

# Energy and Mineral Resources

Surface composition mapping that identifies resources and the changes and impacts associated with their development

**PI: Wendy Calvin**

Professor & Director GBCGE

University of Nevada, Reno

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# Preparatory Activities

- Motivated by nationwide focus on and interest in strategic or critical minerals and renewable energy
  - The two are linked as many renewable energy technologies require strategic materials
- Hypotheses linked to decadal survey and HypsIRI VSWIR, TIR, and combined questions

Testable hypotheses	Expected outcomes
Critical mineral deposits will have unique surface signatures that can be mapped with HypsIRI	Help reduce reliance on imports of critical minerals
High priority renewable energy targets will be identifiable using automated processing tools	Assist in identifying regions for renewable energy development
Renewable energy surface impacts will be smaller than those associated with traditional fossil fuels	Quantify the impacts of renewable energy development
Modern resource extraction can be quantitatively evaluated in terms of land use/land cover change and impact footprint	Quantify the impacts of past and current resource extraction and their evolution over time

# Personnel

- PI – Calvin, UNR since 2000
- Research Scientist – Littlefield, MS 2010
- 2 New MS Candidates, started late August 2013
  - Neil Pearson - Geophysics
  - Gwen Davies - Hydrogeology

# Proposed work

Science task	Site	Additional sites	Study goals
Task 1 Critical minerals	<ul style="list-style-type: none"> <li>Music Valley</li> </ul>	<ul style="list-style-type: none"> <li>Mountain Pass</li> <li>Newberry Hectorite Mine</li> </ul>	<ul style="list-style-type: none"> <li>Map lithologic and mineral associations with REE deposits</li> <li>Observe changes at former mine sites</li> <li>Map lithium clay (hectorite)</li> </ul>
Task 2 Geothermal energy	<ul style="list-style-type: none"> <li>Long Valley</li> <li>Benton Hot Springs</li> <li>Imperial Valley</li> </ul>	<ul style="list-style-type: none"> <li>Steamboat Springs</li> </ul>	<ul style="list-style-type: none"> <li>Identify new locations for geothermal exploration</li> <li>Monitor changes associated with development and operation</li> </ul>
Task 3 Energy impacts	<ul style="list-style-type: none"> <li>Altamont Pass</li> <li>San Geronio Pass</li> </ul>	<ul style="list-style-type: none"> <li>Imperial Valley</li> <li>Ivanpah</li> </ul>	<ul style="list-style-type: none"> <li>Map and monitor surface cover and compositional change associated with development and operation</li> </ul>
Task 4 Mining impacts	<ul style="list-style-type: none"> <li>Leviathan Mine</li> </ul>	<ul style="list-style-type: none"> <li>Yuba or Bear Historic CA mines</li> <li>Penn Mine</li> </ul>	<ul style="list-style-type: none"> <li>Map changing sulfur-bearing mineral compositions with local conditions and on-going remediation</li> </ul>





# Prioritized Efforts in Final Corridors

Science task	Site	Study goals
Geothermal energy	<ul style="list-style-type: none"><li>• Mono Lake/Long Valley</li><li>• Imperial Valley</li><li>• Geysers</li></ul>	<ul style="list-style-type: none"><li>• Identify new locations for geothermal exploration</li><li>• Monitor changes associated with development and operation</li></ul>
Mining impacts	<ul style="list-style-type: none"><li>• Leviathan Mine</li></ul>	<ul style="list-style-type: none"><li>• Map changing sulfur-bearing mineral compositions with local conditions and on-going remediation</li></ul>
Energy impacts	<ul style="list-style-type: none"><li>• Altamont Pass</li><li>• San Geronio Pass</li><li>• Imperial Valley</li></ul>	<ul style="list-style-type: none"><li>• Map and monitor surface cover and compositional change associated with development and operation</li></ul>
Critical minerals	<ul style="list-style-type: none"><li>• Mountain Pass Calibration Site</li></ul>	<ul style="list-style-type: none"><li>• Explore detectability of RE features at HypIRI spatial resolution</li></ul>



# Geothermal Energy

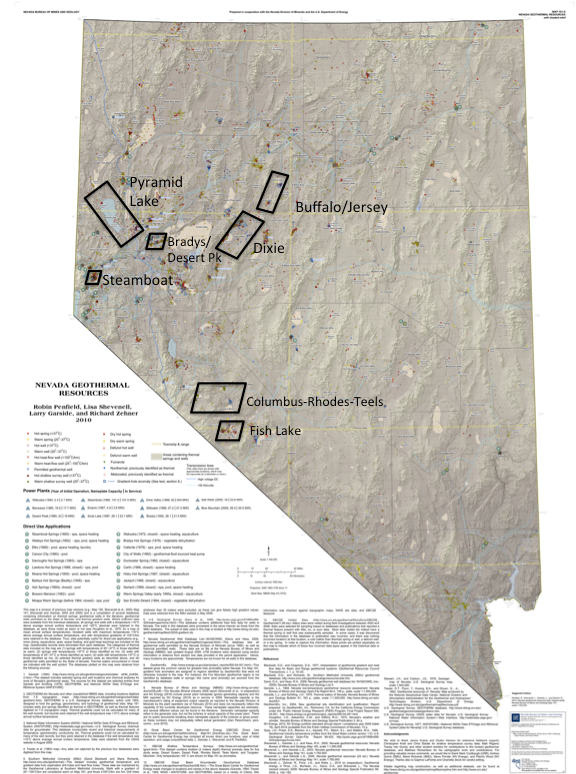
Surface composition and mapping new resource potential

# Surface composition

- Map surface indicators
  - Minerals
    - Sinter
    - Tufa
    - Hydrothermal alteration
    - Playa evaporites
  - Vegetation concentration near springs
  - Thermal anomalies
- Interest in mapping CO<sub>2</sub> gas enrichment over existing plants and as possible indicator of resource potential

# Previous Geothermal Work

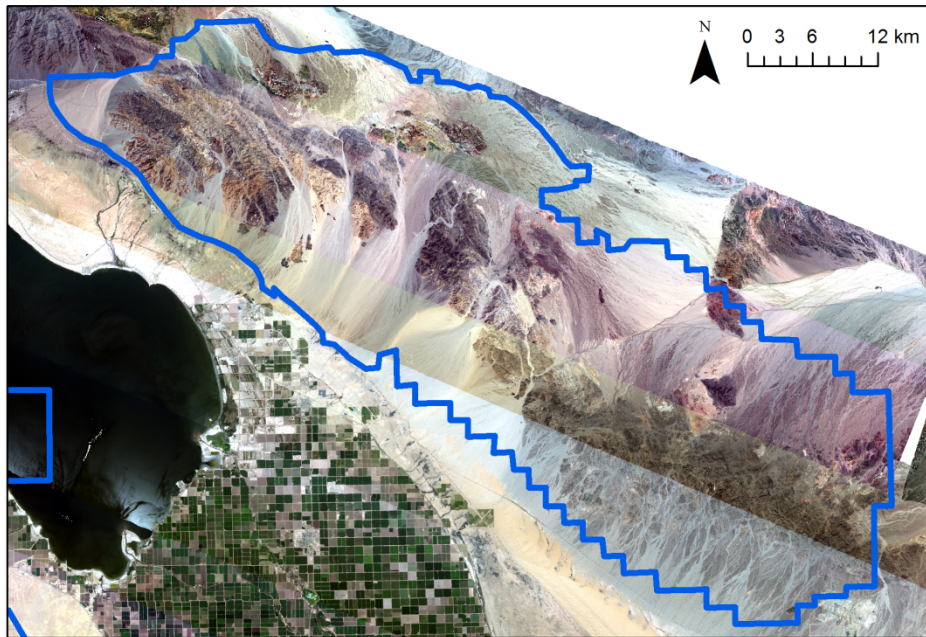
<i>Site</i>	<i>Sensors</i>	<i>Minerals Found</i>
Steamboat Springs	ASTER, MASTER, SEBASS	alunite, jarosite, alunogen, opal, quartz, kaolinite, albite, andesine
Brady's - Desert Peak	ASTER, HyMAP	gypsum, calcite, hematite, opal
Pyramid Lake PTL	ASTER, HyMAP	alunite, carbonate, gypsum, kaolin.-halloysite & montm.-illite
Columbus-Rhodes-Teels	ASTER, Field	Borates: borax, tincalconite
Buffalo Valley	ASTER, MASTER	Weak carbonate and silica only
Fish Lake Valley	MASTER, HyMAP, AVIRIS, SpecTIR, SEBASS	kaolinite, calcite, montm., alunite, jarosite & illite
Dixie Valley	ASTER, HyMap	Gypsum, kaolinite, illite





## Littlefield: Imperial Valley geothermal exploration

Identify new locations for geothermal exploration

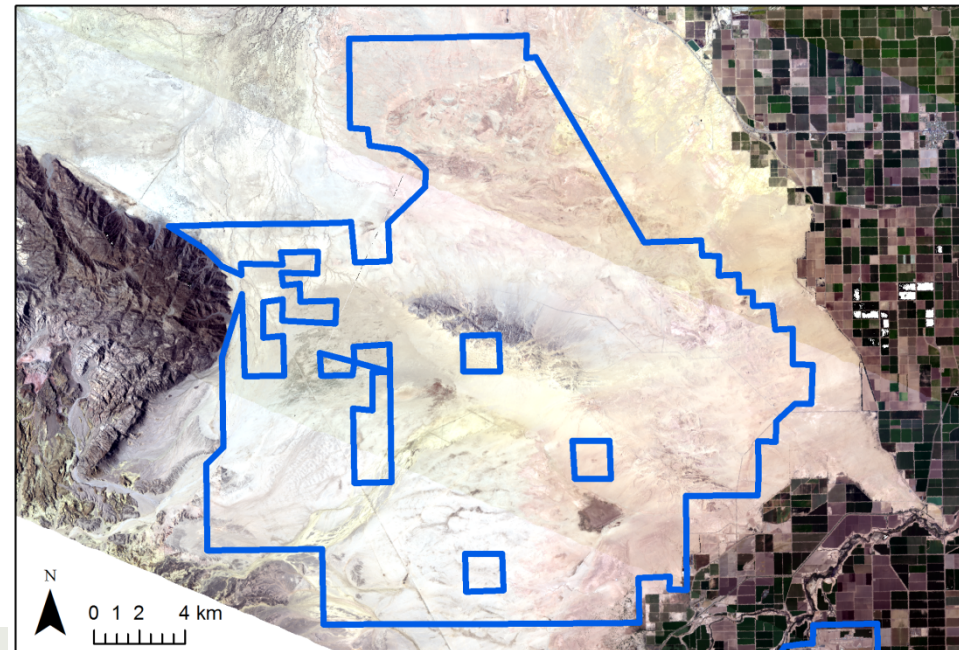


Chocolate Mountains Naval Aerial Gunnery Range

The Navy Geothermal Program Office is actively exploring these two areas

High potential areas may display clay alteration, siliceous sinter, or carbonate travertine

El Centro Naval Auxiliary Air Station  
(Superstition Hills)





# Pearson: Mono Basin and Young Volcanic Geology

Recent volcanism (up to 300 years ago) within the Mono Basin as well as spring upwelling in Mono Lake itself indicate high geothermal potential. Areas of highest potential can be mapped using MIR/TIR data looking for high temperature areas, and SWIR data looking for indicator minerals such as tufa, travertine, and clay minerals.

Left: AVIRIS flightline f130502t01p00r07\_refl showing the Mono-Inyo crater chain. Below: Tufa towers at South Beach Hot Springs Mono Lake. Photo by Neil Pearson





# Mining Impacts



Google earth

Imagery Date: 7/29/2012 1993 839 ft

38°42'18.43" N 119°39'32.78" W elev 7140 ft

Eye alt 11323 ft

Leviathan Mine superfund site



# Leviathan Mine History

- Abandoned open pit sulfur mine
- Mined 1863-1962, open pit after 50's
- Became a superfund site in 2000
- In remediation to control acid drainage into Leviathan creek
- Have SpecTIR and SEBASS data from 2007
  - Allows long term change monitoring as well as seasonal fluctuation
  - Sulfur mineralogy evolves with spring snow melt and summer dehydration
- Seasonal treatment and variation in acid producing materials.

# Davies: Leviathan Superfund Site

AVARIS Spring 2013  
f130502f01p00r10rdn\_e\_sc01\_ort\_img

## Current status of mine site:

- ARCO performing Remedial Investigation/Feasibility Study ordered by EPA, projected completion 2015.
- Continuing AMD remediation through Bioreactor and High Density Sludge Treatment Systems.

## Project Goals:

- Explore what can be identified at various spatial and radiometric scales.
- Explore remote mapping of contaminants in shallow pit lakes and effluent creeks adjacent to mine site.
- Identify seasonal variation in efflorescent sulfate salts.
- Map changes in sulfur-bearing minerals with on-going remediation.
- Test ability to monitor change brought by naturally changing conditions (precipitation, temperature, exposure) and remediation





# Energy and Resource Impacts



Google earth

Imagery Date: 5/27/2012 1995

33°48'29.97" N 115°23'59.65" W elev 689 ft

Eye alt 6265 ft

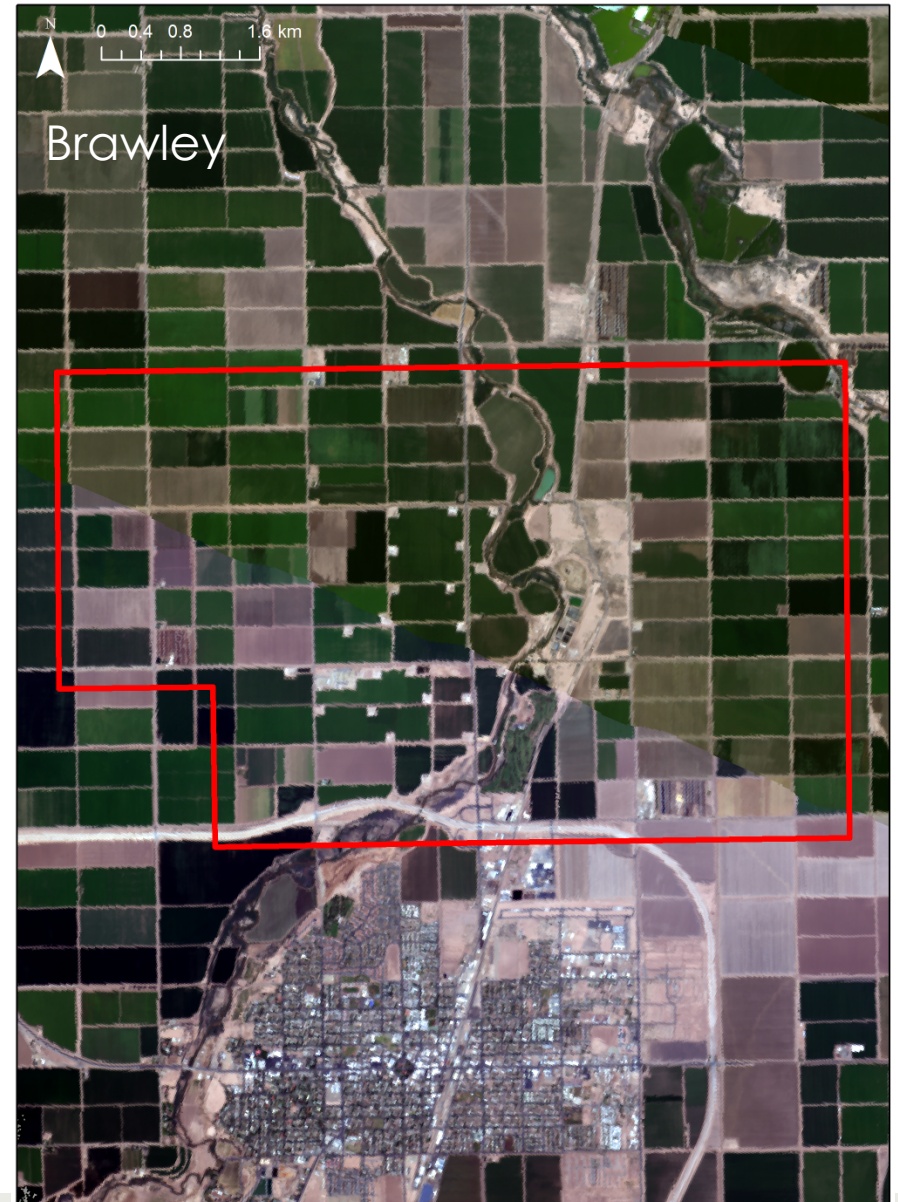
Desert Sunlight solar farm construction near Imperial Valley

# Land surface change associated with large scale energy production

- Map changes in
  - Surface cover
    - Vegetation removal
    - Development of new types of vegetation
  - Land area disturbance
    - Changes in land use (new roadways, infrastructure)
  - Compositional changes
    - Soil surface composition
    - Waste material identification

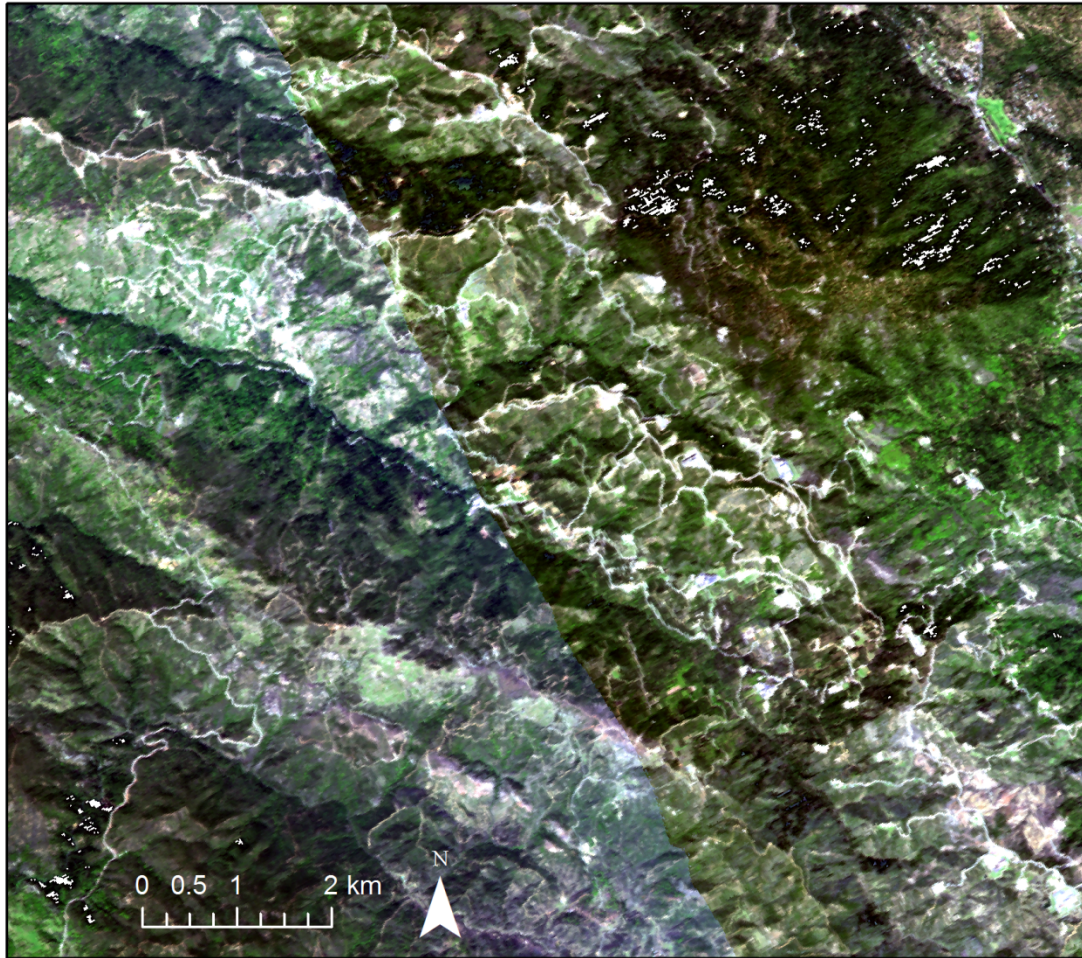


**Imperial Valley geothermal fields:** Monitor changes associated with development and operation of existing geothermal power plants (21 existing power plants in the region)



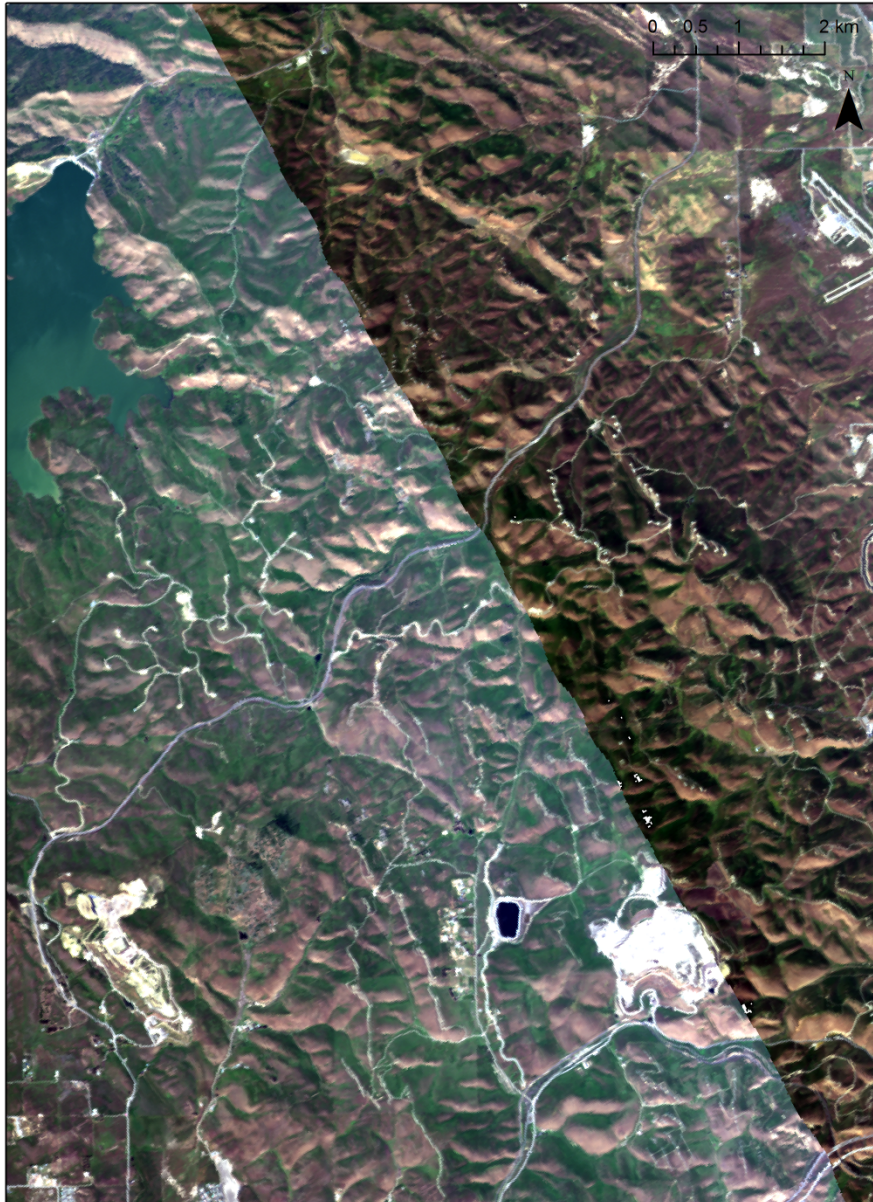


**The Geysers geothermal field:** Monitor changes associated with development and operation of existing geothermal power plants (22 existing power plants in the region)

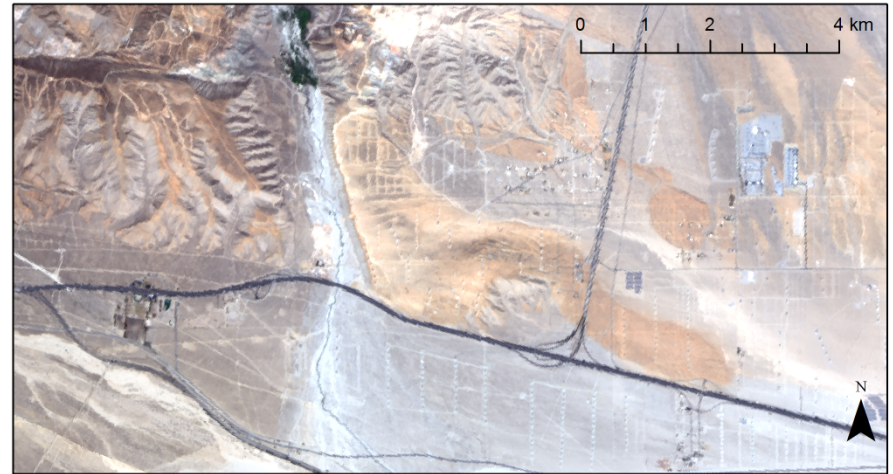




**Energy impacts:** Map and monitor surface cover and compositional change associated with development and operation of wind and solar farms



Altamont Pass wind farm Development began in 1981.

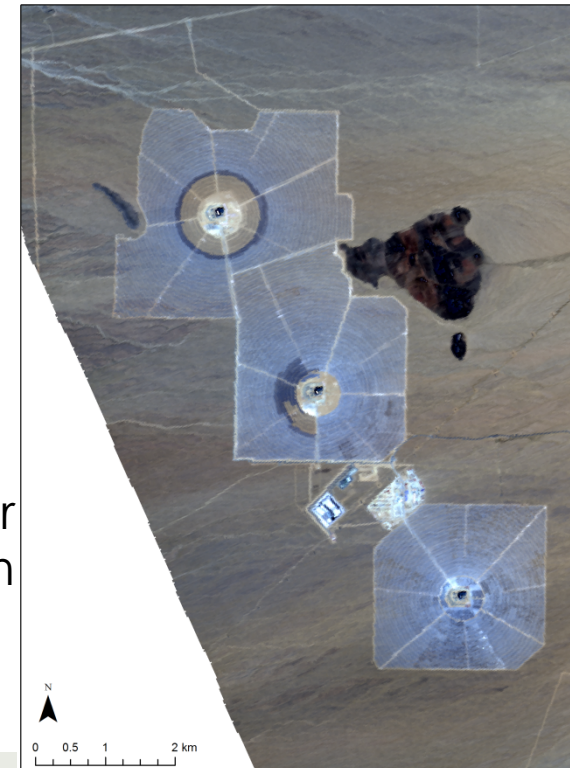


San Geronio  
wind farm

Development began  
in early 1980s.  
Combined with oil  
refinery and storage  
facility.

Ivanpah solar  
farm

Construction began in 2010,  
will be complete this year.  
World's largest solar plant.





# Rare Earth Minerals



Image USDA Farm Service Agency  
Image © 2012 DigitalGlobe  
Image U.S. Geological Survey  
Image © 2012 GeoEye

35°28'46.39" N 115°32'58.64" W elev 4848 ft

Google earth

Eye alt 17383 ft

Mountain Pass rare earth element mine



# Need for Critical Minerals

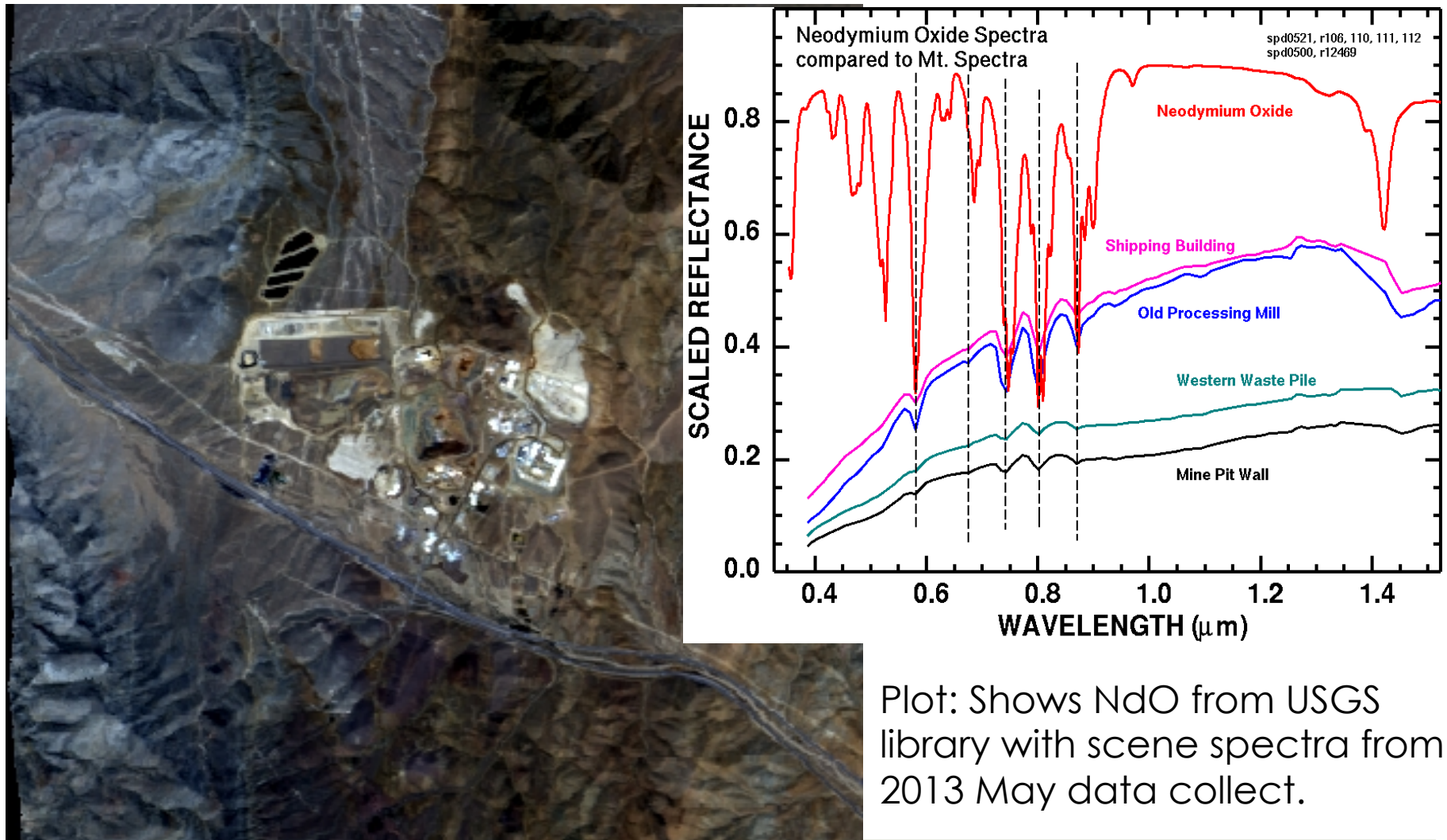
## ■ Rare earth elements

- Demand increasing
- Electronics, rechargeable batteries (cell phones, computers, cameras, electric & hybrid vehicles)
- Photovoltaic cells, energy-efficient lighting, wind power technologies
- Concern that China has supply control

## ■ Lithium

- Demand increasing
- Rechargeable batteries
- Only one lithium mine in the US

# Pearson: Areal Mixing of Rare Earth Elements: At What resolution do we lose REE signatures?



# Next Steps

- We are really just digging in to the data analysis.
- Plan to use reflectance “standard” products, see how well we do, see if we get the same answer over “stable” geologic sites in each season – toward an automated surface mineral cover map (NLCD).
- Assess temporal changes over renewable developments, mine site.
- Provide feedback on standard cal processing.
- Next year students and Betsy should have progress to report at this workshop, GSA or AGU.
  - Special HyspIRI session at AGU, IGARSS, or ASPRS?
  - Proposed session on spectral mineralogy for geosciences at GSA. (Satellite, airborne, field, core)