

Application of Measurement While Drilling Data for Mine Blast Optimization

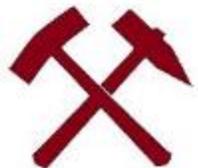
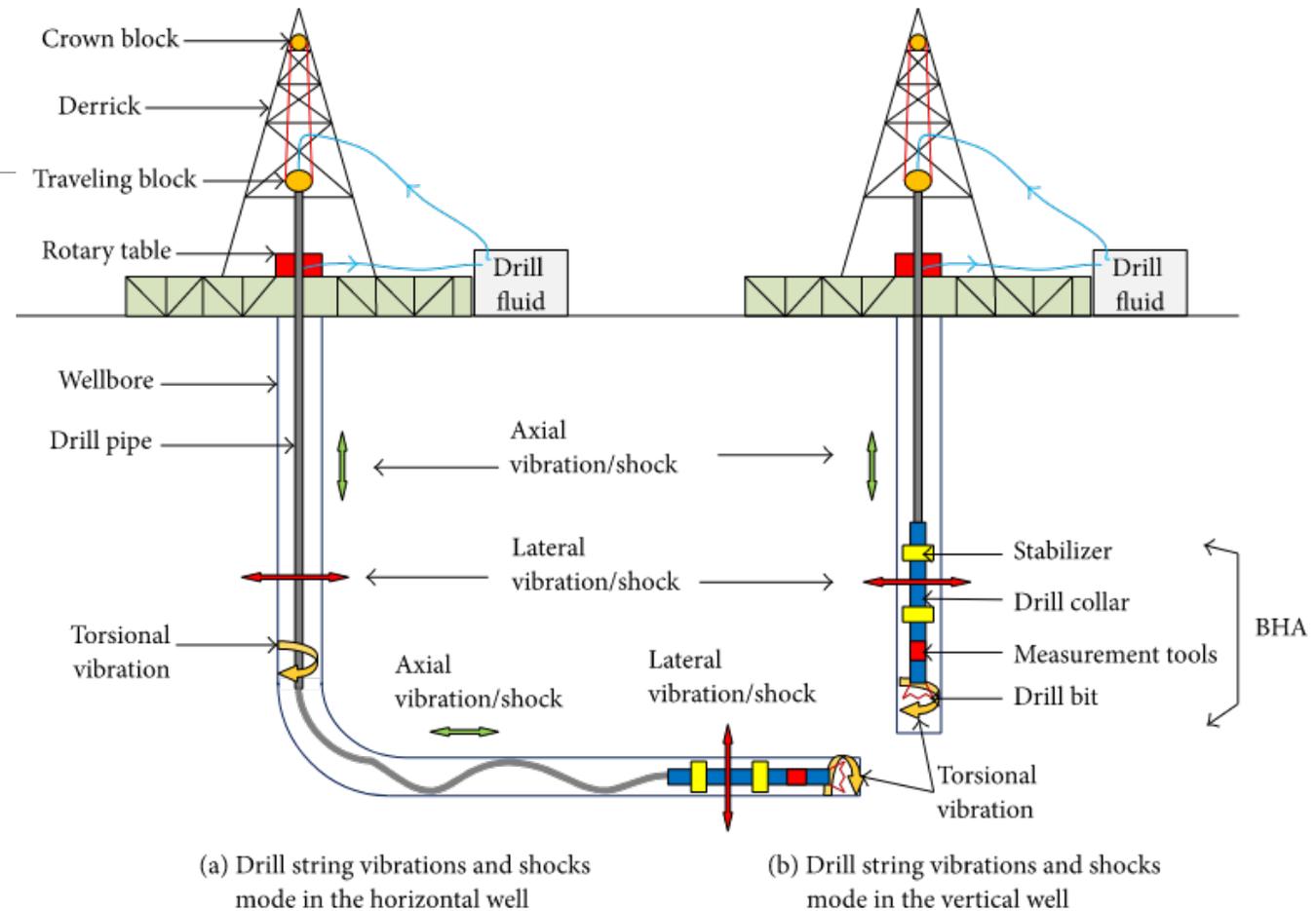
NSF FUNDED REU SUMMER PROJECT WITH SUPPORT FROM CASERM

ERIK WESTMAN, PROFESSOR
MINING AND MINERALS ENGINEERING, VIRGINIA TECH

Background

What is MWD?

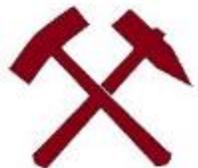
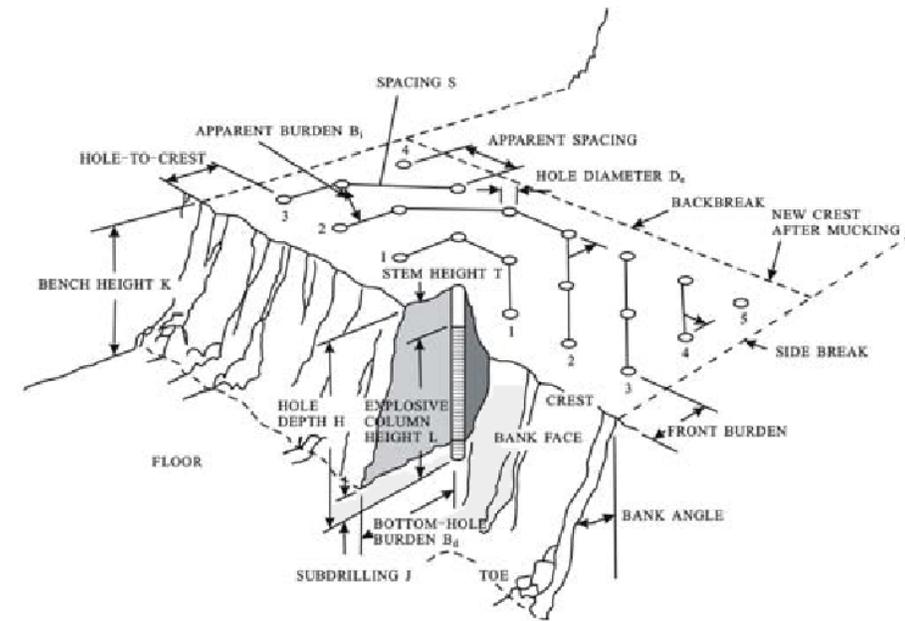
- Definition – use drill rig parameters to infer geology
- History – first work done almost 100 years ago!
- Prior use – Petroleum Industry
 - Geology
 - Bit Life



Goal of Summer Project

Subsurface data and predictions from MWD

Blast optimizations - more desirable fragment sizes.



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CENTER FOR ADVANCED SUBSURFACE
EARTH RESOURCE MODELS

Members

- Joe Fleming - 2022 Mining Engineering
- Ryland Hanson - 2022 Computational Modeling and Data Analytics
- Owen Potts - 2023 Mining Engineering
- Garek Elie - 2023 Mining Engineering
- Mamadou Ba - 2023 Mining Engineering
- Ben Harrington - 2024 Mining Engineering



Background

MWD can determine torque, penetration rate, weight on bit, thrust, as well as other pressures/conditions

Specific Energy and Rock Hardness Relation

Teale's Equation from 1965:

$$e = \left(\frac{F}{A} \right) + \left(\frac{2\pi}{A} \right) \left(\frac{NT}{u} \right) \text{ in. lb/in}^3.$$



Background

Data from Epiroc - DTH Drilling

Equation by Okuchaba for air hammer drilling

Okuchaba Equation utilizes: Impact velocity (V), coefficient of restitution (e), and energy transmission efficiency (η)

$$MSE = \frac{120 \cdot m_{piston} \cdot V_{impact}^2 (1 - e^2) \cdot F \cdot \eta_{transmission}}{Dia^2 \times \pi \times ROP} + \frac{4 \times WOB}{Dia^2 \times \pi} + \frac{480 \times T \times N}{Dia^2 \times ROP} \dots\dots\dots (4.12)$$



The Data

Data from Epiroc (DTH)

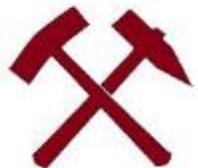
- 25 Boreholes
- Date and time, depth, penetration rate, percussion pressure, rotary pressure, feed pressure
- 5.75" Diameter

Torque into SE using Teale's

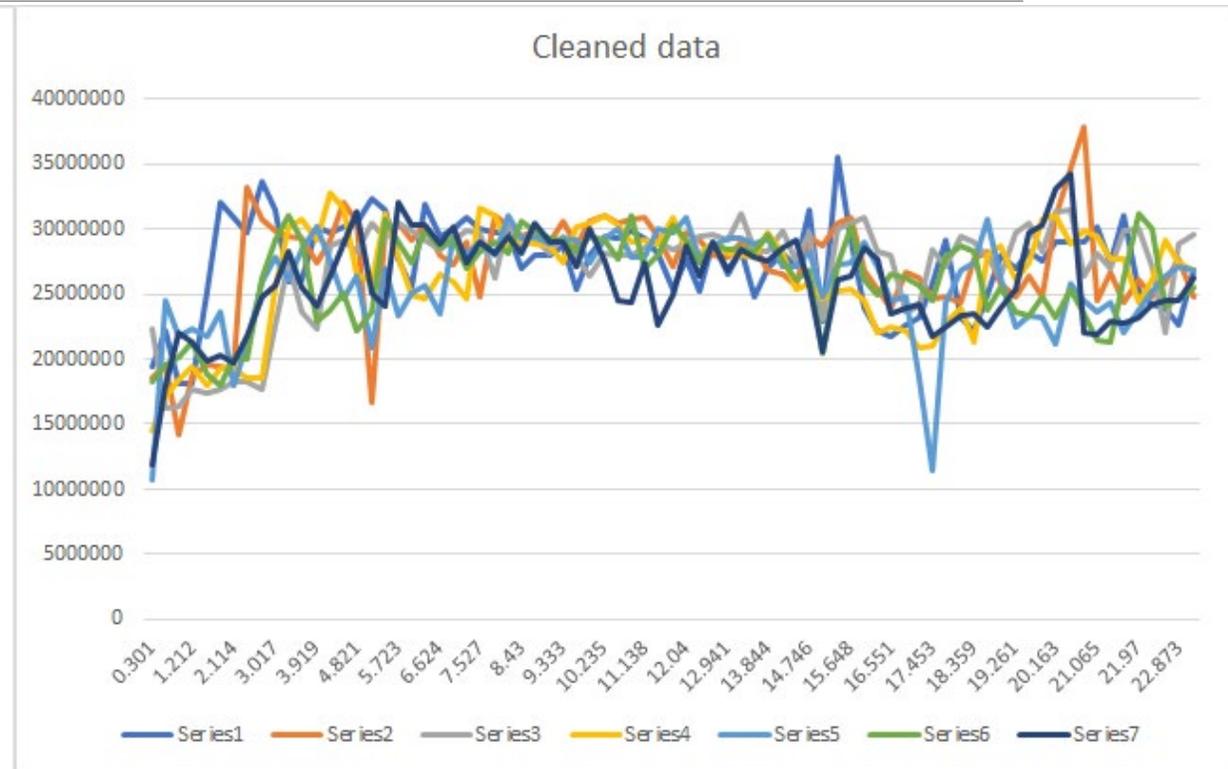
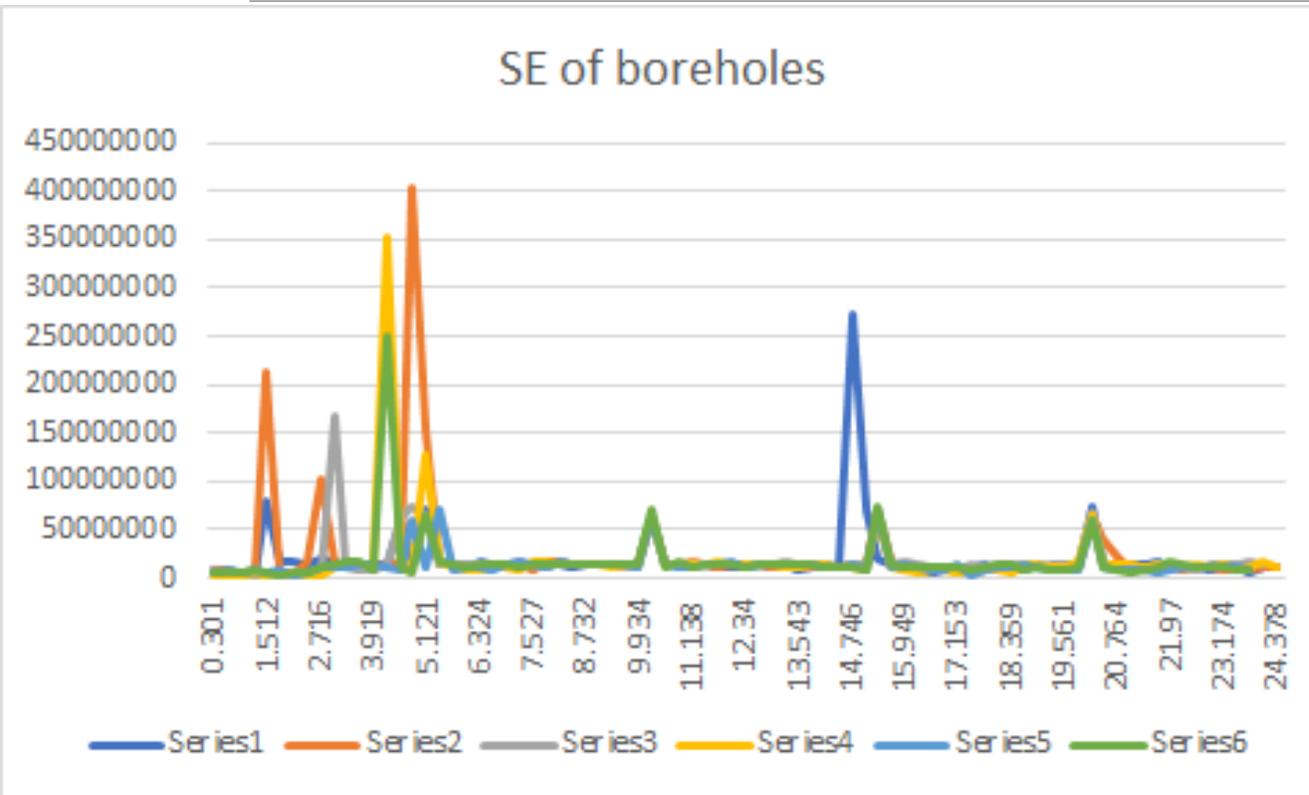
Removal of samples three standard deviations or greater from mean (specific energy)



SmartROC D65 Drill (Epiroc)



Problems



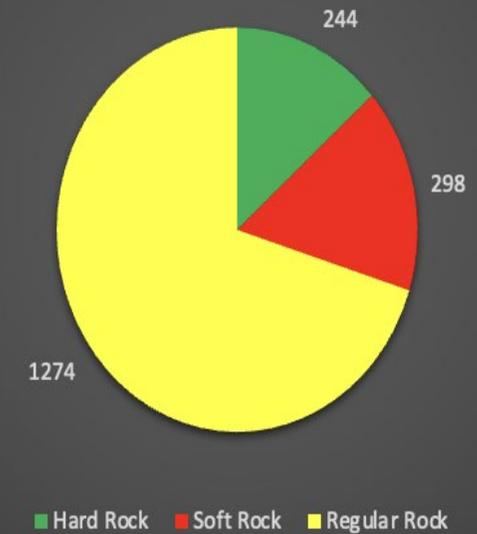
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Initial Data Cleaning

- Average: 10-15s to drill 0.300 m.
- Removed all samples with durations greater than 30s (183 removed, 1,816 remaining)
- $t > 20s$ = Hard Rock, $t < 10s$ = soft rock

Rock Distribution by type based on duration



- Sites
 - Demo Site
 - Demo Work Order
 - Demo Plan
 - Montana Limestone Company
 - KCEE
 - 20191114_KCEE
- Fleet
 - 8992011440
 - Demo Rig 1
 - Demo Rig 2

Explorer 20191114_KCEE x

Search

Drill plan

Name	20191114_KCEE
Hole count	25
Outlier holes	0
Bearing	0.00
Start date	
End date	
Done	False

Rock volume

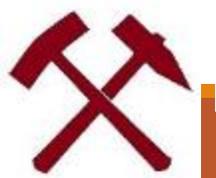
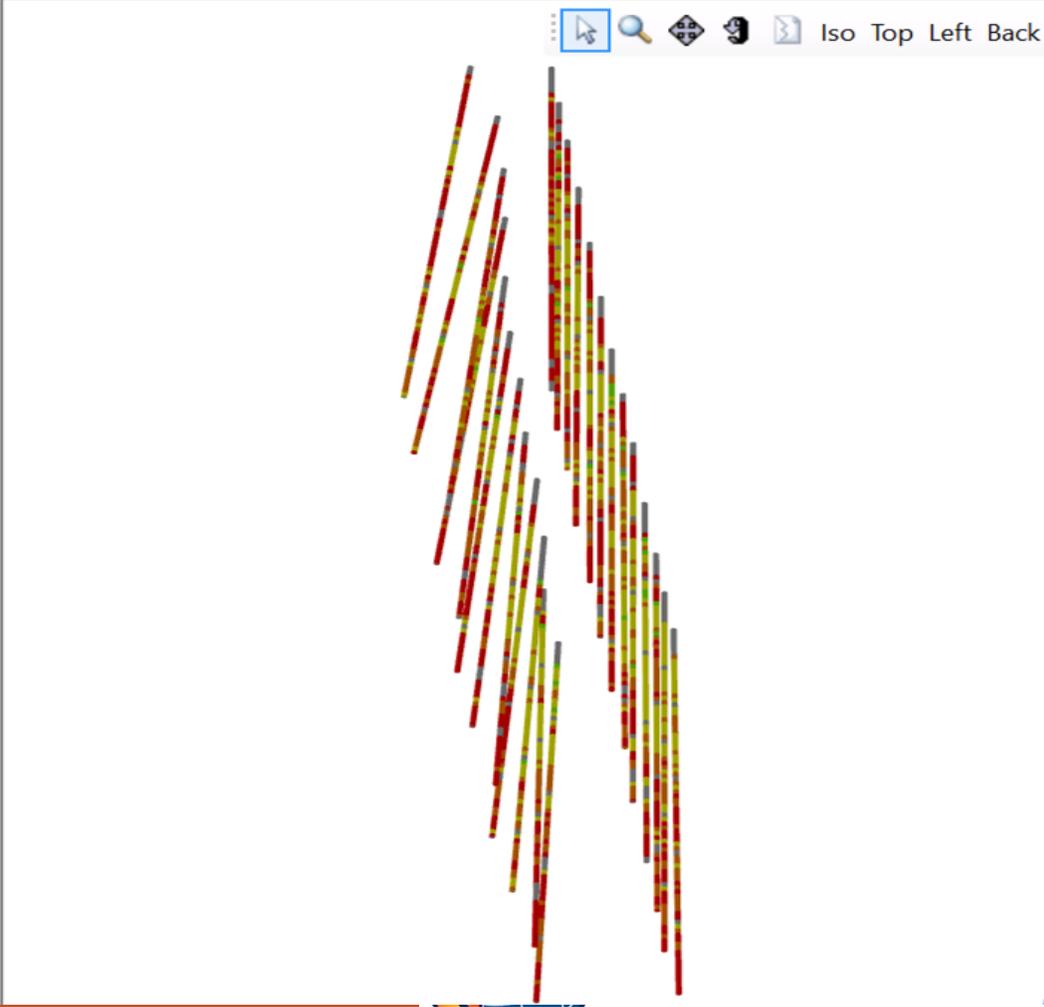
Target height	1696.97
Planned estim	22805.39
Drilled estima	23809.99

- Show planned holes
- Show drilled holes
- Show hole names
- Show planned rock volume
- Show drilled rock volume
- Show boundaries

Show MWD
Parameter:
Hardness

Show volume

- Hole view mode:
- Top
 - Bottom
 - Slice

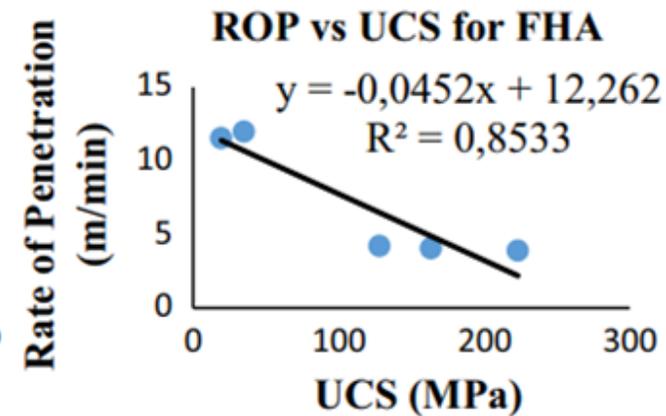
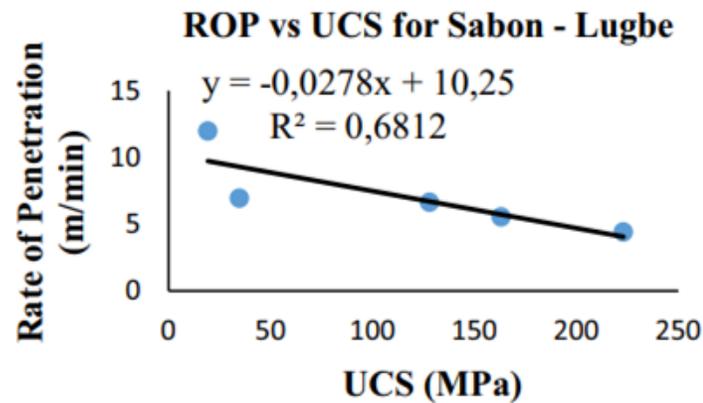
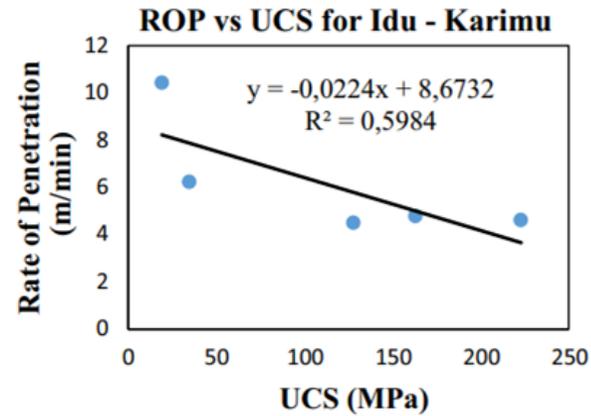
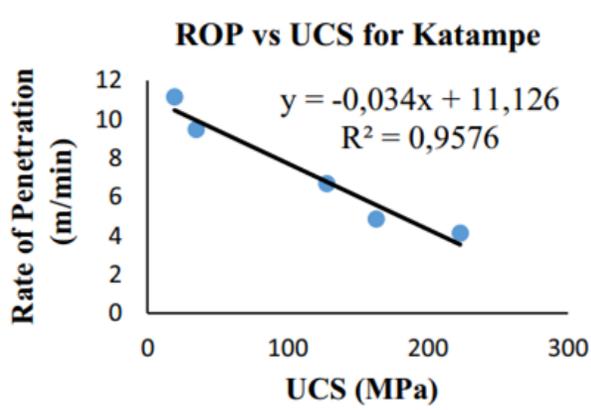


Not Specific Energy

Change in hardness determination - Penetration Rate

Not utilizing Teale's or Okuchaba's SE equation

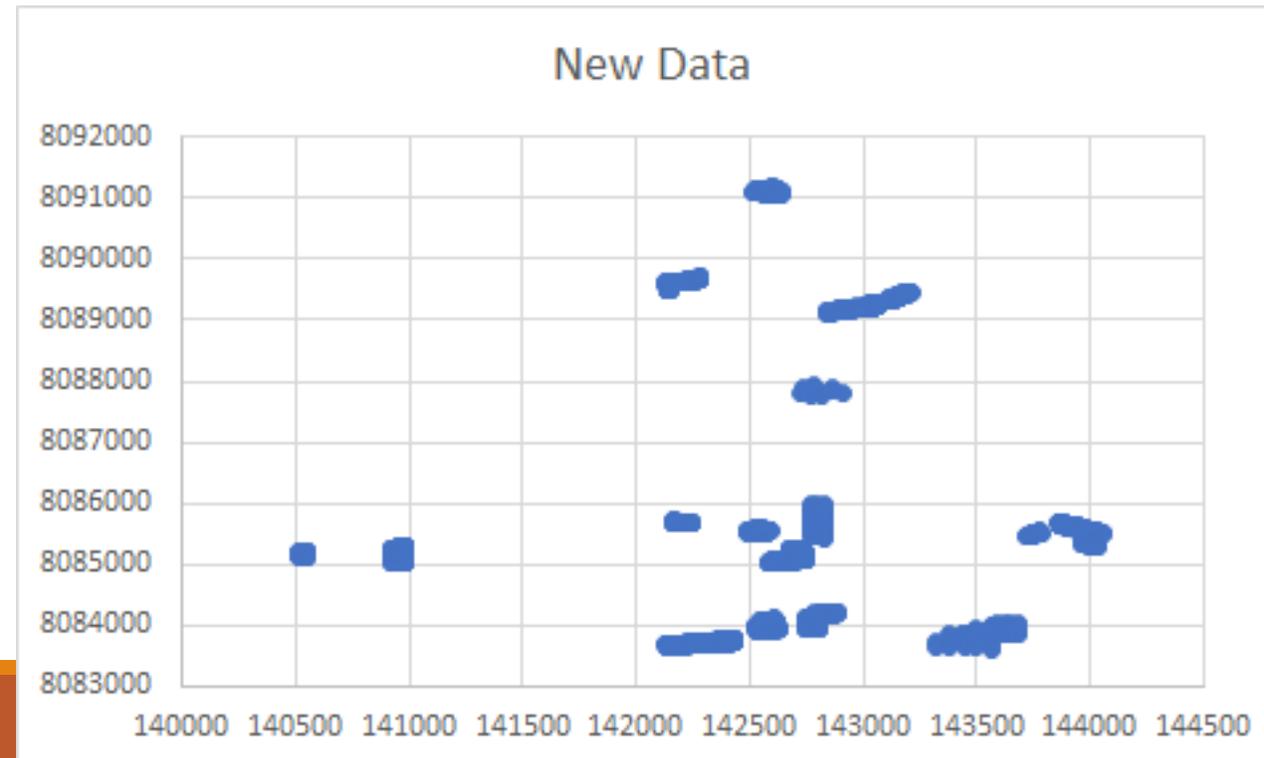
Peter Kolapo - ROP vs UCS



New dataset from industry partner

4000 holes

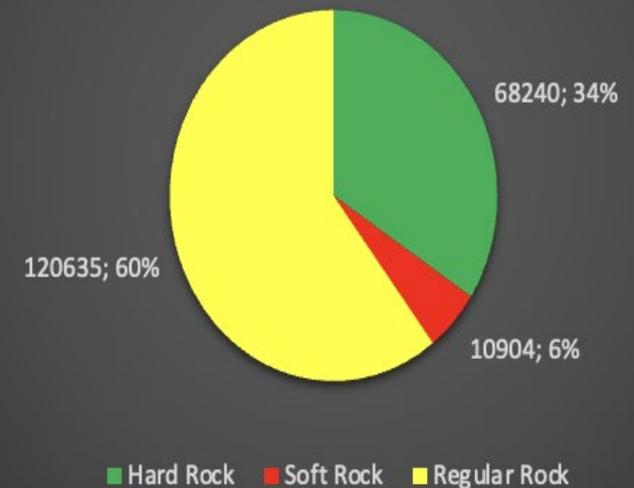
Using penetration rate as proxy for Specific Energy



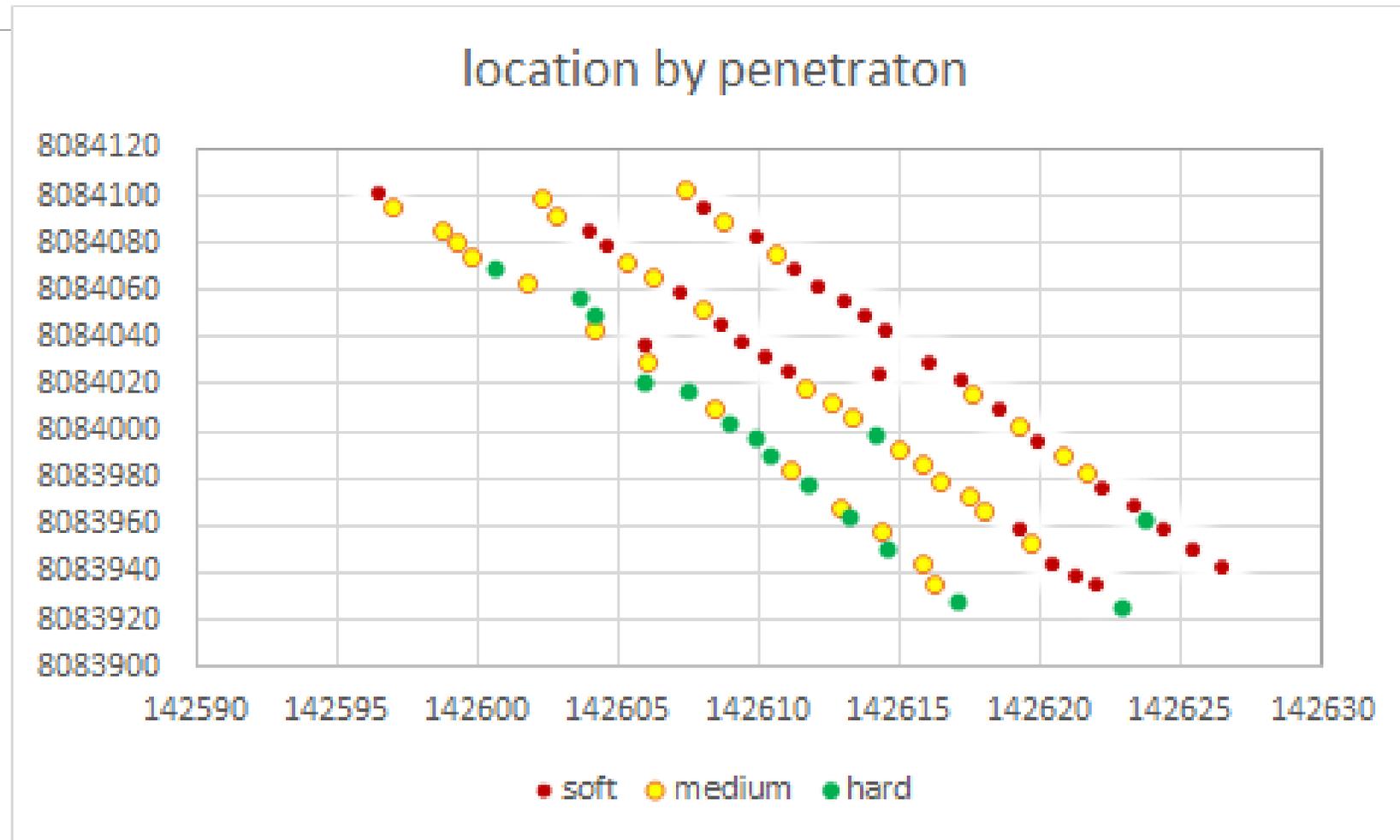
Cleaning of 2nd Data Set

- Raw data had 213,174 entries
- After Data Cleaning had 199,779 entries on roughly 4,300 holes
- Penetration rate
 - $P > 1.8 \text{ m/s}$ = soft rock
 - $P < 0.9 \text{ m/s}$ = hard rock

Rock distribution by type based on penetration rate



Data visualization

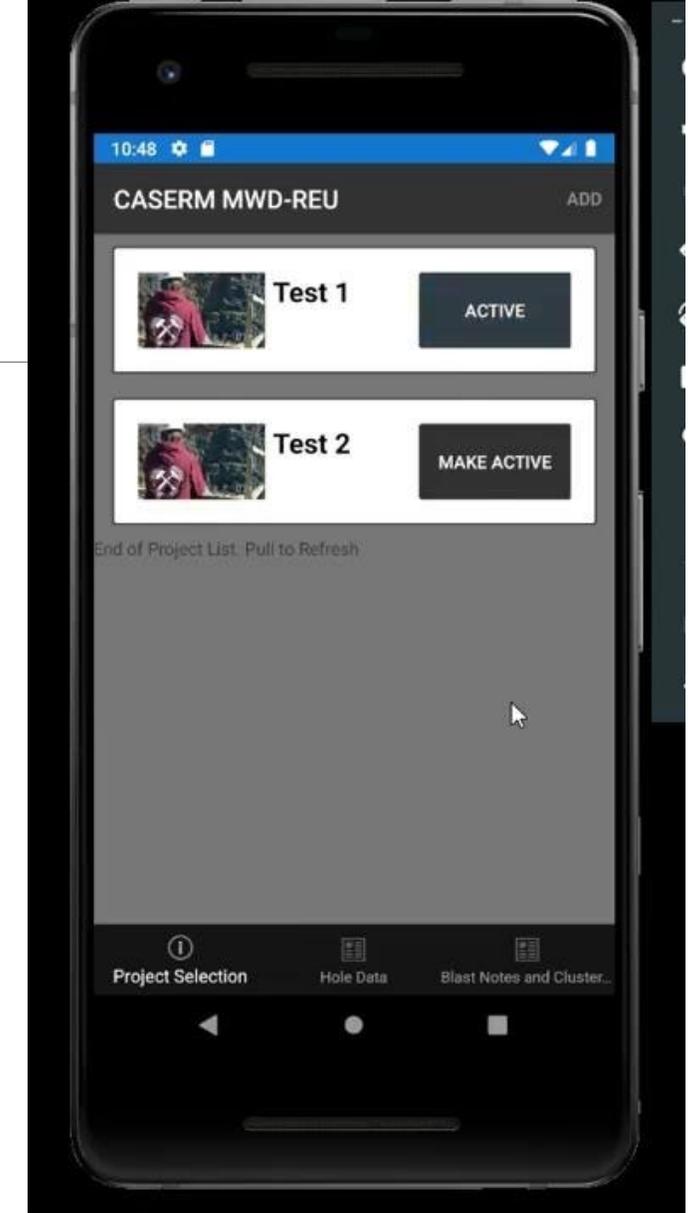
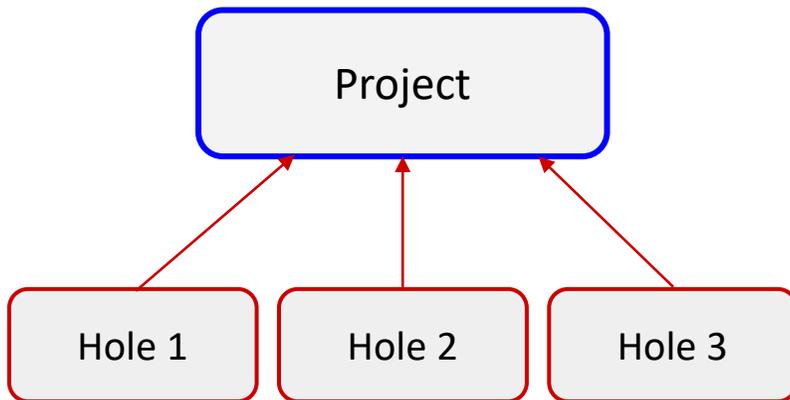


App Homepage

Project oriented

Holes are part of a project

Add and remove projects

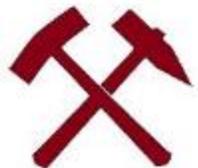
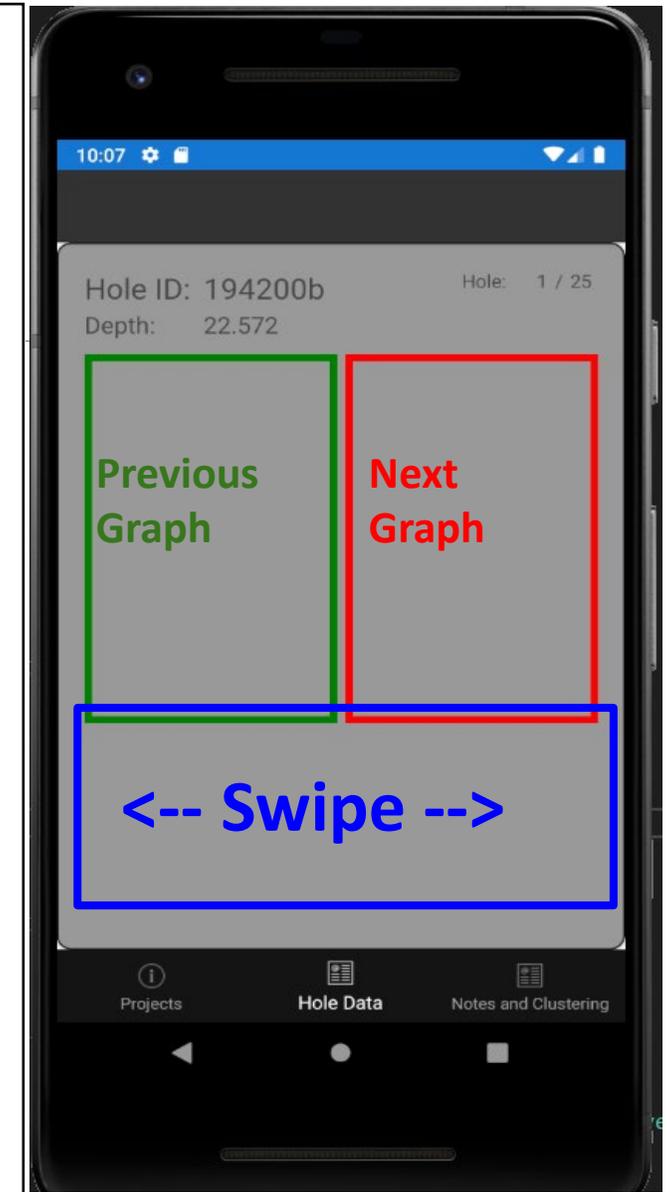


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App Hole View

- HoleID, Depth, and Place
- UI changes between graphs
- Swipe for next hole

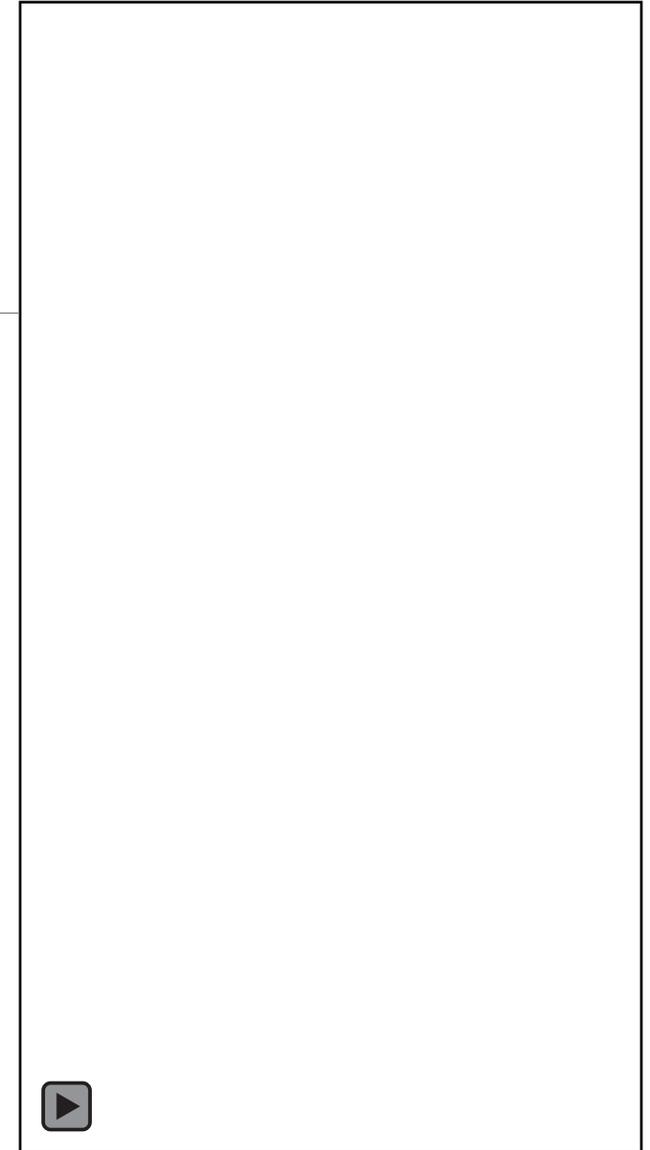


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App Notes and Clustering

- Blast notes section, uploaded to Project URL
- Clustering Images

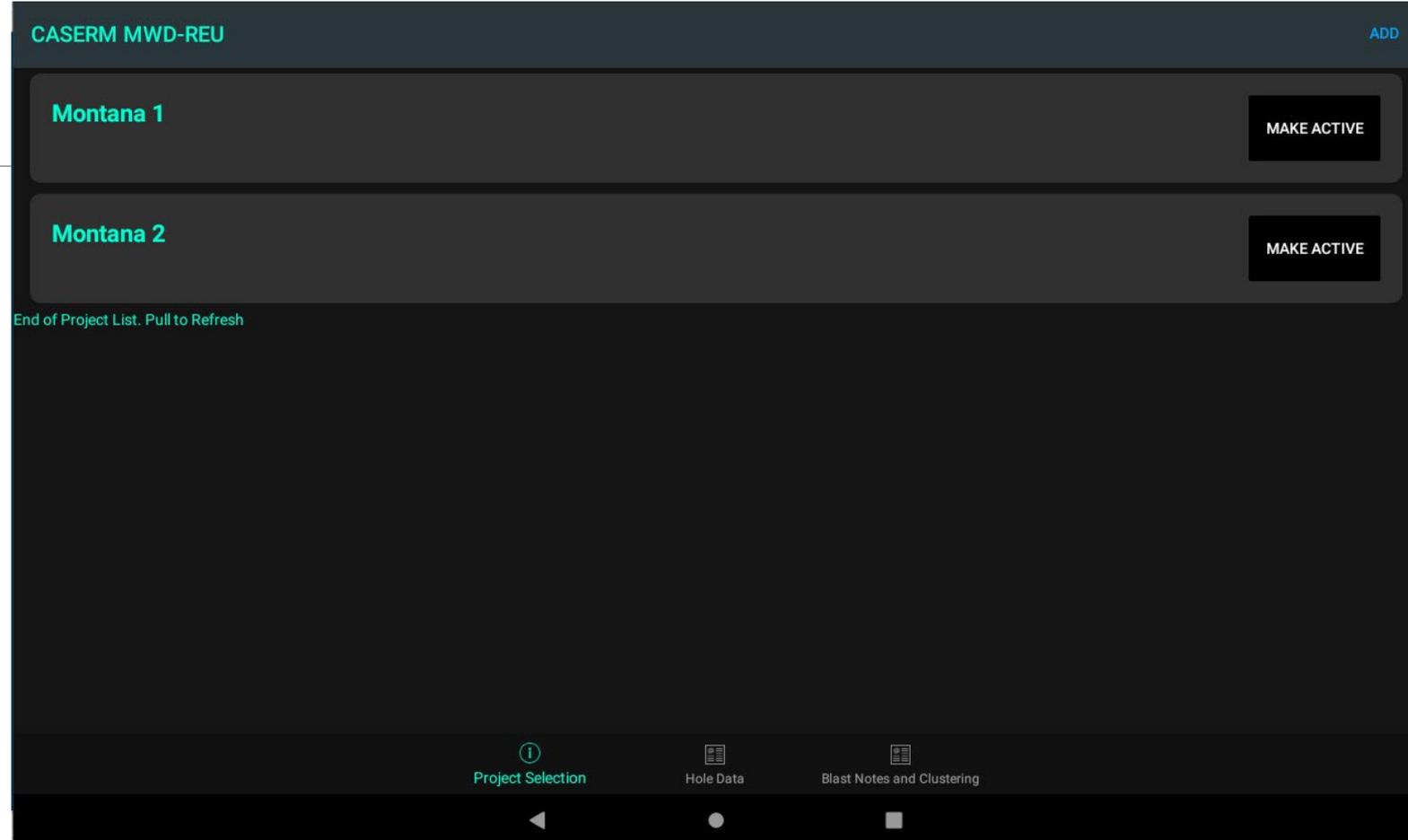


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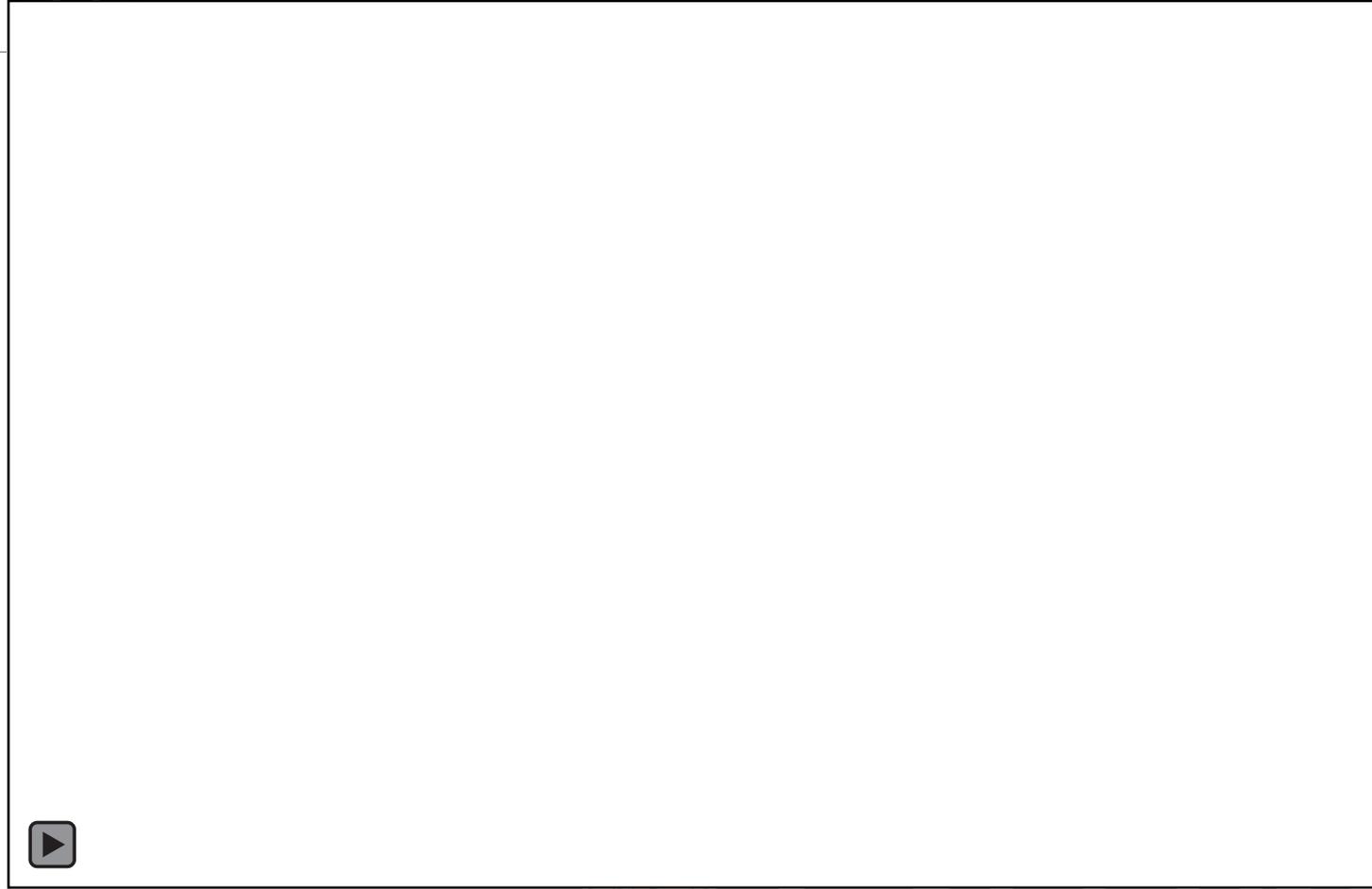
App

- UI Updates
- Tablet Focus
- Easier Navigation
- Exception Protection
- Local Data Storage



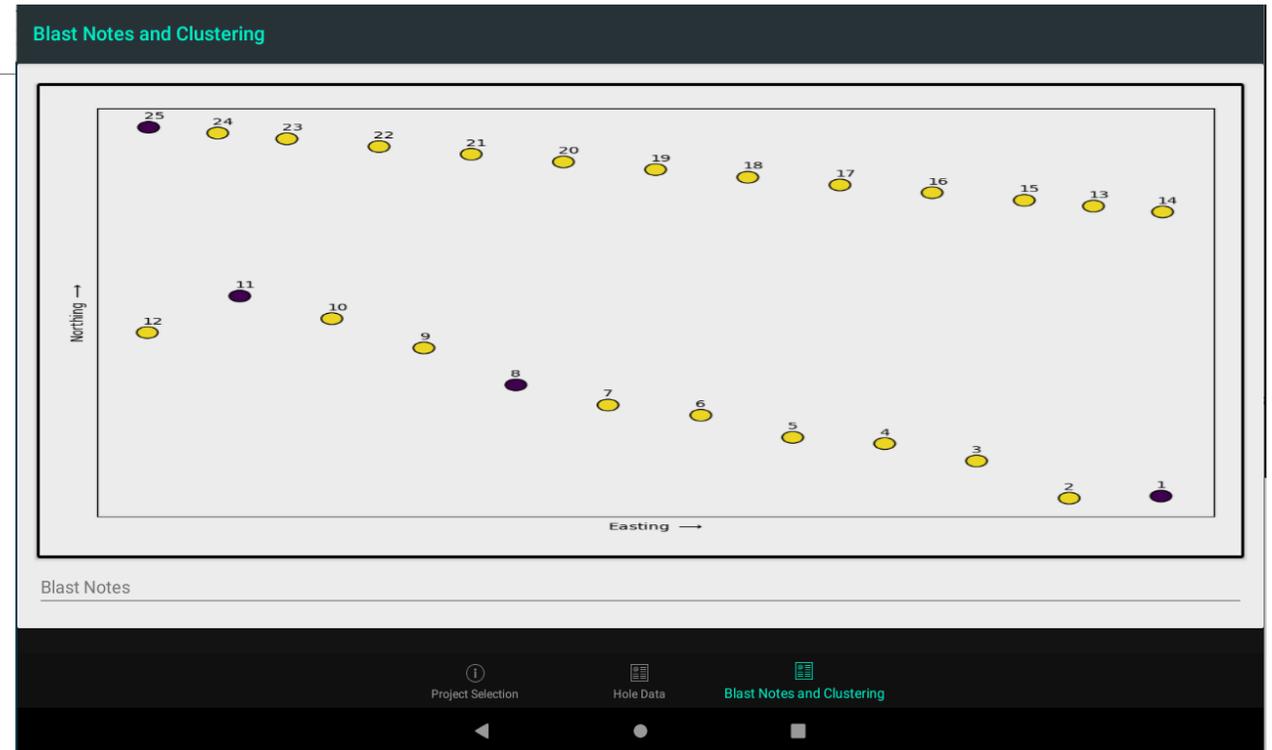
App Hole View Page

- Change holes with buttons
- Select Hole by ID/Location Number
- Zoom Feature
- Shot Minimap



Clustering

- Colors Indicate Similar Holes
- Numbered Holes
- Sync Notes



Future Work

Bit wear

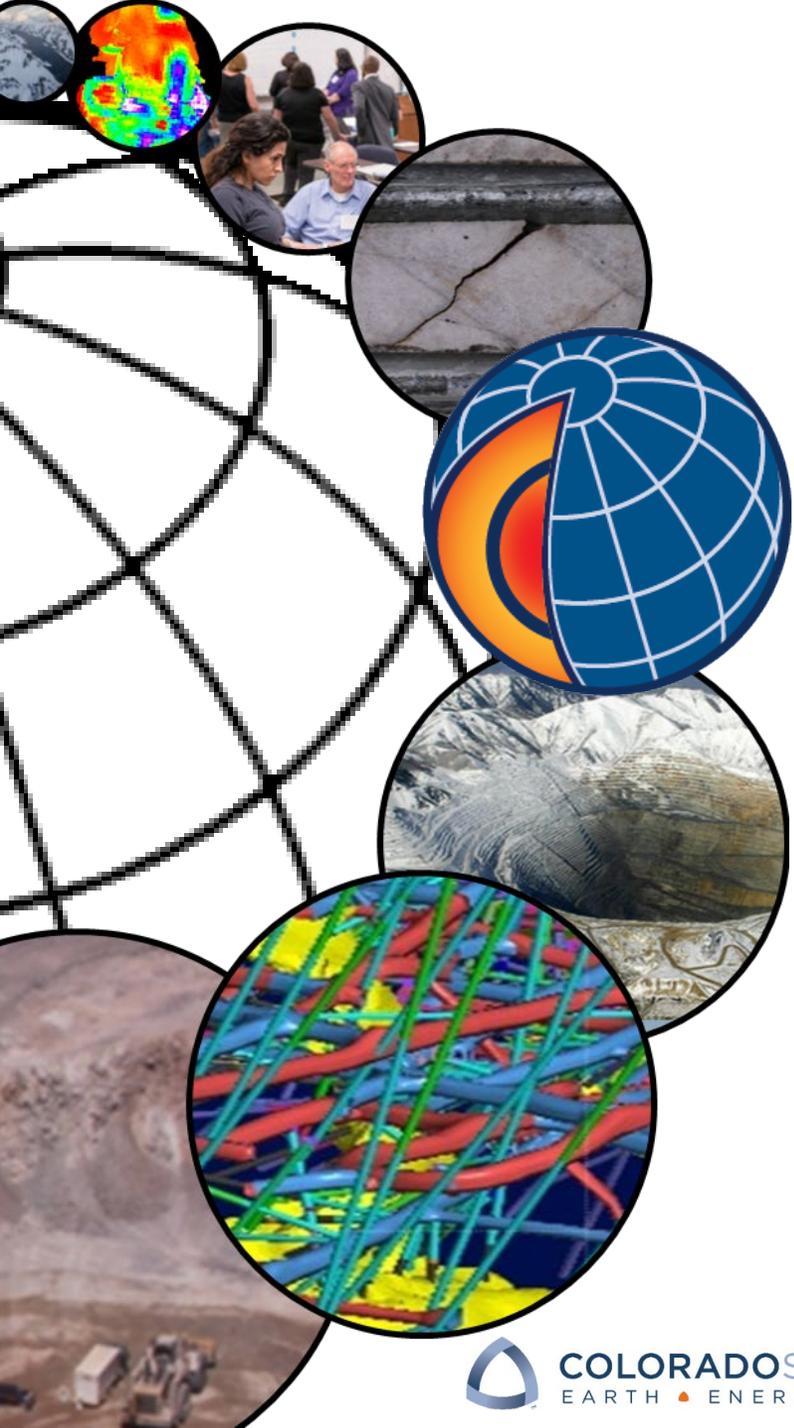
Specific Energy for Down-the-Hole drilling

Expand window of rock classification (from one blast to entire mine)

Increased accuracy through machine learning and additional data sets



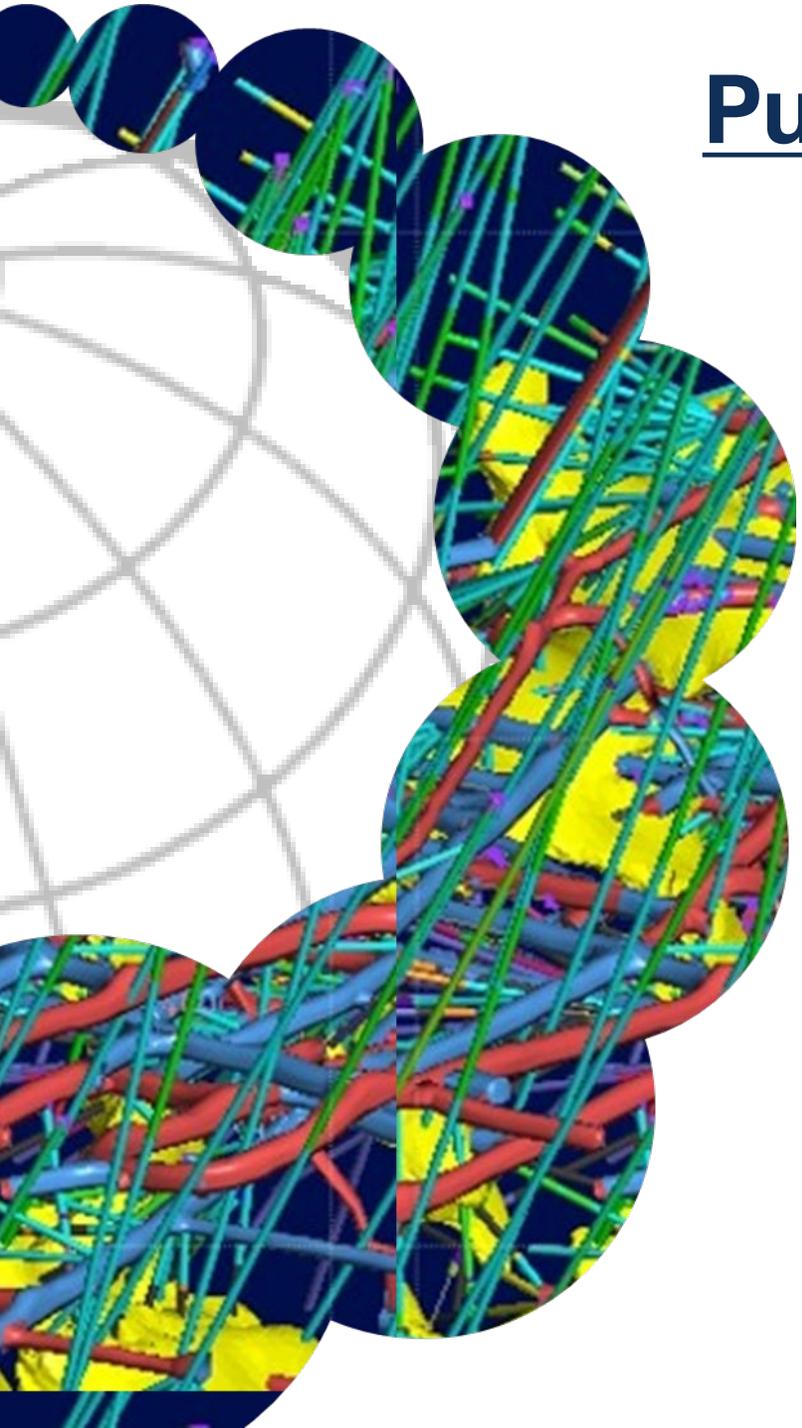
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A research center dedicated to transforming
the way geoscience data are used in the
mineral resource industries.



Purpose

CASERM is a consortium of companies and government agencies who have teamed up with **Colorado School of Mines** and **Virginia Tech** to:

- Transform the way geoscience data are used in the mineral resource industries, beginning with locating, developing, and mining subsurface resources and continuing through mine closure and environmental remediation;
- Address the critical need for trained and prepared employees by educating future researchers, engineers, and scientists.



lundin mining

**INDUSTRY
MEMBERS**



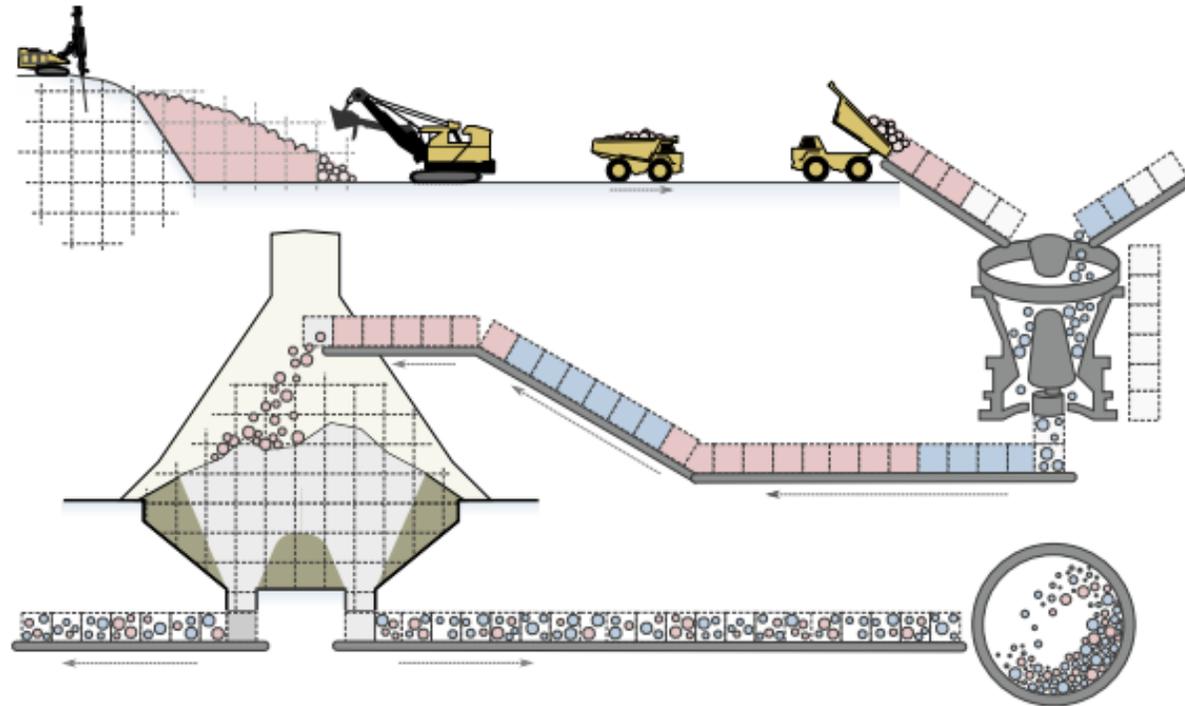
SEEQUENT



RioTinto



Thank you



Digital Twins with Distributed Particle Simulation for Mine-to-Mill Material Tracking; Servin et al.

