British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Role of National Geological Surveys in evaluation of high-purity silica resources

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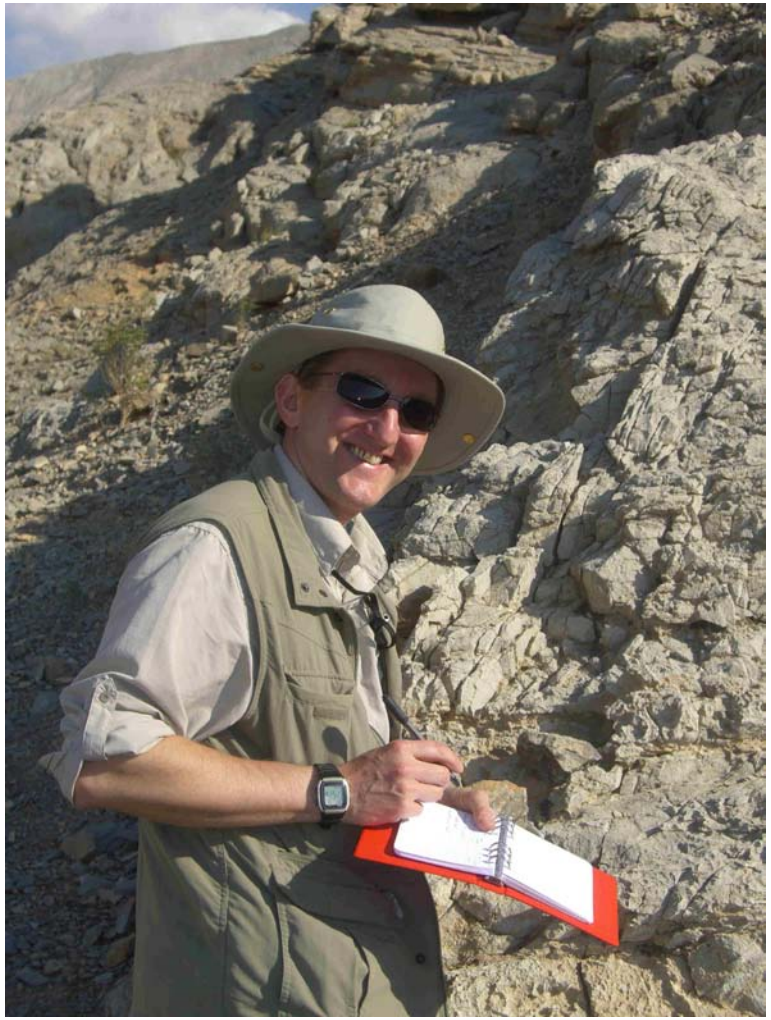
Outline of presentation

- Mineral resource work of a geological survey
- What is silica? Its uses, occurrence & production
- Industrial factors that influence resource evaluation
- World and regional trade in silica
- Minerals information delivery
- Conclusions

Minerals role of a Geological Survey



- The traditional A-Z ‘inventory’ of mineral resources from andalusite and anhydrite to zeolite and zircon is no longer appropriate
- The modern day focus is on:
  - Those minerals in demand for national & international markets
  - Planning information, geospatial datasets & digital maps
  - Production & trade statistics
  - Commodity information for government, industry & the public

Silica: The basics

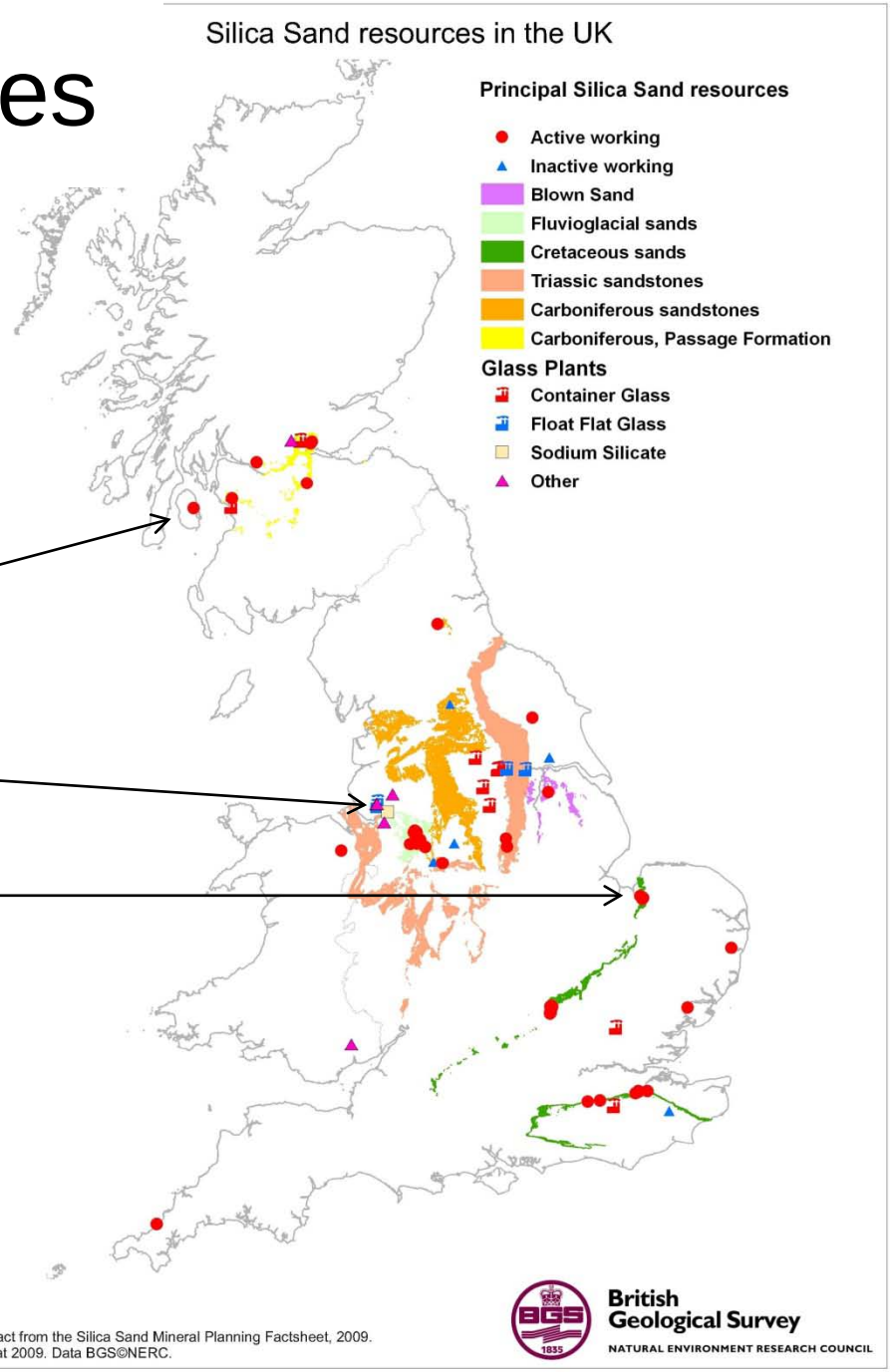
Quartz specimen from the Royal Geological Society of Cornwall Collection
(held at the British Geological Survey)

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

UK silica sand resources

- The UK is nearly self-sufficient in silica sand
- 40 quarries produce 4Mt of silica sand (2010 figures*)
- Sandstone (weakly cemented) e.g. Carboniferous Passage Fm , central Scotland (glass)
- Glacial sand e.g. Pleistocene Chelford Sand Fm, Cheshire (flat glass)
- Near shore marine/ coastal (dune / beach) sand e.g. Lower Cretaceous Sandringham Sands Fm, Leziate, Norfolk (glass)
- Alluvial (river), lacustrine (lake), aeolian (wind blown) sand



* UK Minerals Yearbook www.MineralsUK.com

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

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)

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

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

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

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

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)

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...

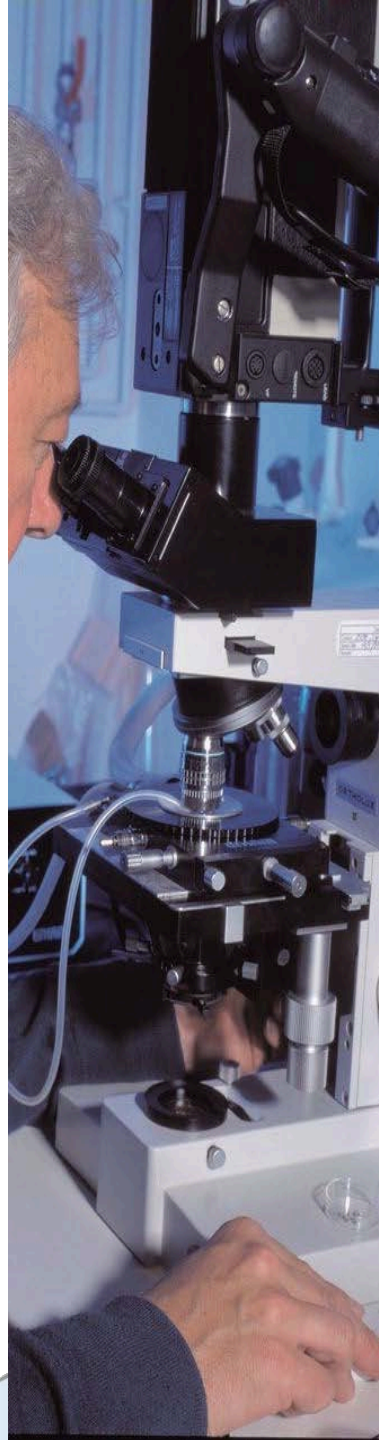
Other contaminants

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

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



Glass sand properties

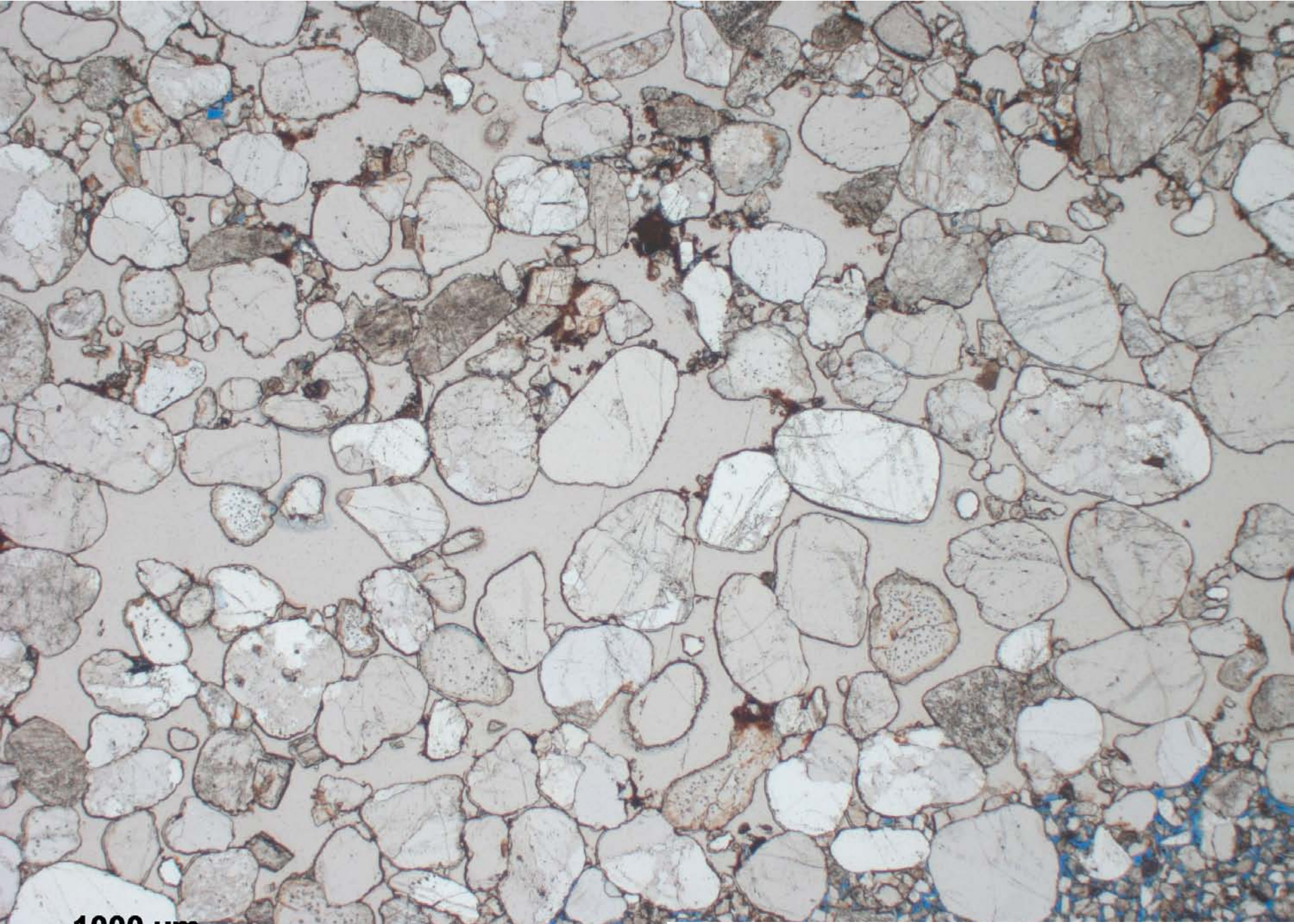
Property	Colourless (Flint) glass containers	Flat glass (Float, sheet & rolled plate)	Coloured (Amber & green) glass containers
Silica (SiO_2) content	98.5 to 99%		
Iron (Fe_2O_3) content	<0.035%	0.04 - 0.1%	0.25 - 0.3%
Alumina (Al_2O_3) content	0.5% max.	0.03% max.	0.2 – 1.6%.
Limits on:	Alkalis (Na_2O & 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?		

Foundry sand properties

Property	Range
Silica (SiO_2) content	98% minimum
Limits on:	CaO and MgO (to reduce the acid demand value & minimise binder demand)
Particle-size	Range from 0.1 to 0.5mm (100 to 500 microns).
Particle-size distribution	Narrow size distribution (improves permeability)
Grain Fineness	AFS (American Foundrymen's Society) index indicates average grain size. Ranges from 45 to 90 AFS (higher = finer) e.g. 50-60 AFS = 250-220 microns
Particle-shape	Rounded to sub-angular grains with reasonable sphericity are preferred (reduces binder demand, and improves compaction and mould strength)

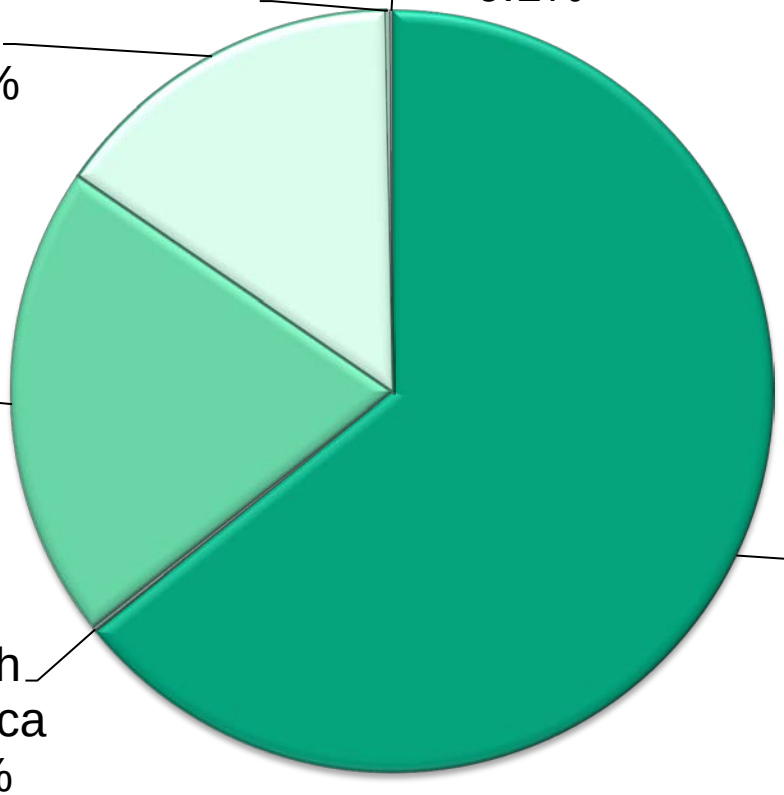
‘Frac’ (proppant) sand properties

Property	Range
Silica (SiO_2) content	>98%
Limits on:	Feldspar, acid soluble matter (such as calcite), clay and fines (<63 microns)
Particle-size	Narrow size-distribution - 90% within API specified size ranges as follows: 12 / 20 # (1700 – 850μm) 20 / 40 # (850 - 425μm), 40 / 70 # (425 - 212μm) 70 / 140 # (212 - 106μm)
Particle-shape	Durable, well-rounded, spherical grains are preferred



Photomicrograph of quartz-rich sandstone, UK

Billion US$ silica sand trade



World imports (2010)

45.6 Million tonnes

US$1.02 Billion

Range of price

US$20 - US$295 per tonne *

* www.indmin.com/prices

Data from United Nations COMTRADE database, *DESA/UNSD* http://comtrade.un.org/db/

Middle East Silica Sand Trade (2008)

Top Exporters	Trade volume (tonnes)	Trade value	Main export destinations
Saudi Arabia	586,177	US$ 44,069,107	UAE, Kuwait & Qatar
Egypt	180,489	US$ 9,709,442	Turkey, Italy & Greece
Jordan	58,982	US$ 3,336,455	Israel, UAE & Saudi Arabia
Total region	841,063	US$ 61,135,225	

Top Importers	Trade volume (tonnes)	Trade value	Main import sources
UAE	670,149	US$ 42,773,694	Saudi Arabia, Oman & Egypt
Turkey	540,237	US$ 17,950,787	Egypt, Bulgaria & China
Kuwait	78,144	US$ 7,542,168	Saudi Arabia, India & Libya
Total region	1,357,990	US$ 80,158,775	

Trade data for HS 250510 Silica sands & quartz sands, whether/ not coloured

Data from United Nations COMTRADE database, *DESA/UNSD* http://comtrade.un.org/db/

UN comtrade

BGS 1835

Welcome to MineralsUK

MineralsUK is the British Geological Survey's Centre for Sustainable Mineral Development. This website has a wealth of information on mineral resources, mineral planning, policy and legislation, sustainable development, statistics and exploration.

Minerals & you

Economic minerals – here you will find out what they are, where they come form and why they are important.

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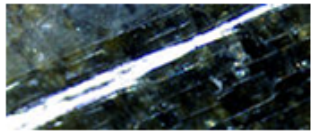

Mineral Planning Factsheet

- Factsheet on silica sand supply to inform UK land-use planning process & decision makers
- Silica sand is economically important for UK industry, for glass there is no alternative
- Resources may coincide with sensitive environments such as heath land, many disused sites are nature conservation areas
- A scarce resource subject to ‘Mineral Safeguarding’, where possible prior extraction before other land development

Office of the Deputy Prime Minister
Creating sustainable communities

British Geological Survey

Mineral Planning Factsheet

Silica sand

This factsheet provides an overview of silica sand supply in the UK. It is one of a series on economically-important minerals that are extracted in Britain and is primarily intended to inform the land-use planning process.

January 2006

Silica (industrial) sands contain a high proportion of silica (up to 99% SiO_2) in the form of quartz and they are used for applications other than as construction aggregates. They are produced from both loosely consolidated sand deposits and by crushing weakly-cemented sandstones. Unlike construction sands, which are used for their physical properties alone, silica sands are valued for a combination of chemical and physical properties. These include a high silica content in the form of quartz and, more importantly, very low levels of deleterious impurities, particularly clay, iron oxides and refractory minerals, such as chromite. They typically have a narrow grain-size distribution (generally in the range 0.5 to 0.1 mm). For most applications, silica sands have to conform to very closely defined specifications and consistency in quality is of critical importance. Particular uses often require different combinations of properties. Consequently, different grades of silica sand are usually not interchangeable in use. Silica sands command a higher price than construction sands. This allows them to serve a wider geographical market, including exports.

Finished float glass, Pilkington's Greengate plant, St Helens.

Silica sand

1 Silica sand

© Pilkington plc

Demand

Silica sands are essential raw materials for glassmaking and a wide range of other industrial and horticultural applications. Historically an important market for silica sand was in foundry casting. However, the progressive decline in UK heavy manufacturing, and notably the foundry industry, has resulted in a significant decline in the demand for foundry sand (Figure 1 and 2). In contrast there has been a recent increase in demand for glass sand. In 2004 glass sand accounted for 53% of total sales of silica sand in Great Britain, foundry sand 11%, sand for other industrial uses 19%, and sand for horticultural and leisure uses 17%.

There are many different types of glass with different chemical and physical properties. Most of the commercial glasses in everyday use, such as bottles and jars (containers), and flat glass (windows, mirrors and vehicle glazing), are soda-lime-silica glasses. These contain between 70–74% SiO_2, the ultimate source of which is silica sand, although increasing amounts of silica are being recovered in the form of recycled glass (known as cullet). Sand by itself can be fused to produce glass, but only at very high temperatures (1700°C). The addition of sodium carbonate (Na_2CO_3) significantly reduces this temperature. Other components, such as calcium oxide (CaO), magnesium oxide (MgO) and alumina (Al_2O_3) are added (in the form of limestone, dolomite and feldspathic minerals) in order to give the glass stability and durability. Sodium carbonate is manufactured from salt and limestone, emphasising the dependence that some industries have on a number of industrial minerals.

The principal glass products using silica sand include colourless and coloured containers (bottles and jars), flat glass, light bulbs and fluorescent tubes, TV and computer screens, and glass fibre, both for insulation and reinforcement. Glass manufacturers are principally concerned with the chemical composition of silica sands, and particularly iron, chromite, and other refrac-

Future silica sand use

- If a shale gas industry develops in the UK, Frac sand will become a major use of silica sand in the future
- Used to prop open fractures in oil & gas reservoirs to enhance recovery
- In the USA, Frac sand was estimated to account for 5% (1.4 Mt) of the industrial sand market in 2001, this leapt to 41% (12.3Mt) in 2011*

* Sand and gravel (Industrial) U.S.G.S. Mineral Commodity Summary 2012

Conclusions

- National Geological Surveys have a wider responsibility than those that are purely geological
- Understanding industrial need and trade in minerals will inform the information and maps we provide
- Minerals information needs to be freely available on the internet - not only an important dissemination tool but is expected by all our stakeholders

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Thank you for your attention

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