Quick Clay – A patented prototype well plug material that will help facilitate the transition to net zero

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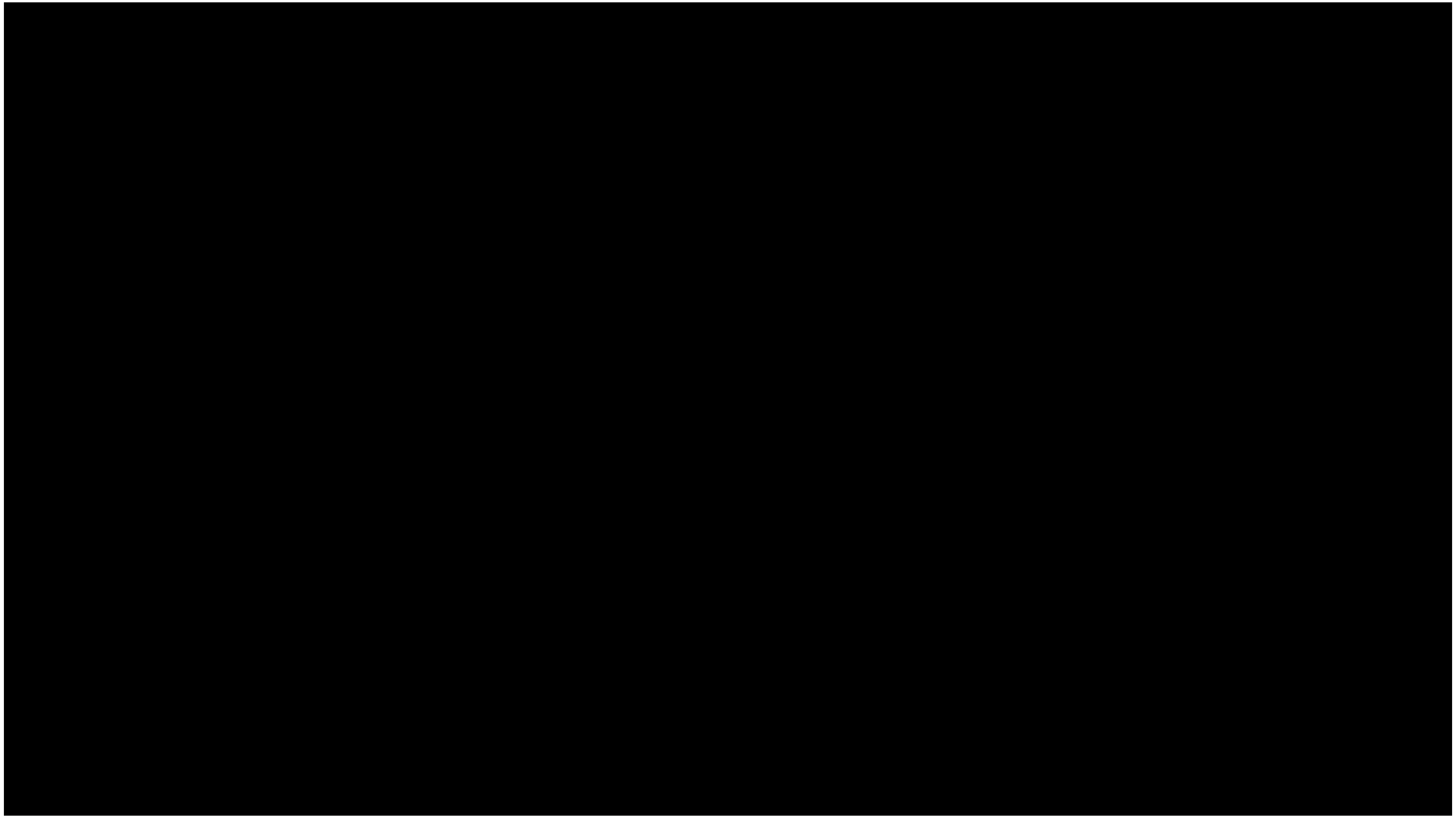
    1. *Providing easier, quicker, less energy intensive and expensive well re-entry if required*
    2. *Lowering the carbon footprint for the "manufacturing" of the barrier material and at the same time reducing material costs*
    3. *Plugging wells in perpetuity – e.g. with an appropriate environmental barrier in the UKNS, or in Canada*
    4. *An aggregate reduction in every day costs and possibly a huge reduction in liability costs*
4. Is the way forward for Quick Clay to TRL6 and beyond via Canada?

An introduction to Quick Clay

Quick Clay



The properties and occurrence of Quick Clay

Quick Clay's Properties

- This is a naturally occurring clay – substantial deposits in the Northern Latitudes
- Comprises 40% Illite, 40% chlorite, 2-4% bentonite/montmorillonite, the rest mica, calcite and silt and sand, particle size less than 40 µm
- Contains little or no NaCl
- Quick Clay is thixotropic, exhibiting strongly non-Newtonian fluid properties (Under investigation by the University of Strathclyde)
- It is non-toxic
- Use in plugging wells is patented/patent pending in Europe, the USA, and Australia
- It is anticipated that it will be considerably cheaper than cement to produce due to less processes and energy being required in its "manufacture"

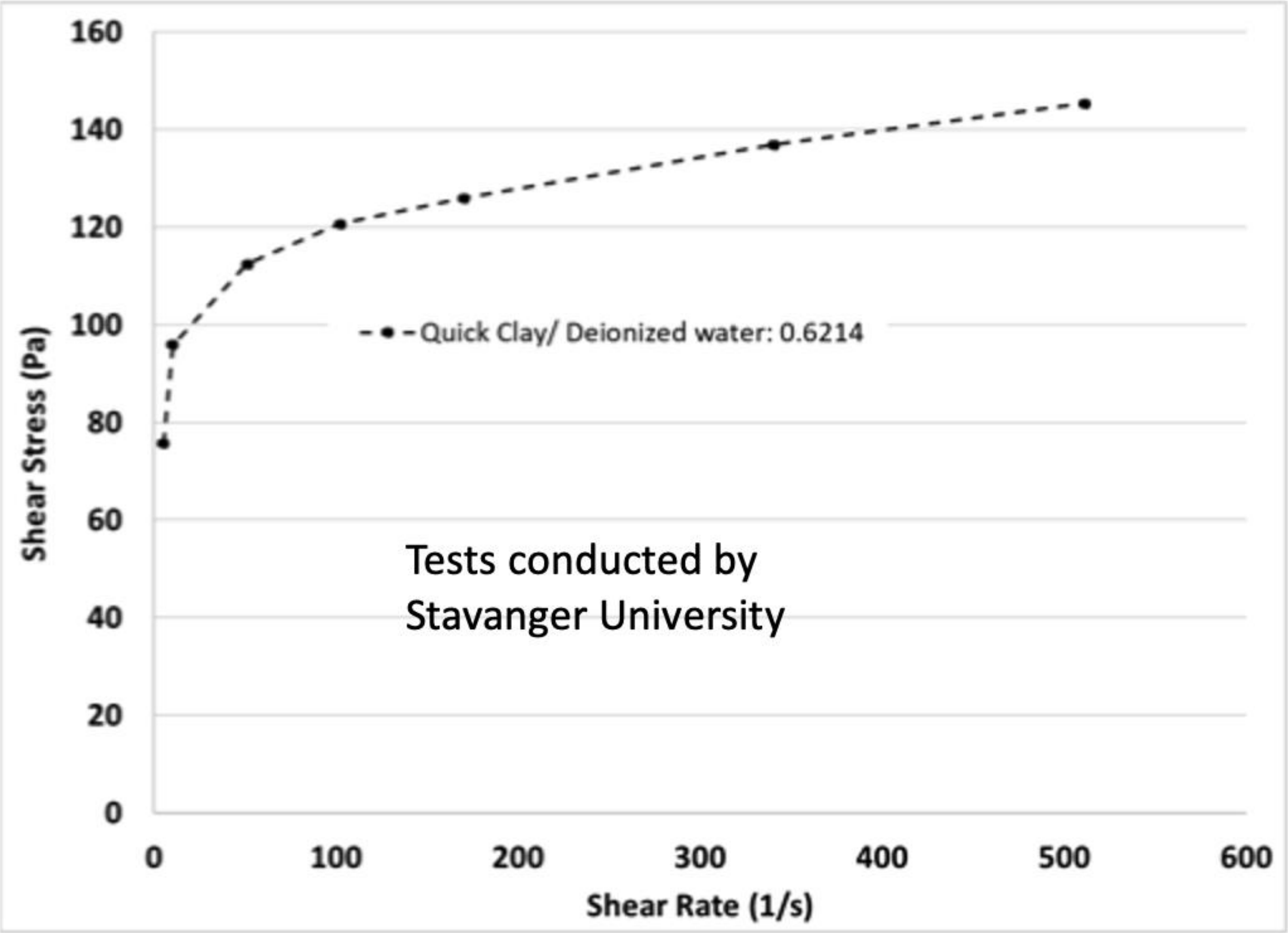
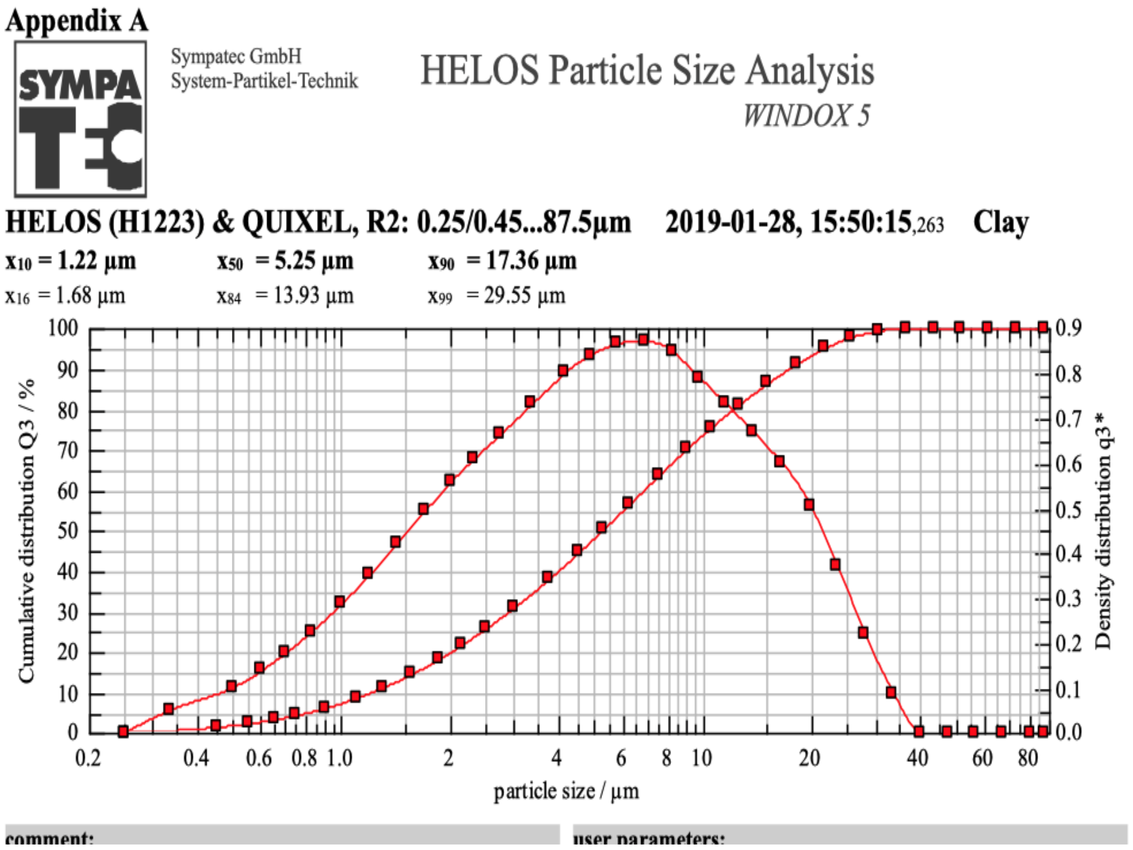


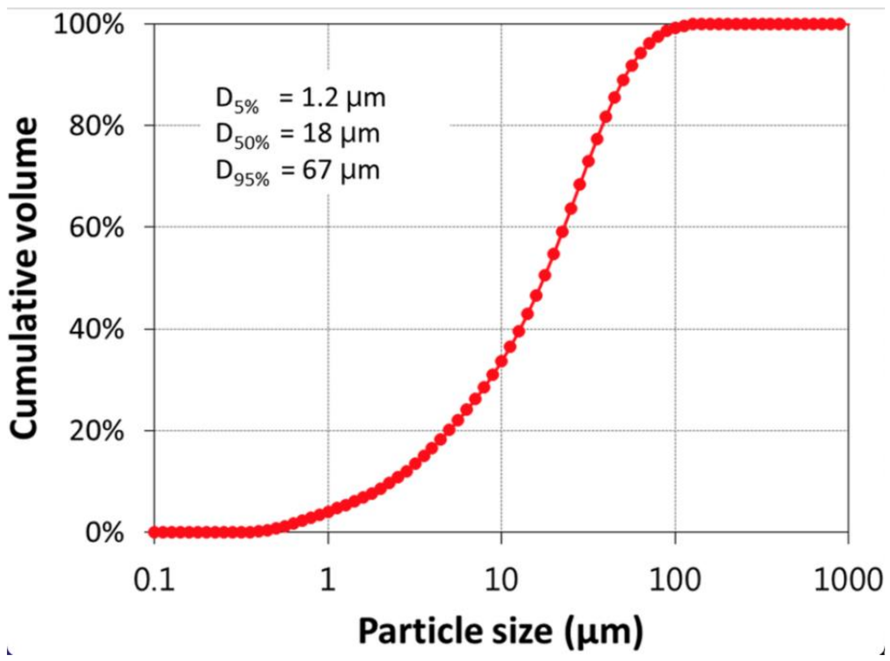
Figure 13 – Shear rate vs. Shear stress at room temperature (24 deg. C)

Quick Clay Particle Size Distribution – smaller particle size should enable microfracture penetration

Quick Clay 70% < 10µm



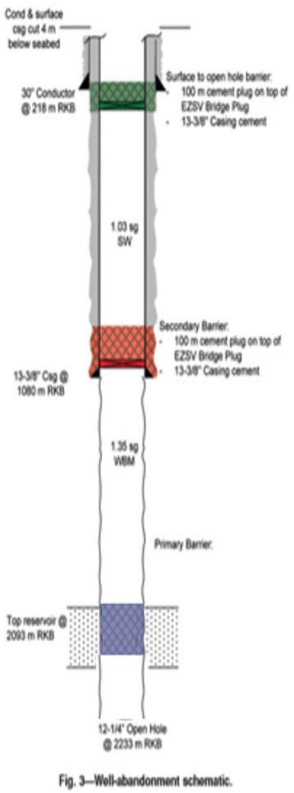
Portland Cement 35% < 10µm



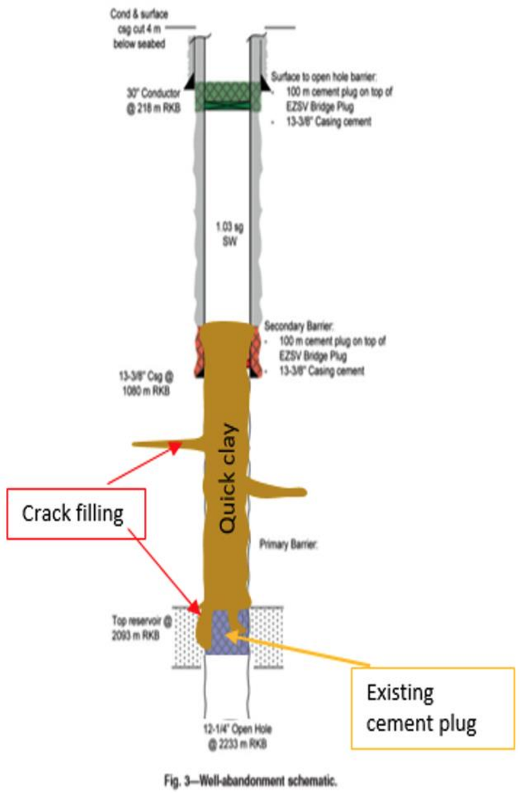
Quick Clay Properties align Quick Clay with well management offering:

- Zero permeability
- Pumpability
- Placement and fracture penetration, bullheading, perf and squeeze, annulus filling
- Accommodation of well and casing distortion without losing plug integrity
- Stable and benign barriers - inert, non-toxic
- Ease of removal (Well Suspension)

State of the art



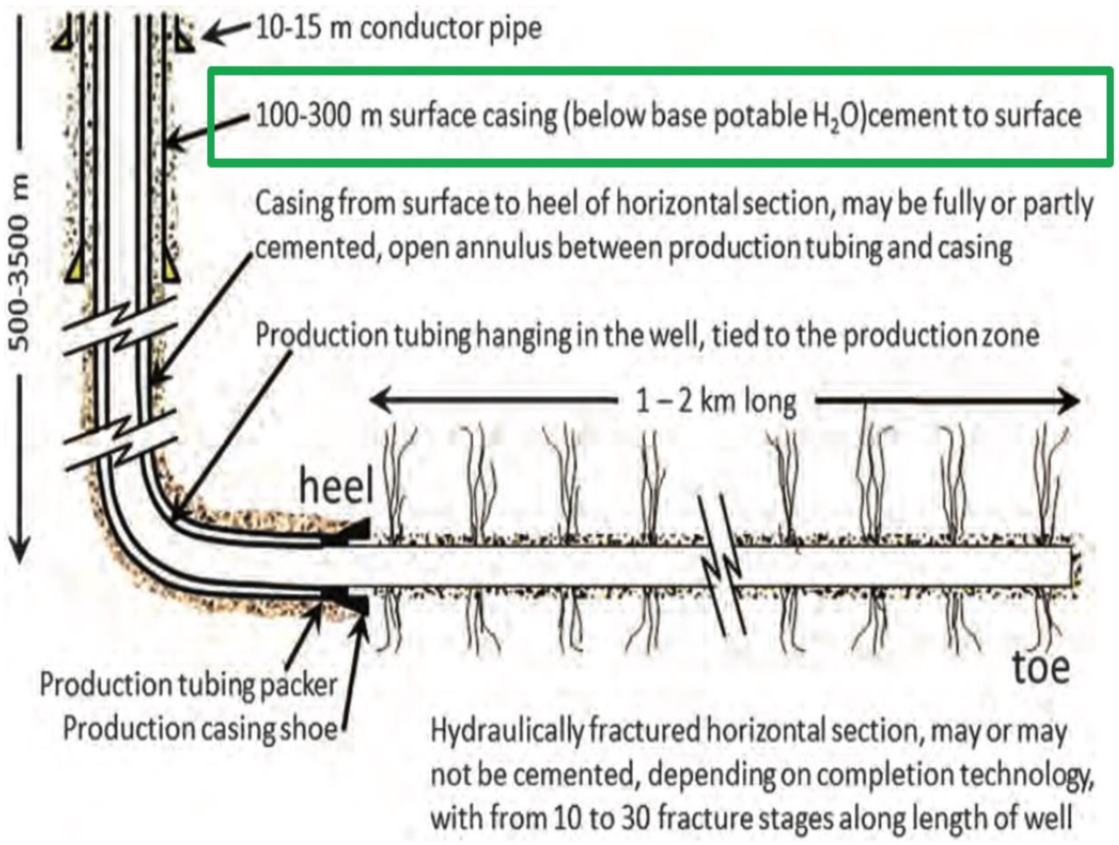
Quick clay as grout



Quick clay full column

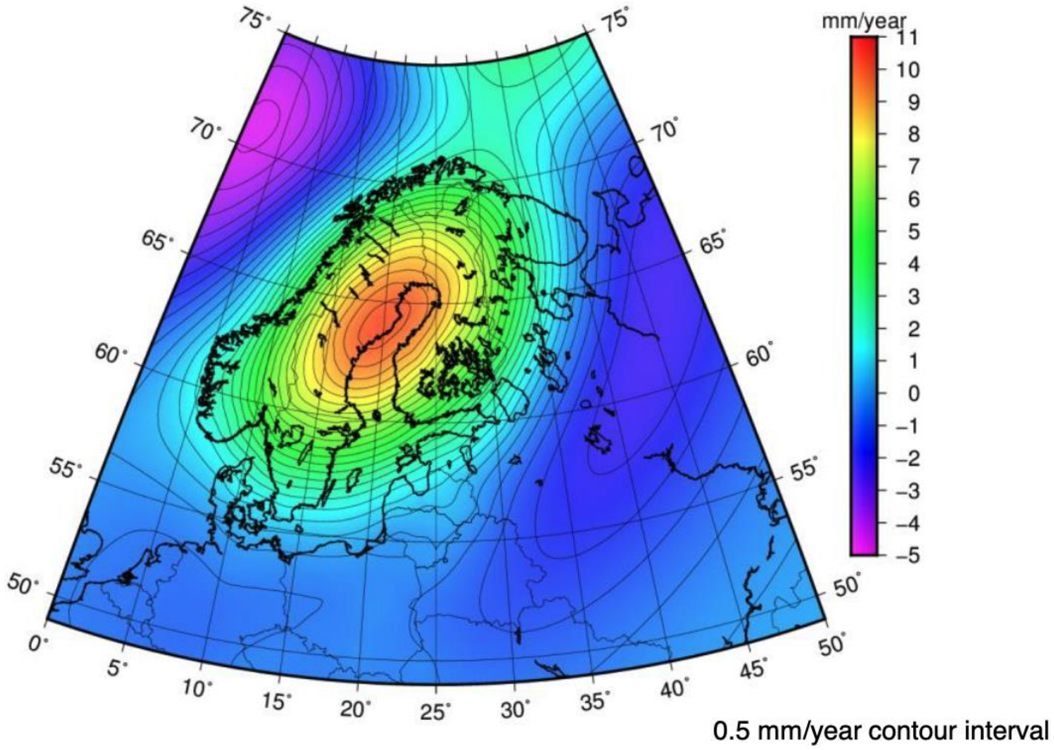
Quick Clay is inert and non-toxic – properties that align Quick Clay with :

- Longevity of barriers placed in abandoned wells
- Placement of non-toxic barriers isolating potable aquifers



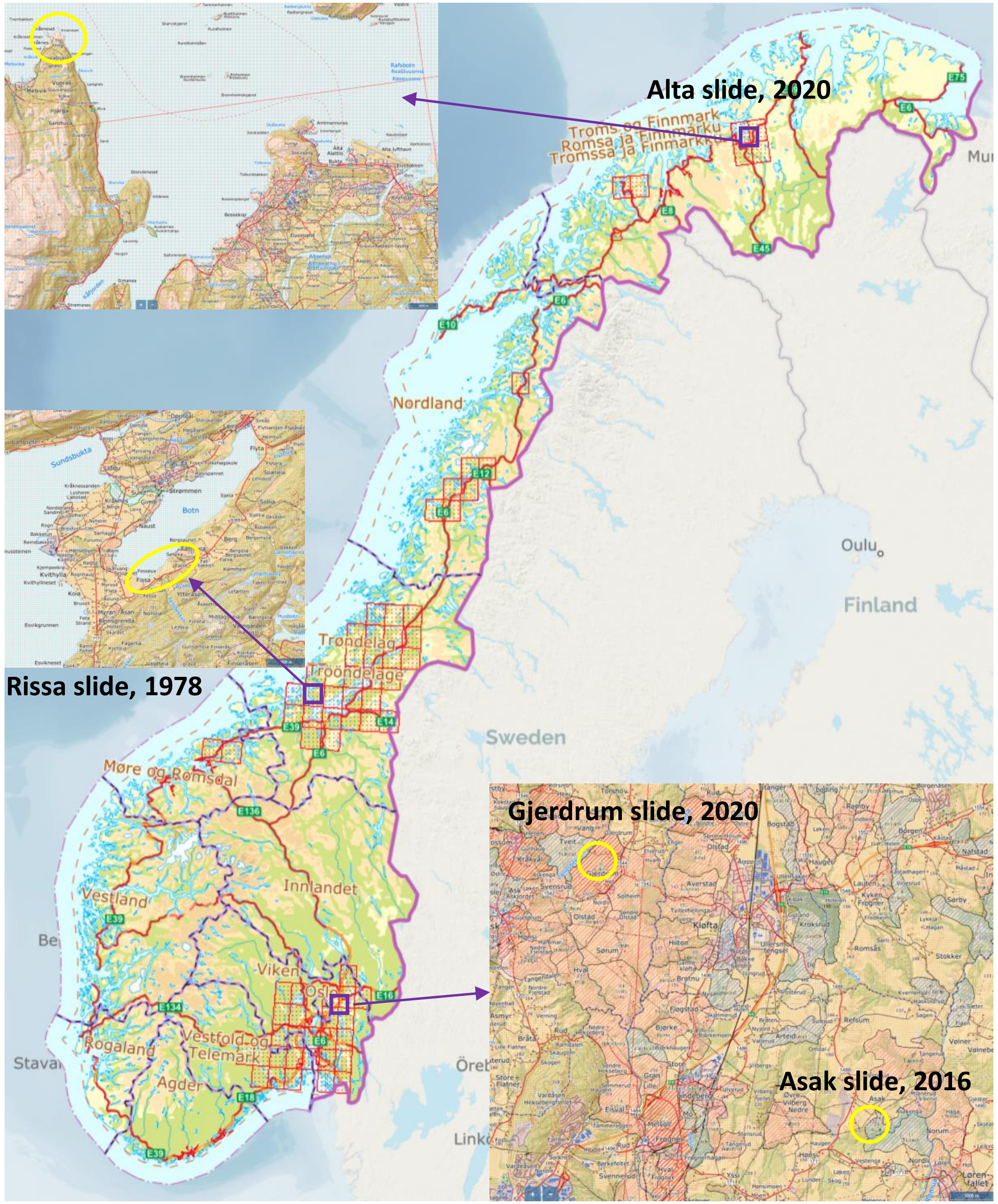
Quick Clay occurrence

- Quick Clay was formed by fresh water washing out salt from formerly marine clay deposits now elevated above sea level
- In Norway 20,000 years ago, the 3,000m thick ice sheet began to retreat causing isostatic uplift – marine clay deposits were lifted above sea level, and fresh water leached out the salt to create "Quick" Clay



Nordic Geodetic Commission

Supply of Quick Clay for the North Sea: thixotropy causes landslides in Norway

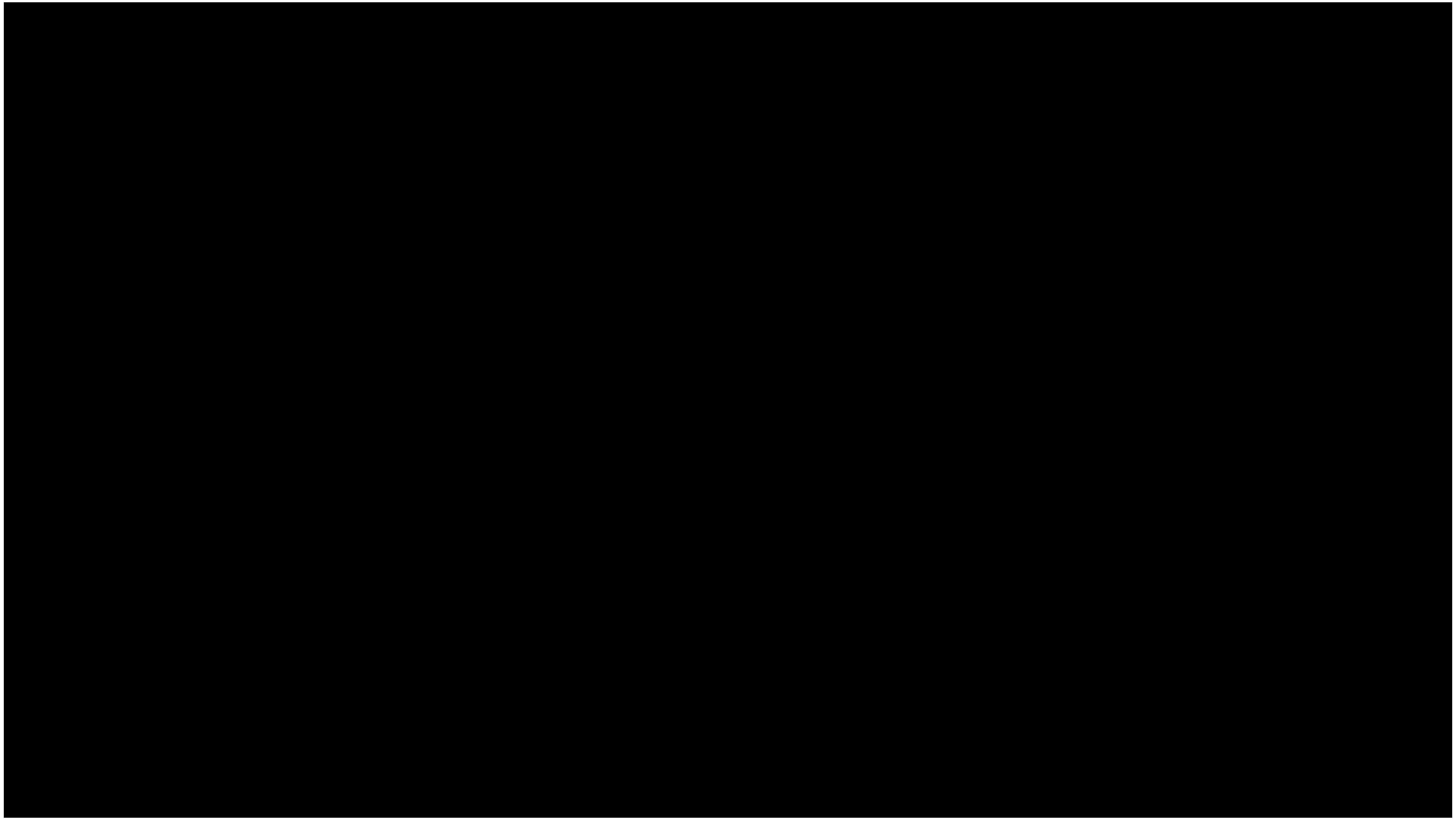


Quick Clay's thixotropy causes landslides

- Over 60 large landslides in Norway traceable back to 1254
- 313 deaths recorded
- Most recent on 30th December 2020 at Ask in the Gjerdrum Region (10 fatalities)
- Alta 3rd June 2020 (0 fatalities) Video
- Sørum 10th November 2016 (3 fatalities) – inspired Fred – samples collected (on our booth)
- Rissa 29th April 1978 (1 fatality) Video available

The Sørum Landslide

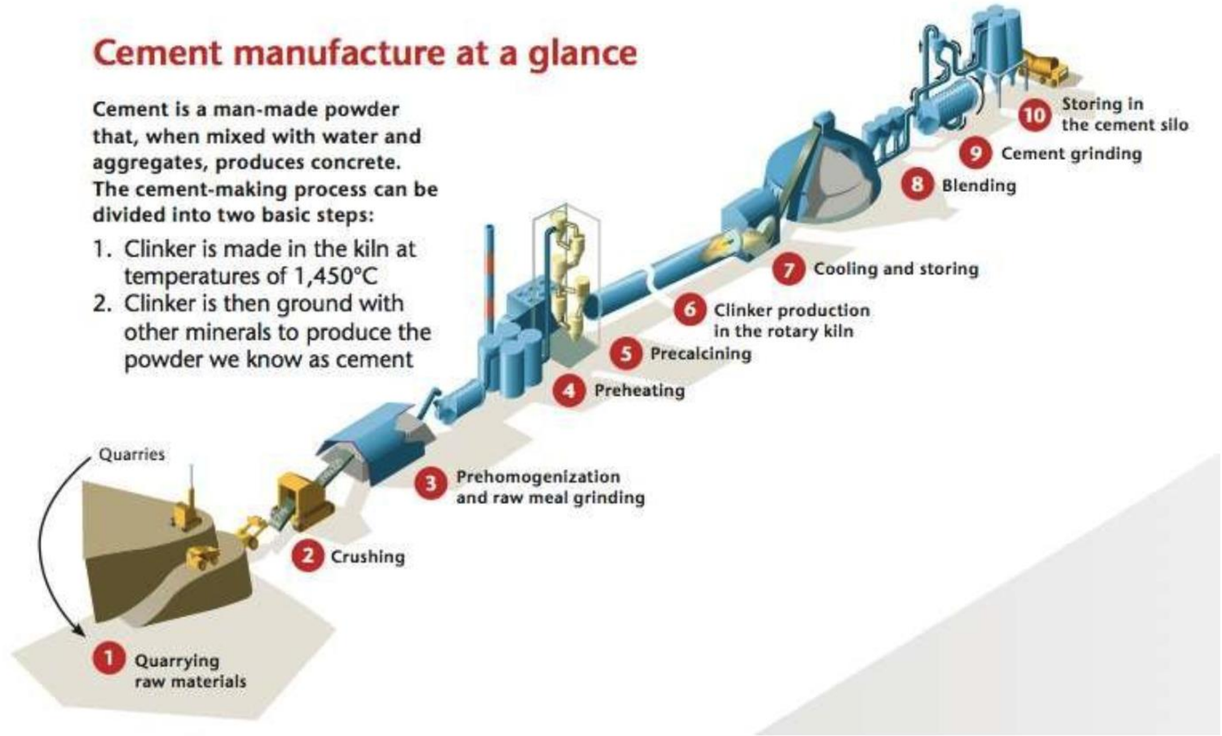
The Alta Quick Clay Slide 3rd June 2020



Quick Clay's four possible contributions to the transition to net zero

Quick Clay can contribute to a transition to net zero by:

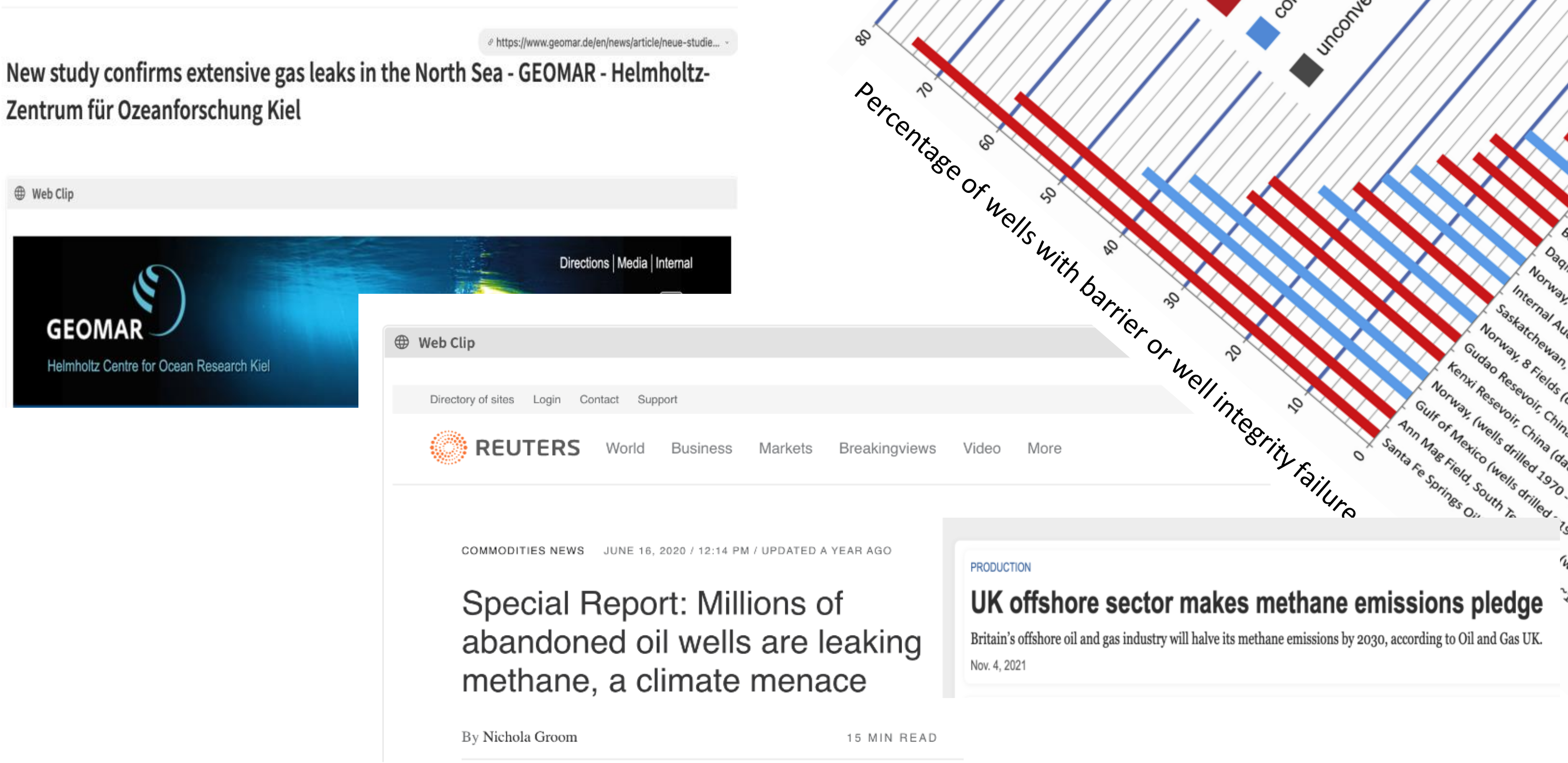
1. Providing easier, quicker, less energy intensive well re-entry if required – quick clay can be flushed out of the well (e.g. for Suspension and Environmental Barrier removal) saving on operating costs
2. Lowering the carbon footprint of manufacturing: 1T cement = 1T CO_2 emissions. Quick Clay "manufacture" estimated to cut this by at least 50% compared to cement, and will lower the cost of the material

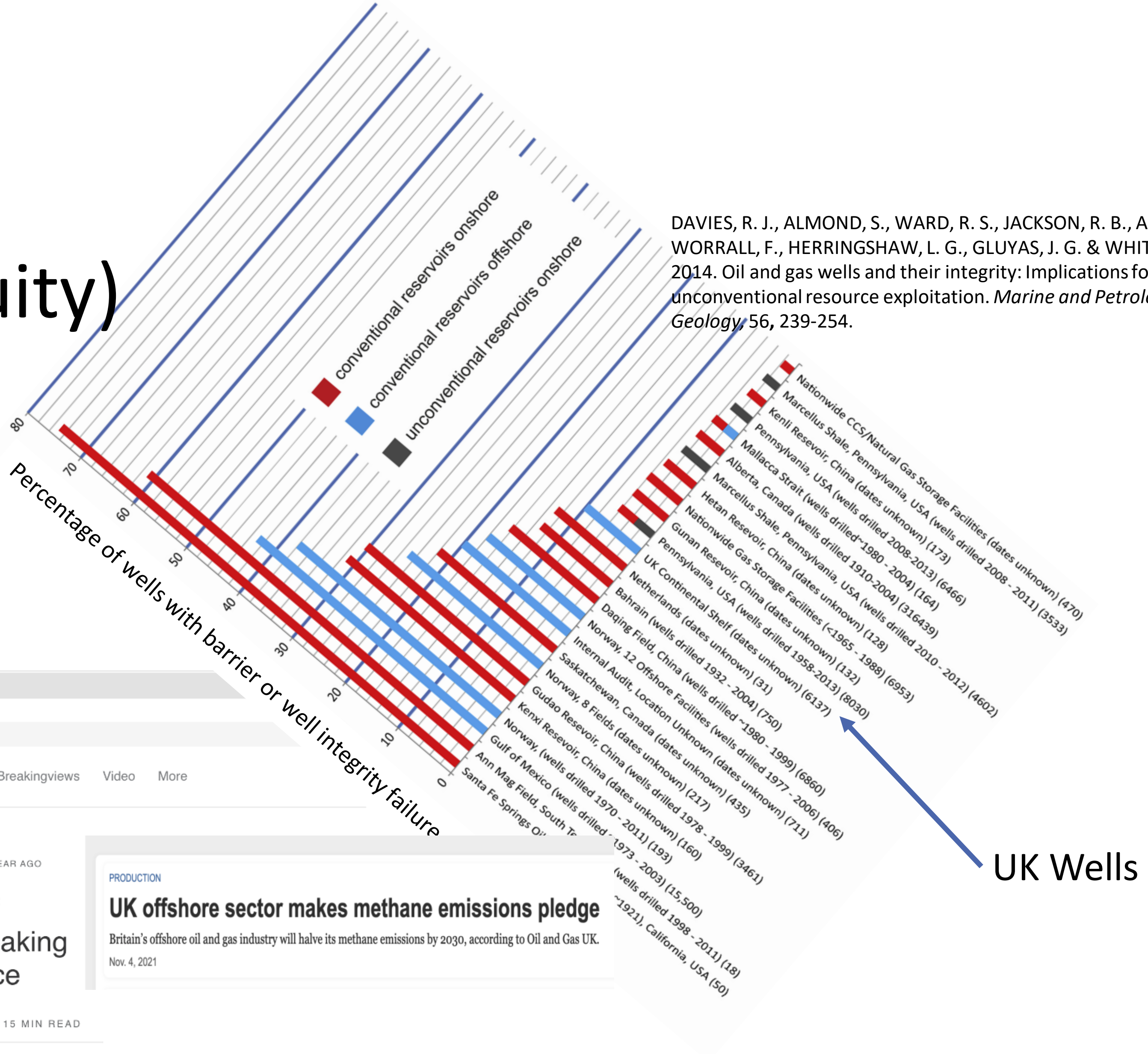


Cement manufacture Source: World Business Council for Sustainable Development & International Energy Agency (2009) 104

Quick Clay can contribute to a transition to net zero by:

3: Plugging wells effectively (in perpetuity)





DAVIES, R. J., ALMOND, S., WARD, R. S., JACKSON, R. B., ADAMS, C., WORRALL, F., HERRINGSHAW, L. G., GLUYAS, J. G. & WHITEHEAD, M. A. 2014. Oil and gas wells and their integrity: Implications for shale and unconventional resource exploitation. *Marine and Petroleum Geology*, 56**,** 239-254.

A case study: The need for more effective plugs in in the North Sea

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International Journal of Greenhouse Gas Control
Volume 100, September 2020, 103119

Greenhouse gas emissions from marine decommissioned hydrocarbon wells: leakage detection, monitoring and mitigation strategies

Christoph Böttner [a], Matthias Haeckel [a], Mark Schmidt [a], Christian Berndt [a], Lisa Vielstädte [a], Jakob A. Kutsch [b], Jens Karstens [a], Tim Weiß [a]

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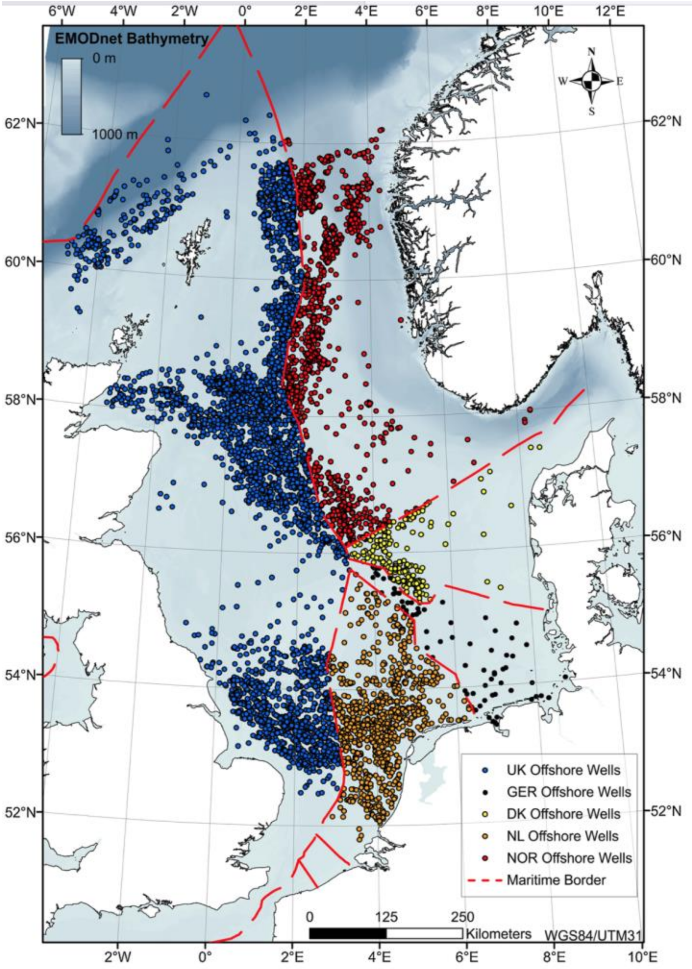
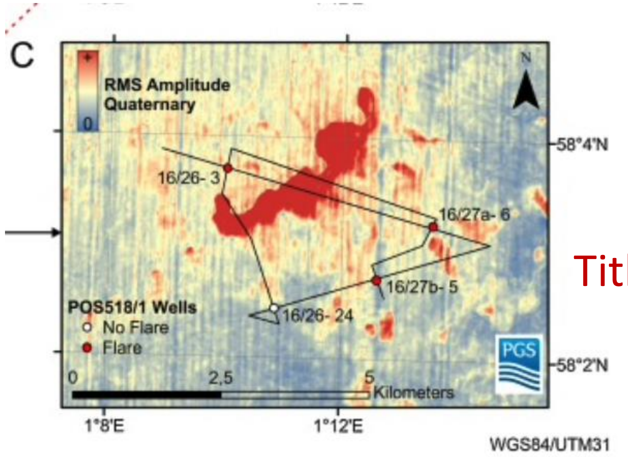


Methane Leaks from the Central UK NS (based on Böttner et al)

- 5,500 abandoned wells in the UK sector of the North Sea
- Leak rate for 1760 wells given at 0.7-4.2kt CH4 per year (with 95% confidence)
- So for the 5,500 abandoned wells in the North Sea CH4 per year emissions = 2-13kt CH_4 per year?
- Isotope analysis shows the leaks to be from shallow gas
- From older wells drilled within 600m of shallow gas above 1000m are the most prone to leak
- Therefore it is likely that the environmental barrier is ineffective – either it is leaking or not long enough



Title

On the basis of investigations directly on the seafloor it was possible to d
escaping gas. Photo: ROV team/GEOMAR

New study confirms extensive gas leaks in the North Sea

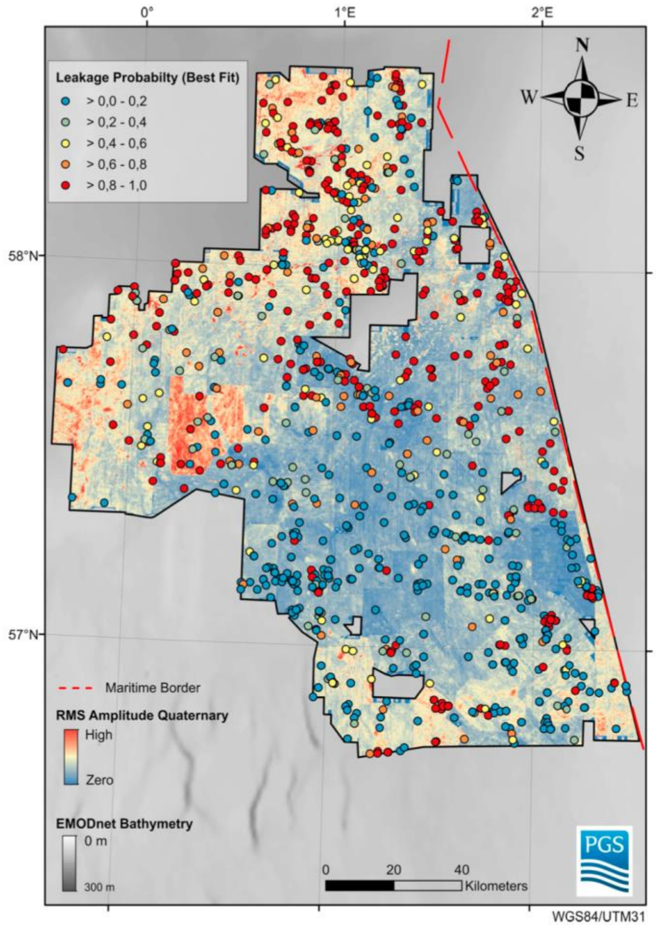
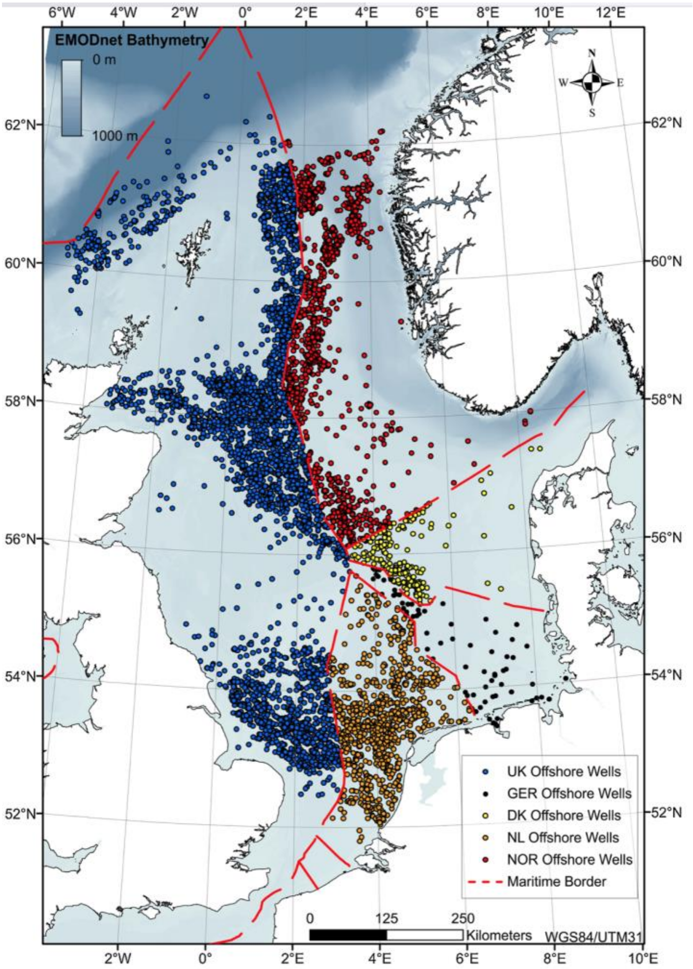


Fig. 8. The transformed logistic regression model predictions of the probabilities of leakage for the 1,792 wells within the 3-D seismic data set in the Central North Sea. The RMS amplitude map of the 3D seismic data is draped on top of the EMODnet bathymetry map and shows leakage probabilities of the 1,792 wells as color-scaled dots.

Measured/Estimated CH4 Leak Rate

Location	**Source**	**Leaking Wells Status**	**Average leaking rate given**	**Annual CH4 leak**	**Longevity on the Perpetual Scale**
UK Surface	Surface infrastructure	-	42kt/year	**42kt directly into atmosphere**	**Reducing toward zero – Linked directly to operations**
UK Offshore Wells	**5,500 wells**	Older Abandoned wells within 600m of gas at < 100m depth – Environmental barrier ineffective?	2-13kt/year shallow gas	**2-13kt into the atmosphere less dissolution 100m water cut-off?**	**Perpetual on COP scale Dissolution = sea acidification**



A negative impact on NZ and potentially a difficult ESG proposition

Quick Clay can contribute to a transition to net zero by:

3. Preventing the future leaking of decommissioned UK North Sea wells – tackle the apparent environmental barrier problem?

State of the art

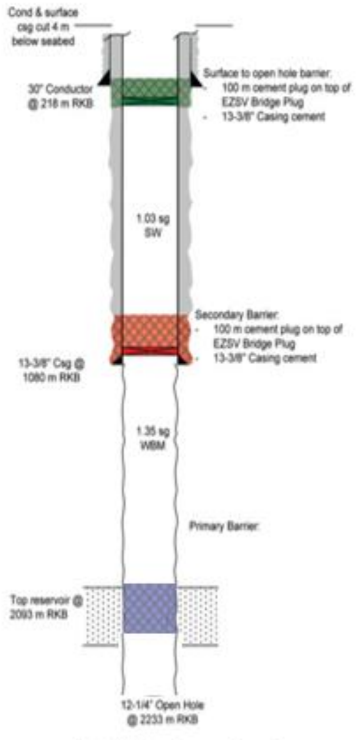


Fig. 3—Well-abandonment schematic.

Quick clay as grout

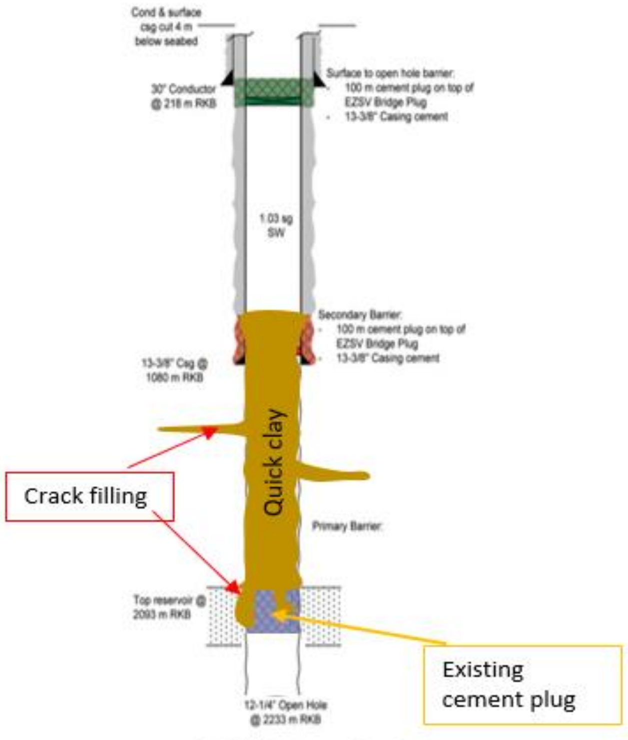


Fig. 3—Well-abandonment schematic.

Quick clay full column

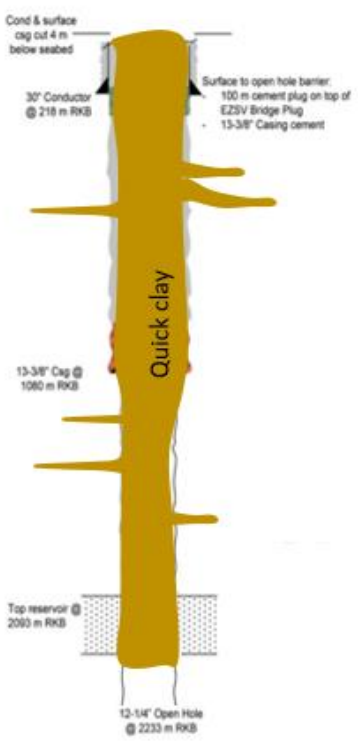


Fig. 3—Well-abandonment schematic.

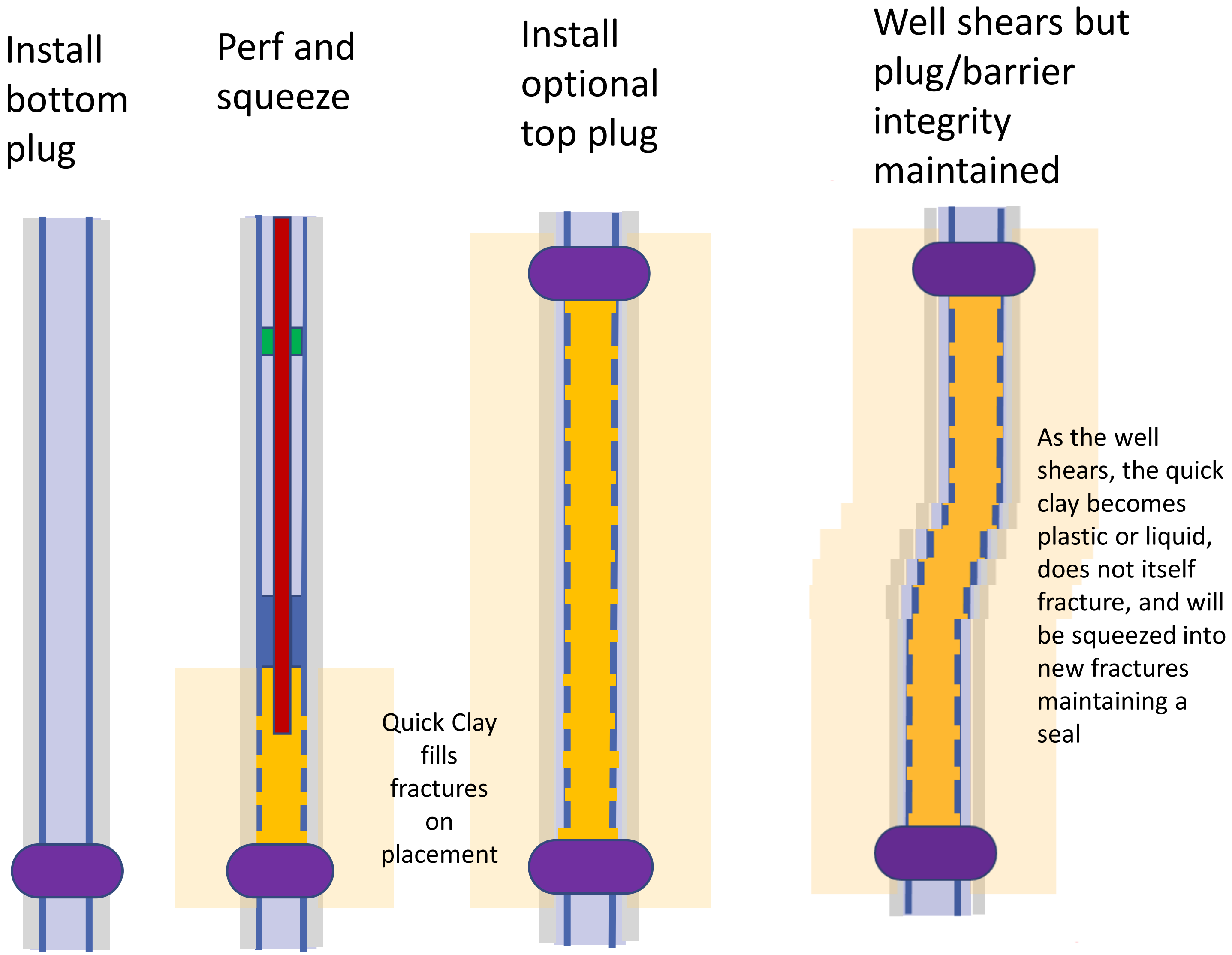
The fundamental difference between using clay and cement is that the cement plug must be placed at planned intervals where it will harden quite rapidly.

The clay can in theory be dropped into the well from the top (Bull-heading) and then it will move progressively under gravity forces. It will not harden until it contacts salt. If a cement plug leaks, Quick Clay can be dropped over it and it will move into all plug cracks and rock fractures

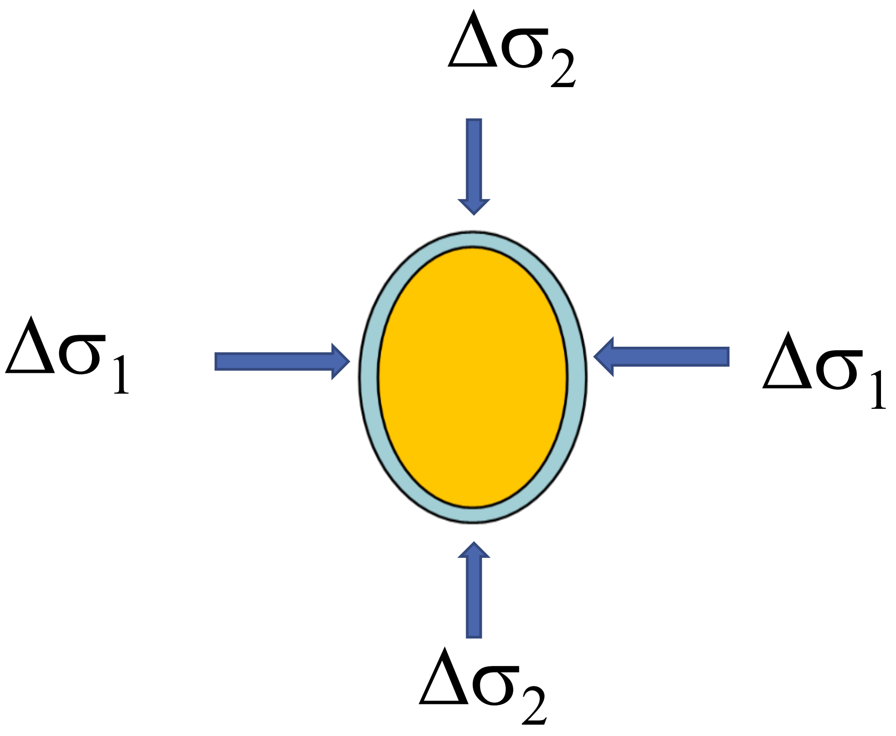
Quick Clay can contribute to a transition to net zero by:

3. Providing more effective long-term plugs, eliminating CH_4 emissions

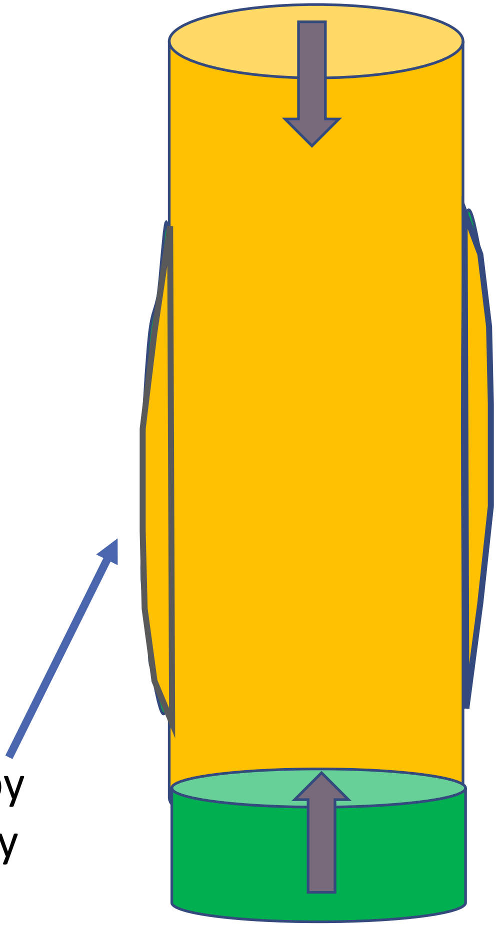
- Because of quick clay's extreme non-Newtonian behaviour we believe it can be used in perf and squeeze operations
- The small particle size of quick clay should enable it to fill fractures and micro fractures
- It will remain malleable and accommodate shear and other well distortions
- It could react to volume (stress) changes by liquidizing and sealing factures



Quick Clay – a self-sealing thixotropic plug



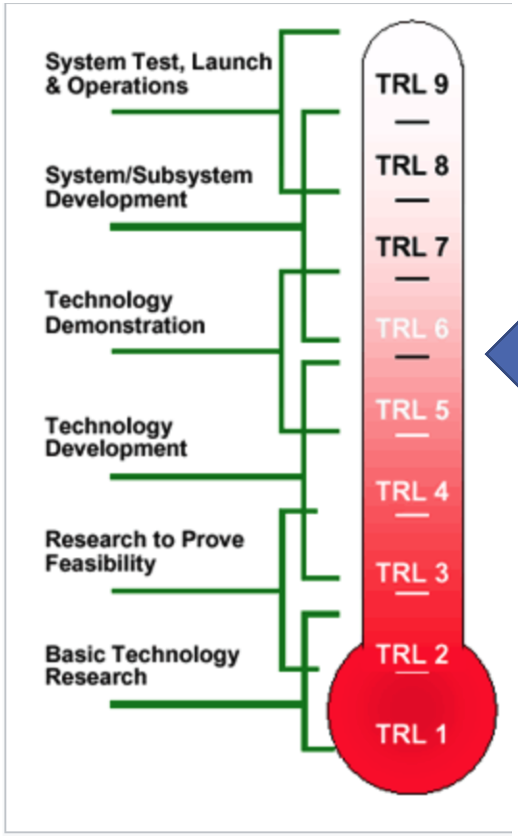
Stress changes due e.g. to reservoir recharge



New fracture filling by thixotropic Quick Clay behaving as a liquid

Where are we in the UK?

- Possible applications identified, addressing the “in perpetuity” responsibility in exisiting oil and gas wells and future CCS wells
- Industry R&D funds not available
- We remain at TRL3
- And so to Canada

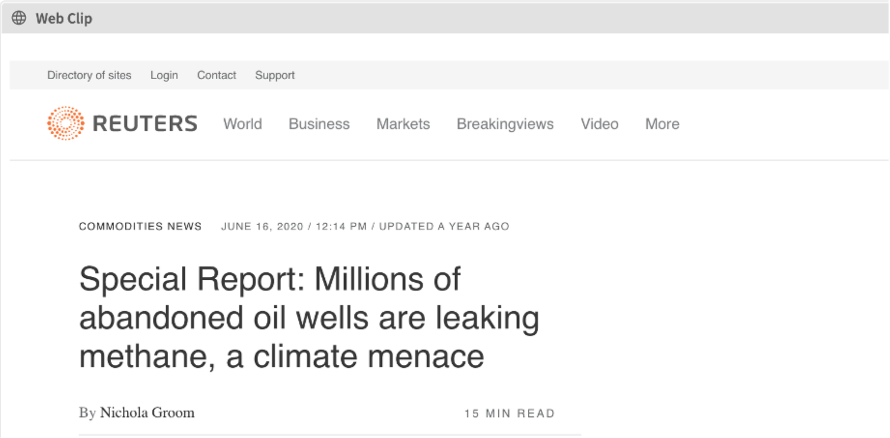


NASA technology readiness levels

Our immediate target

Why Canada? Quick Clay can contribute to a transition to net zero by:

3: Plugging Canada's abandoned onshore wells in perpetuity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COMMODITIES NEWS JUNE 16, 2020 / 12:14 PM / UPDATED A YEAR AGO

Special Report: Millions of abandoned oil wells are leaking methane, a climate menace

By Nichola Groom 15 MIN READ


EDITORIAL | 25 August 2021

Control methane to slow global warming – fast

Carbon dioxide reductions are key, but the IPCC's latest report highlights the benefits of making cuts to other greenhouse gases, too.

Oil and gas operations — such as Inglewood Oil Field in Los Angeles, California — are a key source of methane. Credit: Citizens of the Planet/Education Images/Universal Images Group/Getty

Canada has a significant leaking well problem and extensive Quick (Leda) Clay reserves (and many landslides)

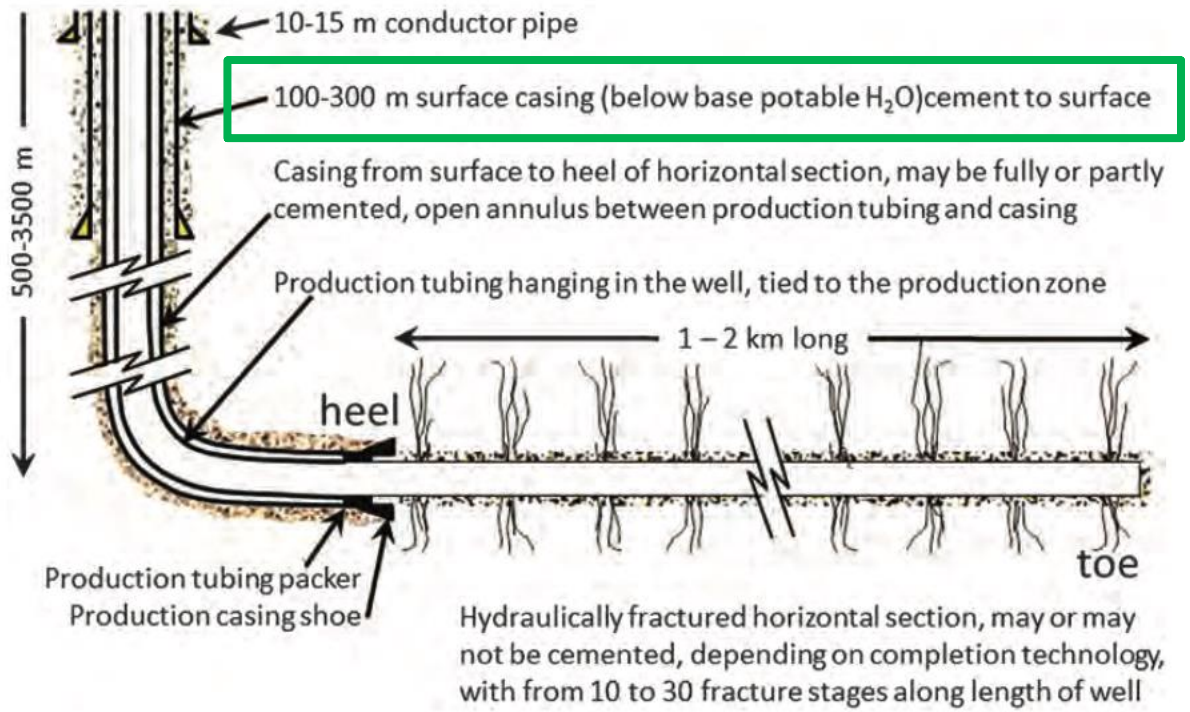
Methane Emissions from Abandoned Oil and Gas Wells in Canada and the United States

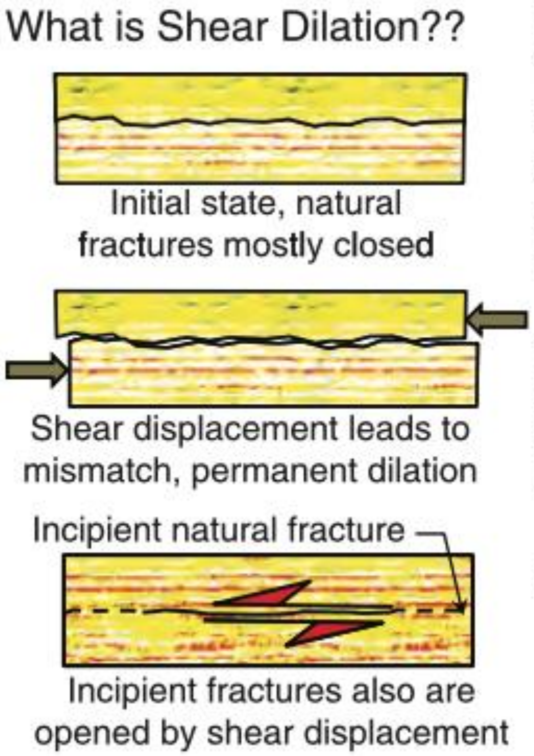
James P. Williams, Amara Regehr, and Mary Kang
Department of Civil Engineering and Applied Mechanics, McGill University, Montrea

*"Abandoned oil and gas wells are one of the most uncertain sources of methane emissions into the atmosphere. To reduce these uncertainties and improve emission estimates, we geospatially and statistically analyze 598 direct methane emission measurements from abandoned oil and gas wells and aggregate well counts from regional databases for the United States (U.S.) and Canada. We estimate the number of abandoned wells to be at least 4,000,000 wells for the U.S. and at least 370,000 for Canada. Methane emission factors range from 1.8 × 10^{-3} g/h to 48 g/h per well depending on the plugging status, well type, and region, with the overall average at *6.0 g/h. We find that annual methane emissions from abandoned wells are underestimated by 150% in Canada and by 20% in the U.S. Even with the inclusion of two to three times more measurement data than used in current inventory estimates, we find that abandoned wells remain the most uncertain methane source in the U.S. and become the most uncertain source in Canada. Understanding methane emissions from abandoned oil and gas wells can provide critical insights into broader environmental impacts of abandoned wells, which are rapidly growing in number around the world."*

* = 19.4kt/year for Canada

Seepage pathway assessment for natural gas to shallow groundwater during well stimulation, in production, and after abandonment
Maurice Dusseault and Richard Jackson, University of Waterloo





Natural and incipient fractures exist in stiff rocks such as shale. Incipient fractures are weakness planes that are not fully fractured but can be opened through pressure, stress and volume changes…

1. Volume changes → shearing
2. Shear propagates fractures
3. Incipient fractures opened
4. The rock mass dilates (open fractures & volume increase)
5. Permeability increases hugely, even with small fracture openings

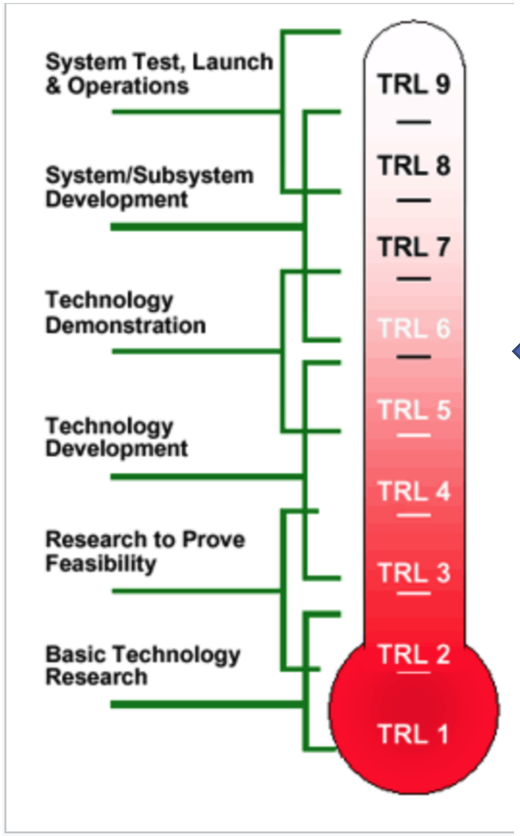
Figure 3. Shear dilation enhances the flow capacity of the rock mass.

Measured/Estimated CH4 Leak Rate

Location	Methane Source	Leaking Wells Status	Leaking rate given	Annual CH4 leak	Longevity on the Perpetual Scale
UK Surface	Surface infrastructure	-	50kt/year	**50kt directly into atmosphere**	**Finite – Linked directly to operations**
UK Offshore Wells	5,500 wells	Older Abandoned wells within 600m of gas at < 100m depth – Environmental barrier ineffective?	0.7-4.2 kt/year shallow gas from 1792 wells	**2-13kt from 5,500 wells into the atmosphere less dissolution (100m water cut-off for entry into the atmosphere?)**	**Perpetual Dissolution = sea acidification**
Canada Onshore Wells	370,000 wells	Orphan or abandoned	6g/hr shallow gas	**19.4kt directly into atmosphere from the 370,000 wells**	**Perpetual Already a high profile ESG challenge**

Where are we in Canada?

- We still want to progress to TRL6
- We have been introduced via our new network in Canada to the Petroleum Technology Alliance Canada (PTAC) who are interested enough to recommend the testing of Quick Clay by InnoTech https://innotechalberta.ca
- We have entered exploratory discussions with InnoTech
- Two Canadian service companies "believe we are on to something"

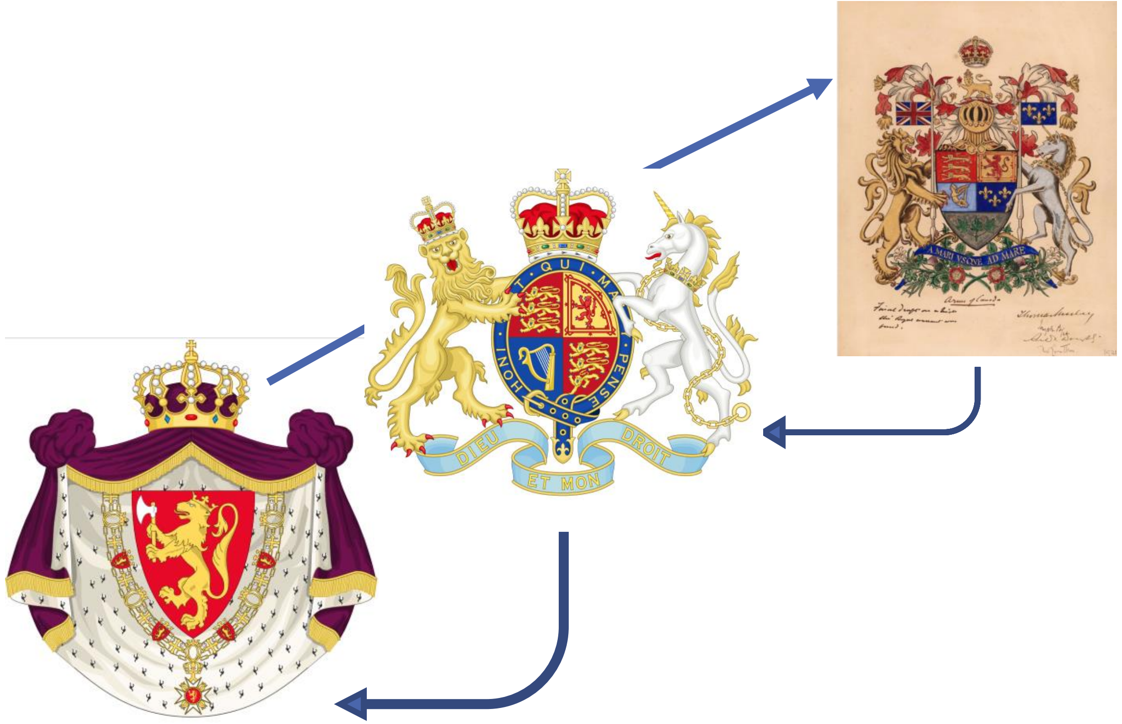


NASA technology readiness levels

Our current Target

Where do we want to be?

- Moving in Canada on a Quick (Leda) Clay project and on to PTAC's and NSTA's emerging technology lists at TRL6.
- Ultimately helping to eliminate the well leakage impediment to achieving net zero globally



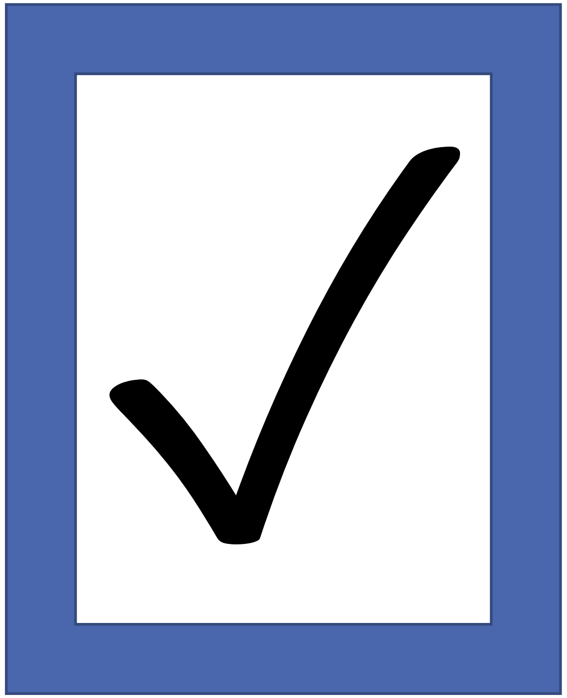
Summary: Quick Clay properties vs Cement properties

Property	Cement	Quick Clay	Deduced Advantage in Favour of Quick Clay or Cement?
Climate Change			
Carbon footprint of production	0.95 CO_2 e/T	Less than 0.48T CO_2 e/T	Quick Clay
Associated Costs			
Production Costs	Involves hard rock mining, comminution, calcination	Will involve front-end loader, digging, screening, breaking, drying - quick clay estimated 30% less than cement	Quick Clay
Handling			
Transport and handling to rig site	Well known supply chain	Supply chain only needs to be modified to accommodate a new starting point i.e. the source of the dry quick clay powder plant	Equal
Plant for placement into well	Well developed	Will work with the same plant as cement	Equal
Physical and chemical properties			
Dry powder density	1.5 T/m^3	1 T/m^3	Equal
Wet density	2.4 T/m^3	2 T/m^3	Equal
Thixotropy	Some pre-setting	High, offering additional placement and removal opportunities	Quick Clay
Pumpability	Manageable until sets, more difficult to pump as temperature	Better than cement - no setting nor temperature dependence	Quick Clay
Placement and penetration	Uses established techniques	To be examined - for example could be locally hardened by adding salt (KCl)	To be determined - but
Setting times	Acts as an operational constraint	Not a constraint - doesn't set, remains as stiff as clay	Quick Clay
Set state	Solid	Stiff clay-like	Quick Clay for deformation accomodation
Chemical stability	Deteriorates over time	Inert	Quick Clay
Bond strength	Depends on cleanliness of surfaces	Doesn't bond - this will be allowed for in plug design and application	Quick Clay
Sealability	Can deteriorate with time	Will retain sealability	Quick Clay
Toxicity	Toxic	non-Toxic	Quick Clay
Mechanical properties			
Accomodation of compression	Will fail as a brittle material	Will deform as a plastic material or become a liquid filling any voids	Quick Clay
Accomodation of tension	Will fail as a brittle material	Will deform as a plastic material or become a liquid filling any voids	Quick Clay
Accomodation of shear	Will fail as a brittle material	Will deform as a plastic material or become a liquid filling any voids	Quick Clay
Property modification	Well known	To be investigated	To be investigated
Removal on re-entry	Requires drilling out	Could be flushed out	Quick Clay
Cost			
Operational Cost		Same plant used as for cement, but less material and cheaper material	Quick Clay

Quick Clay can contribute to a transition to net zero by:

4: Saving costs

- Material Costs
- Operational costs
- Liability costs?

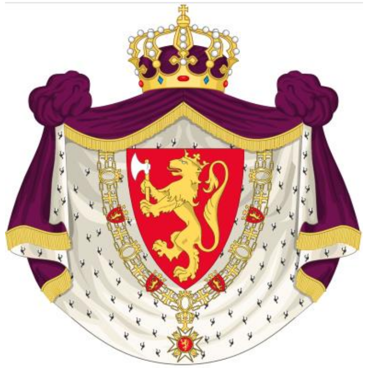


Conclusions

1. Quick Clay appears to have considerable potential as a barrier and plugging material, contributing in several ways to the transition to net zero
2. We are at stage TRL 3 and believe we can move to TRL 6 with our quick clay project by undertaking a pumping and placement trial using conventional plant
3. Canada appears to offer the ideal location for the trials because of possible funding, onshore well configurations, availability of quick clay and in-country interest, - we are pursuing this

Acknowledgements

- Bill Cairn's Encompass ICOE, whose network of professionals brought the authors together
- The Norwegian Government for making a contribution to Quick Clay testing costs
- Prof Rebecca Lunn, Dr Matteo Pedrotti and Lucas Hand , University of Strathclyde for enabling continued quick clay property research
- Our growing network of professionals in Canada, including PTAC and Innotech staff
- Dr David Risk of St Francis Uni for joining us to monitor well emissions before and after the anticipated Leda Clay trial remedial work



Thank you

(See you at our booth)