De-risk Basalt Reservoir via Regional Geologic Modeling and Simulation

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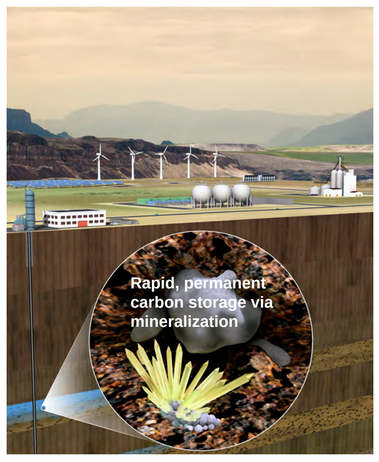
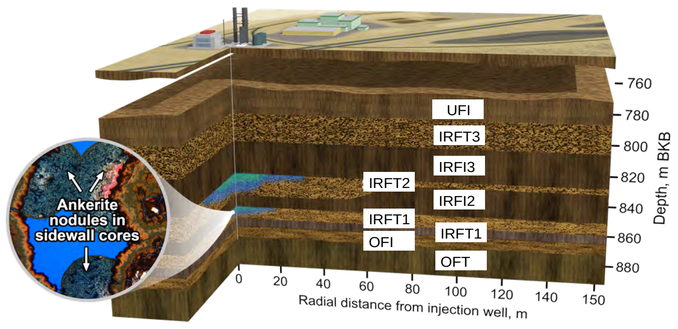
PNNL strives to address the knowledge gap crucial to mitigate uncertainties and risks for commercial scale basalt-hosted carbon storage in the Pacific Northwest. The integration of exploration well logs, reflection seismic profiles, GIS geomodels and products developed from the Wallula CO_2 project (2015) enables us to construct a regional stratigraphic and structural model for potential reservoirs within the Columbia River Basalt Group (CRBG). The resulting geologic model enhances the regional mapping of basalt flows and provides crucial insights for the identification of sites with favorable storage conditions. The characterization of the sites of interest provides constrains to numerically simulate commercial-scale CO_2 injection and estimate key parameters that govern reservoir feasibility for sustainable injection, such as storage capacity, T&P, plume extent and injection rates across the CRBG.

We have an unprecedented opportunity to leverage a groundswell of interest and enthusiasm from potential industry partners; to facilitate conversations between regional regulators, financers, developers, and researchers; and to address crucial gaps in our understanding of how basalt-based storage might deploy at commercial scale in the Pacific Northwest. This work is essential to bring basalt storage closer to parity with sedimentary storage.



Leveraging World-unique Wallula Data for Commercial-scale Basalt CCS

In 2013, with the support of DOE-FE, NETL, the Big Sky Regional Partnership and industrial partners, a PNNL-led field pilot project injected 1,000 tons of supercritical CO_2 into the Columbia River Basalt (CRB) reservoir at Wallula Basalt Pilot well (**Figure 1**).



1) Injection permit issued: Mar 2011
2) 1,000 tons CO_2 injected: Sep - Nov 2012
3) Post-injection monitoring & sampling: 2013 - 2015
4) 60% of CO_2 incorporated into carbonate minerals within two years
5) Reservoir simulation: 2020
6) 50 sidewall cores from 827.8 m to 883.9 m depth
7) Current status: Sidewall core characterization (2017 - present)

Our current project seeks 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. We will perform R&D in two key areas:

1) Regional-scale site screening and sensitivity analyses on key parameters governing reservoir viability for sustainable injection over decadal project lifetimes.
2) Validation of simulation, characterization, and monitoring appvroaches necessary to support successful Class VI application and demonstration for this reservoir class.

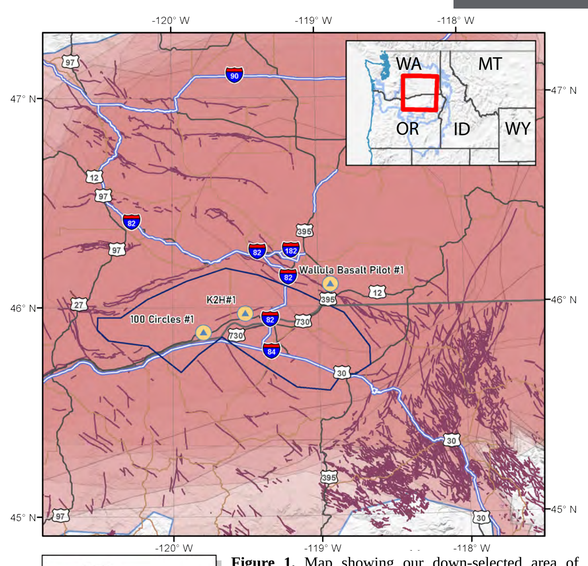
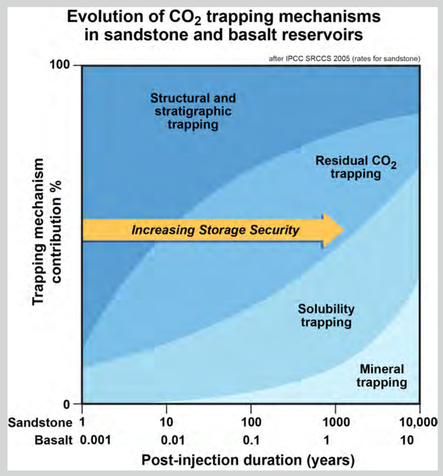
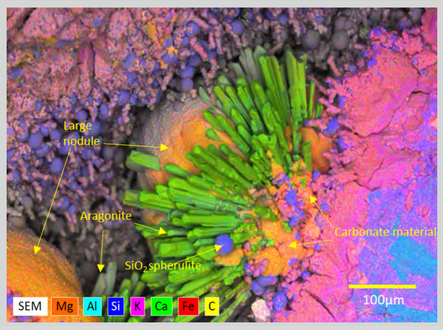


Figure 1. Map showing our down-selected area of interest, a region with minimal faulting, underlain by stacked Grande Ronde Formation flow members, and penetrated by three deep boreholes.

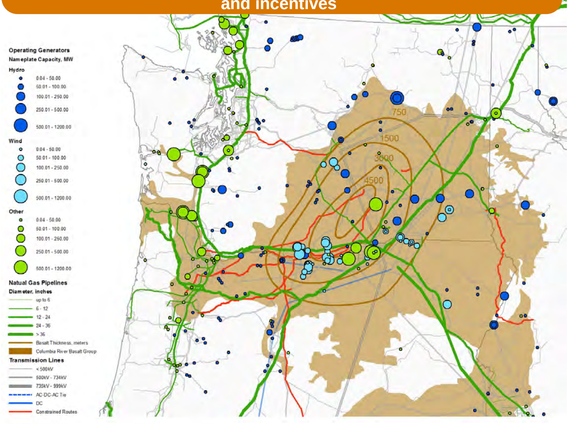
1) Columbia River Basalt Group (CRBG): up to 5 km thick and 168,000 km² extent
2) Highly reactive with supercritical CO_2
3) Self-sealing mineralization
4) Flood basalt = large volumetric thickness





Depp et al., *Pore-scale Microenvironments Control Anthropogenic Carbon Mineralization Outcomes in Basalt*, In Review at ACS Earth & Space Chemistry

CCS business opportunities in the Pacific northwest: Storage resources + Industrial sources + Infrastructure + Demand and incentives



Constructing Regional Geologic Model

1) To optimize injection rates and overall capacity by identifying favorable injection zones targeting brecciated flow tops/bases individual flows in the CRBG.
2) Integrating data from industry exploration wells, Hanford Basalt Waste Isolation Project, and the Wallula CO_2 project to provide an understanding of regional stratigraphy and reservoir potential for the CRBG.
3) Model will be used to conduct simulations of commercial-scale (~1 Mt CO_2/y) CO_2 injection to better constrain storage capacity and injection rates across the CRBG.

The dip azimuth and dip angle logs (**Figure 2A**) suggest the basalt flow members are stacked and sub-horizontally layered with random dip azimuths (**Figure 2B**) and low dip angles (mostly ranges from 5° to 25°, **Figure 2C**). The structural insights for the CRBG at Wallula indicates that we can successfully extrapolate these reservoir properties to the nearby regions

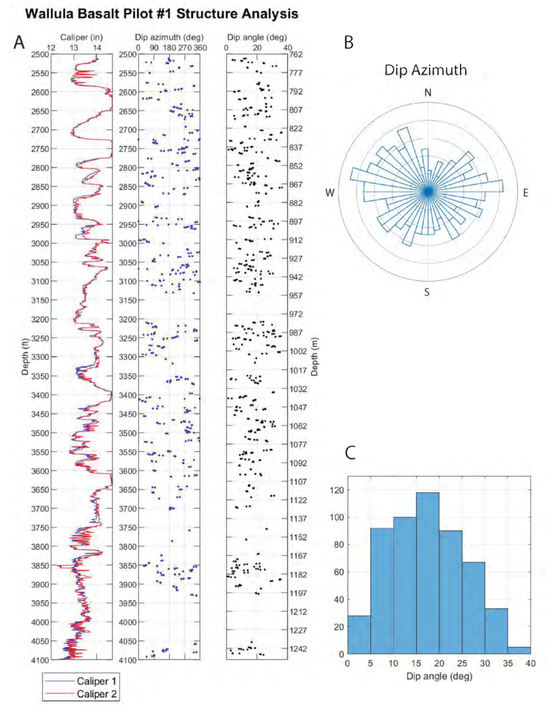
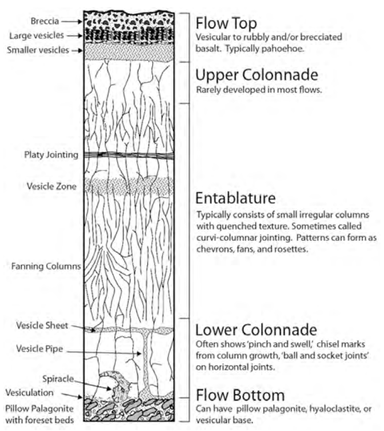
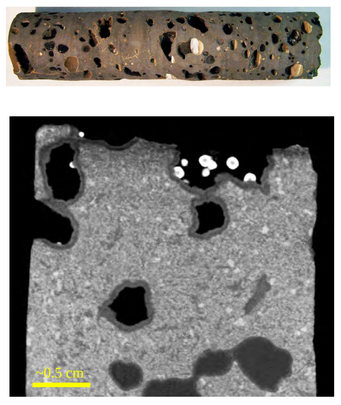


Figure 2. Structural measurements of the Wallula Basalt Pilot #1 well. A) Caliper, Dip azimuth, and Dip angle logs, from left to right; B) Rose diagram of the dip azimuth measurements; C) Histogram of the dip angle measurements.

Grande Ronde Formation Evaluation



Reidel, S.P., Camp, V.E., Martin, B.S., Tolan, T.L., and Wolff, J.A., 2016



Polites et al. 2022, Exotic Carbonate Mineralization Recovered from a Deep Basalt Carbon Storage Demonstration, In Review at ES&T

Flows from 7 members of the Grande Ronde Formation were identified in the Wallula borehole. The flows vary in thickness from 10 to 70 m, with brecciated flow tops about 3–20 m thick and apparent porosity of 20–45%. The majority of the interflow zones have apparent porosity over 15% but only 4 of them uniformly exceed 10 m in thickness: the flow tops of Umtanum, Indian Ridge and Grouse Creek members.

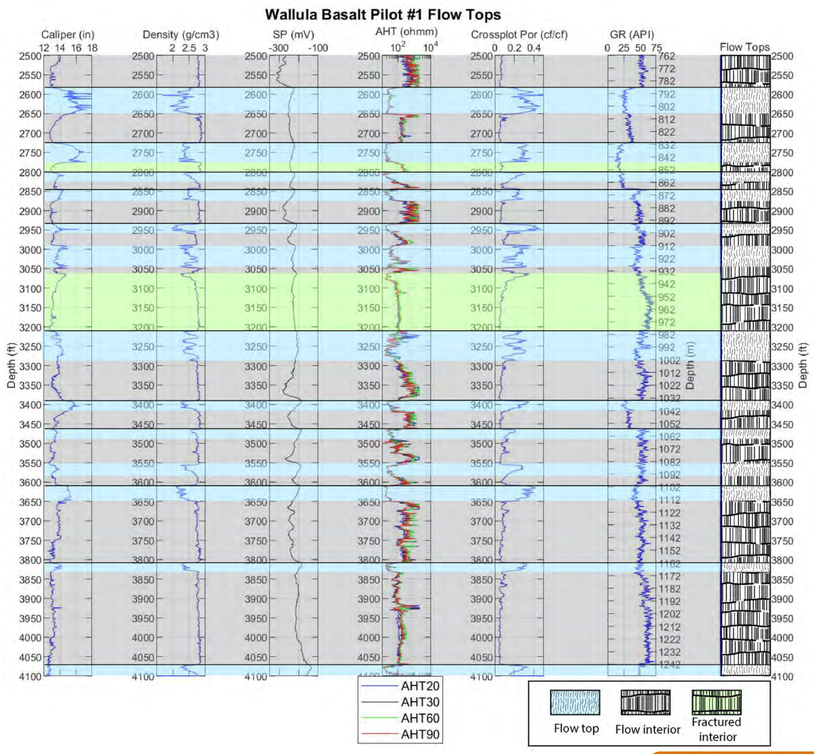


Figure 3. Interpreted flow tops and flow interiors from the supercritical CO_2 region of the Wallula Basalt Pilot #1 well. Log acronyms: SP - Spontaneous Potential; AHT - Array Induction Two Foot Resistivity; Crossplot Por – Computed porosity from density porosity and neutron porosity; GR – Gamma Ray.

1) Interbedded cap rock (flow interior) and reservoir rock (flow top)
2) Blue - flow tops; Gray - flow interiors; Yellow - fractured flow interiors
3) Permeable flow tops: average porosity = 30%; net stacked thickness =152 m (500 ft)
4) Hanford Site Core analysis: flow top porosity = 7 - 30%; flow interior porosity = 0.1 - 8.9%;
5) Hydraulic testing: flow interior conductivity = 10^{-12} - 10^{-13} m/s (10^{-4} - 10^{-5} mD), *Reidel et al., 2002;* flow top conductivity = 10^{-7} m/s (75 - 150 mD), *McGrail et al., 2009*
6) 1/3 of Grande Ronde Formation has reservoir quality rocks

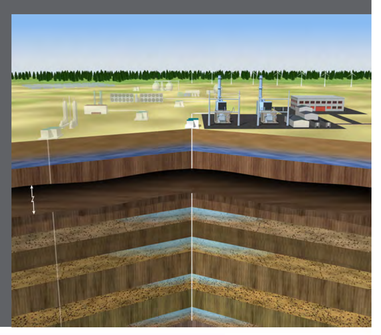
Early Career Contributions Driving Basalt Carbon Storage Advances

Ellen Polites (MLEF) Jade Holliman (MSIPP) Prof. Briana Aguila (VFP) Landon Hardee (VFP) Charles Depp (SULI)

1) Outreach is a keystone of our program, PUIs to RIs
2) Early career researchers include interns, postdocs, staff, visitors, etc
3) Product-driven research experience cultivates and unleashes talent
4) Diversity and inclusion enables innovation and creativity, breadth of perspectives needed for global challenges
5) DOE synergy: FECM (MLEF), SC (VFP, SULI, SCGSR), NNSA (MSIPP)

Advancing the Goal of Commercial-Scale Carbon Storage Hubs in Basalt

Simply put, we have picked up where Wallula left off, working to integrate existing data on the CRBG in WA, OR, and ID with new experimental findings from the Wallula site. We plan to parameterize a regional geologic model of the CRBG, identify high-priority sites for additional characterization; develop guidance for acquisition of additional data (e.g., campaign seismic,aerial gravity/magnetic) to reduce uncertainty in key areas of interest; and to engage regional decision makers, investors and public stakeholder groups to socialize and build advocacy for early deployment opportunities.



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CUSP West

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