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

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Industrial Minerals Specialist
British Geological Survey
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

- Silica is chemical compound silicon dioxide (SiO₂), 61% of earth's 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

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

http://www.bgs.ac.uk/collections/gallery.html
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 ($\text{SiO}_2$), iron ($\text{Fe}_2\text{O}_3$), alumina ($\text{Al}_2\text{O}_3$), alkalis ($\text{Na}_2\text{O} & \text{K}_2\text{O}$), alkaline earths ($\text{MgO} & \text{CaO}$) and heavy metals ($\text{Ni, Co, Cu, Cr}$)

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

<table>
<thead>
<tr>
<th>Property</th>
<th>Colourless (Flint) glass containers</th>
<th>Flat glass (Float, sheet &amp; rolled plate)</th>
<th>Coloured (Amber &amp; green) glass containers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica (SiO₂) content</td>
<td></td>
<td>98.5 to 99%</td>
<td></td>
</tr>
<tr>
<td>Iron (Fe₂O₃) content</td>
<td>&lt;0.035%</td>
<td>0.04 - 0.1%</td>
<td>0.25 - 0.3%</td>
</tr>
<tr>
<td>Alumina (Al₂O₃) content</td>
<td>0.5% max.</td>
<td>0.03% max.</td>
<td>0.2 - 1.6%</td>
</tr>
<tr>
<td>Limits on:</td>
<td>Alkalis (Na₂O &amp; K₂O), colourants (Ni, Cu, Co) &amp; refractory minerals (chromite, ilmenite, zircon, rutile, corundum etc..)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particle-size</td>
<td></td>
<td>0.1 to 0.6mm (100 to 600 microns)</td>
<td></td>
</tr>
<tr>
<td>Particle-shape</td>
<td></td>
<td>Angular quartz grains may aid melting?</td>
<td></td>
</tr>
</tbody>
</table>
# Foundry sand properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica (SiO(_2)) content</td>
<td>98% minimum</td>
</tr>
<tr>
<td>Limits on:</td>
<td>CaO and MgO (to reduce the acid demand value &amp; minimise binder demand)</td>
</tr>
<tr>
<td>Particle-size</td>
<td>Range from 0.1 to 0.5mm (100 to 500 microns).</td>
</tr>
<tr>
<td>Particle-size distribution</td>
<td>Narrow size distribution (improves permeability)</td>
</tr>
<tr>
<td>Grain Fineness</td>
<td>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</td>
</tr>
<tr>
<td>Particle-shape</td>
<td>Rounded to sub-angular grains with reasonable sphericity are preferred (reduces binder demand, and improves compaction and mould strength)</td>
</tr>
</tbody>
</table>
### ‘Frac’ (proppant) sand properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica (SiO₂) content</td>
<td>&gt;98%</td>
</tr>
<tr>
<td>Limits on:</td>
<td></td>
</tr>
<tr>
<td>Feldspar, acid soluble matter (such as calcite), clay and fines (&lt;63 microns)</td>
<td></td>
</tr>
<tr>
<td>Particle-size</td>
<td></td>
</tr>
<tr>
<td>Narrow size-distribution - 90% within API specified size ranges as follows:</td>
<td></td>
</tr>
<tr>
<td>12 / 20 # (1700 – 850μm)</td>
<td>20 / 40 # (850 - 425μm),</td>
</tr>
<tr>
<td>40 / 70 # (425 - 212μm)</td>
<td>70 / 140 # (212 - 106μm)</td>
</tr>
<tr>
<td>Particle-shape</td>
<td></td>
</tr>
<tr>
<td>Durable, well-rounded, spherical grains are preferred</td>
<td></td>
</tr>
</tbody>
</table>
Billion US$ silica sand trade

North America 64.2%
- 99.8% of this are imports into Canada from USA

Europe 20.2%
- Main export sources are Germany, Belgium and France

South America 0.2%

Asia 15.1%
- Main export sources are Australia, Malaysia & Vietnam

Australasia 0.1%

Africa 0.2%

World imports (2010)
- 45.6 Million tonnes
- US$1.02 Billion
- Range of price
  - US$20 - US$295 per tonne
  - * [www.indmin.com/prices](http://www.indmin.com/prices)

## Middle East Silica Sand Trade (2008)

### Top Exporters

<table>
<thead>
<tr>
<th>Exporter</th>
<th>Trade volume (tonnes)</th>
<th>Trade value</th>
<th>Main export destinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saudi Arabia</td>
<td>586,177</td>
<td>US$ 44,069,107</td>
<td>UAE, Kuwait &amp; Qatar</td>
</tr>
<tr>
<td>Egypt</td>
<td>180,489</td>
<td>US$ 9,709,442</td>
<td>Turkey, Italy &amp; Greece</td>
</tr>
<tr>
<td>Jordan</td>
<td>58,982</td>
<td>US$ 3,336,455</td>
<td>Israel, UAE &amp; Saudi Arabia</td>
</tr>
<tr>
<td>Total region</td>
<td>841,063</td>
<td>US$ 61,135,225</td>
<td></td>
</tr>
</tbody>
</table>

### Top Importers

<table>
<thead>
<tr>
<th>Importer</th>
<th>Trade volume (tonnes)</th>
<th>Trade value</th>
<th>Main import sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>UAE</td>
<td>670,149</td>
<td>US$ 42,773,694</td>
<td>Saudi Arabia, Oman &amp; Egypt</td>
</tr>
<tr>
<td>Turkey</td>
<td>540,237</td>
<td>US$ 17,950,787</td>
<td>Egypt, Bulgaria &amp; China</td>
</tr>
<tr>
<td>Kuwait</td>
<td>78,144</td>
<td>US$ 7,542,168</td>
<td>Saudi Arabia, India &amp; Libya</td>
</tr>
<tr>
<td>Total region</td>
<td>1,357,990</td>
<td>US$ 80,158,775</td>
<td></td>
</tr>
</tbody>
</table>

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

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 from and why they are important.

Top downloads

1. Risk list 2011
3. Cement Raw Materials

//Whats new

World Mineral Production 2006-2010
The latest edition of this long-running series is now available.

Rare Earth Elements Profile updated
This publication is now available for download.

//Downloads

Risk list 2011
A new supply risk index for chemical elements or element groups which are of economic value.
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

Silica sand

Silica sand is an essential raw material used in glass, ceramics, foundry sands, and other industries. It is a component of many glass products, such as bottles, windows, and mirrors. The principal glass products using silica sand include bottles, containers, and glassware. The extraction of silica sand is subject to Mineral Safeguarding, ensuring that prior extraction can occur before other land development. This ensures a steady supply of silica sand to meet the demand for glass production.
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.