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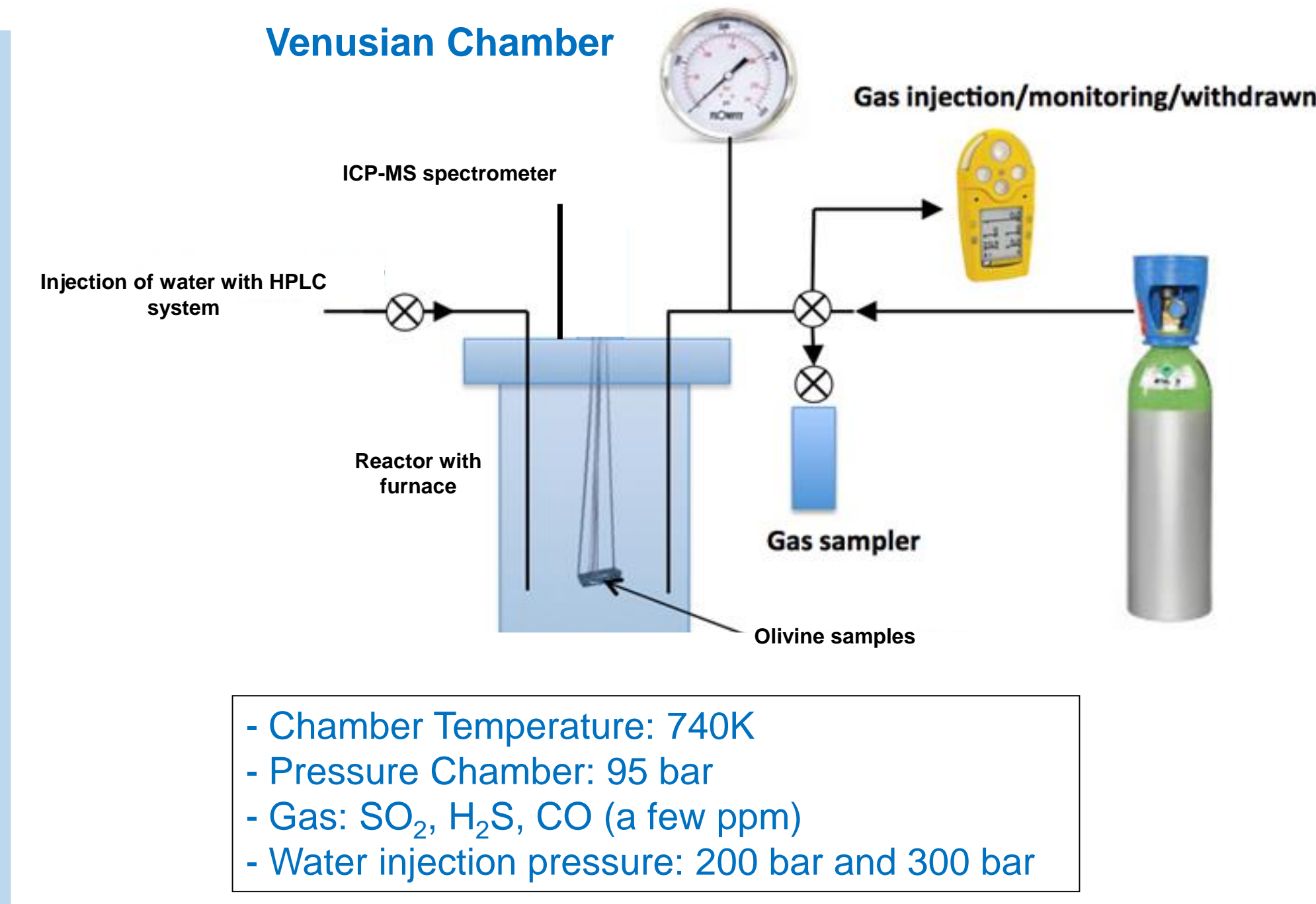
## INTRODUCTION

Harsh present-day VENUS surface conditions, 740K and 95 bar result from high CO<sub>2</sub> partial pressure. Now the VENUS atmosphere is dry (with sulfur). But, during the early ages of the planet, or later, with volcanic events, the VENUS atmosphere could have been significantly wetter.

## OBJECTIVES

-To reproduce VENUS surface conditions in reactor.

-To determine microstructure created during the dry and wet history of the VENUS surface by multi scales techniques (SEM-EDS, RAMAN, XRD and XPS), on volcanic surface samples (olivines).



Olivine Crystals

Candidate material :  
Olivine compounds (Mg<sub>1,8</sub>Fe<sub>0,2</sub>SiO<sub>4</sub>)

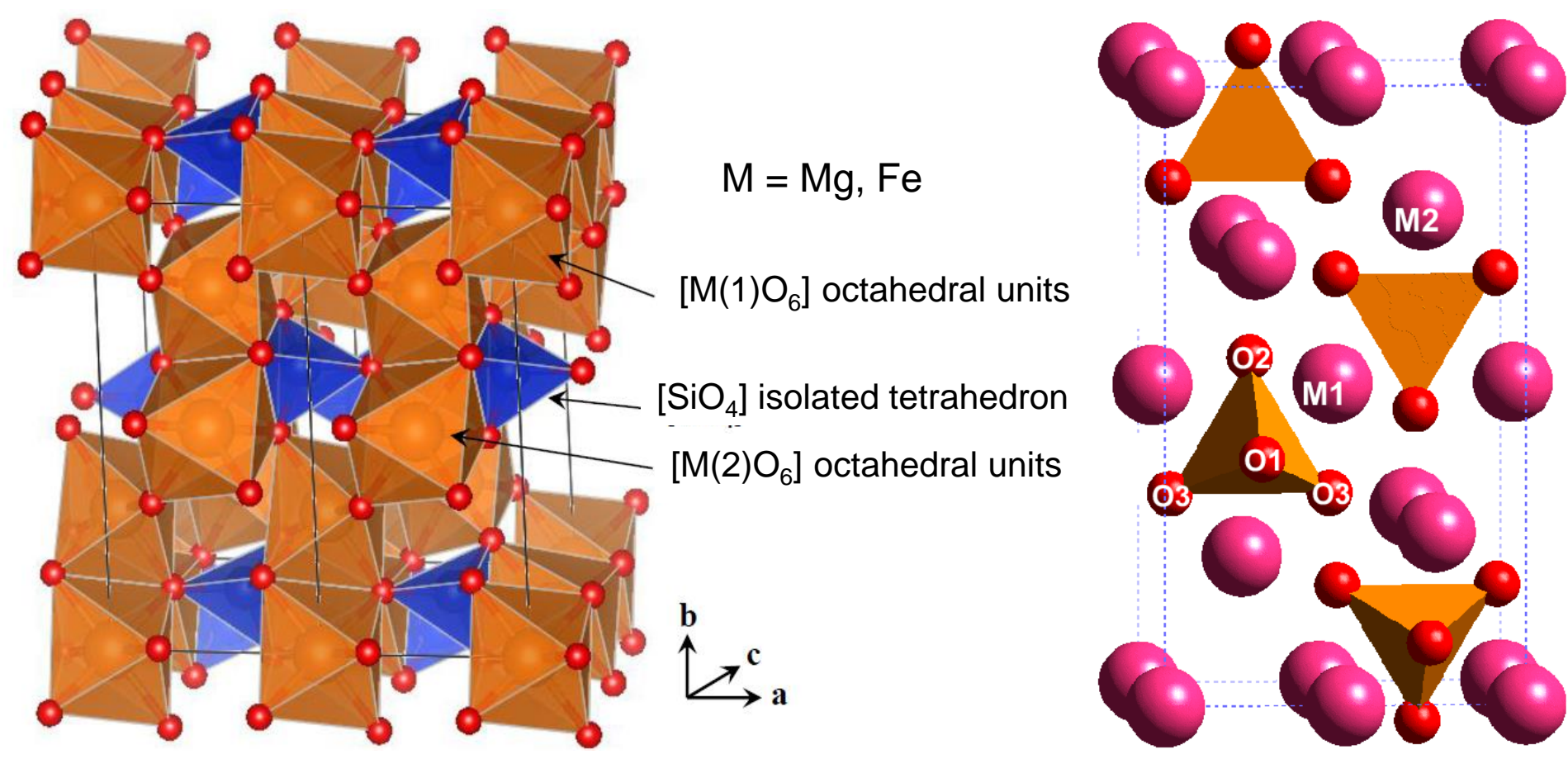
We worked on olivine (Mg<sub>1,8</sub>Fe<sub>0,2</sub>SiO<sub>4</sub>), from tephrite rocks (present on volcanic surface), by multi scales techniques (SEM-EDS, RAMAN, XRD and XPS) after a week treatment with dry VENUS conditions (V24), and with 200 bars H<sub>2</sub>O (V26) and 300 bars H<sub>2</sub>O (V27).

- ➔ Reference: Virgin Olivine (San Carlos)
  - ➔ 740K, CO-H<sub>2</sub>S high, SO<sub>2</sub> weak, dry (V24)
  - ➔ 740K, CO-H<sub>2</sub>S high, SO<sub>2</sub> weak, 200 bar H<sub>2</sub>O (V26)
  - ➔ 740K, CO-H<sub>2</sub>S high, SO<sub>2</sub> weak, 300 bar H<sub>2</sub>O (V27)
- 1 week, under VENUS conditions

## Microstructure: Virgin Olivine

➔ **M(1) octahedron** : sharing 6 edges with neighboring polyhedral and 2 edges with the oxygen tetrahedra [SiO<sub>4</sub>] → C<sub>i</sub> symmetry

➔ **M(2) octahedron** : sharing 3 edges with neighboring polyhedral and 1 edge with the oxygen tetrahedra [SiO<sub>4</sub>] → C<sub>s</sub> symmetry



Crystal structure of olivine *Martínez-González J. A. et al. (2018)*

## Reference : San Carlos Olivine



## EDS : Bulk-Elementary quantification

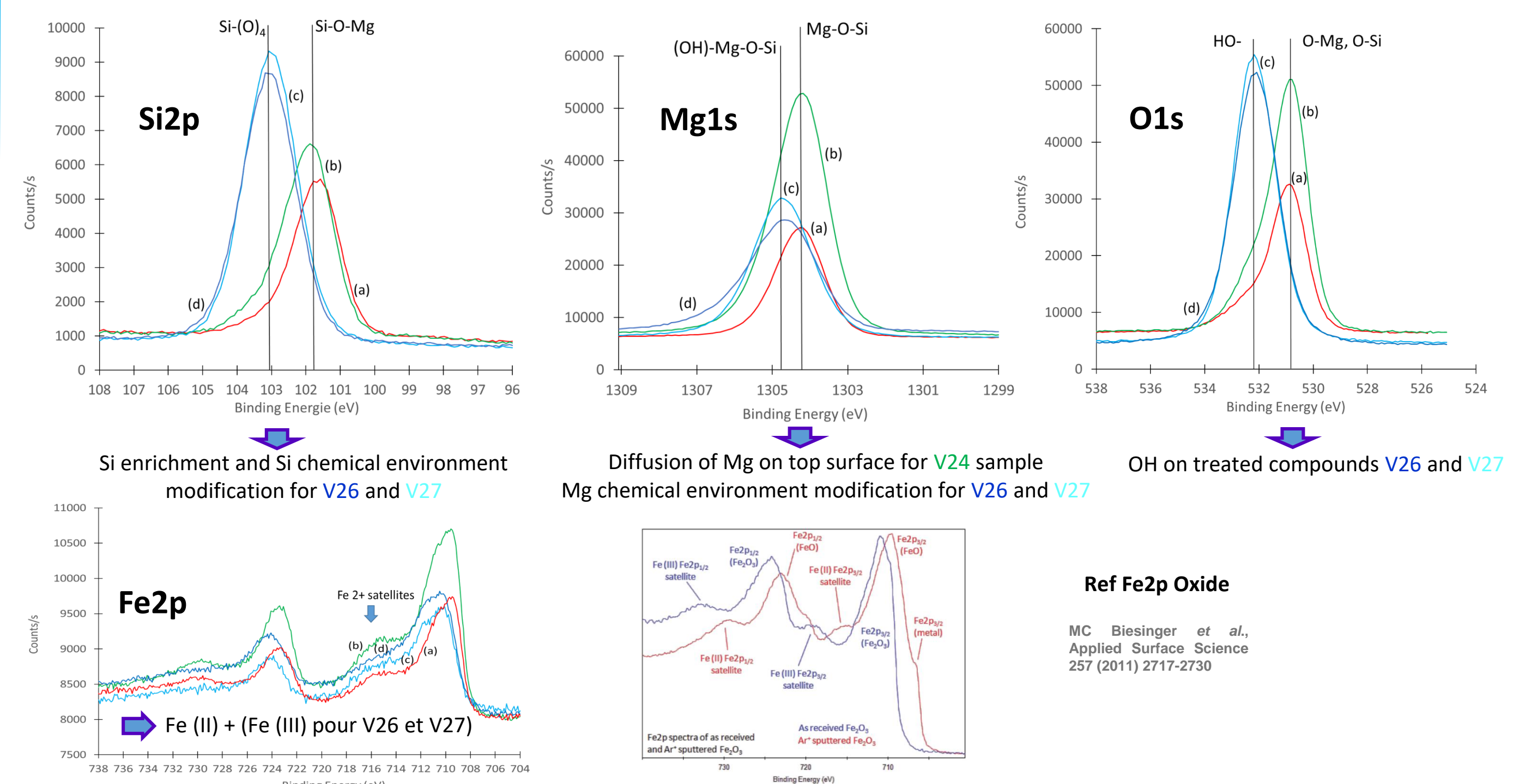
### Normalized Atomics %

	O	Mg	Si	Fe
Olivine 5	59.5	24.3	13.5	2.6
Olivine 4	59.1	24.5	13.6	2.8
Olivine 3	59.1	24.6	13.5	2.7
Olivine 2	59.2	24.5	13.6	2.8
Olivine 1	59.3	24.5	13.5	2.7
average	59.3	24.5	13.5	2.7

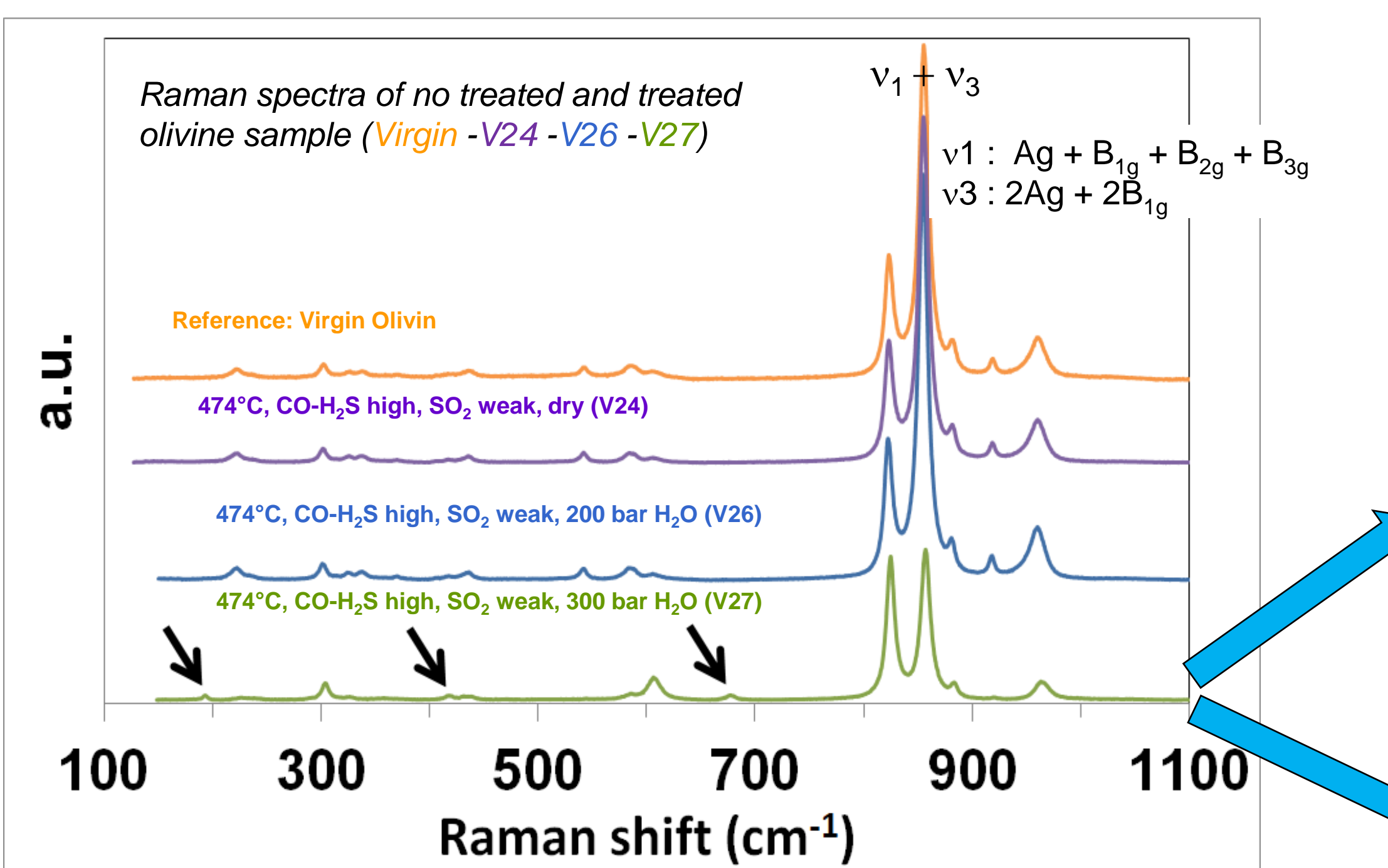
### EDS measurement - Bulk Composition of Olivine (San Carlos)

## XPS : Bonds and Chemical environments on top surface

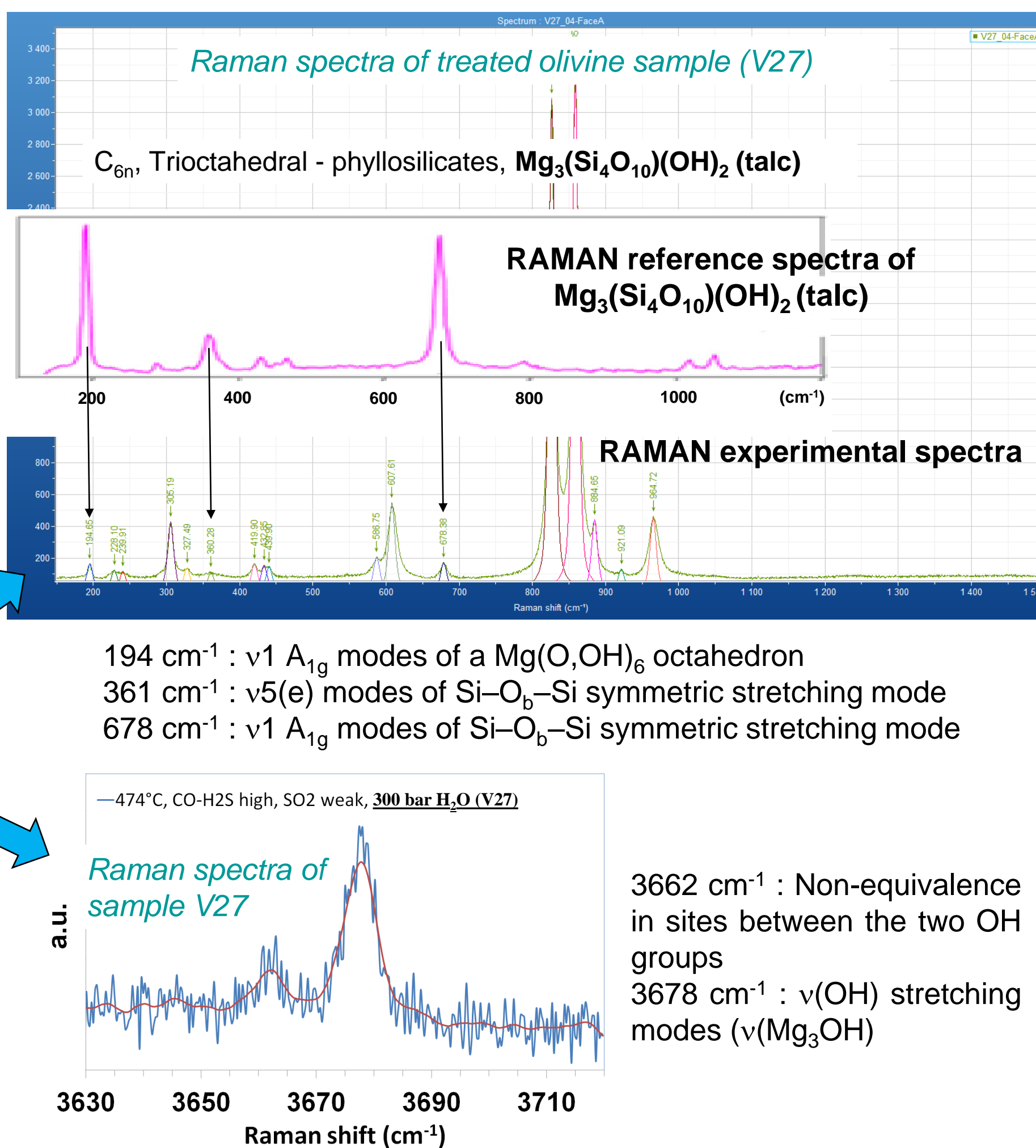
Temp 740K (except Fresh Olivine)	Si 2p B.E (eV)	Si At %	Mg 1s B.E (eV)	Mg At % (Mg2s)	Fe 2p B.E (eV)	Fe At %	O 1s B.E (eV)	O At %
Fresh Olivine (a)	101.7	16.8	1304.3	26.1	710.2	1.7	530.9	55.4
V24 (b) SO <sub>2</sub> weak dry	101.8	16.4	1304.1	24.6	710.2	2.1	530.8	56.8
V26 (c) CO-H <sub>2</sub> S-SO <sub>2</sub> weak 200b H <sub>2</sub> O	103.0	23.7	1304.7	15.2	710.7	0.9	532.2	60.2
V27 (d) CO-H <sub>2</sub> S-SO <sub>2</sub> weak 300b H <sub>2</sub> O	103.2	23.5	1304.8	13.9	710.7	1.4	532.2	61.3



## RAMAN : Bonds and atomic environments

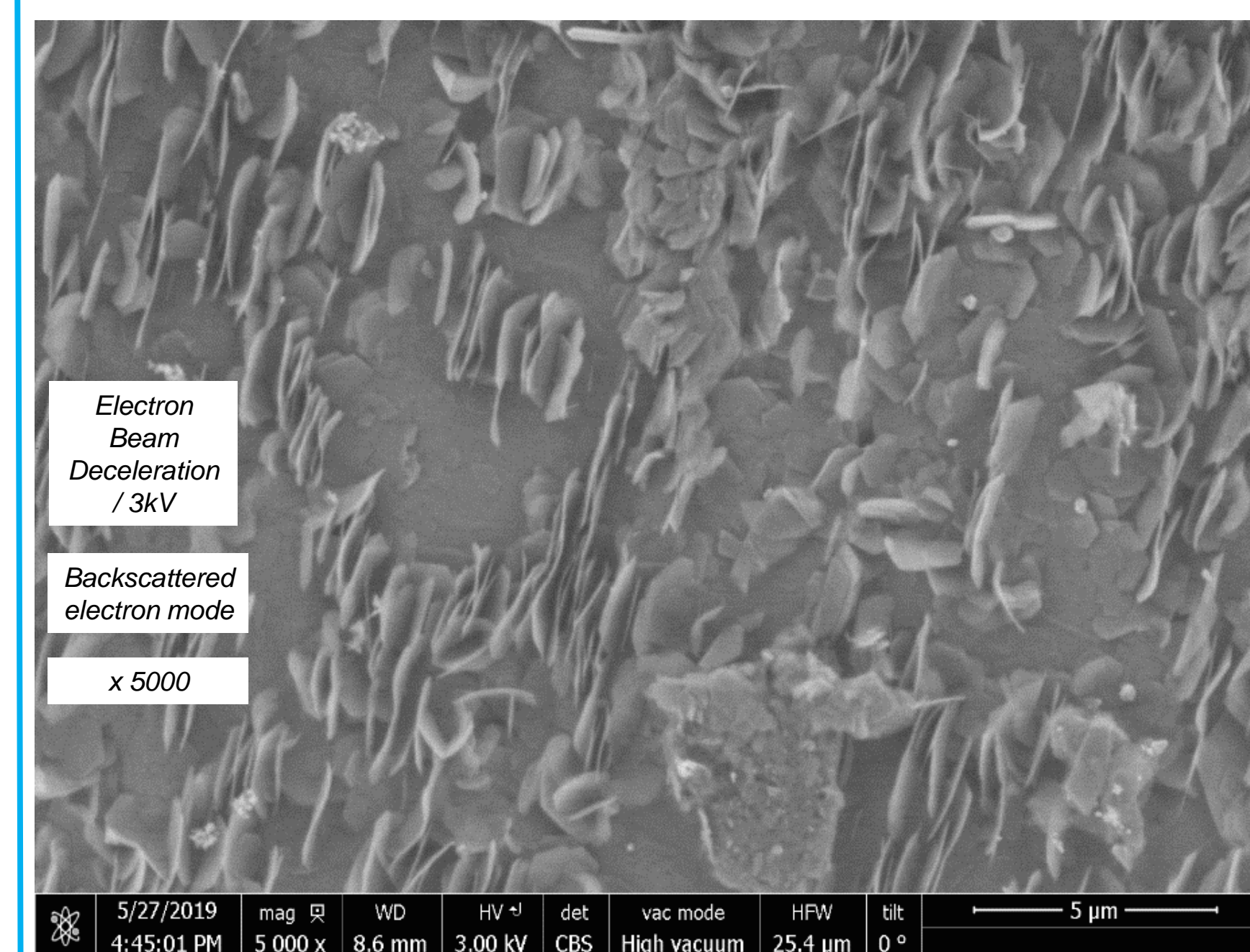


150 cm<sup>-1</sup> to 400 cm<sup>-1</sup> : external, rotational and translational lattice movements of [SiO<sub>4</sub>]<sup>4-</sup> tetrahedral, translational movements of Mg<sup>2+</sup> or Fe<sup>2+</sup> cations octahedral.  
400 cm<sup>-1</sup> to 500 cm<sup>-1</sup> : v<sub>2</sub> internal symmetric bending vibration modes of [SiO<sub>4</sub>]<sup>4-</sup> tetrahedra  
500 cm<sup>-1</sup> to 620 cm<sup>-1</sup> : v<sub>4</sub> internal asymmetric bending vibration modes of [SiO<sub>4</sub>]<sup>4-</sup> tetrahedra  
780 cm<sup>-1</sup> to 1000 cm<sup>-1</sup> : v<sub>1</sub>+ v<sub>3</sub> internal symmetric and asymmetric stretching vibration modes of [SiO<sub>4</sub>]<sup>4-</sup> tetrahedral



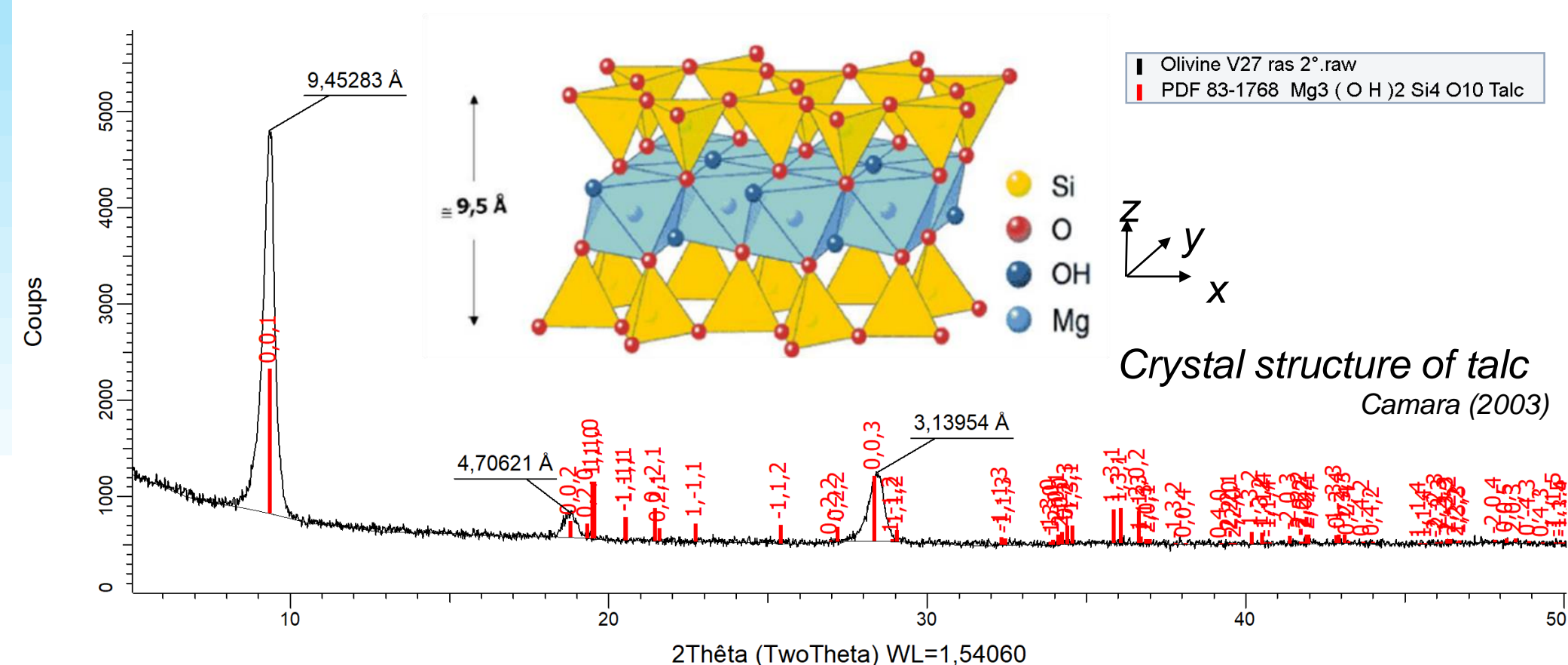
## SEM : Microstructural informations

Olivine treated 474°C, CO-H<sub>2</sub>S high, SO<sub>2</sub> weak, 300 bar H<sub>2</sub>O (V27)



## XRD : Crystalline phases

XRD pattern : V27 olivine sample 740K CO-H<sub>2</sub>S High, SO<sub>2</sub> weak, 300 bar H<sub>2</sub>O



## CONCLUSIONS

### SEM/EDS

- ➔ Composition Virgin olivine (% atom): O: 59,3 Mg: 24,5 Si: 13,5 Fe: 2,7
- ➔ V24 (474°C, SO<sub>2</sub> weak, dry) : NAD
- ➔ V26 (474°C, CO-H<sub>2</sub>S-SO<sub>2</sub> weak, 200 bar H<sub>2</sub>O) : Modified surface
- ➔ V27 (474°C, CO-H<sub>2</sub>S high, SO<sub>2</sub> weak, 300 bar H<sub>2</sub>O) : Modified surface with Mg<sub>3</sub>(Si<sub>4</sub>O<sub>10</sub>)(OH)<sub>2</sub> (talca)

### XPS

- ➔ V24 (474°C, SO<sub>2</sub> weak, dry) : Diffusion of Mg on the top surface, no chemical environment modifications/Virgin Olivine
- ➔ V26 (474°C, CO-H<sub>2</sub>S-SO<sub>2</sub> weak, 200 bar H<sub>2</sub>O) : Si enrichment and Si + Mg chemical environment modification, layers of Si-O<sub>4</sub> and Mg-OH, way of the formation of serpentine: Mg<sub>3</sub>(Si<sub>4</sub>O<sub>10</sub>)(OH)<sub>2</sub> (talca)
- ➔ V27 (474°C, CO-H<sub>2</sub>S high, SO<sub>2</sub> weak, 300 bar H<sub>2</sub>O) : Idem V26
- ➔ No accumulation of Fe. Fe is (+II) in all the samples even if oxidizing conditions. Way to a passivating topotactic change. Mixed Fe (+II) and (+III) in wet conditions, with possibly FeOOH presence.

### RAMAN XRD

- ➔ Virgin olivine : Two crystalline orientations
- ➔ V24 (474°C, SO<sub>2</sub> weak, dry) : NAD
- ➔ V26 (474°C, CO-H<sub>2</sub>S-SO<sub>2</sub> weak, 200 bar H<sub>2</sub>O) : NAD
- ➔ V27 (474°C, CO-H<sub>2</sub>S high, SO<sub>2</sub> weak, 300 bar H<sub>2</sub>O) : Presence of Mg<sub>3</sub>(Si<sub>4</sub>O<sub>10</sub>)(OH)<sub>2</sub> (talca)