It’s in the sand ….

Clive Mitchell
Industrial Minerals Specialist

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Clive at a silica sand quarry in Hampshire
http://www.bgs.ac.uk/staff/profiles/1159.html

Its all about me…

Originally from the West Country

- Congresbury, North Somerset

Family man

27 years at British Geological Survey (BGS) in Nottingham

- Chartered Geologist, specializing in industrial minerals
- Head of Communications, BGS

Beer brewer

Social media

- Twitter @CliveBGS
- YouTube CliveJM

MineralsUK
Centre for sustainable mineral development

BGS 1835

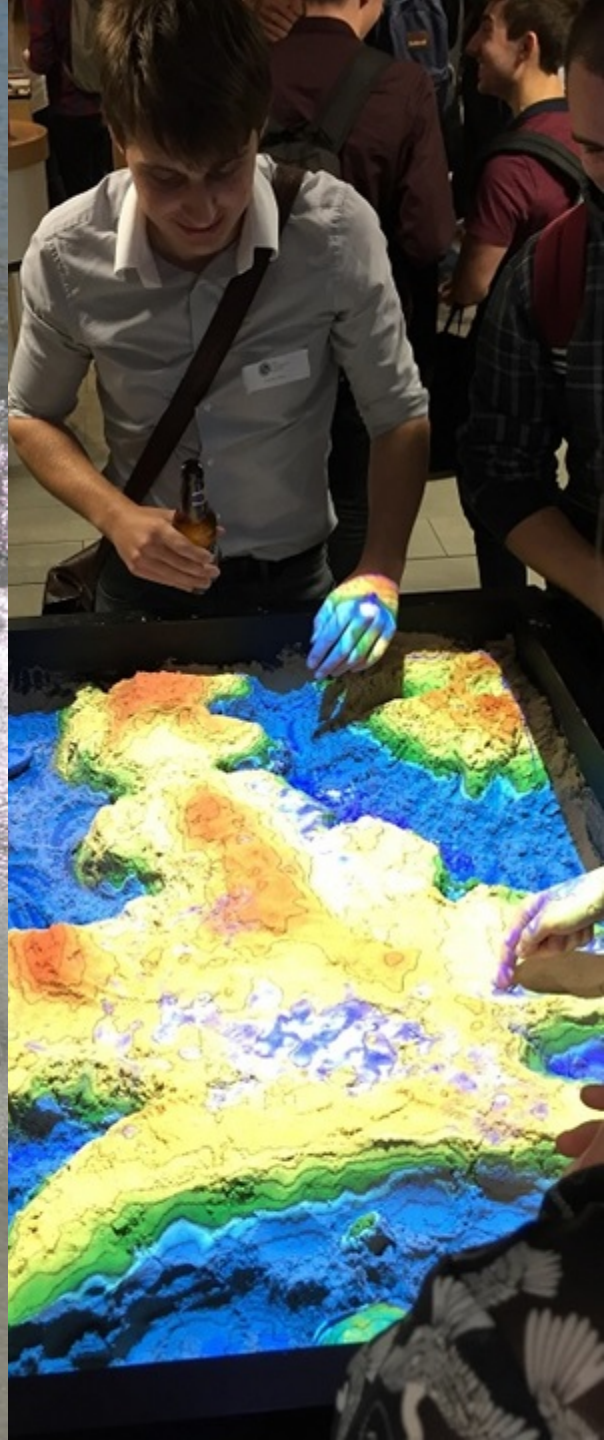
What's it all about…

- What is Sand? Obvious, really….?
- What is it used for? Its as clear as …
- How do you find it? Some fun in the sun…
- How to make it useful …
- Something controversial
- And finally the fun bit at the end …

What is sand?

- Sand is “loose material consisting of rock or mineral grains” with a size between 1/16mm (63 microns) & 2mm
- It can be made of practically anything – the size is the key factor
- Sand is part of a particle-size continuum…..

Clay	< 0.002 mm (2 microns)
Silt	0.002 – 0.063 mm (2 - 63 microns)
Sand	**0.063 – 2 mm**
Gravel	2 – 63 mm
Boulders	> 63 mm



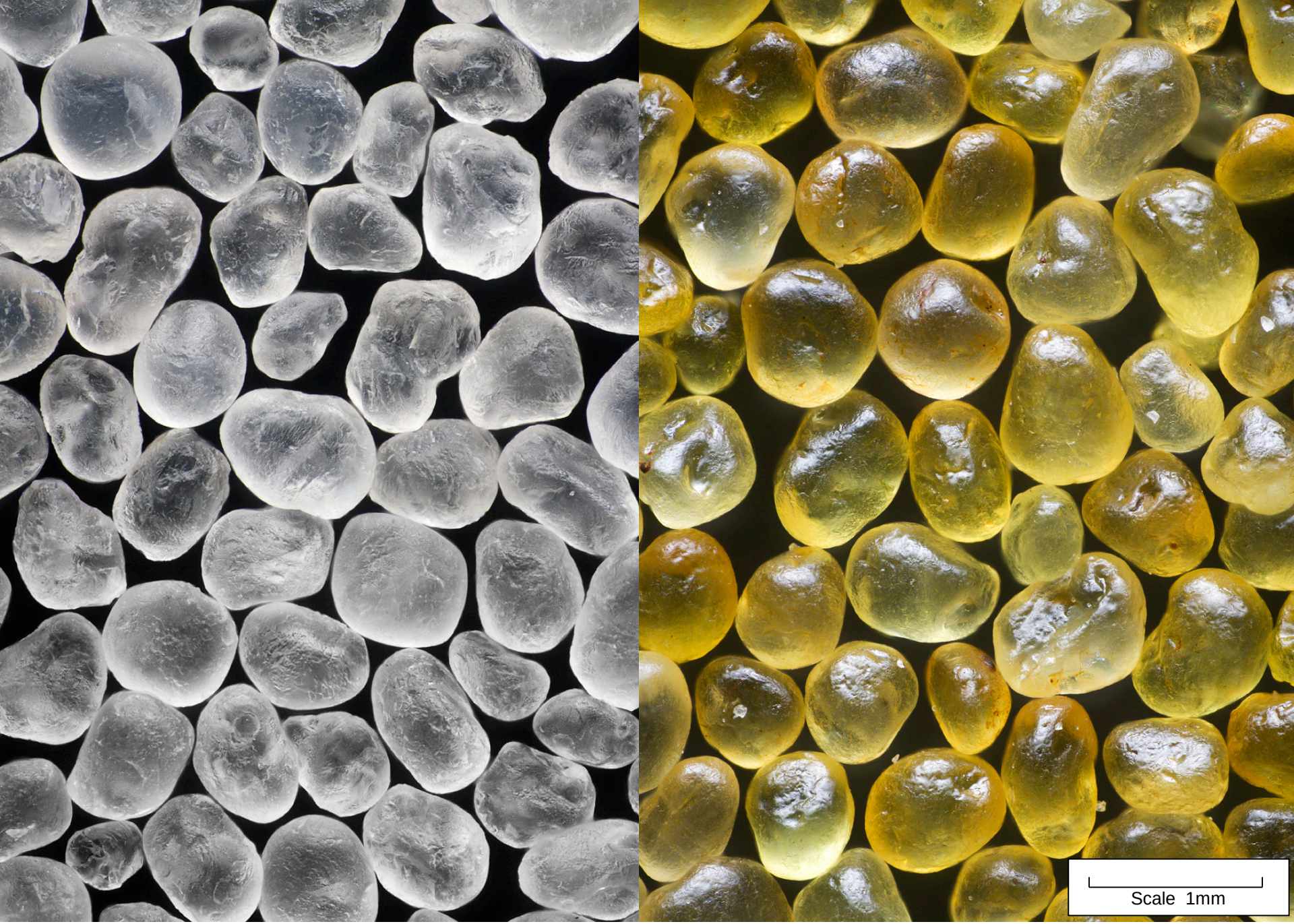
Work, rest and play….

Silica: The basics

Quartz specimen from the Royal Geological Society of Cornwall Collection
(held at the British Geological Survey)

http://www.bgs.ac.uk/collections/gallery.html

- Silica is chemical compound silicon dioxide (SiO_2), 61% of earths continental crust
- Quartz is main form and polymorphs cristobalite & tridymite & cryptocrystalline varieties chert, flint, chalcedony & agate
- Rock forming mineral in granite, gneiss, sandstone, quartzite, pegmatites etc...
- Quartz is hard (Mohs 7), resistant to weathering and concentrated over many erosion cycles to form silica sand
- Silica sand ('Industrial sand') contains a high proportion of quartz and mainly for non-construction uses



Industrial Sand (20/40): Northern White + Resin-coated, Illinois, USA (Courtesy of Fairmount Santrol)

Fulgurite (‘Lightning Stone’) Adrar, Mauritania

Silica sand use in the UK

Main uses (2007 figures *):

- Glass production (39%)
- Foundry sand (11%)
- Horticultural & leisure uses (26%)
- Other industrial uses (24%) including:
  - Abrasive and shot blasting
  - Filter drainage media
  - Production of bricks, ceramics, mineral filler, refractories & rock wool
  - Production of sodium silicate, fused silica, silicon carbide and other silicate reagents

* BGS Mineral Planning Factsheet: Silica sand

Industrial factors for silica sand

Chemical composition

Silica (SiO_2), iron (Fe_2O_3), alumina (Al_2O_3), alkalis (Na_20 & K_2O), alkaline earths (MgO & CaO) and heavy metals (Ni, Co, Cu, Cr)

Particle-size & distribution

Fine or coarse particle size? Narrow or wide distribution?

Particle shape

Round, angular, spherical, platy, acicular?

Refractory minerals

Zircon, chromite, corundum, kyanite, sillimanite, andalusite etc...

Other contaminants

Clay, feldspar, calcite, mica, dust, organic matter, etc…

Glass sand properties

Property	Colourless (Flint) glass containers	Flat glass (Float, sheet & rolled plate)	Coloured (Amber & green) glass containers
Silica (SiO_2) content	98.5 to 99%		
Iron (Fe_2O_3) content	<0.035%	0.04 - 0.1%	0.25 - 0.3%
Alumina (Al_2O_3) content	0.5% max.	0.03% max.	0.2 – 1.6%.
Limits on:	Alkalis (Na_2O & K_2O), colourants (Ni, Cu, Co) & refractory minerals (chromite, ilmenite, zircon, rutile, corundum etc...)		
Particle-size	0.1 to 0.6mm (100 to 600 microns)		
Particle-shape	Angular quartz grains may aid melting?		

Silica sand in the field

- Ideally, viewed with a hand lens quartz grains must be clean and clear, with no inclusions or contaminants.
- Naturally occurring clean, clear, well-sorted, monomineralic quartz sands needing no processing are rare
- Field sampling (pitting, trenching, augering and drilling)


Arabian Gulf
Dubai
Abu Dhabi
U A E
Oman
Saudi Arabia
0
50 km

Clive Mitchell, Industrial Minerals Specialist,

British Geological Survey

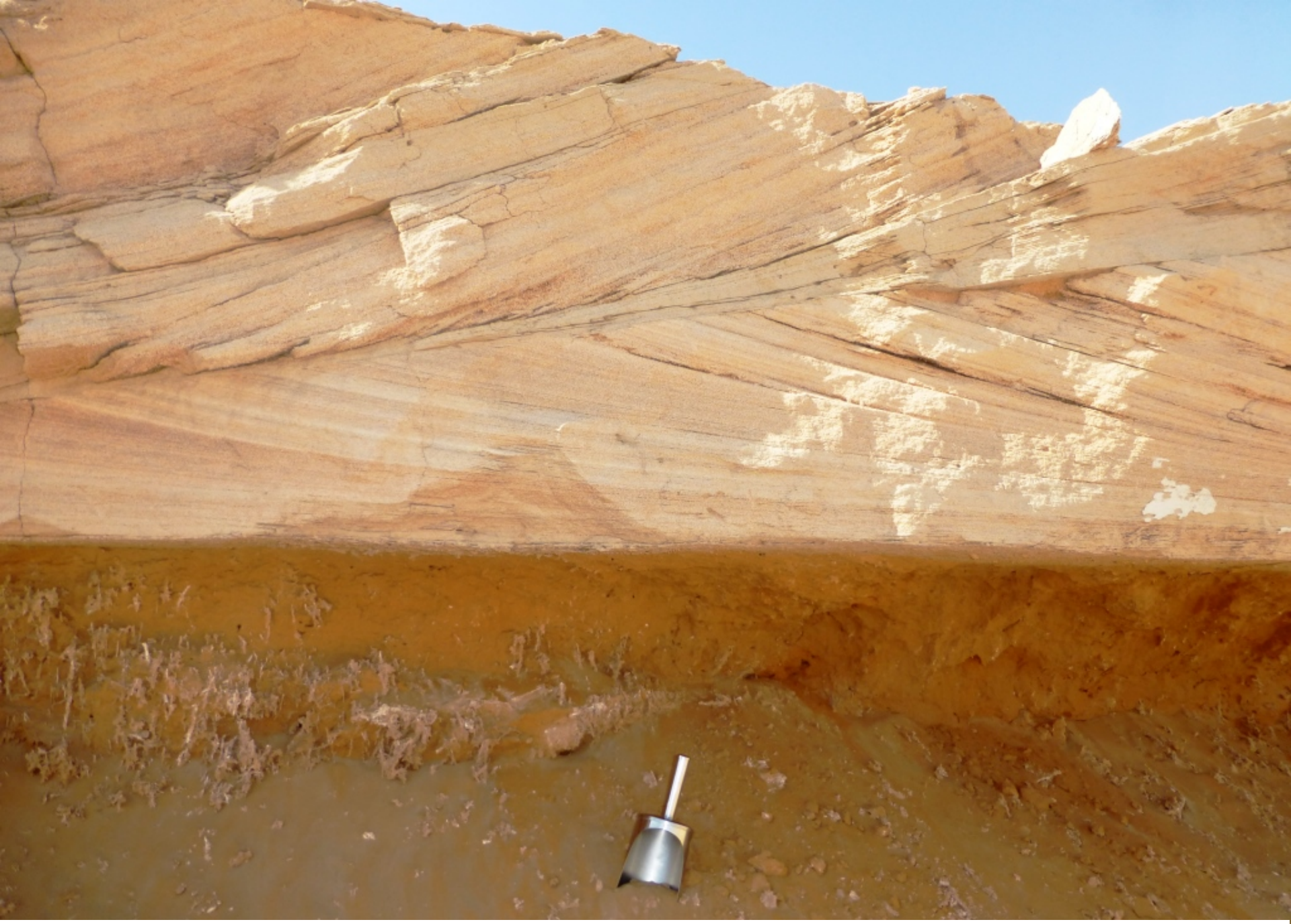
Andy Farrant, Geologist

British Geological Survey

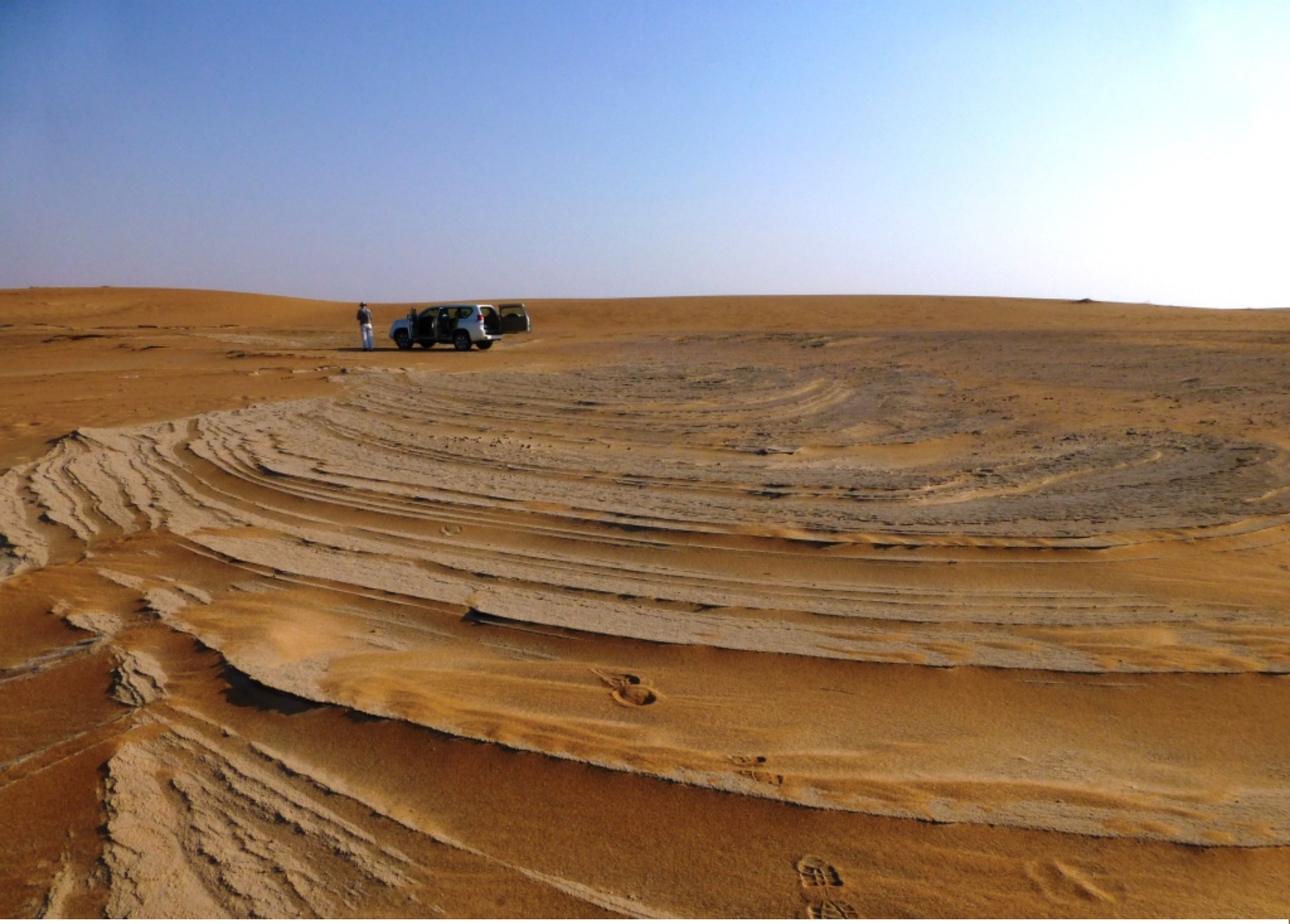
Sampling sandstone

Sampling gravel plain

Sampling modern dune sand



‘Fossilised dune’ sandstone exposed by quarrying



‘Fossilised dune’ sandstone exposed by wind erosion

Zeugen Ghayathi (palaeodune) sandstone with a protective cap of limestone and gypcrete

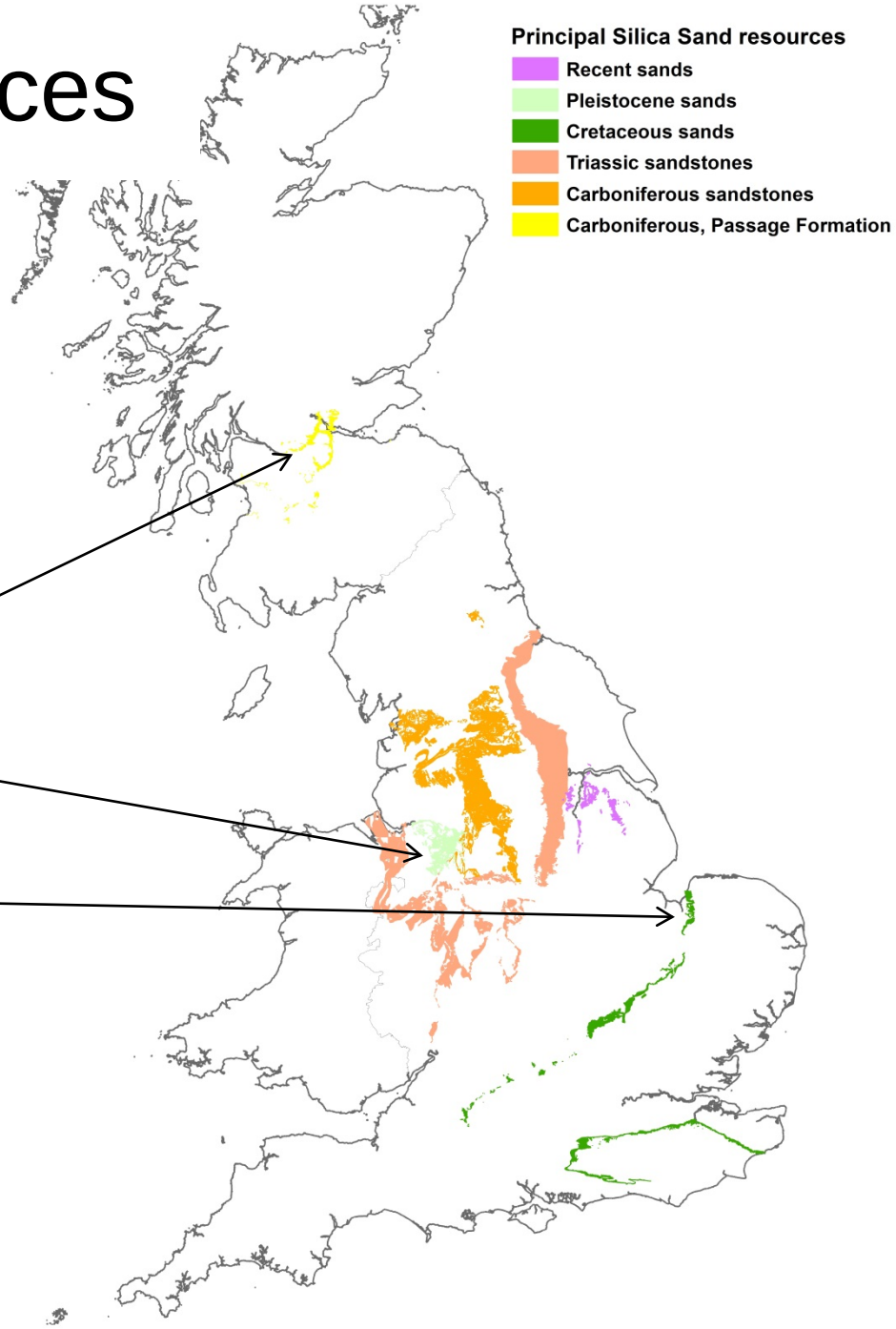
Silica sand in the lab

- Chemical composition (by XRF analysis) and particle-size distribution (by wet or dry sieving) are key properties
- Further use-related properties:

  Mineralogical composition (by XRD analysis); Heavy mineral content (by heavy media separation); Magnetic mineral content (by magnetic separation); Particle-shape (by petrographic analysis)
- Compare data with commercial properties

UK silica sand resources

- The UK is nearly self-sufficient in silica sand
- 39 quarries produce 3.9Mt of silica sand (2012 figures*)
- Sandstone (weakly cemented) e.g. Carboniferous Passage Fm , central Scotland (glass)
- Glacial sand e.g. Pleistocene Chelford Sand F^{m}, Cheshire (flat glass)
- Near shore marine/ coastal (dune / beach) sand e.g. Lower Cretaceous Sandringham Sands F^{m}, Leziate, Norfolk (glass)
- Alluvial (river), lacustrine (lake), aeolian (wind blown) sand



* Office for National Statistics, 2014

Extraction and mineral processing

- **Sand deposits:** Typically 80-85% quartz (rarely >95%) + feldspar, mica, rock fragments, clay & minor accessories
- **Extraction:** surface quarrying by suction dredging or dry working unconsolidated sand; ‘ripping’ soft sandstone
- **Size classification:** by screening and/ or hydrosizing to remove fines (<0.1mm) and coarse sand (>0.6mm)
- **Cleaning grain surfaces:** attrition scrubbing & sulphuric acid leaching to remove Fe oxides, clay and other coatings
- **Further processing:** gravity separation, high-intensity wet magnetic separation or froth flotation to remove non-quartz
- Drying and final product sizing; resin coating (foundry sand); calcination (ceramic quartz); milling (mineral filler)

Congleton Sand: Silica sand quarry, Cheshire, UK

Nottingham Castle Sandstone Formation: Silica sand quarry, Mansfield, Nottinghamshire, UK

Woburn Sand Formation: Silica sand quarry, Leighton Buzzard, Bedfordshire, UK

Woburn Sand Formation: Silica sand quarry, Bedfordshire, UK

Folkestone Sand Formation: Silica sand quarry, Hampshire, UK

Mining of Folkestone Formation, Godstone, Surrey, UK (circa 1900) http://geoscenic.bgs.ac.uk/

Mining of Folkestone Formation, Godstone, Surrey, UK (circa 1900) http://geoscenic.bgs.ac.uk

Passage Formation: Silica sand quarry, Kincardine-on-Forth, Scotland, UK

Passage Formation: Silica sand quarry, Kincardine-on-Forth, Scotland, UK

Nottingham Castle Sandstone Formation: Silica sand quarry, Mansfield, Nottinghamshire, UK

Passage Formation: Silica sand quarry, Kincardine-on-Forth, Scotland, UK

Silica sand processing plant, Leziate Quarry, Kings Lynn, Norfolk, UK (Sibelco UK)

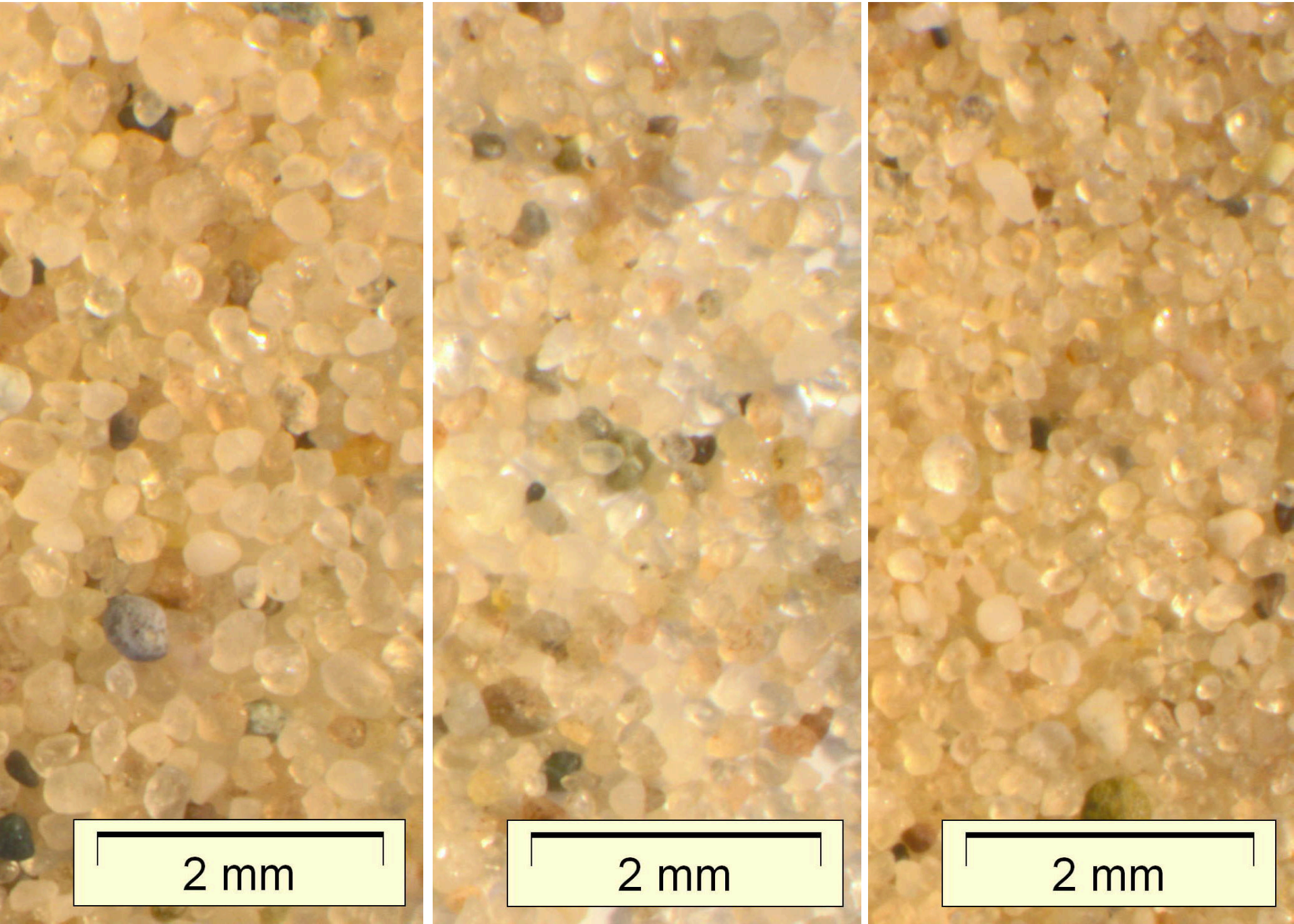
Silica sand drying, Leziate Quarry, Kings Lynn, Norfolk, UK (Sibelco UK)

Passage Formation: Silica sand quarry, Kincardine-on-Forth, Scotland, UK

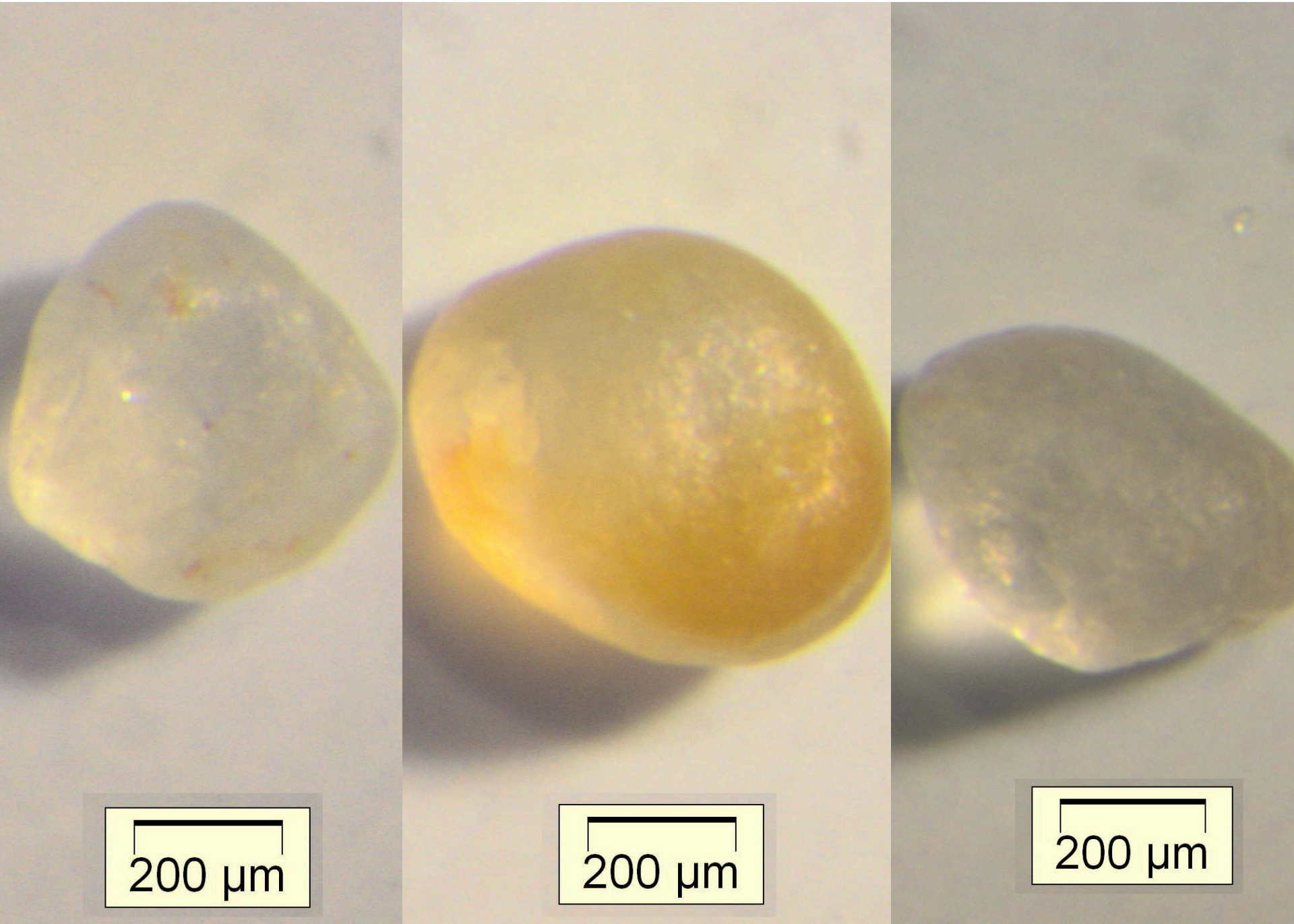
Sandringham Sand Formation: Silica sand quarry, Norfolk, UK

Nottingham Castle Sandstone Formation: Silica sand quarry, Mansfield, Nottinghamshire, UK

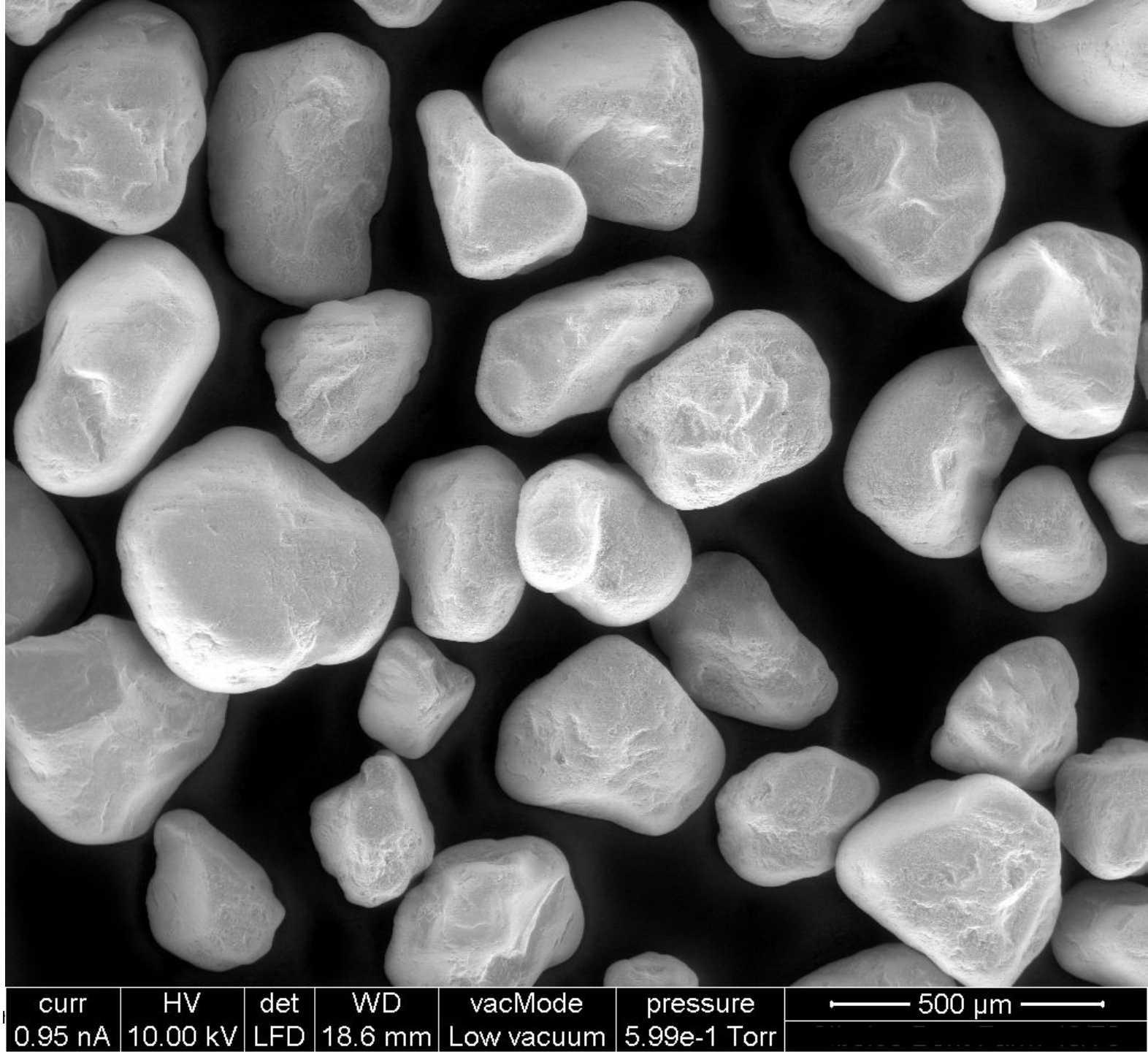
Congleton Sand



Congleton Sand



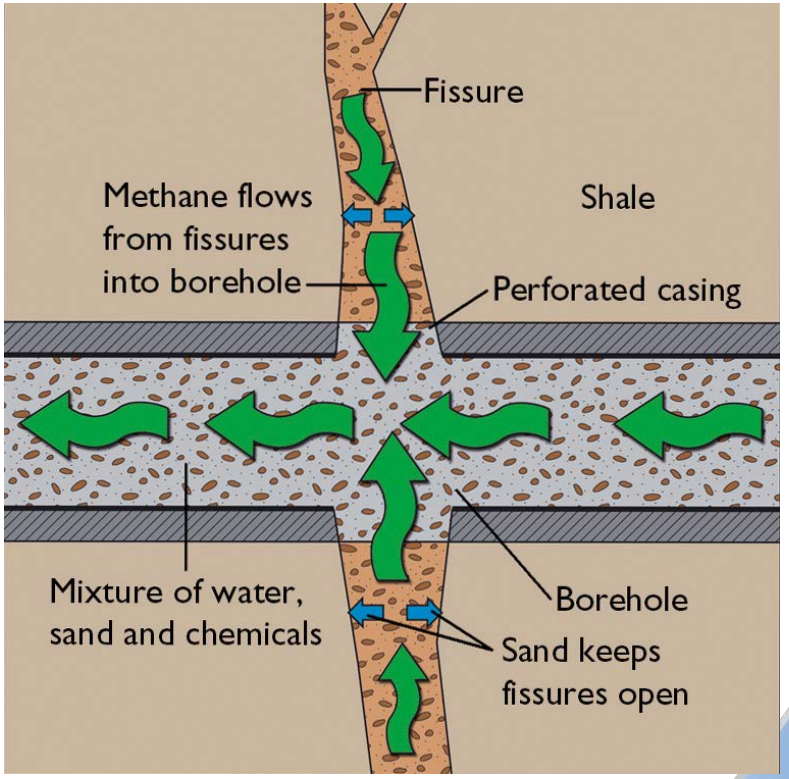
Congleton Sand



Next, something a little more controversial….

Frac Sand

- Silica sand used in hydraulic fracturing treatments to ‘prop’ open fractures in oil & gas reservoirs to enhance recovery
- Also known as ‘Proppant’ sand
- Silica sand is composed of high-purity quartz (SiO_2) sand
- Alternatives – resin coated sand and ceramics (made from calcined kaolin or bauxite)



Frac sand properties

Property	Limits
Composition	>99% Silica, SiO_2 (Quartz or resin coated quartz) or 100% ceramic
Particle-size	Narrow size-distribution - 90% within specified size ranges e.g. 12 / 20 # (1700 – 850 microns) 20 / 40 # (850 – 425 microns) 40 / 70 # (425 – 212 microns) 70 / 140 # (212 – 106 microns)
Particle-shape	Well-rounded, spherical grains (>0.6 for quartz sand and >0.7 for resin coated sand and ceramic proppants)
Crush resistance	Withstand compressive stress 4000 - 6000 psi (28 - 42 MPa), determined at 10% crush material
Acid solubility	Limits on acid soluble material (<2% ≥30/50, <3% <30/50, <7% for resin coated sand or ceramic proppants)
Turbidity	Limits on clay (<2 microns) and silt (2 - 63 microns) content, maximum turbidity 250 FTU (Formazin Turbidity Unit)

BS EN ISO 13503-2:2006 + A1:2009 Petroleum and natural gas industries. Completion fluids and materials. Measurement of properties of proppants used in hydraulic fracturing and gravel-packing operations (related to **API RP-56:1995**)

Frac sand sporting analogy

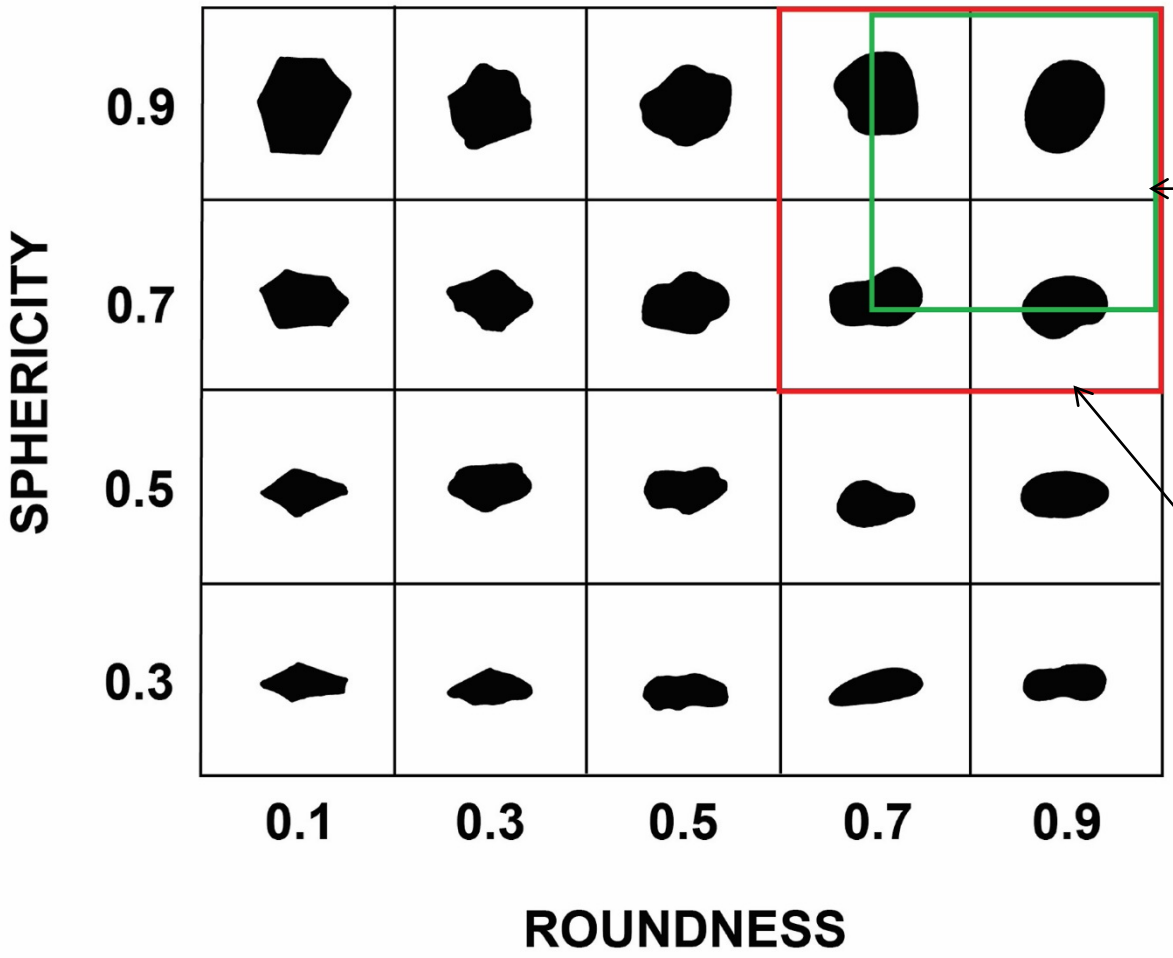
Footballs = 20/40
(850 – 425 microns)

Tennis balls = 40/70
(425 – 212 microns)

Golf balls = 70/140
(212 – 106 microns)

NB Ratios are roughly equivalent between the diameters of the balls and those of the sand grains

Roundness & Sphericity



0.7 Sphericity & 0.7 Roundness for resin coated sand & ceramic proppants

0.6 Sphericity & 0.6 Roundness for Frac Sand

Reference: Krumbein, WC & Sloss, LL (1963) Stratigraphy and Sedimentation, 2nd Edition (Freeman, San Francisco)

Where will frac sand come from?

- Where will the frac sand come from in the UK?
- Foundry sand is a close equivalent - requires high quartz content (98%), round grains with good sphericity, narrow size distribution and free of clay
- Frac sand allows the migration of oil and gas from the reservoir to the well
- Foundry sand allows the gases generated by the contact of molten metal (1200^{o}C) with foundry sand to escape through the mould.
- Gas bubbles trapped at the mould-metal surface create holes and pits, which cause the casting to be rejected.

Potential UK frac sand resources

- Midland Valley of Scotland

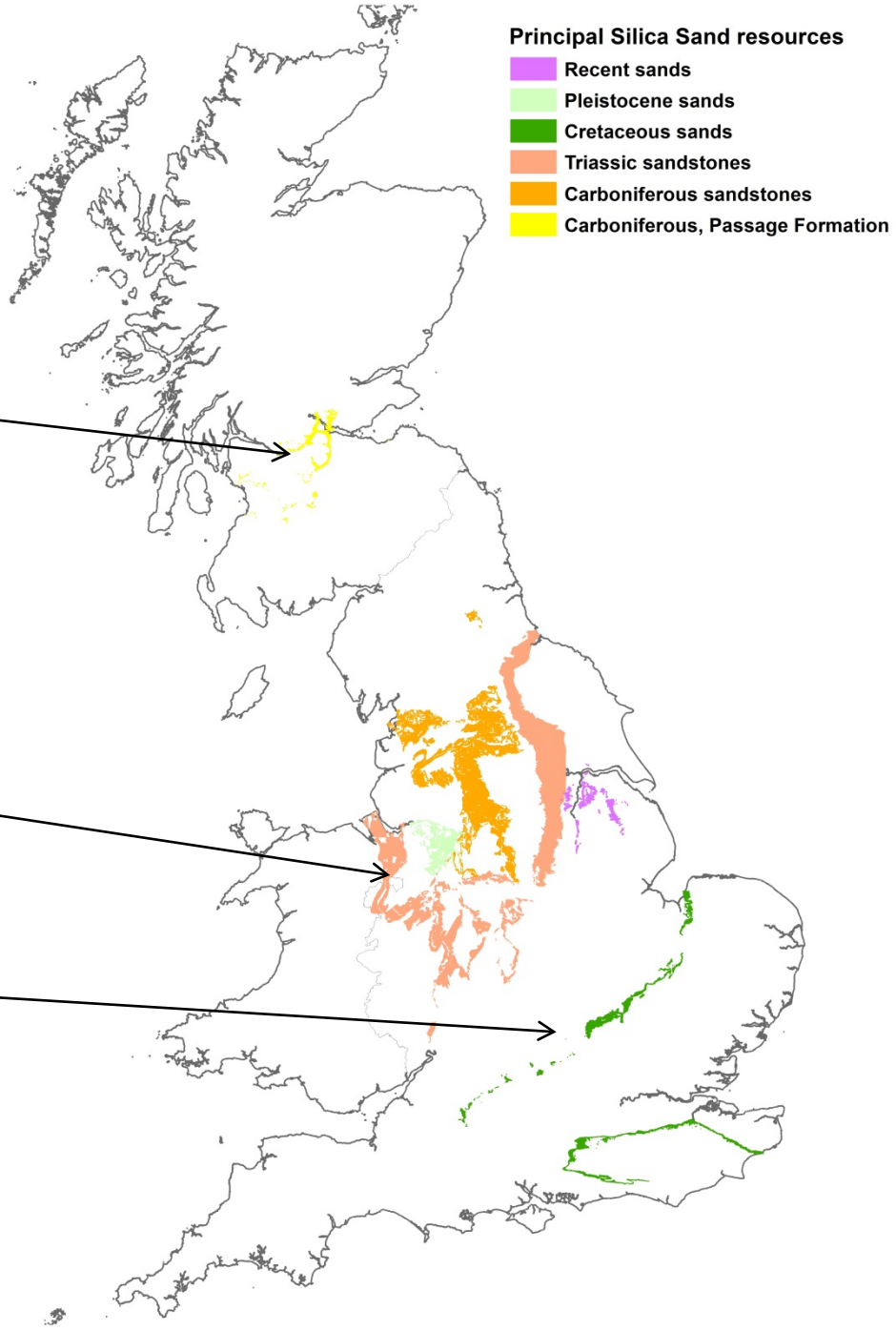
  Sandstone (weakly cemented) e.g. Carboniferous Passage Fm , central Scotland (glass)

- Cheshire

  Pleistocene glacial sands
  e.g. Chelford Sand Formation

- Eastern and southern England

  Near shore marine/ coastal (dune / beach) sand
  e.g. Lower Cretaceous Sandringham Sands Fm, Leziate, Norfolk (glass)

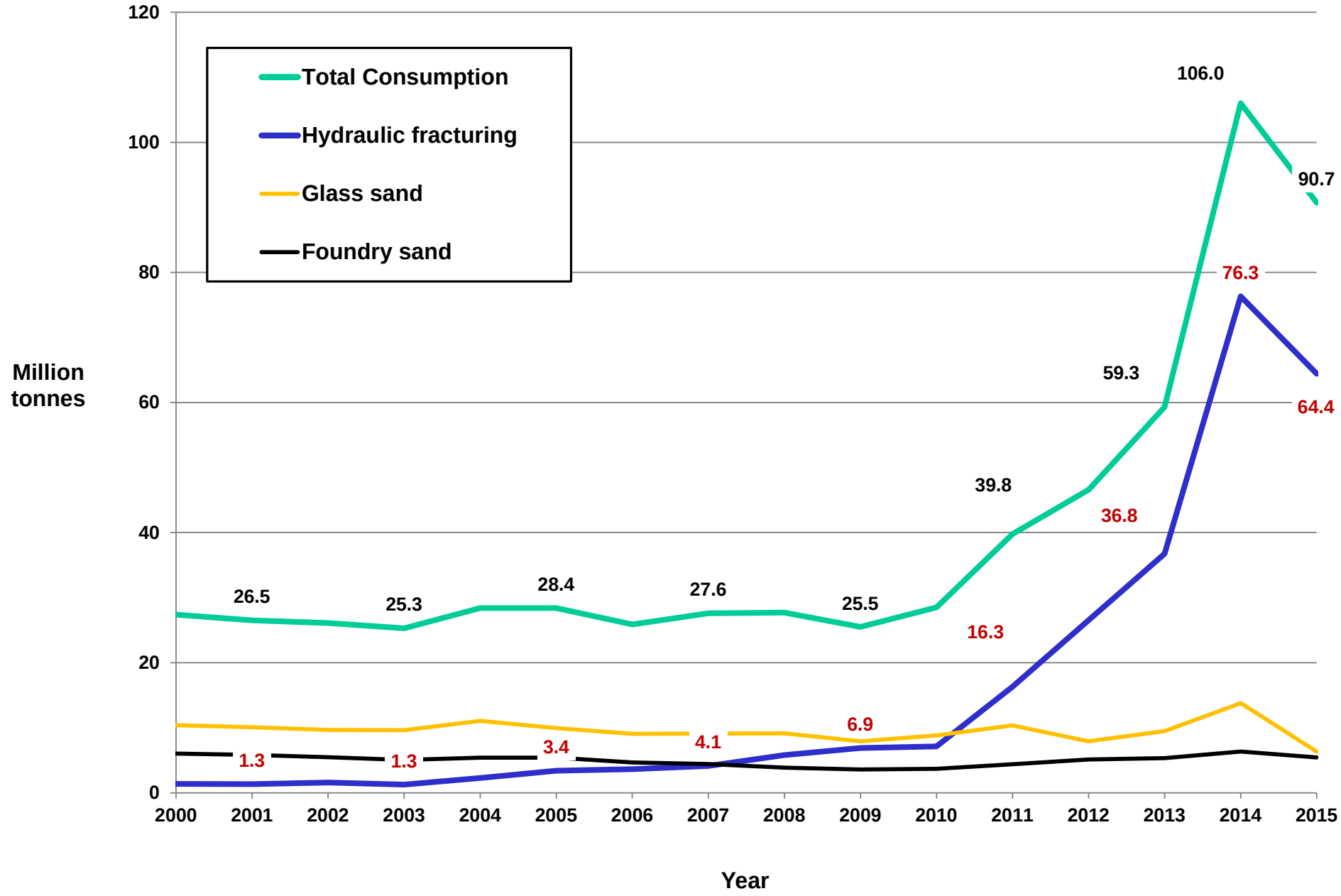


Future for frac sand?

- Depending on well length / number of hydraulic fracturing treatments, 2000 to 10,000 tonnes of frac sand per well
- If shale gas is developed in the UK and depending on fracking activity, frac sand demand could range from 10,000 to 380,000 tpa
- In the USA, frac sand accounted for 5% (1.4 Mt) of the industrial sand market in 2000, in 2014 this leapt to 72% (106Mt) with less consumed in 2015*

* Sand and gravel (Industrial) U.S.G.S. Mineral Commodity Summary 2016

US Silica Sand consumption 2000 - 2015



Conclusions

- Sand is everywhere but only pure sand is useful
- The UK is self-sufficient in sand - extraction and processing is simple given the right sand deposit
- Frac sand is a relatively new application for silica sand - high-purity sand with round grains is the key requirement
- Next time you are on a beach have a close look at the sand!

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And finally the fun bit at the end…

British Geological Survey (BGS)

29th April - 1st May

The Malthouse, Lyme Regis Town Mill

A number of activities themed around the geological map of the UK which has been produced and perfected by generations of BGS geologists and cartographers. We have reproduced the geological map of the UK as a large floor mat which we can roam around. With the aid of 'rock kits' we will introduce you to the geology of the UK and explain the different environments and climates of the past in which rocks formed. Visitors to our stand will be able to see our up to date mapping, as well as some of our earliest maps. We will show you iGeology, our free app which means you can have a geological map in your pocket all the time. Find the geology underneath your house!

You can learn more about geological time at our Discovering Geology website.

As a public sector organisation BGS is responsible for advising the UK government on all aspects of geoscience as well as providing impartial geological advice to industry, academia and the public.'

10am - 5pm; no charge


through time


Climate through time
Our rocks reveal the
story of change
50
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Clive Mitchell

Thank you for your attention!

Clive Mitchell

Industrial Minerals Specialist, British Geological Survey, Keyworth, Nottingham, NG12 5GG, United Kingdom

Tel. +44 (0)115 936 3257 Email: cjmi@bgs.ac.uk

Web: www.bgs.ac.uk Twitter: @CliveBGS