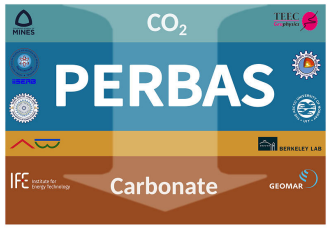
Accelerating CCS Technologies

PERBAS



Permanent sequestration of gigatons of CO_2 in continental margin basalt deposits

Stanislav Glubokovksikh, Erik Sonnentahl — Lawrence Berkeley National Laboratory
Manika Prasad — Colorado School of Mines
Jörg Bialas (PI), Christian Berndt, Hölz, Sebastian — GEOMAR
Sverre Planke, John Millett — Volcanic Basin Petroleum Research
Stefan Bünz — UiT Arctic University of Norway
Stéphane Polteau, Viktoriya Yarushina, Mário Silva — Institute for Energy Technique
Gerald Klein — TEECware GmbH
Nimisha Vedanti — CSIR-National Geophysical Research Institute
Ravi Sharma — Indian Institute of Technology Roorkee
Jyotirmoy Mallik — Indian Institute of Science Education and Research

GEOMAR Helmholtz Centre for Ocean Research Kiel · IFE · COLORADOSCHOOLOFMINES EARTH • ENERGY • ENVIRONMENT · BERKELEY LAB · TEEC Geophysics · UiT

IISER Bhopal INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH BHOPAL

ठोस पृथ्वी में प्रतिष्ठित अनुसंधान संस्थान
A Premier Research Institute in Solid Earth

भारतीय प्रौद्योगिकी संस्थान रूड़की
Indian Institute of Technology Roorkee

PERBAS

Permanent sequestration of gigatons of CO_2 in continental margin basalt deposits

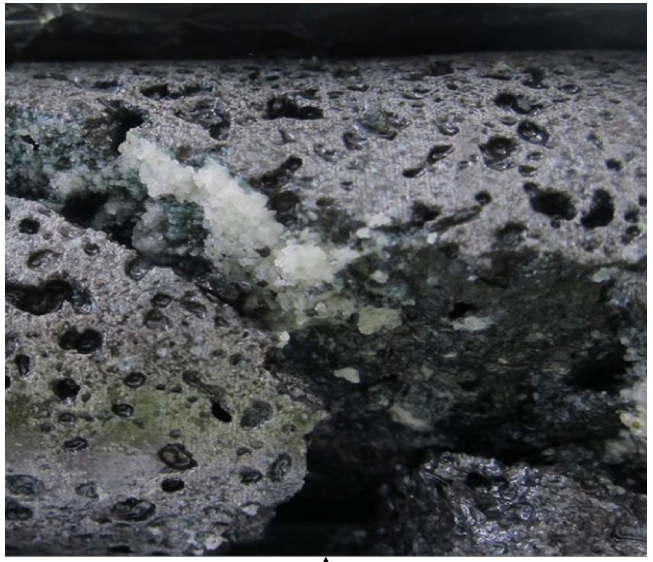
Acknowledgement

PERBAS consortium formed under the ERA-NET ACT4 CCUS initiative. PERBAS grants are funded through the national funding agencies BMWK (Germany, Grants: 03EE5163A), DOE (USA, FP00015801), DST (India, Grants: TBD), and RCN (Norway, Grant: 340823)

Why store in basalts?

Permanent storage through rapid carbonate mineralization

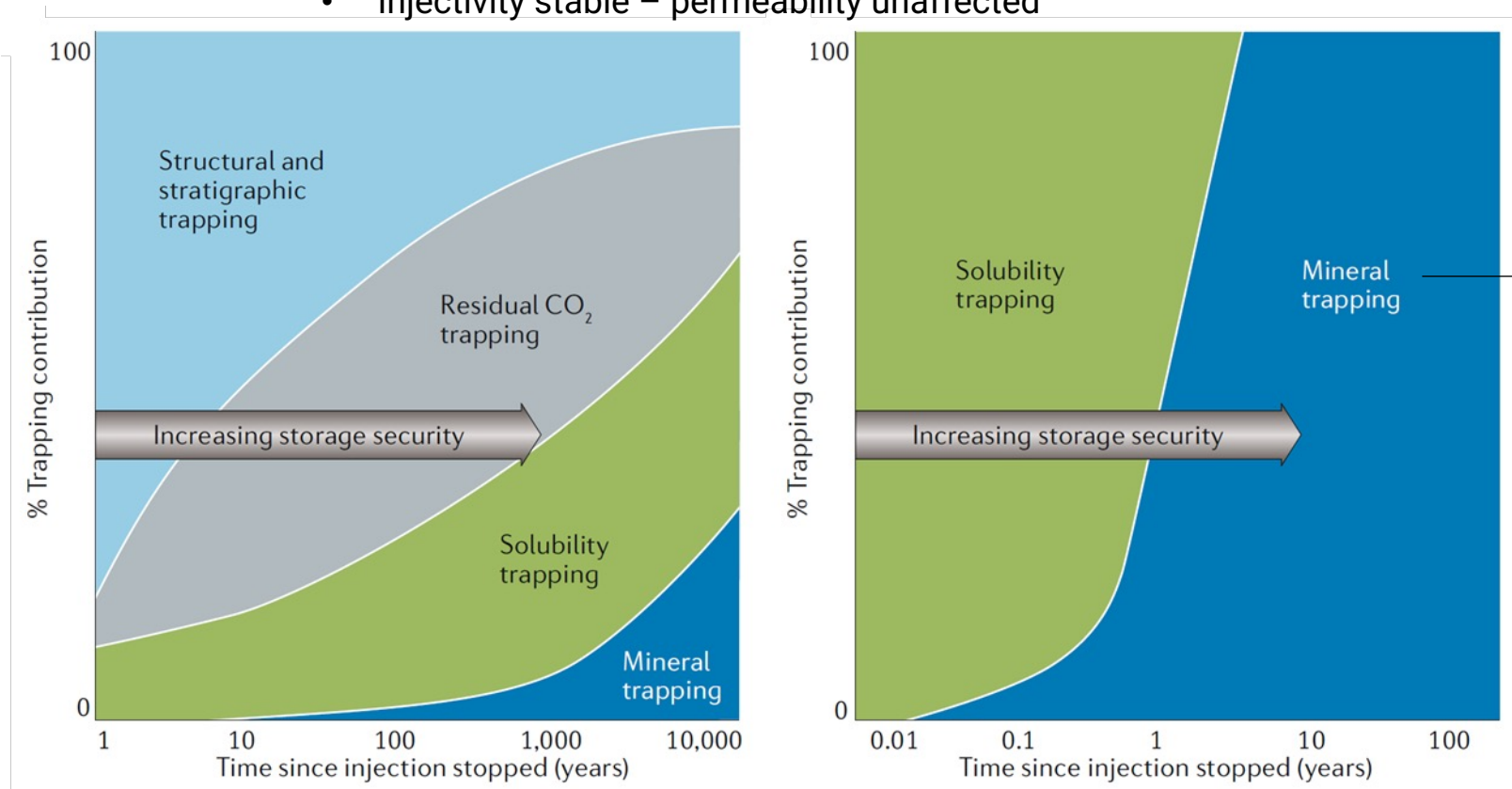
- 1 kg CO_2 reacts with Ca, Mg and Fe in rocks
- Turns into 1.8 kg carbonates in pore space
- Mineralization in 2 yrs – not in 100k yrs
- Injectivity stable – permeability unaffected



$$Mg_2SiO_4 + 2CO_2 = 2MgCO_3 + SiO_2$$
FORSTERITE MAGNESITE QUARTZ

and

$$CaAl_2Si_2O_8 + CO_2 + 2H_2O = CaCO_3 + Al_2Si_2O_5(OH)_4$$
ANORTHITE CALCITE KAOLINITE



BERKELEY LAB

EARTH & ENVIRONMENTAL SCIENCES

Snæbjörnsdóttir et al. (2021)
https://doi.org/10.1038/s43017-019-0011-8

U.S. DEPARTMENT OF ENERGY
Fossil Energy and Carbon Management

What do we know about the CO_2/basalt mineralization in basalts?

Permanent storage through rapid carbonate mineralization

CarbFIX Project (Iceland)

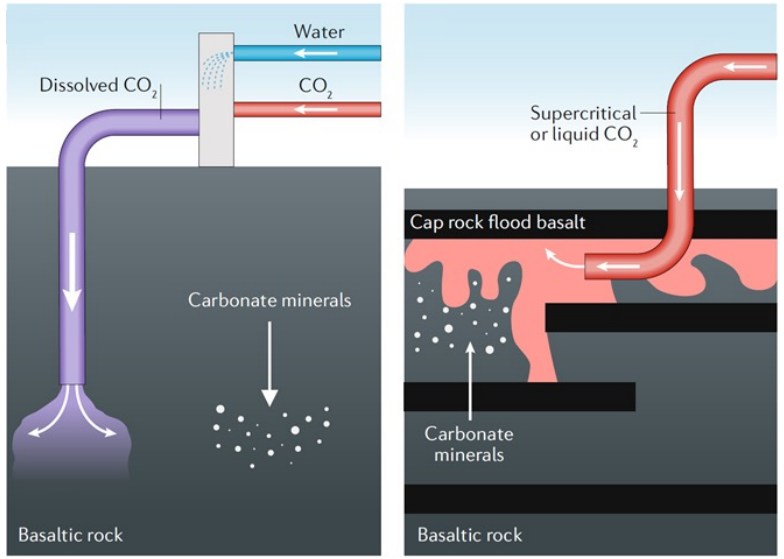
Science & Environment

Experiment 'turns waste CO2 to stone'

By Jonathan Amos
BBC Science Correspondent

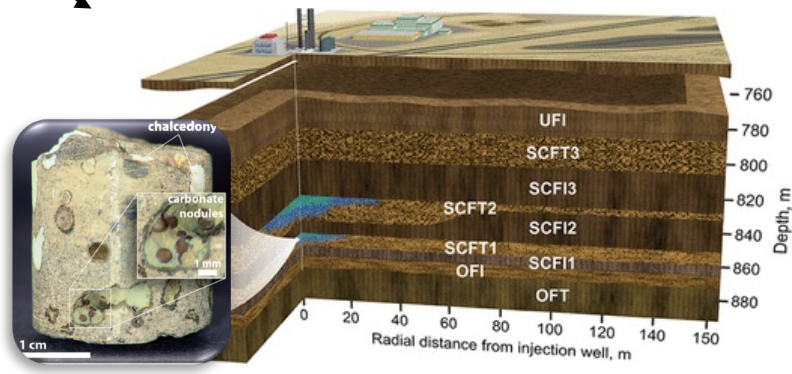
9 June 2016 | Science & Environment

Scientists think they have found a smart way to constrain carbon dioxide emissions - just turn them to stone.



Snæbjörnsdóttir et al. (2021)
https://doi.org/10.1038/s43017-019-0011-8

The Wallula Project (US)



White et al. (2020)
https://doi.org/10.1038/s43017-019-0011-8

- Can we store supercritical **CO_2 at large volumes?**
- We have **no idea about the 3D** distribution of the mineralization and dissolution fronts
- Without **a time-lapse 3D imaging** of the reservoir, we may not understand and optimize storage

A new geophysical imaging is the only option

BERKELEY LAB

EARTH & ENVIRONMENTAL SCIENCES

U.S. DEPARTMENT OF ENERGY
Fossil Energy and Carbon Management

Why the basaltic reservoirs are so hard?

CO_2 flow requires fractures and caverns in the extremely tight basalt rocks

USGS image of a lava flow in Hawaii

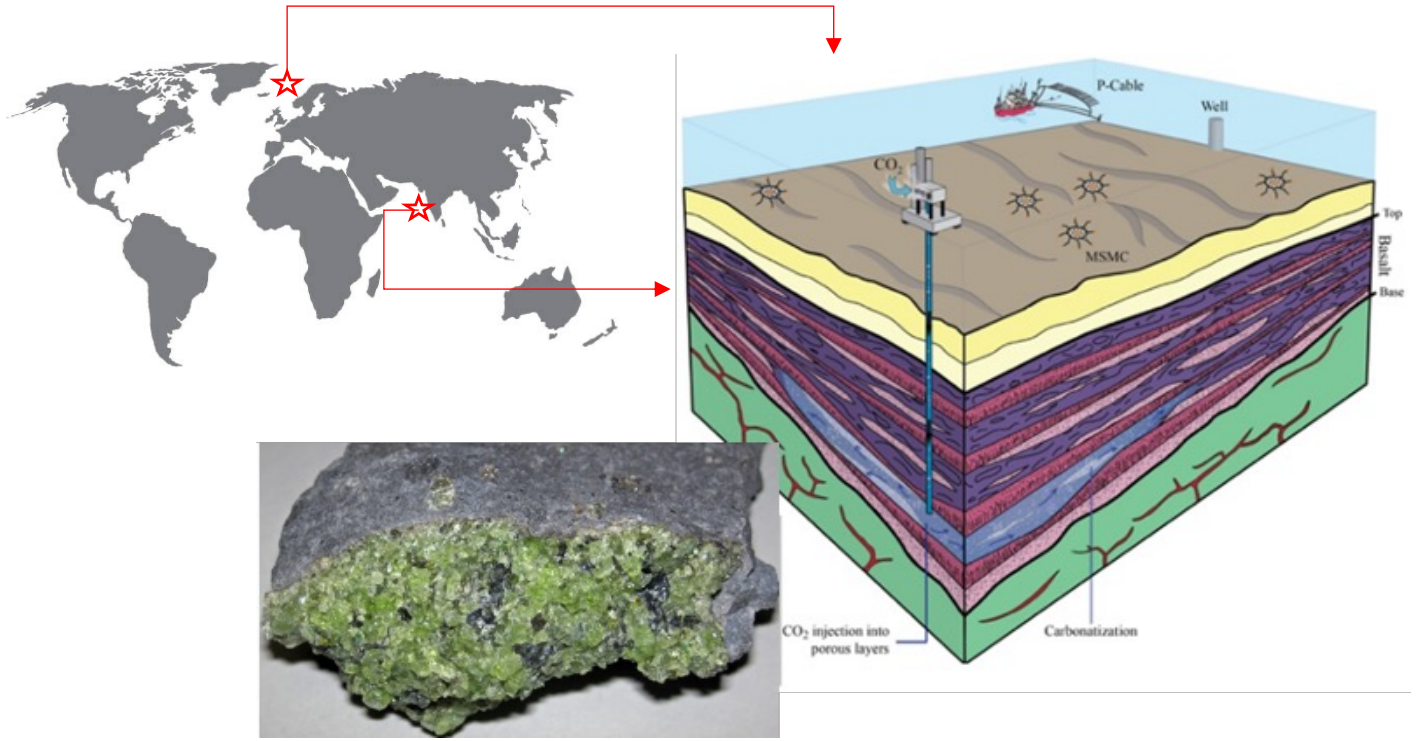
Buried lava flow mapped by VBPR on the Vøring Plateau

Link to video

How PERBAS aids CO_2 storage in basalts?

Development of a pilot for imaging of dissolution/precipitation fronts, monitor containment

Highest-ranked NE Atlantic and W India sites



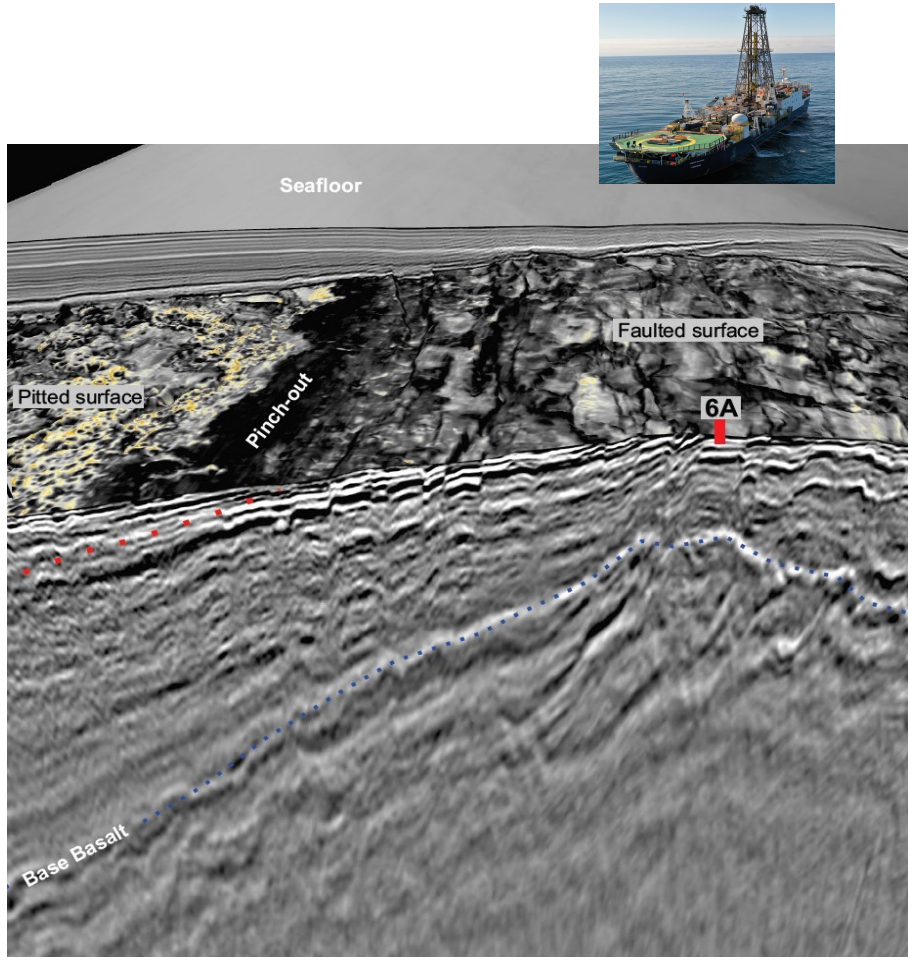
Cartier (2022), EOS

Need for Research Pilot CO2 Storage in Basalts

- Leap in injected volumes from kt to Gt per annum
- Reservoir capacity vs injectivity
- Risks of seismicity, deformation and formation of open fractures
- Reactive rocks: risk of mineralization and clogging of pore space near well-head
- Difficult to image architecture in seismic
- Reservoir connectivity hard to constrain

Structure of the PERBAS project

WP2 | Characterization of sequestration sites (GEOMAR)



The seismic imaging of the Norwegian margin basalts

Build database

- 2D and 3D seismic, EM and borehole data
- European margin and Indian Deccan basalts

Identification of basalt reservoirs

- Integrated interpretation of database
- Ranking of potential storage sequences

Characterization of fluid connectivity

- Strontium isotope analyses on residual salts (SrRSA)
- Core materials from Norwegian margin and India

Baseline 3D HR geophysical surveys

- Skoll High IODP drilling sites using P-Cable system
- Joint OBS and EM survey

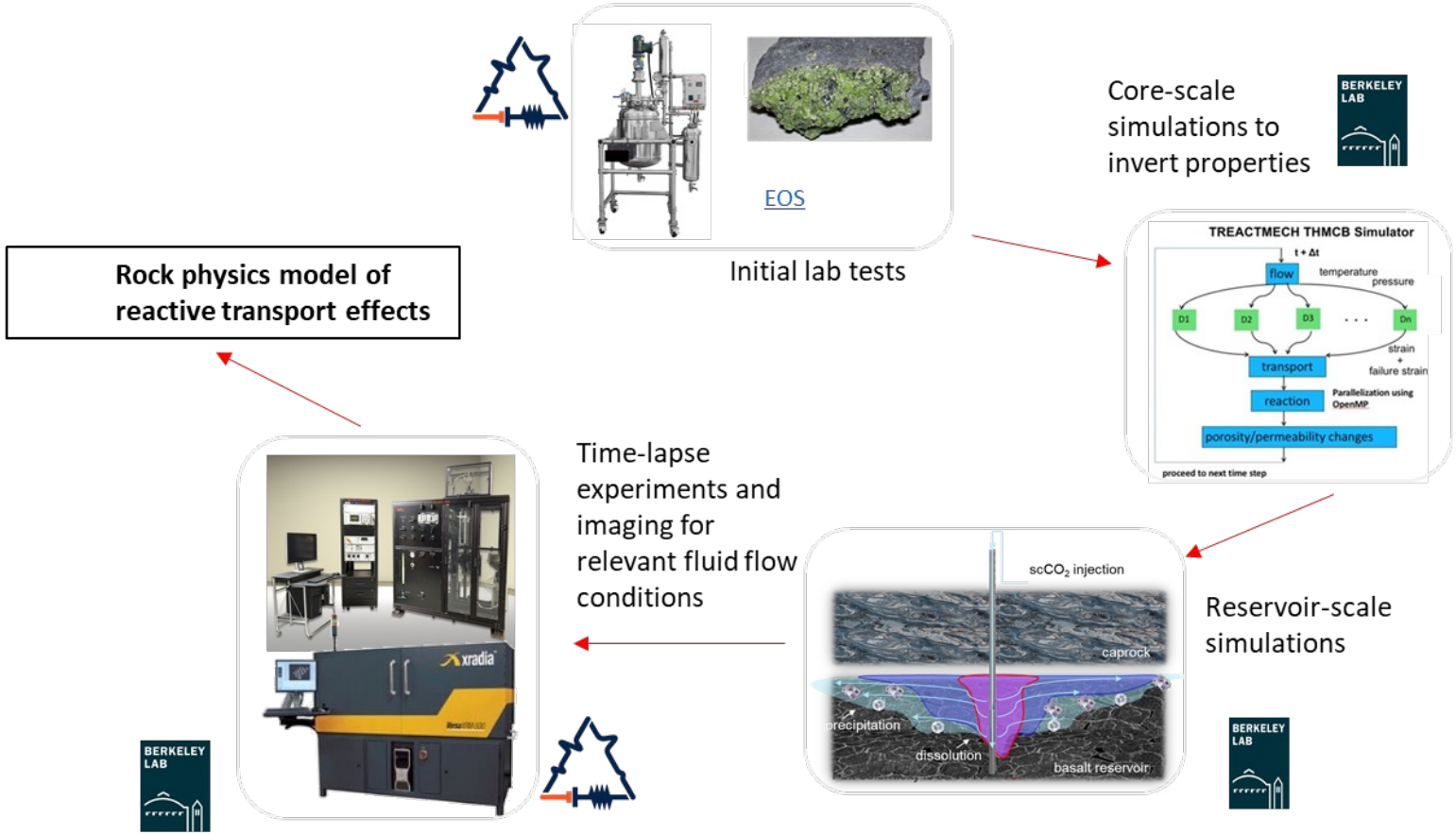
BERKELEY LAB

EARTH & ENVIRONMENTAL SCIENCES

U.S. DEPARTMENT OF ENERGY
Fossil Energy and Carbon Management

Structure of the PERBAS project

WP3 | Rock physics of reactive CO_2 flow through basalts (LBNL)



Reactive transport experiments

- Simulate CO_2 storage in the lab

Numerical models

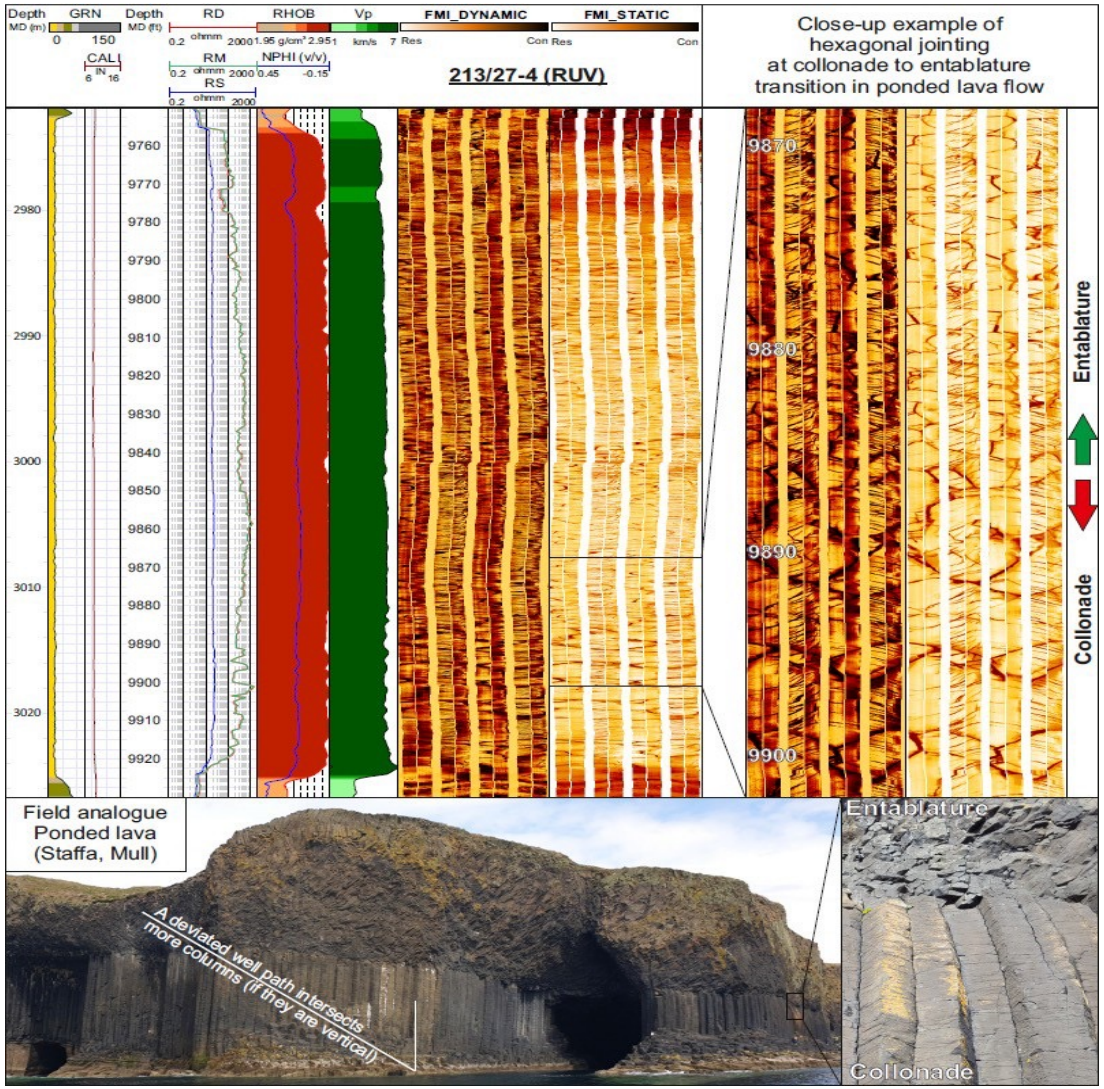
- Reservoir and pore-scale simulation of complex reactive flow - geomechanical model

Shape of the plume and its pore-scale impacts

- Quantify the detectability and geophysical response to

Structure of the PERBAS project

WP4 | Geological and geophysical models of basalt storage sites on volcanic margins (VBPR)



Earth model building software

- Update in-house software

Volcanological Earth models

- Highest-ranked NE Atlantic and W India sites
- Integrated core-log-seismic interpretation

Baseline and timelapse synthetic seismic

- Detectability of supercritical CO_2
- Degree of carbonization

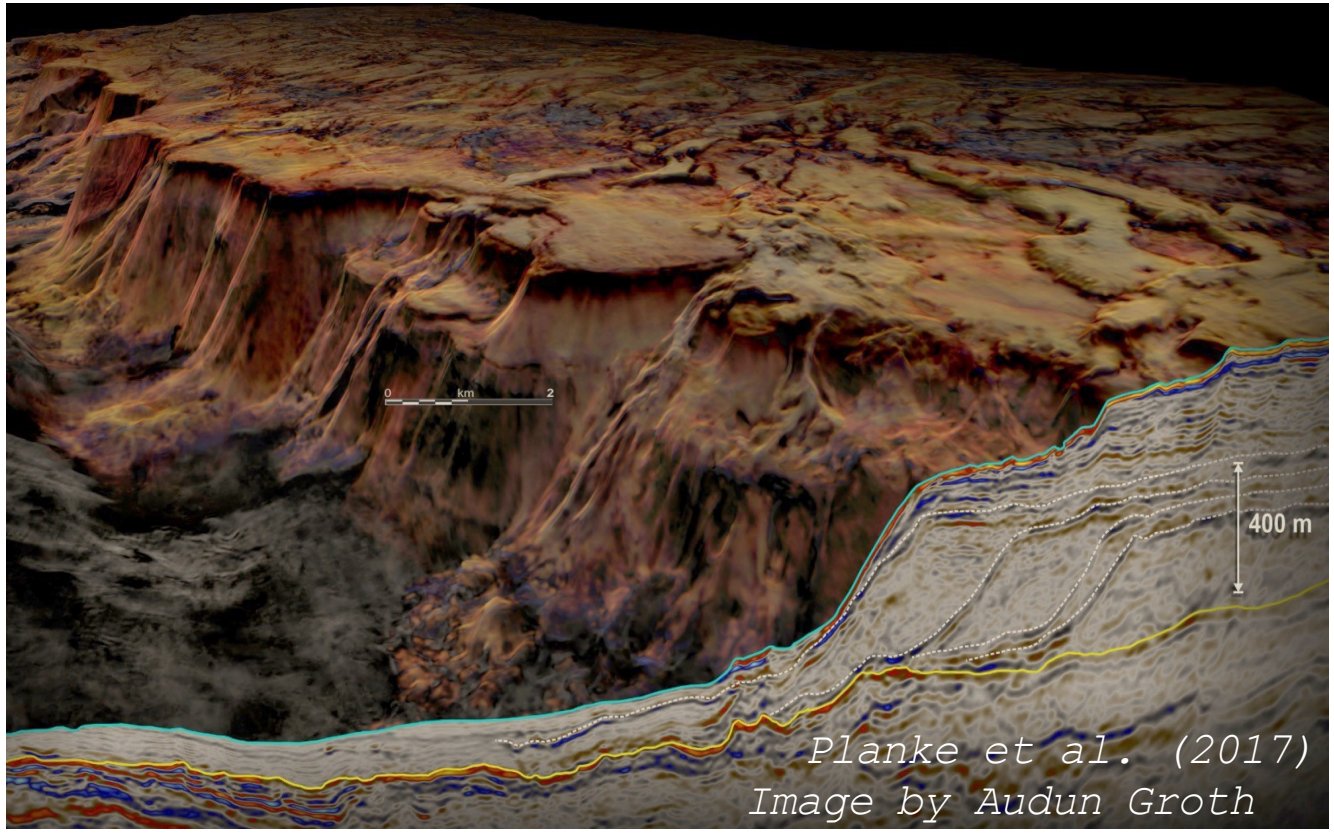
BERKELEY LAB

EARTH & ENVIRONMENTAL SCIENCES

U.S. DEPARTMENT OF ENERGY
Fossil Energy and Carbon Management

Structure of the PERBAS project

WP5 | New tools for integrated reservoir monitoring



New geophysical instruments

- Autonomous platform for operations
- 3C seismic nodes better coupled with seafloor

New data analysis methodologies

- Parametrization and inversion strategies to optimize
- sensitivity
- Training of deep neural network using relevant seismic attributes

Current status of PERBAS and lookahead

We are just starting the work…

Funding received, the Consortium Agreement being finalized, LBNL and Colorado School of Mines will work under bilateral NDA's

Companies joining the Advisory Board

Sverre Planke | co-chief IODP 396 | CEED, Univ. i Oslo & VBPR

Geophysical characterization of the basaltic reservoirs has begun….

BERKELEY LAB

EARTH & ENVIRONMENTAL SCIENCES

U.S. DEPARTMENT OF ENERGY

Fossil Energy and Carbon Management