PROJECT TITLE

ERUPTIVE SCENARIOS FROM PHYSICAL MODELING AND EXPERIMENTAL VOLCANOLOGY

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ACTIVITY REPORT –2nd YEAR

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GENERAL OBJECTIVES

The present research project aims to a quantitative-parametric description of the volcanic process by a close integration of phenomenological-geological data, physical modeling and, when the former are lacking (i.e. in the case of intratelluric phenomena), laboratory experiments related to magmatic or volcanic processes (hereafter referred as experimental volcanology studies).

The role of geological research is seen as the quantitative definition of the field and/or analytical evidences necessary to constrain the physical models to the principal parameters controlling the type of volcanic process and its spatial-temporal evolution. The experimental volcanology research has a twofold function: the first is to forward the physical models the necessary data obtained under controlled conditions in order to integrate the geological observation; the second is to simulate the magmatic or volcanic processes supplementing the analytical models.

The physical modeling, which is today developed on a thermofluid-dynamic basis avoids the limits of the specific cases studied experimentally giving interpretative approaches of more general use.

Supplementing the classical geological research which has been developed in Italy for specific volcanic areas, this project aims also at defining some general principles to understand the way how volcanoes work and to use them to predict the eruptive episodes within global scenarios comprehensive of the process from the appearance of the first precursors to the proper eruptive phases

In the framework of pre-eruptive and eruptive processes that characterize the way how the magmatic-volcanic systems work, there are few topics, corresponding to the **Project Tasks**, that are crucial for the reliability of the possible eruptive scenarios.

The **First Task** concerns the role of the volatile species of magma on the evolution of pre-eruptive and eruptive systems. The composition and concentration of volatiles in the magmatic systems pose a strong control on the way magmas differentiate on cooling within intracrustal reservoirs, climb to the surface and are erupted with a several possible mechanisms. The ultimate objective of the research of the First Task will be the evaluation of the amounts of volatiles species dissolved at magma chambers levels for some italian active volcanoes and their exolution according to specific models of magma ascent patterns from the chambers to the surface.

The **Second Task** analyzes the effects of the interaction between dynamics of the magmatic system within subvolcanic chambers and conduits and the volcanic structures. The proposed approach integrates the experimentally simulated and field data with modeling of the variables linked to stress field variations. It implies the determination of stress fields observed at various volcanic areas and the simulation of the effect of structural features and regional boundary conditions on the local strain/stress fields. The final objective is to operate the comparison between available observations, mainly in pre-eruptive periods, and theoretical simulations in order to develop seismic source models linked to magmatic processes.

The **Third Task** faces the problem of the principles that control the dynamic evolution of the magmatic systems, their ascent to the surface through conduits and the proper eruptive mechanisms. The reference scheme is based on the thermo-fluid-dynamics modeling that, inspite has been often considered a rather crude approximation of the natural environment, is, actually, the sole approach capable to unify quantitatively several processes of the magmatic and volcanic activity. The final objective of the Third task is the integration of magma degassing (Task 1 and Task 4) with models of magma chamber and conduits and the definition of stress field at the chamber walls with models of stress recharges deeloped by Task 2. It will be also developed models for lava flows and tsunami propagation.

The **Fourth Task** aims at verifying through laboratory experiments the feasibility of some processes that have been used as eruptive precursors (i.e.: the magma-water interaction, the dynamics of rock fracturing, the magma ascent kinetics from intracrustal chambers to the surface) and to analyze experimentally the practical applicability of already proposed theories (i.e. the fuel-coolant interaction) to explain some eruption triggering mechanisms (i.e. the hydromagmatic eruptions). The final objective of the Fourth Task is the modeling of magma-water interaction experimental data under different values of controlling variables as well the modeling of laboratory fracturing data to real cases of fracturing, bradyseism, and ground deformation in active volcanic areas. As a further step in cooperation with Task1 and Task3 RU, it will studied experimentally magma ascent process from the intracrustal chambers to surface and its effects on melt vesiculation and phase relations of crystallising phases.

Application of the expected results to italian active volcanoes.

This aspect of the project activities was discussed in the the Project Meeting held in Rome on May 3rd 2002 . The final output was a guidelines formulation integrating the project current researches for the construction of eruptive scenarios. Recalling that virtually all the ongoing researches are already concerning italian active volcanoes even if carried out with the purpose of

developing specific methodologies, it was agreed that RU will work on the data indicated in the guidelines to be applied to build up the eruptive scenarios for the following volcanoes:

1. *Campi Flegrei* (Coord. P. Papale-RU 05)
   RU 05 P.Papale, RU 02 F.Gaeta, RU 13 G.De Natale, RU 15 G.Panza, RU 12 R.Trigila, RU 14 C.Kilburn
2. *Vesuvio* (Coord. G. De Natale-RU 13)
   RU 13 G.DeNatale, RU 01 M.Dragoni, RU 03 G.Macedonio, RU 04 A.Neri, RU 07 C.Cigolini, RU 09 D.Dolfi, RU 15 G.Panza, RU 05 P.Papale
3. *Stromboli* (Coord. M. Carroll-RU 06)
   RU 06 M.Carroll, RU 07 C.Cigolini, RU 10 S.Rotolo, RU 12 R.Trigila
4. *Etna* (Coord. R. Trigila-RU 12)
   RU 11 Pompilio, RU 12 R.Trigila, RU 01 M.Dragoni, RU 10 M.Nuccio, RU 13 De Natale, RU 14 C.Kilburn, RU 15 G.Panza.

The guidelines concern data both on the magmatic systems and on the volcanic structures. The expected scenarios arise from the integration of the two types of data into models of volcanic activity.

TASK 1. PHYSICAL CHEMISTRY OF VOLATILE SPECIES IN MAGMAS

- **RU PARTECIPANTS: 06, Resp. M.Carroll; 07, Resp. C.Cigolini; 08, Resp. B.DeVivo; 09, Resp. D.Dolfi; 10, Resp. M.P.Nuccio; 11 Resp. M.Pompilio; 12 Resp.R.Trigila.**

- **2nd YEAR OBJECTIVES**

They are focusing the role of volatiles on the pre-eruptive magmatic regimes in the light of solid-melt-gas equilibria causing magma chamber overpressures and explosive energies.

In particular, the 2nd YEAR OBJECTIVES are: i) the experimental determinations of H_2O, CO_2, F, and Cl solubility under mixed volatiles conditions in phonolitic and trachytic melts with application to **Vesuvius** and **Phlegrean Fields** magmas respectively; ii) the experimental studies on nitrogen solubility in H_2O-CO_2 bearing silicate melts are applied to **Vulcano** magmas compositions; iii) those on the influence of H_2O melt on phase equilibria and liquid compositions (at 400MPa and magmatic temperatures) are applied to **Stromboli** erupted magmas.). A further application of the above described objectives is the parametrisation of magmatic phase relations taking into account the composition and concentration of volatile species and the estimates of rheological variables related with **Mt**. **Etna** and **Stromboli** recent eruptions.

- **2nd YEAR RESULTS**

Beside the analytical petrological, mineralogical and geochemical investigations carried out with EMP, SEM-EDS, Micro FT-IR, XRF, ICP-AES and MS equipment, the experimental work took place at Roma-La Sapienza, Camerino (new lab!), Brown (Providence, RI-USA) Universities, and at CNRS-ISTO (Orleans, F). All the experiments were performed with fast-quenching TZM or hydrothermal EHPV except than at Orleans, where a fast-quenching IHPV was used.

The experimental method to perform solubility runs for minor reactive species in presence of H_2O and CO_2 at buffered redox conditions was based by adding to the sample weighted amounts of glass having the same bulk composition of the samples but containing known concentrations of the minor reactive species (He, Ar, N, etc.). The experiments on Cl solubility involve sealing known amounts of powdered silicate material and Cl-bearing solutions of variable molality inside Au or

AgPd capsules and then running these capsules at 25-250 Mpa and 850-900°C for times of 5-10 days. The quenched samples (glass) are analyzed with the electron microprobe and fluid Cl molality is calculated by mass balance. The H_2O+CO_2 solubility experiments at "La Sapienza" lab are performed with a TZM modified EHPV equipped with a fast quenching magnetic device, that permits an isobaric quenching at the velocity of about 100°C/s. Rock powders are loaded in Au-Pd capsules, H_2O is added as bidistilled water with a micrometric syringe, CO_2 as Ag_2CO_3 powder; the total weight of the loaded sample is about 100 mg. The quantities of H_2O and CO_2 were added in excess respect to the saturation ones calculated from the solubility model of Papale (1999).

The parametrization of intensive variables giving estimates of phenocrysts P and T was assured by thermodynamic calculations in case of **Stromboli** , **Vesuvius and Mt.Etna** magmas. Other experimental calibrations were performed on specific compositions of the italian active volcanoes using chemical components present in the liquid and in the phenocrysts phases (e.g. clinopyroxene) obtained through experiments performed under controlled oxygen fugacity. (Trigila and Salvetti 2002)**.**

Results for Cl solubility variations in a series of trachytic melts for application to **Campi Flegrei** magmatism, show there is a strong correlation between melt peralkalinity or peraluminosity and Cl solubility. However, in trachytic melts, the Cl content appears to be independent of Na+K/Al. This suggests that crystallization during magma ascent will have little effect on melt-vapor partitioning of Cl as long as melts remain broadly trachytic in composition. The current investigations are developing models of how Cl solubility varies with melt composition and how melt/fluid partitioning of Cl depends on initial H2O/Cl ratio in magmas. These will be used to evaluate and predict Cl degassing behavior in ascending magmas undergoing decompression and partial crystallization (due to loss of water, which raises liquidus temperatures).

It has been completed and published (Raia et al., 2000; Webster et al., 2001) the systematic study of reheated silicate melt inclusions for 29 constituents including H_2O, SO_2, Cl, F, B and P_2O_5 on the magmatic phenocrysts of the entire **Mt Somma – Vesuvius** activity (from 25 ka to 1944 AD) using EMPA and SIMS. The results show the magmas associated with explosive plinian and subplinian activities younger than 3,550 years contained significantly more SO_2 and H_2O than magmas of similar age feeding the relatively passive interplinian eruptions. Other results show that Cl solubility was dramatically reduced with changing liquid composition and, hence, that a chloride brine may have exsolved directly from these Cl-enriched mafic magmas by a process other than first or second boiling (Webster and De Vivo, 2002). These results are complemented by an experimental study on H_2O and Cl solubility in phonolitic and phonotephritic Vesuvius melts at 500 and 2000 bars and 946-1057°C and 1022-1135°C (Webster et al., in press a). Other experiments on synthetic glasses at atmospheric pressure and elevated temperature, have been done to determine the F effects on the liquidus temperatures and on the phase relationships in a relevant portion of the phonolitic system. The experimental runs demonstrate that F has relevant effects on the liquidus temperatures, lowering them up to 150°C as a function of the composition, and does not permit the crystallization of leucite and feldspars, with the exception of nepheline. Finally, it has been published a model for the evolution of the **Somma-Vesuvius** magmatic system based on fluid and melt inclusion data. The proposed model implies the existence of more than one magma chambers (at least 3) at different depths (between 4 and $\underline{\geq}$ 12 km) and a long repose time at the Vesuvius (centuries?) after the last 1944 A.D. eruption (Lima et al., in press).

The thermobarometry of subeffusive ejecta (*clinopyroxene-rich phonotephritic porphyries* and *italites*) of 1944 eruption which are produced by cumulus processes occurring within the subvolcanic environment of **Mt Vesuvius** (RU-07), indicates that these materials crystallised at pressures of about 0.6-0.3 GPa for temperatures ranging from 1260-1130 °C, and variable water contents from about 1.7 wt% to nearly anhydrous conditions (the latter are reached at lower pressures, i.e. at about 0.3 GPa). It has been inferred that magma has suffered progressive degassing during its crystallization in the subvolcanic region. These estimates are basically consistent with

recent geophysical data, obtained by high-resolution seismic tomography, which constrain the depth of the top of the "active" magma chamber at about 12 km (Cigolini et al 2002).

From the compositions of reheated melt inclusions in clinopyroxene phenocrysts from xenoliths interesting results concern a comparative study between the **Campi Flegrei and Mt Somma – Vesuvius** magmatism. These results indicate a close relationship (or link) between the Campi Flegrei and Mt Somma magmatic systems, which have until now been considered separate. The link was established only prior to eruption of the Neapolitan Yellow Tuff (~ 12 ka); indeed the Campi Flegrei older magmatism had close similarities with the volcanism of the older products of Mt Somma (> 25 ka). The results are reported in Danyushevsky and Lima (2001).

Preliminary data aiming at explaining the new eruptive behaviour of **Mt.Etna** (shown by the 2001 and 2002 eruptions) concern the assessment of pressures and depths for the magmatic reservoirs in the Mt. Etna plumbing system. The problem of the volatiles role on the magma ascent patterns was faced with different approaches by the RU 10 (P.M.Nuccio), RU 11 (M.Pompilio) and RU12 (R.Trigila) investigations. In particular RU 11 results show the amphibole on the liquidus in the range of P between 75 and 140 Mpa and at T below 1000°C. while the RU12 results report an amphibole (of same composition) on the liquidus at 200 Mpa and 1040°C. The above preliminary data suggest the observed discrepancies can arise because: i) slight difference in the composition of starting material; ii) slight difference in some control parameters (e.g.: P and fO_2). In any case the crystallisation temperature of amphibole is too lower compared with the measured eruptive temperature (T>1050°C) of the main Etna hawaiite, and indicates that the amphiboles are xenocrysts (RU11) or they come from slightly colder portions of the magmatic reservoir (roof, walls) feeding the eruption where the enhanced crystallisation increased the volatiles (H_2O) content and therefore the amphibole stability (RU11 and RU12). However on the basis of the rheological and physical parameters estimated through the compositional and textural features of 2001-2 tephra of Etna, it can be observed they take part to the single and almost continuous liquid line of descent traced by companion glasses of the other historical eruptions. This allows an estimate of the eruptive temperatures (i.e. from tachilite or sideromelano glasses) using the experimental calibrated geothermometer of Pompilio et al. (1998), and in consequence of useful data on the viscosity and yield strenght of the liquid.

New experiments (UR 10) carried out at the CNRS-ISTO (Orleans) on the recently erupted pumices from **Stromboli** were performed at P=400 MPa with different amounts of water in the liquid and fO_2 varying from NNO + 1 to NNO +3. The phase equilibria under these conditions play an important role in determining different liquid lines of descent, therefore controlling the wide-spectrum of serial transitions characterising Stromboli's petrological evolution. In detail: when phlogopite is stable, liquids are poor in K2O (0.8 - 0.9 % at SiO2= 63 %), and liquids follow a calcalkaline trend; on the other hand the suppression of plagioclase nucleation, due to high melt water contents, generates high-alumina liquids (Al2O3 = 20.0 - 22.1 %). Other experiments performed at the HP-HT Lab of Roma "La Sapienza" at atmospheric pressure, fO_2= NNO, magmatic temperatures, and different cooling rates from superliquidus to liquidus-solidus temperatures (i.e.: 900°C/h or 1°C/h), on 4 **Stromboli** lava samples (SiO_2 = 50.0-54.4 wt% of CA, HK-CA, SHO, KS affinity) put in evidence the kinetic control on the evolution of the experimental liquids and in relation of crystallising phases. By changing cooling rate and quench temperature, the experiments generate two types of textures. The first shows an increase of crystal sizes and melt fraction with decreasing cooling rate while the second involves an increase in the multi-phase assemblage. In general, the fast cooling rate suppresses crystallisation of olivine and less frequently of plagioclase.

Other studies (UR07) on P-T estimates on mafic nodules (gabbroes, grabbronorites and anorthosites) from **Stromboli** in equilibrium with basaltic magmas give P values of 350-250 MPa and T of 1050-900 °C can be representative of Strombolian magma batches that have been stored at depth during their ascent. The companion ultramafic nodules are essentially *dunites* and *wherlites* (with textural features of mantle peridotites) and represent mantle materials that crystallised at

pressures of 0.8-1.1 Gpa (i.e., along the crust-mantle boundary layer below the island of Stromboli). Preliminary data ofU/Th disequilibria on **Strombolian** lavas by the same UR show that basaltic magmas are likely to be stored for longer time within the upper mantle-lower crust regions before being erupted (their relative age is estimated to be around 385 ka) contribute as well for a general model on magma rise and evolution.

- **RESEARCH PRODUCTS OF THE PROJECT**

  - **n° 14** articles published on international journals;
  - **n° 8** articles published on national journals, proceedings, technical reports.
  - **n° 3** invited papers and talks
  - **n° 20** presentation at international meetings
  - **n° 5** presentation at national meetings
  - **n°2** Data base
  - **n°2** Computation codes
  - **n° 3** Other

PUBLICATIONS LIST (inclusive of papers in prints, submitted or accepted by international journals or related to proceedings of international meetings)

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TASK2. DYNAMICS OF THE MAGMATIC SYSTEM AND INTERACTION WITH THE VOLCANIC STRUCTURE

- **RU PARTECIPANTS: 13, Resp. G.DeNatale; 14, Resp. C.Kilburn; 15, Resp. G.Panza.**

- **2nd YEAR OBJECTIVES**

They are related to:

1) Simulations of stress changes and Coulomb stress changes due to the interaction of the magmatic system with the volcanic structure.
2) The analysis of seismic sources through full moment tensor studies and structural models of seismicity by surface wave tomography.
3) The scaling of slow-fracture equations to macroscopic fracturing and faulting.

In particular, the simulations of stress changes associated to inner volcanic sources in homogeneous clastic 3D media and the simulations in 2D and 3D media with structural discontinuities; the strain determinations from geodetic measurements (explained by simulations of Coulomb stress changes due to volcanic sources in heterogeneous media with topography and/or structural discontinuities, eventually due to intrusive dikes) and the simulations of stress and Coulomb stress changes in gravitative media with pre-existing tectonic stress, are used to model ground deformations and earthquakes occurrence at **Campi Flegrei, Vesuvius and Mt. Etna.** The simulations of pressure, temperature changes and deformations, in porous, water saturated media find application for the bradyseismic activity of **Campi Flegrei.**

The analysis of seismic sources through full moment tensor studies and seismicity structural models by surface wave tomography concerns again the areas of **Campi Flegrei** and **Vesuvius** for which an average structural model is in progress.

Finally, the scaling of slow-fracture equations to macroscopic fracturing and faulting are applied to the 1982-84 bradyseismic crisis in **Campi Flegrei.**

- **2nd YEAR RESULTS**

1) The algorithms to compute stress fields due to magmatic sources have been built and tested, using both analytical and numerical (BEM and FEM) methods. The analytical method assumes an heterogeneous elastic model, and computes stress and strain changes due to isotropic pressure changes at point sources and normal dislocation on rectangular dykes. Complex sources can be simulated by point source summation. Numerical methods making use of Boundary Element and Finite Element Concepts have been also used, for 2-D, axial-symmetric and 3-D modelling of stress and strain. Boundary Element Methods are particularly suitable to introduce discontinuities in a homogeneous medium, such as fractures and faults. Finite element methods are the most suitable when assuming a heterogeneous elastic medium. Whatever the methodology used to simulate stress, an algorithm has been built to compute Coulomb stress changes due to magmatic sources, and to identify the shear faulting mechanisms which are most favourably oriented with respect to the total Coulomb stress load, including for instance regional tectonic stress, gravitational stress and magmatic sources. Coulomb stress changes computation is the key to understand the mechanisms of generation of precursory seismic sequences accompanying magma intrusion in the crust, mainly for volcano-tectonic earthquakes. Other methods have been developed (in 1D and 2D) to compute changes in pressure in an elastic, water saturated porous medium, as a consequence of changes in the boundary conditions driving water circulation. In the 1D method, changes in water pressure as a function of depth can be computed from changes in the Peclèt number, which in turns describes the flow regime. The methods so far developed have been used to model ground deformations and earthquake occurrence at **Campi Flegrei, Vesuvius** and **Mt. Etna**. In particular, using elastic modelling with boundary elements, 3D elastic models of static ground deformation and seismicity at Campi Flegrei have been obtained, taking into account the effects induced by discontinuities at collapse boundaries, located from gravimetric results. Such effects have been also shown to be non-linear, in the sense that, for non-vertical caldera ring faults they cause different shape and extension of the deformed area, depending from the sign of pressure change at the source. In particular, the deformed area in long term subsidence episodes should be much larger than for uplift episodes, as it seems confirmed by archaeological evidences of marine ingressions in ancient manufacts.The method has been applied to model the so-called mini-uplift episodes occurring at Campi Flegrei caldera, confirming that observed amounts of deformation are compatible with very small changes in the Peclèt number. Modelling of ground deformation episodes at Campi Flegrei using both 1D and 2D thermal-fluid-dynamical approaches allowed to hypothesise that the time evolution of ground uplift and subsequent subsidence just represents the delayed response of the geothermal system to an initial step-like pulse of overpressure at base of the system. In this perspective, the common perception of hazard related to ground uplift episodes at caldera must be completely reviewed. In fact, maximum hazard should be at the beginning of a new uplift phase, and not at the point of maximum uplift. Moreover, hazard increases for increasing number of subsequent uplift episodes, also if the uplift is partially or totally recovered.

2) Velocity models for the uppermost 2 km of the crust using surface wave tomography and studies on the full seismic source moment tensor by waveform inversion of earthquakes recorded in March 1984 at the **Campi Flegrei** evidence most of the mechanisms were deviatory ones and the isotropic component increased for the events of March 1984, when there was a relatively significant change in the seismicity rate with respect to the interval of time investigated. The tomographic maps obtained from surface waves analysis show anomalies in three different regions around the Pozzuoli Gulf where three different average structural models as representative of the uppermost crust of each area have been proposed. The observed inland negative anomalies correlate well with the low Vs regions singled out by Aster and Meyer (1989) within the uppermost 2 km of the crust.

All the maps evidence a persistent anomaly of group velocity at sea (in the Gulf of Pozzuoli) that has not been observed by other studies. A possible decrease of elastic parameters and density of the sampled materials can explain such result.
A catalogue of 9046 earthquakes associated to the **Vesuvian** volcano activity as recorded at Bunker Est station (BKE), located on Mt. Vesuvius and operated by the Osservatorio Vesuviano (OV), has been compiled. The aim of the catalogue is to integrate the information collected in the catalogue compiled by OV that contains the volcanic earthquakes recorded at station OVO (OVO catalogue) since February 1972. Statistical analysis of the seismicity of the catalogue is now in progress. Last investigation (De Natale et al. 2002), revealed that the seismicity of that period was composed by a background level, characterised by a low and rather uniform rate of energy release and by sporadic periods of increased seismic activity with energy rates and magnitudes progressively increasing in the critical periods. The values of b were progressively decreasing, from about 1.8 to about 1.0. This steady variation could indicate an increasing dynamics in the volcanic system. The catalogue BKE has been realized within the cooperation among the University of Trieste - Department of Earth Sciences, the International Center for Theoretical Physics (ICTP) -Structure And Non-linear Dynamics of the earth (SAND) Group, and the Osservatorio Vesuviano of Naples. The catalogue is now available upon request.
Using the surface-wave tomography at regional scale the thickness and the vertical velocity distribution of the shear waves in the lithospheric layers for the area under **Vesuvius** and **Campi Flegrei** have been determined. Surface waves dispersion curves at regional scale have been determined along different paths, by the Frequency-Time Analysis and the tomography maps have been obtained using the two-dimensional tomography algorithm. Preliminary results show a thin continental crust (about 15 km thick) under the Campi Flegrei and Vesuvio areas. Below the crust there is a mantle wedge with V_s as low as about 3.3 km/s in its deeper part and about 4.3 km/s just below the Moho (the lid); the layering under the wedge is consistent with the presence of a subducted lithospheric slab (Ionian/Adria slab). Under Campi Flegrei and Vesuvio the upper crust contains a well developed low velocity layer, about 10 km thick at a depth of about 10 km. The very shallow low velocity crustal layer could be related to the presence of magma reservoirs.

3) The assumption that large-scale fracturing, which triggers measured seismic events, shows behaviour similar to microscopic cracking was justified retrospectively by the good agreement between expected and observed rates of seismicity. The assumption, however, has not been formally justified. Scaling of the governing equations from microscopic to macroscopic conditions has been achieved by assuming that gravitational loading and magma overpressure create a *fluctuating* stress field in the country rock. Fluctuations are due to the intermittent growth of small cracks that cannot be detected by monitoring instruments. The model also anticipates oscillations in seismic event rate about a mean trend that accelerates with time, and identifies the rate of increase in *peak* event rate (rather than the mean event, as is commonly used) as a key indicator of the approach to eruption.
Under this light the seismic data obtained during the 1982-84 bradysesimic crisis in **Campi Flegrei**, Southern Italy have been analyzed. Data were originally presented as numbers of event per day. At this timescale, no clear accelerating trends could be distinguished against an oscillating variation with a period of about 3 months. After regrouping event rate over a range of timescales, from every four hours to 10 days, three accelerating sequences were found at grouping timescales of 5-10 days. Preliminary studies suggest that each sequence because follows the limiting trend $dN/dt \approx \lambda N$, (see RU 14 2nd year Report) indicates that seismicity was dominated by activating an increasing number of faults with time. The three cycles may indicate the growth of three major fault systems, or a three-stage extension of a single system that increased in size with each cycle. Also unclear is the significance of the 5-10 day grouping for the event rates at which underlying patterns emerge. One possibility is that it is related to the preparation time for activating new faults, events at shorter intervals reflecting reactivations along previously active faults.

- **RESEARCH PRODUCTS OF THE PROJECT**

  - **n° 9** articles published on international journals;
  - **n° 1** of articles published on national journals, proceedings, technical reports.
  - **n° 8** invited papers and talks
  - **n° 8** presentation at international meetings
  - **n° 4** presentation at national meetings
  - **n° 3** data base
  - **n° 3** Other

PUBLICATIONS LIST (inclusive of papers in prints, submitted or accepted by international journals or related to proceedings of international meetings)

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KILBURN, C.R.J., 2002. Heirarchical fracturing as a key to forecasting volcanic eruptions, submitted to J. Volcanol. Geotherm. Res. August.

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TASK 3. THERMAL-FLUID-DYNAMIC MODELING OF MAGMA UPRISE PROCESSES AND SUBAERIAL TRANSPORT

- **RU PARTECIPANTS: 01, Resp. M.Dragoni; 03, Resp. G.Macedonio; 04, Resp. A.Neri; 05, Resp. P.Papale**

- **2nd YEAR OBJECTIVES**

The thermal-fluid-dynamic modeling of the three domains which constitute an erupting magmatic system i.e. the magma chamber emptying, the magma ascent in the conduit, and the subaerial magma transport are the 2nd YEAR OBJECTIVES of RU03, RU05 and RU04 respectively. In the models describing the eruptive phenomena in these domains a key role is taken by the microlite crystallisation process and by vesiculation. Further objectives look for criteria for the evaluation of flow rate in active lava flows or are related to the modelling of tsunamis produced by the light-component of the pyroclastic flows generated by a plinian-subplinian eruptions.

In particular, it is required a test of an already developed model describing the emptying of a volcanic magma chamber in which the pressure distribution is a function of the erupted mass and the conditions of pressure, velocity, etc… at the vent are a function of time. The dynamics of magma ascent, comprehensive of the role of microlite nucleation and vesiculation processes on the large scale eruption dynamics are specifically applied to the AD 79 eruption of **Vesuvius**. Further input data come from the comparative analysis of vesiculation features of **Vesuvius** and **Campi Flegrei** pyroclastic deposits. The application of a multiphase multicomponent pyroclastic dispersal model to the setting of various eruptive scenarios and to parametric studies on pyroclastic flow and surge dynamics (with assessment of the hazards associated to pyroclastic flow and surge dynamics) is concerning still the **Vesuvius** area and the **Campanian plain** as well as the modelling of tsunamis produced by the light-component of the pyroclastic flows generated by a plinian-subplinian eruption.

- **2nd YEAR RESULTS**

The magma chamber emptying was described (UR03-Macedonio) by assuming a model of a two-phase gas/liquid mixture compressible magma (liquid+bubbles). Magmatic fragmentation is assumed to occur when the maximum compaction of the spherical bubbles is reached, that is for gas volumetric fraction of 75%. Gas solubility (water vapour) in the magma is computed as a function of the pressure by using a semi-empirical power-law relation, with the parameters obtained from the model by Ghiorso and Sack (1995). The model for magma flow in the eruptive conduit is based on the solution of the transport equation for an isothermal pseudo-gas, in a constant cross-section conduit. The mass in the magma chamber is obtained by integration of the density in the chamber volume, whereas its time variation is represented by the mass flow rate through the conduit.
Magma ascent and fragmentation has been simulated by RU5-Papale investigations for the well studied AD 79 (Pompei) eruption of **Vesuvius**. Conduit exit conditions produced by simulations of magma ascent have then been used as boundary conditions at the vent for the simulation of the gas-pyroclast dispersion dynamics (UR04-Neri). Choked flow conditions at the conduit exit guarantee a one-way coupling between the two domains: conduit and atmospheric one respectively. The white and gray magmatic phases of the AD 79 eruption have been considered, differing for magma composition and partly for the style of the eruption, the first being markedly sustained or Plinian, and the second still dominantly Plinian but with partial column collapses. In order to investigate the possible consequences of microlite nucleation on the eruption dynamics, we have performed simulations for each eruptive phase either neglecting and considering microlites in the erupted magma. All the conduit exit quantities follow well-defined monotonic trends from the white to the gray phase, apart from pressure. For the white one gas volume fraction and gas and particle velocities are larger, and particle and mixture densities for the gray one, instead, are lower. The conduit diameters in the calculations are about 40 m for the white, and 50 m for the gray phase of the eruption.

In both cases the exit velocities increase of 10-20% when microlites are considered part of the ascending magma. Differently, the exit gas volume fraction and mixture density do not change significantly for the white phase, while they are remarkably different for the gray phase. The case of pressure is reversed, with small changes due to microlites occurring for the gray phase, while for the white phase there is a remarkable increase by about 16% when microlites are considered. Finally, the presence of microlites results in a conduit diameter which is slightly smaller for the white phase, and slightly larger for the gray phase. The results on the gas-pyroclast dispersion dynamics show the white phase results to be buoyant either when we include or we neglect microlites while the gray phase results to be collapsing when microlites are neglected, and buoyant when microlites are accounted for in substantial agreement with the reconstruction of the eruption from the chronicles and from the deposits studies.

A further approach on magma rising and eruption processes is possible through the comparative analysis of vesiculation features of **Campi Flegrei** and **Somma-Vesuvius** pyroclastic deposits (UR03-Macedonio). Bubble size distribution (BSD) and bubble number density (BND) of the samples indicate that in spite of the different eruptive mechanisms the products show relatively minor differences in the vesiculation process, always occurred close to the limit between viscosity controlled and diffusion controlled regime. However most of the sample collected from the plinian deposits of Somma-Vesuvius show evidence of more relevant contribution of the diffusion in bubble growth, possibly resulting from the lower value of magma viscosity.

The 2D multiphase and multicomponent flow model PDAC-2D was completed (UR04-Neri) and applied to the reproduction of the AD 79 eruption of **Vesuvius** and to the assessment of pyroclastic flow hazard.). In detail, the eruption dynamics corresponding to two distinct peaks of mass flow-rate of the 79 AD eruption of Vesuvius were simulated through the coupling of the conduit and pyroclastic dispersal models. The results of the simulations substantially agree with the eruptive dynamics reconstructed by independent vulcanological studies and illustrate the influence that magmatic composition and crystal content had on the eruptive style of this famous eruption.

Similarly, the analysis of the hazard associated to pyroclastic flows at **Vesuvius** was assessed quantifying the arrival times of the flows, their velocity, density, temperature and also the maximum distances reached according to different scenarios characterized by different eruption intensities. The dynamic pressure, the variation of isotropic pressure, and the flow capacity to carry missiles were also determined as a function of distance from the eruptive center and the assumed scenario. This work on the pyroclastic flow hazard assessement at **Vesuvius** was done in cooperation with RU03- G.Macedonio; the work on the AD 79 eruption of Vesuvius was done in cooperation with the RU05- P.Papale. In addition, the results of the pyroclastic flow simulations at Vesuvius were supplied to S.Tinti (RU01 coordinated by M.Dragoni), in order to provide the initial and boundary conditions for the tsunami generation model.

The flows capable to generate a tsunami wave can reach the sea in the gulf of Naples: the dense and slow part will enter the waters, while the lighter and faster part of the flow can travel on the water surface exerting a pressure on it. The research has studied the characteristics of a tsunami produced by the pressure pulse associated with the transit of the pyroclastic flow on the sea surface by means of numerical simulations. The tsunami resulting from the computations is a perturbation involving the whole gulf of Naples, but it is negligible outside, and persists within the gulf long after the transit of the excitation pulse. The size of the tsunami is modest. The largest calculated oscillations are found along the innermost coasts of the gulf at Naples and at Castellammare. The main conclusion of the study so far is that future large eruptions of Vesuvius are not expected to set up tsunamis larger than the one caused by the 1631 eruption. Further sensitivity studies are needed to corroborate this conclusion.

Another invetigation leaded by RU01-Dragoni develop 2D and 3D models considering lava-flows, with different rheologies (both Newtonian and Binghamian), in order to evaluate the effusion rate given the lava flow width, the ground slope, the lava density, the surface flow velocity, and either the lava viscosity or the flow thickness. Lava is considered as a Newtonian fluid to describe the flow near the vent and as a Binghamian fluid far from the vent where, as a consequence of the low temperature, a yield stress develops. The results of the 3D model are compared with those of 2D models, which neglect the presence of levees. Levees greatly affect the dynamics of a typical **Etna** lava flow if its width is less than about 25 m. Where lava is cooler, the Binghamian behavior becomes important and a Newtonian model tends to overestimate the actual flow rate. Similarly, a 2D model tends to overestimate the flow rate when the channel is narrow. The 3D model, connecting the dynamic variables of the lava flow, allows the volume flow rate to be expressed as a function of the maximum surface velocity. Such models may help in producing more accurate estimates of lava fluxes, a key parameter in evaluating lava flow hazards.

- **RESEARCH PRODUCTS OF THE PROJECT**

  - **n°12** articles published on international journals;
  - **n° 4** articles published on national journals, proceedings, technical reports.
  - **n° 2** invited papers and talks
  - **n°20** Presentation at international meetings
  - **n°14** Presentation at national meetings
  - **n° 1** Data base
  - **n° 2** Computation codes
  - **n° 1** Other

PUBLICATIONS LIST (inclusive of papers in prints, submitted or accepted by international journals or related to proceedings of international meetings)

CLARKE A.B., B.VOIGHT, A.NERI, G.MACEDONIO, T.DRUITT, 2002. Computational modelling of the transient dynamics of the August 1997 Vulcanian explosions at Soufriere Hills volcano, Montserrat: influence of initial conduit conditions on near-vent pyroclastic dispersal. The eruption of the Soufriere Hills volcano from 1995 to 1999, Montserrat Antilles, Memoir no. 21 of the Geological Society of London, 319-347,

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ESPOSTI ONGARO T., NERI A., TODESCO M., MACEDONIO G., 2002. Pyroclastic flow hazard at Vesuvius by using numerical simulations. II. Analysis of local flow variables. Bull. Volcanol. 64:178-191,

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NERI A., PAPALE P., DEL SEPPIA D., SANTACROCE R., 2002. Coupled conduit and atmospheric dispersal dynamics of the AD79 eruption of Vesuvius. J. Volcanol. Geotherm. Res. 120:141-160,

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TODESCO M., A.NERI, T.ESPOSTI ONGARO, P.PAPALE, G.MACEDONIO, R.SANTACROCE, A.LONGO, 2002.Pyroclastic flow hazard at Vesuvius by using numerical simulations. I. Large-scale dynamics. Bull. Volcanol. 64:155-177

TASK4. EXPERIMENTAL SIMULATION AND MODELING OF ERUPTIVE PROCESSES AND THEIR PRECURSORS

- **RU PARTICIPANTS: 02, Resp. F.Gaeta; 09, Resp. D.Dolfi; 12 Resp.R.Trigila; 14, Resp. C.Kilburn.**

- **2nd YEAR OBJECTIVE**

All the following objectives imply laboratory experiments as follows:
1) Relations between the melt viscosity (homogeneous melt or crystal mush) vs. the amount of fragmentation and transported mass in the magma-water explosive interactions. Also the effect of vesiculation on the explosive interaction is considered. (HP-HT lab, Roma"La Sapienza")
2) Rock fracturing experiments at high pressure up to 50 MPa and temperature up to 1000°C,(UCL lab London-GB)
3) Experimental study of advective transport in tuff samples and the effect of critical transition of water in tuff samples (MARS lab, Napoli).
4)The effect of magma ascent kinetics from the subvolcanic chambers to the surface, aiming at verifying its effect on crystalline phases stability (namely the amphibole), the phase relations, the composition of final melt and the comparison of the initial $H_2O + CO_2$ content in the melt with $H_2O + CO_2$ residual content in the vesiculated glass through decompression experiments at different ΔP with controlled decompression rates.. (This new objective started during September 2002).

In particular 1) and 4) find application to explain the hydromagmatic component in the 2001-2002 **Mt.Etna** eruption, 4) is pursued in studying the A.D.79 **Mt.Vesuvius** plinian eruption, 2) use **Mt.Vesuvius** k-basalt and **Mt.Etna** hawaiite as starting material and 3) find appplication for an alternative explanation of **Campi Flegrei** bradyseism.

- **2nd YEAR RESULTS**

1) The maqua (magma-water interaction vessel) experiments were limited because of the Roma lab closure from december 2001 to July 2002. The MAQUA vessel was then modified to accept an ultrasonic probe that acts both as passive and active high temperature sensor. In the passive mode, it allows the monitoring of pressure waves with ultrasonic frequencies originated by the magma water explosive interaction or by the melt vesiculation as response to the magmatic decompression. As active mode it allows estimates of magma density variations due to the crystallisation process because it is able to collect either Vp than Vs waves. This sensor was already tested at room temperature giving a good resolution in terms of signal attenuation. Other tests using different standard materials (glass, stainless steel, lavastone) give consistent ultrasonic waves propagation velocities through the sample holder chamber.

Results by the MAQUA experiments giving information on melt fragmentation have been retrieved from a representative set of 11 experimental runs on a Onano lc-tephrite (Vulsini Volcanoes) by the granulometric analyses both of the material left in the sample holder and the material transported into the gasket.. The experiments have been run at the following conditions: confining pressure 8 MPa; melt interaction temperature between 800 and 900°C; water injection pressure 102 MPa and water- melt interaction mass ratio 0.33 – 0.36. If we compare data from experiments performed with the same water injection mode we can see that higher values melt-water interaction temperature produce larger values for the system expansion and amount of mass transported mass but there is no significative effect on melt fragmentation. In the case of a homogeneous melt (powdered starting material), interacting with water at 800°C and 900°C respectively, the increase in volume is about 10%, transport is virtually absent, fragmentation is minimal and it is distributed among the finest grain sizes. If the interacting material is in the partially molten state (granular starting material) fragmentation is much more developed, the modal class is shifted toward the grain size coarse region and the transport involves, in average, 20% of the initial mass. It can be concluded the fragment size distribution for all the experimental products appears to be essentially controlled by the aggregation state of the interacting melt. In particular, the experimental products from granular starting material have an unimodal distribution around 0 _, while products from powdered starting material show a multimodal distribution with a principal

mode around 3-4 _. It is worth noting that the fragment size distribution of the transported mass is very close to the one left in the sample holder, demonstrating that the mass transport along the sample holder "conduit" has no strong additional effects on fragmentation.

2) RU14 at UCL extended Year-1's laboratory experiments on tensile failure to compressional failure at confining pressures from atmospheric to 50 MPa and temperatures from 25° to 1,000°C. The experiments on K-basalt from **Mt**.**Vesuvius** and hawaiite from **Mt.Etna** show that these rocks remain fully brittle up to 600°C with typical strengths of 90 MPa and 100 MPa and Young's Moduli of 60 GPa and 40 GPa respectively. Above 600°C, the elastic modulus and compressive strength decrease steadily wth increasing temperature, reaching 10% of their original values at 900°C (Vesuvius) and 800°C (Etna), when partial melting begins. Full melting occurs at 1100°C in the Vesuvian lava and at 1040°C in the Etnean samples. The results also show that, for the investigated conditions, changes in confining pressure have only a small effect on rock strength, strain rates are important at high temperatures, and rates of fracture energy release vary inversely with temperature.

3) MARS experiments were focused to explain the mini-uplift recorded recently at **Campi Flegrei** as the result of the advective transport of water in porous media and of the critical transition liquid-gas of the water contained inside the cavities of tuff samples (Gaeta et al., 2002).

4) RU09 and RU12 at Roma lab. started with the decompression experiments program on the pumices of A.D. 79 plinian Vesuvius eruption and 2001-2002 ash and lavas of Mt.Etna eruption. Two sets of runs on 2001 eruption samples (both of upper vents than lower vents lavas) have been performed: one under equilibrium conditions and variable volatiles composition (H_2O and H_2O+CO_2) and the other under a decompression gradients (from 200 to 20 MPa in 1 h, 12h, and 24h).

At constant pressure (200MPa) and through the temperature range of 900-1040°C, all the investigated samples (i.e. those representative both of upper vents than lower vents lavas) show the same crystalline assemblage: i.e. plagioclase (An76), diopsidic clinopyroxene, olivine and titanomagnetite. Amphibole is present in the water saturated samples. . These results may indicate that the differences in the porphyricity and crystal assemblage observed respectively for the upper vents and the lower vents samples are not related to a different source of magmatic masses but simply to a different kinetics of the magma ascent.

Decompression experiments with different rates show consistent differences both on crystallinity and vesiculation of the experimental products. These are currently being analysed, anyway looking directely correlated for both parameters in case of the experiments performed under H_2O saturated conditions. In particular products obtained at the slowest decompression rates appear more crystal rich and vesiculated than those obtained with the fast decompression rate.

- **RESEARCH PRODUCTS OF THE PROJECT**

  - **n°4** of articles published on international journals;
  - **n°3** n° of articles published on national journals, proceedings, technical reports.
  - **n°3** invited papers and talks
  - **n°5** Presentation at international meetings
  - **n°3** Presentation at national meetings

PUBLICATIONS LIST (inclusive of papers in prints, submitted or accepted by international journals or related to proceedings of international meetings)

GAETA, F.S., PELUSO, F., ARIENZO, I., CASTAGNOLO, D., DE NATALE, G., MILANO,M., ALBANESE,C., MITA, D.G., 2002. A physical appraisal of a new aspect of bradyseism: the mini-uplifts, submitted to Journ. Geophys. Res

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TRIGILA R., CASTIGLIONE L., 2002. Volcanic Hazard Assessment due to Hydromagmatic Eruptions on the basis of WMI laboratory experiments: the case of Latera Volcano (Vulsini District) and Alban Hills. Proceedings 2nd International Conference on Volcanism, Archeology and Remote Sensing. Sorrento 27-30/6. In press.

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PROJECT TITLE

ERUPTIVE SCENARIOS FROM PHYSICAL MODELING AND EXPERIMENTAL VOLCANOLOGY

Project Coordinator:
Prof. Raffaello Trigila
Dipartimento di Scienze della Terra, Università di Roma "La Sapienza"

RESEARCH UNITS ACTIVITY REPORT –2nd YEAR

RU#	RESPONSIBLE	AFFILIATION
01	**Prof. Michele Dragoni**	**Dip. Fisica, Univ. Bologna**
02	**Prof. Francesco Gaeta**	**MARS Center, Napoli**
03	**Prof. Giovanni Macedonio**	**Osservatorio Vesuviano – INGV, Napoli**
04	**Dott. Augusto Neri**	**IGG-CNR, Pisa**
05	**Dott, Paolo Papale**	**INGV, Pisa**
06	**Prof. Michael Carroll**	**Dip. Scienze della Terra, Università di Camerino**
07	**Dott. Corrado Cigolini**	**DSMP, Università di Torino**
08	**Prof. Benedetto De Vivo**	**Dip. Geofisica-Vulcanologia, Univ. Federico II, Napoli**
09	**Prof. Daniela Dolfi**	**Dip. Scienze Geologiche, Università Roma 3**
10	**Prof. Pasquale M. Nuccio**	**Università di Palermo**
11	**Dott. Massimo Pompilio**	**INGV, Sezione di Catania**
12	**Prof. Raffaello Trigila**	**Dip. Scienze della Terra, Univ. "La Sapienza", Roma**
13	**Prof. Giuseppe De Natale**	**Osservatorio Vesuviano – INGV, Napoli**
14	**Prof. Christopher Kilburn**	**BGHRC, Univ. College, London**
15	**Prof. Giuliano Panza**	**Dip. Scienze della Terra, Univ. di Trieste**

RU 01 DRAGONI

Project Title: Eruptive scenarios from physical modeling and experimental volcanology

ACTIVITY REPORT – 2nd YEAR

RU Responsible: Michele Dragoni.
Affiliation: Dipartimento di Fisica, Università di Bologna.
Title of the research:
a) Thermal and fluid-dynamical models of lava flows (Michele Dragoni).
b) Potential of tsunami generation by pyroclastic flows (Stefano Tinti).

RU PARTICIPANTS

Name	Position	Affiliation	man/month
Michele Dragoni	Professore ordinario	University of Bologna	1
Francesca Quareni	Geofisico associato	INGV Osservatorio Vesuviano	1
Andrea Tallarico	Professore associato	University of Bari	1
Antonello Piombo	Ricercatore	University of Bologna	1
Ida Borsari	Assegno di ricerca	University of Bologna	1
Stefano Tinti	Professore associato	University of Bologna	1
Alberto Armigliato	Assegno di ricerca	University of Bologna	1
Anna Manucci	Dottorato di ricerca	University of Bologna	1
Gianluca Pagnoni*	Borsa di studio	University of Bologna	1
Filippo Zaniboni	Dottorato di ricerca	University of Bologna	1

2nd YEAR OBJECTIVES

a) Criteria for the evaluation of flow rate in active lava flows (M. Dragoni).
b) Modelling of tsunamis produced by the light-component of the pyroclastic flows generated by a plinian-subplinian eruption of Vesuvius (S. Tinti).

2nd YEAR RESULTS

a) The effusion rate of lava from a volcanic vent is the main quantity controlling the length of the ensuing lava flow. The ability to evaluate the lava flow rate is therefore of paramount importance in

order to estimate the hazard connected with the flow. Since the lava flow rate can not be directly measured, as one could do for a liquid flowing in a pipe, it must be calculated from other measurable flow parameters. Due to the difficulty of measuring physical quantities in active lava flows, it is advisable to reduce the number of these parameters as much as possible. For any flow, the obvious way to calculate the (volume) flow rate is multiplying the average flow velocity times the cross-sectional area. However the average flow velocity can not be measured. It can be calculated, but depends on several quantities such as the density and the viscosity of lava, the acceleration of gravity, the ground slope, the flow thickness and width, the yield stress (if the Bingham rheology is assumed). Since the aspect ratio of lava flows (ratio of thickness to width) is generally very small, 2D flow models are often used, owing to their simplicity. In these models, the velocity field has no dependence on the horizontal coordinate, so that friction at the flow levees is neglected, resulting in greatly simplified formulae. We developed models considering both 2D and 3D flows, with different rheologies (both Newtonian and Binghamian), in order to evaluate the effusion rate given the lava flow width, the ground slope, the lava density, the surface flow velocity, and either the lava viscosity or the flow thickness. Lava is considered as a Newtonian fluid to describe the flow near the vent and as a Binghamian fluid far from the vent where, as a consequence of the low temperature, a yield stress develops. The results of the 3D model are compared with those of 2D models, which neglect the presence of levees. Levees greatly affect the dynamics of a typical Etnean lava flow if its width is less than about 25 m. Where lava is cooler, the Binghamian behavior becomes important and a Newtonian model tends to overestimate the actual flow rate. Similarly, a 2D model tends to overestimate the flow rate when the channel is narrow. The 3D model, connecting the dynamic variables of the lava flow, allows the volume flow rate to be expressed as a function of the maximum surface velocity. Such models may help in producing more accurate estimates of lava fluxes, a key parameter in evaluating lava flow hazards.

b) The research has explored the potential of tsunami generation by pyroclastic flows travelling down the flank of the volcano Vesuvius. The eruption history of Vesuvius shows that it is characterized by large explosive eruptions of plinian or subplinian type, during which large volumes of pyroclastic flows can be produced (see 79 AD and 1631 eruptions). The research has used the results of numerical models of magma ascent and of eruptive column formation and collapse that have been published for the Vesuvius volcano by the group of the University of Pisa. These flows can reach the sea in the gulf of Naples: the denser slow part will enter the waters, while the lighter and faster part of the flow can travel on the water surface exerting a pressure on it. The research has studied the charactersitics of a tsunami produced by the pressure pulse associated with the transit of the pyroclastic flow on the sea surface by means of numerical simulations: the forcing pulse features are inferred from the recent studies on Vesuvian pyroclastic flows of the University of Pisa. The tsunami resulting from the computations is a perturbation involving the whole gulf of Naples, but it is negligible outside, and persists within the gulf long after the transit of the excitation pulse. The size of the tsunami is modest. The largest calculated oscillations are found along the innermost coasts of the gulf at Naples and at Castellammare. The main conclusion of the study so far is that future large eruptions of Vesuvius are not expected to set up tsunamis larger than the one caused by the 1631 eruption. Further sensitivity studies are needed to corroborate this conclusion.

RESEARCH PRODUCTS

- 2 articles accepted or in press in international journals;
- 1 presentation at international meetings;
- 1 presentation at national meetings.

PUBLICATION LIST

Quareni, F., Tallarico, A., Dragoni, M., 2003. Temperature field in lava flow levees, *Journal of Volcanology and Geothermal Research*, accepted for publication.

Tinti S., Pagnoni G., Piatanesi A., 2003. Simulation of tsunamis induced by volcanic activity in the gulf of Naples (Italy), *Natural Hazards and Earth System Sciences*, in press.

RU 02 GAETA

PROJECT TITLE

Thermal-fluid-dynamics in porous media in over- and under-critical conditions: theoretical modeling, experimental investigation and numerical simulation.

RU Responsible

Name-Position Prof. Francesco S. Gaeta
Affiliation MARS Center scientific consultant

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Prof. Francesco S. Gaeta – Cons.	MARS	4
Dr. Fabio Peluso – Researcher	MARS	4
Ing. Dario Castagnolo – Researcher	MARS	2
Mr. S. Sorrentino – Technician	MARS	2
Dr. I. Arienzo NO MORE IN THE UR		-

- 2nd YEAR OBJECTIVES

Experimental study of advective transport in tuff samples
Experimental study of critical transition of water in tuff samples
Advective transport modelling in geothermal soils

- 2nd YEAR RESULTS **(max 1 page)**
- Methodologies
- Data acquisition
- Data processing and interpretation
- Others
-

Experimental

Results of second year of research consist mainly of some provisional results in the study of advective transport in porous media and of the critical transition liquid-gas of the water contained inside the cavities of tuff samples.
Among the first, we are still implementing the experimental apparatus to perform the experiments. However time has been spent to collect the experimental data obtained during the first year in two papers, one already published and one still under review. Results have been also presented at a national congress (GNGTS 2002) and at an international one (Nice, 2002)

Theoretical.

Main efforts have been devoted in the second year to the development of a theoretical model of geothermal circulation in calderas. This model has been shown to be able to explain small uplifts registered in Campi Flegrei area. Results have been exposed at an international (Nice, 2002) and national (GNGTS 2002) congresses.

- RESEARCH PRODUCTS
  - n° of articles published on international journals

3 original articles, 2 dealing with experimental results (one published, one still under review), plus one theoretical.

- n° of articles published on national journals, proceedings, technical reports

Two proceedings at international congress, one at a national congress.

- invited papers and talks (None)
- presentations at international meetings
  one presentation at an international meeting

- presentations at national meetings;
  one presentation at a national meeting

- Data bases (none)
- Computation codes (none)
- Other
  Upgrade of an apparatus for the measurements of advective heat and mass transport through porous media.

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

F. Peluso, I. Arienzo, Experimental determination of equilibrium and non-equilibrium properties of natural porous media, ENTROPIE, vol. 239-240, pag. 136.

F.S. Gaeta, F. Peluso, I. Arienzo, D. Castagnolo, G. De Natale, G. Milano, C. Albanese, D.G. Mita, "A physical appraisal to a new aspect of bradyseism: the mini-uplifts. Submitted to J. of Geophysical Research – Solid Earth.

F. Peluso, I. Arienzo, Equilibrium and non equilibrium thermodynamic properties of Neapolitan Yellow Tuff: Experimental determination. Submitted for publication to Transport in porous media.

RU 03 MACEDONIO

PHYSICAL MODEL OF MAGMA CHAMBER EMPTYING

RU Responsible
Giovanni Macedonio – Dirigente di Ricerca
Osservatorio Vesuviano – INGV, Napoli (Italy)

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Giovanni Macedonio, Dirigente Ricerca.	Osservatorio Vesuviano - INGV	3
Matrolorenzo Giuseppe, Researcher	Osservatorio Vesuviano - INGV	3
Augusto Neri, 1° Researcher	CNR, Pisa	1
Paolo Papale, Researcher	INGV, Pisa	1
Antonio Costa, PhD student	Bologna University	5
Antonella Longo, Phd Student	Pisa University	1

- 2nd YEAR OBJECTIVES

Test of the developed model describing the emptying of a volcanic magma chamber. Description of the pressure distribution as a function of the erupted mass. Generation of the conditions of pressure, velocity etc. at the vent as a function of time. Analysis of vesicular characters of the products from explosive eruptions at Phlegraean Fields. Acquisition of stratigraphic, granulometric and morphoscopic data of pyroclastic units. Interpretation and modelling of magma rise mechanisms and magma vesiculation for different types of explosive eruptions.

- 2nd YEAR RESULTS **(max 1 page)**
- *Methodologies*:

The magma chamber emptying was described by assuming a model of compressible magma (liquid+bubbles). The two-phase gas/liquid mixture is considered isothermal, and homogeneous. Magmatic fragmentation is assumed to occur when the maximum compaction of the spherical bubbles is reached, that is for gas volumetric fraction of 75%. Gas solubility (water vapour) in the magma is computed as a function of the pressure by using a semi-empirical power-law relation, with the parameters obtained from the model by Ghiorso and Sack (1995). The model for magma flow in the eruptive conduit is based on the solution of the transport equation for an isothermal pseudo-gas, in a constant cross-section conduit. The mass in the magma chamber is obtained by integration of the density in the chamber volume, whereas its time variation is represented by the mass flow rate through the conduit. Magma rising and eruption processes were also studied through the comparative analysis of vesiculation features of Campi Flegrei and Somma-Vesuvius pyroclastic deposits

- *Data acquisition*

Image analyses of 80 thin sections of epoxy impregnated sections of pyroclastic products collected in all types of explosive deposits of two volcanic areas (Vesuvius and Campi Flegrei).

- *Data processing and interpretation*

Bubble size distribution (BSD) and bubble number density (BND) of the samples indicate that in spite of the different eruptive mechanisms the products show relatively minor differences in magma rising regime, always occurred close to the limit between viscosity controlled and diffusion controlled regime. However most of the sample collected from the plinian deposits of Somma-Vesuvius show evidence of more relevant contribution of the diffusion in bubble growth, possibly resulting from the lower value of magma viscosity.

- *Others*

Detailed analyses of the vesiculation features in the eruptive sequences in order to show the relations between the internal variations and the range of the difference between the types of eruptions.

- RESEARCH PRODUCTS
  - n° of articles published on international journals: **3**
  - n° of articles published on national journals, proceedings, technical reports
  - invited papers and talks
  - presentations at international meetings: **7**
  - presentations at national meetings;
  - Data bases
  - Computation codes: **1**
  - Other

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

Costa A., Macedonio G., Nonlinear phenomena in fluids with temperature-dependent viscosity: an hysteresis model for magma flow in conduits., Geophys. Res. Lett., vol. 29(10), 2002.

Mastrolorenzo, G., Brachi, L., Canzanella, A., (2001). Vesicularity of various types of pyroclastic deposits of Campi Flegrei volcanic field: evidences of analogies in magma rise and vesiculation mechanisms. J. Volcanol. Geotherm. Res.109, 41-53

Mastrolorenzo, G., Palladino, D., Vecchio, G., Taddeucci., J. Th 472 AD Pollena eruption of Somma-Vesuvius (Italy) and its environmental impact at the end of the Roman Empire. J. Volcanol. Geotherm. Res.113 (2002) 19-36.

Presentations

Costa A., Macedonio G., Viscous heating effects in lava flows, EGS XXVII General Assembly, Nice, France, 21-26 April, 2002.

Costa A., Macedonio G., An hysteresis model for lava dome growth, IAVCEI, 1902 Centennial Workshop, Mount Pelée, Martinique on “Explosive Volcanism in Subduction Zones”, May 12-16, 2002.

Mastrolorenzo, G., Petrone, P.P.(2002). Effetti deposizionali delle correnti piroclastiche associate alle eruzioni pliniane del Somma-Vesuvio:eventi delle Pomici di Avellino(3760 yr. B.P.) e di Pompei (79 AD.). 2nd International Conference Archaeology, Volcanism & Remote Sensing. Sorrento 20-22 giugno 2001.

Mastrolorenzo, G., Petrone, P.P., Incoronato, A., Pagano, M., Fergola. L. Effects of the 79 AD Vesuvius Plinian Eruption in the buried sites of Herculaneum Oplontis and Stabiae from an integrated volcanological, anthropological and archaeological study. European Union of Geosciences, Strasburg 2001.

Mastrolorenzo,G., Petrone, P.P. Emplacement and effects of Avellino (3760 yr. B.P.) and Pompei (79 A.D.) eruptions pyroclastic density currents. Montagna Pelee 1902- 2002 Explosive Volcanism in subdution zones. IAVCEI conference, Saint Pierre, Martinique, may 12-16 2002.

Mastrolorenzo, G. Brachi, L., Canzanella, A. Comparision of bubble size distribution of different pyroclastic deposits in Neapolitan area and inferences on eruption dynamics. European Geophysical Society Nizza, aprile 2002.

Mastrolorenzo,G., Petrone, P.P., Geraci,G., Guarino, F,. Incoronato, A. Effects of plinian eruptions of Somma-Vesuvius on people, animals, structures, and objects: inferences from Avellino (3760 yr. BP) and Pompei (79 A.D.) events. European Geophysical Society Nizza, aprile 2002.

RU 04 NERI

FLUID DYNAMICS MODELS OF PYROCLASTIC FLOWS PRODUCED BY COLLAPSING COLUMNS AND IMPULSIVE ESPLOSIVE EVENTS

RU Responsible
Augusto NERI, Head Researcher
Consiglio Nazionale delle Ricerche, Istituto di Geoscienze e Georisorse, Dip.to di Scienze della Terra, Università di Pisa, via S. Maria 53, I-56126 Pisa.

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name – Position	Affiliation	Man-months
Augusto Neri, Head Researcher	CNR-IGG Pisa	4
Giovanni Macedonio, Director of Research	Vesuvian Observatory INGV	1
Paolo Papale, Researcher	INGV Pisa	1
Dimitri Gidaspow, Full Professor	Illinois Institute of Technology	1
Tomaso Esposti Ongaro, PhD Student	University of Pisa	4
Andrea Di Muro, PhD Student	University of Pisa	1

- **2nd YEAR OBJECTIVES**

Application of a multiphase multicomponent pyroclastic dispersal model to the setting of various eruptive scenarios and to parametric studies on pyroclastic flow and surge dynamics. Assessment of the hazards associated to pyroclastic flow and surge dynamics. The activity carried out by this research unit refers to *task* n°.3 of the project "Thermo-fluid-dynamic modelling of magma uprise processes and subaerial transport".

- **2nd YEAR RESULTS**

The research work was organised along the following lines.

1) **Development of the 2D multiphase multicomponent model of pyroclastic density currents**. The development of the 2D multiphase and multicomponent model PDAC-2D was completed and the model was published on an international journal (Neri et al., in press). This achievement allows the description of the multiparticle nature of the eruptive mixture and the quantification of the mechanical and thermal non-equilibrium processes that occurs during the formation and emplacement of pyroclastic density currents. Several simulations of continuously feeded collapsing fountains were carried out on a flat topography and in axisymmetric conditions in order to elucidate on the different spatial and temporal dispersal of the various granulometric components of the flow. Fundamental processes such as particle sedimentation and air entreinment in the flow were also investigated.
   During the year we also made further advancements on the parallelization of the numerical code so as to be able to produce 3D simulations of the phemomenon in the future. In detail, a first parallel version of the 2D code has been obtained and implemented on different platforms in cooperation with the High Performance Supercomputing Group of CINECA (Esposti Ongaro et al., 2002a). Results show a good scalability of the code that indicates a promising extension of it

to 3D. The extension of the code to 3D is part of the research work carried out in the ambience of the European RTD Project EXPLORIS started on Dec. 1st, 2002.

2) **Application of the multiphase pyroclastic dispersal model to real eruptions and pyroclastic flow hazard assessment.** The multiphase flow model PDAC-2D was applied to the reproduction of the AD 79 eruption of Vesuvius and to the assessment of pyroclastic flow hazard. In both cases, the work started in previous EC projects, and continued during the first year of the project, was completed and published in international journals (Neri et al., 2002; Todesco et al., 2002, Esposti Ongaro et al., 2002b). In detail, the eruption dynamics corresponding to two distinct peaks of mass flow-rate of the 79 AD eruption of Vesuvius were simulated through the coupling of the conduit and pyroclastic dispersal models. The results of the simulations substantially agree with the eruptive dynamics reconstructed by independent vulcanological studies and illustrate the influence that magmatic composition and crystal content had on the eruptive style of this famous eruption. Similarly, the analysis of the hazard associated to pyroclastic flows at Vesuvius was completed. The arrival times of the flows, their velocity, density, temperature and also the maximum distances reached were quantified for several scenarios characterized by different eruption intensities. The dynamic pressure, the variation of isotropic pressure, and the flow capacity to carry missiles were also determined as a function of distance from the eruptive center and the scenario assumed.
3) **Dynamics of Vulcanian explosions.** The multiphase flow model PDAC-2D has been applied also to the simulation of Vulcanian explosion dynamics (Clarke et al., 2002a,b). In this case, the code was used to link the unsteady conduit dynamics of Vulcanian explosions to the resulting dispersal of volcanic ejecta. Observational data from well documented explosions at the Soufriere Hills volcano, Montserrat, were used to constrain pre-eruptive conduit conditions and to compare the real event with simulation results. The resulting simulations duplicate many features of the observed explosions and reveal internal dynamics and particle-size segregation mechanisms that may occur in such explosions.

Part of the research was carried out in collaboration with other research units of the project. The work on the AD 79 eruption of Vesuvius was done in cooperation with the research unit leaded by P.Papale, whereas the work on the pyroclastic flow hazard assessement at Vesuvius was done in cooperation with the research unit coordinated by G.Macedonio. In addition, the results of the pyroclastic flow simulations at Vesuvius were supplied to S.Tinti (of the research unit coordinated by M.Dragoni), in order to provide the initial and boundary conditions for the tsunami generation model. Finally, we collaborated with the research group of G.Macedonio for the development of the magma chamber emptying model.

PUBLICATIONS LIST

Clarke A.B., B.Voight, A.Neri, G.Macedonio, Transient dynamics of Vulcanian explosions and column collapse. *Nature*, 415:897-901, 2002a.

Clarke A.B., B.Voight, A.Neri, G.Macedonio, T.Druitt, Computational modelling of the transient dynamics of the August 1997 Vulcanian explosions at Soufriere Hills volcano, Montserrat: influence of initial conduit conditions on near-vent pyroclastic dispersal. *The eruption of the Soufriere Hills volcano from 1995 to 1999, Montserrat Antilles*, Memoir no. 21 of the Geological Society of London, 319-347, 2002b.

Esposti Ongaro T., C.Cavazzoni, G.Erbacci, A.Neri, G.Macedonio, Parallel numerical simulation of pyroclastic flow dynamics at Vesuvius. *Parco 2001 Proceedings*, Imperial College Press, London, 2002a.

Esposti Ongaro T., A.Neri, M.Todesco, G.Macedonio, Pyroclastic flow hazard at Vesuvius by using numerical simulations. II. Analysis of local flow variables. *Bull. Volcanol.* 64:178-191, 2002b.

Neri A., Physical modelling of explosive eruptions. *Volcanic hazard assessment, monitoring and risk mitigation*, J.M.Pacheco Ed. Proceedings of the European Community, Environmental and Climate Programme, Centro de Vulcanologia, University of Azores, Portugal, *in press*.

Neri A., T.Esposti Ongaro, G.Macedonio, D.Gidaspow, Multiparticle simulation of collapsing volcanic columns and pyroclastic flows. *J. Geophys. Res, in press*.

Neri A., P.Papale, D.Del Seppia, R.Santacroce, Coupled conduit and atmospheric dispersal dynamics of the AD79 eruption of Vesuvius. *J. Volcanol. Geotherm. Res*. 120:141-160, 2002.

Todesco M., A.Neri, T.Esposti Ongaro, P.Papale, G.Macedonio, R.Santacroce, A.Longo, Pyroclastic flow hazard at Vesuvius by using numerical simulations. I. Large-scale dynamics. *Bull. Volcanol.* 64:155-177, 2002.

CONGRESS PRESENTATIONS

Baxter P.J., R.Spence, A.Neri, The 1902 eruption of Montagne Pelèe revisited: pyroclastic density currents and the destruction of St. Pierre, . *IAVCEI International Conference Montagne Pelèe*, Martinique, 12-16 May 2002.

Clarke A.B., B.Voight, A.Neri, G.Macedonio, Insights into Vulcanian fountain collapse mechanisms revealed by multiphase numerical simulations and the influence of volatile leakage on eruptive style, *IAVCEI International Conference Montagne Pelèe*, Martinique, 12-16 May 2002.

Neri A., T.Esposti Ongaro, G.Macedonio, D.Gidaspow, Multiparticle simulation of collapsing volcanic columns and pyroclastic flows. *IAVCEI International Conference Montagne Pelèe*, Martinique, 12-16 May 2002.

Neri A., T.Esposti Ongaro, G.Macedonio, D.Gidaspow, Multiparticle simulation of collapsing volcanic columns and pyroclastic flows. Workshop *Modeling and simulation of geophysical mass flows*, Buffalo New York, 18-19 July 2002 (invited talk).

RU 05 PAPALE

PROJECT TITLE: ***Scenari eruttivi attraverso ricerche di modellistica fisica e vulcanologia sperimentale***

RU Responsible: Paolo Papale
Name-Position: Researcher
Affiliation: Istituto Nazionale di Geofisica e Vulcanologia

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Paolo Papale	INGV	2
Margherita Polacci	INGV	3
Dario Del Seppia	DST Univ. Pisa-CNR	4
Antonella Longo	DST Univ. Pisa-INGV	4

2nd YEAR OBJECTIVES

Dinamica di risalita dei magmi, con applicazioni al Veuvio. Confronto fra i risultati sperimentali sui processi di vescicolazione magmatica ottenuti in laboratorio con quelli desumibili dallo studio dei depositi di eruzioni pliniane.

2nd YEAR RESULTS

Dynamics of coupled magma ascent and atmospheric dispersion for the AD 79 eruption of Vesuvius, and role of microlite nucleation on the large scale eruption dynamics.

We have performed detailed simulations of magma ascent and fragmentation for the very famous and well-characterized AD 79 (Pompei) eruption of Vesuvius. Conduit exit conditions produced by simulations of magma ascent have then been used as boundary conditions at the vent for the simulation of the gas-pyroclast dispersion dynamics (UR Neri). Choked flow conditions at the conduit exit guarantee a one-way coupling between the two conduit and atmospheric domains. The results obtained give an overall picture of the large scale dynamics from the conduit base to within the volcanic column and pyroclastic flows, making it possible to understand the roles played by factors that act deep in the conduit on the entire eruption dynamics. We have considered two different magmatic phases of the AD 79 eruption, namely, the white and gray phases, which differ for magma composition and partly for the style of the eruption, the white phase being markedly sustained or Plinian, and the gray phase still dominantly Plinian but with partial column collapses. A peculiarity of both white and gray pumice is that they contain abundant microlites, the origin of which is to be placed within the conduit during ascent of magma, or within the magma chamber in the phases immediately preceding the eruption. In order to investigate the possible consequences of microlite nucleation on the eruption dynamics, we have performed simulations for each eruptive phase by both neglecting and considering microlites in the erupted magma. A summary of the results in terms of conduit exit conditions is reported in Table 1. All the conduit exit quantities in Table 1 follow well-defined monotonic trends from the white to the gray phase, apart from pressure. Gas volume fraction and gas and particle velocities are larger, and particle and mixture densities are lower, for the white than for the gray phase. Differently, exit pressures corresponding to the two gray cases are within the range found for the white cases. The calculated conduit diameters are about 40 m for the white, and 50 m for the gray phase of the eruption.

In both cases the exit velocities increase of 10-20% when microlites are considered in the ascending magma. Differently, the exit gas volume fraction and mixture density do not change significantly for the white phase, while they are remarkably different for the gray phase. The case of pressure is reversed, with small changes due to microlites occurring for the gray phase, while for the white phase there is a remarkable increase by about 16% when microlites are considered. Finally, the presence of microlites results in a conduit diameter which is slightly smaller for the white phase, and slightly larger for the gray phase.

Numerical simulations of the gas-pyroclast dispersion dynamics were made by using the conduit exit conditions at Table 1 as boundary conditions at the vent. The results (more detailed in the report by the UR Neri) show that: 1) the white phase results to be buoyant either when we include or we neglect microlites; 2) the gray phase results to be collapsing when microlites are neglected, and buoyant when microlites are accounted for; 3) therefore, nucleation of microlites can play an important role on the large scale dynamics of volcanic eruptions; 4) the large scale dynamics of the two white and gray phases as obtained from the simulations are in substantial agreement with the reconstruction of the eruption from the chronicles and from the deposits, with the white phase being definitively Plinian (or buoyant), and the gray phase being still Plinian, but less sustained than the white phase, with the possibility (that actually occurred) or partial column collapses due to local conditions in the volcanic column

Table 1. Summary of calculated exit conditions employed in the dispersion simulations

Simulation	$\dot{m}$ (kg/s)	**H_2O** (wt%)	**D** (m)	**P** (MPa)	**v_G** (m/s)	**v_L** (m/s)	α (vol%)	ρ_L (kg/m^3)	$\rho_{MIS.}$ (kg/m^3)
W-ref	$8x10^7$	6	43,3	7,5	195,2	185,8	88,4	2412,9	291,8
W-ref-ml	$8x10^7$	9	41,4	8,9	214,9	203,4	88,8	2466,4	290,8
G-ref	$1,4x10^8$	4	50,6	8,2	160,1	155,6	82,4	2481,7	447,9
G-ref-ml	$1,4x10^8$	6	52,7	8,0	183,2	173,5	85,9	2535,2	369,6
G-ref-p	$1,4x10^8$	4	57,7	6,2	164,6	158,2	86,8	2491,4	424,6
G-ref-dp	$1,4x10^8$	4	50,5	7,6	175,7	164,6	83,4	2484,7	424,6

$\dot{m}$ = mass flow rate; H_2O = the water content of the original magma; D = conduit diameter; P = pressure; v_G = gas velocity; v_L = liquid (liquid + crystals) velocity; α = gas volume fraction; ρ_L = liquid (liquid + crystals) density; ρ_{MIS} = mixture (gas + liquid + crystals) density.

Thermo-fluid-dynamic modelling of magma chamber evolution

We have started an investigation, initially not planned within the objectives of the UR, aimed at the implementation of a new code for the simulation of the internal thrmo-fluid dynamics of magma chambers, and that solves the conservation equations of mass, momentum, and energy, for both incompressible and compressible fluids. Within the wide computational literature, the more appropriate numerical method is the Finite Element method (Fletcher, 1988; Ferziger and Preric, 1996; Hughes, 2000), with discretization both in space and time, Galerkin Least Squares stabilizing parameters (Shakib, Hughes and Johan, 1991), the GMRES iterative algorithm to solve the linear systems (Saad and Schultz, 1986). The C++ programming language and philosophy of code development are the best choice to update, extend and revise the growing code as is needed by the continuous evolution of numerical techniques (Stroustrup, 1993; Eckel, 2000). The C++ OFELI library is an object oriented collection of finite element standard routines for the discretization of equations on the grid of calculation, and for the assembly the resulting matrices and vectors (Touzani, 2002). The set of primitive unknown variables (pressure, velocity, and temperature) is used since it is the it best resolves both domains of fluid motion, allows to prescribe initial and boundary conditions, and to calculate the equations of state of magma (Hauke and Hughes, 1998). The whole numerical code has to

be written as the authors do not release any version of the program (Personal communication, Hauke, 2002). The matrix and right-hand-side vector of the linear system that derives from the discretized equations contain some standard terms typical of the Galerkin technique, and new terms that enhance the performance of the numerical calculus. Up to now the Galerkin method has been implemented and its results are being cheked on well-known cases such as pipe flow, driven cavity, compression corner, and others. The GMRES algorithm has been rewritten and made compatible with the OFELI library language. Two new materials, the perfect gas and the magma, have been built within the OFELI framework. The work described above has resulted in the implementation of a preliminary version of the main of the code, of new classes that represent the new objects needed, and of new functions in the interior of preexisting classes.

Textural characteristics of pumice erupted from dacitic as compared to trachytic eruptions

We have characterized pumice products belonging to the climactic phase of the 1991 Pinatubo eruption and the 800 yr BP Quilotoa eruption. Results of the former have been reported in the I year report; a summary of the most relevant results obtained with the study on Quilotoa is reported in the following. Bulk rock compositions, petrography, mineral and glass chemistry and textural investigations were performed on the three end-member pumice types, namely white, gray and mingled pumices. Despite all the investigated pumice clasts are dacites characterized by the same bulk rock composition and mineralogical assemblage, glass compositions and bulk textures change according to different pumice types. The results show that white pumice has higher crystallinity (~48 wt%), abundant euhedral pheno/microphenocrysts, no groundmass microlites, the most evolved glass compositions (74-78 wt% SiO_2), and heterogeneous vesicle populations marked by deformed and highly coalesced vesicles with thin walls. Gray pumice exhibits lower crystallinity (29-36 wt%), abundant broken and/or resorbed crystals, ubiquitous groundmass phenocryst fragments and microlites, the widest range of glass compositions (69-78 wt% SiO_2), and quite homogeneous poorly deformed and coalesced vesicles with thicker walls. Mingled pumices are characterized by the alternation of bands or patches with white and gray pumice compositional and textural characteristics. As in the case of Pinatubo, we attribute heterogeneities in glass compositions and crystal and vesicle textures to processes occurring within volcanic conduits as magma is ascending to the surface. In particular, this research has highlighted that shear and crystal fragmentation at the conduit walls, together with temperature increase due to viscous dissipation, are processes that may profoundly affect the distribution of magma properties within volcanic conduits, deeply influencing the eruption dynamics.

- RESEARCH PRODUCTS
  - n° of articles published on international journals: 3
  - invited talks: 1
  - presentations at international meetings: 8
  - Computation codes : 1 under development (for magma chamber dynamics)

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

Polacci, M., Papale, P., Rosi, M. (2001) Textural heterogeneities in pumices from the climactic eruption of Mount Pinatubo, 15 June 1991, and implications for magma ascent dynamics. Bulletin of Volcanology, 63: 83-97.

Todesco, M., Neri, A., Esposti Ongaro, T., Papale, P., Macedonio, G., Santacroce, R., Longo, A. (2002) Pyroclastic flow hazard assessment at Vesuvius (Italy) by using numerical modelling. I. Large scale dynamics. Bulletin of Volcanology, 64 : 155-177.

Neri, A., Papale, P., Del Seppia, D., Santacroce, R. (2003) Couplet conduit and atmospheric dispersal dynamics of the AD 79 Plinian eruption of Vesuvius. Journal of Volcanology and Geothermal Research, 120: 141-160.

RU 06 CARROLL

PROJECT TITLE: *Chlorine solubility behavior in evolved alkaline magmas*

RU Responsible
Name-Position: Michael Carroll, Professor
Affiliation: University of Camerino, Department of Earth Sciences

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Michael Carroll, Professor	University of Camerino	1.5
Marco PierMattei, PhD student	University of Camerino	6
Stefano Signorelli, post-doc	CISC, Barcelona	4
Cristina Perinelli, post-doc	University of Camerino	2
Claudio Cottone, technician	University of Camerino	1
Aldo Marchione, technician	University of Camerino	1

- 2nd YEAR OBJECTIVES

The objective for the second year of the project were to study how Cl solubility in magmas varies with melt composition and fluid composition, with particular interest in trachytic magmas. Cl solubility variations are of interest because significant variations in Cl emissions have been observed in volcanic areas but understanding why such variations occur, and what they can tell us about sub-surface processes requires a comprehensive knowledge of how melt-vapor partitioning of Cl varies with pressure, temperature, and magma composition. This work is part of Task 1 of the project (Physical chemistry of volatile species in magmas).

- 2nd YEAR RESULTS **(max 1 page)**
- New experimental facilities in Camerino, consisting of 3 rapid-quench hydrothermal bombs, are now fully functional and in continuous use. Experiments on Cl solubility in trachytic melts, started during the first year of the project, have been completed and some of this work has been published (Signorelli and Carroll, 2002). These experiments involve sealing known amounts of powdered silicate material and Cl-bearing solutions of variable molality inside Au or AgPd capsules and then running these capsules at 25-250 Mpa and 850-900°C for times of 5-10 days. The quenched samples (glass) are analyzed with the electron microprobe and fluid Cl molality is calculated by mass balance.
- Results for Cl solubility variations in a series of trachytic melts are shown in Figure 1. In phonolites and rhyolites there is a strong correlation between melt peralkalinity or peraluminosity and Cl solubility. However, in trachytic melts the melt Cl content appears to be independent of Na+K/Al. This suggests that crystallization during magma ascent will have little effect on melt-vapor partitioning of Cl as long as melts remain broadly trachytic in composition.

- We are currently working on developing models of how Cl solubility varies with melt composition and how melt/fluid partitioning of Cl depends on initial H2O/Cl ratio in magmas. These will be used to evaluate and predict Cl degassing behavior in ascending magmas undergoing decompression and partial crystallization (due to loss of water, which raises liquidus temperatures).
- We also completed related experimental and analytical work (Signorelli and Carroll, 2001) on the source of Cl degassed during the dome-building eruption at Montserrat. In this we were able to show that the magma is not saturated with a brine (the Cl content is too low) and that all of the Cl emissions can be simply explained by crystallization-induced degassing during magma ascent

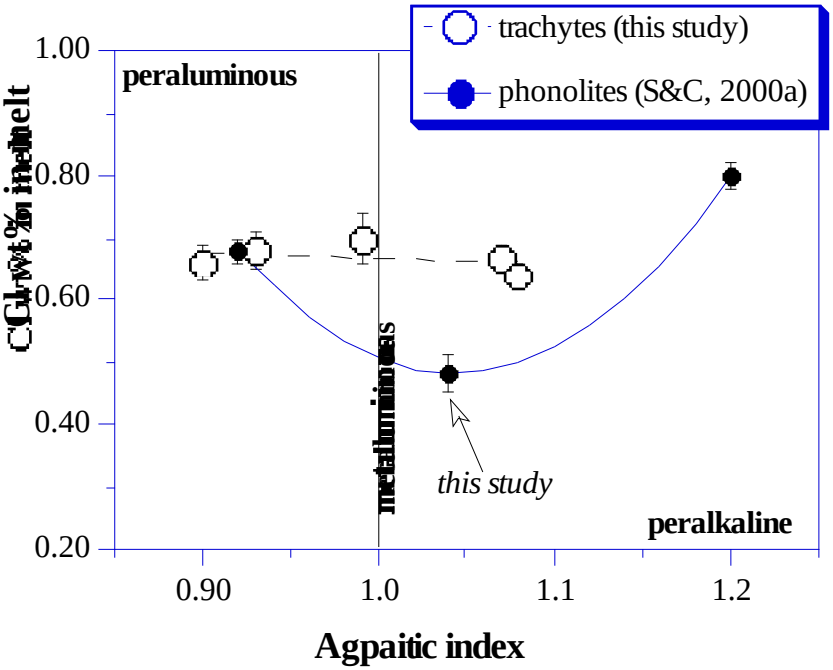

Figure 1. Solubility of chlorine (±1σ standard deviation) at 100 MPa as a function of molar (Na+K)/Al ratio for natural (Signorelli and Carroll, 2000a) and synthetic phonolites (this study), and natural trachytes (this study) saturated with an aqueous fluid + hydrosaline liquid.

- RESEARCH PRODUCTS
  - n° of articles published on international journals - **2**
  - n° of articles published on national journals, proceedings, technical reports - 0
  - invited papers and talks – **2** (December 2001 AGU and Chapman Conference on volcanism and climate, June 2002)
  - presentations at international meetings – **2**, both invited
  - presentations at national meetings; - 0
  - Data bases - 0
  - Computation codes – 2 ; one for doing mass balance calculations (Excel), second for predicting melt-vapor partitioning of Cl during magma ascent (Fortran, not complete – in progress)
  - Other – Member of Scientific Program Committee for Chapman Conference on "Volcanism and the Earth's Atmosphere" – involved organizing meeting, inviting speakers and designing scientific sessions.

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

Signorelli, S., Carroll, MR (2001) Chlorine solubility in peraluminous rhyolites from Soufriere Hills volcano, Montserrat: Implications for magmatic degassing. *Bulletin of Volcanology* 62, 431-440.

Signorelli, S., Carroll, MR (2002) Experimental study of Cl solubility in hydrous alkaline melts: constraints on the theoretical maximum amount of Cl in trachytic and phonolitic magmas. *Contributions to Mineralogy and Petrology* 143, 209-218.

RU 07 CIGOLINI

PROJECT TITLE

Eruptive Scenarios from Physical Modeling and Experimental Volcanology

Reasearch Title: Intracrustal evolution of Vesuvian and Strombolian magmas in the light of cumulates-melt interactions: geochemical processes connected with the eruption dynamics.

RU Responsible

Dr. Corrado Cigolini

Dipartimento di Scienze Mineralogiche e Petrologiche (DSMP), Università degli Studi di Torino

ACTIVITY REPORT –2° YEAR

UR PARTICIPANTS

Name-Position	Affiliation	man/month

1. Cigolini Corrado, Senior Researcher, DSMP Universita' di Torino, man/month 9.
2. Callegari Ezio, Professor, DSMP Universita' di Torino , man/month 6.
3. Rossetti Piergiorgio, Reseracher, DSMP Universita' di Torino, man/month 6.
4*. Marco Laiolo, PhD student, DSMP Universita' di Torino, man/month 4.
5*. Ruffini Raffaella, Researcher, DSMP Universita' di Torino, man/month 6 (died last October 2002).

- II YEAR OBJECTIVES

a. Thermobarometry of Vesuvian and Strombolian magmas to estimate their storage, ascent and degassing in relation to the eruption dynamics.

b. Geochemical modeling of Vesuvian and Strombolian magmas in the light of trace element and isotope data.

- II YEAR RESULTS

Methods

We contructed a grid of reactions to constrain thermobarometric estimates on Vesuvian and Strombolian magmas. These ractions were solved by means of classical equilibrium thermodynamics to obtain P-T estimates for the ascent and storage of Vesuvian Strombolian magmas.

Additional geochemical data were utilized for modelling parent-daughter relationships in Vesuvian and Strombolian magmas in order to infer their source region and constraining the parameters associated with partial fusion (this can be achieve by Sr-Nd isotope data).

The research activity of some of our team has been dedicated to refine data acquisition by EMPA to include selected trace elements. Some minor work has been also dedicated to evaluate radon anomalies at Somma-Vesuvius.

Collection of data

We have used several techniques to analyse selected materials such as cognate mafic and ultramafic nodules found as ejecta at Mount Vesuvius, and within some recent basaltic lavas at Stromboli. We probed these materials (minerals, melt inclusions, as well as interstitial glasses) including the lavas, by means of electron microprobe and a Laser Ablation spectrometer (LA-ICP-MS) operative at the University of Bristol. Glasses of melt inclusions (in olivine and clinopyroxene) were also analysed for water and carbon dioxide by using FTIR.
However, we obtained a complete geochemical data set on Vesuvian lavas and tephra, together with several of Stromboli, by using our ICP-AES operating at our Department.
We are also starting to collect U/Th data (obtained by means of a α spectrometer ORTEC 576A) to investigate the ascent and storage of Strombolian magmas.

Modeling and Interpretations

We concentrated our work on the thermobarometry of subeffusive ejecta which are produced by cumulus processes occurring within the subvolcanic environment of Mount Vesuvius. Our samples are essentially *clinopyroxene-rich phonotephritic porphyries* and *italites* ejected during the last eruption of 1944. The results indicate that these materials crystallised at pressures of about 6-3 kbar for temperatures ranging from 1260-1130 °C, and variable water contents from about 1.7 wt% to nearly anhydrous conditions (the latter are reached at lower pressures, i.e. at about 3 kbar). This indicates that magma has suffered progressive degassing during its crystallization in the subvolcanic region. These estimates are basically consistent with recent geophysical data, obtained by high-resolution seismic tomography, which constrain the depth of the top of the "active" magma chamber at about 12 km.
Similarly we have constrained the P-T estimates for mafic and ultramafic nodules at Stromboli. Comagmatic mafic nodules are represented by gabbroes, grabbronorites and anorthosites. These materials are in equilibrium with basaltic magmas at pressures of 3.5-2.5 kbar and temperatures of 1050-900 °C, and represent Strombolian magma batches that have been strored at depth during their ascent. Ultramafic nodules are essentially *dunites* and *wherlites* (with textural features of mantle peridotites) and represent mantle materials that crystallised at pressures of 8-11 kbar (i.e., along the crust-mantle boundary layer below the island of Stromboli). Preliminary U/Th disequilibria on Strombolian lavas, show that basaltic magmas are likely to be stored for longer time within the upper mantle-lower crust regions before being erupted (their relative age is estimated to be around 385 ka).
Geochemical modeling has been focused on Vesuvian magmas. REE data and Sr-Nd isotopy indicate that these magmas are produced by partial fusion (5-7 %) of an eclogitic source (which suffered a moderate enrichment: ε_{Nd} ranges from –0.9 to –3.7). Addidional geochemical modeling is currently in progress for Strombolian magmas, particularly in trying to identify genetic relationships between calc-alkaline and shoshonitic magmas (this association is also typical of some Oligocene volcanic rocks in Western Italian Alps).

- RESEARCH PRODUCTS

n° 06 (three) contributions for international journals.
n° 03 (three) presentations at international meetings.
n° 03 (three) presentations at national meetings.
n° 02 (two) theses (Tesi di Laurea; M.Sci equivalent) in agreement with some of the goals of the coordinated project.

PUBLICATIONS LIST

Contributions for international journals

LAIOLO M. , CIGOLINI C., 2002. Mafic and ultramafic “xenoliths” in recent basaltic lavas: new insights on the ascent and storage of Strombolian magmas. Bull. Volcanol. (submitted).

CALLEGARI E., CIGOLINI C., Medeot O., D’Antonio M., 2002. Petrogenesis of Calc-alkaline and Shoshonitic Post-Collisional Volcanics of the Cover Series of the Sesia Zone, Western Italian Alps, Geodinamica Acta (accepted).

CIGOLINI C., Gervino G., Marino C., 2002. Possible role of the hydrothermal dynamics in triggering eruptions: evidence from high-resolution survey at Somma-Vesuvius. Manoscritto. (D.L. Luogotenenziale 31/08/1945, n. 660). Journal of Volcanology and Geothermal Research (submitted).

A.Borghi, R.Cossio, F.Olmi, R.RUFFINI, G.Vaggelli (2001)- EPMA Major and trace element analysis in garnet and its petrological applications, Mikrochimica Acta, 139 (1-4): 17-25.

R. RUFFINI, A.Borghi, R.Cossio, F.Olmi and G.Vaggelli (2001) - Volcanic quartz growth zoning identified by cathodoluminescence and EPMA studies. Abstract of the Congress European Microbeam Analysis Society, Mikrochimica Acta, 139 (1-4): 151-158.

Cossio R, Borghi A, RUFFINI R., 2002. Quantitative modal determination of geological samples based on X-ray multielemental map acquisition. Microscopy and Microanalysis 8 (2): 139-149.

Presentations at international meetings

CIGOLINI C., LAIOLO M., 2002. New Insights on the ascent and storage of strombolian magmas: inference from mafic and ultramafic xenoliths. Explosive Volcanism in subduction Zones, Montagne Pelée, Martinique 12-16 Mai, 56.

COPPOLA, D., CIGOLINI, C., 2002. Geometry of lava tubes and rheological properties of basalts: Piton de la Fournaise (Reunion Island). European Geophysical Society, Nice, France, April 21-26.

CIGOLINI, C., RUFFINI, R., LAIOLO, M., 2002. Subeffusive ejecta at Mount Vesuvius: evidence for a "shallow" magma reservoir. European Geophysical Society, Nice, France, April 21-26.

Presentations at national meetings

CIGOLINI C., Gervino G., Laiolo M., 2002. Termobarometria di inclusi femici ed ultrafemici

stromboliani: inferenze sulla genesi, stazionamento e risalita dei magmi alla luce dei disequilibri U-

Th. Convegno SIMP Rende-Cetraro, Settembre 15-18.

ROSSETTI P., Dematteis A., Sacchi E., Mancari G., Vanzo I., Delle Piane L., Perello P., Conti A. (2002) - A multidisciplinary study of late-alpine hydrothermal fillings in the Gran Paradiso Massif (Orco Valley, North-western Alps): an unconventional approach in hydrogeological studies for underground works. 81a Riunione Estiva della Società Geologica Italiana "Cinematiche collisionali: tra esumazione e sedimentazione", Torino, 287-288.

ROSSETTI P., Agangi A., Castelli D., Padoan M., Ruffini R. (2002) - Magmatic versus hydrothermal activity in the roof zone of the Valle del Cervo pluton (Italian Western Alps). 81a Riunione Estiva della Società Geologica Italiana "Cinematiche collisionali: tra esumazione e sedimentazione", Torino, 285-286.

Data bases

A selected collection of samples of Vesuvius and Stromboli (including nodules, accidental xenoliths, pyroclastic material, ashes and minerals) is currently stored at the "Dipartimento di Scienze Mineralogiche e Petrologiche (Università degli Studi di Torino)" and the "Museo Regionale di Scienze Naturali di Torino".

Theses

Cappadona C., 2002. Su alcune lave e proietti delle eruzioni storiche del Vesuvio depositati presso il Museo Regionale di Scienze Naturali di Torino: analisi comparativa dei campioni con i prodotti dell'attività recente. Tesi di Laurea, Dipartimento di Scienze Mineralogiche e Petrologiche, Università degli Studi di Torino, 153 pp. e Allegati.

Spennacchio D., 2002. Osservazioni geologico-petrografiche sullo Haüynofiro di Melfi, Complesso Vulcanico del Monte Vulture, Basilicata). Tesi di Laurea, Dipartimento di Scienze Mineralogiche e Petrologiche, Università degli Studi di Torino, 115 pp.

RU 08 DE VIVO

ACTIVITY REPORT 2ND YEAR (2002)

Prof. Benedetto DE VIVO

PROJECT TITLE

ITALIANO

Modulo A1) Studio geochimico-vulcanologico comparativo dell'attività dei periodi 472-1139 e 1631-1944 (Vesuvio).

Modulo A2) Contenuto di volatili nei magmi potassici e indagini sperimentali sulla solubilità di H_2O, Cl e F (Vesuvio).

Modulo B) Caratteristiche geologico-vulcanologiche, geochimiche, isotopiche e microanalitiche (melts) delle Ignimbriti della Piana Campana.

Responsabile scientifico: De Vivo Benedetto, Professore Ordinario, Università di Napoli Federico II, Dipartimento di Geofisica e Vulcanologia, Via Mezzocannone 8, 80134 Napoli. Tel: 081-2535065; Fax: 081-2535070; E-mail: bdevivo@unina.it.

INGLESE

Project: **A1)** Comparative geochemical-volcanological study of 472-1139 and 1631-1944 activities (Vesuvius).

A2) Volatile contents in potassic magmas and H_2O, Cl and F solubility experimental studies (Vesuvius).

B) Geochemical, isotopic and microanalitic (melts) characteristics of Campanian Plain Ignimbrites.

Scientist Responsible: De Vivo Benedetto, Full Professor, Università di Napoli Federico II, Dipartimento di Geofisica e Vulcanologia, Via Mezzocannone 8, 80134 Napoli. Tel: 081-2535065; Fax: 081-2535070; E-mail: bdevivo@unina.it.

ACTIVITY REPORT–2nd YEAR

PARTECIPANTI ALL'UNITA' DI RICERCA/UR PARTICIPANTS

Nome-Qualifica /Name-Position	***Afferenza /Affiliation***	**Mesi/uomo man/month**
Rolandi Giuseppe – Prof. Associato	Università Napoli Federico II	2
Lima Annamaria – Prof. Associato	Università Napoli Federico II	3
Raia Federica – Assist. Professor	New York City College, N.Y.	1
Somma Renato – Assegnista/Post-Doc	Università Napoli Federico II	8
Tarzia Maurizio - Dottore di Ricerca/PhD	Collaboratore	3

Fedele Luca – Post Doc.	. Università Napoli Federico II	8
Cicchella Domenico –Dottorando/PhD	Univ. Napoli Federico II	5
Bodnar Robert – Full Professor	Virginia Tech, Blacksburg, USA	1
Ayuso A. Robert – Researcher	U.S. Geol. Survey, VA, USA	1
Belkin E. Harvey – Researcher	U.S. Geol. Survey, VA, USA	1
Webster D. James – Researcher	Amer. Museum Nat. History, N.Y., USA	2
Bohrson Wendy – Assistant Professor	Central Washington Univ., WA, USA	1
Spera J. Frank – Full Professor	Univ. Calif. Santa Barbara, USA	1
Danyushevsky Leonid	University of Hobart, Tasmania, Australia	1

2nd YEAR OBJECTIVES

For the second year of research activity, for the Modules A2 and B, it was programmed the following:

A1) During **the following 6 months of the second year**, data will be elaborated and submission of resulting papers to international peer review journals.

A2) During **II year** experimental work on synthetic samples representative of the phonolitic Vesuvius system. Volatile (H_2O e Cl) solubility experiments in melt of Mt Somma-Vesuvius phonolite and phonotephrite samples at 500 and 200 bars and 946-1057°C and 1122-1135°C.

B) During the **II year** continuation of all the analytical work started during the first year chemical analyses (major, minor, trace elements), isotope determinations (Sr, Nd, Pb, O), $^{40}Ar/^{39}Ar$ age dating, microanalyses of silicate-melt inclusions (ME, SIMS, FTIR) and U-Th disequilibria analyses.

2nd YEAR RESULTS

A1) Comparative geochemical-volcanological study of 472-1139 and 1631-1944 activities (Vesuvius):

1) It has been completed and published the study of Somma – Vesuvius skarns (petro-chemistry; fluid inclusions; C, O, Pb, Sr and Nd isotopes). The inclusions show evidence of immiscibility between several fluids (silicate melt- aqueous chloride-rich liquid – carbonate/sulfate melt). There is no evidence for fluid circulation below 700°C and participation of externally derived meteoric fluids in skarn formation. The isotope composition of skarns and the presence of silicate melt inclusion-bearing wollastonite nodules suggests assimilation of carbonate wall rocks by the alkaline magma at moderate depths (< 5 km) and consequent exsolution of CO_2-rich vapor and complex

saline melts from the contaminated magma that reacted with the carbonate rocks to form skarns. The results of the research are reported in Gilg et al. (2001).

2) It has been done and publshed a comparative study between the Campi Flegrei and Mt Somma – Vesuvius magmatism, using compositions of reheated melt inclusions in clinopyroxene phenocrysts from xenoliths in volcanic breccia. The results indicate a close relationship (or link) between the Campi Flegrei and Mt Somma magmatic systems, which have until now been considered separate. We speculate that the link was established only prior to eruption of the Neapolitan Yellow Tuff (~ 12 ka); the Campi Flegrei older magmatism had close similarities with the volcanism of the older products of Mt Somma (> 25 ka). The results are reported in Danyushevsky and Lima (2001).

3) It has been done and published a study on the metallogenic potential of the Mt Somma – Vesuvius magmatic system through the systematic characterization of metallic elements in all the eruptive events of the Mt Somma – Vesuvius (from > 25 ka to 1944). The results are reported in Paone et al. (2001).

4) It has been completed and published the geochemical study (major, trace elements, REE and Sr, Nd, Pb isotopes) of all the interplinian eruptions (Protohistoric, Ancient Historic and Medieval Formations) between 3550 YBP and 1944 AD. The study represents a true geochemical and isotopic stratigraphy of Vesuvius and bring new contribution for the characterization of magma source. The results reported in Somma et al. (2001) have only been preliminary interpreted; the large amount of data produced need still to be worked out in order to decipher completely the message contained in them. A second paper is in progress on the elaboration of the above data.

5) A publication on Sr isotope data is in preparation on the products of the overall Mt Somma – Vesuvius system, covering each single eruptive event, from > 25 ka to 1944 A.D. The data elaboration is in progress; within 2001 a paper will be submitted on a peer review journal.

6) It has been submitted for publication a paper on the U – Th series disequilibria data on all the representative interplinian eruptive events of period 472 – 1139 A.D. (Cortini et al, in stampa).

A2) Volatile contents in potassic magmas and H_2O, Cl and F solubility experimental studies (Vesuvius):

- It has been completed and published (Raia et al., 2000; Webster et al., 2001) the systematic study of reheated silicate melt inclusions for 29 constituents including H_2O, SO_2, Cl, F, B and P_2O_5 on the magmatic phenocrysts of the entire Mt Somma – Vesuvius activity (from 25 ka to 1944 AD) using EMPA and SIMS. Eruptive behavior at Vesuvius was a function of pre-eruptive volatile enrichments, because magmas associated with explosive plinian and subplinian activities younger than 3,550 years contained significantly more SO_2 and H_2O than magmas of similar age feeding the relatively passive interplinian eruptions.
- It has been published a study which demonstrates that Cl solubility was dramatically reduced changing composition and, hence, that a chloride brine may have exsolved directly from these Cl-enriched mafic magmas by a process other than first or second boiling (Webster and De Vivo, 2002).
- It has been completed and published an experimental study on H_2O and Cl solubility in phonolitic and phonotephritic Vesuvius melts at 500 and 2000 bars and 946-1057°C and 1022-1135°C (Webster et al., in press a).
- It has been published a model for the evolution of the Somma-Vesuvius magmatic system based on fluid and melt inclusion data. The proposed model implies the existence of more than one magma chambers (at least 3) at different depths (between 4 and $\geq$ 12 km) and a long repose time at the Vesuvius (centuries?) after the last 1944 A.D. eruption (Lima et al., in press).
- Experiments on synthetic glasses at atmospheric pressure and elevated temperature, have been done to determine the F effects on the liquidus temperatures and on the phase relationships in a relevant portion of the phonolitic system. The experimental runs demonstrate that F has relevant

effects on the liquidus temperatures, lowering them up to 150°C as a function of the composition, and does not permit the crystallization of leucite and feldspars, with the exception of nepheline. The results are in preparation and will be soon submitetd for publication to a peer review international journal (Fedele et al., in prep).

B) Geochemical, isotopic and microanalitic (melts) characteristics of Campanian Plain Ignimbrites:

1) Significantly new volcanological, geochronological ($^{40}Ar/^{39}Ar$) and geochemical data distinguish previously unrecognized ignimbrite deposits in the Campanian Plain, accurately dated at ~ 154, ~ 184 and ~ 205 ka. These ages, coupled with a xenocrystic sanidine component > 315 ka, extend the volcanic history of this region by over 200 ky. The $^{40}Ar/^{39}Ar$ defines the age of the Campanian Ignimbrite at 39.28 $\pm$ 0.11 ka, about 2 ky older than the previous best estimate. In addition the new $^{40}Ar/^{39}Ar$ dating identifies a pyroclastic deposit, dated at 18 ka, outside of the topographic Campi Flegrei basin, expanding the spatial distribution of post-Campanian Ignimbrite deposits. These new discoveries emphasize the importance of continued investigation of the ages, distribution, volumes, and eruption dynamics of volcanic events associated with the Campanian Plain. The results of the above researches are reported in De Vivo et al. (2001). Other $^{40}Ar/^{39}Ar$ age dating of critical ignimbritic outcrops from the Campanian Plain individuate other ignimbrite events dated at 116-109 ka (Rolandi et al., in press).

2) It has been completed and publishedthe study on composition and volatile content in phenocrysts of the different ignimbritic events, between 205 and 18 ka (dated by $^{40}Ar/^{39}Ar$), by means of EMPA and SIMS (Webster et al, in press b). The data elaboration is in progress for a paper to be submitted on a peer review journal.

3) It has been completed the analytical work of major + trace elements, on U – Th series disequilibria and on Sr, Nd and Pb isotopes on the different ignimbritic events, dated by $^{40}Ar/^{39}Ar$ between 205 and 18 ka. The data elaboration is in progress for papers to be submitted on a peer review journals during 2003.

OTHER

In addition to the research Themes A1, A2 and B, the Prof. De Vivo research group is preparing a Data Base, containing all the chemical data (major, minor, trace), isotope data (Sr, Nd, Pb, O, U-Th Series), fluid and melt inclusion data, obtained, in the last 10 years, on the complete activity products of Somma – Vesuvius from > 25,000 YBP to 1944 A.D. The Data Base will be accompanied by a map reporting the distribution of more than 250 samples and will be available to the Scientific Community as a CD.

RESEARCH PRODUCTS

- n° of articles published on international journals: **13**
- n° of articles published on national journals, proceedings, technical reports: **8**
- invited papers and talks: **0**
- presentations at international meetings: **8**
- presentations at national meetings: **1**
- Data bases : **1 (in prep.)**
- Computation codes : **0**
- Other (Edited scientific volumes): **3**

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

1 – DE VIVO B. and G. ROLANDI, 2001. Preface – Special issue: Mt Somma – Vesuvius and volcanism of the Campanian Plain. Mineralogy and Petrology, 73: 1-3.

2 – DE VIVO B., ROLANDI G., GANS P.B., CALVERT A., BOHRSON W.A., SPERA F.J. and H.E. BELKIN, 2001. New constraints on the pyroclastic eruptive history of the Campanian volcanic Plain (Italy). Mineralogy and Petrology, 73: 47-65.

3 –SOMMA R., AYUSO R.A., DE VIVO B. and G. ROLANDI, 2001. Major, trace element and isotope geochemistry (Nd-Pb) of interplinian magmas from Mt Somma-Vesuvius (Southern Italy). Mineralogy and Petrology, 73: 121-143.

4 – GILG H. A., LIMA A., SOMMA R., BELKIN H. E., DE VIVO B. and R. A. AYUSO, 2001. Isotope geochemistry and fluid inclusions study of skarns from Vesuvius. Mineralogy and Petrology, 73: 145-176.

5 – WEBSTER J. D., RAIA F., DE VIVO B. and G. ROLANDI, 2001. The behaviour of chlorine and sulfur during differentiation of the Mt. Somma-Vesuvius magmatic system. Mineralogy and Petrology, 73: 177-200.

6 – PAONE A., AYUSO R. A. and B. DE VIVO, 2001. A metallogenic survey of alkalic rocks of Mt. Somma-Vesuvius volcano. Mineralogy and Petrology, 73: 201-233.

7 – WEBSTER J.D. and B. DE VIVO, 2002. Experimental and modeled solubilities of chlorine in aluminosilicate melts, consequences of magma evolution, and implications for magmatic brine exsolution at Mt. Somma-Vesuvius. American Mineralogist, 87: 1046-1061**.**

8 – CORTINI M., AYUSO R.A., DE VIVO B., HOLDEN P. and R. SOMMA. Isotopic composition of Pb and Th in interplinian volcanics from Somma-Vesuvius volcano, Italy. Mineralogy and Petrology (in stampa).

9 – LIMA A., DANYUSHEVSKY L.V., DE VIVO B. and L. FEDELE. A model for the evolution of the Mt. Somma-Vesuvius magmatic system based on fluid and melt inclusion investigations. In: Melt Inclusions: Methods and Problems (B. De Vivo & Bodnar R.J. Eds), Series “Developments in Volcanology”, Elsevier, Amsterdam, pp. (in stampa).

10 – KAMENETSKY V.S., DE VIVO B., NAUMOV V.B., KAMENETSKY M.B., MERNAGH T.P., VAN ACHTERBERGH E., RYAN C.G. and P. DAVIDSON. Magmatic inclusions in the search for natural silicate-salt melt immiscibility: methodology and examples. In: Melt Inclusions: Methods and Problems (B. De Vivo & Bodnar R.J. Eds), Series “Developments in Volcanology”, Elsevier, Amsterdam, pp. (in stampa).

11 – WEBSTER J.D., DE VIVO B. and C. TAPPEN. Volatiles, magmatic degassing and eruptions of Mt. Somma-Vesuvius: constraints from silicate melt inclusions, solubility experiments and modeling. In: Melt Inclusions: Methods and Problems (B. De Vivo & R.J. Bodnar, Eds), Series “Developments in Volcanology”, Elsevier, Amsterdam, pp. (in stampa, a).

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14 – FEDELE L., WEBSTER J.D. and B. DE VIVO. The effect of fluorine on phase relationships in the silica under-saturated part of the system NaAlSiO4-KAlSiO4-SiO2 at 1 Atm and the speciation of fluorine in silicate melts (in prep.)

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1 - DE VIVO B. and G. ROLANDI (Editors), 2001. Mt Somma – Vesuvius and volcanism of the Campanian Plain. Special Issue of Mineralogy and Petrology, 73 (1-3), 233 pp.

2 – DE VIVO B. and R. J. BODNAR (Editors). Melt inclusions: methods and problems. Series "Development in Volcanology", Elsevier, pp.. (in stampa).

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1 – DE VIVO B., 2002. Preface to the Workshop. Workshop-Short Course on Volcanic Systems. Geochemical and geophysical Monitoring. Melt Inclusions: Methods, Applications and Problems (De Vivo B. and R. J. Bodnar, Edts), Proceedings, Sept 26-30th, 2002, Seiano di Vico Equense (Sorrento Peninsula) – Napoli, Italy, 7 – 10.

2 – KAMENETSKY V.S., DE VIVO B., NAUMOV V.B., KAMENETSKY M.B., MERNAGH T.P., VAN ACHTERBERGH E., RYAN C.G. and P. DAVIDSON, 2002. Magmatic inclusions in the search for natural silicate-salt melt immiscibility: methodology and examples. Workshop-Short Course on Volcanic Systems. Geochemical and geophysical Monitoring. Melt Inclusions: Methods, Applications and Problems (De Vivo B. and R. J. Bodnar, Edts), Proceedings, Sept 26-30th, 2002, Seiano di Vico Equense (Sorrento Peninsula) – Napoli, Italy, 125 – 130.

3 – LIMA A., DANYUSHEVSKY L.V., DE VIVO B. and L. FEDELE, 2002. Evolution of Mt.Somma-Vesuvius magmatic system: fluid and melt inclusion investigations. Workshop-Short Course on Volcanic Systems. Geochemical and geophysical Monitoring. Melt Inclusions: Methods, Applications and Problems (De Vivo B. and R. J. Bodnar, Edts), Proceedings, Sept 26-30th, 2002, Seiano di Vico Equense (Sorrento Peninsula) – Napoli, Italy, 137 – 141.

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1 - DE VIVO B., ROLANDI G., GANS P.B., CALVERT A., BOHRSON W.A., SPERA F.J. and H.E. BELKIN, 2001. New constraints on the pyroclastic eruptive history of the Campanian volcanic plain (Italy). Workshop "Evaluating magmatic processes by laboratory experiments, physical modeling and field measurements". INGV-GNV Framework Program 2000-2002. Programme and Proceedings, Roma, 27-29/6/2001, 39 – 44.

2 - SOMMA R., AYUSO R.A., DE VIVO B. and G. ROLANDI, 2001. Geochemical and isotopic evolution of interplinian magmas erupted from Mt. Somma-Vesuvius (Southern Italy). Workshop "Evaluating magmatic processes by laboratory experiments, physical modeling and field measurements". INGV-GNV Framework Program 2000-2002. Programme and Proceedings, Roma, 27-29/6/2001, 119 - 124.

3 - SOMMA R., AYUSO R.A. and B. DE VIVO, 2001. Preliminary results of Sr isotopic evolution of plinian and interplinian rocks from Mt. Somma-Vesuvius (Southern Italy). Workshop "Evaluating magmatic processes by laboratory experiments, physical modeling and field measurements". INGV-GNV Framework Program 2000-2002. Programme and Proceedings, Roma, 27-29/6/2001, 125 - 129.

4 - WEBSTER J. and B. DE VIVO, 2001. Forecasting violent eruptive behavior of Mt. Somma-Vesuvius from pre-eruptive volatile contents of magmas as determined from silicate melt inclusions, volatile solubility experiments, and modeling. Workshop "Evaluating magmatic processes by laboratory experiments, physical modeling and field measurements". INGV-GNV Framework Program 2000-2002. Programme and Proceedings, Roma, 27-29/6/2001, 139 - 144.

Riassunti/Abstracts

1 – SOMMA R., AYUSO R.A., BELKIN H.E., BOHRSON W., PAONE A: and B. DE VIVO, 2001. Pb isotopic compositions of the Campanian Ignimbrite(s), Italy. Eur. Geoph. Soc., 26th General Assembly, Nice, France, 25 – 30 March. Geoph. Res. Abstracts, Vol. 3, p. 9069.

2 – SOMMA R., AYUSO R.A. abd B. DE VIVO, 2001. Sr isotopic evolution of Mt. Somma-Vesuvius volcano during the last 25 KY B.P. Eur. Geoph. Soc., 26th General Assembly, Nice, France, 25 – 30 March. Geoph. Res. Abstracts, Vol. 3, p. 9070.

3 – PAONE A., WEBSTER J.D., RAIA F. and B. DE VIVO, 2001. Preliminary results of melt inclusion and experimental volaile solubility studies for alkaline magmas of Mt. Somma-Vesuvius volcano. Eur. Geoph. Soc., 26th General Assembly, Nice, France, 25 – 30 March. Geoph. Res. Abstracts, Vol. 3, p. 9126.

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5 – SOMMA R., CORTINI M. and B. DE VIVO B, 2002. Pb isotopic composition and U-Th disequilibria series of whole rocks interplinian volcanics from Mt Somma-Vesuvius. EGS XXVII General Assembly, Nice, 21 – 26 April. Abstracts.

6 – DE VIVO B: and J. D. WEBSTER, 2002. Forecasting violent eruptive behavior of Vesuvius from pre-eruptive volatile contents of magmas as determined from silicate melt inclusions studies. EGS XXVII General Assembly, Nice, 21 – 26 April. Abstracts.

7 – PAONE A., AYUSO R.A., DE VIVO B. and G. ROLANDI, 2002. Evidence of recycling sediments in the Italian peninsula. EGS XXVII General Assembly, Nice, 21 – 26 April. Abstracts.

8 –WEBSTER J.D. and B. DE VIVO, 2002. Interpretation of Magmatic Brine Exsolution at Mt. Somma-Vesuvius Through Studies of Melt Inclusions, Chlorine Dissolution Experiments, and Modeling. Eos. Trans. AGU, 83 (19), Spring Meet. Suppl., Abstracts, S369

9 – PETTKE T., WEBSTER J.D., HALTER W.E., HEINRICH C.A. and B. DE VIVO, 2002. Advantages and limitations of quantifying melt inclusion chemistry by LA-ICPMS, EMP and SIMS. Geoch. Cosmoch. Acta Abstracts of the 12th Annual V.M. Goldscmidt Conference, Davos, August 18-23, 2002, p. A596.

RU 09 DOLFI

PROJECT TITLE: Kinetics of degassing in silicic magmas

RU Responsible **Professoressa associata di Vulcanologia Daniela Dolfi, Università degli Studi di Roma Tre.**

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month

Professoressa associata di Vulcanologia Daniela Dolfi, Università degli Studi di Roma Tre. 6 man/month

PhD student Giada Iacono Marziano, Università degli Studi di Palermo, CFTA Department. 9 man/month

- 2nd YEAR OBJECTIVES

Solubilization experiments of different amounts of water in natural (previously degassed) starting material, at HP (up to 500 MPa) and HT (up to 1200°C) to facilitate water diffusion and homogeneous water distribution in the samples. Decompression experiments at different ΔP with controlled decompression rates and comparison with the residual water content in pumice glass.

- 2nd YEAR RESULTS

We performed and we are still performing experimental runs in TZM type externally heated pressure vessels of the HP-HT Laboratory of the Università degli Studi di Roma "La Sapienza". This kind of apparatus uses Ar as compressive medium and is equipped with a fast quenching magnetic device, that permits an isobaric quenching at the velocity of about 100°C/s.

Two groups of experiments are being carried on: solubility experiments and decompression experiments.

Solubility runs are performed at superliquidus temperature and at 100-200 MPa fixed pressure. Run duration is in the range 24-72 hours, the time necessary to reach vapor-melt equilibrium. Run products consist in crystals free glasses that are considered representative of the superliquidus melts at the pressure of interest. Generally isolate bubbles are present.

Rock powders are loaded in Au-Pd capsules, H_2O is added as bidistilled water with a micrometric syringe, CO_2 as Ag_2CO_3 powder; the total weigh of the loaded sample is about 100 mg. The quantities of H_2O and CO_2 are added in excess respect to the saturation one calculated from the solubility model of Papale (1999).

Relative amounts of loaded volatiles are variable in order to investigate, at constant pressure, H_2O and CO_2 solubilities in function of their molar fraction in the vapor (calculated by mass balance and measured when possible).

Decompression runs are performed at the same way than solubility experiments, but, before quenching, samples are decompressed with a fixed rate (in the range 0.05 and 5 MPa/s) to the final pressure and then rapidly quenched.

Glasses, from both solubility and decompression experiments, are prepared as doubly polished chip to be analyzed by Fourier transform infrared spectroscopy (FTIR).
Transmission FTIR spectra are being acquired on bubble free portions of glass, to measure the amounts of H_2O and CO_2 dissolved. In samples with the presence of some isolated bubbles we are tenting to measure vapor composition inside bubbles, separating the bubble spectrum from the interference of the glass that is present in the IR beam.
Density measurements of the glasses are performed with a Berman Balance on bubble free samples.
Extinction coefficients for H_2O and CO_2 investigated bands are chosen among published data for the compositions of interest; the phonolitic glass is calibrated for CO_2 and carbonate bands, because extinction coefficients for these bands are not known at the moment.

PUBLICATIONS LIST

Dolfi D., Iacono Marziano G., (2001). Parametri strutturali e contenuto di acqua nelle pomici delle eruzione del Vesuvio del 79 DC. Programme and Proceedings of INGV-GNV First Year Workshop: Evaluating magmatic processes by laboratory experiments, physical modelling and field measurements. Pag 45-51.

De Natale G., Chiarabba C., Troise C., Trigila R., Dolfi D., (2001) Determination of 3D Sub-structure of Somma-Vesuvius Volcano: the effect of magma quenching due to gas exolution. EOS. Trans. AGU, 82(47), Fall Meet. Suppl., Abstract V31A-0941, Dec.10-14/12 S.Francisco (Ca) U.S.A

RU 10 NUCCIO

INVESTIGAZIONI SPERIMENTALI SULLA SOLUBILITÀ DI GAS INERTI (HE, NE, AR, N_2) IN MAGMI CONTENENTI H_2O E CO_2 E SUL FRAZIONAMENTO ISOTOPICO TRA VAPORE E FUSO SILICATICO PER H_2O E CO_2.

Responsabile dell'Unità di Ricerca/RU Responsible Unità di Ricerca :
Prof. P.M. Nuccio
Dr. S. Rotolo (joined to the Research Unit of PROF. NUCCIO P.M.)

RAPPORTO DI ATTIVITA' – 2° ANNO/ACTIVITY REPORT –2° YEAR

PARTECIPANTI ALL'UNITA' DI RICERCA/UR PARTICIPANTS

Nome-Qualifica /Name-Position	Afferenza /Affiliation	mesi/uomo man/month
ROTOLO Silvio Giuseppe Ricercatore universitario	Dipartimento di Chimica e Fisica della Terra,	9
DI CARLO Ida Dottoranda di ricerca	Univ. di Palermo	2
PAONITA Antonio Ricercatore INGV-Pa	INGV – Sez. Palermo	5

- OBIETTIVI 2° ANNO / 2nd YEAR OBJECTIVES

Experimental study on nitrogen solubility in H_2O-CO_2 bearing silicate melts
Experimental study at 4 kb pressure on Stromboli magmas: the influence of H_2Omelt on phase equilibria and liquid composition at experimental temperatures 1100-1000 °C.

- RISULTATI 2° ANNO / 2nd YEAR RESULTS

Sviluppi metodologici

- Experimental protocol for high pressure experiments in presence of variably hydrated charges, at CNRS-ISTO di Orleàns (France) .
  - Experimental method to perform solubulity runs for minor reactive species in presence of H_2O and CO2 at buffered redox conditions.

Acquisizione dati

Experiments at 4 kb (on 2 starting compositions) for temperatures in the range (1000 ed i 1100 °C), and various H2O contents.

Interpretazione e modellistica

- Assessment of pressures and depths for the magmatic reservoirs in the Mt. Etna plumbing system
- Evolutionary model of Stromboli magmas at high pressure (4 kb) depending on activities of volatile species.

- PRODOTTI DELLA RICERCA/RESEARCH PRODUCTS
  - **n° pubblicazioni su riviste internazionali**
  - n°1 in press and n°1 submitted
  - **n° pubblicazioni su riviste nazionali, atti, presentazioni a convegni, rapporti tecnici, etc**
  - n° 4 presentations in workshop/congresses.
  - **banche dati**
  - **codici di calcolo**
  - Numerical model and related code to filter effects of dissolution in aquifer on the chemical data of dry gas emissions.
  - Code to assess magmatic degassing pressure by using relative variations in noble gas ratios
  - **altro**

ELENCO PUBBLICAZIONI/PUBLICATIONS LIST (includendo lavori in stampa e sottomessi)

1) ROTOLO S.G., CONTE A.M., DI CARLO I., PERINELLI C., TRIGILA R. (2001). *The transition from high-K calcalkaline to shoshonitic magmatism at Stromboli: preliminary experimental results at P=1 atm.* Annual meeting of Coordinated Project: Hazard assessment of Stromboli volcano.

2) ROTOLO S.G., CONTE A.M., DI CARLO I., PERINELLI C., TRIGILA R. (2001). *Experimental study on the transition from calcalkaline to shoshonitic magma series: an example from Stromboli volcan*. "Evaluating magmatic processes by laboratory experiments, physical modeling and field measurements" Roma I.N.G.V. 27-29 Giugno 2001.

3) CONTE A.M., DI CARLO I., PERINELLI C., ROTOLO S.G., TRIGILA R. (2001) Recent Stromboli magma evolution from calcalkaline to shoshonitic affinity on the grounds of melting experiments, under T, P, fO_2, PH_2O controlled conditions. FIST GEOITALIA 2001. Chieti, 5-8/ settembre 2001.

4) **ROTOLO S.G**., CONTE A.M., DI CARLO I., PERINELLI C., TRIGILA R. (2002). *Kinetic control on liquid composition and phase relations from cooling experiments on Stromboli lavas (Aeolian Isl.,Italy***).** International Symposium on Experimental Mineralogy, Petrology and Geochemistry. Zurich, 24-27 March 2002.

5) DI CARLO I, PICHAVANT M., **ROTOLO S.G.,** SCAILLET B. (2002) *Experiments at 4 kbar on "yellow pumice" of Stromboli (Aeolian Islands): preliminary results.* Plinius

6) CARACAUSI, A., R. FAVARA, S. GIAMMANCO, **P.M. NUCCIO, A. PAONITA**, G. PECORAINO AND A. RIZZO, Mount Etna: *Geochemical signals of magma ascent and unusually extensive plumbing system, Geophys. Res. Lett.*, in press.

7) ANTONIO CARACAUSI, FRANCESCO ITALIANO, **P. MARIO NUCCIO, ANTONIO PAONITA**, ANDREA RIZZO, *Evidence of deep magma degassing and ascent by geochemistry of peripheral gas emissions at Mt. Etna (Italy): assessment of the magmatic reservoir pressure*, J. Geophys, Res., submitted.

RU 11 POMPILIO

PROJECT TITLE

The role of volatiles on physical properties of basaltic magmas

RU Responsible Massimo Pompilio 1 ricercatore
Name-Position
Affiliation Istituto Nazionale di Geofisica e Vulcanologia – Sez. Catania

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
MassimoPompilio – I Ricercatore	INGV-CT	4
Lucia Miraglia – Art. 23	INGV-CT	2
Rosanna Corsaro – Ext. Collab.	Provincia di Siracusa	2
Paola del Carlo	INGV- CT	3

2nd YEAR OBJECTIVES

a) Phase relationship parametrisation

b) Estimates of range of value of physical properties

2nd YEAR RESULTS **(max 1 page)** The unusual eruptive style and magma composition observed in the recent eruptions of Etna (2001 and 2002) led us to focus our attention on products of these eruptions. In particular:

- phase relationship parametrisation have been extended to amphibole-bearing magmas
- Range of values of physical properties have been estimated on natural products of 2001 and 2002 eruption.

*Methodologie*s: Petrological, mineralogical (EMP, SEM-EDS, Micro FT-IR) and geochemical (XRF-ICP-AES and MS) investigation. Experimental petrology (External heated pressure vessels – TZM)

Data acquisition:. The most primitive and less crystalline sample bearing amphibole of the 2001 eruption have been used to constrain experimentally the physico-chemical conditions under which amphibole crystallizes in recent Etnean magmas. Runs have been performed in a TZM apparatus between 950 and 1035 °C of temperature, in the pressures range 50-200 Mpa using a natural sample at Brown University (Providence, RI –USA). The fO_2 was controlled by a CH_4-Ar pressurizing gas mixture set to maintain the charge under the NNO buffer. Melts and minerals have been analysed and compared with natural ones.

Petrological features of tephra erupted during the 2001 and 2002 eruptions including crystal size distribution and data on the chemical composition of the glass constrained eruptive temperatures and provides physical parameters inherent to the eruptied melts.

Data processing and interpretation.

1) Experimental runs produced samples with a crystal content variable from 5 to 40 %. Diopsidic pyroxenes and Ti-magnetite (X_{Usp}=.03-31) are ubiquitous in all the investigated P-T range. At P=140 MPa plagioclase (An57-90) is stable in addition to Ca-Pyroxene and magnetite, but only at T < 980, whereas at lower pressure it crystallizes at all temperatures in the investigated range. At his same pressure, olivine (Fo82-76) appears at a significantly higher temperature (T>1024 °C). Amphibole crystallizes at T<1000-995°C and H2O pressures > 75 Mpa. Experimental amphiboles range from pargasite to Mg-Hastingsite with less frequent kaersutite crystals; they have a lower

silica and an higher alumina content than those measured in natural samples. Experimental glasses in equilibrium with Cpx, Ti-mt and olivine plot along the liquid line of descent observed for natural historical magmas. However, the appearance of the amphibole on the liquidus, induces a significant shift toward compositions with lower MgO-FeOtot and $CaO-Al_2O_3$ ratios. These compositions were not measured neither in the residual natural glasses, nor in glass inclusion in minerals of recent volcanics. The above preliminary data suggest that some fine-tuning of physico-chemical parameters for the magma (e.g fO_2) must be still be done in order to reproduce the natural assemblage, and the abundance and compositions of minerals observed in natural samples. However these refinements will not significantly modify the field of amphibole stability in these magmas. The crystallization of the amphibole only below 1000 °C is in striking contrast with the supposed eruptive temperature (T>1050°C) of the main Etna hawaiite, and indicates that the amphiboles are xenocrysts or they come from colder portions of the magmatic reservoir (roof, walls) feeding the eruption.

2) Rheological and physical parameters have been estimated on the basis of the compositional and textural features observed in volcanic products.

Glass compositions measured in 2001-2 tephra of Etna can be considered as a part (sideromelane glasses in lapilli and ashes) or as an extension (tachylitic groundmass in lapilli and ashes) of a single and almost continuous liquid line of descent traced by historical glasses. Thus the calibration of Pompilio et al. (1998) can be used to estimate the eruptive temperature on the basis of MgO content of the residual glasses. According to the chemical composition average, eruptive temperature measured from tachylite glasses are always lower (~30-40°C) than those calculated using sideromelane glasses. However, eruptive temperature calculated from tachylite glasses are comparable with temperature measured directly or calculated from lava flow glasses of the 1991-93 eruption (Calvari et al, 1994). Similarly, sideromelane glasses yield eruptive temperature fully matching those calculated with same methods for recent Strombolian activity, and slightly lower than those estimated for Fire Fountain activity of previous eruptions.

Glass composition and related estimated temperature have been used to calculate apparent viscosity of the liquid following the Shaw (1970) method. Viscosity shows a pattern similar to that observed for the temperature with sideromelane having a viscosity 0.5-1.0 log unit lower than tachylite. These differences increase significantly (3-4 log unit) if we consider the bulk viscosity of the magma that strongly depends from the crystals fraction. However, both in sideromelane and tachylite glasses have viscosity significantly lower the recent lava bulk property (estimated by channel and flow-rate parameters) pertaining to the 1991-93 lava flow-field.

Yield strength, that would also affect fragmentation processes, has been also estimated on the basis of Ryerson et al. (1988) formula that relate it to the crystal content. Considering a difference of the 50-60 % in the crystal content between the two different kind of clasts, the resulting yield strength of tachylite is about one order of magnitude higher (10^3 Pa) than that of sideromelane (10^2 Pa). The yield strength of tachylite partially matches the lower range of yield strength values estimated in 1991-93 lava on the basis of lava levee and front.

- RESEARCH PRODUCTS
  - n° of articles published on international journals
  - n° of articles published on national journals, proceedings, technical reports
  - invited papers and talks
  - 2 presentations at international meetings
  - presentations at national meetings;
  - Data base
  - Computation codes : for calculating physical parameters on the basis of glass composition and crystallinity

- Other

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

- Corsaro, R.A. , Pompilio, (2002) Magmatic processes in the shallow plumbing system of Mt.Etna as recorded by compositional variations in volcanics of recent summit activity (1995-1999). Submitted to JVGR
- Corsaro R.A., Pompilio M. (2002) Dynamics of magmas at Mt. Etna present and past and past examples. Submitted for the AGU Book – Etna Volcano laboratory
- Corsaro R.A., Pompilio M (2002) Buoyancy of Etnean magmas. Submitted to Terra Nova
- Del Carlo P. & M. Pompilio (2002) The relationship between volatile content and the eruptive style of basaltic magma: the Etna case. Submitted to Annals of Geophysics
- Pompilio M. & Rutherford MJ (2002) Pre-eruption conditions and magma dynamics of recent amphibole-bearing Etna basalt. Eos Trans., AGU, 83 (47), Fall Meeting Suppl., Abstract V61A-1354.
- Taddeucci, J, M. Pompilio, P. Scarlato (2002) Conduit processes during the July–August 2001 explosive activity of Mt. Etna (Italy): inferences from glass chemistry and crystal size distribution of ash particles. Submitted to JVGR

RU 12 TRIGILA

PROJECT TITLE

ERUPTIVE SCENARIOS FROM PHYSICAL MODELING AND EXPERIMENTAL VOLCANOLOGY

RU Responsible: Raffaello Trigila.
Affiliation: Dipartimento di Scienze della Terra, Università di Roma, "La Sapienza".
Title of the Research: a) Experimental studies on magma-water explosive interaction applied to pyroclastic successions from volcanoes of the Mediterranean area. **b)**Experimental parametrisation of the intensive variables controlling the explosive behaviour of the 2001 and 2002 Mt. Etna eruptions.

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position		Affiliation	man/month
Trigila Raffaello,	Prof.ordinario	DST Univ. Roma "La Sapienza"	4
Palladino Danilo M,	Ric. conferm.	DST Univ. Roma "La Sapienza"	2
Gaeta M.	Ric. conferm.	DST Univ. Roma "La Sapienza"	2
Perinelli C.*	Ass.biennale	DST Univ. Roma "La Sapienza"	4
Mincione V.	Dottor. Ric.	DST Univ. Roma "La Sapienza"	4
Nardi A**	Dottor. Ric.	DST Univ. Roma "La Sapienza"	4

*Personel operating in the RU from 1/1/2002
** Personel operating in the RU from 1/11/2002

2nd YEAR OBJECTIVES

- **a)** Magma-water explosive interaction: Relations between the melt.viscosity (homogeneous melt or crystal mush) vs. the amount of fragmentation and transported mass. The effect of vesiculation on the explosive interaction.
- **b)** Amphibole stability at magmatic temperatures and magma chamber pressures under H_2O and H_2O+CO_2 saturated conditions. The effect of decompression on phase relations.

2nd YEAR RESULTS **(max 1 page)**

Methodologies. a) The maqua (magma-water interaction vessel) experiments were limited by the laboratories closure from december 2001 to July 2002. The apparatus has been reinstalled in the last september after the major works appointed by the law 626 on safety on working places have been completed . The MAQUA vessel was then modified to accept an ultrasonic probe, designed and assembled in our lab, that acts both as passive and active high temperature sensor located just below the sample holder via a silica buffer rod. In the passive mode, it allows the monitoring of pressure waves with ultrasonic frequencies originated by the magma water explosive interaction or by the melt vesiculation as response to the magmatic decompression. The monitoring as active mode allows estimates of magma density variations due to the crystallisation process because the sensor is able to collect either Vp than Vs waves. The FFT analysis of the received signal is possible and it may be important to understand its spectral signature i.e. its the way of filtering of the low frequency component. **b)** Amphibole stability was investigated at P=200MPa and T up to 1090°(C) i.e. at the present magma chamber conditions as indicated by

geophysical and thermochemical evidences. The experiments have been run using a rapid quench TZM externally heated pressure vessel. The fO_2 was buffered at the NNO level; the samples were added with with H_2O or H_2O+CO_2 as dihidrate oxalic acid to saturate the liquid. The decompression experiments were performed with different rates (corresponding to the magma different ascent velocities in the volcanic conduit) in order to match the mode of volatiles exolution and mineral assemblages crystallisations respective of the upper vents (above 2750 m asl) and the lower vents (between 2550m and 2250m asl) magmas.

Experimental results

a) Results from MAQUA experiments. Results by the MAQUA experiments giving information on melt fragmentation have been retrieved by granulometric analyses both of the material left in the sample holder and the material transported into the gasket. from a representative set of 11 experimental runs on a Onano lc-tephrite (Vulsini Volcanoes). The experiments have been run at the following conditions: confining pressure 8 MPa; melt interaction temperature between 800 and 900°C; water injection pressure 102 MPa and water- melt interaction mass ratio 0.33 – 0.36. If we compare data from experiments performed with the same water injection mode we can see that higher values melt-water interaction temperature produce larger values for the system expansion and amount of mass transported mass but there is no significative effect on melt fragmentation.. In the case of a homogeneous melt (powdered starting material), interacting with water at 800°C and 900°C respectively, the increase in volume is about 10%, transport is virtually absent, fragmentation is minimal and it is distributed among the finest grain sizes. If the interacting material is in the partially molten state (granular starting material) fragmentation is much more developed, the modal class is shifted toward the grain size coarse region and the transport involves, in average, 20% of the initial mass. It can be concluded the fragment size distribution for all the experimental products appears to be essentially controlled by the aggregation state of the interacting melt. In particular, the experimental products from granular starting material have an unimodal distribution around 0 _, while products from powdered starting material show a multimodal distribution with a principal mode around 3-4 _. It is worth noting that the fragment size distribution of the transported mass is very close to the one left in the sample holder, demonstrating that the mass transport along the sample holder “conduit” has no strong additional effects on fragmentation.

Results from $LiNbO_4$ sensor. This was tested at room temperature giving a good resolution in terms of signal attenuation both in the passive and in the active mode. Other tests using different standard samples materials (glass, stainless steel, lavastone) give consistent ultrasonic waves propagation velocities through the sample holder chamber. HT-HP runs are in progress.

b) Results from experiments on 2001 Mt. Etna eruption samples. The products from two sets of runs: one under equilibrium conditions and variable volatiles composition (H_2O and H_2O+CO_2) and the other under a decompression gradients (from 200 to 20 MPa in 1 h, 12h, and 24h) are being analyzed. However a few preliminary results are the following. At constant pressure (200MPa) and through the temperature range of 900-1040°C, all the investigated samples (i.e. those representative both of upper vents than lower vents lavas) show the same crystalline assemblage: i.e. plagioclase (An76), diopsidic clinopyroxene, olivine and titanomagnetite. These results may indicate that the differences in the porphyricity and crystal assemblage observed respectively for the upper vents and the lower vents samples are not related to a different source of magmatic masses but simply to a different kinetics of the magma ascent. Decompression experiments with different rates show consistent differences both on crystallinity and vesiculation of the experimental products that appear directely correlated for both parameters in case of the experiments performed on H_2O saturated conditions. In particular products obtained at the slowest decompression rates appear more crystal rich and vesiculated than those obtained with the fast decompression rate.

RESEARCH PRODUCTS

- n° of articles published on international journals
- n° of articles published on national journals, proceedings, technical reports: **2**
- invited papers and talks: **2**
- presentations at international meetings: **1**
- presentations at national meetings: **2**
- Data bases
- Computation codes
- Other

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

Trigila R., Salvetti S., (2002), Clinopyroxene-Melt Experimental equilibria from volcanics of Mediterranean Areas related to different geodynamic settings. Proceedings Workshop-Short Course on Volcanic Systems. Geochemical and Geophysical Monitoring. B. De Vivo and R. J. Bodnar, Edts. Seiano di Vico Equense (Na), Sept 26-30th, 2002, 125 – 130.

Trigila R., Castiglione L., (2002), Volcanic Hazard Assessment due to Hydromagmatic Eruptions on the basis of WMI laboratory experiments: the case of Latera Volcano (Vulsini District) and Alban Hills. Proceedings 2nd International Conference on Volcanism, Archeology and Remote Sensing. Sorrento 27-30/6. (accettato per la stampa).

Trigila R., Battaglia M., Macedonio G., (2001) High pressure magma-water interaction experiments: data on energy distribution into system expansion, melt fragmentation and mass transport. EOS. Trans. AGU, 82(47), Fall Meet. Suppl., Abstract V12F-09, Dec.10-14/12 S.Francisco (Ca) U.S.A.

De Natale G., Chiarabba C., Troise C., Trigila R., Dolfi D., (2001) Determination of 3D Sub-structure of Somma-Vesuvius Volcano: the effect of magma quenching due to gas exolution. EOS. Trans. AGU, 82(47), Fall Meet. Suppl., Abstract V31A-0941, Dec.10-14/12 S.Francisco (Ca) U.S.A

Trigila R., Salvetti S., (2002), Experimental data on melts evolution under variable fO_2: the case of basaltic and trachybasaltic compositions from mediteranean volcanoes. Plinius n.28. 275-276; 82°Convegno SIMP, 18-20/9 Cosenza.

Salvetti S., Trigila R., (2002), The effect of fO_2 on the clinopyroxene-basaltic melt equilibria. Plinius n.28. 258-259; 82°Convegno SIMP, 18-20/9 Cosenza.

RU 13 DE NATALE

PROJECT TITLE
Stress and strain changes from magmatic and hydrothermal sources in active volcanic areas

RU Responsible
Giuseppe De Natale – Research Director
Affiliation INGV – Osservatorio Vesuviano

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Giuseppe De Natale	INGV-OV	5
Claudia Troise	INGV-OV	5
Folco Pingue	INGV-OV	3
Elena Cubellis	INGV-OV	1
Francesco Obrizzo	INGV-OV	1
Ugo Coppa	INGV-OV	1
Laura Lungarini*	INGV-OV	3

B) *****Affiliated during the second year; ° PhD supported by this project.

- 2nd YEAR OBJECTIVES

Simulations of stress changes associated to inner volcanic sources in homogeneous clastic 3D media; simulations in 2D and 3D media with structural discontinuities.

Strain determination from geodetic measurements. Simulations of Coulomb stress changes due to volcanic sources in heterogeneous media with topography and/or structural discontinuities, in particular due to intrusive dikes; simulations of stress and Coulomb stress changes in gravitative media, with pre-existing tectonic stress.
Simulations of pressure, temperature changes and deformations, in porous, water saturated media;

- 2nd YEAR RESULTS **(max 1 page)**

Algorithms to compute stress fields due to magmatic sources have been built and tested, using both analytical and numerical (BEM and FEM) methods. The analytical method assumes an heterogeneous elastic model, and computes stress and strain changes due to isotropic pressure changes at point sources and normal dislocation on rectangular dykes. Complex sources can be simulated by point source summation. Numerical methods making use of Boundary Element and Finite Element Concepts have been also used, for 2-D, axial-symmetric and 3-D modelling of stress and strain. Boundary Element Methods are particularly suitable to introduce discontinuities in a homogeneous medium, such as fractures and faults. Finite element methods are the most suitable when assuming a heterogeneous elastic medium. Whatever the methodology used to simulate stress, an algorithm has been built to compute Coulomb stress changes due to magmatic sources, and to identify the shear faulting mechanisms which are most favourably oriented with respect to the total Coulomb stress load, including for instance regional tectonic stress, gravitational stress and magmatic sources. Coulomb stress changes computation is the key to understand the mechanisms of generation of precursory seismic sequences accompanying magma intrusion in the crust, mainly for volcano-tectonic earthquakes. The methods so far developed have been used to model ground deformations and earthquake occurrence at Campi Flegrei, Vesuvius and Mt. Etna.

In particular, using elastic modelling with boundary elements, 3D elastic models of static ground deformation and seismicity at Campi Flegrei have been obtained, taking into account the effects induced by discontinuities at collapse boundaries, located from gravimetric results. Such effects have been also shown to be non-linear, in the sense that, for non-vertical caldera ring faults they cause different shape and extension of the deformed area, depending from the sign of pressure change at the source. In particular, the deformed area in long term subsidence episodes should be much larger than for uplift episodes, as it seems confirmed by archaeological evidences of marine ingressions in ancient manufacts.

Methods have been developed (in 1D and 2D) to compute changes in pressure in an elastic, water saturated porous medium, as a consequence of changes in the boundary conditions driving water circulation. In the 1D method, changes in water pressure as a function of depth can be computed from changes in the Peclèt number, which in turns describes the flow regime. The method has been applied to model the so-called mini-uplift episodes occurring at Campi Flegrei caldera, confirming that observed amounts of deformation are compatible with very small changes in the Peclèt number. Modelling of ground deformation episodes at Campi Flegrei using both 1D and 2D thermal-fluid-dynamical approaches allowed to hypothesise that the time evolution of ground uplift and subsequent subsidence just represents the delayed response of the geothermal system to an initial step-like pulse of overpressure at base of the system. In this perspective, the common perception of hazard related to ground uplift episodes at caldera must be completely reviewed. In fact, maximum hazard should be at the beginning of a new uplift phase, and not at the point of maximum uplift. Moreover, hazard increases for increasing number of subsequent uplift episodes, also if the uplift is partially or totally recovered. The only recent observation of eruption at a caldera, occurred at Rabaul, in 1994, without measurable deformation, i.e. at the beginning of a new unrest after the large uplift and seismicity ending 10 years before, seems to strongly support this new view of caldera precursory patterns. The thermalfluid-dynamical models developed till now are steady state, in the sense they do not take into account the time taken by transient phenomena to reach the final state. Therefore, they cannot be used to simulate intermediate stages of evolution of the phenomena. The next step will be then to develop time-dependent algorithms able to predict the time evolution of deformation phenomena once the fluid dynamic properties of volcanic rocks are conveniently specified. In this perspective, accurate laboratory determination of fluid-dynamical properties of Campi Flegrei tuff samples appears very important.

Retrieval and improvement of seismic data archives has been performed, for time, magnitude and location of local earthquakes at Campi Flegrei and Vesuvius. For example, a new time-magnitude catalogue for Vesuvius has been prepared, based on data from a seismic station closer to the crater with respect to the previous reference station, located in the original Osservatorio Vesuviano. The completeness limit of the new catalogue is about ML=1.0, compared to ML=1.9 for the previous station. This will permit a much more precise statistical analysis of Vesuvian seismicity.

- RESEARCH PRODUCTS
  - n° of articles published on international journals **6**
  - n° of articles published on national journals, proceedings, technical reports -
  - invited papers and talks **7**
  - presentations at international meetings **7**
  - presentations at national meetings **3**
  - Data bases – Compiled a catalogue of seismicity as recorded at the station BKE.

Saraò A., Peresan A., Vaccari F., G. De Natale, A. Mariano 2002. BKE: The Catalogue of Bunker-Est Vesuvian Station, Internal Report, IC/IR/2002/12. The Abdus Salam International Centre for Theoretical Physics-TRIESTE, 72 pp. OV-INGV Internal Report.

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

Lanari, R., De Natale, G., Berardino, P., Sansosti, E., Ricciardi, R., Borgstrom, S., Capauno, P., Pingue, F., Troise, C., *Evidence for a peculiar style of ground deformation inferred at Vesuvius volcano*., Geophys. Res. Lett.,vol.29,n.9,10.1029, 2002.

Troise, C., Pingue F., and De Natale, G. *Coulomb stress changes at calderas: modeling the seismicity of Campi Flegrei (Southern Italy)*, accepted on Journ. Geophys. Res., 2002.

Troise, C. De Natale, G. and Pingue F., *Non linear effects in ground deformation at calderas due to the presence of structural discontinuities*, Pure Appl. Geoph., in press, 2002.

Beauducel F., De Natale G.,Obrizzo F., Pingue F., *3-D modelling of Campi Flegrei ground deformations: An example of trade-off between source and structure*. Pure Appl. Geoph., in press, 2002.

Obrizzo, F., Pingue, F., Troise, C., and De Natale, G., *Bayesian inversion of 1994-1998 vertical displacements at Mt. Etna: evidence for magma intrusion,* submitted to Geophys. Journ. Int., 2002.

Gaeta, F.S., Peluso, F., Arienzo, I., Castagnolo, D., De Natale, G., Milano,M., Albanese,C., Mita, D.G., *A physical appraisal of a new aspect of bradyseism: the mini-uplifts,* submitted to Journ. Geophys. Res., 2002

RU 14 KILBURN

FORMATION OF MAGMATIC CONDUITS BY SLOW CRUSTAL FRACTURES

RU Responsible
Name-Position Christopher Kilburn, Associate Professor
Affiliation University College London

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Christopher Kilburn, Associate Professor	UCL	4
Valentina Rocchi, Research Assistant	UCL	3
*Judith Woo, Research Assistant	UCL	2
*Francesca Frabetti, Research Assistant	UCL	2
Peter Sammonds, Associate Professor	UCL	1

(*New contributors to project)

- 2nd YEAR OBJECTIVES

Task 1. Scaling slow-fracture equations to macroscopic fracturing and faulting.
Task 2. Analysis of seismic data during 1982-84 bradyseismic crisis in Campi Flegrei.
Task 3. Rock fracturing experiments at high pressure (to 50 MPa) and temperature (to 1000°C).

- 2nd YEAR RESULTS **(max 1 page)**

Among volcanoes reawakening after long repose intervals, the final approach to eruption (~1-10 days) is usually characterised by accelerating rates of seismicity. The observed patterns are consistent with the slow extension of faults, which continue to grow until they connect a pre-existing array of subvertical fractures and so open a new pathway for magma to reach the surface. In Year 1, the seismic patterns expected before an eruption were described in terms of a model developed for the nucleation and growth of a population of *microscopic* cracks. The assumption that large-scale fracturing, which triggers measured seismic events, shows behaviour similar to microscopic cracking was justified retrospectively by the good agreement between expected and observed rates of seismicity. The assumption, however, has not been formally justified.

Task 1 for Year 2 (modified from the original schedule to accommodate the success of new results) was to justify the scaling of the governing equations from microscopic to macroscopic conditions. This has been achieved by assuming that gravitational loading and magma overpressure create a *fluctuating* stress field in the country rock. Fluctuations are due to the intermittent growth

of small cracks that cannot be detected by monitoring instruments. The rate of detected events is then determined by (1) the number of active macroscopic faults, and (2) the frequency with which the concentration of strain energy around the tips of faults becomes large enough to permit fault extension. The model yields for detected seismic event rate dN/dt

$$dN/dt = \lambda N_F e^{\gamma N_{sr}}$$

where N_F is the number of active faults, N_{sr} is the number of reactivations along a single fault, and λ and γ (both constant) are inverses of, respectively, a characteristic timescale and fraction of energy released by fracturing. The start of failure is dominated by the activation of an increasing number of existing faults, for which $N \approx N_F$, $N_{sr} \approx 0$, so that $dN/dt \approx \lambda N$. The number of active faults increases to an equilibrium value N^*, after which the event rate is determined by fault reactivation. For this condition, $N_F \approx N^*$ and $N \approx N_{sr}$, so that $dN/dt \approx \lambda N^* e^{\gamma N}$. The two limiting conditions have the same form as those previously identified by analogy with microscopic fracturing. The model also anticipates oscillations in seismic event rate about a mean trend that accelerates with time, and identifies the rate of increase in *peak* event rate (rather than the mean event, as is commonly used) as a key indicator of the approach to eruption.

Task 2 analysed the seismic data obtained during the 1982-84 bradysesimic crisis in Campi Flegrei, Southern Italy. Data were originally presented as numbers of event per day. At this timescale, no clear accelerating trends could be distinguished against an oscillating variation with a period of about 3 months. After regrouping event rate over a range of timescales, from every four hours to 10 days, three accelerating sequences were found at grouping timescales of 5-10 days. Preliminary studies suggest that each sequence follows the limiting trend $dN/dt \approx \lambda N$, indicating that seismicity was dominated by activating an increasing number of faults with time. The three cycles may indicate the growth of three major fault systems, or a three-stage extension of a single system that increased in size with each cycle. Also unclear is the significance of the 5-10 day grouping for the event rates at which underlying patterns emerge. One possibility is that it is related to the preparation time for activating new faults, events at shorter intervals reflecting reactivations along previously active faults.

Task 3 extended Year-1's laboratory experiments on tensile failure to compressional failure at confining pressures from atmospheric to 50 MPa and temperatures from 25° to 1,000°C. The experiments on K-basalt from Vesuvius and hawaiite from Etna show that these rocks remain fully brittle up to 600°C with typical strengths of 90 MPa and 100 MPa and Young's Moduli of 60 GPa and 40 GPa respectively. Above 600°C, the elastic modulus and compressive strength decrease steadily wth increasing temperature, reaching 10% of their original values at 900°C (Vesuvius) and 800°C (Etna), when partial melting begins. Full melting occurs at 1100°C in the Vesuvian lava and at 1040°C in the Etnean samples. The results also show that, for the investigated conditions, changes in confining pressure have only a small effect on rock strength, strain rates are important at high temperatures, and rates of fracture energy release vary inversely with temperature.

- RESEARCH PRODUCTS
  N° of articles in international journals: **2 submitted**
  N° of articles in national journals, proceedings, technical reports
  Invited papers and talks: **1**
  Presentations at international meetings
  Presentations at national meetings: **1**
  Data bases: **Fracture mechanics data on compressional failure**
  Computation codes/Other

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

Kilburn, C.R.J. Heirarchical fracturing as a key to forecasting volcanic eruptions, submitted to J. Volcanol. Geotherm. Res. August 2002.

Kilburn, C.R.J., Rocchi, V., Sammonds, P.2002. Rock fracturing and forecasting volcanic eruptions, Ann. Meeting UK Volcanology Research Group, Geol. Soc. London, Jan. 2002.

Rocchi, V., Sammonds, P.R., Kilburn, C.R.J. Fracture of Etnean and Vesuvian rocks at high temperatures and low pressures, submitted to J. Volcanol. Geotherm. Res. August 2002.

Rocchi, V., Sammonds, P.R., Kilburn, C.R.J. Flow and fracture maps for basaltic rock deformation at high temperatures. J. Volcanol. Geotherm. Res. (in press - since early 2002!)

RU 15 PANZA

PROJECT TITLE
Geophysical constraints on the dynamics of the eruptive process: analysis of seismicity by seismic moment tensor and surface-wave tomography

RU Responsible
Name-Position: Giuliano Francesco Panza – Full Professor of Seismology
Affiliation – Department of Earth Sciences, University of Trieste and
The Abdus Salam International Centre for Theoretical Physics, SAND Group, Trieste.

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Saraò A. - Fellow researcher	DST-UniTs	2
Guidarelli M. - PhD student	DST-UniTs	2
Montera Francesco - PhD student *°	DST-UniTs	11
Peresan Antonella - Fellow researcher*	DST-UniTs	2
Vaccari Franco – Researcher INGV-OV*	INGV-Osservatorio Vesuviano -	2
Nunziata Concettina – Researcher*	Dip. Geofisica e Vulcanologia Univ. Napoli-	1
Natale Maddalena – Fellow researcher*	Dip. Geofisica e Vulcanologia Univ. Napoli-	2
Garofalo Bartolomeo – PhD student*	Dip. Geofisica e Vulcanologia Univ. Napoli-	2

*****Affiliated during the second year; ° PhD supported by this project.
Suhadolc P. and Costa G. present in the first year left this project.

The aim of our project is to single out, by applying the same procedure of investigation at Campi Flegrei, Vesuvio and Etna, the main features of different volcanism.

2nd YEAR OBJECTIVES
Analysis of vesuvian seismicity: seismic source investigation by full moment tensor and structural models by surface wave tomography.
Interpretation of results obtained in the 1 year from the analysis of the seismicity at Campi Flegrei.

2nd YEAR RESULTS **(max 1 page)**
Data processing and interpretation
1) **Interpretation of results obtained in the first year at Campi Flegrei**
We determined velocity models for the uppermost 2 km of the crust using surface wave tomography, and we studied the full seismic source moment tensor by waveform inversion of earthquakes recorded in March 1984 at the Campi Flegrei area, during the last bradyseismic crisis. We found focal mechanisms with P and T axes oriented in agreement with the stress field orientation determined in the area by other independent studies. The analysis of the moment tensor components highlighted that most of the mechanisms were deviator ones and that the isotropic

component increased for the events of March 19, when there was a relatively significant change in the seismicity rate with respect to the time interval investigated. The tomographic maps obtained from surface waves analysis highlighted anomalies in three different regions around the Pozzuoli Gulf where we propose three different average structural models as representative of the uppermost crust of each area. The inland negative anomalies observed in our maps correlate well with the low Vs regions singled out by Aster and Meyer (1989) within the uppermost 2 km of the crust. All our maps evidence a persistent anomaly of group velocity at sea (in the Gulf of Pozzuoli) that has not been observed by other studies. A possible decrease of elastic parameters and density of the sampled materials can explain such result. The observed anomaly is in correspondence with a marked Bouger minimum centred at Campi Flegrei caldera. Our results have been presented at the EGS 2002 Assembly and recently published on Physics of the Earth and Planetary Interiors.
For more details: Guidarelli M., Saraò A. & Panza G.F. 2002. Surface wave tomography and seismic source studies at Campi Flegrei (Italy). Physics of the Earth and Planetary Interiors, 134,157-173.

2) **Analysis of Vesuvian seismicity by full moment tensor**
We investigated 9 events of the vesuvian seismicity with $M_D > 2$ occurred between 1999, Nov. 1 and Dec. 31. These events belong to the seismic swarm occurred after the 1999, Oct. 9 ($M_D=3.6$) earthquake. The study earthquakes have been carefully selected in order to guarantee good quality data and optimal station coverage. For each event several inversions have been done using different structural models taken from the literature and then different damping factors are used in the inversion in order to verify the robustness of the solutions. The events investigated evidence a negligible isotropic component. An internal report containing all the test cases and the relative solutions is in preparation together with a paper containing the main results and interpretation.

3) **Database of Vesuvian seismicity as recorded at the BKE station**
A catalogue of 9046 earthquakes associated to the Vesuvian volcano activity as recorded at Bunker Est station (BKE), located on Mt. Vesuvius and operated by the Osservatorio Vesuviano (OV), has been compiled. The aim of the catalogue is to integrate the information collected in the catalogue compiled by OV that contains the volcanic earthquakes recorded at station OVO (OVO catalogue) since February 1972.
The date and the duration of each earthquake have been extracted from hardcopy of the daily reports sheets compiled by OV, except for the years 1996 and 1997 for which the reports were provided in electronic data formats.
A brief description of the data and of the empirical relations used for the estimate of the magnitude from the duration is provided in the catalogue, together with the essential information about the catalogue source. Statistical analysis of the seismicity of the catalogue is now in progress. We aim to deepen the results obtained by the analysis of the OVO catalogue containing the seismicity recorded during 1972-2000. Our investigation (De Natale et al. 2002), revealed that the seismicity of that period was composed by a background level, characterised by a low and rather uniform rate of energy release and by sporadic periods of increased seismic activity with energy rates and magnitudes progressively increasing in the critical periods. The values of b were progressively decreasing, from about 1.8 to about 1.0. This steady variation could indicate an increasing dynamics in the volcanic system.
The catalogue BKE has been realized within the cooperation among the University of Trieste - Department of Earth Sciences, the International Center for Theoretical Physics (ICTP) -Structure And Non-linear Dynamics of the earth (SAND) Group, and the Osservatorio Vesuviano of Naples. The catalogue is now available upon request.
For more details: Saraò A., Peresan A.,Vaccari F., G. De Natale, A. Mariano 2002. BKE: The Catalogue of Bunker-Est Vesuvian Station, Internal Report, IC/IR/2002/12. The Abdus Salam International Centre for Theoretical Physics-TRIESTE, 72 pp.

De Natale G., Kuznetzov I., Kronrod T., Peresan A., Saraò A., Troise C. & Panza G.F. 2002. The recent seismic crisis of Mt. Vesuvius in the framework of its past 30 years seismic activity. In print on PAGEOPH.

4) **Average structural model in the area of Campi Flegrei and Vesuvio**.

In the framework of a study of the volcanism in the Tyrrhenian Sea and surroundings, we determined the thickness and the vertical velocity distribution of the shear waves in the lithospheric layers for the area under Vesuvio and Campi Flegrei (within a cell 1°x1°), by surface-wave tomography regional study. Surface waves dispersion curves at regional scale have been determined along different paths, by the Frequency-Time Analysis (e.g. Levshin et al., BSSA 1992), and the tomography maps have been obtained using the two-dimensional tomography algorithm (e.g. Yanovskaya and Ditmar, GJI 1990). A paper is in preparation about this study, nevertheless we can report here as preliminary results that a thin continental crust (about 15 km thick) characterizes the area under Campi Flegrei and Vesuvio. Below the crust there is a mantle wedge with V_s as low as about 3.3 km/s in its deeper part and about 4.3 km/s just below the Moho (the lid); the layering under the wedge is consistent with the presence of a subducted lithospheric slab (Ionian/Adria slab). Under Campi Flegrei and Vesuvio the upper crust contains a well developed low velocity layer, about 10 km thick at a depth of about 10 km. The very shallow low velocity crustal layer could reveal the magma chamber.

To refine this average model we are working with local data in order to determine detailed structural model below Vesuvio and Campi Flegrei.

For more details: Panza G.F. & Pontevivo A. 2002. The Lithosphere-Asthenosphere System in the Calabrian Arc and Surroundings Seas. Submitted to Physics of the Earth and Planetary Interiors.

Panza, Pontevivo, Saraò, Aoudia, Peccerillo, 2002. Structure of the lithosphere and volcanism in the Tyrrhenian Sea and surroundings. In preparation.

5) **Refined structural model at Mt. Vesuvius by surface wave measurements.**

To retrieve the structural model of Vesuvius we investigated the local seismicity recorded between 1989-99 by the seismic network maintained by Osservatorio Vesuviano. The group velocity has been determined by FTAN method at periods of 0.02-0.2s from field measurements around the stations, at periods of 0.4-2s from recorded natural events. The non-linear inversion Hedgehog retrieved S wave velocity models. This analysis is still in progress, as example we list here the values selected from the set of results of the inversion at one station of the OSVE network (FTC). This model refines the average one within 31 km of depth.

Depth (km)	Vs (km/s)
0.250	0.50-0.55
1.0	1.10-1.45
4.0	4.0
12.0	2.6
16.0	4.15
31	3.3

Other:
During this year we started a new cooperation with the INGV of Catania in order to study the seismicity that proceeded the 2001 July eruption of Mt. Etna. The investigation of the seismicity of this volcano will be the subject of the third year project.

RESEARCH PRODUCTS
n° of articles published on international journals: **2**
n° of articles published on national journals, proceedings, technical reports: **1**
invited papers and talks: -
presentations at international meetings: **1**
Guidarelli, M., Saraò A., and Panza, G.F. "Modelling the volcano process by the seismic source analysis: the Campi Flegrei as study area". EGS 2002. Session SE7.03 Magmatism and petrology:Advances in volcano physics.
presentations at national meetings; -
Data bases – Compiled a catalogue of seismicity as recorded at the station BKE.
Saraò A., Peresan A., Vaccari F., G. De Natale, A. Mariano 2002. BKE: The Catalogue of Bunker-Est Vesuvian Station, Internal Report, IC/IR/2002/12. The Abdus Salam International Centre for Theoretical Physics-TRIESTE, 72 pp.
Other: Panza G.F. & Pontevivo A., 2002. The Lithosphere-Asthenosphere System in the Calabrian Arc and Surroundings Seas. Submitted to Physics of the Earth and Planetary Interiors.
Panza, Pontevivo, Saraò, Aoudia, Peccerillo, 2002. Structure of the lithosphere and volcanism in the Tyrrhenian Sea and surroundings. In preparation.

PUBLICATIONS LIST (inclusive of papers in prints and accepted)
2001
Panza G.F. & A. Saraò, 2000. Monitoring volcanic and geothermal areas by full seismic moment tensor inversion: are non-double couple components always artefacts of modeling? Geophys. J. Int., 143, 353-364.
Guidarelli, M., A. Saraò & G.F. Panza, 2000. Analysis of seismicity by seismic moment tensor: the Plegraean Fields (Southern Italy) case. Internal Report IC/IR/2000/5 pp 69. The Abdus Salam International Centre for Theoretical Physics.
Saraò A., G.F. Panza, E. Privitera, O. Cocina, 2001. Non double couple mechanisms in the seismicity preceding 1991-1993 Etna volcano eruption. Geophys. J. Int. 145, 319-335.

Saraò A., Guidarelli M. & G.F. Panza, 2001. Campi Flegrei : Studi sulla sorgente sismica e modelli strutturali. First year workshop Proceedings. Roma -INGV 27-29 June 2001, 113-117.

2002

Guidarelli M., Saraò A., Panza G.F. 2002. Surface wave tomography and seismic source studies at Campi Flegrei (Italy). Physics of the Earth and Planetary Interiors, 134, 157-173.

De Natale G., Kuznetzov I., Kronrod T., Peresan A., Saraò A., Troise C. & Panza G.F. 2002. The recent seismic crisis of Mt. Vesuvius in the framework of its past 30 years seismic activity. In print on PAGEOPH.

Saraò A., Peresan A., Vaccari F., G. De Natale, A. Mariano 2002. BKE: The Catalogue of Bunker-Est Vesuvian Station, Internal Report, IC/IR/2002/12. The Abdus Salam International Centre for Theoretical Physics-TRIESTE, 72 pp.