The Lithologic Constitution of the Crust and Mantle in the Hawaiian Area[1]

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NEARLY NOTHING IS KNOWN by direct observation about the composition of either the mantle or the crust below sea level in the Hawaiian region. Almost the only information about either comes from the interpretation of geophysical studies.

We generally refer to the crust beneath the Pacific basin as basaltic but, with the exception of a few samples dredged from widely separated localities (Engel and Engel, 1964), which are indeed basaltic, all we really know about the sub-Pacific crust is the velocity of seismic waves in it.

Above sea level the Hawaiian mountains consist largely of tholeiitic basalt, with a minor cap of alkalic basalt and related rocks ranging from ankaramite to trachyte, and an even smaller volume of nephelinites and related rocks. Below sea level the rock constitution is known only by implication and from a few samples dredged from very limited areas. Evidence suggests considerable isostatic sinking of the older of the Hawaiian Islands, and it may be presumed that the rocks down to as much as 3,000 ft below sea level in the older islands are the same as those we see above sea level in the younger volcanoes. Other than that, tholeiitic basalts have been found by dredging along the east rift zones of Kilauea and Mauna Kea volcanoes and the south rift zone of Mauna Loa, down to a depth of 12,000 ft (J. G. Moore, personal communication).

It has been suggested that the building of the volcanoes through the zone from a depth of a few thousand feet to sea level involved much steam explosion and granulation of the lavas in contact with water, producing large volumes of basaltic ash and hyaloclastite. Evidence from submarine photographs and dredging on the aforementioned rift zones does not support this suggestion; but the evidence is scanty, and it has been argued that the fragmental material has been removed into deep water by currents. Certainly, however, in very deep water, explosion is prevented by the restraining pressure of the overlying ocean, though hyaloclastite formation might take place. The flows should be dense, because the restraining pressure prevents vesicle formation unless the gas content is very much greater than it is in magmas erupting above sea level. This theoretical conclusion is supported by the actual decrease in size and abundance of vesicles in samples of lava dredged from increasing depths of water.

All of the actual evidence suggests that the lower slopes of the volcanic mountains and the adjacent archipelagic aprons, as well as the sea floor at greater distances from the islands, consists of layers of dense tholeiitic basalt. A hole through the Moho in the Hawaiian region would give us our first real direct knowledge of the suboceanic "B layer."

Even less is known about the constitution of the mantle than about that of the suboceanic crust. Hawaiian alkalic basalts and nephelinites contain numerous inclusions of ultrabasic rocks, predominantly dunite, lherzolite, and wehrlite. Some workers have presumed these to be fragments derived from the mantle and carried up by the rising magma. However, at some localities they grade compositionally into gabbro, and even into anorthosite; and some show pronounced compositional banding closely resembling, if not identical with, that found in many big differentiated basaltic sheets such as the Stillwater intrusion in Montana. These are more probably derived from consolidated intrusive bodies at comparatively shallow depth beneath the volcano, well above the mantle boundary. Others may be derived from the mantle, though the evidence for this is slight and far from conclusive. Garnet pyroxenite ("eclogite") inclu-

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sions, found only at Salt Lake Crater on Oahu, show the garnet-omphacite association characteristic of high pressure, and appear probably to be of mantle origin; though it is conceivable that the conditions responsible for the development of the high-pressure mineral facies may have had some other origin.

Because of the very shallow position of the Mohorovicic discontinuity in the central Pacific, few persons still adhere to the belief that it may represent the basalt-eclogite phase transition (though a similar transition may take place from peridotite to olivine-garnet peridotite containing sodic pyroxene at a deeper level within the mantle). However, it has recently been suggested, on the basis of high P-T laboratory studies of basalt in the presence of volatiles, that the Moho beneath the deep oceans may be a phase transition from basalt to glaucophane-lawsonite rock (George Kennedy, address at Berkeley, California, October 7, 1964).

The net conclusion from all available evidence seems to me to be that the mantle beneath the central Pacific probably consists of peridotite approaching in composition the average stony phase of stony meteorites, or the theoretical "pyrolite" of Lovering, undergoing a phase change at depth to olivine-garnet pyroxenite.

In recent years a large amount of important petrologic theory and petrogenic speculation has been based on Hawaiian rocks. We are accumulating a large mass of information on the volcanic rocks above sea level. The evidence is strong that, whatever the processes that give rise to the diversity of rock types in Hawaii, the primary magma or magmas that give rise to them are derived from the mantle. Yet it should be obvious from the foregoing that very little is known directly of the composition of the mantle in the Hawaiian region. A hole through the Moho in this region would give not only incontestable knowledge of the nature of the mantle, but also specific knowledge of its local chemical and mineral composition that can be correlated with the composition of the extensively studied tholeiitic lavas found in Hawaii. Such correlative studies are essential if theories about the origin of magmas are to move out of the realm of speculation onto firmer ground.

REFERENCE

ENGEL, A. E. J., and C. G. ENGEL. 1964. Igneous rocks of the East Pacific Rise. Science 146:477–485.