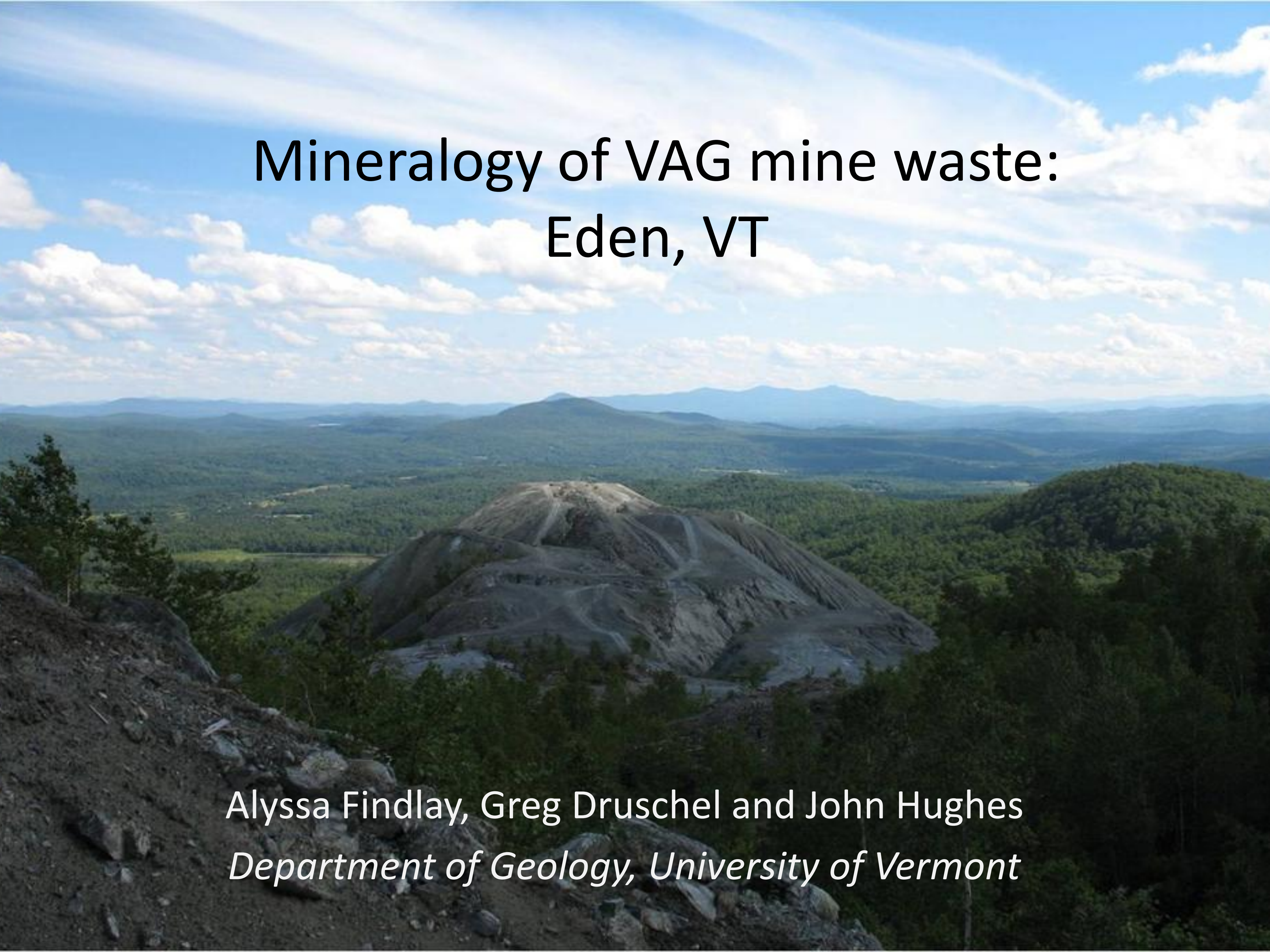
Mineralogy of VAG mine waste: Eden, VT



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Site Background

- Vermont Asbestos Group mine located in Eden and Lowell
- Erosion of mine waste piles containing chrysotile fibers has drawn attention to the environmental impacts of the mine in recent years.
- High concentrations of nickel and chromium have been reported in sediments of local streams
- There is uncertainty concerning the mineral phase(s) in which nickel and chromium may be present.
- Studies of the mine have indicated the presence of mineral phases such as heazelwoodite, chromite, and magnetite that may contain Ni and Cr

Above: Aerial view of VAG mine (from VT Mining, Ali, 2010)
Below: Evident erosion of the Eden tailings pile (from Gale, 2000).

Sample Information

Images of tailings pile (above) and Hutchins brook (below)

Photos by Mr. John Kelley (Weston-START) 10/21/09

- Three samples were taken from the mine and surrounding area by John Schmeltzer from the VT Agency of Natural Resources.
  - Eden tailing pile
  - Deep sediments from a settling pond along Hutchins Brook , ~1 ft below the sediment-water interface
  - Surface sediments from settling pond (shown below left)
- Two samples obtained for comparison:
  - A piece of magnetite from quarry
  - Purified chrysotile fibers (sale product)

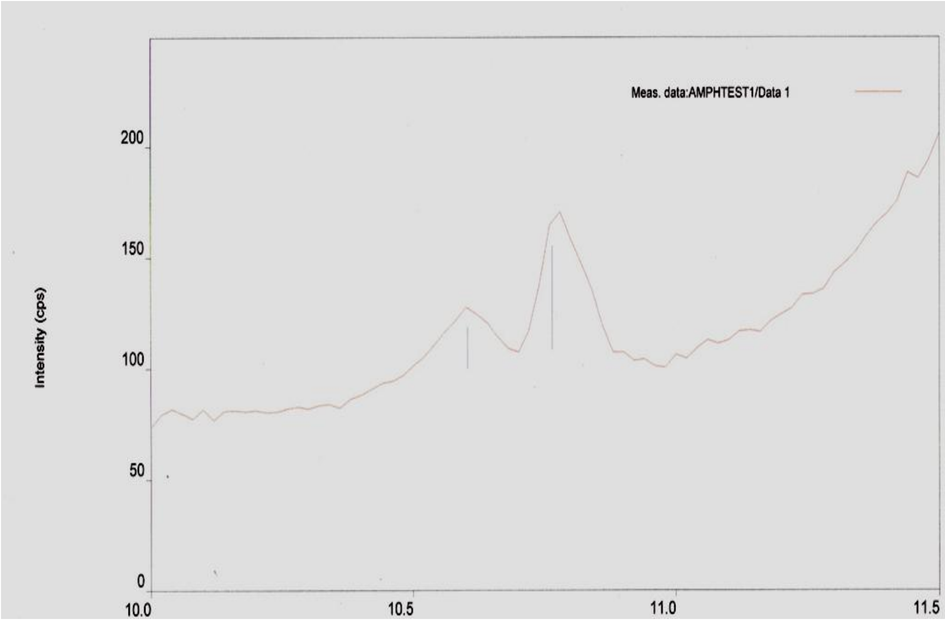
Methods

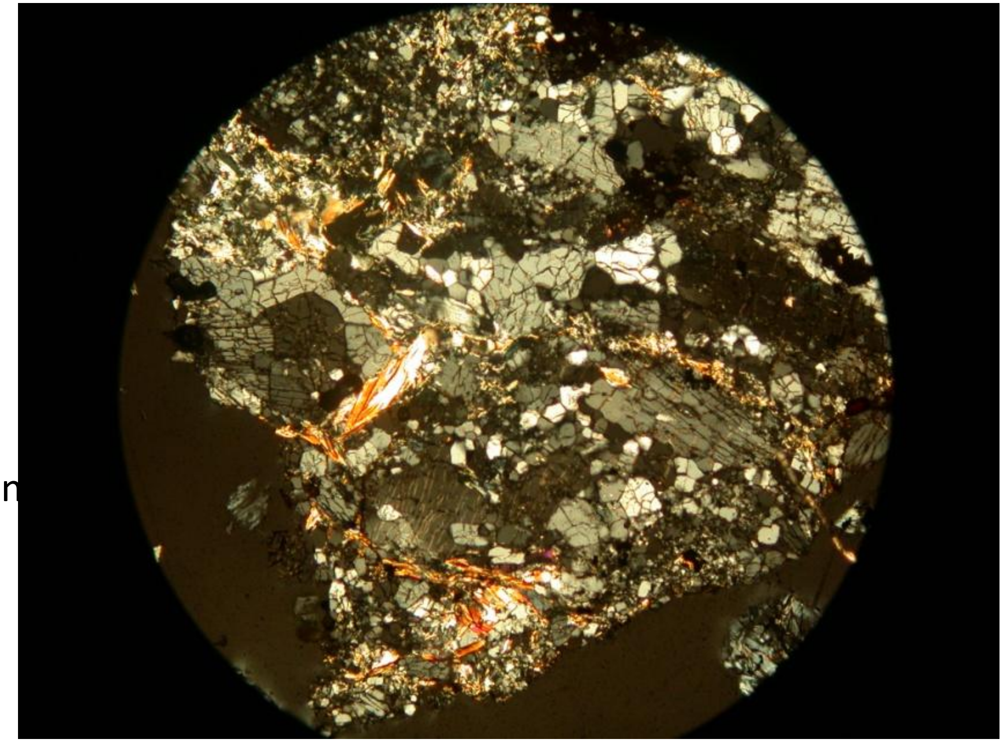
- Polarized light microscopy (PLM) used to determine general mineralogy and composition of samples.
- Powder X-ray diffraction (XRD) was combined with chemical data to identify dominant mineral species and relative abundance.
- X-ray fluorescence (XRF) spectroscopy was used to determine the overall elemental composition of the samples
- Scanning electron microscopy with an energy dispersive spectrophotometer (SEM-EDS) on thin sections and bulk samples was used to map elemental distribution and quantify the amount of nickel and chromium present

Results

- Samples from the tailings pile and deep sediments were dominated by serpentine (80%, +/-5%) and spinel minerals (15%, +/- 2%).
- Sample of the sediments was composed of serpentine(~60%), spinel (~2.5%), quartz (~3%), and clay minerals (~33%). A small peak at 10.765 degrees was observed, which may be amphibole .
- Serpentine minerals may be fibrous (chrysotile) or non-fibrous (antigorite).
- PLM was useful in differentiating sperpentine minerals.

Above right: XRD scan of sediments showing an amphibole peak at degrees.
Below right: PLM image from tailing pile sample

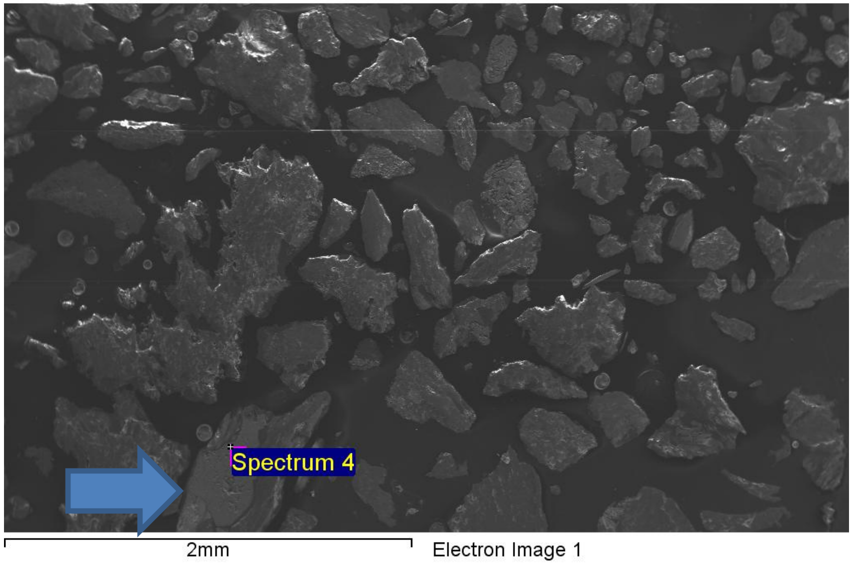




Nickel

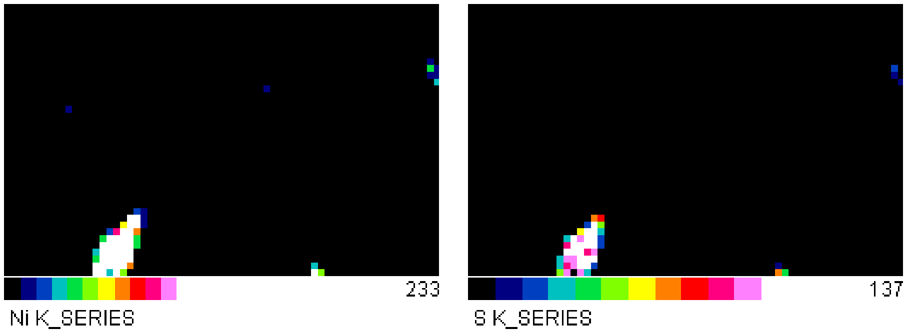
SEM-EDS data indicate nickel present as a sulfide phase containing an approximate 1:1 ratio of Ni:S – consistent with Millerite (NiS)

Element	Atomic%
Mg	2
Si	2
S	51
Ni	**45**
Total	100



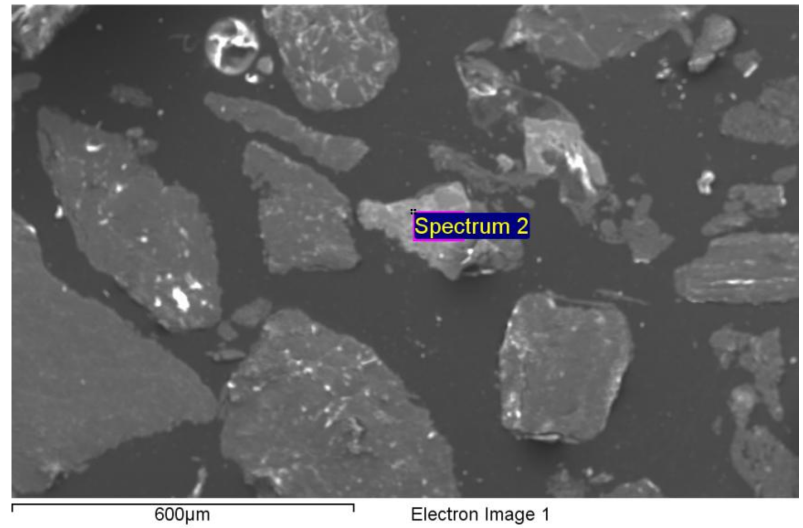
SEM image of deep sediments showing position of NiS grain

SEM image showing areas of concentrated Ni (left) and S (right).



Chromium

- Chromium was found in iron-rich phases (magnetite, chromite).
- Chromium comprised 24-35 atomic % in Cr bearing grains.
- XRD results indicate the presence of spinels, which may contain Cr
- SEM analysis and elemental mapping of magnetite showed areas of concentrated chromium.

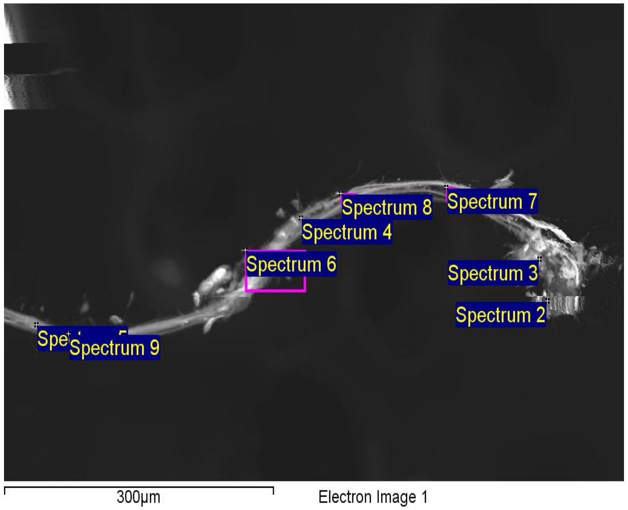


SEM image of tailing sample showing location of a chromium grain

Element	Atomic %
Mg	12
Si	3
Cr	**25**
Fe	60
Ni	1

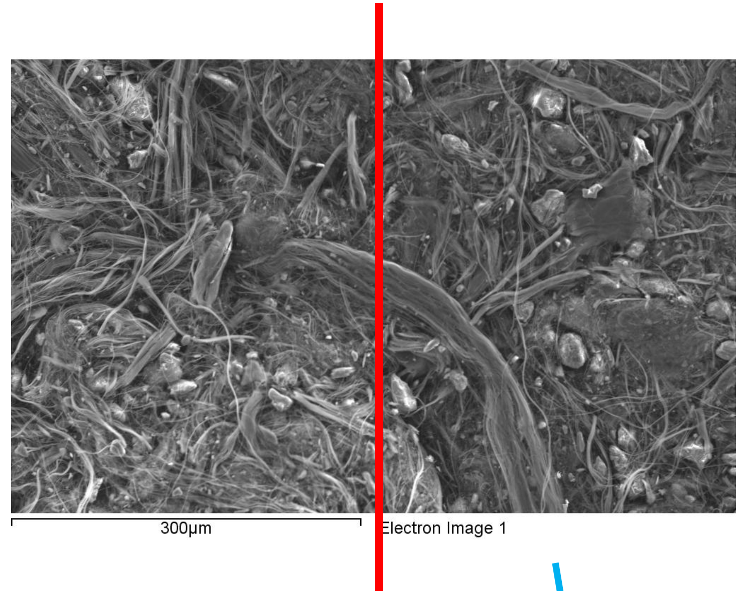
Analysis of fibers

Spectrum	In stats.	O	Mg	Si	Fe	Cr	Ni	Total
Sum Spectrum	Yes	79.62	11.68	7.31	1.11	0.08	0.21	100.00
Spectrum 2	Yes	45.06	18.26	12.78	23.14	0.31	0.44	100.00
Spectrum 3	Yes	57.55	23.29	16.60	2.03	0.11	0.43	100.00
Spectrum 4	Yes	60.91	21.81	15.51	1.38	0.11	0.28	100.00
Spectrum 5	Yes	57.35	23.69	17.55	1.10	0.09	0.21	100.00
Spectrum 6	Yes	63.91	20.78	14.51	0.26	0.31	0.23	100.00
Spectrum 7	Yes	50.49	26.54	19.73	1.99	BD	2.53	100.00
Spectrum 8	Yes	56.31	25.68	17.84	BD	BD	0.93	100.00
Spectrum 9	Yes	54.87	28.89	13.13	0.81	0.38	1.92	100.00
Mean		**58.45**	**22.29**	**14.99**	**3.53**	**0.20**	**0.80**	100.00
Std. deviation		9.66	5.09	3.67	7.39	0.55	0.85	
Max.		79.62	28.89	19.73	23.14	0.38	2.53	
Min.		45.06	11.68	7.31	BD	BD	0.21	



Detailed SEM-EDS analysis of a fiber from deep settling pond sediments. Measurements in weight percent.

SEM image of fibers from fibers, showing a chromium-rich particle



Element	Weight%	Atomic%
O	54	66
Mg	25	20
Si	19	13
Cr	**0.11**	**0.04**
Fe	2.6	0.91
Ni	0.12	0.04

Element	Weight%	Atomic%
O	53	65
Mg	25	21
Si	18	13
Cr	**0.35**	**0.13**
Fe	2.9	1.1
Ni	0.15	0.05

Contribution of each phase

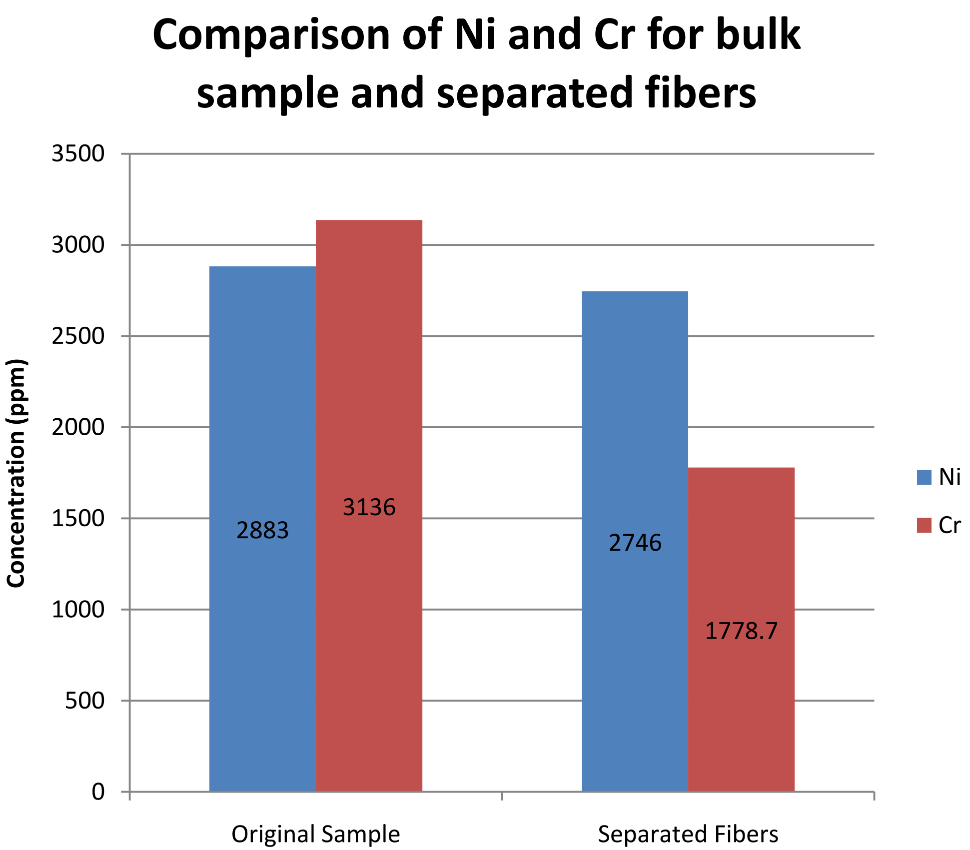
- 1% Chromite, with an average of 30 atomic percent chromium would contribute 3000 ppm Cr
- 0.5% Millerite would contribute 2500 ppm Ni
- From averages of the fibers, 80% chrysotile fibers could contribute between 80 and 400 ppm Ni and between 80 and 300 ppm Cr
- Mineral phases apart from the fibers may be contributing significantly to observed nickel and chromium concentrations

Sample	Ni	Cr
Eden tailings pile	3599	3923
Deep settling pond sediments	2883	3136
Surface Sediments	5709	2372
Magnetite	5644	24100
Pure fibers	2488	1456

XRF Data for bulk elemental concentration in samples. Measurement in ppm.

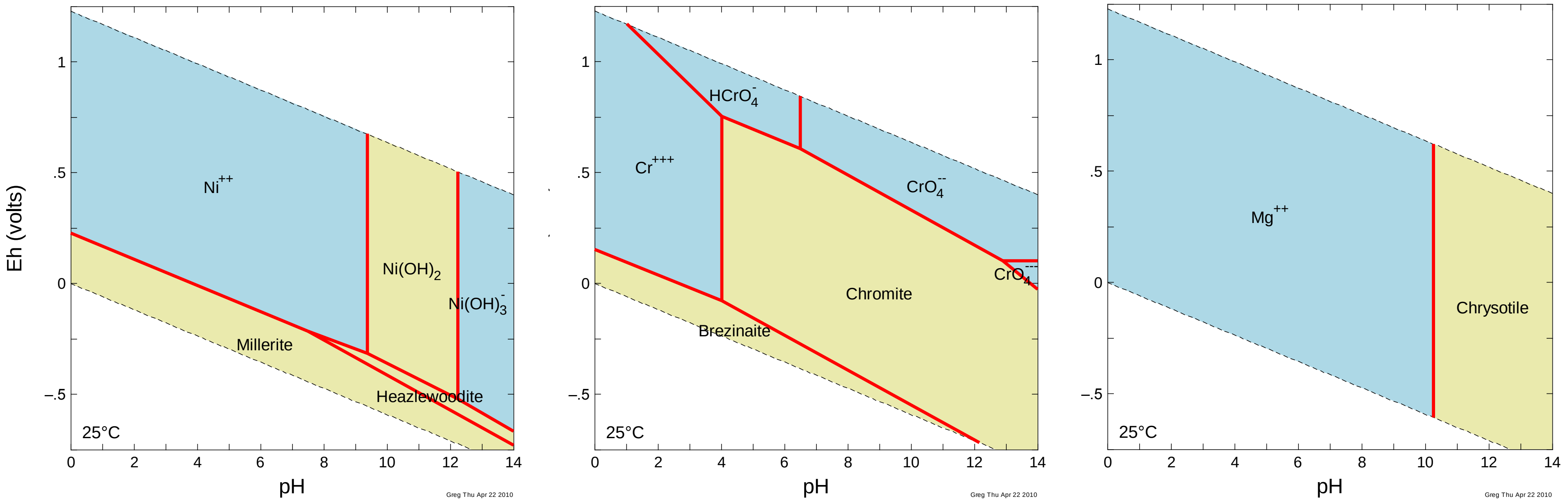
Separation of fibers from heavier minerals

- Panning method used to separate fibers from heavier mineral grains.
- XRD scans of separated material showed similar mineral composition as the original sample, with slightly enhanced spinel peaks.
- XRF analysis of fibers showed significant reduction in chromium concentrations, with little change in nickel with respect to previous scans of bulk sample.



Why should it *phase* us?

- Chrysotile fibers are not the sole contributors to the elevated metal concentrations in stream sediments.
- Nickel and chromium are present in separate mineral phases (Millerite and Chromite).
- Solubility of these minerals in the environment affects how Ni and Cr may be released and will vary between different minerals



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- Assistance with XRD analysis and interpretation by Dr. John Hughes, (Department of Geology, University of Vermont).
- Assistance with scanning electron microscopy and preparation of samples by Michelle von-Turkovitch (Microscopy Center, University of Vermont).

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Cover slide image from VT-DEC Waste Management webpage.