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Mass Wasting and Flooding

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INTRODUCTION

This chapter deals with slumps and slides, debris avalanches, debris flows, and flooding, the processes that account for the largest amount of destruction and number of deaths induced by the March 5, 1987, earthquakes.

LANDSLIDES

Landslide processes are described first, then interpreted in light of the field observations. The descriptions are grouped into three field traverse areas (from W to E) that are progressively closer to the epicenters of the earthquakes, located about 25 km NNW of Reventador Volcano: Quito-Baeza, Baeza-Salado, and Reventador Volcano (Figure 5.1). Field observations for the first two areas were made mostly by land along the Trans-Ecuadorian highway from Quito to the mouth of the Salado River; the observations in the Reventador area were made by car, helicopter, and airplane.

Quito-Baeza

This traverse is divided into three approximately equal parts, each about 25 km long. Midpoints of each of these sections are 90 km, 80 km, and 75 km from the epicenters. The first section is the eastern half of the Inter-Andean Valley, where Quito is located. This depression is filled mostly with pyroclastic materials—primarily "cangahua"—and glacial till (see Chapter 2). Elevations along this section range from 3,000 to 3,500 m, and the climate is temperate. Slopes are relatively gentle, generally not exceeding 20 to 25°. A few slope failures caused by the March 5 earthquakes were

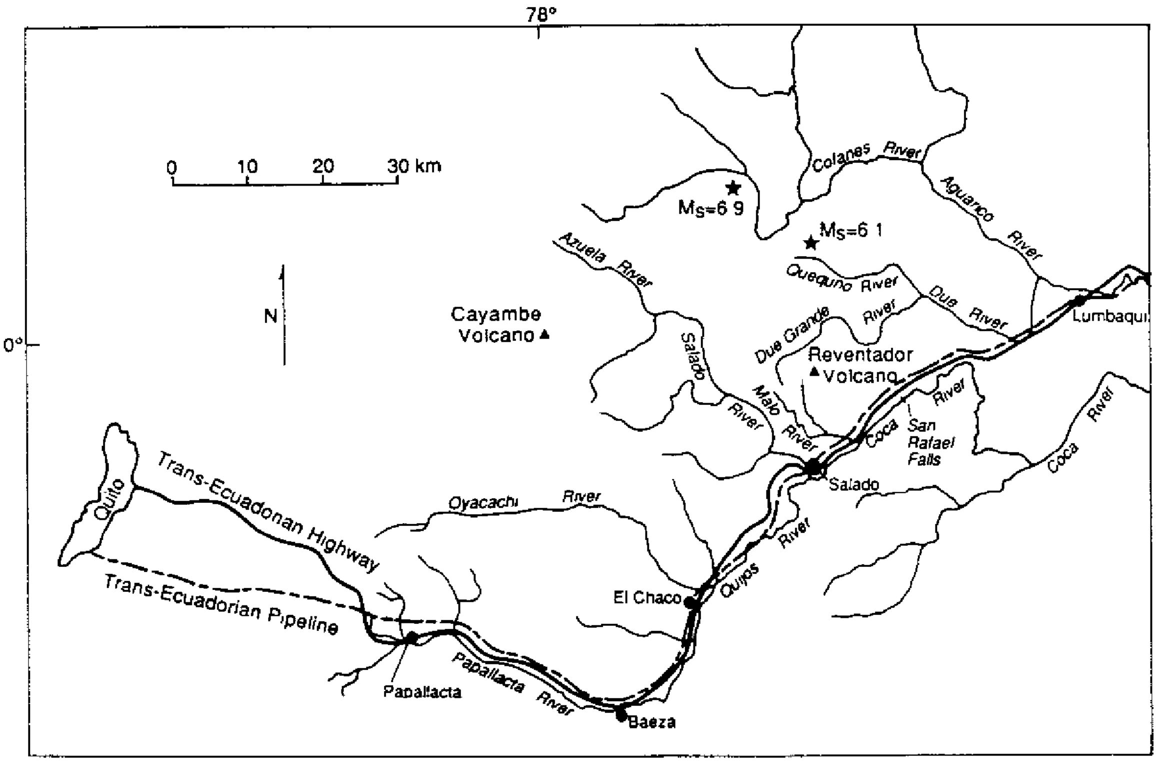

FIGURE 5.1 Map of area E of Quito showing locations of epicenters of the March 5, 1987, earthquakes, the Trans-Ecuadorian pipeline and highway, Reventador and Cayambe volcanoes, and rivers and towns noted in this chapter.

observed in cangahua along very steep to subvertical highway cuts and stream banks. Steep slabs or overhangs failed as falls, topples, and slips. (Mechanical properties and failure mechanisms in the cangahua have been described by Crespo and Stewart [1987]). The types of failures—falls and topples—occurring the farthest from the epicenter confirm observations by Keefer (1984). We also observed fresh slumps and soil flows in sandy morainal deposits at the headwaters of the Papallacta River (Figure 5.1), but ascertaining if these were caused by the March 5 earthquakes is difficult. Further, we observed a couple of examples of old landslide morphology that showed no indication of reactivation.

The next 25 km crosses lava flows that create the divide of the Cordillera Real (Figures 2.1 and 2.2). The lava flows are Quaternary rhyolites, andesites, and basalts. The elevation is about 4,000 m, and the climate is temperate to cold. Relief is high, and soils are nonexistent or colluvial. Slopes are nearly vertical in the lava flows, and moderate—25 to 35°—in talus deposits at the foot of cliffs. Some slopes have columnar joints or stress-relief joints. We observed a few topples, some of which may have been related to the earthquakes, and also a few talus slopes with evidence of some recent movement.

The last 25 km or so to Baeza comprise the descent to the sub-Andean zone (western edge of the Oriente, Figures 2.1). In this stretch, the highway follows the Papallacta River. The rocks are Cambrian and Precambrian gneisses and schists. Elevations range from 3,500 m at the western end to 1,500 m near Baeza. Relief is very pronounced; some slopes are 45° or steeper. Residual soils are thin or absent for most of the section. Only in the lower reaches of the Papallacta River, a few kilometers E of Baeza, did we observe a few debris flows on the highest parts of the Papallacta valley walls. These debris flows were shallow and had the same characteristics as those described in detail in later sections.

Baeza-Salado

This traverse extends from the town of Baeza down the Quijos River, where it joins the Salado River to form the Coca River (Figure 5.1). In general, the denudation around Baeza was only moderate. Some shallow debris flows in residual soils could be seen on the crests of slopes around the town. In addition, a small number of rock slides and rock glides, as well as a few slips and slumps in old and recent alluvial terraces (Figure 5.2), were observed. Landslide intensity increased progressively from El

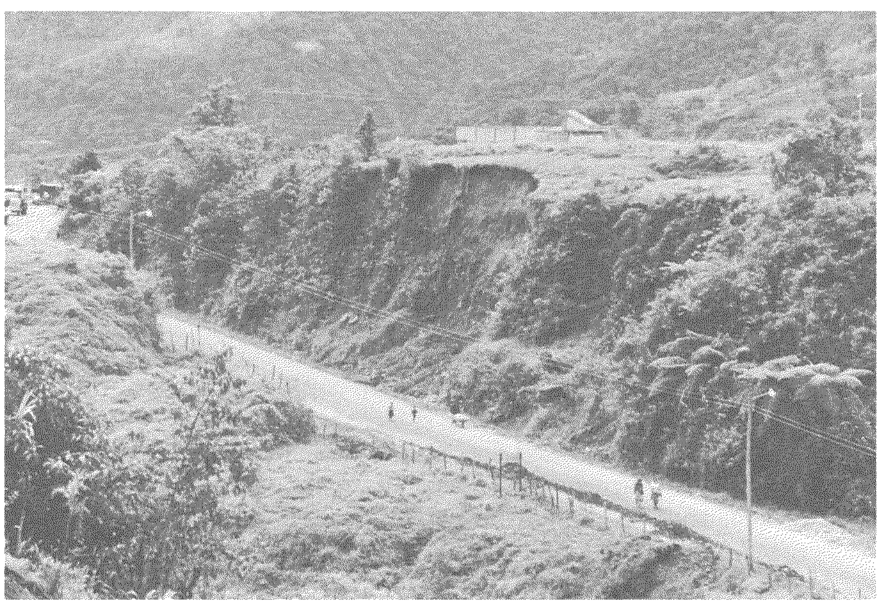

FIGURE 5.2 Thin earth slide (center of photo) on steep face of alluvial terrace on western edge of the town of Baeza.

Chaco to Salado. The pattern of landsliding included initiation points located high on steep slopes covered with shallow residual soil and weathered rock. This pattern, which became apparent in areas closer to the epicentral zone, is discussed in detail below. The most significant observation along this traverse is that very few of the debris flows reached the Quijos River channel. Thus, landslide material contributed little to the sediment load of the Quijos. Some detailed observations along this last portion of our traverse follow:

Young alluvial terraces, 15 to 20 m high near Baeza, have been created by stream degradation (Papallacta River and tributaries). Intense chemical weathering has modified these alluvial deposits, giving them certain characteristics of residual soils. This veneer of residual/alluvial materials commonly was involved in slip/debris-flow failures of the steep terrace slopes. The relatively unweathered alluvial material (probably cemented) underneath this veneer remained unaffected.

From Baeza to about 20 km to the NE, the Quijos River follows the contact between Paleozoic and Mesozoic rocks (Baldock, 1982), probably coincident with a major thrust; the Trans-Ecuadorian highway and pipeline lie on the W (left) side of the Quijos valley (Figure 5.1). For the next 20 km to the confluence of the Quijos and Salado rivers, the highway and pipeline begin to climb over Cretaceous sedimentary and metasedimentary rocks. These lifelines follow high elevations and drainage divides, which, in turn, coincide with hogbacks formed by generally massive quartzose sandstones that occur within the Mesozoic sequence. Note that the residual soil veneer on the steep slope of the hogback is very thin or nonexistent, as is generally the case in this area. Consequently, the earthquake-induced landsliding was also very shallow. Slope failure began as slips at the highest points of the steep slopes; the slip surfaces coincide with the top of weathered rock and the slips moved rapidly downslope, becoming debris flows (Figure 5.3). This type of landsliding endangered the highway and pipeline, but the slips were generally very thin (less than 1 m) and seldom reached the channel of the Quijos (Figure 5.4).

From about 30 km NE of Baeza to the confluence of the Coca and Salado rivers, the highway follows the steep slope of a massive hogback; for most of this distance the highway is closely paralleled by the pipeline. The highway has been located approximately at the contact between the steep upper slope, covered with a very thin veneer of residual soil, and the lower, gentler colluvial slope. Many very shallow rock falls, debris avalanches, and debris flows (Figure 5.5) moved down from above the highway and blocked it. Although these landslides blocked the highway for several kilometers, local volumes of weathered rock and soil were small, and the landslide materials were fairly easily removed by maintenance crews.

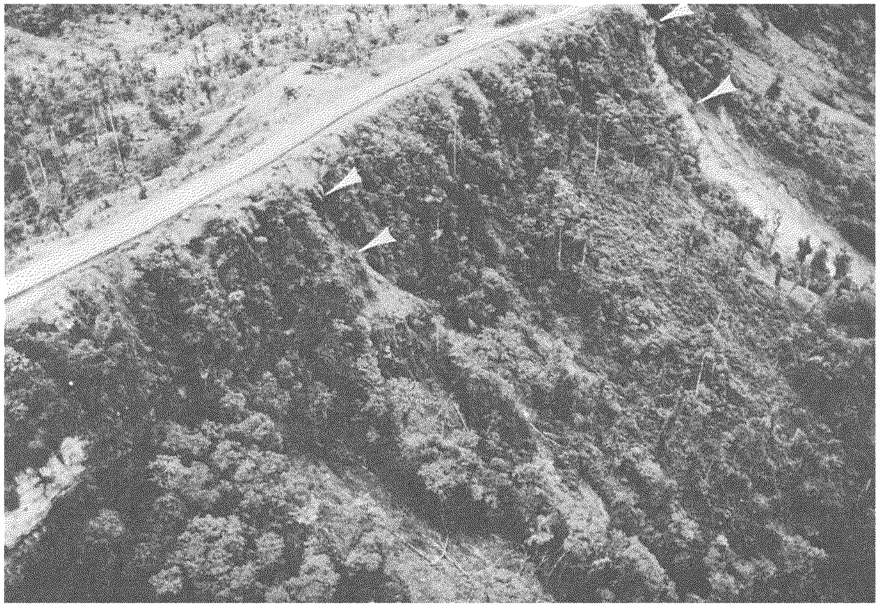

FIGURE 5.3 Landslides (largest examples are indicated by arrows) in residual soils at the top of the N valley wall of the Quijos River between El Chaco and the confluence of the Quijos and Salado Rivers. Because slide-resistant sedimentary bedrock (light-colored outcrop at the lower left) is close to the surface, these slides/ avalanches are shallow and generally limited to existing gullies. Although the slides endangered the Trans-Ecuadorian pipeline and highway (angling across top of photo above the landslides), they caused little actual damage because they were so shallow.

Reventador Volcano

Geological Background

This area includes the greatest intensity of landsliding triggered by the March 5 earthquakes. The Reventador Volcano zone, as defined here, is located in the sub-Andean region; it centers on Reventador Volcano and is bounded by the valleys of the Salado River on the W, the Coca River on the SE, the Quequno River on the N, and the Dué River on the NE (Figure 5.1). The zone includes the greatest intensity of landsliding triggered by the March 5 earthquakes. The earthquake epicenters lie a few kilometers to the N and W of the Reventador area; they are not immediately adjacent to the areas of most intense landslide activity.

The zone presents a large amount of relief both as a unit and locally; elevations range from about 1,550 m on the floor of the valley of the Coca