Hotspot swells & the lifespan of volcanic ocean islands

Kim Huppert ¹, Taylor Perron ², & Leigh Royden ²

¹ GFZ German Research Centre for Geosciences, ² Massachusetts Institute of Technology

Open Access Science Advances paper doi:10.1126/sciadv.aaw6906
The length of time volcanic ocean islands stay above sea level strongly affects the evolution of their landscapes and biota. Island lifespans vary widely…

Island lifetime depends on the rate and magnitude of island subsidence and thus the dynamics of the lithosphere and mantle → Island lifetimes may help clarify the mechanisms that modify seafloor depth at ocean hotspots.
The seafloor surrounding ocean hotspots is anomalously shallow over broad regions, but the processes generating bathymetric swells are uncertain.
End-member mechanisms of swell uplift produce different patterns of seafloor and island subsidence

Subsidence rate depends on extents of lithospheric reheating and thinning

Prediction: Island (and seafloor) subsidence mimics subsidence of young ocean lithosphere

Subsidence rate depends on swell geometry and plate velocity

Prediction: Island drowning coincides with island migration off of swell topography

\[
\text{Swell residence time} = \frac{\text{swell length}}{\text{plate velocity}}
\]
We analyzed swell morphology and island drowning at 14 ocean hotspots.
We used an objective filtering method to isolate swell bathymetry at each hotspot.

Topography, excluding sediment and its compensation ($T_e = 30$ km), above a plate cooling model (km).

Cape Verde Rise

- Santo Antão, 8 Ma
- São Vicente, 9 Ma
- Sal, 26 Ma
- Maio, 22 Ma
- Santiago, 5 Ma
- Fogo, 0 Ma

Contours – optimal robust separator spatial median filtered regional bathymetry (km).

Contour values:
- 0.2
- 0.4
- 0.6
- 0.8
- 1.0
- 1.2
- 1.4
- 1.6
- 1.8
- 2.0
- 2.2
- 2.4
- 2.6
- 2.8
- 3.0
- 3.2
- 3.4
- 3.6
- 3.8
- 4.0
- 4.2
- 4.4
- 4.6
- 4.8
- 5.0
- 5.2
- 5.4
- 5.6
- 5.8
- 6.0
- 6.2
- 6.4
- 6.6
- 6.8
- 7.0
- 7.2
- 7.4
- 7.6
- 7.8
- 8.0

Legend:
- Red: Highest values
- Blue: Lowest values

18 mm/yr

250 km

20° W

25° W

20° N

15° N
We extracted swell profiles through island volcanoes and compiled radiometric ages to measure swell length and plate velocity relative to each hotspot.
Subsidence of observed regional bathymetry outpaces thermal subsidence of reheated and thinned lithosphere.

Expected seafloor depth.

Regional bathymetry.

Conductive cooling.

Seafloor age 149 Ma
Thermal age 28 Ma

Fogo, 0 Ma
Santiago, 5 Ma
Maio, 22 Ma
Sal, 26 Ma
Swell residence times are <10 Myr on fast-moving plates and >20 Myr on slower moving plates.

\[ \text{Swell residence time (Myr)} = \frac{\text{swell length}}{\text{plate velocity}} \]
To compare swell residence time to island lifespan, we bracketed the age of island drowning in each chain using the ages of volcanoes exposed above sea level or that show evidence of past subaerial eruption and erosion.

**Evidence of subaerial eruption & erosion**
- Wave-cut terraces
- Drowned coral
- Rounded cobbles and beach sediment
- Vesicular and/or low sulfur content basalt
- Razed, flat-topped morphology
Swell residence time agrees well with island lifespan in each chain, suggesting an important sublithospheric source of swell compensation.

<table>
<thead>
<tr>
<th>Island</th>
<th>Volcano age (Myr)</th>
<th>Peak volcano elevation (km)</th>
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</thead>
<tbody>
<tr>
<td>Off swell → predict guyots</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off swell → predict islands</td>
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</tbody>
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\[
\text{Swell residence time (Myr)} = \frac{\text{swell length}}{\text{plate velocity}}
\]
Our results explain variations in island lifespan in different tectonic settings, which affect topography, biodiversity, and climate and thereby link the evolution of the solid earth, biosphere, and hydrosphere.

For more details and information, see doi:10.1126/sciadv.aaw6906