Introduction to SEM-CL

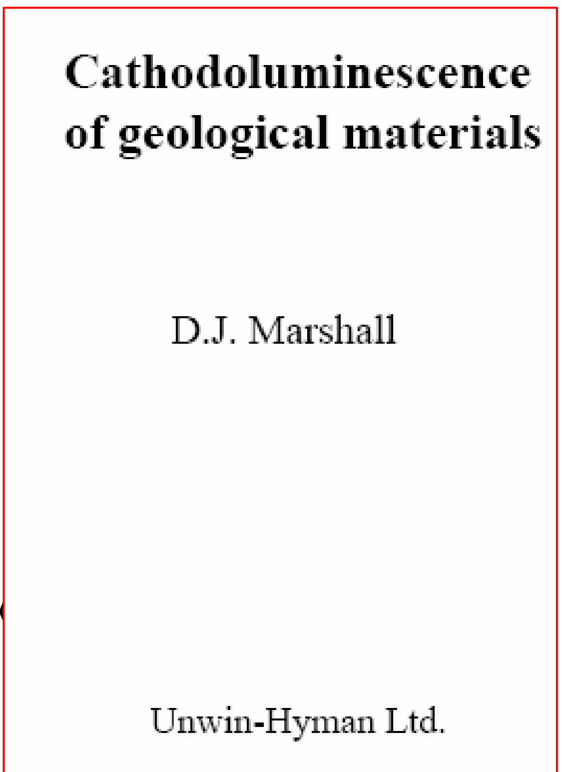
Applications to geology

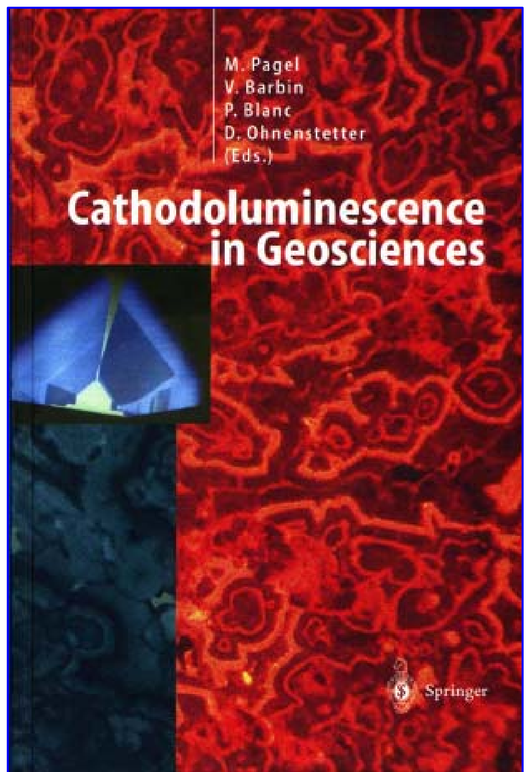
Content

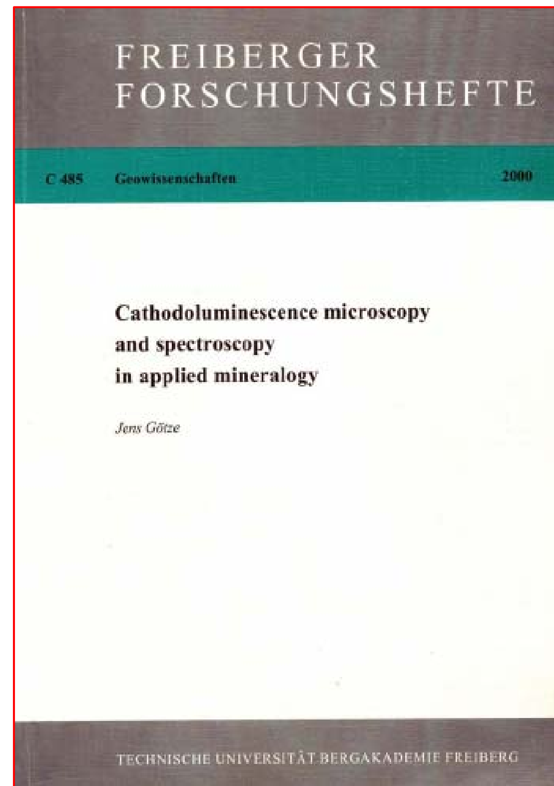
- Literatures
- Principle of Cathodoluminescence
- SEM-CL
- Application of SEM-CL

Literatures

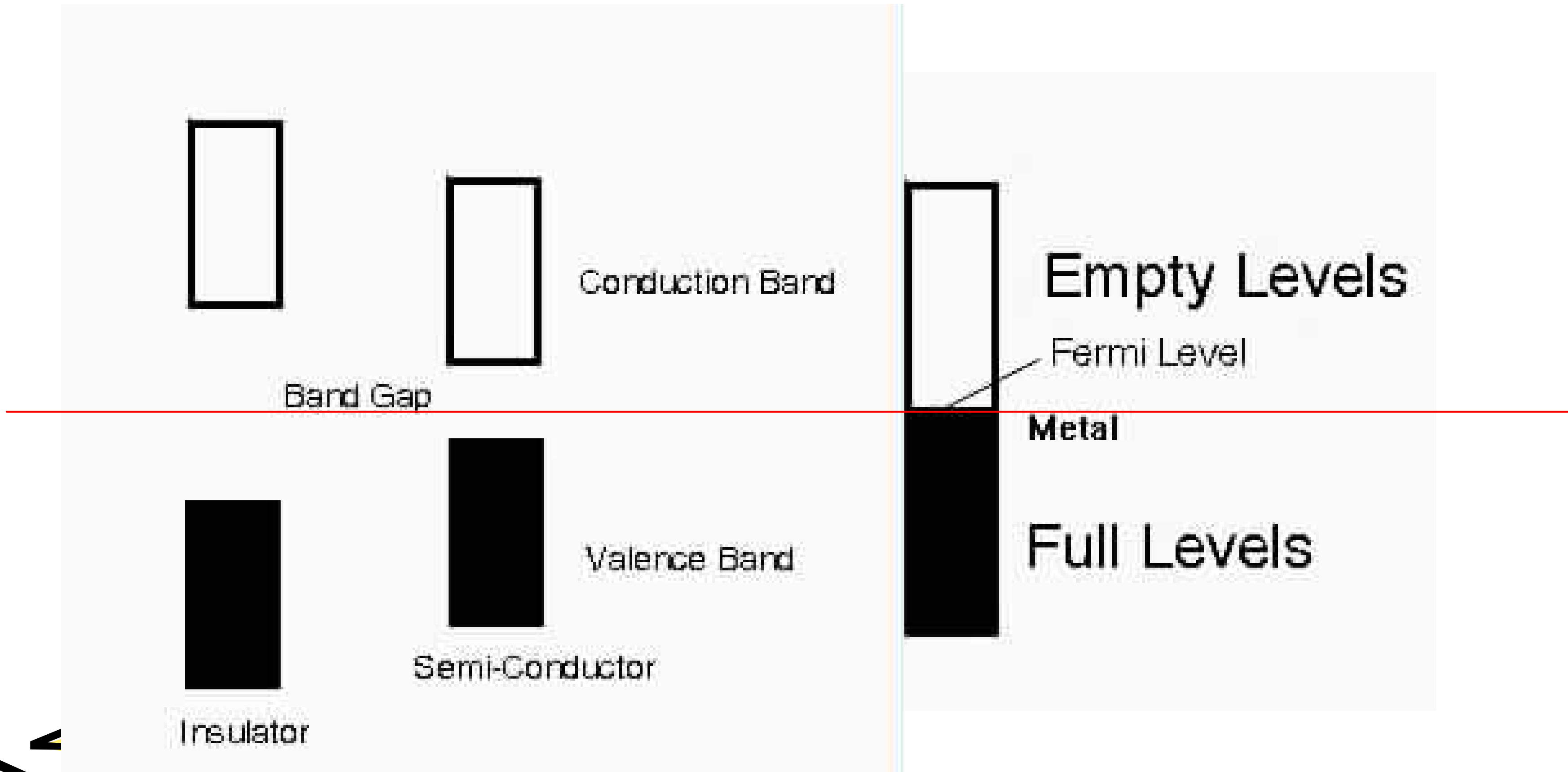
- Various Journal Papers
- CL books specialized in Geosciences



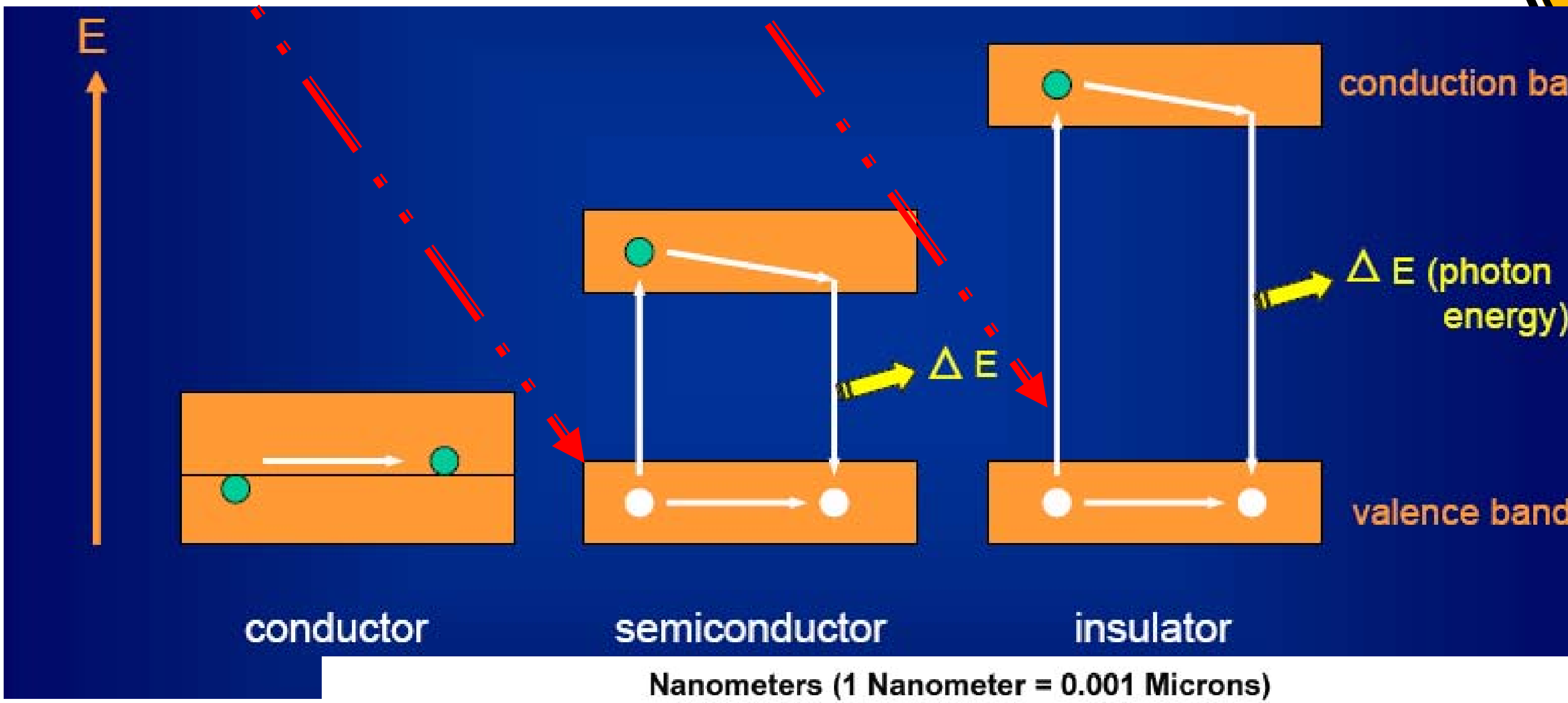


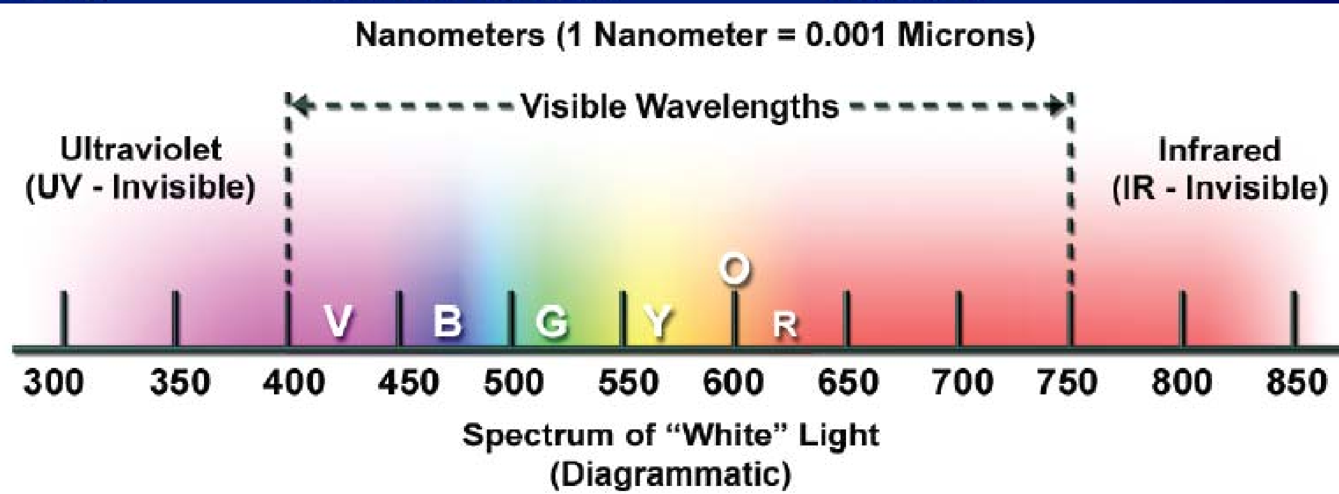


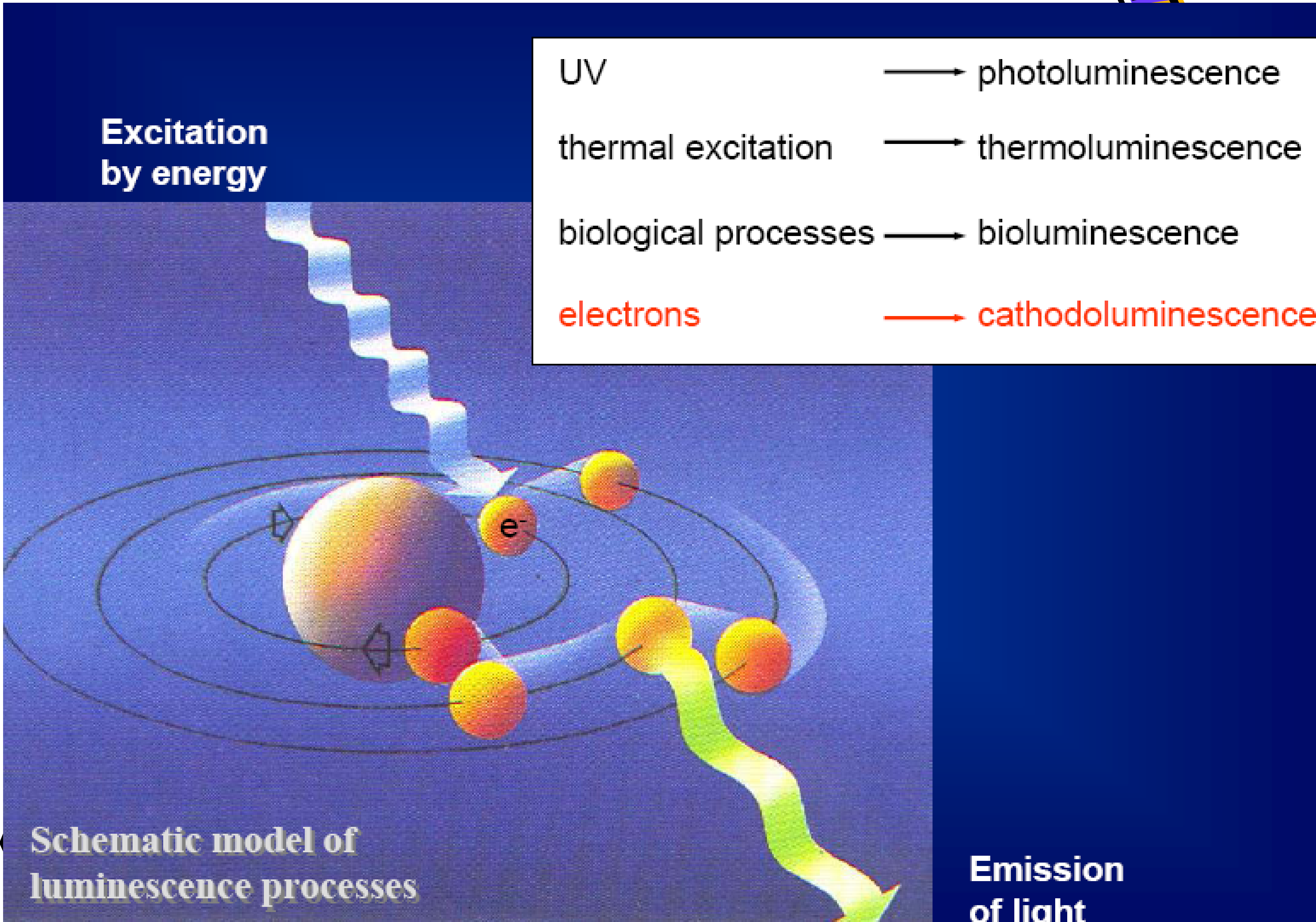
Basic Theory
- energy bands



Electron Transitions






Excitation
by energy
UV → photoluminescence
thermal excitation → thermoluminescence
biological processes → bioluminescence
electrons → cathodoluminescence
e⁻
Schematic model of
luminescence processes
Emission
of light

Summary

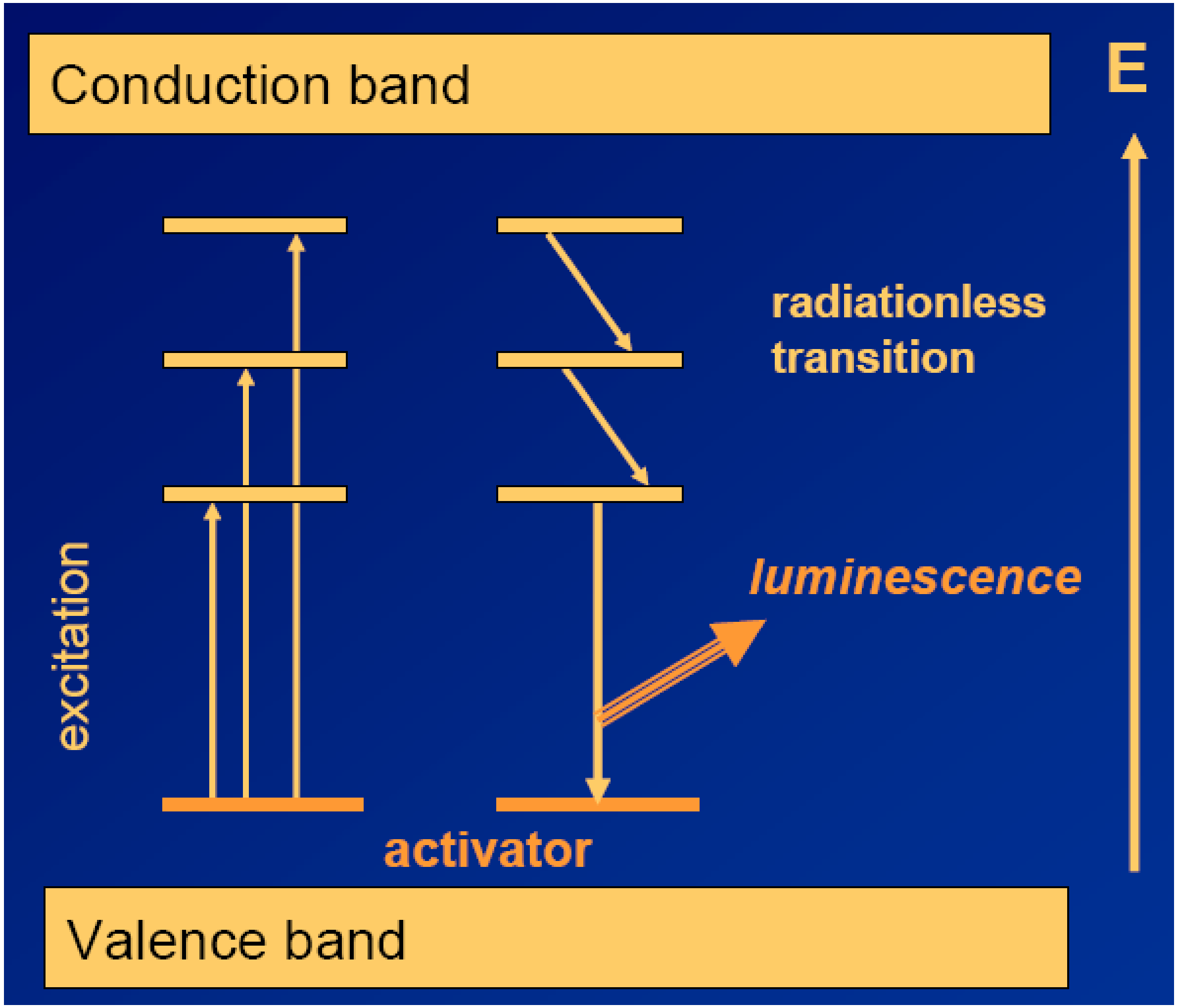
- Metal -- non luminescence
- Semiconductor – strong luminescence
- Insulator 1 – weak luminescence compared to semiconductor
- Insulator 2 – non luminescence due to large band gap

Defects and Impurities

- Structural Defects and impurities in the solid modify the electron properties of materials (band structure)

Activators

Luminescence Center



$$\lambda = \frac{hc}{E}$$

"the energy of a photon is proportional to its frequency"

Photon Energy (E)
Wavelength (λ)
Frequency (c/λ)

Planck's constant (h)
Speed of Light (c)

$h = 6.626 \times 10^{-34}$ J-s ; $c = 3.0 \times 10^{17}$ nm/sec

Defects and Impurities

Application - quartz

$$\lambda = \frac{hc}{E}$$

Table 1. Proposed origins of cause based on impurities/defects

Wavelength	Proposed origin of cause [2]
175 nm	Intrinsic emission of pure SiO_2
290 nm	Oxygen deficient center
340 nm	$[AlO_4/Li^+]$ center
380-390 nm	$[AlO_4/M^+]$ center, M=Li^+, Na^+, H^+
420 nm	Intrinsic emission
450 nm	Intrinsic defect; self-trapped exciton
500 nm	$[AlO_4]^0$ center; $[AlO_4/M^+]$ center, M=Li^+, Na^+, H^+
580 nm	Self-trapped exciton; E' center
620-650 nm	Oxygen vacancy, NBOHC with several precursors (e.g. OH^-)
705 nm	Substitutional Fe^{3+}

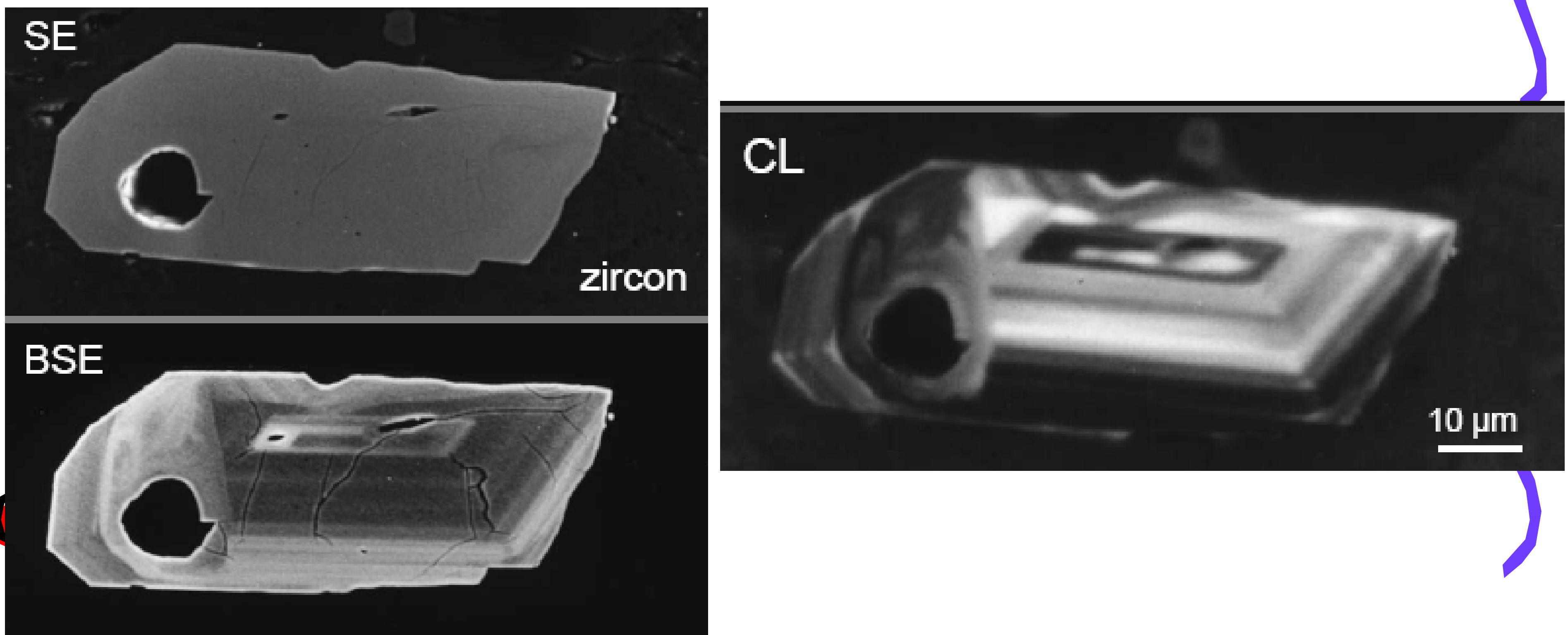
λ = wavelength

Example -- diamond

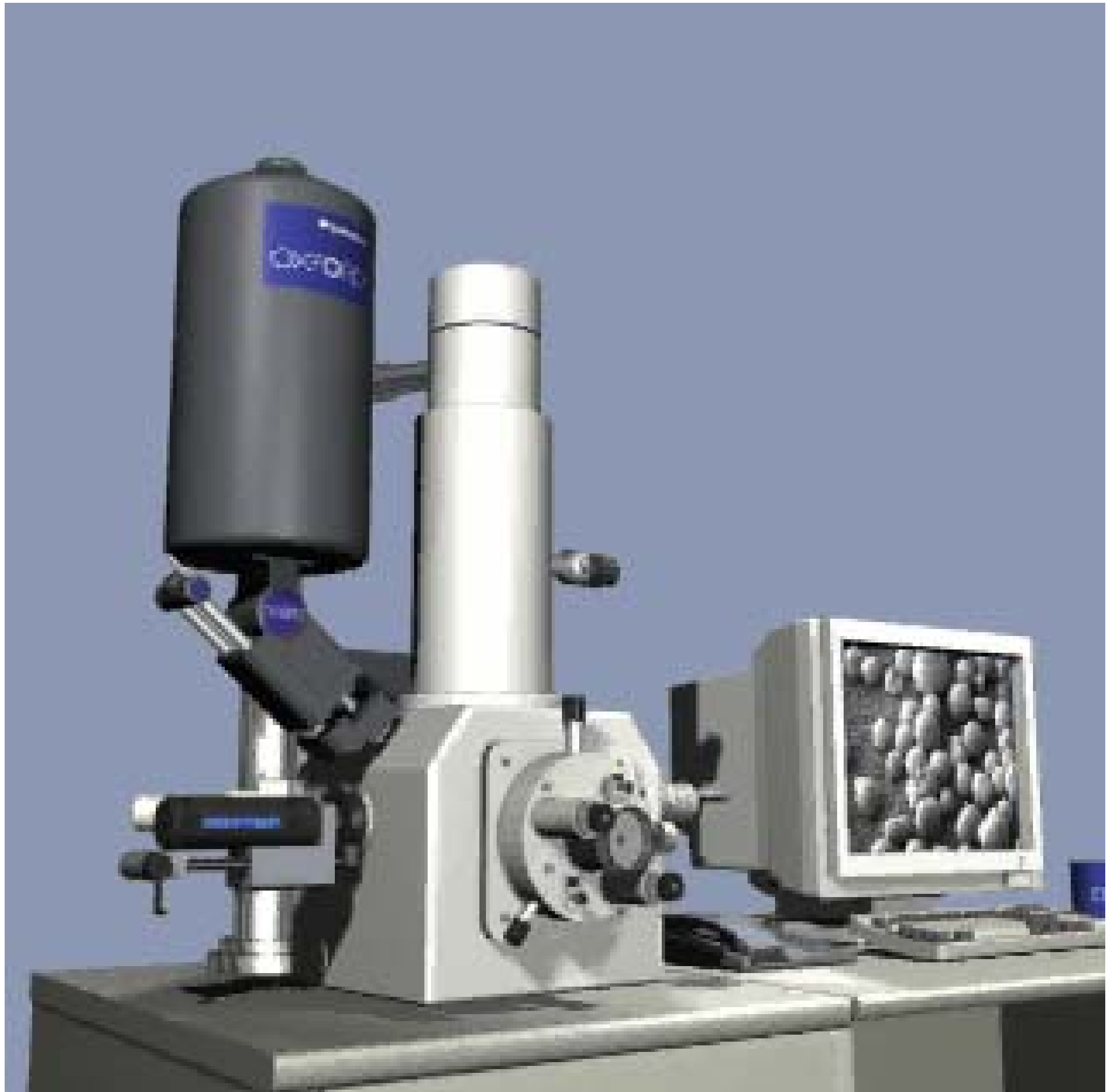
Nitrogen Impurities in Diamond Crystal

Advantage of CL

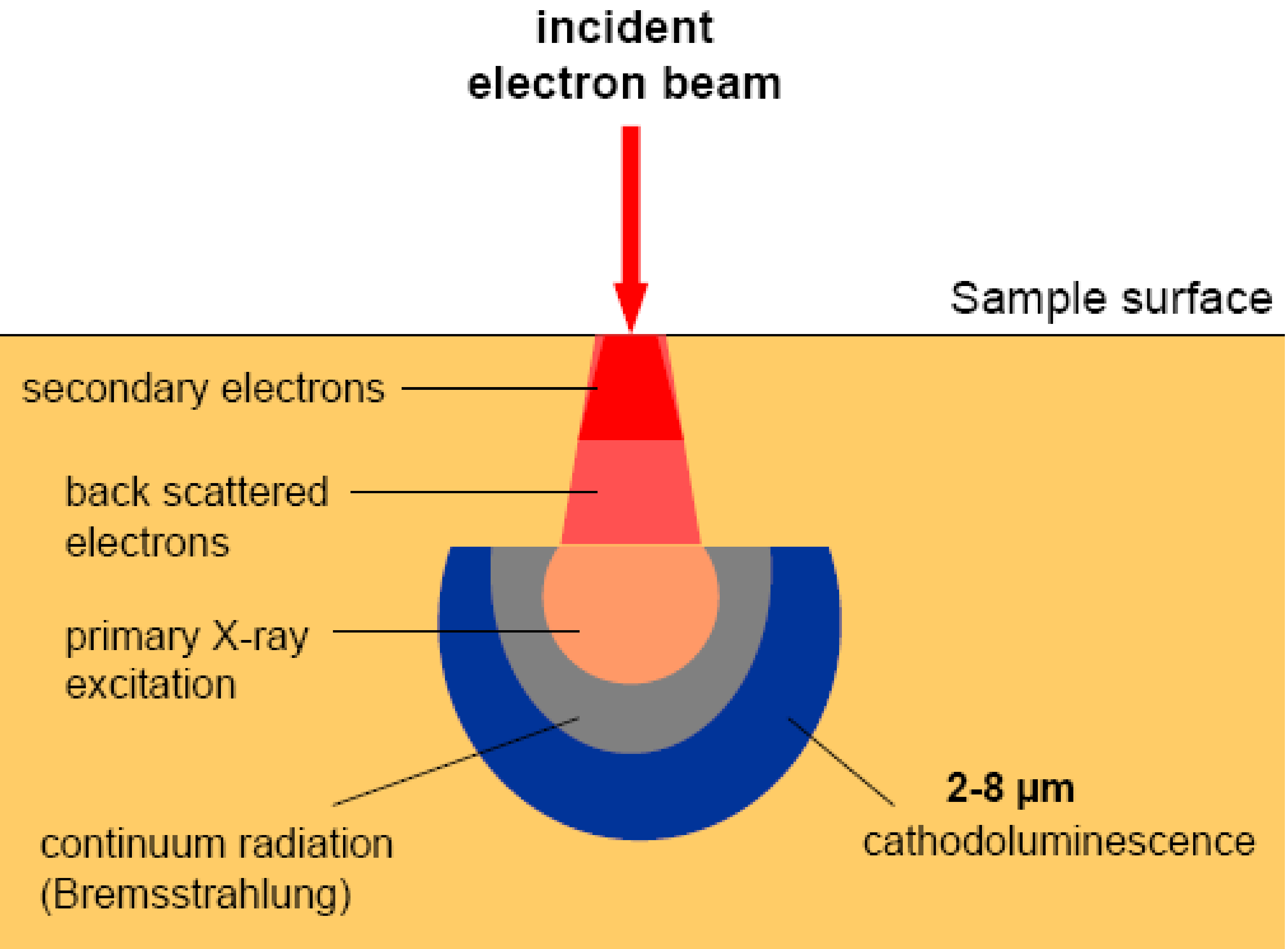
- Imaging structural and chemical variations in non-conductive materials, which are not able viewed by other techniques.



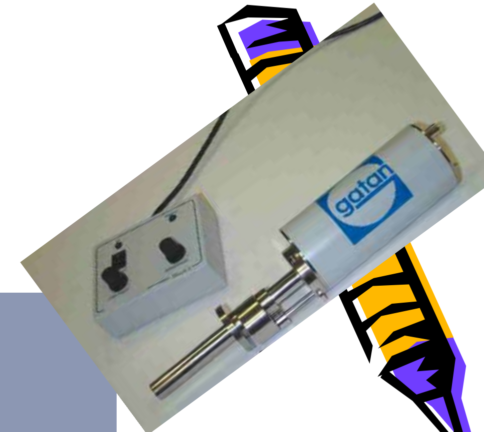
SEM and SEM-CL

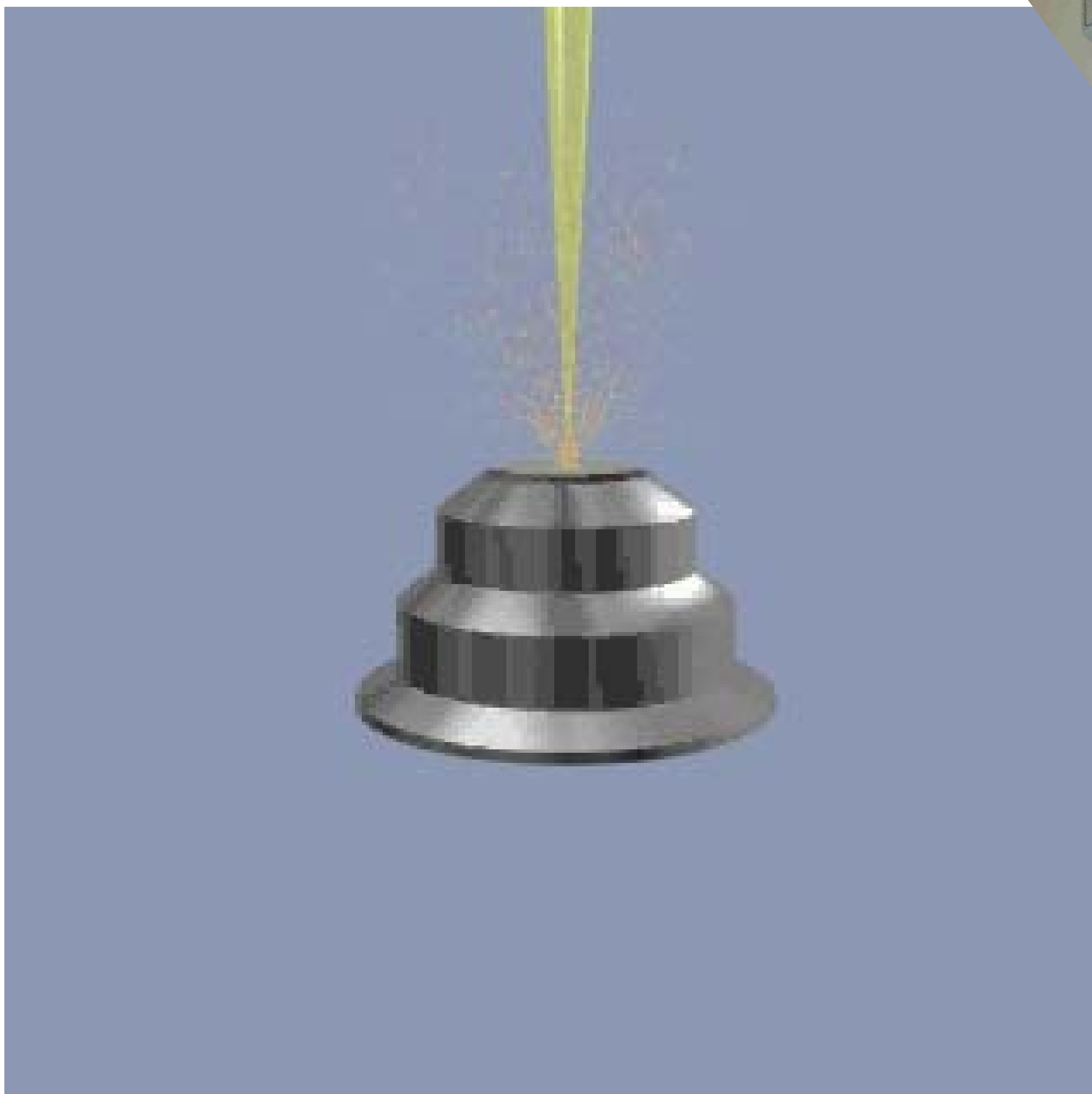


SEM Signals


incident
electron beam
Sample surface
secondary electrons
back scattered
electrons
primary X-ray
excitation
continuum radiation
(Bremsstrahlung)
2-8 µm
cathodoluminescence

SEM Signals



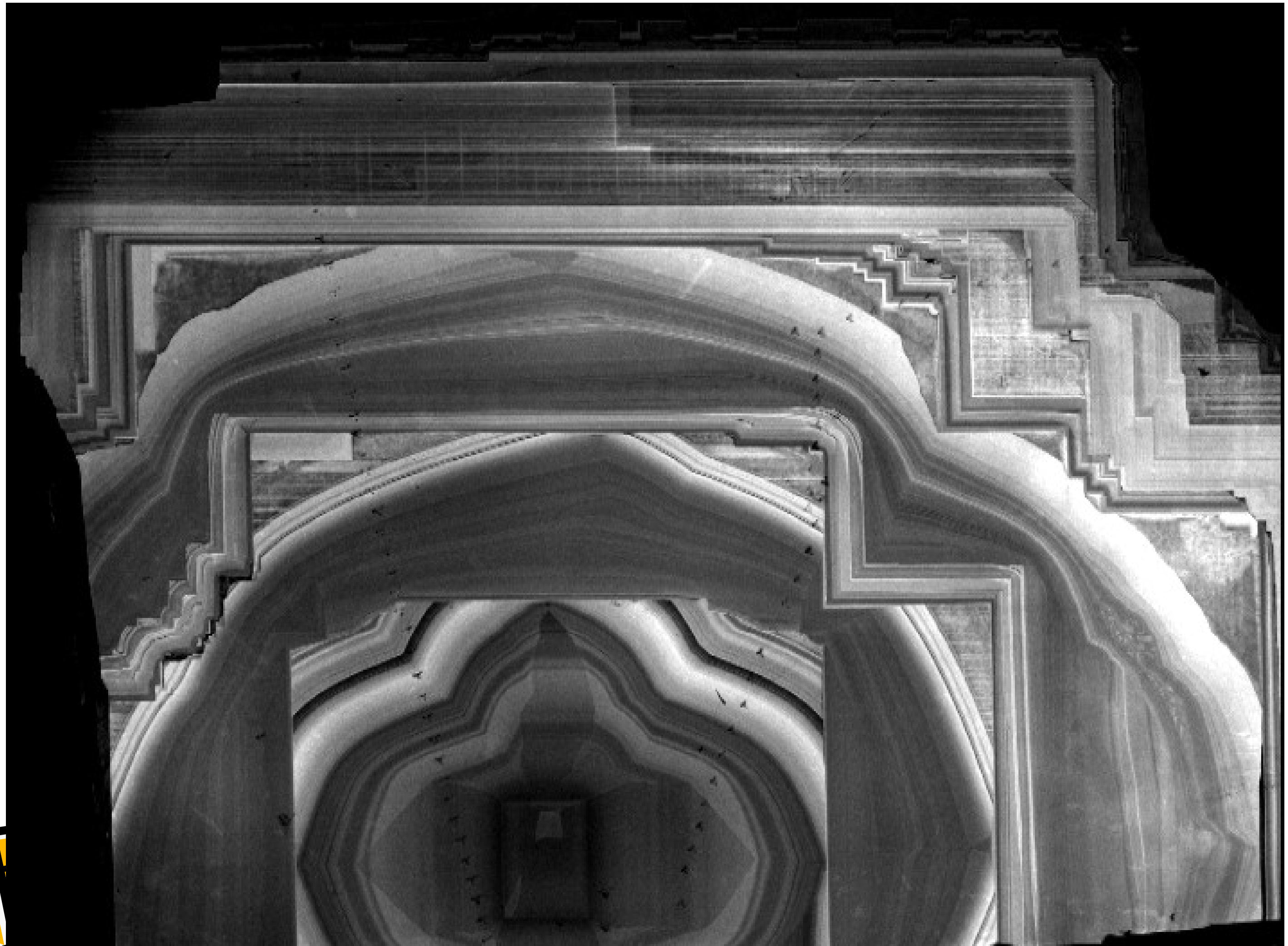


Applications

- Identification of minerals, mineral distribution
- Crystal chemistry
- Primary & secondary microstructure (growth zoning, deformation features, fluid flow, etc.)
- Reconstruction of geological process (mineral formation, alteration, diagenesis)

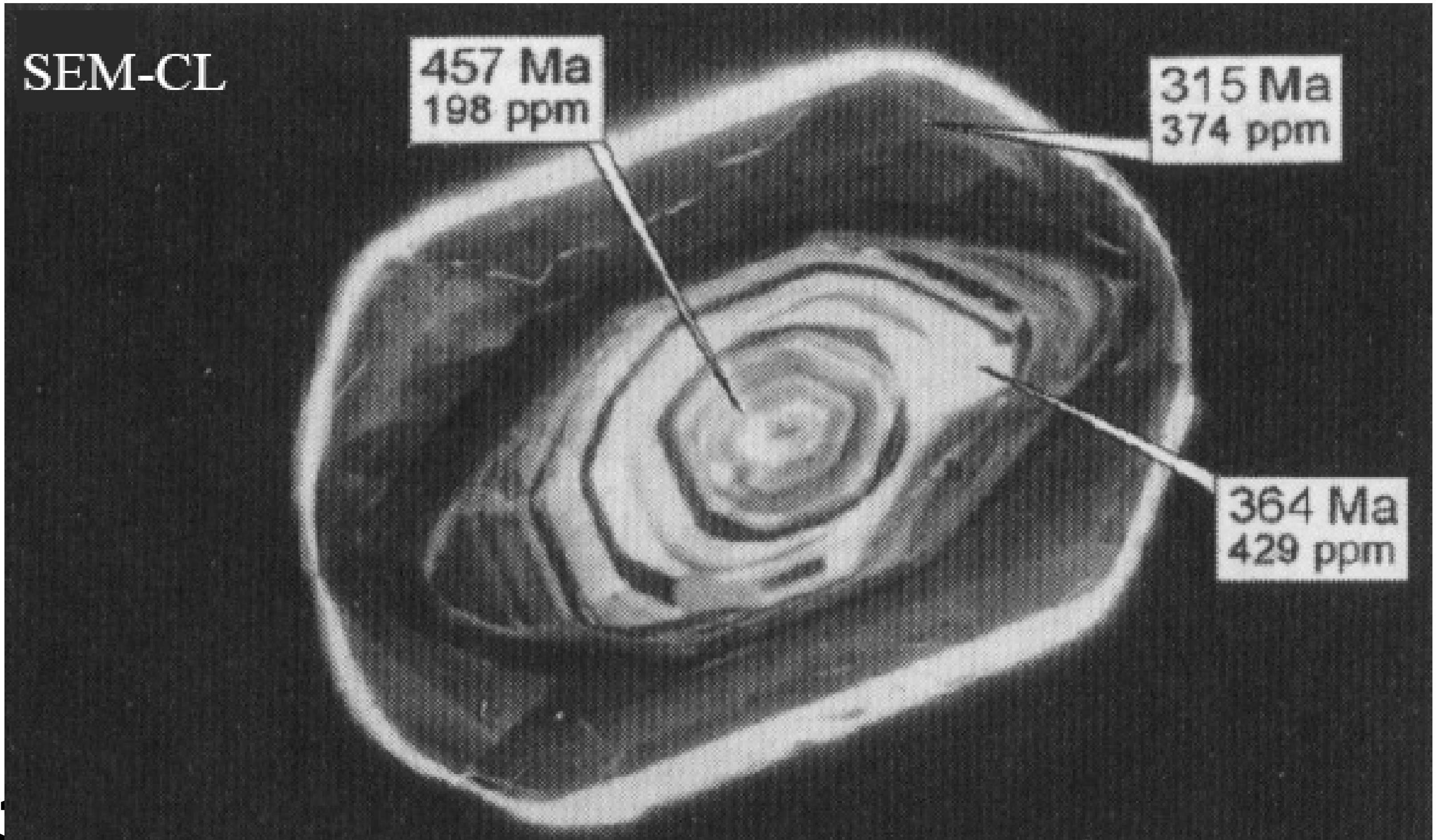
Crystal Chemistry

SEM-CL of Diamond



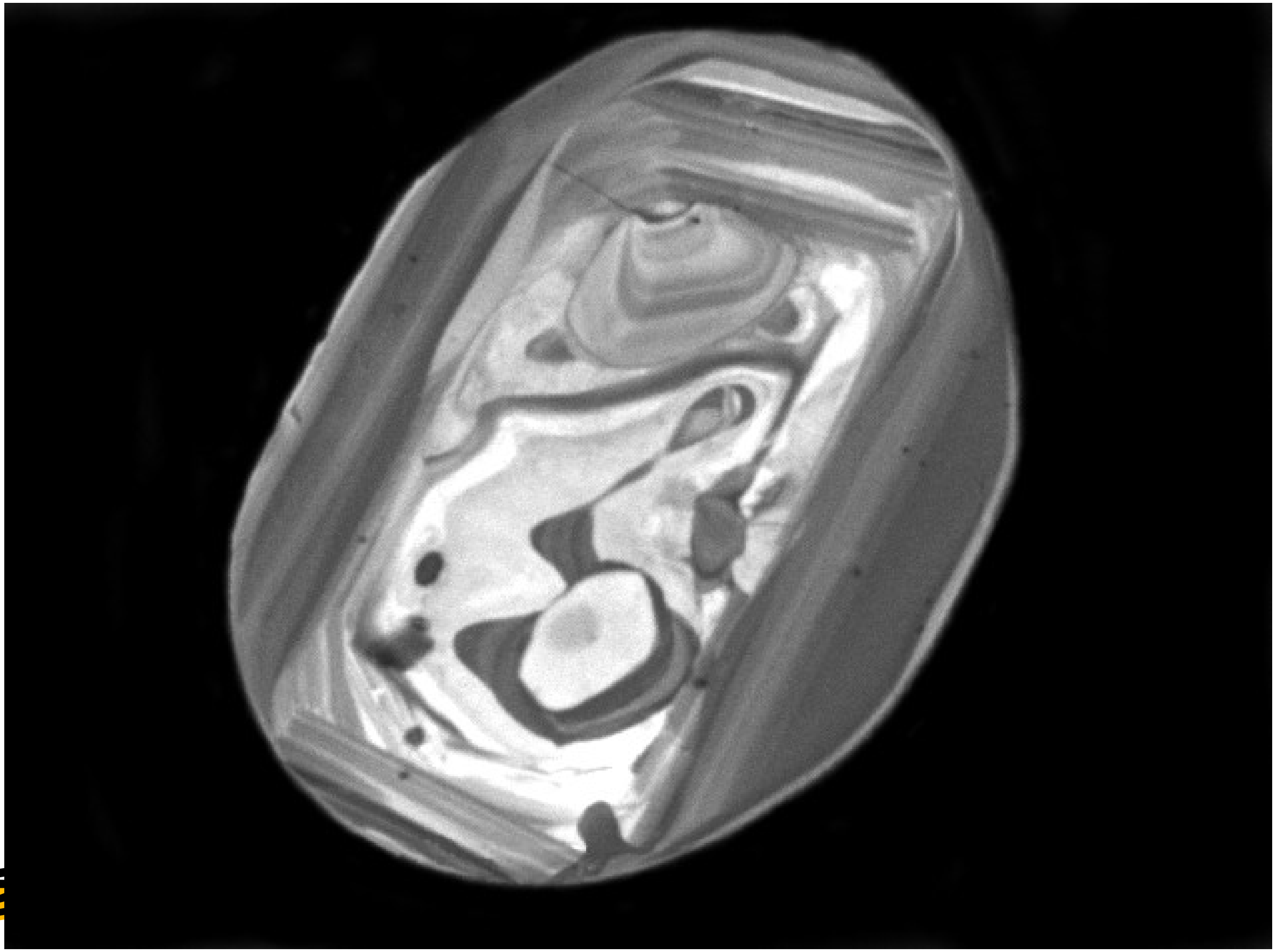
The growth zones reflect small variations in Nitrogen composition (0 to 1226 ppm).

Crystal Grow --zoning



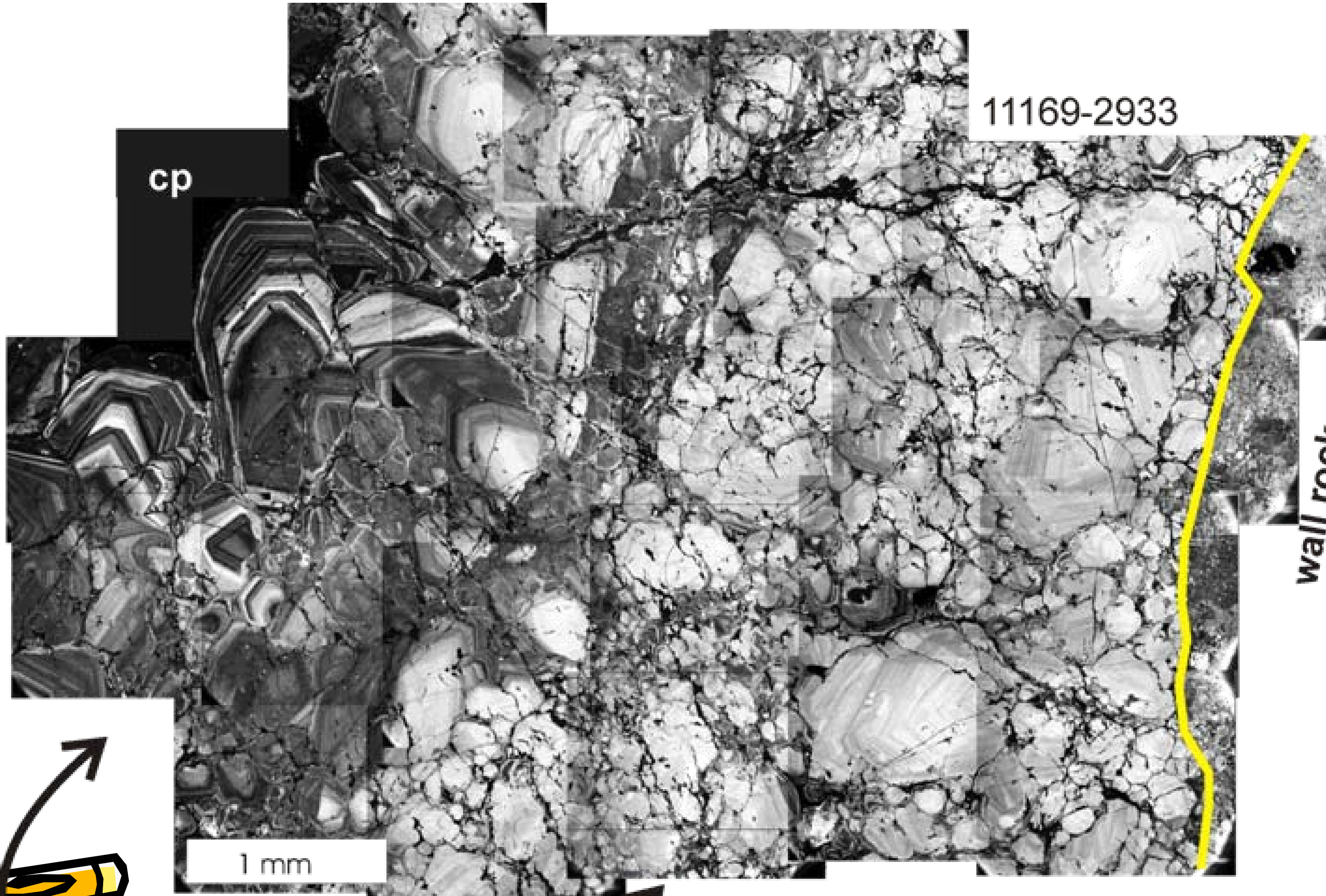
oscillatory

Crystal Grow --zoning



convolute

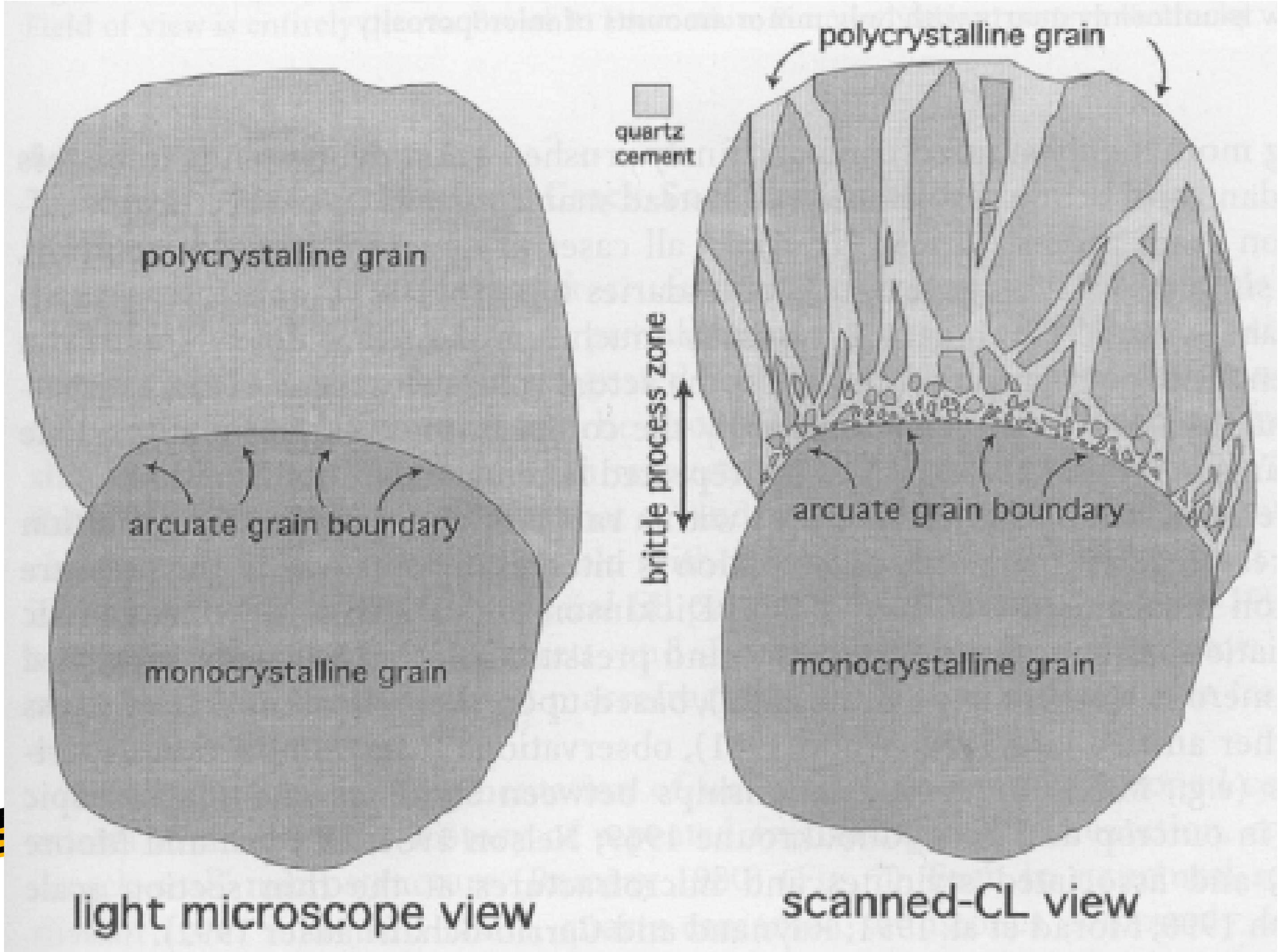
Crystal Grow --zoning



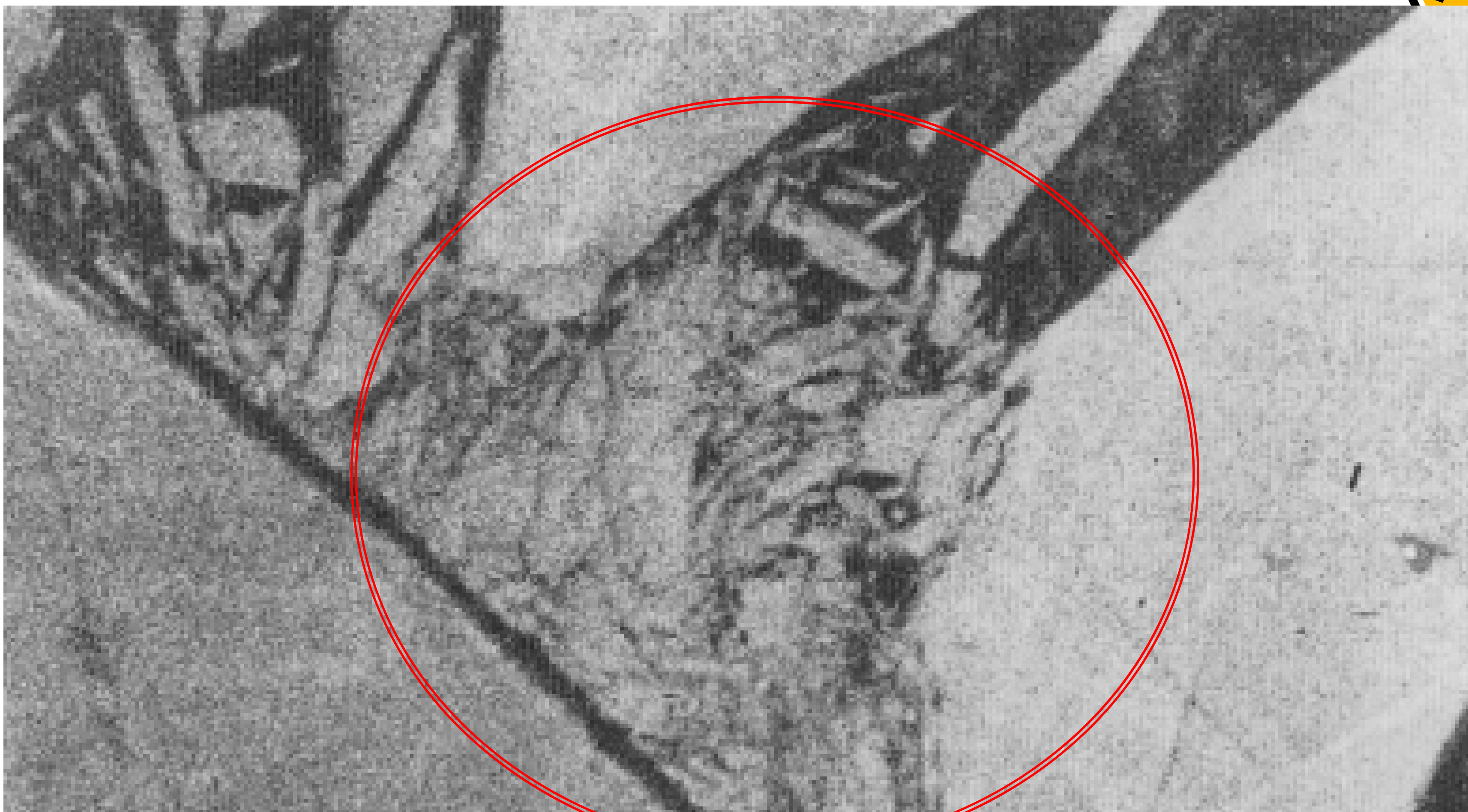
CL-dark overgrowth quartz with euhedral, oriented crystals

CL-bright mosaic of early qz: non-aligned grains with euhedral growth zones, cut by cobwebs & grain boundary dissolution-reprecipitation

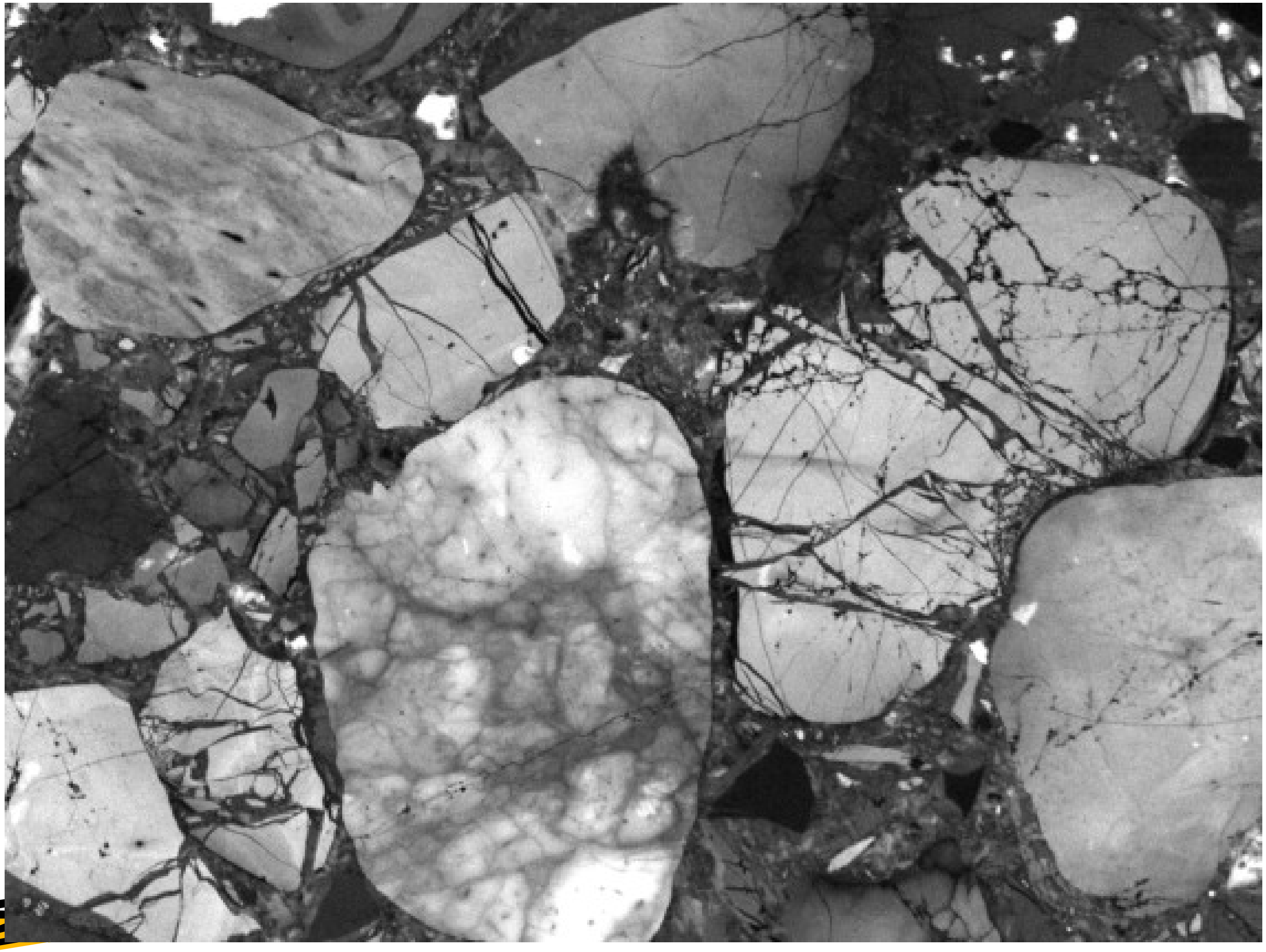
Brittle Deformation -1



Brittle Deformation -1



Micro fracturing --sandstone



- The image shows a series of quartz grains exhibiting typical pressure solution textures and shows graphically that pressure solution is associated with microfracturing.

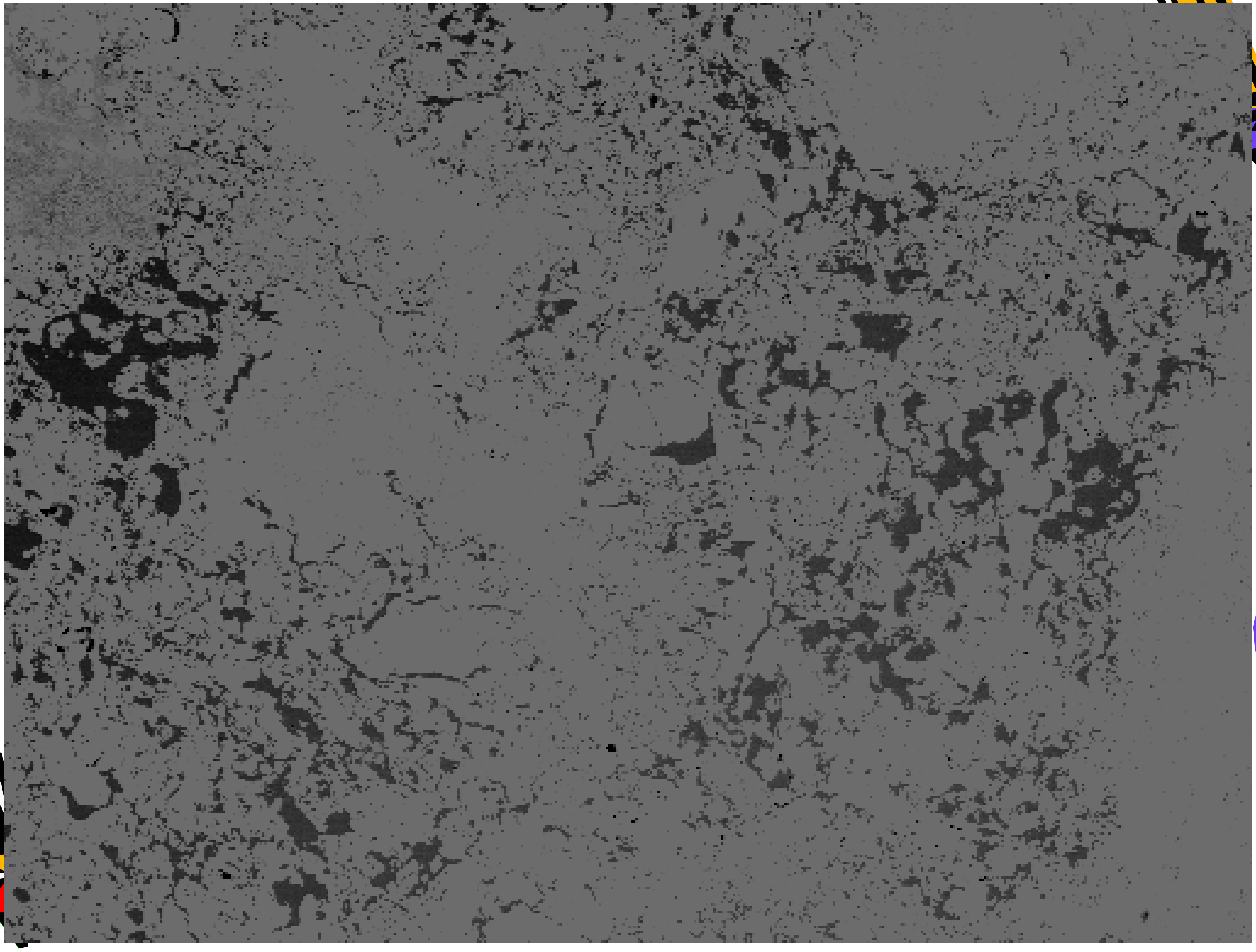
Question?

Safety Rules in the lab

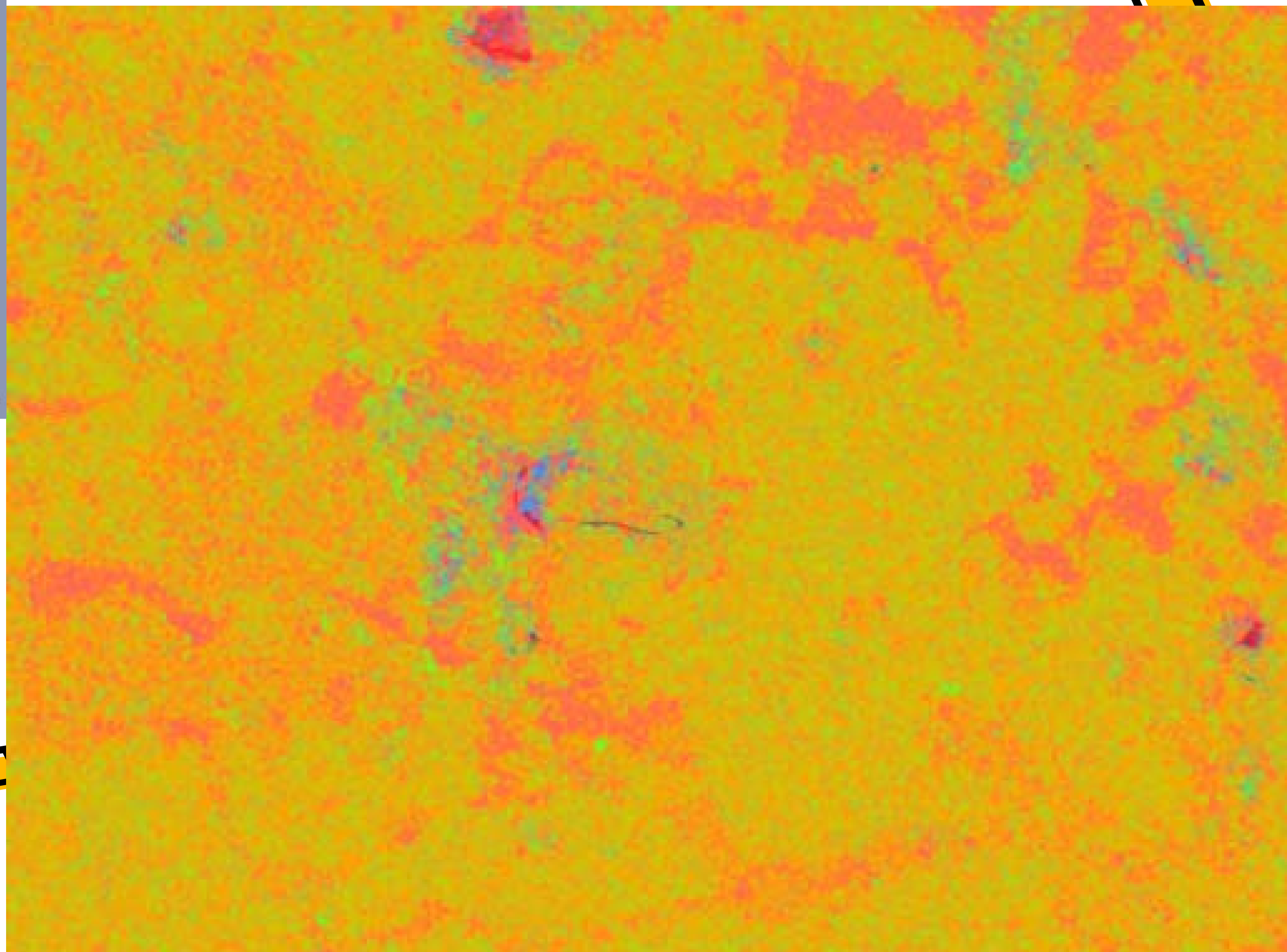
- Construction in the basement, do not enter construction area.

- No practical joke in lab
- No food and drink in the lab
- Do not try to operate any instruments in the lab

Lab tour-1 Searching For "K"

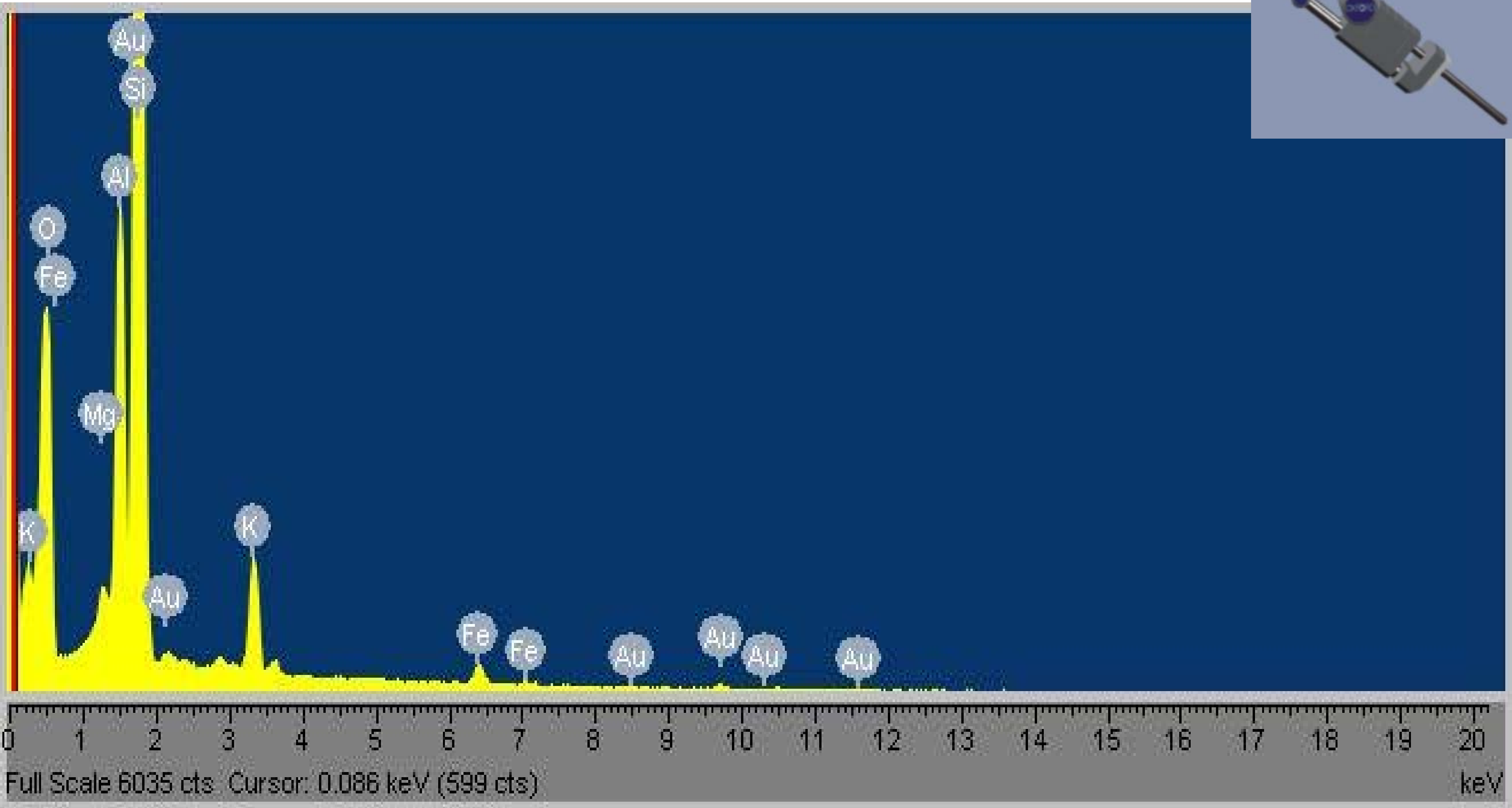


Lab tour-1 Energy Map-“cameo“



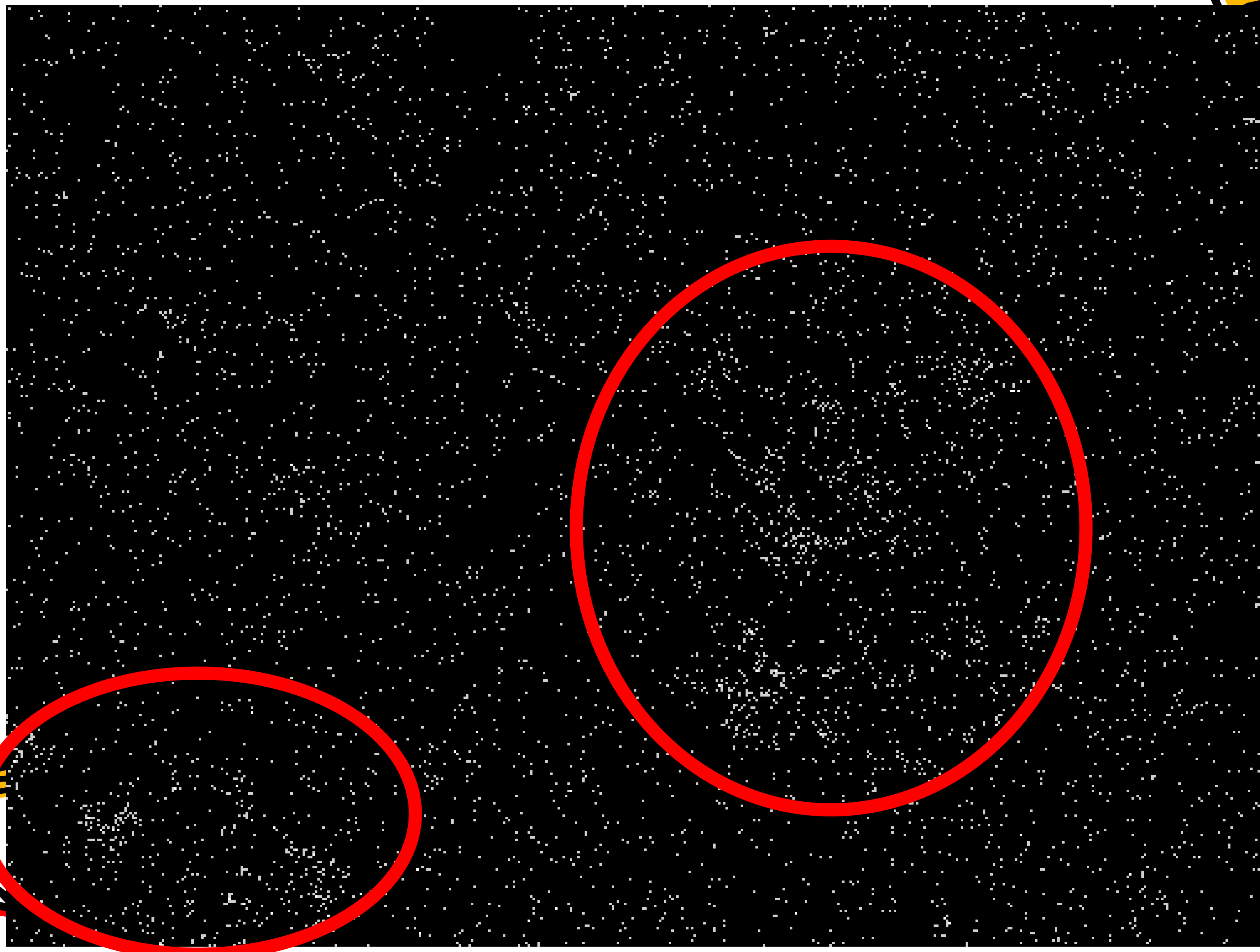
Lab tour-1

EDS Spectrum

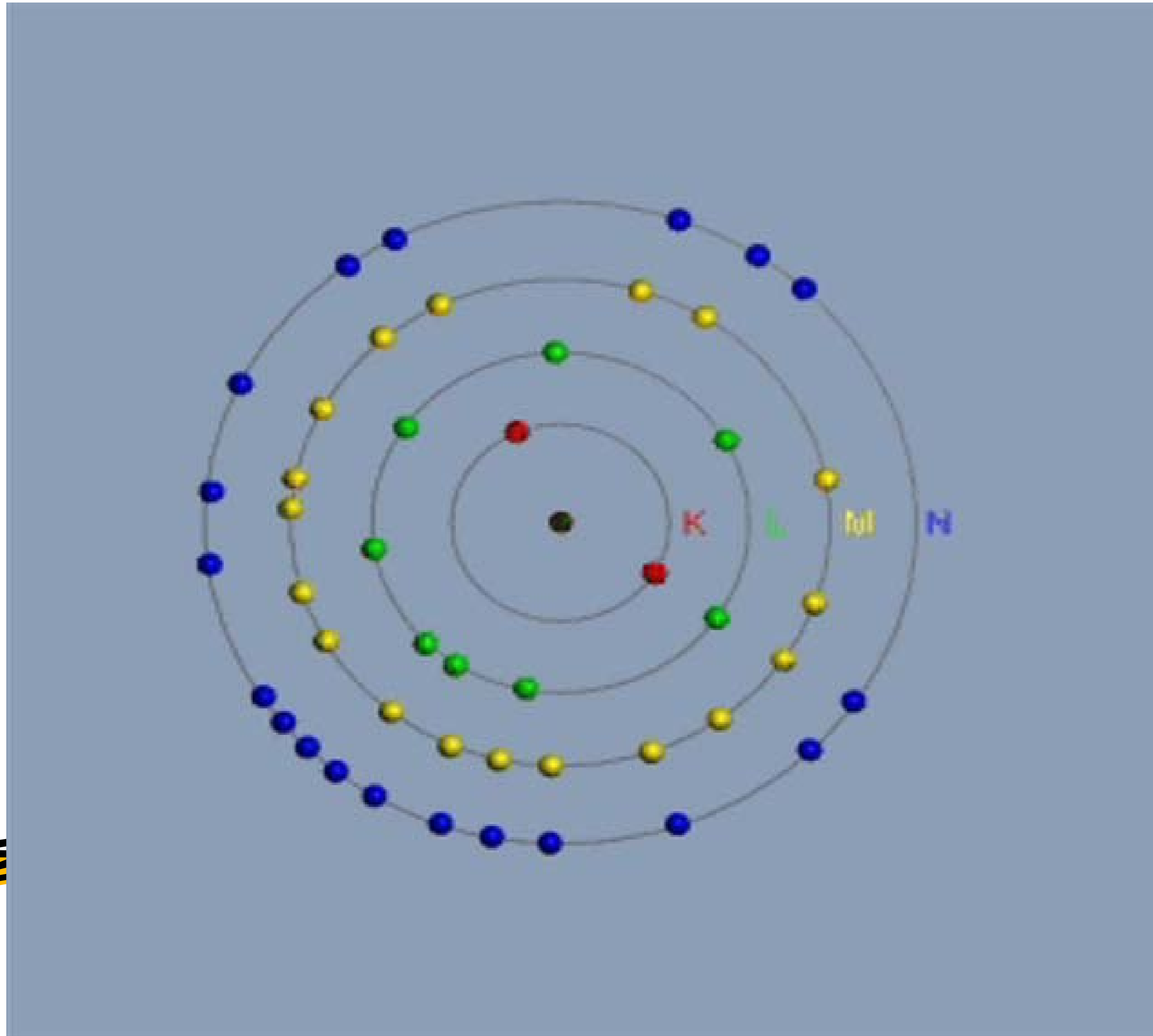


Lab tour-1

Distribution of "K"

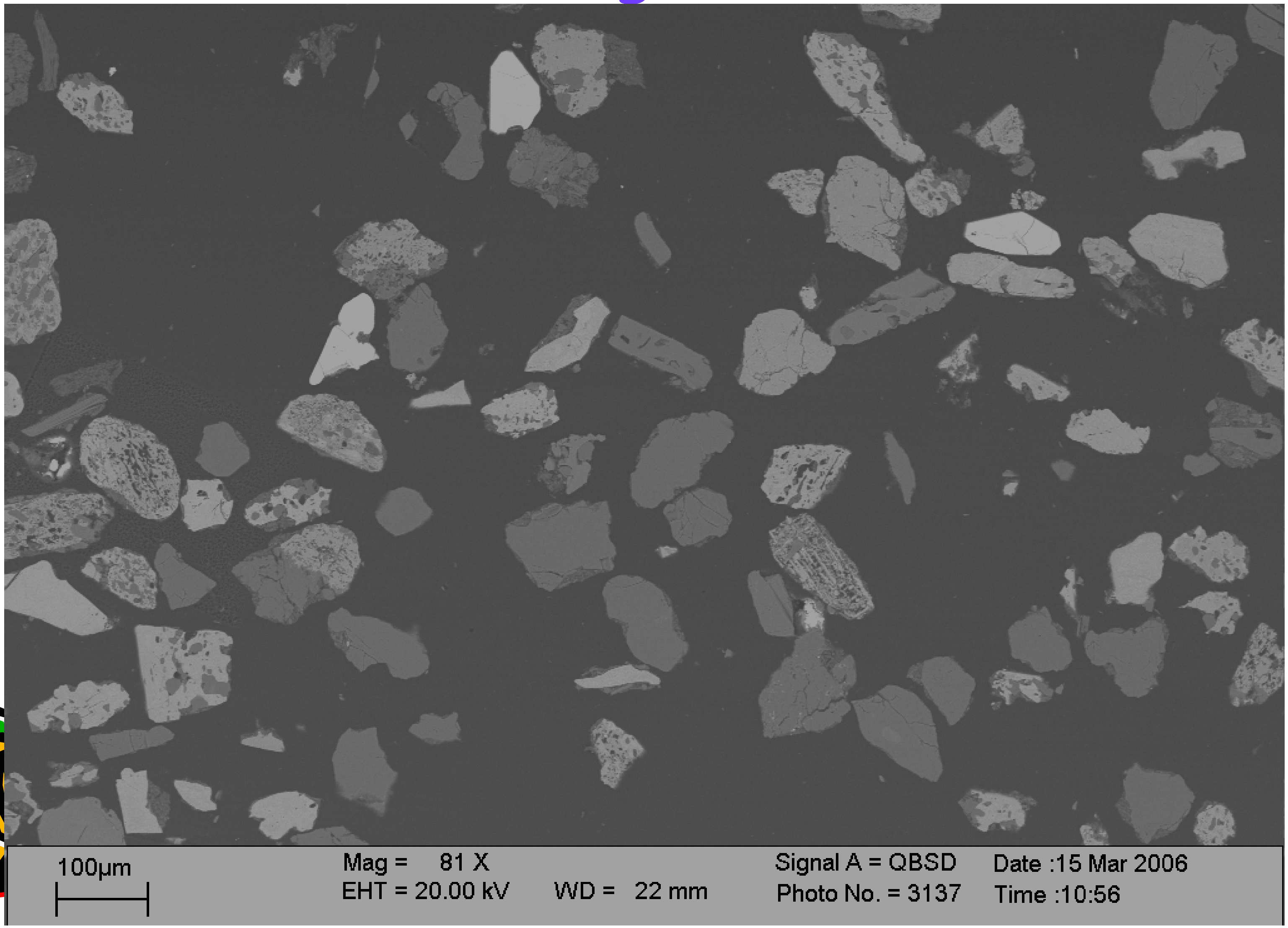


Basic of X-ray element analysis



Lab tour-2

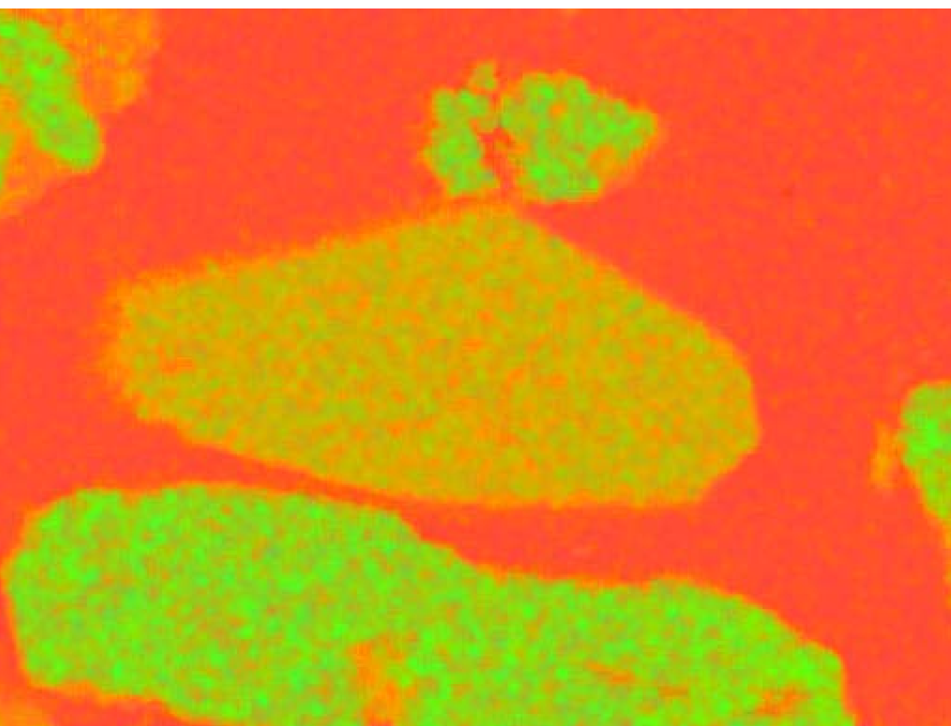
Zircon and Zoning Information



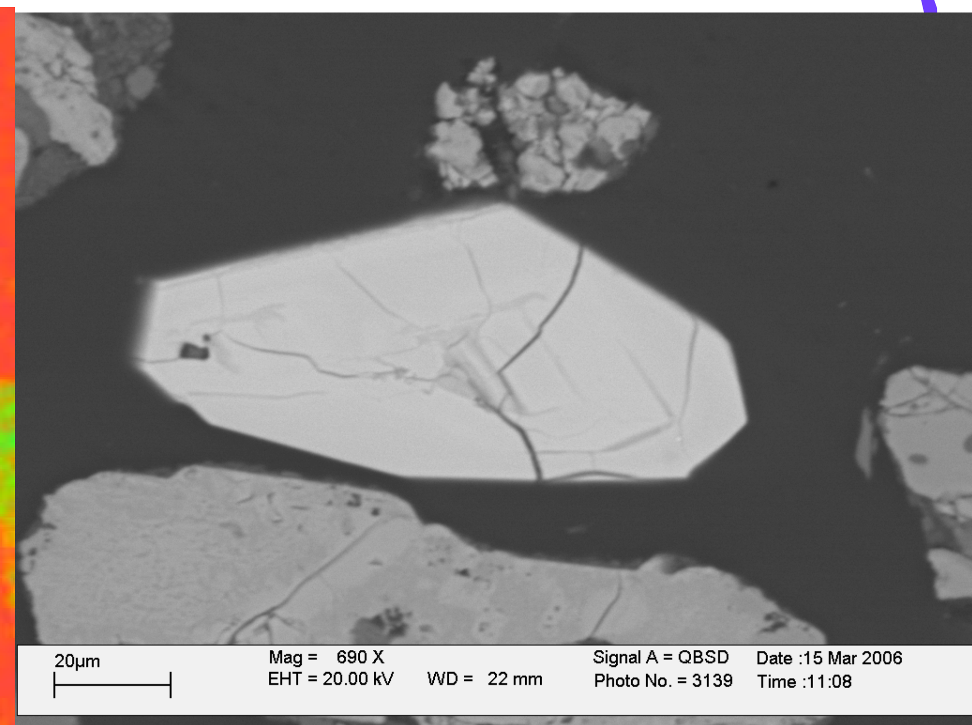
Lab tour

- Locate a zircon particle with combination of other techniques e.g. Energy Dispersive Spectrometry, Back Scattered Electron Detector

EDS Mapping

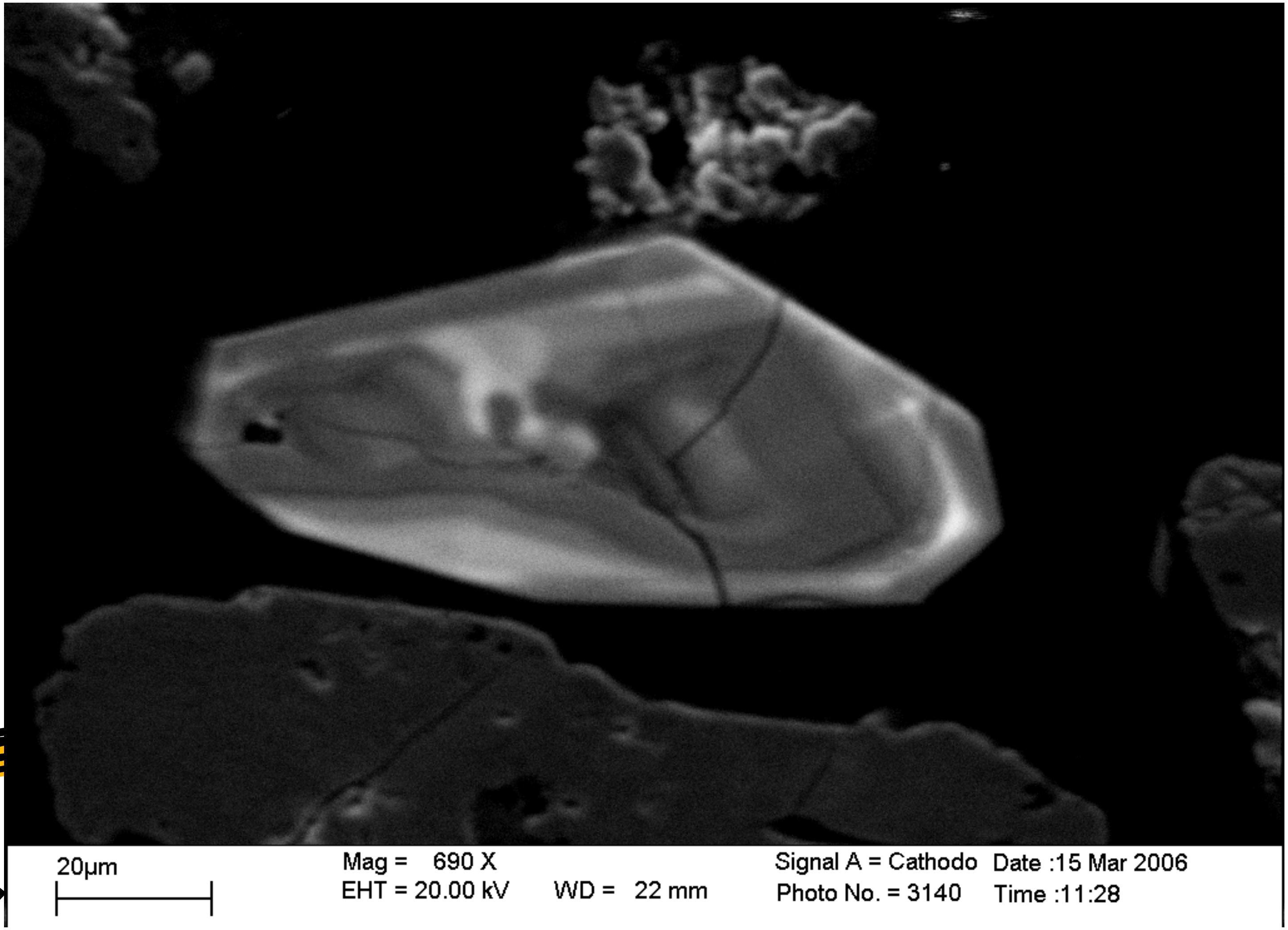


BSD Imaging



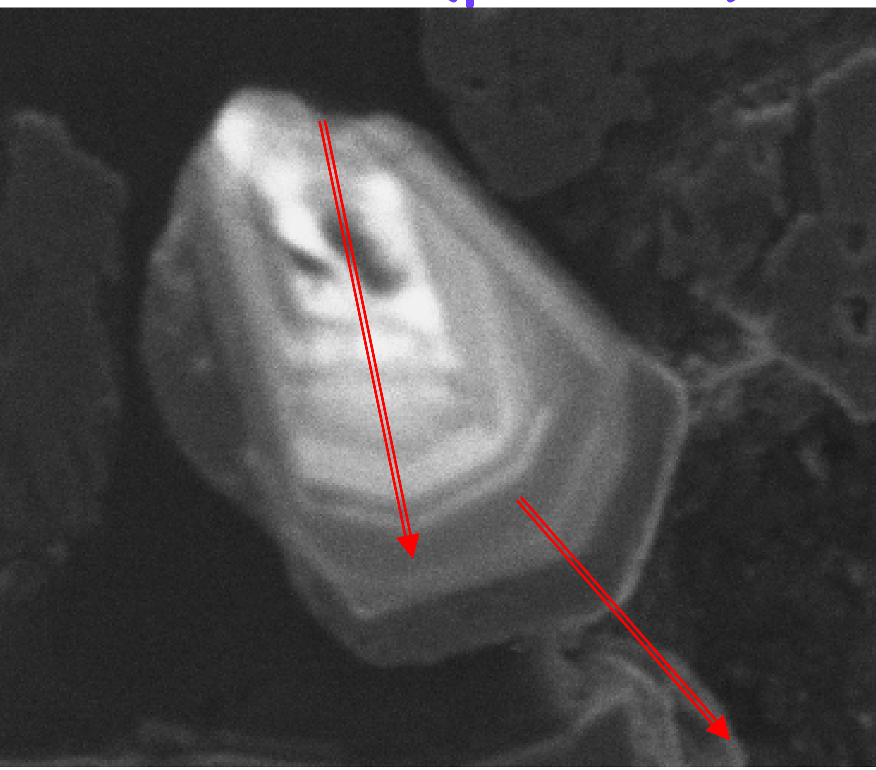
Lab tour

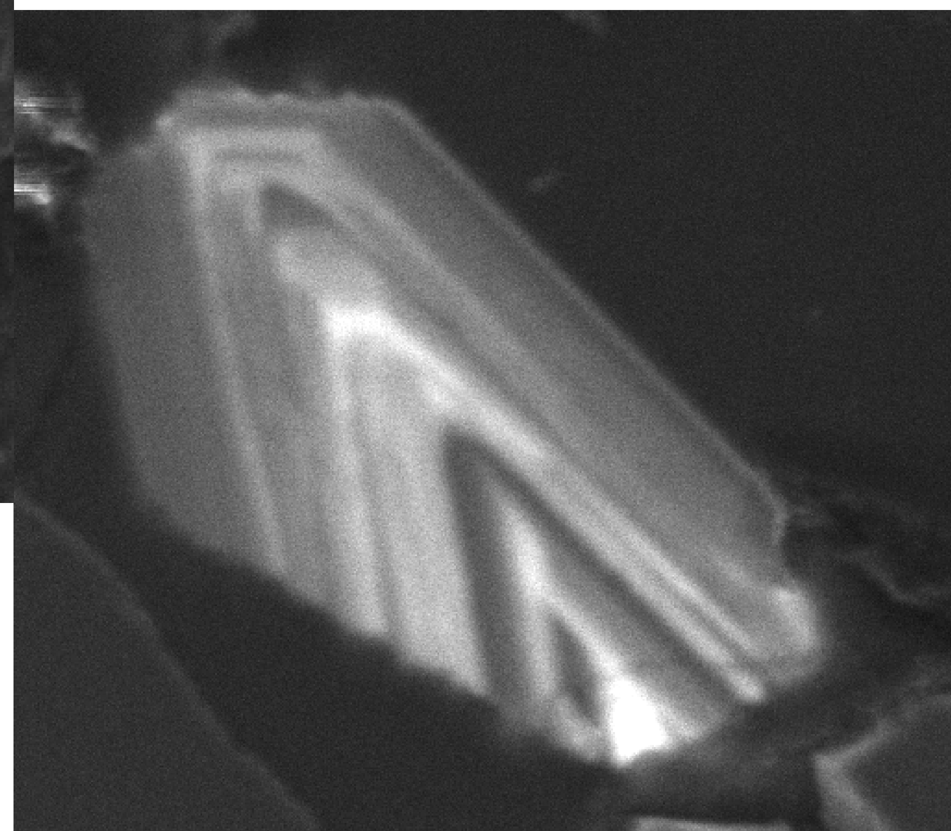
- Zircon CL image



Lab tour

- 2 more (preset) zircon particles viewing





Be Patient

because

image acquisition takes time