Application of the Daubert Standard To Forensic Paint Examinations

Scientific Working Group for Materials Analysis (SWGMAT)

Paint Subgroup

Revised March 2011

What is Paint?

- A manufactured product typically consisting of a mixture of numerous materials (components)
- It is formulated as a liquid or powder which is converted to a solid thin film by a curing process
- Paint manufacturers formulate their products differently
- Any given manufacturer offers a variety of grades or types of paint depending upon its projected end use or its cost
- It is mass-produced using a recipe, often in rather large batches

Paint as Evidence of Association

- Usually encountered in a cured form, often consisting of multiple intact layers commonly called a paint chip
- Each layer of paint has distinct features related to layer function
- In general, the more layers of paint present in a paint chip, the less likely it is for one to randomly encounter another source of paint with the same characteristics (layer sequence and layer components)
- Being mass produced, one has to consider the possibility that a given paint could be applied to a number of different objects

Purpose of Paint Analysis

- Attempt to differentiate two or more paint samples and eliminate the possibility that they have the same origin or source
- If a hypothesis of discrimination cannot be proven, then conclude that the paint samples may be somehow related and attempt to assess the significance of that relationship
- To provide investigative leads when a source for comparison has not been identified (using Paint Data Query or refinisher pages for auto paint, and/or industry contacts for all paints)

Types of Paint Examined

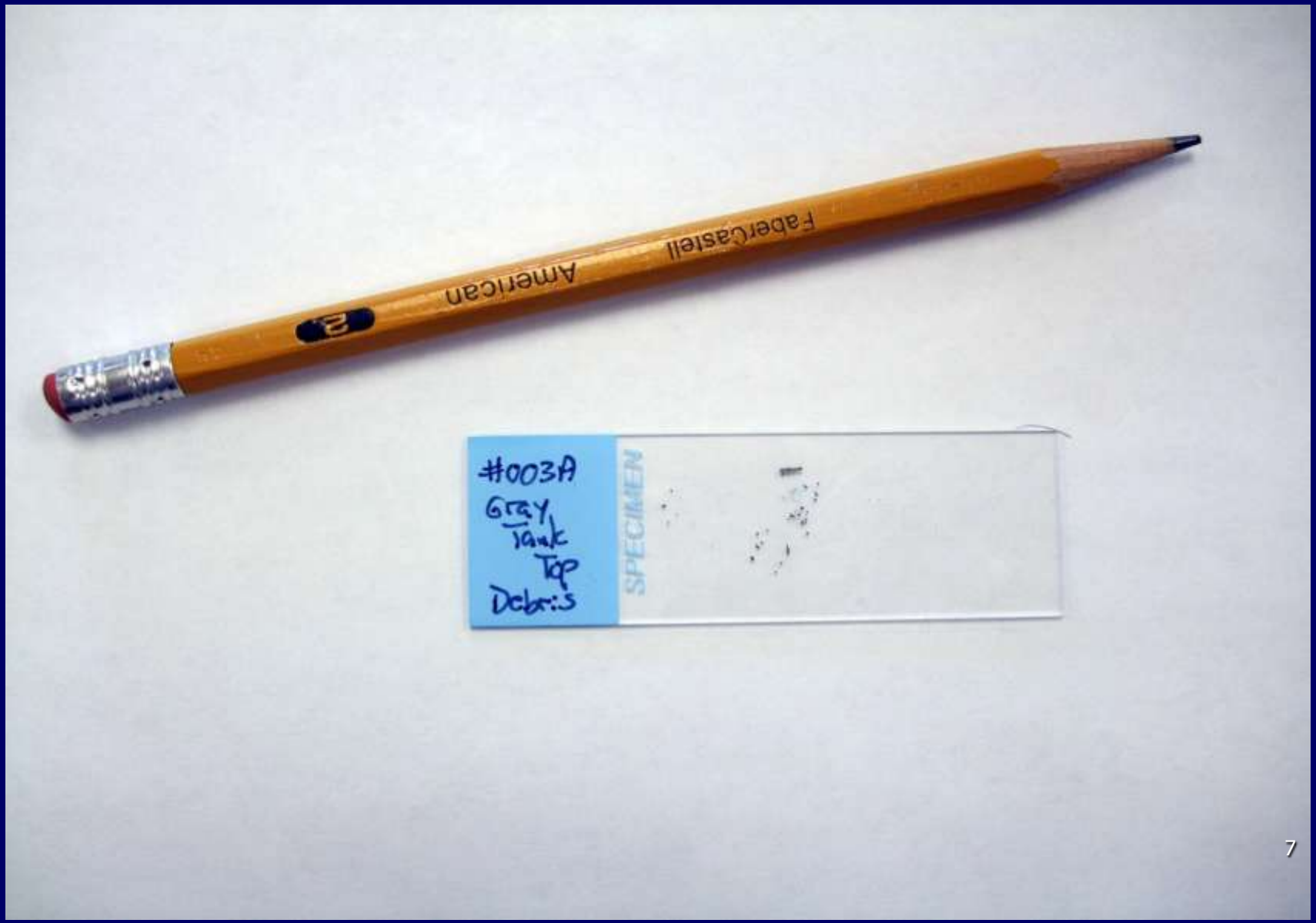
- Automotive
- Architectural
- Maintenance
  - tools, industrial protective housings, traffic control devices, valve knobs, bats
- Vehicular, non-automotive
  - marine, bicycle, scooter
- Can often be recognized by their microscopic and chemical properties

Examples of sampling

Directly from a substrate

Indirectly from clothing

Paint chips from shirt debris after clothing was processed



Paint chips from shirt debris after clothing was processed

Paint chips from shirt debris after clothing was processed

Microscopy

Observation and comparison of physical properties of a paint system using a microscope

Visual and microscopical examinations conducted first

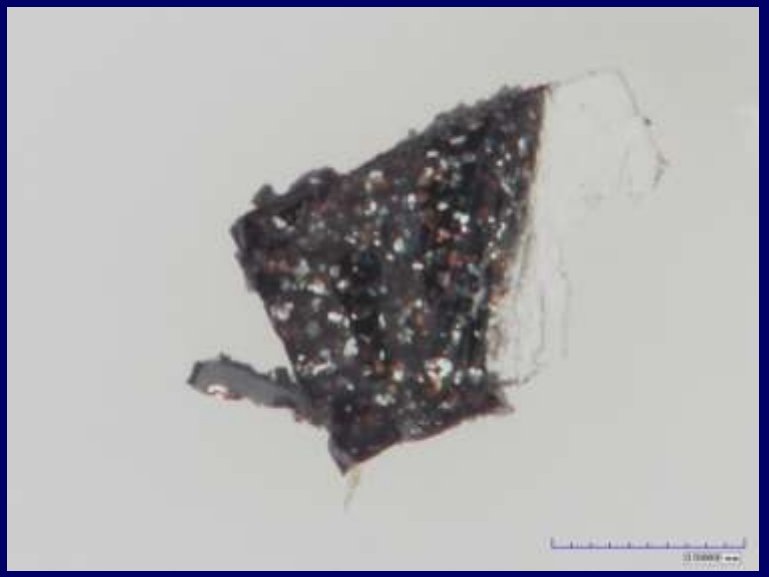
Microscopic observations

- Layer Structure
  - Number, sequence, and type of layers
- Color
- Texture
- Relative Layer Thickness
- Gloss/Sheen
- Anomalies/acquired characteristics
  - Weathering, soil between layers, overspray spots on surface, etc.

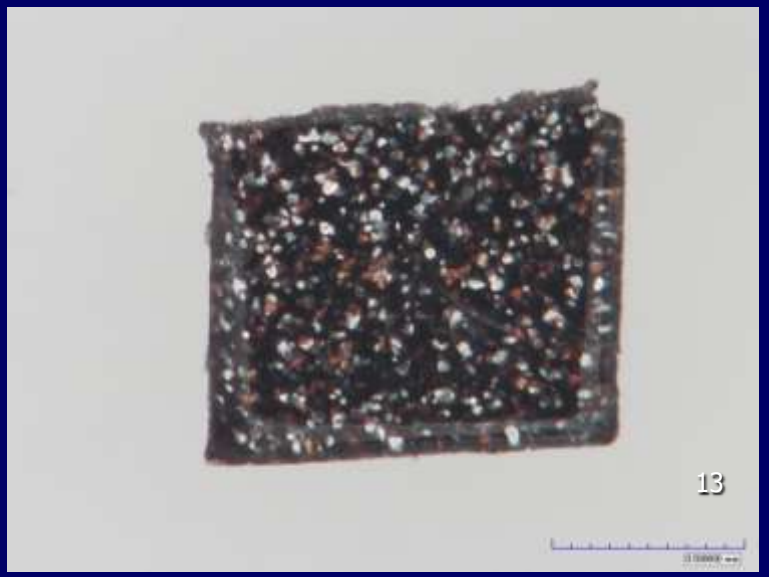
Stereomicroscopic comparison of Exhibit K-1 with Exhibits Q-1 and Q-2

K-1

Q-1

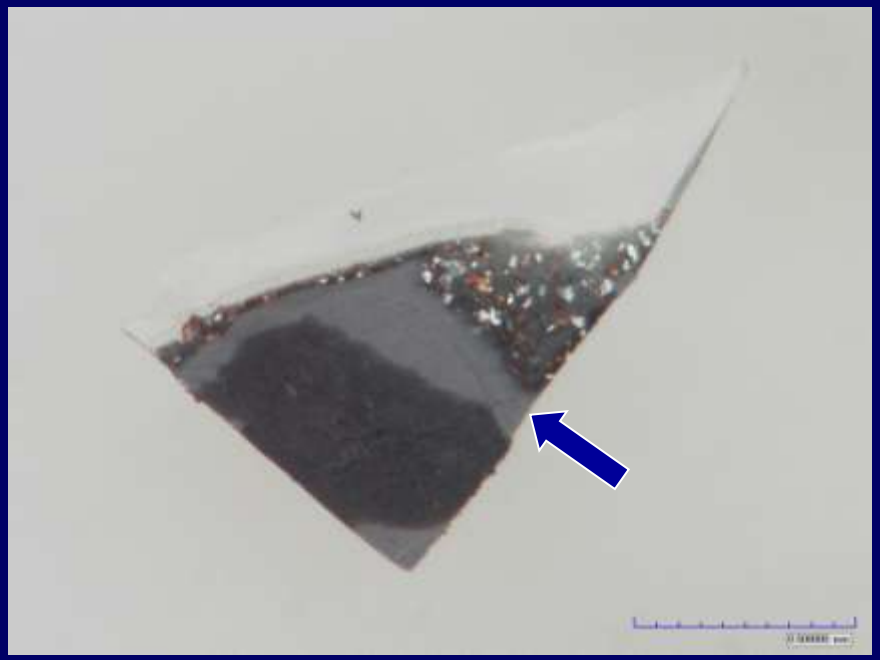


Q-2

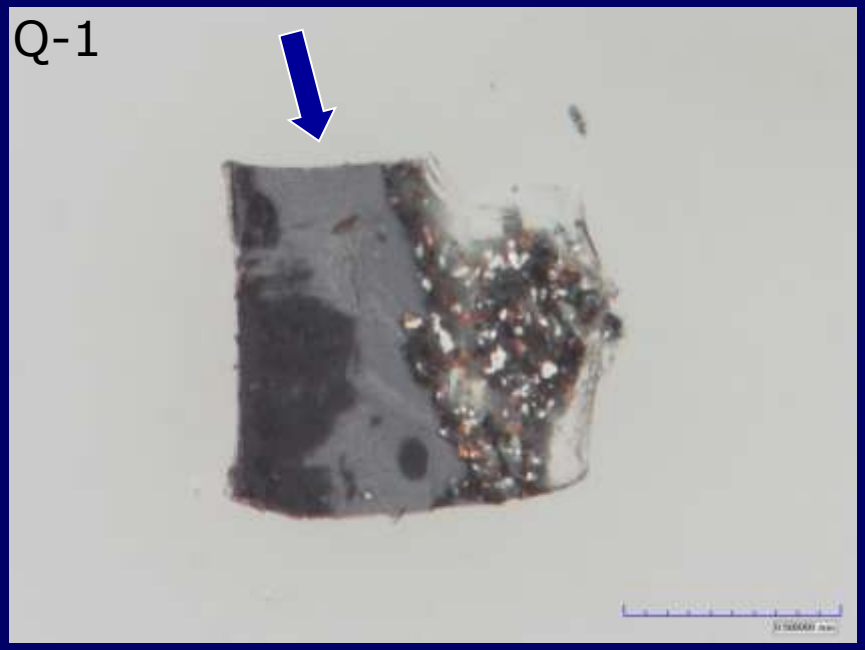


Stereomicroscopic comparison of Exhibit K-1 with Exhibits Q-1 and Q-2

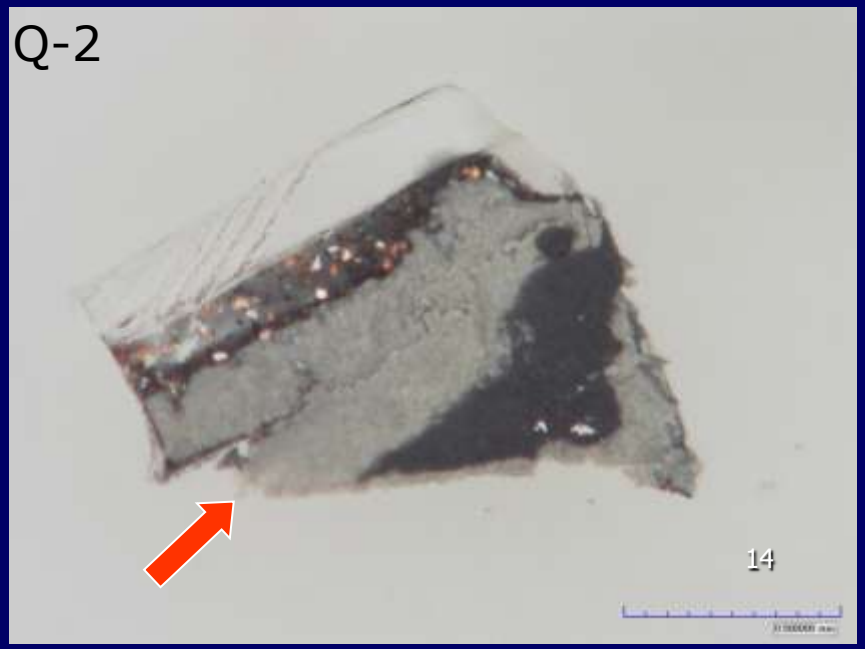
K-1



Q-1

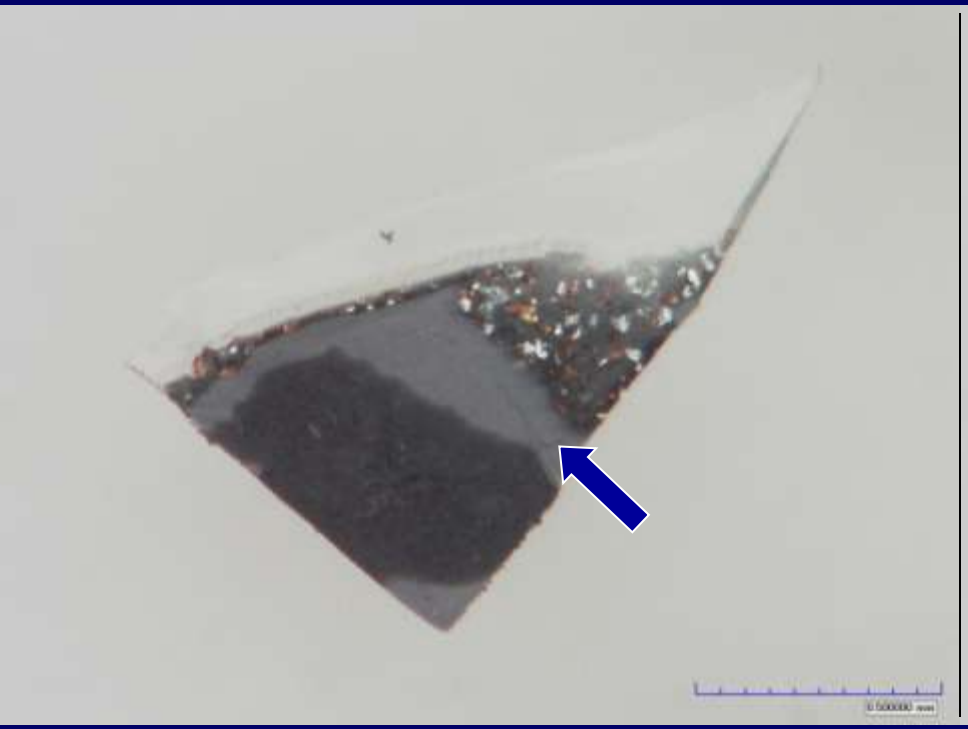


Q-2



Stereomicroscopic comparison of K-1 with Q-2, original equipment manufacture (OEM) automotive paint systems

K-1



Q-2

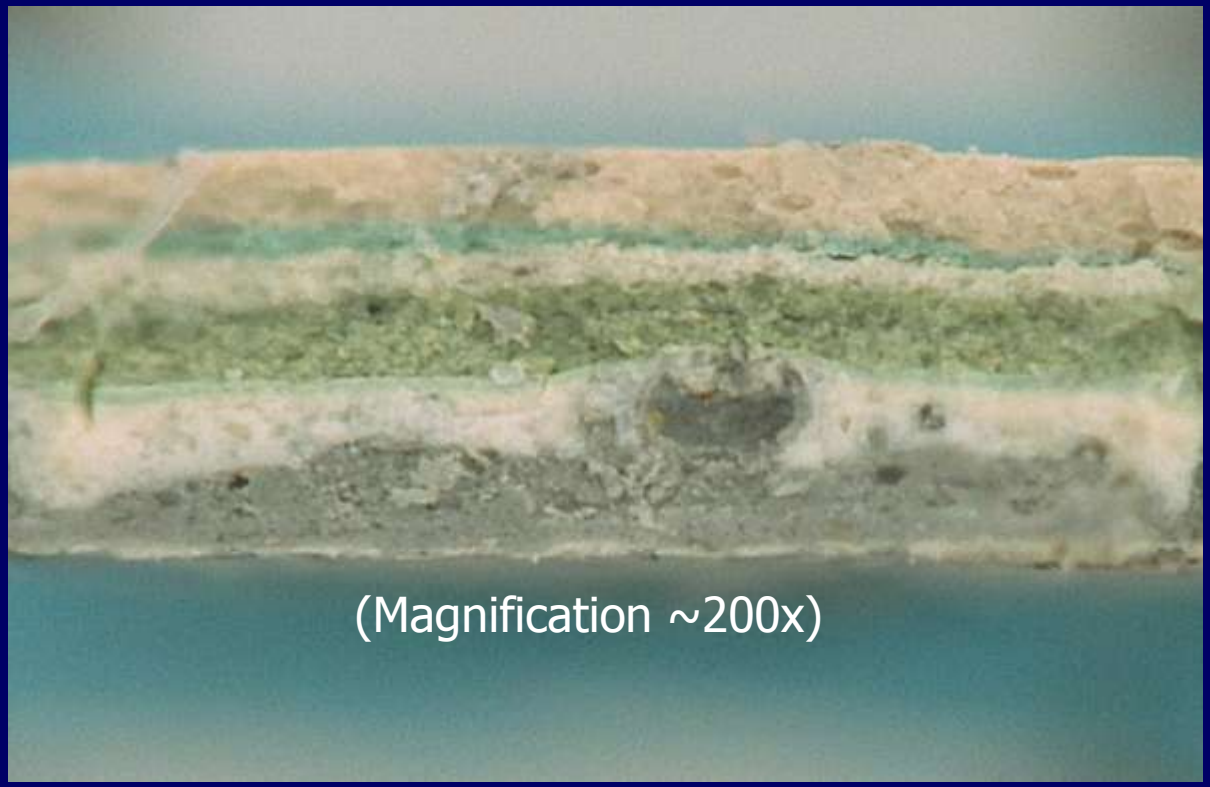
Microscopical comparison of automotive paint cross sections

K-1

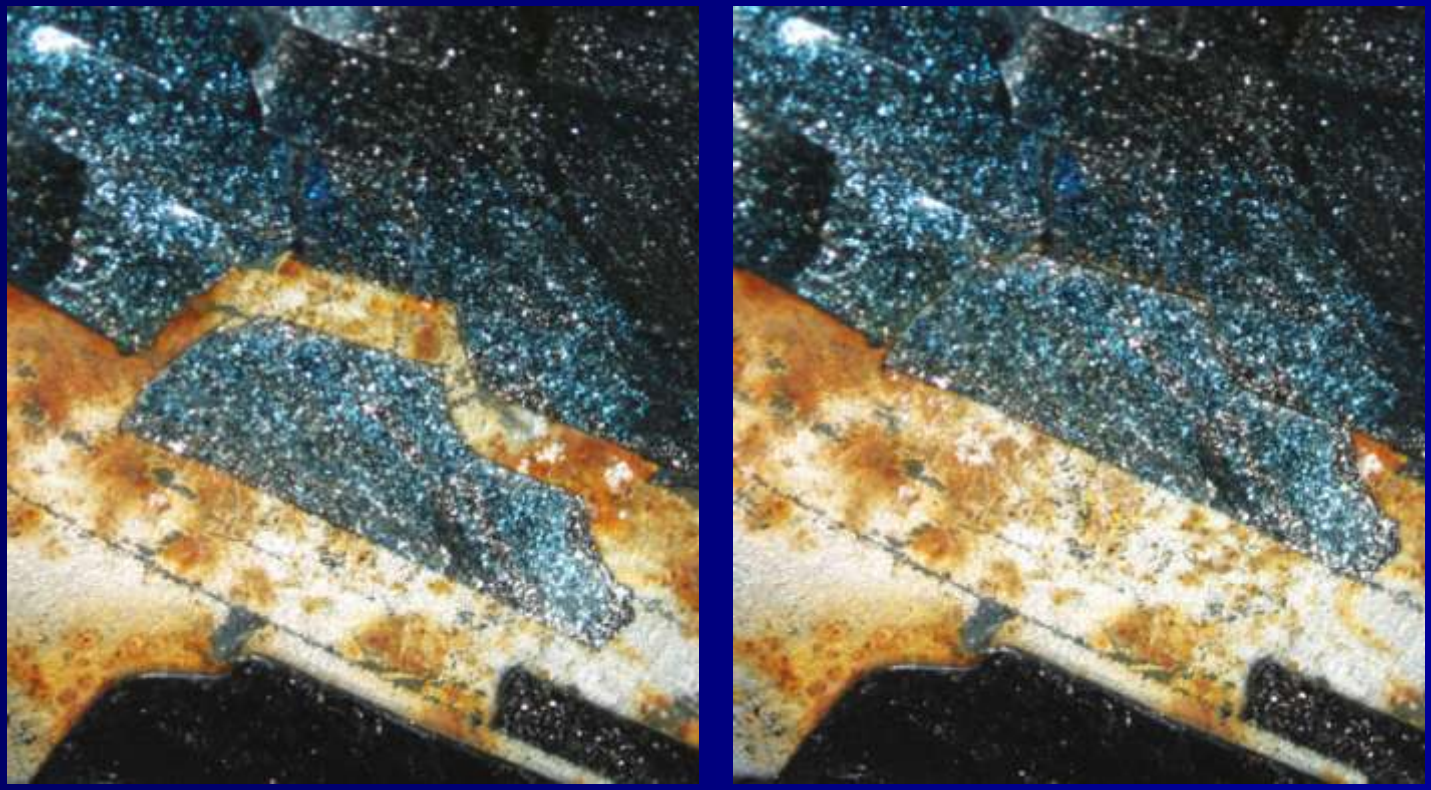
Q-2

Refinish autotmotive paint

Architectural paint



Automotive paint fracture match



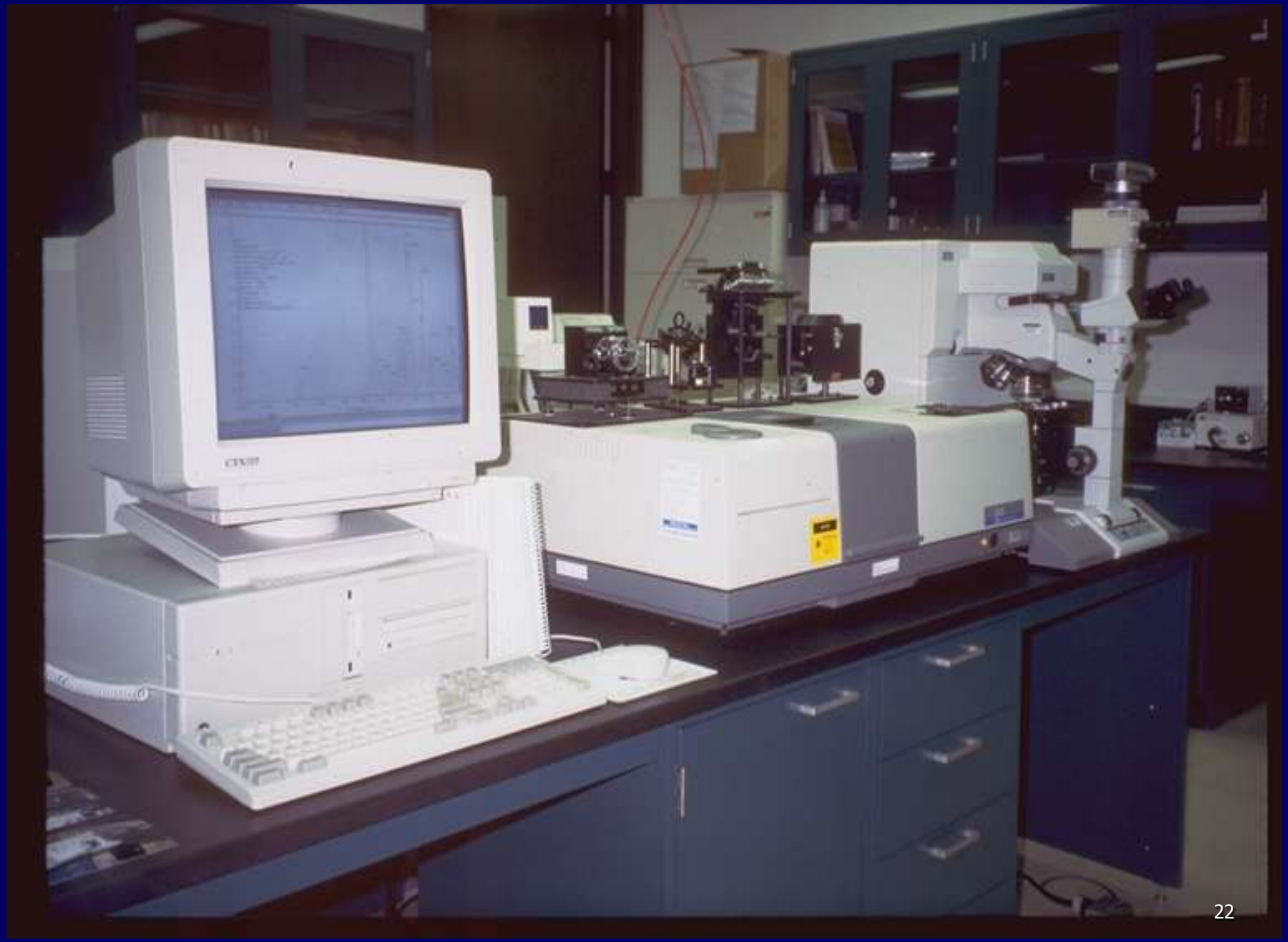
(Magnification ~ 15x)

Fourier Transform-Infrared Spectroscopy (FT-IR)

Instrumental analysis of the chemical properties of the components used in a paint formulation

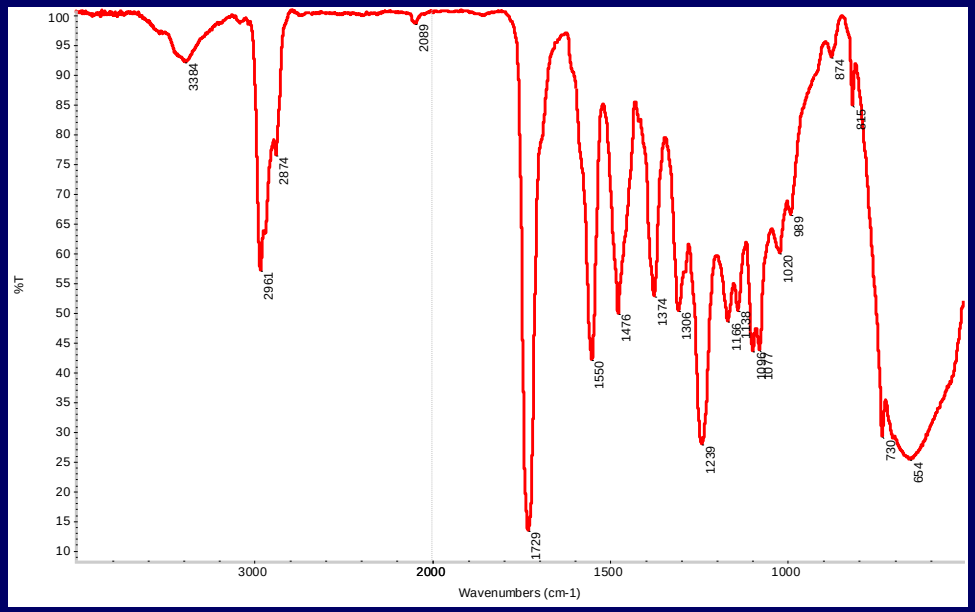
FT-IR Spectroscopy

- Organic composition of binder/resin
  - Is it paint (e.g., does it have a binder)?
  - Is it architectural (e.g., polyvinyl acetate)?
  - Is it automotive?
    - Is it an OEM (e.g., containing melamine)
    - Is it a refinish (e.g., nitrocellulose formulation)
- Inorganic and organic pigment and filler information

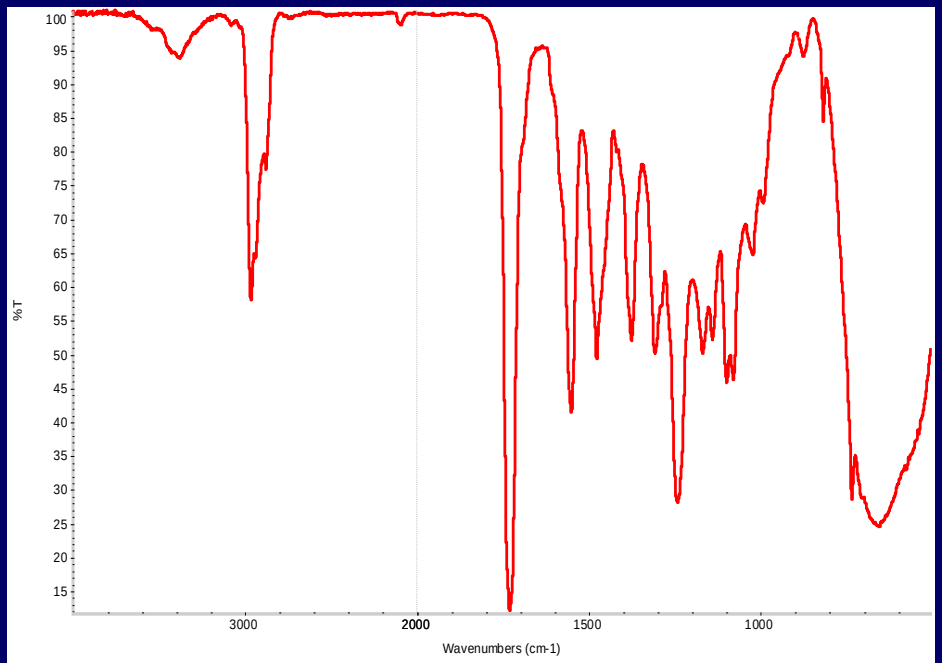


Layer 3 primer-surfacer

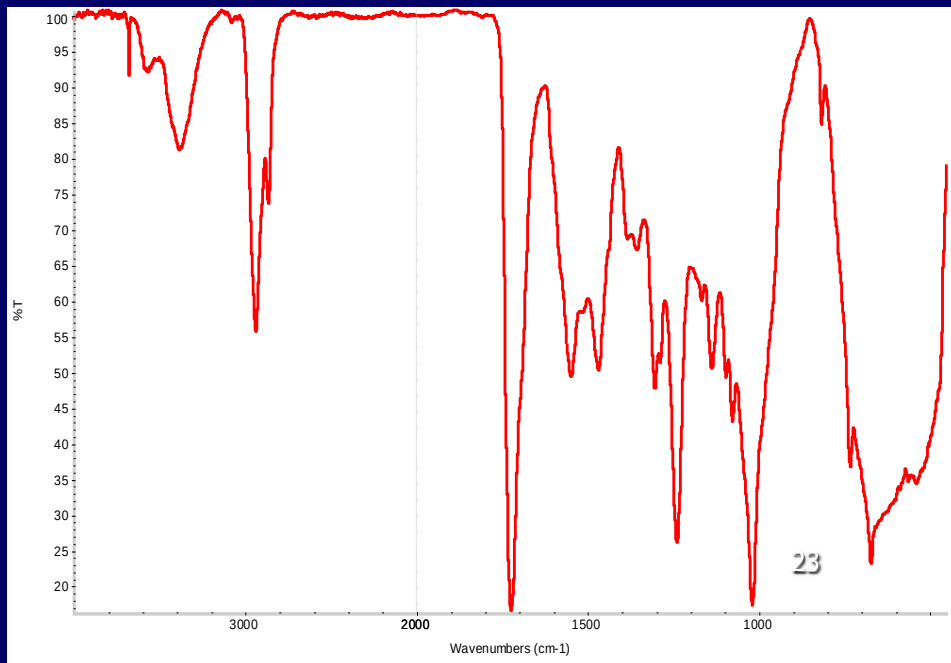
K- 1



Q-1



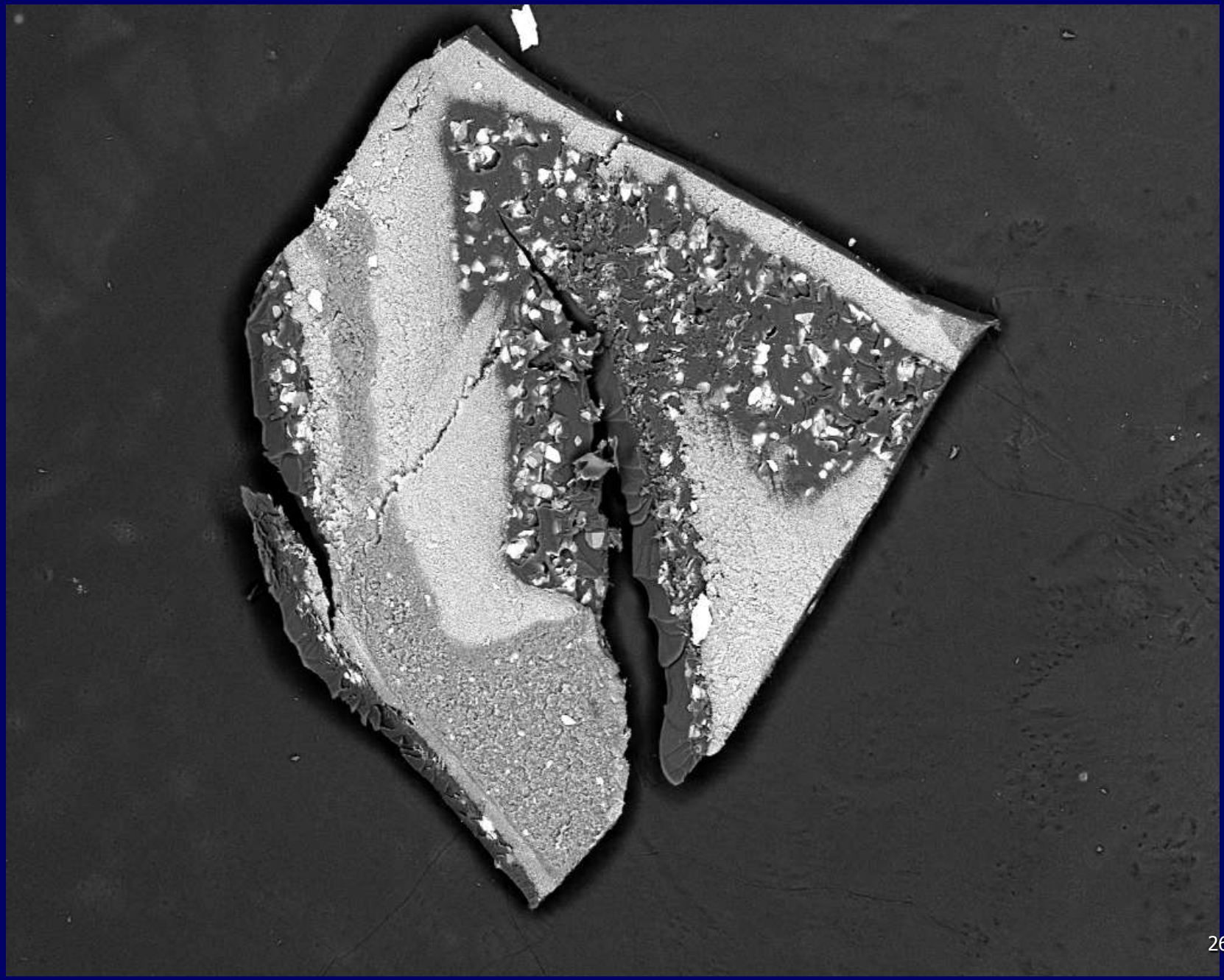
Q-2



Scanning Electron Microscopy-Energy Dispersive Spectroscopy (SEM-EDS)

Imaging of a sample and instrumental analysis of the chemical properties of the inorganic components used in a paint formulation

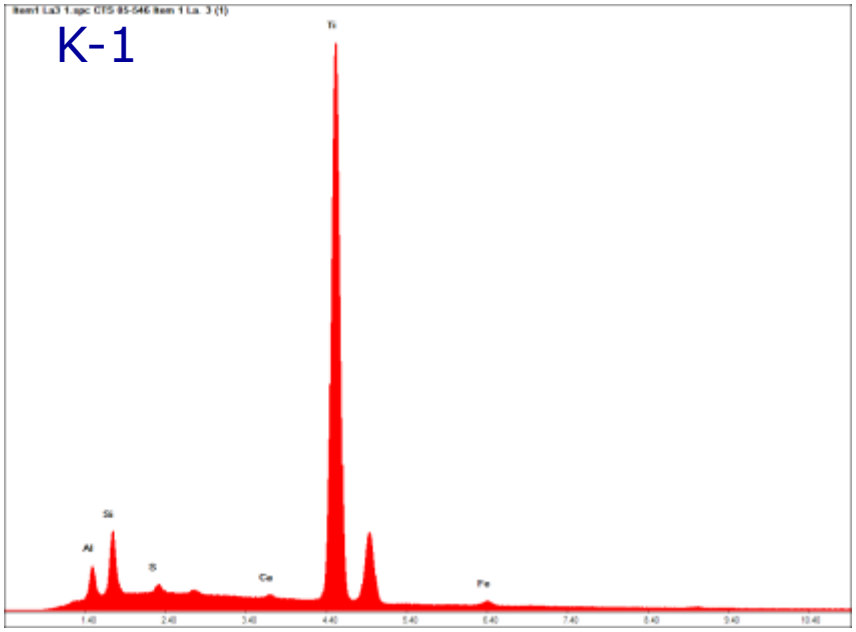
Scanning Electron Microscopy - Energy Dispersive X-ray Spectrometry

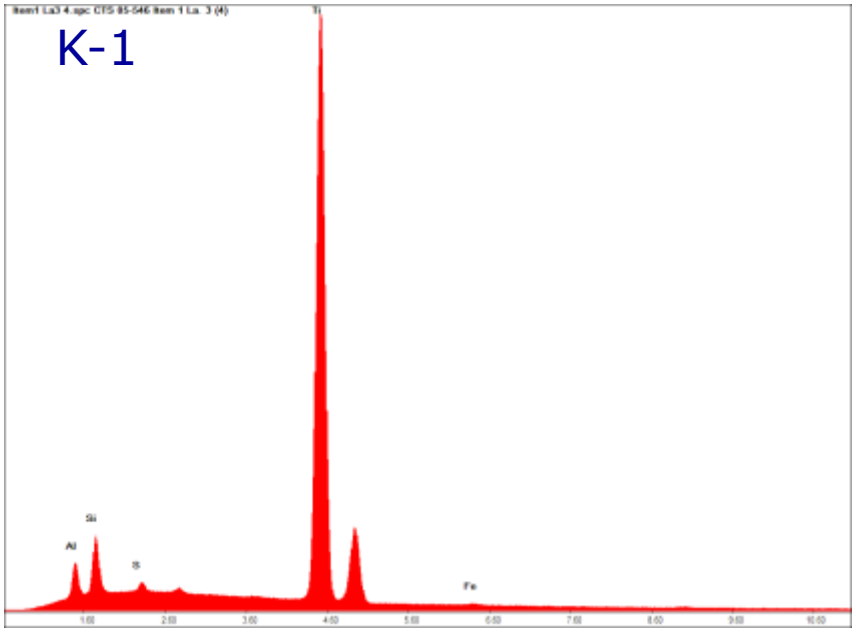


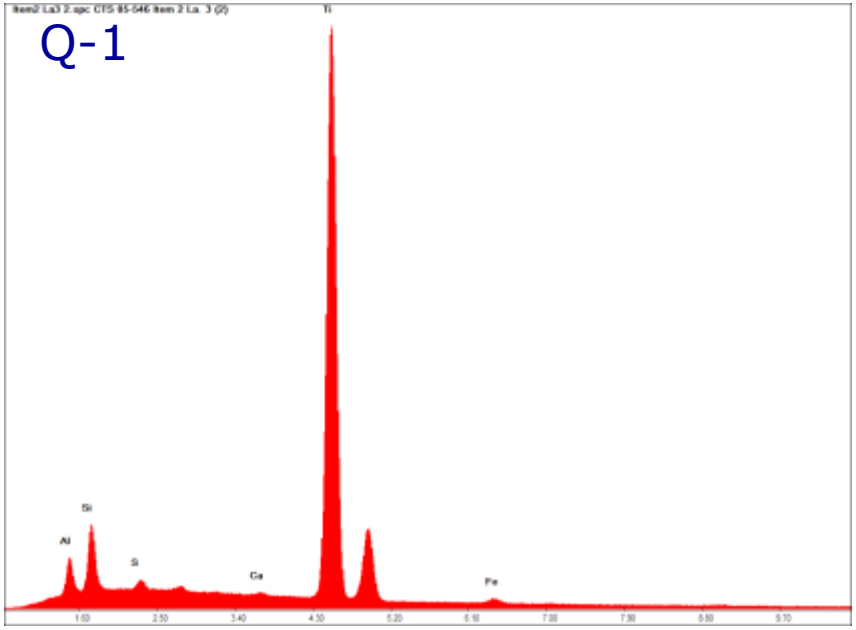
SEM-EDS Spectrometry

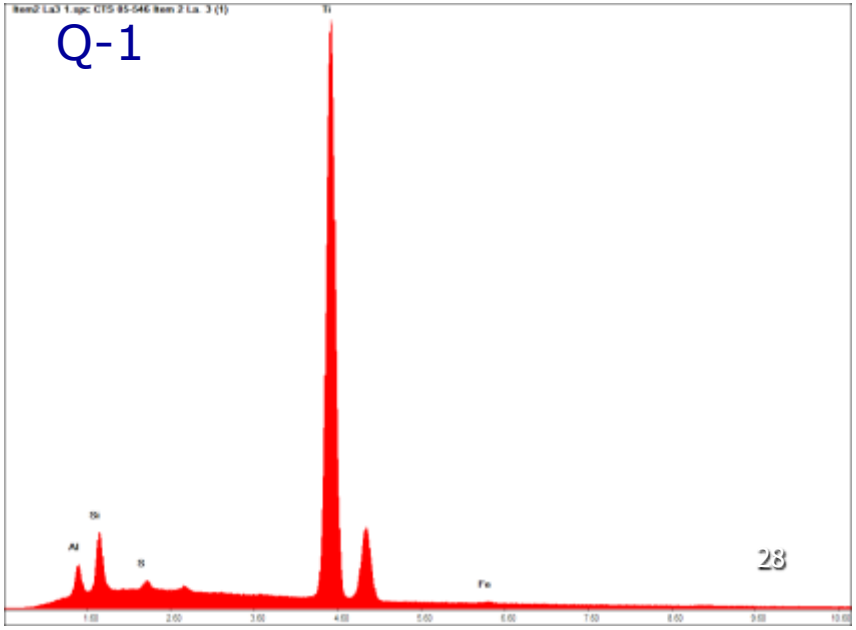
- Inorganic composition of pigment
  - Is there inorganic coloring pigment present?
  - Is there inorganic extender pigment present?
  - Are the elements detected consistent with the pigments noted in the infrared spectra?

Layer 3 primer-surfacer









Other comparative techniques

- Pyrolysis GC or Py-GC/MS – binder information
- Microspectrophotometry (MSP) – color analysis via wavelength absorptions
- Colorimetry – color assessment using standardized color systems
- Solvent tests – non-instrumental binder elucidation (limited to non-enamels)
- X-ray diffraction (XRD) – pigment information

The analytical protocol is optimized for discrimination

- Complementary techniques are chosen to provide additional information regarding sample composition.

- The combination of techniques is chosen to achieve the maximum potential for sample discrimination considering the characteristics of the paint samples.

Example Conclusions

- Based upon the examinations conducted, the following conclusions can be reached regarding the questioned and known paints:
  - Dissimilar and did not have the same source of origin.
  - Like one another and it is possible they originated from the same source
  - No conclusion could be reached

Significance of association

- Not all associations carry the same significance
- Samples may have characteristics that increase or decrease the significance of the association
  - Multiple layers, overspray etc.
  - Rarity of the observed characteristics
  - Limited size or poor condition
- Additional language may be used to convey the strength of the findings.

Daubert considers 5 factors to determine admissibility

- Has the theory or technique been tested using the scientific method?
- Has the technique/methodology been subject to peer review/publication?
- What is the error rate if it can be calculated?
- Are there standards controlling the technique's operation and are they maintained?
- Is there general acceptance within the relevant scientific community?

Testability by employing the scientific method

- Develop a hypothesis
  - The Q and K paints did not originate from the same source (elimination)
- Adopt the null hypothesis
  - The Q and K paints did originate from the same source (only a fracture match is this definitive)
- Test the hypothesis
  - Subject the samples to a series of scientifically valid tests that provide a high degree of discrimination between paint samples in an attempt to disprove the null hypothesis

Testability by employing the scientific method (cont'd)

- If disproved, the null hypothesis must be rejected indicating the original hypothesis is valid
  - Therefore, the paints are different
- If one fails to discriminate between the samples it indicates that the null hypothesis is possible
  - Therefore, the samples *may have* originated from the same source

Is forensic paint analysis able to be tested?

- Paint sample discrimination is often achieved by
  - Visual and/or microscopical techniques due to observed differences (e.g., layer color or layer sequence)
  - Instrumental techniques due to chemical characteristics (e.g., binder, filler, pigment components)
- The methods utilized are not novel

Are analytical methods for paint analysis peer reviewed/published?

- An ASTM guideline exists for paint comparisons (E-1610).
- ASTM guidelines exist for evidence handling and documentation (E-1492 and E-1459).
- These guidelines are reviewed for relevance by the international scientific community and updated as needed approximately every 5 years.

Are analytical methods for paint analysis peer reviewed/published?

- SWGMAT guidelines exist
  - Comparisons in general
  - Examinations using infrared spectrometry
  - Examinations using SEM-EDS spectrometry
  - Examinations using UV-Vis microspectrophotometry
- All are consensus documents written and approved by an international organization of subject matter experts, and published in peer reviewed journals

Are analytical methods for paint analysis peer reviewed/published?

- Can serve as guidelines for good practices in forensic paint analysis.
- All of the common techniques used to analyze paint have also been published in peer reviewed journals (e.g., *Analytical Chemistry*, *Journal of Forensic Science*, *Forensic Science International*, *Journal of the Forensic Science Society, Canadian Society of Forensic Science Journal, Journal of Analytical and Bioanalytical Chemistry*, *Journal of Applied Pyrolysis*).
- Relevant paint analysis articles are cited in the bibliography (Appendix A) provided as a hard copy to the court.

Is the error rate known?

- Multiple types of potential error are known; however, not all can be quantified
  - Instrumental error
    - Minimized through the use of analytical standards, validation protocols and standard operating procedures
    - This type of error is more readily measured and controlled than other types of error
  - Procedural error
  - Human error

Controlling Procedural Error

- Equipment error is detected and corrected through the use of standards and controls.
- The variability of paints and the power of the analytical techniques to discriminate paint samples can be evaluated.
- The ability of scientists and the analytical techniques to distinguish among different formulations can also be evaluated.
- Discrimination studies address the latter two points.

Population studies: random sample sets

- Examples of studies (refer to Appendix B for complete listing) that would best evaluate false inclusions include:
  - Tippett et al., J.For.Sci.Soc., (1968), 8(2): 61-65.
  - Gothard, J.For.Sci., (1976) 21(3): 636-642.
  - Ryland and Kopec, J.For.Sci., (1979) 24(1): 140-147.
  - Gothard and Maynard, (1996) Proceedings of the 13th International Symposium of the Australian and New Zealand Forensic Science Society, September 8-13, 1996, Sydney, Australia.
  - Edmondstone, et al., Can.Soc.For.Sci.J.(2004) 37(3): 147-153.
  - Wright, et al., For. Sci. Int., (2011) 209(1-3): 86-95.

Random population discrimination studies

- Four studies deal with automotive paint comparisons using multiple techniques
  - Gothard (1976), Ryland (1979), Gothard (1996), Edmondstone (2004)
  - These studies indicate that on average only 0.002% of the total possible pairs compared were found to be indistinguishable when the paint samples, in fact, came from different sources (refer to Appendix D for calculations).
  - None of these pairs were refinishes.
  - This conversely indicates that 99.998% of the total possible pairs compared were correctly discriminated.

Random population discrimination studies

- Two studies deal with architectural paint comparisons using multiple techniques
  - Tippett (1968) and Wright (2011)
  - These studies indicate that only 0.0001% of the total possible pairs compared were found to be indistinguishable when the paint samples, in fact, came from different sources (refer to Appendix D for calculations).
  - This conversely indicates that 99.9999% of the total possible pairs compared were correctly discriminated.

Random population discrimination studies

- Two studies deal with automotive finish coat colors
  - Ryland (1981) and Buckle (1987)
  - These studies indicate that typically, depending on the color, over 90% of the vehicles on the road can be eliminated as potential sources of the questioned paint based on general topcoat color alone.

Worst Case Scenario Studies

- Acquisition of sufficient "random sample" populations (e.g. size, variety) that test discrimination power is difficult
- Instead, "worst case scenario" discrimination studies have been conducted
  - Samples that are difficult to discriminate were deliberately selected

Worst Case Scenario Studies

- Studies where discrimination occurred in populations of like samples include (see Appendix C for summaries):
  - May and Porter, J.For.Sci. (1975) 15(2):137-146.
  - Reeve and Keener, J.For.Sci. (1976) 21(4):883-907.
  - Howden, et al., J.For.Sci.Soc. (1977) 17:161-167.
  - Laing, et al., For.Sci.Int. (1982) 20:191-200.
  - Fukuda, For.Sci.Int. (1985) 29:227-236.
  - Ryland, et al., J.For.Sci. (2001) 46(1):31-45.
  - Govaert and Bernard, For. Sci. Int. (2004) 140(1): 61-70.
  - Buzzini and Massonnet, Sci. Just. (2004) 44(3): 123-131.
  - Bell, et al., App.Spect. (2005) 59(11): 1340-1346.
  - Plage, et al., For. Sci. Int. (2008) 177:146-152.
  - Ryland, J. ASTEE (2010)1:2:109-126

Is the human error rate known?

- Analyst data collection and/or interpretation error is controlled through:
  - Formalized training programs
  - Competency testing
  - Technical review
  - Continuing education
  - Industry contacts
  - Review of the relevant literature
  - Proficiency testing
  - Individual certification
  - Laboratory accreditation programs

Existence and maintenance of standards controlling the techniques' operation

- ASTM Guidelines
- SWGMAT Guidelines
- ISO Accreditation Standards
- Forensic Accreditation Standards

General acceptance of paint analyses in the relevant scientific community?

- Locard discussed paint as trace evidence as early as 1930 [Locard, Am.J.Pol.Soc. (1930) 1(3), 276-298].
- Paul Kirk devoted a chapter to paint examinations in his classic text "Crime Investigation" published in 1953.
- Additional texts have appeared over the years having chapters devoted to forensic paint examinations
  - John Thornton's chapter in Forensic Science Handbook, Vol I, 2nd ed., 2002.
  - Brian Caddy's text Forensic Examination of Glass and Paint: Analysis and Interpretation, 2001.
- Interpol includes paint as a discussion topic in its Forensic Science Review, published every 3 years.
- Paint is one of the trace evidence disciplines that comprise the Scientific Working Group for Materials Analysis (SWGMAT).

General acceptance of paint analyses in the relevant scientific community?

- Proficiency testing in forensic paint analysis is commercially available through vendors such as Collaborative Testing Services (CTS) or the European Network of Forensic Science Institutes (ENFSI) annual collaborative exercise in paint.
- Paint industry examination methods are similar to those used for forensic paint examinations.
- Journals and/or trade periodicals such as *Coatings World*, *Paint and Coatings Industry*, *Journal of Coatings Technology and Research*, *Journal of X-ray Spectrometry*, *Journal of Raman Spectroscopy*, *Spectrochimica Acta Part B*, *Microchimica Acta*, and others routinely feature applications and/or research efforts in the examination of paint.