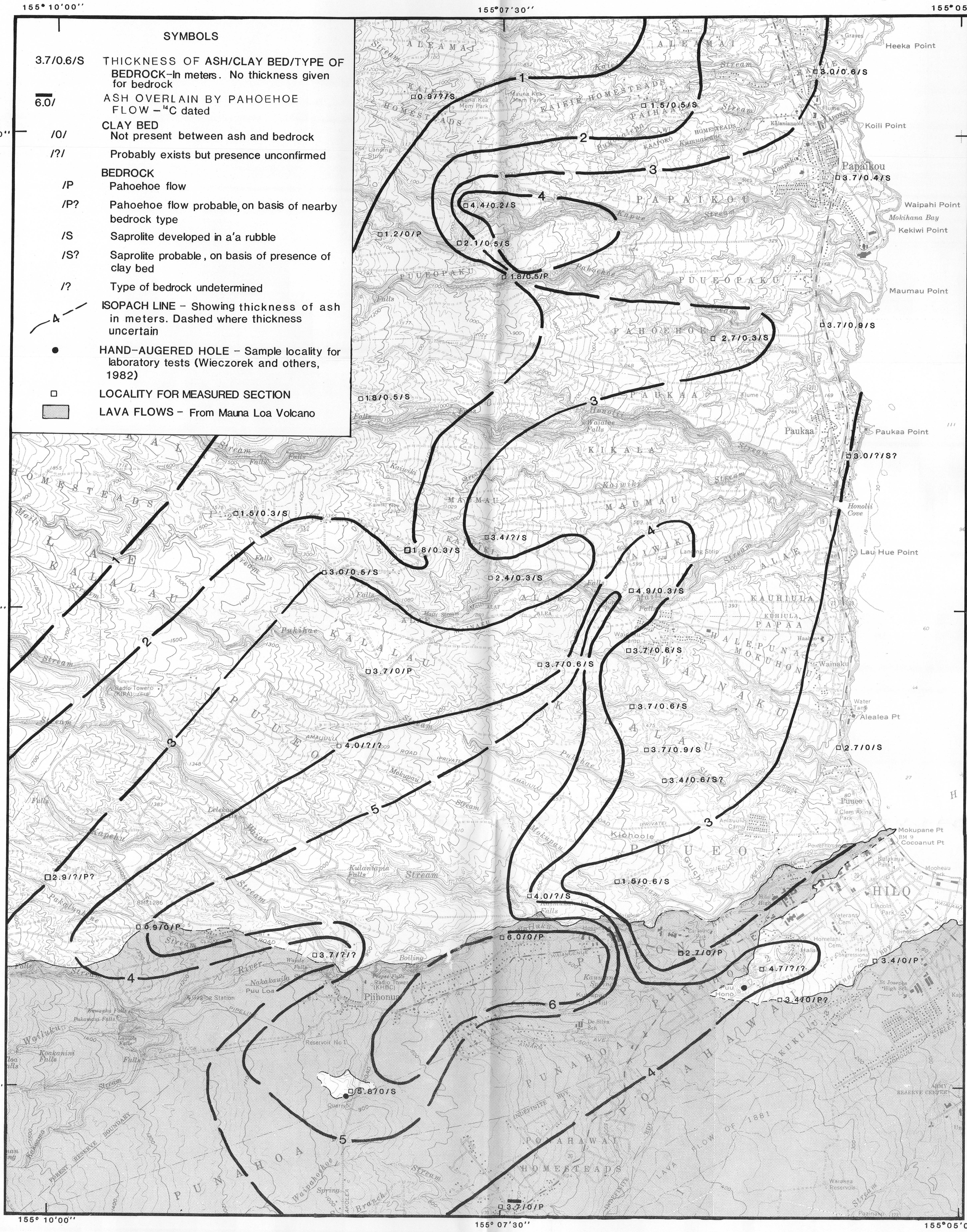
UNITED STATES GEOLOGICAL SURVEY
DEPARTMENT OF THE INTERIOR

MISCELLANEOUS FIELD STUDIES
MAP MF-1499

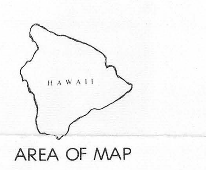


Base from U.S. Geological Survey, 1:24 000, Akaka Falls; Papaikou, 1966; Pi'ihonua, Hilo, 1963

APPROXIMATE MEAN DECLINATION, 1983

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL



Geology compiled 1979-80

RECONNAISSANCE MAP SHOWING THICKNESSES OF VOLCANIC ASH DEPOSITS IN THE GREATER HILO AREA, HAWAII

By

Jane M. Buchanan-Banks

1983

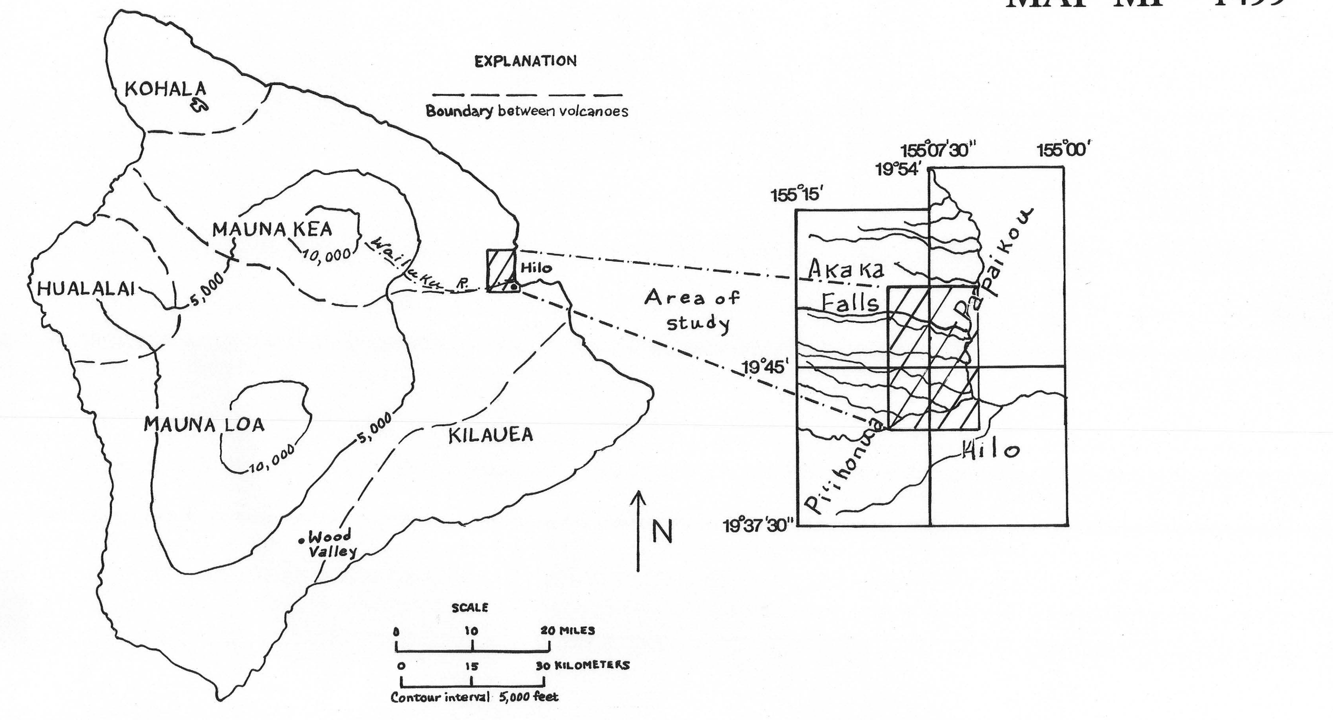


Figure 1.--Index map showing the island of Hawaii (after U.S. Geological Survey, 1976) and the $7\frac{1}{2}$-minute quadrangles covering the area of study.

INTRODUCTION

This study was undertaken to determine the thickness and distribution of volcanic ash deposits in the greater Hilo area, Hawaii, as a step toward evaluating their susceptibility to failure during earthquake shaking. On several occasions their instablity has resulted in serious damage. For example, the 1868 earthquake (m=7+), following a prolonged rainy period, caused a debris flow of hillside ash deposits that killed 31 people in Wood Valley (Brigham, 1869). The 1973 Honomu earthquake (m=6.2) resulted in more damage from shaking to areas underlain by ash deposits in the older part of Hilo than in other areas, and soil slips in ash, as well as rockfalls, were common along the roads north of town (Nielsen and others, 1977).

Three geologic units are represented on the accompanying map: the ash deposits, a clay bed that locally underlies the ash, and the bedrock material.

METHOD OF WORK

Fieldwork in the northwest part of the Hilo quadrangle and parts of the Papaikou, Akaka Falls, and Piihonua quadrangles consisted mainly of traverses along the public roads, sugarcane haulage roads, and in the drainage channels (fig. 1). Dense vegetation adjacent to and in streams, as well as the precipitous embankments of most of the drainage channels, limited data collection in many areas, particularly west of the established haulage roads. Some sections of ash in the present study were near and are similar to those described and measured by Wentworth (1938). However, Wentworth's sites could not be relocated exactly, due to insufficient descriptions, alteration of roads, and overgrown slopes.

The ash exposures were scraped clean to remove vegetation and the weathered surface material before examination of overall color, thickness and color of individual bands, textural differences among bands, and any general similarities or differences between outcrops. The thickness of the ash was measured and the underlying type of lava flow was identified where possible. In some places an underlying clay bed exists and was measured, and in other places the clay bed and (or) bedrock were not exposed.

GEOLOGIC SETTING AND AGE OF ASH DEPOSITS AND LAVA FLOWS

The volcanic ash in the map area mostly overlies basalt and olivine basalt lava flows. North of the Wailuku River, the ash blankets lava flows of the Hamakua Volcanic Series from Mauna Kea Volcano (Stearns and Macdonald, 1946); these deposits are truncated along the coast by wave-cut cliffs as much as 30 m high. The major streams that drain this part of the coast flow from west to east in deeply incised channels. South of the Wailuku River the ash is deposited partly on the Hamakua Series and partly on prehistoric flows of the Kau (pronounced Ka'u) Volcanic Series of Mauna Loa (Stearns and Macdonald, 1946), and in some places the ash deposits are covered by lava flows from Mauna Loa Volcano. In this area streams flow in a general eastnortheast direction, commonly along the margins of recent lava flows; the stream channels range from well defined to amorphous, but all are shallow relative to the Wailuku River channel and the stream channels farther north.

The ages of some lava flows are known from radiocarbon dates on charcoal found beneath them, as well as by stratigraphic relations, and the ages of others have been estimated from their degree of weathering. The ash deposits are dated only by their relation to underlying and overlying flows of known or inferred age. In the map area most of the Mauna Loa flows that lie above and that are interbedded with the ash deposits have been dated, but charcoal has not been found beneath the Mauna Kea flows underlying the ash.

The earliest carbon-14 date within the map area is 24,200 years B.P. (Meyer Rubin, written commun., 1981; fig. 2). This date was obtained on charcoal from beneath a Mauna Loa pahoehoe flow. The earliest carbon-14 date from a Mauna Loa flow that postdates what is believed to be the same ash is 14,500 years B.P. (Meyer Rubin, written commun., 1980). Thus, deposition of much of the ash in the map area began more than 24,000 years ago and ended more than 14,000 years ago. More recent dates have been obtained from beneath Mauna Loa lava flows overlying thin ash deposits. Whether these younger, thin ash deposits that are interbedded with the lava flows were formed by discrete ash-forming eruptions or whether they were derived from older primary deposits that were redistributed by running water is not known.

SOURCE OF ASH DEPOSITS

The ash in the map area is generally believed to be an air-fall deposit erupted mainly from Mauna Kea Volcano, with minor contributions probably from Mauna Loa and Kilauea Volcanoes (Wentworth, 1938, p. 164-165; Stearns and Macdonald, 1946, p. 71-76). A history of episodic deposition and weathering of this ash is suggested from the analyses of the geotechnical properties of a sequence of ash layers in the Hilo area (Wieczorek and others, 1982). Several local names have been applied elsewhere to the ash deposits (including Pahala Ash and Homelani, Pepeekeo, and Waiau ashes), but these are not used here for convenience.

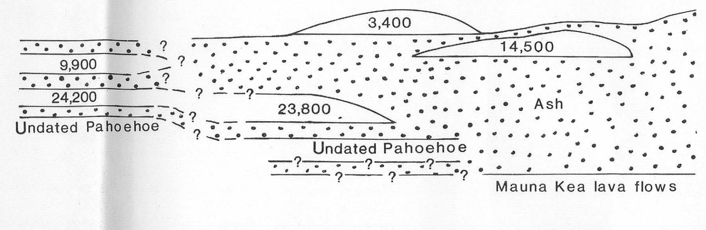


Figure 2.-- Schematic drawing of selected ash and lava exposures and ages (not to scale). Ages are from carbon-14 analyses done at the U.S. Geological Survey Radiocarbon Laboratory, Reston, Va. Ash is stippled; lava is unpatterned, with age (years B.P.) indicated.

UNITS REPRESENTED ON MAP

Three units are represented on the accompanying map. The ash deposits are generally on the surface, but south of the Wailuku River, they are commonly overlain by pahoehoe flows from Mauna Loa Volcano. Where thus overlain, deposits are indicated on the map by a bar symbol above the measured thickness. A yellowish-gray clay bed locally underlies the ash deposits and in turn overlies some of the deeply weathered a'a flows from Mauna Kea Volcano. The clay bed has not been found where ash overlies pahoehoe flows from either Mauna Kea or Mauna Loa. The ash and clay overlie mainly basalt and olivine basalt flows.

Ash Deposits

The ash was originally composed of particles of volcanic glass and crystal fragments, but severe weathering, resulting from high average annual temperatures and abundant rainfall, has altered most of the original constituents to gibbsite, allophane and, locally, halloysite (Bates, 1960; Wieczorek and others, 1982).

From a distance, outcrops of the ash appear generally orangish yellow, but on closer examination, they are banded in colors ranging from pale yellowish orange (10YR8/6) through very dark grayish brown (10YR3/2) (Goddard and others, 1948). The bands may represent ash beds that range in thickness from 1 centimeter to approximately 1 meter. Some textural differences are observable from bed to bed, and changes in geotechnical properties also correlate with the bedding (Wieczorek and others, 1982). The beds, therefore, may have resulted from several different eruptions, but they also could reflect a single prolonged eruption with differences in original grain size, in transportation mechanics, or in the response of various layers to weathering.

Slight differences in the overall grain size and water content were noticed between some outcrops. Two sites, one with a predominance of coarse ash and the other with sequences of beds with fine-to-coarse ash, were selected for geotechnical testing, and their locations are indicated on the map by a solid circle. The results of the tests (Wieczorek and others, 1982) confirm that in general the finer grained ash of Akolea Road, which is typical of most of the ash deposits, has higher water content and plasticity than the coarser grained ash of Pu'u Hono.

Isopach lines on the map depict the thickness of the ash in meters. Where outcrops of the ash are numerous, the isopach lines are solid. However, owing to a scarcity of measureable outcrops, most isopach lines are dashed to reflect an uncertain thickness of the ash. Extensive ash deposits exist both north and west of the mapped area, and a few isolated outcrops of surface ash also occur south of the map boundary; these deposits were not included in the present study. Thicknesses of ash north of the Wailuku River have been decreased by mechanical removal of material during sugarcane harvesting as well as by accelerated fluvial erosion throughout many years. The apparent thinning of the ash toward the northwest may also be a result of intensive agriculture together with general downslope movement of the disturbed ash. The thickest ash (6 m) observed is along the south embankment of the Wailuku River where it is overlain by a pahoehoe flow and thus is protected from erosion.

When weathered surfaces are scraped clean, the ash deposits are typically damp and slippery. The dampness results from an average rainfall of 380 cm per year in the area, as well as the water-retentive properties of the ash; the slipperiness is the result of the large amount of clay-size material. The ash has a water content as high as 392 percent (weight of water/weight of dry sample= water content; Wieczorek and others, 1982). Upon drying, it undergoes irreversible changes in both grain size and plasticity (Terzaghi and Peck, 1967, p. 455; Hirashima, 1948).

Undisturbed ash deposits are relatively well indurated and fairly resistant to erosion. They form steep road cuts (>60°) that reflect the high angle of internal friction of the material (40°-43°, Wieczorek and others, 1982). Nevertheless, landslides frequently occur in the ash and underlying materials following heavy rains, and the consistency of the ash can change when subjected to vibratory stresses. Hirashima (1948) reports that the repeated passage of heavy construction equipment across the ash deposits causes them to become semi-fluid and that this condition reverses when equipment movement ceases.

The ash deposits in the greater Hilo area are classified as medium to very sensitive (Wieczorek and others, 1982; sensitivity is the ratio of the strength of the undisturbed material to the strength of the material after its natural internal structure has been modified by manipulation). Slopes composed of ash with such sensitivities are likely to fail during earthquake shaking; failure would be expected along steep slopes and along road embankments and stream banks where the material is unsupported. However, no evidence of large-scale failures were found during field work for the present study.

Clay Bed

The ash deposits are locally underlain by a yellowish-gray (5Y7/2) clay bed as thick as 0.9 m. The mineralogy of this bed distinguishes it from the overlying ash. X-ray diffraction analyses show that over 55 percent of each of the samples analyzed is the clay mineral illite (J.R. Hein, written commun, 1982). Owing to the large amount of colloidal material, it was not possible to determine sand/silt/clay ratios. However, simple field tests indicate that the clay bed contains a higher percentage of clay-size material than the ash deposits. The clay bed is relatively impermeable, probably because of its high clay content. This may cause water to accumulate at the base of the ash and increase the potential for sliding of both the ash and clay. Two adjacent landslides involving the ash and clay together with some overlying fill material were examined soon after they occurred, following a prolonged period of intense rain in March 1980. The slide surface appeared to be within the upper part of the clay deposit, and the basal part of the ash was noticeably wetter than either its upper part or the underlying clay bed. This wetness, however, may have been the result of movement of water along the slide surface. Lava fragments in the clay bed are similar in composition to the underlying upper a'a rubble and are as large as 13 cm across. This suggests that the clay was at least partly derived from weathering of the a'a rather than from preferential degradation of the base of the overlying ash.

Lava Flows

Pahoehoe and a'a flows compose the bedrock material. They are mainly basalt and olivine basalt from both Mauna Kea and Mauna Loa Volcanoes, but include ankaramites from Mauna Kea.

The Mauna Kea flows are more deeply weathered owing to their greater age. The original material of the pahoehoe flows and rubbles at the top and base of the a'a flows is almost totally altered to a soft, clay-rich residue surrounding a relatively unweathered core of original lava. The weathering has locally produced saprolite consisting of well-rounded to sub-angular rock remnants in a clayey matrix. The matrix cements the a'a rubbles and gives them a cohesion generally not found in rubbles of young a'a flows.

The saprolite that is well developed in the rubbles of the a'a flows is also present, but to a lesser degree, in the dense central part of the flows. At some localities the top of this central cooling unit is severely weathered, whereas the deeper levels of the flow show spheroidal weathering with zones about 1 cm wide of earthy residue surrounding the spheres. According to Bates (1962), these zones represent solution channels along which leaching has occurred, followed by redeposition of colloidal material. Because of their greater resistance to weathering, olivine and pyroxene phenocrysts, when present in the lava flow, also can be identified in the clayey residue of the a'a rubble as well as in the solution channels surrounding the spheroidal remnants in the central part of the flow. Tests were not performed on the saprolites, and the geotechnical properties are unknown. Empirically, nonetheless, the altered material is much weaker than unweathered flows.

Pahoehoe flows from Mauna Loa Volcano both locally overlie and are interbedded with the ash deposits in parts of the Pi'ihonua and Hilo quadrangles. These lavas are substantially less weathered than those of Mauna Kea.

CONCLUSIONS

Reconnaisance geologic mapping of volcanic ash deposits in the greater Hilo area suggests a repetitive history of eruption, deposition, and severe weathering. Ash deposits believed to be erupted mainly from Mauna Kea Volcano are interbedded with and overlain by Mauna Loa lava flows in the study area.

The thickest deposit of ash observed is 6 m and occurs south of the Wailuku River. North of the Wailuku River, the ash thickness undoubtedly has been decreased by sugarcane harvesting procedures that mechanically remove some ash while loosening the surface of the remaining ash. This results in accelerated erosion during rainy periods as well as an increase in downslope movement of the disturbed material.

The ash deposits in the study area are classified as medium to very sensitive. Although slopes with these sensitivities are more likely to fail during earthquake shaking than slopes with slight sensitivity, the ash deposits in the map area show no evidence of large-scale slope failures. However, ash deposits with a sensitivity and water content similar to those in the Hilo area failed at Wood Valley during the 1868 earthquake, which occurred during a prolonged rainy period. The combination of a large magnitude earthquake, prolonged shaking, and saturated ash deposits apparently has not occurred in the Hilo area since the deposition of the ash some 24,000 years ago. Thus, although the sensitivity of the ash indicates a high possibility of failure during earthquake shaking, the probability of large-scale failure in the greater Hilo area does not appear high.

On the other hand, numerous small soil slips in ash and rock falls have been documented as a result of earthquake shaking and during heavy rains. These failures occur where the deposits are steepest, as well as along road embankments and stream banks where the material is unsupported. Whether such failures occur on a small or a large scale, they can be financially and personally devastating to an individual. Damage to property and danger to people can be minimized by careful site selection and appropriate earthquake-resistant design of structures.

The clay bed that locally underlies the ash may also fail during heavy rains as well as during earthquake shaking. Owing to its greater impermeability and finer particle size, it may cause water to accumulate at the base of the overlying ash, increasing pore pressure and thereby reducing stability.

ACKNOWLEDGMENTS

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