SGS FORENSIC LABORATORIES

Understanding Trace Materials Analysis Investigations

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WHAT IS TRACE MATERIALS ANALYSIS?

- Trace materials analysis generally involves substances that are too small to be characterized and identified by human vision
- Instrumental means are usually used to identify materials, such as optical and electron microscopes, spectrometers or other analytical equipment
- The material identity must then be placed into context within the framework of the problem being addressed
- These analyses are typically those that have no specific associated production method and must be investigated individually
- This type of analysis demands a higher level of training and experience than standard production analyses

SCANNING ELECTRON MICROSCOPY

Over thirty years, my job in trace evidence examination can be summed up in one question and one answer:

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Question - WHO IS LYING TO ME TODAY?

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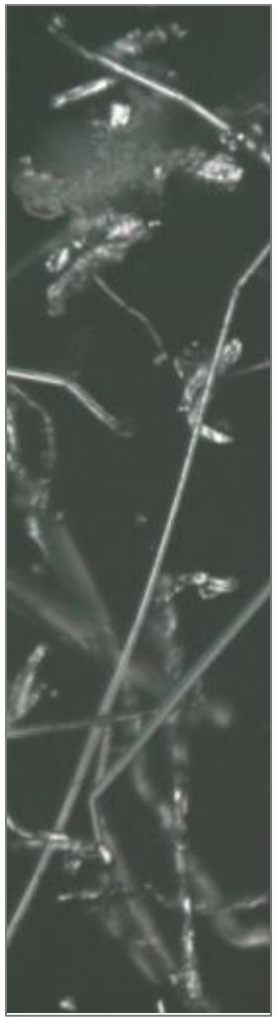
Question - WHO IS LYING TO ME TODAY?

Answer – EVERYONE

CONTEXT & REASONING



Context- What is the true problem that must be solved?

- Not just “what is the unknown material?”
  - May involve “why”, “how” or any number of variables based on the problem.
  - The solution to the problem may specifically call for the application of context
    - e.g.- Servers are crashing in a computer facility. Analysis of dust shows the presence of metal whiskers, identified as zinc. The facility uses galvanized underflooring which can produce zinc whiskers. The whiskers are dislodged and carried in airflow, then deposited from above into servers, where they act as wires and cause short circuits.

Reasoning – What is the thought process that gets us the answer?

✓DEDUCTIVE

Guaranteed True

✓INDUCTIVE

Probably True

✓ABDUCTIVE

Best Guess

(proving the negative)

DEDUCTIVE

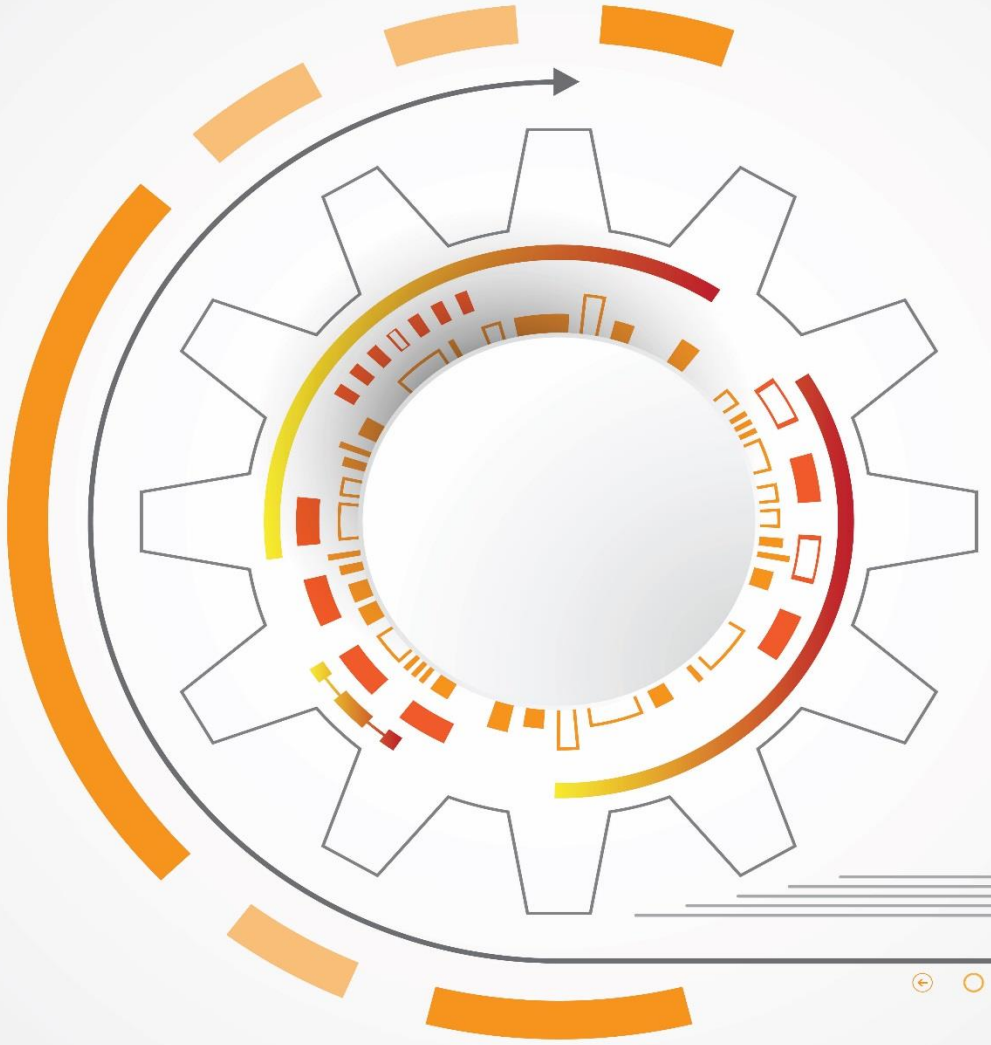
- This rug is composed of an assortment of colored wool fibers.
- When we obtain a selection of fibers from the rug, **WE WILL** obtain a selection of colored wool fibers matching the fibers in the rug.

INDUCTIVE

- We have found an assortment of colored wool fibers in a closet.
- Some, or all, of these fibers are the same color as fibers in this wool rug. The wool rug **MAY HAVE BEEN** in the closet.

ABDUCTIVE

- If an assortment of colored wool fibers from this rug are found in a closet, then the properties of that assortment of fibers **WOULD HAVE** the properties of the fibers in the rug.
- The process of abduction allows us to design experiments that we hope will eliminate all, or many, alternate hypotheses. The more alternate hypotheses that we can eliminate, the more confident we become that our abductive hypothesis is true.



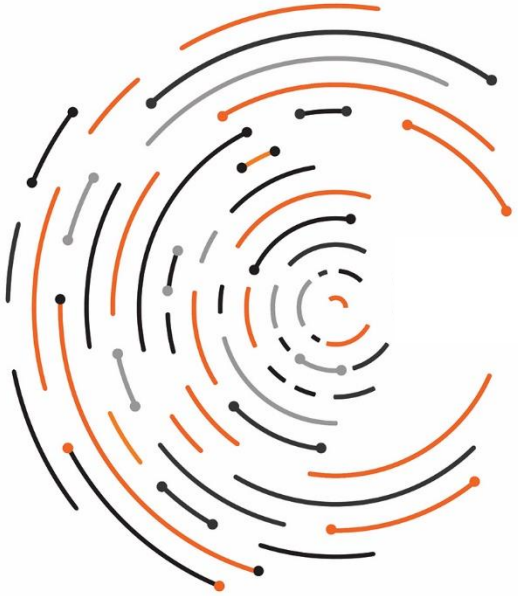
IDENTIFICATION OF MATERIALS

Comparison and Identifications

COMPARISONS

- Is an object consistent with a known object?
  - Requires an exemplar
- Can they share the same source?
- May be an object, an impression, or anything that can be matched to a known.
- Technically, this is generally straightforward since the analyst has a known for comparison. This can be performed with high accuracy and precision.

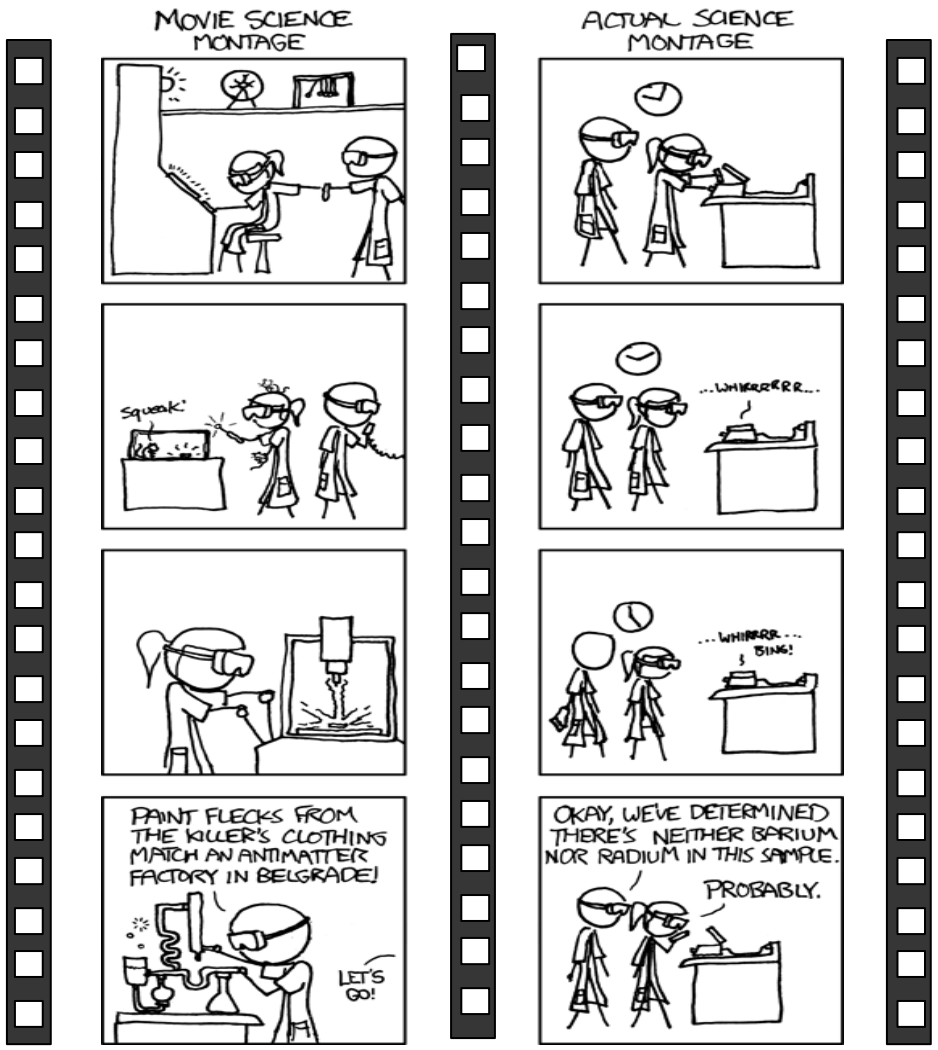
IDENTIFICATIONS

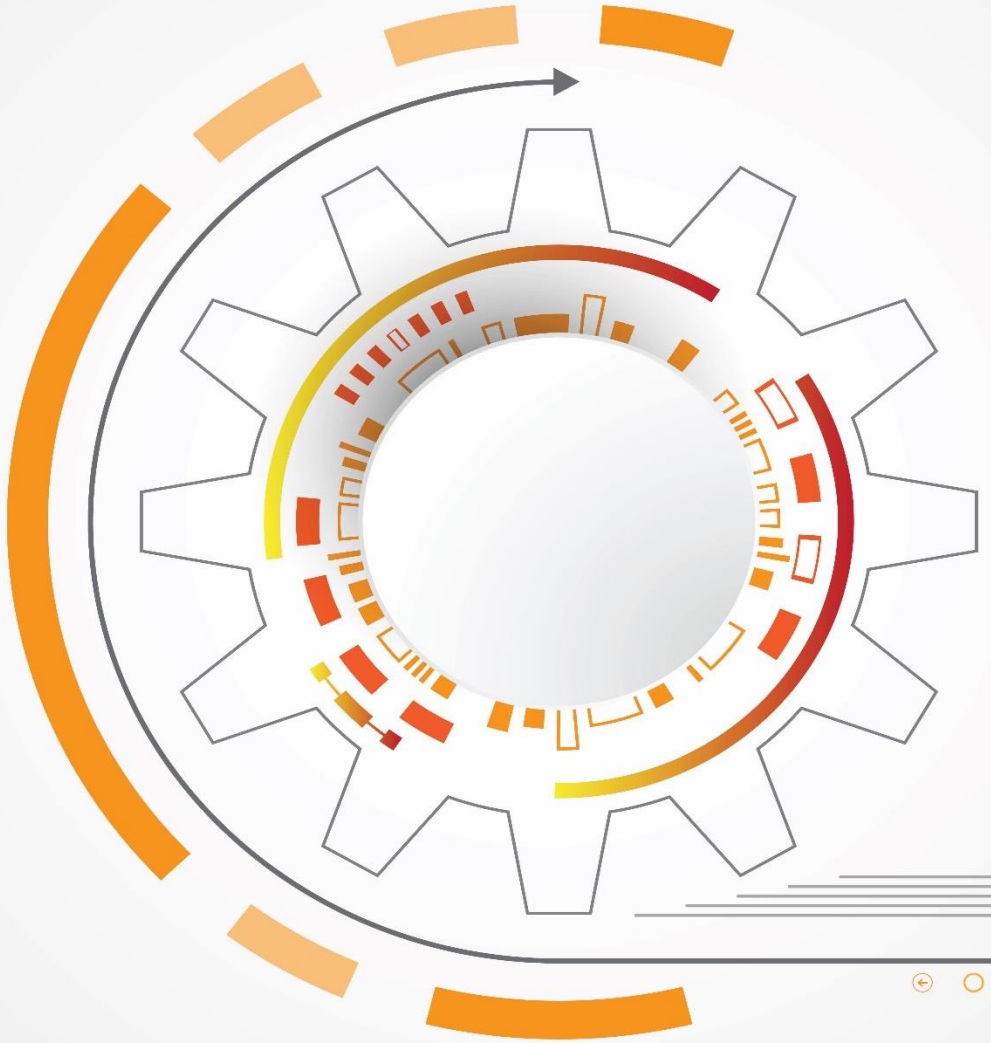


- What is this unknown material?
- Identity must be established first
  - Have we established a unique identity?
- Relevance must then be established
  - Does this unique material have pertinence to a stated problem?

THE CSI EFFECT

The CSI effect (also known as the Black Box effect) is the unrealistic expectation of a client regarding the capacity of an analytical laboratory to resolve a problem in a minimal amount of time at near zero cost yet producing massive amounts of pertinent information and providing vital answers.





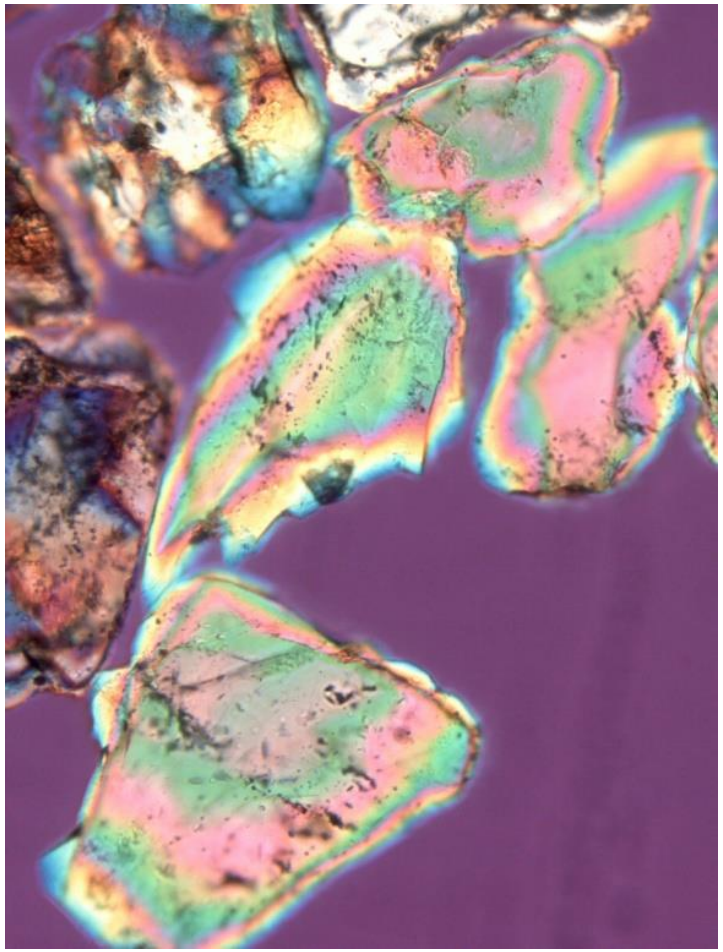
ANALYTICAL TECHNIQUES

THE TRIAD OF TRACE MATERIALS ANALYSIS

- Optical Microscopy
  - Provides: color, size, morphology, crystallinity…
- Electron Microscopy with Energy Dispersive X-Ray Spectrometry
  - Provides: elemental composition
- Vibrational Spectroscopy (FTIR and Raman)
  - Provides: chemical structure

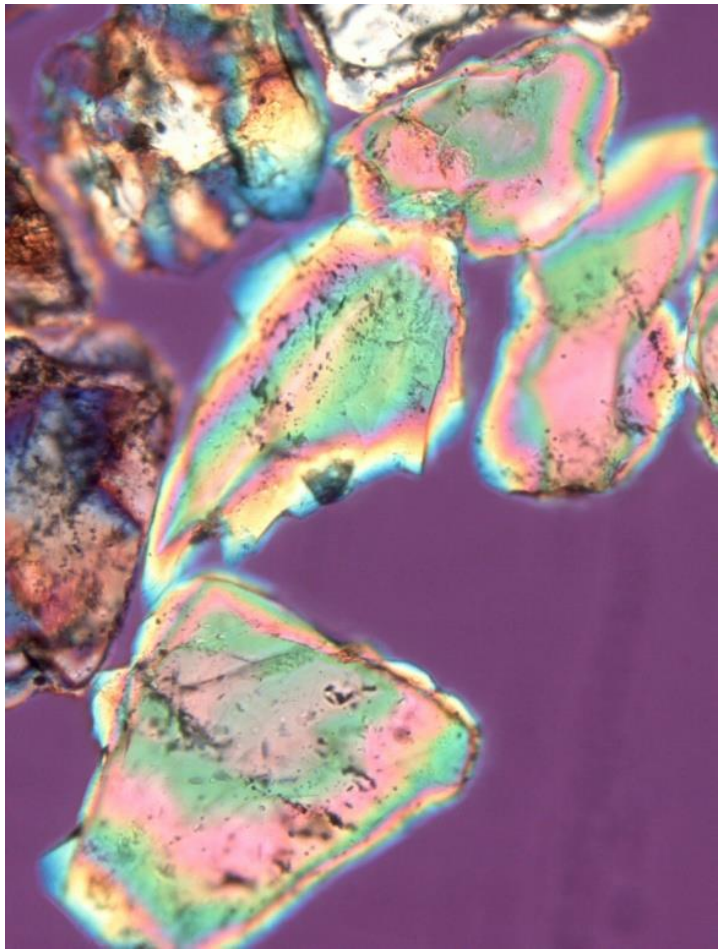
This combination of non-destructive(!) techniques can solve most problems in trace materials analysis. Although many other analytical techniques exist, these three can generally be performed with little specialized sample preparation or instrument setup.

MICROSCOPY



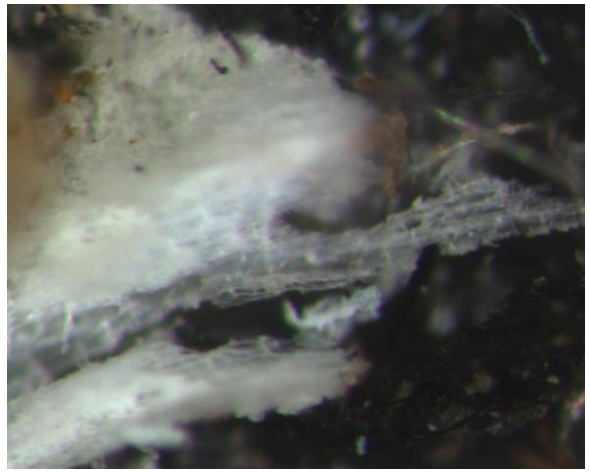
- Makes little things look bigger
- Photons and electrons are both useful
- The right tool for the right job

OPTICAL MICROSCOPY



- Photons only. Particle size is limited by the wavelengths of light, which puts a resolving power limit of about 0.2um on what one can see. The main types of optical microscopes employed are:
- Stereomicroscope
  - Low magnification (1x – 200x)
- Polarized light microscope (PLM)
  - High magnification (25x – 1000x)
- Color!

STEREOMICROSCOPY

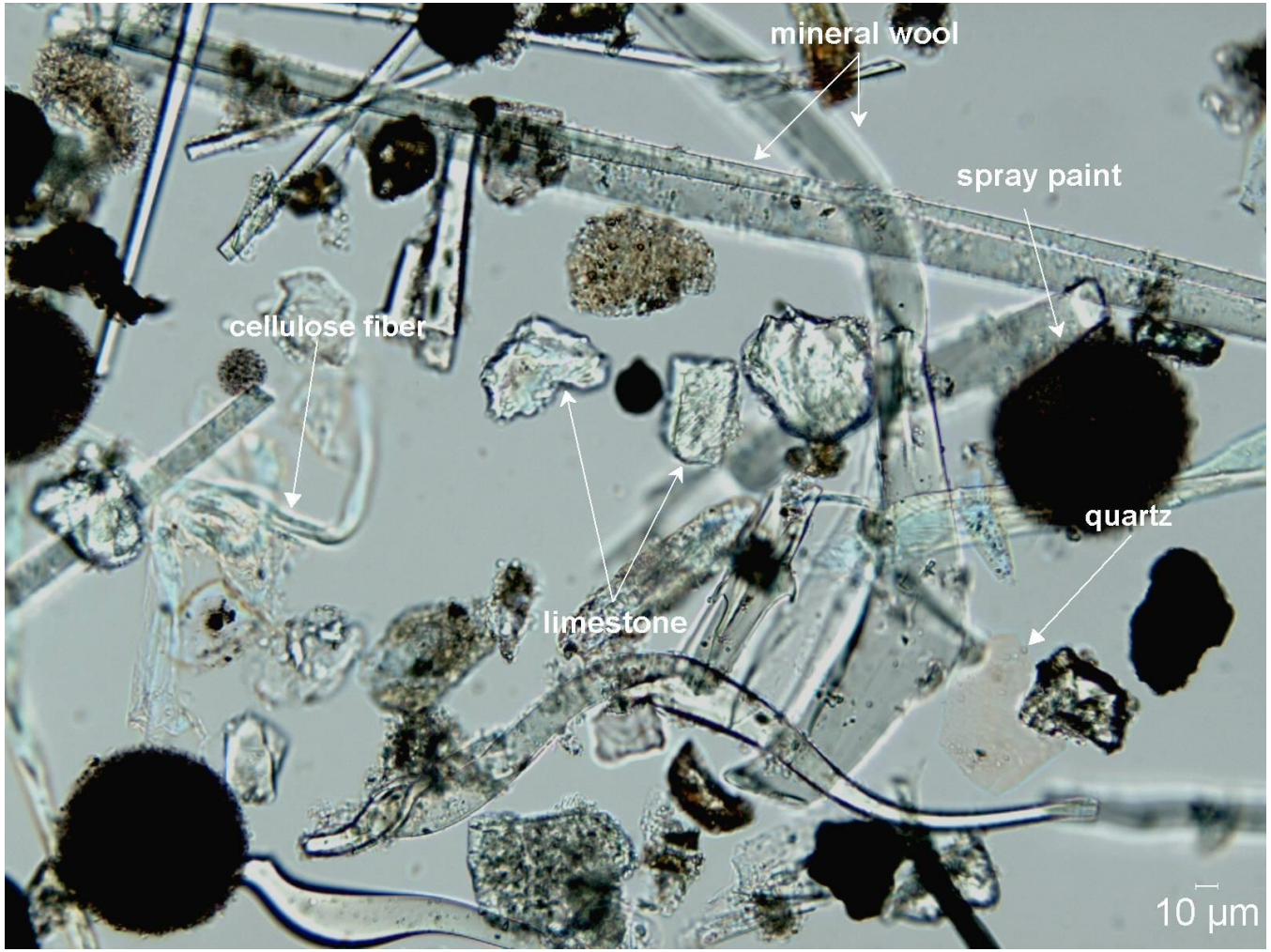


- Magnification range from 1x – 200x
- All kinds of lighting
- A lot of working distance
- Especially good at natural lighting conditions

POLARIZED LIGHT MICROSCOPY (PLM)

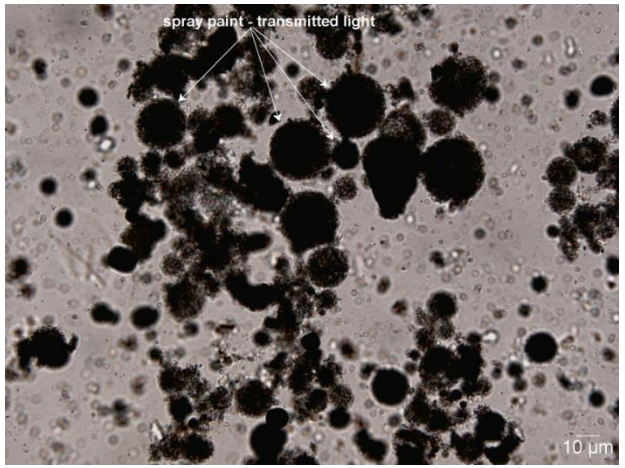
The modern polarized light microscope is one of the most versatile pieces of lab equipment that money can buy!

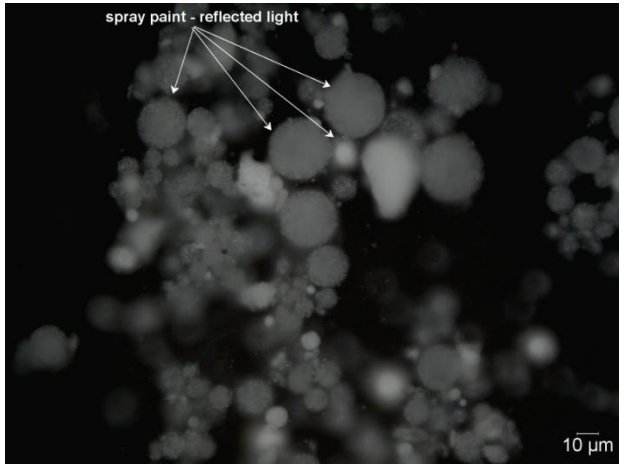
POLARIZED LIGHT MICROSCOPY



- Magnification range of 25x – 1000x
- Polarized light reveals- birefringence, refractive indices, pleochroism
- Reflected light can show surface structure
- Size range of 1um to 500um
- Basic morphology, color, size

POLARIZED LIGHT MICROSCOPY





- Lighting is key!!!!!
  - Transmitted light (slide projector - through sample)
  - Reflected light (human vision - bounced off sample)

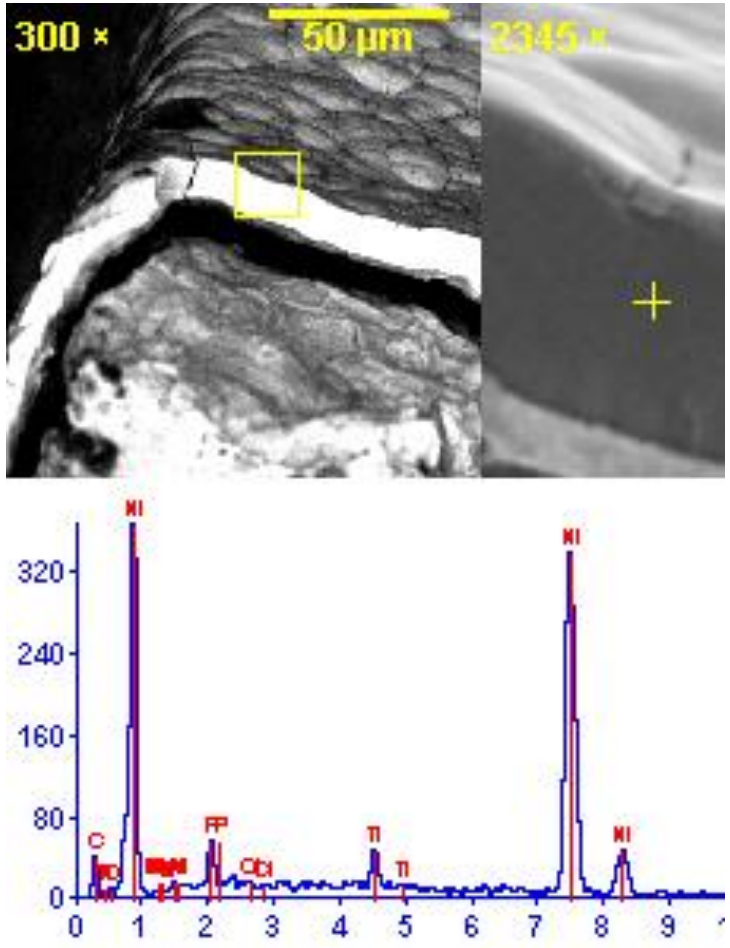
MULITPLE WAYS TO ILLUMINATE SAMPLE

Spray paint in transmitted (upper) and reflected (lower) illumination

ELECTRON MICROSCOPY (EM)

- The SEM uses electrons instead of photons. This means that there's no color to see, but the magnification and resolving power is much greater. There are two basic types of electron microscope:
  - Scanning electron microscope (SEM)
    - Images are from reflection from sample
    - Generally lower magnification range of EM types
    - Can be no prep to severe prep methods depending on instrument
  - Transmission electron microscope (TEM)
    - Images are from transmission through sample
    - Generally higher magnification range of EM types
    - Highly prep dependent, which limits its utility in this type of analysis scheme

SCANNING ELECTRON MICROSCOPY (SEM/EDS)

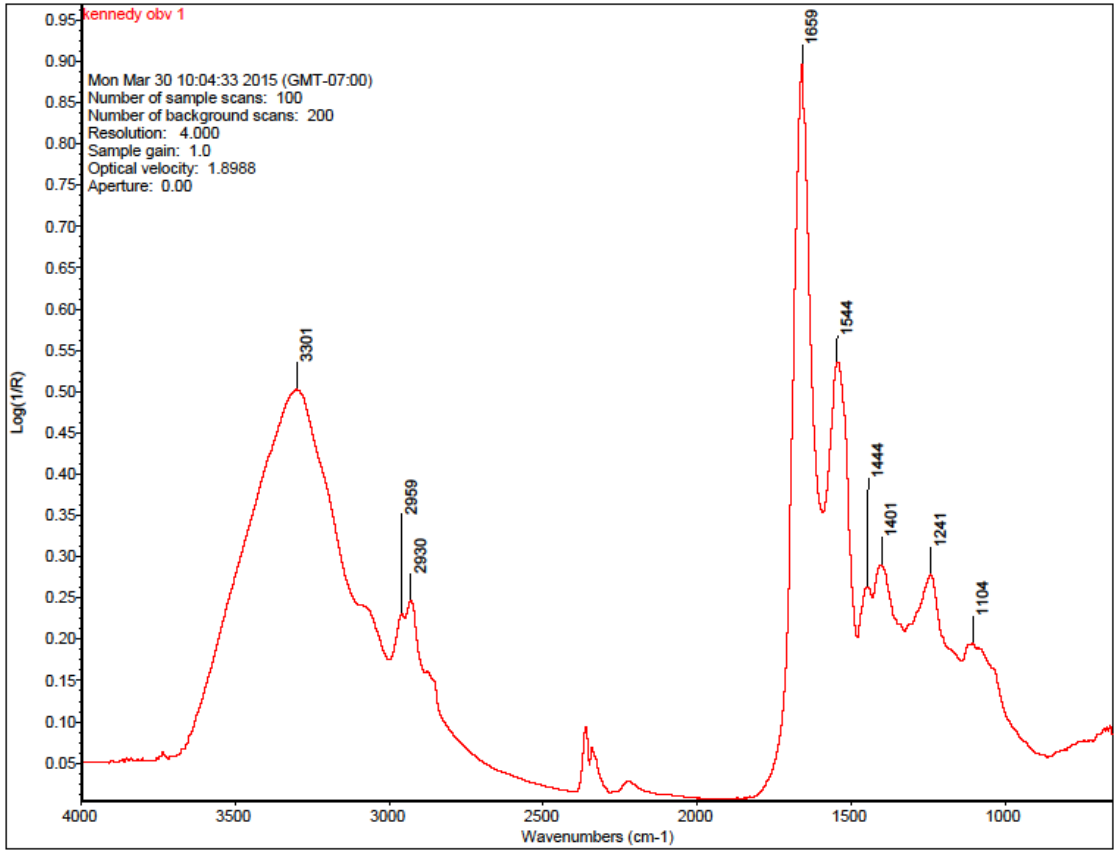


- High magnification range (up to 500,000x)
- Uses electrons, not photons
- Far higher resolution than optical microscopy
- Energy dispersive x-ray spectrometry (EDS) gives breakdown by element (from carbon up)

VIBRATIONAL SPECTROSCOPY

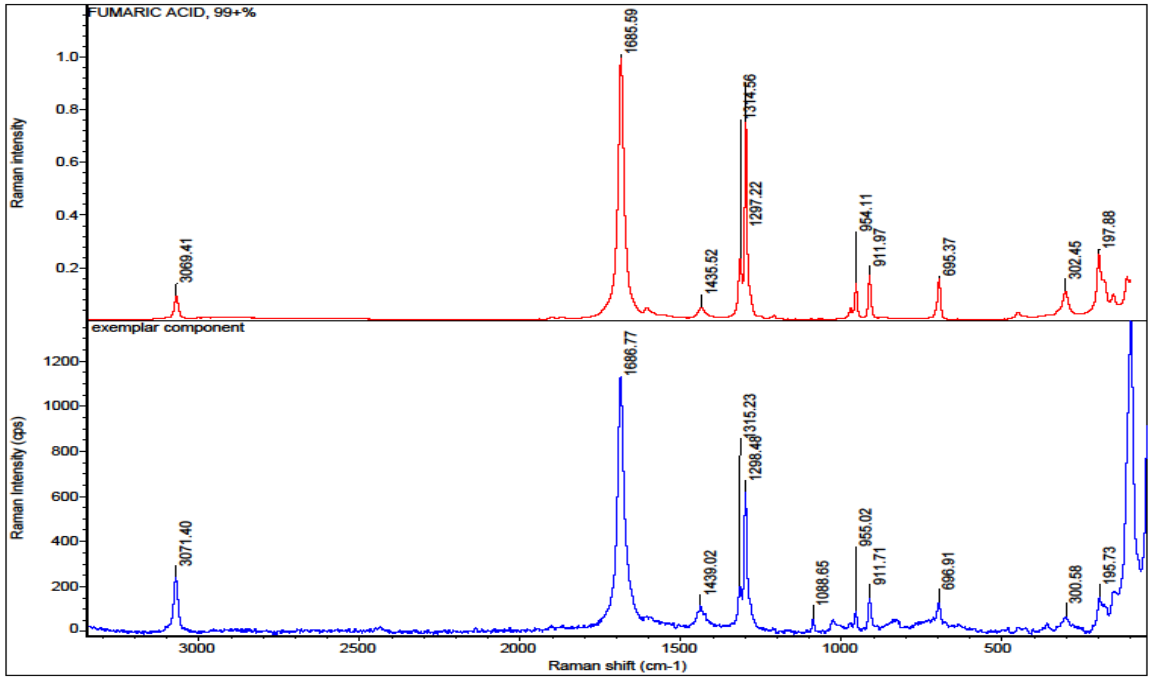
- Vibrational spectroscopy encompasses two types of spectroscopy that measure chemical structure.
  - Fourier Transform Infrared (FTIR) spectroscopy
    - Based on dipole moment
    - Infrared absorption
    - Water is problematic
  - Raman
    - Based on polarizability
    - Raman Scattering
    - Carbon is problematic
- These techniques are very complementary. The combination of both instruments provides a more complete characterization than either alone.

FOURIER TRANSFORM INFARED SPECTROSCOPY (FTIR)



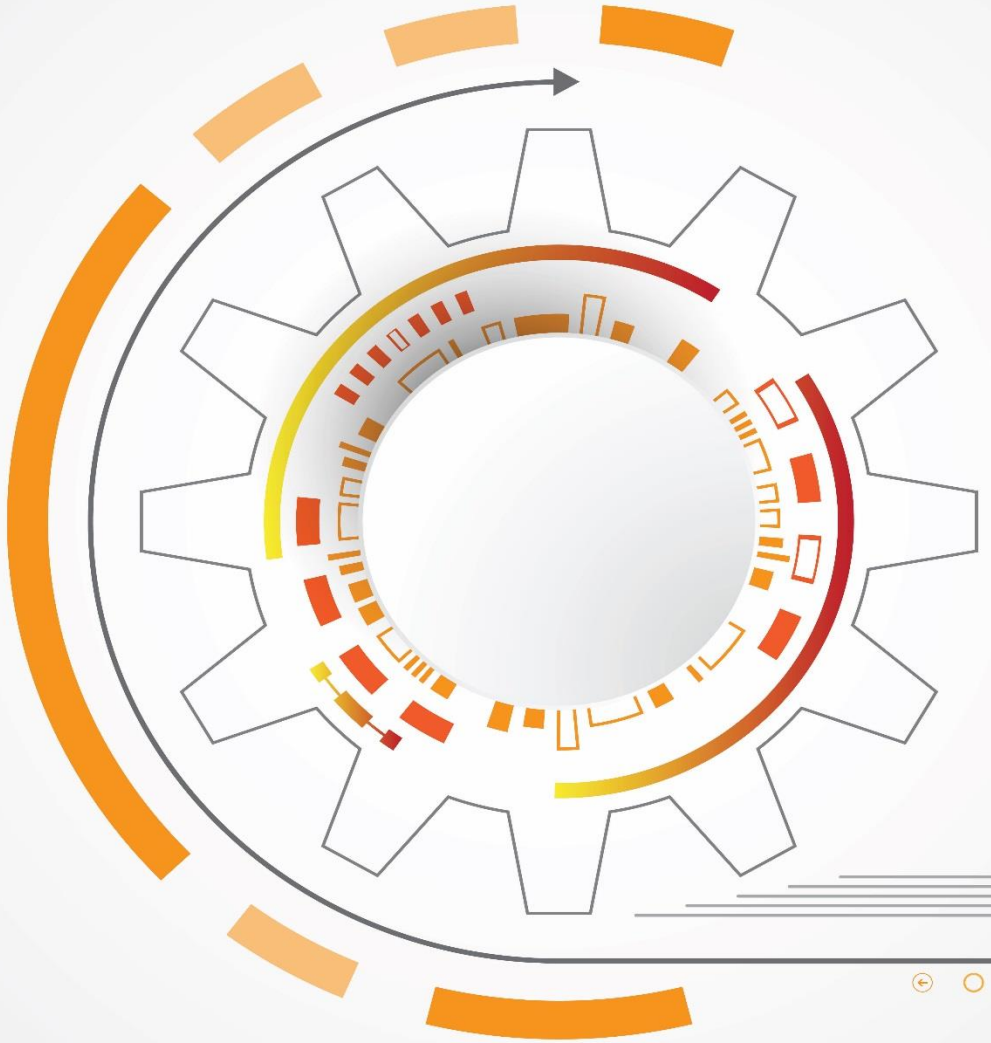
- From <10 to 5000 micrometer particles
- Provides information on chemical structure
- Provides identification of organic material (and some inorganics)

RAMAN SPECTROSCOPY



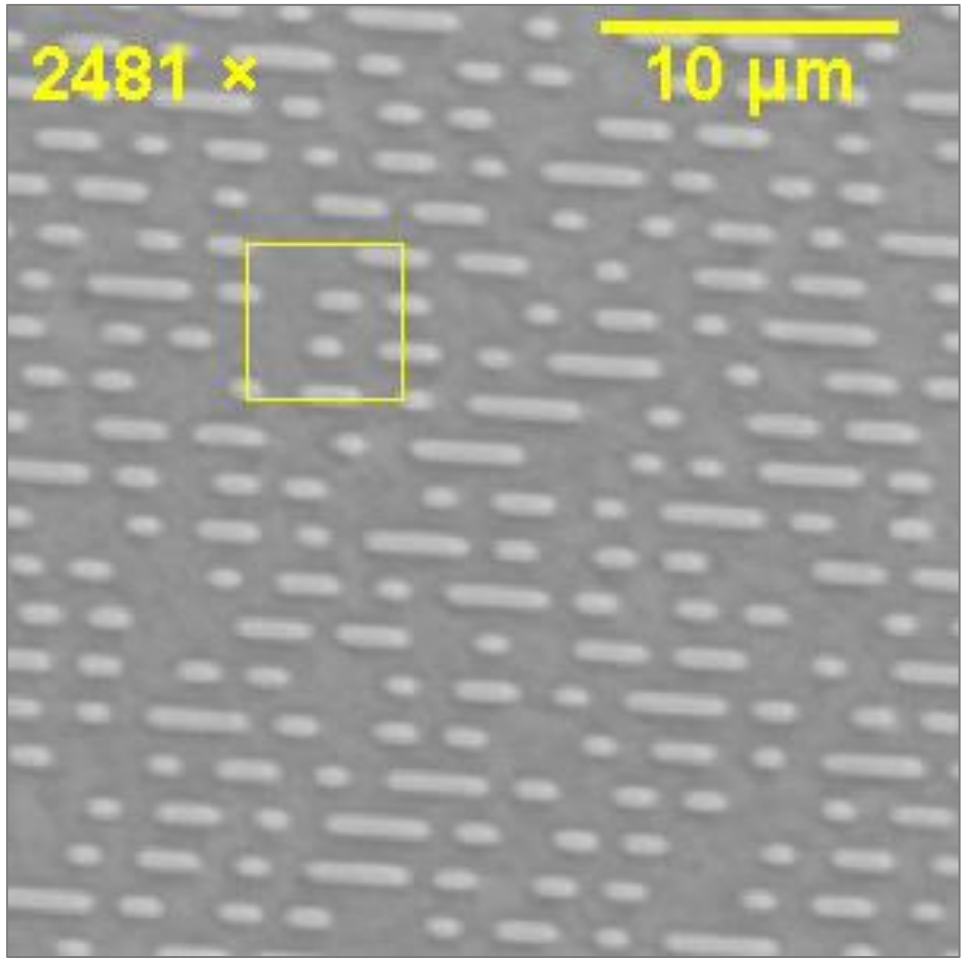
- From <1 to 5000 micrometers
- Uses monochromatic light source (laser)
- Provides information on chemical structure

- Provides identification of organic material
- Superb for minerals



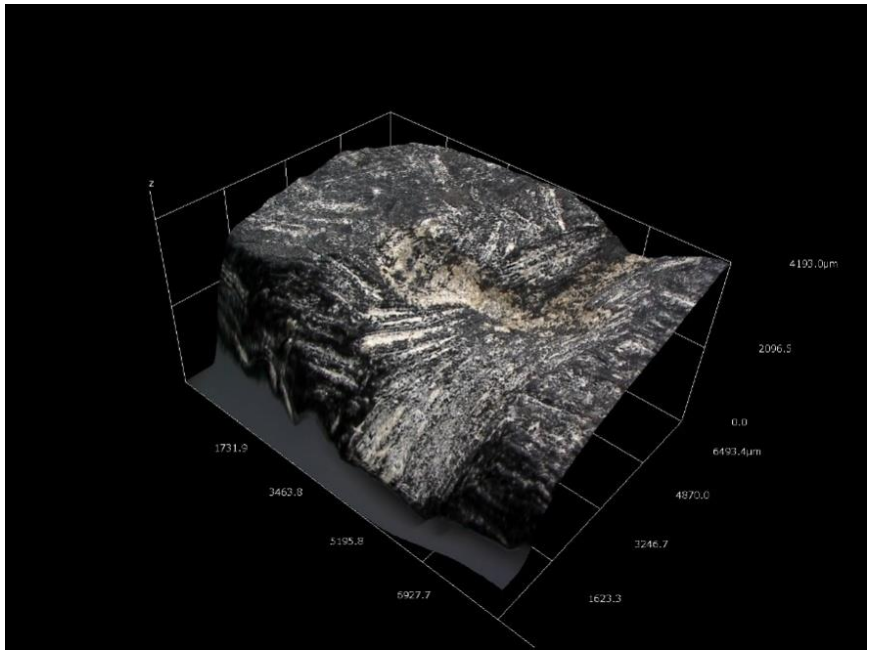
PROJECT EXAMPLES

COMPACT DISC PIRATING



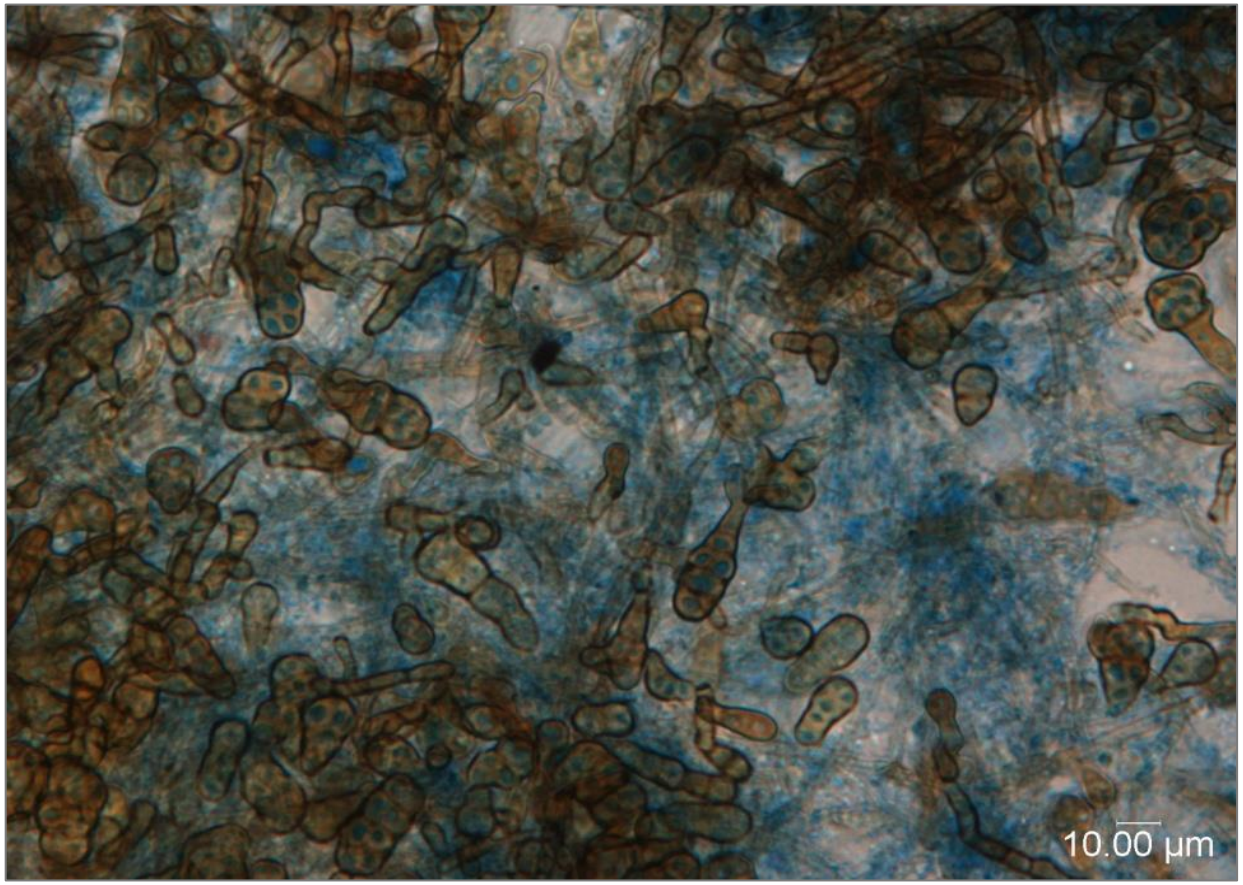
- A full run of compact discs were showing similar read errors.
- Examination of the original master showed scratches consistent with handling errors
- Manufacturer proven to have pirated CDs

ANTIQUITIES AUTHENTICATION



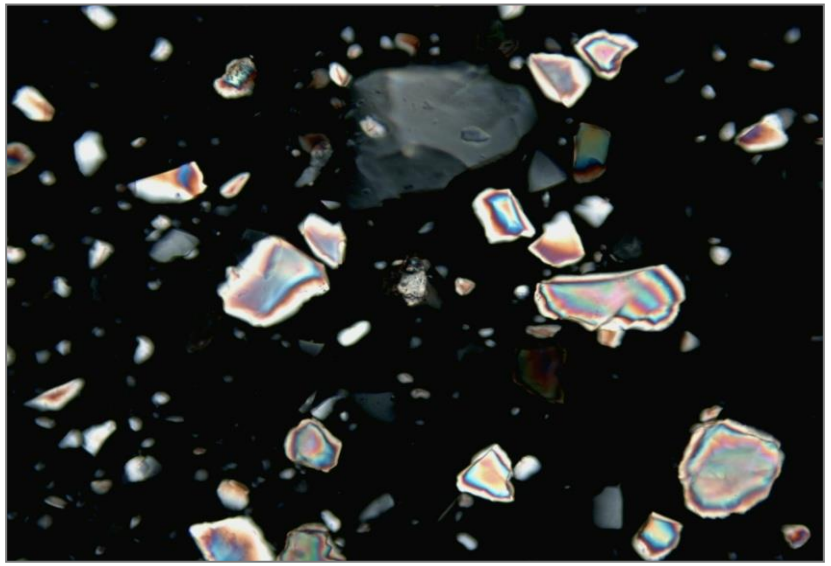
- Seal purportedly from Bactrian Empire, circa 250-350 BCE
- 3D modeling shows the cuts are too sharp
- Supplementary Raman spectroscopy shows the white material is the same piece (steatite)
- Conclusion - piece is not authentic

UNKNOWN BLACK LUMP IN OJ



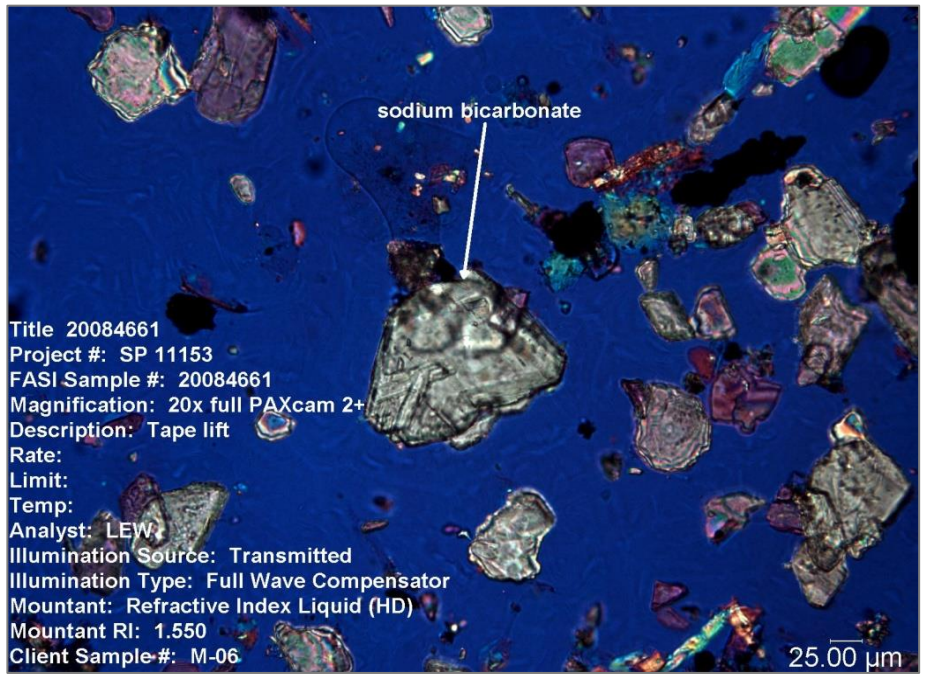
- Black lump of goo in OJ from commercial establishment
- Simple PLM examination shows the mass to be composed of Alternaria sp.

UNKNOWN WHITE POWDER



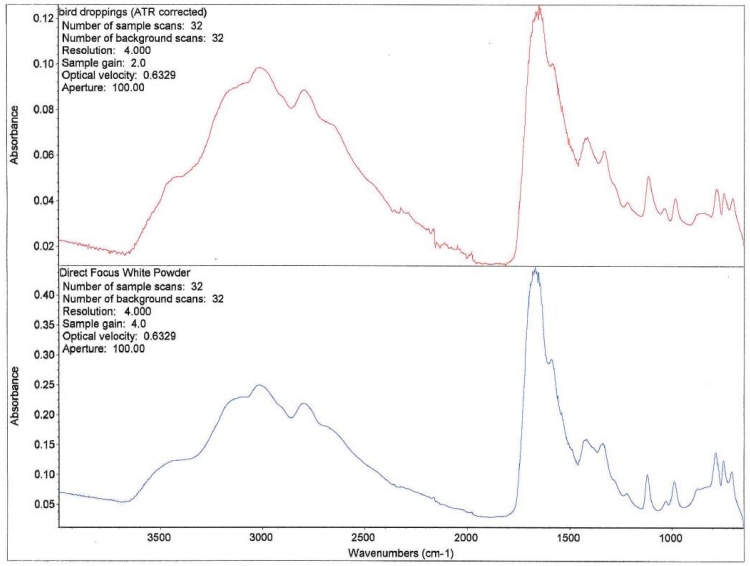
- A government agency had an unknown white powder found strewn in a room.
- Micro-analysis showed the presence of ammonium sulfate, mono ammonium phosphate and muscovite mica. This combination of chemicals is consistent with ingredients of an ABC dry chemical fire extinguisher. Combined with an examination of the deposition of the powder, it was determined that a fire extinguisher had been sprayed through an outside window into the room.

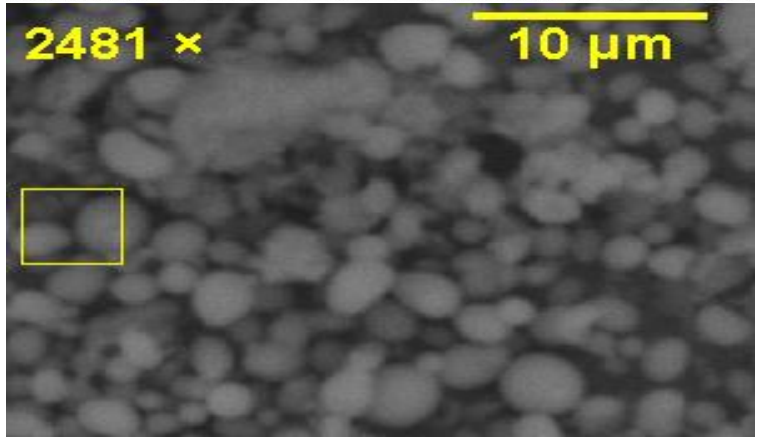
UNKNOWN WHITE POWDER



- Homeowner cleaning house, discovers pile of unknown white powder, suspects drug use by children
- PLM immediately shows characteristic morphology of sodium bicarbonate

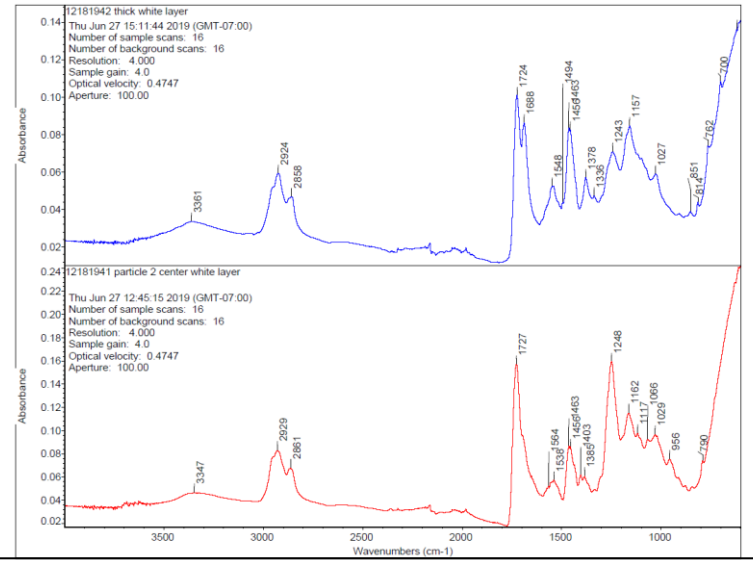
UNKNOWN WHITE POWDER

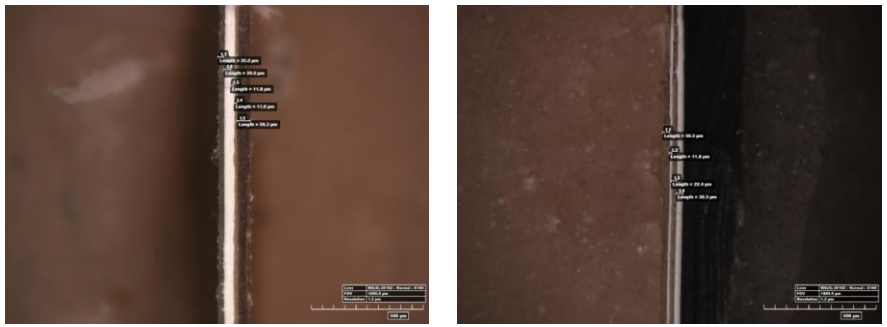




- Man suspects neighbor is poisoning his pool
- SEM shows small nodules, indicating biological origin
- FTIR confirms findings of bird droppings

UNKOWN WHITE POWDER



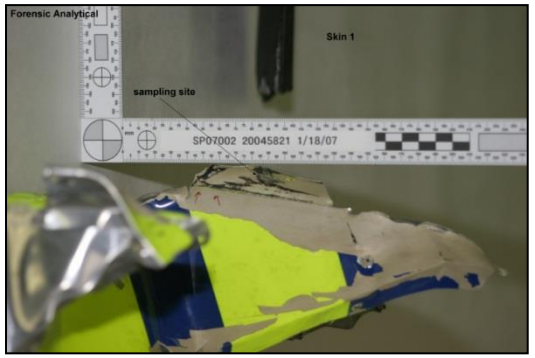


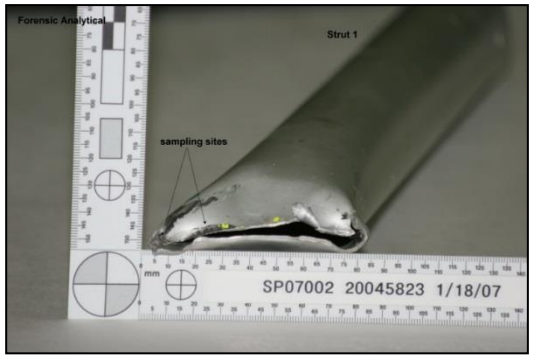
- Auto accident between two white vehicles
- Was there contact between the two?
- Do the layers match?
- Neither layer thickness or composition of paints in layers matched, therefore no contact occurred

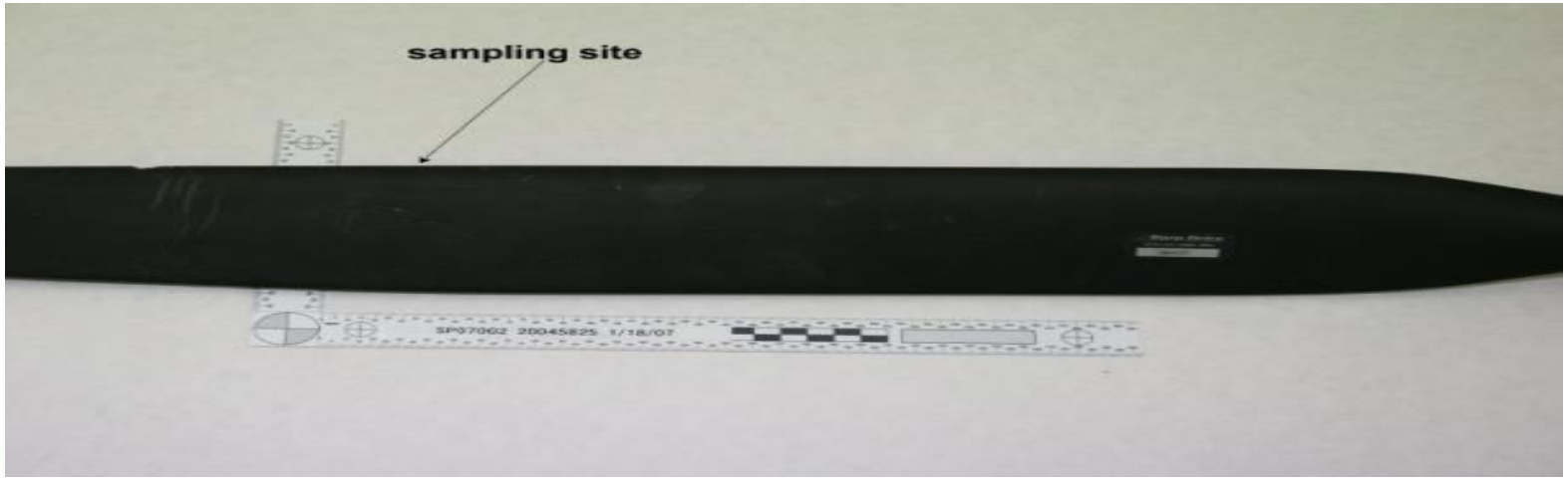
PAINT ANALYSIS –
THICKNESS, COMPOSITION

AIRCRAFT CRASH INVESTIGATION

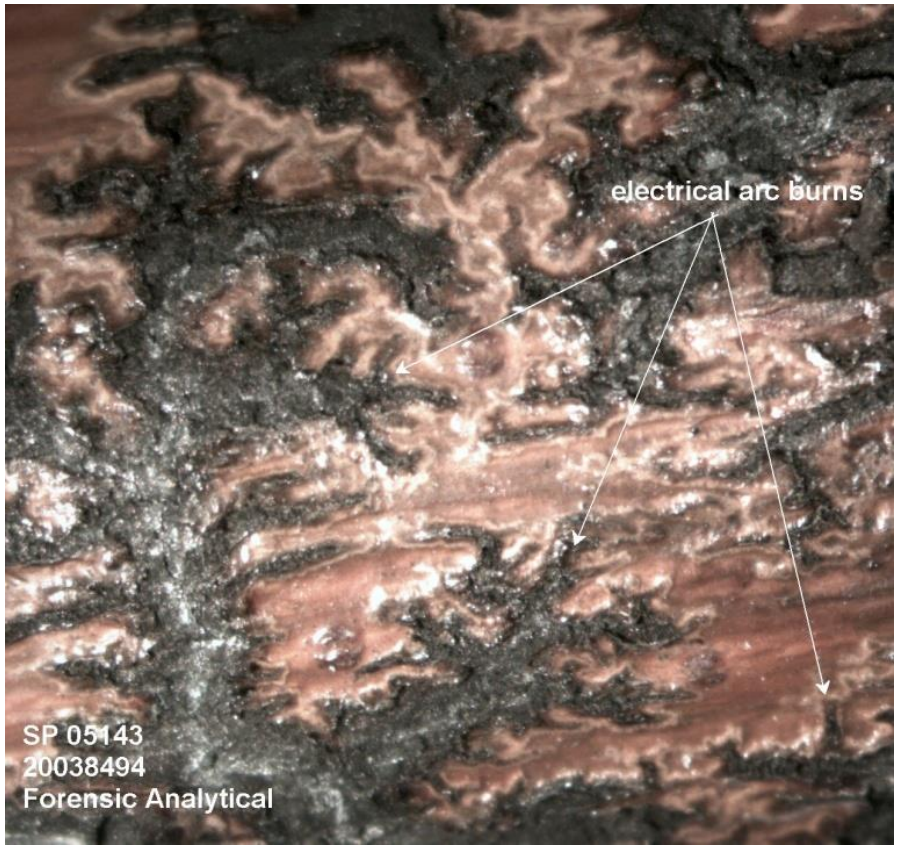
- Single engine aircraft crash
- Microscopy detected carbon fibers consistent with those used in the propeller on smudged areas of fuselage.
- Investigation clearly shows contact of the propeller and portions of the struts and fuselage.







ACCIDENTAL DEATH (P.1)



- Worker installing cable
- As the cable is being strung, an electrical discharge occurs, moving from the line to the ground, electrocuting the worker.
- Lichtenberg figures are characteristic of electrical arc burns

ACCIDENTAL DEATH (P.2)

- The unrolling of the cables from the truck acted as a way to generate charge. The system acted as a giant capacitor.
- The contact point of the line with hanging branches provided a path for the charge to move to ground.
- Microscopic fragments of burnt branch were found embedded in the line.

TO SUM UP

- By using a combination of optical microscopy (OM), electron microscopy (EM) and vibrational spectroscopy (VS) one can obtain the following data:
  - Basic morphology, size, color (OM)
  - Elemental composition (EM)
  - Chemical structure (VS)
- With these three complementary techniques, the data they provide and knowledge of the context of the analysis, most trace materials analysis problems are quite solvable.


QUESTIONS?

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WHEN YOU NEED TO BE SURE