NOTES ON THE FLORA OF VOLCAN RINCON DE LA VIEJA, COSTA RICA

Richard G. Baker

Department of Plant Biology, University of Hull, England

Key Word Index: Volcano, Rincón de la Vieja National Park, Flora, Costa Rica

ABSTRACT

The altitudinally zoned vegetation of Volcán Rincón de la Vieja apparently correlates with the Holdridge Life Zones. These include Tropical Moist Forest, Premontane Wet Forest, Premontane Rain Forest, and Lower Montane Rain Forest. There is also a complex of recolonising vegetation on and around the ashfield of the active crater. Such areas of vegetation exist in harsh environmental conditions, and exhibit many xerophytic features. A recent eruption is also reported, and the damage caused on the summit area is detailed.

Rincón de la Vieja National Park, situated in northern Costa Rica at c. 10°50’N, 85°20’W is a mountain ridge of comparatively recent volcanic origin, 50,000 to 150,000 years B.P. (Williams 1952, Allègre & Condomines 1976) in the Cordilleras de Guanacaste. The Park itself was opened in 1979 and comprises 11,700 ha. There are a number of volcanoes, some local areas of hot springs and pools, and a large area of forest cover broken to the south-west by a part-grassed and part-bare ashfield.

There is one active volcano, Rincón de la Vieja (c. 1763 m) situated about 500 m to the north and downslope from the main summit ridge. The V—shape of the ashfield passes first uphill and then down to the south-west. The last major eruption took place between 1966—70 while a smaller and less violent phreatic eruption occurred in February 1983.

The other five main craters on the ridge are all dormant. The Santa María crater is the highest point of the region at 1916 m. Rincón de la Vieja and the two to the west are unvegetated, owing to the ashfield, while the craters to the east are covered in dense forest.

The climate of the area is distinctly seasonal, with a dry season from November/December to April/May. The northern slope receives rather more rain from the saturated NE Caribbean winds than the Pacific slope and is generally more humid.
than the drier west side. The Life Zone map of Holdridge and Tosi (1969) reflects this, showing Tropical wet Forest as the predominant vegetation of the Caribbean region and Tropical Dry Forest dominating the Guanacaste lowland region. The lowest slopes of Rincón follow the seasonal cycle, whilst the ridge is, even in the dry season, regularly covered in orographic cloud down to 1500 m. This has great significance for the vegetation types at the higher altitudes. Temperature is also important; dry season temperatures were 30–35°C whilst at 1500 m temperatures were around 18–24°C.

Previous scientific work has concentrated mainly on the geology (e.g. von Seebach 1864; Healey 1959; Dengo 1962), while Salas (1971) records the importance of the regional hydrology. There has been some research completed on the avifauna of the Guanacaste area (e.g. Slud 1980) while the general vegetation types are covered by Holdridge and Tosi (1969) in their vegetation map of Costa Rica based on Life Zones.

The map shows the vegetation of Rincón de la Vieja to be altitudinally zoned. As far as can be interpreted the Park encloses six Life Zones which are: Tropical Moist Forest, Moist-Wet Transition, Premontane Wet Forest, Premontane Transition, Premontane Rain Forest, Lower Montane Rain Forest.

This paper briefly outlines the Authors’ view of the area, which was examined on visits made in 1981 and 1983. It is hoped this will form a basis for more detailed ecological research in the future.

Methods

On several occasions the ridge was ascended via the track running from the grassland near the hot springs (800 m) up to the summit ridge near von Braun (1755 m), and a number of other areas were also observed. 1:50,000 maps and enlarged aerial photographs were used to assist in locating sites.

In 1981 the Brathay Exploration Group surveyed the track from the boundary fence (784 m) to where it emerged on the edge of the ashfield (1476 m). 250 m intervals were marked and these assisted in locating the main vegetation zones. In 1983 this survey was extended by the Open University to the active crater and von Braun (1861 m). As time limited detailed research, this was confined to the recolonizing vegetation of the summit area. Notes were made of other sites. Using the general work of Beard (1944), and the detailed survey of Life Zones in Costa Rica by Sawyer and Linsey (1971), the vegetation type for each observed altitudinal zone was characterized.
Lower Grassland and Gallery Forest

Around the southern perimeter of the Park and in the vicinity of the 'Las Pailas' hot springs (c. 750–850 m altitude) there were patches of grassland, ungrazed since the fencing in 1978–9, with tracks of Gallery Forest along the river-banks. When mature the grass grew up to 1 m in height, and contained some regenerating or seedling trees. These were often located on or near rock outcrops, which either protected the plants from grazing, prior to fencing, or from fire. Such trees as Cassia spp. and Quercus oleoides, Plumeria and Bullhorn Acacia were present. The larger trees had Bromeliads and Hylocereus Cacti on their older branches. Agave sp. was also present, especially along the forest edge where Malvhus arboreus, Stachyttapheta frantzi and Bromelia penguin were also common. Small herbs in the grass included Mimosa sp., Abelmoschus sp. and composite species. Such vegetation extended up to, but not into the hot springs and pools. The only signs of life here were tide marks of blue-green algae on the surrounding rocks, and here and there a member of the Cyperaceae, Pycreus polystachyus.

The Gallery Forest was a remnant of the Tropical Moist Forest (see next section) that possibly orginally covered a larger area, previous to clearance by man. The main canopy here was at c. 12–12.5 m and was mainly deciduous or sclerophyllous. The trees noted were Plumeria, Cecropia, Miconia, Cassia and Acacia and other Mimosaceae.

Understorey shrubs included Malvhus and Aphelandra sp. On the steep and shaded banks leading down to the river, dense groves of Chusquea sp. were present or Adiantum ferns nearer to the water. Scuttlearia costaricana was also seen here.

A variety of epiphytic vegetation was present, e.g. Peperomia sp., Passifloraceae, Bromeliaceae and Orchidaceae, the latter higher up. No vegetation was noted growing in the rivers, which were subject to floods from time to time.

Tropical Moist Forest

Of the sites visited this was floristically probably the most diverse. It was the first zone of forest encountered within the reserve and extended from the grass for c. 1250 m along the track up to 944 m altitude. The upper canopy was at about 12 m, and was dominated by deciduous and sclerophyllous species. There were one or two much taller trees, some of them buttressed, e.g. Ficus sp. which also occurred as stranglers. There was plenty of light getting to the forest floor which was covered in a wide variety of species; Selaginella, Hemionites palmata and other ferns, together with Columnnea sp. on fallen logs. Other higher plants including tree seedlings were noted. In the dry season it is dry here although the track is evidently a stream bed during the rainy season. There are many glades, and Chusquea sp. and patches of saplings are common. Some areas along the edge of the reserve have been logged, but not to a great extent, and these in particular are now areas of regenerating vegetation.
Epiphytes were mainly on the biggest trees and included Bromeliaceae, *Peperomia* sp., *Hylocereus* sp., Orchidaceae, Begoniaceae and ferns. Begonias and some orchids were observed growing on large exposed boulders as well as on trees.

This vegetation zone compares well with Sawyer and Linsey’s interpretation of Tropical Moist Forest.

Premontane Wet Forest

This was the largest zone encountered; 250 m wide, from 972–1279 m altitude and it had the highest canopy c. 24–25 m. The canopy was predominantly evergreen as were many of the understorey plants. It was much wetter and more humid here. The soil and leaf litter were often sodden as rain fell even in the dry season as a fine mist, particularly in the upper half of the zone, blown from higher up where the orographic cloud blanketed the ridge.

No tree species were directly identified as much of the tree foliage was inaccessible, although dead leaves in the litter showed members of the Leguminosae, Araliaceae and Clusiaceae, the latter becoming increasingly noticed towards the upper limit, where the canopy became lower, and temperature fell and humidity rose. Many trees were buttressed and *Ficus* figured prominently amongst these. Lawton and Dryer (1980) describe similar vegetation from Monteverde and mention *Lonchocarpus* sp. and *Dussia* sp., members of the Leguminosae, with *Ficus crassiuscula* as a common fig.

Epiphytes were a very important component; some larger trees were more or less covered by vegetation, especially aroids. The crowns had orchids, bromeliads and some ferns, while lower down lianes, ferns, *Philodendron* and other Araceae, *Begonia*, *Peperomia*, strangler figs, filmy ferns and bryophytes were present.

The glades were the only areas where the ground flora became at all dense except for alongside the track. Where the light was adequate the glades were almost solid with vegetation, which included grasses, most notably *Pharus* sp., Palmae, tree ferns, shrubs e.g. *Calathea*, *Heliconia*, tree saplings, creepers and epiphytes.

The forest changed floristically with altitude; light intensity was more or less similar but temperature, rainfall and humidity varied. The orographic cloud was probably implicit in these changes, as the amounts of mist and rain markedly increased in the upper half of the zone.

In the lower regions some deciduous species were notable in the canopy and bryophytes were uncommon. To begin with *Dieffenbachia* sp. grew alongside the path. Further up this did not appear; the ground vegetation and canopy became increas-
ingly evergreen. *Costus, Croton, Annona* and *Capsicum* were all noted alongside the track, as well as clumps of *Heliconia* and *Calathea*.

Higher up, epiphytic palms and tree ferns appeared more often as did filmy ferns and Bryophyta. Palm species, in particular, *Geonoma* and *Chamaedorea* were dispersed throughout. In the upper regions of this zone the ground flora became more dispersed and was mainly evergreen tree seedlings and saplings.

This zone was narrow, with abrupt changes into the zones on either side. It was c. 750 m wide and generally cool and wet, (1308–1391 m). Shade had rapidly increased prior to entering the zone, and the canopy had fallen to c. 14 m. It was characterized by the presence of a single understorey, like a ‘second canopy’ of *Geonoma* and more rarely *Chamaedorea*, which formed a continuous monotypic stand. At the upper and lower ends of the zone the palms were about knee high, whilst in the middle of the zone they rose to 5 m. Two specimens of *Podocarpus oleifolius* were noted growing beside the track, one 3 m, the other 1.5 m high.

The upper canopy was dominated by leathery leaved species including amongst others, *Clusia* and one or two ericaceous shrubs. By the upper end of the zone the canopy had fallen to c. 10–11 m. The ground flora was almost absent with only scattered small plants, palm seedlings and ferns, despite regular gaps in the canopy where trees had fallen. One plant of *Scuttelaria costaricana* was noted by the track here.

*Philodendron* sp., ferns and bryophytes occurred as epiphytes on the larger trees above the level of the palms. Beard (1944) mentions such a formation occurring in Chile and also Venezuela and the Lesser Antilles. He discusses its association with the ‘mist belt’ of such mountains, comparable to the blanket of cloud on Rincón, or the cloud forests of Monteverde (Lawton & Dryer 1980).

**Elfin Forest**

This zone was c. 500 m wide, and occurred between 1391–1476 m. Like the last zone it was cool and almost invariably wet, such that the vegetation dripped water. Cloud could be regularly seen through breaks in the canopy and wisps of it were occasionally blown across more open patches.

The zone was characterized by an almost total canopy dominance of *Clusia*, especially *C. rosea*, which grew up to c. 7 m although it was also lower than this in places. At the lower end of the zone tree ferns were common, but under the shade of the trees, these did not appear. The large leathery leaves of *Philodendron* were everywhere to be seen, carpeting the ground and clambering over the low, stunted and twisted trunks. In the clearings these entangled with vines, which grew in amongst short tree ferns and Ericaceae. The canopy became lower until the track opened out into the recolonizing vegetation around the ashfield.
No epiphytes were noticed on the trunks of Clusia, except for Clusia seedlings, although epiphytic ferns did occur on larger shrubs and small trees of the Ericaceae. A thick humus overlaid a soil which contained some ash layers. The roots of Clusia, upon examination, appeared to be associated with mycorrhizae.

It is most intriguing that Clusia should be able to thrive in such saturated conditions. The leathery, thick leaves are evidently resistant to desiccation, and this is very important to the plant when colonizing bare ash, especially during the dry season.

This must outweigh the disadvantages of a very slow transpiration rate for the remainder of the year. It is possible that the many coarse knobs on the bark are lenticels which, as well as allowing gas exchange, may enhance the otherwise low evaporation rate.

Beard (1944) mentions an Elfin Woodland, c. 8 m high, of ‘stunted, gnarled trees... with thick fleshy leaves. Pure stands of Clusia spp. constitute this formation in some of the Lesser Antilles.’ This apparently compares well with the vegetation here.

Recolonizing Vegetation

The ashfield extends from the summit down to the south-west edge of the reserve. It seemed to be an excellent opportunity to study the succession of plants onto the bare ground at different altitudes. However, the lower end of the ashfield is in fact mostly very old lavas which have poorly weathered to give a grassland with a history of grazing. The grassland is composed mainly of Hyparrhenia rufa, Axonopus sp. and Festuca sp. with a few scattered stunted Quercus trees; more continuous vegetation borders the streams, which drain from high up near the ridge. Near a small area of hot springs in the middle of the grassland, are two valleys, one with a permanent stream, the other with a seasonal stream. 50 m by 5 m transects orientated downstream were set up in each valley and higher plants collected. The seasonal stream valley had six tree or shrub species out of sixty-four individuals sampled. Five were sclerophyllous and one deciduous. The permanent stream valley had nine species out of ninety-two individuals sampled. Four were sclerophyllous, four deciduous, and one was a musaceous shrub. Thus in the permanent stream valley both more species and greater numbers of individuals were existing and despite the lack of further data, this highlights the limiting effects of the environment during the dry season.

Between this area and the more recent ash deposits above the Elfin Forest zone, no areas were examined owing to inaccessibility.

The upper region of ash is much younger, the surface layers of which were deposited between 1966–70. It is a very heavily dissected area, resulting from the un-
doubtedly high rainfall the ridge receives, with deeply eroded gullies, some several hundred feet deep, forming a complex dendritic drainage pattern.

Nevertheless, except for the ground in the immediate area of the active crater which has apparently no life, owing to the toxic sulphurous fumes, the ash in all other areas shows some, albeit limited, plant life, and some animal life also, especially beetles and ants, while lizards and snakes have more rarely been observed.

The ash itself has an indurated crust, making penetration of roots by new seedlings very difficult. However there are many overhanging edges, and cavities between stones and under volcanic bombs where plants can get a hold. Beneath the surface, the ash has apparently weathered very rapidly to form orange-coloured metal oxides and some clay-like minerals. There is some evidence of rapid clay mineral formation during volcanic eruptions from other sites (Hardy 1939; Chen 1961; Newsome 1982) and it is possible the same has occurred here. Nutrients are probably very limiting in this environment. No tests have been carried out; although it is possible nutrients could diffuse up from organic detritus, buried in past eruptions (Stoiber et al. 1971), also nutrients can be supplied by rainfall. It is suspected many of the plants have comparatively slow growth rates on the ash, although some plants are known to have nitrogen-fixing associations e.g. Gunnera sp. (Silvester 1976), which has an unusual blue-green algal association in specialized areas in the leaf bases. Mycorrhizal interactions with the roots of Clusia rosea have already been noted on Rincón.

Other advantages are related to the habit of growth, thus Philodendron by nature can cover a large area while not necessarily utilizing the substrate by means of its long scrambling stems, and can therefore originate in areas at the edge of the ash, but at the same time be covering large patches of otherwise bare ground. Other plants have adaptations for preventing water loss and avoiding unnecessary exposure; thus small sclerophyllous leaves and a low growth habit are common features of many plants.

Around the perimeter of the ashfield there is a plant succession leading up to the forest edge. This is composed of several interesting communities of plants. Where the track emerges from the Elfin Forest, there is a burnt tree zone a few metres wide. Assuming these trees were killed between 1966–70 they show remarkably little sign of decay. Many are still upright and have bark in situ. This is similar to Janzens' observations (1973). Most of these trees appear to be Clusia although some other trees, mainly ericaceous species were also noted. Growing here were young ericaceous shrubs e.g. Pernettya coriacea, Cavendishia crassifolia, also Clusia amongst a ground flora dominated by tussocks of Axonopus sp. with scattered clumps of Eupatorium anisochromum, Carex donnell-smithii, Lycopodium cernuum and Blechnum werkleana. The trunks and stumps had Philodendron sp. and Smilax spinose clambering over them, with a few scattered Bromeliaceae, Philodendron sp. had flowers often near the ground and it was observed that the fruits had been chewed. The only animal observed in this area, of any size, was a nine-banded Armadillo.
The burnt tree zone was apparent mainly on the south and east sides of the recent ashfalls but not to the north and west. This is possibly because on the north slope the winds would tend to carry ash uphill and away from existing vegetation, whilst downwind the vegetation would be more vulnerable to direct ashfall.

Beyond the burnt tree zone the track enters an area of grass up to 250 m wide. On the most exposed ground the grass maintains a continuous cover, with only occasional clumps of *Clusia, Cavendishia* and *Carex* sp., *Lycopodium*, *Pernettya* and *Clusia* seedlings were widely spread. Along the ridge there are some deep holes, probably bomb craters, and these are full of ericaceous shrubs and *Clusia* saplings.

On the north facing slopes of the gullies similar plants occur, with perhaps a greater cover of ericaceous species. Also noted were orchids, bromeliads, (normally epiphytic species taking advantage of poorly colonised sites) (Vélez 1957), *Gunnera* and beautiful pink flowered bushes of *Monochaetum floribundum* spp. *vulcanicum*. This latter shrub when growing beside streams produces great mats of red roots which trail in the water.

On the leeward slopes which are often steeper, there are many dead trees, still upright with dense stands of *Philodendron* beneath.

At around 1544 m the track enters the 'bare' ash quite suddenly from the grass. The ash is in fact colonized by regularly spaced, though stunted *Pernettya coriacea*. *Pernettya* berries are highly toxic to man (Lewis and Elvin-Lewis 1977, also personal observation 1981) and maybe so to other mammals; the foliage is recorded as poisonous to cattle. Therefore the means of seed dispersal is likely to be birds or insects. It is impressive to see such a complete colonization over the ash since presumably it has occurred in only 15 years. *Clusia* is similarly poisonous; the vegetation is violently purgative and the fruits are toxic (Lewis and Elvin-Lewis 1977) and again dispersal by birds rather than mammals is possible. *Clusia* seedlings occur widely scattered on the ash, but where they do occur they are in groups; this is because the seeds are bound together with pith in the fruit, and so several may be held together during dispersal.

Also found on the ash were *Cyperus luzulæ*, and small *Monochaetum* plants. The surface of the ash where silt occurred was full of the stems and leaves of a species of leafy liverwort.

Even the smallest gully provided a niche for plant life. *Pernettya* and other Ericaceae, bromeliads, *Monochaetum*, ferns and *Lycopodium* all took footholds. Volcanic bomb craters also were colonized, *Monochaetum* on the rim, *Pernettya* around the inside of the rim and on the floor, and in the wettest place of the floor *Eleocharis schaffneri* took hold.

As the ridge is ascended, the very rapid change from ash to forest can be seen to the east, with the grass zone becoming more narrowed towards the summit ridge.
A transect was set up on the summit ridge so as to traverse the colonizing vegetation which here was at its narrowest. The quadrats were 3 m by 3 m and orientated with sides facing north to south. Quadrats were spaced different distances apart, as sites were selected subjectively along the transect which ran along the watershed. Quadrat 1 was on the top of a rise overlooking the forest to the east, *Pernettya coriacea* formed a limited vegetation cover. Occasional plants of *Arcitophyllum lavatarum* were present behind stones. The leafy liverwort was present in the silt, and a moss species was present under stones. Quadrat 2 was at the foot of a steep slope very close to the forest. Despite the rocky substrate there was more detritus and organic material here, collecting in the rock gaps. Height of the vegetation was c. 5 cm except for the *Clusia* seedlings which were up to 10 cm. *Pernettya coriacea* and *Arcitophyllum lavatarum* were codominant while *Eleocharis schaffneri*, *Monochaetum, Clusia rosea*, *Gunnera insignis*, *Eupatorium anisochromum*, *Cavendishia crassifolia*, *Miconia* sp., *Ardisia costaricensis*, *Vriesia* sp., *Elephoglossum latifolium*, *Lycopodium cernuum* and *Blechnum werkleanum* were all present, as single plants. A moss species was noted, in addition to those in Quadrat 1, which grew epiphytically around the main stem of *Monochaetum*. Both Quadrate 1 and 2 had very poorly developed soils.

Quadrat 3 however had a humus layer in the soil profile and it was the first Quadrat to have predominant vegetation cover. *Eupatorium* and *Pernettya* were codominants, taking up three quarters of the Quadrat with *Eleocharis* as the next most important species with 10 percent cover. Vegetation height was again around 5 cm, but the sedges, Bromeliaceae and *Clusia* seedlings were as much as 20 cm. All the species from Quadrant 2 occurred here.

Quadrat 4 contained all the previous species together with *Carex donnell-smithii*, *Philodendron* sp. and *Caultheria costaricensis*. No one species was completely dominant, although the vegetation ranged in height from 10 cm to 1.5 m, the 'canopy' rising very rapidly to the east, up into an Elfin Forest formation. The highest shrubs were *Pernettya, Gunnera, Miconia* sp. and *Monochaetum*, although it was evident that *Pernettya* was being competed out and it was not observed further into the Elfin formation. This may be because *Pernettya* does not readily form a 'canopy', only outwardly spreading branches, and therefore other species may overtop this plant. The soil profile here was the best developed of the four sites, with a deep organic layer over well weathered material.

It is interesting that no grasses were recorded in the transect; this may be because of the exposed position on the ridge.

Until now there had been a steady increase in species. The very low Elfin Forest formation, however, was species poor. It covered the slope up to the east for 50 m; accessibility was very difficult as the height ranged from 1.5 to 3 m, and the vegetation was very dense. The canopy was dominated by two main species, *Miconia* sp., from earlier Quadrats, and *Cavendishia crassifolia*; there were also a few scattered *Clusia rosea*. *Miconia* had a stout basal stock up to 25 cm diameter and the trunk
rapidly split into two or three main branches. On the whole it seemed to be slightly higher than Cavendishia which had a smaller basal stock up to 15 cm diameter, with many small branches above this. There was no ground flora; Smilax spinosa and Philodendron tangled the branches. There were several epiphytic mosses and a leathery leaved fern.

After about 50 m the trees became older, although again the trees were all of similar age and size. The canopy was at 5 m, again with Miconia and Cavendishia dominating. Humidity was much higher beneath and everything was wet. The ground flora included Geonoma, Chamaedorea, Heliconia, while epiphytes included Philodendron spp., Cyclanthaceae, filmy ferns and very dense growths of mosses. The canopy is flattened here, as the gentle slope to the north-east faces the blast of the oncoming, and often very fast winds. The south-west slope is a steep drop in contrast, and clothed in tall, open canopied forest.

Occasionally a very old Gunnera with a huge stem is encountered, and this perhaps confirms the early age and seral nature of this woodland. 150–200 m to the east this changes again into a woodland of much greater age and more variation in the sizes of trees. Also a much broader species range is present there too, with more canopy species e.g. Schefflera, and stilt rooted species and a range of aroid, bromeliad and fern epiphytes as well as dense growths of moss. This woodland has many affinities with a woodland examined by the lagoon, which is not so stunted but similar in species composition and humidity. Here beneath the dense canopy at about 7 m are Geonoma, Chamaedorea, Heliconia, tree ferns and smaller ferns on the ground. Filmy ferns are epiphytic at the base of the trees, which have bases up to 40 cm in diameter. Aroids predominate on the main trunks and branches. The lagoon has deep organic sediments; Rhynchospora vulcani, Cyperus luzulae and an apparently new taxon of Isoëtes (Pers. Comm. Gómez 1983) were collected.

From here, this forest changes about 300 m from the bare ash, where a short tangle of Ericaceae, Palmae, Monochaetum and Ficus takes over for about 100 m. Philodendron and vines are common as are tree ferns and Heliconia. Epiphytic mosses are important on the woody trunks. Deep gullies cross the area, and these are overgrown with palms, ferns and a wide range of Bryophyta. Before the ash is reached this zone changes to a Pernettya, Monochaetum and grass zone dominated by Gunnera. This is variable in width between a few and 50 m. Eupatorium and other ericaceous seedlings occur as well as Schefflera seedlings. The grass and sedge cover predominates beneath the Gunnera on flatter ground, while on steeper or more exposed sites sclerophyllous shrubs take over.

Vegetation was also examined on the north slope. The canopy 200 m in from the ash was at c. 7 m with a dispersed palm understorey. Philodendron, vines, lianes and tree ferns were all present although humidity was not high at the time of visit. The trunks were small and much divided, the canopy was apparently sclerophyllous.
Returning towards the ashfield there was a tree fern and vine zone, then a wider grass and *Pernettya* zone before the bare ash. The gullies had Ericaceae and a locally dominant cover of *Gleichenia* sp.

The other main areas of forest that were at the summit were not examined; however from a distance it was apparent that the areas of short forest in the vicinity of the ash, dominated by Ericaceae in the canopy, were seral stages in the succession towards a climax forest. Holdridge and Tosi suggest such a climax would be of a Low Montane type.

Mature forest occurred over the majority of the area; this was tall and open canopied on leeward slopes e.g. south of the watershed, south slopes of the vegetated cones and around parts of the lagoon; and short and flat canopied on windward slopes particularly around the northern side of the watershed.

**Recent Changes**

In February 1983 there was a small eruption on Rincón. Sulphur bombs were ejected up to 500 m away from to cone, mainly to the south-west. Acidic gas blown to the south-west has scorched vegetation in certain areas of the ashfield. However a large component of the eruption, phreatic in nature (Pers. Comm. Thorpe & Brown 1983) poured over the lower side of the crater and flowed downhill clearing everything in its path. This did not lose momentum until it had travelled some way up the vegetated cone to the west (see map) where trees and shrubs now lie flattened out in all directions. Occasional standing timbers have sulphurous rock fragments wedged in the wood. A larger surrounding area has been damaged also, probably by steam. This has caused all the trees of the canopy on the west side of the vegetated cone to shed their leaves and it is possible these trees are now dead. The understorey has a large component of *Philodendron* and this appears to be unharmed. Also a large area of dead but standing vegetation now exists across to the lagoon and some way uphill in the recolonizing vegetation. No areas show signs of burning. The lagoon in March 1983 was still about 7 m lower than usual.

Some plants, mainly rootstock plants such as ferns and Marantaceae were regenerating but owing to the lack of cover were withering. Other eruptions have occurred in the past, as during 1940–55, 66–70 for example and there are other areas below the low side of the crater observable on aerial photographs where vegetation has been devastated, probably by such eruptions.

**Discussion and Summary**

The vegetation of Rincón de la Vieja appears to correlate with the Life Zones of Holdridge and Tosi. Tropical Moist Forest and Premontane Wet Forest were observed. Lack of detailed analysis and comparative studies meant that the transition-
al zones, if present, were not observed. It is possible that Premontane Rain Forest lies to the east of the track prior to the Low Montane Forest which it is believed occurs around the summit. Instead of traversing these, the track emerges onto the ashfield having first passed through Montane and Elfin Forest. It is considered that these are most likely to be seral formations. Observation of the canopy from a distance and on aerial photographs suggest these zones are of limited extent along the edge of the ashfield. Less favourable, more xerophytic conditions during early stages of succession are the most likely reasons for their presence here (Beard 1945; Richards 1952). Both Montane and Elfin Forest usually occur as climax formations at much higher altitudes. If these zones are indeed seral, it would be interesting to obtain evidence of any changes in species composition over a period of time.

Such xerophytic conditions are the main influence on the other recolonizing sites. The ashfield itself is a particularly strong barrier to recolonization. Indurated surfaces, exposure, desiccation during the dry season, and relatively regular eruptions tend to maintain the succession in an early stage. Further stages of succession can only occur on the margins of the ashfield less regularly affected by direct volcanic activity.

The main stages of the succession around the summit of Rincón are:
1) *Pernettya coriacea* association on 'bare' ash; mainly microsclerophylls and fleshy leaved species.
2) Edge of ashfield with Ericaceae, Melastomataceae, Gramineae Cyperaceae and *Gunnera*. Species dominance variable; sclerophylls and fleshy leaved species common; bare ground evident; simple soil structure.
3) Short ericaceous woodland (closed or open canopied) with dense epiphytic moss growth, also aroids and palms in the understorey; a mesosclerophyllous canopy with a low species diversity.
4) Low Montane Forest (closed or opened canopied), Ericaceae and other groups in the canopy. Relatively high diversity in the canopy and understorey components. Humidity allowing a wide range of epiphytic flora, most notably bryophytes and ferns.

**Acknowledgments**

I would like to thank the National Parks Service for permission to work in the area, also for the generous assistance of the Brathay Exploration Group, Ambleside; the Open University, Milton Keynes. I am grateful for advice from Professor L. D. Gómez, R. Aspinall and for assistance with the typescript from C. Helliwell. I am deeply grateful to the staff of the Herbarium, British Museum of Natural History, London for plant identifications, and to M. Randal for supplying surveying data.
Literature Cited


Salas, S. 1971. Proyecto para el establecimiento del Parque, de Parques Nacionales (Mimeografiado).


Photo 1.
In the Montane Forest zone at c. 1350 m altitude, showing the 'second canopy' of Geonoma palms on either side of the track, beneath an upper canopy of larger trees.
Photo 2.
View from the bare ash looking south, near the 1476 m point marked on the map. Note the paler grass zone between the ash and the forest in the background, and the steep sided gully.

Photo 3.
View from the same position as Phot. 2, looking north east to the summit ridge. The bare ash is guillied, while the grass zone between the ash and the forest has hindered gully development.
Photo 4.
The burnt tree zone at 1476 m altitude, on the edge of the ashfield. The dead trees are mostly *Clusia rosea*, while the aroid is *Philodendron* sp., and the grass is *Axonopus* sp.

Photo 5.
Recolonising vegetation in the lee of a ‘bread-crust’ volcanic bomb on the summit ridge ashfield. In the foreground is *Vriesia* sp., with *Clusia* seedlings behind. In the rock crevices is *Monochaetum floribundum* ssp. *vulcanicum.*
Photo 6.
The author in a gully near the edge of the ashfield at the foot of the vegetated crater, in January 1981. This point is marked with an 'X' on Phot. 8. Note the dense vegetation of palms and other shrubs.

Photo 7.
The same site in March 1983. The gully is partially filled with ash and rubble, and the vegetation has been completely destroyed by the February eruption of that year. Both 6 and 7 are looking northwards.
Photo 8. View from the rim of the active crater looking south east, with the vegetated crater, and the lagoon to the right of it in the middle distance. Volcán Santa María can be seen in the far distance. Photographed in March 1983, this shows the low level of water in the lagoon at that time. Also the former limit of vegetation is marked in the foreground, with the limit or destroyed vegetation behind, and the limit of dead, but still standing vegetation marked beyond that; the ‘X’ marks the spot where photographs 6 and 7 were taken. The vegetation was damaged during the eruption of February 1983.

Fig. 1. Map of the summit ridge drawn from aerial photographs, and also incorporating other data. From west to east, 1810 m is on the eastern ridge of an eroded crater; 1895 m and 1861 m are the peaks of von Seebach and von Braun respectively, which share the same crater. 1763 m is the highest point on the rim of the active Rincón de la Vieja crater. The lagoon lies between this crater and the vegetated crater to the east. 1476 m is a point on the edge of the ash just beyond the Elfin Forest zone, on the main track.

--- represents the boundary between the ashfield and the forest.
......... represents the extent of the 1983 eruption; the inner line marking the limit of destroyed vegetation, and the outer line marking the limit of dead but still standing vegetation.