See this page in the course material.

In geology, the places known as **hotspots** or **hot spots** are volcanic regions thought to be fed by underlying mantle that is anomalously hot compared with the surrounding mantle. They may be on, near to, or far from tectonic plate boundaries. Currently, there are two hypotheses that attempt to explain their origins. One suggests that they are due to hot mantle plumes that rise as thermal diapirs from the core-mantle boundary. An alternative hypothesis postulates that it is not high temperature that causes the volcanism, but lithospheric extension that permits the passive rising of melt from shallow depths. This hypothesis considers the term “hotspot” to be a misnomer, asserting that the mantle source beneath them is, in fact, not anomalously hot at all. Well known examples include Hawaii and Yellowstone.

Background

The origins of the concept of hotspots lie in the work of J. Tuzo Wilson, who postulated in 1963 that the Hawaiian Islands result from the slow movement of a tectonic plate across a hot region beneath the surface. It was later postulated that hotspots are fed by narrow streams of hot mantle rising from the Earth’score-mantle boundary in a structure called amantle plume. Whether or not such mantle plumes exist is currently the subject of a major controversy in Earth science. Estimates for the number of hotspots postulated to be fed by mantle plumes has ranged from about 20 to several thousands, over the years, with most geologists considering a few tens to exist. Hawaii, Réunion, Yellowstone, Galápagos, and Iceland are some of the currently most active volcanic regions to which the hypothesis is applied.

Most hotspot volcanoes are basaltic (e.g., Hawaii, Tahiti). As a result, they are less explosive than subduction zone volcanoes, in which water is trapped under the overriding plate. Where hotspots occur in continental regions, basaltic magma rises through the continental crust, which melts to form rhyolites. These rhyolites can form violent eruptions. For example, the Yellowstone Caldera was formed by some of the most powerful volcanic explosions in geologic history. However, when the rhyolite is completely erupted, it may be followed by eruptions of basaltic magma rising through the same lithospheric fissures (cracks in the lithosphere). An example of this activity is the Ilgachuz Range in British Columbia, which was created by an early complex series of trachyte and rhyolite eruptions, and late extrusion of a sequence of basaltic lava flows.

The hotspot hypothesis is now closely linked to the mantle plume hypothesis.

Comparison with island arc volcanoes

Hotspot volcanoes are considered to have a fundamentally different origin from island arc volcanoes. The latter form over subduction zones, at converging plate boundaries. When one oceanic plate meets another, the denser plate is forced downward into a deep ocean trench. This plate, as it is subducted, releases water into the base of the over-riding plate, and this water mixes with the rock, thus changing its composition causing some rock to melt and rise. It is this that fuels a chain of volcanoes, such as the Aleutian Islands, near Alaska.

Hotspot volcanic chains

The joint mantle plume/hotspot hypothesis envisages the feeder structures to be fixed relative to one another, with the continents and seafloor drifting overhead. The hypothesis thus predicts that time-progressive chains of volcanoes are developed on the surface. Examples are Yellowstone, which lies at the end of a chain of extinct calderas, which become progressively older to the west. Another example is the Hawaiian archipelago, where islands become progressively older and more deeply eroded to the northwest.

Geologists have tried to use hotspot volcanic chains to track the movement of the Earth's tectonic plates. This effort has been vexed by the lack of very long chains, by the fact that many are not time-progressive (e.g. the Galápagos) and by the fact that hotspots do not appear to be fixed relative to one another (e.g., Hawaii and Iceland.)

Postulated Hotspot Volcano Chains

Figure 2. Kilauea is the most active shield volcano in the world. The volcano has erupted nonstop since 1983 and it is part of the Hawaiian-Emperor seamount chain.

- Hawaiian-Emperor seamount chain (Hawaii hotspot)
- Louisville seamount chain (Louisville hotspot)
- Walvis Ridge (Gough and Tristan hotspot)
- Kodiak–Bowie Seamount chain (Bowie hotspot)

- Cobb-Eickelberg Seamount chain (Cobb hotspot)
- New England Seamount chain (New England hotspot)
- Anahim Volcanic Belt (Anahim hotspot)
- Mackenzie dike swarm (Mackenzie hotspot)
- Great Meteor hotspot track (New England hotspot)
- St. Helena Seamount Chain – Cameroon Volcanic Line (Saint Helena hotspot)
- Southern Mascarene Plateau–Chagos-Maldives-Laccadive Ridge (Réunion hotspot)
- Ninety East Ridge (Kerguelen hotspot)
- Tuamotu–Line Island chain (Easter hotspot)
- Austral–Gilbert–Marshall chain (Macdonald hotspot)
- Juan Fernández Ridge (Juan Fernández hotspot)

Intraplate Activity

A small amount of geologic activity, known as **intraplate activity**, does not take place at plate boundaries but within a plate instead. Mantle plumes are pipes of hot rock that rise through the mantle. The release of pressure causes melting near the surface to form a **hotspot**. Eruptions at the hotspot create a volcano. Hotspot volcanoes are found in a line (figure 3). Can you figure out why? Hint: The youngest volcano sits above the hotspot and volcanoes become older with distance from the hotspot.

Here is an animation of the creation of a hotspot chain.

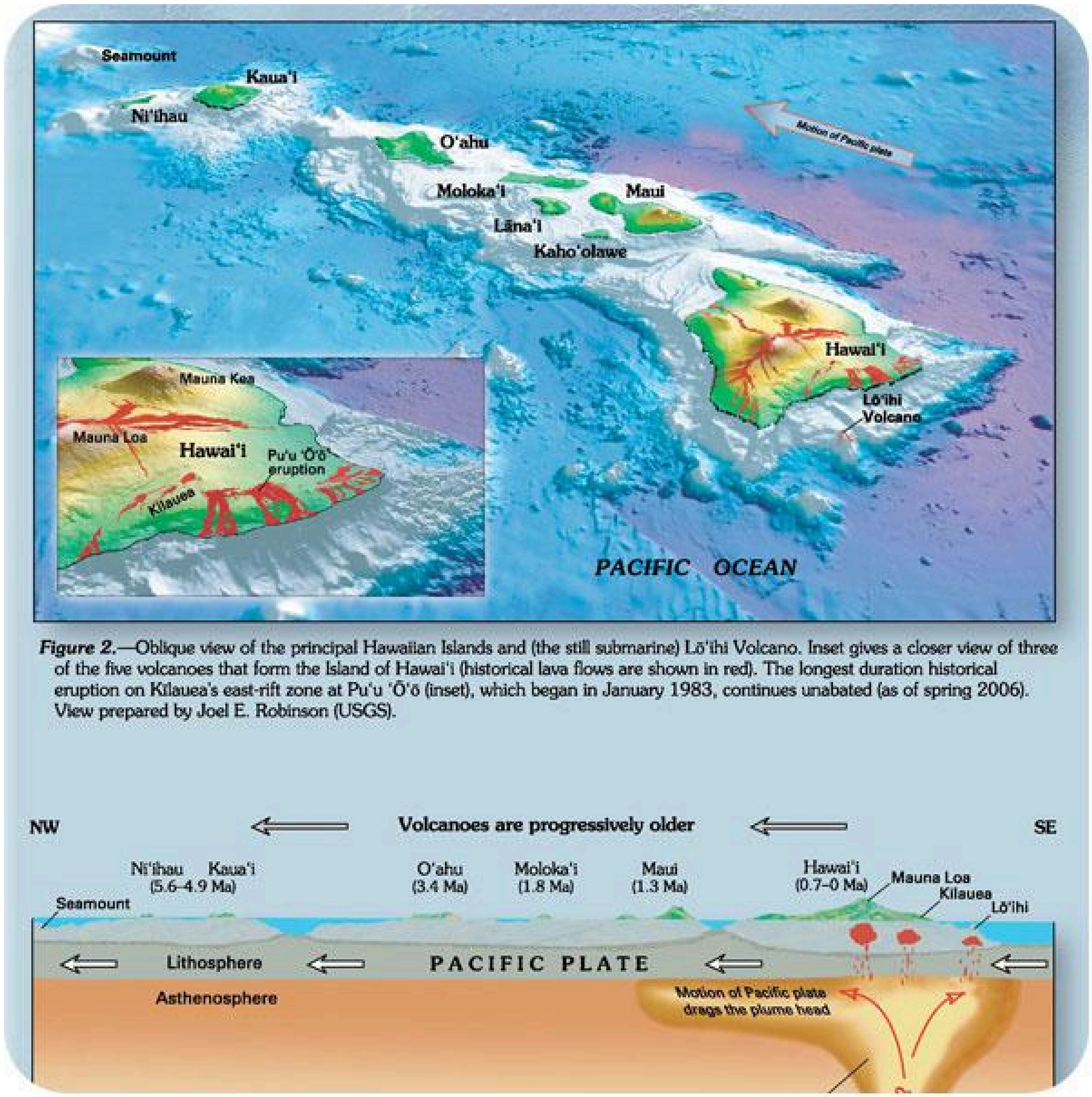

Figure 2.—Oblique view of the principal Hawaiian Islands and (the still submarine) Lō'ihi Volcano. Inset gives a closer view of three of the five volcanoes that form the Island of Hawai'i (historical lava flows are shown in red). The longest duration historical eruption on Kīlauea's east-rift zone at Pu'u 'Ō'ō (inset), which began in January 1983, continues unabated (as of spring 2006). View prepared by Joel E. Robinson (USGS).

Figure 3. The Hawaiian Islands are a beautiful example of a hotspot chain. Kilauea volcano lies above the Hawaiian hotspot. Mauna Loa volcano is older than Kilauea and is still erupting, but at a lower rate. The islands get progressively older to the northwest because they are further from the hotspot. Loihi, the youngest volcano, is still below the sea surface.

Geologists use some hotspot chains to tell the direction and the speed a plate is moving (figure 4).

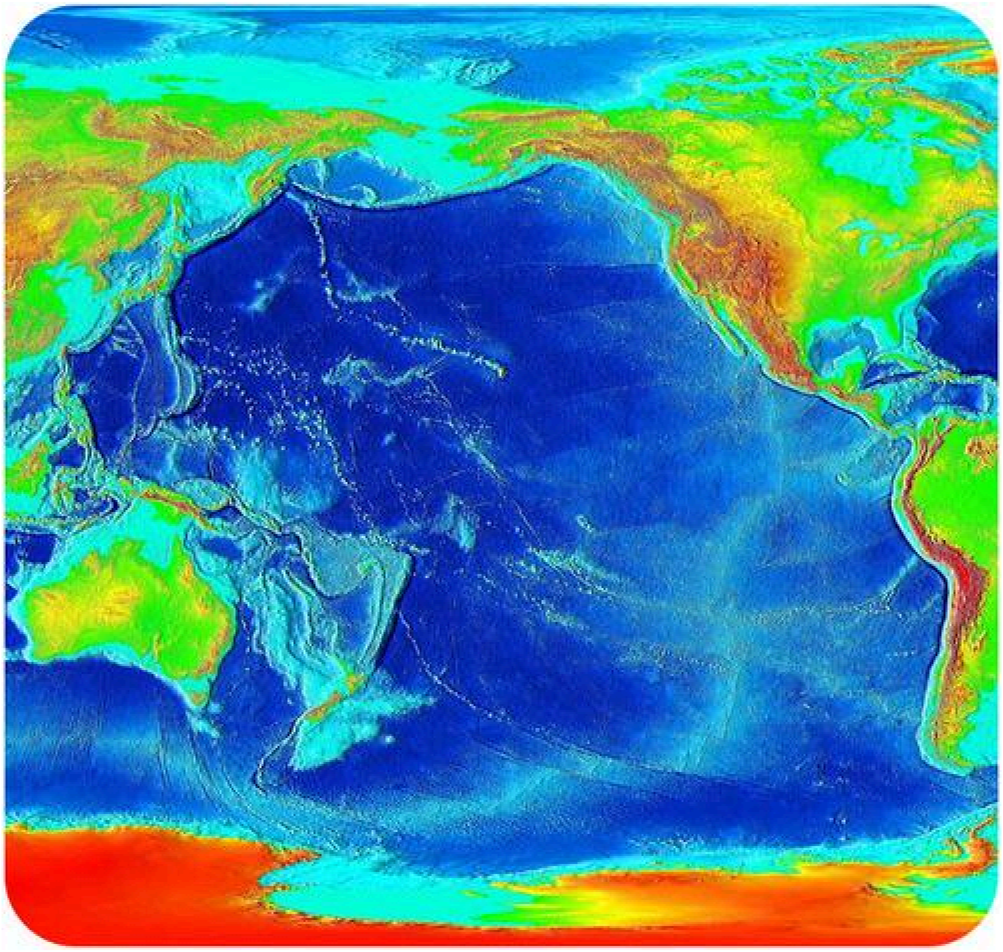

Figure 4. The Hawaiian chain continues into the Emperor Seamounts. The bend in the chain was caused by a change in the direction of the Pacific plate 43 million years ago. Using the age and distance of the bend, geologists can figure out the speed of the Pacific plate over the hotspot.

Hotspot magmas rarely penetrate through thick continental crust. One exception is the Yellowstone hotspot (figure 5).

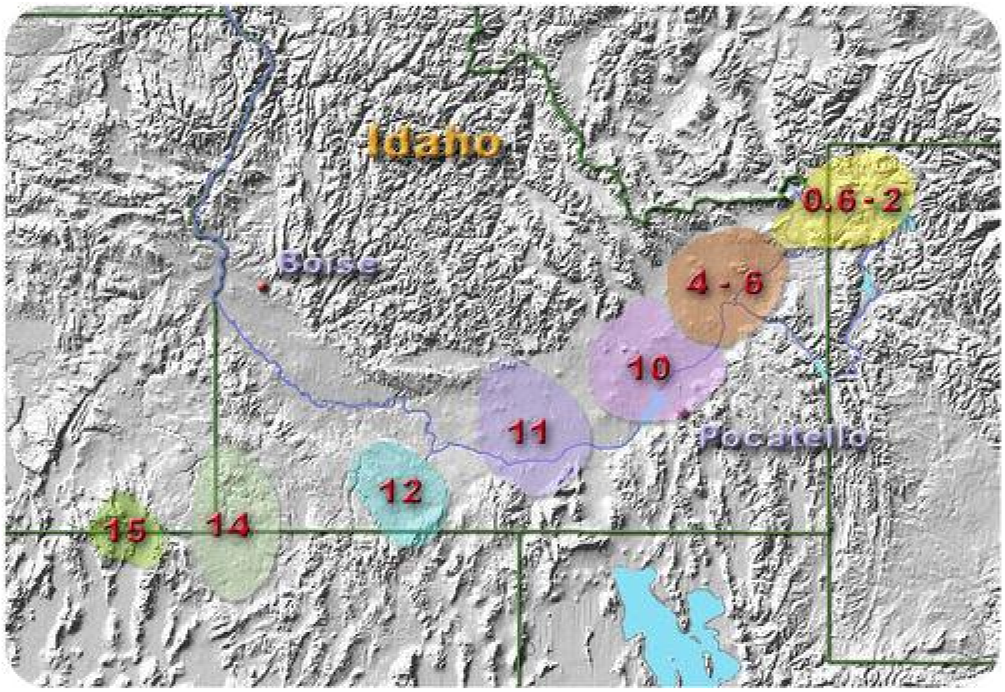

Figure 5. Volcanic activity above the Yellowstone hotspot on the North American Plate can be traced from 15 million years ago to its present location.

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