SAND2014-4764P

Used Fuel Disposition Campaign

Sampling and Analysis of Dusts/Salts from In-Service Storage Canisters at Hope Creek and Diablo Canyon ISFSIs

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Sandia National Laboratories

UFD Working Group Meeting
June 4-6, 2014, Las Vegas

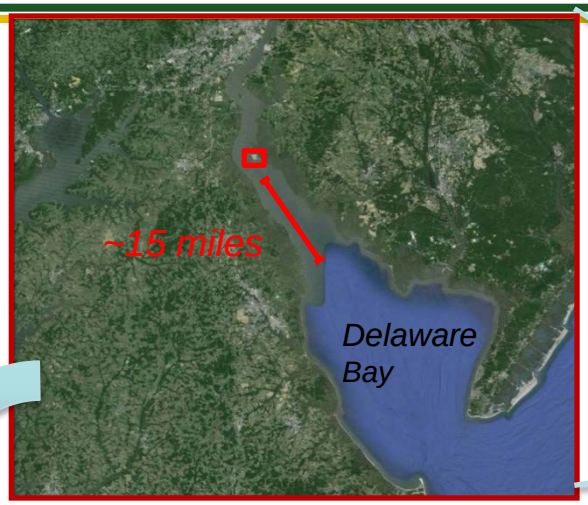
Overview

- Background and ISFSI's sampled
- Types of samples and sampling methods
- Sampling issues
- Analysis methods
- Results, Hope Creek and Diablo Canyon

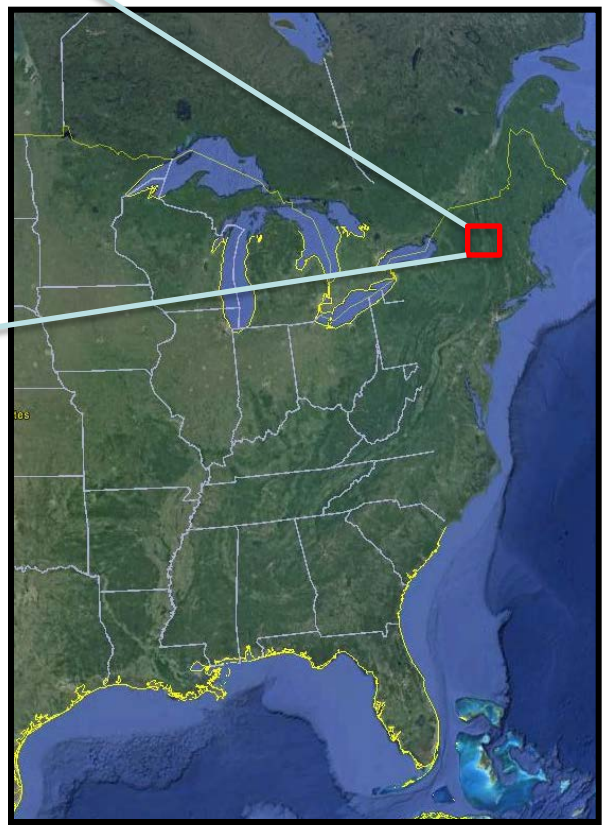
Background

- Stress corrosion cracking (SCC) of stainless steel due to deliquescence of chloride-rich salts on the metal surface is well-known, especially in near-marine environments.
- EPRI sampling program: Assess the composition of dust on the surface of in-service stainless steel SNF storage canisters, with emphasis on the composition of the soluble salts, that could deliquesce as the canisters cool.
- EPRI worked with cask vendors to establish sampling methods and with reactor owners to gain access to three sites
- ISFSI locations to be sampled:
  - Calvert Cliffs: Transnuclear NUHOMS system, horizontal storage canister
  - Hope Creek: Holtec HI-STORM system, vertical canister (sampled Dec 2013)
  - Diablo Canyon: Holtec HI-STORM system (sampled Jan 2014)
- Samples delivered to Sandia National Laboratories for analysis

Hope Creek Site



Eastern U.S.



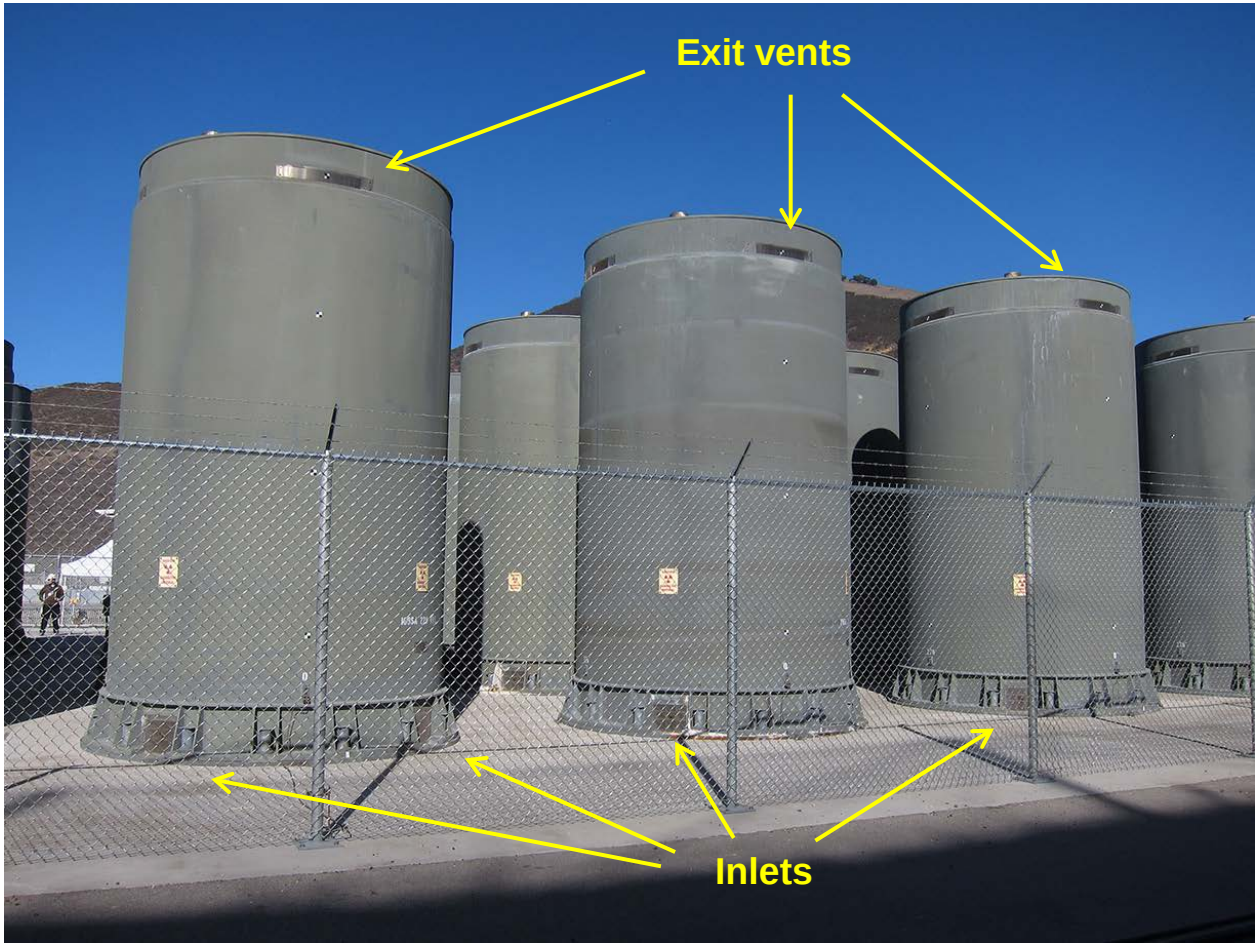
ISFSI is ~0.25 miles from the Delaware River, 15 miles upstream from Delaware Bay.

Diablo Canyon Site

ISFSI is ~1/3 mile from the shoreline, on a hill above the plant.

Sampling of deposits on In-service SNF Interim Storage Canisters

Holtec HI-STORM 100S-218



Salt deposition and corrosion at sea-side inlet vents (Diablo Canyon)

Sampling of deposits on In-service SNF Interim Storage Canisters

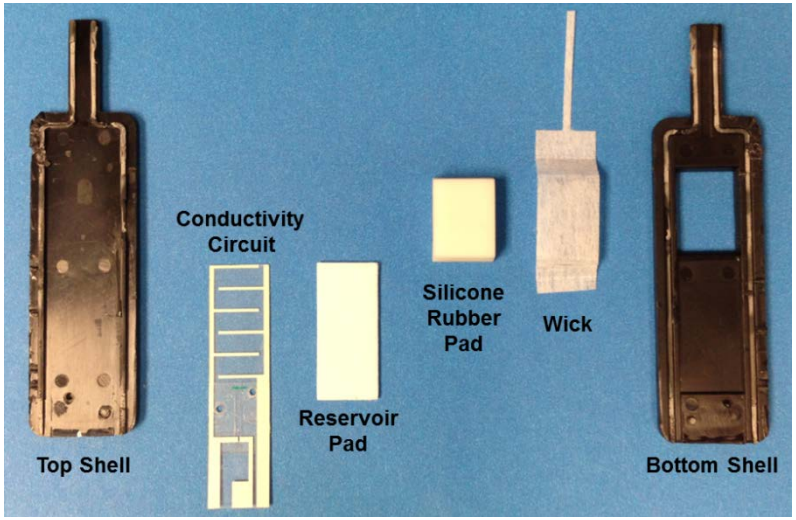
Removing the Gamma Shield

Sampling with remote sampling tool

Types of Samples Collected

Wet samples

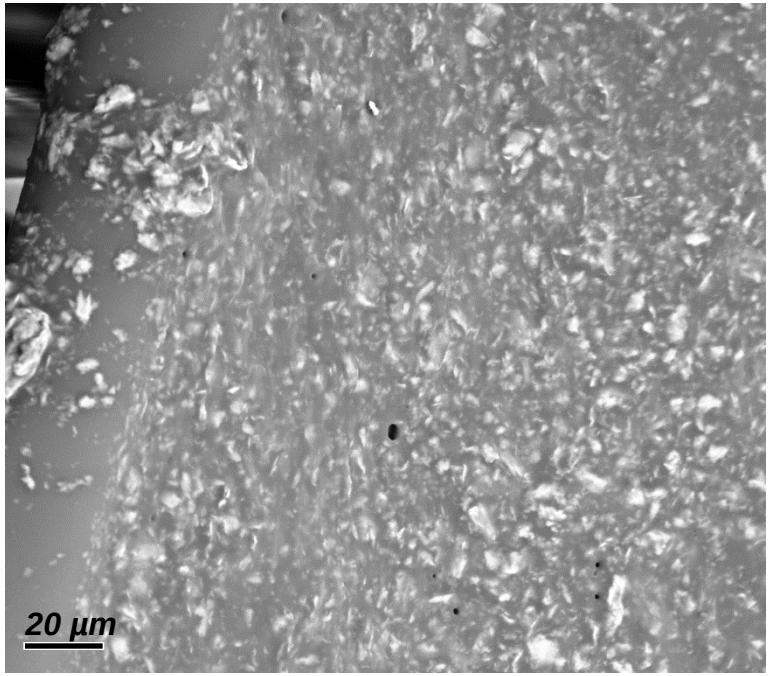
- Salt-smart® sensors
- Used to characterize soluble salts (quantify amount per unit area)
- Pneumatically-activated sampling tool pressed Salt-smart® sensor against canister surface and delivered water to the sensor.
- *Sampling issues*
  - Saltsmart® samplers do not work above ~80ºC
    - Stated range 0 — 50ºC, but manufacturer tested to ~90ºC
    - However, problems observed at >80ºC
      - *Wick adheres to silicone pressure pad*
      - *Reservoir pad is only partially wetted*
  - Diablo Canyon sampling was limited by hot packages; many sample locations were too hot
  - Pads sometimes did not contact the surface flatly
  - *Measured salt concentrations/area may not be representative!*



Types of Samples Collected

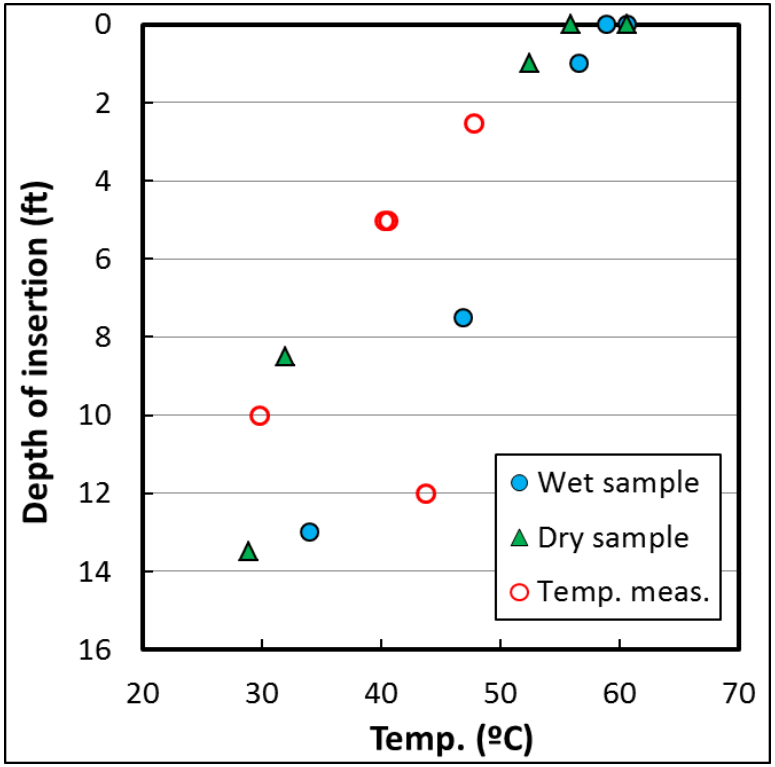
Dry dust samples

- Used to characterize soluble/insoluble components (chemistry, mineralogy, texture); cannot quantify amount per unit area
- At Hope Creek/Diablo Canyon:
  - Holtec-designed sampling tool
  - Scotch-brite® pad pressed against the surface and moved back and forth pneumatically (sides) or using a long rod (top)
- Sampling issues
  - *Recommended pads were not free of abrasive—contained talc (Mg-silicate) as a filler. This interfered with mineral identification by SEM, but not badly.*
  - *Worse—pads leached copious amounts of sodium, phosphate, and sulfate. These species cannot be quantified in the soluble salt leachate from the pads. Chloride and nitrate were not affected.*

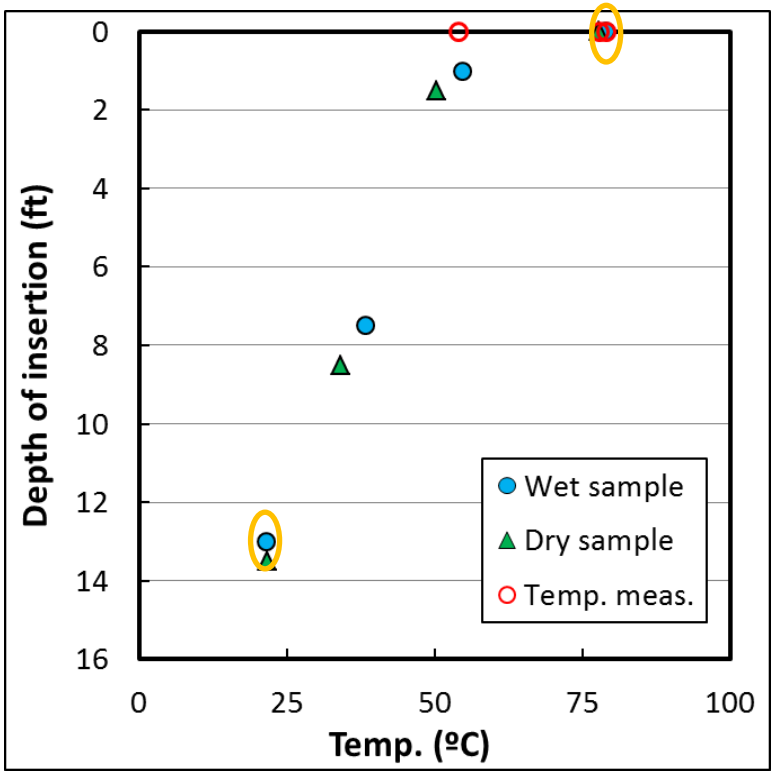


Samples Collected — Hope Creek

MPC-144



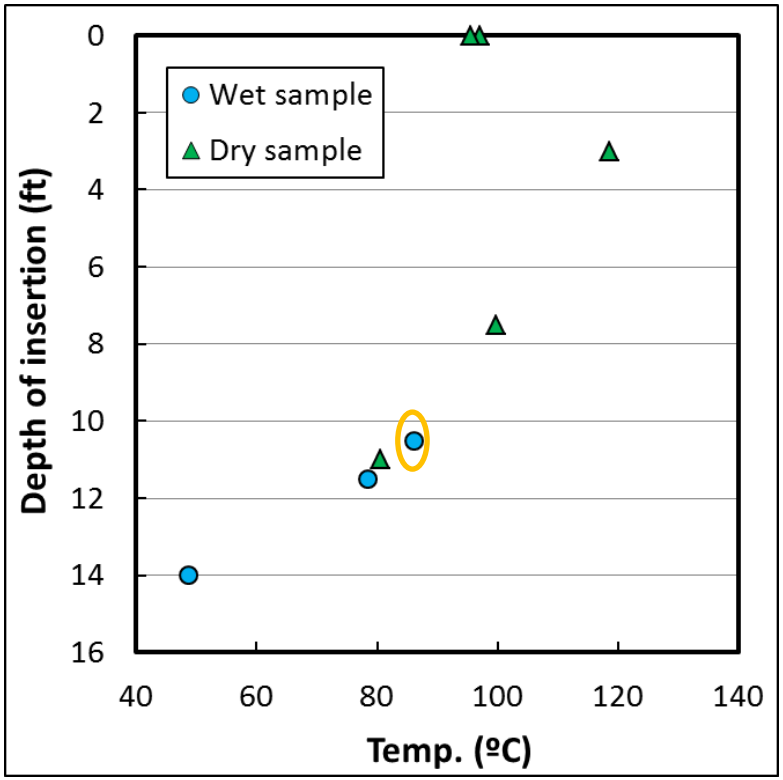
MPC-145



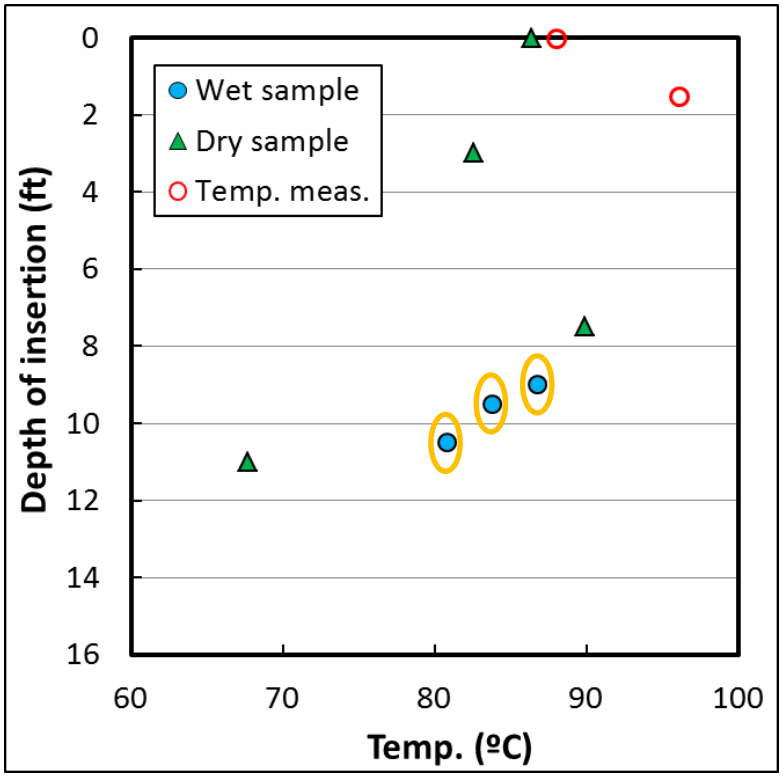
Wick stuck to silicone pressure pad, and/or reservoir pad was only partially wetted

Samples Collected — Diablo Canyon

MPC-123

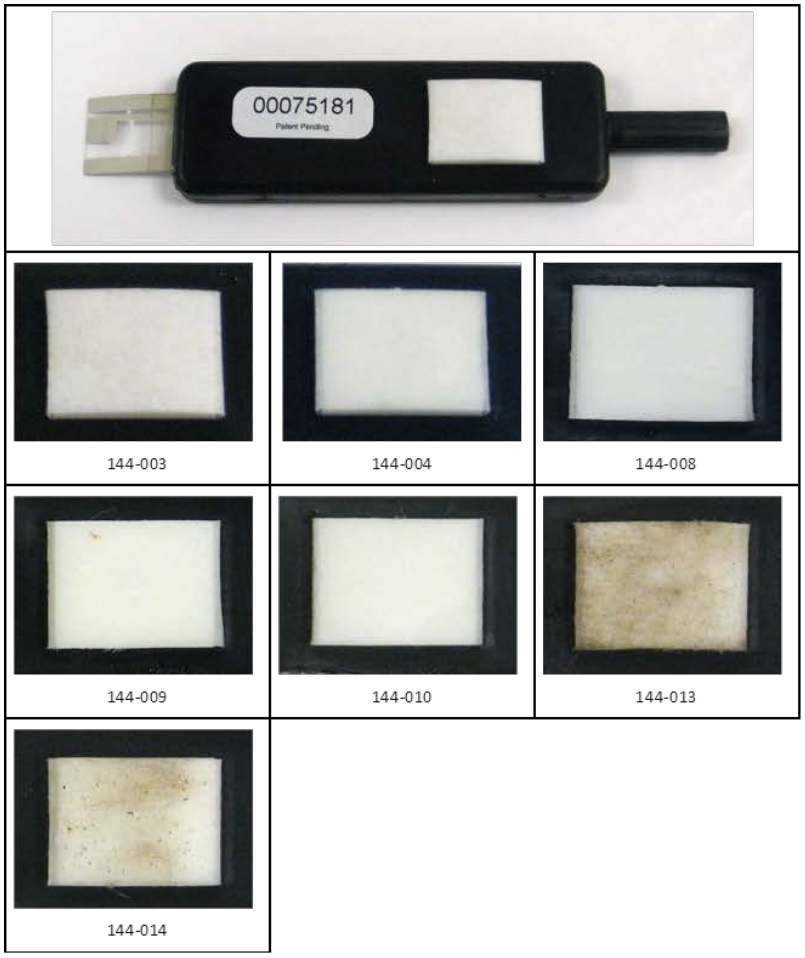


MPC-170



Wick stuck to silicone pressure pad, and/or reservoir pad was only partially wetted

Samples Photographs — Hope Creek (MPC-144)

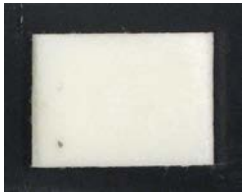


Samples Photographs — Diablo Canyon (MPC-123)

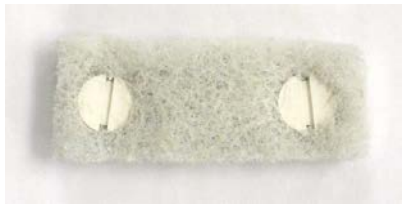

123-002


123-003


123-004


123-005

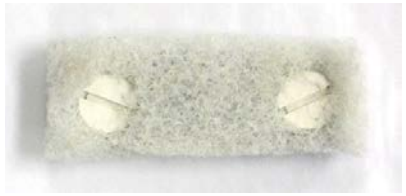

123-010


123-001


123-006


123-007


123--008


123--009


123-011


123-012

Analysis Methods

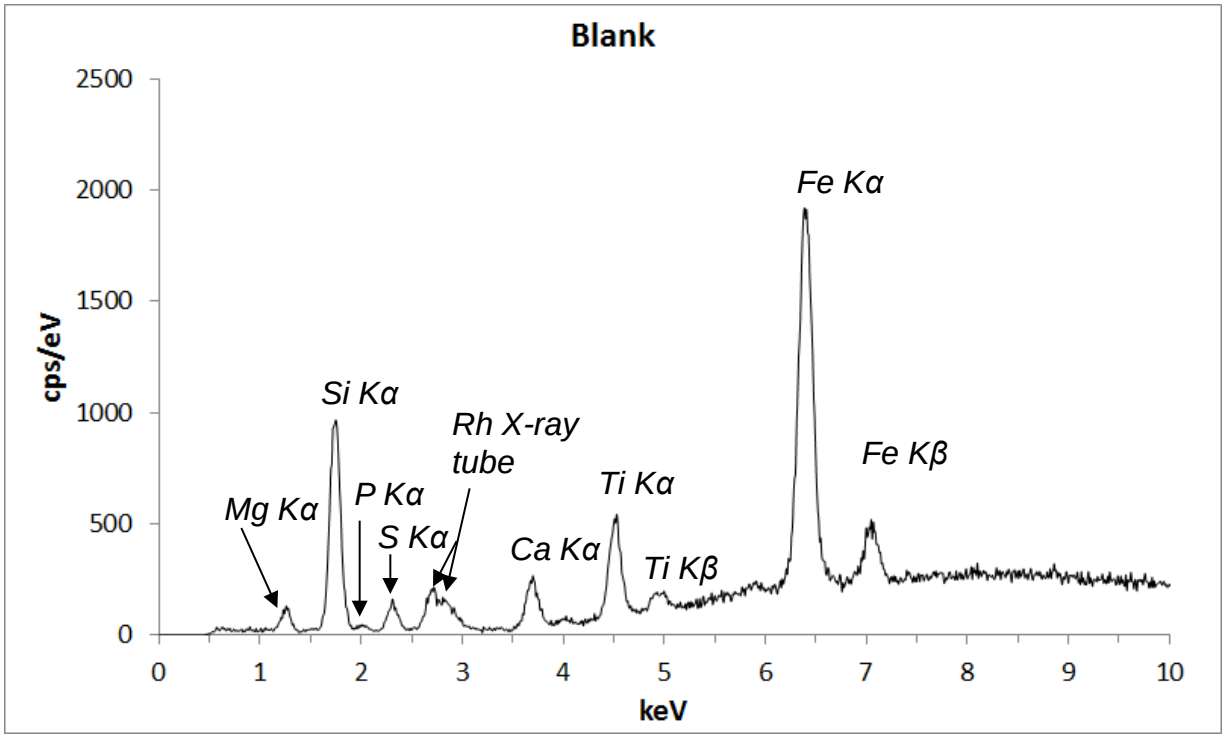
- **X-ray fluorescence analysis**
  - Dry samples
  - Micro-analytical technique—allows chemical mapping of the dry pad surfaces with a resolution of ~50 µm
  - Provides semi-quantitative chemical analyses—yields element ratios that can be used in mass balance calculations
  - Cannot detect elements lighter than Na (and sensitivity to Na is very low)
- **SEM imaging and energy dispersive system (EDS) element maps**
  - Dry samples
  - Provide textural and mineralogical information
  - Identification of floral/faunal fragments in dust
- **X-ray diffraction**
  - Analysis of pads for mineralogical information *(was unsuccessful)*
- **Chemical Analysis**
  - Dry pad and Salt-smart® samples leached with DI water, and the leachate analyzed to determine soluble salts in the dust
  - Insoluble fractions digested and analyzed to determine bulk chemistry

XRF Analysis

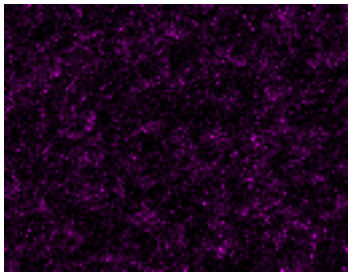
Pad Blank

- ***Pad contains talc ($Mg_3Si_4O_{10}(OH)_2$)***
- ***Pad leaches SO_4^{2-}, PO_4^{3-}, and Na^+***

Vision Quant Results: **Blank**				
Total Area Spc from ROI Map		12:53 PM		10-Feb-14
Elem:	Net	Wt%	At%	I-Error%
MgK	1.57	29.42	35.12	3.79
AlK	0.2	1.2	1.29	18.91
SiK	15.88	47	48.58	1.02
P K	0.45	1.77	1.66	10.07
S K	2.06	4.06	3.68	3.32
K K	0.18	0.22	0.17	25.03
CaK	4.25	3.5	2.54	2.25
TiK	8.81	3.67	2.23	1.62
CrK	0.27	0.08	0.04	43.76
MnK	1.12	0.28	0.15	12.39
FeK	38.9	8.46	4.4	0.73
NiK	0.53	0.11	0.06	30.79
ZnK	0.81	0.17	0.07	21.53
ZrK	0.23	0.05	0.02	36.82



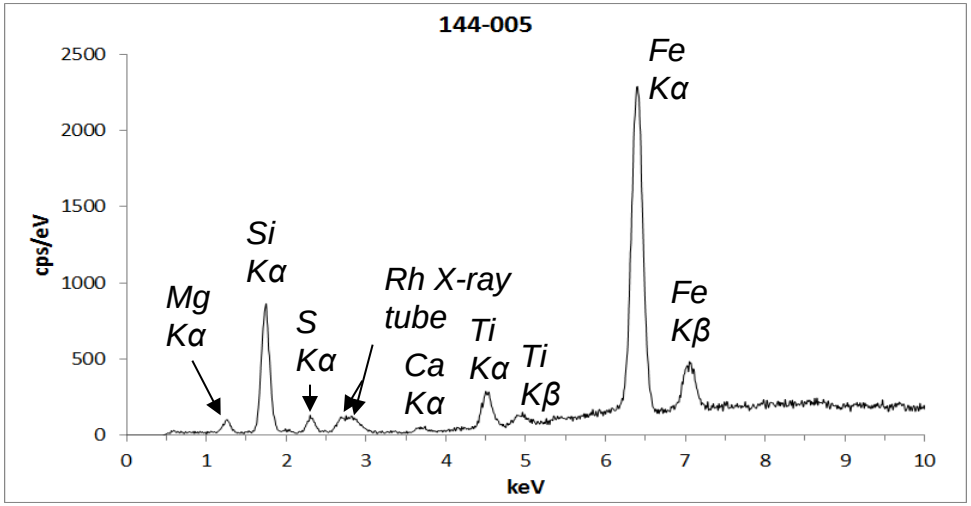
Elemental map for Fe



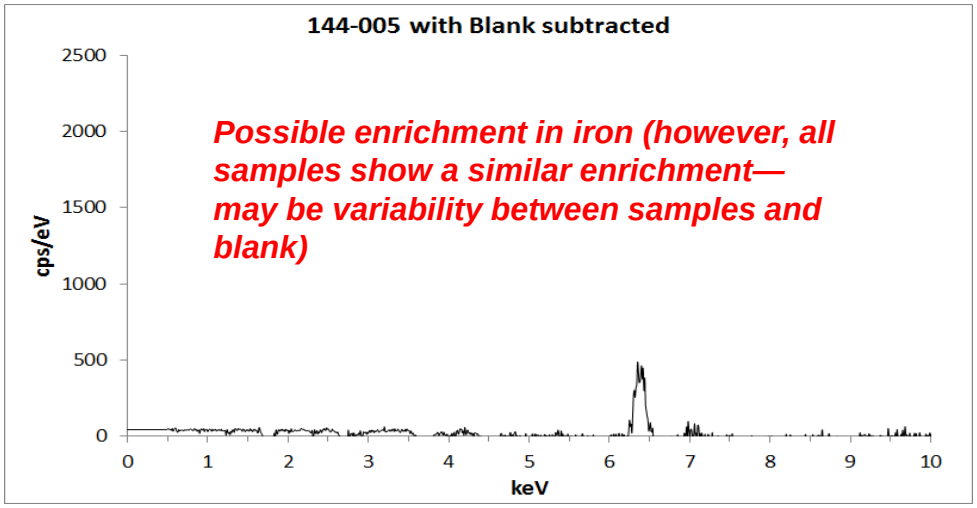
Used Fuel Disposition

XRF Analysis

Hope Creek Sample # 144-005
Side, Insertion Depth 13.5 feet



Vision Quant Results: 144-005				
Total Area Spc from ROI Map		2:04 PM		11-Feb-14
Elem:	Net	Wt%	At%	I-Error%
MgK	1.27	29	34.98	4.35
AlK	0.1	0.72	0.79	34.75
SiK	13.4	46.39	48.44	1.11
P K	0.32	1.46	1.39	12.82
S K	1.71	3.9	3.57	3.66
ClK	1.14	2.57	2.13	4.88
K K	0.17	0.25	0.19	23.98
CaK	0.62	0.6	0.44	8.46
TiK	4.8	2.2	1.35	2.26
CrK	0.54	0.17	0.09	18.27
MnK	0.64	0.17	0.09	17.98
FeK	49.14	12	6.3	0.61
NiK	0.56	0.15	0.07	24.74
ZnK	1.26	0.32	0.14	12.11
ZrK	0.3	0.08	0.03	26.5



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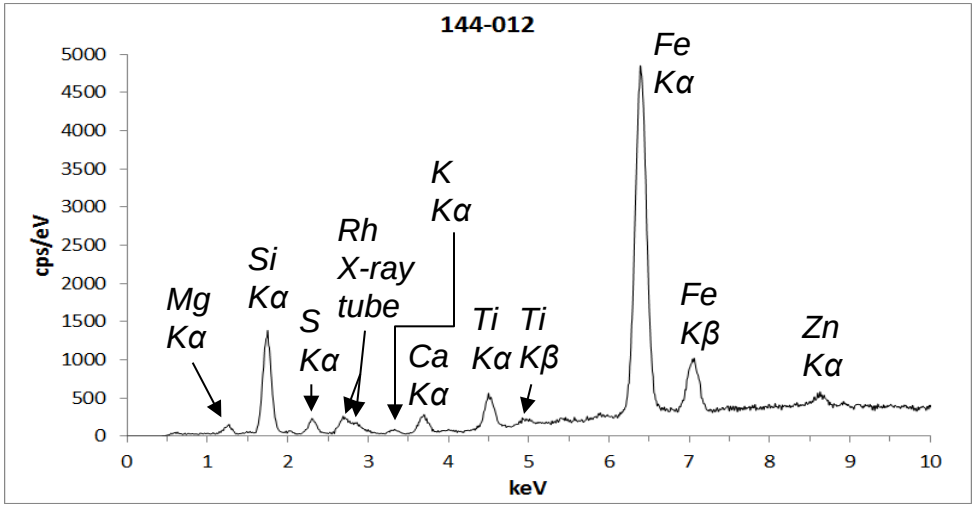
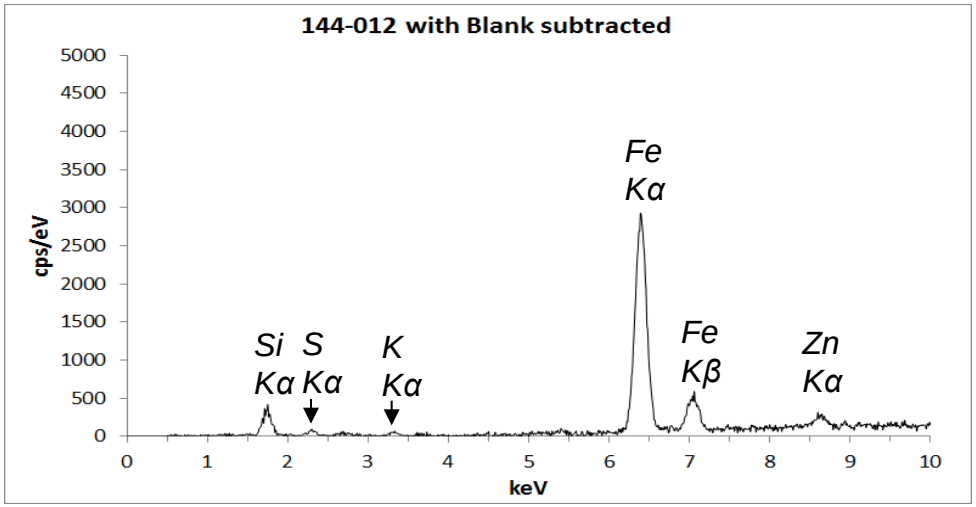
NiK	0.53	0.11	0.06	30.79
ZnK	0.81	0.17	0.07	21.53
ZrK	0.23	0.05	0.02	36.82

Used Fuel Disposition

XRF Analysis

Hope Creek Sample # 144-011 Top





Vision Quant Results: 144-005				
Total Area Spc from ROI Map		2:04 PM		11-Feb-14
Elem:	Net	Wt%	At%	I-Error%
MgK	1.27	29	34.98	4.35
AlK	0.1	0.72	0.79	34.75
SiK	13.4	46.39	48.44	1.11
P K	0.32	1.46	1.39	12.82
S K	1.71	3.9	3.57	3.66
ClK	1.14	2.57	2.13	4.88
K K	0.17	0.25	0.19	23.98
CaK	0.62	0.6	0.44	8.46
TiK	4.8	2.2	1.35	2.26
CrK	0.54	0.17	0.09	18.27
MnK	0.64	0.17	0.09	17.98
FeK	49.14	12	6.3	0.61
NiK	0.56	0.15	0.07	24.74
ZnK	1.26	0.32	0.14	12.11
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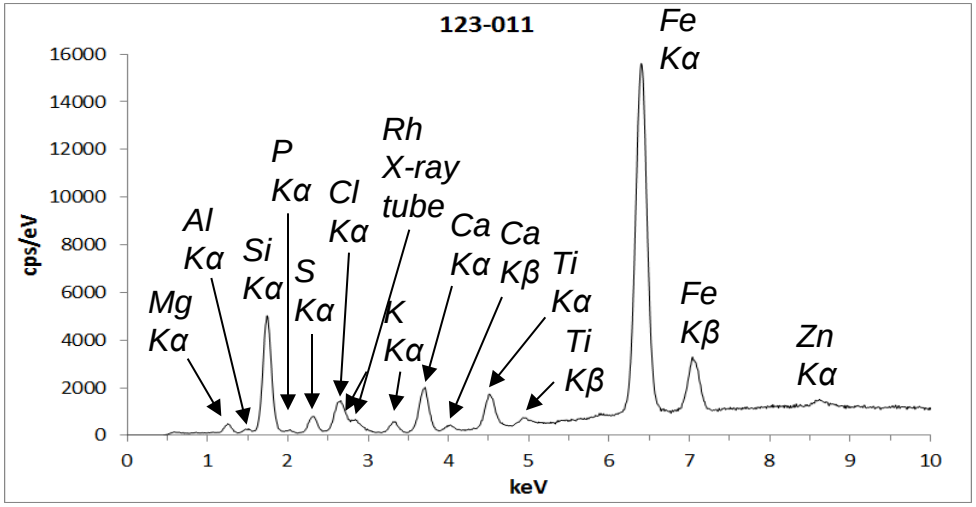
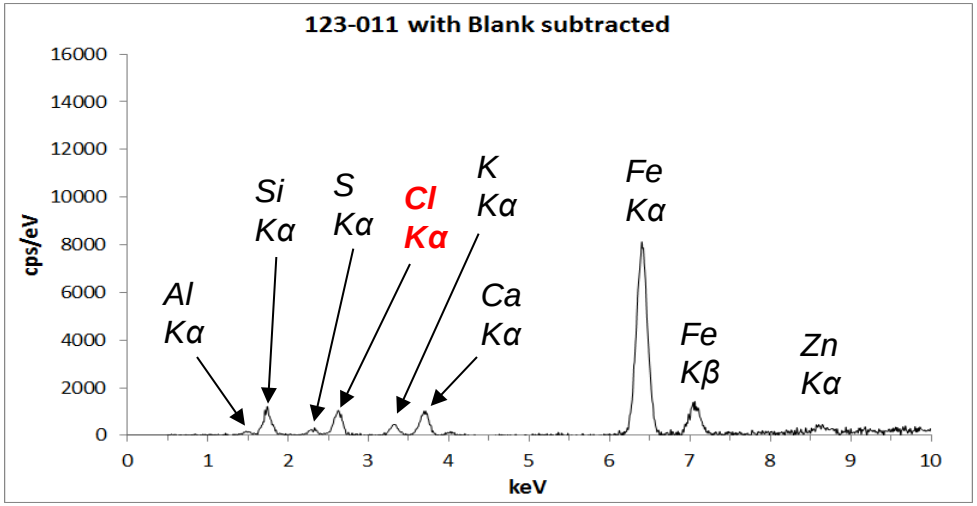
TiK	8.81	3.67	2.23	1.62
CrK	0.27	0.08	0.04	43.76
MnK	1.12	0.28	0.15	12.39
FeK	38.9	8.46	4.4	0.73
NiK	0.53	0.11	0.06	30.79
ZnK	0.81	0.17	0.07	21.53
ZrK	0.23	0.05	0.02	36.82

Used Fuel Disposition

XRF Analysis

Diablo Canyon Sample # 123-011 Top





Vision Quant Results: 123-011				
Total Area Spc from ROI Map		5:57 PM		12-Feb-14
Elem:	Net	Wt%	At%	I-Error%
MgK	1.44	21.30	27.08	2.16
AlK	0.68	2.71	3.11	3.85
SiK	19.89	39.33	43.29	0.46
P K	0.47	1.18	1.18	5.41
S K	3.04	3.77	3.64	1.34
ClK	6.1	7.60	6.62	0.88
K K	1.97	1.77	1.40	1.86
CaK	8.68	5.26	4.05	0.74
TiK	7.18	2.24	1.45	0.92
CrK	0.43	0.09	0.05	13.57
MnK	1.14	0.21	0.12	5.97
FeK	83.69	13.94	7.72	0.23
NiK	0.63	0.11	0.06	13.5
ZnK	2.6	0.45	0.21	3.7
ZrK	0.21	0.04	0.01	24.84

Vision Quant Results: **Blank**				
Total Area Spc from ROI Map		12:53 PM		10-Feb-14
Elem:	Net	Wt%	At%	I-Error%
MgK	1.57	29.42	35.12	3.79
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K K	0.18	0.22	0.17	25.03
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MnK	1.12	0.28	0.15	12.39
FeK	38.9	8.46	4.4	0.73
NiK	0.53	0.11	0.06	30.79
ZnK	0.81	0.17	0.07	21.53
ZrK	0.23	0.05	0.02	36.82

XRF Analysis: Summary

Dusts largely undetectable by XRF. Only spectra from canister top samples a show a convincing contribution from dust

Variation in Fe and Si (and possibly S) largely be due to variation in the pad matrix from sample to blank

Hope Creek

Sample	Location	Fe	Si	Ca	K	S	Zn
144-001		minor	-	-	-	-	-
144-002		-	-	-	-	-	-
144-005	Side (13.5 ft)	minor	-	-	-	-	-
144-006	Side (8.5 ft)	minor	trace	-	-	-	-
144-007	Side (1.0 ft)	trace	-	-	-	-	-
144-011	Top	major	minor	trace	trace	trace	trace
144-012	Top	major	minor	trace	trace	-	trace
145-001		trace	-	-	-	-	-
145-003	Side (13.5 ft)	major	minor	-	-	-	-
145-004	Side (8.5 ft)	minor	minor	-	-	-	-
145-005	Side (1.5 ft)	minor	minor	-	-	-	-
145-012	Top	minor	trace	trace	trace	-	trace

Canister top samples are most heavily loaded

Zn is probably from the Zn-based paint on the outside of the overpacks

Diablo Canyon

Sample	Location	Fe	Si	Ca	K	S	Zn	Cl	Cr
123-001		major	minor	-	-	trace	-	-	-
123-006	Side (11.0 ft)	minor	minor	-	-	trace	-	-	-
123-007		minor	minor	-	-	trace	-	-	-
123-008	Side (7.5 ft)	minor	trace	-	-	-	-	-	-
123-009	Side (3.0 ft)	major	minor	-	-	trace	-	-	-
123-011	Top	major	minor	trace	trace	trace	trace	-	-
123-012	Top	minor	trace	-	minor	trace	trace	minor	minor
170-001		major	trace	-	-	-	-	-	-
170-003	Top	major	minor	-	trace	trace	trace	minor	-
170-004	Side (11.0 ft)	major	minor	-	-	trace	trace	-	trace
170-005	Side (7.5 ft)	minor	minor	-	-	trace	trace	-	-
170-006	Side (3.0 ft)	major	minor	-	-	trace	trace	-	-

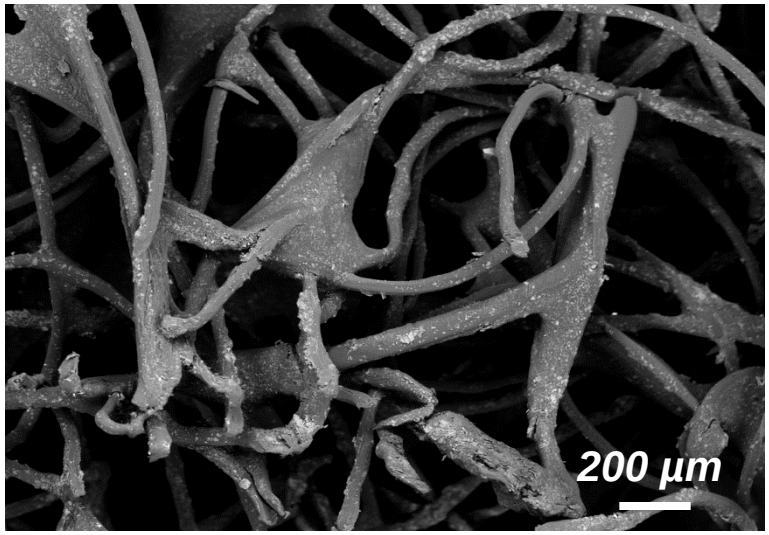
Canister top samples are most heavily loaded

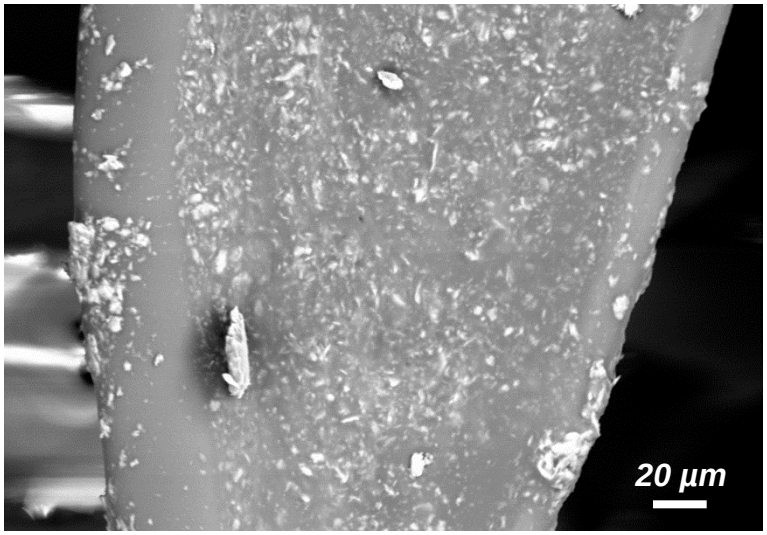
Significant Cl present

Elevated Cr (and apparently Fe in some cases), due to stainless steel particles on canister surface (from surface finishing).

SEM/EDS Analysis

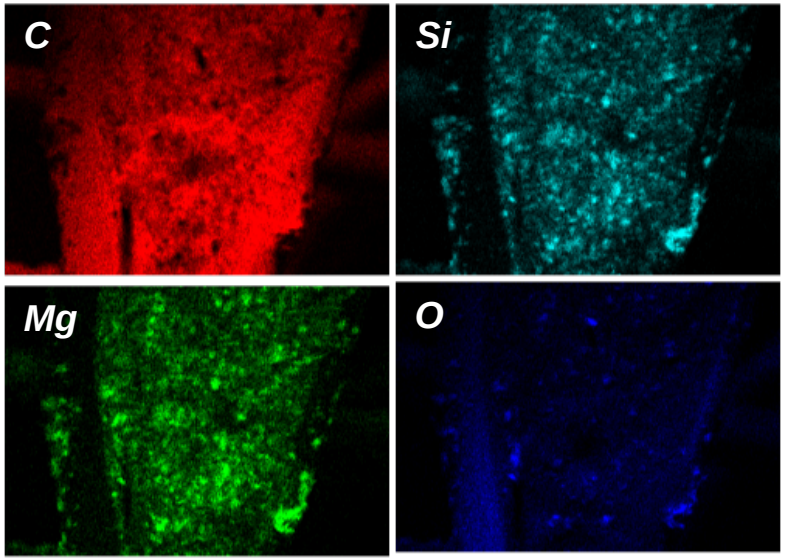
Scotch-brite® pad blank





Scotch-brite® pad blank

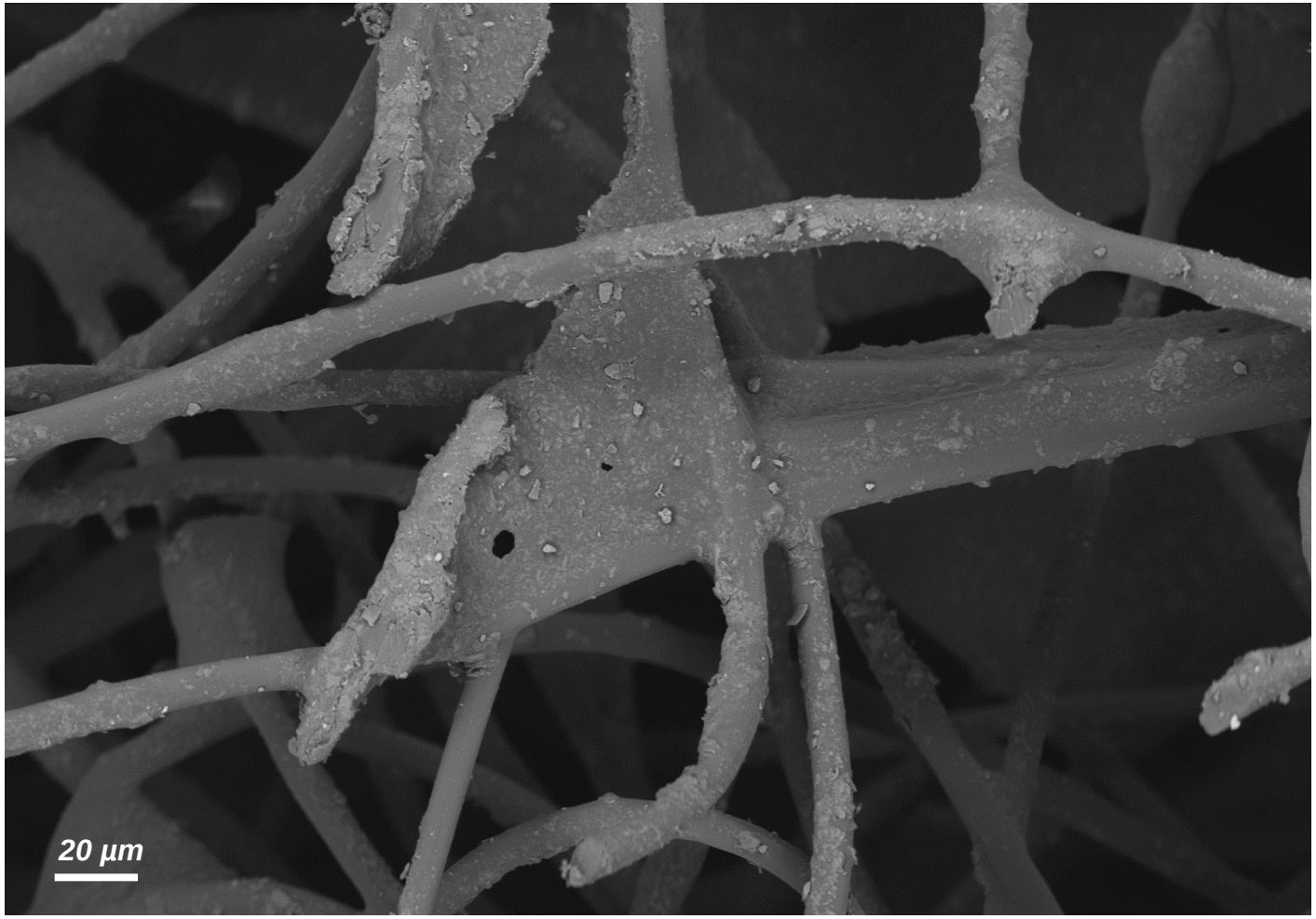
- *Nylon fibers in resin*
- *Talc (Mg-silicate) particles embedded in resin*
- *Trace titanium oxide particles*
- *Few contaminant particulates*
- *Fibers/resin abrade easily, talc flakes apart*



SEM/EDS Analysis

Hope Creek Sample # 144-005: Side, Insertion depth 13.5 ft

Canister sides: very sparse dust

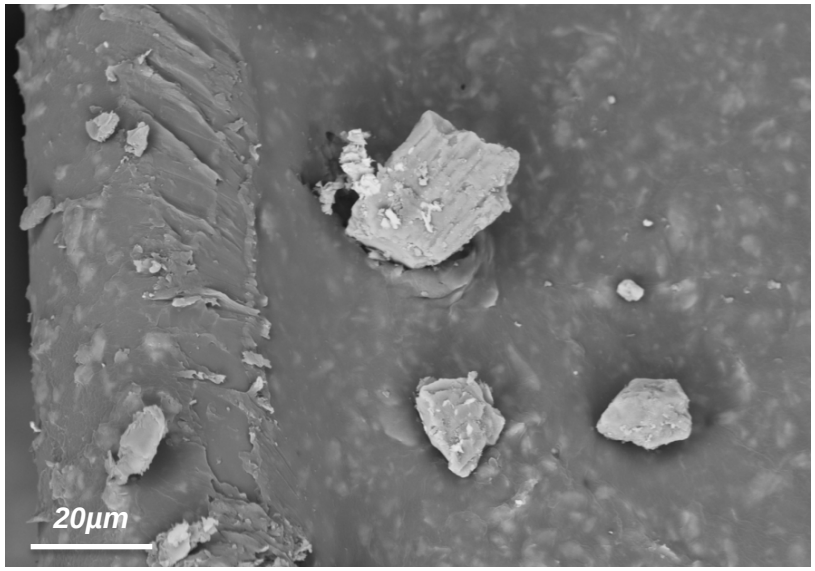


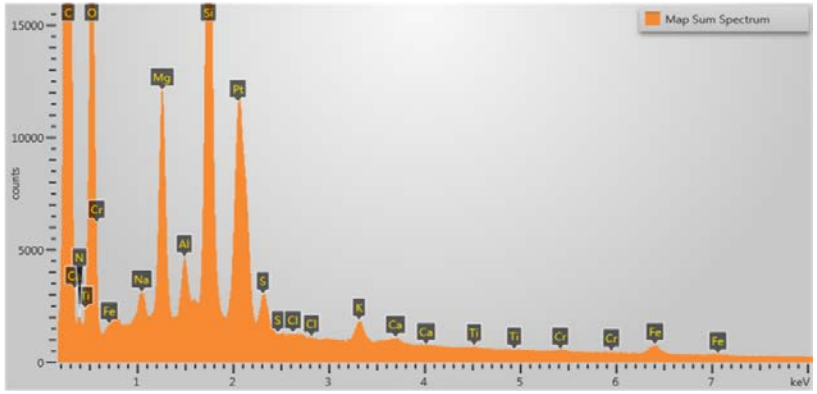
Used Fuel Disposition

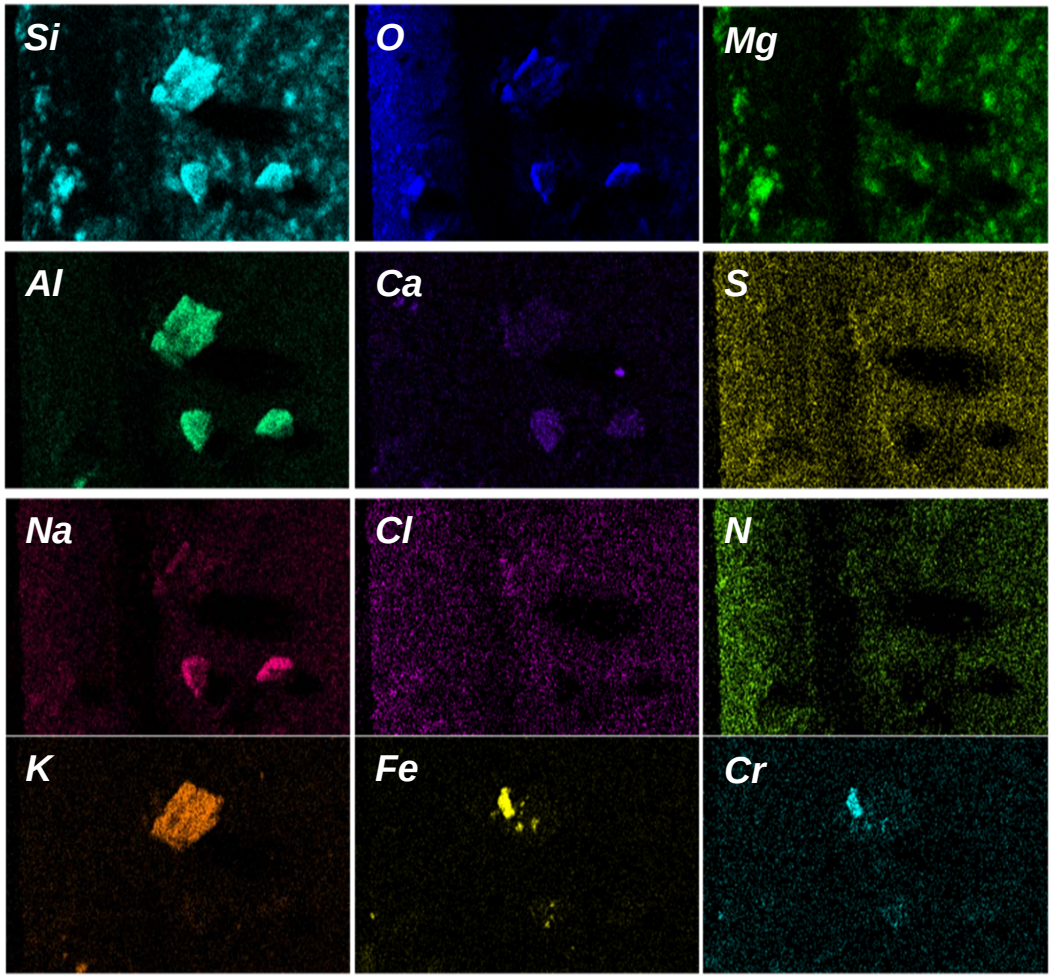
SEM/EDS Analysis

Hope Creek Sample # 144-005: Side, Insertion depth 13.5 ft

Dominant dust phases are aluminosilicates (morphology suggests feldspars), and stainless steel particulates from manufacturing)



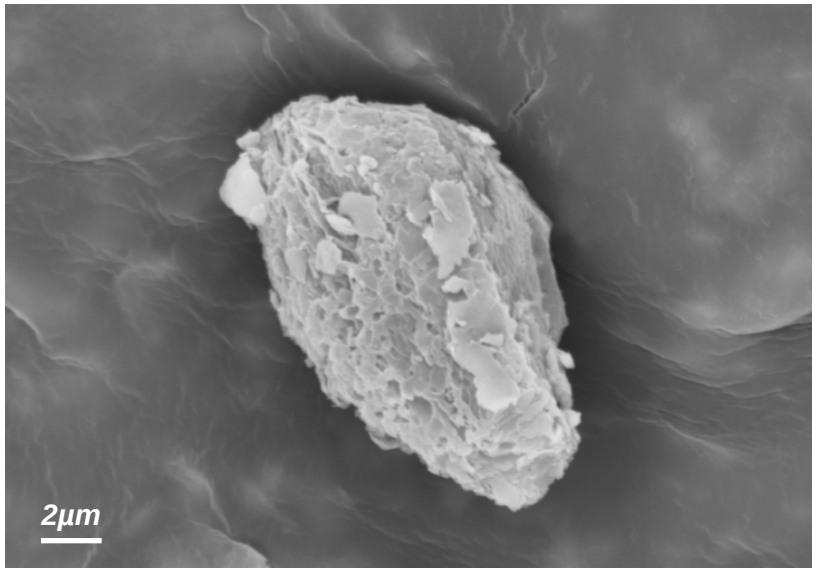


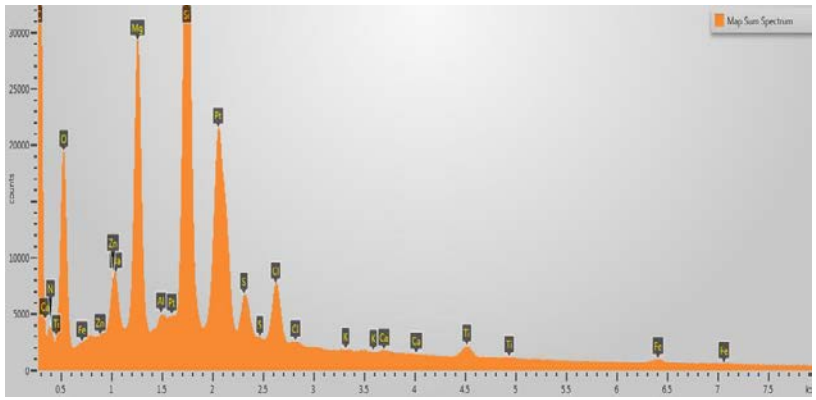


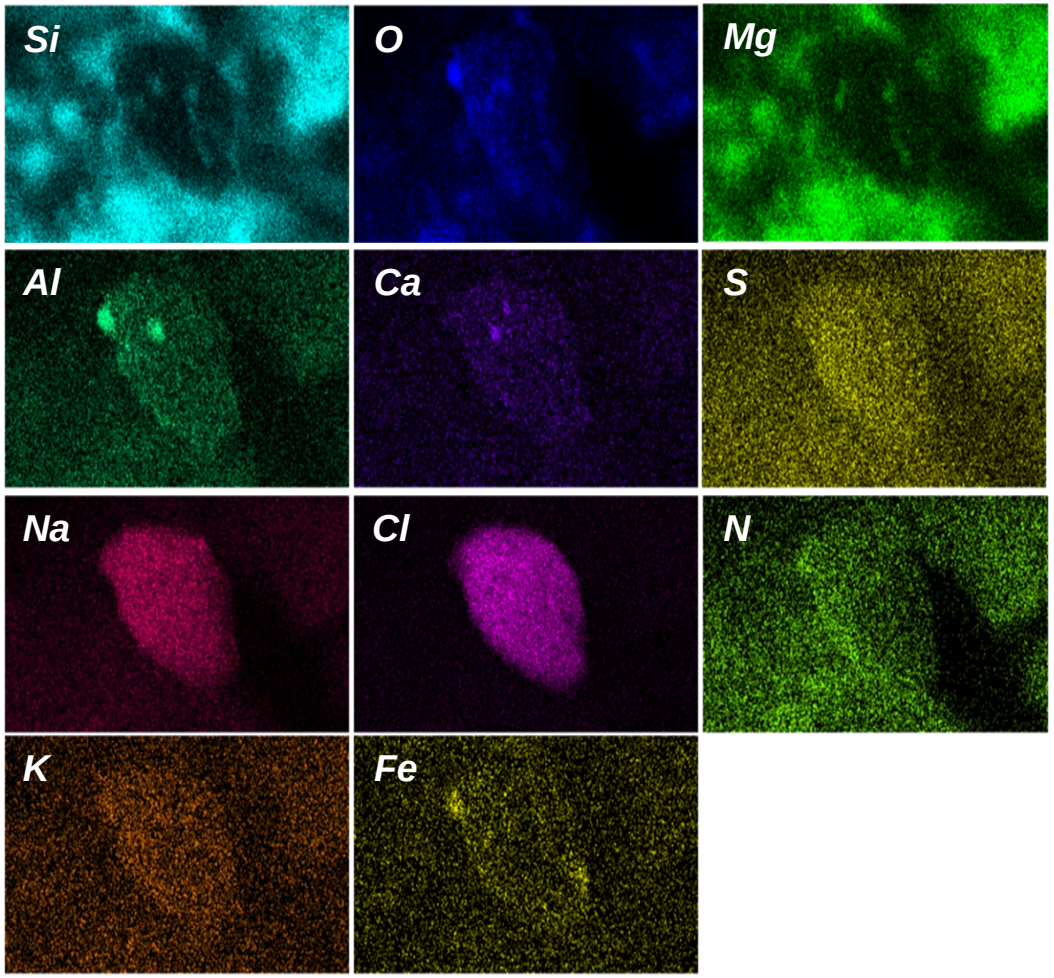
SEM/EDS Analysis

Hope Creek Sample # 144-005: Side, Insertion depth 13.5 ft

Trace chlorides present. Dominantly NaCl (occasional KCl) in small etched grains.







SEM/EDS Analysis

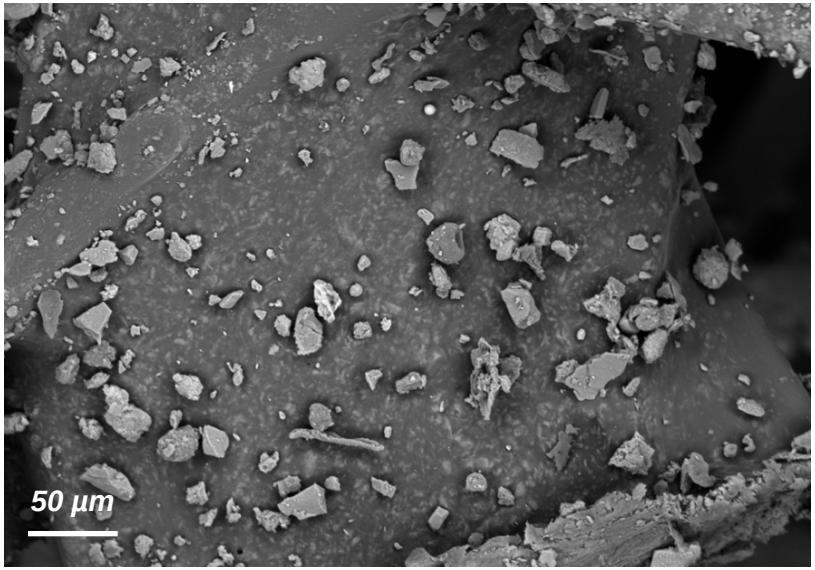
Hope Creek Sample # 144-011: Canister top

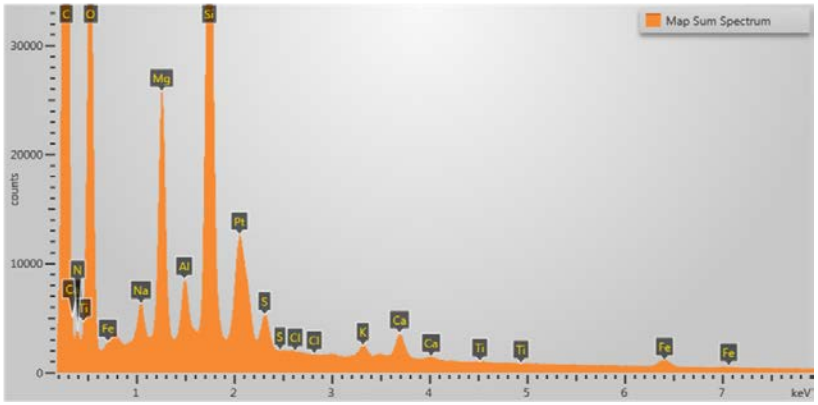
Canister top: heavily loaded with dust

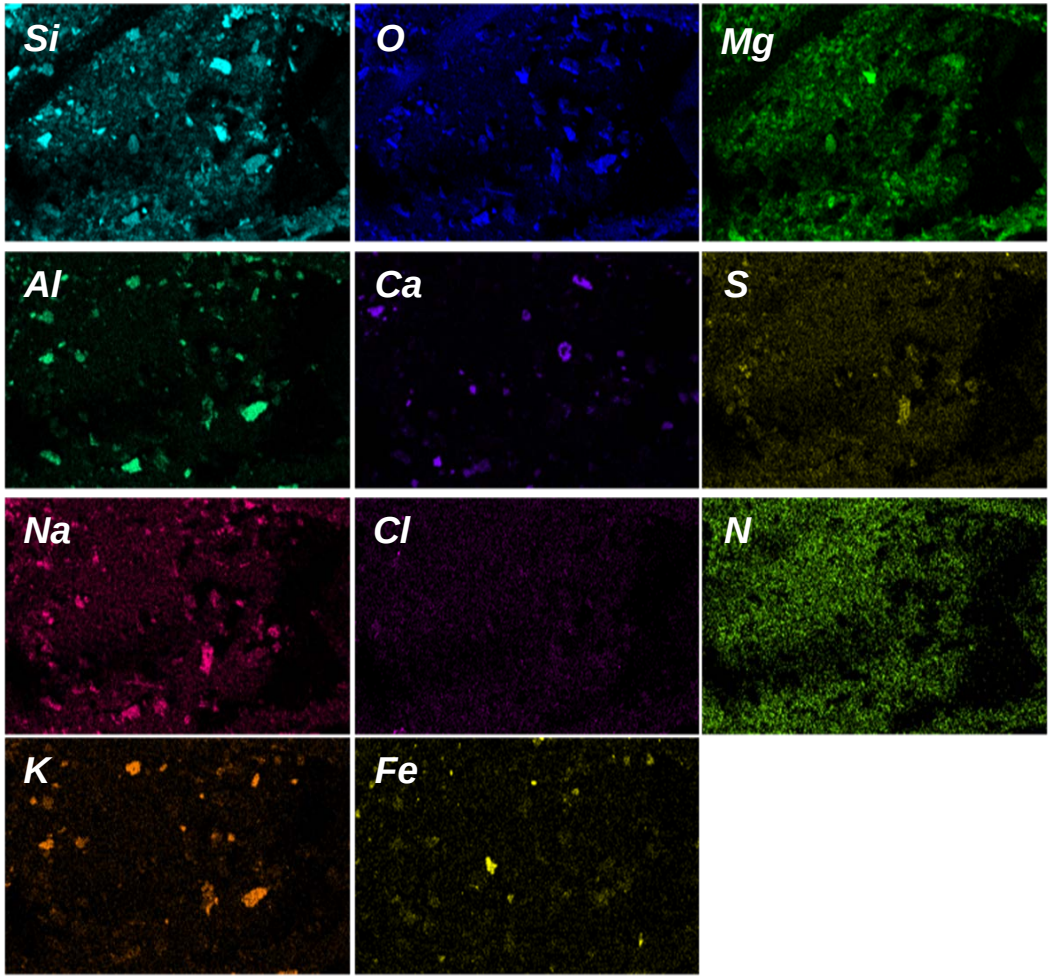
SEM/EDS Analysis

Hope Creek Sample # 144-011: Canister top

Dominantly aluminosilicates. Sparse pollen grains.



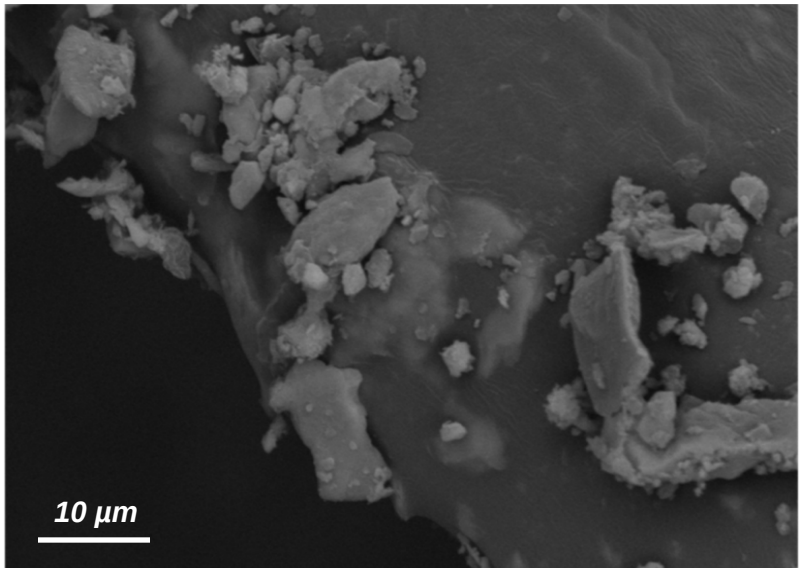


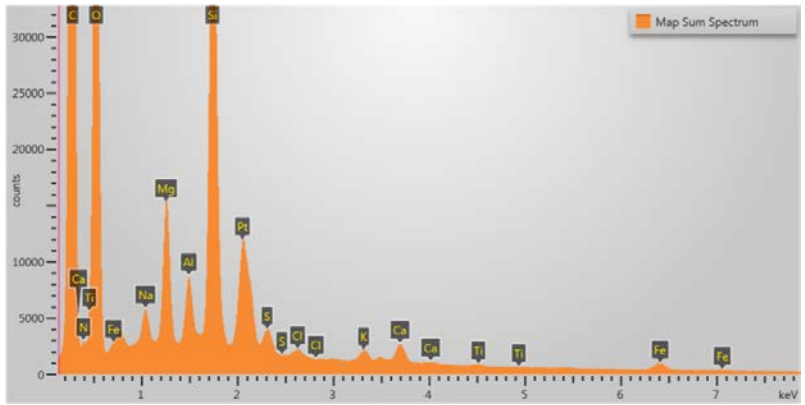


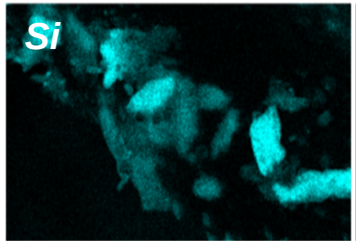
SEM/EDS Analysis

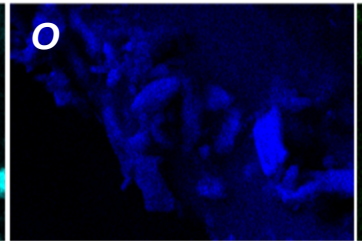
Hope Creek Sample # 144-011: Canister top

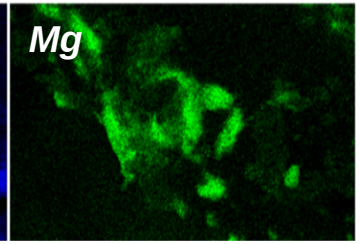
Sparse chloride minerals

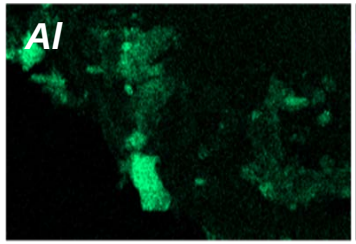


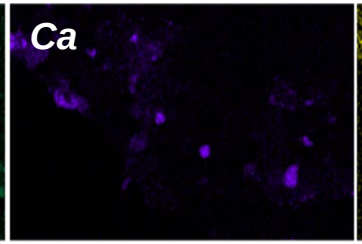


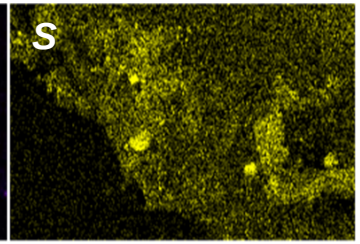


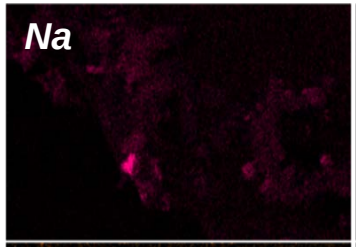


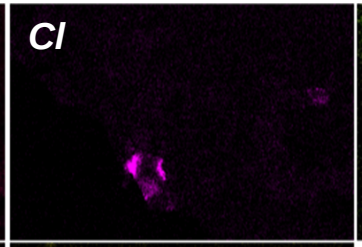


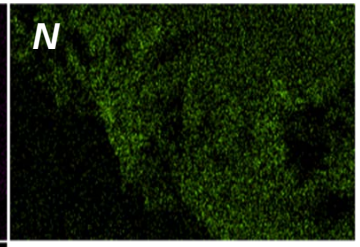


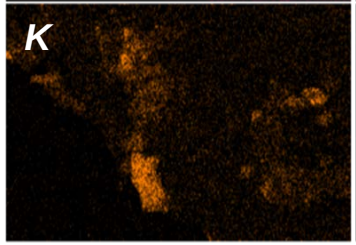


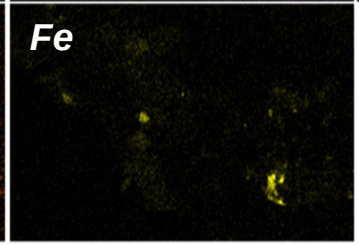








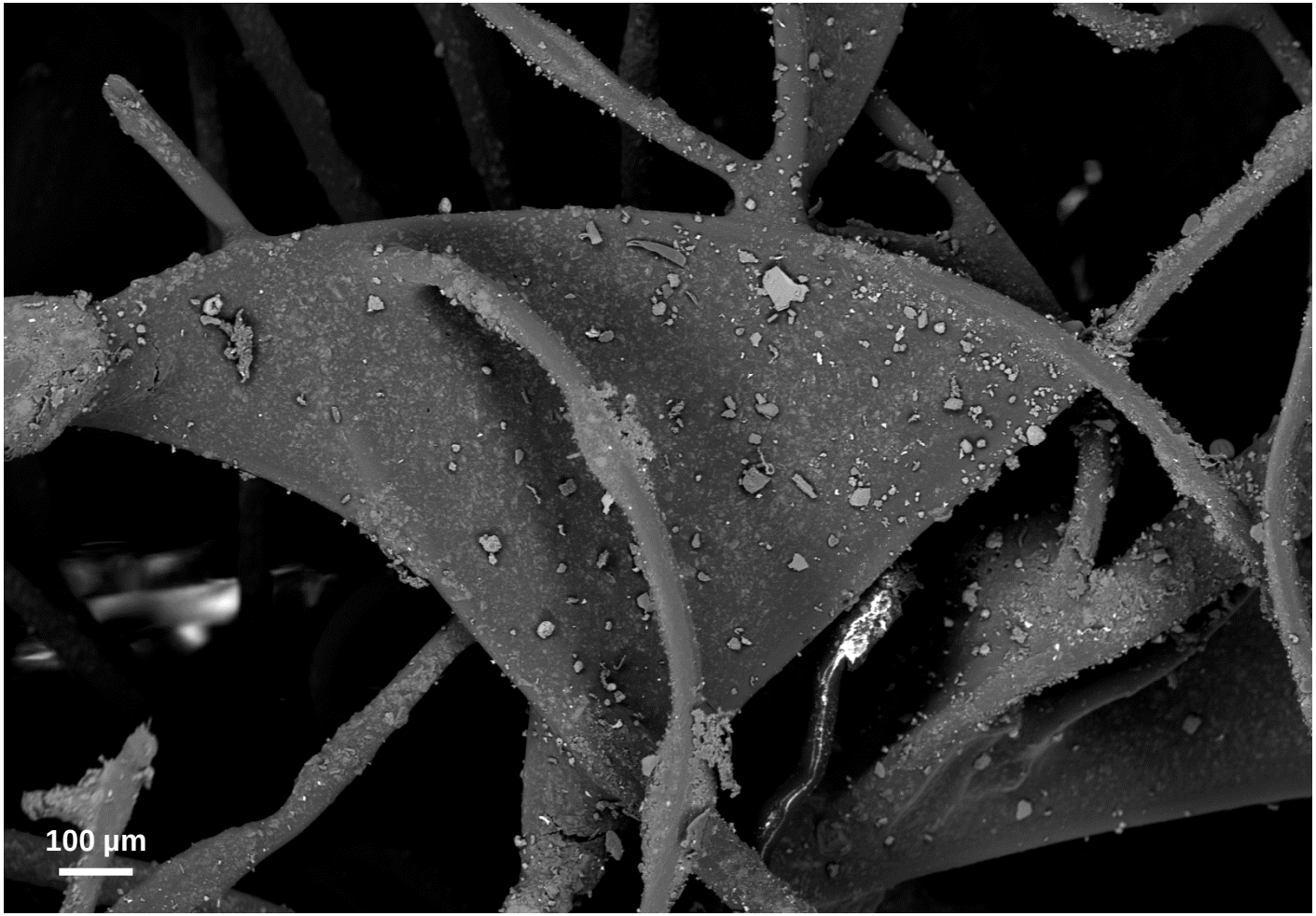




SEM/EDS Analysis

Diablo Canyon Sample # 170-004: Side, Insertion depth 11.0 ft

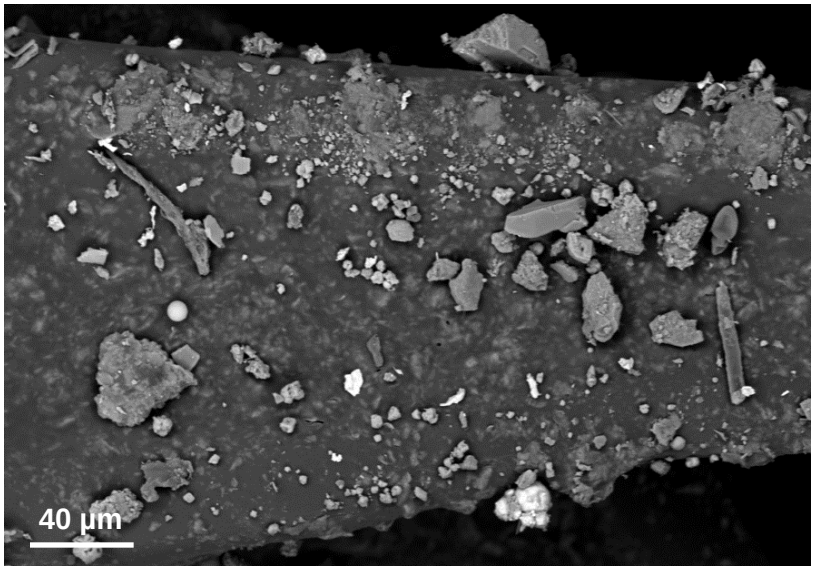
Moderate dust collected form the sides of the canisters.

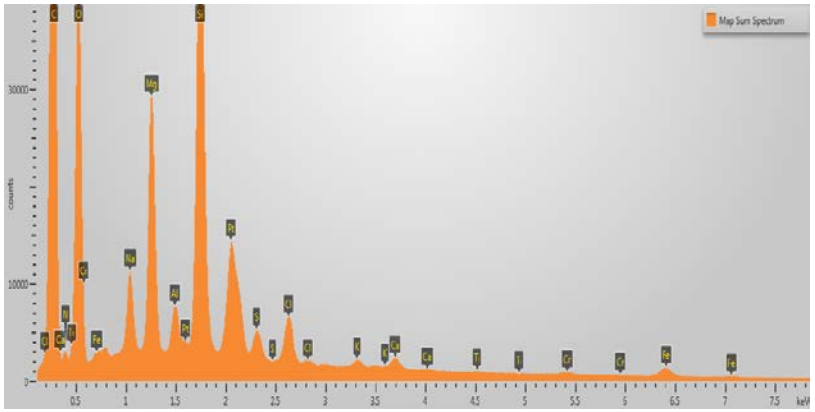


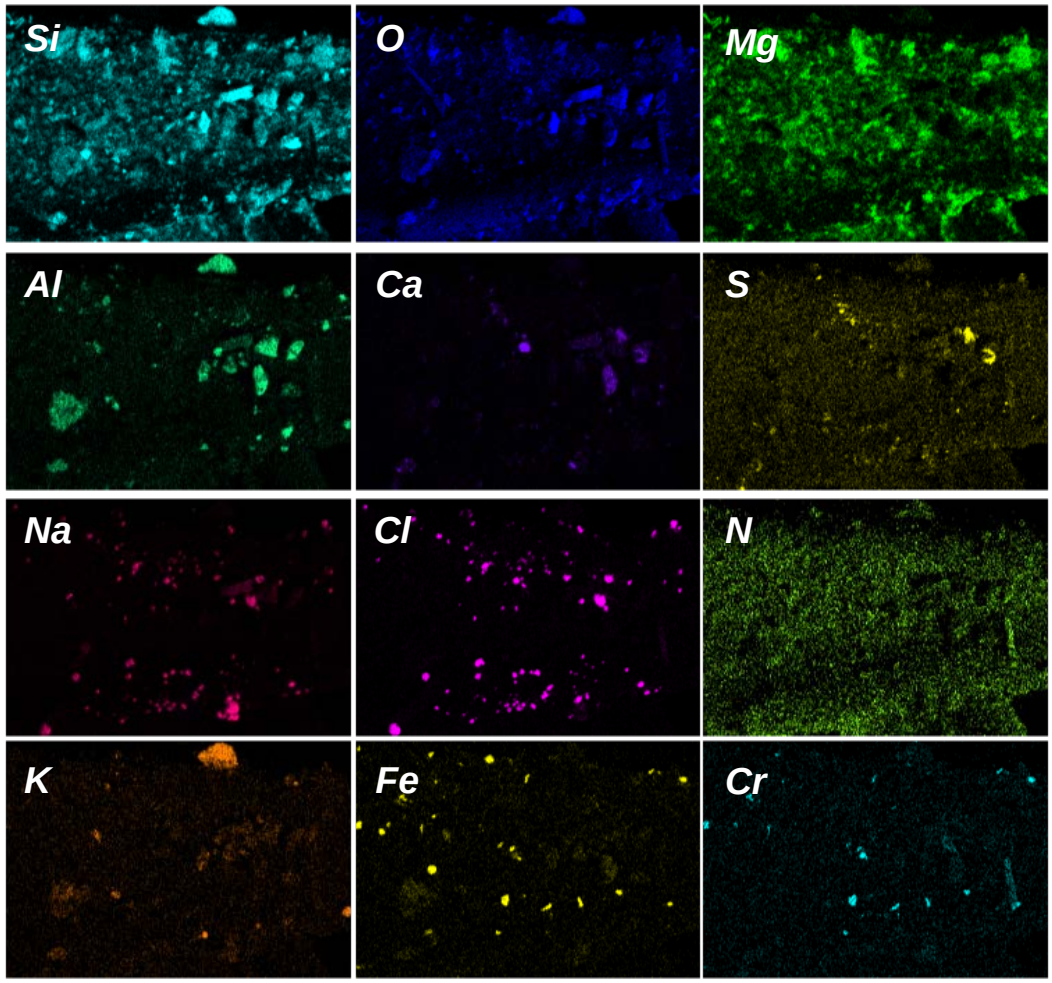
SEM/EDS Analysis

Diablo Canyon Sample # 170-004: Side, Insertion depth 11.0 ft

Abundant fine sea salt grains, aluminosilicates, and steel particles. Some Ca-sulfate.



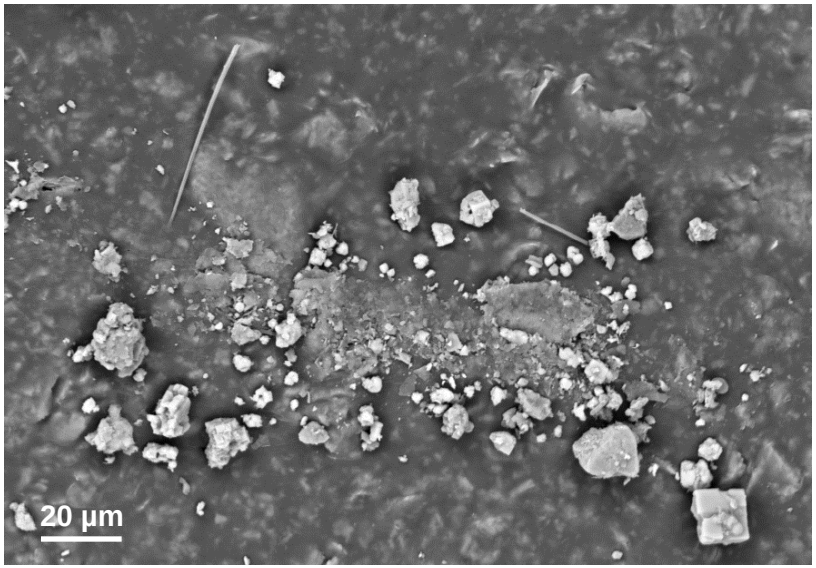


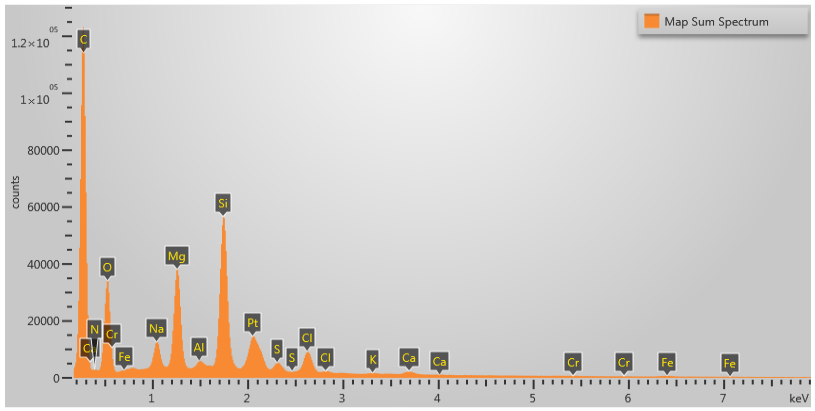


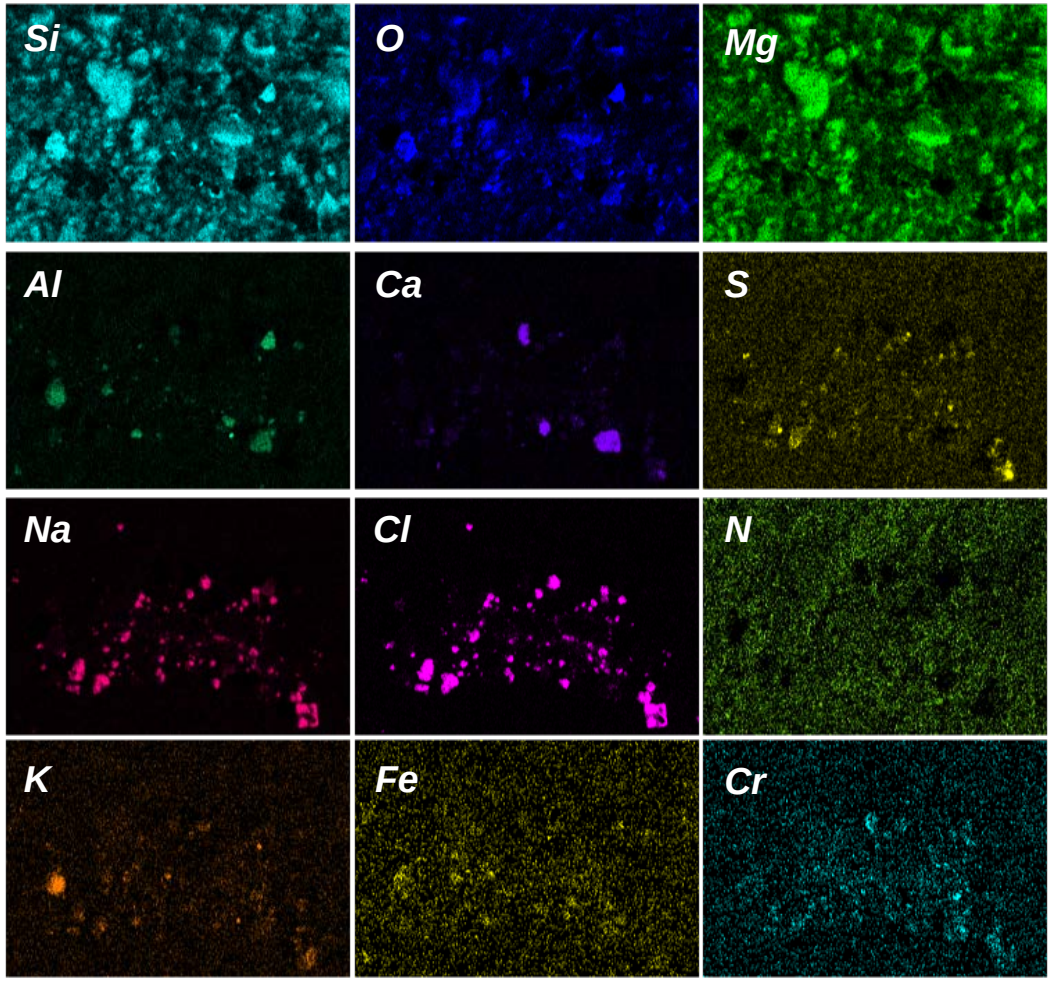
SEM/EDS Analysis

Diablo Canyon Sample # 170-004: Side, Insertion depth 11.0 ft

Abundant fine and coarse sea salt grains, aluminosilicates, and steel particles.



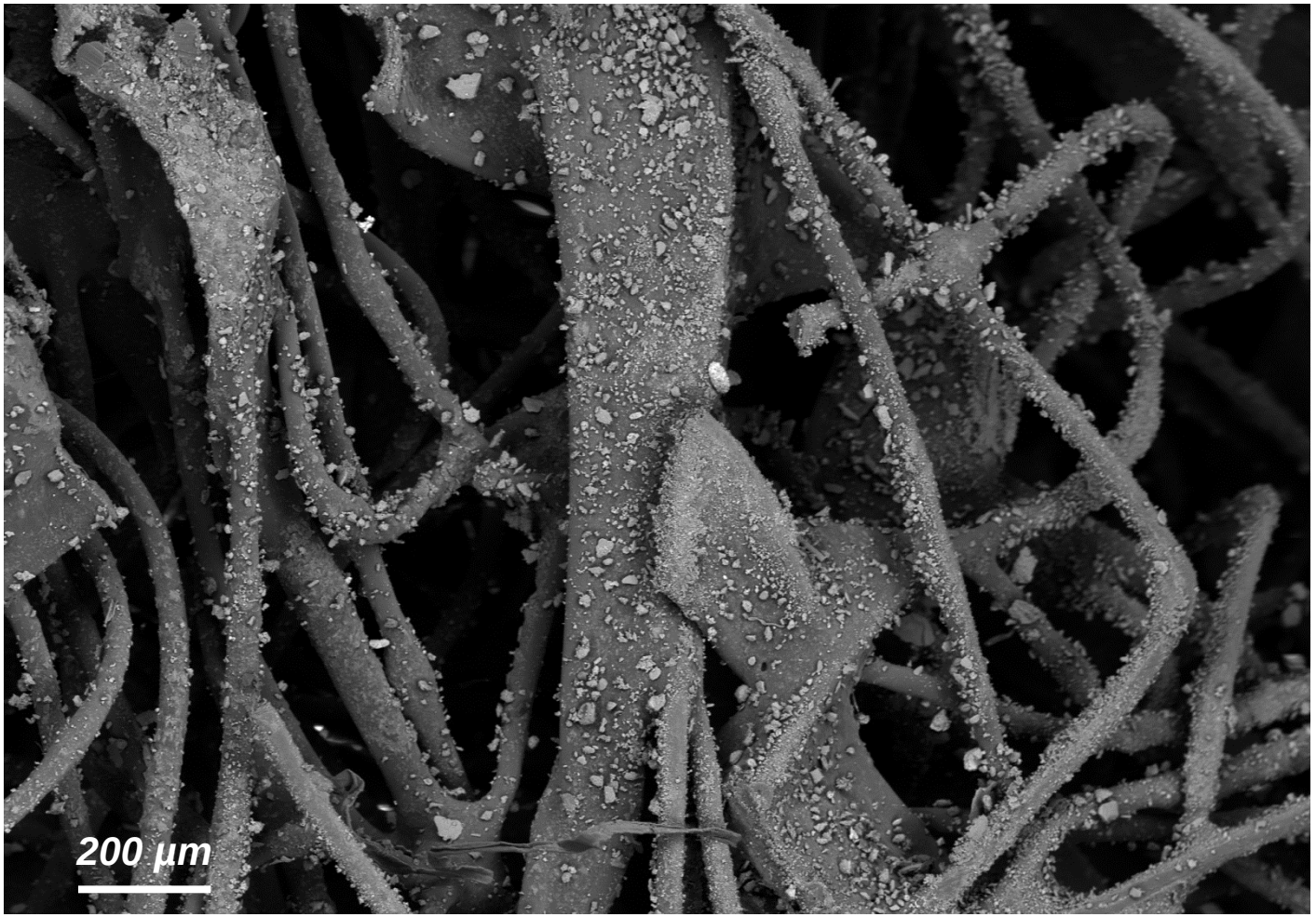




SEM/EDS Analysis

Diablo Canyon Sample # 170-003: Canister top

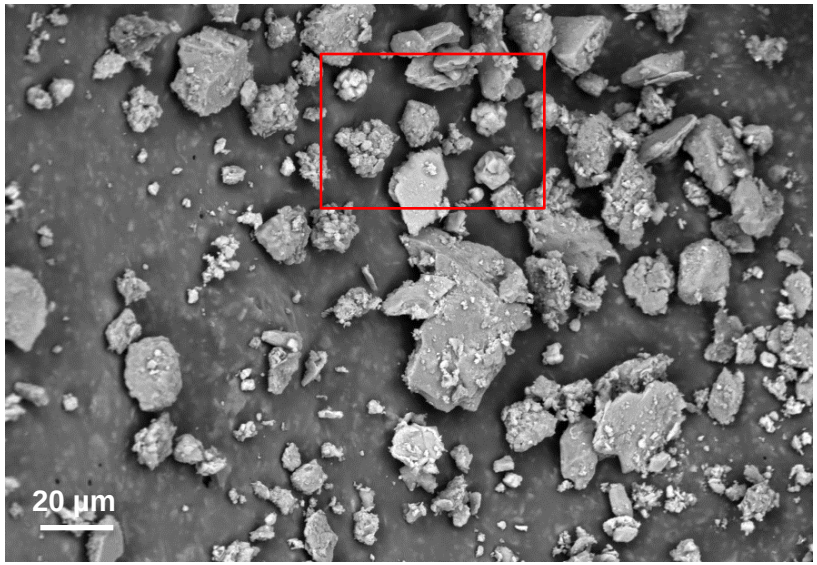
Heavy dust load collected from the top of the canisters.

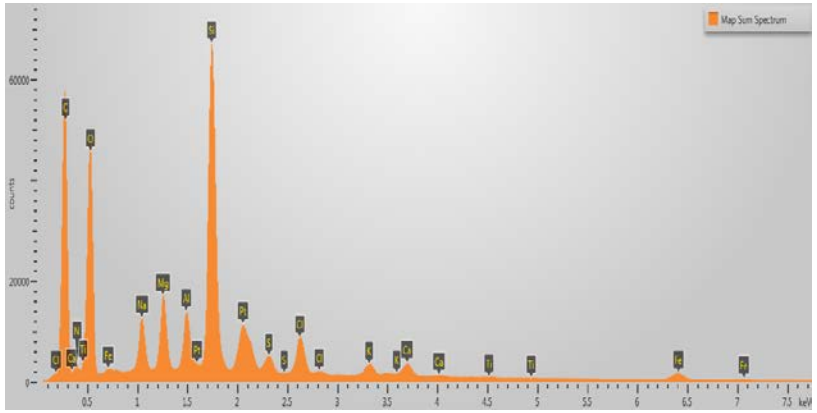


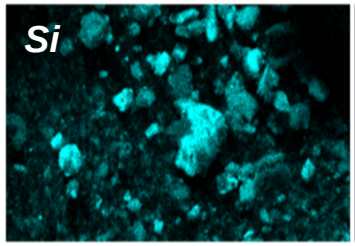
SEM/EDS Analysis

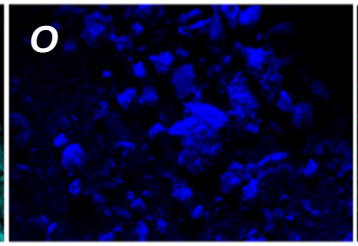
Diablo Canyon Sample # 170-004: Side, Insertion depth 11.0 ft

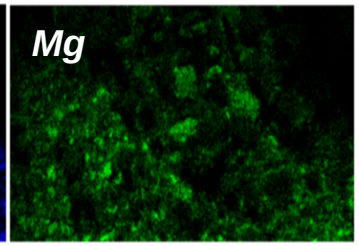
Abundant fine and coarse sea salt grains, aluminosilicates, and steel particles.

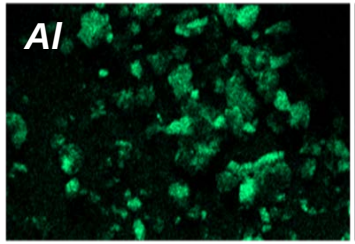


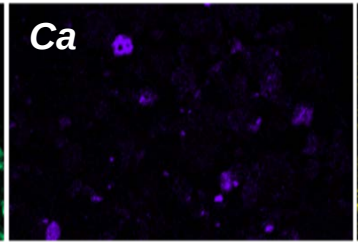


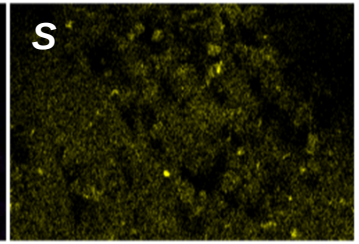


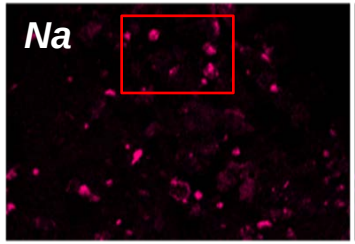


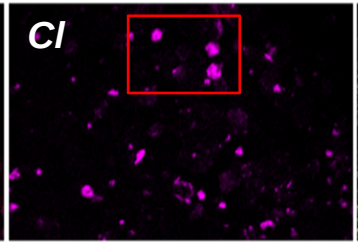


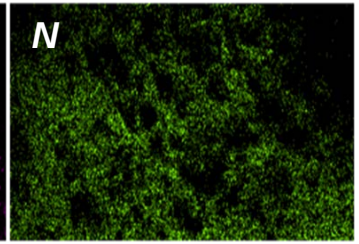


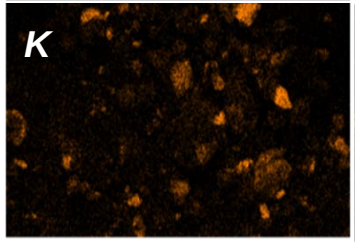


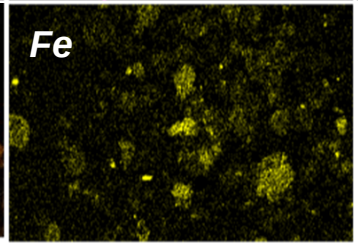








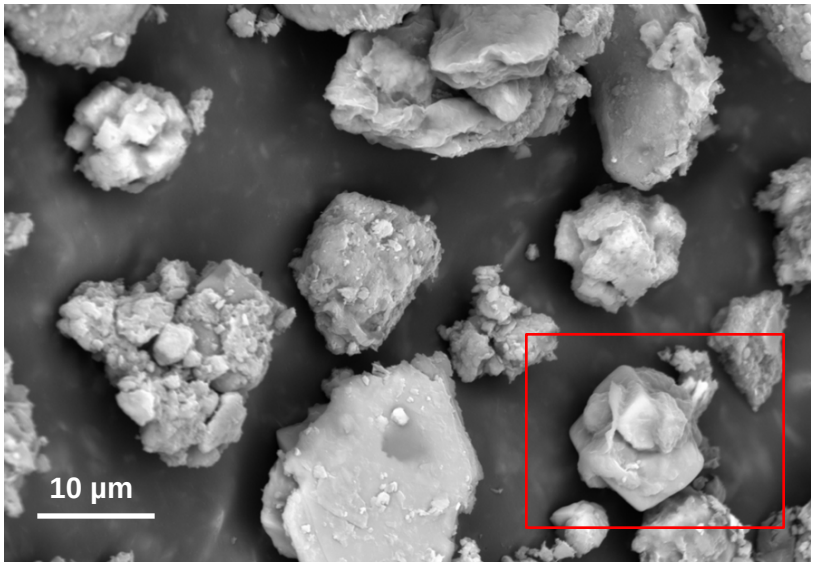


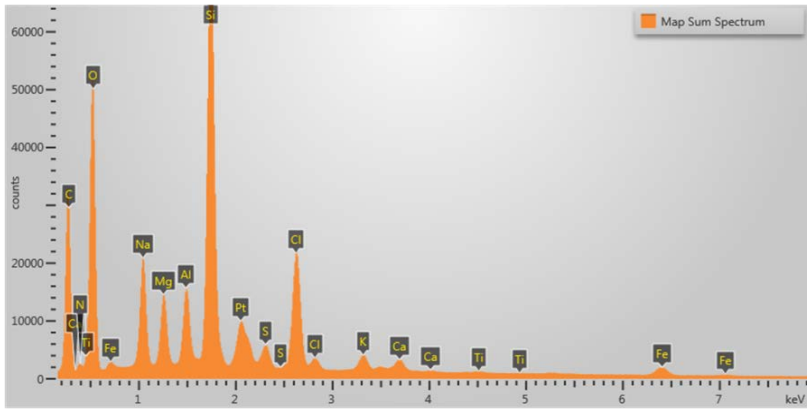


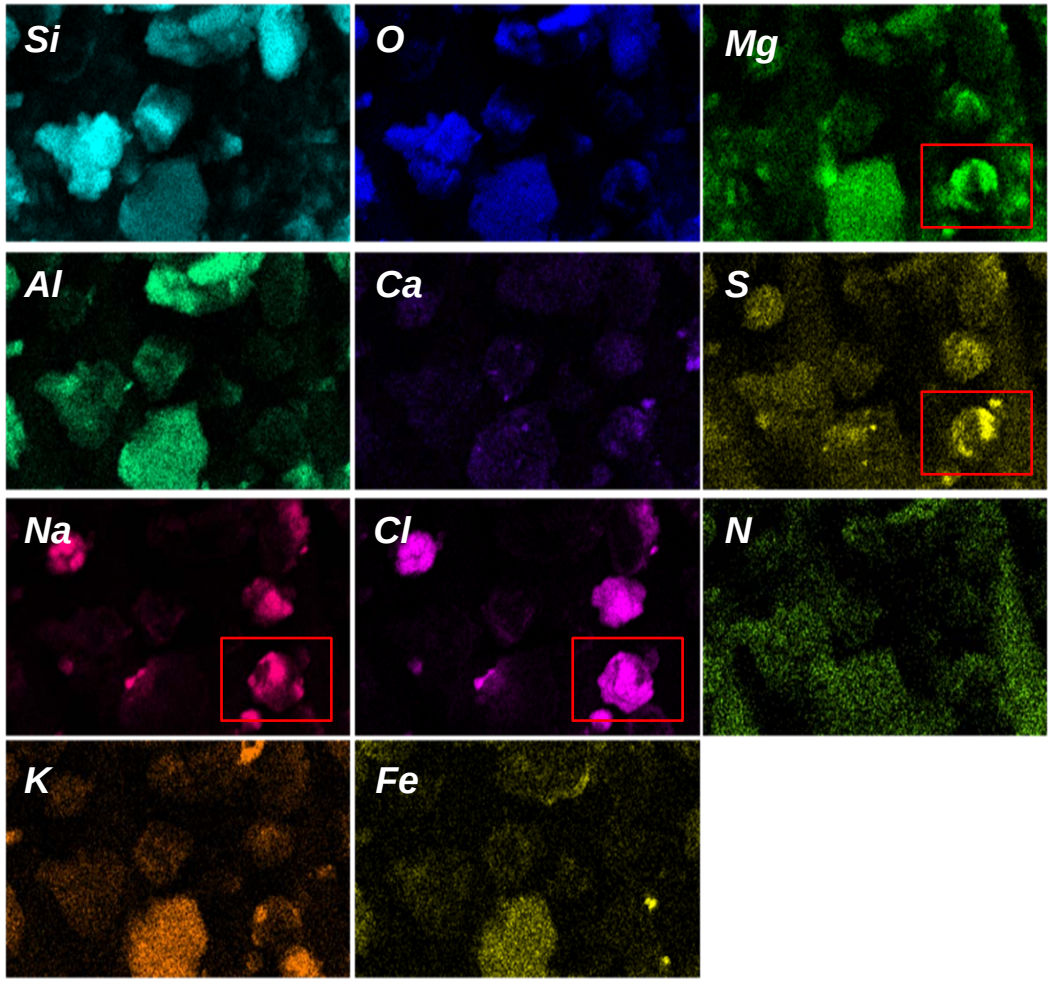
SEM/EDS Analysis

Diablo Canyon Sample # 170-004: Side, Insertion depth 11.0 ft

Abundant fine and coarse sea salt grains, aluminosilicates, and steel particles.



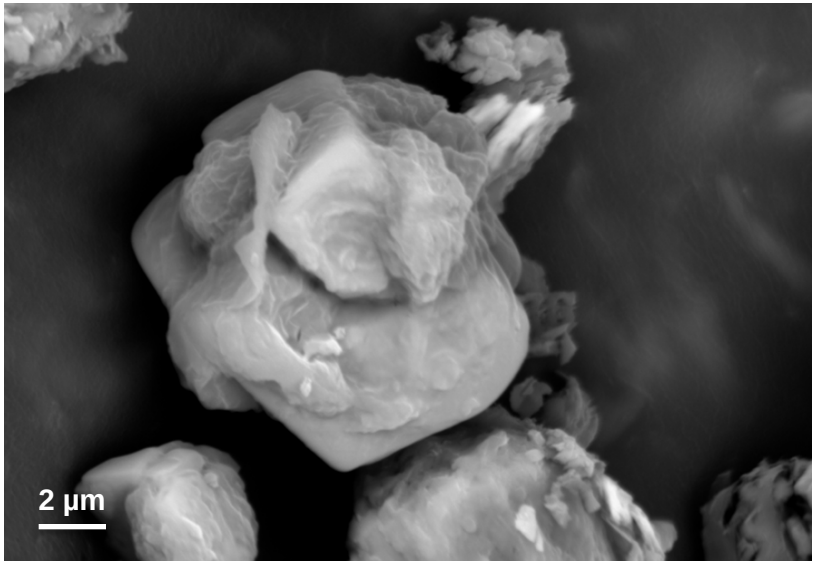


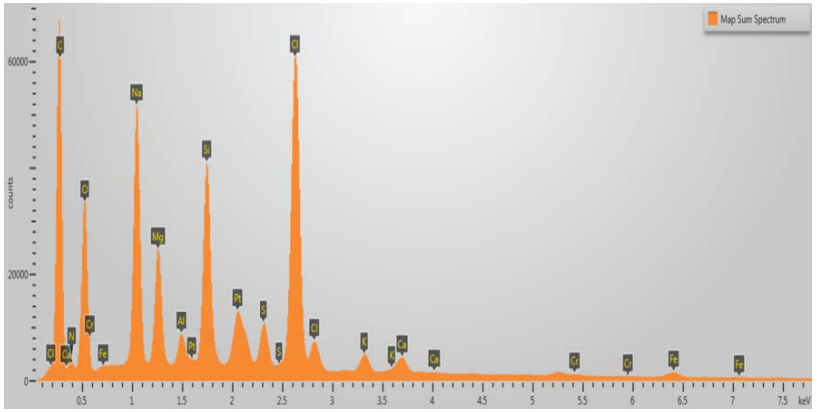


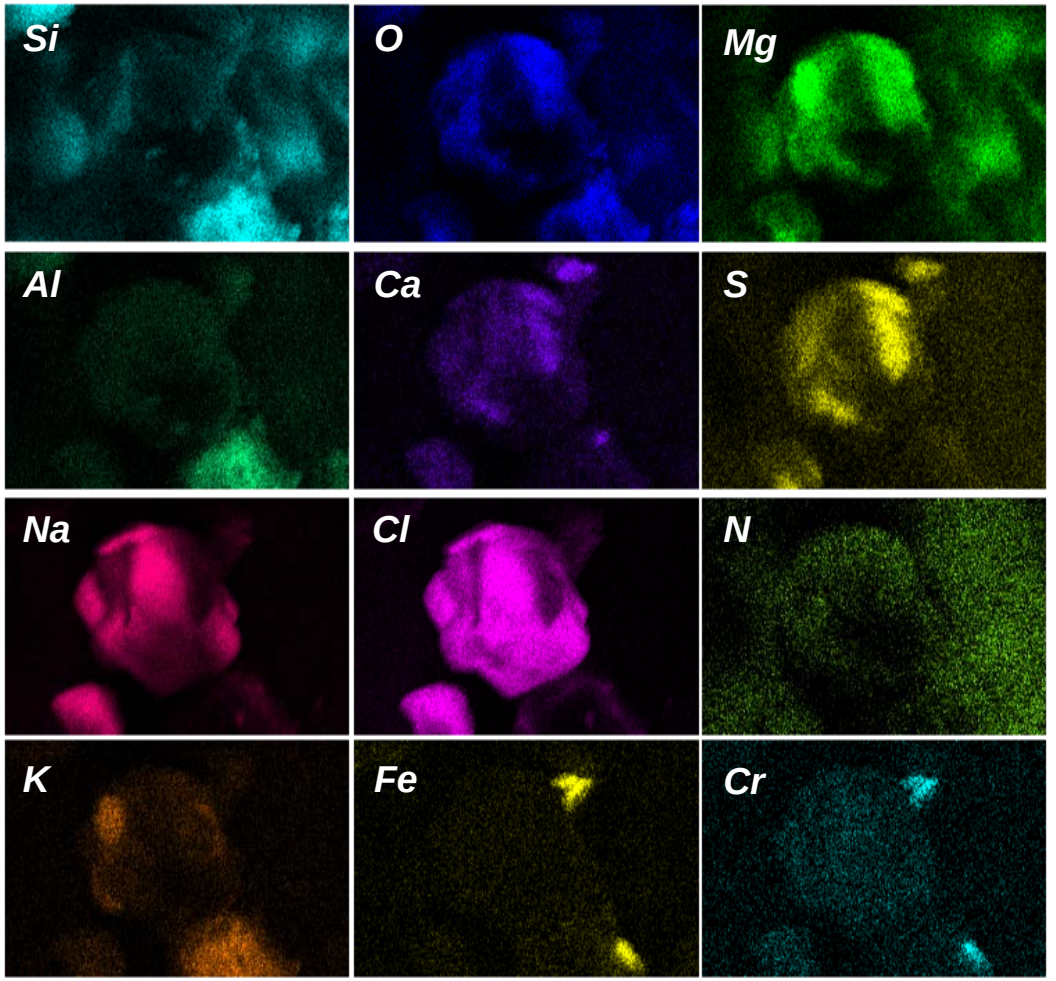
SEM/EDS Analysis

Diablo Canyon Sample # 170-004: Side, Insertion depth 11.0 ft

Abundant fine and coarse sea salt grains, aluminosilicates, and steel particles.







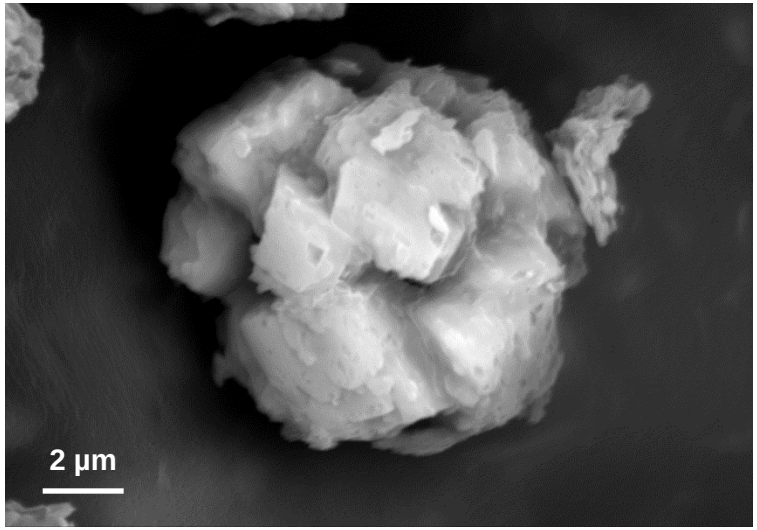
SEM/EDS Analysis

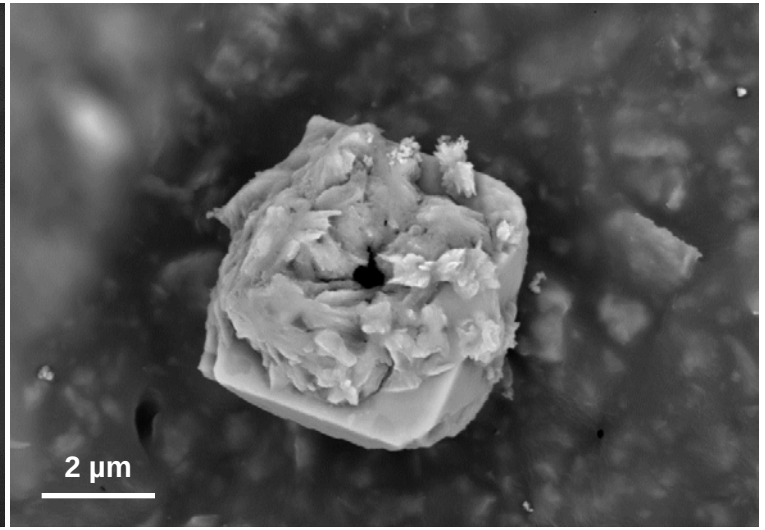
Diablo Canyon Sample # 170-003: Top center

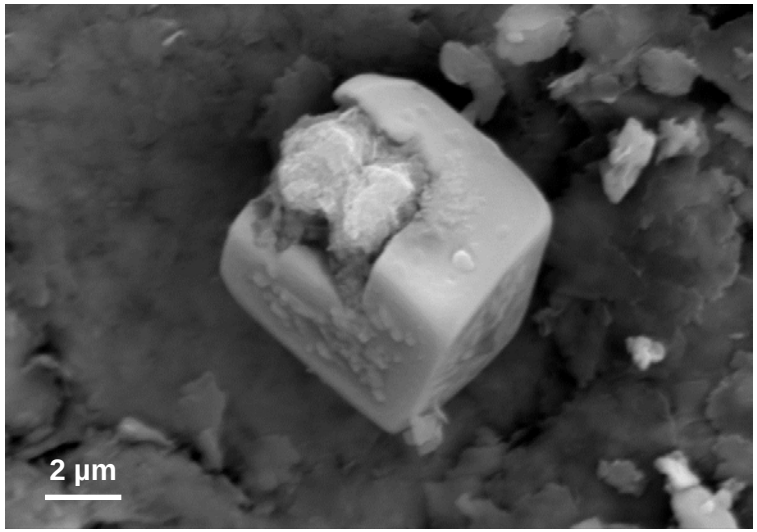
Clusters of sea salts. Dominant minerals are sodium chloride (cubic crystals), and Mg-sulfate (sheaf-like crystals and masses between cubes)

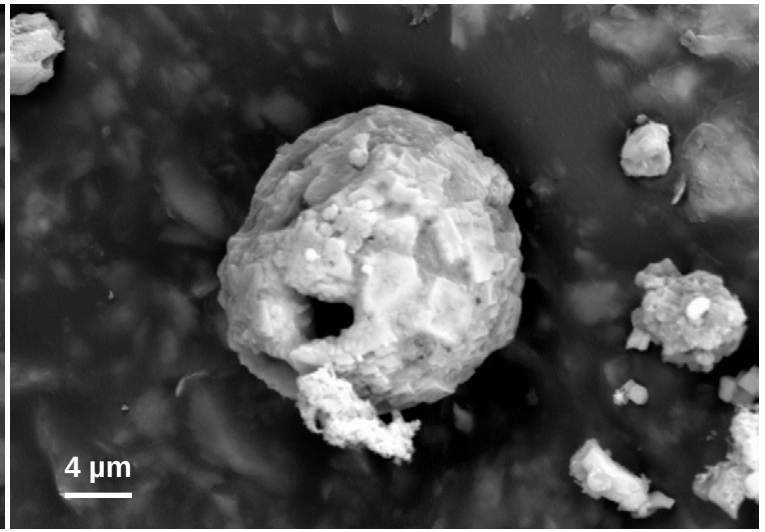
Common morphologies:

- ***Spherical aggregates (hollow)***
- ***Skeletal and hopper crystals***









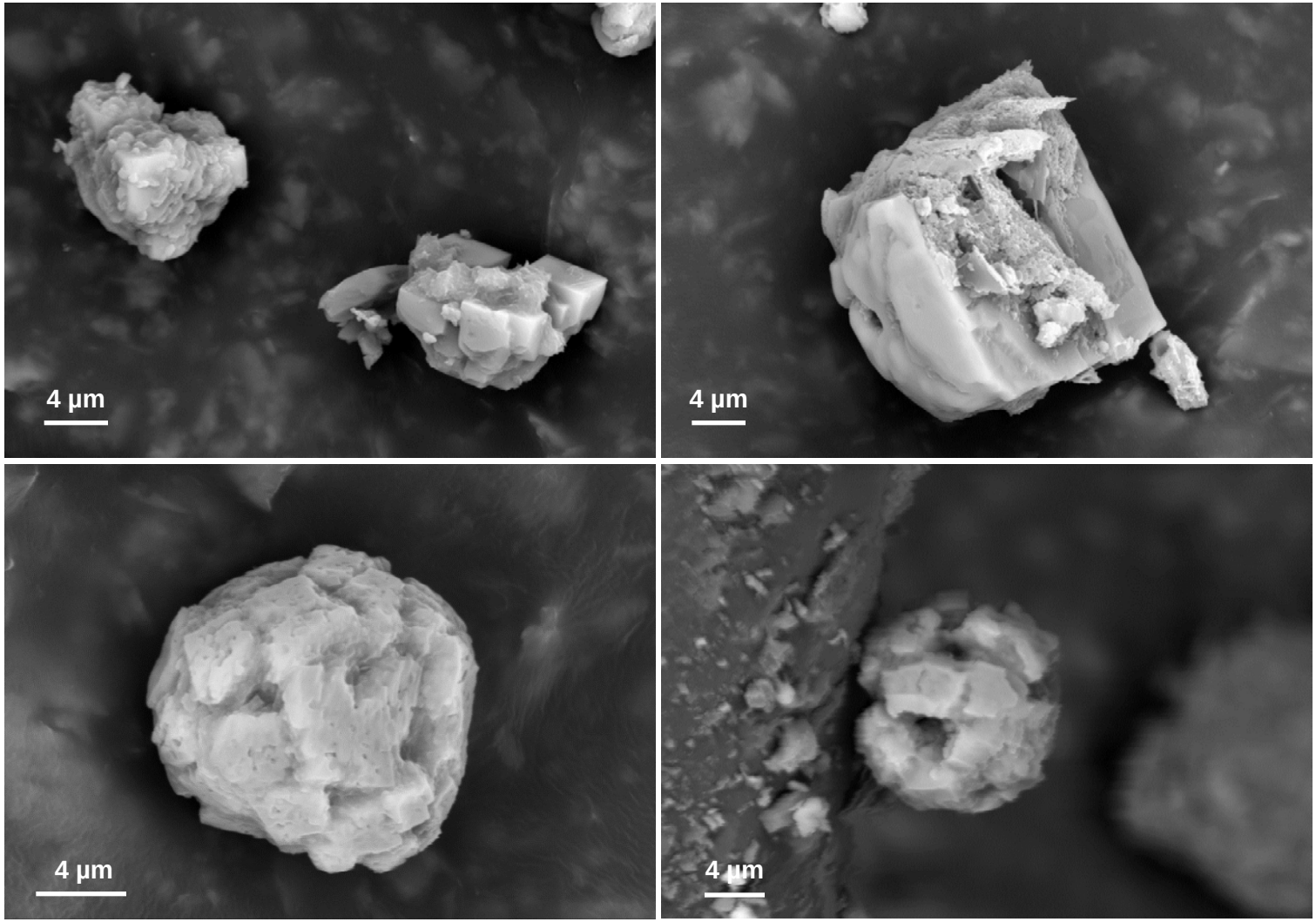
SEM/EDS Analysis

Diablo Canyon Sample # 170-003: Top center

Clusters of sea salts. Dominant minerals are sodium chloride (cubic crystals), and Mg-sulfate (sheaf-like crystals and masses between cubes)

Common morphologies:

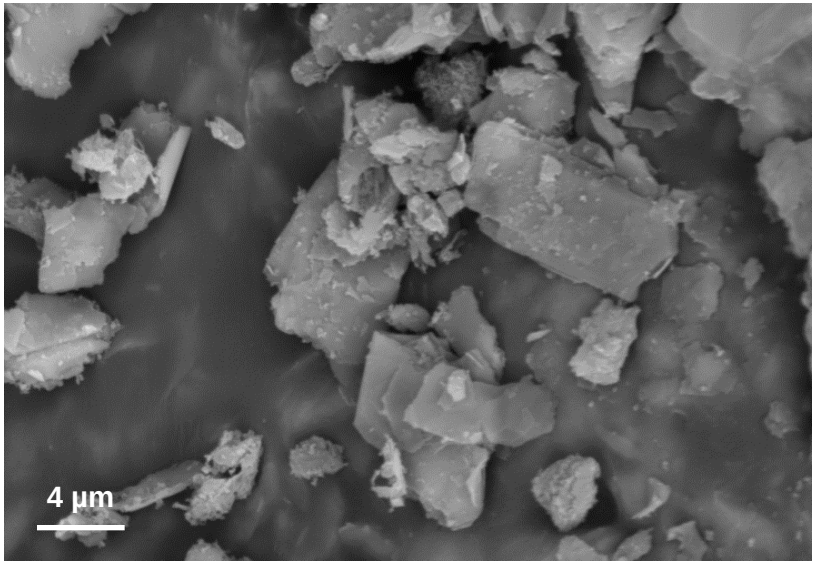
- ***Spherical aggregates (hollow)***
- ***Skeletal and hopper crystals***

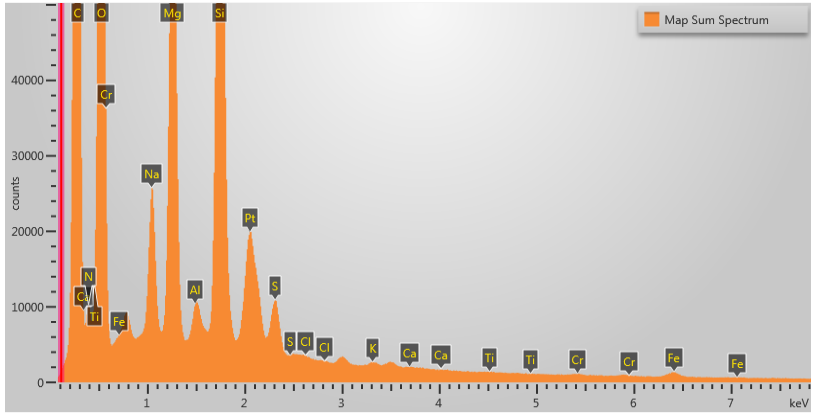


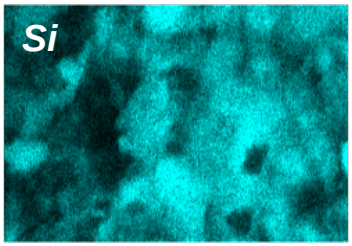
SEM/EDS Analysis

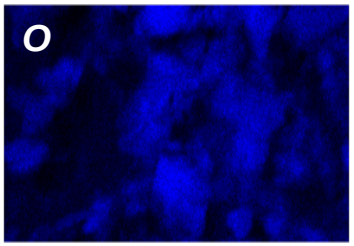
Diablo Canyon Sample # 123-009: Side, Insertion Depth 3.0 ft
Hottest Sample: 245ºF

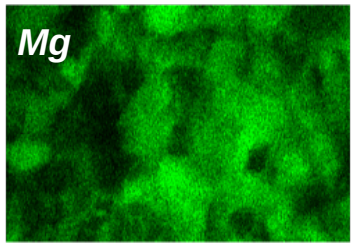
Only the hottest sample that was collected shows evidence of chloride particle conversion to nitrates: combined nitrate-chloride salts.

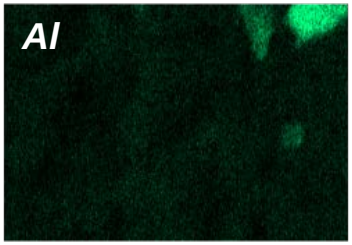


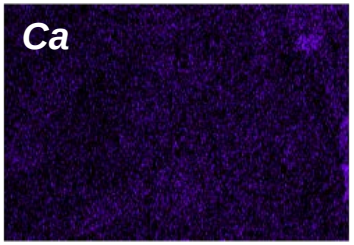


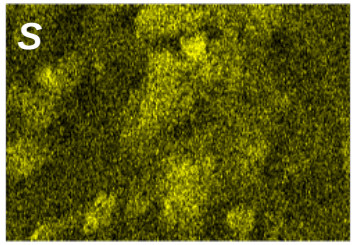


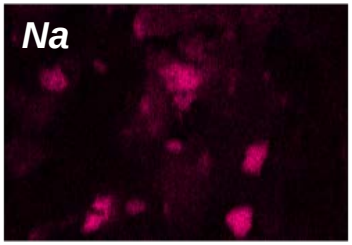


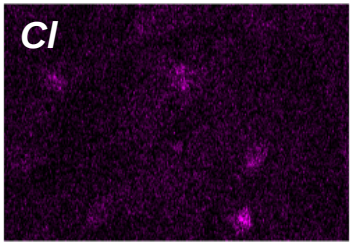


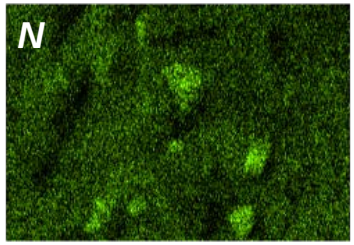


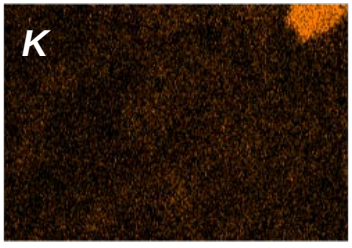


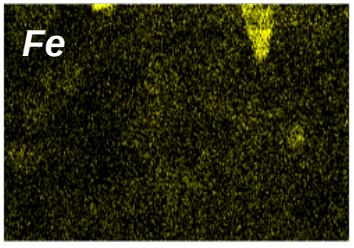


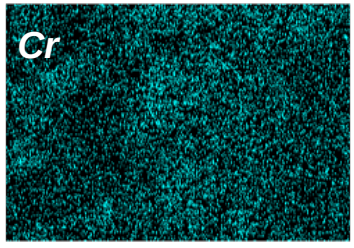










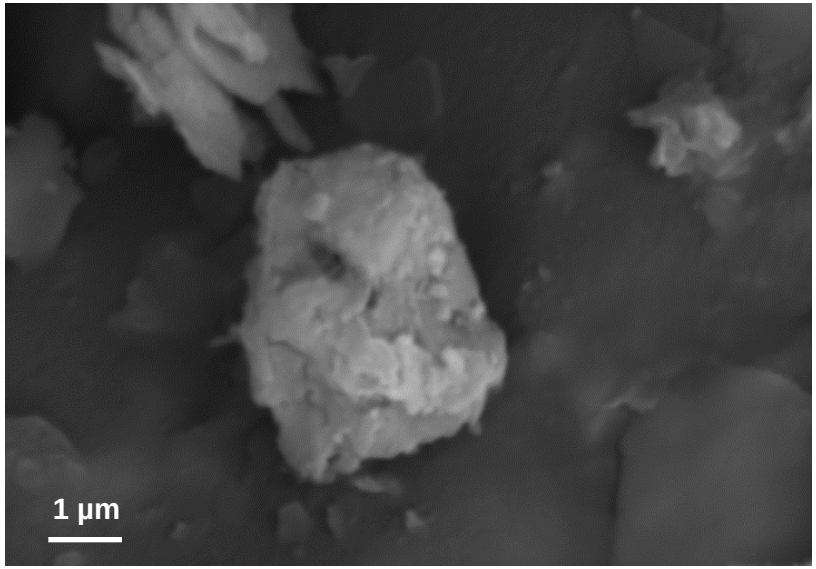


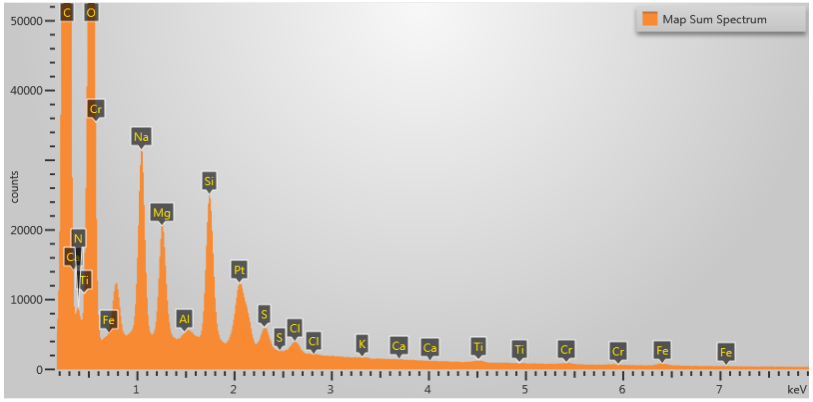
Used Fuel Disposition

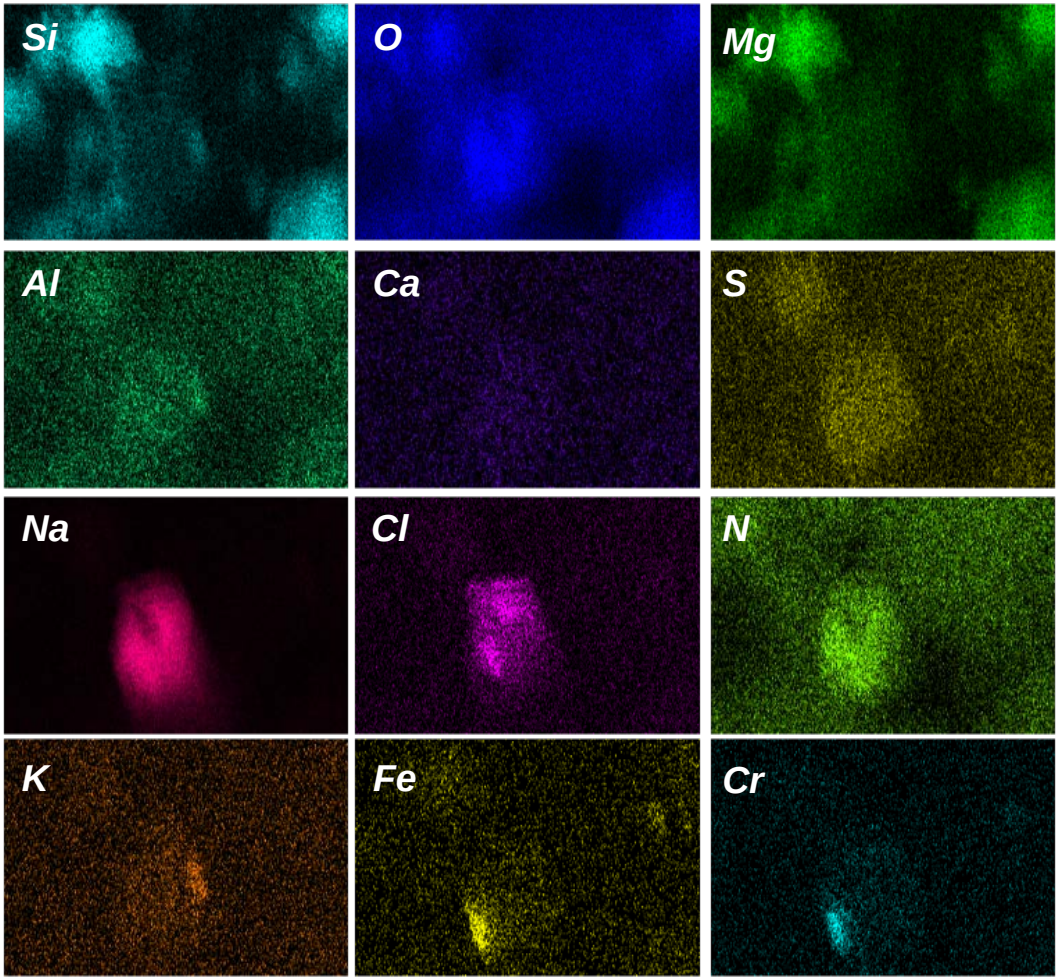
SEM/EDS Analysis

Diablo Canyon Sample # 123-009: Side, Insertion Depth 3.0 ft Hottest Sample: 245ºF

Only the hottest sample that was collected shows evidence of chloride particle conversion to nitrates: combined nitrate-chloride salts.



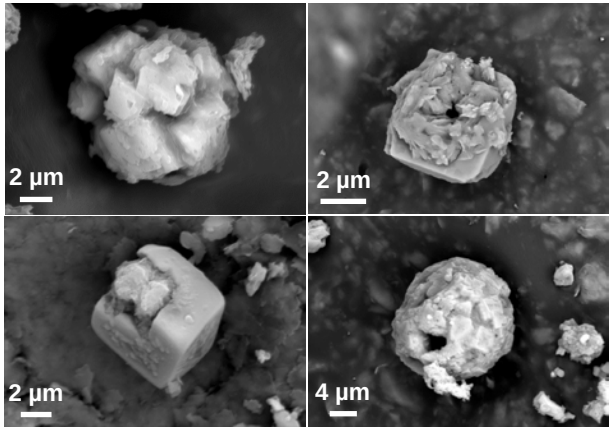




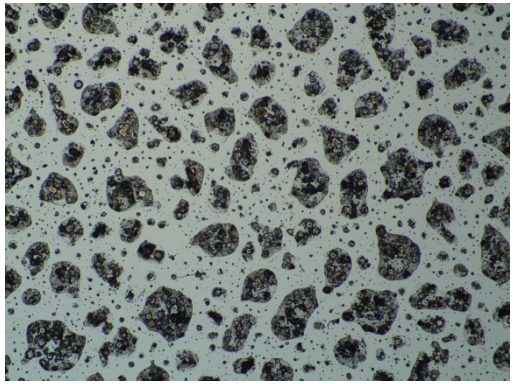
Implications

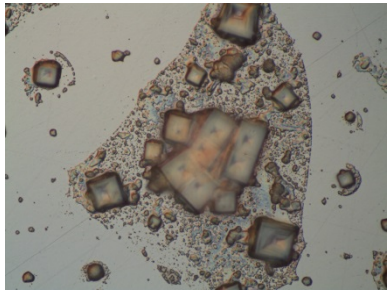
Does salt deposition process affect the results of experiments evaluating corrosion of 304SS SNF storage canisters?

Salts on waste package surface:

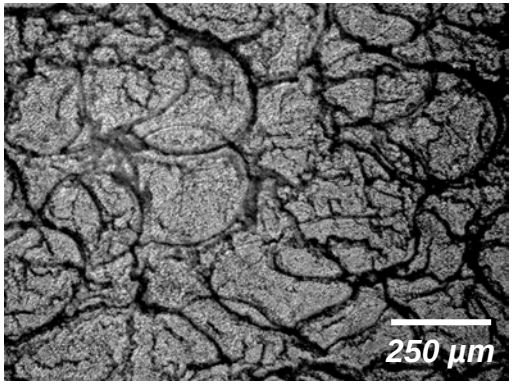


Aqueous solution deposited by airbrush:





Salts in ethanol deposited by airbrush.



120 µg/cm^2

Used Fuel Disposition

Chemistry: Hope Creek Salt-smarts®

Dominant ions

Sample	Loc.	Depth, ft	Temp, °F	Amount present, µg/sample										SUM
				K	Ca	Mg	Na	NH_4^+	F^-	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}	
144-008	Side	13.0	93.2	*0.8*	3.4	0.6	*0.1*	2.7		0.9	2.7		4.1	15.4
144-009	Side	7.5	116.5	1.7	4.5	0.5	*0.1*	2.7		0.9	6.4	*1.1*	6.5	24.3
144-010	Side	1.0	133.9	1.4	4.2	0.4	*0.4*	2.4		1.2	5.0		4.4	19.4
144-013	Top	0.0	138	18	102	33	42	2.8	0.4	4.2	19	4.8	91	317
144-014	Top	0.0	141.2	6.4	29	8.0	13.4	2.7	0.4	18	7.3	*1.3*	55	142
144-003				*0.6*	2.2	0.4		1.4		*0.5*	3.3	1.2	2.1	11.6
144-004				*0.3*	3.2	0.6		2.9		0.8	1.8	*0.5*	1.7	11.8
145-006*	Side	13.0	70.6	2.2	4.4	0.6	*0.5*	2.3		2.2	8.1		4.7	25.1
145-007	Side	7.5	100.8	1.0	2.4	0.6	*0.7*	2.9		2.1	2.2	*0.7*	5.3	17.9
145-014	Side	1.0	130.3	*0.9*	3.2	0.8	*0.6*	3.2		1.2	2.5		9.1	21.5
145-013**	Top	0.0	174.1	15	91	30	32	2.8		2.2	15	3.5	82	273
145-011**				*0.2*	2.3	0.3		3.0		*0.7*	1.3		1.7	9.6
145-002				1.2	4.8	0.5		2.7		*0.7*	5.9	*0.8*	2.0	18.5
SS-Bl-8 min-1					1.3	0.2		1.1		*0.4*	1.6		*0.6*	5.1
SS-Bl-8 min-2					1.2	0.2		1.5		*0.7*	*0.9*	*0.5*	*0.2*	5.2
SS-Bl-15 min					1.5	0.5		5.7	0.2	*0.7*	1.1	1.6	1.7	12.9

* Pad only damp

** Pad only partially saturated

>10 µg/sample

Used Fuel Disposition

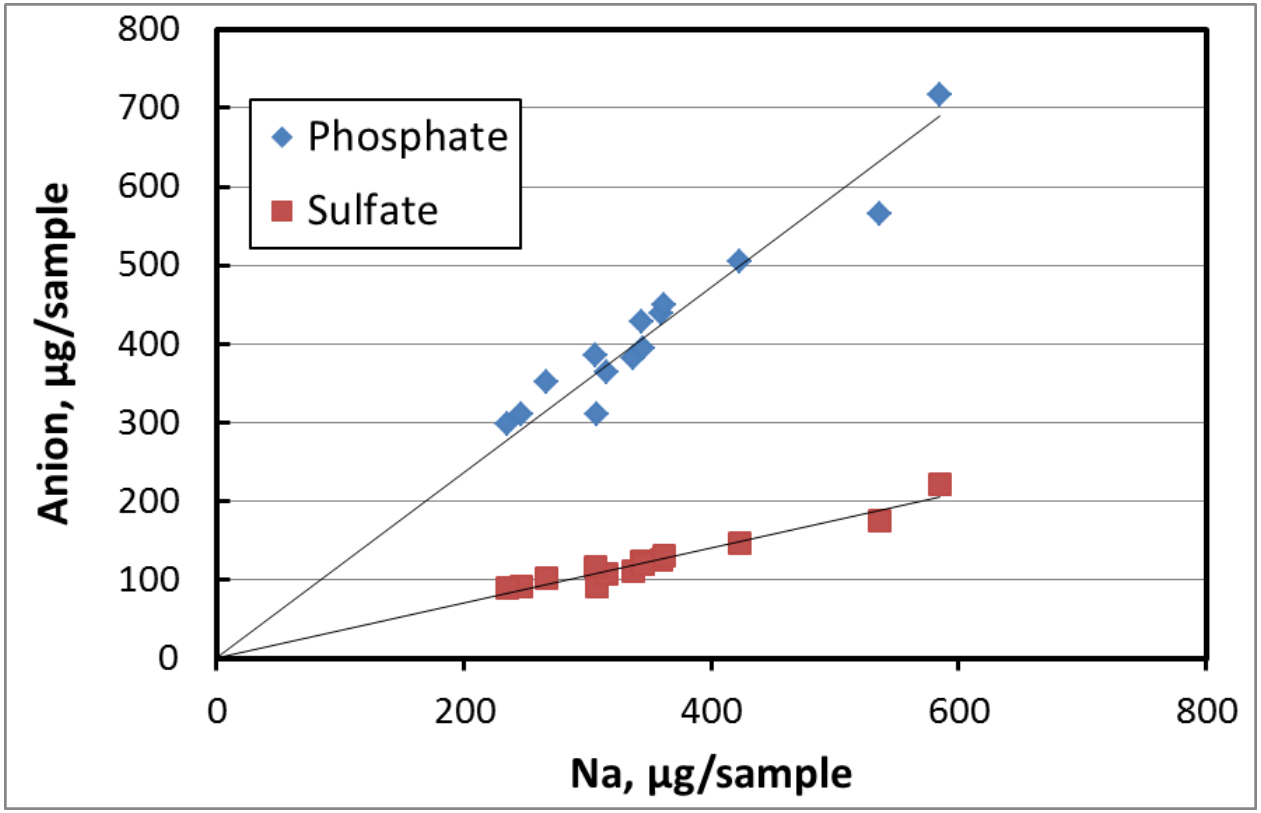
Chemistry: Hope Creek Dry Pads

Sample	Loc.	Depth, ft	Temp ºF	Concentration, µg/sample								
				Na^+	K^+	Ca^{2+}	Mg^{2+}	F^-	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}
144-005	Side	13.5	84.1	337	6.5	0.2	0.8	0.1	5.3	5.5	382	111
144-006	Side	8.5	89.6	308	5.6	0.3	0.8	0.0	5.4	4.9	311	91
144-007	Side	1.0	126.4	315	5.1	0.2	0.7	0.0	5.0	5.5	364	107
144-011	Top	0.0	132.6	536	11.6	1.5	2.3	0.1	8.6	10.7	565	175
144-012	Top	0.0	141.2	423	7.1	1.5	1.9	0.1	6.6	4.2	505	146
144-001				306	6.4	0.5	1.0	0.0	8.3	11.8	386	117
144-002				323	5.6	0.7	0.8	n.d.	n.d.	n.d.	n.d.	n.d.
145-003	Side	13.5	70.9	343	5.8	0.2	0.9	0.0	4.3	5.7	429	123
145-004	Side	8.5	93.3	359	6.0	0.2	1.1	0.0	7.8	6.8	439	125
145-005	Side	1.5	122.5	345	6.5	0.2	0.9	0.1	5.3	9.6	394	121
145-012	Top	0.0	172.1	585	11.4	1.2	2.6	0.1	7.9	8.4	716	222
145-001				362	7.5	0.2	0.9	n.a.	6.1	5.8	449	130
Pad Bl #1				247	3.1	0.1	0.4	0.0	2.2	2.6	310	91
Pad Bl #2				267	2.7	0.1	0.6	0.1	2.2	1.3	352	102
Pad Bl #3				235	2.4	0.1	0.3	0.1	1.9	1.5	298	89

Unfortunately, pads leach copious amounts of Na^+, PO_4^{3-}, and SO_4^{2-}. Can excess Na^+ or SO_4^{2-} from the adhering dust be detected? Note that blanks leach less than the other samples, but the blank pad masses are lighter than other samples.

Chemistry: Hope Creek Dry Pads

The linear relationships between Na^+, PO_4^{3-}, and SO^{4-} show that the contribution leaching from the pad overwhelms any contribution from adhering dust.



Used Fuel Disposition

Chemistry: Diablo Canyon Salt-smarts®

Sample	Location	Depth, ft	Temp, °F	Concentration, µg/sample									Sum, µg/sample
				Na^+	K^+	Ca^{2+}	Mg^{2+}	F^-	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}	
123-003	Side	14.0	119.7	*0.3*	0.6	2.4	0.6	0.3	1.2	1.5	0.4	4.3	11.6
123-004	Side	11.5	173.4	*0.2*	1.2	2.6	0.4	0.1	0.9	3.7	0.1	2.1	11.4
123-005*	Side	10.5	187.0	n.a.	0.3	3.6	0.2	0.3	0.5	0.6	0.5	1.4	7.2
123-002	—	—	—	14.4	0.9	6.0	0.9	0.9	14.1	11.3	n.a.	10.4	58.8
123-010	—	—	—	3.3	1.9	2.2	0.5	1.0	6.2	1.3	0.8	1.6	18.8
170-007*	Side	10.5	177.5	1.0	0.3	2.0	0.3	0.3	1.0	1.9	n.a.	1.4	8.2
170-008*	Side	9.5	182.8	0.2	0.5	2.4	0.2	0.3	0.7	2.3	0.6	0.6	7.9
170-009*	Side	9.0	188.2	0.3	2.3	3.2	0.2	0.2	0.6	9.3	0.6	0.9	17.7
170-002	—	—	—	7.3	1.3	5.9	1.3	0.2	3.2	21.0	0.8	6.2	47.3
B1-6	—	—	—	0.7	0.9	1.8	0.2	0.1	1.0	—	0.7	0.4	8.8
B1-8(1)	—	—	—	n.a.	0.2	1.0	0.1	0.4	0.3	0.2	0.3	0.2	2.8
B1-10	—	—	—	n.a.	0.3	1.3	0.2	0.3	0.6	1.9	0.8	0.3	5.6
B1-12	—	—	—	0.3	0.8	1.1	0.2	0.2	0.9	1.8	0.7	0.3	6.3
B1-14	—	—	—	n.a.	0.1	0.9	0.1	0.3	0.4	0.7	1.0	0.2	3.7
B1-8(2)	—	—	—	n.a.	0.2	1.2	0.2	0.3	0.3	1.0	n.a.	0.4	3.7

* *Wick adhered to silicon pressure pad, and/or reservoir pad was only partially saturated*

Significantly above blanks

Used Fuel Disposition

Chemistry: *Diablo Canyon Dry Pads*

Sample				Concentration, µg/sample								
	Loc.	Depth, ft	Temp, °F	Na^+	K^+	Ca^{2+}	Mg^{2+}	F^-	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}
Pad Bl #1	—	—	—	247	3.1	0.1	0.4	0.0	2.2	2.6	310	91
Pad Bl #2	—	—	—	267	2.7	0.1	0.6	0.1	2.2	1.3	352	102
Pad Bl #3	—	—	—	235	2.4	0.1	0.3	0.1	1.9	1.5	298	89
123-006	Side	11.0	177.2	439	7.7	0.2	1.3	0.2	9.4	9.3	535	158
123-008	Side	7.5	211.7	519	8.8	0.3	1.4	0.2	10.4	9.1	619	171
123-009	Side	3.0	245.5	518	8.6	0.7	1.8	0.2	12.9	9.4	656	172
123-011	Top cntr	0.0	206.8	676	13.7	1.9	4.0	0.2	74	21	732	236
123-012	Top edge	0.0	204.0	638	15.3	1.3	3.3	0.2	79	17.4	693	217
123-001	—	—	—	485	7.5	0.2	1.3	0.1	16.7	11.3	579	173
123-007	—	—	—	478	9.0	0.2	1.4	0.2	11.4	9.1	581	168
170-003	Top cntr	0.0	187.6	710	12.7	0.8	3.5	0.2	67	11.5	818	253
170-004	Side	11.0	153.9	488	8.4	0.1	1.1	0.2	10.3	6.1	578	167
170-005	Side	7.5	193.8	619	10.0	0.5	2.2	0.3	8.2	8.0	758	226
170-006	Side	3.0	180.6	612	9.5	0.3	2.2	0.2	5.9	6.5	—	208
170-001	—	—	—	597	10.2	0.4	2.1	0.2	9.1	29	716	205

Chloride Surface Loads, Hope Creek and Diablo Canyon Saltsmart® Data

Diablo Canyon Saltsmarts®	
Sample	Cl, g/m^2
123-002	0.061
123-003	0.005
123-004	0.004
123-005	0.003
123-010	0.025
170-002	0.013
170-007	0.005
170-008	0.003
170-009	0.003
Bl-6 min	0.004
Bl-8 min-1	0.002
Bl-10 min	0.003
Bl-12 min	0.004
Bl-14 min	0.002
Bl-8 min-2	0.002

Hope Creek Saltsmarts®	
Sample	Cl, g/m^2
144-003	0.002
144-004	0.003
144-008	0.003
144-009	0.003
144-010	0.004
144-013	0.014
144-014	0.060
145-002	0.002
145-006	0.007
145-007	0.007
145-011	0.002
145-013	0.007
145-014	0.004
Bl-8 min-1	0.001
Bl-8 min-2	0.002
Bl-15 min	0.002

These are inconsistent with the chloride observed by XRF, or the high salt loads on the abrasive pads seem by SEM. It is unlikely that the Saltsmarts® worked properly on the hot Diablo Canyon canisters.

Summary

- ***Hope Creek: Saltsmart® data indicate that the dominant salt species are Ca and SO_4, with lesser amounts of Na, Mg, and NO_3, and very little Cl.***
- ***Diablo Canyon: Saltsmart® wet samplers have a limited working temperature range, which was exceeded at Diablo Canyon for many samples. Measured salt loads were very low, and inconsistent with SEM and XRF observations, and dry pad leachate data. Saltsmart® data are probably invalid at higher temperatures.***
- ***Scotchbrite® pads leached high measured concentrations of sodium, phosphate, and sulfate, affecting measured dust leachate compositions and limiting utility of the data. However, we can say:***
  - *Hope Creek pad leachates have very low soluble salt concentrations, and very low chloride.*
  - *Diablo Canyon pad leachates from canister top samples are where chloride-rich, consistent with SEM observations.*
- ***SEM data***
  - *Dusts on Hope Creek Canisters are largely insoluble minerals; salts are limited, and are salts are largely sulfate and nitrate-rich. NaCl was observed as rare isolated grains.*
  - *Dusts on Diablo Canyon Canisters, are sea-salt rich. Sea-salts are largely present as coarse (>2.5µm fraction) spherical aggregates or euhedral crystals of halite with associated Mg-sulfate, and lesser amounts of Ca and K. Smaller particles are also present.*
  - *Mixed chloride-nitrate grains (possibly indicating particle-gas conversion reactions) were only observed on the hottest Diablo Canyon sample, although etched NaCl grains were observed in several samples.*