Reception: **October 29, 2015** | Acceptance: **June 28, 2016**

CHARACTERIZATION OF GRAVITATIONAL PROCESSES IN DIFFERENT GEOLOGICAL ENVIRONMENTS OF CHIAPAS, MEXICO

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— Abstract—

The gravitational processes (GP) are natural phenomena that generate forms of degradative relief in areas of material removal (for example, the erosion cirques), cumulative sometimes (such as slope deposits), so that change and shape the geographical environment.

In the absence of previous comprehensive studies, as well as a government planning it is common that these processes affecting human settlements, sometimes with loss of life, damage to infrastructure, roads and productive areas, among others.

There are different types of movement that vary in their geometry, speed and water content, likewise, these processes are becoming more frequent and vary their destructive effects. Therefore, today are designed methods of classification and study for these processes, for the year 2006, the National Center of disaster prevention employment a proposal that considers three types and nine subtypes of GP.

Therefore, this work focuses on the characterization of different sites where they occur GP, and are associated with geological environments in which they are located, such as igneous, sedimentary and metamorphic rocks, in different areas of the state of Chiapas.

External factors such as weathering and erosion, affect the type of rock different way, so it is important to know the classification according to their origin. For example, predominantly limestone chemical weathering, which fracturing, favors the rockfall. In deposits of landslides or slope flows are presented.

Large blocks of intrusive origin present a physical-spheroidal weathering, themselves that being discovered by erosion, high and roll the elevations reaching considerable distances.

The type of rock, together with other environmental and anthropic elements has a close relationship with the manifestation of the GP.

The use of basic and thematic mapping, and other online applications, provide information that should be complemented with field trips, in order to have greater certainty in the characterization of the site and generate mapping of threats, and infer the negative effects of these processes areas subject to similar conditions.

Keywords

Hazard, risk management, gravitational processes, vulnerability.

According to the United Nations International Strategy for Disaster Reduction (UNISDR, 2009), a threat is "a phenomenon, substance, human activity or hazardous condition that can cause death, injury or other health impacts, such as damage to property, loss of livelihood and services, social and economic disruption, or environmental damage. " Threats in general are a complex problem with multiple dimensions.

As for vulnerability, it is defined as "the characteristics and circumstances of a community, system or good that makes them susceptible to the harmful effects of a threat" (UNISDR, 2009). Wilchex-Chaux (1993) suggests that global vulnerability has nine dimensions: physical, economic, social, educational, political, institutional, cultural, environmental and ideological.

On the other hand, Risk Management is defined as "the approach and systematic practice of managing uncertainty to minimize potential losses and losses" (UNISDR, 2009).

Generally in a disaster scenario, these dimensions manifest themselves simultaneously to different degrees. The PG pose a threat which is understudied in the state of Chiapas, although there are one or two major events a year (Paz et al., 2011). Currently the focus remains on disasters. When they happen, there are no efficient contingency plans that support the population, despite having knowledge of previous events in the area. This, together with other socioeconomic variables, dangerously increases their vulnerability over time making risk management an absent or incipient task. For its study, one of the basic instruments is the integration of an inventory. This will allow us to know sites where they have occurred and will offer a historical reference for the case of recurrence.

Evictions or change of land use, with the consequent restrictions, have imposed radical measures that do not pay off for an efficient management of the risk. One cause is the lack of comprehensive inter- and multidisciplinary work, a situation in which institutionalized civil protection and academic work diverge, adding yet another element to this complex reality.

In this paper, eight cases are recorded on gravitational processes occurring in different geological environments in the north, center and south-central part of the state. It deals with the lithological aspect as one of the conditioners of these events, and rains and human activity as main detonators.

IMPORTANCE OF THE GEOLOGICAL NATURE OF THE TERRAIN

As Lugo et al state, (2005) "Sharpe (1938), Varnes (1958, 1978), and Mencl Záruba (1969), Crozier (1986) and Dikau et al. (1996), the influence of surface and groundwater, lithology, geological structure and relief are considered among the main factors of GP. For their part, Alcántara and Murillo (2008), propose a methodology to integrate an inventory of PG, where the geology of the site is the second important factor after hydrology.

Muñíz and Hernández (2012) place lithology as the first factor to consider in the methodology for PG zoning in Puerto Vallarta, Jalisco. In addition to the type of rock, the structural control by stratification planes, faults and diaclases are determinant in the behavior of these movements.

DETONATING FACTORS

Rains, along with earthquakes or volcanic eruptions, are considered as triggers of the gravitational processes (Mayorga, 2003; Alcantara et al, 2006) cited by Aristizabal, (2010). In the sites visited, rains are combined with cuts of slope for road construction or land leveling for housing construction.

BACKGROUND

From previous tours during eight years, sites of interest for the study of PGs were identified. These have been visited in different occasions from 2009 with groups of students as part of practices of the subject of geomorphology or for the elaboration of their thesis protocol. In May 2013, some of these sites were proposed in order to conduct a tour with INEGI geologists, in charge of designing a Susceptibility Model to Mass Movements. In July of the same year, as part of the Forensic Investigations of Disasters course the Center for Research in Risk Management and Climate Change of the UNICACH, presented the Fundamental Causes Methodology (IRD-FORIN, 2011) and fieldwork was carried out on the southern slope of Tuxtla Gutierrez.

METHODOLOGY

With the previous knowledge of 12 sites, 8 were chosen to be characterized in this investigation, which allow us to know the complex behavior of the PG in different geological environments and under different conditions of occupation.

The geology was obtained through the Series 1 Geological Information in digital format, elaborated by INEGI (1984), and complemented with the field observations. The software that was used was the digital desktop map view Ver. 5.1 (INEGI) and ArcMap ver 9.3 (ESRI). The geographic coordinates were recorded in the field with Garmin ETrex Vista browser, in degrees, minutes and seconds format. For estimation of road distances and other landmarks, we used Google Earth ver. 7.1.1.1888.

CASES

Eight cases were recorded in different geological conditions, mainly in the north, center and south-central of the state (Map 1), which highlight the importance of geology as one of the determining or conditioning factors. Most, because of their size, can only be represented in a timely manner in the conventional scales generated by INEGI 1:50 000, since they do not comply with the minimum mapping area (AMC) (Paz, 2012).

Map 1. Location of the cases that were studied

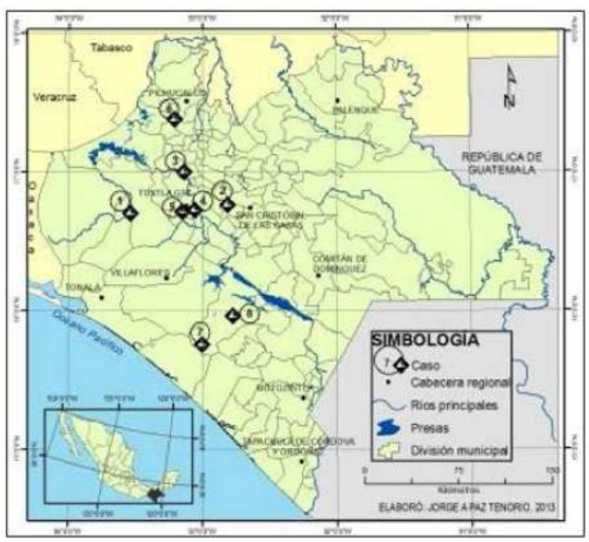


Photo 1. Autopista Ocozocoutla-Arriaga. Paz, 2013

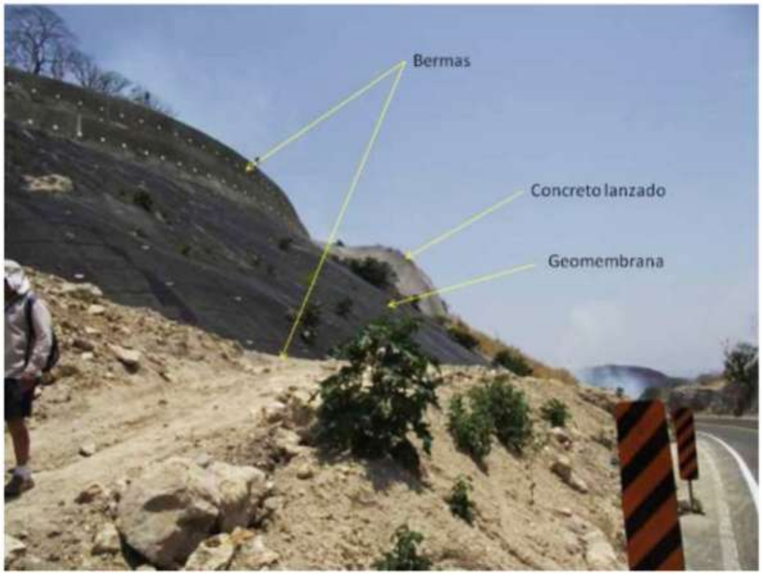


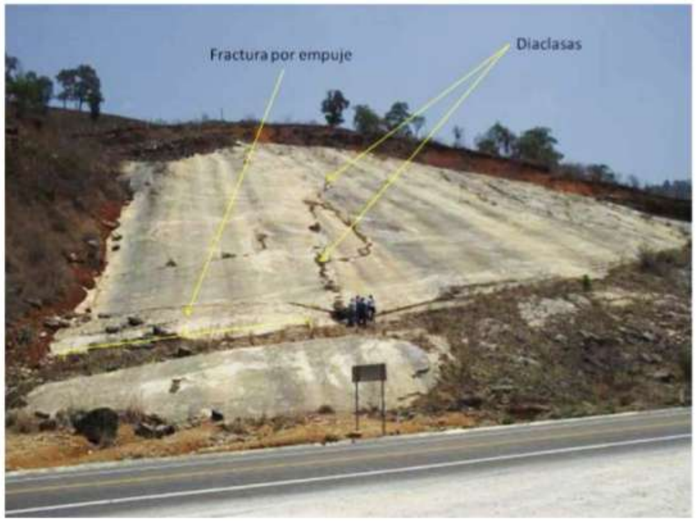
Image 4 Case 1. Ocozocoutla-Arriaga motorway (190 D) (Photo 1).
Location: km 25 (16 ° 41'54.36 "N, 93 ° 32'32.56" W). (Photo 1).
The zone corresponds to the contact of two units: Tritic-Jurassic shale-sandstone and lower Cretaceous limestone-shale.

It is a slope made for the passage of the mentioned highway. At 25 m north, and 20 m above this level is the Pan-American Highway (190) Tuxtla Gutierrez-Tapanatepec, Oaxaca.

The cut caused cracks and unevenness in the latter, and detachment of material that invaded the lane for Arriaga-Ocozocoautla. These fragments were added, others carried by freight trucks, in order to stabilize the PG with the counterweight system. However, when making a schematic for movement, the ideal place for the counterweight to work is located on the other side of the highway (Paz, 2014).

Three years after the activation of the movement, it has not been adequately controlled. The corrective measures implemented are berms, blown concrete to avoid leakage, which presents cracks, and a geomembrane to facilitate the growth of vegetation.

Photo 2. Tuxtla Gutiérrez-San Cristóbal Highway. Paz, 2013



Picture 7 Case 2. Tuxtla Gutiérrez-San Cristobal Highway (190 D) (Photo 2).
Location: km 33 (16 ° 4'41.94 "N, 92 ° 46'25.51" W)
Upper Cretaceous limestones.

Translational slippage facilitated by the arrangement of strata. It was caused by the cut of slope, for the construction of the highway. The diaclases allowed several blocks of different sizes to slide, which invaded both lanes. As the material accumulated, it was removed. Soil cover, and therefore, vegetation cover has been lost, accelerating erosion processes.

Photo 3. Chicoasén-Copainalá Highway . Paz, 2013

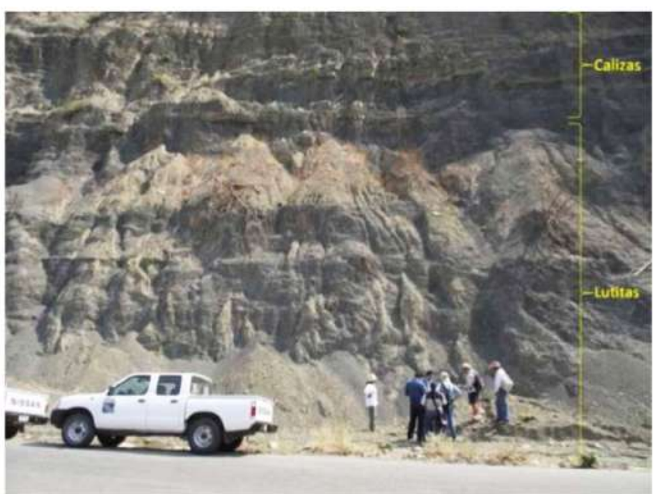


Image 10 Case 3. Chicoasén-Copainalá Highway (102) (Photo 3).
Location: km 7.5 (16 ° 59'56.6 '' N, 93 ° 08'27.48 "W).
Paleocene sandstones that underlie some limestone blocks and conglomerates.

The cutting favors the detachment of intensely weathered material, behaving in the presence of abundant rainfall as a flow of debris. This causes the upper blocks to become destabilized and detached in a second moment due to difference in the lithology.

In the road cut, faults and evidence of old flows are observed. This road is obstructed annually, affecting the transit of people and goods. There is a record of a detached block that struck a vehicle (June, 2011).

Photo 4. Colonia 6th June. Paz, 2013

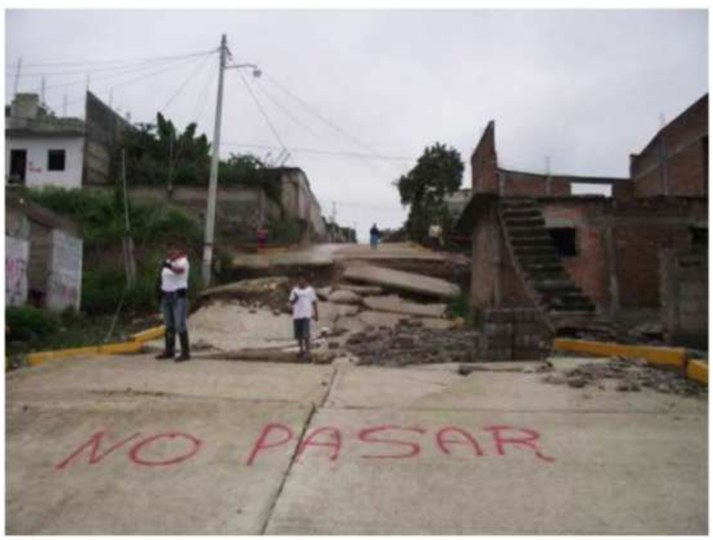
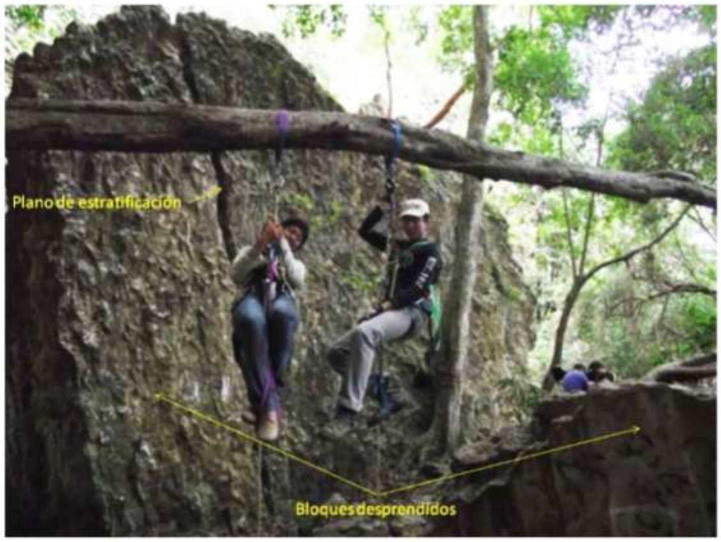


Image 13 Case 4. Colonia 6th June 3rd Section (Photo 4).
Location: south east of the city of Tuxtla Gutierrez (16 ° 43'38.44 "N, 93 ° 4'3.74" W).
Recent deposits (coluvions) on Eocene shale-sandstone.

Rotational sliding occurred on September 9, 2013, caused by different slopes for housing construction, detonated by soil saturation due to heavy rains in addition to leaks in drainage systems and potable water coupled with the burden of housing.

This aspect is addressed Lugo et al, (2005) by mentioning that "the buildings that are located in hazardous areas favor or accelerate the gravitational processes by deforestation, the weight of buildings, drainage, changing the profile of the slopes and the hydrological regime ".

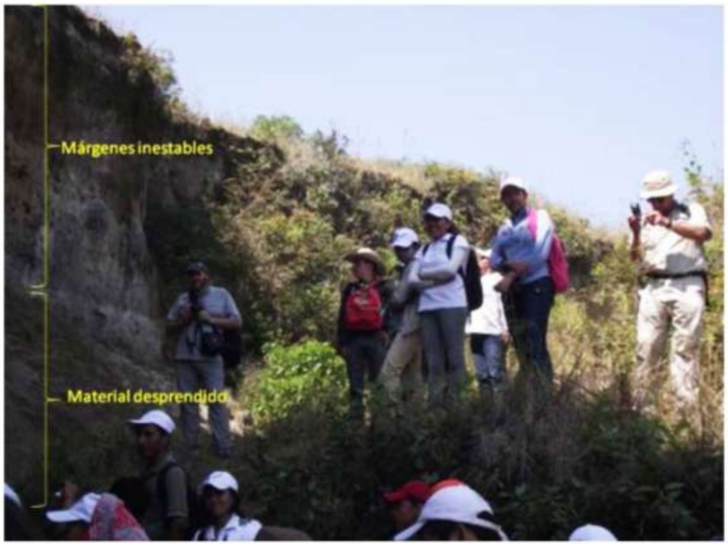
Photo 5. Ladera sur de Tuxtla Gutiérrez. Paz, 2014



Picture 16 Case 5. Ladera sur Tuxtla Gutierrez, base of Cristo de Chiapas (Photo 5). Location: south of the city of Tuxtla Gutierrez (16 ° 43'13.55 "N, 93 ° 7'13.60" W). It is constituted by limestone-shales of the Oligocene. Here are the erosion fences (Paz et al. 2012), generating falls or landslides characterized by large angular blocks.

It is the base of an erosion fence of approximately 70 m in height. For the moment it is an uninhabited zone where the people of the peripheral colonies like Altos del sur and 7 de April go to stock up on water from a spring. At the top and scarcely 10 m from the edge there was built a monument known as Christ of Chiapas, which has a height of 62 m, of which there is not known to by any previous study and so it is exerting a weight on an area very susceptible to PG.

Photo 6. Volcán El Chichón. Paz, 2012

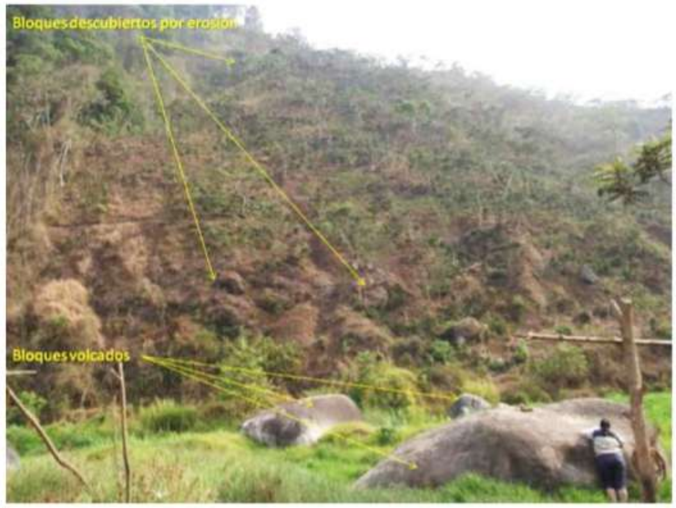


Picture 19 Case 6. El Chichón Volcano, Chapultenango (Photo 6).
Location: eastern slope of El Chichón volcano (17 ° 21'52.20 "N, 93 ° 12'32.60" W)

The lithology corresponds to an intermediate volcanic gap. Floods of soils or debris occur that originate on the slopes of a volcano, generally triggered by intense rains that erode volcanic deposits. Since they correspond to a volcanic structure, they are considered lahares, flows of volcanic materials transported by rainwater. As the arboreal vegetation is scarce, and in the presence of the intense sun that is felt at 9:00 a.m., hikers generally rest in the channels where the shadows of their margins reach up to 8 m in height. There exists the possibility of a slide.

For mapping slopes of this type, where runoffs are first order, Srthaler, 1968, quoted by Lugo et al, (2005), recommends the method of headwaters, monitoring retrogressive erosion.

Foto 7. Cafetal en Cabañas. Paz, 2013



Picture 22 Case 7. Location Cabañas, La Concordia (Photo 7).
Location: foothills of the Sierra Madre de Chiapas, municipality of La Concordia (15 ° 45'27.07''N, 92 ° 59'59.31''W)

The lithology corresponds to the metamorphic complex (Müllerried, 1957), called by INEGI (2015) as Chiapas Massif, consists mainly of granite and granodiorite of the Paleozoic. These are rollovers of large blocks are characterized by a spheroidal weathering, which generates rounded edges that facilitate their movement downhill. They are very dangerous when they come off the high parts as in this case.

The community cultivates coffee on the slopes of the mountains, as well as corn and beans in the lower parts.

Due to their topography, the mountains remain sparsely populated with scarce records of damage to mountain communities. However, many of these locations show rapid growth and constructions are moving towards dangerous areas (Lugo et al, 2005).

Foto 8. La Candelaria. Paz, 2013

Picture 25 Case 8. Location La Candelaria-Nueva Esperanza, La Concordia (photo 8)
Location: 12 km northwest of Jaltenango de la Paz (15 ° 58'08.99 N, 92 ° 47'6.59 "W)

Triassic-Jurassic limonite-sandstones predominate. This is a flow of debris, abundant large limestone blocks and conglomerate, which were dragged from the highlands during the passage of Hurricane Stan in October 2005.

This material is disordered and unstable, so it is susceptible to another removal process. With the next heavy rains, "streams can regain its base level and its own channel, if it has been modified" (Lugo et al, 2005).

CONCLUSIONS

The review of 6 cases in sedimentary and 2 in igneous environments is useful to know the behavior of the PG under different geological conditions, since they are conditioning factors it is convenient to consider them in the design of terrestrial routes, human settlements and areas destined to for agriculture in order to avoid as much as possible the rupture of the balance of the natural slope of the terrain, due to the slopes mainly.

Chiapas is a state with frequent seismicity and exposed to the clash of cyclones, so it should not be ruled out that in some areas, the three detonating factors: rainfall, earthquakes, or slope modification can act simultaneously thus complicating the emergency.

These registered events make clear the need to have an inventory of PG events and highlights the lack of previous studies, construction regulations and efficient technical specifications which would strengthen the work of risk management.

Thanks

Thanks go to the FORIN Project and to the Center for Research in Risk Management and Climate Change (CIGRCC / UNICACH), for the invitation to the International Workshop on Forensic Investigations of Disasters Related to the Occurrence of Slips June-July 2013. The National Institute of Statistics And Geography (INEGI) for the invitation to participate in the work group for the design of the Susceptibility Model to Mass Movements, in 2013. To Dr. Silvia Ramos Hernández, Director of the CIGRCC and the Bachelor of Science Degree in The Earth (UNICACH), for the invitations to the scientific excursions to the volcano El Chichón, March 2007 and 2012. Geographer Elisa M. Sandoval Sierra, from Universidad del Valle (Colombia), for her support in the review and suggestions.

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