PROJECT V3

Sub-Project V3_2 – Campi Flegrei

Project V3
Sub-Project V3_2 – Campi Flegrei

Coordinators:

Paolo Papale, Istituto Nazionale di Geofisica e Vulcanologia, sez. Roma1 "Sismologia e Tettonofisica", via della Faggiola 32, 56126 Pisa. Tel 050 8311931, Fax 050 8311942, papale@pi.ingv.it

Lucia Civetta, Professore Ordinario, Osservatorio Vesuviano-INGV, Via Diocleziano 328 Napoli (Italy) and University of Napoli "Federico II"- Dip. Di Fisica. Tel.: +390816108441, Fax: +390816108344, civetta@ov.ingv.it

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).