Uphill Diffusion and ZFP in Garnets: an Experimental and ATEM Study

D. Vielzeuf – *CRMCN, Marseilles, France*

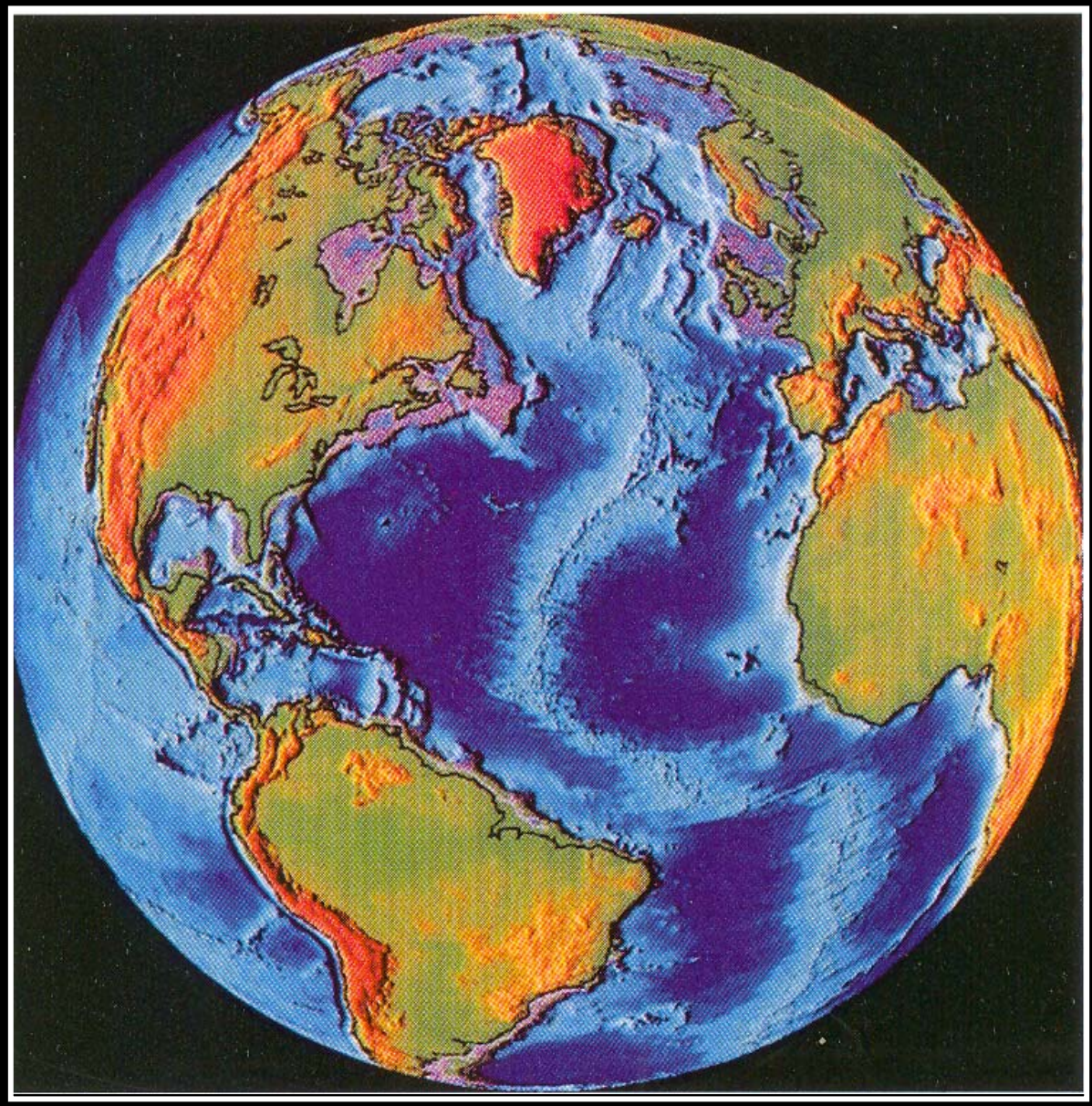
A. Lupulescu – *RPI, Troy, USA*

A. Perchuk – *IGEM – Moscow, Russia*

D. Laporte – *LMV, Clermont, France*

A. Baronnet – *CRMCN, Marseilles, France*

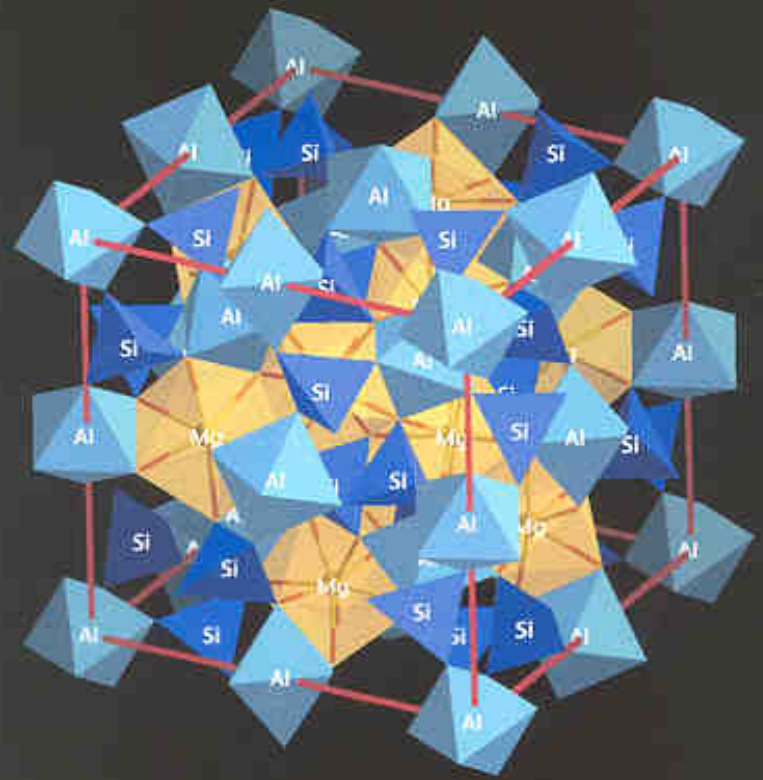
A. Addad – *LSPES, Lille, France*



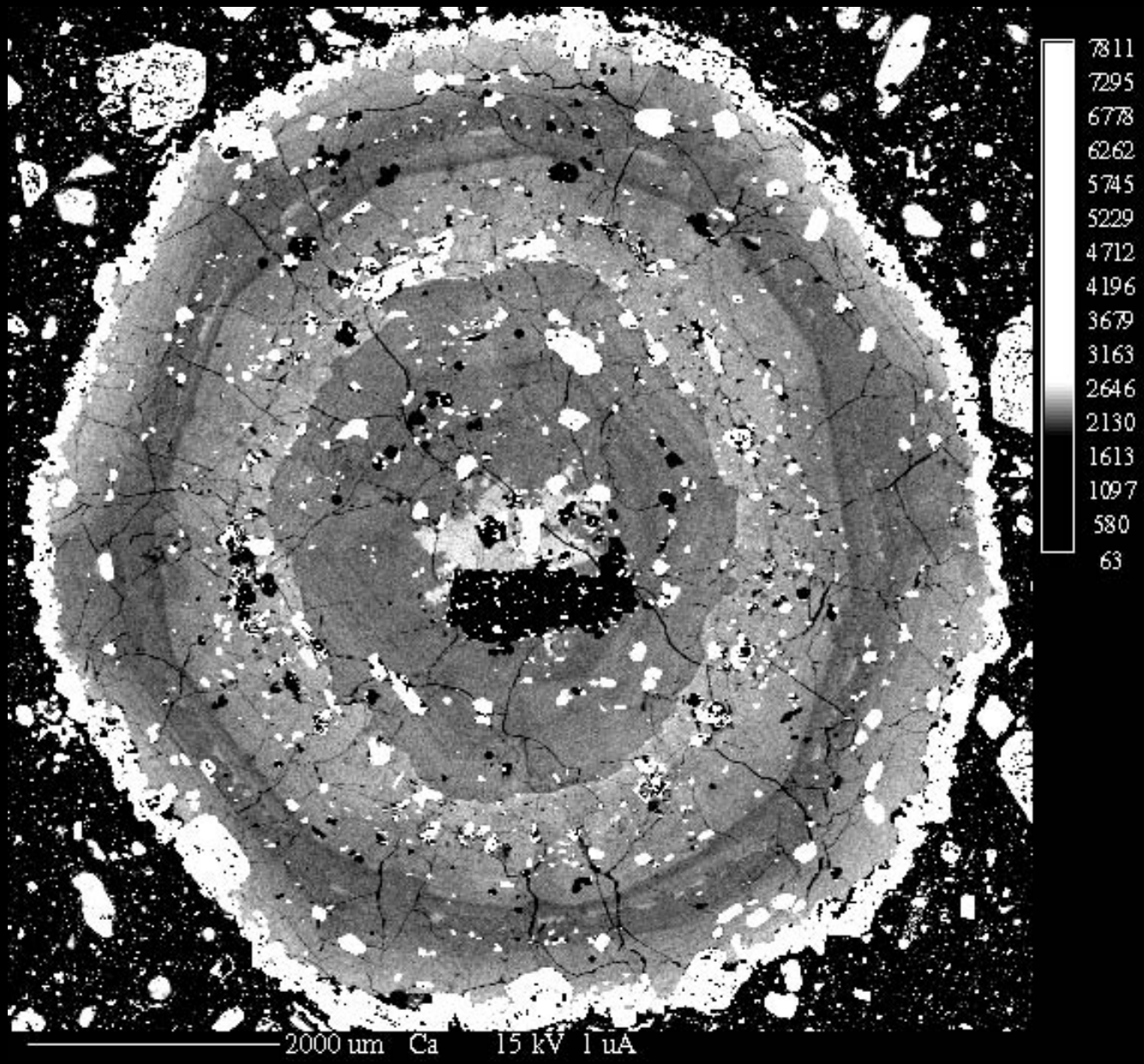
$$X^{2+}_{3}\,Y^{3+}_{2}\,[Si\,O_4]_3$$

avec X = Ca, Fe^{2+}, Mg, Mn^{2+}

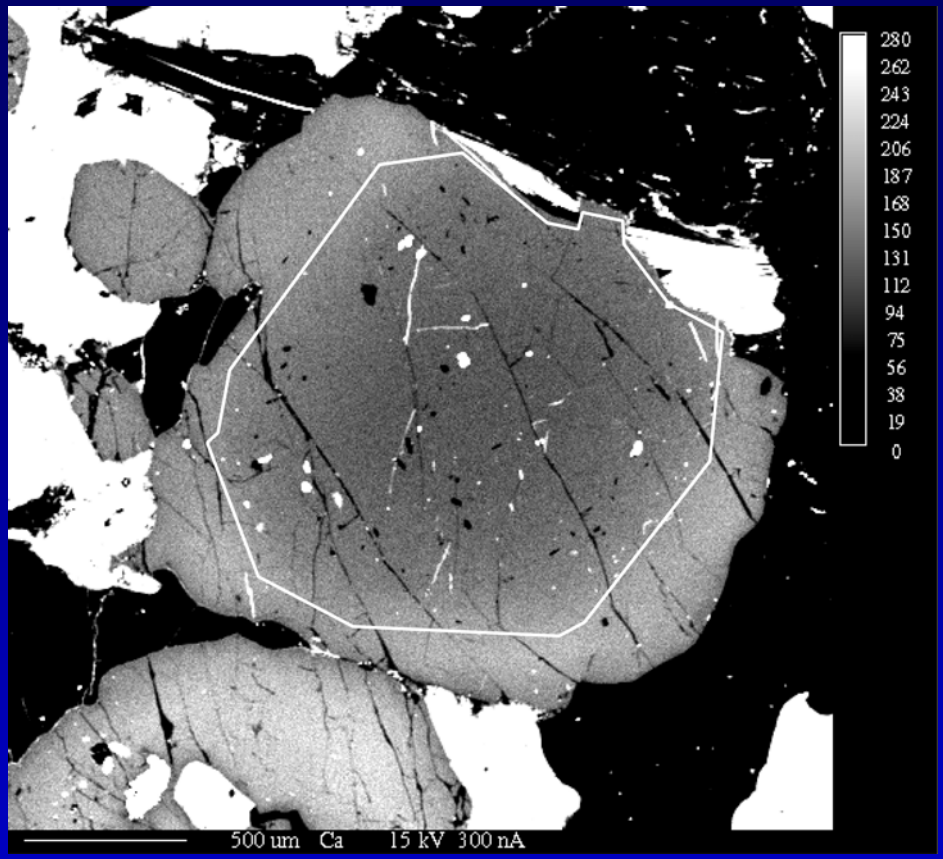
et Y = Al, Cr^{3+}, Fe^{3+}, Mn^{3+}...



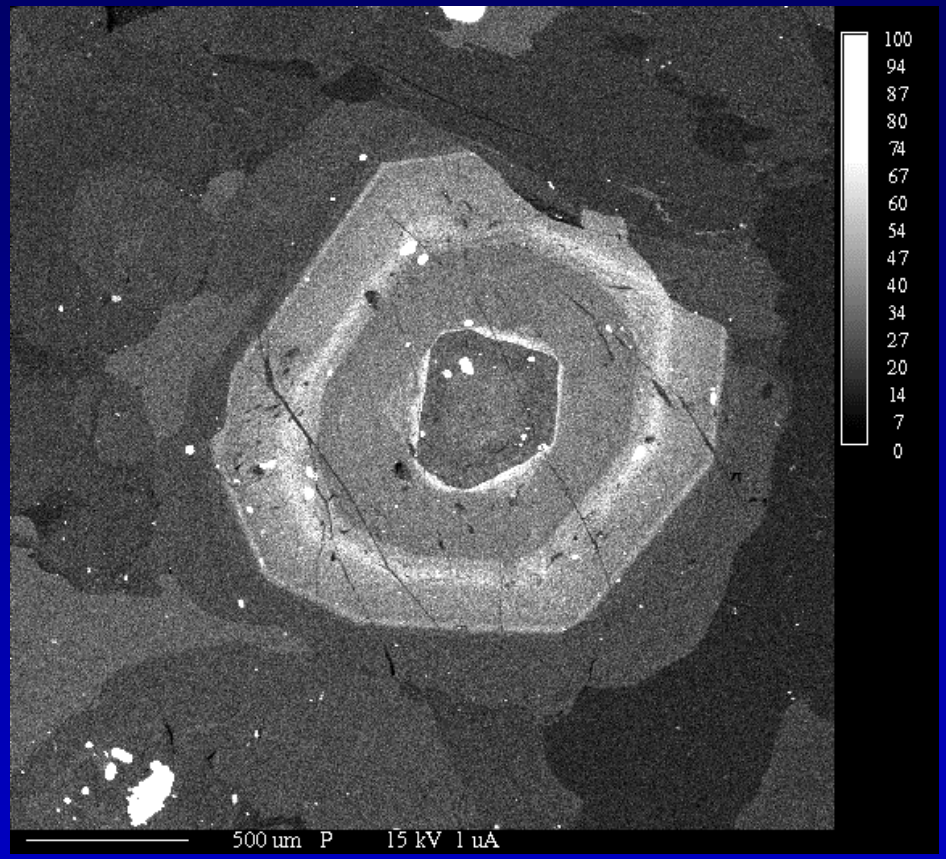
A garnet grown in a magma chamber



Calcium



Phosphorus

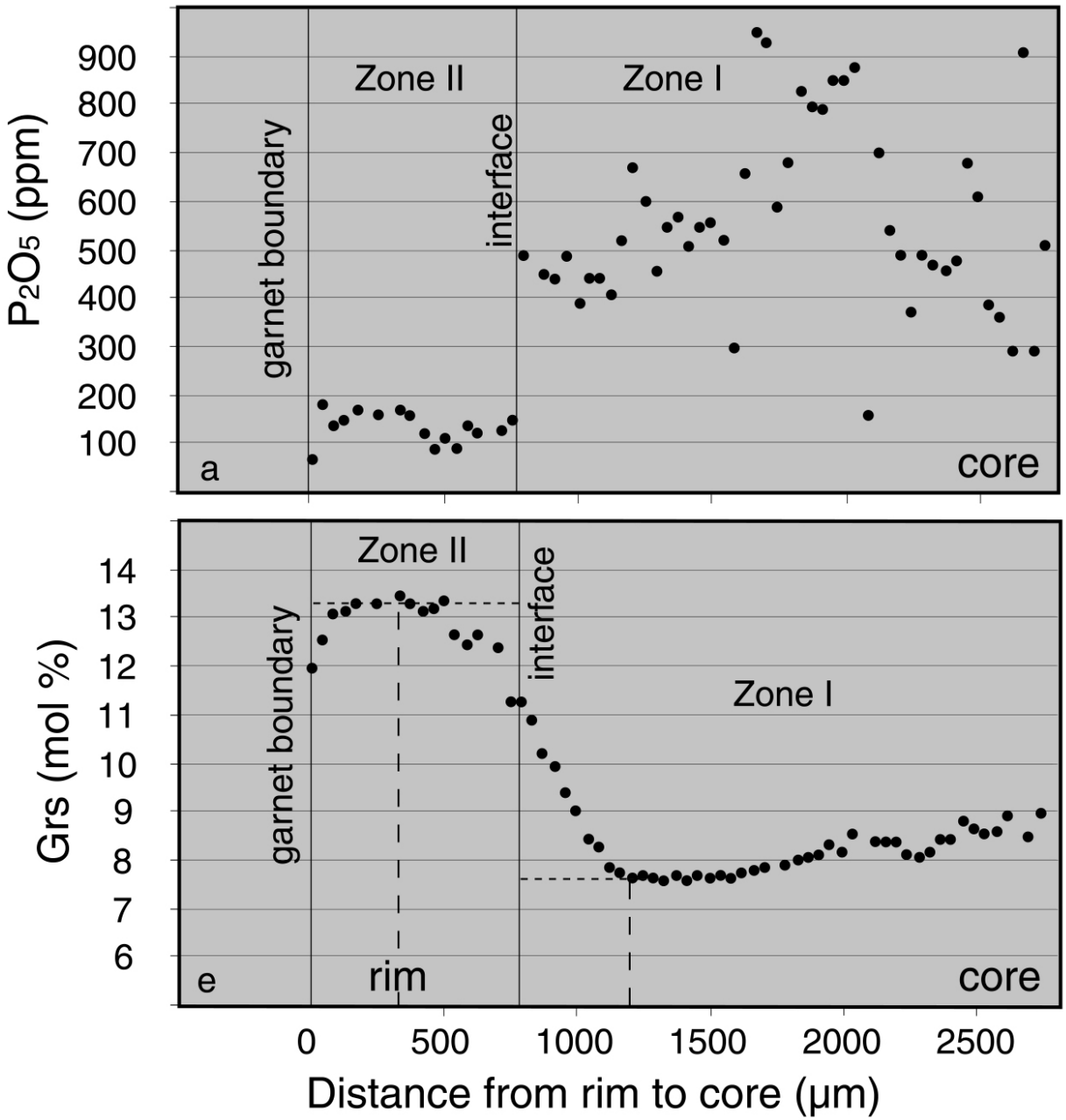


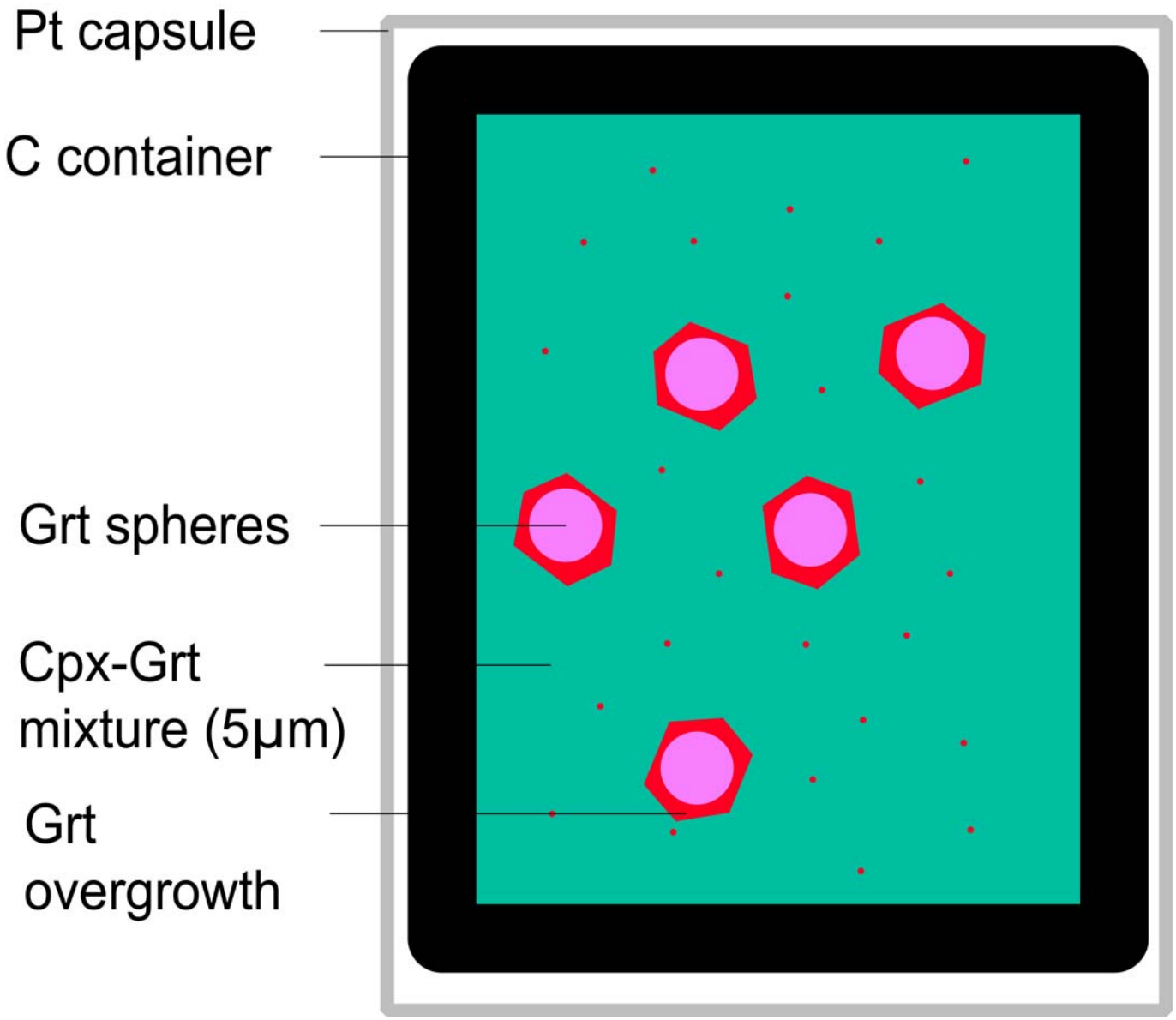
Cameca SX100, Clermont

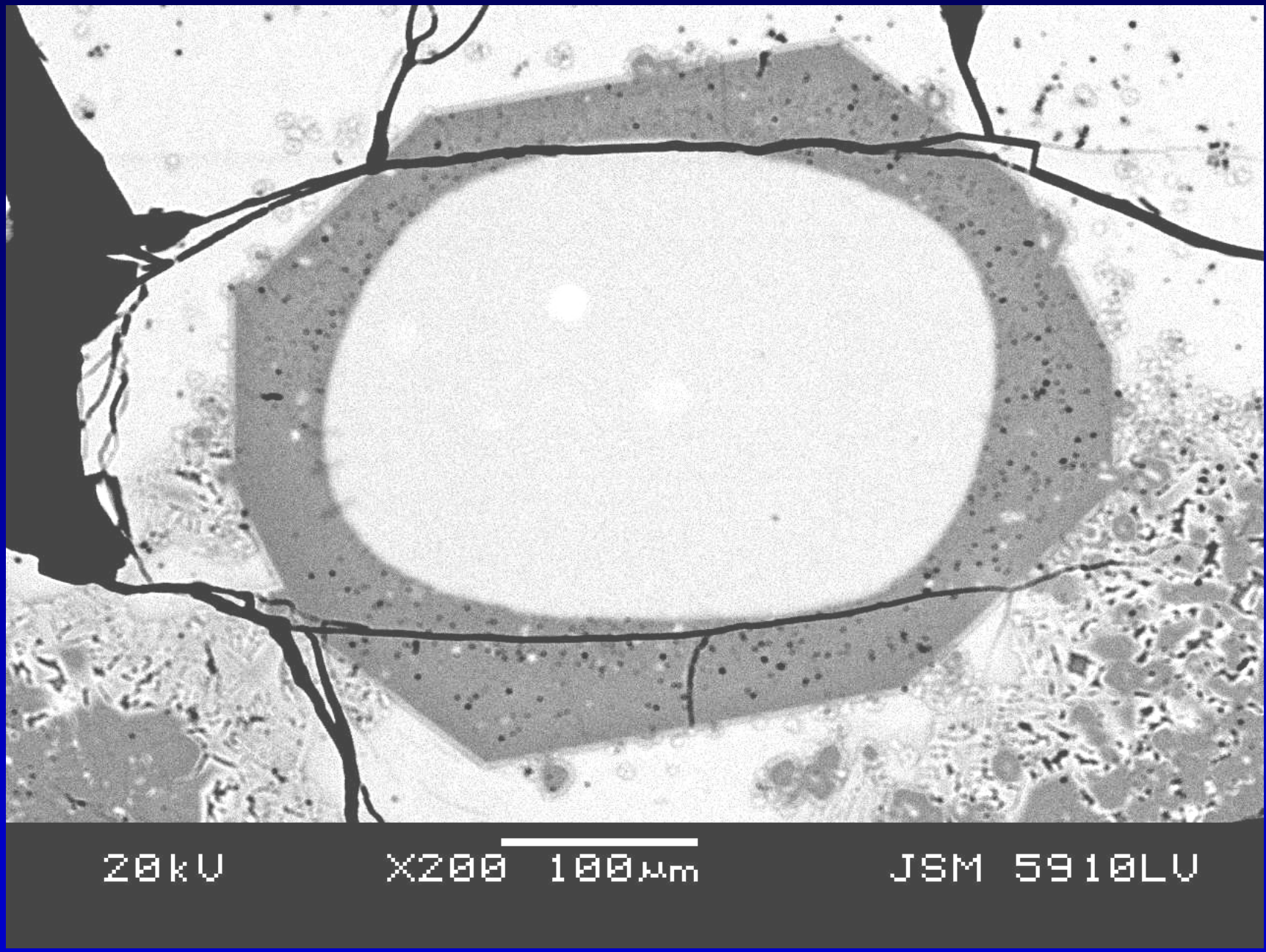
A garnet from a magma chamber in the Pyrénées (France)

Phosphorus

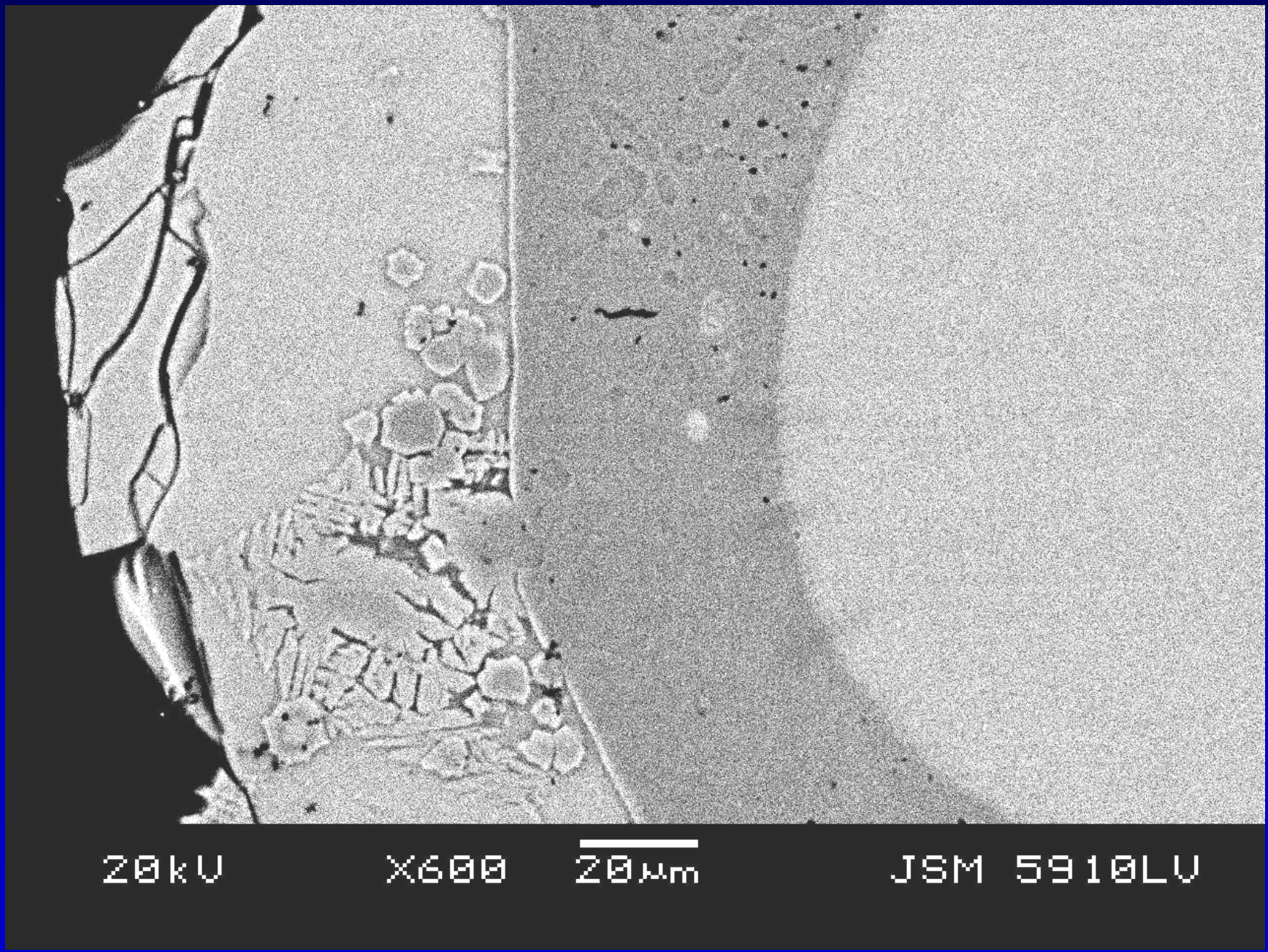
Calcium




Pt capsule
C container
Grt spheres
Cpx-Grt
mixture (5µm)
Grt
overgrowth



1250°C, 13 kbar, 5 days


20kV X600 20µm JSM 5910LV

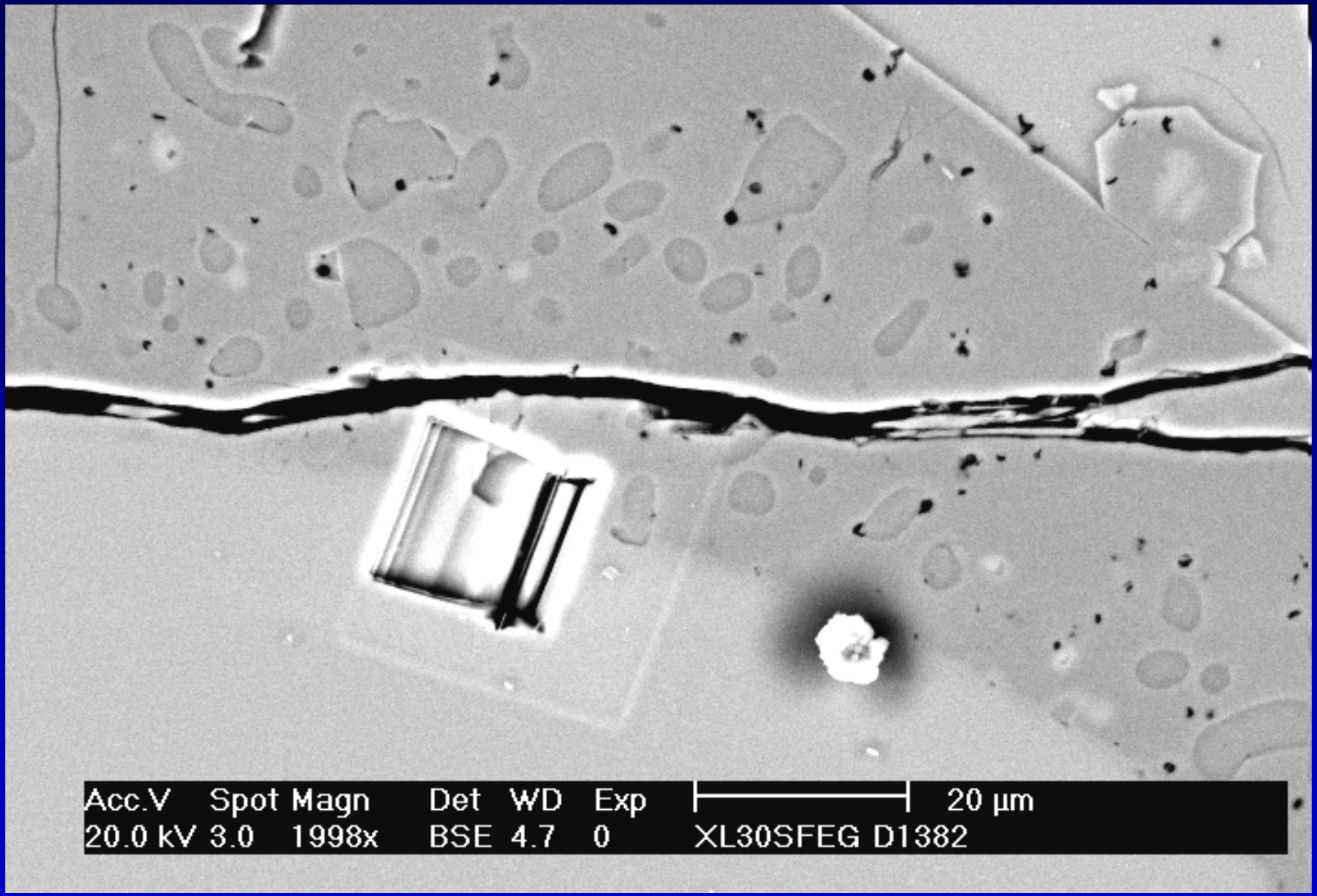
French TEM national facility

CRMCN – Univ. Marseilles and CNRS :

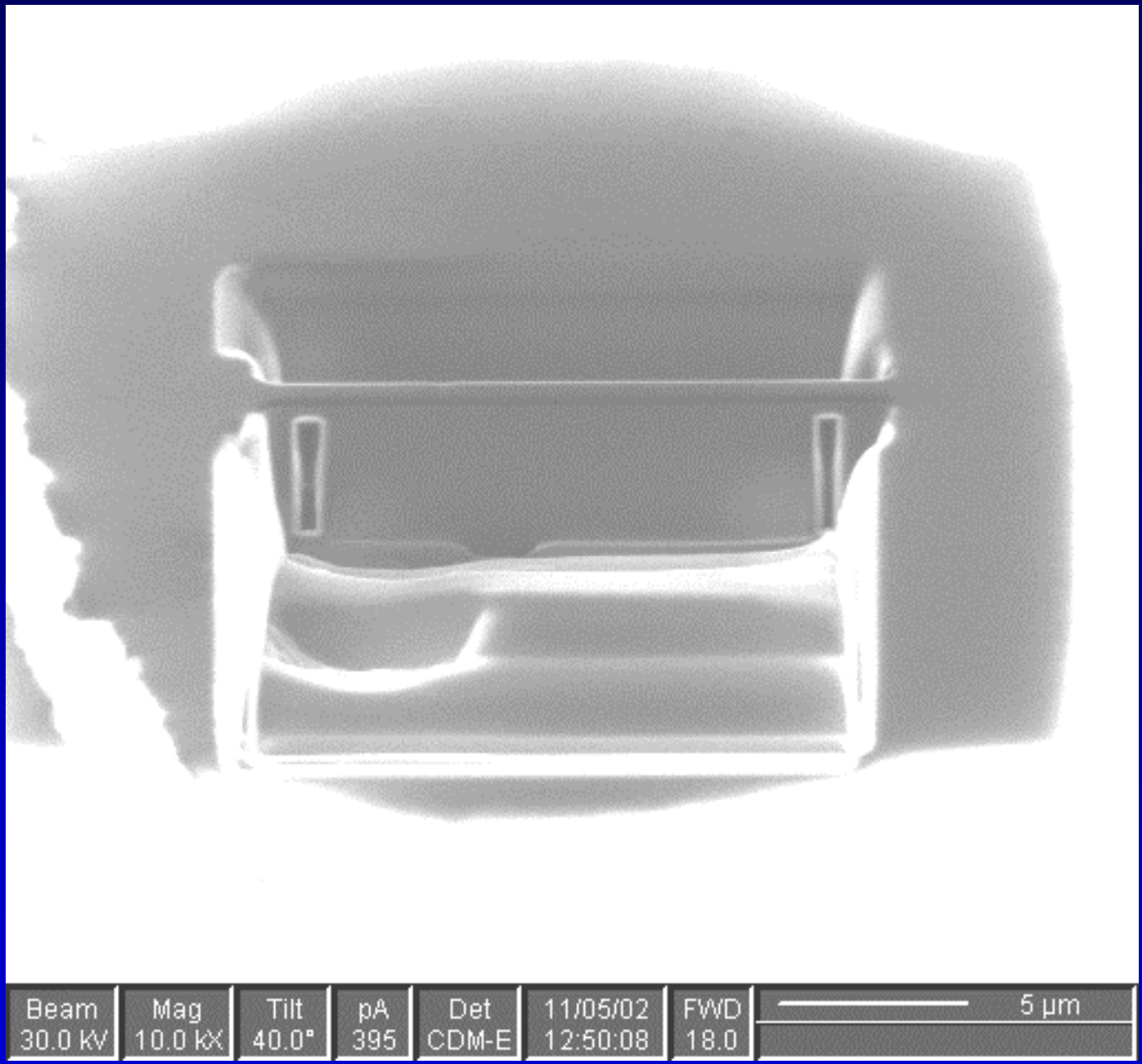
JEOL 2000FX, with EDS TRACOR 2
(spot size 50 nm)

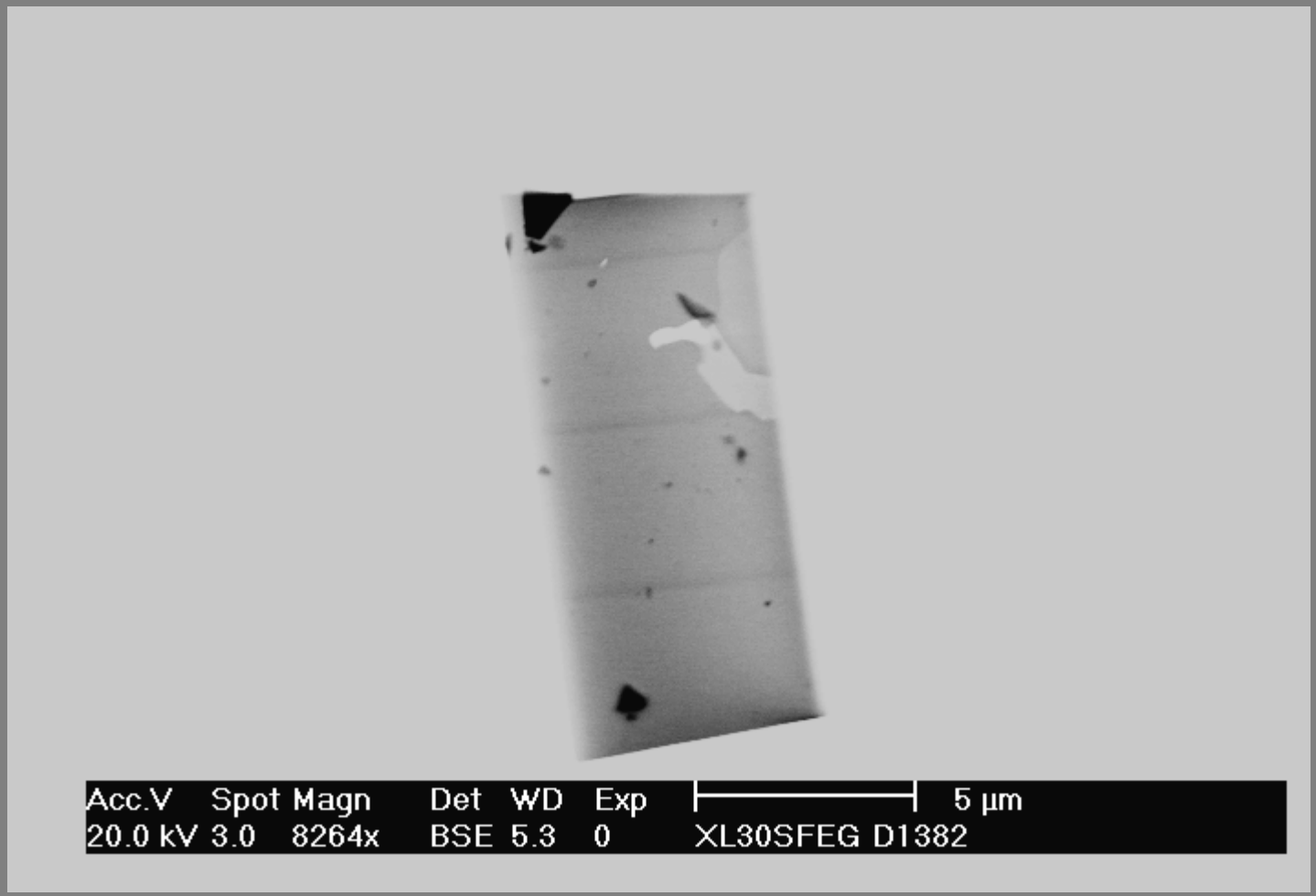
LSPES - Univ. Lille and CNRS :

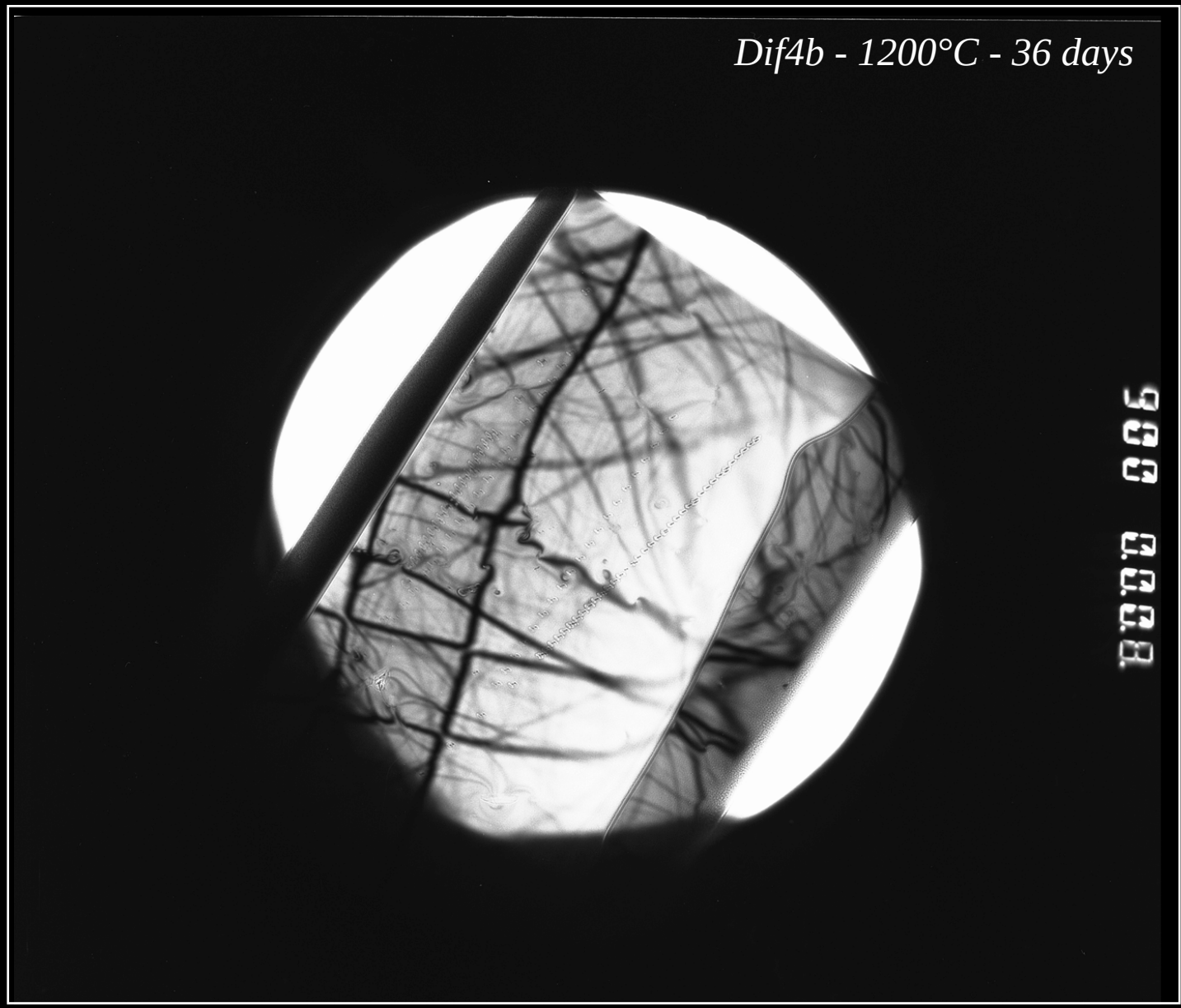
Philips CM30 with NORAN EDS, STEM mode
(spot size, 5.6 nm)

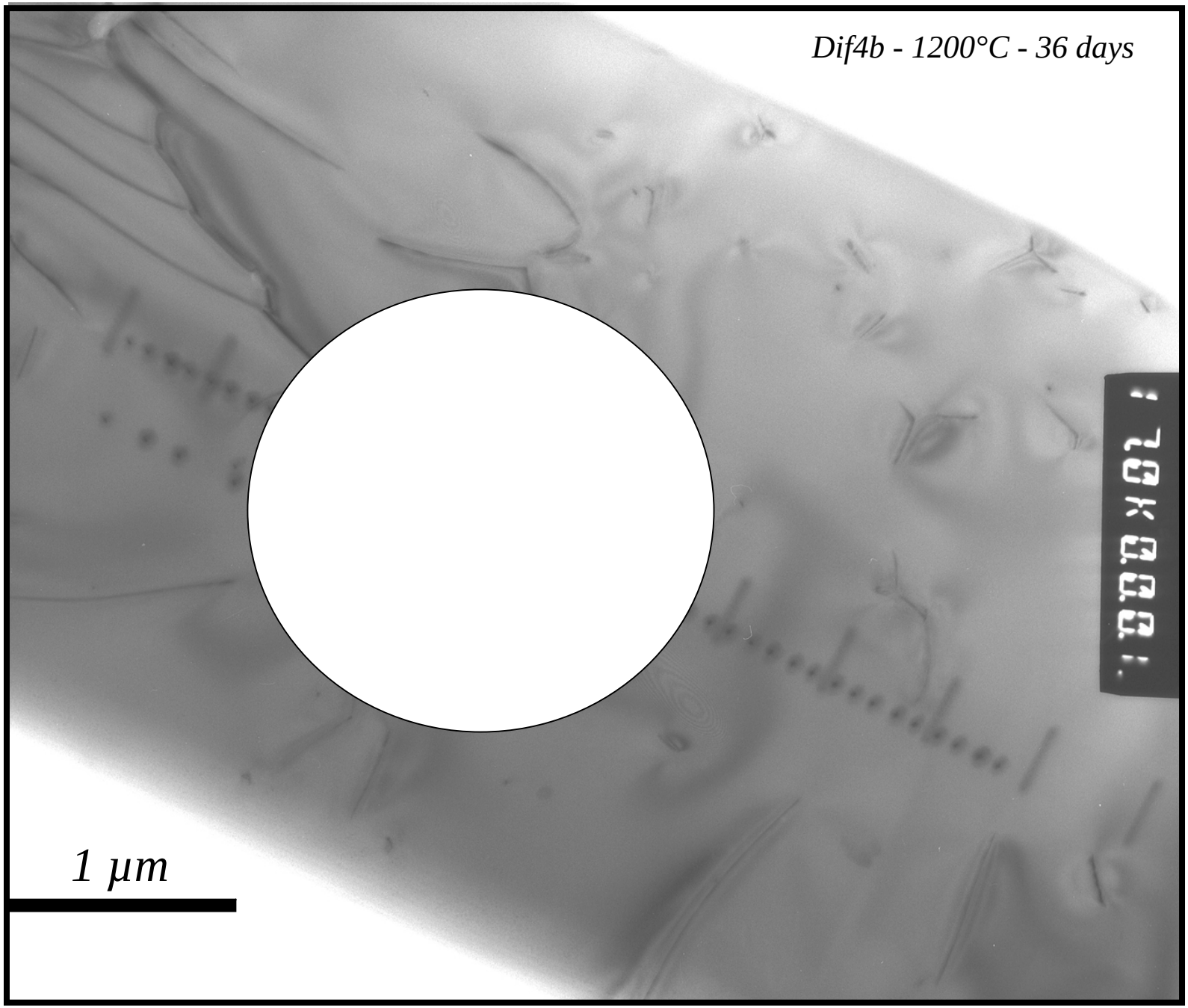


Focused Ion Beam technique

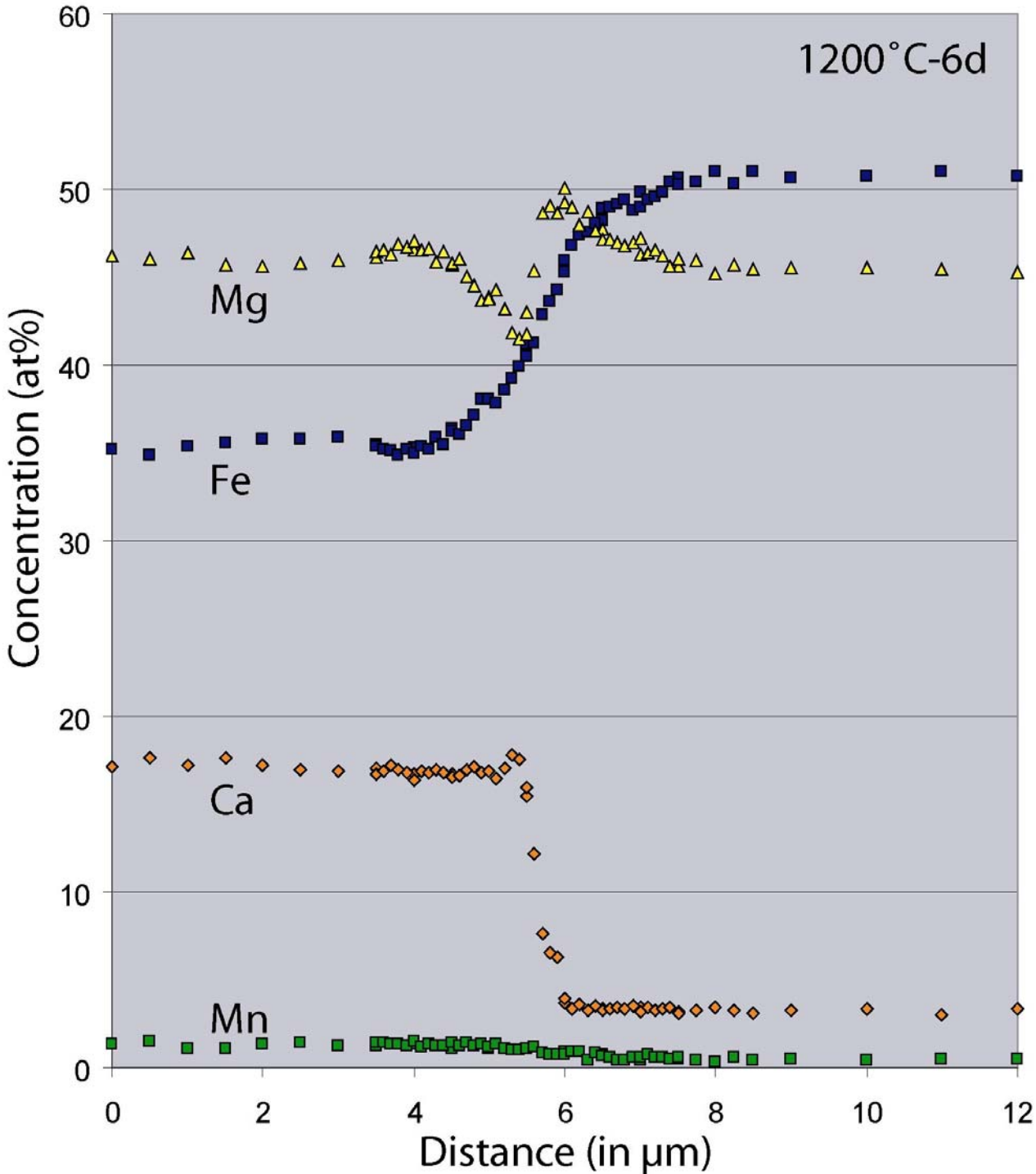

Beam
30.0 kV
Mag
10.0 kX
Tilt
40.0°
pA
395
Det
CDM-E
11/05/02
12:50:08
FWD
18.0
5 µm


Acc.V Spot Magn Det WD Exp 5 µm
20.0 kV 3.0 8264x BSE 5.3 0 XL30SFEG D1382


Dif4b - 1200°C - 36 days

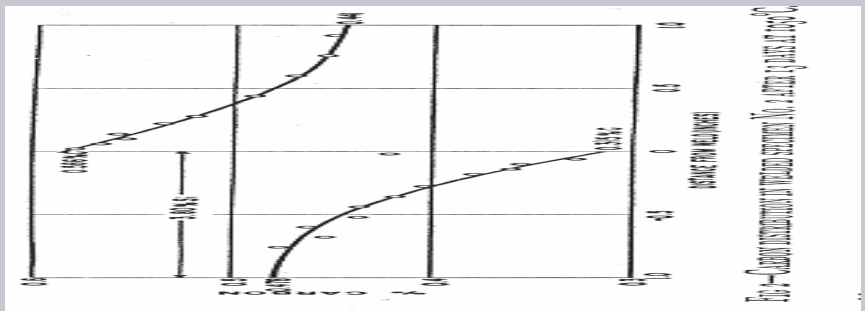

Dif4b - 1200°C - 36 days
1 µm

Some preliminary results


1200˚C-6d
Concentration (at%)
Distance (in µm)
Mg
Fe
Ca
Mn
0
10
20
30
40
50
60
0
2
4
6
8
10
12

Mg

Fe



Darken, 1949

*D matrix calculated with MultiDiFlux**

- *Mn : ignored*
- *Ca : dependent component*

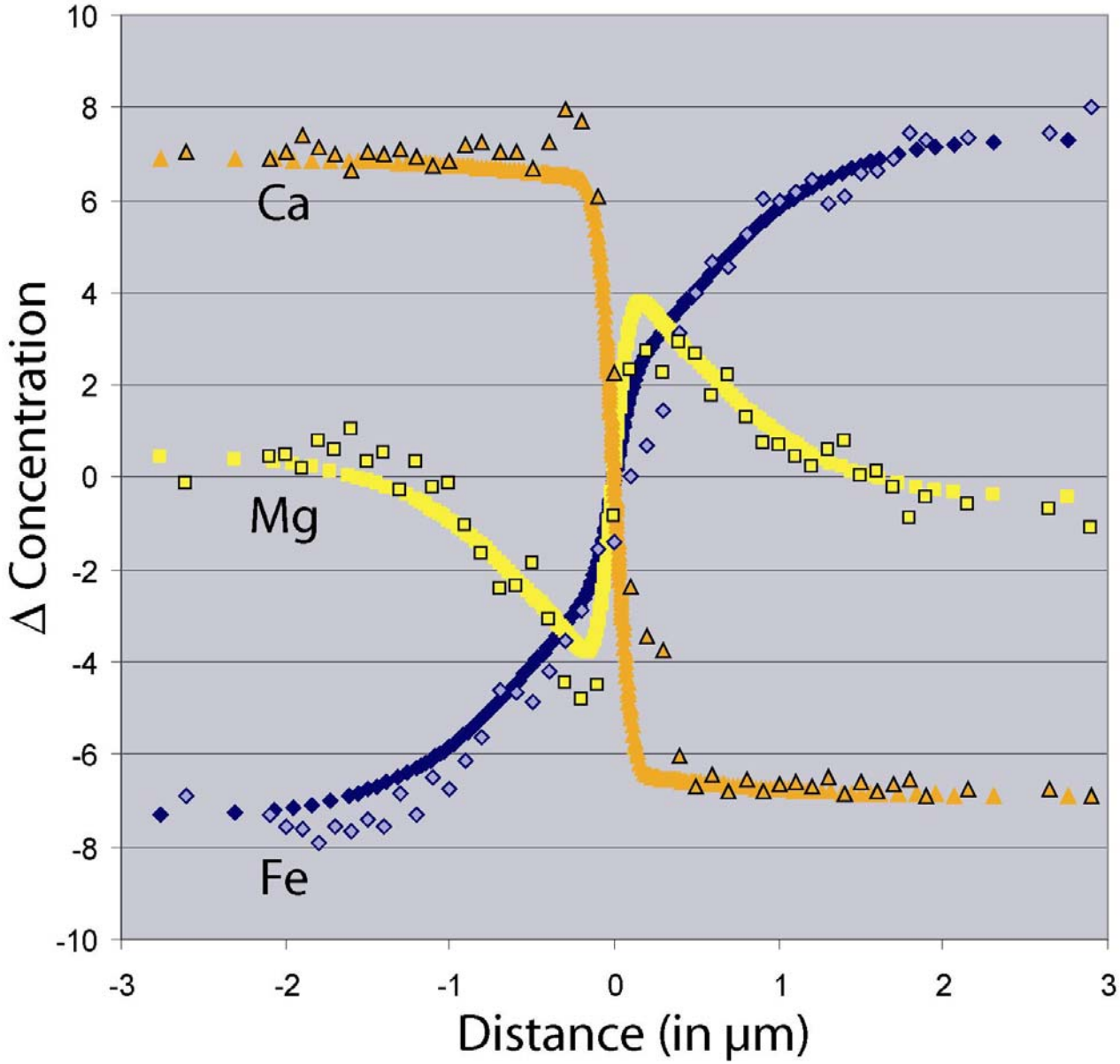
At 1200°C – 1.3 GPa

	Fe	*Mg*
Fe	$5.91e^{-19}$	$-2.15e^{-19}$
Mg	$-5.34e^{-19}$	$2.02e^{-19}$

m^2s^{-1}

** Dayananda and coworkers*

*Curves calculated with Profiler**



**Morral and coworkers*

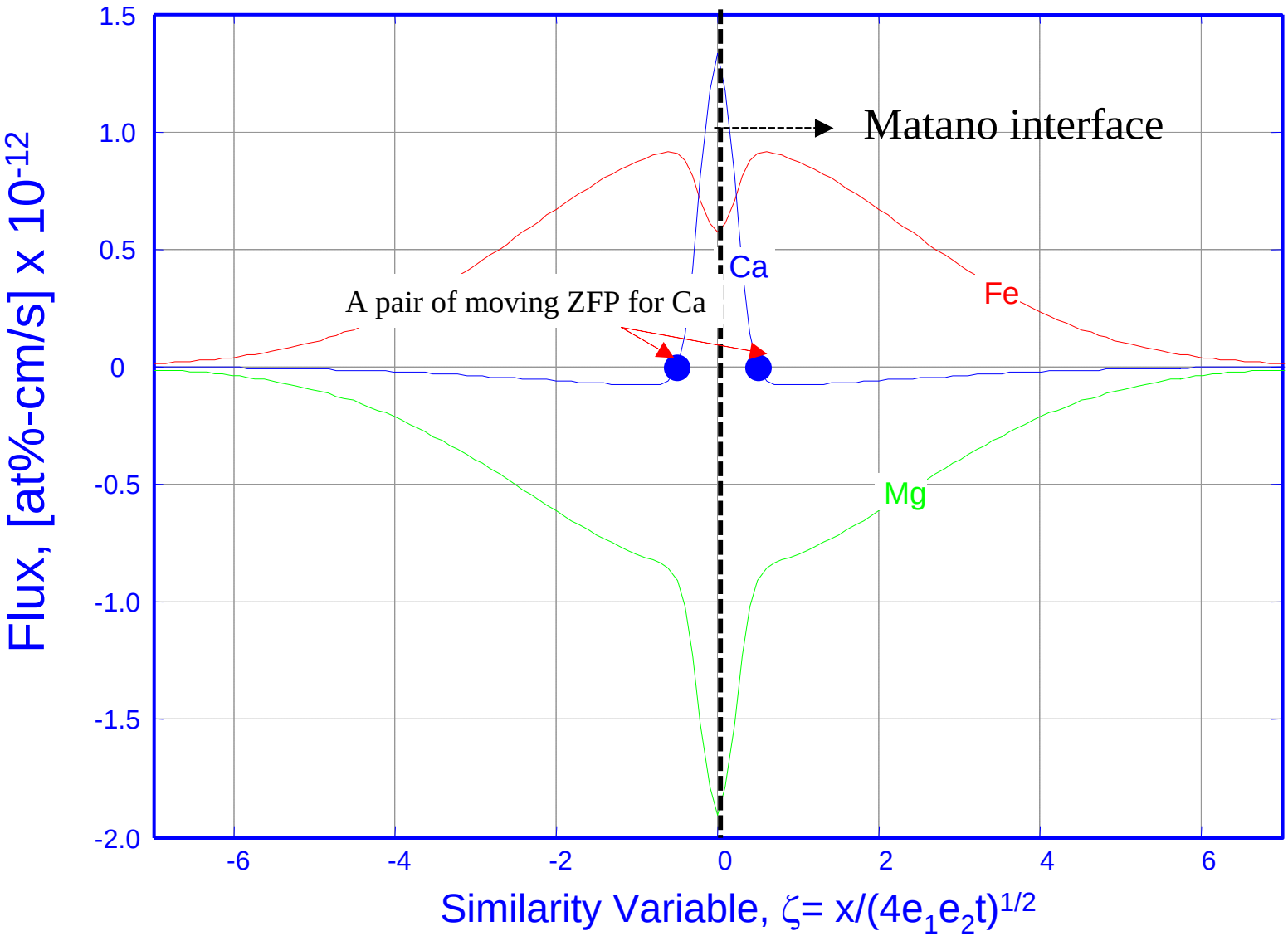
	Fe	*Mg*
Fe	$5.91e^{-19}$	$-2.15e^{-19}$
Mg	$-5.34e^{-19}$	$2.02e^{-19}$

m^2s^{-1}

Zero Flux Planes in Garnet

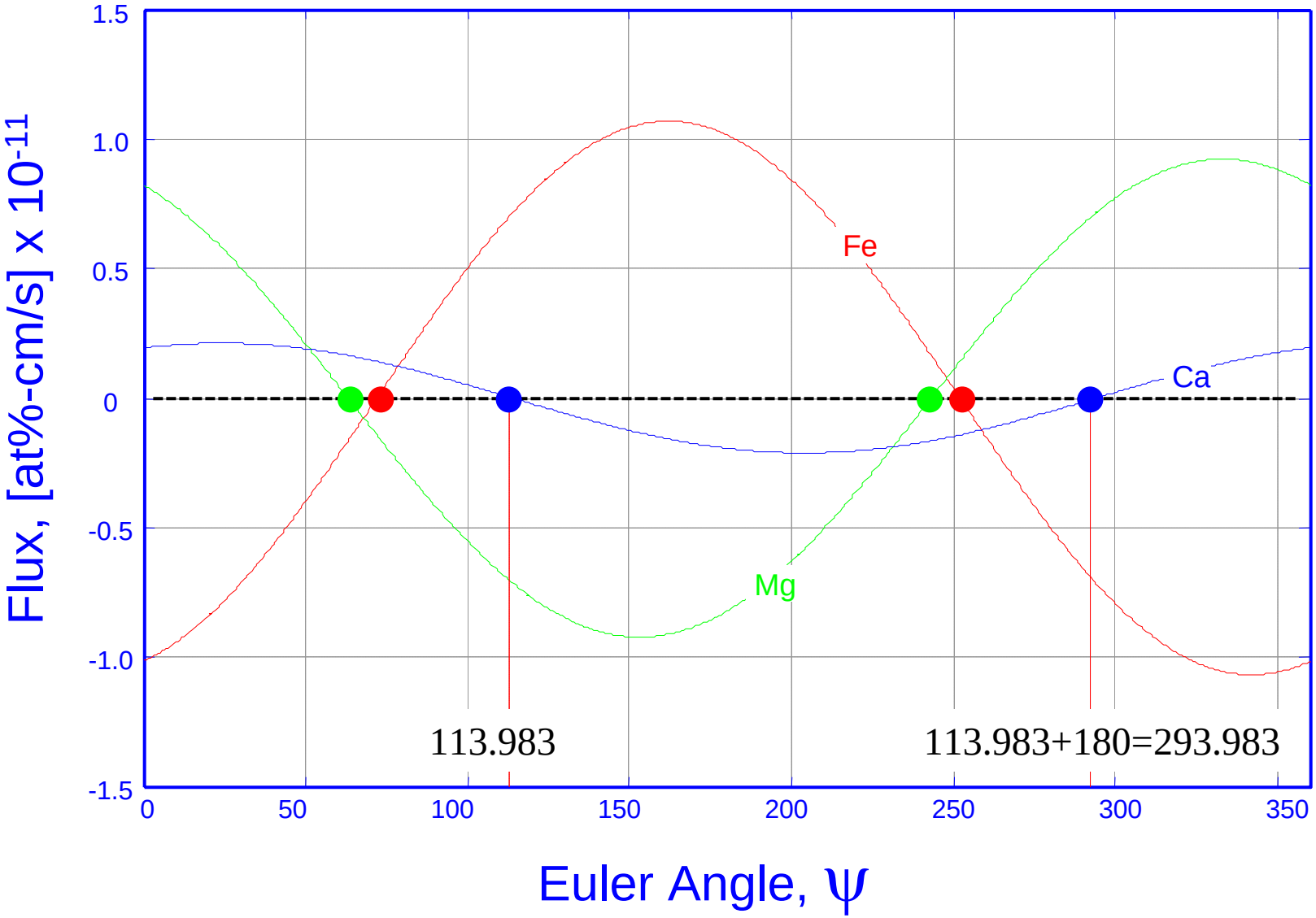
Moving ZFPs for Ca

$\psi = 75^\circ$



Component Fluxes versus Euler Angle

$\zeta = 0$

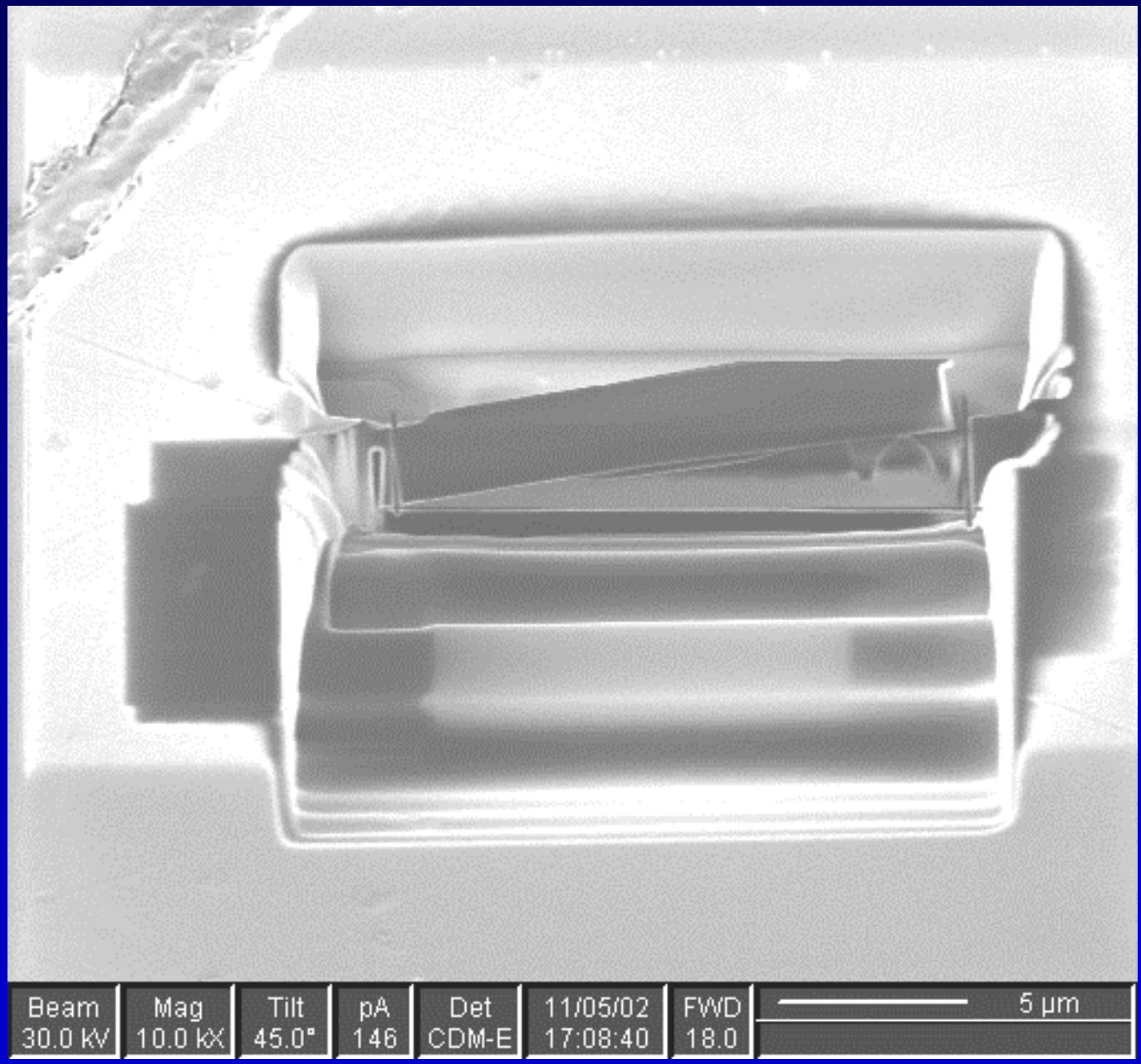


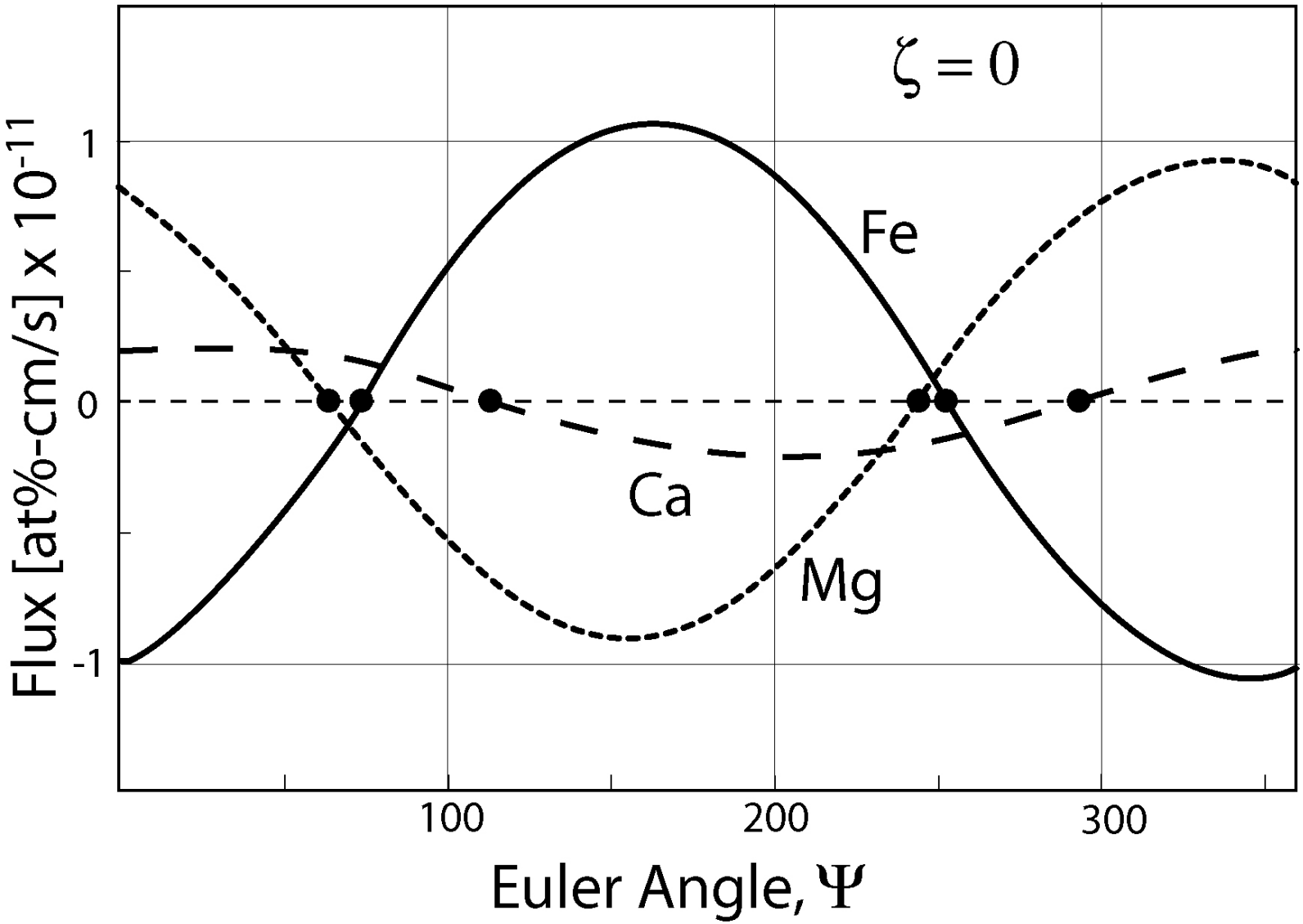
Conclusion

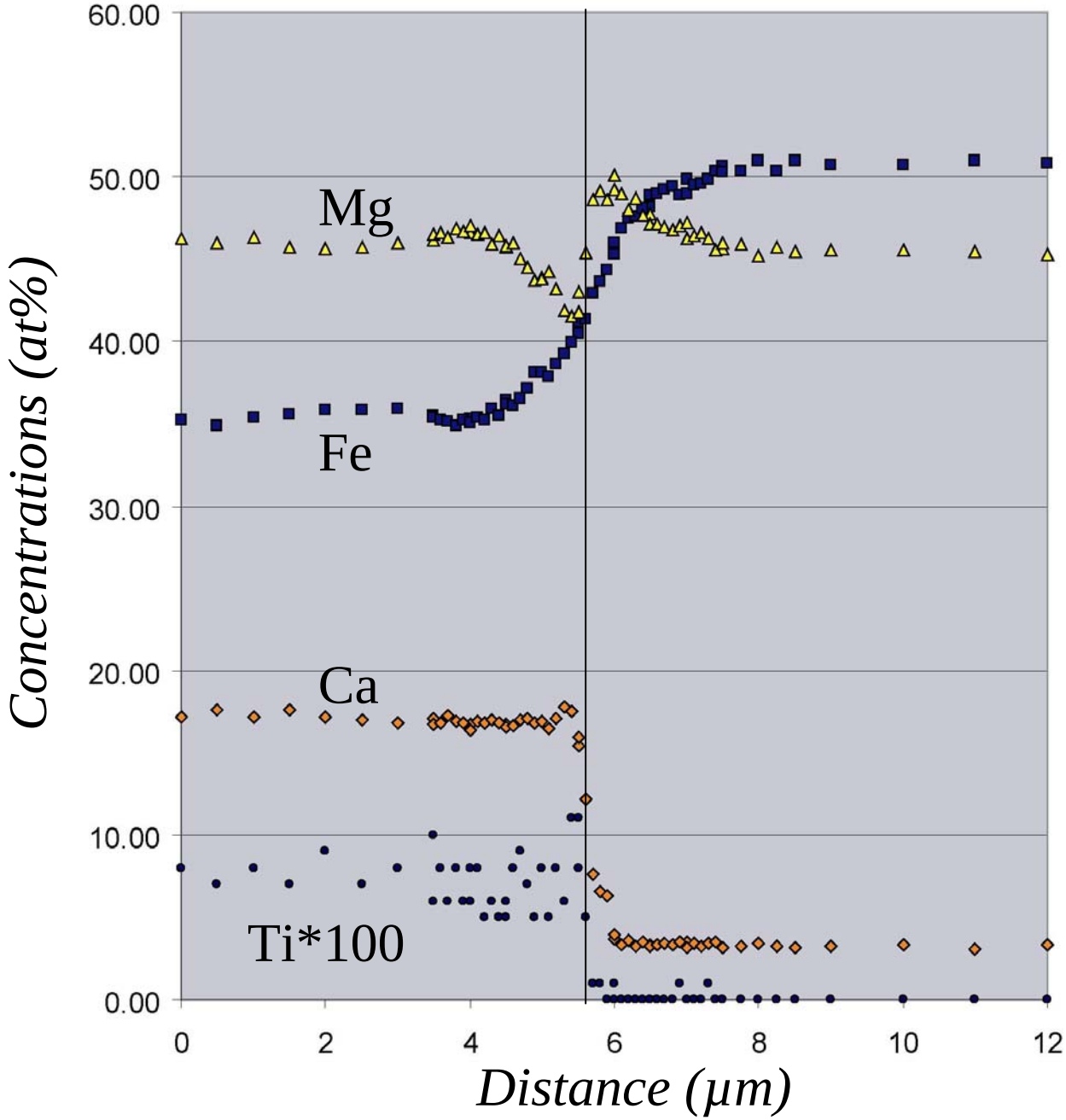
- Garnets are excellent materials to explore multicomponent diffusion in minerals.

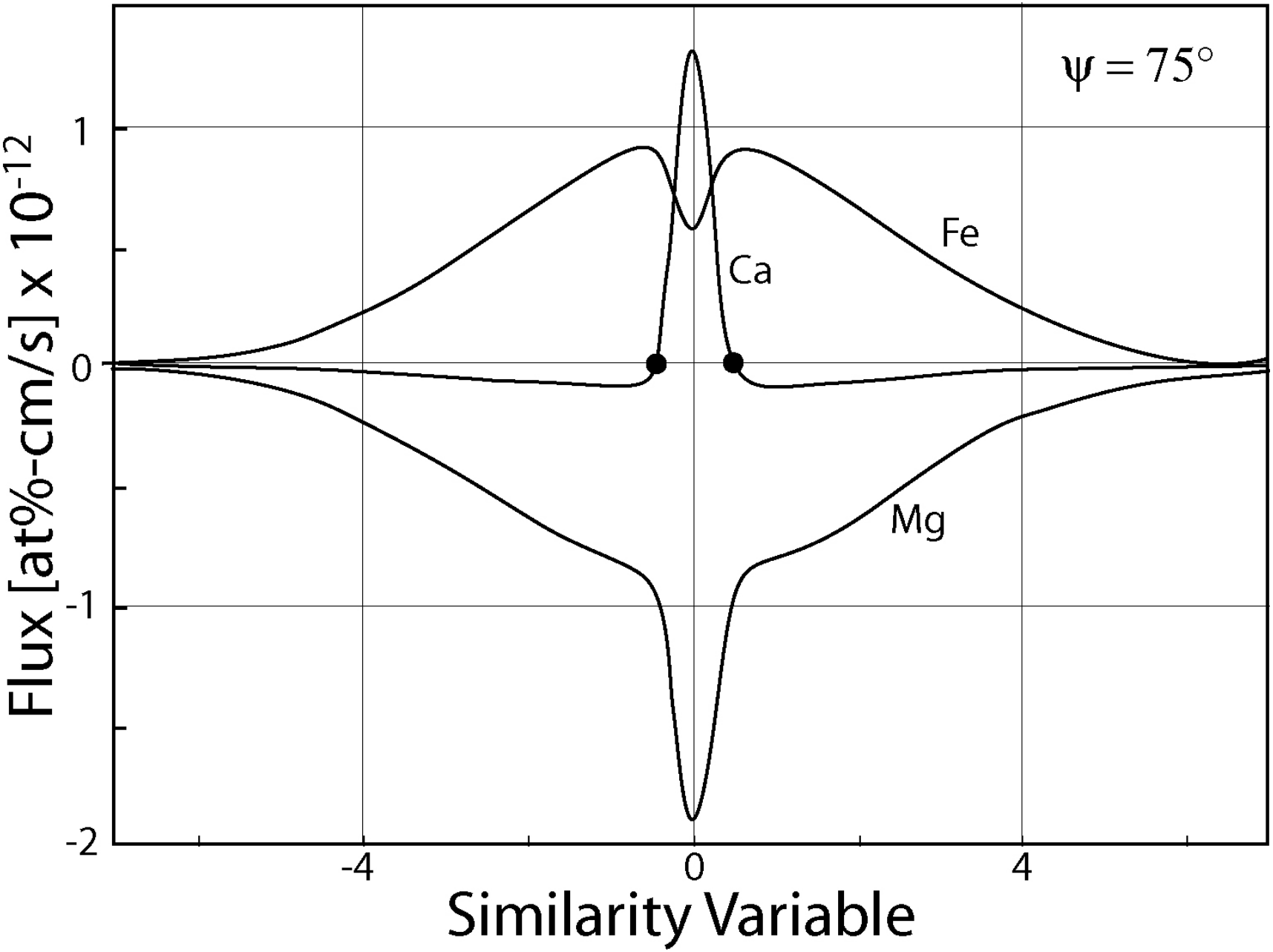
- Our experimental technique coupled with ATEM analyses allows the determination of extremely small diffusion coefficients.

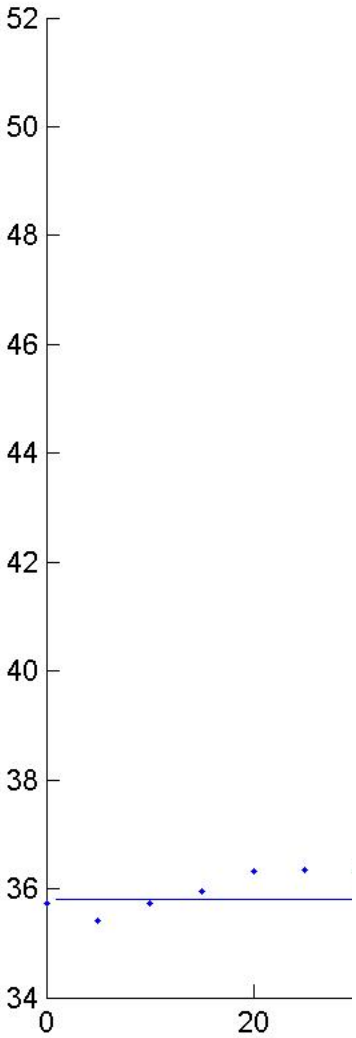
- Concepts developed in Material Sciences can be applied in Earth Sciences. Conversely, minerals might prove useful for a better understanding of diffusion in multicomponent systems.

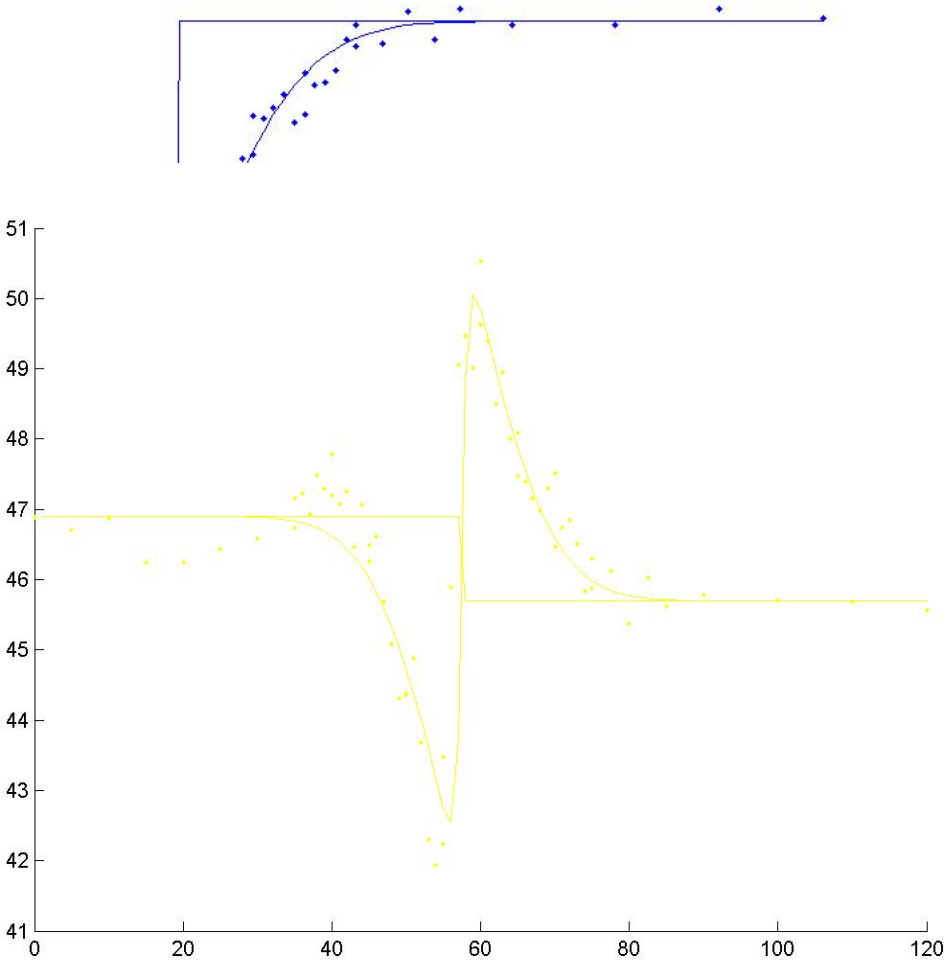

Beam
30.0 kV
Mag
10.0 kX
Tilt
45.0°
pA
146
Det
CDM-E
11/05/02
17:08:40
FWD
18.0
5 µm


ζ = 0
Fe
Ca
Mg
1
0
-1
Flux [at%-cm/s] x 10-11
100
200
300
Euler Angle, Ψ


60.00
50.00
40.00
30.00
20.00
10.00
0.00
Concentrations (at%)
Mg
Fe
Ca
Ti*100
0
2
4
6
8
10
12
Distance (µm)


ψ = 75°
Fe
Ca
Mg
1
0
-1
-2
-4
0
4
Flux [at%-cm/s] x 10-12
Similarity Variable


52
50
48
46
44
42
40
38
36
34
0
20


51
50
49
48
47
46
45
44
43
42
41
0
20
40
60
80
100
120