UNESCO-RAPCA project

Pyroclastic flow hazard associated to the Santiaguito volcano in the Samala river basin, Guatemala

This case study has been developed within the framework of the ITC - UNESCO project *Regional Action Program for Central America (RAP-CA),* which is a subprogram of the programme **"***Capacity Building for Natural Disaster Reduction Program" (CBNDR),* funded by the Netherlands government through UNESCO. This program, launched in 1999, focuses on capacity building for natural disaster reduction. For more information visit the following link http://www.unesco.org/science/earthsciences/disaster/disasterRAP-CA.htm

Summary

This exercise deals with the generation of pyroclastic flow hazard scenarios on the ground near the Santiaguito volcano, Guatemala. The "energy cone" model is used to determine the areas that would be affected by hypothetic pyroclastic flows. Using existing elements at risk data further analysis on vulnerability and risk related aspects are carried out.

Disclaimer

The material in this exercise is for training purposes only. The results should not be used in actual planning of the areas on the ground near Santiaguito volcano as ITC does not guarantee the accuracy and precision of the input data.

The GIS software that will be used in this exercise is the Integrated Land and Water Information System (ILWIS), version 3.x, developed by the International Institute for Geo-Information Science and Earth Observation (ITC). Information: www.itc.nl.

Introduction

Volcanoes pose a serious threat to persons and infrastructure on the ground near erupting volcanoes due to proximal hazards such as lava and pyroclastic flows, mud flows, ash fall, etc: there is the potential for many (perhaps thousands) of deaths and of extensive or total destruction of buildings, roads, dams, pipelines, or any other structures in the area. The surface drainage pattern may be disrupted and arable land or forest temporarily or permanently destroyed. If the scientific community wants to improve is contribution to volcanic hazards contribution, it is necessary find the way to expand the understanding and the techniques to quantify the proximal effects of volcanic activity (Final Report of the CEOS Disaster Management Support Group, 2000).

The Santa Maria - Santiaguito volcanic complex is located in the Samala river basin, approximately 14º44´ N and 91º34´E, on the southern flank of the main Guatemala's mountain range, rural area of the Quetzaltenango and El Palmar municipalities, Quetzaltenango province in Guatemala. The first historic records of intense volcanic activity go back to the beginning of the 20th century. On October 25th 1902 a devastating plinian eruption, considered among the worldwide strongest ten occurred in the last century, took place in the Santa Maria Volcano: the plume reached 8 km height, 5 to 10 km3 of dacitic material were produced and at least 5000 people killed (Sapper, 1903; Rose, 1972). By the end of 1922 a dacitic dome started to grow in the interior of the 1902 eruption's crater. This dome, active since then, was given the name of Santiaguito. Seven years after its birth the Santiaguito volcano registered one of its most catastrophic events with the generation of a pyroclastic flow of considerable volume (1,5 x 10^7 m^3), which extended for more than 10 km from the source, and could have killed from several hundredths to 5000 people (Mercado y collaborators, 1988). More detailed information on the evolution and dynamic of the Santiaguito volcano can be found in Sapper, 1903; Sapper, 1904; Rose, 1987a y b.

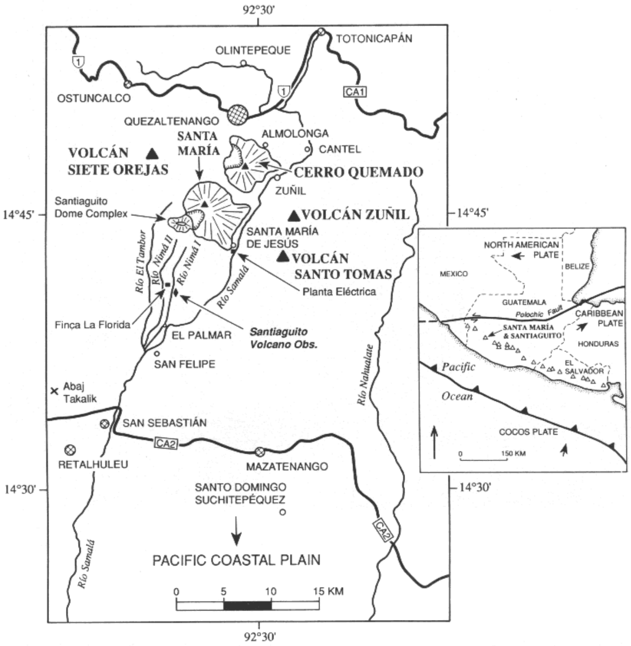
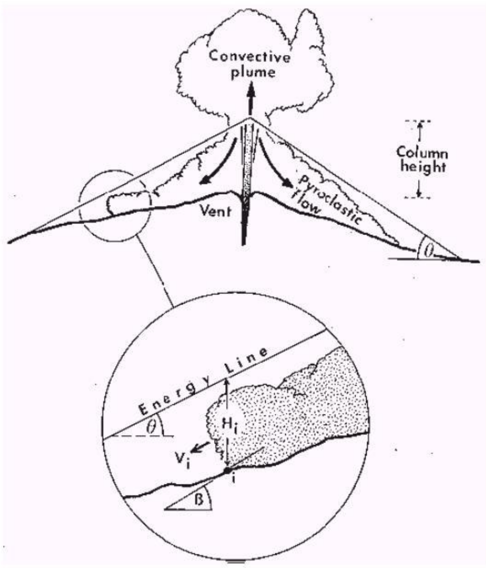


Figure 1. Location of the Santa Maria - Santiaguito volcanic complex in the Samala river basin.

In this exercise the "energy cone" model is used to determine the areas that would be affected by hypothetic pyroclastic flows originated from the Santaguito volcano. The equation used in the model links up different conditioning factors such as the theoretical altitude of the volcanic plume, energy of collapse, topographic characteristics of the terrain and the location of the crater to determine the pyroclastic flow hazard scenario. This is critical information concerning the location of at least 120 small villages in the surroundings of the



volcano that might be affected directly or indirectly in case of an eruption.

Figure 2. Schematic representation of the "energy cone" model. Tomado de Wadge et.al., 1988

A description of the "energy cone" model presented by Hubbard & Sheridan (1996) is as follows

> "Early computer-assisted models of pyroclastic surges (e.g. Malin & Sheridan, 1982; Sheridan & Malin, 1983) utilized a form of the energy line model which was first introduced by Heim (1932) and later described by Hsu (1975) to depict the motions of rockslide- avalanches. Some authors (i.e. Pariseau & Voight, 1979) refer to this paradigm as the sliding block model because it assumes that the only resistance to movement is basal friction. Sheridan, 1979 used this model to illustrate the effect of topography on the kinetics and runout distance of pyroclastic flows.
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> By rotating the energy line 360 about a vertical axis at its source, an energy cone is produced. This figure estimates the potential distribution of pyroclastic flows that move in perfect radial vectors from the source. Its advantage over the energy line is that it shows potential velocity and extent of gravity-driven flows in map view. An energy cone model was used to mimic the extent of surge deposits associated with the 1980 lateral blast surge at Mount St. Helens (Malin & Sheridan, 1982) as well as deposits from ancient & historic eruptions of Vulcano, Lipari, and Vesuvius (Sheridan & Malin, 1983)".

Energy cone model parameters as defined by (Malin et.al, 1982; Sheridan et.al., 1983; Wadges et.al., 1988), are

- Location of the crater, (height value: Hcrater)
- Column height (Hc)
- Energy line (Heim's coefficient, μ)
- Topography (from DTM)
- Distance to crater (Dcrater, from DTM)

Where:

$\mu = \text{Tan}\theta = Hc/L$.
Hc= column height
L= maximum run out distance of the pyroclastic flow
The Heim's coefficient can be derived empirically when enough fieldwork data is available; otherwise data from literature reports could be used. In this exercise several scenarios will be generated using a Heim's coefficient derived from the 1973 eruptions (Hc=500 m; L= 1389 m).

Energy cone (Ec) = Hcrater + Hc – μ Dcrater **Equation 1**
ΔH = Ec – DTM **Equation 2**

ΔH is the elevation difference between the Energy cone and the topography (DTM).

ΔH values larger than cero would correspond to the areas with more possibility of being affected by the selected pyroclastic flow conditions, which are basically given by the column height and the crater's location.

$\Delta H > 0$ = hazard zone.

Figure 3. Aerial view southern flank of the Santa María volcano (in the background) and the Santiaguito volcano (first plane in the center). Photo *Steve O´Meara, Volcano Watch International*

Objectives and practical application

- To generate different pyroclastic flow hazard scenarios for the Santiaguito volcano.
- To define a pyroclastic flow hazard zonation on the ground near the Santiaguito volcano.
- To define criteria allowing a qualitative vulnerability mapping for the defined pyroclastic flow hazard scenarios.
- To prepare a qualitative risk map based on the defined pyroclastic flow hazard scenarios.

Instructions

1.1 Defining the Pyroclastic flow hazard scenario

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- Using equation 1 and the given Heim's coefficient create the energy cone scenarios for seven different column height (Hc) values ranging from 600 to 2500 meters

1.2 Analysing the Pyroclastic flow hazard scenario against geomorphological evidence

How to critically evaluate the reliability of the scenario previously generated, so that it can be handed over to the locally based authorities and communities that are responsible for hazards monitoring and design of mitigation measures? The reader is invited to search extra literature on the subject and to further discuss this topic. Some authors suggest comparing the results of modelled scenarios against the observations registered from geomorphological interpretations, which the model should be able to "reproduce", using the appropriate parameters

As example, use the map provided describing the spatial distribution of past pyroclastic events to draw some conclusions about the defined hazard scenarios.

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- Compare the different pyroclastic flow hazard scenarios against the map describing the spatial extent of previous pyroclastic events; can you draw some conclusions on the reliability of the modelling technique and applied parameters? Explain your answer. Would you deliver this information to the locally based authorities and communities that are responsible for hazards monitoring and design of mitigation measures?
- Compare the towns regarding their average distance and relative height to nearest streams in the area affected by the pyroclastic flow deposits, could you derive any information on threat posed by possible lahars.

1.3 Qualitative risk assessment

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- Prepare a qualitative risk assessment map for the different pyroclastic flow hazard scenarios. Use the existing vulnerability data: populated centres, infrastructure.

References

Bernard E. Hubbard and Michael F. Sheridan; Computer generated flow models of pyroclastic surge: Applications to the 1965 eruptions of Taal Volcano, Philippines, July 1996, in http://www.vhome.alaska.edu/~jdehn/vjourn/poster/hubbard/hubbard4.htm

UNESCO - ITC. Capacity Building for Natural Disaster Reduction (CBNDR) Regional Action Program for Central America (RAPCA). Zonificación de Amenazas Naturales en la cuenca del río Samalá y Análisis de vulnerabilidad y riesgo en la población de San Sebastián Retalhuleu, Guatemala, Centro América. September 2003

Materials

Basic Data /map name	**Format**	**Description**	**Comments**
Geologia	Polygons	Geology Samala River basin.	Scale 1:250000
Geomor-samala	Polygons	Geomorphological units on the ground near the Santiaguito volcano.	Attribute table "GeomorphologicalUnits" also brings information on surficial geology. Use it to locate the crater of the volcano.
Contourlines	Segments	20 meters interval contour lines area of influence pyroclastic flow	Map sheets Colomba y Retalhaleu
Rivers	Segments	Drainage network	Area of influence of the pyroclastic flow
Usot-1999	Polygons	Land use map 1999	Unidentified source
Landsat_1 and Landsat_2	Raster	Landsat images covering the Samala River basin	
Hazard Data/map name	**Format**	**Description**	**Comments**
Pyroclastic_flows	Polygons	Geomorphology and pyroclastic flows Santiaguito volcano	Integrated multi-temporal analysis? Source. Includes the location of the crater.
Piro_29	Polygons	Area covered by the November 1929 pyroclastic flow	Source is not clearly defined.
Piro_s73	Polygons	Area covered by the September 1973 pyroclastic flow	Source is not clearly defined.
Piro_a73	Polygons	Area covered by the April 1973 pyroclastic flow	Source is not clearly defined.
Vulnerability data/map name	**Format**	**Description**	**Comments**
Populated_centers	Polygons	Populated areas Samala basin and some Census data	Attribute table includes data on population distribution by gender, age, education level
Power_lines	Segments	Power lines	Area of influence pyroclastic flows
Roads_pyro	Segments	Main roads	Area of influence of pyroclastic flows Classified on type of pavement
Roads_pyro	Segments	Complete road network	Area of influence of pyroclastic flows. Attribute table with too many empty cells
Poblados_piro	Polygons	Populated areas.	Area of influence of the pyroclastic flow hazard. Attribute table includes data on population distribution by gender, age, education level