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Geomorphological analysis, monitoring and modeling of large rock avalanches in northern Chile (Iquique area) for regional hazard assessment.

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Iquique is a city of about 215,000 inhabitants (Chilean national census 2002) settled on one of the seismic gaps in the South American subduction zone, where a M >8 earthquake with overdue return periods of ca. 100 yr is expected in the near future. The city has only two access roads coming from the east and south. The road to the east comes down along the escarpment that connects the Coastal Cordillera to the Coastal Plain. The road has been blocked by small magnitude earthquake-triggered landslides at least once in recent years. The second road, coming from the south, crosses along the Coastal Plain and connects the city to the airport where at least ten ancient debris deposits related to rock avalanches are found. These facts show the importance of determining the effects of a future high magnitude earthquake on the stability of the slopes in the area and the impact of possible slope failures on people, infrastructure and emergency management.

The present work covers an area of approximately 130 km2 parallel to the coastline to the south of Iquique, divided into the two main morphological units briefly mentioned above. The eastern part corresponds to the Coastal Cordillera, a set of smoothed hills and shallow valleys that reaches up to 1200 m asl. This sector is limited to the west by a steep escarpment followed by the Coastal Plain and a narrow emerged marine plateau (1-3 km wide) locally overlaid by deposits of recent rock avalanches. Rock avalanche events have recurrently occurred at two sites to the north and center of the study area on the Coastal Cordillera escarpment. Another major single event has been mapped to the south. Marls, red and black shales, and shallow marine glauconitic deposits from Jurassic constitute the source rock for the rock avalanches in all sites. Clusters of deposits are found in the first two sites (retrogressive advance) with younger events running shorter distances and partially overlaying the older ones. Multiple lobes have been mapped characterized by well defined lateral levees and clear internal morphological features (ridges and furrows, hummocks). Rock avalanche run out simulations have been carried out to back analyze the sites using DAN 3D and a 3 m pixel resolution digital elevation model (DEM) obtained from stereoscopic Geoeye-1 images to assess parameters that controlled propagation mechanism and impact area extent of the events. The older lobes were dated by radiocarbon methods. Results indicate ages higher than 40,000 yr BP for the northern site. The second site could only be dated relatively with an underlying terrace that resulted older than the age limit of radiocarbon dating (43.500 yr BP). All the deposits are positioned well above (40-70 m) the present sea level rise, and at the reported uplift rates for the area, they could be associated to events older than some hundreds of thousand years. A more complete record of the failure history of the sites will be obtained when results of cosmogenic nuclides (CN) and luminescence dating will become available later this year. Several other smaller rock avalanches have been mapped in the study area. Satellite-based radar interferometry (InSAR) was performed using ERS-1 and ERS-2 scenes from 1995-2000 as well as ENVISAT ASAR scenes from 2004-2010. Both datasets show only small deformation in the area. This deformation includes sliding of small surficial slope deposits and subsidence apparently due to local groundwater withdrawal. No deformation of bedrock along the escarpment edge is observed.

Results show that only major rock avalanches could reach the main access roads to Iquique and currently no large slope segments show signs of large displacement rates. Moreover, there is no strong correlation between M > 8 earthquakes return periods and age of the dated deposits, which implies that large rock avalanches could have been triggered by other factors. Hence, from a hazard and risk perspective, it is unlikely that large rock avalanches, that could block the access roads to the city, would occur in the near future. Results from CN and luminescence dating will help to get a better understanding of the conditioning and triggering of past events.