Title of the project:
IDENTIFICATION AND INTERPRETATION OF THE PRE-ERUPTIVE SEISMIC PATTERNS FOR THE WORLDWIDE EFFUSIVE AND EXPLOSIVE VOLCANOES

Project Scientific coordinator
Warner Marzocchi – Associate Prof.
INGV-Osservatorio Vesuviano

ACTIVITY REPORT – 2° YEAR

PROJECT PARTECIPANTS

RU#	AFFILIATIONA	RESPONSIBLE
1	INGV-OV	Warner Marzocchi
2	Univ. Roma 3	Roberto Scandone
3	INGV-CT	Susanna Falsperla
4	INGV-Roma 1	Antonio Piersanti

GENERAL OBJECTIVES

TASK # 1

- RU PARTECIPANTS: RU1, RU2, RU3.

- II YEAR OBJECTIVES

  - Development of the codes for the multivariate analysis and Pattern Recognition
  - Numerical tests to evaluate the performance of the pattern recognition codes.
  - Analysis of the seismic activity that accompanies the eruptions of the Pinatubo volcano.
  - Description of the seismic characteristic behavior of explosive sequences at Stromboli
  - Analysis of the links between seismic data and volcanic activity.
  - Reconstruction of the mechanisms which are at the origin of these paroxysmal events and insights into replenishment processes.

- II YEAR RESULTS

  - Development of some *Pattern Recognition* numerical codes. The programming language used is FORTRAN. During the I and II year of the project we have developed four codes based on the *K-nearest neighbor rule* (code KNN), the *Binary Decision Tree algorithm* (code BDT), the *Linear Discriminant Analysis* (code LDA), and the *Fisher Discriminant Analysis* (code FIS)
  - Intensive numerical simulations in order to evaluate the performance of the codes reported above. In particular, we have checked the performance of the algorithms in dealing with synthetic dataset with the same characteristics of the dataset we have built during the first year of activity, i.e., composed by few (correlated or not) data and having discrete or nongaussian statistical distributions. The results indicate that the codes BDT and FIS are definitely the best in analysing such a datasets
  - First attempts to apply the BDT and FIS codes to the dataset built during the first year of the project.

- (with RU 4 coordinated by A. Piersanti) Modeling of the remote seismic stress variations induced on the volcanoes which experienced the largest volcanic eruptions of the last century. The model is based on the estimation of the co- (static) and post-seismic (time dependent) stress variation in a spherical, self gravitating, layered viscoelastic model (see RU 4). The results indicate that the volcanoes considered underwent significant stress variations, from tenths to tens of bars, from earthquakes occurred up to decades before and at distances up to one thousand of kilometers. Such modeling confirms the empirical results obtained in a research developed during the first year of the project.
- Modeling of the eruption of the Pinatubo volcano. This event is probably the only case of a large eruption where a detailed seismic monitoring is available. At first, we have collected the seismic data, then we have analyzed them and developed a physical model of the eruption. In particular, we have noted a continuous transition from a predominant effusive with mid-energy explosive activity towards a high-energy explosive activity. This transition is controlled by an increase of the feeding rate from the magma chamber towards the surface, and by an increase of the magma ascent rate.
- Set up of a statistical method to evaluate the environmental impact of the volcanoes that are characterized by a reliable historical activity.
- Application of spectral analysis, multivariate statistics, cluster analysis and polarization analysis to seismic data recorded at Stromboli. Some of these techniques were used also to process volcanic tremor data recorded at Mt. Etna as well.
- Analysis of the time series over several years using data which have been continuously acquired by the permanent seismic network of the Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania. The seismic stations are deployed on the Aeolian Archipelago, Tyrrhenian Sea – three of them on the island of Stromboli – and on Mt. Etna.
- Seismic characterization of the paroxysmal phases, starting our data processing several months before the occurrence of such phases. We have studied the link between seismic parameters and volcanic activity, using the images of the active craters from the video cameras of our institute, as well as periodic reports of the volcanologists. Spectral changes and wavefield parameters - such as the incidence angle of seismic radiation - highlight repetitive seismic features at Stromboli, concurrent with cyclic increments in volcanic activity. We have interpreted our findings as the results of changes in the height of the magma column. In the light of the strict link between seismic and volcanic data, we conclude that the application of statistical techniques may be a useful key to infer from the seismic monitoring of Stromboli the volcano unrest.
- The 2001 Mt. Etna's flank eruption has been the subject of many our analyses, which have been continuing during the current effusive episode, started on October 27, 2002. Based on spectral analysis and statistical techniques, we have focused our attention on the separation of the contribution of different sources within the volcanic system (i.e., the main feeder, dykes, etc.), which may act either separately or concurrently. Quantitative analyses are in progress.

ß RESEARCH PRODUCTS

- n° 10 publications on international journals
- n° 15 publications on national journals, proceedings, technical reports, etc.
- n. 5 numerical codes.

TASK # 2

- RU PARTECIPANTS: RU4

- II YEAR OBJECTIVES

Our objective during the second year of activity was to start the investigations performed by means of the modelling apparatus developed in the first part of the project, on real case studies of possible long distance seismic volcanic interactions.

- II YEAR RESULTS

During the first year of activity we have developed a fully spherical, self gravitating, layered viscoelastic model to compute the coseismic and postseismic time dependent stress field produced by a generic seismic event on a volcanic structure. Since the model needed massive computational resources in order to be applied to a real case study, during this second year of activity we have completed the implementation of a new numerical procedure based on parallel/vectorial codes running on a cluster of NEX SX4 and IBM SP supercomputers [*Melini et al.,* 2002]. Thus, endowing our research unit with all the necessary modelling tools to perform simulations on real cases.

Important results obtained by a purely statistical simulations performed in the framework of activities of task 1 suggested the existence of a significant influence of remote strong earthquakes on the largest explosive eruptions of the last century [*Marzocchi,* 2002]. We have tried to face this problem using our new developed numerical approach [*Casarotti et al.*. 2002]. Our data sets consisted of the focal mechanisms of 777 shallow earthquakes with $M_s \geq 7.0$, worldwide distributed in the period 1900–1999 and of the eruptions coming from the catalog of the Smithsonian Institution that reports 9 volcanic events with VEI ≥5 in the last century (we choose only the largest eruption because they are by far the most important from a social point of view. Moreover, the magmas erupted in large Plinian events are probably gas charged and water saturated so, they are easily disturbed by transient or static stress changes).

Our physical explanation to the statistical evidence reported in [*Marzocchi,* 2002] is connected to the coseismic and postseismic stress diffusion process generated by great earthquakes. We computed the time dependent cumulative stress field produced by the 777 earthquakes of our seismic dataset at the locations of the 9 volcanic eruptions.

Our results show that 4 out of 9 volcanoes, namely Ksudach, Cerro Azul, Bezymianny, and Hudson, experienced extremely strong stress variations (from a few to tens of bars) induced by regional earthquakes, before the onset of the eruptions. Remarkably, in most of the cases (Cerro Azul, Bezymianny, and Hudson), the most influential earthquakes occurred a few decades before the volcanic events. Santa Maria, Novarupta, El Chichon, and Pinatubo underwent strong seismic stress variations between 0.5 and 1 bar. For Santa Maria, Novarupta, and Pinatubo the stress variations are mainly due to earthquakes that occurred from a few months to a few years before the eruptions. For El Chichon, the most influential earthquakes occurred long before, and a few years before. Only, Mount St. Helens experienced preeruptive seismic stress variations less than 0.2 bar.

These results are perfectly in agreement with the ones obtained by the statistical analysis of *Marzocchi* [2002] both in terms of the most influenced volcanoes, and in the time lags found. In particular, the volcanoes that have the larger seismic stress variations (Ksudach, Cerro Azul, Bezymianny, and Hudson) are the same ones that appear to be the statistically more coupled to the remote earthquakes. The same consideration holds for the volcanoes that have the smaller seismic stress variations (Novarupta and Mount St. Helens).

- RESEARCH PRODUCTS

  - 2 articles published on international journals
  - 2 presentations at international meetings
  - 1 presentations at national meetings;
  - Parallel/vectorial version of the code VEI (Vulcan Earthquake global Interaction)

LIST OF PUBLICATIONS

W. Marzocchi, E. Casarotti, A. Piersanti (2002). Modeling the Stress Variations Induced by Great Earthquakes on the Largest Volcanic Eruptions of the 20th Century, *J. Geophys. Res.*, 107, 2320-2327.

L. Sandri, W. Marzocchi (2002). Testing the performance of some nonparametric pattern recognition algorithms in realistic cases. Submitted to *Pattern Recognition*.

L. Sandri, W. Marzocchi, L. Zaccarelli (2002). A new perspective in identifying the precursory patterns of volcanic eruptions. Submitted to *Bull. Volcanol.*

L. Sandri, W. Marzocchi, L. Zaccarelli (2002). On the identification of the precursory pattern of volcanic eruptions, AGU Fall Meeting, San Francisco, Dec. 6-10, 2002.

L. Sandri, W. Marzocchi, L. Zaccarelli (2002). On the identification of the precursory pattern of volcanic eruptions, Meeting IAVCEI, Montagne Peleé 1902-2002, Martinique.

Scandone R., Giacomelli L, 2000, Il risveglio dei vulcani esplosivi, *Le Scienze*, 386, 90-97

Scandone R., Giacomelli L, 2001, The slow boiling of magma chambers and the dynamics of explosive eruption, in press on *J. Volcanol. Geoth. Res.*

De Angelis S., Vignola C., Scandone R., Giacomelli L, 2001, The temporal evolution of large explosive eruptions, in press on *Bollettino di Geofisica Teorica e Applicata*

Scandone R., Giacomelli L, De Angelis S., Fattori Speranza F., 2002, Transitions between effusive eruptions and large explosive eruptions: controlling factors and examples, (abstract) Meeting IAVCEI, Montagne Peleé 1902-2002, Martinique.

Alberico I., Lirer L., Petrosino P., Scandone R., 2002, A methodology for the evaluation of long term volcanic risk, from pyroclastic flows in Campi Flegrei, *J. Volcanol. Geoth. Res*. 116, 63-78

Bonaccorso, INGV-CT Scientific staff (2001). The Evolution of the state of Mt. Etna volcano in the last ten years inferred through multidisciplinary investigations. Poster presentation at the **AGU Fall Meeting**, San Francisco, December10 – 14, 2001, ***EOS***, V31A-0928, *invited paper*.

S. Calvari, INGV-CT Scientific Staff (2001). Dike emplacement triggering the 2001 Etna's flank eruption. Oral presentation at the **AGU Fall Meeting**, San Francisco, December 10 – 14, 2001,

EOS, V22E-01, *invited paper*.

O. Cocina, The 2001 Etna Eruption Seismological Team (2002). Seismological Features and Kinematics constraints for the July-August 2001 lateral eruption at Mt. Etna volcano, Italy. Poster presentation at the 27th General Assembly of the **European Geophysical Society**, Nice, April 21-26, 2002, (abstract).

S. Falsaperla, S. Alparone, S. D'Amico, G. Di Grazia, F. Ferrari, H. Langer, T. Sgroi, S. Spampinato, L. Zuccarello (2001). Characteristics of volcanic tremor preceding and accompanying the eruption of Mt. Etna on July 17, 2001. Poster presentation at the **GNV Annual Meeting**, Rome, October 9 – 11, 2001.

S. Falsaperla and S. Spampinato (2001). New Perspectives on Explosive Paroxysmal Phenomena at Stromboli Volcano (Italy). Poster presentation at the **AGU Fall Meeting**, San Francisco, December 10 – 14, 2001, ***EOS***, V31A-0939.

S. Falsaperla, S. Spampinato, H. Langer, S. Alparone (2001). Characteristics of seismic activity at Stromboli volcano: new perspectives on tectonic seismicity and paroxysmal phases. Poster presentation at the **GNV Annual Meeting**, Rome, October 9 – 11, 2001.

S. Falsaperla (2002). Quadro delle fenomenologie sismiche con origine al vulcano Stromboli dal 1985 al 1999. Oral presentation (seminar) at the INGV, Rome, June 5, 2002.

S. Falsaperla, E. Privitera, B. Chouet, P. Dawson (2002). Analysis of long period events recorded on Mt. Etna (Italy) in 1992, and their relationship with eruptive activity. ***J. Volcanol. Geoth. Res***., 114/3-4, 421-442.

S. Falsaperla, The INGV-CT Research Team (2002). Multidisciplinary insights into the 2001 Mt. Etna flank eruption. Oral presentation at the 27th General Assembly of the **European Geophysical Society**, Nice, April 21-26, 2002, (abstract).

S. Falsaperla, J. Wassermann, F. Scherbaum (2002). Polarization analyses of broadband seismic data recorded on Stromboli volcano (Italy) from 1996 to 1999. ***Geophys. Res. Letters*.** 10.1029/2001GL014300, 22 May 2002.

S. Falsaperla, S. Alparone, S. Spampinato (2002). Seismic features of the June 1999 tectonic swarm in the Stromboli volcano region, Italy. Submitted to ***J. Volcanol. Geoth. Res*.**

S. Falsaperla and S. Spampinato (2002). Seismic insight into explosive paroxysms at Stromboli volcano, Italy. Submitted to ***J. Volcanol. Geoth. Res*.**

H. Langer and S. Falsaperla (2001). Seismic monitoring at Stromboli volcano (Italy) from 1990 to 1998: basic concepts of data reduction and parameter extraction. Oral presentation at the 20th **GNGTS Annual Congress**, Rome 6 – 8 November, 2001 (abstract).

H. Langer, S. Falsaperla, S. Alparone, S. D'Amico, G. Di Grazia, F. Ferrari, T. Sgroi, S. Spampinato (2001). First analyses of volcanic tremor recorded at Mt. Etna during the unrest of July 2001. Poster presentation at the 20th **GNGTS Annual Congress**, Rome 6 – 8 November, 2001 (abstract).

H. Langer and S. Falsaperla (2002). Seismic monitoring at Stromboli Volcano (Italy): a case study

for data reduction and parameter extraction. In print on ***J. Volcanol. Geoth. Res.***

D. Patanè, O. Cocina, S. Falsaperla, E. Privitera, S. Spampinato (2002). Mt Etna volcano: a seismological framework. In print on "***Etna Volcano Laboratory***", ***AGU Monograph***, Eds. S. Calvari, S. Bonaccorso, M. Coltelli, C. Del Negro, S. Falsaperla.

D. Patane', E. Privitera, A. Akinci, S. Alparone, G. Barberi, O. Cocina, S. D'Amico, G. Di Grazia, S. Falsaperla, F. Ferrari, E. Giampiccolo, H. Langer, L. Chiaralucio, E. Maiolino, M. Moretti, A. Mostaccio, C. Musumeci, D. Piccinini, D. Reitano, L. Scarfì, S. Spampinato, A.Ursino, L. Zuccarello, P. De Gori (2001). Seismological evidence of a near-vertical dyke feeding the July 2001 lateral eruption at Mt. Etna volcano (Italy). Poster presentation at the **AGU Fall Meeting**, San Francisco, December 10 – 14, 2001, ***EOS***, S21C-0591.

D. Patanè, E. Privitera, S. Gresta, A. Akinci, S. Alparone, G. Barberi, L. Chiaraluce, O. Cocina, S. D'Amico, P. De Gori, G. Di Grazia, S. Falsaperla, F. Ferrari, Salvatore Gambino, E. Giampiccolo, H. Langer, E. Maiolino, M. Moretti, A. Mostaccio, C. Musumeci, D. Piccinini, D. Reitano, L. Scarfì, S. Spampinato, A. Ursino, L. Zuccarello (2002). Seismological features and kinematic constraints for the July-August 2001 lateral eruption at Mt. Etna volcano, Italy. Submitted to ***Annals of Geophysics***.

Research Staff of INGV, Sez. di Catania (2001). Multidisciplinary approach yields insight into Mt. Etna eruption. ***EOS, Transactions, AGU,*** 82: 52, 653, 656.

D. Melini, E. Casarotti, A. Piersanti, E. Boschi (2002). New Insights on Long Distance Fault Interaction, *Earth Plan. Sci. Lett*., in press.

Title of the project

IDENTIFICATION AND INTERPRETATION OF THE PRE-ERUPTIVE SEISMIC PATTERNS FOR THE WORLDWIDE EFFUSIVE AND EXPLOSIVE VOLCANOES

RU Responsible
Warner Marzocchi – Associate Professor
INGV – Osservatorio Vesuviano

ACTIVITY REPORT – 2° YEAR

RU PARTICIPANTS

Name-Position	Affiliation	Man/month
Marzocchi Warner– Prof. Ass.	INGV-OV	4
Sandri Laura – PhD student	INGV	8
Ricciardi Gianni – Researcher	INGV-OV	3
Zaccarelli Lucia – PhD student	Univ. BO	8

Collaboratori esterni

Name-Position	Affiliation
McNutt Steve – Professor	AVO-Univ. Alaska USA

- II YEAR OBJECTIVES

Development of numerical codes of multivariate statistical analysis and pattern recognition, and codes to homogenize the data collected during the first year of the project. Numerical tests to evaluate the performance of multivariate codes applied to synthetic datasets that have the same characteristic of volcanological datasets.

- II YEAR RESULTS

  - Development of some *Pattern Recognition* numerical codes. The programming language used is FORTRAN. During the I and II year of the project we have developed four codes based on the *K-nearest neighbor rule* (code KNN), the *Binary Decision Tree algorithm* (code BDT), the *Linear Discriminant Analysis* (code LDA), and the *Fisher Discriminant Analysis* (code FIS)
  - Intensive numerical simulations in order to evaluate the performance of the codes reported above. In particular, we have checked the performance of the algorithms in dealing with synthetic dataset with the same characteristics of the dataset we have built during the first year of activity, i.e., composed by few (correlated or not) data and having discrete or nongaussian statistical distributions. The results indicate that the codes BDT and FIS are definitely the best in analysing such a datasets
  - First attempts to apply the BDT and FIS codes to the dataset built during the first year of the project.

- (with RU 4 coordinated by A. Piersanti) Modeling of the remote seismic stress variations induced on the volcanoes which experienced the largest volcanic eruptions of the last century. The model is based on the estimation of the co- (static) and post-seismic (time dependent) stress variation in a spherical, self gravitating, layered viscoelastic model (see RU 4). The results indicate that the volcanoes considered underwent significant stress variations, from tenths to tens of bars, from earthquakes occurred up to decades before and at distances up to one thousand of kilometers. Such modeling confirms the empirical results obtained in a research developed during the first year of the project.

- RESEARCH PRODUCTS

  - n° 3 Publications on international journal.
  - n° 2 presentations to international meetings.
  - n° 4 numerical codes of *Pattern Recognition* (KNN, BDT, LDA, FIS)
  - Several codes in FORTRAN to simulate synthetic datasets and to evaluate the performance of the Pattern Recognition codes

PUBLICATIONS LIST (relative only to the second year of activity)

W. Marzocchi, E. Casarotti, A. Piersanti (2002). Modeling the Stress Variations Induced by Great Earthquakes on the Largest Volcanic Eruptions of the 20th Century, *J. Geophys. Res.*, 107, 2320-2327.

L. Sandri, W. Marzocchi (2002). Testing the performance of some nonparametric pattern recognition algorithms in realistic cases. Submitted to *Pattern Recognition*.

L. Sandri, W. Marzocchi, L. Zaccarelli (2002). A new perspective in identifying the precursory patterns of volcanic eruptions. Submitted to *Bull. Volcanol.*

L. Sandri, W. Marzocchi, L. Zaccarelli (2002). On the identification of the precursory pattern of volcanic eruptions, AGU Fall Meeting, San Francisco, Dec. 6-10, 2002.

L. Sandri, W. Marzocchi, L. Zaccarelli (2002). On the identification of the precursory pattern of volcanic eruptions, Meeting IAVCEI, Montagne Peleé 1902-2002, Martinique.

PROJECT TITLE

IDENTIFICATION AND INTERPRETATION OF THE PRE-ERUPTIVE SEISMIC PATTERNS FOR THE WORLDWIDE EFFUSIVE AND EXPLOSIVE VOLCANOES

RU Responsible
Roberto Scandone-Associate Professor
Dept. Physics, University of Roma 3

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Giuseppe della Monica-Researcher	Dept. Physics	3
Silvio De Angelis-PhD student	Dept. Physics	3
Francesca Fattori Speranza-PhD student	Dept. Physics	3
Lisetta Giacomelli-Res. Fellow		3

- II YEAR OBJECTIVES

Analysis of the seismic activity that accompanies the eruption of the Pinatubo volcano (Philippine); an example of reactivation of a quiescent volcano similar to Mt. St. Helens.

- II YEAR RESULTS

During the second year of the project we have modeled the temporal evolution of the largest esplosive volcanic eruptions. In a second step we have applied such a modeling to the eruption of the Pinatubo. The latter is probably the only case of a large eruption where a detailed seismic monitoring is available. At first, we have collected the seismic data, then we have analyzed them and developed a physical model of the eruption.
In particular, we have noted a continuous transition from a predominant effusive with mid-energy explosive activity towards a high-energy explosive activity. This transition is controlled by an increase of the feeding rate from the magma chamber towards the surface, and by an increase of the magma ascent rate. We have also developed a statistical method to evaluate the environmental impact of the volcanoes that are characterized by a reliable historical activity.

- RESEARCH PRODUCTS
  - n° 2 publications on international journals
  - n° 3 publications on national journals and proceedings of national and international meetings.
  - Codes in FORTRAN language to analyze the temporal evolution of the explosive eruptions.
  -

PUBLICATIONS LIST (inclusive of submitted and in press papers)

Scandone R., Giacomelli L, 2000, Il risveglio dei vulcani esplosivi, *Le Scienze*, 386, 90-97

Scandone R., Giacomelli L, 2001, The slow boiling of magma chambers and the dynamics of explosive eruption, in press on *J. Volcanol. Geoth. Res.*

De Angelis S., Vignola C., Scandone R., Giacomelli L, 2001, The temporal evolution of large explosive eruptions, in press on *Bollettino di Geofisica Teorica e Applicata*

Scandone R., Giacomelli L, De Angelis S., Fattori Speranza F., 2002, Transitions between effusive eruptions and large explosive eruptions: controlling factors and examples, (abstract) Meeting IAVCEI, Montagne Peleé 1902-2002, Martinique.

Alberico I., Lirer L., Petrosino P., Scandone R., 2002, A methodology for the evaluation of long term volcanic risk, from pyroclastic flows in Campi Flegrei, *J. Volcanol. Geoth. Res*. 116, 63-78

A study on periodic replenishment processes and reconstruction of seismic scenarios associated with paroxysmal volcanic events at Etna and Stromboli

RU Responsible
Name-Position: Susanna Falsaperla, researcher (2nd level)
Affiliation: Istituto Nazionale di Geofisica e Vulcanologia, Sez. Catania

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Susanna Falsaperla, Researcher, RU responsible	INGV – Sez. Catania	5
Salvatore Alparone - Researcher	INGV – Sez. Catania	2
Horst Langer - Researcher	INGV – Sez. Catania	1
Salvatore Spampinato - Researcher	INGV – Sez. Catania	3

External co-workers

Name-Position	Affiliation
Frank Scherbaum	Inst. für Geowiss., Potsdam (Germany)
Joachim Wassermann	Inst. für Geowiss., Potsdam (Germany)

- 2nd YEAR OBJECTIVES

Description of the characteristic behavior of paroxysms - e.g., explosive sequences at Stromboli - from the seismic viewpoint. Analysis of the links between seismic data and volcanic activity. Reconstruction of the mechanisms which are at the origin of these paroxysmal events and insights into replenishment processes.

- 2nd YEAR RESULTS
  - Methodologies. We apply spectral analysis, multivariate statistics, cluster analysis and polarization analysis to seismic data recorded at Stromboli. We use a few of these techniques to process volcanic tremor data recorded at Mt. Etna as well.
  - Data acquisition. We analyze time series over several years using data which have been continuously acquired by the permanent seismic network of the Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania. The seismic stations are deployed on the Aeolian Archipelago, Tyrrhenian Sea – three of them on the island of Stromboli – and on Mt. Etna.
  - Data processing and interpretation. To shed light on the long-term changes in the volcanic feeder, we provide a seismic characterization of the paroxysmal phases, starting our data processing several months before the occurrence of such phases. We study the link between seismic parameters and volcanic activity, using the images of the active craters from the video cameras of our institute, as well as periodic reports of the volcanologists. Spectral changes and wavefield parameters - such as the incidence angle of seismic radiation - highlight repetitive seismic features at Stromboli, concurrent with cyclic increments in volcanic activity. We interpret our findings as the results of changes in the height of the magma column. In the light of the strict link between seismic and volcanic data, we conclude that the application of statistical techniques may be a useful key to infer from the seismic monitoring of Stromboli the volcano unrest (see ref. *10* in the Publication list).
  - The 2001 Mt. Etna's flank eruption has been the subject of many our analyses (e.g., ref. *1, 2, 9, 19*), which have been continuing during the current effusive episode, started on October 27, 2002. Based on spectral analysis and statistical techniques, we focus our attention on the separation of the contribution of different sources within the volcanic system (i.e., the main feeder, dykes, etc.), which may act either separately or concurrently. Quantitative analyses are in progress.

- RESEARCH PRODUCTS
  - five articles published or submitted on international journals: (ref. *8, 10, 11, 12, and 18*)

- two invited papers at international meetings: oral (ref. *2*) and poster (ref. *1*) presentations at the AGU Fall Meeting San Francisco, 2001
- three presentations at international meetings: two poster (ref. *5* and *17*) presentations at the AGU Fall Meeting San Francisco, 2001, an oral (ref. *9*) presentation at the EGS congress in Nice, 2002
- five presentations at national meetings: two poster (ref. *4* and *6*) presentations at the GNV annual meeting in Rome, 2001, oral (ref. *13*) and poster (ref. *14*) presentations at the GNGTS annual congress in Rome, 2001, and a seminar (ref. *7*) in Rome on our results during the first year of analyses
- M. Hellweg, S. Falsaperla and Marta Calvache were conveners of the special session – with oral and poster presentations - entitled: "Understanding Volcanoes Through Multiparameter Measurements and Their Interpretation: Martinelli Memorial". **AGU Fall Meeting**, San Francisco, December 10 – 14, 2001
- S. Falsaperla was chairperson at the oral session entitled: "Understanding Volcanoes Through Multiparameter Measurements and Their Interpretation: Martinelli Memorial". **AGU Fall Meeting**, San Francisco, December 10 – 14, 2001
- S. Falsaperla was chairperson at the oral session entitled: "Natural laboratories: swarm earthquakes – a multidisciplinary approach to mechanisms and processes of the upper mantle – crust interaction". 27th General Assembly of the **European Geophysical Society**, Nice, April 21-26, 2002
- editorial activities: M. Hellweg, S. Falsaperla, and M. Calvache are editors of a special volume of ***J. Volcanol. Geoth. Res***. entitled: "Understanding Volcanoes Through Multiparameter Measurements and Their Interpretation: Martinelli Memorial", which will be printed in 2003
- editorial activities: S. Calvari, S. Bonaccorso, M. Coltelli, C. Del Negro, S. Falsaperla are editors of an ***AGU Monograph*** entitled "***Etna Volcano Laboratory***", which will be on sale in 2003.

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

1) A. Bonaccorso, INGV-CT Scientific staff (2001). The Evolution of the state of Mt. Etna volcano in the last ten years inferred through multidisciplinary investigations. Poster presentation at the AGU Fall Meeting, San Francisco, December10 – 14, 2001, EOS, V31A-0928, invited paper.
2) S. Calvari, INGV-CT Scientific Staff (2001). Dike emplacement triggering the 2001 Etna's flank eruption. Oral presentation at the AGU Fall Meeting, San Francisco, December 10 – 14, 2001, EOS, V22E-01, invited paper.
3) O. Cocina, The 2001 Etna Eruption Seismological Team (2002). Seismological Features and Kinematics constraints for the July-August 2001 lateral eruption at Mt. Etna volcano, Italy. Poster presentation at the 27th General Assembly of the European Geophysical Society, Nice, April 21-26, 2002, (abstract).
4) S. Falsaperla, S. Alparone, S. D'Amico, G. Di Grazia, F. Ferrari, H. Langer, T. Sgroi, S. Spampinato, L. Zuccarello (2001). Characteristics of volcanic tremor preceding and accompanying the eruption of Mt. Etna on July 17, 2001. Poster presentation at the GNV Annual Meeting, Rome, October 9 – 11, 2001.
5) S. Falsaperla and S. Spampinato (2001). New Perspectives on Explosive Paroxysmal Phenomena at Stromboli Volcano (Italy). Poster presentation at the AGU Fall Meeting, San Francisco, December 10 – 14, 2001, EOS, V31A-0939.
6) S. Falsaperla, S. Spampinato, H. Langer, S. Alparone (2001). Characteristics of seismic activity at Stromboli volcano: new perspectives on tectonic seismicity and paroxysmal phases. Poster presentation at the GNV Annual Meeting, Rome, October 9 – 11, 2001.
7) S. Falsaperla (2002). Quadro delle fenomenologie sismiche con origine al vulcano Stromboli dal 1985 al 1999. Oral presentation (seminar) at the INGV, Rome, June 5, 2002.
8) S. Falsaperla, E. Privitera, B. Chouet, P. Dawson (2002). Analysis of long period events recorded on Mt. Etna (Italy) in 1992, and their relationship with eruptive activity. J. Volcanol. Geoth. Res., 114/3-4, 421-442.
9) S. Falsaperla, The INGV-CT Research Team (2002). Multidisciplinary insights into the 2001 Mt. Etna flank eruption. Oral presentation at the 27th General Assembly of the European Geophysical Society, Nice, April 21-26, 2002, (abstract).
10) S. Falsaperla, J. Wassermann, F. Scherbaum (2002). Polarization analyses of broadband seismic data recorded on Stromboli volcano (Italy) from 1996 to 1999. Geophys. Res. Letters. 10.1029/2001GL014300, 22 May 2002.

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PROJECT TITLE

IDENTIFICATION AND INTERPRETATION OF THE PRE-ERUPTIVE SEISMIC PATTERNS FOR THE WORLDWIDE EFFUSIVE AND EXPLOSIVE VOLCANOES

RU Responsible
Antonio Piersanti-Senior researcher
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ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Andrea Antonioli, PHD student	INGV, Rome	4
Emanuele Casarotti, PHD student	INGV, Rome	4
Concetta Nostro, Researcher	INGV, Rome	4
Gaia Soldati, Researcher	INGV, Rome	4

- 2nd YEAR OBJECTIVES

Our objective during the second year of activity was to start the investigations performed by means of the modelling apparatus developed in the first part of the project, on real case studies of possible long distance seismic volcanic interactions.

- 2nd YEAR RESULTS (max 1 page)

During the first year of activity we have developed a fully spherical, self gravitating, layered viscoelastic model to compute the coseismic and postseismic time dependent stress field produced by a generic seismic event on a volcanic structure. Since the model needed massive computational resources in order to be applied to a real case study, during this second year of activity we have completed the implementation of a new numerical procedure based on parallel/vectorial codes running on a cluster of NEX SX4 and IBM SP supercomputers [*Melini et al.*, 2002]. Thus, endowing our research unit with all the necessary modelling tools to perform simulations on real cases.

Important results obtained by a purely statistical simulations performed in the framework of activities of task 1 suggested the existence of a significant influence of remote strong earthquakes on the largest explosive eruptions of the last century [*Marzocchi*, 2002]. We have tried to face this problem using our new developed numerical approach [*Casarotti et al.*, 2002]. Our data sets consisted of the focal mechanisms of 777 shallow earthquakes with $M_s \geq 7.0$, worldwide distributed in the period 1900–1999 and of the eruptions coming from the catalog of the Smithsonian Institution that reports 9 volcanic events with VEI ≥5 in the last century (we choose only the largest eruption because they are by far the most important from a social point of view. Moreover, the magmas erupted in large Plinian events are probably gas charged and water saturated so, they are easily disturbed by transient or static stress changes).

Our physical explanation to the statistical evidence reported in [*Marzocchi*, 2002] is connected to the coseismic and postseismic stress diffusion process generated by great earthquakes. We computed the time dependent cumulative stress field produced by the 777 earthquakes of our seismic dataset at the locations of the 9 volcanic eruptions.

Our results show that 4 out of 9 volcanoes, namely Ksudach, Cerro Azul, Bezymianny, and Hudson, experienced extremely strong stress variations (from a few to tens of bars) induced by regional earthquakes, before the onset of the eruptions. Remarkably, in most of the cases (Cerro

Azul, Bezymianny, and Hudson), the most influential earthquakes occurred a few decades before the volcanic events. Santa Maria, Novarupta, El Chichon, and Pinatubo underwent strong seismic stress variations between 0.5 and 1 bar. For Santa Maria, Novarupta, and Pinatubo the stress variations are mainly due to earthquakes that occurred from a few months to a few years before the eruptions. For El Chichon, the most influential earthquakes occurred long before, and a few years before. Only, Mount St. Helens experienced preeruptive seismic stress variations less than 0.2 bar.

These results are perfectly in agreement with the ones obtained by the statistical analysis of *Marzocchi* [2002] both in terms of the most influenced volcanoes, and in the time lags found. In particular, the volcanoes that have the larger seismic stress variations (Ksudach, Cerro Azul, Bezymianny, and Hudson) are the same ones that appear to be the statistically more coupled to the remote earthquakes. The same consideration holds for the volcanoes that have the smaller seismic stress variations (Novarupta and Mount St. Helens).

- RESEARCH PRODUCTS
  - 2 articles published on international journals
  - 2 presentations at international meetings
  - 1 presentations at national meetings;
  - Parallel/vectorial version of the code VEI (Vulcan Earthquake global Interaction)

PUBLICATIONS LIST (inclusive of submitted and in press papers)

D. Melini, E. Casarotti, A. Piersanti, E. Boschi (2002). New Insights on Long Distance Fault Interaction, *Earth Plan. Sci. Lett*., in press.

W. Marzocchi, E. Casarotti, A. Piersanti (2002). Modeling the Stress Variations Induced by Great Earthquakes on the Largest Volcanic Eruptions of the 20th Century, *J. Geophys. Res.*, 107, 2320-2327.