Prehistoric fires in the Chirripó highlands of Costa Rica: Sedimentary charcoal evidence

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Abstract: To determine the long-term history of fire in the Chirripó highlands of Costa Rica, the charcoal content of a 110 cm sediment core from a glacial lake was analyzed. The core was raised from Lago Chirripó, the largest of the approximately thirty glacial lakes in the Chirripó massif. The basal sediments from the core yielded a radiocarbon date of 4110 yr. B.P. The charcoal record indicates that the watershed of the lake has burned repeatedly during the past four thousand years due to human activity, lightning, or both.

Key Words: Costa Rica, glacial lake, Chirripó, sediment, geologic history, páramo fires.

The páramos of the high mountains of tropical Latin America are burned periodically, either intentionally to improve conditions for grazing, or by accident. The widespread occurrence of human-set fires at present and during the recent past has been documented in the Andean páramos (Fosberg 1944, Guhl 1968, van der Hammen 1979, Cleef 1981) and in floristically similar habitats in southern Costa Rica (Weber 1959, Horn 1986). However, the longer-term history of burning is not well known. Charcoal fragments attesting to natural or human-set fires have been discovered in Pleistocene and Holocene sediments in the Cordillera Oriental of Colombia (van der Hammen 1966, González, van der Hammen & Flint 1966), but little evidence exists of ancient fires in other highland areas.

This paper concerns stratigraphic charcoal evidence of the antiquity of fire in the highlands of the Cordillera de Talamanca, Costa Rica (Figure 1). The peaks of this range presently reach above treeline, and support grass- and shrub-dominated páramo vegetation. The Costa Rican páramos show close botanical affinity with the more extensive Andean páramos, and are generally regarded as representing the northernmost limit of páramo vegetation in the neotropics (Weber 1959, Cuatrecasas 1979, Lauer 1981).

The history and ecological role of fire in the Costa Rican páramos has been the subject of considerable speculation. According to Hartshorn (1983) frequent human-set fires have lowered treeline in the Buenavista páramo along the Inter-American highway, resulting in a spread of páramo vegetation. Janzen (1973, 1983) believes that the summit region along the Inter-American highway supported low montane rainforest, rather than páramo, prior to extensive clearing and burning. In the higher and more isolated Chirripó massif, and on other remote peaks in the southeastern part of the Cordillera de Talamanca, the absence of trees is generally regarded as the natural condition (e.g. Holdridge *et al.* 1971, Hartshorn 1983).

In March of 1976 a careless hiker ignited a fire in the Chirripó páramo that eventually burned over 5000 hectares of páramo vegetation and a large area of surrounding oak forest (Chaverri, Vaughan & Poveda 1976, 1977). The fire generated front-page headlines in Costa Rican newspapers, and led to debate among ecologists about the history of fire in the Chirripó highlands and the impact of

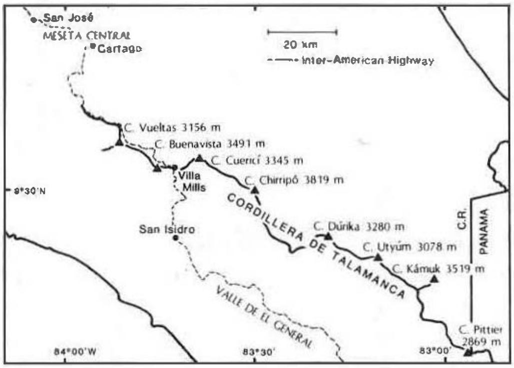

Fig. 1. Location of the Cordillera de Talamanca in southern Costa Rica and major peaks of the range. The heavy solid line indicates the crest. After Hastenrath (1973) and the 1:5000,000 map of Costa Rica published by the Instituto Geográfico Nacional.

burning on the páramo vegetation. Weston (1981) described the intensity and extent of the fire as unprecedented in the Costa Rican páramos, and initially expressed fears (Weston 1976) that some páramo species might never recover from the disturbance.

As detailed in Weston (1981), subsequent field work showed that, contrary to initial predictions, few if any species were totally eliminated from the Chirripó páramo by the 1976 fire. The fire did, however, change the relative abundance of different plant species and associations, as described both by Weston (1981) and Horn (1989).

Other scientists viewed the 1976 fire with less alarm; for them it was simply one more fire in a long succession of fires due to human or natural causes (Budowski 1976, Boza & Bonilla 1978, Valerio 1983). The possibility that some páramo species might be adapted to fire, and that the vegetation as a whole might depend on periodic burning for its maintenance, was also raised (Chaverri, Vaughan & Poveda 1976, Vaughan, Chaverri & Poveda 1976, Valerio 1983).

This paper provides the first direct evidence available of fires in the Chirripó highlands during the prehistoric and early historic periods. The evidence consist of macroscopic and microscopic charcoal fragments preserved in a sediment core recovered from Lago Chirripó, the largest of the approximately thirty glacial lakes in the Chirripó massif. This core, and a second core that was recovered at the same time, together constitute the first lake sediment cores recovered in Costa Rica. A future study will consider the pollen stratigraphy of the sediments and its implications for Quaternary vegetation history; here my concern is the record of past fires preserved in tha charcoal stratigraphy. By studying the fire record in the Chirripó sediment I hoped to provide answers to two questions that have interested both ecologists and resource managers in Costa Rica. First, is fire a recent introduction in the Chirripó páramo, or have fires long affected the highlands? And second, have fire frequencies increased since the mid-century owing to increased recreational use of the area?

LAGO CHIRRIPO

Lago Chirripó, also known as the Laguna Grande de Chirripó or Lago San Juan, is located just below and to the west of the summit of Cerro Chirripó (3819 m), the highest peak in Costa Rica. The lake lies at an elevation of 3520 m, at the head of the glaciated valley known as the Valle de los Lagos (Figure 2). Lago Chirripó is the highest and largest lake in a chain of three lakes dammed by moraines and rock thresholds (Figure 3) (Hastenrath 1973). The lakes and surrounding páramo are included within Chirripó National Park, a protected area of over 50,000 hectares that was established in 1975. Several rough trails, some of which may follow old Indian routes (Kohkemper 1968) provide access to the park, which in 1988 was visited by nearly one thousand Costa Rican and foreign tourists (Servicio de Parques Nacionales unpub. data).

Lago Chirripó has a surface area of 5.4 hectares, and a maximum depth of 22 m (Gocke *et al.* 1981). The lake is fed by surface runoff during storms and by several seasonal tributaries that drain a watershed of approximately one square kilometer. Limnological surveys conducted by Gocke *et al.* (1981) showed that Lago Chirripó is a cold polymictic lake that lacks a stable thermal stratification. The lake appears to overturn nightly due to convection currents and mixing by wind.

The climate at Lago Chirripó, as throughout the Talamancan highlands, is characterized by low annual temperatures and a highly seasonal precipitation regime. Extrapolating from lapse rates, Coen (1983) estimated minimum and maximum average annual temperatures for the summit of Cerro Chirripó of 2.2° C and 7.2° C, respectively; temperatures

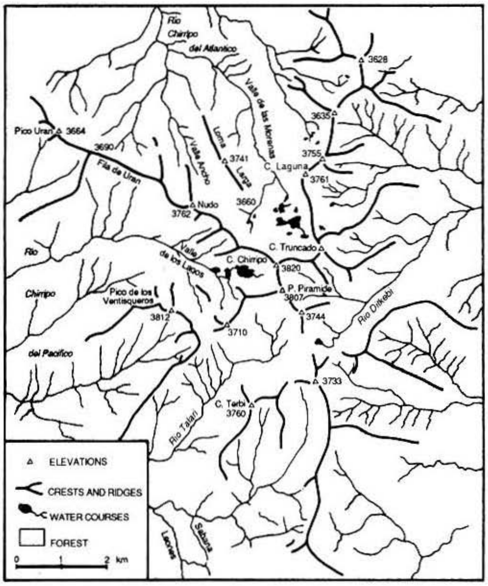

Fig. 2. The Chirripó páramo. Lago Chirripó is the large lake at the head of the Valle de los Lagos. Redrawn from Weber (1959).

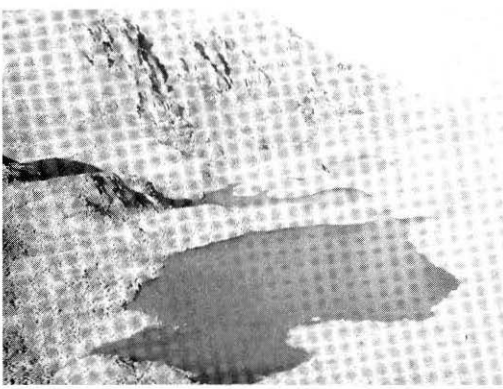

Fig. 3. Lago Chirripó and the second and third lakes in the chain of glacial lakes in the Valle de los Lagos. The core sites were located off the far side of the peninsula visible in the right foreground. The photograph was taken in February 1985, looking west from the summit of Cerro Chirripó.

300 m lower at the lake surface should be slightly higher. The yearly amount and distribution of rainfall is probably similar to that reported for Cerro Páramo (3475 m), a peak about 15 km northwest of the lake in the Buenavista highlands. Here the average annual precipitation during the period 1971-1984 was just over 2500 mm, with about 90% of the total falling during the May to November wet season (Instituto Costarricense de Electricidad unpub. data for station 073080).

The vegetation on the steep slopes surrounding the lake is dominated by the dwarf bamboo *Swallenochloa subtssellata.* Scattered shrubs of *Vaccinium consanguineum, Pernettia coriacea, Hypericum irazuense, Senecio firmipes, Mahonia volcanica, Diplostephium costaricense, Hesperomeles heterophylla,* and *Garrya laurifolia* occur intermixed with the bamboo. The littoral vegetation is poorly developed and consists primarily of tussock grasses (especially *Calamagrostis* spp.) and club mosses (*Lycopodium* spp.). The small aquatic quillwort, *Isoetes storkii*, grows in shallow parts of the lake.

The Lago Chirripó watershed last burned during the major fire that swept through the highlands in 1976 (Chaverri, Vaughan & Poveda 1976). According to Chirripó National Park guard and long-time mountain guide Arcelio Fonseca Vargas (pers. comm. 1985), the Valle de los Lagos also burned during the 1961 fire discussed by Weston (1981) and Boza and Bonilla (1978). A photograph taken in the Lago Chirripó watershed in 1955 by the geologist Richard Weyl (private collection of Porfirio Fonseca Zúñiga, San Gerardo, Costa Rica) shows recently burned shrub and bamboo stems, indicating that part of this area burned sometime during the early 1950s. This burn may have been part of the 1953 Chirripó fire mentioned by Weber (1959) and Kohkemper (1968). Further information about these and other historic fires in the Chirripó highlands is contained in Horn (1986).

Fire seems to have constituted the major form of human disturbance in the Lago Chirripó watershed and in adjacent areas of the national park. The horses that are occasionally used to transport equipment into the park graze the bamboo *Swallenochloa subtessellata* and tussock grasses near the Administration Center in the Rio Talari valley, but grazing damage is slight because the animals are usually led back down the montain soon after the supplies are unloaded. Water pollution and trampling associated with increasing recreational use of the Chirripó massif have also been reported (Horn 1986).

MATERIAL AND METHODS

Field methods: Two short sediment cores were obtained from Lago Chirripó in January of 1985, using plastic tubes (57 mm inner diameter) fitted with rubber pistons. Both cores were recovered from near the northeast shore of the lake (Figure 4). Core 1, taken about 30 m offshore at a water depth of 9 m, was 77 cm long when first recovered and 50 cm long after settling. Core 2, taken about 20 m offshore at a water depth of 6 m, was 124 cm long when recovered and 110 cm long after settling. Neither core reached the base of the sediments, but deeper deposits could not be recovered using the 1.5 m long sampling tubes available.

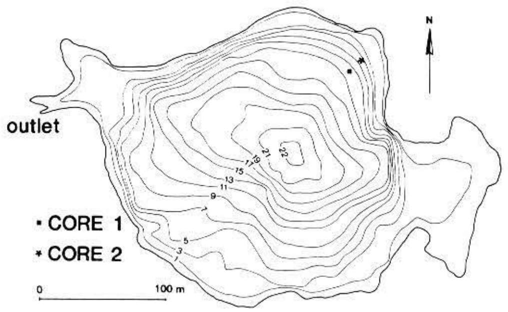

Fig. 4 Location of core sites. Depth contours in meters. From Gocke *et al.* (1981) with minor additions.

The cores were sampled in the field as there was no practical way to carry them out of the study site intact. Core 2, the longer core, was selected for study, but samples were also taken from Core 1 as a source of reserve material. The water column on top of the sediment was drained by drilling holes in the plastic tubes at the sediment/water interface. To speed the settling of Core 2, small holes (3 mm diameter) were made along the length of the tube. The holes were drilled at 2 cm intervals, working from the top down and allowing each hole to stop draining before the next lower hole was drilled. The holes became plugged with mud almost immediately, and the water that filtered through the holes was clear. Below 50 cm the sediments were fairly well consolidated, and very little water drained from the holes. After drainage was complete the plastic tube was sliced longitudinally to remove core samples. Samples were taken at 2 cm intervals from the central section of the core to minimize the risk of contamination. Sampling instruments were wiped clean and rinsed with filtered water (filter pore size .4 μm) between each sampling interval.

Laboratory methods

Sample Preparation

Thirty sediment samples from Core 2 were processed for charcoal analysis in the Palynology Laboratory at the University of California, Berkeley, using a modified version of the nitric acid digestion technique described by Swainn (1973). The procedure differed from standard pollen preparation methods, which are also used to process samples for charcoal analysis, in that most organic matter other than charcoal was removed by extended treatment in hot concentrated nitric acid.

Swain (1973) and Corlett (1979) found that the charcoal content of sediment samples prepared using nitric acid digestion and standard pollen preparation techniques was similar. Clark (1983) carried out additional tests of processing methods and determined that extended treatment in concentrated nitric acid significantly reduced the amount of chaorcal in sediment samples. The relativities between samples were maintained, however, and would lead to the same interpretation. Clark concluded that either method is acceptable for charcoal analysis, as long as all samples in a series are treated identically. The choice of procedure depends on the nature of the research and the time available; if only charcoal fragments are to be examined, it is quicker to use the nitric acid digestion method.

A standard wet sediment volume of 1.2 cm^3 was used for each charcoal extraction. The sample was weighed before processing, and its water content was determined by drying a duplicate sample overnight at 100° C. The dried samples were later ignited for one hour at 550° C and 1000° C to determine total organic and carbonate content (Dean 1974). All centrifugations in the charcoal preparation procedure were for 2 minutes at 2500 rpm (International Centrifuge Model CL). The complete procedure was as follows:

1. Place sample in 15 ml plastic centrifuge tube and disaggregate in distilled water.
2. Remove large detritus by seiving through a perforated crucible with holes 700 um in diameter. Centrifuge and decant filtered samples. Retain detritus for later examination.
3. Remove silicates by boiling for one hour in concentrated HF (48%). Wash once in distilled water after centrifuging and decanting.
4. Remove extraneous organic matter by boiling for one hour in hot concentrated nitric acid (70%). Centrifuge and decant.
5. Fill tubes about one third way with distilled water. Add one *Lycopodium* tablet, each containing an average of 12,077 spores, to each sample as a control. The tablets provide a means of calculating the charcoal concentration in the samples. Adding control spores to the samples *prior* to the nitric acid digestion would have been preferable, but the spores would have been destroyed by the acid treatment. The charcoal concentrations discussed here represent concentrations after acid digestion, which may have destroyed some charcoal particles. However, since all samples were treated in an identical manner, the relativities between samples should not have been affected.
6. Wash twice in distilled water.
7. Dehydrate sample with tertiary butyl alcohol.
8. Transfer to small vials for storage. Add 2-3 drops of silicon oil (2000 centistokes viscosity) to each vial, stirring well. Leave open vials in dust free cabinet overnight to allow alcohol to evaporate.

Radicarbon Dating

Radiocarbon dates were obtained for three sections of Core 1: the base of the core (80-110 cm), and the intervals 28-36 and 54-64 cm. After sufficient material was removed for charcoal analysis, the samples within each interval were mixed together and submitted to Beta Analytic Laboratory for dating of their organic fraction.

Charcoal Analysis

The end results of the extraction process were residues consisting primarily of charcoal fragments and *Lycopodium* control spores. The residues were mounted on microscope slides and examined at 500 x magnification. The charcoal fragments ranged in color from light brown to black or grey, with most particles appearing dark reddish-brown or black. The same range of color was found in samples prepared by grinding pieces of charred wood and leaves collected at Lago Chirripó and at burn sites in the Buenavista highlands and subjecting the particles to the same chemical treatment used for the sediments.

In sediment samples processed using standard pollen preparation methods, charcoal fragments generally appear black or grey in color (Clark 1983). Alternative preparation techniques that involve extended treatment in nitric acid apparently bleach some of the charcoal fragments, resulting in a wider color range. Swain (1973) also reported variation in the color of microscopic charcoal fragments in lake sediment samples treated for one hour in hot concentrated nitric acid. He found that experimentally burned plant tissues showed the same range of color variation when processed with nitric acid, but that unburned plant fragments remained colorless after the treatment. No particles that could be confused with charcoal were created by the chemical treatment.

The area of charcoal on the slides was estimated using the point counting technique described by Clark (1982). This method allows the rapid estimation of projected charcoal area, but has the drawback of not providing information on particle size distributions. An eyepice reticule with an array of points was applied to successive fields of view, and the number of points that were seen to "touch" charcoal was tallied. The number of fields viewed, and the number of *Lycopodium* control spores observed in the fields were also recorded. The array of points was defined by the numbered ends of six of the divisions on an eyepiece micrometer. 1200-2000 points were applied to each slide by moving the field of view along parallel transects spaced evenly at 1 mm intervals. The stage was advanced manually step by step across the slide, with each step 1.5-2 mm farther along the transect. I looked away when moving the stage so as not to bias the results by selecting the field of view.

The ratio of charcoal "hits" to points applied provided an estimate of the areal density of charcoal on the slide. Sufficient points were applied for this value to generally have a relative error of less than 10%, calculated as detailed in Clark (1982). The areal density of charcoal was multiplied by the number of fields viewed and the area of each field (provided by the manufacturer, and checked with a micrometer) to give the total area of charcoal in the fields scanned. The *Lycopodium* count was then used to convert this value to an estimate of the total area of charcoal in the sample. Finally, the original wet weight of the sediment samples and the water content data obtained for duplicate samples were used to express charcoal area on a dry weight basis.

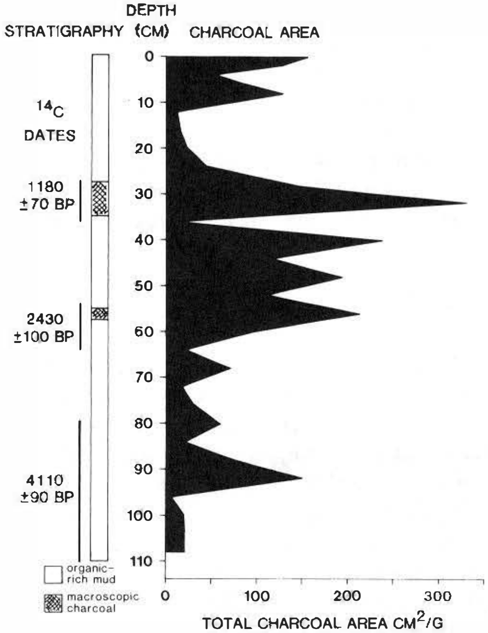

Fig. 5. Charcoal and sediment stratigraphy of Lago Chirripó Core 2. Charcoal area values for samples taken from 2 cm intervals in the core have been plotted at their upper limit; *e.g.*, the 0 cm data point represents the 0-2 cm. sample.

RESULTS

Sediment Stratigraphy and Chronology

The Core 2 sediments consisted of dark, organic-rich mud. The loss on ignition values for 30 samples indicate that the sediments contain 22-55% organic matter and 1-5% carbonate calculated on a dry weight basis. Visual inspection showed no laminations. Macroscopic charcoal fragments ranging in size from less than 1 mm^3 to more than 20 mm^3 were dispersed throughout the length of the core but concentrated in two layers located at depths of 28-35 cm and 55-57 cm.

The results of the radiocarbon analysis indicate that the Core 2 charcoal record spans a considerable length of time. The basal sediments from the core yielded a radiocarbon date of 4110 ± 90 BP. Sediments from the 28-36 cm and 54-64 cm intervals, each of which encompassed one of the layers of macroscopic charcoal, yielded dates of 1080 ± 70 BP and 2430 ± 100 BP, respectively.

The radiocarbon dates indicate that sedimentation rates have been approximately constant over the deposition of the core. Applying each date to the midpoint of the interval analyzed yields the following rates of sediment accumulation: .027 cm/year between 0 and 32 cm, .022 cm/year between 32 and 59 cm, and .021 cm/year between 59 and 95 cm.

Charcoal Analysis

Microscopic examination revealed an abundance of charcoal particles in the samples. The fragments were relatively large and in most cases consisted of groups of cells, although individual cells and parts of cell walls were also present in the samples. Maximum dimensions ranged from a few to several hundred microns. Many of the larger fragments showed morphological features suggestive of Gramineae epidermal tissues (Suman 1983). Other particles showed horizontal rays and banding patterns indicative of wood xylem. Several of the samples contained charcoal fragments that closely resemble charcoal produced by experimental burning of the leaves of the bamboo *Swallenochloa subtessellata.* However, the morphology of the Lago Chirripó charcoal fragments has not yet been studied in detail, and no attempt was made to distinguish different charcoal types in the point counting.

Figure 5 graphs the charcoal values for thirty samples from Core 2 expressed as total charcoal area per gram dry sediment. The samples show considerable variation in charcoal concentration, with the highest levels found in the upper half of the core, particularly between 28-62 cm.

The coarse debris sieved from the samples prior to chemical extraction consisted primarily of larger fragments of charred wood and leaf tissue.

DISCUSSION AND CONCLUSIONS

The very slow rate of sediment accumulation indicated by the radiocarbon dates is consistent with the small size of the Lago Chirripó watershed and the relatively low phytoplankton productivity in the lake (Gocke *et al.* 1981). The slow sedimentation rate had two important consequences for the present study. On the one hand, it reduced the resolution of the fire record, since each 2 cm interval of the core analyzed represented a mixture of sediment deposited over roughly 75 to 100 years. But the low rate of sediment accumulation was an asset in that a relatively long record could be obtained from short cores recovered with simple equipment.

The charcoal record contains the first direct evidence available of fires in the Chirripó highlands during the prehistoric period. The record is interpreted to primarily reflect fires within the watershed of the lake and in adjacent areas of the massif. Although charcoal particles can be blown considerable distances by wind (Patterson, Edward & Maguire 1987), detailed studies of charcoal production and deposition carried out by Clark (1983) showed that most of the charcoal produced by burning remains in place, and that more is removed by water than wind. Clark concluded that most of the charcoal that accumulates in sedimentary basins is derived from fires within the water catchment or in areas close to, but outside, the catchment. Although some of the charcoal microparticles preserved in the Lago Chirripó sediments may have blown in from fires in the foothills of the Talamancan cordillera, the large size of many of the fragments suggests a local origin. The abundance of macroscopic charcoal in the cores supports the interpretation of the charcoal record as chiefly indicating fires within the watershed of the lake.

The most important conclusion to be drawn from the charcoal analysis is that fire has a long history in the Chirripó massif. High-elevation fires are not disturbances introduced by modern human society; such fires have occurred in the highlands for over four thousand years. Recent fires in the Costa Rican páramos have been attributed to human activity, but lightning deserves attention as a possible source of ignition for both contemporary and ancient fires. Maps published by the World Meteorological Organization (1953, 1956) show that Costa Rica experiences one of the highest incidences of thunderstorms in the world. Lightning has been observed striking both the forested slopes (Pittier 1891) and treeless summit of the Chirripó massif (A. Fonseca pers. comm. 1985). Lightning-killed trees are conspicuous in the montane forests of the Cordillera de Tilarán in northwestern Costa Rica, where Robert Lawton (written comm. 1985, also see Lawton 1983) estimated a yearly mortality rate due to lightning of about one tree per ten hectares. In the Cordillera de Tilarán, perennially moist substrate conditions prevent fires from propagating, but in the seasonally dry Chirripó uplands "dry" lightning storms during the first four months of the year could conceivably ignite fires.

Prehistoric fires in the Chirripó highlands also could have resulted from intentional or accidental ignition of the vegetation by people crossing over the massif. Indigenous groups never inhabited the uppermost slopes of the Cordillera de Talamanca, but pre-Columbian population centers existed on both sides of the range and several trails crossed the rugged crest (Stone 1961, 1977, Kohkemper 1968). Highland fires also could have arisen from fires set in the foothills of the range that burned upslope out of control. On the lower Pacific slope there are numerous large savannas, some of which reach elevations of over 2000 meters, that have been attributed to the clearing and burning of forests by pre-Columbian agriculturalists (Barrantes 1965). During very dry years, fires set in these grasslands could have spread into the montane forests, and perhaps burned far enough upslope to ignite the shrublands of the high peaks. A recent example of just such an event is provided by the massive forest fire that swept up the Pacific slope of the Chirripó massif in early 1985 and burned the Sabana de los Leones (Figure 2) and surrounding oak forests in the southern part of Chirripó National Park (McPhaul 1985a, b).

The Chirripó charcoal record provides an important perspective for studies of contemporary fire ecology in the Costa Rican páramos. Research on postfire regeneration carried out by Chaverri, Vaughan and Poveda (1976, and in. prep.) and by Horn (1989) has demonstrated that some páramo species are able to resprout vigorously following burning. As Vaughan and Chaverri (1978) and Horn (1989) have pointed out, resprouting allows for rapid recovery after damage from grazing, wind, and frost as well as following fire, and the resprout ability of certain páramo species did not necessarily evolve in response to fire. However, in the Chirripó highlands it appears likely that periodic burning over the past several thousand years has reinforced the trait.

The jagged nature of the charcoal curve indicates that the magnitude and rate of charcoal production and transport within the Lago Chirripó watershed have varied significantly during the time period represented by the core. Changes in sedimentation rates in the basin also could have affected the charcoal concentrations. However, the relatively constant rate of sediment accumulation indicated by the radiocarbon dates suggests that charcoal fluxes have not been masked by major shifts in lake productivity or the rate of clastic input to the sediments.

Changes in the amount of charcoal produced in the watershed and transported to the core site probably largely reflect changes in fire frequency. Given the low resolution of the charcoal record, it remains impossible to infer absolute fire frequencies from the charcoal data. However, some idea of relative fire frequencies can be gained by comparing charcoal concentrations in successive intervals of the core. Relatively high and low fire frequencies should ideally be reflected by respectively high and low relative concentrations of charcoal in the sediments. The higher charcoal levels in samples from the intervals 0-10 cm, 28-62 cm, and 92-94 cm should correspond to periods of more frequent burning, while the lower charcoal values in the intervening sections should correspond to periods of less frequent burning.

If this interpretation is correct, the charcoal data suggest that the post-1940 fire frequency of one fire every 8-15 years in the Lago Chirripó watershed may not be without precedent. The fact that charcoal is no more abundant in the uppermost sample from the core, than it is in samples deposited between 28-62 cm or 92-94 cm, suggests that similar fire recurrence intervals may have occurred during prehistory.

Several caveats to this interpretation should be stated, however. As Clark (1983) has stressed, the relationship between fire history and charcoal stratigraphy is a complicated one. Changes in fire frequency may not be the only variable affecting charcoal concentrations in the Lago Chirripó sediments. Moreover, an increased fire frequency may not always have led to greater charcoal influx to sediments. The amount of charcoal deposited in lake sediments over a given time period depends on the rate of fuel accumulation as well as on the timing and extent of fires. A time period during which fires were very frequent could conceivably be reflected in a charcoal record by *lower* relative amounts of charcoal than a time period characterized by less frequent fires, if the amount of fuel available (and thus the potential amount of charcoal produced) was much lower under the regime of more frequent fires (Clark 1983). Changes in vegetation alter fuel levels, accumulation rates, and flammability, and in this way also affect both fire frequencies and the nature and rate of charcoal production and transport. Climatic shifts can similarly alter charcoal fluxes. Significant changes in runoff or lake level, for example, would change patterns of charcoal transport, and could also affect vegetation composition and fire frequencies.

Future studies of charcoal morphology and pollen stratigraphy may provide additional information on fire history, and may yield insights regarding the longer term relationship between fire and vegetation in the Chirripó highlands. The identification of charcoal fragments and associated pollen in the sediments will provide information on the nature of the vegetation burned in the Chirripó fires. The pollen stratigraphy of the sediments may reveal long-term changes in the vegetation of the Chirripó highlands that correlate with changes in fire frequencies inferred from the charcoal record.

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RESUMEN

Para determinar la historia de los incendios en el macizo de Chirripó, se estudiaron los fragmentos de carbón en un núcleo de sedimento de 110 cm de longitud extraído de un lago glacial (Lago Chirripó, el más grande de cerca de 30 lagos glaciales en el macizo). La datación radiocarbónica para los sedimentos del fondo del núcleo es 4110 años antes del presente. La estratigrafía del carbón indica que la cuenca del lago ha sufrido incendios periódicos desde ese tiempo, a causa de actividades humanas, rayos o ambos factores.

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