Los Alamos NATIONAL LABORATORY

Perspectives on Future Mining Developments

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DOE Critical Minerals

- Diversify Supply and Develop Alternate Sources (reuse) until mining comes online
- Resource Characterization
- Mining Innovation
- All of above will be private, university, and national lab collaboration

Vision

The Department of Energy will be an essential source of science, technology, and engineering solutions for re-establishing U.S. competitiveness in critical mineral and material supply chains

DOE Critical Minerals and Materials Strategy, 2021

Mine of the Future

- Upcoming DOE-FENCM program
- Inspired by National Academies Panel 2022
  - Self-sustaining
  - Water resource responsible
  - Precision extraction
  - Autonomous systems
  - Narrow and deep
  - Inspiration from other industries (e.g., enhanced recovery)
  - In situ recovery
- What is economical is tied to separation technology (DOE simultaneous focus)
- “What good is a new generation of mines if we don’t know where to look?”

Resource Characterization

- Resource characterization and mining have always gone hand in hand
- Rise of AI/ML potentially changing paradigm of rate and type of characterization
- More data is always better, especially for AI/ML
- Need new systems and methods, especially for in situ analysis
  - ARPA-e RFI
- AI/ML potentially allows for combining of seemingly disparate data

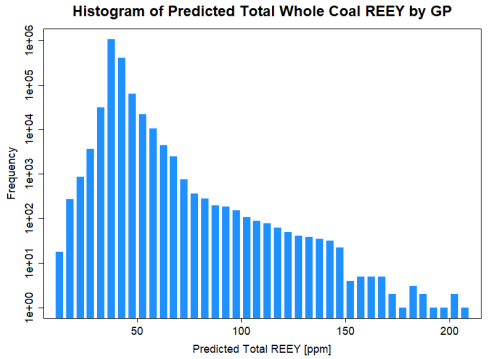


Fig 3: Histogram of Predicted REEY values in the PRB

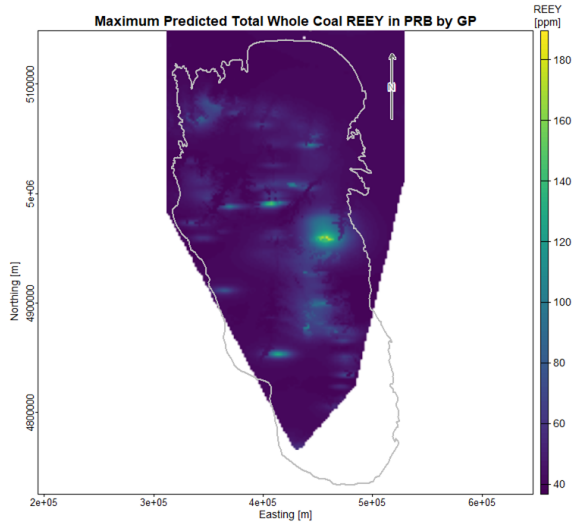
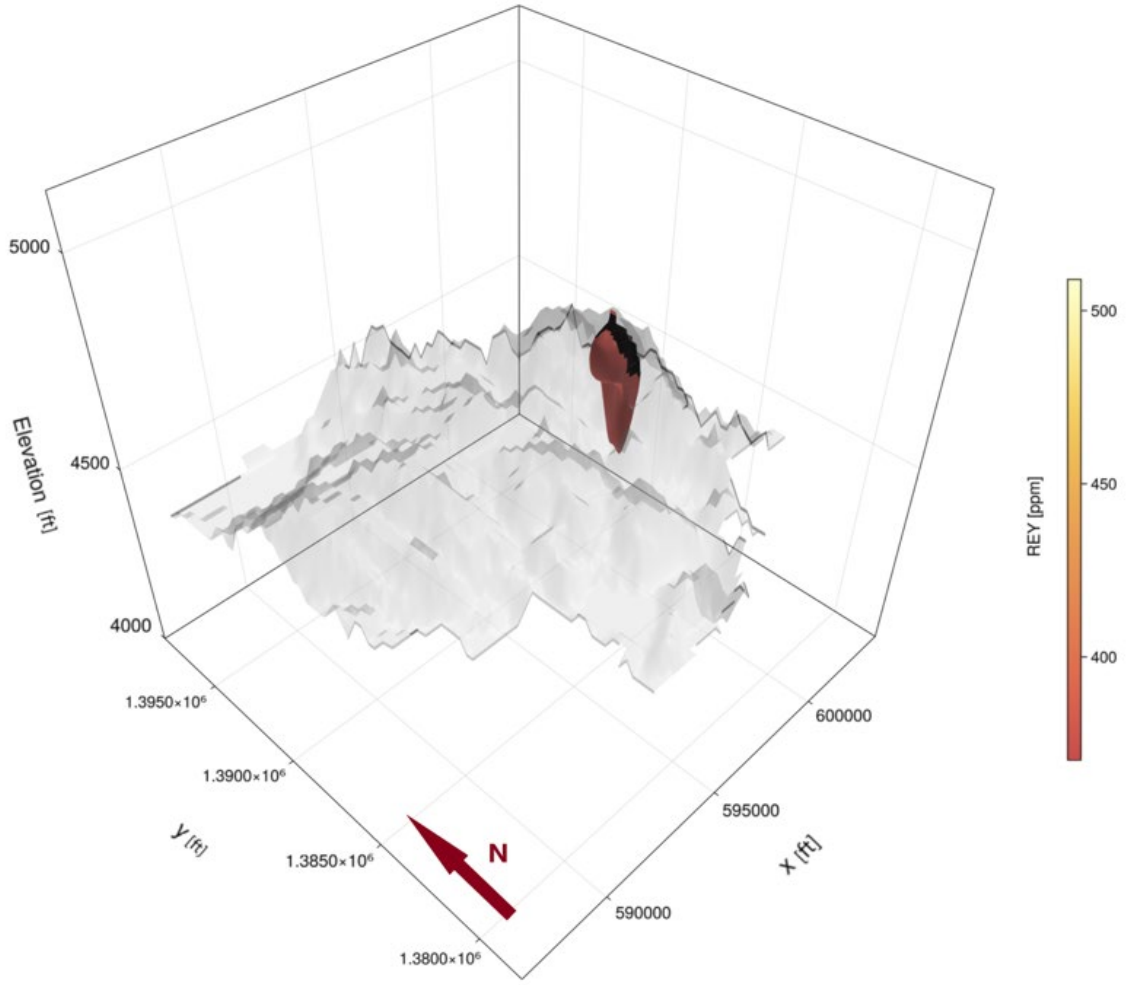


Fig 4: Spatial distribution of REEY concentrations. Rendered in 2D by taking maximum concentration in depth at each point.

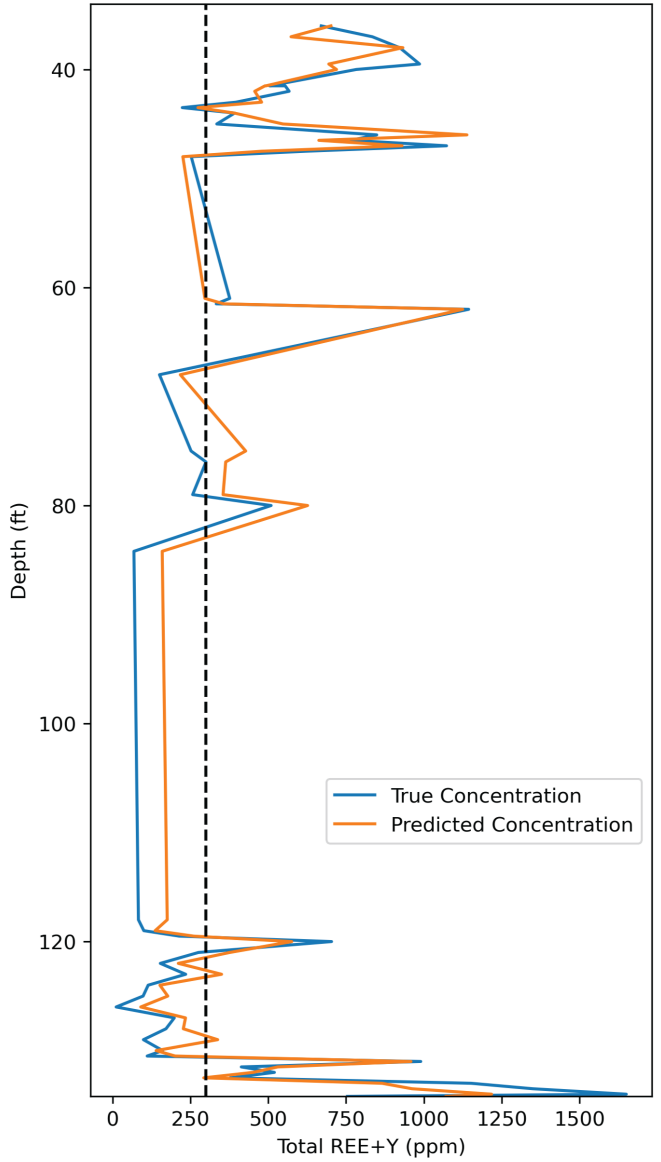
Precision Drives Mining Tech and Vice Versa

- Do we know extent of deposits well enough to be precise?
- How precise do we need to be?
- Nested resource models will be required and will require advancements in fundamental understanding to guide further resource assessment.
- We cant massively survey everywhere/we cant mine everywhere.



Field Based Characterization Enhancements

- Latest generation of field portable and handheld devices (XRF, LIBS)
- New instruments borrowed from other communities (e.g., Martian rover)
- New paradigms for data processing and interpretation
- AI/ML augmentation of data



Critical Role of Workforce Development

- Technology and engineering aware/savvy students
- Rooted in fundamentals of economic geology
- AI/ML aware
- Mining staff that are more tech ready for evolution of resource characterization and instrument repairs