High-purity limestone assessment: from mine to market

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Outline

• Introduction
• Limestone uses
• Planning
• Exploration
• Evaluation
• High-purity limestone in Saudi Arabia
• Conclusions
Introduction

• High-purity limestone >97% CaCO₃ (Calcium Carbonate)
• Suitability defined by industrial end-use
• Chemical, mineralogical & physical properties
• Assessment is guided by industrial requirements
• National Geosurvey role
• Mineral promotion
Applications

• Limestone has more uses than any other IM
• Low value, bulk volume construction material
e.g. aggregate, ballast, dimension stone
• High value, lower volume speciality mineral
e.g. GCC & PCC (Ground & Precipitated Calcium Carbonate)
• High-purity limestone used for lime, glass,metallurgical flux, FGD, sugar refining, mineral fillers (GCC & PCC) and calcium chemicals
INDUSTRIAL LIMESTONE

CRUSHED

CERAMICS
FLUE GAS MAKING, SUGAR REFINING

GAS CHAMBERS

GAS TREATMENT, CHEMICAL INDUSTRY (eg SODA ASH)

GASEOUS EFFLUENT NEUTRALISATION, AGRICULTURE

AND FOOD PRODUCTS, CONSTRUCTION AND

BUILDING PRODUCTS

LIME

CALCINED

FINE TO VERY
FINE FILLERS

COARSE TO MEDIUM
FILLERS

FILLER, TILES

FILTERS, KING GEYER COEVRINGS

AGRICULTURAL FEEDS, ASPHALT

CULTURE, CARPET BACKING,
Planning

• High-purity resources in ‘low-grade’ uses is an issue
e.g. Carboniferous limestone in the UK used as
speciality mineral and construction aggregate
• Many consider this an inefficient use of resources
• Strategic value of high-purity resources
• UK ‘Mineral Safeguarding Areas’, avoid sterilisation
• Competing land use with other environmental
designations
e.g. National Parks & AONBs
Exploration

- Exploration starts with existing geological information
- Calcium carbonate deposits can occur as:
  - Sedimentary (limestone, chalk, shell, travertine, vein & marl)
  - Metamorphic (marble)
  - Igneous (carbonatite)
- Mineral impurities include:
  - Other carbonate minerals (dolomite, siderite)
  - Silica (quartz, chert)
  - Clay minerals (kaolinite, illite, smectite)
  - Mineralisation (fluorite, galena, sphalerite)
  - Organic matter
  - Others (pyrite, iron oxides, etc…)
Sampling limestone in Zambia (2000) and Afghanistan (2007)
Fieldwork & sampling
Reconnaissance Survey

- National Geosurvey explore at national/ regional scale
- Prioritisation of potential high-purity resources
- GIS of existing information
- Field work to collect (representative) samples
- Technical testing:
  - XRF
  - XRD
  - TGA
  - Whiteness ("Brightness")
Portable XRF (used in recent limestone survey)
Laboratory Testwork
## Chemical composition

<table>
<thead>
<tr>
<th>Oxide</th>
<th>Wt %</th>
<th>Oxide</th>
<th>Wt %</th>
<th>Oxide</th>
<th>Wt %</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>&lt;2.0</td>
<td>Na₂O</td>
<td>&lt;0.1</td>
<td>BaO</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>TiO₂</td>
<td>&lt;0.1</td>
<td>K₂O</td>
<td>&lt;0.1</td>
<td>NiO</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>&lt;0.3</td>
<td>P₂O₅</td>
<td>&lt;0.1</td>
<td>CuO</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>&lt;1.0</td>
<td>SO₃</td>
<td>&lt;0.5</td>
<td>ZnO</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Mn₃O₄</td>
<td>&lt;0.1</td>
<td>Cr₂O₃</td>
<td>&lt;0.1</td>
<td>PbO</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>MgO</td>
<td>&lt;3.0</td>
<td>SrO</td>
<td>&lt;0.2</td>
<td>LOI</td>
<td>&gt;42.7</td>
</tr>
<tr>
<td>CaO</td>
<td>&gt;54.3</td>
<td>ZrO₂</td>
<td>&lt;0.1</td>
<td>Total</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Typical chemical composition of high-purity limestone; standard range of major element oxides analysed by XRF at BGS.
## Calcium Carbonate content

<table>
<thead>
<tr>
<th>Limestone classification</th>
<th>CaO (wt%)</th>
<th>CaCO$_3$ (wt %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% limestone</td>
<td>56.03</td>
<td>100.0</td>
</tr>
<tr>
<td>Very high purity</td>
<td>&gt; 55.2</td>
<td>&gt; 98.5</td>
</tr>
<tr>
<td>High purity</td>
<td>54.3 - 55.2</td>
<td>97.0 - 98.5</td>
</tr>
<tr>
<td>Medium purity</td>
<td>52.4 - 54.3</td>
<td>93.5 - 97.0</td>
</tr>
<tr>
<td>Low purity</td>
<td>47.6 - 52.4</td>
<td>85.0 - 93.5</td>
</tr>
<tr>
<td>Impure</td>
<td>&lt; 47.6</td>
<td>&lt; 85.0</td>
</tr>
</tbody>
</table>
## Other Criteria

<table>
<thead>
<tr>
<th>Purity classification</th>
<th>MgO (wt%)</th>
<th>SiO$_2$ (wt%)</th>
<th>Fe$_2$O$_3$ (wt%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high purity</td>
<td>&lt; 0.8</td>
<td>&lt; 0.2</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>High purity</td>
<td>&lt; 1.0</td>
<td>&lt; 0.6</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>Medium purity</td>
<td>&lt; 3.0</td>
<td>&lt; 1.0</td>
<td>&lt; 1.0</td>
</tr>
<tr>
<td>Low purity</td>
<td>&gt; 3.0</td>
<td>&lt; 2.0</td>
<td>&gt; 1.0</td>
</tr>
<tr>
<td>Impure</td>
<td></td>
<td></td>
<td>&gt; 2.0</td>
</tr>
</tbody>
</table>
Mineral Promotion

- Resource maps and reports
- Web pages/downloads: [www.mineralsuk.com](http://www.mineralsuk.com)
- Workshops and seminars
# Saudi High-purity Limestone

<table>
<thead>
<tr>
<th>Deposit</th>
<th>CaO Wt%</th>
<th>MgO Wt%</th>
<th>SiO$_2$ Wt%</th>
<th>Fe$_2$O$_3$ Wt%</th>
<th>Purity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al Kharj: Umm al Ghirban (Aruma Fm)</td>
<td>54.13</td>
<td>0.26</td>
<td>0.52</td>
<td>0.09</td>
<td>High</td>
</tr>
<tr>
<td>Al Kharj (Tuwaiq Mountain Limestone)</td>
<td>55.0</td>
<td>0.38</td>
<td>0.94</td>
<td>0.27</td>
<td>Medium to high</td>
</tr>
<tr>
<td>Al Kharj (Salaiy Fm)</td>
<td>54.42</td>
<td>0.35</td>
<td>0.7</td>
<td>0.06</td>
<td>High</td>
</tr>
<tr>
<td>Riyadh area: Kasm Mazali (Sulaiy Fm)</td>
<td>53.4-55.6</td>
<td>0.2</td>
<td>0.1-0.56</td>
<td>0.08-0.13</td>
<td>High to very high</td>
</tr>
<tr>
<td>Riyadh area: Sudus (Tuwaiq Fm)</td>
<td>54.87</td>
<td>0.07</td>
<td>1.18</td>
<td>0.1</td>
<td>Medium to high</td>
</tr>
<tr>
<td>Wadi at Tarbah area: Umm Wa’al</td>
<td>&gt; 55</td>
<td>n/a</td>
<td>&lt; 5</td>
<td>n/a</td>
<td>Medium to high</td>
</tr>
<tr>
<td>Ad Dammam area (Middle Eocene)</td>
<td>51.8</td>
<td>1.17</td>
<td>1.5</td>
<td>0.25</td>
<td>Low</td>
</tr>
<tr>
<td>Red Sea Coast Wadi Misser (Shayban Fm)</td>
<td>49.6</td>
<td>3.23</td>
<td>1.4</td>
<td>n/a</td>
<td>Low</td>
</tr>
<tr>
<td>Red Sea Coast Wadi Minsah (Proterozoic)</td>
<td>55</td>
<td>0.6</td>
<td>0.7</td>
<td>0.4</td>
<td>Medium to high</td>
</tr>
<tr>
<td>Red Sea Coast Ra’s Marjah (Quaternary)</td>
<td>47.15</td>
<td>2.2</td>
<td>1.7</td>
<td>n/a</td>
<td>Low</td>
</tr>
</tbody>
</table>

Saudi High-purity Limestone

- Purity by lime, magnesia, silica & Iron oxide contents
- Several are not “high-calcium” limestones
  (require 97% CaCO$_3$, equivalent to 54.3% CaO)
- Only one limestone considered very high-purity
- Khasm Mazali, Riyadh area
  (Lower Cretaceous, Sulaiy Formation)
- Micritic (very fine grained), homogeneous, cohesive limestone with enormous potential resources

Conclusions

- Limestone resources are often widespread
- National Geosurveys work at reconnaissance scale
- Technical assessment needs market information
- Ongoing challenge to maintain knowledge base
- Laboratory capabilities a key component
- Outputs largely via the web (www.mineralsuk.com)
Thank you for your attention

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