Critical Minerals Texas Potential: Lignites and Rhyolites

Oklahoma Geological Survey
Critical Minerals Workshop
November 9th, 2021

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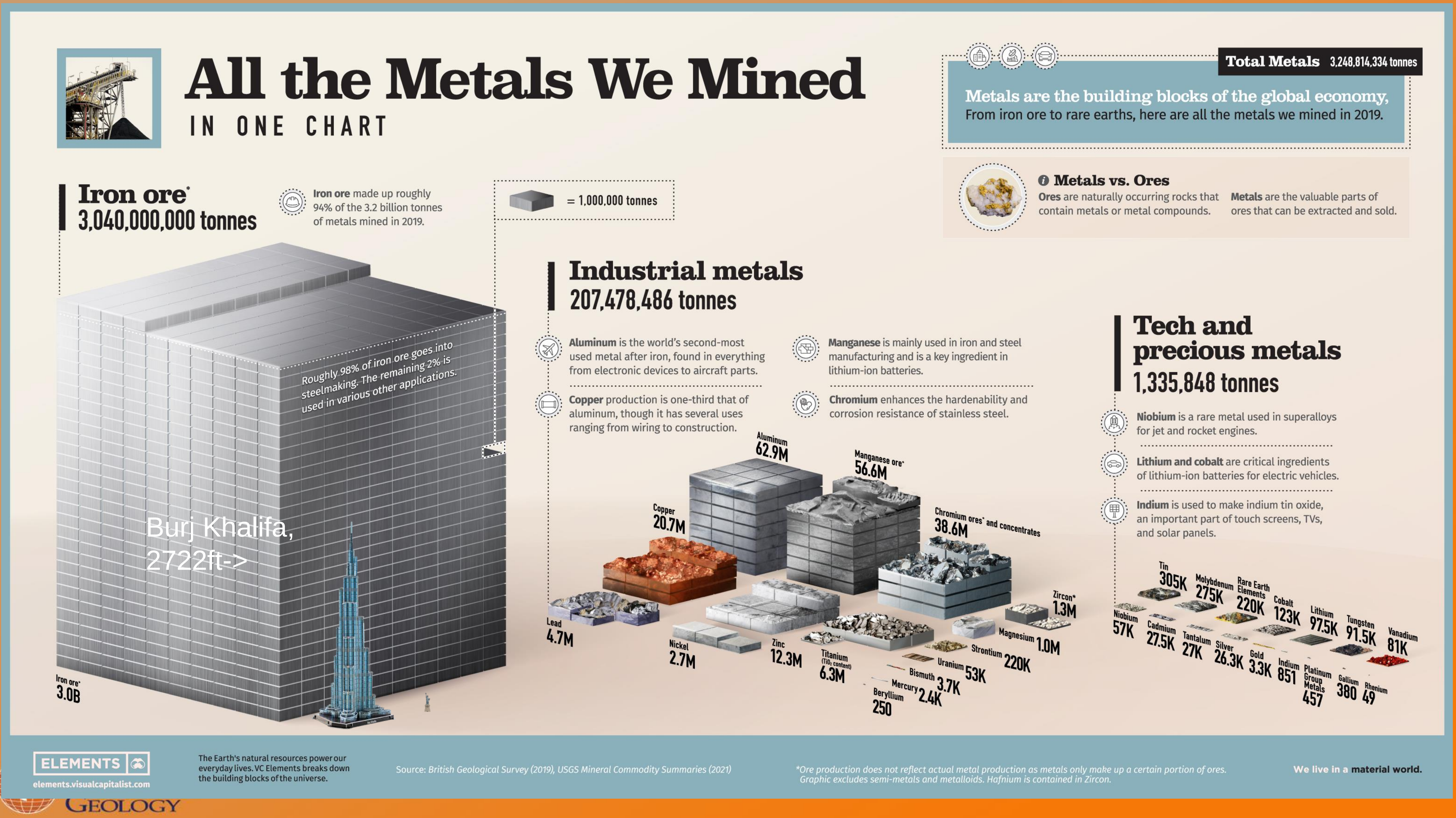
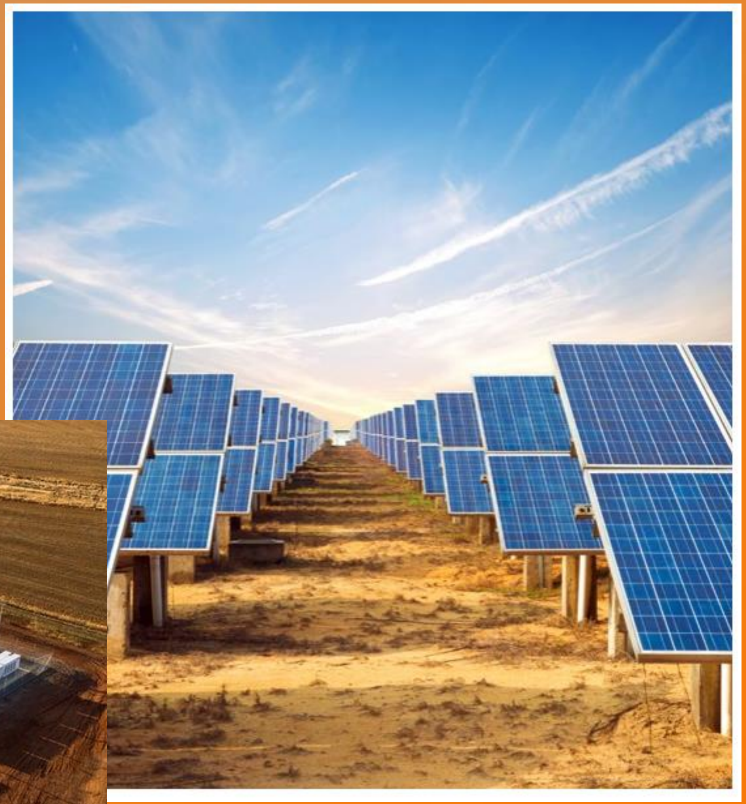


All the Metals We Mined
IN ONE CHART
Total Metals 3,248,814,334 tonnes
Metals are the building blocks of the global economy.
From iron ore to rare earths, here are all the metals we mined in 2019.
Metals vs. Ores
Ores are naturally occurring rocks that contain metals or metal compounds.
Metals are the valuable parts of ores that can be extracted and sold.
Iron ore*
3,040,000,000 tonnes
Iron ore made up roughly 94% of the 3.2 billion tonnes of metals mined in 2019.
= 1,000,000 tonnes
Roughly 98% of iron ore goes into steelmaking. The remaining 2% is used in various other applications.
Burj Khalifa, 2722ft->
Iron ore* 3.0B
Industrial metals
207,478,486 tonnes
Aluminum is the world's second-most used metal after iron, found in everything from electronic devices to aircraft parts.
Copper production is one-third that of aluminum, though it has several uses ranging from wiring to construction.
Manganese is mainly used in iron and steel manufacturing and is a key ingredient in lithium-ion batteries.
Chromium enhances the hardenability and corrosion resistance of stainless steel.
Aluminum 62.9M
Manganese ore* 56.6M
Chromium ores* and concentrates 38.6M
Copper 20.7M
Zinc 12.3M
Titanium (TiO₂ content) 6.3M
Lead 4.7M
Nickel 2.7M
Zircon* 1.3M
Magnesium 1.0M
Strontium 220K
Uranium 53K
Bismuth 3.7K
Mercury 2.4K
Beryllium 250
Tech and precious metals
1,335,848 tonnes
Niobium is a rare metal used in superalloys for jet and rocket engines.
Lithium and cobalt are critical ingredients of lithium-ion batteries for electric vehicles.
Indium is used to make indium tin oxide, an important part of touch screens, TVs, and solar panels.
Tin 305K
Molybdenum 275K
Rare Earth Elements 220K
Cobalt 123K
Lithium 97.5K
Tungsten 91.5K
Vanadium 81K
Niobium 57K
Cadmium 27.5K
Tantalum 27K
Silver 26.3K
Gold 3.3K
Indium 851
Platinum Group Metals 457
Gallium 380
Rhenium 49
ELEMENTS
elements.visualcapitalist.com
The Earth's natural resources power our everyday lives. VC Elements breaks down the building blocks of the universe.
Source: British Geological Survey (2019), USGS Mineral Commodity Summaries (2021)
*Ore production does not reflect actual metal production as metals only make up a certain portion of ores.
Graphic excludes semi-metals and metalloids. Hafnium is contained in Zircon.
We live in a material world.
GEOLOGY

State of Economics - Demand

The Energy Transition



Telsa 100MW station, South Australia (30,000 homes for 1hr)

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State of Economics - Demand

The Energy Transition

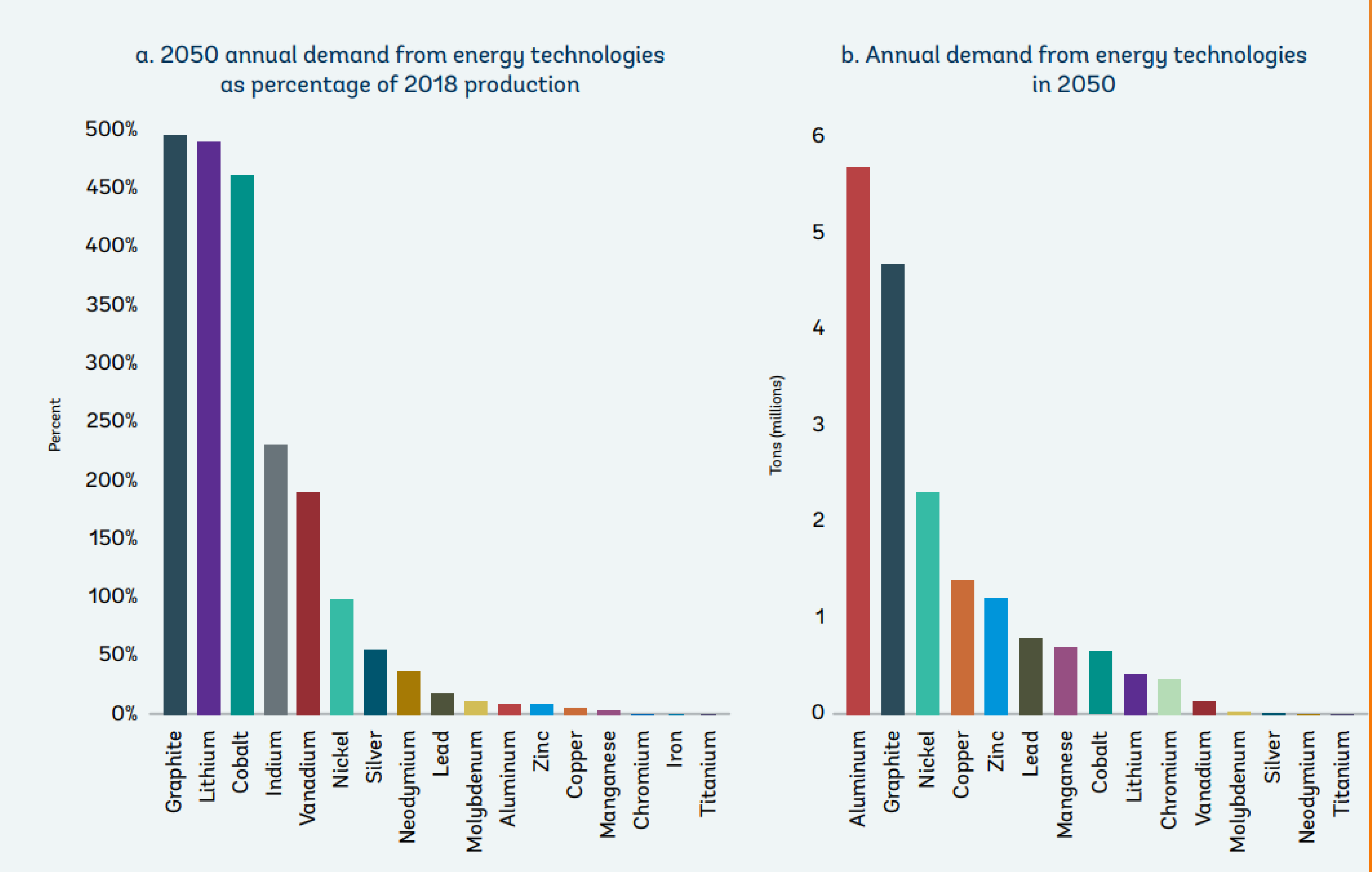
2020 World Bank Report: Minerals for Climate Action

UNFCC Paris Agreement means to limit global warming by 2°C (2DS)

This inherently means more material needed to build energy technology

Increase only accounts for energy technology demand

Figure 4.3 Projected Annual Mineral Demand Under 2DS Only from Energy Technologies in 2050, Compared to 2018 Production Levels



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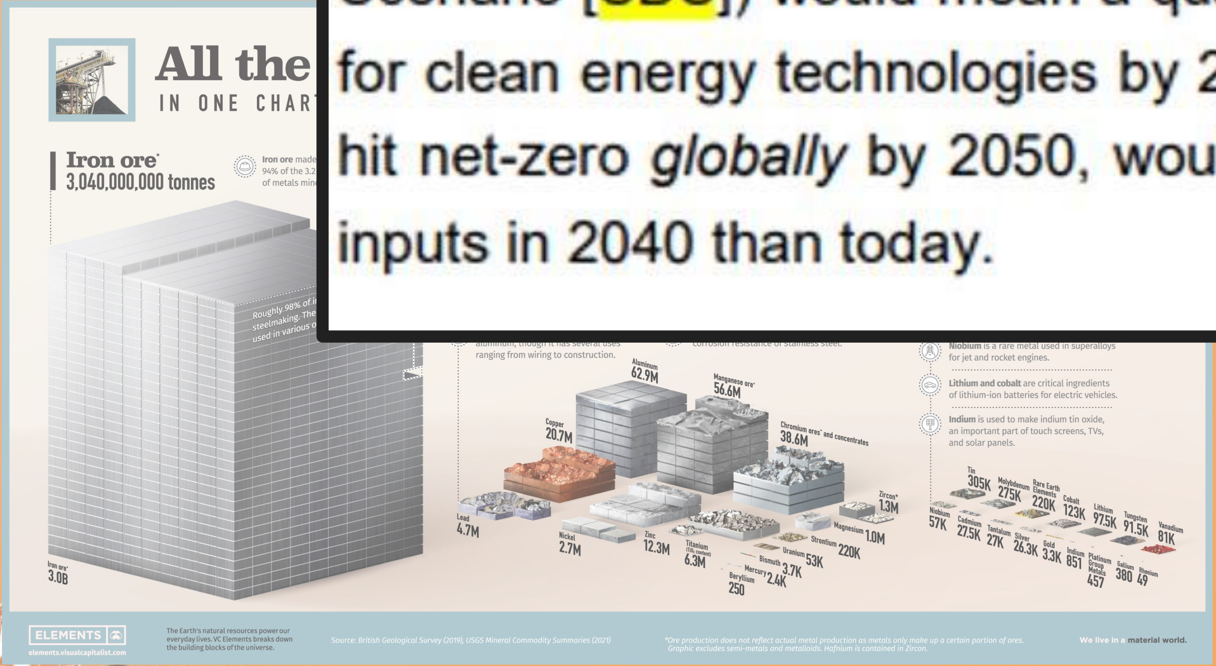
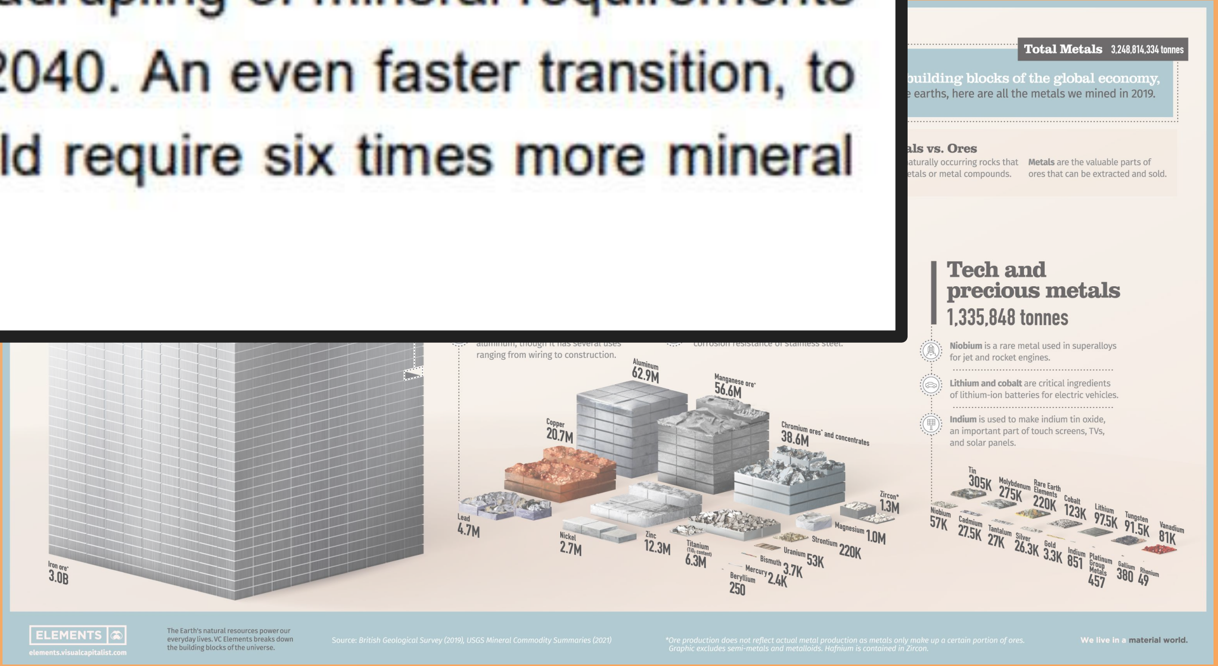



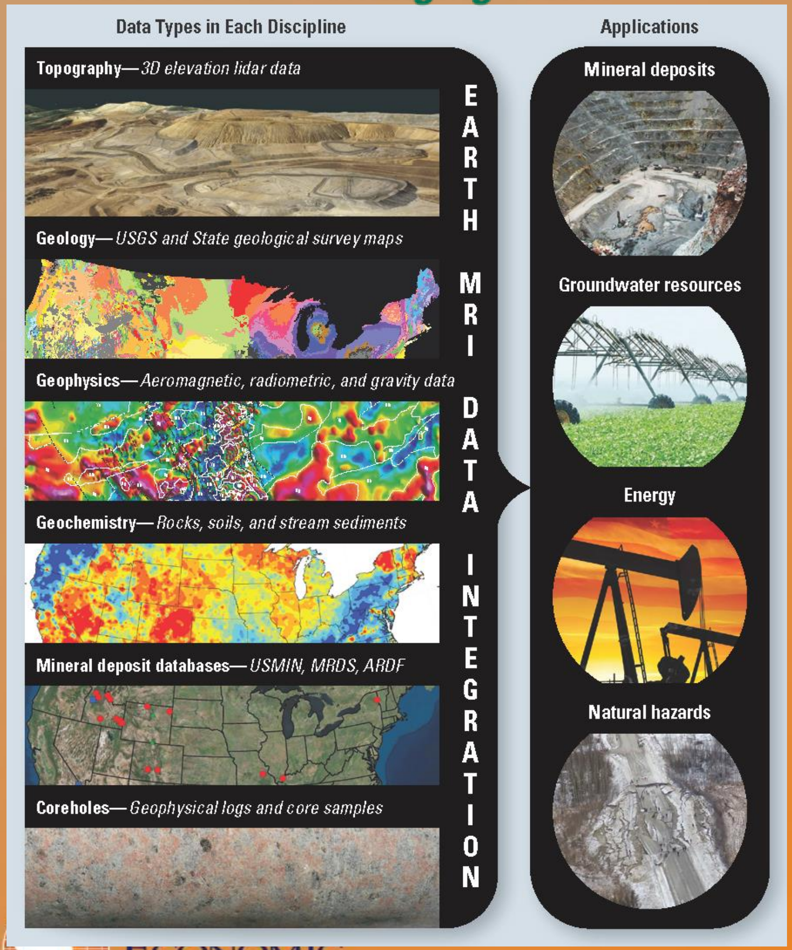
Our bottom-up assessment suggests that a concerted effort to reach the goals of the Paris Agreement (climate stabilisation at "well below 2°C global temperature rise", as in the IEA Sustainable Development Scenario [SDS]) would mean a quadrupling of mineral requirements for clean energy technologies by 2040. An even faster transition, to hit net-zero *globally* by 2050, would require six times more mineral inputs in 2040 than today.

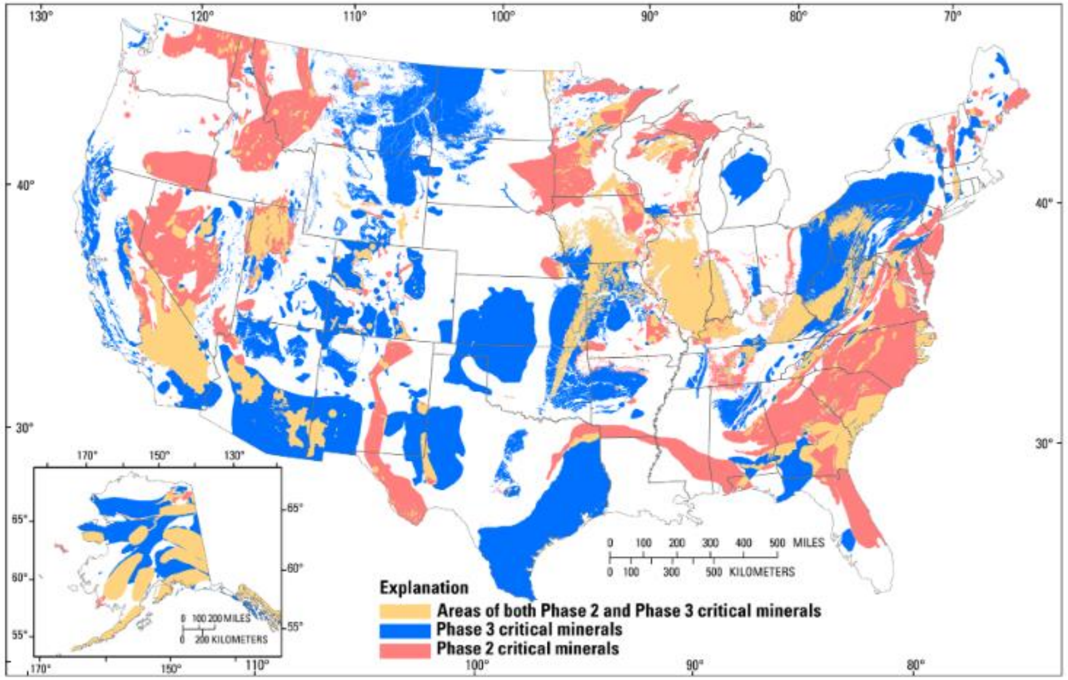
GEOLOGY

State of Economics - Supply

US Response

science for a changing world





Earth MRI Project Phase Critical Minerals

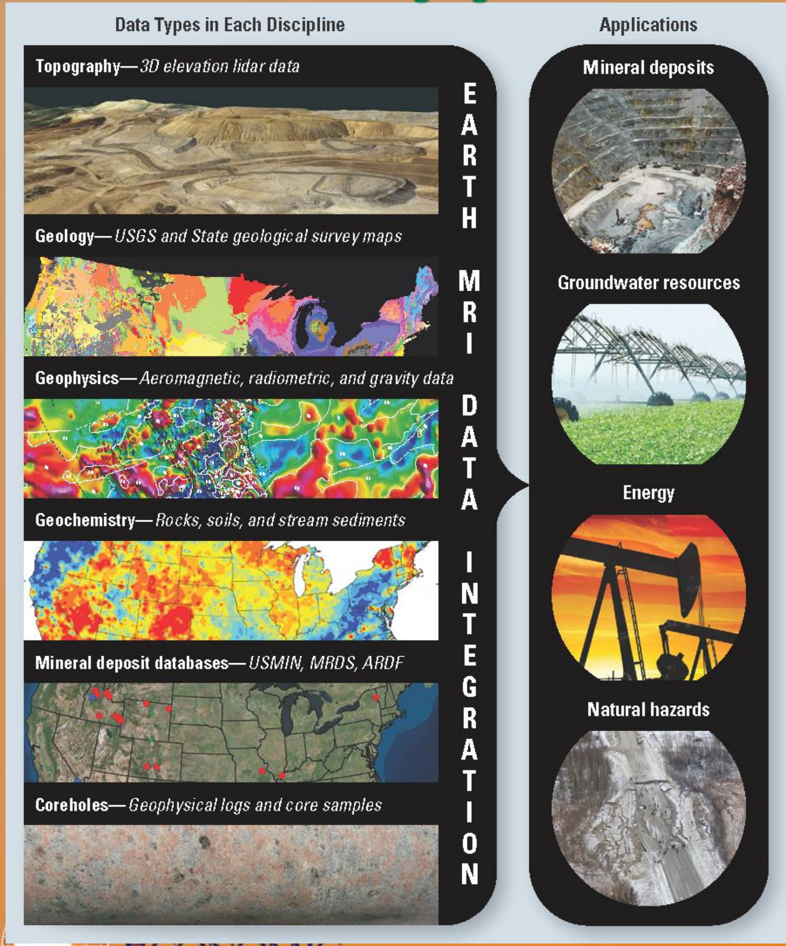
Phase 2	Phase 3
Aluminum	Antimony
Cobalt	Barite
Graphite (natural)	Beryllium
Lithium	Chromium
Niobium	Fluorspar
Platinum group elements	Hafnium
Rare earth element group	Helium
Tantalum	Magnesium
Tin	Manganese
Titanium	Potash
Tungsten	Uranium
	Vanadium
	Zirconium

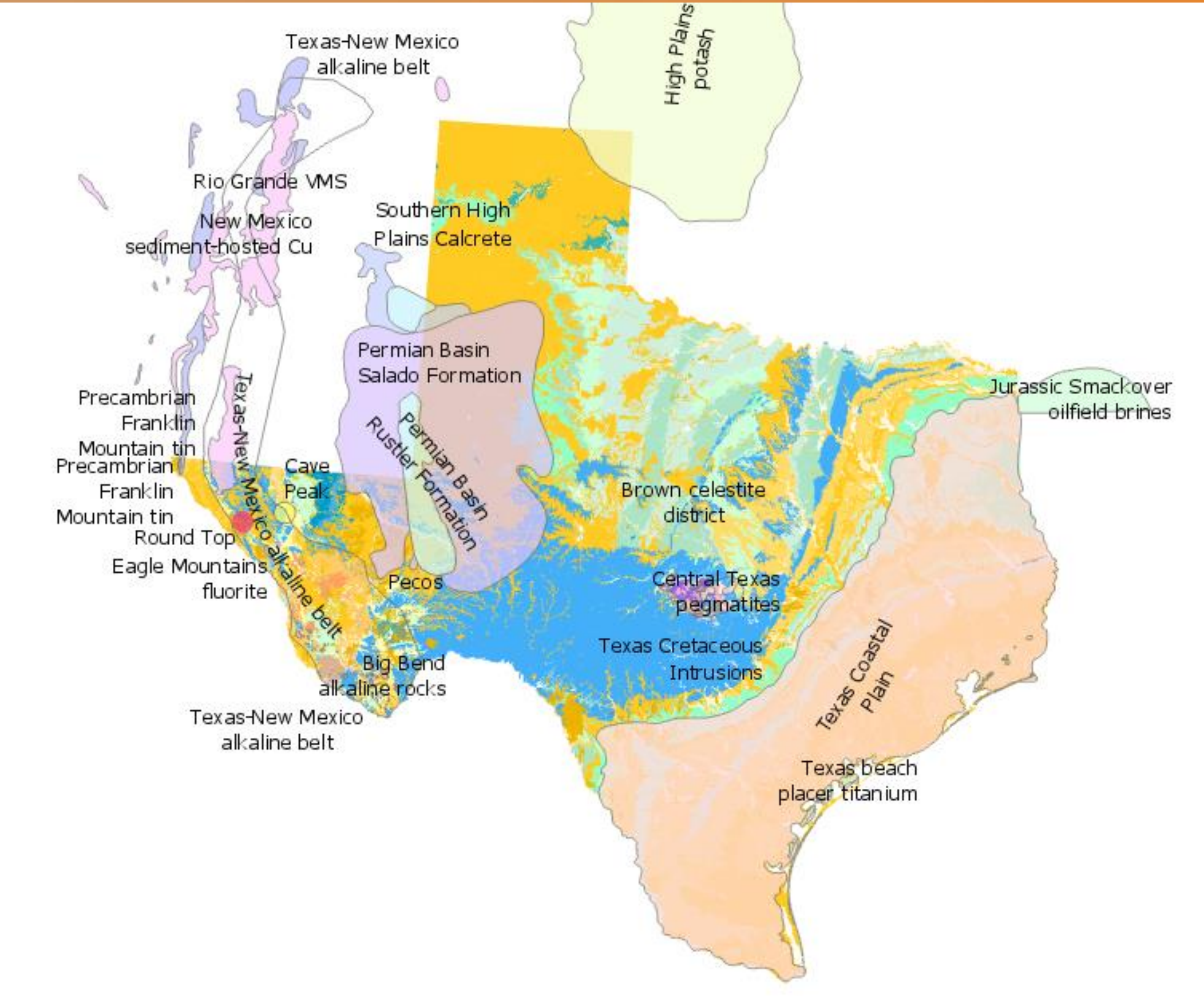
Sources:
Dicken and others, 2021, USGS data release, https://doi.org/10.5066/P9WA7JZY
Dicken and Hammarstrom, 2020, USGS data release, https://doi.org/10.5066/P95CO8LR

USGS

State of Economics - Supply

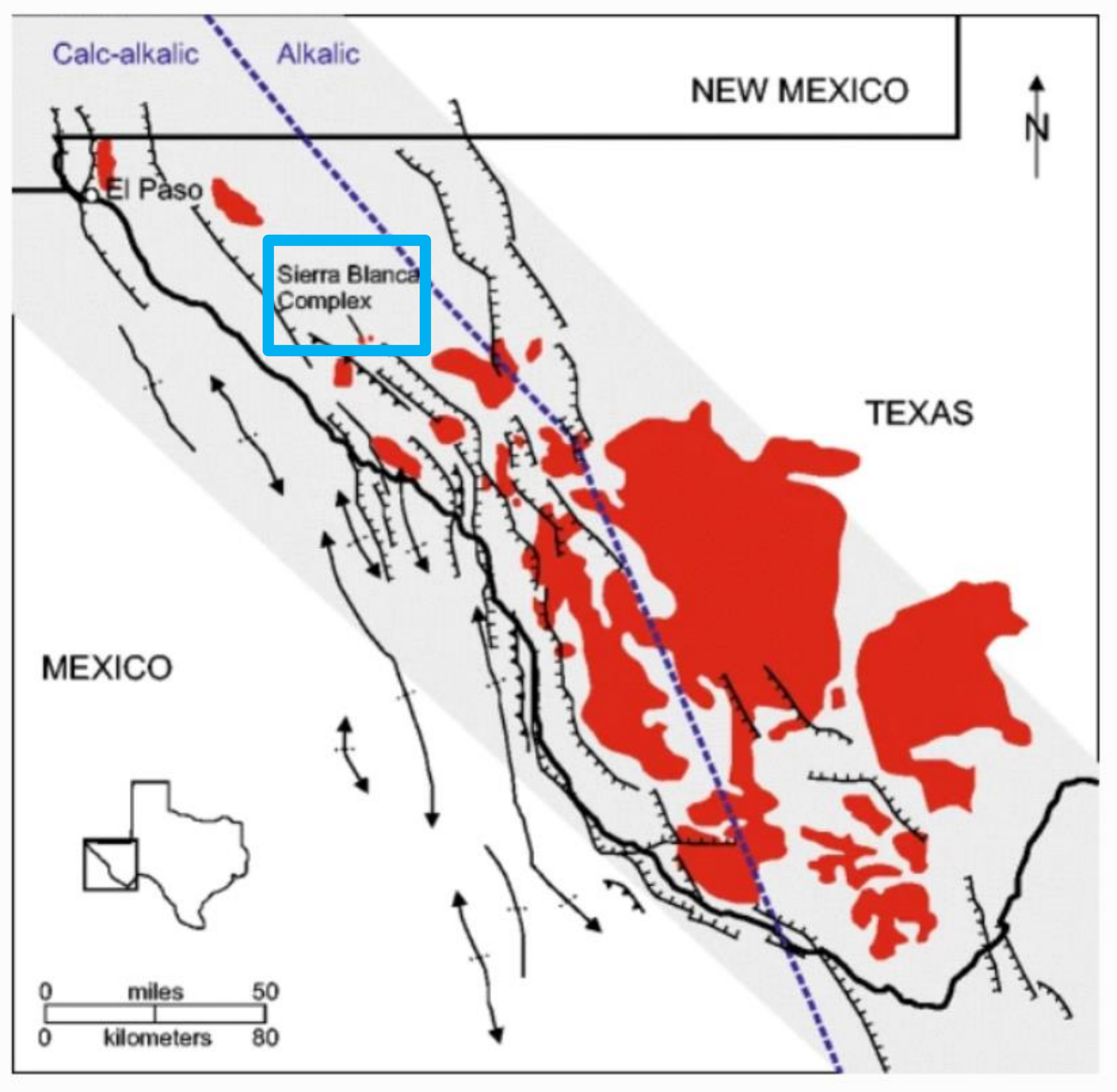
US Response





West Texas – Alkalic Volcanism

- Large magmatic province extending from NM, through West TX, down into Mexico
- Alkalic magmas strongly associated with REE-enrichment
- Long history of metals mining e.g. Van Horn copper, El Paso tin
- Newer proven resources of REE
  - Round Top, Sierra Blanca, TX
  - 303k tonnes rare earth oxides
- ***Are there other Round Tops in West Texas?***



Pingitore et al. 2014; O'Neill et al., 2017

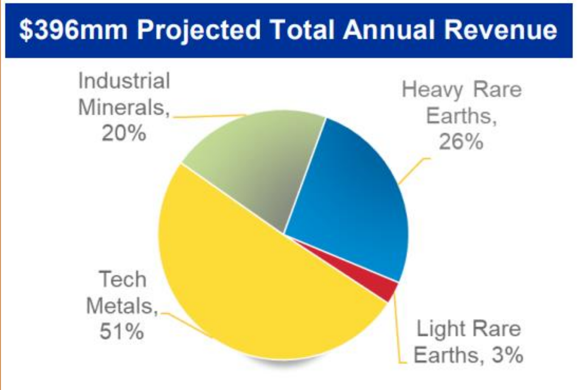
West Texas – Round Top Mine

- Rhyolite, located in Sierra Blanca, TX
- Estimated **20 years** of initial mine life
- Average **annual** revenue of **$396 million**
- Production will consist of REEs, tech metals, and industrial minerals

  Revenue = 1/4 REEs, 2/4 tech metals, 1/4 industrial
- **HREE-rich** (accounts for >70% of total REE, >90% REE revenue)
- Funding from Department of Defense to develop extraction techniques, Continuous Ion Exchange/Chromatography (CIX/CIC) producing 99.999% purity
- 20,000 tonnes/day; 2,200 tonnes/year rare earth oxides
- **Mine-to-magnets strategy by USARE to keep it 100% domestic**

USA | Rare Earth

TEXAS MINERAL RESOURCES CORP.



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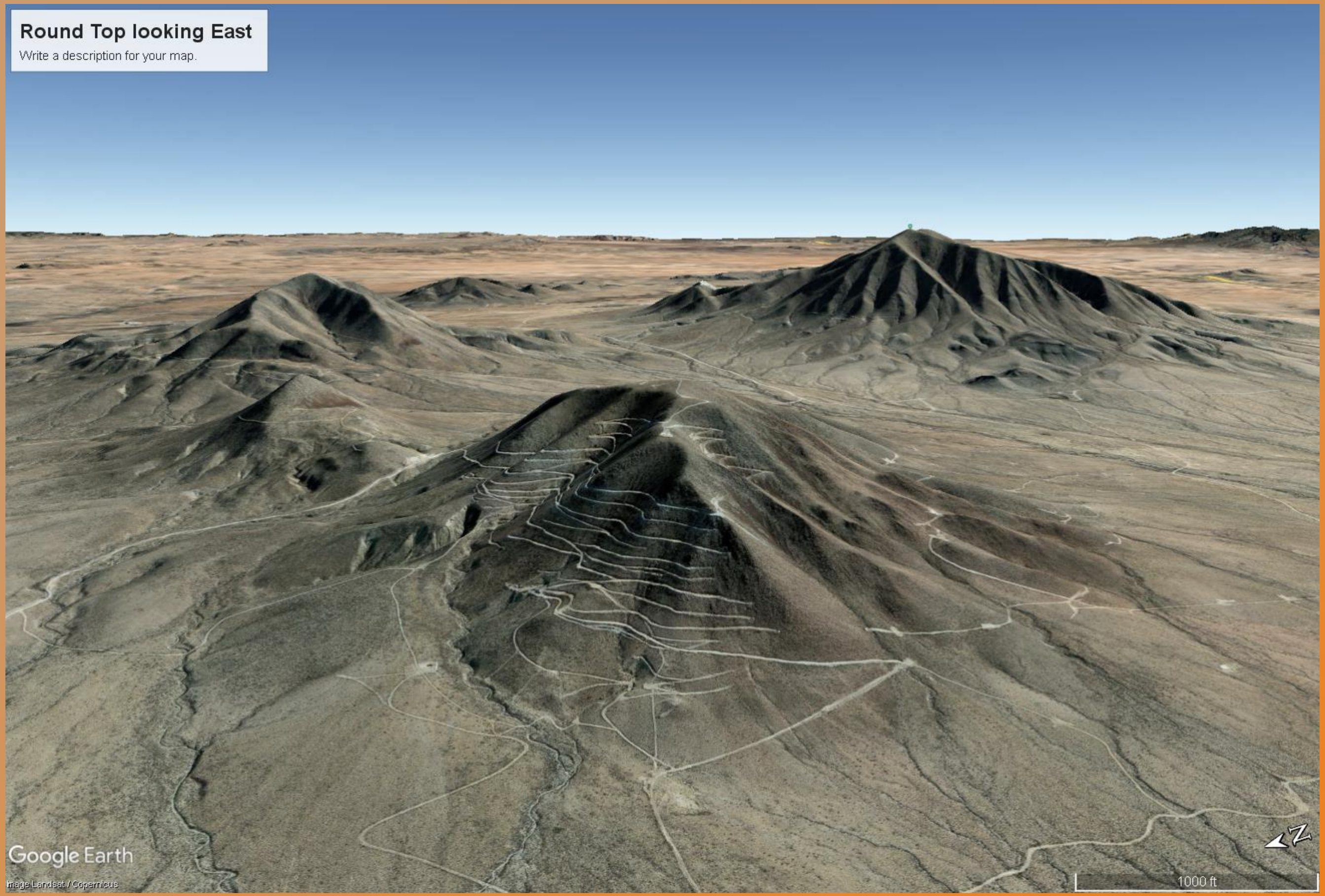
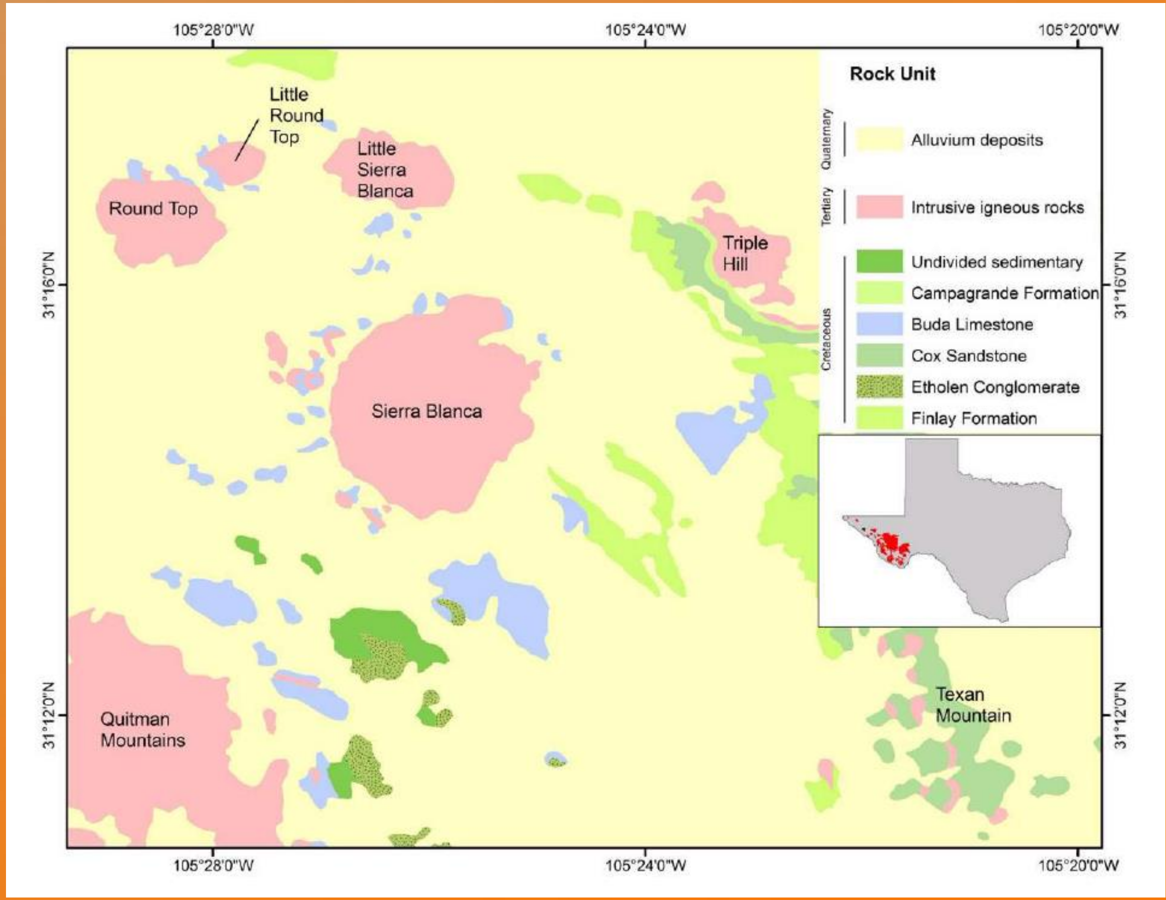
West Texas – Round Top Mine





O'Neill et al., 2017

West Texas – Round Top Mine

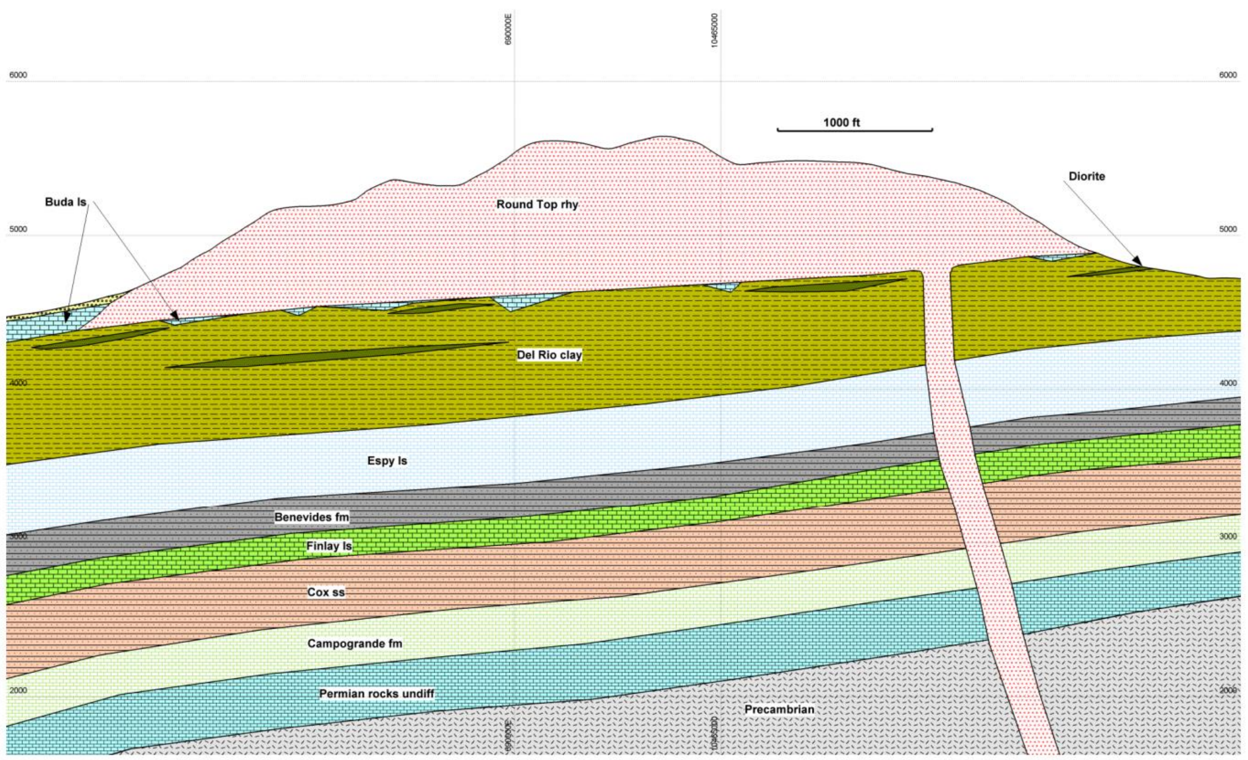
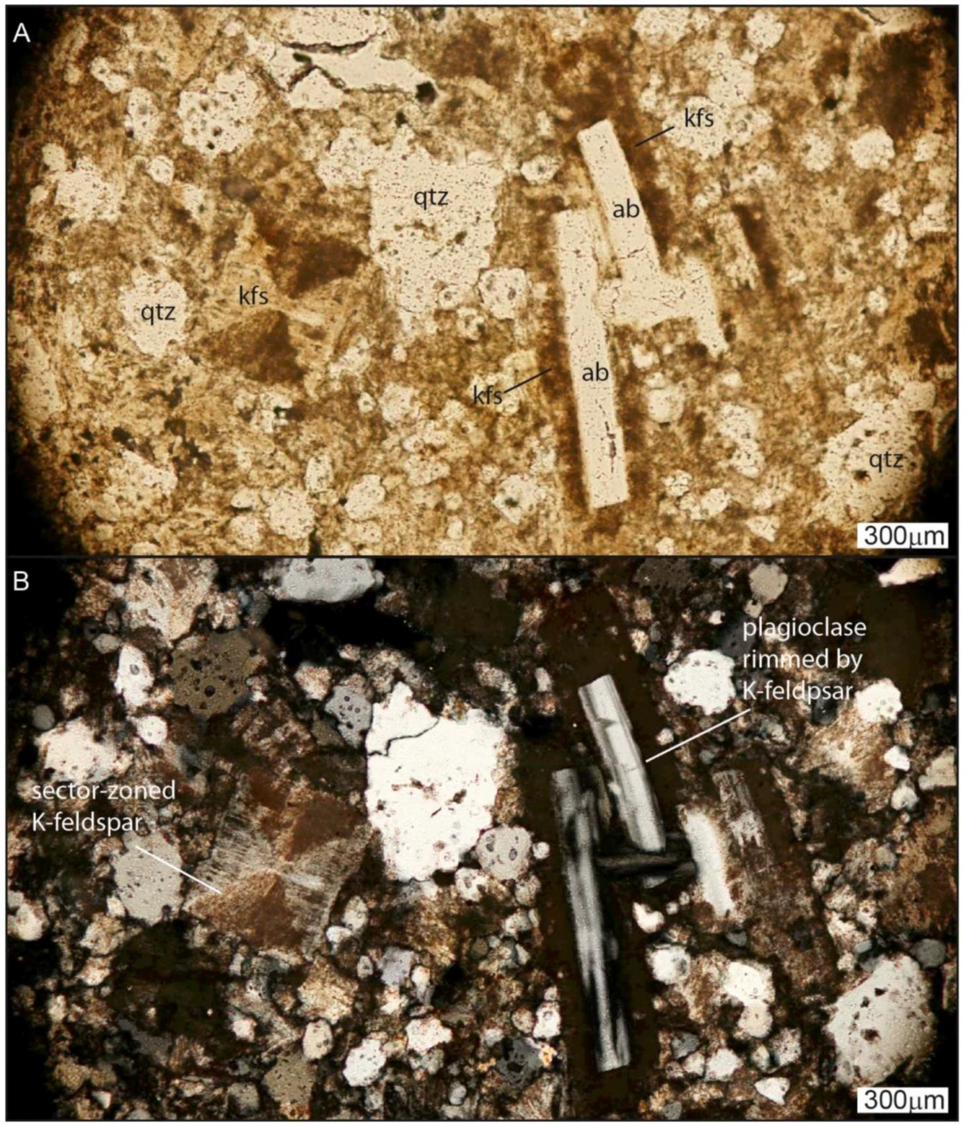


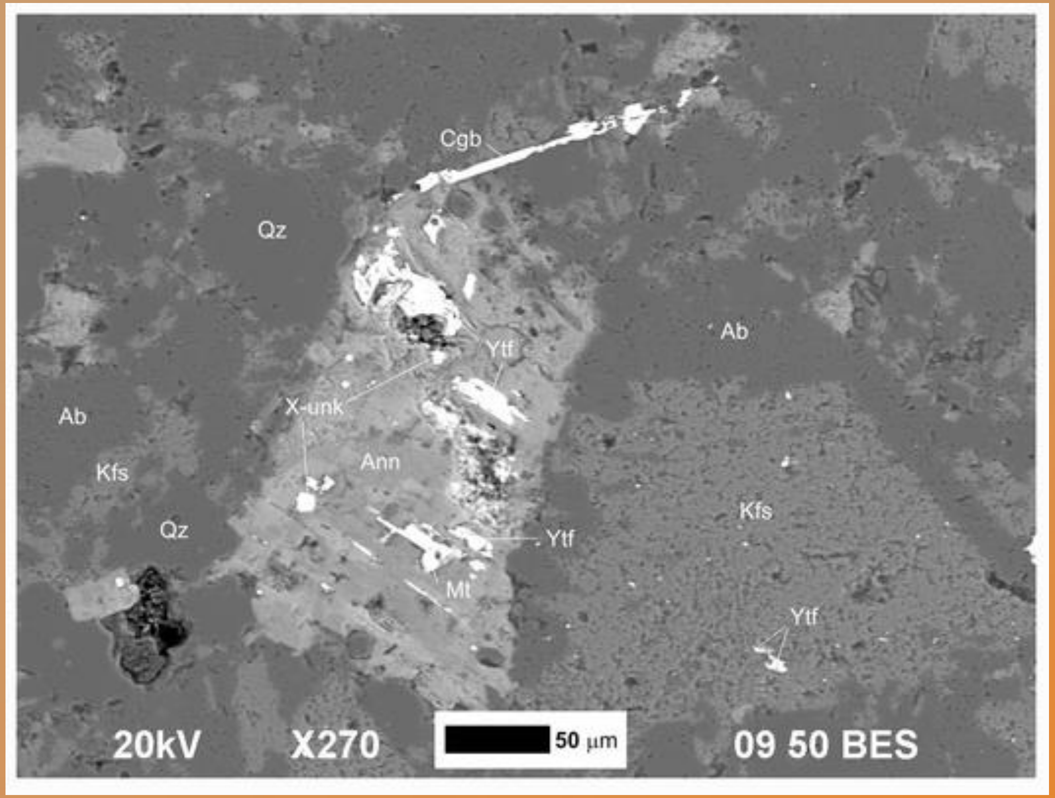
Figure 7-1 NW-SE Section Looking NE Through Round Top Mountain Showing the Underlying Sedimentary Rocks
(Source TMRC)

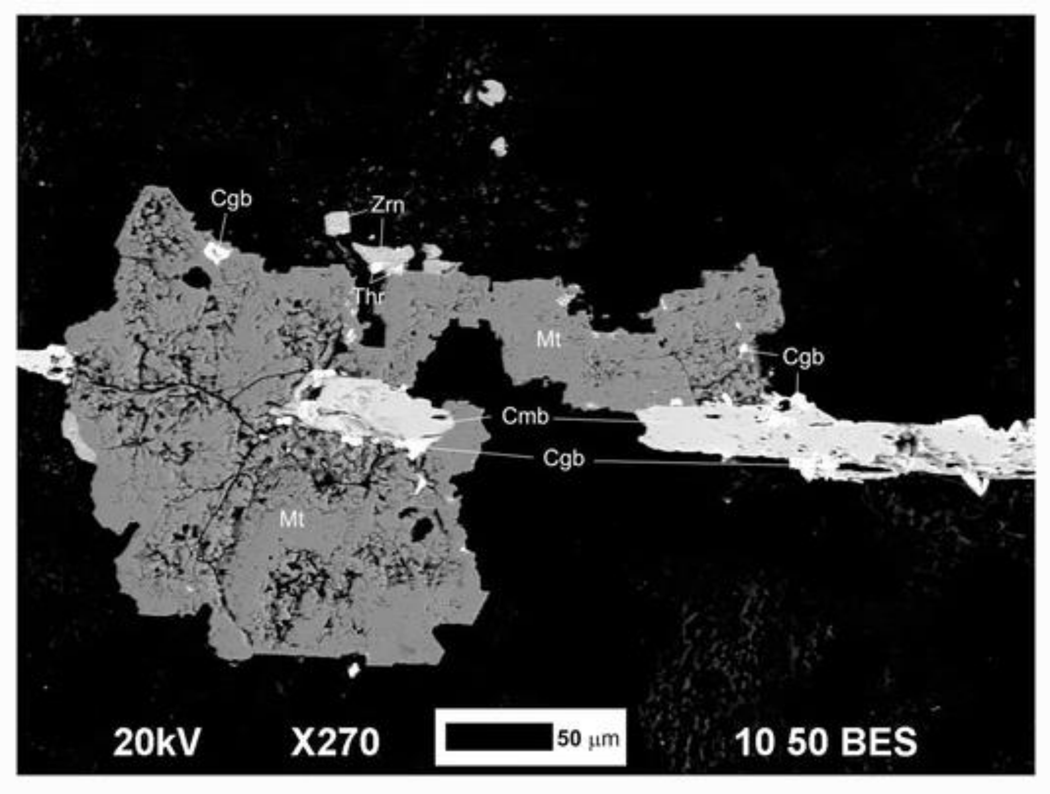
Negron et al., 2016, 2020



O'Neill et al., 2017
Elliot et al., 2018

West Texas – Round Top Mine





Yttrofluorite [(Ca, Y, HREE)F_2]
Yttrocerite [Ca, Ce, LREE, HREE)F_2)

Cerianite [(Ce,Th)O_2]
Changbaitte ($PbNb_2O_6$)
Zircon

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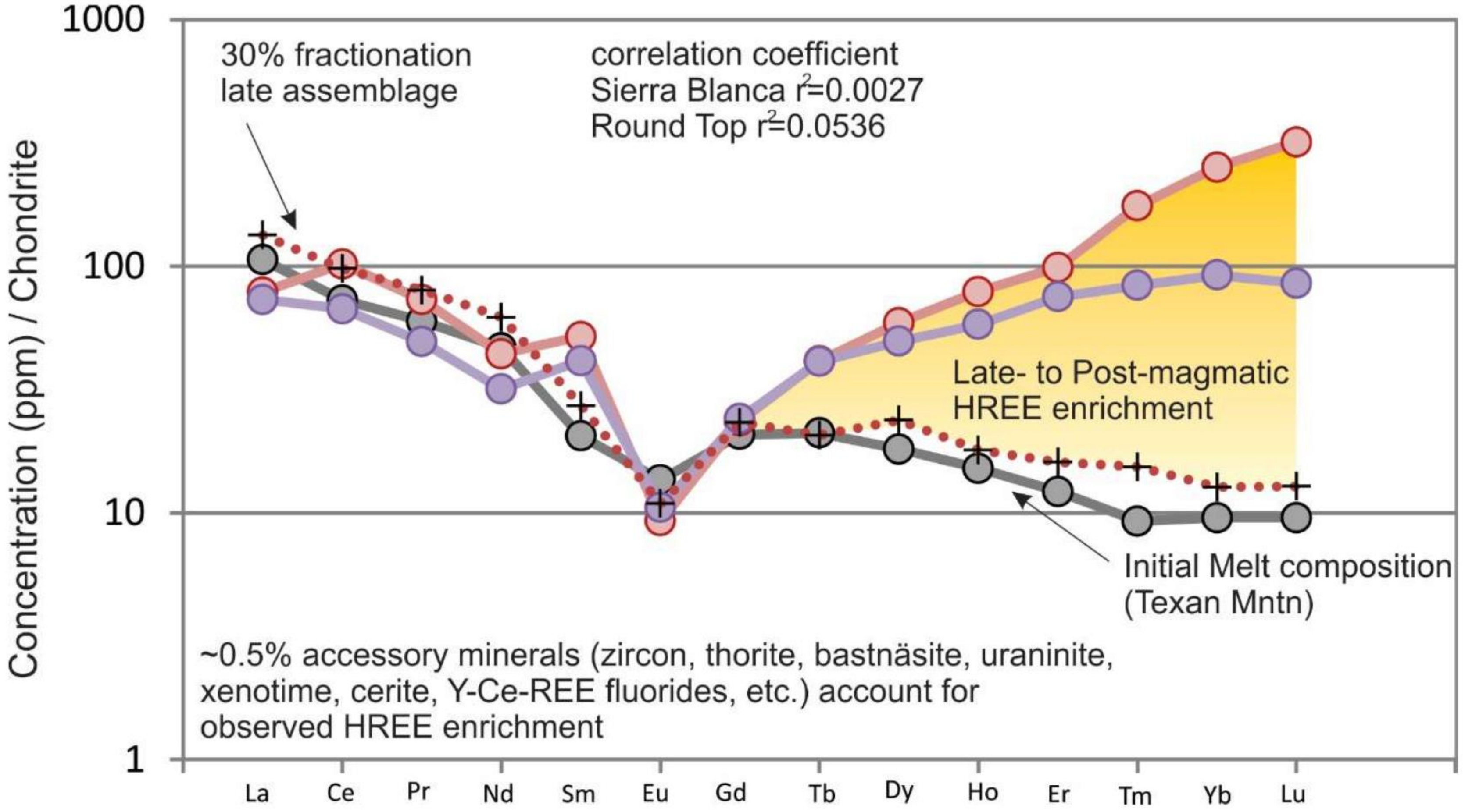
West Texas – Round Top Mine

Pink circles = Round Top rhyolite

Purple circles = Sierra Blanca

HREE enrichment is key to economics. Not well understood, but high H2O, Li, and/or F content thought to be primary complexes that concentrated HREEs in residual melts



Elliot 2018

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West Texas – Alkalic Volcanism

Cornudas, Texas

- Funded activity for 2 years
  - Finish August 2022

- Goals
  - 2 quadrangles
  - 1:24k mapping
  - ~100 samples for geochemistry
- Progress
  - Field mapping largely completed Feb-April 2021
  - Sampled approximately 120 outcrops, veins, and drainages
  - 86 samples sent to USGS for assay analyses
  - 86 samples cut into billets for further microscopy and geochemistry

- To-do
  - Review our work with upcoming USGS aerial survey data
  - Digitize field maps and conform data to GeMS format
  - Develop long-term data-driven strategies for further exploration-type field work in West Texas

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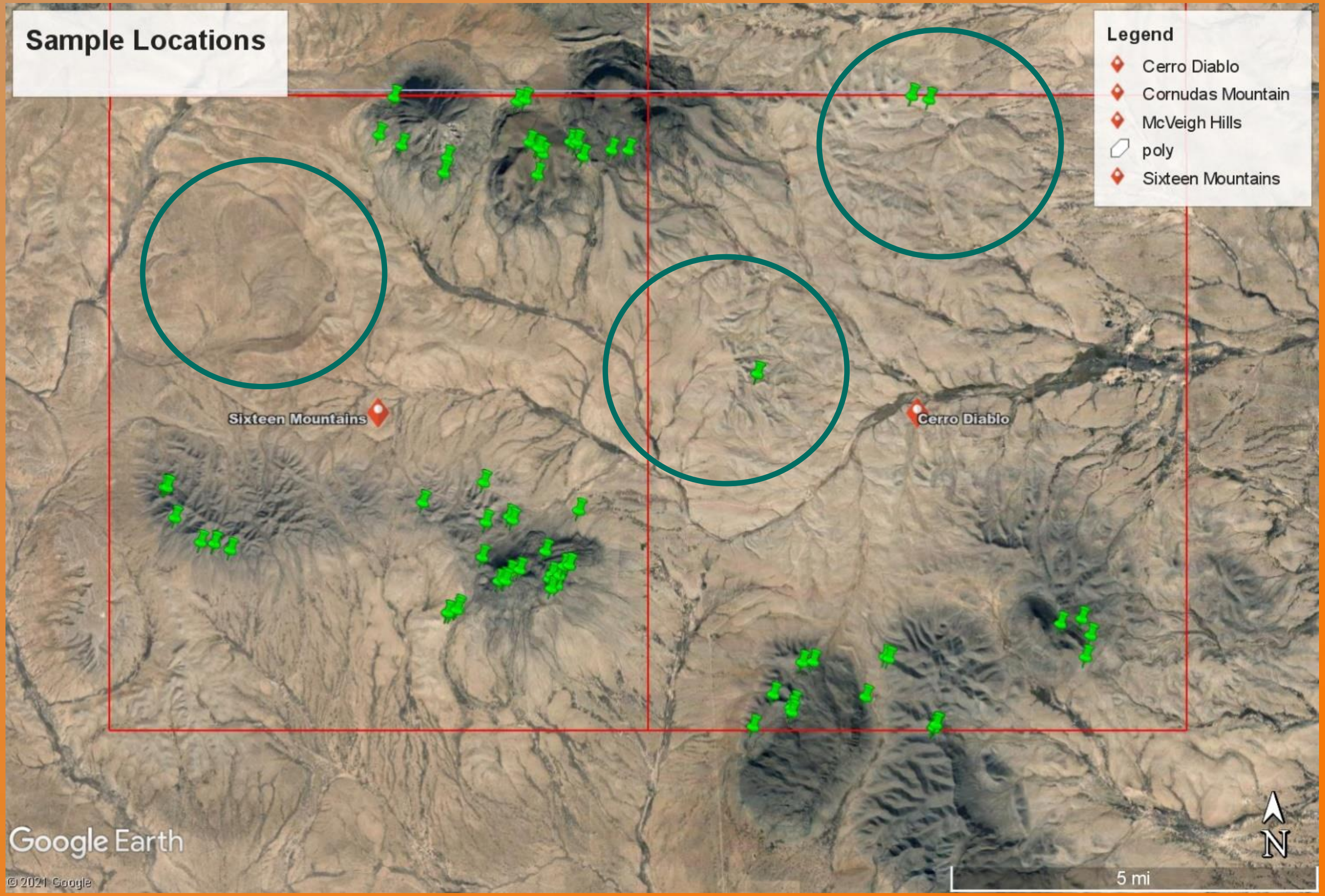
West Texas – Cornudas

- Exploration approach – take "base" samples and samples of unusual formations
  - syenitic/phonolitic bodies, contact rocks, calcite veins, discoloration, drainage wash
- Quadrangle-scale structure often points to intrusive body beneath (with occasional outcrop)
- Calcite veins grow in frequency and size with proximity to intrusive bodies
- Geochemistry, structural data, aeromag and radiometric surveys will tell a story
- Apply what we learn in Cornudas to the rest of West Texas



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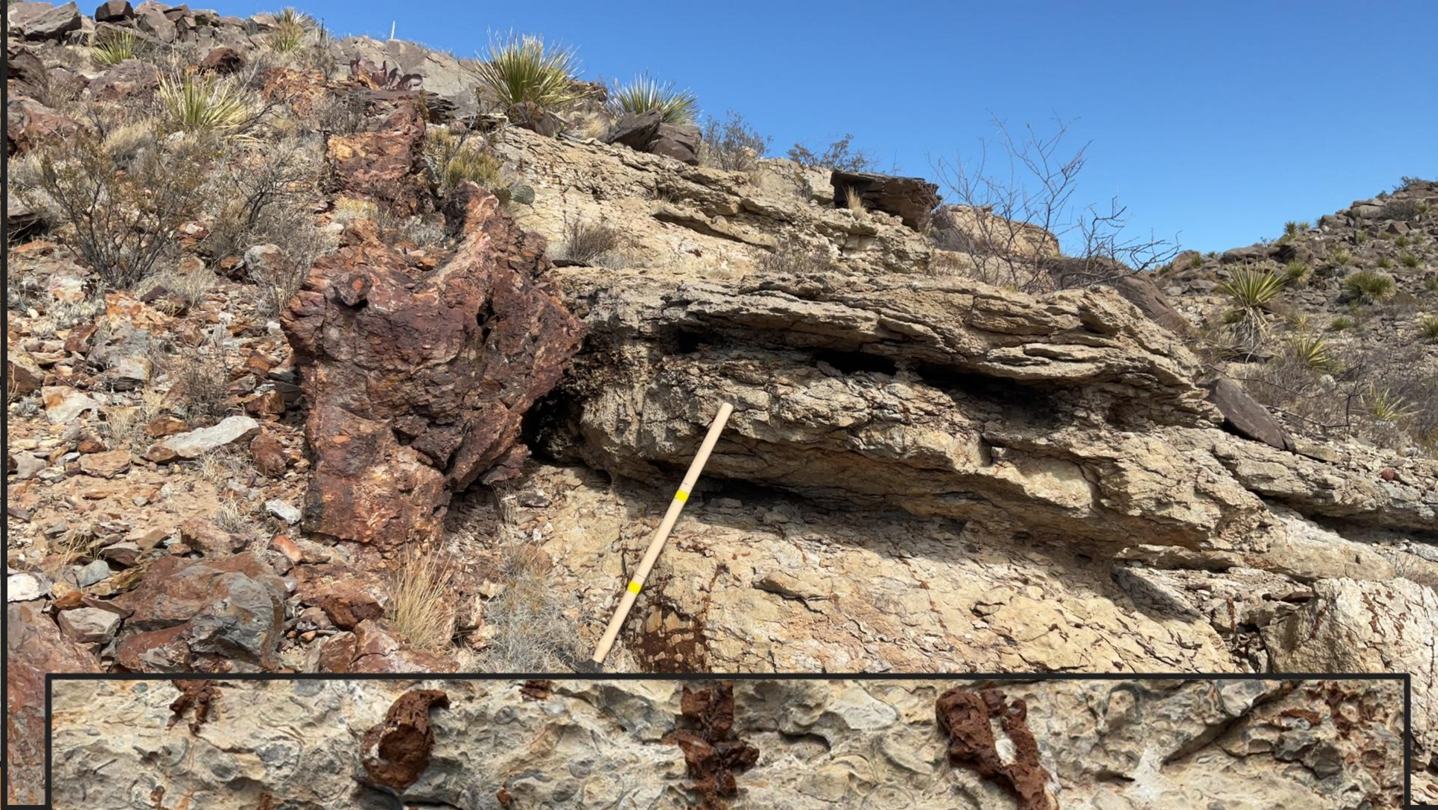

Iron-rich fluids clearly interacting with country rocks near intrusions.

Where did fluids originate? What else was in these fluids?

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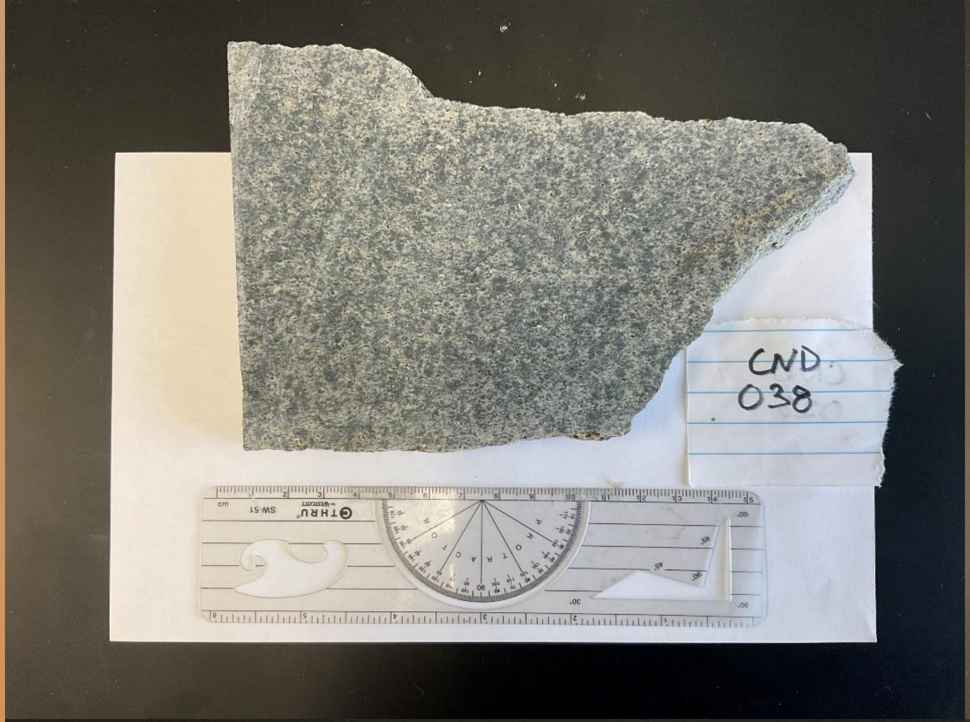
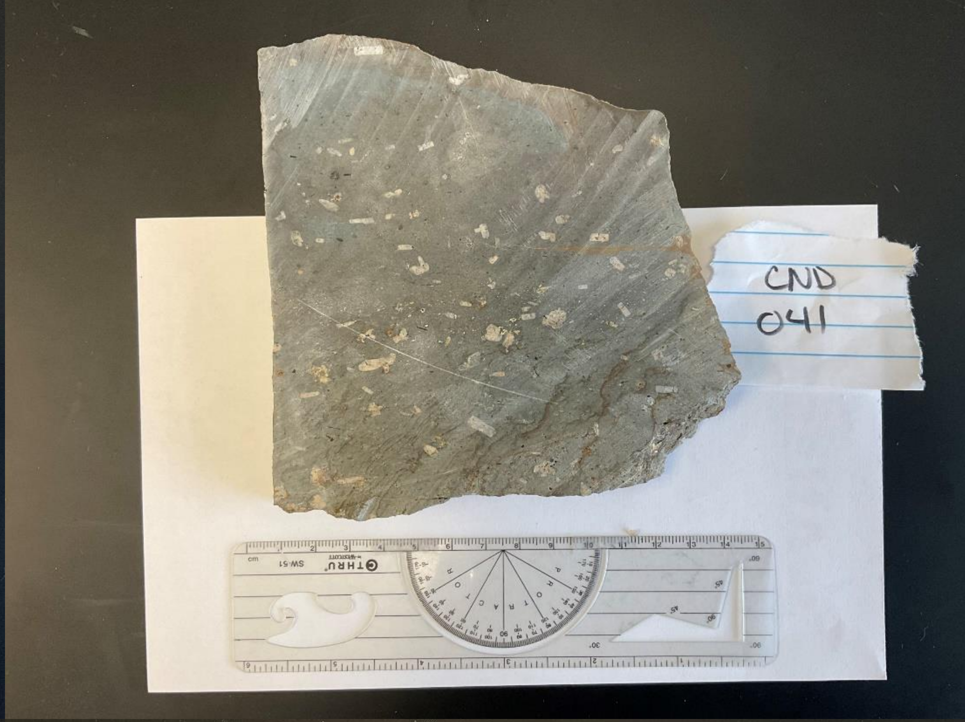
Drainages excellent for finding hidden outcrops and calcite veins. Gravel wash may have clues as to what is covered upstream.

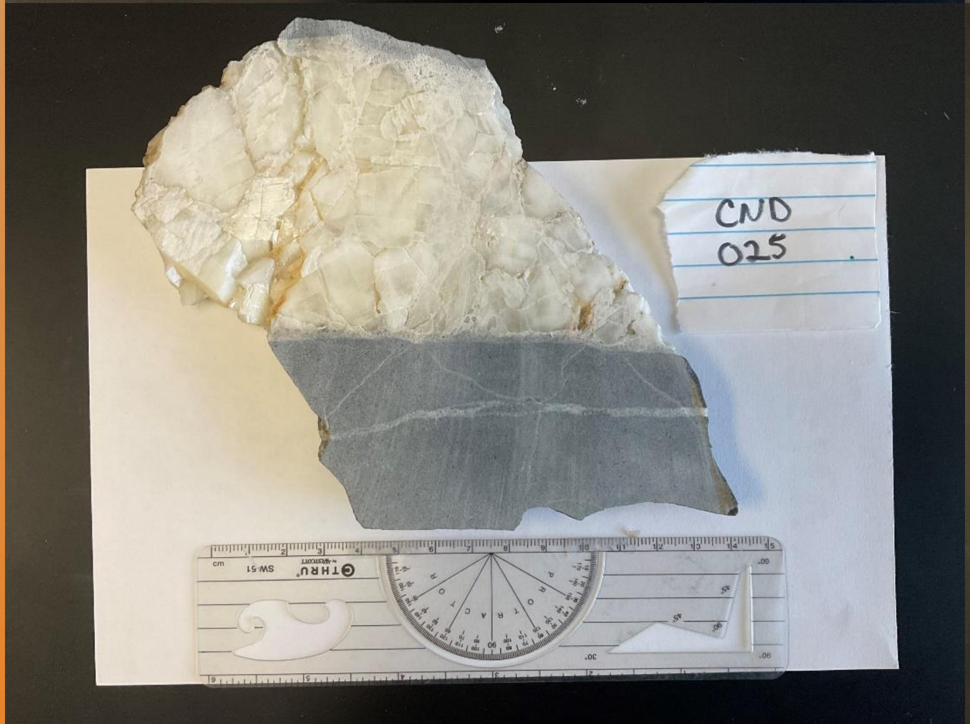
Calcite veins proximal to intrusive bodies likely hold information about the fluids given off during emplacement and crystallization, and may serve as vectors to buried bodies.

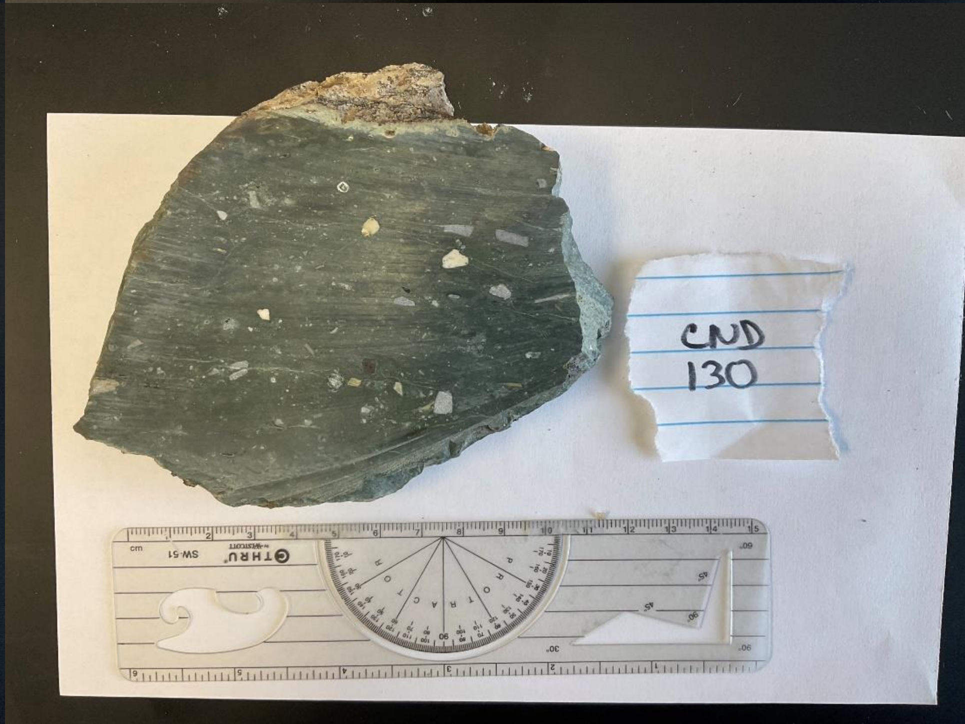
86 samples have been sorted, cut, and prepped for geochemical analyses.

This will help answer questions e.g. timing of intrusions, chemical evolution, pressure and temperature conditions, where do elements of interest occur. This will help us understand the system as a whole and better predict how and where economic concentrations may occur.









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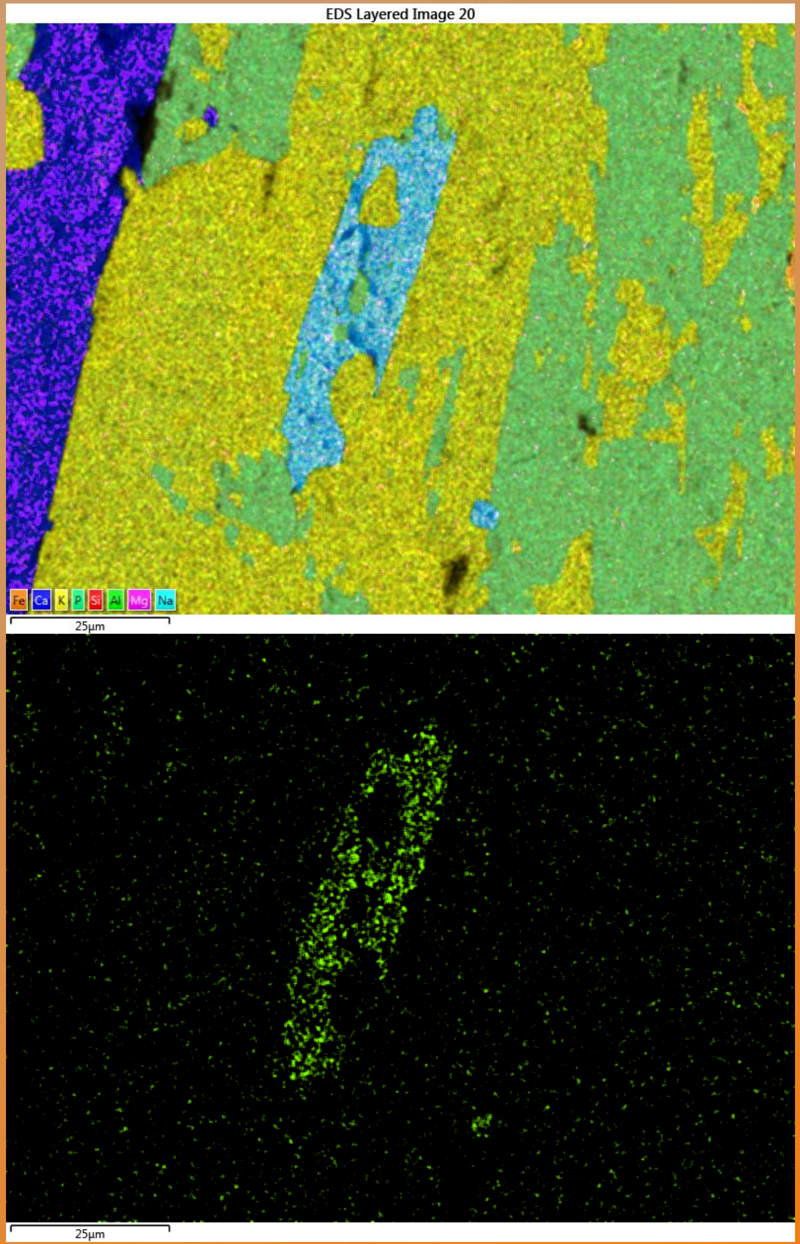
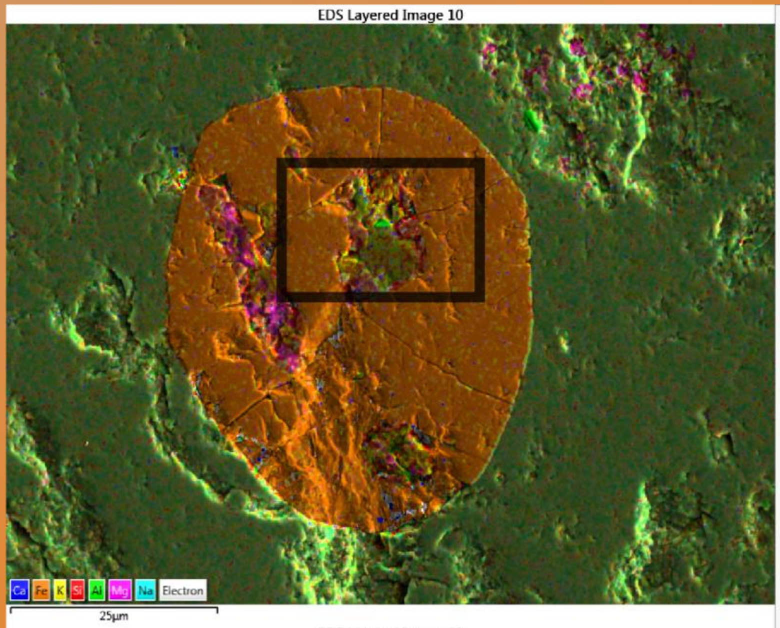
West Texas – Cornudas

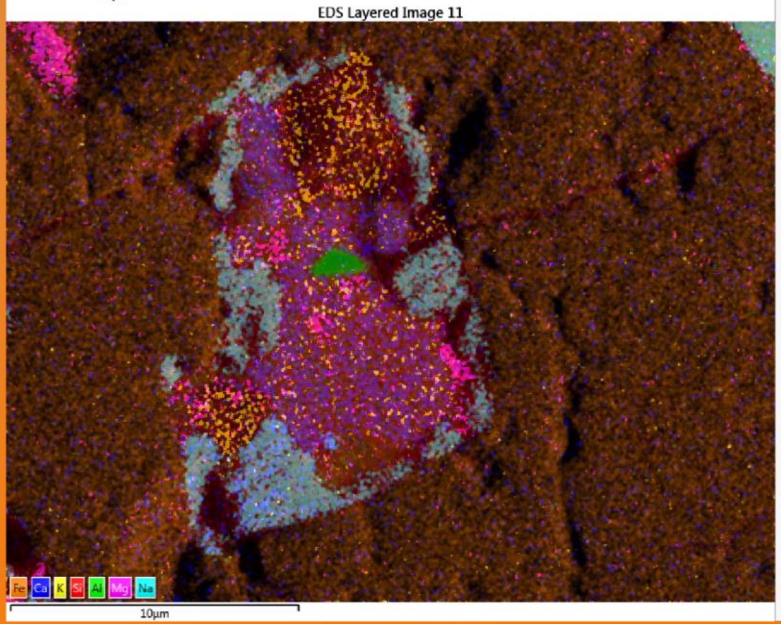
Millier Mountain nepheline-syenite porphyry

Cerium-rich hydroxyapatite in K-spar





Iron oxide spherule in albite, with elongate rectangular magnesium silicate mineral and subhedral plagioclase (enlarged below)



Calcic-plagioclase core with Na-replacement along outer rims, and minor K-alteration, with corundum(?) inclusion in core. Note cracks in surrounding iron oxide that would allow fluid flow from outside spherule

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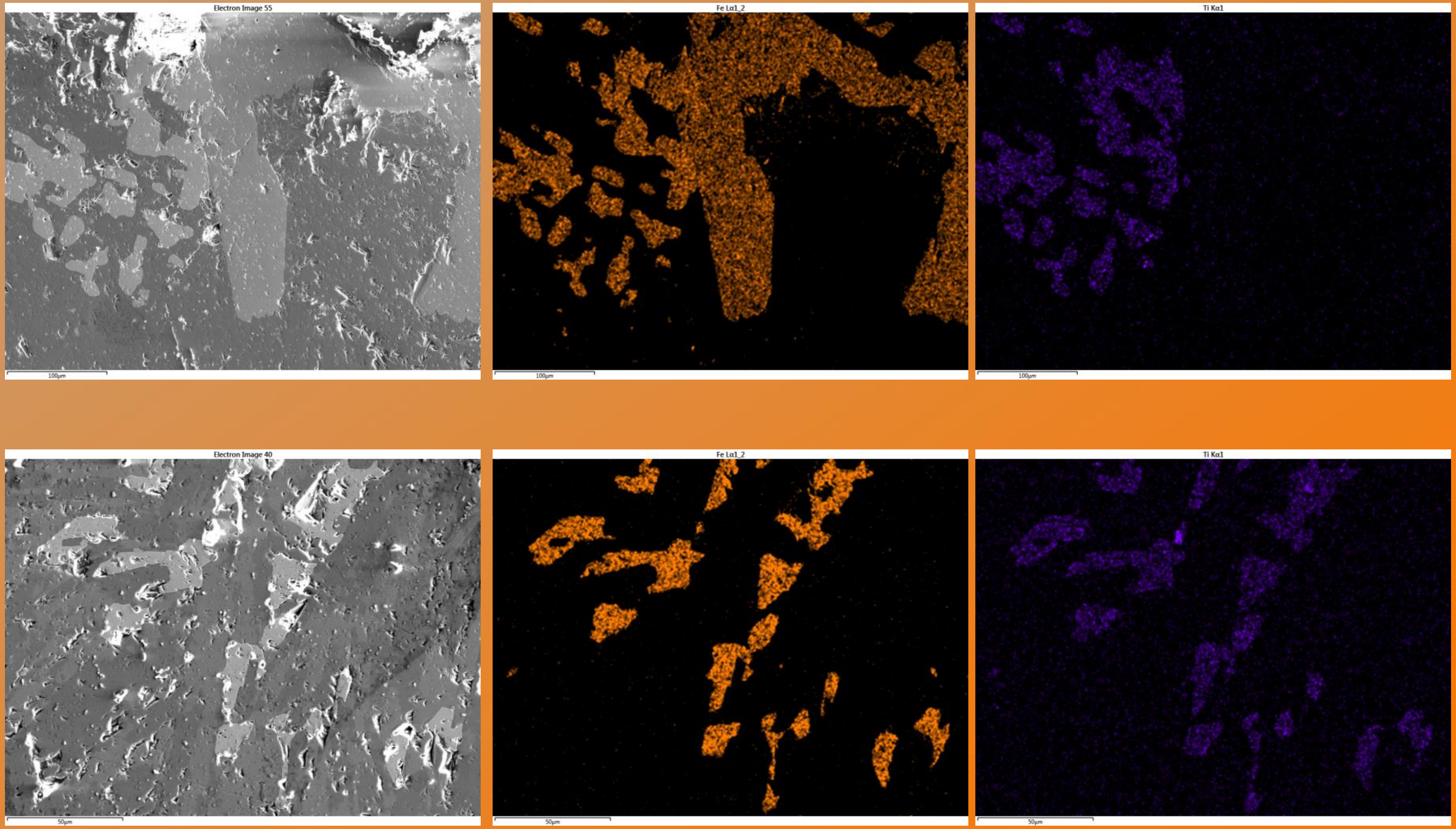
West Texas – Cornudas

Immmiscible Fe-Ti melt (?) included in albite – altered or reprecipitated to arfvedsonite and/or aegerine

BSE | Iron | Titanium



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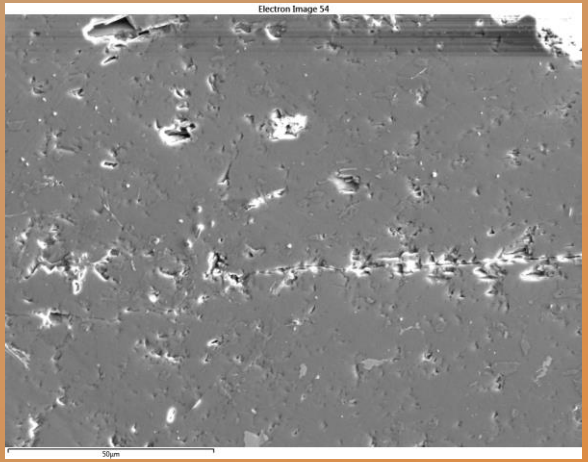
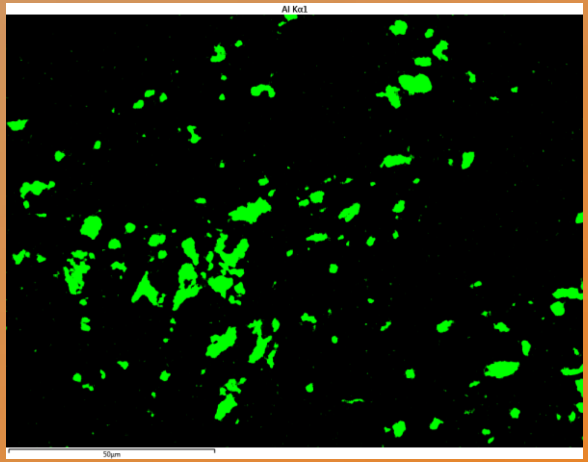
West Texas – Cornudas

Abundant corundum (?) inclusions in albite phenocrysts, alongside Fe-Ti inclusions

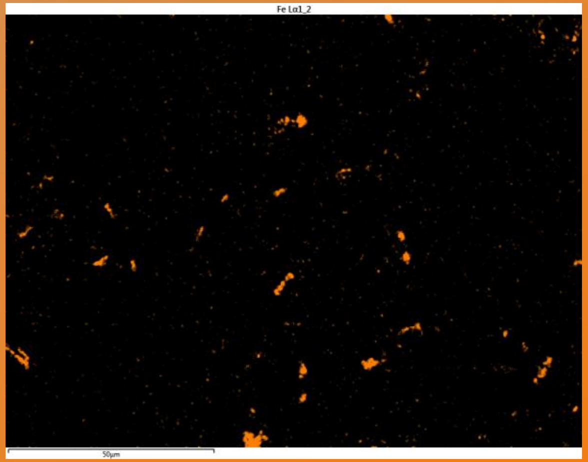
BSE



Aluminum

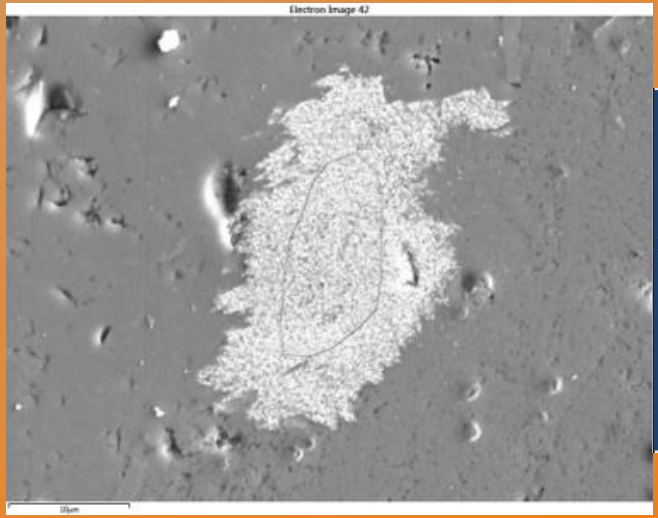


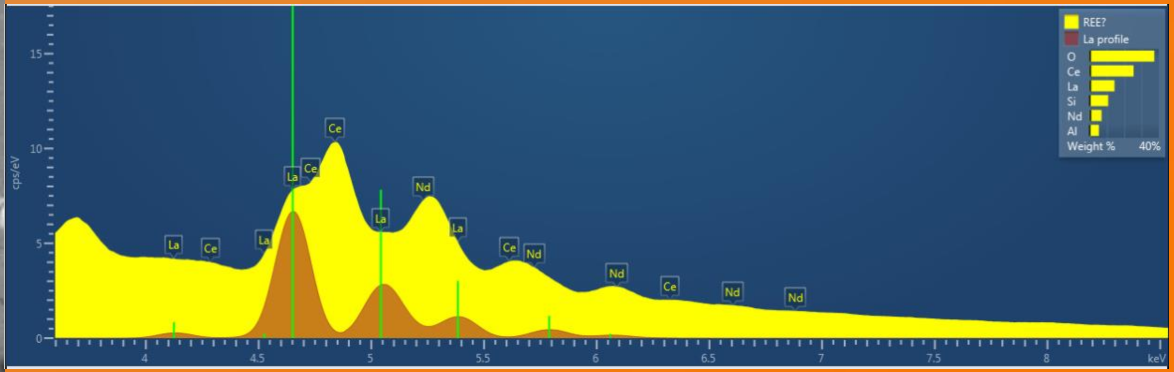
Iron



Potential REE-bearing phosphates

Need further EPMA or LA-ICP-MS to confirm





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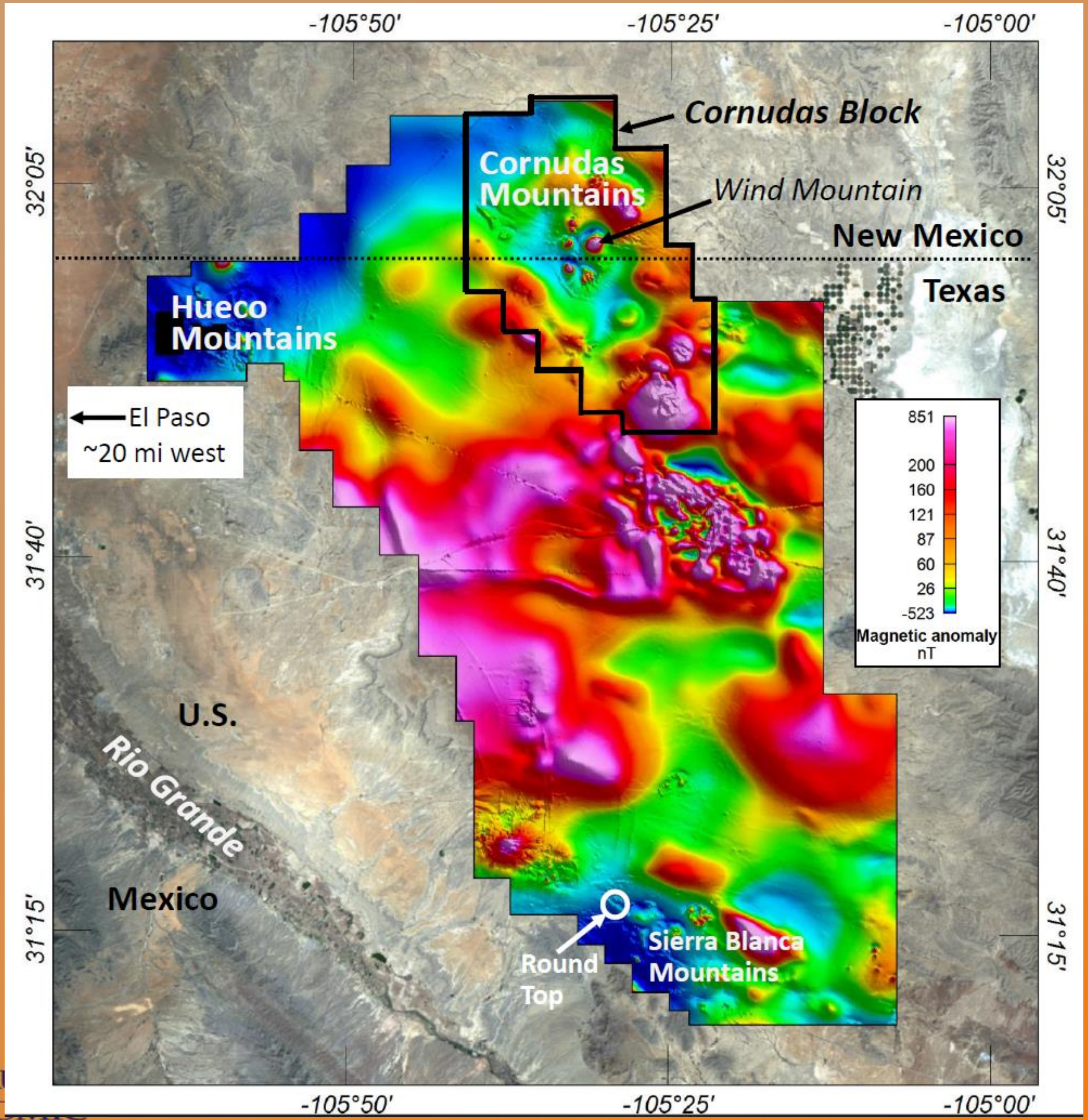
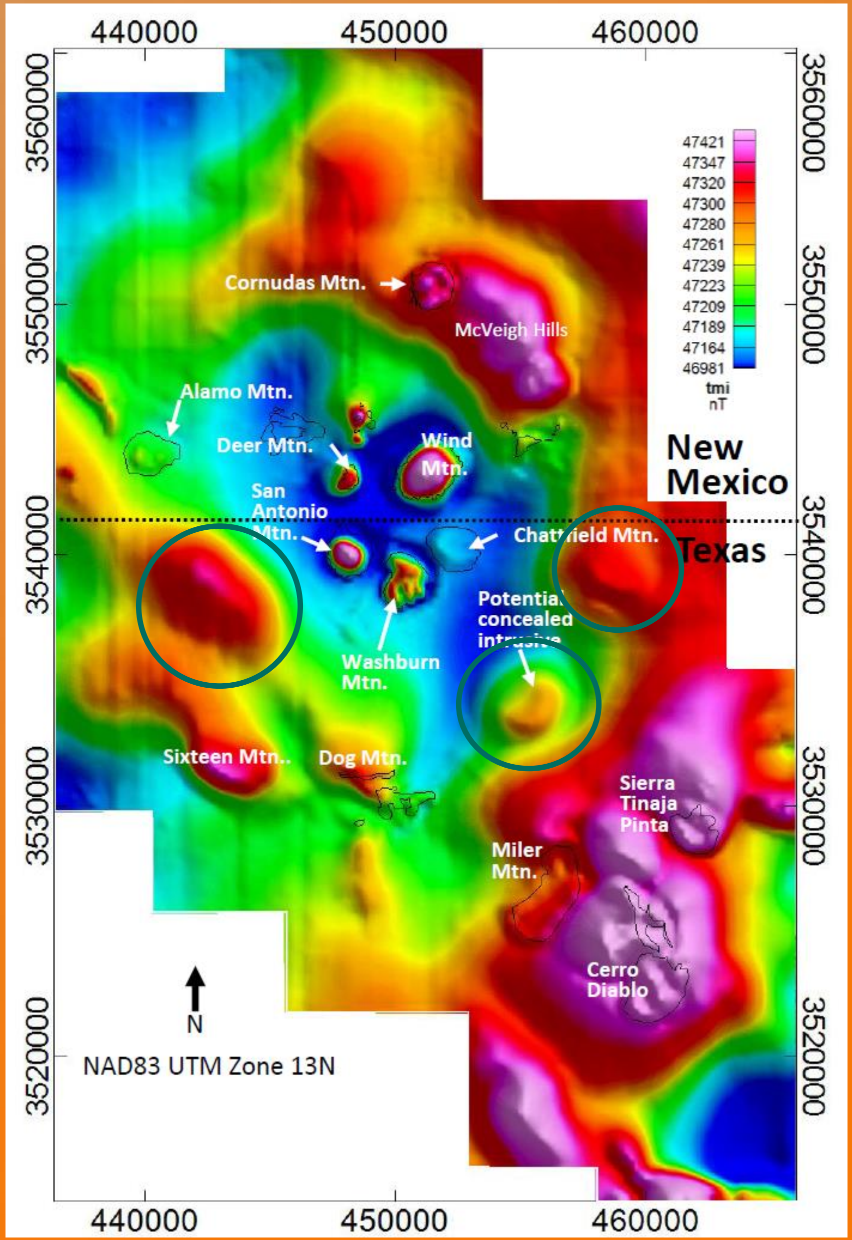
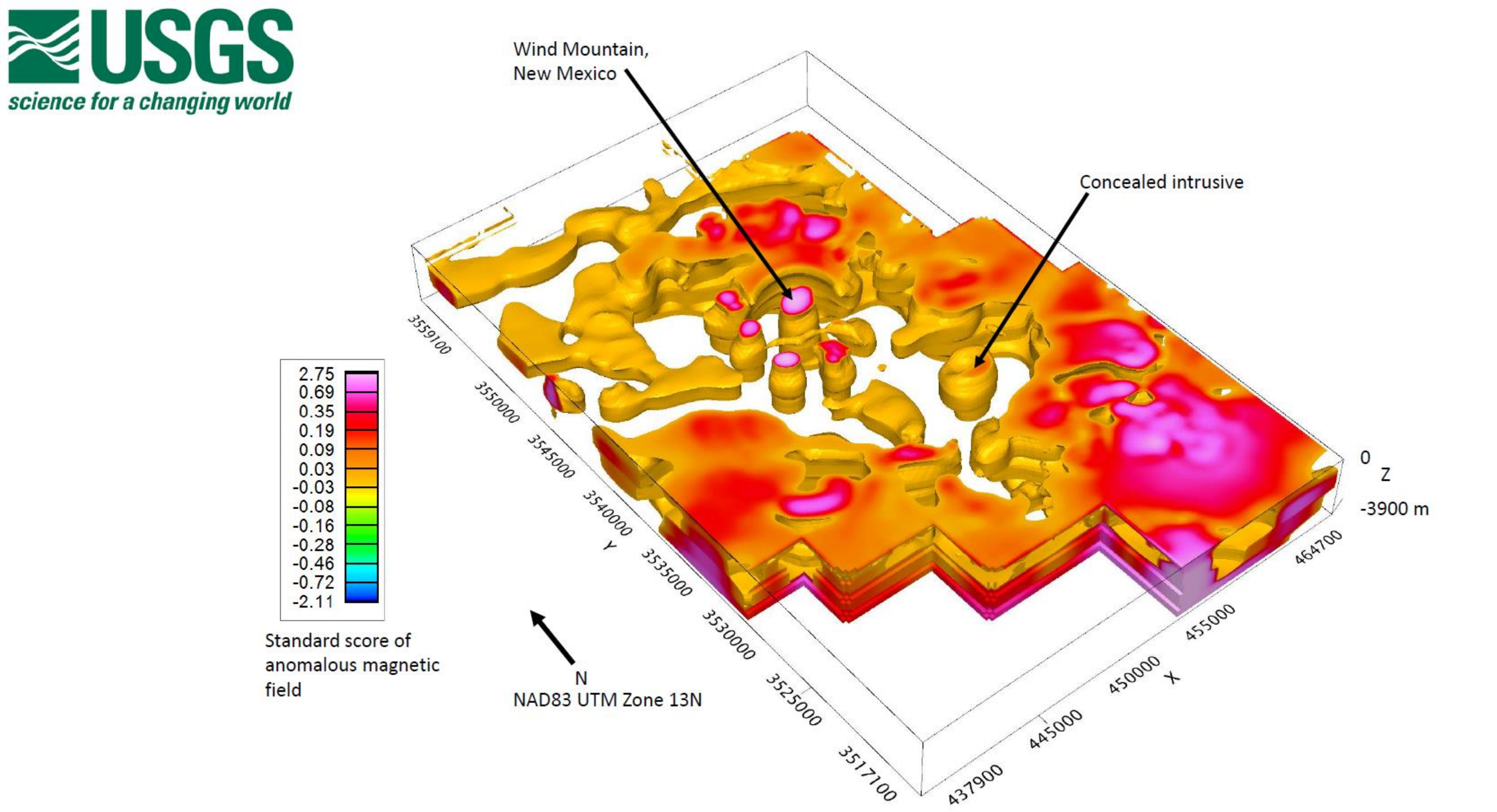
West Texas – Alkalic Volcanism





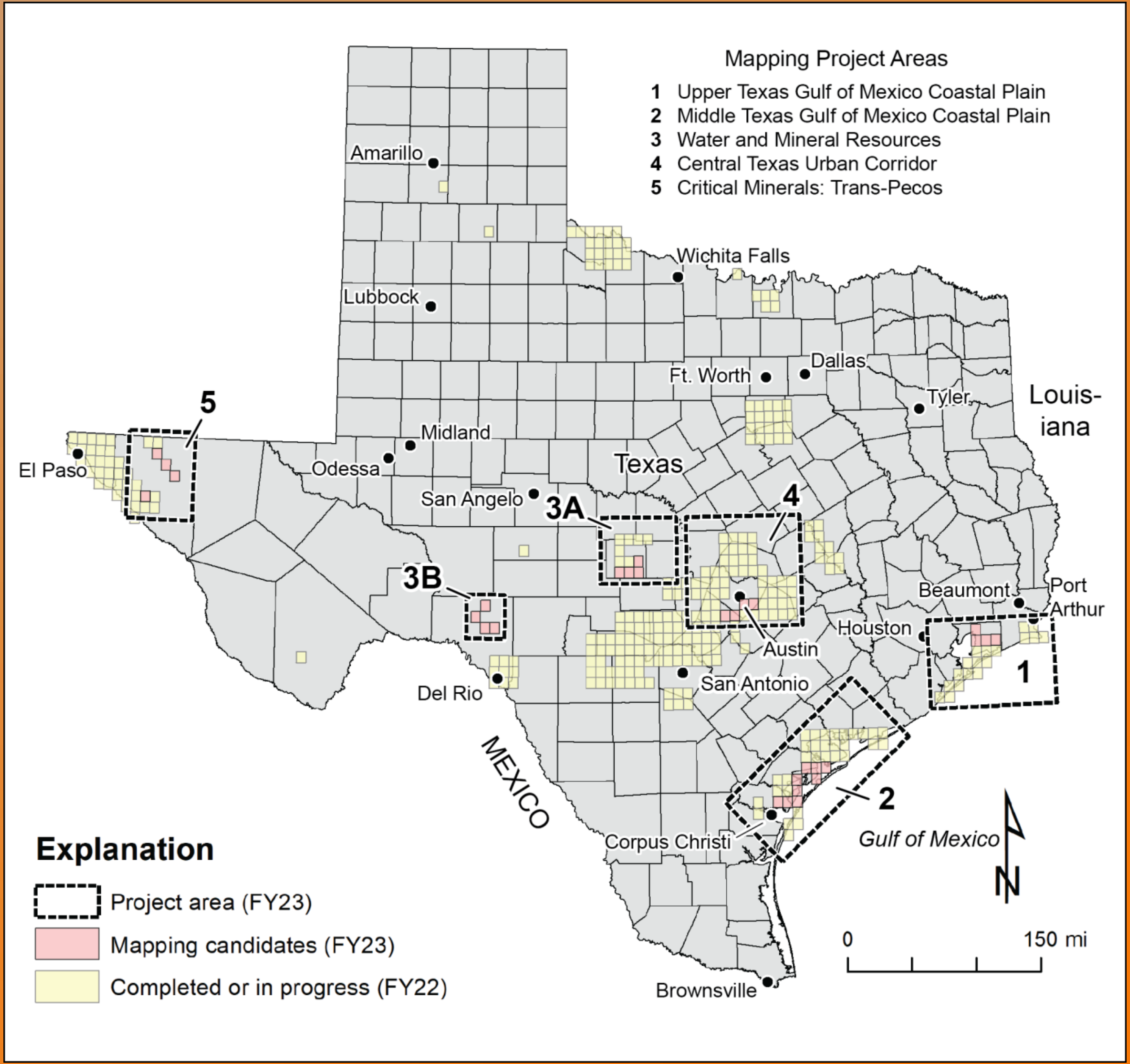
West Texas – Alkalic Volcanism



Three-dimensional representation of high magnetic susceptibility rock (likely to be Tertiary intrusives) in the Cornudas Block, Trans-Pecos aeromagnetic survey.

West Texas – Alkalic Volcanism

With increased funding for StateMap projects, plans to continue mapping and sampling outcropped volcanics in region, working outward from Cornudas within current geophysical survey boundaries (area 5)



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Texas Lignite – REE and CM Potential

Assessment of Rare Earth Elements and Critical Minerals in Coal and Coal Ash in the U.S. Gulf Coast

DOE FOA Carbon Ore, Rare Earth and Crtical Minerals (CORE-CM) Initiative for U.S. Basins

BEG awarded ~$1.5 million for Phase 1 sampling, assaying, and resource estimation for the Gulf Coast

Working closely with many stakeholders to sharpen our goals and avoid reinventing the wheel.

Phase 2 would include pilot plant extraction tests

Texas Lignite – REE and CM Potential

Project Team:

University of Texas at Austin

Bridget Scanlon

Tristan Childress

Bob Reedy

JP Nicot

Rich Kyle

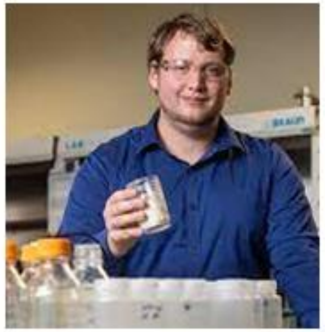
Kristine Uhlman

Peter Warwick (USGS)

Lesli Ruppert (USGS)

Jim Hower (UK)

Charles Nye (UWY)

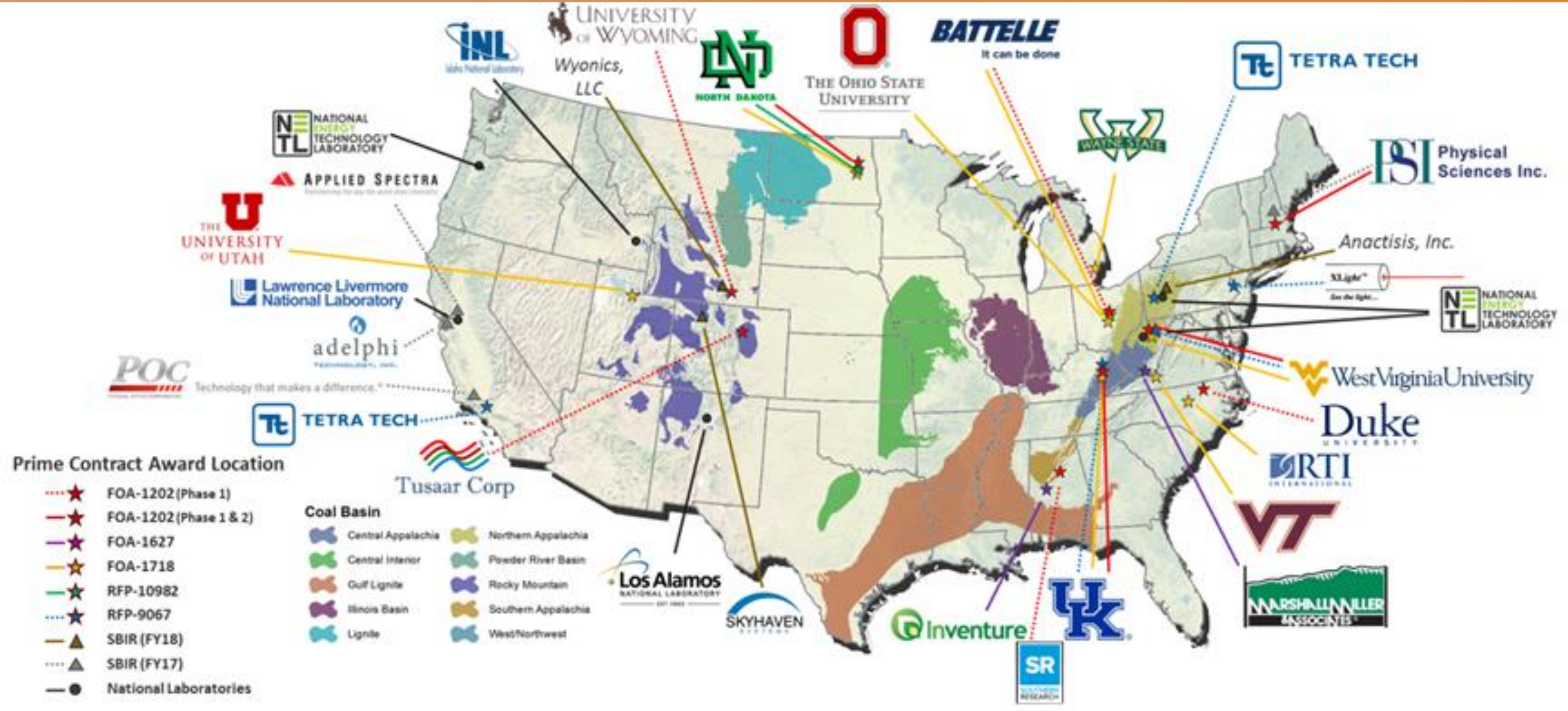


Nolan Theaker (UND)

Sheldon Landsberger

Texas Lignite – REE and CM Potential

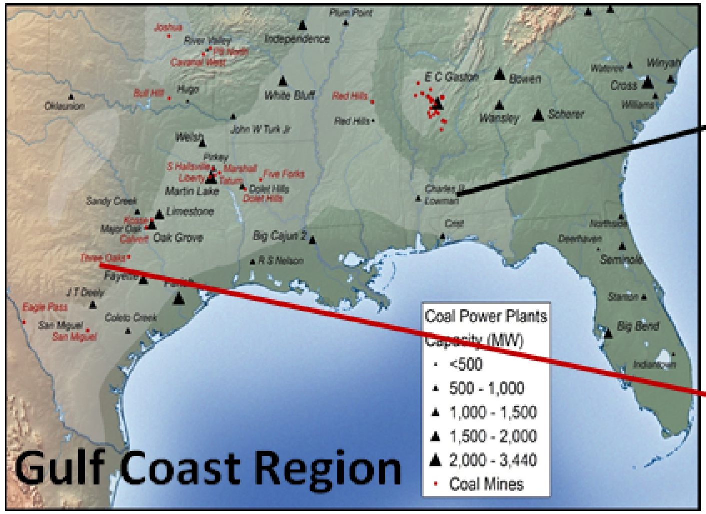
NATIONAL ENERGY TECHNOLOGY LABORATORY



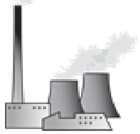
Texas Lignite – REE and CM Potential

Flowchart

Coal & Ash Resource Assessment



Power Plants



Ash

Mines

Coal

Coal/Ash Resources
- Coal
- Fly ash
- Bottom ash
- Refuse

Databases
- USGS mapping
- NCRDS
- USGS CoalQual
- NETL EDX
- EIA power source

Geologic Models
- Coal resource assessment
- Deposition
- Structure

REE + CM + CBP Resource Assessment

- Rare earth elements (REEs)
- Critical Minerals (CMs)
- Nonfuel Coal Based Products (CBPs)

Development

Technology Innovation Center (TIC) Planning

Commercial Processing Industry/Business Markets

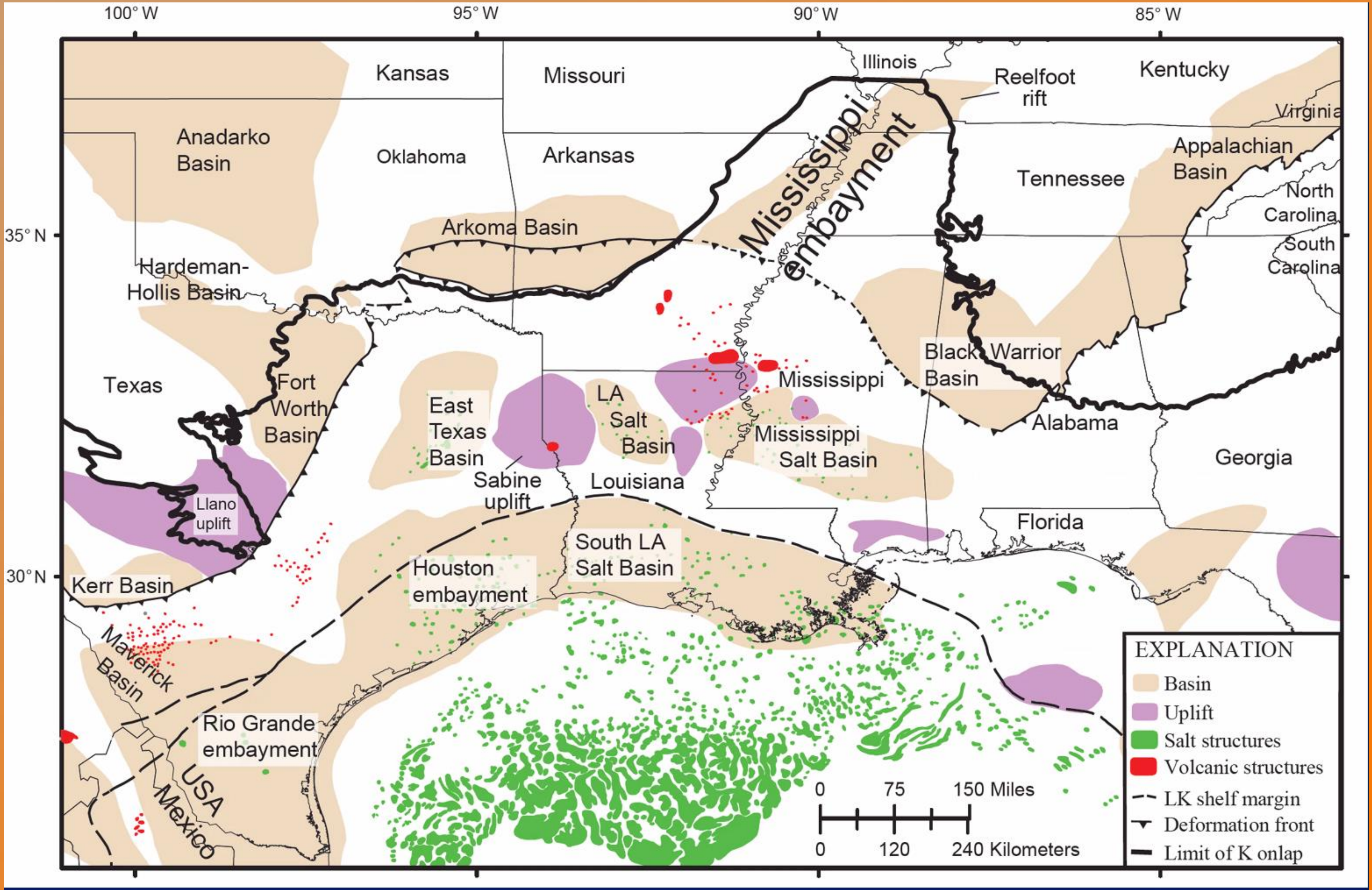
Training Outreach Workforce

NCRDS: USGS National Coal Resources Data System; CORD: Carbon Ore Resources Database; NETL EDX; Energy Data Exchange

Texas Lignite – REE and CM Potential

Map showing Cretaceous landscape features for consideration of coal-forming deposits and sediment deposition

Basins
Uplifts
Late-K volcanics



LK = Lower Cretaceous; K = Cretaceous

Warwick (2017)

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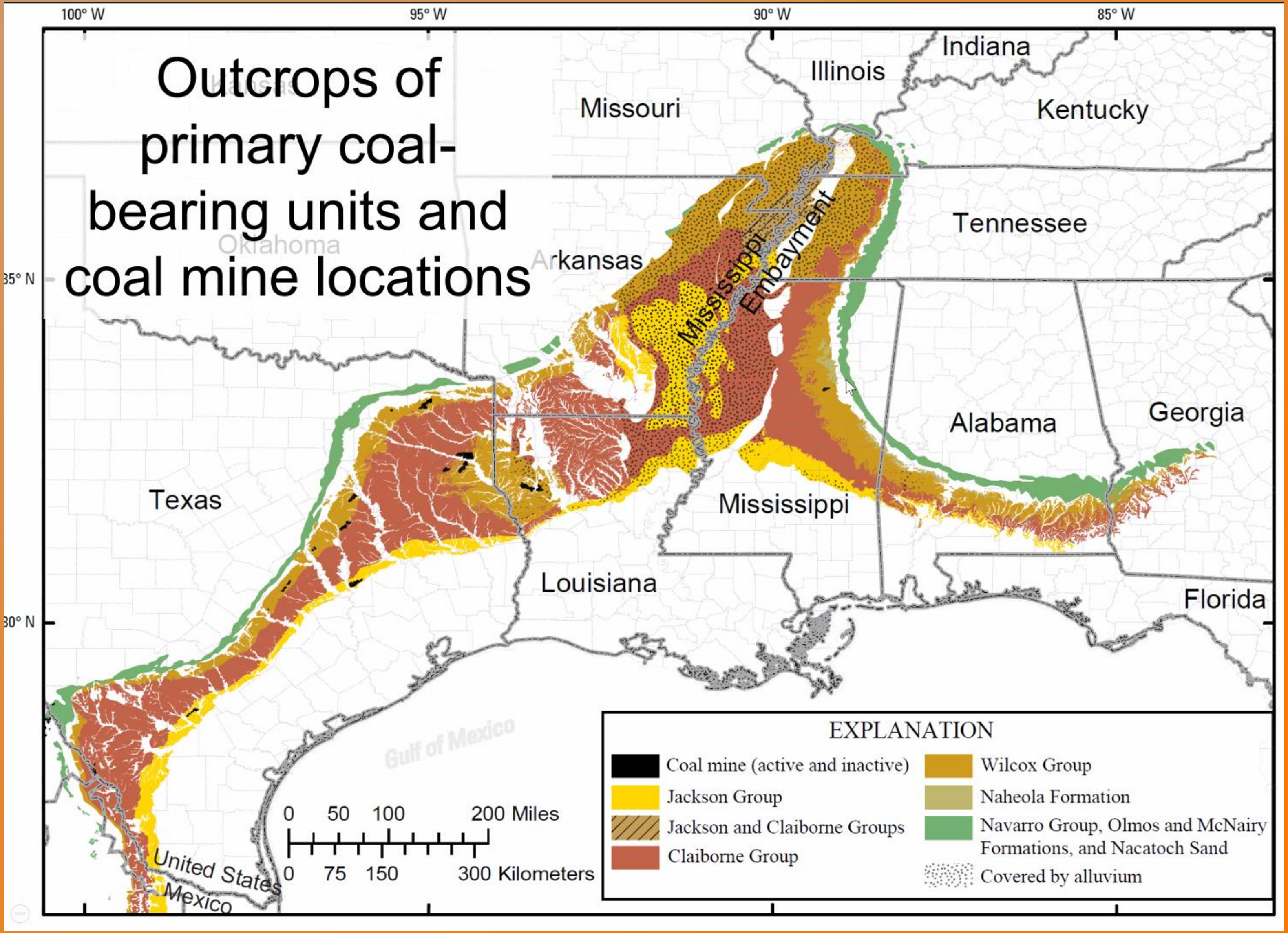
Texas Lignite – REE and CM Potential

Current and inactive coal mines

Primarily located along Wilcox Gr and Jackson Gr



Warwick in prep

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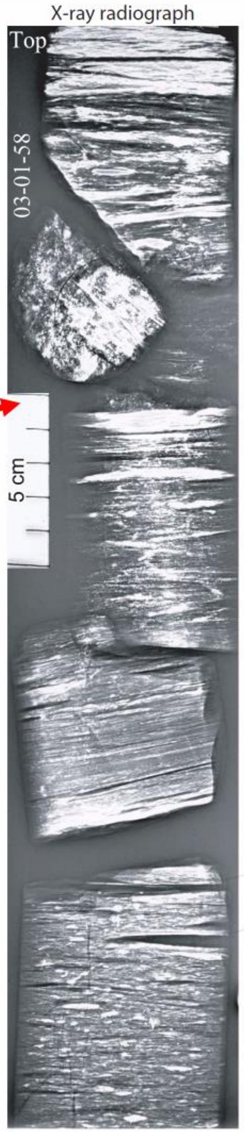
Texas Lignite – REE and CM Potential



Well: Comanche 1-117CR
Sample: 03-01-58
Depth:1189.80 - 1190.80 ft
AR Ash: 16.37%

Coal with shale lenses

Coal with horizontal and vertical burrows

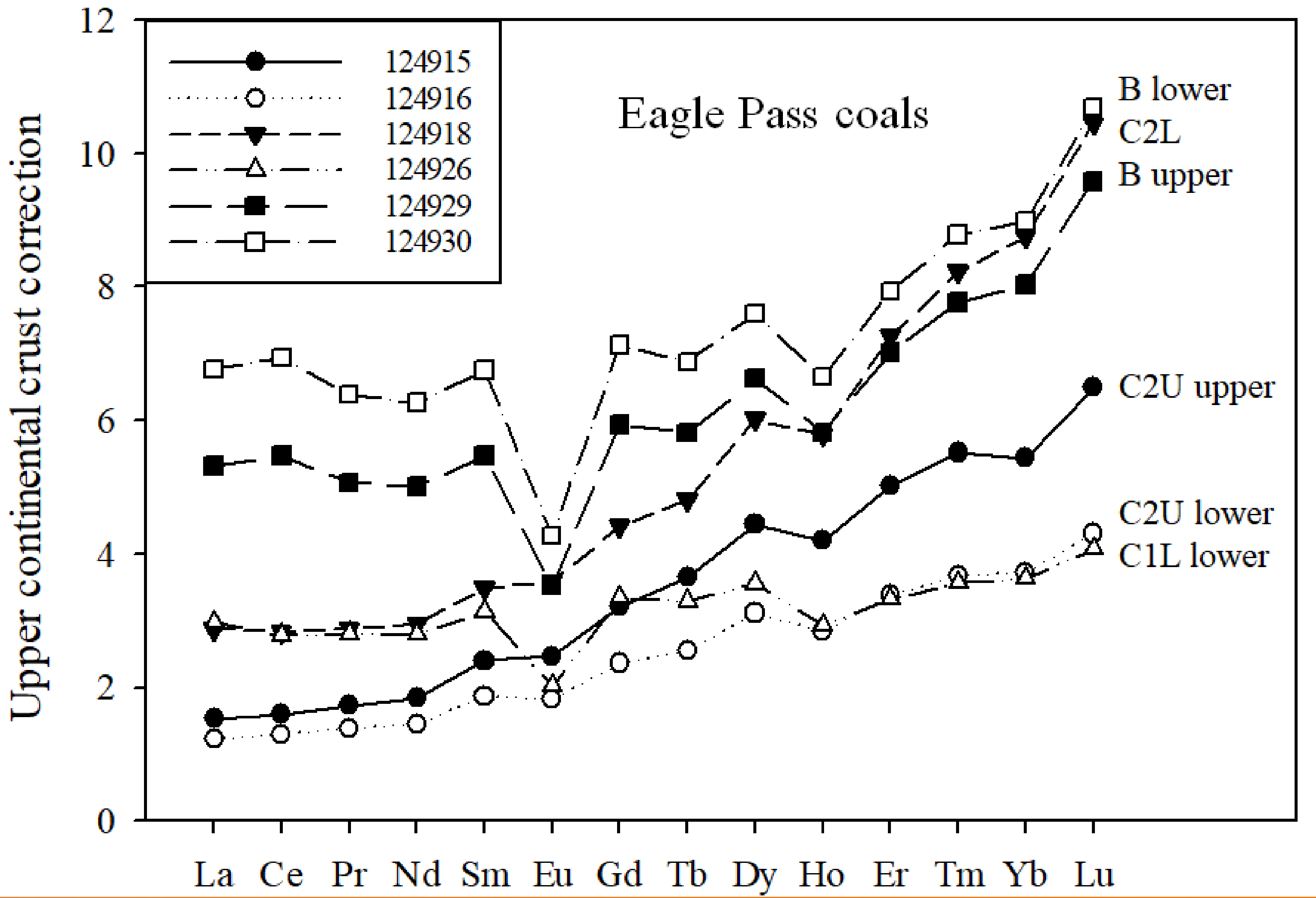
Coal, laminated with horizontal burrows

Woody lenses - compressed root? cross-sections

Coal with horizontal burrows and vertical cleat development

Karlsen and others (2002)

Texas Lignite – REE and CM Potential



B lower (124930), B upper (124929), and C1L lower (124826) have notable negative Eu anomalies. We need to see the ***complete*** minor element distribution in order to make sense of this. None of these analyses can be understood in a void.

All have H-type distributions (Lu>La), although C1L lower is only marginally H-type,

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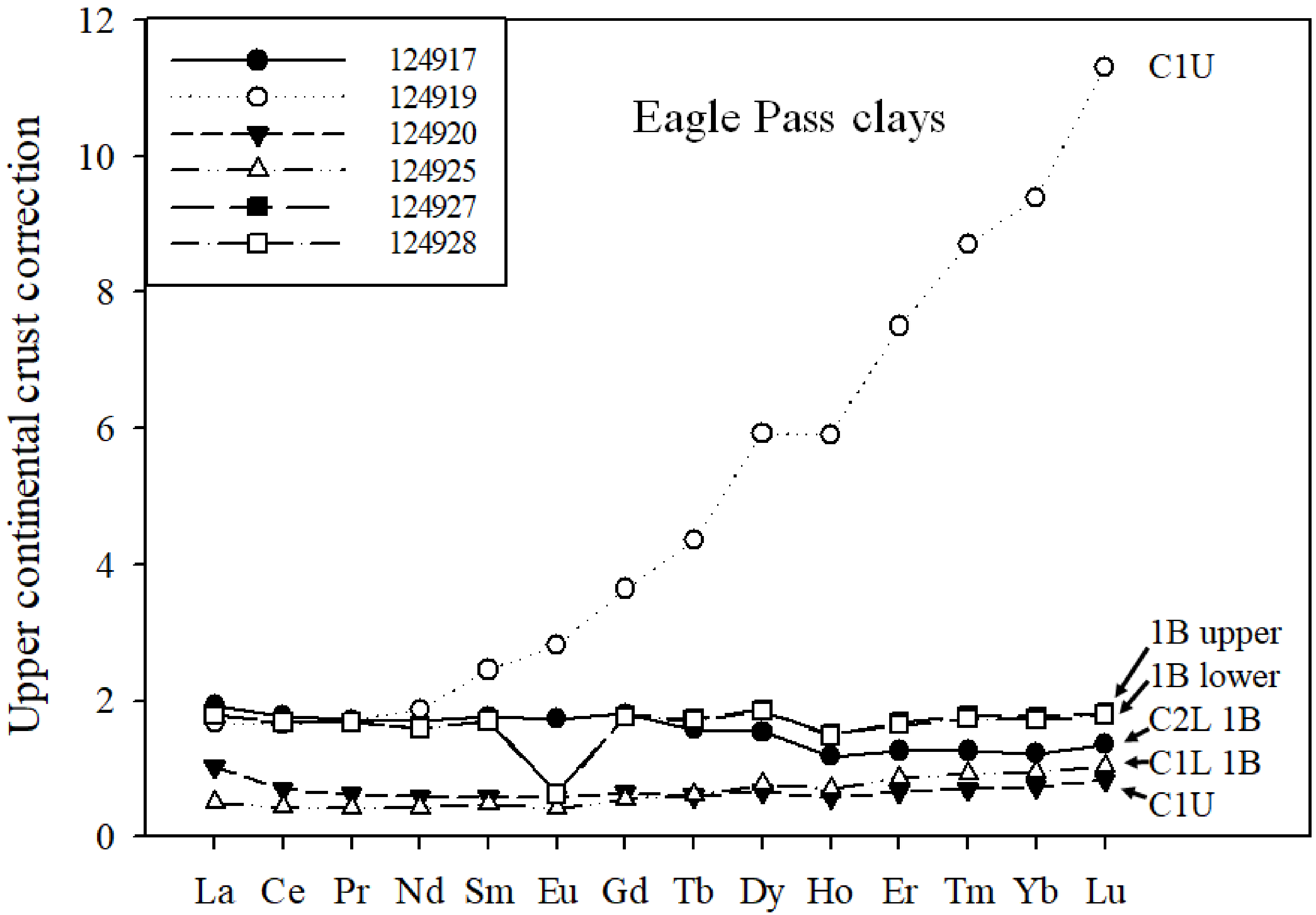

1B lower (124927) and 1B upper (124928) have notable negative Eu anomalies.

The lowermost two coals and two clays are the only samples with notable negative Eu anomalies.

C1U (124919), the only clay with an H-type distribution, deviates from other clays. C1U underlies coal C2L (129418), a high REE sample. C1U clay and C2L coal have similar REE distributions.

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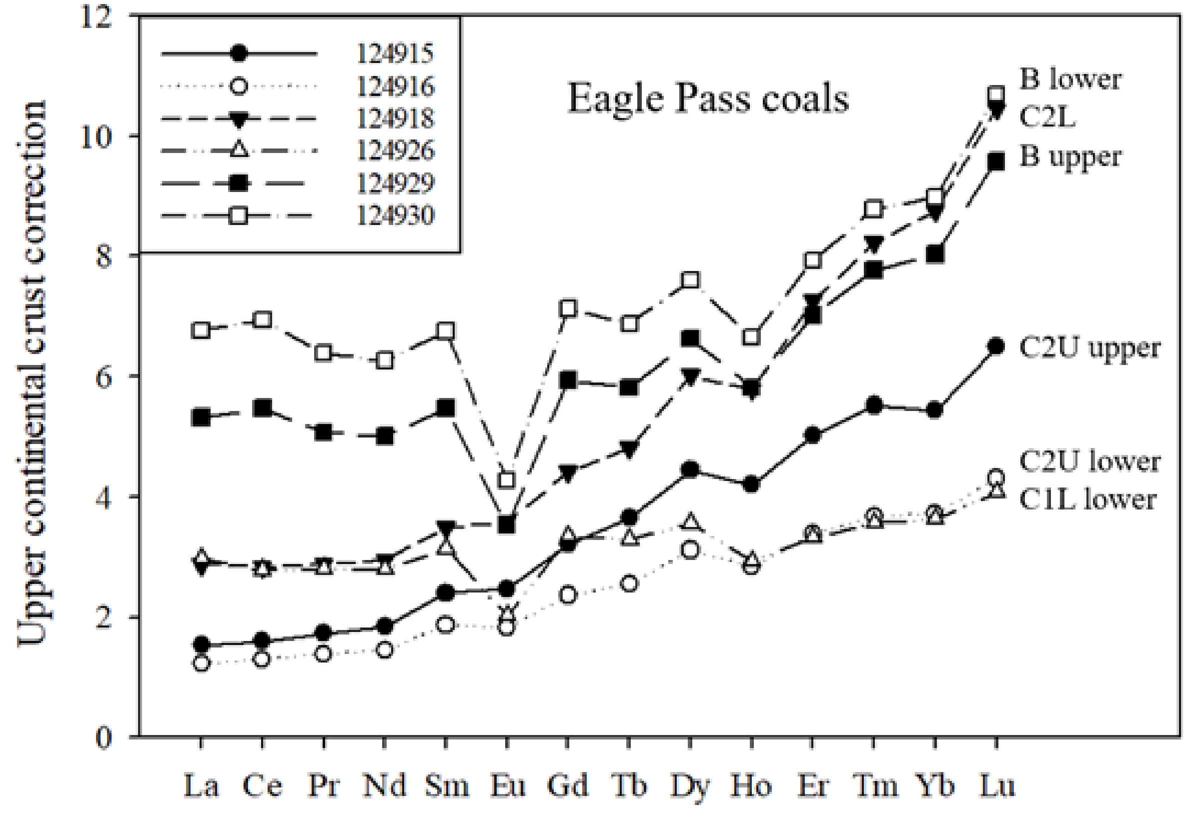
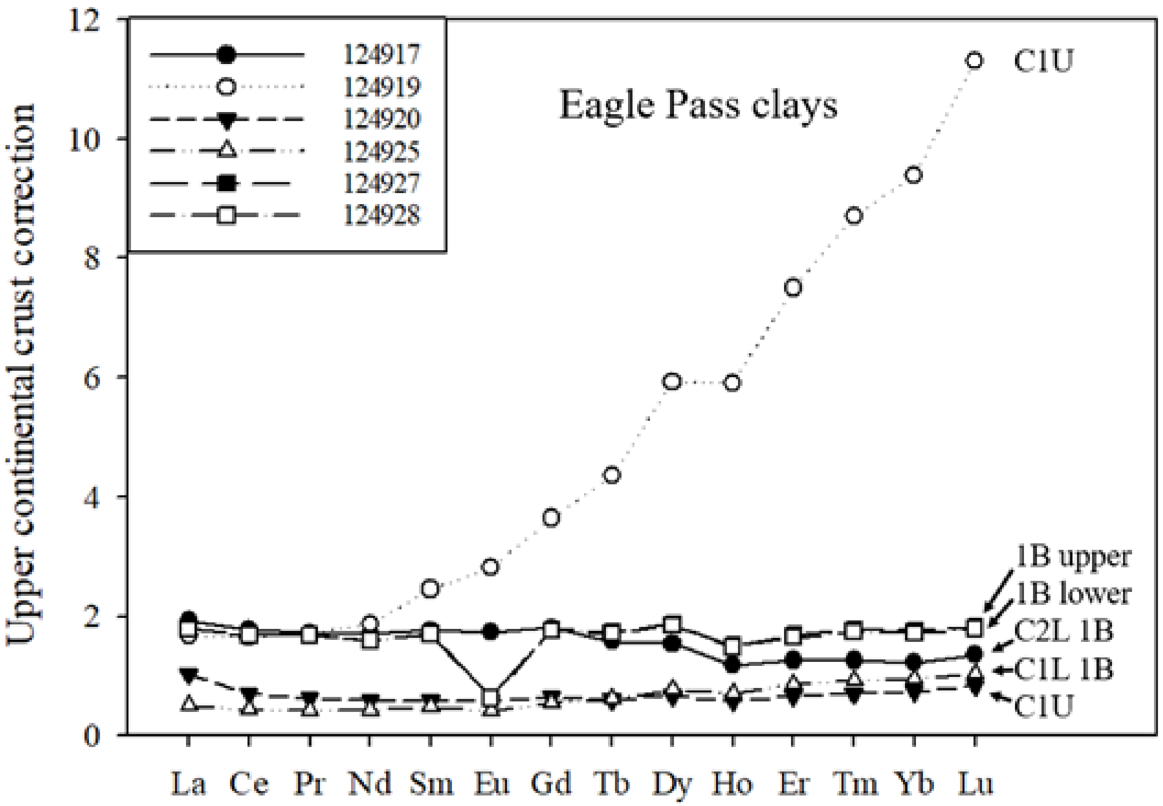




In summary

- REE and CM supply will need to increase at least 2-fold to meet current consumptive growth trends, 4-fold to meet 2-degree Paris Climate Agreement scenario, or 6-fold for globe to meet "net zero" GHG by 2050

- USGS, DOE, and DOD are pushing to categorize and catalogue resources of conventional and non-conventional sources of critical minerals including REEs, as well as development of competitive technologies for mineral separation

- West Texas hosts historical economic deposits of various metals, there may be more Round-Top like resources out there

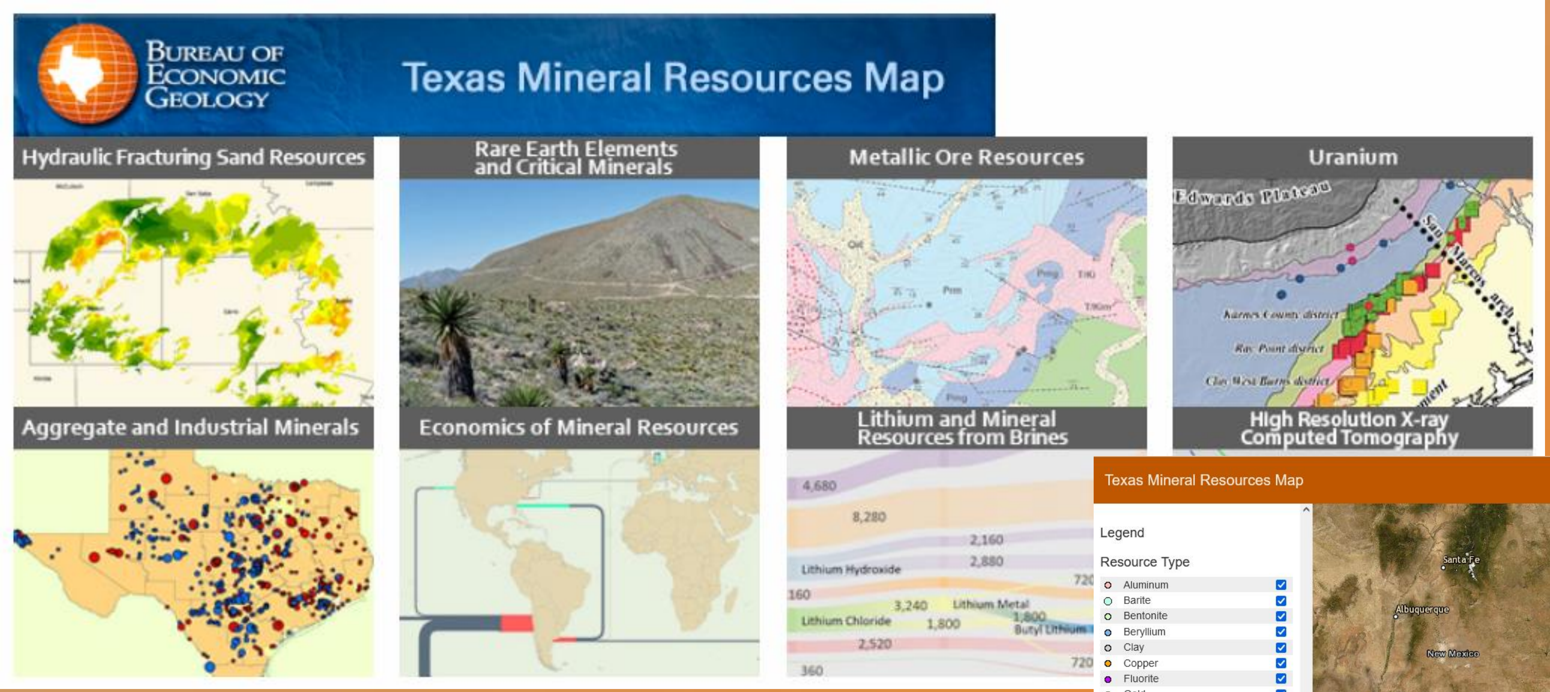
- Cornudas, TX, a potential economic source of critical minerals – waiting for assays, and studies are continuing

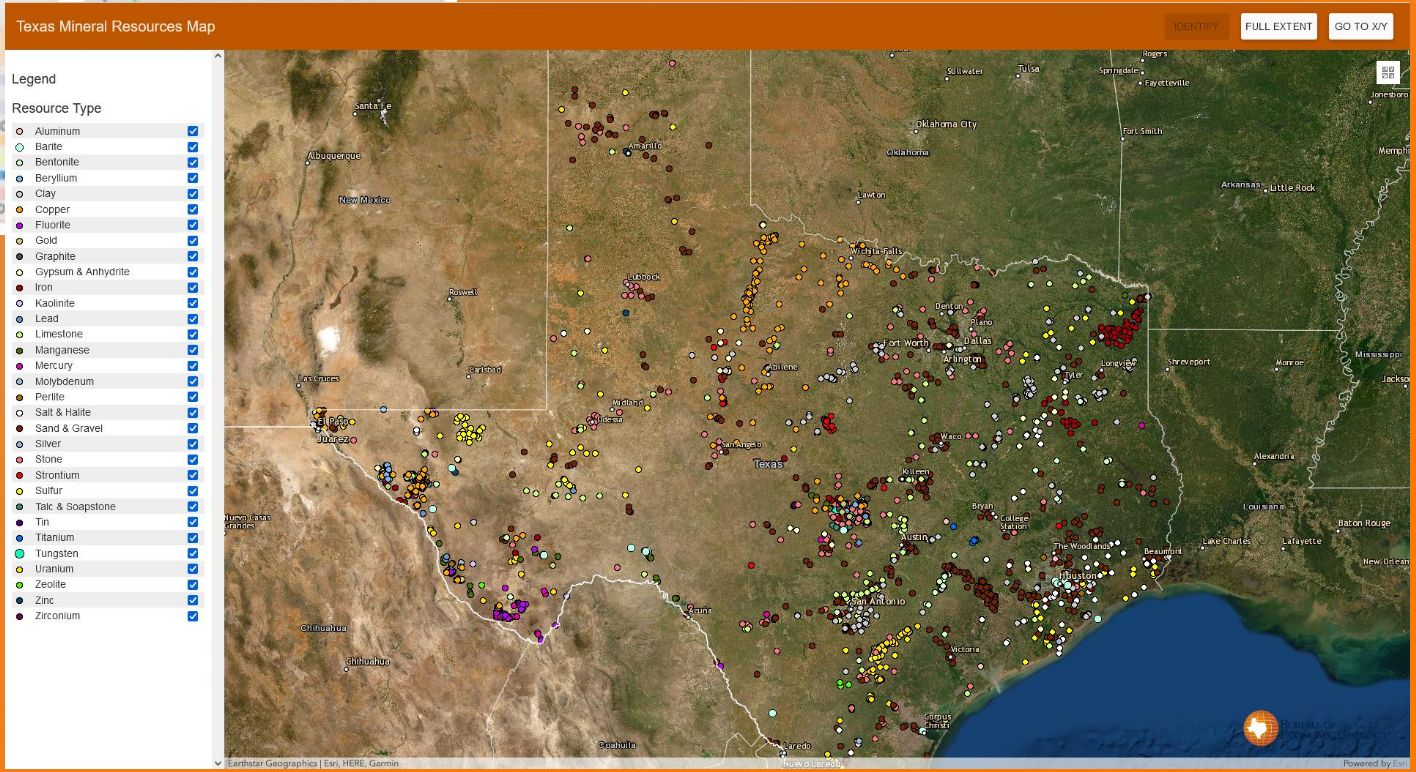
- Gulf Coast lignites and especially their ashes may be a future source of domestic critical minerals

- Additional CM-related work includes inspecting Smackover shales, produced waters, and various waste piles (graphite, bauxite).

Thanks!

https://www.beg.utexas.edu/minerals





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