

Preliminary Observations Concerning the Plant Invasion on Some of the Lava Flows of Mauna Loa, Hawaii.

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DURING an excursion on the island of Hawaii for the purpose of collecting botanical material for the Bishop Museum, an admirable opportunity was offered for making observations on the colonization of a portion of the lava flows of Mauna Loa. Although a limited portion of the mountain has been covered, and observations of this character should extend over a number of years, it is believed that data of enough local interest was obtained for record at this time.

The region visited extends from Puuwaawaa, over the summit of Hualalai, through the districts of Kona and Kau, mainly at an elevation of 4500 feet, which is just above the dense forest belt. One trip was made to the summit of Mauna Loa on the Kailua side, and from numerous localities the forest was penetrated in all directions; the region below the Government road in Kona and the shore line being the only portions from which a representative collection of plants was not taken.

This territory is on the dry or lee side of the island, and for that reason the naturalization of plants on the lava flows may vary somewhat from that of the moister regions; but it is believed that the main factors will prove to be the same, except for rapidity of invasion. The general characteristics of the Hawaiian vegetation have been described by several writers,¹ and in this paper it is the intention to discuss only the flora in the immediate vicinity of the flows visited.

There is probably no better locality in the world for observing the colonization of lava flows than the slopes of Mauna Loa. The

¹ Hillebrand, W.: Flora of the Hawaiian Islands, 1888. Guppy, H. B.: Observations of a Naturalist in the Pacific, vol. ii. Hall, W. L.: The Forests of the Hawaiian Islands, U. S. D. A., Dept. Forestry, Bul. 48, 1904.

whole mountain is a gigantic mass of these lava streams which radiate on all sides from the summit, 13,675 feet, to sea level. The later flows have generally arisen from sources below the summit. The different flows have had irregular courses. Many of them in flowing over older streams have left areas of various sizes of the older flow surrounded on all sides by the newer flow, without apparently harming the vegetation of the resulting island to any appreciable extent. The surrounded areas, known to the natives as "kipuka," may be above or even below the surface of the surrounding flow. Fortunately for a study of this sort the age of many of these flows is known.

The lava flows are of two kinds, generally simply described as the smooth or slaggy, and the rough or scoriaceous; but as these regions differ so much from the country generally traversed by botanists, I quote the fuller word picture of Dana.² "There is the ordinary smooth-surfaced lava called pahoehoe, the term signifying having a satin-like aspect. The surface of the lava cooled as it flowed. Through one means and another the surface is usually uneven, being often wrinkled, twisted, ropy, billowy, hummocky, knobbed, and often fractured. . . . The other most prominent kind of lava stream is the aa. The aa streams have no upper flow-like surface; they are beds of broken up lava, the breaking of which occurred during the flow. They consist of detached masses of irregular shapes, confusedly piled together to a height sometimes of twenty-five to forty feet above the general surface. The size of the masses is from an inch in diameter to ten feet and more. The lava is compact, usually less vesiculated than the pahoehoe, not scoriaceous; but externally it is roughly cavernous, horribly jagged, with projections often a foot or more long that are bristled all over with points and angles. In some cases ragged spaces extend along planes through the large masses, like those of the exterior." Both kinds of lava may be represented in the same flow, either in different parts or closely associated. Many hundreds of these two classes of flows were passed over during the excursion.

The first flow of known date visited was that of 1859. This flow was followed from a point west of Puuwaawaa down to where it crosses the Government road. It is composed of both aa and

²Dana, J. D.: *The Characteristics of Volcanoes*, 1891, p. 9.

pahoehoe. The aa assumes the position of a winding river through the pahoehoe. In places the pahoehoe has flowed around portions of the aa in an irregular manner, leaving sunken islands of aa varying from a few feet to half an acre in area. From the close interrelations between the two there is no doubt that both belong to the same flow. The pahoehoe is jet black and new looking, while the aa has a chocolate tinge, it also appearing very new as compared to adjacent flows.

After several hours spent on the flow it became apparent that, with the exception of the lower cryptogams, most of the vegetation was supported on the pahoehoe and not on the aa. As this was contrary to what I had expected and had heard generally expressed on these islands, I gave particular attention to this point, and also directed my guide to call my attention to any plants he might see on the aa. A portion of the aa stream was followed for a considerable distance down the centre, but nothing was obtained save a liberal supply of cuts and bruises. This scarcity of plants was even true for the small sunken areas of aa, which of all places one would think would be admirable traps for catching seeds and spores. The aa portions of the flow are often white with a certain lichen, and a closer search reveals an occasional moss, but there are no ferns or phanerogams, except on the contact line with the pahoehoe.

The plants which occur on the pahoehoe are to be found growing in the numerous small cracks which cross the flow in various directions, especially where the flow is at all billowy, and between the folds of the ropy lava. The smoother portions are entirely bare of any vegetation. Such cracks act as riffles to catch either disintegrated particles of the flow itself, or dust and other refuse which may be blown over the smooth portions from the outside. At one place I noticed several hundred dead shells of *Eulota similaris* being blown across a portion of the flow, many of them being caught in the cracks. Such soil is stopped on the edge of an aa flow, while apparently not enough accumulates by the weathering of the flow itself in this period of time to fill its smallest spaces.

The following plants were observed scattered here and there in the cracks on the pahoehoe, but they were in no case in suffi-

cient quantity to be conspicuous from a distance. A longer search would probably add quite a few more species to the list:

FILICES.³

<i>Asplenium praemorsum</i> Sw. (<i>Asplenium furcatum</i> , Thbg.)	<i>Pellaea ternifolia</i> (Cav.) Link.
<i>Asplenium trichomanes</i> L., var. (<i>Asplenium densum</i> Brack.)	<i>Psilotum nudum</i> (L.) Griesb. (<i>Psilotum triquetrum</i> Sw.)
<i>Diellia erecta</i> (?) Brack. (<i>Lindsaya erecta</i> Hook.)	<i>Polypodium pellucidum</i> Klf. var. The folded form.
<i>Doryopteris decora</i> Brack. (<i>Pteris decora</i> Hook.)	<i>Sadleria cyatheoides</i> Klf.

PHANEROGAMS.

<i>Cyperus</i> sp.	<i>Asclepias curassavica</i> L.
<i>Amaranthus spinosus</i> L.	<i>Ipomaea congesta</i> R. Br.
<i>Rumex giganteus</i> Ait.	<i>Verbena bonariensis</i> L.
<i>Osteomeles anthyllidifolia</i> (Smith.) Lindl.	<i>Plectranthus australis</i> R. Br.
<i>Meibomia uncinata</i> (Jack.) Kuntz.	<i>Capsicum frutescens</i> L.
<i>Oxalis corniculata</i> L.	<i>Lycopersicum esculentum</i> Mill.
<i>Euphorbia pilulifera</i> L.	<i>Solanum nigrum</i> L.
<i>Sida cordifolia</i> L.	<i>Bidens pilosa</i> L.
<i>Waltheria americana</i> L.	<i>Erigeron canadensis</i> L.
<i>Opuntia tuna</i> (L.) Mill.	<i>Gnaphalium</i> sp.
<i>Metrosideros polymorpha</i> Gaud., var.	<i>Sonchus oleraceus</i> L.
	<i>Raillardia</i> sp.

Of the above, the most frequent species met with are *Metrosideros polymorpha*, *Polypodium pellucidum* and *Sadleria cyatheoides*. With the exception of *Metrosideros polymorpha*, which is the prevailing tree, these plants do not give a conspicuous aspect to the flora in the immediate vicinity of the flow, but constitute what might be classified as the weeds. Of the twenty-three phanerogams, sixteen belong to the naturalized flora and six to the native flora, one of the latter being of wide distribution as a shore plant.

³These are the names recognized in Christensen's Index Filicum, but for the convenience of local readers the names given in Hillebrand's Flora are given in parentheses.

I believe that distribution is mainly by wind, although cattle and goats occasionally cross the flow.

Several days later this flow was again visited at a somewhat higher elevation, at a place not far distant from the Judd road, and about ten miles above Puuwaawaa. There was relatively less vegetation, but distribution was the same as observed in the first case. At this place there are several islands of an ancient aa flow which are covered with vegetation. The following plants were observed in the cracks on the pahoehoe, only the common white lichen being observed on the aa:

FILICES.

<i>Asplenium trichomanes</i> L., var.	<i>Polypodium pellucidum</i> Klf., var.
<i>Doryopteris decora</i> Brack.	The folded form.
	<i>Sadleria cyatheoides</i> Klf.

PHANEROGAMS.

<i>Chenopodium sandwicheum</i> Moq.	<i>Verbena bonariensis</i> L.
<i>Argemone mexicana</i> L. 1 plant.	<i>Solanum nigrum</i> L.
<i>Dodonaea viscosa</i> L.	<i>Erigeron bonariensis</i> L.
<i>Metrosideros polymorpha</i> Gaud., var.	<i>Gnaphalium sandwicenseum</i> Gaud.
<i>Cyathodes Tamciamciae</i> Cham.	<i>Sonchus oleraceus</i> L.

Of the ten phanerogams, five are native and with *Sophora chrysophylla*, which was not observed on the flow, constitute the prevailing flora of the surrounding region. The remaining five belong to the naturalized flora. The prevailing plants on the flow were *Metrosideros polymorpha*, *Polypodium pellucidum* and *Sadleria cyatheoides*.

Dr. W. T. Brigham⁴ visited this flow in 1864. He reports having observed ferns in some of the caves, and a *Polypodium* on the surface cracks, but lichens were rare.

From a station called Honomalino the flows of 1887 and 1907 were visited. The flow of 1887 was observed at the place where it branches and flows around a cone called Puu Ohia.⁵ Both

⁴Dr. W. T. Brigham: Volcanoes of Kilauea and Mauna Loa. B. P. B. M. Mem., vol. ii, no. 4, p. 16.

⁵This cone is called Puu Ohohia on the Government map.

branches were composed of extremely rough aa and supported no vegetation, with the exception of a few *Metrosideros* on the contact edges with the older flows.

The 1907 flow was visited at a point a short distance above Puu o Keokeo, which is about two and one-half miles above Puu Ohia. At this point the flow is entirely pahoehoe, very shiny black and fresh looking. Plants were just beginning to be established in a few of the cracks, the following being observed:

<i>Polypodium pellucidum</i> Klf., var.	<i>Vaccinium penduliflorum</i> Gaud.
The folded form.	<i>Cyathodes Tameiameiae</i> Cham.
<i>Cyperus</i> sp.	<i>Raillardia</i> sp.

All of these plants are indigenous and constitute the prevailing flora at this elevation. The naturalized flora is not yet established to any considerable extent on this portion of Mauna Loa.

The 1907 flow was visited later at the place where it crosses the Government road on the Kona side. At this point it is aa and supports no vegetation except an occasional lichen or moss, apparent only on minute examination.

The flow of 1823 was visited where it crosses the Kau Desert. It is pahoehoe, but unfortunately much of the vegetation had been eaten by goats just before my visit. In a deep crack which crosses the flow, practically all the species of plants which occur in the surrounding region were observed. The following plants were observed in the surface cracks:

<i>Cibotium</i> sp.	<i>Metrosideros polymorpha</i> Gaud.,
<i>Nephrolepis exaltata</i> (L.) Schott.	var.
<i>Psilotum nudum</i> (L.) Griesb.	<i>Solanum nigrum</i> L.

Another recent but unrecorded aa flow was visited above Kapapala near the old Kahuku trail. With the exception of a few lichens, no vegetation was observed upon it.

From these observations of the plant invasion on the flows of known date the following summary might be obtained:

1. A few lower cryptogams, followed by ferns and phanerogams first become established on the pahoehoe.

2. Lower cryptogams become established on the aa at an early date, and eventually cover the flow to a considerable extent, some of these species being rather rare on the pahoehoe.

3. Ferns and phanerogams only become established on the aa a long period of time after these become established on pahoehoe of the same age, other conditions being the same.

4. The plants to be found on the new flow are the same as those found on older flows in the immediate vicinity. *Polypodium pellucidum*, *Sadleria cyathoides* and *Metrosideros polymorpha* were usually the prevailing plants at all points and elevations studied on the pahoehoe, while a species of white lichen was usually common on the aa.

5. A fertile soil is apparently formed in the cracks of the pahoehoe sooner than amongst the aa particles.

Metrosideros polymorpha is one of the important plants which prepare the way for the establishment of many plants on the flow. The roots spread over the smooth portions of the flow, often from one crack to another, forming pockets to catch a soil formed of dead leaves and other debris.

In viewing the older flows it is rather difficult to ascertain their relative ages, for the reason that the Hawaiian flora assumes its mature form at an early date. In passing over many hundreds of flows the prevailing characteristics of invasion were found to be somewhat as shown in the following paragraphs.

In the scrub region above the wet forests there is no great distinction between the flora of the pahoehoe and the aa. The latter, however, has a greater proportion of lichens, occasionally these plants occupying the aa to the exclusion of all other vegetation. The prevailing plants are *Cyathodes Tamciamiac*, *Dodonaea viscosa*, scrub *Metrosideros polymorpha*, *Sophora chrysophylla* and other characteristic mountain plants. Large portions of either variety of flows are bare rock, and when a soil is formed it is usually a very thin layer, limited almost exclusively to the pahoehoe.

In the dense forests of the rainy belt there is usually a good soil on the pahoehoe varying from six inches to a few feet in depth, sometimes only the tops of the billows remaining in sight to record the character of the flow. The aa, however, with few exceptions, still retains its rough file-like character. I find that

the dense koa forests where *Acacia koa* is the prevailing tree, with a thick undergrowth of ferns, labiates and innumerable other species, are limited with remarkably few exceptions, as far as the forests of Kona are concerned, to the pahoehoe.

From any hill the traveler through this district can pick out the aa flows from a distance by the lines of ohia (*Metrosideros polymorpha*) forests, which divide the koa into sections. When he arrives at the rocky flow he will find a totally different character of undergrowth, where such plants as *Polypodium pellucidum* (folded form), *Lycopodium cernuum*, *Vaccinium penduliflorum*, *Raillardia* and certain other plants are conspicuous. From this, I believe that the koa forest is the final type for this region, and when one finds an aa flow supporting koa, it must be relatively very much older than other aa flows in the vicinity.

In later years, however, outside influences, especially cattle grazing, have considerably changed the floral aspect of the country in certain places. On account of greater ease for penetration, a more succulent undergrowth, and perhaps more available water, cattle have worked their way into the forests on the pahoehoe and destroyed the undergrowth. In a few years the introduced flora becomes established, and a park-like meadow, usually in every sense an ideal pasture, is the result. However, the indigenous trees, which after many years have become adapted to the dense undergrowth, epiphytic creepers and moist soil, are much weakened, and are not able to withstand the new, more xerophytic conditions. The weakened trees eventually fall an easy prey to destructive insects, but as far as I was able to observe were not touched by the cattle.

The cattle penetrate to a much less degree on the aa owing to its rough character, while the more xerophytic undergrowth is less succulent. When they do, the character of the flora is less changed for the reason that complete destruction of the undergrowth is impossible, while this ohia, which has not become adapted to such wet conditions as the koa, does not succumb to insect attack. Ohia varies tremendously with the habitat, but any great change in conditions would probably affect it the same as koa.

From the preceding paragraphs it must not be inferred that ohia forests are not found on some pahoehoe flows; for the damp-

est, and consequently the densest forests on these islands are composed of this species; but the prevailing tree in the upper forests of the middle zone on the lee side of Hawaii is koa, while ohia is apparently not the final type for this section.

In the region below the wet forest the pahoehoe flows are occupied almost solely by the naturalized flora, *Psidium guajava*, *Lantana camara* and introduced weeds being very conspicuous. The long lines of native vegetation, consisting mainly of ohia, which cross the Government road in many places throughout Kona, and the rich native flora at Puuwaawaa are on old aa flows.

The region below the Government road and the shore line has not been sufficiently investigated for discussion in this paper.

In summing up the process of plant invasion on a lava flow on the lee side of Hawaii the following sequence might be obtained:

1. Appearance of lower cryptogams, eventually becoming conspicuous on the aa.
2. Appearance of *Polypodium pellucidum* (folded form), *Sadleria cyatheoides* and *Metrosideros polymorpha*, first on the pahoehoe, and at a much later date on the aa.
3. Gradual development of the typical floral aspects of the immediate vicinity, if in the central region an ohia forest.
4. Establishment of the final native vegetation, if in the central region a koa forest.
5. A later stage may be the encroachment of the naturalized flora, due to a change of conditions brought about through human agency.