Sandstones and other Clastic Sedimentary Rocks
What geologists want to learn from Sandstones

• Source area
  – rock type
  – direction
  – weathering environment

• Transport
  – medium, energy
  – distance

• Depositional environment
  – marine or non-marine
  – physical environment (beach, river, delta, etc.)
What clues are present in Sandstones?

- Grain size
- Grain shape
- Grain sorting
- Grain mineralogy
- Sedimentary structures
Grain size

- Detrital or clastic rocks have a huge range in grain size
- We need a log scale to represent this wide size range
- The Phi ($\phi$) Scale: $\phi = -\log_2 (\text{mm})$
  \[ \text{mm} = 2^{-\phi} \]  (memorize)
- Each $\phi$ step represents a doubling (smaller # or more neg.) or halving (larger #) in size
For example

- size in mm = $2^{-\phi}$

- $-6 \phi = 2^6 \text{ mm} = 64 \text{ mm}$
- $0 \phi = 2^0 \text{ mm} = 1 \text{ mm}$
- $2 \phi = 2^{-2} \text{ mm} = \frac{1}{4} \text{ mm} = 0.25 \text{ mm}$
- $4 \phi = 2^{-4} \text{ mm} = \frac{1}{16} \text{ mm} = 0.0625 \text{ mm}$
Size ranges are given names

Gravel > -1 φ (>2mm)

Sand: 4 φ to -1 φ (0.0625mm to 2mm)

Mud < 4 φ <0.0625mm <62.5 μm

Clay < 8 φ <0.004mm <4 μm

### The Udden–Wentworth Grain Size Scale for Clastic Sediments

<table>
<thead>
<tr>
<th>Name</th>
<th>Millimeters</th>
<th>Micrometers</th>
<th>φ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder</td>
<td>4,096</td>
<td></td>
<td>-12</td>
</tr>
<tr>
<td>Cobble</td>
<td>256</td>
<td></td>
<td>-8</td>
</tr>
<tr>
<td>Pebble</td>
<td>64</td>
<td></td>
<td>-6</td>
</tr>
<tr>
<td>Granule</td>
<td>4</td>
<td></td>
<td>-2</td>
</tr>
<tr>
<td>Very coarse sand</td>
<td>2</td>
<td></td>
<td>-1</td>
</tr>
<tr>
<td>Coarse sand</td>
<td>1</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Medium sand</td>
<td>0.5</td>
<td>500</td>
<td>1</td>
</tr>
<tr>
<td>Fine sand</td>
<td>0.25</td>
<td>250</td>
<td>2</td>
</tr>
<tr>
<td>Very fine sand</td>
<td>0.125</td>
<td>125</td>
<td>3</td>
</tr>
<tr>
<td>Coarse silt</td>
<td>0.062</td>
<td>62</td>
<td>4</td>
</tr>
<tr>
<td>Medium silt</td>
<td>0.031</td>
<td>31</td>
<td>5</td>
</tr>
<tr>
<td>Fine silt</td>
<td>0.016</td>
<td>16</td>
<td>6</td>
</tr>
<tr>
<td>Very fine silt</td>
<td>0.008</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Clay</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
</tbody>
</table>
Loose sediments can be separated by sieving

- $-2\phi$ (4mm)
- $-1\phi$ (2mm)
- $1\phi$ (0.5mm)
- $2\phi$ (0.25mm)
- $3\phi$ (0.125mm)
- $4\phi$ (0.062mm)
- closed
Important Textural Features

• Bedding and Layering
• Grain size
• Grain shape
  – Roundness
  – Sphericity
• Sorting
• Others?
Grain size comparator for lithified Sandstone
Sorting by comparison

Very well sorted
Well sorted
Moderately sorted
Poorly sorted
Very poorly sorted
Grain Shape

- **Sphericity** - relative equidimensionality of three mutually perpendicular axes
- **Roundness** - lack of sharp corners; larger grains round faster because of more impacts

![Grain Shape Diagram]

<table>
<thead>
<tr>
<th>Very angular</th>
<th>Angular</th>
<th>Subangular</th>
<th>Subrounded</th>
<th>Rounded</th>
<th>Well rounded</th>
</tr>
</thead>
<tbody>
<tr>
<td>High sphericity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low sphericity</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Minerals of Clastic Sedimentary Rocks
Sandstone Classification

15% to 50% mud, called Wackes, use middle triangle

Sandstones with less than 15% mud, are called Arenites, use the front triangle
Detrital Grain Types: Quartz
Dust rings may show detrital grain boundaries

Note optically continuous and euhedral quartz overgrowths
Polycrystalline Quartz in Ss
Chert is a stable lithic fragment, grouped with Quartz.
Feldspars distinguished from quartz by alteration, twinning and perthite
What’s the large grain?
Microcline in Sandstone
Lithic Fragments
Volcanic and Plutonic Lithic Fragments in a Sandstone
Sandstone Classification

15% to 50% mud, called Wackes, use middle triangle

Sandstones with less than 15% mud, are called Arenites, use the front triangle
Common Accessory Minerals in Sandstones

- Heavy minerals
- Zircon
- Tourmaline
- Rutile
- Some micas
- More muscovite than biotite
Detrital Zircon (ZrSiO$_4$) Separate
Detrital Rutile (TiO$_2$) Separate
“Textural Maturity” of a Ss

- A measure of the progress of a clastic sediment in the direction of chemical, mineralogical and textural stability
- Affected by processes that take a long time
- Maturity increases with total input of kinetic energy
  - time of transport, distance of transport
  - energy of medium
Increasing “Textural Maturity” is indicated by:

- clay removal
- increased sorting
- increased rounding
- breakdown (absence) of unstable fragments
- breakdown (absence) of unstable minerals
- high ZTR (zircon, tourmaline, rutile – super-stable heavy minerals)
Immature Sandstones - limited transport, rapid deposition and burial

- Lots of muddy matrix
- poorly sorted
- poorly rounded fragments and grains
- lots of unstable lithics and unstable minerals
- mostly wackes
- formed in convergent margin settings, arc-trench gap
Super-mature Sandstones

- Clean (no mud matrix)
- well-sorted
- well-rounded grains
- mostly quartz grains
- quartz arenites
- Cratonic, typically recycled, formed in beach or other high energy environment
Increasing Textural Maturity

- Wackes - immature
- Litharenites
- Arkoses
- Subarkose and sublitharenite
- Quartz arenites - supermature
Diagenesis

• Compaction

• Cementation – Common Cements
  – Quartz
  – Calcite
  – Hematite
  – Clay
Calcite (and dolomite)
Cement, stained
Hematite Cement

Where does Fe come from?

SEM long dimension = 1 μm
Clay Coatings

Blue epoxy fills pores in some thin sections

Low-Mag.

Med.-Mag.

Hi-Mag. SEM 5μm
Authigenic clay is perpendicular to grain boundaries

Fe-montmorillonite