Surface-atmosphere interaction: how it may influence in-situ analyses on Venus surface

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Consequences for Venera-D

A few questions

- ✓ Are remote measurements representative of bulk composition ?
- ✓ What surface composition is expected ?
- ✓ How is the scientific payload sensitive to surface modification
- ✓ What is expected as a function of elevation and age ?

Ground observations

granite ?

γ-spectrometry (Venera 8-10)

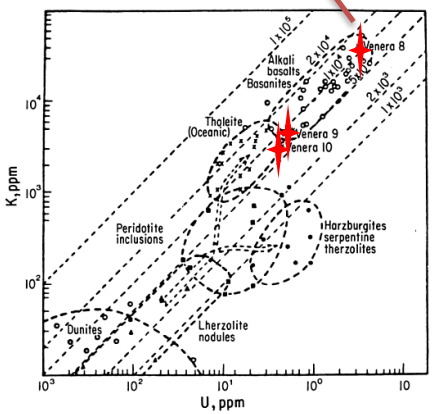
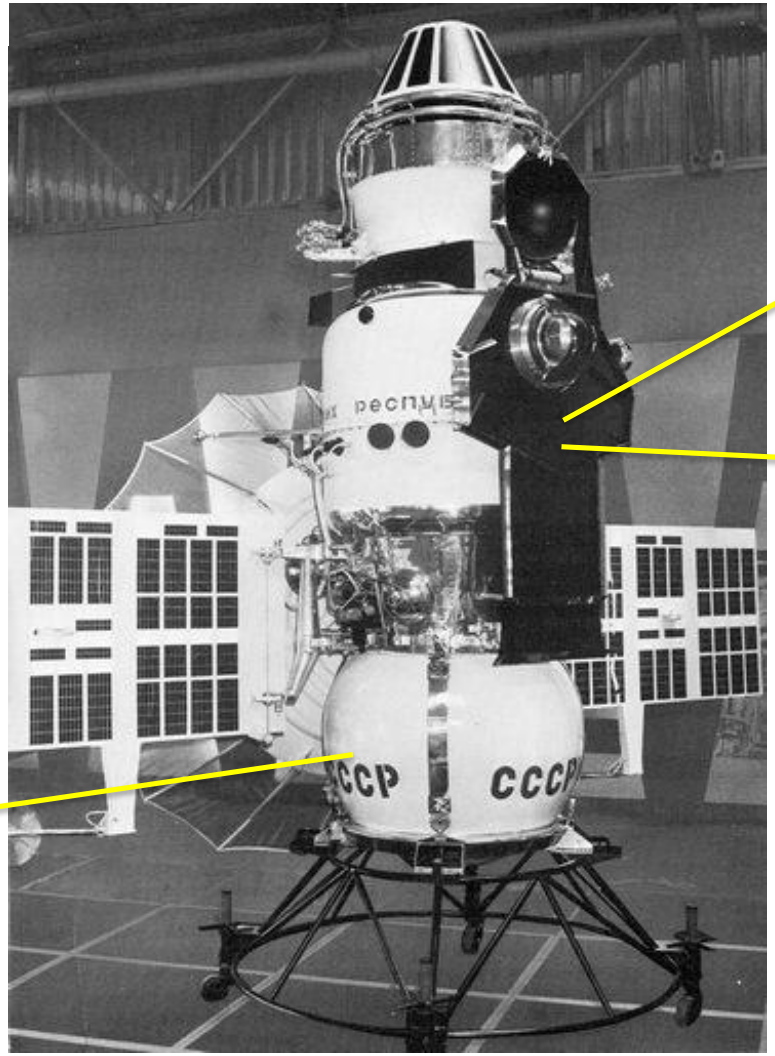
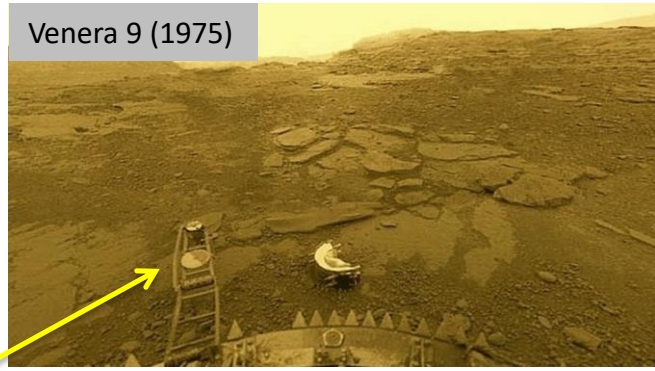
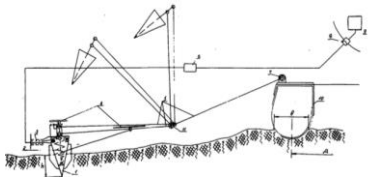


Fig. 2. K/U diagram for the content of potassium and uranium in the major types of Earth and Venus rock.



Venera 9 (1975)

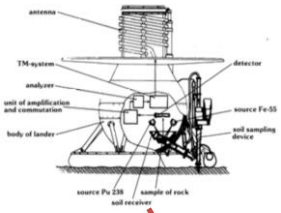




Dynamic penetrometer (physical properties, electric resistivity)

altered basalt ?

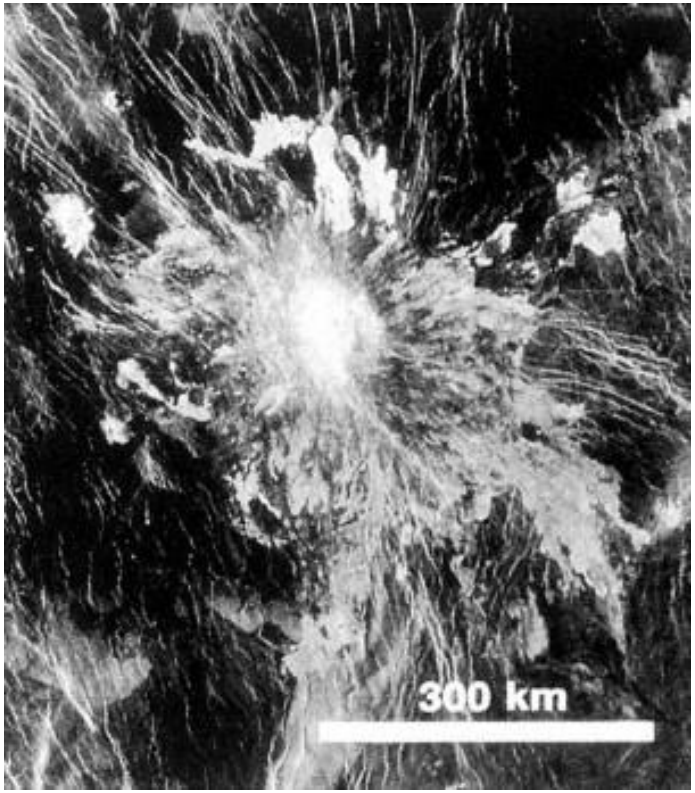
XR-fluorescence (Venera 13-14)



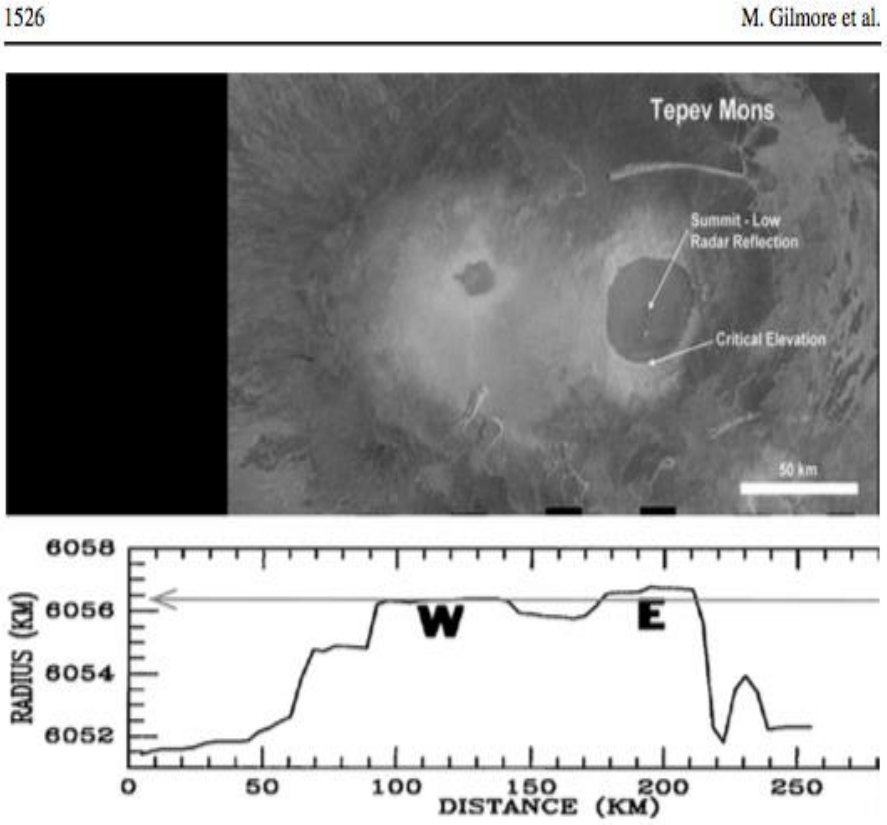
basalt

➢ **Little or not penetrative technics**

Radar reflectivity anomaly, another interesting feature



A variety of radar-bright lava flows radiate from the summit area down the flanks of a shield volcano on Venus. (NASA *Magellan* image.)

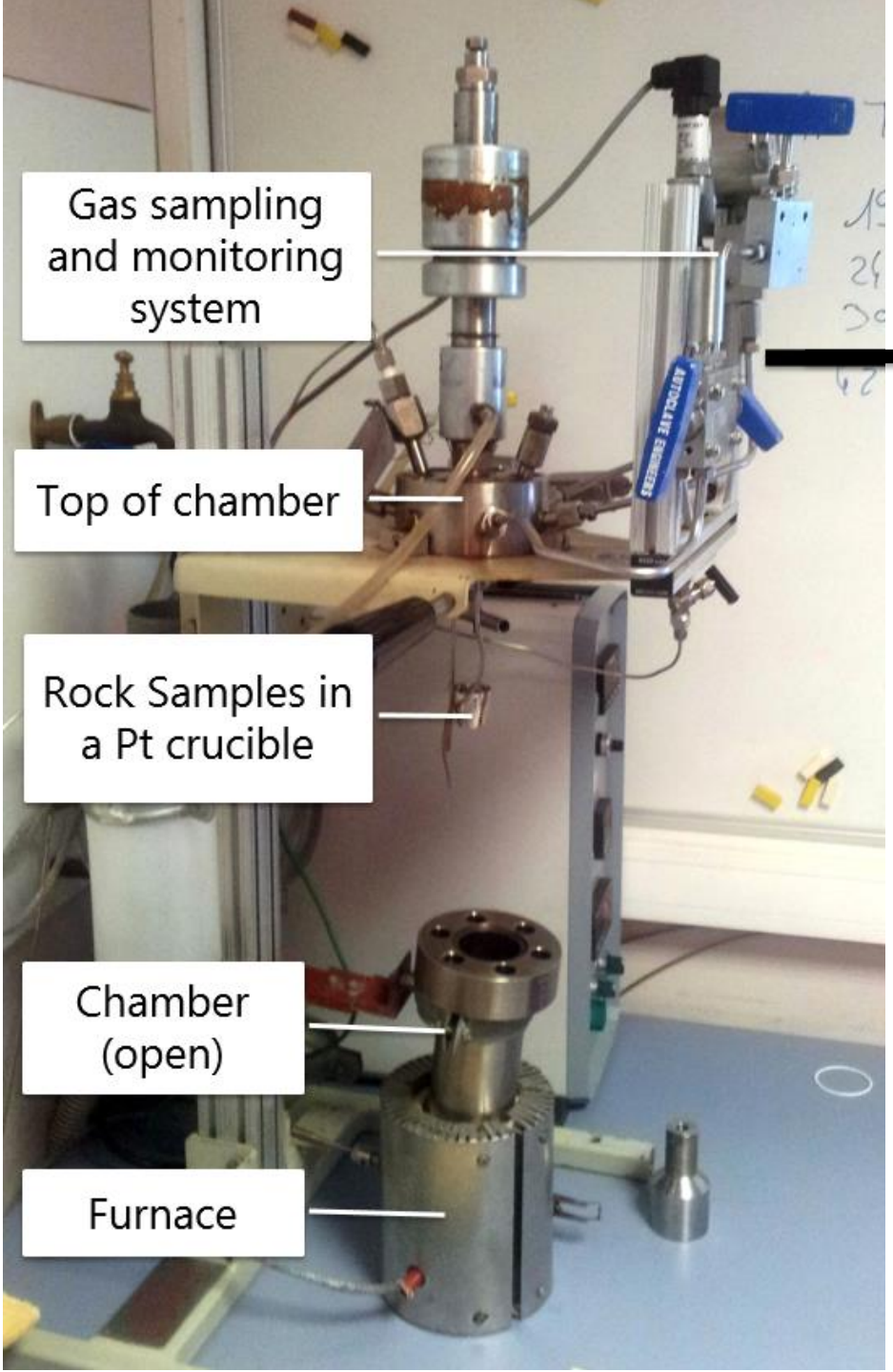


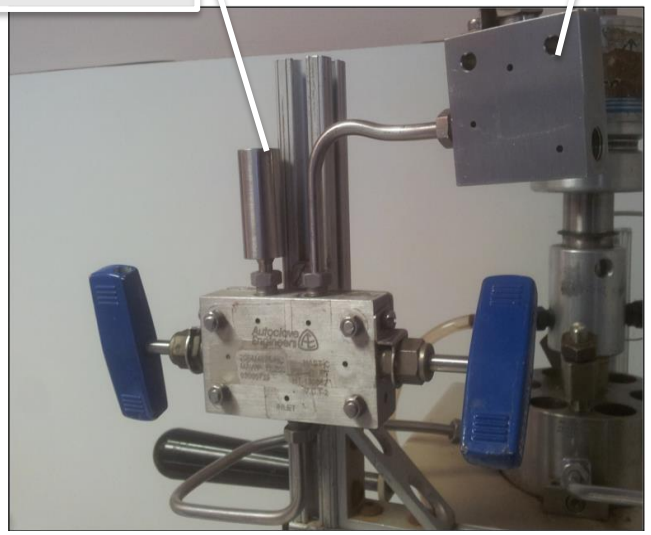
FeS_2 Bi_2Te_3 $(Ca,Na)PO_4$ PbS ?

To be checked:

- ✓ Iron coating on olivine with associated enstatite?
- ✓ Sulfide or sulfate versus temperature
- ✓ Persistence of inherited hydrous silicates (mica, amphibole)
- ✓ Nothing on elementary transfer into the gas phase

Experimental





Gas sampling and monitoring system

Pumice

Picritic basalt

Synthetic basalt glass

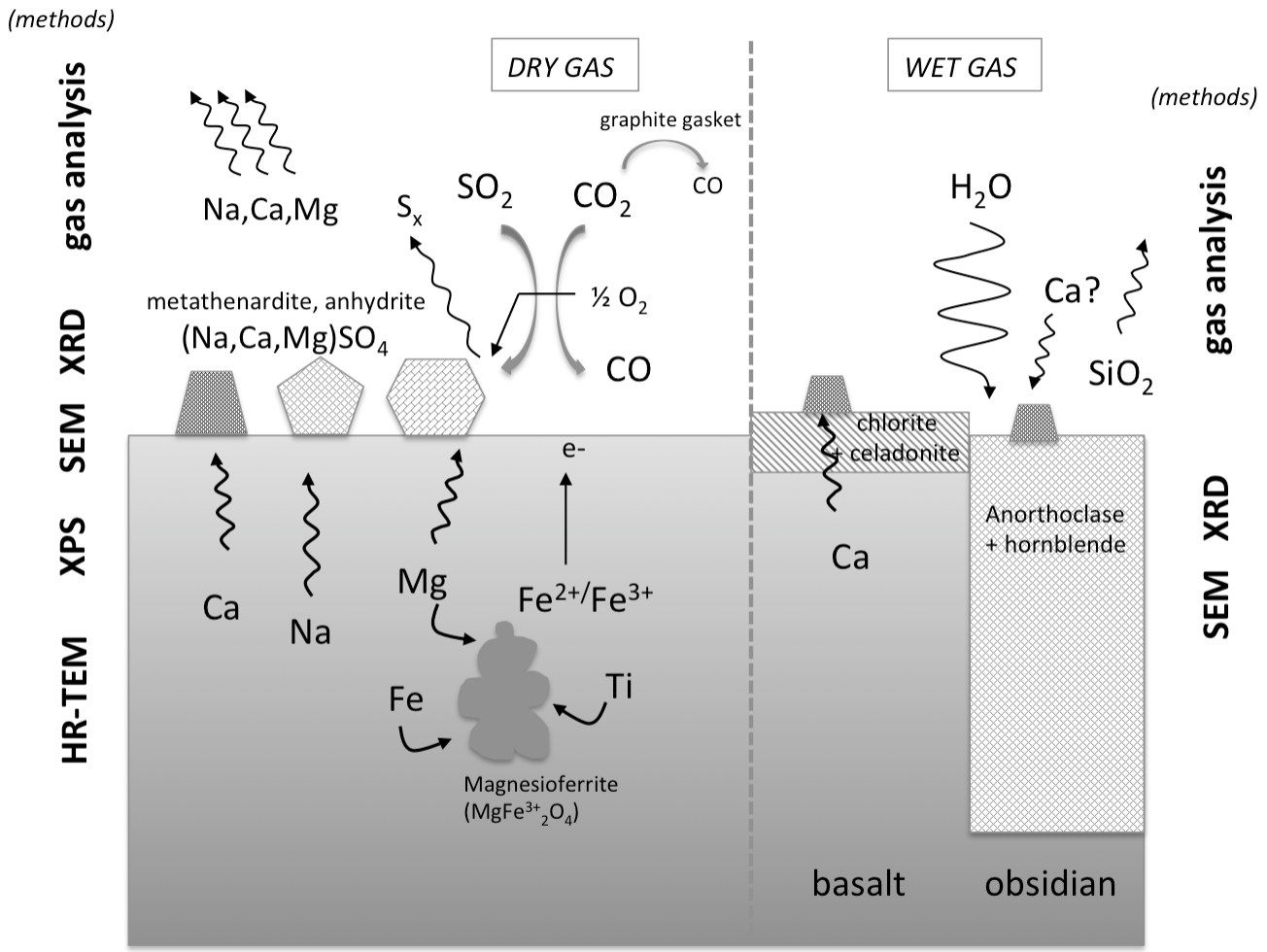
Obsidian

1 week

470°C

90 bar

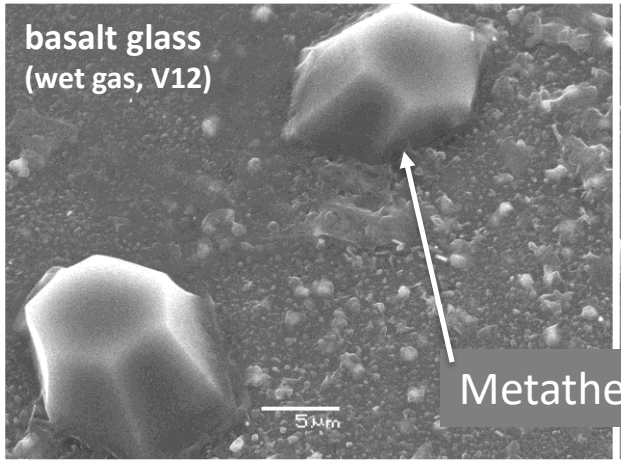
(up to 550 bars with water)

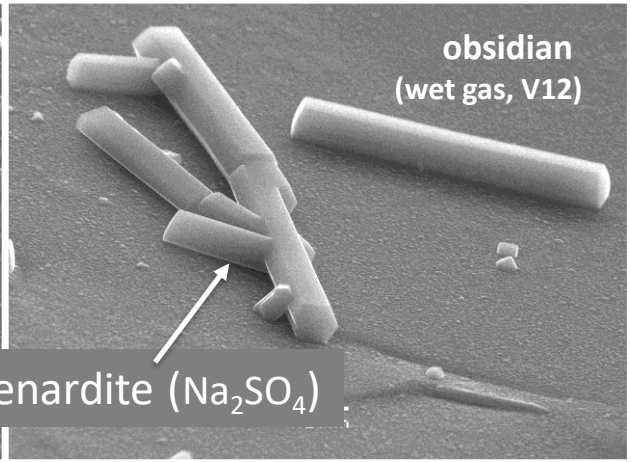


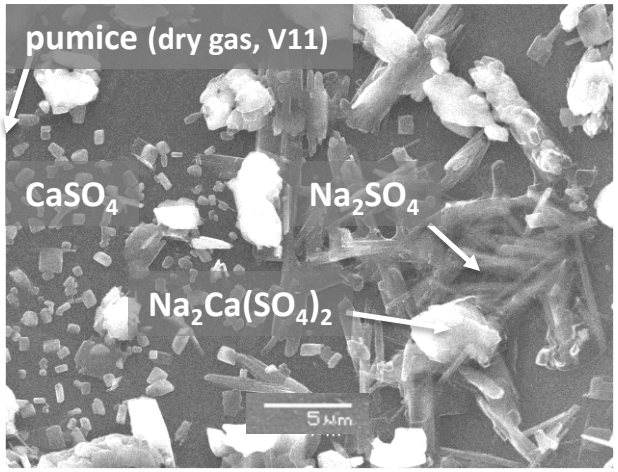
Berger et al., Icarus 2019

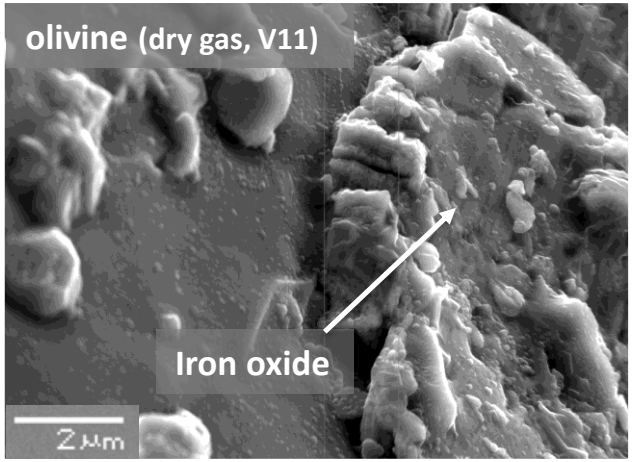
In dry gas

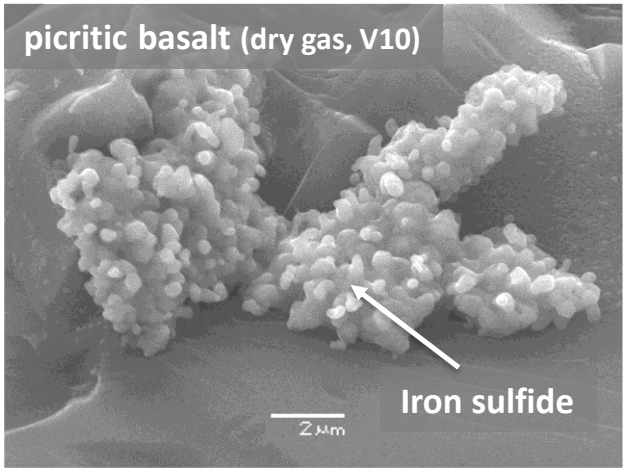
Scanning electron microscopy (SEM)







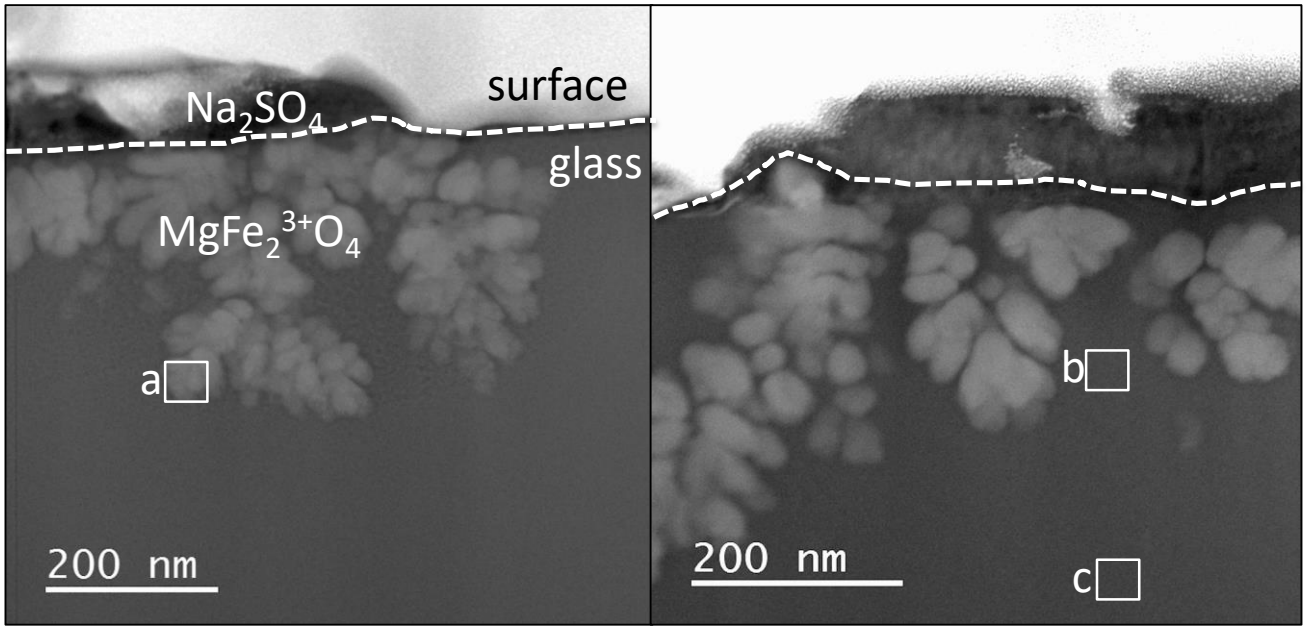


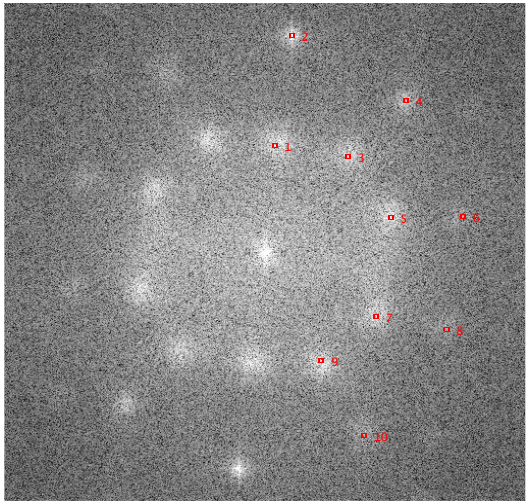


At lower T°C

About the glasses …

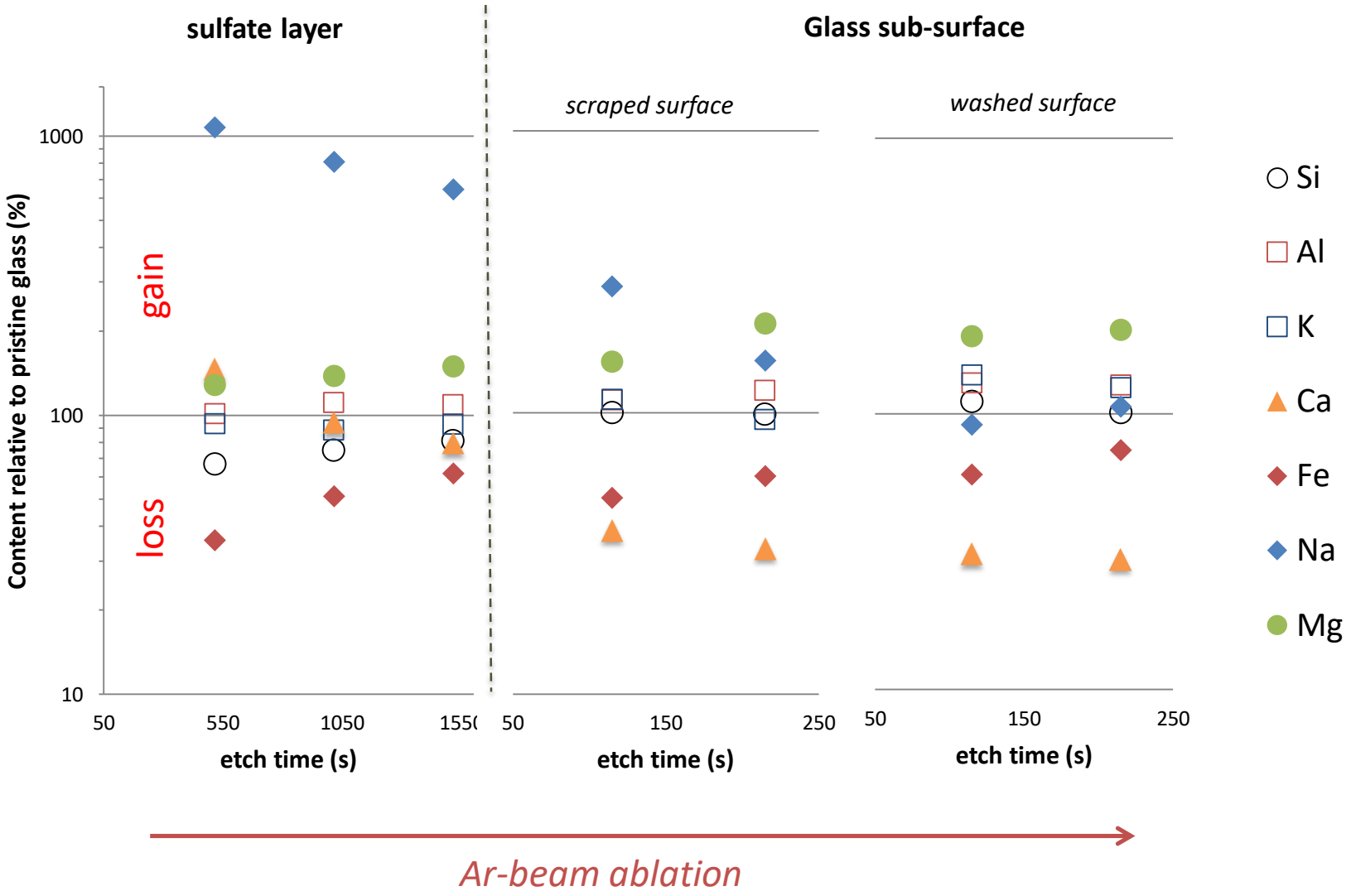
High resolution transmission electron spectroscopy (HR-TEM) on FIB preparations



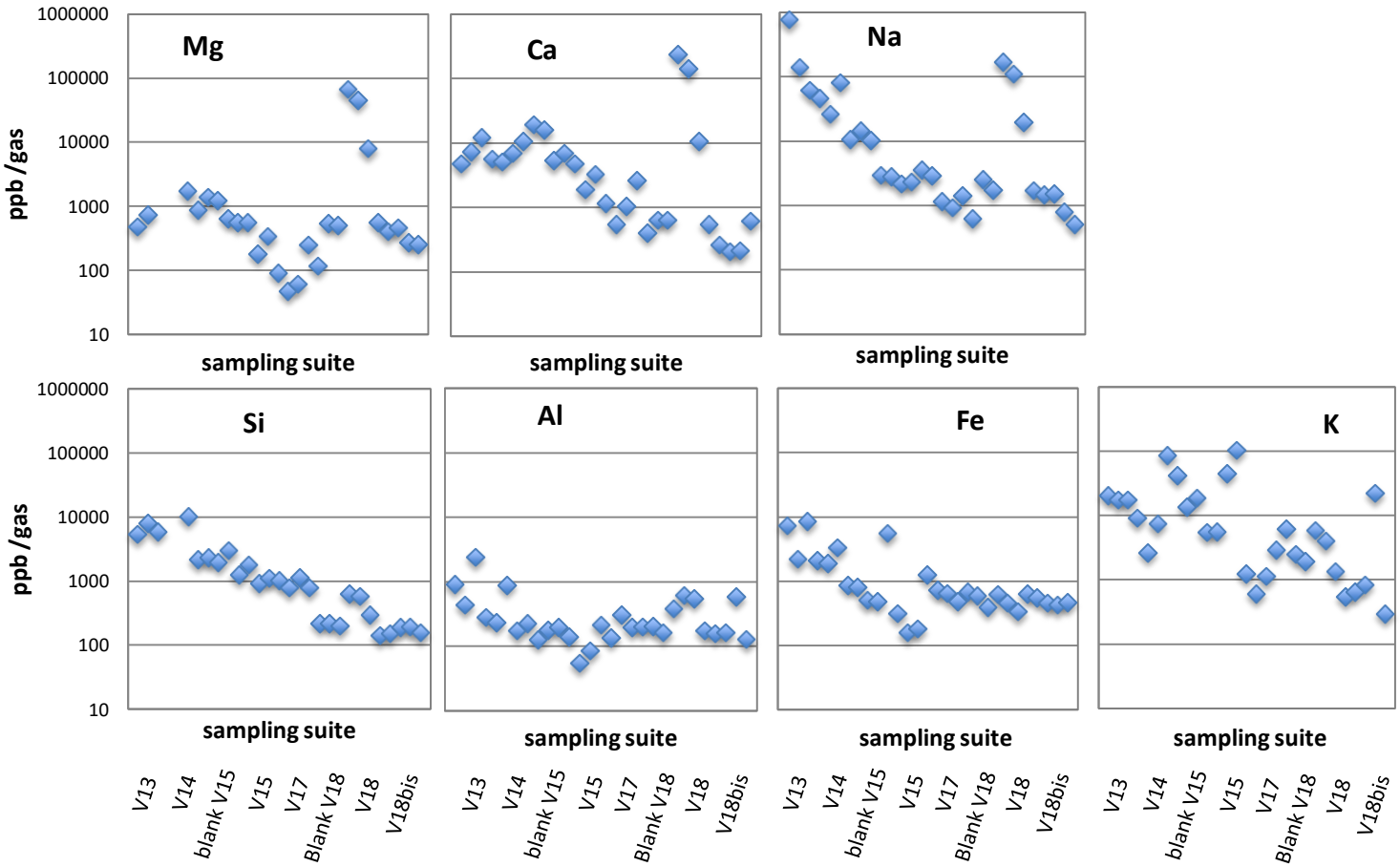


Spot#	d-Spacing (nm)	Rec. Pos. (1/nm)	Degrees to Spot 1	Degrees to x-axis
1	0.2970	3.367	0.00	85.10
2	0.1460	6.847	1.85	83.24
3	0.2554	3.915	34.64	50.46
4	0.1574	6.355	36.81	48.29
5	0.2549	3.924	69.07	16.03
6	0.1654	6.047	74.41	10.68
7	0.2557	3.910	116.44	-31.35
8	0.1677	5.963	109.08	-23.99
9	0.2626	3.809	148.64	-63.54
10	0.1542	6.484	147.72	-62.63

X-ray-photoelectron spectroscopy (XPS)



Gas analyses by ICM-MS after sampling in ammonia



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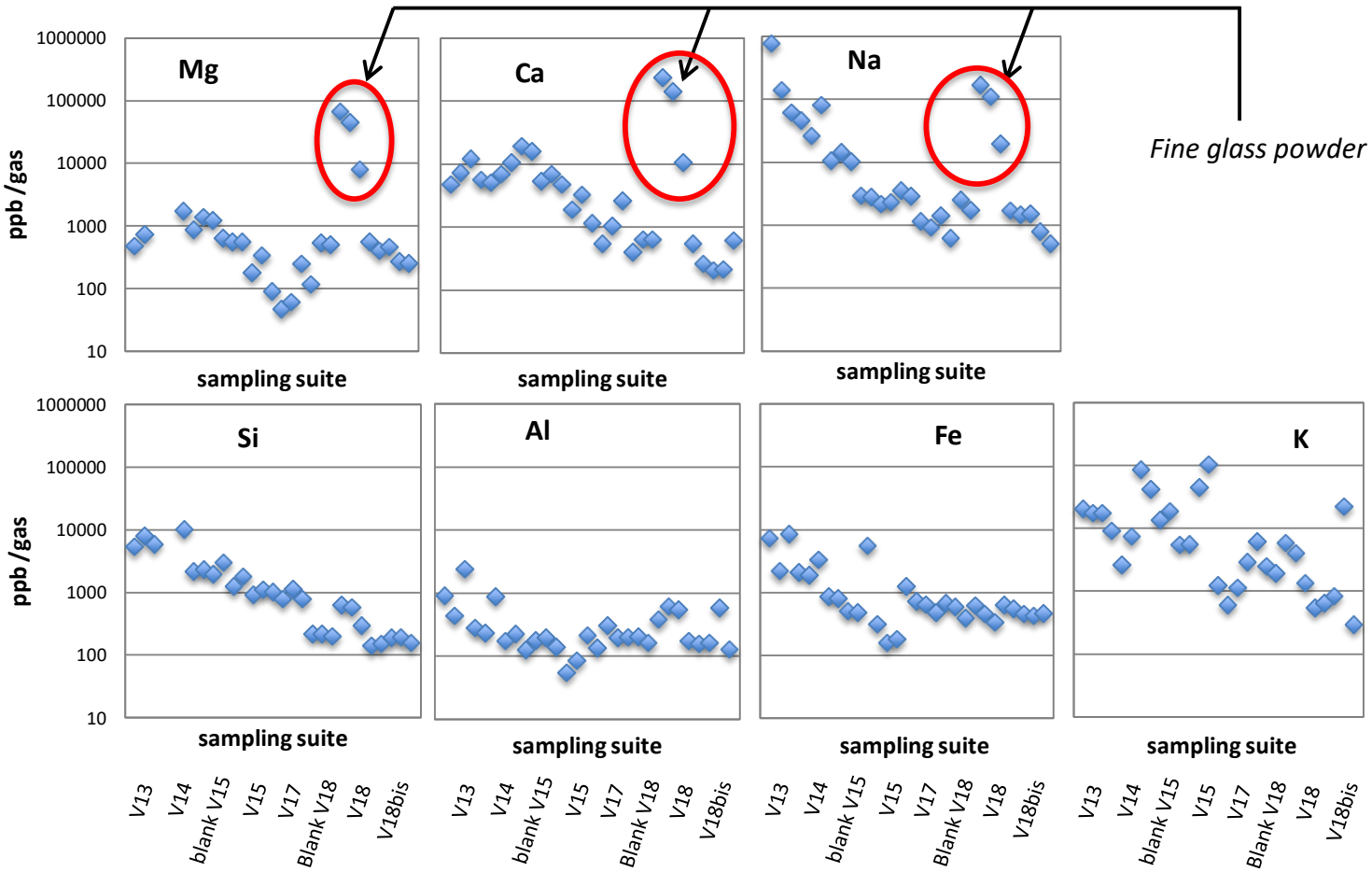
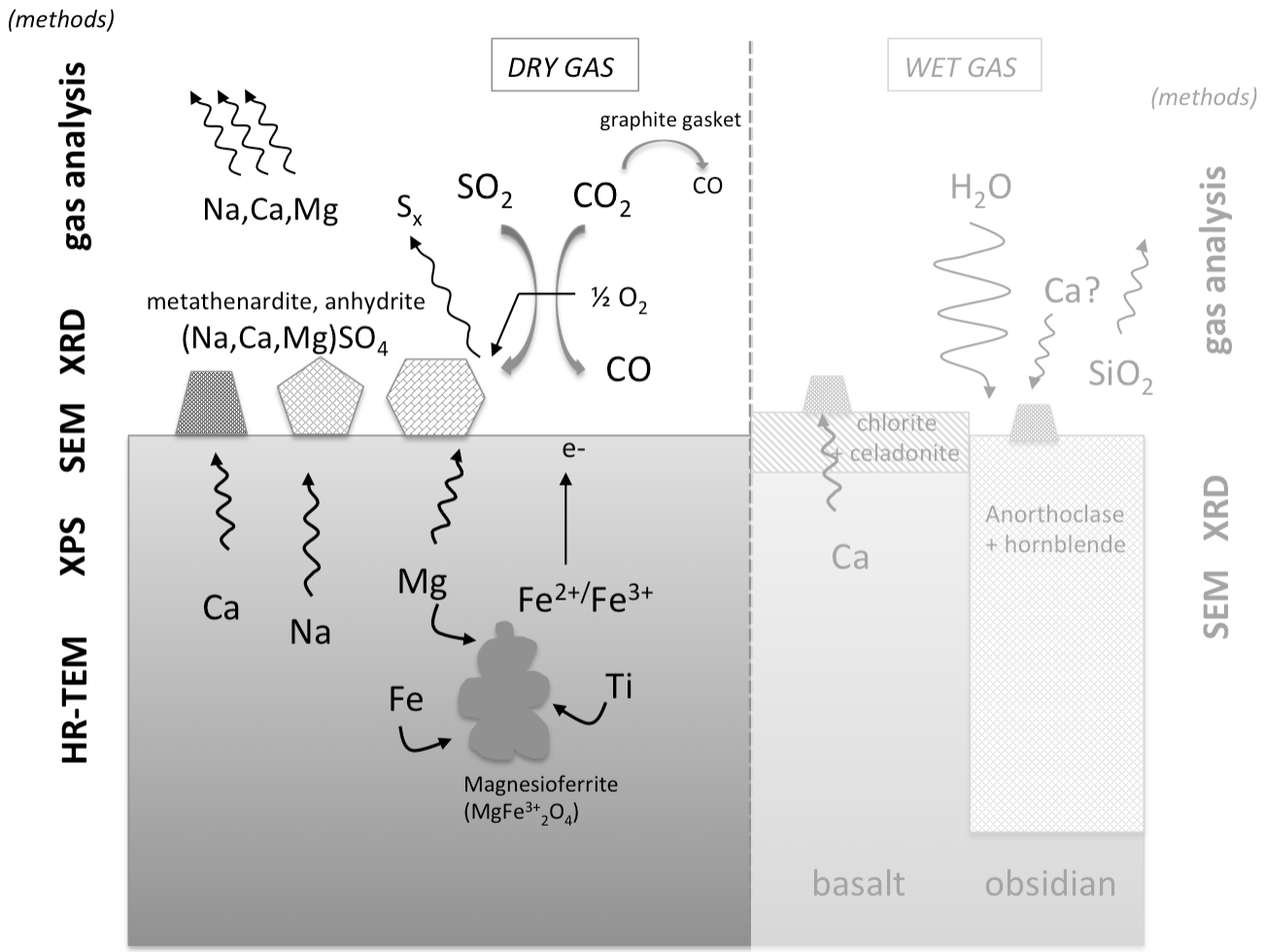


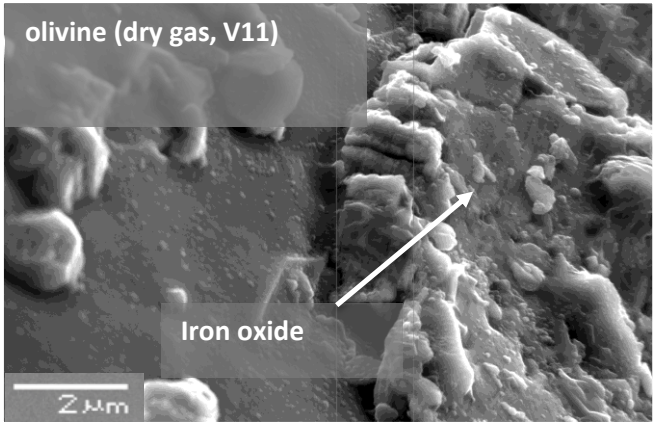


Berger et al., Icarus 2019

about olivine …

Small crystals in basalt: iron coating

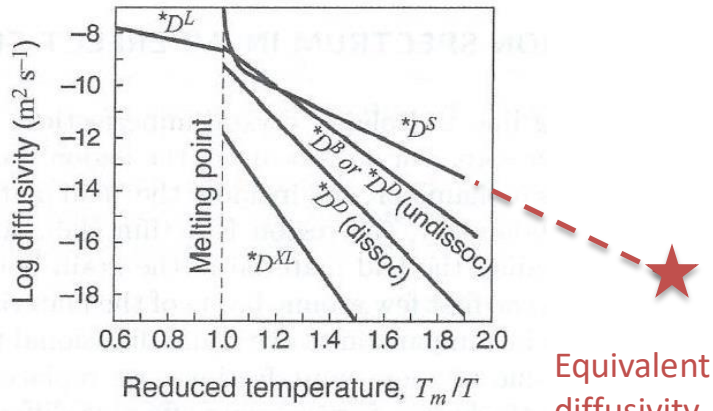
Isolated San Carlos crystal: nothing



Fe comes from neighbor minerals, likely magnetite, by **surface** diffusion

Table 9.1: Notation for Short-Circuit Diffusivities

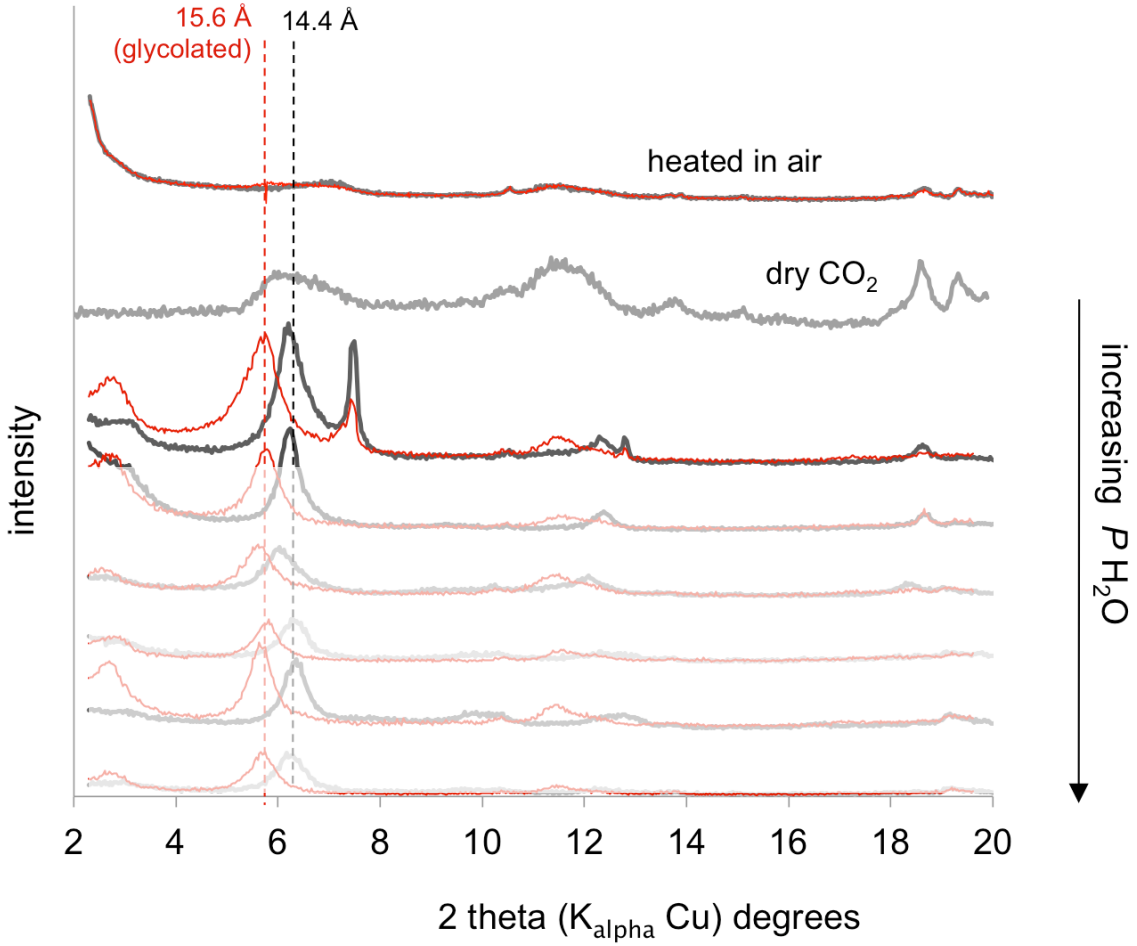
D^D(undissoc)	diffusivity along an undissociated dislocation core (i.e., a cylinder, or a "pipe" of diameter, δ)
D^D(dissoc)	diffusivity along a dissociated dislocation core (i.e., a cylinder, or a "pipe" of diameter, δ)
D^B	diffusivity along a grain boundary (i.e., a slab of thickness, δ)
D^S	diffusivity along a free surface (i.e., a slab of thickness, δ)
D^{XL}	diffusivity in a bulk crystal free of line or planar imperfections
D^L	diffusivity in a liquid



Equivalent to the diffusivity in a bulk crystal at 1100°C

(Balluffi et al., 2005)

Behavior of inherited clays under present-day conditions



Conclusion on the present-day surface alteration

~~To be~~ has been checked:

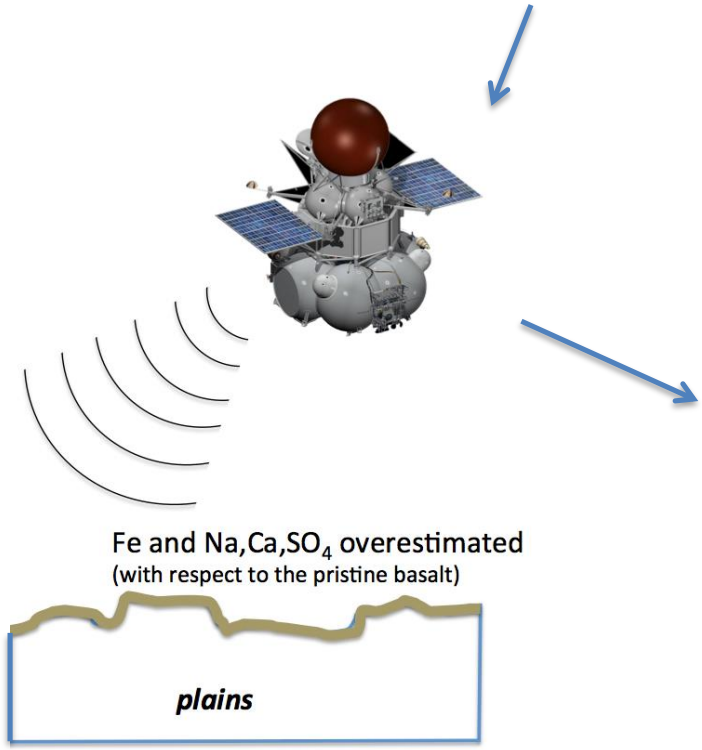
yes no

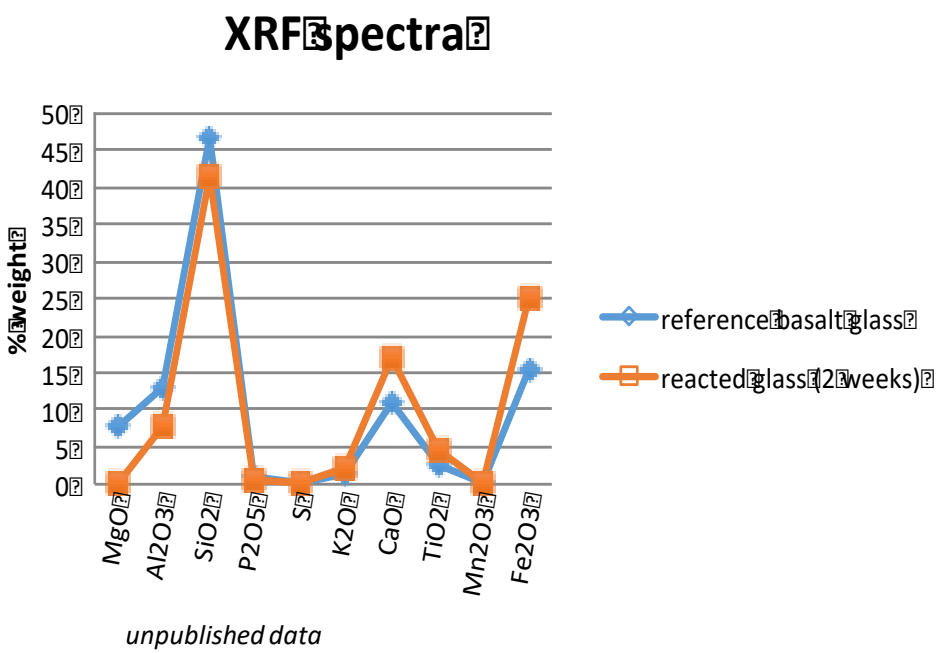
- ✓ Iron coating on olivine with associated enstatite?
- ✓ Sulfide or sulfate versus temperature yes
- ✓ Persistence of inherited hydrous silicates (mica, amphibole) Possibly yes
- ✓ Nothing on elementary transfer into the gas phase Na, Ca, Mg

Key lesson

- ✓ Even in the dry modern atmosphere, some rock constituents (olivine and glass) are chemically modified in the first µm of the surface
- ✓ Deposition of iron oxide and sulfate coating

What measure remote sensing ?





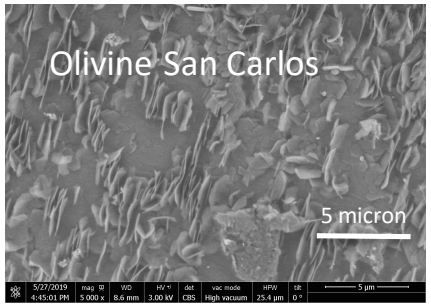
unpublished data

H_2O

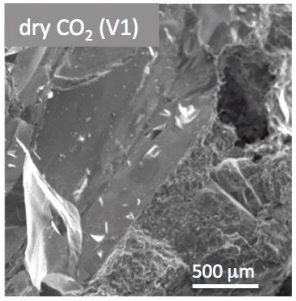
Effect of water

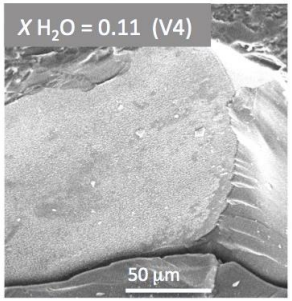
(early Venus or wet volcanic degassing)

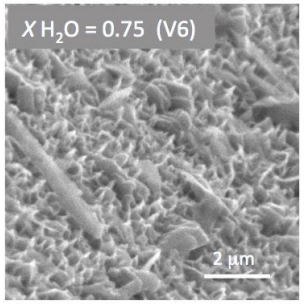
In wet gas



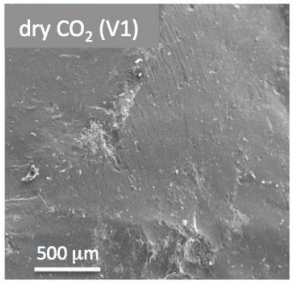
Isolated olivine crystal

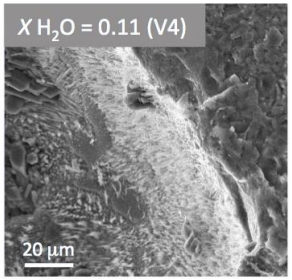


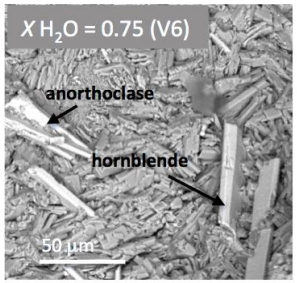




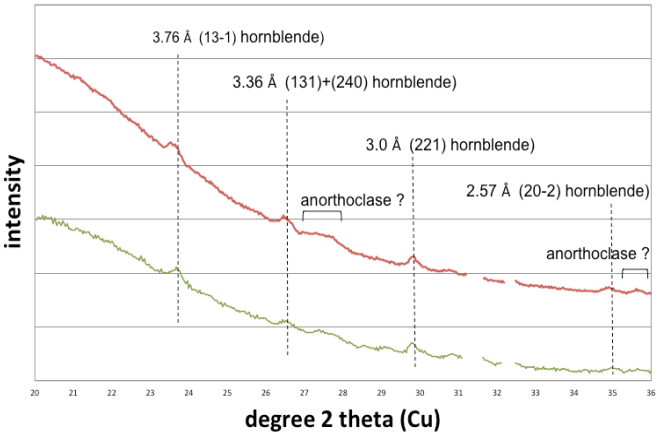
Olivine in rock



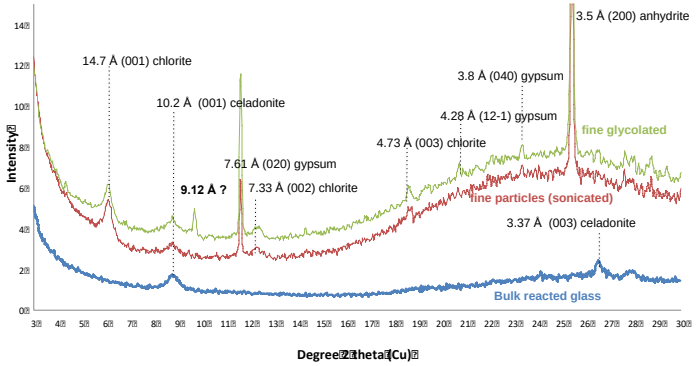


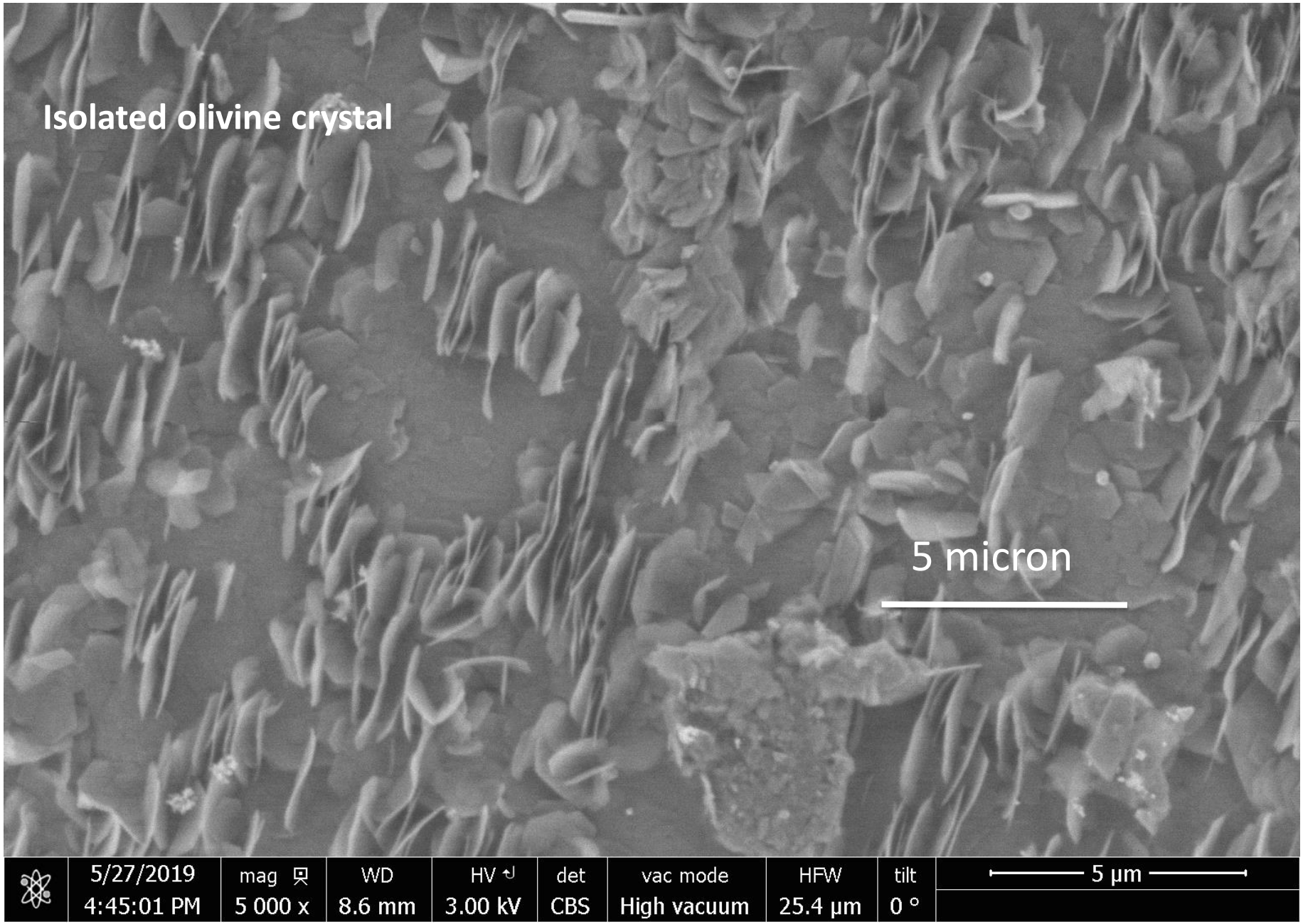


Obsidian glass



Basalt glass



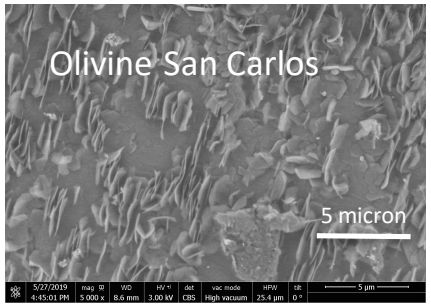

Isolated olivine crystal
5 micron
5/27/2019
4:45:01 PM
mag
5 000 x
WD
8.6 mm
HV
3.00 kV
det
CBS
vac mode
High vacuum
HFW
25.4 µm
tilt
0 °
5 µm

H_2O

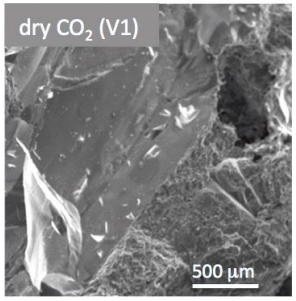
Effect of water

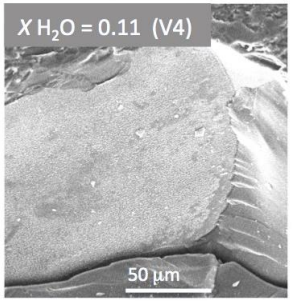
(early Venus or wet volcanic degassing)

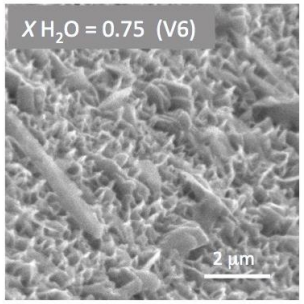
In wet gas



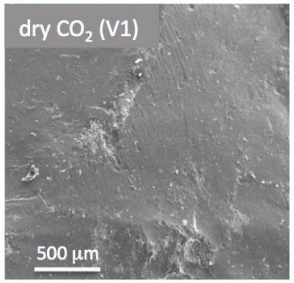
Isolated olivine crystal

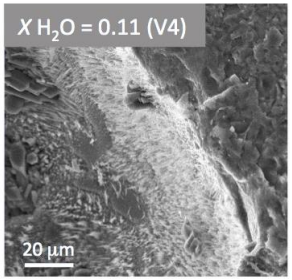


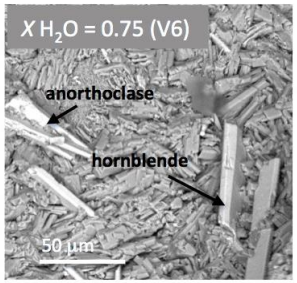




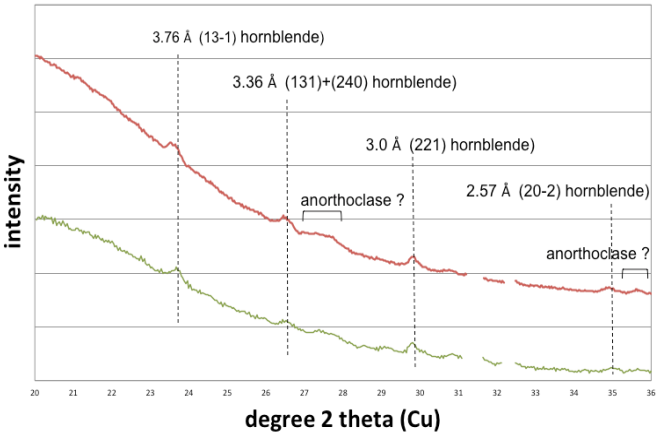
Olivine in rock



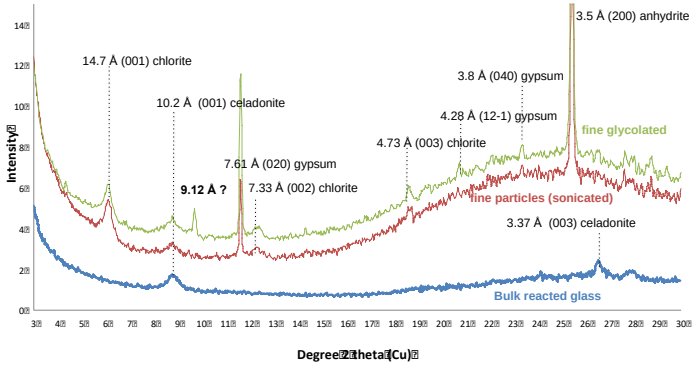


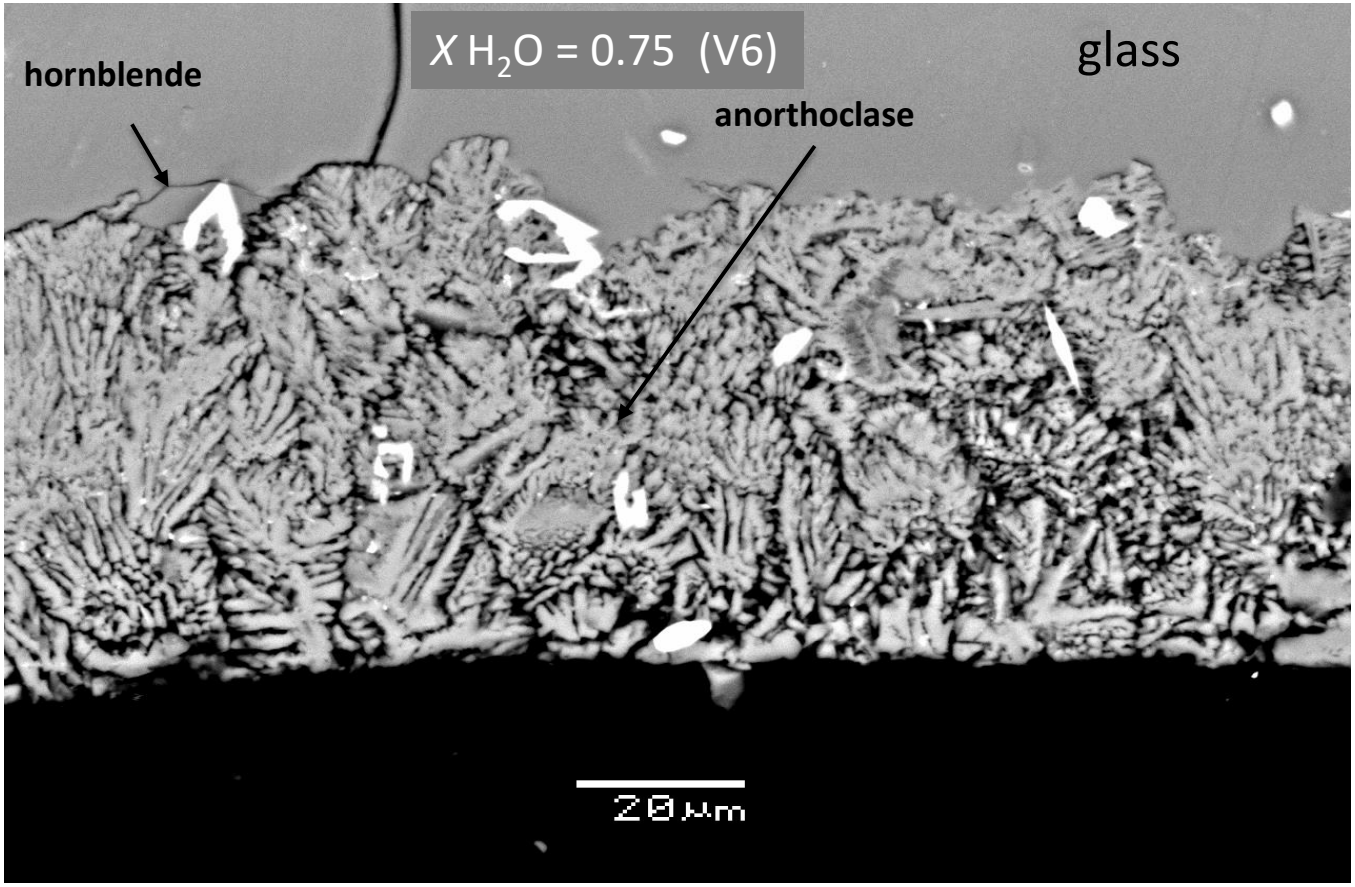


Obsidian glass



Basalt glass



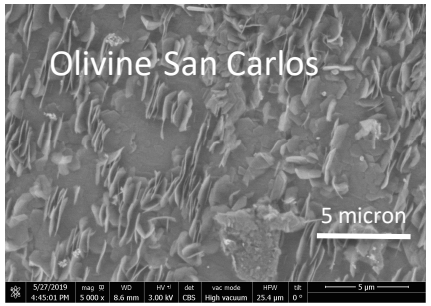

$X\ H_2O = 0.75$ (V6)
glass
hornblende
anorthoclase
20 µm

H_2O

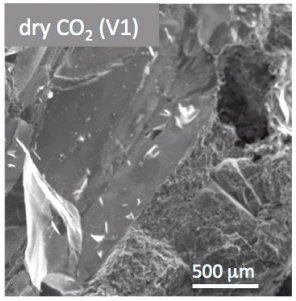
Effect of water

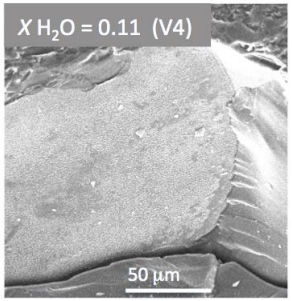
(early Venus or wet volcanic degassing)

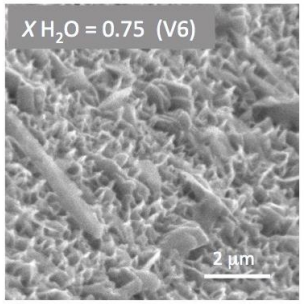
In wet gas



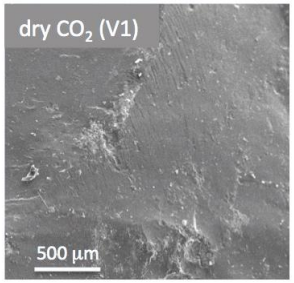
Isolated olivine crystal

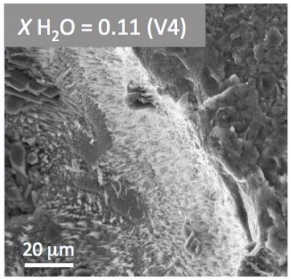


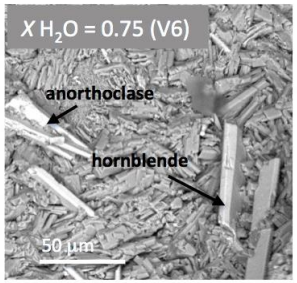




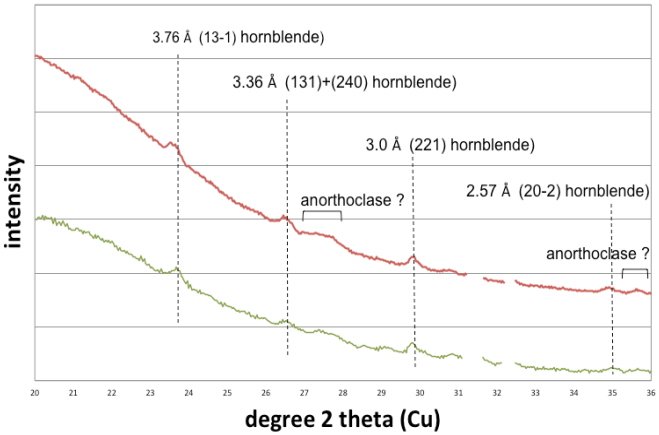
Olivine in rock



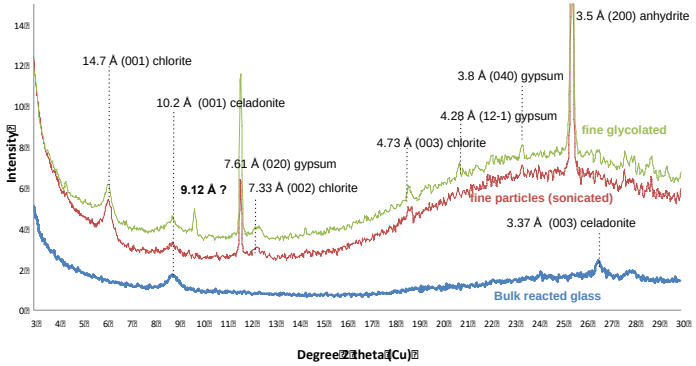




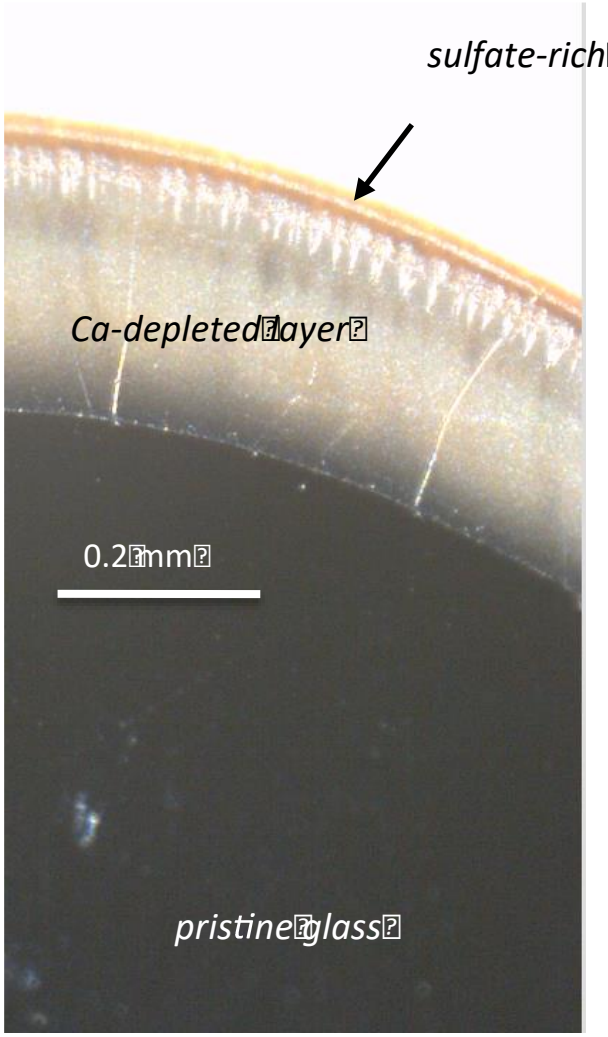
Obsidian glass

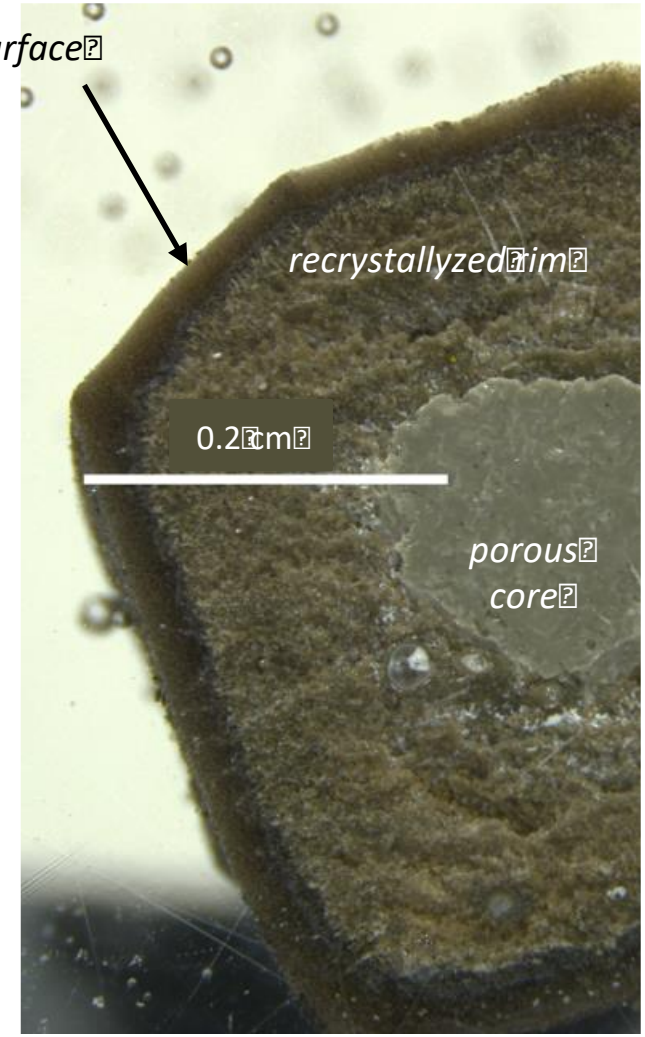


Basalt glass



500 bars H_2O + 50 bars Venus gas

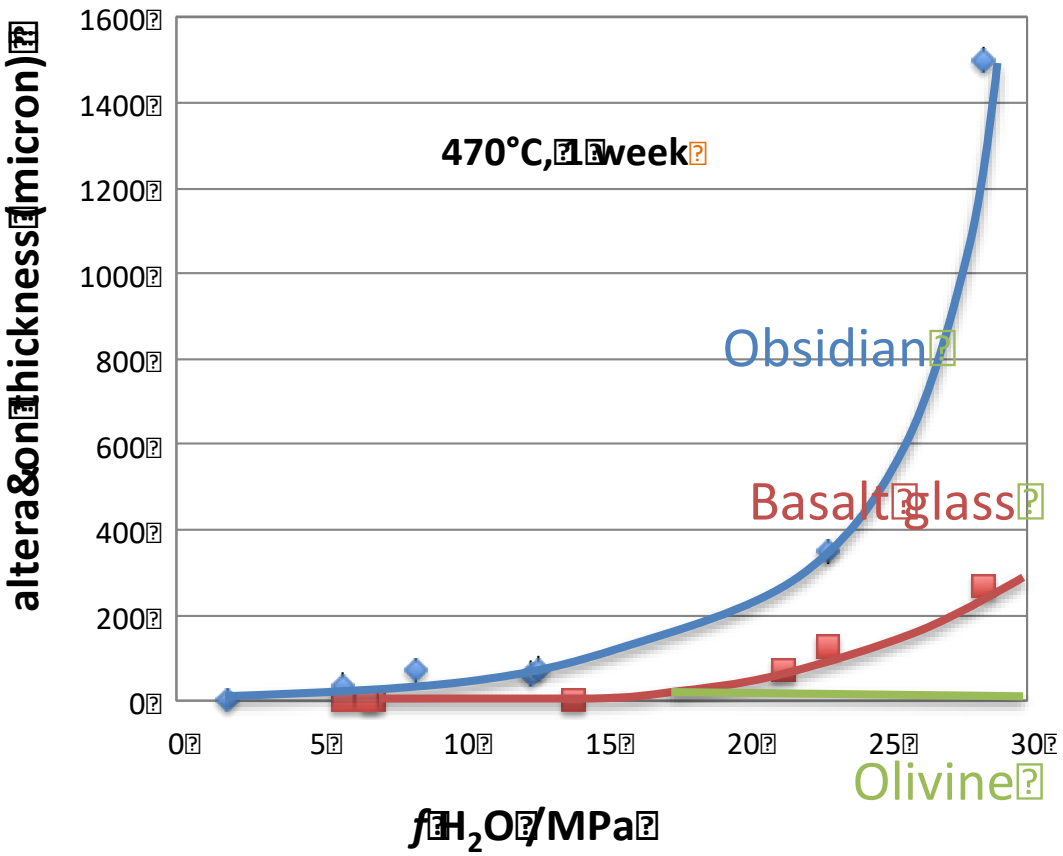




Basalt glass

obsidian glass

Dependence of the alteration layer to water fugacity



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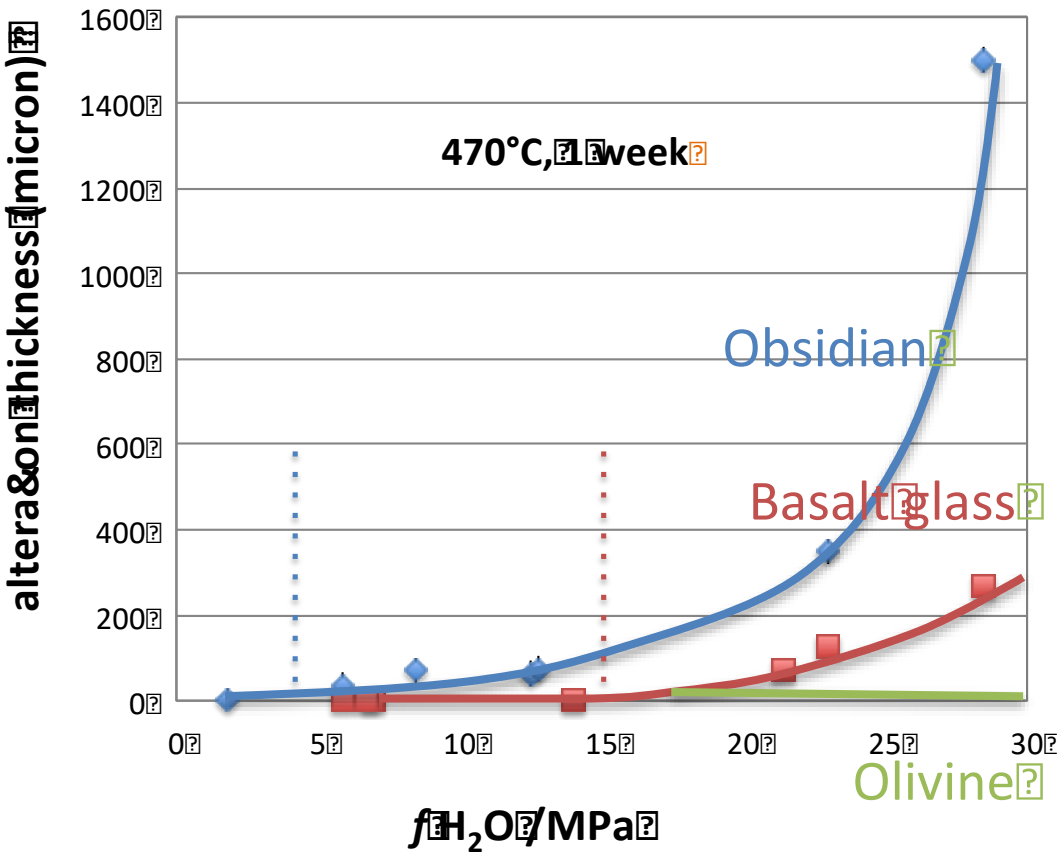
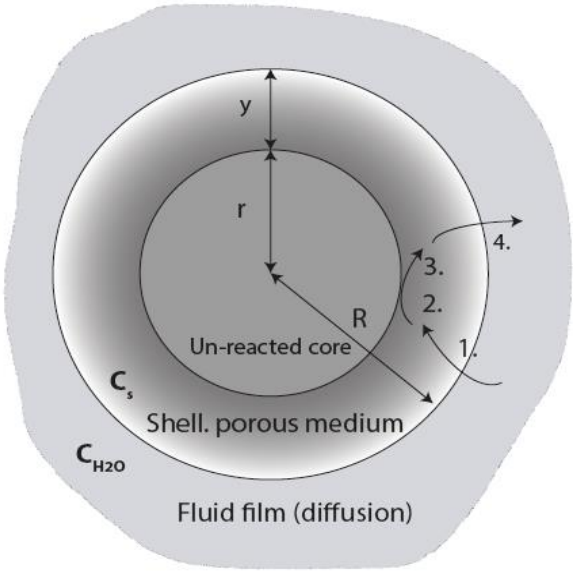
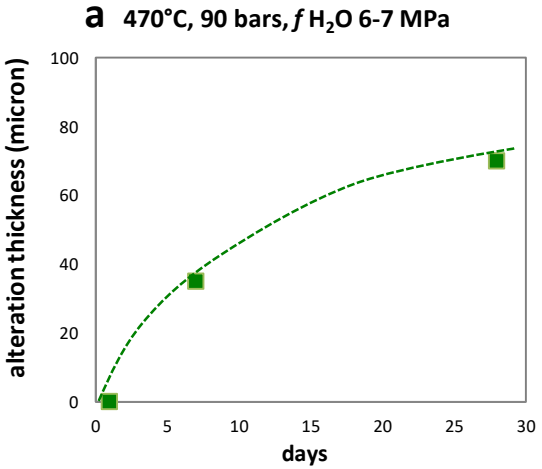
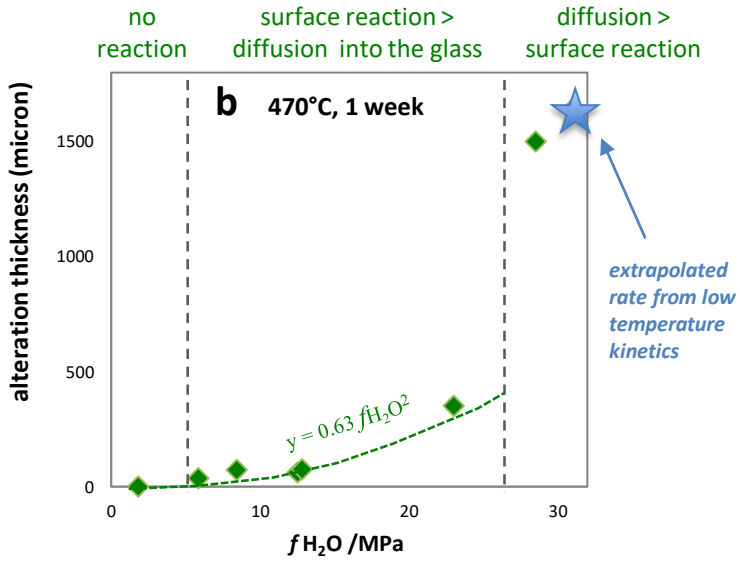
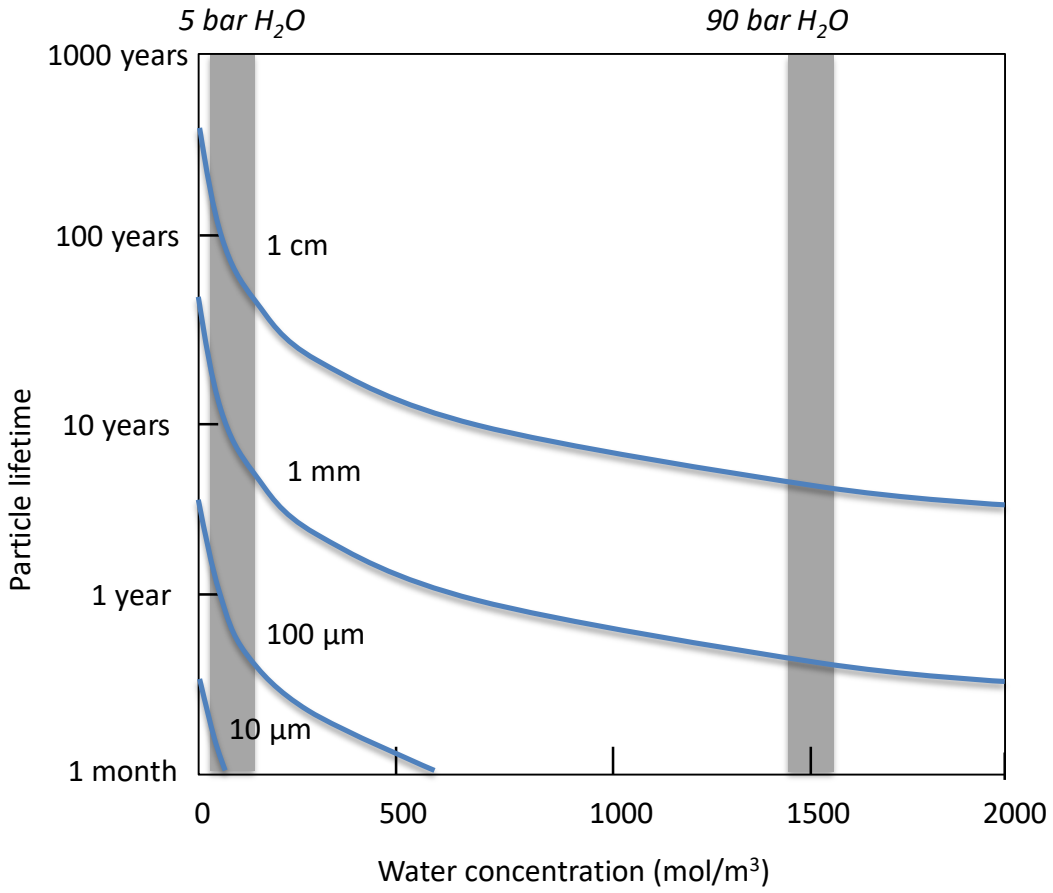


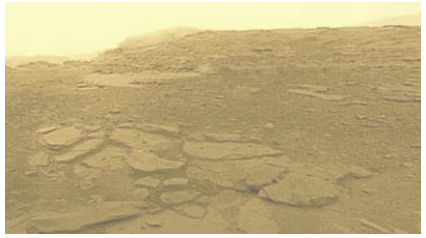

y
r
R
Un-reacted core
C_s
Shell. porous medium
C_{H2O}
Fluid film (diffusion)
1.
2.
3.
4.

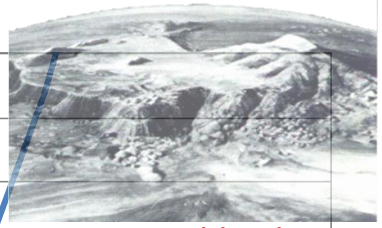

a 470°C, 90 bars, f H2O 6-7 MPa
alteration thickness (micron)
days
0
20
40
60
80
100
0
5
10
15
20
25
30


no reaction
surface reaction > diffusion into the glass
diffusion > surface reaction
b 470°C, 1 week
alteration thickness (micron)
0
500
1000
1500
0
10
20
30
f H2O /MPa
y = 0.63 fH2O2
extrapolated rate from low temperature kinetics


5 bar H_2O
90 bar H_2O
1000 years
100 years
10 years
1 year
1 month
Particle lifetime
1 cm
1 mm
100 µm
10 µm
0
500
1000
1500
2000
Water concentration (mol/m^3)

Present day highlands ?





Plains

Highlands

Equilibrium water vapor pressure

Ideal greenhouse effect for aqueous alteration

Present-day Venus data

Atmospheric pressure (bar)

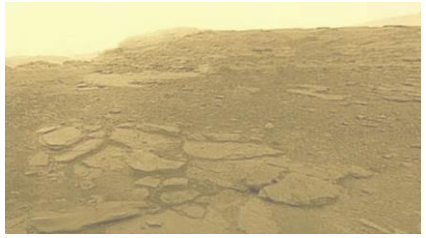
0 5 10 15 20 25 30 35 40 45 50

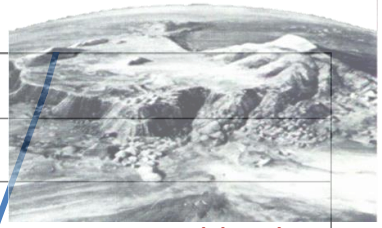
50 100 150 200 250 300 350

Temperature (°C) ≈ elevation

clouds

Present day highlands ?





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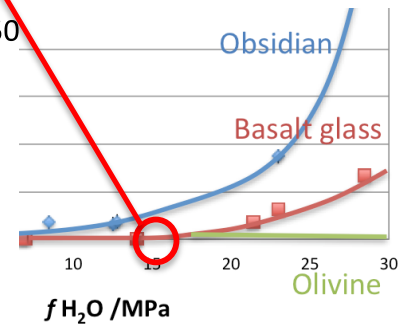
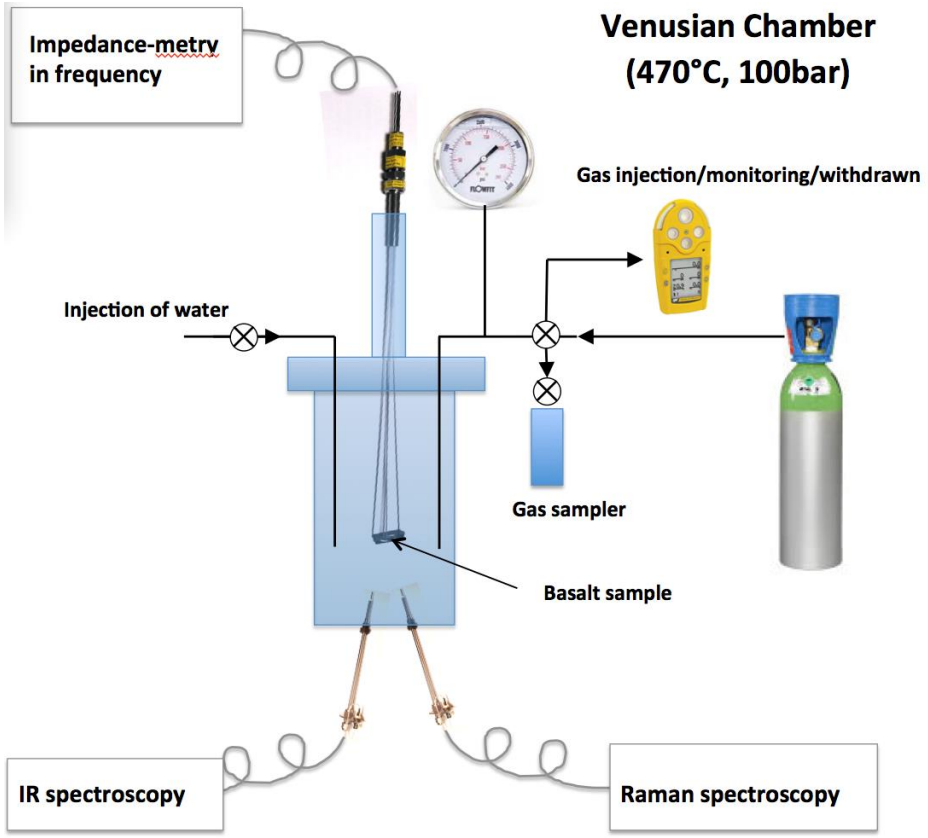
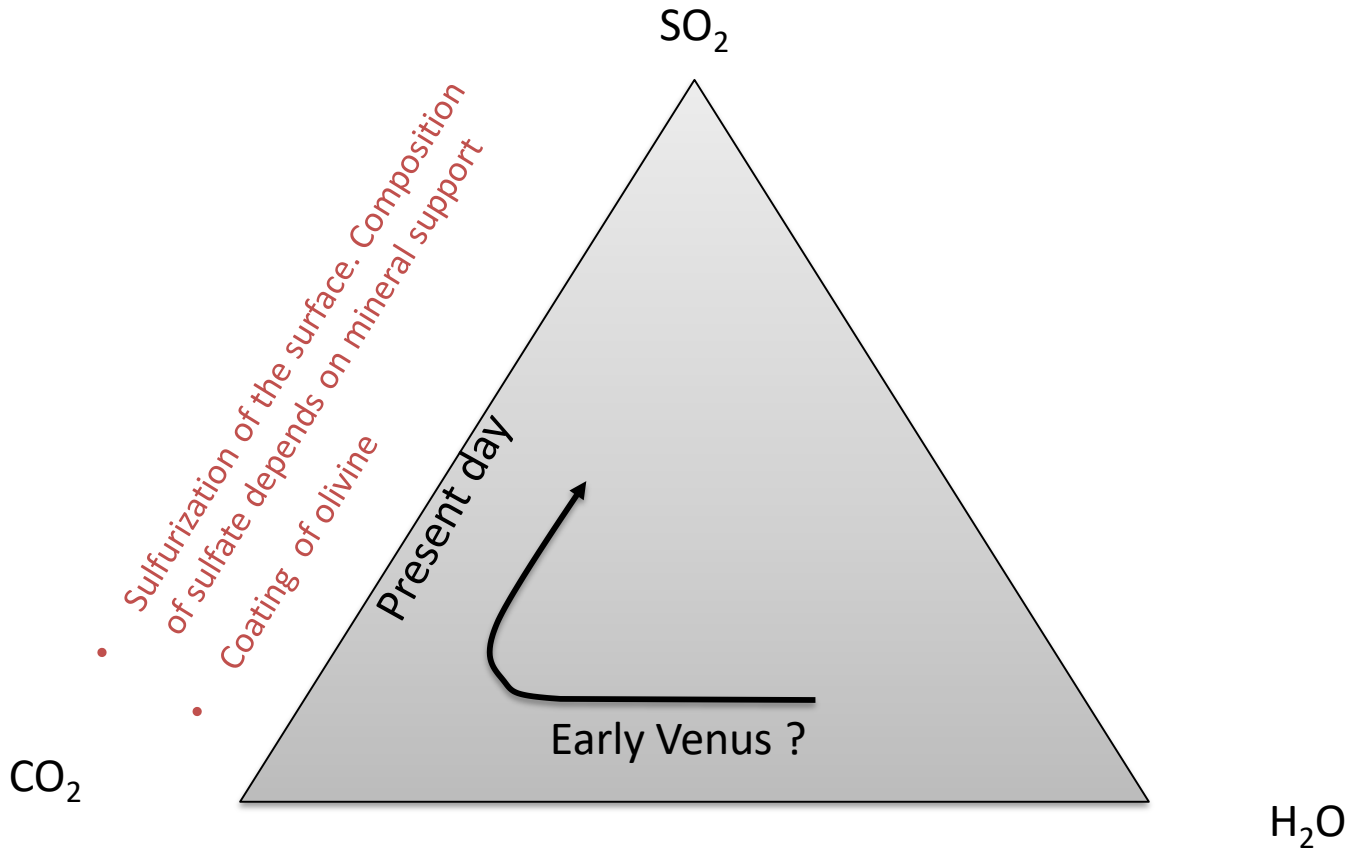


Next future for the laboratory experiments



Thank you

High temperature



- Deep recrystallization of vitreous material
- Nonlinear relation with PH_2O
- Plagioclase and pyroxene seem preserved