HERO Basalt CarbonSAFE

Carbon Storage Assurance Facility Enterprise (CarbonSAFE) Phase II-Storage Complex Feasibility

PROJECT AWARD #: DE-FE0032372
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U.S. Department of Energy
National Energy Technology Laboratory
Carbon Management Research Project Review Meeting
August 5 – August 9, 2024
CARBON TRANSPORT AND STORAGE BREAKOUT SESSION 2
Wednesday 10:30AM, 304/305

Acknowledgement and Disclaimer

***Acknowledgment**: This material is based upon work supported by the Department of Energy under Award Number DE-FE0032372*

THE WORLD NEEDS MORE COWBOYS.

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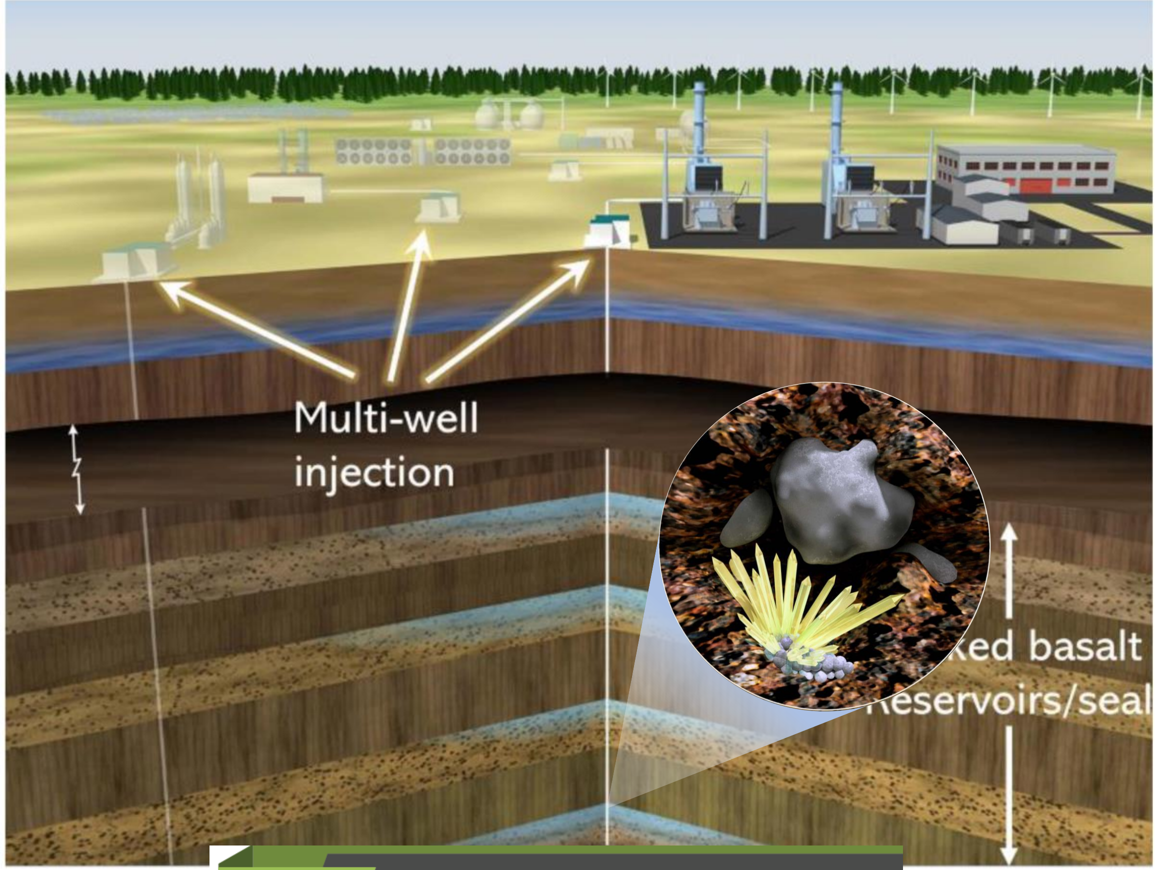
Project Overview

THE WORLD NEEDS MORE ADVENTUROUS SPIRIT.

HERO Project

The PRIMARY OBJECTIVE of the HERO project is to address research gaps crucial to de-risking and demonstrating commercial scale basalt-hosted carbon storage, and to provide critical information to key stakeholders and developers seeking CO_2 storage opportunities in the Pacific Northwest and beyond.



Summary: HERO Basalt CarbonSAFE will accelerate scale-up and deployment of CO_2 capture and storage projects in the Columbia River Basalt Group (CRBG)—proposed as the largest potential CO_2 storage resource in the Pacific Northwest.

Project Award #: DE-FE0032372
Duration: 2 years

Project Partners

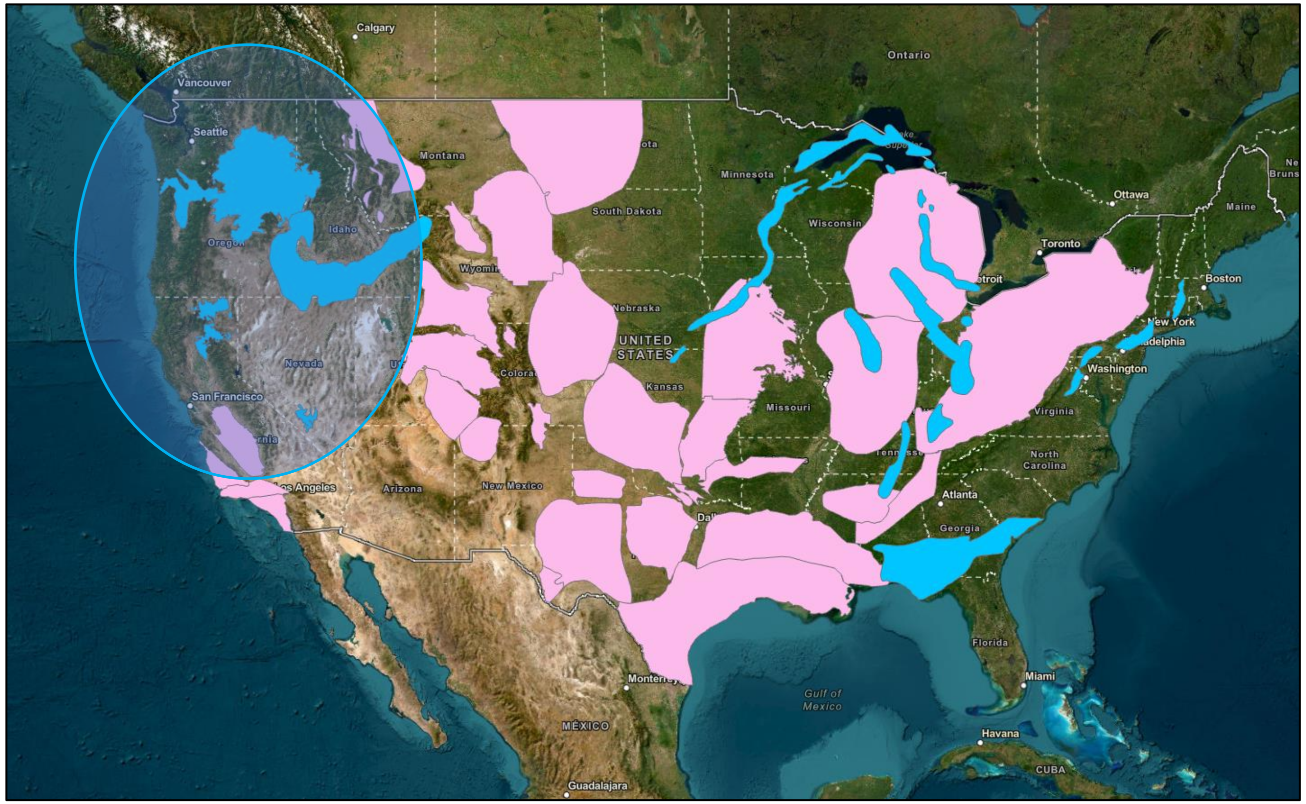
University of Wyoming – School of Energy Resources	Project Management, Data and Regulatory Analysis, Commercial Assessment
Pacific Northwest National Laboratory	Data Analysis, Societal Considerations, Simulations, Commercial Assessment
1POINTFIVE	Field Operations and Data Analysis
CALPINE®	Site Host, CO_2 Source, Commercial Assessment
Carbfix	Basalt Storage Assessments and Outreach
slb	Field Operations and Data Analysis

HERO Project Motivation

- PNW has limited carbon management/storage solutions without basalt

- Provides options to manage Scope 3 emissions on-location

- There are limited studies on basalt injection and mineralization; this project will provide invaluable scientific, community impact, regional regulatory and operational lessons



DOE Carbon Storage Atlas V

Sedimentary Basins
Basalts

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- Provides options to manage Scope 3 emissions on-location
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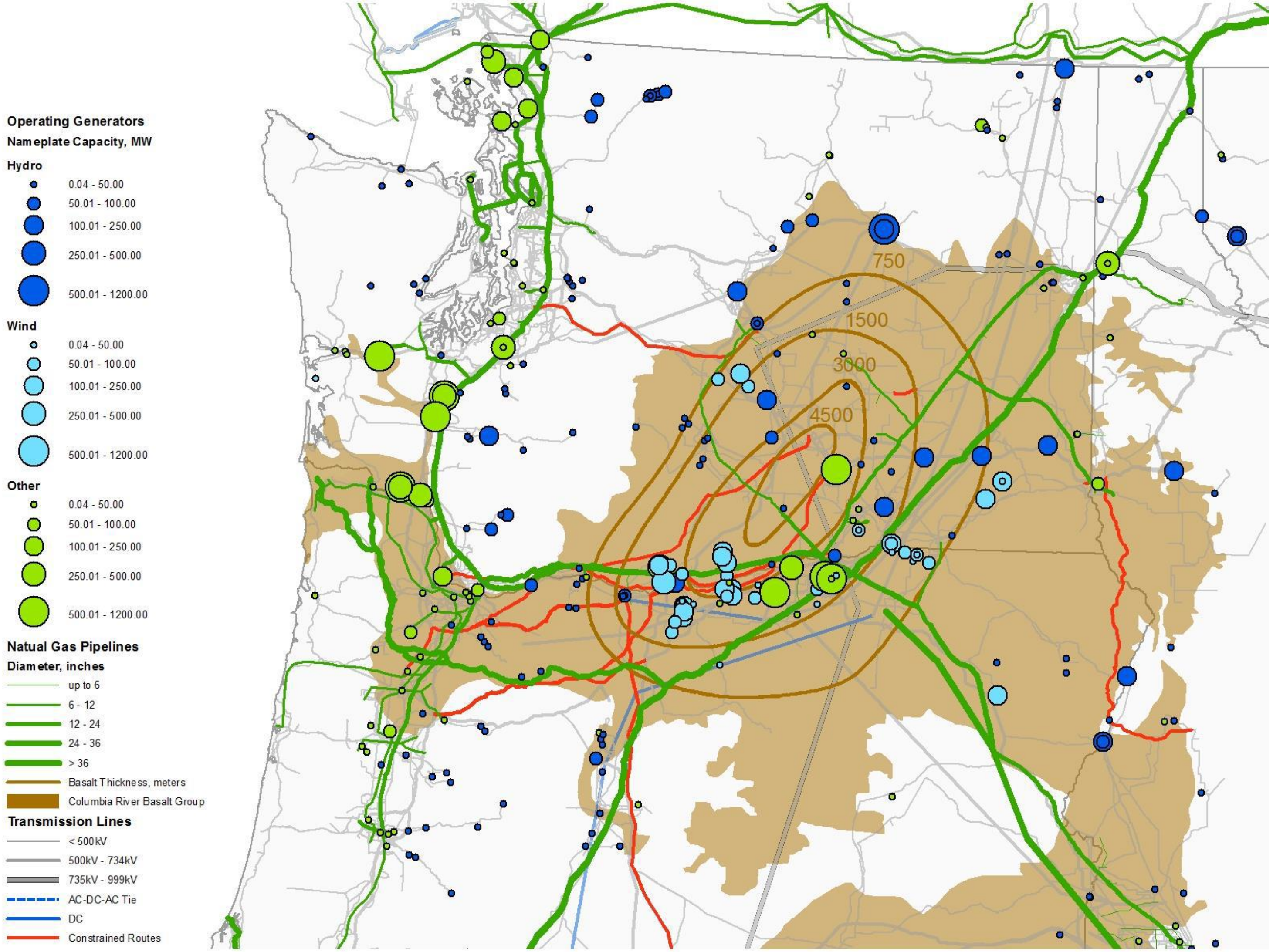


Credit: PNNL

Benefit to the CarbonSAFE Program

1. Effectively doubles the data and analysis performed to-date on deep basalt formations in the US

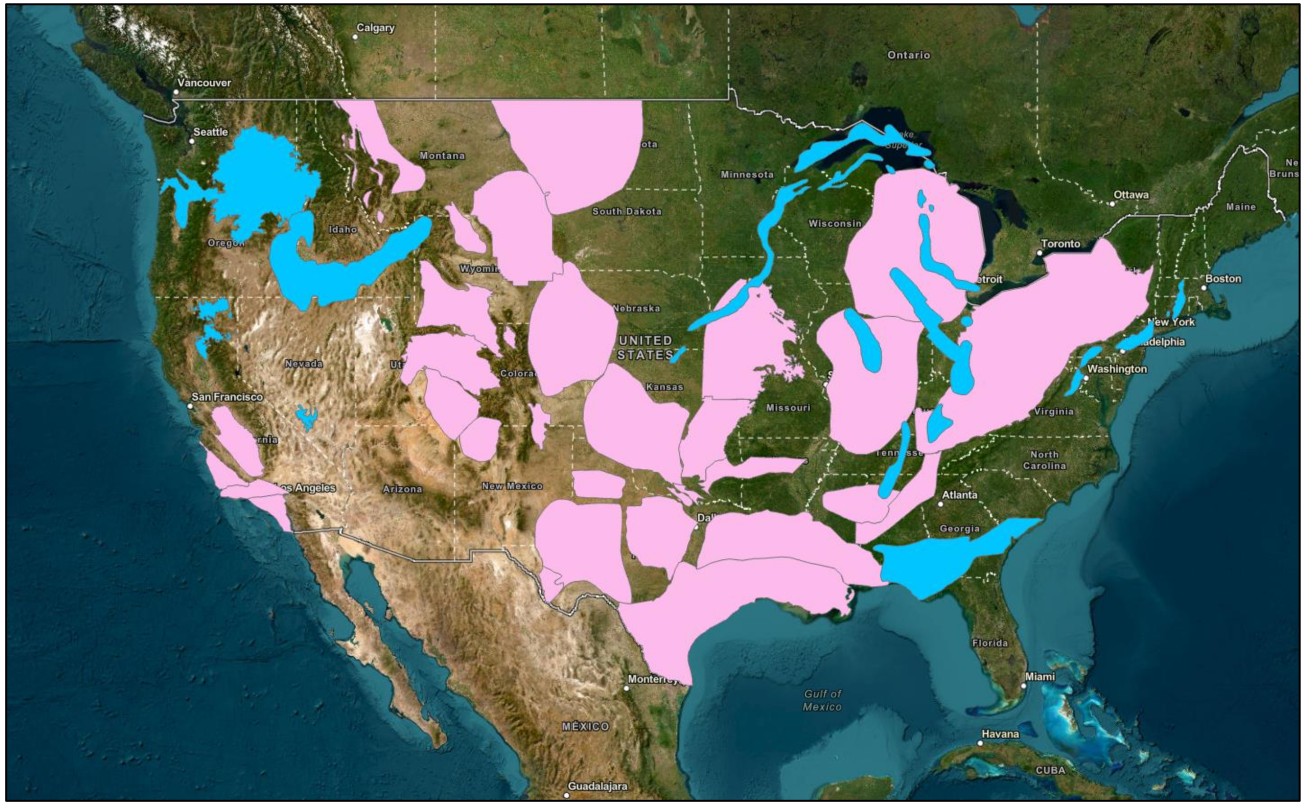
2. Help to refine CCS characterization methodology for basalts

3. Help to define field operation and completion methods, economics, and risk

4. Help to refine mineralization kinetics relative to commercial geologic storage and risk

5. Continued development of Pacific Northwest-focused outreach and education

6. Assessment of regulatory requirements in a region of the US with relatively minimal activity to-date



Sedimentary Basins   Basalts

DOE Carbon Storage Atlas V

Project Background

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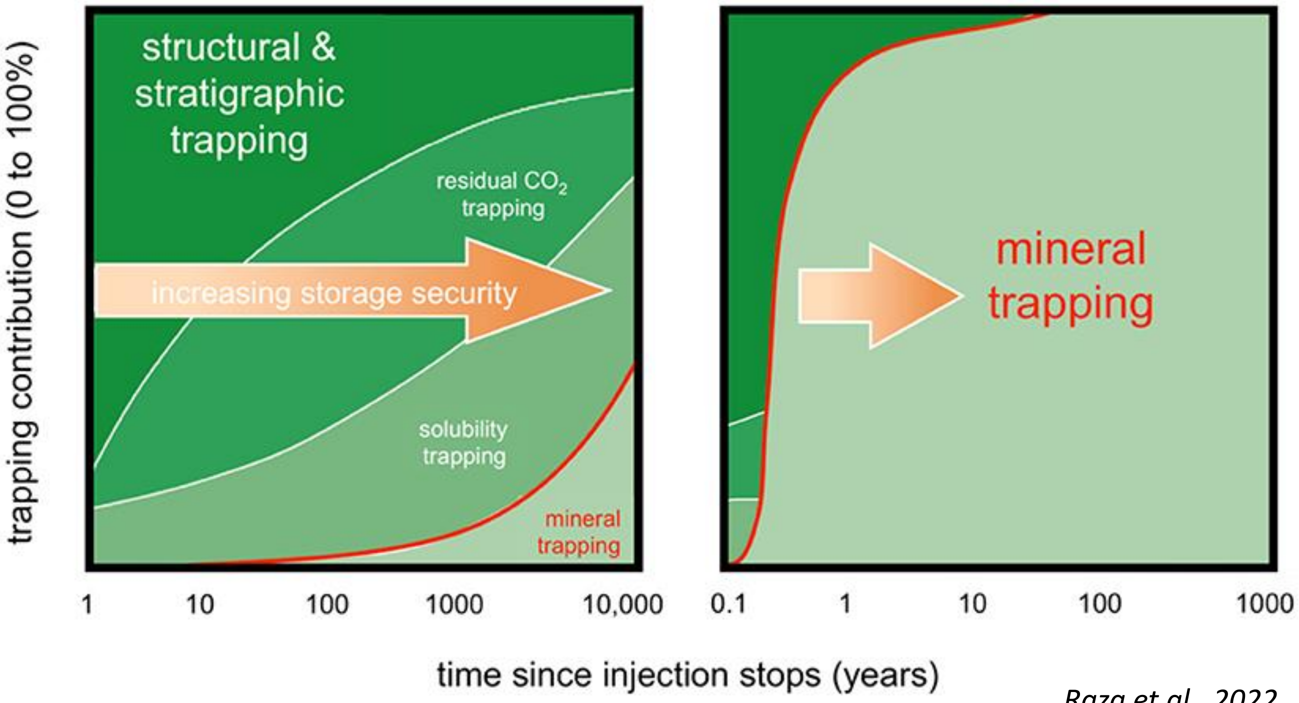
Calpine's Hermiston Power Project

- Located in a rural area of the Deschutes-Columbia Plateau
- Two-turbine natural gas facility
- Operating since August 2002
- 566 megawatts baseload
- ~1.7 MMT/annum
- Markets in the Pacific Northwest and California
- One of the State's cleanest gas facilities
- Offers quick response to grid needs, so it is helping to balance the integration of the region's wind resources with less impacts to the grid
- Committed to providing 50 MMT/30- year period

Perspective on CO2 Sequestration in Basalts

Timeline of key findings for Basalt Sequestration

- Laboratory studies at PNNL confirmed rapid carbonation (2006)
- First field evidence of in-situ carbonate mineralization occurring from supercritical CO_2 injection into a basalt reservoir (2015)
- Developed a hydrologic modeling approach for tracing extent of mineralization (2021)

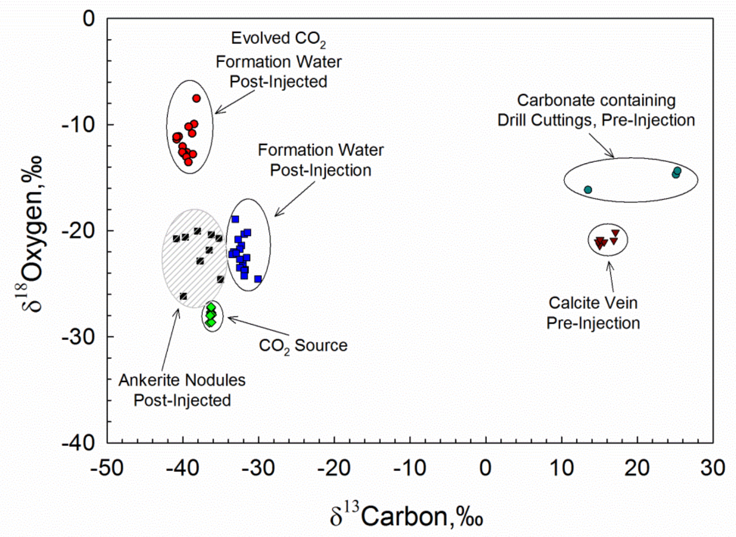


Raza et al., 2022

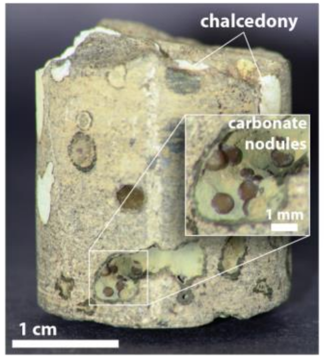
Basalts **convert CO_2 to solid minerals** much more rapidly than other rock types. Mineralized CO_2 is immobile and poses **no risk of leakage.**

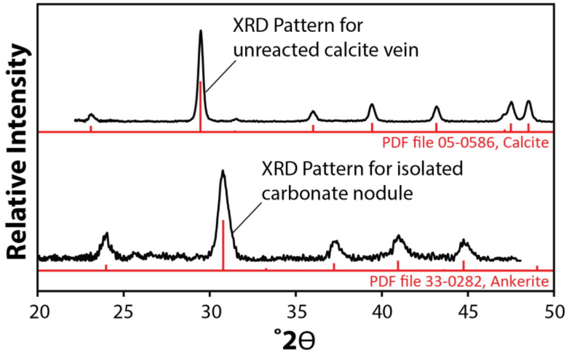
Wallula Field Data

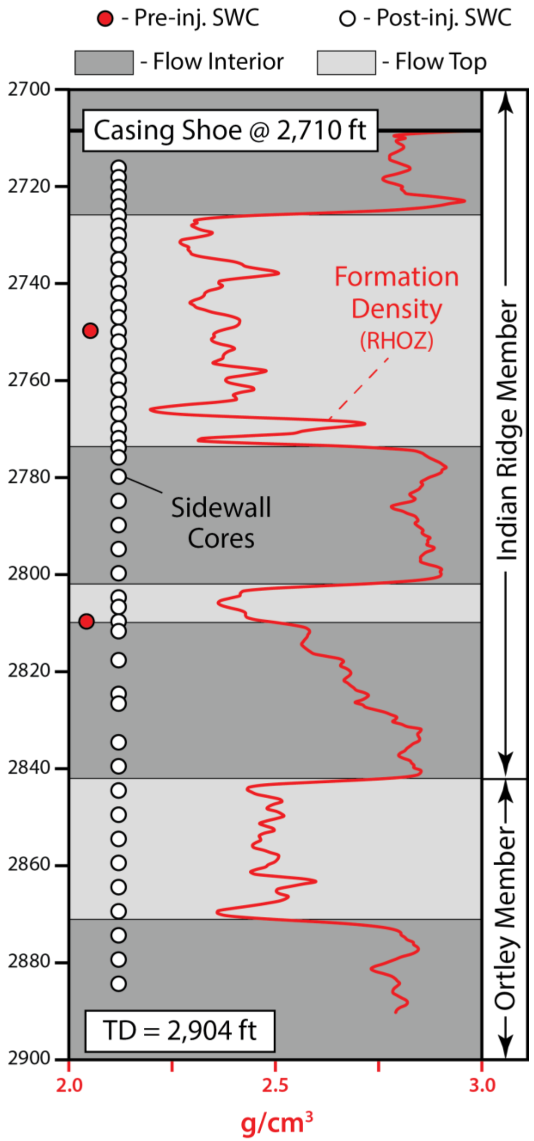
- 1000 tonnes CO2 injected
- 50 sidewall cores (SWC) between 2,716 – 2,900 ft were drilled after a prolonged CO_2 soak
- Carbonate minerals observed on SWCs occurred both as large (up to ~1mm) nodules and as coatings
- XRD of nodule material identified ankerite
- Isotopic signature confirmed the injected CO_2 was mineralized



SWC Sample

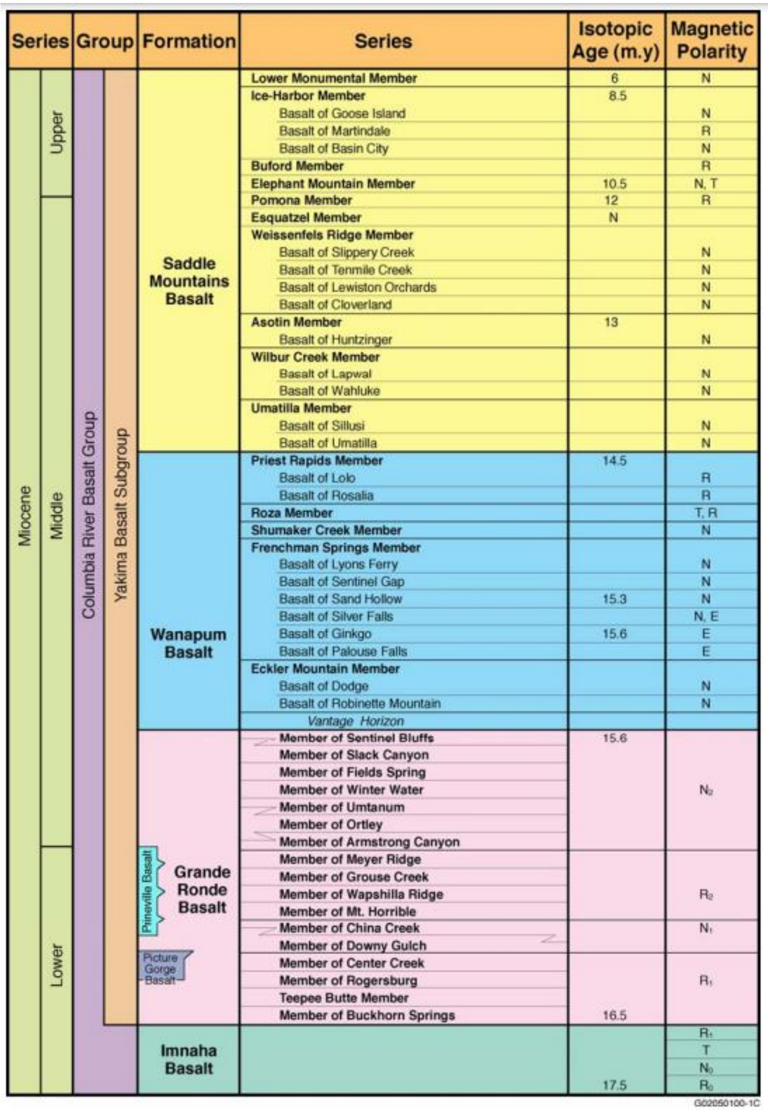






McGrail, Schaef, et al. 2017. "Field Validation of Supercritical CO_2 Reactivity with Basalts." *ES&T, Letters, 4, 6-10.*

Target Fm. - Grand Ronde Basalt



Series	Group	Formation	Series	Isotopic Age (m.y)	Magnetic Polarity
Miocene – Upper	Columbia River Basalt Group – Yakima Basalt Subgroup	Saddle Mountains Basalt	Lower Monumental Member	6	N
			Ice-Harbor Member	8.5	
			Basalt of Goose Island		N
			Basalt of Martindale		R
			Basalt of Basin City		N
			Buford Member		R
			Elephant Mountain Member	10.5	N, T
			Pomona Member	12	R
			Esquatzel Member	N	
			Weissenfels Ridge Member		
			Basalt of Slippery Creek		N
			Basalt of Tenmile Creek		N
			Basalt of Lewiston Orchards		N
			Basalt of Cloverland		N
			Asotin Member	13	
			Basalt of Huntzinger		N
			Wilbur Creek Member		
			Basalt of Lapwal		N
			Basalt of Wahluke		N
			Umatilla Member		
			Basalt of Sillusi		N
			Basalt of Umatilla		N
Middle		Wanapum Basalt	Priest Rapids Member	14.5	
			Basalt of Lolo		R
			Basalt of Rosalia		R
			Roza Member		T, R
			Shumaker Creek Member		N
			Frenchman Springs Member		
			Basalt of Lyons Ferry		N
			Basalt of Sentinel Gap		N
			Basalt of Sand Hollow	15.3	N
			Basalt of Silver Falls		N, E
			Basalt of Ginkgo	15.6	E
			Basalt of Palouse Falls		E
			Eckler Mountain Member		
			Basalt of Dodge		N
			Basalt of Robinette Mountain		N
			Vantage Horizon		
		Grande Ronde Basalt	Member of Sentinel Bluffs	15.6	
			Member of Slack Canyon		
			Member of Fields Spring		
			Member of Winter Water		N_2
			Member of Umtanum		
			Member of Ortley		
			Member of Armstrong Canyon		
Lower		Grande Ronde Basalt (Prineville Basalt; Picture Gorge Basalt)	Member of Meyer Ridge		
			Member of Grouse Creek		
			Member of Wapshilla Ridge		R_2
			Member of Mt. Horrible		
			Member of China Creek		N_1
			Member of Downy Gulch		
			Member of Center Creek		
			Member of Rogersburg		R_1
			Teepee Butte Member		
			Member of Buckhorn Springs	16.5	
		Imnaha Basalt			R_1
					T
					N_0
				17.5	R_0

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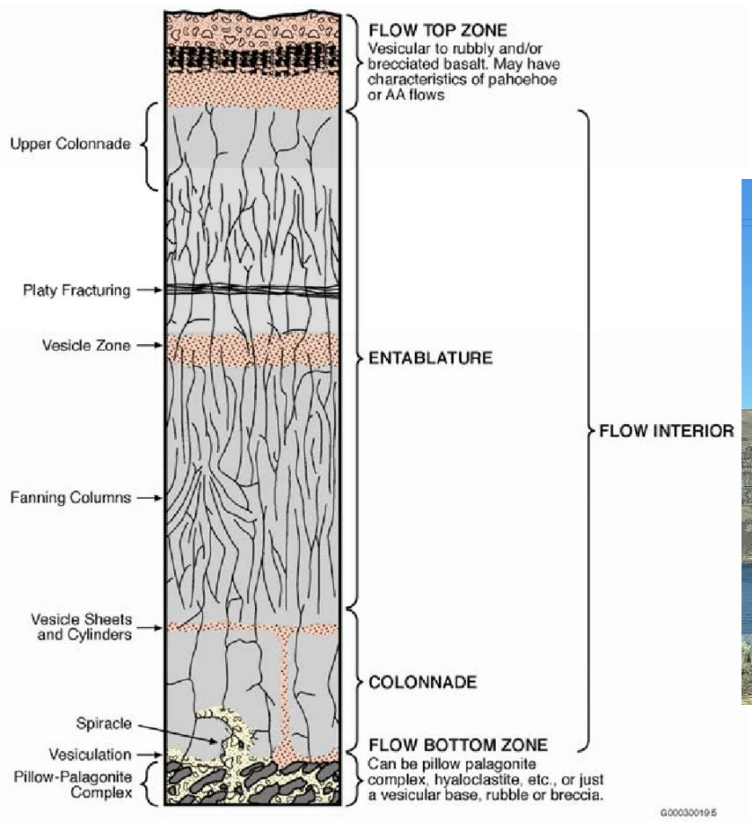
Proposed Storage Formation

Stratigraphic well will extend ~1,524 m (5000 ft) targeting multiple flow zones



Martin et al.,

Technical Approach and Project Scope

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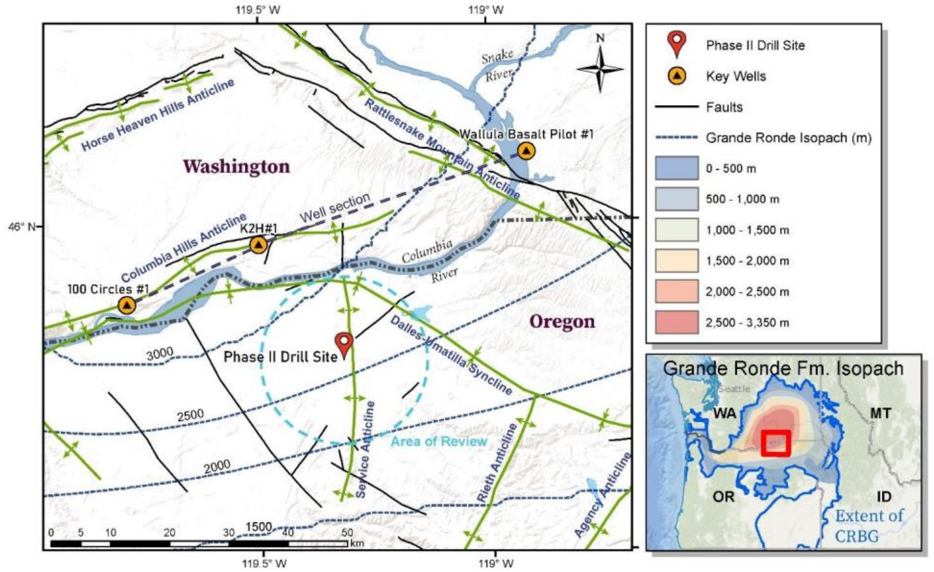
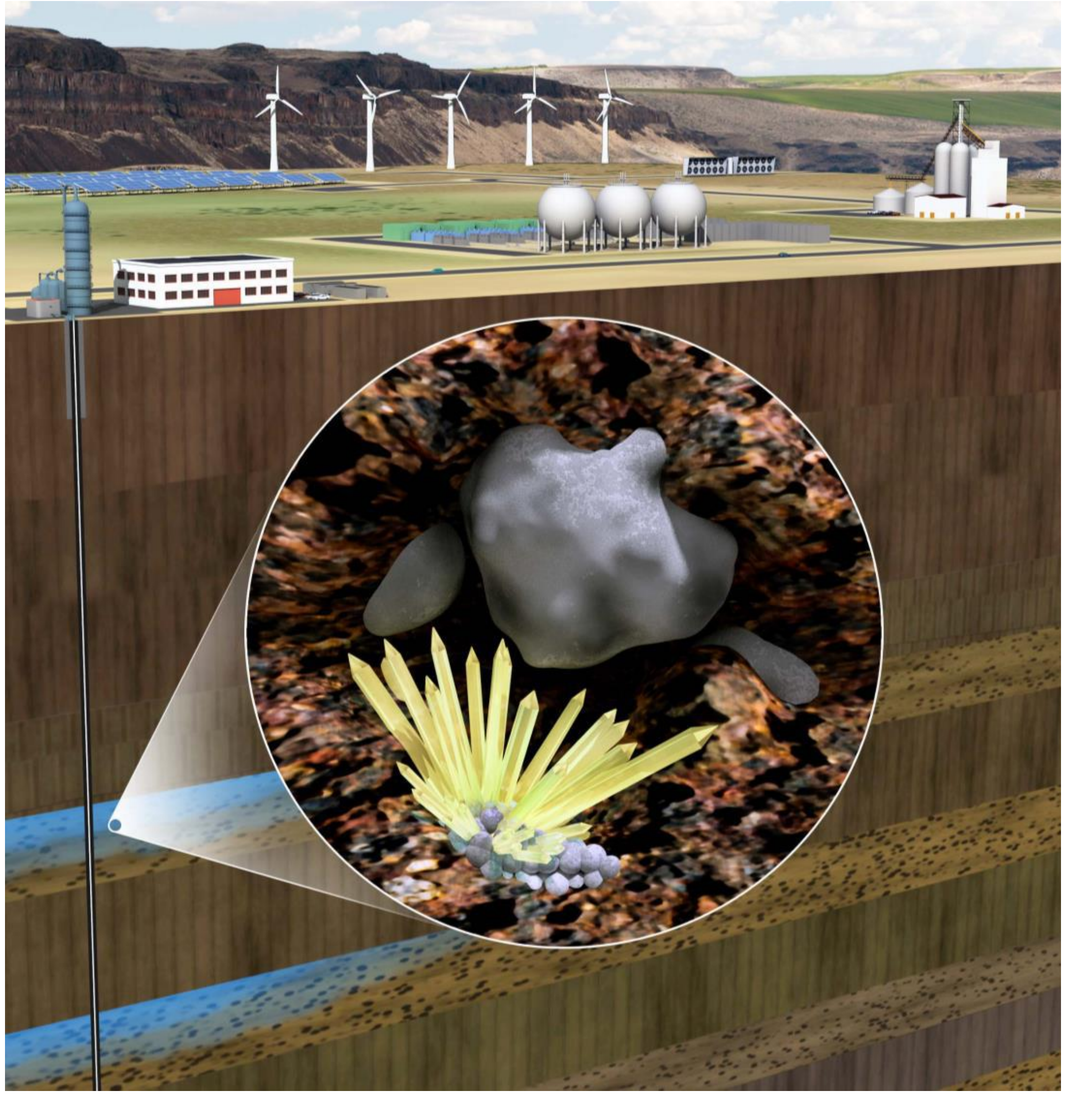
Project Execution Plan

- *Task 1.0: Project Management and Planning*
- *Task 2.0: Societal Considerations and Impacts (SCI) Assessment and Plans*
- *Task 3.0: Field Operations*
- *Task 4.0: Data Analysis, Modeling, and Simulations*
- *Task 5.0: Commercial Feasibility Assessments*



Project Success Criteria & Expected Outcomes

Overall, the utmost success criteria for the project are ***whether these investment scenarios can provide compelling demonstration for subsequent commercialized deployments.***



Desired Outcomes and Success Criteria

Primary Success Criteria for the HERO Project:

1) Successful drilling and completion of the stratigraphic well to a depth of ~5000 ft
   a) Comprehensive well logging and hydrologic testing
2) Complete data collection and integration necessary for injection simulation and reservoir analysis
3) Validation of projected CO_2 plume in the Area of Review by numerical simulations, field tests, and laboratory experiment results (50+ million metric tons)
4) Successful relationship building and partnering with the local communities surrounding the Hermiston site to ensure that our characterization plan incorporates community needs and concerns from the beginning

Integration of these outcomes to:

a) Successfully meet Phase III entry criteria (commercial-scale (50+ million metric tons CO_2) storage complex in the Columbia River Basalt Group)
b) Discover and communicate best practices and challenges for drilling and sampling layered basalts for future research and commercialization efforts.

Community Benefit and Impacts

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Leverage previous experience and engagement of local and regional stakeholders in shaping a community vision

- Carbon storage in basalts can benefit the PNW
- Nucleus for clean energy projects in the region

Identify key stakeholders in surrounding communities

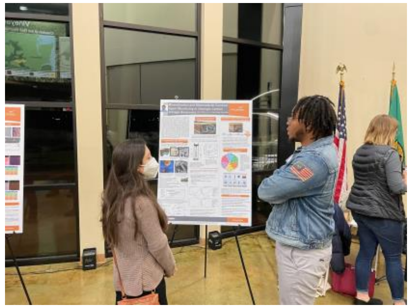
- Work to engage stakeholders to share knowledge about CO_2 storage
- Solicit feedback to help guide project-specific engagement on future phases HERO
- Engage with regional regulatory entities

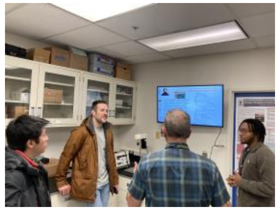
Sharing and soliciting feedback from the local communities

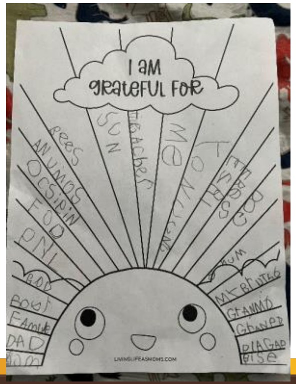
- Build advocacy for clean energy projects
- Collaboratively address non-technical challenges to project development

Stakeholder and Community Outreach

- Early engagement is critical to gain acceptance
- Training next generation scientists from local communities (e.g., community colleges)
- ***Outreach is strategic for clean energy project acceptance***







Current Status and Next Steps

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Current Project Status

- Scientific and operational alignment ahead of funding release
- Drafting of stratigraphic-well permit package submitted to Oregon Department of Geology and Mineral Industries (DOGAMI) – Full review pending plat survey
- Secure host-site access ahead of construction and drilling operations

Next Steps in Phase II

1. Complete permitting with the Oregon Department of Geology and Mineral Industries for the stratigraphic test well

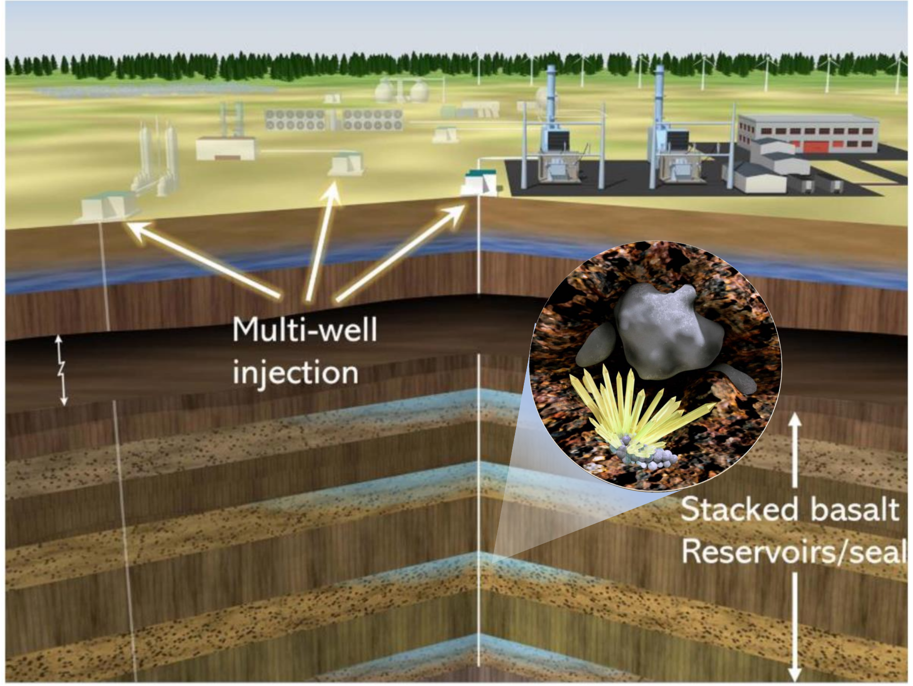
2. Finalize field and science program

3. *Initiate the CBP – Community outreach and workshops*

4. Initiate materials sourcing and rig mobilization

5. *Drill the Stratigraphic Well*

Thank you!



Auxilliary

Summary of Project Risks

Risk: Public acceptance
Mitigation: CBP

Risk: Completion of the drilling and sampling program
Mitigation: Lessons from Wallula, open engagement with the geothermal industry and other DOE-funded PIs, flexibility-based on contingencies

Risk: Costs of in-field activities
Mitigation: Expanded engagement with service and research industry

Perceived Risk	Risk Rating			Mitigation Response/Strategy
	Probability	Impact	Overall	
	(Low, Med, High)			
Financial Risks:				
Escalating Costs	Med	Med	Med	• Communication with our suppliers • Constant effort to identify alternative cost effective sources
Cost/Schedule Risks:				
Supply chain risks associated with drill rig availability and tubing	Med	High	High	• The team understands drilling schedules and is prepared to be flexible (e.g. rearrange task order).
Timelines in completing tasks	Low	Low	Low	• Progress towards milestones and tasks determined during bi-weekly meetings with project team
Technical/Scope Risks:				
Drilling in Basalts	Low	Low	Low	• Drilling team is experienced and aware of challenges with drilling basalts • Alternative drilling approahes identified to account for vaiable conditions and issues encoutered while drilling
Seismic Interpretation	Low	Low	Low	Seismic interpreation for layered basalts is challenging. • HERO team has assembled expertise from Wallula Pilot Project who successfully interpreted seimsic collected from layered basalts. • Plan to collect supplementary vertical seismic profiles (VSP), which will help seismic interpretation.
Management, Planning, and Oversight Risks:				
Project Management	Low	Low	Low	• PI and project team are very familiar with field demonstrations (CarbonSAFE projects and Wallula Field Demonstration Project). • Project team will leverage their expertise to jointly manage, plan, and execute this project.
Oversight Risks	Low	Low	Low	• Continuously engage site owner(s) to identify risks and plan accordingly before initiating field activities.
ES&H Risks:				
Environmental Safety and Health	Low	Low	Low	• OXY (partner) is a leading expert in driling operations and has an excellent ES&H record. • Advisory board will review our ES&H plans and provide additional guidance.
External Factor Risks:				
Supply chain issues	Med	Med	Med	• High degree of planning and communication to ensure alignment with our contractors to address any supply chain issues encountered during this project.

Post-Project/Scale Up Potential

1. Expand storage hub collaborations with additional sources
   - DAC
   - Other industrial emitters

2. Develop Class VI methodology for mineralization-focused storage hubs

3. Develop monitoring technologies for basalt

4. Refine mineralization kinetic parameters for modeling

5. Value-added resource management, including groundwater

The UW School of Energy Resources Energy ELC

The Energy Engagement, Leadership, and Careers (ELC) Program

MISSION: *To lead in the development of a skilled energy workforce, engage industry stakeholders, empower communities by incorporating local knowledge into program development and research, advance social science capacity building, and inspire the next generation of leaders through innovative education.*

ENERGY WORKFORCE DEVELOPMENT

Pioneer workforce development strategies that align with the evolving needs of existing and emerging energy sectors.

ENERGY EDUCATION AT ALL LEVELS

Develop innovative and forward-thinking education programs at all levels to cultivate future leaders in the energy sector.

ENGAGEMENT WITH ENERGY COMMUNITIES

Empower energy communities to embrace and benefit from emerging energy technologies.

SOCIAL SCIENCE RESEARCH

Lead in the application of social science methodologies to address the societal dimensions of emerging energy technologies and inform capacity building for energy communities.

ENERGY LEADERSHIP

Develop and train the next generation of innovative, forward-thinking, and conscientious energy leaders.

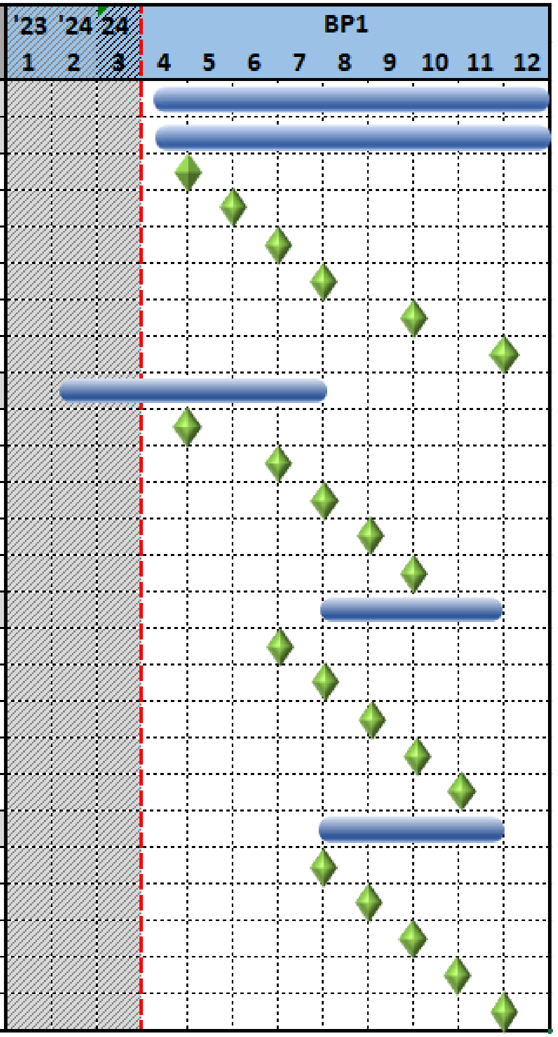
School of Energy Resources

Agenda

- Project Overview
- Project Background
- Technical Approach
- Current Status of Project and Accomplishments
- Community Benefits
- Lessons Learned
- Next Steps

Project Execution Plan

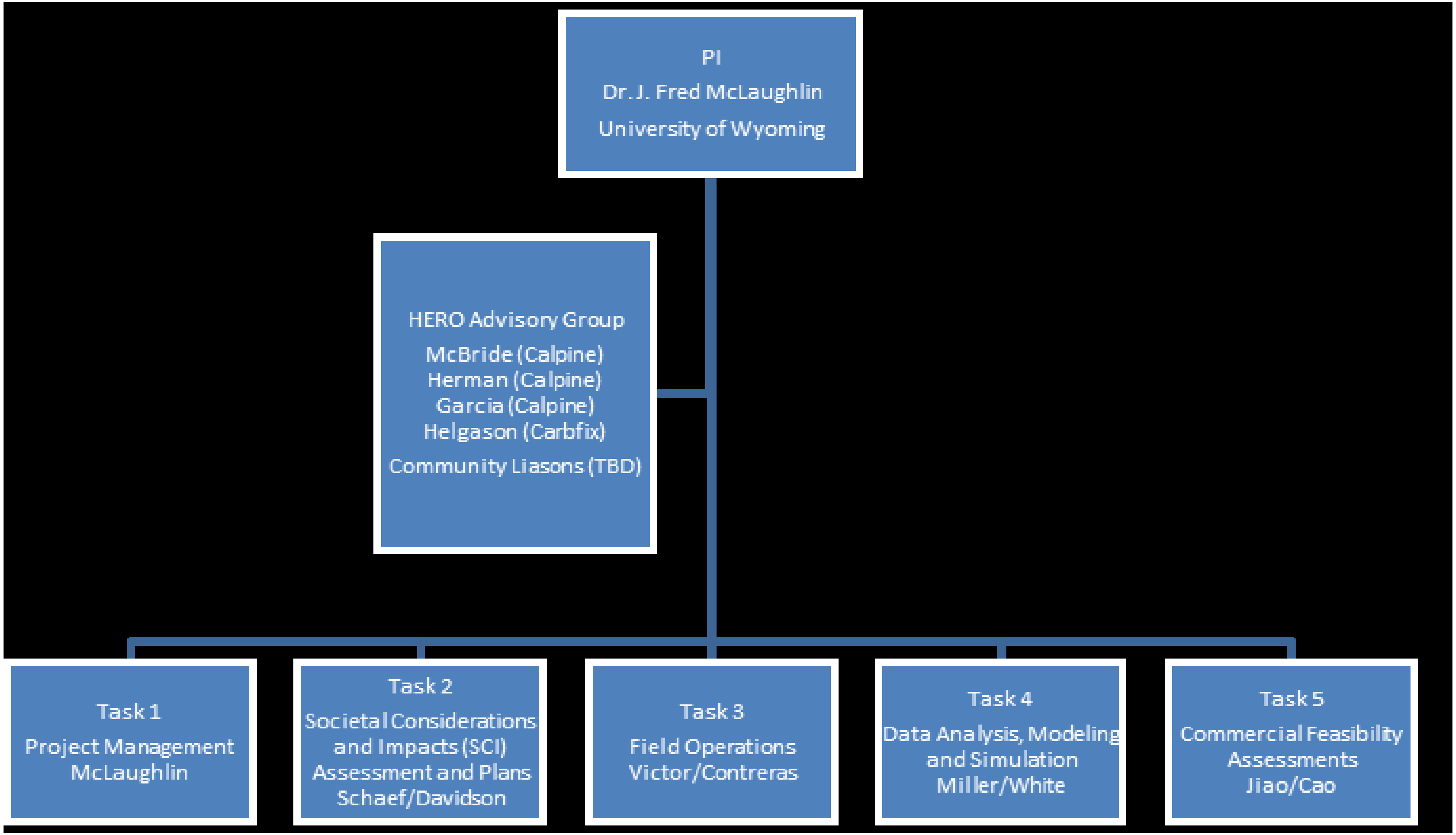
WBS	Task/Milestone Title	G/N	Start	End
Task 1	**Project management and Planning**		1	8
Task 2	**Societal Considerations & Impacts Assessment and Plans (PNNL)**		1	8
M2.1	Initiated outreach in Hermiston, OR & established collaboration with educators		1	1
M2.2	Held public outreach workshop in Hermiston, OR		2	2
M2.3	Held all-hands project meeting on DEIA; focusing on drilling comminutes		3	3
M2.4	Held STEM workshop in Hermiston OR with partners		4	4
M2.5	Finalized student placement with DOE internships		6	6
M2.6	Held community workshop with partners		8	8
Task 3	**Field Operations (OLCV)**		1	5
M3.1	Finalized site access and obtain required permitting		1	1
M3.2	Completed well pad construction & drilling of stratigraphic well		2	2
M3.3	Finalized logging, hydrogeologic testing, and sampling		3	3
M3.4	Demobilized drill rig and restored drill site		4	4
M3.5	Issued site closure and lessons learned report		5	5
Task 4	**Data Analysis, Modeling and Simulations (PNNL)**		3	7
M4.1	Compiled and analyzed existing regional data for conceptional model		3	3
M4.2	Parameterized model with stratigraphic well data		4	4
M4.3	Completed series of numerical CO2 injection simulations		5	5
M4.4	Finalized reactive transport modeling for mineralization		6	6
M4.5	Issues report on Co2 mineralization potential for HERO		7	7
Task 5	**Commercial Feasibility Assessments (UWYO)**		4	8
M5.1	Completed scenario analysis		4	4
M5.2	Finalized report on technical subsurface data evaluation		5	5
M5.3	Conducted regional analysis on Co2 Hub at HERO site		6	6
M5.4	Co2 technical analysis		7	7
M5.5	Issued report on stakeholder analysis outcomes for HERO		8	8



Project Kickoff – October '23

Funding Expected August '24

Organization Chart



Project Funding

Spend Plan by Fiscal Year Format

	FY 2023		FY 2024		Total	
	DOE Funds	Cost Share	DOE Funds	Cost Share	DOE Funds	Cost Share
UWyo	559,379.50	83,617	559,379.50	83,617.00	1,118,759.00	167,233.50
OLCVS	2,994,469	600,00.00	3,250,000.00	600,000.00	5,988,938.00	1,200,000.00
PNNL	650,000.00	75,000.00	650,000.00	75,000.00	1,300,000.00	150,000.00
Calpine	0	160,000.00	0	160,000.00	0	320,000.00
CarbFix	0	25,000.00	0	25,000.00	0	50,000.00
Schlumberger	0	115,000.00	0	115,000.00	0	230,000.00
Total ($)	3,996,453.00	1,058,617.00	3,996,453.00	1,058,616.50	8,407,697.00	2,117,233.00
Total Cost Share %		20%		20%		20%

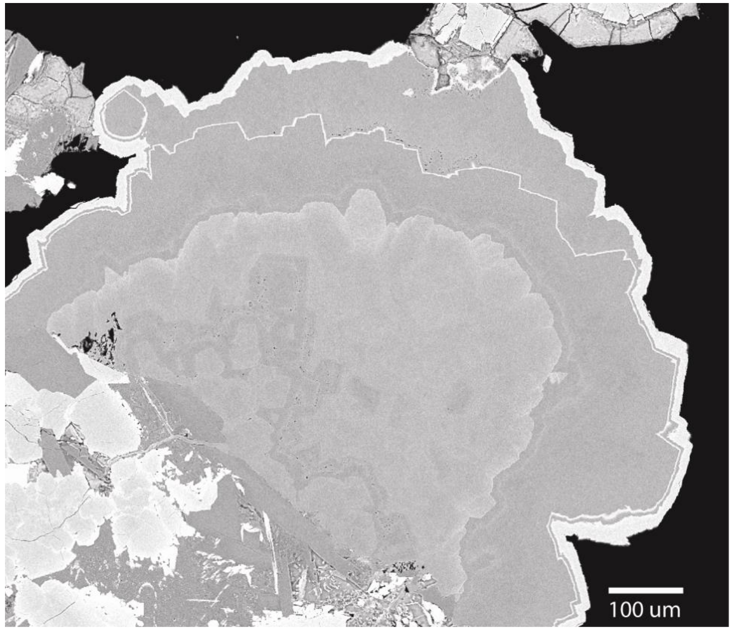
Previous Work in Region

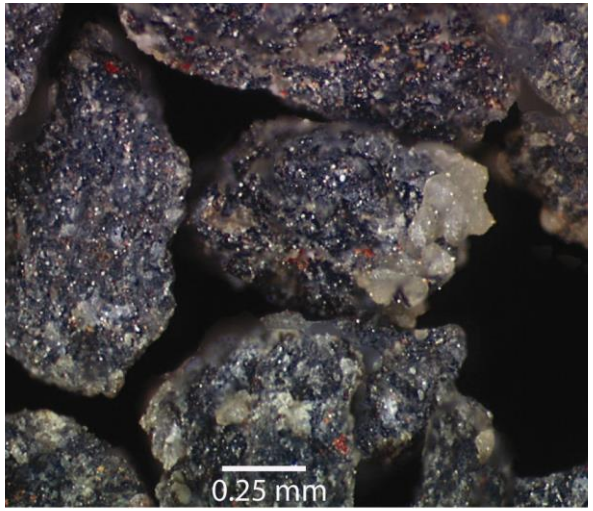
CRBG Mineralization Programs at PNNL: Experimentally Derived Data

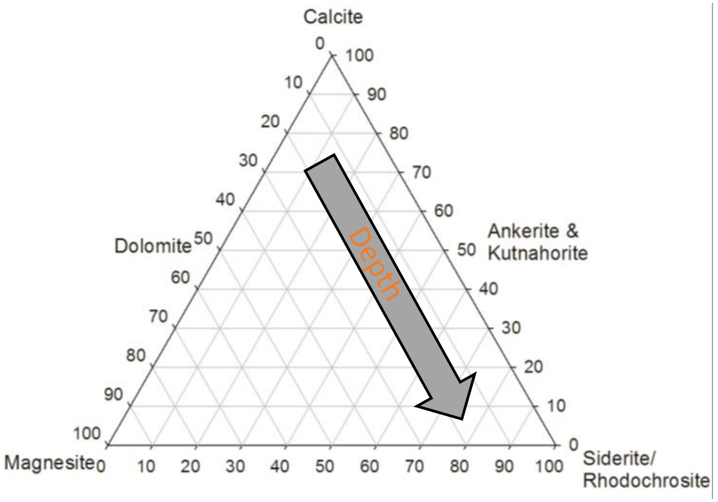
- Reaction products,
  - Calcite
  - Aragonite
  - Rhodochrosite
  - Ankerite
- Variable chemistry
  - Heavily substituted with Fe^{2+}, Mn^{2+}
- Carbonate structure transitions with depth
- Estimated carbonate rate
  - ~0.19 kg m^{-3} yr^{-1}

Schaef, McGrail, et al 2010, "Carbonate mineralization of volcanic province basalts", IJGGC, 1 249-261.

Xiong, Wells, Horner, Schaef, et. al., 2019. "Potential for CO_2 Sequestration in Flood Basalts", Journal of Geophysical Research, Vol 111, B12201.







Milestones

Key milestones

1. Successful community engagement and outreach
2. Complete access agreements and permitting for field operations
3. Stratigraphic test well completion and sampling
4. Mineralization assessment and simulations of storage capacity and risk
5. Commercial assessments

Wallula Refereed Publications

Carbon Storage in Basalt Formations: Wallula Field-Scale Demonstration & Basalt Studies

1. Polites, E. G., H. T. Schaef, J. A. Horner, A. T. Owen, J. E. Holliman, Jr., B. P. McGrail and Q. R. S. Miller (2022). "**Exotic Carbonate Mineralization Recovered from a Deep Basalt Carbon Storage Demonstration.**" Environmental Science & Technology 56(20): 14713-14722.
2. Depp, C. T., Q. R. Miller, J. V. Crum, J. A. Horner and H. T. Schaef (2022). "**Pore-scale Microenvironments Control Anthropogenic Carbon Mineralization Outcomes in Basalt.**" ACS Earth and Space Chemistry 6(12): 2836-2847.
3. White, S. K., F. A. Spane, H. T. Schaef, Q. R. S. Miller, M. D. White, J. A. Horner and B. P. McGrail (2020). "**Quantification of CO_2 Mineralization at the Wallula Basalt Pilot Project.**" Environmental Science & Technology **54**(22): 14609-14616.
4. Xiong, W., R. K. Wells, J. A. Horner, H. T. Schaef, P. A. Skemer and D. E. Giammar (2018). "**CO_2 Mineral Sequestration in Naturally Porous Basalt.**" Environmental Science & Technology Letters **5**(3): 142-147.
5. McGrail, B. P., H. T. Schaef, F. A. Spane, J. B. Cliff, O. Qafoku, J. A. Horner, C. J. Thompson, A. T. Owen and C. E. Sullivan (2017). "**Field Validation of Supercritical CO_2 Reactivity with Basalts.**" Environmental Science & Technology Letters **4**(1): 6-10.
6. McGrail, B. P., H. T. Schaef, F. A. Spane, J. A. Horner, A. T. Owen, J. B. Cliff, O. Qafoku, C. J. Thompson and E. C. Sullivan (2017). "**Wallula Basalt Pilot Demonstration Project: Post-injection Results and Conclusions.**" Energy Procedia **114**: 5783-5790.
7. Schaef, H. T., J. A. Horner, A. T. Owen, C. J. Thompson, J. S. Loring and B. P. McGrail (2014). "**Mineralization of Basalts in the CO_2–H_2O–SO_2–O_2 System.**" Environmental Science & Technology **48**(9): 5298-5305.
8. McGrail, B. P., F. A. Spane, J. E. Amonette, C. Thompson and C. F. Brown (2014). "**Injection and Monitoring at the Wallula Basalt Pilot Project.**" Energy Procedia **63**: 2939-2948.
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