Ocean Crust Composition
Wilson p. 101-138

- In this lecture:
  - Direct evidence for composition of ocean crust
  - Hydrothermal metamorphism
  - Partial melting processes
  - Magma storage
  - Petrography of MORB
  - Major element chemistry of MORB

Direct sampling
Dredging
  - Inexpensive, samples from ocean bottom only
Direct sampling

Drilling

– Ocean Drilling Program (ODP)

Deepest hole penetration

Hole 504B
East Pacific Rise
2,111 m
(Layer 2)

Direct sampling

Diving/Submersibles

Manned: Alvin

Unmanned:
ROV Jason
Woods Hole
Oceanographic Institution

Selective sampling & imaging of seafloor
Direct sampling
Ophiolites

Sections of presumably oceanic crust, obducted into land

---

Direct sampling
Ophiolites

May be from marginal basins rather than normal ocean crust

Influence MOR magma chamber models

Example: Semail Ophiolite, Oman

Wilson (Figure 5.8)
Direct sampling

Ophiolites

Semail Ophiolite, Oman

Largest, best exposed ophiolite

Closure of Tethys Ocean during Cretaceous

- Radiolarian chert
- Pillow lavas
- Sheeted dikes
- Layered gabbros
- Dunite
- Petrologic moho
- Harzburgite (tectonized/deformed)
Direct sampling

Semail Ophiolite

Pillow lavas, intruded by diabase (fine-grained gabbro) dike

Sheeted dikes

Radio-larian chert

Pillow lavas

Hydrothermal systems

Water-rock exchange reactions
Control chemistry of seawater
Form massive sulfide Fe ore deposits
Supports diverse biological communities

Chimney-like vents
Sulfide mounds
Pervasive alteration of basaltic layer 2
Hydrothermal metamorphism
Water-rock exchange reactions
Serpentinites
Higher $^{87}\text{Sr}/^{86}\text{Sr}$ than MORB glass
Circulation of brines through crust up to 10 Myr
Modifies composition of basalt
Adds water
Adds Cl, U, alkali metals
Leaches Pb

Partial melting
Adiabatic decompression (see lecture 5)
Work backward from composition of primary MORB
Most MORB are evolved/differentiated:
Fractional crystallization
Magma mixing + crustal assimilation

Experiments suggest melting 20-30% in field of spinel lherzolite

Trace elements in MORB suggest lower % melting
Magma Storage

Size and shape of magma chambers unknown
Probably replenished, open systems

Fast Spreading ridges
Larger chambers: more uniform magmas

Slow Spreading ridges
Smaller chambers: more differentiated magmas

Petrography of MORB

Glassy to porphyritic (up to 20-30% phenocrysts)
Olivine Fo73-91 ± Mg-Cr spinel
Plagioclase An40-88 + Olivine ± Mg-Cr Spinel
Plagioclase + Olivine+ Augite (rare)

Gabbroic rocks (dredged) rarely do contain orthopyroxene
Also contain apatite, hornblende, sphene, mt

Mineral compositions vary regularly with fractionation
Major Element Composition of MORB

Sub-alkaline, Tholeiitic (Fe-enrichment) magma series
Mainly low K₂O
Lower Ti, P, K₂O compared to OIB, IAT
Silica-rich (rhyolite) is extremely rare
M values [100*Mg(Mg+Fe²⁺)] 50-65
70 is equilibrium with mantle olivine (rare)

No major inter-ocean differences
East Pacific Rise MORB slightly more evolved
(lower M values) than Mid Atlantic Ridge

No major inter-ocean differences in MORB
Comparison to Island arc and Ocean Island basalt
Low K in MORB

Table 5.3 Comparison of the major element geochemistry of MORB with that of a typical oceanic island tholeiite, island-arc tholeiite and continental flood tholeiite.

<table>
<thead>
<tr>
<th>Element</th>
<th>MORB</th>
<th>EPR</th>
<th>IOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>50.69</td>
<td>50.19</td>
<td>50.93</td>
</tr>
<tr>
<td>TiO₂</td>
<td>1.49</td>
<td>1.77</td>
<td>1.19</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>15.60</td>
<td>14.96</td>
<td>15.15</td>
</tr>
<tr>
<td>FeO</td>
<td>9.85</td>
<td>11.23</td>
<td>10.32</td>
</tr>
<tr>
<td>MgO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MgO</td>
<td>7.68</td>
<td>7.10</td>
<td>7.69</td>
</tr>
<tr>
<td>CaO</td>
<td>11.44</td>
<td>11.44</td>
<td>11.94</td>
</tr>
<tr>
<td>Na₂O</td>
<td>1.44</td>
<td>0.14</td>
<td>0.28</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.17</td>
<td>0.14</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Data sources: *Milton et al. (1976); † East Pacific Rise Study Project (1981); ‡ Indian Ocean Ridge; § oceanic island tholeiite; ‖ island-arc tholeiite; ‡‡ continental flood tholeiite.

MORB, Mid-Atlantic Ridge; EPR, East Pacific Rise; IOR, Indian Ocean Ridge; OIT, oceanic island tholeiite; IAT, island-arc tholeiite; CFT, continental flood tholeiite.
Major Element Composition of MORB

Normal versus Plume MORB (N-MORB vs. E-MORB)
Correlation: depth to MOR and chemical composition

<table>
<thead>
<tr>
<th></th>
<th>Normal MORB</th>
<th>Plume MORB</th>
<th>Transition MORB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25%–30%</td>
<td>45%–55%</td>
<td>65%–75%</td>
</tr>
<tr>
<td>SiO2</td>
<td>48.77</td>
<td>53.05</td>
<td>48.77</td>
</tr>
<tr>
<td>Al2O3</td>
<td>18.40</td>
<td>17.64</td>
<td>17.64</td>
</tr>
<tr>
<td>FeO</td>
<td>1.51</td>
<td>1.57</td>
<td>1.57</td>
</tr>
<tr>
<td>MgO</td>
<td>0.82</td>
<td>0.96</td>
<td>0.96</td>
</tr>
<tr>
<td>CaO</td>
<td>11.82</td>
<td>11.64</td>
<td>11.64</td>
</tr>
<tr>
<td>TiO2</td>
<td>2.06</td>
<td>2.04</td>
<td>2.04</td>
</tr>
<tr>
<td>P2O5</td>
<td>0.01</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>LOI</td>
<td>6.10</td>
<td>6.46</td>
<td>6.46</td>
</tr>
</tbody>
</table>

**“Primitive” high-MgO < > Fe-rich evolved magmas**

Mineralogical controls: olivine + plagioclase