Types of OIB Magmas

Two principal magma series

• Tholeiitic series (dominant type)
  – Ocean island tholeiitic basalt, OIT
  – Similar to MORB, but some distinct chemical differences

– Alkaline series (subordinate)
  – Ocean island alkaline basalt, OIA
  – Two principal alkaline sub-series
    • slightly silica oversaturated
    • silica undersaturated
OIBs – evolution in the series
Tholeiitic, alkaline, and highly alkaline
Hawaii-Emperor seamount chain

Global plate motion reconstructions fail to predict the bend

Size of volcanic edifices:
Mauna Loa (still active): 80,000 km³
average stratovolcano: 500 km³

Olympus Mons volcano on Mars compared to the principal Hawaiian islands at the same scale.
Hawaiian Scenario

Hawaiian Emperor Chain Age-Distance Relationship

AGE OF ISLAND / SEAMOUNT IN MILLIONS OF YEARS

DISTANCE FROM HOTSPOT (in kilometers)

(from Ken Hon's website)

8.6 cm per year
Hawaiian Scenario

Cyclic pattern of eruptive history

1. Pre-shield-building stage somewhat alkaline and variable

2. Shield-building stage begins with tremendous outpourings of tholeiitic basalts

3. Waning activity more alkaline, episodic, and violent (Mauna Kea, Hualalai, and Kohala). Lavas are also more diverse, with a larger proportion of differentiated liquids

4. A long period of dormancy, followed by a late, post-erosional stage (Oahu). Characterized by highly alkaline and silica-undersaturated magmas
Hawaiian Scenario

Tholeiitic magma generated during the main stage, at high rates of partial melting.

Mauna Kea  Kilauea  Loihi

CRUST

plate motion

Alkalic magma generated at a late stage, under low rates of partial melting.

60 km depth or greater

MANTLE

source of heat from the lower mantle

Alkalic magma generated at an early stage, under low rates of partial melting.
Hawaiian Scenario
Hawaiian Scenario
Ba high in the uppermost flows of the Mauna Kea section → alkalic basalts; erupted in the waning stage of shield building phase.

The alkalic basalts form because near the end of its life, the volcano drifts off of the plume, and near edge of the plume amount of melting is lower than over the center.
The time taken for this recycling process is thought to be typically about a billion years. By the time the plume melts to produce OIB it has 'aged' isotopically and has higher $^{187}\text{Os}/^{188}\text{Os}$ than the surrounding mantle.

Re-melting of ancient ocean floor

How to unmix Hawaiian cocktails (Halliday *Nature* 399):
Warum die Vulkane auf Hawaii in den Himmel wachsen

Sobolev et al. (2005) Nature 434
Sobolev et al. (2005)
Nature 434
**OIB chemistry - highly variable alkalinity**

Alkali/silica ratios selected ocean island lava suites

<table>
<thead>
<tr>
<th>Island</th>
<th>Alk/Silica</th>
<th>$\text{Na}_2\text{O}/\text{SiO}_2$</th>
<th>$\text{K}_2\text{O}/\text{SiO}_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tahiti</td>
<td>0.86</td>
<td>0.54</td>
<td>0.32</td>
</tr>
<tr>
<td>Principe</td>
<td>0.86</td>
<td>0.52</td>
<td>0.34</td>
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<tr>
<td>Trindade</td>
<td>0.83</td>
<td>0.47</td>
<td>0.35</td>
</tr>
<tr>
<td>Fernando de Noronha</td>
<td>0.74</td>
<td>0.42</td>
<td>0.33</td>
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<tr>
<td>Gough</td>
<td>0.74</td>
<td>0.30</td>
<td>0.44</td>
</tr>
<tr>
<td>St. Helena</td>
<td>0.56</td>
<td>0.34</td>
<td>0.22</td>
</tr>
<tr>
<td>Tristan da Cunha</td>
<td>0.46</td>
<td>0.24</td>
<td>0.22</td>
</tr>
<tr>
<td>Azores</td>
<td>0.45</td>
<td>0.24</td>
<td>0.21</td>
</tr>
<tr>
<td>Ascension</td>
<td>0.42</td>
<td>0.18</td>
<td>0.24</td>
</tr>
<tr>
<td>Canary Islands</td>
<td>0.41</td>
<td>0.22</td>
<td>0.19</td>
</tr>
<tr>
<td>Tenerife</td>
<td>0.41</td>
<td>0.20</td>
<td>0.21</td>
</tr>
<tr>
<td>Galapagos</td>
<td>0.25</td>
<td>0.12</td>
<td>0.13</td>
</tr>
<tr>
<td>Iceland</td>
<td>0.20</td>
<td>0.08</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Strong variation in element ratios (shown in the Table) among the suites → mantle is heterogeneous

- Alkalis are incompatible elements, unaffected by less than 50% shallow fractional crystallization, this argues for **distinct mantle sources** or generating mechanisms
Classification of trace elements
acc. to their geochemical behavior

Plot of ionic radius versus ionic charge with fields of large ion lithophile elements (LILE) and high field strength elements (HFSE).

Ionic potential = charge/size ratio
Trace Elements

- LILE are incompatible and are all enriched in OIBs with respect to MORBs
- The ratios of incompatible elements have been employed to distinguish between source reservoirs
  - N-MORB: the K/Ba ratio is high (usually > 100)
  - E-MORB: the K/Ba ratio is in the mid 30’s
  - OITs range from 25-40, and OIAs in the upper 20’s

Thus all appear to have distinctive sources
Trace Elements

- HFSE also incompatible, and enriched in OIBs > MORBs
- Ratios of these elements are also used to distinguish mantle sources

The Zr/Nb ratio:

- N-MORB generally quite high (>30)
- OIBs are low (<10)
HREEs are fractionated in the OIB samples → garnet was a residual phase.

These melts must have segregated from the mantle at depths > 60 km.

La/Yb (REE slope) correlates with the degree of silica undersaturation in OIBs

- Highly undersaturated magmas: La/Yb > 30
- OIA: closer to 12
- OIT: ~ 4
- → E-MORB and all OIBs appear to originate in the lower enriched mantle
MORB-normalized Spider Diagrams

Data from Sun and McDonough (1989)
MORB-normalized Spider diagrams

Island Arc Basalts

Irregular profile
decoupled HFS - LIL (LIL are hydrophilic)

Data from Sun and McDonough (1989)
Concentrations of trace elements normalized to primitive-mantle concentrations in mid-ocean ridge basalt (N-MORB) ocean island basalt (OIB) island arc basalt (IAB)