FIELD AND LAB TESTING OF TRIDENT-MODEL DRILL TO HELP PREPARE FOR FUTURE MISSIONS

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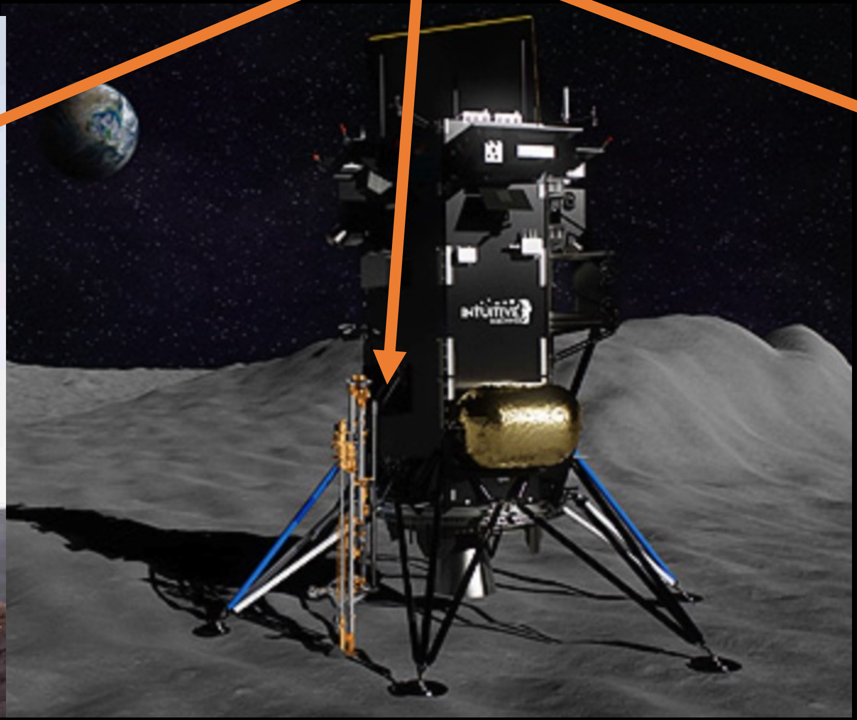
TRIDENT

ARADS 2015-2019

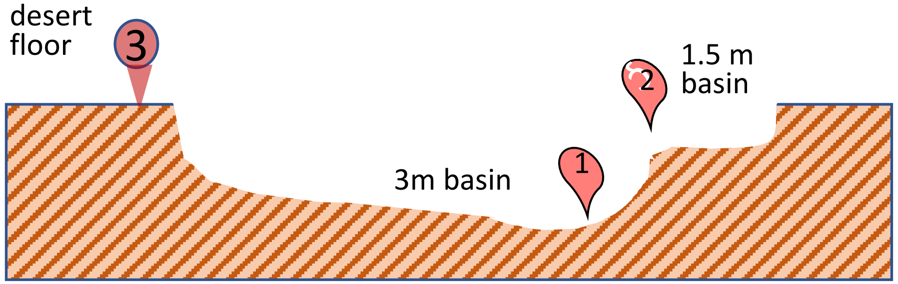


PRIME 1 2023

VIPER 2024

Space Resources Roundtable 2024

Field Work in Atacama Desert Chile in 2019 (ARADS PSTAR)

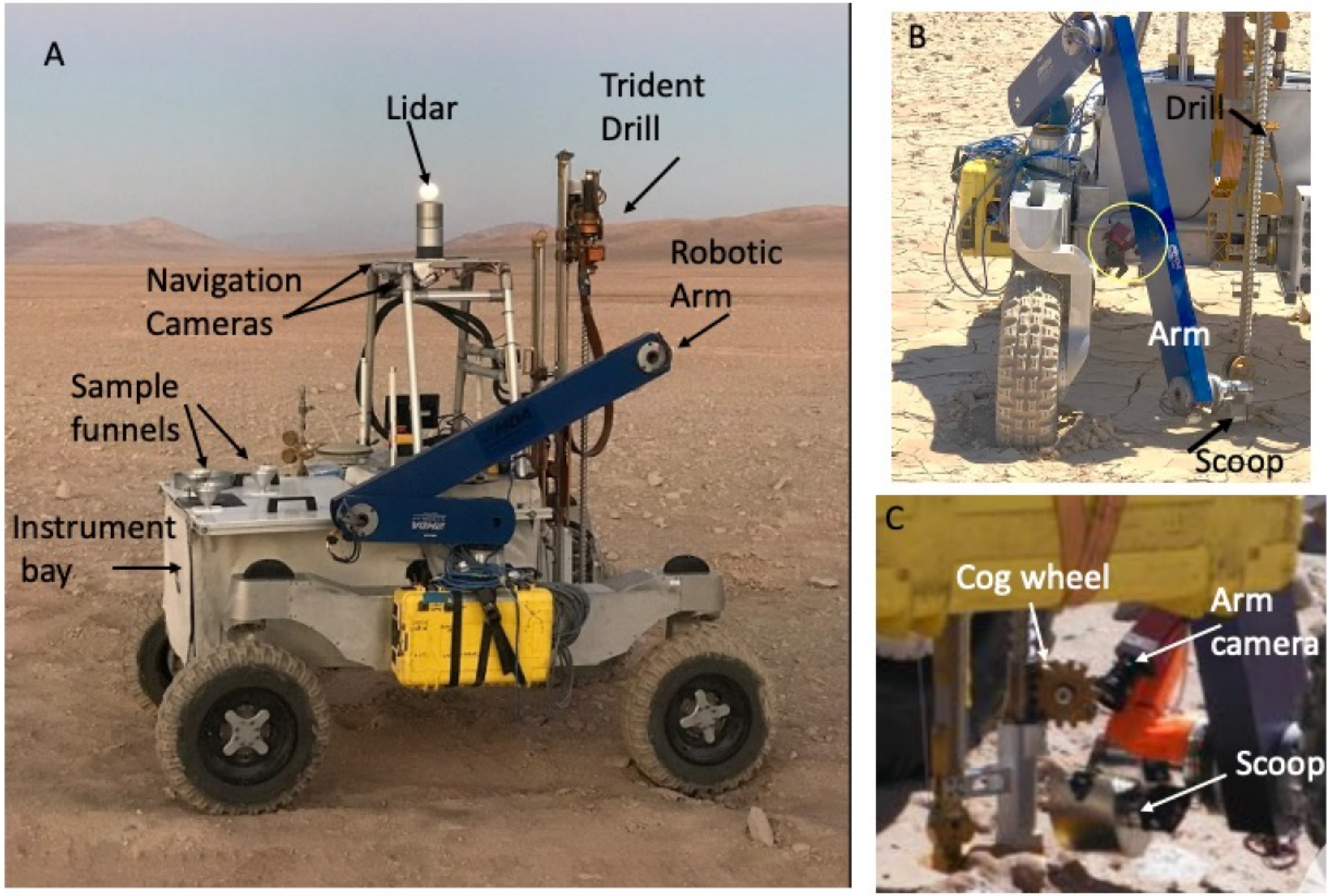


Cross-section √view

- Field site selected by science team remotely using Google Earth imaging.
- Site is a playa basin flooded at some times in the past.
- Surroundings are covered by desert pavement.
- Imaging collected above the site by DJI drone provided topography.
- Science team chose 3 areas for drilling, 2 in basins and 1 in surrounding desert.

Special Issue of Astrobiology Journal with papers about this field experiment. E.g. Stoker et al. 2023, Glass et al. 2023. **Astrobiology** [Vol. 23 Issue 12] pp.1245-1382

ARADS Rover and Sampling Systems



KREX Field rover carried the drill and science payload

1 m Honeybee Robotics TRIDENT drill pulls samples to the surface on auger flutes.

Cog wheel pushes cuttings off the flutes into sampling scoop.

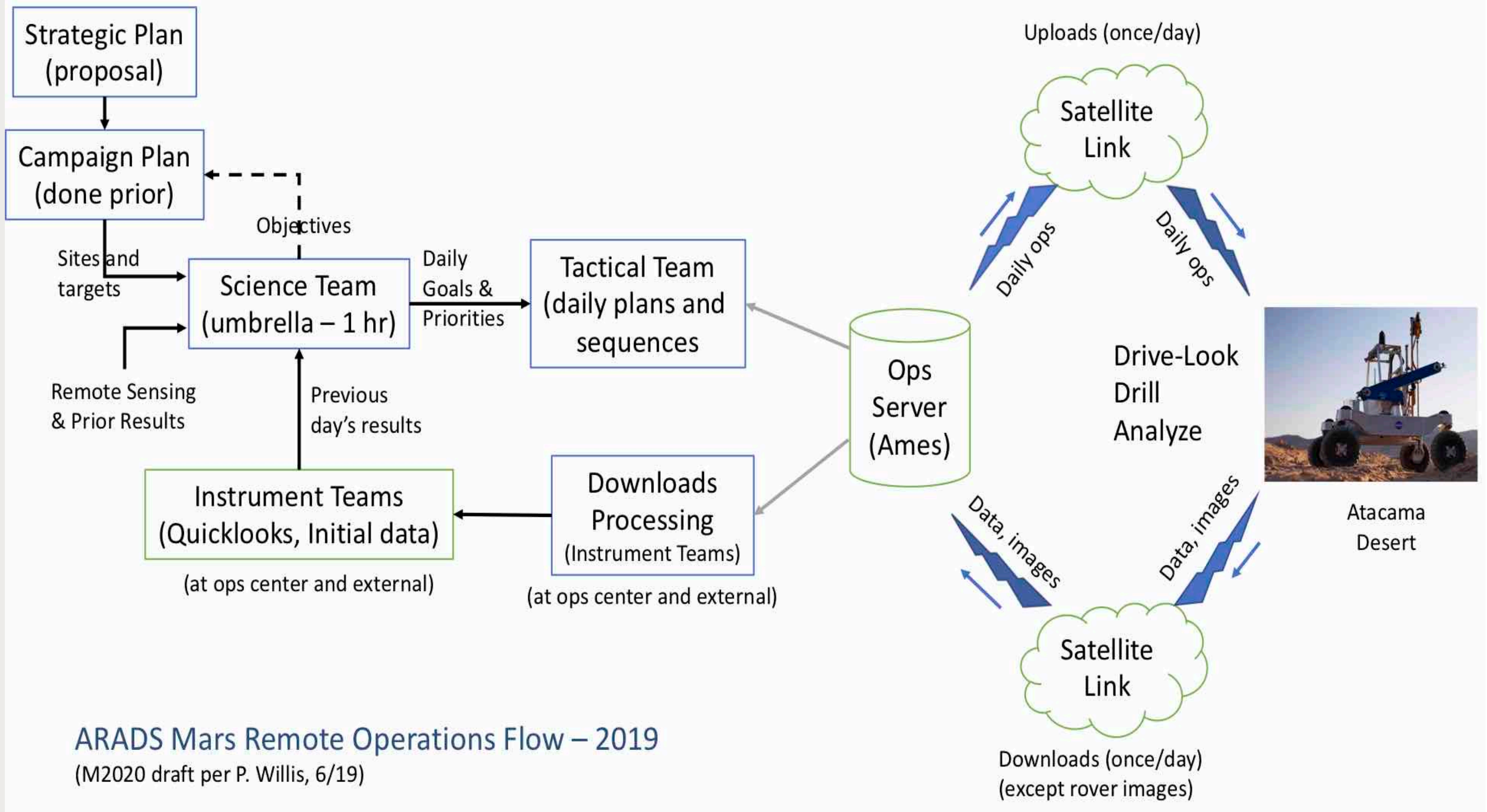
Robotic arm with scoop transfers cuttings to instrument funnels on deck.

Science Instruments located in instrument bay. Samples delivered via funnels on the deck.

ARADS Mission Simulation

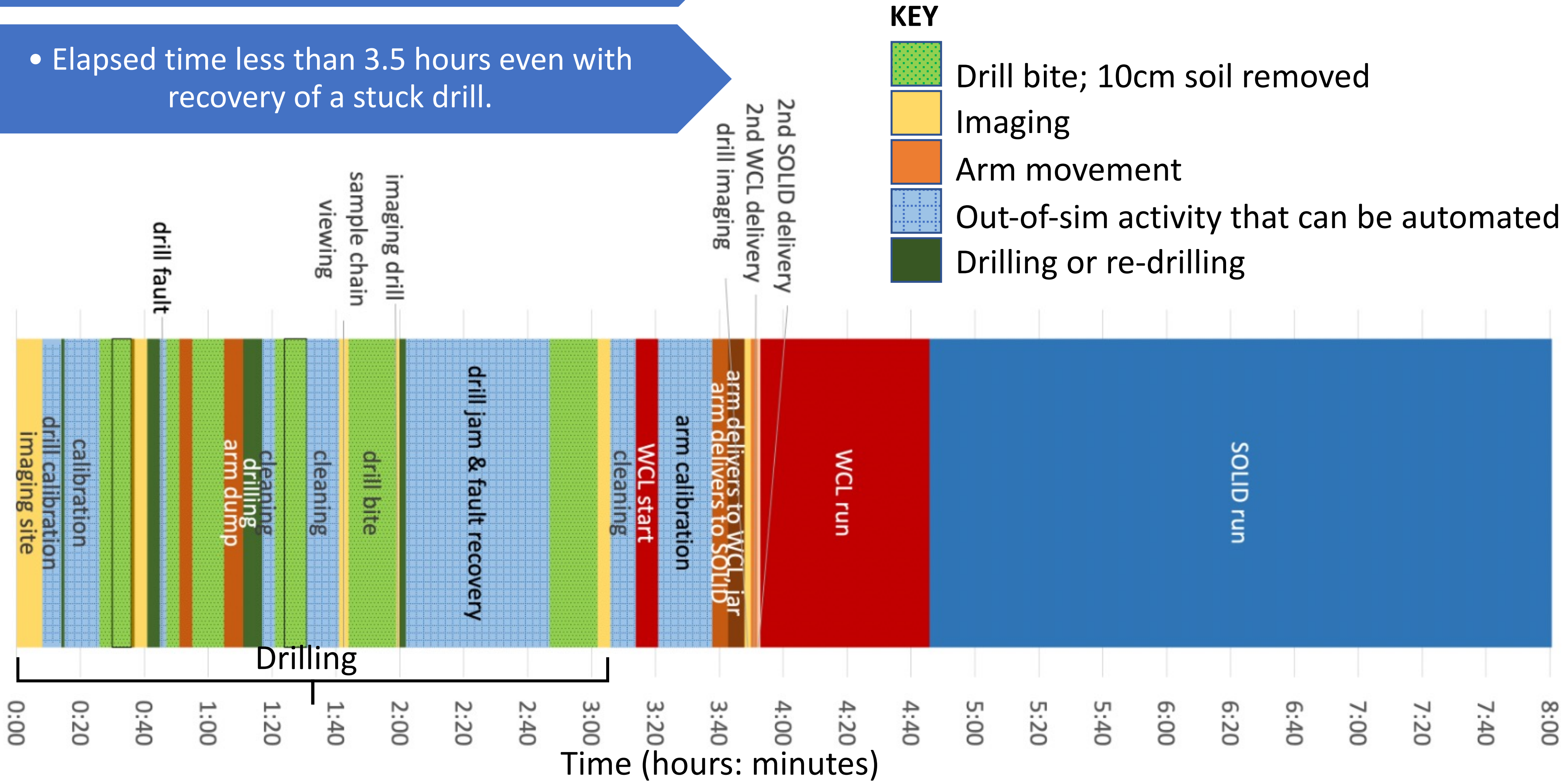
- 6 day mission drilled to 80 cm depth at three sites
- Commands sent from California but teleoperated locally by engineering team in Atacama
- Mission like constraints with 1-3 communication cycle per day between science team (USA) and robotics team (Chile).

Operations adapted from Mars 2020 Perseverance ops plan



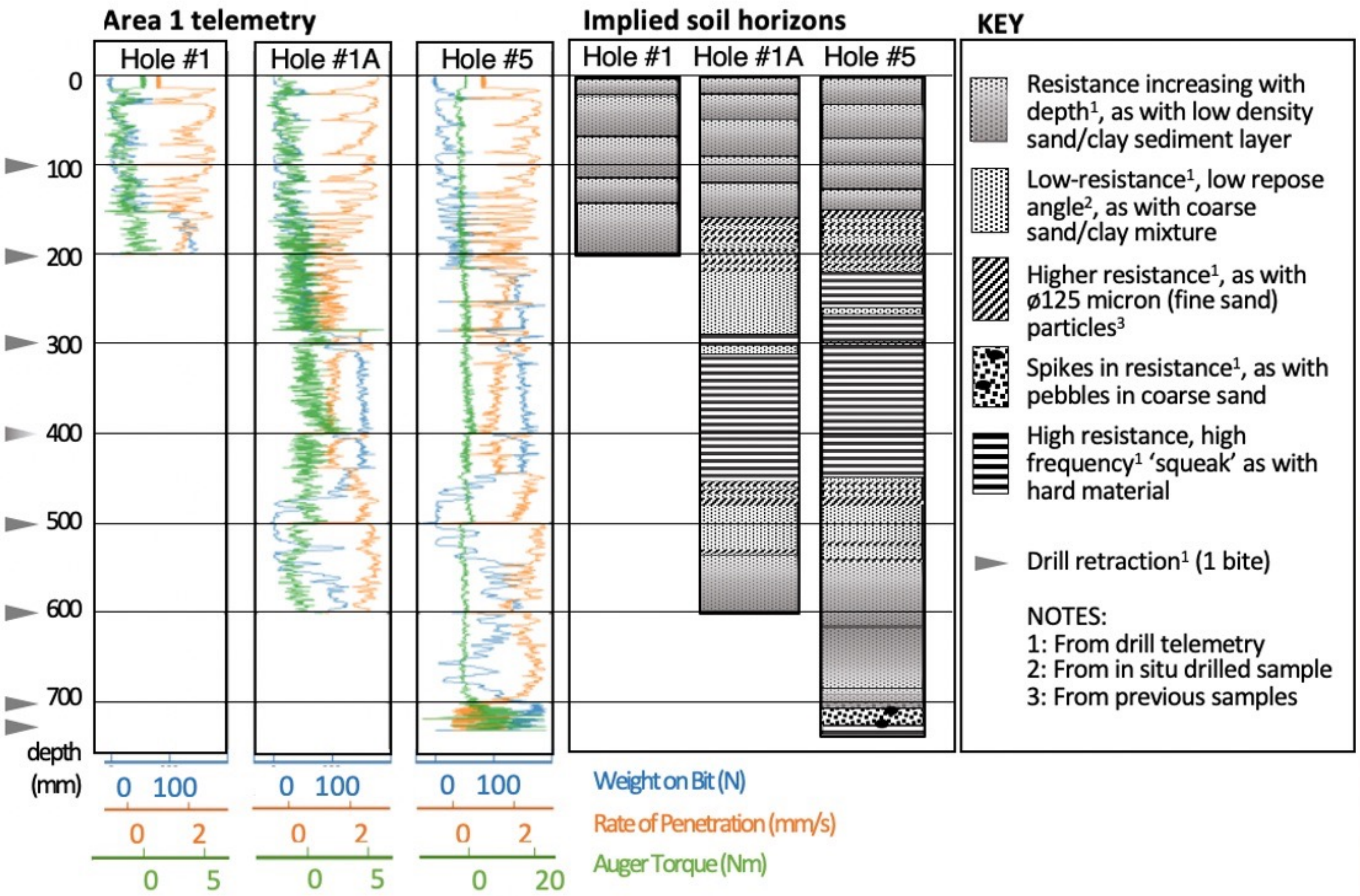
Time and event logs collected for all holes

- Drilling to 80 cm, collecting sample and delivery to instruments took 55 command cycles.
- Elapsed time less than 3.5 hours even with recovery of a stuck drill.

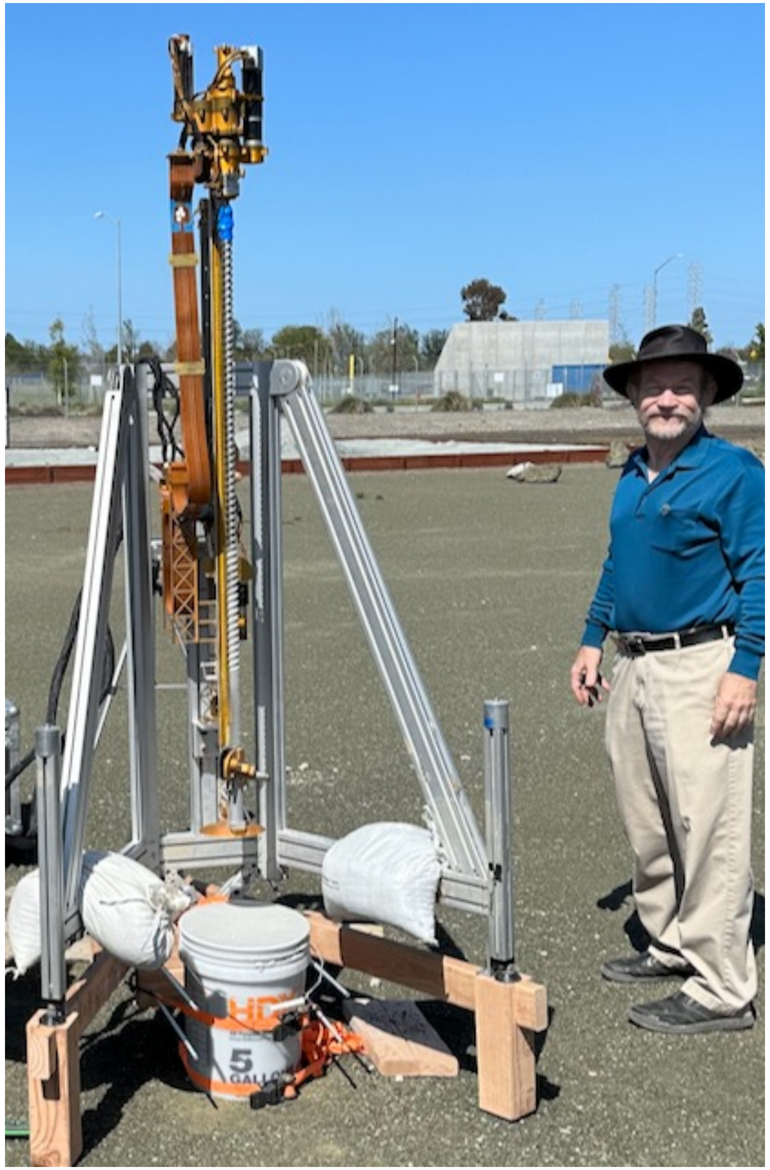


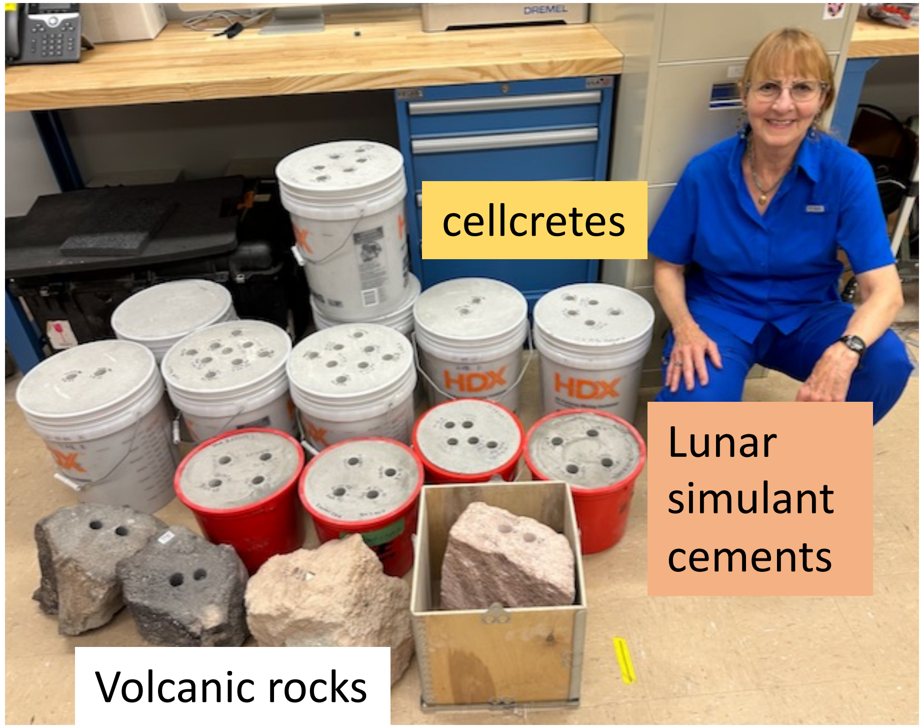
ARADS 2019 Results

Formation properties inferred from drill performance data



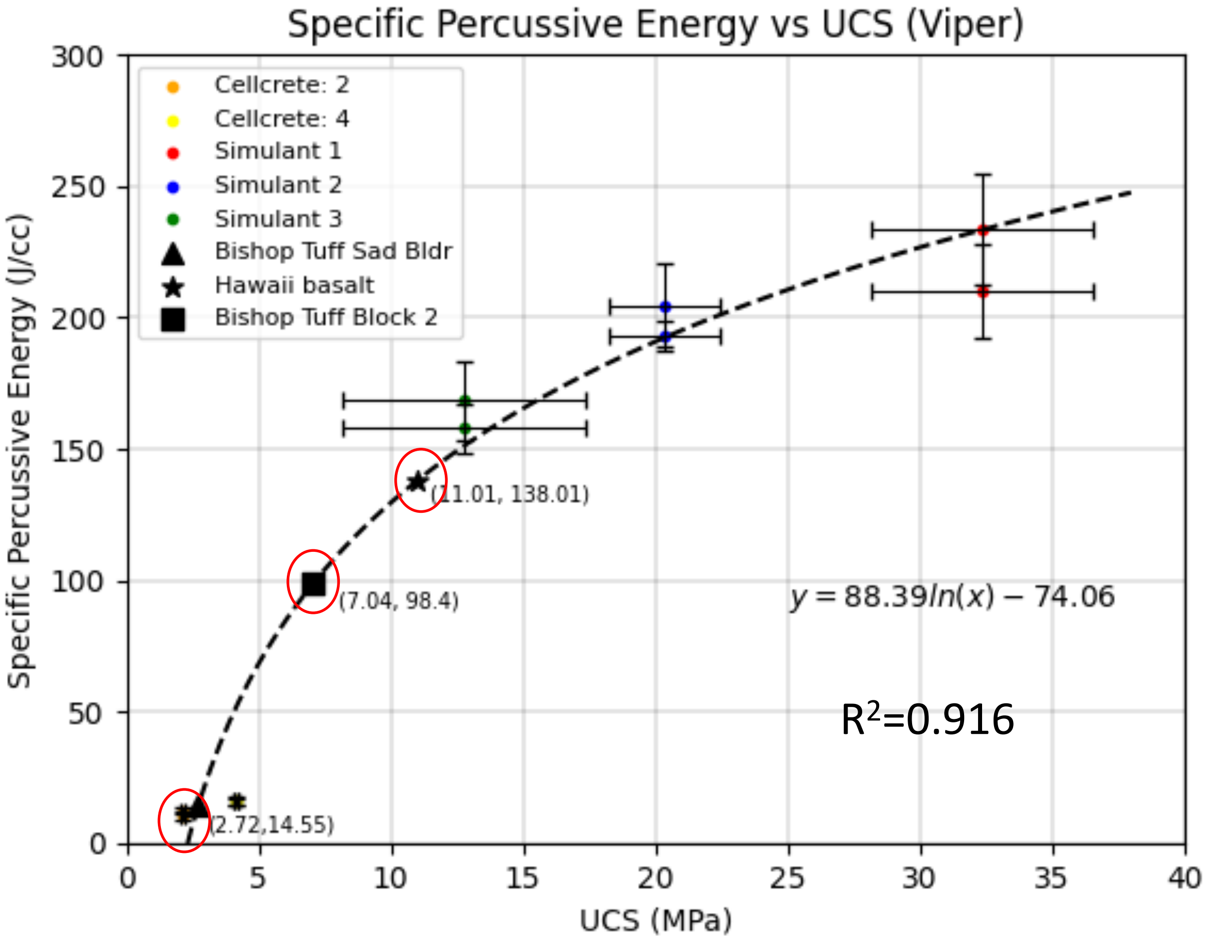
Drill tests in lunar simulants with compressive strengths of 2 Mpa to 40 Mpa



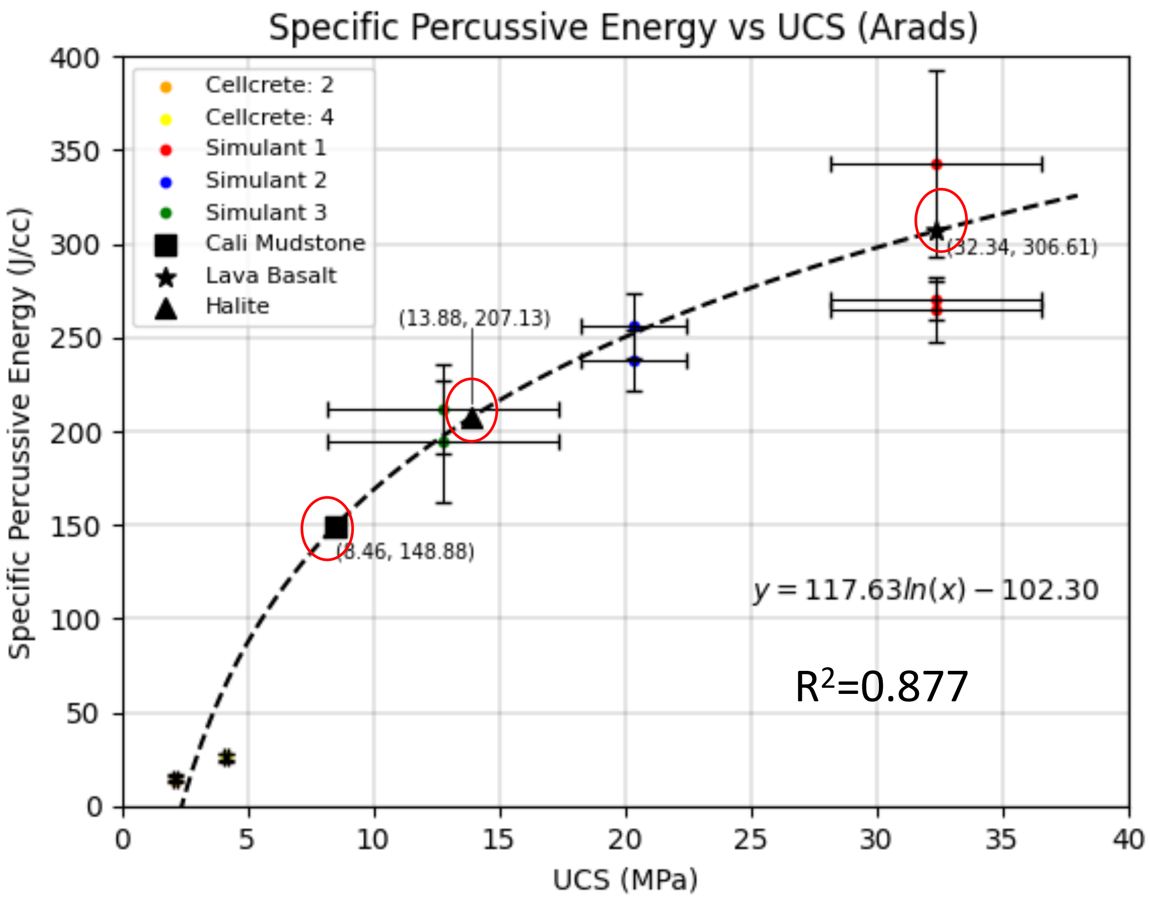


Purpose: Develop quantitative methods to correlate unconfined compressive strength to drill performance data.

VIPER bit

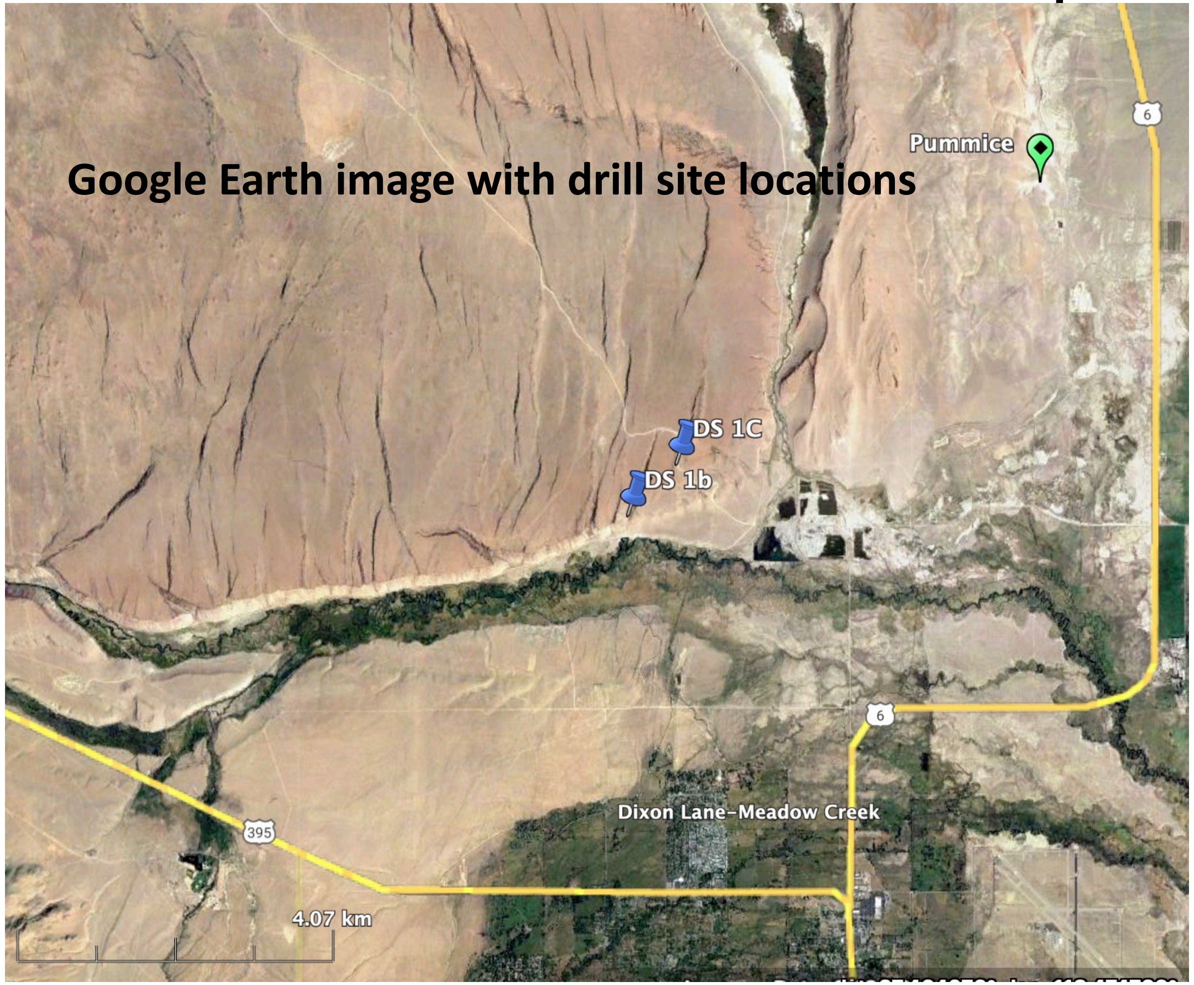


ARADS bit



Strength curve derived from drill data in simulants following procedure in Peters et al. 2018 applied to the drill on Mars Curiosity rover. This was used to estimate compressive strength of new materials drilled (rocks samples).

Field Work in Volcanic Terrain Bishop CA Sept. 2023

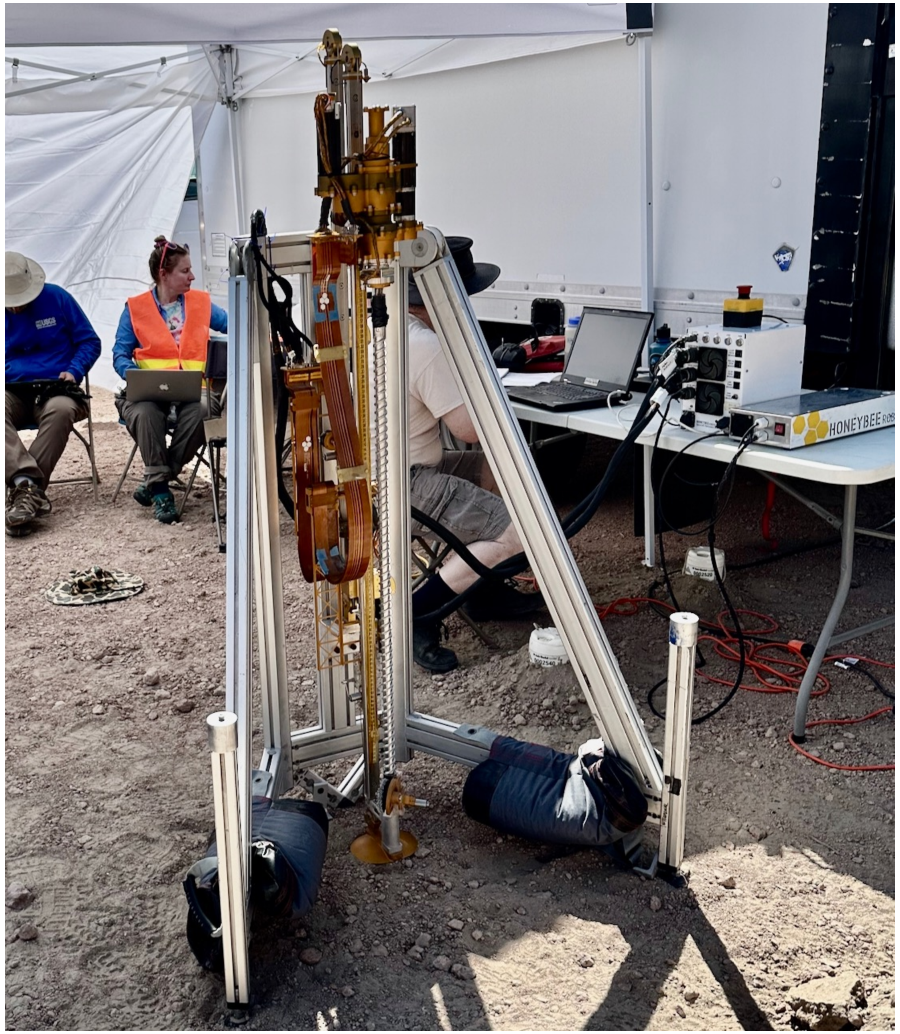


Bishop geology formed from Long ValleyCaldera Eruption 760Kyr ago.

Bishop Tuff is a pyroclastic deposit. Shown is Tuff bedrock exposed by fault near drill site 1C

Pumice is an airfall deposit. Shown is layered structure exposed in wall near drill site.

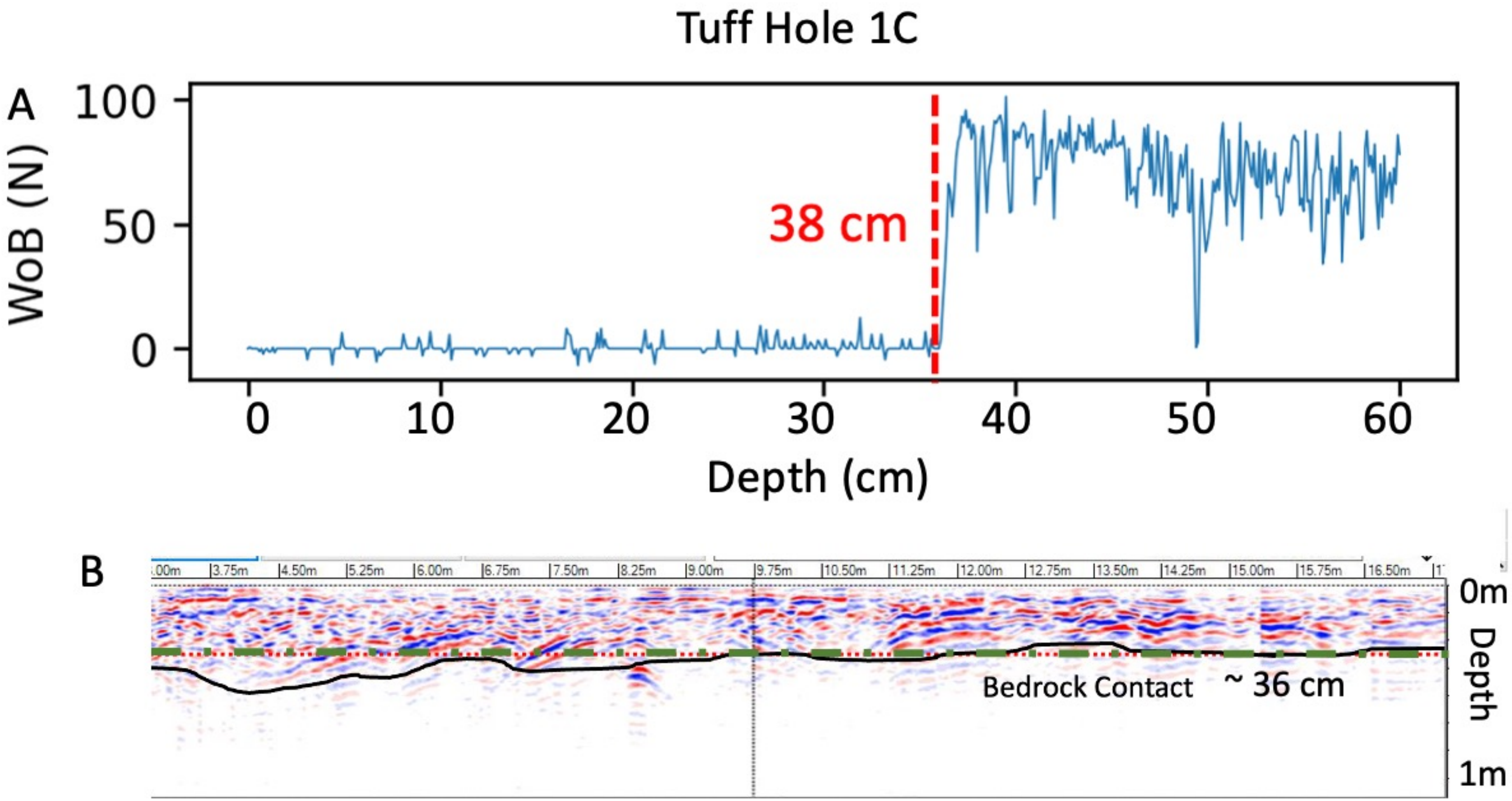
Objectives: 1)Drill in a different, stronger material than Atacama and use drill data to estimate strength of material



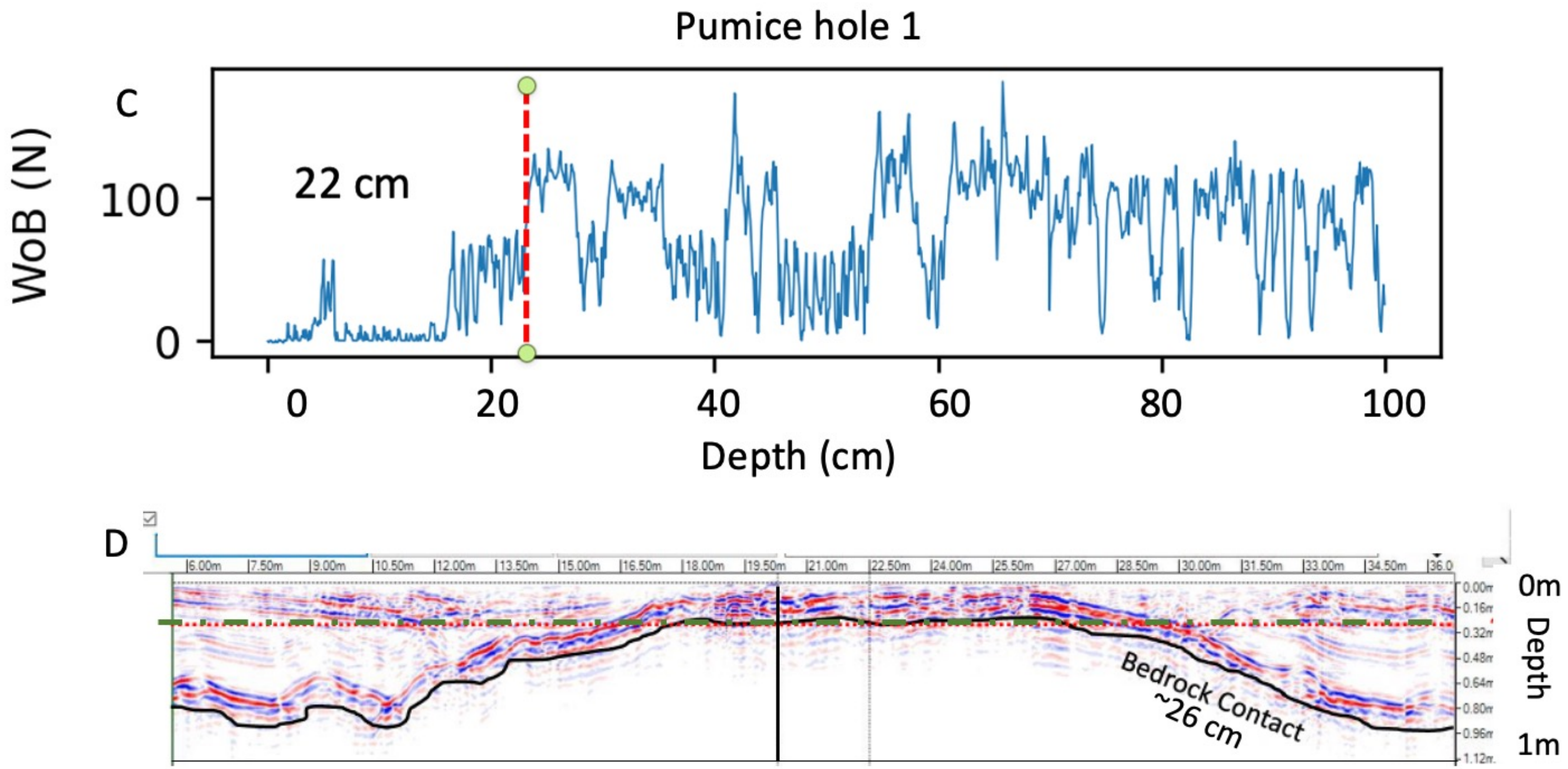
ARADS drill- same as used in Atacama

2) Compare drill derived information on subsurface structure with that derived from GPR.

Bishop Tuff structure from drill vs GPR

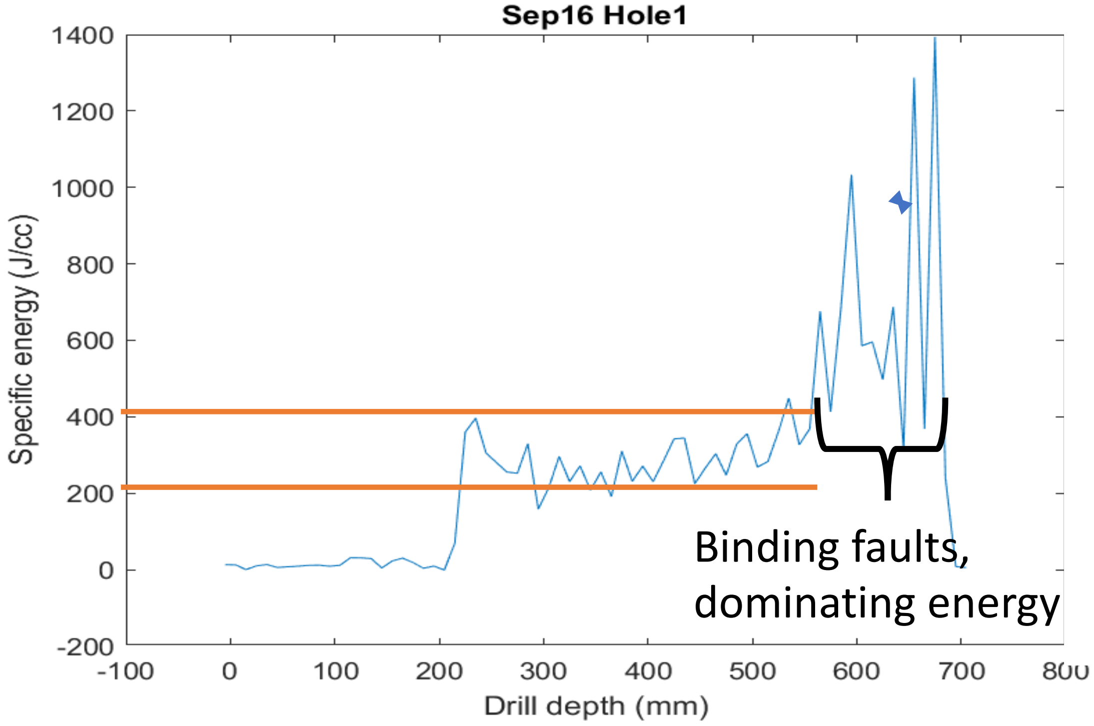


Pumice structure drill vs GPR



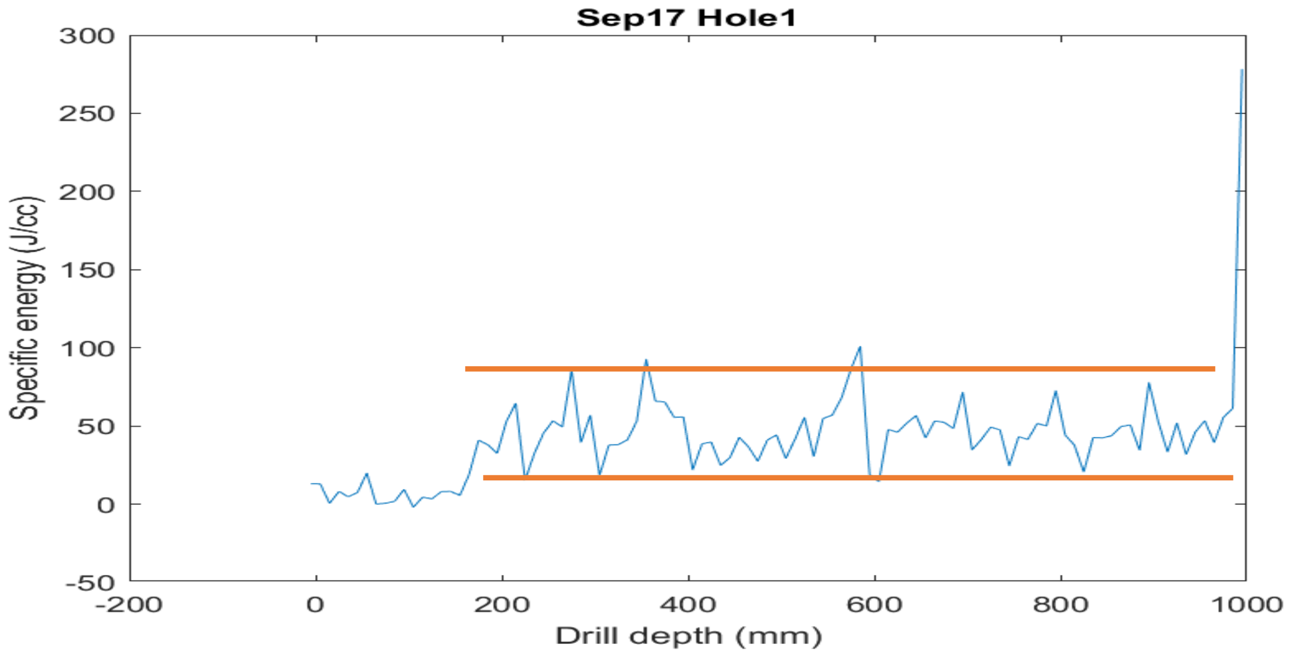
Plots of Specific Percussive Energy of Drilling

Bishop Tuff Hole 1B-1



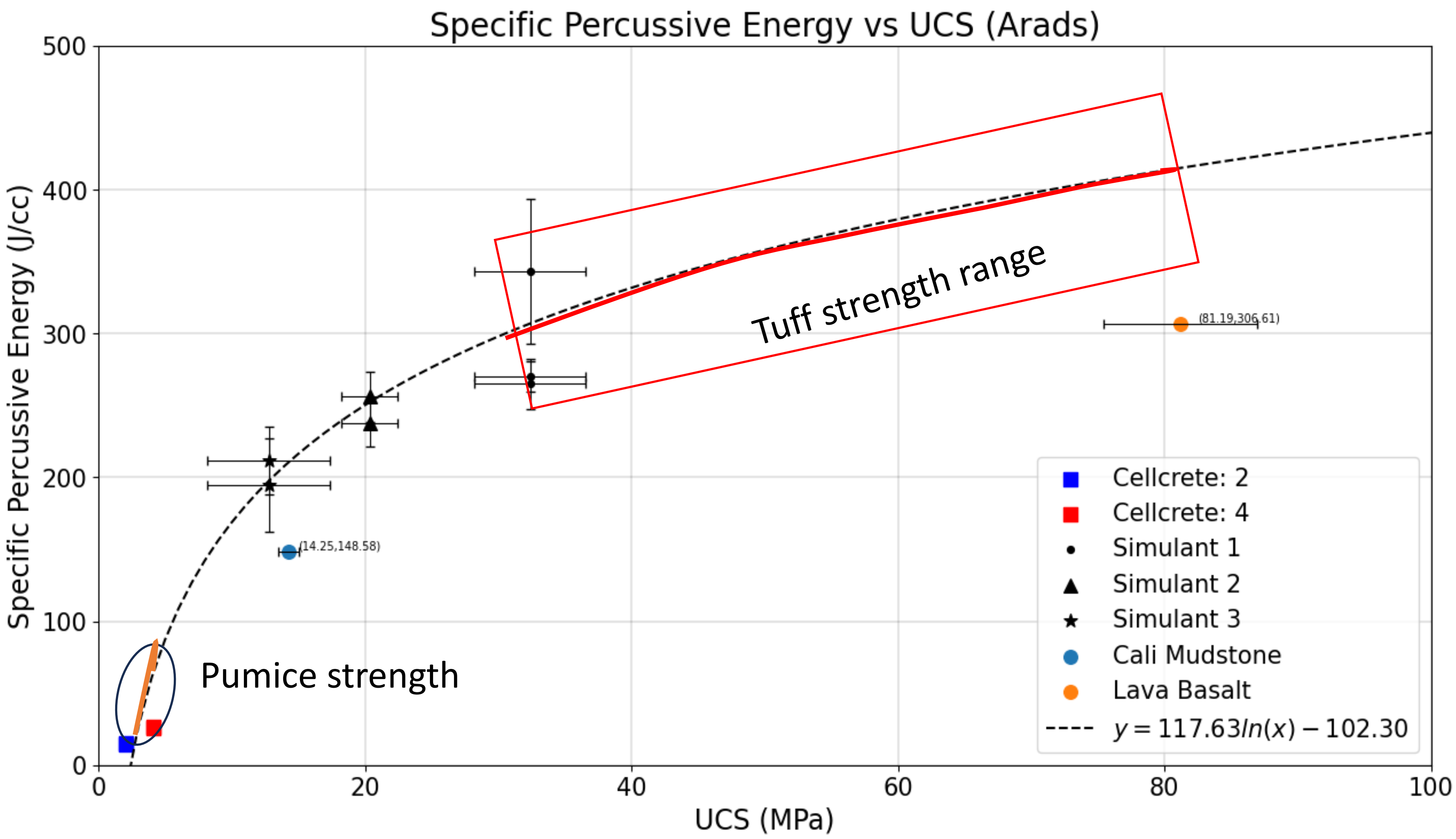
Specific energy of drilling in Tuff fell in the 200-400 J/cc range, related to compressive strength of ~ 30 - 80 Mpa.

Pumice



Peak specific energy in pumice ~80 J/cc, with minimums ~ 25J/cc. That puts the compressive strength estimated at 2-5 Mpa.

Estimated compressive strength of formation from the percussive energy of drilling



Conclusions and Lessons for Upcoming Lunar Missions

- An analytical relationship between unconfined compressive strength and energy of drilling can be deduced from drill data using a simple curve fit to analog data. This can serve as a guide to estimate the strength of unknown material drilled.

- Ground Penetrating Radar is another useful method for determining subsurface structure. It can be done quickly to better target where to drill.

- In Lab and field tests, we experienced the drill stalling in the formation. Smaller bites prevented this stalling in the field and lab, but in the field very small bites were required

  (~ 1 cm) which is time consuming.

- Sudden increase of auger torque and loud squeaking preceded stalling. Drill should automatically stop and retract if this condition occurs.