GEOPHYSICAL MONITORING OF PACAYA VOLCANO

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ABSTRACT

The purpose of this project has been to develop and implement an infrastructure of experimental geophysical sensors for the monitoring of precursor signals related to eruptive activity of the Pacaya volcano, with the purpose of detecting signals that arise prior to eruptions.

Sensors were implemented to monitor the activity of Radon gas using standard acrylic detectors, which measure the radon activity in a weekly fashion During the February 29, 2000 eruption, a precursor signal was detected with one week of anticipation. A network of geo-electrical sensors was implemented with the purpose of detecting geo-electrical self-potentials As in the case of radon, the goal has been to detect induced electrostatic potentials that arise within the ground days or weeks before an eruption During days before and after the February 29, 2.000 eruption large signals were observed. These signals continued up to March 15 of the same year 2000. Two simple magnetic coils were also placed to detect precursor signals induced as a result of the fluctuation in the Earth's magnetic field However, no anomalies where detected which can be assigned as precursors to the eruption.

Additionally, geo-electrical and geo-magnetic sensors where implemented in San Lucas, Sacatepéquez to monitor spurious signals that can be induced by the solar activity, that can affect the sensors in Pacaya volcano. The solar activity is capable of changing the Earth's magnetic field, inducing signals in the magnetic sensors In this sense the San Lucas station is considered as a reference station with respect to the station installed in El Patrocinio in the Pacaya volcano foothills

This article presents a technical description of the equipment implemented and the hypothesis proposed to support the research project, as well as the results and conclusions with relation of this type of geo-physical monitoring.

INTRODUCTION

Pacaya volcano is an active volcano located in the Amatitlan municipality, 35 kilometers south of Guatemala city. It is a strombolian volcano and it has an altitude of 2,500 meters above sea level Until 1961 the volcano had remained inactive. However, in 1961 it began its most recent cycle of activity that has lasted more than four decades.

Due to the fact that many communities are located on the foothills and are at risk, it is necessary to maintain surveillance of its activity to characterize it and to alert these communities in case of an eruption.

In this research three techniques were deployed to monitor volcanic precursors related to magmatic eruptions: radon activity, self-potential measurements, and measurement of magnetic anomalies in the Earth's magnetic field

Scientists of many countries (1-10) have tried to correlate radon activity and volcanic eruptions as well as seismic activity, reporting in many cases the existence of precursor signals and signals which arise during and after such events. Radon is a radioactive gas that emanates from soils, which contain natural uranium ores and other heavy minerals It has the peculiarity of being a noble gas, with a half-life of almost four days. As a gas it flows through gaps and cracks and can reach the surface. In 1996 the authors carried out a series of radon measurements in the foothills of the Pacaya volcano, as a possible application as a technique to detect precursor signals in the case of eruptions.

Additionally, for more than a decade measurements of electromagnetic fields have been undertaken with the purpose of detecting precursor signals which arise as a result of the variations in the pressure within the rocks that induce variations in the electromagnetic fields in the earth. Scientists of many European countries [11-15], specially from Greece and the old Soviet Union, have developed methods to try to detect these electromagnetic precursor signals. It is believed that these precursor signals can be generated via the piezo-electric effect or any similar effect that appears in some types of rocks. This effect has been verified experimentally with granite blocks in Greece [16].

The project has been implemented with the following goals:

- *The development of an infrastructure of geo-physical sensors to monitor pre-eruptive activities of nuclear type (radon gas), electro-teluric (self-potential) and magneto-teluric (magnetic induction) types.*
- *To deploy such an infrastructure and to monitor volcanic activity via these techniques to try to evaluate the applicability of such techniques for the detection of precursor signals related to eruptions.*

HIPOTHESIS

MONITORING THE RADON ACTIVITY:

For the case of volcanic eruptions, the hypothesis is the following:

As the magma thrusts its way up through the mantle, pressure increases specially in the region of the volcanic cone, generating a series of tremors and micro cracks These cracks will promote the surge of additional radon gas. Thus one would expect larger quantities of radon activity prior to and during an eruption.

This hypothesis has been proposed theoretically by R. García, G. Natale, M. Monnin and J. L Seidel [17] on the basis of a geophysical model that describes how anomalies can be produced in the radon concentration as a result of a perturbation produced by the increase pressure of the rising magma. Though the model predicts anomalies before an eruption, the multiple factors included in the theoretical model make it difficult to prove it in a quantitative fashion. Nevertheless, this experiment is a test in a qualitative fashion.

ELECTRO-TELURIC SIGNALS – SELF-POTENTIALS

During the last two decades, scientist of the physics department at the University of Athens in Greece have been detecting precursor signals which can be related to seismic activity[1] Although a formally accepted theory which describes the nature of such signals does not exists as of this publication, laboratory experiments on rock samples indicate that pressure variations applied to rocks promote electrical self-potentials which can be measured externally Experiments show that the induced self-potentials can be correlated directly with the temporal variation of the pressure which the rocks experience [16].

Similar experiments carried out by the authors in the neighborhood of the Motagua Fault in Guatemala have yielded results which display signals prior to seismic activity. In the case of this project, the following hypothesis is proposed: *As the magma rises to the surface prior to an eruption, the rock formations near the cone experience pressure variations Such pressure variations then promote the creation of electric self-potentials which can be detected in the foothills of the volcano near the cone.*

MAGNETIC SIGNALS:

With the purpose of broadening the scope of techniques employed to detect precursor signals, simple coils were constructed and installed near the cone, with the purpose of monitoring variations in the magnetic field of the earth before, during, and after an eruption. In this case, the hypothesis proposed is based on the flow of ferromagnetic materials which are transported by the magma which is rising prior to the eruption However, it is important to note that the Greek scientists who propose the VAN technique have concluded on a theoretical basis that no such magnetic signals should arise as precursors in this type of activity

METHODOLOGY

RADON:

In the case of radon, LR115 type acrylic films were employed. The acrylic films are placed on top of a PVC structure which contains material similar to silica glass to absorb moisture. The structure is sealed and then introduced in a 1-meter long PVC tube buried in the ground. The film is replaced on a weekly basis and it is then sent to the Nuclear Physics Laboratory of the University of Costa Rica for post-processing.

TECHNIQUE FOR MEASURING INDUCED ELECTRICAL SELF-POTENTIALS

In this case, lead-based electrodes are buried in the ground and potential differences between pairs of electrodes are measured on a continuous basis. Lead plates measuring 5 centimeters wide and 20

[1] The technique developed by these scientist is known as VAN, named after the main scientists proposing it: Varotsos, Alexopoulus y Nomicos.

centimeters long are embedded in a wet clay matrix which contains dissolved NaCl to promote conductivity. Voltages arising within pairs of electrodes are processed in an analog interface. Signals are initially filtered (low-pass Butterworth-type filters, below 1 Hz) and then amplified The degree of amplification is selectable via switches and amplification factors of 5, 10, and 20 are accessible. Later on, the signals are fed into an analog/ digital converter interface card and later stored within the hard disk of a PC. For this project, Advantech interface cards model PCL-711S have been employed to perform the analog to digital conversion. These cards allow for eight channel processing and operate on a 12 bit structure.

MAGNETIC SIGNALS

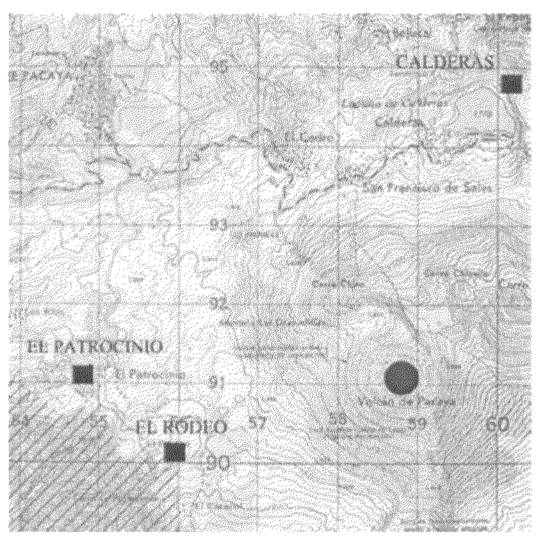
In the case of magnetic signals, simple, 50,000-turn coils have been constructed on standard soft iron rods. The diameter of the rods in 0.50 inches and these measure two feet long. 28 gauge copper wired is employed to make the coils. Generally, three coils have been buried in the ground to a depth of one meter. One coil is oriented in the N-S direction, the other in the E-W direction and finally the third coil is set up vertically. Due to the nature of the coils, these will detect signals only when the Earth's magnetic field is varying. As in the case of the electrical signals, the magnetic signals are filtered, amplified, and later stored in the computer after the analog/digital conversion

SITE SELECTION

Once the systems were constructed and assembled, they were installed on the foothills of Pacaya volcano. Installation began in January 2,000 and was completed in June of the same year. Map 1 display the sites used for this project.

Site selection took into account the tendency of Pacaya volcano to translate its active cone towards the South-Southwest. Stations in El Patrocinio and El Rodeo were selected on the basis of the soil being porous, so that radon emanations could easily be detected.

A reference station was installed in San Lucas Sacatepequez, northwest of Guatemala city and away from the volcano (not shown in map).



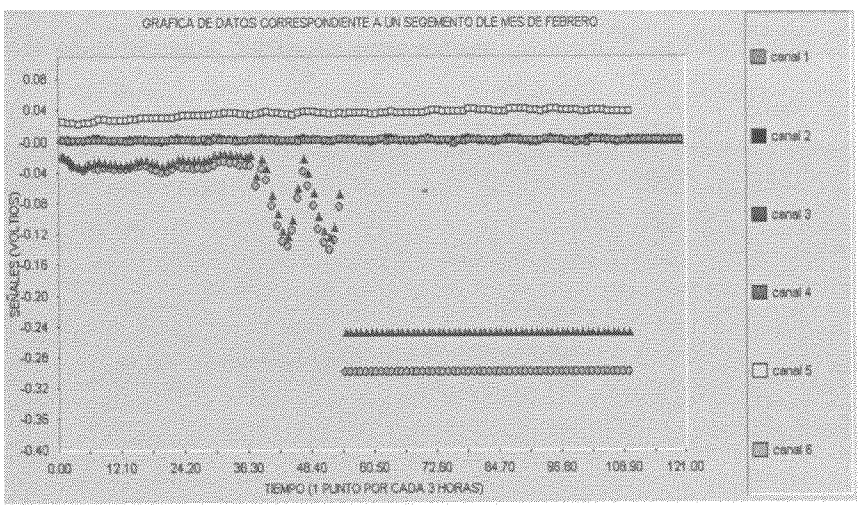
Map # 1: Region of Pacaya volcano foothills. Source: Amatitlán Cartographic Sheet, 1 50,000 scale. Source: National Geographic Institute of Guatemala, IGN.

RESULTS

Since the project began in January 2,000, the acquisition of electromagnetic data has been carried out on a permanent basis in the El Patrocinio and San Lucas stations. During the February 29, 2000 eruption, electric and radon signals were detected, which preceded the eruption by 10 days, and lasted for at least 5 days after the eruption

The next graphs display the electric and magnetic data gathered at the El Patrocinio station corresponding to February and March. Channels 1 and 2 represent magnetic signals (East-West and Vertical components respectively), channels 3, 5 and 6 represent electrical signals and channel 4 displays and acoustic signal gathered via a standard microphone also buried in the ground. Although data is gathered at a rate of 1 sample per 30 seconds, these graphs display data in samples separated by a period of three hours.

Graph # 1 displays the data collected between February 11 and February 25. One can see a prominent signal in channels 3 and 6, which begins on February 16, practically two weeks prior to the eruption. Unfortunately, the signals saturated the electronic amplifiers and after February 18, only straight lines are displayed Additionally, the data-acquisition process was interrupted abruptly on February 25 due to a power surge Monitoring was continued after March 3.



Graph # 1: signals detected between February 11 and February 25, 2,000. The eruption took place on the evening of February 29. Before this eruption, channels 3 and 6 displayed a large variation, which began on February 16. Unfortunately, the signals saturated the electronics until the end of the month.

The presence of this signal in channels 3 and 6 simultaneously can be explained by the fact that these channels monitor self-potentials arising in a common electrode buried in an old lava-river formation with respect to electrodes which are buried in gravel-type soil (pyro-clastic formations). In contrast to these signals, channel 5 does not display any type of signal, as in this case the two electrodes are buried in gravel-type soil.

With respect to magnetic and acoustic signals, the data show no features during the entire record. At this point, it is proposed that if there are signals of these types, these are of such a low magnitude that these cannot be detected with the equipment in use at this time.