Update of State of Nevada research on waste package environments in Yucca Mountain

By

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Are we doing a good job in defining the service environment?

The characterization of existing conditions addresses environmental conditions during the initial waste loading period.

Thus, a major constituent now in tunnel dust - rock flower (aluminum silicates) may not be a major constituent during and after the heat up period.

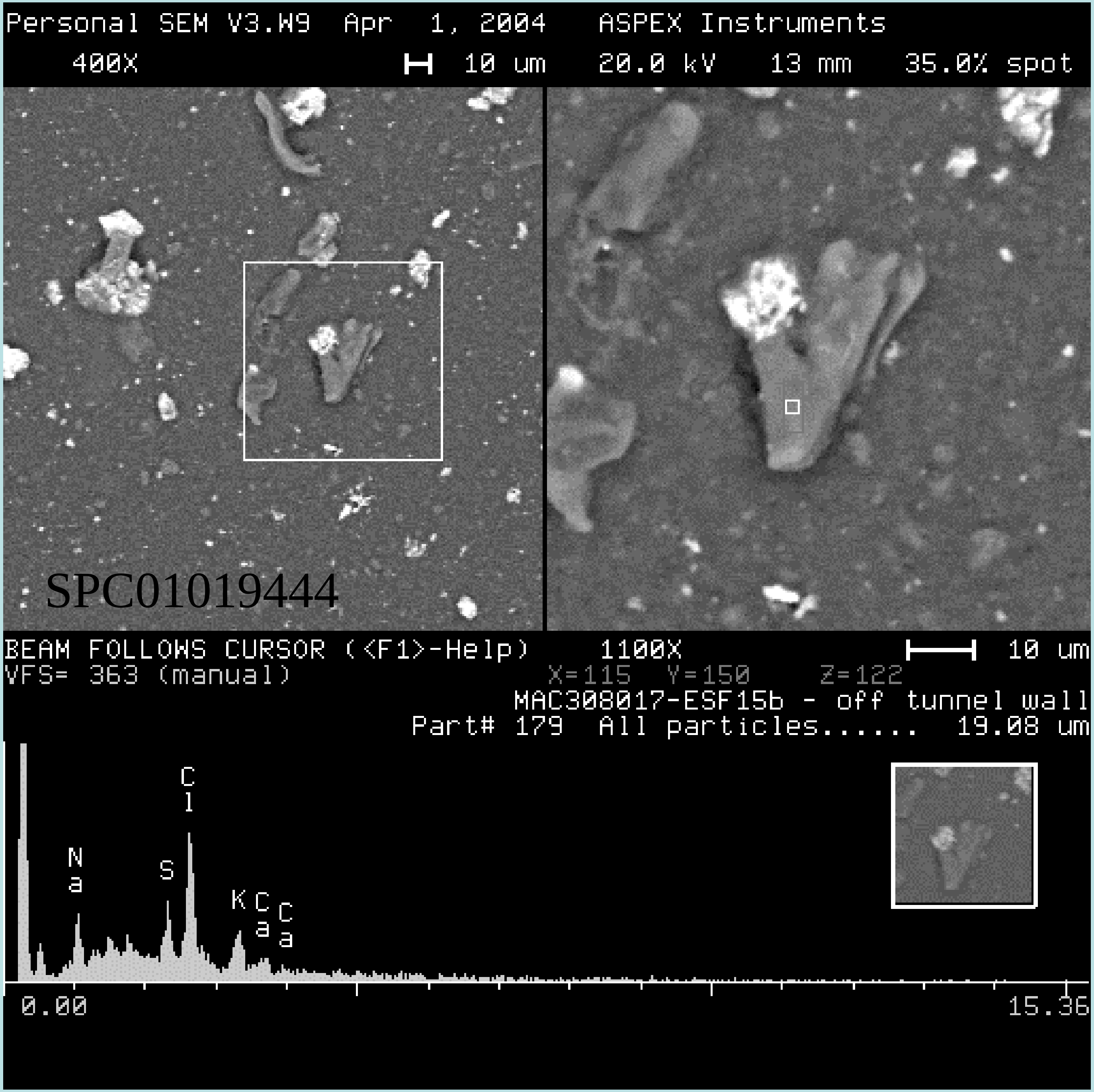
Vadose water seeping into the tunnels during the heat-up period through fracture flow and drip has the potential to form brine solutions.

With evaporation a variety of single and double salts can form.

With increasing raise in repository temperature these salts have the potential to become airborne dust.

When repository temperature falls and humidity rises salts present as rock flower coated-dust particles or as salt dust may deliquesce and form brine solutions that have the potential to corrode the waste package.

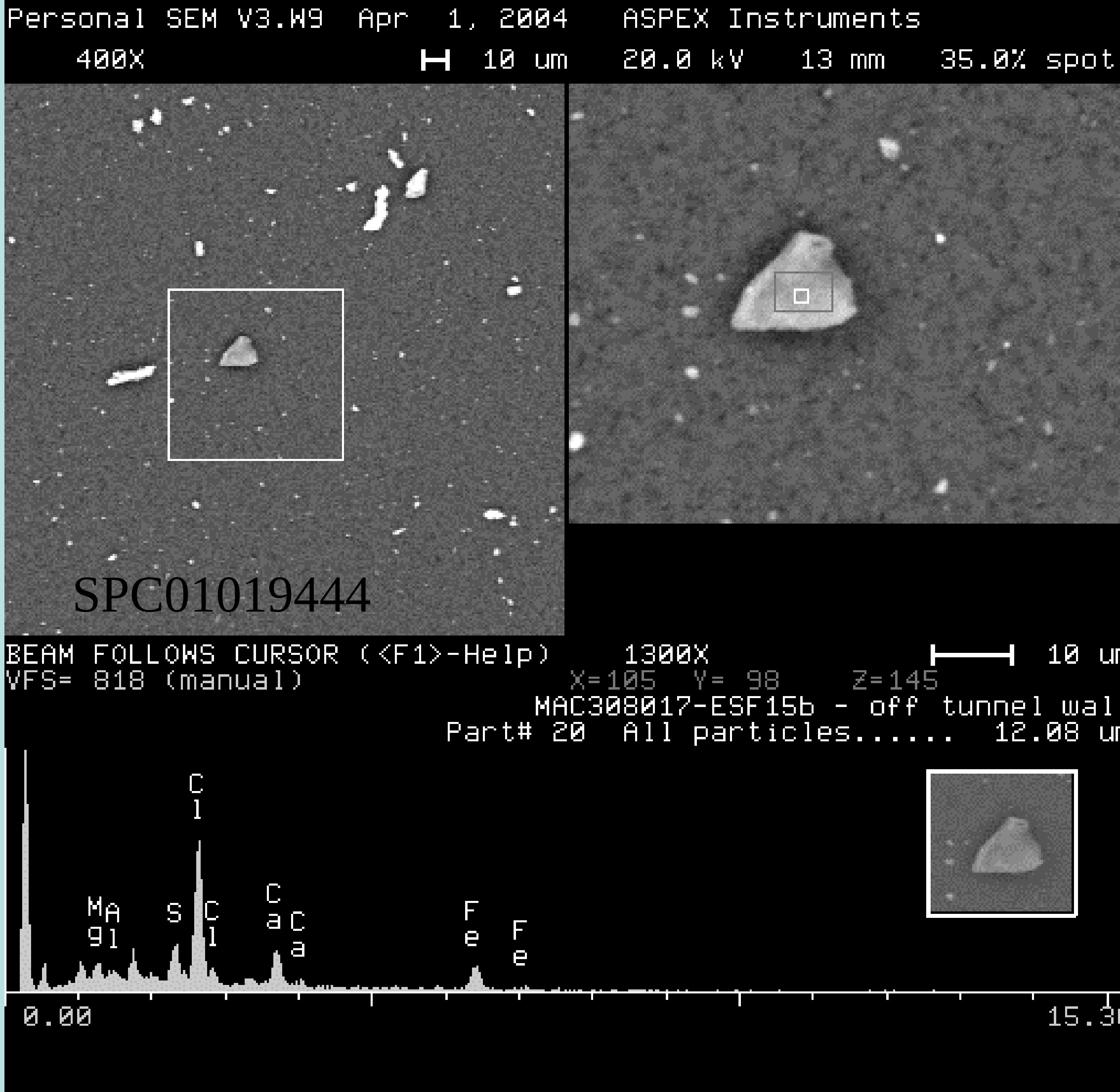
SEM and EDS of Dust Particles off of the tunnel wall



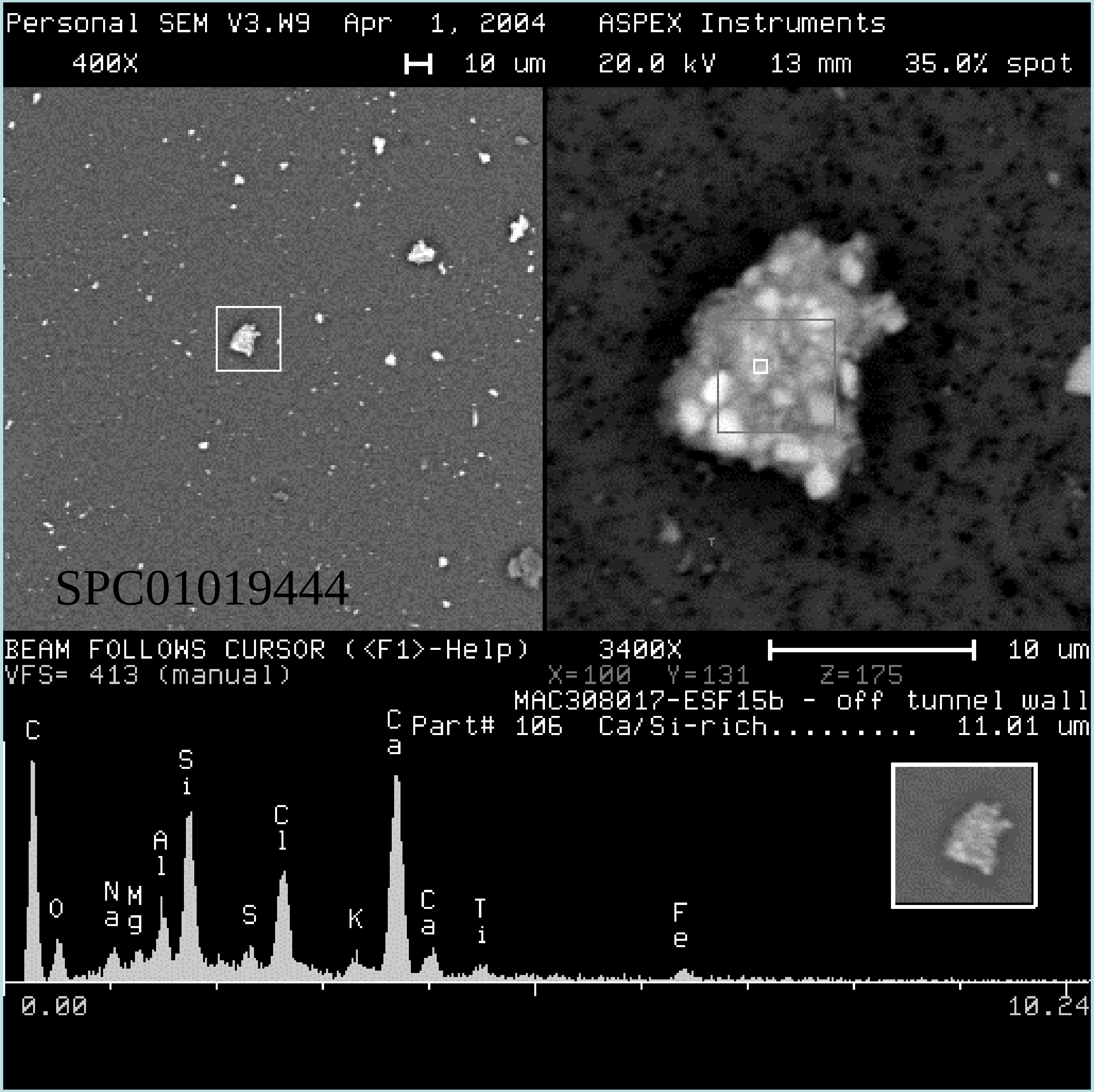
Mixture of Na, K, Ca, Cl, and sulfate

Dust Particles off of the tunnel wall

Mixture of Ca and Mg chloride and sulfate salts on rock flower



Dust Particles off of the tunnel wall



Rock flower with calcite, chloride and sulfate salts

Dust Particles off of air pipe

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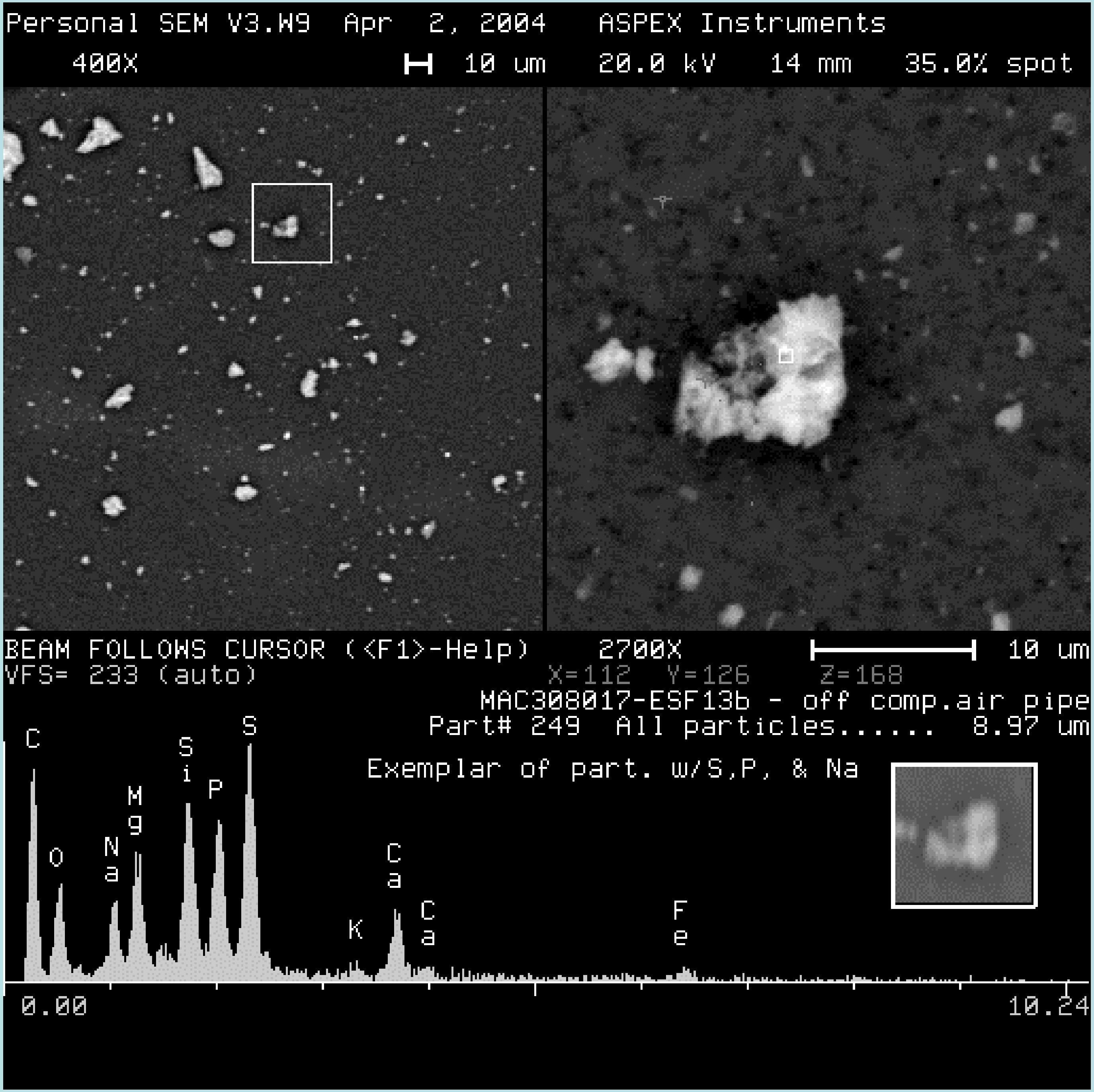
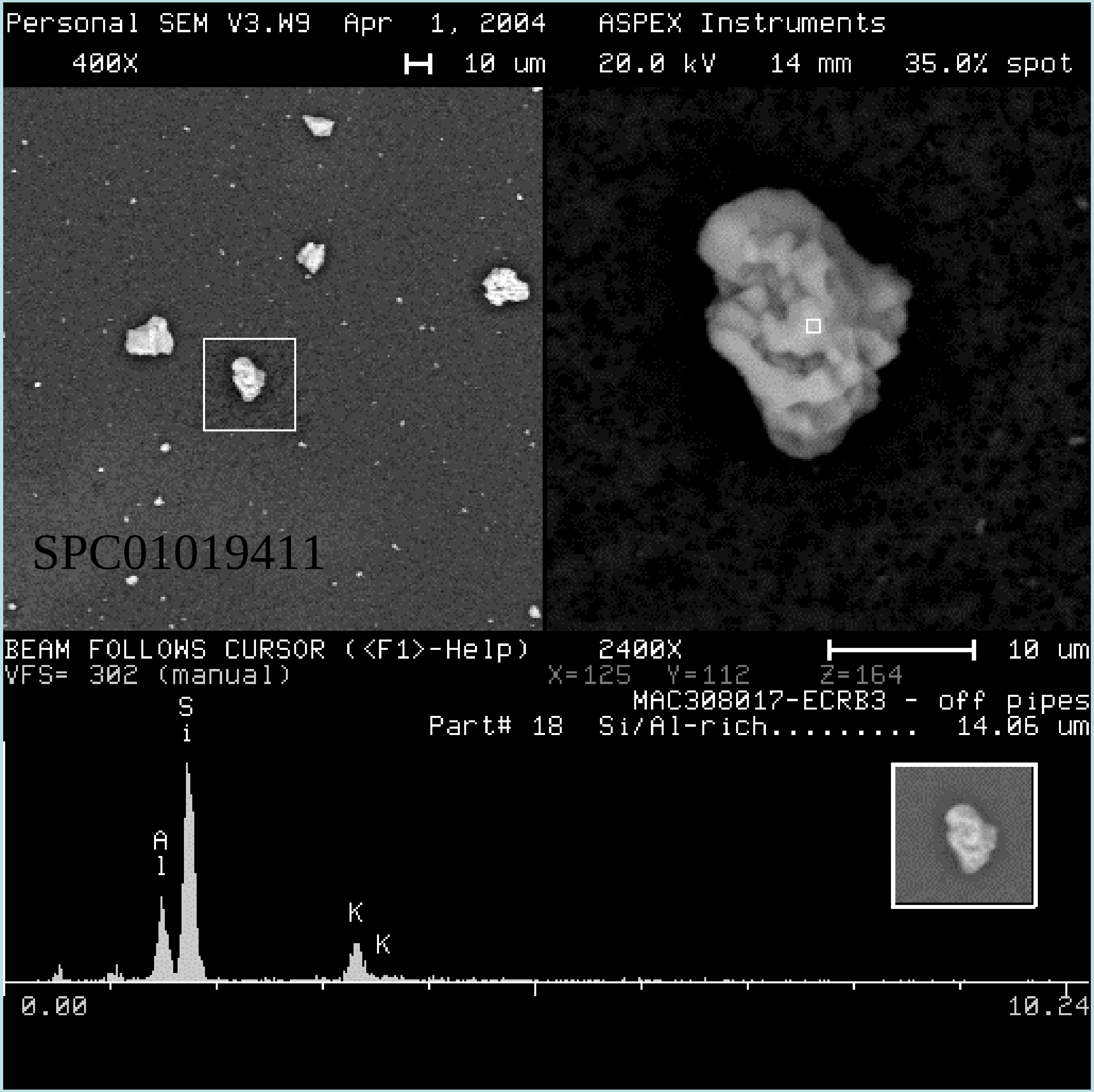


Mixture of Mg, Na, Ca, and K carbonate, sulfate, and phosphates on rock flower

Dust particles

off of air pipe



Rock flower
K-aluminum
silicate

Service Environmental Parameters

How complex are these parameters through the lifetime of waste containment?

- Fixed Surfaces
- Mobile Surfaces
- Variable vadose water compositions
- Variable vadose water flux
- Relative humidity and deliquescence
- Temperature
- Convection
- Decay

Salts on Fixed and Mobile Surfaces

How have we defined the salts that might be present after closure?

The following lists are from:
C. Price (Ed.) 2000. An Expert Chemical Model for Determining the Environmental Conditions Needed to Prevent Salt Damage in Porous Materials, Research Report No. 11, European Commission- EC R&D Programme ‘Environment and Climate’, Archetype Publications, Ltd, London

Single Sodium Salts:

- Halite - NaCl
- Hydrohalite - HaCl.2H20
- Nitratine - NaNO3
- Thenardite - Na2SO4
- Mirabilite - Na2SO4.0H20
- Nahcolite - NaHCO3
- Thermonatrite - Na2CO3.H20
- Sodium carbonate heptahydrate - Na2CO3.7H2O
- Natron - Na2CO3.10H2O

Single Potassium Salts:

- Sylvite - KCl
- Niter - KNO_3
- Arcanite - K_2SO_4
- Potassium sulfate hydrate - $K_2SO_4.H_2O$
- Kalicinite - $KHCO_3$
- Potassium carbonate hydrate - $K_2CO_3.3/2H_2O$
- Potassium carbonate hexahydrate - $K_2CO_3.6H_2O$

Single Magnesium Salts:

- Bischofite - $MgCl_2.6H_2O$
- Magnesium chloride octahydrate - $MgCl_2.8H_2O$
- Magnesium chloride dodecahydrate - $MgCl_2.12H_2O$
- Magnesium nitrate dihydrate - $Mg(NO_3)_2.2H_2O$
- Nitromagnesite - $Mg(NO_3)_2.6H_2O$
- Magnesium hydrate enneahydrate - $Mg(NO_3)_2.9H_2O$
- Kieserite - $MgSO_4.1H_2O$
- Leonhardtite - $MgSO_4.4H_2O$
- Hexahydrite - $MgSO_4.6H_2O$
- Epsomite - $MgSO_4.7H_2O$

Single Calcium Salts:

Sinjarite - $CaCl_2.2H_2O$
Calcium chloride tetrahydrate - $CaCl_2.4H_2O$
Antacticite - $CaCl_2.6H_2O$
Calcium nitrate dihydrate - $Ca(NO_3)_2.2H_2O$
Calcium nitrate dihydrate - $Ca(NO_3)_2.3H_2O$
Nitrocalcite - $Ca(NO_3)_2.4H_2O$
Calcium nitrate - $Ca(NO_3)_2$
Anhydrite - $CaSO_4$
Bassanite - $CaSO_4.1/2H_2O$
Selenite (Gypsum) - $CaSO_4.2H_2O$

Some Double Salts:

Darapskite - $NaNO_3.Na_2SO_4.H_2O$
Glaserite (aphtitalite) - $Na_2SO_4.3K_2SO_4$
Bloedite (astrakanite)- $Na_2SO_4.MgSO_4.4H_2O$
Glauberite - $Na_2SO_4.CaSO_4$
Labile salt - $2Na_2SO_4.CaSO_4.2H_2O$

Carnallite - $KCl.CaCl_2$
Chlorocalcite (baeumlerite) - $KCl.CaCl_2$
Potasasium pentacalcium nitrate decahydrate - $KNO_3.5Ca(NO_3)_2.10H_2O$
Potassium calcium nitrate decahydrate - $KNO_3.Ca(NO_3)_2.3H_2O$
Leonite - $K_2SO_4.MgSO_4.6H_2O$
Schoenite (picromerite) - $K_2SO_4.MgSO_4.6H_2O$
Syngenite - $K_2SO_4.CaSO_4.H_2O$
Pentasalt (gorgeite) - $K_2SO_4.5CaSO_4.H_2O$

Tachhydrite - $2MgCl_2.CaCl_2.12H_2O$

Calcium chloride nitrate tetrahydrate - $CaCl_2.Ca(NO_3)_2.4H_2O$

Where do salts form in very dry desert environments?

Can we use the last 2,000-3,500 years in the Eastern Desert of Central Egypt as a window into salt precipitation?

How might these data form an analogue for dust particles on the top of C-22 canister, and in the invert?

- Void spaces (pores and large voids) are coated with salt precipitates and grains are cemented at contact points where there has been suction due to dryout and there are brine solutions in fractures and pores in the host rock/sediments feeding the drying surface.

- Salts are precipitated in ponded situations where brines have evaporated.

An Oven (2,000 years old) from El Hibeh, Egypt

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

Double wall mud oven

Interior wall of the oven
is coated with selenite crystals
and clay and selenite crystal
dust.

Most void space in the desert vadose zone (limestone or Nile silt/mud sediments) are surface coated with selenite. In the wet Nile floodplain, chlorides are the dominant salt.

Burial Shaft and Chamber with Mummies and Chamber floor debris and shaft floor debris cemented with selenite (3,500 Years)

El Hibeh, Egypt

Our understanding and ability to model the lifetime of Alloy C-22 depends upon some very basic concepts that are fundamental to the following statements:

- Alloy C-22 may respond as an moderately effective short-term barrier to the release of nuclear waste in none aggressive environments. Adequate bounding environmental data and understanding are required to determine the lifetime of Alloy C-22.

- In-Drift dust particles after closure will have mineralogic compositions different than during characterization.

- Salts of various mineral compositions will form as salt facies in environmentally complex and dynamic in-drift conditions.