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Istituto Nazionale di
Geofisica e Vulcanologia

PROGETTO INGV-DPC 2004-2006

PROGETTI VULCANOLOGICI

(Attuazione dei progetti di ricerca vulcanologici di particolare interesse per il Dipartimento della Protezione Civile previsti dalla Convenzione 2004-2006 tra DPC e INGV)

Allegato 2
al Decreto n. 179 - 18 maggio 2005
del Presidente dell'INGV
Prof. Enzo Boschi

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INGV-DPC Project 2005-2006

Volcanology

The Agreement between Dipartimento della Protezione Civile (DPC) and Istituto Nazionale di Geofisica e Vulcanologia (INGV), for the period 2004 – 2006, establishes the organization of five Projects in the general field of Volcanology. The INGV Decree 26/11/2004 N. 387 nominates the responsibles of these projects. The same Agreement defines the general project objectives which must be aimed at providing clear answers to the major issues of interest for DPC. For the research in volcanology, these issues are essentially represented by: i) the assessment of the hazard associated with the various types of volcanic phenomena and with diffuse degassing, ii) the definition of the criticality levels, or the association of signs which indicate significant changes in the state of a volcano, and iii) the development of innovative techniques with the potential to add substantially to the above issues. Hazard and criticality levels are therefore the general objectives of INGV-DPC projects (with the addition of risk assessment, limited to project V5). Accordingly, each project includes a substantial part devoted to hazard assessment and definition of criticality levels, which are the subject of specific research, and are represented by clearly identified research products.

The Table below reports in a synthetic way the five INGV-DPC Projects in Volcanology and the corresponding responsibles.

Project	**Responsibles**
V1*. Prosecution of the activities already financed in 2003 in the frame of GNV	Mauro Coltelli, INGV-CT Francesco Latino Chiocci, Univ. Roma La Sapienza
V2. Monitoring and research activity at Stromboli and Panarea	Domenico Patanè, INGV-CT Alessandro Tibaldi, Univ. Milano Bicocca
V3. Research on active volcanoes, precursors, scenarios, hazard, and risk	Paolo Papale, INGV Roma1 Stefano Gresta, Univ. Catania
V4. Conception, experimentation, and application of innovative techniques to study active volcanoes	Warner Marzocchi, INGV Roma1 Aldo Zollo, Univ. Napoli Federico II
V5. Research on the diffuse degassing in Italy	Giovanni Chiodini, INGV-OV Mariano Valenza, Univ. Palermo

*NOTE: No additional funding is requested for Project V1 in this proposal.

The project responsibles have compiled the present proposal, after having informed and consulted the whole volcanological community through a first presentation of the INGV-DPC Agreement themes during the GNV General Assembly (Naples, December 2004), then through the publication in the web of project pre-proposals defining the project Tasks and requested deliverables of interest for INGV-DPC projects. The responsibles have collected the corresponding proposals of contribution by single research groups, have identified those which better fit the pre-proposal themes and objectives, and have optimized them in the frame of a coordinated project with clear, well-defined, and attainable objectives and deliverables. The resulting projects are organized in a series of interdependent Tasks matching the themes and expected results included in the INGV-DPC Agreement, and focused on the achievement of deliverables of primary interest for Civil Protection purposes.

Project V3, which comprises the research on the Italian active volcanoes with the exception of Stromboli and Panarea (forming the object of projects V1 and V2), is organised in 7 sub-projects dedicated to Colli Albani, Campi Flegrei, Ischia, Vesuvio, Vulcano, Etna, and Pantelleria. Lipari and the volcanoes of the Sicily channel are partly included in the research above (within the sub-projects Vulcano and Pantelleria, respectively), although dedicated research will be organised in the future, possibly, during the second year of project.

The entire Project includes 159 RU's embracing 21 Italian and 1 foreign Universities (30 Departments), 6 CNR Institutes, 4 foreign Research Centers, 1 Italian Private Company, and 6 INGV sections. Participation to the whole Project includes a much larger number of Institutions, comprising 30 Italian Universities, 46 foreign Universities, 9 CNR Institutes plus 6 other Italian Research Centers, 26 foreign Research Centers, 5 Italian and 3 foreign Private Companies. A total of 953 researchers is involved in the Project, for a total of 7239 man/months, or 603 man/years.

For each project (and each V3 sub-project, see the following) at least **three project meetings** are planned.

The first one represents a kick-off meeting, within one month from the official start of the project, and its aim is that of i) providing all participating RU's with the basic knowledge of the research skills in the consortium, and promoting collaborations between RU's; ii) defining the details of project organization and the modalities and timing of exchange of data and results; iii) optimizing the first-year activities within all project Tasks.

The second meeting is planned shortly before the end of the first year of activity, with the aim of i) exerting a general control on the project activities, achievement of first year results, and production of first year deliverables; ii) if necessary, re-addressing part of the research foreseen to better match the project objectives; iii) ensuring further exchange between all RU's participating to the various project Tasks, cross-correlating the results from each RU and each project Task in order to focus on open questions and unresolved issues; iv) organising the first-year project report to INGV.

The third meeting is planned about two months before the date of closure of projects, and its aim is that of i) organizing the further research in view of the end of the project, ii) extracting the general picture emerging from the whole research within each project, and underlying the open questions and unresolved issues; iii) organising the final project report.

A **General Assembly** is foreseen shortly after the end of the Project. During the assembly the Project results will be presented to the Civil Protection and the scientific community.

The organization of a few (indicatively, two per year) **workshops on horizontal themes** of great relevance for the project objectives is greatly auspicated. These workshops should not be just the occasion for presenting the scientific job and results of researchers, rather, they should be focused on the production of a document summarizing the state of the art and guide-lines on the specific workshop theme. The first workshop to be organized shortly after the beginning of projects should be dedicated to Volcanic Hazard, a theme which is generally faced by different research groups on the basis of quite different principles and paradigms. The guide-lines emerging from the workshop should therefore provide a common route for all projects, for which volcanic hazard is the final objective.

Finally, the facilities offered by the existence of the INGV-DPC projects are thought to provide an ideal background for the development of a **INGV Task Force**. The aim of the Task Force should be that of providing scientific, technical, and logistic support during volcanic crises out of the Italian territory. A significant and coordinated participation of Italian researchers in volcanic crises all around the world is an opportunity to export their knowledge and greatly increase their experience in interpreting pre-eruptive signals from unresting volcanoes, in forecasting volcanic scenarios, and in volcanic crisis response and management. This will result in an enormous increase of the capabilities to face and manage volcanic crises in the Italian territory. A document prepared, and circulated among the scientific community, by a Working Group in the frame of the activities related to the 2001-03 GNV program constitutes the basis over which the Task Forxe is thought to develop.

The present project proposal does not include any financial request for the activities related to the organization of the final General Assembly, of the workshops on horizontal themes, and of the INGV Task Force. The possibility that such activities will be started and promoted by INGV in the frame of the present INGV-DPC project will be submitted to the INGV management and decision bodies in case this proposition should be positively evaluated.

The Table in this page reports in a synthetic way the budget requested for the whole INGV-DPC Project in the scientific sector of Volcanology, divided for each single project from V1 to V5. The single projects designed with the above philosophy and objectives, are illustrated in details in the following corresponding sections. Project V1, which represents the continuation of activities on Stromboli and Panarea activated and financed in 2003, is also briefly described in the following. For this project no further financial request is included.

Synthetic prospect of the financial request for the whole 2005-2006 INGV-DPC Project - Volcanology

Project	**Financial Request 2005 (keuro)**	**Financial Request 2006 (keuro)**	**Total Financial Request (keuro)**	**Percentage of Requested Fund**
V1*. Prosecution of the activities already financed in 2003 in the frame of GNV	235	22.5	257.5	3.76
V2. Monitoring and research activity at Stromboli and Panarea	359.65	387.85	747.5	10.9
V3. Research on active volcanoes, precursors, scenarios, hazard, and risk	2248.5	2086	4334.5	63.3
V4. Conception, experimentation, and application of innovative techniques for the study of active volcanoes	415.3	369.8	785.1	11.5
V5. Research on the diffuse degassing in Italy	374	352	726	10.6
Total	**3632.45**	**3218.15**	**6850.6**	**100.0**

*__NOTE__: V1 projects already defined, including financial request, in 2003. No additional funding is requested in this proposal.

NOTE: For the execution of projects V2-V5, the activation of 9.5 two-years “borsa di studio” and 4.5 two-years “assegno di ricerca”, is requested by INGV RU’s. Details are included in the footnotes to the financial Tables related to each project – see the following, and in the “Description of Research Units” volume which constitutes integral part of the present Project. The related costs are not included in the Table above. The costs for personnel requested by non-INGV RU’s are included in the Table above.

PROJECT V1

Prosecution of the activities already financed in 2003 in the frame of GNV

Responsibles:

Mauro Coltelli, INGV Catania
Francesco Latino Chiocci, Univ. La Sapienza, Roma

Project V1

Prosecution of the activities already financed in 2003 in the frame of GNV

Coordinators:

Mauro Coltelli, Senior Researcher, INGV sezione di Catania, Piazza Roma 2, 95123 Catania, coltelli@ct.ingv.it, tel 0957165850, fax 095435801

Francesco Latino Chiocci, Professore Ordinario, Dipartimento Scienze della Terra, Università di Roma "La Sapienza", P.le A. Moro, 5 – 00185 Roma, francesco.chiocci@uniroma1.it, tel.: 06/49914938, 06/44585075 fax: 06 4454729

For this project no further financial request is included in the present proposal. The project was made of six sub-projects financed in the frame of the response activities following the 2002-03 volcanic crisis at Stromboli volcano. Two of these sub-projects (N. 3 and 4 in the prospect below) had a length of one year, and are at present concluded. Other three sub-projects with duration of two years (N. 2, 5 and 6) , and one with duration of three years (N. 1) are still prosecuting their activities, and have presently reached the end of first year.

The activity of the project responsibles will be that of i) recovering the entire project documentation and making the point on the achieved results (already started); ii) coordinating the research activities during next two years, establishing the timing and modalities of scientific and finanacial report together with the responsibles of projects V2-5; iii) harmonizing the research and the activities within the project with those developed under project V2.

The prospect below reports in a synthetic way the aim, funding, and present state of each sub-project. At present the project responsibles are recovering the first year scientific and financial reports, which will be forwarded to INGV as soon as they are available.

Sottoprogetto 1: Studio dei maremoti generati da frane a Stromboli e dei segnali del sistema d'allarme marino installato dalla Protezione Civile (Allegato 1)

Responsabile: Stefano Tinti, Professore Associato, Dipartimento di Fisica, Università di Bologna

Durata del progetto: 3 anni

Finanziamento accordato: 74.000 € per il 1 anno (2003); 55.000 € per il 2 anno (2005), 22.500 € per il 3 anno (2006)

Altre Università o Enti partecipanti: nessuno

Obiettivi:

a) Sistema d'allarme e analisi dei segnali
b) Simulazione del maremoto e modello di frana

Stato delle ricerche:

Ricerca in corso secondo le modalità riportate nel progetto approvato

Sottoprogetto 2: Attività di fotogrammetria digitale e di controllo topografico (Allegato 2)

Responsabile: Maria Marsella, Professore Associato, Dipartimento di Idraulica, Trasporti e Strade, Università di Roma La Sapienza

Durata del progetto: 2 anni

Finanziamento accordato: 90.000 € per il 1 anno (2003); 50.000 € per il 2 anno (2005)

Altre Università o Enti partecipanti:

Dipartimento di Fisica, Università di Bologna (P. Baldi)

Obiettivi:

c) Progettazione e realizzazione di una rete di inquadramento topografico/appoggio fotogrammetrico
d) Restituzioni fotogrammetriche per estrazione di DTM e ortofoto digitali
e) Misure di deformazioni
f) Elaborazioni e interpretazioni dei dati morfologici
g) Predisposizione di un CD Rom per la distribuzione dei dati e dei risultati del progetto

Stato delle ricerche:

Ricerca in corso secondo le modalità riportate nel progetto approvato

Sottoprogetto 3: Studio vulcanologico e geochimica-petrologico dell'eruzione 2002-2003 dello Stromboli (Allegato 3)

Responsabile: Mauro Rosi, Professore Ordinario, Dipartimento di Scienze della Terra, Università di Pisa

Durata del progetto: 1 anno

Finanziamento accordato: 73.000 € per il 1 anno (2003)

Altre Università o Enti Partecipanti:

Università di Cagliari (R. Cioni, Dipartimento di Scienze della Terra)
Istituto Nazionale di Geofisica e Vulcanologia e CEA-CNRS, (A. Bertagnini, P. Landi, N. Métrich)
Università di Firenze (L. Francalanci, E. Germiniani, C. Petrone, Dipartimento di Scienze della Terra)
Università di Urbino (A. Renzulli. M. Mattioli, P. Santi (Istituto di Vulcanologia e Geochimica)
Università di Parma (G.Serri, E.Salvioli, Dipartimento di Scienze della Terra)
Università di Torino (M. Tribaudino (Dipartimento di Scienze Mineralogiche e Metrologiche)

Obiettivi:

a) Individuare un'eventuale ricarica profonda del sistema superficiale e stimarne tempi e modalità
b) Stimare il contenuto in volatili del magma profondo e le sue caratteristiche isotopiche
c) Individuare eventuali variazioni chimiche, mineralogiche ed isotopiche e del contenuto in volatili del magma superficiale coinvolto nell'eruzione

Stato delle ricerche:

Ricerca conclusa, è in atto la rendicontazione scientifica e finanziaria finale

Sottoprogetto 4: Condizioni di iniezione di dicchi nella Sciara del fuoco o nella zona dei crateri sommitali in relazione all'instabilità gravitativa di Stromboli (Allegato 4)

Responsabile Alessandro Tibaldi, Professore Associato, Dipartimento di Scienze Geologiche e Geotecnologie Università di Milano-Bicocca

Durata del progetto: 10 mesi

Finanziamento accordato: 50.000 € per il 1 anno (2003)

Altre Università o Enti Partecipanti:

Università di Urbino, Istituto di Vulcanologia e Geochimica
Università di Parma, Dipartimento di Scienze della Terra
Università di Firenze, Dipartimento di Scienze della Terra
Università di Roma Tre, Dipartimento di Scienze Geologiche

Università dell'Insubria Dipartimento di Scienze Chimiche, Fisiche e Matematiche

Obiettivi:

a) Analisi cinematica dei dicchi con l' obiettivo è di collocare temporalmente e spazialmente ogni dicco per poi procedere al confronto delle sue caratteristiche cinematiche e degli altri parametri
b) Analisi mineralogiche, petrografiche, isotopiche e geochimiche; caratteristiche reologiche dei magmi
c) Modellistica numerica delle differenti condizioni del fianco nord-occidentale del vulcano al fine di individuare quali sono le direzioni di minore resistenza all'intrusione di dicchi
d) Modellazione analogica mirante alla comprensione fisica del meccanismo di iniezione di un dicco in aree con topografia pronunciata e delle possibili cause innescanti

Stato delle ricerche:

Ricerca conclusa, è in atto la rendicontazione scientifica e finanziaria finale

Sottoprogetto 5: Progetto biennale per la prosecuzione delle attività legate all'analisi delle condizioni di stabilità della Sciara del Fuoco (Allegato 5)

Responsabile: Paolo Tommasi, Ricercatore, CNR, Istituto di Ricerca sulla Tettonica, Roma

Durata del progetto: 2 anni

Finanziamento accordato: 44.000 € per il 1 anno (2003); 10.000 € per il 2 anno (2005)

Altre Università o Enti partecipanti: nessuno

Obiettivi:

a) Analisi dettagliata delle caratteristiche morfologiche, strutturali, vulcanologiche legate all'evoluzione del fenomeno, da mettere in relazione con altri fenomeni avvenuti in tempi più o meno recenti e ben documentati.
b) Caratterizzazione dei materiali, che, vista la complessità litologico-strutturale dell'ammasso, dovrà essere a grande scala e riguardare quegli aspetti ancora non investigati del comportamento dei materiali.

Stato delle ricerche:

Ricerca in corso secondo le modalità riportate nel progetto approvato

Sottoprogetto 6: Attività future per lo studio della Sciara sommersa e dei fenomeni correlati all'evento del 30/12/2003 (Allegato 6)

Responsabili: Francesco L. Chiocci, Professore Ordinario, Dipartimento di Scienze della Terra, Università di Roma La Sapienza
Michael Marani, Ricercatore, CNR, ISMAR, Bologna

Durata del progetto: 2 anni (Chiocci), 1 anno (Marani)

Finanziamento accordato: 460.000 € per il 1 anno (2003); 120.000 € per il 2 anno (2005)

Altre Università o Enti partecipanti: nessuno

Obiettivi:

a) Studio della nicchia di frana e dei lineamenti erosivi (F.L. Chiocci);
b) Studio del trasporto e messa in posto del materiale di frana (M.Marani).

Stato delle Ricerche:

Obiettivo a (Chiocci), ricerca in corso secondo le modalità riportate nel progetto approvato
Obiettivo b (Marani), ricerca conclusa, è in atto la rendicontazione scientifica e finanziaria finale

PROJECT V1 – CONTINUATION OF THE ACTIVITIES AT STROMBOLI AND PANAREA

Table RU and related funding request

N. UR	Istituz.	Resp UR	Personale		Missioni				Consumi servizi		Inventariabile	
					Italia		Estero					
			2005	**2006**	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**
UR-1	UNIBO	Tinti	31000		7000	5000	7000	7000	10000	10500		
UR-2	UNIRM1	Marsella	15000		3000		2000		3000		2000	
UR-3	UNIBO	Baldi	15000		3000		2000		3000		2000	
UR-4	CNR-IGAG	Tommasi	4000		3500				2500			
UR-5	UNIRM1	Chiocci	64000		2000		5000		39000		10000	
		TOTALE	**129000**		**18500**	**5000**	**16000**	**7000**	**57500**	**10500**	**14000**	
GRAN TOTALE: 257500												

PROJECT V2

Monitoring and research activity at Stromboli and Panarea

Responsibles:

Domenico Patanè, INGV Catania
Alessandro Tibaldi, Univ. Milano Bicocca

Project V2

Monitoring and research activity at Stromboli and Panarea

Coordinators:

Domenico Patanè, National Institute of Geophysics and Volcanology, Section of Catania, P.zza Roma, 2, 95123 Catania, Italy, patane@ct.ingv.it

Alessandro Tibaldi, University of Milan Bicocca, Department of Geological Science and Geotechnologies, P. della Scienza 4, Milan, Italy, alessandro.tibaldi@unimib.it

Objectives

The main objectives have been individuated on the basis of the contents of the “attached C” on the Institutional Decree of the coordinating committee of the “Framework convention DPC-INGV 2004-06” and on the basis of the general framework of objectives of specific concern for the DPC.

The present project has been constructed through a strong integration of the research units (RU) and the other ongoing project on Stromboli (V1 “Prosecution of already funded activities in the GNV framework in 2003”).

This project will focus on a series of fundamental objectives that we retain of paramount importance for the prosecution of researches finalized to the hazard evaluation. Some of these objectives have been chosen also keeping in mind that they have received less attention in the past. Main hazards for Stromboli are: explosive eruptions, surface and deep landslide phenomena with particular reference to the Sciara del Fuoco area (SdF), subvolcanic intrusions and lava effusions. Tsunami scenarios are already developed within Project V1. For Panarea, the estimate of danger related to the underwater gas emission zone to the east of the island (Lisca Bianca-Dattilo-Bottaro locality) and its eventual connection with a magmatic system at depth, is of particular importance. Moreover, the definition of “critical levels” constitutes an activity of particular concern, or rather of the ensemble of indicators that may suggest significant status changes in the volcanoes under study. In particular, we foresee that any future monitoring and research activity at Stromboli will benefit from a better understanding of the deep and surface structure of the volcano and of its feeding system.

We plan a main experiment of tomography at Stromboli to achieve a better knowdlege of the volcanic structure and of its plumbing system, and to locate the possible magma chamber, which up to now is unknown both for position and dimension. This result will be integrated with data coming from geophysical analysis of the upper feeding system and from field mapping of Holocene structures, dykes and eruptive fissures. All these data will be integrated into a unique three-dimensional structural-volcanological model of the volcano. This information will be also used to improve understanding of the mechanisms that govern the explosive activity and to better interpretate the monitoring data of deformation of the cone. In particular, we planned a series of applied research activities where data coming from various different methodologies of monitoring will be crosscutted for validation and comparison. We believe that all this will increase the base knowledge of Stromboli and will lead to a strong improvement of the comprehension of phenomena and behaviour of this volcano. This, in turn, will facilitate all scientists working on the real-time interpretation of the signals coming from this volcano, leading to a better reaction during possible future crisis.

As regards Panarea, the activities here proposed represent a first reaction to the phenomena of underwater degassing and fracturing occurred during the 2002-03 crisis. Here we propose three main objectives: the study of the origin of fluids outpoured from the sea bottom, the comprehension of the possible causes of the associated kms-long fracture pattern, and a better delineation of the age and nature of the most recent volcanic activity in the area. All these objectives will contribute towards the understanding of the connection of these phenomena with a possible magmatic system at depth. We are aware that a complex geophysical oceanographic survey would be necessary in order to completely fulfil this last task, but neither research teams neither fund availability allowed it at present.

State of the art of the ongoing researches related to the objectives here proposed

A more suitable understanding of the internal structure of the volcano, its feeding system and its crustal roots, surely represent the basic tools to comprehend Stromboli's activity, to develop models used for the study of the source mechanisms of seismic-volcanic events and the deformation field induced by magma upraise in the storage zones and along the feeding conduits, useful for estimating danger and critical levels of the volcano. Notwithstanding this paramount importance, we must recognize that studies aimed at understanding the volcanic structure and the nature of its plumbing system has been started only recently (Pasquarè et al., 1993; Chouet et al., 1998; Saccorotti et al., 1998; Tibaldi, 2001; Chouet et al., 2003; Tibaldi et al., 2003). These comprise geophysical, geological, field structural and geomechanical studies of brittle planes of failures at Stromboli, as well as field studies of lithostratigraphic and geometric characteristics of dykes. All these data have been collected at the surface, or up to 200 m under the crater zone by geophysical methods, thus representing a valuable but partial reconstruction of the volcano structure. Despite in the last two decades a quantity of published seismological studies include waveform and spectral analysis of sparse network data aimed at clarifying eruption dynamics and spatial properties of the source (e.g. Del Pezzo et al., 1992; Neuberg et al., 1994; Chouet et al., 1998), quantitative descriptions of the seismicity and recurrent explosivity (Falsaperla et al., 1992, 1999) the spatial extend and geometrical characteristics of the source and mechanisms of Strombolian explosive activity remain poorly understood, apart from a single work (Chouet et al., 2003). Notwithstanding, additional observations for the investigation of the spatial and temporal characteristics of Strombolian sources are needed as well as the definition of a reliable velocity structure of the volcanic edifice. For the latter only an approximate evaluation (poorly constrained at depths greater than 500 m) derived from the inversion of surface-wave dispersion data is still today available (Chouet at al., 1998). Therefore an effort is necessary to better defining the velocity structure of the volcano by tomography. This in order to enhance both the location of the sources of Strombolian explosion and the simulation of the three-dimensional wave propagation in heterogeneous media.

In January 2003, after the beginning of the 2002-03 eruptive crisis at Stromboli, the geophysical and geochemical monitoring systems of the volcano has been strongly improved. A digital permanent broadband seismic network composed of 13 stations was deployed by INGV and several automatic systems have been developed to recognize both low frequency and landslide seismic signals. Moreover, a system for automatic detection and location of low-frequency signals, such as VLP's, has been implemented. All these monitoring systems have been used during the crisis as a proxy to changes in the input rate of magma and the degree of gas exsolved in the system. It is noteworthy that during last years, considerable work on modelling of the ascent of gas bubbles has been carried out. These kinds of simulation will be useful for modelling gas bubbles rising inside magma conduits, leading to better understanding Strombolian activity. Additionally, recent advances in the simulation of the eruption dynamics allows now to provide new tools for the investigation of time-dependent, multi-phase, 2D/3D magmatic and volcanic processes.

From the geological point of view, given that the system of dykes is magnificently exposed at Stromboli, and taking account that there are several dykes of very recent age, it is auspicious that they are analysed with greater detail, above all through a strong interdisciplinary approach that integrates structural, stratigraphic, petrographic, geochemical data, and numeric modelling. This would represent a further improvement and completion of work begun and started in 2004 in the project V1. In addition, there is a need to proceed with the mapping of the lava flows from

Holocene fissure eruptions outside the SdF; these, representing the surface expression of dykes of very recent ages, will be integrated with all the other data described above. Furthermore, a strong collaboration with the group that is to pursue further and deeper geophysical prospecting of the active feeding (dyke) system is here planned, in such a way as to correlate surface data with information coming from the inner part of the volcano. No geophysical studies at all exist on the magma chamber. Depth and characters of the pluming system has been estimated by petrological studies (Vaggelli et al, 2003, Francalanci et al., 2004, 2005), but uncertainties still remain on geometry and location of the magma chamber.

Regarding the lateral instability of Stromboli, a series of main flank and sector collapses have been individuated mainly on the NW side of the cone and secondarily on the opposite SE side (Tibaldi, 2001, 2003, 2004). In the NW side, multiple nested lateral collapses occurred in the last 13 ky leading to the present configuration of the SdF depression. SdF is also prone to surface landsliding, as the one occurred on 30 December 2002 which produced a tsunami. All this testifies to recent and active deformation of the SdF infill. Monitoring of SdF deformation has been carried out only after the 2002-03 crisis, by means of several different techniques such as laser measurements of benchmarks, GPS stations and ground-based radar interferometry (e.g. Nunnari et al., 2004; Mattia et al, 2004). Possible scenarios of deep-rooted deformations in the SdF have been investigated by numerical modelling based on a wide set of geotechnical and geomechanical field and laboratory tests in 2-D (Apuani et al., 2004, 2005). No comparison of different monitoring data sets have been carried out up to now. Similarly, no studies at all exist on possible rockfalls towards the Stromboli villages.

The dynamics of SdF deformation is linked not only to gravity force, but also to magma lateral force exerted by intrusions. This link is strongly dependant also on the geometry of the upper feeding system. This geometry also is related to possible models of magma ascent dynamics. With this premise, we retain that volcanological researches in general, as well as researches applied to Stromboli hazards, will benefit from strongly tying together all these studies on different aspects of the same problem. Thus, improvement on the knowledge of the feeding system geometry will be useful not only to the studies of the present SdF deformations and of possible future scenarios, but also to magmatological studies. Numerous studies on explosive activity have been carried out recently, regarding both analyses of outpoured products (Rosi et al., 2000; Metrich et al., 2001; Bertagnini et al., 2003; Arrighi et al., 2004), magma dynamics (Vergniolle et al., 1996; Ripepe et al., 2001, 2005; Chouet al., 2003) and crater gas emissions (Allard et al., 2000; McGonigle et al., 2003). Anyhow, further improvements in the understanding of the explosive Holocene and recent most activity are possible and desirable, in terms of eruptive mechanisms, typology and distribution of emitted products, chronology of eruptive events, and estimate of the probability of occurrence of volcanic phenomena. Similarly, further improvements on estimation of mechanisms responsible for the rarer but most dangerous paroxystic explosions are needed.

Description of the activities

The following methodologies are planned basing on the fact that the present project aims to stimulate and promote researches and studies orientated at supplying precise answers to the problematics of prime concern for Civil Protection. For Stromboli, such problematics are essentially made up of estimating the danger related to the various manifestations of volcanic activity (effusive and explosive) and slope instability. For Panarea, understanding what occurred during the 2002-03 crisis and what can be expected in the future, is of prime interest.

At Stromboli tens of years of studies have already been developed. We retain that new achievements can be reached by tying together the various groups which already operated at Stromboli in order to stimulate research in synergy. It is absolutely necessary to discuss all together the enormous amount of data collected by research and monitoring activities. This can be achieved by singling out mixed task forces in which the transverse nature of the disciplines can be implemented. At the same time, taking into account the expected available funding, further new data will be collected under a dual scheme: 1) a few, selected main experiments which have never done before at Stromboli, nominally a tomographic survey and satellite interferometry, and 2) a series of lower-cost data collection mainly oriented to assure a prosecution of ongoing researches.

At Panarea instead, the researches focused on volcanic hazard are more at an embryonic stage. Past works were mainly aimed at understanding the volcanological evolution of the main island. As a consequence, we propose a few researches strongly focused on the new phenomena observed during the recent crisis and to understanding the Holocene geological evolution of the area where these phenomena occurred.

We remind that from the start-up of this project (i.e. during the call for proposals from single research units), we strongly worked to create groups bearing an interdisciplinary expertise aimed at resolving specific problems.

We also wish to stress that other researches at Stromboli have already been financed by special funding during the 2002-03 crisis and thus are not contained in the present project. Nominally they are studies of marine geology and researches focused on tsunami propagation.

In the following, we will describe the methodologies separately for Stromboli and Panarea and for tasks.

Stromboli

Task 1. Studies and investigations aimed at the reconstruction of the present structure of the volcano and its feeding system (Stromboli)

Coordinatore Alessandro Tìbaldi
UR Sonia Calvari, INGV-Catania
UR Alessandro Tibaldi, Università Milano-Bicocca
UR Mario Castellano, INGV-Napoli
UR Domenico Patanè, INGV-Catania

The structural models of Stromboli volcano are mainly based on surface geology and on scarce geophysical data. Moreover, our knowledge of the Stromboli volcano structure is limited to the upper few hundreds meters, whereas the giant volcano edifice is mostly submarine and not accessible to direct investigations. The extreme logistic of the volcano inhibits most of the classical geophysical investigations, including local seismicity and the 3D reconstruction of the sub-surface structure. All these methodologies are limited by the present seismic network density and geometry and need the acquisition of data at both inland and submarine stations. Temporary and permanent short period and broad band seismic stations operated on the volcano since several years. The almost continuous volcanic activity with seismic tremors and explosive events are sources of noise in the frequency band usable for earthquake locations, tomography and analysis of waveforms for the recovering of the deep structure. Therefore, seismological studies of past years mostly focused on the definition of the active long period magmatic sources and the modelling of seismic tremor. Broad band data are still not used for inference on the deep structure. In other Italian volcanoes, the use of 2D and 3D active and passive seismic experiments provided useful and original information on the deep structure. The analysis of broad band data could gives further constraints on the volcano deep structure and the presence of the magma chamber. At Stromboli, these studies are still not done. Therefore in order to get a first reliable image of the internal structure of the volcano and also of the part beneath the sea level, the deposition of a first nucleus of OBS/H around the island (RU Favali) and the joint use of seismic methods based on natural and controlled sources are considered in the present project. The integration of land seismological network with temporary

Ocean Bottom Seismometers and Hydrophones will improve, even over a limited time duration, the land-based network geometry during the experiment. Owing to the lack of recorded local earthquakes, as natural sources useful for tomographic purposes and the high cost of a 3D experiment, a preliminary 2D tomographic study will be done (RU Castellano), through active seismics (a series of inland shots and possibly airgun). Such a study, as preparation to realising a future high resolution 3D tomographic study, should be integrated with an high resolution Receiver Function analysis to define the 1D velocity model beneath each station, aimed to identify the crustal magma chamber and relevant discontinuities beneath the volcano (RU Patanè). Furthermore, to improve the first general structural model of the volcano (Tibaldi, 2004) other geological, petrological and structural investigations are considered in this project (RU Tibaldi and RU Calvari). These comprise detailed mapping of the structures related to the upper magma feeding system, represented by recent (Holocene) dykes and eruptive fissures. The products related to these structures will be analysed in a complete way by means of stratigraphic, lithologic, petrographic and geochemical methods. Absolute dating will also be performed. Structural, lithostratigraphic and petrochemical analyses of the logs of two new 200-m-deep boreholes (logged by Scarpa's group at Punta Lena and Timpone with other Civil Protection funds) will also be performed by Tibaldi's and Calvari's Rus, together with their correlation with known surface lithostratigraphic units. We will integrate also these informations with the data on the hydrothermal system coming from Renzulli's RU. The knowledge on Stromboli surface geology acquired in the past years by various teams will be integrated with the new geophysical and geological data here collected and transferred into a new 3-D model, that is presently lacking.

Evaluation of the dangers of effusive and explosive activity (Stromboli)

Coordinatore Mauro Rosi
UR Fabio Speranza, INGV-Roma 2
UR Lorella Francalanci, Università di Firenze
UR Daniele Andronico, INGV-CT
UR Piergiorgio Scarlato, INGV Roma
UR Antonella Bertagnini, INGV-Roma I
UR Mauro Rosi, Università di Pisa
UR Maurizio Ripete, Universita' di Firenze
UR Luca D'Auria, INGV-OV
UR Paolo Favali, INGV-Roma 2
UR Mario Mattia, INGV-Catania
UR Paolo Papale, INGV-Roma1

The eruptive crisis of December 2002- July 2003, the large scale landslide of 30 December 2002 that also affected the submarine part of the volcanic edifice at Sciara del Fuoco, the *tsunami* that it caused as well as the paroxystic event of 5 April 2003, focused attention on the need to define "critical levels", or rather to characterise well the ensemble of indicators that can highlight important status changes of this volcano. Obviously, the reduction of volcanic risk at Stromboli entails a better understanding of the surface feeding system (Task 1). In fact a better knowledge of the configuration of the shallow plumbing system (Task 1) is essential for understanding eruptive dynamics and trigger mechanisms of paroxysms, which are in some way both linked to the arrival of fresh magma at shallow levels. Recharge of shallow plumbing system is believed to be a cause of explosive eruptions and these data are fundamental tools for discovering new magma inputs in the system.
Although numerous studies on the past explosive activity have been carried out in recent years, further improvements in the understanding of the explosive Holocene activity are still necessary, in

terms of eruptive mechanisms, typology and distribution of emitted products, chronology of eruptive events; estimate of the probability of occurrence of volcanic phenomena in terms of typology, scale and recurrence of expected events; the study of the relationships between volcanic activity and lateral collapses. Also the modern eruptive activity at Stromboli has been the object of many investigations of a volcanological and petrological nature. The studies carried out have significantly contributed to improving understanding of the ordinary eruptive processes related to the external and internal dynamics to the conduits and to better characterising the petrology of emitted products. The research carried out on the ordinary explosions and on the paroxystic events have highlighted a close dependence in the dynamics of the magmas in relations to their volatile content.

New improvements on the evaluation of the dangers of effusive and explosive activity on Stromboli could be achieved by RU's Speranza, Francalanci, Rosi and Bertagnini by i) a carefull characterization of the age of all the Holocene volcanics from Stromboli with paleomagnetic study and mineralogical and geochemical, ii) studies of magmas from the main explosive Holocene events (Secche di Lazzaro, Pizzo Sopra la Fossa and Recent Period II pyroclastic deposits), iii) stratigraphic trench method in sectors not studied before, to further expand the tephrochronology of Stromboli and iv) by an integration of fieldwork, geochemical, textural and mineralogical data and numerical modelling, respectively. This in order to understand the pre-eruptive role of magma in triggering the eruptions and the mechanisms governing paroxysmal explosions. All these researches will be primarily devoted to localization of storage zones basing on petrological models and assessment of the dissolved volatile content gradient in the magma column that feeds the explosive eruptions

Inside the project, a multi-disciplinary study of explosive activity on Stromboli will be performed by RU Andronico by detailed investigations on the processes controlling explosive activity. In this study morphological, textural and compositional analysis will be carried out on selected samples in order to constrain degassing processes, fragmentation, transport, cooling and deposition occurring in the shallow portion of the volcanic conduits in collaboration with the RU Scarlato which will perform a systematic sampling and analysis of ash-sized products from individual, well-observed explosions from a single vent using an airborne platform.

The RU Andronico will complement these studies with novel measurements of the flux and chemical composition of gases emitted during both explosive and quiescent degassing. These results will allow detailed calculations of bubble formation and ascent processes within the conduit of Stromboli, that will feedback directly to the textural/petrological analysis of eruptive products and allow comparison with investigations of visual observations of the explosions producing the analyzed samples and to geophysical parameters measured by RU D'Auria, which will also modeling gas bubble rising in arbitrary conduits. Constraining the fundamental physical and geochemical processes that control the explosive process will complement the modeling studies proposed by the RU Papale and provide comparison with volatile studies undertaken within RU Bertagnini.

The RU Scarlato will also provided a determination of the viscosity of Stromboli magma hydrated and these results will be used as input data for simulations of processes occurring in magma chamber and conduit by RUs D'Auria and Papale

Geophysical studies and researches aimed at defining times and modality of recharging of the surface feeding system will be performed by the RUs Mattia, D'Auria and Ripepe. By these RUs which managed the geophysical monitoring systems (geodetic and seismological) deployed on the volcano, we retain that it will be possible to evaluate in the next years, in real or almost real time, the fundamental parameters associated with the explosive activity of the volcano and define the times and modalities of recharging the system. This obviously in reference also to the explosive phases of paroxystic kind and to verify the probability of new effusive eruptions.

In the field of the forecasting of the greatest danger eruptive phenomena, it proves of basic importance to understand the reasons that lead to the sudden rise of highly gas-rich magmatic masses able to produce the most violent explosions and/or paroxysms. In our opinion these new studies should contribute to understanding the very mechanism of the biggest explosions through the study of emitted products and through the data deriving from visual (telecamera), petrological and geochemical monitoring and should equally be aimed at seizing on eventual precursor phenomena. These could be also allowed to tackle the main problematic on estimating the dangers related to the various manifestations of volcanic activity (effusive and explosive) and to the phenomena of instability of the slopes of the edifice, in particular the Sciara del Fuoco (Task 3).

Task 3. Evaluation of possible scenarios of deformation and dynamics of the Sciara del Fuoco (Stromboli)

Coordinatore Nicola Casagli
UR Nicola Casagli, Università di Firenze
UR Tiziana Apuani, Università degli Studi di Milano
UR Alberto Renzulli, University of Urbino
UR Michael Marani, ISMAR-CNR

The historical and stratigraphic data document that the Stromboli system is in its present condition for a little less than two thousand years. Such behaviour has proved exceptionally stable and rarely disturbed in this arc of time. However, in analogy to what occurred during the recent eruptive crisis of 2002-2003, the geological-structural research into the last 10 Ky of its evolution have shown how the volcano has undergone important slope collapses. One of the biggest collapses of the Sciara del Fuoco (SdF) has moreover been related to a great explosive event whose products covered the entire island and whose dynamics may be interpreted as a product of the sudden depressurization of the magmatic and geothermic system. Recent investigations have outlined the submarine deep-water extension of the outcropping collapse scars of the SdF. Continuous surveys and monitoring of ground deformation along the SdF started during the 2002-2003 crisis can provide information about the failure mechanisms which drive the SdF slope instability and possibly suggest the eventual occurrence of a future possible collapse. We want to ensure that thanks to permanent monitoring activity it is possible to formulate even more precise models of the SdF dynamic. In our opinion a substantial improvement in the evaluation of the slope stability and hazard of the SdF is still necessary and this could derive from the cross validation of the independent deformation data. RU Casagli will elaborate the huge amount of ground deformation data acquired during the eruptive crisis and afterward by the deployed geodetic permanent monitoring systems (GBInSAR and Thedoro system). This in order to define the deformation pattern that have characterised the different portions of SdF and model the recorded ground deformation time series with both stochastic and deterministic approaches. Further numerical model of the SdF slope instability will be performed by the RU Apuani while an evaluation of the hydrothermal alteration state, which can also reduce the rock permeability enhancing the transmission of thermal pressurization, will be performed by the RU Renzulli. Finally a careful study of the transport and depositional processes of the 30/12/2002 by investigation of the unstudied portion of the debris avalanche deposits aimed also to distinguish morphology and thickness of recent and past landslide deposits will be performed by RU Marani. All these new investigations and researches could give a better comprehensive view of the failure mechanisms which drive the SdF slope instability and of its relationship with periodic recharge of the shallow feeding system.
We envisage a strong collaboration between all these groups, which will allow to correlate field data with numerical modelling and with monitoring data. This is not a common procedure because

it requires a complete knowledge of data coming from several different methodologies and from different groups of research, which must really cooperate. By the comparison and correlation between all these data it will be possible to validate simulations, modelling and interpretations. We remind that instability of Sciara del Fuoco, even for small landslides, represents a high hazard for the coasts of Stromboli, of the other Aeolian Islands, as well as for the southern Italian coasts of the peninsula and of Sicily. Landslides also of moderate size can produce tsunami whose recurrence can be very much higher than previously thought.

Task 4. Studies aimed at understanding the circulation of fluids

UR Corrado Cigolini, Università di Torino

Geochemical studies will be aimed at a better understanding of the transfer mechanisms of the magmatic gases from the deep system towards the surface and the individuation of interaction mechanisms with surface structures. These will be achieved by the works of a series of RU dealing with gas measurements all over the islands and in the active plume. Radon will be measured with the use of E-PERM detectors, new in monitoring active volcanoes. These have the advantage of minimising the exposure time to 1-4 days, thus increasing the possibility of correlating radon emissions with variations in the volcanic activity. Data collection, coupled with tracketch detectors (LR115) to overcome short-term fluctuations in radon, will be deployed on all the island, thus completing the present network which covers only the NE side of the cone. This will give a comprehensive view of how the volcano undergoes degassing in respect to its structural and magma dynamics. For this purpose, these data will be correlated with the new fractures developed in the summit part of the island in the last years in cooperation with the Tibaldi RU, with the seismicity patterns in cooperation with the Ripepe RU, and with other gas fluxes surveyed in the plume outpoured from the active craters in cooperation with the Burton RU.

Panarea

Task 5. Reconstruction of the explosive Holocene events and evaluation of the presence of a magmatic body in the area

Coordinatore Claudio Antonio Tranne
UR Claudio Antonio Tranne, Università di Bologna
UR Donatella de Rita, Università di Roma 3

Recent studies in the Panarea area have shown the presence of deposits attributable to younger explosive activity than believed to date. A better knowledge of the most recent volcanic activity will be achieved by field and laboratory analyses focused on the youngermost products cropping out in the Panarea Island and in the various smaller conterminous islands (De Rita RU and Tranne RU). Stratigraphic reconstructions and absolute dating by radiometric techniques of the final explosive and effusive products will be carried out. Facies and sedimentological analyses will allow to define the eruption style and the degree of magma/water interaction. Particular attention will be given to the Palisi and Punta Falcone successions. These islets, in fact, have been interpreted as domes and are aligned along the main NE-striking fracture system whose prolongation coincides with the western margin of Stromboli. Considering that the recent degassing processes in the islets area and the last Stromboli eruption occurred contemporaneously, it is very important to know the exact stratigraphic position of these domes. Isotopic studies will also be performed on these recent products, in order to collect information on the different magmatic events. He/He ratios will be useful not only to know the isotopic composition of the most recent eruptions of Panarea, but also

to interpret the He/He values measured in the fumarolic gases emitted in the islet zone. This will be useful also to understand if these gases have or not a direct magmatic provenience.
We wish to highlight that an oceanographic cruise for geophysical prospecting on the possible presence of a magmatic body in the area east of Panarea has been taken into consideration. This has not been included in the present project for budget reasons as well as because the depth of the sea-bottom in the area is too low for the presently available vessels.

Task 6. Definition of the conditions leading to the development of the fracture field of the 2002-03 crisis along the Panarea-Stromboli axis

UR Massimo Mattei, Università ROMA TRE

At the end of 2002 there were various volcanic and deformation phenomena in the area of Panarea-Stromboli. The temporal coincidence of the phenomenologies and the breadth of the area affected pose notable questions on the causes and dynamics of the processes. In order to evaluate the possible causes triggering the NE-striking fracturing between Panarea and Stromboli, we want to study the influence of the regional tectonics on the local stress/deformations fields of eastern Aeolian islands through the integrations of numeric, analogue and real data (Mattei RU). New field structural data will be collected in the Panarea area and integrated with the data already mapped at Stromboli. These data will be correlated with the ones concerning the historical and instrumental seismicity of the eastern Aeolian archipelago. Published gravimetric, bathymetric and earthquake focal mechanism data will also be considered in order to define the Quaternary tectonic structures and kinematics of the area. All these data will be integrated into numerical modelling based on the Coulomb stress models. These models, widely used to minimise seismic and volcanic hazards, permit to understand the stress changes related to the activity of a fault, a dike, or an inflation source, taking also into account for mechanical heterogeneities and topography. The research group responsible for this task will strongly interact and take account of the on-going results, which will be reached in particular in the context of task 7.

Task 7. Studies aimed at understanding fluid circulation

UR Bruno Capaccioni, Università of Urbino

The Panarea crisis of November 2002 has led to a notable increase in the geochemical activity following the submarine escalation east of the island, in the Lisca Bianca-Dattilo-Bottaro area. Monitoring of the emitted gases has been carried out during this crisis. We want to ensure a prosecution of this monitoring activity as well as to formulate models based on fluid circulation also on the post-2002 data set. A detailed mapping of submarine gas emanations will be carried out by an IR Laser system (RU Capaccioni). In situ measurements (pH, temperature) and collection of gas samples by scuba-diving will be performed. Helium isotope ratios will be analysed from gas samples collected in submarine and sub-aerial conditions. In order to improve the comprehension of the meaning of the geochemical composition of these gases, as already describe above, isotopic data on He/He of the main magmatic products of the Panarea eruptive complex will be correlated. The geochemical aspects linked with the interaction between gas of magmatic origin and/or geothermics with sea water will also be investigated. A comparative analysis of thermo- and redox-sensitive inorganic and organic compounds will allow to better understand the chemical-physical processes acting in the hydrothermal feeding system and their spatial and temporal variability.

4. List of deliverables

Stromboli

Task 1. Studies and investigations aimed at the reconstruction of the present structure of the volcano and its feeding system (Stromboli)

1. Structural models of the volcano
2. Distribution map of Holocene dikes
3. Distribution map of lava flows from Holocene fissure
4. Scenarios of preferential diking in the cone based volcano and the various possible dike parameters
5. 2D seismic tomography sections of the volcano
6. Identification of the main deep discontinuities

Task 2. Evaluation of the dangers of effusive and explosive activity (Stromboli)

1. Reconstruction of eruption history and dating of the principal Holocene explosive events
2. Characterisation of the main explosive Holocene eruptions and reconstruction of their eruptive dynamics
3. Evaluation of the occurrence frequency of volcanic events.
4. Sampling and mapping of the products of ordinary activity and products emitted during past modern paroxysms
5. Laboratory measurements on magma properties
6. Relationships between eruptive dynamics and surface feeding system of the volcano
7. Evaluation of the trigger mechanisms of paroxystic eruptions; analysis of current activity.
8. Broadening of the analysis techniques of low frequency signals (tremor, explosion quakes, LP and VLP) also in terms of automatic processing
9. Deformation fields induced by recharging phenomena in the diverse levels of magma "storage" at Stromboli by means of ground deformations data.
10. Modelling of strain fields caused by the action of the conduit/s, and simulation of expected deformation fields
11. Models of simulation of the eruptive processes
12. Study of the seismicity associated with strong explosions aimed at constraining the variations at depth of the fragmentation level

Task 3. Evaluation of possible scenarios of deformation and dynamics of the Sciara del Fuoco (Stromboli)

1. Expected deformation scenarios of the SdF on the grounds of possible casuistic
2. Determination of the thermal, hydrothermal and pore pressure contributions on the instability of the SdF
3. Evaluation of the hazard linked to the dynamics of the SdF slope.

Task 4. Studies aimed at understanding the circulation of fluids

1. Data sets on geochemical discharge
2. Formulation of geochemical models on the relationships between the geothermic system and the gas interchange with the deeper magma sources.

Panarea

Task 5. Reconstruction of the explosive Holocene events and evaluation of the presence of a magmatic body in the area

1. map of the distribution of the most recent explosive/effusive products
2. dating of the main most recent volcanic events
3. characterisation of the eruptions and reconstruction of the eruptive dynamics

Task 6. Definition of the conditions leading to the development of the fracture field of the 2002-03 crisis along the Panarea-Stromboli axis

1. map of the late-Quaternary regional structures
2. map of the regional/local stress field
3. fracture models of the area

Task 7. Studies aimed at understanding fluid circulation

1. models of fluid circulation in the area
2. models of the cause of the crisis of 2002

PROJECT V2 – STROMBOLI AND PANAREA

TABLE MAN/MONTHS

U.R	Institutions	Principal Responsibles	Task1 Stromboli Present Structure and feeding system	Task2 Stromboli Eruptive dangers	Task3 Stromboli Sciara del Fuoco	Task4 Stromboli Fluid circulation	Task5 Panarea Eruptive history	Task6 Panarea Fracturing	Task7 Panarea Fluid circulation	Mesi p. cofin.	Mesi p. rich.
UR-1	INGV-CT, INGV-OV, UniMI, CNR-IDPA	Calvari, Orsi, Groppelli	@							58	
UR-2	UniMiB, UniIns, UniUrb, UniFi, UniRoma Tre, Acad. NAUK (RU)	Tibaldi, Pasquarè	@							50	17 (UniMiB)
UR-3	INGV-CNT, INGV-CT, INGV-OV, INGV-Rm1, UniFi	Castellano, Chiarabba, Bianco, Pino, D'Auria, Martini, D'Anna	@							75	
UR-4	INGV-CT, INGV-CNT	Patanè, De Gori	@							29	
UR-5	INGV-Rm2, INGV-Rm1, UniAix (FR)	Speranza, Sagnotti		@						24	
UR-6	UniFi, CNR-IGG, GZG-Goettingen (D), UniDarham (UK)	Francalanci, Tommasini, Vagelli, Heumann		@						61	
UR-7	INGV-CT, CNRS (FR), UniBristol (UK)	Andronico, Burton, Corsaro, Allard		@						59	
UR-8	INGV-Rm1	Scarlato, Taddeucci, Freda		@						20	
UR-9	INGV-Rm1, UniPi, CNRS (FR)	Bertagnini, Landi, Pompilio, Metrich		@						40	

UR-10	UniPi, INGV-Rm1, UniCa, CNRS (FR)	Rosi		@						38	
UR-11	UniFi, INOA Fi, UniHawaii (USA), UniAlaska (USA)	Ripepe, Harris		@						48	12 (UniFi)
UR-12	INGV-OV, CNR-IAC, USGS, UniLancaster (UK)	D'Auria		@						30	
UR-13	INGV-Rm2, CNR-ISMAR	Favali		@						28	24 (Borsa di Studio INGV-Rm2)
UR-14	INGV-CT, UCSD (USA), INGV-Rm1	Mattia		@						36	
UR-15	INGV-Rm1, UniPi, SNS-Pi, INGV-OV	Papale, Longo, Barsanti		@						31	
UR-16	UniFi, UniCt, INGV-CT, IPSC-SERAC,	Casagli, Nunnari, Puglisi, Fortuny			@					36	36 (UniFi)
UR-17	UniMi, UniMiB, UniUrb	Apuani, Beretta, Sfrondini, Cancelli			@					29	12 (UniMi)
UR-18	UniUrb, UniPar, UniCopenaghen (DK)	Renzulli, Mattioli, Santi, Salvioli-Mariani, Tribaudino, Serri, Venturelli			@					86	10 (UniUrb)
UR-19	ISMAR-CNR, UniCt	Marani, Gamberi, DI Stefano			@					60	
UR-20	UniTo, UniMi, OpenUni (UK)	Cigolini, Gervino, Bonetti, Callegari, Blake				@				48	10 (UniTo)
UR-21	UniBo, INGV-OV, UniTo, Uni-Freiburg (D)	Tranne, De Astis, Lucchi					@			27	
UR-22	UniRmTr, Ismar, UniBo	De Rita, Dolfi, Gasperini					@			64	12 (UniRmTre)

UR-23	UniRmTre, INGV-CT, RSMAS Miami (USA)	Mattei, di Grazia						@		20	12 (UniRm Tre)
UR-24	UniUrb, UniFi, UniNaII, UniIns	Capaccioni, Vaselli, Tedesco, Dossi							@	43	
Totale										1040	145

PROJECT V2 – STROMBOLI AND PANAREA

Table RU and related funding request

N. UR	Istituz.	Resp UR	Personale		Missioni				Consumi servizi		Inventariabile	
					Italia		Estero					
			2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
UR-1	INGV-CT	Calvari			1500	5000	1500	5000	12000	10000		
UR-2	UNIMiB	Tibaldi	8000	15000	4250	4000	1500	1500	1600	2150		
UR-3	INGV-CNT	Castellano				5000			3000	78000	5000	
UR-4	INGV-CT	Patanè			1500	2000	2500	3000	3000	5000	2000	
UR-5	INGV-Rm2	Speranza			6000	4000	2500	4500	1000	1000	3500	2500
UR-6	UniFi	Francalanci			3000	3000		2000	8000	9000		
UR-7	INGV-CT	Andronico			2000	2000	6000	6000	6000	6000	2500	
UR-8	INGV-Rm1	Scarlato			4000	4000	1000		8000	2000	1000	
UR-9	INGV-Rm1	Bertagnini			4000	4000	1000	1000	10000	10000		
UR-10	UniPi	Rosi			2500	3500	1500	1500	9000	9000		
UR-11	UniFi	Ripepe		18000	3000		3000		1000		2000	
UR-12	INGV-OV	D'Auria			1500	1500	10500	10500	3500	3500		
UR-13	INGV-Rm2	Favali[1]			2000	2500		2000	4000	5500		
UR-14	INGV-CT	Mattia			3000	1500	8000	3000	15000	4500		
UR-15	INGV-Rm1	Papale			2500	2000	2000	2500	6000	6000	3000	3000
UR-16	UniFi	Casagli	30000	17000								
UR-17	UniMi	Apuani	15000		3650	4000		2700	12150	500		
UR-18	UniUrb	Renzulli		14000	3500	2500	2500		6000	1500	6000	
UR-19	CNR-ISMAR	Marani			200	1250	800	1750		15000		
UR-20	UniTo	Cigolini	7000	7000	3000	2000		1000	500	500	2000	
UR-21	UniBo	Tranne			6500	3500	1500	500	3000	6000		
UR-22	UniRmTre	De Rita	8000	8000	2000	1000	1500	2500	5500	5500		
UR-23	UniRmTre	Mattei	18000		2000	2000	1000	1000		1000	2000	
UR-24	UniUrb	Capaccioni			13000	6000		3000	3000	1000		
		TOTALE	**86000**	**79000**	**74600**	**66250**	**48300**	**54950**	**121250**	**182650**	**29000**	**5500**
GRAN TOTALE: 747500												

PROJECT V3

Research on active volcanoes, precursors, scenarios, hazard and risk

Responsibles:

Paolo Papale, INGV Roma1
Stefano Gresta, Univ. Catania

Project V3

Research on active volcanoes, precursors, scenarios, hazard and risk

Responsibles:

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Project Organization

The project is organized in seven sub-projects, each related to a volcanic area in Italy for which research within the project is foreseen. Due to practical difficulty in keeping a close coordination of such a huge project, we propose to be supported by sub-project coordinators, selected among the researchers involved in each sub-project, and who are recognised by the scientific community to have significant skills in that specific volcanic area, as well as coordination capabilities. Sub-project coordinators will keep a closer control and coordination of the activities in their specific volcanic area, will represent the V3 project responsibles in front of sub-project participants, and will provide transfer of information between the project responsibles and participants. V3 project responsibles reported above keep the general responsibility and coordination of the whole V3 project, and also act as sub-project responsibles for the volcanic areas on which their scientific participation is maximum. The proposed sub-project coordinators already gave invaluable help and support to project responsibles in defining the scientific themes and requested deliverables, and managing the organization of each sub-project during the various phases of project preparation.

The seven volcanic areas (and related sub-project number), and the proposed sub-project coordinators are reported in the Table below.

V3 Project Organization		
Sub-Project Number	**Sub-Project Name**	**Proposed Coordinators**
V3_1	Colli Albani	Piergiorgio Scarlato, INGV Roma1 Mario Gaeta, Univ. Roma1
V3_2	Campi Flegrei	Paolo Papale, INGV Roma1 Lucia Civetta, Univ. Napoli and INGV-OV Napoli
V3_3	Ischia	Giovanni Orsi, INGV-OV Napoli Alessandro Aiuppa, Univ. Palermo
V3_4	Vesuvio	Edoardo Del Pezzo, INGV-OV Raffaello Cioni, Univ. Cagliari
V3_5	Vulcano	Gianfilippo De Astis, INGV-OV Piero Dellino, Univ. Bari
V3_6	Etna	Stefano Gresta, Univ. Catania Augusto Neri, INGV Roma1 Ciro Del Negro, INGV-CT
V3_7	Pantelleria	Walter D’Alessandro, INGV-PA Luigi Tortrici, Univ. Catania

Objective of the project

The general objective of the whole V3 project is the definition of the criticality levels and the assessment of the volcanic hazard for the above seven active volcanoes. Criticality levels (or the associations of signs reflecting a change in the state of a volcano) and hazard are not simply a consequence of a better knowledge of the volcanic system, although in-depth knowledge of many different aspects of the system is strictly required. Rather, they are the subject of specific research in the project, and are represented by clearly identified research products.

Although criticality levels and hazard are the common objective of all V3 sub-projects, such an objective will be accomplished at different levels reflecting the different degree of knowledge at each volcano. The specificities of each volcano in terms of its typical activity and/or expected phenomena are also taken into account in the research development and project deliverables. In all cases the general project objectives will be pursued through a strongly coordinated interdisciplinary approach, with intermediate and final research products that according to the INGV-DPC Agreement, are globally the followings: 1) Definition of the feeding system; 2) Definition of the edifice and lithosphere structure; 3) Definition of the hydrologic and geothermal system; 4) Identification and quantification of precursors; 5) Physical modelling and numerical simulation of pre-eruptive processes; 6) Estimate of the typology and scale of expected eruptive events; 7) Reconstruction of the eruptive history through the study of the volcanic deposits; 8) Probability associated with the scale and typology of expected eruptive events; 9) Physico-numerical simulation of sin- and post-eruptive processes; 10) Estimate of volcanic hazard.

The detailed description of the activities foreseen in project V3 and of the expected deliverables, and the details of the financial request and participating RU's, are reported in the following, within the description of each single sub-project. The Table below shows in a synthetic way the financial request under Project V3, divided in sub-projects and year of funding.

Table of financial request per sub-project within Project V3.

Sub-Project	**Financial Request 2005 (keuro)**	**Financial Request 2006 (keuro)**	**Financial Request, Total (keuro)**	**Percent of Financial Request**
V3_1. Colli Albani	349.5	295.5	645	14.9
V3_2. Campi Flegrei	425	409.5	834.5	19.3
V3_3. Ischia	205.5	193.5	399	9.21
V3_4. Vesuvio	335.5	307	642.5	14.8
V3_5. Vulcano	218.5	186	404.5	9.33
V3_6. Etna	576	563.5	1139.5	26.3
V3_7. Pantelleria	138.5	131	269.5	6.22
Total V3	**2248.5**	**2086**	**4334.5**	**100**

PROJECT V3

Sub-Project V3_1 – Colli Albani

Responsibles:

Paolo Papale, INGV Roma1
Stefano Gresta, Univ. Catania

Project V3

Sub-Project V3_1 – Colli Albani

Coordinators:

Piergiorgio Scarlato, Primo Ricercatore, Istituto Nazionale di Geofisica e Vulcanologia, via di Vigna Murata 605 - 00143, Roma, scarlato@ingv.it tel +390651860437, fax +390651860507

Mario Gaeta, Ricercatore, Dipartimento di Scienze della Terra, Università degli Studi di Roma "La Sapienza", P.le Aldo Moro 5 - 00185 Roma, mario.gaeta@uniroma1.it, tel +390649914916, fax +39064454729

State of the Art

The Colli Albani is a quiescent Volcanic District that belongs to the potassic and ultrapotassic Roman Magmatic Province, a northwest-trending chain of volcanoes that developed along the Tyrrhenian Sea margin of Italy during middle and late Pleistocene time.

The volcanic history of the Colli Albani Volcanic District is volumetrically dominated by the explosive eruptive activity of the so-called Tuscolano-Artemisio Phase which started 561 ka and ended 366 ka, At least five large (tens of km^3) pyroclastic-flow deposits together with a significant (approximately 2 km^3) lava flow, were emplaced during the Tuscolano-Artemisio Phase. The formation of a caldera marked the end of this phase of activity. After about 50 kyr of dormancy, a mainly effusive activity took place from 308 to 250 ka; this mainly effusive period was accompanied by strombolian activity at the Monte delle Faete Edifice, situated near the centre of the caldera, and by sub-volcanic activity in the peripheral centers. After another dormancy period of about 50 kyr, a mainly hydromagmatic phase, characterized by pyroclastic-surge eruptions from multiple tuff rings and by the lack of effusive events, started in several centres located to the southwest of the Monte delle Faete Edifice. The Albano maar (<70 ka) represents the most recent and voluminous activity of this phase and cannot be considered extinguished yet.

The primitive Colli Albani magmas is thought to result from the combined effects of crystal fractionation and crustal assimilation on a parental magma derived from a source mantle consisting of a phlogopite-bearing peridotite previously metasomatized by subduction-related fluids or melts. The volcanic products from Colli Albani are ultrapotassic and characterized by a narrow SiO_2 and alkali range, high LREE/HREE ratio, high $^{87}Sr/^{86}Sr$ initial ratio and plagioclase-free paragenesis. On the basis of low SiO_2 and the constant radiogenic isotope ratio Colli Albani magmas were interpreted to be primitive magmas. The difficulty in understanding the petrological evolution of the Colli Albani magmas was due to the unusual SiO_2 depletion of residual melts, to the rare glass-bearing juvenile products and to the scarcity of primitive olivine-bearing cumulate. Plumbing systems of the Roman Province volcanoes emplaced into continental crust, and recent studies demonstrated that the petrogenetic processes in the Colli Albani plumbing system are strongly affected by the high CO_2, Ca, and O_2 activities due to the presence of carbonatic rocks around magma chambers. These studies also suggest a change in the geochemical features of the youngest Colli Albani primitive magmas. This can be interpreted as the exhaustion of the metasomatic phlogopite-bearing veins in the mantle or, alternatively, as a higher degree of partial melting involving the normal peridotitic component of the metasomatised source resulting in a rejuvenation of the plumbing system. In terms of modeling long terms hazard related to volcanic eruptions, it is mandatory to discern between the two hypothesis. Moreover the decarbonation processes occurring at high pressure in a plumbing system emplaced in thick carbonatic rocks can affect the phase equilibria of the primary magmas. Previous works suggest that interaction between magmas and wall rocks can trigger decarbonation processes resulting in diffusion transport of CO_2 in both, the magmatic system, having effects on the differentiation processes, and in the country rocks with possibly effects on the regional degassing.

The Colli Albani Volcanic District, indeed, is presently characterized by a steady-state diffuse exhalation of natural gases from soils and aquifers. These gases were interpreted as geochemical manifestations, at surface, of a the deep volcanic system, still active. Carbon dioxide is the main released gas together with minor amounts of ^{222}Rn, H_2S, He, and trace gases. In 1995 following an episode of strong degassing in water wells and soils, a geochemical micro-zonation hazard assessment was performed. The carbon dioxide turned out to be an excellent marker of faults because acting as pathways for deep fluids. Moreover, anomalous degassing areas were found to be coincident with gravity positive anomaly, drawing at surface, with their geometry the deep structures. Unfortunately this detailed study was carried out only in a small portion of the Colli Albani and the available geochemical data are not useful neither to individuate the areas affected by intense degassing nor to develop a model for the deep fluid circulation or to define the narrow relationships between anomalous degassing and faults.

The crustal structure and seismogenic processes at Colli Albani have been investigated after the 1989-90 seismic swarm. Recent studies have improved the knowledge on the crust and on the state of stress beneath the volcano but the debate on the existence, location and geometry of the magma chamber is still open. The seismic tomography of the upper crust reveals high Vp and Vp/Vs bodies between 3 and 5 km depth beneath the area where the most recent activity occurred. The anomalies were interpreted as solidified magma bodies intruded in the past volcano activity. The seismicity is mainly located around it suggesting that the main volcanic source is located within the intrusive mass. The lack of low velocity anomalies interpretable as molten material suggests that magma reservoir is too small to be detectable by P-wave velocities or that is at greater depth. A teleseismic model down to 22 km depth reveals a high velocity body beneath the Monte delle Faete cone between 5 and 15 km depths, interpreted as a solid magma reservoir, flanked on the western side of the district by a low velocity anomaly, expression of molten material, probably responsible of the recent eruptions. The seismicity in the area is concentrated between 3 and 6 km depth, defining a 12 km NW-SE elongated area, passing through the Albano and Nemi lakes.

Also the strong uplift revealed in the Albano and Nemi lakes region by geodetic data suggests that deep processes are strongly active beneath the NW sector of the volcano. The recent use of geodetic techniques like GPS, high precision leveling SAR, and gravity surveys detected significant ground deformation in the Colli Albani area. Since 1981 data were collected showing significant gravity changes. The InSAR PS technique shows that the zone around the most recent craters of Albano and Nemi underwent, between 1992 and 2000, a steady uplift with rates up to 4 mm/yr. A minor uplift in the Solfotara area and a subsiding area near Marino, of unknown origin (aquifer depletion?) are evidenced. The ground velocity seems to be high also in the southern area of Colli Albani but the lack of data does not allow evaluating the total extent of the uplifting in the southern area.

The area surrounding the Albano Maar Lake, currently is the one most strongly characterized by the occurrence of geophysical and geochemical manifestation of a still-active subvolcanic system which are hazard factors for the resident population. This area is the locus of the most recent magmatic and non-magmatic volcanic activity, including hydromagmatic and possible phreatic and hydrothermal eruptions, as well as secondary mass flows, whose modes and times are still debated. Moreover, the Albano Maar presently hosts the deepest crater lake (-173 m) in Italy. A stratified structure of lake water, with carbon dioxide accumulation at the base, is already known, and must be further studied for its potential hazardousness. Moreover, the inner slopes of the lake are very steep and recent studies indicated that some human structures and infrastructures are exposed to landslide hazard. However there are no rigorous computations of landslide hazard neither quantitative data on the expected landslide intensity.

Description of Activities

The Colli Albani Volcanic District has been identified as a quiescent volcano only recently, and, for this reason, received relatively less attention in respect to other, historically active, volcanoes of Italy. The present project is the first one specifically oriented to a future definition of potential hazards and crisis levels at Colli Albani. Considering gas emissions, seismic swarms, and ground deformation as the most compelling activities of the District, and starting from the actual level of knowledge, this project gives priority to four topics: 1) the evolution and current state of the magmatic system, including the presence and location of possible magma chambers and the role on magmatic processes on the origin of surface gas output; 2) the genesis and mobility of hazardous gases in ground and surface water bodies, degassing cycles, and effects on degassing of anthropic hydrological perturbations; 3) the deep setting of the District and the source of seismicity and regional-scale ground deformation; 4) the dynamics of the District at shallow and surface levels and their interferences with human activities, including local-scale ground deformation, stress field, slope stability, recent eruptive processes, crater lake evolution, quaternary mass flows. These four priorities/Tasks will illuminate the causes of present hazards and serve as a base for further, risk-oriented investigations.

Task 1 Magmatic System
Coordinating: RU1 Gaeta (Università di Roma "La Sapienza")
Participating: RU2 Scarlato (INGV)

In order to investigate the evolution and current state of the magmatic system, the first step will be to sample and analyze primitive lava flows and ultramafic ejecta outcropping in the area. Combining modal and geochemical features of collected samples it will be possible to define the most probable primary magmas and possibly also the primitive one. Once defined the composition of the primary magma and that of the most probable source for the Colli Albani magmas, these compositions will be used as starting material to experimentally constrain the high pressure processes occurring in the plumbing system, and to model the melting processes occurring in a metasomatized mantle, respectively. These data will give constraints on the definition of the geometry and P-T conditions of the source in the structural domain for Task 3. Moreover, by combining petrological information coming from juvenile products, hypoabyssal rocks, glasses and melt inclusions we will define the liquid line of descent and model the differentiation processes. Once defined the possible parental composition of the Colli Albani liquid line of descent, experiments will be performed at subvolcanic pressure and liquidus temperature under high CO_2 fugacity conditions in order to model the processes controlling the peculiar liquid line of descent of Colli Albani magmas, and experimentally constraints the role of CO_2 in the evolution of Colli Albani magmas. In particular, to define the role of magmatic processes on the origin of surface gas output, the processes occurring at the magma/wall rock interface will be experimentally studied throughout decarbonation experiments on primary and parental compositions. The experiments will be performed at volatile buffered conditions, low and high pressures and variable temperatures. High pressure experiments performed on primary composition will give information on the deep portion of the plumbing system (i.e., the magma pool at the base on the carbonatic units) while the low pressure ones, performed on parental compositions, will constraints the environment at shallow levels of the plumbing system (i.e., the magma chamber. In particular, the experiments will give information on the melt composition and liquidus phase stability under Ca and CO_2 high activities and thus they will allow to crosscheck the composition of the Colli Albani parental magma as resulted from petrological studies. Chemical exchanges between carbonate and primary Colli Albani magma should leave in the resulting magma some specific anomalies in trace elements that will be measured on experimental and natural products. Finally, from the decarbonation experiments it can be estimated the amount of CO_2 involved in the decarbonation process and the amount of CO_2 that will escape and eventually reach the surface. We will experimentally constrain the rate of CO_2 released during the carbonate-magma exchange by investigating the rate of calcite dissolution at high pressure and temperature. These results, will permit the interpretation of CO_2 fluxes measured at the surface by Task 2. High pressure experiments will be performed in a piston cylinder at the INGV; low pressure experiments will be performed in an IHPV at the ISTO (Orleans) and at the University of Hannover (Germany). Analyses of natural and experimental products will be performed with different methods such as ICP-MS laser ablation, EMPA, SIMS, FTIR, KFT, and SEM.

Task 2 Water Geochemistry
Coordinating: RU3 Pizzino (INGV)
Participating: RU4 Carapezza (INGV), RU5 Tuccimei (Università di Roma Tre)

The area of the Colli Albani is presently characterised by a steady state diffuse exhalation of natural gases from soils and aquifers. These gases represent the geochemical manifestation, at surface, of the deep volcanic system, still active. Carbon Dioxide is the main released gas, together with minor amounts of ^{222}Rn, H_2S, He and other trace gases, and constitutes actually the main dangerous phenomena for the local population.

This Task will be devoted to study: 1) the chemical-physical characteristics of ground and lake waters in the Colli Albani domain, individuating both the different existing water's families and/or aquifers (shallow and deep); 2) the effect of the groundwater depletion on the concentration of gas dissolved in ground and surface waters; 3) the chemical-physical characterisation of gas phases in order to define their origin and the interaction processes with rocks and waters, 4) definition of P and T conditions of the geothermal reservoir; 5) the cyclicity of deep gas release.

For the studies 1), 2), 3), and 4), 200 private and public springs and wells will be analysed in the Colli Albani area and surroundings; on each site chemical-physical parameters (temperature and salinity, by a conductivity-meter, pH and redox potential by potentiometry), alkalinity (by titration with HCl) as well as dissolved radon content (by alpha and gamma radio-nuclides detection methods) will be measured in the field. Basing on these data, 50 sites will be individuated for the laboratory analyses of major elements (by ionic chromatography), selected minor and trace elements of geo-tectonic interest (SiO_2, Li, B, Br and Sr by IC-Plasma), dissolved gases and isotopic composition of strategic elements. $^3He/^4He$ and $^{12}C/^{13}C$ isotopic ratios will be measured. The aquifer static level will be also measured.

Geochemical campaigns on Albano and Nemi Lakes, temporarily distributed so to cover the main seasons in order to study the possible influence on the water chemistry of seasonal environmental variations will be performed. Samples of deep waters will be collected and chemically and isotopically analysed. Water isotopic composition ($\delta^{13}C$ of total dissolved carbon, oxygen and deuterium) will be determined as well as the $^3He/^4He$ isotopic ratio of dissolved helium, provided that enough He and Rn concentration will be found. The chemical and isotopic composition of the dissolved gas phase will be compared with that of the free gas released from the soil in zones of high emission (e.g. Cava dei Selci, Solforata) in order to investigate the gas origin and the possible occurrence of interaction processes of rising fluids with rocks and waters.

For the studies 5), evidences of deep CO_2 periodic release in the area of Colli Albani volcano are offered from U-series disequilibria dates and O and C isotopic composition analyses of speleothems from a Roman-age quarry. These analyses also showed that periods of deposition interrupted by episodes of CO_2 release at the Colli Albani are connected with earthquakes. This research will be extended to other sites all over the Colli Albani area such as natural or artificial cavities where recent carbonatic deposits have been found, aiming to define the timing of deep gas release connected with seismicity in the area. The research will be integrated with the present day study of the hydrogeological setting and the geochemical characterisation of the ground water in the investigated sites. This represents the background conditions that can be modified by the rock deformation preceding an earthquake. The bulk of these data represents a contribution to model the hydrothermal circuit of the Colli Albani volcanic area as well as the assessment of the end members of the mixing processes between the ground water and the fluid from the Earth interior.

Other researcheas useful for this task will be performed in the V5 project and the results will be integrated and compared with those obtained in this project (see V5 RU Carapezza).

Task 3 Structure of the Lithosphere Underlying the Volcanic District
Coordinating: RU6 De Gori (INGV)
Participating: RU7 Poe (Università di Chieti, INGV)

In order to define the deep setting of the Colli Albani Volcanic District and the sources of seismicity, a passive seismic experiments will be carried out by using a temporary array of at least 20 digital seismic stations, continuously recording, equipped with 5 s or broad band seismometers. The goal of the experiment is to record teleseismic, regional events, and, if any, the background seismicity, and to create a seismic waveforms database suitable for seismological studies. The seismic data, will be then used to obtain a Vp and Vs model of the crust and uppermost mantle and the horizontal components of the teleseismic waveforms, in particular, will be used to interpret converted S phases from the discontinuities with strongest impedance contrasts (i.e. the Moho and the main mantle discontinuities). In a volcanic environment, indeed, this approach is very important in order to study the geometry of the magmatic and intrusive bodies. Furthermore, the creation of a Vs model obtained by the inversion of receiver functions will give us the opportunity of better define the rheology of the volcanic plumbing system in terms of Poisson ratio. New detailed images of the crustal structure will be also obtained by seismic tomography. The joint analysis of Vp, Vp/Vs, and attenuation results will allow to better recognize the crustal heterogeneities, the volumes of magma accumulation or region with a high degree of saturation. All the results referring to the geometry and position of magmatic bodies will be crosschecked with the experimental studies performed on the plumbing system by Task 1 and the Vp and Vs recovered by the seismic tomography will be compared with values obtained on sample rocks by laboratory procedures in order to strengthen the final interpretations. All experimental work regarding the Vp, Vs data will be carried out in the HP-HT Laboratory of INGV in Rome by using a multi anvil apparatus. It will be developed a methodology for the measurement of ultrasonic wave velocities in rocks over a wide range of P and T. Travel to a high-pressure X-ray beamline at either Spring-8 (Japan) or Advanced Photon Source (USA) is requested in order to verify the length (P,T) surface under identical P,T conditions using identical high P assemblies. Moreover, complex impedance spectroscopy will be performed on rocks representative of the Colli Albani magma and of the wall rocks. Some experiments will be preceded by rehydration of volcanic rocks to assess the influence of dissolved water on magma electrical conductivity. Other experiments will involve re-equilibration of the starting materials at varying P, T conditions in order to determine the influence of melt content on bulk conductivity. Forward modelling of the conductivity data will be used to generate 1-D and 2-D apparent resistivity sections for different magma/wall rock configurations.

Task 4 Structure and Dynamics of the Volcanic District
Coordinating: RU8 Riguzzi (INGV)
Participating: RU9 Mariucci (INGV), RU10 Giordano (Università di Roma Tre), RU11 Taddeucci (INGV), RU12 Bozzano (Università di Roma "La Sapienza"), RU13 Marra (INGV)

This Task will focus on recent and current processes occurring at shallow level, either within the volcanic pile or at its surface. However, both gathering the necessary input data and interpreting the results will require a strong cooperation with the other Tasks, in particular with Task 3 on the structure of the deeper part of the area.

Different geodetic techniques, like GPS, high precision leveling, PS-InSAR and gravity surveys, will be used to estimate spatial and temporal distribution of the velocity field and 3D deformation of the area, providing deliverables that will integrate with those achieved by Task 3 in defining the nature and location of the source of seismic and ground deformation. GPS surveys will be carried out to assess reliable horizontal velocity and strain fields. To compute, for the first time at a volcanic area, the absolute values of stress principal axes, hydrofrac tests will be performed in two drillings in key areas of the volcanic district. The two boreholes will also allow to characterize the geo-mechanical behavior of drilled rocks.

Data from deep and shallow boreholes, together with gravity data and systematic study of lithic distribution and types in hydromagmatic pyroclastics, will serve to reconstruct the sub-surface setting of the Colli Albani maar-diatreme system. Moreover, the relative abundance and physical-petrographic features of lithic clasts will illuminate the volume of magma driving hydromagmatic eruptions, the thermal-geochemical environment of the substratum at the time of the eruption, the maximum depth and width of crater excavation, and the possible occurrence and intensity of phreatic and hydrothermal eruptions, the latter favoured at Colli Albani by the presence of “noncondensable” phases like CO_2 and of impermeable caprock covers. To define the vertical and horizontal pathways for endogenous fluid and to find areas prone to gas emissions, field surveys and well log analyses will define the geometry of rock formations and the geometrical-structural relationships among them. The secondary (tectonic) porosity-permeability will be reconstructed by defining the three-dimensional network of faults and fractures.

The study on the fracturation bears also implication on the stability and permeability of the slope of the Albano lake. To copy with landslide hazard in coastal slopes, it is necessary to know if the landslide mass could arrive in the water, how large could be landslide volume and mass, its grain-size composition and the velocity at the impact moment. These are input data for the assessment the landslide tzunamigenic potential in the Albano lake, and will be assessed using geomorphological and aerial photo surveys, GIS-implemented slope analysis, geomechanical characterization by laboratory and/or site tests, and 3D numerical simulation of slope stability. The current DTM of the area does not include the bathymetry of Albano lake, thus producing a lack of important information about possible landslide bodies or sub-lacustrine gas emission centers. The bathymetry of the lake will be acquired coupling a differential based GPS system with a multi-beam echo-sounder. A laser scan survey will be performed along the shorelines of the Albano lake to connect the bathymetry to the DTM.

To define the chronology of recent catastrophic, volcanic events in the Albano area, palaeomagnetic investigations, ^{14}C and $^{40}Ar/^{39}Ar$ dates, and geo-archaeological investigation of both outcropping, excavated, and drilled sections will elucidate the possible relationship between primary and/or reworked volcanic products and archaeological elements which may provide further useful chronological constraints and information about the type and extent of the potential impact of the recent activity on human settlement.

Deliverables

Task 1 Magmatic System
Definition of the primary magmas - Modelling of the mantle source characteristics of the magmas - Definition of the liquid line of descent and modeling of the differentiation processes - Determination of the amount of volatile in the plumbing system through the study of melt inclusions - Evaluation of the amount of CO_2 involved in the decarbonation process and estimate of the amount of CO_2 that possibly escape from the wall rocks and eventually reach the surface.

Task 2 Water Geochemistry
Chemical-physical characterization of gas phases of the Albano Lake and ground waters - pCO_2 and dissolved radon maps - Individuation and classification of existing aquifers - Chemical-physical characterization, origin, and interaction with rocks and waters of the gas phases - Determination of gas sources - Definition of mixing processes between aquifers and reconstruction of the chemical evolution of waters and hydrologic paths - Definition of P-T conditions of the geothermal reservoir/s – Definition of the relationships between stratigraphic and structural setting and upwelling endogeneous fluids - Vertical profiles of T, pH, Eh, Conductivity, and dissolved O_2, chemical and isotopic analyses of water of Albano and Nemi lakes - Identification, quantification and cyclicity of geochemical anomalies.

Task 3 Structure of the lithosphere underlying the Volcanic District
Seismic waveforms database - Reconstruction of the geometry of the main discontinuities within the crust and the mantle - Teleseismic tomography of the crust and the upper mantle beneath the volcanic structure - Small scale reconstruction of the plumbing system by means of Vp, Vp/Vs, Qp and Qs tomography. Model of the source of local seismicity (if detected) - Universal methodology for the measurement of elastic properties of rocks under varying P, T conditions - Elastic and electrical properties of rocks at High Pressure and High Temperature.

Task 4 Structure and Dynamics of the Volcanic District
Spatial and temporal distribution of the velocity field and of 3D deformation - Gravity changes maps - Bouguer anomaly map - Ground velocity and displacement maps - Models of the sources of ground deformation - Definition of the orientation and intensity of the present stress field - maps of fractures and fractures density - Database of xenolith distribution and types - Definition of the stratigraphic and structural setting for the first 1.5 km from surface - Base map and isopach maps of layers impermeable to gas flow - Isopach maps of phreatomagmatic units - Calculation of volumes of deposits - Determination of the volume fraction of magma driving hydromagmatic eruptions - Identification of possible phreatic and hydrothermal eruptions and determination of their magnitude - Thermal, geochemical, and fracturing state of maar substratum - Reconstruction of the depth of excavation and volume of diatremes - Geomechanical characterization of slope rocks - Numerical simulation of slope stability - Definition of the expected slope movements - Test possibility of slope movements involving both the sub-aerial and the sub-lacustrine part of the slopes - Thematic map showing the relationship between archaeological sites and volcanic products - Absolute age of the latest primary and reworked volcanic deposits - Evaluation of the ethnostratigraphic position(s) and of the potential impact of the most recent volcanic activity on human settlements.

SUB-PROJECT V3_1 – COLLI ALBANI

TABLE MAN/MONTHS

U.R	Institutions	Principal Responsibles	Task1 Magmatic system	Task2 Water geochemistry	Task3 Deep litospheric structure	Task4 Shallow structure	Mesi p. cofin.	Mesi p. rich.
UR-1	UniRm1, INGV-Rm1, CNR-IGG, Uni-Hannover (D), UniPg, UniCam, Trinity College of Dublin (IR), ISTO-Orleans (FR)	Gaeta, Freda, Dallai, Peccerillo, Troll	@				46	20 (UniRm1)
UR-2	INGV-Rm1, UniRm1, UniRmTre, ISTO-Orleans (FR), UniPa, McGill Univ (CA), Trinity College of Dublin (IR), LVM-Clermont Ferrand (FR), Univ. Hannover (D), CNR-IGG	Scarlato, Freda, Dolfi, Gaillard, Baker, Troll	@				80	
UR-3	INGV-Rm1, INGV-PA	Pizzino		@			26	
UR-4	INGV-Rm1, UniRmTre, IGG-CNR, INGV-PA	Carapezza		@			24	
UR-5	UniRmTre	Tuccimei, Taddeucci, Delitala, Capelli		@			68	
UR-6	INGV-CNT, INGV-CT	De Gori, Chiarabba, Frepoli, Nostro			@		74	18 (borsa di studio INGV-CNT)
UR-7	UniChi, INGV-Rm1, UCL London (UK)	Poe			@		22	
UR-8	INGV-CNT, UniRm1, INGV-OV, INGV-Rm1	Riguzzi, Di Filippo, Anzidei, Salvi, Berrino				@	95	
UR-9	INGV-Rm1	Mariucci, Montone				@	15	
UR-10	UniRmTre, INGV-OV	Giordano, Faccenna				@	24	24 (UniRmTre)

UR-11	INGV-Rm1, UniRm1, LANL (USA)	Taddeucci, Palladino, Ventura				@	21	
UR-12	UniRm1, INGV-Rm1	Bozzano, Scarascia Mugnozza, Petitta				@	46	
UR-13	INGV-Rm1, CNR-IGAG, UniRm Tor Vergata, Sonoma State Univ.	Marra, Karner				@	23	
Totale							564	62

SUB-PROJECT V3_1 – COLLI ALBANI

Table RU and related funding request

N. UR	Istituz.	Resp UR	Personale		Missioni				Consumi servizi		Inventariabile	
					Italia		Estero					
			2005	**2006**	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**
UR-1	UniRm1	Gaeta	19000	8000	1500	1500	7000	3000	12000	8500	3500	2000
UR-2	INGV-Rm1	Scarlato[1]			1000	1000	7000	7000	17000	19000		
UR-3	INGV-Rm1	Pizzino			500	500			13500	18500		
UR-4	INGV-Rm1	Carapezza			2500	1000		1500	4000	5000	10000	
UR-5	UniRmTre	Tuccimei			500	1000	1000	1000	9500	9000		
UR-6	INGV-CNT	De Gori			3000	2000	3000	3000			4000	1000
UR-7	UniChi	Poe			500	500	2000	6500	7500	3000		
UR-8	INGV-CNT	Riguzzi[2,3]			16000	19000	4000	6000	67000	87000	3000	
UR-9	INGV-Rm1	Mariucci							67000	3000		
UR-10	UniRmTre	Giordano	19000	19000	3000	3000			4000	4000		
UR-11	INGV-Rm1	Taddeucci			1500	1500	5500	3500	3000	9500		3500
UR-12	UniRm1	Bozzano			3500	3000	2500	2000	12000	17000		
UR-13	INGV-Rm1	Marra			1500	3000			7500	8000		
		TOTALE	**38000**	**27000**	**35000**	**37000**	**32000**	**33500**	**224000**	**191500**	**20500**	**6500**
GRAN TOTALE: 645000												

[1] 14000 euros (7000 per year) included under the voice “Consumi e servizi” will be provided to CNRS-ISTO (Orleans, FR) for research activities under the responsibility of F. Gaillard.

[2] 14000 euros (6000 during first year, and 8000 during second year) under the voice “Consumi e servizi” will be provided to the Gravimetry Group of Dip.to di Scienze della Terra, Univ. La Sapienza (Rome) for research activities under the responsibility of Prof. B. Toro.

[3] 18000 euros (2000 during first year, and 16000 during second year) under the voice “Consumi e servizi” will be provided to the Area di Geodesia e Geomatica at Dip.to di Idraulica Trasporti e Strade, Univ. La Sapienza (Rome) for research activities under the responsibility of Prof. M. Crespi.

PROJECT V3

Sub-Project V3_2 – Campi Flegrei

Responsibles:

Paolo Papale, INGV Roma1
Stefano Gresta, Univ. Catania

Project V3
Sub-Project V3_2 – Campi Flegrei

Coordinators:

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State of the Art

The Campi Flegrei caldera is a nested and resurgent structure. Its magmatic system is still active, with the last eruption occurred in AD 1538, widespread fumaroles and hot spring activity, and important unrest episodes in the last 30 years which caused a maximum net uplift of about 3.5 m in the Pozzuoli area. The volcanic hazard in the caldera area is extremely high, also because of its explosive character and the frequent occurrence in the past of high-magnitude high-intensity eruptions. Close to 1.5 million people live within the caldera, with about 350,000 living in its most active portion. Due to the high volcanic hazard and the intense urbanization of the active caldera portion and its surroundings, the volcanic risk is extremely high.

Research activity at Campi Flegrei during last years has been conducted at national and international levels. In particular, the investigation developed in the frame of the 3-year program launched in 2000 by GNV, and within several EU projects, has largely improved the level of knowledge at Campi Flegrei on many aspects including the caldera structure, the volcanic history, the distribution, characteristics, and significance of volcanic deposits, the compositional variability of the erupted magmas, the genesis of magmas and magma chamber processes, the determination of relevant magma properties, the eruption magnitude variation through time over the past 15 ka, the identification of possible low-, medium- and high-magnitude reference eruptions for the hazard studies, the elaboration of hazard maps for opening of a future vent, tephra fallout and pyroclastic currents flowage, the numerical simulation of eruptive scenarios, the definition and zoning of volcanic hazard, and many others. At the same time, new important results from recent tomographic campaigns are substantially modifying our view of the deep structure of Campi Flegrei caldera and size and location of shallow regions of magma storage, requiring a re-consideration of many studies developed before those results were produced. Additionally, recent advances in the simulation of the eruption dynamics provide new tools for the investigation of time-dependent, multi-phase, 2D/3D magmatic and volcanic processes at the global scale from deep magma chambers into the atmosphere and along pyroclastic currents. Finally, a quantitative probabilistic approach to the assessment of the volcanic hazard and definition of critical levels for the state of Campi Flegrei is still missing.

A detailed description of the state of the art at Campi Flegrei is reported in the final reports, dated December 2004, of four devoted GNV 2001-03 projects coordinated respectively by Giovanni Orsi, Paolo Papale, Giovanni Chiodini, and Aldo Zollo, and in a report, dated June 2004, to the presently operating Commission of the Civil Protection for the Update of Emergency Plans at Vesuvius and Campi Flegrei, compiled by Paolo Papale, and including the most significant scientific results and open questions to-date of importance for Civil Protection purposes.

Description of the Activities

The project is organized in 8 Tasks, grouped in 3 Research Lines devoted to a) the definition of the present state, b) the identification and quantification of precursory signals and associated probability of occurrence of volcanic events, and c) the definition of the eruptive scenarios and related probability, and quantitative estimate of the volcanic hazard. The specific Tasks are devoted to: 1) establish a detailed 3D geophysical image of the volcanic structure including the possible location and geometry of deep and possible shallow reservoirs, 2) determine the evolution of the magmatic system, and project it into the present, 3) define the hydrologic and geothermal system, and model the hydrothermal circulation and the thermal state of the caldera, 4) identify and quantify precursory signals and simulate the pre-eruptive magma dynamics and associated changes in the background state, 5) identify the scale and typology of the expected eruptions, 6) determine experimentally relevant transport properties and pre-sin-eruptive magma behavior, 7) simulate the eruption dynamics coupling the magma chamber + volcanic conduit + atmospheric domains 7) integrate the whole information into an updated evaluation of the volcanic hazard.

Research Line 1. Definition of the present state of Campi Flegrei caldera

Task 1. Definition of the caldera and lithosphere structure.

UR Coordinating: Bonafede (Univ. Bologna)
UR Participating: Zollo (Univ. Napoli), Rapolla, Russo (Univ. Napoli), Faccenna (Univ. Roma Tre), Petrillo (INGV-OV Napoli)

This Task, and the following Task 2, provide the system definition and boundary conditions for the investigation at the following Tasks.

Geophysical studies are aimed at determining a general 3D model of the lithosphere below Campi Flegrei. Much of the research foreseen here bases on the results of the recent Serapis tomographic campaign, which will be deeply analyzed and processed together with passive seismic data from the 1984 bradiseismic crisis. A high resolution 3D velocity model will be obtained through double-differences tomographic method where both arrival times and time delays are used. The "common mid point" imaging method will be extended to the exploration of shallow crust in the volcanic environment. Three new seismic reflection profiles about 1 km long will be obtained through the use of a high resolution seismic vibrator in specific areas constituted by i) the shoreline that connects the Monte di Procida with Capo Miseno, ii) parallel to the coast, possibly within the ILVA plant in Bagnoli, iii) from Bagnoli La Pietra to Pozzuoli. The target of these profiles is the shallow structure (500 m depth) of the border areas of Campi Flegrei caldera, and the definition of the caldera limits. A shallow P-wave velocity model will be estimated by a tomographic non-linear inversion of first arrivals. 3D images of the caldera structure will be also obtained by inversion of available gravity and aeromagnetic data, using recently developed techniques including a sequential integrated 3D inversion seismo-gravimetric technique, and by magnetotelluric and new controlled source audio magnetotelluric data. The overall deformation field will be inverted by employing analytical and numerical techniques for the stress field induced by a source embedded within a realistic, elastically layered, underground structure as inferred by seismic tomography and gravimetric inversion data. Anelastic properties of the medium will be taken into account employing visco-elastic constitutive properties at high temperatures, and the Mohr-Coulomb plasticity criterion in the shallow layers. The time evolution of seismicity and uplift will be studied by employing the theory of "effective fractured media" to establish the relationships between uplift rate and seismicity during seismic swarms at CF. A map of the elastic heterogeneities of CF consistent with seismic and gravimetric data will be produced. The structural setting of the area will be investigated through re-elaboration and reinterpretation of pre-existing seismic lines (including those foreseen in this project) and well data, and detailed field work, in order to produce a 3D definition of the faults network. Cross-correlation with the results from other geophysical and petrologic investigation in the project, as well as with stratigraphic reconstructions at Task 5 and from the literature, with new and existing radiometric dating, and with the results of apposite analogue simulations of the 3D deformation field, will be used to construct quantitative maps of probability of vent, fracture, and fissure opening at CF.

Task 2. Definition of the magmatic system.

UR Coordinating: Civetta (INGV-OV Napoli)
UR Participating: Sbrana (Univ. Pisa), Tonarini (CNR Pisa), Poli (Univ. Perugina), De Campos (Univ. Munich)

Petrologic studies are aimed at defining the state of magma presently hosted in deep and possibly shallow reservoirs below CF, for use within the numerical models in the following Tasks. In order to do this, the magmatic history of CF during last 15 ka will be further detailed in terms of depth and temperature of crystallization, composition, time-scale of crystallization, relation between composition of the erupted magma and structural position of vents, magma chamber processes in the deep and shallow reservoirs feeding the past eruptions, mixing/mingling processes, magma interaction with the hydrothermal system, degassing and cooling rates, and evolutionary models will be formulated and projected into the present. The studies will focus on selected past eruptions characterized by different composition of the erupted magma and by vents located in different structural position, both aspects significant for the reconstruction of the magmatic evolution of CF. These studies will include detailed mineralogical, geochemical, U/Th disequilibria, and isotopic analyses (Sr, Nd, Pb, B, O, H) at different scales (whole rock, separated minerals and glass, single minerals, and core-rim of minerals), with the aim of i) tracing the evolution through time of the magmatic system, ii) defining the different magmatic components feeding the CF system and the mixing/mingling processes among the more mafic magma batches, only erupted along regional structures active several times during collapse and resurgence episodes, iii) characterizing the more evolved high explosive trachytic and phonolitic magmas. The physical and chemical dynamics of recently erupted magmas will be also studied by using methods and models of Chaos Theory and Fractal Geometry. Mixing and mingling between trachytic and phonolitic magmas, which has been recognized to have occurred shortly before the 4100 BP Agnano Monte Spina eruption (long considered the Maximum Expected Event at CF), as well as before many recent eruptions, will be investigated through detailed chemical and isotopic analyses of natural samples, hydrothermal experiments, rotation viscometer experiments, and numerical modeling (in cooperation with researchers involved in Tasks 4, 6 and 7). Experimental post-mingling reactions in trachytes and phonolites will be employed to determine the role and timing of mingling in producing eruptions at CF. A combination of methods including ion probe, FTIR, and optical microthermometry will be employed to characterize melt inclusions in crystals and measure volatile contents (H_2O, CO_2, Cl, S) from several past eruptions, both in end-member and mixed magmas. Cooperation with researchers in Task 7 will allow to model the multicomponent liquid-gas equilibria to recover the total (exsolved and dissolved) volatile contents in the considered magmas.

Task 3. Location, size, physico-chemical characteristics and dynamics of the geothermal system and aquifers.

UR Coordinating: Caliro (INGV-OV Napoli)
UR Participating: Civetta (INGV-OV Napoli), Peluso (MARS Napoli)

The physico-chemical characteristics of fluids emitted at the surface are related to the hydrologic and hydrothermal setting of the caldera. Knowledge of the mass and energy transport mechanisms and dynamics, and of the location, size, and physico-chemical characteristics of deep aquifers and geothermal system is crucial for the interpretation of the geochemical, geodetic, seismic, and gravimetric signals registered at the surface. The interaction between aquifers and heat/mass flows associated with magma movement can lead to phreatic explosions or phreatomagmatic eruptions. The Solfatara di Pozzuoli is systematically monitored since 1982, and clearly shows the involvement of a large proportion of magmatic fluids. Data from Solfatara, Pisciarelli, Agnano, and submarine fumaroles will be used to quantify the magmatic and non-magmatic components of fluids released at the surface, to formulate conceptual and 2-3D fluid dynamics circulation models of the hydrothermal system, and to define its geometry and evolution. Two-way coupling between fluid circulation and porous rock deformation will be employed in the TOUGH2 numerical code as well as in a newly developed mixed control-volume finite-element code, and model calibration will be performed by contemporaneously matching gas composition and gravity data. This will be made possible by periodic gravity measurements and by the installation of a continuous gravity station by INGV-OV. The critical transition inside the cavities of the porous rock, and its possible roles in triggering soil deformation, will be investigated through the construction of an appositely designed experimental apparatus, by using pyroclastic rocks from samples excavated at CF. A new conductive/convective thermal model will be developed with the aim of describing the thermal evolution and state of CF since 400 ka, probable age of beginning of the volcanic activity in the Neapolitan area, until today. The model will solve the heat conduction equations together with an up-dated version of the HEAT code for the convective regime in the upper portion of the caldera, and will consider discontinuous magma refilling from the mantle to a deep reservoir, discontinuous rise of magma batches from deep to shallow reservoirs, and the presence of magma bodies of various shape, size and temperature at 8-10 km depth.

Research line 2: Precursory signals and probability of occurrence of eruption phenomena

Task 4. Identification and quantification of precursory signals.

UR Coordinating: Marzocchi (INGV-Roma1 Bologna)
UR Participating: Berardino (CNR-IREA Napoli), Del Gaudio (INGV-OV Napoli), Papale (INGV-Roma1, Pisa)

Knowledge of the background level at CF is the starting point for the identification of possible precursory signals. Such an identification can be done on the basis of phenomenological, physical, and stochastic models for the behaviour of the complex system of Campi Flegrei. The production of multi-parametric databases of unrest at Campi Flegrei and at other calderas in the world allows a significant improvement in the identification and quantification of precursory signals, and in the set up of methods for the estimate of the probability of occurrence of possible events over different temporal scales. Correlation between ground deformation field and local seismicity data, generation of deformation time series, production of a database of seismicity and ground deformation, and analysis of the features and peculiarities of seismic activity (e.g., energy and spatial-temporal distribution of events) will be done at CF and Long Valley calderas. All the monitored unrests at calderas all around the world, especially those mentioned above, will be collected and analyzed through multivariate statistical tools to identify possible repetitive schemes (patterns) in the unrest phenomena. A robust technique that takes into account a large variety of different signals will be employed in different nonparametric Pattern Recognition codes, to face the difficult questions whether unrests occurring before volcanic eruptions at calderas have common patterns, and whether there is an association between possible common patterns and type and size of the following eruption.

In order to recognize deviations from the background level at CF that can be associated to magmatic activity, numerical simulations of natural and forced convection in the CF magma chamber (as defined by the investigation at Tasks 1 and 2) will be performed with the GALES finite element code (described at Task 7). Convection will be induced as a consequence of thermal and/or compositional stratification in magma chamber, or as a consequence of magma chamber replenishment. The 2D numerical results will be processed to determine the associated time-space dependent density-temperature distributions, normal and shear stresses at the chamber walls, high and low frequency pressure transients, and volatile transfer from deep to shallow magma chamber regions, for the investigation of the associated gravity changes, deformation patterns, seismic signals, and temperature and geothermal system evolution at CF (in cooperation with researchers involved in Tasks 1 and 3).

Research line 3: Definition of eruptive scenarios and estimate of the volcanic hazard

Task 5. Identification of the scale and typology of the expected events.

UR Coordinating: Rosi (Univ. Pisa)
UR Participating: Di Vito (INGV-OV Napoli)

The quantitative description of volcanic deposits and reconstruction of past eruptions is essential for the identification of the expected phenomena, their temporal relationships, and the minimum areas which were subject in the past to the volcanic phenomena, as well as for the validation of the results from the numerical simulation of eruptive dynamics. Here we will take advantage of the huge work done in the recent past, and will focus the investigation on specific targets that still need to be fully understood, as well as on specific needs for the present project.

Although much has been done on the volcanological and deformation history of CF, expected eruptive scenarios are mainly based on the detailed reconstruction of a few eruptions on which past investigation has concentrated. One of the most well-known events is the 4100 BP Agnano Monte Spina eruption, which has long been taken as a reference for the maximum expected event at CF, whereas Astroni and Monte Nuovo were considered the medium and low magnitude expected events. These two eruptions have also been the subject of recent investigations. In this project the definition of low, medium, and high intensity expected eruptions at CF will be improved through systematic stratigraphic, volcanological, geochronological, and geochemical investigation of < 5 ka selected events, including the Agnano 3 (medium magnitude) and Fossa Lupara (low magnitude) eruptions, and the 3.7 ka Averno eruption (low magnitude). The latter will be the subject of detailed studies aimed at assessing the role of magmatic versus phreatomagmatic explosivity at CF, a topic which has been long debated and which has important implications on the expected scenarios and associated hazards. A general discussion on the nature of explosivity at CF will be maintained during the entire course of the project, in order to get to a more shared view of the main processes governing the occurrence and dynamics of volcanic eruptions in the area, and to a better definition of the expected events. For this purpose the reconstruction of the volcanic history and dating of selected volcanoes of the western sector of CF, as Capo Miseno, Gauro and Bellavista tuff cones, will improve knowledge of phreatomagmatic processes and their occurrence in the different sectors of CF caldera.

Cooperation with the Soprintendenza Archeologica in studying selected coastal sites and new excavations in the Campanian Plain and on the Apennines will improve the knowledge of the deformation history and its relationships with volcanism, as well as the definition of the origin, transport mechanisms, areal distribution and impact of fine ash layers deposited far from the caldera rims. Isopach and isopleth maps of deposits < 5 ka will be produced to estimate magnitudes and intensities of more recent volcanic eruptions, for use, together with other collected information concerning grain size and componentry, in the numerical simulation studies at Task 7, and for a better definition of the range of variation of eruption size and volcanic hazard evaluation at CF also performed at Task 7.

RU's participating in this Task will be also responsible of sampling for the experimental investigation at Task 6. All the samples will be collected after having carefully selected, jointly by the consortium participating in the project, the eruptions, eruption phases, and volcanic deposits on which to concentrate the investigation in order to better answer the scientific questions posed in each Task, and principally in order to adequately define low, medium, and high intensity expected eruption scenarios for volcanic hazard assessment.

Task 6. Experimental determination of magma transport properties and pre-sin-eruptive behaviour

UR Coordinating: Romano (Univ. Roma Tre)
UR Participating: Piochi (INGV-OV Napoli), Petrini (Univ. Trieste), Iezzi (Univ. Chieti), De Campos (Univ. Munich)

Knowledge of the physical and chemical properties of magmas and of magma behaviour is necessary for the simulation of pre-eruptive and eruption dynamics and scenarios at Tasks 4 and 7, and for the formulation of models of deep and shallow magmatic system at Task 2. Relevant magma properties must be known in the range of P-T-fO_2-composition conditions covering those of interest for the present state and pre- sin-eruptive dynamics modelling. Detailed knowledge of the relationships between magma properties and phase distribution and composition is required to assess the role of compositional changes of the erupted magmas on the volcanic scenarios.

Among the magmatic properties of relevance for the magma and eruption dynamics, viscosity is probably the most crucial. During last years, use of a variety of experimental devices has led to a detailed knowledge of Newtonian viscosity as a function of temperature and water content, for a variety of trachytic and trachy-phonolitic magmas from past eruptions in the area. The step forward in the present project is represented by the experimental determination and parameterization of non-Newtonian multiphase magma viscosity, which will provide one crucial element for more realistic numerical simulations of pre-eruptive and eruptive dynamics at Tasks 4 and 7. This will be accomplished by measuring the viscosity of natural magmas from CF with variable amounts of crystals and liquid water contents, by using both high strain-rate – high-load device at the University of Munich, and low strain-rate – low-load device at the University of British Columbia, and possibly, at the INGV HP-HT Lab in Rome. The combination of both devices allows the exploration of viscous and elastic deformation regimes, hence of the rheology of volcanic materials, under a large set of controlling conditions in terms of fluid content, water pressure, and deformation paths.

Crystallization paths of natural magmas from CF will be experimentally investigated under constant pressure and depressurization/cooling paths with variable H_2O and CO_2 activities in order to i) provide parameterizations to be used within the numerical simulation codes at Tasks 4 and 7, complemented by parameterization of multiphase non-Newtonian magma viscosity at the present Task, ii) provide relationships between measured CSD's (Crystal Size Distribution) and depressurization/cooling paths during volcanic processes, to be used to constrain the eruption dynamics and in the validation of numerical codes at Tasks 4 and 7. Comparison between experimental and natural samples will be done by analysing their crystal and vesicle content, crystal type, size, shape, and distribution in 2-3D textural parameters.

The cooling dynamics and degassing processes during magma rise and fragmentation will be investigated through the characterization of hydrous species in volcanic glasses from selected explosive sequences, further providing direct information into the eruptive dynamics and additional means for the validation of numerical codes of magma ascent dynamics at Task 7. Particularly, the study of the distribution and motional behaviour of water in the glass has implications in the formation and expansion of hydration bubbles and in the dynamics of interaction between magma and external water, yielding the conditions for an explosive burst due to vapour film instabilities. Experimental investigation will be conducted through a combination of hydrogen and deuterium solid-state nuclear magnetic resonance spectroscopy and CPMAS experiments. The study of hydrous species and CO_2 abundance and their distribution at a few micron scale range in glasses and fluid inclusions will be attempted by using the infrared synchrotron radiation beam-line SISSI at Elettra (Trieste), complementing with higher resolution investigation the melt inclusion studies at Task 2. Sr isotopic ratios will be measured in order to distinguish hydrous components of magmatic origin in isotope equilibrium with the glass/melt, and hydrous components due to interaction of magma with external fluids during phreatomagmatic activity. Electron microprobe and back-scattered scanning electron microscopy will complement the analyses.

Task 7. Numerical simulations of eruption dynamics and scenarios, and volcanic hazard

UR Coordinating: Papale (INGV-Roma1, Pisa)
UR Participating: Marzocchi (INGV-Roma1, Bologna), Di Vito (INGV-OV, Napoli), Rosi (Univ. Pisa)

The time-space distribution of the physical quantities characterizing the expected events and scenarios is based on the physico-mathematical modelling and numerical simulation of the eruption dynamics. The definition of appropriate initial and boundary conditions and constitutive equations for the simulations derives from the studies at Tasks 1-6. A combination of numerical codes will be used to simulate the sin-eruption dynamics in the domains from the magma chamber into the atmosphere and along pyroclastic flows. Magma chamber and volcanic conduit dynamics will be investigated by using the GALES finite element code for the transient, multi-D, multicomponent homogeneous dynamics of incompressible-to-compressible fluids. Conduit flow dynamics during sustained eruption phases will be investigated by using the well-established 1D steady multiphase CONDUIT4 code. Implementation of non-Newtonian viscosity and cooling-depressurization-induced crystallization paths from Task 6 is foreseen. Numerical simulations will be carried out mostly with the aim of reproducing conditions appropriate for low, medium, and high intensity eruptions expected at Campi Flegrei. The GALES code will be employed in order to investigate conditions under which pre-sin-eruptive mixing of different magmas can occur in magma chamber and volcanic conduit, to define the global time-scales of magma mixing, and to describe the time-space evolution of the associated convection dynamics. Strong cooperation with RU's engaged in petrologic investigation of magma mixing at Task 2 is foreseen. Additional numerical simulations with the GALES code will investigate the transient opening phases of eruptions in the coupled magma chamber + conduit domains, with the aim of describing magma withdrawal patterns in the chamber and the transient dynamics of conduit flow. Steady 1D conduit flow simulations with the CONDUIT4 code will provide appropriate sets of vent conditions for the simulation of the atmospheric eruption dynamics. Parametric studies aimed at determining the roles of different initial *P*-*T*-composition conditions on the dynamics of transient opening phases and steady conduit flow phases of expected eruptions will be performed. Validation of the numerical results will be done through comparison with experimental mixing time-scales constrained at Task 2, and cooling/depressurization/degassing paths and magma ascent time scales constrained at Task 6. First numerical simulations of pyroclastic current generation and propagation in the 3D topography of Campi Flegrei will be executed with the multiphase flow code PDAC, mostly with the aim of comparing them with similar 2D simulations and produce more reliable distributions of hazardous quantities associated with collapsing volcanic columns. A deterministic/probabilistic approach with the codes HAZMAP and FALL3D will allow to simulate the dispersion and accumulation of volcanic ash from selected past events and from future expected volcanic eruptions at CF as defined at Task 5, by taking into account wind distribution with height and wind variability in the area. The result will be a hazard map from fallout accumulation at CF. All of the above numerical codes for the simulation of the eruption dynamics and scenarios have been developed through the years, and are continuously up-dated, by the consortium involved in the RU coordinating this Task.

The whole knowledge to-date, and the results of the additional investigation in the project, on the stratigraphic and stratimetric characteristics, density, depositional mechanisms, geochemistry, age and attribution, location of the vent area, and emplacement mechanisms of pyroclastic deposits, as well as on structural data on CF caldera, will be made available in a GIS. The GIS will represent a "summa" of the volcanological knowledge at CF from field and lab investigation, and will allow an easy handling of the data for the volcanic hazard assessment described below. The GIS structure will also allow the construction of several thematic maps on the distribution and frequency of different volcanic deposits, vent distribution through time, activation of fractures and deformation through time, etc., also concurring to the realization of a map of the probability of opening of new vents foreseen at Task 1.

The results of the numerical simulations and the thematic maps described above are useful by themselves for volcanic hazard purposes. A much grater improvement in the assessment of volcanic hazard at CF will be made through a statistical estimation of the probability of occurrence of the eruptive events and/or the phenomena considered, by means of an Event Tree quantitative scheme already provided by researchers in the consortium, and further implemented in the course of the project (within project V4). The ET scheme is able to account for all the information available (theoretical models, past data, and monitoring), provides an estimate at different time-scales (long term useful for land planning, and short term useful to manage volcanic crises), and allows to deal with different types of uncertainties. The work proposed in the project will be organised in subsequent steps. In the first step the structure of the ET is defined, accounting for any kind of volcanic event inside the caldera. The second step consists in the definition of the probabilistic rules to merge theoretical models, past data, and monitoring observations in a single probabilistic framework. The third step consists in the definition of the parameters and relative thresholds to estimate the probability density function at each node of the ET. These issues will be achieved through a strong cooperation with all the RU's involved in the project. Finally, the fourth step consists in the integration of all the results obtained in the previous steps in a software tool that visualizes the outcomes of the ET and hazard assessment, and that synthesizes all the results from the project.

List of deliverables

Task 1: Definition of the caldera and lithosphere structure.
Deliverables: high resolution 3D velocity model of the lithosphere below Campi Flegrei (CF) - 3D model of CF lithospheric structures - map of the top of the carbonate basement - isopach map of the Plio-Pleistocene sedimentary and volcanic units and 3D geometry of the sedimentary basin - 3D map of the faults network and their timing of activity - 2D high-resolution seismic tomography and reflection sections - high-resolution seismic imaging of the shallow structure of CF - 3D images of the caldera structure on the base of gravity, magnetic and magnetotelluric data - modelling of different deformation sources at different depths below CF - 3D models of intrusion and related surface deformation - quantitative maps of probability of fractures, vent and fissure opening at CF.

Task 2: Definition of the magmatic system.
Deliverables: Composition, magmatic components and history of the CF deep and shallow magma chambers – petrologic models to project the magmatic evolution into the present and infer the state of the magmatic feeding system below CF - kind and amount of volatiles in the magma and determination of P and T of the deep and shallow magma reservoirs - magma chamber processes before and during eruptions of variable magnitude and composition, and occurred in variable structural position - definition of the time scale of magma storage and differentiation prior to eruption - Experimental and numerical modelling of mixing, mingling and gas phase development processes - probability hazard map for opening of a new vent and related composition of the feeding magma.

Task 3: Location, size, physico-chemical characteristics and dynamics of the geothermal system and aquifers.
Deliverables: Conceptual and 2-3D fluid dynamics circulation models of the hydrothermal system at Solfatara - two-way coupling model between fluid circulation and porous rock deformation - realization of an apparatus for the experimentation at the critical transition liquid–gas inside the cavities of porous material - TFD model for including the deformations in a 2D/3D numerical code; conductive/convective thermal model describing the thermal evolution of CF since 400ka

Task 4: Identification and quantification of precursory signals.
Deliverables: Definition of the background level at CF using the monitoring geodetic network data, as the starting point for the identification of possible precursory signals - production of a database of seismicity and ground deformation at CF and Long Valley calderas - statistical analysis of all the monitored unrests at calderas, for the recognition of common patterns in the pre-eruption unrest - numerical simulations of natural and forced convection in the CF magma chamber(s), and quantitative description of the deviations from the background level at CF that can be associated to magmatic activity

Task 5: Identification of the scale and typology of the expected events.
Deliverables: Reconstruction of the recent (<15 ka) volcanic and deformation history of the western sector of the caldera – chronogram of the deformations events of the whole Neapolitan area - stratigraphic sequences of the exposed deposits, dating, eruption history and dynamics of selected medium magnitude (Agnano3, Averno and Fossa Lupara) eruptions – isopach and isoplet maps, magnitude and intensity of selected less than 5ka eruptions - Map of the areal distribution of products of recent eruptions in mid-distal areas - Geological, historical and archaeological data set – definition of the type, scale, and phenomenology of processes associated to low, medium, and high intensity expected eruptions at CF

Task 6: Experimental determination of magma transport properties and pre-sin-eruptive behaviour
Deliverables: experimental determination and parameterization of non-Newtonian multiphase magma viscosity of the erupted magma - experiments on crystallization paths of natural magmas from CF under constant pressure and depressurization/cooling paths with variable H_2O and CO_2 activities - experimental determination of glass structure and distribution of hydrous species of magmatic origin and hydrous components due to interaction of magma with external fluids during phreatomagmatic activity - relations among magma structure, physical and chemical parameters, and eruption dynamics .

Task 7: Numerical simulation of eruption dynamics and scenarios, and volcanic hazard
Deliverables – GIS database including all the volcanological data collected at CF from field and lab investigations - numerical simulations of conduit flow dynamics for low- medium- and high-intensity eruptions –numerical simulations of the coupled transient 2D eruption dynamics in magma chamber and volcanic conduit - modelling the dispersion and accumulation of volcanic ashes from future expected volcanic eruptions at CF – models of pyroclastic current generation and propagation in the 3D topography of CF, and analysis of the effects of real topography on pyroclastic flow propagation – first numerical simulations of the global eruption dynamics from magma chamber into the atmosphere - Probability tephra fallout hazard map - probability pyroclastic currents hazard map – definition of an Event Tree for global volcanic hazard assessment at CF.

SUB-PROJECT V3_2 – CAMPI FLEGREI

TABLE MAN/MONTHS

U.R	**Institutions**	**Principal Responsibles**	**Task1** **Caldera/lithosphere structure**	**Task2** **Magmatic system**	**Task3** **Geothermal system**	**Task4** **Precursory signals**	**Task5** **Expected events**	**Task6** **Magma properties**	**Task7** **Scenarios and hazard**	**Mesi p. cofin.**	**Mesi p. rich.**
UR-1	CNR-IREA, INGV-OV, JPL-Caltech (USA)	Berardino, Lanari, Fornaro, Ricciardi, Lundgren				@				46	24(CNR-IREA)
UR-2	UniBo	Bonafede, Belardinelli	@							16	24 (UniBo)
UR-3	INGV-OV, UniNa, UniPg, LBNL-CA (USA)	Caliro, Berrino, Chiodini, Todesco			@					64	
UR-4	UniNa, INGV-OV, UniBa, UniRmTre, Brown Univ. (USA), LANL (USA), Univ. Goettingen (D)	Civetta, D'Antonio, Rutherford, Heumann		@	@					75	18 (UniNa)
UR-5	Uni-Muenchen (D), UniNa	De Campos, Courtial, Dingwell, Civetta		@				@		53	
UR-6	INGV-OV	Del Gaudio, Ricco, Borgstrom					@			32	
UR-7	INGV-OV, UniNa, CEA-LSC (FR), UniPi	Di Vito, Isaia					@		@	31	
UR-8	UniRmTre, UniPi, INGV-OV	Faccenna, Sbrana, Funiciello	@							46	24 (UniRmTre)
UR-9	UniChi, UniRmTre, INGV-OV	Iezzi, Di Sabatino						@		39	
UR-10	INGV-Rm1	Marzocchi				@			@	15	
UR-11	INGV-Rm1, UniPi, INGV-OV	Papale, Neri, Macedonio, Longo, Barsanti				@			@	64	24 (Borsa di studio INGV-Rm1)

UR-12	MARS-Na, INGV-OV	Peluso, Bassano, Macedonio			@					10	12
UR-13	INGV-OV, UniNa, UniBa	Petrillo, Patella	@							33	
UR-14	INGV-OV, UniCam, UniPv, CNR-IGG	Piochi, De Astis, Polacci, Carroll						@		28	
UR-15	UniPg	Poli, Perugini, Donati		@						52	
UR-16	UniNa, INGV-OV	Rapolla, Bruno	@							40	
UR-17	UniRmTre, Uni-Muenchen (D), UniChi, British Columbia Univ (CA)	Romano, Dingwell, Poe, Russell, Giordano						@		30	24 (UniRomaTre)
UR-18	UniPI, INGV-Rm1, UniCa	Rosi, Cioni, Landi, Bertagnini					@		@	22	12 (UniPi)
UR-19	UniNa, UniMol	Russo, Capuano, Giberti	@							24	
UR-20	UniPi	Sbrana, Marianelli, Fulignati		@						27	
UR-21	CNR-IGG	Tonarini, Dallai, Dini		@						18	
UR-22	UniNa	Zollo	@							14	24 (UniNa)
UR-23	UniTri, UniPi, CNR-IPCF, UniRm1	Petrini, Forte								24	
Totale										803	186

SUB-PROJECT V3_2 – Campi Flegrei

Table RU and related funding request

N. UR	Istituz.	Resp UR	Personale		Missioni				Consumi servizi		Inventariabile	
					Italia		Estero					
			2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
UR-1	CNR-IREA	Berardino	19000	19000	1500	1500			2000	2000	2000	2000
UR-2	UniBo	Bonafede	19000	19000	1500	1500	2000	2000	3500	3500		
UR-3	INGV-OV	Caliro[1,2]			6000	6000			5000	4000	15000	
UR-4	UniNa	Civetta	9500	19000	3000	3000	7000	9500	19500	23500	2000	
UR-5	Uni-Muenchen	De Campos					4000	3000	8000	7000		
UR-6	INGV-OV	Del Gaudio			1000	1000			4000	4000		
UR-7	INGV-OV	Di Vito			2000	500		1500	7000	8000	2000	
UR-8	UniRmTre	Faccenna	16000	16000	2000	2000	2000	2000	3000	3000	0	
UR-9	UniChi	Iezzi			2000	1600		400	5000	6000	2000	1000
UR-10	INGV-Rm1	Marzocchi			2000	1000	1000	2000	7000	7000		
UR-11	INGV-Rm1	Papale[2]			7000	7000	6000	6000	18000	18000	14000	10000
UR-12	MARS	Peluso	12500	7500	4500	2000		2500	3000	13000		2000
UR-13	INGV-OV	Petrillo			2000	2000			8000	8000		
UR-14	INGV-OV	Piochi			6000	6000			10000	10000		
UR-15	UniPg	Poli			3000	1500		1500	3000	5000	2000	2000
UR-16	UniNa	Rapolla			1500	1500			13500	8000		6000
UR-17	UniRmTre	Romano	19000	19000	1000	1000	1000	1000	4000	4000	1000	1000
UR-18	UniPi	Rosi	16000		3000	3000			5000	11000		
UR-19	UniNa	Russo			500	500	2500	2500	2500	4000	1500	
UR-20	UniPi	Sbrana			3000	3000			13000	13000		
UR-21	CNR-IGG	Tonarini			1500	1500	1000	1000	8500	5500		
UR-22	UniNa	Zollo	16500	16500					9000	9000		
UR-23	UniTri	Petrini			1200	1200	800	800	8000	6000	4000	3000
		TOTALE	**127500**	**116000**	**55200**	**48300**	**27300**	**35700**	**169500**	**182500**	**45500**	**27000**
GRAN TOTALE: 834500												

[1] 15000 euros under the voice "Inventariabile" are for the acquisition of instrumentation for the experimental study of the critical transition of fluids in porous media, for supporting the research of RU #12 (MARS Napoli, resp. Peluso).

PROJECT V3

Sub-Project V3_3 – Ischia

Responsibles:

Paolo Papale, INGV Roma1
Stefano Gresta, Univ. Catania

Project V3
Sub-Project V3_3 – Ischia

Coordinators:

Giovanni Orsi, Full Professor, Istituto Nazionale di Geofisica e Vulcanologia – Osservatorio Vesuviano, Via Diocleziano 328, – 80124 Napoli, orsi@ov.ingv.it, Tel: 0816108343, Fax: 0816108344

Alessandro Aiuppa, Professore Associato, Dipartimento di Chimica e Fisica della Terra ed Applicazioni (CFTA), Università di Palermo, Via Archirafi, 36 – 90123 Palermo, Email: aiuppa@unipa.it, Tel: 0916161574, Fax: 0916168376

State of the Art

The island of Ischia is the emerged top of a large volcanic complex rising more than 1,000 m above sea floor at the north-western corner of the Gulf of Naples. It is an active volcanic field composed of volcanic rocks, landslide deposits, and subordinate terrigenous sediments, reflecting a complex history of alternating constructive and destructive phases due to an interplay among tectonism, volcanism, volcano-tectonism, erosion and sedimentation. The volcanic system is still active, as testified by the intense volcanism in historical times, widespread fumaroles and thermal springs, and by seismic activity. Volcanism at Ischia began prior to 150 ka B.P. and continued, with centuries to millennia of quiescence, until the last eruption occurred in 1302 A.D. Recent studies have demonstrated that during the time interval between 74 and 55 ka B.P. there was a dramatic change in the structural setting of both magmatic system and volcanic edifice. This time interval, previously regarded as a mainly quiescent period, bore witness to a complex volcanic activity with the largest eruptions recorded on the island. This period culminated with the caldera-forming Mt. Epomeo Green Tuff eruption (55 ka) which was followed by block resurgence of the caldera floor, at least since 33 ka. Resurgence dynamics influenced the later volcanic activity determining the conditions for magma ascent mainly within the eastern portion of the island and along pre-existing regional faults. During the last period of activity, started 10 ka B.P., volcanism was mainly concentrated around 5 ka and in the past 2.9 ka. In the past 5 ka, reactivation of faults and related volcanic activity, are accompanied by emplacement of deposits generated by surface gravitational movements. These deposits preceded and followed the emplacement of volcanic rocks, testifying that slope instability conditions were induced by reactivation of vertical movements, which also generated faults and fractures through which volcanism was fed. Furthermore, the availability of large amount of loose material, rapidly accumulated along the slopes during eruptions, predisposed the conditions for landslide generation.

Volcanic hazards assessment and long-term forecasting of a future eruption at Ischia have to be the prime objectives of future researches on the island. Although variable researches have been carried out on the island in the last decades, they have never been finalised to volcanic hazards assessment. Therefore it is necessary to formulate a multidisciplinary and coordinated project with the aim of finalising the available data and filling the knowledge gaps. Still a large amount of information necessary for formulating a comprehensive hypothesis on the behaviour of the volcano and its magmatic feeding system, is lacking. The structure of the volcano and its underlying lithosphere needs to be better defined through combination of structural and geophysical data. As only one third of the volcano is above sea level, data from marine geology and geophysical investigations are needed. This is true also for the definition of the geomorphic characteristics of the entire volcano. According to the present knowledge, the portion of the volcanic and deformation history of the system, most useful for volcanic hazards assessment, is related to the past 10 ka. But, as previously mentioned, the knowledge of the intense volcanism and deformation (74 - 55 ka), which has likely affected the later behaviour of the volcanic system, is quite poor. Therefore, in order to understand the present state of the volcano, it is necessary to investigate its volcanic, magmatic and deformation history over the past 74 ka. Through these investigations, the sequence of events and its timing should be defined. The behaviour and structure of the magmatic system should be assessed as well, also in terms of physical and chemical parameters, rheological properties and glass structure. The diffuse occurrence of hot-water springs and fumaroles testifies the existence of active geothermal and hydrothermal systems. Investigation of these systems and definition of their physico-chemical characteristics are important pieces of information for hazards assessment. Another hazard on the island, closely related to volcanism, is the occurrence of surface gravitational movements which generate landslides deposits at variable scale. This implies that investigations need to be carried out also on these deposits, in order to have a more complete picture of the geological hazards on the island. Landslides could also generate tsunamis which would effect all the coast of the Neapolitan area. Such a possibility has to be investigated in order to define the likely effects. The present knowledge of Ischia eruption precursors is very poor. Therefore, in order to construct a dataset necessary for a future definition of the alert levels, it is useful to collect geological, historical and archaeological data on the precursors of the Ischia eruptions.

Description of the Activities

The project is organized in 5 Tasks, each entrusted to a scientific responsible, grouped in 2 Research Lines devoted to a) the definition of the present state, b) the definition of the eruptive scenarios and related probability, and quantitative estimate of the volcanic hazard. The specific Tasks are devoted to: 1) the definition of the structural and geomorphological evolution and preset setting; 2) the reconstruction of the volcanological history, with particular reference to the past 74 ka; 3) the definition of the evolution, structure and present state of the magmatic feeding system; 4) the characterization of the groundwater and geothermal systems; 5) the assessment of volcanic and landslide hazards.

Each RU will work in coordination with the others and in particular with those involved in the same task. The coordinator of the project and the scientists responsible of each task will encourage coordination among RUs. An annual meeting of all RUs will be held and meetings of RUs of one or more tasks will be encouraged.

Research Line 1. Definition of the present state of Ischia Island

Task 1. Structure and geomorphology.

UR Coordinating: de Vita (INGV-OV)
URs Participating: Rapolla (Univ. Napoli), De Alteriis (CNR-IAMC), Capuano (Univ. Molise)

Task 1 includes structural, geophysical, stratigraphical, sedimentological and geomorphological studies aimed at: a) defining the structural setting of both emerged and submerged portions of the Ischia volcano and of its underlying lithosphere; b) defining the relationships among tectonic and volcano-tectonic deformational features, location of volcanic vents and slope instability; c) reconstructing the stratigraphic sequence of landslide deposits and defining their physical characteristics, transport and depositional mechanisms.
The structure of the emerged part of the island will be investigated by carrying out a field survey of the macroscopic and mesoscopic deformational features. The structural data will be statistically analysed in order to define the related stress field. A geological survey will be carried out in order to: a) define the relationships among tectonic and volcano-tectonic deformational features, location of volcanic vents and slope instability; b) reconstruct the stratigraphic sequence of landslide

deposits and define their physical characteristics, transport and depositional mechanisms. Absolute age determinations will be performed in coordination with Task 2. A quantitative geomorphic analysis will be performed in order to better constrain the landscape modifications and to extract structural and volcanological features. Both conventional photo interpretation and automatic feature recognition and classification approaches will be used in the analysis and interpretation of a high spatial resolution DTM in GIS environment. Thermo-mechanical modelling will be performed to simulate the intrusion of magma into the crust and analyse the surface deformation under different tectonic regimes and pre-existing fault structures. The submerged part will be investigated through: a) interpretation of the existing DTM; b) advanced boundary analysis of the magnetic field; c) matching the morphobathimetry with seismic data and volcanological and structural framework; d) sedimentological and geochemical analysis of available rock samples. The deep structure will be investigated through: a) development and implementation of innovative techniques of analysis and interpretation of active/passive seismic data recorded during Serapis project and already available gravity data; b) reinterpretation and partial processing of OGS digital data, acquired in the Naples Bay offshore during the 1973 and the offshore M-30 and M-36 CROP lines; c) acquisition and interpretation of a new aeromagnetic dataset; d) definition of the spatial distribution of radioactivity, by the use of a helicopter-borne gamma ray spectrometer device; e) self potential survey and 3D tomographic inversion of the related data.

Task 2. Volcanology and geochronology

UR Coordinating: Orsi (INGV-OV)
URs Participating: Guillou (LSCE-CEA), Sprovieri (CNR-IAMC)

This task includes stratigraphical, volcanological, geochronological, geophysical, historical and archaeological investigations aimed at filling the gaps of knowledge on the volcanic history of Ischia over the past 74 ka and to produce data essential to volcanic hazards assessment. In particular, the stratigraphic sequences of the volcanic deposits aged between 74 and 50 ka and younger than 10 ka will be reconstructed. Investigation of the 74-50 period is important in order to constrain the mechanisms that resulted in modification of the volcanic system and evaluate their effects on the subsequent activity. Key deposits in the volcanic sequences will be dated by $^{40}Ar/^{39}Ar$ and AMS ^{14}C methods, in order to constrain the timing of the volcanism. Samples to be dated will be selected in cooperation with other Tasks of the project in order to constrain also the deformation and gravitational movement events, and the timing of the magmatic processes. For each recognised deposit, the spatial distribution and the sedimentological, stratimetrical, structural and textural features will be defined. Components analyses will be performed on fallout deposits in order to collect data useful for both understanding the character of the explosions and modelling the eruption columns. For these deposits, isopachs and isopleths maps will be also constructed. In addition to thickness, also the density of variable types of fallout deposits will be measured in order to define their load on the ground. The distal ash deposits of the Ischia explosive eruptions will be investigated through the analysis of the 33-meters long MD01-2473 core, recovered in the Tyrrhenien Sea, about 50 km N of Stromboli. All these data will allow to: a) locate the vent/vent area, b) evaluate the volume of erupted magmas through a computer assisted (GIS-based) method, c) estimate the eruption dynamics, d) define the transport mechanisms for all eruptions, and e) estimate the magnitude and intensity of the explosive eruptions. They will also allow to construct areal distribution and frequency maps for lava flows and domes, and fallout and pyroclastic current deposits, as well as frequency maps for load on the ground by fallout deposits. Integrating the data collected within the activities of this Task and Task 1, a chronogram of the volcanic, deformation and gravitational-movement events will be constructed.

To identify eruption precursors and the ground deformation background level also archaeological researches and historical documents analyses will be carried out. All these investigations will permit to evaluate the effects of eruption precursors such as ground movements, fracturing and faulting on manufacts. Reinterpretation of DInSAR Satellite Interferometry data collected since 1992, and levelling data acquired since 1984, will allow definition of the ground deformation background level.

Task 3 Evolution, structure and present state of the magmatic feeding system

UR Coordinating: Sbrana (Univ. Pisa)
URs Participating: D'Antonio M. (Univ. Napoli), Petrini (Univ. Trieste),Tonarini (CNR Pisa)

Task 3 will be devoted to petrological investigations on volcanic rocks representative of the 74-55 ka and of the past 10 ka periods of activity, aimed at the definition of the behaviour of the magma feeding system through time and its present state. In order to achieve this goal, petrological data will be acquired through many different analytical techniques on whole-rocks, separated minerals and glasses from volcanic rocks representative of the selected periods of activity, sampled in cooperation with RUs Orsi and de Vita.

Petrographic, mineralogical, geochemical and isotopical (Sr, Nd, Pb, O and B) investigations will be carried out on bulk rocks, groundmasses and separated minerals. Whole-rock major and trace element analyses will be performed by ICP-AES and ICP-MS techniques. The major oxide analyses of minerals and glass will be performed by EDS-WDS electron microprobe techniques. The isotopic analyses will be performed by thermal ionisation mass spectrometry techniques. The data will be interpreted in order to identify the geochemical characteristics of the magmas inherited from the mantle source, and to define the magma evolution processes occurring in deep and shallow reservoirs.

Solid-state nuclear magnetic resonance spectroscopy investigations will be applied to the study of silicon site speciation in the network structure of volcanic glasses, with the aim of identifying and quantifying the hydrous environments, in order to determine the distribution of molecular water in the glass. The study of hydrous species and CO_2 abundance and the mapping at a few micron scale in glasses and fluid inclusions will be attempted by using an infrared synchrotron radiation source. The structure of glasses and the structural characteristics of hydrous species will be related to the glass chemistry and surface analysis. The nature of solutes in aqueous components will be investigated by isotopic measurements.

Silicate melt inclusion investigations in phenocrysts will be carried out through optical microthermometry and microanalysis, aimed at defining PTX conditions of the Ischia magmatic feeding system. Microthermometry will determine the homogenization temperature of the inclusions, correspondent to the minimum temperature of crystallization of the host mineral and magma. Major elements, Cl and S in glasses, melt inclusions and host minerals will be analysed by EDS-WDS microanalysis. H_2O and CO_2 analyses in trapped melts will be carried out by FTIR. The volatile contents of magmas will allow assessment of crystallization and storage pressures from models of solubility for H_2O and CO_2 in silicate melts.

Geochronological determinations will be carried out through U and Th decay series disequilibria by TIMS techniques. Detailed internal isochrons will help to unravel the timescales of processes that formed the magmas feeding the 74-55 ka period of activity.

Task 4 Hydrogeological setting and geothermal system

UR Coordinating: Aiuppa (Univ. Palermo)
URs Participating: Luzio (Univ. Palermo), Sbrana (Univ. Pisa)

The diffuse surface hydrothermal manifestations on Ischia Island are clear evidences of the vigorous interaction between deep-rising magmatic/hydrothermal volatiles and shallow fluids of meteoric and/or marine derivation. Establishing the complex spatial-temporal mixing relations between the different fluid components is a pre-requisite for the definition of a quantitative model of the groundwater/hydrothermal system. In turn, such an interpretative model is essential for predicting the potential geochemical signals accompanying an eventual future volcanic unrest on the island.

This task attempts at a multi-disciplinary and systematic characterisation of the structure and chemical-physical properties of the Ischia island groundwater/hydrothermal system, by combining: a) a hydrogeochemical survey of surface thermal manifestations; b) a geochemical, petrological and mineralogical characterisation of surface alteration facies, and c) an electrical and electromagnetic geophysical survey. Hydrogeochemical investigations will be devoted to a chemical characterisation of thermal manifestations, including the determination of major and minor (B, Li, Sr, Fe, Mn) dissolved species, trace elements (with particular reference to ore-forming elements Cu, As, Zn, Sb, Tl, Hg, ect.), and dissolved gases (CO_2, CH_4, O_2, N_2). Isotope markers (O and H isotopes of H_2O and C, B, S and He isotope composition of dissolved carbon, boron, sulphur, and helium, respectively) will be used for assessing and mapping the extent of interaction between deep-derived volatiles (either hydrothermal or magmatic) and the groundwater system, and for the reconnaissance of the relative contribution of end-member components (i.e., geothermal reservoir brines, meteoric water and seawater). This reconnaissance study will also provide the quantitative background for the selection of a few samples to focus on the analysis of temporal trends. Also, cross correlation of thermal waters compositional data with the mineralogical, geochemical and isotopic features of hydrothermal paragenesis (from analysis of deep-seated xenoliths present in the exposed pyroclastic sequences) will allow quantitative modelling of water-rock interaction processes and reconstruction of T-dependent mineral-solution equilibria. This task will also benefit from fluid and melt inclusion investigations, allowing P-T-salinity conditions of the deep seated hydrothermal reservoir(s) to be derived. The reconstruction of the vertical and lateral continuity of both the shallow-groundwater system and the deep-hydrothermal reservoir(s) will also be attempted by the use of geophysical prospecting methods (electrical vertical soundings and TEM), such methods being adequate to model the distribution of permeable and impermeable bodies.

Research line 2: Definition of eruptive scenarios and estimate of the volcanic hazard

Task 5. Volcanic and related hazards assessment

UR Coordinating: Orsi (INGV-OV)
URs Participating: de Vita (INGV-OV), de Alteriis (CNR-IAMC), Tinti (Univ. Bologna)

This task includes geological and volcanological investigations, and physical modelling and numerical simulations devoted to: a) defining the areas at variable probability of opening of a new vent; b) defining probabilities for the expected eruption scenarios; c) defining the expected surface gravitational movements at variable scale; d) physical modelling and numerical simulation of the expected volcanic events; e) constructing probability hazards maps for vent opening, lava flows and domes, tephra fallout, pyroclastic currents, and surface gravitational movements; f) assessing tsunami hazard in relation to gravitational movements.

All the data and maps produced within the activities of this Task and of the other Tasks will be statistically elaborated to produce a single probability definition of the expected eruption scenarios, and probability hazard maps for opening of a new vent, fallout and pyroclastic currents. The use of an ash transport model previously developed will permit to assess the ash loading probability for each given threshold in the areas potentially affected by fallout. Application of a probabilistic model based on the "maximum slope" will be calibrated by using information on the past effusive eruptions at Ischia and will permit both to estimate the probabilities of vent opening in different areas, and to construct a probability lava hazard map.

The variable recognized landslide deposits will be classified, their volume will be estimated and the expected gravitational movements will be defined. A probability map of occurrence of new or remobilisation of older landslides onshore-offshore will be constructed.
The ability of SAR interferometry to point out diffuse deformation at variable scale, will be used to study the surface gravitational movements of Ischia. Through this technique it is possible to evaluate amplitude and direction of the ground movements. The comparison with geodetic data will permit to discriminate the differences in coherence with neighbouring areas. In order to point out the main factors controlling the slope instability, selected areas will be related to different backscattering values, which will be referred to the intrinsic soils properties to characterize them in terms of structural and physico-chemical properties.

The dynamics of the tsunami generation by landslides will be investigated by the double model already used for the Holocene collapse of the Sciara del Fuoco and for the recent 2002 landslides at Stromboli. Improvement of this model will be considered, especially to deal with the high-mobility and large fragmentation feature of the large debris avalanche to the south of Ischia. A second approach will also be attempted and a preliminary version of a code will be built to handle the landslide mass as a second high-density fluid. Tsunami evolution in the near- as well as in the far-field will be computed, the tsunami impact along the coast of Ischia and of the Gulf of Naples will be calculated, and inundation map along these coasts will be produced.

List of deliverables

Task 1: Structure and geomorphology

Deliverables: modelling of the structural setting of the lithosphere beneath the volcano, with particular reference to location and size of the magmatic system - structural map of the volcano - stratigraphic sequence and physical characteristics database of the surface gravitational movement deposits - morphological database constructed on high spatial resolution data (DEM, DTM, Remotely Sensed Imagery) - digital thematic maps - 3D visualization - GIS database.

Task 2: Volcanology and geochronology

Deliverables: stratigraphic sequence of the exposed deposits - maps of the areal distribution of the deposits of effusive eruptions and pyroclastic currents - isopachs and isopleths maps for fallout deposits - frequency maps for lava domes and flows, and pyroclastic current and fallout deposits - frequency maps of load on the ground by fallout deposits - chronogram of the volcanic, deformation and surface gravitational movement events - maps of the active vents through time – database of the physical parameters of the volcanic eruptions – database of the geological, historical and archaeological – definition of the background level using the monitoring network data.

Task 3: Evolution, structure and present state of the magmatic feeding system

Deliverables: modelling of the mantle source characteristics of the Ischia magmas – modelling of the magma chamber processes before and during eruptions of variable magnitude and occurred in variable structural conditions – database of the physical and chemical parameters, and rheological properties of the erupted magmas – modelling of volatiles in the magmatic reservoir/s - experimental determination of glass structure and distribution of hydrous species - relations among magma structure, physical and chemical parameters, and eruption dynamics - time of growth of large magma chamber;.

Task 4: Hydrogeological setting and geothermal system

Deliverables: geochemical maps of the spatial distribution of major, minor and trace species and dissolved gases in the groundwater system - assessment of the budget of volatiles (CO_2, He) transported by the groundwater system - identification of hydrogeochemical precursors of volcanic unrests - graphical two-three dimensional representations for the geometry of the deep-seated hydrothermal reservoirs

Task 5: Volcanic and related hazards assessment

Deliverables: probability hazard map for opening of a new vent - eruption scenarios - modelling of eruption column and fallout deposits - database of the physical parameters of the expected hazardous phenomena needed for vulnerability evaluation – modelling of lava flows - probability tephra fallout hazard map - probability pyroclastic currents hazard map – probability lava flows and domes hazard map - classification and volume estimation of landslides deposits in both emerged and submerged portions - surface gravitational movements hazard map - modelling of tsunami generation and propagation - tsunami inundation maps of the island and of the Gulf of Naples.

SUB-PROJECT V3_3 – ISCHIA

TABLE MAN/MONTHS

U.R	Institutions	Principal Responsibles	Task1 Structure and geomorphology	Task2 Volcanology and geochronology	Task3 Magma feeding system	Task4 Geothermal system	Task5 Volcanic hazard	Mesi p. cofin.	Mesi p. rich.
UR-1	UniPa, INGV-PA	Aiuppa, D'Alessandro, Pecoraino				@		22	24(UniPa
UR-2	UniMol, UniNa, UniSannio	Capuano, Russo, De Matteis	@					26	
UR-3	UniNa, INGV-OV	D'Antonio, Civetta			@			12	24 (UniNa)
UR-4	INGV-OV, UniRmTre, UniRm1, UniPi	De Vita, Casero, Faccenna, Nappi	@					63	
UR-5	CNR-IAMC, UniRm1	De Alteriis	@				@	24	
UR-6	CEA-CNRS (FR), INGV-OV	Guillou, Scaillet		@				8	24 (CEA_CNRS)
UR-7	UniPa, INGV-PA	Luzio, De Luca				@		32	
UR-8	INGV-OV, UniNa, Sopr. Arch. Na, Univ. Goettingen (D), INGV-CT, UniFi, UniTri	Orsi, de Vita, Heumann, Tommasini		@			@	54	12 (assegno di ricerca INGV-OV)
UR-9	UniTri, UniPi, CNR-IPCF, UniRm1	Petrini, Forte, Lupi			@			23	12 (UniTri)
UR-10	UniNa, UniCal	Rapolla, Florio, Pece, Di Maio	@					50	
UR-11	UniPi	Sbrana, Marianelli, Fulignati			@	@		24	
UR-12	CNR-IAMC, CNR-ISMAR, INGV-OV	Sprovieri		@				40	

UR-13	UniBo	Tinti, Armigliati, Zaniboni					@	41	12 (UniBo)
UR-14	CNR-IGG	Tonarini, Dallai, Dini			@			12	
Totale								431	108

SUB-PROJECT V3_3 – ISCHIA

Table RU and related funding request

N. UR	Istituz.	Resp UR	Personale		Missioni				Consumi servizi		Inventariabile	
					Italia		Estero					
			2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
UR-1	UniPa	Aiuppa	16000	16000	4500	4000	2500	3000	9000	9000		
UR-2	UniMol	Capuano			1500	1500	1500	1500	4500	4500	1500	
UR-3	UniNa	D'Antonio	19000	19000	2000	1000		1000	3500	5000	2000	
UR-4	INGV-OV	De Vita			4500	3850		1650	2500	4000	2000	
UR-5	CNR-IAMC	De Alteriis			2000	2000	2000	1500	4000	4000		
UR-6	CEA-CNRS (FR)	Guillou	16000	16000			1000	1000	1000	1000		
UR-7	UniPa	Luzio			6000	4000			1000	1000	1500	1000
UR-8	INGV-OV	Orsi[1]			3500	4900	1500	2100	12500	14500	5000	
UR-9	UniTri	Petrini		19000	1000	1000	1000		2000	1000	2000	
UR-10	UniNa	Rapolla			1000	1000			21000	4000		
UR-11	UniPi	Sbrana			4000	4000			9000	9000		
UR-12	CNR-IAMC	Sprovieri			1250	1500	1250	1500	6000	2000		
UR-13	UniBo	Tinti	8000	8000	1250	1250	1250	1250	3000	3000	2000	1000
UR-14	CNR-IGG	Tonarini			1400	1200	600	800	5000	5000		
		TOTALE	**59000**	**78000**	**33900**	**31200**	**12600**	**15300**	**84000**	**67000**	**16000**	**2000**
GRAN TOTALE: 399000												

[1]8000 euros (4000 per year) included under the voice "Consumi e servizi" will be provided to Univ. of Goettingen (D) for research activities under the responsibility of A. Heumann.

PROJECT V3

Sub-Project V3_4 – Vesuvio

Responsibles:

Paolo Papale, INGV Roma1
Stefano Gresta, Univ. Catania

Project V3

Sub-project V3_4– Somma-Vesuvius

Coordinators:

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State of the art

The high population density and the large variability of its past explosive activity make Somma-Vesuvius (SV) one of the highest-risk volcanoes of the world. Many aspects of its volcanic history, composition of the products and geological structure have been investigated in detail in the past, giving a good, even if still partially incomplete picture of the volcano. The recent experiment of a 3D seismic tomography resulted in a large amount of data which significantly improved our knowledge of the subsurface structure of the volcano, suggesting the presence of a huge, partially molten body at a depth around 8 km and the absence of magma reservoirs larger than 0.3 km in the first 5 km. Petrological studies on melt inclusions in mafic minerals support the existence of a deep magmatic reservoir where magma is stored and starts differentiating. Data from Plinian and sub-Plinian eruptions indicate magma storage and differentiation at shallower levels, thus suggesting the existence, at least in some periods of SV history, of different reservoirs. The large compositional variability of SV products is not compatible with the existence of a unique, large reservoir. Efforts should be directed to obtain a higher resolution of the seismic data so that they can be able to detect small, shallower reservoirs, and to define possible lateral discontinuities in the deep reservoir.

The stratigraphic record of SV activity is characterised by deposits of eruptions of variable Intensity, Magnitude and magma composition. Based on the assumption of a positive relationship between the length of the repose period preceding an eruption and Magnitude and Intensity of the eruption, the present approach of hazard assessment is based on a single scenario defined on a sub-Plinian type Maximum Expected Event (MEE) in the case of a mid-term reactivation. There is now a general agreement on the need to enlarge the spectrum of possible eruption scenarios to events with different Intensity and Magnitude, trying to assess to each scenario its own probability of occurrence.

The identification and quantification of precursory phenomena of a magmatic unrest is still a partially unsolved problem at Vesuvius. Very poor data exist on the past eruptions and an approach only based on analog volcanoes can be misleading. The refinement of the background level of geophysical and geochemical signals is a first step into the definition of the expected precursory signals. The definition of criticality levels for the different geophysical and geochemical signals and the timing of their occurrence is now a top level priority. This can be pursued by a multidisciplinary approach, by using the results of experimental data and numerical modeling.

The problem of hazard assessment at SV has been addressed by considering the multiple aspects of the problem. The present emergency plan is based on a hazard zonation accounting for tephra fallout (yellow zone), pyroclastic flow (red zone) and lahar invasion (blue zone). An improvement of the state of the art can be achieved by integrating field data derived from the study of past eruptions and the results of numerical modeling for different eruption scenarios as indicated by the volcanological studies. The definition of volcanic hazard on a probabilistic basis is a further necessary step to account for the complex behaviour of volcanic systems.

Description of the activities

The project is organized in 4 Tasks, each addressed to answer to one or more of the following fundamental questions:

- Is (are) there a shallow (< 8 km depth) active magma chamber(s) under Somma-Vesuvius and of which depth, size and shape?
- Which are the PTX conditions and rheological characteristics of magmas expected to drive a next eruption?
- Which are the precursory phenomena of an impending eruption and how can they be distinguished from the background signals?
- What can we learn from the past Somma-Vesuvius eruptive history?
- Which are the possible scenarios of the expected eruptions?
- How can we define the criticality levels for the volcano?

In particular, the specific tasks are devoted to: 1) define the deep and shallow plumbing system of the volcano through a multidisciplinary approach which integrates volcanological, magmatological and geophysical data; 2) identify the precursory phenomena in terms of their expected phenomenology and timing by using data from geophisics, volcanology and experimental petrology, in order to define criticality levels for the volcano; 3) improve the present knowledge of the past eruptive history by studying the distal fallout deposits and the main depositional and physical features of pyroclastic density currents of different large to mid-intensity eruptions; 4) obtain a quantitative definition of the eruptive scenario of expected events and of the related hazards.

Task 1 The volcanic structure and the magma feeding system

RU Coordinating: Civetta
RU Partecipating: Berrino De Vivo, Del Pezzo, Dingwell, Mattei, Nunziata, Santacroce, Scaillet, Patella

Task 1 is aimed at defining in quantitative terms the deep and shallow volcanic structure, and to characterize the different styles of magma evolution (in terms of its composition, rheology and volatile content). A multidisciplinary approach, with the coordination of geophysical, volcanological and petrological research issues, is fundamental for the success of the Task. This will provide the necessary constraints for defining the boundary conditions to the assessment of hazard and criticality levels.
Geophysical and volcanological studies suggest that present Vesuvius magmatic structure is characterized by a deep magma reservoir, whose top is at about 8 km b.s.l. . Shallower magma chambers were formed before eruptions by repeated arrivals of distinct magma batches from the deep reservoir. The style of magma storage and evolution in the deep reservoir regulates magma ascent to the surface. Recent studies suggest that during the post-1631 period several mid-intensity eruptions involved also volatile-rich mafic to mildly evolved magma coming from the depth. The studies will focus now on some eruptions of the Middle Age activity, to extend the existing database and to verify the effective variability of the deep feeding magma. A melt inclusion approach will be used, in order to get information also on the volatile component of this magma *(RU Santacroce)*. The direct contribution of deep magma to eruptive activity will also be verified in the products of the few parasitic vents which formed at the feet of the volcano since the Middle Age, in the assumption that magma was issued through these vents without an important interaction with shallow reservoirs *(RU Santacroce, RU Mattei)*. To verify this assumption, a structural study will also be addressed to the characterization of the stress field responsible for the formation of these lateral fissures *(RU Mattei)*. The presence of shallow level reservoirs has been

always supported by volcanological studies, even if seismic tomography images never showed traces of magma above a depth of about 8 km. Studies will be addressed to a better definition of the depth, size, shape, composition, and internal dynamics of the magma chambers related to the main Plinian and sub-Plinian recent Vesuvius eruptions, to identify the magmatic components present in the reservoirs and the new arrivals of deep magma, and their possible role in triggering eruptions, as well as the processes of pre-eruptive magma crystallization and degassing *(RU Civetta, RU Santacroce)*. An estimation of the times of magma residence in the reservoirs will be achieved by studying trace element and zoning of single phenocrysts *(RU Civetta)* and by using elemental diffusion techniques in melt inclusion studies *(RU De Vivo)* All these data are fundamental to understand the significance of possible changes in the volcano dynamics revealed by the surveillance data. Eruptions to be studied in detail are those of the last 3500 years of activity, and efforts will be concentrated on some of the presently less studied events (AD 472, AD 512, AD 1631, Middle Age activity, AP eruptions). The Plinian eruptions of Avellino and Mercato will also be investigated. General studies on the phase relations which characterize the different Vesuvius magmas *(RU Scaillet)*, the solubility of volatile species at different PTX conditions *(RU Scaillet, RU de Vivo),* and the rheological properties of different magmas as a function of their composition, volatile and crystal content *(RU Dingwell)* will give the base for the interpretation of all the results and some of the state equations necessary to the numerical simulation of magma ascent and eruption.
The knowledge of the structure of the volcanic complex is the base for any dynamical model of its behaviour. Recently the seismic tomography has revealed the presence of a huge, partially molten body at a depth of 8 km. The lateral extent of this body is unknown, as well as the details of the Moho depth in the region surrounding SV. Great effort will be given in this project to increase the knowledge of the details of the geological structure beneath SV and the surrounding region, and possibly its actual dynamics . This will be achieved using several approaches. The deformation field will be obtained using DInSAR data. The objective is to have a detailed image of the ground deformation in order to possibly identify actually active structures, and to obtain a physical model of the stress field *(RU Berrino)*. Gravity data will be used to investigate the structural setting of SV; the possible time variation of the delta factor will be obtained with continuous data acquisition *(RU Berrino)*. Passive seismic data will be used to complement the velocity tomography results with new scattering and attenuation tomography *(RU Del Pezzo)*. The detail of the proposed methods could add information about the debated existence of shallow magma bodies. The joint interpretation of the different tomographies will add insights into the physical interpretation of the rock composition. High resolution magnetotelluric surveys will improve the knowledge of the general structure of SV, giving a high resolution imaging of the fault zones *(RU Patella)*. A reappraisal of the active seismic profile data will improve the knowledge of the general structure (crust and upper mantle) in the region of SV, with a new constraint given by the study of the teleseismic receiver functions, using data from local BB stations *(RU Del Pezzo)*. Such information will be complementary to the one retrieved by the study of seismic velocity dispersion curves, which in turn will be constrained at surface by the study of seismic velocity dispersion of noise *(RU Nunziata)*.

Task 2 Identification and quantification of precursory phenomena and definition of criticality levels

RU Coordinating: Del Pezzo
UR Partecipating: Cioni, Peresan, Pingue, Quareni, Scaillet

The identification of precursory activity at a dormant volcano is a topical issue for Civil Protection purposes. The distinction between low-level restlessness and precursory activity is not trivial, and the definition of criticality levels for the different geophysical and geochemical signals and the timing of their occurrence can be considered now a top level priority. In Task 2 a multidisciplinary

approach, by using the results of experimental data (both from the geophysics and volcanology) and numerical modeling will be used to define the expected precursory phenomena in the case of a next reactivation of SV and to refine the background levels for the different parameters, in order to assess the levels of system criticality.
The seismic catalogue characteristics will be examined with new statistical algorithms aimed at the quantification of the probability of occurrence for earthquakes with large magnitude *(RU Peresan)*. The background seismicity level will be assessed through the analysis of local earthquakes and seismic noise. Emphasis will be given to the detection of the possible insurgence of volcanic tremor and LP quakes, events generated by fluid dynamics. Particular attention will be focused to the monitoring of Shear Wave Splitting and attenuation parameters, in order to detect any their change *(RU Del Pezzo)*. Existent ground deformation data sometimes suffered of very long temporal gaps. For this reason, the first step consists in the creation of a high quality and, if possible homogenised, ground deformation data base. Using advanced statistical tools applied to these data, the background level of the ground uplift changes will be calculated *(RU Pingue)*. The thermal evolution of SV after the last 1944 eruption will be modeled, having the available temperature measurements as a constraint and some of the result of Task 1 (magma density, specific heat, thermal conductivity, solidus and liquidus temperatures, latent heat of fusion) as input parameters. The result will be checked against the geochemical and geophysical observation (rate of degassing, seismicity, and magnetization) and will be very useful to the interpretation of the background signal *(RU Quareni)*. At Vesuvius, our knowledge of precursory signals for eruptions preceded by a significant dormancy is limited to the 79 AD and 1631 AD eruptions. A volcanological approach for the definition of the style of pre-eruptive magma degassing and the quantification of the timing of magma approach to the surface will be used. The deposits of the initial phases of eruptions preceded by a significant repose will be studied by assessing their volume, volatile composition and content, and timing of the onset of magma ascent to the surface will be assessed from experiments on degassing-induced crystallization *(RU Cioni, RU Scaillet)*. The results will constitute an important dataset for the modeling of the expected geophysical and geochemical anomalies.

Task 3 Intensive parameters of past eruptions as deduced from the study of volcanic deposits

RU Coordinating: Di Vito
UR Partecipating: Santacroce, Zanella

Task 3 is dedicated to complement the study of the volcanic deposits of SV, in order to improve our knowledge about the main physical parameters describing the different past eruptions. This is essential also to the hazard assessment studies of Task 4, and in particular to the evaluation of impacted areas in the past eruptions and to the validation of the results from the numerical simulation of eruptive dynamics. Given the quite large knowledge of most of the SV eruptions, the activity will be limited to two nodal points like the distal distribution of fall ash (both related to fallout phases of sustained eruptions and to co-ignimbrite clouds) and to define some of the main physical parameters of pyroclastic density current deposits of Plinian and sub-Plinian eruptions.
Despite recent advances in the stratigraphic record of Vesuvius, the ash deposits has been poorly characterised and consideration of the associated hazards have not yet been fully addressed. Good records of medial and distal ash deposits are available from outcrops, historical data, lacustrine and marine cores. A cross-correlation between tephra layers recorded within different marine and lacustrine cores (e.g. Lago di Monticchio and Adriatic cores) will be performed in order to evaluate the distal impact of past eruptions of different Magnitude and Intensity *(RU Santacroce)*. These data will also provide important constraints to the evaluation of the volume of magma erupted during past eruptions. The deposits of pyroclastic density currents of past eruptions will be studied both in the proximal and medial areas, in order to define the main processes controlling pyroclast dispersal and deposition *(RU Di Vito)*. Paleomagnetic TRM studies *(RU Zanella)* on lithic

fragments from the deposits of pyroclastic density current associated to different eruptions (Avellino, AD 472 Pollena, AD 1631) will provide strong constraints to the temperature of these flows to be used for hazard assessment purposes and also to validate the results of the numerical simulations performed in Task 4. Important constraints to the processes of interaction between the pyroclastic density currents and small scale roughness of the substrate (e.g. buildings) will be given by detailed AMS studies of selected local situations *(RU Zanella)*, and they will be compared with the results of numerical simulations.

Task 4 Scenario definition, numerical simulation and hazard assessment of expected events

RU coordinating: Cioni
UR Partecipating: Dellino, Gasparini, Neri, Pareschi, Scandone

The assessment of the volcanic hazard and the definition of the criticality levels for the volcano are the specific questions posed to the volcanological community by the Civil Protection. The answer to these questions has to be direct and circumstantiate, not only an indirect result of wide-ranging researches. Task 4 is mainly devoted to the assessment of volcanic hazard through an integrated approach which uses probabilistic studies on the past activity of SV and other volcanoes, volcanological definition of expected eruption scenarios and numerical simulation of different eruptive scenarios.
A study of the commonly observed precursors during several recent well studied awakening of dormant volcanoes and the proposal of a reliable physical model to explain their causes and role in the subsequent outbreak of the eruption will be done *(RU Scandone)*. The objective is a general model for precursors and its possible departures from the model due to the known peculiarities of each volcanic system. The model of precursors based on the chosen analogues will then be compared with the structural model of Vesuvius (Task 1) as well as the known aspects of its past historical renewal of activity (Task 2). A better definition of the chronology of SV activity and of the duration of the quiescence periods preceding the different eruptions will be pursued by using Ar/Ar and 14C techniques *(RU Cioni)*. In order to be prepared to face different types of volcanic emergencies, a Civil Protection system must be aware of the different possible scenarios in the case of a next reactivation of the volcano. Of the different possible scenarios for pyroclastic activity at SV, eruptions characterised by prolonged ash emission activity and violent strombolian phases has been up to now disregarded, even if they are clearly recorded in the stratigraphy of the recent eruptions. These will be studied in detail trying to assess the most important physical parameters (volume, intensity, grain size of the eruptive mixture, volatile ontent and composition of the erupted magma, duration of the eruption) necessary for the assessment of the related hazards and to the numerical simulation of the involved eruptive dynamics *(RU Cioni)*. New developments of the Event Tree technique will be applied to update and complete the volcanic hazard assessment of Mount Vesuvius. This will also implement the results from the research on precursory and scenario definition described above, and on the duration of quiescence periods preceding the different eruptions. A software code (based on fuzzy logic) able to visualize any possible scenarios will be produced *(RU Gasparini)*. The output of this code will represent an alternative to the ordinary hazard maps.
The study of the pyroclastic density current deposits related to the past activity of SV will give new indications on the impact parameter of such processes, to be compared with the results of numerical simulations. For the same reason, mesoscale (involving hundreds of kilograms of particles) experiments on the dispersion, transportation and sedimentation of pyroclasts will also be carried on. *(RU Dellino)*. Characterisation of recent and past debris flow deposits, including laboratory experiments, and collection of rainfall data in the Campanian area (intensity, duration, recurrence time) will be preparatory for the definition of slope stability of pyroclastic deposits through a probabilistic approach, including different rainfall conditions and different tephra typologies, both

on Vesuvius and Apennine slopes *(RU Pareschi)*. Numerical simulations will be performed both for fallout ash and pyroclastic density currents dispersal, and for debris flow as well. The results from all the numerical modelling will be finalised to the construction of thematic hazard maps. The application of the CALPUFF System and the multiphase flow code PDAC for the analysis of the dynamics and hazard of tephra fallout and PDCs, respectively, will be done*(RU Neri)*. Improvement of the actual attempts will be achieved improving the present physical formulation of the model in terms of more accurate gas and solid turbulence closures, boundary conditions at the ground, etc ; analyzing the turbulent flow structures, entrainment and deposition processes, vertical concentration, temperature and velocity profiles; produce large- and small-scale simulations of the flow on 3D topographies and urban settlements for scenarios relevant to the hazard assessment. These results will be compared with data obtained in Task 3 from volcanological and paleomagmetic researches, and will be finalised to quantify the main hazardous variables associated to PDCs. The simulation of the PDCs will also provide important input conditions and constrains for the analysis of the atmospheric dispersal produced by co-ignimbrite columns, to be modeled with CALPUFF. Data on ash grain size and dispersal will be derived from the results of different RUs from Tasks 3 and 4. Different types of numerical simulations will be used in the project in order to compare the results. A further implementation of a 2D code for PDC simulation developed during the past GNV project will be specifically written for the conditions generating impulsive multiphase gas-solid flows. A Eulerian-Lagrangian approach will be used. The fundamental flow parameters (temperature, density, concentration, velocity, static and dynamic pressure) and their expected distribution over the territory for the scenarios emerging at Vesuvius will be calculated *(RU Dellino)*. Physical and numerical models (including also semi-empirical laws) to define debris flows paths in the expansion areas will also be developed and applied *(RU Pareschi)*, in order to obtain maps based on “simulated probability” for the hazard from lahar invasion in the plain surrounding SV.

List of deliverables

Task 1: The volcanic structure and the magma feeding system
Deliverables: - Fine structure of SV deduced from joint tomographic (seismic velocity, attenuation and scattering and MT) interpretation- Constraints to the actual structural model of the region surrounding SV from passive seismic (Receiver function and Surface wave dispersion) and gravimetric data - Definition of the lateral continuity of the deep magma reservoir - Definition of the stress field responsible of lateral fissures - Depth and size of magma chambers related to selected past eruptions - Compositional and thermobarometric features of products from past eruptions - Measures of magma viscosity and yield strength - Style and fluid composition of deep magma degassing

Task 2 Identification and quantification of precursory phenomena and definition of criticality levels
Deliverables: - Definition of the Seismic and Ground deformation dynamic background pattern necessary for the definition and quantification of the background changes. Quantification of seismic precursors based on Shear wave splitting and changes in wave propagation properties. Definition and quantification of the background thermal state of SV - Timing of the onset of pre-eruption magma ascent during past eruptions - Compositions of fluids escaping deep and shallow reservoirs to define the background for geochemical monitoring.

Task 3 Intensive parameters of past eruptions as deduced from the study of volcanic deposits
Deliverables: - Maps of ash dispersal for eruption of different Intensity and Magnitude - General map of total isopachs for all eruptions with distal data constraints - Evaluation of the effects of pyroclastic density current deposits from past eruptions - Estimates of deposition temperatures for pyroclastic density currents from selected events

Task 4 Scenario definition, numerical simulation and hazard assessment of expected events
Deliverables: Absolute ages of a complete sampling of Somma-Vesuvius stratigraphic sequence - Definition of repose time preceding past eruptions - Volcanic scenarios of mid-intensity type events Quantification in terms of probability (event-tree) of the SV hazard - Protocols for the definition of criticality levels of precursors at Vesuvius - Hazard maps from numerical simulations of ash fallout and pyroclastic flow propagation at Vesuvius - Numerical modelling of co-ignimbrite ash dispersal and related hazard maps - Hazard maps based on the impact parameters (ash concentration, temperature, dynamic pressure) for selected pyroclastic flow events - Temporal succession of expected precursors for the next eruption of Vesuvius, and protocols for the definition of criticality levels of precursors at Vesuvius - Definition of the recurrence time of debris flows after an eruption and during periods of volcanic quiescence – Zonation of debris flows source and expansion areas - Maps of hazard zonation for debris flow - Definition of general protocol for lahar related hazard

SUB-PROJECT V3_4 – VESUVIO

TABLE MAN/MONTHS

U.R	**Institutions**	**Principal Responsibles**	**Task1** **Structure and gefeeding system**	**Task2** **Precursory phenomena**	**Task3** **Eruption parameters**	**Task4** **Scenarios and hazard**	**Mesi p. cofin.**	**Mesi p. rich.**
UR-1	Unina, INGV-OV	Civetta, D'Antonio, Di Vito	@				32	12 (UniNa)
UR-2	INGV-OV, UniNa, Univ. Clermont Ferrand (FR), CSIC (ES)	Berrino, Ricciardi	@				33	
UR-3	UniNa, Am. Museum New York (USA), USGS (USA), Univ. Tasmania (Australia), Univ. Bristol (UK)	De Vivo, Lima, Webster	@				54	
UR-4	INGV-OV, UniBo, UniNa, UniSannio, INGV-Rm1, INGV-MI, Missouri-Columbia (USA), UniRmTre	Del Pezzo, Saccorotti, Bianco, La Rocca, Maresca, Gaudiosi	@				84	
UR-5	Univ. Muenchen (D), UniRmTre	Dingwell	@				12	
UR-6	UniRmTre, UniFi	Mattei, Funiciello	@				46	
UR-7	UniNa, UniTri, UniRm1, INGV-OV	Nunziata, Doglioni	@				43	
UR-8	UniPi, INGV-OV, CNR, Univ. Hawaii (USA), Univ. Paris (FR), UniBa, GFZ-Potsdam (D)	Santacroce, Marianelli, Zanchetta, Fulignati	@		@		54	

UR-9	ISTO-Orleans (FR), UniCa	Scaillet, Pichavant	@	@			26	
UR-10	UniNa, INGV-OV, UniBa	Patella, Petrillo	@				26	
UR-11	UniCa, INGV-CT, INGV-Rm1, CNRS-LSCE (FR), UniPi, Univ. Eugene (OR-USA), CNRS-ISTO (FR), Univ. Cambridge (UK), Univ. Coventry (UK)	Cioni, Bertagnini, Scaillet, Cashman, Andronico		@		@	46	24 (UniCa)
UR-12	UniTri, Russian Academy of Science (RU)	Panza, Peresan, Rotwain		@			21	
UR-13	INGV-OV, UniMol, UniNaII	Pingue		@			31	
UR-14	INGV-OV	Quareni		@			16	
UR-15	INGV-OV, Sopr. Archeol. Na, Soc. Xenia	Di Vito, Isaia			@		14	
UR-16	UniTo, Univ. Hawaii (USA)	Zanella, Lanza, Gurioli			@		26	
UR-17	UniBa, Univ. Wuerzburg (D), Soc. Flowlab Na	Dellino, La Volpe, Zimanowski				@	86	
UR-18	UniNa, INGVRm1	Gasparini, Marzocchi				@	20	24 (UniNa)
UR-19	INGV-Rm1, INGV-OV, UniPi, SNS-Pi, Soc. INC Concorde (USA), Univ. Cambridg	Neri, Esposti Ongaro				@	32	24 (borsa di studio INGV-Rm1)

UR-20	INGV-Rm1, UniPi, UniBa	Pareschi, Favalli				@	27	
UR-21	UniRmTre	Scandone, Plastino				@	40	
Totale							769	84

SUB-PROJECT V3_4 – VESUVIO

Table RU and related funding request

N. UR	Istituz.	Resp UR	Personale		Missioni				Consumi servizi		Inventariabile	
					Italia		Estero					
			2005	**2006**	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**
UR-1	UniNa	Civetta	19000		1500	1500	1500	2500	2000	8000	2000	
UR-2	INGV-OV	Berrino			1000	2000	3000	3000	6000	4000		
UR-3	UniNa	De Vivo			500	500	2500	2500	9000	9000		
UR-4	INGV-OV	Del Pezzo			3000	3000	6000	6000	20000	20000	3000	3000
UR-5	Uni-Muenchen (D)	Dingwell					5000	3000	15000	10000		
UR-6	UniRmTre	Mattei			1500	1500	1500	1500	2000	4000	2000	
UR-7	UniNa	Nunziata							5000	5000		
UR-8	UniPi	Santacroce[3]			5000	5000	5000	5000	19000	18000	2000	2000
UR-9	CNRS-ISTO (FR)	Scaillet B.					4000	5000	12000	11000		
UR-10	UniNa	Patella							9000	9000		
UR-11	UniCa	Cioni[1]	16000	16000	6000	5000	4000	5000	18000	18000	3000	
UR-12	UniTri	Peresan			200	500	1800	2000	2000	2000	1000	500
UR-13	INGV-OV	Pingue			3000	3000			6000	6000	3000	3000
UR-14	INGV-OV	Quareni			1000	1500	1000	1500	5000	6000	4000	2000
UR-15	INGV-OV	Di Vito			2000	500		1500	6000	6000		
UR-16	UniTo	Zanella			5000	4000		1000	8000	8000	2000	
UR-17	UniBa	Dellino			3500	3500	1500	1500	9000	7000		
UR-18	UniNa	Gasparini	19000	19000	1500	1500	1500	2500	2000	2000		
UR-19	INGV-Rm1	Neri[2]			2000	2000	1000	2000	6000	5000	2000	2000
UR-20	INGV-Rm1	Pareschi			2000	2500			5500	6500	3000	2000
UR-21	UniRmTre	Scandone			1000	1000	2000	2000	7000	7000		
		TOTALE	**54000**	**35000**	**39700**	**38500**	**41300**	**47500**	**173500**	**171500**	**27000**	**14500**
GRAN TOTALE: 642500												

[1] 16000 euros (8000 during the first year, and 8000 during the second year) included under the voice "Consumi e servizi" will be provided to the Laboratoire du Geochronologie of CNRS-LSCE (Gif sur Yvette Cedex, FR) for research activities under the responsibility of S. Scaillet.

[2] 6000 euros (3000 each year) included under the voice "Consumi e servizi" will be provided to Earth Tech Inc. (USA) for research activities of J. Scire.

[3] 13000 euros (7000 first year, 6000 second year) are for research activities of Dr. Paola Marianelli, within Task 1. 24000 euros (12000 first year, 12000 second year) are for research activities of Dr. Gianni Zanchetta, within Task 3.

PROJECT V3

Sub-Project V3_5 – Vulcano

Responsibles:

Paolo Papale, INGV Roma1
Stefano Gresta, Univ. Catania

Project V3

Sub-Project V3_5 – Vulcano

Coordinators:

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State of the Art

Vulcano lays along a NNW-SSE oriented regional strike-slip fault acting on a thinned continental crust (18-20 km). The island covers an area of about 22 km^2 and is entirely made up of volcanic rocks. The last eruption (1888-90 A.D.) gives name to a peculiar type of explosive activity, which is characterized by numerous closely timed eruptive pulses (vulcanian activity).

At present, the island is site of intense fumarolic emissions, which are concentrated on the active crater of La Fossa cone, and of degassing activity on diverse areas of its northern sector. The high temperature of gas emissions, their chemical and isotopic composition and the knowledge of the hydrothermal and magmatic systems, leave no doubt on the presence of magmatic melts under the volcano, which in the future should give way to new eruptions.

Recent investigation that combine the geophysical information on the structure of the crust under the volcano and data deriving from the study of the fluid inclusions in crustal xenoliths, suggest the presence of various type of magmatic reservoirs at different depth, which were active in the recent past and likely represent the sites of preferential storage of present magmas. The eruptive activity of the subaerial part of the island dates back to more than 100 ka and has been characterized by the formation of various volcanic edifices that, over time, migrated from SSE toward NNW.

Recent eruptions, which were characterized by products of shoshonitic to rhyolitic composition, occurred inside a volcano-tectonic structure, La Fossa Caldera. The volcanic apparatus of Vulcanello (active between 183 B.C. and 1550 A.D.) formed along the continuation toward N of this structure. Inside this structure, in older times the most voluminous eruptions of Vulcano occurred, and later on La Fossa Cone formed, which has been the most active centre of the last 6 ka.

The eruptions of Vulcano were characterized by relatively small volumes of eruptive products (fractions of km^3) when compared with those of other Italian active explosive volcanoes. Anyway, the particular type of activity, which has been characterized by phreatomagmatic explosions generating pyroclastic density currents (with subordinate amounts of fallout products and lava flows), poses striking questions about the volcanic risk. This is due also to the peculiar distribution of the anthropic activities on the island (the majority of buildings is concentrated at the foot of the active cone of La Fossa) and to the fact that during summer time the population of the island grows up to many thousands people.

Studies on the eruptive mechanisms and on the volcanic hazard have been carried on in recent times at Vulcano, leading to the definition of quite coherent scenarios in the case of a renewal of the eruptive activity from the crater of La Fossa cone. However, eruptive scenarios for other areas of the island, in particular the northern sector of La Fossa Caldera, are lacking. In this area the ascent and eruption of new magma, both in subaerial and subaqueous conditions, needs to be taken into account. The distinct probability that at longer terms it can lead to explosive activity spreading the products both over Vulcano and Lipari, as occurred in the past and testified by recent studies on the eruptions of Tufi di Grotte dei Rossi, needs to be assessed. Also, hazard maps on which are drawn the contour lines of the probability of the impact parameters expected in a future eruption represent new results to reach in this project. Furthermore, even though quite detailed studies on the structure of the volcano and on the hydrothermal–fumarolic system have been carried out in the recent past, synthetic elaboration of data leading to a clear picture of the levels of criticality of the volcano are lacking.

Description of the Activities

In the time-span of a two years project, a significant improvement of the knowledge on the superficial and deep magmatic alimentation systems, on the volcanic hazard, and on the levels of criticality of Vulcano, can be reached only with a high level of coordination between diverse volcanological, geochemical and geophysical competences. The multidisciplinary approach that is needed for finalizing the project results to the Civil Protection requests, not only requires a tight integration and dissemination of results among research units, but also needs the focusing of efforts on specific priority tasks that then need to communicate and disseminate intermediate results in due time during the project. For this reason, the main themes of the research project are subdivided into three main tasks, each responding to particular requests and each having a coordinator that will serve as a link for the general project focusing and finalization. The three tasks are

Task 1. Eruptive products, eruptive scenarios and hazard
Task 2. Structure of the volcano

Task 3: Levels of criticality of the volcano

In the following we describe in more detail the structure of the Tasks and the relative aims

Task 1. Eruptive products, eruptive scenarios and hazard

RU coordinating (P. Dellino, University of Bari)
RU participating (De Astis, Osservatorio Vesuviano – Naples)

This task will be mainly devoted at understanding how the volcano worked during past eruptions, and which lesson we learn from Vulcano's past behaviour in order to forecast the type and intensity of activity in a future eruption. For this aim, the principal source of information are rocks and rock components. They will be studied by means of an integrated multidisciplinary approach that we hope will help in the products-process characterization, and in particular in constraining the relevant physical parameters representing the source of hazard, i.e. the impact parameters. After such a reconstruction, by means of experiments and calculations, scenarios will be drawn for constraining the possible impact parameters of a future eruption, and a range of expected values will be given and distributed over the territory with the eventual result of obtaining hazard maps.

The first step in this quest will be the precise stratigraphic reconstruction of deposits of the main eruptive periods, which will serve to categorize products as a function of eruptive and transportation processes and of timing and recurrence of eruptive types. This study will be carried on at La Fossa Cone by RU Dellino and at La Fossa Caldera and Vulcanello by RU De Astis.

Scenarios at short terms will consider La Fossa cone as the possible location of a new vent opening and as the most hazardous expected events the type and intensity of the recent phreatomagmatic eruptions generating dilute pyroclastic density current will be considered. Scenarios at longer terms will consider the likelihood of the possible opening of new vents along the rims of La Fossa caldera and especially in its northern sector, which in the past probably was the source of the most intense explosive eruptions of Vulcano. The assessment of eruption characteristics of these distinct scenarios not only will consist of the volume calculation of products of past eruptions, their dispersal area and measurement of the main structural and textural features of pyroclasts (RUs Dellino and De Astis). A detailed sampling of the most significant eruptive units will also make available carefully selected material on which specific laboratory analysis will be carried on for quantitatively assessing the fragmentation and transportation dynamics of explosive events (multicomponent-multimodal grain size, shape, density and aerodynamic characterization - RU Dellino) and some processes occurred after the emplacement (alteration, pedogenesis - RU De Astis). On selected samples of pyroclastic material rheology and explosion experiments will be carried on (UR Dellino) for reconstructing both the various type of magma fragmentation processes and the budget of mechanical energy released during explosions at Vulcano. Particle characteristics will be also used for reconstructing, by numerical calculation methods, the impact parameters (velocity, particle concentration, density, dynamic pressure) of pyroclastic density currents of the most significant past eruptions. Mechanical energy information and particle characteristics will be also used as input parameters in multiphase numerical simulations, based on an Eulerian-Lagrangian approach, which will help understanding the time-space evolution of pyroclastic density currents and the distribution of impact parameters that we expect in the future scenarios. The simulations, which will be carried on by RU Dellino, will be particularly helpful in understanding the variability of the physical parameters of the currents as a function of vent location and actual topography.

Mesoscale experiments on the trasportation, dispersion and sedimentation of particles will be carried on by RU Dellino. They will involve hundreds of kilograms of actual pyroclastic particles, in a controlled environment, by forcing the flow of pressurized gas throughout a modified shock tube with initial pressure and volume of gas and particles suggested by field studies and fragmentation experiments. These experiments will be monitored by sensors, multipoint video analysis and ash trap devices and they will mainly serve for checking the sensitivity and variability of the parameters used in the numerical calculation and simulations, and eventually for validating models hypothesis and assumptions.

We believe that this multidisciplinary approach will lead to assess in a robust way the range of solutions of impact parameters for the expected scenarios and therefore to furnish statistically significant confidence intervals for the impact parameters. The sum of results will allow the obtainment of the distribution over the territory of the basic impact parameters (velocity, density, temperature, particle concentration, static and dynamic pressure) of the potentially dangerous events and this will lead to the construction of hazard maps for the emerging scenarios of explosive eruptions at Vulcano.

This task will strongly benefit from results of other tasks, and in particular from task 2 concerning the location, dimension and characteristics of magma batches located at various depth and from task 3 in understanding what kind of escalation is to be expected, starting from the present state of the volcano, for the triggering of new eruptions.

Task 2. Structure of the volcano

UR Coordinating: P. Bruno (INGV-OV, Naples)

UR Participating: Gambino (INGV- Catania), De Astis (INGV-OV, Naples), De Rosa (Università della Calabria- Cosenza), Romagnoli (University of Bologna) , Piscitelli (CNR – Institute of methodologies for environmental analysis, Potenza), Fedi (Università Federico II, Naples), Dellino (Università di Bari)

Previous volcanological and magmatic studies on young Vulcano products (20 ka to Present) suggest the presence of a complex magma feeding system underneath the present La Fossa Caldera (FC), including the cones of La Fossa and Vulcanello. In the last 20 ka, most of the eruptions occurred inside and along the rims (e.g. Mt.Saraceno, La Roja) of the present FC, involving both mafic and variably evolved magmas. Merging of geophysical and petrological data indicated that at different depths, between ~22 and ~1.3 km, four main crustal discontinuities exist. Potassic magmas can storage and evolve in these "reservoirs". Evidence of this type must be confirmed and supported by more detailed data coming from different disciplines. Therefore, the definition of the structural relationships between the deeper and the shallower reservoirs (sills, elongated dykes, etc.) is critical to evaluate the future evolution of the plumbing system, the possible upraising of new magmas to the surface, the possible new vents. Moreover, the possible renewal of activity on the island (pre-eruptive scenario and eruptive style) can be determined by the interaction of magmas with different composition (mixing and mingling processes) and by magma-water interaction (i.e. eruption in shallow water). In other words, potassic mafic magmas (Vulcanello type) coming rapidly from deeper levels could interact with the trachy-rhyolitic liquids located at shallower depths, or with sea-water due to vent opening under the sea-level. In this frame, structural and magmatic processes are tightly connected and can originate different kind of events.

In order to fully understand the influence of tectonic lineaments and magma transfer on the plumbing system behaviour and their mutual relationships, geophysical and petrological data have to be collected, processed and synthetically interpreted.

Seismic reflection and seismic refraction data, along 2 selected profiles, together with new high-resolution aeromagnetic surveys in the same areas will be collected (RU Bruno) and provide information on the shallower levels of the crust beneath the FC (main structural boundaries, active faults, buried small-scale structures, etc.). Along the same profiles, 2D high resolution ERT and SP measures will be performed with the same aim and integrated with sub-surface soil temperature (T) and soil gas (SG) measurements (RU Piscitelli). A detailed density imaging of northern FC sectors based on gravimetric survey (in about 100 stations) will be also carried out (RU Dellino), processed trough topographic correction and constrained by geo-vulcanological and structural evidence. Density contrasts will provide geometries of anomalous bodies underneath that area.

Investigations at larger and deeper scale on the Vulcano structures will be carried out by exploiting the already existing seismic, geodetic, magnetic and geo-electrical data using new powerful software and algorithm (RU Fedi, RU Gambino). A significant improvement in the knowledge of Vulcano seismic activity will be possible trough the acquisition of new data from broad band stations, that will replace the short periods ones at the very beginning of the project (RU Gambino). From the analysis of these data, important information on the Tindari-Letoianni regional dynamic and on the deeper crustal levels should derive. Discrete (GPS and levelling) and continuous (tilt and GPS) survey will provide information on the Lipari-Vulcano (i.e. Fossa Caldera) ground deformation pattern (RU Gambino).

The dynamics between different magma reservoirs and magma ascent up to the phases of eruption and emplacement will be studied by RUs De Rosa and De Astis that will operate in close cooperation both in the field work (measures and sampling of FC volcanic successions) and in the choices of products to be analysed. Quantitative description of the products will help in evaluating the magma supply from FC and possible rate in the last 20 ka. Laboratory investigations will increase the data set on the pre-eruptive volatile content of La Fossa and Vulcanello magmas, to constrain degassing processes and flow regime in the conduit. They also will provide a crucial parameter like viscosity with the final aim to know the rheology of the Vulcano melts at the storage depths (RU De Rosa). New geochemical and isotopic analyses on these and other selected FC products will be carried out (RU De Astis) to get a detailed record of the compositional variations shown by the magmas erupted in the last 15-20 ka, also considering the already available compositional data.

As regard the knowledge of La Fossa structure not directly related to volcanic eruption, but with the dangerous NE sector of the edifice (see also task 3), a new survey of the submarine morpho-structural features will be carried out (RU Romagnoli) and will complete the data set already acquired trough the last GNV project.

A close cooperation between all the RUs involved in the Task - 2 aimed to identify the location, shape and features of magma batches located at various depth and the sectors with higher probability of vent opening - has been planned. Contributes to task 1 deliverables can be also foreseen.

Task 3: Levels of criticality of the volcano

UR Coordinating: Inguaggiato (INGV- Palermo)
UR Participating: Diliberto (INGV – Palermo), Gambino (INGV- Catania), Tommasi (CNR – IGAG, Rome), Capaccioni (Università di Urbino)

The present state of the volcano shows that the hydrothermal system is very active as testified by the strong variations in temperatures and fluxes occurred during the ’80 and ’90, up to present (2004). The increasing of these parameters (e.g. T=400-500°) indicates that the magmatic system is active and is responsible at least for some of the changes recorded at the surface. Furthermore, the dynamics related to the hydrothermal system can trigger further hazardous phoenomena. In fact, sources of risk at Vulcano Island are multiple and not only related to volcanic activity. They range from toxic gaseous phenomena to slope instability possibly affecting La Fossa cone flanks. Therefore, the definition of the critical levels approached by the different geophysical and geochemical parameters is a key-issue for the new researches on La Fossa and surrounding areas. New and already available data set will be elaborated in order to define the background level of the volcano and the criticality threshold that can lead to irreversible hazardous activities.

As regard Vulcano seismicity, earthquakes originating in the area of La Fossa could be associated with both fracturing and degassing processes. The former are likely represented by the occurrence of sporadic swarms of low-magnitude shocks, with shallow foci (< 4 km). The other type of events are related to the background seismic activity and are represented by weaker quakes, which originate at shallower depths (<1.5 km). However, it is difficult to discriminate between the two types and the seismic background level of the volcano is not really constrained, yet. Geophysical studies by RU Gambino are aimed to characterize the baseline dynamic of La Fossa cone trough the reinterpretation of the geodetic and seismic data set. A further better characterization of Vulcano local seismicity and a significant improvement of hypocenter location and source parameters will be carried out, even with the support of new data obtained by using a new broad-band array as already mentioned in task 2.

Levels of criticality deriving from heat flux measures (along vertical axis of the soil) will be studied by Diliberto’s RU. The comparison of the thermal gradient in the soil out of the fumaroles area with heat flux estimates obtained trough steam output measures and with fumaroles temperatures and even with local seismicity will provide estimation of the different quotes of energy release (heat, steam and CO2 flows). Interpretation and elaboration of these data, combined with other geochemical parameters deriving from fumaroles, will allow the investigations of trends in the time series, thus leading to the definition of the background levels and to infer on the possible anomalies to be expected close to critical thresholds of La Fossa hydrothermal system.

As regard the slope instability processes affecting the NE sector of La Fossa cone (P.te Nere, Le Forge), the RU Tommasi will study the geotechnical material properties and the weakening of the mechanical strength also due to the circulation of the hydrothermal fluids (in cooperation with

RU Diliberto) for assessing the likelihood of flanks failure.

The impact on the environment of light alkenes and aromatics released from fluids discharge will be evaluated trough discrete sampling and subsequent analyses by several methodologies (RU Capaccioni). The same RU will use remote sensing (infrared laser) and accumulation chamber with infrared sensor in order to better estimate the fluxes from La Fossa crater and surrounding areas. A final assessment of the toxic elements for human being will be possible.

New sampling methods and analytical techniques will be developed and tested, also by means of international inter-laboratory standardization for nitrogen isotopic composition (RU Inguaggiato). Coupled with noble gases, these isotopes seem to be very promising in identifying the magmatic imprinting on the fumarolic gases and, in particular, the component deriving from subduction-related processes. Based on 2-years sampling, background levels of $\square^{15}\mathbf{N}_{\mathbf{N2}}$values could also be defined and thus contributing to a better understanding of volcanic criticality.

Results from this task will greatly benefit task 1 for the investigation of the possible escalation toward pre-eruptive scenarios.

List of Deliverables

Task 1. Eruptive products, eruptive scenarios and hazard

1) Databases on the chemical-physical characters of eruptive products and melts
Major and trace elements of glass shards and mineral phases. Newtonian and non Newtonian viscosities of melts. Multimodal-multicomponent size characteristics of pyroclastic particles. Size-dependent density of pyroclastic particles. Hydraulic and aerodynamic coefficients of pyroclastic particles
2) Energy release of explosive eruptions
Budget of mechanical energy of impulsive eruptions subdivided into the shock-wave, fragmentation and transportation components
3) Graph and diagrams of expected scenarios based on probability density functions
4) Codes for the calculation of impact parameters of pyroclastic density currents and applications to the case of Vulcano
5) Hazard maps of pyroclastic density currents and vulcanian events for the short-term and the long-term scenarios.

Task 2. Structure of the volcano

1) 2D cartoon of depth and location of magma reservoirs
2) Map of possible vents opening derived from identification of horizontal and vertical structures (extended to the shallow su-marine sector around la Fossa cone)
3) Complete geochemical and isotopical data-set of the products erupted during the last 20 ka
4) Trends of temporal variation of magma supply rate during the last 20 ka

Task 3. Levels of criticality of the volcano

1) baseline of Vulcano seismicity with possible discrimination of source mechanisms (fracturing and degassing).
2) Characterization of the degassing hydrothermal system by Heat fluxes and geochemical parameters (Nitrogen, CO_2, toxic fluids) and definition of background levels and criticality thresholds.
3) Geotechnical characterization of the slopes of La Fossa cone for the assessment of the likelihood of flank failures (P.te Nere and Le Forge sectors)

SUB-PROJECT V3_5 – VULCANO

TABLE MAN/MONTHS

U.R	Institutions	Principal Responsibles	Task1 Scenarios and hazard	Task2 Volcano structure	Task3 Levels of criticality	Mesi p. cofin.	Mesi p. rich.
UR-1	UniBa, Univ. Wuerzburg (D), Soc. Flowlab Na, INGV-OV	Dellino, La Volpe, Schiavone, Zimanowski, Loddo, Mele, Esti	@	@		95	
UR-2	INGV-OV, UniTo, Univ. Hawaii (USA), UniBo, Open Univ. London (UK), UniCal	De Astis, Piochi, Lanza, Zanella, Tranne, Lucchi	@	@		59	12 (borsa di studio UniTo)
UR-3	INGV-OV, INGV-Rm, CRdC-AMRA Na, Univ Burgos (ES)	Bruno, Chiappini, De Ritis, Montenegro		@		33	
UR-4	UniBo, UniRm1, CNR-IGAG	Romagnoli, Chiocci		@		26	
UR-5	CNR-IMAA, CNRS-CEREGE (FR), INGV-PA, Imperial College London (UK)	Piscitelli, Lapenna, Matthai, Revil		@		59	
UR-6	UniNa, INGV-CT	Fedi, Di Maio		@		13	
UR-7	UniCal, INGV-Rm1, UniPi, Univ. Hannover (D)	De Rosa, Ventura, Mazzuoli, Holtz, Behrens, Gioncada		@		46	24 (UniCal)
UR-8	INGV-PA, BGR (D), Unam-Mexico	Inguaggiato			@	20	

UR-9	UniUrb, UniFi, UniNaII, UniIns	Capaccioni, Vaselli, Tedesco			@	46	
UR-10	INGV-PA	Diliberto			@	14	
UR-11	INGV-CT, INGV-OV	Gambino, Alparone, Mattia, Ursino, Calvari, Velardita		@	@	60	
UR-12	CNR-IGAG, INGV-OV, UniRm1, UniNaII, UniRm3, CNR-ISMAR	Tommasi			@	24	
Totale						495	36

SUB-PROJECT V3_5 – VULCANO

Table RU and related funding request (Progetto V3_5)

N. UR	Istituz.	Resp UR	Personale		Missioni				Consumi servizi		Inventariabile	
					Italia		Estero					
			2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
UR-1	UniBa	Dellino			10000	10000	2000	2000	17000	17000	2000	1000
UR-2	INGV-OV	De Astis[1]			7200	6000	1800	1000	12000	23000		
UR-3	INGV-OV	Bruno			6500	2500			27000	1000		4500
UR-4	UniBo	Romagnoli			4000	2000			29000	5000		
UR-5	CNR-IMAA	Piscitelli			4500	4500	2500	2500	3000	5000	2000	3500
UR-6	UniNa	Fedi			1500	1500	1500	1500	2500	2500		
UR-7	UniCal	De Rosa	19000	19000	1000	1000	1500	2000	2000	5000		
UR-8	INGV-PA	Inguaggiato			2000	2000	7000	8000	3000	3000		
UR-9	UniUrb	Capaccioni			5000	5000			1000	1000		
UR-10	INGV-PA	Diliberto			4000	2000	1000	2000	9000	9000		
UR-11	INGV-CT	Gambino			8000	5000	2000	2000	5000	13000		
UR-12	CNR-IGAG	Tommasi			2000	1500			10000	9500		
		TOTALE	**19000**	**19000**	**55700**	**43000**	**19300**	**21000**	**120500**	**94000**	**4000**	**9000**
GRAN TOTALE: 404500												

[1]16000 euros (during the second year) included under the voice “Consumi e servizi” will be provided to Univ. of Torino, for the activation of a one-year “borsa di studio” dedicated to the research foreseen by the RU.

PROJECT V3

Sub-Project V3_6 – Etna

Responsibles:

Paolo Papale, INGV Roma1
Stefano Gresta, Univ. Catania

Project V3

Sub-Project V3_6 - Etna

Responsibles:

Ciro Del Negro, Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania, Piazza Roma 2, 95123 Catania, delnegro@ct.ingv.it

Stefano Gresta, Dipartimento di Scienze Geologiche, Università di Catania, Corso Italia 57, 95129 Catania, gresta@unict.it

Augusto Neri, Istituto Nazionale di Geofisica e Vulcanologia, Sezione Roma1, Centro per la Modellistica Fisica e Pericolosità dei Processi Vulcanici, via della Faggiola 32, 56126 Pisa, neri@pi.ingv.it

Foreword

The project focuses on the hazard assessment at Etna through the development of geophysical and geochemical techniques, the investigation of chemical and physical properties of magmas, the quantitative analysis of monitoring signals for the identification of precursors, the reconstruction of the eruptive history, and the development of physical and numerical models of pre-eruptive and eruptive processes. The variety of the project tasks has lead to the creation of a project consortium including many different expertizes from a large number of research Institutes (INGV, CNR, etc.) and Universities. Therefore, the main target of this 2-year project is to make a substantial step forward in the understanding of the different behaviours and critical levels of Mt. Etna and, as a consequence, in the assessment of the different hazards it poses.

State of the Art

Mt. Etna is one of the most active and investigated volcanoes in the world. In particular, the last two decades have represented a time period characterized by a great variety of eruptions and by a large data acquisition, both instrumental and from field surveys. As testified by the conspicuous literature, the present knowledge of the different eruptive styles of the volcano is rather good and includes the study of Plinian eruptions in historical age, small phreatic eruptions at the summit craters, long quiet lava effusions, as well as large flank eruptions. Also the internal structure of the volcano is roughly well-known, even though some crucial questions, as the existence or not of a main magma chamber, remain still unanswered and more detailed information are required for the shallower parts of the volcano. Geological maps of the volcano (funded by the National Geological Survey and other projects) are in progress and many the basic petrologic features of the erupted magmas are known. The eruptive mechanisms of some single eruptions have been well-studied, even if an integrated multidisciplinary approach was often lacking. Significant statistical investigations on the eruptive precursors were lacking too. The modelling and numerical simulation of pre-eruptive processes have been mostly carried out by using inverse models and need to be complemented by promising results coming from direct analytical and numerical models. During the last decades, new modern techniques of volcano monitoring have been also implemented in order to mitigate the volcanic hazard. The amount of available data produced represents a huge database. However, a significant amount of work is still required to understand the volcano behavior and hazard issues. Different kinds of hazard affect the volcano and the surrounding areas: short-lived explosions (threatening tourists and/or scientists close to the summit craters), ash clouds (threatening civil aviation), lapilli/ash fallout and lava flows (affecting large inhabitated areas), earthquakes triggered by magma intrusions, landslide (also submarine), toxic gas emissions (Rn and/or CO_2). Each of these scenarios should be preceded and accompained by variation of geophysical and geochemical parameters. Nevertheless, strong improvement in terms of evaluation of the statistical significance of that variation, as well as in interpretation needs. Then, the identification and characterization of precursory signals represent a fundamental issue that would drastically improve our capability to forecast the volcanic phenomena, in terms of both time occurrence and magnitude. Moreover, despite the frequent occurrence of eruptive activity, significant steps forwards still need to be done in the quantification of its hazards. Lava flows and the generation of small- to medium-scale ash columns represent certainly the most known hazards. About lava flows, the production of accurate lava flow invasion maps represents an important step for the assessment of the medium and long-term hazard associated to this phenomena. Similarly, the development of reliable quasi real-time lava flow models will allow to forecast different scenarios of lava propagation and to plan the appropriate mitigation measures. As far as the explosive activity is concerned, the recent 2001 and 2002 eruptions of Etna have clearly shown the huge impact of this phenomenon on the metropolitan area of Catania, as well as on the Fontanarossa and Sigonella airports that were forced to interrupt traffic operations with a huge economic loss. On this respect, it is necessary to improve the present observational and forecasting capabilities regarding the dispersal of the ash cloud. It is therefore necessary to produce hazard maps, able to provide robust information on the medium- and long- term hazard, as well as nearly real-time forecasting tools able to simulate the ash clouds dispersal and characteristics. Eruptive events as well as hazard maps should be possibly described in terms of probability of occurrence of specific phenomena at a given place and time by producing probabilistic event/logic trees and also considering the uncertainty associated to the system.

Description of the Activities

During recent decades, new insights on the behaviour of Mt. Etna have been gained regarding the understanding of past eruptive activity, the dynamics of the volcano, the magma transfer processes, and the geophysical and geochemical monitoring. A number of expertises are now available in many fields of investigation but no major effort has been made for an effective integration of this knowledge. Furthermore, many studies so far conducted have been only scarcely finalized to a quantitative assessment of hazard despite the important hazard implications they have. Such a lack of multi-disciplinarity and integration of observations and theoretical studies has been strongly prejudicial to the development of a deeper understanding of the volcano dynamics and to the construction of efficient early-warning systems and hazard assessment facilities. Therefore, in the present project, we avoid a thematic approach - which cannot take into account all the constraints of the system – and develop a multi-disciplinary and integrative approach to the hazard assessment in which all participants contribute with a specific methodological approach.
This project gathers the efforts of 41 Research Units (RU) to the project, belonging to 12 Italian Universities, 4 Foreign Institutions, 4 CNR Institutes, and 7 INGV Sections. To assume an efficient management of this consortium and to build a good communication network, this project, though centrally managed by three coordinators, relies upon seven Tasks managed by specific task coordinators:

Task 1. Plumbing system and structure of the volcano from the lithosphere to the surface;
Domenico Patanè (INGV-Sezione di Catania);
Task 2. Physical and chemical properties of magma and volcanic rocks;

Roberto Moretti (INGV-Osservatorio Vesuviano);

Task 3. Modelling and simulation of pre-eruptive processes;
Giuseppe Puglisi (INGV-Sezione di Catania);

Task 4. Identification and characterization of precursors;
Stefano Gresta (Università di Catania);

Task 5. Reconstruction of the eruptive record and characterization of eruptive typologies and probability of the expected events;
Mauro Coltelli (INGV-Sezione di Catania);

Task 6. Simulation of lava flows and associated hazard;
Ciro Del Negro (INGV-Sezione di Catania);

Task 7. Simulation of atmospheric dispersal processes and associated hazard;
Augusto Neri (INGV-Sezione di Roma 1).

For each Task several Working Packages (WP) have been identified to respond to the request of the project. These task coordinators are specialists of the WPs involved in their Tasks. The role of these persons is to coordinate the WPs of their Tasks. They will also ensure a tight commUniv. cation between RUs and they will organise the WPs.

A brief description of each Task will be presented in the next pages together with a list of expected deliverables (according to the activities planned by each Research Univ. t) and the inter-connections between them. A detailed description of the scientific activities is left to the forms compiled by the research Univ. ts.

Task 1. Plumbing system and structure of the volcano from the lithosphere to the surface

RU Coordinating: Patanè D. (INGV-CT)
RU Partecipating: Burton (INGV-CT), Chiocci (Univ. Roma La Sapienza), Corsaro (INGV-CT), Cristofolini (Univ. Catania), Hirn (IPG-Parigi), Monaco (Univ. Catania), Murru (INGV-RM1), Neri (INGV-CT), Patanè G. (Univ. Catania), Siniscalchi (Univ. Bari), Pompilio (INGV-RM1)

Description of the activity
The knowledge of the plumbing system and structure of the volcano plays an important role in order to improve our understanding of its behaviour. The existence, location and properties of deep and shallow magma bodies are indeed fundamental for a correct interpretation of monitoring data and to better forecast the style of future activity. Magmatic properties, such as composition and volatile contents, are also necessary to better constrain the eruption dynamics. Similarly, the characterization of the volcano structure, in terms of major active faults and fractures but also of physical and mechanical properties, is crucial for a better interpretation of monitoring data and production of susceptibility maps. As a consequence, in this task, the processes governing the magmatic feeding system during the time-evolution of Etna and the mechanisms of magma degassing as well as the behaviour of silicates and volatiles during and after eruption processes, from magma chamber to atmospheric levels, will be investigated. To gain new insights into magma storage and transfer processes we will perform geochemical and petrological modelling at Etna to constrain processes affecting magma properties at depth, quantify rates and time-scales of eruptions of Etna in relationship with storage and transport processes, recognize the geochemical fingerprints of “master events”, and improve the present understanding of deep to shallow degassing processes.

Work-Packages:
1.1 Definition of the plumbing and magmatic system

1.2 Definition of the volcano structure

Deliverables:
1.1.1 Location and characteristics of the main magma body
1.1.2 Definition of feeding structures and shallow magma batches
1.1.3 Determination of composition and volatile content of magma
1.2.1 Definition of the edifice and basement structure
1.2.2 Distribution of active faults, eruptive fractures and vents
1.2.3 Definition of the conduit/dike system within the volcanic pile
1.2.4 Influence of regional and local tectonic structures in the magma uprising and stocking
1.2.5 Susceptibility maps based on geological, geochemical, magnetic, gravimetric, electrical, seismological, and ground deformation data

Task 2. Physical and chemical properties of magma and volcanic rocks

RU Coordinating: Moretti (INGV-OV)
RU Partecipating: Armienti (Univ. Pisa), Dingwell (Univ. Monaco, Germania), Paonita (INGV-PA)

Description of the activity
The knowledge of the physical and chemical properties of magma and volcanic rocks are necessary to provide realistic constitutive equations to the interpretation of monitoring data and theoretical descriptions of the eruptive phenomena. Rheological properties of the multiphase magmatic mixture, volatile solubility data, but also density, velocity, permeability, porosity, conductivity and magnetization of the volcanic structure are just some examples of fundamental properties used by direct and inverse models that need further investigations. In fact, any attempt of modelling, for instance, the stability of the volcano (sectorial collapse of the edifice, emplacement of dikes, evolution of pre-eruptive crises) requires some knowledge of the mechanical, electric, magnetic properties of the rocks as well as of the circulation of fluids in the system (in terms of porosity, permeability, etc.). Present-day modelling allows to take into account a large number of parameters but only a few data on the physical properties of volcanic rocks and magmas are available, though essential to constrain and use the theoretical models. Sampling will be conducted following precise geo-statistic rules in order to obtain representative samples. Physical properties measurements will be carried out on specimens of size and shape suited for the specific property investigated. These data will be acquired keeping in mind the fundamental need to provide input data and constraints to the physical models developed. Field experiments of limited extension (from a few meters to a few kilometres) will be also conducted to test the scale-dependency of some variables and parameters.

Work-Packages:
2.1 Physical and chemical properties of the magmatic mixture
2.2 Physical and mechanical properties of volcanic rocks

Deliverables:
2.1.1 Viscosity of the magmatic mixture (vs. composition, crystals, bubbles, volatiles, temperature)
2.1.2 Yield strength of the magmatic mixture (vs. composition, crystals, bubbles, volatiles, temperature)
2.1.3 Volatile solubility data and correlations
2.1.4 Gas diffusivity
2.2.1 Visco-elasto-plastic properties of the edifice and their variation with T and P
2.2.2 Density and velocity models of the volcanic edifice
2.2.3 Permeability, porosity, capillary pressure and texture of the rock fabric

2.2.4 Electrical and thermal conductivity models of volcanic rocks
2.2.5 Zeta potential and wettability of the rock surface

Task 3. Modelling and simulation of pre-eruptive processes

RU Coordinating: Puglisi (INGV-CT)
RU Partecipating: Bonafede (Univ. Bologna), Carbone (INGV-CT), Giunchi (INGV-RM1), Saccorotti (INGV-OV)

Description of the activity
This task is devoted to the development, validation and application of theoretical models of pre-eruptive processes typical of Etna's activity. The models developed will employ the observational and experimental data determined in Tasks 1 and 2 and will represent an effective tool to better interpret the monitoring data during pre-eruptive phases. In fact, in order to identify and interpret correctly the sources of the broad band of geophysical signals associated to volcanic activity, it is of the uttermost importance to properly model the deformation, seismic, gravity, magnetic, and electric fields, as well as their changes with time. To this aim, several advanced numerical tools are available today. Models able to correlate the edifice deformations observed to a specific source, taking into account the perturbations due to the topography and medium elasto-visco-plastic properties, will be developed. Similarly, models describing the dynamics of the intrusion of the multiphase magmatic mixture into the conduit/dike system will provide further constraints in the interpretation of monitoring data and eruptive mechanisms occurring during the magma ascent.

Work-Packages:
3.1 Deformation modelling
3.2 Magma intrusion modelling

Deliverables:
3.1.1 1D/2D Analytical models of medium deformation
3.1.2 2D/3D transient models of stress/strain fields due to the action of conduits, dikes, etc.
3.1.3 Temporal simulation of expected deformation and potential fields
3.1.4 Experimental analogue models of structure deformation and collapse
3.2.1 Multidimensional, multiphase and transient models of magma intrusion in conduit/dikes
3.2.2 Fluid-structure models of magma intrusion with phase-change and heat transfer to conduit walls

Task 4. Identification and characterization of precursors

RU Coordinating: Gresta (Univ. Catania)
RU Partecipating: Berardino (CNR-Napoli), Burton (INGV-CT), Fedi (Univ. Napoli), Gurrieri (INGV-PA), Meloni (INGV-RM2), Moretti (INGV-OV), Mulargia (Univ. Bologna), Nunnari (Univ. Catania), Pergola (CNR-Potenza), Privitera (INGV-CT), Puglisi (INGV-CT), Ripepe (Univ. Firenze)

Description of the activity
This task is focused on the identification and characterization of precursory signals and therefore is strongly based on the quantitative analysis of data coming from monitoring activity. Complete and long time-series of geophysical, geochemical and petrologic data are indeed available at Mt. Etna. An objective of this task is to combine multi-disciplinary real-time data (such as seismic, geodetic,

magnetic, electric, gravity, electromagnetic, resistivity, gas emissions) and analyzed them applying methods ranging from the classical ones (i.e. cross-correlation analysis) to new pattern recognition algorithms (i.e. neural networks). Blind tests will also be done. Quantitative definition of precursors - in terms of threshold values, time-window of validity, kind of "predicted" eruptions needs - as well as validation of precursors - in terms of number of number of successes, false alarms, and failed predictions - are the main goals. Attention will be payed to the definition of the "backgrond level" of a given parameter, as well as the "critical levels" that define the transition between different stages of activity of the volcano.

Work-Packages:

4.1 Background levels of signals at Etna
4.2 Identification of precursory signals

Deliverables:

4.1.1 Definition of the ranges of variation of geophysical, geochemical, petrologic, etc. data representing the background levels at Etna
4.1.2 Definition of "critical levels" for each monitoring signal
4.2.1 Creation of a multi-parametric database of monitoring signals
4.2.2 Quantitative statistical models for the identification and quantification of precursory signals
4.2.3 Analysis of Coulomb stress failure (magma intrusions triggering earthquakes and large earthquakes favouring magma intrusions)
4.2.4 Automatic or semi-automatic warning systems for forecasting eruptive events

Task 5. Reconstruction of the eruptive record and characterization of eruptive typologies and probability of the expected events

RU Coordinating: Gresta (Univ. Catania)
RU Partecipating: Incoronato (Univ. Napoli), Milano (Univ. Napoli), Monaco (Univ. Catania), Pompilio (INGV-RM1, Pisa)

Description of the activity

This task is devoted to the production of an as much as possible complete record of the Etna eruptive history through the completion and integration of existing studies and datasets on the history of the volcano. In particular, it is necessary to integrate the knowledge coming from the detailed reconstructions of deposits with the information deriving from catalogues and historical chronicles. Each eruptive event reported in the so obtained catalogue will also be classified in terms of the main properties characterizing the phenomenon such as its typology, age, magnitude, intensity, composition, product dispersal, and so on. The final dataset will indeed represent the basic information for the carrying out of numerical simulations of the eruptive phenomena and for the quantification of the related probability of occurrence. On the basis of the eruptive record and the analysis on monitoring data it will be possible to identify the scenarios and eruptive typologies that should be investigated for hazard purposes. A formal way to do this is to implement and use statistical tools and techniques, such as the Bayesian approach through the definition of Event and Logic Trees, able to quantify the probability of occurrence of a specific event. By using these techniques is also possible to take into account the uncertainty related to the dynamics of the eruptive process itself as well as the uncertainty related to the lack of knowledge.

Work-Packages:

5.1 Reconstruction of the eruptive history on the basis of geological and paleomagnetic studies and of historical chronicles
5.2 Characterization of expected eruptive categories
5.3 Statistical analysis of the eruptive records and definition of Event Trees (ET)

Deliverables:
5.1.1 Database of the eruptive history as reconstructed on the basis stratigraphic and paleomagnetic studies
5.1.2 Database of the eruptive history on the basis of historical chronicles and catalogues
5.1.3 Integrated database summarizing the whole eruptive history
5.2.1 Definition of eruption categories to be considered in the hazard scenarios
5.2.2 Characterization of eruption categories in terms of magnitude, intensity, composition, product properties
5.3.1 Characterization of the volcano behaviour in terms of recurrence time, steadystate vs. cyclic behaviour

Task 6. Simulation of lava flows and associated hazard

RU Coordinating: Del Negro (INGV-CT)
RU Partecipating: Crisci (Univ. della Calabria, CS), Dragoni (Univ. Bologna), Fortuna (Univ. Catania), Pareschi (INGV-RM1, Pisa)

Description of the activity
The quantitative description of the dynamics of the eruptive phenomena requires the development, validation and application of accurate and robust physico-mathematical models able to forecast the spatial and temporal evolution of the volcanic processes. In particular, given the most common styles of activity exhibited by Mt. Etna, the development of lava flow models has a high priority. Existing and new models based on different physical formulations and approaches (deterministic versus probabilistic, Eulerian vs Lagrangian, one-dimensional versus multidimensional, homogeneous versus multiphase, etc.) will be developed and applied to real cases in order to make model inter-comparisons and more robust forecasts of the phenomena. Models will also use, as much as possible, data deriving from the other tasks such as observational data, for model validation, and experimental data, for constitutive equations.
This task is also aimed at the carrying out of products able to provide quantitative estimates of the lava flow hazard at Mt. Etna. These include hazard maps able to identify the most dangerous areas surrounding the volcano as well as numerical forecasting simulations to be used during the crisis for the quantitative description of the phenomena. Forecasting simulations should be used in quasi real-time in order to predict the evolution of the phenomena and their hazard on the surroundings. Quantification of hazard in terms of probability according to the lines described in the Task 5 will be possibly pursued.

Work-Packages:
6.1 Modelling and simulation of lava flows.
6.2 Medium- and long-term hazard mapping.
6.3 Hazard forecast simulations.

Deliverables:
6.1.1 2D/3D deterministic models of lava flows
6.1.2 Numerical simulation results describing the evolution of single lava flows and their dynamics
6.1.3 Probabilistic models of lava flow and estimates of invasion areas

6.1.4 Inter-comparison between models
6.2.1 Hazard maps of lava invasion
6.3.1 Simulation forecasts of lava flow invasion areas
6.3.2 Simulation forecasts of lava flow evolution

Task 7. Simulation of atmospheric dispersal processes and associated hazard

RU Coordinating: Neri (INGV-RM1, Pisa)
RU Partecipating: Pareschi (INGV-RM1, Pisa), Taddeucci (INGV-RM1)

Description of the Activity
Etna's activity is characterized by tephra fallout episodes mostly produced by weak ash plumes. During recent eruptions such low-energy ash-generating phases have produced considerable damage and disruption to the surrounding towns as well as major economic losses for the impact on operations at the nearby Fontanarossa Airport. However, in the last 10000 years, Etna has also produced a few basaltic Plinian eruptions with a significant impact on the surrounding environment. Currently, quantitative fallout hazard maps for land-use planning and human hazard assessment, as well as forecasting tools to describe the movements of ash during an eruptive crisis at Etna do not exist. To partially face these needs, a preliminary modelling tool able to describe the dynamic of the atmospheric dispersal process will be developed and applied in the present project. This code will allow to forecast the atmospheric dispersal and ground deposition of ash under the forcing of realistic time-varying and 3D meteorological conditions. Validation of the model will be also carried out through a comparison between model predictions and observations. To this aim, particularly useful will be the collection of remote sensing data able to map in 2D volcanic ash and aerosols using satellite optical data as well as the collection and reconstruction of ground deposition data on a systematic basis. Hazard maps for some selected small-scale scenario and related numerical simulations of ash dispersal will be carried out.
A deeper understanding of the mechanisms leading to the generation of ash during eruptive phases at Etna will be also gained through laboratory experiment of the fragmentation of basaltic melts under different conditions. In particular, experiments will focus on non-hydromagmatic fragmentation mechanisms with variable groundmass crystallization and at various operative conditions.
Finally, substantial experience on the impact of fine ash on health, gained in the eruption of the Soufriere Hills volcano, Montserrat, will be transferred and further extended to Etna. Work is planned on modelling ash hazards for environment and human health effects and for the socio-economic impacts of life-line and transport disruption caused by ash fallout. The long-term aim is to combine new modelling capabilities for these problems and to develop integrated hazard maps and forecasting simulations as output.

Work-Packages:
7.1 Modelling and simulation of ash dispersal.
7.2 Medium- and long-term hazard mapping.
7.3 Hazard forecast simulations

Deliverables:
7.1.1 1D/2D/ 3D models of the eruptive plume
7.1.2 2D/3D models of ash cloud dispersal
7.1.3 Numerical simulation results of the dynamics of the rising plume
7.1.4 Numerical simulation results of the dynamics of the ash cloud dispersal
7.1.5 Inter-comparison between models

7.2.1 Hazard maps of lava invasion
7.2.2 Hazard maps of ash fallout
7.3.1 Simulation forecasts of ash dispersal in the atmosphere
7.3.2 Simulation forecasts of ash dispersal on the ground
7.3.3 Simulation forecasts of the hazardous actions produced by the ash

List of deliverables

Task 1. Plumbing system and structure of the volcano from the lithosphere to the surface
Deliverables: Location and characteristics of the main magma body - Definition of feeding structures and shallow magma batches - Determination of composition and volatile content of magma - Definition of the edifice and basement structure - Distribution of active faults, eruptive fractures and vents - Definition of the conduit/dike system within the volcanic pile - Influence of regional and local tectonic structures in the magma uprising and stocking - Susceptibility maps based on geological, geochemical, magnetic, gravimetric, electrical, seismological, and ground deformation data.

Task 2. Physical and chemical properties of magma and volcanic rocks
Deliverables: Viscosity of the magmatic mixture (vs. composition, crystals, bubbles, volatiles, temperature) - Yield strength of the magmatic mixture (vs. composition, crystals, bubbles, volatiles, temperature) - Volatile solubility data and correlations - Gas diffusivity - Visco-elasto-plastic properties of the edifice and their variation with T and P - Density and velocity models of the volcanic edifice - Permeability, porosity, capillary pressure and texture of the rock fabric - Electrical and thermal conductivity models of volcanic rocks.

Task 3. Modelling and simulation of pre-eruptive processes
Deliverables: 1D/2D Analytical models of medium deformation - 2D/3D transient models of stress/strain fields due to the action of conduits and dikes. - Temporal simulation of expected deformation and potential fields - Experimental analogue models of structure deformation and collapse - Multidimensional, multiphase and transient models of magma intrusion in conduit/dikes - Fluid-structure models of magma intrusion with phase-change and heat transfer to conduit walls.

Task 4. Identification and characterization of precursors
Deliverables: Definition of the ranges of variation of geophysical, geochemical, petrologic data representing the background levels at Etna - Definition of "critical levels" for each monitoring signal - Creation of a multi-parametric database of monitoring signals - Quantitative statistical models for the identification and quantification of precursory signals - Analysis of Coulomb stress failure - Automatic or semi-automatic warning systems for forecasting eruptive events.

Task 5. Reconstruction of the eruptive record and characterization of eruptive typologies and probability of the expected events
Deliverables: Database of the eruptive history as reconstructed on the basis stratigraphic and paleomagnetic studies - Database of the eruptive history on the basis of historical chronicles and catalogues - Integrated database summarizing the whole eruptive history - Definition of eruption categories to be considered in the hazard scenarios - Characterization of eruption categories in terms of magnitude, intensity, composition, product properties - Characterization of the volcano behaviour in terms of recurrence time, steadystate vs. cyclic behaviour - Definition of logic trees of events - Identification of the probability density distribution of relevant events - Definition of a stability criterion - Characterisation of the volcano in terms of recurrence time.

Task 6. Simulation of lava flows and hazard assessment
Deliverables: Mps of laser scanner intensity - Updated Etna topographies - 2D/3D deterministic models of lava flows - 3D model for the formation of lava tubes - Numerical simulation results describing the evolution of single lava flows and their dynamics - Probabilistic models of lava flow

and estimates of invasion areas - Hazard maps of lava invasion - Simulation forecasts of lava flow invasion areas - Simulation forecasts of lava flow evolution.

Task 7. Simulation of ash clouds and hazard assessment
Deliverables: 1D/2D/ 3D models of the eruptive plume - 2D/3D models of ash cloud dispersal - Numerical simulation results of the dynamics of the rising plume - Numerical simulation results of the dynamics of the ash cloud dispersal - Energy budget for the formation of ash by different eruptive styles - Hazard maps of ash fallout - Simulation forecasts of ash dispersal in the atmosphere and at the ground - Simulation forecasts of the hazardous actions produced by the ash.

SUB-PROJECT V3_6 – ETNA

TABLE MAN/MONTHS

U.R	Institutions	Principal Responsibles	Task1 Plumbing system	Task2 Magma/ rock properties	Task3 Modeling pre-eruptive processes	Task4 Precursors	Task5 Eruptive history	Task6 Lava flow simulation and hazard	Task7 Ash cloud simulation and hazard	Mesi p. cofin.	Mesi p. rich.
UR-1	UniPi	Armienti		@						13	
UR-2	CNR-IREA, JPL Caltech (USA), INGV-OV	Berardino, Lanari, Lundgren				@				30	
UR-3	UniBo, INGV-Rm1, INGV-CT	Bonafede, Belardinelli, Bonaccorso			@					22	12 (UniBo)
UR-4	INGV-CT, UniCt, CSIC-UCM (ES), Univ. Hokkaido (JP)	Carbone, Nunnari, Napoli, Currenti, Del Negro, Budetta, Greco			@					108	
UR-5	INGV-CT, CNRS-LPS (FR), Univ. Cambridge (UK), INGV-Rm2	Burton, Caltabiano, Allard, Metrich, Oppenheimer, Bongiorno	@			@				52	
UR-6	UniRm1, INGV-CT, UniBo, CNR-IGAG, CNR-ISMAR	Chiocci	@							31	
UR-7	INGV-CT, SGA-Bo, CNR-IDPA, UniMi, Soc. Aspinall (UK), Vrije Univ. Amsterdam (NL)	Coltelli, Branca, Del Carlo, Groppelli					@			48	24 (borsa di studio INGV-CT)
UR-8	INGV-CT, CNRS.LPS (FR), UniNa, UniTri, UniCT	Corsaro, Andronico, Miraglia, Polacci, Metrich, Allard	@							50	

UR-9	UniCal, CNR-IRPI, INGV-CT	Crisci						@		46	12 (UniCal)
UR-10	UniCt, INGV-CT	Cristofolini, Ferlito	@							44	
UR-11	INGV-CT, Univ. Paris XIII (FR), Univ. Florida (USA), UniBo, NIED Tsukuba (JP), Shizuoka Univ. (JP), Tohoku Univ. (JP), Soc. Hitachi Ltd (JP), UniRm1	Del Negro, Herault, Coltelli, Napoli, Marsella						@		65	
UR-12	Univ. Muenchen (D), UniRmTre	Dingwell, Hess		@						12	
UR-13	UniBo, UniBa	Dragoni, Tallarico						@		18	18 (UniBo)
UR-14	UniNa	Fedi, Roberti				@				12	
UR-15	UniCt	Fortuna						@		12	
UR-16	UniRm1, UniBo, INGV-CT	Giunchi, Cianetti, Bonafede			@					38	
UR-17	UniCt, INGV-CT, INGV-Rm1, UniUd, Colenco Baden (CH)	Gresta, Privitera, Marzocchi				@				58	24 (UniCt)
UR-18	INGV-PA, UniCt	Gurrieri				@				25	
UR-19	IPG Paris (FR), INGV-CT, CSIC Barcelona (ES)	Hirn, Langer	@							20	24 (IPG Paris)
UR-20	UniNa, CNR-IAMC	Incoronato					@			20	
UR-21	INGV-Rm2	Meloni				@				13	
UR-22	UniNa	Milano, Di Maio					@			42	
UR-23	UniCt	Monaco, Tortorici	@							28	24 (UniCt)

UR-24	INGV-OV, INGV-PA, INGV-CT, INGV-Rm1, UniPa, McGill Univ. (CA)	Moretti, Baker		@		@				40	
UR-25	UniBo, Univ. Montpellier (FR)	Mulargia				@				14	24 (UniBo)
UR-26	INGV-Rm1, ETH Zurich (CH), NIED Tsukuba (JP), INGV-CT, UniCt, UniMe	Murru	@							41	
UR-27	INGV-Rm1, INGV-CT, INGV-OV, Soc. ET Concorde (USA), Univ. Cambridge (UK), Soc. Aspinall (UK), Univ. Bristol (UK), Univ. Libre Bruxelles (B)	Neri A.							@	36	
UR-28	INGV-OV, CNRS-LPS (FR), INGV-OV, INGV-PA, INGV-Rm1, UniRm3, UniPa	Neri M., Allard, Bencke	@							54	
UR-29	UniCt	Nunnari				@				10	
UR-30	INGV-PA, UniPa, CNRS-ISTO (FR)	Paonita, Scaillet B.		@						30	
UR-31	INGV-Rm1, CNR-IGG, INGV-CT, INGV-Rm2, UniRmTre	Pareschi, Mazzarini, Merucci, Favalli	@					@	@	62	

UR-32	INGV-CT, INGV-CNT, UniBa, UniCt, Univ. Wisconsin (USA)	Patanè D., Chiarabba, De Gori, De Lorenzo	@							75	
UR-33	CNR-IMAA, UniBas	Pergola, Telesca, Tramutoli, Lapenna				@				68	
UR-34	INGV-Rm1, Brown Univ. RI (USA), UniPav, CNR-IGG, INGV-Ct, Univ. Tasmania (Australia), UniFi	Pompilio, Rutherford	@				@			34	
UR-35	INGV-CT, INGV-OV	Privitera, Maiolino				@				62	
UR-36	INGV-CT, UniRm1, CSIC Madrid (ES), Almeria Univ. (ES), PoliMi, Miami Univ. (USA)	Puglisi, Bonaccorso, Bonforte, Gambino, Mattia			@	@				60	
UR-37	UniFi, INOA Fi, Univ. Hawaii (USA), ERI Tokio (JP)	Ripepe				@				52	12 (UniFi)
UR-38	INGV-OV, INGV-CT, Univ. College Dublin (IE)	Saccorotti, La Rocca, Di Grazia, Patanè, Bean			@					92	
UR-39	UniBa, CNR-IMAA, TEICH (GR)	Siniscalchi, Piscitelli	@							44	
UR-40	INGV-Rm1, INGV-CT, Univ. Wuerzburg (D)	Taddeucci, Zimanowski							@	15	
Totale										1596	174

SUB-PROJECT V3_6 – ETNA

Table RU and related funding request

N. UR	Istituz.	Resp UR	Personale		Missioni				Consumi servizi		Inventariabile	
					Italia		Estero					
			2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
UR-1	UniPi	Armienti			3000	3000			4000	4000		
UR-2	CNR-IREA	Berardino			1000	1000			2000	2000	2000	2000
UR-3	UniBo	Bonafede	10000	10000	1500	2000	1500	2000	5000	5000	1000	
UR-4	INGV-CT	Carbone			1000	1000	3000	3000	8000	8000	2000	2000
UR-5	INGV-CT	Burton			2000	1000	7000	4000	4000	4000		
UR-6	UniRm1	Chiocci			3000	3000			34000	11500	3000	2500
UR-7	INGV-CT	Coltelli[1]			3000	4000			12000	13000		
UR-8	INGV-CT	Corsaro			2000	2000	4000	4000	5000	4000		
UR-9	UniCal	Crisci		16000	1000	1000	3000	3000	7000	5000	4000	
UR-10	UniCt	Cristofolini			2000	2000	1000	1000	5500	5000	1500	1000
UR-11	INGV-CT	Del Negro[2]			1500	1500	4000	4000	12000	13000	5000	5000
UR-12	Uni-Muenchen (D)	Dingwell					2000	2000	6000	6000		
UR-13	UniBo	Dragoni	8000	16000	500	500	1500	1500	1000	1000	2000	2000
UR-14	UniNa	Fedi			2000	2000	2000	2000	4000	4000		
UR-15	UniCt	Fortuna			500	1000	1500	2000	7000	6000		
UR-16	INGV-Rm1	Giunchi			1500	1500	2000	2000	2000	5500	2500	
UR-17	UniCt	Gresta	19000	19000	2000	3000	2000	2000	10000	10000	1000	2000
UR-18	INGV-PA	Gurrieri			500	500	1500	1500	5000	5000	5000	5000
UR-19	IPG Paris	Hirn	16000	16000			2000	2000	2000	2000		
UR-20	UniNa	Incoronato			4000	2500		1500	4000	4000		
UR-21	INGV-Rm2	Meloni			1200	1200	1800	1800	3000	3000	3000	3000
UR-22	UniNa	Milano			2000	2000	1000	1500	2500	3500	1500	
UR-23	UniCt	Monaco	16000	16000	2000	2000			5000	5000	2000	2000
UR-24	INGV-OV	Moretti[3]			5000	5000			6000	8000	6000	
UR-25	UniBo	Mulargia	19000	19000	2000	2000	2000	2000	3000	2000		2000
UR-26	INGV-Rm1	Murru			2000	1000		1500	2000	1500		
UR-27	INGV-Rm1	Neri A.[4]			4000	4000	4000	4000	19500	19000	5000	8000
UR-28	INGV-CT	Neri M.			2000	1500		1500	3000	2000		

UR-29	UniCt	Nunnari		16000	2000	2000			2000	2000		
UR-30	INGV-PA	Paonita[5]			1500	1500	3000	3000	10000	10000		
UR-31	INGV-Rm1	Pareschi			5000	5000			17000	17000		
UR-32	INGV-CT	Patanè D.			2000	2000	6000	6000	9000	7500	3000	2000
UR-33	CNR-IMAA	Pergola			4000	4000			3500	3500	1500	1500
UR-34	INGV-Rm1	Pompilio			2000	2000	3000	3000	8000	8000		
UR-35	INGV-CT	Privitera			1000	2000	3000	3000	3000	4000	2000	
UR-36	INGV-CT	Puglisi			2000	2000	6000	6000	2500	2000		
UR-37	UniFi	Ripepe	19000		2000	2000			1000		2000	2000
UR-38	INGV-OV	Saccorotti			1000	1000	3000	3000	5000	5000		
UR-39	UniBa	Siniscalchi			7000	5000		2000	6000	6000		
UR-40	INGV-Rm1	Taddeucci[6]			600	700	1400	1300	9000	9000		
		TOTALE	**107000**	**128000**	**82300**	**80400**	**72200**	**77100**	**259500**	**236000**	**55000**	**42000**
GRAN TOTALE: 1139500												

[1]8000 euros (4000 during the first year, and 4000 during the second year) included under the voice "Consumi e servizi" will be provided to CNR-IDPA (Milano) for research activities under the responsibility of D. Groppelli. 5000 euros during the second year, included under the voice "Consumi e servizi" will be provided to the society "Aspinall & Associates (Beaconsfield, UK), for research activities under the responsibility of W. Aspinall.

[2]8000 euros (4000 each year) included under the voice "Consumi e servizi" will be provided to Dip.to Scienze della Terra, Univ. La Sapienza (Roma) for research activities under the responsibility of M. Marsella.

[3]8000 euros (4000 each year) included under the voice "Consumi e servizi" will be provided to McGill University (Canada) for research activities under the responsibility of D. Baker.

[4]12000 euros (6000 each year) included under the voice "Consumi e servizi" will be provided to Earth Tech Inc. (USA) for research activities of J. Scire. 12000 euros (6000 each year) under the voice "Consumi e servizi" will be provided to the society "Aspinall & Associates (Beaconsfield, UK), for research activities under the responsibility of W. Aspinall.

[5]6000 euros (3000 each year) included under the voice "Consumi e servizi" will be provided to CNRS-ISTO (Orleans, FR) for research activities under the responsibility of B. Scaillet.

[6]15000 euros (approx. 7500 each year) included under the voice "Consumi e servizi" will be provided to the Physikalisch-Vulcanologisches Labor, Univ. of Wuerzburg (D) for research activities under the responsibility of B. Zimanowski.

PROJECT V3

Sub-Project V3_7 – Pantelleria

Responsibles:

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Project V3

Sub-Project V3_7 – Pantelleria

Coordinators:

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State of the Art

The island of Pantelleria represents the top of a large active volcano developed on the Africa continental crust in front of the Sicilian-Maghrebian thrust system. The volcano is located within a NW-SE trending tectonic depressions related to the opening during the Neogene-Quaternary of a rift system within the Pelagian Block. The area is characterized by a continental crust less than 20 km thick, by a relatively high heat flow (100 mW/m^2) and by positive Bouguer anomalies ranging between +40 and + 80 mGal. The structural setting of the island is strictly related to the rifting processes acting in this area and its large-scale setting is characterized by two main discontinuity systems trending NW-SE and N-S, respectively. The former structures have been interpreted as right-lateral strike-slip faults whereas the latter as normal faults. The overall geometry of these structures, due to Late Quaternary to Present deformation, has been interpreted as a large scale composite pull-apart basin whose general architecture controls the volcanism of Pantelleria. The island is also characterized by an intense ground fracturing associated to both volcanic and tectonic activity. These minor structures show a more complex pattern characterized by the occurrence of four systems of discontinuity that only partially correspond to the regional trends. The volcanism of the island was characterized by both effusive and explosive eruptions fed through time by minor mafic and predominant per-alkaline silicic magmas (pantellerites). The early history of the island (300-45 ka) was dominated by widespread acidic and peralkaline pyroclastic flows, subordinate fall-deposits and lavas, and two concentric caldera collapses. The first formed around 110 ka and the second at 45 ka, just after the emission of the Green Tuff ignimbrite (GTI). The most recent activity (< 25 ka) is characterized by widely diffused intracaldera pantelleritic (and subordinate trachytic) pumice fall deposits and subordinate small-volume pyroclastic flows and surges. Radiocarbon dating gave ages of 4-5 ka for the latest silicic activity, whereas historical records describe a basaltic eruption occurred in 1891, along NW-trending fissures, offshore northwest of the island. Silicic eruptions have mainly produced three types of volcanoes: pumice cones, shield volcanoes and partially collapsed edifices. Pumice cones are composed of fallout beds and pyroclastic-current deposits intercalated with variably welded layers. Shield volcanoes are built up by eruptions which began with explosive phases, continued with generation of spatter-fed agglutinates, and ended with massive lavas. Eruptions of per-alkaline magmas, characterised by high fluidity despite of their high viscosity, are the result of a complex combination of physico-chemical processes. The most recent volcanism is strictly related to the dynamics of the resurgence. Basaltic eruptions have generated cinder cones and lava flows. The island is also characterized by hydrothermal manifestations, including fumaroles and hypothermal to boiling waters, testifying to the existence of an active hydrothermal system. Recent studies highlighted also a huge diffuse CO_2 degassing of the island mainly concentrated in two anomalous degassing areas (Favara Grande area and Specchio di Venere lake). In these areas, located inside the most recent caldera, CO_2 levels lethal to small animals are often reached and worry about human health has sometime been expressed. Moreover recent surveys evidenced in these areas also high levels in soil Rn, which creates also concern for human health. Furthermore the lake Nyos disaster highlighted the potential hazard connected with lakes in quiescent volcanic areas. The lake Specchio di Venere being located in one of the most exhaling areas could act as a potentially dangerous CO_2 trap. Pantelleria is also affected by recent deformation highlighted by an EDM and GPS monitoring network operating since 1978 by the INGV-Ct and covering the entire island. Strong geological and geophysical evidences, acquired through these geodetic techniques, support a recently proposed model that postulates the presence of a currently deflating shallow magma chamber. In this framework, in 1999 three tilt and GPS permanent stations have also been installed and new short-term ground deformation researches have been carried out to improve the monitoring of the volcanic hazard in this island. Moreover, a successful experiment with InSAR technique has been applied and better informations about the location of the shallow magmatic source have been achieved. Finally, in order to cover an important deficiency in the geophysical dataset, two permanent broadband seismic stations are going to be deployed by INGV-Ct on the island with the aim to classify the volcanic-related seismic aspects of Pantelleria and to improve the geometry of the seismic network in the area of the Sicily Channel.

Description of the Activities

The project is organized in 4 Tasks devoted to define: i) the major volcano-tectonic features of the island, ii) the short and long term ground deformation, iii) the definition of the magmatic and geothermal degassing and iv) the possible hazard scenarios.

Task 1. Volcano-tectonic features and feeding system

The task 1 is organized in two major research lines. The first concerns researches on the volcanic products to define the volcanological history and to evaluate the possible eruptive scenarios occurring in the island, whereas the second line is devoted to define the major volcano-tectonic structures and the lithospheric features of the volcano.

Volcanic products

UR coordinating: Orsi (Osservatorio vesuviano-INGV)

UR Participating: D'Antonio (Univ. Napoli), Landi (INGV-Pisa), Lanzafame (INGV, Catania), Rotolo (Univ. Palermo)

To define the volcanic history of the island, firstly field investigations, carried out using standard field survey techniques, will be performed to reconstruct a detailed stratigraphy of the more recent products (< 20 ky) also revising unpublished geological maps. Relationships between volcanic bodies and palaeomorphology will be also investigated. Filed investigations will be aimed to define the shape of the exposed rock bodies and their geometric relations. Studies will be realized to define the sedimentological features and dispersal of pyroclastic deposits (thickness, and maximum pumice and lithic clast of beds) and the rheomorfic characteristics of the variably welded deposits. In particular some key areas such as Mursia cinder cones and basaltic lava flows, and the silicic Cuddia di Mida pumice cone, Cuddia Mueggen shield and Cuddia Randazzo partially collapsed edifice will be accurately investigated. Moreover geo-volcanological investigations of the Agrigento-Sciacca coast will be carried out to verify the occurrence of volcanoclastic products related to known and unknown submarine eruption occurred on the Pantelleria district.

Laboratory studies on collected samples will include whole rock chemistry (XRF, ICP-AES, ICP-MS) as well as petrographic and compositional study of mineral and glass phases (SEM-EDS, EPMA). The results will permit to identify melt/mineral equilibria and, as a whole, to define the evolutionary history of the studied magmas. A melt inclusions study will be mainly directed to the determination of the volatile abundance. H_2O and CO_2 will be measured by means of FT-IR spectroscopy in naturally quenched glasses. Chlorine and fluorine abundance, as well as major elements, will be measured in melt inclusions and residual glass by EPMA. Comparison and feedback with the results of experimental petrology obtained by UR-Rotolo will provide further constraints to the chemico-physical parameters of these magmas. The data obtained on the abundance of the different volatile components dissolved in melt in pre-eruptive conditions will be used to estimate the volatile pressure and the depth of storage of the different magmas at the time of crystallisation, taking also into account the contribution of the high abundance of halogens to the total volatile pressure. The relative variations of volatiles with different solubility will give insights into the degassing path of these magmas in pre-eruptive conditions, and will permit to assess the relationships between degassing modality and eruptive style of Pantelleria magmas. Isotopic analyses (Sr, Nd, Pb, B, O) will be also performed by TIMS at O.V., I.N.G.V. (Napoli) and at I.G.G., C.N.R. (Pisa). Rheological and thermodynamic properties will be moreover determined at Munich University measuring viscosity-temperature relationships, glass transition temperature, heat capacity, thermal history and effect of H2O on viscosity. The shear dry viscosity in the T range 1600-1100°C will be measured using a rotational viscometer. The dry and hydrous viscosity in the T range 400-800°C will be investigated using the micropenetration method. Glass transition temperature and heat capacity will be determined using a Differential Scanning Calorimetry. Volatile contents will be measured to investigate the structural complexity of peralkaline melts. H2O and CO2 contents will be determined by FT-IR at the O.V., I.N.G.V. on glass inclusions trapped in crystals and in the matrix glass; Cl and F contents will be determined through EMPA and/or ICP-MS analyses. The distribution of structural units in glass will be studied by experimental determinations of the Si and Al chemical environment through 29Si and 27Al NMR spectroscopy at the University of Trieste, in order to characterize peralkaline melt properties such as the degree of polymerization. The network distribution of hydrous species will be addressed by 1H NMR experiments in order to evaluate the H2O permeation and the role of diffusion during magma degassing. The role of F- will be explored by 19F through synchrotron spectroscopy. Isotopic data will be obtained to investigate the source of volatiles. Grain size analysis of loose pyroclastic rocks; components analyses of pyroclastic deposits; SEM morphoscopic analyses of pumice and ash particles; textural analyses of variably welded deposits and lavas in thin sections; density determinations of variably welded deposits; density-profiles reconstruction of selected pyroclastic units in various locations, also according to the palaeomorphology; aspect ratio determination of juvenile components in variably welded deposits will be also carried out.

Volcano-tectonic features
UR coordinating: Tortorici (Univ. Catania)
UR Participating: Brancolini (OGS, Trieste)

A detailed study will concern the recognition of the geometry and kinematics of the active tectonic features interacting with the landscape evolution and the measurement of parameters useful to reconstruct their evolution and activity vs. time. The expected results will consist of a preliminary mapping of the active structures, by interpretation of 1:5000 scale aerial photographs and elaboration of satellite SPOT and LANDSAT 5 TM imagery. The second step of the analysis will consist of detailed structural analysis that will be carried out along the principal fault segments to define the kinematics of the entire fault system affecting the island. These analyses will be made on the fault developed along the major structures and within the deformed volcanics. The whole deformation pattern of the island will be evaluated by the analysis of the distribution of tectonic fracturing. The fracture pattern will be evaluated by collecting data in structural stations taking into account geometric features, spacing and frequency. The kinematic analysis will be also useful to define the geometry of the main component of the present-day stress field acting on the island. A detailed mapping at scale !:10000 of the volcano-tectonic features (vent alignments, caldera rims, eruptive fractures ecc.) will be carried out. Lithospheric features will be investigated by the analysis of several seismic lines acquired in the Sicily Strait between Pantelleria and Malta Islands (MS14, MS 19, MS 111, 116, MS 118-122) together with other seismic profiles acquired in the frame of the CROP (CRosta Profonda) Italian Project (M23A, M23AA, M24, M25, M39). In order to provide a fine reconstruction of the structural and sedimentary setting of the study area a non-conventional processing procedure will be performed (i.e., pre-stack depth migration) on key multichannel seismic lines (both MS and CROP profiles), to image in detail the rift-related structures, to individuate possible sub-surface volcanic bodies, and identify the principal seismogenic faults, particularly those associated with neo-tectonic activity. The identification of the main morpho-structural features will led then to compile a structural map of the investigated area, to be integrated with available bathymetric information. A gravity (free-air) and magnetic map to recognize and map the distribution of anomalous (volcanic) bodies in the surface and/or sub-surface, which are possibly related to the rift activity characterizing the Sicily Strait region will be created. The structural maps derived from seismic data interpretation, integrated with the geophysical maps (gravity and magnetic maps) will be used to model, through data inversion, the deep structural setting of the island of Pantelleria in the framework of the Sicily Strait lithosphere, and propose a plausible model for the rift system.

Task 2. Ground deformation
UR coordinating: Mattia (INGV, Catania)
UR Participating: Tortrici (Univ. Catania)

Short term and long-term deformation of the island will be investigated with geological and geophysical methods. Geophysical researches will be summarized in the following points:
1) Analysis of datasets from tilt and GPS permanent stations and from GPS discrete surveys will be carried out.
2) Comparison of the results with other data (geological, geochemical, etc.) finalised to a first model of magma transfer processes from depth to surface.
3) Definition of common procedures of data filtering from meteorological and, generally, from exogenous phenomena (tides, antropic environment) in seismic and ground deformation data.
4) Creation of a database of seismic events in the area of Pantelleria and, in general, in the channel of Sicily using mainly INGV data from seismic permanent networks but also data from all the mediterranean seismic networks.
5)Analysis of the seismic events related to the volcanic activity.
6)Modelling of strain fields induced by shallow and deep volcanic sources with InSAR data. A database of ERS and ENVISAT images will be realized in order to realize a complete time serie of ground deformation at the scale of the island since '90th.
7)Analysis of seismic data from temporary deployed seismic arrays.

From geological poit of view significant information on long-term vertical deformation affecting the island will derived by detailed study on distribution of marine surfaces and paleoshorelines. Uplifted marine notches, caves and vermetus bio-constructions will be detailed mapped to also define ground deformation curves and velocity diagram of vertical deformation. The analysis of marine terraces will be complemented by absolute dating of deposits sampled on different orders of the studied terraces to obtain precise age constraints necessary to evaluate the different vertical deformation rates. Combining ages and elevations of terraces and paleoshorelines with OIT stages of high sea-level stands and absolute sea-level variations will be thus possible to accurately evaluate the uplift rates affecting the analysed regions. This information will be compared with short term deformation data deriving from GPS and levelling networks. Finally the effects of the vertical uplift on the slope stability will be evaluated classifying the major landslides and rock-fall occurring on the island.

Task 3. Hydrogeological setting and geothermal system

UR coordinating: D'Alessandro (INGV, Palermo)

Reconnaissance soil gas survey covering the entire area of the island with an adequate number of randomly selected soil CO_2 flux measurement sites (4 sites/km^2) will be carried out. Soil flux measurements will be made with the method of accumulation chamber. Contemporaneously collected soil gas samples at the depth of 50 cm will be analysed both for chemical (N_2, O_2, CH_4, CO_2, Rn) and isotopic (CO_2-C) composition. The main gas manifestations will be also sampled and the gases analysed for chemical and isotopic composition. Data elaboration with statistical softwares will allow the production of the distribution maps of CO_2-fluxes and gas concentrations (CH_4, CO_2, Rn) and the estimation of the total diffuse CO_2 emission of the island. The obtained CO_2 degassing budget, together with the CO_2 solubility data obtained by the petrologic studies of task 1, will be important for the constrain the magma volumes of the magmatic feeding system. Detailed soil gas surveys of the most exhaling areas, evidenced by the previous surveys, with a higher measurement density (50 points/km^2) will be made. Basing on the results of the structural studies of Task 1 the degassing of the main structures will be also studied with a series of perpendicular traverses. Furthermore soil gas distribution maps (CO_2, Rn) will be the necessary basis for some of the thematic hazard maps of task 4. The set up of a continuous monitoring station at lake Specchio di Venere will be made after a preliminary survey around the previously identified high degassing area for the choice of the site. The station will automatically measure and acquire many parameters (CO_2 flux from the soil, soil temperature, CO_2 concentration in air at two (or three) different heights – (10,) 50, 150 cm – and meteorological parameters – temperature, atmospheric pressure, wind speed and direction, rainfall). Gas flux data acquired by the continuous monitoring station, will be compared with seismic data obtained by UR-Mattia to investigate possible correlations, and will be also necessary for the comparison of discrete flux measurements made in different periods. A reconnaissance survey of the waters of Specchio di Venere will be performed. Water samples collected at different depth along a transect of the lake will be analysed for their chemical and isotopic composition and for their dissolved gas content. This first survey will be made in the dry season followed by a second in the wet season. A survey of submarine hydrothermal vents will be carried out with a fishfinder along the coast of the island and in the area of the last underwater eruption. Obtained data will be helpful in correlating subaerial and offshore tectonic structures. Sampling of underwater released fluids will be made by scuba diving.

Task 4. Hazard mapping

UR coordinating: D'Alessandro (INGV, Palermo), Tortrici (Univ. Catania), Orsi (Osservatorio vesuviano-INGV)
UR Participating: Brancolini (OGS, Trieste), D'Antonio (Univ. Napoli), Landi (INGV-Pisa), Lanzafame (INGV, Catania), Mattia (INGV, Catania), Rotolo (Univ. Palermo).

The whole data obtained by the activities of the above mentioned tasks will be elaborated to construct hazard maps. A vents location map with relative magma composition erupted through time will be produced. For each explosive eruption, magnitude and energy will be evaluated. Plots of magnitude and energy variation through time, will be constructed. These eruption parameters, as well as the sequence of variable eruption phenomena during a single eruption, and its relationship with magma composition and vent position, will be statistically analysed to define the probability of occurrence of variable explosive eruption scenarios. For the effusive eruptions, often including low-magnitude explosive phases, the sequence of variable phases will be defined and correlated to the erupted magma composition and vent position. Also these data will be statistically elaborated to define the probability of occurrence of variable scenarios. All collected data will be integrated to produce a single probability definition of the expected eruption scenarios. Probabilistic hazard maps for tephra fallout, pyroclastic currents and lava domes and flows will be constructed. Maps showing relations between CO_2 degassing and fractures will be performed for key areas.

List of deliverables

Task 1: Volcano-tectonic features and feeding system
Deliverables: - Modelling of the mantle source characteristics - Magma chamber processes before and during eruptions – Physical and chemical parameters, and rheological properties of the erupted magmas – Kind and amount of volatiles in the magmatic reservoir/s - Experimental determination of glass structure and distribution of hydrous species - Relations among magma structure, physical and chemical parameters, and eruption dynamics - Stratigraphic sequence of the exposed deposits - Maps with pattern distribution of surface fractures, eruptive fractures and vent distribution - Data base of available reflection and refraction seismic data -Data base of the gravimetric data in the Sicily Channel-Reinterpreted seismic profiles – Density distribution models based on gravimetric data – Structural map of the offshore Pantelleria island.

Task 2: Ground deformation
Deliverables: Database of seismic events in the area of Pantelleria and Sicily Channel - Model of strain fields induced by shallow and deep volcanic sources with InSAR data - Distribution map of Quaternary paleoshoreline and marine terraces - Late Quaternary-Holocene and present uplift rates - Map of slope stability and landslides.

Task 3: Magmatic and geothermal degassing
Deliverables: - Spatial distribution maps of soil gas concentrations of CO_2 and Rn and soil CO_2 fluxes - Detailed spatial distribution maps of soil gas concentrations of CH_4, CO_2 and Rn and soil CO_2 fluxes of anomalous degassing areas - Map of submarine hydrothermal vents - Identification of relationships between tectonic and volcano-tectonic structures and soil CO_2 outgassing – Gas hazard estimation - Hydrological and geochemical budget of the lake Specchio di Venere with special emphasis on CO_2 accumulation - Quantification of CO_2 outgassing of the island.

Task 4: Hazard mapping:
Deliverables: – Probability hazard map for opening of a new vent - Eruption scenarios - Probability tephra fallout hazard map - Probability pyroclastic currents hazard map – Classification and volume estimation of landslides deposits - Surface gravitational movements hazard map – Gas hazard map.

SUB-PROJECT V3_7 – PANTELLERIA

TABLE MAN/MONTHS

U.R	**Institutions**	**Principal Responsibles**	**Task1** **Volcano tectonics and feeding system**	**Task2** **Ground deformation**	**Task3** **Magmatic/geothermal degassing**	**Task4** **Volcanic hazard**	**Mesi p. cofin.**	**Mesi p. rich.**
UR-1	OGS Trieste	Brancolini	@				16	
UR-2	INGV-PA, INGV-Rm1, UniPa	D'Alessandro, Pecoraino, Pizzino, Parello			@		40	
UR-3	UniNa, UniTri, INGV-OV, CNR-IGG, Uni-Muenchen (D)	D'Antonio, Dini, Petrini	@				44	
UR-4	INGV-Rm1, UniCa, UniPi, CNRS-LPS (FR)	Landi	@				21	
UR-5	INGV-CT, UniFi	Lanzafame, Santo	@				26	
UR-6	INGV-CT	Mattia, Bonaccorso		@			38	
UR-7	INGV-OV, UniTri, UniNa	Orsi, Isaia, Scaillet S.	@			@	49	
UR-8	UniPa, CNRS-Orleans (FR)	Rotolo, Pichavant	@				14	12 (UniPa)
UR-9	UniCt, INGV-CT, INGV-Rm1	Tortorici, Monaco, Grasso, Catalano	@	@			62	24 (UniCt)
Totale							310	36

SUB-PROJECT V3_7 – PANTELLERIA

Table RU and related funding request

N. UR	Istituz.	Resp UR	Personale		Missioni				Consumi servizi		Inventariabile	
					Italia		Estero					
			2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
UR-1	OGS-Tri	Brancolini			2000	2000	1500	1500	7500	7500		
UR-2	INGV-PA	D'Alessandro			8000	8000	2000	2000	15000	14000		
UR-3	UniNa	D'Antonio			4500	2400	1000	600	4000	7500		
UR-4	INGV-Rm1	Landi			3000	1500			3000	4500		
UR-5	INGV-CT	Lanzafame			1700	1700	800	800	6000	6000		
UR-6	INGV-CT	Mattia			2000	2000	4000	4000	7000	7000		
UR-7	INGV-OV	Orsi[1]			4000	4000	1000	1000	7000	11000		
UR-8	UniPa	Rotolo	16000	4000	1000	1000	3000	3000	2000	2000		
UR-9	UniCt	Tortorici	20000	20000	3000	3000	1000		7500	9000		
		TOTALE	**36000**	**24000**	**29200**	**25600**	**14300**	**12900**	**59000**	**68500**		
GRAN TOTALE: 269500												

[1]8000 euros (4000 each year) included under the voice "Consumi e servizi" will be provided to CEA-CNRS (Gif-Sur-Yvette, FR) for research activities under the responsibility of S. Scaillet.

PROJECT V4

Conception, verification, and application of innovative techniques to study active volcanoes

Responsibles:

Warner Marzocchi, INGV Roma1
Aldo Zollo, Univ. Federico II Napoli

Project V4

Conception, verification, and application of innovative techniques to study active volcanoes

Coordinators:

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Objectives:

The development of innovative and quantitative methods is one of the main ingredients for future progresses in volcanic risk assessment and management at long- and short- term time scales.
The complexity of volcanic systems originates from the strong heterogeneity of their internal structure (in terms of spatial variation of physical rock properties) and the large variety of thermo-mechanical processes which may precede and accompany the magma rise and eruption. The most comprehensive understanding of volcanic processes necessarily calls for a multi-disciplinary, integrated approach of data acquisition, analysis and modeling.
During the past three decades, we have been witnessing a strong technological development leading to a rapid growth of multidisciplinary studies of volcanoes. The controlled, repeatable experimentation is nowadays replaced by dense monitoring projects, where the analysis strategy is often dictated afterwards, depending on the data produced. Volcano monitoring networks (geophysical, geochemical, geodetical,..) produce terabytes of data, only a small fraction of them is practically used for research and/or survey purposes.
It comes out the need for implementing new strategies of data management able to analyze and mine in the near-real-time huge data flows, having the targets 1/ to exploit the whole available information, 2/ identify and measure quantitative risk indicators useful for volcanic risk monitoring and emergency management and 3/ develop advanced tools for process simulation and event prediction based on the real time analysis and modeling of observed data.
Due to the multi-disciplinary nature of the object under study, innovative approaches and techniques for volcano monitoring may concern an ultra-wide disciplinary domain (geophysics, geochemistry, geology, remote sensing,…). The present project focuses on a restricted number of tasks which are believed to be prior in terms of needed scientific effort and development and possible gain of knowledge about volcanic processes:

- Volcanic hazard estimation based on a quantitative probabilistic approach
- High resolution imaging of the volcanic structure by using advanced seismic tools
- Real-time seismic and thermal monitoring of volcanoes integrating on-land and sea-bottom systems of observation

State of the Art:

Quantitative methods for probabilistic estimation of volcanic hazard
The probability of any particular area being affected by a destructive volcanic event within a given period of time defines the volcanic hazard whose quantitative estimation is actually a challenging

task due to the scarce number of databases collecting sets of seismic variables relative to unrest and eruptive phases of explosive volcanoes. The probabilistic nature of such an important issue derives from the fact that, as the largest part of natural phenomena, volcanic activity is a complex process, characterized by several and usually unknown degrees of freedom that are often linked by nonlinear relationships. The result of this complexity is an intrinsic (and maybe unavoidable, at least over time intervals of more than few days) unpredictability of the time evolution of the volcanic system (except in sporadic cases) from a deterministic point of view. Despite the huge practical importance of this issue, a full probabilistic hazard estimation and quantitative levels of alert have not been yet proposed for almost all the worldwide active volcanoes.

The present project proposes to adopt and implement innovative approaches based on a quantitative estimation of any kind of volcanic hazard and individual risk, by merging theoretical models of the eruptive process, past (historical and geological) data, and data from monitoring of the volcano. At this purpose, we intend to implement quantitative probabilistic schemes such as Bayesian Belief Network (BBN), and "Event Tree". The methods allow representing all the possible relevant events connected to the volcanic activity and calculating the Bayesian probability and uncertainty. The method also allows aleatoric and epistemic uncertainties of the model to be dealt with in a formal way, and all to be accommodated in a hazard or risk assessment.
Notably, this way of thinking and strategy concerns the delicate problem of defining and assigning an appropriate volcanic alert levels, based on rigorous, quantitative analyses of observations, theories, models and expert opinions. The challenge is to formulate an approach that can satisfactorily provide a synthesis of all direct and indirect pieces of information into a framework for supporting alert level decisions.

<u>High resolution imaging of the volcanic structure</u>
Tomographic models inferred from the inversion of first arrival times have not a sufficient resolution to accurately define the morphology and location at depth of the main crustal reflectors (included the top of the magma reservoir) beneath volcanoes. The imaging of complex, in-land, volcanic structures (irregular topography, highly heterogeneous propagation medium) by seismic reflection is a challenging task both from the data acquisition and modeling point of views: unmodeled multi-path arrivals, very energetic direct and ground roll phases, diffraction and scattering phenomena may often lead to poor quality of reflected signals. It is therefore necessary to develop new techniques of data processing and analysis able to work on unconventional data acquisition geometries (sparse, irregular, distribution of source/receivers) and complex waveforms in the complete incidence angle range (from near-vertical to wide-angle). This requires a further step in the analysis of seismic reflection images which implies the modeling of reflection wave amplitudes vs offset (incidence angle) which can give important insights about the physical/lithological nature of the reflectors. The spatial variations of both P and S velocities fields, as represented by tomographic images, can be analyzed and interpreted as lithological and rheological features for characterization of rocks. This interpretation is made by using theoretical modeling of velocities through biphasic structures based on field data as well as from laboratory experiments.

The volcano seismology today aims at the understanding of the dynamics of seismic sources associated with the injection and transport of magma and related hydrothermal fluids. The modeling of the seismic wave field in 3D heterogeneous structures is a key factor in the studies concerning the translation of the seismic observations into quantitative information about the dynamics of the magmatic system. The advances of computational environments allow for the successful applications of numerical algorithms for the simulation of the seismic wave field in 3D heterogeneous velocity structures. The conventional 3D approaches so far applied in non-volcanic areas describe only approximately the dissipative medium and do not account for the possible anisotropy. Innovative methods for simulating the three-dimensional seismic wave field radiating in a heterogeneous, anisotropic and anelastic volcanic structure will be developed in the present project. It is expected that the hazard evaluation and monitoring of the volcanic activity would be greatly improved by the simulation of the observed seismic signals by means of advanced algorithms that take into account the 3D complex structure.

The volcano structural complexity are well quantified by the parameters of seismic attenuation and anisotropy. New techniques for imaging the attenuation properties, based on non-global linear strategy, reveal their importance especially when a joint interpretation of the (scattering and intrinsic) attenuation and velocity is possible. With this approach high intrinsic attenuation zones may be distinguished from highly heterogeneous zones (strong scattering strength) helping in the detection of possible magma chambers. The detailed study of the crustal anisotropy , moreover, adds important information to the image of the heterogeneities, through the systematic spatial analysis of the splitting parameters. Application of these techniques in volcanic environments may provide useful hints for the location and characterization of buried heterogeneities associated with structural complexities. Based on the availability of advanced seismic waveform modeling techniques, the present project propose the validation and tests on synthetic data of developed tools for measurements of anisotropic and anelastic parameters simulating realistic complexity of the propagation medium and lay-out acquisition.

Real time seismic and thermal monitoring, integration of sea-bottom and on-land seismic networks
The existence of national infrastructures (managed by INGV) for the operation of seismic monitoring tasks in Italian volcanic areas allows the development of new and innovative observational tools. The availability of a truly real-time, seismic system able to process and analyze huge streams of multi-channel data and communicate with remote probes installed on- and offshore (i.e., a sea-bottom observatory continuously linked to the on land network) is of particular relevance for the process of decisions and actions to be taken during emergency phases. Available continuous seismic recordings can be used to develop quantitative almost-real time signal analysis aimed at the measurement of indicators of risk monitoring and emergency management, detection of exceeding alert thresholds and activation of automatic *early-warning* procedures and protocols of decisions-making. The seismological monitoring needs different analysis techniques for covering the wide manifold of seismo-volcanic signals. Locations suffers for the complex structure of volcanoes, so 3D velocity models (from seismic tomography) greatly improves their quality. High resolution tomographic velocity models for several Italian volcanoes are now available, and accurate techniques for earthquake location and mechanism determination have to consider the heterogeneous nature of the propagation medium. The best suited location tools for complex structures are non-linear search based methods such as NonLinLoc developed by A. Lomax. Furthermore, the use of Equal Differential Time technique improves the robustness of locations by neglecting large outliers. The most dangerous italian volcanoes (Vesuvius and Campi Flegrei) show currently a predominant volcano-tectonic seismicity, but tools for the analysis of LP and VLP signals should be rapidly working in case of unrest and be able to provide a rapid estimation of the source location and mechanism (moment tensor) parameters. In addition, an efficient seismological monitoring system of volcanoes needs both a rapid real-time automatic analysis of data and long term databases for a comparison of the current volcano status with the past activity. This result may be obtained developing procedures that carry out continuous analysis, putting results in a database, accessible via a user-friendly web interface.

Considering that most of Italian active volcanoes have their edifice entirely or partly submerged, seismological instruments deployed on sea bottom with real time data transmission to onshore centers will be an important new tool for volcanic monitoring in the next future. Data acquisition of earthquake waveforms on the sea bottom is performed since several decades using Ocean Bottom

Seismometers (OBS). Usually data are acquired in continuous mode and locally stored over periods from some weeks to more than one year, according to the autonomy of the batteries. A retrieval system controlled by acoustic command, releases the ballast allowing the OBS pop-up. Data are available only after the recover of the instrument. Monitoring of volcanic activity requires data transmission in real or near-real time and new technology to retrieve the data are now in development. Recently data acoustic transmission systems for a sea bottom instruments are under development to extent real time data acquisition to the seafloor in the framework of a cooperative project seeing the partnership of research (INGV, University of Naples) and industrial partners (Alenia WASS). Integrating the experiences and know-how gained by carrying out this and other linked projects for sea bottom observatories conducted at Roma-2 section of INGV, the present project will design, develop and realize in a prototype form, sea bottom seismic station with real time transmission connected to the monitoring system of Neapolitan volcanic area.

Ground-based thermal imaging (direct ground measurements and infra-red imaging) has recently been introduced in volcanology and applied to a number of different volcanic phenomena. Excellent results have been obtained during 2002-03 Etna and Stromboli eruptions, when daily thermal imaging measurements allowed us to observe magma movements within the summit conduits, the opening of fissure systems, the development of fractures on the flanks, and also to discriminate lava flow field structures such as lava tubes, ephemeral vents, tumuli and to distinguish active lava flows. Thermal images can be also used to provide quantitative measures of lava effusion rates. In this project, we intend to develop new measurement techniques, and quantitative computational methods to allow near real-time analysis of thermal imagery based on the already existent observational experiences carried out on several Italian volcanoes. For instance the TIIMNet project (Thermal Infrared Imagery Monitoring Network) allowed to design and to develop a volcanic surveillance system for the continuous monitoring of the shallow thermal structure of active volcanoes. The technological approach was specifically developed for Vesuvius and Solfatara craters, based on the integration of image monitoring systems, in the thermal IR wavelengths range, with the existing geochemical surveillance systems.

Description of the Activities:

The project is organized in 3 Tasks, that will be achieved through the development of research activities coordinated in specific 11 Work-Packages.
The Tasks have been identified to get the global objectives:

- Volcanic hazard assessment based on probabilistic techniques, and eruption forecasting.
- High resolution seismic imaging of volcanic structures.
- Real-time observations and measurements.

Task 1. Estimation of the volcanic hazard based on probabilistic techniques, and eruption forecasting

UR coordinating: W. Marzocchi (INGV, Roma 1)
UR participating: S. Falsaperla (INGV Catania) , R. Campanini (Univ. Bologna), L. Crescentini (univ. Salerno)

This task is mainly focused on developing innovative techniques to estimate quantitatively the long- and short-term volcanic hazard. WP1.1 is mainly devoted to develop probabilistic tools to merge information provided by theoretical models, past geological/historical data, and monitoring observations; WP1.2 aims to identify precursors of volcanic activity on different time scales, by analyzing with innovative techniques monitored volcanic eruptions. WP1.3 is focused on improving the knowledge of the stress/deformation changes in volcanic areas.

WP1.1: Probabilistic tools to assess short- and long-term volcanic hazard

We propose to implement and to improve the probabilistic method proposed by Marzocchi et al. (JGR 2004) based on the Event Tree (ET) scheme. ET is a powerful quantitative tool that estimates the probability of all the relevant possible outcomes of a volcanic crisis, and, in general, it quantifies VH and risk. The most important improvement is relative to the introduction of the Fuzzy Logic to overcome all the technical, practical, and theoretical problems raised by the use of "rigid" thresholds at the nodes. For instance, the passage to a quiet state to a state of unrest (node 1 of ET) is sharp depending on the overcoming of a threshold for one or more selected parameters. The Fuzzy Logic allows a more gradual transition from one state to the other, replacing the single threshold with a more appropriate interval of values. Another issue to be improved may be the set of probabilistic rules used to merge the monitoring data with past data and theoretical models, and to evaluate the epistemic and aleatoric uncertainties. The implementation of the models is mainly related to the design of a software tool to visualize the outcomes of ET. We plan to design the code for end user with different technical backgrounds. The software code will replace the usual "hazard maps", since it provides an answer for a complete set of possible queries, from the probability to have a generic or specific kind of eruption in the next month, to the probability map of lahars, pyroclastic flows, or tephra for some specific kind of eruption or for a weighted average of all possible scenarios. The code also furnishes a visual representation of the uncertainties of volcanic hazard assessment. In general, this tool allows probabilities to be continuously updated, and therefore both the long- and short-term VH to be estimated. In particular, the long-term VH assessment (years to decades) is usually estimated only from past data it allows different kinds of hazards (volcanic, seismic, industrial, floods, etc.) in the same area to be compared, which is very useful for cost/benefit analysis of risk mitigation actions, and for appropriate land-use planning and location of settlements. In contrast, monitoring on mid- to short-time scales assists with actions for immediate vulnerability (and risk) reduction, for instance through evacuation of people from danger areas.

WP1.2: Precursory patterns at different time scales

We will develop quantitative tools to evaluate volcanic hazard focusing on seismic signals, as they are recorded in several volcanic areas and are excellent markers of changes within the volcano feeder. We have two main targets: first, we will analyze multivariate seismic databases of some monitored recent eruptions in order to recognize possible seismic precursors, and to identify possible patterns indicating the magnitude (VEI) of the impending event. At this aim, we will use a Support Vector Machine (SVM) classifier that is proved to be one of the best tool for a large variety of quite different fields, such as computer-aided diagnosis, gene classification, industrial processes, video surveillance, face detection in digital images, etc. We will also focus our attention on detecting the seismic variables which are the most important ones in order to correctly forecast a volcanic eruption. This problem will be addressed by means of a feature reduction technique known as a Recursive Feature Elimination (RFE) in collaboration with a Genetic Algorithm (GA): the classification performance will be explored recursively eliminating some of the less discriminant seismic variables according to the cost function of SVM, thus ending up with a restricted set of seismic variables. This reduction is very important in practice, because it may lead to a faster analysis of seismic signals during unrest. Our second target is the application of the Bayesian Belief Network (BBN) technique to structured information stemming from monitoring system combined with: geostatistical analysis and stochastic methods contained in the Deducing Eruptions of Volcanoes In Near Future program (Jaquet et al. 2005), Hidden Multi-state Markov models (Aspinall et al. 2005), Dynamical Systems parameters (Carniel et al. 2003), Material Failure Forecasts (Ortiz et al. 2003), or other multivariate time series statistics. Accommodating the various strands of evidence - from the classification and characterization of seismic signals to statistical data and results of the above listed methods - into the BBN, we will develop an integrated tool which, by indicating probabilistically the progression of state of the volcano unrest, may be used to support alert level decisions. To review precedents, the integrated analysis method will be applied and "tuned" on basaltic volcanoes with persistent activity like Mt. Etna and Stromboli, using past and recent eruptive events, for which continuous data are available. Successive near real time applications for monitoring will then be possible. We will also test applications to volcanoes like Soufriére Hills, Montserrat and Tenerife, Spain.

WP1.3: Mapping and monitoring stress/deformation changes in a volcano
The inversion of geodetic and seismic data is intrinsically nonlinear and results in cost functions with a rough landscape and several local minima. Local optimization techniques can fall into a local minimum, which depends strongly on the starting model. Among the global optimization techniques, we have used ASA (adaptive simulating annealing) to invert geodetic and seismic data for the sources of strong Italian earthquakes occurred last century. Other researchers have used GA (genetic algorithm) to determine the parameters of a volcanic intrusion. As global optimization techniques require to solve many forward problems, time-consuming techniques like 3D finite-element modeling can not be integrated in the inversion codes, but can be used to generate synthetic data sets to test them. On the other hand, it is unrealistic to model the magma chamber as a point source of volume change and a dike as an opening-mode dislocation, assuming that the earth is a homogeneous, isotropic, elastic half-space. We propose to develop two numerical codes for the inversion of geodetic and seismic data and check their feasibility for alert systems. The two codes will use two different optimization techniques, based on ASA and GA, to reinforce results. Besides taking into account the possibility of faulting, we will compute ground deformation and gravity changes using an elasto-gravitational layered Earth model, including a topmost water layer to calculate sea level changes, and a spherical volcanic intrusion. Possible dike intrusion will be modeled as a rectangular tensile fault in a layered earth, using ad hoc variants of the codes by Pollitz (1997) and Wang et al. (2003), originally developed for calculating coseismic deformation. In this case we will estimate the zeroth-order gravity effects due to uplift, water table fluctuation, and density change inside the dike.The inversion codes will be calibrated using synthetic data sets (which we will generate by finite-element modeling) and tested using data from the Campi Flegrei area, which is presently monitored by means of seismic and ground deformation networks and three high-sensitivity Sacks-Evertson dilatometers (installed in 2004), as well as the Monserrat and Long Valley volcanic areas.

Task 2. High resolution seismic imaging of volcanic structures

UR coordinating: A. Zollo (Univ. Napoli, Federico II)
UR participating: J. Virieux (Geoscience Azur), E. Priolo (OGS), A. Piersanti (INGV, Roma 1), F. Bianco (Roma 1).

This task is devoted to investigate, develop and apply innovative tools for a refined seismic imaging of the volcanic structure, which uses the whole waveform amplitude information retrievable on seismic data (arrival times and amplitudes of primary and reflected/converted phases). The rugged model of the volcanic structure can be estimated by seismic reflection methods adapted to work in highly heterogeneous media and non-standard acquisition lay-outs. Rock physical parameters will be studied at the seismological scale by inverting the tomographic images using the medium effective theory, as well as modeling amplitude variation with offset of reflected/converted arrivals. Numerical simulations of the seismic wave-field in a heterogeneous, anisotropic, anelastic medium will allows to analyze the effects of medium complexity on seismic waveforms and calibrate tools for imaging velocity discontinuities, spatial variation of anisotropy and anelastic attenuation parameters. Techniques for the measurement of time and spatial variation of anisotropy/attenuation parameters from local earthquake seismograms will be developed and tested using real and synthetic data.

WP2.1: Reflection seismics in strongly heterogeneous media: application to the detection / modeling of interfaces beneath volcanoes

1/ Processing and analysis of seismic reflection data acquired in unconventional lay-out geometries, global offset ranges and heterogeneous structure environment.

It is proposed the development of methods for move-out and stack(semblance) analysis of reflected and converted arrivals in 2D/3D media which includes the design of 'ad hoc' time and frequency/wavenumber filters able to remove multi-path and coherent noise signals from record sections. It will be investigated the implementation of techniques for the estimate of stack velocity models (based on tomographic models) in lateral heterogeneous structure to be used for the velocity analysis of global-offset data.

2/ Reflector morphology from modeling/migration of reflected/converted phases for global offset data. We propose the development and implementation of a 2D/3D technique for reconstructing the reflector morphology based on depth migration/modeling of reflected/converted arrivals and an 'a priori' knowledge of the heterogeneous background velocity medium. The technique operates on active seismic data, acquired on volcanoes in unconventional lay-outs and is able to work in presence of strong lateral velocity gradients. The method will be based on dynamic ray tracing for heterogeneous velocity models. The possibility to export the technique to passive seismic data acquired by a local network will be also explored.

3/ Converted phases analysis from local earthquake seismograms

Considering this smooth recovered velocity structure, we shal perform scattering analysis for oriented scatterers inside the medium. These oriented points might help us to draw a geological interpretation of the subsurface beneath a volcano. Converted phases will be identified and travel-times will be picked for stacking the converted phase energy. By introducing this new data set, one may hope to improve the resolution of the background model, especially in volcanic zones where complexity is expected.

4/ Amplitude waveform inversion

Linearized waveform inversion might even go further especially for initial waveforms in order to improve our model reconstruction. Only 2D investigation wil be performed taking into account the rather numerical intensive task of the forward modeling. We shall design a tool for this optimization which expect the initial model to be nearby the final one.

WP2.2: From tomography/reflection seismic images to rock physical properties and lithology

1/ Characterization of impedance contrasts at discontinuities in a volcanic structure.

The measurement of amplitude variation of the reflected/converted wave field vs offset allows for investigating the physical properties of the reflecting body by modeling the impedance contrast at the interface. A generalization of this approach to earthquake and active seismic data collected in volcanic area, would require refined source location and mechanism estimations, in addition to an adequate waveform amplitude modeling which accounts for lateral elastic/anelastic medium heterogeneities. We propose the development of a technique for the estimation of the impedance contrast at buried interfaces beneath volcanoes (basement top, magma chamber top) to be used for a physical/lithological characterization of the seismic discontinuity. The amplitudes of principal and secondary (reflected/converted) phases will be computed through a multi-phase seismogram based on the ray-theory.

2/ Retrieval of rock physical parameters from tomographic images.

We shall investigate our to extract information from seismograms in complex zones as volcanic structures. In order to do so, we must design specific tools for first-arrival delayed-time tomography in 3D smooth heterogeneous medium.

We must combine accurate travel-time estimator (Podvin & Lecomte Finite-Difference Eikonal solver) with iterative LSQR matrix inversion technique. We shall introduce Fresnel zones in our tomographic tool for improving resolution. Volcanic rocks are complex with at least two phases at small scales (Foward biphasic formulation). We shall introduce effective medium theory to model this complexity. We shall calibrate these parameters on measured data on rock samples collected in wells through laboratory experiments under well-controlled pressure and temperature. This forward tool will be the kernel of our interpretation in term of rock physics. Recovered seismic velocity images will be interpreted in terms of rock properties by using a simple grid approach which will scan potential values of acceptable rock parameters. This extraction of rock parameters must both reconstructed velocity structures and therefore will be compatible with travel-time data. This interpretation tool will help us to understand what kind of rocks we may expect at depth inside a volcano.

WP2.3: Realistic simulation of volcanic earthquake wave motion

The objectives of this WP will be pursued by two independent RUs through different techniques. The first one will perform the simulations by means of an improved version of the 3D seismic wave field simulation code developed by the same RU. The software is based on the staggered-grid Fourier pseudo-spectral scheme which, using a coarser sampling of the spatial domain, allows the accomplishment of large scale simulations on massively parallel supercomputers. The existing code, written in Fortran 90 with MPI protocol, will be improved in order to account for both medium viscosity and anisotropy in the elasto-dynamic equation and to solve the seismic wave propagation accurately also in the presence of sharp impedance contrasts and irregular topography. Volcanic earthquake sources with arbitrary geometry, size and mechanism will be considered. The reciprocity principle will be exploited in the computation of the Green's functions to simulate a large number of source points. The simulations will be performed using a set of kinematical source models described by space-time functions consistent with the state of the art knowledge of the volcanic seismic sources (fluid-filled crack models). The structural models to be used as input for the simulations will be build up using the Gocad commercial software. The output will consists in snapshots of the seismic wave field as well as in time series collected by arrays of receivers at surface. The maximum effort will be put in pursuing not only a qualitative but also a quantitative reproduction of the volcanic earthquakes, in order to provide a tool for the refinement of the interpretation of the seismic observations in terms of the activity of magmatic systems.

The second RU will develop and modify the Tromp original SEM (Spectral Elements Method) code in order to make it suitable for extremely small scale applications. Then, it is planned to use the Etna and Vesuvio topographic and tomographic models as an input for the modified SEM code in order to simulate the complete wave field produced by an arbitrary volcanic earthquake source in a heterogeneous, anelastic, anisotropic 3D structure. One of the major achievements of SEM approach is the possibility of considering a complete anisotropy of the medium. Therefore, the SEM could be used to test if the shear-wave splitting may become an important indicator of volcanic activity. After modifying it, we plan to run the SEM code both at Caltech and in the parallel linux cluster implemented at INGV by the RU (Hydra). Presently, the SEM code is optimized to run in 32 bit architectures. At INGV we are planning to start the test of 64 bit architectures. The MPI optimization of the SEM code for 64 bit architectures will be one of our goal for the second year of the project. This development would allow us to simulate wavefield with a greater high frequency content.

WP2.4: Estimation of anelastic attenuation and anisotropy parameters

In the first year of the project the attenuation studies will be addressed to the following activities: i) development of a new tomographic inversion technique based on the linearization of the Zollo and de Lorenzo (JGR., 2001) method; ii) implementation of a new technique of Rayleigh waves inversion, based on the semblance among synthetic and observed waveforms, to infer the 1D anelastic Qp and Qs structure of surface layers from high resolution seismic shots; iii) formulation of a Bayesian method to jointly invert P polarities and P pulse widths to obtain source and Q parameters; iv) development of a technique to model P body waves with different rupture velocity time histories and Q models. In the same period the studies on anisotropy will be addressed to the following activities: i) definition of quantitative criteria for automatic data selection and quality detection of splitting measurements; ii) development of a methodology to measure both the splitting parameters simultaneously in a (quasi)automatic way; iii) development of an array technique to measure the splitting parameters; iv) accurate definition of the measure errors on both the splitting parameters.; v) individuation of the spatial (depth and lateral) extent of the crustal anisotropy in some test areas (possibly Vesuvio/Etna).; vi) definition of the fracture criticality level for the test areas. In the second year of the project the attenuation studies will be addressed to the following activities: i) application to synthetic and real cases (Flegrei, Serapis, Etna, Vesuvio) of the techniques implemented in the first year. In the same year, the studies on anisotropy will be addressed to the following activities: i) time variation of crustal anisotropy in some test areas (possibly Vesuvio/Etna); ii) Quantification of the average pore pressure from splitting measurements.

Task 3. Real-time observations and measurements

UR coordinating: G. Iannaccone (INGV-OV)

UR participating: M. Martini (INGV-OV), G. Vilardo (INGV-OV), G. Romeo (INGV-Roma 1), L. Lodato (INGV-Catania)

The task 3 aims to provide new tools of real-time analysis of seismic and thermal monitoring data, an to design and test of a prototype, sea-bottom multi-parametric station integrated to an on-land existing monitoring network. The real time seismological monitoring needs different analysis techniques for covering the wide manifold of seismo-volcanic signals. Automatic techniques for real-time detection, location and moment tensor estimation of seismic events (short-period, long- and very long- period signals) will be developed and made able to work in 3D heterogeneous volcanic structures. Concerning the experimentation of prototypes for data acquisition in hostile environments it will be developed and tested a sea bottom seismic station with real time transmission connected to the monitoring system of Neapolitan volcanic area. New instruments for thermal monitoring will be conceived and tools to analyze thermal images in near real-time.

<u>WP3.1: Real-time estimation of earthquake source parameters</u>

Major efforts will be devoted in 2005 for the adoption of 3D velocity models in hypocenter location. First existing 3D tomographic models will be collected and eventually merged together and adapted to fit region of interest around Neapolitan volcanic areas. Then the whole existing database (together with the new data from 1984 data reprocessing) will be relocated using a non-linear EDT approach. In a second stage this technique will be implemented as a standard in automatic location procedure of the monitoring system.

A seismological multiparametric database, containing information as tremor amplitude, wavefield spectra, polarization, array slowness estimates and raw waveforms, will be developed and joined together with the pre-existing hypocenters database. The new system will be designed according to the experience acquired on the Stromboli data analysis (EOLO system). The seismic data contained in this global database, coming from different subnetworks, will be stored adopting standard data formats, useful for data exchange with other monitoring centers. The system will be able to automatically recover data possibly lost during network downtimes. All of the data, both stored and real-time, will be available to the users with a common and coherent interface.

In 2006, two more tools will be added to the Neapolitan volcanic area monitoring system. The first will be a neural network based seismic discrimination system, based on an algorithm has shown to be efficient in Vesuvius area in discriminating true earthquakes from thunders and artificial explosions. The second is a moment-tensor inversion system based on non-linear search algorithms. The access to the whole database will be implemented using an user-friendly web interface that will allows an efficient check of the temporal variations, the cross-correlations and the statistical analysis of the seismic source parameters.

<u>WP3.2: Design and test of a prototype, sea-bottom multi-parametric station integrated to an on-land existing monitoring network.</u>

The main objective of the two years project is to develop and test an OBS with real time transmission connected to the monitoring system of Neapolitan volcanic area. In the frame of the PON project an OBS with standard seismological instruments will be acquired and modified to monitor in real time data collected at the sea bottom. The instrument will be connected by means of a cable to an existing large floating platform (fishing farm). A free-wave radio provides I.P.-based telemetry between the platform and a control center in order to transfer in real time the seismic information recorded at the sea bottom. On the platform a power supply system with solar panels and rechargeable batteries will provide the necessary energy for continuous operation of the sea bottom instruments. The platform operate in the Gulf of Pozzuoli at about two miles offshore where depth of the sea is about 100m.

The first year will be devoted to:

- identify the OBS model to acquire
- define the technical specifications for the cable connection
- define the technical specification of the cable
- propose solutions to connect cable to the floating platform
- test the complete system (OBS+cable+radio transmission) in laboratory
- install the necessary equipments on the platform
- install the OBS on the sea bottom and test all components
- plan and develop of an electronic prototype data logger system for OBS case equipment (OB-GILDA)

The activity of the second year will be:

- testing of OB-GILDA
- to experiment the acoustic link developed by WASS in the frame of the PON project
- to develop and test a software management of the acquisition system. This software will be able to request any time slice of interest, regardless of when the data were recorded. The time slices will be defined on the basis of a daily/weekly catalogue published by UF Centro di Monitoraggio of OV-INGV; and by an event list generated by the data logger. All digitized data could be also telemetered to the control center.

For a practical application we will evaluate the possibility of integrating the undersea system on Campi Flegrei or Stromboli monitoring networks.

<u>WP3.3: Surface thermal imaging</u>

The work inside this WP consists of different activities, ranging from the conception of new instruments for thermal monitoring, and tools to analyze thermal images in real-time (or near real-time). As regards the first activity, we plan to improve the design of the thermal head, the production of two arrays, and the permanent installation of one of them in a site (i.e., Campi Flegrei) for a continuous thermal gradient measurement and to allow the calibration of the existing IR imaging system. As regards the second objective, the planned activities will involve i) the collection of a comprehensive database of TIR images to characterize the background level of the thermal emissions at Vesuvius, Campi Flegrei; ii) TIR images calibration to account for absorption and atmospheric parameters variations due to normal seasonal variations and local weather conditions; iii) complete automation of the processes of extraction from the TIR image data of numerical parameters; iv) development of programs for real-time data analysis and information visualization for the continuous monitoring of the space-time evolution of both the temperatures field and the associated geochemical and atmospheric parameters; v) development of new quantitative computational advanced methods to allow near real-time analysis of thermal imagery for estimation of lava effusion rates during volcanic crises. Part of the planned work on these issues will be devoted to apply and verify the methods to real cases.

Deliverables list

Task 1. Estimation of the volcanic hazard based on probabilistic techniques, and eruption forecasting: - Implementation of the Event Tree scheme including Fuzzy Logic - Visualization and computation code to estimate volcanic hazard - Development of quantitative tools to analyze multivariate seismic database in order to recognize potential precursory patterns of volcanic eruptions - A software pattern recognition package, aimed to find precursory patterns of volcanic eruptions - Definition of probabilistic rules to quantify short-term volcanic hazard - Results from finite element modeling of ground deformation and gravity - Inversion codes for near real-time applications to study ground deformation and gravity.

Task 2. High resolution seismic imaging of volcanic structures: - Development of methods for processing and analysis of seismic reflection data and converted phases analysis from local earthquake seismograms - Testing (application to synthetic/real data sets) of methods for determining reflector morphology from modelling/migration of reflected/converted phases and for linearized amplitude waveform inversion - Development of methods for the characterisation of impedance contrasts at discontinuities in a volcanic structure and retrieval of rock physical parameters from tomographic images - Testing (application to synthetic/real data sets) of methods for the characterisation of impedance contrasts at discontinuities in a volcanic structure and retrieval of rock physical parameters from tomographic images - Implementation of Komatish and Tromp SEM code to volcanic application - Simulation of the complete wave field produced by volcanic earthquake sources (double- and not double couple sources, low frequency events, tremor,…) in heterogeneous, anelastic, anisotropic 3D structures - Database of synthetic wave field - Development and implementation of Fortran Codes to infer 3D Anelastic attenuation and rheological models of volcanic structures - Development and implementation of Fortran, Matlab and Mathcad Codes to measure space and time variation of the anelastic attenuation and anisotropy properties of the volcanic rocks - Results from the application of the methodologies to real and synthetic data and, consequently, definition of 3D Anelastic attenuation and rheological models.

Task 3. Real-time observations and measurements: - Developments of techniques aimed at automatic classification and discrimination of seismic signals - An integrated multiparametric seismic database - Real-time estimation of earthquake source parameters in a volcanic area (Earthquake location, magnitude/moment, moment tensor) - System Architecture design of OBS - Implementation and test in a volcanic area - Continuous real-time surface thermal measurements at the Vesuvius and Solfatara sites, and background assessment – Database of TIR images with associated parameters, and of gradiometer arrays measurements - Integrated report on the implementation and test in a volcanic area of data acquisition, analysis and modelling of surface thermal images - System Architecture design of gradiometer arrays.

PROJECT V4 – NEW TECHNIQUES

TABLE MAN/MONTHS

U.R	**Institutions**	**Principal Responsibles**	**Task1 Coordination**	**Task2 Probabilistic techniques for volcanic hazard**	**Task3 High resolution seismic imaging**	**Task4 Real time observations and measurements**	**Mesi p. cofin.**	**Mesi p. rich.**
UR-1	INGV-Rm1	Marzocchi	@	@			17	
UR-2	INGV-CT, Soc. Aspinall (UK), UniUd, Colenco Baden (CH), Univ. Leeds (UK), NIIZK St. Petersburg (RU)	Falsaperla, Aspinall, Carniel, Neuberg, Psenichny		@			79	
UR-3	UniBo	Campanini		@			24	24 (UniBo)
UR-4	UniSa, INGV-Rm, CIW (USA)	Crescentini, Amoruso, Scarpa		@			34	24 (UniSa)
UR-5	UniNa, UniSan	Zollo, De Matteis	@		@		24	24 (UniNa)
UR-6	Geosciences Azur (FR)	Virieux, Vanorio			@		48	
UR-7	OGS Tri	Priolo			@		8	24 (OGS)
UR-8	INGV-Rm1, Caltech Inst. (USA)	Piersanti			@		34	
UR-9	INGV-OV, UniBa, INGV-CT, Univ. Edinburgh (UK)	Bianco, Del Pezzo, De Lorenzo			@		97	12 (borsa di studio INGV-OV)
UR-10	INGV-OV, UniSa, USGS (USA)	Martini, Chouet				@	35	
UR-11	INGV-OV, UniNa	Iannaccone				@	50	

UR-12	INGV-Rm1	Romeo, Quattrocchi				@	17	
UR-13	INGV-OV	Vilardo, Chiodini				@	24	
UR-14	INGV-CT, Univ. Hawaii (USA), Univ. Alaska (USA), Cambridge Univ. (UK)	Lodato, Harris				@	24	
Totale							515	108

PROJECT V4 – NEW TECHNIQUES

Table RU and related funding request

N. UR	Istituz.	Resp UR	Personale		Missioni				Consumi servizi		Inventariabile	
					Italia		Estero					
			2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
UR-1	INGV-Rm1	Marzocchi			2000	3000	3000	3000	13000	13000	13000	10000
UR-2	INGV-CT	Falsaperla[1]			2000	2000	3000	3000	32000	32000		
UR-3	UniBo	Campanini	16000	16000	1000	1000	1000	1000	4000	4000	2000	2000
UR-4	UniSa	Crescentini	19000	19000	1500	1500	2500	2500	3000	4000	3000	2000
UR-5	UniNa	Zollo[2]	38500	38500	1000	1000	3000	3000	19800	19800	2500	2500
UR-6	Geoazur	Virieux					12000	12000	14000	14000	4000	4000
UR-7	OGS Tri	Priolo	25300	25300	2000	2000	2000	2000	4700	4700		
UR-8	INGV-Rm1	Piersanti			1000	1000	5000	5000	1000	1000	8000	8000
UR-9	INGV-OV	Bianco			2000	2000	3000	3000	13000	17000	4000	
UR-10	INGV-OV	Martini				2000			4000	7000	20000	
UR-11	INGV-OV	Iannaccone			2000	2000	2000	6000	20000	16000	20000	10000
UR-12	INGV-Rm1	Romeo			2000	6000			21100	2000	3400	
UR-13	INGV-OV	Vilardo			3000	3000	2000	2000	11000	11000		
UR-14	INGV-CT	Lodato			1000	1000	3000	3000	14000	14000		
		TOTALE	**98800**	**98800**	**20500**	**27500**	**41500**	**45500**	**174600**	**159500**	**79900**	**38500**
GRAN TOTALE: 785100												

[1]32000 euros (16000 each year) included under the voice "Consumi e servizi" will be provided to the Univ. of Udine for research activities under the responsibility of R. Carniel.

[2]The cost for personnel (38500 euros per year) corresponds to the full cost per year of a European post-doc researcher (35000 euros) with a "CoCoCo" contract, and includes the costs under the voice "IRAP" which must be covered by the engaging institution.

PROJECT V5

Research on the diffuse degassing in Italy

Responsibles:

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Mariano Valenza, Univ. Palermo

Project V5

Diffuse Degassing in Italy

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Objective of the project

The emission of endogenous gases from the soil (mainly CO_2) is a phenomena which affects large areas of the Italian territory. Gas emissions characterize areas of active and extinct volcanism, volcanism, geothermal areas and non volcanic regions. The gas is emitted both by diffuse degassing along active structures or by focused vents forming mofete, mud volcanoes, bubbling pools etc..

In most of the cases the main component of the gases is CO_2 whose density is much higher of air density and which in absence of wind accumulate in the morphological depressions forming river and lakes of gas. The humans and the animals which fortuity enter these invisible traps are destined to a secure death. Many accidents involved in the past not only domestic and wild animals but also people. The periodical occurrence of such accidents alerted the Civil Defense which financed this project whose main objective is the mitigation of gas hazard in Italy trough a coordinated and multidisciplinary study of the earth degassing in Italy.

The numerous data acquired during the project will be useful also for the achievement of important scientific results concerning the origin of the anomalous gas emission which affect the Italian territory, the global carbon budget and the relations between Earth degassing and geodynamics.

State of the Art

A general map of CO_2 earth degassing in Central South Italy has been recently elaborated on the base of the geochemical and isotopic characterization of the carbon dissolved in the main aquifer of the region (Chiodini et al., 2000 JGR; 2004 GRL; Fig. 2.1)

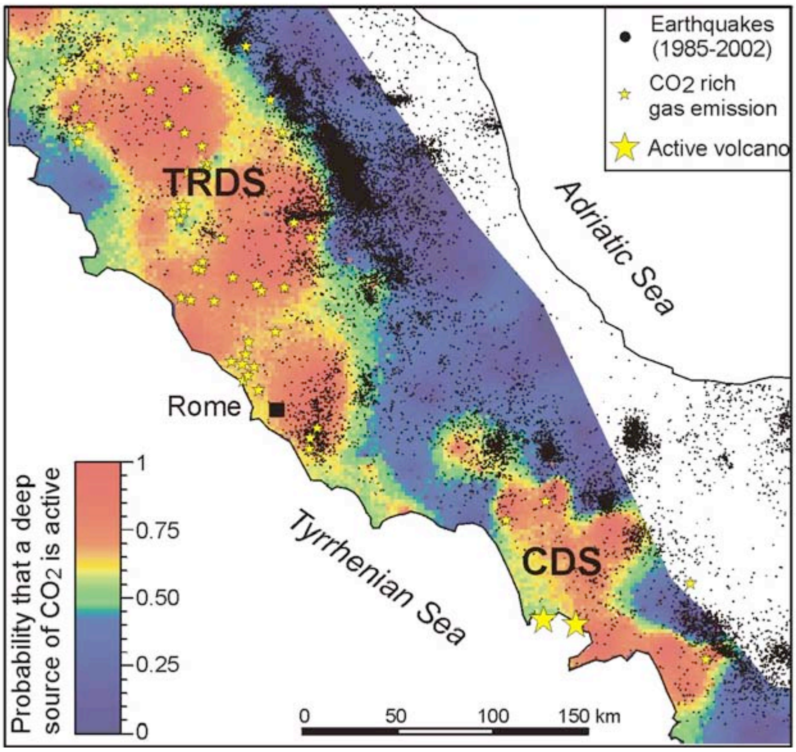

Fig. 2.1 Map of Earth degassing in central south Italy The figure shows the probability that a deep source of carbon is present at any location (Chiodini et al., 2004 GRL). The map is compared with the recent seismic activity recorded by the National Seismic Network of INGV; the large historical earthquakes in the region are also concentrated in the same belt. The location of active volcanoes and of the main gas emissions is reported for comparison.

The map highlights the presence of two large degassing structures in the Tyrrhenian sector of Italy.

The first is bordered by the Tyrrhenian sea at W, by the Apennine at E and includes Tuscany, Latium and Umbria regions while the second coincides with the Tyrrhenian sector of the Canpania region. These are two regional structures degassing deeply derived CO_2 as evidenced also by the widespread occurrence of strong gas emissions and Quaternary travertine deposited by CO_2 rich groundwater. The northern structure partially overlaps the Tuscany, Roman magmatic province (TRDS, Tuscan Roman degassing structure) while the southern structure relates to the Campanian volcanism (CDS, Campanian degassing structure). The two volcanic provinces are characterised by quaternary potassic and ultrapotassic magmas rich in fluids with high CO_2/H_2O ratios (Foley, 1992 Lithos). Geochemical features of the magmas are consistent with the melting of a mantle source metasomatised by crustal material (Peccerillo, 1999 Geology). It is reasonable that the TRDS and CDS reflect the degassing process of this metasomatized, uprising mantle. In the eastern sector of Italy, where the CO_2 anomaly disappears, the process of Earth degassing is characterized by gas emissions rich in hydrocarbons. Also these emissions will be investigated during the project.

The total amounts of deeply derived CO_2 released from TRDS and CDS have been estimated to be 1.4×10^{11} mol/y and 0.7×10^{11} mol/y respectively (Chiodini et al., 2004 GRL). The total CO_2

released by TRSD and CDS is globally significant, being ~ 10% of the present-day total CO_2 discharge from subaerial volcanoes of the Earth (Kerrick, 2001 Reviews in Geophysics). This result suggests an underestimation on CO_2 globally released by the Earth, because unquantified processes of CO_2 earth degassing from non-volcanic environment affect almost all the tectonically active areas of the world.

Both TRDS and CDS are characterized by the presence of numerous emissions of gas rich in CO_2 (Fig. 2.2).

Fig. 2.2 A) CO_2 'lake' in the Amiata region. The gas accumulation has been made visible by igniting a smoke bomb in the morphological depression. The yellow color highlights the zone where CO_2 concentration is lethal. The manifestation caused the dead of a person the 20^th^ November 2003. B) The animals and the persons which fortuity enter in this invisible gas traps are destined to secure death. The picture shows a wild pork killed by the gas emitted at Palidoro, a gas emission located few kilometers north of Rome.

Normally these gas emissions are characterized by both focused vents and diffuse soil degassing. The gas emitted by some of these manifestations caused in the past lethal accidents. At Mefite d'Ansento (Avellino) two young archeologists died during 1990's; at Tivoli, near Rome, the gas emitted by a river saturated in CO_2 killed some boys; at Colli Albani (Rome), many lethal accidents involved in the past animals and people; at Veiano the gas killed some fishermen along a river affected by strong gas emissions; some people died at Mt Amiata (Siena) where the last lethal accident occurred in November 2003; at Manziana many people died during the second world war entering in a cave full of CO_2; the drilling of wells in some areas constitute a continuous risk because often CO_2 pressurized levels are encountered; etc.

This list is largely incomplete because a specific research on the accidents caused by the gas has never been done. Furthermore a catalogue of the gas emissions, and in particular of the dangerous areas where accidents periodically occur, is still missing. In non-volcanic areas and in areas of extint volcanism, the flux of only few gas emissions have been already measured (Rogie et al., 2001 JGR; Chiodini et al., 1999 Chem. Geol.). Contrary many Italian volcanic areas have been already the objective of detailed studies of CO_2 soil diffuse degassing such as Vulcano (Badalamenti et al., 1991 Nature; Chiodini 1996 Bull. Volcanol.; Diliberto et al., 2002 Bull. Volcanol.), Stromboli (Carapezza e Federico, 2000 JVGR), Etna (Badalamenti et al., 1994 Acta Vulcanol.; Giammanco et al., 1998 Bull. Volcanol.), Campi Flegrei (Chiodini et al., 2001 JGR), Ischia (Chiodini et al., 2004 JVGR), Vesuvio (Frondini et al., 2004 Bull. Volcanol.) and Colli Albani (Chiodini e Frondini 2001 Bull. Volcanol.; Carapezza et al., 2003 JVGR; Pizzino et al., 2002 Natural Hazard). As an example of volcanic active area, the diffuse soil CO2 degassing of Mt Etna is reported in fig.2.3.

However, excluding few works on Colli Albani, most of these studies were aimed to the volcanic surveillance rather than to define the hazard related to the presence of the gas emissions. In any cases these studies confirmed the presence of numerous zones where CO_2 (and sometimes H_2S) fluxes are so high that represent a serious danger for people and animals.

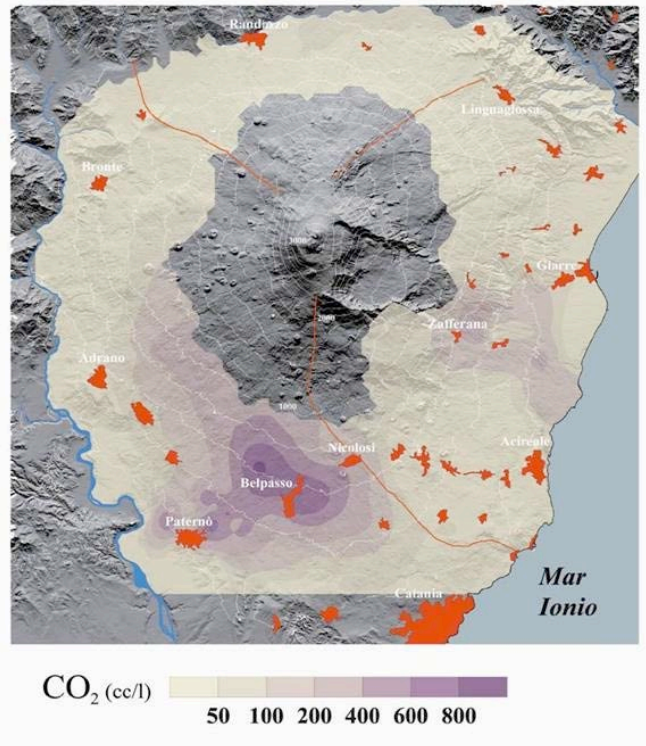

Fig. 2.3 Diffuse soil CO2 degassing at Mt. Etna volcano. Two areas of intense soil degassing are respectively located in the South and East side of the volcanic edifice (Parello et al.2001 GNDCI-CNR, pubbl. n. 2190).

In the geothermal areas (Larderello, Amiata, Latera) there are many geochemical studies both of the fluids emitted by natural manifestations and of the geothermal fluids founded by the geothermal wells. However also in this case detailed researches on the danger of the natural manifestations are missing as well as studies on the relations among the flow rates of the natural emissions and the amount of fluids extracted by the geothermal activity.

This project has the aim to cover this lack of knowledge trough the constitution of the catalogue of the Italian gas emissions which will comprehend the accurate location of the gas emissions, the chemical and isotopic composition of the gases, the extension of the degassing areas, a rough evaluation of the fluxes, the relations with the geological and hydrogeological setting, the relations with the anthropological feature (i.e. distance from houses, villages, town etc.), the possible presence of dead animals, the possible record of historical accidents involving humans and finally, where possible, the evaluation of the gas hazard. The more dangerous manifestations will be investigated in greater details with specific gas flux campaigns while physical numerical modeling of the process including the genesis of the gas emission and the gas dispersion in air will be applied in few selected manifestations.

Is our opinion that the proposed objectives are within the capacity of the Italian scientific community and in particular of the team proposing this project. People of this team set up methods for gas flux measurements (Guerrieri e Valenza, 1998 Rend. Soc. It. Mineral. Petrol; Chiodini et al., 1998 Appl. Geochem.), developed portable measurement instruments and automatic stations (Badalamenti et al. 1994 Acta Vulcanol, Chiodini et al., 1996 Bull. Volcanol.), performed methodological studies for the comparison of different measurement techniques (Carapezza e Granieri, 2004 Appl. Geochem.), investigated statistical and geo-statistical tools suitable for the gas flux data treatment, for the production of maps, ecc. (Cardellini et al., 2003 JGR; Granieri et al., 2003 EPSL).

Description of the Activities

The project is organised in 4 tasks grouped in two Research lines. The research lines are: a) Italian Catalogue of the gas emissions and b) gas hazard and risk mitigation. The specific tasks are devoted to 1) Identification and characterisation of the gas emissions, relations with the structural and hydrogeological setting and with seismic activity in Central Italy and in Campania regions, 2) Identification and characterisation of the gas emissions, relations with the structural and hydrogeological setting and with seismic activity in Basilicata, Calabria and Sicily regions; 3) Definition of the scenarios and estimation of the gas hazard; 4) Evaluation of the vulnerability and risk, and risk mitigation.

The activities will be done by 15 different reserach units (RU) whose distribution in the 3 Tasks of the project is reported in Table 1.

Research Line 1 **Italian Catalogue of the gas emissions**		**Research Line 2** **Gas hazard and risk mitigation**			
TASK 1 and 2		**TASK 3**		**TASK 4**	
UniRM3-Capelli	RU1	INGVRM1-Carapezza	RU2	UNIRM3-Barberi	RU15
INGVRM1-Carapezza	RU2	INGVOV-Chiodini	RU4		
UNINA-Castaldi	RU3				
INGVOV-Chiodini	RU4				
INGVRM2-Etiope	RU5				
INGVPA-Favara	RU6				
UNIPG-Frondini	RU7				
INGVPA-Giammanco	RU8				
INGVPA-Italiano	RU9				
UNIPA-Parello	RU10				
INGVRM1-Quattrocchi	RU11				
CNRPI-Raco	RU12				
UNIPA-Valenza	RU13				
UNIFI-Vaselli	RU14				

Research Line 1. Italian Catalogue of the gas emissions

For a betterr coordination this reserach line has been divided in two tasks which refer to different areas but which are characterised by the same activities.

TASK 1 Identification and characterisation of the gas emissions, relations with the structural and hydrogeological setting and with seismic activity (Central Italy and Campania)
RU Coordinating: Chiodini (INGVOV)
RU Partecipating: Capelli (UniRM3), Carapezza (INGVRM1), Castaldi (UNINA), Etiope (INGVRM2), Frondini (UNIPG), Quattrocchi (INGVRM1), Raco (CNRPi), Vaselli (UNIFI)

TASK 2 Identification and characterisation of the gas emissions, relations with the structural and hydrogeological setting and with seismic activity (Basilicata, Calabria and Sicily)
RU Coordinating: Valenza (UNIPA)
RU Partecipating: Favara (INGVPA), Giammanco (INGVPA), Italiano (INGVPA), Parello (UNIPA)

The main objective is the production of the catalogue of the Italian gas emissions (CIGE). The main questions to answer for a better knowledge of the degassing process magnitude, of the natural processes controlling the degassing, and to provide data for the definition of hazard connected to the gas emissions and for the risk mitigation are:

- which and where are the areas characterised by a potentially hazardous soil gas emissions?
- What is the magnitude of gas flux?

- What are the chemical and isotopic compositions of the released gas? And, in particular, what are the concentrations of the gas species potentially dangerous for humans and animals?
- What is the origin of the gas emitted, what are the relations between the gas and the geodynamic and structural regional setting and what are the relation with the local hydrological setting and the local ambient parameter?
- What are the correlation between the degassing and other processes in the study areas? In particular, what is the relation between degassing and the seismicity?

To answer the questions listed above, the following activities, grouped in 5 different workpackages (WP), will be performed.

WP 1 - Exploration and production of the catalogue of the Italian gas emissions: the activities related to WP 1 are: localisation and characterisation of the areas characterised by anomalous gas emission (also with collection of the existing specific bibliography); sampling and analysis of chemical and isotopic composition of the gas released; characterisation of the geological, structural and hydrogeological setting of the studied areas; collection of data about compositions of deep drilling fluids eventually present in the area and comparison with the gas emitted at the surface; inventory of lethal accident occurred in the areas.

UniRM3-Capelli	RU1
INGV-RM1-Carapezza	RU2
Uni-Na-Castaldi	RU3
INGV-OV-Chiodini	RU4
INGV-RM2-Etiope	RU5
INGV-PA-Favara	RU6
Uni-PG-Frondini	RU7
INGV-PA-Giammanco	RU8
INGV-PA-Italiano	RU9
Uni-PA-Parello	RU10
INGV-RM1-Quattrocchi	RU11
CNR-PI-Raco	RU12
Uni-PA-Valenza	RU13
Uni-FI-Vaselli	RU14

Fig. 3.1 Areas investigated in the project and involved RU

To create an archive of the degassing areas, every RU will fill an electronic form including: name of the area, geographical position, typology of the gas emission, physical and chemical parameters of fluid released, qualitative information about the morphology, records of accidents, presence of dead animals, qualitative estimation of the hazard connected, video documentation. The distribution in the territory of the RU is shown in Fig. 3.1. This WP will start at the beginning of the project and will continue until the end. The CIGE will be continuously updated with the information acquired by the RU during the two years of the project.

WP 2- Gas flux measurements: in the main and/or more hazardous degassing areas (20-40), specific surveys of the diffuse degassing from soil will be performed. These surveys will be devoted to the definition of the degassing structures (i.e., detailed mapping of gas flux from soil) and to the quantification of the gas release, trough appropriate statistical and geostatistical tools. Furthermore, a quantification of the gas released by vents (e.g., fumaroles, dry vents, bubbling pool etc.) will be performed. Where the gas forms 'gas rivers' or 'gas lakes' the flow and/or the accumulation of the gas will be highlighted by tracers (smoke bombs) and documented with videos. The results will be included in the CIGE. During the first year project all the data already available will be inserted in the CIGE and specific campaigns will be done in the anomalous zones of Amiata and Latera (Monti Vulsini) where the investigations started before the beginning of the project. During the second year of the project new areas selected in the CIGE will be investigated.

WP 3 Conceptual and physical-numerical models of the gas emissions: in order to better understand the origin of the manifestations and the mechanisms controlling the process, some gas emissions, selected among the most dangerous, will be investigated in great detail in order to define a conceptual geochemical model. The development and evolution of gas emissions at these selected locations (Mt. Amiata, Latera, Mefite d'Ansanto), will be then simulated by applying the TOUGH2 coupled heat and fluid flow model (Pruess et al., 1999 LBNL report). Following a procedure successfully applied in volcanic areas (Todesco, 1997 JVGR; Chiodini et al., 2003 GRL; Todesco et al., 2003 JVGR; 2004 Geothermics), the physical model will be set up based on available knowledge of subsurface geology, and incorporating all information deriving from the geochemical conceptual model, and from measurements carried out in WP 1 and 2. Simulation of multi-phase and multi-component fluid flow through heterogeneous porous media will describe the degassing process according to different scenario. Results will be used to investigate the origin of gas emissions and their relation with the geological structures in the subsurface. Results will provide also boundary conditions for gas dispersion models (task 3) and will contribute to risk evaluation (task 4).

WP 4 Sink-holes and CO_2 degassing: the term "sinkhole" refers to collapse phenomena of the subsoil. Often sinkhole phenomena occurs in alluvium terrains overlaying carbonatic formations and in most cases has been noted the presence of fluids in the subsoil (CO_2, H_2S, etc.) which could favour the phenomena forming acidic solutions which dissolve the carbonatic rocks. This WP is aimed to improve the catalogue of the sinkholes of the Latium region which already was produced. This new catalogue will have more information then the older, it will have data of localization, information on geological and hydrogeological setting of the sites, on the shape of the collapsed structures, and on the geochemistry of the fluids circulating in the sinkhole areas. The catalogued phenomena will be classify in relation to the four genetics typology already defined from previous studies (Cover subsidence sinkhole, Cover collapse sinkhole, Cave collapse sinkhole and "Spring sinkhole typical of the Latium region"). The catalogue will place at "Dipartimento della Protezione Civile" disposal. Main characteristic of the research will be the study of the interaction between rock-water-gas in relation to the specific features of two areas (geological structural and hydrogeological setting, anthropic activity). In particular, during the first year it will inquire the knowledges about the area of Doganella-Laghi del Vescovo (LT), while during the second, the area of Cotilia-Peschiera (RI), as regard about 15 sinkholes. In one of the studied sinkhole will be installed probes that will check the parameters of gas and water. The research main aim is the definition of evolution modelling that could help in the individuation of precursor elements of the collapse events.

WP 5 Hydrogeochemical studies of CO_2 – water interaction; the map of Fig. 2.1 and Fig. 2.3 has been derived by a detailed hydrogeochemical study of the groundwaters finalised to quantify the input of deeply derived CO_2 in the aquifers. This kind of study will continue during the project in areas not already investigated. In particular the aquifers of Sicily will be investigated by RU 13, while the aquifers located in Tuscany will be studied by RU7 and RU4. In total 200-300 samples of groundwater will be collected and analysed. The areas characterized by high anomalous gas content in the aquifers will be investigated for the diffuse soil degassing. Furthermore the relationship between the soil gas distribution and the active tectonic structures will be investigated. General maps of CO_2 earth degassing of the investigated areas will be produced at the end of the project. The results of these studies, integrated with those of previous investigations, will contribute to the definition of the origin of the released gas in volcanic and non-volcanic environments and to define the relation between degassing and seismic activity, in particular comparing the distribution of the gas anomalies with the distribution of the recent and historical seismicity.

Research Line 2. Gas hazard and risk mitigation

TASK 3 Definition of the scenarios and estimation of the gas hazard
RU Coordinating: Carapezza (INGVRM1)
RU Partecipating: Chiodini (INGVOV)

The hazard related to the gas emissions mainly depends on the high concentration of dangerous gases (CO_2 and H_2S) in the air near the manifestations. The accumulation and the dispersion of the gases in the air depend on many factors such as the flow rate of the gas emission, the morphology of the emission area, the meteorological conditions, etc.. In particular relevant questions are:

- How the CO_2 and H_2S concentration in air depends on the degassing rate and on the type of emission (i.e. focused vents, diffuse degassing areas, ecc.)?
- What are the space-temporal variation on the gas concentration in air and in groundwaters, and what factors control such variations?
- What is the area of influence of a gas emission?

In order to give an answer to such questions, the activities of TASK 2 are divided in two WPs.

WP1 Implementation of specific gas dispersion codes: gas emissions develop in regions where a gas source exists at depth and hydrogeological conditions and human intervention, such as drillings and excavations, allow for gas propagation to the surface. Gas propagation through porous media can be described by a multi-phase version of Darcy's law, accounting for the coupled transport of heat and fluid through heterogeneous and anisotropic media. Once the surface is reached, the dispersion of the gas cloud denser than air is governed by the gravity and by the effects of lateral eddies which increase the mixing with air around the edges of the plume, decreasing the density. In the initial phase, the negative buoyancy controls the gas dispersion and the cloud follows the ground (gravitational phase). In this phase, the dispersion of heavy gas is markedly different from a passive or a positively buoyant gas dispersion. When the density contrast is not important, gas dispersion is basically governed by the wind and atmospheric turbulence (passive dispersion). Simulations of these phenomena can be achieved by using physical-numerical models based on the transport equations for mass, momentum, energy and species. Gas emission rate and temperature will derive from both field measurements and from modeling of subsurface gas flow (TASK 1 -2, WP3). Physical modeling of coupled heat and fluid transfer through porous media will be performed by applying the TOUGH2 model (Pruess et al., 1999 LBNL Report). According to selected scenarios, different conditions will be considered to characterize feeding of main gas emissions, also accounting for CO_2 transitions from super- to subcritical conditions, where required (Pruess, 2004

Soc. Pet. Eng. J.,). Then modeling of gas dispersion into the atmosphere will be performed, based on previous experiences derived from studies on geologic carbon sequestration sites (Oldenburg and Unger, 2003; 2004 Vadose Zone Journal). Complete and computationally expensive models are based on the transport theory (Macedonio & Costa, 2002 Proceedings of the Arezzo Seminar in fluids Geochemistry). This approach is able to simulate dispersion of a heavy gas accounting for obstacles, topographic effects, and variation of atmospheric conditions. An alternative method is given by the shallow layer approach which uses depth-averaged variables to describe the flow behavior (Hankin et al.,1999 J. Hazard. Mater; Venetsanos et al., 2003 J. Hazard. Mater). These models will also be used to describe gravity driven flows of dense gas over complex topographies at selected sites. Finally the main product of this WP will be the evaluation of gas dispersion in air within different scenarios, and as a function given controlling parameters such as gas flow rate, morphology, meteorological conditions. Modeling results will be integrated with expert judgment, case histories and measured data to contribute to risk evaluation, together with RU involved in Task4.

WP2 Selection of testing sites and validation of the gas dispersion codes: surveys carried out within the WP1 will allow to identify and characterize the main and most hazardous sites of gas emissions. At some of these sites (2-3), to be defined together with the other URs involved in Task 1 and 3 (risk evaluation), modeling of carbon dioxide dispersion will be performed to evaluate possible flow patterns as a function of local topography, gas emission rate through the soil, and atmospheric conditions. Local topography and site features, as well as meteorological conditions, will be determined during the project. The first test site will be Cava dei Selci. Cava dei Selci, on the NW slope of the Colli Albani volcanic complex, is a site of very high gas emission. The emitted gas mainly consists of CO_2 (over 98%vol) with about 1 vol% of H2S. CO_2 soil flux has been regularly measured since the year 2000 on a fixed grid of 120 measurements points over a surface of 6350 m2. Flux variation of about one order of magnitude have been recorded, apparently in relation with local and regional seismicity and variations in the water table depth. CO_2 soil flux, CO_2 and H_2S air concentration, environmental parameters such as wind direction and speed, air and soil T, soil moisture, atmospheric P have been continuously recorded since the end of 2003. As several lethal accident have occurred to animals (and to a man), this site deserves a special attention and thank to previous studies, almost all data needed for a physical-numerical model of gas dispersion in the atmosphere are available and this will permit the definition of an hazard scenario. We plan to complete the existing automatic station by installing a new sensor for CO_2 air concentration so to have a simultaneous recording of CO_2 and H_2S, air concentration at the same height from the soil. CO_2 soil flux and environmental parameters will be also measured so that at the end of the first year of the project we will have two years of continuous record of the data needed for a physical-numerical modeling of gas dispersion. The model will be elaborated taking also into account the detailed morphology of the site. All data will be statistically processed in order to recognize the conditions under which gas concentration in air reaches dangerous values. Furthermore the results of the modelling will be validated by the data of CO_2 and H_2S air concentrations from the above automatic stations. (NOTA: Model set up and scenario simulations carried out for the above mentioned site will allow for a quick hazard evaluation in case of peculiar episodes; similar application will be possible also at different sites, after appropriate model set up and providing enough information will be available to characterize the site)

TASK 4 Evaluation of the vulnerability and mitigation of the risk
RU Coordinating and partecipating: Barberi (UNIRM3)

Much has still to be learned about the human hazard of natural soil gas emissions in particular CO_2 and H_2S. This is increasingly becoming a problem in Italy, where many dangerous high degassing areas exist. Marked increases of soil CO_2 flux, sometimes with lethal consequences, have occurred in association with volcanic unrest or eruption, as observed at Vesuvio, Campi Flegrei, Mammoth Mountain, Nyragongo, Vulcano. Catastrophic release of huge masses of CO_2 stored in hydrothermal systems occur in phreatic explosions such at Dieng, Indonesia, and by crater lake rollover, such as at Monoum and Nyos, Cameroon. The most common and diffuse hazard is CO_2 accumulation in dwellings by diffuse degassing from the ground. In closed spaces, without ventilation, concentration can reach fatal threshold very quickly. Devices have been developed to measure CO_2 soil flux and environmental parameters and to control gas concentration in air. At Cava dei Selci and Vigna Fiorita (Colli Albani), houses have been built over high gas emission grounds. Here any excavation or well crossing a surface impermeable layer, produces a strong gas emission that may dangerously accumulate in cellars. The same situation occurs in the inhabited area of Vulcano Porto, where fatal accidents have also occurred. A somewhat different situation occurs at Fiumicino (Rome). Here apparently there are no relevant natural gas manifestations at the surface, but shallow wells crossing an impervious clay layer at a depth of only a few tens of meters cause frequently emission of CO_2, that diffusing into porous surficial sands may reach dangerous concentrations in dwellings. In an accident of this kind occurred on February 2005 seven persons were hospitalized and only by chance they escaped death. The toxicology of CO_2 and H_2S needs a review aimed at a more precise definition of the tolerable risk levels. An almost entirely new research fields is that of the remediation measures to reduce gas exposure risk in houses, although some examples can be extrapolated from Rn risk reduction.

A full and comprehensive review of the CO_2 toxicology will be delivered. The report will provide the scientific basis for setting indoor hazard levels and should allow civil protection to define tolerable risk levels for the population. As far as H_2S is concerned, the work done by regulatory agencies worldwide will be reviewed and the report applicable to indoor air exposure will be delivered. Results will serve also for the selection of the dangerous areas which should be enclosed, for the predisposition of the text for danger signals and for the formulation of rules for the access and for living in areas near the dangerous gas emissions. Cava dei Selci, Vigna Fiorita, Fiumicino and Vulcano Porto have been selected as study areas. At Cava dei Selci there is a good background information on CO_2 soil flux and gas air concentrations, that will be continuously recorded during the project by the automatic station run by the RU working on Task 2. Here a feasibility study for risk mitigation will be carried out, investigating the possibility of drilling a well that could disperse the gas into the atmosphere drastically reducing the ground gas emission. Accidental gas blowout occurred at geothermal or water wells will be studied as potential analogues. Chemical devises developed by Enel to reduce the H_2S release from geothermal plants will also be considered for environmental purpose. Vigna Fiorita, Fiumicino and Vulcano Porto appear as ideal sites to address the problem of indoor gas hazard as many houses are located on high gas emissive grounds. To this scope low-cost devises will be selected and tested to control the gas concentration of indoor air, with an alert signal calibrated to selected concentration levels. A report will be delivered on soil gas remediation technologies and their applicability specifically for CO_2, with recommendation for the specific house construction types of the studied areas. Two prototypes for indoor CO_2 and H_2S automatic concentration measurement with alert calibrated to selected thresholds will be tested in the frame of the project. Technical precautionary prescriptions will be formulated for drillings and excavations in gas hazard prone areas.

List of deliverables

The deliverables of the project, divided per task and wordpackages are listed here below.

TASK 1 & 2 Identification and characterisation of the gas emissions, relations with the structural and hydrogeological setting and with seismic activity

Deliverable 1.1.1*(WP1)* Set up of the electronic form for gas emissions. The form will be used during the project by each involved RU and will contain the following information: Latitude and Longitude; Name; Type; Description of the access; Description of the structural- geological-hydrogeological features; Qualitative flow rate, Qualitative extension; Presence of dangerous topographic depressions; Record of accidents involving people and, if yes, details of the accidents; Record of accidents involving animals and, if yes, details of the accidents; presence of dead animals and, if yes, description of the animals (number, type, etc.); Photo of the emission (in electronic format); Specific bibliography

Deliverable 1.1.2 *(WP1)* Results of gas emission field surveys (electronic forms and reports)

Deliverable 1.1.3 (*WP1)* Chemical and isotopic analyses of the gases (reports and gas emission forms) Chemical analyses: (H_2O), CO_2, H_2S, CH_4, N_2, Ar, O_2, He, H_2, CO. Chemical analyses of hydrocarbons. Isotopic analyses of C (CO_2, CH_4). Isotopic analyses of He (^3He, ^4He)

Deliverable 1.2.1 *(WP2)* Diffuse soil CO_2 flux surveys (reports, thematic maps, total output estimation, gas emission forms)

Deliverable 1.2.2 *(WP2)* Measurements of CO_2 flux from vents (reports, gas emission forms)

Deliverable 1.3.1 *(WP3)* Identification of relevant gas emission sites for which conceptual models will be designed. Set up of physical model of subsurface gas flow feeding the selected gas emissions (i.e.: definition of domain's geometry and properties, initial, and boundary conditions which enable to describe of observed surface degassing), report and simulation results

Deliverable 1.4.1 *(WP 4)* Catalogue of sinkholes in Latium

Deliverable 1.4.2 *(WP 4)* Sinkholes, geology, structures and geochemical study of the fluids, reports

Deliverable 1.4.3 *(WP 4)* Sinkholes, individuation of precursor elements of the catastrophic events

Deliverable 1.5.1 *(WP 5)* Chemical and isotopic composition of groundwaters, reports

Deliverable 1.5.2 *(WP 5)* Thematic maps of CO_2 water interaction, reports

Deliverable 1.6.1 *(ALL WP)* Catalogue of Italian gas emissions (final product, data base in electronic form)

TASK 3 Definition of the scenarios and estimation of the hazard

Deliverable 3.1.1 *(WP 1)* Set up of physical models of gas dispersion in air at selected gas emission sites; coupling of subsurface-surface flow models; comparison among results and performance of different models.

Deliverable 3.2.1 *(WP 2)* Modeling of gas dispersion in air within different scenarios, at selected gas emission sites (i.e. Cava dei Selci and possibly others); identification of system conditions leading to hazardous gas concentration in the air; set up and validation of an effective procedure (data collection, model set up, and process simulation) to be applied for hazard assessment where dangerous gas emission occur.

TASK 4 Evaluation of the vulnerability and mitigation of the risk

Deliverable 4.1.1 Review of CO_2 toxicology, report
Deliverable 4.1.2 Soil gas (CO_2) remediation technologies, report
Deliverable 4.1.3 Feasibility study for risk mitigation at Cava dei Selci
Deliverable 4.1.4 Tests of prototypes for indoor CO_2 and H_2S automatic concentration, report
Deliverable 4.1.5 Remediation techniques for gas leakage caused by shallow drillings, report

PROJECT V5 – DIFFUSE DEGASSING

TABLE MAN/MONTHS

U.R	Institutions	Principal Responsibles	Task1 Inventory of gas emissions – Central Italy and Campania	Task2 Inventory of gas emissions – Basilicata, Calabria, Sicilia	Task3 Scenarios and hazard	Task4 Vulnerability and risk	Mesi p. cofin.	Mesi p. rich.
UR-1	UniRmTre, INGV-Rm1	Capelli, Mazza, Delitala	@				54	24 (UniRmTre)
UR-2	INGV-Rm1, UniRmTre, INGV-PA, CNR-IGG	Carapezza, Barberi	@		@		52	
UR-3	UniNaII, CNR-IGAG, UniFi, Univ. Rochester (USA), GFZ Potsdam (D)	Castaldi, Tedesco, Gianfrani, Voltaggio, Minissale	@				72	
UR-4	INGV-OV, INGV_Rm1	Chiodini, Granieri, Caliro	@		@		68	
UR-5	INGV-Rm2, INGV-PA, UniRmTre, Univ. Cluj (RO), UniChi, UniRm1, CNR-IGAG, ARPA Emilia Romagna, IBIMET Fi	Etiope	@				27	
UR-6	INGV-PA, UniPa, UniRm1	Favara		@			28	
UR-7	UniPg	Frondini, Cardellini, Collettini		@			72	18 (UniPgS)
UR-8	INGV-PA, CNRS-LPS (FR), UniPa, JSI Lubiana (SL)	Giammanco, Badalamenti		@			42	
UR-9	INGV-PA, UniRm1, Russian	Italiano, Caracausi		@			46	

	Academy of Science, UniPa							
UR-10	UniPa, INGV-PA	Parello, Luzio		@			32	
UR-11	INGV-Rm1, UniRm1	Quattrocchi, Lombardi	@				54	
UR-12	CNR-IGG, Enel Pisa	Raco, Cioni Rob., Guidi	@				41	14 (CNR-IGG)
UR-13	UniPa, INGV-PA	Valenza, Dongarrà, Parello, Aiuppa, Gurrieri		@			52	18 (UniPa)
UR-14	UniFi, CNR-IGG, UniUrb, CNIT, UniNaII	Vaselli, Minissale, Buccianti	@				50	15 (UniFi)
UR-15	UniRmTre, Univ. Cambridge (UK), INGV-Rm1, MRC Inst. Leicester (UK), Univ. Sheffield (UK)	Barberi				@	26	24 (UniRmTre)
Totale							716	109

PROJECT V5 – DIFFUSE DEGASSING

Table RU and related funding request

N. UR	Istituz.	Resp UR	Personale		Missioni				Consumi servizi		Inventariabile	
					Italia		Estero					
			2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
UR-1	UniRmTre	Capelli	16500	18500	2000	2000			3000	4000	3000	1000
UR-2	INGV-Rm1	Carapezza			3000	4000	2000	2000	20500	20500	5500	2000
UR-3	UniNaII	Castaldi			4500	4500	1500	1500	5000	5000		
UR-4	INGV-OV	Chiodini			9000	9000	6000	6000	11500	12500	5000	2000
UR-5	INGV-Rm2	Etiope			4000	4000	3000	3000	9000	10000		
UR-6	INGV-PA	Favara			2500	4000			6500	7000		
UR-7	UniPg	Frondini	12000	20000	7500	4000		3000	6500	5000	4000	
UR-8	INGV-PA	Giammanco			2000	2000	3000	3000	10500	11000	3500	
UR-9	INGV-PA	Italiano			2000	2500		2500	16000	16000		
UR-10	UniPa	Parello			7000	7000	2000	2000	11500	14500	5000	
UR-11	INGV-Rm1	Quattrocchi			1500	1500	1500	1500	19000	16000	2000	
UR-12	CNR-IGG	Raco	16000	4000	2500	2500			3500	3500	3000	3000
UR-13	UniPa	Valenza	12000	12000	7000	9000	3000	3000	20000	20000	5000	2000
UR-14	UniFi	Vaselli	6000	12000	8000	9000			3000	3500		
UR-15	UniRmTre	Barberi	18000	18000	2000	2000	1500	1500	23000	12000	1000	1000
		TOTALE	**80500**	**84500**	**64500**	**67000**	**23500**	**29000**	**168500**	**160500**	**37000**	**11000**
GRAN TOTALE: 726000												