Ion/Specimen Interactions

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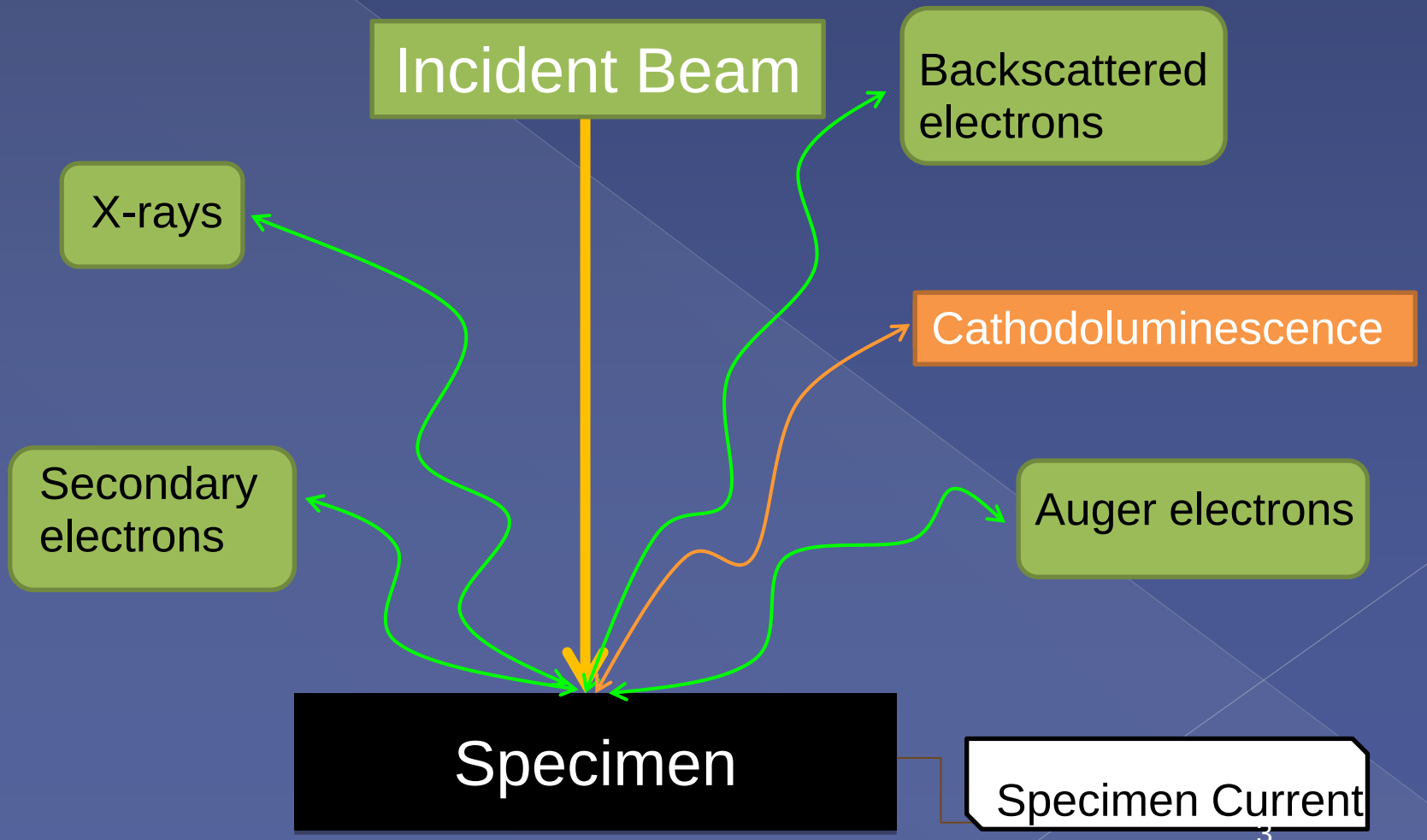
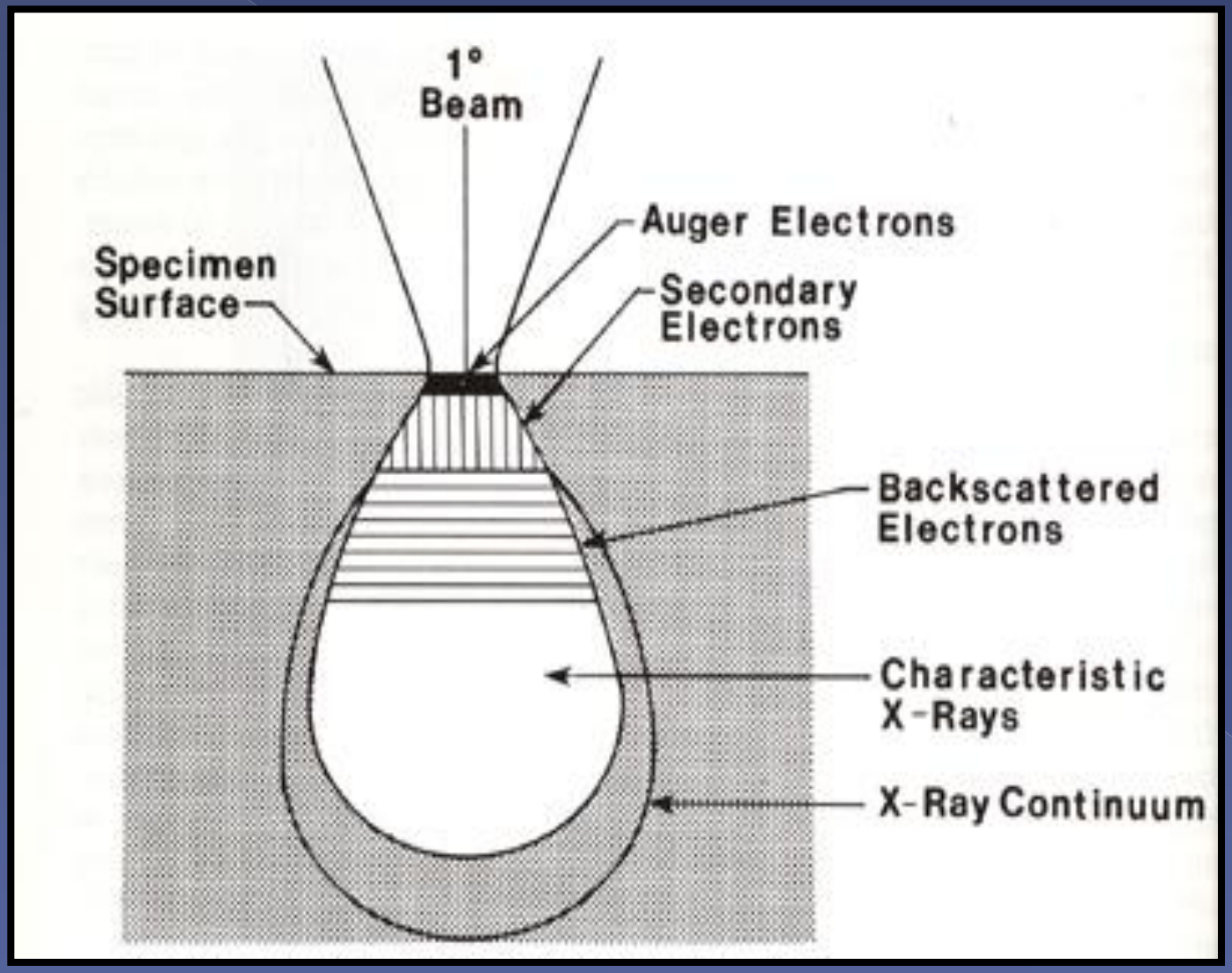
How to obtain an image using SEM?

- Through ion/specimen interaction
  - In brief, we shoot high-energy electrons on specimen, and analyze the outcoming electrons/X-ray

SEM Setup

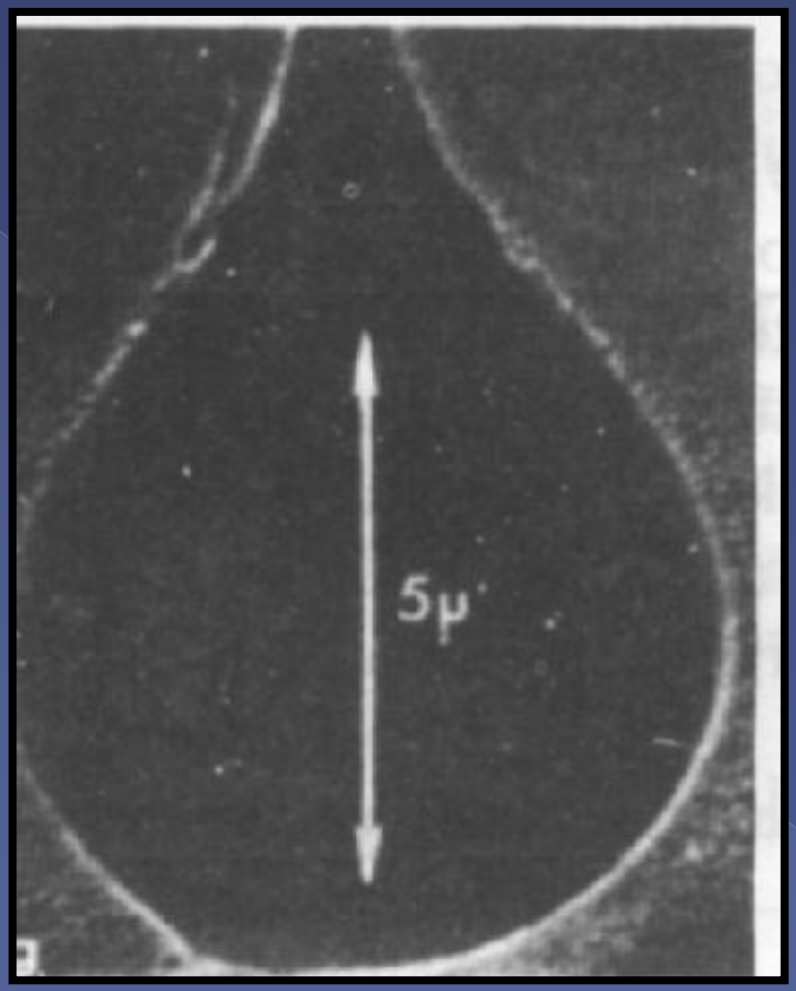
- When incident beam strikes on sample, electrons are scattered elastically or inelastically; this gives various signals





- Primary Signals:
  - Secondary electrons *(topographical)*
  - Backscattered electrons *(atomic number and topographical)*
  - X-Ray *(thickness composition info)*

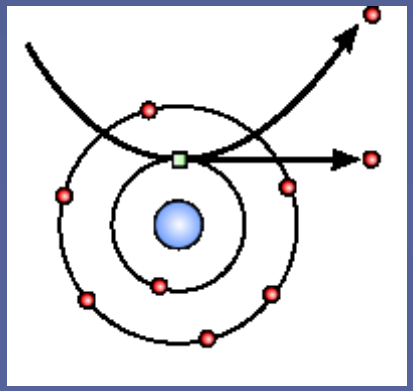
Interaction Volume



Actual image of beam penetration into PMMA showing size and dimension of region of primary excitation

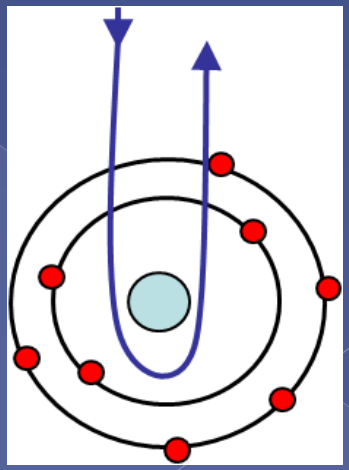
Secondary Electrons (SE)

- Inelastic collision between the incoming electrons and the loosely bounded outer electrons from the atom
- Low energy (10-50eV)
- Generated close to surface (topographic information)
- Number of SE is greater than the incoming electrons

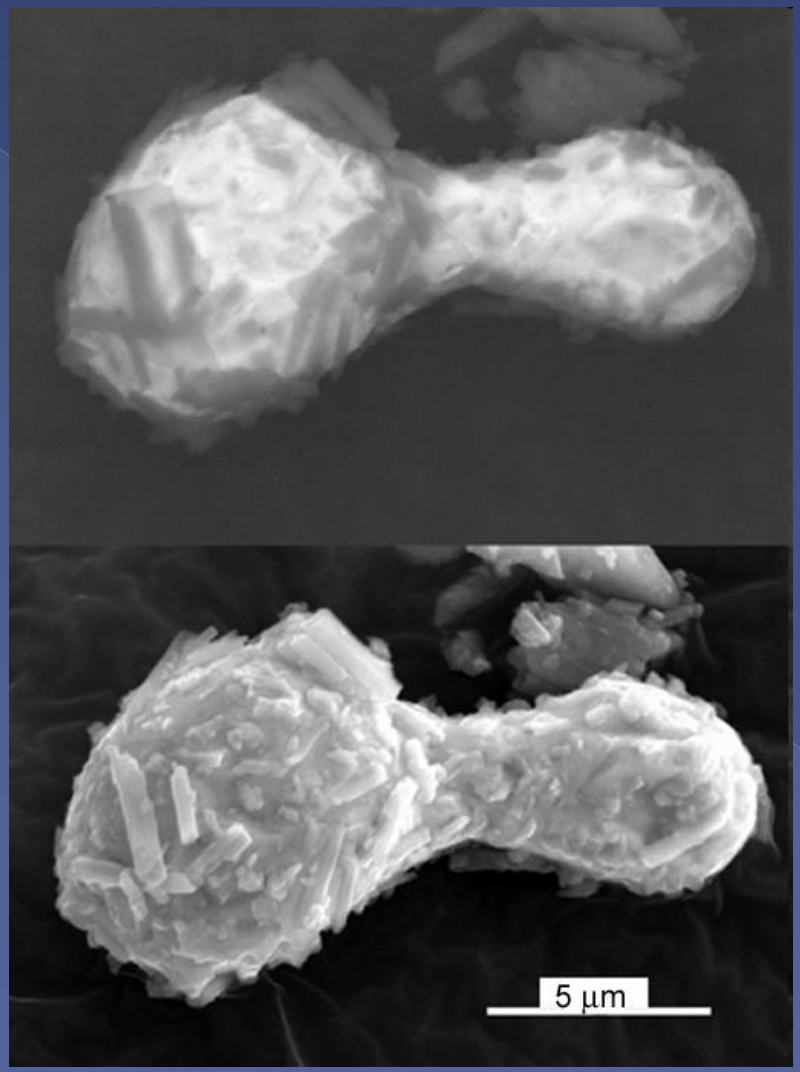


Backscattered Elections (BSE)

- Elastic collisions with the atom of the specimen
  - A fraction of incident electrons is retarded by the electro-magnetic field of the nucleus
- Higher energy electrons
- Generated from deeper region of the specimen
- Fewer BSE than SE
- Give atomic number information

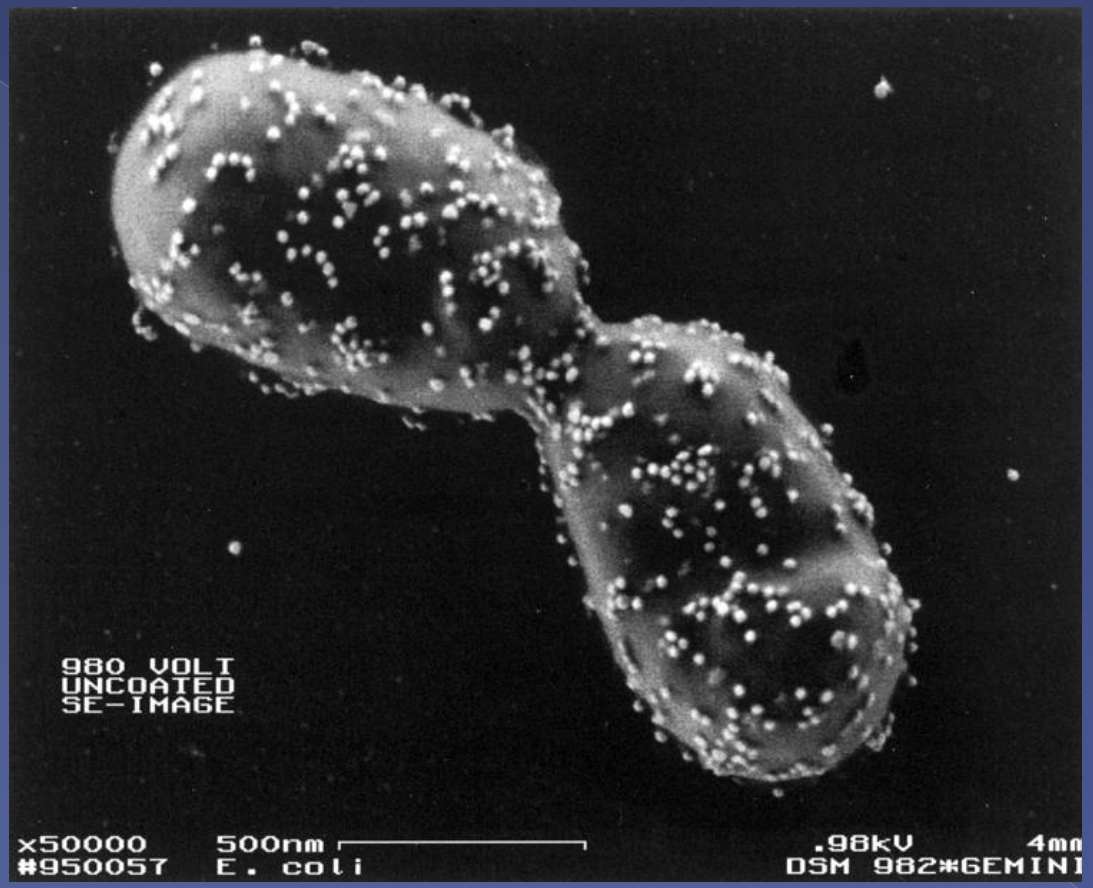


BSE vs. SE Image



Images: Greg Meeker, USGS

BSE Image

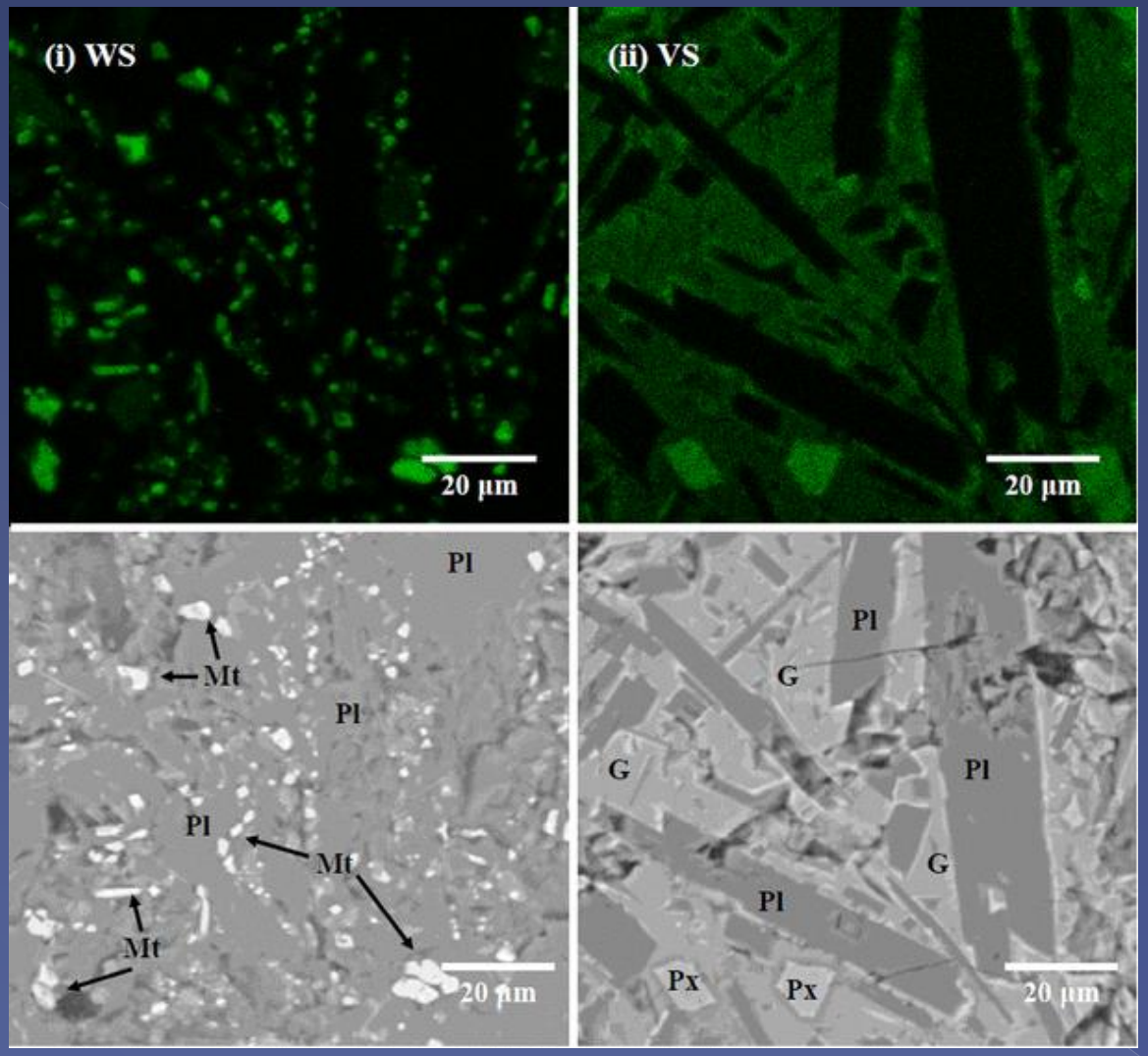


Gold particles on E.Coli appears bright due to the higher percentage of BSE compared to the low atomic weight specimen

Images: Greg Meeker, USGS

X-Ray

- Photons
- High energy, escape from very deep region in specimen
- Most common spectrometer: EDS (energy-dispersive spectrometer)
- Each element has a fingerprint X-Ray signal
- Poorer spatial resolution
- Fewer X-ray signals are emitted (long colleting time required)

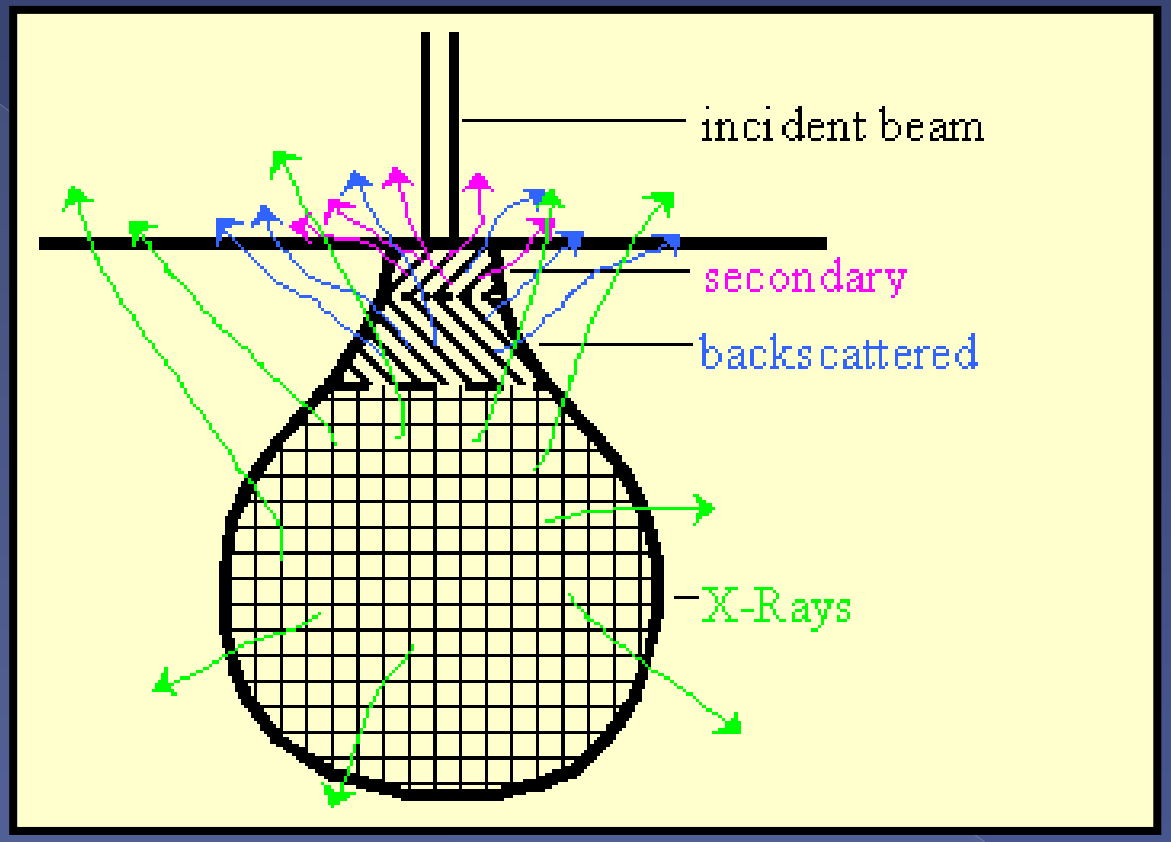


Top: SEM X-Ray map of Fe distribution in the Strombolian samples

Bottom: Backscattering map

K.Genareau,.A. Greg,. Bulletin Of Volvanology, Vol 72, p593-607

Resolution

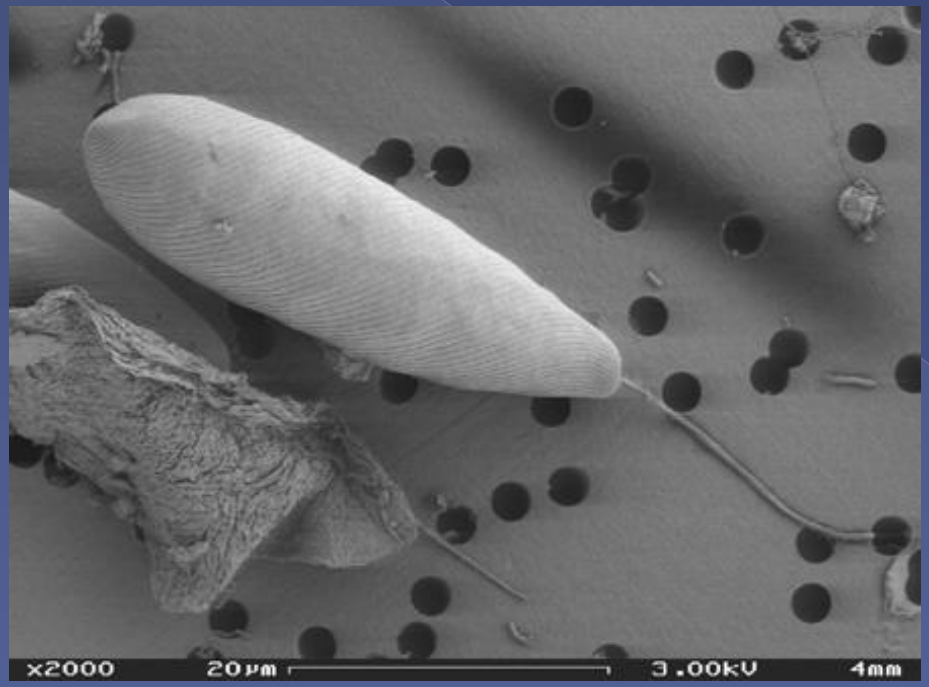


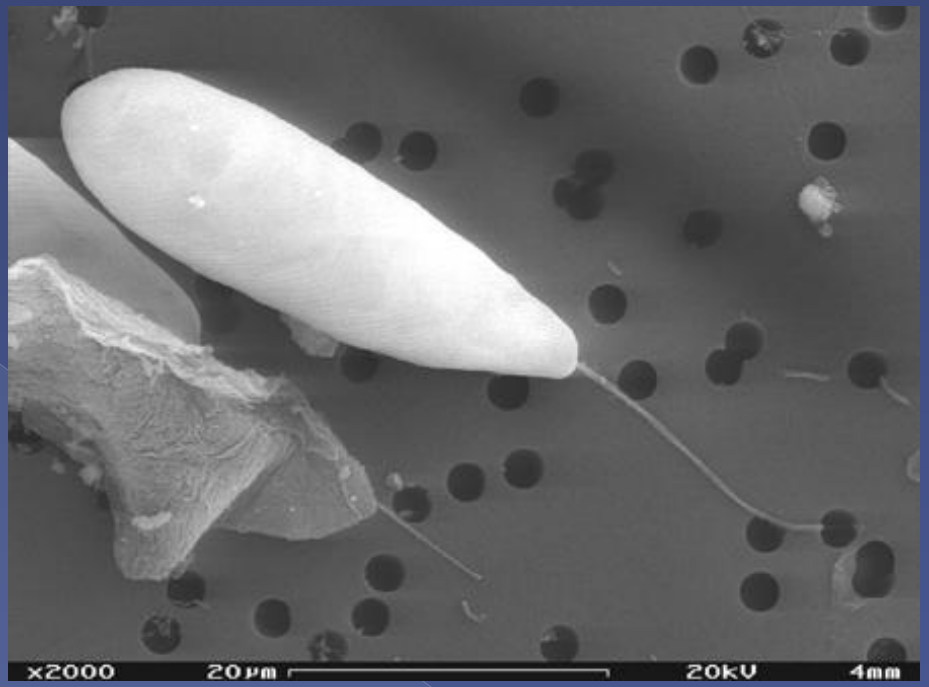
- Resolution in SEM is determined by the region where the signal is produced
- For the same region of excitation, the resolution of the three signals decreases from SE to BSE to X-Ray

Factors affecting size of the interaction region

- Diameter of the primary beam
- Energy of the primary beam (accelerated voltage)
- Atomic weight of the specimen
- Coating of specimen

Accelerated Voltage



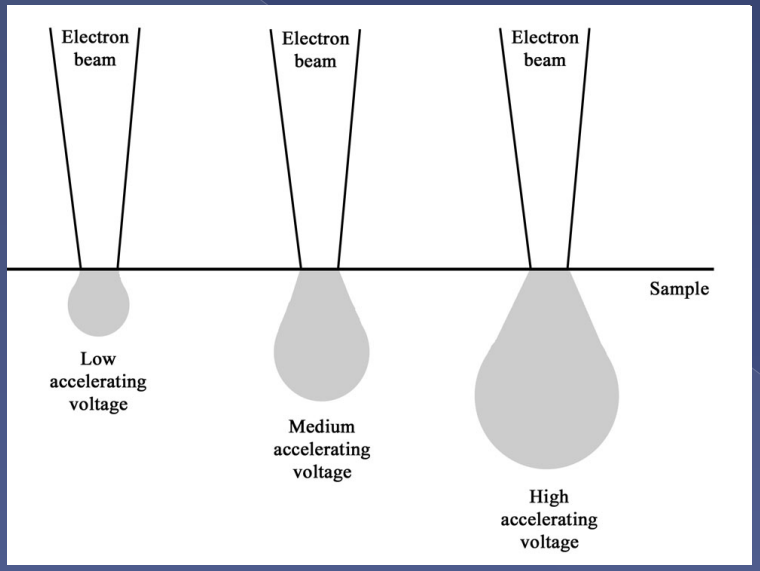


3.0 keV

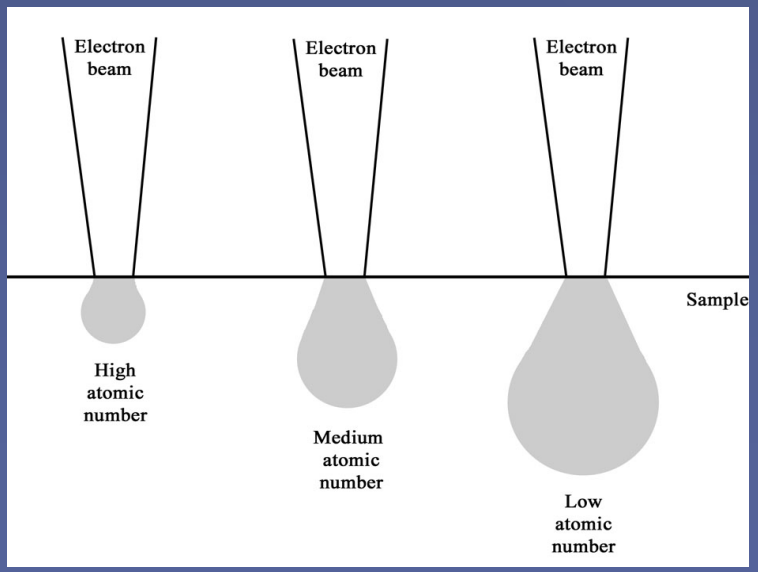
20.0 keV

Accelerated voltage give more signal and brighter image

Effects of acceleration voltage and atomic weight

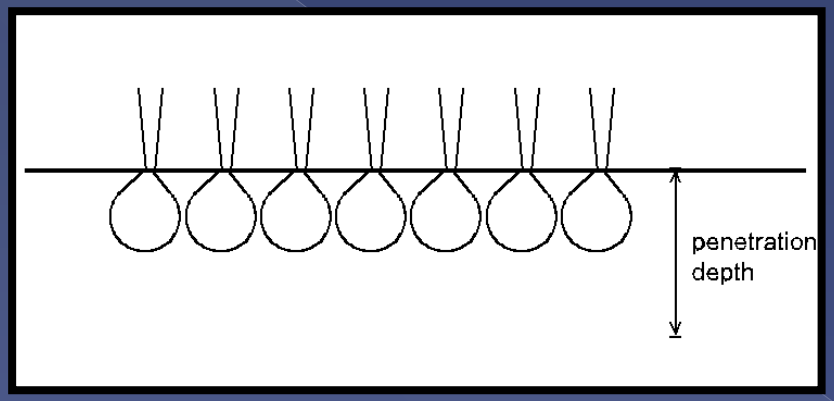


- Interaction volume increases with increasing acceleration voltage

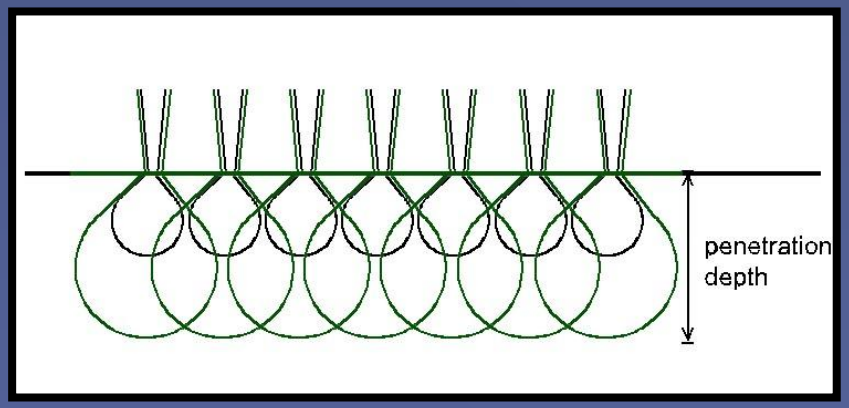


- Interaction volume decreases with increasing atomic number

Images: Smith College Northampton, Massachusetts



- Small excitation region, no overlapping of produced signals
- Resolved image



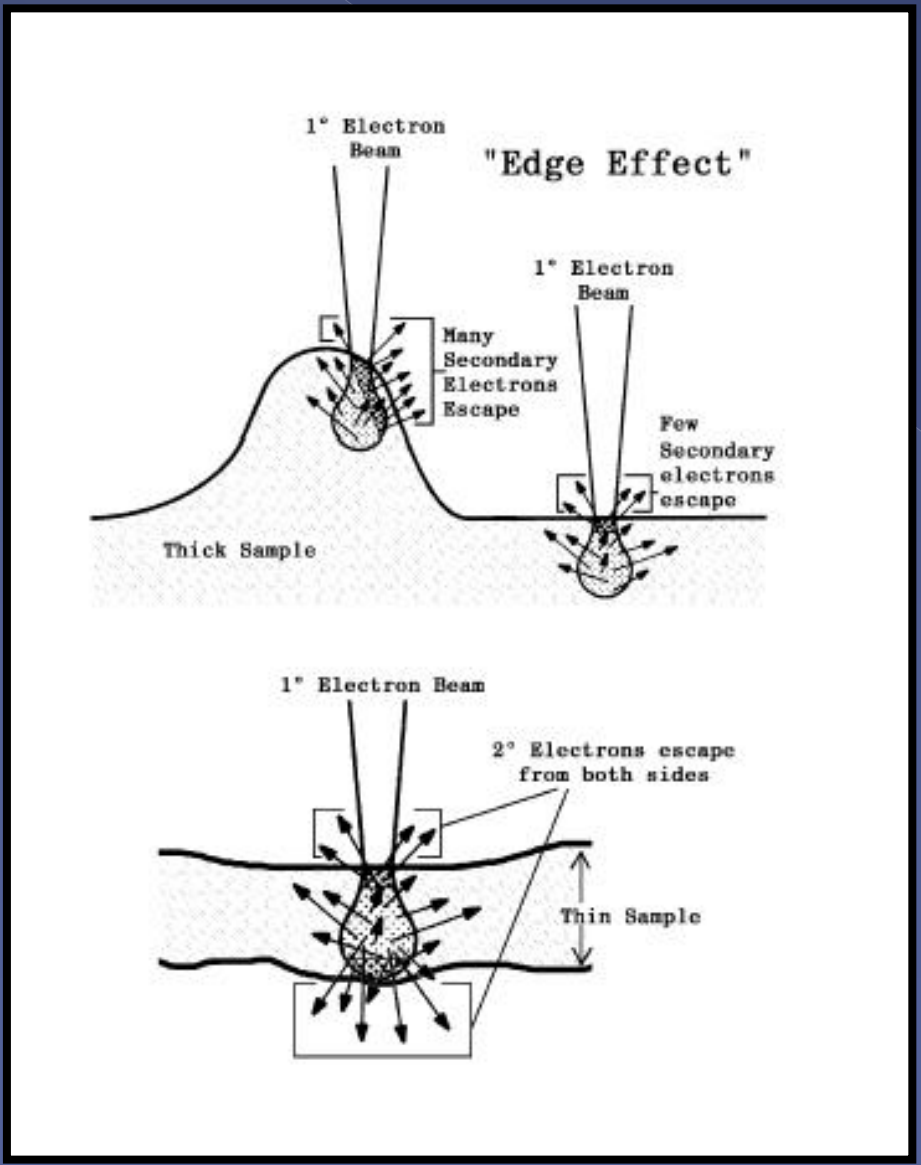
-Larger excitation region, overlapping of produced signals
- Image not resolved

Coating of Specimen

Sputtered Gold

Chromium

Effects of beam strike angle and distance



- The angle of which the beam strikes the specimen (or local curvature) is important for how much signals escape
- Distance from the surface are also important

Summary

- Secondary electrons: topography
  - Low energy, high resolution
- Backscattered electrons: chemistry
  - High energy, signal dependent on atomic numbers
- X-Ray: chemistry
  - Longer recording time, give element fingerprint X-ray signal