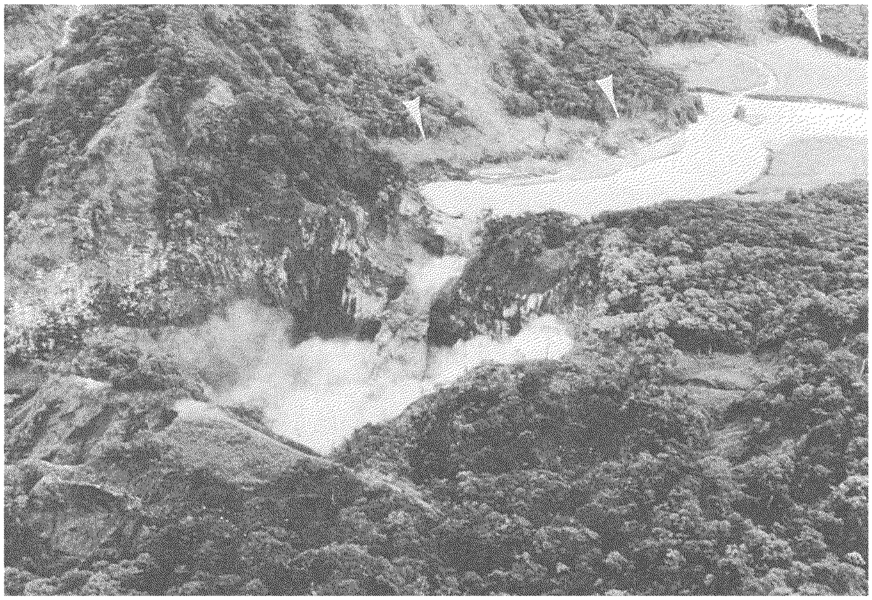

FIGURE 5.7 April 1987 aerial view of San Rafael Falls on the Coca River downstream from Reventador Volcano. Note the vegetation trim line (arrows), which indicates the maximum height of the debris flow/flood, about 20 m above the current level of the Coca River. There is a strong probability that constriction of the river at the falls caused short-lived "hydraulic" damming of the river.

Salado River have overall slopes that usually are between 25 and 35° in their middle reaches. Tributaries of the Salado have variable overall slope angles, about 40° in their midcourses but lower values in their lower courses and uppermost reaches. The valley/gully walls of first- and second-order tributaries of the Salado have slope angles that range from 40 to 60°, or even greater.

The zone has distinct microclimates that vary from cold and dry (annual precipitation of less than 1,500 mm in the highest portions), to temperate in the tributaries of the major rivers, to subtropical (annual precipitation of more than 4,000 mm along the valleys of the lower parts of the Salado, Coca, and Dué rivers). Consequently, the vegetation is a function of elevation. Oaks and some evergreens grow at the highest elevations, shrubs and low trees in the middle elevations, and rain-forest vegetation below 2,500 m.

Rainfall occurs throughout the year, but increases in intensity from March to July. Significantly, anomalously high precipitation occurred in the area in January and particularly in February 1987. On February 3 and 20, the

INECEL gaging station just upstream from San Rafael Falls (Figures 5.1 and 5.7) on the Coca River registered flow rates of 2,600 and 3,400 m^3/sec, respectively. These discharges have estimated return periods of 5 and 20 years, respectively. A few days before the earthquake, the flow rates diminished. Thus, the gaging station measured 450 m^3/sec at 1700 on March 5; the estimated discharge at 2300 was 600 m^3/sec. These values, however, are more than twice the average flow of the Coca River.

Most of the Reventador zone is underlain by subhorizontal and gently dipping sedimentary rocks of Jurassic/Cretaceous and Cretaceous ages (Figure 5.6). The formations mapped in the Reventador zone are from the oldest to the youngest: pyroclastic sedimentary rocks (Misahualli Member of the Chapuzi Formation), quartzitic sandstones (Hollin Formation), shales and limestones (Napo Formation), and red clay shales (Tena Formation). The western boundary of the Reventador zone is composed of Paleozoic gneisses and schists in contact with the sedimentary rocks to the E by major overthrusts. The sedimentary rocks adjacent to the overthrusts have undergone low-grade metamorphism along a belt a few kilometers wide that extends close to the western edge of the Reventador volcanic complex. In the vicinity of Reventador Volcano, the rocks are lavas and pyroclastics, ranging in age from late Pleistocene to Holocene.

Rectangular drainage in some areas and lineaments observable in airphotos provide evidence of strong fracturing. This fracturing affects even the volcanic materials of Holocene age. The most important fracture systems trend N-S and NE-SW. The latter may be responsible for SW-NE course of the Quijos/Coca River.

Away from the flood plains and alluvial terraces of the main rivers and high-order tributaries, the soils are either colluvial or residual. The colluvial soils occur at the foot of the slopes and were generally not involved in the March 5 landsliding. The residual soils range from saprolites to laterites. Because the relief is significant and the area is well drained, the residual mantle is not very thick—from a few centimeters to a few meters at most—and grades rapidly into weathered fractured rock. These soils have very high void ratios and natural water contents; the values of the latter are practically equal to the liquid limits. Under these conditions, these soils have sensitive structures.

General Characteristics of Landslides in the Reventador Zone

More than 90 percent of the observed landslides began as shallow slips or slides of residual soils and highly weathered rock on the uppermost parts of the slopes of the main valleys or on the slopes of the lower-order tributaries (Figure 5.8). Average thicknesses of these slips were from 1.5 to 2.0 m, with a thickness range of a few decimeters to 5 m. The failing masses

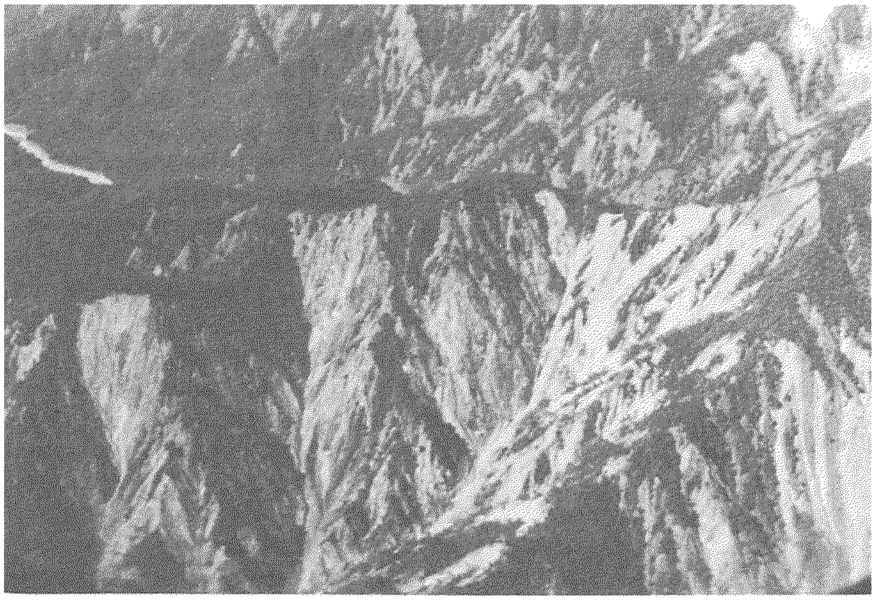

FIGURE 5.8 Ridge NW of Reventador Volcano from which jungle vegetation has been stripped by landslides triggered by the earthquakes. The slope failures started as thin slips on the steep (about 50°) upper slopes. As they moved downward, the saturated, vegetation-charged masses were transformed into debris avalanches and then to debris flows that discharged into the Dué Grande River (out of the photo at the bottom). (Photograph by Ken Nyman, Cornell University).

either were transformed into debris avalanches and then into debris flows or, in some cases, were reworked almost immediately into debris flows with high fluidity. Whether they began on a main valley slope or the valley slope of a lower-order stream, flows moved to the channels of the lower-order tributaries and entrained the colluvial/alluvial fills along the channels, eroding the material to the bedrock surface. The debris flows then proceeded to the higher-order tributaries or to the main river valleys. Smaller debris flows stopped lower on the slopes of the main river valleys or in the bottoms of gullies. Debris flows starting higher above the valley floor were also more apt to reach the floodplain than those from lower heights. A large number of the landslide scars displayed unweathered bedrock, attesting to the shallowness of the residual soil mantle.

Overall preearthquake slope angles and gully slope angles on topographic maps at locations of the earthquake-induced slope failures were measured; the locations were determined from postearthquake vertical and oblique airphotos. These measurements indicated that on the left valley wall of the