Geochemical analysis of the basaltic rocks from volcanoes of the Hawaiian Island: Implications for their evolutionary stage of development

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Abstract

The Island of Hawaii consists of five different volcanoes. These volcanoes have been active over the last million years and erupted predominantly basaltic lavas. These lavas differ in age and chemistry, which is related to their position over a large mantle plume that continually feeds magma to these volcanoes as the oceanic lithosphere moves over this hot spot. The geochemistry of these lavas changes over time and provides insight into the processes operating during their eruption activity.

This project is concerned with analyzing the geochemical signature in basaltic rocks from the five main volcanoes of Hawaii. From north to south these include: Kohala, Hualalai, Mauna Kea, Mauna Loa, and Kilauea. Samples were collected and prepared in the Department of Geological Sciences and analyzed for major oxides and trace elements using X-ray fluorescence techniques. The goal of this project is to investigate the changes in geochemical signature with respect to time and position related to the mantle plume beneath the island of Hawaii.

Sample Preparation & Analytical Methods

X-ray Fluorescence is the emission of x-rays onto a material, and the secondary x-rays that the material produces provides insight into its chemical composition. Two methods were employed for geochemical analysis, fusion glass beads and pressed pellets.

Fusion beads are utilized for major oxide analysis whereas, pressed pellets are used for trace element analysis. The XRF system is fully automated and results typically obtained within a few hours.

All samples of basalt were crushed and pulverized into gravel size (<4 mm) using the jaw crusher. Crushed material was placed in a ball mill between 40 to 90 minutes. The resulting fine powder was used to prepare the samples into pressed pellets and fusion beads. (n.b. if the powder was not fine enough, the larger grains would alter the ratio of chemical composition in the rock, which would give an inaccurate analysis of the abundance of certain elements in the rock.)

Pressed pellets were prepared by drying the powder for 1 hour to drive off any water present. Powders were then mixed with an inert binding material. The sample was then compacted using 20 ton of pressure.

Fusion beads were prepared by mixing the powder with lithium tetraborate in a 1:7 ratio. Then, approximately 0.250 g was measured to calculate the mass of lithium tetraborate in the sample. This data is recorded for any mass, that may have been present in the sample. Both were put into separate graphite crucibles, and sealed in the muffle furnace for 20 minutes. Every 5 minutes, the powder mixed with the lithium tetraborate was taken out, and swirled to promote the complete mixing of the material.

Samples were cooled for an hour, and the result of the powder and lithium tetraborate mixture was a fusion bead, similar in appearance to a small glass disk. Then, the glass was polished prior to placing it into the XRF for analysis.

Geologic Setting

The Hawaiian Islands are comprised of large shield volcanoes that erupt large volumes of basaltic lavas. These large volumes and enormous outpourings of lava are a result of the motion of the Pacific tectonic plate moving over a relatively stationary hot spot, or mantle plume.

In Hawaii, there are five major volcanic centers that are in various stages of development depending on their position over the hot spot. Activity brings in a pre-shield building stage as the area moves onto the hot spot. This stage is characterized by alkali-rich lavas termed alkali basalts. As the plate moves directly over the mantle plume, the volcanic transitions to the main shield building stage. It is this stage that is responsible for the massive outpourings and significant growth of a volcano. This stage is characterized by less alkali-rich lavas termed tholeiite basalts. As the plate continues to move over the main hotspot, the volcanic transitions to the post-shield building stage, characterized once again by alkali-rich lavas (alkali basalts). Finally, the volcanic center becomes inactive and enters an erosional stage as it no longer receives magma from the plume.

This project focused on the five volcanic centers on the Big Island of Hawaii: 1) Kohala; 2) Hualalai; 3) Mauna Kea; 4) Mauna Loa; and 5) Kilauea.

Shield Volcanoes

Kohala

Hualalai

Mauna Kea

Mauna Loa

Kilauea

Project Objectives

1) Collect basalt samples from different volcanic centers of Hawaï. 2) Crush and pulverize samples and prepare for whole-rock geochemical analysis. 3) Perform X-ray fluorescence analysis on whole-rock basalt samples using fusion glass beads for major oxides and press pellets for trace element analysis. 4) Evaluate and determine the eruptive stage of each volcano based on the geochemical signature.

Geochemical Results

Conclusions

There are three developmental stages for volcanoes evolution on the Island of Hawaï. These stages include 1) pre-shield building stage, 2) main shield building stage, and 3) post-shield building stage. The developmental stage is dependent on the position of Hawaï over that mantle plume.

Geochronological dating of the lavas shows: 1) Hualalai and Kohala are alkalic and hence are in their post-shield building stage, entering the erosional stage; 2) Mauna Kea, Mauna Loa, and Kilauea are tholeiitic and within the main shield building stage; and 3) Geochemical discrimination diagrams are consistent with the geologic setting of the volcanoes with Hualalai and Kohala representing oceanic island alkali basalts (OIB) and Mauna Loa and Kilauea plotting within the oceanic island tholeiite field.

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