INTRODUCTION

Seven geographic features have been designated as Natural Landmarks in the National Natural Landmark program:

- Diamond Head, Oahu
- Koolau Range Pali, Oahu
- North Shore Cliffs, Molokai
- Iao Valley, Maui
- Kanaha Pond, Maui
- Mauna Kea, Hawaii
- Makalawena Marsh, Hawaii

Nine additional features have been proposed for such designation:

- Alakai Swamp, Kauai
- Waimea Canyon, Kauai
- Olokele Canyon, Kauai
- Coastal Cliffs, Kauai
- Koko Head, Oahu
- La Perouse Bay Rift, Maui
- Hana Shoreline, Maui
- Mount Hualalai, Hawaii
- Waipio Canyon, Hawaii

This paper has been prepared as a contribution to the evaluation of these additional sites as appropriate Landmarks in the National program.

The official criteria for Landmark designation are geologic, ecologic, and scenic importance. In addition to comments on the geology, ecology and visual appearance of the sites proposed for designation, I have in some cases provided comments on their climate, hydrology, past and present use, and risk of disfigurement (or degree of protection).

The climate and hydrology of the sites is reflected in their geomorphology and biota, and hence affect their geologic, ecologic, and scenic importance. Past use is of significance in the evaluation only to the extent that the use has resulted in losses of natural character of the aspects to which the evaluation criteria apply.

The importance of a Landmark has no relation to the risk of its disfigurement, but the risk of disfigurement and the importance of a Landmark should be taken into account in determining how a Landmark should be managed.
KAUAI

Introduction

Among the seven national landmarks in Hawaii listed in April 1978 as on the national register of such landmarks, none are on Kauai. However, four Kauai landmarks are on the proposed list. Three of these, and at least an important component of the fourth may be considered mutually contiguous: the Alakai Swamp, Olokele Canyon, Waimea Canyon, and the Na Pali component of the Coastal Cliffs of Kauai. Because of commonalities in the geologic geomorphic background of these landmarks, it is easiest to discuss them in common rather than individually. In certain respects the discussion must naturally extend to other parts of the region of which these landmarks constitute the major part, notably the western slope of Kauai, west of Waimea Canyon, the Mana plain, the Makaweli region south of Olokele Canyon, and Wainiha Valley.

Alakai Swamp, Olokele and Waimea Canyons, and Na Pali part of Coastal Cliffs: Geology

The Kauai shield volcano

The island of Kauai is a shield volcano composed for the most part of basaltic lava flows. The major relatively undissected remnant of the flanks of this volcano is the western slope of the island from the west rim of Waimea Canyon to the southern part of Na Pali (The Cliffs) and their southerly extension in the part of the sea cliff that is now separated from the slope by the Mana coastal plain.

The thin-bedded lava flows of which the original flanks of the volcano are composed are best exposed in the west wall of Waimea Canyon and in Na Pali. For this reason, the geologic unit including these flows has been named the Na Pali formation of the Waimea Canyon volcanic series. The Na Pali lava flows were fed from vents, several of whose cones are on the west rim of Waimea Canyon. The dikes representing the lava cooled in the underlying fissures are particularly well exposed in the west wall of Waimea Canyon and in the more northerly, deeper valleys of the Na Pali coast.

Caldera development

Toward the end of the period of construction of the Kauai shield volcano, an unusually broad caldera developed by repeated collapse of the central part of the shield. Continuing eruptions filled the caldera as it subsided, but the lavas, being confined in the caldera rather than free to flow down the flanks, formed very thick, massive flows. These flows are particularly well exposed in some of the tributaries to the Waimea River, especially Olokele Canyon, and hence the geologic unit to which they belong has been called the Olokele formation of the Waimea Canyon Volcanic series.

The Alakai Swamp represents an almost undissected remnant of the surface of the caldera fill.

The fault boundary of the caldera is best exposed in Olokele Canyon, where it consists of two faults, along which there is talus interbedded with the caldera filling flows. The boundary fault is also well exposed at the head of Waimea Canyon, and it is expressed topographically in a now somewhat subdued scarp extending northward from Waimea Canyon through the Kokee region and thence northeastward to Kilohana on the edge of Wainiha Valley. This scarp forms the northwest boundary to the Alakai Swamp.
A branch from the northwest boundary fault of the caldera is well exposed in the east wall of Kalalau Valley in Na Pali and can be traced northwestward across Hanakoa Valley to a sea cliff.

The main caldera fault on the east is thought to lie west of the eastern edge of the Alakai Swamp at Waialeale, but another branch is thought to lie farther east in the headward parts of the Wailua Valleys.

The swamp area is so deeply weathered, so heavily vegetated, and so little dissected that it is difficult to identify the Olokele formation vents, but one has been tentatively located on the headwaters of the Koaiie tributary to the Waimea River, and another on Kumuweia Ridge between the Kokee and Poomau tributaries.

Graben development

Toward the end of or after the development of the caldera and its fill, another collapse occurred on its southwest side, this time forming a triangular sector graben. The apex of the triangle lies in Waimea Canyon in the vicinity of the confluences of Poomau and Koaiie Streams with the Waimea River, but there was considerable displacement to the south coast of the island at least on the west boundary fault, which lies in Waimea Canyon.

Like the caldera, the graben was partially filled, as it developed, with lavas some of which poured from the caldera area over the northeast boundary fault scarp, others of which were erupted along the northeast boundary fault. Especially as they accumulated against the western boundary fault scarp, these graben-filling flows, like the caldera-filling flows are massive.

These flows are particularly well exposed in the canyon of the Makaweli River, to which Olokele stream is tributary, and the formation of which they form the major part has, therefore, been called the Makaweli formation of the Waima Canyon volcanic scene.

The buried, eroded fault scarp forming the northeast-boundary of the graben is well exposed in the valley of Waialae stream, a tributary to the Waima River, and in the valley of Mokuone stream, a tributary to the Makaweli river. The buried, eroded fault scarp forming the west boundary of the graben is well exposed in Waimea Canyon. Talus is buried beneath the Makaweli lava flows along the eroded fault scarp where exposed in the Waimea Canyon itself and in the Waialae Valley. Conglomerate derived from the northeast boundary fault scarp and interbedded with the Makaweli flows is well exposed in the walls of the Mokuone Valley, from which the talus and conglomerate unit takes its name.

Erosional effects

With the development of the caldera and the graben, not only the lava flows but drainage from the central part of Kauai, were cut off from the volcano flank areas lying to the northwest, west, and southwest. The rainfall of the flatter portions of the flank to the west and southwest is low. Hence, the stream valleys on this portion of the flank are still geomorphically youthful. On the steeper northwest portion of the flank, in an area of higher rainfall, valley development proceeded much more rapidly, while at the same time the sea eroded the coast back vigorously. The result of the erosion are the combination of steep valley walls and sea cliffs of Na Pali.
The highest point of the surface of the caldera fill was probably somewhat north of Waialeale. The headwater portion of the Wainiha Valley, whose southwestern edge is the northeastern boundary of the Alakai Swamp, developed in consequence of the northwestern slope of the surface of the fill of the northwestern part of the caldera. However, there is a northeastern jog to the axis of the Wainiha Valley where it crosses the caldera boundary fault, which probably represents an offset along the surface swamp at this boundary. North of this jog, the course of the Wainiha is north, consequent to the original slope of the north flank of the original shield. Because the Wainiha drainage basin, and particularly its upper portion, is in a high rainfall area, the Wainiha River cut a very deep valley. The surface of the caldera fill southwest of the Wainiha originally sloped west and southwest. However, streams whose courses were consequent to this slope were diverted southward and southeastward at the caldera boundary scarp. The westwardmost tributary of the Waimea River, Halemanu stream, and the head of the Waimea River itself, follow the west and southwest portions of the caldera boundary fault. The parent Waimea River flowing southeastward along this swamp must have been fed by the Poomau, Koaie, and Waialae streams, and possibly the Mokihana, Mokuone, Kahana, and Olokele streams, all developed on the southwest slope of the caldera fill.

Where the parent Waimea River originally crossed the caldera-boundary scarp and flowed southward to the coast is now uncertain because, with the graben development, a new southern route was opened. However, as the graben was filled with lava flows from the northeast, the Waimea River was forced against the western boundary of the graben. It developed its present course in part by excavating the Na Pali formation flows well to the west of the western graben fault.

The lower portion of the Waialae and Mokihana tributaries to the Waimea River, the Mokuone and Kahana tributaries to the Makaweli River, and the Makaweli River itself, developed consequent to the southwestern slope of the graber fill.

All of the major tributaries of the Waimea and Makaweli Rivers are fed from the high rainfall area of the Alakai Swamp. The size of the canyon excavated by the Olokele stream is especially large, primarily because the rainfall in the upper part of the drainage basin of this stream is especially high. The Waimea Canyon owes its larger size to the collection by its tributaries of almost all of the drainage from the Alakai Swamp; and to the development of the graben.

Post-erosional volcanism

Although development of the major erosional features in the Waimea Canyon-Olokele Canyon area was permitted by the cessation, or at least great reduction, of volcanic activity in the area, considerable eruptive activity continued after these features were developed. The major effects of the continuing or renewed volcanism are in the eastern half of Kauai, most recently in the area of Koloa, from which the products of the volcanism, the Koloa volcanic series take their name.

Although the effects of the Koloa volcanism did not alter the major features of the terrain in the western part of the island, they contributed a number of interesting details.
Lava flows filled the bottoms of the lower parts of the valleys of the Waimea, Kahana, Olokele, and Makaweli. All of the vents have not been located, but two vents are well exposed, one on the wall of Kahana Valley near it crosses the northeast graben fault, the other on the wall of Olokele canyon near where it crosses the southwest caldera fault.

Subsequent stream erosion has reduced the remnants to occasional terraces underlain by the flows, which are generally quite dense and in many places overlie older stream conglomerates. A flow in the lowermost part of the Waimea Valley, near Waimea, (at the Mokihana ditch. See discussion of archaeology below) is unusual in presence of pillow lavas at its base.

One or more Koloa flows also filled the bottom of Wainiha Valley, where it was associated with particularly dense conglomerate. There are here also only terrace remnants, but the terraces are especially pronounced near the mouth of the valley.

Post-volcanic effects

All of the principal valleys on the Na Pali coast were excavated, at their mouths, below present sea level. The deeper excavation is clear from the fact that the mouth of these valleys are filled with alluvium to levels below present sea level. The time of deepest excavation may have been a glacial period when the sea level floor was lower than at present. Alternatively, since the excavation occurred, crust bearing the island of Kauai may have been depressed due to the weight of the island, as is known to have occurred in the case of the island of Oahu.

The oldest alluvium in these valleys not only extends to below sea level, but extends to levels considerably above the present stream grades, having accumulated when sea level was higher then it is now, when there was a coastal plain along the coast similar to that still present at Mana, or when the climate was drier than at present and the streams less capable of delivering sediment to the sea. With subsequent re-erosion, the old alluvial fills have been reduced to terrace remnants, many of them much broader than the present stream flood plains.

A mile or two off the western part of the Na Pali coast there is a submarine ridge whose top is on the order of 100 feet below sea level. Between that ridge and the shore there is a deeper area, nearly flat. This submarine terrain is similar to, but a couple of hundred feet lower than, that of the present Mana and Haena coastal plains which front the sea cliffs respectively representing southerly and easterly extensions of the Na Pali. Diving has indicated, however, that the ridge is an ancient reef, which has been named the Kahiko reef, whereas the ridge along the shore of the Mana coastal plain is a dune ridge. The deeper water closer to shore represents a lagoon behind the Kahiko reef.

At Nualolo Landing, on the north coast, there is a very small barrier reef with partially enclosed lagoon.
Alakai Swamp, Olokele and Waimea Canyons, and Na Pali part of Coastal Cliffs: Other aspects

Rainfall and hydrology

At Waialeale, at the eastern end of the Alakai swamp, the world’s highest rainfall is recorded, in excess of 450 inches per year. The rainfall decreases markedly to the west and south. In the upper part of Waimea Canyon it is about 40 inches per year, and at the mouth of the canyon it is only about 20 inches per year. The rainfall on the Mana Plain is still lower.

The distribution is due to the orographic effect of the island, which is particularly marked on the tradewind (summer) rainfall and less marked on the kona storm (winter) rainfall.

All of the main tributaries of the Waimea River are perennial. Their low water flows are fed by natural storage in the Alakai Swamp. The Olokele and Wainiha River are perennial principally because of the essentially continuous rainfall in their headwaters, although their low water flows, particularly that of Wainiha, are supplemented by springs supplied by groundwater impounded by dikes.

The major streams of the northeast part of Na Pali, including Hanakapiai, Hanakoa, Kalalau, Honopu, Awaawapuhi, Nualolo, and Milolii are perennial, their low water flows being supplied principally by dike water. Kalalau stream is fed, in addition, by springs controlled by the northerly branch from the caldera fault.

The streams of the drier south part of Na Pali and farther south on the west flank are intermittent.

Flora and Fauna

I am certain that other consultants can discuss far better than I, both the unique features of the flora and fauna of the region, and the features it shares with other Hawaiian regions.

Archaeology and History

Before 1800 there was intensive Hawaiian occupation of the Waimea and Makaweli Valleys, the coastal plains at Mana and Haena, Wainiha Valley, and many of the Na Pali valleys. There are extensive remains of taro patches and the associated auwais in these valleys, and also house platforms and probably heiaus. One auwai near the mouth of Waimea Canyon, is unique in the cut stone work of which it is constructed. In Hawaiian tradition, the construction of this auwai is attributed to the legendary Menehune.

Travel between Hawaiian settlements farther east and those in Kalalau Valley on the north and the Mana Plain and Waimea Valley on the south was by trail and canoe. There was also a trail between Waimea and Wainiha, which ran up Waimea Canyon, climbed to and crossed the Alakai swamp, and passed down the precipitous Wainiha Valley side below the Kilohana lookout. The settlements in Milolii, Nualolo, and Honopu Valleys could be reached only by canoe. A "trail" between Nualolo Landing and Nualolo Valley is represented by holds and hand holds carved in a cliff face. Awaawapahi Valley was accessible from Nualolo Valley.
In the early part of the 19th century, the population of the more accessible Hawaiian settlements was reduced, and the more inaccessible settlements on the Na Pali coast valleys and the upper parts of the other valleys were abandoned.

Although there had probably been little earlier use of the interior of the island of Kauai other than the valleys, there was extensive sandalwood harvesting in the interior in the early part of the 19th century.

An attempt was made to establish a coffee plantation in Hanakapiai Valley sometime in the middle of the 19th century. This failed, but many coffee bushes continue to grow there. By about the end of the 19th century, even taro cultivation had been given up except in the lower portion of the Waimea and Wainiha Valleys.

With the growth of the sugar industry on the island in the latter part of the 19th century, the Menehune ditch, was restored, as the Waimea ditch, to supply water for sugar cane irrigation on the coastal plain. Later a very extensive ditch system, mainly in tunnel was constructed to divert water from Olokele Stream and carry it along the east wall of Olokele Canyon (mainly in tunnels) and deliver it to sugar cane fields on the surface of the graben fill to the east.

About 1905, a ditch system was constructed to divert water from the Wainiha Stream, carry it along the west wall of Wainiha Valley to a point in the lower valley where it was dropped through a penstock for the development of electric power that was transported through the highlands of the eastern portion of the island to the south side where it was used for pumping water from the Hanapepe pipes for sugar cane irrigation.

Somewhat later three higher ditch systems were constructed in the Waimea drainage basin. The highest, the Kokee ditch, diverts the headwaters of the western tributaries to the Waimea, and transports it westward more or less along the edge of the Alakai Swamp and above the canyon portions of the valleys, through Kokee and then to the western flank for sugar cane irrigation and incidentally hydroelectric power development.

The middle system picks up water from Poomau and Waialeale Streams in Waimea Canyon, and transports it for a few miles along the west wall of the Canyon to a point where the water is dropped again through a penstock for power development.

Immediately below the power plant, the lowermost of the three most recent ditch system, the Kekaha ditch, picks the water up again from the Waimea River, transports it for several miles along the east side of Waimea Valley, thence by an inverted syphon to the west wall of Waimea Canyon, and thence along the west wall to the volcano flank when it is used for sugar cane irrigation.

The water in all these "ditch" systems is actually carried mainly in tunnels.

Present use

The water developments already discussed continue in use. Sugar cane is grown on the lower and more southerly parts of the western flank, on the graben-fill surface east of the Makaweli River, and on the Mana Plain. The graben-fill area between the Makaweli and Waimea Rivers, parts of the western flank, the lower part of Wainiha Valley, and at least until recently Kalalau Valley are used for cattle ranching.
Highways from Kekaha, on the Mana plain, to the Kokee area and along the west rim of Waimea Canyon give access to canyon lookouts. A highway continues northward to a lookout over Kalalau Valley. These highways are heavily used by tourists. In Kokee there are a ranger station, a small museum, and a few residences. Nearby there is a satellite tracking station. Trails and unimproved roads provide recreational access to the northern part of the western flank, the ridges between the Na Pali valleys, and the eastern part of the Alakai Swamp. A few trails cross the Alakai Swamp, notably one from the road servicing the Kokee Ditch north to the Kilohana lookout at the edge of Wainiha Valley, and one from the upper Waialae Valley to Waialeale. The latter is used very infrequently, mainly in servicing the raingage.

There is extensive goat hunting in the Na Pali area and pig hunting along the southwest margin of the Alakai Swamp. The Hawaiian trail between Haena and Kalalau, which been maintained and improved, is heavily used by hikers, and the valleys to which it provides access are extensively used by campers. Helicopters and boats provide access to Kalalau, Honopu, Nualolo, and Milolii, and those valleys are extensively used by campers.

**Scenic aspects**

The scenic importance of Waimea Canyon and the Wainiha Valley, as well as the geologic, geomorphologic, climatic, and other natural historic underpinning of the scenery, have led the National Geographic Society to include these two landmarks in a book on canyons that they are preparing. Waimea Canyon is not only scenically magnificent, but lookouts in its western rim especially are easily accessible. Relatively few people see any of the Wainiha Valley except its mouth.

The Na Pali coast also is magnificent, and seen by many from Haena at the north and from the Kalalau lookout, and by somewhat fewer people from Polihale at the north end of the Mana plain, from other lookouts accessible from the Kokee region, from the sea, from the air, or by hiking along the Na Pali trial from Haena to Kalalau.

Olokele Canyon also is magnificent, but seen by few people primarily because of the private control of the roads giving access to its principal lookout on the west rim.

From a distance, the Alakai Swamp area is seen merely as the high central area of Kauai. The views of Waialeale from the east are spectacular because of the cliffs at the heads of the Wailua tributaries, but the swamp ends at the top of these cliffs.

**Land ownership and control**

The ownership of most of the region is in the hands of the State of Hawaii and a very few large private land holders.

All of the Na Pali coast, the Alakai Swamp, and Olokele Canyon, and all except the lowest portions of Waimea Canyon and Wainiha Valley are in the State Conservation District. The western slope and the Makaweli area seaward of Olokele Canyon are in the State Agricultural District.
Threats

There are really no significant threats to geomorphic and scenic aspects of the region as a whole. The primary threats are those to the more vulnerable components of the flora and fauna, to some of the archaeological remains of the Na Pali, and simple recreational overcrowding of some areas. The overcrowding and archaeological threats are becoming particularly marked in some of the Na Pali valleys, not only Hanakapiai and Kalalau that are accessible by trail, but also Honopu, Nualolo, and Milolii to which commercial access by boat, helicopter, or both is now provided.

Grazing by the goats in the Na Pali area is not only a threat to rare plant species and to the vegetation as a whole, but results in accelerated erosion.

The water developments of the past are almost invisible and have negligible effects on the flora and fauna. However, a large reservoir proposed by the State in Koai Valley on the margin of the Alakai Swamp may have a significant effects on the flora, particularly through the increased public access to the area that the project will provide.

Boundaries

Major parts of Na Pali, the Alakai Swamp, and Olokele Canyon are contiguous. Conceivably these landmarks might be separated from the Waiamea Canyon landmark by a narrow strip of land around the head of the canyon below the swamp proper and extending southward to and across the graben area. However, there seems little reason to do so, and boundary questions will be much reduced if this strip is not excluded from the landmarks.

The major issues will concern the placement of the southern boundary of Na Pali, whether the Makaweli Canyon should be included in the Olokele Canyon Landmark, whether the graben area between the Makaweli Canyon and the inner Waiamea Canyon can be included in the Waiamea Canyon Landmark, and whether, somehow, the Landmark group could also include Wainiha Valley and even perhaps the next, also magnificent and essentially untouched valley, Lumahai.

I recognize that the Kauai Coastal Cliffs Landmark may be intended to cover much more than Na Pali, and will attempt later to discuss other significant coastal cliffs of Kauai.

The extent of resistance to extension of the boundaries of the Landmarks will depend critically on the extent to which possible future developments, or even perhaps the use of recent development, might be foreclosed by the Landmark designation. As I have indicated, there is little threat to the significance of the proposed Landmarks is posed by most of the most kinds of development in them.

Coastal Cliffs other than Na Pali

Although Na Pali are the most magnificent coastal cliffs of Kauai, other coastal cliffs of the island have more or less importance geologically, scenically, or both. From the eastern end of Na Pali clockwise around the island, other Kauai cliff coasts are the following:
Haena

Cliffs 2000 feet high cut by marine erosion in the Waimea Canyon series lavas. These represent the eastward continuation of Na Pali. Like Na Pali these cliffs are somewhat indented by stream valleys but unlike Na Pali they are now fronted by a coastal plain. Famous wave-cut caves at Haena, one sand-floored, two partly filled by fresh basal ground water. Good exposures of dikes in cliffs at these caves.

Wainiha to Hanalei

Cliffs 2000 to 3000 feet high cut in Waimea Canyon lavas, deeply indented by stream valleys, and now separated from the sea by lava fans of Koloa lavas. The Koloa lavas also are cut by stream valleys and, along the shore, by marine erosion to cliffs 25-50 feet high.

Hanalei to Kalihiwai

Cliffs 50 to 100 feet high cut in Koloa series lavas, fronted at east end of Hanalei Bay by a coral reef and at Anini and Kalihiwai by a very narrow coastal plain and reef.

Kalihiwai to Kilauea

Cliffs 50 to 400 feet high cut in Koloa lavas and, at near at Kilauea light house, a Koloa vent cone. Columnar structure notable in a massive flow on east side of Kalihiwai Bay. The cliffs are especially picturesque at Kilauea lighthouse where an offshore island (an erosion remnant) is a nesting site for sea birds, and farther east where there is a small island with tombolo.

East coast

Low sea cliffs (less than 50 feet high) cut in Koloa series lavas. Inland are higher marine cliffs cut in Waimea Canyon, now subdued by weathering and erosion.

Nawiliwili to Mahaulepu

Cliffs, 1000 feet and more high, cut in Waimea Canyon series lavas of the Haupu Range, partly marine, partly fluvial. Fronted at Kipukai by a narrow coastal plain with drowned indurated sand dunes.

Mahaulepu

Cliff 50 feet high cut in sand dune formed at a low stand of the sea and subsequently indurated.
Makahuena

Low cliff cut in Koloa series vent cone.

Kukuiula to Hanapepe

Cliffs 30 feet high at east, 100 feet high at west, and 300 feet high at Lawai, cut by some valleys. The cliffs rise direct from the sea at some places, but mostly from a wave-cut bench.

There are two Spouting Horns, one near Kukuiula, the other west of Nawai Valley. These represent marine caves cut below the wave-cut bench with orifices to the surface of the bench. At Nomilo there is a Koloa series cinder cone with a crater lake. The lake was connected some time ago with the sea by a tunnel, so as to serve as a fish pond. The west side of the cone has been extensively quarried for cinders, but the effects of the quarrying do not spoil views from the east.

Waimea to Polihale

Southeast continuation of Na Pali, but fronted by the broad Mana coastal plain with beaches, beachrock, live and indurated dunes, lagoon sediments, etc.

General comments

No landmarks on Kauai have been designated so far as National Natural Landmarks. Of those proposed, I consider the designation most appropriate in the case of the Alakai Swamp, Waimea Canyon, Olokele Canyon, and the Na Pali part of the Kauai Coastal Cliffs. For reasons indicated in my May 1979 paper, I consider that these landmarks should share common boundaries.

The risk of destruction of the major geologic features in these four landmark areas is negligible. Biological sensitivity is greatest in the Alakai Swamp and perhaps next greatest in the Na Pali area. The risk of loss of archaeological sites is greatest in the Na Pali area. Simple recreational overcrowding is already a problem in the Na Pali area. Obliteration of major scenic features is not a significant risk in any of the four areas, but minor disfigurements might result if development were allowed (and were economically attractive).

Of the Coastal cliffs other than Na Pali, I would rank the Kalihiwai to Hanalei cliff coast highest in order of merit for landmark status, and, perhaps the Nawiliwili to Makaulepa and Kukuiula to Hanapepe coast next. The major geologic and scenic features of these coasts are very unlikely to be obliterated, but there is some risk of local disfigurement.

The major reference on the geology of the sites proposed for Landmark designation is Macdonald, Davis, and Cox, Geology and Groundwater Resources of the Island of Kauai, Hawaii Div. Hydrography Bull. 13.
Koko Head

The proposed Koko Head Landmark would include Koko Head, Koko Crater and other crater said to be "a smaller and more recent crater that lies on the eastern slope of Koko Head". This description does not fit any crater, but there are a number of vent cones on the Koko Rift in addition to Koko Head and Koko Crater. Designation of the entire Koko Rift as a Landmark should be seriously considered.

Koko Head itself is not a simple cone of a single vent but a composite cone constructed by several vents active more or less simultaneously (or a vent that shifted position from time to time as the eruption proceeded). The cone is not composed of lava (as stated in a memo proposing Landmark status), but tuff. The inward- and outward-dipping tuff beds of the several vents are readily visible on the sides of Hanauma Bay, which occupies the coalescent crater of the vents. Incorporated in many of the tuff beds are many fragments of reef rock blasted from the sea floor by the eruption.

A well-developed coral reef has been developed in Hanauma Bay, as stated in the proposing memo, and also a beach composed of olivine as well as calcareous sand grains. On both sides of Hanauma Bay there are prominent wave-cut benches whose surfaces drop in elevation toward the head of the bay. In the bench on the north side of the Bay is exposed a very small lava flow or dike (I can't remember which).

Between Koko Head and Koko Crater there are at least two more vents: 1) a low tuff cone whose crater is occupied by a rifle range; and 2) a fissure, in a swale between that tuff cone and Koko Head and seaward of the Koko Head-Blowhole highway, from which a small lava flow was erupted.

Koko Crater, a tuff cone, is of course the highest cone on the Koko Rift. The Blowhole, on the shore of Koko Crater, is a sea cave, mostly below sea level, with an orifice at the top through which water and spray are driven by air compressed by waves entering the cave. Exposed on the east slope of Koko Crater in Koko-Head-Blowhole highway cuts are deposits that have been identified as formed by nuées ardentes.

North of Koko Crater there are at least four more vents on the Koko Rift: 1) a fissure in a valley on the south side of the Koolau Range crest from which a lava flow was erupted; 2) a fissure on the sea cliff on the north side of the Koolau crest from which a lava flow and spatter were erupted (the lava flow formed the fan on which Oceanic Institute and Sea Life Park are located); 3) a spatter cone and lava flow forming Kaohikaipu Island off the north shore; and 4) a tuff cone forming Manana Island (Rabbit Island) farther off the north shore.

All of the vents of the Koko Rift were active at about the same time. The activity of the Koko Rift was more recent than that of any other rift of the Koolau Volcano (or the island of Oahu), except perhaps for the Tantalus rift. It may be post-glacial. The eruptions on this rift not only created Kaohikaipu and Manana islands on the north coast, they also extended greatly the south coast of the island. Maunalua Bay was created by the construction of the Koko Crater-Koko Head ridge and promontory. A coral reef and beach bars constructed in this bay cut off the head of the bay as a lagoon. The Hawaiians constructed a wall on the beach bars, converting the lagoon into a fish pond. Through dredging and filling the lagoon area has been converted to the Hawaii Kai subdivision with its small boat channels.
As indicated above, the entire Koko Rift may well qualify as a Landmark. References on the rift features and their origin include Stearns and Vaka Vaksvik Geology and Groundwater Resources of Oahu, Hawaii Div. Hydrography Bull. 1; the accompanying map in Bull. 2, a 1930's paper by Wentworth and Winchell on the Honolulu Volcanic Series; a paper published about 10 years ago on the age of Koko Head (actually minimum age); and a paper published only a year or two ago on the nuées ardentes deposits, those papers were all published, I think, in the Geologic Society American Bulletin.

General comments

Diamond Head and the Koolau Pali are already designated Landmarks on Oahu. Like Diamond Head, the Koko Head rift is a volcanic feature. I would risk the importance of the Koko Head-Koko Crater, or the Koko Rift in its entirety, as a landmark at least equal to the importance of Diamond Head, although Diamond Head is by far more famous.

The Koolau Pali is primarily erosional feature, and hence not directly comparable with the Koko Rift. Incidentally, the description of the Koolau Pali as three miles south of the village of Kaneohe is quite misleading. The Pali extends about 20 miles, from Halapuu Valley to Makapuu, and Kaneohe is a good-sized town if not a city.

MAUl

La Perouse Bay Rift

I can add little to the discussion of the La Perouse Bay Rift beyond what is in proposing memoranda. It should be noted that the coastal part of the proposed Rift Landmark is not so remote and inaccessible as is suggested in those memoranda. A rough road leads to La Perouse Bay, and there is a residence there. The upper part of the proposed Landmark is, however, in ranch land and not easily accessible.

References that should be checked, in addition to Stearns and Macdonald, Geology and Groundwater Resources of the island of Maui, Hawaii Div. Hydrography Bull. 7, include a paper or abstract by Grote Reber on radiocarbon dates of flows near Makena. This paper may have been in the Geologic Society American Bulletin or American Geophysics Union Trans, about 15 years ago. I think its conclusions need to be taken with several grains of salt. Also a paper of about the same date by Oostdam and/or Veeh on the date of the La Perouse eruption based on an illustration in the report of the La Perouse expedition.

The La Perouse rift is significant because the eruption on it is historic (although the exact date is uncertain). This is the only historic eruption of Haleakala, or for that matter of any Hawaiian volcano other than those on the island of Hawaii.

Hana shoreline

One of the proposing memoranda describes the Hana shoreline as scenically and scientifically interesting because of its waterfalls, pools, and extensive exposures of black lava. There is a spatter cone at Hana Harbor as well as lava flows. Many of the lava flows of the Hana coast are relatively fresh because they are very recent members of the Hana volcanic series. However, the description of the proposed landmark as including waterfalls and pools suggests that it is intended to cover much more than the coast at Hana itself. There is a "pool" in the form of Waianapanapa Cave, a lava tube partly filled by groundwater, near Hana. However, the closest streams and waterfalls are in the Nahiku area to the northwest and at Kipahulu to the southwest.
The general geology of the Hana area itself, and of the east end of Maui, is well described in Stearns and Macdonald's Bull. 7, and the coastal geology in Moberly et al. (1963). I can add nothing significant to those descriptions.

General comments

Iao Valley and Kanaha Pond, both on Maui, are on the list of already designated Landmarks.

Iao Valley is an erosional feature which exposes some very interesting geologic structure and is extremely beautiful.

Kanaha Pond is of importance only as a site for waterfowl, and this importance is recognized on its designation as a bird sanctuary. Although the list of Landmarks indicates that the owners of Kanaha Pond have agreed to protect it as a Landmark, the County of Maui has constructed a sewage treatment plant on the beach-dune ridge separating the pond from the sea. This plant is at least a minor disfigurement.

I consider Iao Valley of much greater importance as a landmark than the Hana Shore or La Perouse Bay Rift, but from a geologic standpoint, at least, the La Perouse rift is more important than Kanaha Pond. I cannot assign an importance to the Hana Shore without knowing its intended extent.

The risk of disfigurement is significant on the lower part of the La Perouse Rift and at Hana, but not significant with respect to the entire La Perouse Rift or the entire east-end coast of Maui.

Both the La Perouse Rift and the Hana Shore are parts of Haleakala Volcano. Neither Haleakala Volcano nor even Haleakala Crater are proposed for designation as Landmarks. Haleakala Crater, and its Koolau and Kaupo Gape, are volcanic and erosional features of far greater importance than the La Perouse Rift and Hana Shore, and the only reason for the failure to designate the Crater as a Landmark may be that it is in a National Park. This seems to confuse the criterion of natural significance with a criterion of already existing protected status.

HAWAI'I

Hualalai Volcano

Hualalai is one of five volcanoes on the island of Hawaii, and one of the three that have been active in historic times. The geology and activity of Hualalai have been well described by Stearns and Macdonald in Hawaii Div. of Hydrography Bull. 9, and other papers. I can add nothing to those descriptions.

A memo in the materials recently received suggests that, if Hualalai is designated a Landmark, the designated area should include the part of the volcano more than 5000 feet in elevation and, in addition, the Kaupulehu lava flow of 1800-01. This area would not include the Huehue flow of about 1800, nor the Waawaa trachyte pumice cone and the trachyte lava flow that is believed to be associated with that cone. The cone is a feature that might well warrant Landmark status on its own account, and there seems to reason for not including the Waawaa cone, the associated flow, and perhaps the Huehue flow in the Hualalai Landmark.
Waipio Valley follows the boundary between Mauna Kea and Kohala volcanoes, and lava flows of both volcanoes are exposed the east wall of its lower, canyon-like portion. The head of the canyon exposes dikes of the Kohala rift zone as well. However, the valley is of interest primarily for its geomorphology. The canyon is an example of a U-shaped Hawaiian valley not formed by glaciation. Waipio Stream is fed by numerous dike springs as well as by surface runoff. The low flows are diverted by the Lower Hamakua Ditch which runs (in tunnel) in the east wall of the valley. (The upper Hamakua Ditch diverts water from the streams before the plunge into the deep part of the valley.) Some of the waterfalls at the head of the valley are spectacular, but viewpoints from which they can be seen are not easily accessible.

The valley was intensively used in pre-historic times, and taro was cultivated in it until the late 1940's at least. There are extensive remains of taro patches and auwais, and probably house platforms and heiaus.

General comments

Makalawena Marsh and Mauna Kea are already designated Landmarks on Hawaii.

Mauna Kea is one of the five volcanoes of the island, a major scenic feature and a feature of major geologic interest. I suppose the interest in Makalawena Marsh is biological.

Kilauea and Mauna Loa, the two most active volcanoes are not on the list of designated Landmarks, probably for the same reason that Haleakala Crater (Maui) is not on the list. However, there are parts of Kilauea and Mauna Loa volcanoes that have considerable importance but are not within Hawaii Volcanoes National Park—for example the eastern part of the Puna Rift. Protection of parts of this rift would seem of about equal importance to protection of the Hualalai summit area, and the risk of disfiguring development seems greater in Puna than at the Hualalai summit.

However, I would rank Hualalai high on the list of proposed Landmarks.

Waipio Valley is important primarily as an erosional feature rather than a volcanic one. The neighboring Waimanu Valley has, I believe, been designated as a national natural area of some sort. Waipio is in the State Conservation District but has no nationally designated protected status. I would consider its importance significant but ranking lower than that of Hualalai.