Not Your Typical Iron Lung
A μ-XRF Study of a Soldier's Lungs

Millicent P. Schmidt
Department of Geosciences
Stony Brook University
Stony Brook, New York

Abstract

U.S. soldiers returning from combat in the Middle East are showing an unusual incidence of pulmonary pathophysiology, specifically, an increased incidence of asthma in patients exhibiting no previous symptoms. One such returned soldier has experienced decreased lung capacity with physical activity since returning from Iraq where the patient managed a troop laundry facility. After chest x-rays showed diffuse opacity, a lung biopsy was performed. The biopsy was sectioned on Ultralene Mylar and Silicon Nitride mounts and studied at Brookhaven National Laboratory's National Synchrotron Light Source at X-26-A and X-27-A using coupled micro-X-ray Fluorescence (u-XRF) and micro-X-ray Diffraction (u-XRD). Analysis of multiple sections revealed a high correlation between iron and titanium. Titanium has no natural source in the body and is not a micronutrient. Areas with high iron and titanium contents were selected for u-XRD. Small grain sizes and strong scatter from the paraffin (the setting agent used to maintain tissue morphology) prevent exact determination of the contaminating species, but iron/titanium ratios and comparison with known XRD patterns indicate an iron titanium oxide with a high iron/titanium ratio. These results require further exploration in other patients and possible contaminant sources such as oxidized explosive materials and environmental dusts.

Results

Tissue 2 Analyzed at X-26-A

Beam size ≈ 5 μm Beam Energy = 17.2 keV

Ultralene Mylar Mount

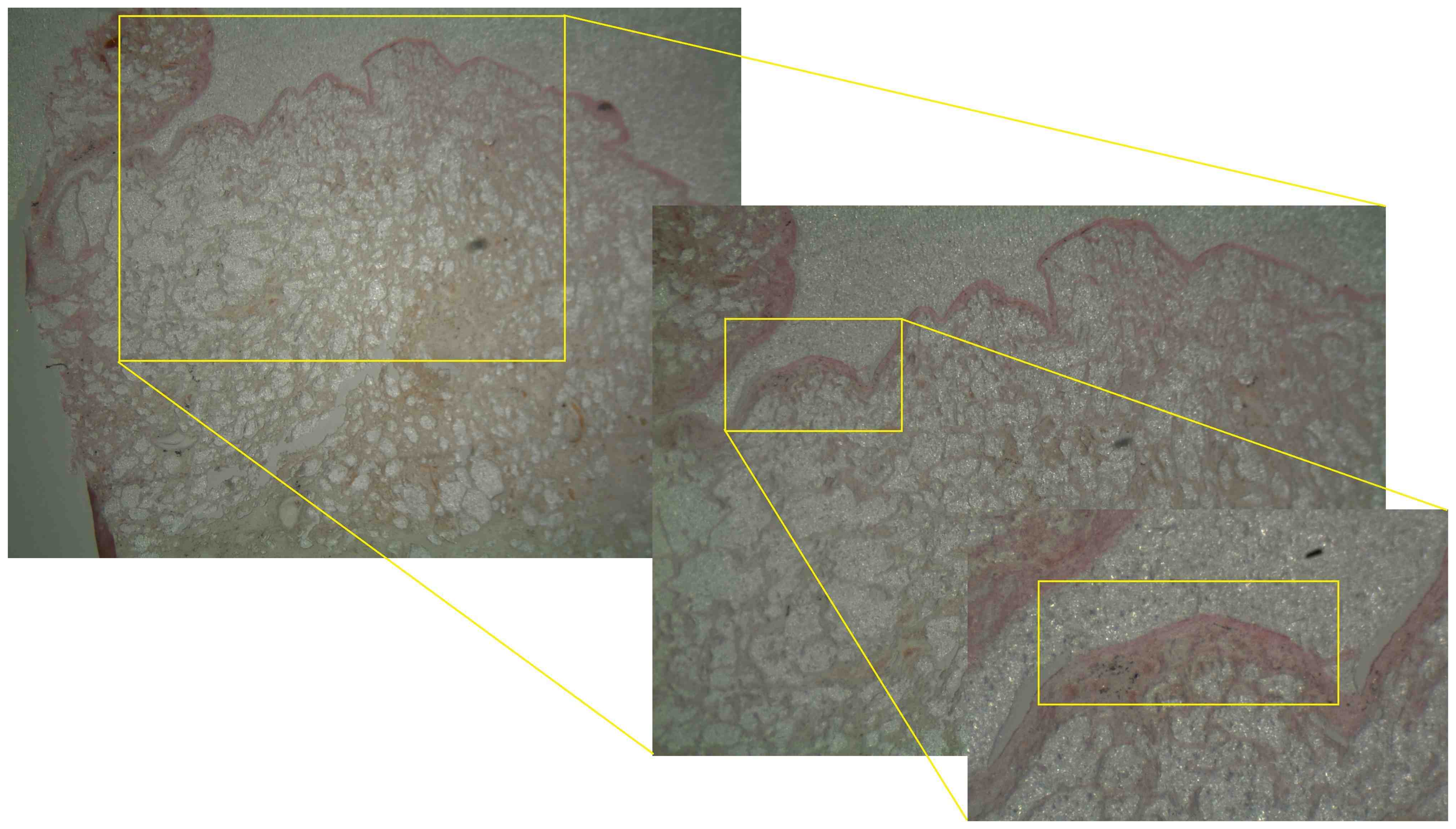


Figure 1. Light microscope images of Tissue 2.

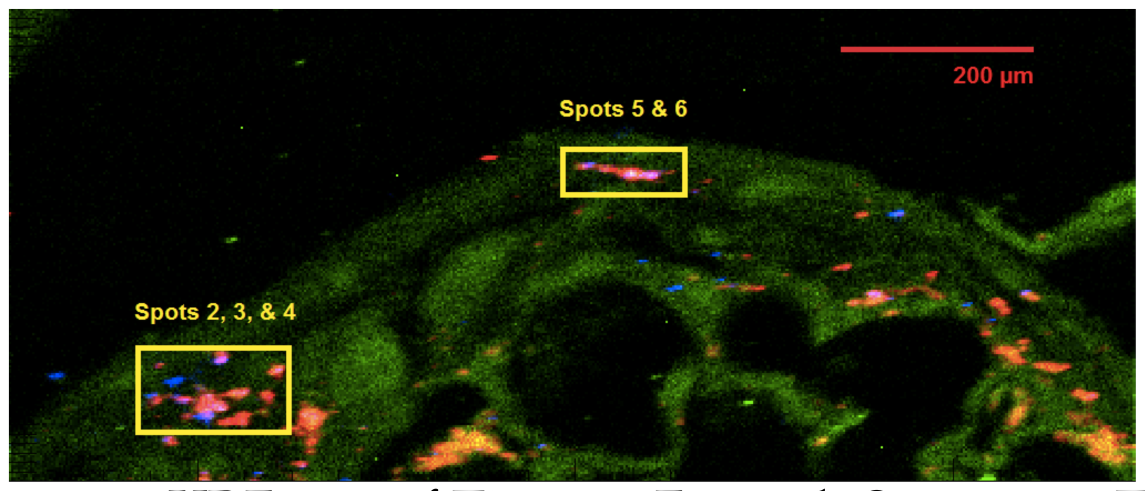


Figure 2. u-XRF map of Tissue 2; Fe = red, Ca = green, Ti = blue.

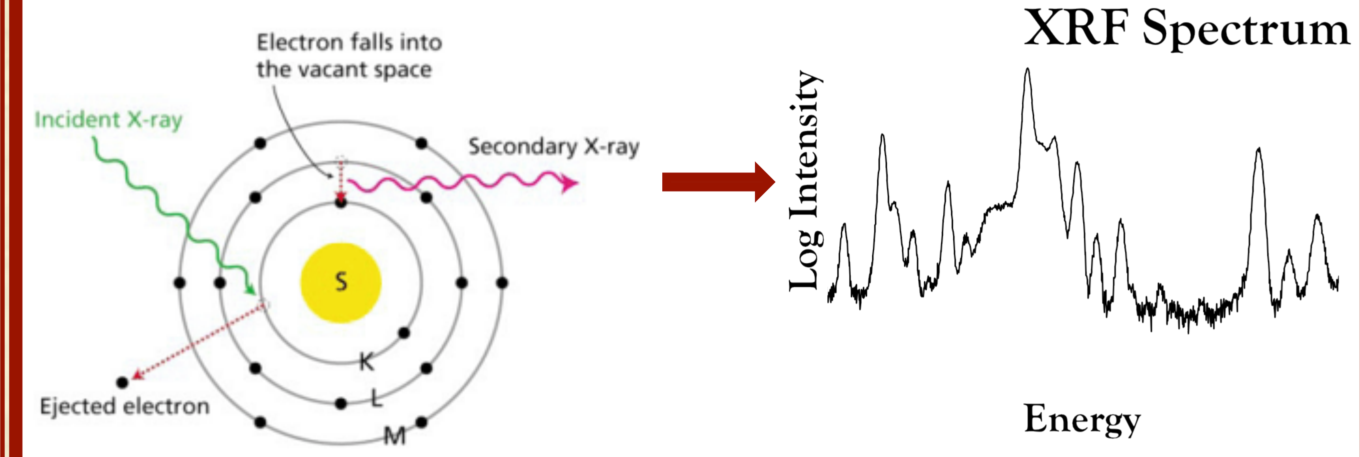
Acknowledgements

This work was funded by the NSF through the IGERT 3MT Program at Stony Brook University and the DOE. Analytical work was completed at beamlines X-26-A and X-27-A at Brookhaven National Lab's National Synchrotron Light Source. Special thanks to the beamline scientists for their invaluable assistance: Antonio Lanzirotti, Bill Rao, and Ryan Tappero.

Analytical Methods

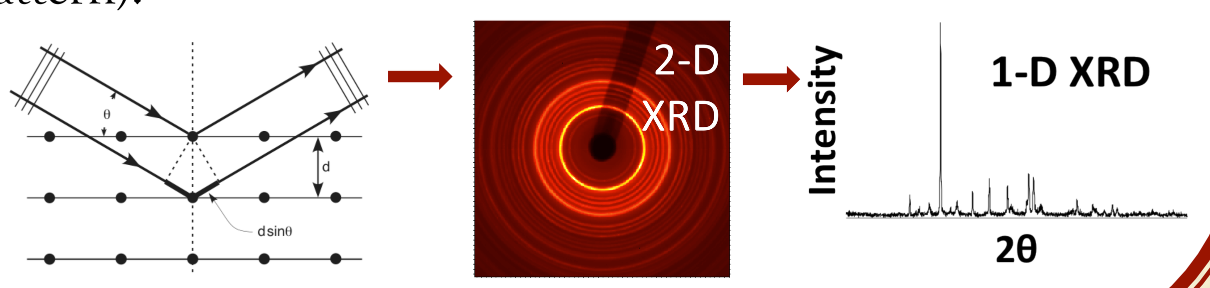
X-ray Fluorescence (XRF)

Elements who's core electrons have binding energies below the energy of the incident x-ray energy will fluoresce (i.e. produce secondary x-rays).



X-ray Diffraction (XRD)

Atoms arranged in a repeating pattern (as in minerals) reflect x-rays in a characteristic pattern (a diffraction pattern).



Results: Fe/Ti Ratios

Derived by comparison to standard thin sections.

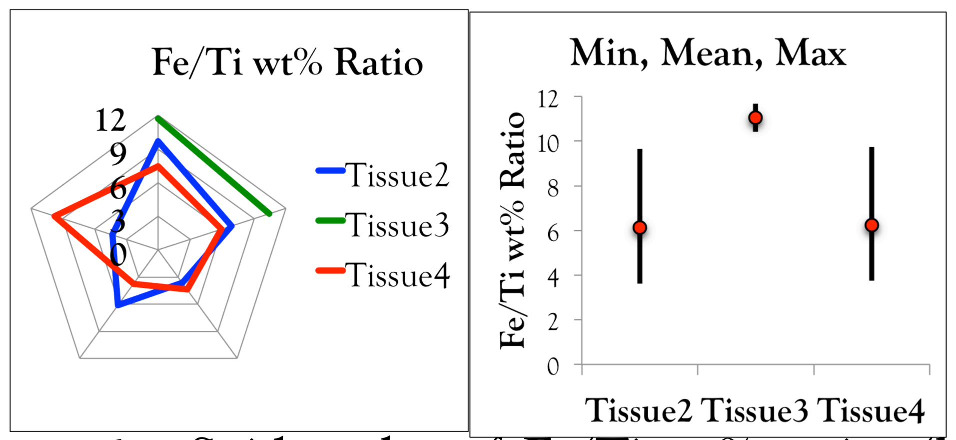


Figure 6. Spider plot of Fe/Ti wt% ratios (left) and a stock-type plot of the same data (right).

Results: XRF and XRD

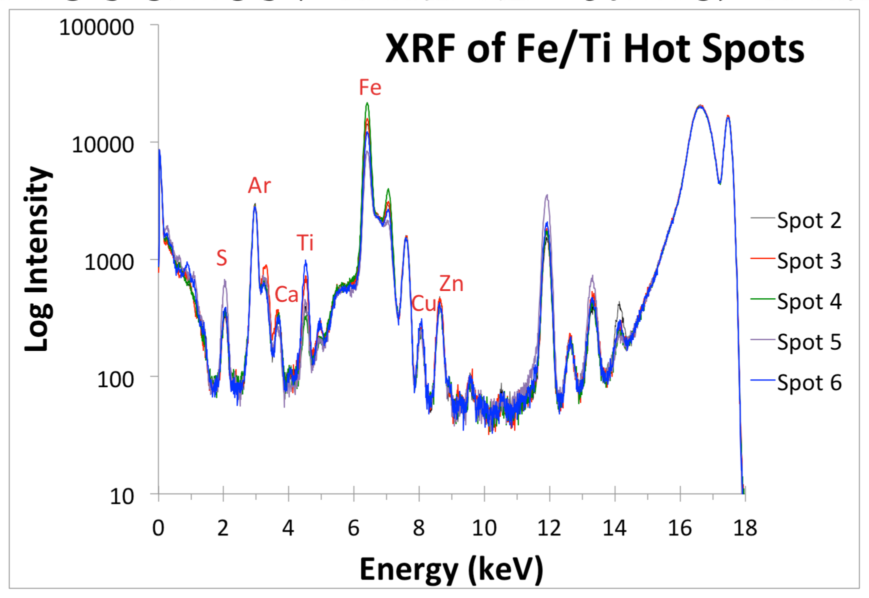


Figure 3. μ-XRF spectrum of Fe/Ti hotspots 2 – 6 showing only small intensity differences; Argon peak arises form the beam traveling through air; peak intensity is related to element concentration and fluorescence energy.

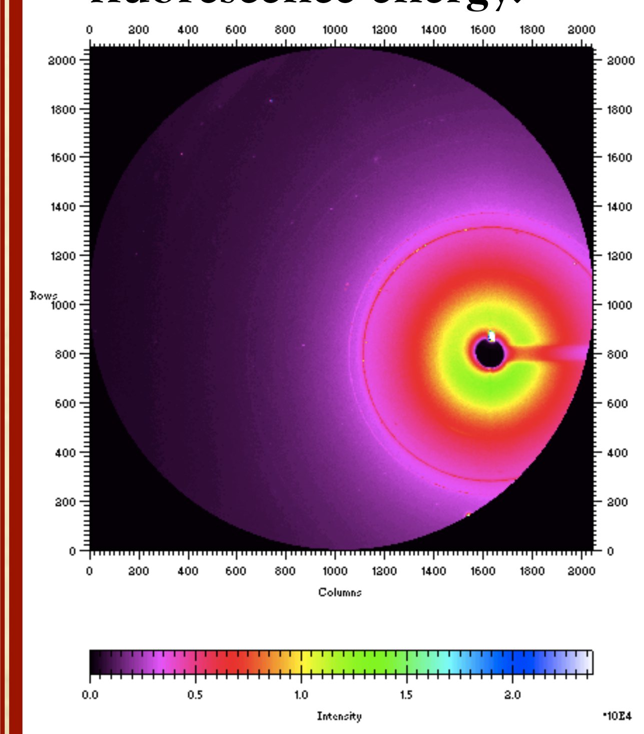
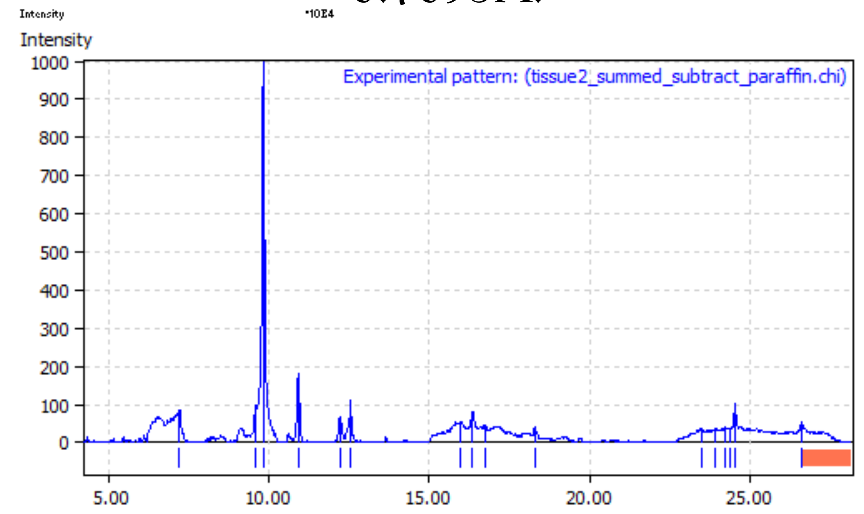


Figure 4. 2-D summed μ-XRD of spots 2 – 6; paraffin subtracted.

Figure 5. 1-D summed μ-XRD of spots 2 – 6; paraffin subtracted; radially integrated from 2-D intensities; λ = 0.7093Å.



Conclusions

The exact mineral species of the contaminating materials cannot be determined because of small grain size and lack of available comparison patterns for higher Fe/Ti ratio oxides, but this study shows unprecedented evidence of titanium contamination and a novel application of μ-XRF to lung tissues.

Future Considerations

- X-ray-transparent tissue setting agent (e.g. OCT)
- Higher energy incident x-rays to look for Pb with μ-XRF
- Measure background blood Fe levels in the tissue
- X-ray Absorption Near Edge Structure for oxidation states of Fe, Ti, and Cr