Mineral storage of CO_2 in basalt — the CarbFix project

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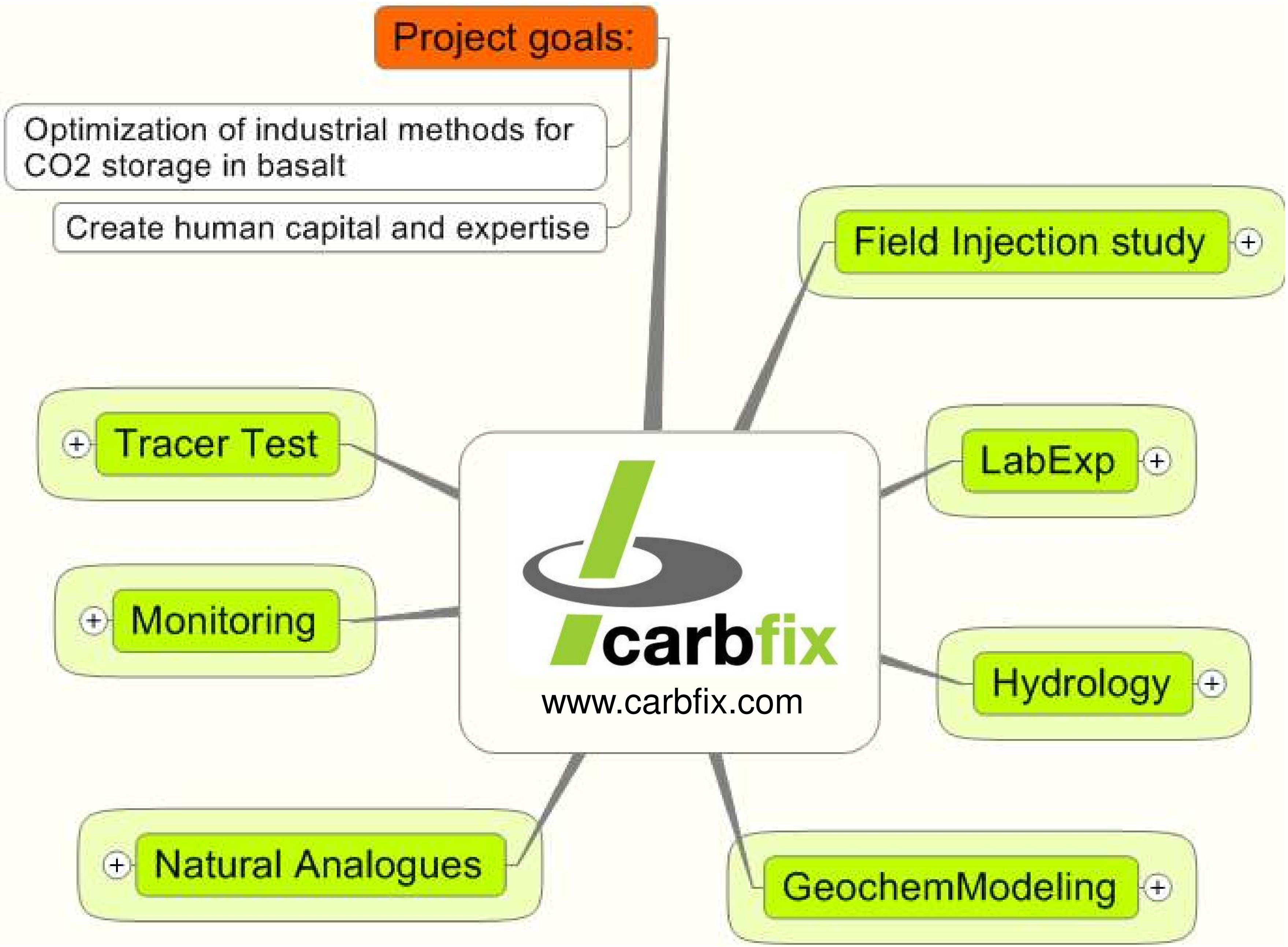
(4) Reykjavik Energy, Iceland

carbfix



Project goals:
Optimization of industrial methods for CO2 storage in basalt
Create human capital and expertise
Field Injection study
Tracer Test
LabExp
Monitoring
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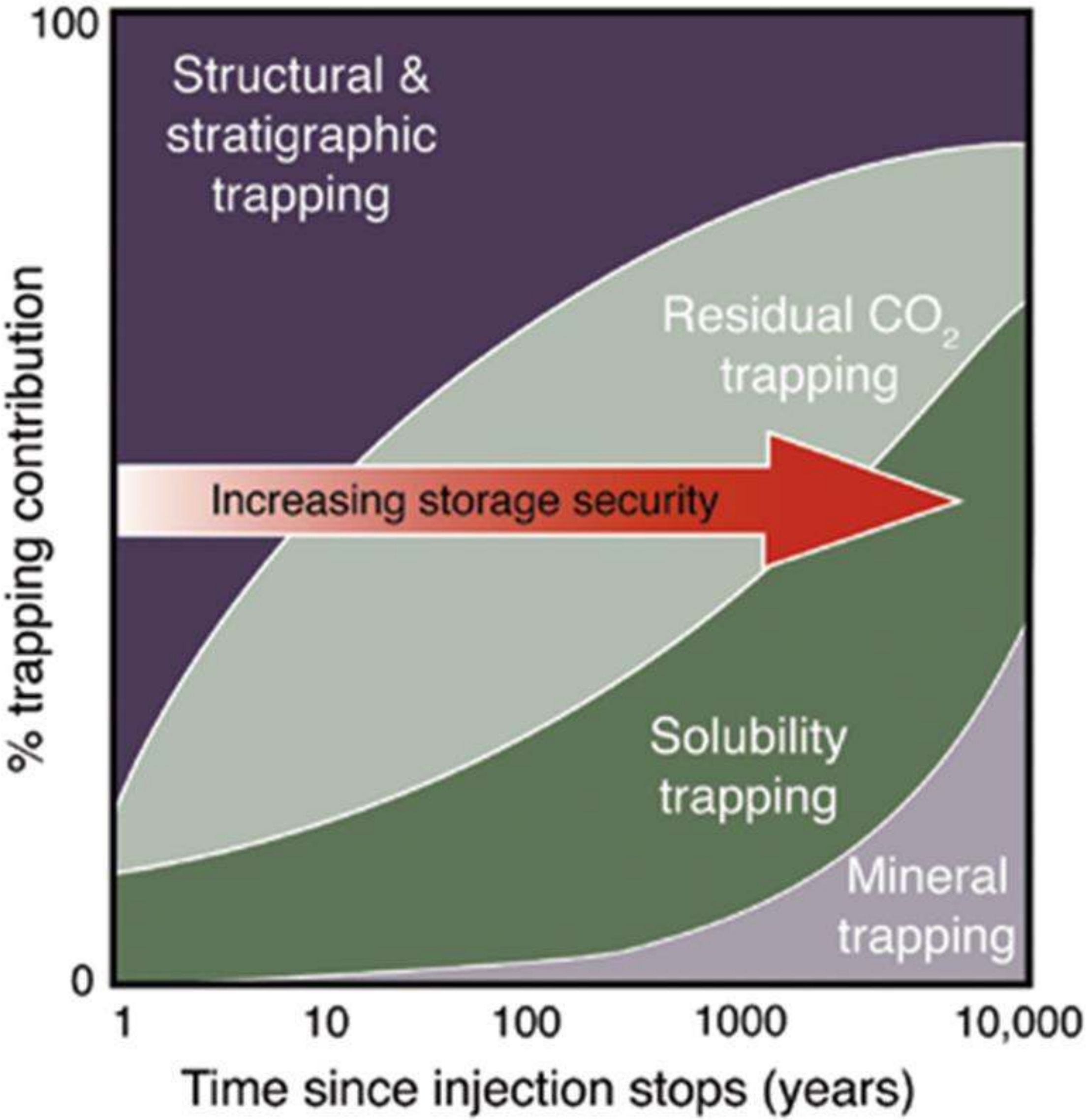
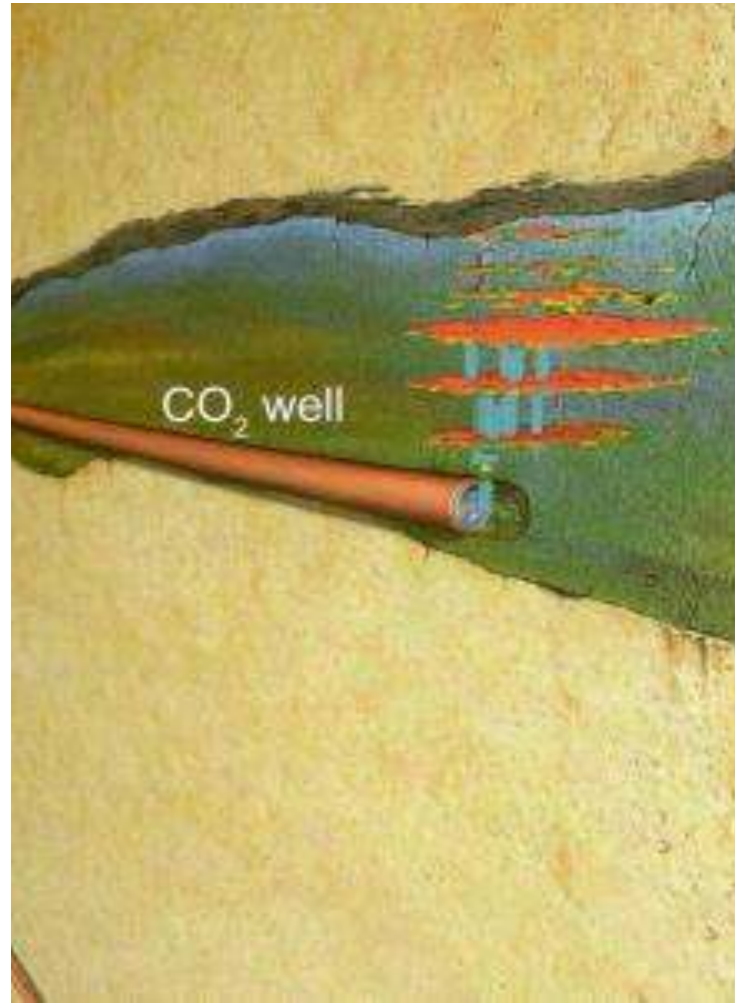
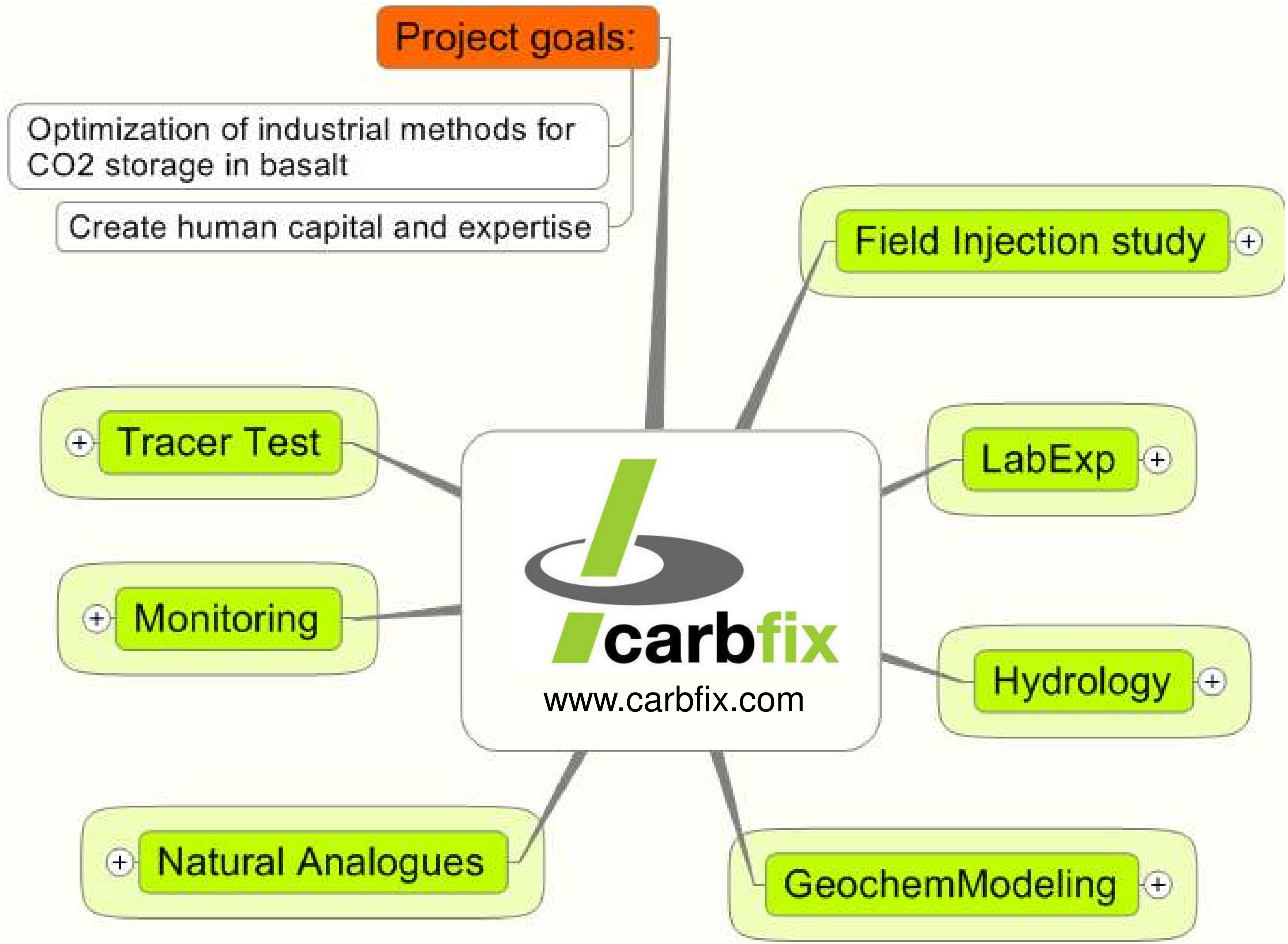
Hydrology
Natural Analogues
GeochemModeling

A general representation of the evolution of trapping mechanisms over time. Actual trapping mechanism and evolution vary from site to site





(IPCC 2005, Torp and Gale 2003)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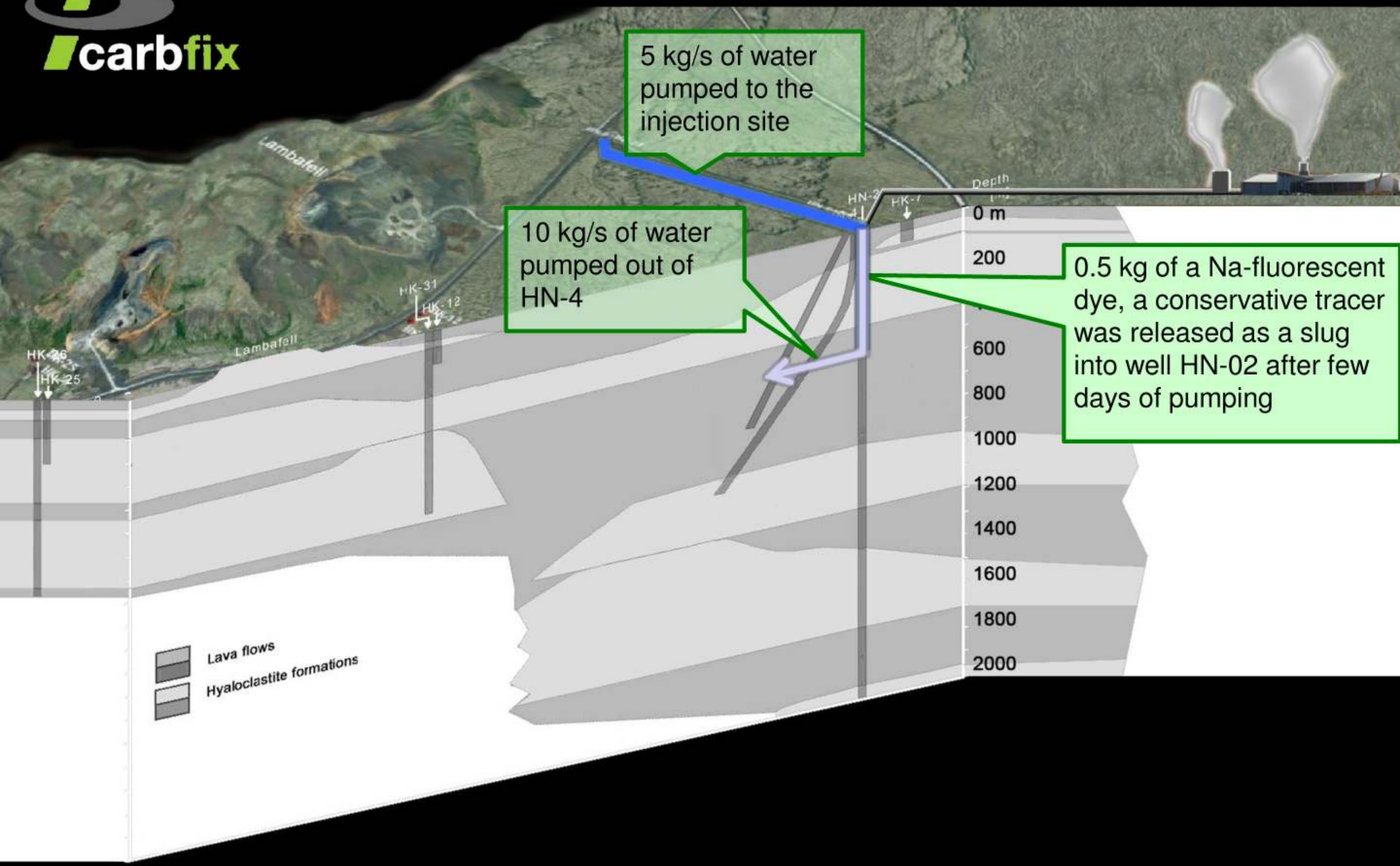
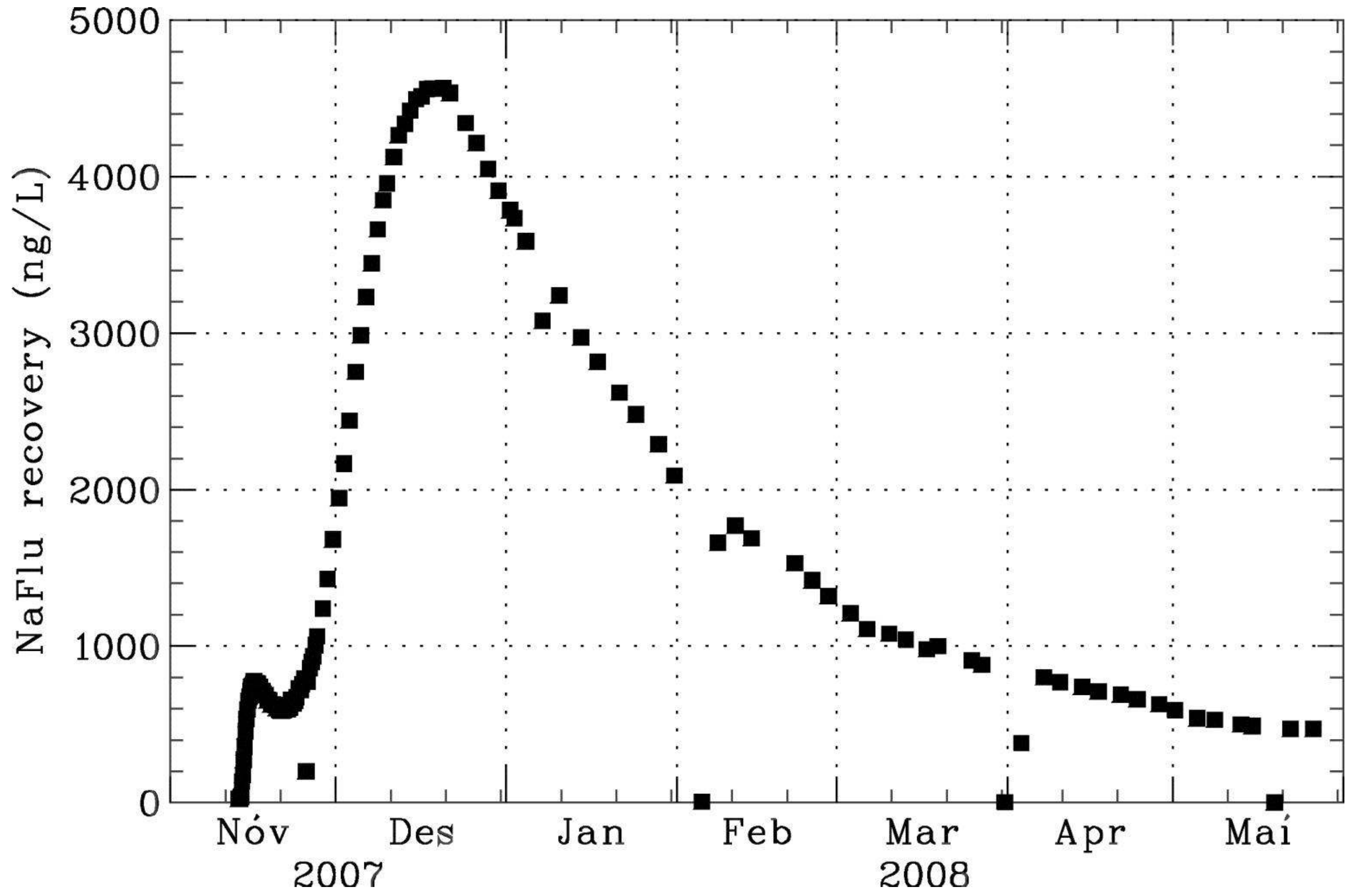
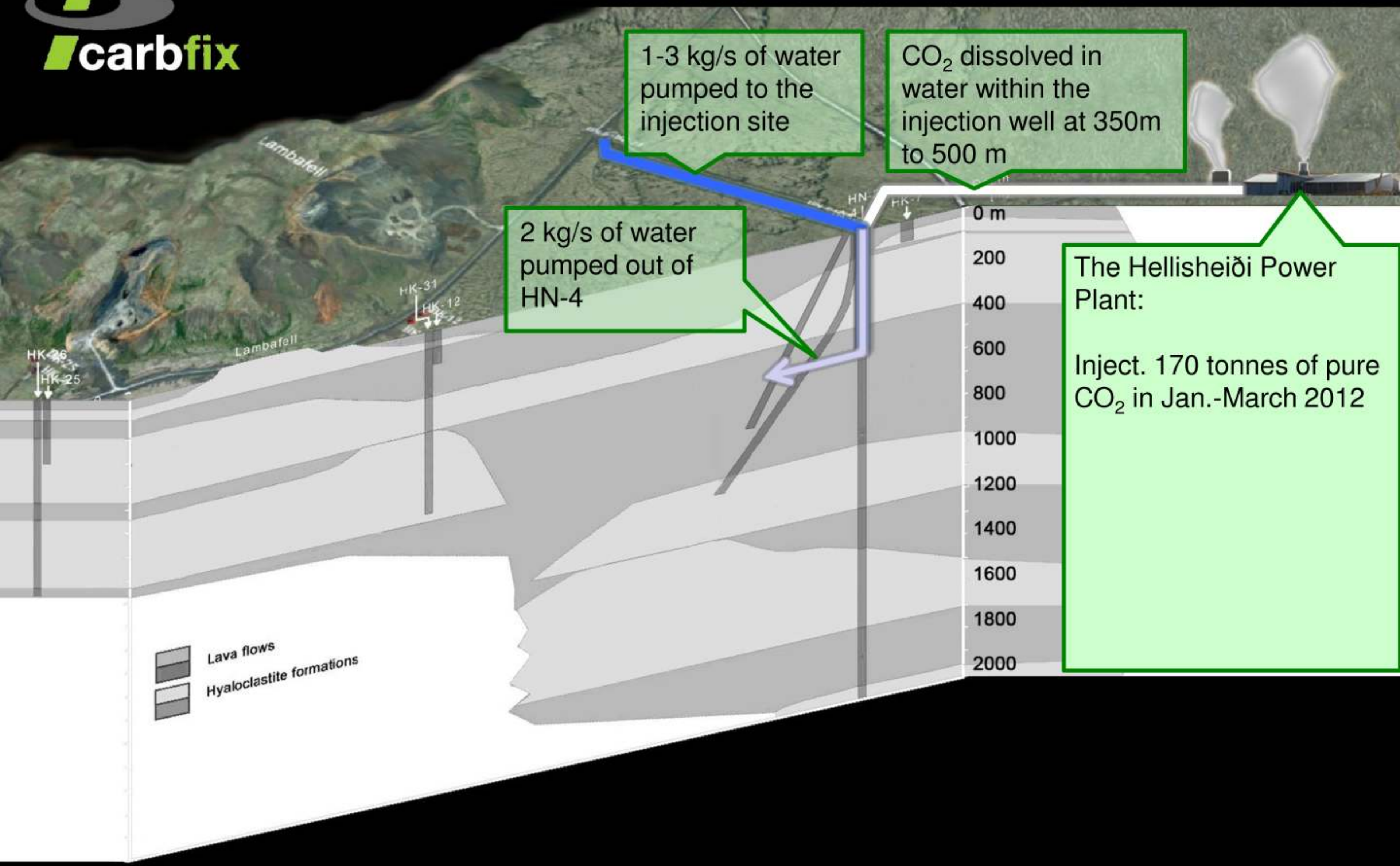
THE CARBFIX STORAGE SITE


5 kg/s of water pumped to the injection site
10 kg/s of water pumped out of HN-4
0.5 kg of a Na-fluorescent dye, a conservative tracer was released as a slug into well HN-02 after few days of pumping
Lambafell
Lambafell
HK-31
HK-12
HK-26
HK-25
HK-7
Depth
0 m
200
600
800
1000
1200
1400
1600
1800
2000
Lava flows
Hyaloclastite formations

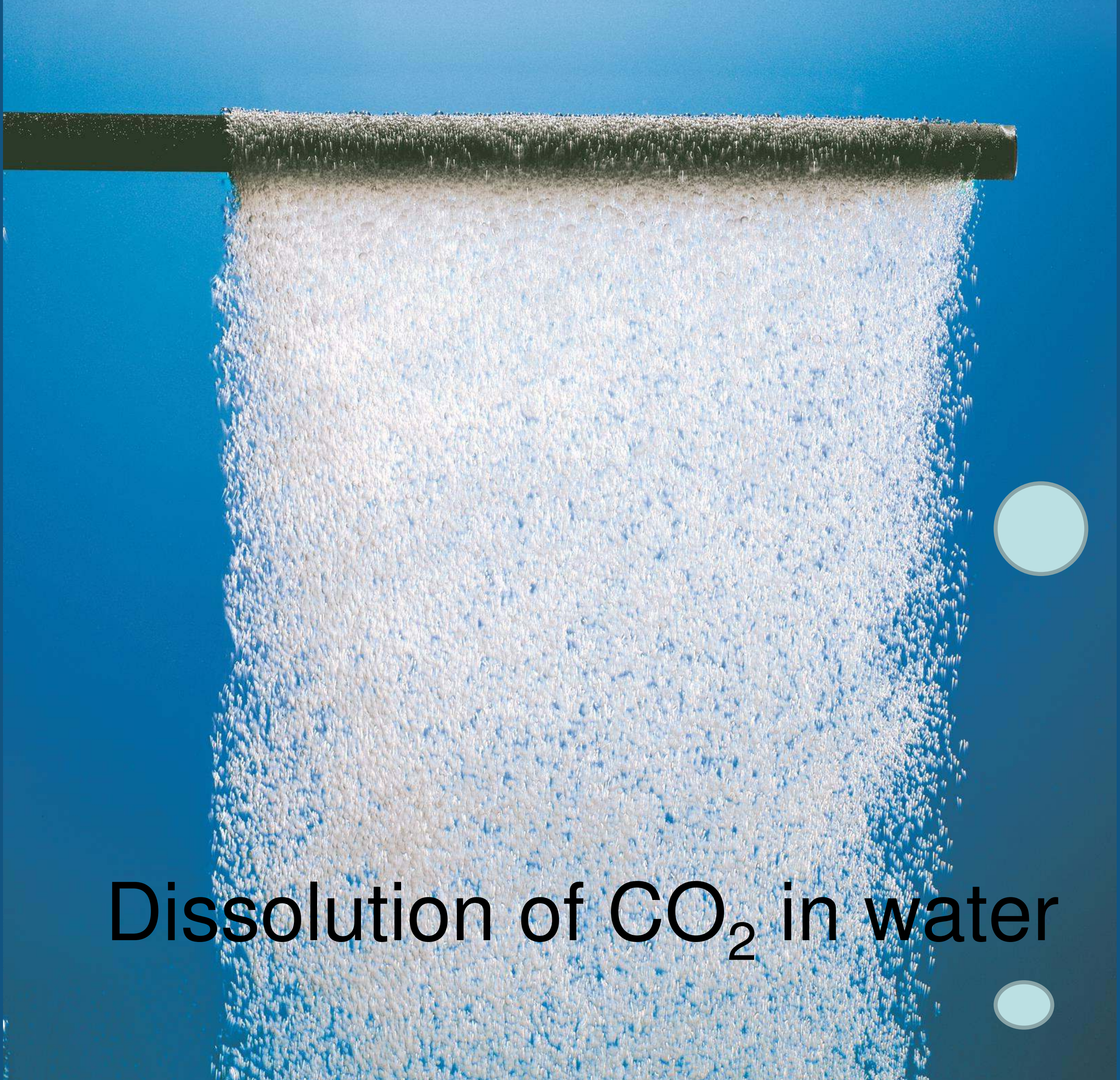

MERCEDES-BENZ
EUR



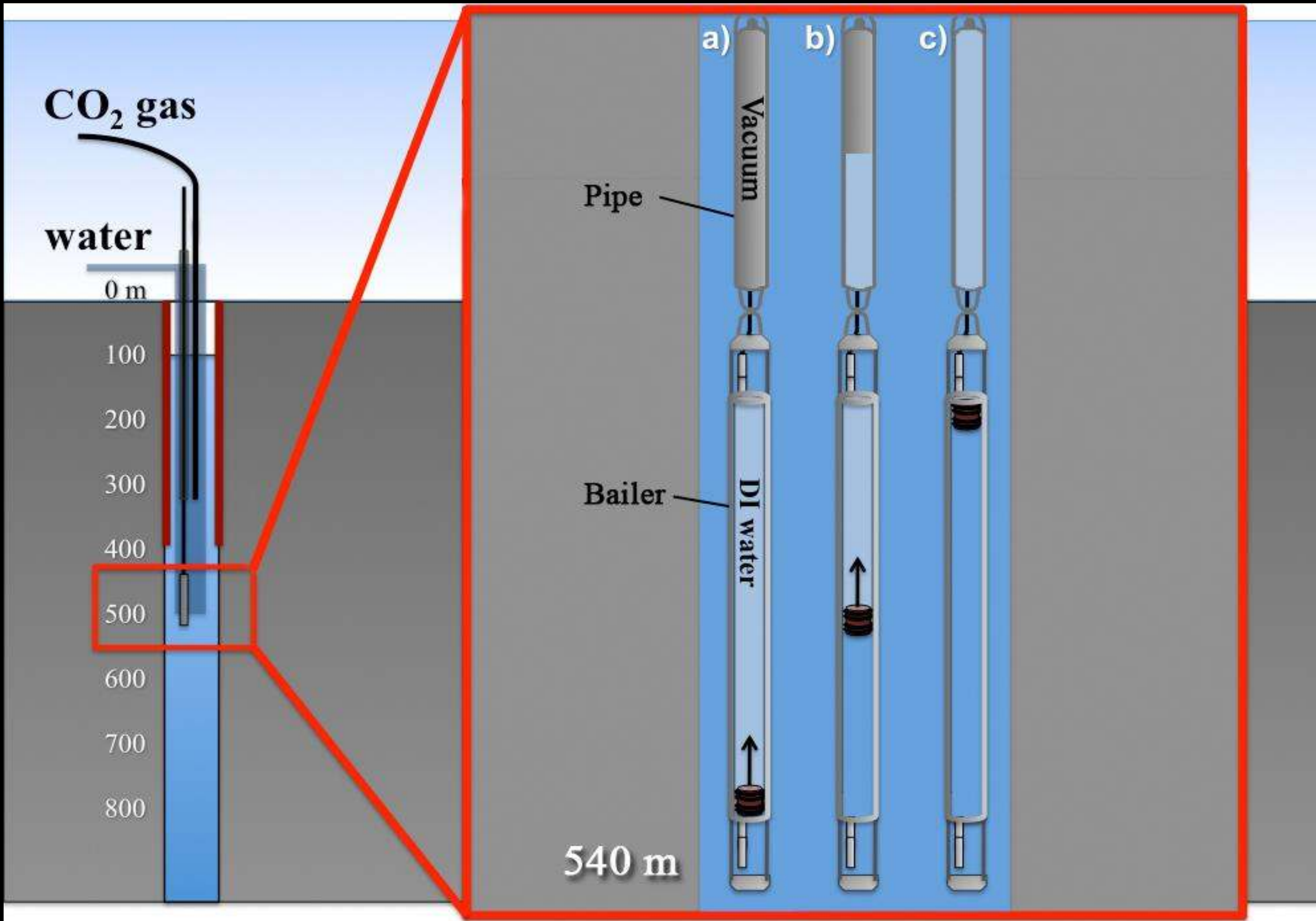
Na-fluorescent dye recovery from well HN-4 during forced-flow mini-test. Close to 60% of tracer recovered. Velocities = 1.7 – 6 m/day.


1-3 kg/s of water pumped to the injection site
CO_2 dissolved in water within the injection well at 350m to 500 m
2 kg/s of water pumped out of HN-4
The Hellisheiði Power Plant:
Inject. 170 tonnes of pure CO_2 in Jan.-March 2012
Lambafell
Lambafell
HK-31
HK-12
HK-26
HK-25
0 m
200
400
600
800
1000
1200
1400
1600
1800
2000
Lava flows
Hyaloclastite formations

Injection well HN-2



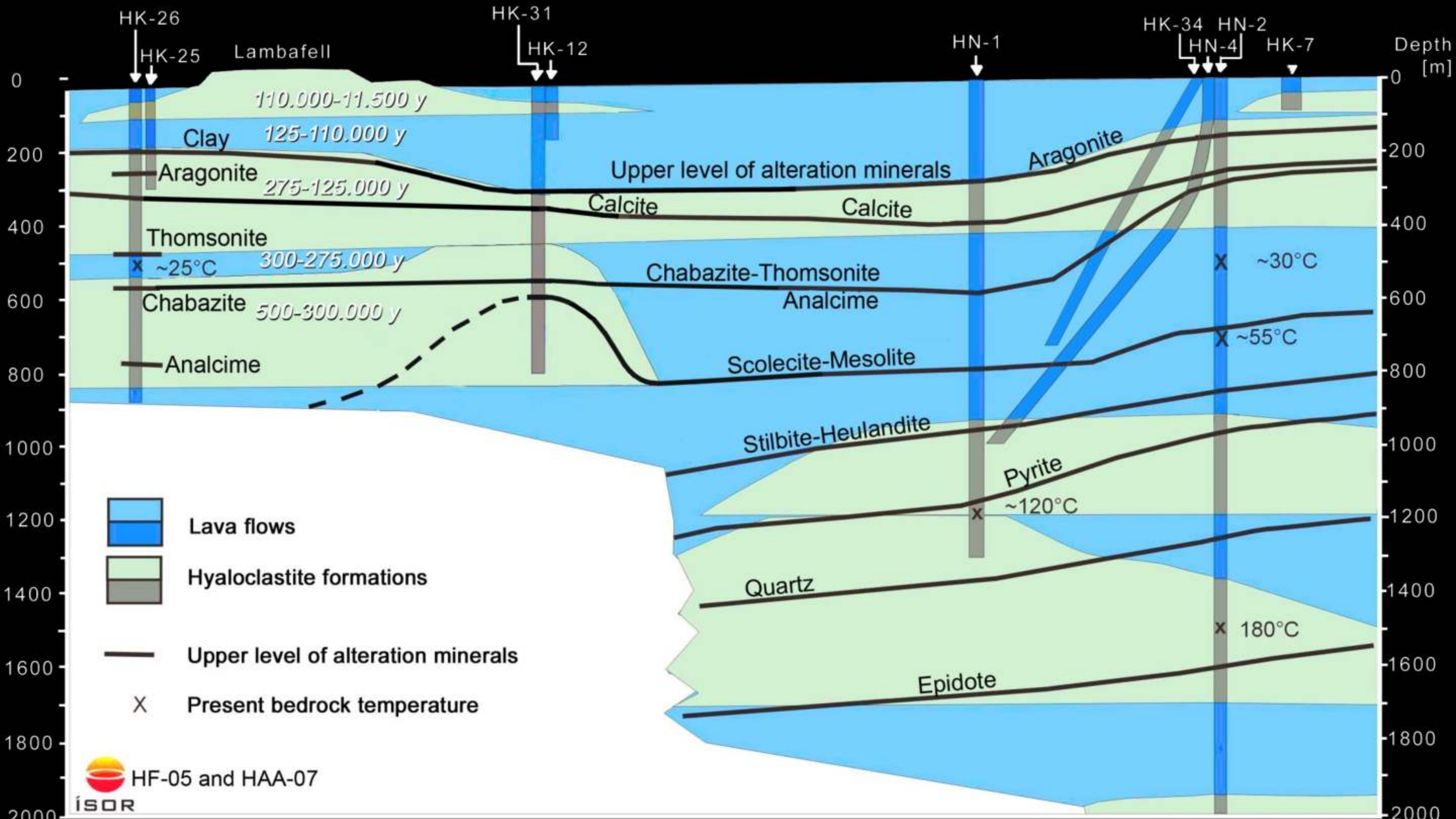
Dissolution of CO_2 in water



Alfredsson et al. EP 2011; Geofluids 2013 subm.

Picture from 482 m within the injection well: Gas dissolved, no bubbles

Mineral storage of CO_2



Alfredsson (2013) IJGGC

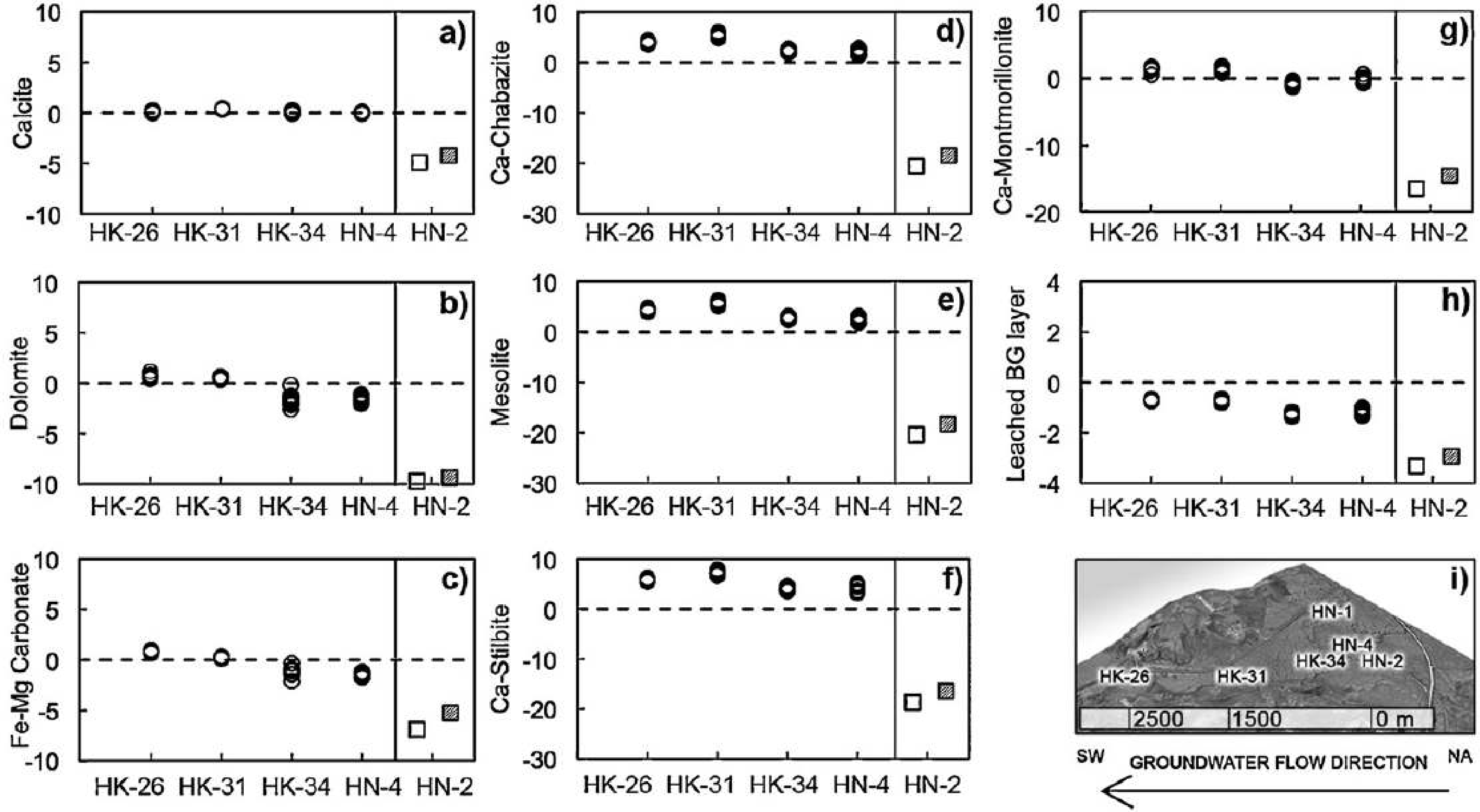
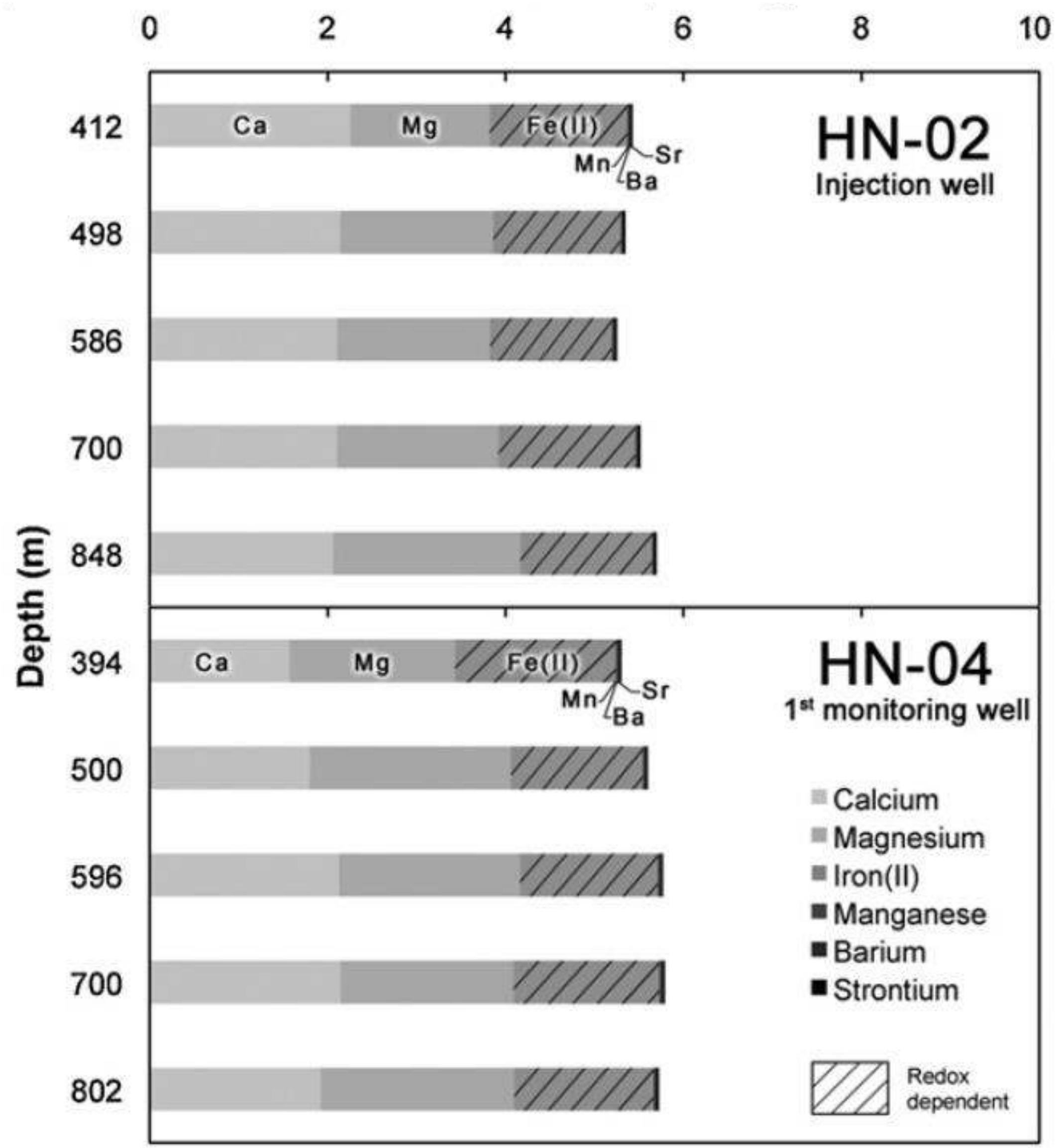


Fig. 12. Spatial distribution of saturation indices in the pre-injection deep groundwaters for several primary and secondary phases (circles) and those predicted in HN-2 during gas equilibration calculations. The white and gray squares correspond to calculations performed using aqueous fluids equilibrated with pure CO_2 and CO_2–H_2S–H_2 gas mixture equilibrated fluid, respectively, at 25 bars of pressure and 25 °C: (a) Calcite, (b) Dolomite, (c) Fe–Mg Carbonate, (d) Ca-Chabazite, (e) Mesolite, (f) Ca-Stilbite, (g) Ca-Montmorillonite, (h) Basaltic glass (leached BG layer). (i) Spatial distribution of the wells and groundwater flow direction shown on this areal photograph.

Alfredsson et al. IJGCC 2013

Divalent cations concentration in mole/kg rock in the target zone



Alfredsson et al. IJGCC 2013

Dissolution and precipitation

Dissolution reactions:

$CO_{2(g)} + H_2O = H_2CO_3$

$H_2CO_3 = HCO_3^- + H^+$

Basaltic Glass + $xH^+ \rightarrow Mg^{2+} + Ca^{2+} + Fe^{2+} + \ldots\ldots$

$\mathbf{Mg_2SiO_4} + 4H^+ \rightarrow 2Mg^{2+} + 2H_2O + SiO_2(aq)$

Forsterite

$\mathbf{MgCaSi_2O_6} + 4H^+ \rightarrow Mg^{2+} + Ca^{2+} + 2H_2O + 2SiO_2(aq)$

Diopside

$\mathbf{CaAl_2Si_2O_8} + 8H^+ \rightarrow Ca^{2+} + 2Al^{3+} + 2SiO_2(aq) + 4H_2O$

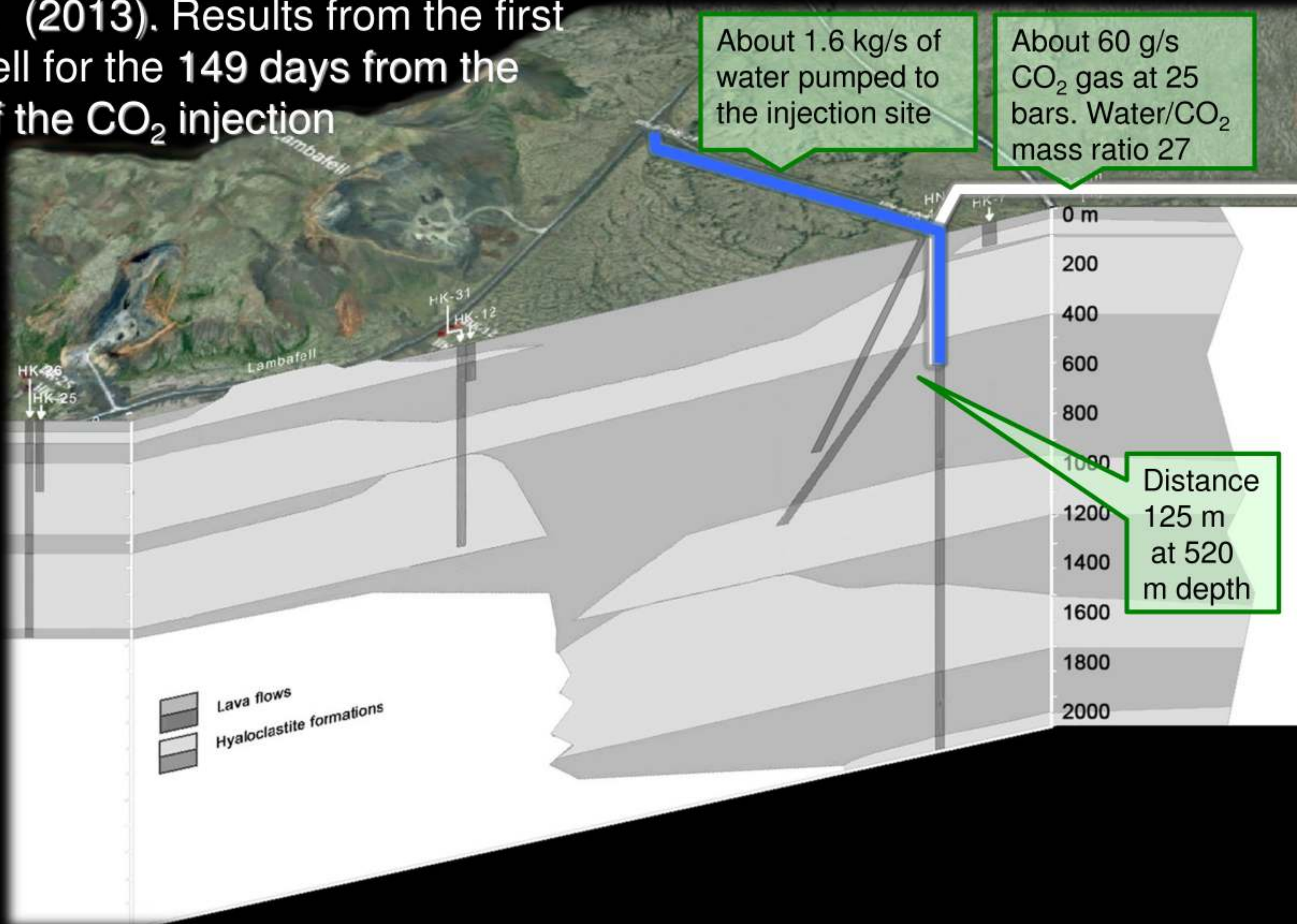
Ca-plagioclase

Precipitation reactions:

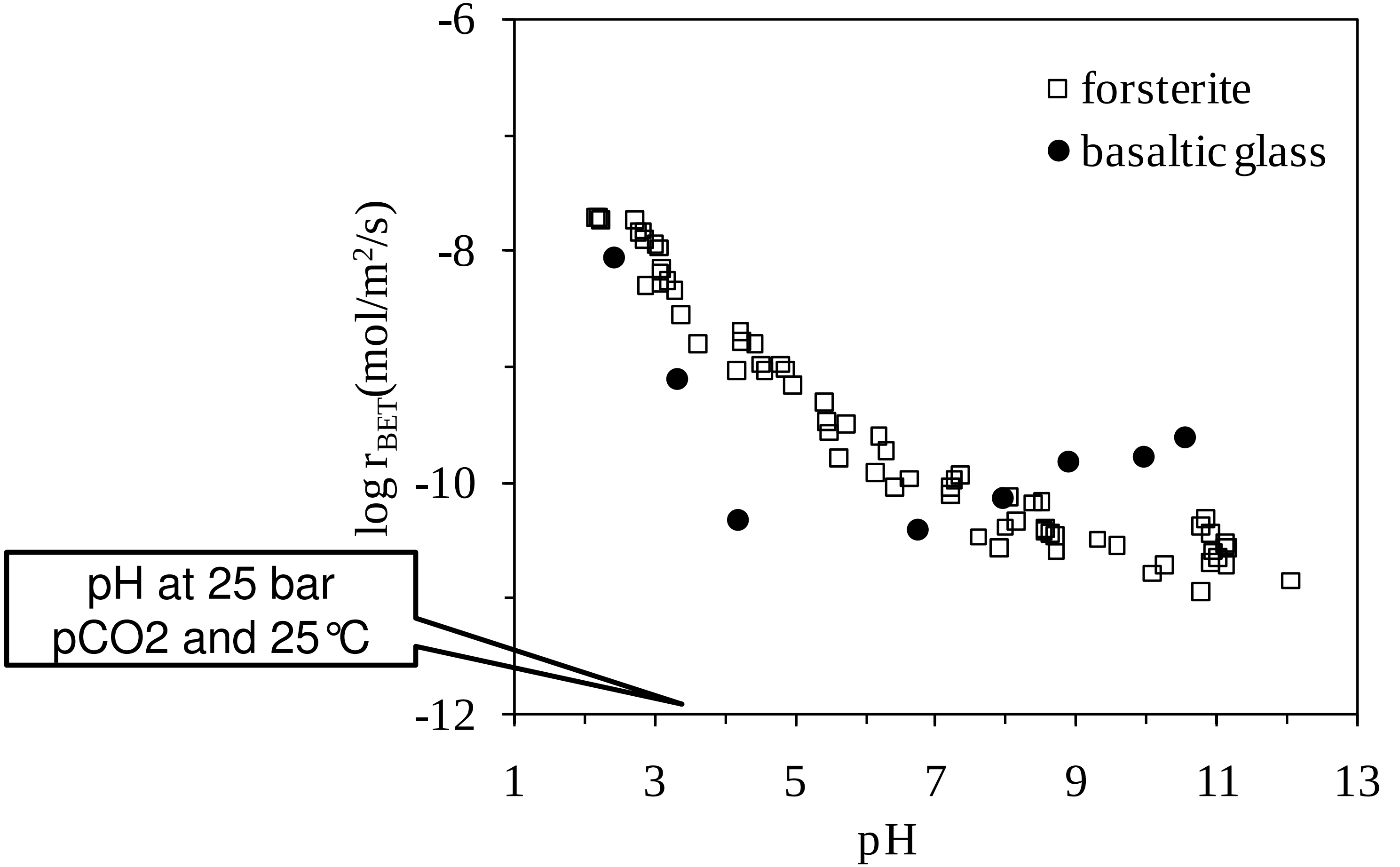
$(Fe,Ca,Mg)^{2+} + CO_2 + H_2O \rightarrow \mathbf{(Fe,Ca,Mg)CO_3} + 2H^+$

siderite, calcite, magnesite, ankerite, ankerite-dolomite…….

Mesfin et al. (2013). Results from the first moitoring well for the 149 days from the beginning of the CO_2 injection

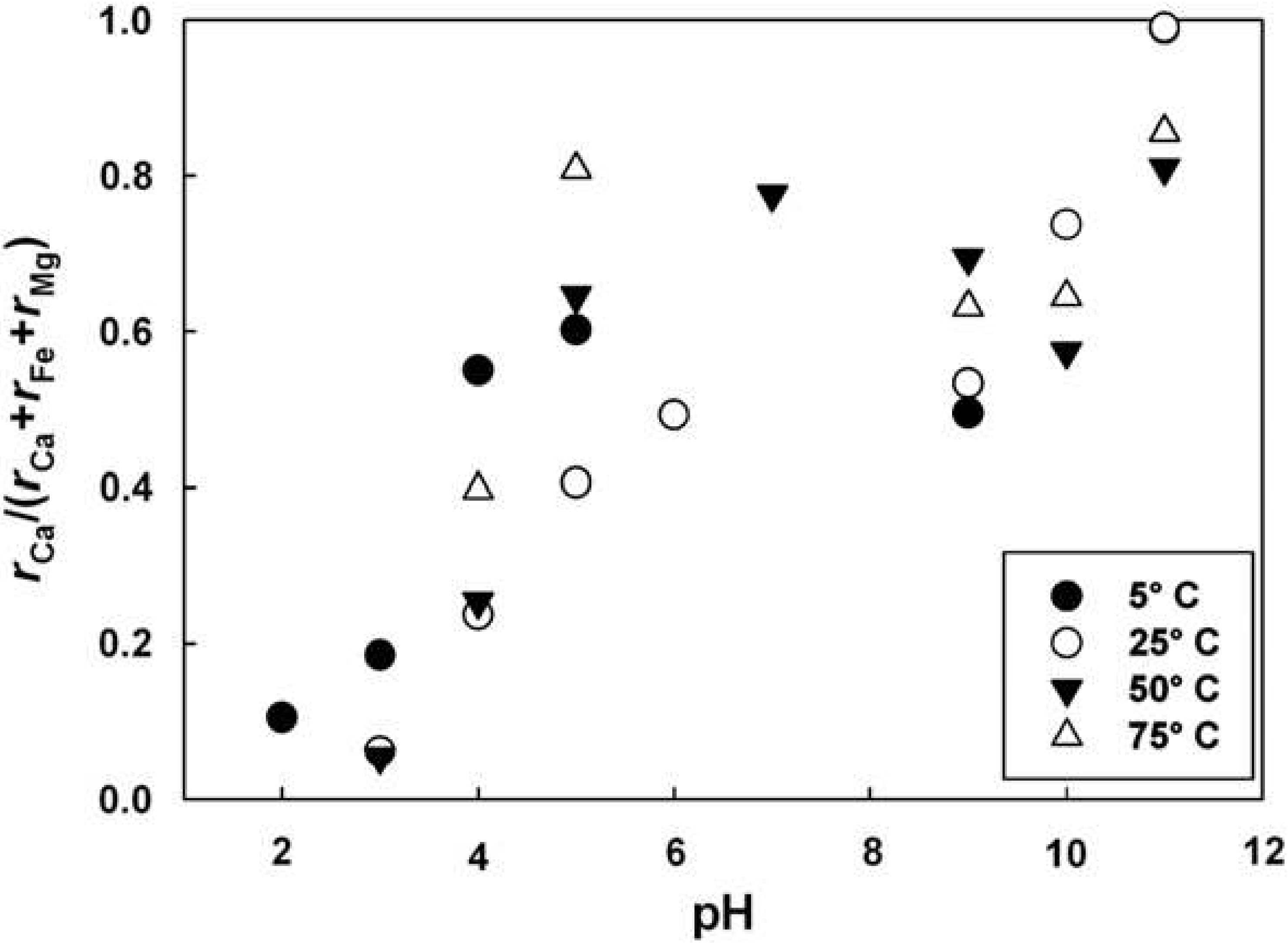


Dissolution rates of the basaltic minerals and glasses are pH dependent. The release of divalent cations will vary with pH



Forsterite at 25℃, Pokrovsky and Schott GCA (2000).
Basaltic glass at 30℃, Gislason and Oelkers GCA (2003).

Ca release rates divided by the sum of the release rates of the major divalent cations from crystalline basalt versus pH at the indicated temperatures.



Gudbrandsson et al. 2011 GCA

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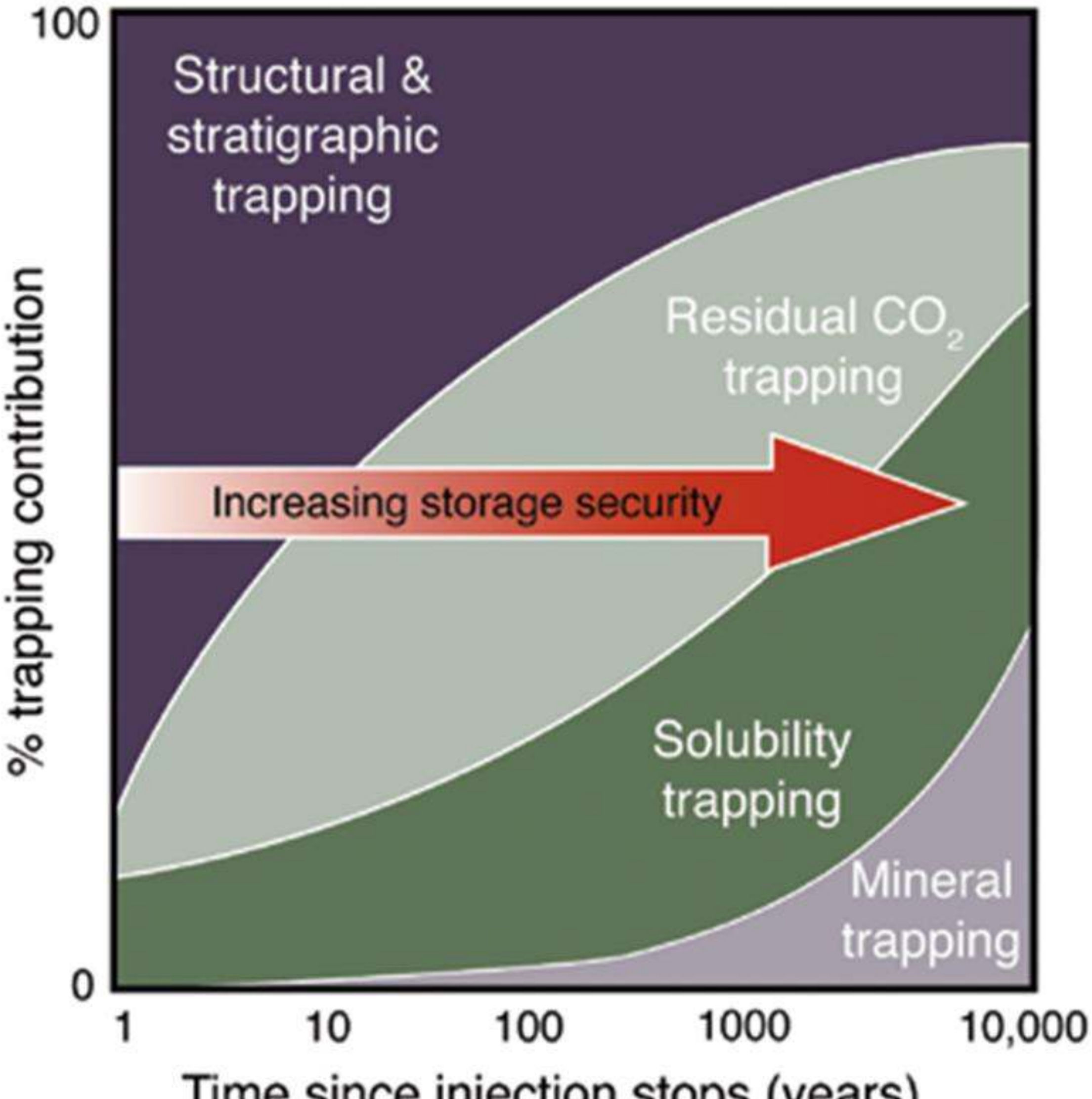

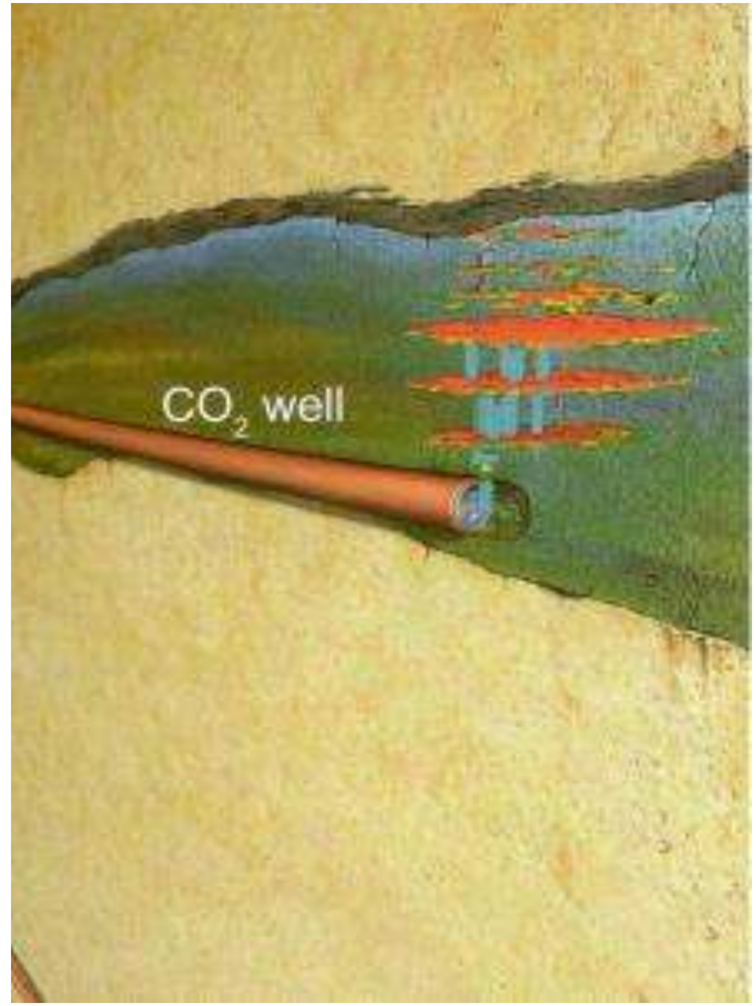

(IPCC 2005, Torp and Gale 2003)

NORDICCS
The CO_2 storage capacity of Iceland

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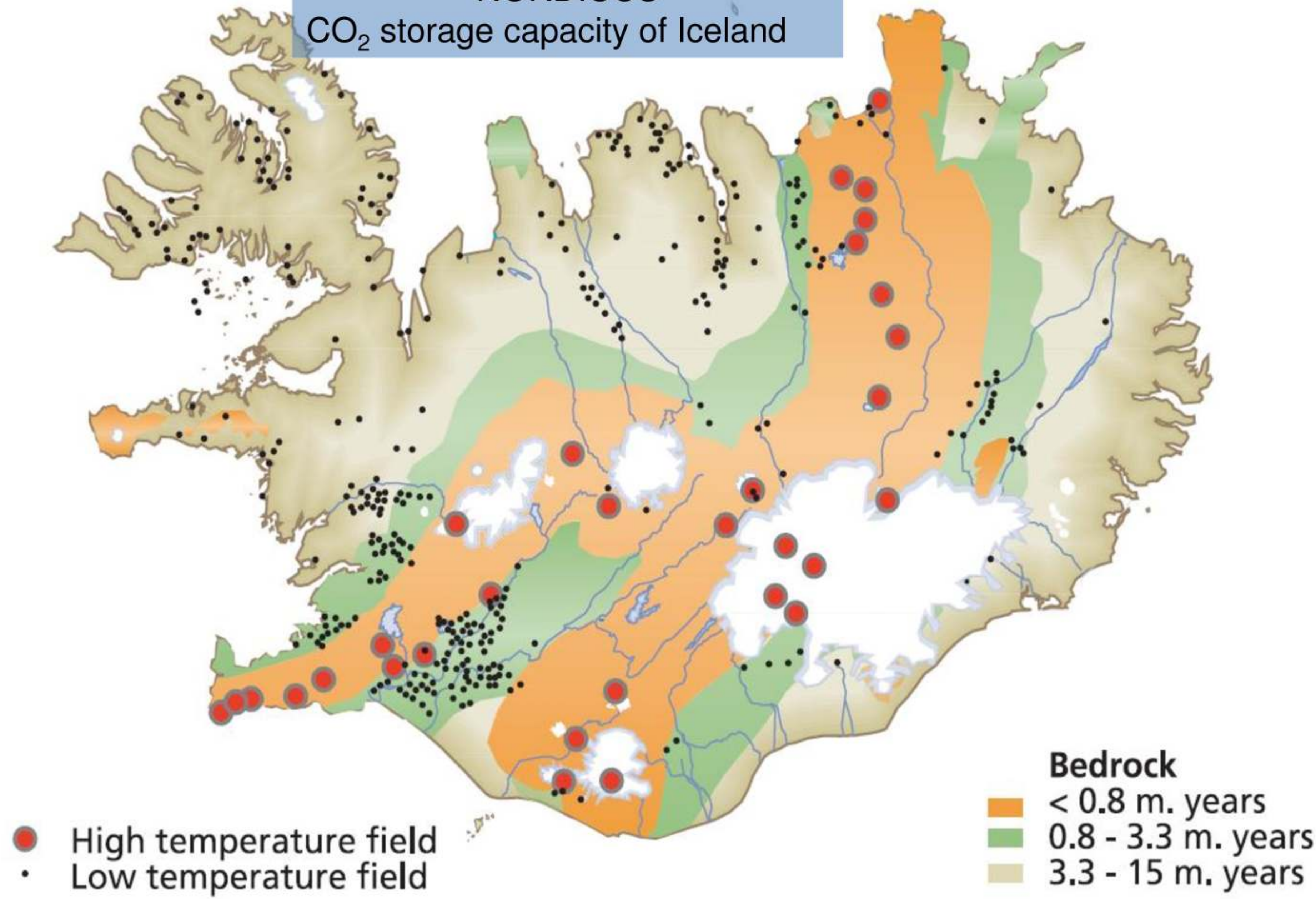
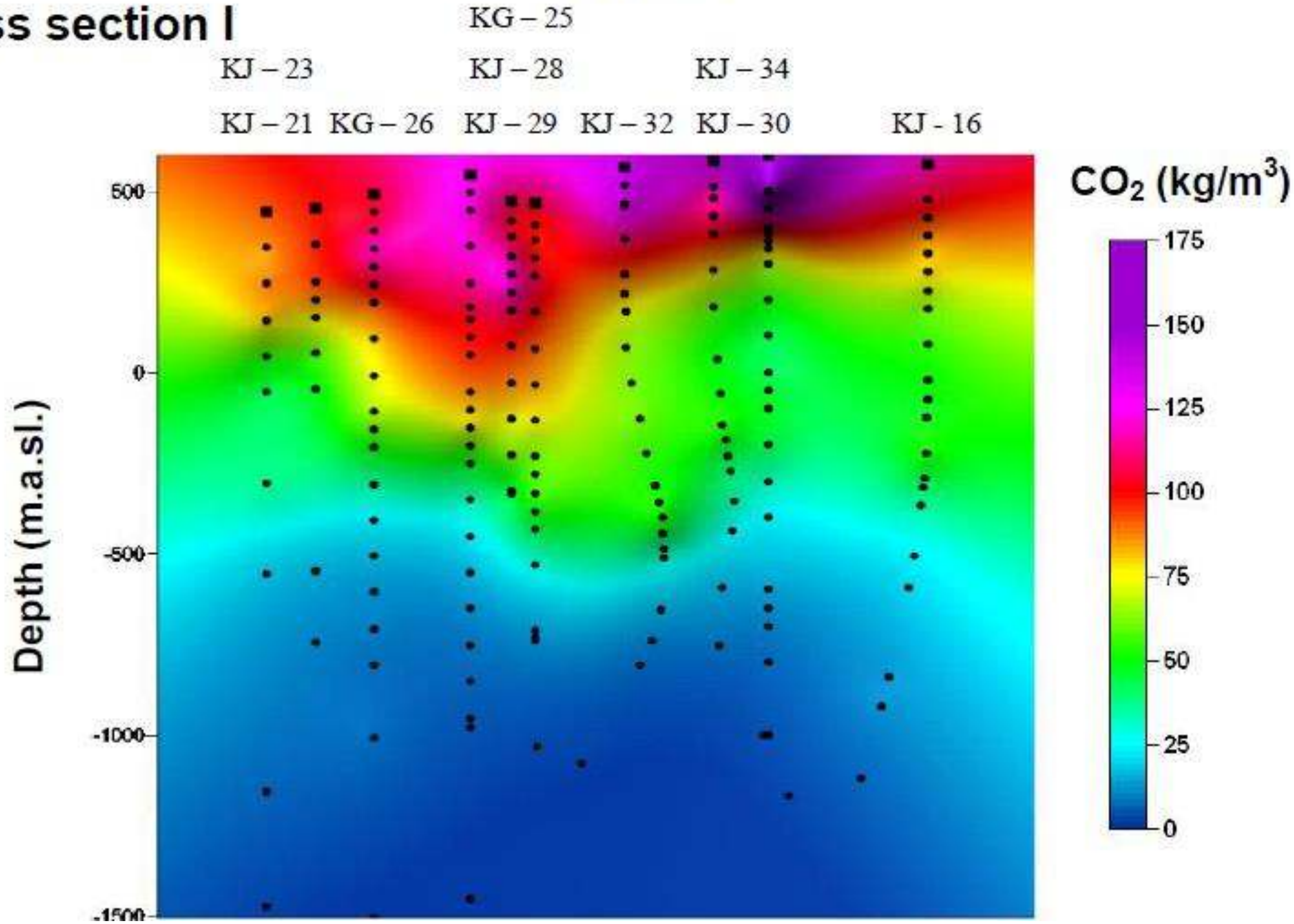
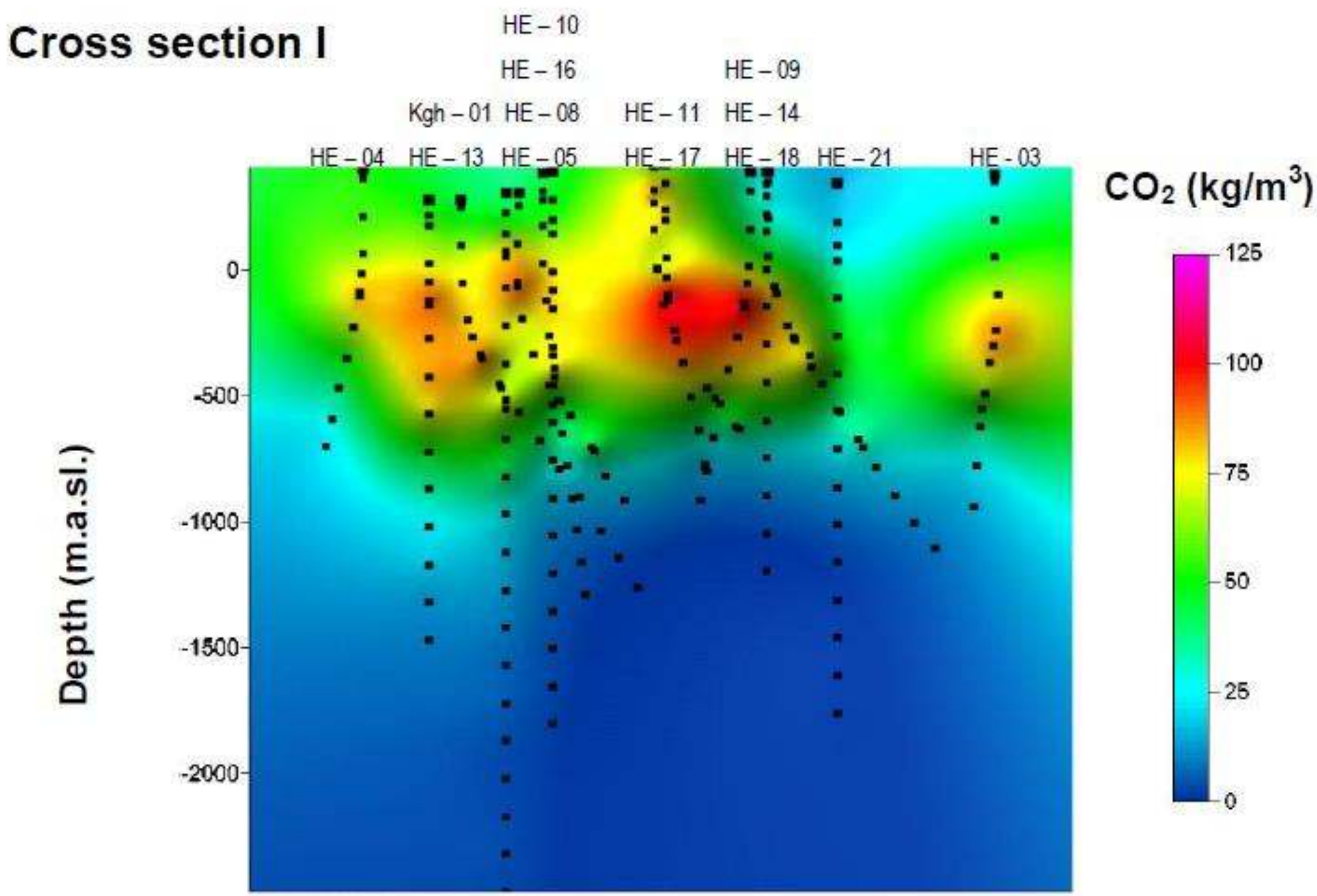


Krafla

Cross section I



Hellisheidi



About 100 kg CO_2/m^3, is stored over 500 m depth interval in the high-temperature geothermal systems in Iceland (Wise et al. 2008). The systems are located within the rift zone of Iceland where the rocks are young and still porous and normal faults are common. If this number is extended over about 1% of Iceland, 1000 km^2, about 50 Gt CO_2 (13.6 CtC) could be stored in carbonates at 500-1000 m depth within the rift zone of Iceland.

Ocean ridges are mostly made of reactive basalt (MORB) and about 10% of the continents are covered with basalt.

At the ocean ridges there is unlimited water source that can be used for solubility trapping during injection