

EXPLOSIVE ERUPTIONS OF ITALIAN ACTIVE VOLCANOES - ERUPTIVE SCENARIOS, HAZARD AND RISK MAPS: VESUVIO, VULCANO, LIPARI

Scientific Coordinator

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ACTIVITY REPORT – 2nd YEAR

PROJECT PARTICIPANTS

<i>RU</i>	<i>Affiliation</i>	<i>Responsible</i>
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2	Dip. Geomineralogico Universita' di Bari	Luigi La Volpe
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GENERAL OBJECTIVES

The final objective concerns the reconstruction of the eruptive scenarios, in terms of both external (sized) phenomena and internal causes, of few selected explosive eruptions of medium magnitude (V.E.I.= 3-5) occurred in the recent past (<10,000 years) at Vesuvius (eruptions AP2 e AP3, 472 AD, 512 AD, 1631), Vulcano (eruptions VIth century AD “Commende”, “Pietre Cotte” and 1888-1890) and Lipari (explosive rhyolitic eruptions younger than 20 ka). Hopefully, the results will cover the phenomenological variability of events expected at short-medium period for the studied volcanoes. The different scenarios for the different volcanoes are acting as base for the validation and the improvement of the models of behaviour, (existing - Vesuvius, Vulcano - or produced during the project - Lipari]) as well as for the establishment or the updating of hazard zonation maps. These maps will form layers of GISs, produced or updated within the project, allowing the transition to preliminary risk zonation maps.

The project is developing through thematic researchs grouped into three consequent and imtercommunicating, main lines or tasks:

1. Plumbing systems
2. Eruption dynamics, transport and emplacement mechanisms
3. Hazard and risk zonation

TASK 1 - Plumbing systems

• 2nd YEAR OBJECTIVES

Vesuvio (RU 6,7):

1. Depth, evolution and degassing processes in shallow magma chambers; role of syn-eruptive degassing in the eruptive style.
2. Physico-numerical models of magma chamber evolution
3. Experimental constraints on tephrites genesis

Vulcano and Lipari (RU 1,3,5,6)

1. Generation and storage of Lipari and Vulcano magmas
2. Degassing processes at La Fossa and Environmental impact of magmatic degassing and hydrothermal circulation at La Fossa

• 2nd YEAR RESULTS

Vesuvio

1. The study of the modalities of growth of Vesuvius magma chambers followed through analyses of skarn fragments from the chamber walls ejected during explosive eruptions of different magnitude and intensity. Isotopic data (472 deposits) indicate that the metasomatic process that generates skarn is dominated by magmatic fluids and/or by direct interaction between magmas and carbonates producing endoskarn and magmatic skarn respectively. New data on fluid inclusions in 79 AD skarn show very high temperatures of homogenization (780-880 °C) and salinities (65-80 NaCl wt% equivalents) suggesting that the genetic mechanism at the origin of this type of skarn is the infiltration of magmatic fluids into carbonate wall rock and they can be considered as exoskarn. The large variability observed in water content of 472 AD silicate melt inclusions agrees with the different chemical-physical conditions of crystallization of host minerals. The water speciation for these inclusions shows a general agreement with the experimental relationship found in phonolitic glasses (RU 6).
2. A model has been developed to reconstruct the thermal and compositional evolution of magma within a simplified Vesuvius shallow chamber of constant vertical extension, assumed to be regularly supplied by magma batches of fixed mass, composition and temperature. Each feeding event is followed by cooling periods driven by country rocks of fixed thermal conductivity. Searching for a validation of the model, it was firstly applied to the 1872-1906 period of open conduit activity in order to define the best fitting of the parametric values with a reasonably well constrained actual case. Results were encouraging in applying the model to the evolution of a magma chamber below Vesuvius starting from its last eruption in 1944. The model's prediction of temperature and composition of magma within such a chamber could be relevant for hazard assessment (RU 6).
3. The determination of the genesis and crystallisation conditions of mafic magmas at Vesuvius was being primarily achieved using a phase equilibrium approach as well as results concerning evolved magmas. However, the attainment of first year objectives required more work than initially planned. Therefore, the scientific results concern mainly the refinements of the determination of the pre-eruptive conditions of evolved magmas. The results of polybaric experiments can be summarised as follow: the amphibole stability is extremely sensitive to the bulk composition. The mineral is stable down near 100 MPa for Pompei (at H₂O-poor conditions only) and only down to 150-200 MPa for the Mercato and Avellino. It does not appear at 300 MPa in the Pompei, whereas it is stable at this pressure in both Mercato and Avellino. Thus, for the Pompei, the amphibole stability curve shows a pronounced back bending as pressure increases. Similarly, leucite appears not to be stable in this composition at 300 MPa. In the Mercato and Avellino phonolites, garnet stability shows a strong dependence on pressure. In a P-XH₂O projection, its stability curve exhibits a negative dP/dXH₂O slope, such that its stability field expands at lower pressures (Mercato and Avellino compositions). Co-crystallisation of amphibole and garnet in the Avellino composition at 200 MPa requires melt water contents of about 3 wt%, and a magma close to its solidus. The most likely pre-eruption conditions of the magma chamber that fed the Pompei event appear to be the following: P : 210±25 MPa, T= 815°C±10, H₂O in melt = 6-6.5 wt%, XH₂O fluid = 0.8±0.05, and fO₂ at NNO+0.5±0.5. For the other studied compositions, additional low temperature experiments (ie at 750-775°C) are needed. Available results suggest that pre-eruption temperatures of Mercato and Avellino magmas were probably below 800°C (RU 7).

Vulcano and Lipari

- One of the most peculiar features of Aeolian rhyolitic eruptions of the last 40ka is the early emission of mixed magmas followed by aphyric to sub-aphyric rhyolitic lavas. All collected data are coherent in indicating that rhyolitic magmas are deep-sited (at least 7 Km), volatile rich (about 5 wt%), and able to mobilise without external trigger. The rising rhyolitic magma intersects shallow small-size mafic body giving way to zoned explosive eruptions in which a denser mixed juvenile is erupted first, followed by unmixed low-density rhyolitic magma. Fractal analysis show that whole rocks compositions are fractal objects with fractal dimension $D=1.01-1.84$, the D increase reflecting the transition from fractal mixing to homogenization. The regime in the conduit, where mixing is supposed to happen, was turbulent. (RU1).
- The Lipari rhyolites are possibly generated by processes of differentiation from andesitic-latic magmas characterized by an increase in their incompatible element content in time. The processes should involve fractional crystallization coupled to assimilation of crustal material similar to the Calabrian Arc lithotypes. In the eruptions in the southern part of Lipari (42-22 ka), syneruptive mixing processes occurred between probably genetically unrelated rhyolitic and latitic magmas (RU3).
- Fluid and melt inclusion studies on magmatic and metamorphic enclaves allowed the recognition of a polybaric evolution of magmas from several Aeolian islands. Two main depths of magma accumulation have been detected: 20-25 km, at the mantle-crust boundary, and 3-4 km. An intermediate depth magma chamber (10-15 km) can be moreover suggested at Vulcano. The deeper magma chamber is the site of primitive magmas accumulation, mixing and assimilation of crustal material. The shallow level magma chambers is the site of dominant fractional crystallisation processes. The intermediate-depth magma chamber at Vulcano (and possibly at Lipari) is the site of extensive fractional crystallisation with generation of acid melts. Fluid inclusion studies on metamorphic xenoliths suggest that the shallow magma chambers at Vulcano are fed by the deep one, with the deep magma residing for short time in the shallow reservoir, before being erupted at the surface. This leads to conclude that input from the deep reservoir shortly predates and probably triggers volcanic eruption at Vulcano (RU 5).
- Pre eruptive contents of $H_2O < 1$ wt% was measured in La Fossa latites irrespective of their stratigraphic position. Cl is in the range 2500-3500 ppm and CO_2 is below detection limit of FTIR method. Higher water contents and chlorine were found in trachites from Palizzi pumice fall. The collected data are under interpretation. A set of contouring maps of trace element distribution on rock coatings was performed. These show the influence of the fumarole plume on the la Fossa surroundings (RU 6).

TASK 2 - Eruption dynamics, transport and emplacement mechanisms

- 2nd YEAR OBJECTIVES

Vesuvio (RU 1,2):

- 1 Textural and compositional analyses of Plinian and Subplinian fallout deposits.
- 2 Fragmentation dynamics of selected eruptions (472, 1631, AP 2 ed AP3) (laboratory analyses)

Vulcano and Lipari (RU 1,2,3)

- Lipari stratigraphic succession
- Eruptive mechanisms of selected eruptions of La Fossa (breccia di Commenda and 1888-90) (laboratory data); Density and velocity profiles of selected pyroclastic flows (dynamic pressure)

- 2nd YEAR RESULTS

Vesuvius

- The compositional modes of pyroclastic fall of plinian and subplinian eruptions were determined. Plinian eruptions are characterized by high fragmentation index being the relative

abundance of components independent of the energy of the eruption. High energy plinian eruptions show the wider range of JI (Juvenile index) and the relative abundance of free crystals (FcrI index) is independent of the amount of ash in the deposit. In compositionally zoned deposits (i.e. 79 A.D. plinian fall) juvenile fragments increase with decreasing abundance of crystals and the compositional change is marked by the highest CrI and FCrI values (RU1).

- The combined interpretation of field investigation, grain-size, SEM and density data of the AD 472 Pollena products lead to confirm that the eruption was a complex sequence of plinian-phreatomagmatic activities. The initial phase was mostly characterized by the repeated formation of both sustained eruptive columns, which formed pyroclastic fall deposits, and dilute and turbulent pyroclastic density currents, which emplaced base-surge deposits. A preliminary processing of data allowed testing the applicability of the physical sedimentological model implemented during the first year for reconstructing flow parameters of such pyroclastic density currents. The first results allows hypothesizing that such base-surges, which represent a distinct source of hazard at Vesuvius, had a dynamic pressure in the range of 4-5 kPa at the foot of the cone. In the case of AP2 eruption, base-surges were characterized by lower values of dynamic pressure (RU2)

Vulcano and Lipari

1. On the island of Lipari, the stratigraphic reconstruction of the eruption deposits that occurred in the last 20ka has been completed. Some details in the stratigraphy of Tranne et al. (2000), with a distinction between the western and eastern outcrops in cycle VIII, on a petrographical and geochemical basis. (RU 1, 3).
2. The combined interpretation of grain-size, SEM and density data of the 1888-1890 products of la Fossa allowed the constraint of the main fragmentation processes during the eruption. Such processes were mostly related to magma/water interaction dynamics, similar to those of other eruptions of La Fossa, but less energetic. Image analysis data were processed for comparing the products of laboratory experiments (carried in collaboration with researchers of the Wuerzburg University) with those of base-surge deposits of La Fossa. Data elaboration allowed assessing the energy partitioning of representative phreatomagmatic explosions, which represent the main source of hazard at Vulcano. For a single explosion, a maximum mechanical energy of 2.75×10^{13} J was calculated, 90% of which released as fragmentation and shock wave energy (RU2).

TASK 3 - Hazard and Risk Zonation

β 2nd YEAR OBJECTIVES

Vesuvio (RU 4,6):

1. Lahars related hazard maps in circumvesuvian areas by mathematical and semiempirical methods
2. Scenarios of subplinian eruptions and mixed strombolian-vulcanian eruptions: AP2 and AP3 eruptions
3. Advancement in hazard mapping

Vulcano and Lipari (RU 4,6)

1. Geological and geomorphological features of lahars from Vulcano (RU 4)
2. Environmental impact of magmatic degassing and hydrothermal circulation at La Fossa

β 2nd YEAR RESULTS

Vesuvio

1. Preliminary simulations of debris flows at Vesuvius were performed using a bidimensional hydraulic model on gridded topographic data from the DEM. available for the area (Pareschi et

al., 2000). The simulations concerned four different catchments on the Vesuvius slopes where, on the basis of morphological calculation, different debris flow volumes may be expected. Simulations have been also performed for the floods of the Nola depression. Different scenarios related to different ash distribution on ground, rain distribution, ash permeability have been computed and the parossistic and average conditions evidenced. An extensive field survey on Apennine buttress allowed the recognition of several syn-eruptive debris flow deposits linked to the main eruptions of Vesuvius, revealing the existence of this hazard in downwind mountainous areas at Vesuvius. The slope stability simulation of fallout deposits on steep slopes was performed by the ArcView (GIS) extension SINMAP (stability index mapping), by using input data (permeability, grain-size, internal friction angle, cover thickness ect) from the main Vesuvius fall deposits. It has been possible, therefore, to estimate the maximum volumes potentially unstable for a given ranges of meteoric events. Using empirical relationships (flow mobility, travel distance downfan, etc) obtained from the study of recent Southern Campania volcaniclastic debris flows, a preliminary zonation of the areas potentially inundable by debris flows in the Apennine chain was attempted. A fairly good agreement was found between syn-eruptive debris flows deposits and the zonation proposed using empirical relationship.

2. The geochemical and petrological study of AP eruptions (subplinian and strombolian-vulcanian events occurred between Avellino and Pompeii Plinian eruptions) revealed they emptied the topmost portions of a large Plinian chamber, residual from the 3500 BP Avellino event, reactivated through the arrival of fresh tephritic magma batches. The phenomena occurred mostly consisted of pumice and scoria fallout from shorty lived eruption columns whose discontinuous collapse generated small pyroclastic flows and surges. Physical-numerical studies suggest that magma eventually present within a periodically supplied, shallow (3-6 km) magma chamber could have volume of 0,3-0,4 km³ and temperature in the range 950-1050°C, qualitatively compatible with explosive emission.
3. The work updating the tephra fallout hazard mapping was completed and the related paper was recently published. The processing of data for drawing hazard maps related to the emplacement of pyroclastic flows during Subplinian eruptions is in progress (RU 4,6).

Vulcano and Lipari

1. The La Fossa di Vulcano debris flows were studied to obtain data concerning the triggering mechanism and evolution of debris flow on volcanic slope covered by loose and unvegetated volcanic material. Extensive sedimentological and morphological investigations were carried out on debris flow source areas and related deposits. The study of rainfall records allowed estimating a rain threshold for the triggering of these debris flows. Simple hydraulic calculation produced results in reasonable agreement with the rain record. Characteristic of deposits, aspect ratio and mobility are in good agreement with results obtained from large-scale flume experiments, but the particularly simple morphology of the source areas of the La Fossa debris flows suggests to use the data for phenomena initiated by channel-bed failure only (RU 4).
2. The data collection was completed on a wide range of metals and trace elements in rock coatings. A set of contouring maps of trace element distribution on rock coatings was performed. These show the influence of the fumarole plume on the la Fossa surroundings (RU 6).

RESEARCH PRODUCTS OF THE PROJECT

- n° of articles published or in press on international journals: 22
- n° of articles published on national journals, proceedings, technical reports: 4
- invited papers and talks: 1
- Presentation at international and national meetings (uncomplete): 16
- PHD thesis: 1

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

Articles published or in press on international journals

1. Andronico D., Cioni R. (2002). Contrasting styles of Mt. Vesuvius activity in the period between the Avellino and Pompei Plinian eruptions, and some implications for assessment of future hazards. *Bull. Volcanol.* 64: 372-391
2. Bisson M., Cosimi G., Favalli M., Leoni F.M., Mazzarini F., Pareschi M.T., Santacroce R., Sgro S., Sulpizio R., Zanchetta G. (2002). GIS database for the assessment of debris flow hazard in two areas of the Campania region (southern Italy). *Il Nuovo Cimento*, 25, 1-15.
3. Büttner, R., Dellino, P., La Volpe, L., Lorenz, V., Zimanowski, B. (2002). Thermohydraulic explosions in phreatomagmatic eruptions as evidenced by the comparison between pyroclasts and products from Molten Fuel Coolant Interaction experiments. *J. Geoph. Res.* 107, 2277, doi:10.1029/2001JB000511.
4. Calanchi N., Peccerillo A., Tranne C., Lucchini F., Rossi P.M., Kempton P., Barbieri M., Wu T.W. (2002) Petrology and geochemistry of the Island of Panarea: implications for mantle evolution beneath the Aeolian island arc (Southern Tyrrhenian Sea, Italy). *J. Volcanol. Geotherm. Res.*, 115, 367-395.
5. De Rosa R., Donato P., Gioncada A., Masetti M. & Santacroce R. (in press): The Monte Guardia eruption (Lipari, Aeolian islands): an unusual example of magma mixing sequence. *Jour. Volcanol. Geotherm. Res.*
6. De Rosa R., Donato P., Ventura G. (2002): Fractal analysis of mingled/mixed magmas: an example from the Upper Pollara eruption (Salina island. Southern Tyrrhenian Sea, Italy). *Lithos*, Vol. 65, pp. 299-311.
7. De Rosa R., Guillou H, Mazzuoli R., Ventura G., (in press): New unspiked K-Ar ages of volcanic rocks of the western and central section of the Aeolian islands: reconstruction of the volcanic stages. *Jour. Volcanol. Geotherm. Res.*
8. Dellino, P., Isaia, R., La Volpe, L., Orsi, G. (in press). Interaction between particles transported by fallout and surge in the deposits of the Agnano-Monte Spina eruption (Phlegraean Fields, Southern Italy). Accepted on *J. Volcanol, Geotherm. Res.*
9. Dellino, P., Isaia, R., La Volpe, L., Orsi, G. (2001). Statistical analysis of textural data from complex pyroclastic sequences: implications for fragmentation processes of the Agnano-Monte Spina tephra (4.1 ka), Phlegraean Fields, southern Italy. *Bull. Volcanol.* 63, 443-461.
10. Dellino, P., Isaia, R., Veneruso, M. (in press). Turbulent boundary layer shear flows as an approximation of base-surges at Campi Flegrei (Southern Italy). Accepted on *J. Volcanol, Geotherm. Res.*
11. Dellino, P., Liotino, G. (2002). The fractal and multifractal dimension of volcanic ash particles contour: a test study on the utility and volcanological relevance. *J. Volcanol, Geotherm. Res.* 113, 1-18.
12. Frezzotti M.L., Peccerillo A., Bonelli R. (in press): Magma ascent rates and depths of magma reservoirs beneath the Aeolian volcanic arc (Italy): inferences from fluid and melt inclusions in crustal xenoliths. In: *Explosive Volcanism*, Elsevier Amsterdam.
13. Fulignati P., Kamenetsky V.S., Marianelli P., Sbrana A., Mernagh T.P. (2001): Melt inclusion record of immiscibility between silicate, hydrosaline, and carbonate melts: application to skarn genesis at Mount Vesuvius. *Geology* , 29: 1043-1046.
14. Fulignati P., Marianelli P., Metrch N., Santacroce R., Sbrana A. (in press): Towards a reconstruction of the magmatic feeding system of the 1944 eruption of Mt Vesuvius. *Journal of Volcanology and Geothermal Research*,
15. Fulignati P., Sbrana A., Luperini W., Greco, V. (2002): Formation of rock coatings induced by the acid fumarole plume of the passively degassing volcano of La Fossa (Vulcano Island, Italy). *Journal of Volcanology and Geothermal Research*, 115, 397-410.

16. Gioncada A., Mazzuoli R., Bisson M., Pareschi M.T. (in press) "Petrology of volcanic products younger than 40 ka on the Lipari-Vulcano complex (Aeolian Islands, Italy): an example of volcanism controlled by tectonics", *J Volcanol Geotherm Res.*
17. Pareschi M.T. (2002). Evaluation of volcanic fallout impact from Vesuvius using GIS. D.J. Briggs et al., (eds), *GIS for Emergency Preparedness and Health Risk Reduction*, 101-114. Kluwer Academic Publishers.
18. Pareschi M.T., Santacroce R., Sulpizio R., Zanchetta G. (2002). Volcaniclastic debris flows in the Clanio Valley (Campania, Italy): insights for the assessment of hazard potential. *Geomorphology*, 43, 219-231.
19. Santacroce, R., Cioni, R., Longo, A., Macedonio, G., Sbrana, A., Sulpizio, R., Andronico, D. (2002): Assessing pyroclastic fall hazard through field data and numerical simulations. The example of Vesuvius. *Journal of Geophysical Research-Solid Earth*, 107, 567-589.
20. Zanchetta G., Sulpizio R., Pareschi M.T., Leoni F.M., Santacroce R. (in press). Characteristic of May 5-6, 1998 volcaniclastic debris-flows in the Sarno area (Campania, southern Italy): relationships to structural damage and hazard zonation. *Journal of Volcanology and Geothermal Research*
21. Zanon V., Frezzotti M.L., Peccerillo A., Nikogossian I. (in press) Magmatic feeding system and crustal magma accumulation beneath Vulcano Island (Italy): evidence from fluid inclusions in quartz xenoliths. *J.Geophys. Res.*
22. Zimanowski, B., Wohletz, K., Dellino, P., Büttner, R. (2002). The volcanic ash problem. *J. Volcanol, Geotherm. Res.* 2557, 1-5.

Articles published on national journals, proceedings, technical reports

1. Fulignati P., Marianelli P., Sbrana A. (2001): Interazione tra fluidi magmatici e rocce carbonatiche incassanti: evidenze dallo studio delle inclusioni fluide in xenoliti dell'eruzione vesuviana del 472 AD. *Atti Soc Tosc. Sci. Nat., Mem., Serie A* , 107:27-31.
2. Fulignati P., Marianelli P., Sbrana A. (2002): Concentrazione e speciazione dell'acqua in inclusioni silicatiche dell'eruzione vesuviana del 472 AD. *Atti Soc Tosc. Sci. Nat., Mem., Serie A*,
3. Toyos G., Oppenheimer C., Pareschi M.T., Sulpizio R., Zanchetta G., Zuccaro G. (in press). Modelling building vulnerability to debris flows in the Sarno Area, Southern Italy. Davos conference
4. Zanchetta G., Sulpizio R., Pareschi M.T., Bisson M., Cosimi G., Favalli M., Santacroce R., Sgrò S. (in press). Volcaniclastic debris flows in the Clanio Valley (Campania, Italy). Fast slope movement prediction and prevention for risk mitigation, Sorrento 2003, FMS paper n. 036 (5 pp.).

PHD thesis

1. Longo A. (2002): Modelli termo-fluidodinamici per l'evoluzione delle camere magmatiche. PhD thesis, Univ. Pisa, Dottorato di Ricerca in Scienze della Terra, XIII ciclo, 153 pp.

Invited papers and talks

1. Frezzotti M.L., Peccerillo A., Nikogossian I. (2002) Silica-rich melts in quartz xenoliths from Vulcano Island and their bearing on processes of crustal melting and crust magma interaction in the Aeolian Arc, Italy. Workshop – Short course in Volcanic Systems Geochemical and Geophysical Monitoring, Napoli, September 26-30, Abstract book, 71-74. (invited speaker)

Presentations on national and international meetings

1. Bonelli R., Frezzotti M.L., Peccerillo A., Zanon V. (2002) Evolution of the volcanic plumbing system of Alicudi (Aeolian Islands): evidence from fluid inclusions. Workshop – Short course

in Volcanic Systems Geochemical and Geophysical Monitoring, Napoli, September 26-30, Abstract book, 25-29

2. Cecchetti A., Cioni R., Fulignati P., Longo A., Marianelli P., Santacroce R., Sbrana A. (2001): Advances in the knowledges on Vesuvius feeding system and on Vulcano magmatic-hydrothermal system. *Gruppo Nazionale Vulcanologia, Istituto Nazionale Geofisica e Vulcanologia, Dipartimento Protezione Civile, Assemblea annuale, Abstracts*: 85-86.
3. De Astis G., Kempton P.D., Peccerillo A., Wu T.W. (2002) Intraplate vs. subduction-related volcanism in southern Italy: implications for mantle evolution and geodynamics. IAVCEI Meeting Mount Pelée 11902-2002, Ile de La Martinique, 12-16 maggio 2002.
4. De Rosa et al.: unprecised presentation at a national meeting
5. Dellino P, La Volpe L. (2001): Dimensione frattale e multifrattale delle ceneri: utilizzazione per lo studio dei processi di Frammentazione. Studio delle dinamiche di trasporto dei surge dell'eruzione di Pollena, 472 A.D.. Poster at the *annual GNV meeting*, 9-11 October, 2001
6. Dellino P, La Volpe L. (2002): Turbulent boundary layer shear flow as an approximation of pyroclastic surge: implication for hazard assessment at Phlegraean Fields. Oral presentation at the IAVCEI conference, Martinique, May 2002.
7. Frezzotti M.L., Peccerillo A., Zanon V., Bonelli R. (2002) Modelling of magma ascent beneath the Aeolian Islands: fluid inclusion study in quartz-rich xenoliths. IAVCEI Meeting Mount Pelée 11902-2002, Ile de La Martinique, 12-16 maggio 2002.
8. Fulignati P., Kamenetsky V.S., Marianelli P., Sbrana A., Mernagh T.P. (2001): The 472AD (Pollena eruption) Vesuvius magma chamber: immiscibility and skarn genesis at the crystallizing margins as evidenced from melt inclusion study. *Geoitalia 2001, Federazione Italiana di Scienze della Terra, Riassunti*: 723-724.
9. Fulignati P., Marianelli P., Santacroce R., Sbrana A. (2001): Evolution of Vesuvius magma chamber-wall rock interface as constrained by fluid inclusion study. European Union of Geosciences, Abstract volume, VPP4, 809
10. Fulignati P., Marianelli P., Santacroce R., Sbrana A. (2001): Melt and fluid inclusion study as a tool for investigating the feeding system of Vesuvius and the evolution of the magma chamber-wall rock interface. *Geoitalia 2001, Federazione Italiana di Scienze della Terra, Riassunti*: 724-725.
11. Fulignati P., Marianelli P., Santacroce R., Sbrana A. (2001): The feeding system of 1944 eruption of Vesuvius: P-T-X conditions from melt and fluid inclusion data. *Geophysical Research Abstract*, 3, 9115
12. Gioncada A., Mazzuoli R. (2001) "The rhyolitic explosive eruptions younger than 22 ka at Lipari island (Aeolian islands, Italy): a petrological study aimed to the reconstruction of the magma chamber processes and the eruptive dynamics.". *Convegno Nazionale GNV*, Roma, ottobre 2001, poster.
13. Peccerillo (2002) Il magmatismo del Tirreno meridionale. Invited Talk, SIMP, Cosenza, September 2002.
14. Peccerillo A. (2002) Compositional variations of Plio-Quaternary magmatism in central-southern Italy: geological, geophysical and geodynamic implications. IAVCEI Meeting Mount Pelée 11902-2002, Ile de La Martinique, 12-16 maggio 2002.
15. Scaillet B., Pichavant M., Cioni R., Sbrana A., Marianelli P. (2001): Experimental constraints on pre-eruption conditions of plinian events at Vesuvius. *Geophysical Research Abstract* , 3, 91134.
16. Scaillet B., Pichavant M., Metrich N., Cioni R., Sbrana A., Clocchiatti R., Marianelli P. (2001): Phase equilibrium and melt inclusion constraints on the conditions of magma evolution at Vesuvius and Vulcano volcanoes. *Gruppo Nazionale Vulcanologia, Istituto Nazionale Geofisica e Vulcanologia, Dipartimento Protezione Civile, Assemblea annuale, Abstracts*: 87-88.

RU 1

Determination of the compositional and textural parameters for the study and characterization of pyroclastic deposits.

RU Responsible

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ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

<i>Name-Position</i>		<i>Affiliation</i>	<i>man/month</i>
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Gioncada Anna	AR	Univ. Pisa	5
Donato Paola	Dr	Univ. Bologna	5

• 2nd YEAR OBJECTIVES

During the second year the study of the samples has been completed. A first result analysis for eventual verifications and deepening is attempted. On the island of Lipari, the stratigraphic reconstruction of the eruption deposits that occurred in the last 20ka has been completed and textural and compositional product investigation is initiated.

• 2nd YEAR RESULTS

At the Aeolian islands the studies were focused on the most explosive rhyolitic eruptions occurred during the last 40ka. One of the most peculiar and unusual feature of these eruptions is the early emission of mixed magmas followed by aphyric to sub-aphyric rhyolites. Component analysis, and petrographic, mineralogical, geochemical investigations and melt inclusions studies coupled with a detailed volcanological study of the eruptive sequences allow to reconstruct the mixing process and to assess the pre-eruptive chemico-physical magmatic conditions. At the onset of the eruptions, the rhyolitic magma is deep-sited (at least 7Km), volatile rich (4.6 wt%), and able to mobilise without necessarily a mafic input as trigger. The rising rhyolitic magma intersects shallow small-size mafic body giving way to zoned explosive eruptions in which a denser mixed juvenile is erupted first, followed by unmixed low-density rhyolitic magma. Fractal analysis and a detailed petrographic and geochemical study were made on the juvenile component showing macroscopic mingling/mixing evidences in order to find a relation between mixing degree, i. e. composition, and fractal dimension. Chemical analysis by XRF showed that the whole rock compositions of fragments lie on mixing trends between a mafic end-member (which is represented by a HK andesite at Pollara and a dacite at M.te Guardia) and a rhyolite. S.E.M.- EDAX analysis showed that a great variability between the same end-members compositions is present in glasses of single heterogeneous samples. The results show that they are fractal objects with a fractal dimension D between 1.01 and 1.84. Comparing fractal analysis with geochemical data revealed that D values are lower for end members, unmixed compositions and increases with the increasing of magma interaction. According to Ten et al (1997) model we conclude that the increase of D observed in the samples reflects the transition from fractal mixing to homogenization. End-member magmas represent isolated mixing regions while homogenized magmas represent active mixing regions. Besides, as turbulent flows are characterized by D -values larger than 1.33-1.35 whereas laminar flows show lower D -values (Sreenivasan and Meneveau,1986), we can conclude that the regime in the conduit, where mixing is supposed to happen, was turbulent.

At Vesuvius the studies were focused on the determination of the compositional modes of pyroclastic fall of plinian and subplinian eruptions. By considering the thickness and areal

distribution of the falls , samples were collected at different distance from the volcano, along the dispersal axis, and at different levels.

Component distribution were obtained either for the coarse-grained and fine-grained fraction of each samples using different techniques and textural and compositional parameters were calculated to represent the modal distribution of the different components.

Plinian eruptions are characterized by high fragmentation index but the relative abundance of components is independent of the energy of the eruption. High energy plinian eruptions show the wider range of JI (Juvenile index) and the relative abundance of free crystals (FCrI index) is independent of the amount of ash in the deposit. In compositionally zoned deposits (i.e. 79 A.D. plinian fall) juvenile fragments increase with decreasing abundance of crystals and the compositional change is marked by the highest CrI and FCrI values.

- RESEARCH PRODUCTS

- n° 3 articles published or in press on international
- 1 presentation at national meetings;

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

De Rosa R., Donato P., Ventura G., 2002, Fractal analysis of mingled/mixed magmas: an example from the Upper Pollara eruption (Salina island. Southern Tyrrhenian Sea, Italy). *Lithos*, Vol. 65,pp. 299-311.

De Rosa R., Guillou H, Mazzuoli R., Ventura G., 2003, New unspiked K-Ar ages of volcanic rocks of the western and central section of the Aeolian islands: reconstruction of the volcanic stages. *Jour. Volcanol. Geotherm. Res.*,in press

De Rosa R. Donato P., Gioncada A., Masetti M. & Santacroce R., 2003, The Monte Guardia eruption (Lipari, Aeolian islands): an unusual example of magma mixing sequence. *Jour. Volcanol. Geotherm. Res.*, in press

RU 2

Explosive eruptions of Italian active volcanoes – eruptive scenarios, hazard and risk maps: Vesuvius, Vulcano, Lipari

RU Responsible

Luigi La Volpe – Full Professor of Volcanology

Dipartimento Geomineralogico, Università di Bari, Italy

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
La Volpe Luigi/PO	Università di Bari	5
Dellino Pierfrancesco/PO	Università di Bari	5
Veneruso Mariacira/AR	Università di Bari	5
Mele Daniela/DR	Università di Bari	11
Sulpizio Roberto/AR	Università di Bari	6
Zimanowski Bernd/PA	Università di Wuerzburg (FRG)	2
Buettner Ralf/RC	Università di Wuerzburg (FRG)	2

• 2nd YEAR OBJECTIVES

- 1) Vesuvius: study of the fragmentation dynamics of selected eruptions (472, 1631, AP 2 ed AP3) (laboratory analyses); velocity and density profiles of selected pyroclastic surge (dynamic pressure).
- 2) Vulcano: eruptive mechanisms of selected eruptions of La Fossa (breccia di Commenda and 1888-90) (laboratory data); density and velocity profiles of selected pyroclastic surge (dynamic pressure). Partition of eruptive energy in phreatomagmatic eruptions at Vulcano.

The research, which is centered in the physical volcanology, is focused on obtaining quantitative information to be used for the assessment of hazard.

• 2nd YEAR RESULTS

- methodologies (*the methodological aspects are shared with the project that is coordinated by R. Santacroce of which L. La Volpe is responsible of a RU and P. Dellino is a participant*): 1) an experimental method for the determination of the drag coefficient of pyroclastic particles has been implemented and successfully tested. It consists of video acquisition of particles falling on a settling tube and data processing by means of quantitative image analysis; 2) the method for reconstructing the dynamic pressure of dilute and turbulent pyroclastic density currents, and its relevance for quantitative hazard assessment, has been refined and tested on deposits of significant eruptions of Campi Flegrei and Vesuvius; 3) an experimental setup for simulating brittle fragmentation processes occurring during the Campi Flegrei explosive eruptions has been designed and tested at the physical volcanology laboratory of the Wuerzburg University with which there is a collaboration inside the project; 4) quantitative image analysis methods for the numerical characterization of the shape of pyroclastic particles have been further implemented for accommodating the fractal dimension and new classificatory diagrams.
- Data acquisition: 1) Vesuvius: field investigation, grain-size, SEM, component and density analysis of Pollena and AP2 eruptions of Vesuvius were almost completed. Field investigation on the products of the 1631 eruption at Vesuvius was started. 2) Vulcano: grain-size, SEM, component and density analysis of the 1888-1890 eruption at Vulcano

were completed. Grain-size, SEM, component and density analysis of the breccia di Commenda eruption at Vulcano were started.

- Data processing and interpretation: 1) Vesuvius: the combined interpretation of field investigation, grain-size, SEM and density data of the Pollena products lead us to interpret the eruption as a complex sequence of plinian-phreatomagmatic activities. The initial phase was mostly characterized by the formation of plinian and subplinian eruptive columns, which formed pyroclastic fall deposits. During this phase, also dilute and turbulent pyroclastic density currents formed, which emplaced base-surge deposits. A preliminary processing of data allowed testing the applicability of the physical sedimentological model we implemented during the first year for reconstructing flow parameters of such pyroclastic density currents. The first results allows hypothesizing that such base-surges, which represent a distinct source of hazard at Vesuvius, had a dynamic pressure in the range of 4-5 kPa at the foot of the cone. In the case of AP2 eruption, base-surges were characterized by lower values of dynamic pressure. 2) Vulcano: the combined interpretation of grain-size, SEM and density data of the 1888-1890 products of la Fossa allowed the constrainment of the main fragmentation processes during the eruption. Such processes were mostly related to magma/water interaction dynamics, similar to those of other eruptions of La Fossa, but less energetic. Image analysis data were processed for comparing the products of laboratory experiments (carried in collaboration with researchers of the Wuerzburg University) with those of base-surge deposits of La Fossa. Data elaboration allowed assessing the energy partitioning of representative phreatomagmatic explosions, which represent the main source of hazard at Vulcano. For a single explosion, a maximum mechanical energy of 2.75×10^{13} J was calculated, 90% of which released as fragmentation and shock wave energy.

- RESEARCH PRODUCTS

- n° of articles published on international journals: 4
- n° of articles published on national journals, proceedings, technical reports
- invited papers and talks

presentations at international meetings: *Turbulent boundary layer shear flow as an approximation of pyroclastic surge: implication for hazard assessment at Phlegraean Fields. Oral presentation at the IAVCEI conferece, Martinique, May 2002.*

presentations at national meetings: Dimensione frattale e multifrattale delle ceneri: utilizzaaione per lo studio dei processi di Frammentazione. Studio delle dinamiche di trasporto dei surge dell'eruzione di Pollena, 472 A.D.. Poster at the annual GNV meeting, 9-11 October, 2001.

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

Büttner, R., Dellino, P., La Volpe, L., Lorenz, V., Zimanowski, B., 2002. Thermohydraulic explosions in phreatomagmatic eruptions as evidenced by the comparison between pyroclasts and products from Molten Fuel Coolant Interaction experiments. *J. Geoph. Res.* 107, 2277, doi:10.1029/2001JB000511.

Dellino, P., Isaia, R., La Volpe, L., Orsi, G. (2002). Interaction between particles transported by fallout and surge in the deposits of the Agnano-Monte Spina eruption (Phlegraean Fields, Southern Italy). Accepted on *J. Volcanol, Geotherm. Res.*

Dellino, P., Isaia, R., La Volpe, L., Orsi, G., 2001. Statistical analysis of textural data from complex pyroclastic sequences: implications for fragmentation processes of the Agnano-Monte Spina tephra (4.1 ka), Phlegraean Fields, southern Italy. *Bull. Volcanol.* 63, 443-461.

Dellino, P., Isaia, R., Veneruso, M. (2002). Turbulent boundary layer shear flows as an approximation of base-surges at Campi Flegrei (Southern Italy). Accepted on *J. Volcanol, Geotherm. Res.*

Dellino, P., Liotino, G. 2002. The fractal and multifractal dimension of volcanic ash particles

contour: a test study on the utility and volcanological relevance. *J. Volcanol, Geotherm. Res.* 113, 1-18.

Zimanowski, B., Wohletz, K., Dellino, P., Büttner, R., 2002. The volcanic ash problem. *J. Volcanol, Geotherm. Res.* 2557, 1-5.

RU 3

The rhyolitic eruptions younger than 22 ka at Lipari (Aeolian Islands, Italy): a petrological study aimed at the reconstruction of the magma chamber processes and the eruptive dynamics

RU Responsible

Roberto Mazzuoli, full professor of Petrology

Dipartimento di Scienze della Terra, University of Pisa, Italy

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

<i>Name-Position</i>		<i>Affiliation</i>	<i>man/month</i>
Mazzuoli Roberto	PO	Dip. Scienze della Terra Univ. Pisa	3
Gioncada Anna	AR	Dip. Scienze della Terra Univ. Pisa	5
Cristiani Chiara	DR	Dip. Scienze della Terra Univ. Pisa	2

– 2nd YEAR OBJECTIVES

Individuation of the processes occurring during the generation and storage of rhyolitic magmas, through a detailed geochemical study of the products of the most important rhyolitic eruptions.

– 2nd YEAR RESULTS

In the course of the 2nd year the research was devoted to the geochemical study of the products of the rhyolitic eruptions occurred at Lipari since 42 ka to historical times. The investigations dealt with particular detail with the eruptions occurred around 22 ka ago in southern Lipari. Major and trace element data of bulk rocks were collected by XRF and ICP-MS analysis at Dipartimento di Scienze della Terra di Pisa, carefully isolating the frequent mafic enclaves. Mineral chemistry was investigated through EDS (Pisa) and WDS (Firenze) analysis; the data obtained allowed to individuate and characterize the different populations of crystals present in the rhyolites as a consequence of mixing. Preliminary trace elements determinations on selected phenocrysts in equilibrium with the rhyolitic and the latitic magmas were obtained through Laser Ablation and ICP-MS analysis at Southampton.

The results of the petrochemical study of the products joined to the field work allowed to introduce some details in the stratigraphy of cycles VII and VIII sequences by Crisci et al. (1991). The sequence obtained is substantially in agreement with that presented in Tranne et al. (2000), except for a distinction between the western and eastern outcrops in cycle VIII, on a petrographical and geochemical basis.

A model is proposed to explain the geochemical variations of rhyolites erupted in the last 42 ka at Lipari. The rhyolites may be generated by processes of differentiation from andesitic-latitic magmas characterized by an increase in their incompatible element content in time. The differentiation processes should involve fractional crystallization coupled to assimilation of crustal material similar to the lithotypes outcropping in the Calabrian Arc. In the rhyolitic eruptions in the southern part of Lipari (42-22 ka), syn-eruptive mixing/mingling processes occurred between rhyolitic and latitic magmas that may be genetically unrelated to each other.

– RESEARCH PRODUCTS

- n° of articles published on international journals 2
- n° of articles published on national journals, proceedings, technical reports

- invited papers and talks
- presentations at international meetings
- presentations at national meetings;
- Data bases
- Computation codes
- Other

1

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

Gioncada A., Mazzuoli R., Bisson M., Pareschi M.T. (2002) "Petrology of volcanic products younger than 40 ka on the Lipari-Vulcano complex (Aeolian Islands, Italy): an example of volcanism controlled by tectonics", in press on J Volcanol Geotherm Res.

Gioncada A., Mazzuoli R. (2001) "The rhyolitic explosive eruptions younger than 22 ka at Lipari island (Aeolian islands, Italy): a petrological study aimed to the reconstruction of the magma chamber processes and the eruptive dynamics.". Convegno Nazionale GNV, Roma, ottobre 2001, poster.

De Rosa R., H. Guillou, R. Mazzuoli, G. Ventura (2003); New unspiked K/Ar ages of volcanic rocks of the western and central sector of the Aeolian Islands: reconstruction of the volcanic stages. In press on: J. Volcanol. Geotherm. Res.

RU 4

Lahar simulation and volcanic risk evaluation

RU Responsible

Maria Teresa Pareschi, Research Chairman

CNR-ISTITUTO DI GEOSCINZE E GEORISORSE

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

<i>Name-Position</i>	<i>Affiliation</i>	<i>man/month</i>
M.T. Pareschi Research chairman	CNR-IGG	2
R. Santacroce PO	University of Pisa	2
G. Zanchetta AR	University of Pisa	4
R. Sulpizio AR	University of Bari	4
M. Bisson researcher	CNR-IGG	2
M. Favalli researcher	CNR-IGG	2

• 2nd YEAR OBJECTIVES

The main goals of the 2nd years have been:

- i) preliminary simulation of debris flows at Vesuvius using hydraulic model;
- ii) geological investigation of recurrence, extension and flow typology of syn-eruptive debris flows along the Apennine chain downwind of the fallout dispersion of the main explosive eruptions of Vesuvius;
- iii) Slope stability simulation of fallout deposits on steep slopes, preliminary estimations of volumes potentially unstable and related zonation of basins where geological evidence indicated past initiation of syn-eruptive debris flows.
- iv) Preliminary zonation of the areas potentially inundable by debris flows in the Apennine chain using empirical parameters;
- v) Geological and morphological investigations on recent volcanoclastic debris flows at La Fossa Volcano (Vulcano Island).
- vi) Flood hazard for reduced volcanic ash permeability

• 2nd YEAR RESULTS (max 1 page)

Preliminary simulations of debris flows at Vesuvius were performed using a bidimensional hydraulic model (O'Brien et al., 1993; 1999). Gridded topographic data were obtained from the Digital Elevation Model available for the area (Pareschi et al., 2000). Initial volumes of debris flows were assessed assuming a complete mobilisation of pyroclastic material produced by a theoretical eruption like AD 1631 on slope >25°. The debris flows hydrograph was assumed triangular (Iverson et al., 1999). In absence of direct measurement (foreseen for the next years) flow rheology (viscosity and yield stress) was assumed identical to some well-studied natural granular slurries (O'Brien et al., 1999). Preliminary simulations were performed using two different slurry rheologies. Simulations were performed for four different catchments on the Vesuvius slope where, on the basis of morphological calculation, different debris flow volumes may be expected. Using different rheology no appreciable differences in terms of velocity and flow height were obtained from the same catchment. Some discrepancies have been found between simulated and field debris flow travel length. Further simulations are necessary to improve the matching.

Simulations have been performed for the floods of the Nola depression. Different scenarios related to different ash distribution on ground, rain distribution, ash permeability

have been computed and the parossistic and average conditions evidenced. A paper on these results has been submitted.

As concern the geological investigation for the identification of syn-eruptive debris flows on Apennine buttress an extensive field survey permitted to recognised tents of deposits strictly linked to the main explosive eruptions of Somma-Vesuvius during the Holocene. This indicates as syn-eruptive debris flows hazard in mountainous areas downwind of an explosive eruption is a feature of volcanic hazard so far underestimated at Vesuvius. The ArcView (GIS) extension SINMAP (stability index mapping, Pack et al., 1998) was used to simulate the unstable areas of fresh pyroclastic material covering the source areas of debris flows. As input data (permeability, grain-size, internal friction angle, cover thickness ect) were used the characteristics of the main pyroclastic fall deposits of the Vesuvius. Through the SINMAP it is possible, therefore, to estimate the maximum volumes potentially unstable for a given ranges of meteoric events. Using previous estimated empirical relationships (flow mobility, travel distance downfan, etc) obtained from the study of recent volcanoclastic debris flows occurred in the Southern Campania (e.g. De Riso et al., 1999; Pareschi et al., 2000; Pareschi et al., 2002; Zanchetta et al., 2003) a preliminary zonation respect to the maximum volume mobilizable in the source areas was undertaken. In particular a fairly good agreement was found between syn-eruptive debris flows deposits and the zonation proposed using empirical relationship for the areas of the flow inundation.

The study of the debris flows at La Fossa Volcano was undertaken with the aim to obtain some data concerning the triggering mechanism and evolution of debris flow on volcanic slope covered by loose and unvegetated volcanic material (an occurrence that simulates an ideal case of syn-eruptive debris flows initiation). La Fossa Volcano is a very useful natural laboratory for its limited size and the recurrence of debris flows activity. Extensive sedimentological and morphological investigations were carried out on debris flow source areas and related deposits. The study of rainfall records allowed estimating a rain threshold for the triggering of these debris flows. Simple hydraulic calculation, assuming a progressive saturation of loose volcanic material on source areas, produced results in reasonable agreement with the rain record. Characteristic of deposits, aspect ratio and mobility are in good agreement with results obtained from large-scale flume experiment (i.e. Iverson, 1997; Major, 1997). However, the particularly simple morphology of the source areas of the debris flows of La Fossa Volcano permit to use the data only for debris flows initiation due to channel-bed failure. This occurrences is probably common on loose material at the bottom of relatively steep channels (i.e. Takahashi, 1991; Tognacca et al., 2000) but is not generalisable in case of extensive volcanic cover of steep slopes.

• RESEARCH PRODUCTS

- n° 5 of articles published on international journals
- n° 3 of articles published on national journals, proceedings, technical reports
- n° 1 invited papers and talks
- n° 4 presentations at international meetings
- n° 3 presentations at national meetings;
- Data bases
- Computation codes
- Other

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

Ambrosio M., Dellomonaco G., Fagioli M.T., Giannini F., Pareschi M.T., Pignatelli L., Rosi M., Santacroce R., Sulpizio R., Zanchetta R. 2000. The sounding rod and AF shallow corre system in the assesement of thickness and stratigraphy of volcanoclastic covers affected by debris flow-

forming detachments (in italian). *Geologia Tecnica & Ambientale (Journal of technical & environmental Geology)*, 1, 23-32.

Bisson M., Cosimi G., Favalli M., Leoni F.M., Mazzarini F., Pareschi M.T., Santacroce R., Sgro S., Sulpizio R., Zanchetta G. 2002. GIS database for the assessment of debris flow hazard in two areas of the Campania region (southern Italy). *Il Nuovo Cimento*, 25, 1-15.

Pareschi M.T., 2002. Evaluation of volcanic fallout impact from Vesuvius using GIS. D.J. Briggs et al., (eds), *GIS for Emergency Preparedness and Health Risk Reduction*, 101-114. Kluwer Academic Publishers.

Pareschi M.T., Favalli M., Giannini F., Sulpizio R., Zanchetta G., Santacroce R., 2000. May 5, 1998, debris flows in circumvesuvian area (southern Italy): insight for hazard assessment. *Geology*, 28(7), 639-642.

Pareschi M.T., Santacroce R., Sulpizio R., Zanchetta G., 2002. Volcaniclastic debris flows in the Clanio Valley (Campania, Italy): insights for the assessment of hazard potential. *Geomorphology*, 43, 219-231.

Toyos G., Oppenheimer C., Pareschi M.T., Sulpizio R., Zanchetta G., Zuccaro G. 2003. Modelling building vulnerability to debris flows in the Sarno Area, Southern Italy. Davos conference, in press.

Zanchetta G., Sulpizio R., Pareschi M.T., Leoni F.M., Santacroce R., 2003. Characteristic of May 5-6, 1998 volcaniclastic debris-flows in the Sarno area (Campania, southern Italy): relationships to structural damage and hazard zonation. *Journal of Volcanology and Geothermal Research*, in press

Zanchetta G., Sulpizio R., Pareschi M.T., Bisson M., Cosimi G., Favalli M., Santacroce R., Sgrò S. 2003. Volcaniclastic debris flows in the Clanio Valley (Campania, Italy). *Fast slope movement prediction and prevention for risk mitigation*, Sorrento 2003, FMS paper n. 036 (5 pp.). in press.

RU 5

Relationship between magma evolution processes, P-T conditions in magma chambers and eruption dynamics at Vulcano, Aeolian Archipelago

RU Responsible

Angelo Peccerillo, Full professor of petrology

Dipartimento di Scienze della Terra, Università di Perugia

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

<i>Name-Position</i>	<i>Affiliation</i>	<i>man/month</i>
Angelo Peccerillo (PO)	Università di Perugia	3
Gianpiero Poli (PO)	Università di Perugia	3
Pier Francesco Zanazzi (PO)	Università di Perugia	2
Carmelita Donati (RI)	Università di Perugia	5
Vittorio Zanon (Ass.)	Università di Perugia	6
Maria Luce Frezzotti (RI)	Università di Siena	6
Gianfilippo De Astis (RI)	Osservatorio Vesuviano	3
Tsai Wan Wu (RI)	University Western Ontario	2
Pamela Kempton (RI)	NERC, Keyworth, UK	1

2nd YEAR OBJECTIVES

The objectives of the Perugia Research Group include:

1. Understanding magma genesis and low pressure evolution processes of Aeolian arc magmas, with particular emphasis on Vulcano, by petrological and geochemical investigations of volcanic rocks and separated minerals.
2. Placing constraints, through geochemical and fluid inclusion studies, on depth of magma chambers beneath the Aeolian arc volcanoes, with particular emphasis on the Island of Vulcano.
3. Studying the crystal chemistry characteristics of clinopyroxenes in rocks from various ages and islands with the aim of investigating depth changes of magma chambers through time.
4. Investigating interaction between magma and wall rocks by study of fluid and melt inclusions in the lava phenocrysts and metamorphic enclaves.
5. To integrate geochemical, petrological, fluid inclusion and geophysical data to work out models of the plumbing system of the Aeolian arc volcanoes, and in particular of the Vulcano Island.
6. To establish, through fluid inclusions and experimental studies, residence time of melts in shallow level magma chambers.

§ 2nd YEAR RESULTS (max 1 page)

- **methodologies:** whole rock petrological, geochemical and isotopic investigations; crystal chemistry of clinopyroxenes; fluid and glass inclusions in magmatic minerals and in minerals of metamorphic enclaves.
- **Data acquisition:** major, trace element and isotopic (stable and radiogenic) data have been obtained on whole rocks and separated minerals from all the Aeolian arc islands. Data on fluid and melt inclusions have been obtained on enclaves from Alicudi, Filicudi, Salina and Vulcano. Sampling has been carried out at Stromboli to collect high-pressure magmatic enclaves to study for mineral chemistry, geochemistry and fluid inclusion compositions.
- **Data processing and interpretation:** Geochemical and isotopic data have allowed to put constraints on the evolution of various islands, including Panarea, Salina, Alicudi and Vulcano. Fluid and melt inclusion studies on magmatic and metamorphic enclaves have

allowed to recognize a polybaric evolution for magmas in several islands. In particular, two main depths of magma accumulation have been detected. One occurs at the mantle-crust boundary (20-25 km), and one at shallow depths (about 3-4 km). An intermediate depth magma chamber (10-15 km) has been detected at Vulcano. It is interesting to note that similar depth has been envisaged for the magma chamber at Lipari by the Research Group of Mazzuoli. The deep magma chambers have been detected also by geophysical investigations. According to whole rocks geochemistry, fluid inclusion and melt inclusion data, the deep magma chamber is the site of primitive magmas accumulation, mixing and assimilation of crustal material. The shallow level magma chambers is the site of dominant fractional crystallisation processes. The intermediate-depth magma chamber at Vulcano (and possibly at Lipari) is the site of extensive fractional crystallisation with generation of acid melts. Fluid inclusion studies on metamorphic xenoliths suggest that the shallow magma chambers at Vulcano are fed by the deep one, with the deep magma residing for short time in the shallow reservoir, before being erupted at the surface. This leads to conclude that input from the deep reservoir shortly predates and probably triggers volcanic eruption at Vulcano

§ RESEARCH PRODUCTS

- n° of articles published on international journals: 8
- n° of articles published on national journals, proceedings, technical reports: 0
- invited papers and talks: 2
- presentations at international meetings: 16
- presentations at national meetings: 2
- Data bases
- Computation codes
- Other

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

1. Calanchi N., Peccerillo A., Tranne C., Lucchini F., Rossi P.M., Kempton P., Barbieri M., Wu T.W. (2002) Petrology and geochemistry of the Island of Panarea: implications for mantle evolution beneath the Aeolian island arc (Southern Tyrrhenian Sea, Italy). *J. Volcanol. Geother. Res.*, 115, 367-395.
2. De Astis G., Peccerillo A., Kempton P. D., La Volpe L, Wu T.W. (2000) Transition from calcalkaline to potassium-rich magmatism in subduction environments: geochemical and Sr, Nd, Pb isotopic constraints from the Island of Vulcano (Aeolian arc). *Contrib. Mineral. Petrol.*, 139, 684-703.
3. De Rosa R., Ventura G., Peccerillo A., Mazzuoli R., Barbieri M., Wu T.W. (2003) Magmatic evolution of Salina Island (Aeolian Archipelago, Southern Tyrrhenian Sea). In *Preparazione*
4. Doglioni C., Harabaglia P., Merlini S., Mongelli F., Peccerillo A., Piromallo C. (1999) Orogens and slabs vs. their direction of subduction. *Earth Sci. Review*, 45, 167-208.
5. Frezzotti M.L., Peccerillo A., Bonelli R., Magma ascent rates and depths of magma reservoirs beneath the Aeolian volcanic arc (Italy): inferences from fluid and melt inclusions in crustal xenoliths. In: *Explosive Volcanism*, Elsevier Amsterdam, in press.
6. Frezzotti M.L., Zanon V., Peccerillo A., Nikogossian I. (2002) Silica-rich melts in quartz xenoliths from Vulcano Island and their bearing on processes of crustal melting and crust magma interaction in the Aeolian Arc, Italy. Submitted to *J. Petrology*,
7. Nazzareni S., Molin M., Peccerillo A., Zanazzi P.F. (2001) Volcanological implications of crystal chemical variations in clinopyroxenes from the Aeolian arc, Southern Tyrrhenian Sea (Italy). *Bull Volcanol.*, 63, 73-82.

8. Peccerillo A. (2001) Geochemical affinities between Vesuvius, Phlegraean Fields and Stromboli volcanoes: petrogenetic, geodynamic and volcanological implications. *Mineral. Petrol.*, 73, 93-105.
9. Peccerillo A. (2001) Geochemistry of Quaternary magmatism in central-southern Italy: genesis of primary melts and interaction with crustal rocks. *Geochimica-Geochemistry International*, 2001, 6, 579-592.
10. Peccerillo A. (2001) Quaternary magmatism in Central-Southern Italy: a new classification scheme for volcanic provinces and its geodynamic implications. *Boll. Soc. Geol. It.*,
11. Peccerillo A., Panza G. (1999) Upper mantle domains beneath central-southern Italy: petrological, geochemical and geophysical constraints. *Pure Appl. Geophys.*, 156, 421-443.
12. Bonelli R., Frezzotti M.L., Zanon V., Peccerillo A.: Evolution of the volcanic plumbing system of Alicudi (Aeolian Islands): evidence from fluid inclusions. *Ann. Geofisica*, submitted.
13. Zanon V., Nikogosian I. (2003) Fluid inclusion study and implications for plumbing volcanic system at Salina, Aeolian arc. *Mineral. Petrol.* submitted
14. Zanon V., Frezzotti M.L., Peccerillo A., Nikogosian I. (2002) Magmatic feeding system and crustal magma accumulation beneath Vulcano Island (Italy): evidence from fluid inclusions in quartz xenoliths. *J. Geophys. Res.*, in press.

Lavori presentati a congressi

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2. Barnekow P., Hoefs J., Peccerillo A. (1999) The Genesis of volcanic rocks from central Italy. In situ UV laser oxygen isotope determination. EUG 10, Strasbourg, Francia, 28 March-1 April 1999
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RU 6

Eruptive scenarios and volcanic hazard evaluation related to Subplinian and Vulcanian eruptions at Vesuvius and Vulcano.

Role of the feeding systems and assessment of the degassing processes

RU Responsible

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Dipartimento di Scienze della Terra, Università di Pisa

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

<i>Name-Position</i>	<i>Affiliation</i>	<i>man/month</i>
Alessandro Sbrana PO	DST - Università di Pisa	5
Roberto Santacroce PO	DST - Università di Pisa	3
Raffaello Cioni PA	DST – Università di Cagliari	3
Paolo Fulignati RU	DST - Università di Pisa	5
Paola Marianelli RU	DST - Università di Pisa	5
Antonella Longo AR	DST - Università di Pisa	6
Alessandra Cecchetti DR	DST - Università di Pisa	6

• 2nd YEAR OBJECTIVES

Vesuvio

Depth, evolution and degassing processes in shallow magma chambers; role of syn-eruptive degassing in the eruptive style.

Physico-numerical models of magma chamber evolution

Scenarios of subplinian eruptions and mixed strombolian-vulcanian eruptions: AP2 and AP3 eruptions

Advancement in hazard mapping

Vulcano

Degassing processes at La Fossa

Environmental impact of magmatic degassing and hydrothermal circulation at La Fossa

β 2nd YEAR RESULTS

Methodologies

SEM-EDS microanalysis was carried out on minerals, MI in phenocrysts and matrix glasses using a Philips XL30 apparatus equipped with EDAX-DX4 to determine major elements, Cl, S (Dipartimento di Scienze della Terra, Pisa). Operating conditions were 20kV voltage and about 0.1 nA beam current. A raster area of about 100 μm^2 was employed for glass analysis to reduce the light element loss.

XRF on bulk rocks using a spectrometer ARL 9400 XP, Dipartimento di Scienze della Terra, Pisa).

H₂O and CO₂ contents on MI and on glassy matrix were determined by FTIR, using a Nicolet Magna-IR 560 spectrometer coupled with a NicPlan infrared microscope (Dipartimento di Scienze della Terra, Pisa). Spot size ranged from 10 to 60 μm . Typical analyses employed 512 scans.

Microthermetries heating experiments were carried out on melt and fluid inclusions from both skarn xenoliths and cognate xenoliths using a TS 1500 Linkam heating stage.

Data acquisition

Vesuvio

For a good comprehension of the magma chamber wall rock interactions, oxygen and hydrogen isotope analyses (30 analyses) on biotite and amphibole from skarn and cognate xenoliths and from juvenile fraction of 472AD eruption were carried out, furthermore oxygen and carbon isotope composition of calcite from 472AD skarn was determined (in collaboration with A. Boyce and A. Fallick SUERC, East Kilbride, Scotland). A new set of microthermometric data on about 40 multiphase fluid inclusions hosted within cognate and skarn xenoliths of the 79 AD eruption was carried out. Silicate melt inclusions from 472 A.D. juvenile products and foid-bearing syenite cognate xenoliths were investigated by FTIR spectroscopy (23 analyses). Water concentration and water speciation were determined. A wide range of water concentration (from 1.5 to 8.1 wt%) was observed.

Vulcano

It was further implemented the geochemical data base on La Fossa volcano. Pre eruptive contents of H₂O <1 wt% was measured in latites irrespective of their stratigraphic position. Cl is in the range 2500-3500 ppm and CO₂ is below detection limit of FTIR method. Higher water contents and chlorine were found in trachites from Palizzi pumice fall. As regard the environmental impact of fumarolic emissions it was completed the data collection on a wide range of metals and trace elements in rock coatings.

Data processing and interpretation.

Vesuvio.

Isotopic data (472 products) indicate that the metasomatic process that generates skarn is dominated by magmatic fluids and/or by direct interaction between magmas and carbonates producing endoskarn and magmatic skarn respectively. The new data on fluid inclusions in 79 AD skarn show very high temperatures of homogenization (780-880 °C) and salinities (65-80 NaCl wt% equivalents) suggesting that the genetic mechanism at the origin of this type of skarn is the infiltration of magmatic fluids into carbonate wall rock and they can be considered as exoskarn. The large variability observed in water content of 472 AD silicate melt inclusion agrees with the different chemical- physical conditions of crystallization of host minerals. The water speciation for these inclusions shows a general agreement with the experimental relationship found in phonolitic glasses.

A model has been developed to reconstruct the thermal and compositional evolution of magma within a simplified Vesuvius shallow chamber of constant vertical extension, assumed to be regularly supplied by magma batches of fixed mass, composition and temperature. Each feeding event is followed by cooling periods driven by country rocks of fixed thermal conductivity. Searching for a validation of the model, it was firstly applied to the 1872-1906 period of open conduit activity in order to define the best fitting of the parametric values with a reasonably well constrained actual case. Results were encouraging in applying the model to reconstruct the growth and evolution of a magma chamber below Vesuvius starting from its last eruption in 1944. The model's prediction of temperature and composition of magma within such a chamber could be relevant for hazard assessment

The geochemical and petrological study of AP eruptions (subplinian and strombolian-vulcanian events occurred between Avellino and Pompeii Plinian eruptions) revealed they emptied the topmost portions of a large Plinian chamber, residual from the 3500 BP Avellino event, reactivated through the arrival of fresh tephritic magma batches. The phenomena occurred mostly consisted of pumice and scoria fallout from shorty lived eruption columns whose discontinuous collapse generated small pyroclastic flows and surges. Physical-numerical studies suggest that magma eventually present within a periodically supplied, shallow (3-6 km) magma chamber could

have volume of 0,3-0,4 km³ and temperature in the range 950-1050°C, qualitatively compatible with explosive emission.

The work updating the tephra fallout hazard mapping was completed and the related paper was recently published. The processing of data for drawing hazard maps related to the emplacement of pyroclastic flows during Subplinian eruptions is in progress.

Vulcano.

The collected data on pre eruptive volatile content is under interpretation. A set of contouring maps of trace element distribution on rock coatings was performed. These show the influence of the fumarole plume on the la Fossa surroundings.

• RESEARCH PRODUCTS

- n° of articles published on international journals 5
- n° of articles published on national journals, proceedings, technical reports 2
- invited papers and talks
- presentations at international meetings 3
- presentations at national meetings; 4
- Data bases
- Computation codes
- PhD Thesis 1

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

Articles published on international journals

Andronico D., Cioni R. (2002). Contrasting styles of Mt. Vesuvius activity in the period between the Avellino and Pompei Plinian eruptions, and some implications for assessment of future hazards. *Bull. Volcanol.* 64: 372-391

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PHD thesis

Longo A. (2002): Modelli termo-fluidodinamici per l'evoluzione delle camere magmatiche. PhD thesis, Univ. Pisa, Dottorato di Ricerca in Scienze della Terra, XIII ciclo, 153 pp.

Presentations on national and international meetings

- Cecchetti A., Cioni R., Fulignati P., Longo A., Marianelli P., Santacroce R., Sbrana A. (2001): Advances in the knowledges on Vesuvius feeding system and on Vulcano magmatic-hydrothermal system. *Gruppo Nazionale Vulcanologia, Istituto Nazionale Geofisica e Vulcanologia, Dipartimento Protezione Civile, Assemblea annuale, Abstracts: 85-86.*
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- Fulignati P., Marianelli P., Santacroce R., Sbrana A. (2001): Melt and fluid inclusion study as a tool for investigating the feeding system of Vesuvius and the evolution of the magma chamber-wall rock interface. *Geoitalia 2001, Federazione Italiana di Scienze della Terra, Riassunti: 724-725.*
- Fulignati P., Kamenetsky V.S., Marianelli P., Sbrana A., Mernagh T.P. (2001): The 472AD (Pollena eruption) Vesuvius magma chamber: immiscibility and skarn genesis at the crystallizing margins as evidenced from melt inclusion study. *Geoitalia 2001, Federazione Italiana di Scienze della Terra, Riassunti: 723-724.*
- Fulignati P., Marianelli P., Santacroce R., Sbrana A. (2001): The feeding system of 1944 eruption of Vesuvius: P-T-X conditions from melt and fluid inclusion data. *Geophysical Research Abstract* , 3, 9115
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RU 7

Experimental constraints through a phase equilibrium and melt inclusion approaches on the conditions of magma evolution, extraction and degassing at Vesuvius and Vulcano volcanoes

RU Responsible:

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ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

<i>Name-Position</i>	<i>Affiliation</i>	<i>man/month</i>
Scaillet Bruno	CNRS	6
Pichavant Michel	CNRS	2
Métrich Nicole	CNRS	2
Clochiatti Robert	CNRS	3

2nd YEAR OBJECTIVES

The research objective of the second year was mainly the determination of the genesis and crystallisation conditions of mafic magmas at Vesuvius, this task being primarily achieved using a phase equilibrium approach as well as results gained from the first year objective (determination of genesis and crystallisation conditions of evolved magmas). However, the attainment of first year objectives required more work than initially planned. In addition, repeated failure of our high temperature furnace device has delayed the high temperature part of the phase equilibrium work, which has only started recently. Therefore, the scientific results presented below concern mainly the refinements of the determination of the pre-eruptive conditions of evolved magmas.

2nd YEAR RESULTS

- *methodologies*

The methodology is based mainly on hydrothermal phase equilibria (see first year report) performed on four selected magma compositions (the most evolved compositions ejected during the Mercato, Avellino, Pompei and Pollena events).

- *Data acquisition*

A total of 174 phase equilibria have been now performed on the four selected phonolitic to tephri-phonolitic compositions. We have explored in a more systematic way the effect of pressure (100-300 MPa, isothermal sections), as well as extended the temperature interval covered (down to 750°C). Isothermal-polybaric sections were established at 800°C, which was considered as a likely pre-eruption temperature for Plinian events at Vesuvius, although subsequent results showed it to be probably too high for both Mercato and Avellino phonolitic magmas.

- *Data processing and interpretation*

Data processing consisted in electron microprobe and SEM analyses of run products. The results of polybaric experiments can be summarised as follow: the amphibole stability field appears to be extremely sensitive to the bulk composition. It is stable down near 100 MPa for Pompei (at H₂O-poor conditions only) and only down to 150-200 MPa for the Mercato

and Avellino compositions. It does not appear at 300 MPa in the Pompei, whereas it is stable at this pressure in both Mercato and Avellino. Thus, for the Pompei, the amphibole stability curve shows a pronounced back bending as pressure increases. Similarly, leucite appears not to be stable in this composition at 300 MPa. In the Mercato and Avellino phonolites, garnet stability shows a strong dependence on pressure. In a P-XH₂O projection, its stability curve exhibits a negative dP/dX_{H₂O} slope, such that its stability field expands at lower pressures (Mercato and Avellino compositions). Co-crystallisation of amphibole and garnet in the Avellino composition at 200 MPa requires melt water contents of about 3 wt%, and a magma close to its solidus. The melt water content is in accord with recent melt inclusion constraints (Sigborelli et al. 1999) but is incompatible with the near liquidus character (ie crystal-poor) of the phonolite. Temperatures lower than 800°C are required to help reconcile experimental and observational features in this case.

In contrast, for the Pompei composition, it is possible to find a unique set of T-H₂O_{melt} conditions that reproduces the natural assemblage and that matches with melt inclusion constraints on pre-eruptive melt water content (Cioni, 2000). Because amphibole is not stable at 300 MPa-800°C, the most likely pre-eruption conditions of the magma chamber that fed the Pompei event appear to be the following: P : 210±25 MPa, T= 815°C±10, H₂O_{in melt} = 6-6.5 wt%, X_{H₂O fluid} = 0.8±0.05, and fO₂ at NNO+0.5±0.5.

For the three other compositions, we need to perform additional low temperature experiments (ie at 750-775°C) and process them before any final conclusion can be drawn. As stated above, available results suggest that pre-eruption temperatures of both Mercato and Avellino magmas were probably below 800°C.

- *Others*

On going work on melt inclusions hosted by primitive olivine in magmas emitted during the 1794, 1822, and 1872 eruptions at Vesuvius shows that entrapment pressures are in the range 400-500 MPa. Primary magmas injected in recent periods in the deep plumbing system of Vesuvius have elevated H₂O and CO₂ contents, as well as Cl, F and S. Preservation of such inclusions implies rapid ascent of mafic magma in the shallow reservoir that has fed the recent explosive activity at Vesuvius.

— RESEARCH PRODUCTS

- n° of articles published on international journals: By the end of the first year of the project we initially planned to submit a paper to a special issue of *Journal of Geothermal and Volcanological Research* on Vesuvius and Campi Phlegrei. However, due to the unexpected complexities of the phase relations of Vesuvius phonolites, we decided to withdraw our contribution to this volume because we were still not in position to provide any definitive conclusions as to which were the pre-eruptive conditions of the studied events. Such a target should be attained in the next months.
- n° of articles published on national journals, proceedings, technical reports: none
- invited papers and talks: none
- presentations at international meetings: planned at the next EGS meeting
- presentations at national meetings; meeting in Roma, October 2002, with all other RU
- Data bases: none
- Computation codes: none
- Other: none

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

see above