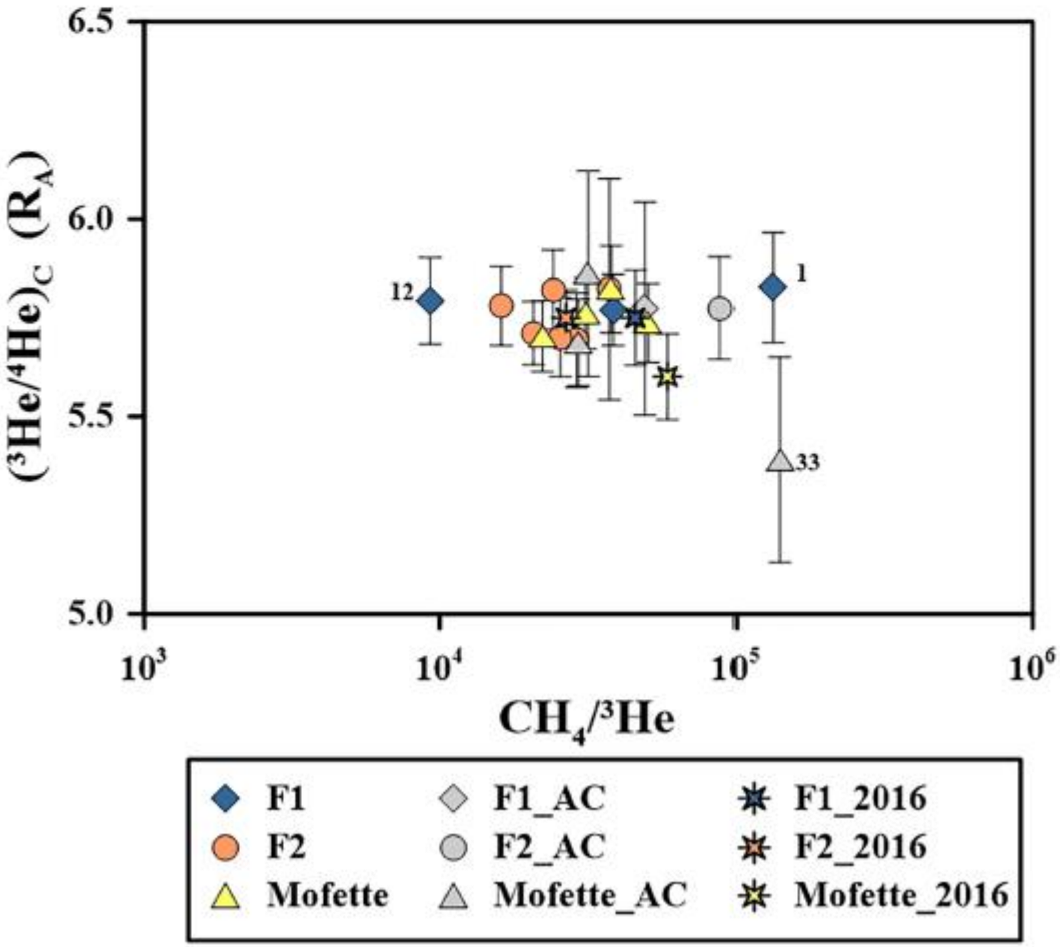
Daskalopoulou et al. (2021) Front. Earth Sci. 9:615766. doi: 10.3389/feart.2021.615766

Hartoušov Helium R_A vs. $CH_4/^3He$



Air-corrected $(^3He/^4He)c$ vs. $CH_4/^3He$ diagram (cf. Poreda et al., 1988). The abbreviation _AC stands for air contamination, while data of samples collected during 2016 are from Bräuer et al. (2018).

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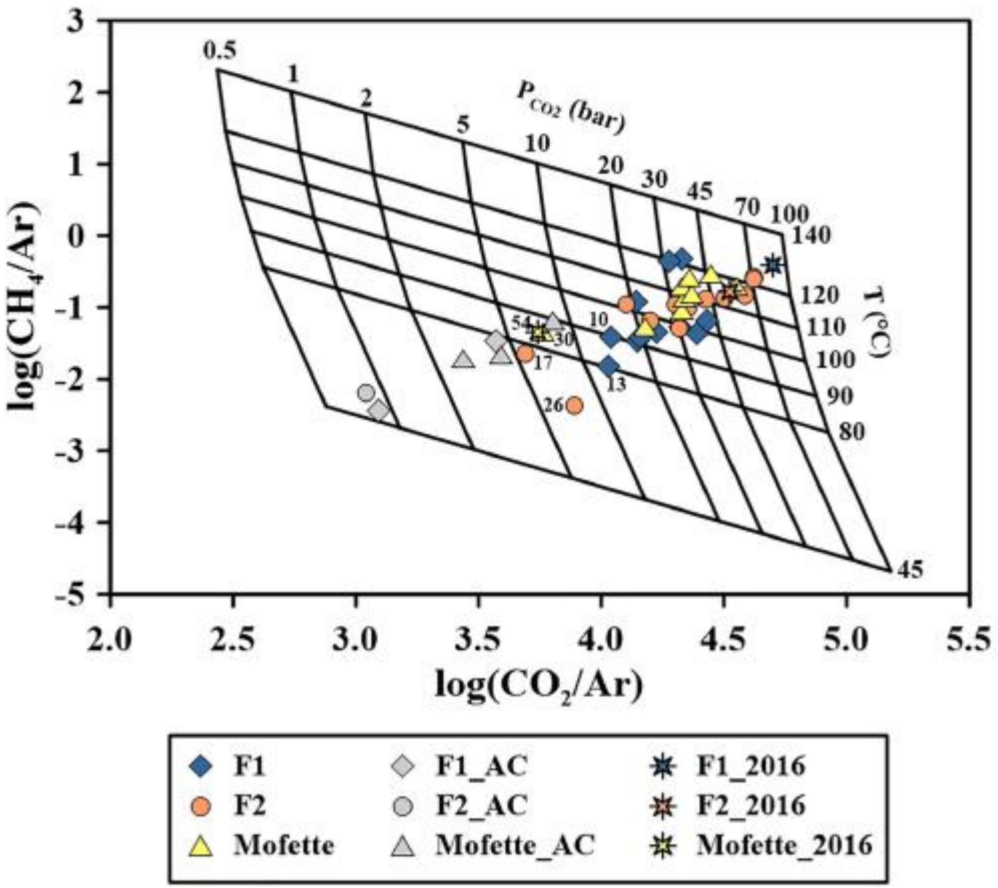
Hartoušov CH_4/Ar vs. CO_2/Ar



Plot of log(CH_4/Ar) vs. log(CO_2/Ar) after Chiodini et al. (2007). The theoretical P_{CO2}-T grids assume that the redox conditions are fixed by the D'Amore and Panichi (1980) buffer. The abbreviation _AC stands for air contamination, while data of samples collected during 2016 are from Bräuer et al. (2018).

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Děkuji pěkně!
tack så mycket!
Thank you!
Vielen Dank!