Distributed Mafic Rock Resources for CO_2 Mineralization in Arizona

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U.S. DEPARTMENT OF ENERGY

UA SCIENCE ARIZONA GEOLOGICAL SURVEY

NAU NORTHERN ARIZONA UNIVERSITY

ASU Arizona State University

Project Overview

Carbon Conversion
FOA2614: AOI 4
DE-FE0032252
2 Year Project
6/28/2023 – 6/27/2025

We are here!

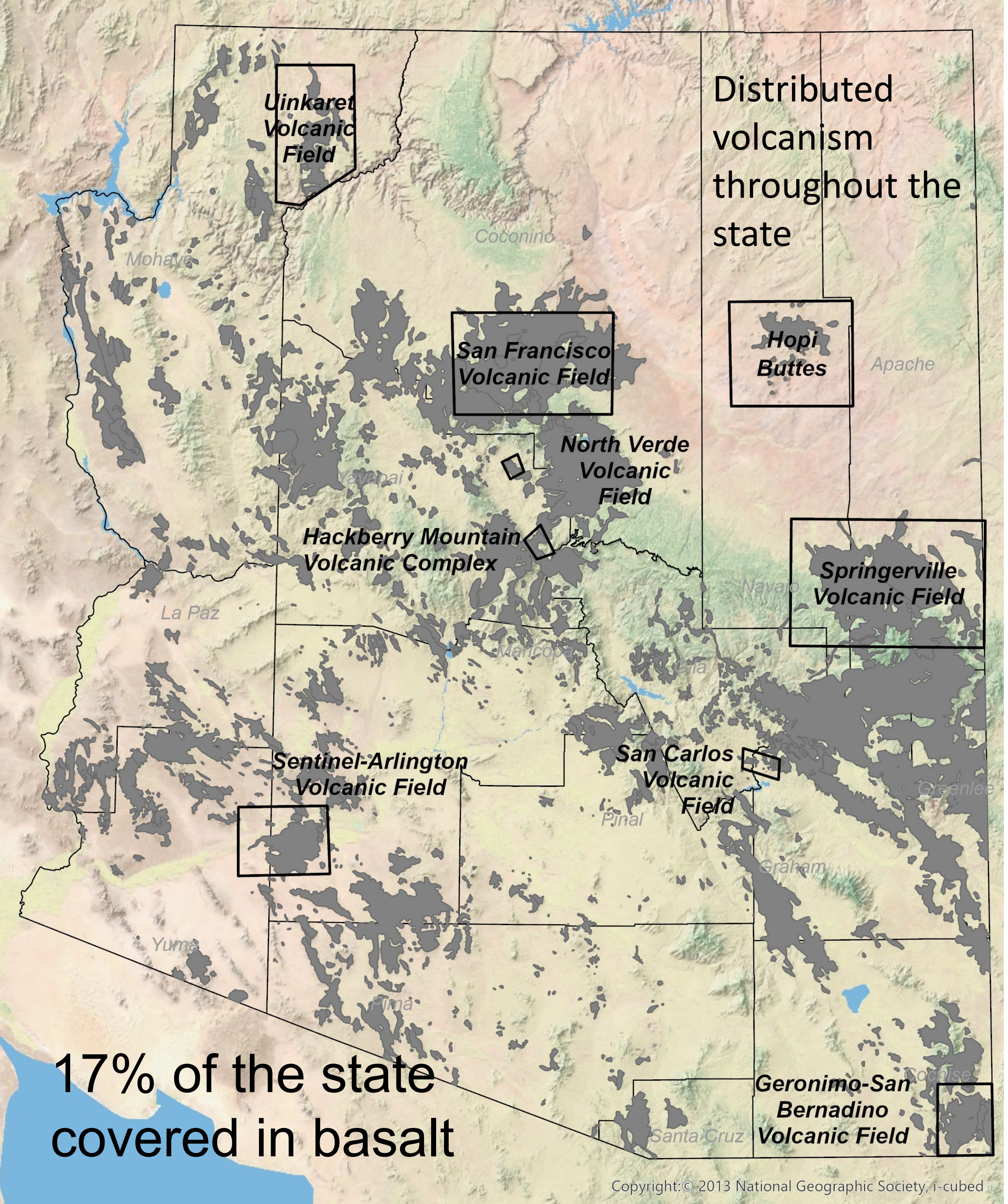
- Task 1: PM
- Task 2: MMRI research
- Task 3: Carbonation
- Task 4: MMRI database creation
- Task 5: Systems model
- Task 6: Outreach
- Task 7: Reporting

NAU: Ex-situ CO_2 reactivity testing of cinder at high temperatures and pressures

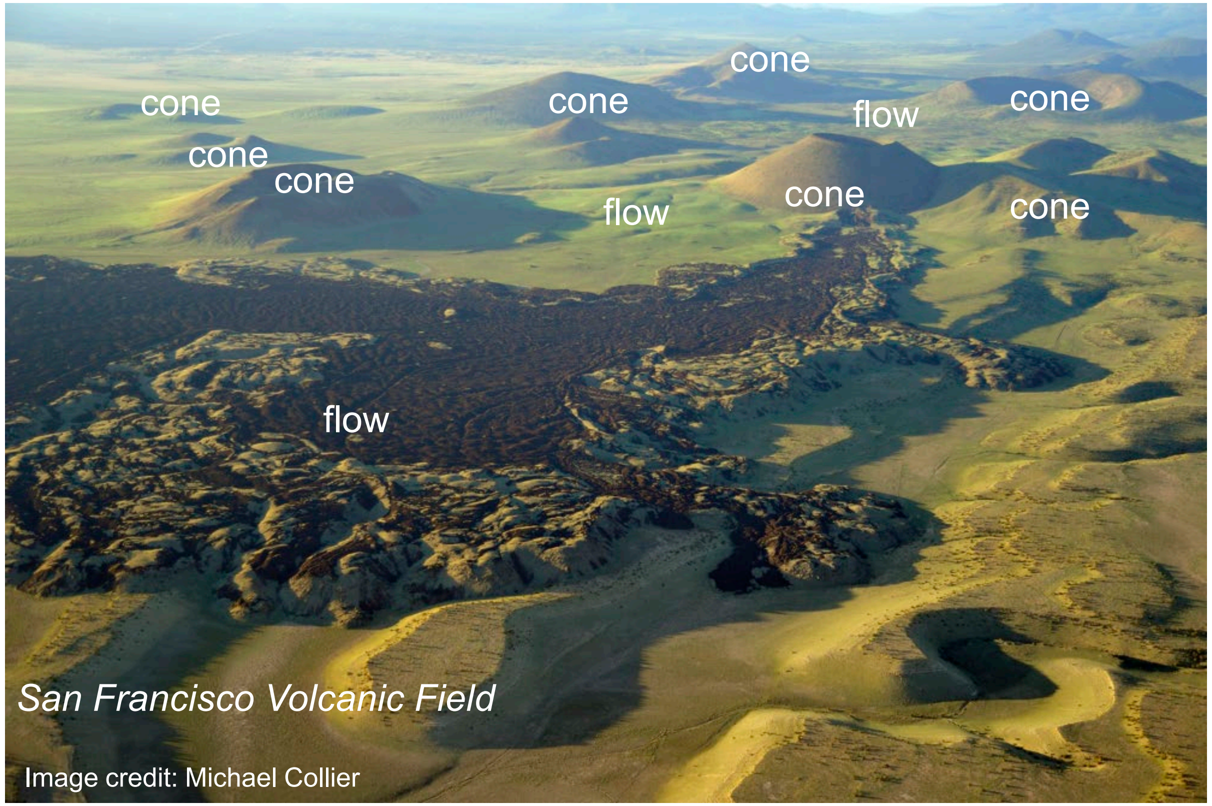
The Mafic Rock Resource Inventory (MMRI)

Direct Air Capture to Mineralization (DACM) systems model

Mafic volcanism in Arizona



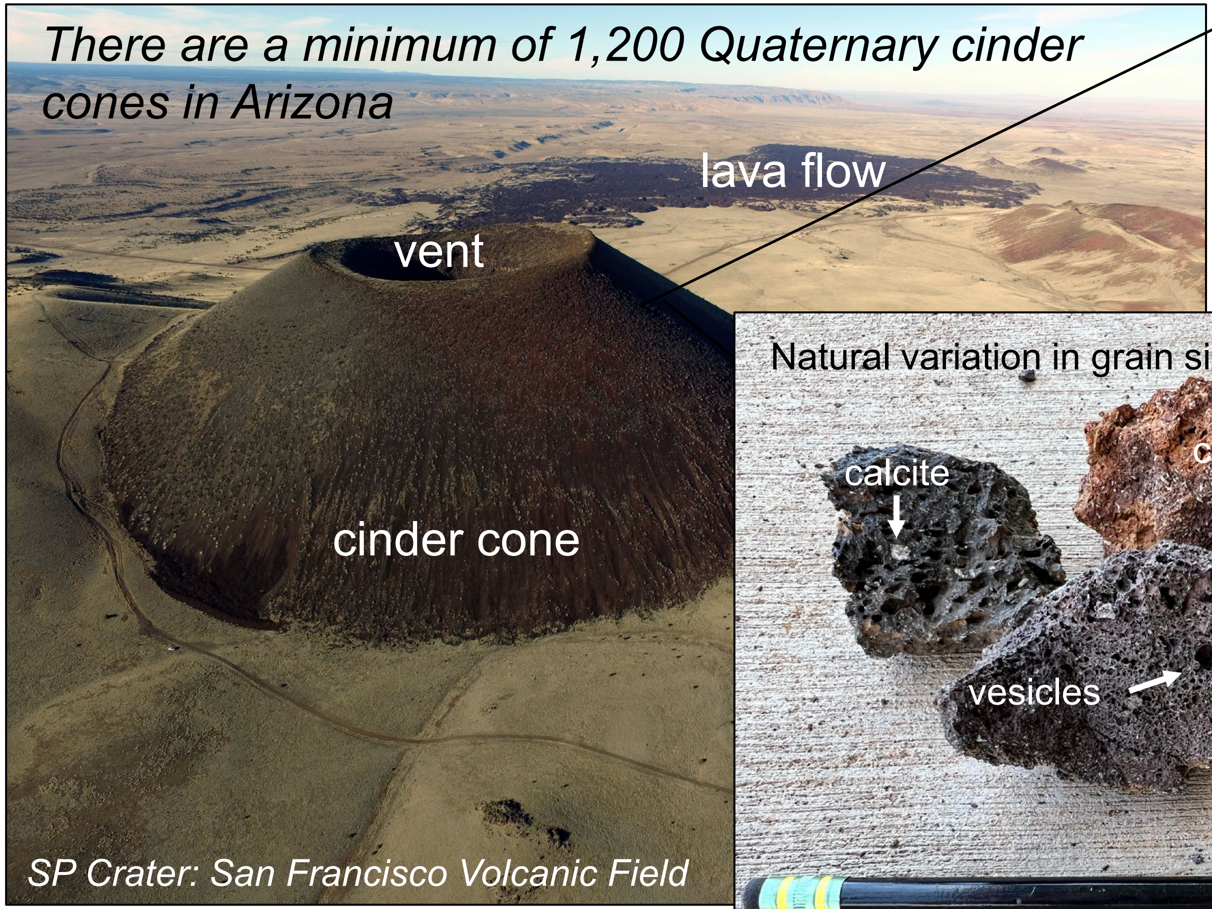
Geologically young mafic volcanic fields have many eruptive centers (cones) and lava flows

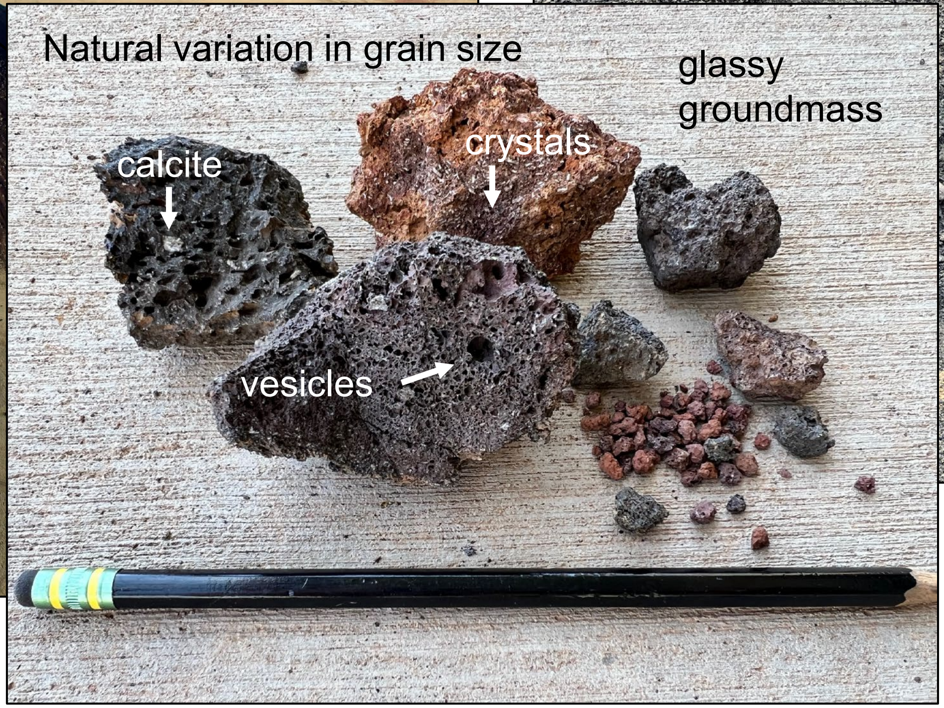


This Study's Focus: Cinder

Cinder cones occupy <1 km^3

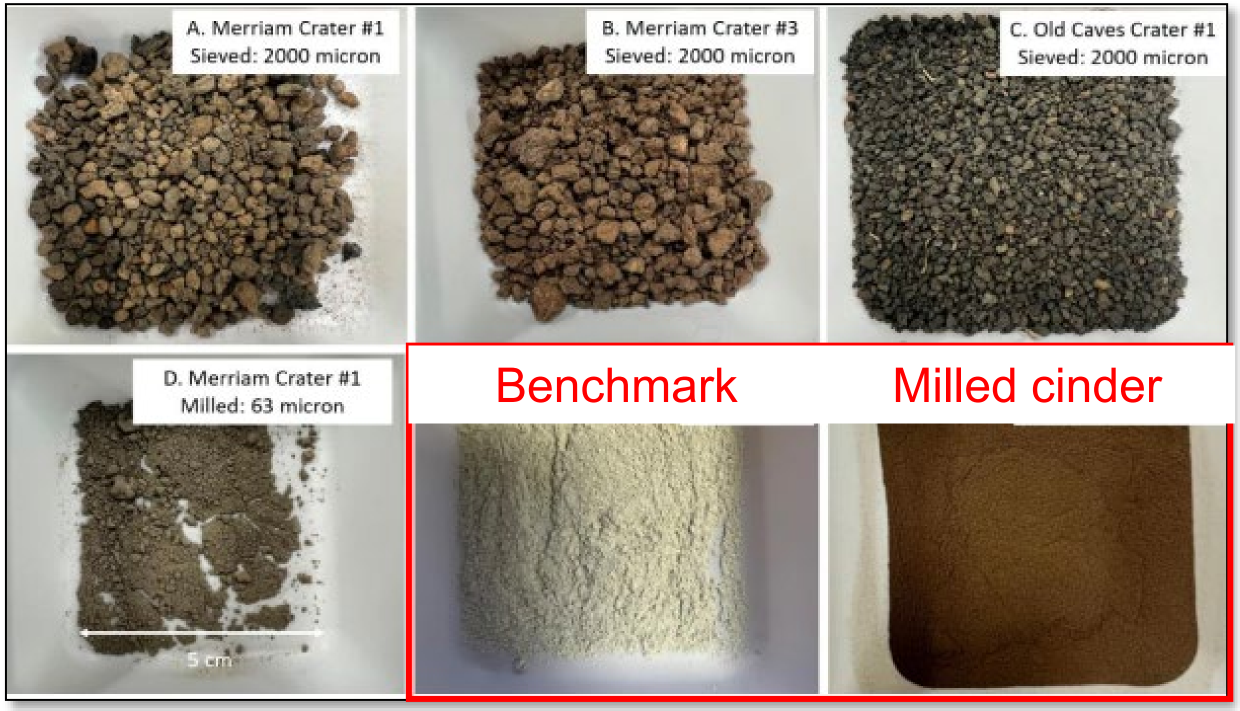
Cinder (scoria) is naturally fragmented, vesicular, and glassy

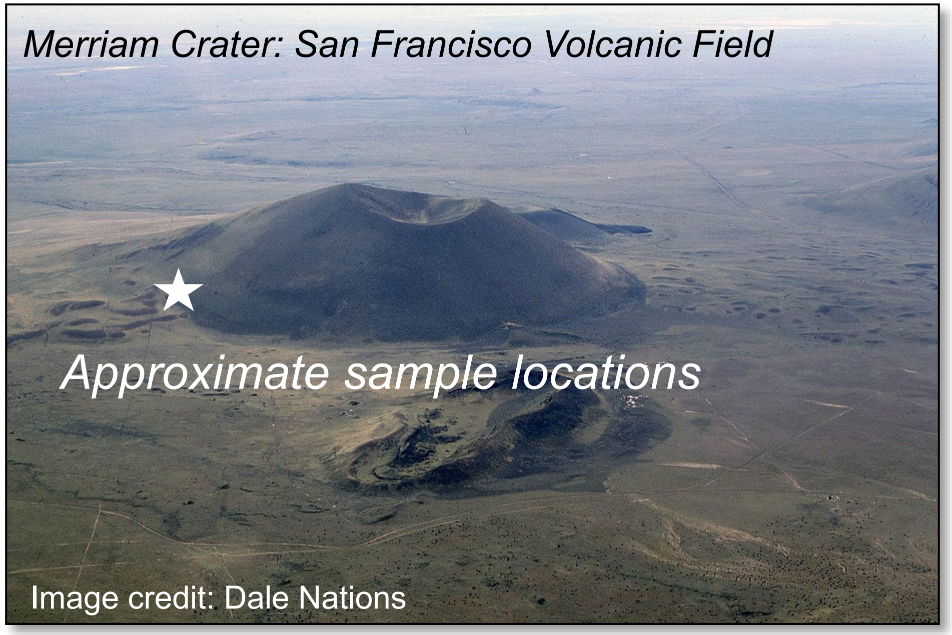




Preliminary studies: Ex-situ Cinder CO_2 Reactivity

Testing the efficacy of reacting CO_2 with cinder at **ambient temperatures/ pressures**





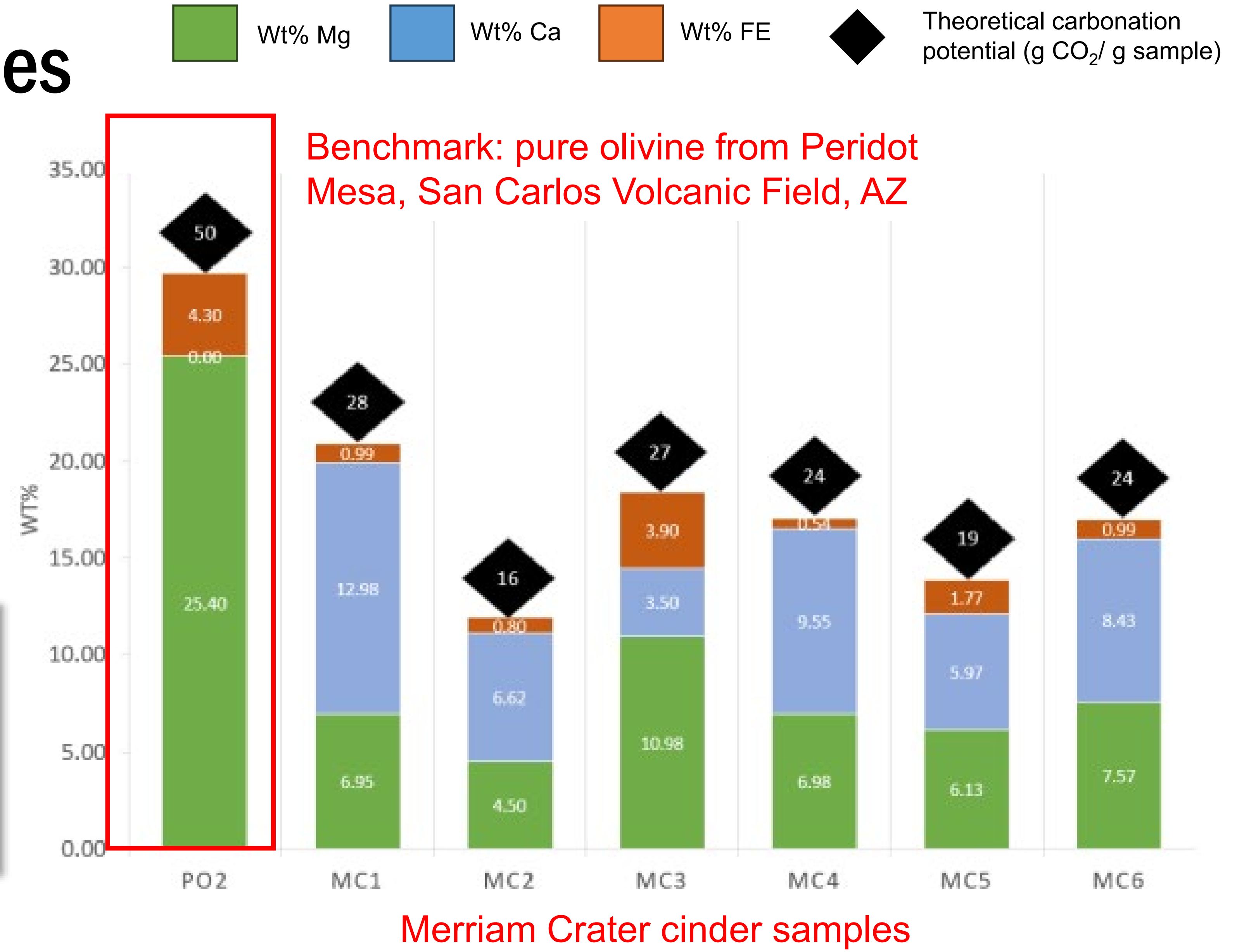
1. Mill then sieve to <63 micron powder
2. React in a buffered aqueous solution of 0.64 M $NaHCO_3$ supersaturated with CO_2 from a soda stream
3. Low intensity reactions over severl weeks

NAU

Preliminary studies: High Mg & Fe samples

Ideal is >10 wt% MgO

Powder XRF shows variable MgO, FeO, and CaO composition in unreacted samples



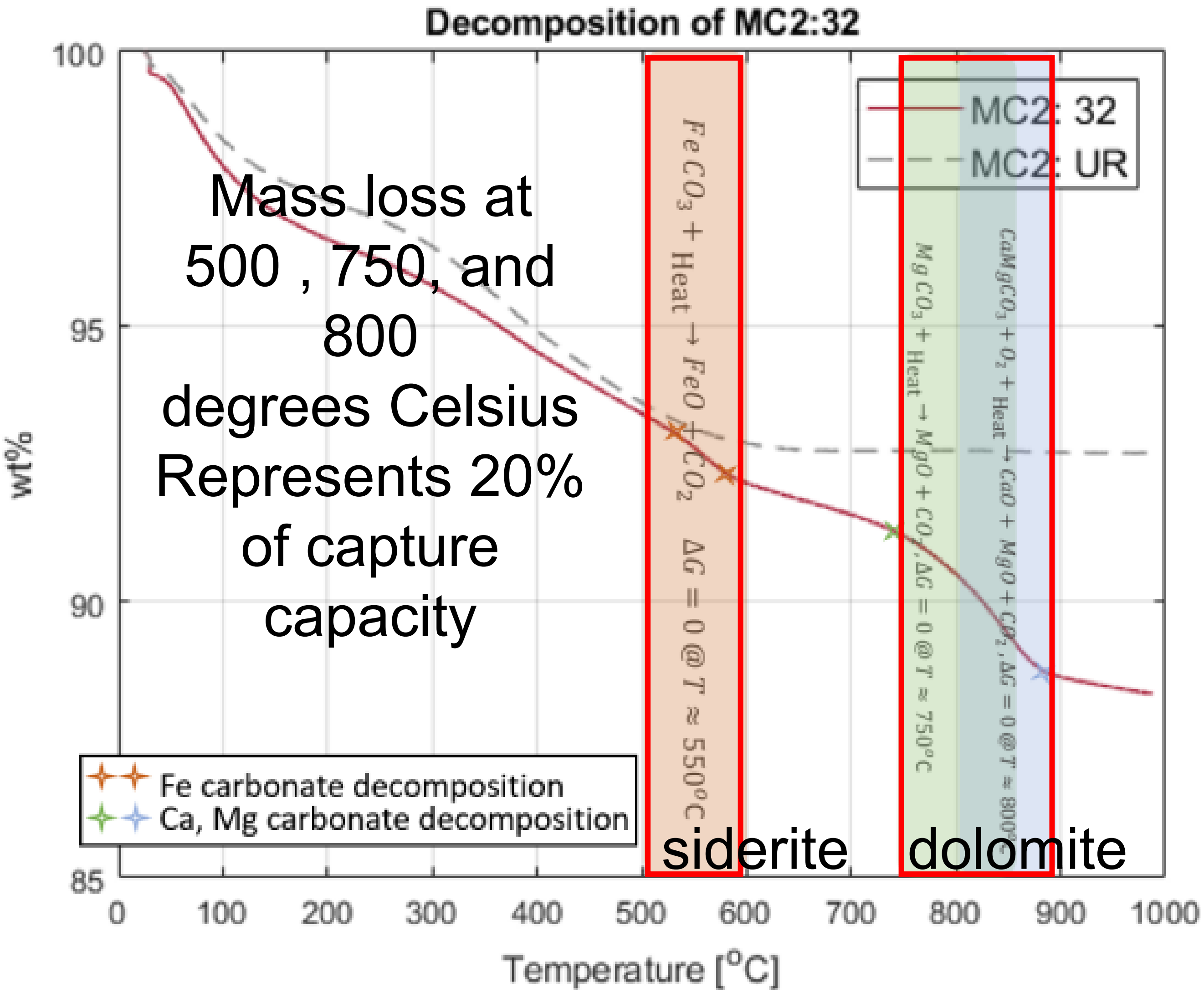
Preliminary studies: Reacted samples & produced carbonate

Test how much carbonate was produced through thermalgravimetric analysis (TGA)

TGA shows $FeCO_3$ (siderite) and $MgCO_3$ (dolomite) produced during mineralization

Ambient T/P

Reacted sample



Theoretical Capture Capacity

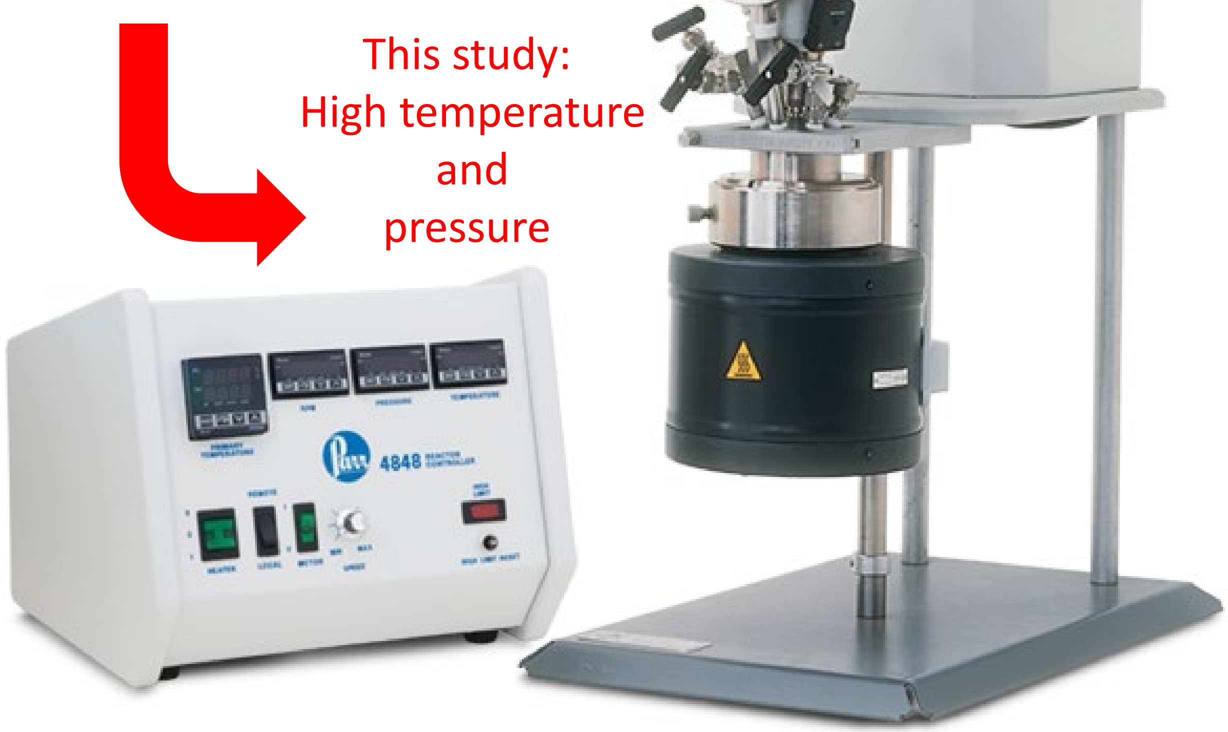
Theoretically, a 0.5 km^3 cinder cone with a bulk rock density of 2.8 g/cm^3 and an MgO average of 10 wt% would trap 11 wt% of CO_2 as $MgCO_3$. This is equivalent to **30 million metric tons of CO_2 per cone** if only 20% of the Mg is reacted.

(Fe trapped in carbonate is not accounted for in this theoretical calculation)

This study: Ex-situ mineralization at high T&P

Preliminary: Ambient temperature and pressure

This study:
High temperature
and
pressure



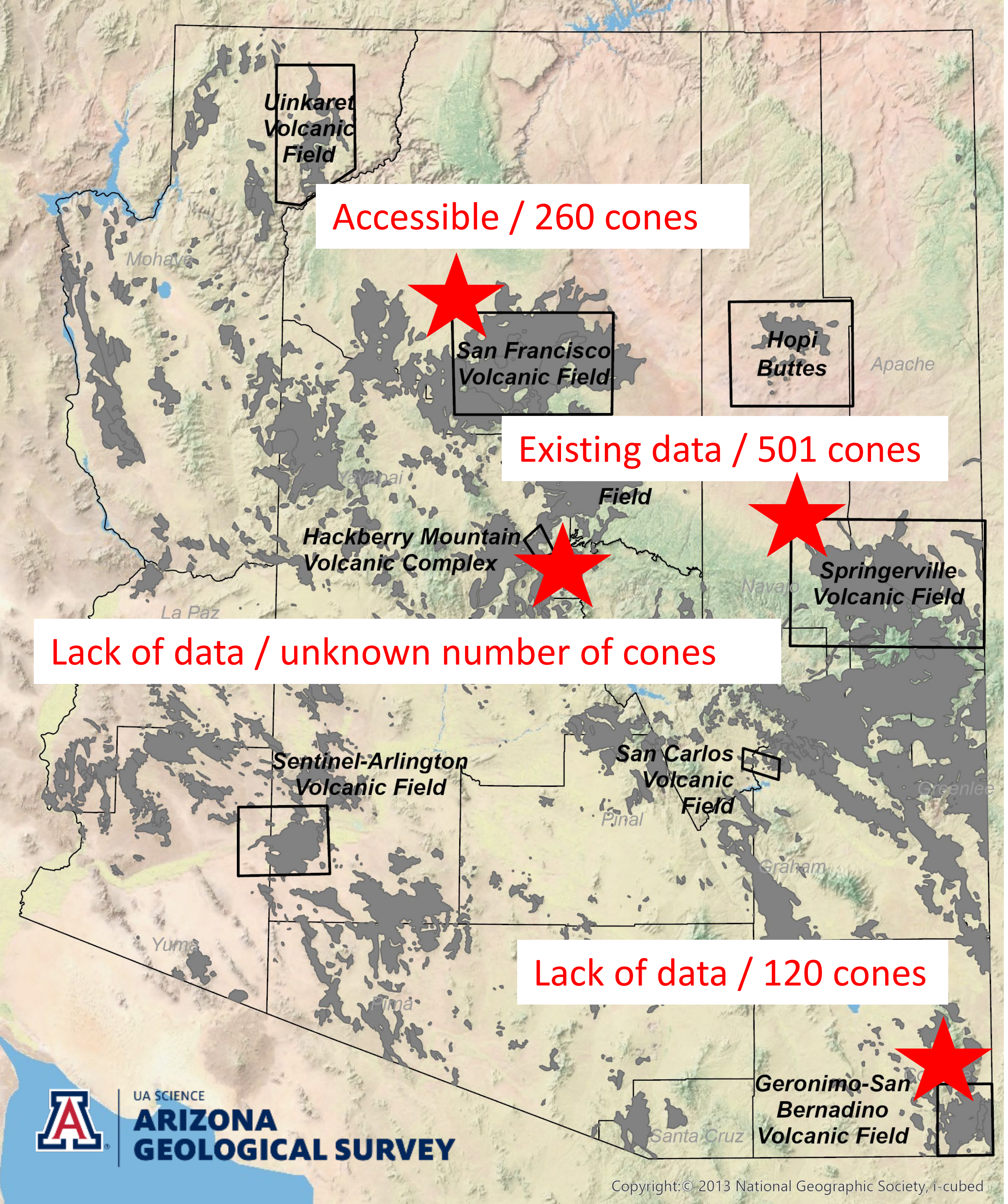
Benchmarked Direct Aqueous Mineralization [1]

- pH = 6.5 (NaHCO3 buffer)
- PCO2 = 140 bar
- T = 185 degrees Celsius
- Time ≤ 24 hours
- Mineral size = 34-100 microns
- Solid Loading: 15 wt%
- San Carlos olivine as benchmark

Objective: Maximize Reaction Extent, Accelerate Kinetics, Minimize energy intensity with parameters:

- Water Load
- Water salinity
- PCO_2 and T
- Particle Size

[1] *Environ. Sci. Technol.* 2007, 41, 7, 2587−2593

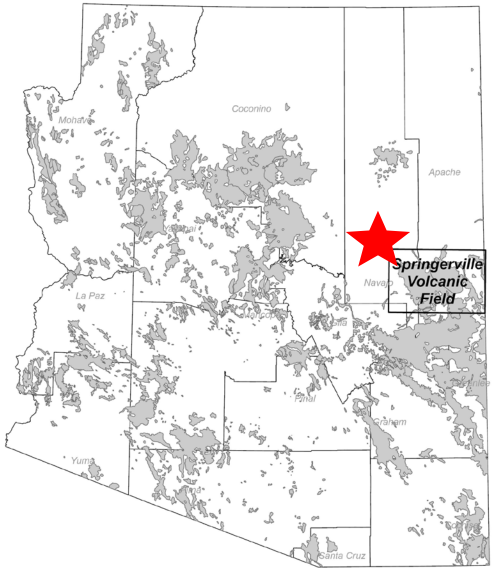


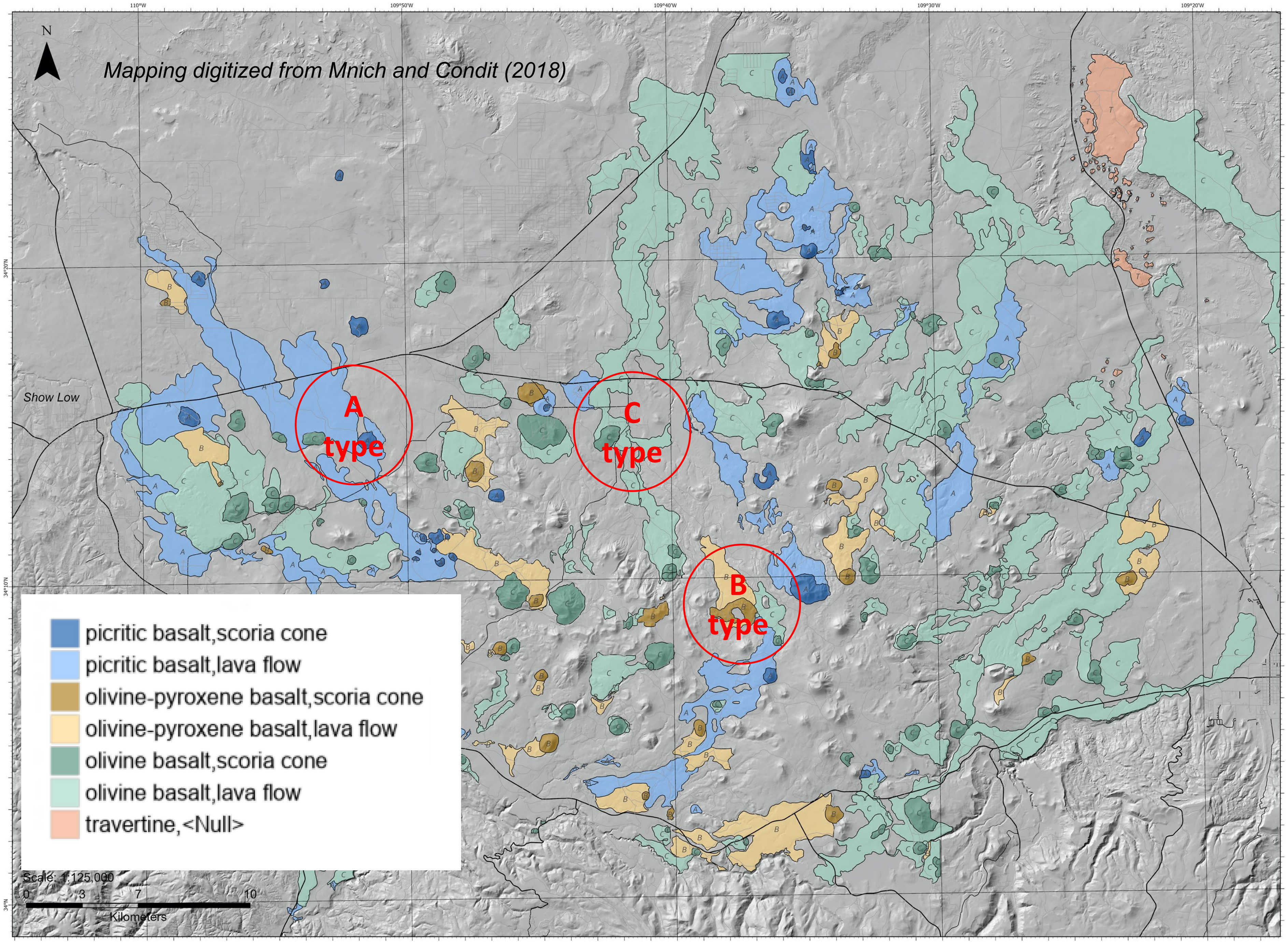
Mafic Rock Resource Inventory

Published data	• geochemistry • mapping
New 1:24K geologic mapping	• Cinder cone facies • Fill in data gaps
Cinder sampling/ handheld XRF	• Grain size/crystallinity variations
Whole rock geochemistry	• Statewide sample database
Thin section analysis	• Pre-reaction mineral ID and abundance
Porosity/permeability	• Pre- and post reaction physical properties
TGA/XRF/XRD/SEM	• Post-reaction mineral ID
Reaction kinetics	• Parameters and reaction extent • Kinetics
Land use/ water chemistry	• Economize ex-situ reactions • Systems model development

Magmatic Mapping:

Cones and flows related to one another by chemistry & ranked by olivine content

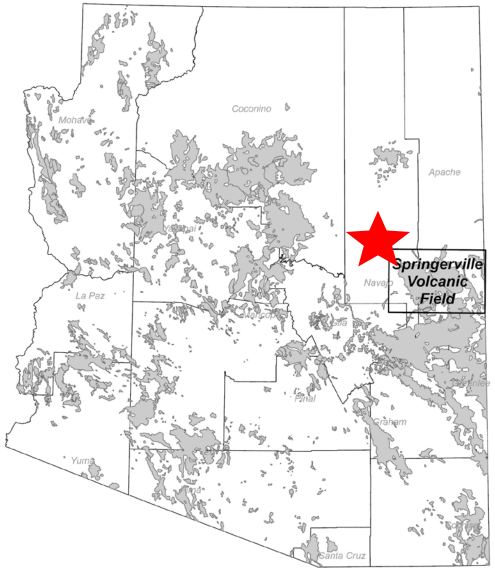


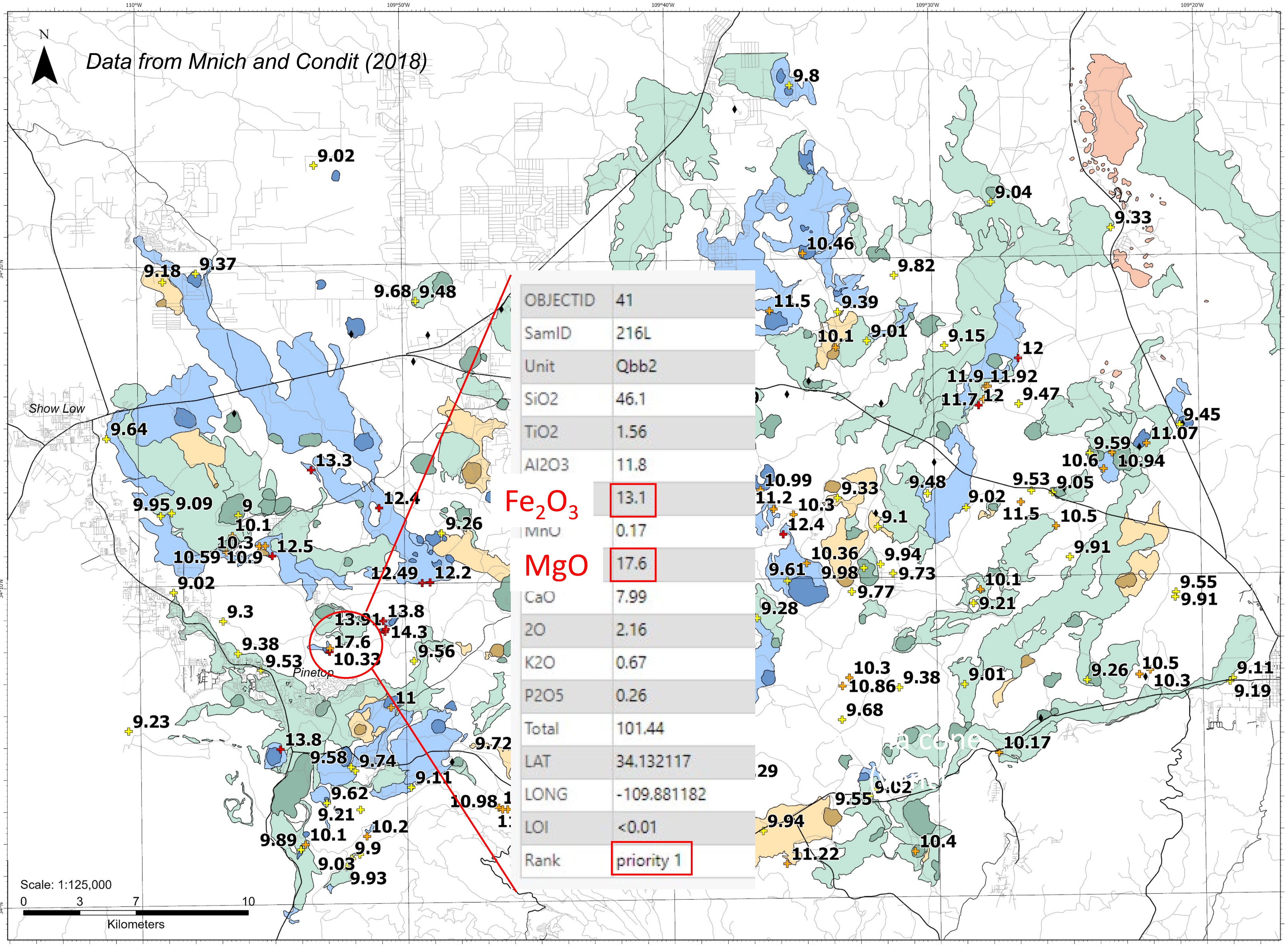


Whole rock geochemistry

Bulk rock major element analysis

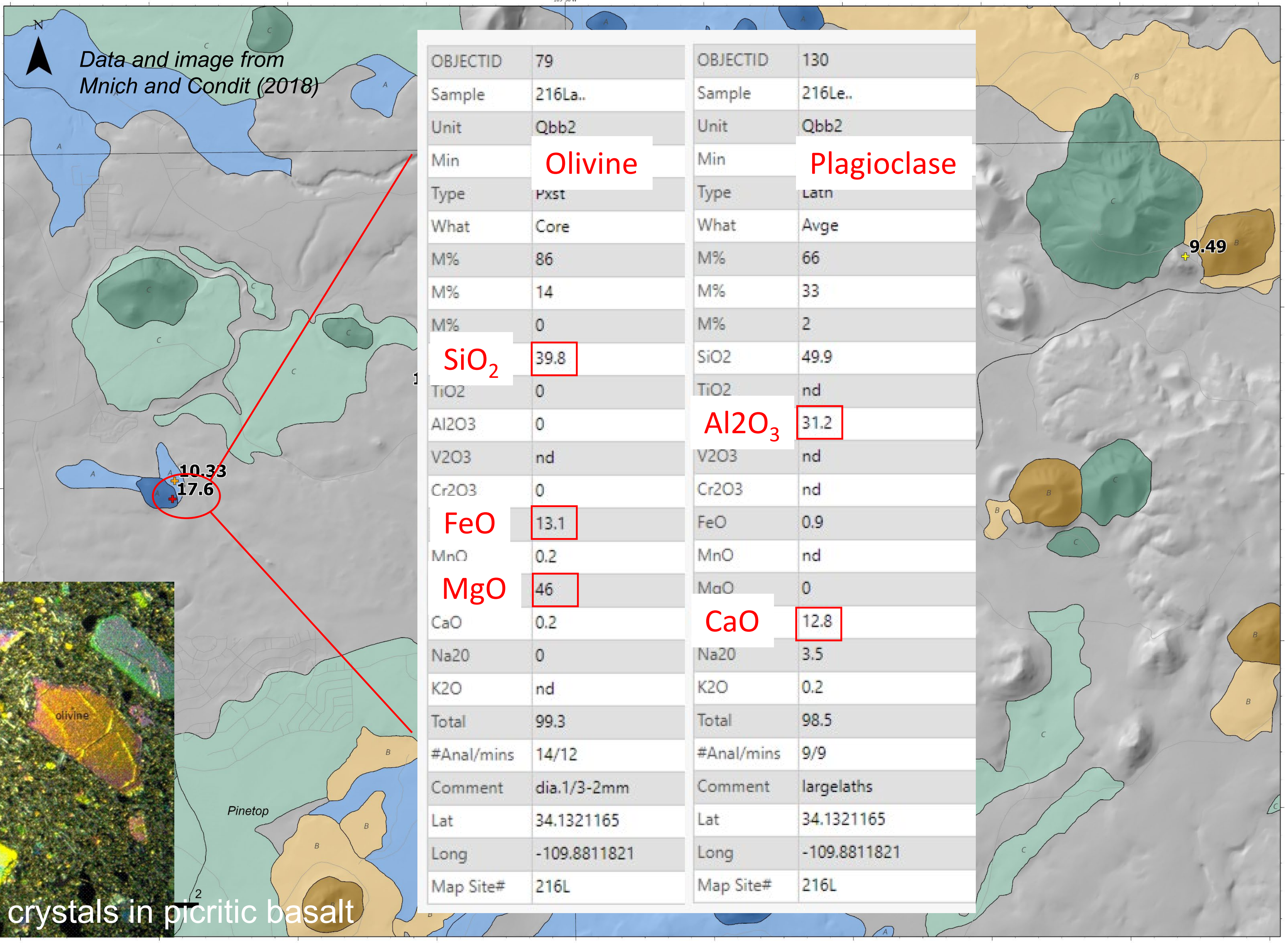
MgO >10% wt% will guide sampling strategy





Mineral chemistry

Mineral major element analysis contextualizes reactivity rates and products



OBJECTID	79
Sample	216La..
Unit	Qbb2
Min	Olivine
Type	Pxst
What	Core
M%	86
M%	14
M%	0
SiO2	39.8
TiO2	0
Al2O3	0
V2O3	nd
Cr2O3	0
FeO	13.1
MnO	0.2
MgO	46
CaO	0.2
Na20	0
K2O	nd
Total	99.3
#Anal/mins	14/12
Comment	dia.1/3-2mm
Lat	34.1321165
Long	-109.8811821
Map Site#	216L

OBJECTID	130
Sample	216Le..
Unit	Qbb2
Min	Plagioclase
Type	Latn
What	Avge
M%	66
M%	33
M%	2
SiO2	49.9
TiO2	nd
Al2O3	31.2
V2O3	nd
Cr2O3	nd
FeO	0.9
MnO	nd
MgO	0
CaO	12.8
Na20	3.5
K2O	0.2
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Comment	largelaths
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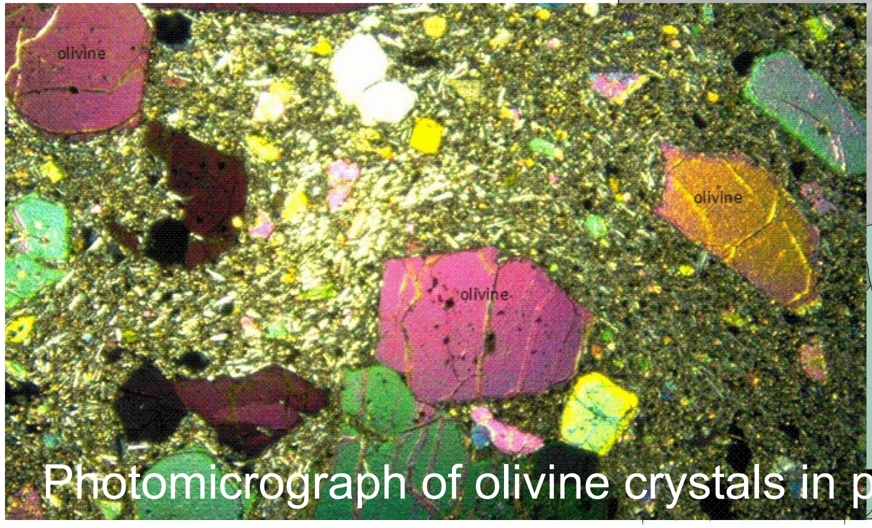
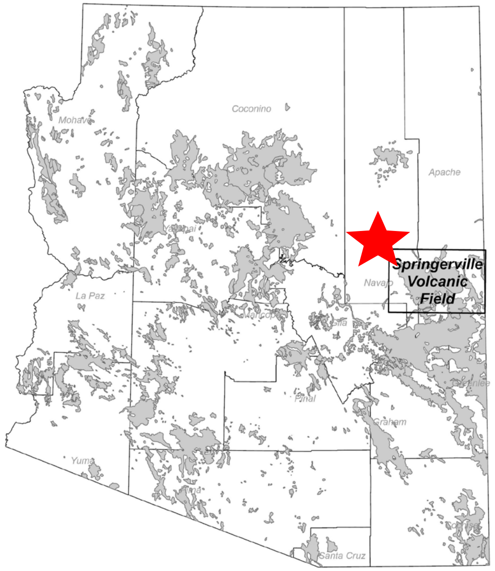
Map Site#	216L

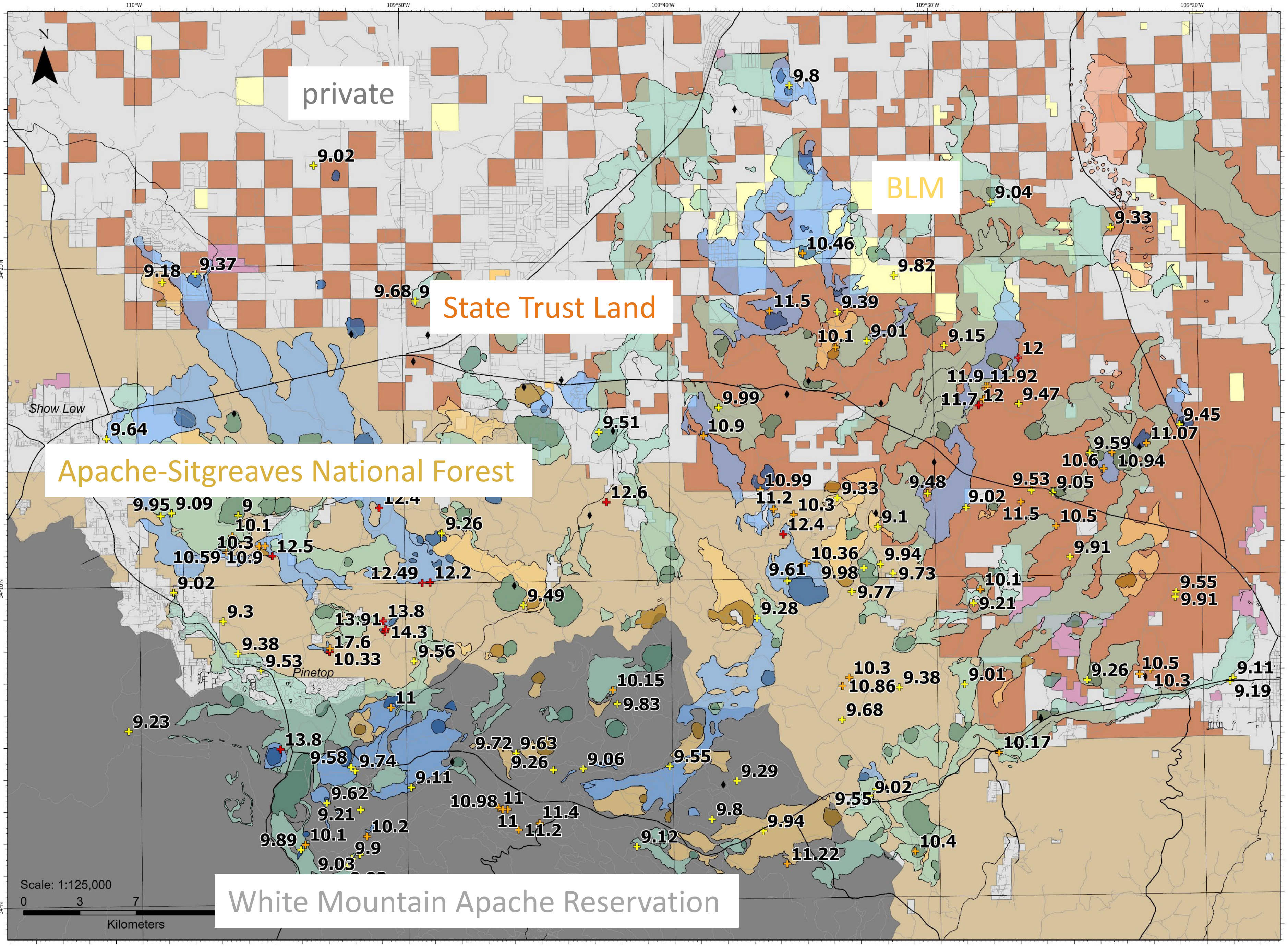


Photomicrograph of olivine crystals in picritic basalt

Land ownership

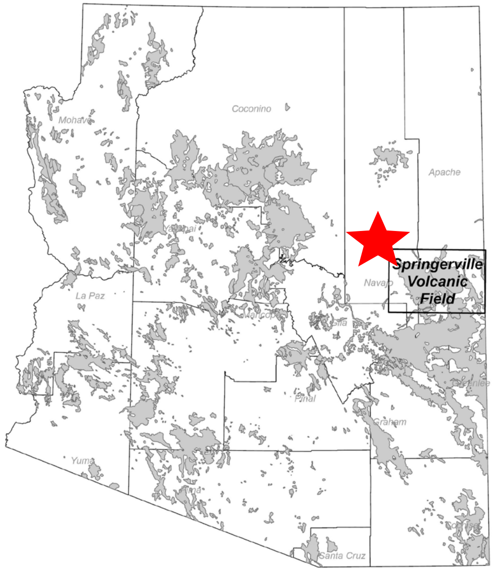
Land ownership intersected with high priority targets to inform an economic model

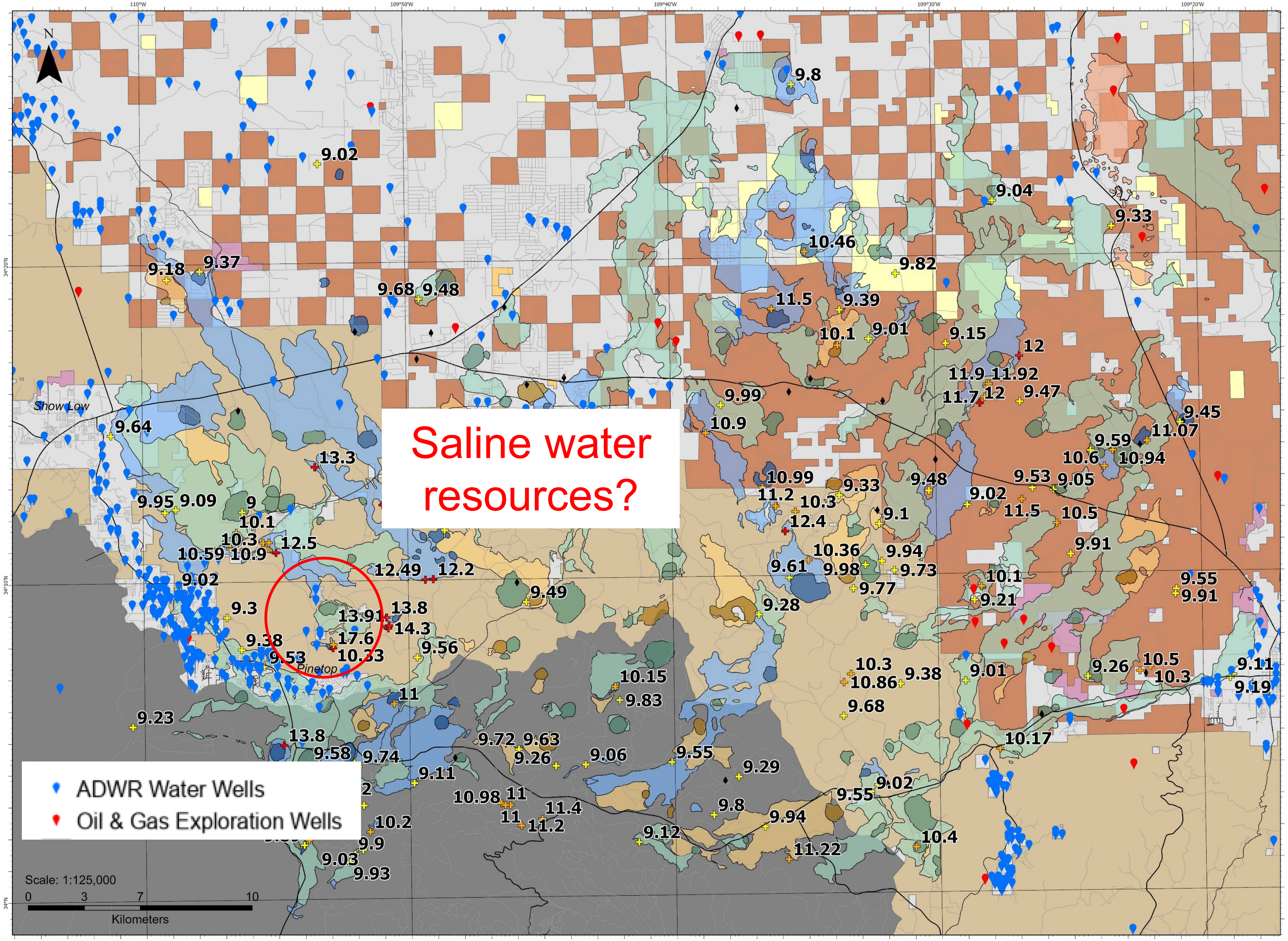




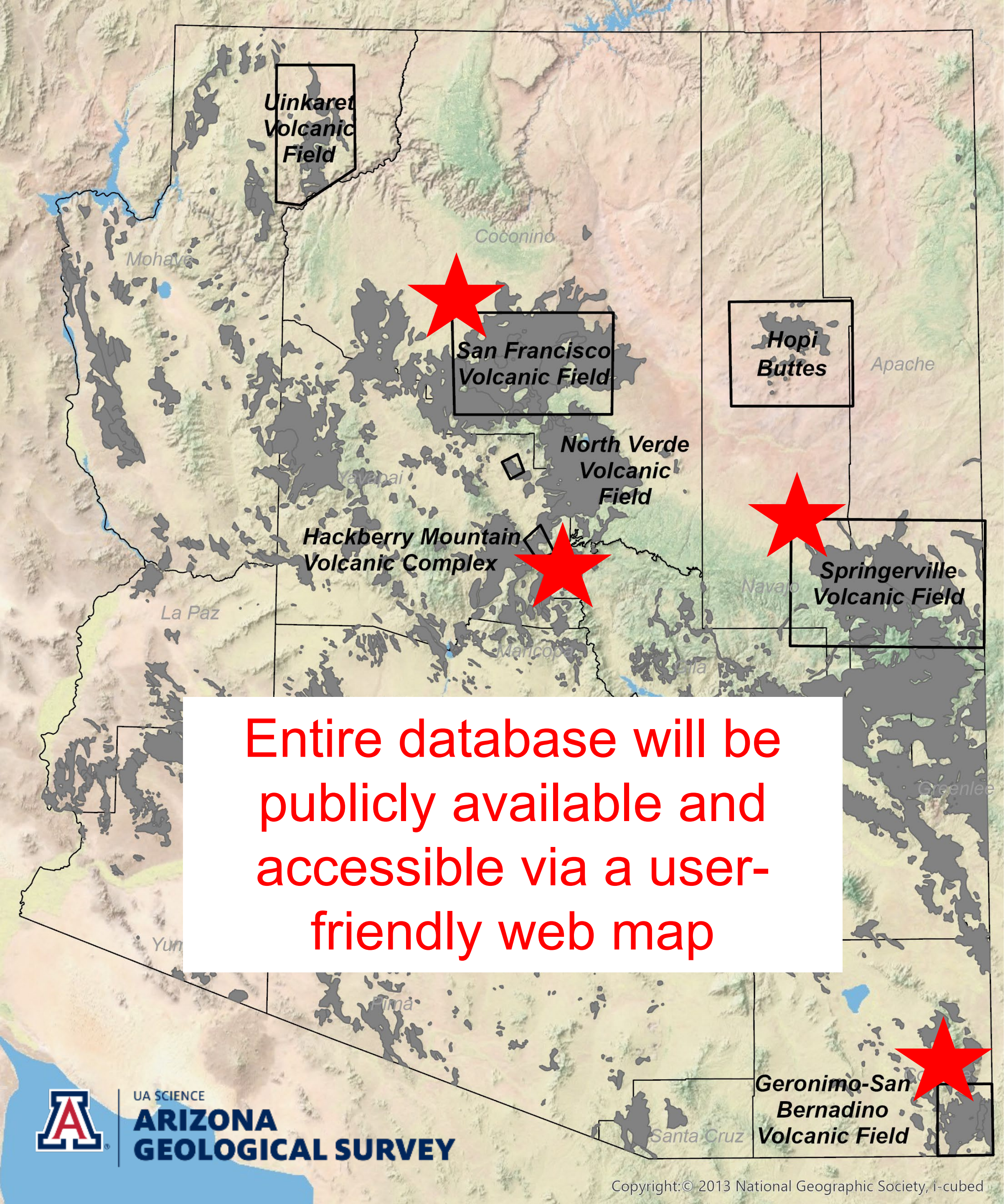
Water quality

Wells with total dissolved solids (TDS) data appended for systems model





Mafic Rock Resource Inventory



Entire database will be publicly available and accessible via a user-friendly web map

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Many cones are already mined

Cinder is mined throughout the state for landscaping and road surfacing material

Direct Air Capture to Mineralization Systems Model

DAC
Mechanical
Trees capture
1 T CO_2/day

+

Mine, sieve, mill, react cinder on site

+

Renewable
Energy

CO_2 delivered in bicarbonate brine using saline groundwater

Provide a quantifiable model that describes generic implementation

What amount of capital, equipment, energy, water, and disposal are required?

What are the environmental impacts?

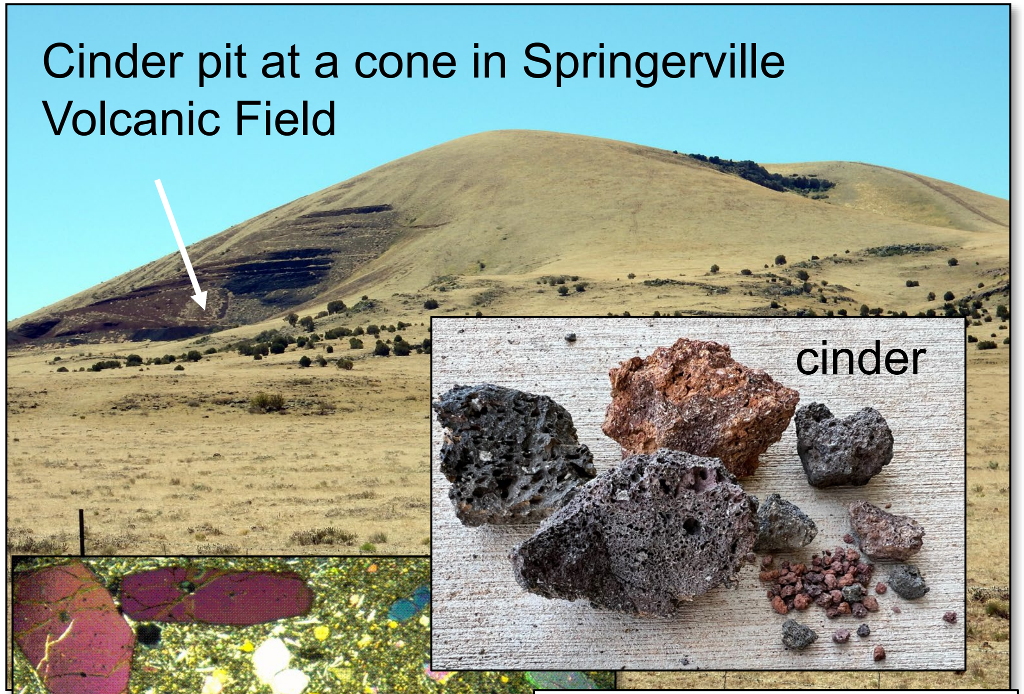
Environmental Justice considerations?

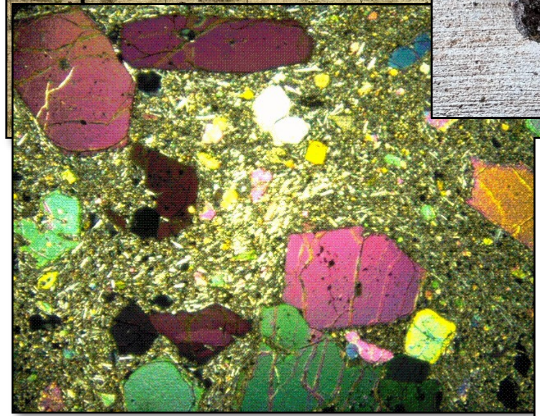
What uses are there for the reacted material?

Arizona State University

Summary

- Low intensity CO_2 reactions with cinder produce iron carbonate and dolomite; represents 20% of the theoretical CO_2 capture capacity of sample (prelim to Task 3).
- Equipment for high intensity reactions is being procured (Task 1)
- MMRI is being developed in ArcGIS synthesizing published data (Tasks 2 and 4)
- DACM will leverage data from MMRI and reaction experiments





Photomicrograph of olivine crystals (bright colors) in picritic basalt

Next steps: Geologic mapping, sampling, and reacting!

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at the University of Arizona

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