CO2 storage risk and liability for CCS

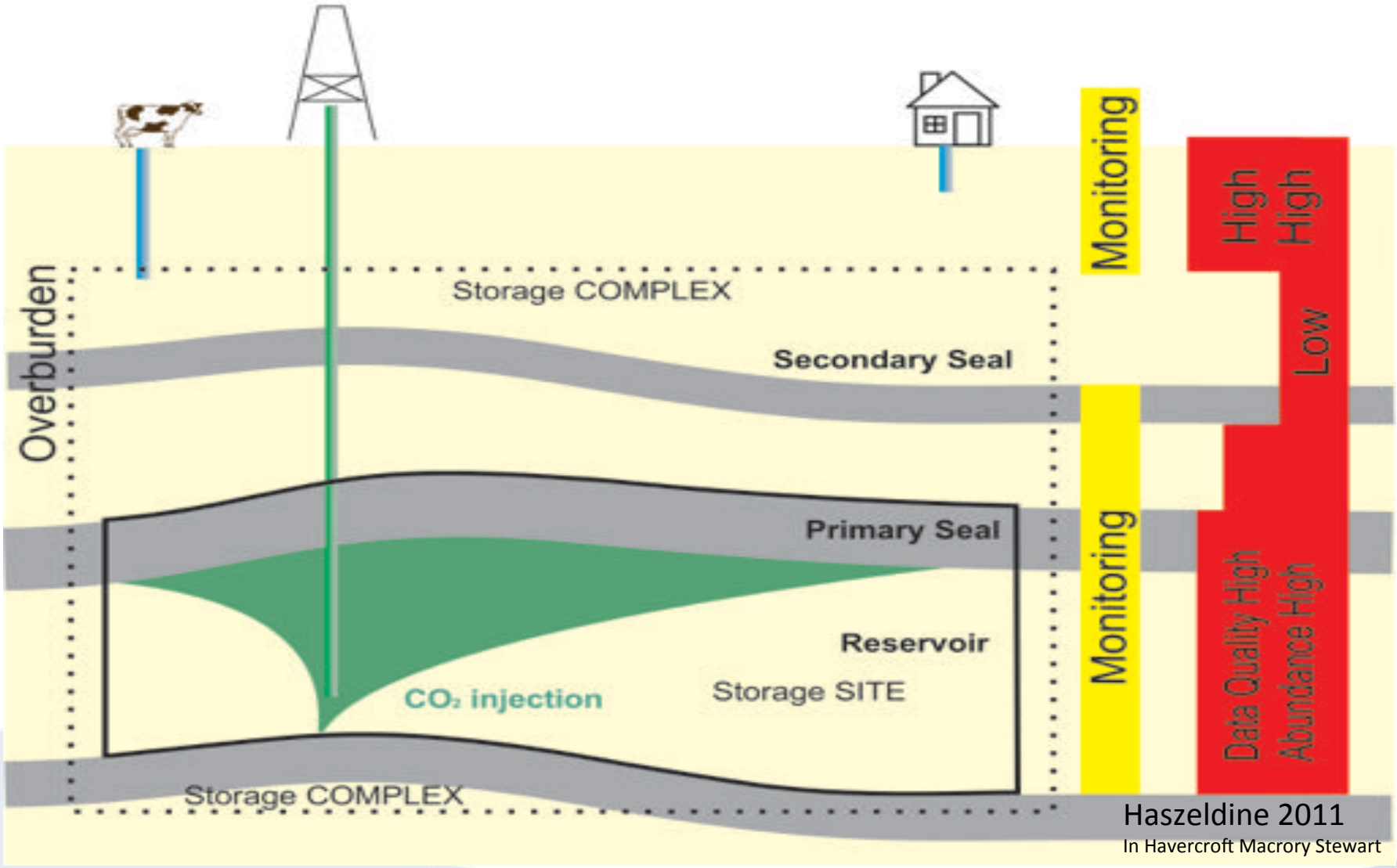
Professor Stuart Haszeldine
SCCS Director, and UKCCSRC storage
University of Edinburgh

Paris 20 April 2015

Scottish Carbon Capture & Storage

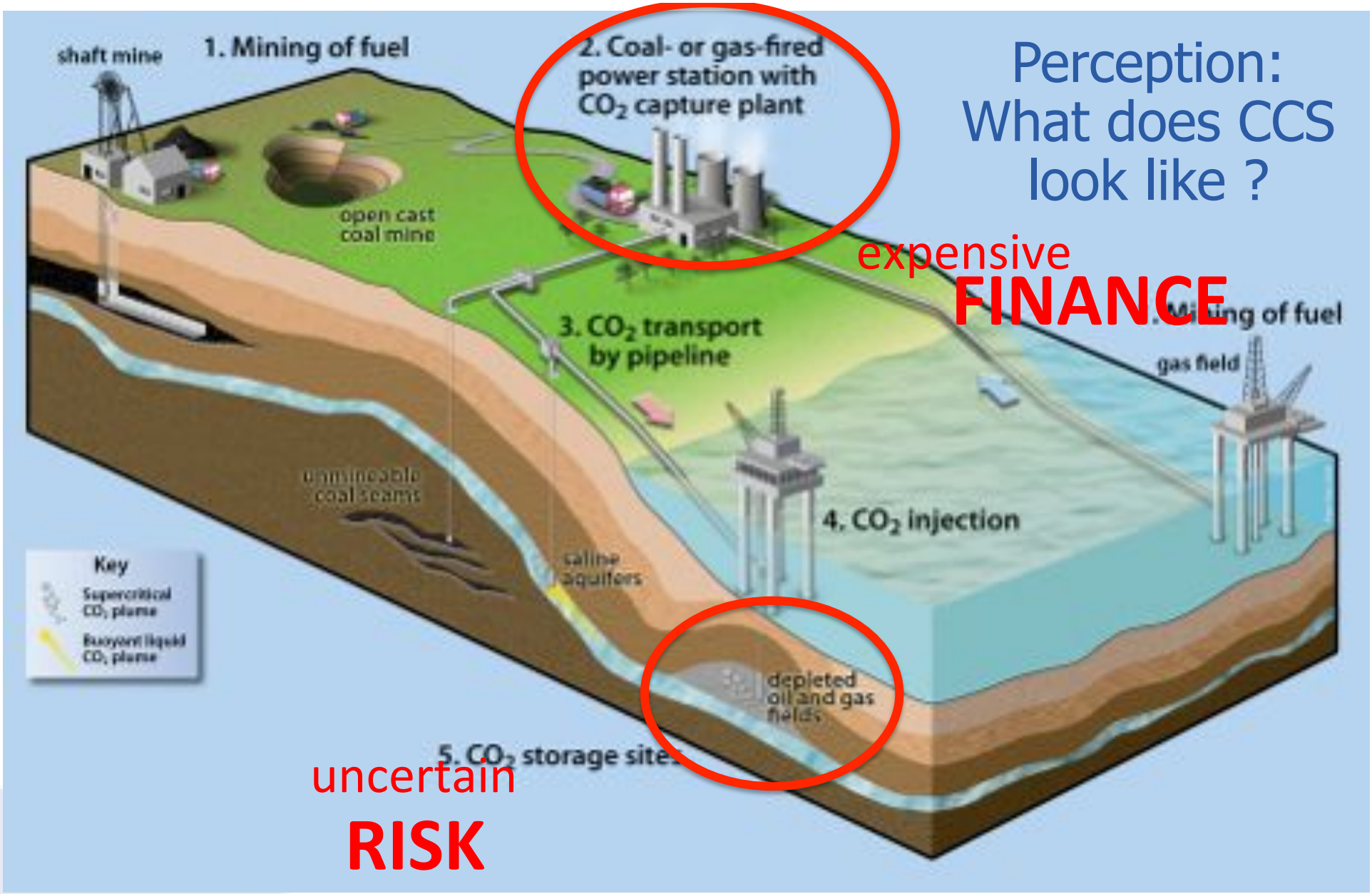
Murchison House, West Mains Road, Edinburgh EH9 3LA
Telephone +44 (0)131 650 0270 www.sccs.org.uk

Perception, and conceptual images



Haszeldine 2011
In Havercroft Macrory Stewart

Perception: What does CCS look like ?



expensive

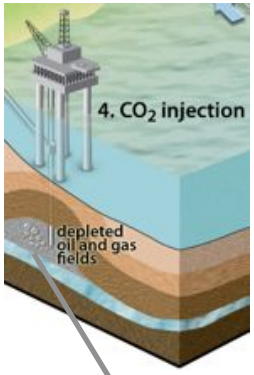
FINANCE

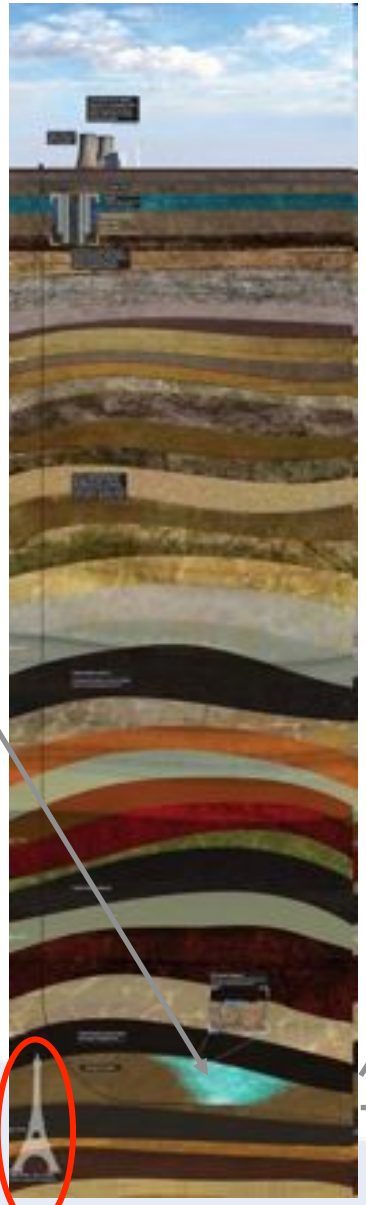
uncertain

RISK

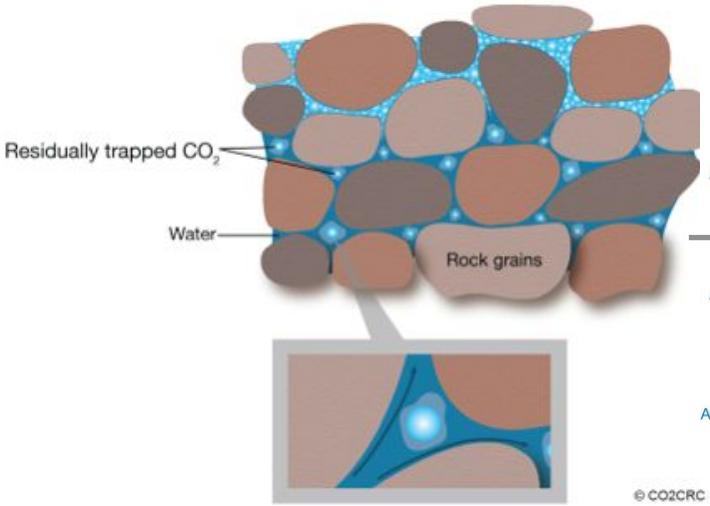
Cartoon suitable for illustrating the pathways and process. But false proximity = **RISK**

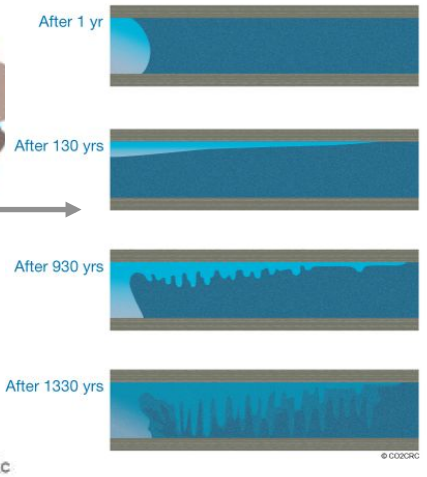
True scale representation: Geological CO2 storage

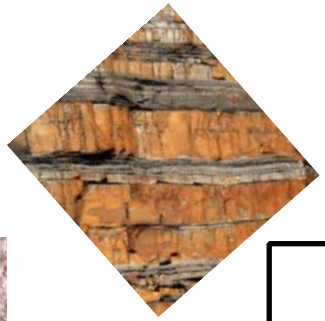


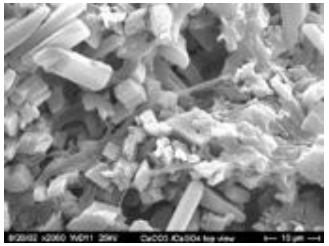


2.5 km depth







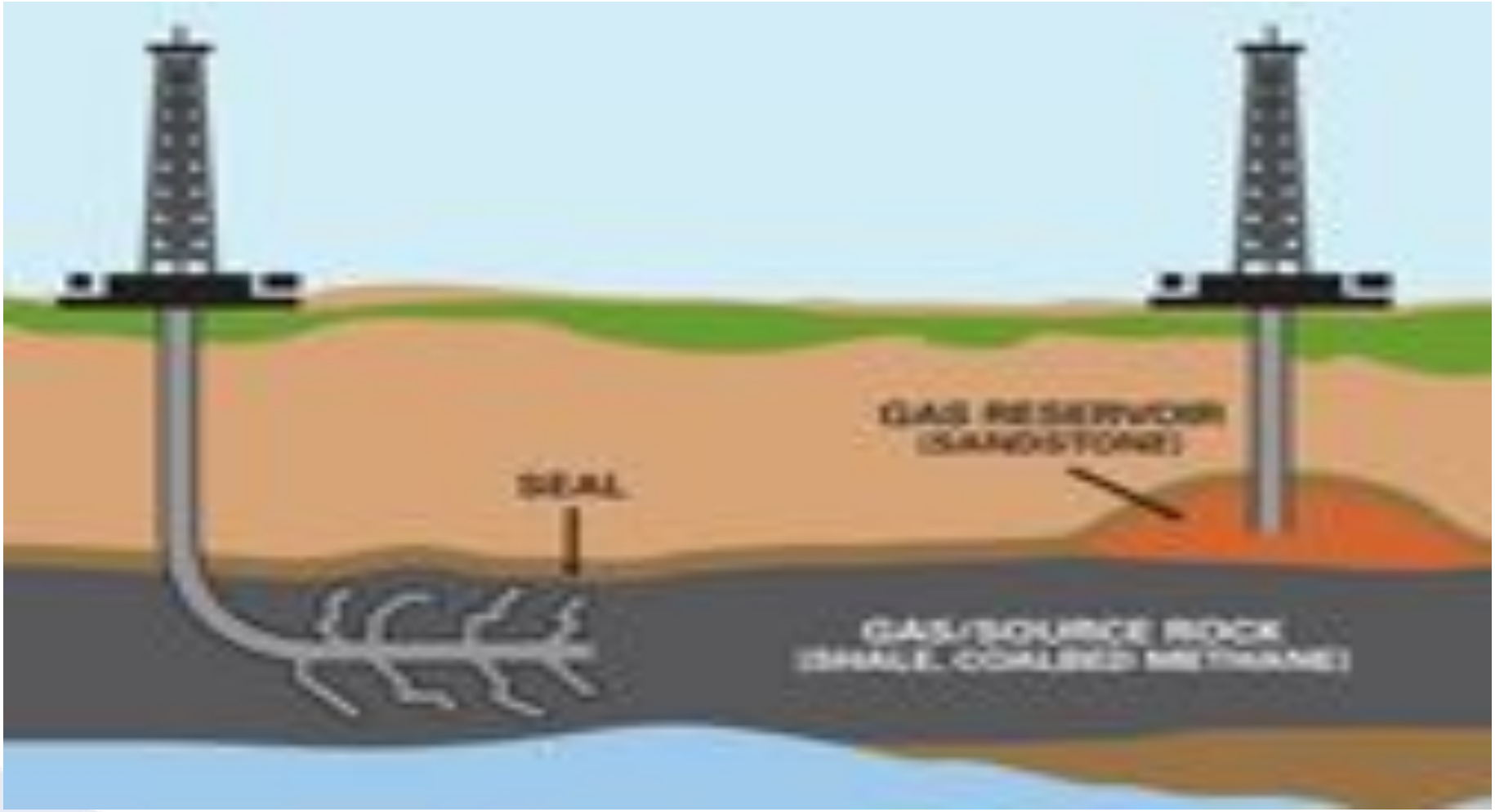


A LONG way down

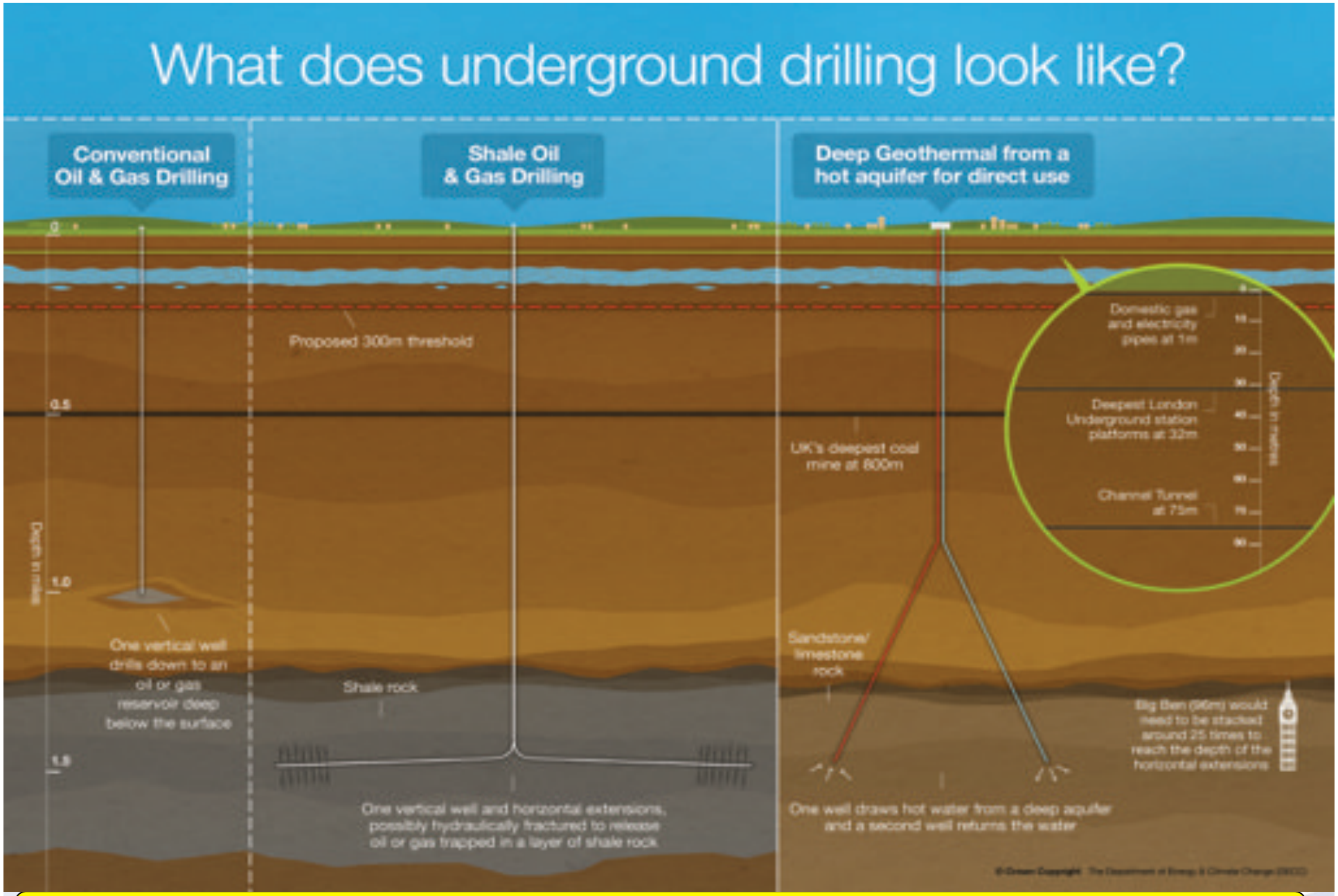
Eiffel Tower: 324m

CO2 storage is geologically (millions of years) secure

Fracking perception



Cartoon suitable for illustrating the pathways and process. But false proximity = **RISK**



Government cartoon trying to illustrate **scale = LOW RISK** but clock tower too large ….

Actual data

CCS :

Greatest risk – through boreholes
Operational 1996
Fewer than 20 boreholes pure CCS
One leak In (Salah) – theft of valves

CO2-EOR
Operational 1972
Many thousand boreholes
No reported leaks (?)

CO2 production
Since 1930's
No regulation
Blowouts – Sheep Mountain, Hungary
All closed down simply
Deaths / km pipe 0.3 x hydrocarbon

FRACKING (high volume) :

Greatest risk – through boreholes
Operational 1992
More than 10,000 boreholes USA
100 – 1,000 leaking B/H

Health effects possible
Few enough to need statistical analysis
Huge amplification in media

Poor trust in motives
Poor trust in operational ability
Agreement (USA) by personal payment
Agreement (EU) not achieved

Perception of risk not rooted in numbers, facts make little impact

Shell Peterhead – Goldeneye public engaged

Peterhead :

Extensive dialogue locally
Politicians
Regulators
Interest groups on/off shore
Other businesses
Public(s)
Schools

Slow build of confidence
Listening not just talking

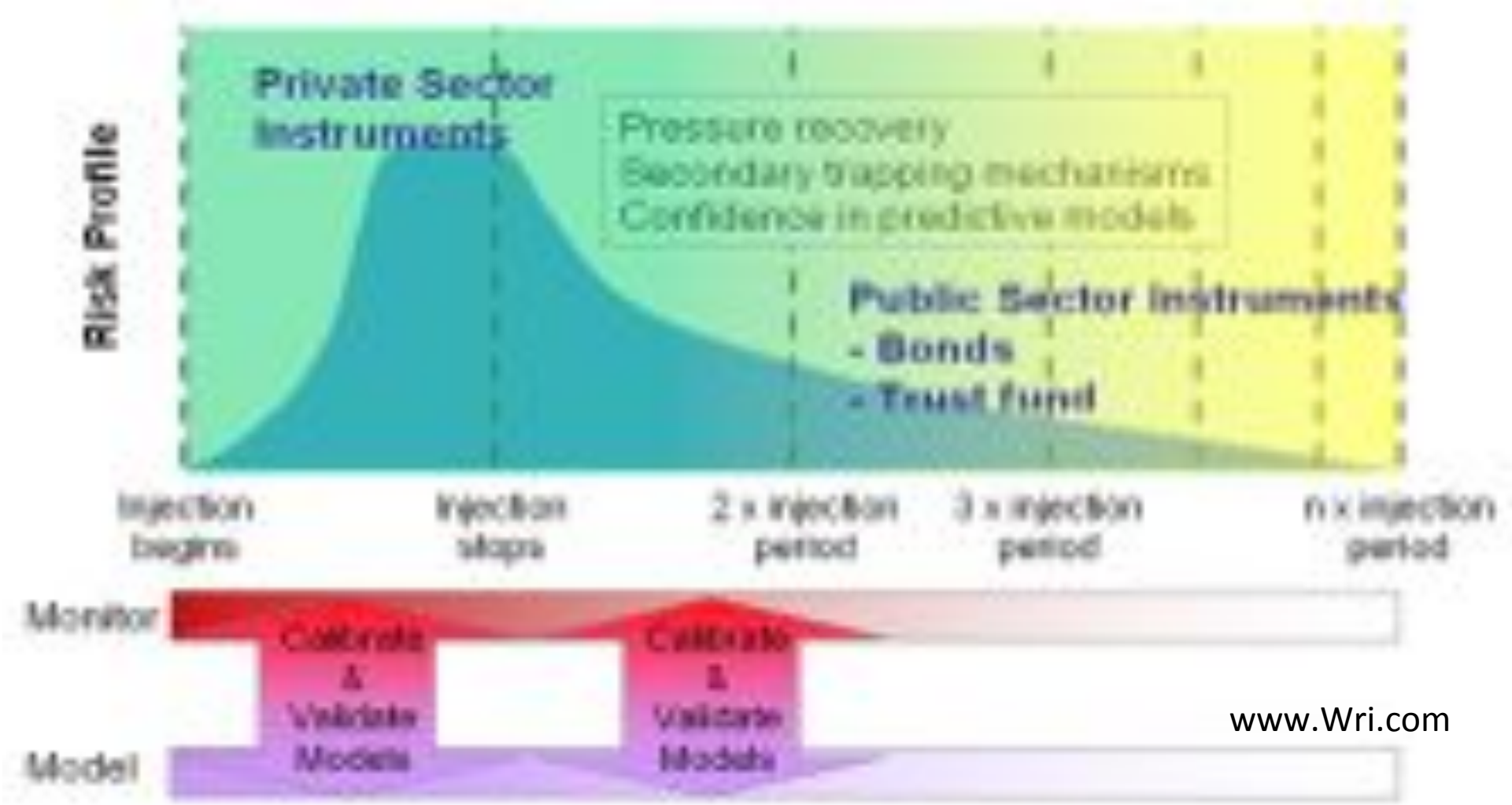
Jobs, jobs, jobs is local +ve
Supply chain & procurement
Confidence in honest operation
Innovation, global quality
Ability to manage the unexpected

A realistic image scale, which enables publics to understand the size, and teases to discover more

By national advertisement, both developer and Government become committed

How to work CCS injection

Example of risk profile



Most risk early during operations = oil & gas; State takeover > 3x injection
problem is to fund, determine and guarantee payment 1x - 3x injection

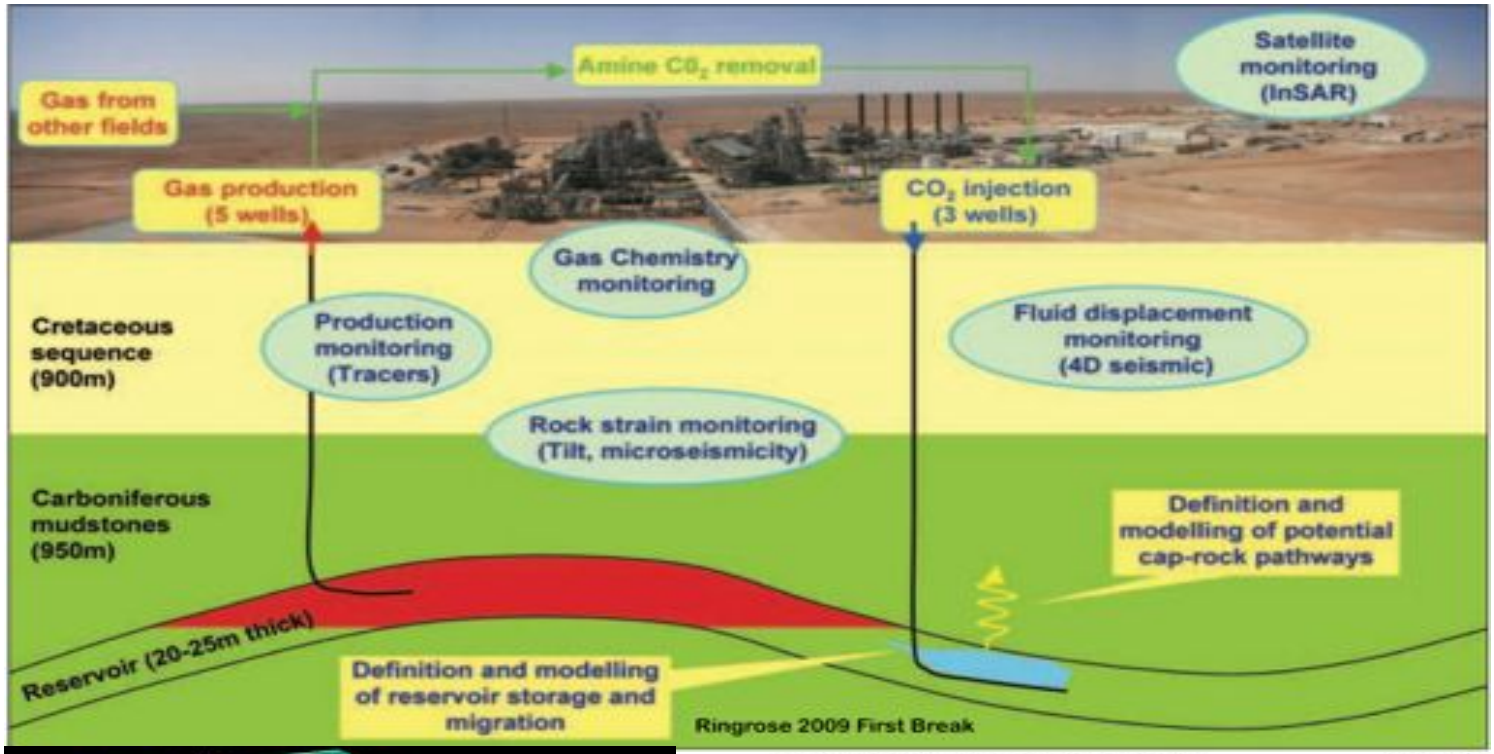
Perception

A secure and safe design With many observation sensors

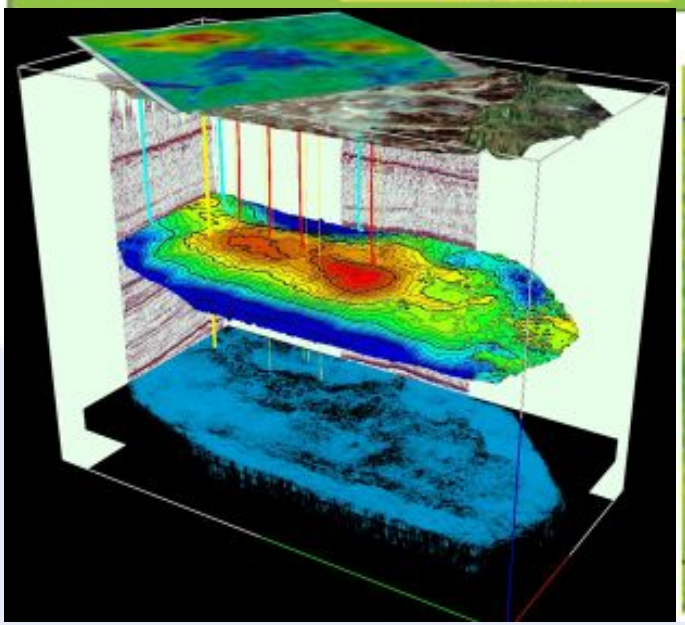
Needs skilled people and systems to operate

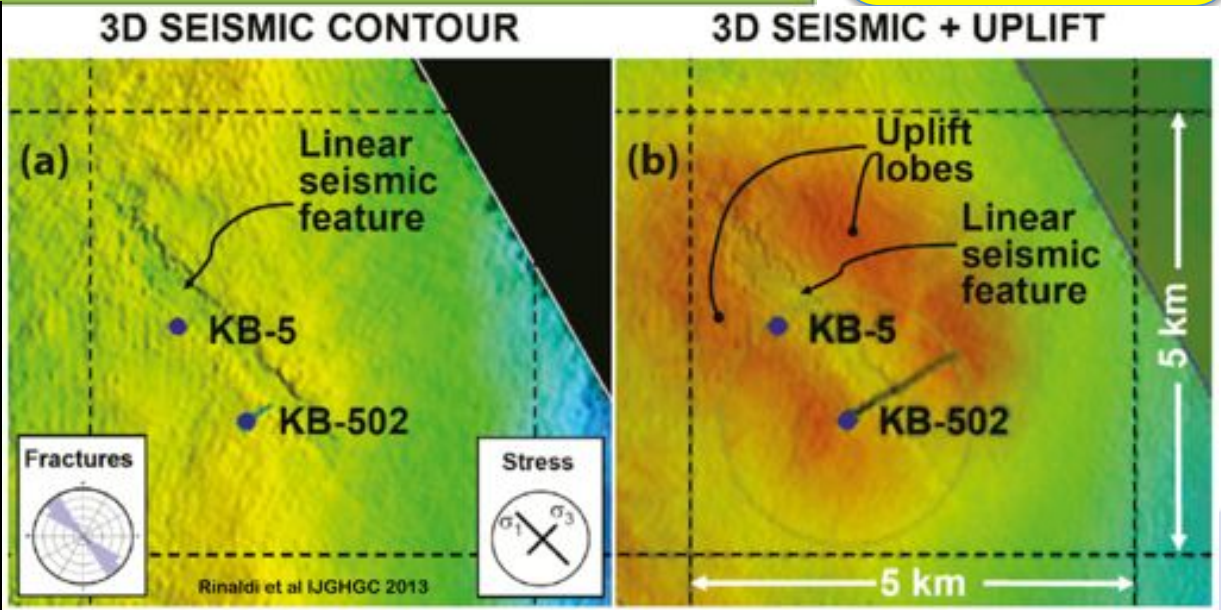
And accidents still occur

Induced fractures : In Salah Algeria

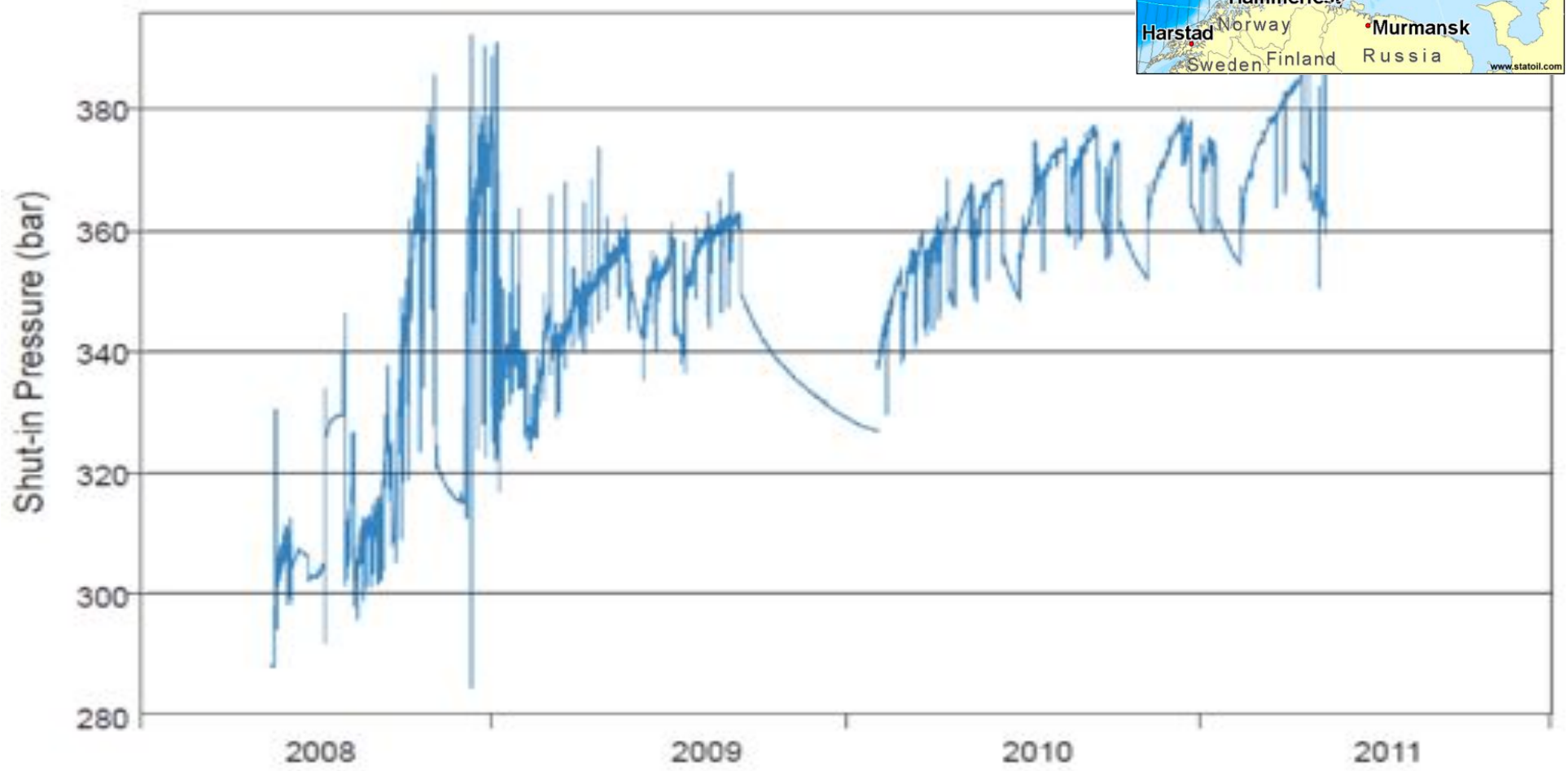


InSar & seismic detected anomaly Closed down





Snohvit
observation of pressure buildup

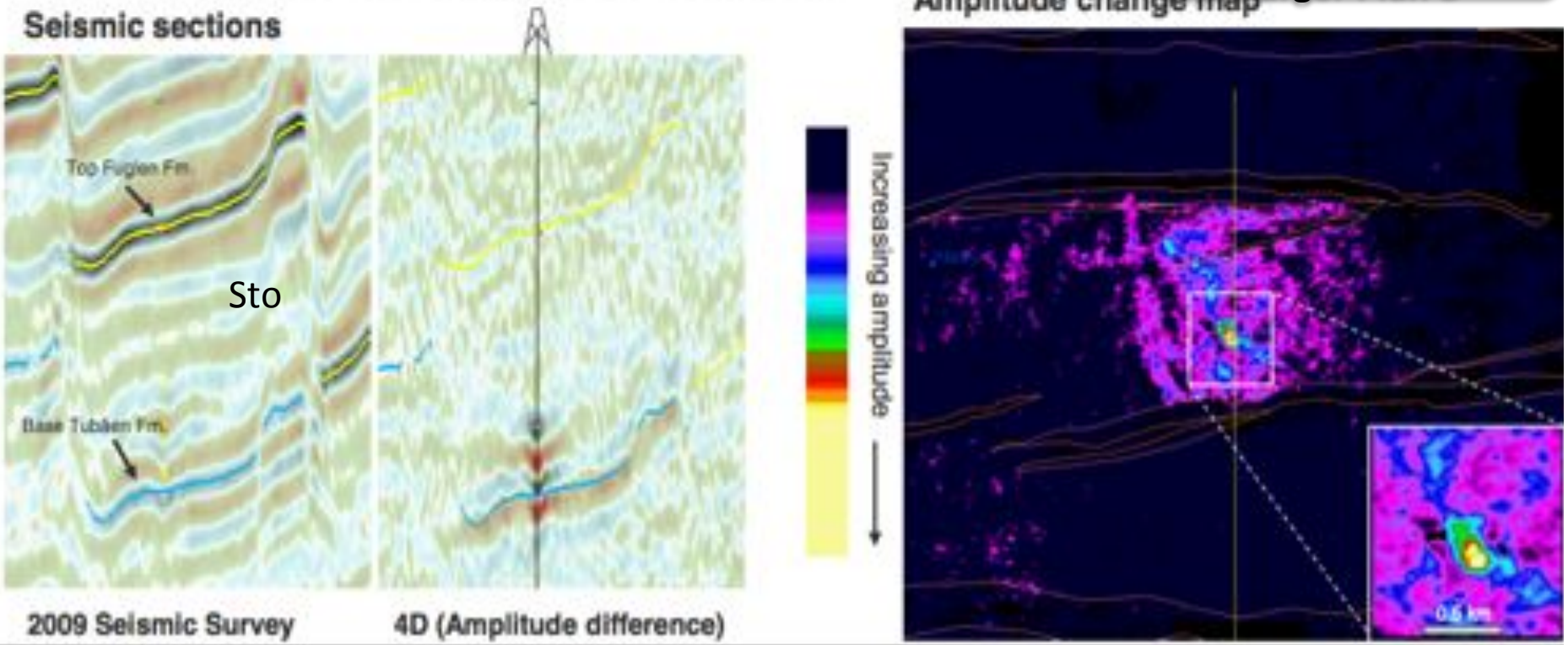


CO2 injection into channel sands below gas reservoir → range of possibility predicted
Pressure rising after 3 months. Borehole treatment. Still rising to limit at 36 months.

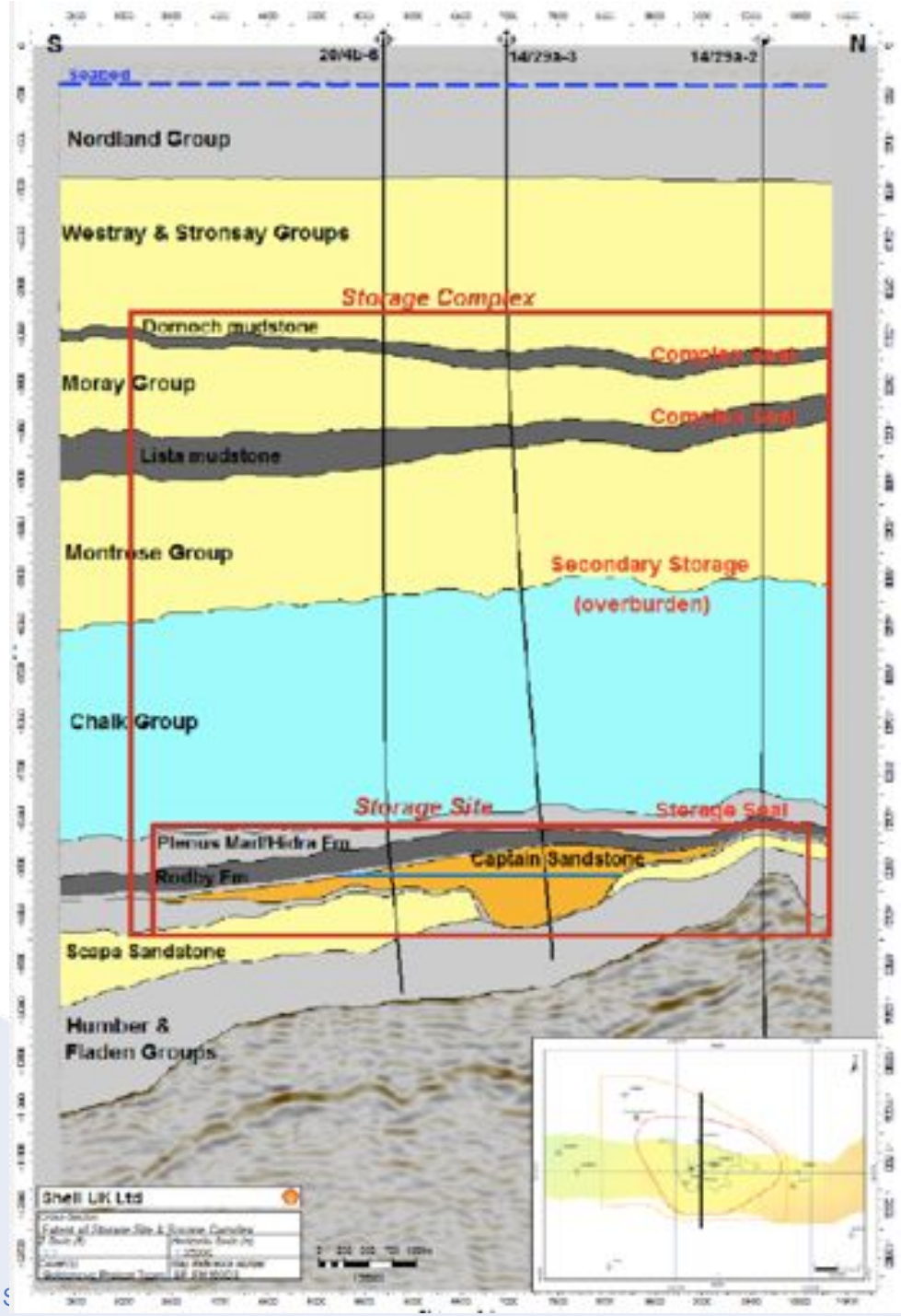
Snohvit : driving properly with Plan B

- Gradual rise in reservoir pressure indicated limited injection rate/capacity
- Repeat seismic survey (2009) showed CO_2 injection mainly confined to lower unit – reservoir permeability lower than expected
- Well Intervention operation successfully completed May 2011
- Well recompleted in overlying Stø Formation

Plan A fault compartment : go to larger Plan B



Site and Complex



At Goldeneye storage for Peterhead, to Site is a depleted gas field 3km below sealevel. This is extremely well understood from Shell's operational history of gas extraction

The reservoir (in the Site) will be under-filled

There are 3 rock seals between reservoir and seabed. And a 1,000m thick chalk aquifer, to dissolve and disperse CO2. These will retain CO2 within the Complex.

And seabed sediment, to dissolve CO2

ALL scenarios of leakage have been considered, with mitigation plans.

Chance of leakage - minimal

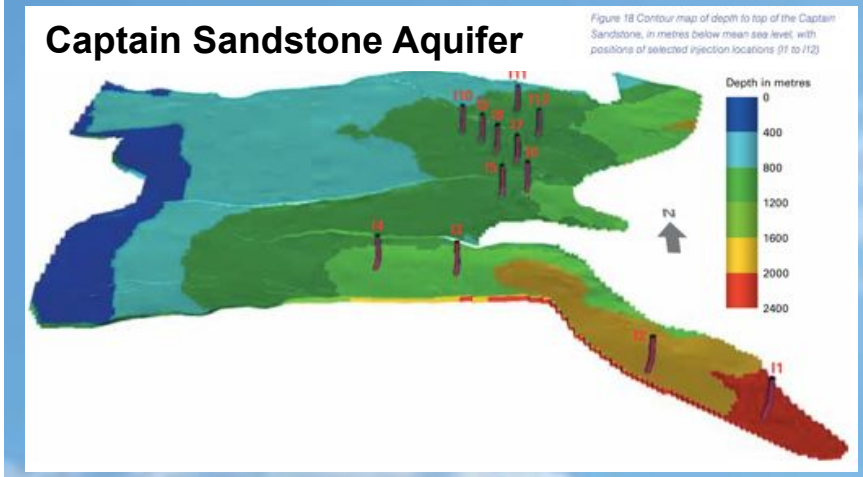
North Sea storage: SCCS reports 2009, 2011, 2015

SCCS

Progressing Scotland's CO_2 storage opportunities

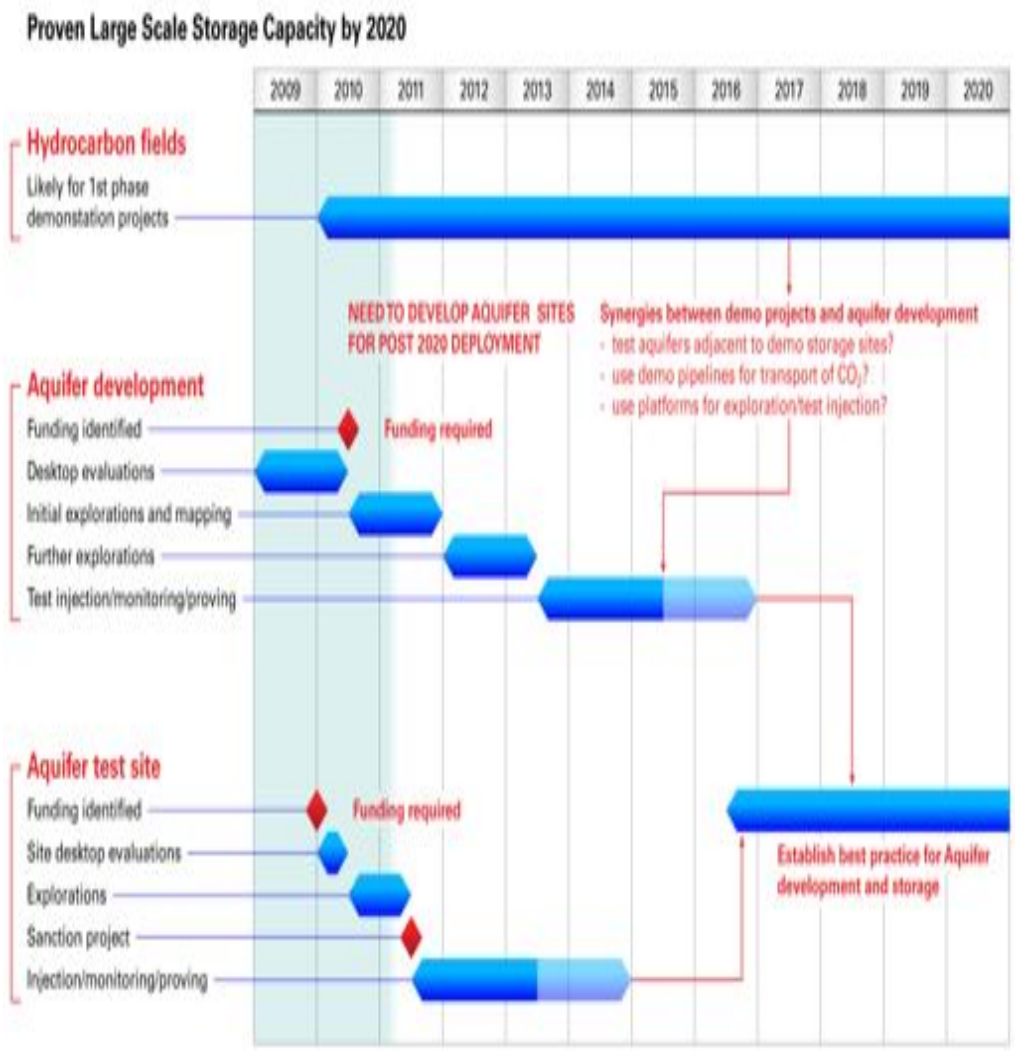
March 2011

Captain Sandstone Aquifer



Aquifer mapping, injections flow simulations, Seabed siting, costs, jobs

The Scottish Government

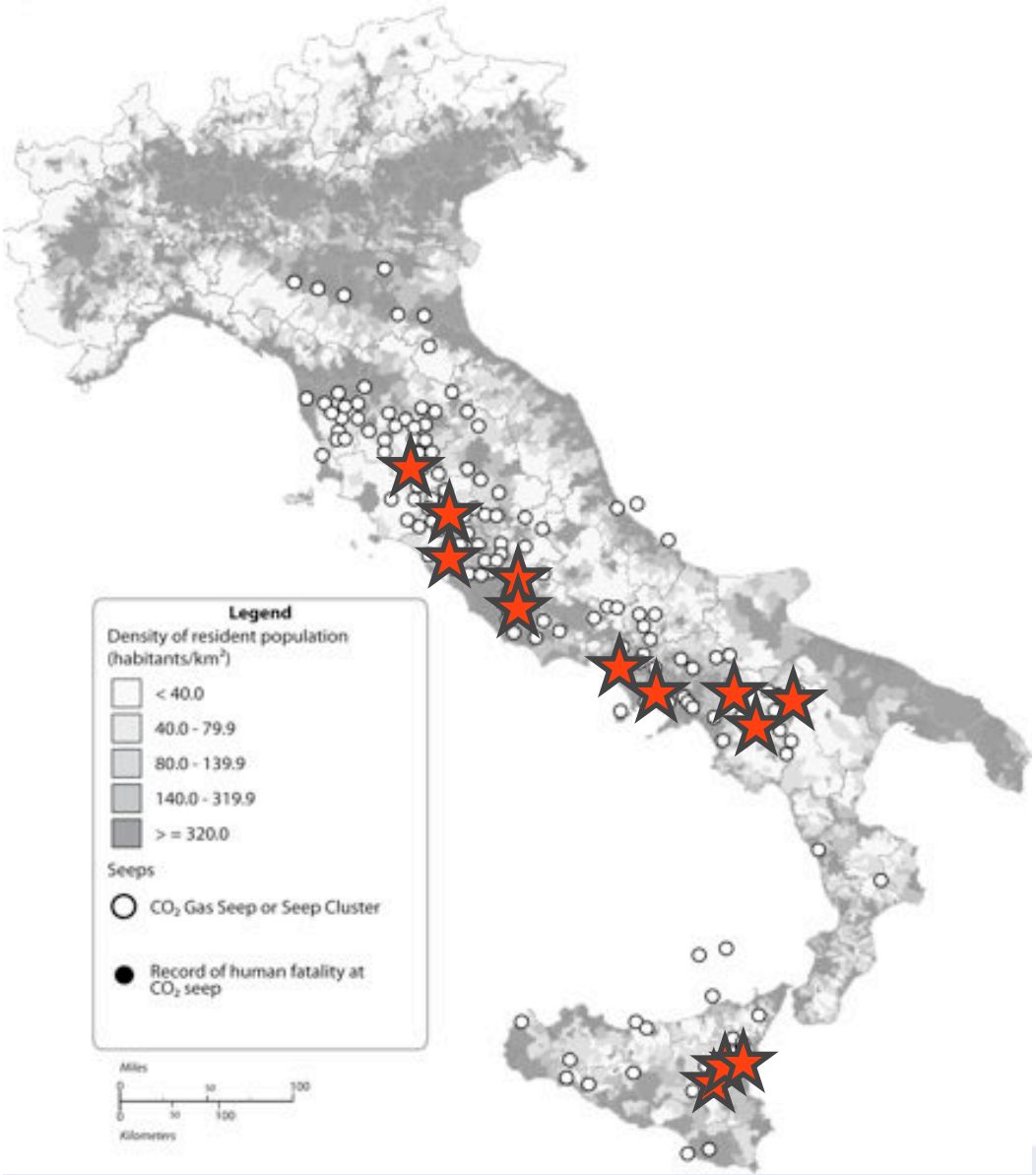


Identified best regions and timelines for work

How significant is un-anticipated performance, or a leak ?

Cartoon suitable for illustrating the pathways and process. But false proximity = **RISK**

Analogues: Mortality at Italian CO2 Seeps



★ = human fatality

19 deaths in 50 years.

13 seeps

11 deaths in 20 years ≡ "full" record

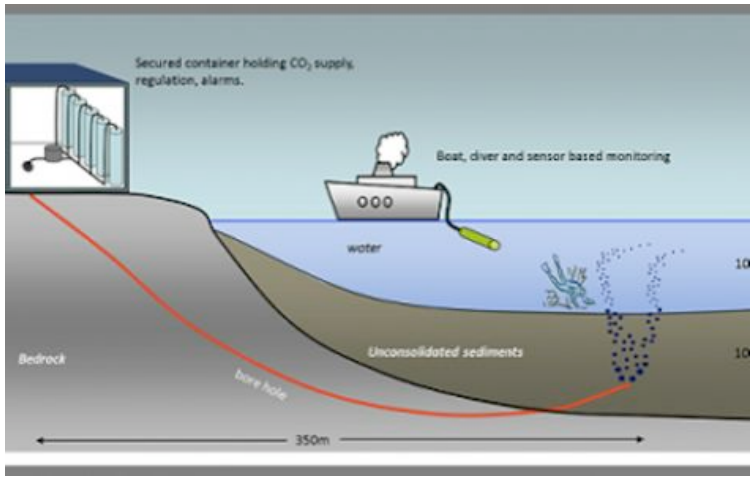
If no death year recorded - assumed > 20 yrs.

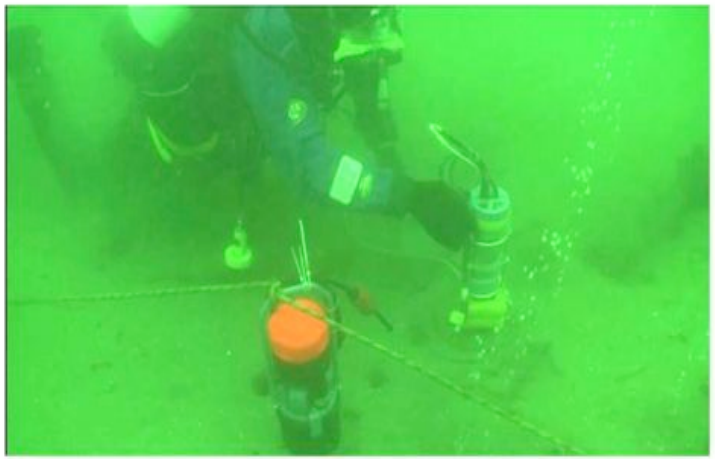
Risk of fatality 2.8×10^{-8}

1: 36,000,000

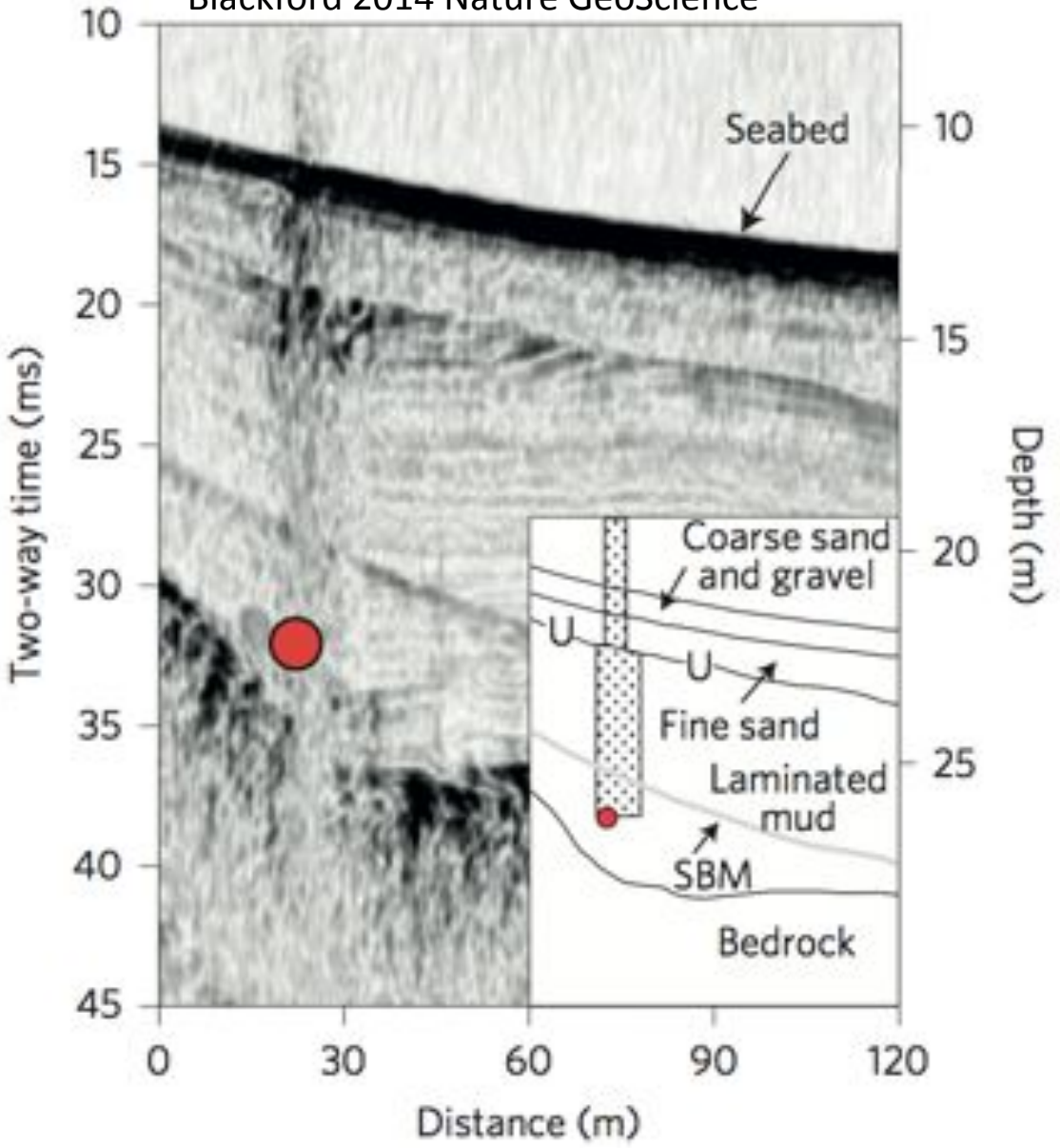
Roberts Wood Haszeldine PNAS 2011

Seabed fractures: QICS in Sco2tland



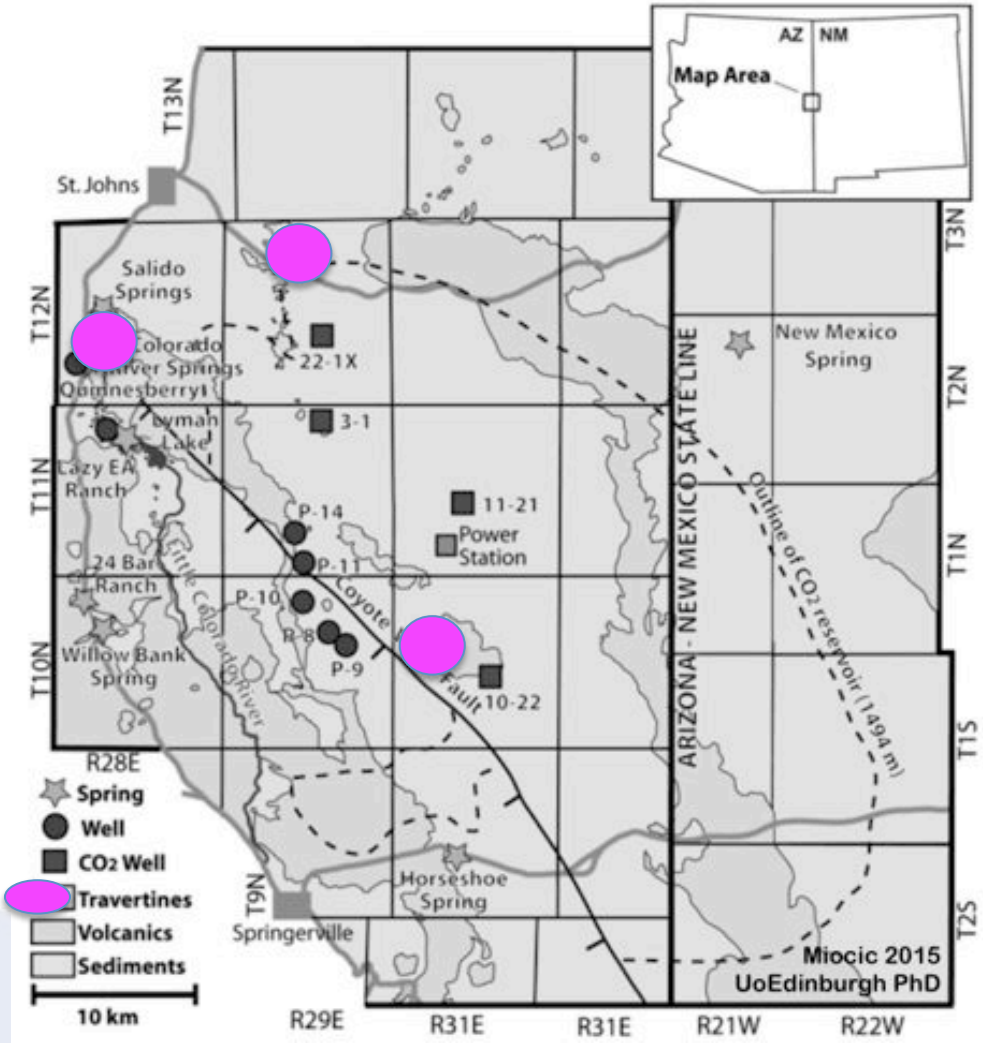


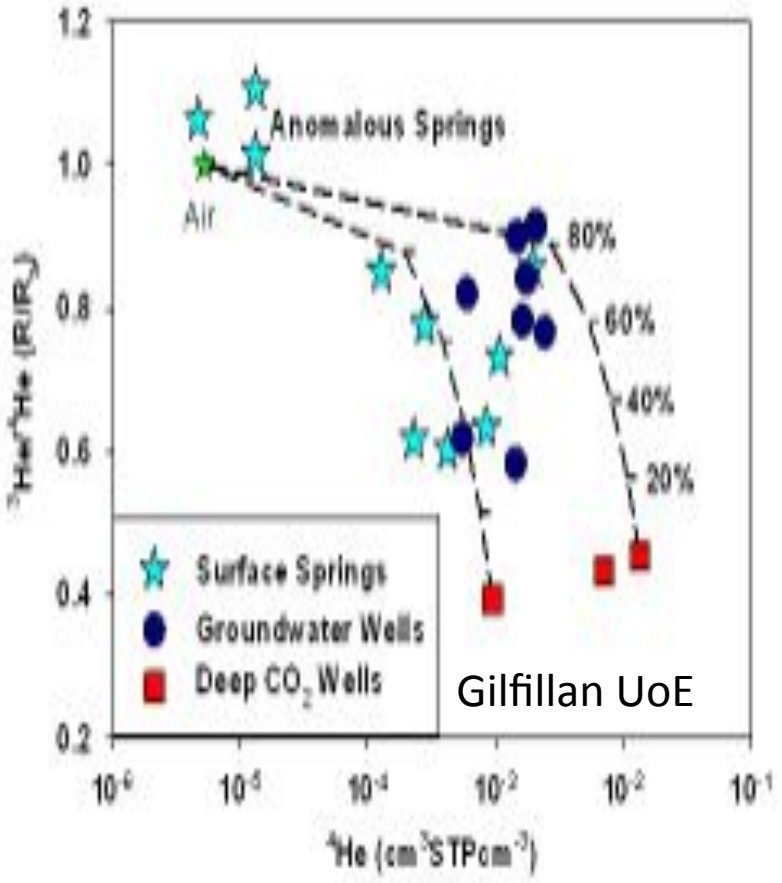
Blackford 2014 Nature GeoScience



QICS, 4.2 t CO2 injected into seabed, <u>focused plume fracture flow</u>, and 85% CO2 retained

Arizona natural structure trap : St Johns





Age dates of surface travertine 390-50 kyr. ie >400ky to become empty for 1,000Mt CO2 **SLOW**

Leaks at crest, tip, GWC
Noble gas traces surface to source

Release of CO2 : Blowout of gas, not liquid

Blowout of CO2 well 1083m depth Becej Serbia 1969 (near depth of gas/fluid phase change)

Blowout
Nov 1968 to June 1969.
Self-killing by collapse at 300-850m depth

30 shallow monitoring holes

Several 10x more CO2 released from reservoir, than arrived at surface. Dissolved into groundwater

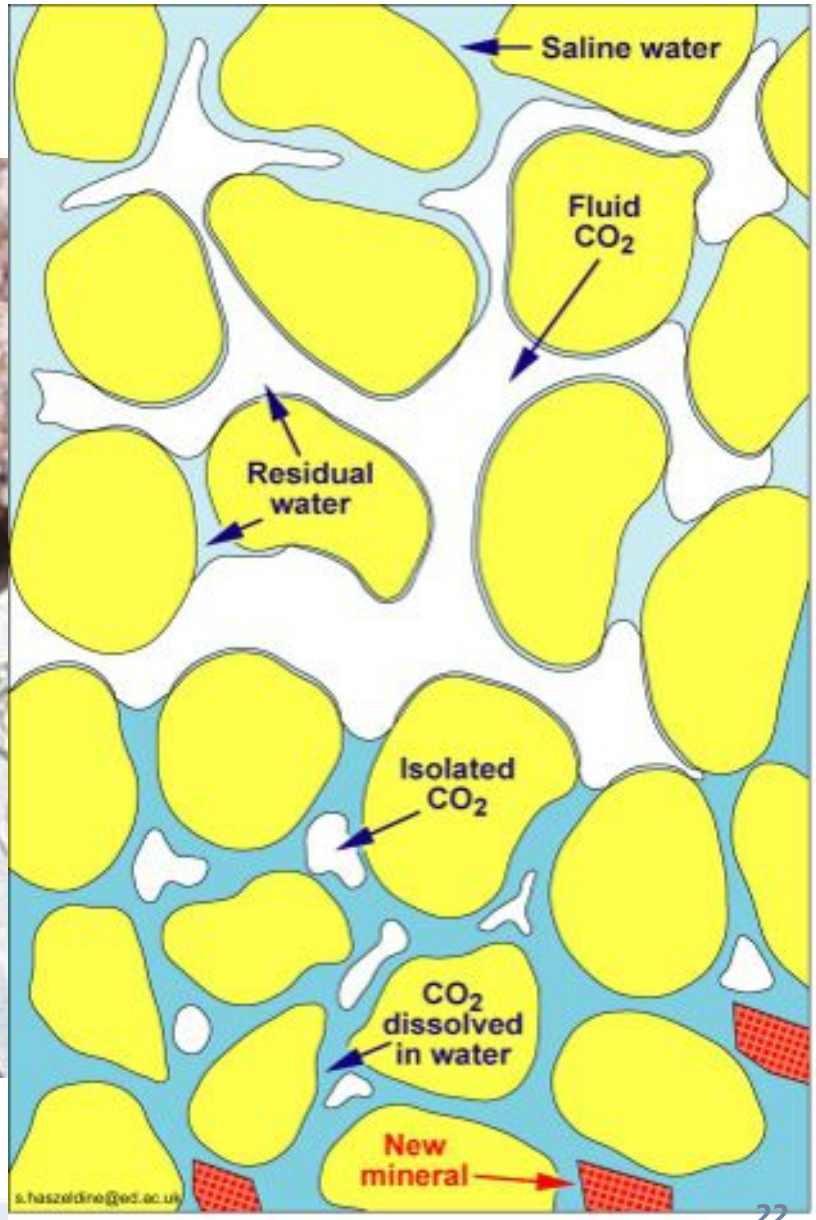
Seepage of CO_2 gas continued into the shallower aquifers above the CO_2 reservoir

Large uncontrolled emission of CO2.
No deaths. No damage to property.
Monitored, but fixed itself

Mirecol FP7 2015
Mark Wilkinson UoE

Where does the CO_2 go?

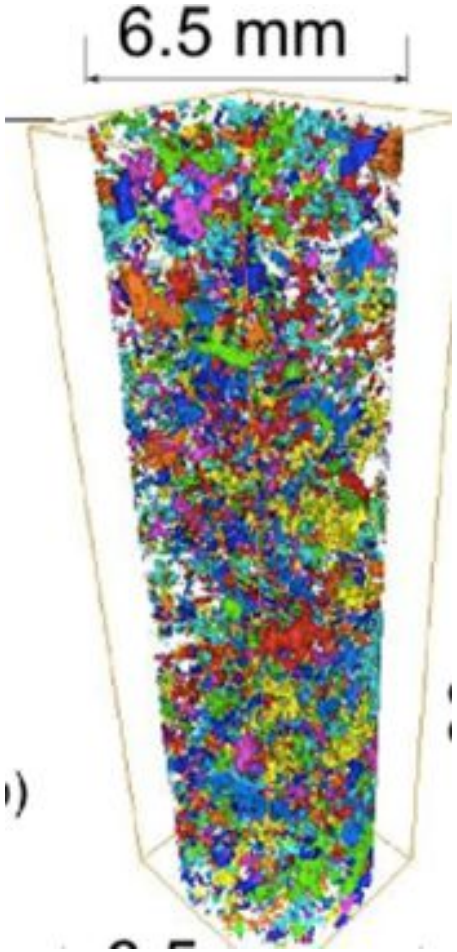
CO_2 fills microscopic pores in sandstone



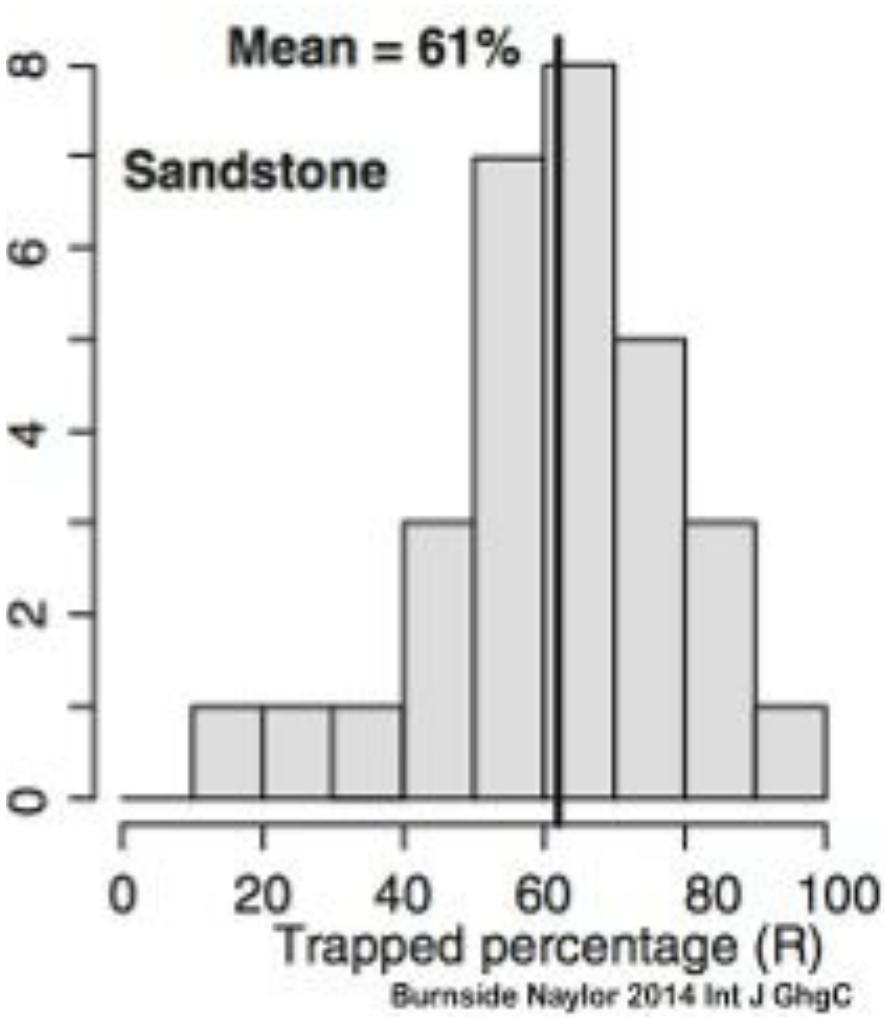
4 x trapping mechanisms: physical, soluble, residual, mineral

Can injected aquifer CO2 be released ?

Recent Laboratory measures (Andrew Bijeljic, Blunt Int J GHG C 2014)
Carbonates 13 -20%
Sandstones 32 %



CT scan of core shows residual CO2 in porosity



Compilation of experimental data modes. 61% up to 95% CO2 retained

Summary

1) Communication of CO2 geological burial/storage/disposal to publics, and anybody, needs careful content. Cartoon diagrams may mis-inform as well as inform. Facts are not easy to imagine. Images are better

2) CCS and Fracking (and any underground operation) are easily confused

3) Risk is highest during injection operations. Pressure management is usually balanced against rate of injection. Examples of site management during injection show that hydrocarbon techniques and technology successfully works to enable remediation

4) Even if leakage occurs outside the site, and even outside the complex, surface and seabed impacts are minimal. Even at a gas blowout, only small surface damage caused.

5) Physics of CO2 residual saturation, dissolution, and dispersion, means that it is **very difficult to remove injected CO2 from the sub-surface**. Leak impacts will be tiny. **Most CO2 will dissolve in the subsurface.** Legal requirements for post closure observation, and cleanup should be based on calculated, not imagined, impacts.

The public impact of risks seems to be very small, needs better quantification