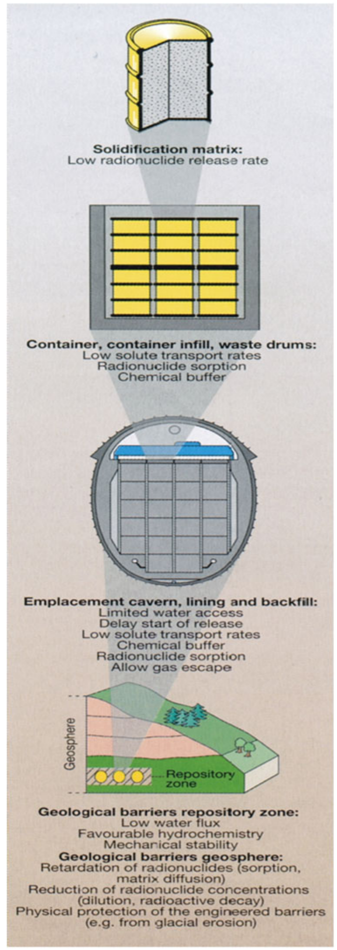
Harpur Hill High pH Industrial Archaeological Analogue Site: scene setting

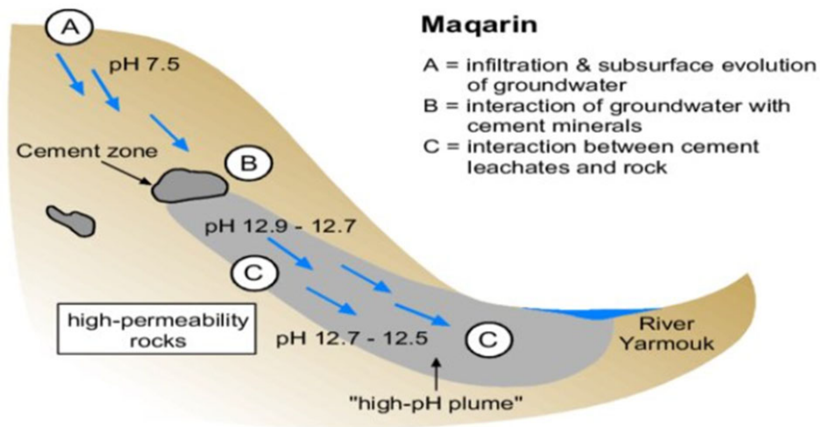
A.E.Milodowski (BGS)

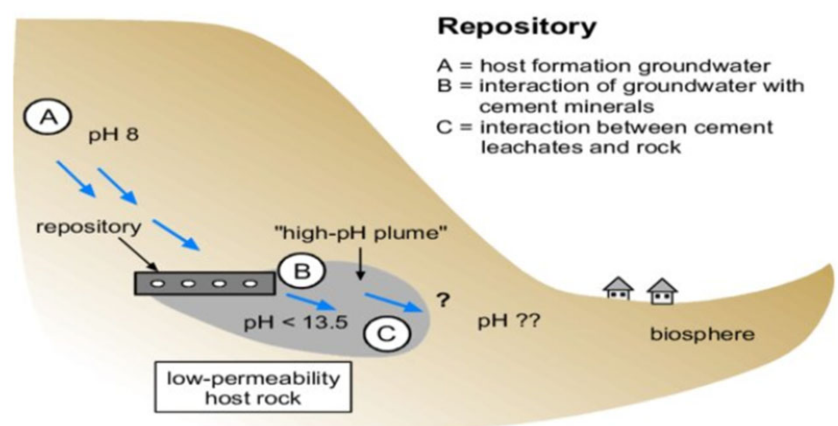
(presented on his behalf by W.R.Alexander)

Why Harpur Hill?

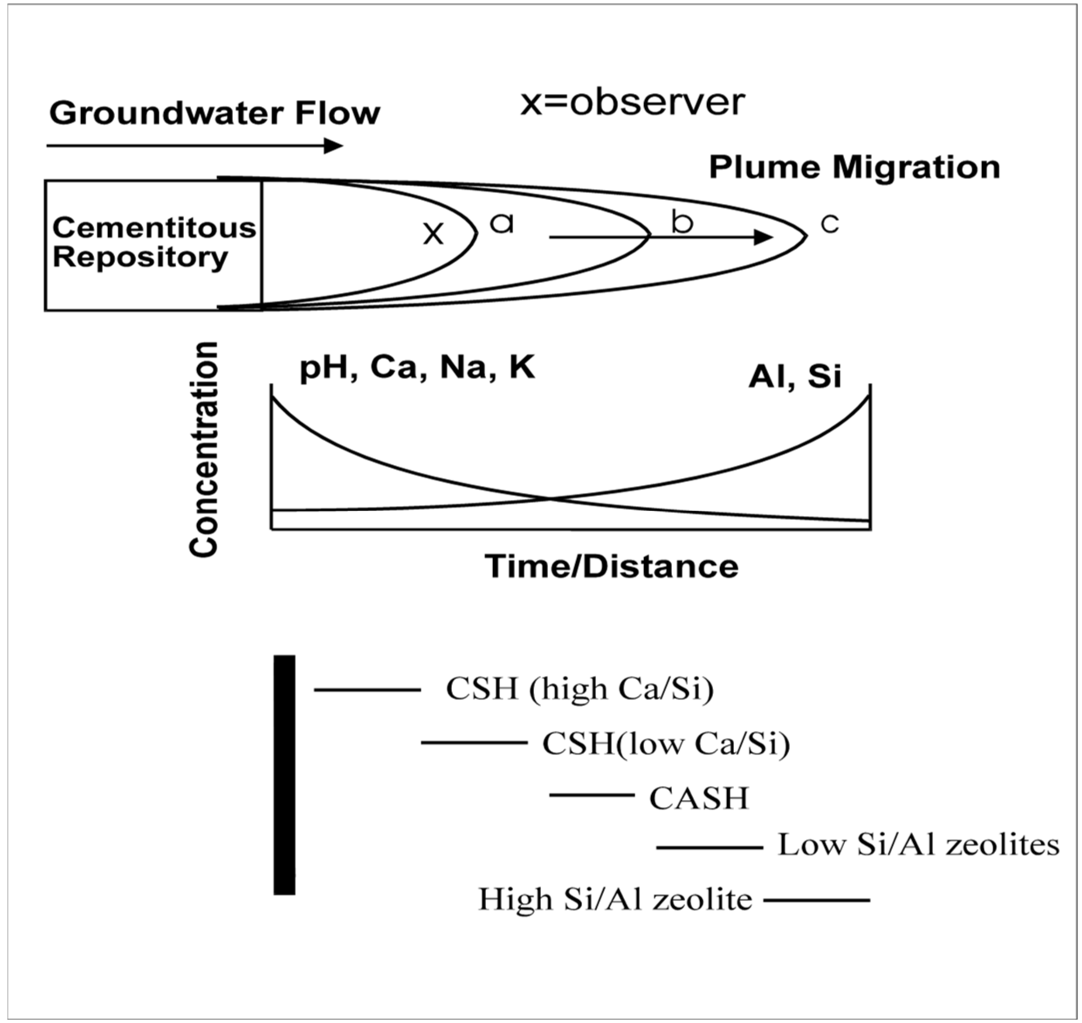


Basis of the analogy





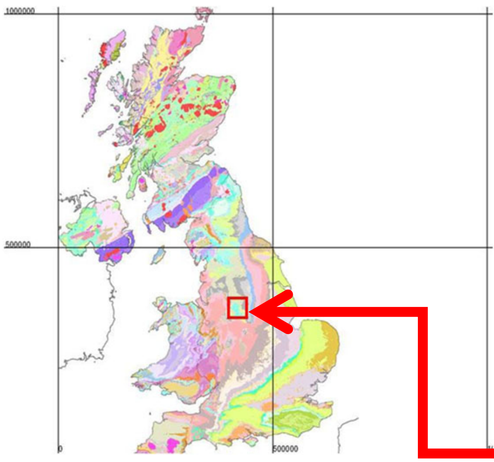
Why Harpur Hill?



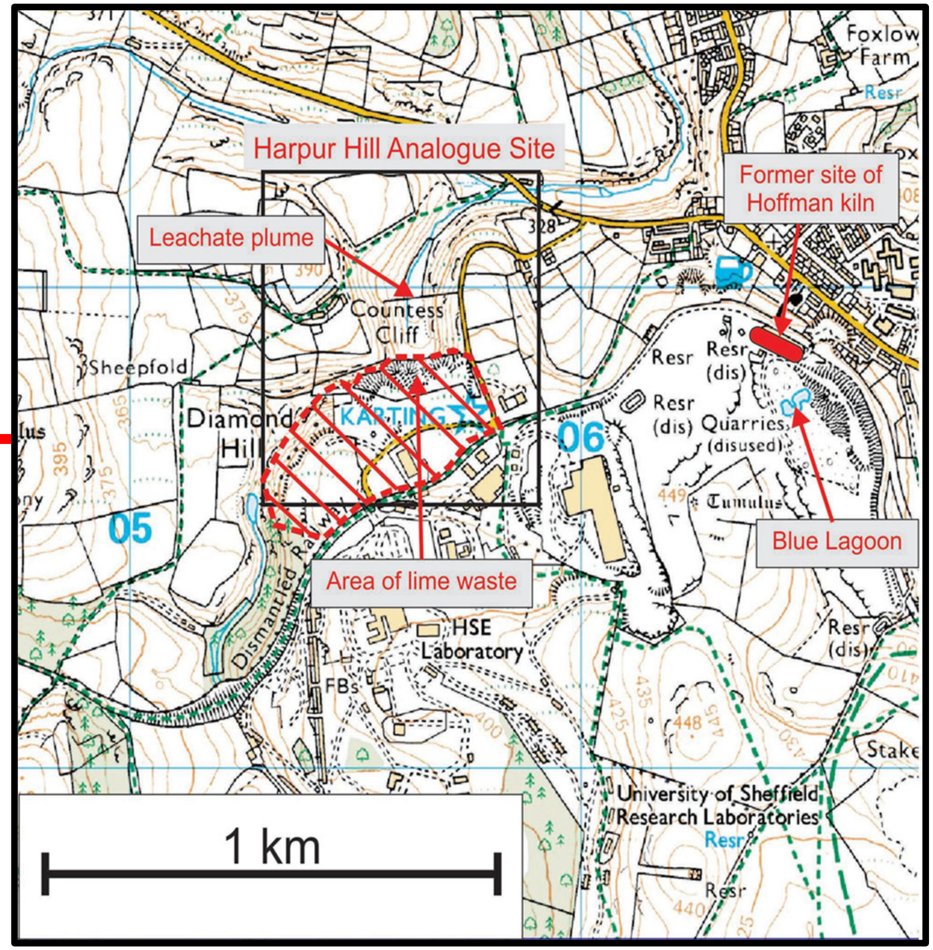
Introduction to Harpur Hill

- Extensive high-pH (pH 12-13) calcium hydroxide [$Ca(OH)_2$] plume and major associated $CaCO_3$ tufa deposits
- Related to shallow groundwater leaching of historic lime kiln clinker waste
- Waste contains significant residual lime, plus portlandite [$Ca(OH)_2$]) hydration product ± possible minor calcium silicates.
- One of similar high pH leachate sites throughout the UK associated with the leaching of lime-bearing and calcium silicate wastes from historic industrial processes (lime kilning, steel and chrome smelting slags)

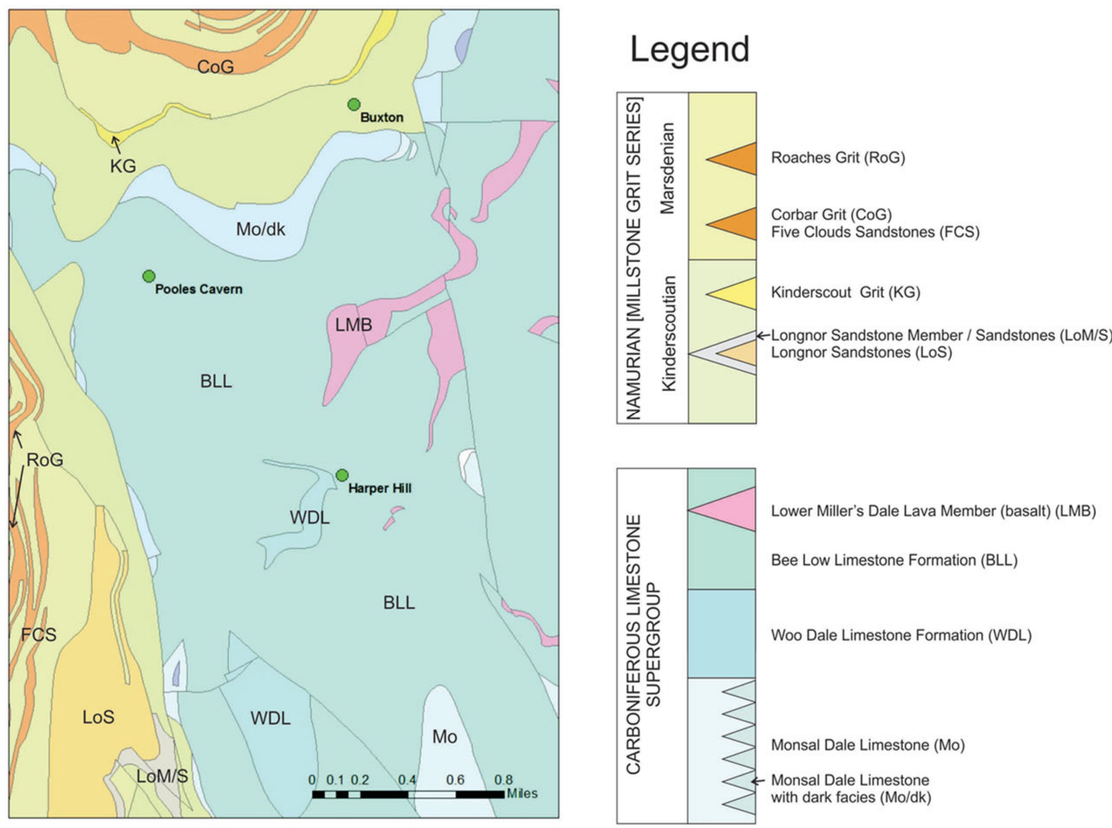
Location and principal site features



Buxton
Peak district, Derbyshire



Geological background



History of lime burning in the Harpur Hill area

Mid 1600's: earliest records of lime kilning on Grin Low

1662: well established lime burning industry in NW area of Grin Low

1734: peak production at Grin Low with over 130 kilns between 17th and 19th centuries

1819: lime kilning has ceased in NW Grin Low and area landscaped (over Poole's Cavern)

1835: First major kilns built at Harpur Hill

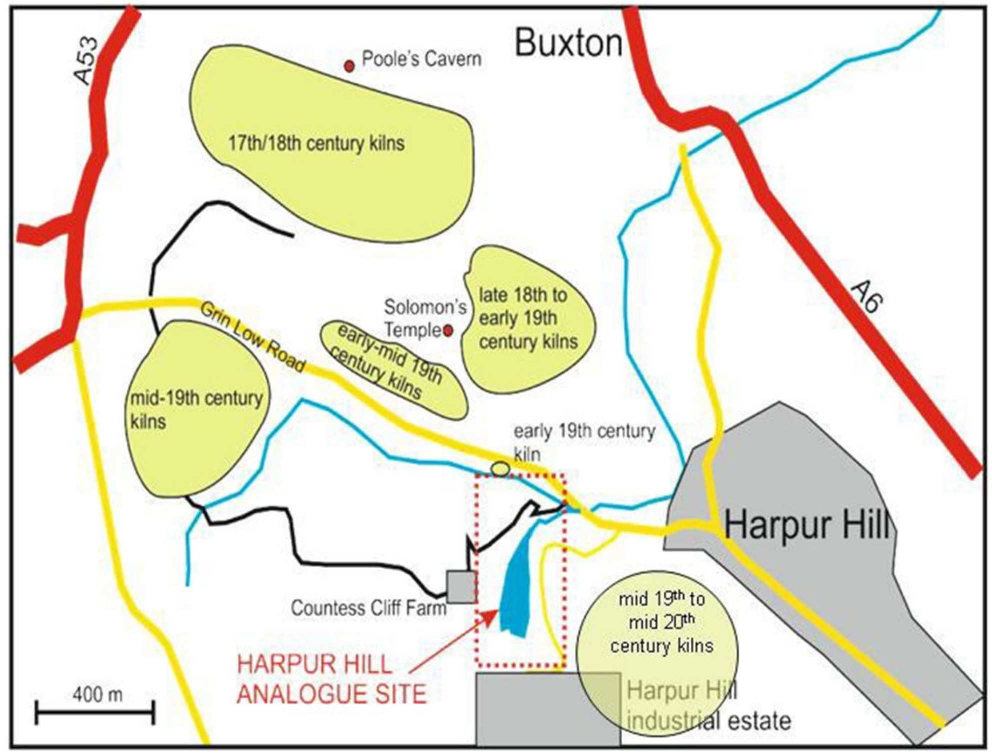
1842: Kilning concentrated to S and SE of Grin Low by this time

1872: Construction of Hoffman kiln at Harpur Hill

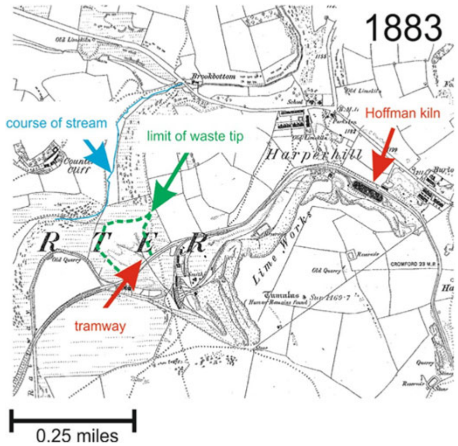
1883-1938: 12 kilns in continuous operation at Harpur Hill

1952: Lime burning ceased at Harpur Hill

1980: Hoffman kiln demolished



Development of lime waste



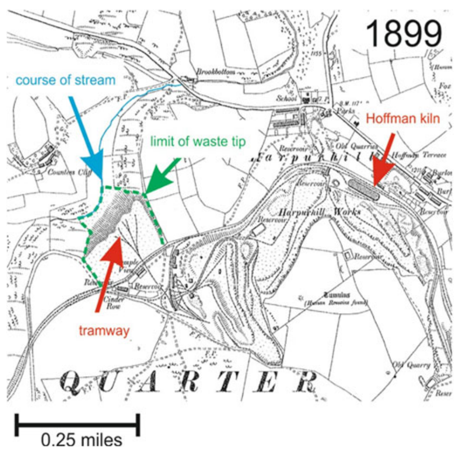
1883: lime waste tip in Brook Bottom valley well-established

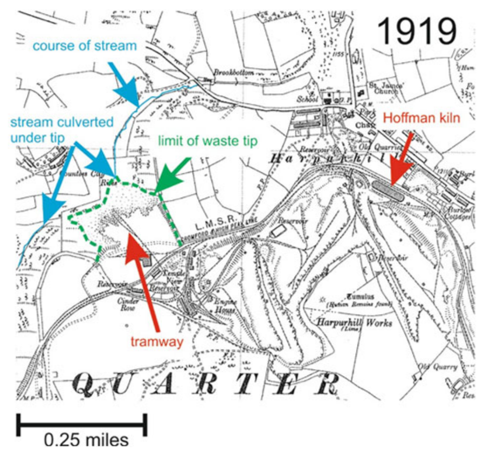
1899: lime wste tip reached the stream and is virtually at its maxmum extent in the north

1919: lime waste tip expanded to inundate the stream, further tipping mainly to southwest

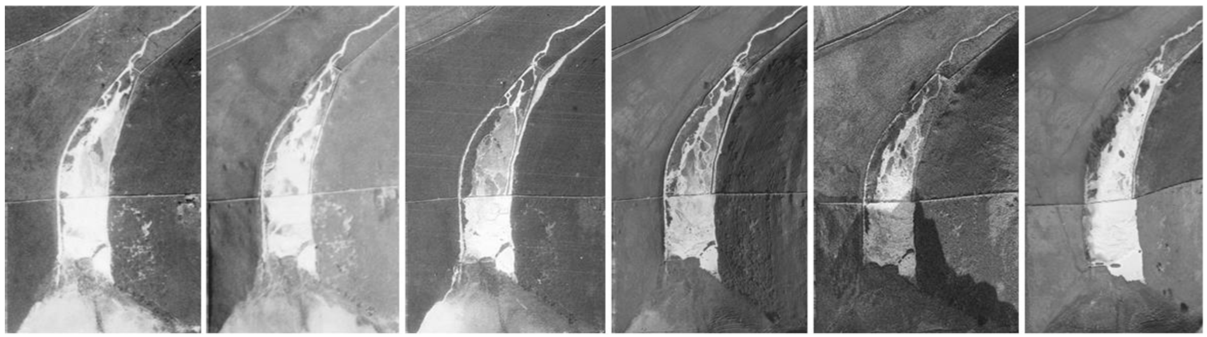
Between 1899 and 1919: the stream was culverted (brick culvert in south west of site)

1919: OS maps now show springs ("Rises") at base of the tip, suggesting that leachate plume may have started by now

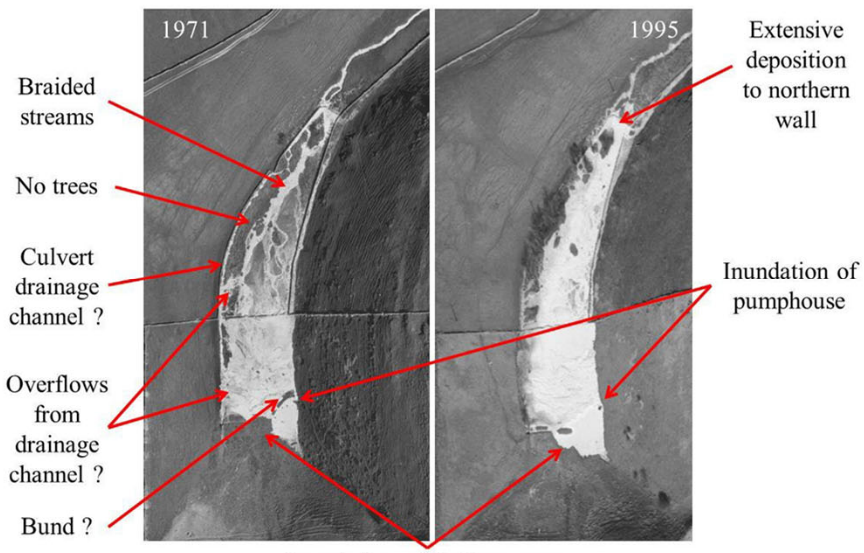




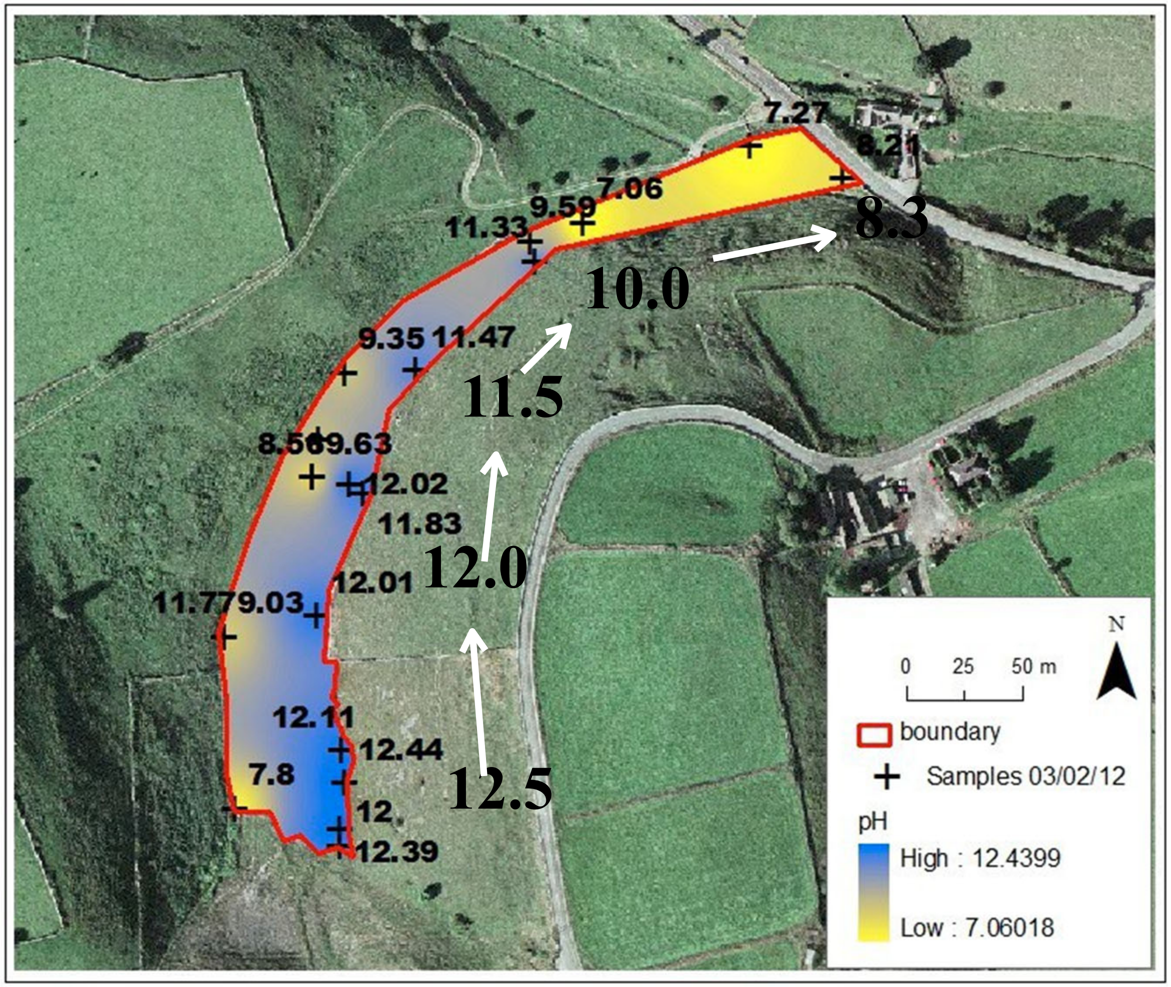
Development of the alkaline plume



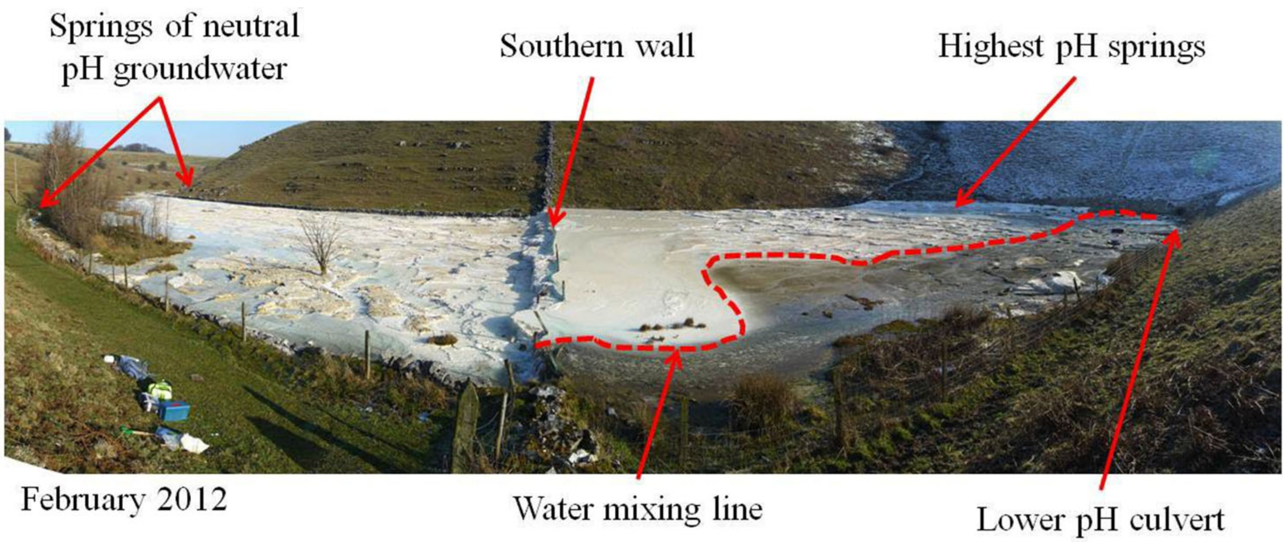
1945 1948 1955 1971 1973 1995



pH distribution

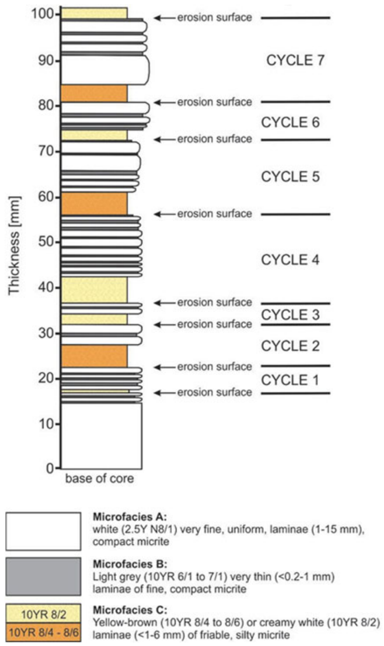


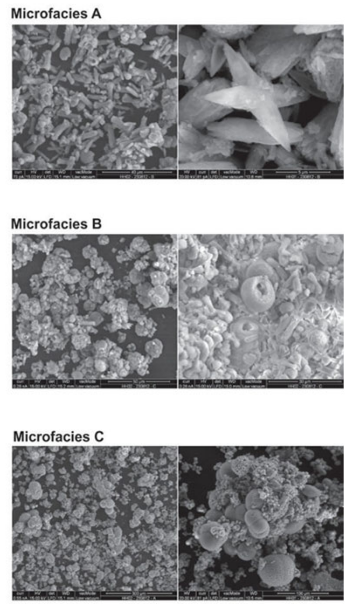
Evolution of the akaline tufa

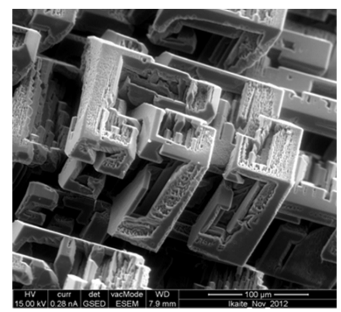


- Complex (bio)geochemistry in surface waters – highly variable, depending on weather conditions (principally rainfall but also temperature)
- Variations on scale of days to weeks
- Dry weather – High pH uniformly across most of the site (~pH11-12.5); stream pH 12.5
- Heavy rainfall / snow melt – pH very variable across the site:
- Toe of tip / upper bund area pH12.5 (or higher)
- Stream inflow pH7
- Lower tufa areas – highly variable pH 7 to 12
- Channels with freshwater constantly migrating across the site
- Microbial “blooms” with changing and lower pH – microbiology changing

Evolution of the akaline tufa





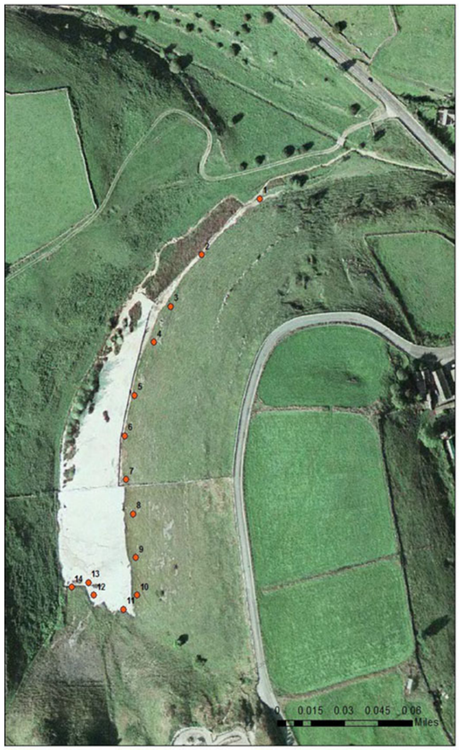


Ikaite
$CaCO_3.6H_2 0$

- Cyclic sedimentology reflecting changing environmental (weather, flood events)
- Carbonate precipitation mechanism constantly changing or changing bias:
- Mixing of freshwater and alkaline leachates
- Reaction of atmospheric CO_2 with alkaline leachates
- Ikaite formation in cold weather (<10 C)
- Flooding – erosion, channel flow channels migrating, eroding,reworking and redepositing the calcareous sediments
- Organic blooms in wet weather (lower pH – higher biological activity)

Inventory assessment

Detailed walkover survey



Inventory summary

Plant species (living and dead) including (High interest)	Metals and metallic materials (High interest)	Building materials (Moderately low interest)	Naturally derived materials (High interest)	Plastics (Low interest)	Other (Moderately high interest)
Grass (cellulosic)	Copper metal	Bricks	**Wood**	Polythene	**Newspaper**
Trees	**Lead metal**	**Concrete**	Sandstone	Polystyrene	**Glass**
Herbaceous plants, horsetails, algae and mosses	Gold metal	Bitumen	Soils, inc. **clays**, silicates etc	PET	Various kiln glazes
	Aluminium alloy		Limestone		
	Various steels inc. galvanised steel		Slag (lime and silicate)		
	Brass		Rubber		
	Plastic coated steel and copper metal		Part burnt coke and coal		

Relevance and issues

•Many of the materials are in the oxic, near-surface waters or exposed to air: {How relevant is this to reducing repository environment?}

•Near surface waters constantly oscillating in chemistry and microbiology {not anticipated in the repository environment}

•Focus should be on materials contained deeper with the sedimentary pile, where conditions more stable regardless of weather and where it may be reducing {more relevant to repository environment} – but locating these may be problematic

•Cellulosic materials present and degrading {grass remains present at original soil- sediment interface and wood (trees, posts) buried deep in the sedimentary pile}

•Alkaline interaction with clays and other silicate minerals at depth beneath the alkaline tufa deposits. Appear to be associated with some microbial mineralisation features (Fe alteration)

•Stable high pH (>12.5) in “upper bunded area” at depth (>0.5 m) regardless of weather conditions {most relevant to the repository environment}

•Formation of metastable ikaite related to carbonation reactions with Ca(OH)2 porefluids may be important with regard to cement alteration through carbonation, under permafrost and cold environmental conditions

Some images of the site

Some images of the site

Some images of the site

Last word – the Blue Lagoon

Bibliography

- Alexander, W.R. & Reijonen, H.M. (2023). Natural Analogues – a catalogue. GTK Research Report for NWS Ltd, UK (archive no. GTK/175/03.02/2020). GTK, Espoo, Finland.
- Deakin, D., West, L.J., Stewart, D.I., Yardley, B.W.D. 2001. Leaching behaviour of a chromium smelter waste heap. Waste Management, 21, 265-270
- Field, L.P.; Milodowski, A.E.; Shaw, R.P.; Stevens, L.A.; Hall, M.R.; Kilpatrick, A.; Gunn, J.; Kemp, S.J. ; Ellis, M.A.. (2017). Unusual morphologies and the occurrence of pseudomorphs after ikaite ($CaCO_3 \cdot 6H_2O$) in fast growing, hyperalkaline speleothem. Mineralogical Magazine 81, 565-589.
- Hartland, A., Fairchild, I.J., Lead, J.R., Dominguez-Villar, D., Baker, A., Gunn, J., Baalousha, M. & Ju-Nam, Y. (2010). The dripwaters and speleothems of Poole's Cavern: a review of recent and ongoing research. Cave and Karst Science 36, 37-46.
- Milodowski, A.E., Shaw, R.P. & Stewart, D.I. (2013). The Harpur Hill site: its geology, evolutionary history and a catalogue of materials present. BGS CR/13/104. BGS, Keyworth, UK.
- Milodowski A, Rushton J, Purser G, Rochelle C, Kemp S, Shaw R & Ellis M (2014) The formation of ikaite ($CaCO_3.6H_2O$) in hyperalkaline springs associated with the leaching of lime kiln waste. Goldschmidt Abstracts, 2014, 1697.
- Moyce, E.B.A., Milodowski, A.E., Morris, K. & Shaw, S. (2015). Herbert's Quarry, South Wales – an analogue for host-rock alteration at a cementitious radioactive waste repository? Mineralogical Magazine, 79, 1407 – 1418.
- Smith, S L.; Rizoulis, A; West, J M.; Lloyd, J R.. (2016). The microbial ecology of a hyper-alkaline spring, and impacts of an alkali-tolerant community during sandstone batch and column experiments representative of a geological disposal facility for intermediate-level radioactive waste. Geomicrobiology Journal 33, 455-467.
- Wragg, J.; Milodowski, A.E.; Shaw, R.P. (2014). The Harpur Hill Site : an assessment as an analogue to a cementitious GDF. Nottingham, UK, BGS CR/14/060N. BGS, Keyworth, UK.

- Ongoing microbiology studies addressing the 2023 NWS microbiology roadmap by Jon Lloyd's group at the University of Manchester (e.g. Rebecca Snow's previous presentation) and BGS