The Potential of Mineral Varieties for Forensic Soil Analysis

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Lack of Trace Labs Analyzing Soil Evidence and Possible Reasons

- Soil has been used as evidence in criminal investigations for over 100 years, and yet currently only ~25% of trace labs analyze soil (Parent and Koch 2009)
- Soil is complex
  - Numerous organic components
    - Pollen, spores, micro-organisms, plant waxes, etc.
  - Numerous inorganic components
    - Many minerals, often with variable properties
  - Numerous anthropogenic components
- Lack of consensus over methods, with published methods including comparison of:
  - Color, particle size, bulk chemistry, pH, isotopes, pollen, fungal content, enzymes, mineralogy (by PLM, SEM/EDS, XRD), FTIR spectroscopy, microbial DNA profiling, organic components by GC/MS, and more
- Lack of expertise or equipment

Why We Should Try to Change This

- Soil is a potentially valuable form of trace evidence
  - Very common in the environment
  - Highly individualistic
  - Highly likely to be transferred
- There are numerous compelling case examples providing evidence of its value (Murray, 2004; McPhee, 1997)

How We Can Change This

- Develop a method of soil comparison that meets the following criteria:
  - Utilizes existing personnel and their existing skill sets with minimal additional training
  - Utilizes existing equipment readily available in most trace laboratories
  - Is efficient and effective for typical forensic soil samples
- Once soil becomes an established form of trace evidence, labs can move towards a more comprehensive method like the one advocated by Skip Palenik (2007)

Proposed Method: Mineral Varieties

- Every mineral has a potential range with respect to a number of its properties
- Groups of a mineral that are similar with respect to these properties are mineral varieties
- They have been used by sedimentary geologists as early as 1928 and are still used today (Brammal 1928)
- Geologists originally focused on properties observable by PLM (grain size, degree of rounding, mineral color, inclusions, twinning, zoning, overgrowths, streaks and fractures); now chemical analysis, isotopic analysis and CL imaging are more common (Mange, 1992; Morton,1985; Weltje, 2004)

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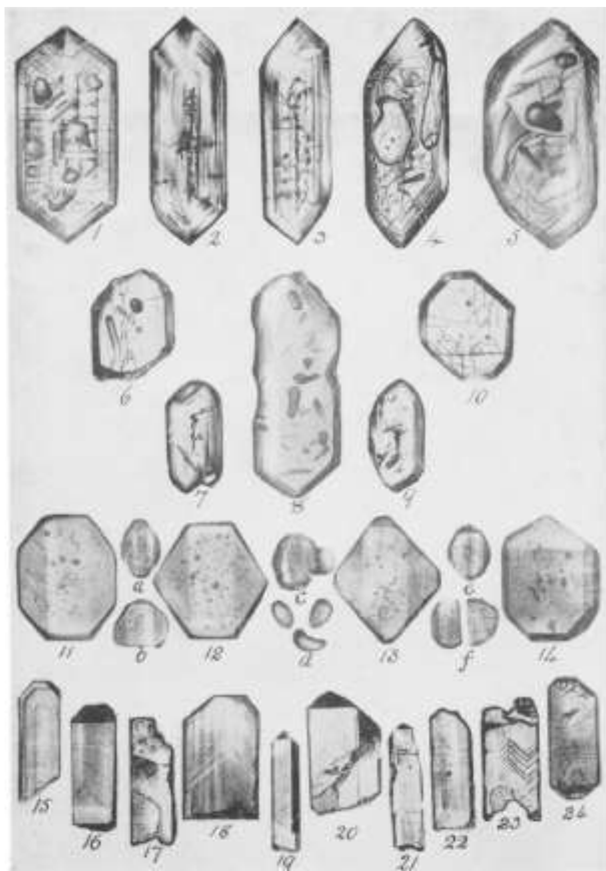
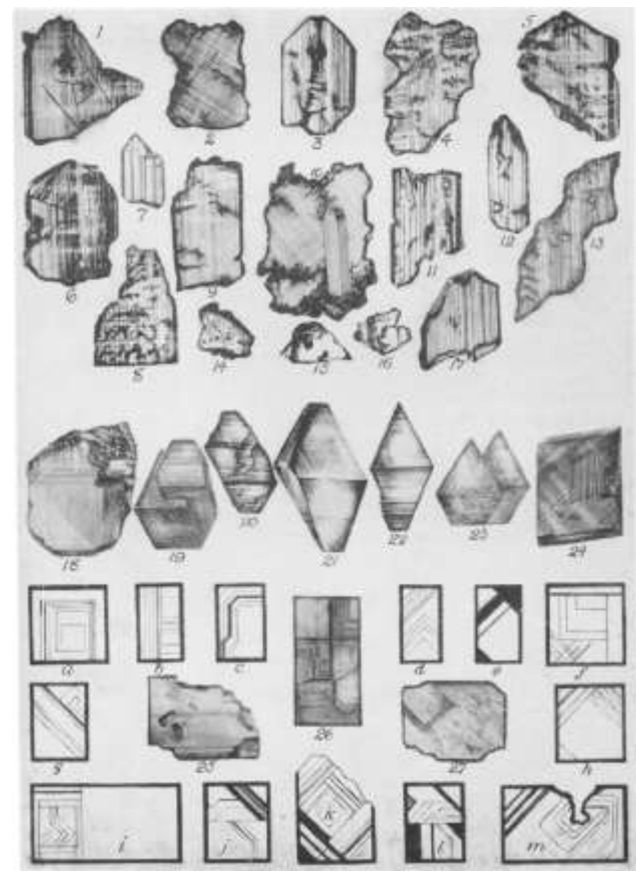
Source of the Idea

- "As a clue to provenance the varietal features of a species in a detrital assemblage may be of greater significance than the mere presence of that species"
  Figures and quote from Brammal (1928)





Mineral Varieties in Forensic Science

- Mineral varieties in a questioned soil can be characterized and compared to those present in a known soil sample
- Forensic scientists have been doing this for a long time
  - In the Margarethe Filbert case in 1908, Georg Popp described quartz grains in various soil samples as being “splintery” or “milky” (Thorwald, 1967)
- Skip Palenik has long advocated the use of mineral varieties in soil comparisons
  - “We have come to place perhaps more than ordinary importance on the concept of mineral variety when comparing samples by means of their heavy minerals” Palenik (2007)

Proposed Research

- However, this has never been done systematically (the one exception being a study by Bull and Morgan, 2006 that focused on SEM of quartz)
- Proposed research would focus on several commonly occurring minerals
- Study a large number of soils covering a variety of soil types to determine
  - Which minerals show the most potential to discriminate between different soils
  - What properties are most variable for each mineral
- Obtain insights into intra-sample and inter-sample variability, and the scale of this variation

Uses Existing Personnel and Existing Skills

- Uses the same principles involved in fiber analysis, performed by >90% of trace labs (Parent and Koch, 2009)
- Identify a small number of minerals by polarized light microscopy
  - Color, pleochroism
  - Relief, Becke line test
  - Birefringence
  - Extinction characteristics
  - Sign of elongation
- Further describe the minerals on the basis of properties observable by PLM

Uses Existing Equipment

- Uses polarized light microscopes, available in approximately 90% of trace evidence laboratories (Parent and Koch, 2009)

Efficient and Effective in Forensic Contexts

- Efficient separation – only a single fraction of fine sand-sized minerals needed
- Efficient analysis – only a few minerals would be considered
- The method should be effective for very small samples
- Mineral varietal studies are performed by geologists because they eliminate hydraulic, diagenetic and mixing problems
- For the same reason, they would potentially be robust to differential transfer and persistence, as well as contamination

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Potential Mineral Candidates - Quartz

- Grain Morphology
  - Euhedral, subhedral, anhedral
  - Equant, elongated
  - Rounded, sub-rounded, angular
- Polycrystallinity
  - Single crystal
  - Polycrystalline
  - Number of crystals per grain
  - Equidimensional or different sizes
- Undulosity
- Inclusions
  - Number, type, organization (randomly oriented or aligned)
- Surface Features

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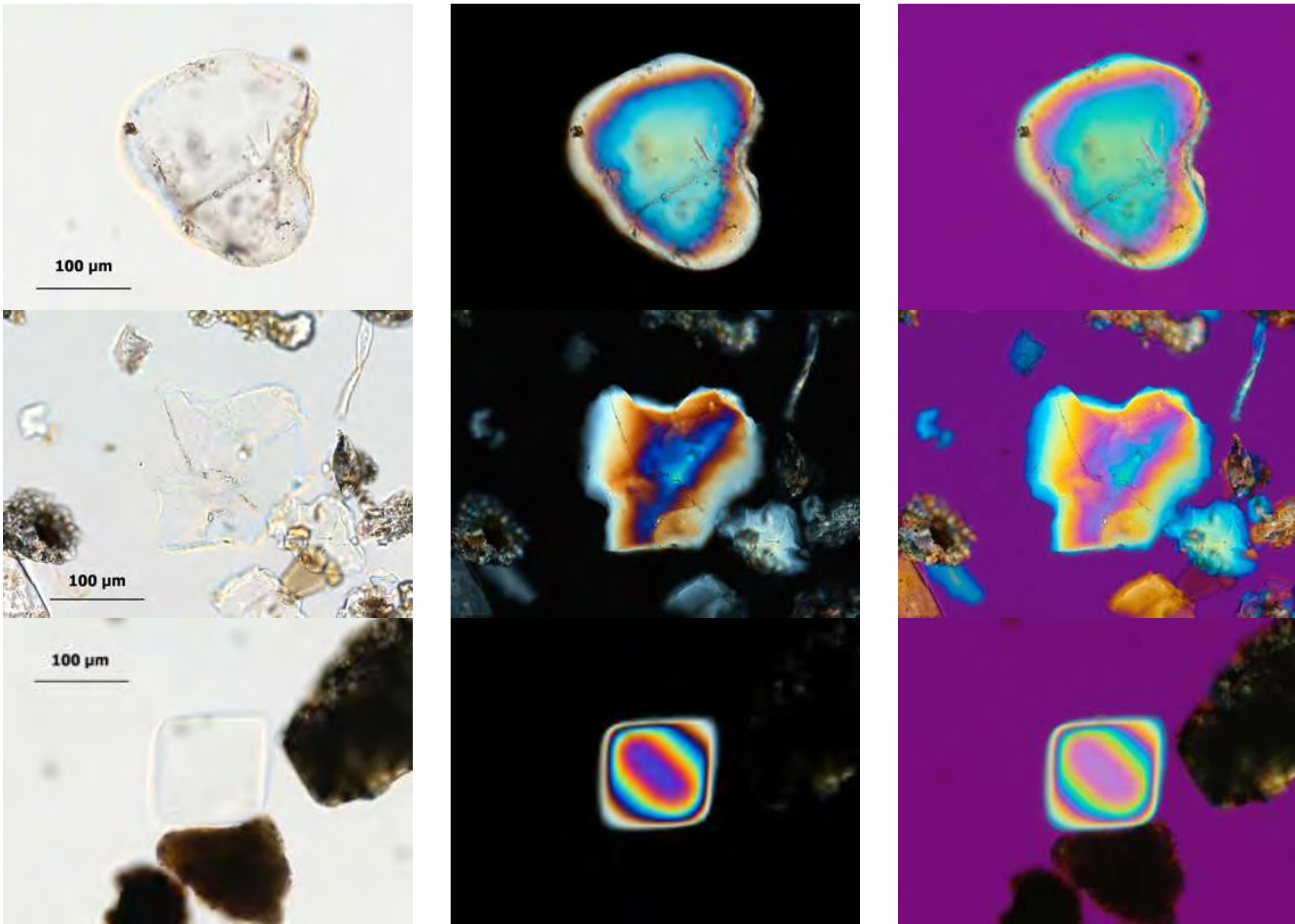
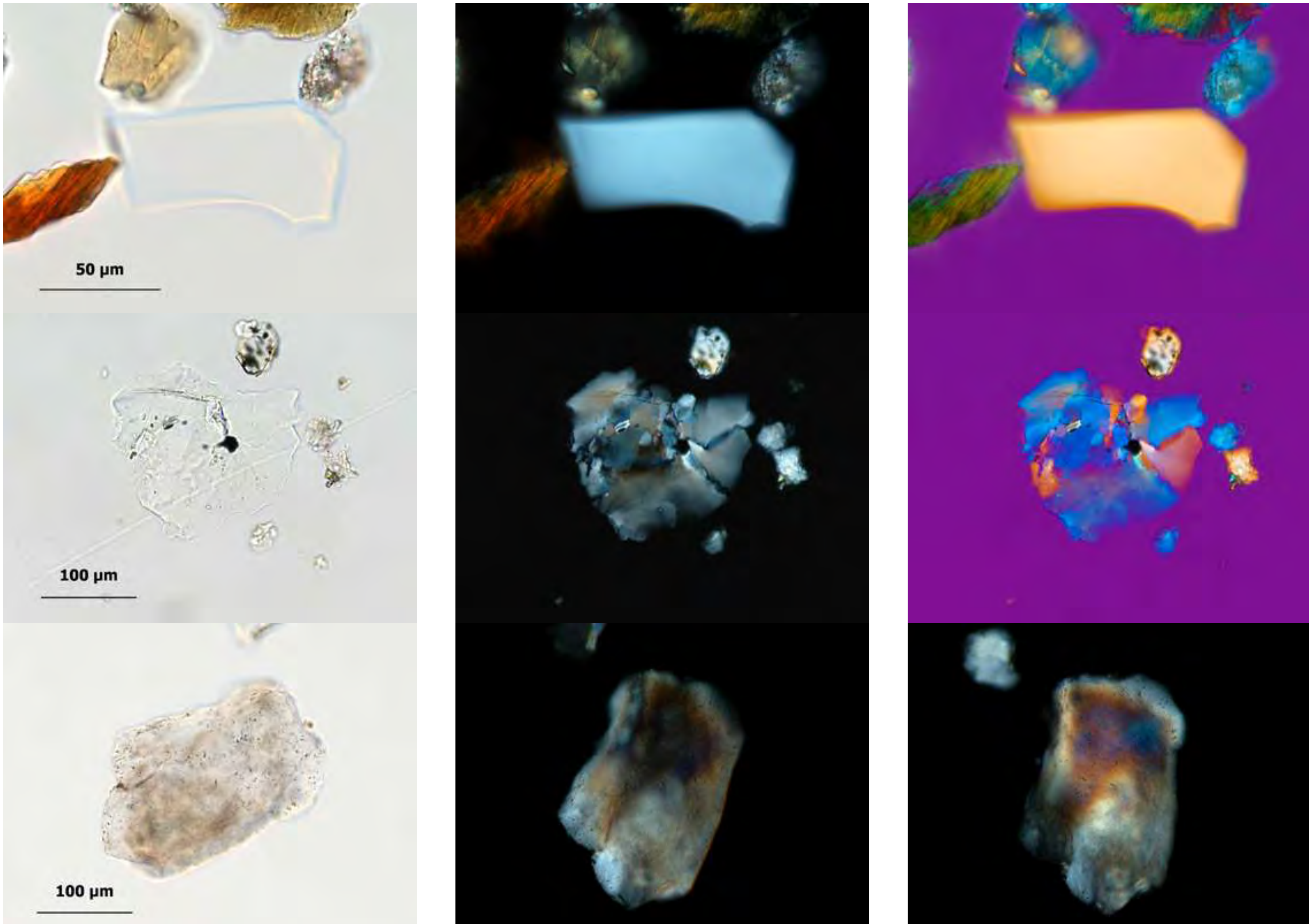
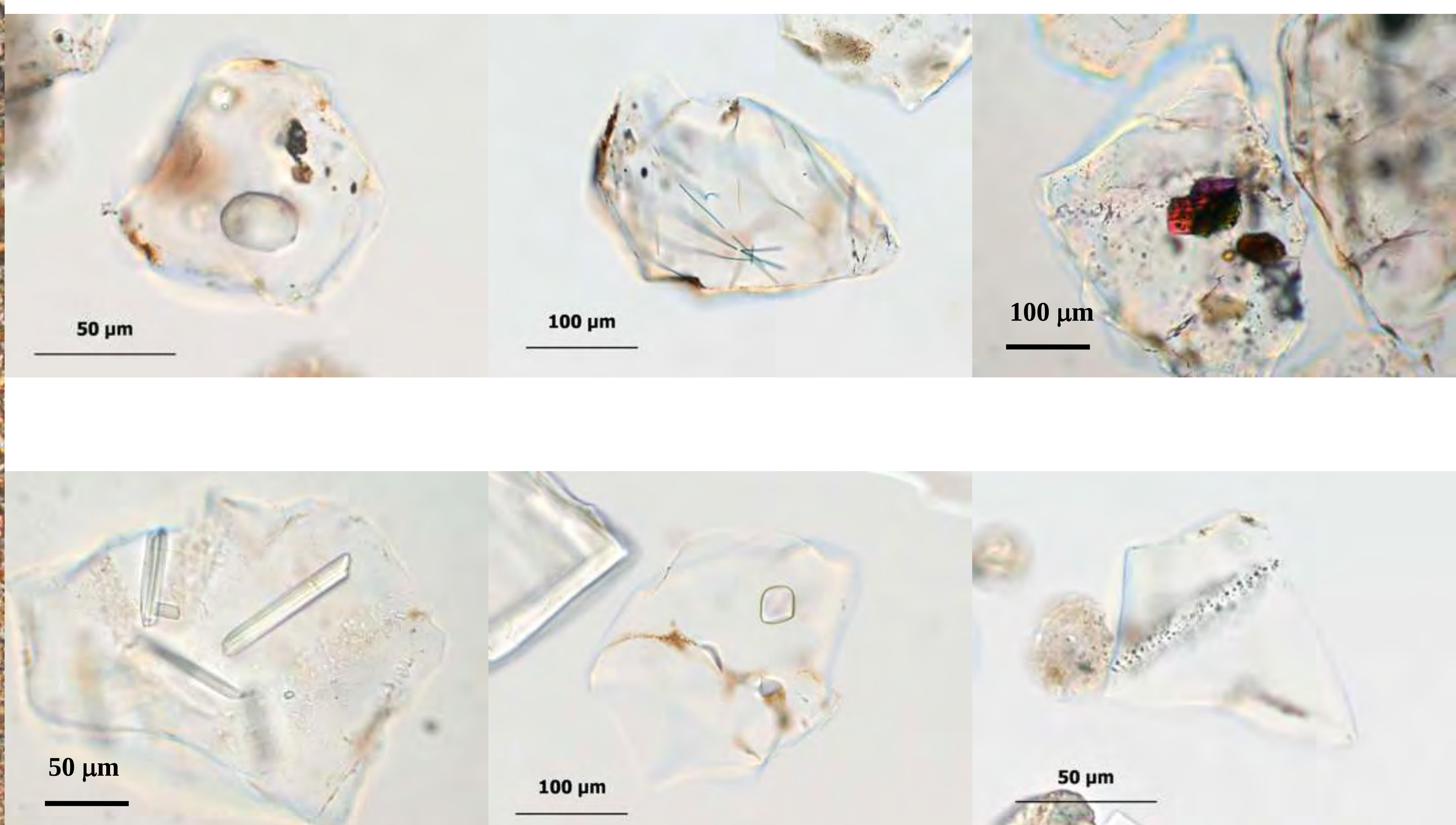
Quartz Grain Morphology



Quartz Crystallinity, Undulosity



Quartz Inclusions



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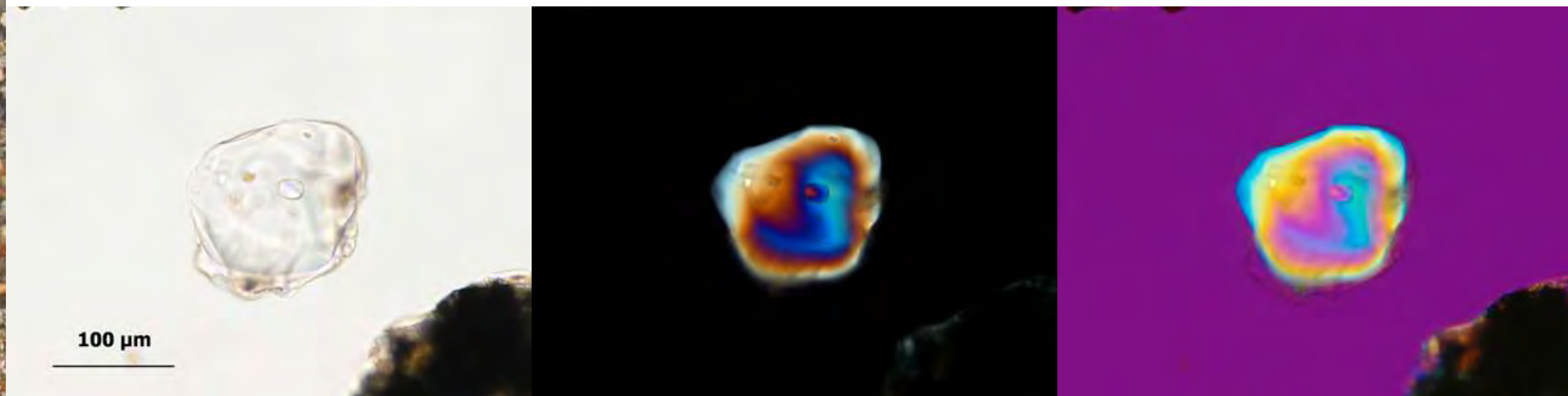
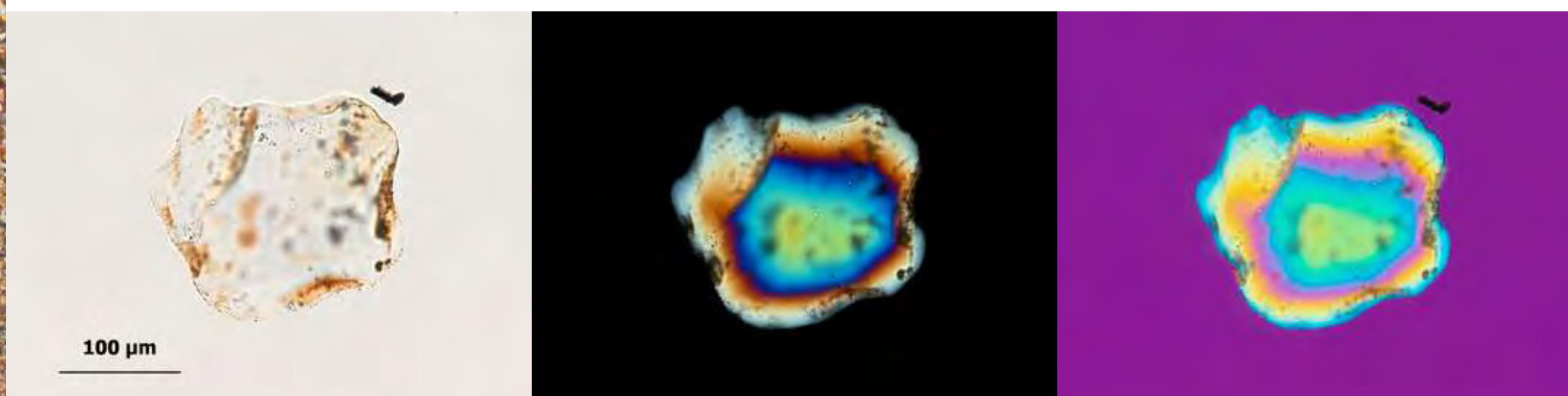
Quartz Surface Coatings





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Potential Mineral Candidates – Alkali Feldspar

- Grain Morphology
  - Euhedral, subhedral, anhedral
  - Equant, elongated
  - Rounded, sub-rounded, angular
- Twinning
  - Un-twinned, simple twins, tartan twinning
- Exsolution
  - Homogeneous, coarse exsolution lamellae, fine lamellae
- Inclusions
  - Number, type, organization (randomly oriented or aligned)
- Alterations
  - Fresh unaltered to highly altered
- Surface Features

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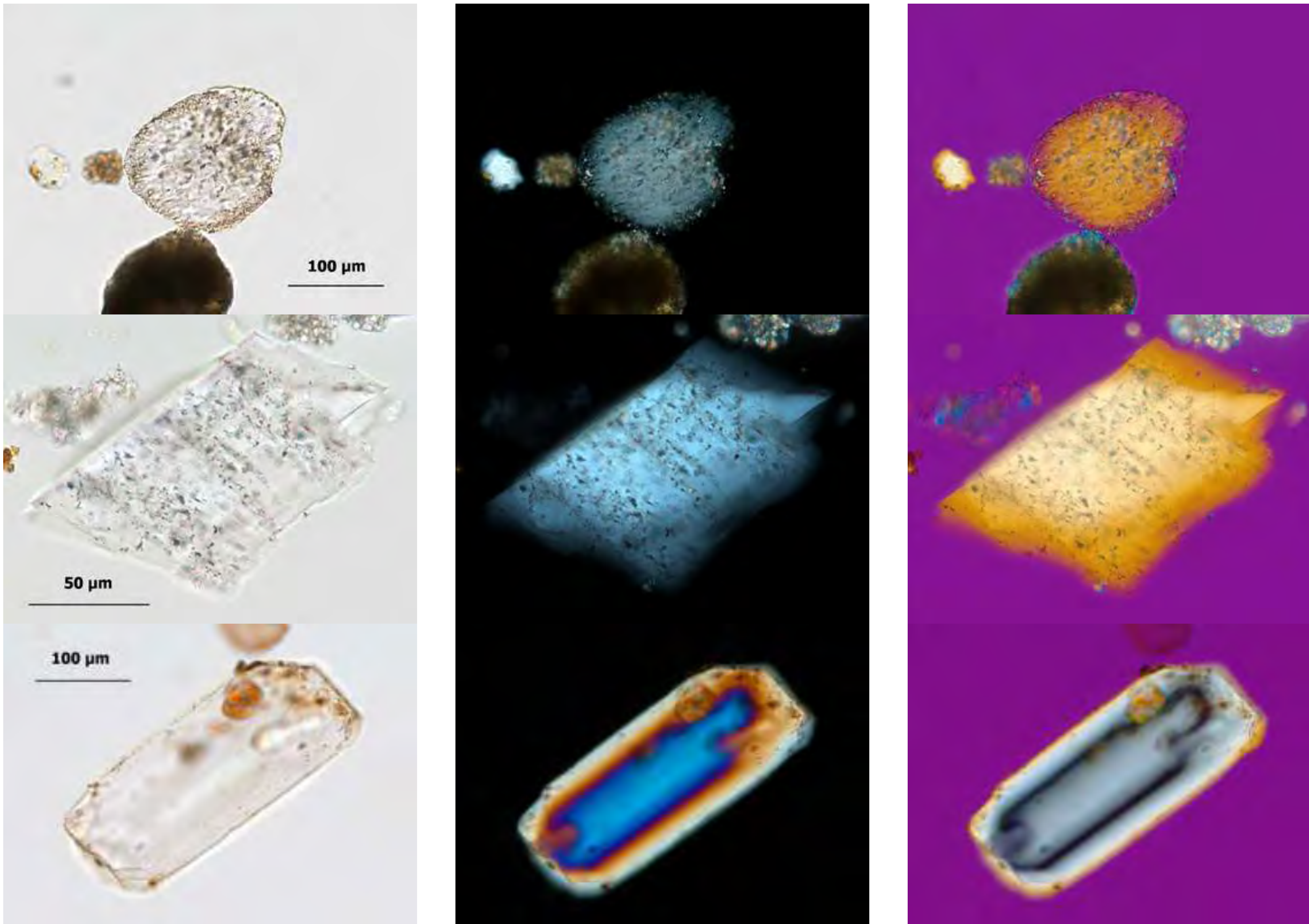
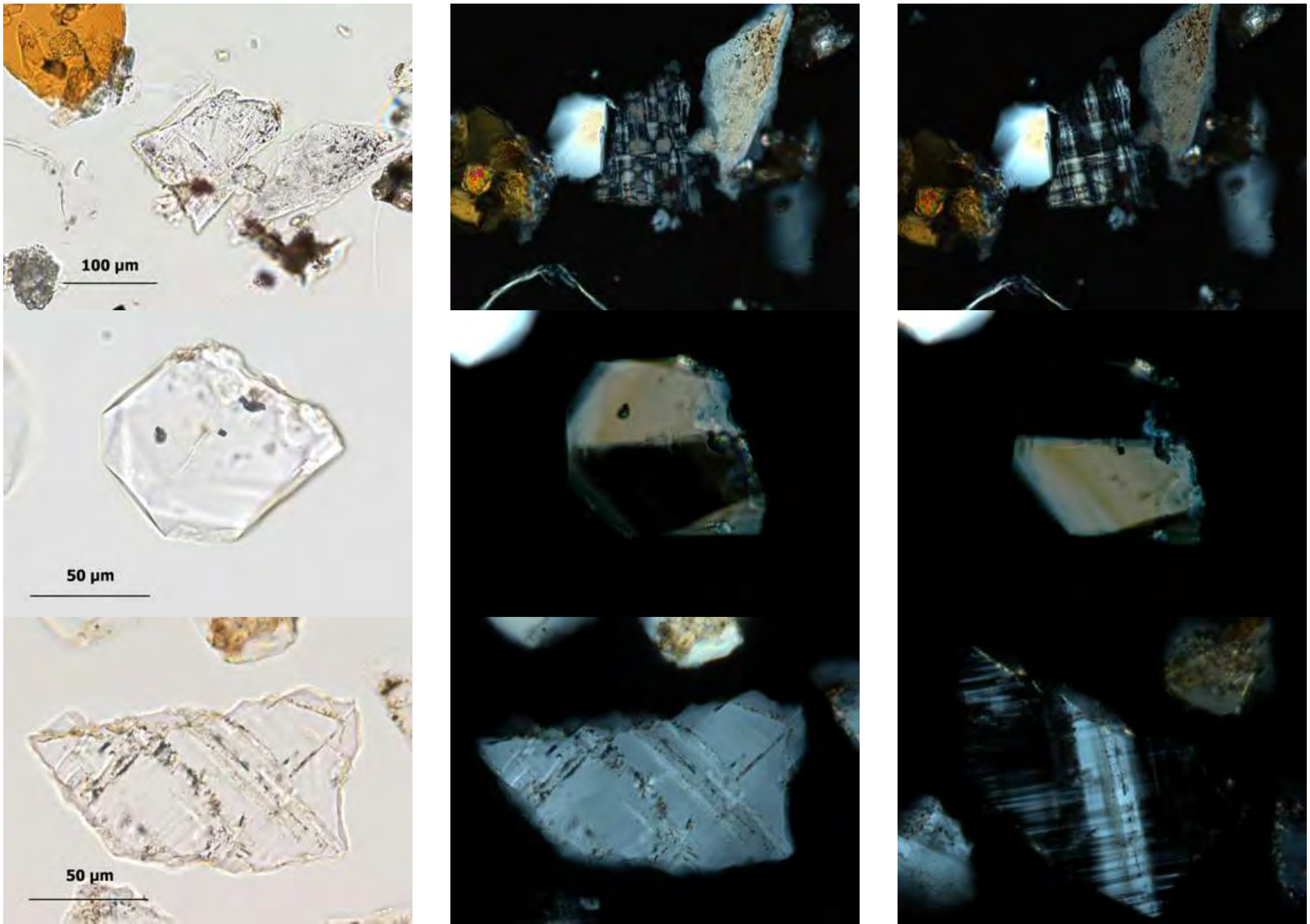
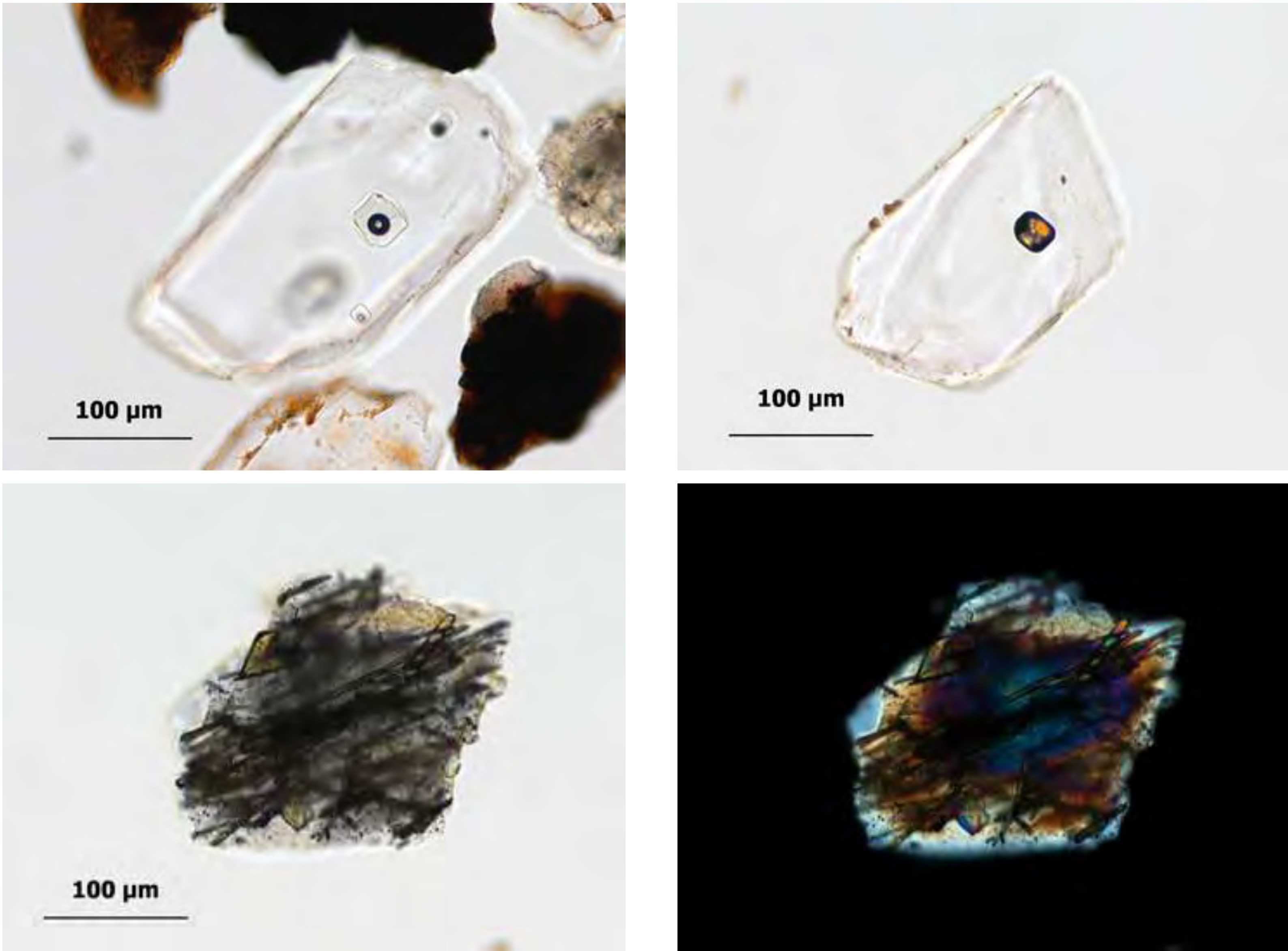
Alkali Feldspar Grain Morphology



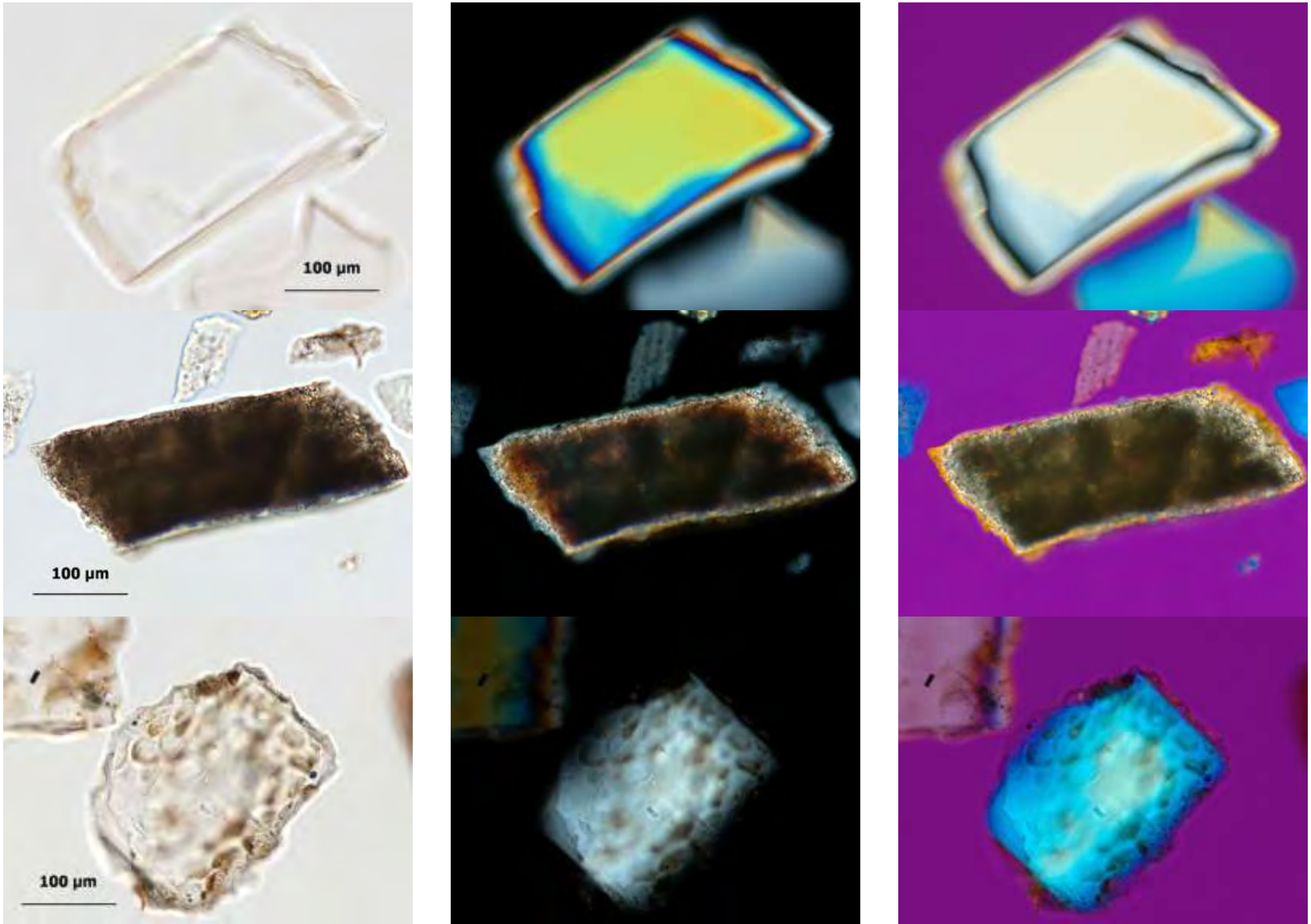
Alkali Feldspar Twinning and Exsolution



Alkali Feldspar Inclusions



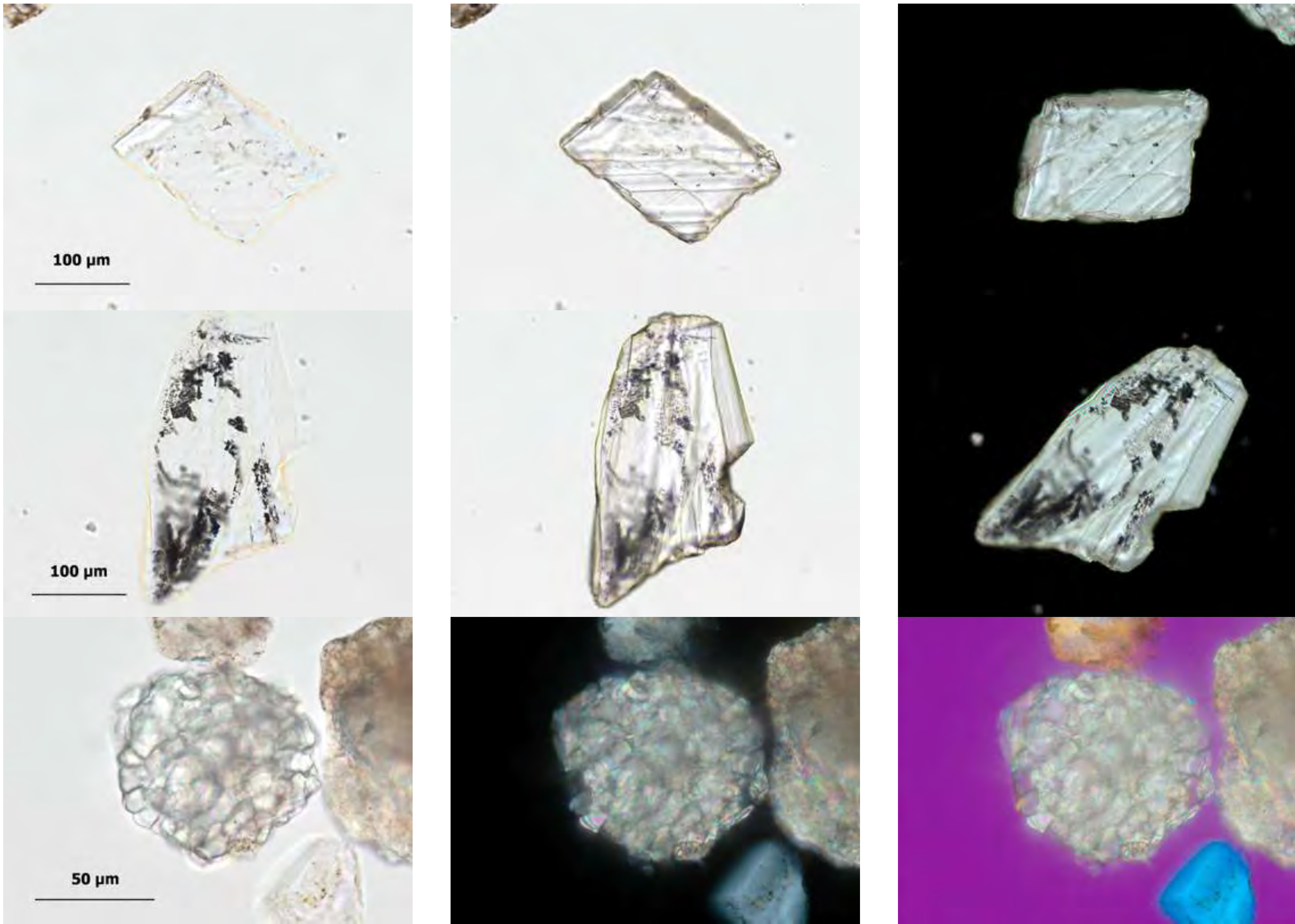
Alkali Feldspar Alteration and Surface Coatings



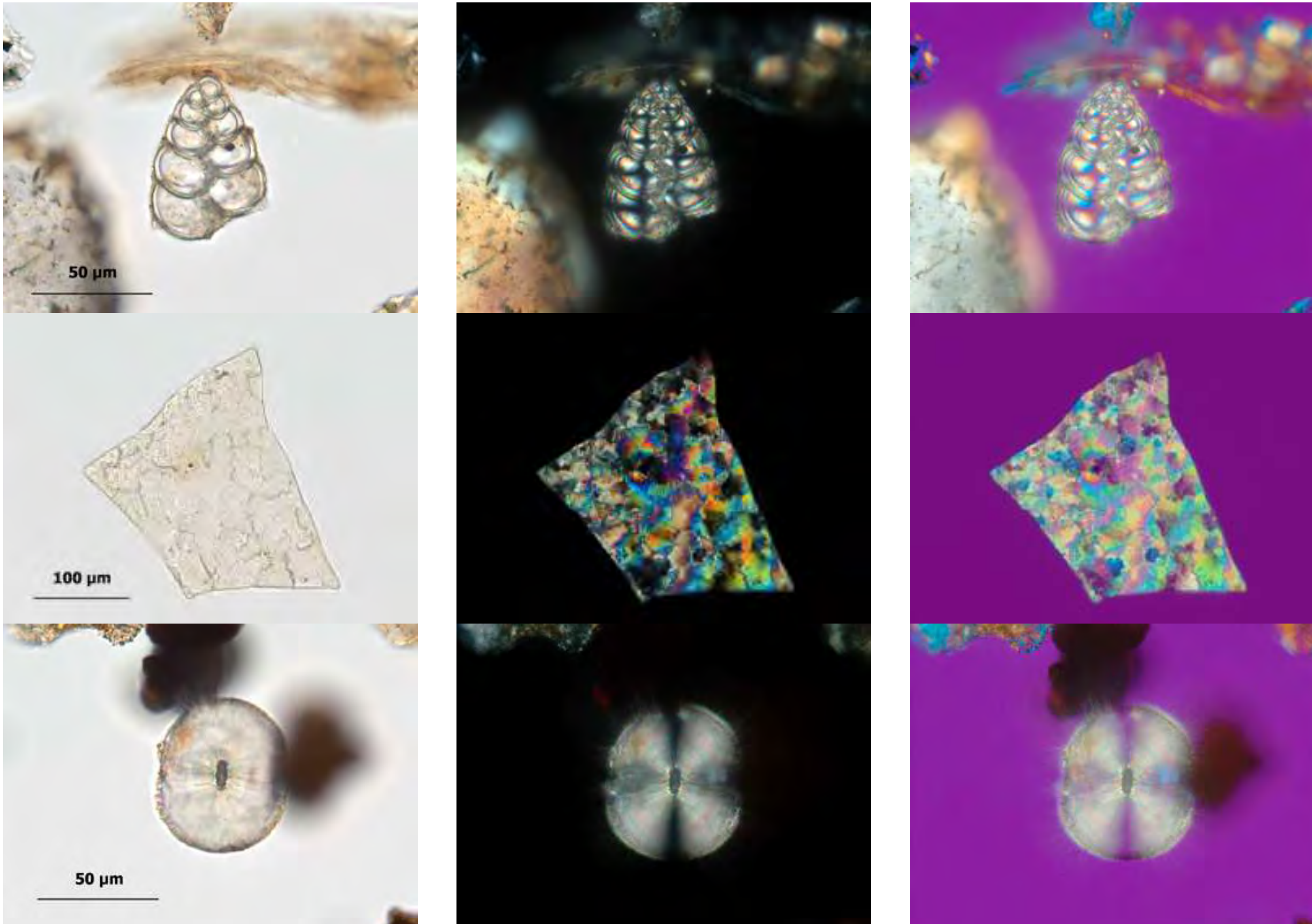
Potential Mineral Candidates – Calcite

- Grain Morphology
  - Euhedral (cleavage fragments), subhedral, anhedral
  - Biogenic (tremendous variety of types)
- Twinning
  - Twinned, un-twinned
- Crystallinity
  - Single crystals, polycrystalline
- Alterations
  - Fresh unaltered to highly altered
- Inclusions
  - Number, type, organization (randomly oriented or aligned)
- Surface Coatings

Calcite Grain Morphology, Crystallinity



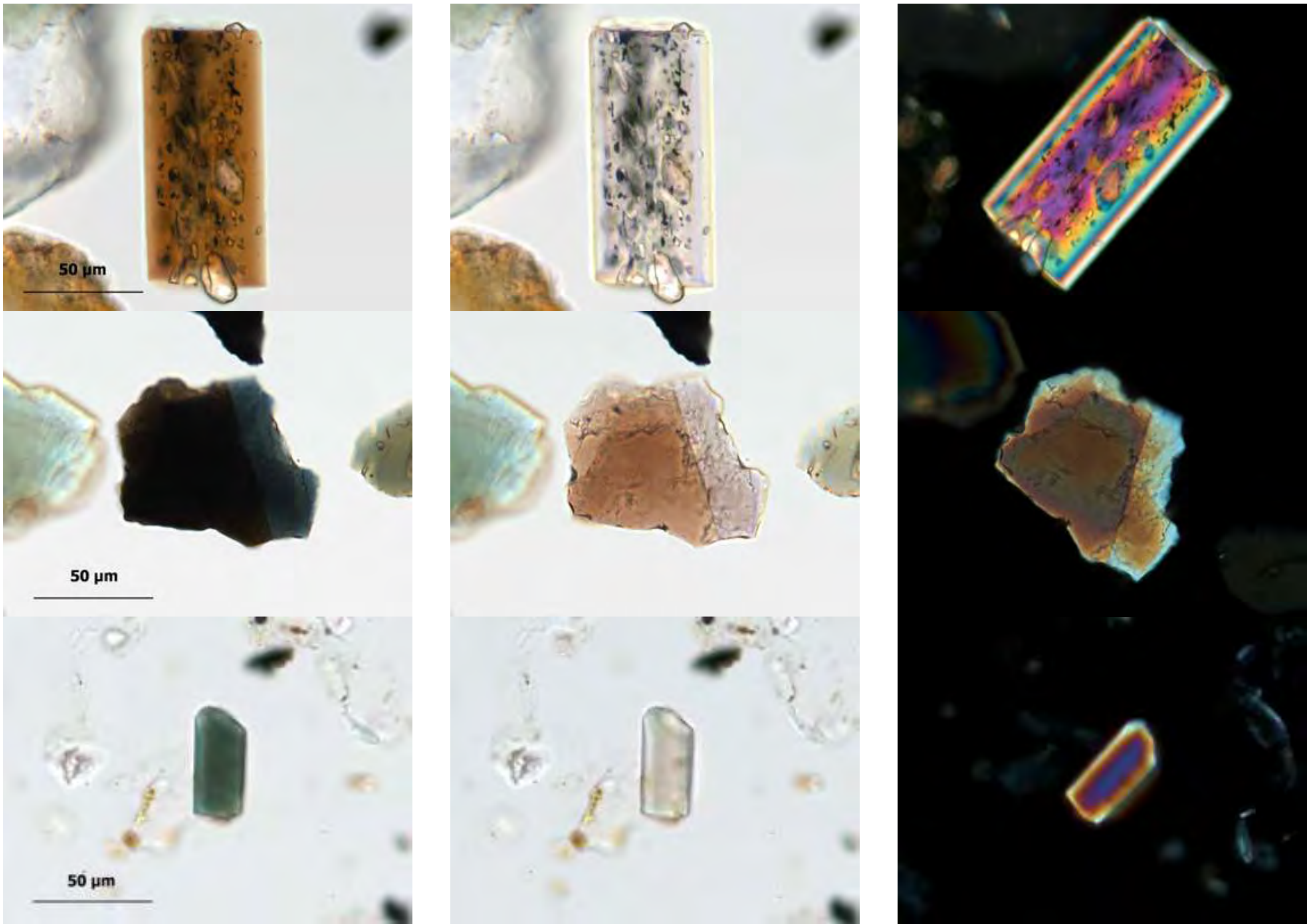
Biogenic Calcite, Ooids



Potential Mineral Candidates – Tourmaline

- Grain morphology
  - Euhedral, subhedral, anhedral
  - Equant, elongated
  - Rounded, sub-rounded, angular
- Pleochroic scheme
  - Variable colors and intensities
- Inclusions
  - Number, type, organization (randomly oriented or aligned)
- Surface coatings, alterations

Tourmaline Grain Morphology



Interpretation Caveats

- Varieties for different minerals not necessarily independent
  - Volcanic quartz commonly has certain properties, as does volcanic feldspar
- Different varieties of the same mineral can generally be considered independent
- Ratios of mineral varieties for same mineral, or minerals with similar density and shape can likely be considered independent as well
  - Note: Bull and Morgan (2006) cautioned that comparing ratios of mineral varieties requires certain assumptions that may not always be valid
- These last two points should be confirmed by research

Conclusions

- A new method for forensic soil comparison based on mineral varietal types is proposed here
- Research is needed to determine proof of concept
- If it works, it has some attractive features: It could use existing personnel, skills and equipment, and could be robust to many of the problems faced in forensic soil analysis
  - Small sample size, differential transfer and persistence, contamination

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T R A C E S Y M P O S I U M

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