Landslide in Cerro Renca, Metropolitan Region, Chile

Introduction

In June of 1984, there was a rotational landslide on the west flank of Cerro Renca, near the community of the same name, in the Metropolitan Region of Santiago, Chile. This slide mass has demonstrated perpetual downslope movement in response to intense pluvial cycles (rainy seasons). In the last 19 years, the front has advanced 450 m, and the frontal lobe is approximately 150 m from affecting the road and houses of the neighbouring population (Figure 1).

The vast volume of material involved and the vigour of its displacement have created a growing concern among the municipal authorities and the local community with respect to future movement. For this reason, with the support of the local municipality, studies have been carried out to characterize the morphology, geology, structural and geotechnical processes to define the trigger mechanisms, quantifying their magnitude, predicting their behaviours, and defining mitigation and/or control procedures. This work considers systematic monitoring, new measures of control, and new communication protocol with the authorities and local community.

The Slide

The slide involves volcanic, sedimentary, and intrusive Tertiary rocks, as well as colluvial deposits and alluvial fans. In contact zones between stratified and intrusive rocks, alteration aureoles have generated white to orange, friable clay-altered rocks. The colluvial deposits and alluvial fans include gravels and diamictons containing lithic fragments of various sizes and compositions in an abundant matrix of clay, silt, and silty clay. These deposits were found blanketed by a massive discontinuous sequence of soils that show evidence of numerous fractures (0.9 to 1.8 m long and 0.5 to 1.5 m deep), predominantly filled by dark grey to black clay and silty clay material, that when dry, demonstrate a high resistance, but when saturated with sufficient added water content, become plastic.

In the initial phase (June 1984), the lobe front of the slide would have been displaced approximately 55 to 60 m (Figure 1), with a height of 5.5 to 6.0 m. During the following 9 months, it advanced (March 1985) 135 to 140 m. An aerial photograph taken on January 24, 1995, shows evidence of the front having advanced about 175 m. Two years later, another aerial photograph (taken on February 26, 1997) indicates that the front was situated approximately 22 m from the previous point (Figure 1). The present available registry indicates that the lobe front has advanced around 450 m, with an average "advance" of 2.4 m/month (28.8 m/year). The actual positions of the lobe front vary and do not correspond to the calculated advances at regular intervals in time, which signifies that the velocity obtained should only be considered an estimate, as the movement is episodic and can't be used to predict future behaviour.

Since its start, the mass movement morphology resembled that of a rotational slide, expressed by the presence of a semicircular head, with a local width of 65 m, a scarp of 35 to 40 m, and a length of approximately 220 m. The initial volume of the slide mass is estimated at approximately 210,000 to 215,000 m^3. At present the volume is estimated at 300,000 to 350,000 m^3. With sustained progress of deformation and displacement, the initial mass movement evolved gradually from the simple rotational type, by the incorporation of at least three secondary scarps (manifested by the presence of conspicuous terraced or collapsed features in its longitudinal profile), to a true multirotational slide (Figure 2). Concordant with this activity, the matrix of the mass slide experienced a compositional variation: a predominance of clastic elements during the initial phase, characterized by the presence of boulders and cobbles from 0.5 to 1.0 m in the upper segment, was gradually replaced in the lower segment by clasts of smaller size, immersed in an abundant matrix of clay and silt.

The identification of certain morphological, geological, and structural features allows scientists to establish that maximum activity of the slide was below the secondary middle scarp (Figure 2), recognized by the development of a series of deformations, undulations, and the presence of abundant fractures, as longitudinally extensive as they are transversall. In this distal or terminal segment, the slide's behaviour has a character much like a mudflow.

Causes

The local geomorphology is characterized by steep slopes subjected to intense deforestation, and the construction of access roads designed for recreational use. These constitute complementary factors that might induce mass wasting. Water runoff, concentrated in this case along the axis of an incipient ravine, would have infiltrated, creating the unfavourable condition of ground saturation in intensely fractured and exposed rocks covered with thick superficially cracked soils. The incorporation of water would have resulted in the reduction of the initial effective intergranular pressures and friction and destroyed the pre-existing capillary tension. The significant displacement during the last half of the year 2000 can be attributed to the fluid action of the frontal or distal segment in response to the 279.8 mm of precipitation during the month of June. Also, it is likely that seismic activity plays a role, as seen on March 3, 1985, when the area was shaken by a violent earthquake that reached magnitude 7.8 on the Richter scale, but no observations were made following this event.

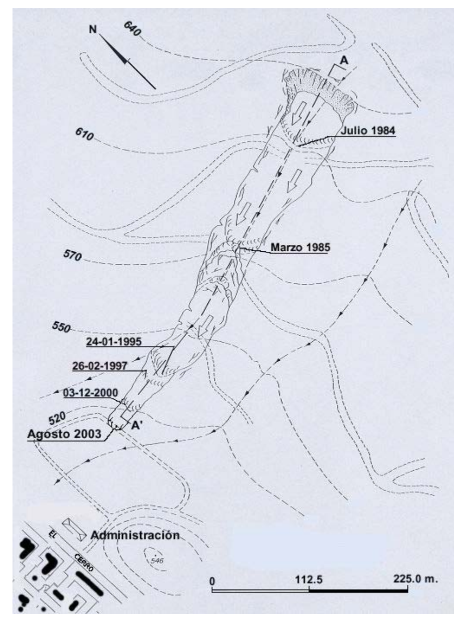

Figure 1.
Plan view of the slide.

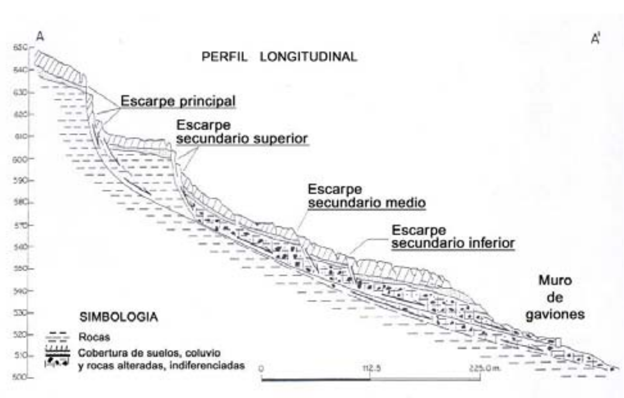

Figure 2.
Profile of the slide.

Evaluation of the Hazard

The slide must travel an additional 150 m to reach the homes located in its trajectory. The displacement of the lobe front would involve a slow, low-volume mudflow of low destructive energy. As well, starting from the present location of the lobe front, the ground changes to a flat plain towards the lower zone where the city neighbourhood lies. Assuming a constant velocity of displacement of 20 to 30 m each year, it will reach the Park Administration and, eventually, the urban zone, in 7 to 11 years (Figure 1).

Prevention and Monitoring Carried Out

Monitoring. The recent activity determined that technical personnel of the Renca Municipality develop a monitoring plan consisting of the installation of a series of stakes, located in the head, middle, and lobe front. The measurements began on August 22 , and concluded on September 26, 2000. At the end of the 34 days of monitoring, the middle portion of the head registered an average backward movement of 0.45 m, while the lobe front advanced an average of 2.5 m.

Drainage. A ditch or gutter was constructed, arranged parallel to and some metres upslope from the head of the slide. Its objective is to limit the entry of the water into the body of the slide mass.

Containment Wall. Due to the latest advances of the lobe front, technicians from the municipality of Renca opted to arrange for the placement of a containment structure with a base of gabions, with a length of 15 m, width of 0.6 m and height of 1.5 m (Figure 2). In its present condition, the wall, although perceived by the community as an effective control element, is vulnerable to displacement from the slide mass due to its limited dimensions.

Forestation. The area presently occupied by the slide mass and its surroundings has been reforested. Species with elevated water consumption have become well established.

Prevention and Future Monitoring

Sealing. The surface of the lower segment, starting from the secondary middle scarp, should be reprofiled, creating a plane, flat-faced structure with slight inclination. The action of mass wasting, mixing, and compaction of material will determine the seal of the surficial section of the mass slide, limiting the entry of rain water. This method should concentrate on the middle and lower segments.

Reduction of Stress. As soon as the stress causing the downslope movement becomes gravitational, the reduction of the slide's mass contributes powerfully to the final stability of the section. Normally, measures required to reach this condition include the removal of predetermined volumes of soil from the surficial section of the mass slide.

Monitoring. With the sole objective of minimizing the risk of reactivation of the present mobile mass (for example, due to precipitation of unusual intensity), the alternative of defining and applying a rigorous monitoring program designed to predict abnormal situations should be investigated. The monitoring can be continuously carried out through the installation of fixed bases (monoliths), in both the actual body of the slide mass and on its flanks. Periodic surveys or dGPS instruments will quantify reactivations. Also, records of deformations in the surface of the mass slide, together with the detection of cracks, constitute effective premonitory signs of reactivation.

Community Communication

The slide's location within urban limits of the city of Santiago and its unmistakable morphological characteristics of this type of geological process make this a singularly valuable and instructive place of interest for study at an academic and community level. For these reasons it was selected as the Case Study area for applying the communications process within the framework of the MAP:GAC project.

The present growing demand for knowledge of geologic hazards by the community and the recognition of its relevance to land-use planning increases the importance and applicability of the selected slide in the process of introducing geoscience to the community.

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