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STRONG AND WEAK PRECURSORS OF VOLCANIC ACTIVITY

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ABSTRACT: Short-term precursors of volcanic activity ideally must be characterized, on statistical basis, by a small percentage of unpredicted events and of false alarms (strong precursor). Seismic activity and ground deformations may be considered as typical strong precursors of volcanic eruptions. Radon anomalies, resistivity, and temperature variations may be considered as weak precursors. The Grandori-Cuagenti theory of double precursor systems is presented and applied to Kilawea and Mt. St. Helens. The combination of a strong precursor (such as ground deformation) and a weak precursor (such as Radon anomalies) leads to an increase of prediction capability of the precursors system.

THE UNDERGROUND LABORATORY FOR GEODYNAMICS

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Summary: The laboratory is adapted for earth tides and

seismic measurements. It is equipped with gravimeters, clinometers, water-tubes, seismometers, strainmeters, thermometers, barometers...

Prototypes were tested in relation with different foreign laboratories. An important know how is at disposal for new developments.

CANARIAN VOLCANISM

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Introduction: From all the european countries (Italy, Iceland, France, Portugal and Spain) where volcanic eruptions have occurred in the present century, Spain is the only country that lacks an state agency or scientific organization that officially takes charge of surveying and monitoring the volcanic activity (see for instance Machado, 1g89). As a matter of fact, up until now, the volcanic monitoring in the Canary Islands is due to the initiative of different research groups. In any case, I hope that all these initiatives will be shortly integrated in a Volcanological Research Program not only for the Canarian Archipelago but also for all the active areas of the european countries.

MONITORING SYSTEMS ON ICELANDIC VOLCANOS

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Abstract: The Nordic Volcanological Institute (NVI) has worked extensively on the utilization of new sensors for volcano monitoring as well as systems for data acquisition and manipulation to facilitate interpretation of complex and rapidly incoming data during a volcanic crisis situation.

The rifting and volcanic activity at Krafla in Northern Iceland which started in 1975 was the motivation for the development of continuously recording tiltmeters at the Nordic Volcanological Institute. The tilt sensor is a stationary magnetoresistor located in the magnetic field of a permanent magnet which is mounted on a pendulum. The instrument has

proven to give very satisfactory results. It has a sensitivity in the order of nanoradians, recording earth tides as well as large crustal movements spanning a dynamic range of at least 500 microradians. The instrument is borehole mounted and is equipped with mechanism for computer controlled zeroing and calibration which can be performed downhole.

Other sensors which are either in use or being tested include a sensor for water level, water chemistry (pH, conductivity) and gas composition.

The data acquisition system built by the NVI consists of a field unit with a dedicated computer programmed to record signals from the respective sensors and send the information by radio or telephone to a UNIX operated computer located in the area. A host computer at the NVI main office in Reykjavik then receives the information at preselected intervals from all regional computers around the country. The evaluation of the data is fully automatic and the computer can react intelligently to a prescribed situation.

MONITORING ACTIVE VOLCANOES IN ALASKA

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Alaskan volcanoes are remote and most are only accessible by light-plane or helicopter. Of the about 40 historically active volcanoes less than half a dozen are instrumented. In Cook Inlet, where 75% of the population of Alaska lives (about 300,000 people), the Alaska Volcano Observatory (AVO) operates radio telemetered networks of short-period seismographs on 3 volcanoes: Mt. St. Augustine, Redoubt Volcano and Mt. Spurr. At present Redoubt is undergoing an eruptive cycle and we have successfully forecast 6 of 20 vulcanian eruptions. We have also forecast and monitored major eruptions of Mt. St. Augustine in 1976 and 1986.

A most useful new monitoring technique that proved to be of great value during the present eruptive cycle of Mt. Redoubt is real time observation of eruptive phenomena by radio-telemetered slow-scan television systems. Video coverage of eruption show the dynamic processes of plume rise and plume dispersal. A near crash of a KLM Boeing 747 jetliner on December 15, 1989, which encountered an ash plume from Redoubt and temporarily lost all of its 4 engines

has produced requests from the airline industry to provide plume trajectories for each eruption in near real time. Satellite monitoring of eruptive plumes using AVHRR data from the NOAA 10 and 11 weather satellites has proven to be very useful for our daily plume trajectory analyses which we now routinely pass on to national and international carriers. Lightning is common in ash-rich plumes. A PC-based lightning detection system allows us to track ash-rich plumes by mapping the lightning strikes.

So far we had not much luck with radio-telemetered tiltmeters on Alaskan volcanoes but we have established a geodetic grid on Mt. St. Augustine in anticipation of its next eruption expected to occur within about a decade. We have also experimented with microgravity, telluric and magnetic geophysical monitoring techniques. Gas monitoring of SO₂ and HCL is also routinely done.

In this paper I will discuss our continuous geophysical monitoring efforts for eruptions of Mt. St. Augustine in 1976 and 1986 and Mt. Redoubt in 1989 and 1990 I will also discuss how this work was applied to practical interaction with the public.

MAGNITUDE OF DEFORMATION OF ACTIVE VOLCANOES IN ICELAND

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ABSTRACT: Measurements of ground deformation in Iceland during about 25 *years* have demonstrated that the active volcanoes exhibit great variability in the pattern and magnitude of surface deformation. Certain volcanoes are constantly deforming at a relative steady rate. Other are apparently constantly deforming, but at greatly variable rate of deformation. Still other volcanoes appear to be deforming only in sudden jerks, either during volcanic eruptions or during earthquakes or earthquake swarms. The rate of deformation, expressed as tilting of the ground, of constantly deforming volcanoes has been observed as low as 0.2 microradians per year, and as high as 100 microradians per year. Displacement of the ground, either vertical or horizontal, has been observed as great as several meters, but vertical fault displacements as small as one millimeter have been observed. The greatest observed ground displacements

are associated with non-elastic processes as fault displacements or opening of fissures, but purely elastic processes are known to have caused vertical ground movement exceeding 2 meter.

Long baseline tilt measurements with differential fluid pressure tiltmeters

Dieter Emter¹, Edi Meier² and Rolf Schick³ Abstract

A new type of long baseline fluid tiltmeter has been operated in the Black Forest Observatory Schiltach (BFO) for several years. Instead of fluid levels at both ends the pressure difference at the center of the instrument is used as a measure for tilt. This type of instrument is easy to install and to maintain and has proven to be superior to short baseline tiltmeters in the case of quantitative measurement of tidal tilt. Attempts have been undertaken to construct a similar, less sophisticated and less sensitive instrument for field measurements in volcanic areas. Those instruments are equipped with commercially available differential pressure transducers. One of these instruments reached tidal sensitivity at a baselength of 20 m and showed a remarkable long term stability.

Design and construction of instruments adapted to volcanic zones.

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Introduction: Earth tides studies have permitted us to master different kinds of instruments and measurements techniques of very high precision in order to put forward the earth crust's deformations. A certain number of instruments described here lower may be useful for volcanologic surveys. We will study with more attention the clinometers for they permit the measure of the tilt of the local axes in comparison with the vertical, and the strainmeters showing the ground deformations in a specified direction.

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ABSTRACT: Since 1987 and as a part of the research project that is carrying out the Instituto de Astronomia y Geodesia of Madrid in Canary Islands, a geodynamic permanent station is working in Lanzarote Island, the most northerly and easterly of the main islands of Canarian Archipelago.

The station has two fundamental objectives: (a) to test different instruments developed in the context of the tide research and to apply them to other areas of earth research; and (b) to investigate the possible correlations of earth responses to tidal forces and other phenomena, such as crust structure and thickness, volcanism, geothermic anomalies and heat flow, seismicity, mass displacements inside the crust, ocean and atmospheric tides, meteorological influences, deformations, etc...

In this paper, we present the instrumentation working in the three modules of the Lanzarote Geodynamics Station actually, and the main results obtained so far.

GPS AND TILT SURVEYS IN THE ALBANI HILLS AREA (Rome, Central Italy)

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ABSTRACT : The Albani Hills volcanic complex (Rome, central Italy) stretches over an area of more than 60 Km in diameter South East of Rome. It was originated during Upper Pliocene by extensional tectonics that built up large tectonic structures along the Apenninic chain and the Tyrrhenian coast.

This area is often interested by seismic activity of low magnitude, shallow depth hypocentres and characterized by seismic swarms.

The first GPS campaign of the Albani Hills GPS network and the data processing are described in the paper. Furthermore preliminary results about two underground bubble tiltmeter stations located in the same area are shown.

Mesure en continu des déformations dans le Rift d'Asal, Djibouti.

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Mouvements du sol holocènes dans le rift d'Asal à Djibouti

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Résumé Les dépôts lacustres du Lac holocène d'Asal, en République de Djibouti, sont affectés de déformations importantes marquant l'activité sismotectonique du rift d'Asal. Les traces de rivage correspondant au niveau d'expansion maximale du lac il y a 6000 ans environ, ont été identifiées et leurs altitudes actuelles mesurées précisément par rattachement au réseau géodésique implanté dans cette région pour l'étude des déformations actuelles. Ces mesures mettent en évidence un approfondissement général de l'axe du rift atteignant 70 m, soit une vitesse moyenne supérieure à 1 cm/an. Les discontinuités dans les niveaux actuels indiquent quelles ont été les principales failles actives du rift depuis 6000 ans. Ces résultats sont discutés par rapport à ceux des mesures géodésiques réalisées depuis 1973.

Holocene crustal movements in the Asal Rift, Djibouti

Abstract - The Holocene lacustrine deposits of Lake Asal, in the Republic of Djibouti, recorded important deformation which is associated with the seismo-tectonic activity of the

Asal Rift. The shoreline associated with the level of maximum extent of the Holocene Asal lake (about 6,000 years B.P.), has been identified and its present altitude accurately measured relative to a precise geodetic network. The results indicate that the rift zone underwent vertical movements reaching 70 m, showing principally a subsidence of the inner floor of the rift. These results are compared with vertical displacements deduced from the geodetic monitoring carried out since 1973. The tectonic activity of normal faults is discussed in relation to the rift evolution.

Tiltmeter network observations at Piton de la Fournaise Volcano (Reunion Island), 1985-1990.

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Abstract: Since 1985 a telemetered network of five tiltmeter stations has been established around the central eruptive cone of Piton de la Fournaise. Silica tiltmeters of high sensitivity, set up on the surface, are recorded continuously at high rate. The associated electronics allow 12 bits resolution, and a 0,5 μ Rd sensitivity. Measurement of the temperature of the air and of the ground permits an approximate correction for diurnal thermic effects. During eruptive phases, the observed deformations are of high amplitude (more than 200 μ Rd), and temperature corrections are then negligible.

Analysis of the results provided important informations during eight intrusive crises. The rapid displacement (30 to 180 minutes) of the lavas during those intrusions was very well observed in real time by the Volcanological Observatory, giving precious indications of the possible outlet of the lavas. During the intrusive crises, the correlation with seismic hypocenters was excellent. The quasi-elastic response of the ground is noteworthy. At higher distance (more than 5 kms), the deformations are very low (less than 0,1 μ rad), but the analysis of results given by very sensitive tiltmeters, in a deep tunnel, gives valuable information on the long-term effects of the global variations in the magma chamber at depth. These effects are in fact masked in the other portions of the network by the diurnal effects on the surface and a lower sensitivity of the tiltmeters.

In 1988, a telemetered geodimeter was added to the network. The dynamic effects of the intrusions (around 50 cm), as well

as long-term variations (around 4 cms in 1 GO days), are very well observed across a 700 meter section of the central Dolomieu crater. A satisfactory modelling of those intrusions is possible using these measurements.

A recording platform for acoustic signal installed on the Kelut volcano.

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An experimental station has been set up in July 1988 on the crater lake of mount Kelut in order to monitor the volcanic activity through the recording of acoustic noise. The platform consisted mainly of two hydrophones and their associated home made electronics which calculate a smoothing average of acoustic energy in three ranges (1-50HZ), (200-5000Hz) and (over 20kHz).

The Kelut volcano erupted on February 10th, 1990. We discuss the variations of acoustic signal in low, audio and ultra sonic frequencies during the three months crisis preceding the eruption.

A METHOD FOR REMOTE MONITORING OF ACTIVE VOLCANOES

M. LARDY

The PIRPSEV (1) had undertaken to all the various initiatives, skills and facilities, and to promote suitable tools and a network for the light and low cost remote observation of active volcanoes, using the ARGOS system.

After implementation of the experiments of ETNA (1982) (2), a similar system was set up by ORSTOM (3) on MATTHEWS since 1986 (4) and HUNTER since 1988 (4) volcanoes, at the southern end of the New Hebrides island arc (South West Pacific).

Fumarole temperatures, heat flow, meteorological data, and seismic event counting at different thresholds are measured every four hours and transmitted eight times a day by ab ARGOS PTT.

The automatic recovery, processing and archiving of the informations is done by the CTIV (5). This data bank is easily accessible to the entire scientific community with the short delay through all the existing electronic network facilities (EARN, TRANSPAC, MINITEL, ...).

Seismicity and ground deformation studies at Soufrière volcano, St. Vincent Lesser Antilles

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Paper presented at the meeting of the European tester for geodynamics and seismology 'Geodynamical Instrumentation Applied to volcanic areas Luxemburg October 1990

ON THE USE OF GEOPHONES WITH EXTENDED RESPONSE IN MICROSEISMIC NETWORKS

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ABSTRACT: The use of high frequency geophones in seismic networks has become possible by means of the electronic extension of its frequency response. The use of operational amplifiers with very low noise level permits the obtention of performances similar to those of the 1 Hz geophones widely used in microseismic networks. We present the design of the electronic circuit of a seismic station with a 4.5 Hz geophone extended to 1 Hz. This

station may operate directly either on the recording device or on analog telemetry (FM). The evaluation of the prototype has been carried out at the seismic station of Cadi Geodynamic Station (La Cerdanya, Eastern Pyrenees), in which a geophone of 4.5 Hz with its response extended to 1 Hz has been in operation simultaneously with a 1 Hz short period three components seismic station for a period of six months. The obtained digital records from both systems have been analyzed and compared, showing a very similar response. The electronic design is presented, including the input preamplifier, the extend amplifier, variable gain amplifier and the voltage controlled oscillator used for the analog telemetry in modulated frequency.

VARIATIONS LENTES DU CHAMP MAGNETIQUE TERRESTRE SUR LE PITON DE LA FOURNAISE RELATIONS AVEC L'ACTIVITE VOLCANIQUE

SLOW MAGNETIC VARIATIONS ON PITON DE LA FOURNAISE VOLCANO CORRELATIONS WITH VOLCANIC ACTIVITY

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SUMMARY: On Piton de la Fournaise volcano (Mascareignes Archipelago, latitude 21.2°S, longitude 55.6°E), up to seven autonomous, telemetered, stations are measuring the magnetic field intensity with an accuracy of .25 nT (figure 1). The sampling interval is one minute. In the last five years twenty eruptions have occurred, some of them inside the summital crater Dolomieu, and the others on the north or south flanks of the cone. Volcanomagnetic signals of a dozen nanoteslas in amplitude have been associated with some of these eruptions. The spatial distribution of the signals moves with the volcanic activity. The time constants of these signals associated with individual eruptions are spread between one minute (our sampling rate) and several weeks.

Moreover very slow, irreversible, volcanomagnetic signals - several years, up to 45 nT - are observed (figure 2). They are tightly related with the features and the localizations of families of eruptions (eruptions on the summit, on the north or south flanks). When the eruptions occurred on the summit, slow volcanomagnetic signals are mainly observed on the

cone while signals migrate on the flanks when the eruptions are focused on the volcano flanks. The rate of variations of these signals are correlated with the extent of the eruptions.

On these slow volcanomagnetic signals are superimposed annual variations which amplitude can reach twenty nanoteslas (figures 2 and 4). The features and the amplitude of these annual waves are studied from the variations of the magnetic field intensity itself (figures 3, 4 and 5). These annual waves are essentially located on the main fractures zones which cut the whole volcano from the south-east to the north-east (figure 1). The geometry of these annual waves is anisotropic. Along this fractures axis the decrease is on the order of 25% at a distance of 2.5 km while the decrease is 80% in the orthogonal direction. This annual wave which takes its origin in the existing of major fractures zones seems to associated with electrokinetics effects.

MAGNETOTELLURIC METHOD FOR VOLCANO SURVEILLANCE. DESIGN OF AN MT SPECIFIC INSTRUMENT

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Introduction: The application of the magnetotelluric method (MT) in active volcanic regions dates from several years back. The method has been generally applied to determine the deep structure of the volcanic edifice (DUPIS & DECRIAUD, 1984; BALLESTRACCI & NISHIDA, 1987). In the theoretical sense, the possibility to determine magmatic chambers by MT has been discussed and patterns of it have been laid out (NEWMAN et al., 1985). The volcanological research group of the C.S.I.C. has been working on MT since 1980, focusing their investigations over different active volcanoes: Teide and Timanfaya in the Canary Islands (ORTIZ et al., 1986), in Phlegrean Fields, Italy (ORTIZ et al., 1984). There are, as well, several experiences made to carry out the method for volcano surveillance in Vulcano (1984) and in the Etna (1985-1986) within the volcanological research programs between C.S.I.C. (Spain) and C.N.R. (Italy). The results obtained from these surveys have allowed the development of a light instrument, able to work rapidly to determine the volcanic structure (Fig. 1) while the Etna experiences (Fig. 2)

obtained before and after the 1985 eruption show the possibility of using the MT in the volcanoes surveillance.

Self potential monitoring in two sites of Central Italy

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Abstract: In order to investigate the correlation between self potential variations and local seismicity, self potential measurements were performed.

We used four copper stakes as a North-South/East-West direction at 10 m distance from each other, and connected to a two-channel PC-based digital acquisition system.

Data were stored in MS-DOS compatible format. All instrumental devices were designed and assembled in Italy by the National Institute of Geophysics (*IATG*).

The acquisition software allows real-time data processing.

GEOMAGNETIC ANOMALY FIELD OF CANARY ISLANDS DERIVED FROM MAGSAT SATELLITE

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Abstract: The anomalies of the geomagnetic field over a region centred on the Canary Islands have been analysed. Data from the MAGSAT satellite have been selected and processed in order to produce an adequate set of magnetic anomaly data. After producing anomaly maps by simply contouring grid averages, an analytical model of the vector anomaly field over such area has been obtained. The technique used is known as Spherical Cap Harmonic Analysis (SCHA). The region to be studied has to be defined by a spherical cap and the analysis enables radial extrapolations and satisfies the zero curl and divergence conditions.

Global and regional analysis of the scalar and vector anomaly field have been already developed with different purposes. The aim of this study is to define the contribution

of the Canarian active volcanic area to the crustal field. With this objective individual passes were analysed trying to find any magnetic signature related with the known volcanic features characterised by other geophysical methods.

MODELLING EARTH CURRENT PRECURSOR OF VOLCANIC ERUPTIONS DOMENICO : PATELLA

Abstract: During the etnean volcanic activity of october 1989 an E-W self-potential (SP) profile was measured perpendicular to the NNW-SSE fracture system, which opened in the south-eastern sector of the volcano. In this note we interpret the SP anomaly observed across the fractures, by admitting the development of a cracking-fluid diffusion mechanism provoked by a magmatic intrusion rising towards the free surface. The electrokinetic phenomena coexisting with the fluid invasion into the opened fractures, are assumed to generate a large enough electric charge separation capable of explaining the observed earth current field. The SP anomaly is then modelled by a forward approach in a 2D volcanological environment including in its interior a suitable number of bipolar electrical sources.

SOIL TEMPERATURES AND FLUXES : IMPLICATIONS FOR A VOLCANO STRUCTURE. EXAMPLES OF MATTHEWS AND HUNTER (S.W. PACIFIC)

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Abstract: Temperature is one of the easiest parameter to be acquired on a remote volcano and transmitted via the CTIV (Centre de téléobservation informatisée des volcans). When recorded along vertical profiles, soil temperatures allow the calculation of the heat flux, of it's transient variations and also of it's steady value over an annual cycle. These data can be a valuable indicator for the presence of heat sources inside the volcano. Since september 1986, one such profile has been recorded on Matthews, and since september 1988 on Hunter. On both volcanoes neither unsteady nor steady abnormal flux of heat has been observed. This result, which differs from

what had been obtained on Mount Etna, can be used in order to define upper limits for the depth or magnitude of possible sources of heat. This type of flux measurements would be very interesting if undertaken on a series of locations on the same edifice, in order to obtain a map of flux differences which could be used for a better description of the internal structure of volcanoes.

TEMPERATURE MEASUREMENTS

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Summary:

We describe electronics adapted to solid state thermistors placed in probes for boreholes.
Applications are detailed:

1° temperature profiles in the Walferdange laboratory gallery.

2° temperature profiles in a borehole at the Royal Observatory of Belgium.

3° micro Kelvin thermometers installed in the Walferdange laboratory.

HIGH PRECISION THERMAL MEASUREMENTS IN THE VOLCANIC TUBE OF 'LA CORONA' (LANZAROTE)

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Abstract Since 1988, under the existing collaboration between the Instituto de Astronomia y Geodesia, the

Observatoire Royal de Belgique and the European center for Geodynamics and Seismology, thermal measurements have been made in the geodynamic station cueva de los Verdes (Lanzarote, canary Islands), that have been used to check the quality of the sensors used as well as the thermal stability of the laboratory.

Several experiments have been performed: measurements of vertical and horizontal thermal profiles, continuous records of rock temperature, in different points, and ambiental temperature in the tunnel, where the laboratory is located.

The measures of the temperature profiles have been made in three observation campaigns whose results we are offering here in. We have achieved precisions in the range of 10^{-2} °c. We have found a vertical gradient $0.03^{\circ}\text{c}/\text{m}$ in the vertical thermal profile.

The long and short period variations of rock and ambiental temperature have been studied. The results of the harmonic analysis of those temperatures are presented here.

Measurements needed for a better comprehension of the petrogenetic evolution in island arc volcanoes, to get the eruption probability of the volcano and some characteristics of the volcano system del Marmol M.A.

Abstract: Measuring temperature at the extrusion point of a volcano surmounts the difficulty to observe coexisting minerals in equilibria that are needed to calculate a confident pre-eruptiom temperature. With a reliable maximal temperature, the oxygen fugacity and water content would be more easily determined by petrological observations and thermodynamical calculations and by comparison with experimental work. Pressure, oxygen fugacity, molar fraction of water and temperature are precisely the parameters that will help to define the conditions under which the minerals crystallized, their sequence and the petrogenetic evolution by which the rocks developed.

Temperature, water content, crystallinity, vesicularity, silica content are some of the factors linked to viscosity which itself is directly connected to the likelihood of a lava reaching the surface, the eruption probability (Marsh, 1981), at a certain temperature and/or degree of crystallinity.

From the average velocity ($V_p=(D P/L) a^2/4 \mu$) measured

across the eruptive vent, a estimation for the pressure gradient can be obtained.

Estimation of the volume of a magma chamber ($V=t Q$) in a system that is continuously fed and emptied can be made using the crystal size distribution (CSD) theory expanded to a geological context by Marsh (1981), The CSD ($\ln n$ vs L) plot is based on a population balance resulting in a differential equation relating the population density (n) of crystals to crystal size L : at steady state $n=n^0 \exp(-L/Gt)$, where n^0 is nucleation density, g is the average crystal growth rate, t is the average residence time, and the nucleation rate is $J=n^0 G$.

The flux rate Q (in cm^3/sec) is a measure needed to obtain the estimated volume of the system.

CONTINUOUS MEASUREMENTS of RADON in SOIL GAS of VOLCANIC AREAS

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The radioactive gas radon-222 is a versatile tracer of the circulation of fluids in the ground. When measured continuously in soil gas, radon concentration may correlate with tectonic or volcanic activity. Nevertheless, the endeavor to use radon measurements in soil gas as a tool for predicting seismic or volcanic activity has been hindered by the currently inadequate available technology. Indeed, the widespread Track-Etch method needs at least a one-week integration time, a span that conceals the most relevant short-lived radon signals.

A significant breakthrough in radon measurement techniques was made by the French Commissariat ~ l'Energie Atomique, from which electronic radon sensors (BARASOL), designed for geophysical studies - and not specifically for uranium or geothermal prospection

- are now commercially available. With two such instruments; we have been carrying out experiments for one year on several Indonesian volcanoes. The enclosed figures show a sample of the automatically recorded radon concentrations in a volcanic soil far from active centers (Mt.

Merapi), and close to a crater with fumarolic activity (Mt. Tangkuban Perahu), with a one-hour integration time. Concentration peaks, up to twice the background level, are observed only in the latter case, whereas in the former case, a steady increase of the radon background fairly correlates with a lull in the rainy season.

Till now, however, no clear correlation has been proven between the radon spikes recorded, e.g., at Mt. Tangkuban Perahu, and the geophysical. (mainly seismic) activity as recorded on the volcano. Nevertheless it is clearly established that the spikes, vanishing when the distance from the active centers increases, are related to volcanic activity : they could be used conceivably as a tool for predicting volcanic eruptions.

Description d'un réseau de transmission numérique par balise radio pour la collecte de données volcanologiques.

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Un réseau de balises de transmission hertzienne sur batteries (faible consommation) a été mis au point par le laboratoire afin de rapatrier un message numérique de proche en proche depuis une station d'acquisition jusqu'à un PC où les données peuvent être traitées.

The Calculation of 'Volcanic Activity Parameters

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Introduction: The origin of seismic signals on an active volcano is of manifold nature: Shear and tensile fractures, collapse of cavities, gas explosions and pressure fluctuations of the non-stationary fluid flow of magma and/or gas. The resulting seismic ground vibrations consequently cover a wide range of amplitudes and a broad frequency band. At least at times of higher volcanic activity, seismic signals generated by the activity of a volcano are nearly continuously observed, a fact which prohibits data reduction by event triggering methods. A seismic station with three components, an amplitude resolution of 16 bits and a frequency bandwidth of 100 Hz requires a data storage capable of handling up to

100 MBytes/day. High data rates not only cause technical difficulties, they also hamper obtaining a quick overview on the information content of the incoming signals and of recording gap free data.

UNE METHODOLOGIE POUR LA TELEOBSERVATION DES VOLCANS ACTIFS

M.LARDY*, J. TABBAGH**, C. PAMBRUN***.

- Nous nous sommes fixé deux objectifs pour comprendre et mieux appréhender les éruptions volcaniques.

1° Etude sur le long terme

A partir de l'étude du comportement passé d'un édifice volcanique pendant une longue période par des études géologiques comportant

- un travail détaillé de terrain

- des études en laboratoire à partir d'échantillons (pétrologiques, volcano-sédimentologiques, datations chronologiques . . . par ex.

Une telle approche caractérise l'évolution des produits émis, la fréquence et le dynamisme des éruptions.

D'où l'élaboration d'un modèle d'évolution future et de scénarios susceptibles de se produire.

2° Etude sur le court terme

Elle passe par exemple par une surveillance instrumentale qui peut se faire à partir des modifications de certains paramètres géophysiques ou géochimiques perceptibles en surface.

PORTABLE DIGITAL SEISMIC ARRAY FOR VOLCANO MONITORING

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INTRODUCTION: The seismic activity in an active volcano is one of the most spread technics of volcano surveillance (ARANA & ORTIZ, 1984). However, they are many volcanoes which still lack a seismograph and most of the instruments simply have analogic registers. The present development of personal computers allows to fulfill at a very low cost acquisition systems of digital data (BARBERI et al., 1990). This is a technique very easy to implement on standard equipments and with commercial ADC boards for the standard BUS-PC. These equipments require a stable power supply and they must be protected against vibrations, dust and humidity. The use of portable processor has the difficulty of using a non standard BUS. The power requirements of the ADC boards are excessive for portable PCs. However, many portable PCs dispose of bidirectional Centronics parallel ports. This port can be used as an entry for data proceeding from an ADC module designed for that purpose. In this way it is possible to build a low cost portable unit of digital seismic register. The system can be configured as an isolate seismic station or as a seismic network with radio telemetry or telephonic line (Fig. 1).

PC-SYSTEM ACQUISITIONS AND THE BELGIAN SEISMIC NETWORK

Marc Snissaert
Observatoire Royal de Belgique

A data acquisition system based on PC-technology has been developed at the Royal Observatory of Belgium. It includes a 8 channels 15-bits analog to digital converter. The sampling rate is issued from the carrier frequency of an external DCF-receiver. Possibilities like programming the order and the corner frequency of the anti-aliasing filter, the sampling rate and the number of active channels are provided.

3 different operating modes are working at the present time:

Stand alone stations with STA/LTA detection algorithm : the mass storage device is a 20 or 40 Mbyte harddisk. An optional videotape recorder (2 gigabyte) may improve the autonomy of the system in case of continuous acquisition. One station of this type has been adapted to record 6 broad-band seismometers. The long-periods are filtered and resampled in order to be recorded continuously on 3 different frequency ranges (from the tide to seismic surface waves). A pressure correction is assured in real time on the vertical

component.

A DOS-gateway is provided so that it is possible to consult, copy or delete files while the acquisition is still running in background.

Telemetered stations on switched lines : a modem card is added to the system; a fast transfer protocol with data compression reduces the transfer time. The data acquisition runs continuously during the communication. A restricted DOS-gateway is provided on the remote side. The calling station may visualize directly the sent files. The trigger parameters can be modified by the calling station.

Telemetered stations on galvanic lines up to 4 stand-alone stations can be connected in real time to a central PC. The collecting computer handles the communications and detects the events by coincidence on a time window.

Some software like quick sort and analyzing program with FFT and ground displacement restitution are available.

Now seven PC-seismic stations are running in Belgium. They have proved their reliability and will replace most of the older stations of the network in a near future. The low cost of this installation type, the easy realization and the high flexibility make it the solution for data recordings.

MICROGRAVITY MONITORING AT ACTIVE VOLCANOES: A REVIEW OF THEORY AND PRACTICE

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Abstract: In recent decades systematic microgravity studies over some 20 active volcanoes in Central America, Iceland, Italy, Japan, Papua New Guinea and the USA have yielded valuable data on sub-surface mass redistribution associated with eruptions. In almost all cases of reported residual microgravity change (D gr) magma movements in sub-surface chambers, feeder systems, vents and fissures (dykes) appear to be required and the calculation of mass change is usually determined by the preferred source

geometry. Although detailed interpretations depend on local circumstances, in general, the smallest values of D_{gr} are associated with eruptions from volatile-poor basaltic vents and fissures whereas the highest D_{gr} values occur over stratocones built from volatile-rich andesitic magma. Arguably the most intriguing yet difficult data to interpret derives from large-volume, infrequently-erupting volcanic systems where unrest is now becoming well-documented and the ultimate hazards are most severe.

To maximise their value, surveys that are frequent relative to the timescale of natural events are required, with observations at the highest instrumental precision using field surveys containing ample data redundancy. Concurrent elevation control is a crucial factor if interpretation ambiguity is to be reduced, leading to a better understanding of magma dynamics. This follows because, once the microgravity response to edifice deformation has been isolated, residual gravity changes relative to the free-air gradient define mass redistributions while those relative to the Bouguer-corrected free-air gradient reflect sub-surface changes in density. Future modifications to this simple theory (i) involving field observations of real free-air gradients, and (ii) applying the calculated gravitational effect of deforming non-planar geometries, may improve the rigour with which residual gravity changes are defined.

GRAVITY CHANGES AND VOLCANIC DYNAMICS

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Summary: Periodic gravity surveys are carried out at some active volcanic areas of Southern Italy.

The obtained results show that where an intense dynamics is in process, temporal gravity changes correlated to the geodynamical parameters appear.

If the dynamic processes have a deep origin then the temporal gravity variations show a long term pattern and for short time intervals local effects may mask the signals of deeper origin.

THE USE OF MICROGRAVITY FOR MONITORING AND PREDICTING VOLCANIC ACTIVITY: POAS VOLCANO, COSTA RICA.

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Abstract: The technique of microgravity applied to volcanoes, involves high precision gravity measurements, and concurrent elevation control. If data are precise to approx. 10 μ Gal and 5 cm, then useful deductions may be made about sub-surface magma movements. There are some examples in the literature of magma movements being recorded using this technique, but the case highlighted here is unique, in that gravity changes were recorded as a *precursor* to a volcanic eruption. Systematic increases in gravity at crater stations with respect to reference stations on the volcano flank correlated with power output increases at the summit, and after a 4 year build up, culminated in an ash eruption lasting several weeks. Microgravity is an under-used technique, but it clearly has potential as a useful, and relatively rapid and cheap method of volcano monitoring.

New feedback electronics for La Coste & Romberg gravimeters

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Summary: Since several years we develop a feedback electronics called "Maximum Voltage Retroaction" to replace the original GPI card. The feedback voltage is applied to the capacitor selected by rates of charge comparison for the two arms of the bridge. The force and the range are directly proportional to the square of the voltage.

For an high precision system with a large range it is

necessary to increase both feedback voltage and selection frequency to improve the S/N ratio.

Main technical problems are to minimize delay and hysteresis.

The output is under analogical and digital forms (on/off cycle counting).

Up to now we tested three different prototypes : (Van Ruymbeke M. 1989, 1990).

GRAVIMETRIC STUDY OF LANZAROTE ISLAND

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Abstract:A gravimetric survey of the volcanic island of Lanzarote (canary Islands) is presented. The data are studied, determining two anomalies component wave by means of least square prediction. The final anomalies model is considered to obtain information about the inner mass density distribution, reproducing the underground perturbations as spherical bodies. Difficulties of regional trend definition are found, nevertheless several conclusions about the mass distribution are pointed.

A SOFTWARE TO MODEL THE TIDAL TRIGGERING FOR VOLCANIC AND SEISMIC ACTIVITIES.

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Paper and practical demonstration presented in the Workshop on Geodynamical Instrumentation of the European Center for Geodynamics and Seismology. October, 1st to 3d 1990, Walferdange -G.D. Luxembourg.

Summary In this paper, associated with practical demonstration in this Meeting, we present the software adopted in the Royal Observatory of Belgium (ROB) for the research of triggering of seismic and volcanic activities by Earth gravity tides (SMT system). This software follows a logical sequence to facilitate possible geo-physical interpretations even without a computation of the hydrostatical stress produced by the tidal components.

**CORRELATION BETWEEN EARTH GRAVITY
TIDES AND SEISMIC ACTIVITY AT JOAO CAMARA
- BRAZIL**

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Paper presented in the Workshop on Geodynamical Instrumentation of the European Center for Geodynamics and Seismology, October, **1st to 3th** 1990, Walferdange - G.D. Luxembourg.

Summary: The tidal triggering of volcanical and seismic activities is today an open field for study. Arbitrary temporal sequences of globally distributed earthquakes do not show any correlation with earth gravity tides, but **there are** evidences of tidal triggering associated with isolated. tectonic features for short temporal earthquake sequences. In this paper we present the research of correlation between seismic activity and Earth gravity tides at Joao Camara, Brazil, in an **active** tectonical region of the South American platform, for a sequence of events in the period of August/1986 to May/1990. By the evidences in the analysis, a study for interpretation is proposed.

**CONTRIBUTION OF GROUNDWATER TO
VOLCANOLOGY GROUNDWATER PERTURBING
EFFECT CORRECTION ON INSTRUMENTATION. IN
SITU PARAMETERS ESTIMATE**

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Abstract: Internal fluid pressure and water-level variations induce land surface displacement that can disturb the station stability. An attraction variation effect caused by the variable water-masses can perturb e.g. the gravimetric records too. On the other hand water-levels and internal fluid pressures can respond to Earth tides, to atmospheric pressure changes and to seismic waves. In situ parameters of the layers can be estimated from those responses. At the Royal Observatory of Belgium we apply various models of responses to three water-level variation data sets recorded in the borehole drilled by the Belgian Geological Survey (e.g. Delcourt-Honorez, 1988, 1989, 1990a, b, 1991a, b in press). Water-level changes are recorded by capacitive transducers "Nivocaps" (Van Ruymbeke & Delcourt-Honorez, 1986). The research we develop by using the water-levels in the three wells at the Royal Observatory of Belgium validates a procedure to estimate in situ parameters differing from classical tests usually performed in Hydrogeology. It is a contribution to the Rn problem too (Delcourt-Honorez, 1991c in press). Moreover the Earth tidal, seismic and barometric responses can be observed in fractured rocks too : such a study could be applied to volcanic configurations. It will be discuss how the study of those hydrological phenomena can contribute to Volcanology.

Internal fluid pressure changes and water-level variations can induce land surface displacement. The land subsidence due to groundwater, oil and gas withdrawal is a well known phenomenon. Observed subsidences in the San Joaquin Valley (e.g. Lofgren, 1975. Poland et al., 1975, etc, ..), above the gas reservoir at Groningen (Geertsma, 1973) and in the Venetian Lagoon (Gambolati & Freeze, 1973) are largely reported. Most of reports on land surface changes describe the land level response to water-level declines. In our larger study we also consider the opposite phenomenon, i.e. the response to the rises of the pressure or of the water-levels too that induce an uplift of the land surface.

Land surface displacement induced by internal fluid pressure changes and by water-level variations can disturb the stability of a station and of the instrumental measurements

too. The stability of a station due to groundwater changes is commented in DELCOURT-HONOREZ, afterwards referred as DH, 1990a, b.

Some reflections about tidal triggering in volcanic zones.

M.van Ruymbeke¹, A.Somerhausen.

Abstract: We analyse the tidal triggering of seismic events from the different energy variations. The water moved by the tides could enter in contact with magma in phase with the tidal effect.

Keywords: Tides, tidal triggering, seismic events in volcanoes, aquifers reacting to tides.

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