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Deliquescence Behavior of Salts Deposited Inside the Drifts of a Potential High-Level Waste Repository

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Objective and Outline

- Objective of study: determine geochemical properties and deliquescence relative humidities of materials potentially present in a geologic repository
- Outline
  - Background
  - Chemistry results
  - Mineralogic results
  - Deliquescence results
  - Observations and conclusions

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Yucca Mountain, Nevada

- Site of potential deep geologic nuclear waste repository
- About 145 km NW of Las Vegas, Nevada, in the Mojave Desert
- Construction and operation by U.S. Department of Energy (DOE) if licensed by U.S. Nuclear Regulatory Commission

Deliquescence

- Defined: rapid absorption of water from air by salts to form a brine solution
- Deliquescence point varies by temperature and humidity
- Radioactive decay gives off heat and will raise the repository temperature
- When repository temperature falls, humidity will rise
- Salts present in dust and evaporated seepage water may deliquesce
- Brine solution may affect corrosion of waste package depending on composition

Technical Approach

- Samples collected by U.S. Geological Survey (USGS) from the Exploratory Studies Facility (underground tunnel) and Yucca Mountain surface
- Analyzed soluble and insoluble fractions
  - Anion, cation by Ion Chromatography (IC)
  - Metals by Inductively-Coupled Plasma (ICP)
  - Scanning Electron Microscopy (SEM)
  - Energy Dispersive X-ray Spectrometry (EDS)
  - X-ray Diffraction analysis (XRD)
- Determined weight fraction of soluble material
- Conducted deliquescence experiments

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Soluble Fraction Analysis

Analysis	Surface Sample (mg/kg)	Tunnel Sample (mg/kg)
Calcium	56.5	918
Sodium	17.8	686
Potassium	31.2	205
Silicon	42.9	21.9
Magnesium	8.84	101
Boron	0.72	3.03
Phosphorus	3.87	0.956
Molybdenum	-	0.910
Lithium	0.064	9.36
Iron	-	1.51
Manganese	-	7.28

Analysis	Surface Sample (mg/kg)	Tunnel Sample (mg/kg)
Sulfate	19.6	1920
Chloride	8.59	2350
Nitrate-N	1.69	218
Phosphate-P	3.22	-
Fluoride	1.40	14.1
Bromide	-	23.8
Nitrite-N	0.857	3.45

Soluble Fraction Weight Percent:

Surface Sample: <0.1%

Tunnel Sample: 0.69%

*Note: this data does not include analysis of H, O, or C.

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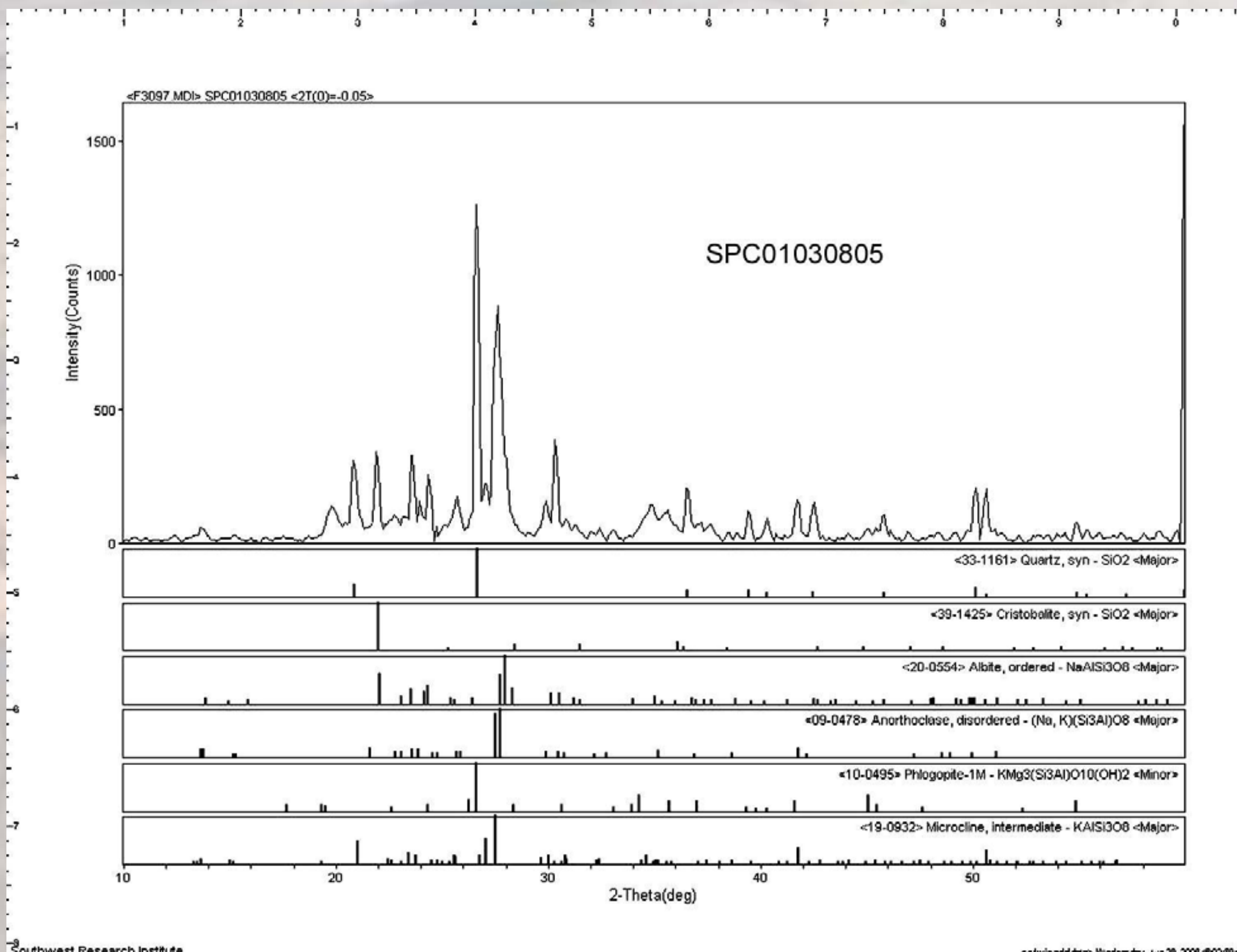
XRD: Whole Dust, Surface Sample



Primary Minerals:

- Quartz SiO_2
- Cristobalite SiO_2
- Albite, ordered $NaAlSi_3O_8$
- Anorthoclase, disordered $(Na,K)(Si_3Al)O_8$
- Microcline, intermediate $KAlSi_3O_8$

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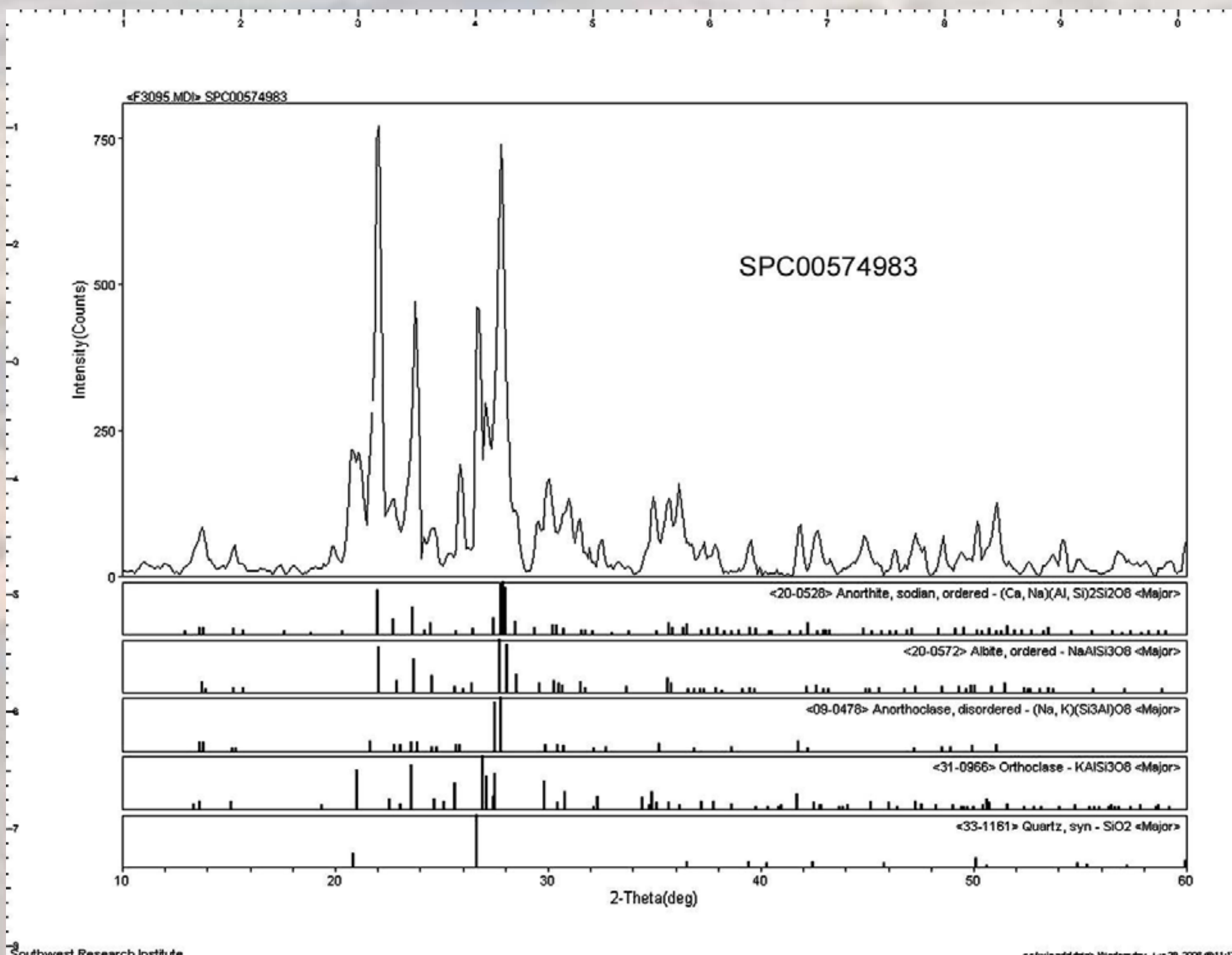
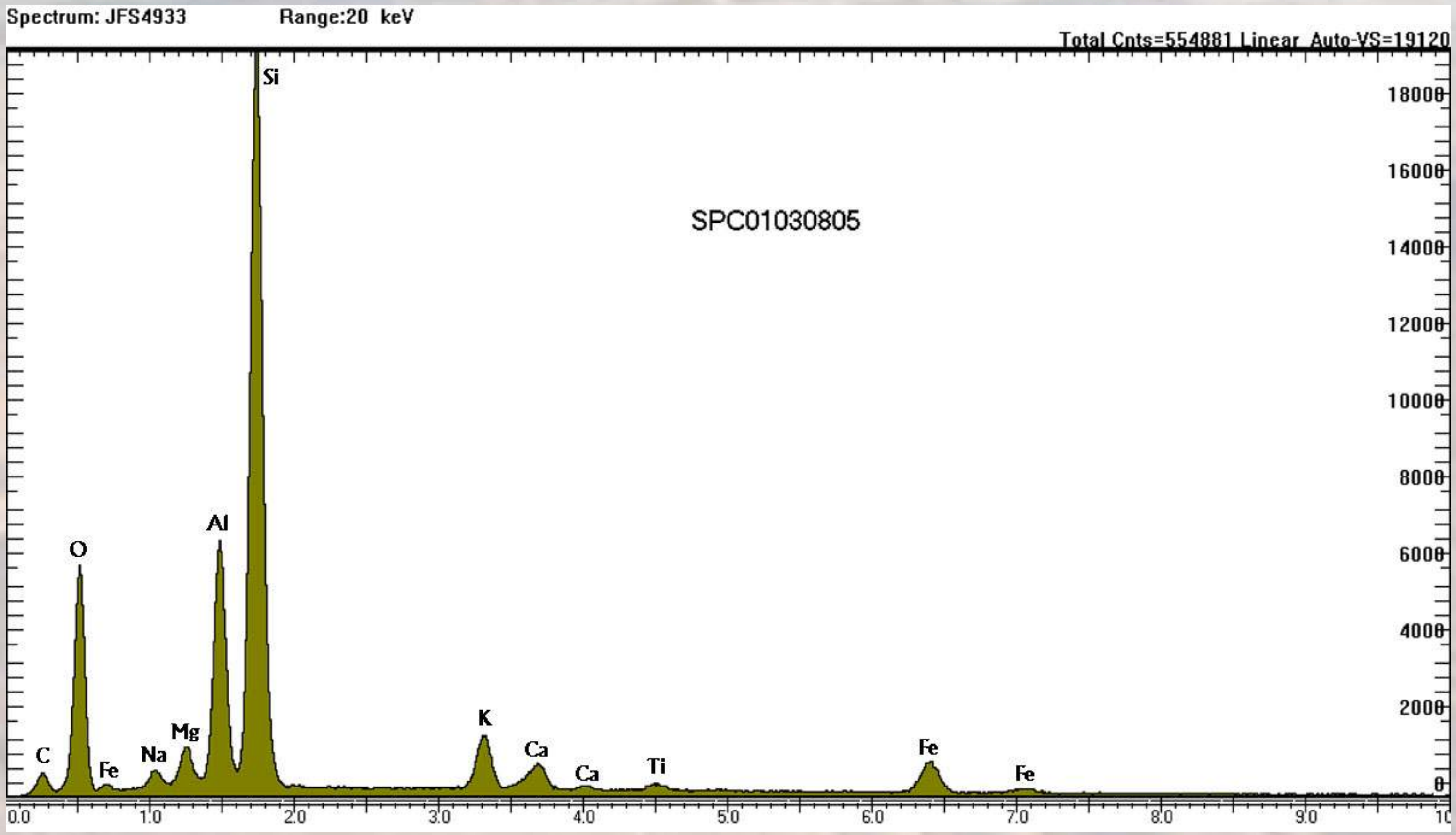
XRD: Whole Dust, Tunnel Sample



Primary Minerals:

- Anorthite, sodian, ordered $(Ca,Na)(Al,Si)2Si_2O_8$
- Albite, ordered $NaAlSi_3O_8$
- Anorthoclase, disordered $(Na,K)(Si_3Al)O_8$
- Orthoclase $KAlSi_3O_8$
- Quartz SiO_2

EDS: Whole Dust, Surface Sample



Silicon, 63.0%; Aluminum, 17.3%; Potassium, 5.8%; Iron, 6.7%; Sodium, 1.3%; Calcium, 2.9%; Magnesium, 2.1%

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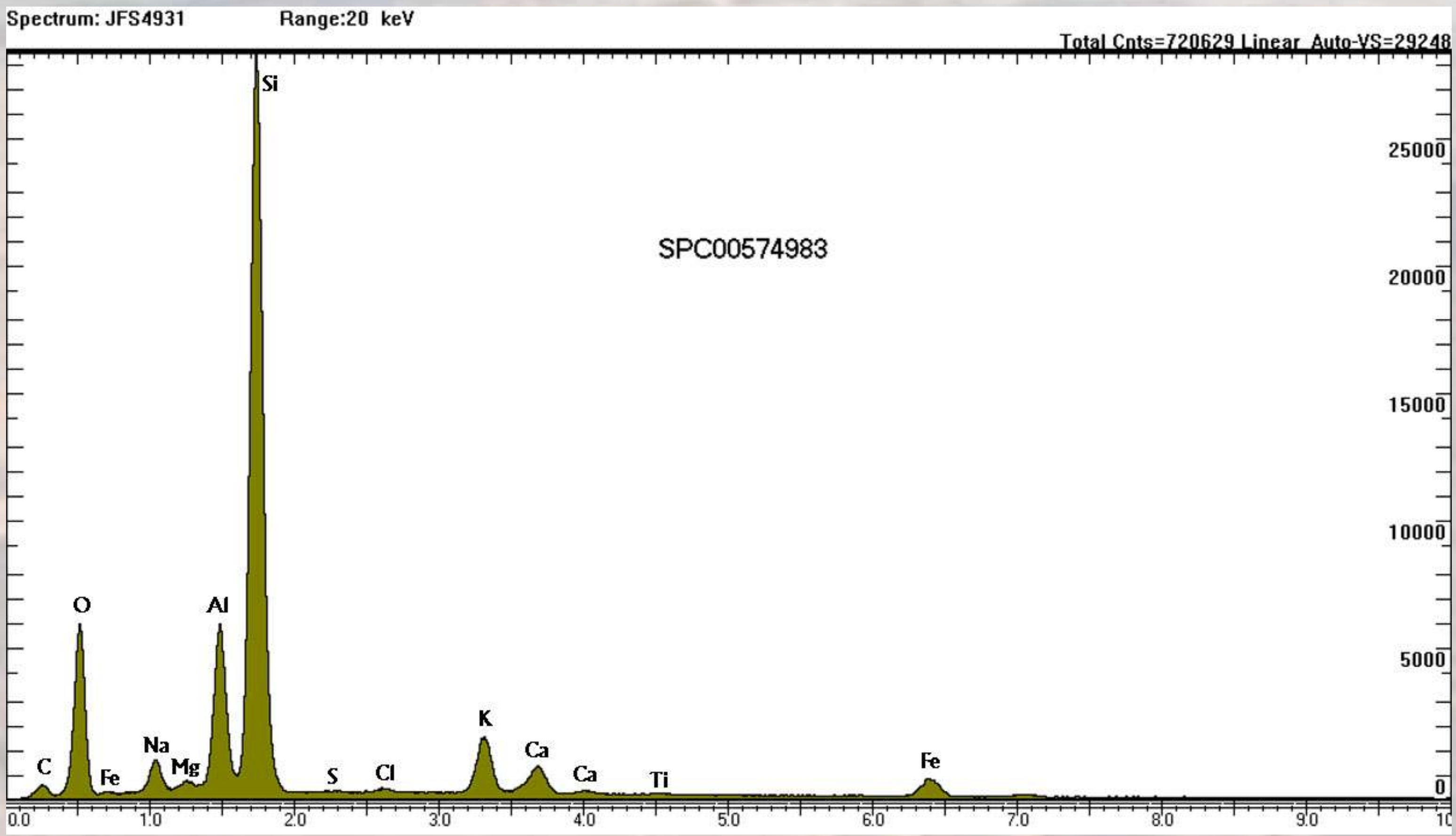
EDS: Whole Dust, Tunnel Sample



Silicon, 67%; Aluminum, 12.6%; Potassium, 7.1%; Iron, 4.2%; Sodium, 4.2%; Calcium, 3.4%

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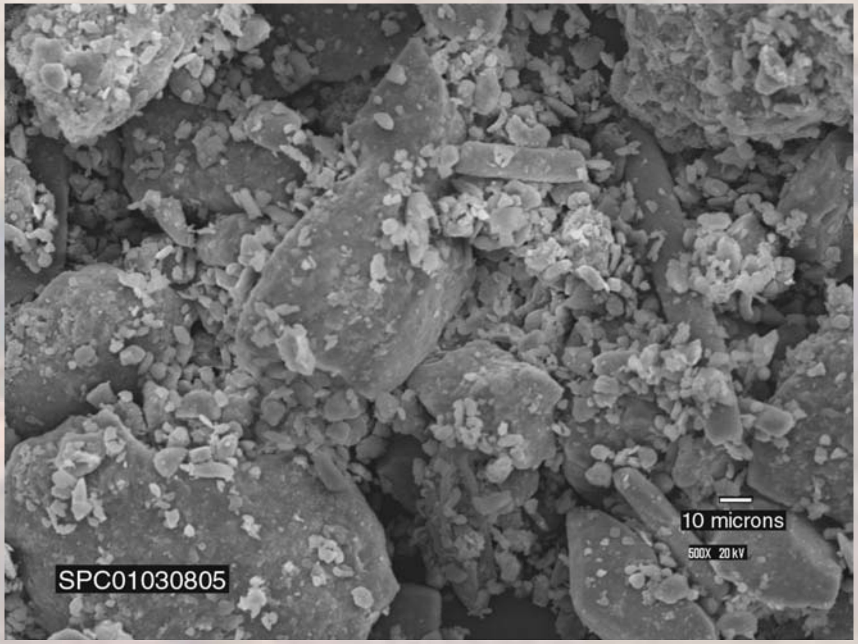
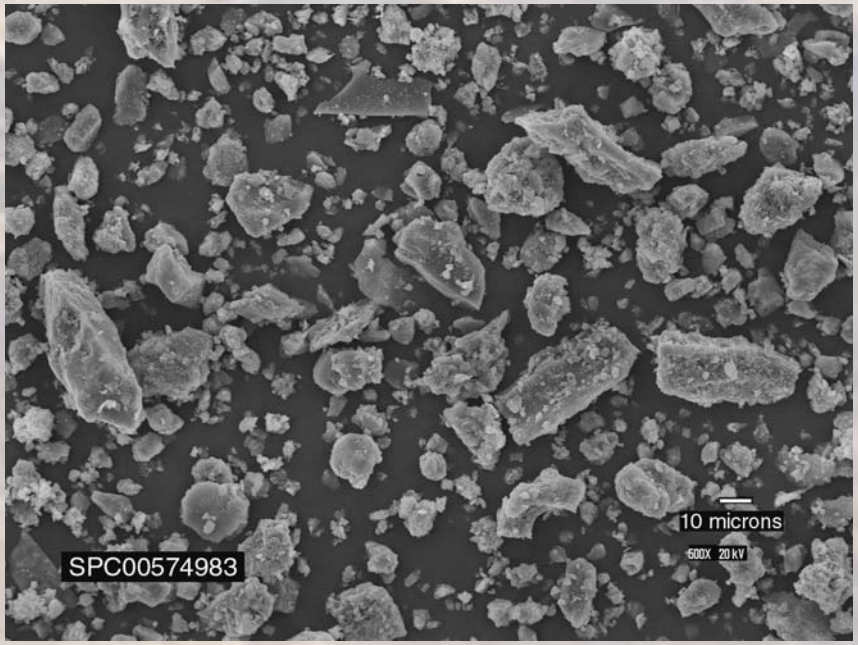
SEM of Whole Dusts

Surface Dust



Tunnel Dust



Deliquescence Experiment

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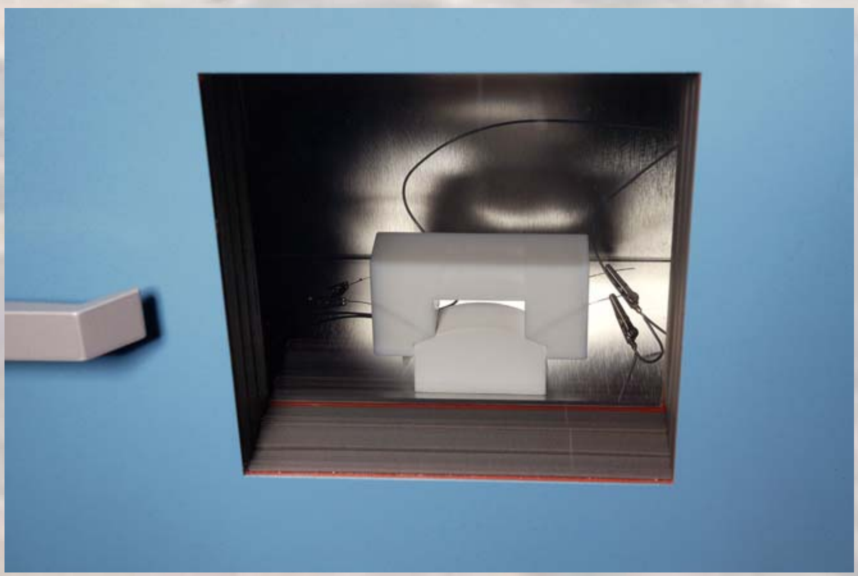
Deliquescence Experiment

- Impedance method used to detect Deliquescence Relative Humidity (DRH)
- Equipment
  - Thunder Scientific Model 2500 High Precision Humidity Chamber
  - Quadtech Model 7600 LCR meter
  - Custom-made Teflon conductivity cell fitted with filter paper between two platinum electrodes
- Filter paper creates a salt bridge that carries current depending on moisture availability



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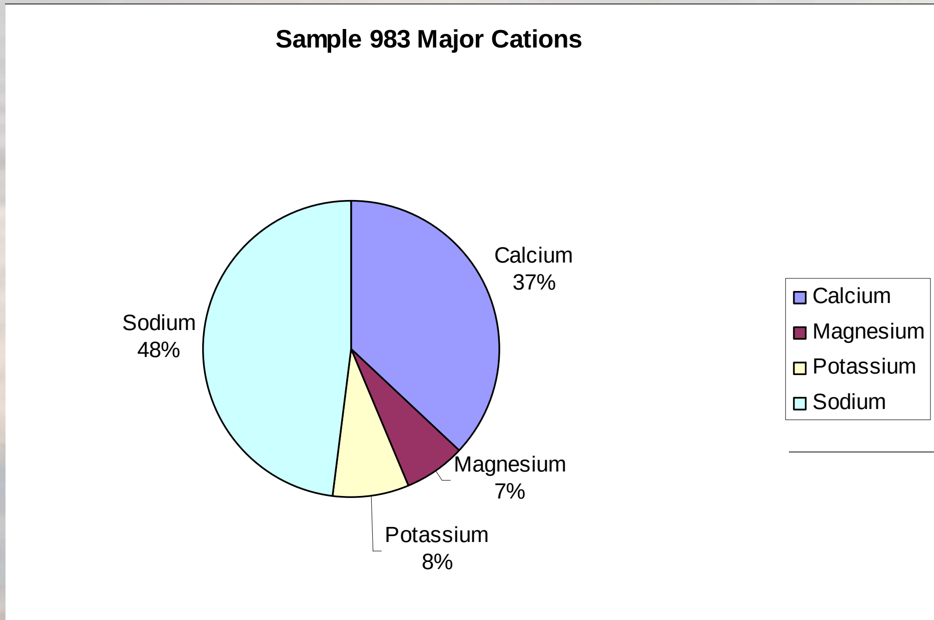
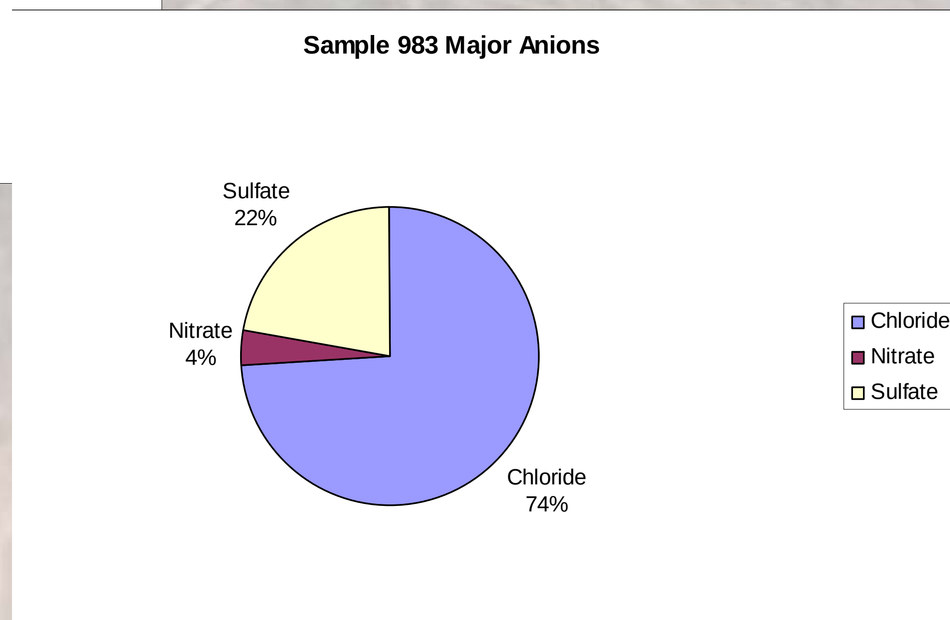
Synthetic Mixture Composition



- Trace elements ignored for simplicity



- Lithium and bromide used as tracers, ignored for synthetic composition

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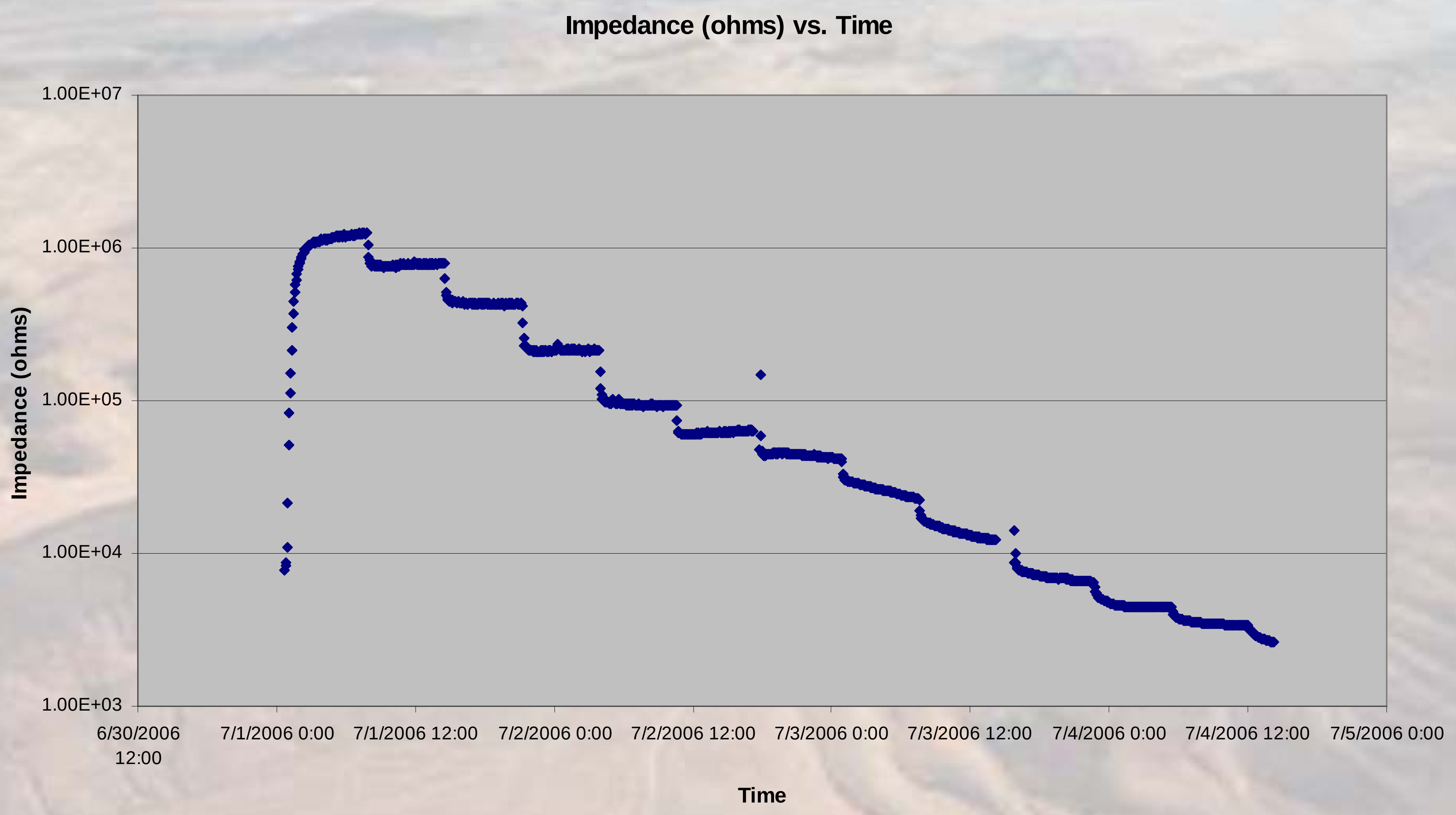
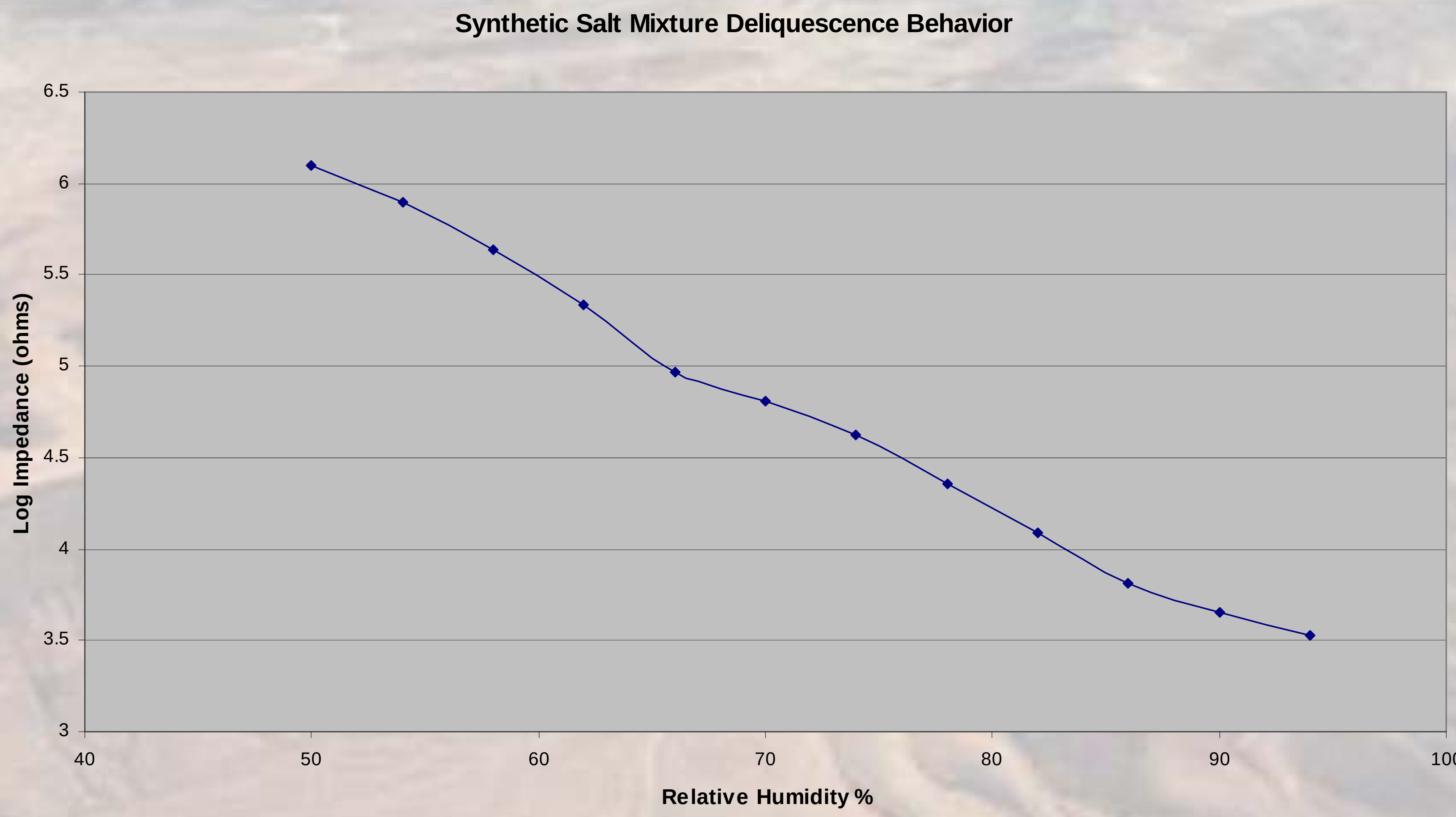
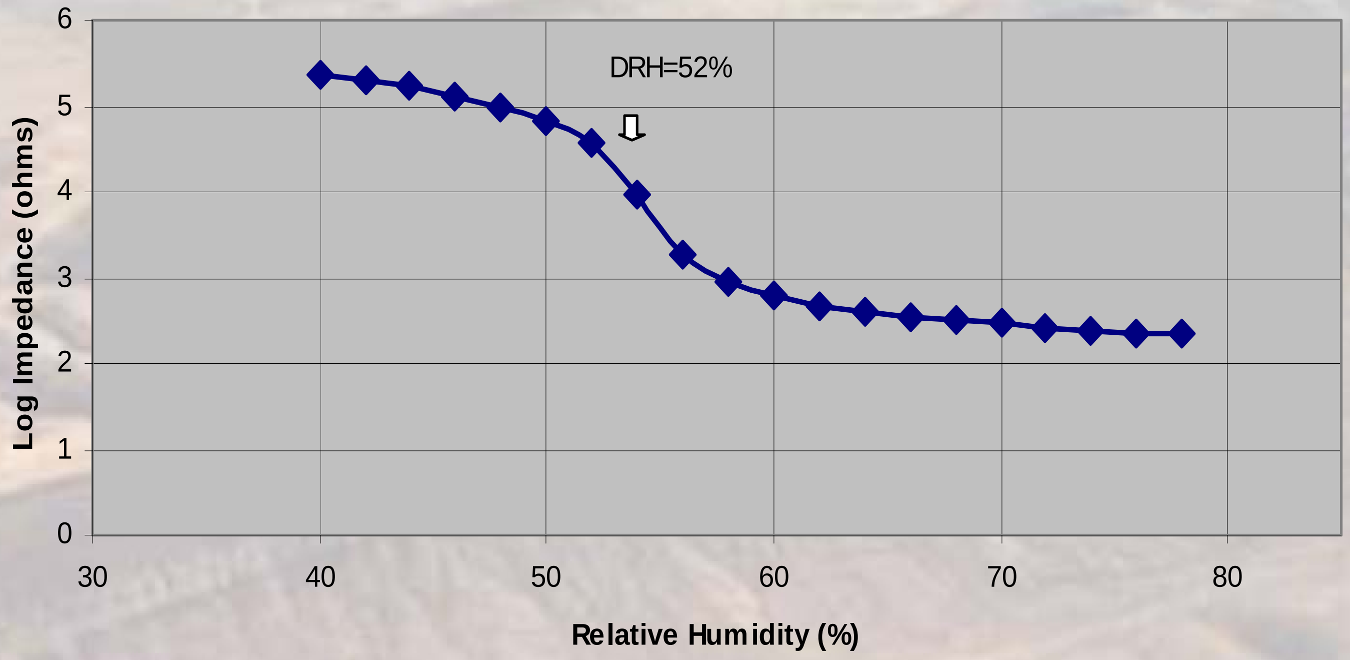
Deliquescence Behavior



Deliquescence Behavior (continued)



Example of Deliquescence Data



Data from the system $Na/K/Cl/NO_3$ showing typical impedance behavior resulting from deliquescence as humidity is increased

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Observations and Conclusions

- Deliquescence behavior is observed in a synthetic soluble fraction of the tunnel dust sample
- Chemical analyses show the presence of chloride, a species that can enhance localized corrosion, as well as nitrates and sulfides, which can mitigate localized corrosion of waste packages
- Higher concentrations of chloride were observed than typically discussed in DOE studies
- The fraction of soluble salts is very small (<1%) and greater in tunnel dust than in surface dust, perhaps due to rain washing and underground water flow

Ongoing Studies

- Additional studies of in-drift samples have been initiated using mixtures of soluble salts with insoluble dust (quartz powder)

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Acknowledgments

- Special thanks to
  - Zell Peterman of USGS for providing the samples used in this study
  - Jim Spencer of Southwest Research Institute for XRD, EDS, and SEM analyses
  - Bobby Pabalan and Jim Myers of Center for Nuclear Waste Regulatory Analyses (CNWRA) for technical support

- This presentation describes work performed by the CNWRA for the U.S. Nuclear Regulatory Commission (NRC) under Contract No. NRC–02–02–012. The activities reported here were performed on behalf of the NRC Office of Nuclear Material Safety and Safeguards, Division of High-Level Waste Repository Safety. This presentation is an independent product of CNWRA and does not necessarily reflect the view or regulatory position of NRC.